

# Height Datum & Height Determination using GNSS in Singapore

Dr Victor Khoo

Land Survey Division

# Singapore

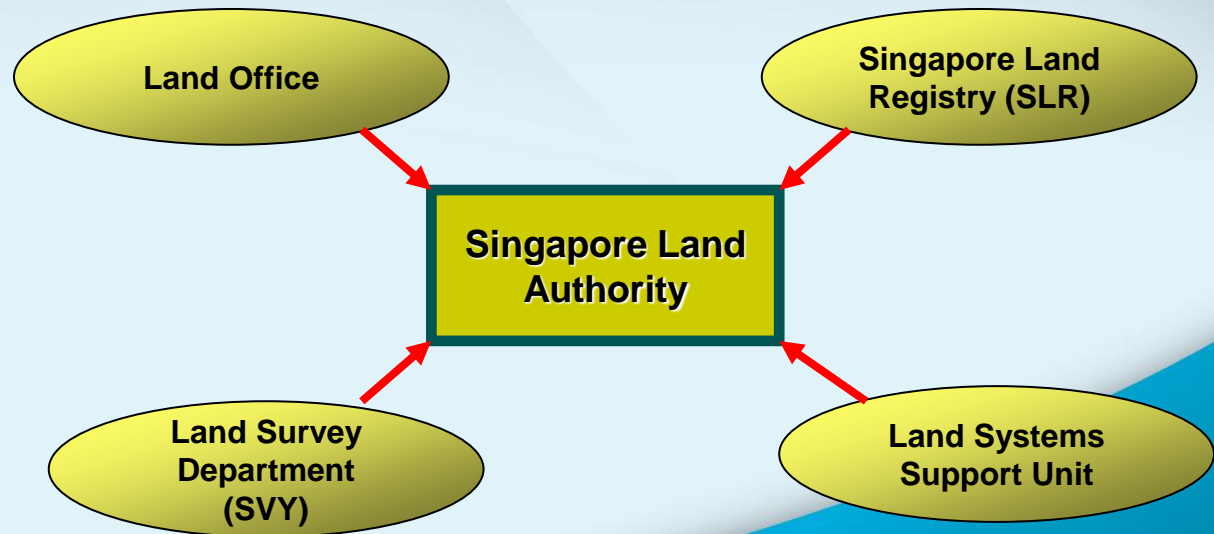


**716.1 sq km**



# 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



**Berlin**

Chaya

Pier 14

Gateway  
Apartments &  
Town Homes

Plant C

Google



Business Location Center  
**Berlin-Brandenburg**

Stadtmmodell © Der Senat von Berlin  
Image © 2007 AeroWest  
© 2007 Europa Technologies  
Image © 2007 GeoContent

©2007 Google™

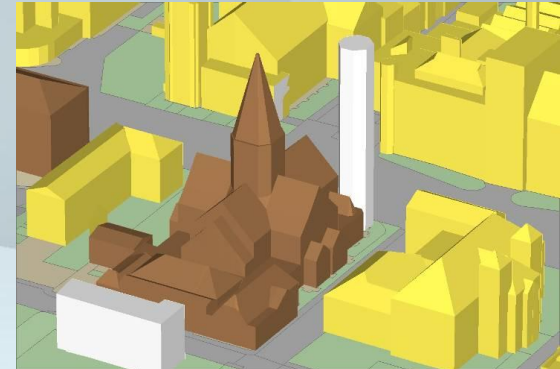
©SLA 2015

# 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

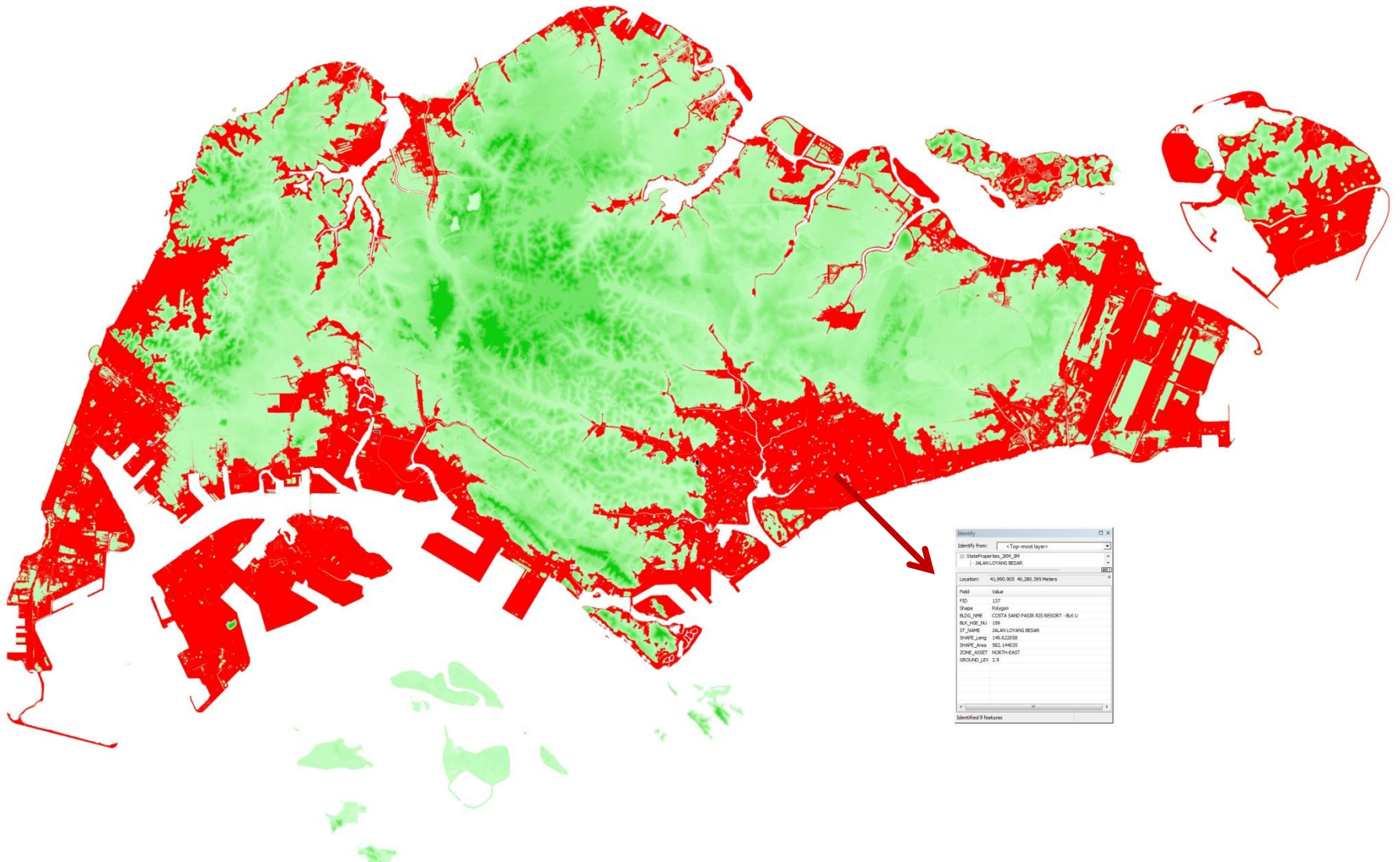
# ICSM (Australia & New Zealand) – Cadastre 2034

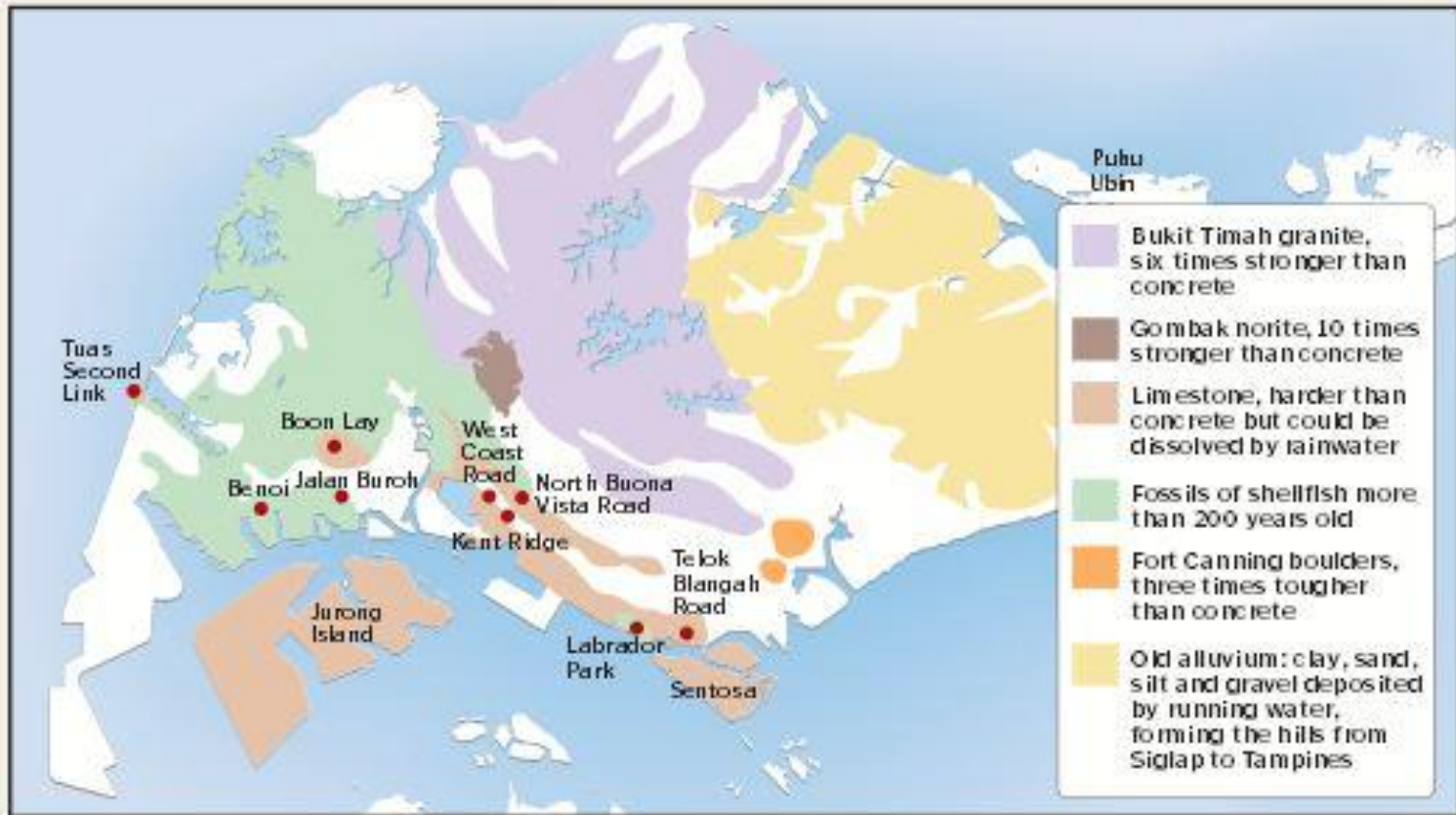
- Vision for Cadastre 2034 - “A cadastral system that enables people to readily and confidently identify the location and extent of all rights, restrictions and responsibilities related to land and real property.”



