US Army Corps
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Los Angeles District

Prado Basin Ecosystem Restoration and Water Conservation Study

APPENDIX N

Water Conservation and Sediment Transport Analysis

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Santa Ana River/Orange County
Prado Basin Feasibility Study

WATER CONSERVATION AND SEDIMENT TRANSPORT ANALYSIS REPORT

Hydraulics Section
Hydrology & Hydraulics Branch
U.S. Army Corps of Engineers
Los Angeles District

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Prado Basin, California, Water Conservation Memorandum of Agreement - 7 July 2006

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Technical Memorandum, Evaluation of Suitable Discharge Rate from Prado Dam to Surface Water Recharge System - February 5, 2013, OCWD

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Prado Basin Daily Discharge Estimate for 2021 and 2071, Using the Wasteload Allocation Model - December 2013, Wildermuth Environmental, Inc.

1. INTRODUCTION

The purpose of the Prado Basin Feasibility Study (Feasibility Study) is to investigate alternatives to restore environmental resources within Prado Basin and downstream of the Prado Dam, within the Santa Ana River (SAR). This study will also evaluate the alternatives to increase the existing volume of water conservation potential from what is currently identified as part of the approved water control plan. This effort in support of the Feasibility Study, as provided in this appendix, will focus on restoring aquatic, wetland and riparian habitats for endangered and other significant species, increasing water conservation benefits and reducing problems caused by sediment trapped by Prado Dam. All the elevations in this appendix are with respect to the National Geodetic Vertical Datum of 1929.

The U.S. Army Corps of Engineers (USACE), Los Angeles District, conducted a water conservation study for Prado Dam in 2004, where five alternatives were evaluated. In this 2004 study, Alternative 4, which is to maximize the water conservation elevation up to 505 ft at any time of year, was selected for further evaluation. This was a favored alternative to pursue with consideration for the local sponsor's preference, and it introduced little to no impacts with respect flood risk management regulation/operation. In this appendix, this alternative will be referred to as the "re-entrainment measure".

The baseline or current approved regulation at Prado Dam is to maximize water conservation up to elevation 498.0 ft in the flood season, and up to 505.0 ft in the non-flood season (Alternative 2 of the USACE 2004 study). In this appendix, the baseline condition will be referred to as "without project condition".

In the 2004 water conservation study, the reservoir capacity rating curve was developed using 1998 survey data. In the current study, the reservoir capacity rating curve was updated based on the 2008 survey data. Inflow hydrographs were also updated since the 2004 water conservation study to best reflect existing project conditions.

In addition to the water conservation study, a sediment transport analysis was also conducted for the Santa Ana River reaches upstream and downstream of the Prado Dam.

2. STUDY AREA

The Prado Basin Study Project Management Plan provides the study area information. Prado Basin is located within the Santa Ana River watershed. The Santa Ana River drainage area that is controlled by Prado Dam regulation encompasses about 2,255 square miles of the Santa Ana River watershed, making it the largest watershed in southern California. The study area is approximately 50 square miles within which all storm water and groundwater flows drain into the Prado Basin. Four major

watercourses drain into Prado Basin: Chino Creek, Cucamonga/Mill Creek, Santa Ana River, and Temescal Creek. The Chino Creek channel drains the western boundary of the study watershed area. The Cucamonga and Day Creeks are concrete lined channels traversing the center of the study area and merging to form Mill Creek before entering the Prado Basin; the Santa Ana River is the main watercourse entering the Basin from the northeast, and Temescal Creek enters near the southern boundary of the Basin. The study area extends downstream of the Prado Dam along the Santa Ana River for approximately 8 miles. Figure 1 shows the Santa Ana River Watershed.

The study area will encompass the Prado Basin to elevation 566 ft and each of the four major watercourses to the approximate area where the channels change physical characteristics or are adjacent to another project. The Chino Creek will be included upstream from the basin to just upstream of Soquel Canyon Parkway where the creek is channelized. The study area will extend upstream along Mill Creek to approximately Hellman Avenue where the creek is channelized. The Santa Ana River portion will extend upstream to Hamner Avenue. The Temescal Creek will be included upstream to Lincoln Avenue where the creek is channelized.

Downstream of Prado Dam, the Santa Ana River continues for about 31.2 miles to the Pacific Ocean. The approximately 8 miles immediately downstream from the dam to Weir Canyon Road represents a relatively natural channel with riparian and aquatic habitat as the river meanders within the banks. The channel segment will be included in the study area. The lower portion of the river has been modified for efficient flood risk management conveyance of storm water runoff to the ocean. Figure 2 shows the Prado Basin study area.

3. BACKGROUND INFORMATION ON PRADO DAM

3.1 General

The Prado Dam was authorized by Congress 1936 for "flood control and other purposes." The primary purpose is to provide flood protection to the metropolitan area of Orange County. During times of minimal flood threat, the dam can be regulated to control runoff in order to supply water to the OCWD. The valley portion of the watershed above Prado Dam is rapidly urbanizing; consequently average annual runoff is increasing.

The current approved water control plan for Prado Dam acknowledges use of the reservoir for water conservation up to elevation 490.0 ft. In addition, Prado Dam can be operated for water conservation during the flood season when weather conditions are favorable up to the top of Buffer Pool elevation of 498.0 ft. During the non-flood season, Prado Dam's buffer pool elevation can be further maximized up to elevation 505.0 ft.

3.2 Pertinent Data

Construction of Prado Dam was completed in May 1941, as part of a general plan for the construction of flood control facilities in the Santa Ana River Basin. The dam is located on the Santa Ana River 30.5 miles upstream from the Pacific Ocean. For reasons of continuous and rapid urbanization of the watershed which consequently led to generating increased surface runoff, Prado Dam required modification. Authorization for the modification of Prado Dam is contained in the Water Resources

Development Act of 1986, (P.L. 99-662). The purpose of this modification is to provide additional capacity for storage of floodwaters and sediment by enlarging the existing Prado Dam and Reservoir and to take advantage of increased downstream channel capacity by increasing the release capacity of the outlet works. The modification authorized by Congress is based on the plan recommended by the Los Angeles District of the USACE, as described in a document entitled, Design Memorandum No. 1, Phase II GDM on the Santa Ana River Mainstem including Santiago Creek, Volume 2 - Prado Dam, dated August 1988.

The pertinent data for Prado Dam with the Phase II modifications in place are shown in Table 1. Based on the USACE 2003 Prado Dam Interim Water Control Plan document, Figure 3 presents the current approved water control plan.

Prado Dam modification per the Phase II GDM is still in progress. It includes an earth fill embankment which rises 134 ft above the streambed, with a crest length of 3,050 ft. The reservoir formed by the dam will hold about 335,409 ac-ft of water at spillway crest (2008 survey), covering about 9,634 acres of land. The modification to the existing spillway crest is to raise up to elevation 563.0 ft NGVD 29. The newly installed reservoir outlet sill is at elevation 470.0 ft. The new outlet works structure consists of 6 main outlet gates, each 9.75 ft wide by 14.75 ft high, and two low flow 3 ft diameter steel pipe conduits. The low-flow valves can pass a total of 450 cfs with the water surface at elevation 505.0 ft.

3.3 Current Water Control Plan

Prado Dam is the key element in the flood control system protecting downstream Orange County. The downstream channel is managed by Riverside County for about the first 2.8 miles below the dam and then by Orange County Public Works, formerly the Orange County Public Facilities and Resources Department (OC PF&RD), for the remaining distance to the Pacific Ocean. The dam achieves flood risk management by capturing large inflows and releasing lesser flows that are non-damaging. During the winter flood season extending from October 1st to the end of February, the reservoir is always drained as rapidly as possible to create storage space in preparation of any subsequent storm runoff events. During times when there are no threats of significant storm runoff, the dam can then be regulated to temporary impound water for water conservation purposes.

The 2003 Interim Water Control Plan officially identifies a maximum flood season top of water conservation pool elevation at 494.0 ft, and that maximum impoundment for water conservation can be further maximized up 505.0 ft linearly from March 1st to March10th. However, following the completion of the 2006 water conservation Feasibility Study, the maximum buffer pool elevation for water conservation during flood seasons was allowed to be increased. In a *Memorandum Subject: Prado Basin, California, Water Conservation Memorandum of Agreement dated 7 July 2006*, the water conservation pool was officially recognized to maximize up to elevation 498.0 from elevation 494.0 during winter flood forecasting (See Attachment A). After March 10th, the pool would still be allowed to be maximized up to 505.0 ft from 498.0 ft. In addition, all water impounded behind the dam was required to be released prior to the 1st of September of each year in order to allow maintenance at the dam and reservoir.

Further, during the non-flood season, should the pool elevation exceed elevation 498.0 ft, in

accordance with the Biological Opinion and agreements with the USFWS, the dam must discharge a running average of 500 cfs in order to limit the duration of inundation impacts to any sensitive habitat existing within the reservoir. The downstream OCWD recharge facility capacity can vary monthly; therefore, Attachment B of this appendix also provides a technical memorandum documenting the evaluation of the suitable discharge rate from Prado Dam and the estimated OCWD SAR diversion capacity.

4. CLIMATE CHANGE CONSIDERATION

Scientific evidence shows that in some areas climate change is shifting the climatological baseline about which natural climate variability occurs. Extreme seasonal conditions of rainfall and runoff may become more common in some regions. These conditions may be intensified by future changes in the condition of native vegetation and societal demands for energy and water. Therefore USACE projects, programs, missions, and operations must assess these potential changes to remain reliable in spite of this baseline shift. A qualitative assessment of potential climate change threats and impacts that may be potentially relevant to this study was conducted to address this issue. This qualitative assessment was performed under the guidance of ECB No. 2016-25 (USACE 2016).

4.1 Current Climate and Climate Change Trends

The coastal regions of southern California are characterized as having a Mediterranean climate with warm to hot, dry summers and mild, moderately wet winters. However, further inland where part of this study area is situated, the areas can turn more semi-arid. The study area is situated across Riverside and San Bernardino Counties. The climate in Riverside County is semi-arid with hot, dry summers and mild, relatively wet winters. The average annual precipitation in the Prado Basin averages between 11 and 19 inches annually (CDM Smith 2016).

According to USACE (2015), over the historic period there has been an increasing trend in observed mean, daily minimum, daily maximum air temperature across the southwest, inclusive of the study region. A strong positive linear trend in mean air temperature has been observed over the period 1950-2000 in the winter (December-February) and spring (March-May), a lesser increase in the summer (June- August), and decreasing temperature in the fall (September-November) in the study area (Wang et al. 2008). In the third National Climate Assessment (NCA), Garfin et al. (2014) show temperatures in a recent 22-year span (1991-2012) were above the average for the period 1901-1960 by up to 2°F for the California Region, inclusive of this study area. Details on statistical significance were not provided in the NCA, however these trends are consistent with two separate studies. Tebaldi (2012) identified a decadal temperature increase of 0.16°F for California with a 95% confidence interval (C.I.) and a study by Hoerling et al. (2013) identified an increase in average annual daily temperature of 0.9 to 4.5°F between 1901 and 2010 with 95% C.I. Hoerling et al. (2013) also reported statistically significant (95% C.I.) increase in both minimum and maximum annually averaged daily temperature for the California Region of up to 5.4°F from 1901 to 2010.

Several studies evaluating national precipitation trends have failed to report statistically significant trends in total annual precipitation for the study area. Grundstein (2009) found no significant trend in soil moisture index, which is a function of both precipitation and evaporation (ET) and can be used as a representation of trends in both precipitation and ET. A study by Kunkel et al. (2013)

focused on the southwestern U.S. region, including the area of study, found no statistically significant trends in historical annual, seasonal or extreme precipitation from 1895 to 2011. There were also no trends found in the frequency of extreme precipitation events. In the third NCA, Walsh et al. (2014) reported annual precipitation changes from 1991-2012 compared to 1960-2012 for the California Region with areas in southern California showing a decrease in precipitation, however no details about statistical significance were provided with the report. Studies by Tebaldi et al. (2006) and Wang and Zhang (2008) forecasted increases in the intensity and the number of high volume storm events by the end of the 21st century for the California Region.

The USACE Climate Hydrology Assessment Tool was used to examine observed streamflow trends in the vicinity of the study area. Since the study focuses on water conservation within the Prado Dam basin, inflows from the four major contributing rivers were analyzed for trends in annual peak instantaneous streamflow. Four gages, one for each contributing river or creek, were chosen from the set of USGS gages used for calibration in the Wasteload Allocation Model (WLAM) in the development of hydrographs for the basin (Wildermuth Environmental Inc. 2009). The hydrologic time series of annual peak instantaneous streamflows at Santa Ana River (Gage No. 11059300), Chino Creek (Gage No. 11073600), Temescal Creek (Gage No. 11072100), and Cucamonga/Mill Creek (Gage No. 11073495) are shown on Plate 1 through Plate 4. The p-value is a metric by which to measure statistical significance. Commonly, the threshold for statistical significance is the 95% confidence and a p-value of less than 0.05 is considered an indication of a statistically significant trend. All four gages show a trend of increasing streamflow, however only Cucamonga Creek (p-value = 0.0008) and Santa Ana River (p-value = 0.02) had a statistically significant trend. The remaining gages had no statistically significant trends as indicated by high p-values, Chino Creek (p-value = 0.19), and Temescal Creek (p-value = 0.29).

The USACE nonstationarity tool was used for each of the gages that had at least 30 years of streamflow data at the time of this climate assessment. Stationarity is the assumption that time-series hydrologic data is constant through time. However, the impact of climate change has led to circumstances under which this assumption does not hold true resulting in nonstationarity. The presence of non-stationarity in the peak streamflow dataset indicates that there is variance in the mean within the data that is not independent of time. There were no nonstationarities in the hydrologic time series for Temescal Creek as can be seen in Plate 7. The tool did identify nonstationarities or change-points in the mean of time series data for Santa Ana River, Chino Creek, and Cucamonga Creek. Plates 5, 6, and 8 show that for Santa Ana River, Chino Creek, and Cucamonga Creek there is a change of the mean annual peak streamflow within different segments of the time series data. The heatmap graphical representation shows under which method a non-stationarity was detected and the color of the bar indicates the corresponding statistical parameter the statistically significant change was detected. Chino Creek time series data was determined to have no statistically significant trend. Trend analysis (not shown) of the Cucamonga Creek time series data indicate a statistically significant positive trend of the mean annual peak streamflow and the trend analysis for Santa Ana River had a positive trend that was statistically significant under one of the two statistical significance tests used in the tool.

The National Oceanic and Atmospheric Administration (NOAA) National Environmental Satellite Data and Information Services (NESDIS) released a report in January 2013 (NOAA 2013) assessing climate trends under high and low emission scenarios into the next 50-100 years for the southwest

region. The report indicates that over the period of record (1895-2011) for the southwest region, annual temperatures have generally increased over the past 115 years, however, annual precipitation shows no long-term trend. To account for climate change, the projected meteorological conditions in the region considers the past temperature and precipitation records, as well as the modeled future conditions in the area through 2070. Under the high emissions scenario, a warming trend and increase of days above 95°F and a precipitation trend towards slightly drier conditions in areas of California prone to low precipitation can be expected over the next 50 years. However, these estimates have significant uncertainty and spatial variation.

4.2 Projected Climate Change and Business Line Impacts

Future changes in streamflow should be considered as they have potential impact to Flood Risk Reduction business line, which is of concern for this project. A climate change analysis was conducted for the Santa Ana River Watershed as part of the U.S. Bureau of Reclamation Santa Ana River Watershed Basin Study (2013). Their summary findings include a decreasing trend of April 1st snowfall water equivalent (SWE) for water years 1950 -2099 due to warming across the region. SWE on April 1st is used as a proxy for subsequent spring-summer runoff conditions. The annual runoff follows the long-term declining trend pattern similar to that of precipitation. The study also reported slight decreases to runoff in the December-March winter season and the April-July summer season over the simulated years 2050-2099.

Increased ambient temperatures and increase number of extreme heat days will cause an increase in water temperatures. Increased water temperatures are associated with water quality concerns including a decrease in dissolved oxygen trends. This increase in temperature is also associated with nuisance algal blooms impacting wildlife and their food supplies (USACE 2015). Droughts associated with increased ambient temperatures may lead to loss of vegetation which is important for sediment stabilization. Resulting sediment loading can lead to geomorphic changes within rivers and tributaries.

The USACE Climate Hydrology Assessment tool was used to identify projected trends for the overall Southern California Coastal Watershed in support of this qualitative assessment. Plate 9 displays the range of the forecast annual maximum monthly stream flows computed by 93 different hydrologic climate models for the period of 2018-2099. The overall projected trend in annual maximum monthly streamflow generally increases overtime as shown in Plate 10, however, this increase is not statistically significant as indicated by the high p-value (p-value = 0.63). This finding suggests that there is no statistically significant change in flood risk in the future in the study area relative to the current time. While other studies (US Bureau of Reclamation 2013 and USACE 2015) indicate decrease precipitation and SWE, an increase of streamflow by the Climate Hydrology Assessment over the larger Southern California Coastal area may be indicative of vulnerabilities associated with urban development, as discussed below.

The USACE Watershed Vulnerability Assessment Tool was used to analyze the vulnerability of the study area in impacts to the flood risk management business line (Plate 11) and the ecosystem restoration business line (Plate 12). This study area is within the Southern California Coastal Basin (HUC 1807). For this basin, the tool projects a high vulnerability to flood risk throughout the 21st century (epochs 2050 and 2085) in both wet and dry periods. A breakdown of the flood vulnerability

indicators for wet and dry periods in each epoch are shown in Plate 11. For all four scenarios, the biggest contributing indicator of an increase in flood vulnerability was acres of urban area within the 500-year floodplain. This indicates that the principal vulnerability is an increase of urbanization and impervious area within the floodplain of the study area leading to increased runoff volumes. The tool projects vulnerability to the ecosystem restoration business line for epochs 2050 and 2085 for both wet and dry periods as well. The dominant indicator for all scenarios is the percentage of freshwater plant communities at risk of extinction. Reduced flow rates and increased sedimentation in streams are possible causes of high values in this category. The second highest indicator is monthly coefficient of variation (CV) of runoff. This high indicator value points to high short-term variability in monthly runoff within a year.

Overall, no strong signal exists within the qualitative analysis in this example to indicate what definitive impacts climate change will hold for this project's hydrology. The literature indicates no significant trend in flow magnitude for the California region. The strongest consensus amongst the literature supports the trend of increasing temperatures. Based on this climate assessment, the recommendation is to treat the potential effects of climate change as occurring within the uncertainty range calculated for the current hydrologic analysis. There are not currently methods in place for applying this qualitative assessment of climate change impact to a quantitative engineering-based analysis.

5. DESCRIPTION OF WATER CONSERVATION TERMINOLOGY

5.1. Yield

Yield as used in this study is, the total volume of water delivered to the OCWD Spreading Grounds on an annual basis. This definition is consistent with Reservoir Yield as defined in the "Glossary of Hydrology", by Shuh-shiaw Lo, dated 1992 and distributed by the Water Resources Publications, which says "Reservoir Yield is the amount of water which can be supplied from the reservoir in a specified interval of time". The yield for Present Conditions is an estimate of the average annual volume of water presently diverted to the OCWD spreading grounds. The alternative operations evaluated in this study allow water to be held at Prado Dam (up to a certain elevation) until it can be accommodated by the downstream spreading grounds, which effectively increases the average annual yield. While the water surface is below the designated pool elevation, reservoir releases are limited to the intake capacity of the downstream spreading facilities.

5.2. Water "Lost"

Water "Lost" as presented in this Appendix is simply the difference between the average annual flow in the Santa Ana River above the Orange County spreading facilities minus the average annual yield for the downstream spreading grounds. In the hydrologic models, it is shown as the volume of water which passes by the spreading grounds diversion. The volume of water actually "lost" to the Pacific Ocean is affected by other factors en route such as evaporation, percolation, etc, mainly as a result of flood events and flood control operations that exceed intake capacity at the spreading grounds.

5.3. Present Conditions

Present Conditions are for water year 2021 in the watershed, which include urbanization estimated for the year 2021 and inflow from upstream reclamation plants. Present conditions assume that modifications to Prado Dam have been completed. The elevation-area-capacity used in the models is based on the 2008 survey for Prado Reservoir. The Present Conditions long-term downstream capacity for daily spreading operations by OCWD will be fixed at 350 cfs, which is a value based on historical capacity of the spreading basins to take flow.

5.4. Future Conditions

Future Conditions are for water year 2071. Urbanization adjustments were made to the daily inflows to represent changes over the 50-year project life. Future Conditions yields presented in this appendix include the effects of sedimentation. The sediment yield for Prado Dam was estimated to be 0.75 ac-ft per mi^2 per year. Thus, for Future Conditions (WY 2071; 50 years) the sediment accumulation would be about 35,000 ac-ft. This volume was distributed throughout the reservoir up to the future spillway crest (el. 563.0 ft) and the elevation-area-capacity relationships were modified accordingly. The Future Conditions long-term downstream capacity for daily spreading operations by OCWD will be fixed at 350 cfs. It is unlikely that OCWD can realistically increase this capacity due to the infiltration of available lands for infiltration basins.

5.5. Debris Pool

Before flood control discharge can be made from the dam, the debris pool (up to elevation 490.0 ft) is built which serves to settle out excess debris and sediment, preventing them from entering and plugging up the outlet works. There are no seasonal restrictions on filling the debris pool. When draining the debris pool, discharge can be coordinated to accommodate a rate that the downstream recharge facilities can divert (usually 0-600 ft^3/s).

5.6. Buffer Pool

Water can be temporarily stored behind the dam during the flood season up to a specific elevation (up to elevation 498.0 ft during flood season and up to 505.0 ft during non-flood season) when weather conditions are favorable, and discharge from the dam can be limited to the intake capacity of the downstream spreading facilities. If runoff forecast indicates that an impending storm will bring significant inflow into the reservoir, the Buffer Pool will be emptied enough to account for the estimated inflow volume, or even drained entirely back down to the top of debris pool elevation of 490.0 ft, if needed. The Buffer Pool is a temporary storage of water to benefit water conservation, therefore, the entire storage volume within the buffer pool space will always be available for flood runoff storage to fulfill the project's primary authorized purpose for flood control.

5.7. Seasonal Pool

After the flood season is over, water conservation pool can be maximized up to a specific elevation (currently elevation 505.0 ft). Within this seasonal pool elevation, releases from the reservoir can be limited to the intake capacity of the downstream spreading facilities (350 cfs). Under Future Conditions, the long-term spreading rate is approximately 350 cfs. The Seasonal Pool maximum elevation is linearly increased from the 1st to the 10th of March to the maximum Seasonal Pool elevation.

6. LOWER SANTA ANA RIVER REACHES

The Santa Ana River basin below Prado Dam comprises about 208 mi², excluding about 19 mi² tributary to Carbon Canyon Creek above Carbon Canyon Dam. The lower Santa Ana River flows about 30.5 miles from Prado Dam through Santa Ana Canyon and the cities of Yorba Linda, Anaheim, Orange, Santa Ana, Fountain Valley, Costa Mesa, and Huntington Beach before emptying into the Pacific Ocean.

The lower Santa Ana River channel can be divided into three geomorphic reaches. The first channel reach commences near Prado Dam and ends at North Weir Canyon Road. This reach is referred as canyon reach or Reach 9. The USACE is currently constructing bank protection along Reach 9.

The second geomorphic unit is the groundwater recharge reach, extending from North Weir Canyon Road to the Garden Grove Freeway (22 Freeway). This section has a natural bed, but its banks have been significantly modified. The river in this reach is contained within a regular, trapezoidal channel with a bottom width of about 325 ft (99.1 m). Several drop and grade control structures were constructed in this reach to help maintain the river slope and prevent undue degradation. Temporary levees are regularly constructed, maintained and modified by OCWD within the prismatic flood control channel to enhance infiltration of water into the river bed in the groundwater recharge reach. These temporary structures are designed to maximize wetted area in the river bed for percolation. These structures are designed to self-level during high flows, thereby preserving the full capacity of the SAR channel for flood control purposes. Flow diversion structures located in this river reach divert flows to adjacent infiltration ponds

The final geomorphic reach is located between the downstream end of the recharge reach (downstream of the Garden Grove Freeway) and the Pacific Ocean. This reach has a mild longitudinal slope and has been converted to a trapezoidal shape. A portion of the channel is concrete lined. The first stretch of this reach runs through a golf course and appears to have a somewhat natural shape. A hardscape (grouted stone) channel exists under the golf course fill. Below the golf course (just above 17th Street) the channel is fully concrete-lined to just above Adams Avenue. At the lower channel portion (below Adams Avenue) it has a natural river bed with concrete lined earthen levees and flood walls and is subjected to tidal fluctuations. It is therefore prone to periodic sediment deposition depending on flood flows and tidal patterns (Golder 2009).

The 8 miles immediately downstream of the dam (Reach 9) is included in the study area. The lower

portion of the river has been modified for efficient flood risk management to the ocean.

7. RESERVOIR SIMULATION

7.1. Representative Period of Record

Runoff records for inflow into Prado Dam exist for the period 1920-present. Determining a representative period of record facilitated data management and presented a more reasonable picture of current conditions. Establishing the representative period of record required the examination of long-term records of annual totals for precipitation gages and annual volumes for stream gages located in various areas above Prado Dam. In the 2004 Prado Water Conservation Study by COE, the representative period of record was selected using 1949 through 1988. This period includes both wet and dry weather conditions of the Prado Basin. In this study, the representative period of record was also selected using 1949 through 1988. It represents the characteristic inflow condition for the Prado Dam.

Average annual rainfall data from 1950 to 2014 for downtown Los Angeles is shown as Diagram A. This diagram demonstrates the rainfall pattern of the past 64 years in Southern California. As shown in this diagram, 1949 through 1988 can serve as a representative period. Additional data from 1989 to 2014 does not change the characteristics of the Prado dam inflow hydrograph.

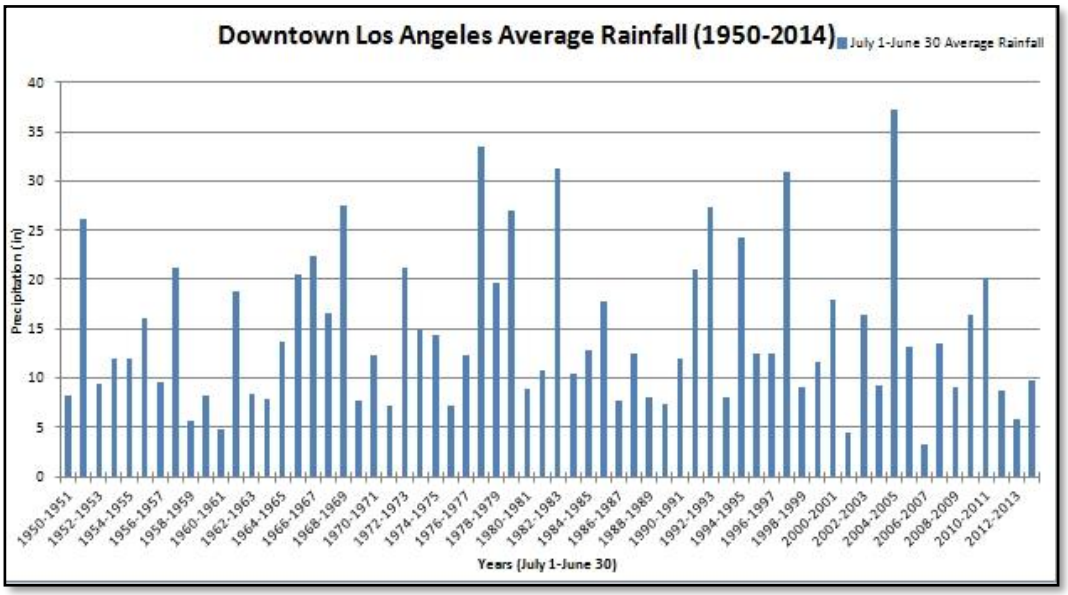

Diagram A

7.2. Flood Frequency

One of the major premises of the water conservation study is that modifications to the operating plan for water conservation at Prado Dam will not have any significant impact on flood control, i.e., will not significantly decrease the level-of-protection afforded by the dam. If the Buffer Pool is not evacuated prior to a major storm, there is some impact on flood control. To evaluate this, the

reservoir design flood (RDF), which is based on the Standard Project Flood (SPF), was routed through the reservoir under several different scenarios. The RDF for Prado Dam is equal to 92% of the SPF and is based on a 4-day general storm with a runoff volume of 415,800 ac-ft. The 2-year to 1,000-year frequency flood routings were also evaluated. One of the worst and most remote scenarios which could impact on flood control would be to have no advanced warning (no forecast) of a RDF at Prado Dam when water is being held to the top of the Buffer Pool. Flood control releases did not begin until inflow reached the reservoir and were only made only while the water surface exceeded the Buffer Pool elevation.

7.3. Data Collection

The inflow data downstream of Prado Dam and the evaporation data were collected from the COE 2005 Water Con Study database.

7.4. Inflow Adjustments and Projections

As mentioned in Section 7.1, the representative period of record used for the simulation analysis is from 1949 through 1988. The mean daily flows for the representative period of record required adjustments in order to properly simulate flows for Present (WY 2021) and Future (WY 2071) Conditions. The adjustments are mainly for the future land use and the wastewater discharge projections in the watershed. Wildermuth Environmental Inc. conducted the data adjustment and projections for OCWD and provided the daily inflow hydrographs for the study.

Table 2 presents the adjusted annual inflow of 39 years period of record adjusted to watershed for the years 2021 and 2071. The table shows the total inflow for the years 2021 and 2071 are 8,457,605 acre-ft and 6,681,353 acre-ft respectively. The projected year 2071 future condition inflow is much less than the year 2021 present condition inflow. The detailed presentation of the years 2021 and 2071 daily inflow analysis is shown in the Wildermuth Environmental Inc., report as attached in Attachment C.

7.5. Evaporation

Evaporation was computed by compiling average monthly pan evaporation at Lake Mathews and the average monthly precipitation at Corona from Riverside County's "Hydrologic Data for 1979-80, 1980-81, 1981-82 Seasons". Each station was selected for its proximity to Prado Dam. Using the net evaporation equation for reservoirs:

Net Reservoir Evaporation = 0.70 (EVAP - PRECIP)

where;

0.70 = the Pan Coefficient for this region;
EVAP = Average Monthly Pan Evaporation; and,
PRECIP = Average Monthly Precipitation

All units presented are expressed in inches per month.

The average monthly evaporation rates for Prado Dam used in the HEC-5 models are presented in Table 3.

