Translating Sediment Science Into Action: Documenting Beneficial Sediment Reuse

May 2023

PREPARED BY
San Francisco Estuary Institute

IN PARTNERSHIP WITH
Alameda County Flood Control and Water Conservation District, Zone 7

SFEI
SAN FRANCISCO ESTUARY INSTITUTE

FUNDED BY
San Francisco Bay Water Quality Improvement Fund, EPA Region IX

A PRODUCT OF **PREPARING FOR THE STORM**

FINAL ZONE 7
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Introduction

Sediment is a valuable resource and commodity in the San Francisco Bay Area. Bayland habitats will require an increasing amount of sediment to keep pace with current and future sea level rise. However, over the past 200-plus years, the processes of sediment transport and storage within local watersheds have been altered and have reduced the total volume of sediment that is delivered to the baylands. The combination of increasing bayland sediment demand and altered watershed sediment supply has necessitated creative and non-traditional methods and solutions be developed and utilized to provide sediment to locations where it is needed.

Historically, the watersheds of the Bay Area delivered sediment to the Bay through natural geomorphic processes, with variation across time and space dictated by the underlying geology, topography and climate. This sediment delivery allowed for the development and maintenance of salt marshes and other bayland habitats for thousands of years. With the arrival of Euro-American settlers, drainage networks began to be modified, connected, rerouted, lengthened, dammed, and diverted to enable agriculture and development. Gradual channel modification continued through the late 1800s and early 1900s until after World War II, when population, urban development, and the resulting channel network modifications rapidly increased. More complex landscape modifications, such as the construction of larger reservoirs, began due to this rapid population growth and the need for reliable drinking water supplies and flood protection. In addition, the 1950s brought a series of major flood events to the region, triggering the design and construction of several flood control channels to further protect the developing cities from flood risks (Stanford et al., 2013, Bigelow et al., 2008).

The construction of reservoirs and flood control channels in the 20th century significantly modified the drainage network, affecting the deposition and downstream transport of water and sediment. Reservoirs capture nearly 100% of sediment delivered from the upstream watershed, preventing it from reaching the Bay. But for flood control channels, only a portion of the total sediment delivered to flood control channels is trapped and stored, with deposition caused by gradient, constrictions, and channel capacity. Although very few flood control channels have data on the grain size distribution of sediment that is in storage, an analysis of the grain size distribution of stored sediment in the Alameda Creek Flood Control Channel reveals that a larger proportion is coarse (e.g. sands, gravels, and cobbles) as compared to the grain size distribution that was delivered to the channel from the upstream watershed (SFEI-ASC, 2017b).

This deposited sediment is problematic for managers of the channel networks, including local flood control districts, cities, and counties that must periodically remove the sediment to maintain capacity of the creeks, rivers and reservoirs (such as Alameda Creek, Walnut Creek, and Corte Madera Creek). Removal of sediment is expensive, requires permits that are increasingly difficult to obtain due to the increased requirements that protect in-channel habitat, is disruptive to the channel and the habitat it provides, and requires a location to dispose of the sediment.

Sediment deposition and storage in flood control channels and reservoirs significantly reduces the volume of sediment delivered to the baylands (Pearce, et. al., 2021). This deposition reduces the sediment volume that is available to build new marsh and other habitat areas, as well as the volume available to be deposited on existing marsh plains to increase marsh elevation within bayland habitats. These bayland areas provide a wide variety of ecosystem services such as habitat for multiple fish and wildlife species (Goals Project, 2015), flood protection for urbanized areas around the Bay (SFEI-ASC, 2017a), and natural filters for anthropogenic-derived pollutants (Cecchetti, et. al., 2020) that are essential for healthy baylands. The 2021 report *Sediment for Survival* (Dusterhoff, et. al., 2021) quantified the total amount of sediment needed by Bay Area bayland habitats to maintain those habitats in the face of sea level rise, as well as to construct the 24,000 acres of marsh restoration aspired by the Baylands Habitat Goals (Goals Project, 2015). Sediment for Survival projects that sediment supply will not meet the demand from extant and restored tidal marshes due to pressure from climate change and sea level rise (Dusterhoff, et. al., 2021).

