Satellite-Derived Bathymetry:
Optimising New Promising Technology for Low-Water Line (Baselines) Delineation

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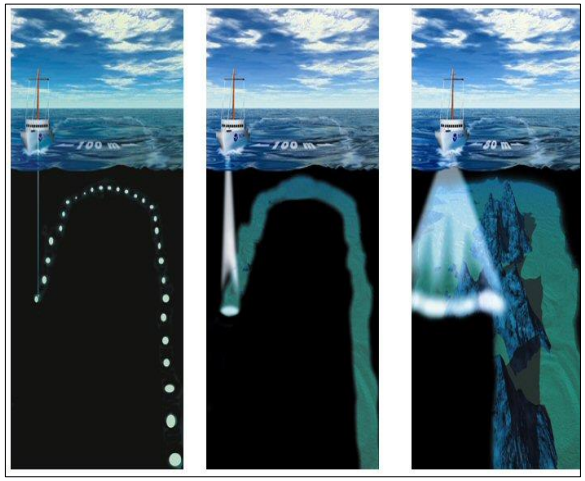
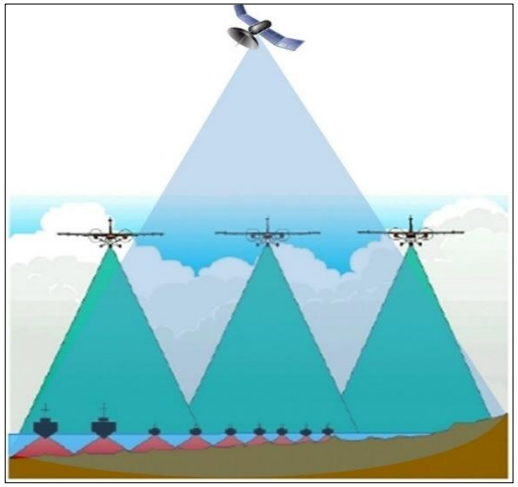
SDB – An Overview

- Acquisition technique of bathymetric data has evolve from shipborne platform to airborne and even by means of space-borne acquisition





shipborne → airborne → space-borne

Images retrieved from the NOAA Office of Coast Survey website: https://www.nauticalcharts.noaa.gov.

SDB – An Overview

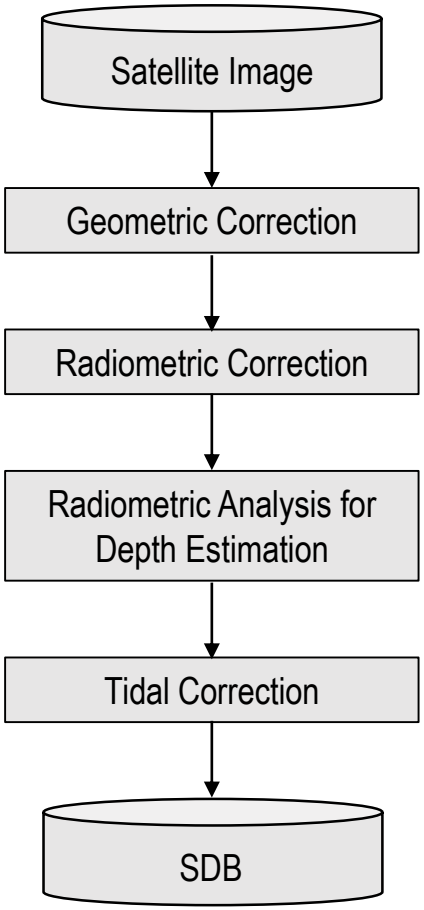
- SDB is a survey method related to a systematic analysis modelling of light penetration through the water column in visible of satellites' multi-spectrometers bands
- Various factors affected
  - height and direction of the sun
  - clouds and shadow
  - wind and sea surface condition
  - nature of seabed/sea bottom albedo
  - absorption and diffusion of light by the water column (turbidity, algae etc)
  - atmospheric condition
  - type of spectral bands

SDB – An Overview

Algorithms used for depth estimation/derivation from satellite images

- Banny and Dawson
  - Basic method.
  - Uses one band only.
- Lyzenga's
  - Uses multiple visible bands
  - Applicable to variable seafloor reflectivity
- Stumpf and Holderied
  - Adapting blue and green bands
- Lee's
  - Inversion method
  - Requires multiple bands (>5) and high resolution

SDB – An Overview

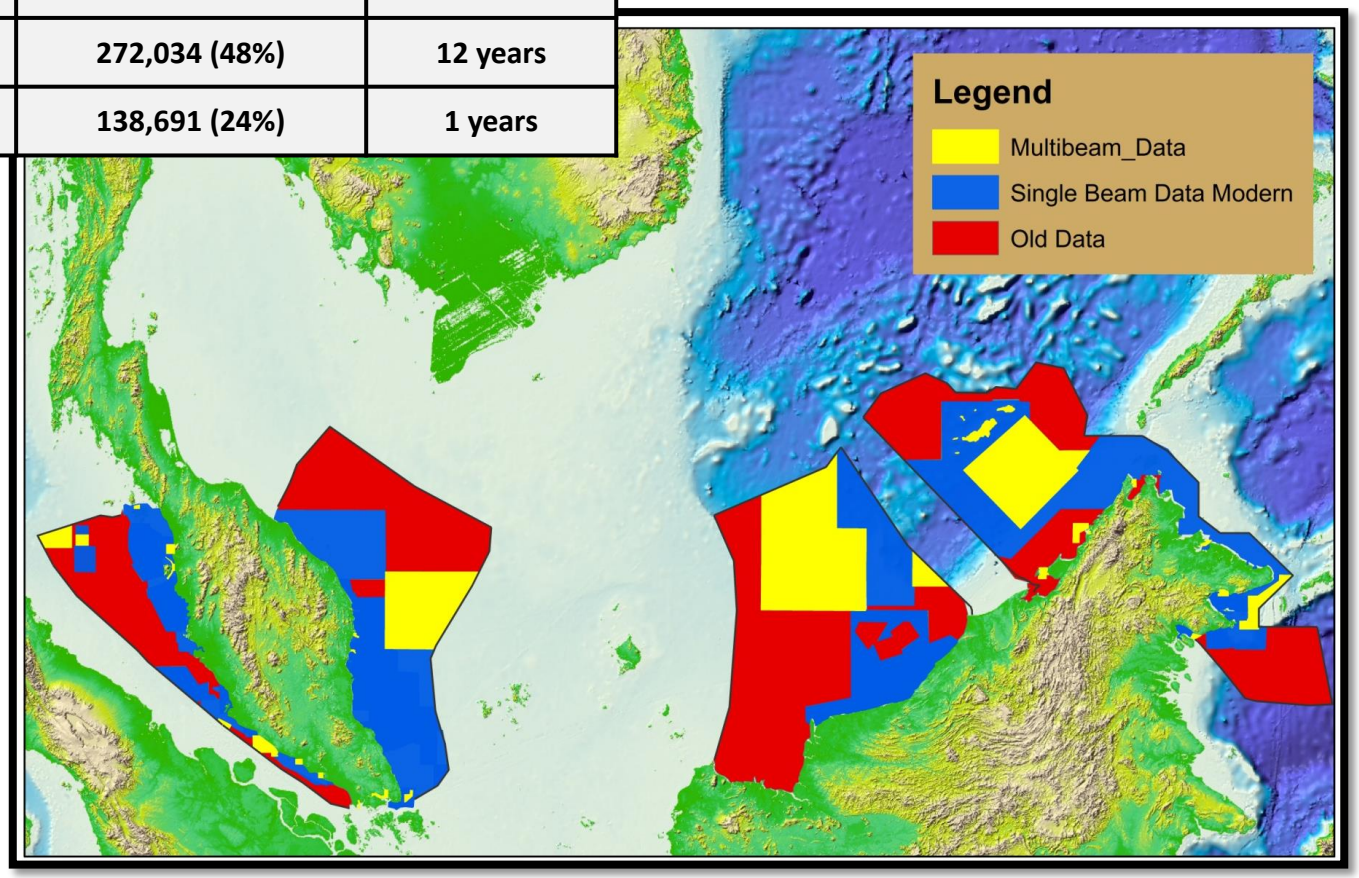


SDB General Process Flow

- Geometric Correction
  - Correcting distortions of image
  - Improving horizontal accuracy
- Radiometric Correction
  - Calibration of recorded variance value reflected
  - Conversion to ToA radiance, *ToA reflectance*, sun-glint correction and atmospheric correction
- Radiometric Analysis for Depth Estimation
  - Ground truthing (radiative transfer model)
- Tidal Correction

