# memorandum

date December 21, 2023

to Noah Downing
City of Santa Cruz

cc

from James Gregory, PE
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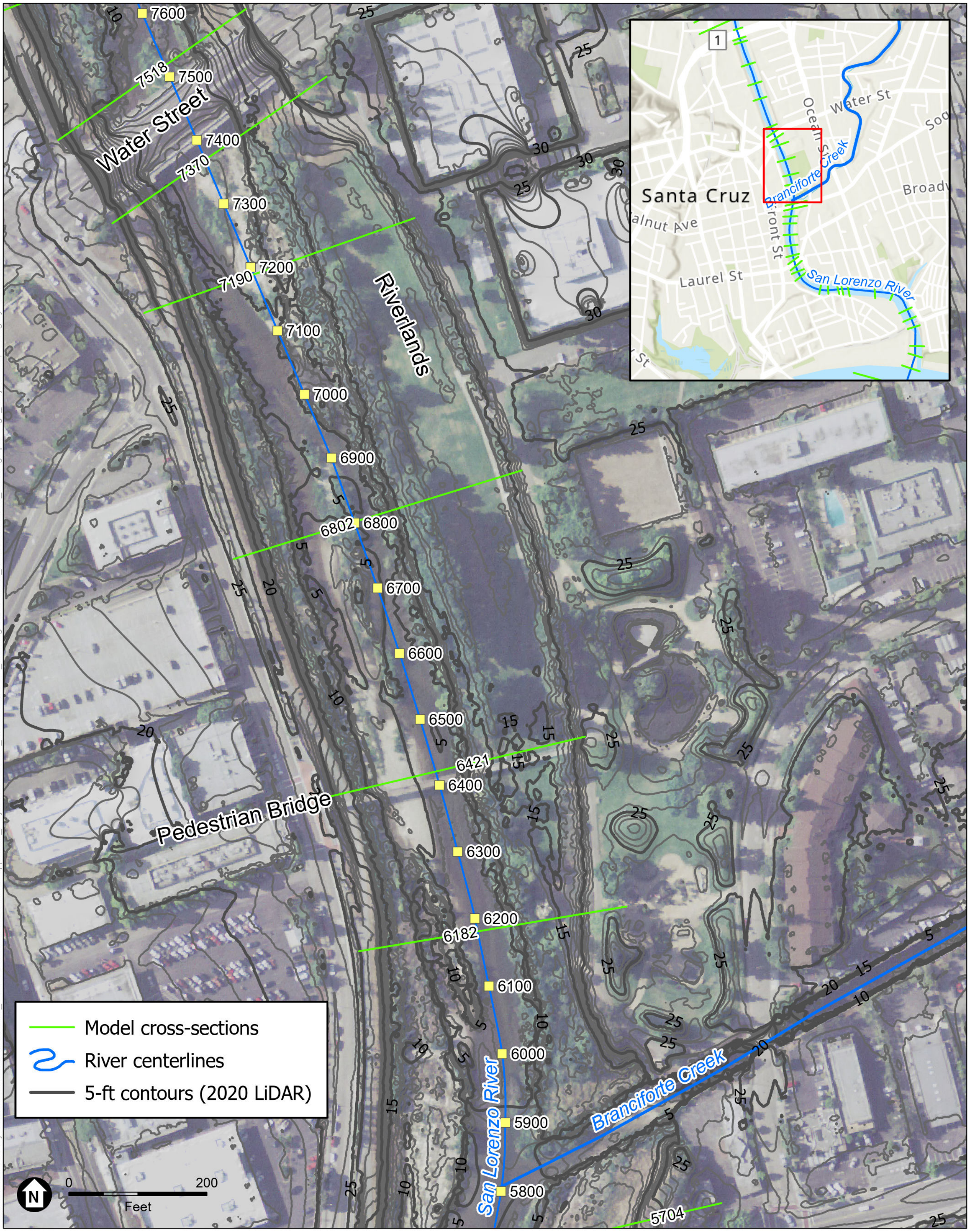
Environmental Science Associates

subject San Lorenzo River Channel Enhancement Initial Engineering Analysis

The City of Santa Cruz Parks and Recreation department (City) is engaged in a master planning process to evaluate options for developing a multi-benefit project on the 'Riverlands' area of the San Lorenzo River to provide ecological uplift, public access, and recreation on a section of the San Lorenzo River. The Riverlands area is situated on the left bank of the river and extends from Water Street at the upstream end to the confluence with Branciforte Creek at the downstream end (Figure 1). The City has contracted with ESA to support evaluation of potential channel enhancement projects, drawing on existing data sources and hydrologic, hydraulic, and sediment transport analyses we have conducted in prior studies.

The Riverlands area is an inset bench in the San Lorenzo River which formed by deposition following dredging and levee construction as part of a flood control project built by the USACE in the 1950s. A low berm that appears from field evidence to be a natural depositional levee has formed between the Riverlands bench and the main channel along which mature riparian trees have established. Flows are contained in this segment of the channel between a floodwall on the right (west) bank, and high ground on the left (east) bank. This channel segment is also tidal and subject to backwater effects of high tides and lagoon breaching and closure dynamics at the mouth of the river. The Riverlands area has been inundated frequently over the past decade including during the above-average rainfall 2022/2023 winter season. A photo provided by the City for the December 31, 2022 atmospheric river which inundated the Riverlands is shown in Figure 2. A cross-section surveyed on the channel prior to this event is also shown in the figure (Waterways survey late 2021/early 2022).




