DRAFT WHITE PAPER

Documentation of Design Deficiencies for the Ventura Levee System (VR-1)

1. Description

As originally constructed, the Ventura Levee System (VR-1) was an approximately 2.65-mile-long levee system placed along the left (east) bank of the Ventura River (see Figure 1: Location Map for VR-1). On the riverward side, VR-1 was protected with grouted riprap revetment everywhere upstream of a point beginning approximately 750 feet upstream of Main Street, which is located just north of the Ventura Freeway (Highway 101); and was protected with loose riprap revetment from the Pacific Ocean to a point located about 750 ft upstream of Main Street. On the landward side, the embankment height of VR-1 was up to 10 feet above natural ground. The upstream terminus of VR-1 is located where the Cañada de San Joaquin joins the Ventura River. The downstream terminus ends where the Ventura River outfalls into the Pacific Ocean, in the City of San Buenaventura, Ventura County, California. Construction of VR-1 began on April 2, 1948; and was completed on December 31, 1948 (USACE 1949, Revised 1963).

<u>Initial Design of Original Project</u>

VR-1 was constructed by the U.S. Army Corps of Engineers (USACE) to provide flood risk reduction to the western part of the City of San Buenaventura, as well as the suburban areas adjacent and to the north, from a flood with a peak discharge of 150,000 cubic feet per second (cfs). At the time of construction of VR-1, the design peak discharge of 150,000 cfs was the maximum discharge estimated to occur as the result of a severe regional storm. It is noted that the most current Federal Emergency Management Agency (FEMA) Flood Insurance Study (FIS) lists a peak of 79,166 cfs for the regulatory flood (a flood with an annual exceedance probability [AEP] of 1 percent), and lists a peak of 105,500 cfs for a flood with an AEP of 0.2 percent (FEMA 2010).

Design velocities for a peak discharge of 150,000 cfs were computed to vary between 8 feet per second and 17 feet per second. As an additional safety factor to accommodate the passage of a 150,000 cfs peak discharge, a freeboard of 3 feet was provided in the upper reaches and a freeboard of 5 feet was provided in the lower reaches of VR-1. Per the USACE as-built drawings for the original VR-1 project (dated January 1949), erosion protection in the form of grouted rock riprap was placed upstream of Main Street; and a blanket of dumped derrick stone was used protect the levee from scour from Main Street to the Pacific Ocean. The thickness of the levee revetment ranged from 2.0 feet to 6.0 feet, tapering to 2.0 feet at the top at some locations, and widening to 6 feet at the toe, where it was to extend a minimum of 10 feet below grade where it met the streambed on the riverward side, which was about 8 feet below the river thalweg. The USACE as-built drawings indicate that the maximum blanket weight for the levee revetment was set at 6 tons. A 2.0-foot-thick filter zone was included between the rock revetment and the levee material. The levee side-slopes were set at two horizontal to one vertical (2H:1V) for both the landward and riverward sides of the revetted levee. Recent hydrologic and hydraulic reports (DOI 2006, DOI 2009) prepared by the Bureau of Reclamation for the Matilija Dam Ecosystem Restoration Project state that, along VR-1, “The hydraulic model indicated that all discharges from the 2-year to the 500-year flood are confined by the Ventura Levee.”

K:\PR\planning\Levee Certification\Levee Maps\VR-1.mxd

Figure 1: Location Map for VR-1

Revised Design of Original Project

Changes that have affected VR-1 since its original completion in December 1948 include:

- Highway 33 was constructed.
- A railroad penetration was converted to a bike path.
- A parapet wall was added to the top of levee beginning at the downstream railroad and proceeding along a distance of about 0.45 miles. This parapet wall was apparently constructed because the railroad removed one of their spans, which restricted the flow and caused higher water-surface elevations along this segment of VR-1.
- At several locations along VR-1, adjacent property owners constructed a building and retaining walls, and also excavated into or next to the levee.
- Several local drainage penetrations have occurred through VR-1. The most notable of these are Dent Drain (90-in RCP); Ramona Street Drain (72-in RCP); and Mission Street Drain (56-in RCP).
- The County retrofitted the bike-path penetration in January of 2010.

