HICO Data User's Proposal

Enhanced water management through advanced monitoring of Adelaide's coastal waters, South Australia

Principal Investigators

Associate Professor Michael Burch,
South Australian Water Corporation
Australian Water Quality Centre
250 Victoria Square
Adelaide SA 5000
Australia
Ph: +61 8 7424 1012
Fax: +61 8 7003 1012
Mike.Burch@sawater.com.au

Professor Tsair-Fuh Lin,
National Cheng Kung University
Dept. of Environmental Engineering,
1 University Road
Tainan City 701
Taiwan (ROC)
Ph: +886 6-275 7575 ext. 65836
Fax: +886 6-275 2790
tflin@mail.ncku.edu.tw

Co Investigators:

Assistant Professor Chih-Hua Chang, National Cheng Kung University, chihhua@mail.ncku.edu.tw
Professor Cheng-Chien Liu, National Cheng Kung University, ccliu88@mail.ncku.edu.tw
Dr Milena Fernandes, SA Water, Milena.fernandes@sawater.com.au
Dr Andrew McGrath, Senior Research Fellow, andrew.mcgrath@flinders.edu.au
PhD candidate Charnsmorn Hwang, National Cheng Kung University, P58027059@mail.ncku.edu.tw

Signatures

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PI signature and date
Designated official signature, date, name and title
(a representative that can commit the university or other organization)

Abstract/project summary
The loss of over 50 km^2 of seagrasses from the metropolitan coast of Adelaide (South Australia) has been documented with aerial photography taken irregularly since the 1950s. The analysis of this historical trend is compromised by the low temporal resolution of datasets and problems stemming from classification of aerial photography (e.g. inability to differentiate vegetated bottom types or dead/live seagrass).

The proposed project aims to improve our ability to map seagrass distribution in the near-shore marine environment by developing new approaches for the interpretation of hyperspectral data from multiple platforms. The novel aspect is the use of towed or deployed underwater sensors to generate reliable (and potentially near real-time) ground-truthing data for aerial and airborne sensors for more efficient monitoring of large areas.

The outcome will be a more robust and cost-efficient tool to monitor seagrass distribution and condition that can be used at seasonal and/or yearly time-scales for adaptive management of anthropogenic discharges and pressures to metropolitan coastlines.

1. Statement of work/project description

The main goal of the project is to develop and calibrate a multi-platform hyperspectral system that allows the reliable and cost-efficient mapping of seagrass distribution in the near-shore marine environment at frequent time intervals. Effective remote sensing of these seagrass populations depends on the ability of a sensor to identify the distinct spectral features of a representative substratum in the optically shallow water environment. With cooperation from National Cheng Kung University (NCKU), the Instrument Technology Research Center (ITRC) in Taiwan recently designed and developed a new underwater hyperspectral imager (UHI) that can be mounted on a towed V-Fin for underwater surveys. The resulting benefits for the benthic mapping based on UHI data, include a reduction in three major uncertainties from conventional airborne and satellite measurements; these include: (1) direct measurement of underwater reflectance which can prevent the development of uncertainties from air/water interface and atmosphere effects; (2) bottom reflectance is retrieved at centimetre-scale (~2cm at nadir), preventing uncertainties due to the spectral mixing of more than one bottom types; and (3) the uncertainties related to bathymetry can be reduced with the information provided by the co-deployed acoustic meters. With the application of UHI in this project, the hyperspectral libraries generated from sea-truthing can enhance the classification of benthic communities from imagery taken by airborne and satellite sensors, such as HICO.

