Side Scan Sonar Target Comparative Techniques for Port Security and MCM Q-Route Requirements

Garry Kozak
L-3 Communications Klein Associates, Inc.
Salem, NH

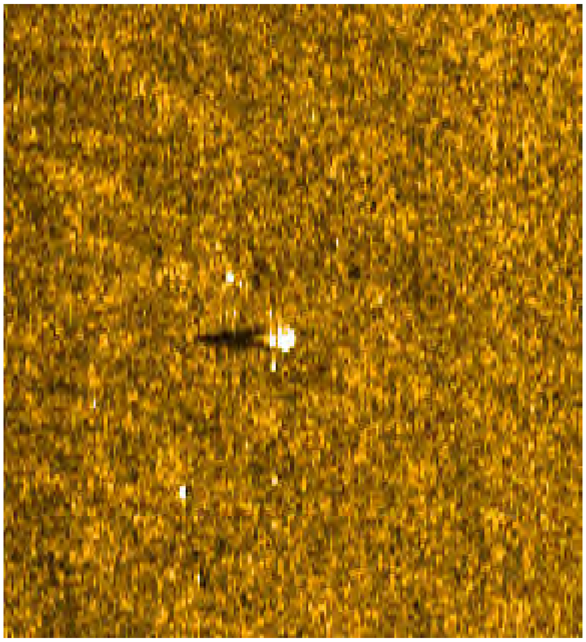
Naval MCM Q-Routes and port security concerns for harbor and ship berth areas have the common requirement to survey these areas prior to vessel movement for possible hostile MLO (mine-like-object) or IED (improvised explosive device) contamination. Today's very high resolution sonar systems like the Klein System 5500 allow detection of small hostile targets; however, the problem of classifying the target as "new" in cluttered channels and harbors can be very challenging. This presentation will describe methods for real time and post processing comparative techniques to a baseline data set using currently available off-the-shelf software such as SonarWizMap (SWM).

Side Scan Sonar

Side scan sonar systems have been in existence since the 1950's. In the 1970's Westinghouse built the first side scan sonar using complex arrays and phase shift techniques for creating multiple, dynamically range focused beams. The benefit was improved along track resolution, and 100% seafloor area coverage at high tow speeds exceeding 10 knots. Klein Associates, Inc. introduced the first commercial multi-beam side scan sonar in the 1990's called the System 5500. It is in use today for demanding applications by both military/government agencies as well as commercial operators. Today it is one of the highest performing systems available for small target detection on the seafloor.

Klein System 5500 Side Scan Sonar Towfish being deployed from a US Navy MCM ship

Small targets like the Italian Manta mine were once considered stealth for most sonar detection, but today's very high resolution Klein 5500 side scan sonar can easily detect these small mine objects or other IEDs. The problem in channel and port conditioning where a survey is done to detect any new objects that may be a threat, is not the question "will the target be detected" as much as "will the target be recognized". Creating a known baseline data-set so change detection comparative techniques can be applied is the most effective way of "recognizing" new objects that may pose a threat.