7.6. Elevation-Area-Storage Capacity Curve.

The elevation-area-storage capacity curves were developed for the present and future conditions using the Prado Dam 2008 survey and the Empirical Area-Reduction Method in EM 1110-2-4000. This method was developed by Borland and Miller in 1958 for the Bureau of Reclamation. It is recommended for use under extreme reservoir operation conditions or when the reservoir shape is unusual. EM 1110-2-4000 does not provide a definition of "extreme operation conditions." However, in comparison with many dams which have large conservation pools, any single purpose flood control reservoir which is nearly dry at the beginning of an event, then fills rapidly and then drawn down until it is nearly dry again as quickly as possible, could probably be characterized as having extreme operation conditions. Based upon this reason and that this method has been used in previous studies for Prado Dam, this method was selected to distribute sediment in the Prado Reservoir. The same assumptions utilized in the distribution of the 100-year sediment allowance for the Phase II GDM were used in the distribution computations of this study.

Using the 2008 survey, a sediment deposition volume of 9,100 ac-ft (700 ac-ft per year) for present condition and 44,100 ac-ft (700 ac-ft per year) for the future condition were distributed throughout the reservoir area up to the spillway crest, elevation 563 ft. The elevation-storage capacity data for Present conditions is shown in Table 4, and the elevation-storage capacity data for future condition is shown in Table 5.

7.7. Present Condition: Flood Season Water Conservation to Elevation 498.0 ft plus Non-Flood Season Water Conservation to Elevation 505.0 ft.

When inflow to Prado Dam is greater than the percolation capacity of the downstream spreading grounds, the existing Debris Pool (elev. 490.0 ft) can be used to provide incidental water conservation any time during the year. The existing operation schedule calls for controlled releases up to 600 cfs until the reservoir reaches elevation 490.0 ft. Also, during the flood season, it allows encroachment into the Flood-Control Pool up to elevation 498.0 ft (top of Buffer Pool) for water conservation purposes when weather conditions are favorable. When the threat of unfavorable weather is forecast, the reservoir will be drawn down enough (490.0 ft, if necessary) to accommodate the anticipated inflow volume from the storm(s) to ensure there is storage available for flood control operations.

During the non-flood season, water can be held up to elevation 505.0 ft (top of Seasonal Pool) for water conservation purposes. Beginning the 1st of March, the maximum allowable water surface elevation for conservation is linearly increased from elevation 498.0 ft to elevation 505.0 ft on the 10th of March. The pool may be maintained as high as elevation 505.0 ft until the 30th of September. However, if maintenance is required, the reservoir must be evacuated before the 1st of September. If summer flood runoff occurs in the month of September, the dam can be operated for water conservation up to elevation 505.0 ft, provided that the impoundment does not interfere with maintenance requirements.

Releases from Prado Dam, during water conservation operations, will be based on the estimated rate that the downstream spreading channel can percolate. If hydrologic forecasts and reservoir conditions indicate that the water surface elevation will exceed elevation 505.0 ft, the reservoir is put in full flood control mode and outflows can be made up to the downstream channel capacity of the Santa Ana River (approx. 30,000 ft^3/s).

7.8. Re-entrainment Measure: Water Conservation to Elevation 505.0 ft Year-Round

As mentioned in the Introduction of this appendix, Alternative 4 (re-entrainment measure) of the USACE 2004 study was selected for further evaluation. When inflow to Prado Dam is greater than the percolation capacity of the downstream spreading grounds, the current Debris Pool (elev. 490.0 ft) can be used to provide incidental water conservation any time during the year. The existing operation schedule calls for controlled releases up to 600 cfs until the reservoir reaches elevation 490.0 ft. According to memorandum dated 5 February 2013 (Attachment B), OCWD stated that they conserve approximately 350 cfs in average.

Also, during the flood season allow encroachment into the Flood-Control Pool up to elevation 505.0 ft for water conservation purposes when weather conditions are favorable. When the threat of unfavorable weather is forecast, the reservoir will be drawn down enough (490.0 ft, if necessary) to accommodate the anticipated inflow volume from the storm(s) to ensure there is storage available for flood control operations.

During the non-flood season, water can also be held up to elevation 505.0 ft (top of Seasonal Pool) for water conservation purposes. The pool may be maintained as high as elevation 505.0 ft until the 30th of September. However, if maintenance is required, the reservoir must be evacuated before the 1st of September. If summer flood runoff occurs in the month of September, the dam can be operated for water conservation up to elevation 505.0 ft, provided that the impoundment does not interfere with maintenance requirements.

Releases from Prado Dam, during water conservation operations, will be based on the estimated rate that the downstream spreading channel can percolate. If hydrologic forecasts and reservoir conditions indicate that the water surface elevation will exceed elevation 505.0 ft, the reservoir is put in full flood control mode and outflows can be made up to the downstream channel capacity of the Santa Ana River (approx. 30,000 ft^3/s).

7.9. Sediment

The average annual sediment deposition rate assumed for this study is based on the rate determined for the modified Prado Dam. As documented in Santa Ana River, Design Memorandum No 1, Phase II GDM on the Santa Ana River Mainstem including Santiago Creek, Volume 2 – Prado Dam, August 1988, the sediment allocation for the authorized plan of the modified Prado Dam is 70,000 acre-ft. This allocation corresponds to a design annual deposition rate of 700 acre-ft per year based on the project life being 100 years. This rate was determined by multiplying the average annual sediment yield of 0.75 acre-ft per year per square mile by the future sediment-producing area of 935 square miles, which takes into account the future urbanization of the basin and Seven Oaks Dam.

7.10. Analysis Overview

The operation for Prado Dam was simulated using the HEC-5 computer program (Hydrologic Engineering Center's Simulation of Flood Control and Conservation Systems). The current approved operation plan for the reservoir was modeled and modified for Re-entrainment Measure to account for the improved outlets and downstream channel. The 2008 survey was used to estimate available storage and area. Inflows for a representative period of record were adjusted to account for urbanization and wastewater effluent. The HEC-5 model was used to estimate the water conservation yields at the downstream spreading facilities.

The model also includes local inflow from the area between Prado Dam and the downstream spreading facilities. These flows were also established for the representative period. There were no adjustments to Present Conditions inflows, including the area downstream from Prado. The Future Condition flow required adjustments for urbanization, effluent, and sediment deposition.

7.11. Results

The Present Conditions average annual yield for Prado Dam which was used for alternative comparison is 151,000 ac-ft. This is an estimate of the volume of surface water spread in the downstream OCWD spreading grounds. It includes releases from Prado Dam and local flow from the intervening area between Prado Dam and the downstream spreading facilities. The average volume of water "lost" to the Pacific Ocean for Present Conditions on an annual basis is approximately 73,200 ac-ft. These results are presented in Table 6. The Future without project Conditions yield is 93,400 ac-ft with 86,200 ac-ft "lost" to the ocean. These results are presented in Table 8. The present with project simulation results and the future with project simulation results are presented in Table 7 and Table 9 respectively. Table 10 presents the comparisons between with and without project condition results. For the present condition, the with-project condition will yield 6,000 acre-ft per year more than the without-project condition. For the future condition, the with-project condition will yield 11,600 acre-ft per year more than the without-project condition.

Frequency-based days of inundation (duration) were estimated for selected pool elevations. Frequency-duration pairs were computed using the following process:

- HEC-5 computed reservoir elevations (elevations) were sorted from highest to lowest for each water year.
- 20 duration-elevation pairs were sampled from each water year ranging from one to 360 days of inundation.
- The sampled duration-elevation pairs were transposed and the elevations were ranked from highest to lowest for each duration followed by the assignment of an exceedance value based on the Chegodayev plotting position formula. Given that there are only 39 years of data, the lowest exceedance value attained is 0.018, which corresponds to a 56-year event.
- Curve-fitting was applied to known frequency-elevation pairs for the purpose of extrapolating to the 100-year event for each sampled duration. Due to the magnitude of the extrapolation (from a 56- to 100-year event), the extension of the fitted curves produced results that have a high degree of uncertainty and were not always consistent with the expected trend of

decreasing pool elevations, which generally decrease with increasing duration. To limit the ambiguity of this process, the same curve type was applied to each duration and for each alternative. Where an extrapolated elevation for a given duration was not physically possible, interpolation was used. While applying consistent curve fitting across all durations for all alternatives does not reduce the amount of uncertainty linked to the results of an alternative by itself, it does lend more meaning to the comparative results between two alternatives.

Table 11 presents the inundation duration analysis results for the present without-project condition. Table 12 presents the inundation duration analysis results for the present with-project condition and the increase of inundation from the present without-project condition. Table 13 presents the inundation duration analysis results for the future without-project condition. Table 14 presents the inundation duration analysis results for the future with-project condition and the increase of inundation from the future without-project condition.

7.12. Sensitivity Analysis

The water conservation simulation modeling with HEC-5 model presented above was assumed with fixed 350 cfs recharge and 350 cfs minimum release from Prado Dam. However, both of the minimum Prado Dam release and the spreading ground recharge rate may be variable. To evaluate the effect from different Prado Dam minimum release rate and the downstream spreading ground recharge rate, sensitivity model runs were conducted and are presented in this section.

In the sensitivity model runs, the minimum Prado Dam release is 450 cfs and the spreading ground recharge rate is as follows.

Month	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Recharge(cfs)	450	450	450	450	450	420	400	350	350	450	450	450

The simulation results are presented in Tables 15 through 23. These tables are in the same format as Tables 6 through 14.

Table 10 presents the benefit of the project from 350 cfs fixed recharge. Table 19 presents the benefit of the project from 450 cfs and variable recharge. A comparison of these two tables shows that the slightly higher recharge rate produces a slightly higher benefit.

7.13. Flood Risk Due To Project Alternative

The current Prado Dam operation is to keep water level at 498 ft during the flood season and to raise to elevation 505 ft for the non-flood season. The project alternative is to keep water level at 505 ft year round. The increased volume for the project condition is 10,500 acre-ft. The top of dam capacity is 770,839 acre-ft. Therefore, the increased volume for the project condition is only 1.3% of the total reservoir capacity. The current Prado Reservoir operation is that when inclement weather is forecast, the reservoir will be drawn down to make space for the anticipated inflow, ensuring there is adequate storage available for the flood control operations. In addition, ResReg Section will increase monitoring to ensure safety due to the deviation. With the facts presented above, we conclude that the upstream and downstream increase in flood risk to operate the conservation pool at elevation 505 year round is very minimal.

8. SEDIMENT TRANSPORT – UPPER SANTA ANNA RIVER (USAR)

Sediment transport modeling of Upper Santa Ana River (USAR) was performed by Golder Associates Inc. (Golder) using the HEC-RAS model (version 4.1) for the following two purposes:

- To analyze the effects of creating a sediment trap and increasing the slope of the channel into the sediment trap using a transition channel on sediment deposition/scour and bed grain size.

- To evaluate the effects of increasing the reservoir water conservation elevation during flood season (October through February) from 408 feet NGVD 29 to 505 feet NGVD 29 on sediment deposition/scour and bed grain size.

The extent of the sediment transport modeling is from the San Bernardino County/Riverside County line on the upstream end and Prado Basin on the downstream end for approximately 20 miles (See Figure 4). The downstream end of the model corresponds to the downstream end of the transition channel.

8.1 Effects of Sediment trap and transition channel

To analyze the effects of creating a sediment trap and increasing the slope of the channel into the trap using a transition channel, two scenarios were modeled for comparison; 1) an existing conditions scenario ("base case scenario") and 2) a scenario with a dredged sediment trap and realigned transition channel into the trap ("trap scenario"). The model was run for a 10-year period for both base case and trap scenarios.

Various sediment trap scenarios are under consideration for the feasibility project (see Figure 5). The current trap scenario modeled is shown in Figure 4. The transition channel modeled has a slope of 0.33 percent, 80-foot bottom width, 4H:1V side slopes, and an 18.5-foot depth. The design has since been changed to include 5H:1V side slopes. However, the change in side slopes does not seem to have an appreciable effect on the results within the transition channel. The model does not include the full sediment trap. Instead, considering that the sediment trap bottom elevation is sufficiently low as to be influenced by the reservoir water surface elevation, the reservoir water surface elevation based on the current dam operation was used as the downstream boundary condition of the trap scenario; i.e., 498 feet from September through February and 505 feet from March through August. Under the base case scenario, the downstream end of the model is not influenced by the reservoir water surface elevation; therefore, a normal depth is used as the downstream boundary condition.

Information about data and assumptions used in the development of the sediment transport model are detailed in the technical memorandum by Golder (Golder 2015a).

8.1.1 Modeling Results

Figures 6 and 7 show the river bed profile change after 10-year simulation for the base case and trap scenarios, respectively. The river bed profile change for the base case scenario (Figure 6) shows areas of deposition present immediately downstream of Hamner Avenue and River Road Bridge, and immediately upstream of I-15 with a maximum deposition of about 10 feet. Areas of scour are present throughout the reach with a maximum scour of about 15 feet, between Van Buren Blvd. and I-15. The river bed profile change for the trap scenario (Figure 7) is similar to the base case scenario in the upstream portions of the modeled reach. The main differences are in the area of the transition channel and sediment trap as well as upstream for some distance. Figure 7 clearly shows that river bed degradation starting at the transition channel propagates upstream until reaching a point immediately downstream of Hamner Avenue.

Figure 8 shows the average channel slope change comparison of the base case and trap scenarios after 10-year simulation over selected four segments. The modeled reach was broken into four segments based generally on grade breaks present under existing conditions. The figure shows that the slope of the trap scenario stays fairly consistent in the upstream two segments. However, the downstream-most segment (i.e., transition channel and trap) significantly flattens, whereas the slope of the next upstream segment increases. Steepening of the next upstream segment is mainly due to an abrupt slope change from the flattened transition channel downstream to the milder river bed upstream.

Figure 9 shows the average D50 change comparison of the base case and trap scenarios after 10-year simulation over selected six segments. The six segments are the same segments that were used to input varying particle size distributions during the model setup. The figure shows an overall coarsening of the downstream four segments under the trap scenario after 10-year simulation. The base case scenario also shows a coarsening of the downstream five segments, but its degree of coarsening is not as much as the trap scenario in the downstream three segments.

8.1.2 Conclusions

Per the modeling results, the sediment trap and the transition channel will degrade and coarsen the river bed of the transition channel as well as upstream for some distance. It is predicted that the river bed degradation and coarsening stop downstream of Hamner Avenue after 10 years. However, common geomorphology knowledge dictates that the degradation should continue upstream. The rate at which it continues upstream is difficult to predict but it is possible that the degradation could eventually adversely affect piers of the upstream bridges. It is recommended that the potential for upstream migration be investigated further prior to implementation of the trap and transition channel.

8.2 Effects of Increasing Reservoir Water Conservation Elevation

To evaluate the effects of increasing the reservoir elevation during flood season, two scenarios were modeled for comparison; 1) a scenario representing the existing reservoir operations - water conservation level of 505 feet from March through August and 498 feet from September through February ("1st scenario") and 2) a scenario representing the proposed modification of the water conservation elevation - water conservation level of 505 feet from October through August and 498 feet during September for maintenance purposes ("2nd scenario"). The model was run for a 10-year period for both scenarios.

The 1st and 2nd scenarios are different only by the downstream boundary condition within the reservoir. The reservoir response to the modeled incoming flow (October 1, 1975 to September 30, 1985) was modeled by OCWD in their recharge facilities model with a varied water conservation level (498 or 505 feet) and the resulting reservoir elevation was used as the downstream boundary condition for both scenarios.

Information about data and assumptions used in the development of the sediment transport model are detailed in the technical memorandum by Golder (Golder 2015b).

8.2.1 Modeling Results

Figures 10 and 11 show the river bed profile change after 10-year simulation for the 1st and 2nd scenarios, respectively. The river bed profile change for the 1st scenario (Figure 10) shows that areas of deposition are present upstream of Market Street, upstream of the railroad bridge, and consistently between River Road and I-15 Bridge. These areas exhibit aggradation after 10-year simulation ranging between 5 and 10 feet. The river bed profile change for the 2nd scenario (Figure 11) is very similar to the 1st scenario. Because the downstream end of the reach is only seldom influenced by the change in reservoir operation rules, the difference between the 1st and 2nd scenarios in river bed profile is minimal.

8.2.2 Conclusions

The modeling results show that increasing the reservoir water conservation elevation does not significantly affect deposition or scour pattern along the modeling reach. Deposition occurs at the downstream end of the reach for both scenarios, when higher reservoir water surface elevations are encountered. When water surface elevation decreases, the deposition is reduced for both scenarios.

9. SEDIMENT TRANSPORT – LOWER SANTA ANNA RIVER (LSAR)

The removed sediment from upstream of Prado dam as a result of creating sediment traps would be eventually re-entrained in the flow released from Prado dam and transported to the Lower Santa Ana River (LSAR). Golder (Golder 2017) studied the effects of this sediment re-entrainment on the long-term sediment transport through Reach 9 and entire reach of the LSAR.

Golder initially performed a slope analysis to estimate the slope change that will develop in Reach 9 under varied flow conditions, re-entrainment concentration, and re-entrained sediment size. These calculations were used to estimate the long-term slope that this reach of the river may reach as a result of several years of re-entrainment. Following the slope analysis, 10 years of sediment re-entrainment was simulated using the HEC-RAS model (version 5.0.3) over the entire reach of the LSAR from Prado Dam to the Pacific Ocean. Following 10 years of re-entrainment, an additional 5-year period was modeled with only the existing sediment load through the dam to simulate how the deposited sediment changes if re-entrainment stops.

9.1 Re-entrainment Slope Analysis in Reach 9

Two analyses were performed to determine the effects of the sediment re-entrainment on the bed slope in Reach 9. A reach-wide, incremental flow analysis using manual calculations with Meyer-Peter Muller equation was conducted to calculate average deposition or scour based on a particular sediment gradation and concentration by weight over a range of expected flows. The results of this analysis were compared to those from the HEC-RAS model of the reach simulating the same conditions.

The HEC-RAS model was constructed with an estimated flow series, fine and medium sand gradations, and 1% and 5% sediment concentration by weight. Five years of re-entrainment were simulated and the bed slope after each year was analyzed. Figures 12 through 15 show the comparison of the beginning Reach 9 river bed profile, the simulated profile at the end of the 5-year simulation, and a linear trend line overlain on the simulated profile with the elevation at the Weir Canyon Road grade control structure assumed to remain consistent for the following four assumed re-entrainment sediment concentration scenarios; 1% fine sand, 1% medium sand, 5% fine sand, and 5% medium sand, respectively. More simulation output figures are included in Golder report (Golder 2017). With all four simulations, the slope continues to increase throughout the 5-year simulation period. In general, the slopes calculated for the 5% concentration scenarios increase more quickly than for the 1% concentration scenarios.

Figures 16 through 19 show the re-entrained sediment, deposited sediment estimated using the HEC-RAS model, and deposition manually calculated using the Meyer-Peter Muller equation for Reach 9. In the modeling, it was assumed that the maximum re-entrainment sediment load was 1 yd^3/sec (or 27 cfs). Therefore, these figures show that deposited sediment generally increases with the amount

being re-entrained until the re-entrainment sediment load becomes 27 cfs. When the re-entrainment sediment load is greater than 27 cfs (approximately water discharge of 5,000 cfs when 1% sediment concentration by weight is used), deposited sediment generally decreases as the re-entrainment sediment load increases.

9.2 Long-term Sediment Transport Modeling in LSAR

The HEC-RAS model was used to simulate the long-term sediment re-entrainment through the LSAR. The model was set up to simulate 10 years of re-entrainment for both fine and medium sand gradations at a 1% re-entrainment concentration by weight. Base case scenario was run without re-entrainment using the existing sediment load from the dam. Following the 10-year simulation, an additional 5-year period was simulated with no re-entrainment to study the effects of stopping re-entrainment on the deposition that had occurred. These "clear water" runs only have sediment inflow that is being released from Prado Dam. The reservoir discharge sediment load is estimated by the USACE in the GDM (USACE 1988). These simulations are summarized as follows.

Simulation Scenarios	Model Duration	Incoming Sediment Load	Incoming Sediment Gradation
Base Fine Sand	10 Years	Existing flow from dam	Assumed Gradation: Fine Sand
1% Fine Sand	10 + 5 Years	Existing flow from dam and 1% concentration by weight re-entrainment load for 10 years; and existing flow from dam only for 5 years	Assumed Gradation: Fine Sand
1% Medium Sand	10 + 5 years	Existing flow from dam and 1% concentration by weight re-entrainment load for years; and existing flow from dam only for 5 years	Assumed Gradation: Medium Sand

Information about data and assumptions used in the development of the long-term sediment re-entrainment HEC-RAS model are detailed in Golder report (Golder 2017). LSAR river bed profile changes over time throughout re-entrainment are presented in Figures 20 through 22.
Figure 20 (base fine sand) shows continued degradation upstream of Gypsum Canyon Road, minor aggradation/degradation changes throughout the majority of the remainder of the modeled reach, and some aggradation downstream of a grade change near the Adams Street Bridge. Figure 21 (1% fine sand) shows aggradation immediately downstream of the dam, minor aggradation between Gypsum Canyon Road and the 91 Freeway Bridge, and more pronounced deposition between the 405 Freeway

Bridge and the ocean. Figure 22 (1% medium sand) shows greater deposition just downstream of the dam than even the fine sand scenario (Figure 21), little change in river profile between Gypsum Canyon Road and the 405 Freeway Bridge, and deposition between the 405 Freeway Bridge and the ocean. The deposition between the 405 Freeway Bridge and the ocean is noticeably less for the 1% medium sand scenario (Figure 22) when compared to the fine sand scenario (Figure 21) which is most likely due to the fact that more sediment had dropped out just downstream of the dam than with the fine sand simulation.

Figures 23 and 24 show the results of the clear water analysis compared against the results after 10 years for 1% find sand and 1% medium sand scenarios, respectively. The change in river bed profile, which is degradation only, in 5 years of clear water flows is generally limited to the areas just downstream of the dam that showed large deposition during re-entrainment. The remainder of the modeled reach remains generally unchanged from year 10 to year 15.

9.3 Conclusions

Reversing of channel incision within the reach downstream of Prado Dam can be accomplished by re-entraining fine or medium sand downstream of Prado Dam based on the following analysis and modeling results:

- Per the re-entrainment slope analysis, the river bed slope continues to increase throughout the 5-year model period. In general, the slopes calculated for the 5% concentration models increase more quickly than for the 1% concentration models. Deposited sediment generally increases with the amount being re-entrained as long as sediment concentration is maintained during the sediment re-entrainment.
- Per the long-term sediment transport modeling by re-entraining fine or medium sand at a 1% concentration by weight downstream of Prado Dam, the potential exists for areas of excess deposition to occur in some locations, notably just downstream of the dam. Therefore, additional modeling may need to be performed to vary the re-entrainment schedule or concentration to mitigate against the excessive deposition.

- It has been shown that stopping re-entrainment for a period of time can reverse the effects of large amounts of deposition, even though clear water modeling for 5 years after 10-year re-entrainment shows that the change in profile (degradation) is generally limited to the areas just downstream of the dam.

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TABLE 1: PERTINENT DATA - WITH PHASE II MODIFICATIONS
PRADO DAM AND RESERVOIR

Reservoir Elevation	
Debris Pool	490.0 ft
Flood Control Pool (spillway crest)	563.0 ft
Top of Dam	594.4 ft
Reservoir Gross Capacity	
Debris Pool	4,688 ac-ft
Spillway Crest	351,700 ac-ft
Allowance for Sediment (50-year)	35,000 ac-ft
Allowance for Sediment (100-year)	70,000 ac-ft
Reservoir Area	
Debris Pool	768 ac
Spillway Crest	10,280 ac
Dam – Type	Rolled Earthfill
Height above Original Streambed	134 ft
Top Length	3,050 ft
Top Width	30 ft
Freeboard	4.5 ft
Outlets	
Type of Gates	Vertical Lift
Number and Size of Gates	6 - 9.75' W x 14.75' H
Invert Elevation	470.0 ft
Regulated Outflow at Spillway Crest	30,000 ft3/s
Spillway	
Type	Overflow Concrete
Crest Length	1,000 ft
Design Discharge	481,000 ft^3/s
Includes Phase II GDM modifications to Prado Dam	

TABLE 2: PROJECTED ANNUAL INFLOW FOR 2021 AND 2071

Year	Inflow-2021 (acre-ft)	Inflow-2071 (acre-ft)
1950	158031	110468
1951	132793	84895
1952	294218	250176
1953	146898	100463
1954	203256	150415
1955	156158	111243
1956	211313	166570
1957	164854	121377
1958	287917	243665
1959	128759	80022
1960	146352	101144
1961	116152	65728
1962	192853	147758
1963	165498	121316
1964	140727	95711
1965	165545	123199
1966	247658	200881
1967	296873	257355
1968	163480	117290
1969	688821	647592
1970	157234	108722
1971	150390	102192
1972	150982	102531
1973	218100	176057
1974	192296	136774
1975	163456	118182
1976	156016	109769
1977	167130	120665
1978	442187	406418
1979	251909	205139
1980	590663	547853
1981	153159	104857
1982	233848	191431
1983	409874	365979
1984	147910	101597
1985	159205	112061
1986	201271	158325
1987	136631	89623
1988	167190	125913
Total	8457605	6681353

TABLE 3: MONTHLY EVAPORATION RATES FOR PRADO DAM USED IN HEC-5 MODEL

Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
4.00	2.00	1.06	0.30	0.64	1.93	3.28	4.96	6.03	7.48	7.48	5.41
Monthly evaporation in inches.											

TABLE 4: ELEVATION-AREA-CAPACITY RELATIONSHIP PRADO DAM PRESENT CONDITIONS – YEAR 2021

Elevation (ft)	Area (ac)	Storage (ac-ft)	Elevation (ft)	Area (ac)	Storage (ac-ft)
470	0	0	509	2146	24699
471	0	0	510	2224	26892
490	437	1266	511	2316	29174
491	513	1747	512	2412	31549
494	730	3646	513	2524	34027
495	802	4419	514	2643	36908
496	869	5260	515	2770	39352
498	1015	7159	516	2885	42188
499	1105	8245	517	3015	45191
500	1197	9411	518	3123	48273
501	1327	10753	519	3228	51457
502	1411	12138	520	3350	54788
503	1491	13599	525	3908	73008
504	1630	15194	530	4626	94444
505	1733	16885	540	6004	148081
506	1830	18685	550	7448	215492
507	1940	20584	560	9057	298081
508	2039	22582	563	9634	326283
Elevations in ft MSL; 1929 datum				Debris Pool = 490 ft	
Area and Storages based on 2008 Survey				Spillway Crest = 563.0 ft	
2021 volumes adjusted for sedimentation				Top of Dam = 594.4 ft	

TABLE 5: ELEVATION-AREA-CAPACITY RELATIONSHIP PRADO DAM FUTURE CONDITIONS – YEAR 2071

Elevation (ft)	Area (ac)	Storage (ac-ft)	Elevation (ft)	Area (ac)	Storage (ac-ft)
470	0	0	509	1628	14089
471	0	0	510	1705	15764
490	437	1266	511	1793	17525
491	60	25	512	1887	19375
494	260	541	513	1998	21328
495	320	838	514	2116	23683
496	380	1193	515	2243	25599
498	525	2114	516	2353	27906
499	612	2708	517	2479	30375
500	703	3380	518	2588	32922
501	828	4226	519	2695	35572
502	904	5109	520	2818	38370
503	982	6062	525	3381	53941
504	1120	7148	530	4107	72760
505	1223	8328	540	5518	121368
506	1319	9618	550	7032	184249
507	1427	11005	560	8807	263513
508	1524	12489	563	9634	291341
Elevations in ft MSL; 1929 datum				Debris Pool = 490 ft	
Area and Storages based on 2008 Survey				Spillway Crest = 563.0 ft	
2071 volumes adjusted for sedimentation				Top of Dam = 594.4 ft	

TABLE 6: HEC-5 RESULTS - WITHOUT PROJECT – PRESENT CONDITIONS (ALT2-2021) 350 cfs Recharge Rate

Water Year	Prado Dam			Local Inflow (ac-ft)	Total Water Spread (ac-ft)	Water "Lost" (ac-ft)
	Max WSE (ft)	Max Release (cfs)	Prado Inflow (ac-ft)			
1950	499.2	2810	158000	5050	147000	16300
1951	494.7	350	133000	1980	135000	0
1952	512.1	5340	294000	21200	170000	144000
1953	498.4	1430	147000	4040	145000	5760
1954	506.4	5000	203000	7840	149000	61100
1955	498.6	2300	156000	7770	150000	14000
1956	521.3	10650	211000	365	129000	82700
1957	505.9	5000	165000	4070	142000	26400
1958	508.5	5000	288000	11900	176000	122000
1959	498.4	1390	129000	0	124000	4880
1960	498.4	1650	146000	3800	139000	11300
1961	496.6	350	116000	9150	124000	1690
1962	500.1	3970	193000	7030	143000	56500
1963	504	5000	165000	3340	143000	23200
1964	499.8	650	141000	4290	146000	1270
1965	505.5	5000	166000	4380	148000	21100
1966	518.5	8850	248000	1610	142000	107000
1967	518.8	10700	297000	11400	177000	130000
1968	503.9	2240	163000	9850	154000	18900
1969	531.2	19830	689000	21700	183000	525000
1970	501.2	4720	157000	3210	139000	21200
1971	499.1	2740	150000	3420	135000	18200
1972	504.3	5000	151000	3970	122000	32700
1973	506.9	5000	218000	4000	163000	58300
1974	508.4	5000	192000	9340	144000	56900
1975	505	1390	163000	2250	159000	5370
1976	500.6	4080	156000	3650	139000	20400
1977	501.9	2970	167000	1270	151000	16900
1978	516.7	7670	442000	31900	174000	299000
1979	507.3	5000	252000	4650	173000	82700
1980	522.3	13640	591000	22200	178000	432000
1981	500.1	2800	153000	4350	139000	18500
1982	508.7	5000	234000	6840	164000	75800
1983	516	8470	410000	41300	205000	242000
1984	498.8	2190	148000	710	140000	10700
1985	500.5	3230	159000	1840	140000	20900
1986	505	5000	201000	12600	164000	48800
1987	498.7	1950	137000	4040	135000	6050
1988	498.9	2370	167000	5450	159000	12800
Average:	**505.7**	**4760**	**217000**	**7890**	**151000**	**73200**

