Podcast: Selecting ADVM Measurement Volumes

Recording time is about 17 minutes

Slide 1:

Welcome. This is a podcast produced by the USGS Hydroacoustics Work Group on selecting measurement volumes for side-looking acoustic Doppler velocity meters or ADVMs. My name is Molly Wood, and I'll be your narrator. I'm currently the Surface Water Specialist in the Idaho Water Science Center and a member of the Hydroacoustics Work Group. The examples discussed in this podcast focus primarily on SonTek sidelooking ADVMs; however, the concepts translate to other types of side-looking ADVMs. Keep in mind that the use of trade names does not imply endorsement by the USGS.

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So you are responsible for the installation of an ADVM, perhaps at a streamgage where you plan to develop an index-velocity rating. There are a number of considerations when selecting the appropriate volume or portion of the channel where you will measure velocity.

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Here is a schematic showing a side-looking ADVM that is measuring velocity in the horizontal direction across a stream channel. In this example, you are looking down on the stream channel. The primary flow direction is from top to bottom, and the ADVM is mounted on the right streambank. The ADVM emits acoustic pulses along two beams which are angled to the primary flow direction and compute with-stream and cross-stream velocity components. The installer of the ADVM needs to identify how much of the stream can be measured, called the measurement volume, by selecting a cell begin and cell end. Most ADVMs allow the user to measure velocity in a relatively large measurement volume, called the range-averaged measurement volume, in addition to velocities in individual sections or "cells" within the larger volume. The distances to the cell begin, cell end, and the individual cells are measured perpendicular to the front of the ADVM. Important reasons to measure both the range-averaged measurement volume and individual cells are that:

- #1) you can evaluate whether individual cells, a combination of cells, or the range-averaged volume produce the best relation between index and mean channel velocity, and
- #2) if anything adversely affects the range-averaged volume, such as a log or a drop in signal amplitude, you may still be able to use some of the cells closer to the ADVM to develop the rating

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Selection of an appropriate ADVM measurement volume is governed by 4 things:

- Distribution of velocity within the channel ,
- Obstructions and boundaries ,
- Wake or flow disturbance, and
- Whether there is a sufficient amount of “scatterers” in the water to reflect the acoustic signal at a level that is substantially above the instrument’s noise level

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The first step in selecting the ADVM measurement volume is to perform a thorough reconnaissance of the channel in the vicinity of the ADVM. This means measuring transects with an ADCP upstream, downstream and at the ADVM installation site, looking for velocity distribution, obstructions, and any unusual flow patterns that should be avoided. For example, in the ADCP transect at the top of the slide, you might want to avoid the “slack” water present on the left bank. If the ADVM will serve as an index-velocity meter, the goal should be to measure velocities that are at or above the mean channel velocity. Other considerations might include: visual examination of flow disturbance caused by any structures in the area (such as the bridge and gage structure in the picture at bottom left) and the presence of any debris or other obstructions. The photo at bottom right shows floating and partially submerged logs that have the potential to obstruct the ADVM beams.

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The second step, after an ADVM has been installed at least temporarily, is to perform a beam amplitude check. The beam amplitude check will show the following:

- Whether the ADVM transducers are functioning correctly
- Whether there are any obstructions within the measurable range of the ADVM and
- Whether there are sufficient “scatterers” in the water at that given time to adequately reflect the acoustic signal.

I’ll review a beam check in more detail in a few minutes.

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The next step is to select an initial measurement volume. Keep in mind that the measurement volume that you select now may not be appropriate over a range of seasons and hydrologic conditions, so it’s important to re-evaluate your measurement volume on a regular basis, particularly during the first year of data collection. The SonTek ADVM range-averaged measurement volume is composed of a cell begin and a cell end. The individual cells are composed of a blanking distance (which usually should be set to the same value as cell begin), individual cell size, and the number of cells to measure. The next slides will go into a little more detail on these configuration parameters.

