INTERNATIONAL FEDERATION OF SURVEYORS

INTERNATIONAL HYDROGRAPHIC ORGANIZATION

INTERNATIONAL CARTOGRAPHIC ASSOCIATION

STANDARDS OF COMPETENCE FOR CATEGORY "B" HYDROGRAPHIC SURVEYORS

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Comments arising from the experience gained in the application of the standards are welcome. They should be addressed to the Chair of the International Board on Standards of Competence for Hydrographic Surveyors and Nautical Cartographers at the above address. This document is published periodically. Please check with IHO for the latest edition, including current amendments.

1. PREFACE

All components of the hydrographic surveying and nautical cartography professions face challenges as how best to ensure the continuance of high standards and how best to ensure the continuation of best practices based on minimum standards of competence world-wide. To meet these challenges, three international organizations (FIG, IHO and ICA) have developed Standards of competence which detail the minimum competences considered necessary for the specified category of nautical cartographer or hydrographic surveyor, have been developed by the International Board of on Standards of Competence for Hydrographic Surveyors and Nautical Cartographers (IBSC).

The IBSC is composed of members of known competence in the civil, governmental or educational sectors of hydrographic surveying and nautical cartography, selected to provide as wide as possible a spectrum of knowledge and experience in educational practices, hydrography and nautical cartography, from different geographical areas. The members of the IBSC belong to three international organizations: International Federation of Surveyors (FIG), International Hydrographic Organization (IHO) and International Cartographic Association (ICA).

Changes to these standards will be released by the IHO as a New Edition, Revision, or Clarification as per the IHO Resolution 02/2007. The associated version control numbering to identify changes (n) to these S-8 and S-5 Standards is as follows:

- **New Editions** denoted as **n**.0.0
- **Revisions** denoted as n.**n**.0
- **Clarifications** denoted as n.n.**n**

Edition 2 of the S-5B Standard involved broad consultation with the international hydrographic community of the expected tasking of a Category B qualified hydrographic surveyor for the next 10 years, and a comprehensive review of the educational and training needs of a student to meet these tasks. As a result, there are significant changes. New concepts and content have been introduced while in some areas the content has remained similar, but the knowledge levels have been changed from Basic to Intermediate to reflect the changing knowledge needs as technology and methods have evolved and will continue to do so. In other areas, traditional techniques have been reduced from Intermediate to Basic knowledge levels. Some of the historical S5B Nautical Science topics (GMDSS, safety induction, safe working practices, emergency procedures and firefighting/ watertight integrity) have been removed from the standard. These items are common to many marine operations and other national and IMO recognised maritime safety courses deliver this content to approved standards, whereas the coverage in the S5B standard was not sufficient to be recognised as meeting national or IMO training requirements. Accordingly seagoing hydrographic surveyors would be required to undertake recognised maritime training in addition, leading to unnecessary duplication. Note also that S5B is a minimum standard, and institutions can add additional maritime safety elements to meet their own requirements if they wish. The removal of these nautical science topics has enabled the expected duration of a S5B programme to remain the same as previously, despite the increases in knowledge levels and content in other technical and hydrographic specific areas.

2. INTRODUCTION

The IBSC recognizes two different categories of programmes: Category A and Category B. A Category A programme provides comprehensive and broad-based knowledge in all aspects of the theory and practice of hydrography, nautical cartography and allied disciplines. A Category B programme provides a practical comprehension of hydrographic surveying, nautical

cartography and related subjects.

The intention is that a Category A qualified individual with appropriate experience, would be a senior professional in their chosen field (government, industry, academia). Category B qualified individuals with appropriate experience would be technical practitioners preparing and delivering products and services to meet specifications and outcomes.

Institutions and professional bodies must align with the Standards when submitting their education/training programmes and competence schemes for IBSC Recognition.
In addition, even if they are not applying for Recognition, education and training providers should adopt the Standards for planning, scheduling and delivering their programmes.

This document provides the details of the subjects, topics, their levels of knowledge and learning outcome that are required to meet the Category B Standard in hydrographic surveying. A student that completes a recognized programme should have achieved the required levels of knowledge, however this alone does not translate directly into a level of competence. Competence is achieved by a combination of knowledge and experience. The IBSC has recognized a number of competency schemes for individuals. These schemes assess both the level of knowledge and the specific experience of an individual in order to certify their competence.

3. DEFINITIONS

3.1. Subjects

The S5-B standard contains the following list of ***B****asic subjects* and ***E****ssential subjects*:

Topics and Elements:

- Each **Essential** or **Basic** *subject* is comprised of a list of *topics* which are denoted by Ex.y or Bx.y;
- Each *topic* contains *elements* which are denoted by Ex.y<c>.

For example, the *subject* E5 "Hydrographic practice" contains the *topic* E5.1 "Hydrographic survey projects" which has the *element* E5.1a "Hydrographic surveys purposes".

3.2. List of Content, Learning Outcomes and Level of Knowledge

It is important to understand that each *element* is associated with:

1.1.1 A list of *content*. This list is associated with one or more *learning outcomes* and describes the theoretical knowledge or practical/technical context which the course syllabus should address as a minimum, in order achieve a particular *learning outcome*. In some topics a common list of content is given for a number of closely related *elements*. Where this occurs the *content* should be considered against all *elements* to which it is relevant. Note that the content is intended to guide the conduct of learning so that the *learning outcomes* are achieved. Not every element of the *content* needs to be tested.

1.1.2 One or more intended *learning outcomes*, that a student should be able to achieve on completion of the programme. All *learning outcomes* must be assessed.

All *learning outcomes* must be assessed prior to commencement of the final project. This may be done through one or a combination of: examination, assessed exercise, laboratory report, presentation or practical exercise.

For the sake of clarity, a level of knowledge associated with each element has been defined. It is indicated in italics in the left column, by a letter (B: Basic, I: Intermediate; see "Guidelines for the Implementation of the Standards of Competence for Hydrographic Surveyors and Nautical Cartographers"). This letter designation is complemented by the verbs included in each learning outcome description which indicate the level of knowledge tested (refer Blooms Taxonomy).

3.3. Terminology

For the purpose of this publication the words:

1.1.3 must: indicates a mandatory requirement;

1.1.4 should: indicates a recommended requirement;

1.1.5 may: indicates an optional requirement

4. COMPREHENSIVE FINAL FIELD PROJECT (CFFP)

Programmes must include a supervised and evaluated Comprehensive Final Field Project with a minimum aggregate period of at least four weeks.