TABLE 7: HEC-5 RESULTS – RE-ENTRAINMENT MEASURE – PRESENT CONDITIONS
(ALT4-2021) 350 cfs Recharge Rate

Water Year	Prado Dam			Local Inflow (ac-ft)	Total Water Spread (ac-ft)	Water "Lost" (ac-ft)
	Max WSE (ft)	Max Release (cfs)	Prado Inflow (ac-ft)			
1950	505.5	1800	158000	5050	156000	6470
1951	494.7	350	133000	1980	135000	0
1952	515	6730	294000	21200	172000	142000
1953	502.5	350	147000	4040	151000	18
1954	510.9	5050	203000	7840	150000	59800
1955	505.1	500	156000	7770	159000	4170
1956	521.3	10650	211000	365	138000	73100
1957	506	2620	165000	4070	151000	17200
1958	511.7	5220	288000	11900	181000	117000
1959	502	350	129000	0	129000	0
1960	501.1	620	146000	3800	148000	1480
1961	496.6	350	116000	9150	124000	1690
1962	506	3820	193000	7030	156000	43000
1963	505.5	1800	165000	3.34	152000	5750
1964	500	350	141000	4290	154000	121
1965	507.2	3940	166000	4380	148000	21100
1966	519.3	9390	248000	1610	151000	97600
1967	521.3	12370	297000	11400	182000	124000
1968	505.3	1440	163000	9850	164000	8560
1969	532.1	20980	689000	21700	183000	525000
1970	505.9	2910	157000	3210	145000	15400
1971	505.6	2430	150000	3420	145000	8,430
1972	506.4	4070	151000	3970	132000	23000
1973	511.3	5170	218000	4000	164000	57400
1974	511.2	5190	192000	9340	152000	49000
1975	505.3	1010	163000	2250	162000	2430
1976	505.7	2130	156000	3650	148000	11300
1977	505.6	2460	167000	1270	160000	7180
1978	518.2	8890	442000	31900	174000	299000
1979	511.7	5250	252000	4650	173000	82500
1980	522.7	13950	591000	22200	178000	432000
1981	505.6	2990	153000	4350	146000	11100
1982	512.9	5680	234000	6840	164000	75700
1983	516.9	9030	410000	41300	205000	241000
1984	504.6	350	148000	710	150000	0
1985	505.8	2660	159000	1840	149000	11100
1986	508.2	4290	101000	12600	167000	45700
1987	502.8	350	137000	4040	140000	0
1988	505	350	167000	5450	170000	1660
Average:	**508.8**	**4300**	**217000**	**7890**	**157000**	**67200**

TABLE 8: HEC-5 RESULTS - WITHOUT PROJECT – FUTURE CONDITIONS (ALT2-2071) 350 cfs Recharge Rate

Water Year	Prado Dam			Local Inflow (ac-ft)	Total Water Spread (ac-ft)	Water "Lost" (ac-ft)
	Max WSE (ft)	Max Release (cfs)	Prado Inflow (ac-ft)			
1950	502.2	3600	110000	552	86700	29200
1951	500.8	990	84900	2180	82400	4520
1952	514.6	6370	250000	23	111000	162000
1953	501.2	1900	100000	4420	91800	12900
1954	509.3	5000	150000	8540	86200	72500
1955	500.7	2640	111000	8400	92300	27200
1956	524.5	13740	167000	403	75300	91500
1957	510.2	5010	121000	4430	87900	37800
1958	511.4	5150	244000	12900	119000	137000
1959	498.9	2240	80000	0	65700	14300
1960	499.2	2220	101000	4130	78900	26300
1961	498.2	910	65700	9910	68800	6790
1962	503.1	4250	148000	7640	85800	69500
1963	508.7	5000	121000	3640	87500	37200
1964	505	2610	95700	4690	84900	15300
1965	506.1	5000	123000	4790	88500	39100
1966	521.6	10740	201000	1770	83700	119000
1967	521.7	12540	257000	12400	113000	156000
1968	508.5	4320	117000	10700	90300	37500
1969	532.7	21720	648000	23500	141000	529000
1970	502.7	5000	109000	3540	75700	36500
1971	500.2	3290	102000	3760	78900	27000
1972	506.8	5000	103000	4370	66500	40300
1973	509.9	5000	176000	4410	101000	78700
1974	508.4	5000	137000	10100	81600	65100
1975	505	2800	118000	2480	93300	27100
1976	502.5	4150	110000	4010	75700	38000
1977	505	3010	121000	1420	92700	28800
1978	518.8	9040	406000	34500	126000	314000
1979	510.9	5050	205000	5140	116000	94300
1980	523.5	14430	548000	23800	132000	438000
1981	500.5	3720	105000	4780	82100	27400
1982	513.2	5160	191000	7490	101000	97100
1983	517.4	9320	366000	44300	156000	251000
1984	501.4	2840	102000	789	78200	26200
1985	501.1	4230	112000	2030	84800	29200
1986	507	5000	158000	13600	103000	68900
1987	498.9	3350	89600	4430	79700	14300
1988	505	3400	126000	5920	97800	33700
Average:	**508.1**	**5520**	**171000**	**8560**	**93400**	**86200**

TABLE 9: HEC-5 RESULTS – RE-ENTRAINMENT MEASURE – FUTURE CONDITIONS (ALT4-2071) 350 cfs Recharge Rate

Water Year	Prado Dam			Local Inflow (ac-ft)	Total Water Spread (ac-ft)	Water "Lost" (ac-ft)
	Max WSE (ft)	Max Release (cfs)	Prado Inflow (ac-ft)			
1950	505.4	2060	110000	5520	107000	8580
1951	500.9	350	84900	2180	86900	0
1952	516.6	7390	250000	23	121000	152000
1953	505.3	950	100000	4420	103000	1580
1954	511.5	5160	150000	8540	98400	60300
1955	505.7	2540	111000	8400	106000	13000
1956	524.7	13960	167000	403	81500	85300
1957	512.9	5650	121000	4430	99500	26000
1958	513.8	6020	244000	12900	130000	126000
1959	505.3	1270	80000	0	76400	3550
1960	505.4	1560	101000	4130	97700	7350
1961	502.3	350	65700	9910	73200	2350
1962	506.3	4050	148000	7640	102000	53600
1963	510.6	5030	121000	3640	97600	24700
1964	505.3	1080	95700	4690	99500	2840
1965	501.9	4020	123000	4790	94100	33500
1966	523.2	11830	201000	1770	101000	101000
1967	523.4	13630	257000	12400	128000	141000
1968	508.5	3470	117000	10700	103000	24700
1969	533.6	22830	648000	23500	142000	528000
1970	505.9	4150	109000	3540	88900	23200
1971	505.9	2760	102000	3760	88600	17300
1972	511.3	5120	103000	4370	72800	34100
1973	512.7	5700	176000	4410	117000	63000
1974	511.9	5560	137000	10100	90800	55900
1975	505.6	2270	118000	2480	106000	13900
1976	501.9	4020	110000	4010	92300	21100
1977	505.6	3000	121000	1420	99700	21800
1978	519.4	9940	406000	34500	132000	308000
1979	512.8	5660	205000	5140	129000	80600
1980	523.8	14620	548000	23800	136000	435000
1981	505.8	3040	105000	4780	91300	18100
1982	514.2	6540	191000	7490	118000	80500
1983	517.7	9480	366000	44300	173000	233
1984	505.5	1610	102000	789	96900	7440
1985	507.3	3350	112000	2030	93500	20500
1986	511.2	l,100	158000	13600	116000	55100
1987	505.8	2190	89600	4430	87500	6510
1988	505.8	2190	126000	5920	120000	11800
Average:	**510.9**	**5370**	**171000**	**8560**	**105000**	**74400**

TABLE 10: Project Benefit Analysis

350 cfs Fixed Recharge Rate

Scenario	Condition	Recharge	Water Lost
Alt 2 (Current Condition)	2021	151,000	73,200
Alt 4 (505 Yr Round)	2021	157,000	67,200
Benefit		6,000	(6,000)
Alt 2 (Current Condition)	2071	93,400	86,200
Alt 4 (505 Yr Round)	2071	105,000	74,400
Benefit		11,600	(11,800)

TABLE 11: INUNDATION DURATIONS FOR PRADO DAM

Without Project – Present Conditions - 350 cfs Recharge Rate
Flood Season Water Conservation with Forecasting to 498.0 ft + Non-Flood Season Water Conservation to 505.0 ft

Frequency (Years)		Duration of Inundation (Days) at various elevations ALT2_2021										
		470	**480**	**490**	**494**	**498**	**500**	**505**	**510**	**520**	**530**	**540**
2		124	112	100	65	20	6	0	0	0	0	0
5		191	168	152	129	71	57	1	3	0	0	0
10		199	188	176	156	117	93	10	1	0	0	0
25		220	190	178	166	142	119	20	10	2	0	0
50		269	256	220	188	155	139	20	14	7	0	0
70		270	259	240	215	156	141	20	14	7	2	0
100		272	263	254	251	236	227	20	12	7	4	0
Average Monthly	**October**	3	2	1	0	0	0	0	0	0	0	0
	November	12	10	8	4	0	0	0	0	0	0	0
	December	16	14	13	9	1	0	0	0	0	0	0
	January	23	22	20	14	2	1	1	0	0	0	0
	February	22	21	19	15	2	1	1	0	0	0	0
	March 1-14	10	10	8	6	4	3	0	0	0	0	0
	March 15-31	12	11	10	8	6	6	0	0	0	0	0
	April	17	16	15	13	11	10	0	0	0	0	0
	May	12	11	10	8	5	4	0	0	0	0	0
	June	3	3	3	2	2	1	0	0	0	0	0
	July	1	1	1	0	0	0	0	0	0	0	0
	August	1	1	1	0	0	0	0	0	0	0	0
	September	2	1	1	0	0	0	0	0	0	0	0
Average Annual		133	123	110	81	35	26	2	1	0	0	0

TABLE 12: INUNDATION DURATIONS FOR PRADO DAM

Re-entrainment Measure – Present Conditions - 350 cfs Recharge Rate
Water Conservation to Elevation 505.0 ft Year Round

Frequency (Years)		Duration of Inundation (Days) at various elevations ALT4_2021 *(Increase from Alt. 2 Present Conditions)*										
		470	**480**	**490**	**494**	**498**	**500**	**505**	**510**	**520**	**530**	**540**
2		148	137	126	110	85	65	5	0	0	0	0
		24	25	26	45	65	59	5	0	0	0	0
5		196	183	163	151	128	110	20	3	0	0	0
		5	15	12	23	57	53	15	1	0	0	0
10		215	192	178	168	155	146	30	6	1	0	0
		16	5	2	12	38	54	20	1	1	0	0
25		233	212	195	184	171	157	50	12	3	0	0
		13	22	17	18	30	38	30	2	1	0	0
50		270	260	247	223	206	195	50	16	7	2	0
		1	3	27	35	51	56	30	2	1	2	0
70		271	261	252	238	214	203	50	16	8	3	0
		1	2	12	23	58	62	30	2	1	1	0
100		272	265	257	254	251	250	50	17	9	5	0
		1	2	3	4	15	23	30	5	1	1	0
Average Monthly	**October**	3	3	2	1	0	0	0	0	0	0	0
		1	1	1	0	0	0	0	0	0	0	0
	November	12	10	8	4	1	1	0	0	0	0	0
		0	0	0	0	1	1	0	0	0	0	0
	December	16	15	14	11	8	6	1	0	0	0	0
		0	0	1	2	7	6	0	0	0	0	0
	January	25	24	22	20	17	14	2	0	0	0	0
		1	2	3	6	15	13	1	0	0	0	0
	February	26	26	25	23	19	17	2	1	0	0	0
		4	5	6	8	16	16	1	0	0	0	0
	March 1-14	12	12	12	11	9	8	1	0	0	0	0
		2	3	3	5	5	5	1	0	0	0	0
	March 15-31	14	14	13	12	10	9	1	0	0	0	0
		3	3	3	4	4	3	1	0	0	0	0
	April	21	20	19	17	13	11	0	0	0	0	0
		4	4	4	4	2	1	0	0	0	0	0
	May	13	12	11	8	6	4	0	0	0	0	0
		1	1	1	0	0	0	0	0	0	0	0
	June	3	3	3	2	2	1	0	0	0	0	0
		0	0	0	0	0	0	0	0	0	0	0
	July	1	1	1	0	0	0	0	0	0	0	0
		0	0	0	0	0	0	0	0	0	0	0
	August	1	1	1	0	0	0	0	0	0	0	0
		0	0	0	0	0	0	0	0	0	0	0
	September	2	1	1	1	0	0	0	0	0	0	0
		0	0	0	0	0	0	0	0	0	0	0
Average Annual		149	141	131	109	86	71	7	2	0	0	0
		16	18	22	29	51	45	5	0	0	0	0

TABLE 13: INUNDATION DURATIONS FOR PRADO DAM

Without Project – Future Conditions - 350 cfs Recharge Rate
Water Conservation to Elevation 505.0 ft Year Round

Frequency (Years)		Duration of Inundation (Days) at various elevations ALT2_2071										
		470	480	490	494	498	500	505	510	520	530	540
2		72	63	54	51	27	16	2	0	0	0	0
5		121	109	94	81	50	37	10	3	0	0	0
10		146	137	128	122	97	84	10	5	1	0	0
25		174	163	153	143	125	108	20	10	3	0	0
50		197	187	177	166	138	117	20	14	8	2	0
70		198	189	180	176	150	119	20	14	8	3	0
100		199	192	185	182	179	178	20	15	9	5	0
Average Monthly	October	2	2	2	1	0	0	0	0	0	0	0
	November	8	8	8	6	1	0	0	0	0	0	0
	December	9	9	8	7	1	0	0	0	0	0	0
	January	13	13	13	11	3	1	1	0	0	0	0
	February	12	12	12	10	3	1	1	0	0	0	0
	March 1-14	7	7	7	6	4	3	0	0	0	0	0
	March 15-31	9	9	9	8	7	6	0	0	0	0	0
	April	13	13	13	11	9	7	0	0	0	0	0
	May	5	5	5	5	4	3	0	0	0	0	0
	June	1	1	1	1	1	1	0	0	0	0	0
	July	0	0	0	0	0	0	0	0	0	0	0
	August	1	1	1	1	0	0	0	0	0	0	0
	September	1	1	1	1	0	0	0	0	0	0	0
Average Annual		79	79	79	66	32	23	3	1	0	0	0

TABLE 14: INUNDATION DURATIONS FOR PRADO DAM

Re-entrainment Measure – Future Conditions - 350 cfs Recharge Rate
Water Conservation to Elevation 505.0 ft Year Round

Frequency (Years)		Duration of Inundation (Days) at various elevations ALT4_2071 *(Increase from Alt. 2 Future Conditions)*										
		470	**480**	**490**	**494**	**498**	**500**	**505**	**510**	**520**	**530**	**540**
2		97	89	81	78	71	54	5	0	0	0	0
		25	26	27	27	44	38	3	0	0	0	0
5		146	138	129	126	108	95	20	4	0	0	0
		25	28	35	45	58	58	10	1	0	0	0
10		170	162	154	151	136	127	30	7	2	0	0
		24	25	26	29	39	43	20	1	0	0	0
25		175	166	157	153	148	139	50	13	3	0	0
		1	3	4	10	23	30	30	3	0	0	0
50		243	234	223	208	175	164	50	16	8	3	0
		46	47	46	42	38	47	30	2	0	1	0
56		244	236	227	220	205	194	50	16	8	4	0
		47	47	48	44	55	74	30	2	0	1	0
100		246	239	233	230	227	226	50	18	9	6	0
		47	47	48	48	48	48	30	2	0	1	0
Average Monthly	**October**	2	2	2	2	1	1	0	0	0	0	0
		1	1	1	1	1	0	0	0	0	0	0
	November	10	10	10	9	6	4	0	0	0	0	0
		2	2	3	3	5	4	0	0	0	0	0
	December	14	14	14	13	11	9	1	0	0	0	0
		5	5	5	6	9	8	1	0	0	0	0
	January	20	20	20	18	15	13	2	1	0	0	0
		7	7	7	8	12	12	1	0	0	0	0
	February	19	19	19	18	15	13	2	1	0	0	0
		7	7	7	8	13	12	1	0	0	0	0
	March 1-14	9	9	9	8	6	6	1	0	0	0	0
		2	2	2	2	3	3	1	0	0	0	0
	March 15-31	10	10	10	9	8	7	1	0	0	0	0
		1	1	1	1	1	1	1	0	0	0	0
	April	13	13	13	11	9	7	0	0	0	0	0
		0	0	0	0	0	0	0	0	0	0	0
	May	5	5	5	5	4	3	0	0	0	0	0
		0	0	0	0	0	0	0	0	0	0	0
	June	1	1	1	1	1	1	0	0	0	0	0
		0	0	0	0	0	0	0	0	0	0	0
	July	0	0	0	0	0	0	0	0	0	0	0
		0	0	0	0	0	0	0	0	0	0	0
	August	1	1	1	1	1	0	0	0	0	0	0
		0	0	0	0	0	0	0	0	0	0	0
	September	1	1	1	1	1	0	0	0	0	0	0
		0	0	0	1	1	0	0	0	0	0	0
Average Annual		105	105	105	95	76	63	8	2	0	0	0
		26	26	26	30	44	40	5	1	0	0	0

TABLE 15: HEC-5 RESULTS - WITHOUT PROJECT – PRESENT CONDITIONS (ALT2-2021) 450 cfs Recharge Rate

Water Year	Prado Dam			Local Inflow (ac-ft)	Total Water Spread (ac-ft)	Water "Lost" (ac-ft)
	Max WSE (ft)	Max Release (cfs)	Prado Inflow (ac-ft)			
1950	498.4	2210	158000	5050	155000	7970
1951	493.4	450	133000	1980	135000	0
1952	512.1	5330	294000	21200	180000	135000
1953	497.6	450	147000	4040	151000	0
1954	505	4990	203000	7840	159000	51200
1955	498.6	2290	156000	7770	153000	10600
1956	521.3	10640	211000	365	130000	81400
1957	505.1	5000	165000	4070	149000	19300
1958	508.5	5000	288000	11900	193000	106000
1959	498.2	1120	129000	0	127000	1920
1960	498.4	1430	146000	3800	147000	2990
1961	496	450	116000	9150	125000	411
1962	499.3	3920	193000	7030	154000	46100
1963	503.8	4910	165000	3340	144000	24400
1964	498.2	450	141000	4290	145000	0
1965	505.5	5000	166000	4380	151000	18700
1966	518.3	8740	248000	1610	154000	94700
1967	518.8	10680	297000	11400	182000	126000
1968	503.8	2110	163000	9850	161000	11700
1969	531.1	19760	689000	21700	206000	502000
1970	501.2	3980	157000	3210	143000	17300
1971	498.8	2380	150000	3420	141000	12700
1972	504.5	5000	151000	3970	124000	30900
1973	501	5000	218000	4000	177000	44700
1974	508.1	5000	192000	9340	147000	54800
1975	505	1370	163000	2250	163000	2120
1976	500.6	4070	156000	3650	140000	19200
1977	501.5	2980	167000	1270	149000	18500
1978	516.6	7600	442000	31900	197000	275000
1979	501.5	5000	252000	4650	194000	62100
1980	522.3	13640	591000	22200	201000	410000
1981	499.4	2440	153000	4350	146000	11700
1982	509.3	5000	234000	6840	179000	60700
1983	515.8	8360	410000	41300	234000	212000
1984	498.3	1160	148000	710	146000	4100
1985	499.8	2870	159000	1840	143000	17600
1986	505	5000	201000	12600	176000	37700
1987	498.6	1820	137000	4040	135000	5170
1988	498.9	2370	167000	5450	163000	8890
Average:	**505.4**	**4610**	**217000**	**7890**	**159000**	**65300**

TABLE 16: HEC-5 RESULTS – RE-ENTRAINMENT MEASURE – PRESENT CONDITIONS (ALT4-2021) 450 cfs Recharge Rate

Water Year	Prado Dam			Local Inflow (ac-ft)	Total Water Spread (ac-ft)	Water "Lost" (ac-ft)
	Max WSE (ft)	Max Release (cfs)	Prado Inflow (ac-ft)			
1950	503.1	450	158000	5050	163000	0
1951	493.4	450	133000	1980	135000	0
1952	514.9	6710	294000	21200	189000	126000
1953	497.6	450	147000	4040	151000	0
1954	509.4	4610	203000	7840	166000	44400
1955	503.9	450	156000	7770	161000	2670
1956	521.3	10640	211000	365	140000	72000
1957	505.7	2130	165000	4070	160000	8670
1958	510.3	5010	288000	11900	198000	101000
1959	499.8	450	129000	0	129000	0
1960	500.3	450	146000	3800	150000	419
1961	496	450	116000	9150	125000	411
1962	506.1	3780	193000	7030	165000	34.9
1963	505.4	1750	165000	3.34	153000	7450
1964	498.2	450	141000	4290	152000	0
1965	507.3	3720	166000	4380	151000	18700
1966	519.5	9510	248000	1610	169000	80200
1967	521.3	12380	297000	11400	201000	107000
1968	505.2	1100	163000	9850	169000	3970
1969	532.1	20970	689000	21700	206000	502000
1970	505.9	2800	157000	3210	149000	11300
1971	505.4	1450	150000	3420	151000	2900
1972	506	3780	151000	3970	134000	21300
1973	511.l	5200	218000	4000	177000	44400
1974	511.3	5230	192000	9340	156000	45200
1975	505	450	163000	2250	165000	0
1976	505.6	1970	156000	3650	150000	8930
1977	505.7	2160	167000	1270	159000	8770
1978	518.2	8860	442000	31900	197000	275000
1979	511.7	5240	252000	4650	194000	61900
1980	522.7	13950	591000	22200	201000	410000
1981	505.4	1400	153000	4350	154000	3550
1982	512	5290	234000	6840	183000	56800
1983	516.8	8980	410000	41300	243000	204000
1984	499.6	450	148000	710	150000	0
1985	505.8	2380	159000	1840	153000	7850
1986	506.8	3180	201000	12600	176000	36700
1987	502.2	450	137000	4040	141000	25
1988	502.5	450	167000	5450	171000	1180
Average:	**508**	**4090**	**217000**	**7890**	**165000**	**59200**

TABLE 17: HEC-5 RESULTS - WITHOUT PROJECT – FUTURE CONDITIONS (ALT2-2071) 450 cfs Recharge Rate

Water Year	Prado Dam			Local Inflow (ac-ft)	Total Water Spread (ac-ft)	Water "Lost" (ac-ft)
	Max WSE (ft)	Max Release (cfs)	Prado Inflow (ac-ft)			
1950	502.2	3590	110000	552	90600	25300
1951	499.4	950	84900	2180	84500	2470
1952	514.6	6360	250000	23000	119000	154000
1953	501.1	1910	100000	4420	94600	10200
1954	509.3	5000	150000	8540	92200	66600
1955	500.2	2640	111000	8400	96000	23500
1956	524.5	13740	167000	403	76800	90100
1957	510.2	5010	121000	4430	93500	32200
1958	511.4	5150	244000	12900	132000	124000
1959	498.9	2240	80000	0	68100	11900
1960	498.9	2200	101000	4130	83300	21900
1961	4982	920	65700	9910	71000	4650
1962	502.8	4120	148000	7640	91800	63500
1963	508.7	5000	121000	3640	88100	36700
1964	505	2580	95700	4690	87400	12800
1965	506.1	5000	123000	4790	92300	35500
1966	521.5	10610	201000	1770	90500	112000
1967	521.7	12510	257000	12400	121000	149000
1968	508.4	4, 180	117000	10700	93600	34300
1969	532.7	21790	648000	23500	165000	505000
1970	502.6	5000	109000	3540	79100	33100
1971	500.1	3430	102000	3760	81700	24200
1972	506.8	5000	103000	4370	68100	38800
1973	510	5000	176000	4410	111000	68900
1974	508.4	5000	137000	10100	86100	60700
1975	505.0	2730	118000	2480	97300	23200
1976	502.7	4020	110000	4010	77500	36200
1977	505	3020	121000	1420	93800	27900
1978	518.8	9030	406000	34500	142000	298000
1979	510.7	5030	205000	5140	125000	85400
1980	523.5	14450	548000	23800	152000	419000
1981	5002	3450	105000	4780	85900	23700
1982	512.8	5630	191000	7490	110000	88900
1983	517.4	9320	366000	44300	176000	231000
1984	5012	2820	102000	789	81200	23200
1985	501.3	4140	112000	2030	87600	26500
1986	507.1	5000	158000	13600	109000	63000
1987	498.8	3340	89600	4430	81300	12700
1988	504.4	3380	126000	5920	103000	29000
Average:	**508.0**	**5490**	**171000**	**8560**	**99400**	**80200**

TABLE 18: HEC-5 RESULTS – RE-ENTRAINMENT MEASURE – FUTURE CONDITIONS (ALT4-2071) 450 cfs Recharge Rate

Water Year	Prado Dam			Local Inflow (ac-ft)	Total Water Spread (ac-ft)	Water "Lost" (ac-ft)
	Max WSE (ft)	Max Release (cfs)	Prado Inflow (ac-ft)			
1950	505.4	2000	110000	5522	110000	5870
1951	500.0	450	84900	2182	87000	0
1952	516.5	7330	250000	23014	129000	144000
1953	503.4	450	100000	4419	105000	0
1954	510.8	4780	150000	8537	105000	53300
1955	505.4	2250	111000	8404	110000	9910
1956	524.7	13900	167000	403	82700	84100
1957	512.3	5420	121000	4429	105000	20300
1958	514.0	6100	244000	12916	146000	110000
1959	505.2	989	80000	0	78800	1210
1960	505.4	1460	101000	4132	102000	2870
1961	501.9	450	65700	9911	74800	829
1962	506.4	3940	148000	7640	110000	44800
1963	510.5	5020	121000	3638	98500	25800
1964	505.2	981	95700	4687	99500	1200
1965	508.1	3870	123000	4792	96600	31100
1966	523.1	11700	201000	1769	111000	91100
1967	523.4	13600	257000	12436	136000	134000
1968	508.4	3370	117000	10725	109000	18600
1969	533.6	22800	648000	23536	165000	505000
1970	506.0	3950	109000	3544	91200	21000
1971	505.8	2380	102000	3759	94100	11800
1972	511.4	5140	103000	4372	74300	32500
1973	512.3	5510	176000	4409	130000	50200
1974	512.0	5600	137000	10120	94300	52500
1975	505.5	2180	118000	2483	109000	11800
1976	508.0	3990	110000	4007	93000	20500
1977	505.6	3000	121000	1418	101000	21000
1978	519.6	10100	406000	34465	153000	287000
1979	511.8	5260	205000	5139	147000	62500
1980	523.8	14600	548000	23843	158000	413000
1981	506.0	2640	105000	4951	97600	11900
1982	514.0	6320	191000	7494	131000	67100
1983	517.6	9420	366000	44537	198000	208000
1984	505.1	848	102000	789	101000	2880
1985	506.6	2990	112000	2033	96300	17700
1986	511.8	5240	158000	13595	126000	46000
1987	505.7	2100	89600	4433	88300	5680
1988	505.8	2220	126000	5923	123000	8940
Average:	**510.7**	**5240**	**171279**	**8574**	**111974**	**67589**

TABLE 19: Project Benefit Analysis

450 cfs Maximum Recharge Rate

Scenario	Condition	Recharge	Water Lost
Alt 2 (Current Condition)	2021	158,282	65,969
Alt 4 (505 Yr Round)	2021	165,051	59,220
Benefit		6,769	(6,749)
Alt 2 (Current Condition)	2071	98,890	80,760
Alt 4 (505 Yr Round)	2071	111,974	67,589
Benefit		13,084	(13,171)

TABLE 20: INUNDATION DURATIONS FOR PRADO DAM

Without Project - Present Conditions – 450 cfs Recharge Rate
Flood Season Water Conservation with Forecasting to 498.0 ft + Non-Flood Season Water Conservation to 505.0 ft

Frequency (Years)	Duration of Inundation (Days) at various elevations ALT2_2021										
	470	**480**	**490**	**494**	**498**	**500**	**505**	**510**	**520**	**530**	**540**
2	94	75	55	42	12	4	0	0	0	0	0
5	145	130	108	91	49	37	8	3	0	0	0
10	173	163	154	148	104	79	10	5	0	0	0
25	196	184	167	156	126	110	20	14	3	0	0
50	236	211	184	170	144	118	30	14	6	0	0
70	240	222	204	180	150	121	30	14	7	2	0
100	242	225	208	201	154	131	60	15	8	3	0

TABLE 21: INUNDATION DURATIONS FOR PRADO DAM

Re-entrainment Measure – Present Conditions - 450 cfs Recharge Rate
Water Conservation to Elevation 505.0 ft Year Round

Frequency (Years)	Duration of Inundation (Days) at various elevations ALT4_2021 *(Increase from Alt. 2 Present Conditions)*										
	470	**480**	**490**	**494**	**498**	**500**	**505**	**510**	**520**	**530**	**540**
2	117	95	77	64	47	36	5	0	0	0	0
	23	20	22	22	35	32	5	0	0	0	0
5	169	154	131	118	99	84	19	4	0	0	0
	24	24	23	27	50	47	11	1	0	0	0
10	173	164	155	151	141	133	51	7	1	0	0
	0	1	1	3	37	54	41	2	1	0	0
25	218	205	181	169	157	151	79	16	3	0	0
	22	21	14	13	31	41	59	2	0	0	0
50	244	231	212	202	182	168	86	17	7	0	0
	8	20	28	32	38	50	56	3	1	0	0
70	246	237	228	219	190	177	89	17	8	3	0
	6	15	24	39	40	56	59	3	1	1	0
100	246	238	229	226	200	180	100	17	8	4	0
	4	13	21	25	46	49	40	2	0	1	0

TABLE 22: INUNDATION DURATIONS FOR PRADO DAM

Without Project – Future Conditions - 450 cfs Recharge Rate
Flood Season Water Conservation with Forecasting to 498.0 ft + Non-Flood Season Water Conservation to 505.0 ft

Frequency (Years)	Duration of Inundation (Days) at various elevations ALT2_2071										
	470	**480**	**490**	**494**	**498**	**500**	**505**	**510**	**520**	**530**	**540**
2	70	61	52	41	20	10	2	0	0	0	0
5	96	87	77	68	44	27	9	3	0	0	0
10	144	133	117	106	80	65	19	7	2	0	0
25	167	155	139	132	119	99	20	14	4	0	0
50	171	163	154	151	126	106	20	14	7	1	0
70	172	164	155	152	126	106	20	15	8	3	0
100	172	164	156	152	131	110	30	15	8	5	0

TABLE 23: INUNDATION DURATIONS FOR PRADO DAM

Re-entrainment Measure – Future Conditions - 450 cfs Recharge Rate
Water Conservation to Elevation 505.0 ft Year Round

Frequency (Years)	Duration of Inundation (Days) at various elevations ALT4_2071 *(Increase from Alt. 2 Future Conditions)*										
	470	**480**	**490**	**494**	**498**	**500**	**505**	**510**	**520**	**530**	**540**
2	95	85	76	66	52	40	7	0	0	0	0
	25	24	24	25	32	30	5	0	0	0	0
5	121	113	105	102	89	77	19	5	0	0	0
	25	26	28	34	45	50	10	2	0	0	0
10	147	139	132	129	126	115	50	8	2	0	0
	3	6	15	23	46	50	31	1	0	0	0
25	171	162	153	149	137	131	75	16	4	0	0
	4	7	14	17	18	32	55	2	0	0	0
50	216	205	172	163	153	145	76	17	8	2	0
	45	42	18	12	27	39	56	3	1	1	0
70	219	211	202	195	177	161	77	17	8	4	0
	47	47	47	43	51	55	57	2	0	1	0
100	219	212	204	201	188	179	86	17	8	5	0
	47	48	48	49	57	69	56	2	0	0	0

