Hydrographic Surveying Using the SAIC ISS-2000 System

Walter Simmons, Richard Nadeau, Shannon Byrne, and Steven Lemke
Science Applications International Corporation
221 Third Street, Suite 1, Newport, RI 02840-1087 USA.

Abstract

In support of hydrographic surveys with very large data sets, Science Applications International Corporation (SAIC) developed the ISS-2000 Integrated Survey System. This is a fully integrated survey planning, data acquisition, data management, data processing, and data presentation software package that has been used for the past six years to execute surveys for nautical charting, environmental monitoring, and sub-sea cable routing.

Use of the ISS-2000 will be illustrated through examples from the NOAA northeast nautical charting surveys, the Scripps South Florida survey, a cable route survey, and USACE disposal site surveys. For many surveys, the ISS-2000 is used to produce the final products. However, for cable route surveys data are ported to the SAIC Chart Management System (SCMS) for the production of route alignment charts. Multibeam sounder data are maintained in ***Generic Sensor Format (GSF)*** [1] binary files that also contain the record of all processing actions applied to the data.

The Survey Planning, and the Navigation/Data Acquisition modules were initially developed by SAIC for the ISS-60 system used in the NAVO survey vessels. SAIC, Newport, RI, continued to develop these systems, and added the Survey Analysis module to form the ISS-2000 system. The ISS-2000 provides the ability to manage, analyze, and report large data sets including soundings and imagery.

ISS-2000 Survey Planning

SAIC ISS-2000 is a dynamic, suite of survey planning, data acquisition, and data processing software developed and maintained at the Newport office. The suite of survey planning tools is in a GUI, menu driven format that sets up a file system accessible during all phases of the data collection and processing.

A new project is developed in a folder unique to the project. As the user develops the survey plan, directories, folders and files are created to house the newly created areas, zones, survey plans and survey schedules. A network interface allows the Hydrographer to make changes to existing plans and schedules as well as add fill lines and change schedules offline while data collection is in progress and then incorporate those changes in real time without experiencing collection down time.

When starting a new survey, the user first creates a new survey project by designating the proper projection and Ellipsoid. If appropriate, the area end points detailed in the project instructions are used to create an area. The area can be used as a polygon for automatic construction of survey transects at the desired line spacing and azimuth orientation. The areas and transects can be displayed over the most recent raster navigation chart image. The ability to compare the chart with the proposed survey assists in identification of potential hazards and evaluation of line spacing and line orientation required to meet project specifications. Figure 1, Figure 2, and Figure 3 illustrate the importance of checking project area specifications against navigation charts.

