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INNOVATIVE APPLICATIONS OF OCEAN ACOUSTICS AND OTHER TECHNOLOGIES FOR MARINE WATER QUALITY MONITORING AND ASSESSMENT—EFFLUENT PLUME STUDIES OF THE MWRA OUTFALL

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INTRODUCTION

USEPA and NOAA performed plume studies in Massachusetts Bay of the Massachusetts Water Resource Authority (MWRA) outfall. This is the highest-capacity discharge rate system for treated sewage effluent into United States coastal waters. The outfall is located 9 miles offshore. Effluent is conveyed though an outfall tunnel beneath the seabed to risers that reach to the seafloor. This system includes a novel diffuser designed to create a sewage effluent plume confined most of the year within the ocean waters by water column density gradients. Massachusetts Bay is rich in plankton, which are distributed in vertical patterns throughout the bay. The area of the diffuser is rich in internal wave activity and thus has areas of significant vertical mixing.

USEPA and NOAA performed plume studies in July 2001, in part to verify the model predictions for plume behavior and dilution in the Bay under representative conditions of stratification and water movement. USEPA and NOAA cooperated with MWRA and its contractors to carry out concurrent studies of the discharge. The USEPA/NOAA studies used dye tracers introduced by MWRA and its contractors at the Deer Island sewage treatment facility. USEPA/NOAA also used ocean acoustics integrated with other ocean technologies.

BACKGROUND

USEPA and NOAA conducted a background study of Massachusetts Bay in 1995 to determine whether ocean acoustics technologies could be used to study the secondary-treated effluent plume from the planned 9-mile MWRA outfall tunnel after the discharge commenced. (NOAA, 1996). This study also provided a synoptic characterization of water column structure and dynamics in Massachusetts Bay during a period when the water column structure was well stratified. Knowledge of the continuity and distance of water column gradient horizons and of naturally occurring particulate matter horizons is important in understanding effluent and other plume dilution, and understanding exposure probabilities for organisms at different water column depth horizons. (Stamates, et al, 1996). In particular, it is important to help evaluate the exposure to a diluting plume of zooplankton, the important food of the severely endangered Northern Right Whale. Among other things, this pre-discharge study concluded that ocean acoustics could be used to study the effluent plume discharged from the 9-mile outfall tunnel.

RESULTS

The plume was quickly located and tracer-marked effluent was tracked over three days using integrated data types including acoustics, dye, salinity, temperature and depth. Some representative graphics follow to illustrate topics and issues addressed in both studies (NOAA, 1996, and NOAA, 2003). Figure 1 is an acoustic backscatter visualization (ABV) from the 1995 study that clearly shows a transition of water masses and scattering layers as the ship transits from Massachusetts Bay into Boston Harbor (NOAA, 1996). The ship tracked over the area of the 9-mile outfall.

