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LAND AUTHORITY

Height Datum & Height Determination using GNSS in Singapore

Dr Victor Khoo

Land Survey Division

SLA
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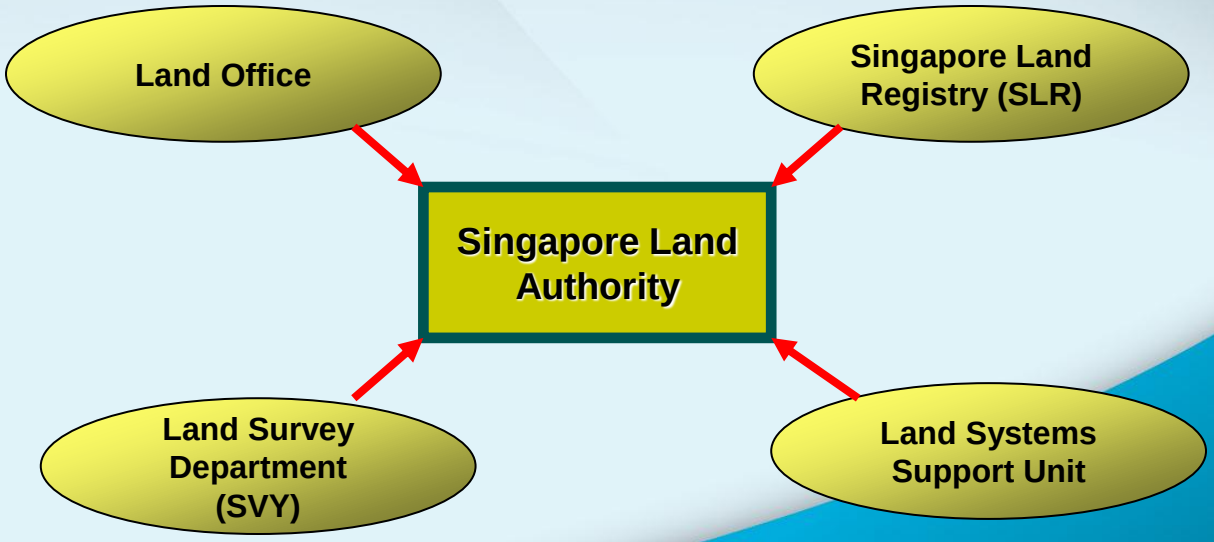
Singapore


SingTel
OCBC Bank

Singapore Land Authority (SLA)

- SLA is a statutory board formed by an Act of Parliament in Jun 2001.
- Merger of 4 former land departments



SLA's Vision

- Limited Land • Unlimited Space
  - highlights the nation's constraints and SLA's commitment in addressing them

- SLA's role
  - ensure the best use of State land and buildings,
  - provide an effective and reliable land management system, including the issuance and guarantee of land titles and geo-spatial demarcation of land, and
  - enable the full use of land information for better land management and creation of new business opportunities.

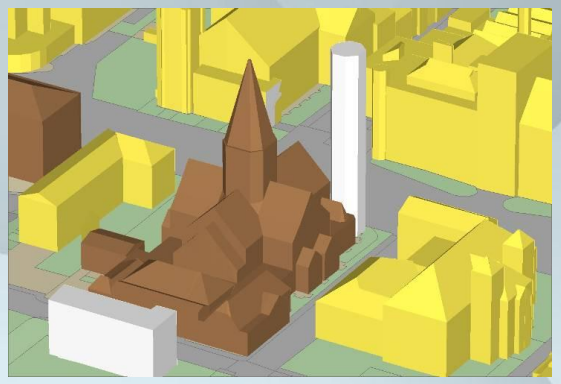
New Maps are 3D

What drives 3D mapping?

- Expectation and Demand
  - “Explore the world without leaving your living room with our unique **3D maps.** All you need is a web browser”
- 3D applications are becoming increasingly important
- Convergence of hardware, software and data model to support 3D

UNGGIM - Trends in Technology and the future direction of data creation, maintenance and management (2013)

- The trend of moving from 2D mapping through to 3D and on to 4D visualisations is technology-driven and will accelerate.
- Users will expect much more complex and realistic models, to enable effective planning and management and to optimise resources.



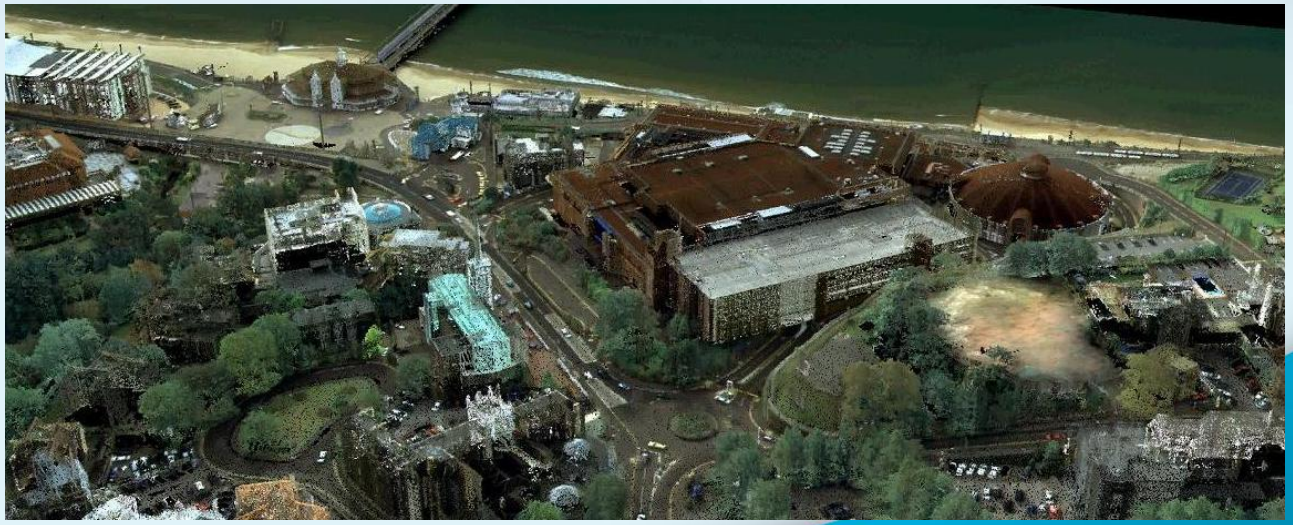


FIG - Beyond Cadastre 2014

- Multipurpose Cadastre
- Describe 6 characteristics of future cadastres
  1. Survey-Accurate Cadastres
  2. Object-Oriented Cadastres
  3. 3D/4D Cadastres
  4. Real-Time Cadastres
  5. Global Cadastres
  6. Organic Cadastres

Rohan BENNETT, Abbas RAJABIFARD, Mohsen KALANTARI, Jude WALLACE and Ian WILLIAMSON, Australia

ICSM (Australia & New Zealand) – Cadastre 2034

- Vision for Cadastre 2034 - “A cadastral system that enables people to readily and confidently identify the location and extent of all rights, restrictions and responsibilities related to land and real property.”

- A digital representation of the cadastre that is 3-dimensional, dynamic and survey accurate