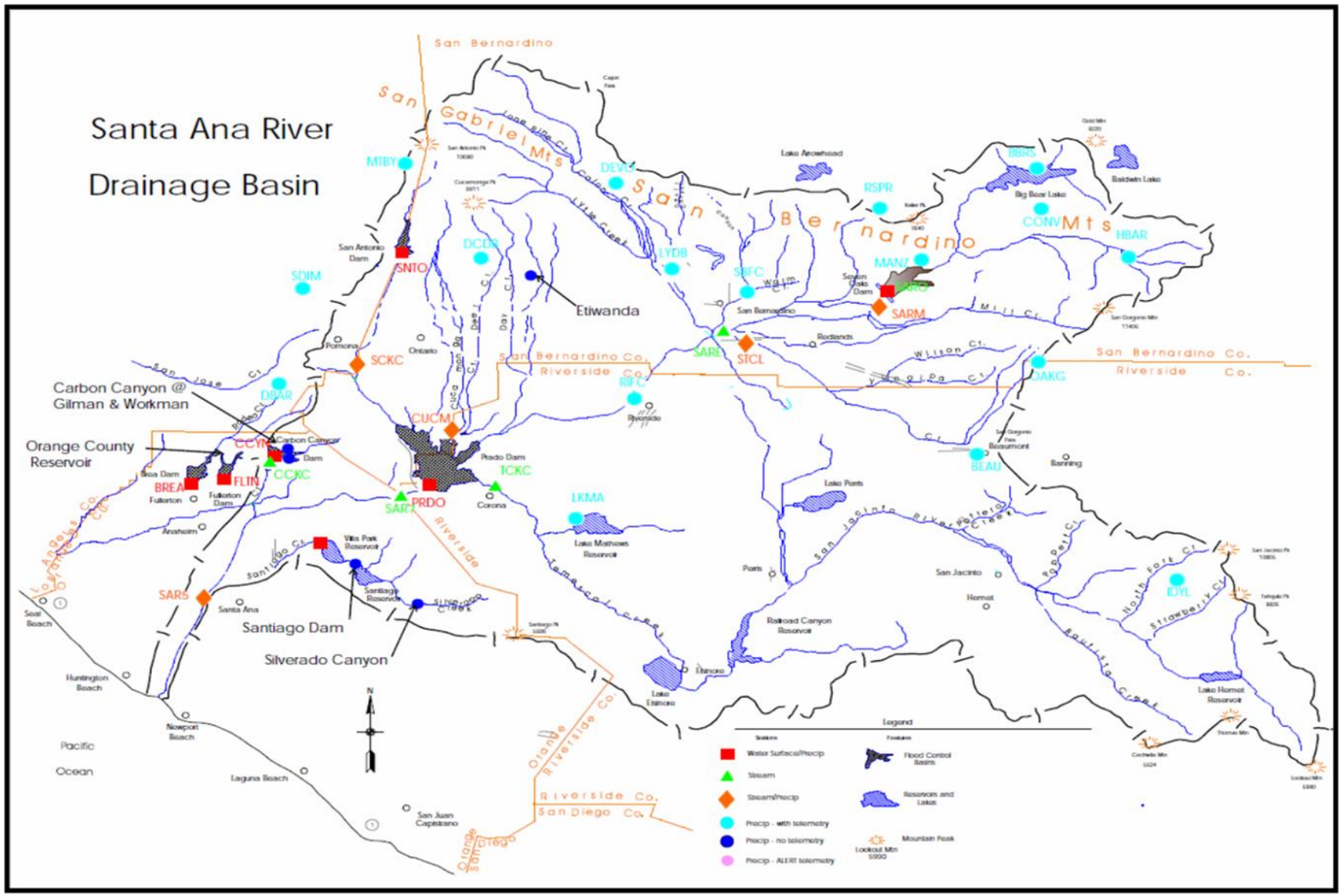


Figure 1: Santa Ana River Drainage Area Basin Map

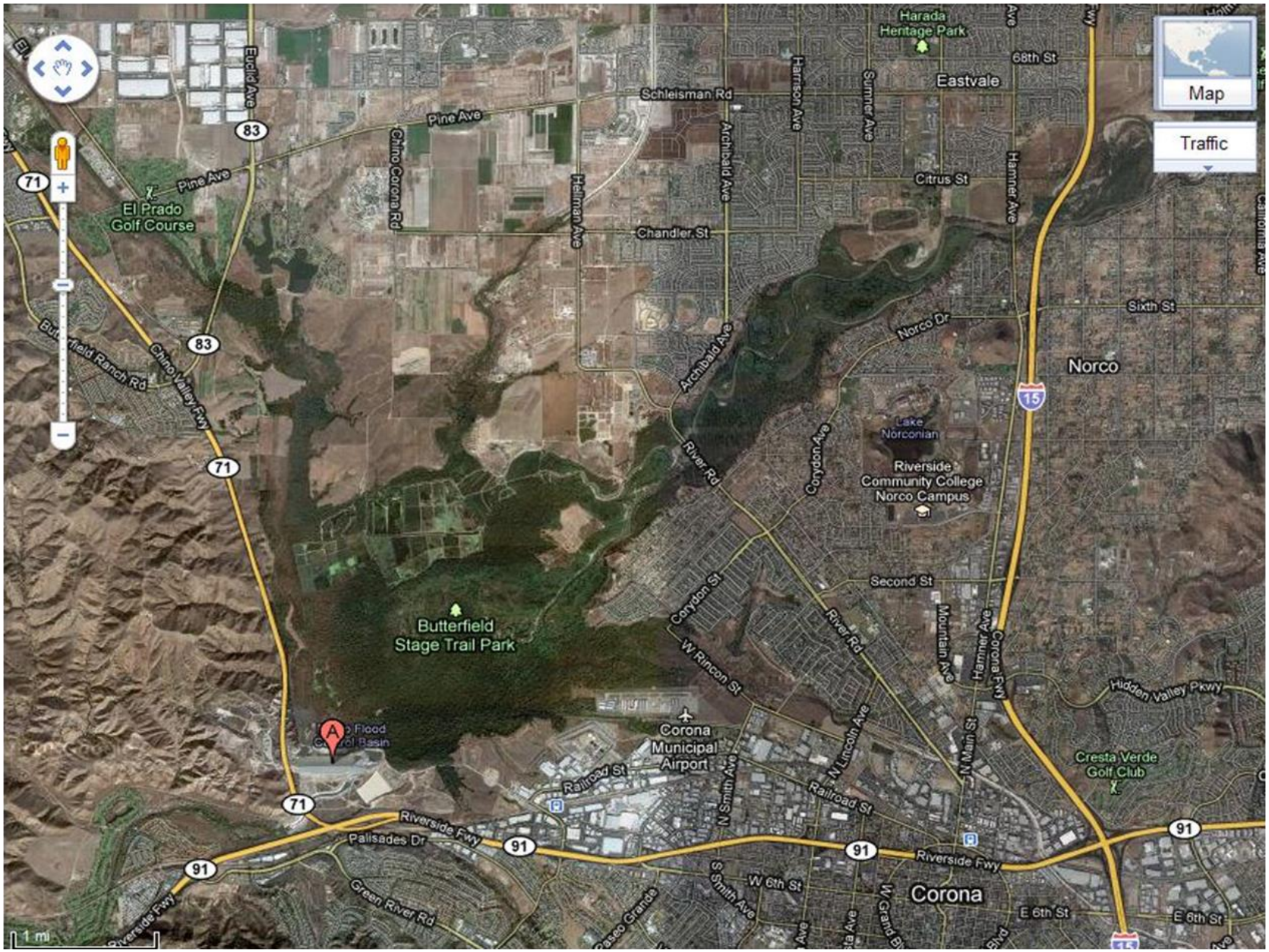


Figure 2: Prado Basin Study Area Map

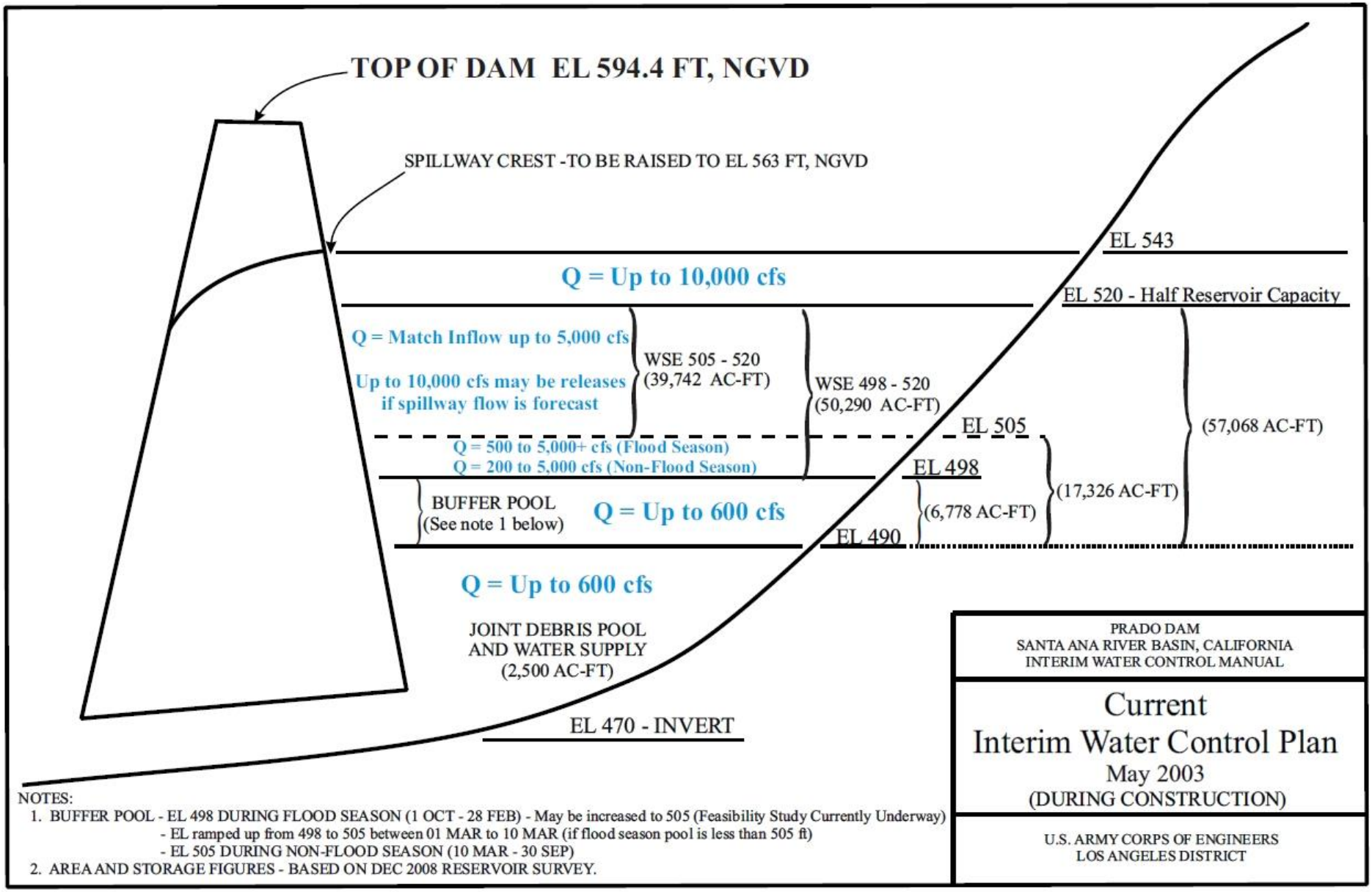


Figure 3: Interim Water Control Plan – May 2003

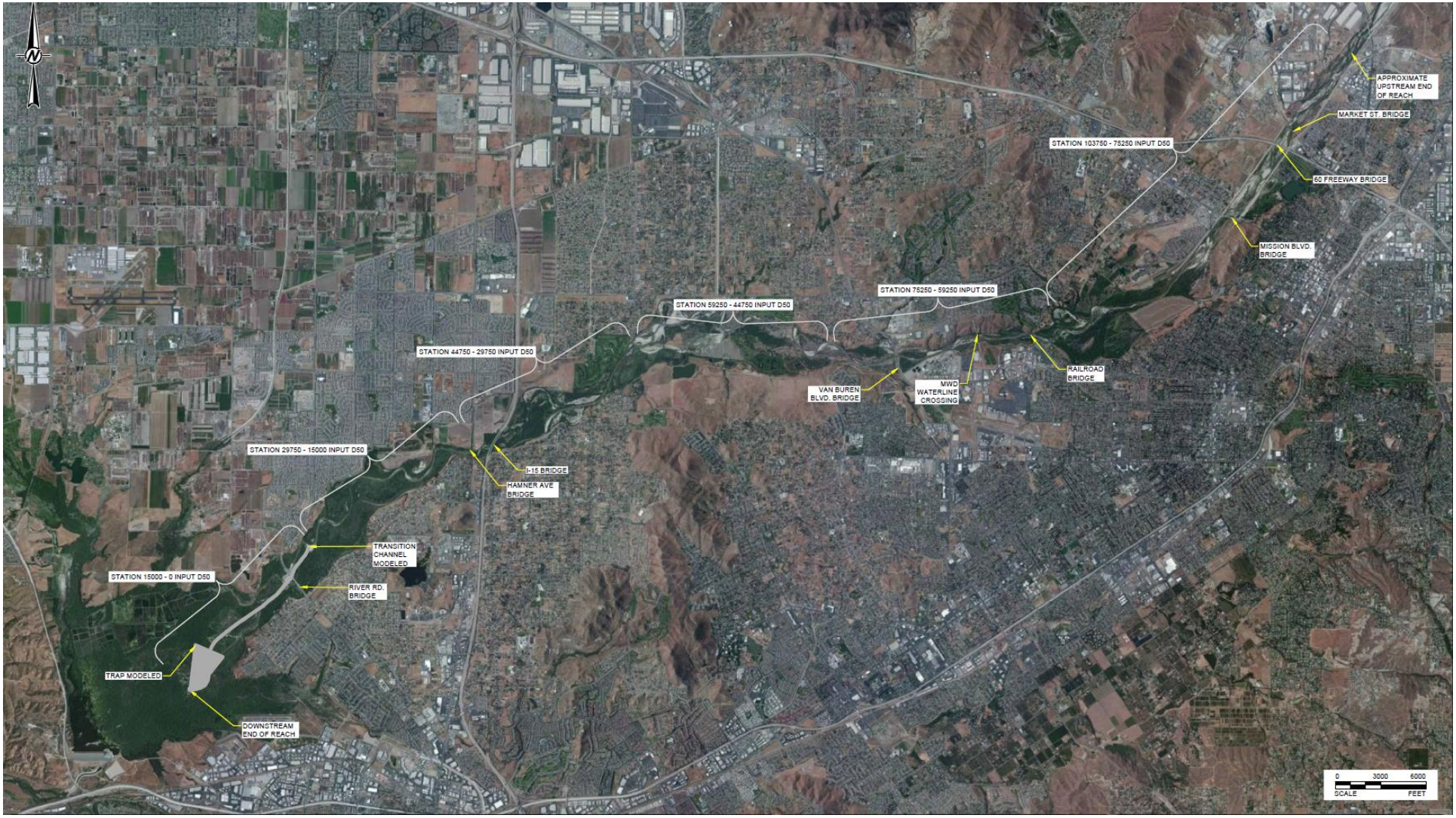


Figure 4: Modeling Extent and Trap Scenario Modeled (Golder, 2015a)

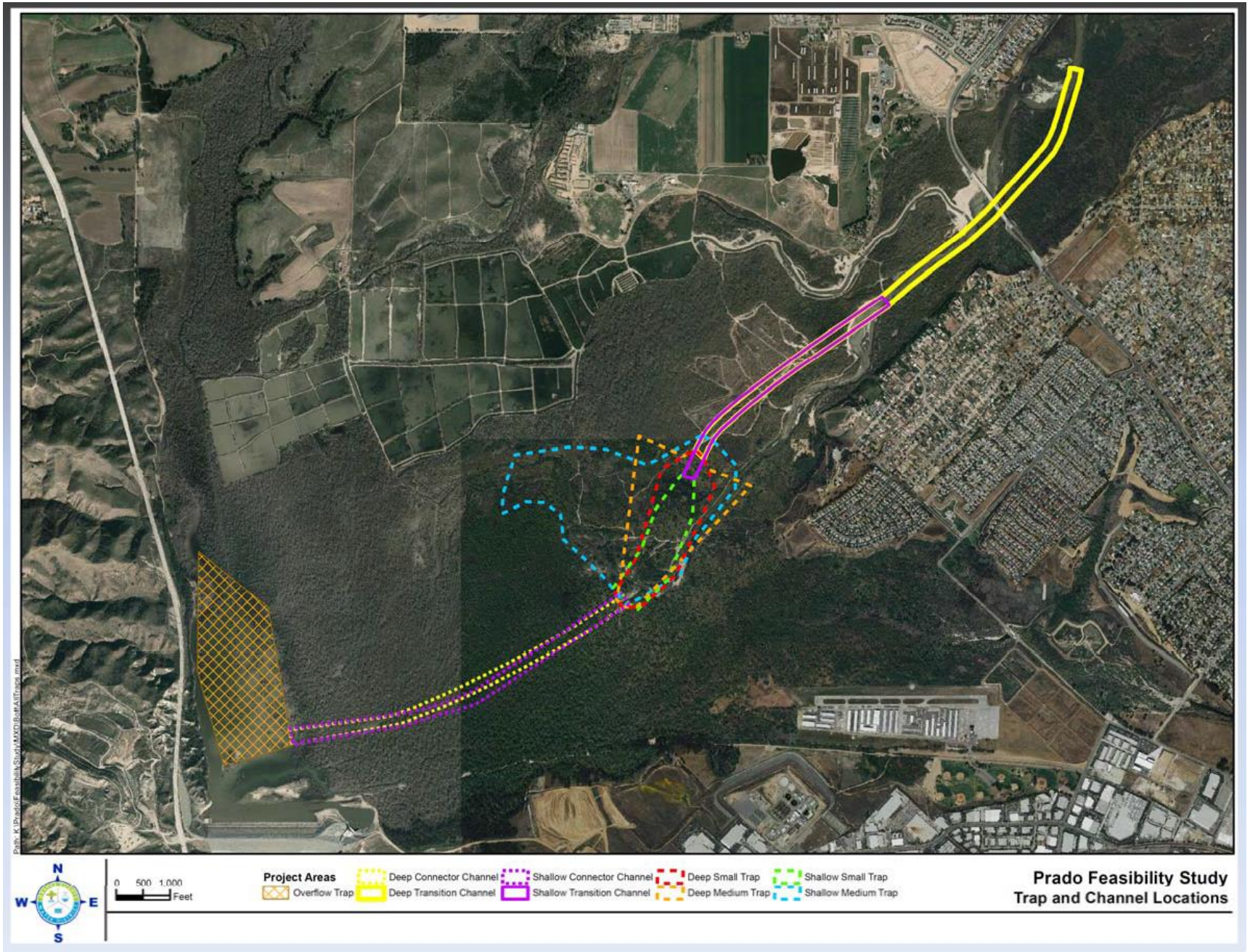


Figure 5: Proposed Sediment Trap and Transition Channel Configurations (Scheevel, 2015)

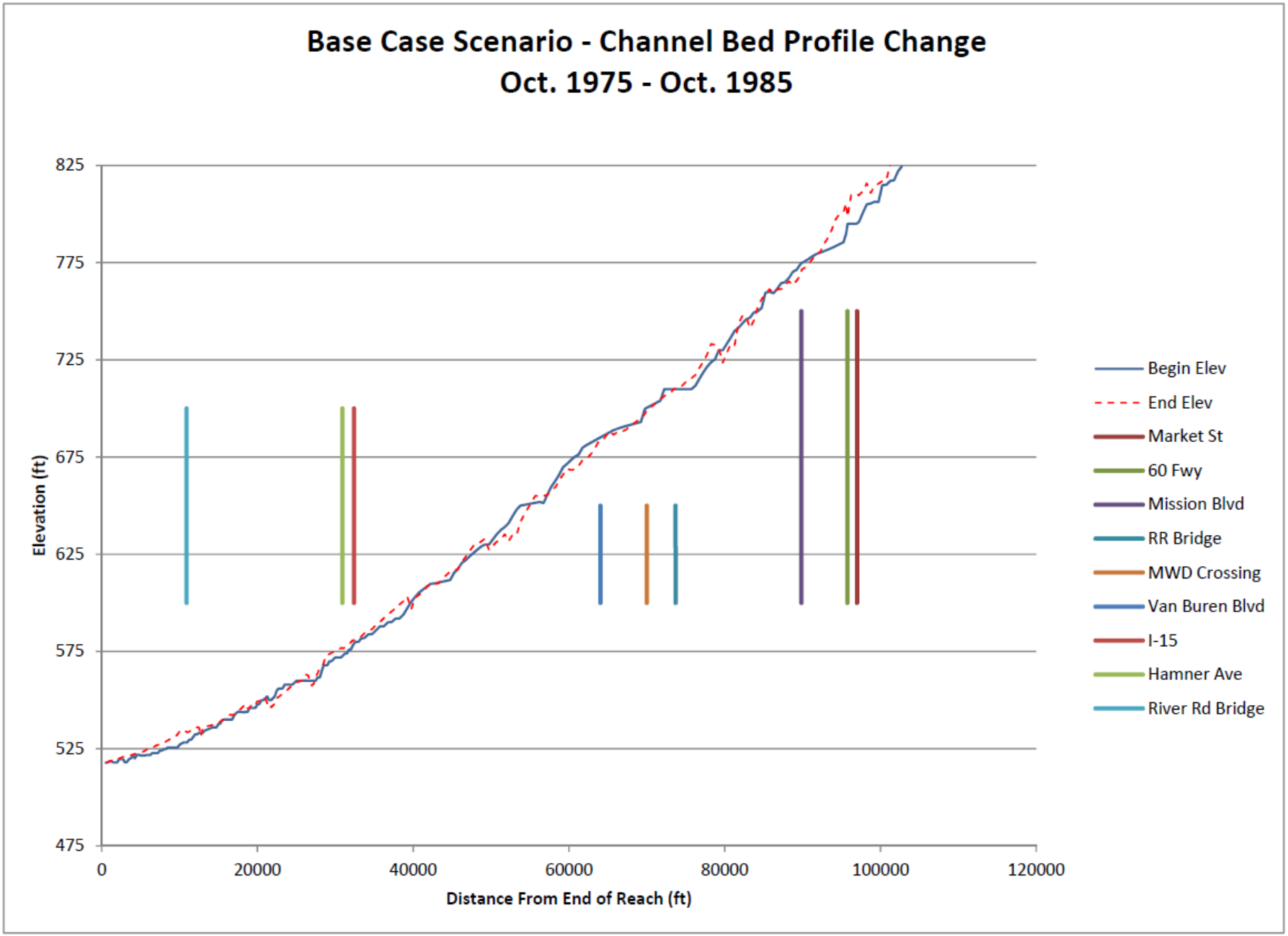


Figure 6: River Bed Profile Change after 10 Years for Base Case Scenario (Golder, 2015a)

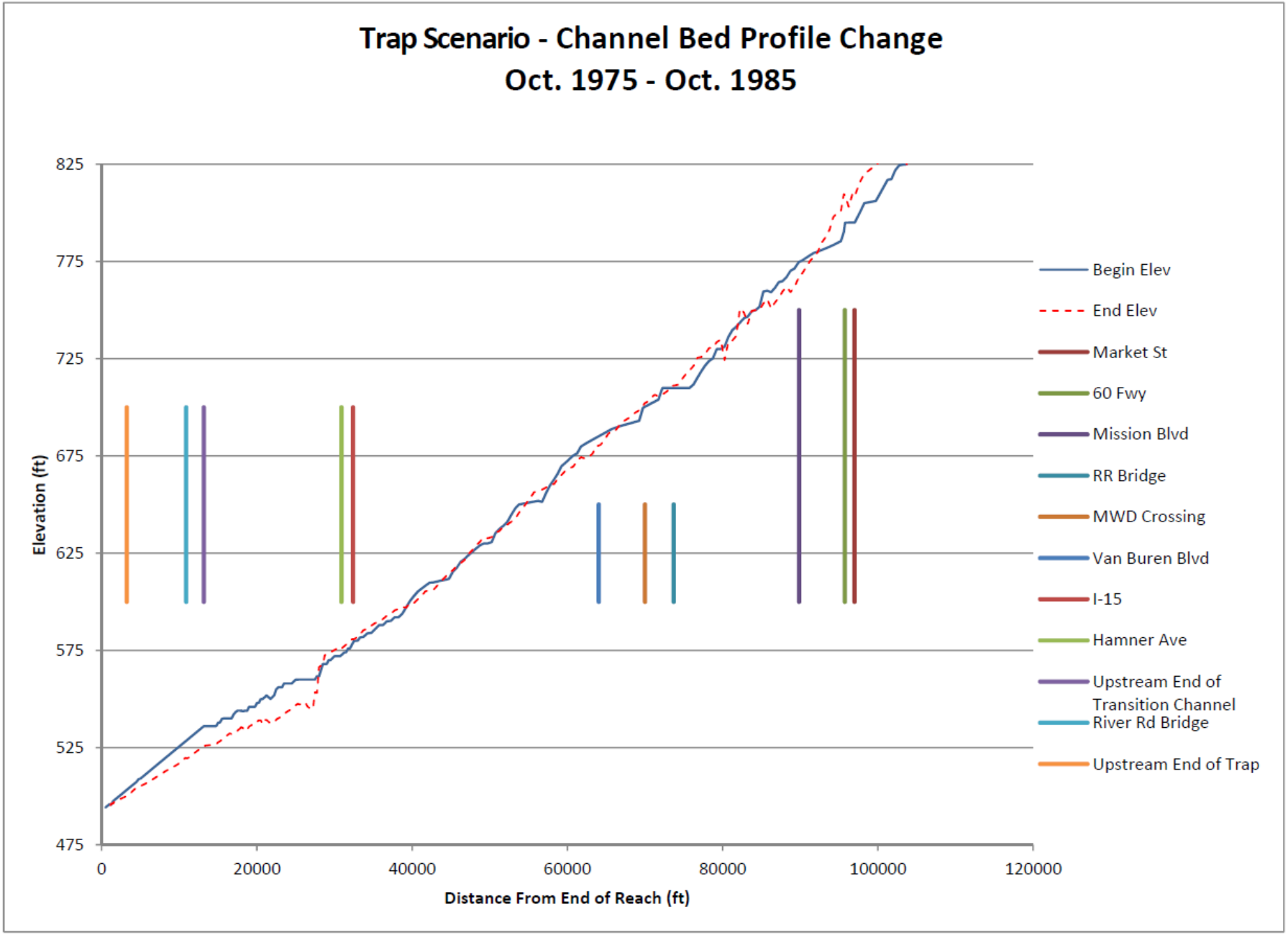


Figure 7: River Bed Profile Change after 10 Years for Trap Scenario (Golder, 2015a)

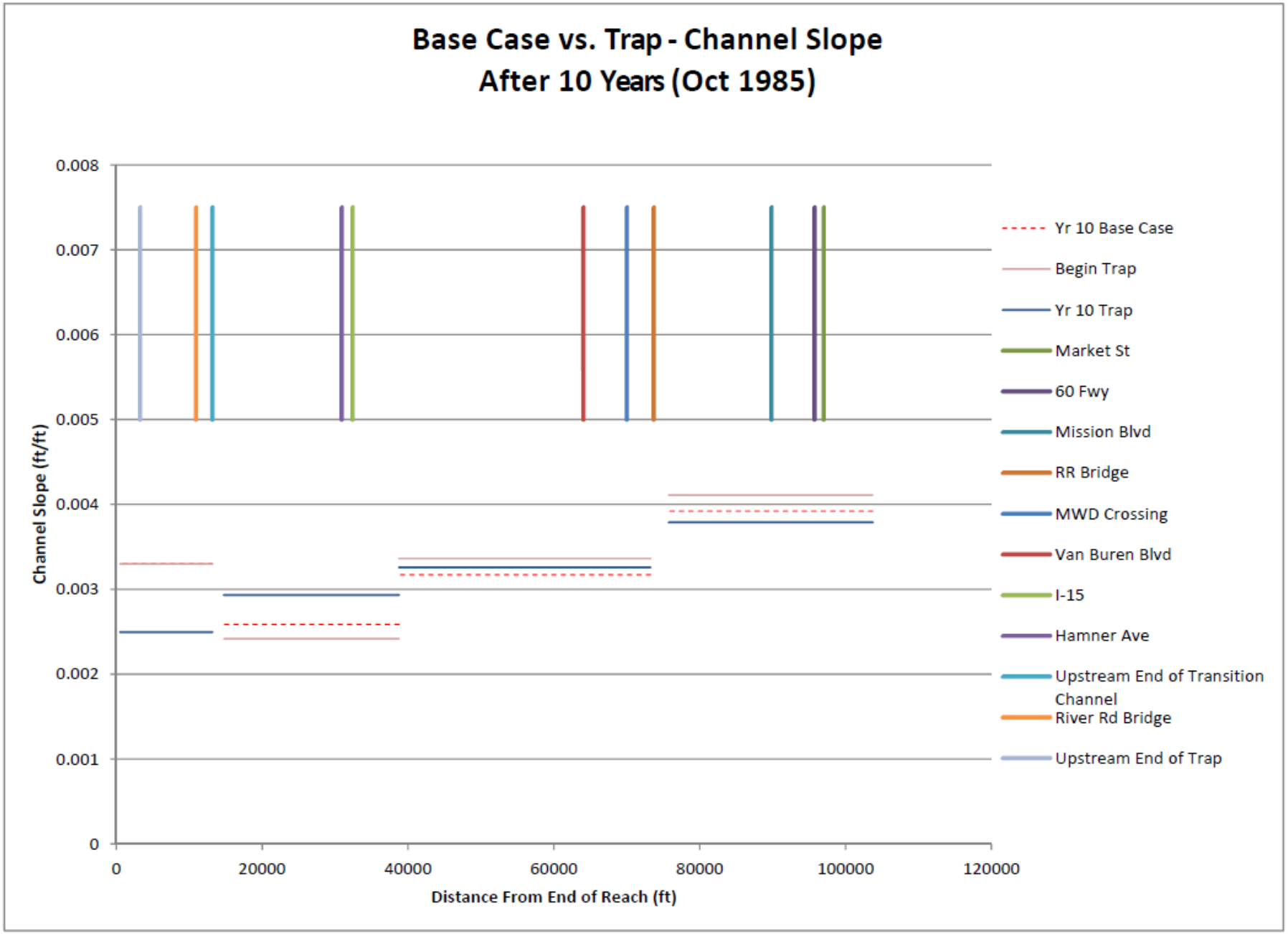


Figure 8: Comparison of Channel Slope Change after 10 Years (Golder, 2015a)