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

# Climate Change and Height Datum

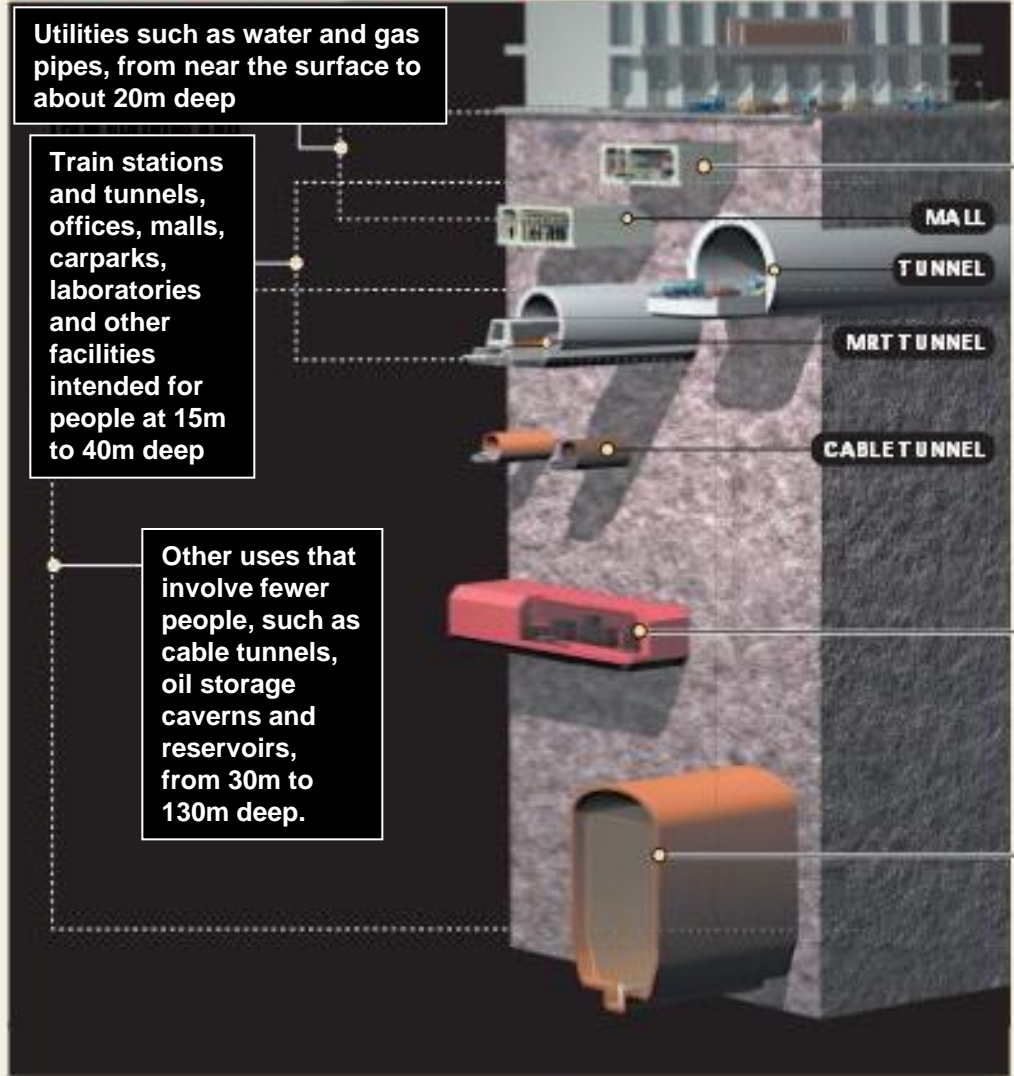




# GOING UNDERGROUND

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?



Utilities such as water and gas pipes, from near the surface to about 20m deep

Train stations and tunnels, offices, malls, carparks, laboratories and other facilities intended for people at 15m to 40m deep

Other uses that involve fewer people, such as cable tunnels, oil storage caverns and reservoirs, from 30m to 130m deep.



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

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

# Underground Science City



# Building “Spaces” in Singapore?



# Building Industrial “Space” over Expressway in Singapore





CNET > Tech Industry > Singapore plans to be world's first 'Smart Nation'

# 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

[0](#) / [0](#) / [293](#) / [150](#) / [g+](#) / [more +](#)



**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

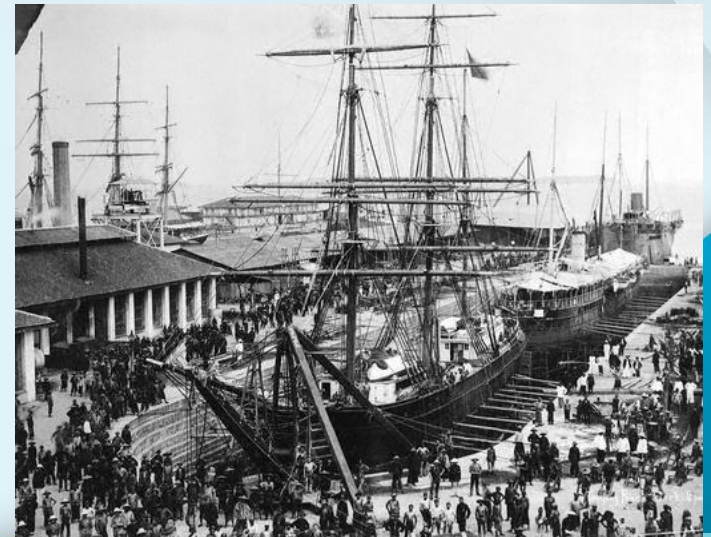


# Extent of Underground Ownership

- 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)