The Comprehensive Final Field Project for Category "B" level shall comprise a comprehensive

field survey incorporating different aspects of hydrography in a complex environment with varying sea-floor and oceanographic conditions.

Students should undertake:

- Survey specification and planning;
- Hydrographic and oceanographic measurements using a comprehensive suite of instruments which shall include as a minimum MBES, SBES & SSS;
- Data processing, quality control and quality assurance;
- Preparation of different types of product deliverables and reports.

Note: Prior to commencement of the Comprehensive Final Field Project all learning outcomes in this standard must be evaluated and exercised, either by or through a combination of assessment, examination, laboratory work or practical exercise.

5. PROGRAMME PREPARATION AND SUBMISSION FOR RECOGNITION

The preparation of a programme submission to the IBSC should be done in accordance with the document entitled "GUIDELINES FOR THE IMPLEMENTATION OF THE STANDARDS OF COMPETENCE FOR HYDROGRAPHIC SURVEYORS AND NAUTICAL CARTOGRAPHERS". This document is available from the IHO website: https://iho.int/en/standards-and-specifications

The cross-reference table is a mandatory requirement for a programme submission and **MUST** be completed. A template is specified and is available from the IHO website: https://iho.int/en/ibsc-templates

LIST OF ACRONYMS AND INITIALISMS USED IN THIS DOCUMENT

1D	One-dimensional
2D	Two-dimensional
ADCP	Acoustic Doppler Current Profiler
AI	Artificial Intelligence – a form of Expert System
AIS	Automatic Identification System
ASV	Autonomous Surface Vehicle
AUV	Autonomous Underwater Vehicle
B	Basic (level of knowledge)
C++	A powerful, general-purpose, and compiled programming language
CFFP	Comprehensive Final Field Project
COLREGS	International Convention for prevention of collisions at sea
DGNSS	Differential Global Navigation Satellite System
EPIRB	Emergency Position Indicating Radio Beacon
FIG	International Federation of Surveyors
GIS	Geographical Information System
GMDSS	Global Maritime Distress and Safety System
GNSS	Global Navigation Satellite System
GRS80	Geodetic Reference System (1980)
GSM	Global System for Mobile Communications
I	Intermediate (level of knowledge)
IBSC	International Board on Standards of Competence for Hydrographic Surveyors and Nautical Cartographers
ICA	International Cartographic Association
ICESAT-2	NASA's Ice, Cloud, and Land Elevation Satellite equipped with high precision Advanced Topographic Laser Altimeter System (ATLAS)
IHO	International Hydrographic Organization
IMU	Inertial Motion Unit
INS	Inertial Navigation System
LAN	Local Area Network
LiDAR	Light Detection And Ranging
MBES	Multi Beam Echo Sounder
MSDI	Marine Spatial Data Infrastructure
MSL	Mean Sea Level
NAVTEX	Navigational Telex
Python	A high-level, general-purpose programming language
RAM	Random Access Memory
ROV	Remotely Operated Underwater Vehicle
S-44	IHO Publication S-44 - *Standards for Hydrographic Surveys*
S-100	IHO Publication S-100 *Universal Hydrographic Data Model*
S-101	IHO Publication S-101 *ENC Product Specification*
S-102	IHO Publication S-102 *Bathymetric Surface Product Specification*
S-122	IHO Publication S-122 *Marine Protected Areas*
S-131	IHO Publication S-131 *Marine Harbour Infrastructure*
SARSAT	Search And Rescue Satellite Aided Tracking

SBES	Single Beam Echo Sounder
SDB	Satellite Derived Bathymetry
SDI	Spatial Data Infrastructure
SG	Self-guided exercises (or student's personal independent work)
SOLAS	Safety of Life at Sea Convention
SSDM	IOGP Seabed Survey Data Model
TIN	Triangulated Irregular Network
UNCLOS	United Nations Convention on the Law of the Sea
USBL	Ultra Short Baseline
UAV	Uncrewed Aerial Vehicle
USV	Uncrewed Surface Vessel
UTM	Universal Transverse Mercator
UUV	Uncrewed Underwater Vehicle
WGS84	World Geodetic System (1984)
WiFi	Wireless network protocol allowing wireless communication
XML	Extended Markup Language
ZOC	Zones of Confidence

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S-5B STANDARDS

INTENDED LEARNING OUTCOMES AND ASSOCIATED CONTENT

1. BASIC SUBJECTS

B1: Mathematics, Statistics, Theory of Errors		
Topic/Element	**Content**	**Learning outcomes**
B1.1 Linear Algebra *(B)*	(i) Vector and affine spaces, vector and inner products, norms. (ii) Linear equations, determinants. (iii) Analytical geometry, line and plane equations. (iv) Linear operators, matrix representation, composition, inverse, transpose. (v) Translations, rotations, coordinate transformations.	*Describe* 2D transformations involved in surveying and mapping. (E4.1c) *Explain* how linear equations are solved using matrix methods.
B1.2 Trigonometry *(B)*	(i) Basic trigonometry (ii) Sphere, great circle, rhumb lines, sphere angles, spherical triangles and spherical excess.	*Explain the use of* plane and spherical trigonometry to solve surveying problems.
B1.3 Statistics *(B)*	(i) Random variables, mean, variance, standard deviation (ii) Covariance and correlation (iii) Estimation of mean, variance, covariance (iv) Normal distribution	*Explain* what is meant by a random variable, estimate the mean, variance and standard deviation for a random variable, and also the covariance between random variables.
B1.4 Theory of errors *(B)*	(i) Linear observation equations (ii) Covariance propagation law	*State* the variance propagation law in relation to a linear observation equation, and explain measurement uncertainty as a function of observables' covariances.
B1.5 Least squares *(I)*	(i) Least squares procedure (ii) Covariance of estimated parameters (iii) Use of unit variance factor estimate (iv) Interpretation of ellipses of confidence	*Analyze* results from a least square estimation applied to survey measurements.