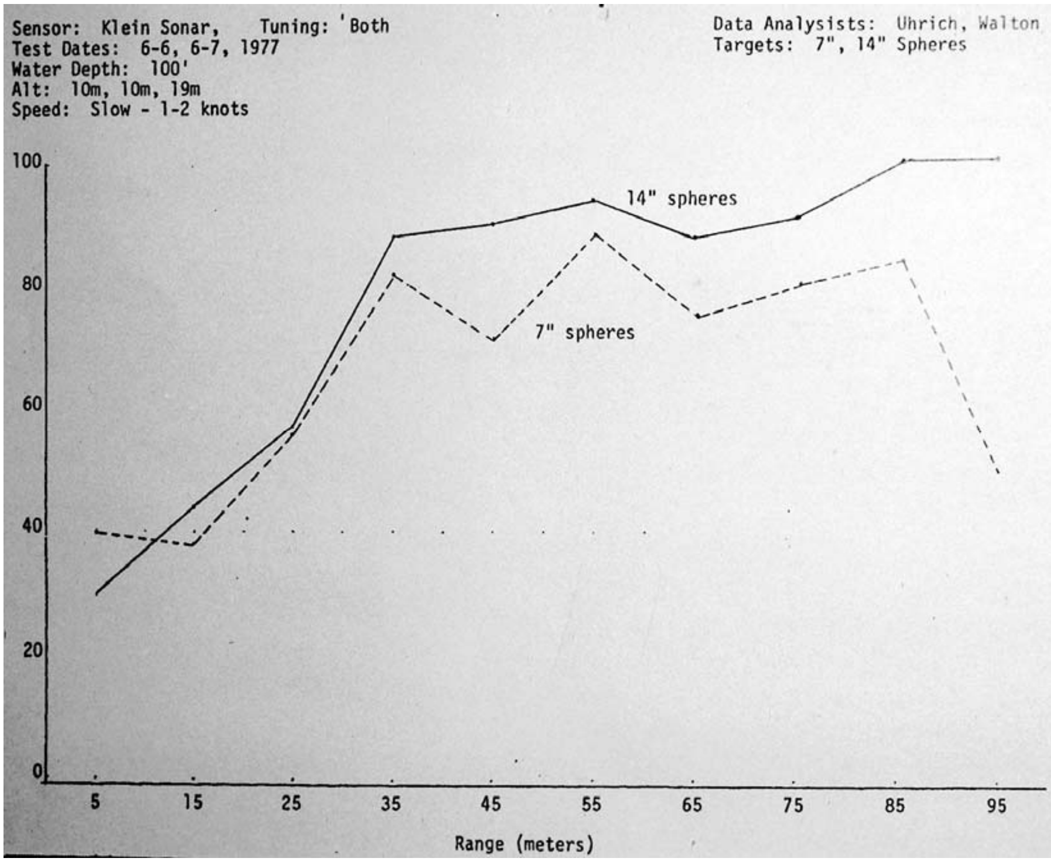
Klein System 5500 sonar image of a Manta mine

Baseline Data Set

The first order of business to be able to do change detection for IEDs or MLOs is to collect a clean non-corrupted baseline data set of the channel or harbor area of interest. Proper housekeeping for collection of the side scan sonar data must be observed.

Sonar Range Scale, Survey Line Spacing, Repeatability and the Nadir Zone

It has been proven by many trials that the maximum optimum range for a high PD (probability of detection) of a small target is about 100 meters. Longer ranges have a lower ping rate resulting in a drop in PD and this can be seen in the graphed results from PD trials by Walton and Uhrich. A 100 meter range scale is a very common mandate by different Navies around the world for Q-Route surveys. My involvement in PD trials over the past 28 years has reinforced that a 100 meter range scale is acceptable most of the time; however PD can be significantly raised by using a 75 meter range scale. This is the preferred range scale for difficult areas of complex geology or high clutter.