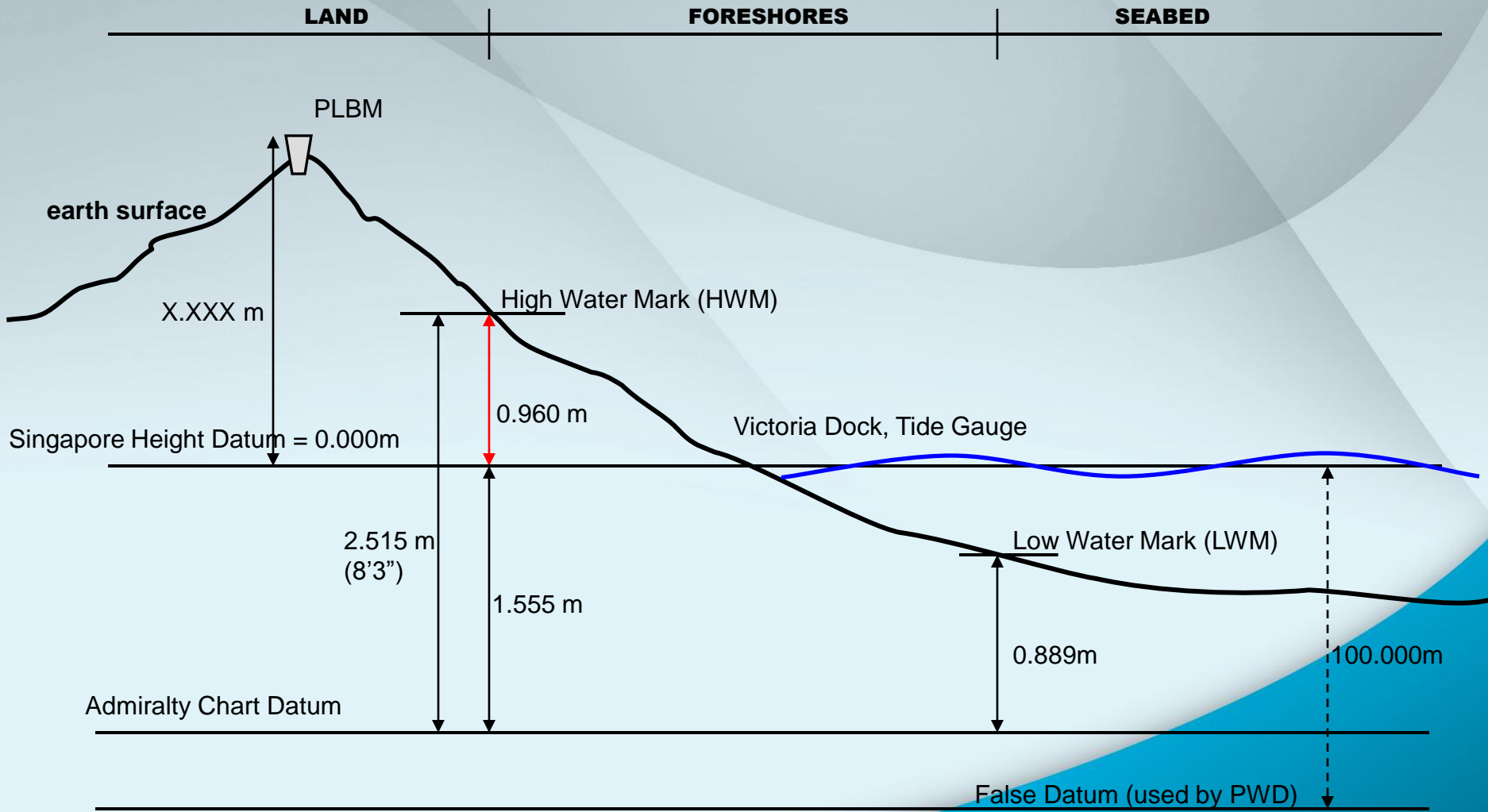
# Tide Gauge at Victoria Dock

- 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

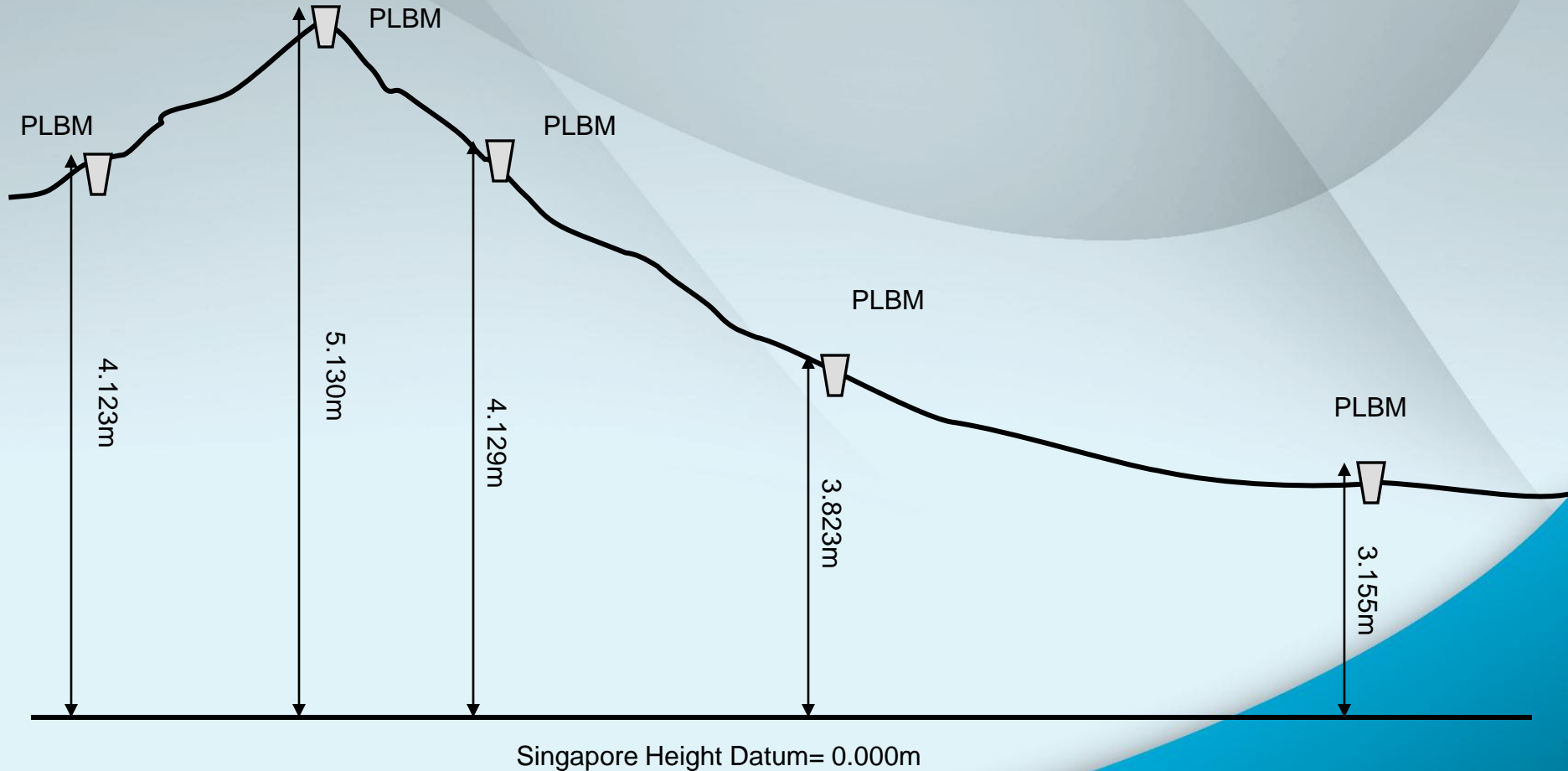
# What is HWM?

- 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



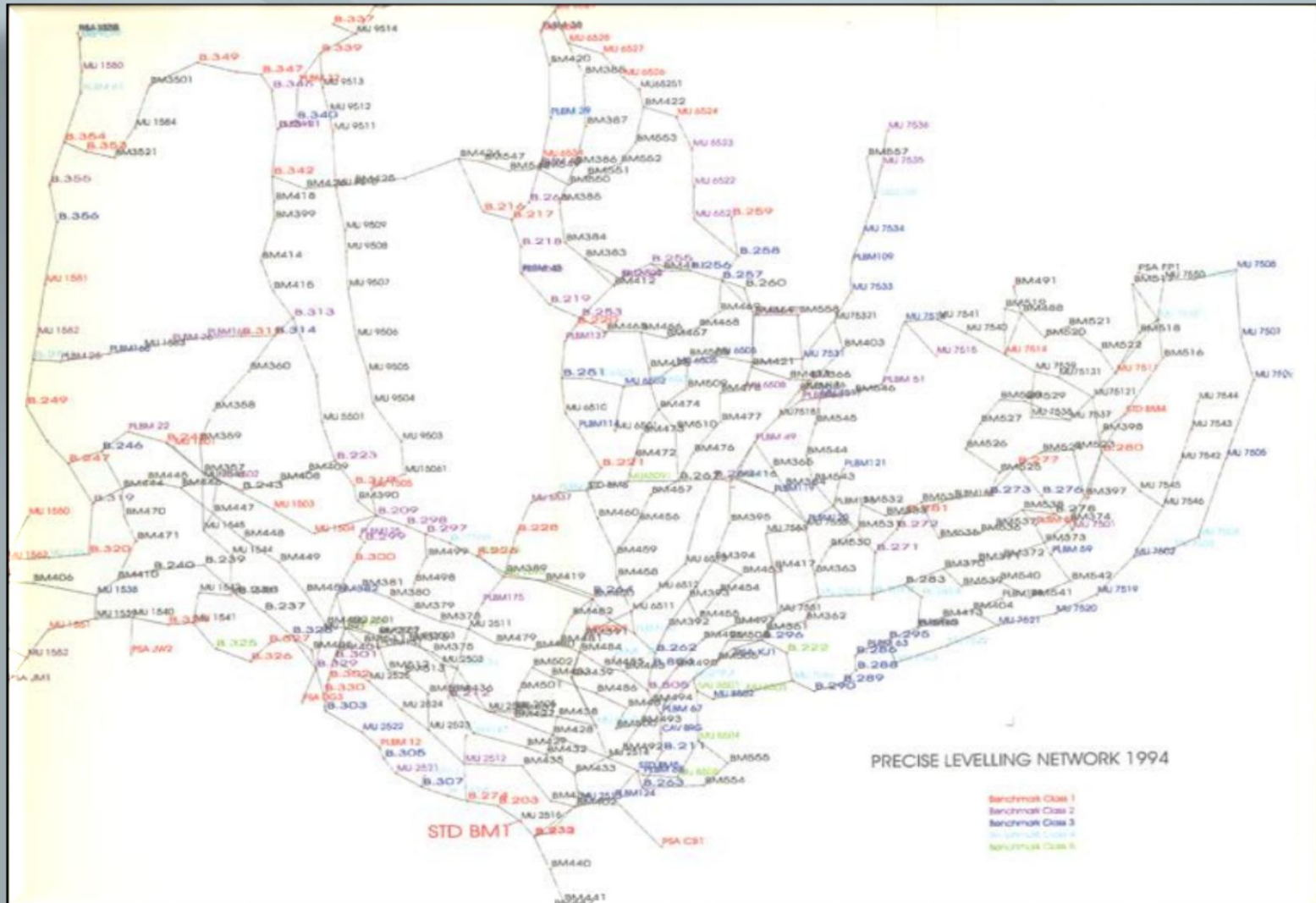


# Precise Levelling Network

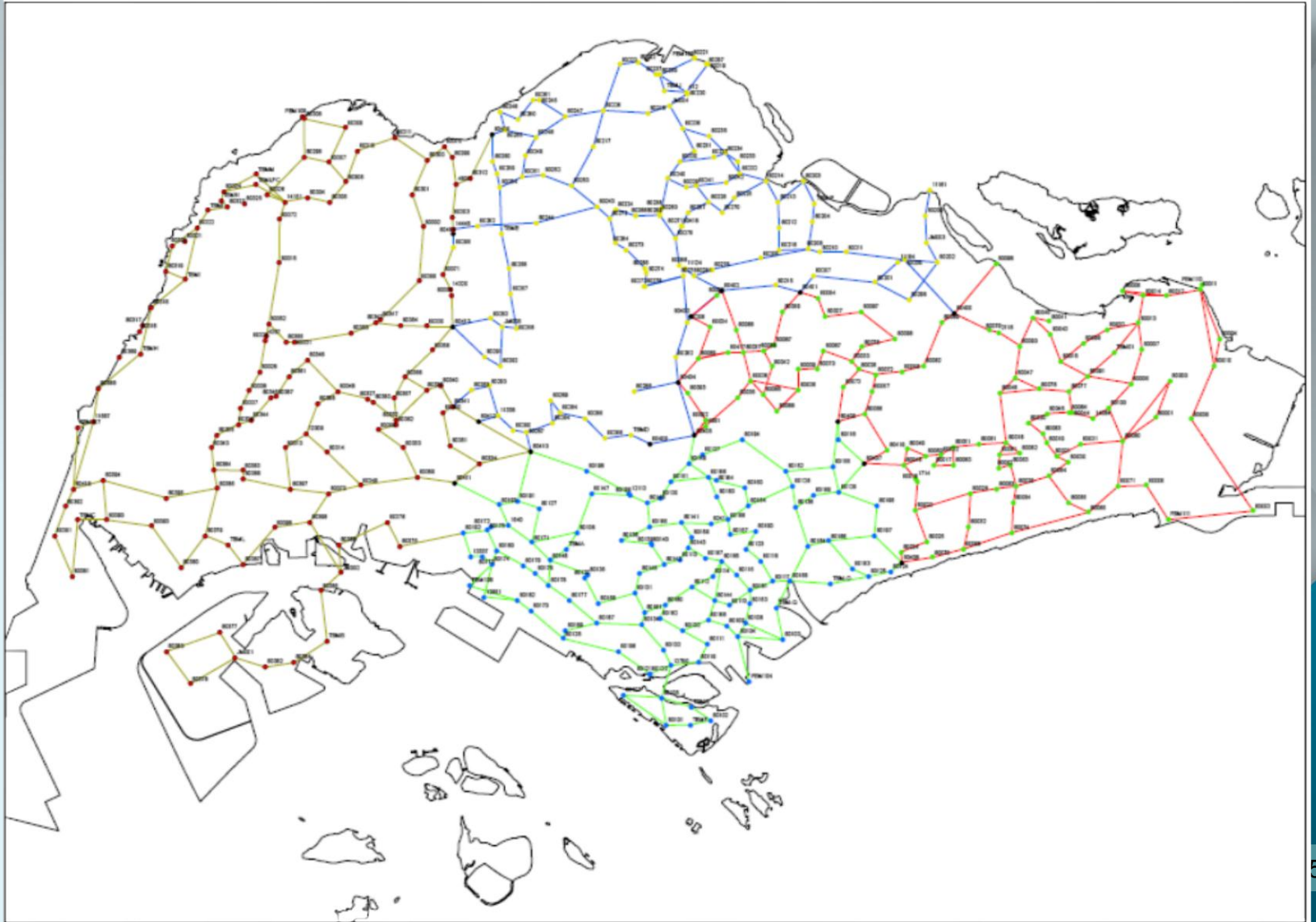
- Mapping Unit and Survey Department are the main agencies responsible for the infrastructure
- Since 1937, there were 8 levelling campaigns to densify and upgrade the infrastructure

