



Electromagnetic Field Measurements (EMF)

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Oregon Wave Energy Trust (OWET) is a nonprofit public-private partnership funded by the Oregon Innovation Council. Its mission is to support the responsible development of wave energy in Oregon. OWET emphasizes an inclusive, collaborative model to ensure that Oregon maintains its competitive advantage and maximizes the economic development and environmental potential of this emerging industry. Our work includes stakeholder outreach and education, policy development, environmental assessment, applied research and market development.

1. EXECUTIVE SUMMARY

The Oregon Wave Energy Trust (OWET) commissioned this study to develop protocols and methods to achieve affordable, reliable, and repeatable electromagnetic (EM) measurements in the near-shore environment. The study was conducted in several stages, with a number of technical reports provided at each stage to document and describe findings. A synopsis of each technical report is provided herein.

1.1 Objective and Results

The major objective of this project was to demonstrate an ability to achieve affordable, reliable, repeatable EMF measurement protocols in support of wave and tidal energy technology development and deployment. As such, this report was prepared to describe the prototype instrumentation fabricated with affordable and available components, calibration results to provide the basis for repeatability, and a data summary of the ambient background and energized power cable measurements conducted during at-sea measurement deployments. Thus, the team designed and constructed an instrument to demonstrate that available components could be assembled to achieve basic measurement objectives. The instrument was deployed in-situ at two different near-shore marine environments, and acquired EM field data near an operating submarine power cable-of-opportunity to show the efficacy of the system to quantify EM emanations due to the influence of the power cable within the environment. As part of this activity, the instrument was calibrated in a laboratory to ensure a valid and repeatable methodology for measurements. Data acquired clearly showed the presence of strong electric (E-field) and magnetic (B-field) power line frequencies and harmonics (namely 60 Hz, 180 Hz, 300 Hz, and 420 Hz discrete lines) near the power cable.

The affordability, reliability, and repeatability objectives of the study were demonstrated. Modeling, calibration, measurement, and processing protocols and techniques identified within this study serve to advance the science of marine EM measurements in coastal waters, and promote a standardized methodology that is both reliable and repeatable.

1.2 Summary Conclusions and Recommendations

The following summary conclusions and recommendations as a result of this study are made:

1. Substantial published data is lacking on observed effects to marine species from EM fields at power frequencies (60 Hz and harmonics). Application of equipment and techniques documented within this study could easily be adapted to provide repeatable, quantifiable EM field data to ensure that observable conclusions are based on valid data sets.

Recommendation: Conduct additional biological study to better understand and quantify observed effects to biota from man-made EMF. Apply equipment and techniques developed in this study in support this of biological research.

2. Due to the limited scope of the study, the long-term temporal variability of naturally occurring EM fields was not quantified in terms of range or extent. Longer term monitoring or periodic sampling would provide better insight into the naturally occurring environment, as well as that of operating energy generating facilities. Scientific documentation of concurrent conditions over longer time horizons (weeks, months, seasons) will add to the physical understanding, and hence, biological understanding of measured EM fields.

Recommendation: Conduct long-term monitoring with energized cables. As part of monitoring, collect electrical and physical data to correlate measured levels to physical phenomena.

3. Modeling and predictions of E- and B-field strengths in the coastal environment are strongly dependent on local conditions, including the underlying geology. In particular, local conditions substantively affect longer-range propagation of EM fields. The existing modeling framework together with a larger set of physical measurements of in-situ data using technologies demonstrated within this study can account for these phenomena and lead to a better understanding and predictions for impacts to potential wave energy sites.

Recommendation: Evaluate and improve existing modeling capabilities with measured data at wave energy sites. Consider performing this activity while concurrently monitoring energized cables along Oregon's coast.

1.3 Technical Reports

The results provided in this report are the culmination of a series of thirteen studies to investigate methods, protocols, and other significant input parameters for establishing reliable, repeatable, and affordable EM measurements at wave project sites. The following reports were prepared to investigate, analyze, and report on current near-shore EMF knowledge base, to research state-of-the-art and available technologies in measurement approaches and equipment, and prepared to review measurement physics, including sources and modes of EM generation and propagation. Methods were assessed and summarized, with alternatives and recommendations provided to achieve the project objectives. Data for these reports were obtained through literature reviews, market surveys, computational activities, and laboratory and field tests.

- ***Effects of Electromagnetic Fields on Marine Species: A Literature Review, report 0905-00-001.*** This report summarizes the results of a top-level literature survey on the topic of the electromagnetic (EM) effects on marine biota. The primary driver for this survey was to determine the basic state of knowledge on the topic of potential biological effects that EM fields (EMF) may have on marine species, and then to apply that knowledge to identify EMF sensing requirements. A number of species were reported in the literature to be sensitive to EM fields, and could potentially be affected by EM fields created by wave energy devices and cables.
- ***Estimated Ambient Electromagnetic Field Strength in Oregon's Coastal Environment, report 0905-00-002.*** This report describes characteristics of ambient background EM field strength characteristics in Oregon's near-shore marine environment, including estimated results near Reedsport, Oregon. Background levels are a natural by-product of local and global scale activities, including wave motion (wave height, frequency, and direction), bathymetric conditions, coastal and tidal currents, and the Earth's magnetic field strength and direction, and other external factors such as geologic and solar-scale conditions, as well as local weather.
- ***The Prediction of Electromagnetic Fields Generated by Wave Energy Converters, report 0905-00-003.*** This report describes the characteristics of electromagnetic (EM) fields emitted from wave energy converters (WECs) in the marine environment. The basic physical theory was derived from the fundamental laws of electrical current and magnetism using basic analytical magnetic and electric dipole sources, with boundary conditions were applied to determine the local EM field effects. This report presents a basic model for estimating the electromagnetic fields propagating from a point electromagnetic emission source in a homogeneous medium. In practice, the decay of the electric and magnetic fields depends on the nature of the source, and the physical parameters of the surrounding media, e.g. seawater and sediments.