B1.6 Interpolation *(B)*	(i) 1D polynomial interpolation (ii) Spatial interpolation by inverse distance weighting methods	*Compare* 1-D and spatial interpolation methods. Create and compare interpolated surfaces from one set of sparse survey measurements using appropriate software under different configurations.
B2: Information and Communication Technology		
Topic/Element	**Content**	**Learning outcomes**
B2.1 Computer systems *(I)*	(i) Central Processing Unit (ii) RAM, data storage (iii) Communication board, serial links, communication ports buffers, Ethernet links, data transmission rates (iv) Communication protocols (v) Clocks, clocks drift, time tagging and synchronization of data (vi) Operating systems (vii) Device drivers (viii) System integration faults	*Examine* different components of a real-time data acquisition system, including various modes of communication and time-tagging. *Explain* the role of a device driver and its relation to data exchange. *Diagnose* and solve common faults with system integration
B2.2 Web and network communications *(B)*	(i) Networks (LANs) (ii) Internet (iii) Networks integrity (iv) Communication protocols	*Describe* the different network communication protocols used in remote data exchange applications.
B2.3 Principles of Remote Desktop Operations *(I)*	(i) Remote desktop applications (ii) Communication links, e.g. short range and over the horizon (iii) Remote monitoring and control of computer systems.	*Demonstrate* the ability to *install, set up and operate* remote desktop software
B2.4 Programming *(I)*	(i) Basic operations of a computer program or script (ii) File types (binary, text, XML) (iii) Algorithms (loops, conditional instructions) (iv) Scientific computation environments (v) Application to data exchange, file conversion (vi) Modern programming languages, e.g Python, C++	*Write* a program for data format conversion and/or basic algorithm computation.
B2.5 Databases *(B)*	(i) File types (binary, text, XML) (ii) Relational databases (iii) Geospatial databases	*Describe* different types of geospatial data and their representation.

B3: Physics		
Topic/Element	**Content**	**Learning outcomes**
B3.1 Mechanics *(B)*	(i) Kinematics (angular and linear velocities, accelerations) (ii) Coriolis Effect (iii) Newton's law, forces, accelerations, energy	*Describe* the relationship between linear and rotational motions through acceleration and velocity
B3.2 Gravity *(B)*	(i) Gravity field of the earth (ii) Equipotential surfaces	*Describe* the gravity field of the earth in terms of acceleration and potential
B3.3 Waves *(B)*	(i) Electromagnetic waves (ii) Pressure waves (iii) Ocean waves (iv) Wave Propagation (v) Electromagnetic spectrum (vi) Radiation, emission and absorption (vii) Reflection, refraction, diffraction	*Explain* the types of waves and their generation and propagation. *Explain* how medium parameters affect wave behavior.
B4: Earth Sciences		
Topic/Element	**Content**	**Learning outcomes**
B4.1 Geography and geology *(B)*	(i) Plate tectonics, earthquakes zones (ii) Different types of rocks (iii) Erosion and deposition (iv) Rivers and estuaries	*Describe* the internal structure, the physical characters and dynamics of the Earth referring to ocean basin structure, and the major processes affecting coastal morphology
B4.2 Substrates *(B)*	(i) Sediment types (ii) Sedimentary cycles (iii) Siltation (iv) Submerged aquatic vegetation (v) Corals	*Describe* the ocean bottom as a multilayered structure composed of sediment deposits. *Compare* the characteristics of common seafloor types
B5: Maritime Operations		
Topic/Element	**Content**	**Learning outcomes**
B5.1 Conventional aids to navigation *(B)*	(i) Types of buoys and beacons (ii) Radar beacons (iii) AIS systems	*Describe* the principal fixed and floating aids to navigation and the use of automatic identification systems.
B5.2 Navigation regulations (*B*)	(i) International Convention for prevention of collisions at sea (COLREGS) (ii) IMO Rules for Marine Autonomous surface ships (iii) National rules for remotely operated or autonomous uncrewed vessels	*Explain* the requirements and regulatory challenges of operating uncrewed vessels for survey operations.

B5.3 Nautical charts *(B)*	(i) Content, datum, projection, scale and types of nautical charts (ii) Chart symbols (iii) Chart graticules (iv) Uncertainty indicators (e.g. source diagram, reliability diagram, zone of confidence, notes) (v) Navigational hazards (vi) Plotting instruments	*Layout* a route on a nautical chart, plot positions, identify navigational hazards and revise navigational plan as required. *Describe* the content of a nautical chart and explain datum, projection, scale *Describe* the uncertainty indicators associated with nautical charts.
B5.4 Navigation publications *(B)*	(i) Sailing directions, (ii) Light and radio lists, (iii) Tides and current tables (iv) Notice to mariners	*Explain the* content of nautical publications in a survey planning context.
B5.5 Compasses *(B)*	(i) Earth magnetic field (ii) Magnetic compasses (iii) Gyros (iv) Compass error and corrections	*Describe* the capabilities, limitations and errors of magnetic and gyro compasses. Determine and apply corrections for magnetic and gyro compass error.
B5.6 Rope and wires *(B)*	(i) Types of wire and rope (ii) Characteristics (stretch, floating, strength) of ropes. (iii) Basic knots	*Select* and tie basic knots. *Select* appropriate wire or rope.
B5.7 Towed and over the side instruments *(I)*	(i) Rosette systems and instruments (ii) ROVs, AUVs, towed systems, catenary and layback (iii) A-frames, cable blocks, electro-mechanical wire, slip rings and optical cabling (iv) Moonpools (v) Launch and recovery (vi) Station keeping and maneuvering	*Deploy* and recover oceanographic and hydrographic equipment
B5.8 Anchoring *(B)*	(i) Shipboard ground tackle including anchor, chain, windlass, stoppers (ii) Small boat anchoring (iii) Multiple anchors	*Describe* ship and small boat anchoring and ground tackle.
B5.9 Instrument moorings *(I)*	(i) Launch and recovery (ii) Anchors and acoustic releases (iii) Scope, wire, flotation, tension (iv) Weights (v) Other considerations, e.g. bottom type, tidal stream, seabed slope	*Prepare, deploy* and recover seabed instruments.

