

C. Flood Velocity Determination

C.1 Velocity Data

Determining the design floodwater velocity (velocity associated with base flooding) is important to properly design manufactured home foundations. Only hydraulic modeling or measurements from historic events can produce actual estimated velocity values. In addition to those resources, this section presents some of the tools and sources of information available that can help to provide an estimate of the floodwater velocity.

C.1.1 Hydraulic Modeling

Hydrologic and hydraulic (H&H) modeling is done as part of floodplain mapping. Through hydraulic models such as the USACE's Hydrologic Engineering Center's River Analysis System (HEC-RAS), riverine systems are modeled to determine the elevation of a given flood, such as the base flood, and the extent of flooding. Hydraulic modeling tools also provide additional helpful information about flood scenarios, including average channel and overbank floodwater velocities at particular cross-section locations. These velocities can be used as design velocities for structures when they correspond to a cross-section at or very near the development site. Figure C-1 shows an example of output from a HEC-RAS model run that includes overbank velocities. While these data can be very helpful, communities are expected to use the best available data, and overbank flood velocities may not be readily available in FIS reports.

Generally, the most easily accessible tool to use in estimating velocities will be the community's FIS. As described in Section 5.2.4, mean floodway velocities are determined during hydraulic modeling and can be obtained from the FIS using the following 3-step process:

- Step 1: Locate the manufactured housing site on the FIRM or DFIRM. This first step is illustrated in Figure C-2 using an example DFIRM.
- Step 2: Locate the stream cross-section on the FIRM or DFIRM that is located closest to the manufactured housing site. This second step is illustrated in Figure C-3 using an example DFIRM.
- Step 3: Match the cross-section for a particular stream on the FIRM or DFIRM with the cross-section in the stream's Floodway Data Table found in the FIS. This third step is illustrated in Figure C-4 using an example Floodway Data Table. At cross-section A, the mean floodway velocity is 0.4 fps.

It is important to note that the floodway's mean velocity is not a good measure of the actual flood velocity within the flood fringe, but it can be used as a general measure to determine

Figure C-1. Example HEC-RAS output.

profile corresponds to event frequency (e.g., 50- or 100-year)