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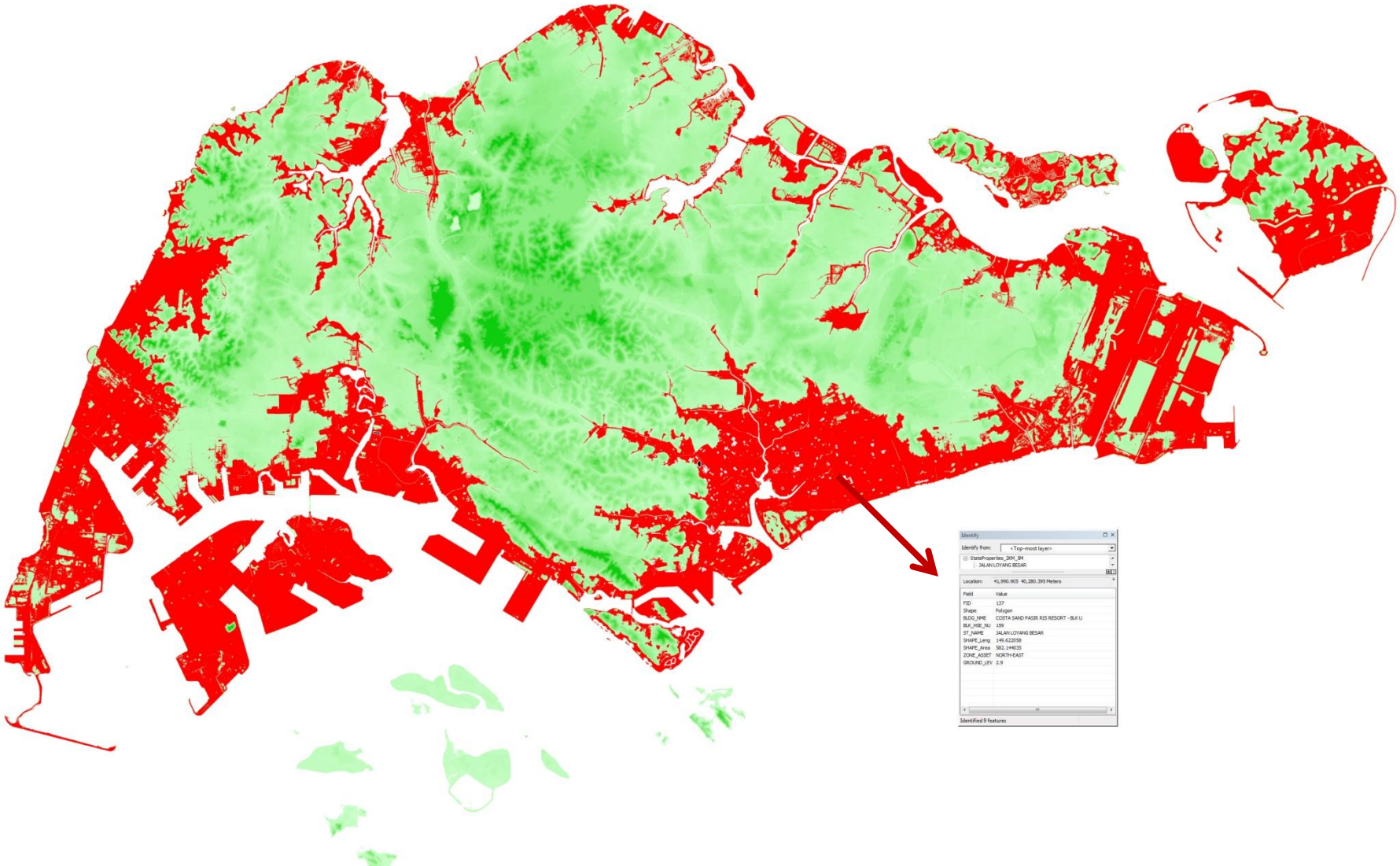
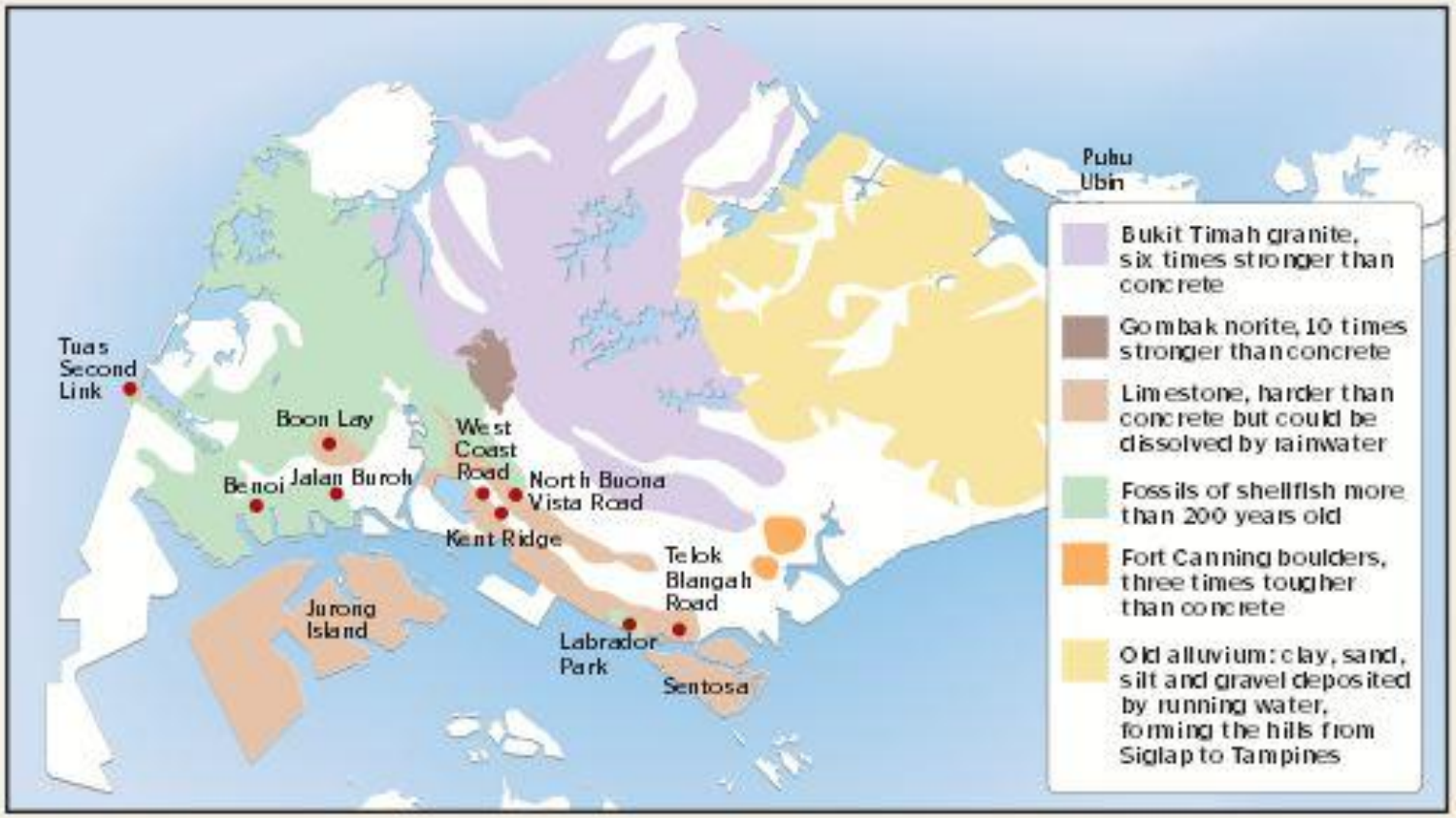
Climate Change and Height Datum

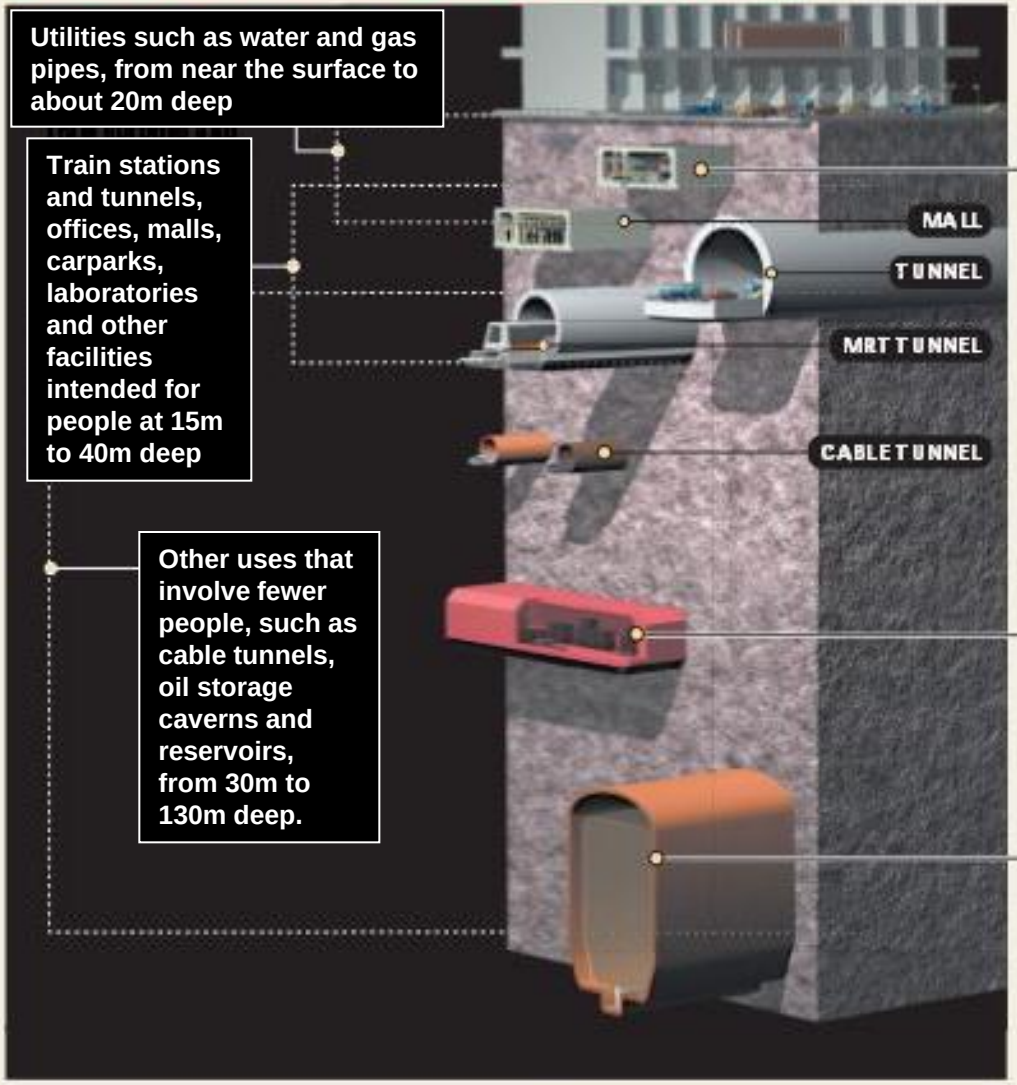




GOING UNDERGROUND

Singapore has many different types of rocks under its surface, from granite and norite, which are much harder than concrete, to limestone, which could be dissolved by rainwater. Here are some of the rock formations and a snapshot of Singapore's underground projects.

HOW DEEP DOES IT GO?



Source: Geology of Singapore, 2nd edition, published by GSTA

Common Services Tunnel
This tunnel system houses power cables,
Pipes and other infrastructure for the Marina Bay area

SAF Underground Ammunition Facility
It is located in Mandai at an unknown depth, under disused quarry, and is for ammunition storage

Jurong Rock Caverm
It is being built 130m below Banyan Basin on Jurong Island to store crude oil and other petroleum products

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Underground Science City

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Building “Spaces” in Singapore?

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Building Industrial “Space” over Expressway in Singapore

Singapore plans to be world's first 'Smart Nation'

The city-state unveils plans for sensors that can help manage traffic congestion, detect air pollutants, and even remind you to take your trash out.

by Aloysius Low @longadin / June 17, 2014 5:15 AM PDT

Smart Nation needs *3D Geospatial Information*, as key information to support its development and operation

The Jurong Lake District in Singapore will be used as a trial area for Singapore's ambitious Smart Nation plan.

Urban Redevelopment Authority of Singapore

Concept of Ownership

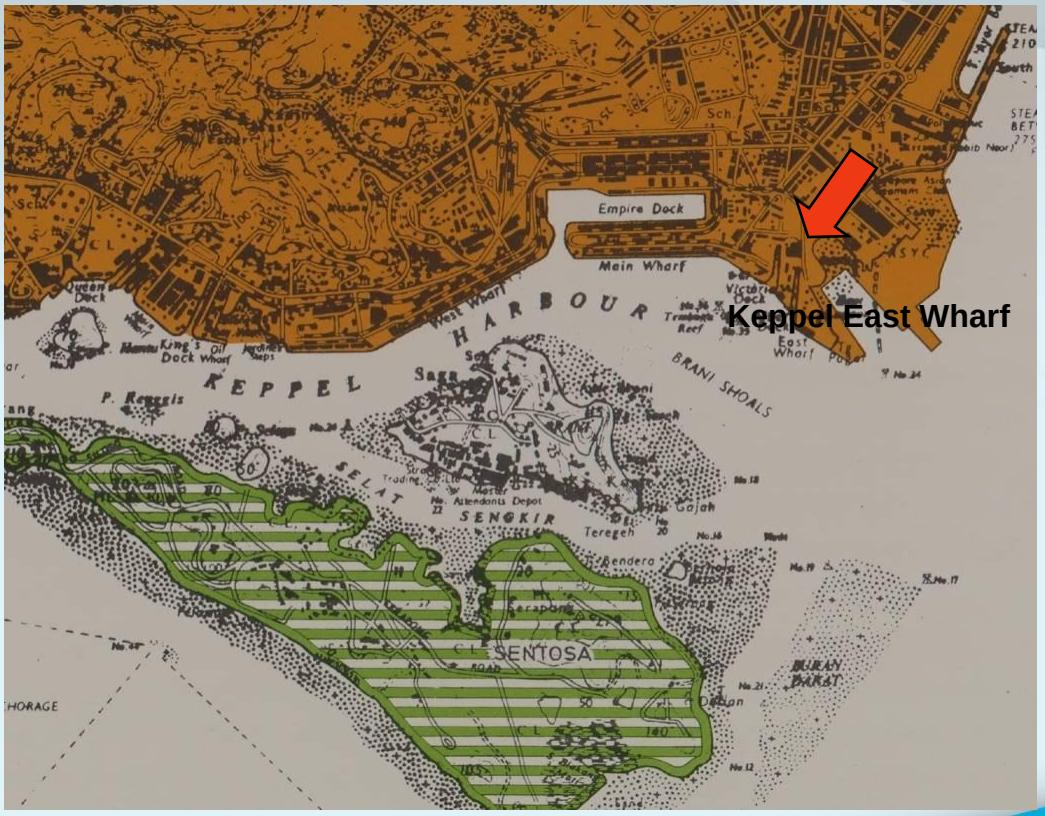
- 2D Cadastre - one owned everything from the centre of the earth to the heaven