B6: Meteorology		
Topic/Element	**Content**	**Learning outcomes**
B6.1 Weather fundamentals *(B)*	(i) Vertical structure and the variability of the atmosphere (ii) Temperature, humidity, dew-point, frost-point (iii) Pressure systems, winds (iv) Clouds (v) Precipitation - rain, snow (vi) Visibility, advection fog and radiation fog (vii) Geostrophic winds, anabatic and katabatic winds (viii) Wind waves (ix) Instruments and sensors used to measure temperatures, pressure, direction and intensity of wind	*Define* physical meteorological Parameters. *Describe* instruments and sensors used to measure temperature, pressure, direction and intensity of wind. *Identify* characteristics of weather by simple observation of the sea and the sky.
B6.2 Wind *(B)*		*Explain* the relation between atmospheric pressure, temperature and wind. Describe wind circulation around pressure systems and the effect of friction. *Explain* the effects of wind and current / tidal stream on sea surface and their impact on survey operations.
B6.3 Interpreting weather forecasts *(B)*	(i) Synoptic charts (ii) Weather forecast	*Describe* a synoptic chart. Discuss the expected weather forecast based on meteorological information, weather bulletins and facsimile charts

2. ESSENTIAL SUBJECTS

E1: Underwater Acoustics		
Topic/Element	**Content**	**Learning outcomes**
E1.1 Acoustic Theory		
E1.1a Generation of acoustic waves *(B)*	(i) Plane and spherical waves in terms of wavelength, amplitude and frequency. (ii) Speed of sound in relation to water properties and profile in the water column. (iii) Acoustic units, intensities and sound levels (iv) Active Sonar Equation including sound source, causes of propagation loss in relation to water properties together with characteristics of the sea floor and targets, noise level and directivity (v) Refraction and the path of sound rays through the water column. (vi) Transducer principles and beam characteristics (vii) System parameters including bandwidth, pulse length, pulse repetition rate, gain, detection threshold, range resolution and spatial resolution.	*Explain* how transducer parameters impact upon beam characteristics.
E1.1b Propagation of acoustic waves *(I)*		Using appropriate units, *describe* acoustic wave behavior with reference to physical properties of the water column. *Analyze* a sound speed profile from water column measurements and describe its effect on the acoustic ray path.
E1.1c Reflection, scattering and system performance *(B)*		*Identify* sources of noise and the impact of noise on operation of acoustic systems.
E1.1d Reception of acoustic waves *(B)*		*Explain* how a system is optimized in terms of environmental factors for measurement and target detection.
E1.2 Single Beam Systems & Side Scan Sonar		
E1.2a Single beam echo sounders *(I)*	(i) Split beam and dual beam echo sounders (ii) Components of a single beam echo sounder. (iii) Operation of single beam echo sounders. (iv) Bottom detection principles. (v) Full-echo-envelope returns (vi) Sub-bottom profiling systems. (vii) Validation & Calibration. (viii) Principles, components, geometry and deployment of side scan sonar systems. (ix) Side scan sonar backscatter and sea floor reflection. (x) Side scan images and sources of distortion.	*Set up, deploy* and *operate* a single beam echo sounder. *Optimize* appropriate range, scale, frequency and pulse repetition rate for specific applications in relation to spatial resolution, bottom penetration and depth of water.
E1.2b Single beam echo sounder data recording. *(I)*		*Interpret* echo sounder returns and identify different bottom types and characteristics of the return signals.
E1.2c Range uncertainty *(I)*		*Analyze* and quantify components contributing to uncertainty in derived ranges.

E1.2d Side scan sonar *(I)*	(xi) Combining sources of uncertainty.	*Set up, deploy* and *operate* side scan sonar. *Interpret* side scan sonar records considering target characteristics, system configuration, potential sources of noise and distortion.
E1.3 Swath Systems		
E1.3a Beam characteristics *(B)*	(i) Transducer elements and arrays. (ii) Beam forming and beam steering	*Define* characteristics of beams in relation to transducer settings. *Compare* phase and interferometric systems with multi-beam systems
E1.3b Backscatter and water column returns *(B)*	(iii) Principles and geometry of multi-beam and interferometric (phase measurement) sonar systems (iv) Amplitude and phase bottom detection	*Describe* characteristics of returns in the context of seabed type, angle of incidence and scatter from within the water column
E1.3c Bottom spatial coverage *(I)*	(v) Variations in beam spacing and footprint size (vi) Backscatter and seabed classification	*Calculate* sounding density and object detection capability as functions of system parameters
E1.3d Installation and configuration *(B)*	(vii) Hull and pole mounting of transducers considering platform motion. Integration of components including time stamping, attitude compensation, sensor offsets and networking.	*Describe* suitable mounting structure and location for transducers given operational constraints
E1.3e Range and angle uncertainty *(I)*	(viii) Surface and water column sound speed monitoring (ix) Gain, power, pulse length	*Discriminate* between error sources in phase and amplitude detection modes. Examine sources of range and angle uncertainty depending on acoustic parameter configuration
E1.3f Operation *(I)*	(x) Quality control procedures	*Set up, deploy* and *operate* a swath sonar system. *Analyze* problems or artefacts in on-line data due to inappropriate configuration or changing environmental parameters. *Apply* acoustic parameters for optimum performance. *Apply* quality control procedures to data acquisition and on-line processing

E2: Remote Sensing		
Topic/Element	**Content**	**Learning outcomes**
E2.1 LiDAR		
E2.1a Airborne LiDAR systems *(B)*	(i) Wavelength, water penetration and ground detection (ii) Scanning frequency and pattern in relation to power, coverage and spatial density (iii) Influence of sea surface roughness, water column turbidity on the beam pattern and penetration. (iv) Seabed optical characteristics and bottom detection. (v) Secchi disc and Secchi depth (vi) Optical characteristics of coastal terrain. (vii) Influence of geometry and waveform on feature detection. (viii) Integration of components including time stamping, attitude compensation, sensor offsets and networking. (ix) Combined bathymetric and topographic LiDAR systems (x) Portable laser scanners	*Explain* the principles, capabilities and limitations of topographic and bathymetric LiDAR. *Describe* the physical environment and operational situations in which bathymetric LiDAR surveys are complementary to echo sounder surveys
E2.1b Airborne LiDAR data products *(I)*		*Interpret* high and low water lines from bathymetric and topographic LiDAR data sets. *Use* topographic and bathymetric LiDAR data to complement other spatial data.
E2.1c Terrestrial LiDAR *(I)*		*Use* terrestrial LiDAR data to complement other coastal spatial data.
E2.1d Underwater LiDAR *(B)*		*Discuss* uses and deployment of underwater LiDAR to complement hydrographic surveys
E2.2 Remote Sensing		
E2.2a Remotely sensed bathymetry *(B)*	(i) Multispectral imagery and water penetration in relation to wavelength (ii) Satellite Derived Bathymetry (SDB) (iii) Spatial resolution and accuracy available (iv) Space based LiDAR e.g. ICESAT-2	*Compare* techniques and data sources for remotely sensed bathymetric data and *Explain* the spatial parameters associated with each. *Describe* Satellite Derived Bathymetry (SDB) concepts, solutions and factors in determining uncertainties
E2.2b Shoreline delineation *(I)*	(i) Multispectral imagery, reflectance in relation to wavelength and terrain characteristics. (ii) Geometrical properties of satellite images and aerial photographs	*Describe* geometrical properties of images and use them to create a shoreline map from images and aerial photographs. *Use* imagery to delineate shoreline.

