A Comparison of the Sediment Flux in the Channel and the Shoals of the Estuarine Maximum Region of the Chesapeake Bay

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Abstract

The purpose of this research project was to compare sediment flux in the channel and the shoals of the Maryland Esturarine Turbidity Maximum Region of the Chesapeake Bay and to determine whether the sediment flux is greater in the channel or the shoals. The research is based on the data collected by an Acoustic Doppler Current Profiler (ADCP) in May 2001 near Chestertown, Maryland.

In order to conduct this research project, first the raw backscatter data collected from specific stations had to be averaged. Then the average backscatter measurements from these stations were correlated to physical measurements of total suspended sediment. From this data, a regression line was formed. In this research project, the equation for the regression line was found to be: $f(x) = 0.0963x - 3.6301$, where $f(x)$ is the log10 of the suspended sediment concentration in milligrams per liter and $x$ is the ADCP backscatter intensity in decibels.

Using this regression line, the raw backscatter data collected from additional transects was converted into concentration measurements. Then a MatLab computer program graphed the velocity, concentration and sediment flux of the transects. By studying these graphs, the channel was determined to be separate from the shoals at a depth of about six meters. The total depth integrated sediment flux was totaled for each transect, and the percentage of the total flux occurring in each region was found for each transect. These percentages were averaged for all the transects.

The analysis of the transect data showed that 58.8 percent of the sediment flux occurs in the channel and 41.1 percent occurs in the shoals. This was determined with a 5.0 percent margin of error at 95% confidence.

This data supports the previously held belief that sediment flux is greater in the channel than in the shoals. The significance of these results, however, lies in the large percentage of sediment flux occurring in the shoals. In traditional studies of sediment flux, the role of the shoals has been overlooked. This research, however, shows that it is no longer sufficient to consider just the channel when researching sediment flux, because a significant fraction of the sediment flux in an ETM region occurs in the shoals.
Introduction

An estuary is the “region where a river meets the inlet of the sea.” (The Open University, p.116) An estuary can be divided into three regions: the marine or lower estuary, the middle estuary and the fluvial or upper estuary. The marine estuary is the region in connection with the open sea. The middle estuary is the area in which the freshwater and salt water are “subject to mixing,” and the fluvial estuary is the region in which freshwater is predominant, but still influenced by the tidal movement of the sea. (The Open University p.116)

Estuaries are classified by tidal ranges into three main types: salt wedge, partially mixed, and well-mixed. A partially mixed estuary occurs when a river empties into a sea with a “moderate tidal range.” In a partially mixed estuary, the whole water column moves with the tides. As a result, the moving water creates friction on the bed of the estuary, and this friction creates turbulence in the water column. This turbulence contributes to even more effective mixing of the freshwater and saltwater throughout the water column. (The Open University p.119)

The saltwater moves landward through the estuary due to the mixing by tides and the tendency of the heavier seawater to flow under fresher river water. The freshwater is moving seaward, in the rivers flowing to the sea. At the point where the pure freshwater and slightly salty water meet, there is no net movement of water. This point is known as the null point. The null point is also the point at which the saltwater runs into the bed of the estuary and stops flowing landwards. (The Open University p.119)
The null point is important to the study of sediments because it is the location where sediment transport ceases. The flow of the water toward the sea is strong enough to transport sediments as far as the null point. (The Open University p.124) Although there is no transport of sediment at the null point, there are turbulent water currents formed by the mixing and combining of the freshwater and saltwater. This turbulence contributes to the formation of an Estuarine Turbidity Maximum. (The Open University p. 124)

An Estuary Turbidity Maximum (ETM) is a special feature of partially mixed estuaries, which occurs at the null point of the estuary. The ETM is a region of an estuary in which the concentration of suspended sediment is very high, around “10 to 100 times higher than the concentrations” found on either side of the ETM. In an ETM region, there are tremendous amounts of suspended sediment even though strong river currents wash sediment seaward. (Nichols and Biggs, 1985) Such a region is found in the upper Chesapeake Bay (Figure 1)

The Chesapeake Bay is a partially mixed, “microtidal estuary, with a tidal range of 0.2-0.9 m.” The Bay consists of a large channel approximately 270 km long, with several branching tributaries and many smaller ones. The main tributary of the Chesapeake Bay is the Susquehanna River, “which drains an annual average of 1098 m$^3$/s of water and 2.5 megatons of sediment.” (Nichols and Biggs, 1985)

