Review of District Avulsion Method
Using Nora Flood on Tiger Wash

FCD 2011C002

Work Assignment 11

Task 2

Performed by

JE Fuller/ Hydrology and Geomorphology, Inc

Tempe, AZ

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Background

The District has developed a methodology to predict major avulsion potential on alluvial fan landforms. As part of FCD2011C002 Task 2, JEF performed analyses to evaluate the performance of this method based on a historic event on Tiger Wash. In late September 1997, remnants of Hurricane Nora traversed northwestern Maricopa County dropping significant rainfall within the Tiger Wash watershed. Almost 12 inches fell within a 24-hour period at the top of Harquahala Mountain. Over 4 inches fell at the gage near the apex.

Approach

JEF developed two FLO-2D models to hindcast the hydraulic characteristics of part of the Tiger Wash alluvial fan near its historic apex location near the FCD ALERT gage before (pre-Nora) and after (post-Nora) the 1997 rainfall and flood. A third FLO-2D model (predicted) was created to include an avulsion channel with a predicted size based on the results of the pre-Nora FLO-2D model. The pro version of the FLO-2D model (from 3:38pm April 11, 2014) was used for all of the modeling done for this report. The models were created outside of the GDS.

Topography for the post-Nora condition was compiled from a combination of 2014 point surveys provided by the District and 2001 10-foot contours. The pre-Nora topography was created by editing the 2001 10-foot contours with reference to 1953 aerial photography. The predicted topography was created by editing the pre-Nora contours to include a predicted avulsion channel. Figures 1 through 3 show the topography used in each FLO-2D model.

A model grid size of 20 feet was selected to represent the ground surface for the pre-Nora, post-Nora, and predicted conditions.

Manning's n-values were also adjusted to reflect the pre-Nora, post-Nora, and predicted conditions. Figure 4 shows a comparison of three model n-values.

An input hydrograph was constructed from previous HEC-1 modeling performed by the District and modified by JEF as part of work on Tiger Wash in 1999-2000. A model which attempted to recreate the Nora flood event was constructed using FCD ALERT rainfall data and a HEC-1 model developed by Steve Waters. An additional diversion was added to the model to reflect the new avulsion upstream of the current FLO-2D model. The resulting hydrograph is shown in Figure 5. The model peak discharge is about 5,200 cfs. Slope-area computations of flood high water marks performed by JEF in 2000 indicated about 3,800 cfs upstream of the apex. A map from the JEF, 2000 report showing the peak flow estimates from slope-area surveys is shown in Figure 6.

Models were run with the 5,200 cfs peak hydrograph (full) as well as a ratioed 3,800 cfs hydrograph (ratio) to match the slope-area peak. Hydrographs were input to the FLO-2D grid about 3,000 feet upstream of the avulsion resulting from the Nora flood in order to allow the model to stabilize well upstream of the avulsion location.