	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		
<b>STD BM6</b>				<b>6.554</b>	<b>6.558</b>	<b>6.553</b>	<b>6.553</b>	<b>1</b>

# 1994 Singapore Precise Levelling Network



# 2009 Singapore Precise Levelling Network





W4

W3

W2

W1

80405



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?

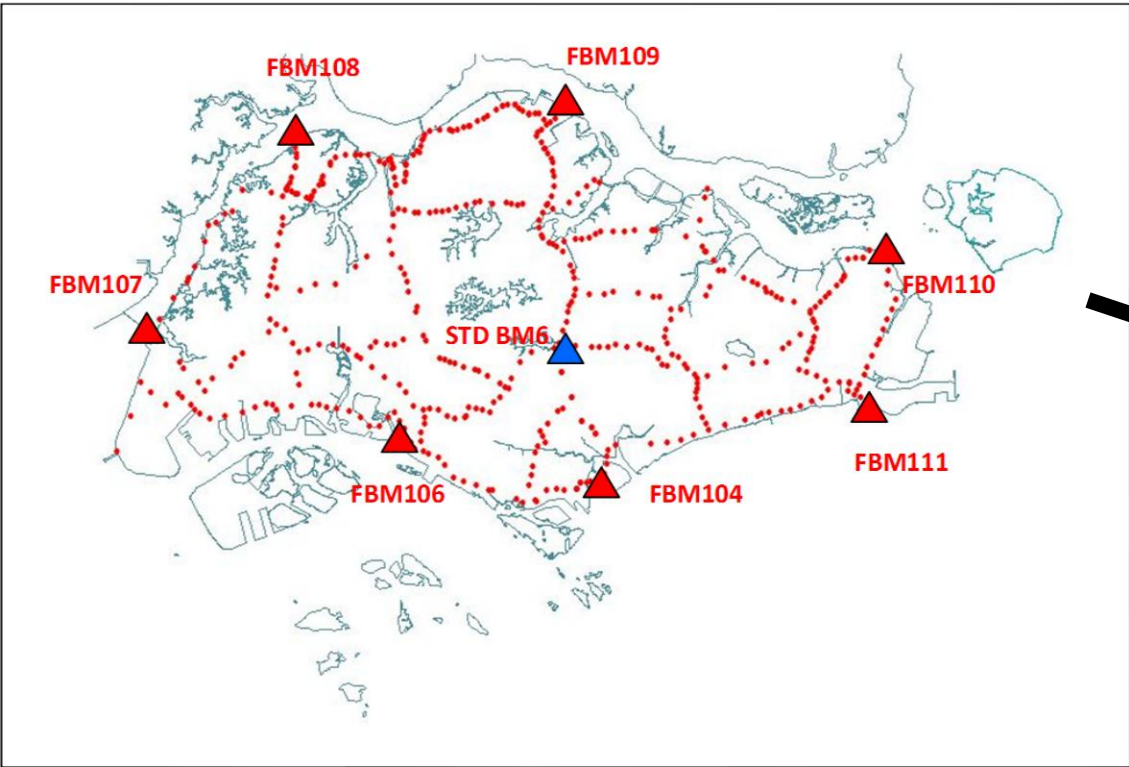
- Standardise ID – PLBM, BM, B., MU etc (cross-search)
- Introduction of Fundamental BM (FBM)
- New datasheet
- New location plan and site plan (sketches)
- RTK coordinates
- Photograph of site

# 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	105	0	13337
47	80145	BM501	106	80198	B798
48	80146	0	107	80199	BM753
49	80147	BM574	108	0	12113
50	80148	BM576	109	80411	BM449
51	80149	BM580	110	80408	B288
52	80150	BM583	111	80406	BM365
53	80151	BM727	112	80407	0
54	80152	BM730	113	80405	STDBM6
55	80153	CAVBRG			
56	80154	MU6512			
57	80155	MU7553			
58	80156	MU8502			
59	80157	PLBM130			

# Fundamental Bench Marks







 SCDOT  
South Carolina Department of Transportation  
FUNDAMENTAL BENCHMARK  
NO. 117  
Established in 1988  
Caution: This marker was installed in  
1988 and may not meet the current  
requirements of the Survey Benchmarks Act of  
2002. The Survey Benchmarks Act of 2002  
requires that all survey benchmarks be  
installed in accordance with the current  
standards of the International Association of  
Bridge and Structural Engineers (IABSE).



**Palawan  
Beach Walk**

W2



W1



W3



W4



80101



**Palawan Beach**

12/12/2008

Precise Level  
Benchmark

80060

Singapore Land Authority  
Do Not Destroy

SURVEY  
DEPARTMENT



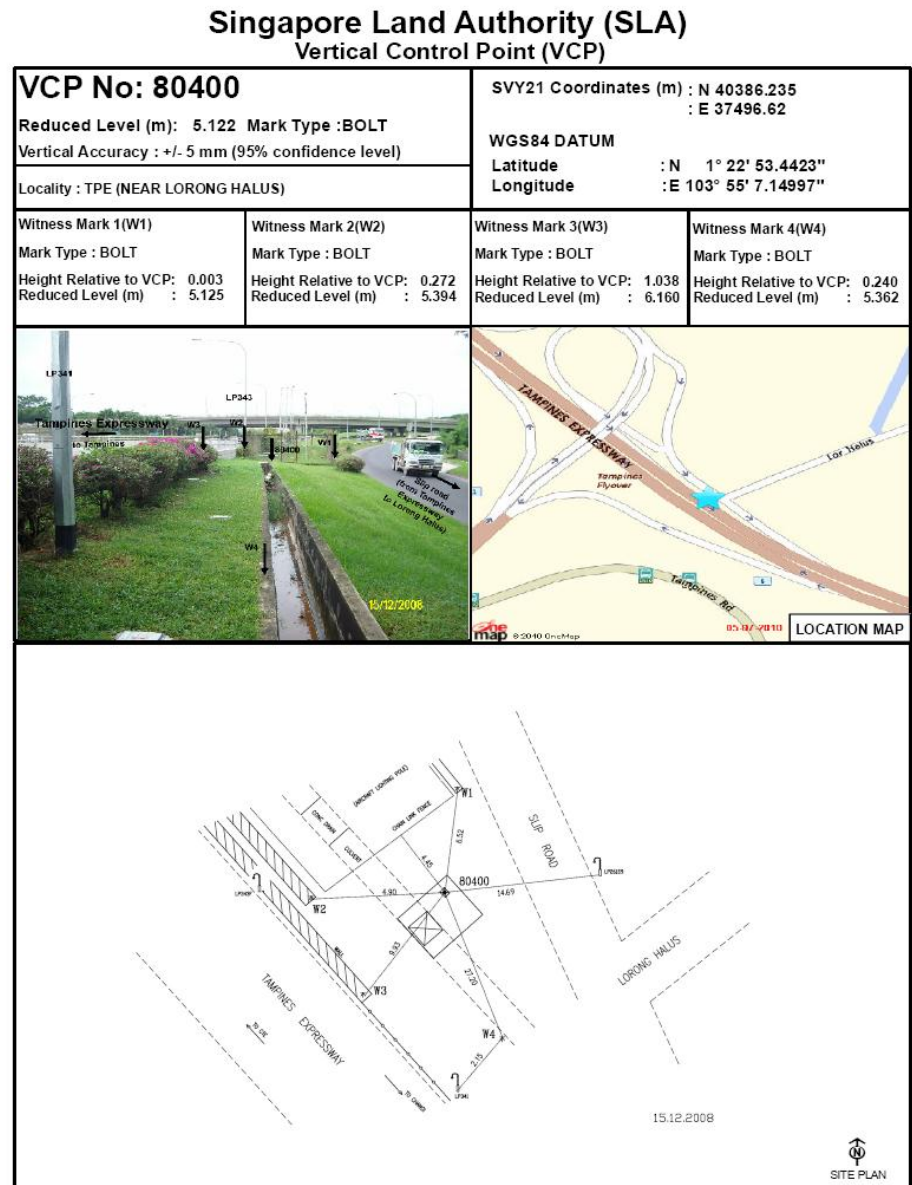
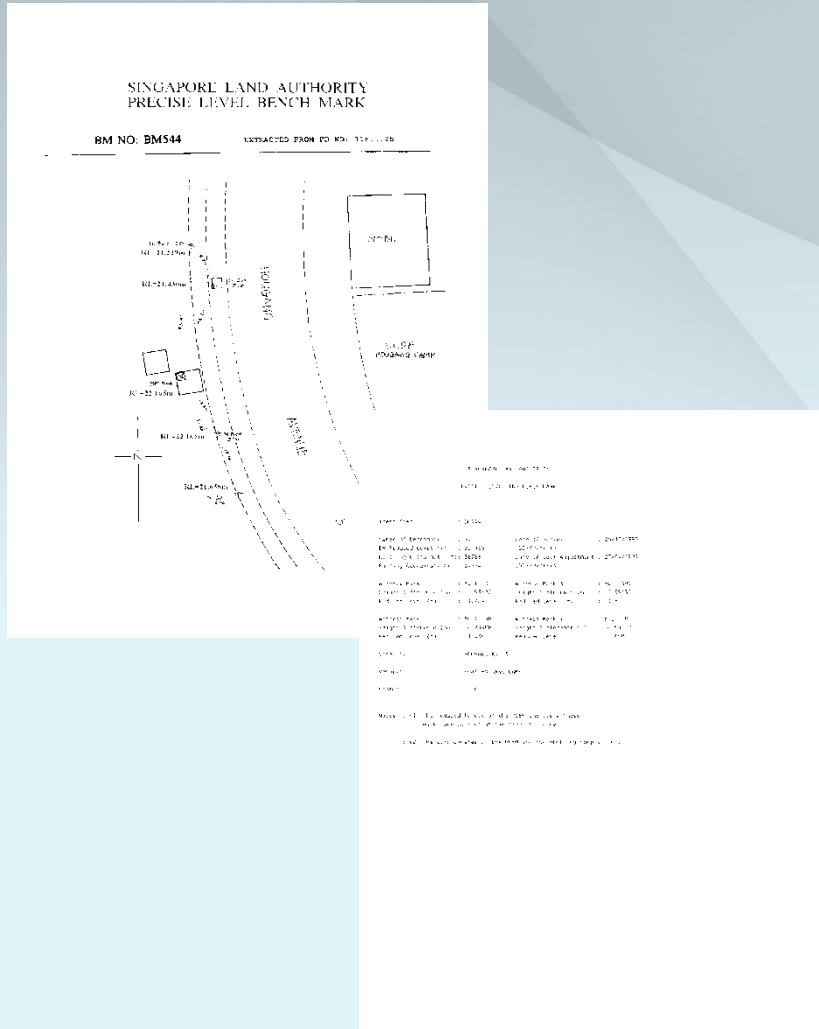
BM 134