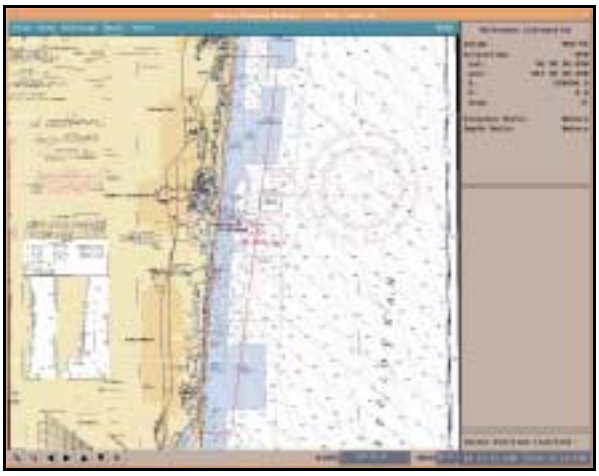

Figure 1. *Survey Area Over NOAA Chart 11466*

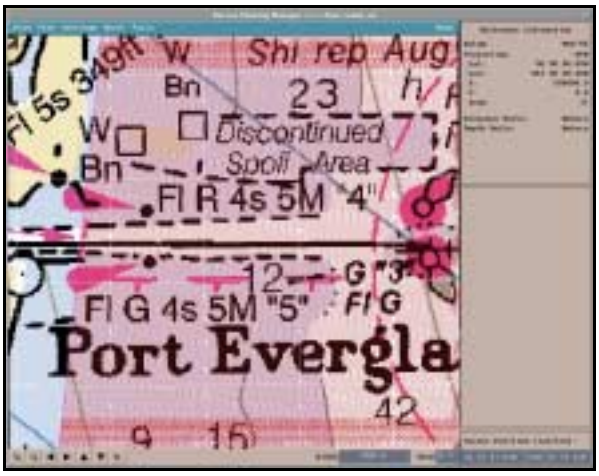

Figure 2. *Survey Over NOAA Chart 11466, Enlarged for Detail*

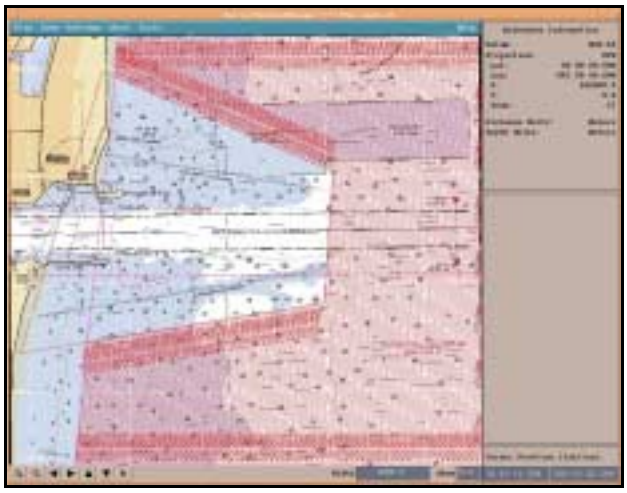

Figure 3. *Survey Over NOAA Chart 11470, Enlarged for Detail*

Figure 4 shows the results of surveys of the above area in a color-shaded grid with selected soundings and contours shown in meters. These data were collected and processed by SAIC under contract to Scripps Institute of Oceanography.

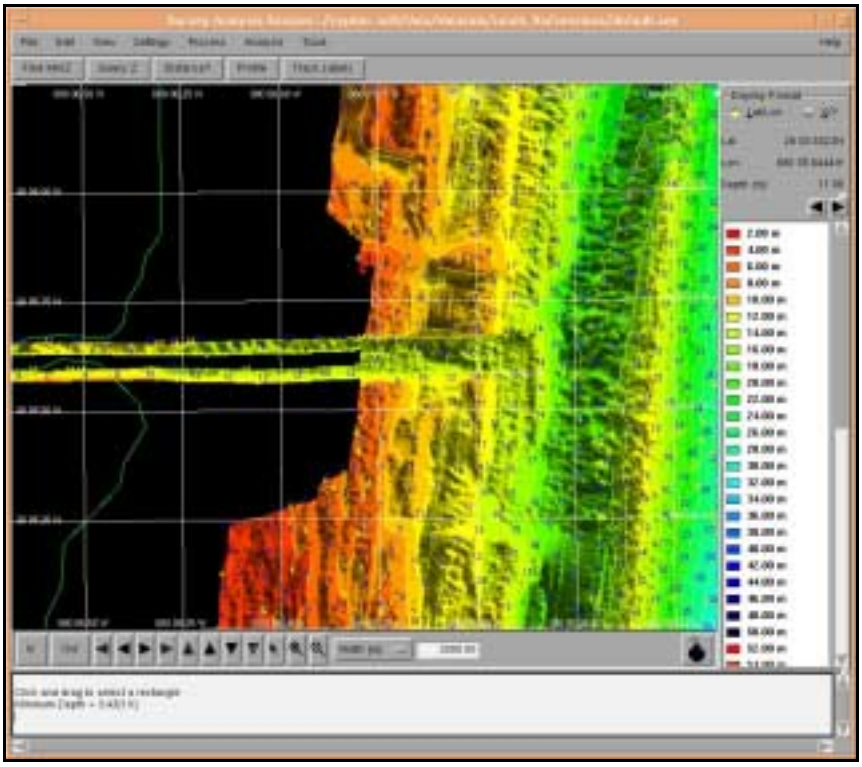

Figure 4. *Color-Shaded Grid of Data Collected With RESON 8101 and ISS-2000*

Surveys can be developed by filling areas (polygon, ellipse, or rectangle), by constructing ladder surveys (corner point or center point reference), by individual transects, or by waypoint. Cross check lines can be created automatically in the survey, or created as a separate survey. Multiple surveys can be viewed at the same time.

