Balance Hydrologics, Inc., "Assessment of Potential Impacts Resulting From Cumulative Hydromodification Effects, Selected Reaches of the Santa Clara River, Los Angeles County, California" (October 2005)

Assessment of potential impacts resulting from cumulative hydromodification effects, selected reaches of the Santa Clara River, Los Angeles County, California

Report prepared for:
GeoSyntec Consultants

Prepared by:
Scott Brown
Barry Hecht

Balance Hydrologics, Inc.

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A report prepared for:

GeoSyntec Consultants
55 SW Yamhill Street
Suite 200
Portland, OR 97204
(503) 242-1416
Attn: Lisa Austin

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Balance Project Assignment 205018

by

Scott Brown
Hydrologist, Geomorphologist

Barry Hecht, CEG 1245, CHg 50
Principal

841 Folger Avenue
Berkeley, California 94710-2800
(510) 704-1000
sbrown@balancehydro.com
bhecht@balancehydro.com

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1. INTRODUCTION

1.1 Background and purpose

The Newhall Ranch Specific Plan projects will urbanize a portion of the Santa Clarita Valley in Los Angeles County during the coming decades. The project is an extension of prior community growth, which commenced in earnest during the 1960s, in accordance with the adopted General Plan and adopted growth projections. Concern has been expressed that future urbanization may result in changes in the Santa Clara River, a stream of regional scale draining westward from northern Los Angeles County through Ventura County, flowing into the Pacific Ocean near Oxnard. Prior analysis by Geosyntec Consultants (2005) indicates that cumulative future urbanization in the upper watershed of the Santa Clara River, of which Newhall ranch will contribute a portion, will reach approximately 9 percent at "built-out" conditions. A survey of the literature (reviewed in GeoSyntec, 2002) shows that many western-state streams begin to exhibit effects when impervious areas exceed a threshold of about 10 percent, with some considerable site-by-site variability. Additional studies by GeoSyntec in the San Francisco Bay area (2004) and a recent Southern California regional study (Coleman and others, 2005) indicate that, for watersheds smaller than about 25 square miles, channels in granular, non-cohesive sediments may become unstable downstream from urbanizing areas when impervious coverage reaches as little as 2 to 3 percent.

This report uses an empirical approach to assess the potential effects of urbanization on channel morphology associated with the implementation of the Newhall Ranch Specific Plan, combined with other existing and future development in the upper watershed of the Santa Clara River as described in the adopted General Plan. We use historical changes in the Santa Clara River channel pattern to help bracket potential morphological effects on the river of hydromodification due to accumulated urban development. We note that historical changes (both natural and human-induced) in the three factors most likely to affect the Santa Clara River stability (magnitude and frequency of stormflow events, sediment supply and caliber, and channel vegetation) are very large relative to the effects, if any, of the Newhall Ranch project and other planned future urban development. We hypothesize that it will prove useful to learn from history, and to assess the nature and general degree of change that may result from future urbanization by applying these insights.

Much of what is learned from this analysis may be applicable in other aspects of planning and managing the Santa Clara River in the Newhall Ranch reach and reaches downstream. It is not, however, an immediate objective of this report to develop management plans, to assess potential changes in tributary channels, or to explore how habitat conditions might be changed by potential hydromodification, beyond that which is related to the physical channel form and dynamics.

1.2 Technical approach

The history of the Santa Clara River in the Santa Clarita Valley and eastern Ventura County allows us to explore the three factors most likely to affect the stability and morphology of the river downstream from existing and future development in the Santa Clarita Valley (including Newhall Ranch):

- High streamflows, including increased peak flows, volumes, and/or durations of stormflows,
- Coarse-sediment supply, including sharp curtailment of sediment entering the river following completion of Castaic (1974) and Santa Felicia-Piru (1958) Dams.
- Mature riparian vegetation, with interpenetrating roots, which can stabilize the banks and maintain the channel pattern.

We consider the 'pre-urban' condition to be the form and functions of the river during the 1950s and 1960s, prior to significant urban growth and modification of the flow and sediment regimes due to the construction of the Castaic and Santa Felicia-Piru Dams. Historic deviations from the pre-urban condition can be evaluated using the geomorphic evidence left by a period of floods and high flows from 1938 to about 1945. The effects of sediment supply can be evaluated by quantifying effects of eliminating coarse-sediment delivery from Castaic Creek (with a drainage area of 155 square miles, approximately 25 percent of the Santa Clara watershed at the L.A./Ventura County line. Supporting evidence can also be obtained similarly at Piru Creek (approximately 40 percent of the watershed at its confluence with the Santa Clara River at Piru).

1.3 Report organization

The analysis begins with an overview of the factors affecting the form and geomorphic history of the Santa Clara River (Chapter 2). The larger events and fluctuations, and manner in which they may have affected the river, are considered in Chapter 3. The fourth chapter explains the source materials and methods used to quantify the river's response to these perturbations, which are summarized in Chapter 5. Chapter 6 is a discussion of what we have learned from this study, and Chapter 7 draws conclusions as to how these findings relate to potential hydromodification effects in response to anticipated future watershed urbanization.

2. GEOMORPHIC SETTING

2.1 Channel pattern influences

Several previous reports have described the overall and geomorphic histories of the Santa Clara River (c.f., Schwarzberg and Moore, 1995; SCREMP 2005). In each case, authors have noted that the forms and functions of the river have varied with climatic cycles and with episodes such as floods and fires. It is this variability that is characteristic of the river. In the this report, we utilize the study of historic influences of some of the more pronounced events and cycles to better understand the impacts of drainage changes, if any, that can be expected to result from the anticipated future development in the Santa Clarita Valley, including Newhall Ranch.

2.1.1 Physiography

The Santa Clara River flows through a complex, tectonically-active trough generally bounded by reverse faults on the San Cayetano Mountain and South Mountain fronts. Some of the most rapid rates of geologically-current uplift in the world are reported from the Ventura anticline and San Gabriel Mountains, just to the northwest and southeast, respectively, of the river. Slopes are very steep, with local relief of 3000 to 4000 feet being common. These faults bring harder, more resistant sedimentary rocks over softer and younger sedimentary formations, but all formations are fundamentally soft and erodible. On either side of the faults, sandstone (generally multi-cyclic and fine-grained) and mudstones prevail. The northeastern and southeastern corners of the watershed are underlain by deeply-weathered granitic and schistose rocks, which produce sands that are coarser than those of other rock units when they weather and erode. The San Gabriel fault crosses the valley near the county line, bringing slightly more resistant rock to the surface and creating a local base level reflected as a slight rise or 'bump' on the river's longitudinal profile.

Most geologic materials in the watershed decompose mainly to silts and clays and to sand, with some coarser materials. Rhea Williams and his colleagues at the U. S. Geological Survey found that most sediment moved by the Santa Clara River and its main tributaries are quite fine, with less than 5 percent bedload-sized material (>0.25 mm, or about 0.01 inches in diameter). Some gravels and cobbles do occur within the beds of the streams and in their alluvium. Nonetheless, both the bed and the sediment transported by the river tend to be finer than in most Southern California watersheds (c.f., Knudsen and others, 1992).

The Santa Clara River watershed drains a watershed of 1,600 square miles, of which 625 square miles are within Los Angeles County, upstream of the "county-line gage" (USGS No. 11108500), near the western edge of the Newhall Ranch Specific Plan area.

2.1.2 Climate

Much of the watershed upstream of the Newhall Ranch Specific Plan area receives rainfall averaging about 18 to 25 inches per year (NOAA). As throughout Southern California, rainfall in the Santa Clara watershed alternates between wet and dry periods, a variation that is central to understanding the cultural and geomorphic histories of the upper watershed (Schwarzberg and Moore, 1995; Lynch, 1931; Reichard, 1981). Wet cycles tend to persist for several years, sometimes for periods of 6 or 8 years, during which rainfall, although variable, may average about 140 to 150 percent of the long-term average. For the woody riparian vegetation along the banks and on islands in the braided channels, these are crucial periods for establishment and growth. During dry cycles, the roots of the riparian vegetation must grow downward to the water table or perched zones, and where it cannot do so, this band of vegetation will die back.