The Study - Motivation

Area (km^2)		Time Taken
< 50 m	159,120 (28%)	30 years
50 – 1000 m	272,034 (48%)	12 years
> 1000 m	138,691 (24%)	1 years



The Study - Motivation

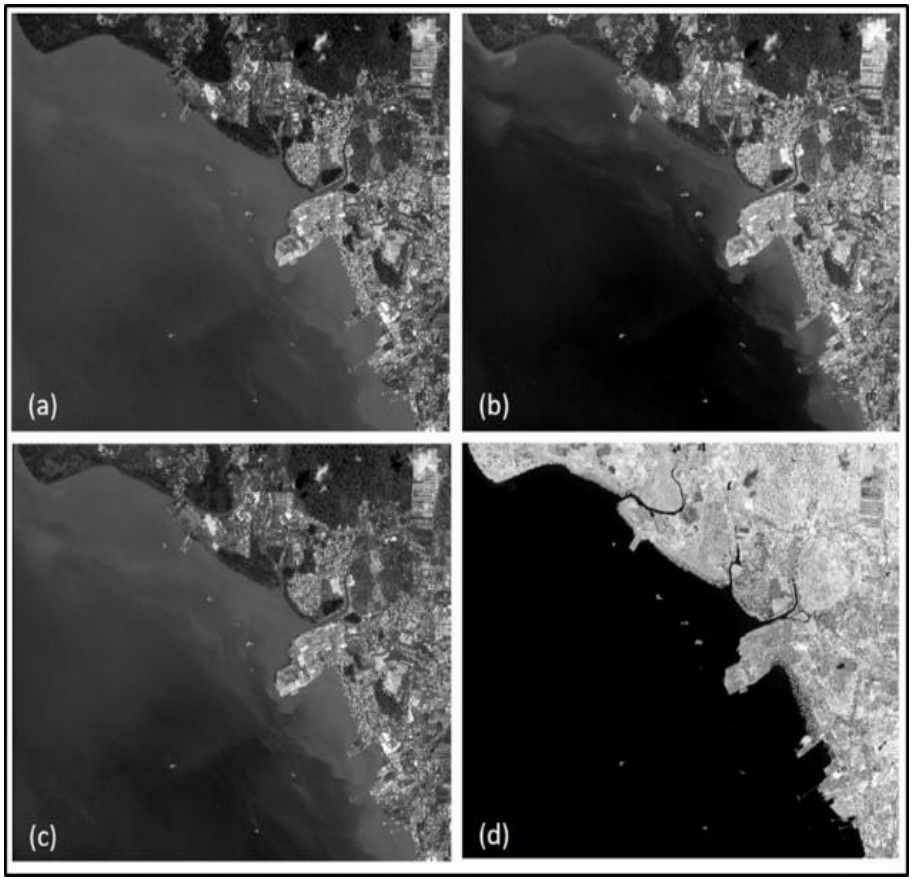
- Many studies has recognised SDB as an alternative method which capable to provide a cost and time effective solution in delivering an acceptable depth estimation
- Unfortunately, most of the studies primarily inclined into remote sensing environments
- Lee et al. (1999), Gould et al. (2001), Lee et al. (2002), Maritorena et al. (2002), Brando and Dekker (2003) and Albert and Gege (2006) were primary focused in the development and enhancement of semi-analytical algorithms for determination of water properties including depth
- Hogfe, et al. (2008), Bachmann, et al. (2012) and Bramante et al. (2013) partly covered the precision of derived depths but no attempt in analysing the results comparing with the hydrographic surveying industry

The Study - Motivation

- Most of the studies outcomes are indirectly beneficial to hydrographic survey industry
- Nevertheless, the studies did not well cover the major issues in answering the fundamental question that mystifying amongst surveyor community in Malaysia; particularly to acknowledge the detail accuracy of the depth estimations produced by the SDB technique
- Precision and accuracy are always the subject of interest to surveyors
- Timely to have a detailed research in Malaysia particularly to assess, evaluate and analyse comprehensively the capability and consistency of SDB outcomes in Malaysia's environment settings (tropical environment) which might have different parameter settings compared to most of the studies worldwide
- The depth estimations produced by the SDB need to be analyse with the requirement laid out in the IHO Standards for Hydrographic Surveys (IHO, 2008)

The Study – Research Area

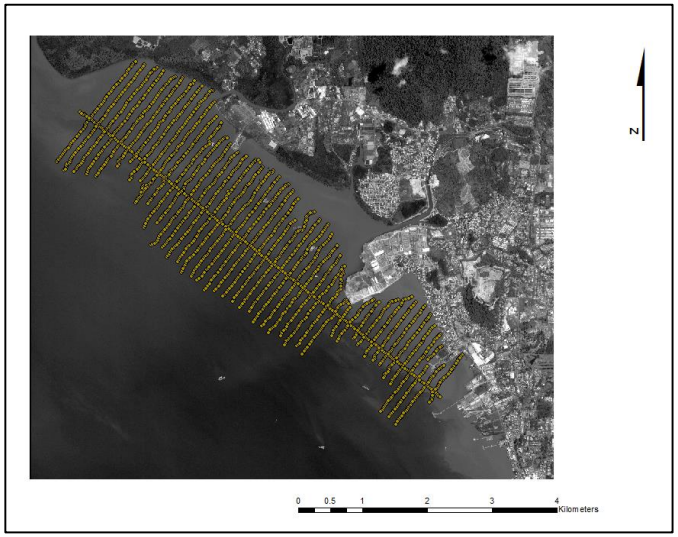
The Study- Processing

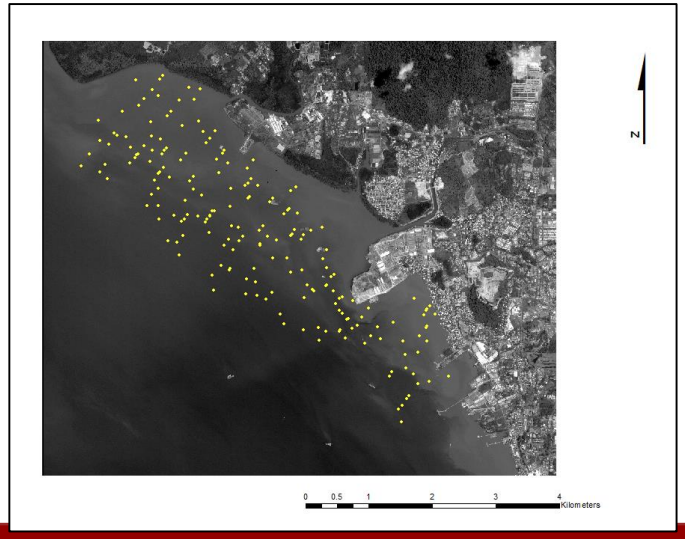


PROJECT 1: TAWAU

- Area : Tawau (fronting Indonesia and Philippines borders)
- Data: Pleiades (12 July 2016)
- Resolution: 0.5 meter
- Bands : Blue, Green, Red and NIR - (a) Blue Band; (b) Red Band; (c) Green Band; and (d) NIR Band.