SOURCE: ESA, 2023 (model data). QSI, 2020 (LiDAR data)

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**Figure 1**
Project Area

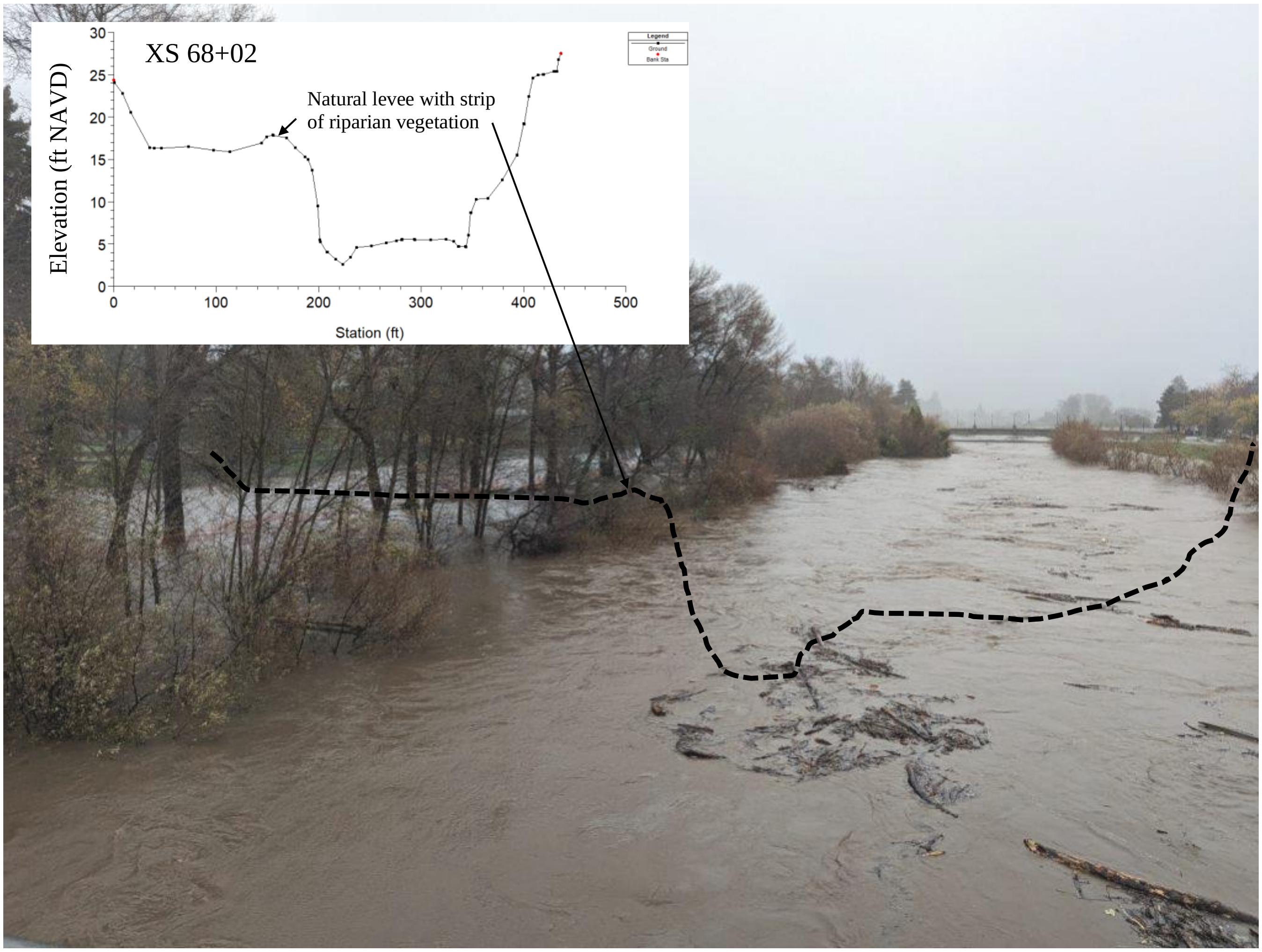


**Figure 2. Riverlands inundation December 31, 2023 and channel cross-section surveyed in 2021/2022**

ESA conducted a site walk with City staff on October 30, 2023. Our initial findings from the site walk include:

- The geomorphic configuration of the Riverlands area, including channel/bench elevations and available lateral space supports a potential opportunity for a channel enhancement project to support ecological, flood management, and recreational goals.

- Recent deposition of sand and finer material was observed which is in line with our understanding that the river conveys high sediment loads and this reach of the channel experiences active deposition during high flow events.

- Prior modeling conducted by ESA shows that, while this reach conveys the 1% annual chance event (ACE) (also known as the 100-year event), there is minimal freeboard on the left (east) side of the channel.