Once the Hydrographer is satisfied with the line spacing and orientation, a survey schedule can be developed for use in the Navigation/Data Acquisition module. The entire survey can be scheduled in the order the plan was developed or it can be varied to accommodate vessel constraints, i.e. turning characteristics, to avoid hazards to navigation identified in the chart review evaluation, or to optimize the survey efficiency. Multiple surveys can be included in a schedule.

For a cable route type survey, a transect route line can be developed with AC points input manually or imported from a route position list (RPL). For developing a corridor about a route, a series of ladder surveys can be created. A separate survey can be created for each leg of the survey and displayed for determining end point overlaps. Line length, number of lines, line spacing, and azimuth orientation, as well as cross check lines can be selected and viewed. Any parameter can be changed to develop the best fit for the specific project.

To assist in vessel safety, and to alert the watchstander to important aspects of the survey, a target file can be created, with a unique name displayed for each target. The watchstander also has the ability to add target waypoints to the survey in real time acquisition mode.

All survey plans have the capability to create lead-in and lead-out lines of any selected length. Survey lines have a unique name and number, using a convention designated by the

Hydrographer. As a planning tool, all line statistics are summarized, including total distance (kilometers or nautical miles) and number of lines.

Tide zone areas are developed in survey planning based on analysis of range and time of tide across the area. These zones are used in real time acquisition, and in Survey Analysis to apply water level correctors to the sounding data. The tide correctors and range ratios are used in Survey Analysis to develop water level correctors from predicted or observed water levels. The predicted correctors can be applied in real time, and either predicted or observed correctors can be applied in Survey Analysis.

A coverage grid is also created in survey planning to be utilized for real time display of multibeam coverage.

ISS-2000 Real Time Data Collection

The real time collection module of ISS-2000 is activated through System Control. Each sensor is interfaced to the system through a software module called a Data Transaction Center (DTC.) As new sensors are integrated into ISS-2000 a new DTC with sensor settings such as sensor parameters, calibration parameters, quality control parameters, input formats, output file format, etc., is added without changing the user operation of the software significantly. Whether the data input is through a COMM port or an Ethernet port the adjustable settings within the DTC make the integration of different sensors virtually seamless. For example, a BOT Moving Vessel Profiler was incorporated into ISS-2000 using such a sensor-specific DTC, which allowed a sound velocity profile to be taken, processed and automatically applied to the multibeam data in less than 5 minutes.

Selection of the sensors to be used on a survey is made in the System Control window. The sensors selected and their status are shown in the bottom portion of the window. Color of each sensor name indicates whether the quality control parameters are all being met, if logging of data is enabled, if the sensor itself is enabled, or any combination of the above. Figure 5 illustrates some of the views available in the ISS-200 real time system.