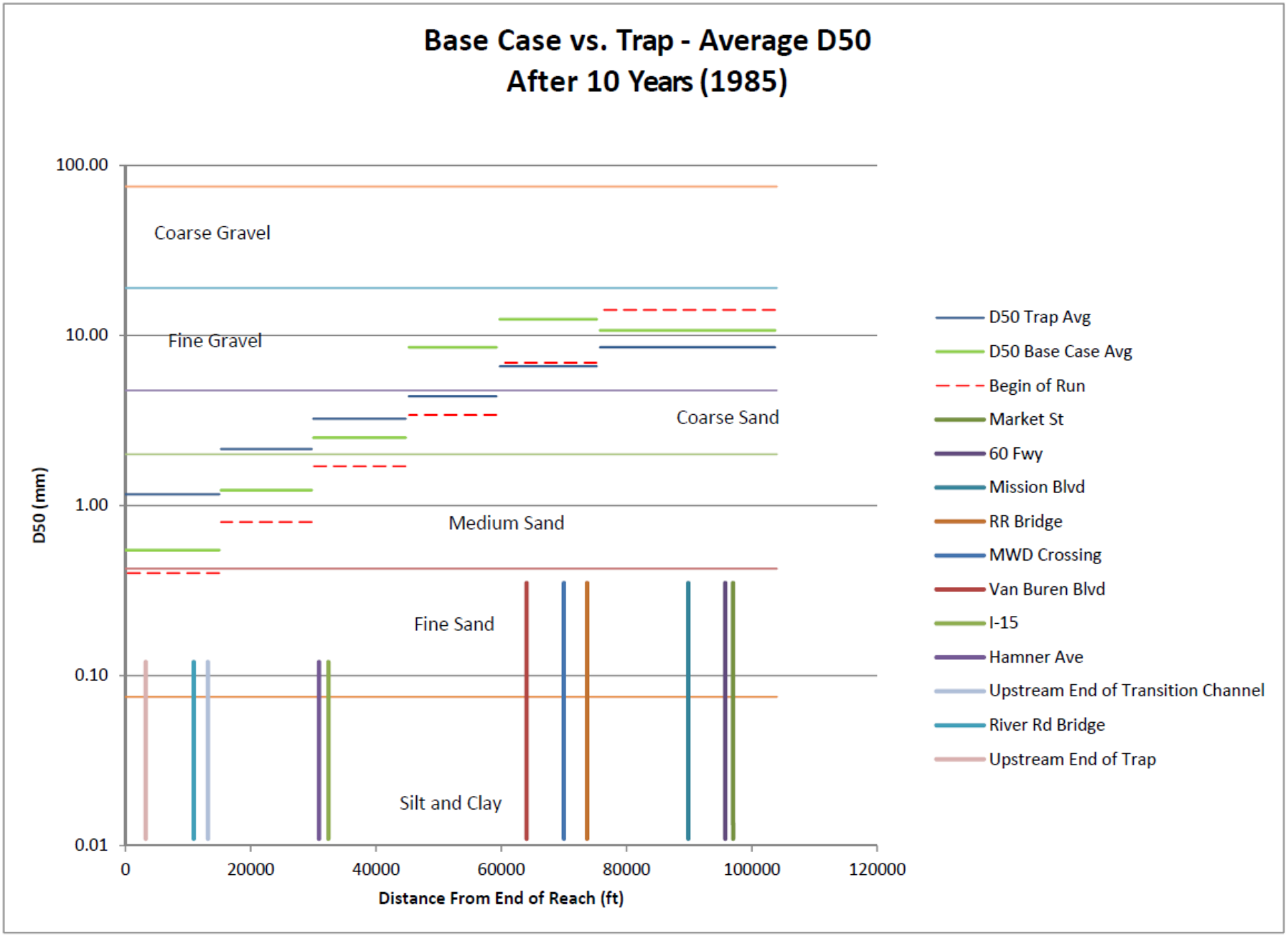


Figure 9: Comparison of Average D50 Change after 10 Years (Golder, 2015a)

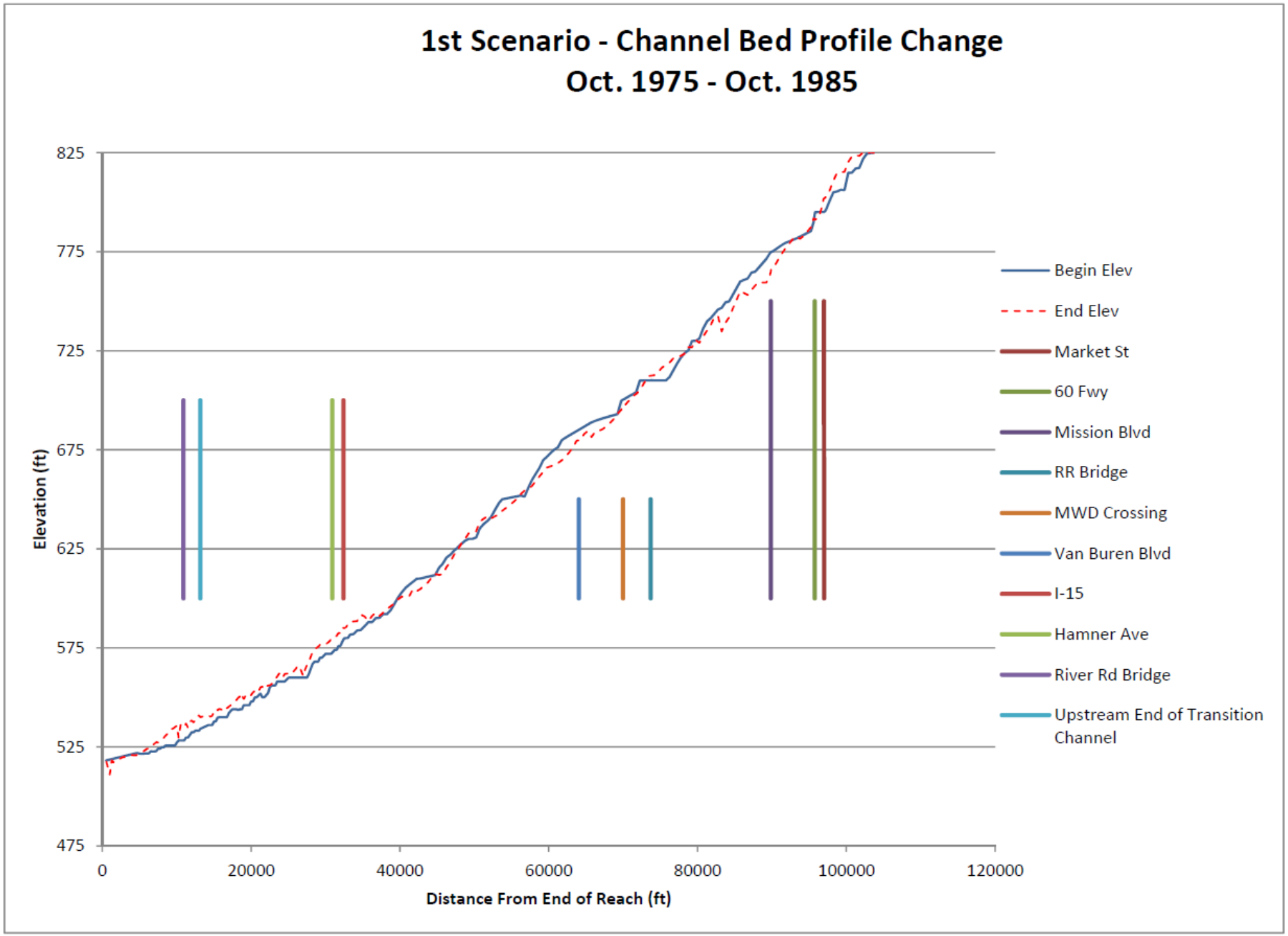


Figure 10: River Bed Profile Change after 10 Years for 1st Scenario (Golder, 2015b)

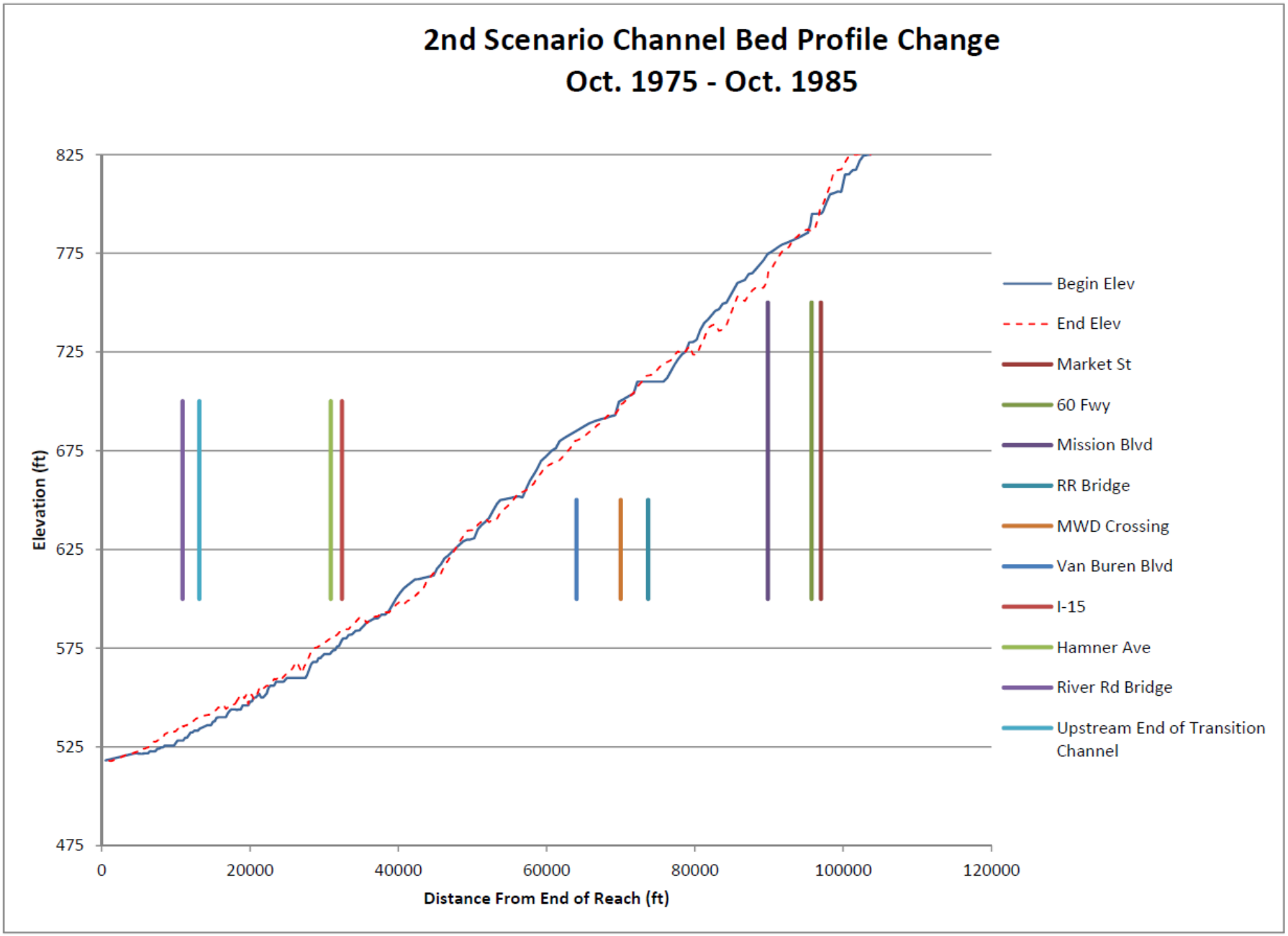


Figure 11: River Bed Profile Change after 10 Years for 2nd Scenario (Golder, 2015b)

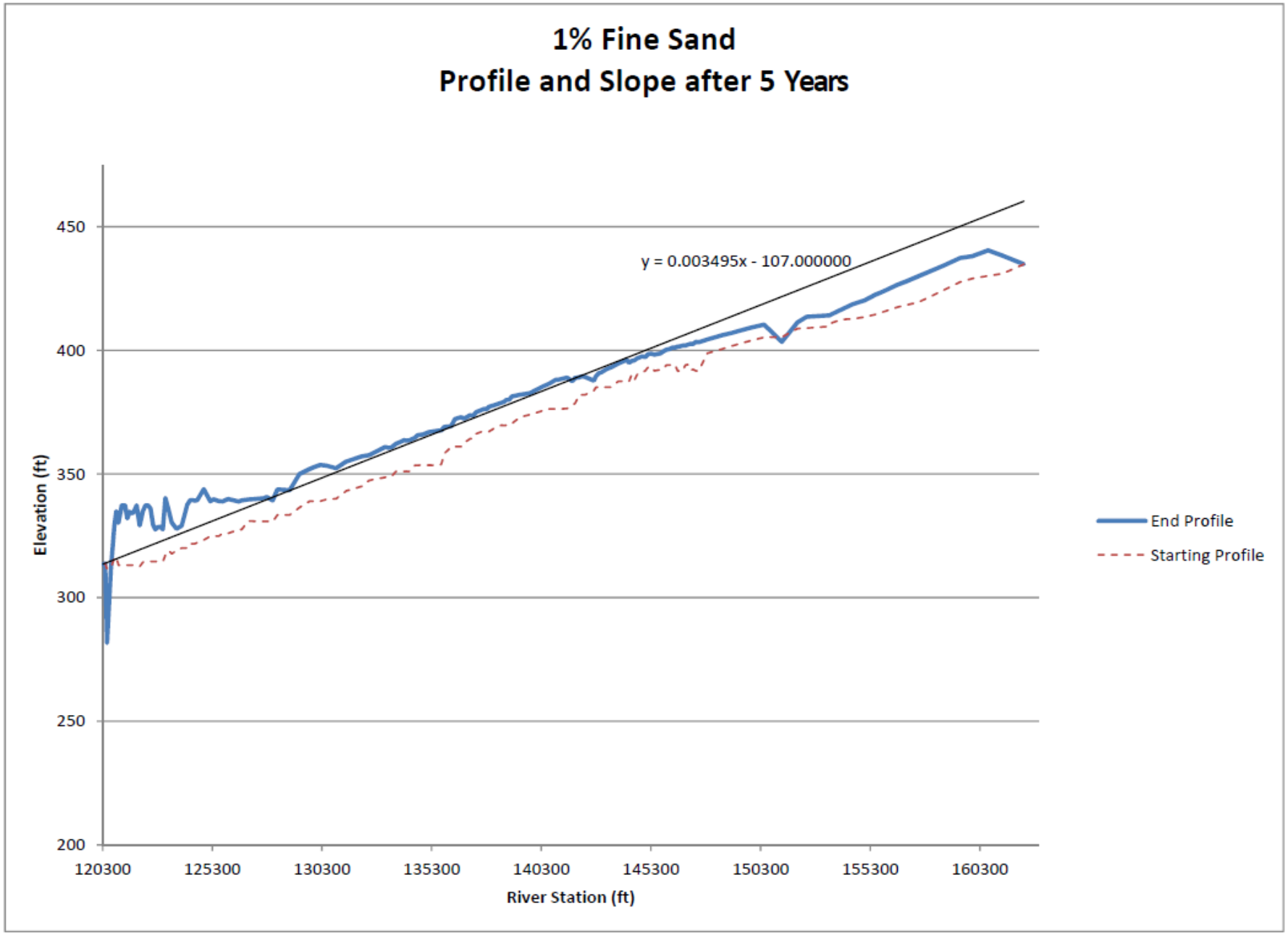


Figure 12: River Bed Profile and Slope after 5 Years – 1% Fine Sand (Golder, 2017)

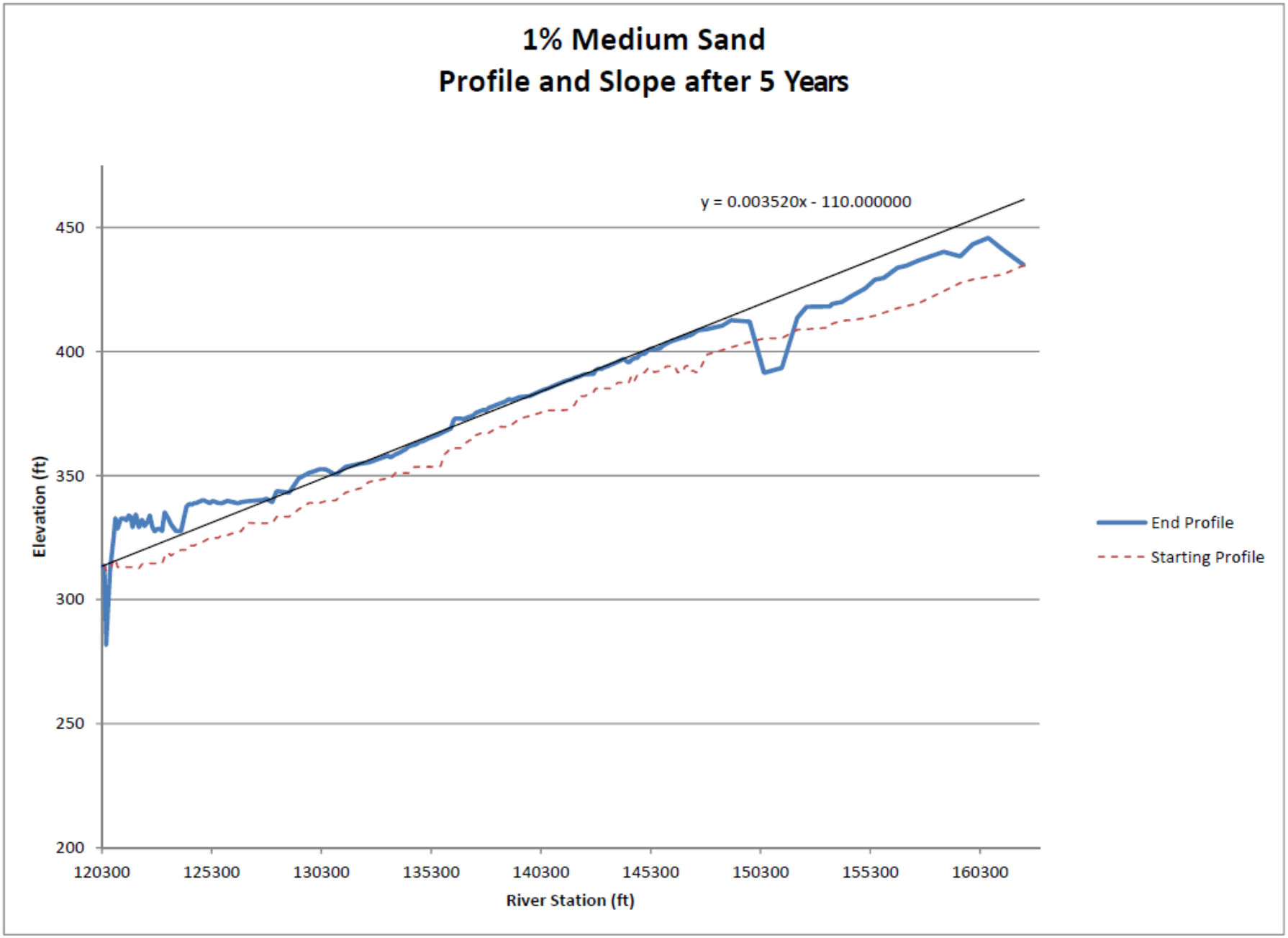


Figure 13: River Bed Profile and Slope after 5 Years – 1% Medium Sand (Golder, 2017)

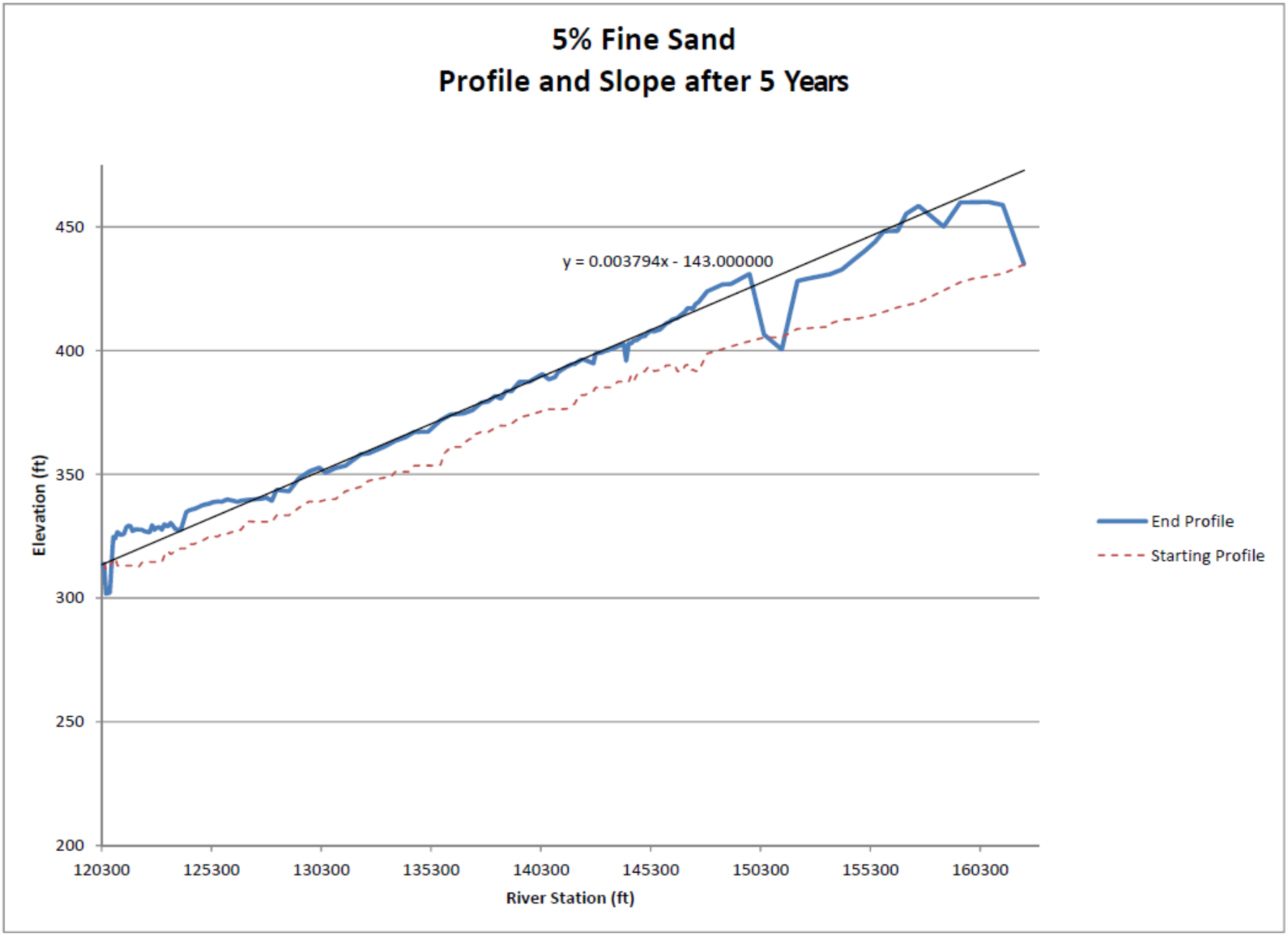


Figure 14: River Bed Profile and Slope after 5 Years – 5% Fine Sand (Golder, 2017)

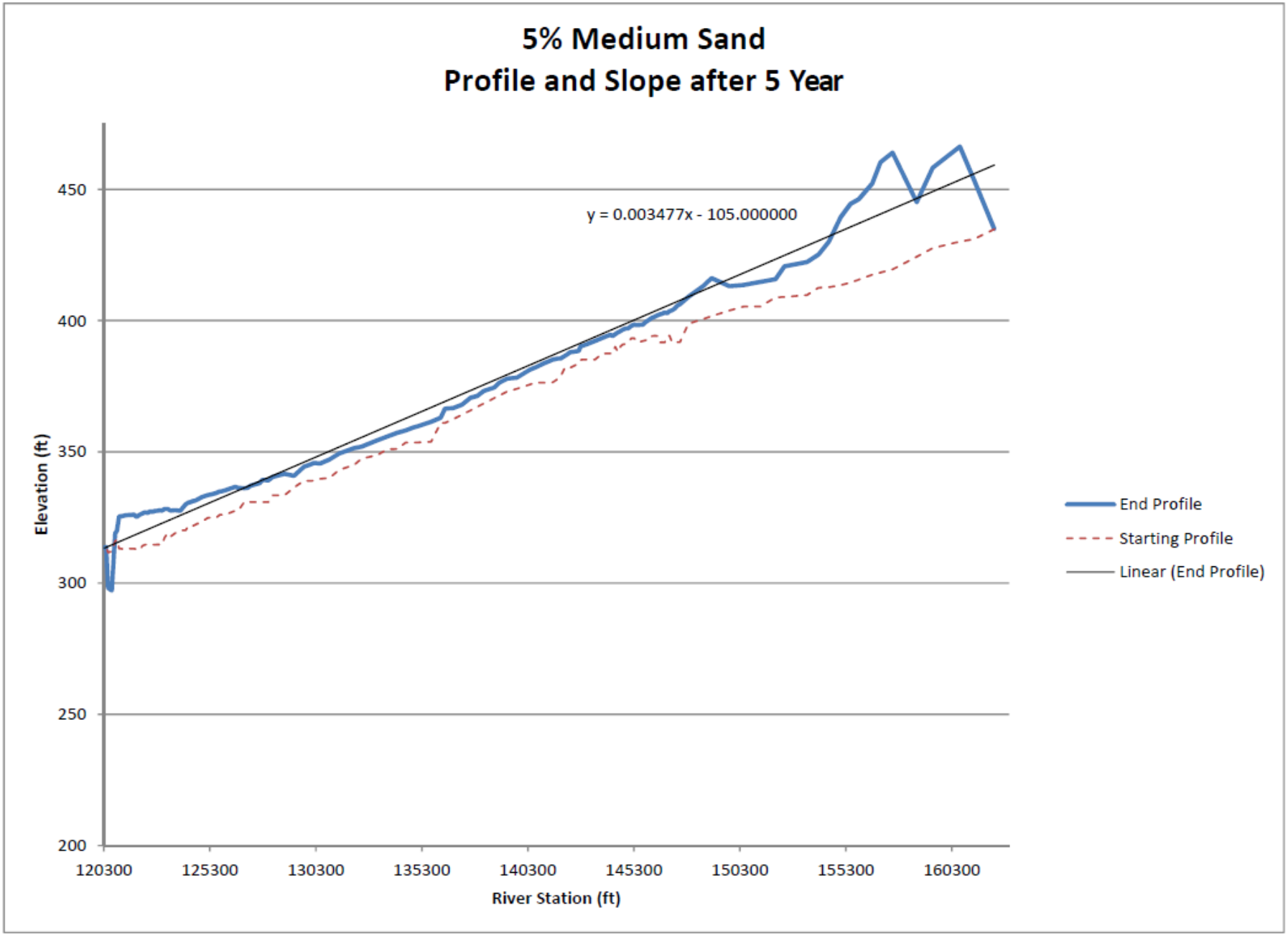


Figure 15: River Bed Profile and Slope after 5 Years – 5% Medium Sand (Golder, 2017)

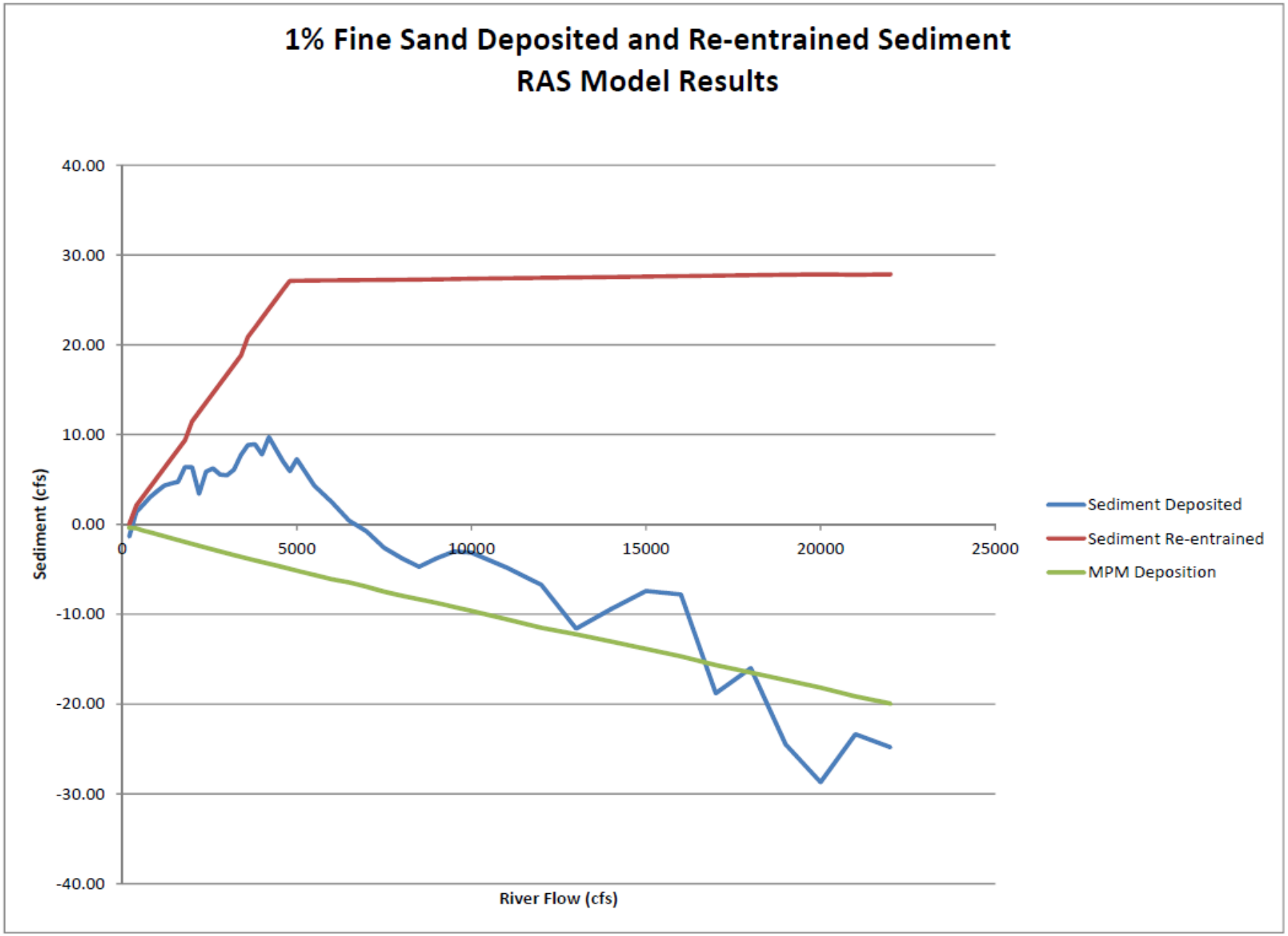


Figure 16: Deposited and Re-entrained Sediment – 1% Fine Sand (Golder, 2017)