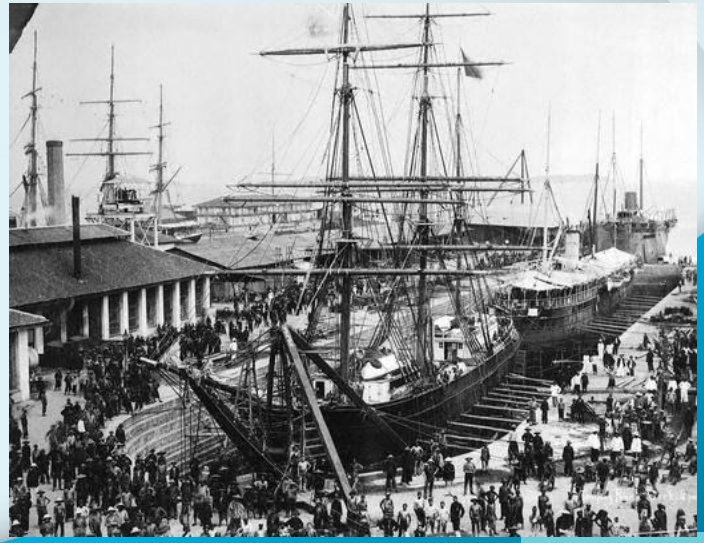
Extent of Underground Ownership

- Early this year - Amendments to the State Lands Act and the Land Acquisition Act are passed to facilitate the Government's long-term planning for the use and development of underground space in the future
- The amendments to the State Lands Act clarified that surface landowners own the underground space up to 30 metres under the Singapore Height Datum, unless otherwise specified in the State title.
- The amendments will not affect how landowners currently use and develop underground space, and landowners will continue to own all the space they need.

Survey Department Datum (now known as Singapore Height Datum)

- Based on the MSL determined at tide gauge located at the Victoria Dock (1935 – 1937)





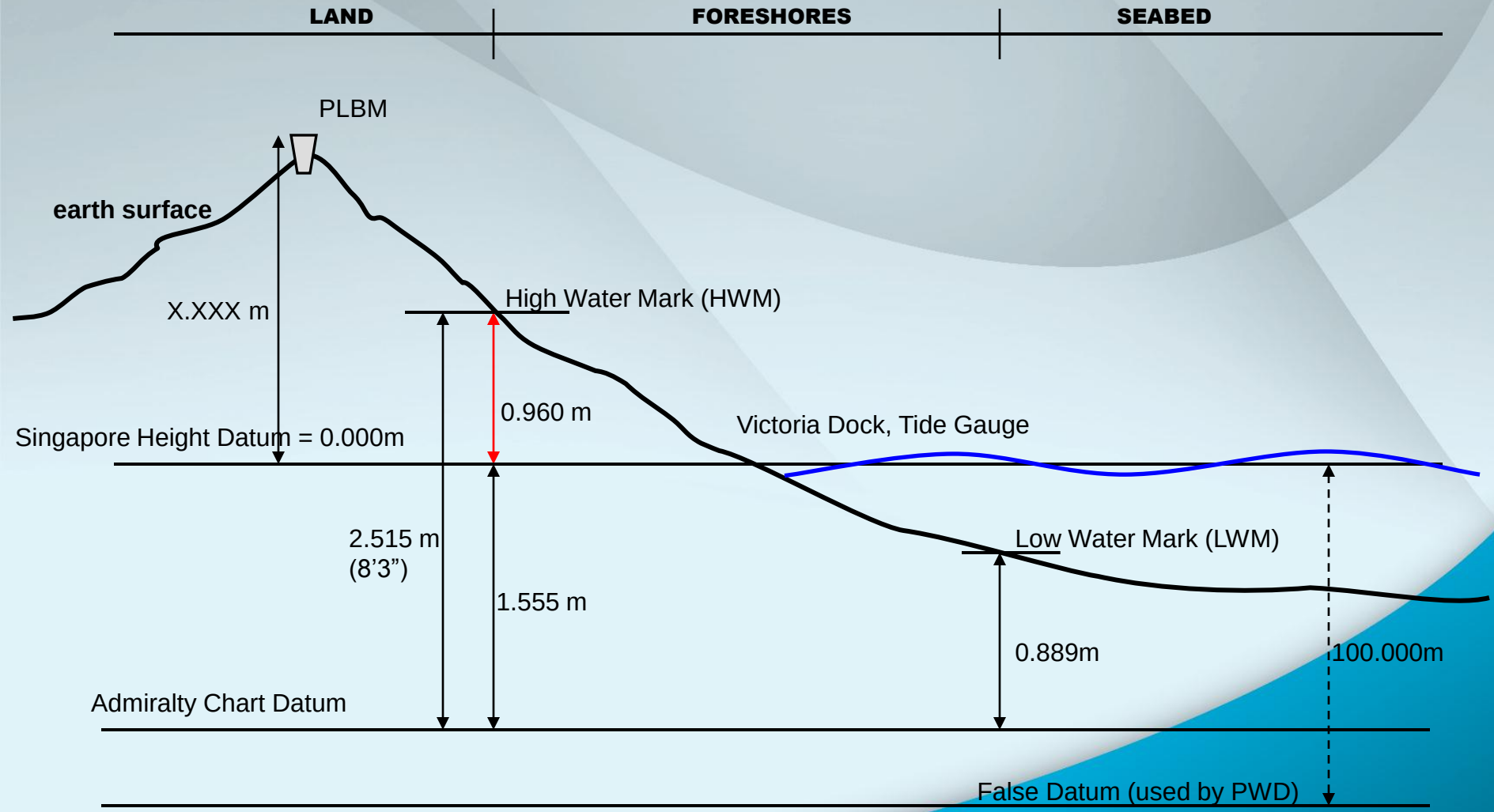
Tide Gauge at Victoria Dock

- Tidal observation between 1935 to 1937 to determine the mean sea level at Victoria Dock
- Standard BM No. 1 was established in 1958
- Tide Gauge was demolished in 1982

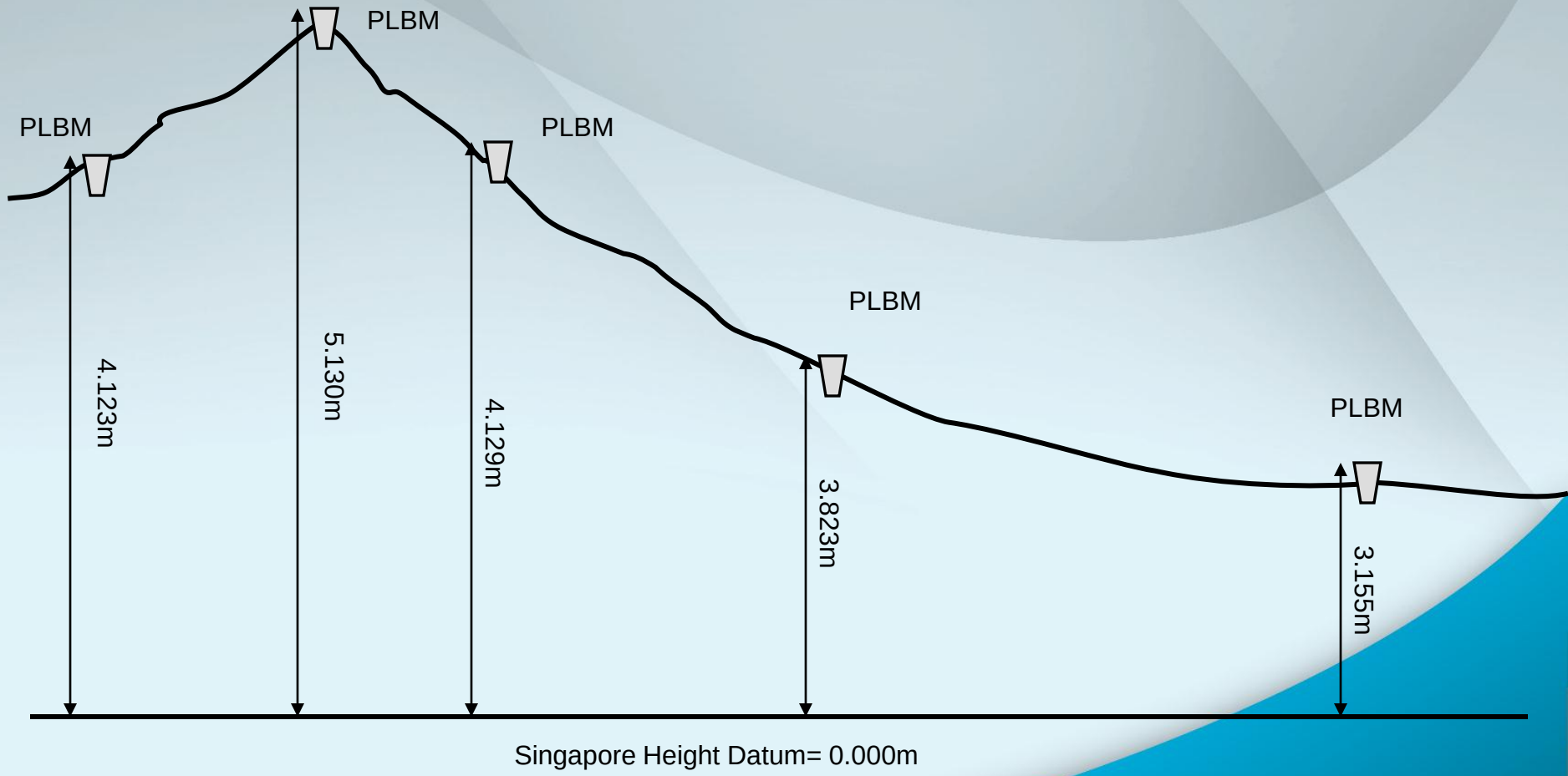
What is HWM?