Detailed technical analysis, including hydraulic and sediment transport modeling, would be required to assess the feasibility of alternatives to grade and/or revegetate the Riverlands area. This would include a careful evaluation of additional roughness introduced to the conveyance area caused by planting or recreational features that may obstruct flow. Roughness is a critical metric which characterizes the degree of resistance to flow (i.e. drag) which governs depth, velocity, and sediment transport dynamics. Depth and deposition potential both increase with roughness, thus, planting the Riverlands area alone would increase flood risk for the City. Additional roughness could be offset by increasing conveyance area, which would need to be modeled as part of evaluating alternative feasibility.

In this memorandum we summarize existing channel dynamics pertinent to project considerations, describe potential project concepts, key variables, and other considerations, provide a roadmap for future analysis, design, regulatory compliance, permitting, and construction, and cover conclusions and recommendations.

# Existing channel dynamics

The segment of the San Lorenzo River downstream of California State Route 1 (CA-1) has seen significant sedimentation since the original USACE channel excavation project in 1959. The channel bed is highly dynamic with consistent aggradation particularly in the reach upstream of Water Street. Conversely, during extreme high flow events, the channel scours significantly which causes peak water levels to be lower than estimated if the bed were assumed static. The high sediment yield of the watershed and the effect of scour on peak water surfaces present critical considerations for any project that will modify the channel. This section presents key information with respect to channel hydrology, hydraulics, and sediment transport.

## Hydrology

Peak flows estimated for the San Lorenzo River upstream and downstream of Branciforte Creek (USACE, 2010) are summarized in Table 1.

**Table 1. Peak flow for multiple annual chance events and historical peaks**

| ACE (%) | Representative Return Period | Flow (cfs) | |
|---|---|---|---|
| | | Upstream of Branciforte Creek | Downstream of Branciforte Creek |
| 50% | 2-year | 6,131 | 7,152 |
| 20% | 5-year | 13,700 | 16,070 |
| 10% | 10-year | 19,640 | 23,200 |
| 5% | 20-year | 26,100 | 30,520 |
| 2% | 50-year | 34,800 | 39,900 |
| 1% | 100-year | 41,580 | 47,120 |
| 0.5% | 200-year | 47,340 | 53,750 |
| 0.2% | 500-year | 57,010 | 62,910 |

Based on this table peak flows and estimated recurrence intervals for notable large flow events are summarized in Table 2:

**Table 2. Historic large flow events and approximate annual chance**

| Event date | Peak flow at City gage (cfs) | Approximate Annual Chance (~return period) |
|---|---|---|
| January 09, 2023 | 20,900 | 1/12 (~12 year) |
| February 07, 2017 | 18,700 | 1/9 (~9 year) |
| February 03, 1998 | 19,000 | 1/9 (~9 year) |
| January 05, 1982 | 31,500 | 1/36 (~36 year) |

## Hydraulics

Based on modeling analysis conducted by ESA, most of the Riverlands area in its current topography would begin to flood at water surface elevations ranging from about 14 to 16.5 feet NAVD88[1]. For the main area upstream of the pedestrian bridge, this would correspond to a San Lorenzo River flow of about 11,000 to 12,000 cfs, and just downstream of the pedestrian bridge this may correspond to a slightly lower flow of approximately 10,000 to 11,000 cfs. The flow frequency shown in Table 1 indicates that the Riverlands will be inundated approximately every 2-5 years.

Manning's roughness ('n') values calibrated by the USACE (2014) with updated calibration performed by ESA (2017) in the project reach range from 0.065 at low flows (<5,000 cfs) linearly decreasing with flow to 0.025 at high flows (>22,500 cfs). The n-value reflects the degree of resistance to flow which will affect water surface elevations and sediment transport dynamics. In most channel conditions, roughness decreases with flow and depth because, for higher flows, a smaller proportion of the conveying water is in contact with roughness elements. Additionally, more flexible vegetation in the channel such as willows will cause less resistance under higher flows as the vegetation is bent towards the bed. Higher roughness values generally cause higher water surface elevations as well as lower velocity and thus more depositional conditions.

This reach of channel is contained by a floodwall on the right bank which is part of the USACE project levee system for the San Lorenzo River which has been transferred to City ownership. Flow is contained by high ground on the left bank; however, the left bank is not a project levee and is approximately 2-3 feet lower than the right bank. Based on modeling conducted by ESA in 2023, the channel contains the 1% annual chance flow event with minimal freeboard[2] (<0.5 ft) on the left bank. The upper pathway of the park adjacent to the Riverlands defines the top of the left (east) bank. This suggests that the water surface tolerance to additional vegetation (and thus roughness) is limited. This could be offset with grading that increases the conveyance area, however, expanding the channel area will lower velocities causing potential sediment deposition that could in turn reduce flood conveyance. Freeboard downstream of Soquel Avenue to the river mouth is over 3 ft indicating that the Riverlands segment would be the first to overtop in a large enough flood. A successful restoration design would need to balance planting, grading, and sediment dynamics to be compatible with flood management requirements.