overbank velocities

| Profile Output Table - Standard Table 1 | | | | | | | | | | | | | | |
|--|-----------|---------|-----------------|------------------|---------------|----------------|---------------|----------------|----------------|--------------------|-----------------|-------------------|----------------|-------------|
| HEC-RAS Plan: Prop-Final River: RIVER-1 Reach: Reach-1 | | | | | | | | | | | | | | |
| Reach | River Sta | Profile | Vel Left (ft/s) | Vel Right (ft/s) | Q Total (cfs) | Min Ch El (ft) | W/S Elev (ft) | Crit W.S. (ft) | E.G. Elev (ft) | E.G. Slope (ft/ft) | Vel Chnl (ft/s) | Flow Area (sq ft) | Top Width (ft) | Froude # Ch |
| Reach-1 | 17257 | PF 1 | 3.68 | 2.52 | 3013.00 | 107.50 | 113.86 | 113.21 | 114.43 | 0.014495 | 7.61 | 659.31 | 298.22 | 0.56 |
| Reach-1 | 17257 | PF 2 | 4.20 | 2.85 | 3800.00 | 107.50 | 114.31 | 113.66 | 114.92 | 0.014584 | 8.06 | 800.13 | 322.62 | 0.59 |
| Reach-1 | 17257 | PF 3 | 4.34 | 3.06 | 4380.00 | 107.50 | 114.64 | 113.94 | 115.25 | 0.014135 | 8.24 | 908.61 | 336.13 | 0.58 |
| Reach-1 | 17257 | PF 4 | 4.48 | 3.24 | 4964.00 | 107.50 | 114.94 | 114.24 | 115.56 | 0.013843 | 8.42 | 1011.90 | 348.50 | 0.58 |
| Reach-1 | 16157 | PF 1 | 1.67 | 1.19 | 3013.00 | 103.06 | 109.86 | 108.55 | 109.91 | 0.002237 | 2.59 | 1889.14 | 766.00 | 0.21 |
| Reach-1 | 16157 | PF 2 | 1.85 | 1.36 | 3800.00 | 103.06 | 110.21 | 108.55 | 110.26 | 0.002351 | 2.79 | 2153.03 | 766.00 | 0.22 |
| Reach-1 | 16157 | PF 3 | 1.99 | 1.48 | 4380.00 | 103.06 | 110.41 | 108.59 | 110.48 | 0.002492 | 2.95 | 2310.87 | 766.00 | 0.23 |
| Reach-1 | 16157 | PF 4 | 2.12 | 1.60 | 4964.00 | 103.06 | 110.61 | 108.69 | 110.68 | 0.002610 | 3.09 | 2462.66 | 766.00 | 0.23 |
| Reach-1 | 13116 | PF 1 | 2.16 | 1.63 | 3013.00 | 89.24 | 97.67 | 96.60 | 98.93 | 0.019093 | 9.44 | 438.99 | 256.45 | 0.68 |
| Reach-1 | 13116 | PF 2 | 2.78 | 2.15 | 3800.00 | 89.24 | 98.33 | 98.26 | 99.47 | 0.017073 | 9.53 | 626.36 | 318.52 | 0.63 |
| Reach-1 | 13116 | PF 3 | 3.02 | 2.23 | 4380.00 | 89.24 | 98.82 | 98.62 | 101.49 | 0.014932 | 9.32 | 797.12 | 386.10 | 0.60 |
| Reach-1 | 13116 | PF 4 | 3.17 | 2.31 | 4964.00 | 89.24 | 99.22 | | 100.13 | 0.013551 | 9.19 | 966.16 | 445.03 | 0.57 |
| Reach-1 | 12006 | PF 1 | 2.03 | 1.63 | 3013.00 | 83.04 | 92.90 | | 93.07 | 0.002317 | 4.38 | 1148.22 | 278.95 | 0.28 |
| Reach-1 | 12006 | PF 2 | 2.21 | 1.75 | 3800.00 | 83.04 | 93.74 | | 93.92 | 0.002273 | 4.59 | 1391.58 | 303.27 | 0.28 |
| Reach-1 | 12006 | PF 3 | 2.35 | 1.86 | 4380.00 | 83.04 | 94.21 | | 94.40 | 0.002345 | 4.81 | 1537.46 | 316.96 | 0.28 |
| Reach-1 | 12006 | PF 4 | 2.46 | 1.94 | 4964.00 | 83.04 | 94.69 | | 94.89 | 0.002353 | 4.96 | 1694.05 | 331.02 | 0.28 |
| Reach-1 | 11855 | PF 1 | 1.93 | 1.11 | 3266.00 | 82.20 | 92.75 | 87.22 | 92.85 | 0.001083 | 3.22 | 1522.42 | 595.65 | 0.18 |
| Reach-1 | 11855 | PF 2 | 2.18 | 1.35 | 4140.00 | 82.20 | 93.58 | 87.91 | 93.70 | 0.001159 | 3.51 | 1754.00 | 646.74 | 0.19 |
| Reach-1 | 11855 | PF 3 | 1.36 | 0.95 | 4840.00 | 82.20 | 94.15 | 87.99 | 94.21 | 0.000740 | 2.90 | 3127.28 | 683.81 | 0.18 |
| Reach-1 | 11855 | PF 4 | 1.40 | 1.02 | 5492.00 | 82.20 | 94.63 | 89.34 | 94.70 | 0.000742 | 2.98 | 3467.55 | 707.76 | 0.18 |
| Reach-1 | 11801 | PF 1 | 3.88 | 3.67 | 3266.00 | 82.00 | 91.95 | 88.96 | 92.63 | 0.007024 | 7.73 | 578.65 | 520.98 | 0.44 |
| Reach-1 | 11801 | PF 2 | 5.12 | 3.10 | 4140.00 | 82.00 | 92.27 | 89.90 | 93.40 | 0.011054 | 9.92 | 622.96 | 549.72 | 0.58 |
| Reach-1 | 11801 | PF 3 | 5.69 | 3.59 | 4840.00 | 82.00 | 92.67 | 90.65 | 93.95 | 0.012169 | 10.68 | 678.70 | 562.37 | 0.58 |
| Reach-1 | 11801 | PF 4 | 6.18 | 4.01 | 5492.00 | 82.00 | 93.01 | 91.13 | 94.42 | 0.013106 | 11.33 | 726.84 | 573.29 | 0.62 |
| Reach-1 | 11751 | | Bridge | | | | | | | | | | | |
| Reach-1 | 11686 | PF 1 | 3.43 | 2.81 | 3266.00 | 80.40 | 91.73 | | 92.19 | 0.004542 | 6.44 | 708.05 | 574.84 | 0.38 |
| Reach-1 | 11686 | PF 2 | 4.07 | 3.36 | 4140.00 | 80.40 | 92.42 | | 92.99 | 0.005314 | 7.27 | 789.22 | 592.33 | 0.38 |
| Reach-1 | 11686 | PF 3 | 4.58 | 3.79 | 4840.00 | 80.40 | 92.80 | | 93.49 | 0.006143 | 8.00 | 834.95 | 600.02 | 0.42 |
| Reach-1 | 11686 | PF 4 | 5.04 | 4.19 | 5492.00 | 80.40 | 93.11 | 90.55 | 93.91 | 0.006963 | 8.67 | 871.22 | 606.11 | 0.45 |