The U.S. Army Corps of Engineers defines beneficial reuse as productive and positive uses of dredged material, which cover broad use categories ranging from fish and wildlife habitat development, to human recreation, to industrial/ commercial uses (USACE, 1987). Beneficial reuse is about understanding that sediment is a resource that should not be wasted, and that effective reuse can be an important part of regional sediment management and meeting regional habitat goals. Efforts such as the development of SediMatch (www.sedimatch.sfei.org), a planning tool to assist partners in identifying potential matches for the beneficial reuse of sediment, have helped increase awareness of regional reuse. Others are focused on improving regional coordination and increasing beneficial reuse. The recently initiated efforts by the Bay Conservation and Development Commission (BCDC) and the San Francisco Bay Regional Water Quality Control Board (RWQCB) such as *New sediment management policies for wetland restoration and climate change resilience in San Francisco Bay* will create a coalition of stakeholders to support additional sediment use at bayland restoration sites, help develop policy improvements in the BCDC San Francisco Bay Plan amendment, and develop a financing strategy to support the beneficial reuse of sediment in bayland restoration projects. There is a great need for the beneficial reuse of sediment in restoration projects around the Bay to bring the ground surface up to marsh elevation (e.g. the South Bay Salt Pond Restoration Project [SBSPRP], Hamilton/Bel Marin Keys Wetland Restoration, and Bair Island Restoration Project, among many others). To date, only a few large projects have been successful in reusing sediment due to factors such as the volume of sediment needed, the timing of sediment availability (partially due to the irregular timing of removals), sediment quality, sediment grain size, location and hauling costs, and regulatory requirements (Pearce et al., 2021). The *Sediment for Survival* report (Dusterhoff, et al., 2021) quantifies the outstanding need for sediment around the Bay Area, a call that has been echoed by many in the restoration community. Dusterhoff et al. (2021) serves as a roadmap to guide the region on the volumes, locations, and the timing of sediment that is needed. However, there will likely not be enough sediment available to fulfill the region's needs. This will likely require the region to reassess their goals and prioritize projects based upon the