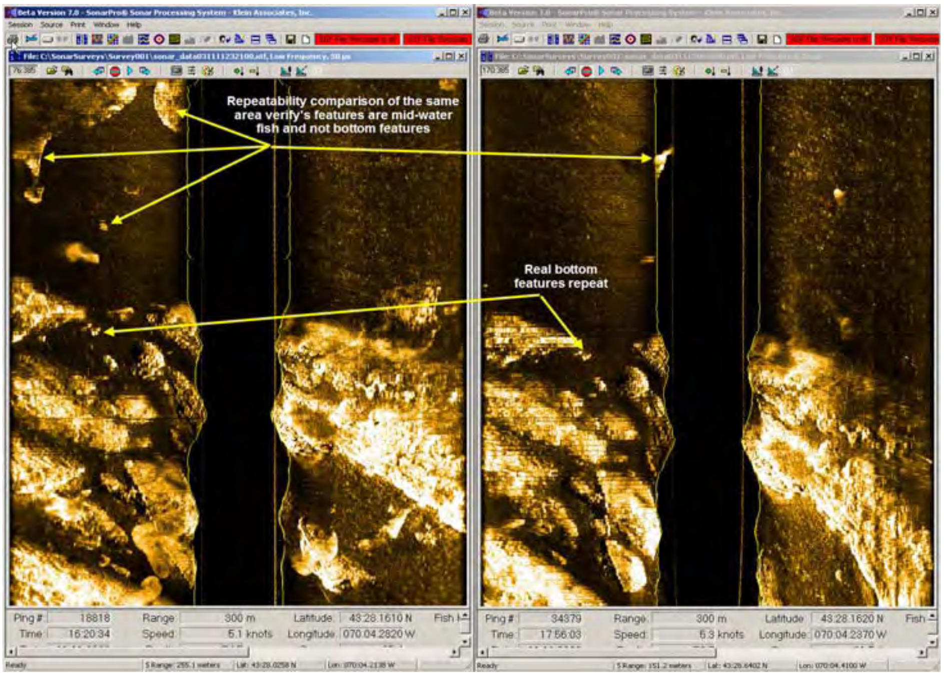


PD (probability of detection) vs. Range for a 7 inch and 14 inch sphere target

The Walton and Uhrich PD graph also confirms that the nadir region, the part of the seafloor that is directly under the side scan sonar towfish, has a very low PD for small target detection. This will require that the survey line spacing selected will ensure that the nadir zone is always viewed off to the side of an adjacent survey line pass.

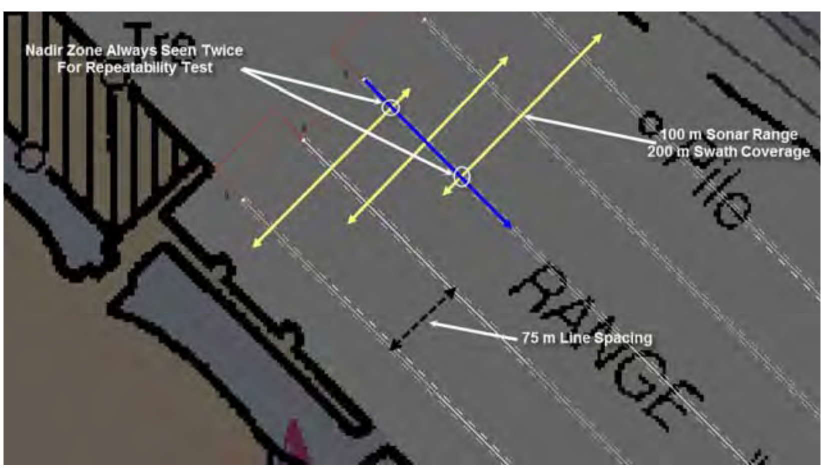
The last important consideration when selecting line spacing is the requirement to see every part of the seafloor a minimum of 200%. A true target on the seafloor will be repeatable 100% of the time when imaged by the side scan sonar. It is common for midwater anomalies such as schools of fish, etc. to appear as real bottom features. By applying the practice of repeatability, the viewing and comparing of the same area of seafloor data collected at different times, it is possible to recognize and eliminate random anomalies from real bottom targets.

The following comparative example shows how applying repeatability allows the data analyst to classify correctly what are schools of fish and real seafloor geology.



Target Repeatability

Taking into account PD, Nadir zone, and 200% bottom coverage so repeatability can be applied in data interpretation, the optimum lane spacing for the survey will be 65% to 75% of the selected sonar range.