The Study- Processing

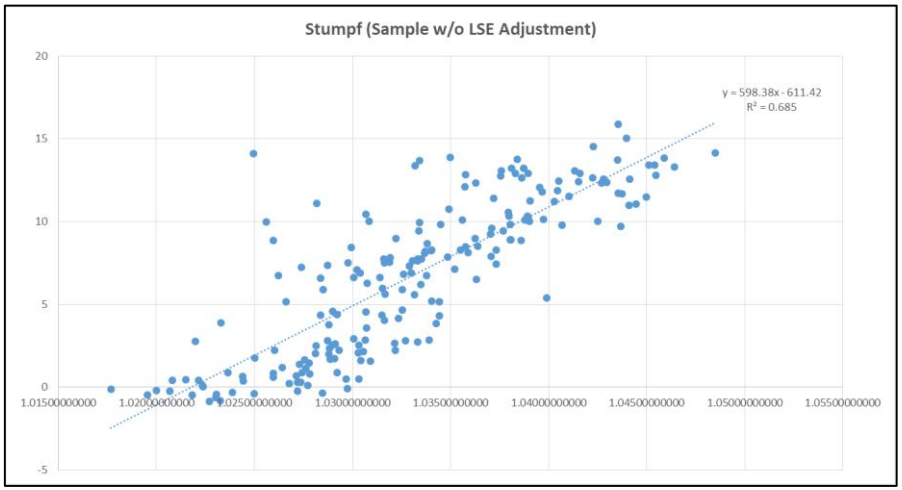


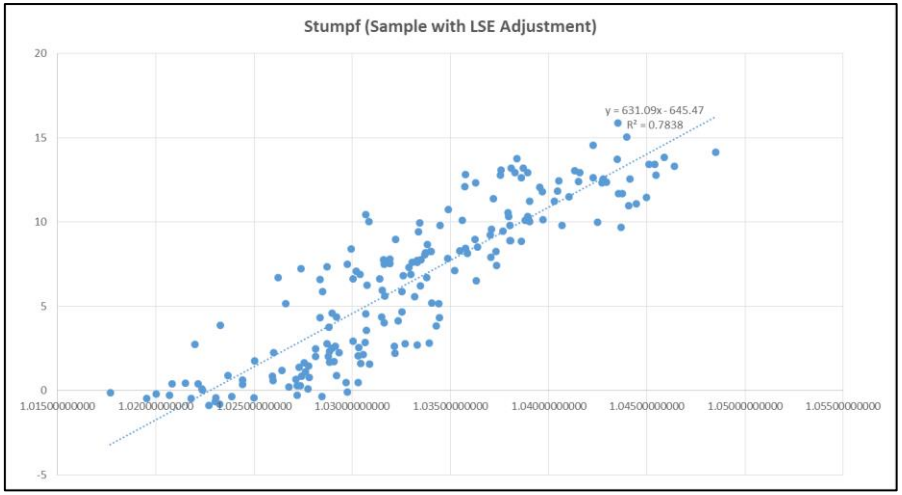


Bathymetry Data

- SBES Data (November, 2016)
- Data divided into 2 categories, the random dataset and full dataset
- Random dataset is a set of randomly selected data used for the calibration process
- Full dataset is the entire data consist of 2452 sample depths used for accuracy analysis

Results & Analysis





- Apply simple filtering algorithm using least square adjustment method for linear regression

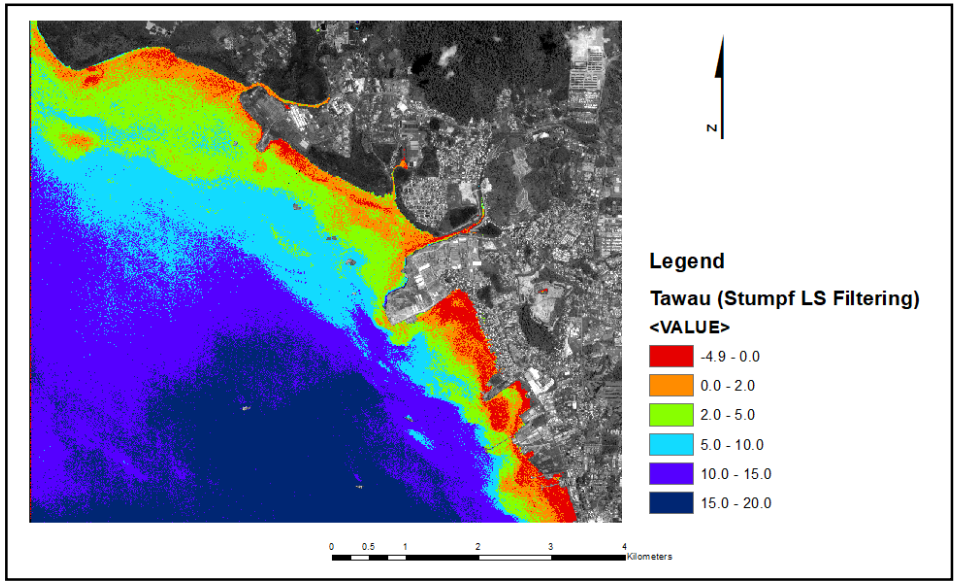
where

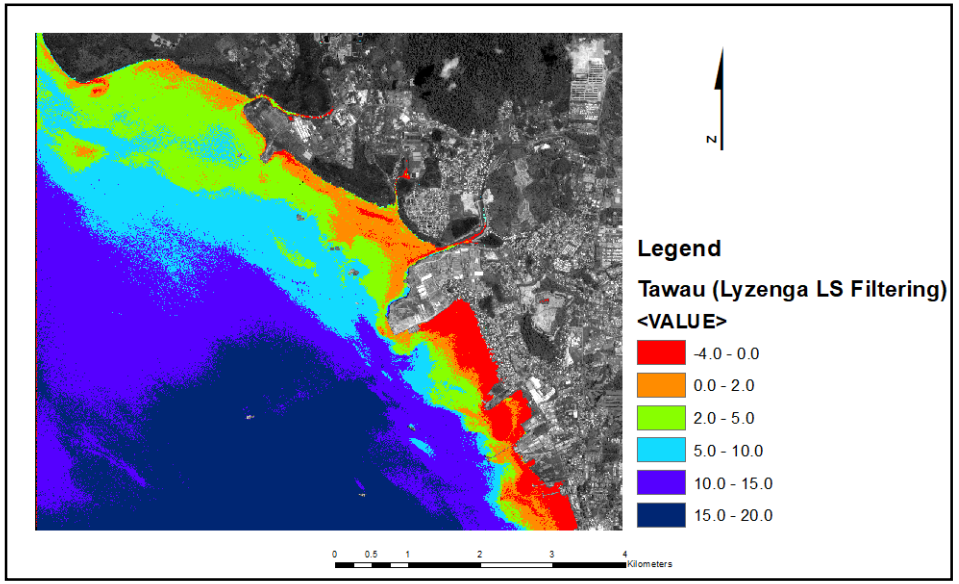
$$\hat{X} = \left(A^T P A\right)^{-1}\left(A^T P F\right)$$

$$F = Ax$$

Results & Analysis

- Images of the result of SDB produced by using Stumpf' and Lyzenga' algorithm model





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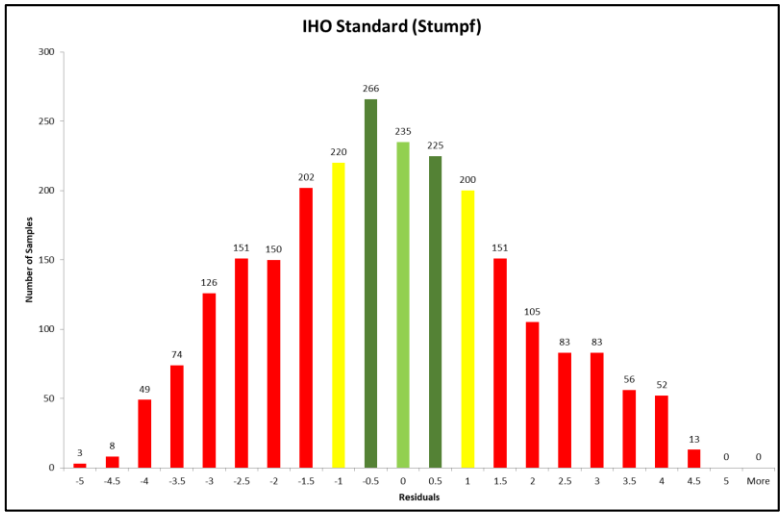
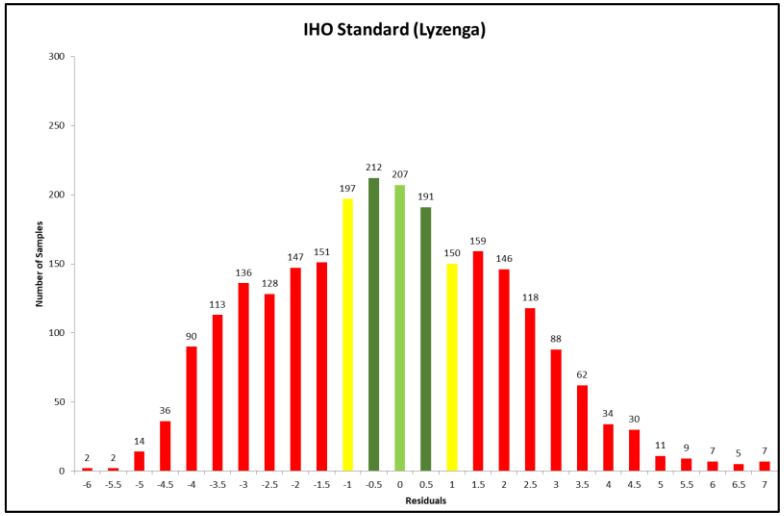