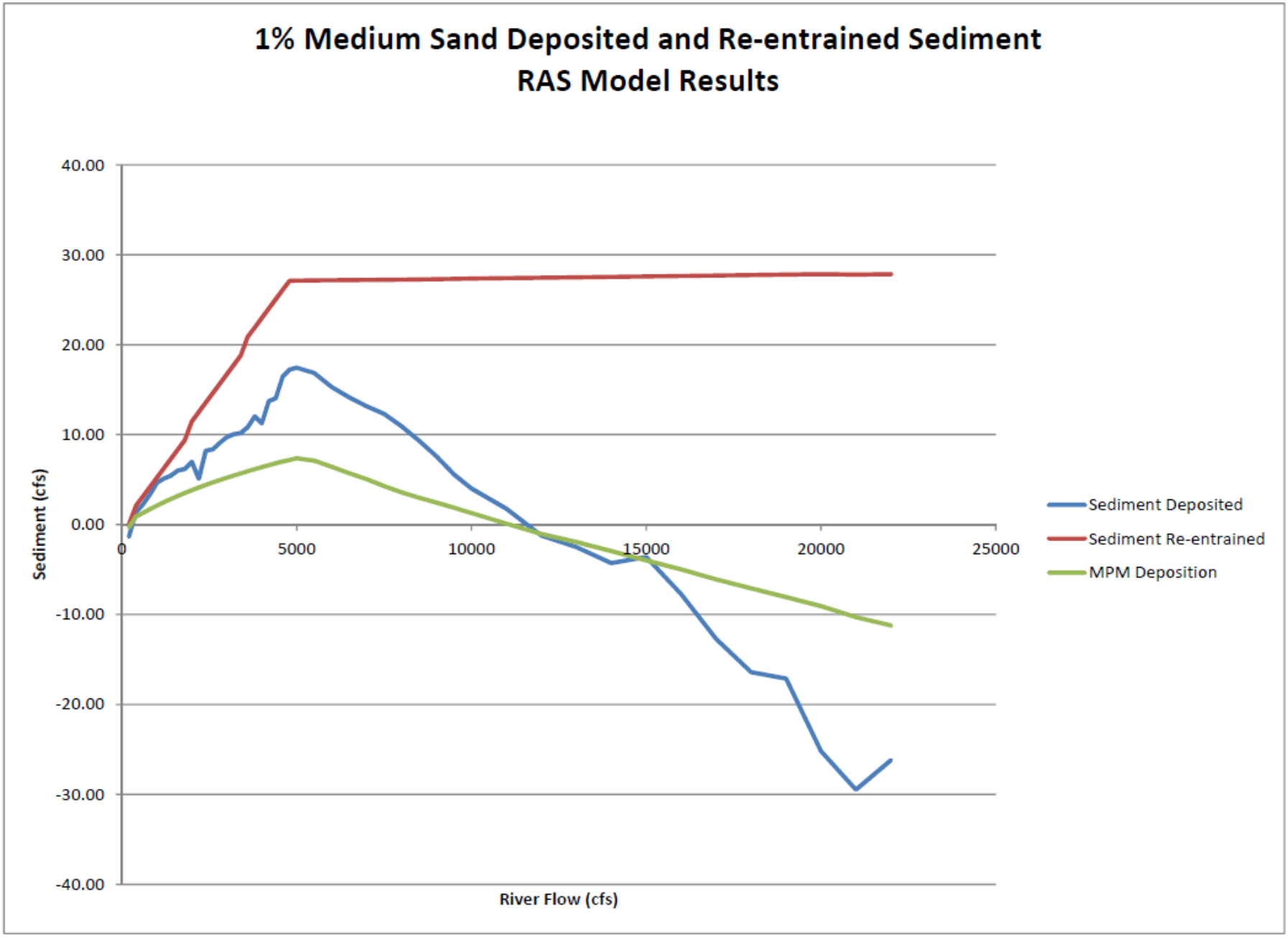


Figure 17: Deposited and Re-entrained Sediment – 1% Medium Sand (Golder, 2017)

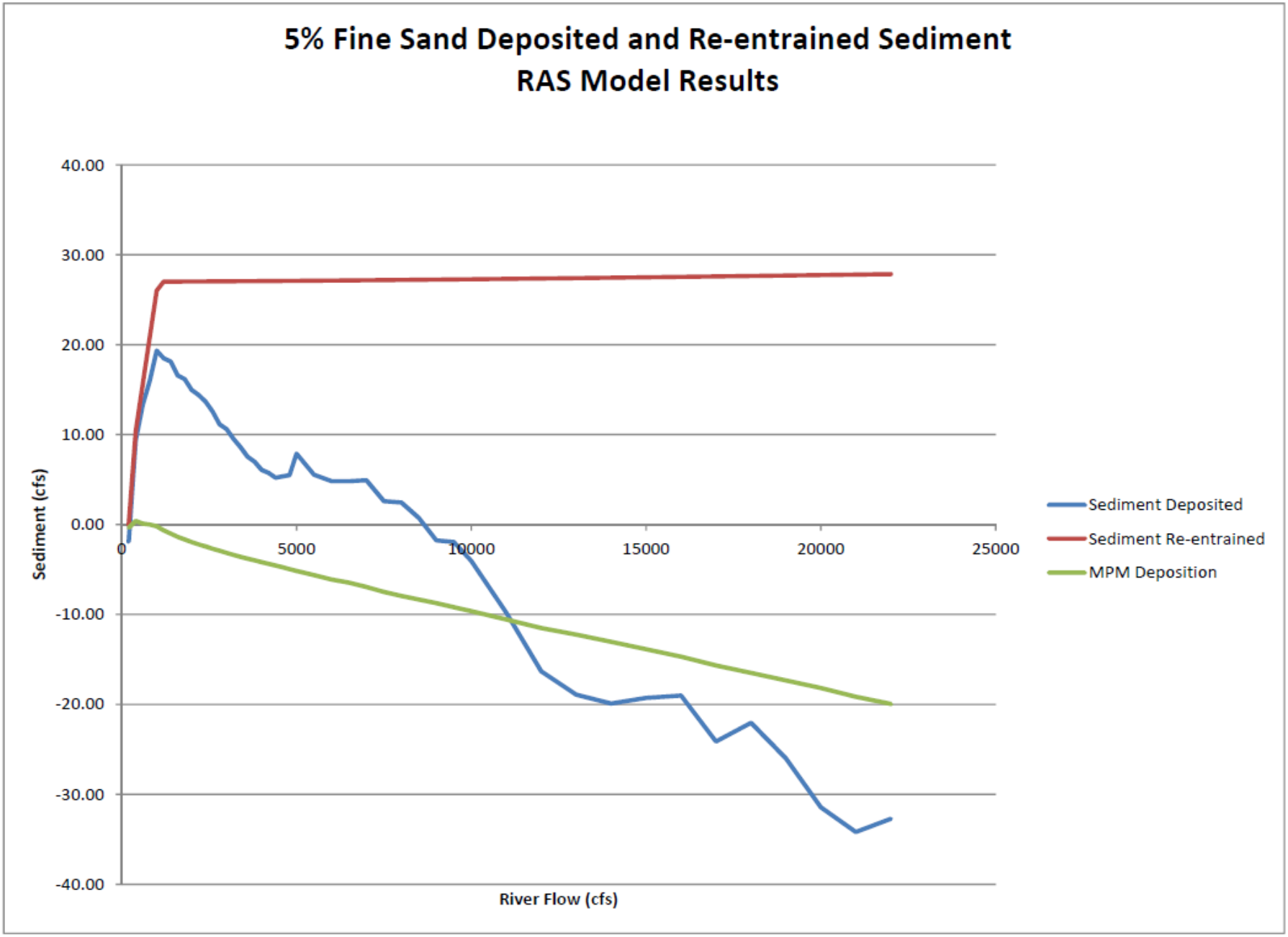


Figure 18: Deposited and Re-entrained Sediment – 5% Fine Sand (Golder, 2017)

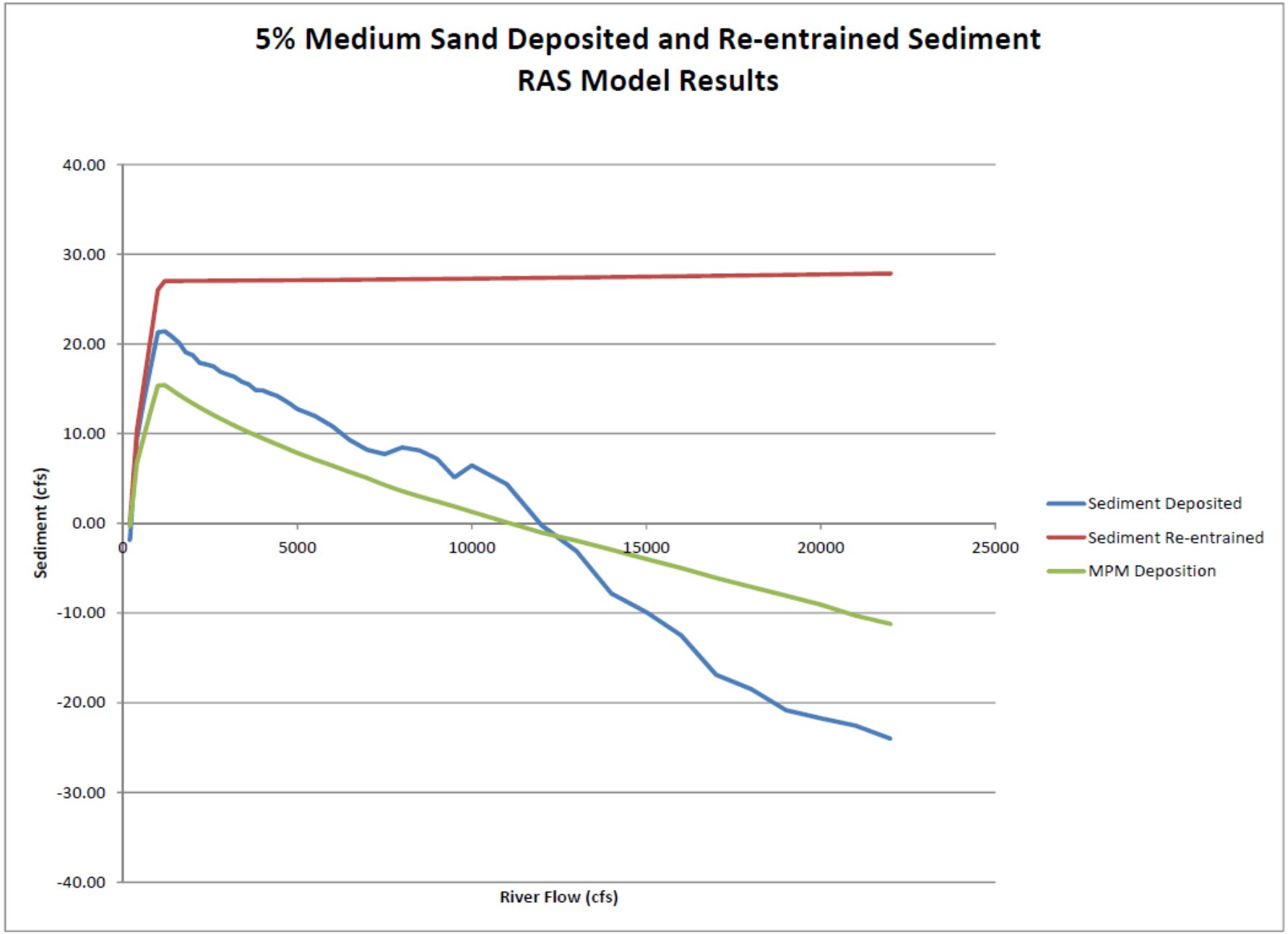


Figure 19: Deposited and Re-entrained Sediment – 5% Medium Sand (Golder, 2017)

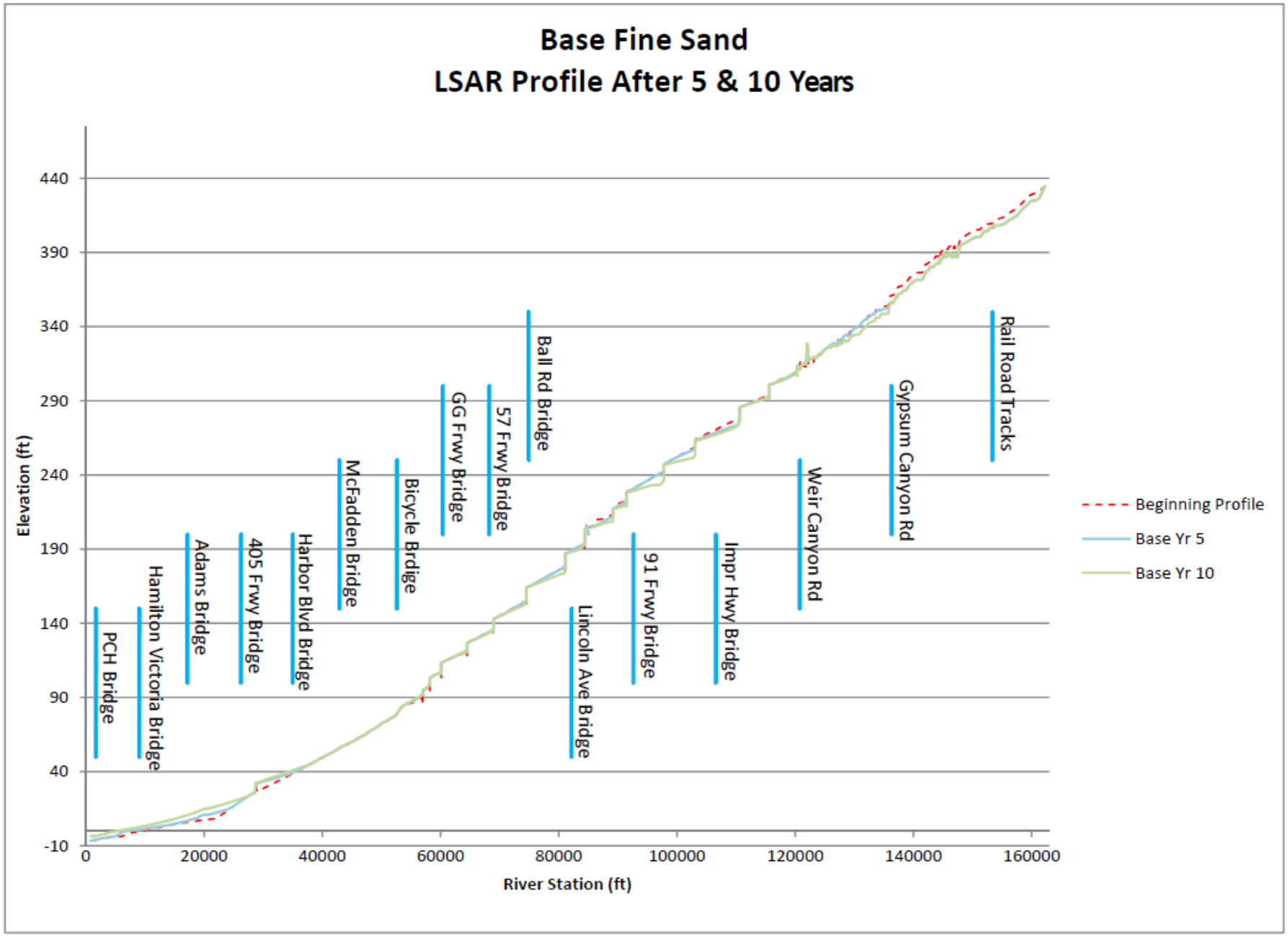


Figure 20: River Bed Profiles after 5 and 10 Years – Base Fine Sand (Golder, 2017)

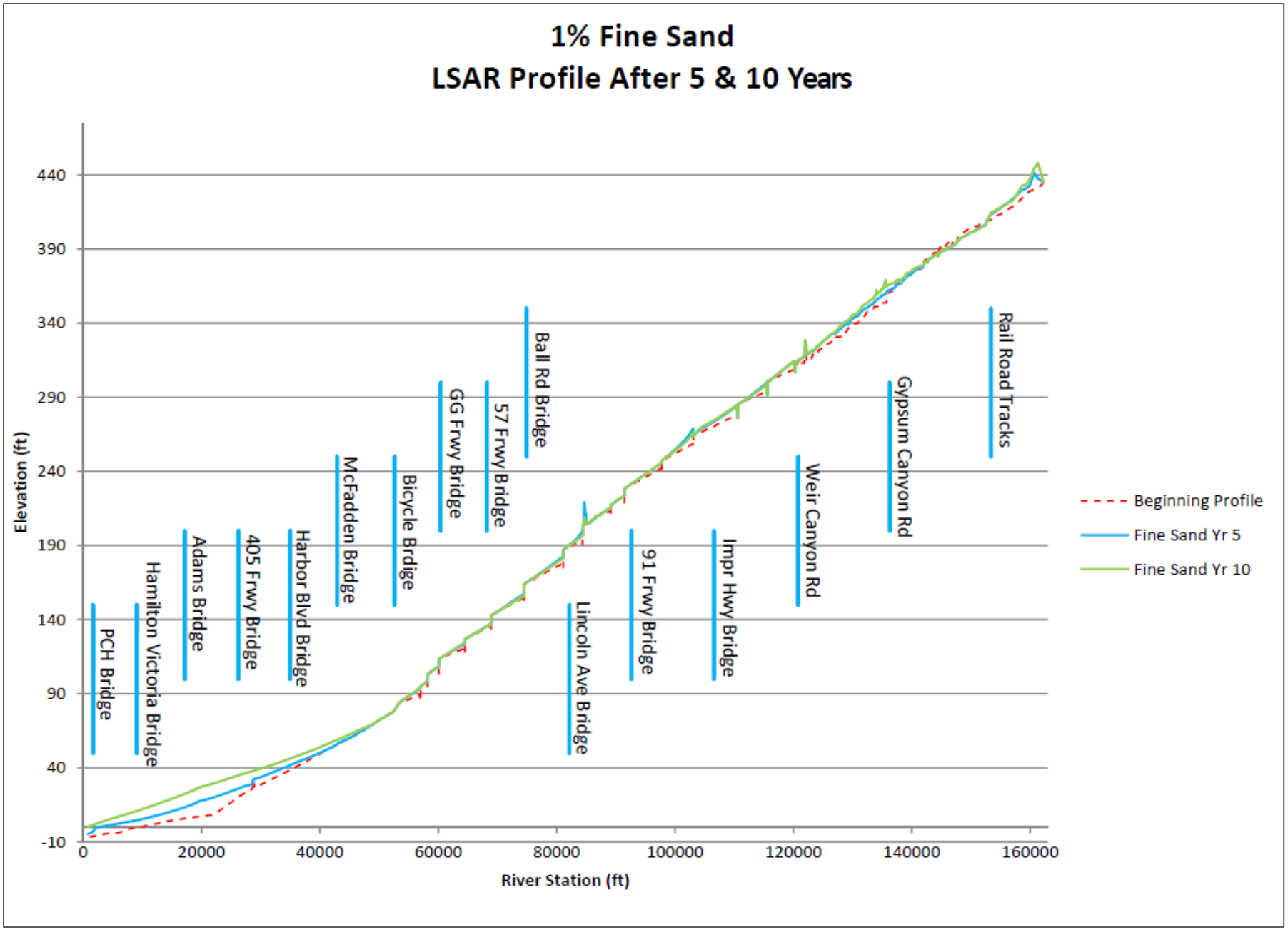


Figure 21: River Bed Profiles after 5 and 10 Years – Base Fine Sand (Golder, 2017)

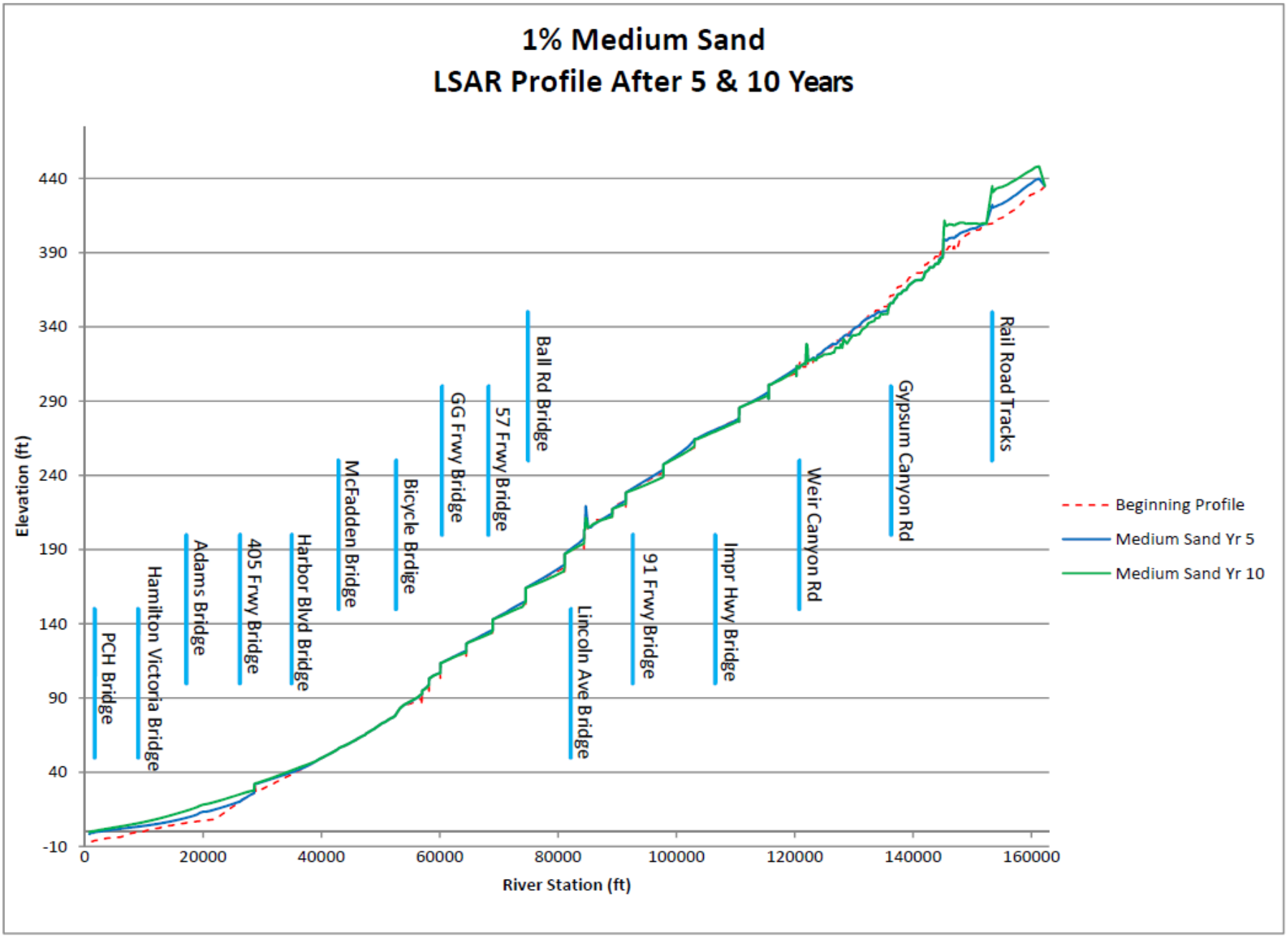


Figure 22: River Bed Profiles after 5 and 10 Years – 1% Medium Sand (Golder, 2017)

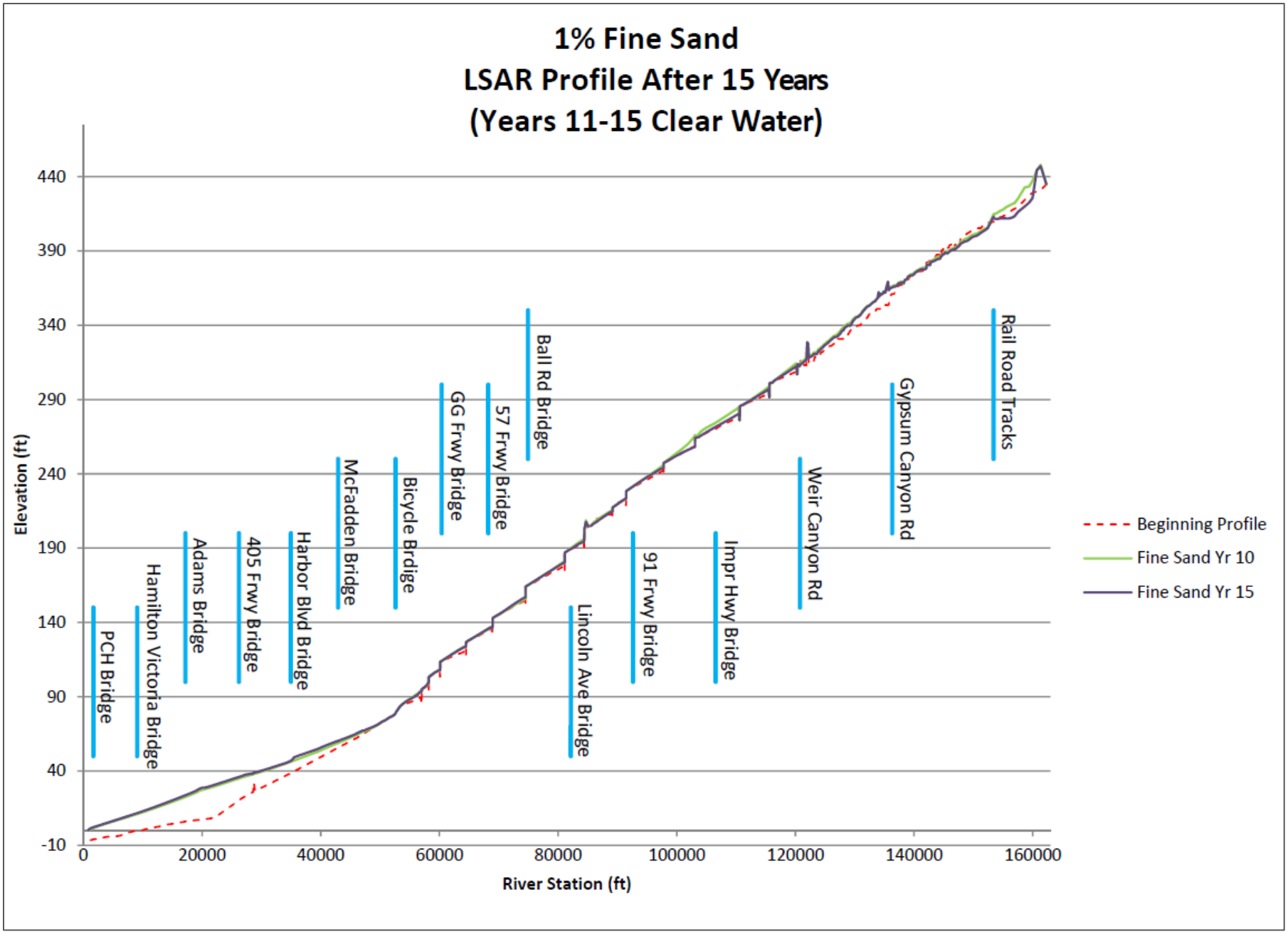


Figure 23: River Bed Profiles after 15 Years – 1% Fine Sand (Golder, 2017)

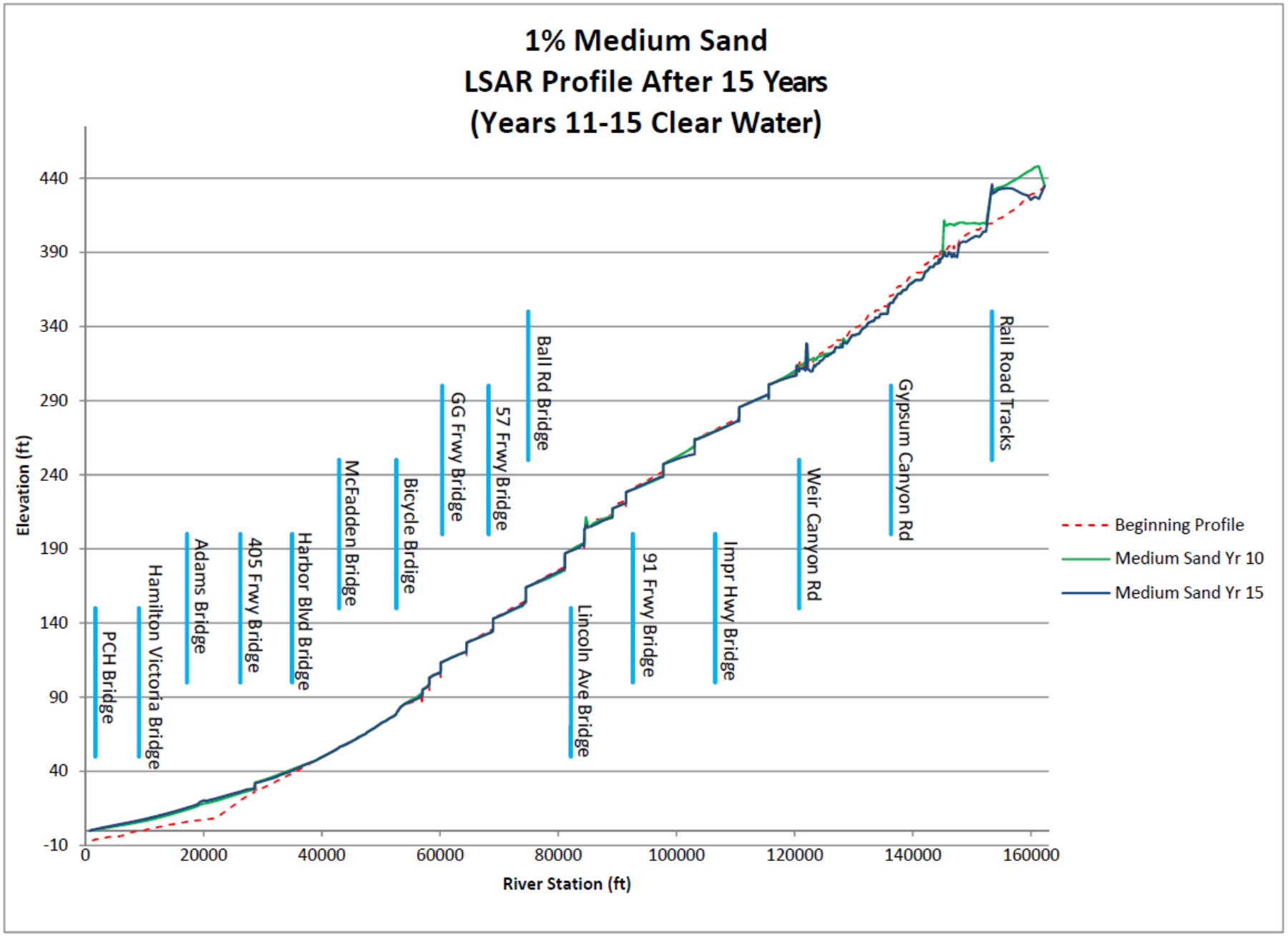


Figure 24: River Bed Profiles after 15 Years – 1% Medium Sand (Golder, 2017)