2.1.3 Flows

Flows in the Santa Clara River, as in most southern California streams, are highly episodic. For the gaged period between 1953 and 1996 annual flow at the Los Angeles/Ventura County line gage ranged between 253,000 acre-feet (1969) and 561 acre-feet (1961). In general, however, streamflow, and especially dry-season streamflow, has increased over the past few decades primarily due to discharges from two wastewater treatment plants. Mean annual flow at the County Line increased from 25,700 acre-feet in 1972 (averaged over a 20-year record) to 35,360 acre-feet in 1988 (36-year record), with a significant decrease in the number of very low years over that period (UWCD and CLWA, 1996). Downstream of the County line, however, the Santa Clara River flows through the Piru groundwater basin, which represents a "Dry Gap" where dry-season streamflow is lost to groundwater.

Annual peak flows at the County line between 1953 and 1996 ranged from 68,800 cfs (1969) to 109 cfs (1960). Of note is that the second highest annual peak, 32,000 cfs in 1966, was less than half of the highest peak (68,800 in 1969). Both of these events occurred in the late pre-urban to early-urbanization stages within the Santa Clarita Basin and no consistent increase in peak flow is evidence since this time. Flow data for the 2005 flood event are not yet available, however the peak flow at the County line may have approached the flow observed in 1969. As discussed below these large episodic events have a significant impact on the geomorphic characteristics of the Santa Clara River mainstem.

2.1.4 Ground-water supported riparian vegetation

The Santa Clara River is underlain by several distinct alluvial ground-water basins—the Piru, Fillmore, and Santa Paula Basins (Reichard and others, 1999; SCREMP 2005). These basins are divided longitudinally by sills or ridges of bedrock that support areas of locally-high ground water, including the area upstream from the County line (above the Piru Basin), and upstream from the mouth Sespe Creek (the transition between the Piru and Fillmore Basins). This locally-high ground water sustains summer baseflow and riparian vegetation within the Santa Clara River corridor even through relatively dry climatic cycles.

3. PERTURBATIONS

This section describes several major perturbations (those with the potential to affect channel- and floodplain-form) that occurred in the Santa Clara River watershed since the early 1900s (summarized in Figure 1). Aerial photographs were selected to bracket these events and analyzed, both qualitatively and quantitatively, to try to discern and quantify responses of the Santa Clara River channel to:

(1) changes in flow regime during wet and dry multi-year cycles,

(2) sediment supply, notably describing the channel's adjustments to construction of large dams, and

(3) development of mature riparian vegetation with interpenetrating roots.

3.1 Streamflow cycles and events

As described above, streamflow within the Santa Clara watershed is highly episodic, and can vary drastically from year to year. However, decade-scale patterns of wet and dry periods have been identified in the historic record—as early as the 1700s. Previous wet periods (with associated high flows) are reported from 1810 to 1817, 1831 to 1840, 1883 and 1893, and 1903 to 1916, during each of which periods the area received a total of an additional 60 to 80 inches above the mean annual rainfall over the duration of the wet cycle. Prolonged static or drying periods similar to that observed between 1945 and 1977 also occurred from 1780 to 1810, 1842 to 1882, and 1919 to 1935 (with associated reductions in streamflow). The river is likely to have remained most stable during the latter periods, with the notable exceptions of a few major storms of record, such as 1862 (c.f., Lynch, 1931; Reichard, 1981; Schwartzberg and Moore, 1995). The primary wet periods in this study occurred between 1938 and 1946, and 1978 to 1983 (Figures 1 and 2). Other large storm events occurred in 1966, 1969, 1972, 1983, 1998, and 2005. Notable dry periods occurred between 1946 and the late 1960s, and 1983 and 1991.

3.2 Dam construction

Castaic Dam was completed on Castaic Creek (a tributary of the Santa Clara River just upstream of the Newhall project) in 1974. The watershed area above the dam is approximately one-quarter of the watershed area of the Santa Clara River at the L.A./Ventura County line, downstream of the Castaic confluence, and therefore the dam effectively reduced the sediment contributing area by about 25 percent. For comparison purposes, we also considered the effects of the construction of the Santa Felicia Dam (Lake Piru), which resulted in an approximate 38 percent decrease in sediment contribution area below the confluence of Piru Creek and the Santa Clara River[1].

3.3 Urbanization

Settlement of the Los Angeles County portion of the watershed transitioned from rural to mixed-use suburban during the mid- to late-1960s. This change initiated a period of ongoing urban expansion, with associated increases in the area of impervious or compacted surfaces as homes, commercial and industrial centers, highways and diverse infrastructure have developed throughout the Santa Clarita Valley. Future General Plan urbanization within the upper watershed, inclusive of Newhall Ranch, will bring the percent of urban area west of the County line to about nine percent (GeoSyntec, 2005).

3.4 Treated effluent discharge

Since the 1960's, treated effluent from two water reclamation plants (Saugas and Valencia) has been released directly to the Santa Clara River. This, combined with an increase in applied, imported agricultural water, has led to increased summer baseflows in the Santa Clara River at the County line, which had only rarely occurred under pre-urban conditions. This led to an increase in available water to support woody riparian vegetation. The increase in baseflow is evident in the USGS gaging record at the county line (Figure 2). In some stream corridors, vegetation growth in response to increased baseflow can provide additional bank cohesiveness and reduce erosion; though in others heavy in-channel vegetation growth (riparian encroachment) can serve to destabilize the stream and induce lateral erosion by directing flows toward the banks.

Newhall Ranch has proposed an additional plant that would ultimately treat approximately 5.8 million gallons per day at project build-out. However discharge from the plant in the summer is not expected, as this water will be re-used for irrigation purposes, and we therefore do not expect further change in riparian vegetation growth as a result.

3.5 Saint Francis Dam Breach

On March 12, 1928 the Saint Francis Dam, located in San Francisquito Canyon upstream of the Newhall project, failed and released approximately 30,000 acre-feet of water over the course of a few hours, with an estimated peak discharge of up to 800,000 cubic feet per second (Newhall,

[1] Drainage area calculations were based on USGS gaging station watershed data at Piru and Castaic Dams, and gages on the Santa Clara River at the L.A./Ventura County line and near Piru.

1928; and SCREMP, 2005). This event had drastic effects on the stream reaches downstream, as the resulting flows were much higher than anticipated from any natural event. Aerial photograph coverage during this time period is limited, however, and therefore an assessment of this event was not feasible. In addition, because of the extreme size of the event, it is unlikely that an assessment would be beneficial for assessing hydromodification impacts.

4. METHODS

We analyzed aerial photographs from 1927, 1947, 1957, 1966/67, 1989, 2002, and 2005 to describe channel change in response to the major episodes described above. The main criteria described were the width of the active braiding area (or meander belt width if there was no braiding), bank vegetation, number of channels, and width of the active channel. Also described, where they could be identified, were the width and length of "islands" (vegetated mid-channel bars) within the stream. Islands were typically easier to identify where vegetation was heavy, as the color of the vegetation highlighted the differences between channel and meta-stable islands.

The aerial photographs were analyzed in two different ways. First, a qualitative comparison of the alluvial corridor shown in the different years' photos was made, describing general differences in channel pattern and vegetation on a reach-wide scale. Second, specific cross sections were defined and the above parameters measured for each year with photo coverage in that area to provide a quantitative comparison of channel change at these standard locations along the Santa Clara River (Figure 3).

4.1 Descriptions of analysis criteria

4.1.1 Width of active braiding corridor

For braided reaches, the active channel width was identified primarily by noting the extent of active channels or recent sediment deposition. In many cases the active corridor was bounded by a significant change in vegetation or sediment deposition characteristics.