Figure 1. Pre-Nora Topography

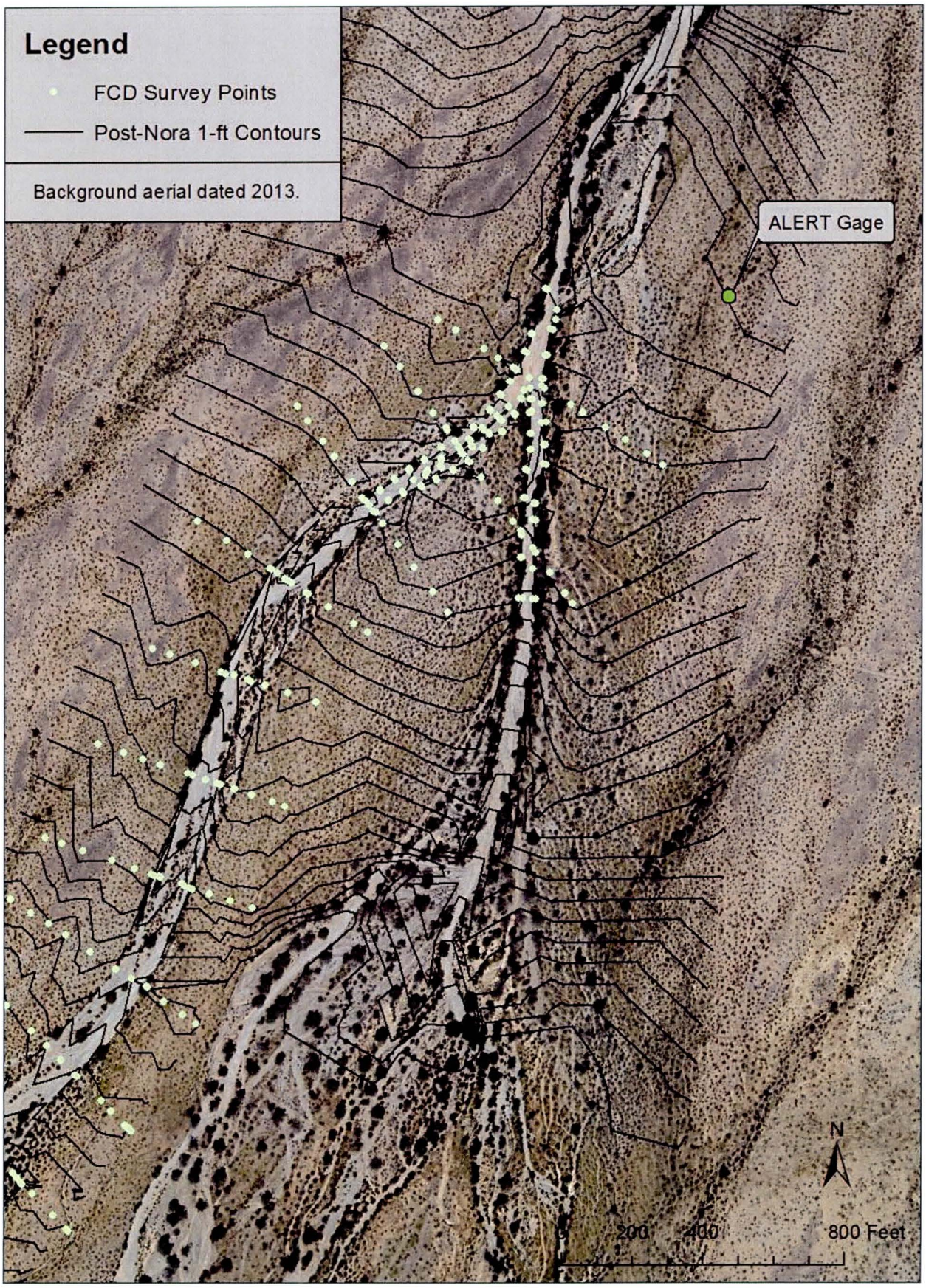


Figure 2. Post-Nora Topography

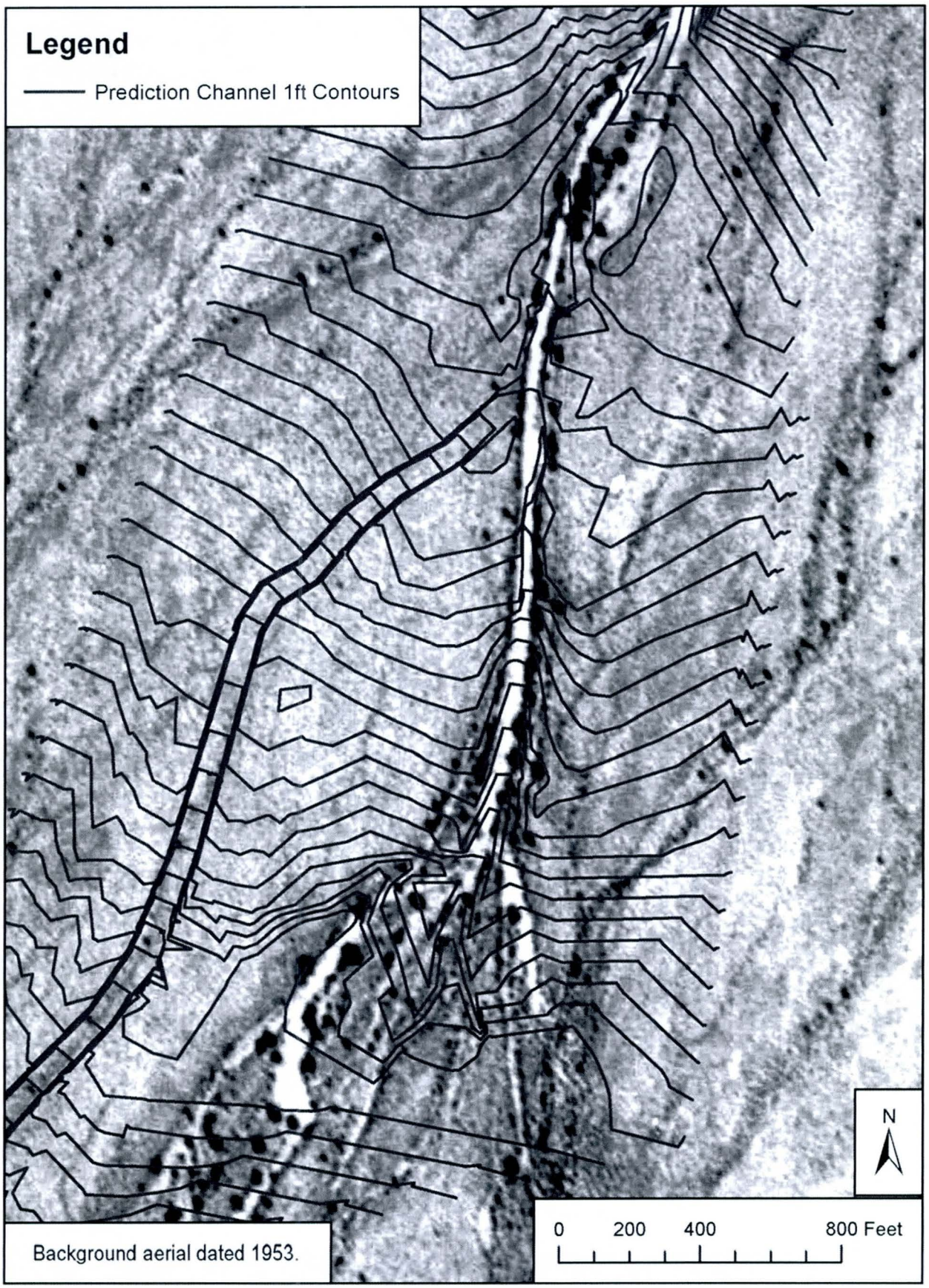


Figure 3. Predicted Topography

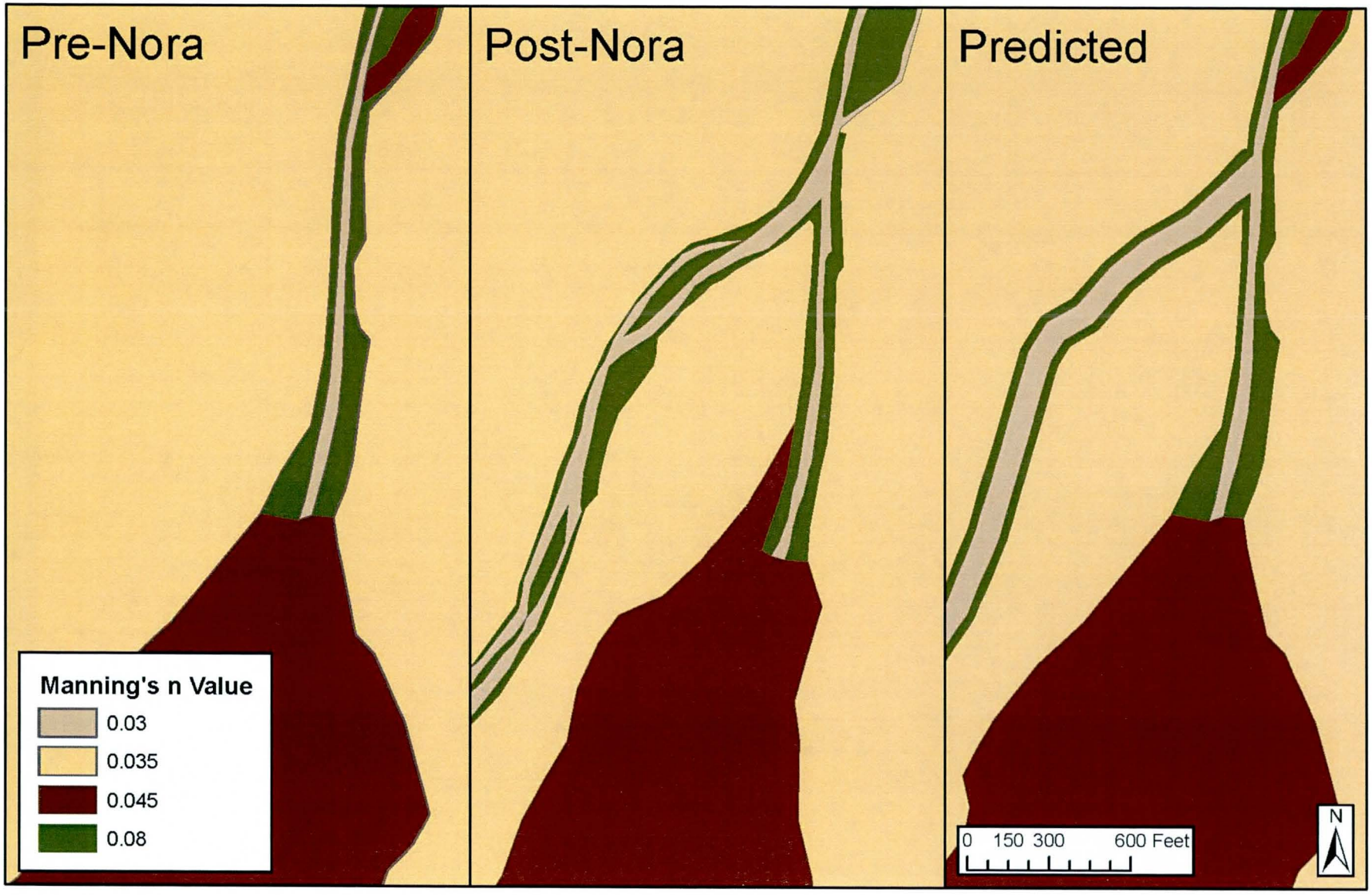


Figure 4. Pre-Nora, Post-Nora, and Predicted Conditions Manning's n-values

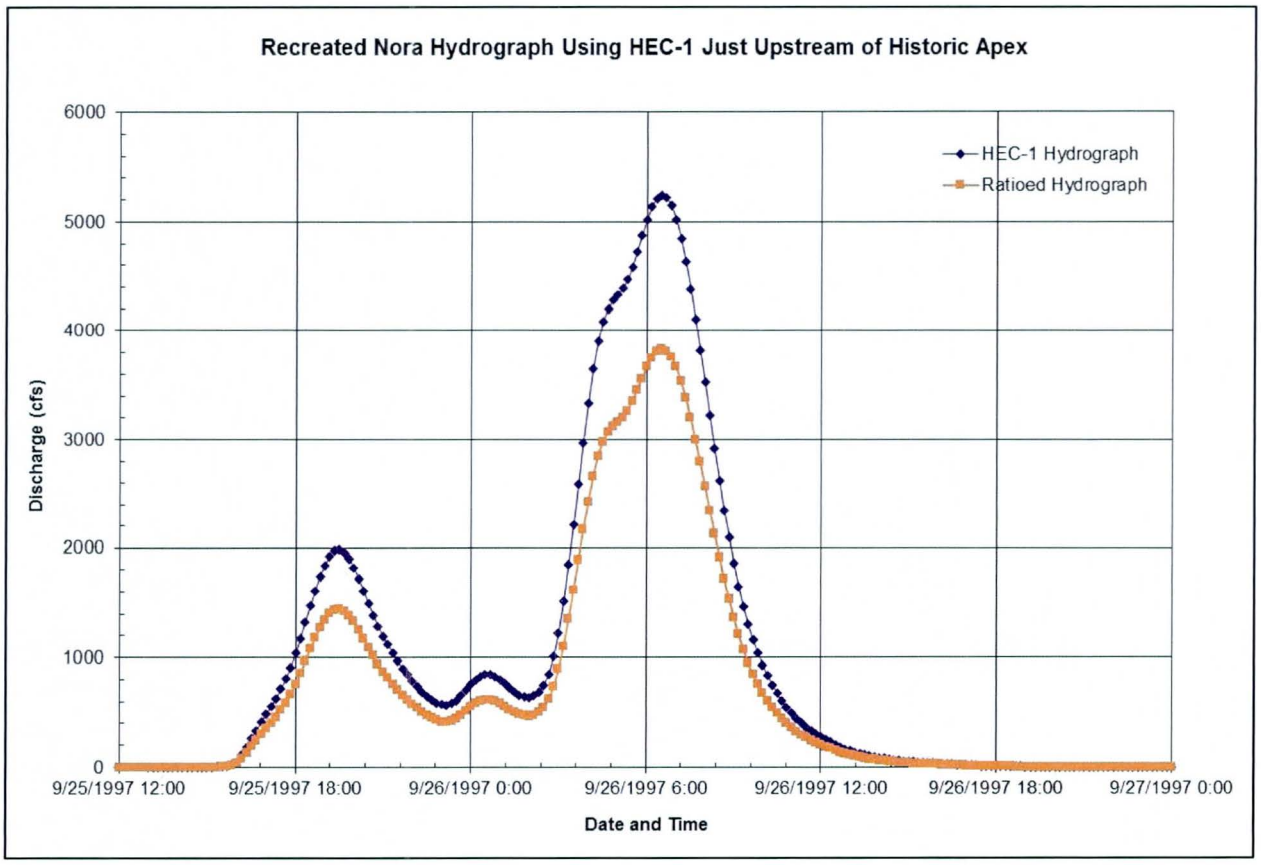
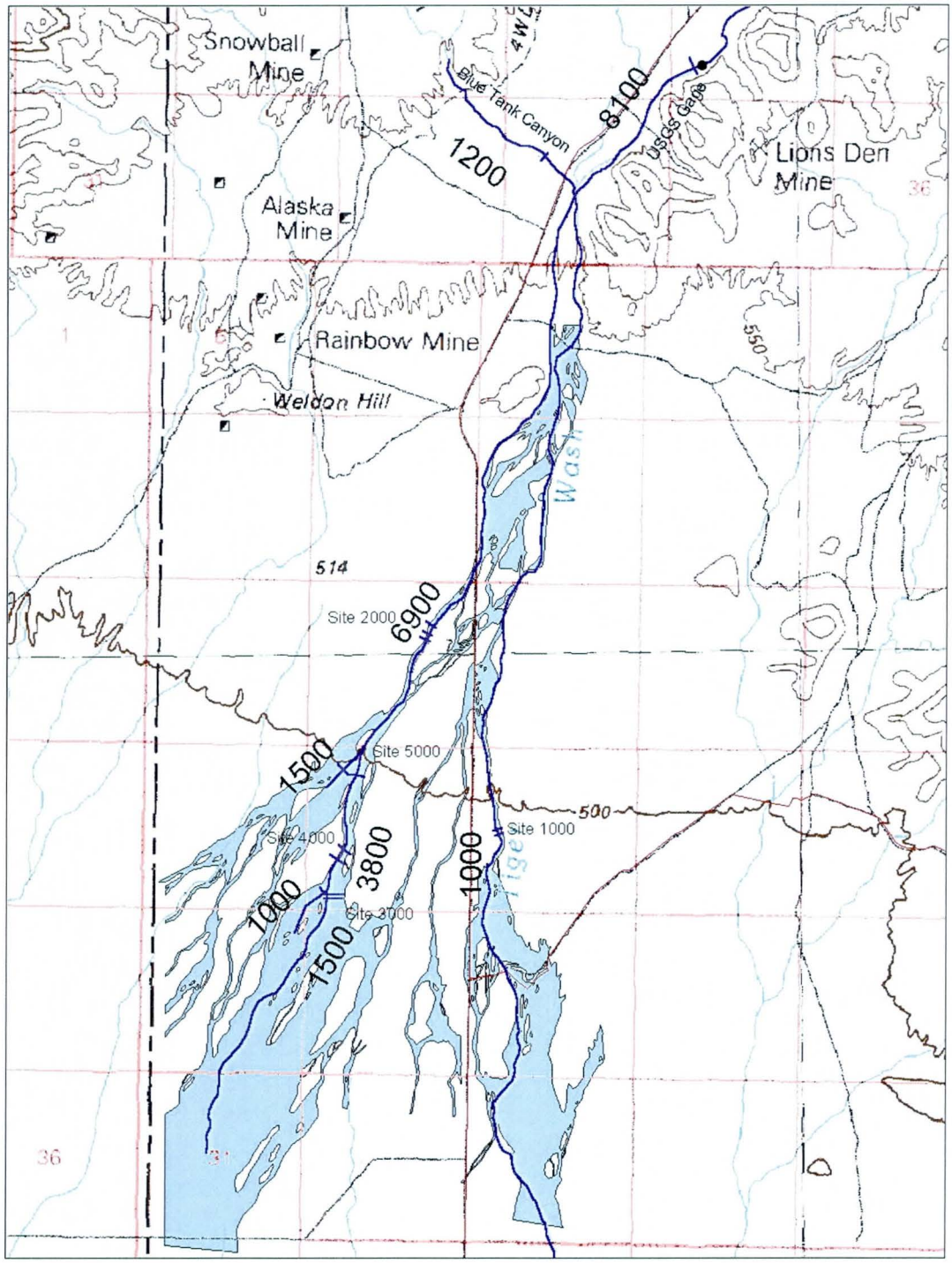


Figure 5. Recreated Nora flood hydrograph at historic apex



Note: All discharges given in cubic feet per second.

Figure 1. TS Nora Flood Inundation, September 26, 1997

FCD No. 98-48
Assignment No. 2
Subtask 2
JE Fuller / Hydrology & Geomorphology, Inc.
in association with the Arizona Geological Survey
March 2000

N

3000 0 3000 6000 Feet

1:36000

Figure 6. Nora flood peak flow estimates from JEF, 2000.

Cross Sections

Floodplain cross sections were added to each of the models to better understand and compare model results. Cross sections XS 01 through XS 08 are the same for each of the models. The adding of cross sections was an iterative process. Because of the iterations, all of the cross sections are shown, though not all of the results are reported in detail.

