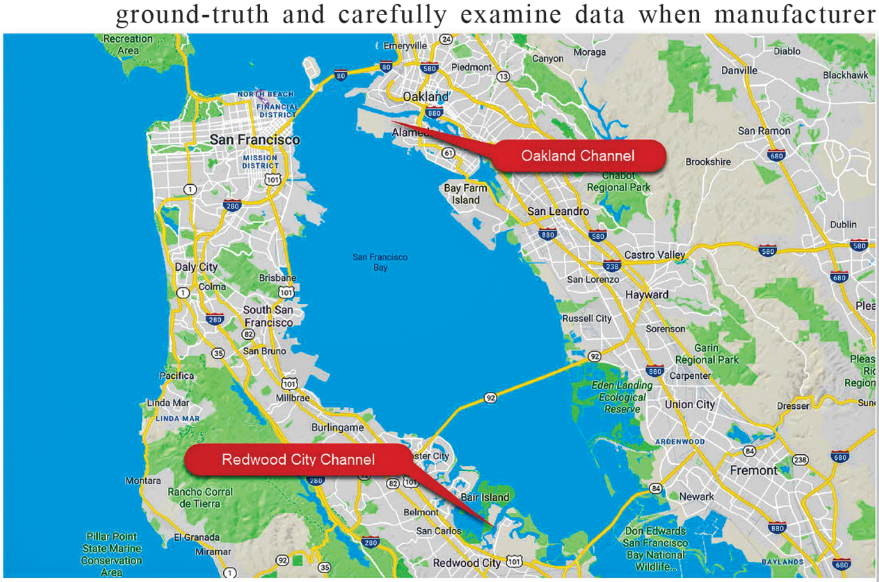
Single-Pass Dual-Frequency
Multibeam Dredge Surveys

Not long ago, most surveyors used dual-frequency single beam echosounders, and one-pass dual-frequency dredge surveys were common-place. These dual-frequency surveys often revealed areas of suspended or soft sediments as the lower of the two frequencies used would penetrate through soft sediments while the higher frequency generally would not. This would be evident in the cross-sections and surfaces generated, which would display deeper depth values associated with the low-frequency data than with the high-frequency data. Commensurate with the introduction of multibeam echosounders to the market, one-pass dual-frequency surveys, and the information they provided, disappeared. The many advantages of multibeam echosounders made them a more useful tool for surveyors despite multibeam technology being limited to collecting data for only a single frequency surface.

Fortunately, advancements in multibeam technology have voided this limitation, and the ability to identify areas of suspended or soft sediments from a one-pass multibeam survey using two frequencies is now available. eTrac, Inc is a US-based firm that owns and operates a fleet of geophysical survey vessels and provides hydrographic surveys to US public and private sectors. The survey vessels are designed and configured for a variety of subsea mapping applications, which includes the performing of navigation channel assessment and dredge payment surveys.

eTrac has standardized on a single source of multibeam sonars (R2Sonic, Inc.) as well as positioning and inertial systems (Applanix, Inc) for its fleet to maintain a high level of consistency in data quality. Constraining the technology choice and combining the use of the systems with consistent methods and procedures allows for the unique ability to perform further, more detailed analysis of the survey datasets. Measuring a dynamic subsea environment that is subject to sediment infill, erosion and excavation with frequent data collection over long periods allows eTrac to ground-truth and carefully examine data when manufacturer updates to the sonar systems are released.



Dredging Channels
Image Courtesy of Google Maps

eTrac recently conducted surveys in two active dredging areas in San Francisco Bay: Oakland Navigation Channel and Redwood City Navigation Channel. The US Army Corps of Engineers manages the dredging of the Oakland channel on an annual basis and the Redwood City channel on a, typically, biennial basis.

Figure 1 below shows the two areas in the San Francisco Bay area. The Oakland channel experiences relatively strong currents and high sedimentation rates and a sediment type of soft bay muds. The Redwood City channel has lower current speeds and sedimentation rates and a similar soft bay mud sediment type.

Figure 1: Survey Areas in San Francisco Bay

eTrac surveyed the two channels with a vessel outfitted with an R2Sonic 2020 Multibeam Echosounder and supported by an Applanix POS MV Inertial Navigation System. Using the latest firmware update from R2Sonic, eTrac conducted these surveys using multiple frequencies in one pass. Specifically, the sonar interleaved two frequencies, 200 kHz and 400 kHz resulting in two surfaces for each survey area (up to five frequencies of choice can be selected).

The extra information gleaned from the additional surfaces in each area provided a significant amount of information. Some of the information that resulted from the dual-frequency surveys were as expected from past dual-frequency singlebeam surveying. Some of the results, however, shed new light on the possibility of multibeam surveying at two concurrent frequencies.