4.1.2 Relict channel corridor

The relict channel corridor is the portion of the flood plain that does not appear to have been active in the recent past (within the last 5 years or so). Typically the relict corridor is identified by areas of heavy or scattered vegetation containing no or few distinct channels, or areas that do not appear to have experienced recent sediment deposition. Alternatively, identification was based on the width between farmed fields[2]. Measurements of this feature were made from outside bank to outside bank, and include the active corridor.

[2] The total width of the former channel migration corridor is difficult to identify in aerial photographs due to past and present agricultural field reclamation following major perturbations. Where necessary, we used the width between agricultural fields as a estimate of the relict corridor.

4.1.3 Channel width

Where a distinct channel or channels could be identified, the widths of the individual channels were measured. The number of individual channel threads was also recorded, where threads could be distinguished. In some cases, measurement of these features was complicated by poor photo resolution or contrast, and difficulty in distinguishing major channels from minor ones (where a full spectrum was present).

4.1.4 Vegetation

Vegetation was described qualitatively as bare, scattered, moderate, and heavy. The location of specific areas of vegetation, such as vegetated islands, vegetation within the relict corridor, or vegetation along banks, was also described. Where the resolution was adequate, the growth form of vegetation, or state of maturity, was also described (trees or shrubs).

4.1.5 Number of vegetated islands

The number of distinct vegetated islands (mid-channel bars) was also recorded at each cross-section, where the resolution of the photographs was adequate. Where islands could be identified, measurements of width and length were recorded.

5. RESULTS

5.1 Qualitative descriptions

Initial inspection of the series of aerial photographs showed that significant changes in channel planform have occurred throughout the 1900s, as would be expected in a large, braided stream in southern California. Vegetation within the relict corridor (see definition above) near the Newhall Ranch planning area appears to become progressively heavier through time, likely due to the increase in agricultural water and discharge of treated effluent to the channel through the summer months.

The photos show many areas of net deposition, and corresponding channel shifts in major depositional areas. Single-thread, dominant channel segments are rarely present, especially in years following large events. Even when there is one main channel, secondary channels are often present within the active channel corridor.

Portions of the stream have been altered for flood control purposes, including stabilization of banks bounded by orchards and fields, or construction of levees within the active corridor. These levees are most prominent in the 1989 photographs (upstream of the L.A./Ventura County line), where the substantial segments of the main channel are confined in a flood control channel approximately 225 feet wide. By 2002, however, little evidence can be discerned in the aerial photographs of these levees.

The 2005 flood events caused significant changes within the Santa Clara River. Vegetation within the channel was almost all completely washed out (compared to 2002 conditions), and many areas of significant bank-widening were identified, even in areas of heavy bank vegetation (Figure 4).

There appears to be little change in agricultural constriction of the Santa Clara River over the span of photographs reviewed. Through the Newhall reach, the agricultural areas appear to be well buffered by the relict channel and the vegetation supported there. There were only a few places identified where the active channel cut into agricultural areas rather than staying within the relict corridor. In contrast, within the Piru Basin (downstream of the Newhall reach), significant agricultural constriction and subsequent channel widening occurred over the time span of the photos reviewed.

Areas of shallow ground water between Piru and Sespe Canyon[3], which support denser riparian vegetation than typical for the river between Valencia and Fillmore, show little if any significant change for all years in the studied photo-sets. Both the density and extent of vegetation in these areas does not appear to change over time (despite significant differences in climate and other watershed factors) nor does the amount of vegetation appear to significantly affect channel planform, compared to upstream and downstream reaches (the braided channel does not shift to a single-threaded channel through the wetted reach).

5.2 Quantitative results

For the quantitative portion of the aerial photograph analysis we looked at four different types of criteria to identify physical changes to the Santa Clara River channel (Table 1; see also section 4.1.1 for descriptions of criteria). Because of difficulties in identifying and measuring the width/number of channels and number/dimensions of vegetated islands, because of the varying resolutions and contrasts of the photographs, we concluded that analysis of these two criteria were less meaningful for this study. In other words, there was more variation due to the ability to identify the features for the varying quality of the photos than there was actual variation in the system. While we believe that these criteria may be a valid indicator of channel change, more study would be needed to adequately quantify these features so they were used a supplementary qualitative metric.

For this study we found that measurement of the "active corridor" (see section 4.1.1) was the most useful and easiest to work with to identify channel changes. In most cases there is enough vegetation along the banks that the active braiding corridor is easily identified, and changes in the width of the corridor can be tracked from year-to-year.

Figure 5 summarizes the changes in active corridor width over the time span of the reviewed photos. Within the Newhall reach, the width of the "active corridor" at the four measured cross-sections varies from year-to-year by as much as 500 feet, though most of the variation is considerably less. One station, in the narrows above the Piru Basin, has a very consistent channel width, varying by less than about 50 feet from year to year.

To provide additional analysis, we looked at a series of recent photos (1994, 2000, and 2002-2005) at one cross section downstream of the Castaic confluence. For this photo set, the channel widened significantly between 1994 and 2000 (probably in response to the 1995 or 1998 large

[3] See Reichard and others (1999) for a discussion of the hydrogeology of these shallow ground water areas; although downstream from the Los Angeles County line, results are applicable to the upstream as well, as discussed later in this report.

storms), but showed almost no change between 2000 and 2004 (Figure 6). The channel then widened considerably again in response to the high-flow events in 2005.

As a secondary check of the numbers derived for the measured standardized cross sections, we also measured active channel widths at approximately twenty different locations through the Newhall Reach on three different photo sets—1967, 2004, and 2005. From these measurements an average active braiding corridor width was calculated and compared with the other years. In 1967, the average channel width was approximately 580 feet, which was significantly wider than the average width in 2002 (392 feet). However, after the 2005 storms, the active width was approximately 560 feet, similar to the 1967 conditions.

The "relict corridor" (see section 4.1.2 for definition) also proved useful as a secondary criterion, providing a measurement of potential changes due to agricultural encroachment or constriction of the flood corridor. Measurement of the "relict corridor" at the standard cross sections showed that while there was some variation between photos, there is no consistent trend of agricultural constriction to the Santa Clara River flood corridor. These measurements, along with qualitative observations that within the Newhall reach agricultural activities were generally restricted to outside the active corridor, suggest that agricultural encroachment has not historically affected the geomorphology of the Santa Clara River within the Newhall Reach.

6. DISCUSSION

The Santa Clara River is a dynamic, episodic system. The above analyses highlight the magnitude of geomorphic change over the course of recent history, in response to natural and human disturbances in the watershed. Understanding the magnitude of past response is a key factor in assessing the potential response to future urbanization within the watershed.

The construction of Castaic Dam in 1974, regulating approximately 25 percent of the watershed at the L.A./Ventura County line, cut off a significant supply of sediment to the Santa Clara River. This change, however, does not appear to have had an effect on the channel dimensions of the Santa Clara River mainstem. The width of the active corridor, as well as the general form of the channel, are generally consistent both before and after construction of the dam. It appears that the Santa Clara River adjusted without morphological expression to absorb this change. One factor contributing to the lack of change is the seemingly large volume of sediment stored in the tectonic basin above the county line—a result of bedrock control associated with movement along the San Gabriel fault, which supports the large extent of semi-consolidated and alluvial deposits adjoining the drainage net.

The amount of vegetation within the Santa Clara River corridor appears to have increased since the 1960s, likely due to the increased summer return flows from agricultural water and to year-round augmentation of baseflows due to treated effluent discharge to the river. However, this vegetation does not seem to provide enough erosion resistance to maintain a "stable" channel capable of withstanding regular 're-sets', which occur at intervals averaging about a decade – or much less than the expected lifetime of the riparian woodlands which do get established. Despite heavy vegetation on the active channel banks near Newhall ranch and in areas of shallow ground-water, the stream still responds to large events by a general widening and/or shift of the channel. The role of vegetation in large-channel stability and morphology in Southern and Central California does fundamentally differ from that of smaller streams and streams elsewhere in the country. The geomorophic and historical record shows that resets have been occurring throughout the recent geologic past in basins exceeding a certain size. One partial explanation may be that 're-set' flood events in these larger channels exert stresses beneath or around the riparian vegetation exceeding the vegetation's threshold of stability[4].