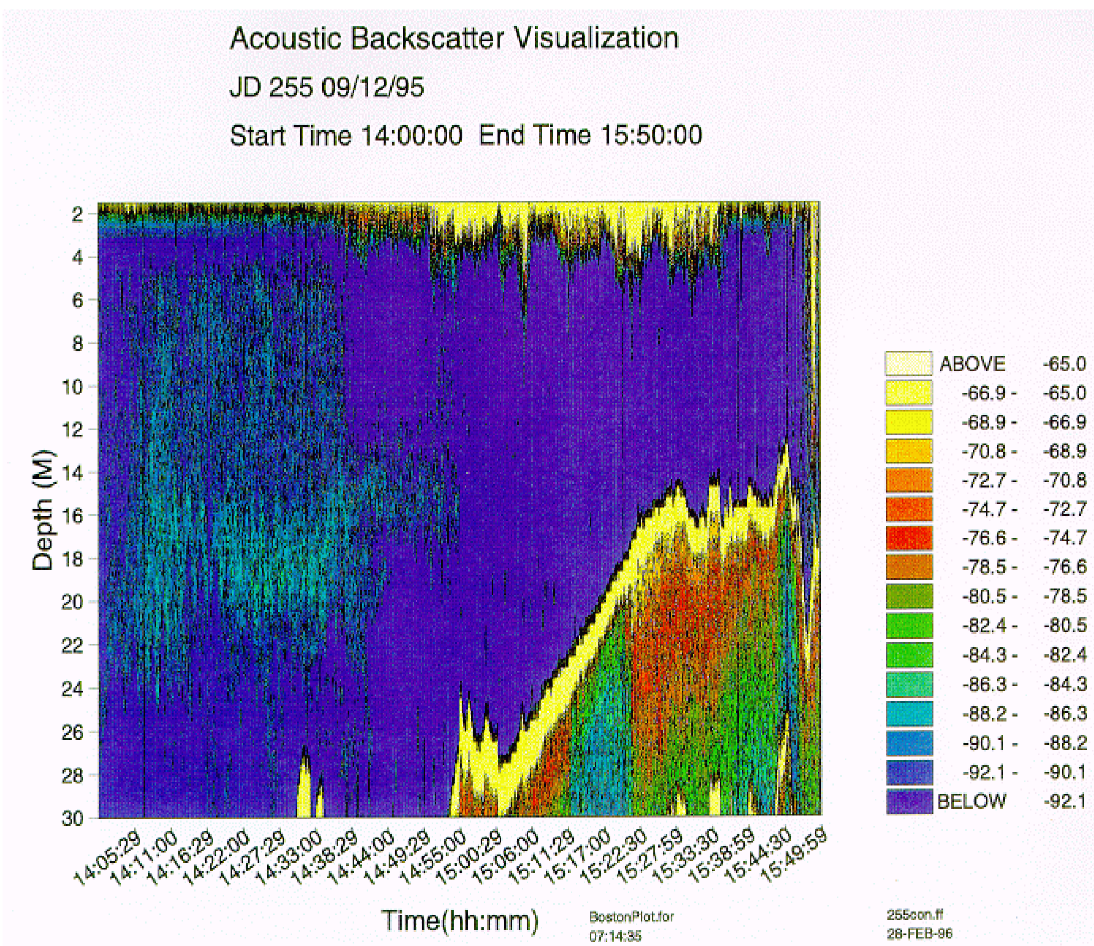

Figure 1. Acoustic backscatter visualization (ABV) clearly shows a transition of water masses and scattering layers as the ship transits from Massachusetts Bay

Figure 2 is an ABV that shows the presence of internal waves (NOAA, 1996).