- Also known as Mean High Water (MHW)
- HWM-average of all high waters observed over a sufficiently long period
- Common Law boundary for titling purpose
- HWM was determined to be 8’3” (2.515 m) above ACD at Victoria Dock
- Admiralty Chart Datum was established in 1882 and the value was adjusted in 1937

Datum Relationships



Realisation of Datum
- Precise Levelling Network

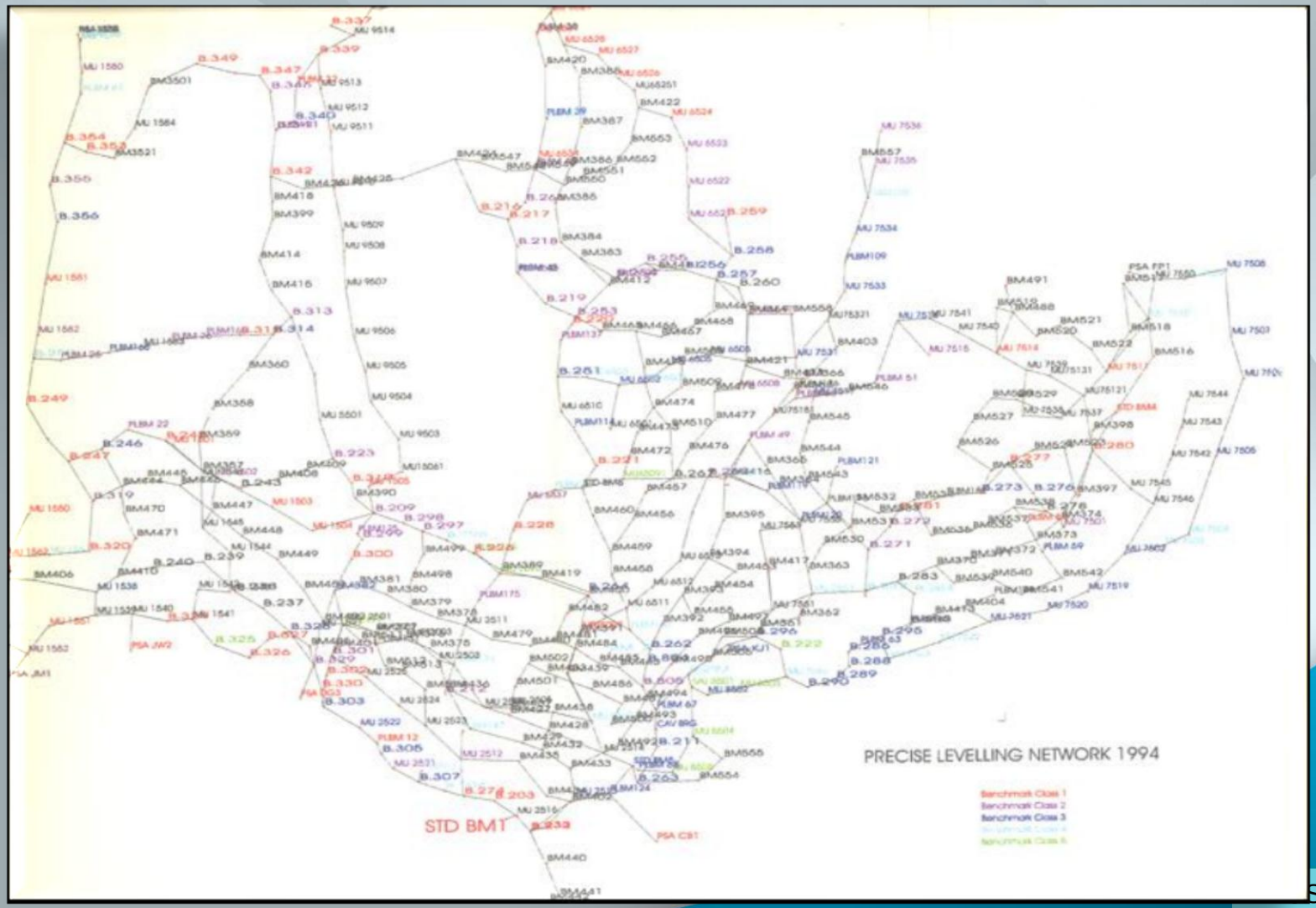


Precise Levelling Network

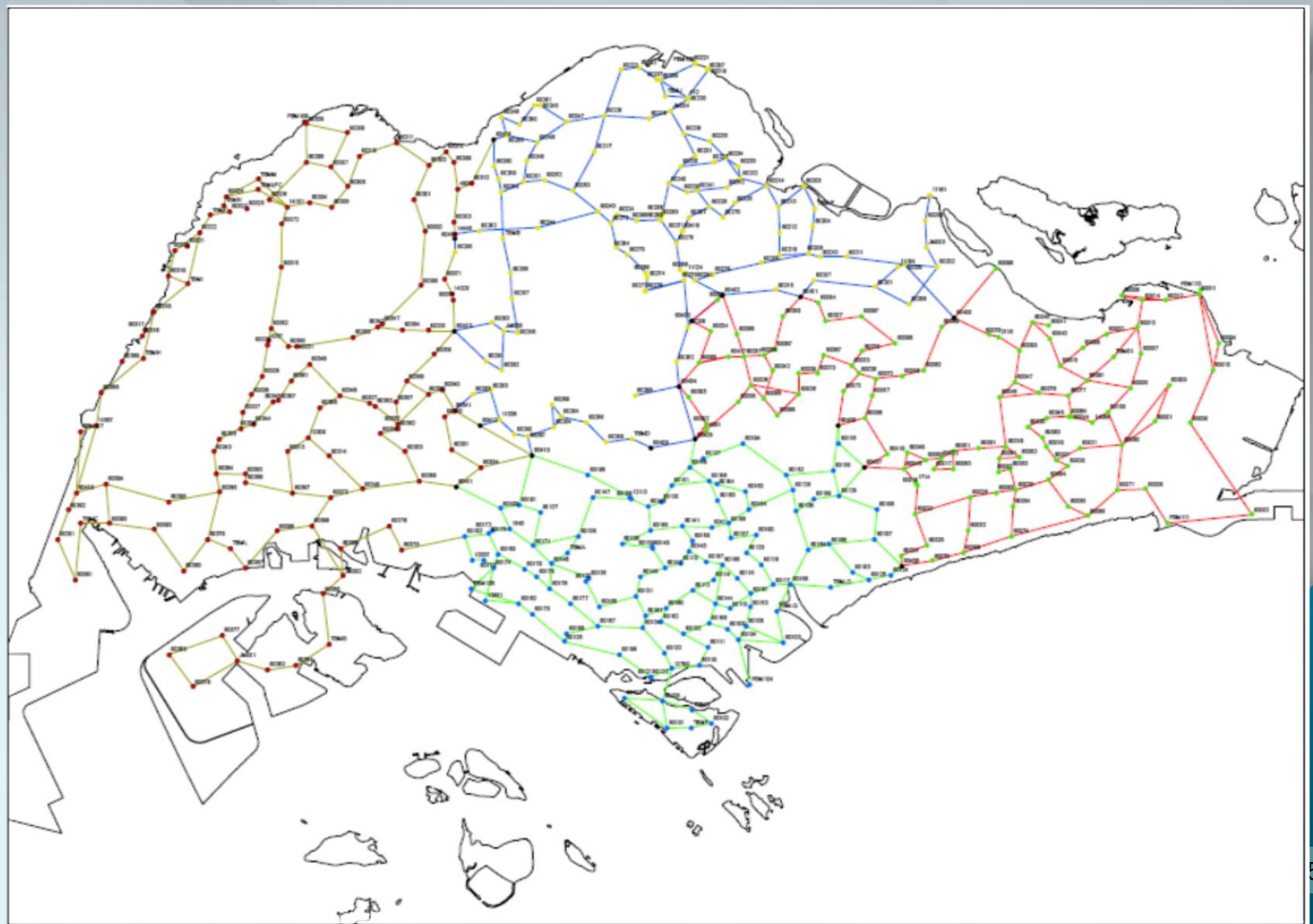
- Mapping Unit and Survey Department are the main agencies responsible for the infrastructure
- Since 1937, there were 8 levelling campaigns to densify and upgrade the infrastructure

	1937	1958	1977	1983	1987	1994	1997	Class
PSA TK1						3.58		
PSA TK3					4.011			
STD BM1		2.565		2.582	2.565	2.565		1
STD BM4		27.519		27.491	27.492	27.49		2
STD BM5				8.092	8.102	8.083		
STD BM6				6.554	6.558	6.553	6.553	1

1994 Singapore Precise Levelling Network



2009 Singapore Precise Levelling Network




W4
W3
W2
80405
W1
CAR PARK
B
Precise Level
Benchmark
80405
Singapore Land Authority
Do Not Destroy
10/03/2009
Standard BM 6 – used as the level datum
02/12/2008
In existence since 1983

Cavenagh Bridge

80153

W3

W2

W1

W4

to Asian Civilizations Museum

Oldest Bench Mark

In existence since 1882

22/11/2008

What is New in VCP?

- Standardise ID – PLBM, BM, B., MU etc (cross-search)
- Introduction of Fundamental BM (FBM)
- New datasheet
- New location plan and site plan (sketches)
- RTK coordinates
- Photograph of site