## Deposition and scour

As described above, the San Lorenzo River is a high sediment yield watershed with observed deposition particularly in the reach upstream of Water Street to CA-1. A plot of the channel bed profile in the 20-years following the USACE 1957 channel excavation is shown in Figure 1. Figure 2 displays a channel cross-section within the Riverlands area showing the USACE's 1957 baseline and proposed design conditions compared to a 2021 survey. As this figure demonstrates, an elevated bench feature existed in the channel prior to the original USACE project and has reestablished at nearly the same elevation (~14ft MSL, ~16.76ft NAVD88[3]). This indicates that the Riverlands area is a persistent geomorphic feature built up by periodic sediment deposition on the left side of the river.

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[1] Topographic data for existing conditions described in this report is based on survey data collected in late 2021/early 2022 (Waterways, 2022), and LiDAR data collected in 2020 (QSI, 2020).

[2] Based on preliminary modeling currently in review by the City and FEMA

[3] MSL is approximately equal to NGVD29. Conversion to NAVD88 = NGVD29 + 2.75 feet based on FEMA's countywide conversion factor for Santa Cruz County (FEMA, 2017).

During high flows, such as the February 1982 event, substantial scour in the channel reduces peak water surface elevation. High water marks collected during the event were significantly lower than predicted using a static bed hydraulic model (USACE, 2014). Though the channel has aggraded over time and is generally depositional during typical winter flows, during a large flow event the bed is likely to scour. The effect of this scour on peak stage is a key consideration for evaluating potential flood risk on the San Lorenzo River downstream of CA-1.

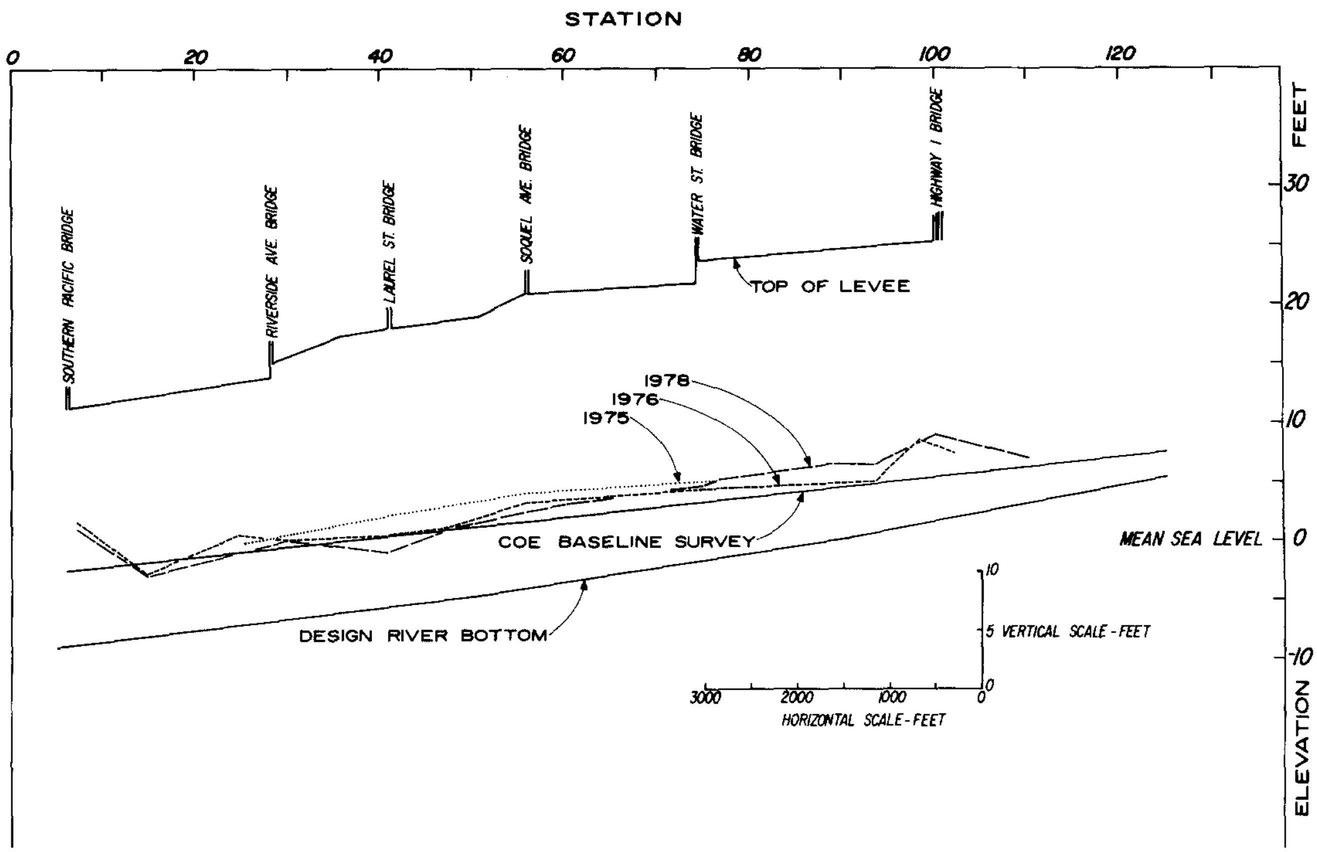



**Figure 3. Channel bottom elevation (MSL) for 1957 USACE baseline and design channel, compared to 1975, 1976, and 1978 conditions (reproduced Figure 3 from Griggs & Paris, 1982)**