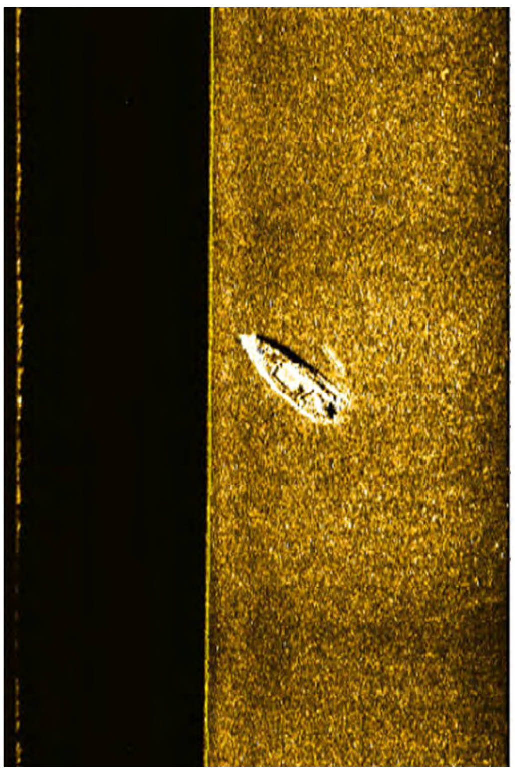


Line Spacing accounting for Nadir, Repeatability and good PD

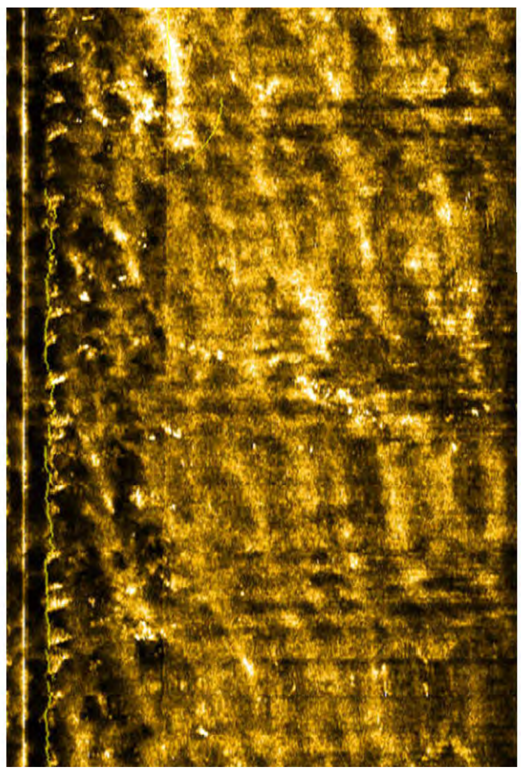
Other Considerations for Collecting a Quality Dataset

The collection of side scan sonar data in channel and harbor locations present several problems due to the shallow water, and at times, confined areas which can compromise the quality of the dataset.

Wind generated white caps on the surface are a very good acoustic reflector. The surface return clutter from the white caps can significantly corrupt the quality of the dataset to such an extent that it makes it unreliable for small target detection. The following example shows a small wreck on the seafloor imaged when the sea surface was calm with no white caps and later when the wind picked up producing surface white caps. It is a vivid example of why the surveyor must recognize surface effects and when to make the decision to terminate data collection operations until surface effects abate.



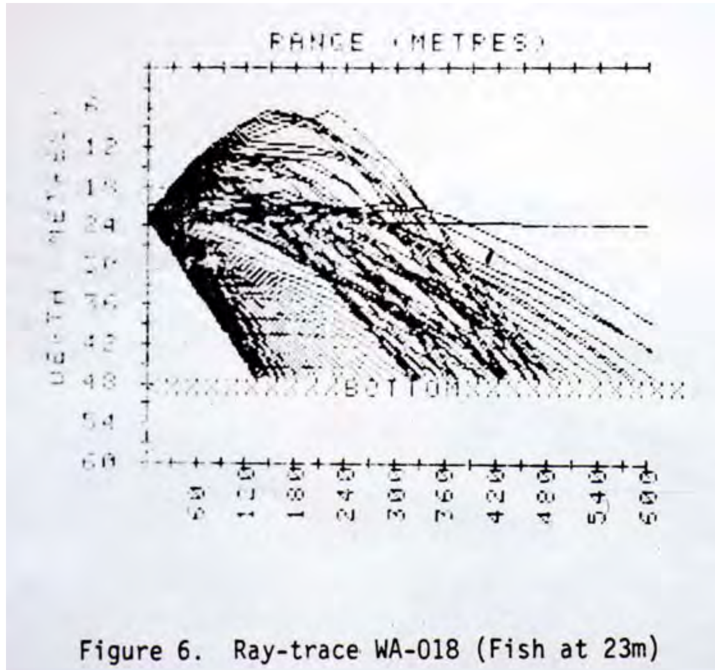
Small wreck imaged in a harbor with the sea surface calm