cross-section locations within the floodplain where floodwaters will move relatively faster or slower, and to provide an upper limit for velocities in the flood fringe.

Hydraulic modeling with the potential to provide overbank flood velocities might also be available. Modeling used to complete a community’s FIS can be ordered through FEMA’s Project Library by completing a FIS data request form (http://www.fema.gov/plan/prevent/fhm/st_order.shtm). These data are usually, but not always, available for communities with existing FISs. Depending on the data format (e.g., paper, diskettes, or microfiche), it may be possible to determine overbank velocities at cross-sections without significant effort. While this modeling can be helpful, the community is not expected to use it to create any new data; use of the best available data is all that is necessary. However, there is a possibility that this modeling will be available locally, perhaps through the municipal engineer, especially if new or updated modeling for the FIS has been recently completed.

H&H modeling might also be available regionally or locally if other agencies have done studies. Table 5-1 lists several Federal, State, and local agencies that might have information about past flooding events. These same agencies are the ones most likely to have performed flood studies, separate from the communities’ FIS reports, for a localized area. Such studies might be performed in order to further characterize flooding in a particularly vulnerable area or to

provide updated information about an area that may have experienced significant development since the FIS was completed.

C.1.2 Documented Historic Information

Another potential source of documented floodwater velocities are post-flood reports. Refer to Table 5-1 for Federal, State, and local agencies that often publish post-event flood information. Such documentation might include information about observed damages, flood elevations, and other flood characteristics, including floodwater velocities. One such example of these types of reports is the Delaware Geologic Survey (<http://www.udel.edu/dgs/index.html>) Open File Reports completed after coastal storms in 1992 and 1998. These reports provide synopses of the events, high water mark survey results, rainfall and stream gauge records, and wave height records. Another example is The South Florida Water Management District, which offers reports documenting past flood events via its website (<http://www.sfwmd.gov>). Additionally, the Harris County (Texas) Flood Control District provides a summary of past flooding, including observed damages noting areas that were hardest hit, on their website (<http://www.hcfcd.org>). Local officials (e.g., engineers, floodplain managers, building inspectors, planners) are probably the best resource for determining if these types of reports exist and where they can be found.

One agency listed in Table 5-1, the U.S. Geological Survey (USGS), measures stream flow characteristics at established gauges throughout the U.S. during flood events. The specific characteristics measured depend on the gauge's capabilities, but can include discharge and mean channel velocity. These data are available at the USGS website via the National Water Information System (NWIS) Web Water Data system (<http://waterdata.usgs.gov/nwis>). The USGS also frequently takes measurements of depth and velocity at discrete cross-section locations along gauged streams during flood events. This information is not available online, but can be obtained from the appropriate USGS office.

C.2 Alternate Methodologies for Estimating Velocities

In the absence of hard data such as those found in stream modeling or historic measurements and reports, local expertise and evaluation of site indicators can be used to determine relative velocities. To estimate site floodwater velocities, local officials, such as engineers and floodplain managers, with knowledge of past flood events can be consulted. Additionally, there are some site indicators that local officials can use to estimate relative velocities.

C.2.1 Knowledge of Past Flooding

Local floodplain management and building officials are encouraged to use their knowledge of past flood events and exercise their judgment in determining relative flood velocities in the absence of hard data. Some questions to consider include the following:

- Have base flood conditions consisted of very shallow (less than 1 foot) or ponding (slow draining, no velocity) flooding?

If the answer to this question is yes, then a pier foundation with dry-stacked blocks would be appropriate. With no velocity and/or very shallow floodwaters, the stability and strength provided by either surface bonded mortar or grouted/rebar/anchored piers may not be necessary.

- Have structures at or near the site been damaged by high velocity flows in the past?