19/02/2009



SINGAPORE  
LAND AUTHORITY

# Datasheet (old & new)



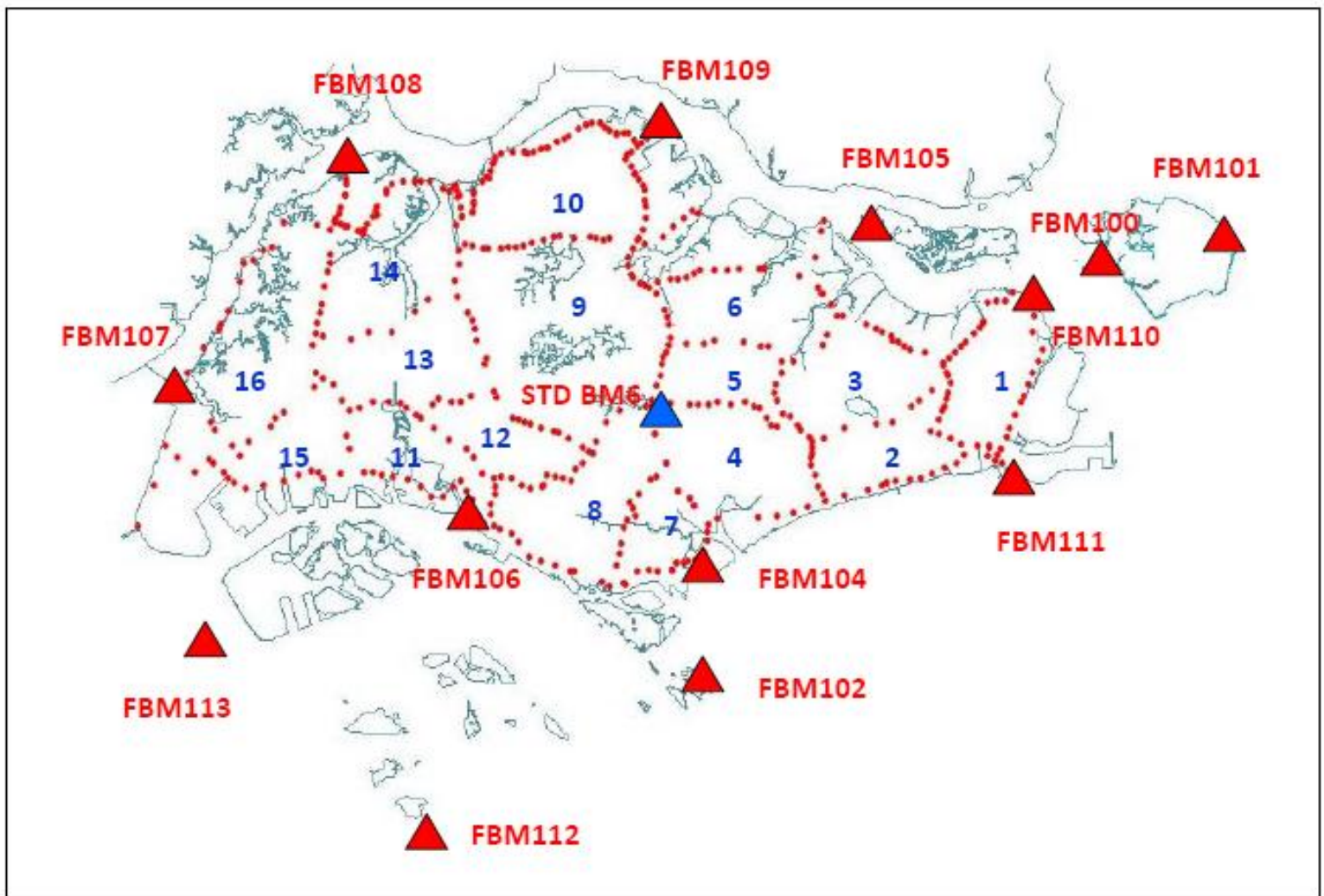
The coordinates stated are for the purpose of locating the VCP only.  
The reduced level is based on the Singapore Survey Department  
Precise Levelling Datum and measured to the top of the bolt

Datasheet updated on : 05-07-2010  
Copyright©2010 Singapore Land Authority. All Rights Reserved.  
Note: Location Map & Site Plan not to scale

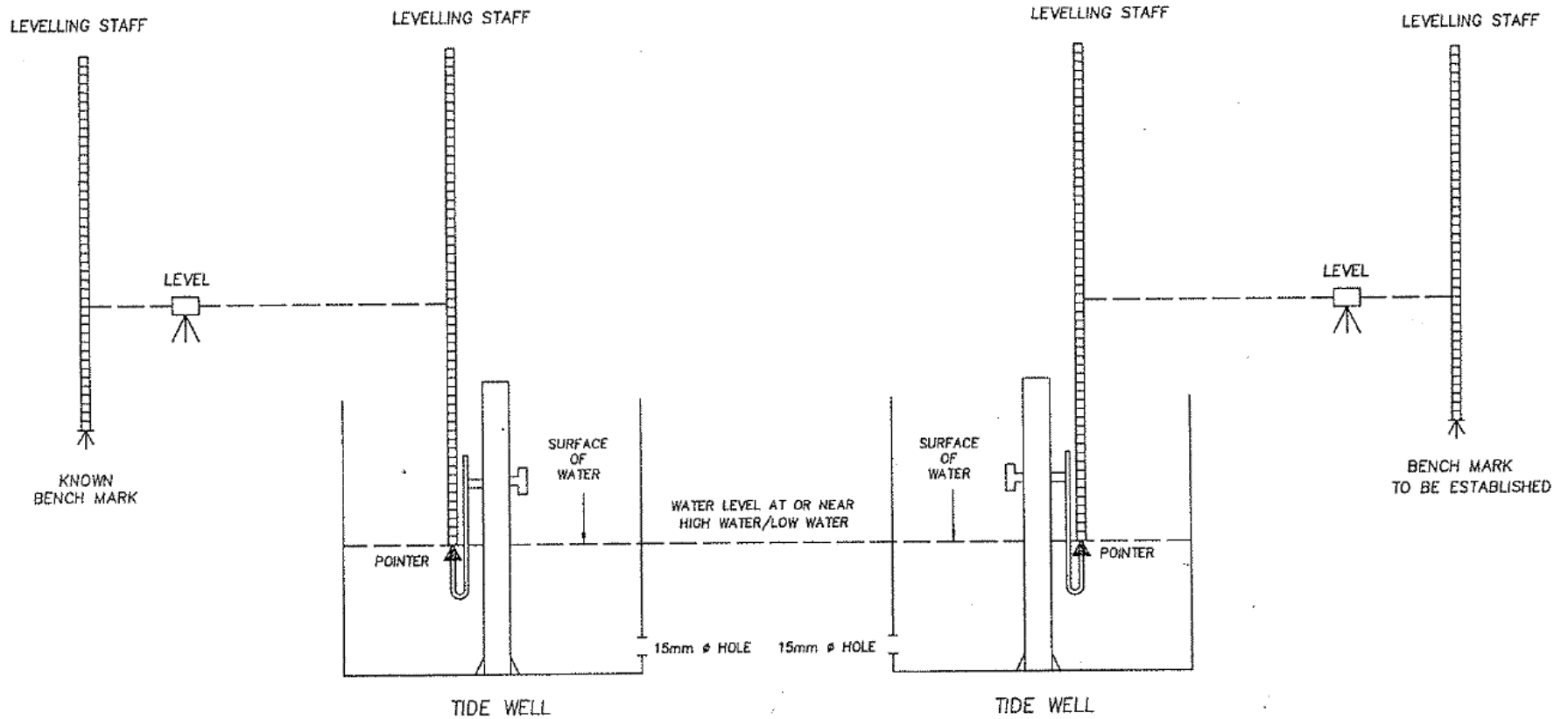
# Transferring of Height Datum to Offshore Islands