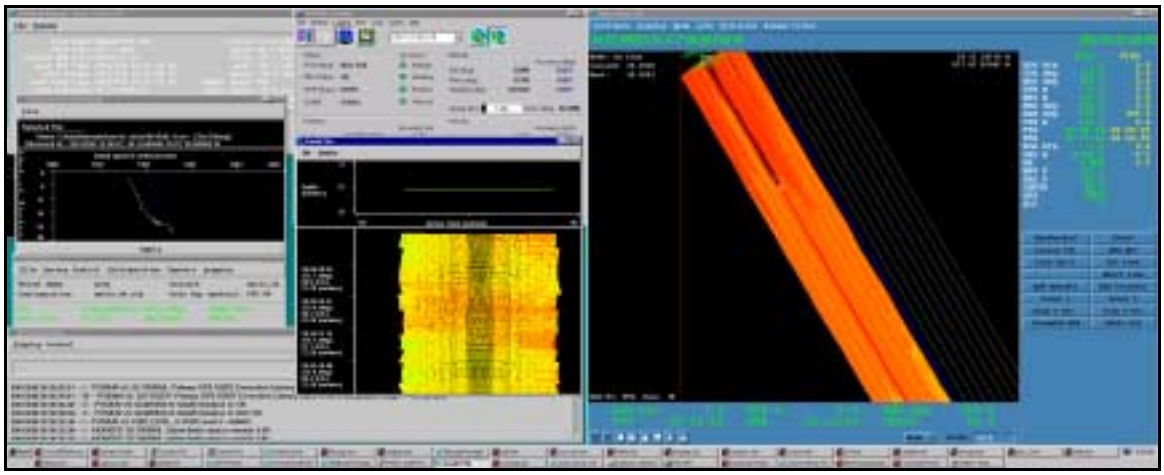

Figure 5. *ISS-2000 Real Time Operations Display*

Each of the DTC modules stores the data from its corresponding sensor in the appropriate file format, and assigns the appropriate name to each file. Most data files are ASCII text files, but binary GSF (Generic Sensor Format) is used specifically for multibeam data. Each filename is unique and includes which sensor the data are from, the date they were collected, and a sequential

extension. This prevents any possible overwriting of files even if more than one project is worked in a day.

A benefit of ISS-2000 is that all echo sounder correctors can be applied during data collection. Unlike many systems, which require post-processing application of correctors such as sound velocity profiles and offsets, ISS-2000 applies these correctors in real time. By doing this, all data displayed for real time QC has the highest level of accuracy possible at that point, including application of predicted tides and alignment calibration bias. Every corrector applied in real time can be corrected in Survey Analysis. Each GSF echo sounder file not only stores all information necessary to provide the depth for each beam, but each file also contains a history record of every action taken on the data file. Information stored includes the date/time of application, the computer (host name) that was used, the program that was applied, and action specific information. For example, if the multibeam data were edited in post-processing, the number of beams flagged or cleared would be stored.

At the heart of the ISS-2000 system is the Message Manager. In this GUI, the user can see all information related to the sensors, the survey, and the system operation. Informational and progress messages appear in white text and simply scroll through the message window. Messages that indicate a potential failure to meet survey specifications appear in yellow text, appear in a warning window, and require acknowledgement by the operator to silence an audible alarm and clear the warning. Messages that indicate failure to meet quality control parameters appear in red text, appear in a warning window, and require acknowledgement by the operator to silence an audible alarm and clear the warning. Another message will appear when the data return to normal. The operator can also use the Message Manager to enter Events into the message file.

Messages include date/time, DTC affected, and the critical information. The message display is buffered so that messages may be viewed some time later if the user is occupied with something more critical at the moment. All messages are stored in ASCII text files so that a post-processor may see exactly what was happening to the system at any time.

There are several quality monitors included in ISS-2000. The Coverage Monitor displays the multibeam coverage in real time by filling in a grid on the navigation window. Coverage Monitor populates a coverage grid that was defined in the Survey Planner. Coverage can be filled by the last, minimum, or average depth to hit the cell. This allows the user to know immediately if line spacing needs adjusting. The coverage is color-coded by depth and can be used to better predict what depths are coming up as the survey is performed. Coverage Monitor also allows the real time operator to build gap-filling lines on the real time screen. As lines are run, whether they were created in real time, survey planning, or survey analysis, the fill can be verified for coverage before heading to the next area.

The Environmental Monitor allows the user to view a graph of the output of several sensors as function of time. Even more important is that they display the sensor information as it compares to the quality assurance procedure. One example of this is that single beam echo sounder information is compared with the depth of the center beam of a multibeam transducer.