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To set the cell begin and blanking distance, you need to consider 2 things:

- instrument limitations, which dictate a minimum cell begin and blanking distance based on instrument frequency, and
- anything present in the stream that might cause flow disturbance near the beginning of your measurement volume. An example of this might be a bridge pier on which you have mounted your ADVM. An example of such an installation is provided here.

To determine the extent of flow disturbance that should be avoided in your ADVM measurement volume, you can calculate what is called the zone of wake turbulence, according to the following equation:

- b equals c times the square root of d times x.

B is the lateral distance from the centerline of the pier or other object to the edge of the theoretical wake zone; in other words, the minimum blanking or cell begin distance you would want to set to avoid measuring in this zone. D is the width of the pier or object. X is the distance from the ADVM to the upstream face, and c is a factor that represents the shape of the pier or object. Keep in mind this is a guideline that is independent of flow condition – the zone of wake turbulence may change, so be conservative.

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To initially set the cell end, you'll need to look at your beam check. This example is from a Sontek sidelooker. Beam amplitude is plotted on the y axis and distance from the ADVM is plotted on the x axis. The ADVM is at point "0" on the x axis. The blue and red lines represent the amplitudes from each beam that measures velocity. As the beams measure out in the channel away from the ADVM, the amplitudes should at first increase sharply and then continually decrease with increasing range. Deviations between the red and blue beams should be small. You want to look for any spikes, gradual increases, or leveling in the beam amplitudes that indicate that a beam or beam sidelobe is hitting an obstruction such as the streambed, debris, rocks, or the water surface. The green line represents the vertical beam that measures water level above the ADVM. The left-most vertical dashed line represents what is currently set as the cell begin. The right-most vertical dashed line represents what is currently set as the cell end. The gray line shows the theoretical decay curve of the beam amplitudes, which shows the general trend the beam amplitudes should follow for that frequency ADVM and water salinity given ideal conditions such as sufficient scatterers in the water. You want your beam amplitudes to follow the general trend of this line, but some deviation is ok. In general, you do not want abrupt deviations or differences greater than 20 counts between the measured and theoretical curve over the range of the system. The horizontal dashed line at the bottom shows the instrument's noise level, or the level at which the ADVM will be unable to differentiate between the returned acoustic signals and its own base electrical "noise" in that environment.

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Your cell end should be selected so that:

- there are no obstructions indicated by spikes or increases in 1 or more beam amplitudes in the measurement volume,
- beam amplitudes at cell end are 10-20 counts above the noise level
- the distance from a boundary is greater than 10% of the range from the ADVM OR a distance in the following table based on pulse lengths of various ADVM frequencies.
    - For example, for a 1500 kHz ADVM, the cell end should be no closer to a boundary than 10% of the range from the ADVM or 0.25 m, whichever is greater.

Note that these criteria are specific to Sontek ADVMs. Check manufacturer's recommendations when using other ADVMs.

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The ADVM individual cells also need to be configured using the blanking distance, number of cells, and cell size. Note that each ADVM manufacturer has different limits on the maximum number of cells that can be measured. In most cases, the cell size should be divided equally. For example, if your range-averaged measurement volume is 100 m and you wish to measure multicell data in 10 cells, the size of each cell must be 10 m. Technically, you can configure your cells to measure a zone different from your range-averaged measurement volume. Unless you have a specific reason for doing this, we recommend that you configure your cells to measure the same volume as the range-averaged volume.

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Let's step through an example on selecting an ADVM measurement volume.

In this example, a 500kHz SonTek Argonaut sidelooker is used to illustrate the concept. Higher frequency ADVMs are available that have shorter measurement ranges and may be better suited for other streams.

A recon was conducted near the location where the sidelooker was to be mounted on the left bank. Based on the ADCP velocity contour plot shown, you can see that the maximum velocities are fairly well distributed across the middle of the channel. Ideally, you would want to check the flow distribution in the channel over a range of flows.