E3: Water Levels and Flow		
Topic/Element	**Content**	**Learning outcomes**
E3.1 Principles of Water Levels		
E3.1a Tidal fundamentals *(B)*	(i) Tide generating forces, the equilibrium and real tides. (ii) Major harmonic constituents and different types of tide. (iii) Amphidromic points and co-tidal charts. (iv) Geomorphological influences on tidal characteristics	*Explain* tidal characteristics in terms of tide raising forces and local and regional morphological features.
E3.1b Tidal information *(I)*	(i) Tide and current tables (ii) Tide prediction tools	*Use* tide tables and appropriate software to determine predicted water levels and tidal currents.
E3.1c Non-tidal water level variations *(B)*	(i) Changes in water level caused by: atmospheric pressure, wind, seiches, ocean temperature and precipitation (ii) Water level variations in estuaries, wetlands and rivers (iii) Water level variations occurring in inland lakes, rivers, reservoirs and canals.	*Describe* the effect of non-tidal influences on tidal water levels in the conduct of a hydrographic survey *Describe* sources of water level variations occurring in inland waters

E3.2 Water Level Measurement		
E3.2a Water level gauges *(I)*	(i) Operating principles of various types of water level gauges including pressure (vented and unvented), GNSS tide gauge buoys, float, radar, acoustic sensors and tide poles/boards/staffs. (ii) Installing water level gauges, establishment and levelling of associated survey marks (iii) Networks of water level gauges (iv) Reference levels such as MSL, chart datum, and mean high water. (v) River and lake datums (vi) Uncertainties associated with measurement devices (vii) Uncertainties associated with duration of observations. (viii) Uncertainties associated with spatial separation of water level measurements.	*Select* the appropriate type of water level gauge for the survey area. *Install*, level and *calibrate* water level gauge.
E3.2b Tidal measurement *(I)*		*Optimize* water level gauges for logging data, data communication, data download and for network operation with appropriate quality control measures. *Interpret* GNSS tide gauge data and connect to geoid
E3.2c Water level datums *(B)*		*Define* various tidally based reference levels on the basis of tide time series and explain how these values are computed. *Describe* how vertical reference levels in rivers and lakes are defined and determined in practice.
E3.2d Uncertainty in water level *(I)*		*Correlate* uncertainty in water levels to uncertainties in measurement, duration and distance from water level gauge.

E3.3 Water Level Reduction		
E3.3a Water level reduction of soundings *(I)*	(i) Vessel draft, squat (ii) Lever-arms and Position Reference Point offsets (iii) Vertical datums for sounding reduction (iv) Predicted tides versus measured tide reduction (v) Co-tidal charts (vi) Reduction of survey data to a datum using GNSS observations (vii) Reduction of survey data using water level observations	*Use* tidal information, and vessel parameters to reduce soundings to a specified datum.
E3.3b Reduction of soundings using GNSS observations *(I)*		*Use* vessel GNSS to reduce soundings to a specified datum.
E3.4 Currents		
E3.4a Tidal streams and currents *(B)*	(i) The relationship between currents and tides (ii) Rectilinear and rotary tidal streams (iii) Methods for measuring tidal streams and currents, including current meters, acoustic current profilers (ADCP) and (iv) drogues. (v) Current surveys (vi) Surface current radar observation Portraying current data	*Explain* the forces behind currents and change in currents with tides.
E3.4b Current measurement and portrayal *(B)*		*Describe* techniques for current measurement and identify appropriate methods for acquiring and displaying current data.

E4: Geodesy, Map Projections and Positioning		
Topic/Element	**Content**	**Learning outcomes**
E4.1 Geodesy		
E4.1a Introduction to Geodesy *(B)*	(i) Shape of the Earth as a sphere, ellipsoid of revolution and the geoid; (ii) Definitions of astronomical terms and time. (iii) Geodetic computations on the ellipsoid. (iv) Local geodetic reference frames (v) Vertical datums (vi) Terrestrial reference systems and reference frames. (vii) Modern geodetic datums WGS84, GRS80. (viii) Datums and datum transformation techniques (ix) Ellipsoid separation models	*Describe* the shape of the Earth in terms of potential and ellipsoidal models
E4.1b Coordinate systems, frames and datums *(B)*		*Describe* modern geodetic reference systems and associated reference frames.
E4.1c Geodetic transformations and associated computations *(B)*		*Describe* horizontal and vertical datum transformation concepts
E4.1d Ellipsoidal computations *(B)*		*Describe* geometry of lines on the ellipsoid and perform forward and inverse computations on the ellipsoidal surface using available software.
E4.1e Geoid ellipsoid separation *(I)*		*Describe* contemporary ellipsoid separation models and their uncertainties *Use* an ellipsoid separation model to compute geoidal heights and uncertainties
E4.2 Map Projections		
E4.2 Map projections *(B)*	(i) Geometrical properties of map projections (ii) Conformal, cylindrical, conical projections including the UTM system and stereographic (iii) Analytical projection formulae and planimetric coordinates (iv) Distortions in distance and direction associated with different map projections	*Describe* the properties and distortions in different types of projections used in maps and charts. *Explain* the selection of projection type and apply appropriate projection formulae.
E4.3 Positioning Measurements, Methods and Techniques		
E4.3a Positioning fundamentals *(I)*	(i) Principles of distance measurement and angle measurement (ii) Principles of 2D adjustment (iii) Total station (iv) Legacy positioning devices	*Perform* control surveys, install marks and describe control stations, *perform* horizontal positioning procedures, *apply* appropriate methods and *use* corresponding instruments for positioning.