As-Constructed Project Design

Construction of the project was completed in December 1948, as indicated in the document titled *Operation and Maintenance Manual, Ventura River Basin, California, Ventura River Improvement, Ventura River Levee, Ventura, California*, prepared by the Los Angeles District of the U.S. Army Corps of Engineers, March 1949 (Revised May 5, 1949). As-built drawings of VR-1, dated January 1949, are contained in a single set of drawings comprised of a cover sheet and 18 plans sheets. In particular, the plans indicate that the toe of the levee revetment was constructed to a depth of generally greater than 10 feet below the existing ground at the levee, and 8 feet below the channel thalweg, or the lowest adjacent point across the channel. The project, as constructed, did not take into account the fact that flow impingement points would move along the levee as the low-flow channel meandered within the riverbed—particularly as a result of a significant reduction in upstream sediment supply created by the construction of Matilija Dam (1947), Lake Casitas Dam (1959), Robles Diversion Dam (1958). Several small debris basins have been constructed to capture increased sediment production due to fires however their influences are insignificant relative to the watershed. See Figure 2: Dams and Debris Basins within the Ventura River Watershed (Tetra Tech 2008).

2. Past Performance History and Potential (Future) Performance

The following text summarizes the past performance history and potential (future) performance of VR-1 (Tetra Tech/AMEC 2009).

- The 1949 as-built plans for VR-1 reveal that a minimum of 8 feet of toedown was provided below the channel thalweg when the levee was initially constructed. Over the last 60 years, the Ventura River has degraded along the VR-1 levee to a point where currently, there is minimal to no toedown protection.
- Approximately 1.4 miles of the Ventura River thalweg along VR-1, from Station 64+00 to Station 138+50, is either below or very close to the existing levee toedown. There are no geological features, such as bedrock, or manmade feature, such as rock groins, that would prevent the thalweg of the river from migrating toward the levee and undermining the