If there are any indications that high velocity floodwaters have caused damage to structures in the past, none of the pre-engineered foundations described in Appendix H should be used. Some examples of foundation failure as the result of high velocity floodwaters include: 1) structures shifting from their foundations (sliding failure), 2) scour occurring at the foundation, and 3) uplift of the structure from the foundation (in conjunction with buoyancy forces). Section 5.2.4 provides further information on hydrodynamic forces and foundation failure.

- Have moving floodwaters damaged appurtenant structures such as decks and porches?

Floodborne debris often consists of lumber and other pieces of decking and porches. High velocity floodwaters damage attachments, such as carports, decks, porches, and awnings, and/or their connections and can lead to structural failure of the attachment. Field observations have noted that the primary cause of this failure has been inadequate support; the attachments' support systems were simply not designed or constructed to withstand the hydrodynamic loadings imposed upon them. At or near sites where appurtenant structures have been severely damaged or destroyed by fast moving floodwaters, only designs for high velocity foundations (not Appendix H foundations) should be used.

C.2.2 Site Indicators

Another set of tools to use in estimating relative velocity are characteristics of the site and/or the surrounding watershed. These indicators provide a broader frame of reference for estimating relative velocities.

The proximity of a site to the flood source (stream or river) is one of the most basic gauges of floodwater velocity. Generally, the velocity of floodwater will decrease from the channel center out to the edges of the flood fringe as illustrated in Figure C-5. The floodway is the area of the stream where floodwaters are likely to be the deepest and have the highest velocities. Therefore, in the outer edges of the flood fringe, velocities can be expected to be relatively low. Sites located well within the flood fringe closer to the floodway will tend to have higher floodwater velocities. Figure C-6 shows an aerial view of a stream with the floodway highlighted in dark gray and the floodplain outlined in white. Within the floodway, velocities will be higher. As you move outwards to the edges of the flood fringe, velocities will decrease.

Figure C-4. Floodway Data Table and mean velocity.

| CROSS SECTION | DISTANCE | FLOODWAY | | | BASE FLOOD WATER-SURFACE ELEVATION (FEET NAVD) | | | |
|---|--------------------|--------------|----------------------------|---------------------------------|--|------------------|---------------|----------|
| | | WIDTH (FEET) | SECTION AREA (SQUARE FEET) | MEAN VELOCITY (FEET PER SECOND) | REGULATORY | WITHOUT FLOODWAY | WITH FLOODWAY | INCREASE |
| Country Club Creek | | | | | | | | |
| A | 800 ¹ | 100 | 2,210 | 0.4 | 596.5 | 596.5 | 597.5 | 1.0 |
| B | 2,120 ¹ | 70 | 170 | 3.2 | 617.4 | 617.4 | 618.4 | 1.0 |
| C | 2,250 ¹ | 80 | 360 | 1.5 | 625.6 | 625.6 | 626.6 | 1.0 |
| D | 2,430 ¹ | 30 | 83 | 4.8 | 628.6 | 628.6 | 629.6 | 1.0 |
| E | 2,590 ¹ | 100 | 700 | 0.6 | 634.0 | 634.0 | 635.0 | 1.0 |
| F | 2,940 ¹ | 70 | 140 | 2.9 | 634.3 | 634.3 | 635.3 | 1.0 |
| G | 3,640 ¹ | 30 | 71 | 5.2 | 648.8 | 648.8 | 649.8 | 1.0 |
| H | 5,120 ¹ | 60 | 122 | 2.9 | 702.0 | 702.0 | 703.0 | 1.0 |
| I | 5,900 ¹ | 30 | 78 | 4.5 | 740.5 | 740.5 | 741.5 | 1.0 |
| Country Club Creek North Tributary | | | | | | | | |
| A | 180 ² | 30 | 69 | 5.8 | 626.1 | 626.1 | 627.1 | 1.0 |
| B | 1,520 ² | 20 | 46 | 8.7 | 652.4 | 652.4 | 653.4 | 1.0 |
| C | 3,160 ² | 20 | 53 | 7.0 | 701.7 | 701.7 | 702.7 | 1.0 |
| D | 3,310 ² | 110 | 760 | 0.5 | 711.4 | 711.4 | 712.4 | 1.0 |
| E | 3,860 ² | 50 | 104 | 3.5 | 716.8 | 716.8 | 717.8 | 1.0 |
| Day Creek | | | | | | | | |
| A | 600 ³ | 220 | 1,813 | 4.6 | 639.1 | 639.1 | 640.1 | 1.0 |
| B | 1,070 ³ | 300 | 1,713 | 4.8 | 640.5 | 640.5 | 641.5 | 1.0 |
| C | 1,600 ³ | 380 | 2,339 | 3.6 | 644.2 | 644.2 | 645.2 | 1.0 |
| D | 2,300 ³ | 430 | 1,207 | 8.3 | 649.0 | 649.0 | 650.0 | 1.0 |
| E | 2,800 ³ | 600 | 2,346 | 3.7 | 653.4 | 653.4 | 654.4 | 1.0 |

