YELLOWSTONE RIVER
FLOOD STUDY

REPORT TEXT

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TECHNICAL REPORT

Prepared for:

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1.0 INTRODUCTION

1.1. BACKGROUND

Livingston City officials and residents have expressed objections over the proposed flood insurance mapping and associated flood data presented by the Federal Emergency Management Agency (FEMA) for the Yellowstone River and Fleshman Creek within the City of Livingston. In particular, the broad extent of the flood boundaries and large number of properties included in the floodway are of primary concern. Given the magnitude of such implications, Clear Creek Hydrology, Inc. (CCH) has been retained by the City of Livingston to assess the validity of the original study, and subsequently re-map flood and floodway boundaries for the Yellowstone River from Highway 89 to the north (downstream limit) and Interstate 90 to the south (upstream limit). A summary of CCH's findings are presented in this Technical Report prepared for the City of Livingston and FEMA.

1.2 REVIEW OF CORPS OF ENGINEERS STUDY

The original flood insurance study (FIS) within the City of Livingston was completed by the U.S. Army Corps of Engineers (Corps), Omaha District, Omaha, Nebraska in 2006. Hydraulic modeling and subsequent flood boundary mapping within the FIS indicated a large portion of the City of Livingston would be subject to flooding from Fleshman Creek as a result of water overtopping the banks of the West Branch of the Yellowstone River along Sacagawea Park and flowing into the Fleshman Creek drainage channel.

An engineering review of the hydraulic model and assumptions was completed by CCH to evaluate the Corps' findings and to prepare a revised flood study as necessary. The review included detailed field surveys to check the precision of the topographic mapping data and elevations that were used for calculations of potential overflow from the West Branch of the Yellowstone. The work also included a review of effective discharges, cross-section spacing and skew, ineffective flow areas, roughness coefficients (manning's "n" values), and assumptions used in the estimation of flow calculated by the Corps. Information ascertained by CCH as part of this review is provided below.

- Peak discharges used by the Corps in the analysis for the Yellowstone River were obtained by frequency analysis of the long-term USGS gage record at Livingston and were deemed to be valid. No further work is necessary in regard to effective discharges used in the FIS with the exception of flow distributions as discussed below.
- Cross-sections developed by the Corps were not consistent with the available topography. In general, they were skewed incorrectly for most areas, especially within the left overbank of the river and Fleshman Creek, causing concern regarding the calculation of the flood profiles for the entire study reach, particularly for the Fleshman Creek calculations. This is consistent with a memorandum prepared by Mike Knutson for the State of Montana Department of Natural Resources and Conservation (DNRC) expressing concern with the flow paths, layout of cross sections for Fleshman Creek, and resultant flood elevation and floodway calculations.
- Several ineffective flow areas were placed by the Corps within the geometric data which do not reflect the actual cross sectional area that would be available for flow throughout the entire study reach. Physical barriers were placed within cross section data by the Corps which are non-existent within the floodplain areas.

- Roughness coefficients as high as 0.65 used in the Corps study are not consistent with values that are reasonable, generally less than 0.200.
- Following detailed ground surveys by CCH, the assumptions used by the Corps to calculate weir flow from the West Branch Yellowstone River and flow into Fleshman Creek were determined to be errant. Based on their calculations, 4,592 cfs would leave the West Branch of the Yellowstone River during the 100-yr flood.
- CCH's field surveyed natural ground elevations were found to be high enough to prevent water from leaving the West Branch of the Yellowstone channel which would flow into Fleshman Creek for all of the return frequency floods that were studied (10-, 50-, 100-, and 500-year).

The combination of the issues and errors identified above, particularly with the flooding source removed from weir flow into Fleshman Creek, were considered sufficient to require a re-study of Yellowstone River hydraulics and geometry to recalculate the necessary flood data needed to develop new floodplain boundaries and floodway mapping for the FIS. CCH was authorized by the City of Livingston in April 2008 to develop a new hydraulic model and revise the flood boundaries and floodway mapping of the Yellowstone River through the study reach. The study was to be submitted by the end of May, 2008 at the request of FEMA officials.