- 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

# FBM on Islands



# Hook Gage (Modified)



Adopted from Mr. Tan Choo Haw

# Hook Gage - Equipment

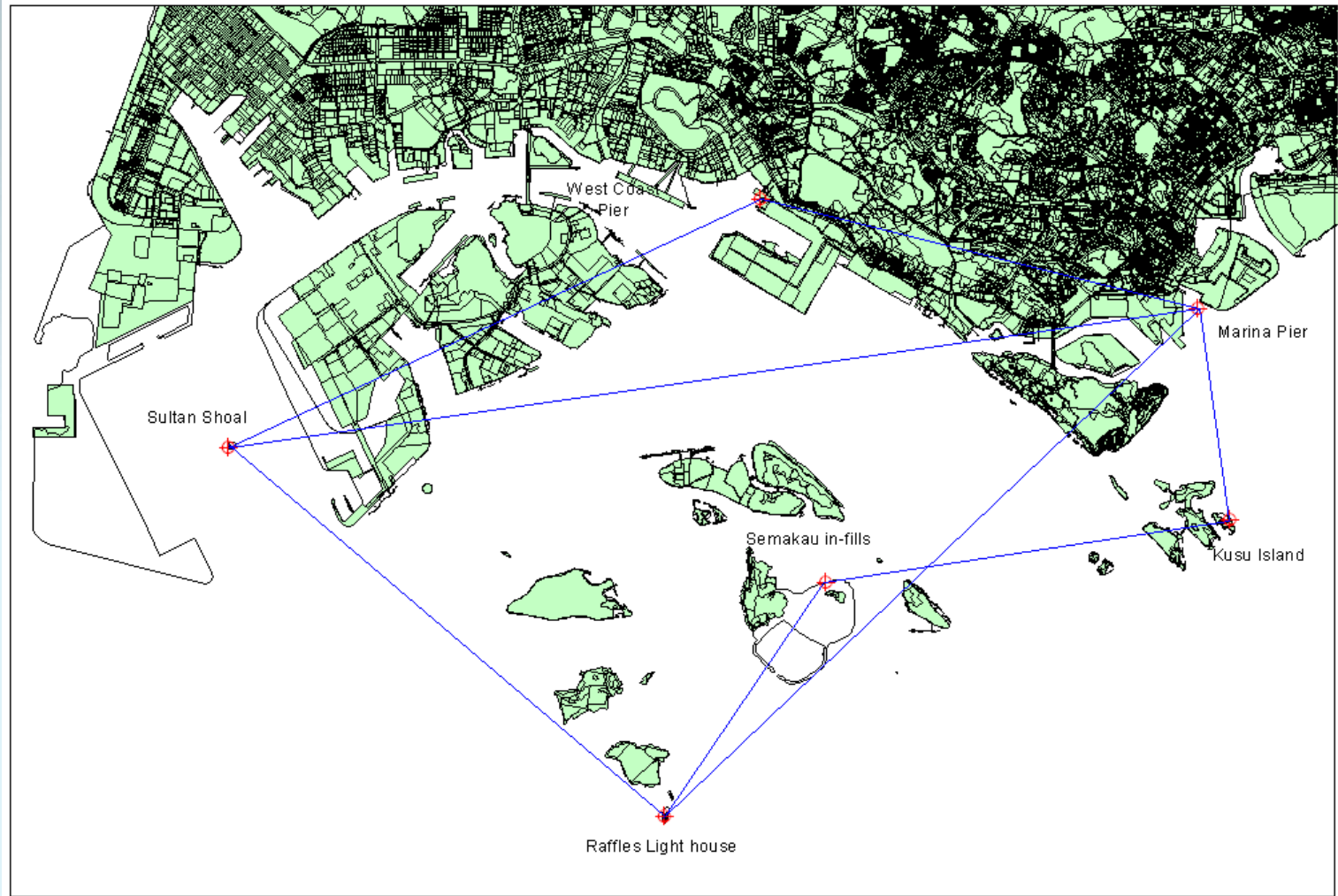




# Observation



# Progress Updates

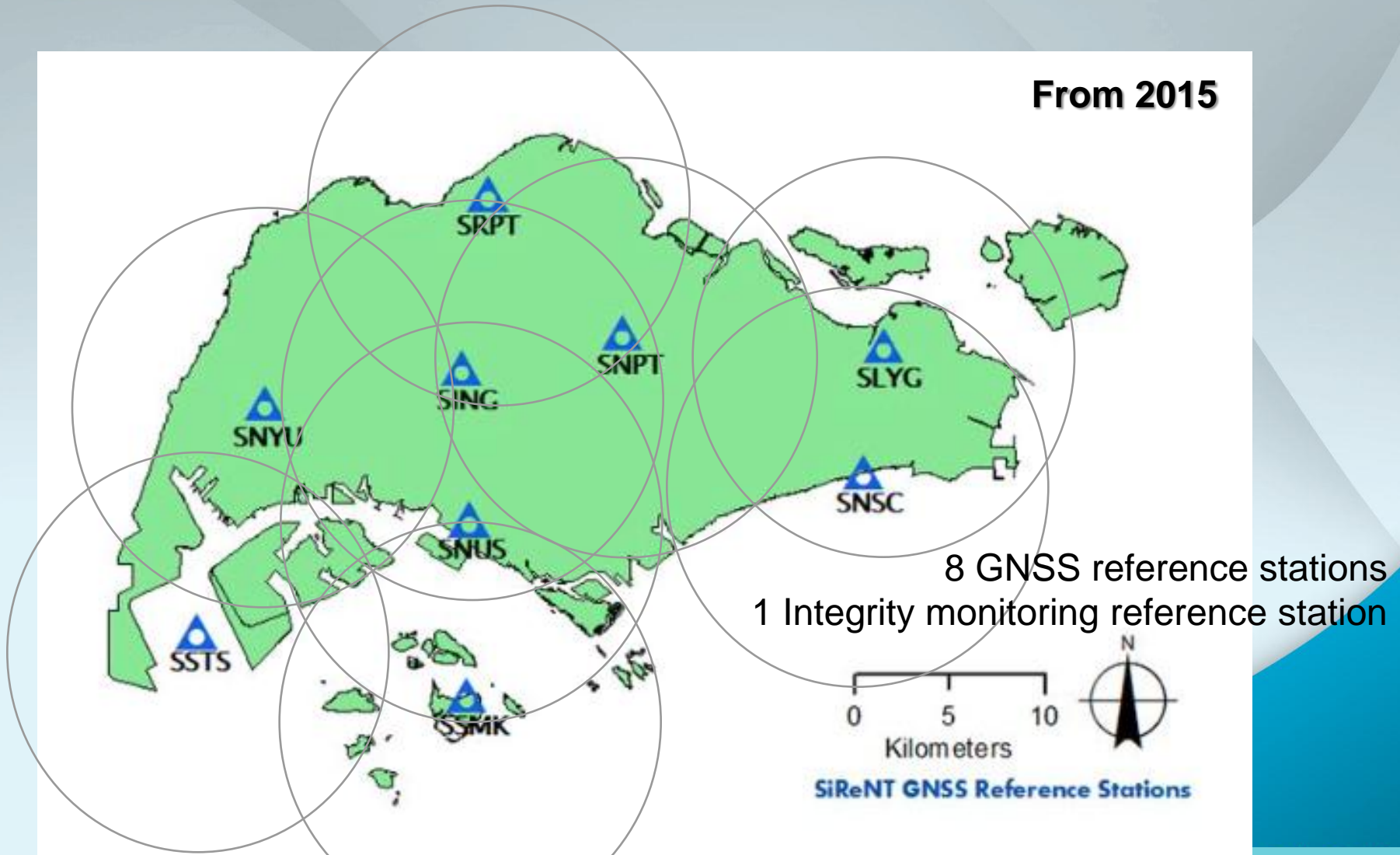


# SiReNT in Singapore

## Singapore Satellite Positioning Reference Network

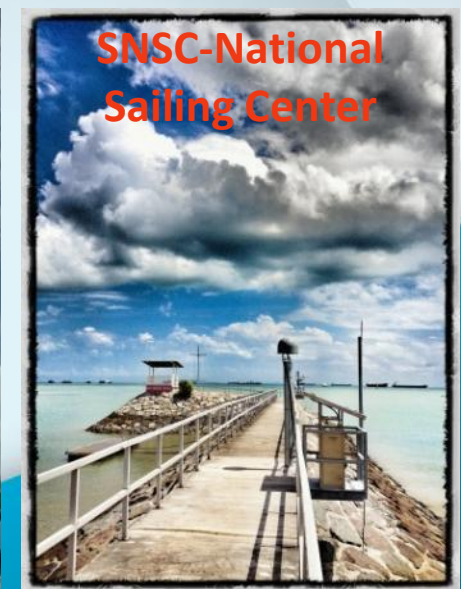
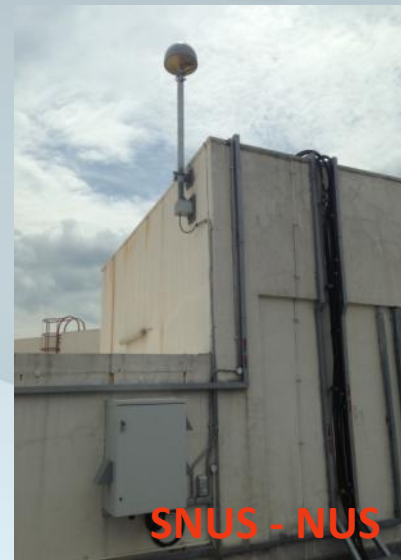
- SiReNT is our National Differential GPS infrastructure that provides
  - consistent mapping and positioning coordinate system
  - fast, reliable and high accuracy positioning
- Started as a research project with NTU since 1999
- SiReNT was in operation since in 2006
- Primary objective is to support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