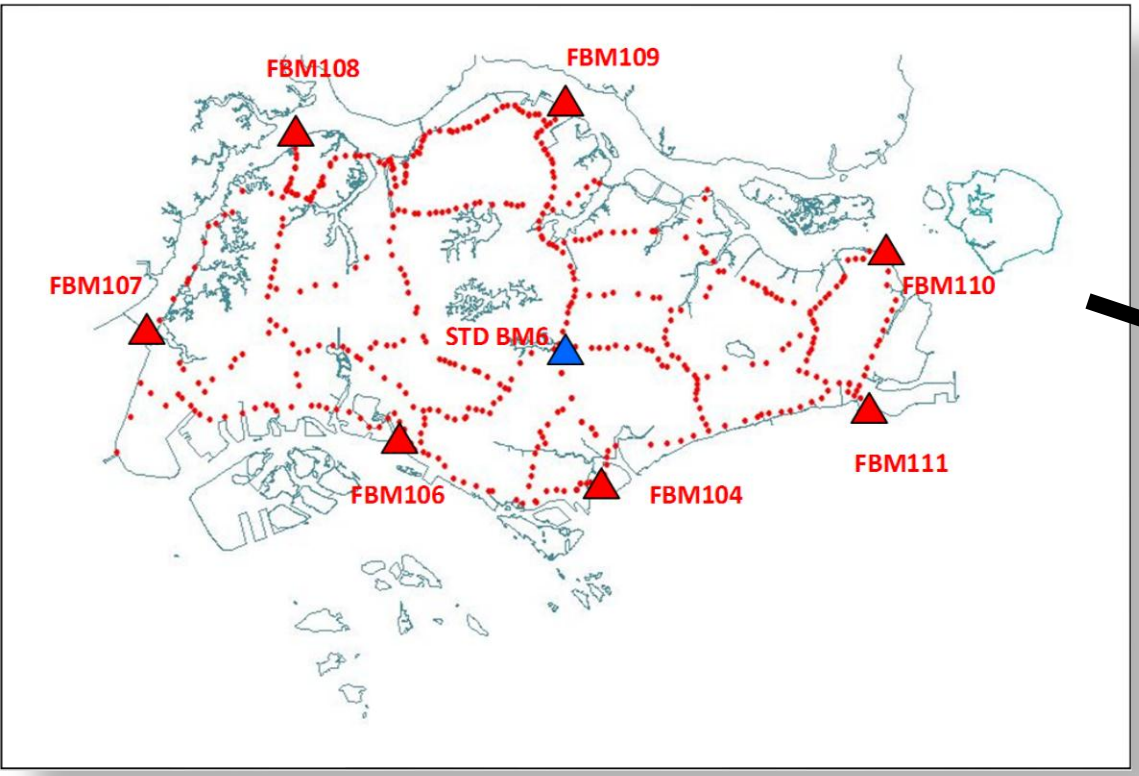
Standardisation

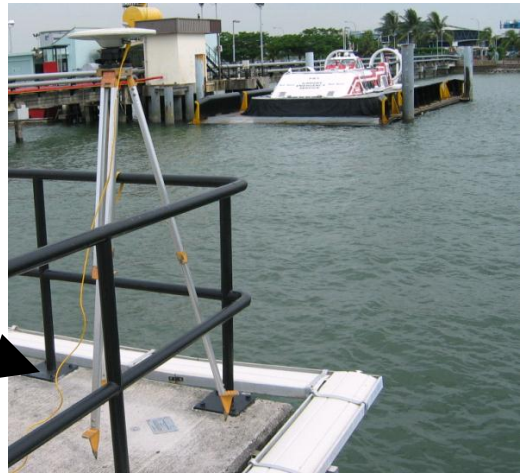
- Marker ID – 80XXX
- Identification plate
- Type of benchmark
- Type of witness marks
- Location plans – latest base on SLA street map
- Site plans (sketches) – CAD drawing

46	80144	BM500
47	80145	BM501
48	80146	0
49	80147	BM574
50	80148	BM576
51	80149	BM580
52	80150	BM583
53	80151	BM727
54	80152	BM730
55	80153	CAVBRG
56	80154	MU6512
57	80155	MU7553
58	80156	MU8502
59	80157	PLBM130

105	0	13337
106	80198	B798
107	80199	BM753
108	0	12113
109	80411	BM449
110	80408	B288
111	80406	BM365
112	80407	0
113	80405	STDBM6

Fundamental Bench Marks






FUNDAMENTAL BENCHMARK
NO. 167


W2
W3
W4
W1
80101
Palawan
Beach Walk
Precise Level
Benchmark
80101
Singapore Land Authority
Do Not Destroy
16/02/2009
Palawan Beach
12/12/2008


Precise Level
Benchmark
80060
Singapore Land Authority
Do Not Destroy
SURVEY
DEPARTMENT
DH 734
19/02/2009

Datasheet (old & new)

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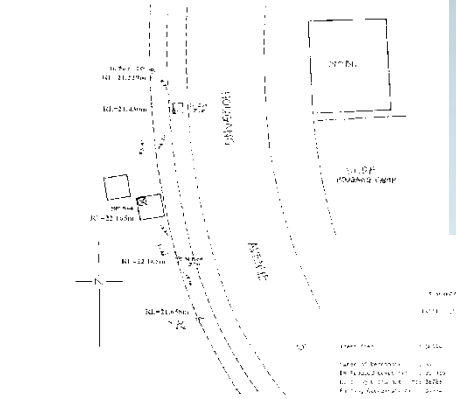
PRECISE LEVEL BENCH MARK

BM NO: BM544



Singapore Land Authority (SLA)
Vertical Control Point (VCP)

VCP No: 80400

Reduced Level (m): 5.122 Mark Type :BOLT

Vertical Accuracy : +/- 5 mm (95% confidence level)

Locality : TPE (NEAR LORONG HALUS)

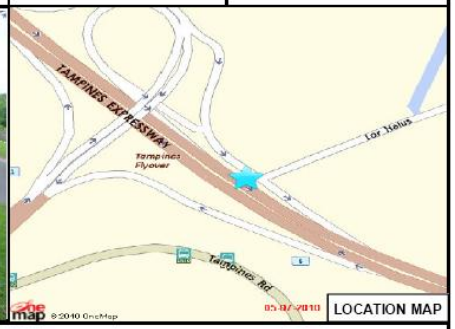
SVY21 Coordinates (m) : N 40386.235
: E 37496.62

WGS84 DATUM

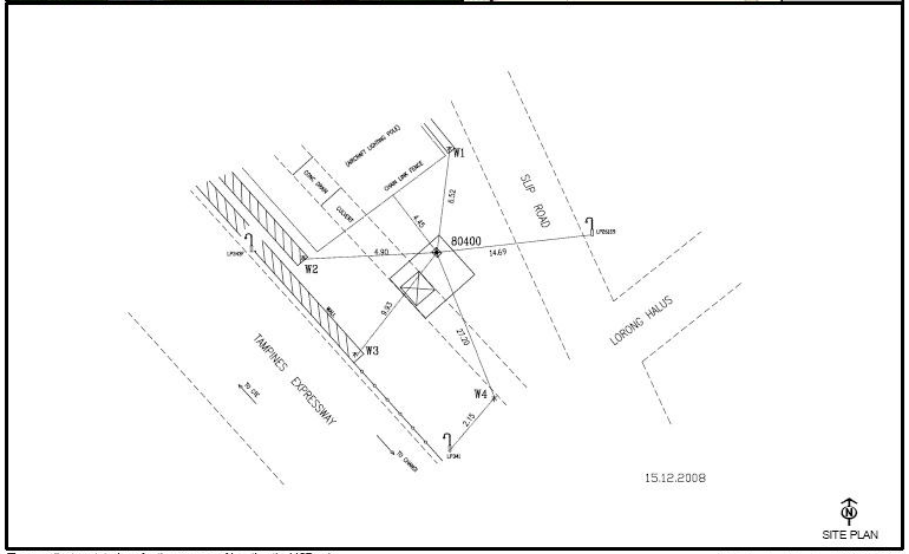
Latitude : N 1° 22' 53.4423"

Longitude : E 103° 55' 7.14997"

Witness Mark 1(W1)	Witness Mark 2(W2)	Witness Mark 3(W3)	Witness Mark 4(W4)
Mark Type : BOLT	Mark Type : BOLT	Mark Type : BOLT	Mark Type : BOLT
Height Relative to VCP: 0.003	Height Relative to VCP: 0.272	Height Relative to VCP: 1.038	Height Relative to VCP: 0.240
Reduced Level (m) : 5.125	Reduced Level (m) : 5.394	Reduced Level (m) : 6.160	Reduced Level (m) : 5.362



LOCATION MAP



SITE PLAN

The coordinates stated are for the purpose of locating the VCP only.
The reduced level is based on the Singapore Survey Department Precise Levelling Datum and measured to the top of the bolt

Datasheet updated on : 05-07-2010

Note: Location Map & Site Plan not to scale

Transferring of Height Datum to Offshore Islands

- Why transfer height datum to offshore islands
  - Vast development in islands (i.e. Jurong, Semakau)
  - Existing marks are lost
  - Last survey was in 1969
  - Need to have national standard in height measurement
- Hook Gage (Modified) method
- Aim to complete the survey by the end of 2010