Figure 1 A generalized map of the Chesapeake Bay, ETM region is shaded. (Houde et al. 2000)
Research conducted in the physical aspect of the marine sciences involves many instruments that measure temperature, salinity, depth, velocity, grain size distribution and concentration of suspended sediments. The Acoustic Doppler Current Profiler (ADCP) is one of these instruments. The ADCP uses reflected sound waves to measure the velocity and concentration of sediments throughout the entire water column (Figure 2). It measures in 0.25m (0.8 ft) bins from just below the instrument, which is mounted on the vessel. “The ADCP transmits short acoustic pulses along narrow beams at a fixed frequency…It receives and processes the echoes from changes in the frequency. Using the Doppler Effect the ADCP can calculate the velocity of the sediments along each beam.” The ADCP then averages the velocities along each beam in order to obtain the velocity in x, y, and z directions.

A second measurement of the ADCP is the backscatter intensity for the beams. The backscatter intensity corresponds to the Echo Level received. This backscatter intensity can be used to calculate the concentration of suspended sediment in the water column. (Reichel and Nachtnebel yr. 1993)

Figure 2 ADCP Standard Beam Geometry throughout water column. (Reichel and Nachtnebel, 1993)
**Purpose**

The purpose of this research project is to use data collected by an ADCP in May 2001 to determine whether sediment flux is greater in the channel or the shoals of the ETM region of the Chesapeake Bay.

In order to conduct this research I will be addressing the following questions:

- Can the ADCP backscatter measurements be correlated to the measurements of suspended sediment concentration taken physically by VIMS personnel?
- Can computer programs such as MatLab help calculate the sediment flux?
- Is there a certain depth at which the channel and the shoals become distinct?
- Does the velocity of the concentration have a greater impact on the average sediment flux?

**Materials and Methods**

The data used in this investigation were gathered by the ADCP in May 2001. The two sets of data that the ADCP collects are station data and transect data. Station data is data collected from the same location over an extended amount of time, whereas transect data is collected while constantly changing location. At certain determined stations (Figure 3), the ADCP spends a period of time, about ten minutes, over a single location, giving backscatter and velocity measurements. The transect readings, however, are taken by the ADCP while the vessel is moving. The beam of the ADCP is never in the same location during transects. Transects cover much larger distances, and are able to show the depth of the sea floor, in addition to the velocity and backscatter measurements.
First, the raw station backscatter readings were converted from the ADCP into ASCII text files from binary files. While converting the data into ASCII files, the computer averaged the backscatter readings of each beam over the whole time period. Averaging the results from the ADCP over a period of time ensures that the backscatter measurements will be more reliable. Then, the data from the ASCII files was used to create a spreadsheet in EXCEL. In EXCEL, the readings from the four beams were averaged at each depth throughout the water column. Another spreadsheet in EXCEL was created containing the station number, the depth, backscatter measurements at certain depths, and the concentration of suspended sediment in the water at the same depth. The total suspended sediment concentration was determined by filtering and weighing water samples taken in the field. These water samples were taken and processed by VIMS personnel.

Using the information on this spreadsheet, and MatLab Program 1, a regression curve correlating the beam intensity of the ADCP to the concentration of total suspended sediments was formed. Then the coefficients and constants of this regression curve were placed into MatLab Program 3 (see Appendix C).

Next, the transect data were converted into ASCII files. By using both MatLab Program 2 (see Appendix B) followed by MatLab Program 3, the computer graphed the velocity, backscatter, concentration, percent good, sediment flux, and depth integrated flux (Figure 6).

Using the numerical transect data provided by MatLab Program 3 (see Appendix D) a depth was decided upon at which the shoals could be considered distinct from the channel. The transects were examined; only the complete transects sampling large
amounts of both channel and shoal measurements could be analyzed. The data for the shoal flux was separated from the data for the channel flux. The sediment flux was totaled for each transect by adding the flux in the shoals and channel, and the percentage of the flux occurring in each region was calculated. The percentage of sediment flux occurring in each region was averaged over all the transects. Lastly, a confidence test was done to determine the reliability of the results.

