Field Demonstrations in Anthropogenic Waste or Unexploded Ordnance Sought for USGS Marine Induced Polarization (IP) Streamer System Technology

Since 2001, researchers at the U.S. Geological Survey (USGS) have teamed with industry partners to explore the commercial applications of the USGS-patented (2001) Marine Induced Polarization (IP) Streamer system that has the ability to rapidly map very low percentage mineral and metallic particle distributions on and beneath the seafloor in three dimensions and with high resolution.

Fantail of NOAA research vessel *Ferrel*

Description of the Marine IP Streamer System

The Marine IP streamer system takes its electrical measurements from a moving vessel (fig. 1) and consists of a multiconductor cable with elaborate electrical shielding, special nonpolarizing detector electrodes, optical isolation, pre-amplification, floating ground, and other noise-suppression techniques. The streamer also has active galvanic electrical (titanium) transmitter electrodes that are used to inject current directly into the seafloor. The acquired data are converted to digital form and processed onboard the towing vessel. Postprocessing, analysis, and 2D and 3D data-representation development follow the data-acquisition phase.

Initial field demonstrations focused on the technology that enables the streamer to detect placer heavy minerals, certain clays, and disseminated metals on the seafloor from a moving vessel. During sea trials, it was realized that the system also detected metallic debris on the seafloor, even when buried beneath meters of inert mud. See Types of Visual Information available from IP Streamer on page 3.

In 2007, the IP Streamer was licensed to Williamson & Associates of Seattle, Wash. (Williamson), as the result of the partners earlier Cooperative Research and Development Agreement involving the technology. Williamson, a diversified geophysical consulting firm and Zonge Engineering and Research Organization of Tucson, Ariz., an electrical engineering company with broadband electrical and electromagnetic expertise, field tested the IP Streamer technology in a large-scale commercial mineral survey off the coast of South Africa in 2007. See Bismark Mineral Identification Trials on p. 3.

In 2008, the partners are developing field testing opportunities for waste and ordnance identification.

Marine IP Towed Array

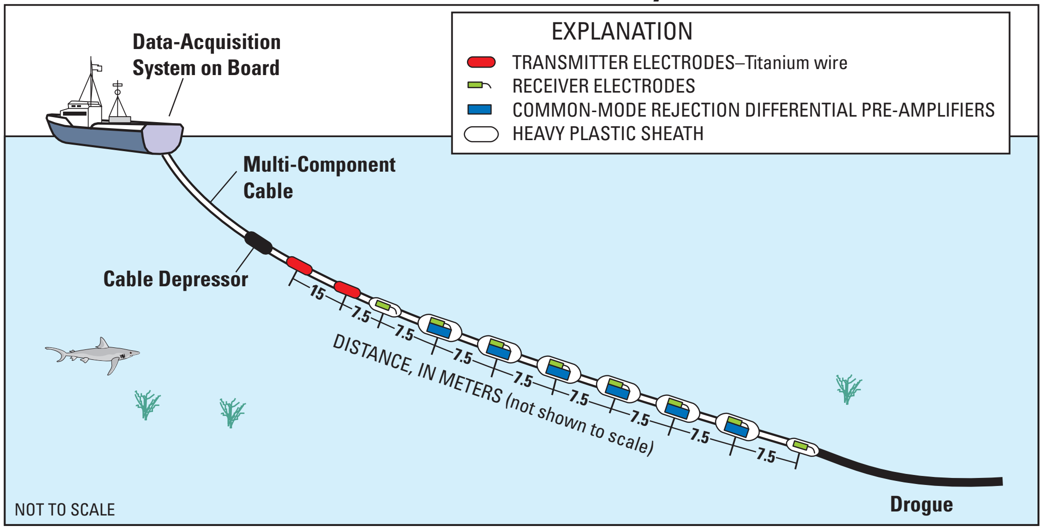


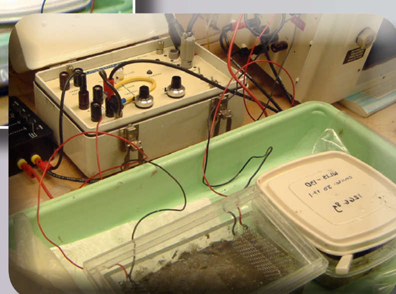
Figure 1. The Marine IP Streamer system sweeps across the seafloor while towed behind the research vessel.