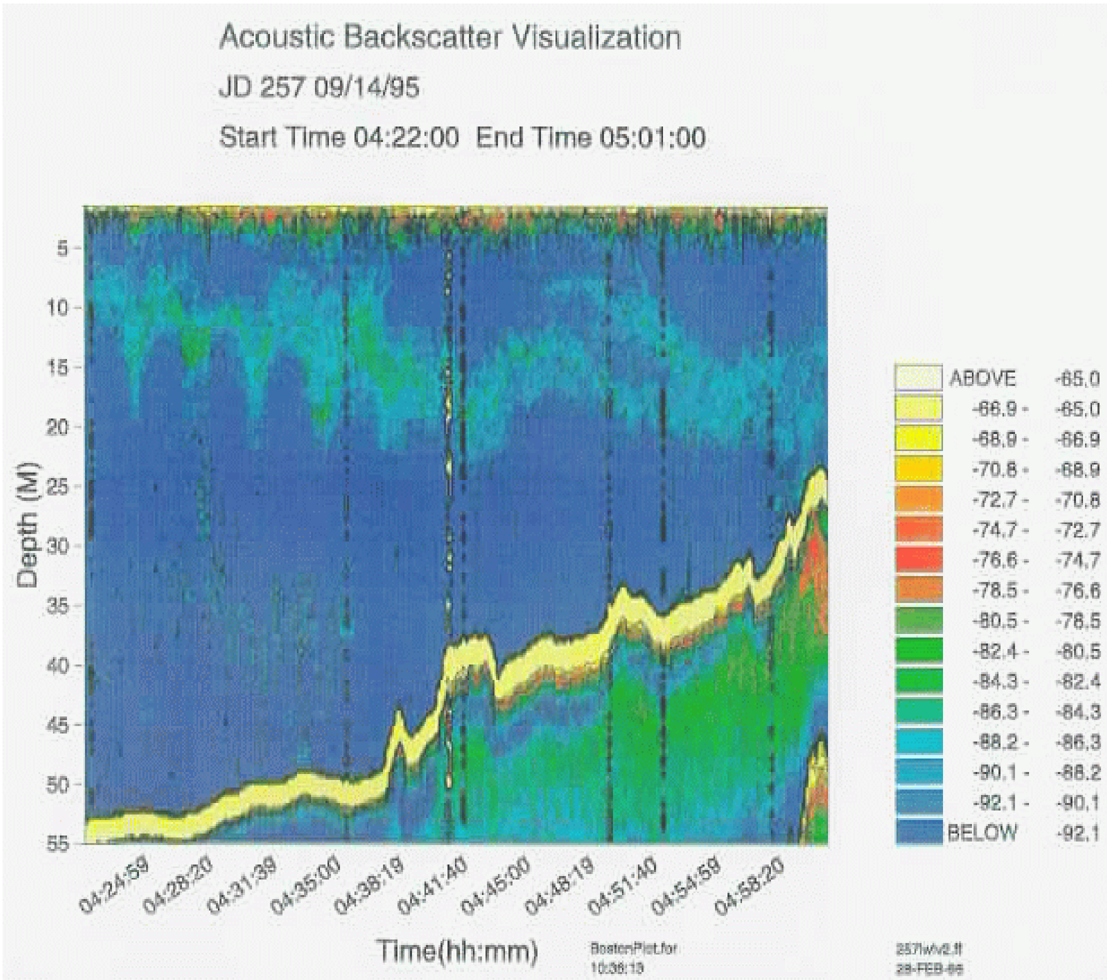

Figure 2. ABV shows the presence of internal waves and acoustic reflectors distributed within water column density horizons (from NOAA, 1996).

Figure 3, an ABV of a track sub-segment over the length of the 9-mile outfall diffuser, shows the effluent discharge through the water column from the risers to near the surface (NOAA, 2003).