[4] Sedimentologists note that crossbeds in the alluvium of the Santa Clara River are often 8 to 12 feet high, equal or greater than the depth to which roots can interpenetrate in most riparian settings in the region.

As stated above, the Santa Clara River, as with many streams in semi-arid southern California, is highly episodic. Concepts of "normal" or "average" sediment-supply and flow conditions have limited value in this "flashy" environment where episodic storm and wildfire events have enormous influence on sediment and stormflow conditions. Many of these channels are actively adjusting to lower flows than the last major event, which may have occurred some years before[5] (Hecht, 1993). In these streams, a large portion of the sediment movement events can occur in a matter of hours or days. In many of these channels most sediment is moved—and most bed changes occur—during the large flow events resulting from storms that may be expected approximately every 5 to 15 years (c.f., Capelli and Keller, 1993; Hecht,1993; Inman and Jenkins, 1999; Knudsen and others, 1992; Kroll and Porterfield, 1969).

Evidence of episodic channel changes can be seen in the Newhall reach of the Santa Clara River. Based on aerial-photograph interpretation of a near-yearly sequence of aerial photographs from within the last decade, the channel appears to maintain a consistent planform during average or dry rainfall years (such as between 2000 and 2004). Large events, however, (such as that which occurred in February 1998 and January 2005) can significantly modify this channel form. This widened and/or shifted channel (like that which was present after the 1998 or 2005 stormflow events) then sets the geomorphic template for subsequent normal to dry years. This model, similar to that described for the Ventura River by Capelli and Keller (1993), suggests that the geomorphology of the Santa Clara River is primarily driven by these large events.

Other perturbations which potentially affect channel geometry appear to have transitory or minor manifestations. For example, effects on the channel width due to 1980s levee construction are barely discernible by the first few years of the 21st century, probably mostly due to morphologic compensation associated with the mid- to late-1990s storm events.

[5] Actively adjusting channels may be aggrading, incising, expanding or otherwise changing channel dimensions, depending on the magnitude, type, and various effects of the episodic event.

7. CONCLUSIONS

Based on the study of historic aerial photographs described above we conclude that:

- Major perturbations within the Santa Clara River watershed (dam construction, levee construction, changes in flows in response to decadal-scale climatic patterns, and increases in woody vegetation) do not appear to have had a significant impact on the geomorphic expression of the Santa Clara River, as quantified from measurements made from a series of historical aerial photographs flown during the years 1927 through 2005.

- Large events (those which are typically not as affected by increases in impervious area and associated increases in stormwater peaks and runoff volume) can completely alter the form of the Santa Clara River channel. We call these events "re-set" events. These events, perhaps occurring on average once every ten years, are a dominant force in defining channel characteristics.

- The geomorphic dominance of "re-set" events overwhelms geomorphic effects of hydromodification on smaller events. Due to these episodic "re-sets" we do not expect hydromodification feedback "unraveling" of the Santa Clara River mainstem, as is seen in many smaller southern California watersheds[6]. The "re-set" events appear to adequately buffer changes that may occur in short-term sediment transport.

- While there is no expected increase in summer flows due to additional treated effluent discharge to the Santa Clara River, even if summer baseflow do increase we would not expect a significant change within the channel. Additional growth in the extent or density of vegetation is not anticipated, as the reach near Newhall already appears to have enough flow to support summer vegetation, and the existing vegetation does not appear to affect channel form for durations longer than the "re-set" interval. Further, re-sets occur at intervals significantly shorter than the period required for maturation of riparian vegetation, such that full development of bank-holding properties is frequently interrupted.

- Given that the channel morphology of the Santa Clara River mainstem has not adjusted significantly to much larger perturbations in flow, sediment yield, and riparian

[6] In many smaller streams, hydromodification of moderate events can induce incision of the stream bed, which reduces the connection of the stream to the floodplain. This disconnect, in turn, increases the erosive forces of the flows (concentrating more flow in the channel) and causing further erosion, and thus a positive feedback response.

vegetation growth factors, within the Newhall reach, we do not expect a significant geomorphic impact to the Santa Clara River mainstem due to the anticipated increase in 'urban area' from four to nine percent.

8. LIMITATIONS

The analyses in this report were designed to help bracket the range of likely effects on the geomorphology of the Santa Clara River due to proposed urban expansion under the General Plan, inclusive of the Newhall Ranch Specific Plan projects. It does not consider specific elements of the project or of evolving mitigation measures; rather, it focuses upon the susceptibility to perturbation of the Santa Clara River corridor as a whole. We believe that it conforms with the standard of care applicable to reconnaissance studies of this nature; no other warranty, expressed or implied, is made.

The above analyses and discussion were intended to assess the potential cumulative impacts to the Santa Clara River *mainstem* (not tributaries) due to the anticipated urban expansion in the watershed. While we conclude that urban expansion from approximately four- to nine-percent urbanized (not 'impervious') will not significantly affect the channel geomorphology of the Santa Clara River, we do expect that there might be a response to urbanization on a larger scale. However, further study would be required to define what the likely threshold and magnitude of response might be.

We ask readers to note that this is a reconnaissance report. It is intended to bracket likely future conditions, to identify factors which must be better known, and to help guide initial planning. This report should *not* be used to site or design individual facilities without further site-specific investigations. Similarly, it is *not* intended to serve as basis for flood management or detailed floodplain planning, both of which should be conducted by well-defined and site-specific procedures, and which frequently require multiple lines of evidence.

The application of geomorphic history to inferring future channel and corridor change has a long and respected record in the earth sciences. As with all history or archival analysis, the better the record is known and understood, the more relevant and predictive the analysis can be. We do encourage readers who have knowledge of other events or processes which may have affected the river to let the authors know at the first available opportunity. The authors and their contacts via several different media are given on the signature page of this report.

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TABLES

Table 1. Aerial photograph cross section data at selected locations near Newhall Ranch, Los Angeles County, CA. See text for explanation and interpretation of data. Locations of cross section are labeled on Figure 2. Photo sources are listed in Appendix A.

Cross section	location description	photo date	width of active braiding corridor	width of relict braiding corridor	is there one primary channel visible?	width of main channel	number of identifiable channels	total width of channels (including main)	number of islands	length of islands encountered	width of islands	vegetation	other descriptions
			(feet)	(feet)		(feet)		(feet)		(feet)	(feet)		
X1	downstream of Castaic	8/16/1947	570	1247	yes?	71	3?	107	can't define	n/a	n/a	moderately vegetated with some portions of relict corridor heavily vegetated	Just downstream a heavily vegetated bar is cut by a very distinct secondary channel
		7/20/1966	729	1173	yes	27	1	27	1	497	86	almost no vegetation within primary corridor except two areas near the primary channel and scattered small patches, only scattered vegetation on relict corridor	while there is only one main channel the rest of the primary corridor is section is almost deltaic in planform, spreading out from constriction upstream (possibly high sediment load coming in from Castaic)
		5/26/1989	173	1171	yes, but small	43	1	43	0	n/a	n/a	banks of meander corridor have scattered vegetation (less than 2000) with very little within braiding corridor	meander corridor is very distinct and straight, could be from flood control dredging;
		6/1/1994	337	1167	yes	72	2	97	1	551	171	light to moderate vegetation on braiding corridor banks	very little vegetation within braiding corridor
		2/1/2002	505	984	yes	42	2	50	poorly defined	n/a	n/a	relict braiding corridor is well-vegetated; meander belt/bar is lightly to moderately vegetated; at least one main channel bank is well-vegetated (alternates w/ meanders)	secondary channel essentially cuts off meander
		4/1/2004	505	978	no	n/a	3	87	2	929, 251	248, 56	heavy vegetation along former primary channel; relict corridor also heavily vegetated	there are two distinct channels, approximately the same size
		3/1/2003	510	965	yes	75	1	45	0	n/a	n/a	heavy vegetation on northern bank; some scattered vegetation within active corridor and surrounding low-flow channel	channel branches just downstream of cross section; very similar to 2002 and 2004 photos
		2/1/2005	601	999	no	n/a	3	106	poorly defined	n/a	n/a	no vegetation in main portion of channel; right bank has heavy tree cover, left bank has few trees	the main channel is about 340 feet wide with an obvious overbank deposition area (with very little vegetation)
X2	Upstream of County line	8/16/1947	532	1197	yes	89	2	133	1	355	133	vegetation is heavy (probably trees) on relict corridor; moderate (probably scrub) within active corridor (difficult to distinguish)	very distinguishable difference between active and relict corridor within this reach
		3/6/1963	491	1352	no	n/a	difficult to define	n/a	6	252, 283, 82, 441, 94, 410	44, 57, 52, 76, 38,63	several well-defined islands behind established vegetation (individual shrubs or small trees); relict corridor has moderate to heavy tree cover	very braided planform; switches to predominately single-thread channel just downstream
		5/26/1989	651	651	yes	43	3	108	1	2385	477	relict corridor has scattered trees with moderate to heavy shrub or grass cover; central island (along levee) has similar vegetation	well-defined flood control channel, but has been breached and there is a significant secondary channel to the north of the levees; included a portion of the island between the flood control channel and the secondary channel in the relict channel (no sign of recent deposition)