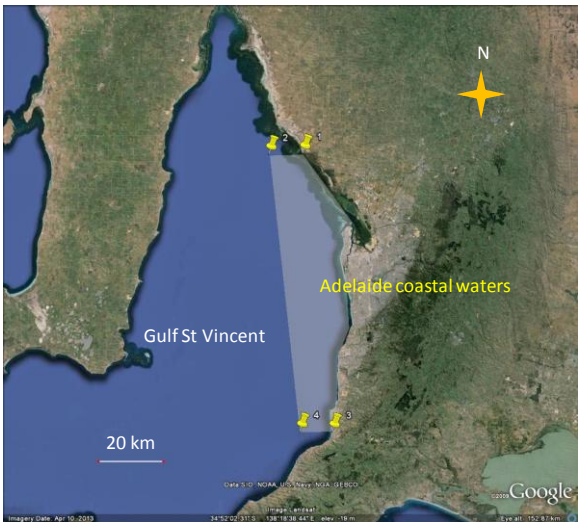

Figure 1. Study area is indicated by the polygon between waypoints 1-4 and the coastline.

The work will aim at the detection of early ecosystem changes necessary to support adaptive management of anthropogenic discharges. It will be applied to the Adelaide coast (Figure 1) where more than 50 km^2 of seagrasses have been lost since the 1950s. The coordinates of the area highlighted in Figure 1 are summarized in Table 1.

Waypoint	Latitude	Longitude
1	34°33'45.40"S	138°20'56.96"E
2	34°33'54.84"S	138°14'7.94"E
3	35°19'48.03"S	138°26'54.93"E
4	35°19'46.78"S	138°20'21.07"E

Table 1. Waypoints summarizing the location of the study area.

In an earlier study, Blackburn and Decker (2006) reviewed results from aerial photography in the period 1949-2004 and compared these results with satellite multispectral images (Quickbird II) and airborne hyperspectral (CASI) data for the region in 2003-2004. Fieldwork was also conducted to parameterize the hyperspectral inversion optimization method used to classify the images. The proposed work will thus make use and refine the spectral libraries developed in this earlier study, including data for seagrass species, macroalgal species and sediments.

An important step in the improvement of ground-truthing capability is the acquisition of field information from deployed sensors. In this respect, the National Cheng Kung University has developed an underwater hyperspectral sensor to assess the condition of Taiwanese coral reefs (Chang *et al*., 2014). The methodology relies on an optical sensor towed behind a boat, which compares the environmental signal with a detailed spectral library to classify the image and map the seafloor. This new technology will be explored further in this work to provide ground-truthing information to calibrate and validate aerial and HICO images.

By the end of 2014, we expect to have further refined NCKU's underwater hyperspectral sensor to collect underwater monitoring and mapping data in the Adelaide coast. Based on this fieldwork, hyperspectral references will be added to the currently existing spectral library and summary of findings will be reported. By 2015, we expect to be using this signal library to interpret aerial and satellite images. Additional deliverables to occur by 2015 include: submission of a progress report, publication of at least one scientific journal article, and holding of multiple meetings/workshops between Taiwan and Australia.

2. Biographical sketch and available facilities

This work involves the collaboration of **National Cheng Kung University** (Tainan, Taiwan), **Flinders University of South Australia**, and the **Research and Innovation Branch of the South Australian Water Corporation** (SA Water, Adelaide, South Australia).

National Cheng Kung University (NCKU) is ranked as one of the top two universities in Taiwan and among the leading universities in Asia in recent surveys in Taiwan and Asia. The principal researchers involved in this collaborative project are Professor Tsair-Fuh Lin and Chih-Hua Chang of the Department of Environmental Engineering, and Professor Cheng-Chien Liu, who is in the Department of Earth Sciences. The proponents from NCKU have extensive experience, recognised internationally, in water resources management, treatment and modelling, and environmental monitoring and assessment.

Professor Lin is a Distinguished Professor and the Director of Water Quality Research Center at NCKU and has published more than 60 refereed papers, co-authored and co-edited two books, and has 7 patents. He has been actively involved in several national and international professional societies including as former Chair (2009-2011) and the current Secretary (2012-2013) of the Specialist Group in Off-Flavours in the Aquatic Environment, International Water Association (IWA); the Secretary of the Specialist Group in Lake and Reservoir Management, IWA (2009-2013), and a former Secretary General (2009-2010) and Executive Director of the Chinese Institute of Environmental Engineering (with ~1,800 members) in Taiwan (2011-2012). Professor Lin was also elected as a Fellow of the IWA in 2012.