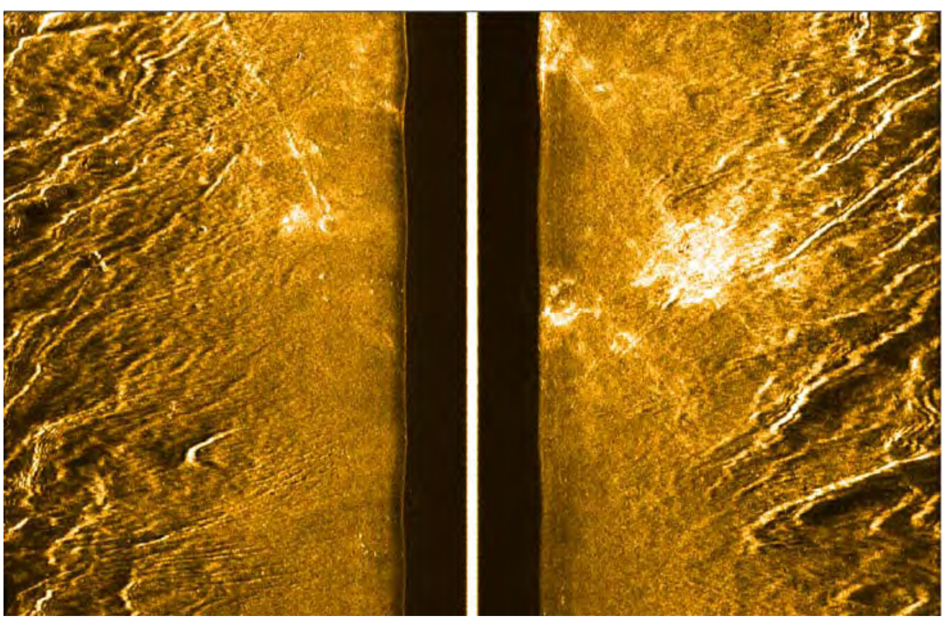
Small wreck imaged in harbor with the surface return from white caps

A non-isodensity water column causes the ray path for the outgoing transmit pulse as well as the returning target echoes to follow a distorted or curved path.

Thermo-clines are the most frequent cause of this ray path distortion, but this effect can also be experienced whereever mixing of fresh water with seawater occurs, for example where a river is feeding into the ocean. The ray path distortion results in echoes from different parts of the seafloor to arrive back at the towfish transducer at the same moment in time. These complex echo's from different locations on the seafloor result in a corrupting pattern on the side scan sonar data that can mask and hide small targets. Refraction effects can be minimized at times by simply changing the depth at which the towfish is being flown.

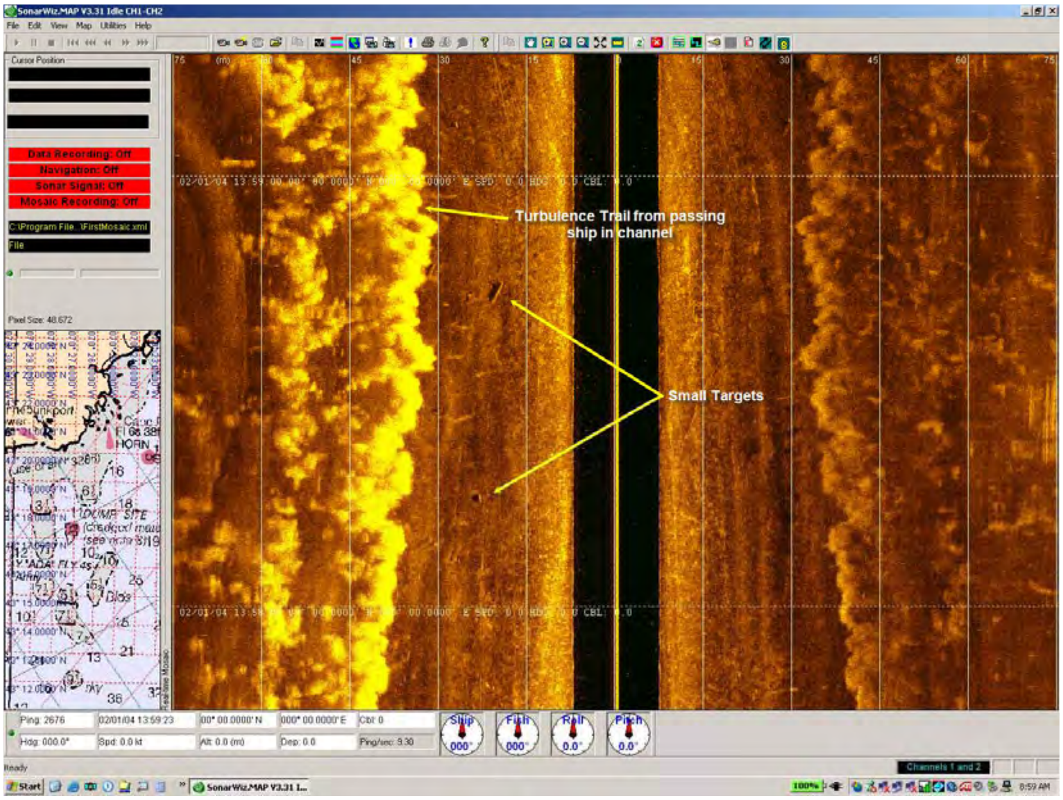


Example of ray path distortion due to a thermo-cline



Wavy pattern at the end of sonar range is caused by refraction due to a thermo-cline.