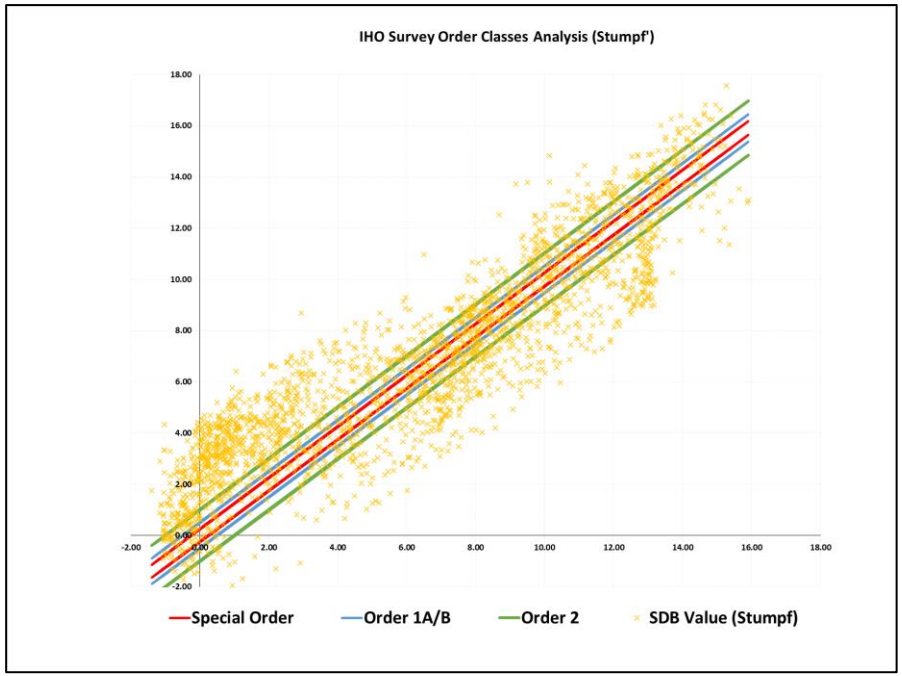


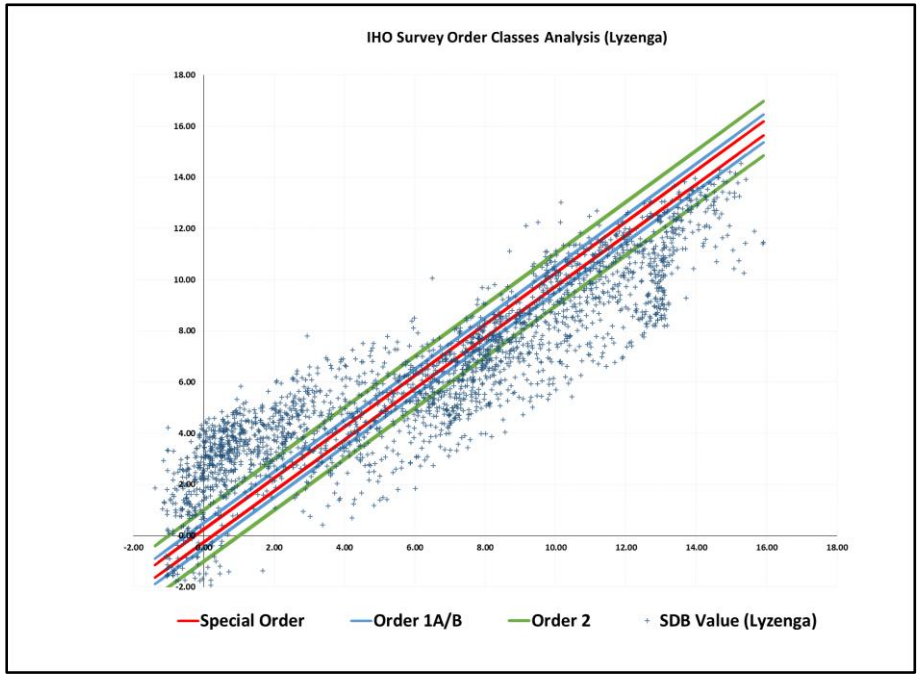
- Histogram graphs show results from the accuracy assessment for both Stumpf and Lyzenga derivation model
- Distribution of IHO S-44 Special Order (light green), Order 1 (A&B) (dark green) and Order 2 (yellow)

Derivation Algorithm Model	RMSE		Maximum Variance		Minimum Variance	
	Without LSE Adjustment	With LSE Adjustment	Without LSE Adjustment	With LSE Adjustment	Without LSE Adjustment	With LSE Adjustment
Stumpf	1.624 m	1.432 m	4.491 m	3.672 m	-5.751 m	-4.575 m
Lyzenga	1.915 m	1.728 m	6.848 m	5.086 m	-6.358 m	-4.957 m

Results & Analysis

- Error distribution patterns of SDB values derived from Stumpf' and Lyzenga' model compared to IHO Survey Order classes





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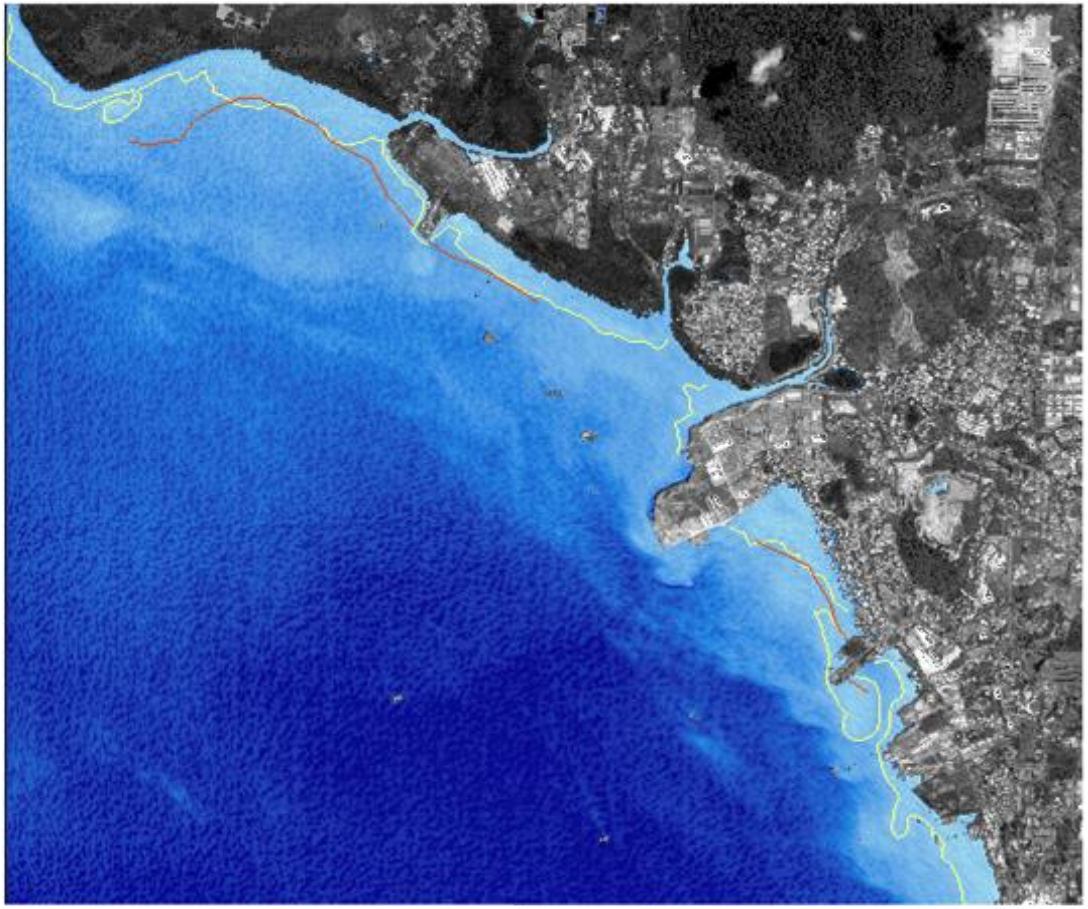

