CENTERLINE AND CROSS-SECTIONAL WILLAMETTE RIVER BATHYMETRIC DATA COLLECTED IN SUPPORT OF MODEL CONSTRUCTION FOR WILLAMETTE BASIN TEMPERATURE TMDLS

Summary

A U.S. Geological Survey (USGS) field crew collected centerline and cross-sectional bathymetric data in selected reaches of the Willamette and Santiam Rivers. Depth data were collected using an RD Instruments Broadband Acoustic Doppler Current Profiler (ADCP) for the cross-sections and a Lowrance LCX 15-MT Echo Sounder for the centerline data. Location data were collected using differential global positioning system (GPS) signals.

The collected centerline and cross-sectional data consist of UTM coordinates for latitude and longitude and depth readings at each location. Depths from the centerline data were converted to river-bottom elevations using elevation datums from a set of reference locations adjacent to the river. Reference elevations were derived from survey-grade GPS measurements, stage measurements at established USGS streamflow gages, or extrapolated from adjoining datasets, taking into consideration the dates that each centerline dataset was collected. Having no other information, water surface profiles between reference datum locations were assumed to be linear.

Cross-sectional data were derived from the beams of the ADCP unit in conjunction with the differential GPS signal. Because the ADCP has 4 beams, each pass over the cross-section creates four datasets. Up to six passes were made for each cross section in the process of collecting streamflow data; therefore, up to 24 individual cross sections may have been collected at each cross-sectional measurement location. Cross-sectional data were collected roughly every mile along the river. River-bottom elevations for the cross-sectional data were derived by forcing a match to the river-bottom elevation from the point of intersection of each cross section to the centerline data.

Streamflow and above-water bank angle measurements also were measured at each cross-sectional location. Streamflow data were derived from the ADCP; bank angles were derived from a set of simple measurements with a laser rangefinder and an inclinometer.

Data Package

All bathymetric data in the electronic files are in X Y Z format, delimited by tabs, with a short header that explains the units. X (easting) and Y (northing) horizontal data are in UTM coordinates (meters, NAD27, UTM Zone 10). Bed elevation data (Z) are in meters above sea level (NAVD88). The bathymetric data are limited to the submerged parts of the channel at the time of measurement.

Centerline datafiles were named according to their approximate river mile locations. For example, the centerline file for the Willamette River containing data from river mile 42 to 28 was named **rm042_028_btm_elev.txt**.

Cross-sectional data files were named according to their approximate river mile location, the pass index (a-e for passes 1-6), and the beam number (1-4). For example, the cross-

sectional data from beam 3 of the ADCP during the second pass across the river at river mile 42 was named **rm042b.txt.3**.

Methods

The centerline data had to be referenced to true elevations. Elevations at a set of reference locations were established using survey-grade GPS instruments (Ashtech Z-XII and Trimble 4000 Ssi). Data at each location were recorded for 4 hours @ 30-sec epochs. Data were processed via the NGS OPUS program using precise orbits (the 3 nearest continuously running GPS stations were used to locate each point). The horizontal reference frame was NAD83 (CORS96). The vertical reference frame was NAVD88 (ortho hgt refers to elevation). Table 1 shows the GPS locations for the 12 reference stations with their associated root mean square (RMS) error in the horizontal and vertical directions. All horizontal location data were later changed to NAD27 UTM coordinates. Data for the GPS reference locations were collected on March 20, 21, and 28, 2002. Reference locations were selected for their proximity to the reaches of interest as well as a clear view to the sky and the satellite data.

Table 1. Locations and elevations of surveyed GPS reference points (RM = river mile)