Cost-Effective Anthropogenic Waste & Ordnance Detection

The USGS IP Streamer technology is capable of providing a cost-effective method for identifying and tracking sewage outfalls, garbage-barge dumps and industrial waste that contain metal content. The Comparison Table (page 4) contrasts the IP Streamer capabilities against other traditional methodologies for seafloor mapping.

The offshore regions in the 200-mile wide U.S. Exclusive Economic Zone equate to more than 3 million square miles (~8 million square kilometers) of "land" that has not been scientifically mapped, categorized, or explored below the water-sediment interface. In addition to the lack of scientific and mineral information about the Economic Zone, many areas have been used as urban-waste dumps for centuries. As a result, these waste deposits are causing pollution, which is affecting human health and ecosystem balance, as well as creating navigation hazards. These issues need to be better understood, quantified, and subject to remediation, when and where possible.

USGS research and laboratory measurements show that anthropogenic waste (such as sewage outfalls, garbage-barge dumps, and industrial waste) has significant metal content, which is self-reducing because of the associated bacterial content to metallic or metallic-sulfide form. These deposits are also generally moving due to tides and longshore ocean currents. Furthermore, metallic particles in the sewage (especially) and waste (in general), are usually extremely fine. These particles maximize surface area versus volume percentage content, and, thus, increases its IP detectability for very small percentages. USGS laboratory-scale studies also indicate a strong correlation of a specific multifrequency IP spectral signature for identification of this type of waste and suggest a potential ability to map its movement over time through additional surveys.

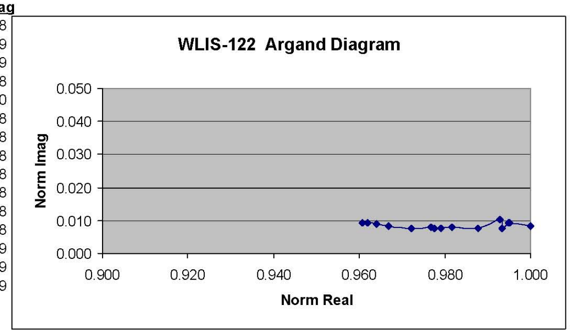


A scientist performs laboratory analyses of Clostridium-infected samples that were extracted (dredged) from Long Island Sound, N.Y. These anoxic sediments were derived from sewage that has been dumped into the Connecticut River over the past centuries.

A dredge sample from one of the Long Island offshore waste-collection areas was measured in the laboratory, and the distinictive IP spectral signature is shown here.

Long Island Sound Samples 11-Jun-02
from Marilyn tenBrink Spectral Induced Polarization Signatures
WLIS-122 Cruise JD 97-1 1349.1 g Blocks 93, 94, 95

Harmonic	Freq	Mag	Phase	NormReal	NormImag
1	0.125	0.004654	-8.3	1.000	0.008
3	0.375	0.004631	-9.2	0.995	0.009
5	0.625	0.004630	-9.4	0.995	0.009
7	0.875	0.004623	-7.8	0.993	0.008
9	1.125	0.004621	-10.4	0.993	0.010
1	1	0.004597	-7.6	0.988	0.008
3	3	0.004568	-8.0	0.982	0.008
5	5	0.004557	-7.8	0.979	0.008
7	7	0.004550	-7.7	0.978	0.008
9	9	0.004546	-8.0	0.977	0.008
1	8	0.004524	-7.8	0.972	0.008
3	24	0.004500	-8.7	0.967	0.008
5	40	0.004487	-9.3	0.964	0.009
7	56	0.004478	-9.5	0.962	0.009
9	72	0.004471	-9.7	0.961	0.009