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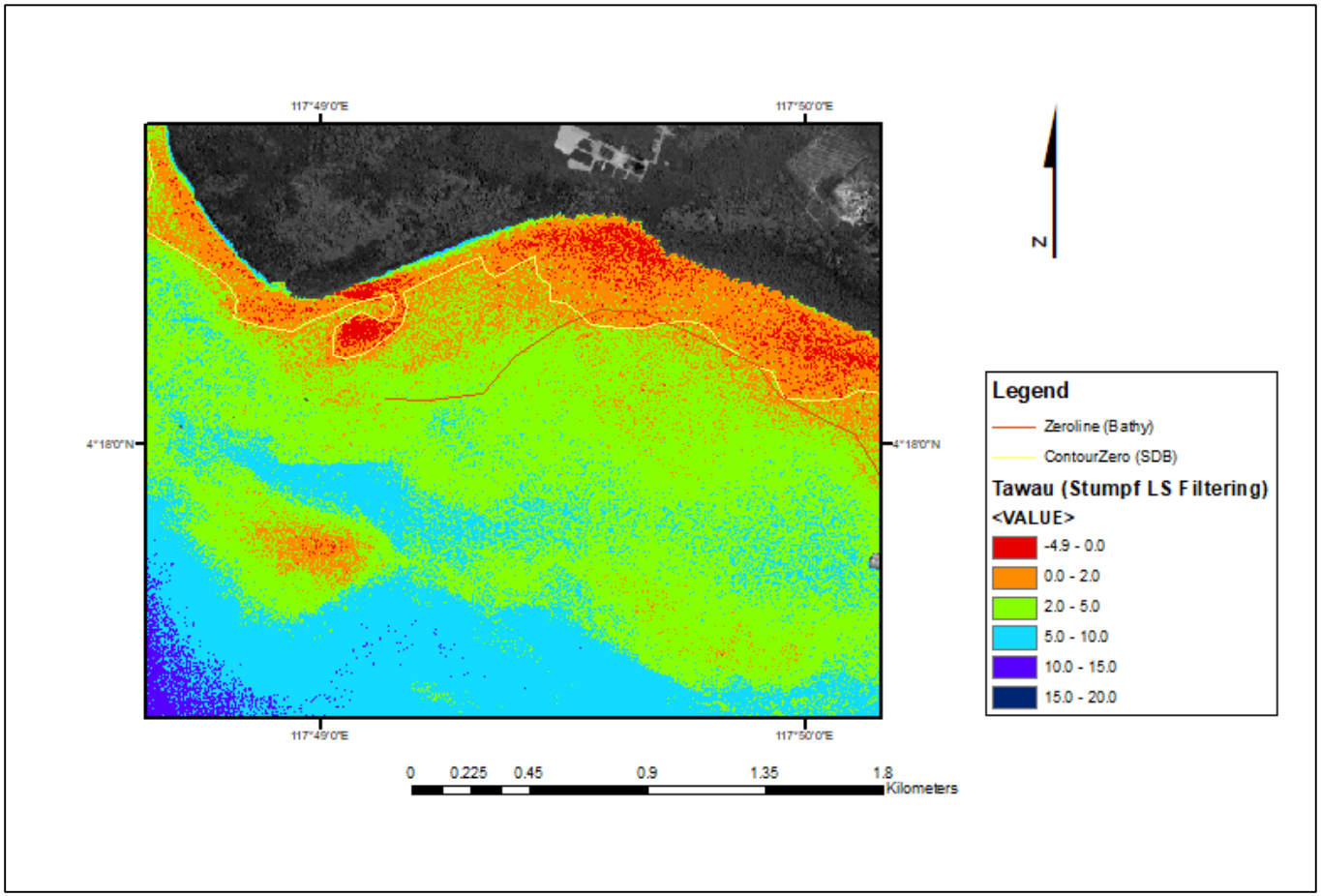

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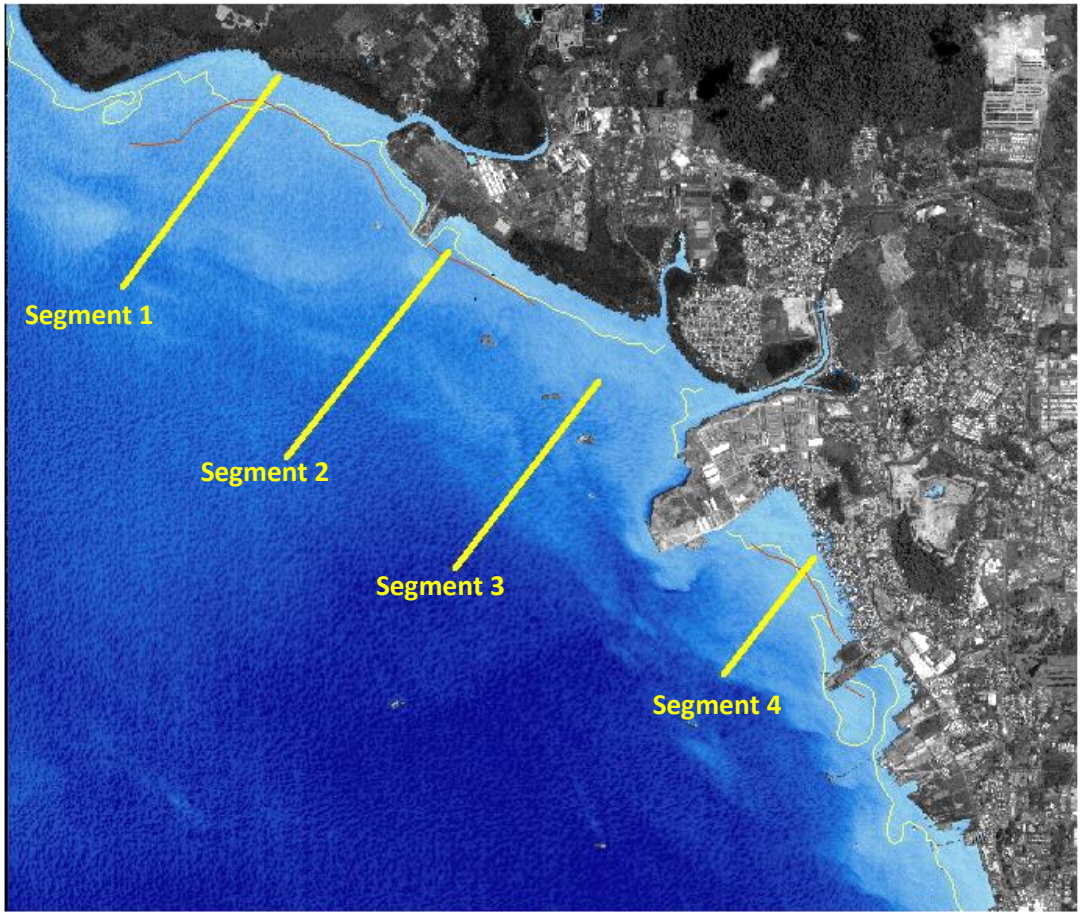
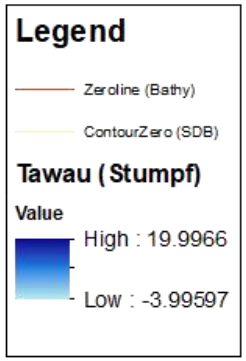
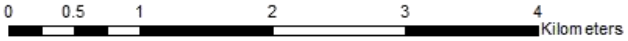


Tawau Port (SDB)
Cross Profile Segments





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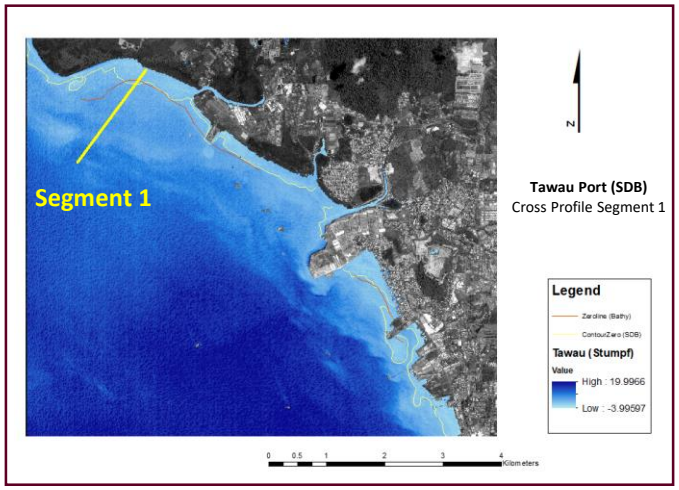