E4.3b Satellite positioning *(I)*	(v) Intersection, Resection, Polar and Traverse (vi) Astronomic methods for determination of orientation. (vii) Principle of GNSS positioning (viii) GNSS services characteristics (single baseline, network, Precise Point Positioning) (ix) Performance of code vs. carrier; differential vs. autonomous modes; multiple vs. single frequency; fixed vs. float ambiguity resolution (x) Atmosphere (troposphere, ionosphere) effects on GNSS signals (xi) Control stations (xii) Logistical aspects of providing control	*Explain* the GNSS concept and principles. *Define* pseudo ranging and carrier phase based modes of satellite positioning. *Discriminate* between base station and permanent networks, real-time and post-processing.
E4.3c Positioning systems *(I)*		Field test and *use* distance and angle measurement instruments. *Apply* field validation procedures. *Perform* sun azimuth observation and computation. *Operate* GNSS and DGNSS equipment, assess accuracy and precision, post-process GNSS data using appropriate software.
E4.3d Historical surveys *(B)*		*Describe* historical surveys using legacy positioning methods and *compare* uncertainties
E4.3e Survey control *(I)*		*Construct*, mark, and describe control stations, particularly hydrographic stations.
E4.4 Vertical Positioning		
E4.4a Height systems *(B)*	(i) Height systems (dynamic, orthometric and normal) (ii) Leveling instruments (iii) Total stations (iv) Effects of curvature and refraction (v) GNSS observations	*Compare* gravity-related and ellipsoidal heights
E4.4b Elevation measurements and computation *(I)*		*Describe* methods for determining elevation differences. *Use* GNSS equipment to determine height. *Use* leveling instruments with correct observation techniques to determine height differences. *Compute* elevations and leveling networks from observed leveling data.

E4.5 Acoustic Positioning		
E4.5a Acoustic positioning concepts *(B)*	(i) Long baseline (ii) Short baseline (iii) Ultra-short baseline (iv) Transponders (v) Depth sensors (vi) Integration with INS and velocity sensors (vii) Use of acoustics for positioning towed vehicles, ROVs and AUVs (viii) Use of acoustics for underwater dimensional control	*Describe* the deployment, calibration, signal structure and performance of acoustic positioning devices. *Describe* the use of acoustic positioning systems in offshore survey operations.
E4.5b Acoustic positioning systems *(B)*		*Describe* the principles of integrated subsea positioning systems and their application to remote survey platforms
E4.6 Inertial Navigation		
E4.6a Inertial Measurement Units *(B)*	(i) Gyros and accelerometers (ii) IMU (iii) Procedures for INS static and dynamic alignment (iv) Use of IMU in heave estimation (v) Aided Inertial navigation: ● ADCP/INS ● GNSS/INS ● USBL/Depth/INS	*Describe* principles and use of IMU's including north finding and heave estimation. *Compare* IMU heading measurements with magnetic and gyro compasses.
E4.6b Inertial Navigation Systems (*B*)		*Compare* IMUs and INS, and describe dynamic alignment of INS. *Explain* the concepts of aided inertial navigation system.
E4.7 Uncertainty in Positioning		
E4.7 Sources of uncertainty *(I)*	(i) Static surveys: ● GNSS observations ● Total stations ● Leveling instruments ● Acoustic positioning (ii) Mobile surveys: ● GNSS equipment ● IMU/INS ● Acoustic positioning (iii) Total propagated uncertainty	*Analyze* the sources and magnitude of uncertainties associated with each positioning method and positioning system. *Operate* and *analyze* the performance of each positioning system to be used including repeatability, precision and accuracies of relative and absolute positions using appropriate statistical tools.

E5: Hydrographic Practice		
Topic/Element	**Content**	**Learning outcomes**
E5.1 Hydrographic Survey Projects		
E5.1a Hydrographic survey purposes *(I)*	(i) IHO S-44 and other survey quality standards. (ii) Hydrographic instructions and tenders (iii) Purpose of surveys, such as: ● Safety of navigation ● Maritime boundary delimitation ● Ports, Harbor and waterways ● Engineering works and dredging ● Coastal engineering for construction and renewables such as wind farms ● Inland waters ● Erosion and land-sea interface monitoring ● Environmental impact assessment ● Deep sea investigation ● Seismic and geomagnetic ● Pipeline and cable routes, installation and laying	*Interpret* hydrographic instructions and tenders and *prepare* a survey plan to achieve survey specifications.
E5.1b Hydrographic survey execution requirements *(I)*		*Analyze* the different survey purposes and *correlate* platform and equipment selection considerations associated with purposes of survey operations.
E5.1c Hydrographic survey project organization *(I)*		*Discriminate* the roles and responsibilities of individuals within a survey team.
E 5.1d Hydrographic survey platforms (*B*)	(i) Types of platforms, such as: ● Airborne ● Crewed surface vessels and USV/drones ● Sub-surface vehicles ● ROV / Autonomous	*Compare* the advantages and limitations of different survey platforms (airborne or maritime, vessel size, crewed or uncrewed) for differing survey purposes, survey extents, complexities and depth ranges.
E5.2 Hydrographic Survey Operations		
E5.2a Operational survey data transfer *(I)*	(i) Remote water level measurement (ii) Shore based stations in support of positioning systems (iii) Use of remote survey platforms and real time communication of data acquired. (iv) Data telemetry links including radio, satellite, 4/5GSM, WiFi, Bluetooth and underwater communications. (v) Compatibility between equipment and	*Describe* data telemetry and transmission links used in hydrographic surveying, including latency, bandwidth, redundancy, and cybersecurity and encryption considerations. *Operate* a remote real-time data telemetry link between a survey infrastructure component and a survey system.

	communications devices. (vi) Latency, bandwidth, and redundancy considerations in hydrographic data transfer. (vii) Cybersecurity and encryption protocols for secure data transmission.	
E5.2b Uncrewed Survey Vessels *(B)*	(i) Types of USV, UUV, UAV (ii) Telemetry, data communication System and range/coverage (iii) Power supply and payload and endurance (iv) Launch and recovery (v) Sensor integration, installation and calibration (vi) Safety protocol, regulatory compliance and emergency procedure (vii) AI and autonomous navigation systems for USVs/UUVs, including collision avoidance and route optimization.	*Describe* various types of uncrewed survey vehicle, capabilities, limitations, range and coverage. *Explain* basic procedures in operating various types of uncrewed survey vehicles including launch and recovery, safety protocols, and emergency procedures. *Compare* communication methods for controlling uncrewed survey vessels *Describe* the operation of AI enhanced autonomous navigation to optimize seabed survey coverage
E5.2c Survey systems *(I)*	(i) Installation and calibration requirements for: ● Echo sounders ● Swath systems ● MBES systems ● Side scan sonar ● Laser scanner ● Surface and sub-surface positioning system ● IMU/INS (ii) Sound velocity probes and profilers (iii) Data acquisition and integration systems (iv) Bar check (v) Patch Test (vi) Boresight calibration for alignment bias (vii) Layback calculations	*Set-up* and *integrate* survey system including: sensors, acquisition system time-stamping strategy and measure physical sensor offsets. *Demonstrate* the importance of the correct installation, calibration and determination of the attitude and position of each sensor and survey system integration. *Identify* and *solve* problems/faults in vessel integrated survey system and computer network
E5.2d Calibration and corrections *(I)*		*Analyze and calibrate* survey system and *determine* appropriate time, pitch roll, yaw and other relevant corrections. *Explain* the purpose and *apply* speed of sound measurements in acoustic systems.