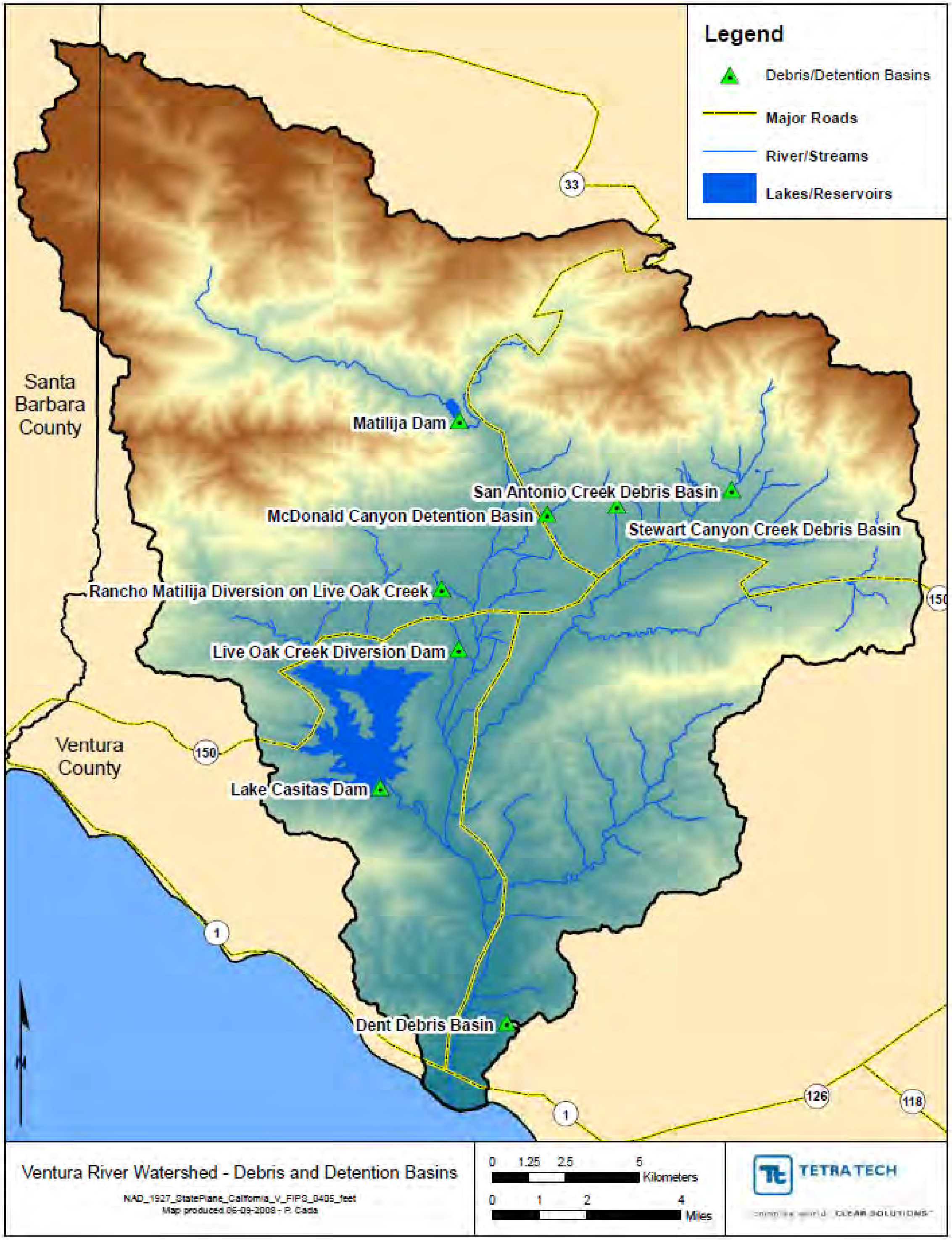

Figure 2: Dams and Debris Basins within the Ventura River Watershed

toedown. Thus, in its current condition the existing VR-1 levee has a reasonable failure potential due to toedown undermining during major flood events.

- From about levee Station 119+00 to Station 124+00, the river channel along VR-1 has eroded in close proximity to the levee structure. A high potential exists for undermining of the levee at this location.
- From Station 39+80 to Station 46+24, modifications to the VR-1 levee landside slope, such as undercutting and construction of retaining structures, have been performed over time that are considered to have a negative potential impact upon the stability of the slope.
- At Station 35+33, the adjacent landside slope along VR-1 has been subjected to heavy erosion. Some areas on the embankment slope have ungrouted riprap that cannot be observed, either because the riprap is missing or it is buried with soil/debris.
- The maintenance road is failing near VR-1 levee Station 121+00
- There are concerns regarding the adequacy of the riprap revetment protecting the VR-1 levees related to undermining of the levee toe and the potential for direct, high-angled flow impingement to occur at unpredictable future locations.

3. Conditions for Recommending Corrective Action

As stated in ER 1165-2-119, it is a general policy of the Chief of Engineers that completed Corps projects be observed and monitored by the Corps to ascertain whether they continue to function in a satisfactory manner and whether potential exists for better serving the public interest. While, generally, significant modifications to existing projects require authorization by Congress, occasionally, a project may deserve modification because its original development was inherently deficient. Given certain conditions and qualifications, measures to correct such deficiencies may be undertaken. Construction to correct a design deficiency may be recommended for accomplishment under existing project authority without further Congressional authorization if the proposed corrective action meets all the following conditions from ER 1165-2-119 (USACE 1982):

1. It is required to make the project function as initially intended by the designer in a safe, viable and reliable manner; e.g., pass the original design flow without failure. This does not mean the project must meet present-day design standards. However, if current engineering analysis or actual physical distress indicates the project will fail, corrections may be considered a design or construction deficiency if the other criteria are met.
2. It is not required because of changed conditions.
3. It is generally limited to the existing project features. Remedial measures that require land acquisitions or new project features must not change the scope or function of the authorized project.
4. It is justified by safety or economic considerations.
5. It is not required because of inadequate local maintenance.

Conditions 1 and 4 are particularly applicable to VR-1, for the reasons articulated below.

Figure 3: 1945 Aerial Photo of VR-1

Present and Potential (Future) Conditions along VR-1

Design and Construction Deficiencies

Construction of VR-1 was completed in December 1948, and the levee was constructed within the active channel of the Ventura River. Historical aerial photography, flown in 1945, reveals

that at that time there were no less than four (4) separate locations along VR-1 where the primary braid of the Ventura River impinged directly against the east bank of the river at abrupt flow angles (see Figure 3: 1945 Aerial Photo of VR-1).

In this regard, review of as-built drawings does not indicate that any special design considerations were considered at these locations when grouted rock-riprap revetment was installed to arrest scour/erosion on the riverward side of VR-1. A recent (2007) aerial photograph reveals that three (3) out of four (4) of the points of impingement that existed in 1945 have been abated (see Figure 4: 2007 Aerial Photo of VR-1). Reasons for this abatement follow.