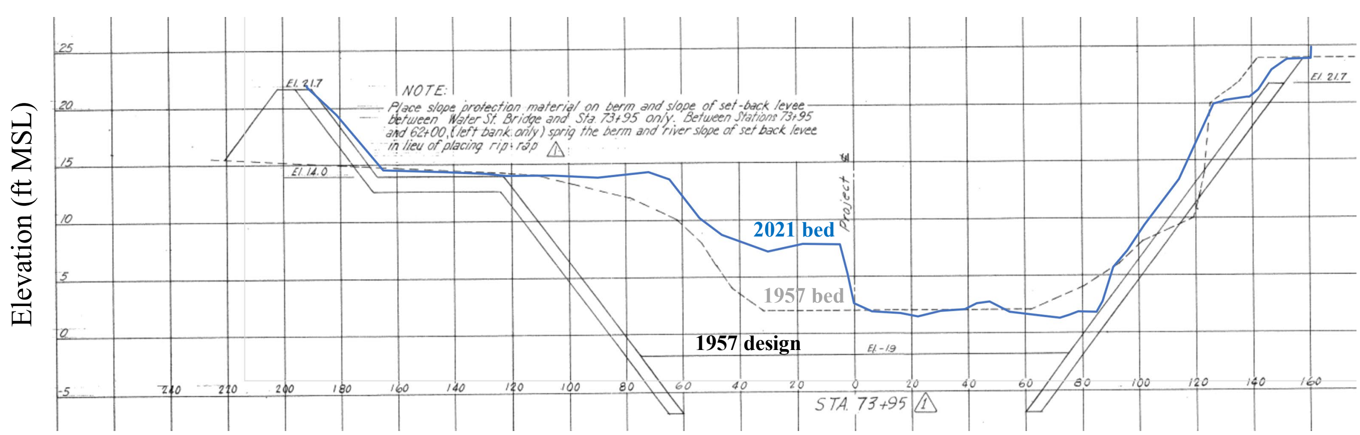



**Figure 4. USACE 1957 baseline, design, and 2021 surveyed cross-section approximately 25-feet downstream of Water Street**

# Channel enhancement concepts

The City is considering a range of conceptual channel modifications in the Riverlands reach to support ecosystem and recreation goals. This section discusses physical considerations for two possible concepts (1) constructing a side channel which will carry flow at a specified flow and stage and (2) creating a frequently inundated alcove. These concepts are example opportunities; however, a full alternatives analysis should be conducted to evaluate project potential. This analysis would include defining project goals, identifying opportunities and constraints, developing a set of alternatives (typically 3-4) with technical input from relevant City departments and potential public stakeholders, and as well as technical analysis and additional review to identify a preferred alternative.

## Side channel concept

One key concept under consideration for the Riverlands is grading a side channel to convey some fraction of the flow during high flow events. The side channel would add conveyance area, channel complexity, and riparian habitat, create a high flow refugia for native fisheries, and would be combined with recreational features to add public access opportunities to the Riverlands. A conceptual graphic of the side channel concept is shown in Figure 4. This graphic includes a conceptual cross-section with simplified geometric assumptions for a geomorphically stable sand-bed channel at an elevation that would inundate during the summer and winter. The actual channel geometry would need to be analyzed through iterative grading and modeling to evaluate the hydraulic and sediment transport dynamics at play.

Key considerations for this concept include:

- Expanded conveyance area could provide a flood benefit by drawing down water levels in the project reach and potentially upstream.
- Roughness added by additional riparian habitat should be factored into flood risk modeling analysis.
- Channel grading should minimize impact to existing native vegetation. The alignment shown in Figure 4 preserves existing mature riparian trees with some loss of smaller diameter trees (primarily willows) at the downstream junction. Planting would replace all trees that were removed with appropriate native species, subject to flood analysis.
- The expanded channel alignment would likely increase sediment deposition potential in this reach. Deposition in the main and side channels would need to be assessed under a range of events to evaluate deposition frequency, depth, and extent to inform channel design and O&M.
- The upstream flow split between the main and side channels would need to be designed to prevent the side channel from becoming the primary flowpath.

The hydraulic and sediment transport models developed by ESA could be used to conduct further analysis of this alternative. The models would be used to analyze flow, stage, and scour/deposition dynamics for a conceptual channel and could be used to refine details of the concept. If carried forward for design, further modeling would be conducted to inform grading and planting design and assess project performance and O&M implications.

Modeling scenarios should include a range of events to capture hydraulic and sediment transport dynamics under present and future restoration and climate conditions. A list of model scenarios to evaluate this concept should include:

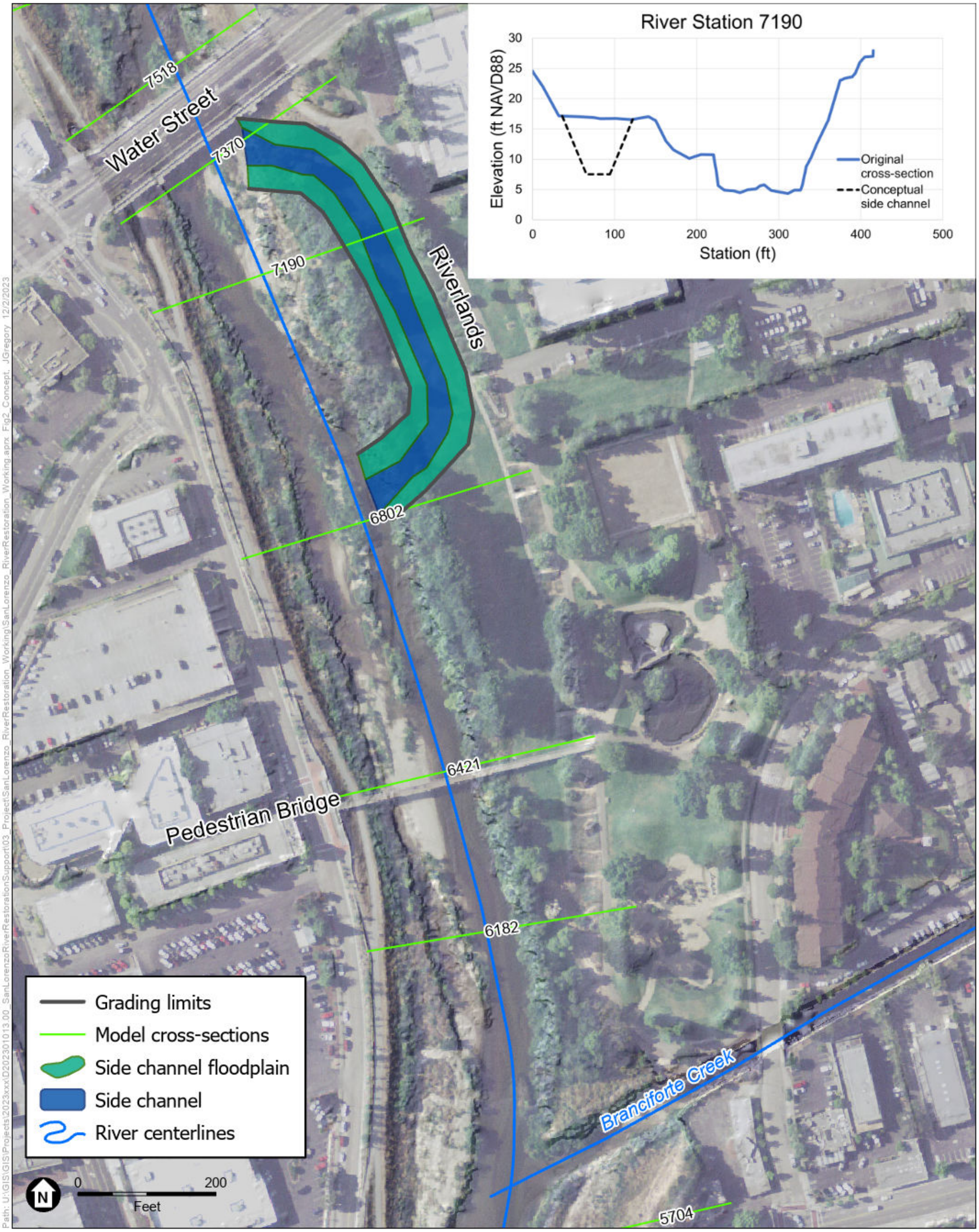
1. Channel scenarios
    a. Baseline conditions - This modeling has already been completed and provides a reference point for comparing the impacts of restoration alternatives.
    b. Conceptual project – This would include a set of model runs to test conceptual grading and roughness assumptions. These features could be adjusted iteratively based on the modeling results and requirements of the project.
2. Climate scenarios
    a. Present-day conditions – The present-day climate conditions, including flow frequency relationships have already been analyzed. This forms a basis for comparing future climate conditions.
    b. Future climate – The City has contracted with ESA to analyze future climate which will include a range of emissions scenarios and future time periods. These scenarios could be incorporated into analyzing project performance under future climate effects on flow, sediment, sea level, and vegetation.
3. Flow scenarios
    a. Design events – A range of design events with estimated return periods should be analyzed to evaluate project performance. This would include analysis of frequent events (2-year, 5-year) to assess channel stability, erosion potential, and bank protection effectiveness, medium-frequency events (10-year, 25-year) to evaluate potential for deposition in the restored and main channel areas and inundation on the Riverlands floodplain area, and low-frequency extreme events (50-year, 100-year) to ensure conveyance is maintained and to evaluate channel and floodplain response to high-erosion events. Flow events would be paired with an appropriate range of conditions for concurrent sea levels and opening/closure assumptions for the lagoon mouth.
    b. Multi-year flow scenario – A reconstruction of a historic period of flow and sea level conditions should be analyzed to evaluate erosion and deposition trends as well as inform design and operations and maintenance implications for the restored site. This scenario would include several years of measured flow and tides to evaluate channel response for pre- and post-project conditions.
4. Sediment scenarios
    a. Baseline conditions – Existing sediment transport models have been successfully calibrated to measured data. The calibrated models provide a reference point for sensitivity comparisons.

b. Sediment sensitivity – Given the uncertainty in sediment transport modeling analysis should include a plausible range of assumptions for sediment input parameters.

A sample table summarizing potential model runs is provided in Table 3.

