Meeting the Environmental and Engineering Challenges of Climate Change Through the TSA's Bespoke Inland Hydrography Training Course

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SUMMARY

The significant increase in regional flooding events and other consequences of climate change, prompted the TSA's Survey School to expand its syllabus with the addition of an inland hydrography module specifically designed to provide land surveyors (who undertake much of the inland water-related surveys) with a sound grasp of the principles for surveying inland water bodies.

The course, which includes aspects of the UK's Environment Agency and the Maritime and Coastguard Agency's Civil Hydrographic Program specifications, has been carefully devised to build on the existing skills and knowledge of the principles familiar to land surveyors.

The paper discusses the rationale and structure behind the short course, in particular, the focus on the individual modules how they link together in such a way as to build on familiar land surveying techniques through the necessary development of an awareness and elementation of the hydrographic principles.

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1. Introduction

We are all painfully aware that the frequency of major flooding events has dramatically increased over the last 25 years, claiming lives, forcing people to leave their homes, destroying property, and damaging regional economies. The culprit is our changing climate; increasingly severe named storms, and sea levels rising from thermal expansion and increased ice melt. The UK's Environment Agency's chief executive, Sir James Bevan when launching the Flood Action Campaign warned that "Climate change is likely to mean more frequent and intense flooding…" (Environment Agency, 2018).

Since 2015, the Environment Agency has invested €2.9bn in flood defence measures, and the UK government has earmarked a further €5.7bn for 2020/2021. As Sir James pointed out, "flood defences reduce the risk of flooding, and our flood warnings help keep communities safe when it threatens..." but the fact remains that a great deal more needs to be invested into defensive measures if the economic and social costs of massive flooding events are not to be overwhelming.

Behind the preventative flood and coastal erosion projects, sustaining all the engineering and construction works and underpinning the hydrological models, are the digital maps and plans produced by the nation's geomatics specialists and those government departments represented in the national geospatial strategy (Cabinet Office / Geospatial Commission, 2020). It was to raise awareness of the surveyors' role and provide a knowledge base for the profession, that The UK Land and Hydrographic Survey Association's (TSA) Survey School in 2019 decided to expand its syllabus to include a short introductory inland hydrographic surveying module specifically designed to provide geomatics practitioners with a sound grasp of the principles behind surveying inland water bodies.

TSA has some 190 geomatics corporate members. Its Survey School in Worcester has a history reaching back some 30 years, and today is home to the popular TSA Surveying Course and a full range of educational and training courses accredited by the Chartered Institution of Civil Engineering Surveyors. The TSA Surveying Course is run alongside the ProQual Level 3 Diploma in Engineering Surveying, providing a successful student with a recognised qualification and a direct route into the Construction Skills Certification Scheme (CSCS).

The School's principal is Alan Mansell FCInstCES whose links to the School reach back to his early career. The Senior Tutor is Andrew Crumpler FRICS MCInstCES MCQI BSc who has over 40 years' experience of professional practice in the UK and overseas.

2. Course basis

There is a significant difference between marine hydrographic surveying (and its wider hydrography elements demanding an in-depth understanding of aspects such as tidal regimes, ocean current and water movements, vessel dynamics, propagation physics etc), and hydrographic surveying for inland waters, and it is this latter that forms the focus of the TSA course.

In the context of the module, the emphasis is primarily towards the processes behind delivering quality hydrospatial data for engineering and infrastructure works, and particularly for flooding studies and defence projects through populating:

- Hydrological models – for analysing and predicting water movements, e.g. groundwater flow and the rate and volume of surface run-off, transport of suspended sediments in water flow, and other elements of the water cycle.
- Hydraulic models – for analysing and evaluating surface water flow, e.g. rivers and water courses for channel flooding studies, storm drainage systems and networks, etc.
- Hydrodynamic models – for predicting and analysing flood effects.