By showing this, the user not only has a profile of where the vessel has been, but also a continuous comparison between the sensors. Sound velocity from a surface sound velocimeter may be compared with the surface sound velocity on the profile currently being applied to the multibeam data. If the sound velocity differs by a user-specified amount (indicating that it may be time to take a new profile), a message is sent to the user via Message Manager. GPS Monitor is used to compare navigation from the primary navigation source to an independent secondary navigation source. If the difference between measurements is too high, a message notifies the user.

It can easily be seen that ISS-2000 is a useful tool for meeting all the specifications required in shallow water multibeam hydrographic surveys. ISS-2000 addresses the critically important need to be aware of any problems with the sensors as soon as possible during real time

operations. Storing all of the system messages in real time also helps to alleviate any potential confusion for post-processors who may not have been on the survey vessel. Finally, the crucial part of this integrated survey system is the incorporation of new sensors. Whether the data input is through a COMM port or an Ethernet port the adjustable settings within the DTC make the integration of different sensors virtually seamless.

Survey Analysis

SAIC's Survey Analysis product provides a state of the art hydrographic and bathymetric data analysis software package. Survey Analysis is the post-processing component of SAIC's Integrated Survey System (ISS-2000), which, in addition to post-processing and charting capabilities offers mission planning, and real-time data acquisition and survey control components. Survey Analysis is designed to process hydrographic and bathymetric data in support of nautical charting surveys, seafloor characterization surveys, cable route surveys, and search and locate surveys. [2], [3], [4], [5]

Survey Analysis provides an intuitive approach capable of handling today's large seafloor datasets in a rigorous and efficient manner. The approach supports a standardized processing flow to ensure the consistency of results across a spectrum of analyst capabilities. Quantitative quality assurance is provided to fully characterize processing results. All of these factors support the objectives of streamlining the effort required to produce data products and minimizing survey rework when these processes are applied in the shipboard environment.

Figure 6 illustrates the graphical user interface (GUI) for SAIC's Survey Analysis module. The data displayed in Figure 6 were acquired and processed by SAIC under contract with NOAA to survey Salem Sound, MA. The minimum depths of approximately 1 meter are displayed in red and the maximum depths of approximately 19 meters are displayed in blue. Bowditch Ledge is in the upper left, and the Hardy Rocks are in the lower right of the figure.