Historical disruption of system-wide sediment continuity has occurred along the Ventura River that, over time, has had a very significant impact upon the fluvial geomorphology of VR-1. What was historically a braided channel system, created by an over-abundance of sediments emanating from upstream, steep-sloped mountainous regions, was abruptly modified via significant downstream sediment depletion initiated after the construction of the Matilija Dam in 1947; which was further exacerbated by the subsequent construction of the Robles Diversion Dam (1958), Lake Casitas Dam (1959), and several small debris basins that were constructed in the upstream contributing watershed areas of the Ventura River during the past 65 years. The downstream depletion of sediment supply, in turn, has led to stream-channel degradation, which has created a more pronounced, higher capacity, primary flow channel that conveys ordinary flows more to the center and western side of the Ventura River, partly due to flow confinement on the east by the VR-1 levee. In addition, this pronounced, higher capacity, primary flow channel has developed a more defined inner thread (low-flow-thalweg) that meanders in a gradual fashion inside the primary flow channel, causing an exacerbation of unanticipated scour problems. Furthermore, the depletion of the upstream sediment supply, which has led to long-term channel degradation (i.e., channel deepening), has also coarsened the in-situ distribution of streambed sediments, to some extent, thus exacerbating the tendency of the low-flow channel to meander within the primary channel of the Ventura River. In addition, due to a reduction in flood magnitude and sediment supply, created by upstream flood-control impoundments and watershed urbanization, respectively, a significant increase in both in-channel and near-channel riparian growth has occurred, which to some extent has tempered the meandering of the low-flow thalweg. All of these phenomena have been previously documented by others (USACE 2004; DOI 2004, DOI 2006; DOI 2009).

During both ordinary and extraordinary flow events, a wandering low-flow channel will create a highly non-uniform flow distribution along VR-1, which in turn will increase the potential for the initiation of high-angled flow impingements against the levees at various locations along the system, such as existed in 1945 before the presence of the extensive flood-control works that today exist within upstream watershed areas. As stated above, these altered flow conditions have, over the past 65 years, undoubtedly led to greater than originally anticipated channel degradation at the toe of VR-1.

Figure 4: 2007 Aerial Photo of VR-1

In the future, once removal of Matilija Dam has occurred as planned, the system-wide sediment continuity will again be disrupted, as historical rates of sediment supply will be partially restored to the system and the pronounced single-channel geometry that currently exists along VR-1 will attempt to reverse, partially, its ongoing degradational trend. In fact, the Ventura River, as a whole, will likely attempt to return to historic flow profiles (i.e., more like the braided flow conditions that existed before Matilija Dam and other flood-retarding structures were constructed in the Ventura River contributing watershed). However, past (and future) manmade "improvements" along the VR-1 levee will likely arrest the tendency of the river to braid to historic proportions. Consequently, the sediments transported from upstream watershed areas will likely "dump" in the channel…which will both lower the flood-carrying capacity of the channel and create bars and islands that will more than likely create multiple low-flow thalwegs, as once existed in 1945, thus exacerbating the potential for high-angled flow impingement to occur along VR-1, as it historically used to do. In order to mitigate this potential condition, one needs to be able to predict, with reasonable certainty, site-specific locations where the braiding and high-angled impingements will impact the VR-1 levee; but the problem is that no one can predict, with any real accuracy, where these problems might occur in the future.

The preceding types of geomorphic and hydraulic phenomena were not evaluated at the time of design and construction of Matilija Dam, in 1947. That is, at the time of the design and construction of VR-1 a very critical element was not considered—the significant sediment depletion that would be created by manmade upstream watershed changes such as, in 1947, the completion of Matilija Dam and, subsequently, the additional dams and debris basins that were constructed in the Ventura River Watershed since completion of the VR-1 levee. Given their dates of completion, it is safe to say that neither were they considered at the time of design and construction of the the Robles Diversion Dam or the Lake Casitas Dam as well. Thus, unanticipated loss of channel conveyance and increased scour at levee toes represent two significantly negative conditions that demonstrate VR-1 had inherent design deficiencies at the time of its design and construction.