In the UK, it has been customary for land and geospatial engineering surveyors to undertake much of the inland water-related surveying, consequently the School's course has been carefully devised to build and expand on the existing surveying skills, knowledge, and geomatics principles familiar to land surveyors. To this end, the taught module examines the more common acquisition tools and methods for bathymetric measurements, imaging bedforms for engineering details and hazards, and for collecting other visual imagery and soil samples. The lessons would be incomplete without considering suitable positioning systems, acquisition platforms (crewed and un-crewed), and an overview of safe and lawful operations.

To meet the various student nationalities for which the TSA school caters, the course reflects a cosmopolitan expectation of what is regarded as best practice built around, among other sources, the relevant aspects of the UK's Environment Agency and the Marine & Coastguard Agency's Civil Hydrographic Program specifications widely regarded as paradigms for sound practice outcomes.

UK Main Rivers are designated by statute and depicted on the official Main Rivers maps – e.g. by the Environment Agency in England, Natural Resources for Wales, and the Scottish Environment and Protection Agency. Few main rivers remain unmanaged to some extent, therefore the surveyor engaged in preparing information for engineering and flood management purposes requires best practice solutions for delineating and describing accurately water management and control structures and the associated infrastructure. In some cases, engineering infrastructure can pose serious safety issues to the unwary surveyor or boat handler, hence the course's focus on safe operations and risk assessment.

Lastly, the majority of inland hydrographic acquisition takes place in non-saline waters, some of which can be heavily turbid with suspended sediments and organic matter, or even polluted with agricultural or toxic industrial chemicals. Rivers in particular can exhibit sudden changes in current velocity and direction, therefore an appreciation for such hazards runs through all the lessons.

3. Course bounding considerations

The course is currently limited to considering the natural and artificial processes, water management and control infrastructure of canals and rivers (non-tidal and tidal), reservoirs, lakes, and industrial ponds.

As an introductory course with an emphasis on capturing environmental and climate-change impact relevancies, it was necessary to develop a simple but meaningful course structure that made the most efficient and effective use of limited lecture time to provide students with an appreciation for the most appropriate data acquisition methods, tools, and systems for hydrographic / hydrospatial surveys of inland waters. This was somewhat complicated by the fact that transition zones between land and hydrospatial surveying are not always obvious, particularly when specifications, by necessity, provide for substituting poles and staves for surveying cross sections of water courses with echosounders when environmental conditions demand.

In the matter of survey theory, most land surveyors are familiar with applying error theory in their work but not necessarily in the context of hydrospatial acquisition. Similarly, vertical control / datums and some aspects of basic geodesy require amplification.

Rights and access to waterways in the UK can be a minefield for the unwary therefore the course includes an overview of the legal and permitting aspects of property ownership, boundaries and riparian law, waterways legislation and operating / licensing requirements.

Finally, hydrospatial / hydrographic tasks perforce employ vessels and work platforms, typically small open boats (inflatables, RIBs), launches / cabin cruisers, small Unmanned Surface Vehicles (USV) (mostly operator controlled), and lightweight observation ROVs.

Echoboat R/c hydrographic survey USV. Courtesy NOAA

4. Content structure

The course is divided into thirteen sessions of which two – Tides and Geodesy – can be removed from the taught course in the event more student face time is needed for the core modules. These excluded modules then become distant-learning modules supported by the course tutor via email/video conferencing. Following experience of the first course, the sequence of the modules was changed and expanded to better meet the logical learning process; for example, the module on Rivers, Canals etc, originally Module 2, was better towards the end where it could be adapted for example projects. The module on errors was brought forward and expanded, and the Tide and Geodesy modules added.

Module 1 - Managing errors: A common misconception is that hydrographic surveying is “less accurate” or less demanding than regular land survey. The module addresses this misunderstanding by focusing students’ attention on the reality of maximising the achievable. For experienced land surveyors, the module is a useful reminder of error theory, and for all students it delivers an appreciation for managing errors in a hydrospatial environment. The module also introduces the concept of the Error / Uncertainty Budget.