Another common problem encountered when surveying channels or harbors is boat traffic. Passing ship traffic will produce turbulence trails that are very high in acoustic reflectivity. The turbulence shows up as cloudy trails on the sonar data, and any small target like a mine or IED can be masked such that it cannot be detected by the sonar operator or data analyst.



Two small targets if under the turbulence trail would not be detected

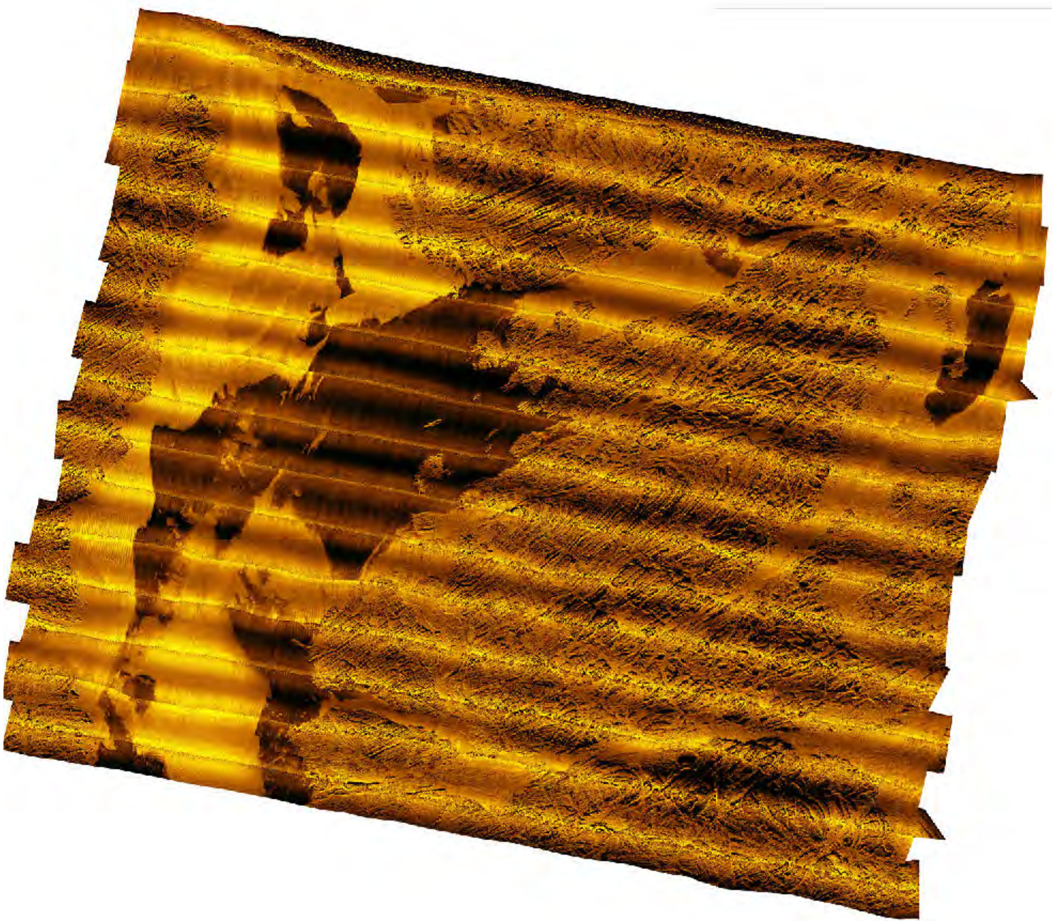
Other problems surveyors must be trained to recognize and deal with that can corrupt the data quality are second sweep returns that are common in harbor or river environments, and distortion due to towfish motion.