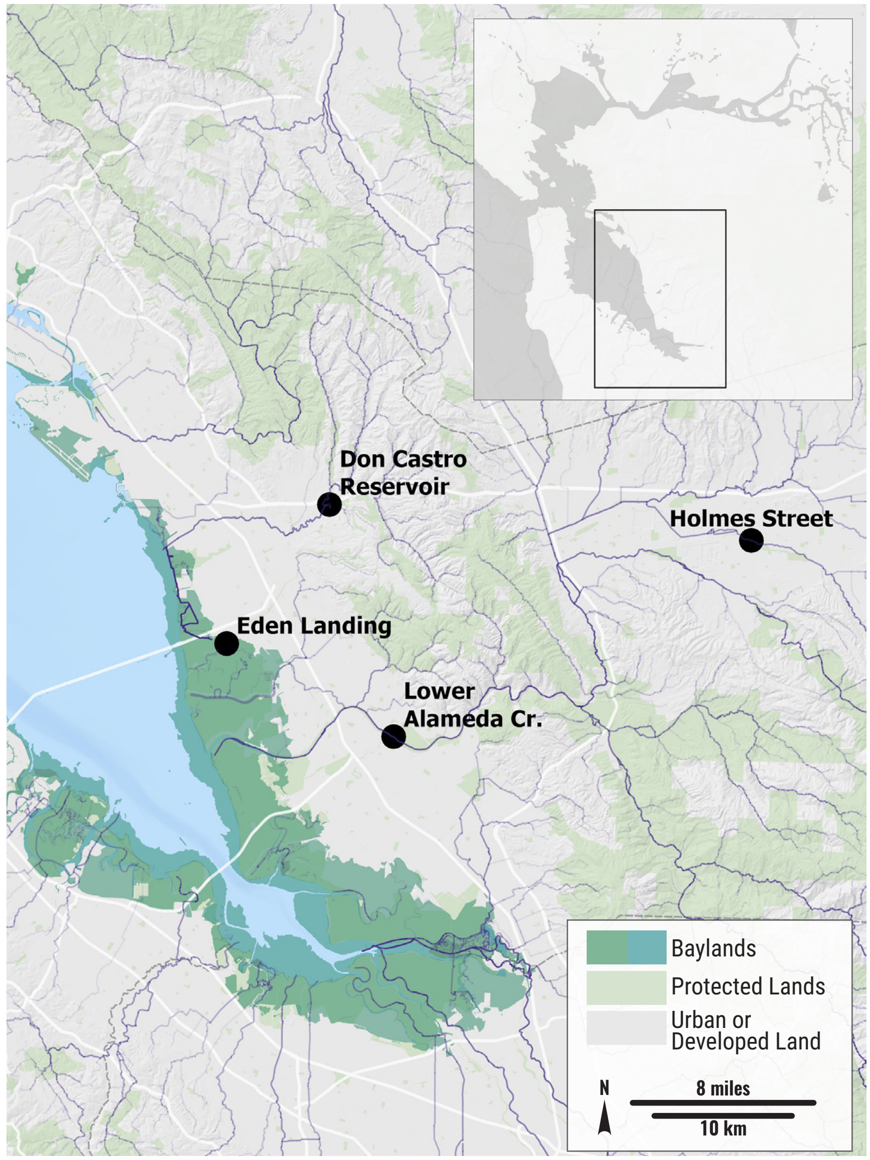


Figure 1: Location of the four case studies. Baylands data from SFEI-ASC, 2017b

amount of sediment that is actually available. In other words, future projects will have to be designed based upon the volumes of sediment that can realistically be obtained.

Together, the community must find a way to increase the total volume of sediment that is beneficially reused so as to meet our restoration goals. But there are challenges and hurdles to overcome, many of which have been documented in previous studies such as the companion *Preparing for the Storm* document Towards a Coarse Sediment Reuse Strategy (Pearce et al., 2021). One recommendation from that study was to document actual cases of beneficial reuse (or attempted beneficial reuse) from around the Bay Area to highlight challenges and successes encountered. This recommendation aims to assist and provide knowledge to other groups that are beginning a reuse project, help highlight specific issues and roadblocks encountered in these projects, and provide a catalyst for moving channel and reservoir-generated sediment reuse from concept to reality.

The *Preparing for the Storm* project, led by Zone 7 Water Agency (Zone 7) and funded by the US Environmental Protection Agency (EPA) Water Quality Improvement Fund, aims to develop science-based plans, strengthen existing and new partnerships, and pilot new methodologies for tackling these issues surrounding coarse sediment. As a task within this larger project, this report describes four projects in the East Bay that serve as case studies for beneficial reuse of sediment. Each example highlights a project with sediment that could be reused (in lieu of landfilling) or a project that needs additional sediment and could benefit from deliveries of sediment that normally would not have been beneficially reused. The project locations are shown in Figure 1, and include:

- The Lower Alameda Creek low flow channel modification project,
- Eden Landing sediment reuse by Ducks Unlimited,
- Don Castro Reservoir sediment slurry pipeline, and
- Sediment removal in Livermore, CA at Holmes Street Bridge.

Each case study describes the scope and goals of the project, the challenges faced, the costs and other constraints, as well as characteristics of the project that are conducive to the reuse ultimately being a success in the future. Data and information for each case study was gathered by speaking directly with key personnel involved in each project, including staff from the Alameda County Flood Control and Water Conservation District and their consultants, the South Bay Salt Pond Restoration Project, Ducks Unlimited, City of Livermore, and the Alameda County Resource Conservation District. Each case study was then reviewed and edited by these staff before being included within this report.

Restoring and adapting bayland habitats requires increasing sediment delivery to the baylands. This will only be accomplished through accelerated planning, coordination, implementation, and reconfiguring the on-the-ground costs and logistical equations for moving sediment from watersheds, the channels, and other upland sources to the baylands. These case studies are intended to provide practical and actionable information to assist policy-makers, regulators, sediment producers and restoration practitioners increase the volume of beneficially reused sediment. Over the next few years, beneficial reuse science and policy will continue to make strides through a number of different efforts. As described before, BCDC will improve regional coordination, develop policy improvements, and develop a financing strategy for increasing beneficial reuse. The San Francisco Estuary Institute, through a Water Quality Improvement Fund award from the EPA, will conduct a project named Sediment Solutions that will explore integrated sediment management for improved watershed-bayland ecosystem resilience. The project will work towards developing local management approaches that increase bayland sediment supply while also supporting and enhancing watershed ecosystems under a changing climate. And other large bayland habitat projects, such as the SBSPRP, will continue to obtain and utilize large volumes of sediment from multiple sources, improving the science and monitoring that support this beneficial reuse.

