Map MODERNIZATION

Federal Emergency Management Agency

FEMA's Flood Hazard Mapping Program

Guidelines and Specifications *for* Flood Hazard Mapping Partners

Appendix B: Guidance for Converting to the North American Vertical Datum of 1988

FEDERAL EMERGENCY MANAGEMENT AGENCY

www.fema.gov/mit/tsd/dl_cgs.htm

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Appendix B

Converting to the North American Vertical Datum of 1988

B.1 Background

Every Flood Insurance Study (FIS) Report and Flood Insurance Rate Map (FIRM) that contains detailed flood hazard information is prepared based on hydraulic analyses that are referenced to a specific vertical datum. The two standard datums in use nationwide are the National Geodetic Vertical Datum of 1929 (NGVD29) and the North American Vertical Datum of 1988 (NAVD88). Information on these datums and on software that is available to convert NGVD29 to or from NAVD88 is provided in Subsections B.1.1, B.1.2, and B.1.3.

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B.1.1 National Geodetic Vertical Datum of 1929

Historically, the most common vertical datum used for FEMA flood hazard studies/restudies and map revisions has been NGVD29. NGVD29 assumed that 26 tide gages in the United States and Canada all represented the same zero elevation, which was mean sea level. As survey technologies became more accurate, it became increasingly apparent that NGVD29 constraints were incorrectly forcing surveys to fit different tide stations (all zero elevation or mean sea level) that actually had different elevations relative to each other. NGVD29 essentially warped the geoid, which represents an equipotential surface where gravity, and elevations, should be the same. Fortunately, the maximum warp anywhere in the United States, caused by forced constraints of NGVD29 at 26 tidal stations, is no more than 1.5 meters. Although there are exceptions, the warping found over smaller geographic areas, such as the area within a county, is small.

[February 2002]

B.1.2 North American Vertical Datum of 1988

In the 1970s, the National Geodetic Survey (NGS), and counterpart agencies in Mexico and Canada, decided to adopt a vertical datum based on a surface that would closely approximate the Earth's geoid. The new adjustment, NAVD88, was completed in June 1991 and is now the only official vertical datum in the United States. NAVD88 was created by adding 625,000 kilometers of leveling, performed since NGVD29 was established, and performing a major least squares adjustment that constrained only a single tide station at zero elevation. The height of the primary tidal bench mark at Father Point/Rimouski, Quebec, Canada, was held fixed as the constraint, enabling NAVD88 and the International Great Lakes Datum of 1985 (IGLD85) to be one and the same.

Now, other tide stations may have elevations other than zero. Subsequent to the establishment of NAVD88, new flood hazard studies are preferably referenced to that datum.

[February 2002]

B.1.3 Conversion Software

The NGS and the U.S. Army Corps of Engineers (USACE) have developed software, which may be obtained free of charge, for performing conversions between NGVD29 and NAVD88. Interested Mapping Partners may download the PC-compatible NGS VERTCON software from the NGS home page at www.ngs.noaa.gov, by selecting the NGS Geodetic Tool Kit option. Similarly, interested Mapping Partners may download the USACE CORPSCON software from the U.S. Army Topographic Engineering Center home page at www.tec.army.mil; by selecting What We Do; Products and Services; Software Available, and CORPSCON. The CORPSCON software can be use to convert horizontal datums (between the North American Datum of 1927 [NAD27] and NAD 83) as well as vertical datums (between NGVD 29 and NAVD 88) based on NGS NADCON and VERTCON software. Both programs compute the modeled differences in orthometric heights (elevations) between NGVD29 and NAVD88 for a given location specified by geographic coordinates (latitude and longitude). CORPSCON also allows Universal Transverse Mercator or State Plane coordinates to be entered in lieu of geographic coordinates. The Mapping Partner may obtain identical results using either the VERTCON or CORPSCON software.