Geo-Referencing the Collected Datasets

The comparison of a baseline dataset to a later survey requires the datasets to be accurately geo-referenced. Positioning of the side scan sonar towfish by either a layback algorithm or by the use of a towfish mounted USBL (ultra short baseline) acoustic positioning system is required. GPS X, Y, and Z, offsets need to be accurately measured and then entered into the programs where required for the highest possible positioning accuracy of the sonar towfish.

Mosaic Software for Bottom Change Detection

Several companies market software for processing side scan sonar datasets into area mosaics. These software programs were originally created for the mosaic process, but can be applied for bottom-change detection to aid in easily recognizing newly added MLO or IED targets. SonarWizMap from Chesapeake Technologies is used in this paper to illustrate how off-the-shelf software can easily be used for bottom-change detection. SWM (SonarWizMap) is primarily a mosaic processing software program. It easily and quickly imports sonar files and electronically merges the geo-referenced side scan sonar data into high quality mosaics.



SonarWizMap typical processed mosaic

SWM software also includes a feature to allow the importation of geo-referenced navigation charts or satellite imagery as a background layer.

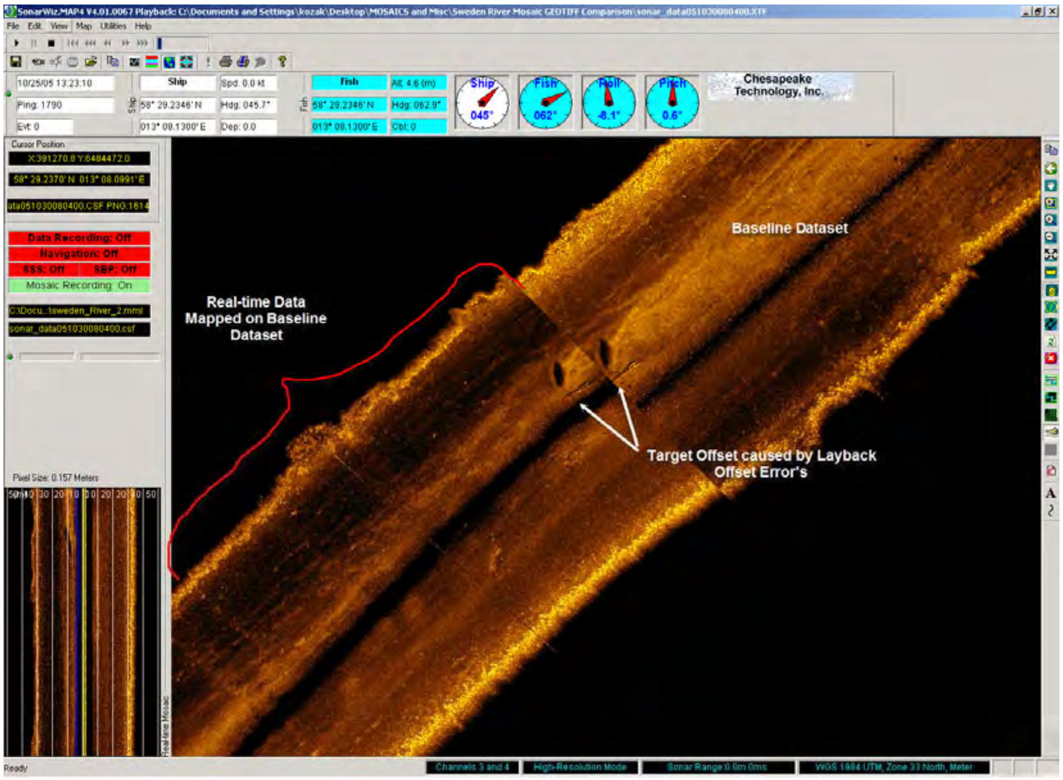
Example SWM mosaic with an imported geo-referenced satellite image in the background as a base map.

SWM has a second feature that allows the exporting of a survey line or complete mosaic as a high resolution Geo-Tiff. These are the two features used in the technique for bottom change detection.