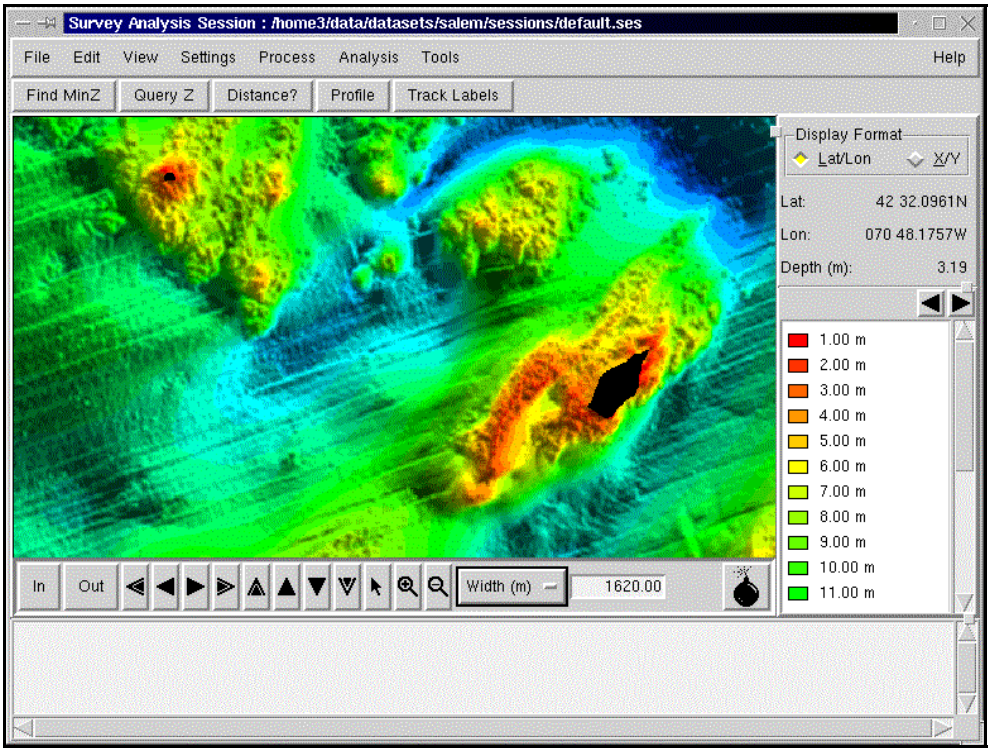

Figure 6. *Survey Analysis Graphical User Interface*

This user interface provides the focal point for the ISS-2000's geo-spatial data analysis. From this user interface various geo-spatial data layers may be superimposed for visualization and analysis. Supported data layers include: planned survey transects, tidal zoning, sheet boundary definitions, coastlines, various formats of vector data, gridded bathymetry, contours, sidescan mosaics, targets, survey track lines, selected soundings, junction statistics, and raster nautical charts.

The menu structure for Survey Analysis is organized to follow typical data flow through post-processing. Swath oriented bathymetry and sidescan imagery data may be geo-referenced immediately following acquisition for initial processing. The geo-spatial gridded bathymetry files are created in an internal grid file format.

A complete suite of swath oriented and navigation processing tools are available to assist with data editing and post-survey corrections on an as needed basis. Survey Analysis uses the GSF file format to read and process bathymetry data. Use of the GSF format provides full traceability for all corrections and edits to the data. This is a key feature necessary to ensure that all required corrections to the bathymetry data may be re-applied in post-processing if necessary. This complete level of traceability is maintained from initial data acquisition through final sounding selection for all edits and corrections to the bathymetry. In the shipboard environment, new data can be incorporated into Survey Analysis as it becomes available. The data can be edited as required, it can be used to assess coverage and it can be used to assist with the planning of fill-in transect lines to ensure adequate bottom coverage.

Surface ship and sub-sea navigation processing tools include the ability to identify and invalidate fliers in the position data. A forward/backward Kalman filter may be used for driving down residual errors in the raw navigation data, and, if appropriate, bridging short outages. For sub-sea navigation, complete reprocessing from the raw acoustic ranges, including application of appropriate calibration values, is supported.

Targets that have been identified from sidescan sonar or other imaging systems may be imported and layered over the bathymetry for contact analysis. Contacts can be organized, associated with other contacts and related to the most appropriate bathymetry sounding to assist with the determination of contact significance.

Once editing and final corrections have been completed, tools are available to assist with quality assessment. Junction analysis of the bathymetry data may be performed at cross line to main scheme line intersections and sheet-to-sheet intersections. A statistical report is provided to quantify the results. Shaded relief display of the bathymetry data using operator selectable azimuth and elevation angle of the light source may be used for quality assessment.

Survey Analysis provides a geo-spatially oriented sounding reduction algorithm. The approach takes into account the sheet scale, and all appropriate input data. The sounding reduction results may be used to attribute the GSF data files. Sounding selection results may be displayed as a layer over a gridded depth layer, or on top of a raster chart for further quality assurance.

Figure 7 shows a selected soundings layer displayed over a NOAA raster chart. These data where acquired and processed by SAIC under contract with NOAA to survey Salem Sound, MA. The soundings shown in blue are the selected soundings resulting from a 100% bottom coverage survey using a RESON 8101 multibeam sonar.