SITE NAME	NORTH LATITUDE NAD83	WEST LONGITUDE NAD83	LAT RMS ERROR (m)	W LONG RMS ERROR (m)	ORTHO HGT [Geoid99 NAVD88] (m)	ORTHO HGT RMS ERROR (m)
Rogers Bend	44 07 51.13989	123 07 01.87122	0.009	0.004	113.240	0.07
Marshall Island Access	44 11 16.74474	123 08 47.38366	0.006	0.006	103.348	0.025
Harrisburg Park	44 16 19.60078	123 10 26.52218	0.011	0.007	92.090	0.039
Irish Bend Campground	44 21 46.81042	123 13 13.02490	0.013	0.009	80.191	0.032
Willamette @ RM 114	44 40 34.86883	123 07 02.95461	0.035	0.047	56.900	0.078
Buena Vista Park	44 46 06.97308	123 08 51.15330	0.013	0.006	50.510	0.071
Independence River Access	44 51 11.52628	123 10 54.80957	0.021	0.009	43.889	0.087
Lloyd Strange Fishing Hole	44 53 06.45695	123 08 28.87773	0.035	0.018	41.723	0.046
Spongs Landing	45 01 05.91939	123 04 35.08634	0.019	0.019	33.287	0.044
Wheatland Crossing	45 05 29.33253	123 02 44.35861	0.021	0.011	30.400	0.042
French Prairie	45 16 48.61377	122 48 52.14537	0.017	0.017	30.298	0.035
Bernert Landing	45 20 19.06797	122 38 57.25817	0.009	0.016	18.887	0.029

The difference in elevation between these GPS reference locations and stakes placed near the river bank were determined using standard surveying techniques. These stakes were then used as reference points to determine the river stage at the time of measurement of the centerline bathymetric data. Stage was measured at these stakes with a tape measure from the top of the stake. True elevations of the river water surface for the day of centerline data collection, then, was derived from the stage and GPS reference location data. For some reaches, these GPS reference elevation data were augmented using stage and reference elevation data from established USGS or National Weather Service streamflow gages.

The reference elevations for the stakes, and the datums for the two reference gages, are listed in table 2. Table 3 lists the stage measurements used at various stake locations. Dates for the collection of each centerline bathymetric reach are shown in table 4.

Table 2. Elevations of the reference locations (RM = river mile)

SITE NAME	Approximate River Mile	Station Type	Stake or Datum Elevation (m)
Rogers Bend	174.2	surveyed stake	111.839
Marshall Island Access	168.75	surveyed stake	103.166
Harrisburg Park	160.8	surveyed stake	92.090
Irish Bend Campground	150.9	surveyed stake	79.134
Corvallis gage (National Weather Service)	131.45	gage	58.506
Albany gage (U.S. Geological Survey)	119.31	gage	50.957
Willamette @ RM 114	114.1	surveyed stake	54.457
Buena Vista Park	106.5	surveyed stake	50.516
Independence River Access	95.5	surveyed stake	43.974
Lloyd Strange Fishing Hole	91.6	surveyed stake	41.723
Spongs Landing	77.5	surveyed stake	33.661
Wheatland Crossing	71.9	surveyed stake	29.905
French Prairie	41.0	surveyed stake	20.066
Bernert Landing	28.4	surveyed stake	18.647

Table 3. River stage data at selected stake locations.

Water to stake (feet)	Date	River Mile	Water to stake (feet)	Date	River Mile
-2.00	3/6/2002	28.40	-1.40	3/19/2002	174.20
-2.60	3/7/2002	33.80	-1.80	3/20/2002	146.00
-1.70	3/8/2002	41.00	-0.60	3/20/2002	150.90
-2.10	3/14/2002	114.10	-6.58	3/20/2002	160.80
-1.70	3/14/2002	102.00	-1.00	3/21/2002	141.00
-1.00	3/14/2002	106.50	-1.90	3/21/2002	146.00
-0.55	3/15/2002	91.60	-2.42	3/22/2002	119.60
-1.49	3/15/2002	95.50	-1.70	3/22/2002	127.20
-1.90	3/15/2002	96.80	-1.12	3/25/2002	71.90
-2.70	3/15/2002	102.00	-1.20	3/25/2002	77.50
-1.40	3/18/2002	168.00	-6.10	3/25/2002	114.10
-2.60	3/18/2002	168.75	-1.36	3/25/2002	120.00
-1.90	3/18/2002	172.00	-2.35	3/26/2002	40.00
-6.51	3/19/2002	160.80	-2.35	3/26/2002	41.00
-2.00	3/19/2002	172.00	-5.55	3/26/2002	43.00

Table 4. Dates for the collection of centerline bathymetric data.