Cross sections XS 01 through XS 04 were originally added to understand how the flow is being split at the avulsion.

Cross section XS 05 is a cross section that was requested by the District. Cross section XS 05 shows the flow at the location where the observed avulsion occurred. The cross section is shown parallel to the bank of the main wash to capture the flow that would have overtopped the bank in the existing conditions to create the avulsion. The hydrograph from cross section XS 05 for the pre-Nora model is shown as Figure 7. The output files HYCROSS.OUT and CROSSMAX.OUT from the FLO-2D model show a spike for the peak discharge at XS 05. The model was re-run with a lower courant number to try to eliminate this issue, but was unsuccessful. The spiked peak discharge occurs between time steps and is believed to be an issue with the model rather than representative of the actual hydrograph. The spiked peak discharge was discounted and not shown in Figure 7 since it is not consistent with the overall shape of the hydrograph.

Cross sections XS 06 through XS 08 were added to help size the predicted avulsion channel. The thought behind the predicted avulsion channel was to size it based solely off the results of the pre-Nora model and not using the advantage of hindsight. Even though cross section XS 05 was drawn where avulsion actually occurred, the existing model shows an out brake about 300 feet upstream. A major reason for the difference in where the pre-Nora model shows an outbreak and where the observed avulsion occurred can likely be attributed to the use of 10-foot contours to create pre-Nora model topography as discussed in the Approach section of this report. Of the three cross sections (XS 06 through XS 08), the peak discharge from cross section XS 08 was used to size the predicted avulsion channel.

In addition to these eight cross sections, cross section XS 09 was added in the post-Nora and predicted conditions to compare the observed avulsion hydrograph verses the predicted avulsion channel hydrograph. Finally, cross sections XS 10 and XS 11 were added to the post-Nora condition for the purpose of using the District's major channel avulsion method on two additional potential outbreaks shown in the post-Nora model as discussed in the conclusion section of this report.

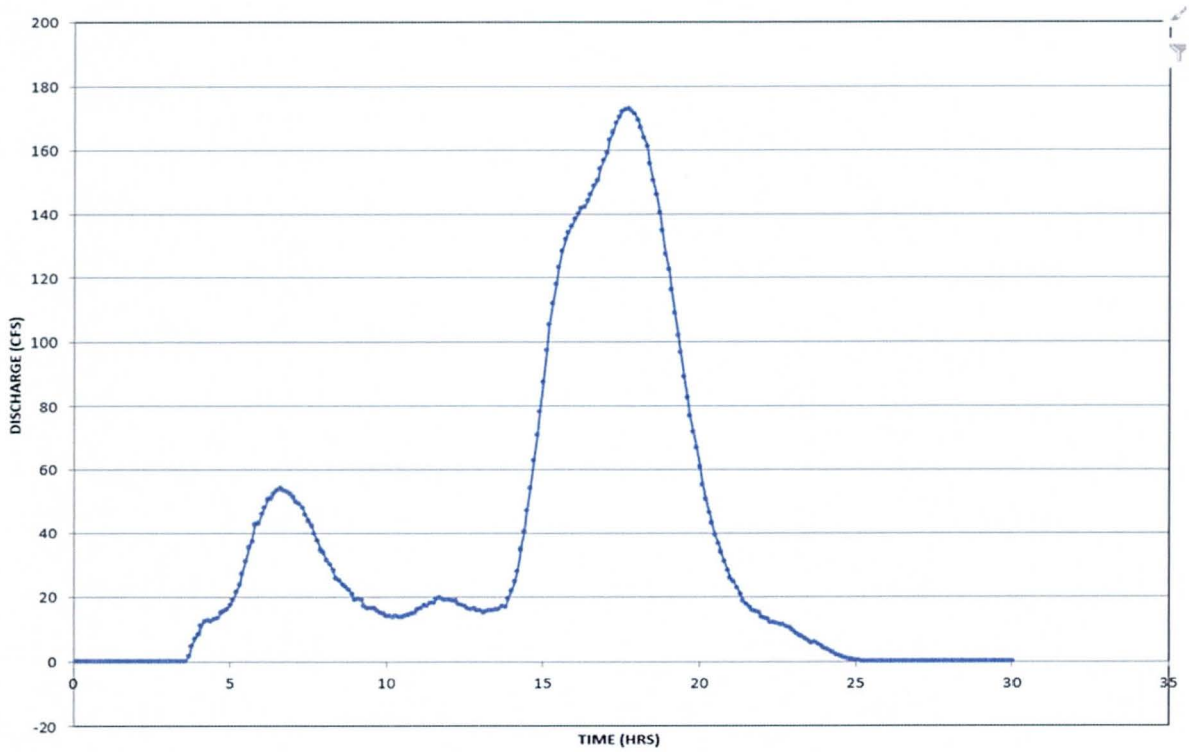


Figure 7. Pre-Nora Ratio Cross Section XS 05 Hydrograph

Results

Results for the pre-Nora, post-Nora, and predicted conditions are reported below. Figure 8 shows the pre- versus post-Nora flood depths and peak discharges at four cross sections for the full HEC-1 hydrograph. Figure 9 shows the same comparison for the hydrograph ratioed to the slope-area peak just upstream of the apex.

The resulting peak discharges for the pre-Nora condition in the right overbank (XS 08) were used to compute channel forming depths and widths based on the USACE figures from EM1110--2-1418 as described in the Districts major channel avulsion method. The application of the results to the Corps figures are also shown in Figures 10 and 11. Note that the D50 is not known for the avulsion area. However, it is reasonable to assume based on field observations made previously that the D50 is probably somewhere between coarse sand and 1 to 2 inches (20-50 mm) (Figure 8). For the channel forming width, Tiger Wash in the vicinity of the avulsion probably lies somewhere between Curve 2 and Curve 3.

The results for the predicted avulsion channel depth and width with these assumptions are compared in Table 1 along with an estimate of observed channel depth and width made from examination of the District survey data and recent aerial photographs. Note that the predicted channel widths compare reasonably well with the observed range of channel widths in the avulsion channel. Predicted channel depth appears to be overestimated.

The dimensions of the predicted avulsion channel used for the predicted conditions model were based off of the results from the ratioed pre-Nora condition model. The cross sectional shape of the predicted avulsion channel is trapezoidal with 4:1 side slopes. This assumption came from looking at the cross section of the pre-1997 Tiger Wash channel shown on page 19 of Geomorphology and Hydrology of an

Alluvial Fan Flood on Tiger Wash, Maricopa and La Paz Counties, West-Central Arizona report (AZ Geological Survey, 2004). The width of 75 feet estimated from Figure 11 is applied to the median depth of the cross section. The alignment for the predicted avulsion channel is based off of an aerial photo of the wash after the 1997 Nora storm event. Figure 12 shows a comparison of depths for the predicted avulsion channel verses the observed avulsion modeled in the post-Nora conditions. The hydrographs for the predicted and observed post-Nora avulsion are compared in Figure 13. While the shape of the hydrograph is similar for the observed and predicted channels, the peak magnitude of the predicted avulsion channel is approximately 1.3 times greater than the observed avulsion. This increase is due to the increased efficiency of the uniform predicted avulsion channel.

It should be noted that the post-Nora model results indicate a relatively even split in peak discharge between the new avulsion channel and the pre-Nora main channel. Since more than 15 years has passed since the Nora flood, it is possible that the observed characteristics have been influenced by discharges through the 1997 avulsion channel.