# New Locations of Reference Stations



# 8 GNSS Reference Stations

## 8 GNSS CORS



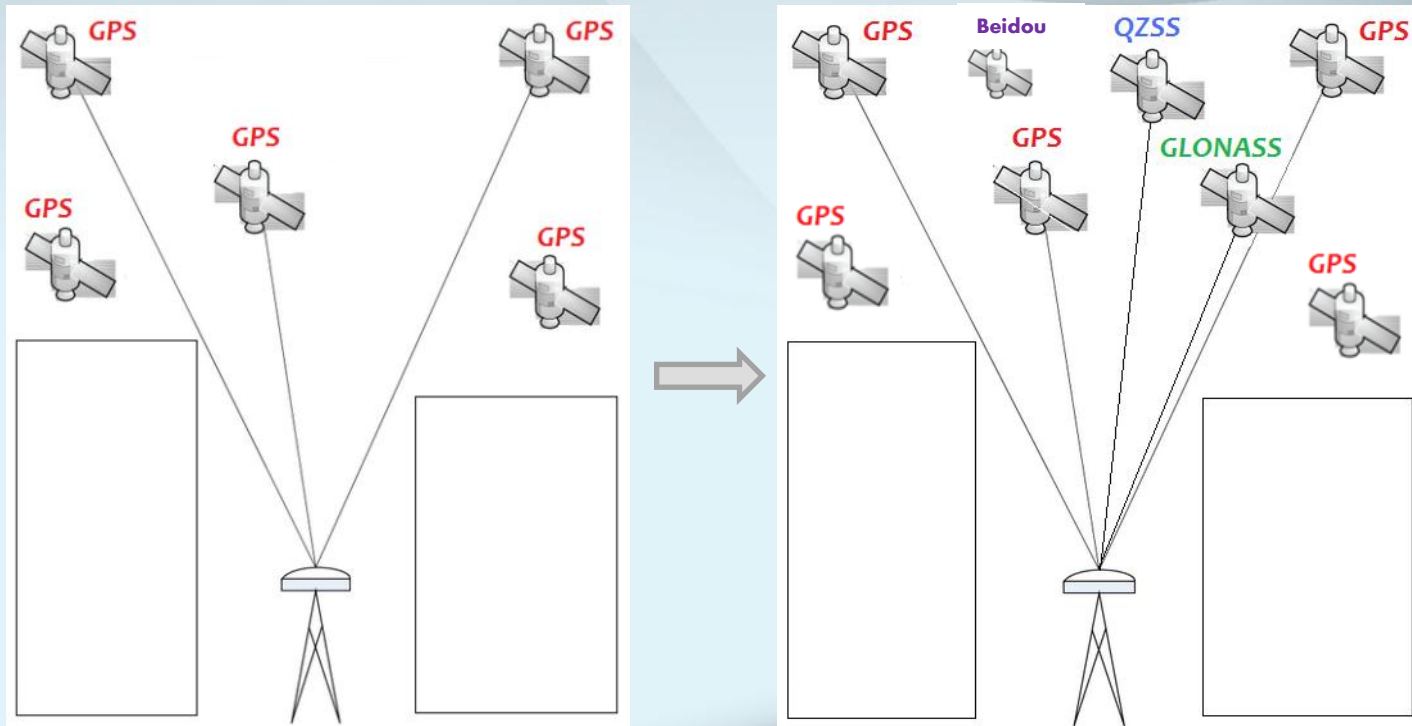
# GNSS Reference Station Setup

Compact and efficient setup.



# Benefits of New SiReNT in Urban Environment

- Enhanced satellite availability
- Enhanced positioning efficiency



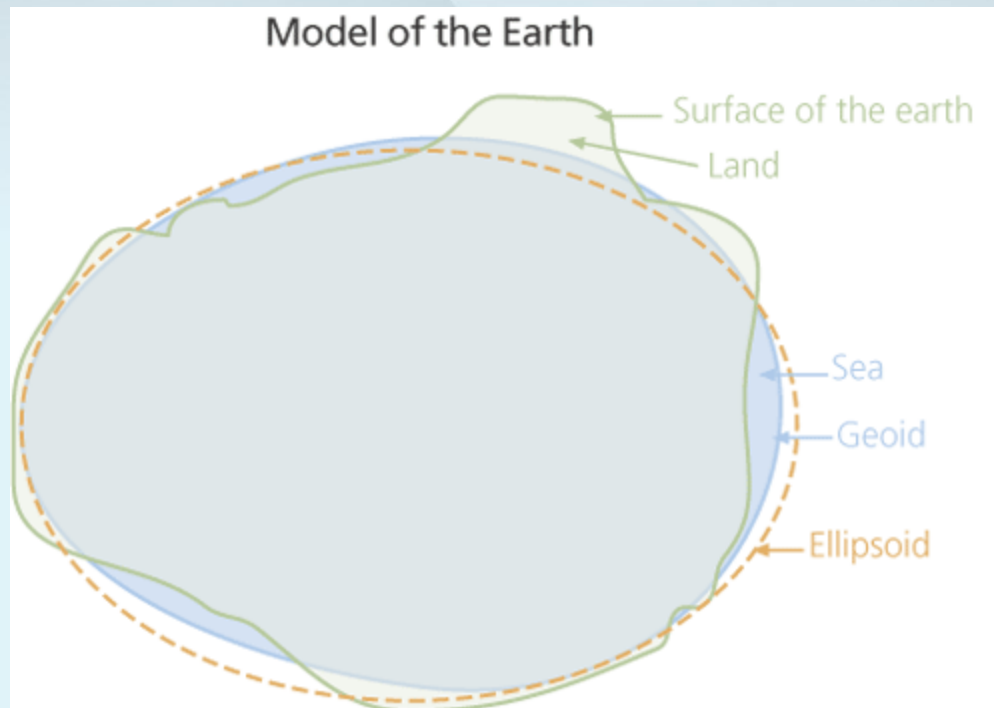
# Development of SGEOID09

- 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?

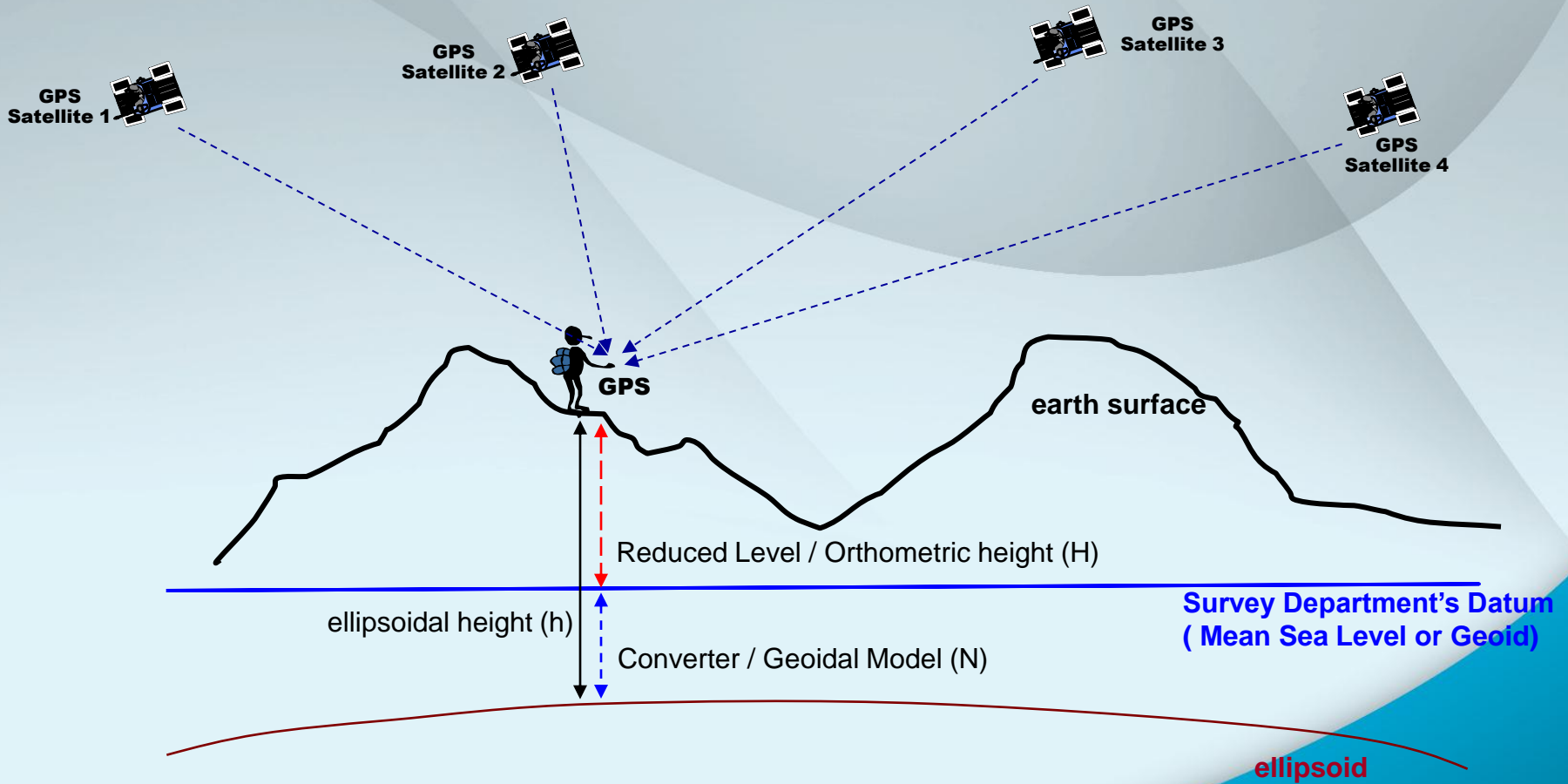
- Geoid is that equipotential surface of the Earth gravity field that most closely approximates the mean sea surface