SWM for Bottom Change Detection

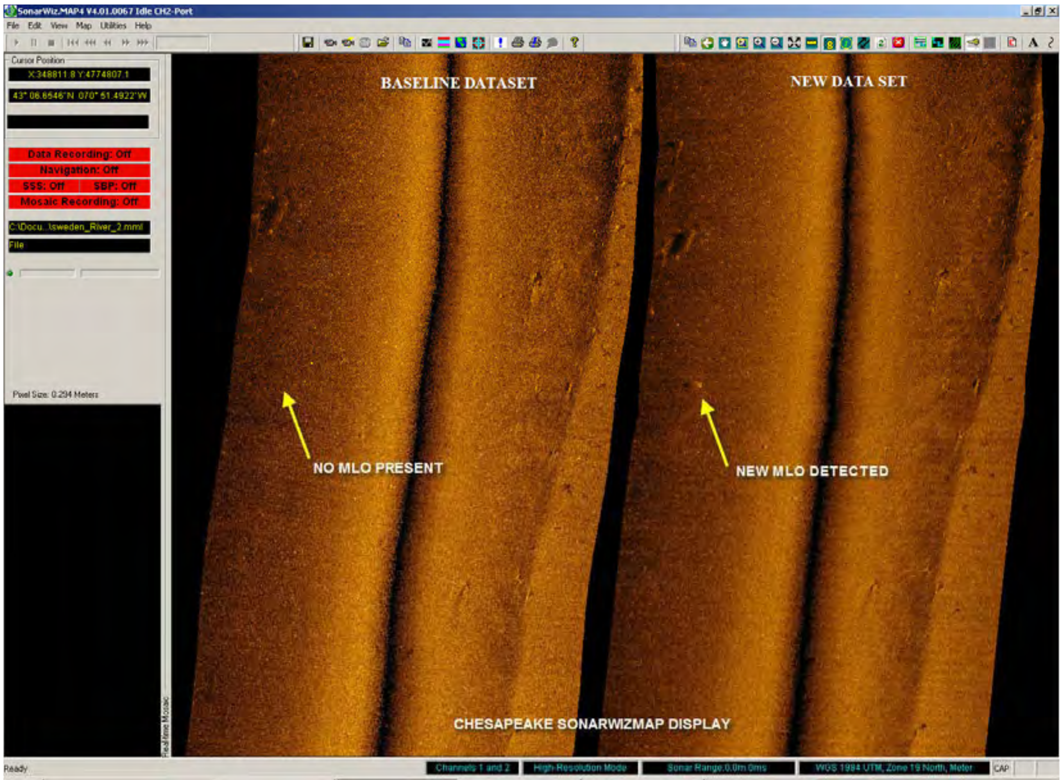
The base line data set will need to be saved as a high resolution GeoTiff for the comparative technique. SWM allows the user to define the level of resolution the GeoTiff image will be stored at and if set high enough the GeoTiff will have full sonar resolution.

SWM software can be used in a real–time comparison mode where on-line data is compared to an imported baseline dataset (GeoTiff). The Baseline dataset is imported as the base map before the beginning of the new survey, and now as the new data is collected it will be mapped in real-time onto the baseline data set. This technique allows the operator to easily recognize any newly added targets that could be a threat. Below is an example showing the new data being mapped onto the baseline dataset.



Real-time comparison of new data to a baseline dataset.

SWM can also be used in a post processing mode where the new data to be compared to the baseline dataset (GeoTiff) is offset for a side by side comparison. Offsetting the new line to the baseline allows the analyst by eye to easily recognize any new targets that have been placed on the bottom. The comparison by eye allows terrain matching which would not be possible by any other technique. The following example is of an area surveyed and collected for use as the baseline dataset. A MLO was later dropped and the area was re-surveyed to collect a new dataset for the offset comparison technique. This example shows how easily the new MLO is detected using the comparative technique.



Post processed line offset comparison showing newly detected MLO

Summary

The perfect scenario for bottom change detection is to have this automatically performed by advanced software. However, when you realize that the size of many MLO's are less than 1 meter by 1 meter, for any software to do this automatically, the absolute geo-referencing of every seafloor feature must be repeatable 100% of the time to an accuracy of less than 1 meter. Experienced side scan sonar operators know that achieving this level of positioning accuracy of all points on the seafloor is unrealistic. It will not be achieved; making automatic change detection of MLO's unreliable. A trained analyst using his eye and the above techniques will have a far higher, more reliable detection rate.