Professor Chang is an Assistant Professor at NCKU. His research focuses on environmental quality and pollution source monitoring with multi-staged remote sensing platforms, including shipborne and underwater spectrometry, airborne spectral imaging system and satellite images. Professor Chang developed a genetic and semi-analytical algorithms (GA-SA) approach that integrates various algorithms to retrieve the water constituents from ocean colour remote sensing (Chang *et al.*, 2007), and has applied this GA-SA method to categorize the dispersal patterns of river-borne substances in a river-mouth system (Liu *et al*., 2009). Furthermore, with the aim of examining the coral reef status in Taiwan, he extends the GA-SA approach to integrate and develop the genetic algorithm with shallow water semi-analytical (GA-SSA) which can simultaneously retrieve the water column inherent optical properties and identify the bottom types from the measurements of remote sensing reflectance in optically shallow waters (Chang *et al*., 2014).

Under instruction of Assistant Professor Chih-Hua Chang, **Charnsmorn Hwang** is currently pursuing her doctorate in remote sensing of seagrasses and geospatial assessment of nutrient fluxes in water bodies at the Department of Environmental Engineering at National Cheng Kung University, Taiwan. She received her B.Sc. in Biology and M.Sc. in Watershed Hydrology from William Paterson University of New Jersey, USA, and Southern Illinois University Carbondale, USA, respectively. Her research interests also include urban hydrology, fluvial geomorphology and restoration ecology.

Professor **Cheng-Chien Liu** is a Professor of the Department of Earth Sciences, the Director of Global Earth Observation and Data Analysis Centre (GEODAC) and the Director of Sponsored Program Division, Office of Research and Development (SPDORD) at NCKU and has published more than 30 refereed papers. He is an internationally recognised specialist in the field of Remote Sensing and Ocean Optics ranging from the fundamental theorem and numerical modelling of radiation transfer in the water body, the applications of ocean colour satellite data, the auto-processing of FORMOSAT-2 imagery operated by Taiwan, and various applications on natural disasters and environment monitoring.

Dr. **Andrew McGrath** is a senior research fellow at Airborne Research Australia (ARA), part of the School of the Environment at the Flinders University of South Australia. With more than 60 published papers, he has extensive experience in airborne remote sensing field work, as well as instrument development, operation, calibration and data processing. He is ARA's primary hyperspectral expert, developing operating procedures and data processing algorithms for airborne hyperspectral instrumentation as well as directly operating the instrumentation and processing substantial hyperspectral datasets such as the multi-terabyte surveys collected by ARA for TERN/AusCover. In the visible and near-infrared (VNIR) wavelength range, ARA has an "Eagle-2" hyperspectral scanner made by Specim with excellent SNR characteristics, ~1000 spatial pixels and up to ~500 wavebands spanning 400nm to 1μm. ARA operates this instrumentation from one of their Diamond HK-36 Eco-Dimona, an aircraft specifically designed as an environmental sensing platform and ideally suited to the task. ARA has a rich, 30-year history of extensive and fruitful collaborations with many prestigious Australian and international partners.

The **Research & Innovation Branch of SA Water** has a long-standing collaboration with NCKU, in particular with the Department of Environmental Engineering. This collaboration goes back to 2004 and includes joint projects (5 projects) and exchange visits. The visits include periods of study leave by senior Academic Faculty staff (Professor Lin for 6 months in 2006) and hosting 8 separate post-graduate engineers, who have worked for a total of approximately 50 months on projects related to reservoir management and water quality. South Australian researchers have also had reciprocal exchanges to NCKU for project work and meetings. In addition, SA Water has been invited to join a new International Water Centre being developed by NCKU and the China Steel Corporation, a Taiwanese company with credentials for environmental management and water reuse who is the primary industry partner. This Centre will develop joint water management projects and was established early in 2013.