Vegetation

It is noted that under Section 3, *Conditions for Recommending Corrective Action*, Condition 5 states that the corrective action must not be because of inadequate local maintenance. In this regard, while there had been a lack of vegetation removal along the VR-1 that has, over time, led to a significant increase in both in-channel and near-channel riparian growth, this growth has not contributed in any way to the fundamental cause of VR-1 deficiencies—historical disruption of system-wide sediment continuity along the Ventura River which has led to channel degradation to the point where the VR-1 levee toe now has a reasonable failure potential due to toedown undermining during major flood events.

Safety and Economic Considerations

As stated previously, the 1949 as-built plans for VR-1 reveal that a minimum of 8 feet of toedown was provided below the channel thalweg when the levee was initially constructed. Over the last 60 years, the Ventura River has degraded along the VR-1 levee to a point where currently, there is minimal to no toedown protection. Approximately 1.4 miles of the Ventura River thalweg along VR-1, from Station 64+00 to Station 138+50, is either below or very close to the existing levee toedown (see Figure 5: Profile Along VR-1). There are no geological features, such as bedrock, or manmade feature, such as rock groins, that would prevent the thalweg of the river from migrating toward the levee and undermining the toedown. Thus, in its

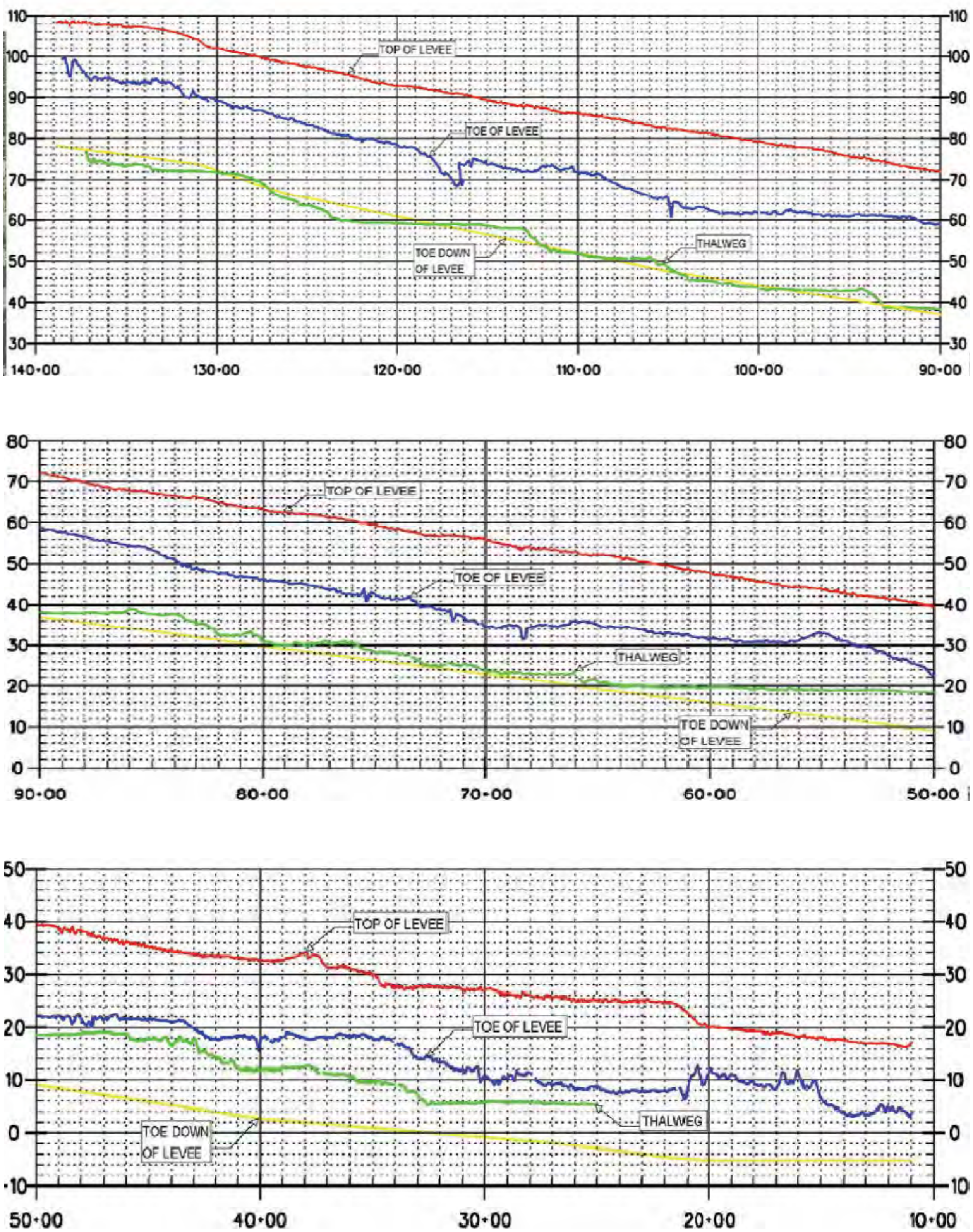

Figure 5: Profile along VR-1

current condition the existing VR-1 levee has a reasonable failure potential due to toedown undermining during major flood events. Failure of the levee would result in countless millions of dollars of urban infrastructure and commercial/residential property losses, not to mention the potential for significant loss of life—particularly if a portion of the levee were to collapse suddenly during the night.

4. Summary

On a relative wide stream such as the Ventura River, which historically had exhibited robust braided-flow conditions, it is not possible to predict the location of future high-angled flow impingements on the VR-1 levee. At the time of the design and construction of VR-1 a very critical element was not considered—the significant sediment depletion that would be created by manmade upstream watershed changes such as, in 1947, the completion of Matilija Dam and, subsequently, the additional dams and debris basins that were constructed in the Ventura River Watershed since completion of the VR-1 levee. The oversight which occurred by not accounting for this critical element during initial design and construction now renders the VR-1 levee, as originally constructed, susceptible to failure due to long-term channel degradation and the subsequent undermining