Cross section	location description	photo date	width of active braiding corridor (feet)	width of relict braiding corridor (feet)	is there one primary channel visible?	width of main channel (feet)	number of identifiable channels	total width of channels (including main) (feet)	number of islands	length of islands encountered (feet)	width of islands (feet)	vegetation	other descriptions
		6/1/2002	608	1258	yes	131	1	131	0	n/a	n/a	relict corridor on north bank has heavy tree cover; meander bends are eroding tree bank vegetation in places	stream has meandering planform, though meander belt (400' wide) has high sediment deposition and little vegetation; no evidence of flood control levees (meanders have widened to erode levees); active channel includes meander belt and area of significant recent sediment deposition to the north of the meander belt
		2/1/2005	674	1240	yes	97	3	192	1	475	155	almost no vegetation within active channel; relict corridor on both banks has moderate tree cover; much vegetation eroded away since 2002	numerous very small channels present as well
X3	downstream of county line	8/16/1947	362	805	yes, at this xs	80	2	121	can't define	n/a	n/a	outer banks of braiding corridor seem heavily vegetated	there seems to be one main channel through this reach, with extensive deposition of sediment outside of the channel
		7/20/1966	140	714	yes	51	2	77	0	n/a	n/a	banks of braiding corridor are heavily vegetated	
		5/26/1989	273	864	yes	91	2	114	1	136	23	only scattered vegetation on banks of braiding corridor	braiding corridor looks as though it may be a leveed flood control channel
		2/1/2002	249	1466	yes	41	3	79	2	344, 219	66, 36	scattered vegetation on u/s ends of islands; some recent deposition of sediment within relict braiding corridor (which is predominately heavily vegetated	
		2/1/2005	587	1472	yes	97	3	145	1	543	110	no vegetation in active corridor; right bank has heavy shrub cover with some trees, left bank has light shrub cover	
X4	upstream of Piru Basin	8/16/1947	282	885	yes	121	1	121	can't define	n/a	n/a	little to no vegetation within braiding corridor; relict braiding corridor has heavy tree/shrub cover	
		7/20/1966	281	383	no	n/a	3	26	poorly defined	n/a	n/a		
		5/26/1989	318	591	yes	68	1	68	1	91	23	meander belt banks lined with trees; meander belt itself covered with shrubs	"braiding corridor" is actually the meander belt; meander belt outside of channel is heavily vegetated
		2/1/2002	266	426	yes	35	3	45	1	340	36		secondary channels may be present in other photos, but resolution is poor, esp. 1948
		2/1/2005	281	495	yes	44	1	44	0	n/a	n/a	vegetation on right bank of main channel has diverted some flow over the relict corridor, though conditions are similar in 2002; moderate to heavy trees and shrubs on both banks	conditions are very similar to 2002, but with slightly wider and much clearer channel

Cross section	location description	photo date	width of active braiding corridor	width of relict braiding corridor	is there one primary channel visible?	width of main channel	number of identifiable channels	total width of channels (including main)	number of islands	length of islands encountered	width of islands	vegetation	other descriptions
			(feet)	(feet)		(feet)		(feet)		(feet)	(feet)		
X5	upstream of Piru confluence	4/1/1927	1834	3191	no	n/a	many	n/a	3	3060, 1170, 468	540, 450, 90	sparse scrub vegetation within active corridor, but enough to define the complex channel pattern; only slightly more vegetation (or possibly just less recent sediment deposition) in relict corridor	relict channel is mainly an artifact of flow deflection by several long levees just upstream; typical braided stream with channels of varying widths and scales (can not define number of channels due to complexity and scale variation of channels); only measured large islands
		8/16/1947	1449	3066	no	n/a	0	n/a	1	1282	279	island appears heavily vegetated; relict channel has moderate vegetation, possibly some farming	active channel is very burnt in; no evidence of levees, but would be difficult to see
		11/10/1966	957	3051	no	n/a	complex channel pattern	n/a	too complex to define	n/a	n/a	no vegetation within active corridor; sparse scrub vegetation within relict corridor, but very patchy (may be due to clearing)	flood control channel is present down middle of active corridor (196' wide); stream has complex braiding pattern, even with flood control channel present
		6/20/1989	1796	2993	no	n/a	complex channel pattern	n/a	too complex to define	n/a	n/a	light scrub vegetation within active corridor; vegetation is obviously stabilizing small islands, at least until the next big event; relict corridor is sparsely vegetated	little evidence of flood control channel but may have been some excavation in middle of active corridor (~300' wide);
		6/1/2002	1730	2452	no	n/a	5	1000	3	1200, 1085, 1520	384, 406, 400	moderate scrub vegetation on islands within active channel, similar to 1989 but slightly heavier	channels were relatively easy to pick out due to moderate scrub vegetation; channel width does not necessarily correlate to other measurements (where the only measurable parameter was wetted width)
X6	downstream of Piru confluence	4/1/1927	1713	1983	yes	18	1	18	0	n/a	n/a	no vegetation within braiding corridor; only scattered vegetation on relict corridor; heavy trees along portions of the south bank of relict corridor	very wide braided corridor with little definition (too burnt-in to define secondary channels)
		8/16/1947	1767	1983	no	n/a	0	n/a	0	n/a	n/a	looks similar to 1927 conditions	
		9/1/1957	1220	1449	yes	25	3	51	2	875, 1750	325, 425	very sparse scrub vegetation in active corridor; some small trees on relict corridor (where corridor is present)	well-defined flood control channel through this reach (136' wide), but there are several secondary channels outside the levees; diversion ponds present near the north bank; larger island cut by flood control channel
		11/10/1966	1132	1563	yes	32	4	388	2	2125, 750	850, 250	large island is moderately vegetated with scrub and one line of heavy vegetation; relict braiding corridor is similarly vegetated	braiding corridor has been confined on both sides by levees (especially on the northern portion); looks like the southern levee was recently overtopped (that area was included in the relict corridor); main channel divides in two in some areas
		6/20/1989	1082	1082	no	n/a	n/a	n/a	1	685	180	sparse scrub vegetation growing on poorly-defined islands within channel and near piers	lots of recent grading within the channel, several levees in the middle of the corridor and a series of piers on the southern bank
		6/1/2002	1050	1245	no	n/a	none	n/a	0	n/a	n/a	very little vegetation in this portion of the stream; some scattered scrub on relict corridor, even less within active channel	217-foot wide flood control channel begins just d/s of xs (poorly defined, though)