Figure 3 The ETM region of the Chesapeake Bay. The 22 stations from which data is collected are plotted.
Data Analysis

### ADCP Beam Intensity and Suspended Sediment Concentration at Certain Depths

<table>
<thead>
<tr>
<th>Station</th>
<th>Top Depth (m)</th>
<th>Top Int (db)</th>
<th>Top TSS (mg/L)</th>
<th>Mid Depth</th>
<th>Mid Int (db)</th>
<th>Mid TSS (mg/L)</th>
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<td>62.875</td>
<td>11.20</td>
<td>21.40</td>
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</table>

**Figure 4** This data table correlates the ADCP Beam Intensity to the T.S.S. Concentration for MatLab Program.
When given ADCP beam intensities and concentration of total suspended sediment, as shown in the Figure 4, MatLab Program 1 (see Appendix A) will create and graph a regression line (Figure 5). The regression curve which best fits the data is a linear function in which x is the backscatter intensity in decibles(dB) and f(x) is the log_{10} of the concentration of suspended sediment in milligrams per liter (mg/L). The equation for the regression line is: \( f(x) = 0.0963x - 3.6301 \).

The Correlation Between ADCP Backscatter and TSS Concentration

Figure 5 This is the regression line correlating ADCP Backscatter to T.S.S. Concentration
Figure 6
MatLab Program 3 gives graphs depicting the velocity, backscatter, percent good, sediment concentration, sediment flux and depth integrated sediment flux for each transect. Figure 6 is a good example of the separation between the channel and the shoals. Having analyzed graphs from over 30 transects, the depth at which the channel and shoals were classified as distinct is 6 meters, as shown in the velocity graph.

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**Figure 6** An example of the graphs obtained by MatLab Program 3. This represents only one transect; the others are stored electronically.
All measurements taken at a depth above 6 meters were classified as shoal measurements, and all those taken at a depth below 6 meters were classified as channel measurements. After averaging the percentage of the total sediment flux occurring in each region, the data showed that 58.8 percent of the total sediment flux in the Chesapeake Bay occurs in the channel, and 41.1 percent of the total sediment flux occurs in the shoals (Figure 7). This data supports the previously held belief that sediment flux is greater in the channel than the shoals.

<table>
<thead>
<tr>
<th>Percentage of Flux in Channel and Shoals</th>
</tr>
</thead>
<tbody>
<tr>
<td>% Flux in Shoals</td>
</tr>
<tr>
<td>------------------</td>
</tr>
<tr>
<td>26.48721894</td>
</tr>
<tr>
<td>48.32806292</td>
</tr>
<tr>
<td>43.70844053</td>
</tr>
<tr>
<td>50.12658199</td>
</tr>
<tr>
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</tr>
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<td>53.28687881</td>
</tr>
<tr>
<td>38.15369102</td>
</tr>
<tr>
<td>41.94929223</td>
</tr>
</tbody>
</table>

Average % Flux in Shoal: 41.1742084
Average % Flux in Channel: 58.8257916

Margin of Error at 95% Confidence: 5.08850968

Figure 7 Data table showing the percentage of sediment flux in each region
Discussion

These results support the previously held belief that sediment flux is greater in the channel than in the shoals. The greater flux can be attributed to the greater water velocity in the channel. Although the channel velocity is greater, the concentration of suspended sediments is greater in the shoals. The higher concentration of suspended sediment in the shoals is due to the mixing of the freshwater and saltwater, which is caused by wind and wave energy. In the channel, however, there is stratification between the saltwater and the freshwater. This stratification, which is caused by differences in the densities of the two waters, prevents mixing.

Although the majority of the flux occurs in the channel, there is still a large percentage of sediment flux in the shoals. The significance of this research, in fact, lies in the sediment flux of the shoals. In traditional studies of sediment flux, the role of the shoals has been underestimated. This research project, however, shows that it is no longer sufficient to consider just the channel when researching sediment flux; a significant fraction (Figure 8) of the sediment flux in the Chesapeake ETM region occurs in the shoals.

Figure 8 A significant fraction of the total flux occurs in the shoals
Conclusion

The purpose of this research project was to compare sediment flux in the channel and the shoals of the Estuarine Turbidity Maximum Region of the Chesapeake Bay and to determine in which region the sediment flux is greater. The data, which was collected by an ADCP, shows that 58.8 percent of the total sediment flux occurs in the channel and 41.1 percent occurs in the shoals. There are, however, many sources of error with this project. There are sources of error with the instrument itself. It is not possible to obtain reliable results from the very top and very bottom of the water column. As a result those values are estimated based on observations that are near but not at the surface or bottom. There are also times during which the instrument does not obtain good echo readings. The data is not reliable when the percent good pings are much below 100 percent, and this must be taken into consideration. Also, the calibration of the ADCP backscatter data is a regression line; it is only an estimate of the suspended sediment concentration. Lastly, the experimenter chose the depth at which to separate the channel from the shoals. This distinction could alter the final results somewhat.