Example of a distinctive and unusual "flat" IP spectra from a Long Island Sound sediment sample with significant sewage content (high carbon, anoxic, finely disseminated sulfides)

Comparisons of Existing Seafloor-Mapping Technologies

Technology	Physical principles	Potential targets	Strengths	Limitations
Marine IP Streamer system	Induced polarization; IP spectra; resistivity	Sewage; industrial waste; buried unexploded ordnance; nonferromagnetic metals; titanium-rich sands; buried shipwrecks; freshwater incursion; shallow bedrock hazards; disseminated sulfides	Detects very small volume-percents; detects small, buried objects; target focused; uses three physical parameters; images multiple layers; high lateral resolution; can "see" below mud layer; covers large areas quickly	Must keep streamer on the seafloor
Resistivity	Resistivity contrast	Freshwater incursion; shallow bedrock	Can use a floating streamer; small risk of hardware damage	Requires large volume percentages of freshwater; poor resolution; seawater is highly conductive
Sidescan	Velocity contrast	Discrete objects on seafloor; seafloor topography	Target focused; wide synoptic view	Does not penetrate seafloor; surface features only
Subbottom profiling	Velocity contrast	Subbottom stratigraphy	Target focused; good resolution	Requires substantial velocity contrasts; cannot detect small, buried objects
Magnetics	Magnetic susceptibility	Ferromagnetic materials; iron ships	Simple technology	Not target focused; poor resolution
EM	Resistivity contrast	Deep hydrocarbons	Can supplement seismic information in hydrocarbon exploration	Requires large volume-percentages; seawater is highly conductive; poor resolution
Radiometrics	Radioactivity	High-potassium seafloor sediments; radioactive ordnance	A different physical property	Extremely limited penetration (top 1–2 centimeters of the seafloor sediments)

The scientific principle behind the electrical streamer is that IP is a surface-effect electrochemical methodology that is particularly sensitive to low-volume percentage, finely disseminated minerals, and metallic debris. Because of the signature nature of most anthropogenic waste, the technology permits simultaneous accurate mapping of various types of underwater debris with a single collection. An example of this is its ability to differentiate sewage outfalls from industrial-waste debris and their respective locations.

Finally, the equipment utilized in the IP Streamer identification is compact and can be deployed from almost any type of boat or vessel on the water's surface, thereby taking advantage of a municipality's or entity's existing water-vehicle infrastructure.

Summary

USGS and its partners, Williams & Assoc., and Zonge Engineering, are interested in doing full-scale testing to map underwater environmental contamination in ecologically sensitive rivers, bays, estuaries, and sounds with known environmental issues related to human and industrial waste. The partners are also looking for field-demonstration opportunities that could include metallic debris (such as unexploded ordnance) or other metal-containing materials which would exhibit an IP response, as described in the USGS patents: *U.S. Patents 6,236,211 B1* (May 2001); and *6,236,212 B1* (May 2001).

For additional articles discussing and contrasting the technology from existing underwater imaging systems, see: *http://volcanoes.usgs.gov/jwynn/5offshore.html*

Capabilities of the Marine IP Streamer

The test in the Bismarck Sea demonstrated that the system could detect widely dispersed sulfide haloes surrounding massive sulfide (ancient "black smoker") deposits at depths as deep as 3,500 meters.

During the 6 weeks that the technology was deployed in South Africa, the partnership and its mining-company client gathered information on 1,200-line kilometers of ocean floor and generated about 830,000 IP and resistivity measurements, which were sampled simultaneously at four to seven different depths.

The study confirmed that the USGS Marine IP Streamer system technology could:

- Verify that the paleo channels, which the company was mining on land, can be mapped along and beneath the seafloor;
- Identify the existence of similar mineral profiles of interest to the company that had not been tested by the client with vibracoring; and
- Establish a 3D vertical distribution for minerals of interest by pinpointing IP anomalies to a depth of 20 meters, which indicates that mineral resources exist below the test zone area.