- ***EMF Synthesis: Site Assessment Methodology, report 0905-00-004.*** This report synthesizes the expected ambient Electromagnetic (EM) conditions at a wave energy test site in Reedsport, Oregon with the anticipated EM emissions from wave energy converters (WEC), underwater equipment, and associated cables to estimate the minimum and maximum field conditions as if the site were developed. These predictive results were then used to develop sensory instrumentation and spatial considerations to enable the specification of adequate and affordable methodologies that ensure a scientifically valid approach to assessing EM field conditions at the site, both before and after development. The results of this synthesis have been described to provide an extensible methodology to evaluate other potential wave energy sites, inclusive of longer-term monitoring needs.
- ***EMF Measurements: Data Acquisition Requirements, report 0905-00-005.*** This report describes the recommended data acquisition requirements for obtaining valid electromagnetic field (EMF) assessments of potential wave energy sites, taking into account various input processes such as ocean wave activity, local bathymetric conditions, coastal and tidal currents, and knowledge of the Earth's magnetic field strength and direction. The provided methodology recommends data acquisition parameters based on the underlying temporal variability, frequency content, and general statistical character of EM fields in the near-shore environment. In particular, this report addresses measurement of EM fields that are a result of, or are directly affected by, wave energy conversion equipment and associated cables.
- ***EMF Measurements: Instrumentation Configuration, report 0905-00-006.*** This report describes specific calibration methods for EM measurement instrumentation using best engineering practices to achieve valid instrumentation calibration results. Calibration of measurement instrumentation is an essential part of the scientific process; calibration results are critical to the full understanding and correct interpretation of the underlying physical phenomena to be sensed. Specific procedures were developed as a result of completed modeling studies, literature and commercial surveys, and recommended measurement solutions. The report describes important factors, calibration methods, and provides test procedures to conduct the calibrations.
- ***The Prediction of Electromagnetic Fields Generated by Submarine Power Cables, report 0905-00-007.*** This report describes the emissive characteristics of electromagnetic (EM) fields from submerged power cables in the marine environment. Expected EM field levels were analyzed and synthesized for a basic homogeneous environment in which energized power cables were superimposed. Basic physical theory was derived from fundamental laws of electrical current and magnetism for a homogeneous environment, and boundary conditions were applied to estimate first-order predictions of local EM field effects from energized cables representative of the subsea power cable industry.

- ***Ambient Electromagnetic Fields in the Nearshore Marine Environment, report 0905-00-008.*** This report describes the ambient background field strength characteristics of electric and magnetic fields in the nearshore marine environment of the continental shelf. The results were prepared by collecting and summarizing existing data on the nearshore electric and magnetic field ambient conditions to serve as a surrogate for the existing conditions suitable for an environmental baseline of wave energy projects on the Oregon coast. It was noted during the literature survey phase that there was a paucity of EMF data available for the coastal environment. Factors describing sources, environment, and temporal character of marine EM fields are stated, and a range expected values is provided.
- ***Trade Study: Commercial Electromagnetic Field Measurement Tools, report 0905-00-009.*** This report describes commercially available methods and instrumentation currently used in marine electromagnetic applications. The report describes state-of-the-art marine electromagnetic (EM) methods within their historical context and identifies the instrumentation necessary to achieve these methods, including those used for geophysical exploration, marine corrosion surveys, locating sub-sea objects such as cables and pipelines, and ship signature measurements.
- ***EMF Measurements: Field Sensor Recommendations, report 0905-00-010.*** This report presents a review of instrumentation and data acquisition requirements for near-shore marine measurements, including a comparison of existing tools and sensors available to conduct such measurements. Recommendations are made for optimal instrumentation configuration suitable for characterization of EM fields in natural conditions and within the presence of energized wave energy power equipment, with a focus on sensors, data acquisition equipment, optional auxiliary sensors to aid in data interpretation, and implementation recommendations.
- ***Summary of Commercial EMF Sensors, report 0905-00-012.*** This report summarizes the results of a market survey for available electric and magnetic field sensors and measurement equipment suitable for the near-shore marine environment. Commercially available sensors and data acquisition hardware are identified, with information provided from public sources of information, manufacturer data sheets, and evidence gathered from users (typically academic researchers) using such equipment for field work or laboratory studies.
- ***Wave Energy Converter Measurement Project Plan, report 0905-00-014.*** This report, together with an available Microsoft Office Project file, describes the preparation and execution of EMF signature assessments of various aspects of a Wave Energy Converter (WEC), including in-air testing, single- and multiple-device testing, as well as associated in-water cabling. This plan may be used to prepare for conducting a signature assessment of a device or multiple devices, and then comparing the result to predicted or modeled expectations. A Microsoft Office Project 2007 plan has been prepared that matches the narrative description for the WEC measurement plan, and includes estimated resources

such as labor hours, generic costs, materials, and other direct costs required to conduct a suite of measurements.

- ***Electromagnetic field measurements: environmental noise report, report 0905-00-015.***
This report describes the configuration and use of a stand-alone EM instrument to demonstrate that available components could be assembled to achieve basic instrumentation objectives for nearshore marine EM measurements. The instrument was deployed in-situ in two different near-shore marine environments, and included acquisition of data near an operating submarine power cable-of-opportunity to show the efficacy of the system to quantify EM emanations due to the influence of the power cable within the environment.

Reports are available from the Oregon Wave Energy Trust, <http://www.oregonwave.org/>.