River	Reach (River Mile)	Date Recorded
Willamette	30-28	3/6/2002
Willamette	34-30	3/7/2002
Willamette	39-34	3/8/2002
Willamette	42-39	3/8/2002
Willamette	115-106	3/14/2002
Willamette	89-102	3/15/2002
Willamette	106-102	3/15/2002
Willamette	175-169	3/19/2002
Willamette	162-169	3/19/2002
Willamette	162-156	3/20/2002
Willamette	146-156	3/20/2002
Willamette	141-146	3/21/2002
Willamette	127-142	3/21/2002
Willamette	127-119	3/22/2002
Willamette	77-72	3/25/2002
Willamette	120-114	3/25/2002
Willamette	50-41	3/26/2002
Santiam	6-0	3/30/2002

The centerline bathymetric data consist of horizontal location information and river depth. Bed elevations were derived for these centerline bathymetric data by subtracting the river depth from the elevation of the water surface. Although the reference datums provide high-quality data for the river's water surface elevation at each of the reference locations, the elevation of the river's water surface is not known at all locations. For this work, the river's water surface was assumed to decrease linearly between the reference locations. The water surface elevation at any point was calculated via linear interpolation between and near reference locations, according to the following equation:

$$WATER\ SURFACE\ ELEVATION = \left(\frac{(Y_2 - Y_1)}{X_2 - X_1}\right)(X - X_1) + Y_1 \qquad (1)$$

where the Y values are the water surface elevations at two reference points, X is the longitudinal distance along the reach of interest, and X_1 and X_2 are longitudinal distances for the two reference points.

Computations for Centerline and Cross-Sectional Data

River miles 28 to 42

Four centerline datasets were combined (see table 4). Centerline file rm030_028.txt was recorded on 3/6/02. Centerline file rm034_030.txt was recorded on 3/7/02. Centerline files rm039_034.txt and rm042_039.txt were recorded on 3/8/02. Stage corrections were made for files rm030_028.txt and rm034_030.txt to account for the difference in stage on these dates. Water surface tape-downs were done on 3/6/02 for river mile 28.4 and on 3/8/02 for river mile 41 (table 3). GPS reference points were established at Bernert

Landing and French Prairie (table 1) and surveyed down to stakes placed near the river's edge (table 2) where additional measurements characterized the water surface elevation on the day of data collection (table 3). Because the water surface tape downs were not all done on the same day, adjustments to the water surface of rm030_028.txt and rm034_030.txt were made using the recorded gage height from the USGS gage at Oregon City above Willamette Falls (14207740). This allowed all of the centerline data in this reach to be referenced to a water surface elevation for 3/8/02.

The data were organized and put into a spreadsheet that used equation 1 to calculate a linearly decreasing water-surface elevation. The water surface elevation was then added to the depth values from the collected data to establish the elevation of the river bottom.

The cross-sectional data that fell between river miles 28 and 42 were then referenced to the centerline elevations using a Perl script (appendix A). This script forced the river-bottom elevations of the cross-sectional and centerline data to match where they intersect by adjusting the cross-sectional depth data, thus converting the depth data to bed elevation data.

River miles 41 to 50

Centerline file rm050_041.txt was recorded on 3/26/02. Using the overlap from this reach and the one from river miles 28-42 (above), the water surface was extrapolated from the previous reach to cover this one, with an adjustment for the difference in the date of data collection based on the measured gage height difference on those dates from the USGS gage on the Willamette River at Newberg (14197900).

The data were organized and put into a spreadsheet that used equation 1 to calculate a linearly decreasing water-surface elevation. The water surface elevation was then added to the depth values from the collected data to establish the elevation of the river bottom.

The cross-sectional data that fell between river miles 50 and 41 were then adjusted to match the bed elevations in the centerline data using a Perl script, as above (appendix A).

River miles 72 to 77

Centerline file rm077_72.txt was recorded on 3/25/02. Water surface tape-downs were collected on 3/25/02 at river miles 77.5 and 71.9 (table 3). GPS points were established at Spongs Landing and Wheatland Crossing (table 1) and surveyed down to the water surface tape-down stake locations (table 2) to establish the true elevation of the water surface for the day in question.

The data were organized and put into a spreadsheet that used equation 1 to calculate a linearly decreasing water-surface elevation. The water surface elevation was then added to the depth values from the collected data to establish the elevation of the river bottom.

The cross-sectional data that fell between river miles 77 and 72 were then adjusted to match the bed elevations in the centerline data using a Perl script, as above (appendix A).