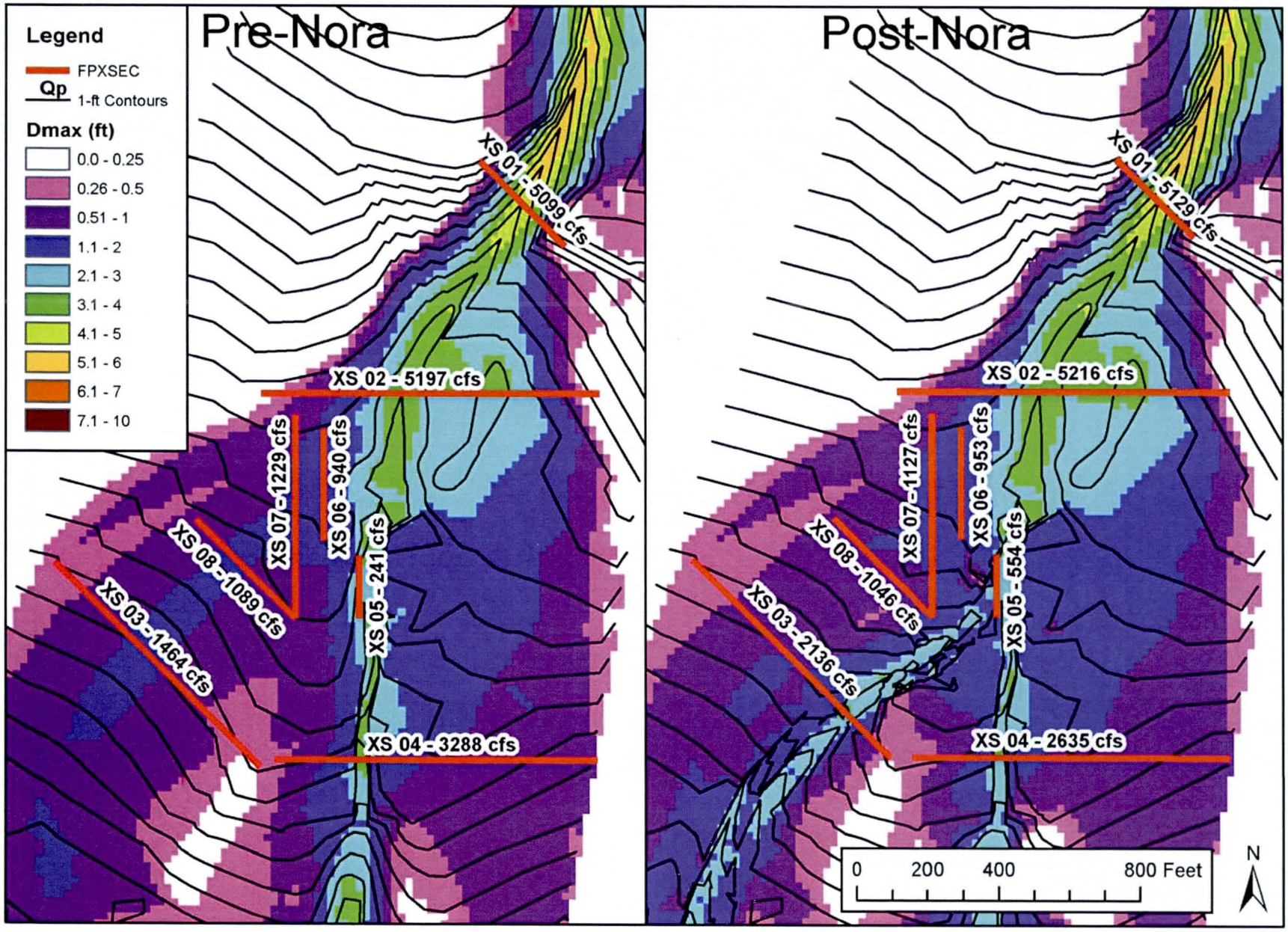


Figure 8. Comparison of Pre- vs. Post-Nora FLO-2D Results - Full HEC-1 Hydrograph