If this research project were to be conducted in the future, more data should be collected containing both transects and shoals. To expand on this project, a researcher could look at different aspects of the ETM, such as water flux as compared to sediment flux. The sediment flux of the ETM region could be studied over a period of time. The data collected in the Chesapeake ETM could also be compared to studies conducted in different ETM regions.
Acknowledgements

The past five weeks have been an amazing experience! I am very grateful to have had the opportunity to work at the Virginia Institute of Marine Science. There are certain people that I would like to thank now for all that they have done to make my time here both enjoyable and rewarding. Thank you to my two amazing mentors, Grace Battisto and Carl Friedrichs. Day after day, you have volunteered your time, attention and advice. Without you, and your wealth of knowledge and experience, I would have been hopelessly lost. I would also like to thank Susan Haynes in the Marine Advisory Center at VIMS for helping to organize our time here, and for always being available if I had a question or concern. Thank you Cheryl Simmers and Amy Ford with the Governor’s School Program for driving us to VIMS everyday, and ensuring that our time at CNU was unforgettable! Last, but not least, thank you Lynsey Ellis and Carrie Snyder for helping me, and sharing with me many of your lessons and your laughs!
Bibliography


Appendix A

MatLab Program 1

In this program the first column is the station. The second column is the depth (m). The third column is
the ADCP reading for averaged beam intensity (db), and the last column is the amount of total suspended
sediment (mg/L).

```
d=[...
    471  7.00  72.075  08.70
    472  3.50  74.375  21.20
    473  2.50  73.975  34.10
    474  6.00  65.250  20.20
    475  1.50  72.950  33.80
    476  3.50  75.200  37.70
    477  1.80  71.350  16.50
    478  2.50  75.125  41.50
    479  2.50  65.250  37.40
    515  3.90  65.875  12.30
    516  2.40  64.475  13.20
    473  4.80  79.175  53.20
    474  13.0  79.975  129.2
    475  3.24  88.775  168.5
    477  3.61  78.350  26.50
    478  5.00  81.375  56.50
    479  4.50  74.775  41.00
    511  6.70  82.600  41.50
    512  1.80  69.975  11.20
    513  3.50  65.325  18.30
    514  4.00  64.775  18.00
    515  7.50  80.375  126.0
    516  4.20  65.325  15.30
    517  8.80  74.775  46.30
    518  8.60  72.875  66.40
    520  3.40  70.400  15.00
    521  5.60  69.675  21.40
    522  5.00  62.875  11.20];
```

```
station=d(:,1); depth=d(:,2); adcp=d(:,3); tss=d(:,4);
tssadcp=tss(depth>0); adcp=adcp(depth>0);
a=polyfit(adcp,log(tssadcp),1)
at=[55,90]; ct=exp(a(2))*exp(a(1)*at);
semilogy(adcp,tssadcp,'o',at,ct);
ylabel('TSS (mg/liter)');
xlabel('ADCP backscatter (dB)');
```
Appendix B

MatLab Program 2

This program is used only to define values that will be necessary for MatLab Program 3.

