Delta Levee Classification Analysis Assumptions & Limitations

Enclosed is an analysis of the Delta levee system. The criteria used for the analysis include the template geometry for HMP and PL84-99 levee design standards. Numerous assumptions were made in conducting this analysis which affect the potential use. This document identifies some of the more important assumptions, and outlines the intended uses for this analysis. Use beyond the intended purpose is not considered appropriate.

This analysis was intended for planning purposes and to track general progress towards meeting geometry standards across the Delta. It should not be used for site-specific design or assessment purposes.

This analysis classifies Delta levees according to four categories: “Below HMP”, “Minimally Below HMP”, “HMP But Below PL84-99”, and “PL84-99”. The concept is simple. Actual ground surface elevations are compared to an idealized “prism” representing a levee standard design geometry, where crown heights must have sufficient freeboard and side slopes must be at least as flat as required according to the appropriate standard. Illustrations of levees below, near, and above the HMP standard design geometry are included as attached Figures 1-3.

Although this analysis does utilize the HMP design template for the classifications, this analysis does not constitute a true determination of HMP compliance for FEMA disaster reimbursement eligibility due to the numerous assumptions that were made, including some critical items discussed in more detail below. HMP compliance for FEMA disaster reimbursement eligibility shall be determined on a site-by-site HMP compliance analysis as conducted by FEMA, and not using this analysis.

This analysis represents a “best available” evaluation of the levees. As such, surveys used vary in survey method, quality of geodetic control, vintage, etc. depending upon the local maintaining agency and individual cross sections. The survey method can affect the classification. Since the Delta levees settle and deform, over time their geometry classification can change since the time of the survey used in the classification. Additionally, new maintenance and rehabilitation work could have improved the geometry classification since the time of the last available survey. As such, this analysis is a living analysis that will change over time, and so awareness of both the vintage of the surveys and of the recency of the analysis itself is important when interpreting the results.

Critical Assumptions for All Cross Sections

1. **The 100-year flood stages are the appropriate stages at each cross section for analysis of levee geometry classification.**

   There are several issues posed by the 100-year flood stages to any analysis of levee geometry. For clarification, the 100-year stage is a critical number for such an analysis, because it governs the design levee crown height and side slope elevations. See the attached Figure 4 for an illustration, which shows how different 100-year flood elevations can affect the levee classification.

The LIDAR-based analysis used an interpolated grid of flood elevations, where the flood elevations used were the values given in the USACE Special Study dated from 1992. The 100-year stages from 1992 were based on NGVD29, so the grid was then converted to NAVD88 using a dense VERTCON conversion grid to facilitate analysis against the LIDAR. The 1992 Special Study is the most recent Delta-wide study of flood elevations that has been conducted in the Delta.

By contrast, RD engineer HMP elevations and templates are generally derived from 100-year stages from the 1982 USACE Hydrology report, which analyzed historic stages no more recently than 1972. The RD engineers use this older stage because it is the stage proscribed by FEMA in Amendment 5, dated April, 1987, which dictates determination of HMP compliance.

The stages are often similar, but in some cases, they are not. They can differ by more than a foot in some cases. Neither stage is necessarily “correct”, for potentially numerous reasons. In general, these stages are only statistical constructs in the first place, and should be treated as such. The 1992 Study includes more of the historical record, including the flood years in the 1980’s. However, the LIDAR-analysis simply uses an interpolated grid, which can misleadingly characterize backwater effects by a few tenths of a foot. The critical point is that it should be understood, then, that the design elevation standard for some cross sections varies from that of others depending on whether or not it is DWR or the RD engineers who performed the survey and then determined a classification from that survey.

It is known that the 100-year hydrology for the Delta requires modernization. The existing 100-year stages were determined according to the old vertical datum, and were determined without the period of record for two of the higher-stage events the Delta has experienced (1997 and 2006). Whenever 100-year stages are compared to data involving surveys in some way based on geodetic control using NAVD88, conversions (often involving VERTCON) are utilized, which can lead to error. Furthermore, local effects (e.g. localized wind-wave runup) are ignored.

This analysis ignores any potential “errors” in the 100-year stages that are utilized from whatever the “true” 100-year stages are.

2. **The cross section interval of 1000 feet fairly represents the Delta levee system and captures the variability adequately.** This analysis uses a 1000-foot interval between cross sections. The 1000-foot interval was specified by Amendment 5 (discussed above). The Delta levees are known to be heterogeneous with respect to elevations, and so it is possible that lower or higher sections of levees occur between the 1000-foot intervals. Many of the Reclamation District engineering surveys have been conducted at this spatial interval as well. The LIDAR data was

produced at a horizontal resolution of one meter, and the original underlying analysis conducted with LIDAR that was used to populate this analysis was conducted at 50-foot intervals.