River miles 89 to 95

Centerline file rm089_102.txt was recorded on 3/15/02. This dataset was split into two files, and the reach from river miles 95 to 102 was added to the rm106_102.txt file. This

allowed more accurate utilization of the GPS reference locations. Water surface tape-downs were measured on 3/15/02 at river miles 95.5 and 91.6 (table 3). GPS points were established at Independence River Access and Lloyd Strange Fishing Hole (table 1) and surveyed down to the water surface tape-down stake locations (table 2) to establish the true elevation of the water surface for the day in question.

The data were organized and put into a spreadsheet that used equation 1 to calculate a linearly decreasing water-surface elevation. The water surface elevation was then added to the depth values from the collected data to establish the elevation of the river bottom.

The cross-sectional data that fell between river miles 89 and 95 were then adjusted to match the bed elevations in the centerline data using a Perl script, as above (appendix A).

River miles 95 to 106

Centerline files rm106_102.txt and rm089_102.txt were recorded on 3/15/02. Data from rm089_102.txt for the reach from river mile 95 to 102 were added to rm106_102.txt, which allowed more accurate utilization of the GPS reference points. Water surface tape-downs were measured on 3/14/02 at river mile 106.5 and on 3/15/02 at river mile 95.5 (table 3). GPS points were established at Buena Vista Park and Independence River Access (table 1) and surveyed down to the water surface tape-down stake locations (table 2) to establish the true elevation of the water surface for the day in question. Because the water surface tape downs were not all done on the same day, the water surface elevation for the reference point at river mile 106.5 was adjusted using the difference established by the tape-down at river mile 102 that was measured on both days (table 3).

The data were organized and put into a spreadsheet that used equation 1 to calculate a linearly decreasing water-surface elevation. The water surface elevation was then added to the depth values from the collected data to establish the elevation of the river bottom.

The cross-sectional data that fell between river miles 95 and 106 were then adjusted to match the bed elevations in the centerline data using a Perl script, as above (appendix A).

River miles 106 to 115

Centerline file rm115_106.txt was recorded on 3/14/02. Water surface tape-downs were done on 3/14/02 at river miles 114.1 and 106.5 (table 3). GPS points were established at river mile 114.1 and at Buena Vista Park (table 1) and surveyed down to the water surface tape-down stake locations (table 2) to establish the true elevation of the water surface for the day in question.

The data were organized and put into a spreadsheet that used equation 1 to calculate a linearly decreasing water-surface elevation. The water surface elevation was then added to the depth values from the collected data to establish the elevation of the river bottom.

The cross-sectional data that fell between river miles 106.5 and 114 were then adjusted to match the bed elevations in the centerline data using a Perl script, as above (appendix A).

River miles 114 to 120

Centerline file rm120_114.txt was recorded on 3/25/02. Water surface tape-downs were measured on 3/25/02 at river mile 114.1 (table 3). A GPS point was established at river

mile 114.1 (table 1) and surveyed down to a water surface tape-down stake (table 2) to establish the true elevation of the water surface for the day in question. The river stage and datum for the USGS gaging station at Albany (14174000, river mile 119.31, table 2) were used to establish a second water surface elevation for the day in question.

The data were organized and put into a spreadsheet that used equation 1 to calculate a linearly decreasing water-surface elevation. The water surface elevation was then added to the depth values from the collected data to establish the elevation of the river bottom.

The cross-sectional data that fell between river miles 114 and 120 were then adjusted to match the bed elevations in the centerline data using a Perl script, as above (appendix A).

River miles 119 to 127

Centerline file rm127_119.txt was recorded on 3/22/02. The river stage and datum for the USGS gaging station at Albany (14174000, river mile 119.31, table 2) were used to establish a water surface reference elevation at one end of this reach. The other water surface reference elevation was established at river mile 127.25, using overlapping data from the analysis of data from the next reach upstream (RM 127-146) and adjusting that water surface elevation for changes in stage from 3/21/02 to 3/22/02 using stage data from the Corvallis gage.

The resulting data were organized and put into a spreadsheet that used equation 1 to calculate a linearly decreasing water-surface elevation. The water surface elevation was then added to the depth values from the collected data to establish the elevation of the river bottom.