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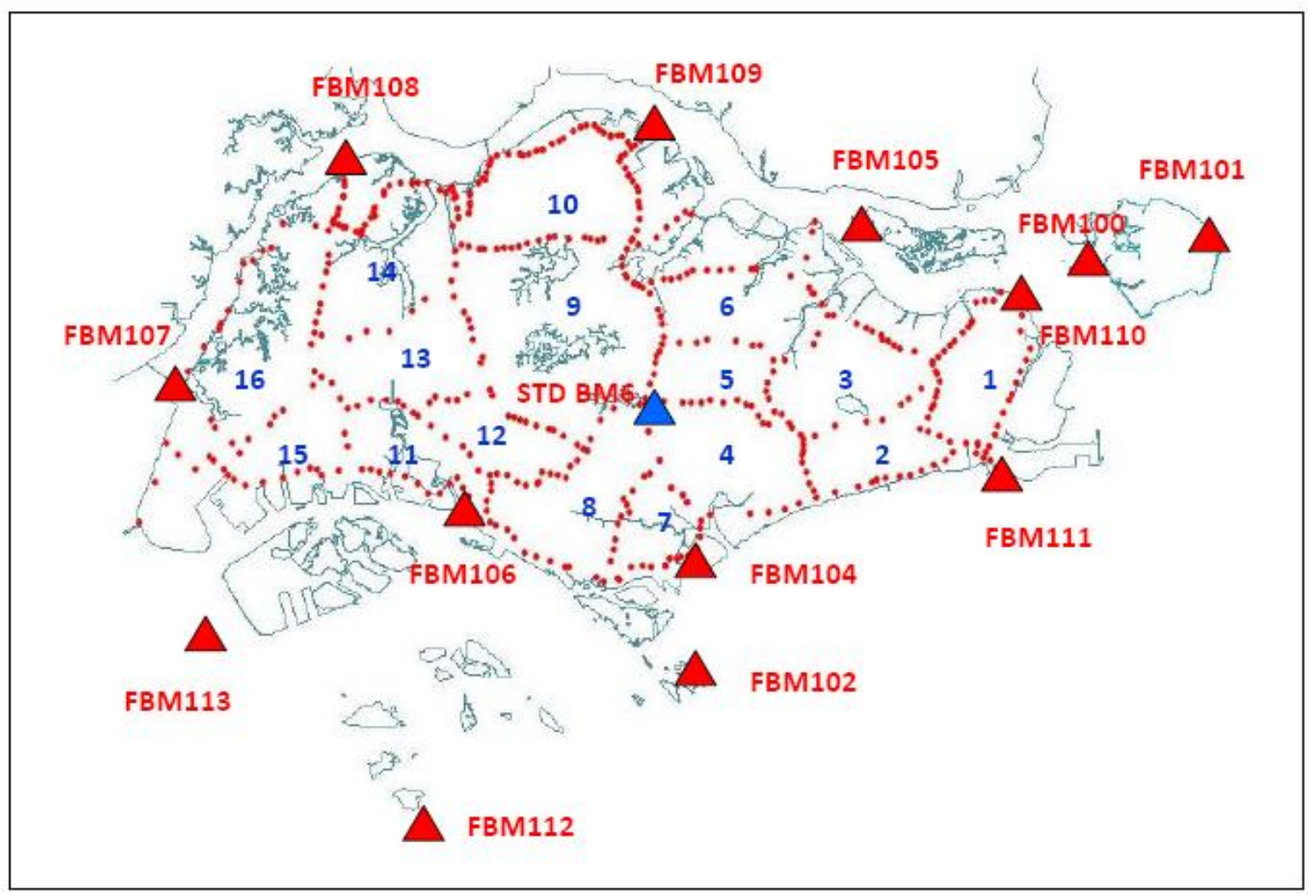
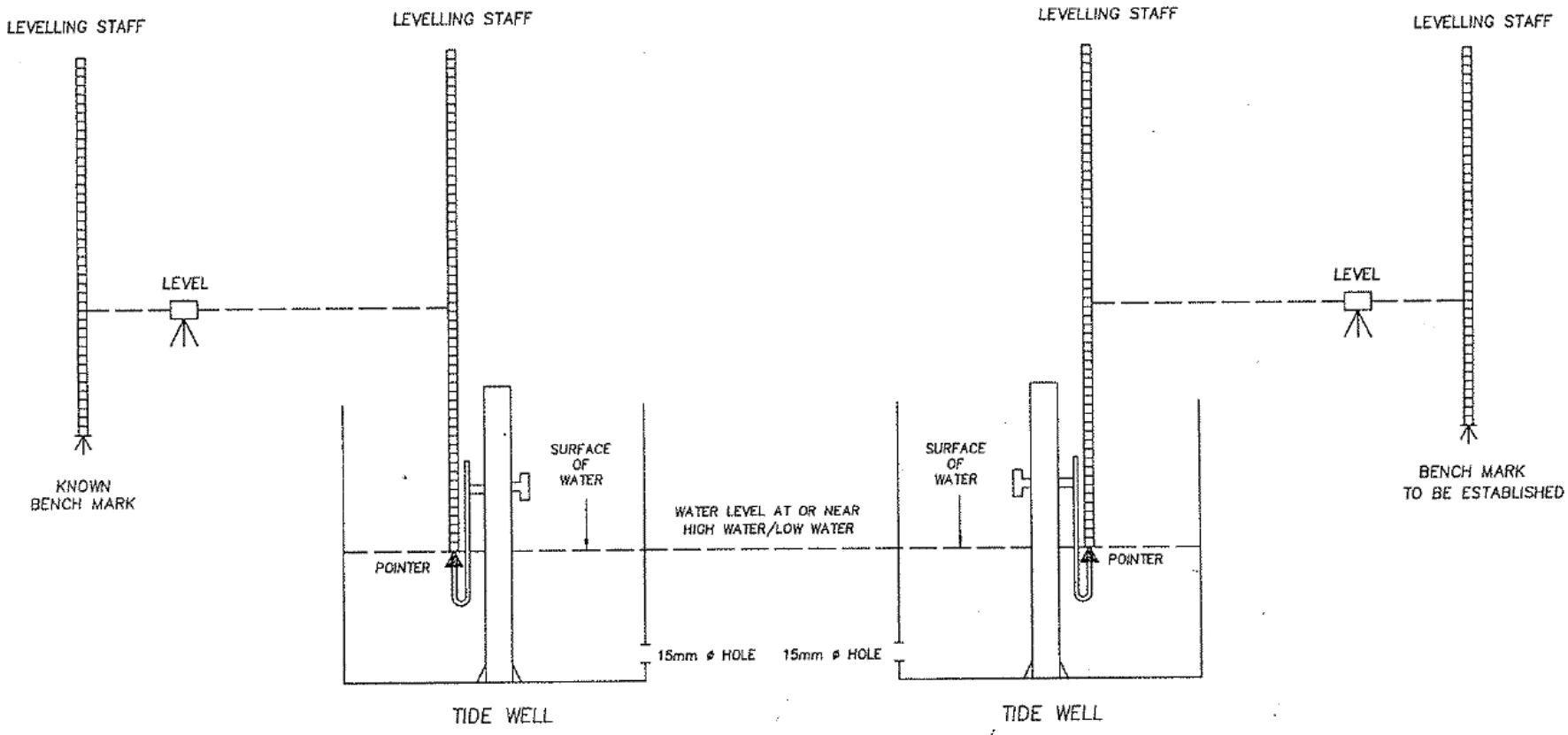
FBM on Islands



Hook Gage (Modified)

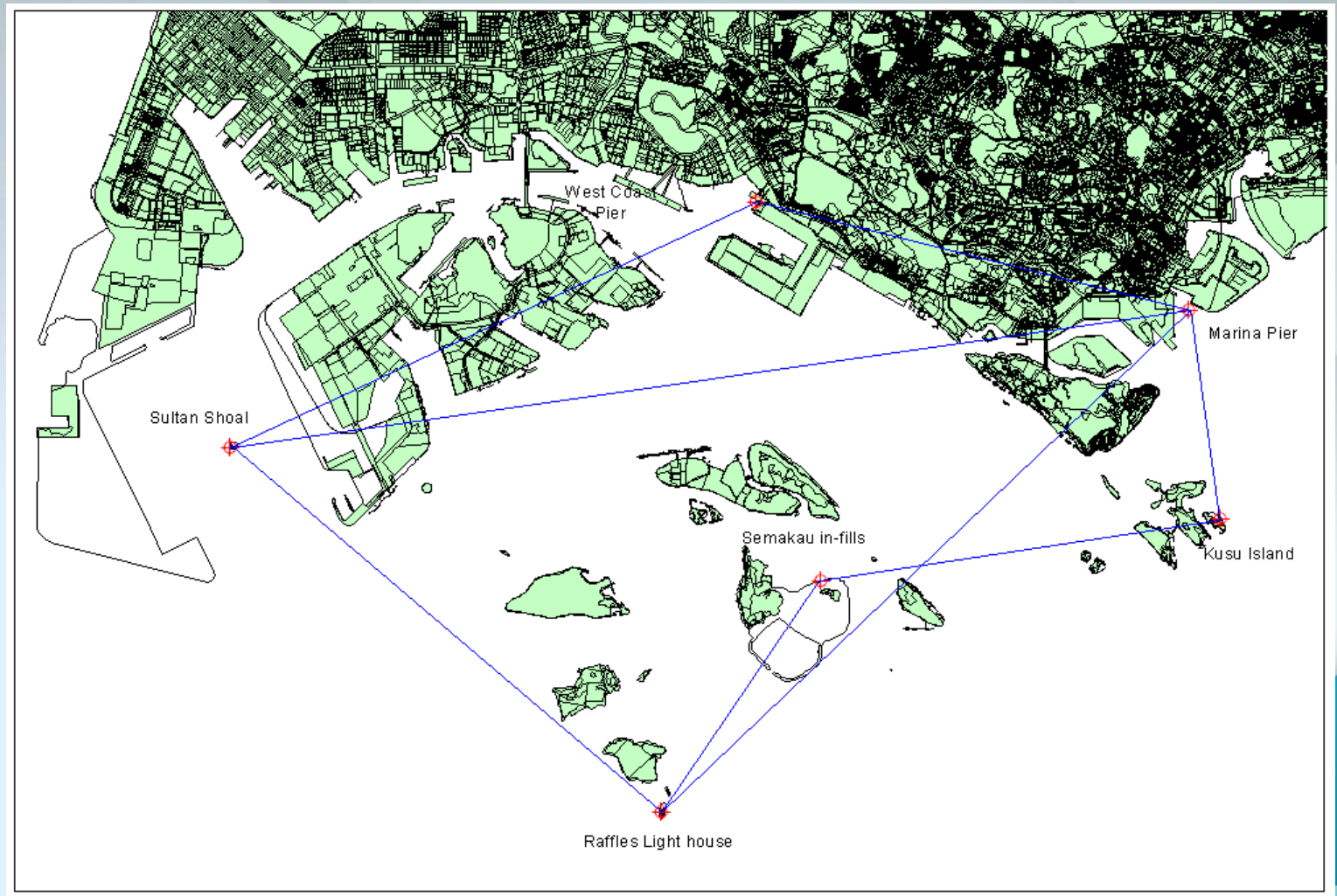


Adopted from Mr. Tan Choo Haw

Hook Gage - Equipment

Observation

Progress Updates

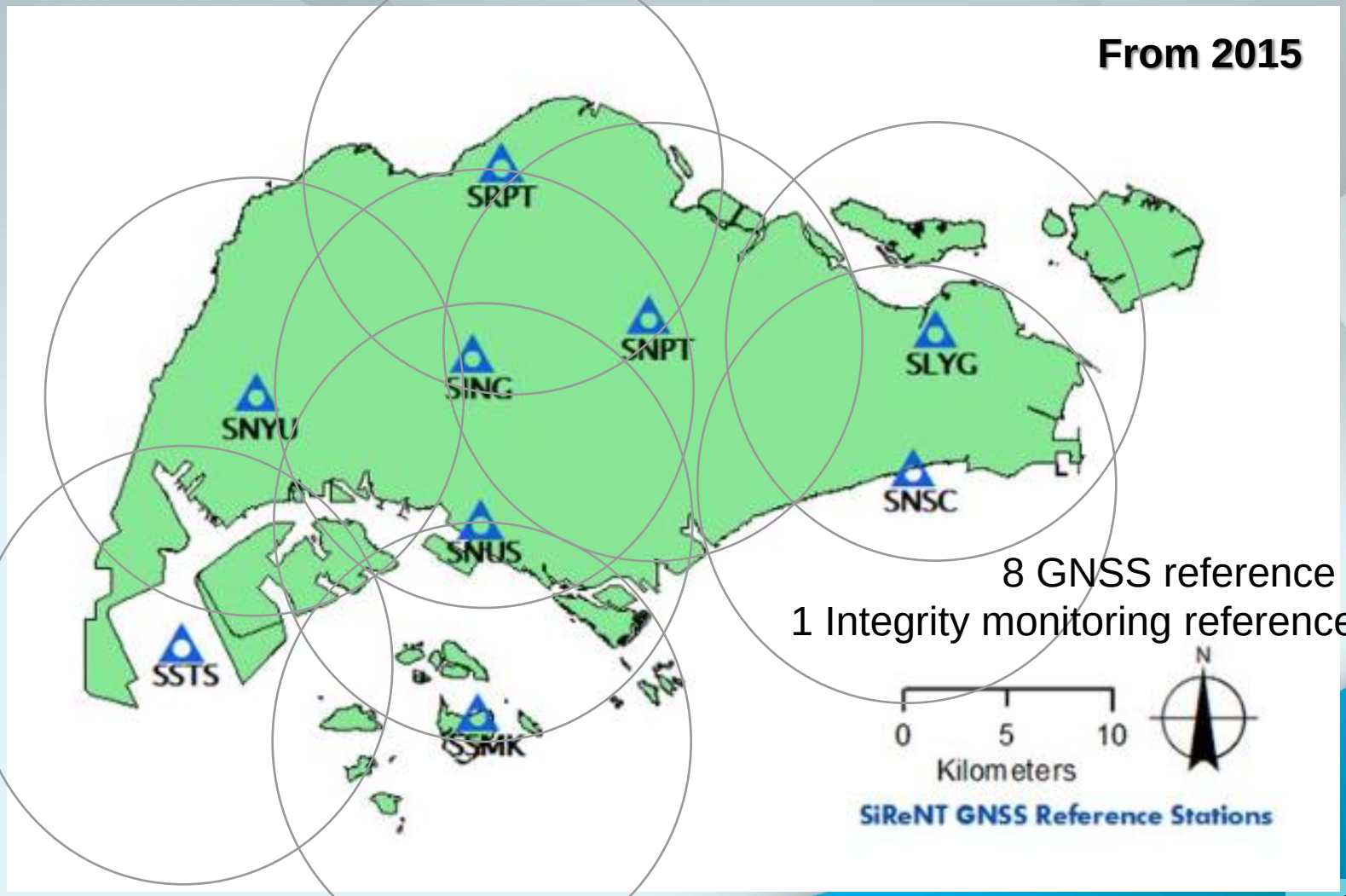


SiReNT in Singapore

Singapore Satellite Positioning Reference Network

- SiReNT is our National Differential GPS infrastructure that provides
  - consistent mapping and positioning coordinate system
  - fast, reliable and high accuracy positioning
- Started as a research project with NTU since 1999
- SiReNT was in operation since in 2006
- Primary objective is to support our national cadastral survey system