CASE STUDY #1:
Lower Alameda Creek low flow channel modification

Project Description

Alameda Creek is the largest watershed in the Bay Area (excluding the Sacramento-San Joaquin River watershed), draining 652 mi^2 (1,688 km^2) to the head of tide, including the Zone 7 service area of the Livermore-Amador Valley. The watershed contains three major water supply reservoirs: Calaveras Reservoir (constructed in 1925), San Antonio Reservoir (constructed in 1964), and Lake del Valle (constructed in 1968). After a series of large and devastating floods in the 1950s, the Alameda Creek Flood Control Channel was constructed between 1965 and 1975 by the U.S. Army Corps of Engineers, and was built to contain approximately the 300 to 500-year flood. The low-gradient channel traverses the historical Alameda Creek alluvial fan through the cities of Niles, Fremont, and Union City, delivering water and sediment supplied from the upper watershed and urban areas to the Bay (Fig. 2).

Alameda County Flood Control and Water Conservation District (ACFCWCD or the District) manages the flood control channel, and is responsible for maintaining flood protection for the adjacent communities. The channel fills with sediment during storm events, requiring portions to be dredged to maintain the required channel capacity. A series of desilting events occurred between 1975 and 2001, for a total of 996,000 CY of sediment removed (SFEI-ASC, 2017a; Fig. 3). Early ACFCWCD records are not complete, so it is not clear how much of the previously removed sediment was stockpiled, was taken to an appropriate landfill, or was given to developers to use in construction projects. Removing sediment from the channel is very costly, and includes staff and consultant time, permitting, construction, and disposal costs, and represents a significant maintenance cost for the District.

In addition to being costly, permitting the sediment removal events is increasingly difficult, as the resource agencies are balancing in-channel habitat value with the channel capacity requirements (SFBCDC, 2016a; SFBCDC, 2016b). The habitat of Alameda Creek supports a small population of native fish (Leidy, 2007), including migrating steelhead trout (*Oncorhynchus mykiss*). For many years a handful of steelhead have been observed swimming upstream in Alameda Creek to access spawning habitat in the upper watershed. However, fish passage has been blocked by the flood protection Bay Area Rapid Transit (BART) weir. In 2022, a fish ladder was completed at this location, opening up access to reaches upstream. Yet, these steelhead still must navigate the full length of the flood control channel from the Bay upstream to Niles Canyon before reaching natural channel areas.

The current channel cross-sectional geometry includes a low-flow channel inset within a wide, vegetated surface that is composed of the sediment that has been deposited since the last dredging event. This low-flow channel does not have the adequate size and slope to most efficiently transport sediment downstream in bankfull flows (e.g., the 1-2 year flow events), meaning that sand and gravel sized sediment regularly deposits on the bed. This deposition shallows the water depth, creating a series of water depth-related passage issues for fish (<0.6 ft at 25 cfs), particularly in the reach between Decoto Road and the BART weir.

To address the inefficient sediment transport during bankfull flows as well as the water depth-related passage issues, ACFCWCD designed a sediment removal project that will excavate a new, more appropriately sized low-flow channel within the existing flood control channel (Fig. 2). This project aims to meet two objectives: creating a low-flow channel geometry that will more effectively transport sediment downstream at the bankfull flow by increasing shear stress during these flow conditions, and simultaneously provide deeper low-flow water depths to allow for easier fish passage. ACFCWCD anticipates that the completion of this project will reduce the long-term maintenance and sediment removal costs from Alameda Creek, as well as providing improved fish passage through the flood control channel, justifying the current costs of completing this project. The designed channel