of the levee toe, along with potential failure due to increased toe scour caused by the enhancement of impinging flow from an enlarged low-flow channel. As a result, these underlying deficiencies have had an adverse impact upon the performance of VR-1 over the long term, as measured from its initial construction in December 1948 to the present. Furthermore, a recent profile assessment along VR-1 demonstrates that the existing condition of the levee no longer meets either the original design criteria or current criteria at a number of locations. The documented trend toward continued channel lowering exhibited along VR-1 clearly indicates that without rehabilitation, a sudden collapse or breach of the levee is likely in the future due to undermining of the levee toe caused by a significant amount of degradation and scour. Failure of the levee would result in countless millions of dollars of urban infrastructure and commercial/residential property losses, not to mention the potential for significant loss of life—particularly if a portion of the levee were to collapse suddenly during the night.

5. References

U.S. Army Corps of Engineers. 1949/1963. *Operation and Maintenance Manual, Ventura River Basin, California, Ventura River Improvement, Ventura Levee, Ventura, California.*

U.S. Army Corps of Engineers. 1949. *As-Built Contract Plans, Ventura River Basin, California, Ventura River Improvement, Ventura River Levee, Plan for Levee Construction, Ocean to Cañada de San Joaquin.*

U.S. Army Corps of Engineers. 1982. *ER 1165-2-119—Modifications to Completed Projects*.

U.S. Army Corps of Engineers. 2004. *Matilija Dam Ecosystem Restoration Feasibility Report*.

U.S. Department of the Interior, Bureau of Reclamation. 2004. *Hydrology, Hydraulics, and Sediment Studies of Alternatives for the Maitlija Dam Ecosystem Restoration Project, Ventura, California - Final Report*.

U.S. Department of the Interior, Bureau of Reclamation. 2006. *Hydrology, Hydraulics and Sediment Studies for the Matilija Dam Ecosystem Restoration Project*.

U.S. Department of the Interior, Bureau of Reclamation. 2009. *Hydrology, Hydraulics, and Sediment Studies for the Meiners Oaks and Live Oak Levees* - Final Draft Report - *Matilija Dam Ecosystem Restoration Project*, Ventura, CA.

Federal Emergency Management Agency. 2010. *Flood Insurance Study, Volume 1 of 3, Ventura County, California, and Incorporated Areas*.

Tetra Tech. 2008. *Data Summary Report, Ventura River Watershed Hydrology Model*. Prepared for Ventura County Watershed Protection District, Ventura, California.

Tetra Tech/AMEC. 2009. *FEMA Levee Certification, Ventura County, California, Ventura River Levee (VR-1), Pacific Ocean to Canada de San Joaquin, Evaluation Report.* Prepared for Ventura County Watershed Protection District, Ventura, California.