Cross section	location description	photo date	width of active braiding corridor (feet)	width of relict braiding corridor (feet)	is there one primary channel visible?	width of main channel (feet)	number of identifiable channels	total width of channels (including main) (feet)	number of islands	length of islands encountered (feet)	width of islands (feet)	vegetation	other descriptions
X7	between Piru and Sespe (ground-water upwelling)	8/16/1947	1694	2472	no	n/a	4	difficult to define the widths	can't define	n/a	n/a	this area is heavily vegetated; difficult to distinguish active braiding corridor from relict corridor	looks like there has been some flood control work in this area, two very straight channels through here, but masked some by vegetation
		9/1/1957	1446	2253	yes	168	4	370	2	4624, 8500	272, 408	northern portion of the corridor (including flood control channels) have heavy vegetation outside of the channels; the southern portion of the corridor has sparse vegetation	the main channel, and possibly the secondary channel, have been altered for flood control
		6/20/1989	749	2697	yes	37	2	150	1	1386	449	thick vegetation (with trees) along main channel; very little vegetation otherwise within active braiding corridor; moderate vegetation in northern portion of relict corridor, but only scattered brush in southern	no evidence of flood control alteration; downstream the corridor has been severely constrained by encroaching agriculture
		6/1/2002	551	2767	yes	42	2	65	1	396	108	heavy vegetation (trees) along secondary channel along north bank; scattered shrub (with some trees) vegetation within active corridor, some defining the edges of bars; heavy scrub vegetation on south relict corridor with scattered trees; heavy trees and scrub on northern relict corridor	just upstream there is a distinct main active corridor and an overbank area of deposition; the main active corridor has portions lined with heavy trees, but becomes less distinct further upstream (no vegetation)
X8	just downstream of Sespe Creek	8/20/1947	2003	2003	no	n/a	6	601	can't define	n/a	n/a	limited, if any	photo very burnt in, but channels less well-defined than in other photos
		8/13/1967	701	2203	yes	100	3	250	1	2804	401	limited, if any	one single-thread channel with one minor channel
		6/20/1989	1532	1723	yes, but less so than 1967	153	5	306	poorly defined; small and well-vegetated	n/a	n/a	islands are more heavily vegetated away from main channel; main channel bank is ~75 vegetated w/ thin vegetation line; more vegetation than in other photos	
		6/1/2002	670	1820	no	n/a	3	170	1	801	216	islands are moderately well-vegetated; relict corridor has scattered vegetation, Sespe mainstem has heavy vegetation along low-flow channels	interpretation complicated by Sespe confluence, but looks very similar to 1989 photo

FIGURES

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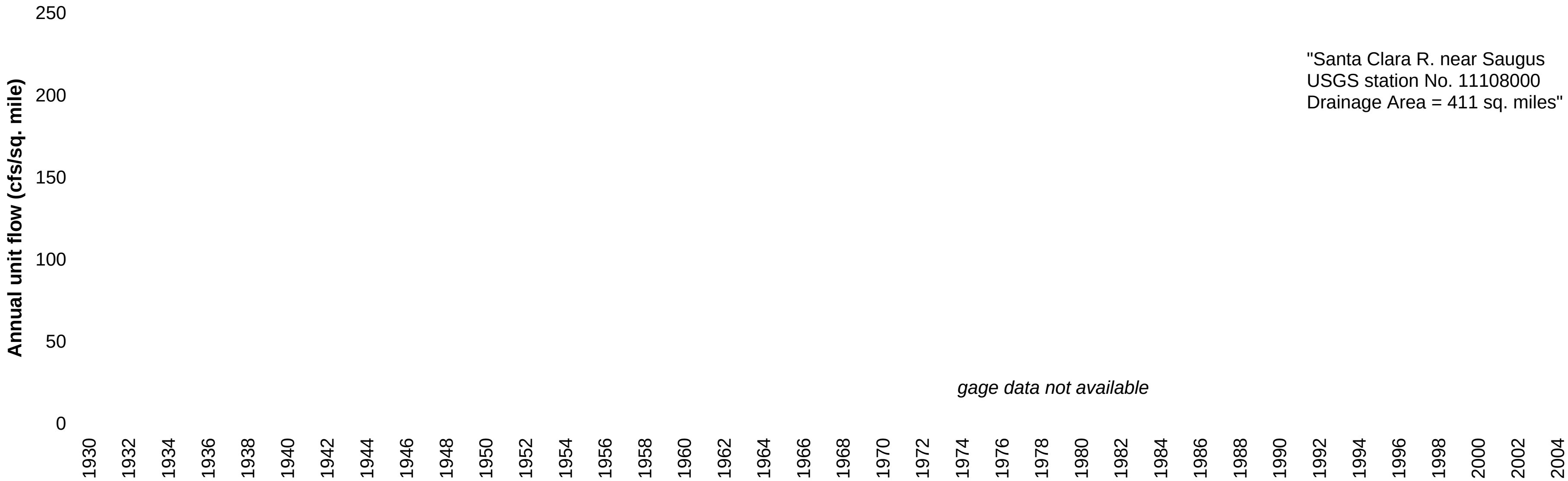
Figure 1. Timeline of selected major events in the upper Santa Clara River, California. Also shown (at top) are the years for which aerial photographs were analyzed.