1) Choose a HUC-4
1807-Southern California Coastal

Search for Gage within HUC-4 by Name
Contains "santa ana"

3) Include Only Years *(If Desired)*
1757 to 2016

2) Click Map Location or Name to Select Stream Gage

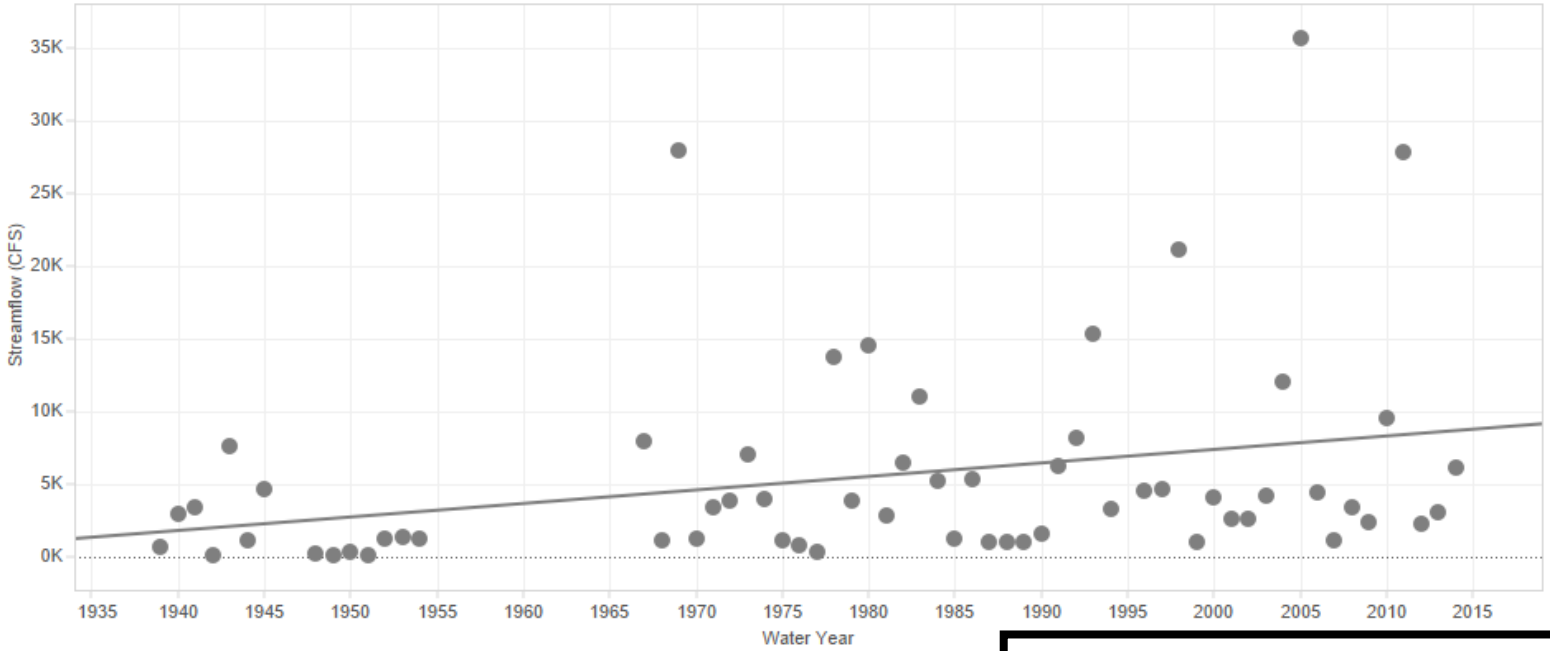
Site Number	
11117800	SANTA ANA C NR OAK VIEW
11075755	SANTA ANA R A BALL RD AT ANAHEIM CA
11074500	SANTA ANA R A COUNTY LINE BL PRADO DAM CA
11059300	SANTA ANA R A E ST NR SAN BERNARDINO CA
11075600	SANTA ANA R A IMPERIAL HWY NR ANAHEIM CA
11066440	SANTA ANA R A MISSION BLVD AT RIVERSIDE CA
11066460	SANTA ANA R A MWD CROSSING CA
11067890	SANTA ANA R A PRADO PARK NR CORONA CA

Annual Peak Instantaneous Streamflow, SANTA ANA R A E ST NR SAN BERNARDINO CA Selected

(Hover Over Trend Line For Significance (p) Value)

Climate Hydrology Assessment Tool v.1.0

Analysis: 11/8/2017 1:26 PM



The p-value is for the linear regression fit drawn; a smaller p-value would indicate greater statistical significance. There is no recommended threshold for statistical significance, but typically 0.05 is used as this is associated with a 5% risk of a Type I error or false positive.

Value = 92.8001*Water Year + -178207
R-Squared: 0.0849002
P-value: 0.0227072

Prado Basin San Bernardino County California

ANNUAL PEAK INSTANTANEOUS STREAMFLOW
SANTA ANA RIVER AT E STREET

U.S Army Corps of Engineers
Los Angeles District

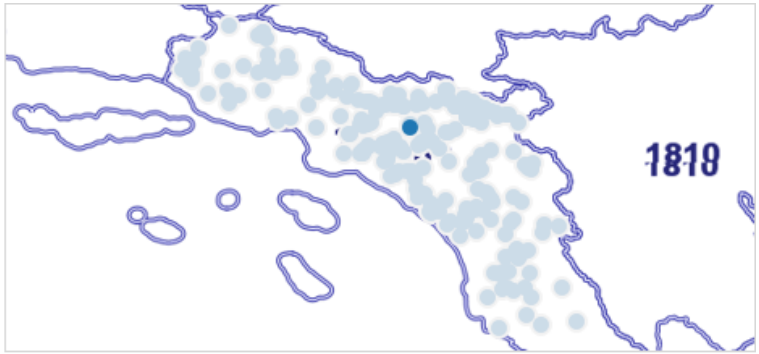
1) Choose a HUC-4
1807-Southern California Coastal

Search for Gage within HUC-4 by Name
All

3) Include Only Years *(If Desired)*
1757 to 2016

2) Click Map Location or Name to Select Stream Gage

Site Number	
11108145	CASTAIC C NR SAUGUS CA
11073360	CHINO C A SCHAEFER AVENUE NR CHINO CA
11073500	CHINO C NR PRADO CA
11055800	CITY C NR HIGHLAND CA
11055801	CITY C NR HIGHLAND CA.+ CANALS CA
11106400	CONEJO CREEK ABOVE HIGHWAY 101 CA
11090700	COYOTE C A LOS ALAMITOS CA
11090500	COYOTE C NR ARTESIA CA

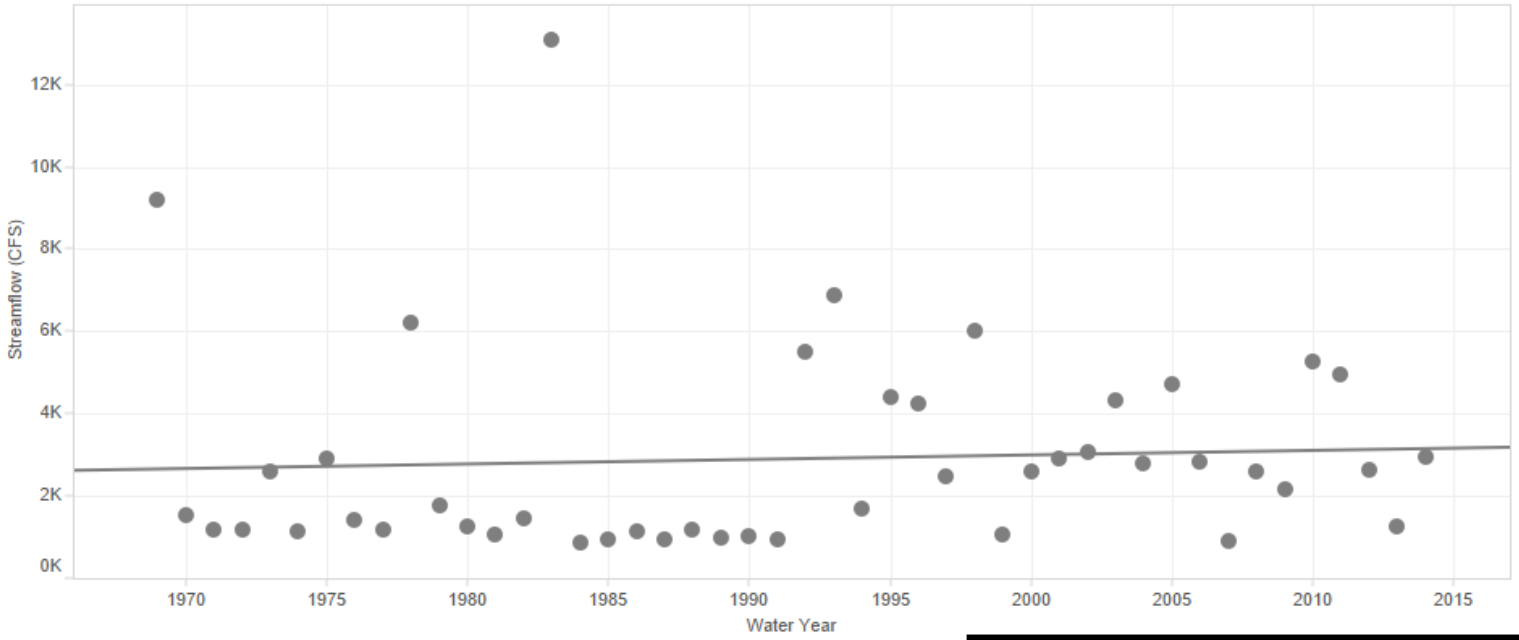


Annual Peak Instantaneous Streamflow, CHINO C A SCHAEFER AVENUE NR CHINO CA Selected

(Hover Over Trend Line For Significance (p) Value)

Climate Hydrology Assessment Tool v.1.0

Analysis: 11/8/2017 1:39 PM



The p-value is for the linear regression fit drawn; a smaller p-value would indicate greater statistical significance. There is no recommended threshold for statistical significance, but typically 0.05 is used as this is associated with a 5% risk of a Type I error or false positive.

Value = 11.0115*Water Year + -19027.9
R-Squared: 0.0035992
P-value: 0.692064

Prado Basin San Bernardino County California

ANNUAL PEAK INSTANTANEOUS STREAMFLOW
CHINO CREEK AT SCHAEFER AVENUE

U.S Army Corps of Engineers
Los Angeles District

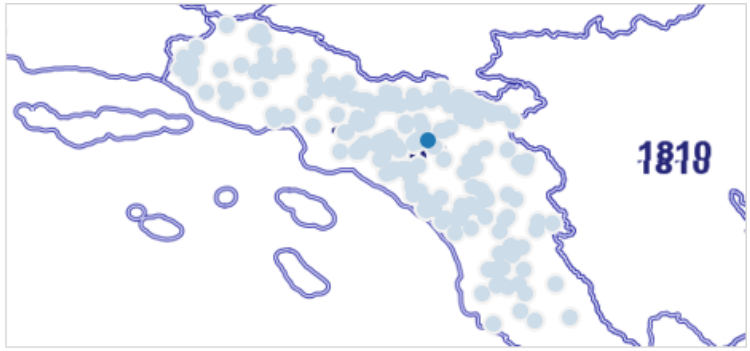
1) Choose a HUC-4
1807-Southern California Coastal

Search for Gage within HUC-4 by Name
All

3) Include Only Years *(If Desired)*
1757 to 2016

2) Click Map Location or Name to Select Stream Gage

Site Number	
11071900	TEMESCAL C A CORONA LK NR CORONA CA
11072100	TEMESCAL C AB MAIN ST A CORONA CA
11072000	TEMESCAL C NR CORONA CA
11013000	TIJUANA R NR DULZURA CA
11013500	TIJUANA R NR NESTOR CA
11104000	TOPANGA C NR TOPANGA BCH CA
11094000	TUJUNGA C BL MILL C NR COLBY RANCH CA
11094500	TUJUNGA C NR COLBY RANCH CA

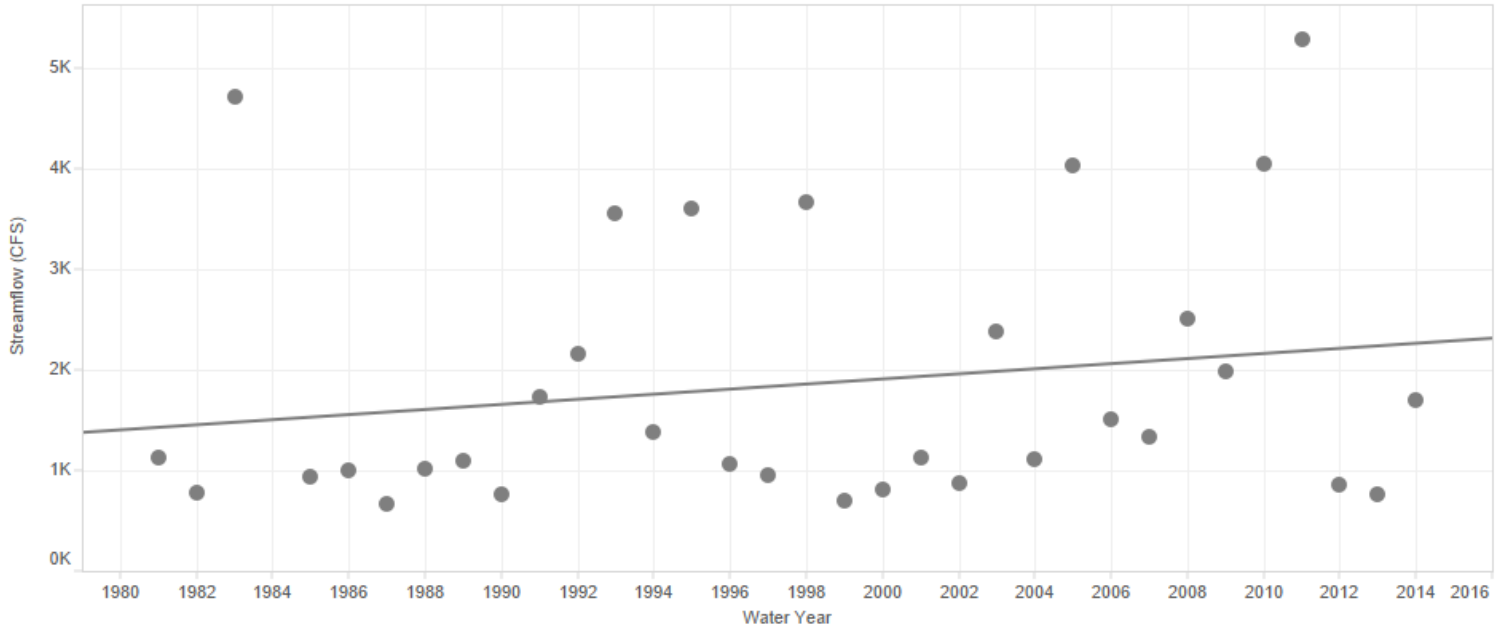


Annual Peak Instantaneous Streamflow, TEMESCAL C AB MAIN ST A CORONA CA Selected

(Hover Over Trend Line For Significance (p) Value)

Climate Hydrology Assessment Tool v.1.0

Analysis: 11/8/2017 1:44 PM



The p-value is for the linear regression fit drawn; a smaller p-value would indicate greater statistical significance. There is no recommended threshold for statistical significance, but typically 0.05 is used as this is associated with a 5% risk of a Type I error or false positive.

Value = 25.3171*Water Year + -48725.8
R-Squared: 0.0356223
P-value: 0.292843

Prado Basin Riverside County California

ANNUAL PEAK INSTANTANEOUS STREAMFLOW
TEMESCAL CREEK ABOVE MAIN STREET

U.S Army Corps of Engineers
Los Angeles District

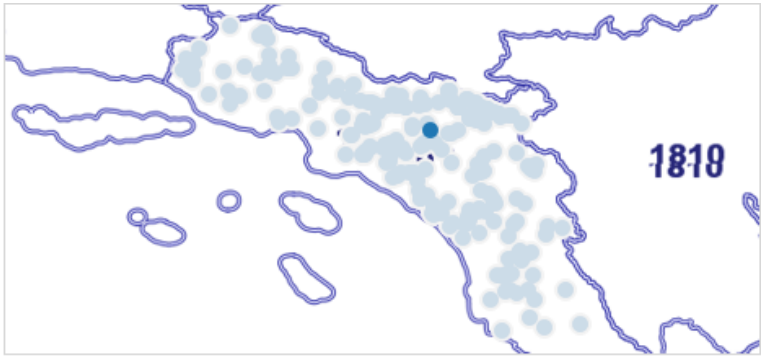
1) Choose a HUC-4
1807-Southern California Coastal

Search for Gage within HUC-4 by Name
All

3) Include Only Years *(If Desired)*
1757 to 2016

2) Click Map Location or Name to Select Stream Gage

Site Number	
11118000	[illegible]
11117600	COYOTE CREEK NEAR OAK VIEW CA
11046360	CRISTIANITOS C AB SAN MATEO C NR SAN CLEMENTE ..
11046350	CRISTIANITOS C NR SAN CLEMENTE CA
11073495	CUCAMONGA C NR MIRA LOMA CA
11073470	CUCAMONGA C NR UPLAND CA
11086000	DALTON C NR GLENDORA CA
11067000	DAY C NR ETIWANDA CA
11044800	[illegible]

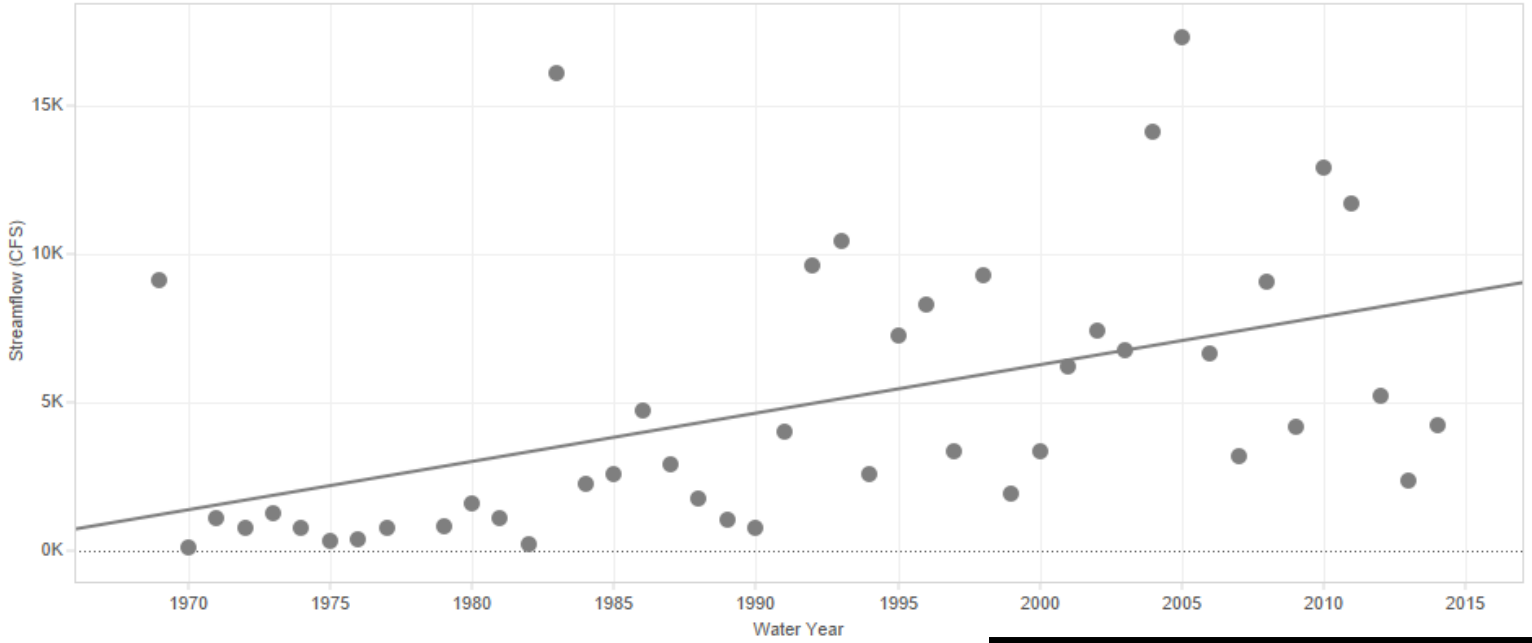


Annual Peak Instantaneous Streamflow, CUCAMONGA C NR MIRA LOMA CA Selected

(Hover Over Trend Line For Significance (p) Value)

Climate Hydrology Assessment Tool v.1.0

Analysis: 11/8/2017 1:50 PM



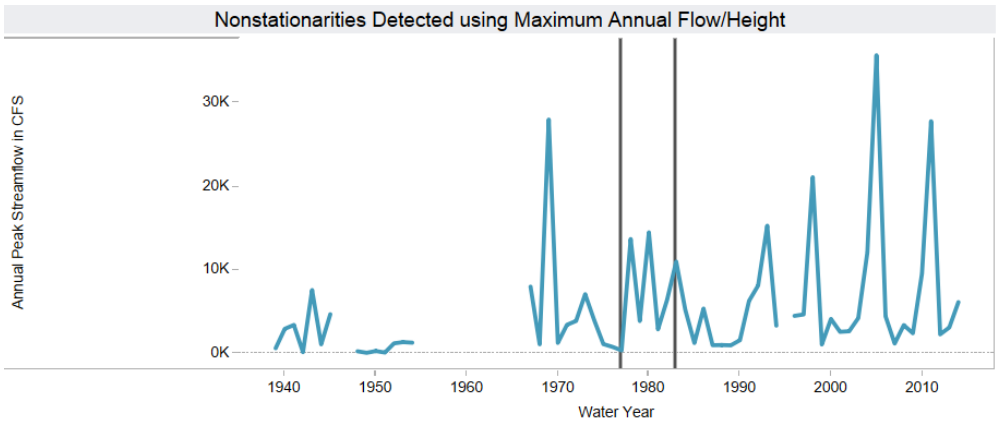
The p-value is for the linear regression fit drawn; a smaller p-value would indicate greater statistical significance. There is no recommended threshold for statistical significance, but typically 0.05 is used as this is associated with a 5% risk of a Type I error or false positive.

Value = 162.808*Water Year + -319368
R-Squared: 0.230916
P-value: 0.0008348

Prado Basin Riverside County California

ANNUAL PEAK INSTANTANEOUS STREAMFLOW
CUCAMONGA CREEK NEAR MIRA LOMA, CA

U.S Army Corps of Engineers
Los Angeles District

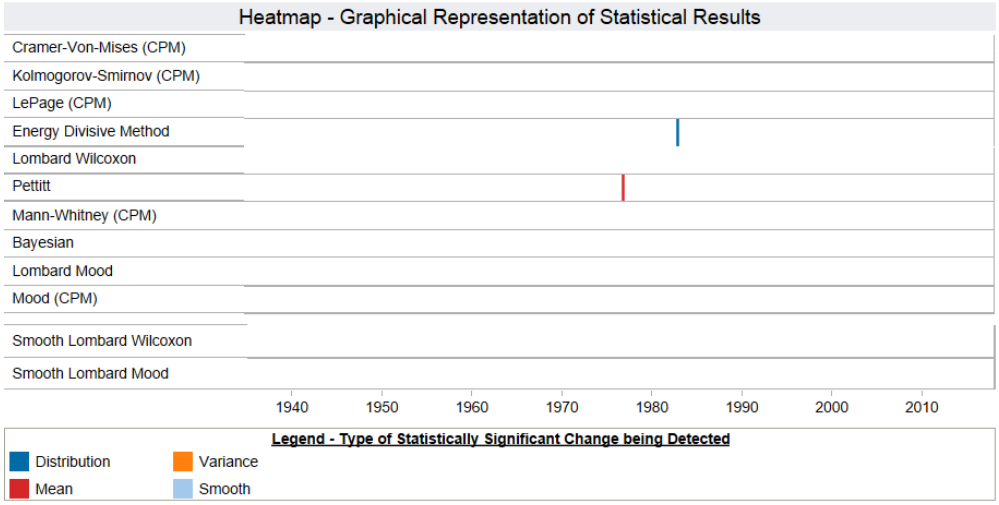


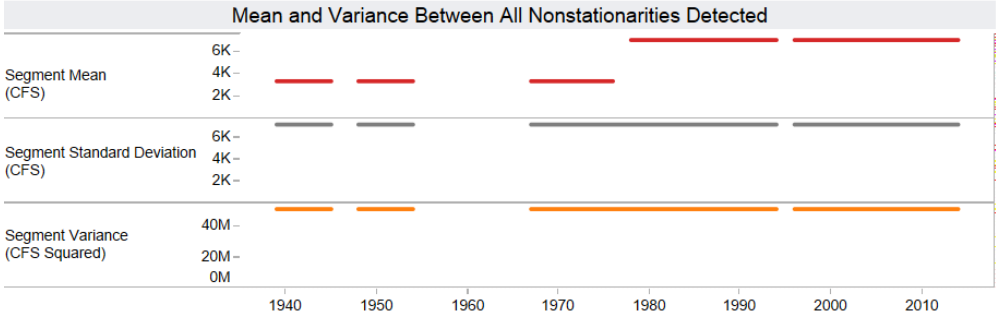
This gage has a drainage area of 541.0 square miles.

WARNING: The period of record selected has missing data points. There are potential issues with the changepoints detected.

The USGS streamflow gage sites available for assessment within this application include locations where there are discontinuities in USGS peak flow data collection throughout the period of record and gages with short records. Engineering judgment should be exercised when carrying out analysis where there are significant data gaps.

In general, a minimum of 30 years of continuous streamflow measurements must be available before this application should be used to detect nonstationarities in flow records.





Parameter Selection

- (●) Instantaneous Peak Streamflow
- ( ) Stage

Site Selection

Select a state
CA

Select a site
11059300 - SANTA ANA R A E ST NR SAN BE..

Timeframe Selection
1939 to 2065

Sensitivity Parameters
(Sensitivity parameters are described in the manual. Engineering judgment is required if non-default parameters are selected).
Larger Values will Result in Fewer Nonstationarities Detected.

CPM Methods Burn-In Period
20

CPM Methods Sensitivty
1,000

Bayesian Sensitivty
0.5

Energy Divisive Method Sensitivty
0.5

Smaller Values will Result in More Nonstationarities Detected

Lombard Smooth Methods Sensitivity
0.05

Pettitt Sensitivity
0.05

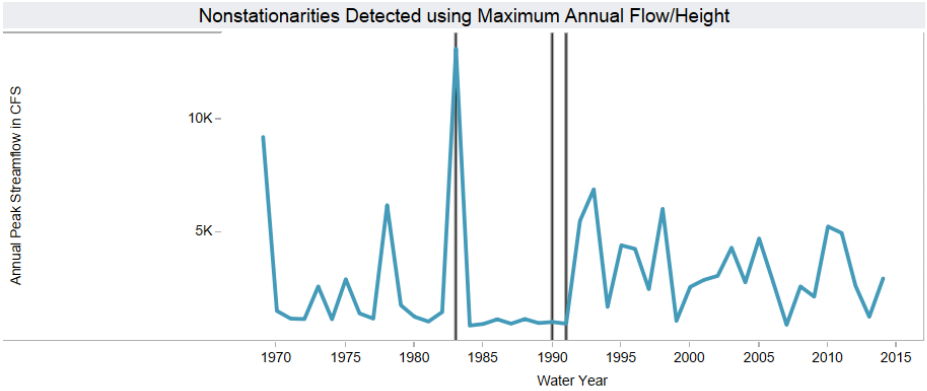
Please acknowledge the US Army Corps of Engineers for producing this nonstationarity detection tool as part of their progress in climate preparedness and resilience and making it freely available.

Prado Basin San Bernardino County California

NONSTATIONARYITY ANALYSIS OF MAXIMUM ANNUAL FLOW

SANTA ANA RIVER

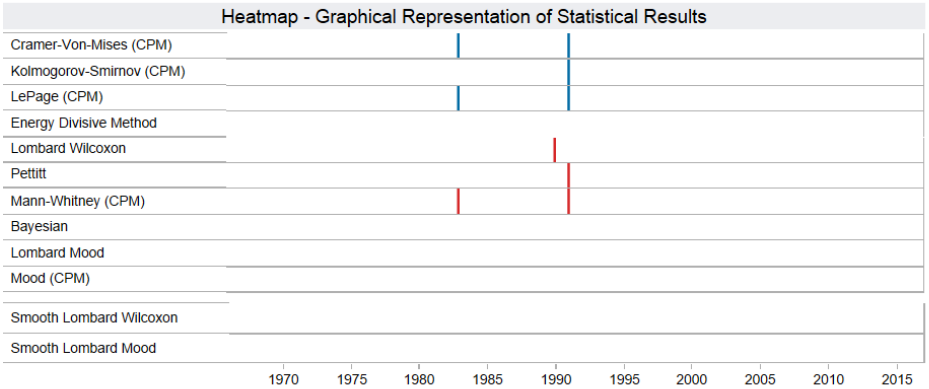
U.S Army Corps of Engineers
Los Angeles District



This gage has a drainage area of 48.90 square miles.

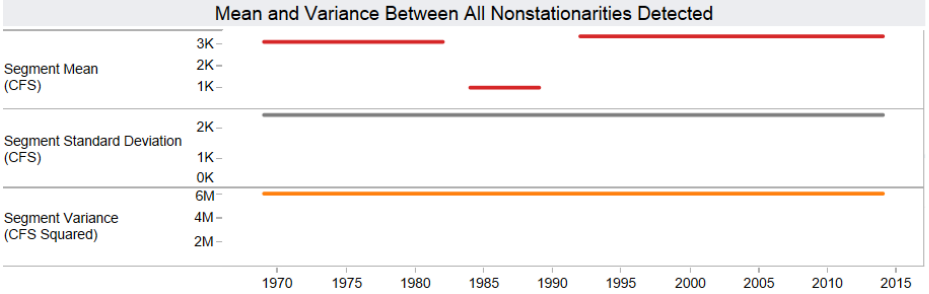
The USGS streamflow gage sites available for assessment within this application include locations where there are discontinuities in USGS peak flow data collection throughout the period of record and gages with short records. Engineering judgment should be exercised when carrying out analysis where there are significant data gaps.

In general, a minimum of 30 years of continuous streamflow measurements must be available before this application should be used to detect nonstationarities in flow records.