To discuss possible demonstration sites or to find out more about this technology, contact:

Jeff Wynn, PhD
U.S. Geological Survey
Vancouver, Washington
Phone: 360-993-8919
jwynn@usgs.gov

Michael Williamson, PhD, CEO
Williamson & Associates
Seattle, Washington
Phone: 206-285-8273
mikew@wassoc.com

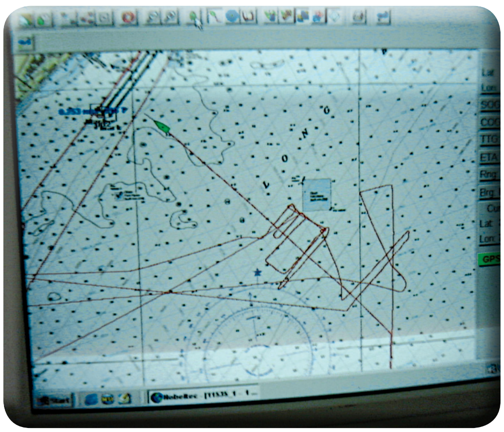
Technology Transfer
USGS Office of Policy & Analysis
201 National Center
Reston, VA 20192
Ph. 703-648-6616

Author~~Jeff Wynn

Sample of Visual Information Developed by IP Streamer Collection

A

B



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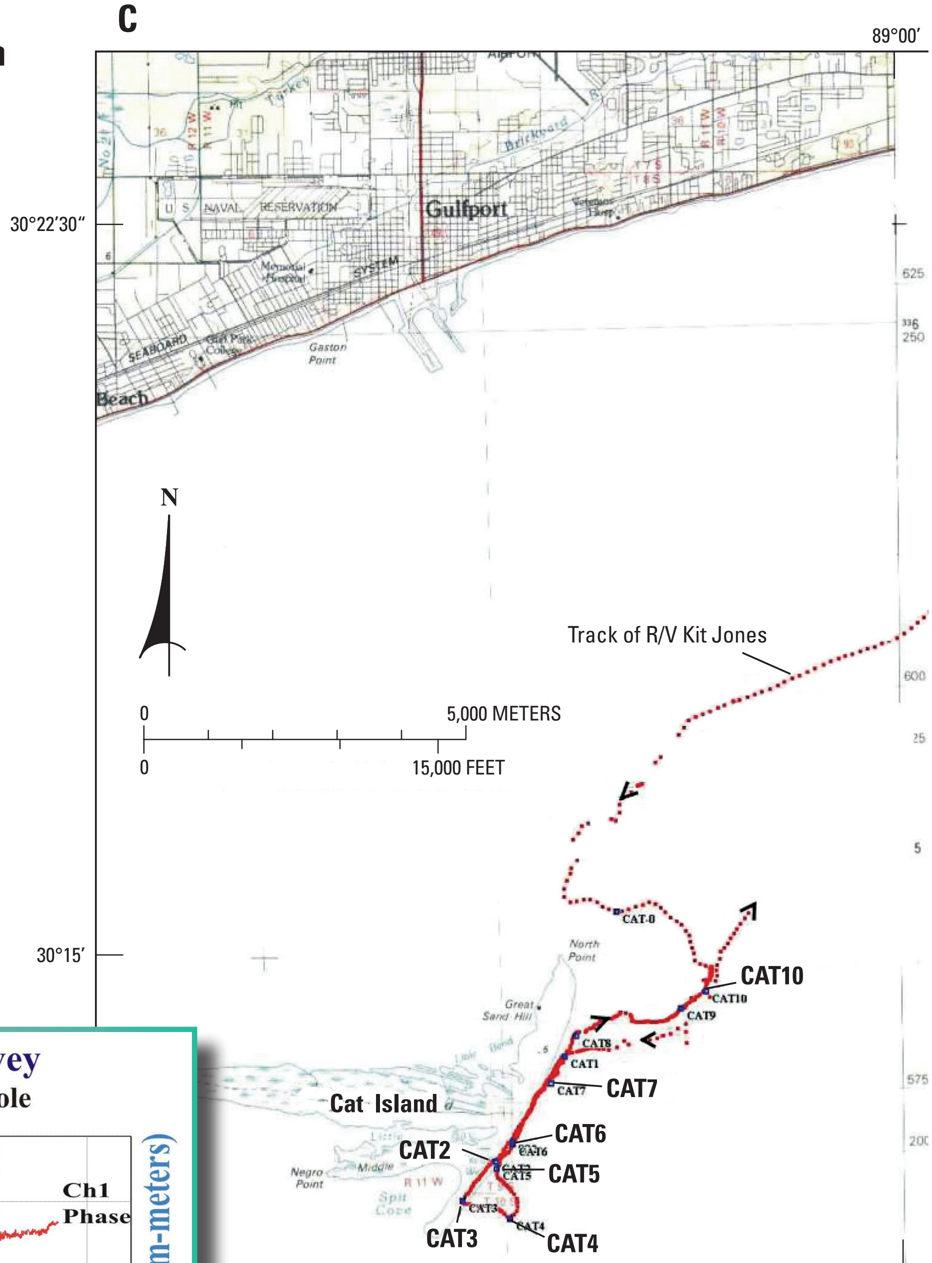