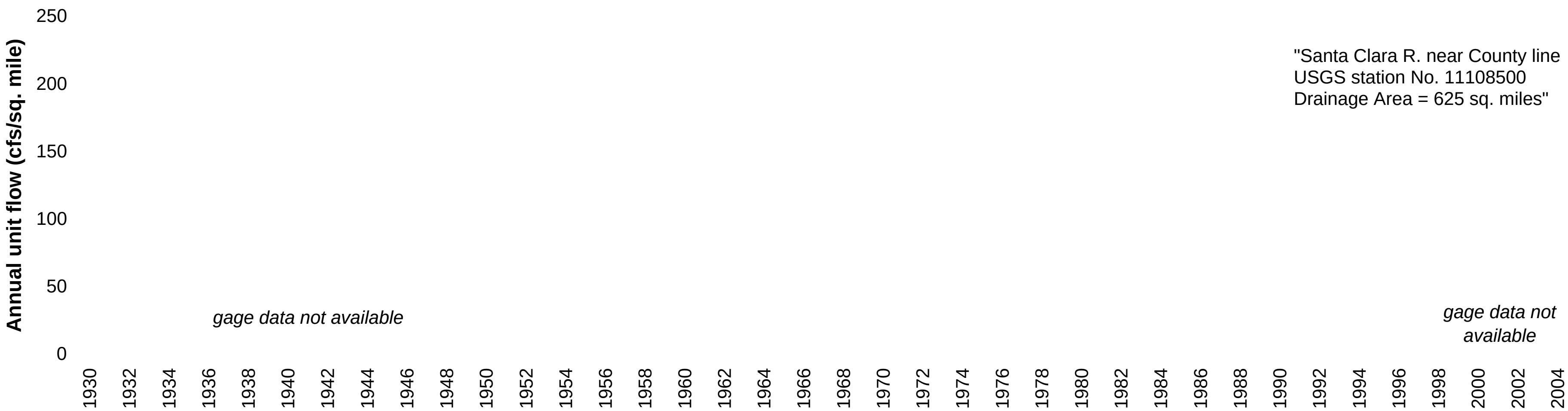


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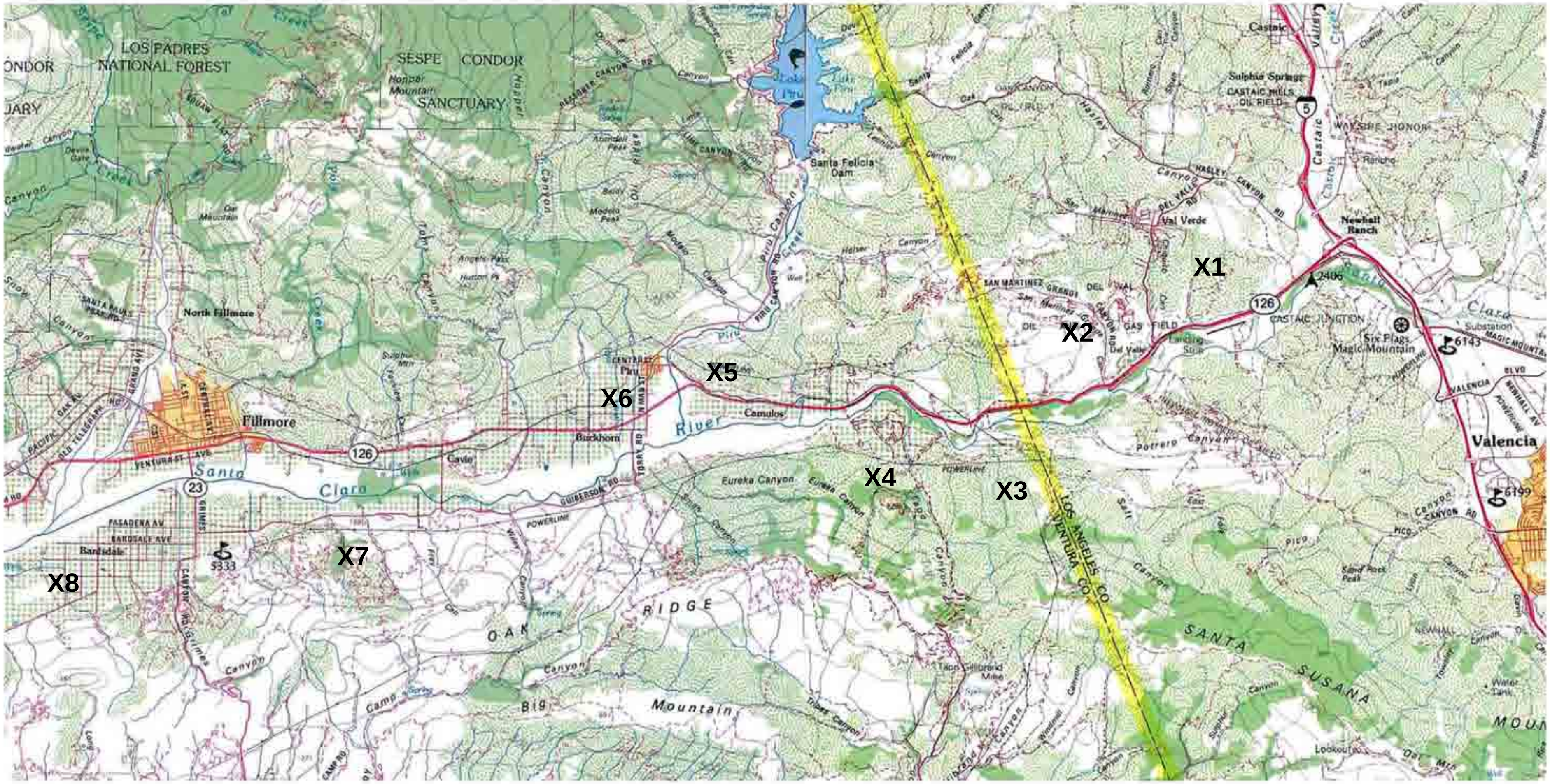
Figure 2. Annual unit runoff (annual flow per square mile) for the Santa Clara River near Newhall at two separate gaging stations. Note that flow in drier years has increased since the 1960s, most likely due to release of treated effluent to the River.

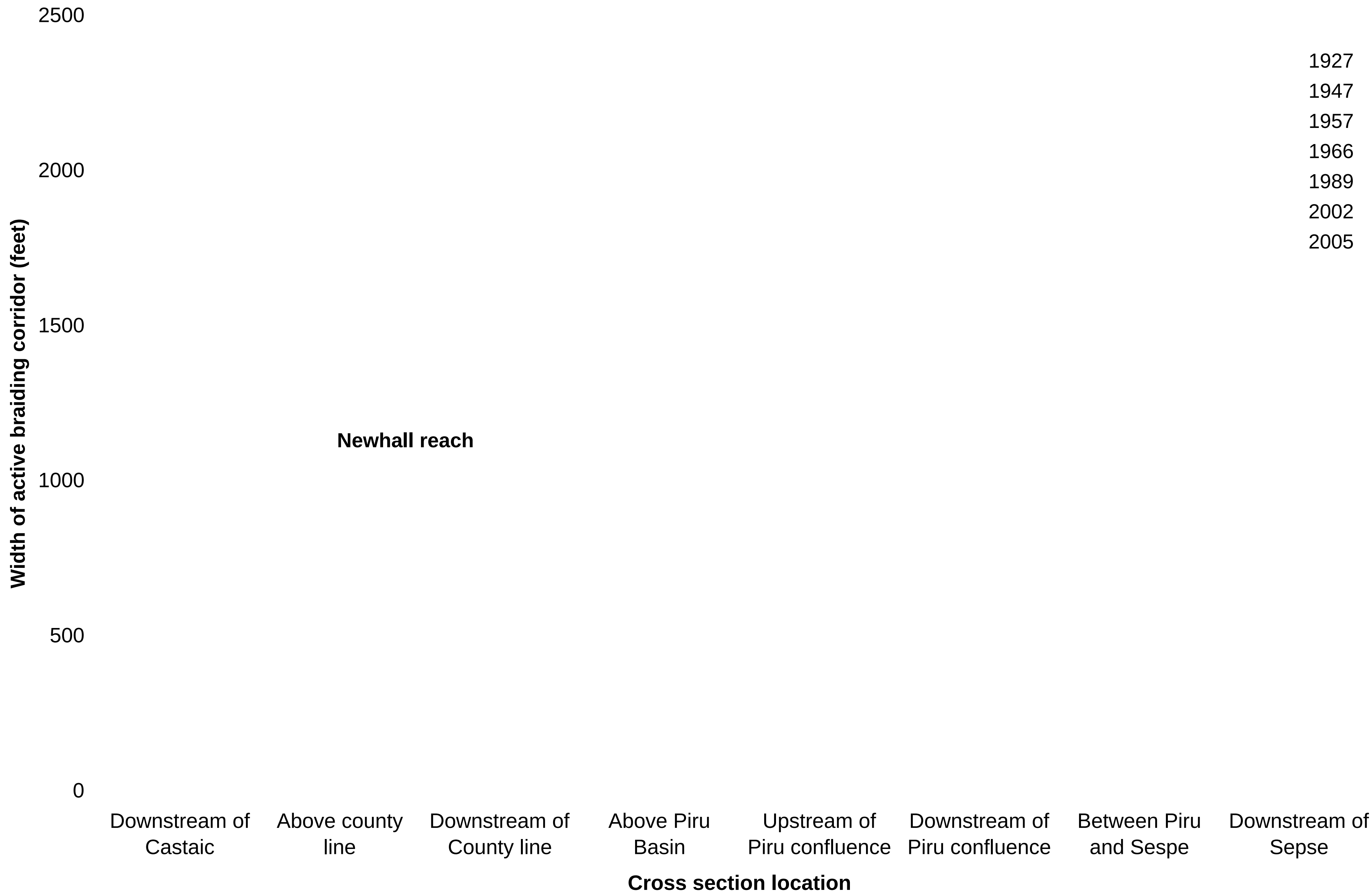


Balance Hydrologics, Inc.

Figure 3. Location of channel cross sections on the Santa Clara River, measured on aerial photographs.

Balance Hydrologics, Inc.