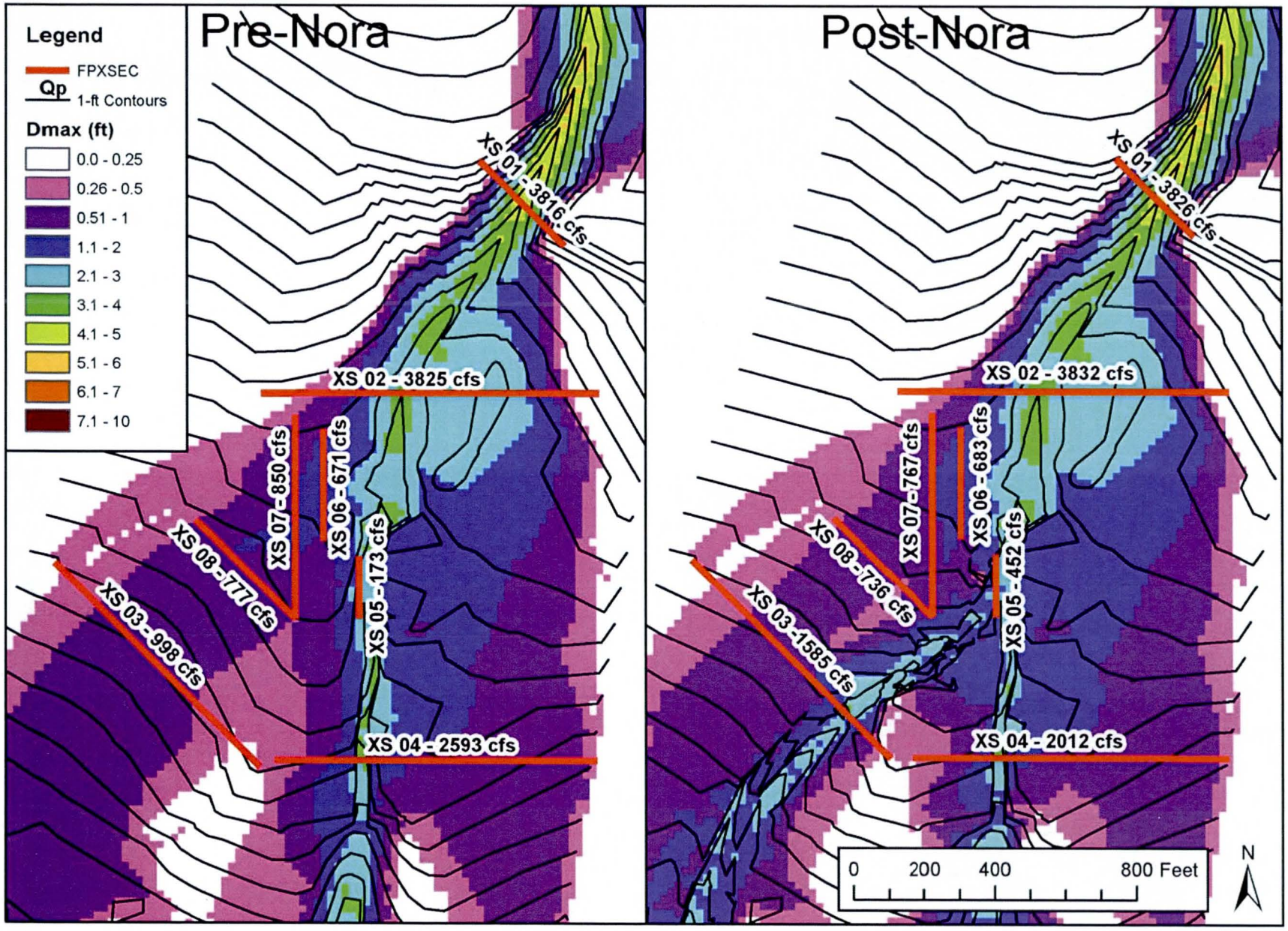


Figure 9. Comparison of Pre- vs. Post-Nora FLO-2D Results - Ratioed Hydrograph

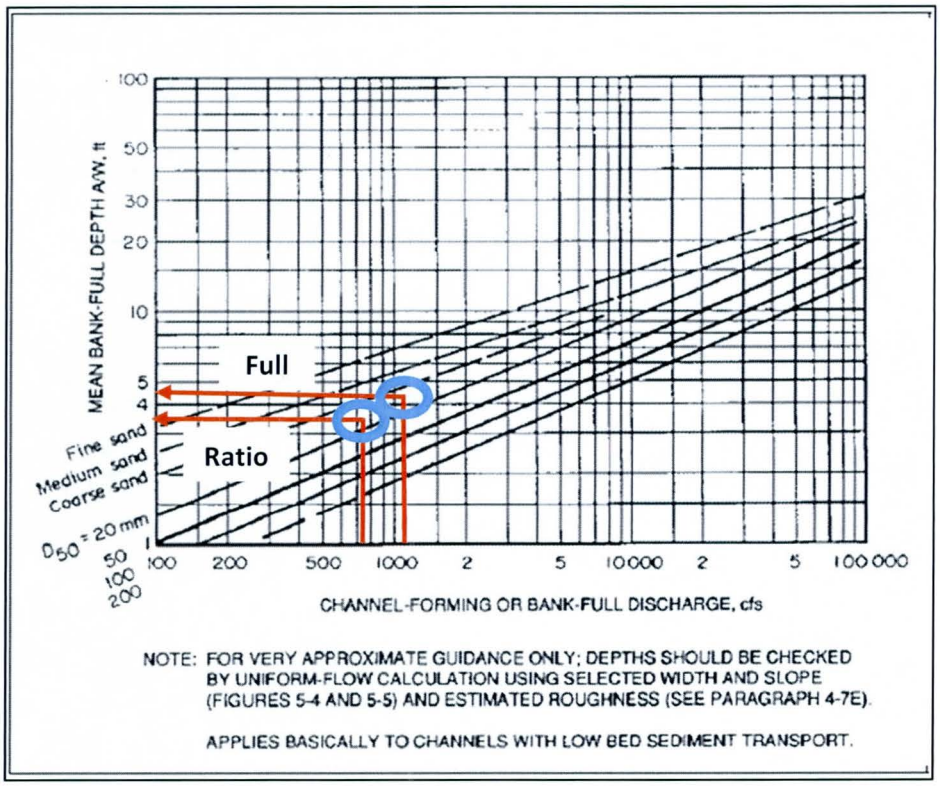


Figure 10. USACE Channel Forming Depth vs. Discharge (USACE, 1994)

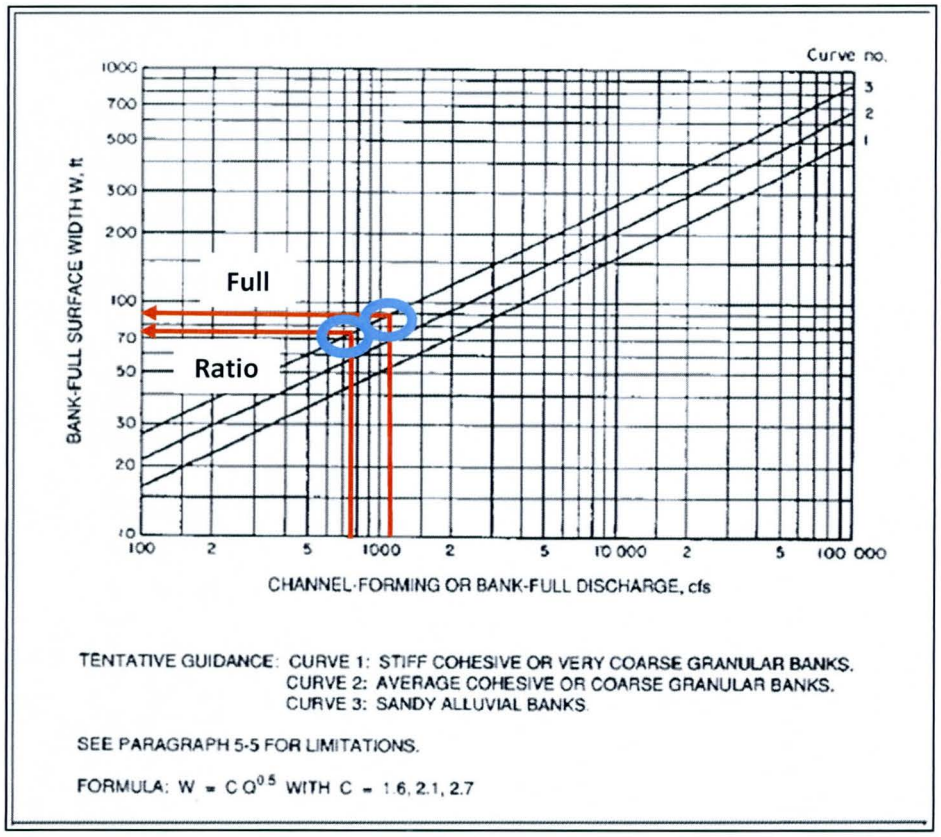


Figure 11. Channel Forming Width vs. Discharge (USACE, 1994)