Figure 2: Example of an eTrac Survey vessel outfitted with an over-the-side-mounted multibeam sonar

Pre-dredge Surveys:

The 200 kHz and 400 kHz pre-dredge surfaces were compared, with difference measurements calculated for Mean and Median depth, and standard deviation. The Oakland Channel pre-dredge 200 kHz surface had a Mean depth deeper by 0.17 feet, a Median depth deeper by 0.18 feet, and a standard deviation of 0.07 feet compared to the 400 kHz surface (Figure 3). The Redwood City Channel surface comparison showed similar results. Specifically, the pre-dredge 200 kHz surface had a Mean depth deeper by 0.12 feet, a Median depth deeper by 0.12 feet, and a standard deviation of 0.05 feet compared to the 400 kHz surface.

In both pre-dredge surveys, the 200 kHz surfaces were deeper than the 400 kHz surfaces, which was expected given the softer bottom-type. The statistics showed the differences to be stable and evenly distributed, which was consistent with channel bottoms undisturbed by any irregular activity, such as dredging.

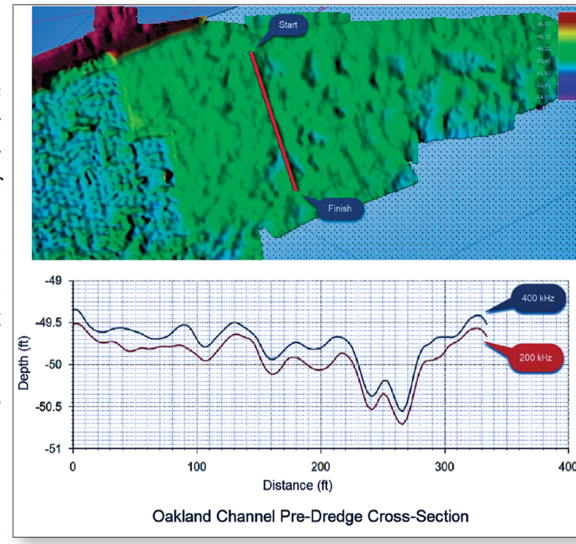


Figure 3: Oakland Channel Pre-Dredge Survey

Post-dredge Surveys:

The 200 kHz and 400 kHz post-dredge surveys were also compared, with difference measurements calculated for Mean and Median depth, and standard deviation. Similar to the pre-dredge results, the Oakland Channel post-dredge 200 kHz surface had a Mean depth deeper by 0.16 feet, a Median depth deeper by 0.16 feet, and a standard deviation of 0.06 feet, compared to the 400 kHz surface.

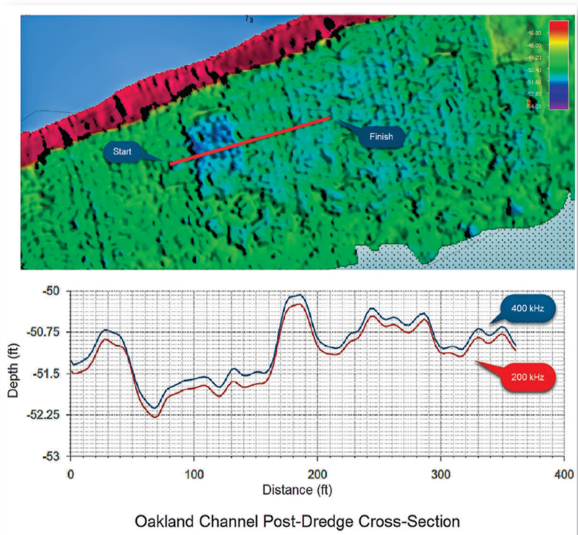
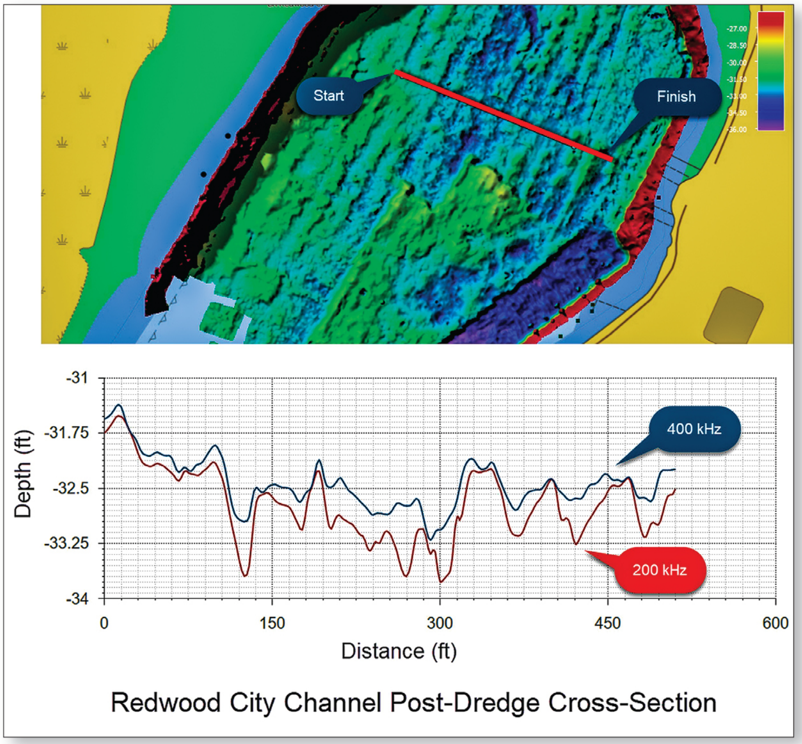


Figure 4: Oakland Channel Post-Dredge Survey

The Redwood City Channel post-dredge surface did not follow suit in this case. The post-dredge 200 kHz surface had a Mean depth deeper by 0.29 feet, a Median depth deeper by 0.31 feet, and a standard deviation of 0.21 feet compared to the respective 400 kHz surface.