3. **The PL84-99 landside slope is 3:1.** In reality, PL84-99 landside slopes depend upon the soil organic content. The required landside slope flattens as organics increase. Since many Delta levees contain organic soils, this assumption clearly influences the results from what they would be for a site-specific PL84-99 determination. The level of soil data was insufficient to support an analysis not making this assumption. But it is critical to be aware of it.

4. **Waterside slopes offshore from terrestrial surveys have no influence on analysis results.** This analysis does not consider what happens on the lower parts of levees that are underwater.

5. **Classifications can ignore any survey error, uncertainty, or other assumption effects.** For both LIDAR and RD engineer-supplied surveys, the final analysis takes any deficiency or surplus in the cross section as true and sufficient to "punish" or "reward" a levee classification. In effect, this means that even 1 inch of deficiency in height results in a levee to be classified to a lower level of protection (e.g. from "HMP" to "below HMP"). Or, conversely, that even 1 inch of additional levee height results in the higher level of protection to be achieved. In both cases, the numerous errors, uncertainties, and assumptions are basically being ignored. As a more important matter, although two levee cross sections may be classified identically as "below HMP", there is obviously a real-world difference between a levee with a few spots one inch below required design height and one with whole sections a foot or more below required design height.

<u>Critical Assumptions for Cross Sections Classified by LIDAR Data Analysis</u>

1. **LIDAR data is of sufficient accuracy for the analysis.** The LIDAR data's posted vertical accuracy specification is that 90% of points are within 5 inches of truth and that 95% of points are within 6 inches of truth. These specifications were determined on unvegetated, unobstructed surfaces. Many Delta levees have vegetation and other obstructions, which degrade the quality of the LIDAR dataset correspondingly. Although we have taken measures to remove vegetation from the cross section analysis, the plain reality is that all of the vegetation effects cannot be removed, and they influence the results somewhat. It should be noted that the general influence of vegetation and obstructions is, in general, to increase elevations, and therefore to bias the classifications towards meeting a higher design standard than they do in reality.

2. **2007/2008 topography is unchanged.** The LIDAR survey was conducted in 2007 (~90% of Delta) and 2008 (~10% of Delta). While we attempted to include recent and planned construction into the summary table, such levee work is merely noted, but not adjusted in the analysis. It is possible that work has occurred and will occur beyond what is indicated in the table and on the

maps. Additionally, levee subsidence/settlement may have occurred at each section since the time of the LIDAR survey.

3. **Centerlines derived from LIDAR analysis correspond to true levee centerlines.** In order to do the LIDAR analysis, levee centerlines that corresponded to the crowns (where crowns themselves were determined from LIDAR) were developed and used. Because of the timetable for the analysis, the draft version of these centerlines were used. There were known errors with the centerlines that were used at the time of the analysis. This effect is illustrated in Figure 5. It is estimated that these errors could affect 5-10% of the classifications.

4. **The theoretical HMP or PL84-99 prism cannot be moved off the centerline in order to find a cross section of the levee not anchored to the centerline that would achieve HMP/PL84-99.** The analysis fixes the standard design levee prisms to the LIDAR-derived centerline. In reality, levees are in some cases not symmetrical or uniformly centered upon a centerline, and if one could manually "move" the prism within the cross section, it is possible that one could achieve a higher levee design standard classification. This effect is illustrated in Figure 6. It is estimated that this issue affects less than 5% of the levee system classifications.

Critical Assumptions for Cross Sections Classified by RD Engineer Supplied Surveys

1. **The geodetic control used by different local maintaining agency engineers and surveyors is of equivalent quality.** The analysis assumes all geodetic control is equal. In reality, the geodetic control monuments used by different consulting firms supporting the local maintaining agencies are of differing quality.

2. **Survey methods, datum conversions, etc. used by different local maintaining agency engineers and surveyors are equivalent with respect to effect on survey accuracy.** No adjustment on the basis of differences in survey techniques is appropriate for this analysis. But it is important to remember that it is unlikely that all survey methods are identical with respect to vertical accuracy.

3. **The time since the last survey has no differential effect upon levee design standard classification.** We assumed that the most recent RD engineer-supplied surveys since 2005 should govern the final classification for each cross section. Of course, this results in the fact that the RD engineer-supplied surveys are of different vintages with respect to one another and to the LIDAR survey. There is unquestionably some influence by using surveys of varying vintages on the final analysis results.