E5.2e Line planning *(I)*	(i) Planning for data acquisition including line spacing and sample locations in alignment with tasks to be performed on surveys and equipment to be used. (ii) Planning of survey operation considering currents, tides and survey speed. (iii) Track guidance and route following information systems including AI. (iv) AI-assisted methods during survey line keeping to minimize gaps and improve line adherence.	*Prepare* a vessel survey line plan including consideration of towed, remote vehicle and autonomous vehicle lines in space and time.
E5.2f Line keeping *(B)*		*Explain* the methods of maintaining a survey vessel or survey system on a planned survey line or route. *Describe* the effects on the survey quality due to the vessel motion (speed over the ground, angular velocity). *Discuss* the use of AI during survey operations to minimize data gaps
E5.2g Survey operations *(B)*	(i) Survey parameters including: ● scale, ● positional accuracy and precision, ● survey speed, ● line orientation, ● environmental and oceanographic parameters ● survey lines, interlines and cross lines, ● sounding density and spatial resolution ● overlap ● data coverage. (ii) Quality control of: ● Horizontal position ● Vertical position (heave, squat, water level) ● Coverage and overlap ● Swath system data ● Sound speed	*Describe* the roles and the relationships of the following survey parameters: scale, positional accuracy, survey speed, line orientation, survey lines, interlines, cross lines, fix intervals, data coverage. *Explain* how seabed type and sediment movement impact historical comparisons of repeated surveys and influence required frequency of re-survey.
E5.2h Quality control *(I)*		*Employ* methods for quality control of survey data and the quality assurance of survey operations.
E5.2i Environmental considerations and impacts *(I)*	(i) Permanent and temporary threshold shifts (hearing) for marine mammals. (ii) Use of physical techniques such as bar sweeps in environmentally sensitive areas. (iii) Respect for cultural traditions in relation to use of the environment (iv) Marine protected areas (v) Marine Pollution	*Apply* appropriate procedures and limitations for use of surveying equipment in compliance with environmental laws and marine protected area regulations. *Develop* survey procedures to minimize potential pollution or environmental damage from survey vessel operations and equipment deployment.

E5.3 Hydrographic Survey Documentation		
E5.3a Documentation *(I)*	(i) Production of reports associated with the survey to include items such as: ● Coverage including special investigation areas ● Features such as rocks, wrecks, obstructions, wellheads and pipelines (least depth, extent and position) ● Track charts ● Geodetic control on features such as shoreline and navigation aids (ii) Metadata to include data types of data obtained together with associated quality measures such as positional, thematic and temporal uncertainty as well as lineage. (iii) Maintaining survey notes on event-by-event findings during data acquisition. (iv) Quality control procedures implemented, and calibration reports produced (v) Compliance with survey specifications and standards.	*Prepare* documents associated with survey procedures and reporting requirements using files, charts and reporting tools. *Analyze* survey results, including comparisons with previous surveys/charts and explain differences. *Analyze* the sources and methods by which metadata files are created and populated.
E5.4 Legal Aspects		
E5.4a Liability of the hydrographic surveyor *(B)*	(i) Nautical charts. (ii) Notice to mariners. (iii) Survey reports. (iv) Fundamentals of professional liability relating to surveying	*Describe* the role and responsibilities of the hydrographic surveyor as required under professional ethics, industry standards and national/international legislation/conventions. *Explain* the potential liability of the hydrographic surveyor
E5.4b Maritime Boundaries *(B)*	(i) UNCLOS • Base points • Baselines – normal (including closing lines); straight and archipelagic • Internal waters • Territorial seas • Contiguous zones • Exclusive Economic Zone • Extended continental shelf • High seas	*Describe* the types of baselines under UNCLOS and how the territorial sea limit is projected from them, including the use of low tide elevations. *Explain* the various maritime zones and their restrictions in relation to foreign vessel activities within them.
E5.4c The National Hydrographic Authority *(B)*	(i) UNCLOS/SOLAS obligations. (ii) National legislation	*Describe* the roles and responsibilities of the National Hydrographic Authority

E6: Hydrographic Data Management		
Topic/Element	**Content**	**Learning outcomes**
E6.1 Real-Time Data Acquisition and Control		
E6.1a Hydrographic Data acquisition *(I)*	(i) Integration and logging of data from various sensors in accordance with survey specifications to include equipment such as: ● Echo sounder (SBES, MBES) ● LiDAR ● Laser scanner ● Sound velocity profiler, surface velocity probe ● Side-scan sonar ● Surface positioning system ● IMU / INS ● Sub bottom profiler ● Subsea positioning system (USBL) ● ROV / AUV / USV (ii) Data acquisition system and software (iii) Time-tagging (iv) Data visualization	*Optimize* the configuration of data acquisition and recording software, including sampling rates, gating and filtering settings, to log and monitor data from multiple sensors. *Demonstrate* the process of on-line data monitoring and validation.
E6.1b Real-time data monitoring *(I)*		*Demonstrate* that the data meets survey requirements through on-line monitoring of display and visualization tools. *Use* monitoring software to detect possible biases and errors in the data.
E6.1c Data transfer and storage *(I)*	(i) Content of files in different formats used to record data in survey planning, data acquisition and products, such as point clouds and backscatter (ii) Organization of survey databases (iii) Data storage and backup systems including cloud solutions (iv) Implementation of cloud-based or edge computing solutions for real-time survey data processing and sharing.	*Analyze* the required data types that will be part of standard exchange formats. *Configure* systems for secure storage, transfer and backup of survey data, including remote/online data transfer