¹ Feet Above Limit of Detailed Study
² Feet Above Confluence With Country Club Creek
³ Feet Above Point 120 Feet Downstream of Lucretia Avenue

Mean Floodway Velocity at Cross-Section A: 0.4 fps

| | | |
|----------------|--|----------------------|
| TABLE 7 | FEDERAL EMERGENCY MANAGEMENT AGENCY | FLOODWAY DATA |
| | RIVERSIDE COUNTY, CA AND INCORPORATED AREAS | |
| | COUNTRY CLUB CREEK – COUNTRY CLUB CREEK NORTH TRIBUTARY – DAY CREEK | |

Figure C-5. Flood velocity profiles.

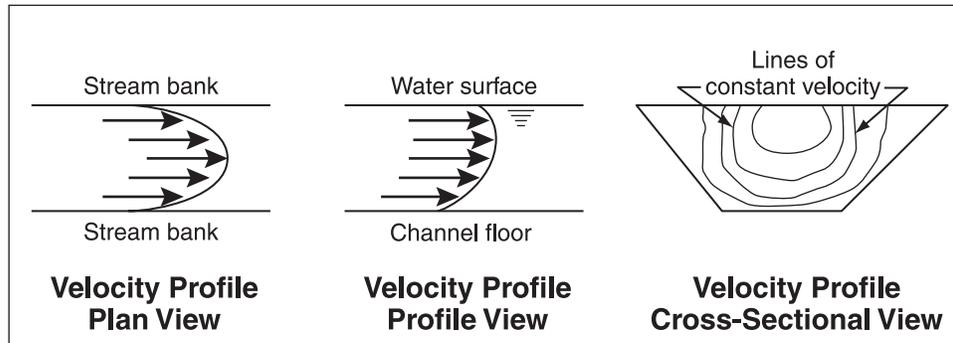


Figure C-6. Floodwaters in the floodway (dark gray) will have higher velocities than those in the flood fringes (between black and gray).



Terrain characteristics can also help to provide some clues about floodwater velocities. Flood velocity is largely dependent on the slope and roughness of the stream channel and overbank terrain. Water moves downstream faster when the channel and overbank areas are steeply sloped. Water also flows faster over paved or smooth surfaces such as roadways or parking lots as opposed to densely vegetated stream banks. Streams in steep or mountainous areas tend to have higher floodwater velocities capable of more damage than those in flatter areas. Figure C-7 shows a damaged home along a stream that is surrounded by steep, mountainous terrain and subject to flash flooding.



Figure C-7. Home damaged along a stream subject to flash flooding due to surrounding mountainous terrain.

Velocity patterns are also affected by the sinuosity of a waterway. Within streams with some meandering characteristics, channel velocities are higher along the exterior bends of streams. Stream banks along the exterior bends of meandering streams are subject to erosion due to forces exerted by moving waters while deposition of material often occurs along interior bends due to lower velocities. Therefore, sites along the exterior bends of streams should be considered at risk for higher floodwater velocities. Figure C-8 illustrates a meandering stream system where there are several exterior bends.

Stream hydraulics can be greatly impacted by flow constrictions within the waterway, including bridges, culverts, and levees. Higher floodwater velocities are often observed both within the constricted area and directly downstream of these constrictions. Velocity within an open stream is equal to the discharge rate divided by the flow area. When a constriction reduces the area that water may flow through, water must either flow faster or pond up (thereby reducing the discharge rate); it often does both.

Typically there is some ponding or storage upstream of a constriction during major flooding, but the velocity is also likely to increase dramatically through and just downstream of the

constriction. As the flow area decreases, the depth of the water will also increase through the constriction and continue to be elevated for some time downstream of the constriction as the flow area gradually expands into more natural terrain. Therefore, areas just downstream of constrictions may be prone to high velocity waters during flooding.



Figure C-8. Meandering stream system. Velocities are generally higher along the outer bends of streams.