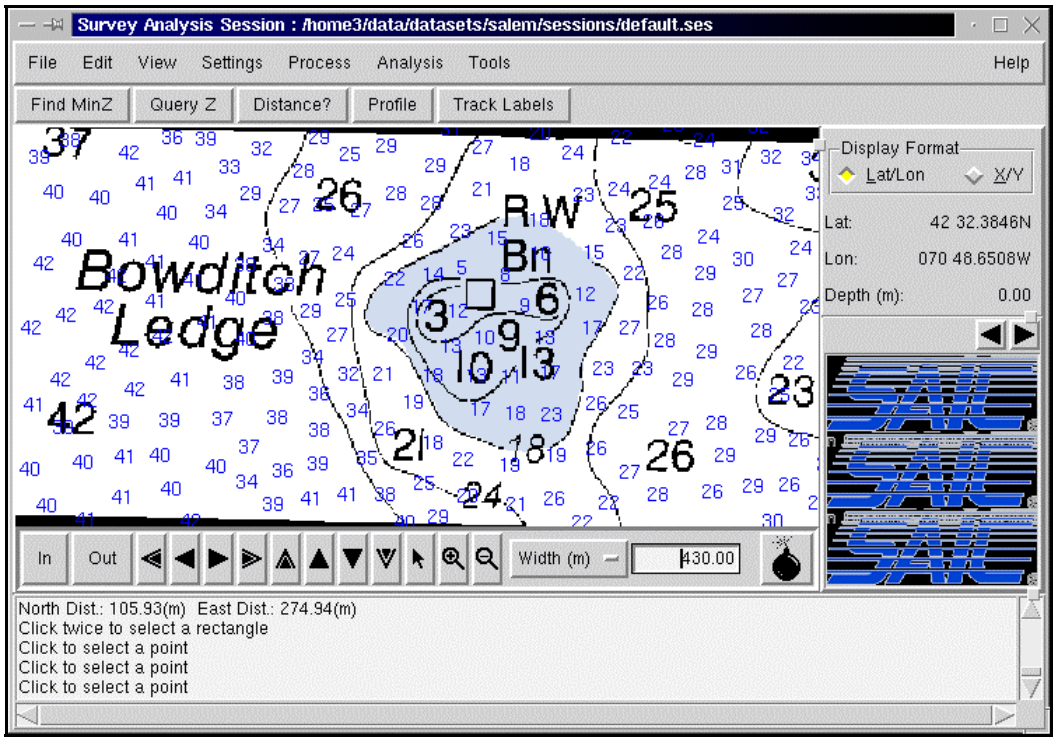

Figure 7. *Selected Sounding Comparison with Raster Chart*

Survey Analysis also provides the capability to support channel engineering operations. This includes the ability to compare the results of a channel survey to the channel design, and the computation of volume of dredged material. Additionally, the software provides marine cable engineering functions, including design of route position lists (RPLs) and the production of alignment charts. Figure 8 illustrates an alignment chart for a cable route survey.

Figure 8. *An Example of an Alignment Chart*

Conclusion

SAIC's commercial ISS-2000 software has been used to efficiently plan and conduct surveys, acquire and process data, and rigorously analyze large shallow water hydrographic datasets. These datasets have varied in size, up to and including in excess of over one billion soundings over a single sheet. Full traceability is maintained from data acquisition through to the final product generation.

References

1. **Ferguson, J.S., and Chayes, D.A.** "Use of a Generic Sensor Format to Store Multibeam Data." *Marine Geodesy*, Volume 18, pp. 299-315, 1995.
2. **Evans, R.E. and Simmons, W.S.** "Outsourcing of Coastal Hydrographic Survey An Industry Perspective of a Partnership With the Government", Hydro International, March, 2001, pp 46 – 49.
3. **Evans, R.E., Morton, R.W., Simmons, W.S.**, "A Dual or Single Vessel Solution to Conducting Multibeam and Sidescan Surveys for NOAA in the Gulf of Mexico: A Lessons Learned Approach", *Proceedings from U.S. Hydrographic Conference*, April, 1999.
4. **Parker, J.H., Miller, J.E., and Schoenherr, J.** "Collection and Processing of Multibeam and Side-Scan Data to Hydrographic Standards." *Proceedings of Oceans 96*, September, 1996.
5. **Miller, J.E., Ferguson, J.S., Byrne, Simmons, W.S.** "Use of an Integrated Hydrographic Survey System in Long Island Sound and Vineyard Sound." *The Hydrographic Journal*, April, 1996.