%function readtx(fname); %,mav);
%function readtx(fname,mav);
% where fname is adcp ascii 't-file' name w/0 extension (.000 will be added)
% and mav is number of raw ensembles to block average
% Built from:
%(function merge(irun) where irun is run number (1:23) in Eliz R/Craney study)
% to read data from RDI's TRANSECT ascii out.
fid=fopen([fname '.000']); % adcp file
%eval(['load ..\gpslog\gps' int2str(irun)]); % nav file: gpsK.mat
%tlim=max(nt);
line=fgetl(fid); line=fgetl(fid); % 2 "notes" lines
line=fgetl(fid), % line C
n=0;
first=1;
while 1
 line=fgetl(fid); disp(line)
 if ~isstr(line) break, end % jump out of loop on eof
 n=n+1;
 [xx, count]=sscanf(line, '%f'); if count~=13, error('bad count'), end
%   size(xx), pause
 line1(n,:)=xx'; % for now, just keep all of line 1, incl PRHT,
% etc. for save
 yr=xx(1); mo=xx(2); day=xx(3); hour=xx(4); min=xx(5); sec=xx(6);
 sec=sec+xx(7)/100; % add hundredths of seconds
%   sec=sec+15; % For these 30-s avg ensembles, add 15 s to
%     start time
 t(n)=hour;
 line=fgetl(fid); %disp(line) %bottom track stuff
 xx=sscanf(line, '%f'); h(n)=mean(xx(9:12)); %xx(9:12)
 ub(n)=xx(1); vb(n)=xx(2); %may want to include individual depths later
 line=fgetl(fid); %disp(line) %elapsed dist, time
 line=fgetl(fid); %disp(line) %nav stuff
 line=fgetl(fid); %disp(line) %discharge stuff
 line=fgetl(fid); %disp(line) %bins, units, ref
 m=sscanf(line, '%d', 1);
 pro=fscanf(fid, '%f', [13,m]); %pro=pro'; %leave it!
 uu(n,:)=pro(4,:); vv(n,:)=pro(5,:); d(n,:)=pro(1,:);
 err(n,:)=pro(7,:); pg(n,:)=pro(12,:);
 i1(n,:)=pro(8,:); i2(n,:)=pro(9,:); i3(n,:)=pro(10,:); i4(n,:)=pro(11,:);
line=fgetl(fid); disp(line)  % apparently, need to "skip" line
%   if t(n)<nt(1), disp('t < min nav time'), n=0, pause, end
if first, n=n-1; first=0; end  %discard first ensemble--time weird
end

t=t(:); h=h(:); ub=ub(:); vb=vb(:);
%lon=interp1(nt, nlon, t); lat=interp1(nt, nlat, t);
%[xsp,ysp]=geo2sp(lon,lat);
% I keep adding more and more to output file!
%outfile=[
    eval(['save ' fname ' t line1 ub vb h d uu vv err pg i1 i2 i3 i4'])
fclose(fid);
figure(1), clf
num=length(t); mb=60;
for i=1:num
    subplot(2,1,1)
    plot([uu(i,1:mb)' vv(i,1:mb)'], -d(i,1:mb)')
    axis([-120 120 -16 0])
    subplot(2,1,2)
    plot([i1(i,1:mb)' i2(i,1:mb)' i3(i,1:mb)' i4(i,1:mb)'], -d(i,1:mb)')
    axis([40 90 -16 0])
    pause
end
Appendix C

MatLab Program 3

This is the MatLab program in which the regression curve found in MatLab Program 1 is placed. The highlighted line is the line containing the regression line found in MatLab Program 1.

```matlab
%clear; fname='MYO1039T'; readtx3
usize=size(uu);
Nprofiles=usize(1);
Nbins=usize(2);
z=(1.05-.25)+.25*(1:Nbins);
zmax=1.05:0.25:max(h);
utot=0; vtot=0; n=0;
for j=1:Nprofiles
  for k=1:Nbins
    if z(k) > (h(j)-.5) | z(k) < 1.25
      ones_or_NaN(j,k)=NaN; ones_or_zeros(j,k)=0;
    else
      ones_or_NaN(j,k)=1; ones_or_zeros(j,k)=1;
      utot=utot+uu(j,k); vtot=vtot+vv(j,k);
    end
  end
end
percentgood=pg.*ones_or_NaN;
percentgood1=pg.*ones_or_zeros;
nonzero_bins=sum(ones_or_zeros');
deepbin=1.3+(nonzero_bins-1)*.25;
imean=(i1+i2+i3+i4)/4;
speed=sqrt(uu.^2+vv.^2);
direction=atan2(vv,uu);
rotation=atan2(vvtot,utot);
mag_degrees=90-rotation*180/pi
u_along=ones_or_NaN.*speed.*cos(direction-rotation);
u_across=ones_or_NaN.*speed.*sin(direction-rotation);
u_along1=ones_or_zeros.*speed.*cos(direction-rotation);
u_across1=ones_or_zeros.*speed.*sin(direction-rotation);
backscatter=ones_or_NaN.*imean;
backscatter1=ones_or_zeros.*imean;
a=[0.0963  -3.6301]; % ADCP calibration from May ETM Data
concentration=exp(a(2))*exp(a(1)*backscatter);
concentration1=exp(a(2))*exp(a(1)*backscatter1);
flux=concentration.*u_along/100;
flux1=ones_or_zeros.*concentration1.*u_along1/100;
for j=1:Nprofiles
  depth_integ_flux(j)=sum(flux1(j,:))+(1.3-.25/2)/.25*flux1(j,2)
```