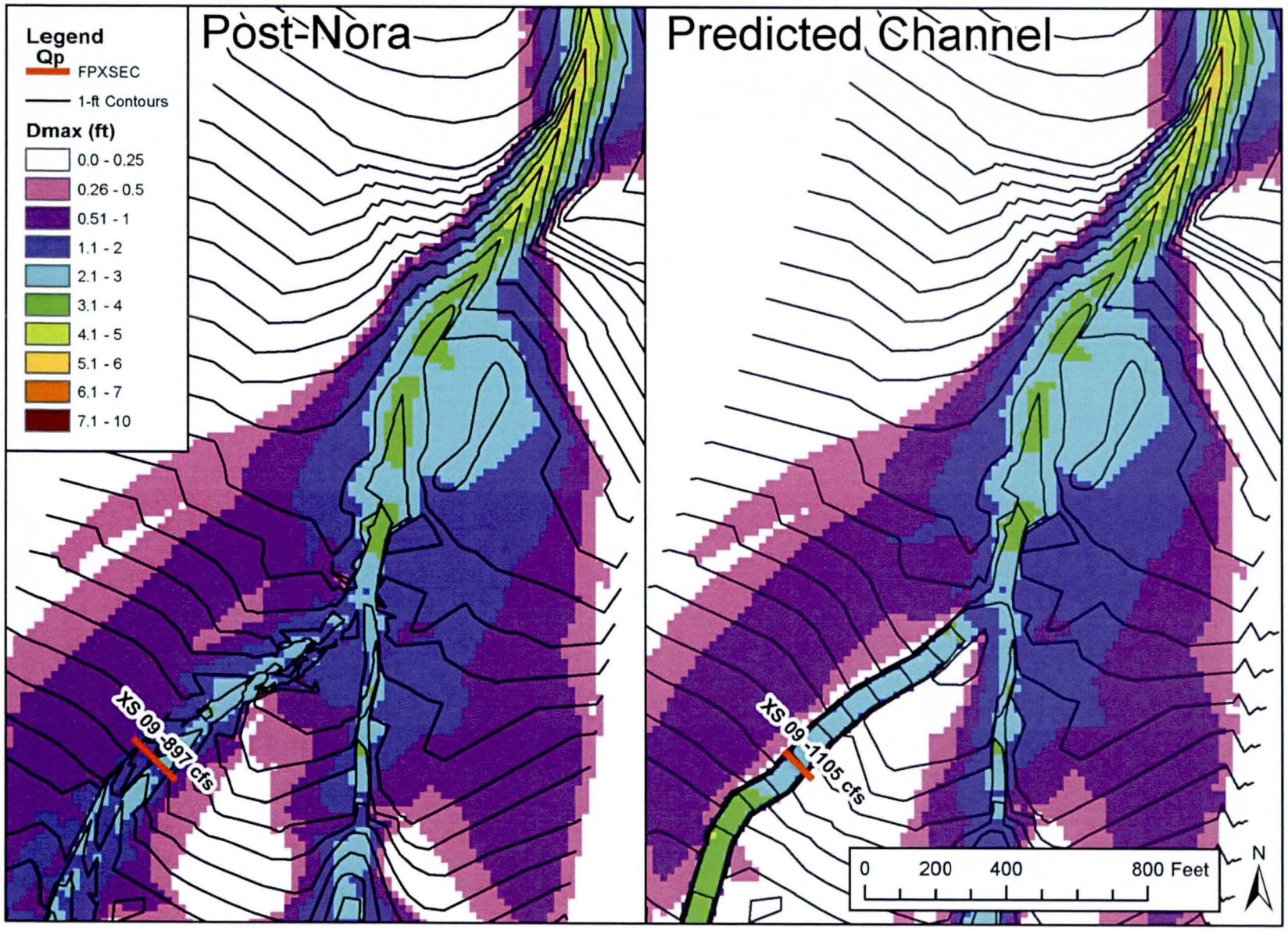


Figure 12. Comparison of Post-Nora vs Predicted Condition Results – Ratioed Hydrograph

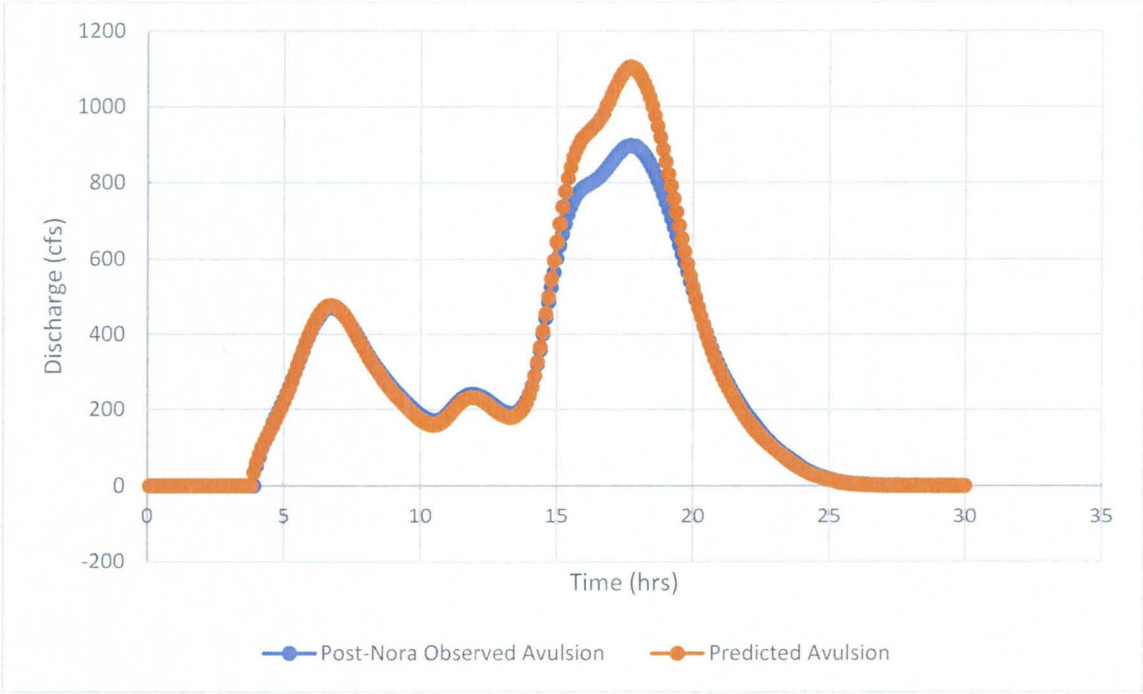


Figure 13. Post-Nora Observed Avulsion vs. Predicted Avulsion Channel Hydrograph at Cross Section XS 09

Table 1. Comparison of Computed and Observed Avulsion Channel Geometries

Scenario	Peak Discharge in ROB	Channel Forming Depth	Channel Forming Width
Full HEC-1 Hydrograph	1089 cfs	4.5 ft	90 ft
Ratioed to 3,800 cfs	777 cfs	3.5 ft	75 ft
Observed	1000 cfs*	~ 2 ft	70 to 110 ft
'* avulsion peak estimate from slope-conveyance estimate JEF, 2000			

Conclusion

Comparison of one of the District's major channel avulsion methods appears to reasonably predict potential channel avulsion width. Channel depth may be somewhat overestimated based on this one example. It should be noted that numerous approximations were required to develop the pre-Nora topography. Better pre- and post-Nora topography is suggested before fully vetting the accuracy of this avulsion prediction method.

Based on the modeling results of the post-Nora ratioed conditions, it appears there are two potential future outbreaks which might cause an avulsion. The peak discharges of the outbreaks and application to the Corps tables are shown in Figures 14 through 16. The predicted avulsion dimensions are presented in Table 2.

Table 2. Potential future avulsion dimensions

Cross Section	Peak Discharge	Channel Forming Depth	Channel Forming Width
XS 10	462 cfs	3.0 ft	60 ft
XS 11	814 cfs	3.5 ft	80 ft