Module 2 - Control & positioning: All land surveyors are proficient in using GNSS and total stations for control and topographic detail, therefore the course has no need for discussing the technology per se. Both GNSS and range & bearing (usually by robotic total station) solutions are typically employed for inland water surveying, the significant difference from land surveying is the need for adaptive positioning solutions due to the prevalence of sky-blocking by, for example, built structures, terrain, and vegetation, and managing the effects of working close to water surfaces, e.g. multipath and refraction.

Module 3 – Vertical datums: Land surveyors are of course well acquainted with vertical datums and orthometric levelling therefore the module focusses on the sorts of datums in common use on tidal rivers and estuaries (LAT / chart datum) and the various upstream vertical datums that can take many forms. National vertical datums such as OS Datum Newlyn, bespoke engineering datums, stepped datums, pounding levels and other purpose-specific reference surfaces are discussed and common error sources explored.

Module 4 – Acoustics: The module considers how sound is propagated through the water column and how sound velocity, amplitude and phase are used for underwater remote sensing. Common errors associated with acoustic measurements are discussed, with detection examples, and the precautionary measures needed.

Module 5 – Single beam echosounders (SBES): One of the more common watercourse land-to-hydrospatial transitionary systems, SBESs are still widely employed for small / confined areas, river sections, even in lakes and quarries, and frequently installed in the smaller types of USV. The module looks at SBES calibration, sounding operations, position of soundings and typical sources of error and its detection.

Module 6 – Swath systems: The concept of swath bathymetry is similar in many aspects to the point-cloud laser scanning systems employed in measured building and engineering surveys. The superior performance and adaptability of swath technology make these systems particularly adaptable for the inland waters environment. The module is subdivided into three sections each dealing with the function, use and calibration of i) Multibeam echosounders, ii) interferometric sounders, iii) sidescan sonar.

Module 7 – Vessel dynamics: Many land surveyors are familiar with the use of positioning and motion compensation systems used in rapid street mapping acquisition, in railways and tunnel monitoring etc. The module considers the more complex dynamics of vessel motions, of currents, windage, squat etc., all of which, if ignored, become major sources of 3D position errors, and how these are managed and corrected within a vessels reference frame.

Module 8 – Imaging and sampling: The module introduces typical scanning sonars and underwater cameras, together with examples of imagery, and managing equipment deployment issues. The module also includes common methods for collecting material samples and storage.

Module 9 – Specifications and standards: This module considers the typical specifications encountered for inland water surveys. In particular, the Environment Agency and the referenced elements of the Maritime & Coastguard Agency's Civil Hydrographic Program is discussed together with the more common standards cited within the contractual environment.

Module 10 – Water courses and flood defence mapping: This extended module examines the specific subject of hydrospatial surveying for flooding studies and how the data is collected and presented in proscribed formats for integration into flood agency models. In this respect the Environment Agency's specification forms the focus.

Module 11 – Survey platforms and waterways guidance: The module looks briefly at the pros and cons of the typical sort of vessel platforms employed, and the increasing use of small, unmanned surface vehicles the operation of which is similar to aerial drones with which many land surveyors are familiar. The chief part of the module is focused on waterways guidance and the Inland Waters Code (health & safety, and mandatory requirements / licencing / permits and training), legal considerations, boundaries, and riparian law.

Module 12 – Rivers, canals, lakes, and reservoirs. This extended module was originally at the beginning of the course; however, it now forms the conclusionary where the students' new knowledge can be applied to different types of waterways and operations. Points covered include characteristics, natural and artificial watercourse processes, water management and control infrastructure, tidal rivers and estuaries, impact of climate change on natural processes (incl. toxicity and increased levels of eutrophication).

Module 13 Tides. This module has been designed such that it can excluded from the taught course if time is short. A set of course notes are available (see later) with support from the lecturer online. While tides are relevant to the entire marine environment, in the context of the short course the subject is restricted to tidal rivers and smaller estuaries.