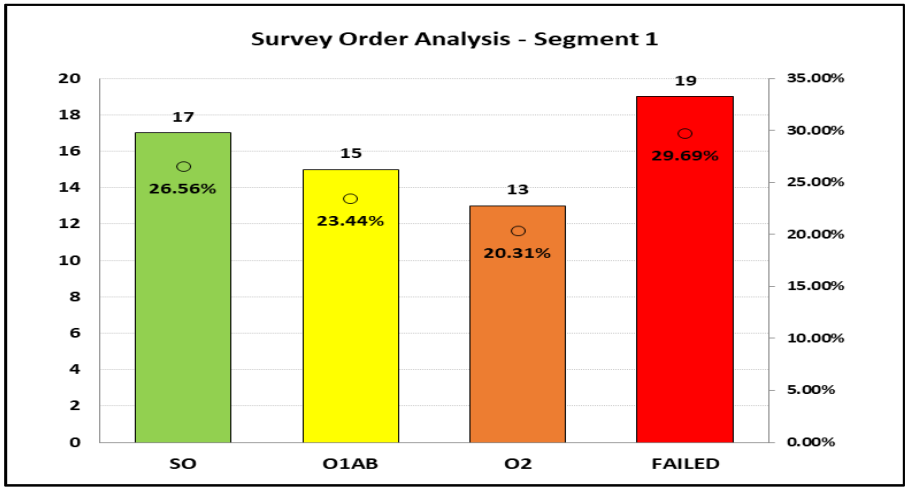

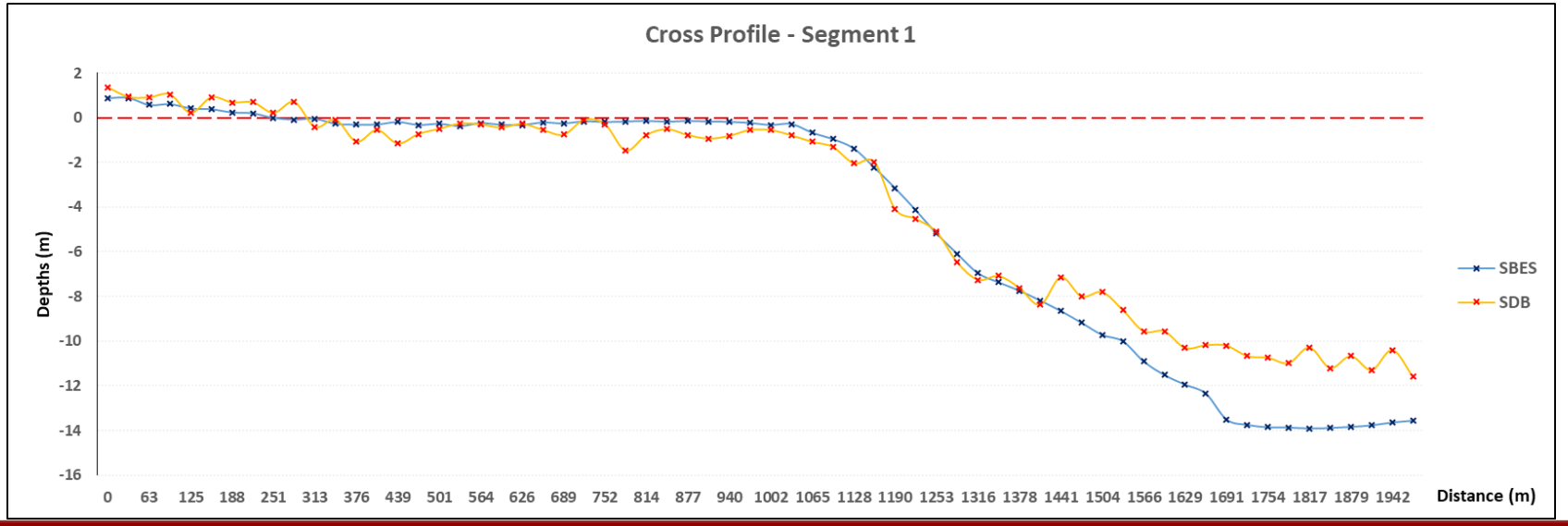

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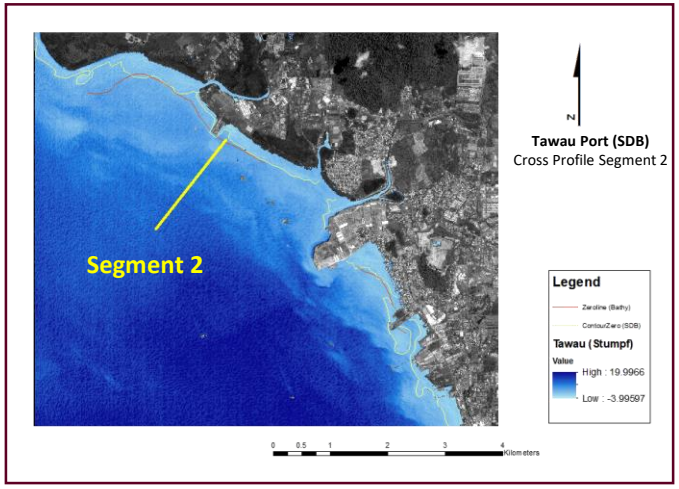