E6.2 Data Processing and Analysis		
E6.2a Spatial data cleaning and validation *(I)*	(i) Data cleaning and validation techniques (manual, automated and AI enhanced) (ii) Implementation of cloud-based or edge computing solutions for real-time survey data processing and sharing. (iii) Identification of outliers (iv) Identification of real features	*Apply* data cleaning techniques using appropriate software and compare AI enhanced with other methods. *Compare* the advantages and limitations of on-board versus cloud-based / data-linked remote data processing during survey operations and discuss the implications for uncrewed vessels *Discriminate* between noise, outliers & real features
E6.2b Spatial data quality control *(I)*	(i) Total propagated uncertainty - horizontal (ii) Total propagated uncertainty - vertical (iii) Comparing crossing or adjacent data between survey lines (iv) Comparing overlapping data between survey platforms (v) Identification of systematic errors	*Compute* the total propagated uncertainty of survey data relative to the survey specification *Apply* procedures used to assess, accept and reject data.
E6.2c Dataset Compilation *(I)*	(i) Data analysis, (ii) Considerations and rules and procedures for combining data sources	*Analyse,* and deconflict datasets from multiple (and/or multi-temporal) sources by applying dedicated procedures, and *compile* a final dataset in various required formats.
E6.2d Spatial data representation *(I)*	(i) Data interpolation techniques (ii) Grids and TINs (iii) Contouring (iv) Volume computations	*Apply* spatial data processing methods to create digital terrain models or gridded surfaces and contouring. *Apply* estimation procedures to survey measurements and volume computations.
E6.3 Data Organization and Presentation		
E6.3a Databases *(B)*	(i) Raster and a vector data model (e.g. S-100) and commonly used file types, (ii) Spatial Data Infrastructures including MSDI and GIS (iii) Importance of metadata and metadata standards. (iv) Databases to hold different types of feature and geospatial data and information (v) Open-source software and database management (vi) Database queries	*Compare* the concepts of raster data and a vector data model. *Describe* the concepts of Spatial Data Infrastructures (SDI). *Identify* file types and products that support the exchange of hydrographic data to transfer data between acquisition, database and GIS environments. *Compare* open-source software available for database creation and management.

E6.3b Marine GIS basics *(I)*	(i) Features and feature types of point, line and polygon with marine examples. (ii) Marine and coastal databases (iii) Coordinate reference system (iv) Vertical datums (v) Survey metadata (vi) Base maps and images	*Explain* the concept and use of Geographical Information Systems (GIS) within the marine environment. *Construct* a GIS project using marine geospatial data. *Integrate* and *reconcile* geospatial data of different origins by applying datum and projection transformations.
E6.3c Visualization and presentation *(I)*	(i) Symbology (ii) Use of color schemes (iii) Shading and illumination (iv) Resolution (v) Vertical scale / exaggeration	*Optimize* parameters of a geospatial application to highlight features of interest within a hydrographic data set.
E6.3d Deliverables *(I)*	(i) Products provided directly from source data such as sounding data, backscatter, point clouds, etc. files and metadata. (ii) Feature databases such as wrecks, rocks and obstructions (iii) Data required for sailing directions, light lists, port guides and notices to mariners. (iv) Data required for offshore hazards and anomalies survey (v) Digital and paper products derived from source data for various survey types and usage such as MSDI, GIS and/or geo-referenced images. (vi) Reports on quality control, uncertainty, results and conclusions detailing processes adopted within (vii) survey operations and data processing. (viii) Product standards and specifications including: ● IHO S-100 product specifications such as S-102, S-122 and S-131 ● Seabed Survey Data Model (SSDM).	*Identify* hydrographic deliverables and produce paper and digital products in accordance with specifications and standards. *Prepare* and compile a report on a hydrographic survey.

E7: Environment		
Topic/Element	**Content**	**Learning outcomes**
E7.1 Oceanography		
E7.1a Physical properties of sea water *(I)*	(i) Units used in measuring and describing physical properties of sea water, normal ranges and relationships including: salinity, conductivity, temperature, pressure, density. (ii) Oceanographic sampling and methods for measuring common oceanographic parameters and profiles (iii) Oceanographic sensors (e.g. for temperature, conductivity, and depth) and need for calibration	*Use* oceanographic sensors to measure physical properties of sea water and *compute* speed of sound using observed physical properties of sea water.
E7.1b Oceanographic measurements *(I)*		*Use*, test and *compare* oceanographic survey sensors to meet specifications.
E7.1c Ocean Waves *(B)*	(i) Wave parameters and elements involved in the wave growth process including fetch and bathymetry (ii) Breaking waves, long-shore drift and rip current processes.	*Outline* wave generation processes and discuss mitigation tactics against the impact of waves in planning survey operations.
E7.2 Marine Geology and Geophysics		
E7.2a Seabed characteristics *(B)*	(i) Seabed samplers such as grabs, corers and dredges and basic sediment types. (ii) Types of seabed (iii) Processes involved in seabed dynamics	*Explain* the objectives of seabed sampling detailing sampling equipment and how samples are stored and analyzed.
E7.2b Magnetic surveys *(B)*	(i) Magnetic fields and anomalies (ii) Objectives of magnetic surveys to detect pipelines, cables, resource exploration, wrecks / debris and ordnance. (iii) Magnetometers	*Describe* Earth's magnetic field and *explain* the use of magnetometers and the objectives of magnetic surveys.
E7.2c Seismic surveys *(B)*	(i) Continuous reflection/refraction seismic profiling. (ii) Typical sound sources, receivers and recorders. (iii) High resolution seismic systems (iv) Sub-bottom profilers	*Explain* the objectives of seismic surveys and the equipment used to conduct such surveys.

E8: Comprehensive Final Field Project (CFFP)

Programmes must include a supervised and evaluated Comprehensive Final Field Project with a minimum aggregate period of at least four weeks.

The Comprehensive Final Field Project for Category "B" level shall comprise a comprehensive field survey incorporating different aspects of hydrography in a complex environment with varying sea-floor and oceanographic conditions.

Students should undertake:

- Development of the survey specification and planning of survey operations;
- Hydrographic and oceanographic measurements using a comprehensive suite of instruments which shall include as a minimum MBES, SBES & SSS;
- Data processing, quality control and quality assurance;
- Preparation of different types of product deliverables and reports.

Note: Prior to commencement of the Comprehensive Final Field Project all learning outcomes in this standard must be evaluated and exercised, either by or through a combination of assessment, examination, laboratory work or practical exercise.