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The ADVM was installed temporarily at the site to check conditions. The beam amplitudes decrease steadily with increasing range from the ADVM, with no major spikes, leveling off, or increases out to about 65 m. An obstruction was noted at about 65 m, which was likely the channel bottom near the opposite streambank. The beam amplitudes before this obstruction are more than 20 counts above the instrument noise level. You can also see that the beam amplitudes follow the theoretical decay curve fairly well. If the beam check had indicated obstructions throughout the range or other problems, we may have needed to select a different site or measure a smaller portion of the channel. One possible concern in this beam check is that there appears to be a very slight leveling-off at about 50m, which could indicate that a sidelobe on one of the beams is glancing the water surface. You would need to watch this to determine if it is a consistent pattern or if it gets worse as the gage height decreases. In that case, you might want to re-align the ADVM or reduce the sampling volume. For now, let's focus on the major obstruction at 65 m.

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The ADVM at this site was installed on a slide track mount. The end of the slide track was placed on the downstream side of a large rock to protect the ADVM from damage from debris moving down the channel. However, the rock likely causes a flow disturbance near the ADVM that you would want to avoid in your measurement volume. Therefore, the cell begin should start beyond this zone of turbulence.

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Some measurements were made to estimate the size of the turbulence zone induced by the rock. Remember the wake turbulence equation earlier in the podcast. The factor "b" is the distance to the edge of the wake turbulence zone and should be considered the minimum cell begin and blanking distance. Since the rock was round, the shape factor was estimated at 0.62. The rock was about 2 m wide, and the distance from the ADVM to the upstream face of the rock was about 2.2 m. Plugging these numbers into the equation, the factor "b" is then 1.3 m. In this case, we rounded up to 2 m to be conservative, considering the size of the turbulence zone may change with different flows.

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Based on the beam check, we noted an obstruction at about 65 m. For a 500kHz Sontek, you should reduce the cell end away from the obstruction at a distance that is the greater of 10% times the range to the obstruction or 1.0 m. In this case 10% of the range is 6.5 m so that is the larger criterion. So, the cell end would be 65 m minus 6.5m or 58.5 m. In this case, we rounded down to 58 m to be conservative and to have a whole number for the range-averaged volume.   You will need to perform a beam check at every site visit to be sure that beam amplitudes within the measurement volume do not become "contaminated" by a new obstruction or a decreased water level. You must also be sure that the beam amplitudes are no less than 10 - 20 counts above the noise level at the cell end. According to the beam check, the beam amplitudes were about 90 counts above the noise level at 58 m, well above the criterion. However, remember that we need to be sure to check this over seasons and a range of hydrologic conditions, as the amount of "scatterers" in the water can vary significantly.

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So, to review what was selected so far….. the cell begin and blanking distance were set to 2 m to avoid the flow disturbance zone induced by the rock. 58 m was selected as the cell end. Therefore, the measurement volume is 58 minus 2, or 56 meters. Do you think this measurement volume is likely to be a good "index" of the mean channel velocity? Looking at the ADCP contour plot, it appears that we are measuring in a zone at or above the mean channel velocity, so this is good. Again, it will be helpful to evaluate the velocity distribution over a range of flows to ensure we are always measuring a good index zone.

Since this is a Sontek Sidelooker, we can choose to measure velocities in up to 10 individual cells in addition to the range-averaged velocity. We decided to measure all 10 cells and divide them up equally within the range-averaged measurement volume. So, with a 56 m measurement volume and 10 cells, each cell will be 5.6 m long.

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Here is an overlay of the selected measurement volume on the ADCP velocity contour plot. The ADVM was mounted in about this location on the left bank. Cell begin is at 2 m, and the range-averaged measurement volume and 10 individual cells extend through most of the channel and end at 58 m.

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This concludes our USGS HAWG podcast on selecting ADVM measurement volumes. If you'd like to learn more, please visit hydroacoustics.usgs.gov. Thank you.