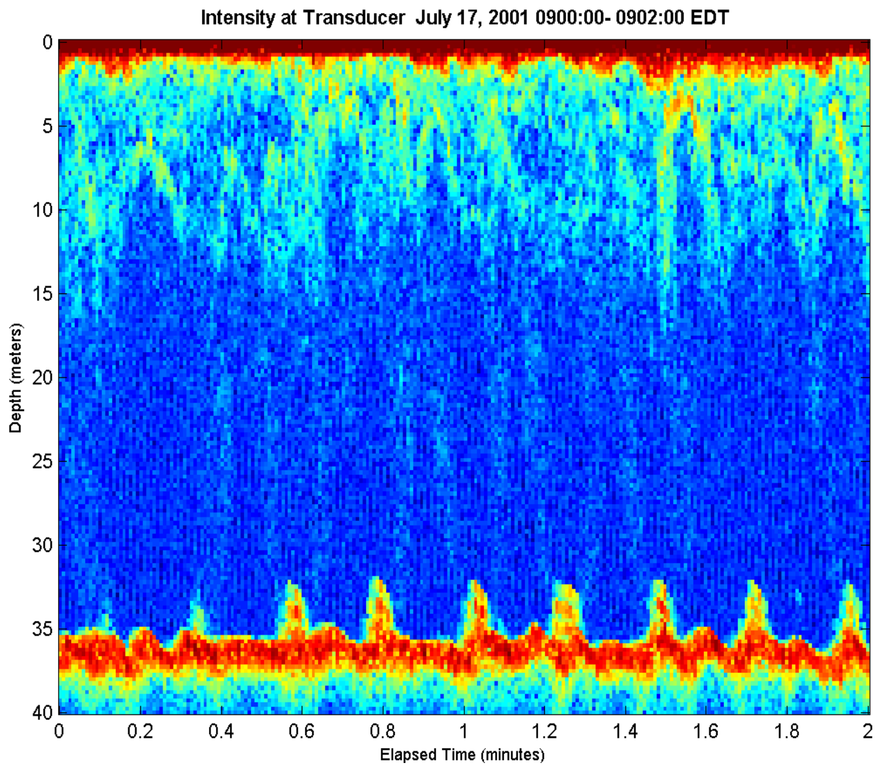

Figure 3. ABV of a track sub-segment over the length of the 9-mile outfall diffuser that shows the effluent discharge through the water

Figure 4 is an ABV of a track perpendicular to the outfall diffuser transiting over the end two risers (NOAA, 2003). Figure 5 shows the optical backscatter, dye, and Chlorophyll-a time series for this track segment.

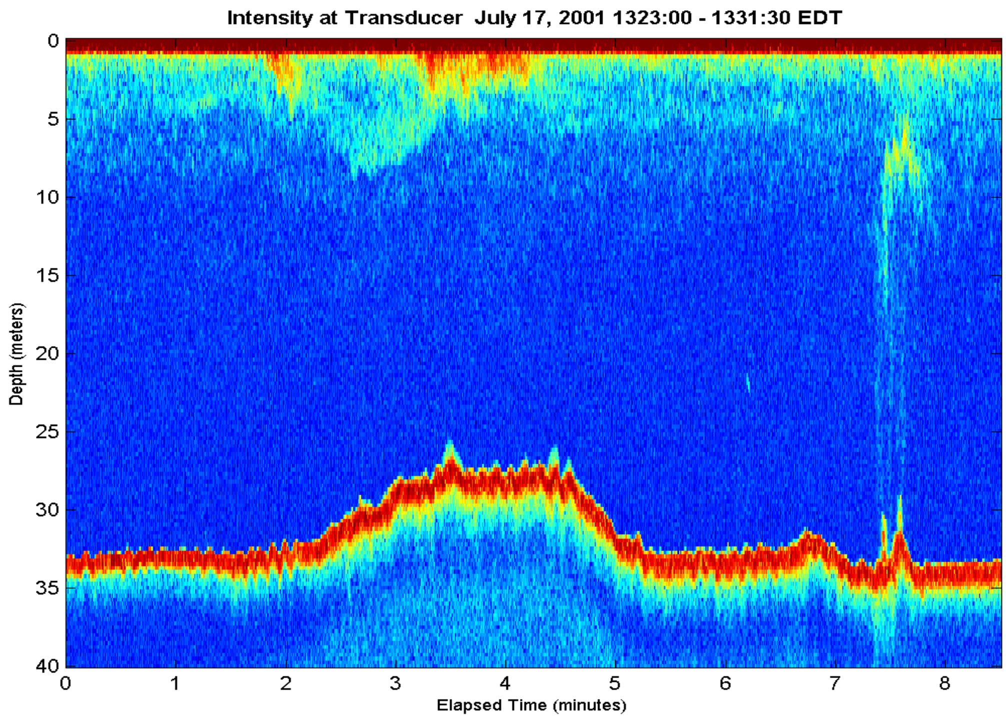

Figure 4. ABV of a track perpendicular to the outfall transiting over the end two risers (from NOAA. 2003).