...
+(h(j)-deepbin(j)-.25/2)/.25)*flux1(j,nonzero_bins(j)+1);

u_along2(2*j-1,:)=u_along(j,:); u_along2(2*j,:)\text{=}u\text{ along}(j,:);

u_across2(2*j-1,:)=u_across(j,:); u_across2(2*j,:)\text{=}u\text{ across}(j,:);

backscatter2(2*j-1,:)\text{=}backscatter(j,:); backscatter2(2*j,:)\text{=}backscatter(j,:);

concentration2(2*j-1,:)\text{=}concentration(j,:);

concentration2(2*j,:)\text{=}concentration(j,:);

percentgood2(2*j-1,:)\text{=}percentgood(j,:); percentgood2(2*j,:)\text{=}percentgood(j,:);

flux2(2*j-1,:)\text{=}flux(j,:); flux2(2*j,:)\text{=}flux(j,:);

end

logconcentration=real(log10(concentration2));

subplot(321)
pcolor((1:Nprofiles*2)*50,-zmax,u_along2(1:2*Nprofiles,1:length(zmax))');
axis([0,(1+Nprofiles*2)*50,-max(zmax),0]);
shading('interp'); colormap(jet);
caxis; colorbar
%xlabel('distance (m)'); ylabel('depth (m)');
title('along-channel velocity (cm/s)')
hold on; plot((1.5:2:2*Nprofiles)*50,-h); hold off;

subplot(322)
pcolor((1:Nprofiles*2)*50,-zmax,backscatter2(1:Nprofiles*2,1:length(zmax))');
axis([0,(1+Nprofiles*2)*50,-max(zmax),0]);
shading('interp'); colormap(jet);
caxis; colorbar;
%xlabel('distance (m)'); ylabel('depth (m)');
title('backscatter (dB)')
hold on; plot((1.5:2:2*Nprofiles)*50,-h); hold off;

subplot(323)
pcolor((1:Nprofiles*2)*50,-zmax,percentgood2(1:Nprofiles*2,1:length(zmax))');
axis([0,(1+Nprofiles*2)*50,-max(zmax),0]);
shading('interp'); colormap(jet);
caxis; colorbar
%xlabel('distance (m)'); ylabel('depth (m)');
title('percent good pings')
hold on; plot((1.5:2:2*Nprofiles)*50,-h); hold off;

subplot(324)
pcolor((1:Nprofiles*2)*50,-zmax,logconcentration(1:Nprofiles*2,1:length(zmax))');
axis([0,(1+Nprofiles*2)*50,-max(zmax),0]);
shading('interp'); colormap(jet);
caxis; colorbar
%xlabel('distance (m)'); ylabel('depth (m)');
title('log10 of sediment concentration (mg/liter)')
hold on; plot((1.5:2:2*Nprofiles)*50,-h); hold off;
subplot(325)
pcolor((1:Nprofiles*2)*50,-zmax,flux2(1:Nprofiles*2,1:length(zmax))); axis([0,(1+Nprofiles*2)*50,-max(zmax),0]); shading('interp'); colormap(jet);
caxis([-max(max(-flux1)) .5*max(max(flux1))]); colorbar;
xlabel('distance (m)'); ylabel('depth (m)');
title('sediment flux (kg/m^2/s)')
hold on; plot((1.5:2:2*Nprofiles)*50,-h); hold off;

subplot(326)
scaled_depth=h/max(h)*max(depth_integ_flux);
depth_averaged_pg=sum(percentgood1')./(nonzero_bins);
scaled_pg=depth_averaged_pg/100*max(depth_integ_flux);
plot((1.5:2:2*Nprofiles)*50,depth_integ_flux,(1.5:2:2*Nprofiles)*50,scaled_depth)
axis([0,(1+Nprofiles*2)*50,0,1.1*max(depth_integ_flux)));
xlabel('distance (m)'); ylabel('kg/m/s')
title('depth-integrated flux (also avg % good)')
Appendix D

MatLab provides the numerical data for each of the graphs provided in MatLab Program 3. This data table gives the depths and the corresponding depth integrated flux of the transect depicted in Figure 4.

### Depths and Depth-Integrated Flux for Figure 4

<table>
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<th>Depths Classified as Shoals</th>
<th>Depth Integrated Flux for Shoals</th>
<th>Depths Classified as Channel</th>
<th>Depth Integrated Flux for Channel</th>
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