The cross-sectional data that fell between river miles 119 and 127 were then adjusted to match the bed elevations in the centerline data using a Perl script, as above (appendix A).

River miles 127 to 146

Centerline files rm127_142.txt and rm141_146.txt were combined to form file rm146_127.txt. Both datasets were recorded on 3/21/02. The river stage and datum for the National Weather Service gaging station at Corvallis (river mile 131.45, table 2) were used to establish a water surface reference elevation near one end of this reach. The other water surface reference elevation was established at river mile 146.3, using overlapping data from the analysis of data from the next reach upstream (RM 146-162) and adjusting that water surface elevation for changes in stage from 3/20/02 to 3/21/02 using tape-down measurements from RM 146 (table 3).

The data were organized and put into a spreadsheet that used equation 1 to calculate a linearly decreasing water-surface elevation. The water surface elevation was then added to the depth values from the collected data to establish the elevation of the river bottom.

The cross-sectional data that fell between river miles 127 and 146 were then adjusted to match the bed elevations in the centerline data using a Perl script, as above (appendix A).

River miles 146 to 162

Centerline files rm146_156.txt and rm162_156.txt were combined to form file rm162_146.txt. Both datasets were recorded on 3/20/02. Water surface tape-downs were

measured on 3/20/02 at river mile 150.9 and on a later date at river mile 160.8 (table 3). GPS points were established at Irish Bend Campground and Harrisburg Park (table 1) and were surveyed down to the water surface tape-down stake locations (table 2) to establish the true elevation of the water surface for the day in question. The measured stage for the USGS gaging station at Harrisburg (14166000) was used to adjust the tape-down measurement at river mile 160.8 to what it would have been on 3/20/02.

The data were organized and put into a spreadsheet that used equation 1 to calculate a linearly decreasing water-surface elevation. The water surface elevation was then added to the depth values from the collected data to establish the elevation of the river bottom.

The cross-sectional data that fell between river miles 146 and 162 were then adjusted to match the bed elevations in the centerline data using a Perl script, as above (appendix A). The cross section at river mile 149 was too shallow to use the ADCP; instead, the depth sounder was used, so only a single signal is available for each pass.

River miles 160.5 to 169

Centerline files rm162_169.txt and part of file rm162_156 were combined to form file rm169_160.5.txt so that this reach would include two GPS reference locations. Dataset rm162_169.txt was recorded on 3/19/02, while dataset rm162_156.txt was recorded on 3/20/02. Water surface tape-downs were measured on 3/18/02 at river mile 168.75 and at a later data at river mile 160.8 (table 3). The tape-down measurement at river mile 168.75 was adjusted to account for the change in stage between 3/18/02 and 3/19/02 according to the tape-down measurements on those days at river mile 172.00 (table 3). The measured stage for the USGS gaging station at Harrisburg (14166000) was used to adjust the tape-down measurement at river mile 160.8 to what it would have been on 3/19/02. GPS points were established at Harrisburg Park and Marshall Island (table 1) and were surveyed down to the water surface tape-down stake locations (table 2) to establish the true elevation of the water surface for 3/19/02.

The Harrisburg stage data also were used to adjust the recorded depth data from river mile 160.5 to 162 to what the depths would have been on 3/19/02. These points overlap those from the river mile 146 to 162 dataset, but were needed to establish the longitudinal distance along the river channel from the Harrisburg Park reference point up to river mile 162.

The data were organized and put into a spreadsheet that used equation 1 to calculate a linearly decreasing water-surface elevation. The water surface elevation was then added to the depth values from the collected data to establish the elevation of the river bottom.

The cross-sectional data that fell between river miles 160.5 and 169 were then adjusted to match the bed elevations in the centerline data using the PERL script, as above (appendix A). The cross section at river mile 165 was too shallow to use the ADCP; instead, the depth sounder was used, so only a single signal is available for each pass.

River miles 169 to 175

Centerline file rm175_169.txt was recorded on 3/19/02. Water surface tape-downs were measured on 3/19/02 at river miles 174.2 and on 3/18/02 at river mile 168.75 (table 3). The tape-down measurement at river mile 168.75 was adjusted to account for the change

in stage between 3/18/02 and 3/19/02 according to the tape-down measurements on those days at river mile 172.00 (table 3). GPS points were established at Rogers Bend and Marshal Landing (table 1) and surveyed down to the water surface tape-down stake locations (table 2) to establish the true elevation of the water surface for the day in question.