Associate Professor **Mike Burch** is the Senior Manager, Research & Innovation for the South Australian Water Corporation. He is also an Affiliate Associate Professor, School of Earth and Environmental Sciences, at the University of Adelaide. He is responsible for Research & Innovation activities of SA Water, including Management of R&I Group comprised of 30 scientists and technical staff and students; strategic planning of research; administration of R&I budget, IP management and relationships with external research partners including Universities. Associate Professor Burch is recognised by Australian and international water authorities as an expert in the research and management of water quality issues in the fields of Limnology and Ecology and has 38 years experience in the area of aquatic ecology, i.e. biology, chemistry and management and modelling of lakes and rivers. This includes monitoring and assessment of phytoplankton populations by fluorescence techniques. He is a founding member of the International Water Association Specialist Group on Lake and Reservoir Management. He is also an author on over 150 publications including papers in peer-reviewed journals, book chapters, conference proceedings and reports.

Dr **Milena Fernandes** is a senior research scientist at the Research & Innovation branch of the South Australian Water Corporation. She has worked and published on a range of topics related to marine

biogeochemistry and ecosystem health, from lipid biomarkers and organic matter preservation to productivity and nutrient dynamics. Her work currently focuses on coastal ecosystems, including studies on nutrient cycling, eutrophication and seagrass loss, carbon capture in seagrass meadows as well as the development of a habitat suitability model for seagrasses along the Adelaide coast. She has authored 123 scientific publications, including 31 papers in scientific journals and books, 50 publications in proceedings of conferences and workshops, and 42 technical reports for industry and government. In the last five years, she has played a key role in developing a better understanding of biogeochemical cycles in coastal ecosystems in South Australia to support adaptive management of anthropogenic discharges in the region.

3. Output and deliverables

The overall goal of the project is to redress deficiencies and develop a better understanding of Adelaide's near-shore coastal ecosystem in order to ultimately better sustainably manage problems with seagrass loss, seabed instability and water quality degradation. The use of HICO data will extensively improve description of the complex benthic community's spectral shape, unlike other satellite sensors with only a limited number of spectral bands or only small-scale and/or infrequent mapping. In particular, HICO's 128 wavelengths will provide very fine hyperspectral resolution, which is key to developing a reference library of spectral profiles that can classify differences amongst seabed communities (Lucke *et al*., 2011).

Three specific deliverables will be produced at the end of a successful study. First, temporal and spatial seagrass map for the Adelaide Coastal Water Study (ACWS) area (Figure 1) will be created at a higher resolution and larger scale; such technology and mapping will provide a powerful yet cost-efficient tool to monitor changes in seagrass distribution over time. Second, a ship-based platform for taking optical measurements will be established. This platform will help allow for routine collection of sea truthing data on the distribution of seagrass. Furthermore, ground truthing in select locations will allow HICO to gain substantially enhanced data and retrieval algorithms associated with its products. Finally, information collected and processed will add to the current body of knowledge and hence produce a more developed reference library for regions similar to Adelaide.

Pending the success of this project study, we expect to provide the HICO program with four major returns. These include an optical measurement platform, algorithm development, refined HICO imaging data of the ACWS area, and broadcasting of the HICO program and the quality of its data. By developing a novel approach for collecting sea truthing data for this study area, we expect to produce an optical measurement platform to help refine HICO data. Furthermore, we will develop an ocean color retrieval algorithm when combining HICO data with sea truthing data. This will produce a more refined and synthesized HICO image of the ACWS area. Based on our results, we expect to report the importance of HICO data for understanding the health of Adelaide's benthic marine community in the form of technical publications and conferences. This information will be reported in multiple technical publications, which include government reports and peer-reviewed journals. Since we are committed to report and discuss our application of HICO data related to South Australia's marine waters, we expect to attend and present at multiple conferences, of which we hope will include an annual HICO team meeting.

4. References

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