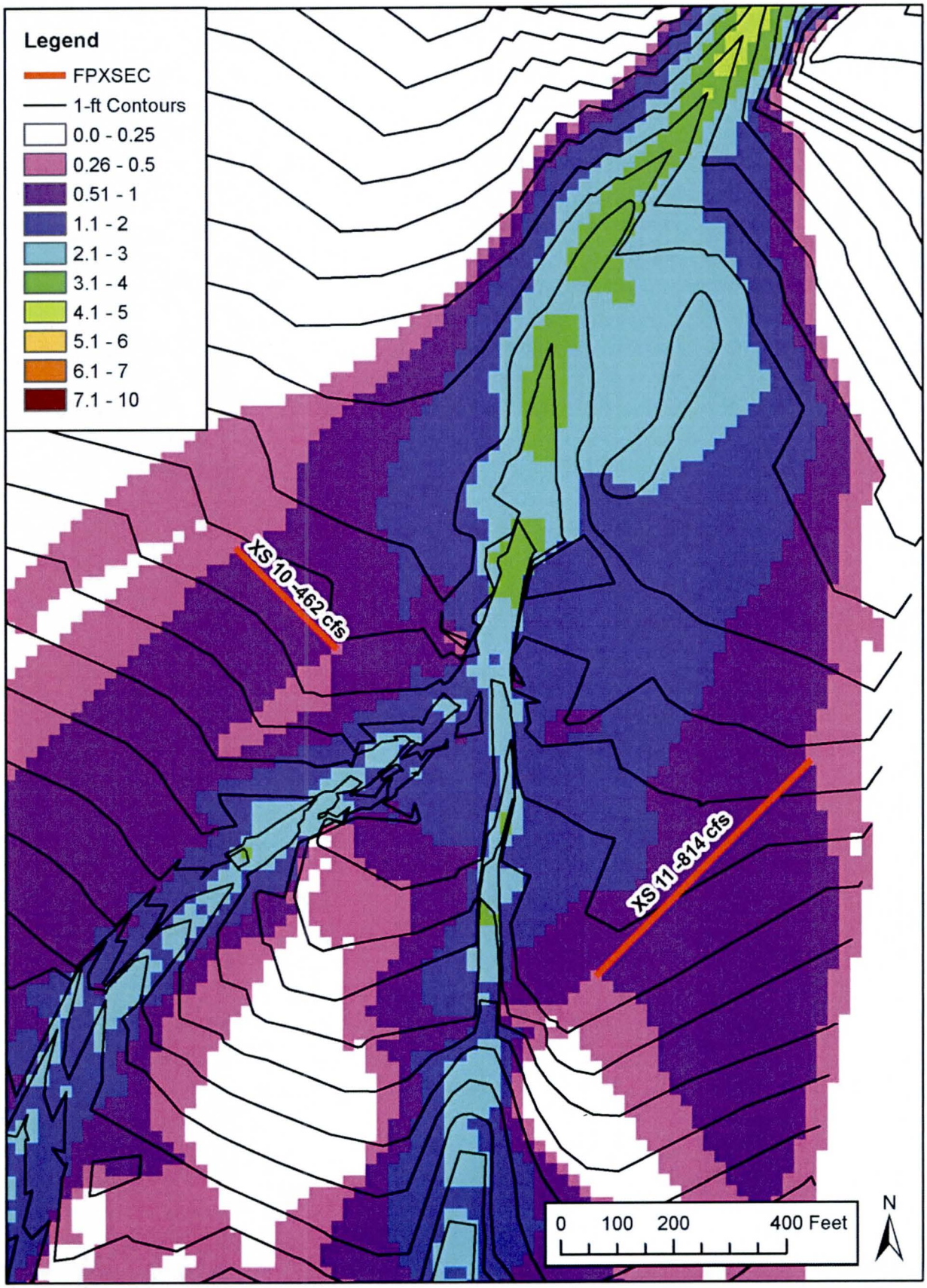


Figure 13. Potential Future Outbreak Locations Based on the Post-Nora Ratio Conditions Model

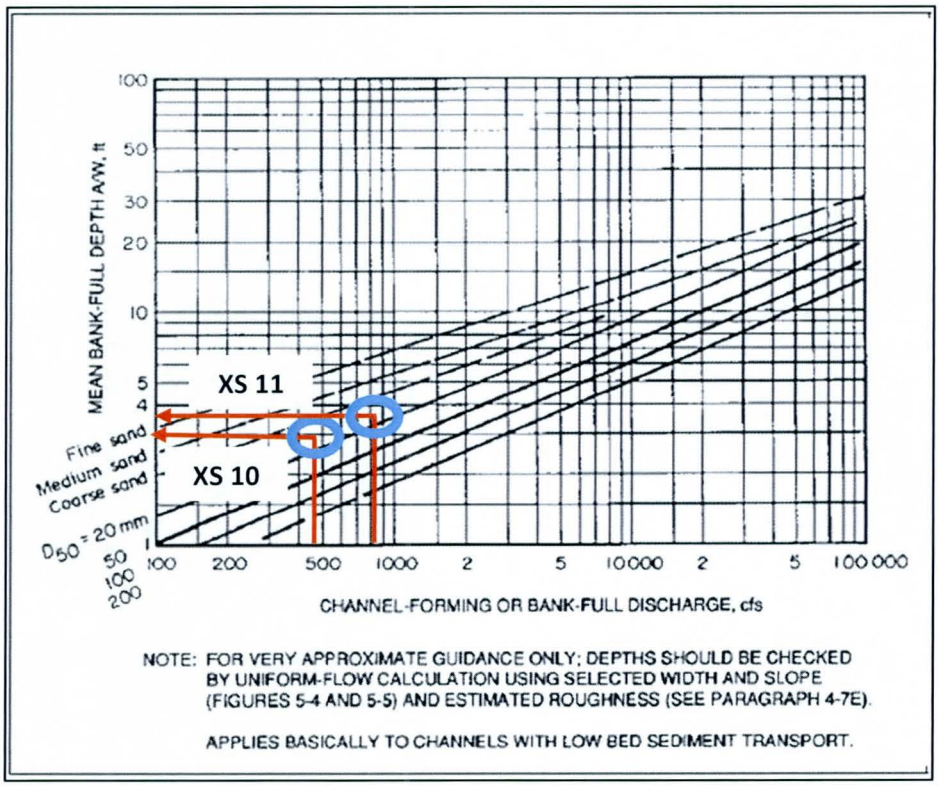


Figure 14. USACE Channel Forming Depth vs. Discharge (USACE, 1994)

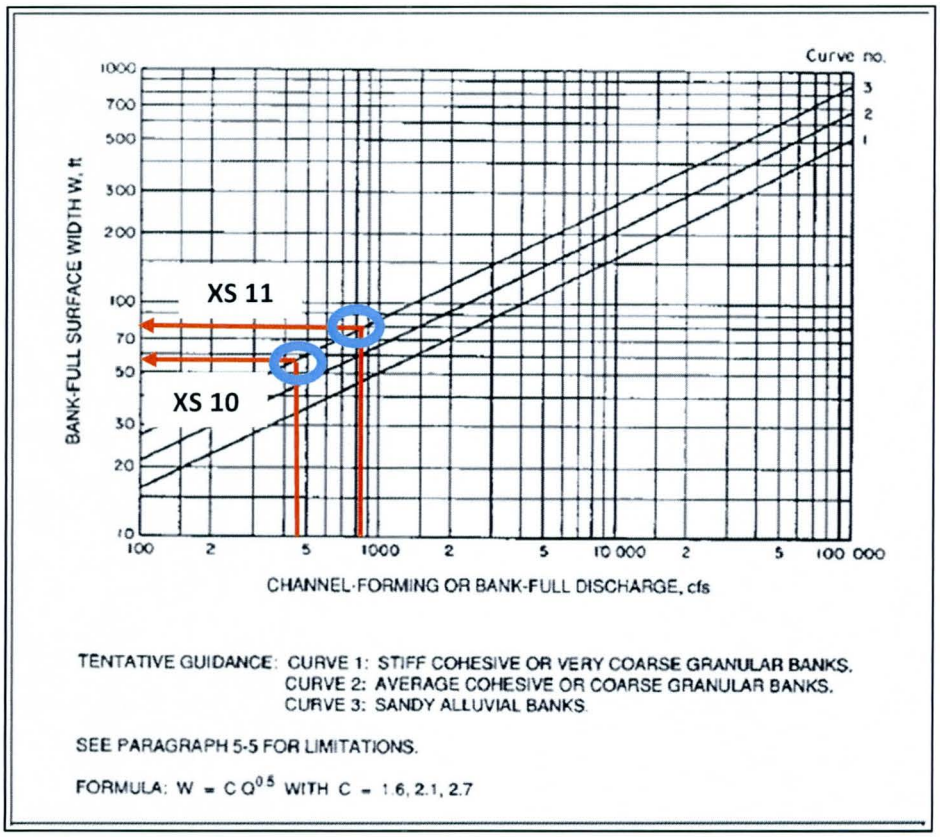


Figure 15. Channel Forming Width vs. Discharge (USACE, 1994)

References

JEF, 2000, Detailed Inundation Mapping of the September 1997 Flood on the Tiger Wash Piedmont Distributary System, performed for FCDMC under FCD 98-48, Assignment No. 2, in association with Arizona Geological Survey.

USACE, 1994, Channel Stability Assessment for Flood Control Projects, EM 1110-2-1418, USACE, Dept. of Army, Washington, DC.