New Locations of Reference Stations



8 GNSS Reference Stations

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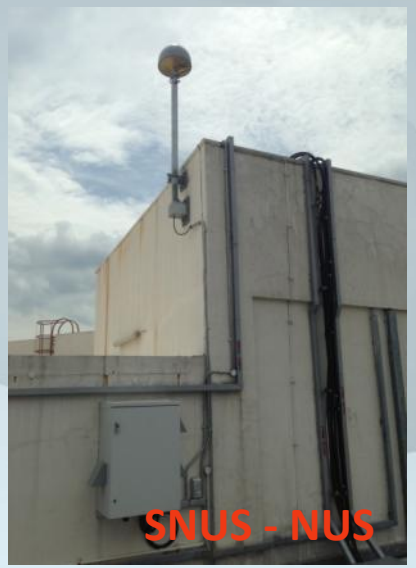
8 GNSS CORS



GNSS Reference Station Setup

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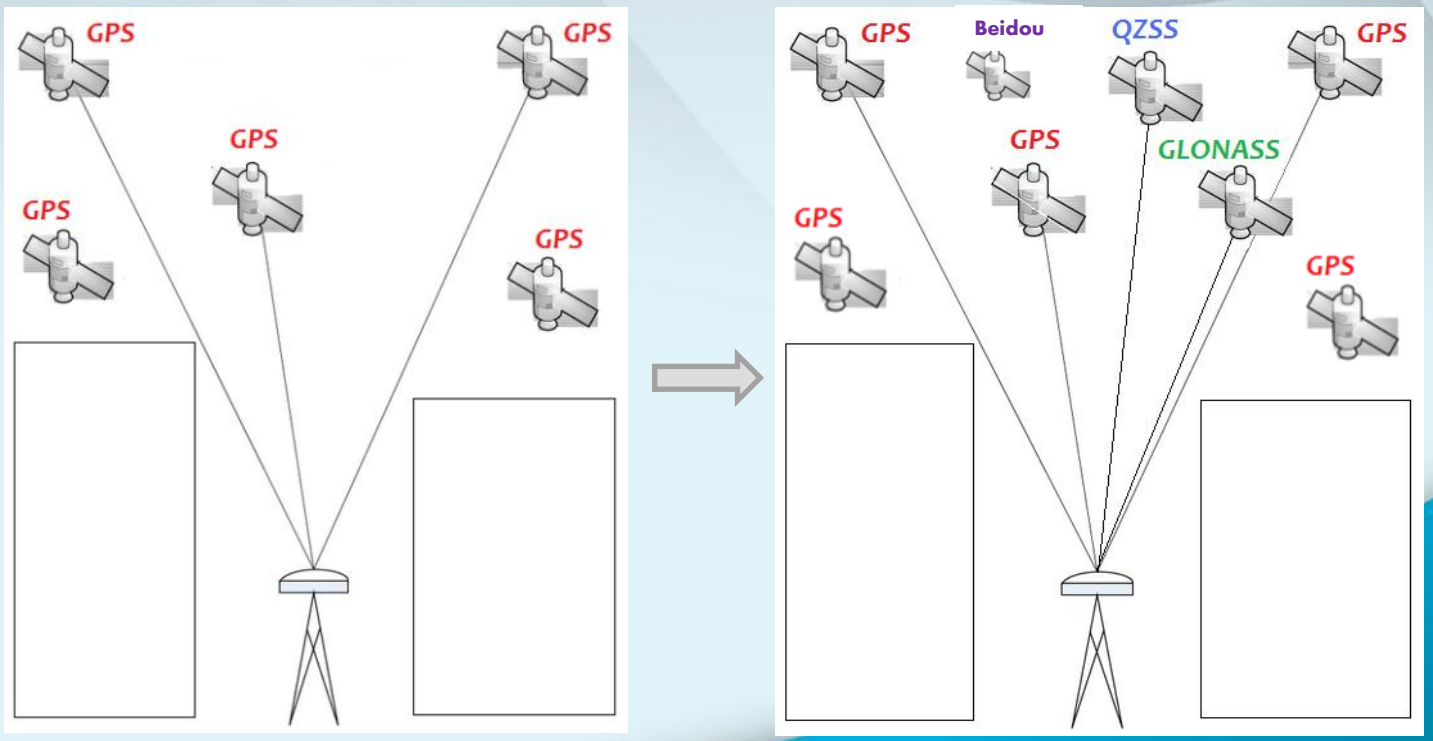
Compact and efficient setup.

Benefits of New SiReNT in Urban Environment

- Enhanced satellite availability
- Enhanced positioning efficiency

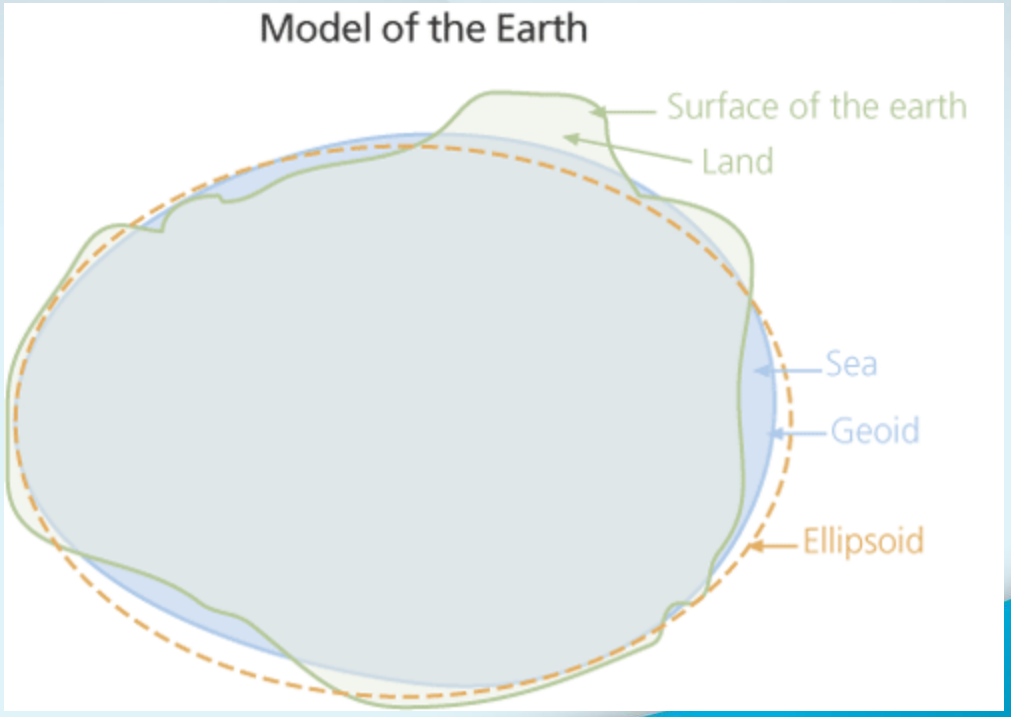


Development of SGEOID09

- Height is determined base on Survey Department Levelling Datum
- To used height data from GPS meaningfully in Singapore, a converter is required
- Countries e.g. UK, Australia, NZ, Malaysia have such conversion tools/models easily available
- SGeoid09 to convert GPS height (based on ellipsoid) to the height above national height datum

What is Geoid?

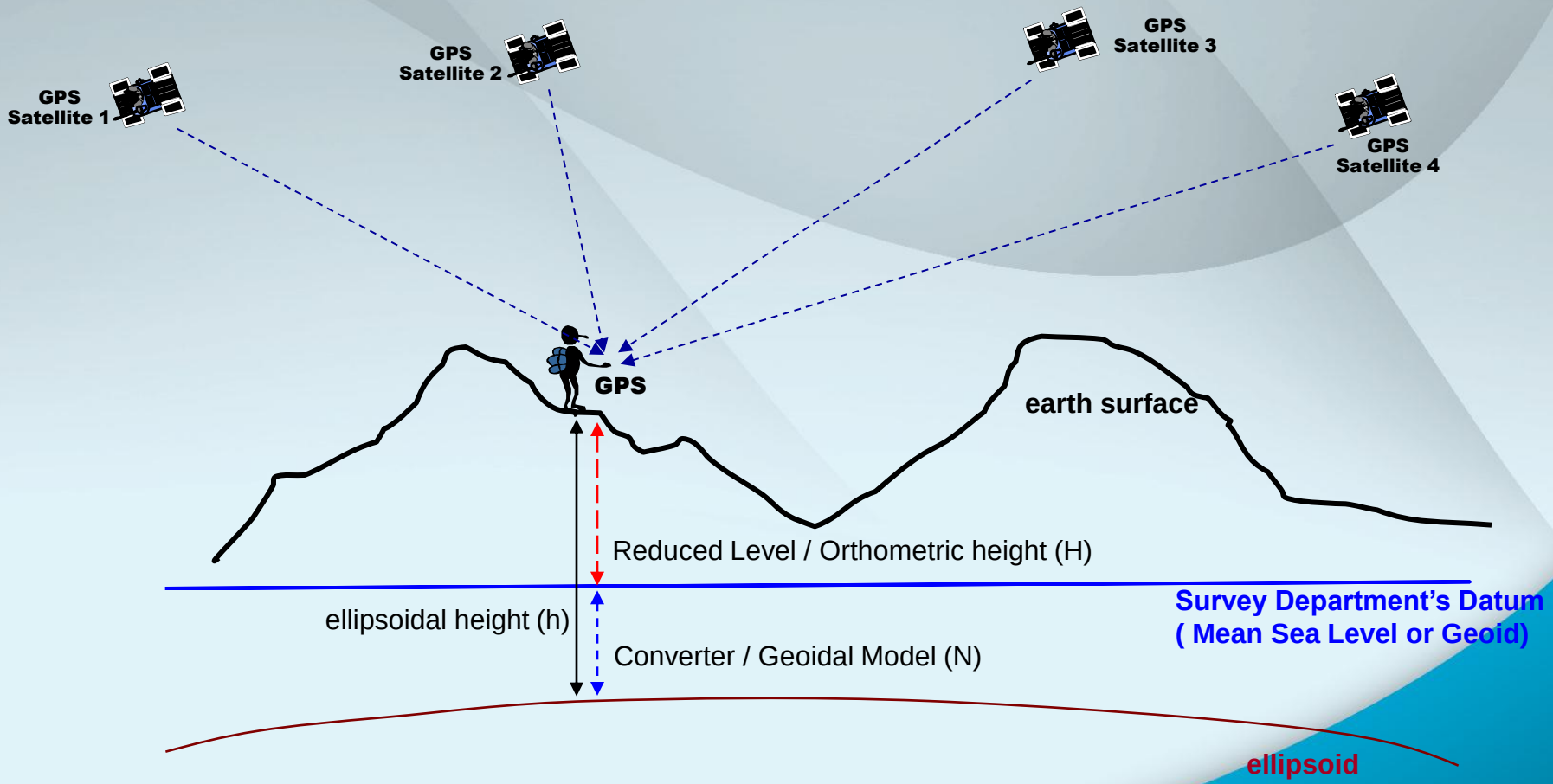
- Geoid is that equipotential surface of the Earth gravity field that most closely approximates the mean sea surface