[February 2002]

B.2 Data Collection

One of the stated goals of FEMA's Map Modernization Program is to convert all flood maps from NGVD29 to NAVD88. The Mapping Partner that performs a study/restudy for FEMA or submits a map revision request will be responsible for applying proper vertical datum protocols for new and/or revised flood hazard data when preparing or revising flood hazard study/restudy materials that have been chosen for the datum conversion. FEMA recognizes that there are, and will continue to be, limiting factors in achieving this conversion. To evaluate the suitability of a subject jurisdiction for datum conversion, the Mapping Partner shall gather the following information during the initial coordination efforts for a study or restudy:

- Datum used for the existing study, if one exists, and the extent of changes that will occur as a result of the restudy;
- Number (percentage) of streams that will be revised and the number of unrevised flooding sources that must be converted from NGVD29 to NAVD88 if the datum conversion option is chosen;
- Conversion factor from NGVD29 to NAVD88 for the subject community, whether or not the conversion factor for the community is constant, and maximum offset from the established conversion factor (see Section B.4.1);
- Reference datum used by FEMA for adjacent communities;
- Datum of choice for the local surveyors and any known difficulties that the community would have with the use of NAVD 88; and
- Approximate effort (man-hours) associated with conversion to NAVD 88.

[February 2002]

B.3 Conversion Criteria

To eliminate possible confusion and misuse of elevation information, the flood elevations for all flooding sources studied by detailed methods within a given community must be referenced to the same datum. Therefore, if a Mapping Partner undertakes a restudy or map revision that does not include all flooding sources studied by detailed methods, the elevations for the flooding sources also must be converted to NAVD88.

Therefore, it is essential for the Regional Project Officer (RPO) and the Mapping Partner to make an initial sound decision about which vertical datum can and should be used for a study, restudy, or map revision. Once the Mapping Partner has gathered the information specified in Subsection B.2, FEMA, in consultation with the Mapping Partner, will make the final decision regarding the datum to which the new, revised, and unrevised flood hazard information will be referenced. When a new or revised study is being processed, the decision to use NAVD88 over NGVD29 will depend largely on the data gathered early in the process. Criteria that facilitate a conversion from NGVD29 to NAVD88 are as follows:

- All flooding sources in the community are being studied or restudied by detailed methods.
- Less than 50 percent and fewer than 20 miles of detailed study streams that are not being restudied will have to be converted from NGVD29 to NAVD88.
- No more than 5 percent of the total printed FIRM panels for the community have to be revised solely to convert the elevations for the flooding sources that were not restudied from NGVD29 to NAVD88.
- The maximum offset from an established average conversion (from NGVD 29 to NAVD 88) for the subject jurisdiction does not exceed 0.25 foot. Protocol for determining an average conversion factor as well as a maximum offset value is provided in Subsection B.4.1.
- The Mapping Partner performing the flood hazard analysis is able to use NAVD88 for the study/restudy or map revision.
- The community is familiar with NAVD88.

If the mapping activity undertaken by the Mapping Partner is a comprehensive restudy of all flooding sources studied by detailed methods, or if the Flood Map Project is resulting in a first time FIRM, all flood elevations shall be referenced to NAVD88 unless otherwise specified during the Scoping process.

The above criteria are provided for general guidance to aid the RPO and Mapping Partner in making a technically sound, cost-effective, and user-friendly decision.

[February 2002]

B.4 Conversion of Unrevised Flood Elevations

There will be occasions were a Mapping Partner submits restudy or map revision information referenced to NAVD88 to FEMA to support preparation of a new or revised FIRM but does not address the remainder of the unrevised flood elevations. In those circumstances, FEMA will decide whether the Mapping Partner that performed the study/restudy or the Mapping Partner that prepares the Preliminary FIS Report and FIRM will convert the flood hazard information for the entire community to NAVD88. This decision will be made on a case-by-case cost-benefit assessment. If FEMA determines that the cost to convert the entire community is reasonable (considering the other scope of work), the Mapping Partner that is selected to complete the conversion shall follow the procedures in Subsections B.4.1, B.4.1.1, B.4.1.2, and B.4.1.3 of this Appendix.

[February 2002]

B.4.1 Protocol for Determining Conversion Factor

The Mapping Partner responsible for conducting the new or revised flood hazard analyses shall establish single or multiple conversion factors to be applied to the unrevised 1-percent annual-chance flood elevations in the FIS Report and on the FIRM. To determine an average conversion factor from NGVD29 to NAVD88, the steps below shall be followed:

Step 1 - Locating the Subject Jurisdiction

The Mapping Partner shall locate the subject jurisdiction on U.S. Geological Survey 7.5-minute series topographic quadrangle maps.