The Oakland Channel post-dredge survey results (Figure 4) indicate that the bottom sediments in the channel resettled to their pre-dredge state after the dredge had gone through. The very close



results of the pre- and post-dredge 200 and 400 kHz surface differences confirmed that post-dredge settlement occurred.

The post-dredge Redwood City results (Figure 5) did not show the same consistency as compared to the pre-dredge survey results. The post-dredge Mean and Median differences were approximately 2.5 times greater than that of the pre-dredge survey, and the standard deviation of depth differences was significant in magnitude.

These results indicate the sediment transport mechanisms in the Redwood City Channel are likely less active than those of the Oakland Channel, causing lighter sediments to remain suspended rather than being carried away. The shorter wavelength of the 400 kHz frequency detected the widely distributed suspended sediments in the water column resulting in a much shallower surface than the pre-dredge 400 kHz surface.

Figure 5: Redwood City Channel Post-Dredge Survey

Dredge Interface Survey:
At the time of the survey, the Oakland Channel was being actively dredged by a clamshell dredge, and the survey vessel moved in and out of the active area, maintaining a safe distance from the dredge. At the dredge interface, the 200 kHz surface had a Mean depth deeper by 0.15 feet, a Median depth deeper by 0.1 feet, and a standard deviation of 1.41 feet compared to the 400 kHz surface.

Figure 6 shows the random separation distances between the 200 kHz surface (green) and the 400 kHz surface (blue). The active dredging added energy to the environment, increasing the amount of suspended sediment, which was then detected by the 400 kHz frequency.

The difference between the 400 kHz and the 200 kHz surfaces were not only random but indicated arguably unreliable results. The center of the cross-section in Figure 6 shows the two surfaces crossing each other with the 400 kHz surface showing deeper depth values, which is not believed to be correct.

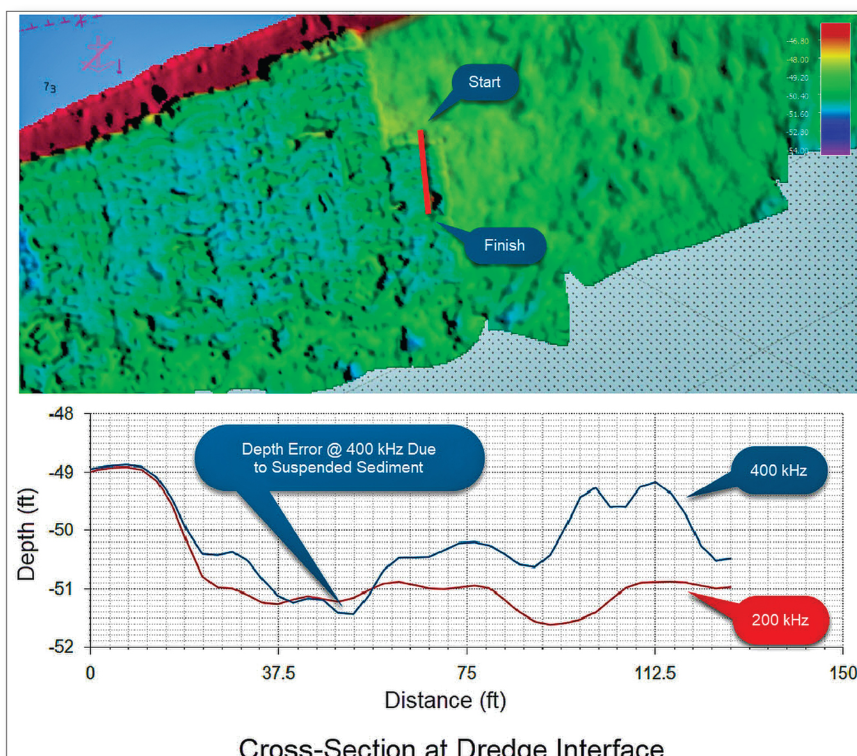


Figure 6: Dredge Interface Cross-Section

Conclusion
One-pass dual-frequency dredge surveys, with 100 percent bottom coverage, are now possible using the latest generation of multibeam echo-sounders. All parties involved in the dredging process now have mission-critical information to assess the survey area knowledgeably and effectively.

Such critical information includes presence and estimated thickness of soft-bottom sediments, as well as the presence of suspended sediments in the water column, which may affect the accuracy of higher frequency surfaces. Moving forward with the use of modern multibeam sonars and modern survey techniques serves the dredging community with a complete picture of what is occurring both below the waterline as well as at the upper sediment/water interface layer. ❍