2.0 YELLOWSTONE RIVER RE-STUDY

The FIS re-study was initiated by CCH extending from U.S. Highway 89 to the north (downstream limit) to Interstate 90 (upstream limit). Similar to the Corps study, HEC-GeoRAS in ArcView Version 8.3 was utilized to obtain all of the required hydraulic data and develop new flood boundary mapping. Conditions and assumptions incorporated into the re-study are listed in the following.

- Existing topography provided by the Corps is sufficient for digitizing new cross sections.
- Detailed field survey data would be obtained and utilized to enhance topographic data to provide additional accuracy to the digitized cross sections where critical elevations are required.
- Overflow from the West Branch of the Yellowstone to Fleshman Creek as computed by the Corps does not occur. This was verified by detailed ground surveys.
- The 10-, 50-, 100-, and 500-year effective discharges from the Corps study were used in the re-study.
- All existing levees for all reaches of the Yellowstone River including the East and West Branches are not certified and were not considered for any hydraulic calculations.
- The man-made divide between the East and West branches of the Yellowstone River immediately upstream of Interstate 90 is not effective (FEMA requirement). This condition resulted in recalculation of flow distribution within the East and West Yellowstone channels.
- Down stream boundary conditions (water surface elevations) for the required profiles were taken form the profiles developed by the Corps.
- Aerial photography of the 1974, 1996 and 1997 historic flood events were utilized as a guide for precisely orienting the location of new cross sections.

Specific activities completed as part of the re-study and revised mapping include: (1) detailed field surveys of natural ground elevations and associated topography, (2) HEC-RAS hydraulics modeling, and (3) flood boundary and floodway mapping. These three elements are briefly described in subsequent sections.

2.1 FIELD SURVEY

Detailed field surveys were completed by CCH to validate assumptions as well as provide additional detailed topography information within critical areas for the re-study. Specific emphasis was given to the reach along Sacajawea Park where the Corps had indicated flow would leave the West Branch of the Yellowstone River and flow into Fleshman Creek. A plot of the natural ground elevations surveyed by CCH compared with that of the Corps elevations and calculated water surface elevations for the 100-year flow is included as an attachment to this report. Surveys were completed for the study reach extending from Interstate 90 to the south and Highway 89 to the north. All vertical data were referenced to NAVD88.

2.2 HYDRAULICS

HEC-GeoRAS was used to initiate the hydraulic model setup for the Yellowstone River as well as complete flood boundary and floodway mapping. HEC-RAS 3.1.3 was used for the hydraulic calculations and modeling. The original Corps triangular irregular network (TIN) elevations were used to extract cross sections, stream length, and overbank floodplain flow lengths. This base information was supplemented with field surveys of underwater cross-sections, over-bank floodplain areas, and natural ground elevations along the left bank of the Yellowstone River to provide additional detailed ground elevation information.

Downstream boundary conditions in the model were taken directly from the existing Corps values near the Highway 89 bridge crossing. Development of the flow boundary conditions for the East and the West branches for the 10-, 50-, 100- and 500-year discharges was done by trial and error until an energy balance was achieved between the two branches.

It should be noted that there are minor differences in calculated water surfaces immediately upstream of Highway 89, where cross sections overlap with the Corps data, because of newer, more detailed field survey data, new digitized cross-section information, and detailed field survey information used for underwater portions of the cross sections.

Additionally, as required by FEMA standards, the divide between the West and East branches of the Yellowstone, immediately upstream of Interstate 90, were not considered to be effective. This resulted in the distribution of flows for the CCH study to be different when compared to the Corps study values. Without consideration given to the earthen divide more flow is calculated to be contained in the East Branch of the Yellowstone. This naturally reduces the amount of water that was previously considered for the West Branch.

Revised flow distribution values were calculated using data generated within the HEC-RAS model. The resultant flow values for all study areas are contained in the modeling results included with this report.

Aerial photography of the 1974, 1996 and 1997 high water events were utilized to lay out cross section locations for the main channel and overbank floodplain areas. The new HEC-RAS model (including the Main, West and East Branches) contained a total of 59 cross sections compared to a total of 38 for the Corps study (beginning at CCH cross section 45310 at the downstream end).