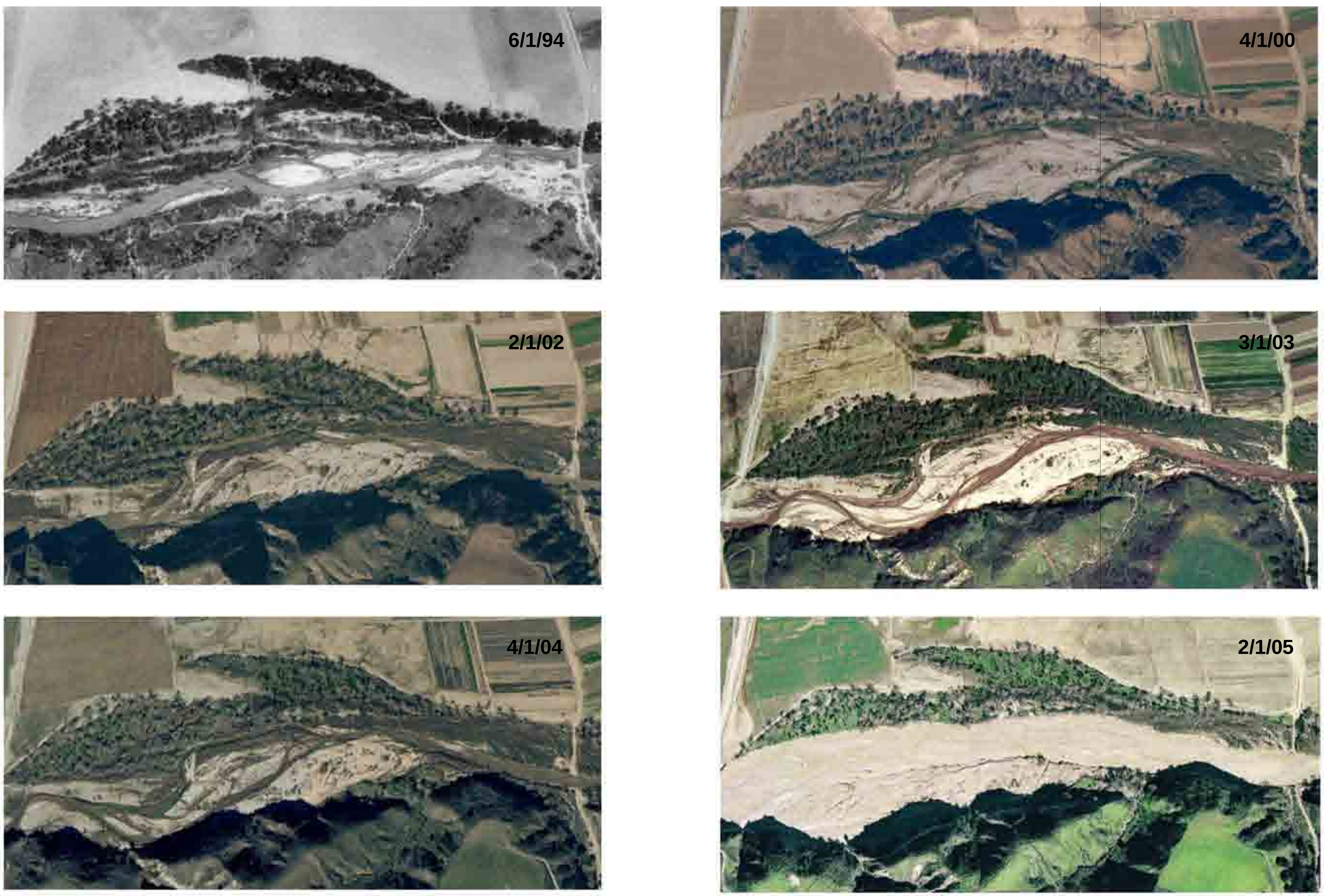
Figure 4. Comparison of 2004 and 2005 conditions on the Santa Clara River, just downstream of the L.A./Ventura County line. Note that significant channel widening occurred in response to the 2005 events, even in heavily vegetated areas. See appendix A for photo sources.



Balance Hydrologics, Inc.

Figure 5. Measurements of active braiding corridor width from aerial photographs, for cross sections on the Santa Clara River.

Photo cross section data.xls, Summary graph



Balance Hydrologics, Inc.

Figure 6. Progression of aerial photographs downstream of Castaic Canyon, showing channel change between 1993 and 2005. Note that there was little change between 2000 and 2004, but the active corridor widened significantly in response to the 2005 events, and that channel traces within the active corridor were effectively erased. See appendix A for photo sources.

APPENDICES

Appendix A: Summary of aerial photographs used for assessment of potential hydromodification effects on the Santa Clara River, Newhall, California.

Date	Number of photos	Nominal Scale	Hard Copy?	Electronic copy?	Image Type	Source/Vendor	Remarks
1927	6	2000	yes	yes	b/w	Whittier College: 80, 82, 84, F27, F28, F31	Only available photography prior to the March 1928 collapse of the Saint Francis Dam. Photos show area near Piru confluence
August 16, 1947	34	24000	no	yes	b/w - Vert Cart	USGS_GS-EM, Rolls 3, 5, 7	Previews downloaded already are sufficient.
1957	2	2000	yes	yes	b/w	Whittier College: 109, 123	1957 photos are for justdownstream of Piru Creek. Piru Dam was closed in 1957.
March 6, 1963	1 (2)	21670	no	yes	b/w - Vert Recon	USGS_ARMC630001L0049 a,b	high resolution scans
July 20, 1966	2 (4)	21670	no	yes	b/w - Vert Recon	USGS_ARM6625001L1362 a,b USGS_ARM6625001R1357 a,b	high resolution scans
August 19, 1966	1 (2)	21670	no	yes	b/w - Vert Recon	USGS_ARM6628502L1314 a,b	high resolution scans
September 13, 1966	1 (2)	21670	no	yes	b/w - Vert Recon	USGS_ARM6631405R1165 a,b	high resolution scans
November 10, 1966	2 (4)	21670	no	yes	b/w - Vert Recon	USGS_ARM6638605L1238 a,b USGS_ARM6638605L1242 a,b	high resolution scans
August 13, 1967	1	30000	no	yes	b/w - Vert Cart	USGS_AR1VBUK00010110	Preview already obtained. Downstream of Sespe Creek
May 26, 1989	5	31680	yes	yes	b/w	WAC-89CA, 27-42	LA County
						WAC-89CA, 27-62	LA County
						WAC-89CA, 27-84	LA County
						WAC-89CA, 27-109	LA County
						WAC-89CA, 27-135	LA County
May 1, 1989	6	2000	yes	yes	Color	PAS_89 06-20 PW VEN 7-229	Ventura County
						PAS_89 06-20 PW VEN 7-231	Ventura County
						PAS_89 06-20 PW VEN 7-233	Ventura County
						PAS_89 06-20 PW VEN 7-235	Ventura County
						PAS_89 06-20 PW VEN 7-269	Ventura County
						PAS_89 06-20 PW VEN 7-237	Ventura County
June 1, 1994	n/a	unknown			b/w, georeferenced	GlobeXplorer	downloaded select sections from LA and Ventura County
April 1, 2000	n/a	unknown	no	yes	color, georeferenced	GlobeXplorer	downloaded select sections from LA and Ventura County
February 1, 2002	4	Unknown	no	yes	Color, georeferenced	AirPhotoUSA (from GeoSyntec)	Covers all of Newhall project area

Date	Number of photos	Nominal Scale	Hard Copy?	Electronic copy?	Image Type	Source/Vendor	Remarks
July 23, 2002	n/a	unknown	no	yes	Color, georeferenced	GlobeXplorer	downloaded select sections from LA and Ventura County
March 1, 2003	n/a	unknown	no	yes	Color, georeferenced	GlobeXplorer	downloaded select sections from LA and Ventura County
April 1, 2004	n/a	unknown	no	yes	Color, georeferenced	GlobeXplorer	downloaded select sections from LA and Ventura County
October 13, 2004	n/a	unknown	no	yes	Color, georeferenced	GlobeXplorer	downloaded select sections from LA and Ventura County
February 1, 2005	n/a	unknown	no	yes	Color, georeferenced	GlobeXplorer	only avaialable for LA County