Step 2 - Determining Conversion Factors for Quadrangle Corners

The Mapping Partner shall use VERTCON or CORPSCON to determine the conversion factor for each quadrangle corner that falls inside the jurisdiction boundary and each quadrangle corner that lies within 2.5 miles outside of the jurisdiction boundary. This information is to be entered into a table that will be used in the FIS Report (sample table provided below.) Details for the production of FIS Reports are provided in Appendix J.

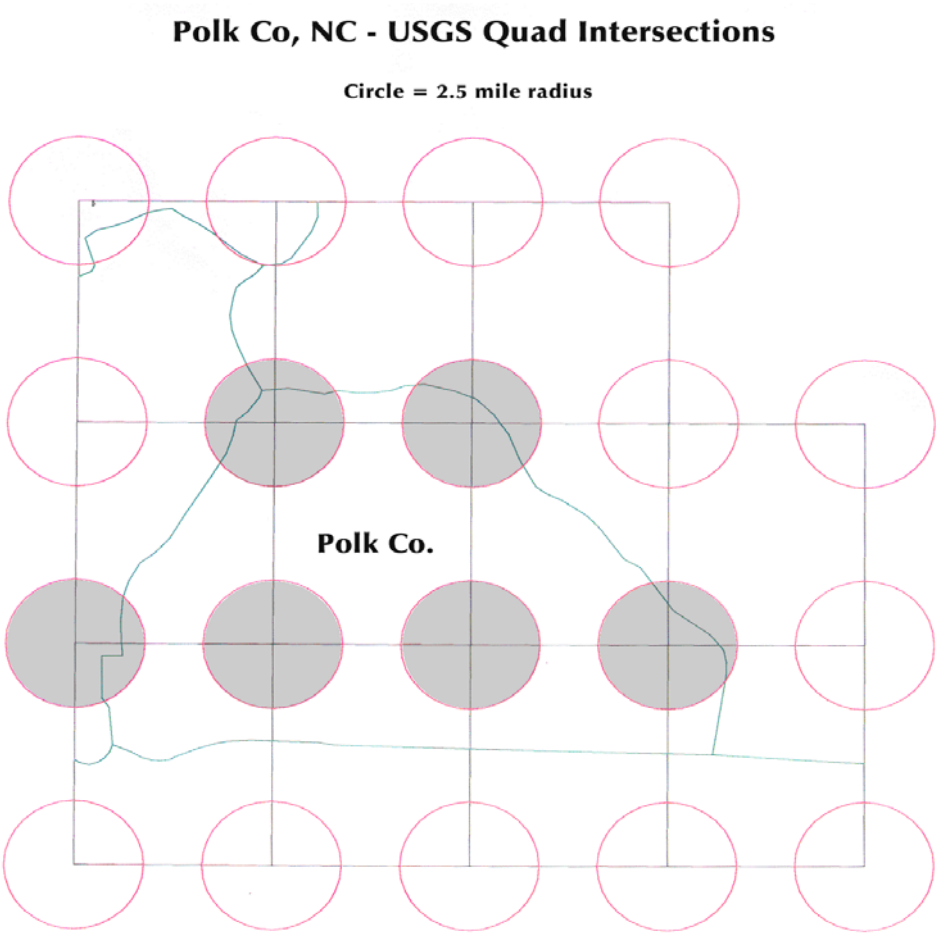
Quad Name	Corner	Latitude	Longitude	Conversion from NGVD29 to NAVD88
Johnsonville West	SE	35.375	82.125	-0.54 ft
Johnsonville East	SE	35.375	82.250	-0.32 ft
Gilberts Corner	SW	35.250	82.000	-0.54 ft
Farmville	SW	35.250	82.125	-0.37 ft
Taylor's Grove	SW	35.250	82.250	-0.25 ft
Thompsonville	SW	35.250	82.375	-0.14 ft

Figure B.1 shows five quadrangle corners within the county, and one outside the county but within 2.5 miles of the county boundary. (This corner is thus to be included in the calculation of

average conversion factors.) The shaded circles represent the quad intersections that meet the selection criteria.

[February 2002]

Figure B-1



For quadrangles that include oceans or other major water bodies, quadrangle corners that are more than 2.5 miles away from land shall not be used, except in the case of small islands or narrow bands of land that would not be represented by quadrangle corners on either side. When this occurs, the Mapping Partner's discretion may be used in selecting the nearest quadrangle corner to ensure that conversion factors for small islands or terrain such as the North Carolina Outer Banks are considered in determining the average conversion factor to be applied to a county.