Module 14 – Introduction to geodetic systems: Inclusion of this module is subject to the student composition as most land surveyors are already familiar with the subject. The module has been designed such that it can be a relatively short 'recap' or a more in-depth lesson. It can be excluded from the taught course when time is short – the subject is discussed in the students' course notes with online support available from the lecturer as and when needed.

Module 15 – Survey planning, processing, reporting: This is the closing module and builds on all that has gone before. The UK's Environment Agency's specific presentational requirements provides the kernel for practical discussion.

5. Student interaction and support information

Students are encouraged to interact with the tutor – this is particularly focal in such a compressed course. It is the tutor's judgement call whether to respond at the time or address the issues raised during the module Q&A sessions. From experience, the productive response has been to provide a succinct answer first but, if the student appears at a loss, to discuss it during the break periods or at day's end.

Those modules that lend themselves to group or individual tasks include 15 minute slots for problem solving or on-line research such as finding a suitable echosounder for a shallow lake survey. These slots provide some relief and an opportunity for students to engage with what has been learned.

Forecourt of the TSA Survey School during the 2020 River Seven flooding

To augment the lectures, a comprehensive 135 page .pdf set of course notes is available to the students covering all the topics discussed and providing further course material. As a further support resource for the students, web links to, or copies of, up-to-date papers and articles on aspects of inland waterways and hydrographic surveying are made available together with:

- International Hydrographic Organization's Standards for Hydrographic Surveys, SP-44, Ed. 6.0.0. and the Manual on Hydrography
- Marine and Coastguard Agency's Inland waterways and categorisation of waters, the UK Civil Hydrography Programme's Survey Specification, and the Merchant Shipping (Boatmasters' Qualifications) Regulations
- Canal & Rivers Trust surveying guidance, safety, and Boater's Handbook
- TSA, RICS and CICES relevant guideline documents
- The Environment Agency's National Standard Technical Specifications for Surveying Services and accompanying Guideline documents
- The Scottish Environment Protection Agency's Flood Modelling Guidance for Responsible Authorities

6. CONCLUSIONS

A short course is limited in what it can achieve. Although the taught elements of the course provide a thorough overview of the subject, there is little time for practical student tasks or in-depth tutorials, and no field work. This may be addressed and expanded in the future through partnering arrangements with waterways organisations, university departments or engineering contacts.

The course is specifically aimed at practicing land & engineering surveyors, and final year students, and as such is a cross training exercise focusing solely on creating a clear appreciation for the unfamiliar aspects of hydrospatial survey. The pragmatist recognises that climate change is real and, to some extent, unstoppable, although should the world come together there is every chance the worst excesses might be avoided (Matthews and Soloman, 2013). In meeting the environmental and engineering challenges of climate change, the TSA's course seeks to address the growing demand for heightened awareness among those in the land geospatial community considering the logical step into inland hydrography. Although Category A waters (MCA 2015) are easily surveyed by traditional land survey methods, and probably account for more than a third of the water courses regularly surveyed for flooding studies in the UK, it is the Category B to D rivers and water bodies, the main natural drainage arteries, where the TSA course becomes most relevant.

Our rivers, canals, lakes etc are barometers of the direction our rural and urban environments are moving in terms of climate change, and therefore the capacity to deliver quality surveys and accurate data gathering, sampling etc., becomes ever more critical to the scientists, engineers, urban developers, conservationists, and all who strive to protect and preserve our delicate aquatic environments.

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BIOGRAPHICAL NOTES

Ed Danson began his career in the public / civil engineering surveying sector before moving into the marine geospatial and environmental fields. He has held senior and executive positions with some of the world's leading international land, geophysical and hydrographic survey companies as well as his own consultancy firm of Swan Consultants Ltd.

He has some 60 published papers and articles on aspects of hydrography and geospatial engineering to his name and is the author of narrative history books and papers on early surveying science. He is a Fellow of the Royal Institution of Chartered Surveyors, and a Fellow and Past President of the Chartered Institution of Civil Engineering Surveyors.

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