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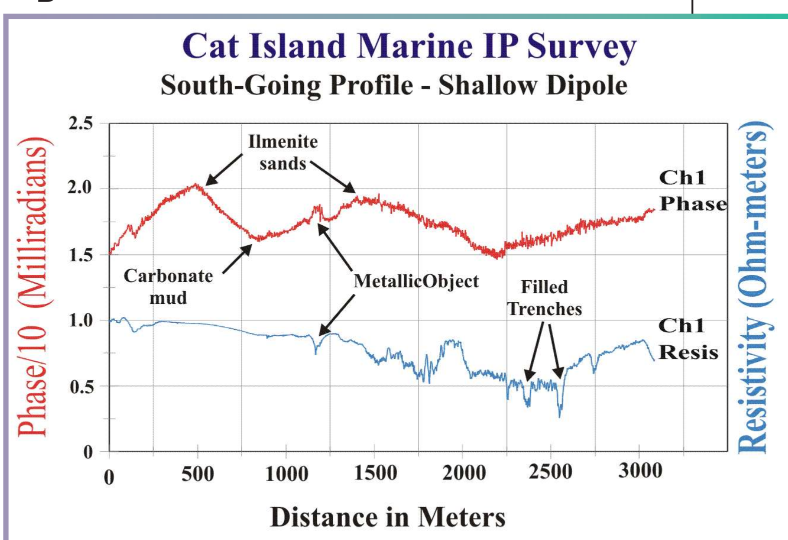

NOAA vessel R/V *Ferrel* (fig. A) cruises off Cape Fear, N.C., gathering marine IP data. Figure B shows the ship's tracks being monitored by scientists in realtime via an onboard computer. The reddish track plotted on the bathymetric map displayed on the monitor repeatedly crosses a paleochannel, an ancient river from the last glacial low-water period known to host heavy placer minerals. Figure C shows a similar track from the Mississippi Mineral Resource Institute vessel R/V *Kit Jones* as it conducted a marine IP survey in the gulf of Mexico. Figure D shows two types of data collected off Gulfport, Miss. The Ch1 Phase plot shows the IP metallic mineral response from beneath the seafloor; the Ch1Resis plot shows the resistivity profile at a set depth of several meters beneath the seafloor (predetermined by scientists prior to the survey by setting the array spacing).

As depicted in the Cat Island Marine IP Survey graph, the resistivity profile denotes a "metallic object" where a bronze 17th century Swedish cannon was known to have been dredged. The "metallic object" gives an IP anomaly and a corresponding resistivity low (the anomaly was initially detected about 20 meters from the object). The graph also shows the profile of an area having "filled trenches." These are previously dredged ship channels that were filled over time with sand and/or seafloor material when the seafloor was disturbed during hurricane and tropical storm events. The profile of filled trenches shows that slightly higher porosity gave rise to lower resistivity; therefore, no IP anomaly was detected.