The data were organized and put into a spreadsheet that used equation 1 to calculate a linearly decreasing water-surface elevation. The water surface elevation was then added to the depth values from the collected data to establish the elevation of the river bottom.

The cross-sectional data that fell between river miles 169 and 175 were then adjusted to match the bed elevations in the centerline data using a Perl script, as above (appendix A). The cross section at river mile 169 fell between the data in this centerline file and the one for river miles 160.5 to 169. That cross section was processed by connecting the two centerline files so that a point of intersection between the centerline and cross-sectional data could be found. The cross section at river mile 175 was just beyond the extent of this most upstream centerline file, thus providing no point of intersection. The last point in the centerline dataset at river mile 175 was close to a point of intersection with the cross-sectional data, however, so a fictional point with an identical bed elevation was created just on the other side of the cross sections so that a point of intersection could be found.

Santiam River: River Miles 0 to 6

Santiam River centerline file rmsant6_0.txt was recorded on 3/30/02. That file intersects Willamette River centerline file rm115_106.txt, which was recorded on 3/14/02. To establish a reference location where the Willamette and Santiam Rivers intersect, the elevation of the river bottom at the point of intersection was forced to be the same. Using that point of intersection, a water surface elevation for 3/30/02 at that point was estimated using the water depth data collected on that day at that location. For the upstream water surface reference, the measured stage at the USGS gage station at Jefferson (14189000, river mile 9.62) was used to establish the water surface elevation at the upstream end point of data collection, which fell at river mile 6.2, assuming a linearly decreasing water-surface elevation.

The data were organized and put into a spreadsheet that used equation 1 to calculate a linearly decreasing water-surface elevation. The water surface elevation was then added to the depth values from the collected data to establish the elevation of the river bottom.

The cross-sectional data that fell between river miles 0 and 6 were then adjusted to match the bed elevations in the centerline data using a Perl script, as above (appendix A).