Step 3 - Determining an Average Conversion Factor

Once conversion factors for all eligible quadrangle corners have been established, the Mapping Partner shall determine an average conversion factor by calculating a simple, unweighted arithmetic mean of all points for the entire jurisdiction. In the example shown in Figure B.1, the average conversion factor is –0.36 foot.

Step 4 - Establishing a Range of Conversion Factors

The Mapping Partner shall establish a range of conversion factors from all eligible points (minimum and maximum values) for the subject jurisdiction from the values documented in Step 2. In the sample table above, the range of conversion factors is between –0.14 foot and –0.54 foot. The Mapping Partner shall use the range of conversion values, combined with the average conversion factor determined above, to determine if a conversion is needed, or if a passive-conversion approach is feasible. A passive conversion, discussed in more detail in Step 6 (below), is defined as applying the average conversion factor determined above to the FIS Report (tables) only. The FIRM and Flood Profiles would not be affected by a passive conversion decision.

Step 5 - Determining the Maximum Offset

The Mapping Partner shall determine the maximum offset from the average conversion factor, compared with the minimum and maximum conversion factors. In the above example, the maximum offset is 0.22 foot (0.36 foot to 0.14 feet). If the Mapping Partner determines that the maximum offset exceeds 0.25 foot for any of the qualifying quadrangle corners, the multiple-conversion protocol (stream-by-stream conversion) detailed in Section B.4.1.2 shall be applied. The exception to this rule is situations whereby qualifying exterior quad corners are the sole cause for the subject jurisdiction being ineligible for the application of a standard conversion value. To determine if this is the case, the Mapping Partner shall replace anomalous conversion values that are obtained from quadrangle corners outside the subject jurisdiction with locations along the jurisdiction boundary closest to the anomalous quadrangle corner (one per quadrangle corner). Once this has been done, if the jurisdiction continues to be mathematically ineligible for conversion to NAVD88 using a standard jurisdiction-wide conversion value, the Mapping Partner shall use the stream-by-stream conversion approach detailed in Section B.4.1.2.

Step 6 - Establishing the Conversion Factor

Using the values documented above, the Mapping Partner shall establish a single average conversion factor or multiple conversion factors and apply the factor(s) to existing effective data to be converted to NAVD88. The criteria for determining whether a single conversion factor, or multiple conversion factors will be used, are described in Subsections B.4.1.1, B.4.1.2, and B.4.1.3. If the average conversion factor above is less than 0.1 foot, there may be only a passive datum conversion applied. As noted in Step 4, a passive conversion would affect the values shown on data tables in the FIS Report, but would not affect the 1-percent-annual-chance flood elevations shown on the FIRM or on the Flood Profiles in the FIS Report. The Mapping partner shall apply the average conversion factor determined in Step 3 above to all data tables in the FIS Report containing flood elevations referenced to NGVD29. The use of this option is contingent on the range of conversion values determined in Step 4. An average conversion of 0.1 foot or less could be deceiving in areas that contain conversions to NAVD88 that show plus and minus values. To illustrate this point, the following table shows a hypothetical county where the average conversion to NAVD88 was calculated to be -0.09 foot. However, it is also shown that the county contained a large range of conversion values thereby rendering a passive-conversion decision inappropriate.

Range of conversion values	- 0.38 through + 0.24
Average conversion factor	- 0.09
Maximum variance from the average conversion	0.33
Maximum variance from a no-conversion value	0.38

This table demonstrates that, although a jurisdiction may have an insignificant average conversion value (0.1 foot or less), the range of conversion values indicates that there are quadrangle corners that are more than 0.25 foot askew of a zero conversion factor. The situation shown in the above table indicates that a passive-conversion approach could yield up to a 0.38-foot discrepancy in the jurisdiction. For this reason, a 0.25-foot tolerance was established as the maximum variance acceptable from a passive-conversion value. It is also worth noting that this hypothetical jurisdiction also would be ineligible for the application of an average conversion factor. A multiple conversion (stream-by-stream) approach as detailed in Section B.4...1.2 below would be required for this jurisdiction.

[February 2002]

B.4.1.1 Single Conversion Factor

A single conversion factor from NGVD29 to NAVD88 may be applied when the maximum offset from the average conversion factor does not exceed 0.25 foot. When a decision has been made during the Project Scoping phase (discussed in detail in Volume I, Section 1.3) to apply a datum conversion and a single conversion factor is appropriate, the Mapping Partner responsible for the new or updated flood hazard analyses shall apply the following procedures.