**Table 3. Table of model runs for analyzing conceptual project alternatives.**

| Channel scenario | Flow scenario | Climate scenario | Sediment scenario |
|---|---|---|---|
| Baseline | Design events (2- to 100-year) | Present day | Baseline |
| | | | Sensitivity |
| | | Future climate | Baseline |
| | | | Sensitivity |
| | Multi-year flow scenario | Historic | Baseline |
| | | | Sensitivity |
| Conceptual project<br>(initial assumptions and iterative refinements) | Design events (2- to 100-year) | Present day | Baseline |
| | | | Sensitivity |
| | | Future climate | Baseline |
| | | | Sensitivity |
| | Multi-year flow scenario | Historic | Baseline |
| | | | Sensitivity |




SOURCE: ESA, 2023

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**Figure 5**
Conceptual Side Channel

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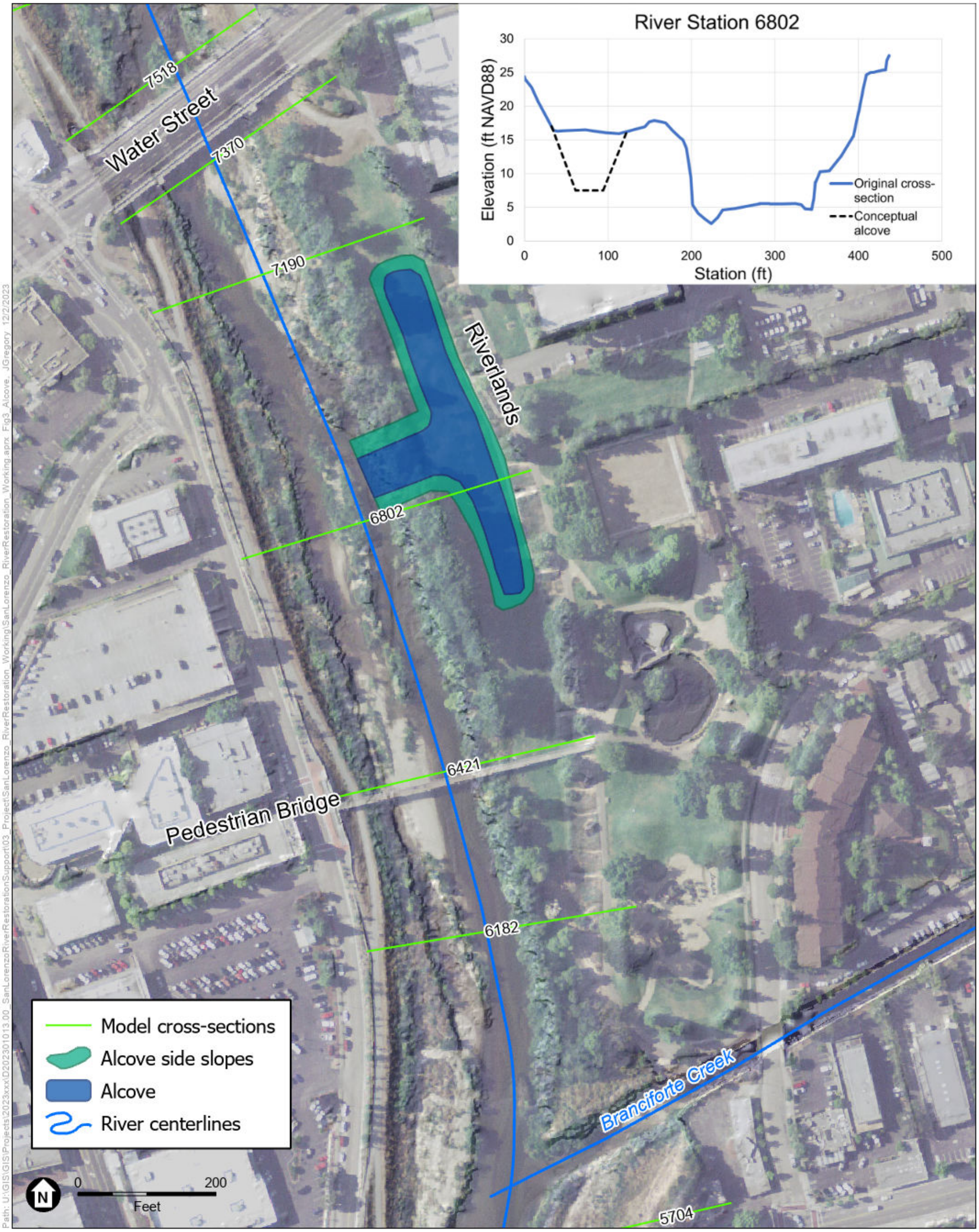
## Alcove concept

This concept would involve grading an alcove into the Riverlands area with a single opening into the main channel to allow frequent inundation under typical conditions, and more extensive inundation during high flows. This concept would increase riparian habitat, create a high flow refugia for native fisheries, and would be integrated into potential recreation concepts. The concept is shown graphically in Figure 5. This graphic includes a conceptual cross-section with simplified geometry for a sand-bottom alcove at an elevation that would inundate during the summer and slope towards the channel for drainage. Key physical considerations for this concept include:

- The alcove would be designed to inundate frequently to support new riparian habitat and serve as a low velocity zone for native fisheries.
- Roughness added by additional habitat should be factored into flood risk modeling analysis.
- The alcove would be sloped for positive drainage towards the main channel to avoid ponding and fish stranding during falling flows.
- The junction between the alcove and the main channel should be designed to limit deposition which may reduce inundation and habitat potential in the alcove.