Computation of Geoid Model

- Computation based on geometric method, precise levelling and GPS height measurements
- Stepwise Multiple Regression using the method of forward selection was used to compute the polynomial equation for the geometric geoid
- Over 450 points were used in computation
- The model is verified using independent points

Concept



$$H = h - N$$

What was done

- In 2004, we started work to create our own “converter” (Geoid Model)
- Scope of work involves
  - Intensive field work of precise levelling and DGPS heighting
  - Data processing to validate field results
  - Creation of Geoid model by consultant
  - Field verification of Geoid model (converter)

Converter / Geoid Model

$$N = 8.94184 + 2.08529*E - 0.16502*N - 0.661429*E^2 - 0.139884*N^2 + 0.232462*E^6*N$$

Where,

$$E = \frac{(\text{Easting} - 4813.123)}{43462405}$$

$$N = \frac{(\text{Northing} - 25542573)}{24037.684}$$

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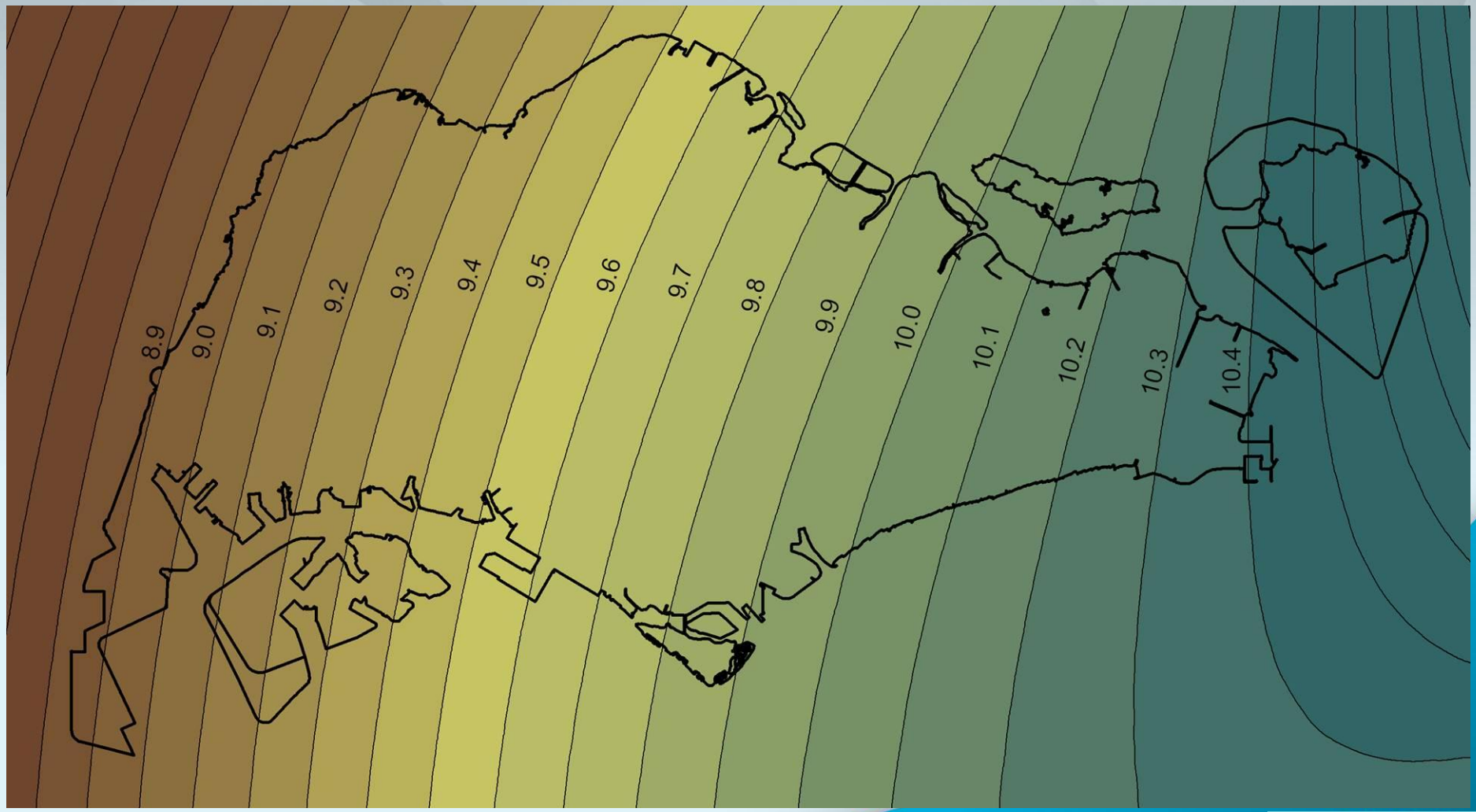
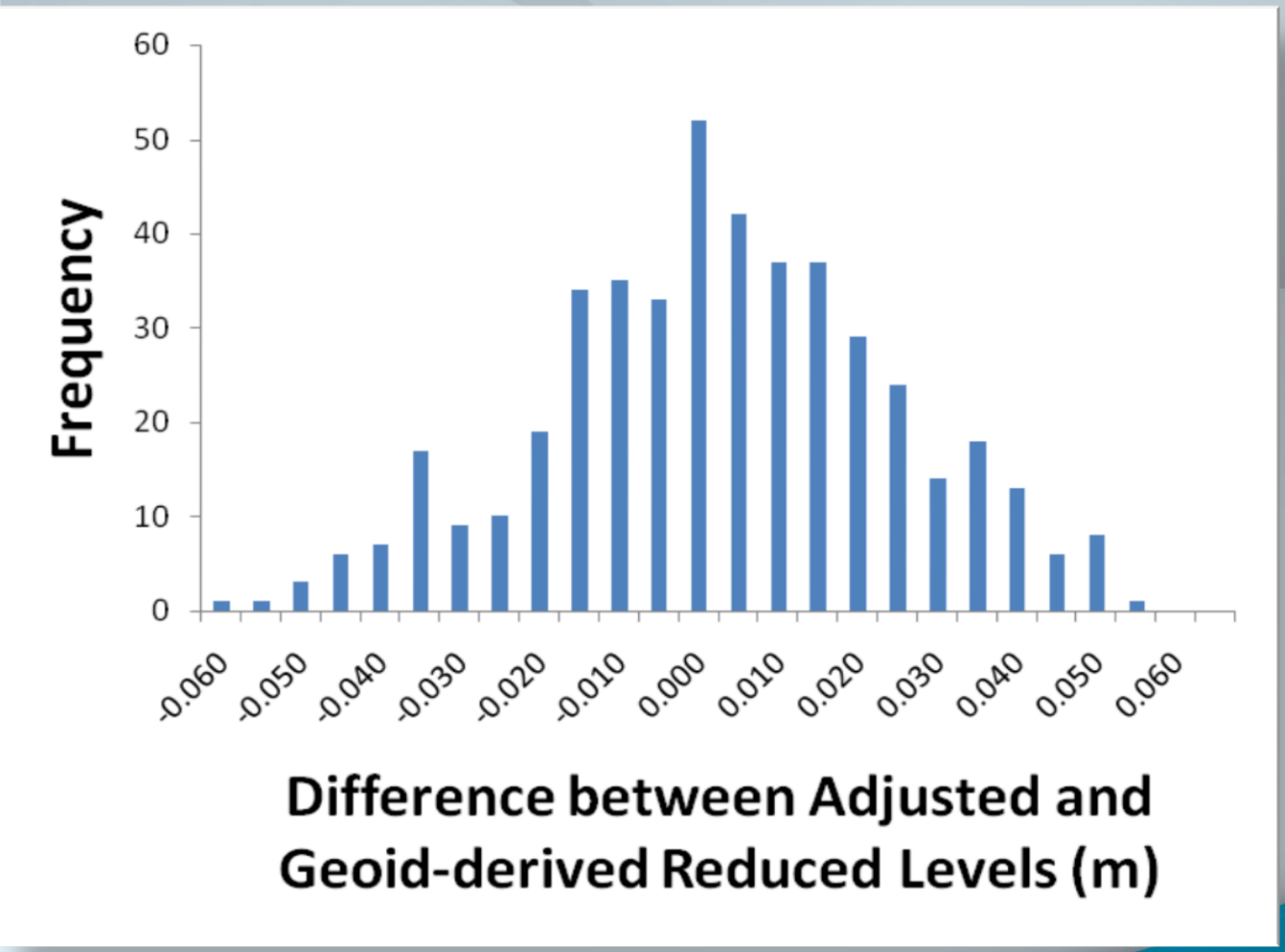
“Geoid Model” or Converter (N)



Benefits of SGeoid09

- Realisation of a full 3D GPS Infrastructure through SiReNT and SGeoid09
- Standardisation of height in Singapore
- Faster acquisition of height data for lower accuracy mapping activities

Distribution of the differences between the surveyed and the geoid-derived reduced level



- Total test marks = 456
- Differences between the surveyed and geoid-derived reduced levels confined within
  - 82% - ±0.030 m
  - 95% - ±0.040 m
  - 99% - ±0.050 m

Online conversion on SiReNT website

- Allows users to enter existing GPS coordinates, one point at a time, to obtain a converted height in our datum

Incorporated in end-user products

- End-user equipment and software e.g.
  - Capturing real-time height data in GPS equipment
  - Post-processing of GPS results in GPS software
  - Using GIS software to display heights from SGeoid09

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Thank You