Legend - Type of Statistically Significant Change being Detected

- Distribution
- Variance
- Mean
- Smooth



Parameter Selection

- (●) Instantaneous Peak Streamflow
- ( ) Stage

Site Selection

Select a state
CA

Select a site
11073360 - CHINO C A SCHAEFER AVENUE N..

Timeframe Selection
1969 to 2065

Sensitivity Parameters
(Sensitivity parameters are described in the manual. Engineering judgment is required if non-default parameters are selected).
Larger Values will Result in Fewer Nonstationarities Detected.

CPM Methods Burn-In Period
20

CPM Methods Sensitivty
1,000

Bayesian Sensitivty
0.5

Energy Divisive Method Sensitivty
0.5

Smaller Values will Result in More Nonstationarities Detected

Lombard Smooth Methods Sensitivity
0.01

Pettitt Sensitivity
0.05

Non-default value selected for one or more sensitivity parameters.

Please acknowledge the US Army Corps of Engineers for producing this nonstationarity detection tool as part of their progress in climate preparedness and resilience and making it freely available.

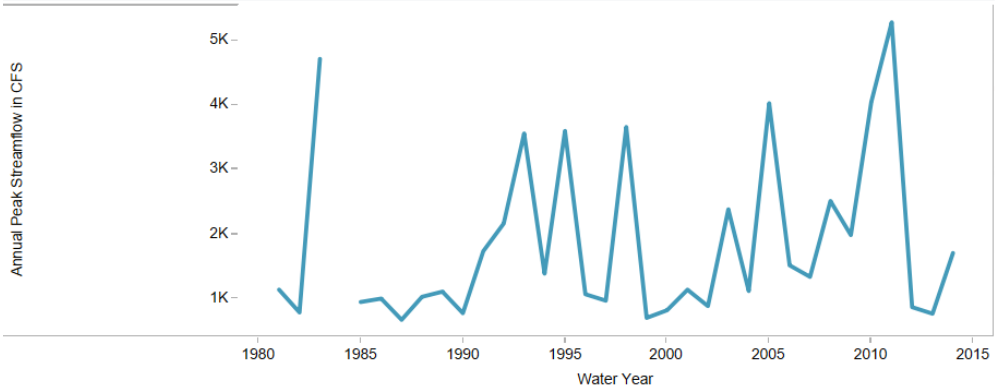
Prado Basin San Bernardino County California

NONSTATIONARYITY ANALYSIS OF MAXIMUM ANNUAL FLOW

CHINO CREEK

U.S Army Corps of Engineers
Los Angeles District

Nonstationarities Detected using Maximum Annual Flow/Height



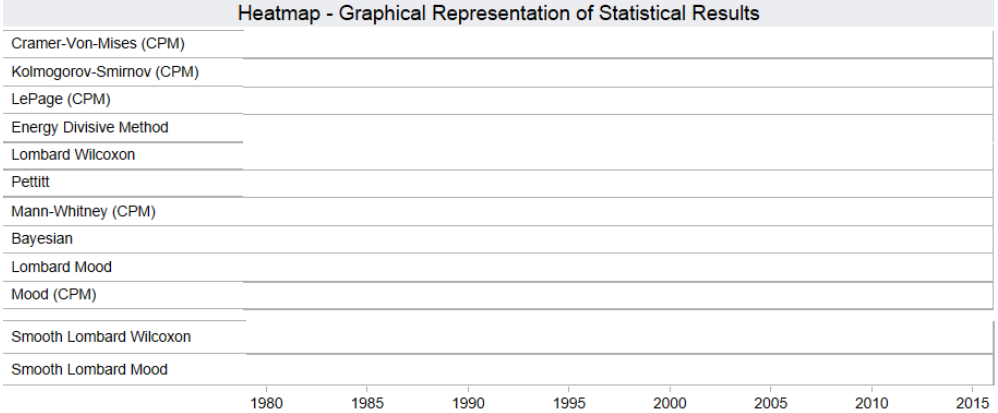
This gage has a drainage area of 224.0 square miles.

WARNING: The period of record selected has missing data points. There are potential issues with the changepoints detected.

The USGS streamflow gage sites available for assessment within this application include locations where there are discontinuities in USGS peak flow data collection throughout the period of record and gages with short records. Engineering judgment should be exercised when carrying out analysis where there are significant data gaps.

In general, a minimum of 30 years of continuous streamflow measurements must be available before this application should be used to detect nonstationarities in flow records.

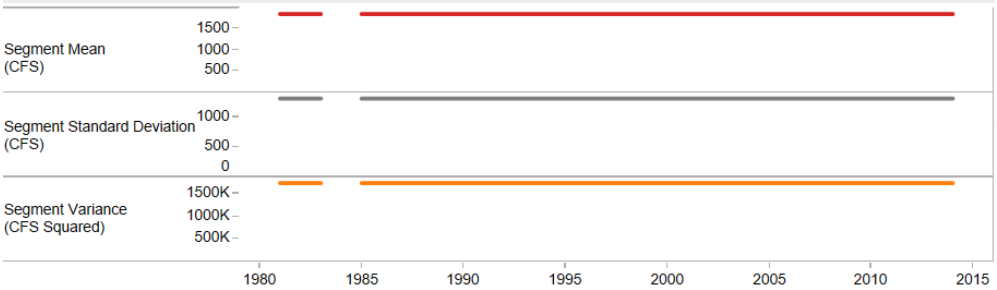
Heatmap - Graphical Representation of Statistical Results



Legend - Type of Statistically Significant Change being Detected

- Distribution
- Variance
- Mean
- Smooth

Mean and Variance Between All Nonstationarities Detected



Parameter Selection

- (●) Instantaneous Peak Streamflow
- ( ) Stage

Site Selection

Select a state
CA

Select a site
11072100 - TEMESCAL C AB MAIN ST A COR..

Timeframe Selection
1939 to 2065

Sensitivity Parameters

(Sensitivity parameters are described in the manual. Engineering judgment is required if non-default parameters are selected).

Larger Values will Result in Fewer Nonstationarities Detected.

CPM Methods Burn-In Period
20

CPM Methods Sensitivty
1,000

Bayesian Sensitivty
0.5

Energy Divisive Method Sensitivty
0.5

Smaller Values will Result in More Nonstationarities Detected

Lombard Smooth Methods Sensitivity
0.05

Pettitt Sensitivity
0.05

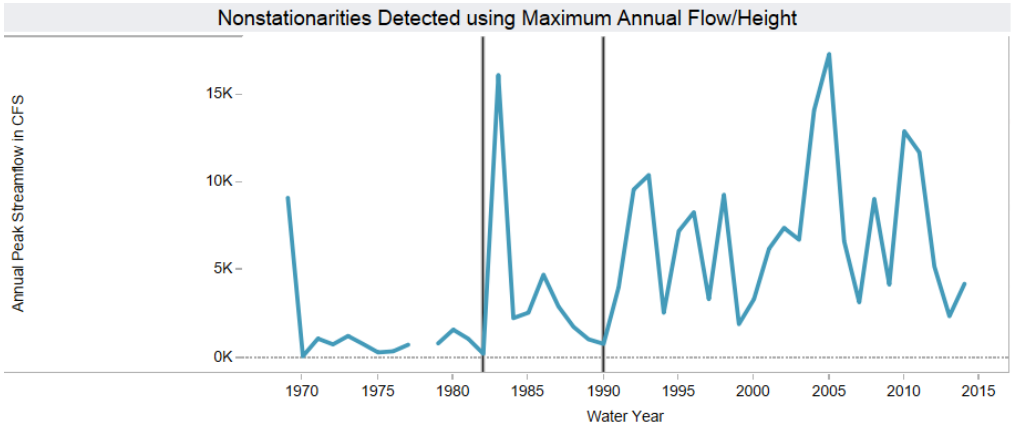
Please acknowledge the US Army Corps of Engineers for producing this nonstationarity detection tool as part of their progress in climate preparedness and resilience and making it freely available.

Prado Basin Riverside County California

NONSTATIONARYITY ANALYSIS OF MAXIMUM ANNUAL FLOW

TEMESCAL CREEK

U.S Army Corps of Engineers
Los Angeles District

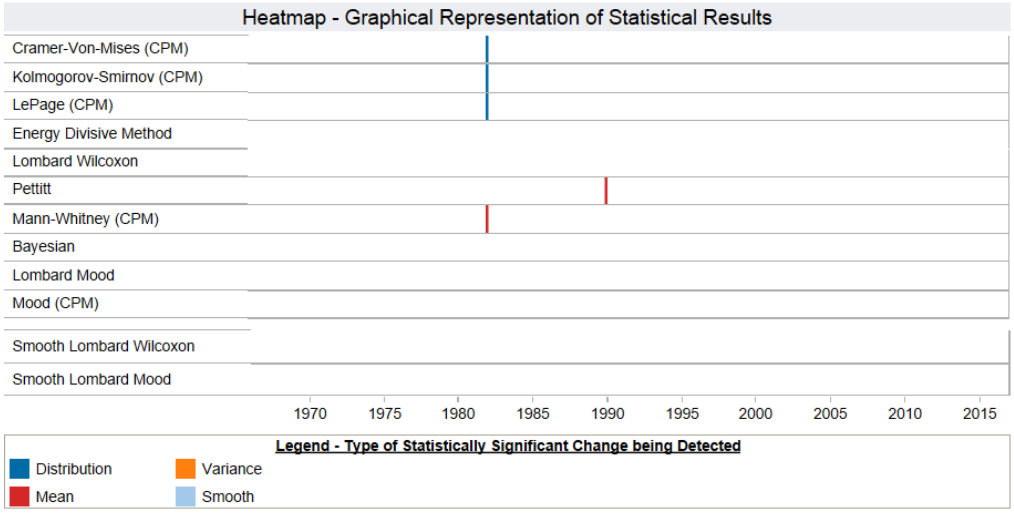


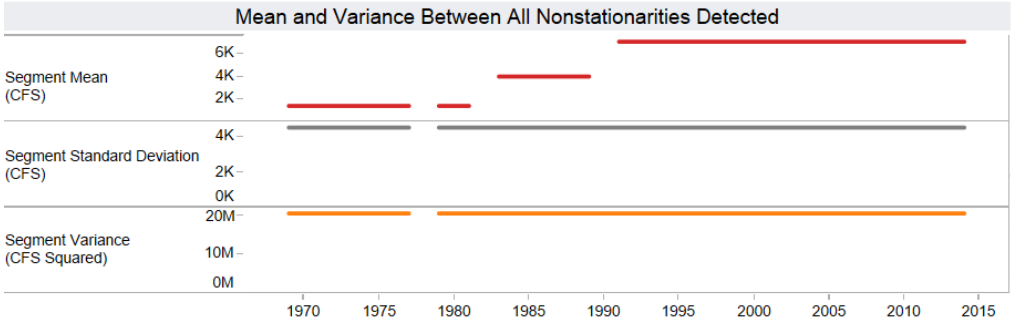
This gage has a drainage area of 75.80 square miles.

WARNING: The period of record selected has missing data points. There are potential issues with the changepoints detected.

The USGS streamflow gage sites available for assessment within this application include locations where there are discontinuities in USGS peak flow data collection throughout the period of record and gages with short records. Engineering judgment should be exercised when carrying out analysis where there are significant data gaps.

In general, a minimum of 30 years of continuous streamflow measurements must be available before this application should be used to detect nonstationarities in flow records.





Parameter Selection

- (●) Instantaneous Peak Streamflow
- ( ) Stage

Site Selection

Select a state
CA

Select a site
11073495 - CUCAMONGA C NR MIRA LOMA CA

Timeframe Selection
1969 to 2065

Sensitivity Parameters
(Sensitivity parameters are described in the manual. Engineering judgment is required if non-default parameters are selected).
Larger Values will Result in Fewer Nonstationarities Detected.

CPM Methods Burn-In Period
20

CPM Methods Sensitivty
1,000

Bayesian Sensitivty
0.5

Energy Divisive Method Sensitivty
0.5

Smaller Values will Result in More Nonstationarities Detected

Lombard Smooth Methods Sensitivity
0.05

Pettitt Sensitivity
0.05

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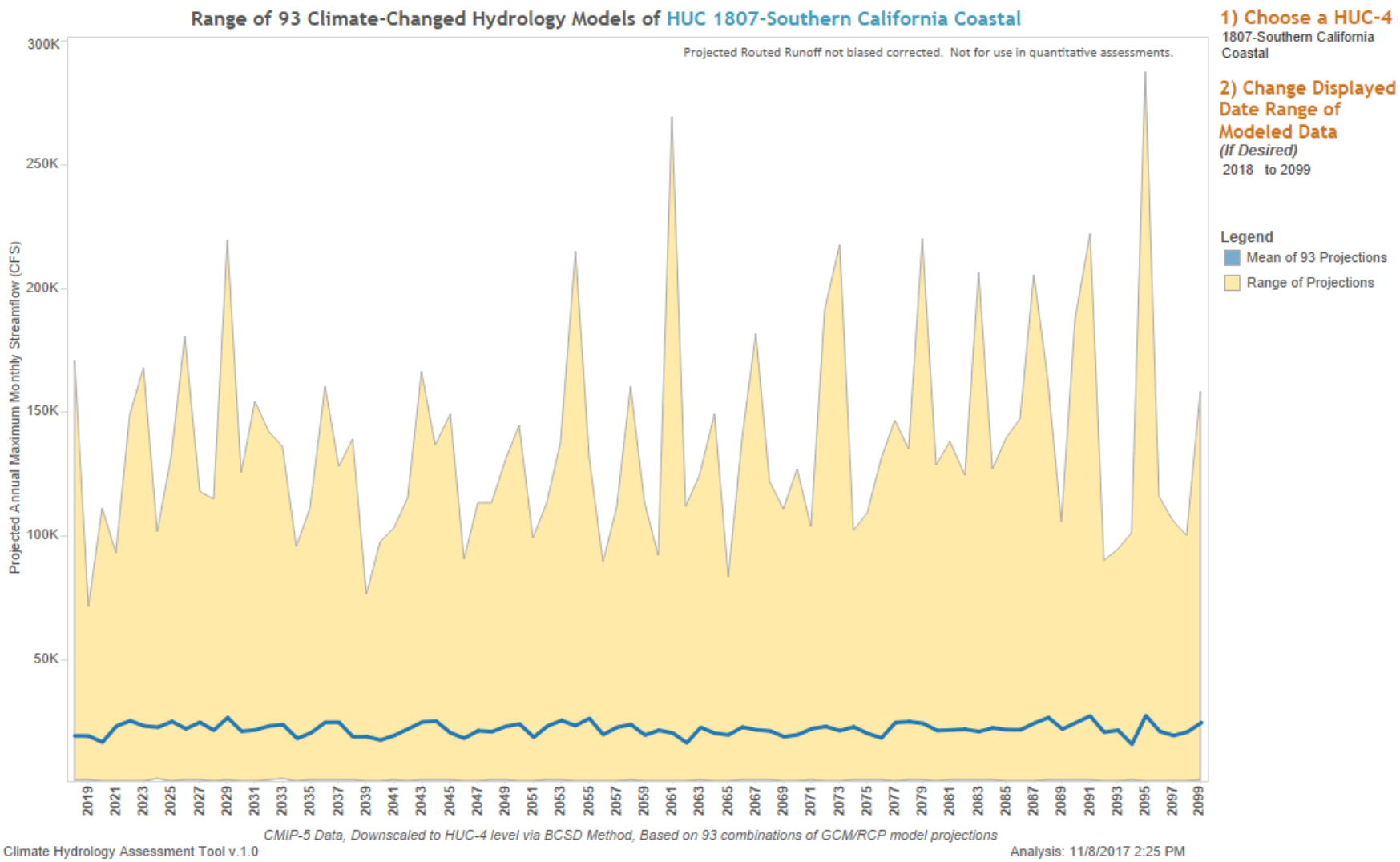
Prado Basin Riverside County California

NONSTATIONARYITY ANALYSIS OF MAXIMUM ANNUAL FLOW

CUCAMONGA CREEK

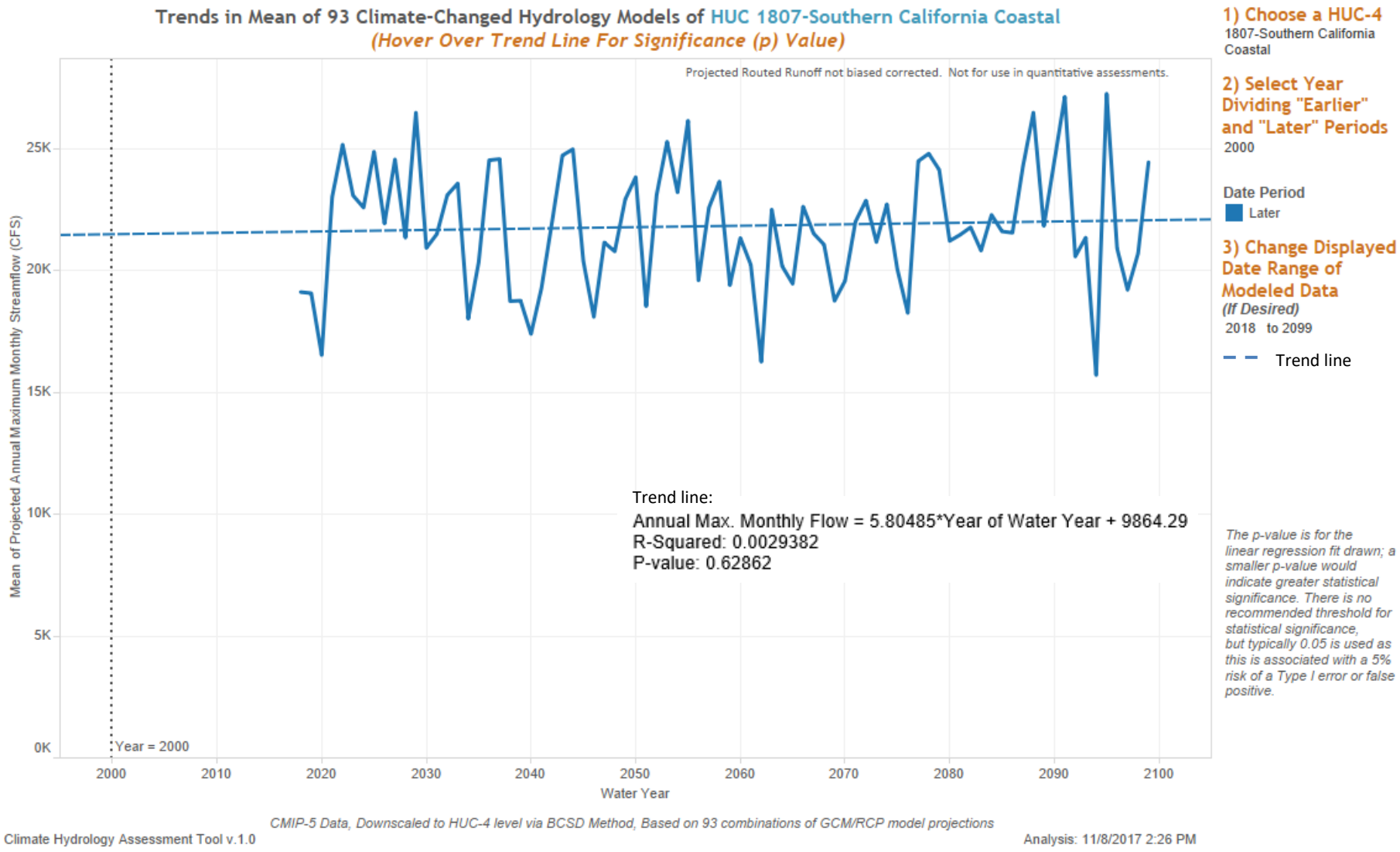
U.S Army Corps of Engineers
Los Angeles District



Prado Basin Riverside County California

RANGE IN THE PROJECTED ANNUAL MAXIMUM MONTHLY FLOWS, HUC 1807

U.S Army Corps of Engineers
Los Angeles District



Prado Basin Riverside County California

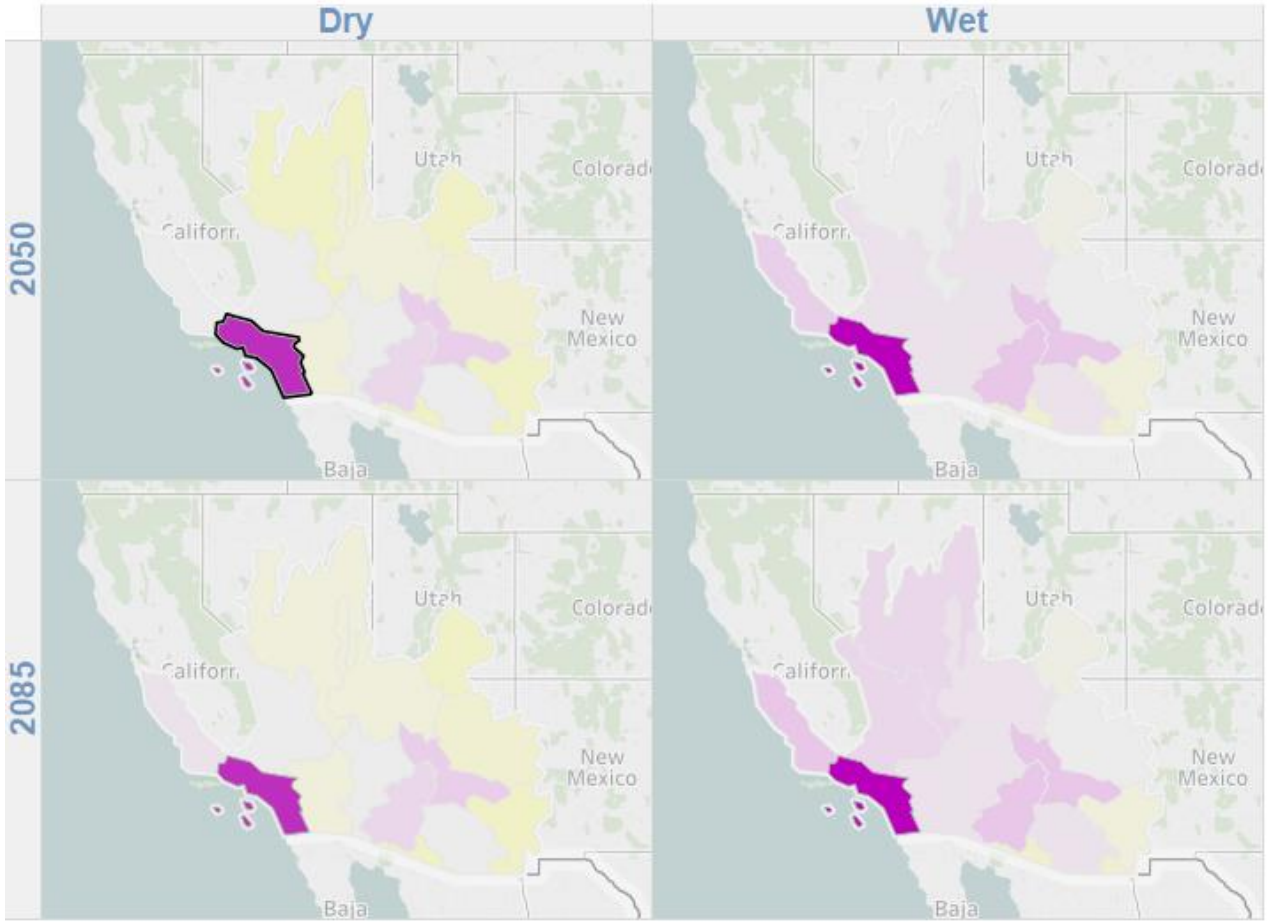
MEAN PROJECTED ANNUAL MAXIMUM MONTHLY STREAM FLOW, HUC 1807

U.S Army Corps of Engineers
Los Angeles District

Summary of HUC Results

Business Line	Climate Data Source	Integrated Analysis Type	Threshold	ORness
Flood Risk Reduction	CMIP-5 (2014)	EACH	20%	0.70

Dataset: 2/2016 – data update for selected indicators

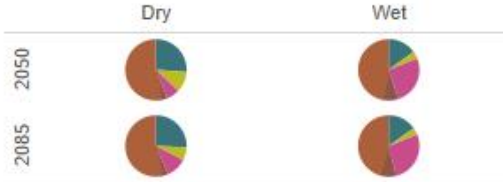


Select a HUC or HUCs to show the districts in each HUC and a summary of the vulnerable HUCs and indicator contributions to those HUCs.

WOWA Score

35.66 — 76.07

	Dry	Wet
2050	1 HUC(s) selected 1 HUC(s) vulnerable	1 HUC(s) selected 1 HUC(s) vulnerable
2085	1 HUC(s) selected 1 HUC(s) vulnerable	1 HUC(s) selected 1 HUC(s) vulnerable



Indicator

- 175C Annual Cov
- 590 500YR Urban Floodplain
- 277 Runoff Precipitation
- 568C Flood Magnification
- 568L Flood Magnification

HUC	District
1807	SPL

National Standard Settings?

Yes

Prado Basin Riverside County California

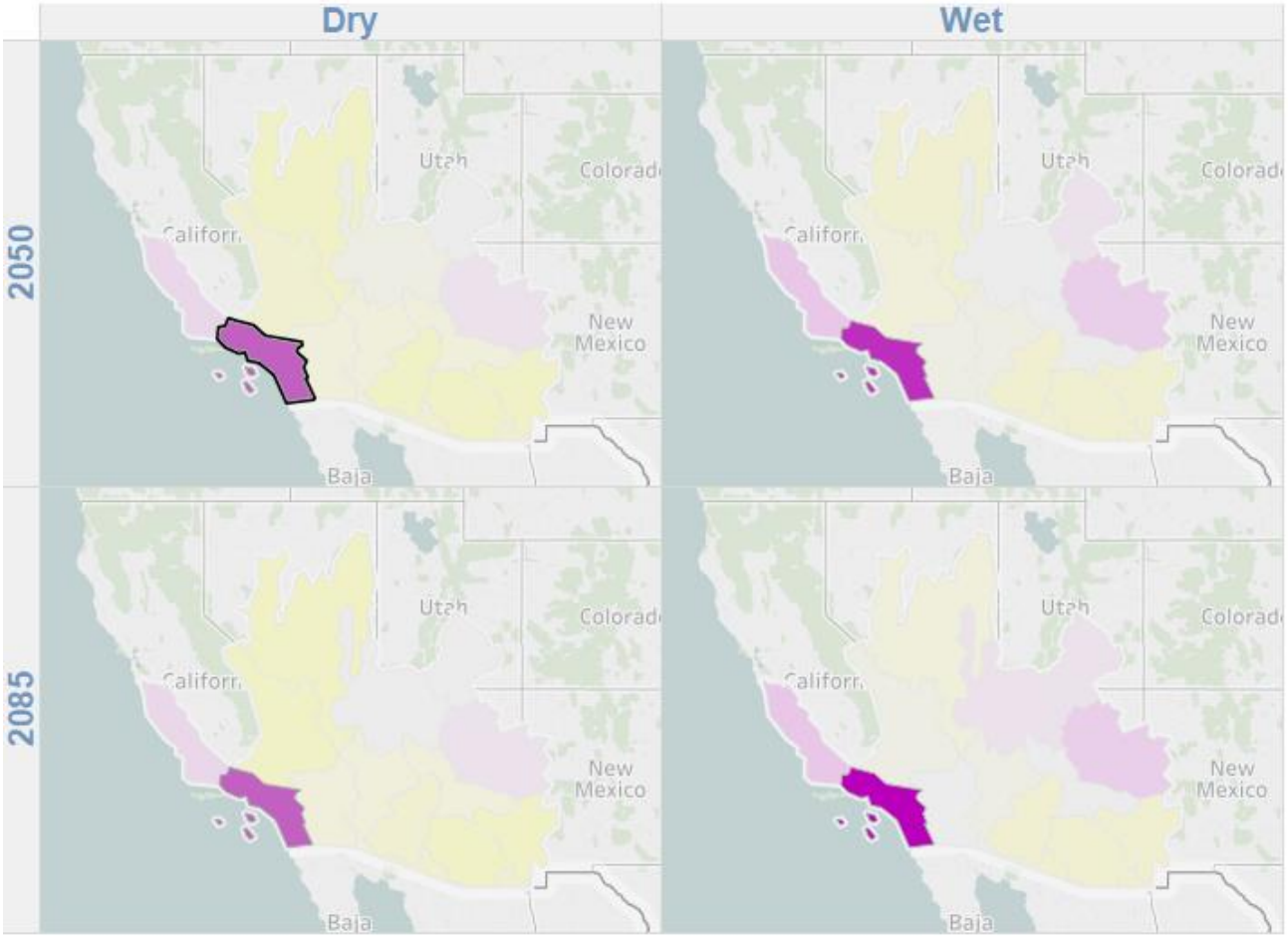
PROJECTED VULNERABILITY FLOOD RISK REDUCTION BUSINESS LINE FOR HUC-1807

U.S Army Corps of Engineers
Los Angeles District

Summary of HUC Results

Business Line	Climate Data Source	Integrated Analysis Type	Threshold	ORness
Ecosystem Restoration	CMIP-5 (2014)	EACH	20%	0.70

Dataset: 2/2016 – data update for selected indicators

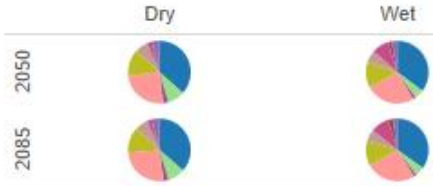


Select a HUC or HUCs to show the districts in each HUC and a summary of the vulnerable HUCs and indicator contributions to those HUCs.

WOWA Score

65.36 — 79.65

	Dry	Wet
2050	1 HUC(s) selected 1 HUC(s) vulnerable	1 HUC(s) selected 1 HUC(s) vulnerable
2085	1 HUC(s) selected 1 HUC(s) vulnerable	1 HUC(s) selected 1 HUC(s) vulnerable



Indicator

- 8 At Risk Frshwtr Plant
- 65 Mean Ann Runoff
- 156 Sediment
- 221C Monthly Cov
- 277 Runoff Precip.
- 297 Macroinvertebrate
- 568C Flood Magnification
- 568L Flood Magnification
- 70 Low Flow Reduction

HUC	District
1807	SPL

National Standard Settings?

Yes

Prado Basin Riverside County California

PROJECTED VULNERABILITY ECOSYSTEM RESTORATION BUSINESS LINE FOR HUC-1807

U.S Army Corps of Engineers
Los Angeles District

Attachment A

Prado Basin, California, Water Conservation Memorandum of Agreement – 7 July 2006

Attachment B

Evaluation of Suitable Discharge Rate from Prado Dam to Surface Water Recharge System – February 5, 2013, OCWD

Attachment C

Prado Basin Daily Discharge Estimate for 2021 and 2071 Using the Wasteload Allocation Model - December 2013, Wildermuth Environmental, Inc.