# 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

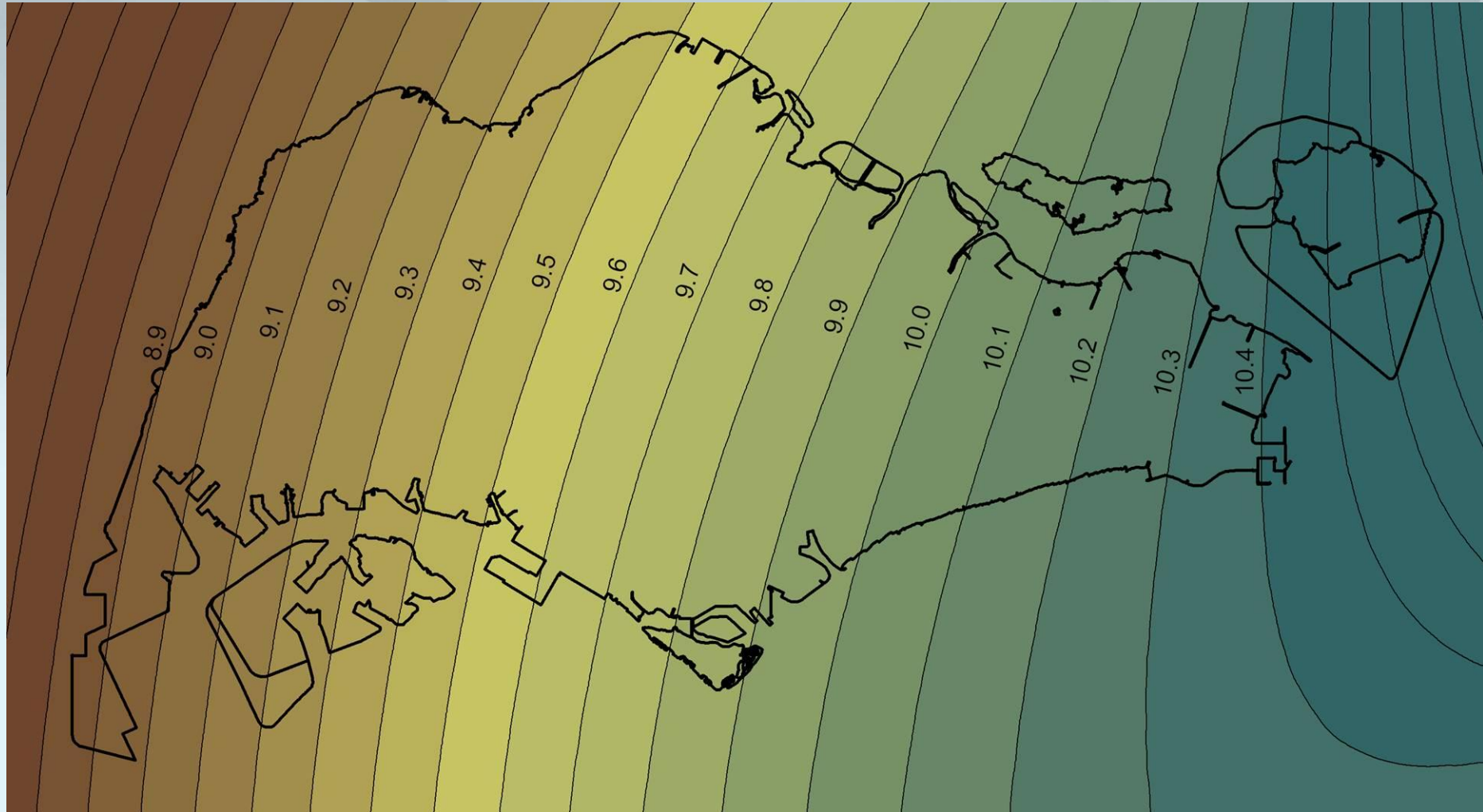
$$N = 8.94184 + 2.08529 * E - 0.16502 * N - \\ 0.661429 * E^2 - 0.139884 * N^2 + \\ 0.232462 * E^6 * N$$

Where,

$$E = \frac{(\text{Easting} - 4813123)}{43462405}$$

$$N = \frac{(\text{Northing} - 25542573)}{24037684}$$

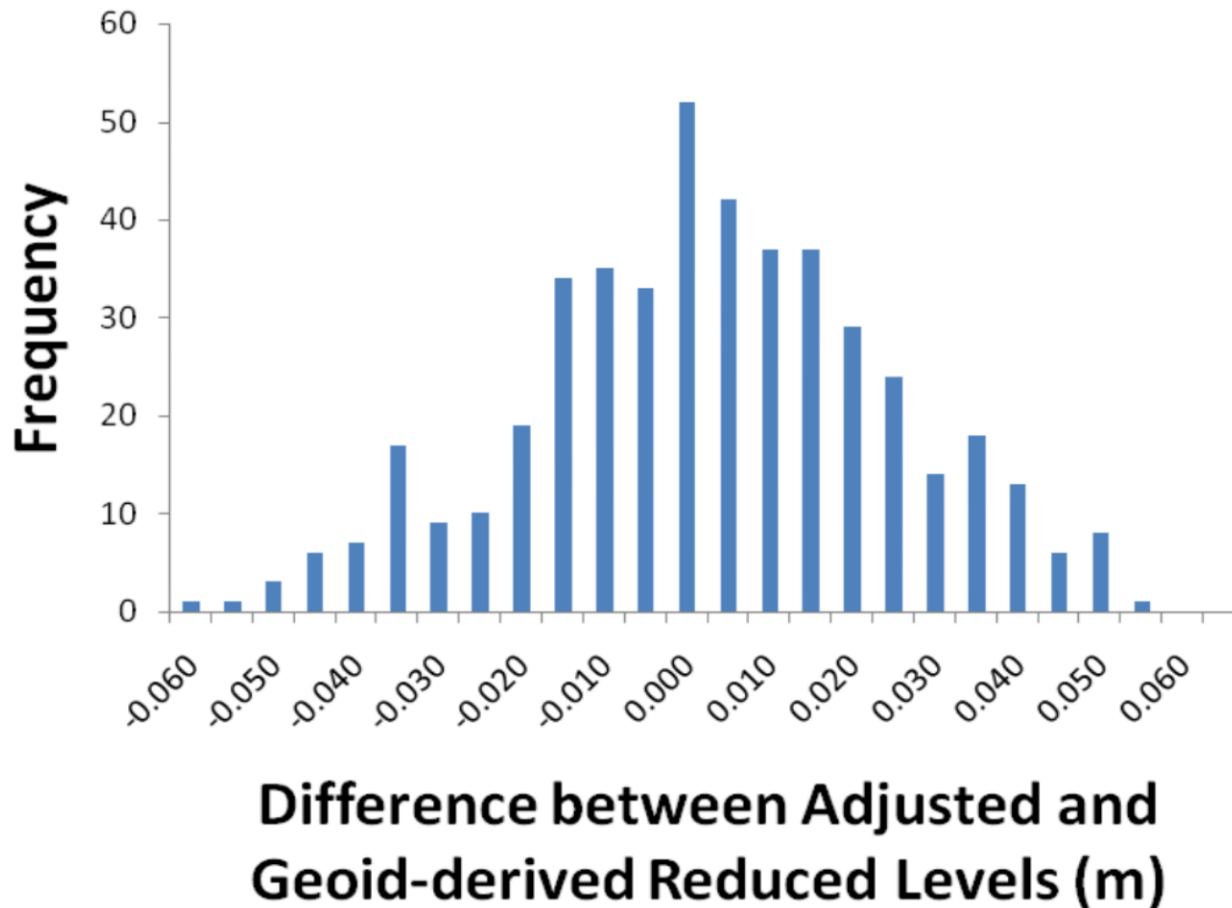
# “Geoid Model” or Converter (N)



# 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% -  $\pm 0.030$  m
  - 95% -  $\pm 0.040$  m
  - 99% -  $\pm 0.050$  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

The screenshot displays the SiReNT website interface. At the top, there are logos for SLA (Singapore Land Authority) and Singapore Government, along with navigation links like 'Rate Our Website', 'Contact Info', 'Feedback', and 'Sitemap'. A search bar is also present. The main content area is titled 'SiReNT Secured' and features a login form with fields for 'Username' (containing 'MSLAPP04') and 'Password\*', and a 'Login' button. Below the login form are links for help, trial accounts, and subscriptions. A 'Latest Highlights' section lists recent news items. The central part of the page is titled 'Try it out SGeoid09' and explains the conversion function. It includes a 'Step 1 of 2' section with input fields for 'Northing (m)', 'Easting (m)', and 'Ellipsoidal Height (m)', and 'Reset' and 'Compute' buttons. A 'Disclaimer: Use of SGEOID09 Service' is provided at the bottom, stating that the service is free and valid only for mainland Singapore. The footer includes contact information for the helpdesk and a copyright notice for SLA 2015.

**SLA**  
SINGAPORE  
LAND AUTHORITY

**SIRENT**  
SINGAPORE SATELLITE POSITIONING REFERENCE NETWORK

Singapore Government  
Integrity • Service • Excellence

Rate Our Website

Contact Info | Feedback | Sitemap

Search  - Keywords -

INLIS | Home | About SiReNT | Services | Technology Focus | SGEOID09 | Downloads | FAQ | Highlights | Useful Links | SiReNT Status | Terms & Conditions

**SiReNT Secured**

Username

Password\*

\*case sensitive

- Get [Help](#) for Login problems Not Registered yet?
- Get a [free trial](#) account
- Get [subscribed now](#)

**Latest Highlights**

- [Taking Remote Control into the Real Industries](#)
- [A discussion on RTK Occupation time](#)
- [IP Rating](#)
- [SiReNT showcased at PS21 Excel Convention](#)

**Helpdesk Tel :**  
(65) 6356 6546  
**Helpdesk Email :**  
sla\_sirent@sla.gov.sg  
**Operation Hours :**  
8.30am - 6.00pm, Mon - Fri  
Best viewed in 1024x768 resolution,  
using IE 5.5+

Try it out  
**SGeoid09**

This function allows you to perform conversion of Ellipsoidal height to reduced level height for Survey Department's datum.

Step 1 of 2

To specify SVY21 Coordinates and WGS84 Ellipsoidal height

Northing (m) :

Easting (m) :

Ellipsoidal Height (m) :

Last Update : 23 June 2010

**Disclaimer: Use of SGEOID09 Service**

The SGEOID09 Service is provided by SLA free to users for converting ellipsoidal height obtained in the SVY21 coordinate system to a height value reference to Survey Department's Datum. The user has the sole and complete responsibility to assess whether this service is suitable for the purpose which is intended and decide whether the results obtained from this service could be used for his purpose. The service is only valid for use with coordinates within mainland Singapore.

Maintained by :

©SLA 2015

# 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

# Thank You