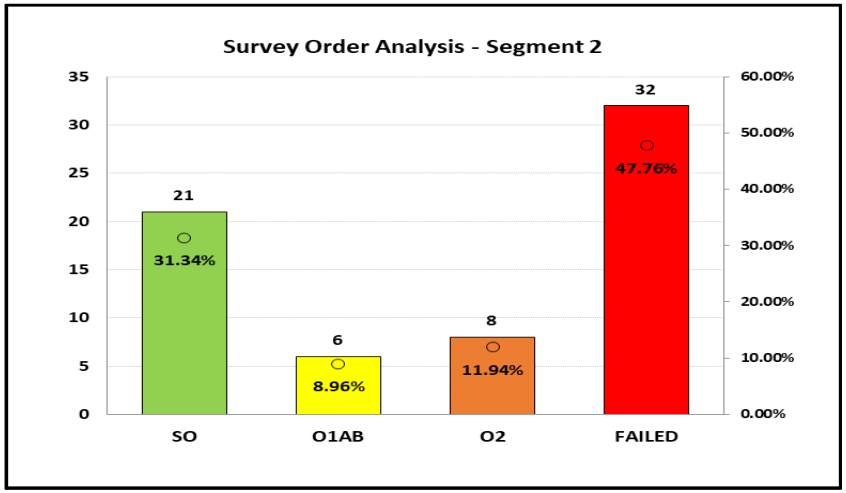

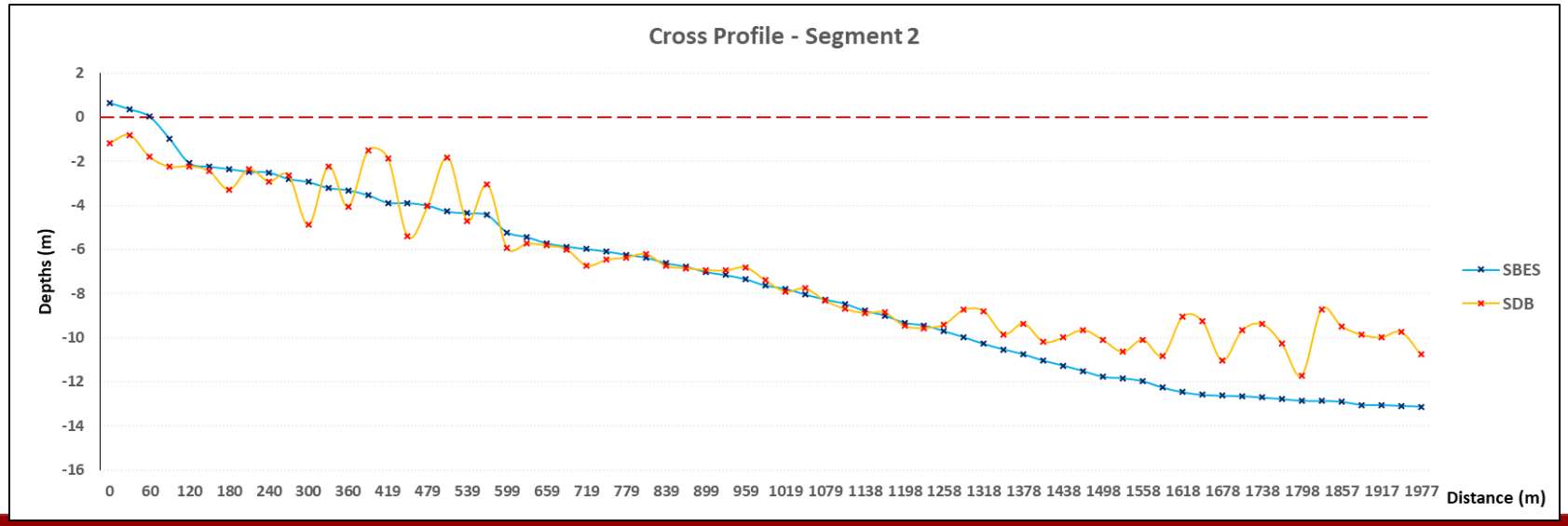

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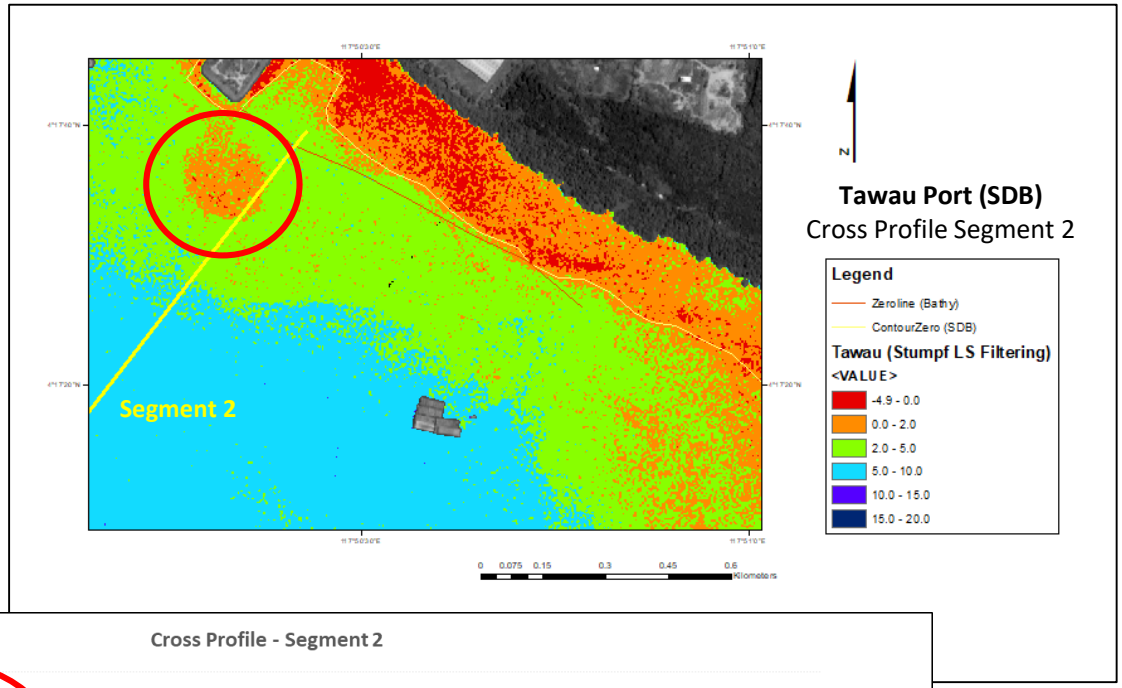

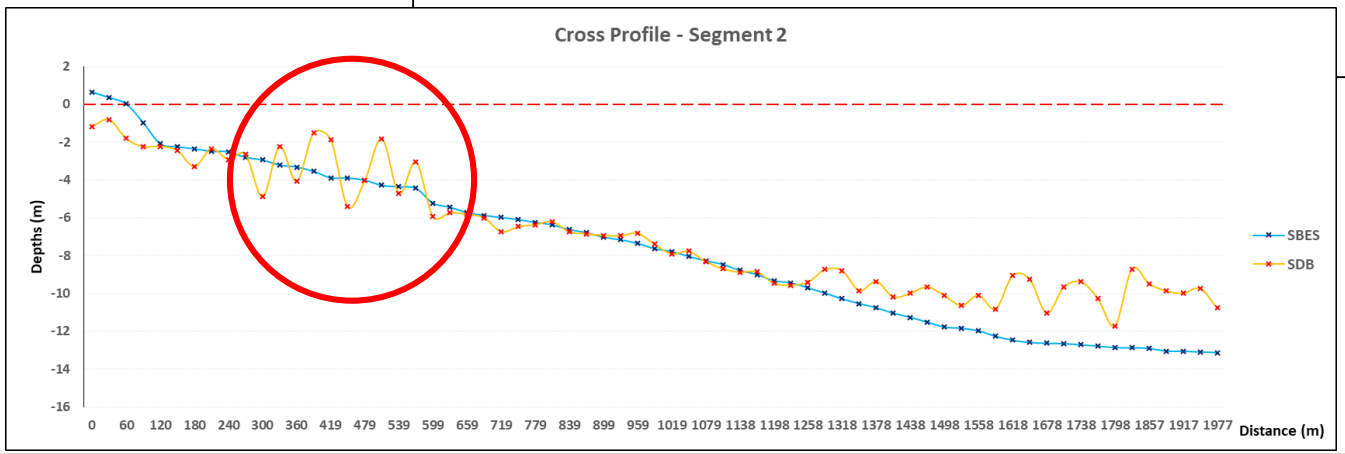

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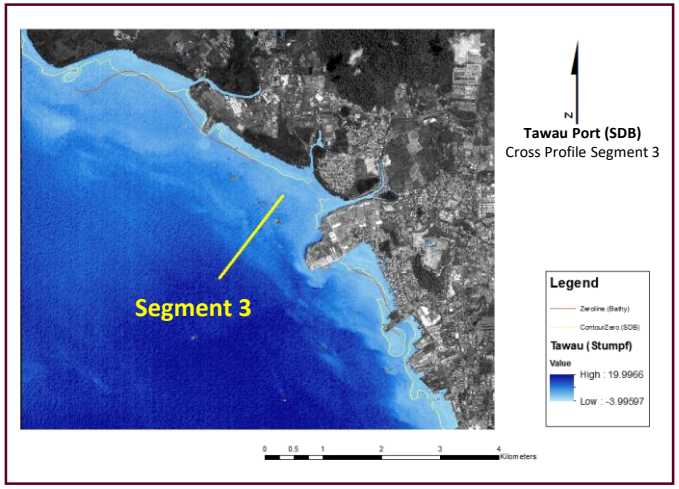