As with the side-channel concept, the alcove could be incorporated into existing models to evaluate flow, stage, and sediment transport dynamics to assess feasibility and inform further analysis and design. The model scenarios would include the same set described above and summarized in Table 3.




SOURCE: ESA, 2023

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**Figure 6**
Conceptual Alcove

ESA

## Roadmap for analysis, design, CEQA, permitting, and construction for a multi-benefit channel project

Building on our experience developing, analyzing and implementing channel restoration and enhancement projects we have developed the following roadmap to support further development of the concepts the City is currently exploring:

1. **Define and Confirm Project Goals and Objectives**
    a. Habitat (aquatic, fish passage and rearing, riparian, etc)
    b. Aesthetics
    c. Education, stewardship
    d. Flow/flood conveyance
    e. Public safety
    f. Recreation and public access
2. **Identify Site Opportunities and Constraints**
    a. Traffic & loading
    b. Fire/emergency access
    c. Utility locations (Electrical, Gas, Comms., Water, etc)
    d. Recreation and access (public input opportunity)
    e. Tree (existing) locations and potential impacts
3. **Develop preliminary conceptual layouts for a range of project alternatives**
    a. Define basic spatial and geometric conditions for each alternative.
    b. Plan view of layout, sections through proposed channel configurations to show depth/width and transitions from and to main channel.
    c. Develop engineer's estimate of anticipated construction costs (coincident with conceptual level of design) for each alternative.
4. **Perform Hydraulic and Sediment Transport modeling analysis**
    a. Demonstrate 'proof of concept'.
    b. Conduct feasibility analysis with emphasis on sediment dynamics and flood risk.

c. Evaluate conveyance capacity and impacts to hydraulic and deposition/scour conditions for each alternative.

d. Compare against existing conditions.

5. **Analyze other impacts (assuming a feasible concept)**

   a. Proposed recreation uses

   b. Traffic & loading

   c. Cost/maintenance

   d. Impacts to existing trees

   e. Impact on historic 'fabric'/civic space and structure

   f. Gage level of public support (public input opportunity)

   g. Geotechnical

   h. Cultural resources

6. **Develop preferred alternative design**

   a. Develop design (plans, specifications, and engineering) for preferred alternative in stages (30%, 60%, 90%, final).

   b. Develop cost estimates.

**7. CEQA**

   a. Develop CEQA compliance approach and conduct necessary studies.

   b. Evaluate opportunities for "cutting the green tape" CEQA approach such as the Statutory Exemption for Restoration Projects (expires in January 2025 but may be renewed), or the State Water Board Statewide Restoration General Order Consolidated Programmatic EIR.

**8. Permitting**

   a. Conduct interagency meetings to present the project and identify required federal, state, and local permits.

   b. For this type of project, likely permits based on our experience with similar channel enhancement projects could include USACE Section 404 Nation Wide Permit 13/27, CDFW Habitat Restoration Enhancement Act CESA and LSAA coverage, SWRCB Section 401 Water Quality Certification, and depending on the species present, potential consultation with USFWS and National Marine Fisheries Service.

## 9. Construction

a. Plan, bid, and construct project including site grading, revegetation and irrigation (if needed), and recreation features following design docs.

b. Post-construction monitoring

# Conclusions and recommendations

ESA analyzed existing data on the Riverlands area to support the City in assessing potential projects that would ecologically enhance the riparian habitat while also providing new public access and recreational amenities. We have the following conclusions and recommendations:

**Conclusions**

- The Riverlands area offers an exciting opportunity to enhance riparian habitat and recreation access given its geomorphic configuration and available space.
- The site experiences frequent inundation and substantial deposition of sediment, requiring considerations for channel hydraulics, sediment transport dynamics, and flooding.
- Estimated peak flood stage for the 1% annual chance event has very little freeboard on the left channel bank. Detailed analysis, including modeling sensitivity ranges for increased roughness, will need to be conducted to ensure project concepts do not induce flooding during this event.
- Concepts like a side channel or alcove to increase aquatic area seem potentially feasible based on initial site data.

**Recommendations**

- Conduct an alternatives analysis to fully evaluate project options against defined goals and constraints.
- Use hydraulic and sediment transport modeling to demonstrate proof of concept and assess the impact on conveyance capacity, flood stage, scour, and deposition rates for the initial concepts developed to date.
- For concepts expanding in-channel vegetation, analyze the impact of increased roughness on water levels.
- Develop recreation plans in coordination with habitat restoration goals.
- Complete additional technical studies like geotechnical evaluations and cultural assessments to support future design.
- Coordinate regulatory consultations to confirm permitting requirements early.

Based on our initial evaluation of the site and understanding of site hydrology, hydraulics, and sediment transport, the site has potential for this type of project. We recommend further development and analysis of initial concepts to understand their potential impact on flood risk and deposition/scour dynamics.

# References

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