APPENDIX A

This appendix lists the "match.pl" perl script that was used to match the bed elevations of the cross-sectional data to the centerline bed elevations.

```
#!/usr/opt/bin/perl
#
# perl script that reads in the centerline bed-sediment elevations:
#   X, Y, Z (elevation in meters)
# and the cross-sectional depth files:
#   X, Y, Z (depth in meters)
# and then adjusts the cross-sectional data by matching its depths
# to those that correspond in the centerline file.

($centerline_file, $xsection_file) = @ARGV;

#
# Read in centerline file.
#
open (CENTER, $centerline_file) || die "unable to open $centerline_file";
$linein = <CENTER>;
$nc = -1;
while ( defined( $linein = <CENTER> )) {
    chomp $linein;
    $linein =~ s/^\s+//;
    $linein =~ s/\s+$//;
    $nc++;
    ($xc[$nc], $yc[$nc], $zc[$nc]) = split(/\s+/, $linein);
}
close (CENTER);

#
# Read in cross-section file.
#
open (XS, $xsection_file) || die "unable to open $xsection_file";
$linein = <XS>;
$ns = -1;
while ( defined( $linein = <XS> )) {
    chomp $linein;
    $linein =~ s/^\s+//;
    $linein =~ s/\s+$//;
    $ns++;
    ($xs[$ns], $ys[$ns], $zs[$ns]) = split(/\s+/, $linein);
}
close (XS);

#
# Cross-sectional files have 4 datasets of equal length.
# Each will be processed separately.
#
$ns = ($ns + 1) / 4;
for ($nx=0; $nx<4; $nx++) {
    print "Cross-section number $nx:\n";
    $gotit = 0;

#   Loop over the points on the centerline and the points on the cross-section.
    print "  Looking for point of intersection...";
    for ($c=0; $c<$nc; $c++) {
        if ($xc[$c+1] - $xc[$c] != 0.) {
            $mc = ($yc[$c+1] - $yc[$c]) / ($xc[$c+1] - $xc[$c]);
            $mc_bad = 0;
        } else {
            $mc_bad = 1;
        }
        $xc2 = $xc[$c+1];
        $xc1 = $xc[$c];
        $yc2 = $yc[$c+1];
```

```
        $yc1 = $yc[$c];
        $zc2 = $zc[$c+1];
        $zc1 = $zc[$c];

#       Find the point of intersection.  Find 4 nearest points and do the adjustment.
        for ($s=$ns* $nx; $s<$ns*($nx+1)-1; $s++) {
            if ($xs[$s+1] - $xs[$s] != 0.) {
                $ms = ($ys[$s+1] - $ys[$s]) / ($xs[$s+1] - $xs[$s]);
                $ms_bad = 0;
            } else {
                $ms_bad = 1;
            }
            if ($mc == $ms || ($ms_bad && $mc_bad)) {
                print "PARALLEL LINES...skipping...";
                next;
            } elsif ($mc_bad) {
                $xp = $xc[$c];
                $yp = $ms * ($xp - $xs[$s]) + $ys[$s];
            } elsif ($ms_bad) {
                $xp = $xs[$s];
                $yp = $mc * ($xp - $xc[$c]) + $yc[$c];
            } else {
                $xp = ($ys[$s] - $yc[$c] - $ms * $xs[$s] + $mc * $xc[$c]) / ($mc - $ms);
                $yp = $mc * ($xp - $xc[$c]) + $yc[$c];
            }
            if ( abs($xc[$c+1] - $xp) <= abs($xc[$c+1] - $xc[$c]) &&
                 abs($xc[$c]   - $xp) <= abs($xc[$c+1] - $xc[$c]) &&
                 abs($xs[$s+1] - $xp) <= abs($xs[$s+1] - $xs[$s]) &&
                 abs($xs[$s]   - $xp) <= abs($xs[$s+1] - $xs[$s]) &&
                 abs($yc[$c+1] - $yp) <= abs($yc[$c+1] - $yc[$c]) &&
                 abs($yc[$c]   - $yp) <= abs($yc[$c+1] - $yc[$c]) &&
                 abs($ys[$s+1] - $yp) <= abs($ys[$s+1] - $ys[$s]) &&
                 abs($ys[$s]   - $yp) <= abs($ys[$s+1] - $ys[$s]) ) {
                $gotit = 1;
                print "done\n";
                $xs2 = $xs[$s+1];
                $xs1 = $xs[$s];
                $ys2 = $ys[$s+1];
                $ys1 = $ys[$s];
                $zs2 = $zs[$s+1];
                $zs1 = $zs[$s];
            }
            last if ($gotit);
        }
        last if ($gotit);
    }

    if (! $gotit) {
        print "not found -- PROBLEM\n";
        next;
    }

#   Interpolate z value on centerline.
    $dc  = sqrt(($yc2-$yc1)**2 + ($xc2-$xc1)**2);
    $dcp = sqrt(($yp -$yc1)**2 + ($xp -$xc1)**2);
    if ( $dc != 0.) {
        $z_c = $dcp * ($zc2 - $zc1) / $dc + $zc1;
    } else {
        $z_c = $zc1;
    }

#   Interpolate z value on cross-section.
    $ds  = sqrt(($ys2-$ys1)**2 + ($xs2-$xs1)**2);
    $dsp = sqrt(($yp -$ys1)**2 + ($xp -$xs1)**2);
    if ( $ds != 0.) {
        $z_s = $dsp * ($zs2 - $zs1) / $ds + $zs1;
    } else {
        $z_s = $zs1;
    }

#   Find the z-offset and apply it.
```

```
    $outfile = $xsection_file . sprintf(".%1d", $nx+1);
    $outfile =~ s/.*\///;

    open (OUT, ">$outfile") || die "unable to open $outfile";

    print "  Z offset is ", $z_c - $z_s, "\n";
    print "  Writing output file $outfile...";
    print OUT "# X and Y coordinates in UTM (meters, NAD27).\n";
    print OUT "# Bed elevation in meters above sea level (NAVD88).\n# \n";
    print OUT "# Easting      Northing       Bed_Elevation\n";

    for ($s=$ns* $nx; $s<$ns*($nx+1); $s++) {
        printf OUT "%s %s      %.3f\n", $xs[$s], $ys[$s], $zs[$s] - $z_s + $z_c;
    }
    close (OUT);
    print "done\n\n";
}

exit;
```