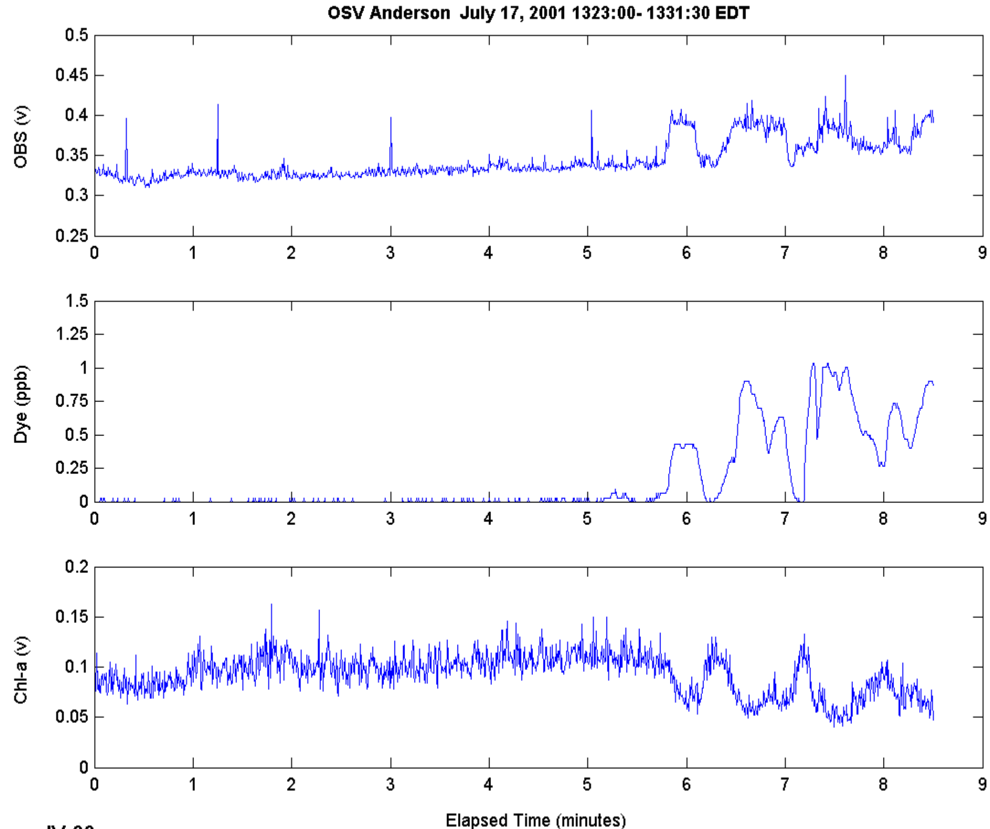

Figure IV-33

***Figure 5**. The optical backscatter, dye, and Chlorophyll-a time series for the track segment shown in Figure 4 (from NOAA, 2003).*

CONCLUSIONS

This study demonstrates the utility of acoustics in assessing the operational performance of the diffuser. It also indicates the presence and effects of internal waves on the dispersing plume and on measurement results. The uniqueness of the diffuser design and the ubiquitous nature of ambient internal waves in Massachusetts Bay add to the significance of this case study. Adaptive sampling of the water column clearly has advantages over pre-positioned sampling sites within the water column. The observations and conclusions reached in the joint NOAA/EPA pre-effluent discharge study in 1995 have been confirmed in this present study. Clearly measurements of outfall effects and properties must include concomitant ambient internal wave observations. Internal wave induced mixing in Massachusetts Bay is potentially a key feature of effluent mixing in Massachusetts Bay.

Significant effluent subfield correlations in space and time exist in the diffuser vicinity. For given depth horizons: 1. Generally, the optical backscatter field and the salinity field are anti-correlated, so that optical backscatter is enhanced over the axis of the diffuser while salinity is depressed. 2. Chl-a is generally anti-correlated with the optical backscatter field. 3. The temperature field is generally anti-correlated with the optical backscatter field. Those three correlations generally exist along the axis of the diffuser and are largely not induced by ambient internal waves. Correlations are complex in this environment because both the ambient internal wave fields and the disposition of the subsurface plumes result in correlations among different measured parameters.

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