1. Determine an average conversion factor for the subject community following the procedures detailed in Subsection B.4.1 and apply the average to the dynamic flood elevations.

2. Convert static (primarily, lacustrine) flood elevations using VERTCON or CORPSCON.

3. Apply the conversion factor to the FIRM and to all components of the FIS Report that display 1-percent-annual-chance flood elevations (i.e., Flood Profiles, data tables).

4. Document the datum conversion details as specified in Appendix J of these Guidelines.

5. Ensure that all unrevised hydraulic models and supporting backup information are clearly labeled in the Technical Support Data Notebook (see Appendix M of these Guidelines) to indicate that the FIRM and FIS Report reflect a datum conversion and specify the conversion criteria that was applied.

[February 2002]

B.4.1.2 Multiple Conversion Factors (Stream by Stream)

In situations where the range of conversion factors across the subject community is prohibitively high (thereby resulting in a maximum offset from the established average conversion factor of greater than 0.25 foot), the Mapping Partner shall not apply a standard conversion factor for the

entire community. In the event that conversion to NAVD88 remains a desirable option, the Mapping Partner shall convert the unrevised flood elevations on a stream-by-stream basis.

Under this approach, the Mapping Partner shall develop an average conversion factor for each stream or flooding source by establishing three conversion factors at three locations and developing an average conversion factor from those data. If the maximum offset from the average conversion factor determined for a flooding source converted in this fashion exceeds 0.25 foot, the Mapping Partner shall follow the protocol described in Subsection B.4.1. When multiple conversion factors are applied, on a stream-by-stream basis, the Mapping Partner shall present the conversion factors in a table to be placed on the FIRM and in the FIS Report. An example of the table to be used in this scenario is shown in the below as well as in Appendix J of these Guidelines. As noted in Subsection B.4.1.1 when a datum conversion is conducted on unrevised flood elevations, the Mapping Contractor responsible for preparing the Technical Support Data Notebook (see Appendix M) shall ensure that all unrevised hydraulic models and supporting backup information are clearly labeled to indicate that the FIRM and FIS Report reflect a datum conversion and shall specify the conversion criteria that was applied.

[February 2002]

Stream Name	Minimum Conversion	Maximum Conversion	Average Conversion	Maximum Offset
Jones Branch	-0.74	-0.92	-0.81	0.11
Mud River	-0.59	-0.80	-0.74	0.15

B.4.1.3 Conversion of Hydrologic and Hydraulic Models

In situations where the range of conversion factors for a given flooding source is prohibitively high (thereby resulting in a maximum offset from the average established for the flooding source of greater than 0.25 foot) the Mapping Partner shall remodel the subject stream by applying either the VERTCON or the CORPSCON program to the effective hydrologic and hydraulic models. (NOTE: To date, these details and protocols have not been finalized and FIS Report paragraphs have not been formulated to address this situation.)

[February 2002]

B.5 Conversion from NAVD88 to NGVD29

Although a datum selection shall normally be determined during the Project Scoping phase (Volume I, Section 1.3) of a study/restudy, situations may be encountered when the Mapping Partner responsible for the new or revised flood hazard analysis provides flood hazard data referenced to NAVD88, but FEMA determines that a full conversion is not an acceptable solution because of cost constraints or other reasons. In this case, the Mapping Partner responsible for preparation of the Preliminary FIS Report and FIRM shall develop an average conversion factor and apply it to convert the flood elevations provided by the Mapping Partner responsible for the new or revised flood hazard analysis from NAVD88 to NGVD29. For static flood elevations, the Mapping Partner responsible for preparation of the Preliminary FIS Report and FIRM may apply VERTCON or CORPSCON to convert the NAVD88 elevations to NGVD29. In those situations where an average conversion factor is not practical, the Mapping Partner responsible for preparation of the Preliminary FIS Report and FIRM may apply the approaches outlined in Subsections B.4.1.2 and B.4.1.3 as warranted.

[February 2002]

B.6 Paragraphs for Flood Insurance Study Report

For all studies/restudies and map revisions, the Mapping Partner responsible for preparing the Preliminary copies of the FIS Report and FIRM shall follow the guidelines provided in Appendix J, which detail the appropriate paragraphs to address datums and datum conversions.

[February 2002]