Water surface elevations resulting from the new, more detailed HEC-RAS models were thoroughly evaluated and compared to surveyed ground elevations to determine if there were any locations where Yellowstone flood water may overflow into the Fleshman drainage. It was concluded that both the 100-year and the 500-year Yellowstone River flood events would be confined to the Yellowstone channel and adjoining floodplain areas, without overtopping the natural bank/ground elevations and getting into the Fleshman Creek drainage. A comparison of the calculated water surface profiles for the 100-year flood and the natural ground profiles for the area in the vicinity of Sacajawea Park are presented as an attachment to this report.

Roughness coefficients (manning's' "n" values) were selected using a detailed review of the existing aerial photography and a ground survey of high water flow events recorded on May 19th and 20th, 2008. A horizontal variation of "n" values was used to more precisely reflect variable roughness coefficients throughout the entire boundary of the cross section data.

2.3 Flood Boundary and Floodway Mapping

When all of the HEC-RAS data requirements were finalized and verified, they were imported back to HEC-GeoRAS for identifying the floodplain and floodway boundaries. Flood boundaries for the 100- and 500-year floods and the floodway are shown on the enclosed flood maps. There are several areas where the calculated 100-, and 500-year flood elevations are close to overtopping natural ground elevations. State law require a flood limit to be set based on actual ground elevations even though the calculated flood elevations may be very near to overtopping the natural ground elevations.

The effective flow area widths that were generated by the HEC-RAS model were selected with use of the detailed topographic mapping at a scale of 1:1200 with a 2 foot contour interval. In most cases, these widths are presented as the floodplain limits and shown on the flood boundary/floodway maps. Due to the precision of the topographic mapping there may be areas that are either above or below the calculated water surface elevations for the 100-and/or 500-year year floods but are not designated as such on the maps.

Fleshman Creek and its independent floodplain and floodway were not specifically part of this study. Corrections to the Corps study and mapping show that the flood flows associated with the Yellowstone River 100-, and 500-year events remains within the Yellowstone channel and adjacent over-bank floodplain areas. The hydraulic modeling indicates that floodwaters from the Yellowstone do not flow into the Fleshman Creek drainage. Accordingly, previous mapping of the floodplain and floodway boundaries for the Yellowstone River proposed by FEMA has been determined to be in error. The revised floodway boundary as calculated for the Yellowstone River containing the entire flow of 38,300 cubic feet per second (cfs) is presented on the new maps developed as a part of this re-study.

Floodways were initially calculated using an equal conveyance reduction and a target water surface rise of 0.5 feet. Actual encroachment stations were then established using Method 1 for final calculations. The resultant boundaries are shown on the flood boundary/floodway maps and values that were calculated for the encroachments are also included with the data provided with this report.

3.0 CONCLUSION

Because of more detailed field surveys and revisions to the hydraulic models of the Yellowstone River prepared by CCH for the Main, West and East Branches of the Yellowstone River between the State Highway 89 bridge, upstream to Interstate 90, the preliminary FIS flood mapping and associated hydraulic and floodway data presented by FEMA have been determined to be invalid. Flood flows previously determined by the Corps to leave the Yellowstone River channel and flow into Fleshman Creek will not occur due to the presence of natural high natural ground along the western bank of the Yellowstone.

For this study, only the Yellowstone River was to be considered. Since the calculated water surface elevations were unknown at the beginning of this study the initial cross section layout included the Fleshman Creek channel and overbank areas. However, no floodplain data were calculated specifically for Fleshman Creek above cross section 49588. Downstream of this section the Yellowstone River does flow into the Fleshman Creek drainage during the 500-year flood event. These areas are shown on the floodplain/floodway maps.

It is believed that for future study of the Fleshman Creek channel, the 100-year flood depths associated with this creek will most likely have an average depth of less than 2 feet. (The existing Corps model shows calculated depths for the 100-year event as great as 6 feet for the overbank floodplain areas). It is believed that most of the homes located within the Fleshman Creek overbank areas are elevated such that very few residences and buildings will be impacted by floodwaters during the 100-, and 500-year flood events. The majority of the floodwaters associated with Fleshman Creek will likely be contained within the street areas and it is believed that the calculated floodway will remain at or very near the top of banks associated with the main channel area. Without the Yellowstone River contributing floodwaters to the Fleshman Creek drainage, the floodplain and regulatory floodway boundaries for Fleshman Creek should be determined independently from the 22.5 square mile contributing watershed.

4.0 REFERENCES

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