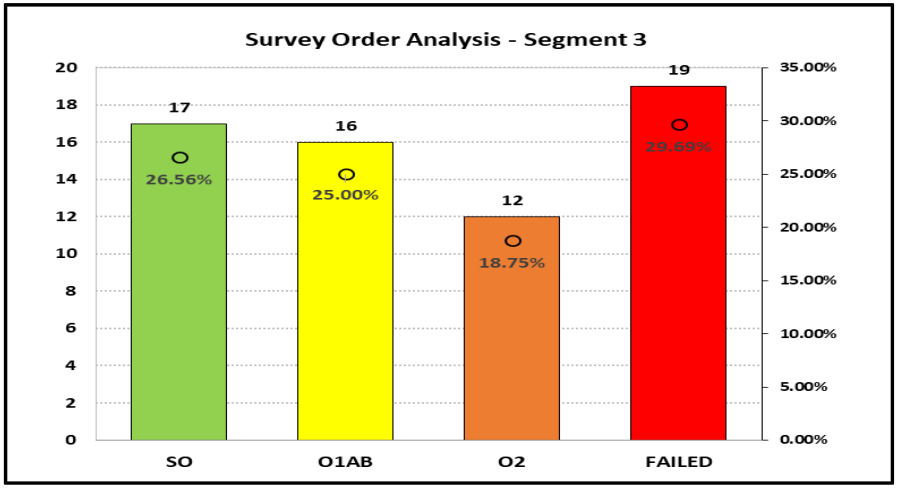

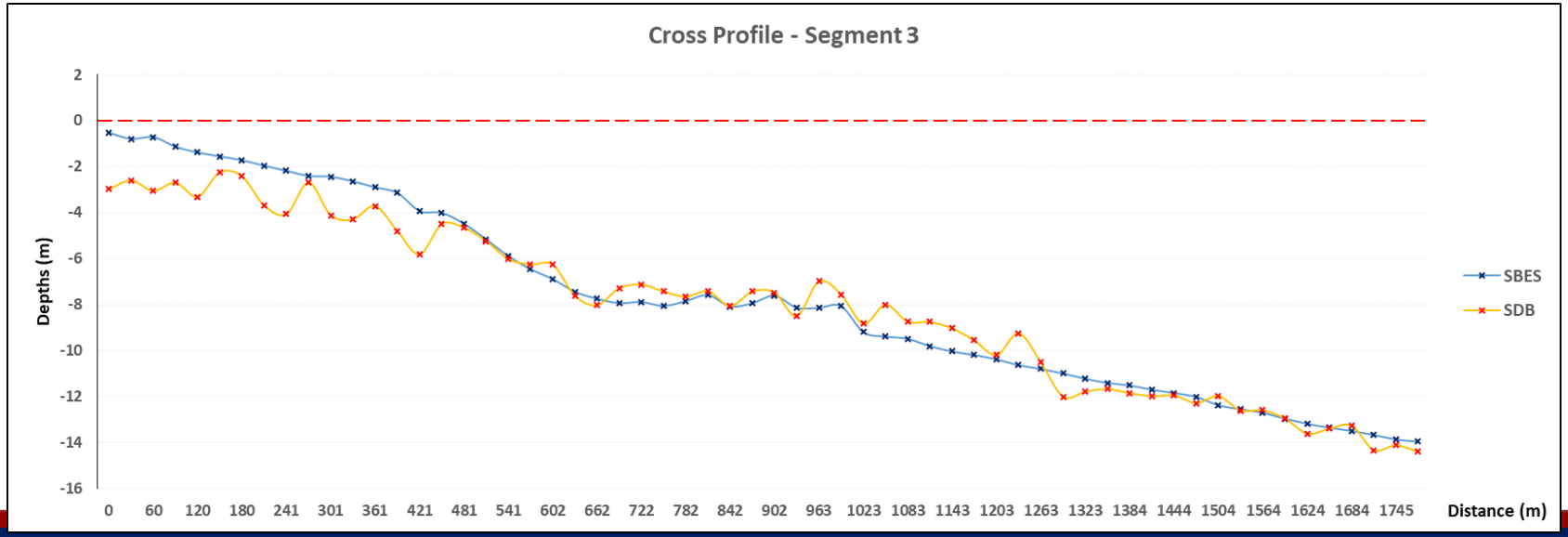

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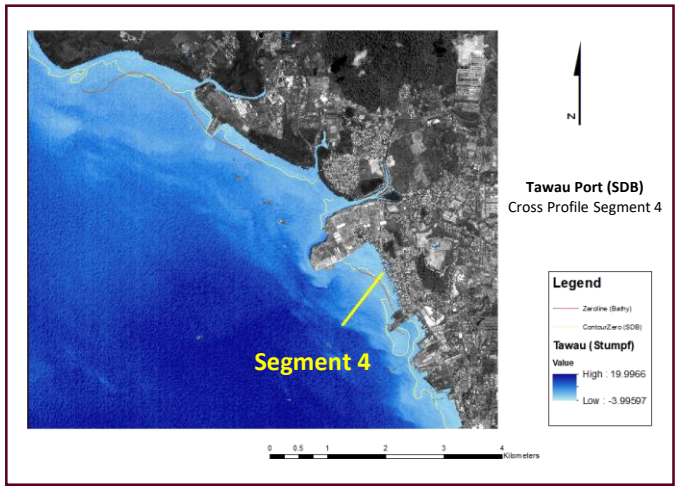

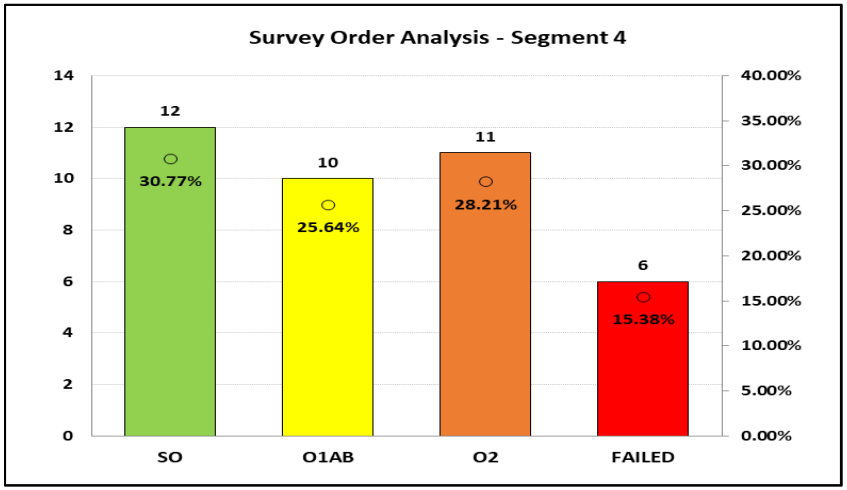

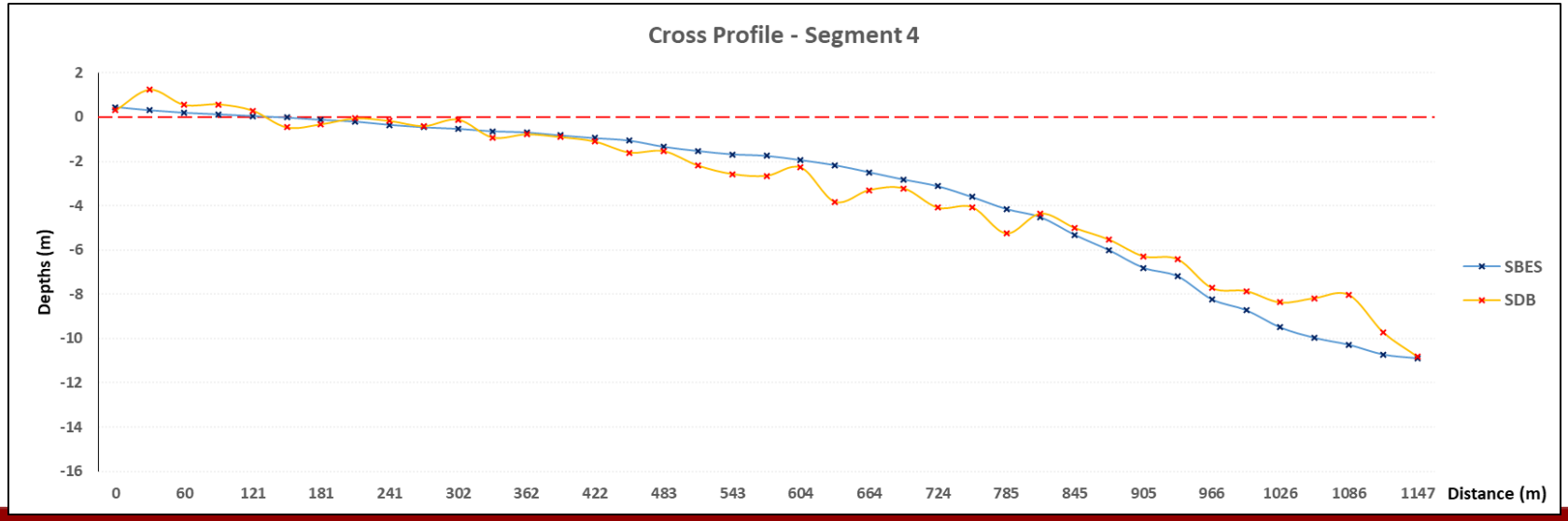

Challenges

- Difficult to have good quality image
  - Minimum change to have an ideal condition/'acceptable' quality
- Complex processing
  - SDB heavily required an experience hydrographic surveyor supervision/simplify (automation) is needed
- Rough replication of seabed
  - Features not always detected and/or difficult to determine
- Low depth (acceptable) penetration
  - 10 m on average – depends on water clarity
  - Unable to meet S-44 Special Order and Order 1a
- Sea bottom albedo effect
  - Radiance/luminance very depending on seabed types, alga etc
  - Require detail analysis especially on the factor of bottom type/albedo

Conclusion

- SDB is not a rhetorical application for LWL (TSB) delineation
  - Further study still required to improve the consistency (very shallow area)
  - Can be adopted for maritime boundary negotiation in near future
- Urgent need - to establish the standards for SDB application
  - Achievable as a number of national hydrographic offices such as SHOM and the UKHO are willing to work on a framework
- About time to have a detail guideline for SDB application (shallow water area)
  - At very least using this promising technology as an assessment tool
  - Positive progress and promising results – on going development
- Will give significant contributions to HOs/relevant agencies
- More area to analyse especially on the factor of bottom type/albedo

Dedication

- Special thanks to various organisations and agencies for the unconditional support to this study especially to
  - National Hydrographic Centre,
  - Department of Survey and Mapping Malaysia,
  - Malaysia Remote Sensing Agency; and
  - Acburn Marine Automation Sdn Bhd (Kongsberg Maritime local representative)
- Also to the Ministry of Education Malaysia and Universiti Teknologi Malaysia for funding this research under Research University Grant (Vote number: Q.J130000.2527.17H97)

Thank You

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