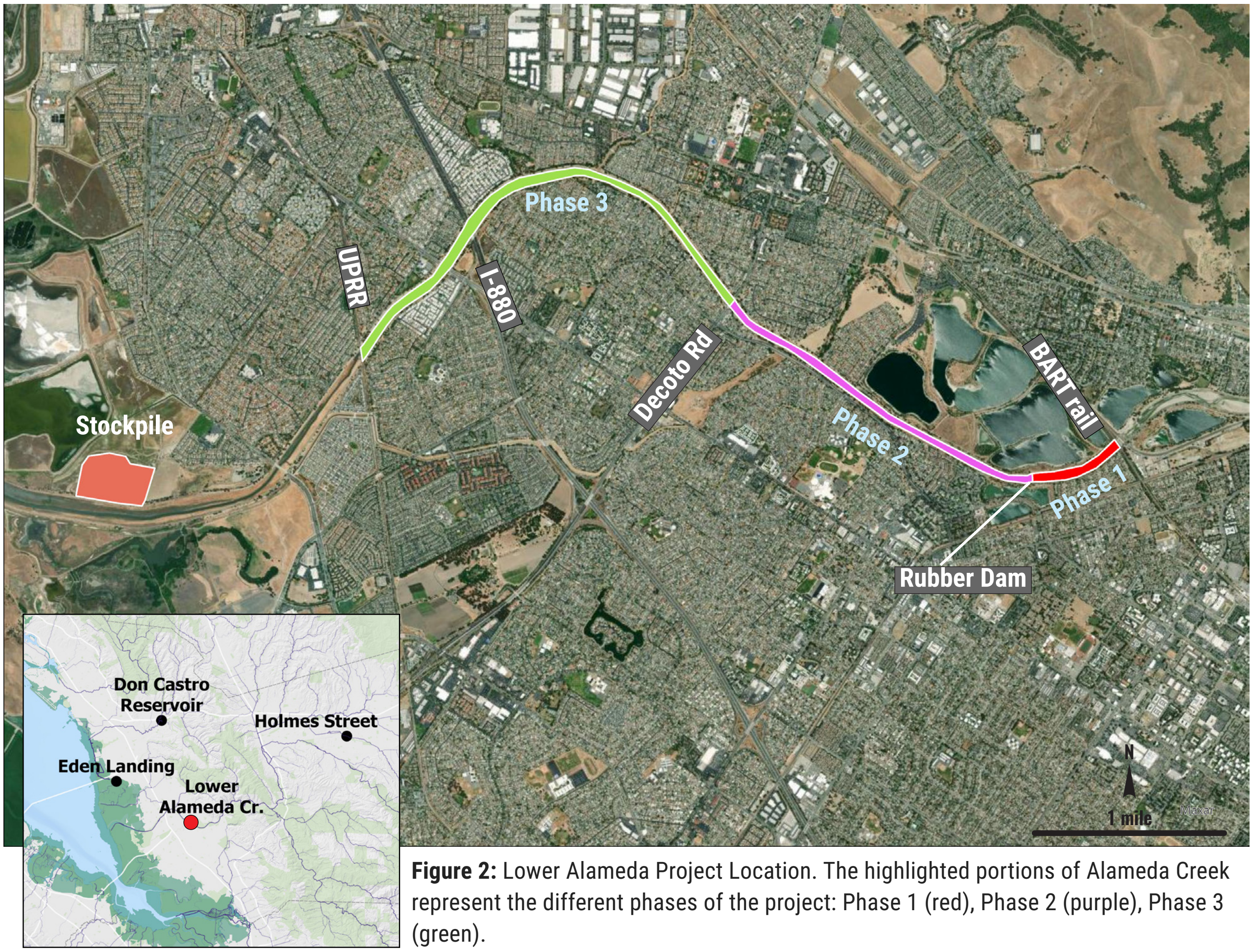


Figure 2: Lower Alameda Project Location. The highlighted portions of Alameda Creek represent the different phases of the project: Phase 1 (red), Phase 2 (purple), Phase 3 (green).

will be approximately 9 ft deep and 24 ft wide bottom width, with an alternating sloped bed to encourage slight meander, along with a series of debris-jam analog structures to encourage localized scour along the thalweg. The project has been designed to occur in three phases, with Phase 1 extending from the BART weir to Rubber Dam 2, Phase 2 extending from Rubber Dam 2 to the grade control sill just upstream of Decoto Road, and Phase 3 extending from the grade control sill just upstream of Decoto Road downstream to the head of tide location at the UPRR. Phase 1 is expected to start during the summer/fall of 2024, while Phase 2 will occur in 2025. Phase 3 is currently entering the design phase, and is expected to occur in 2026. Based upon the current design, Phases 1 and 2 are expected to remove 32,700 CY and 170,300 CY of sediment, respectively, from Alameda Creek. Phase 3 will likely remove an additional 270,500 CY, for a project total of 474,000 CY. This amount of sediment represents a medium to large volume from a single source that is relatively close to the Bay, and that potentially could be used in bayland habitat projects.

For this low-flow channel modification project, ACFCWCD will ultimately truck the sediment to a stockpile location along the north side of lower Alameda Creek. The District owns this property, part of which is immediately adjacent to muted tidal marsh habitat but is currently being used for low-impact agricultural use, while the other part already contains stockpiled sediment from previous removals from multiple channels within the District. Stockpiling the sediment represents a no-cost disposal location for the District, with a low likelihood of becoming habitat itself, and also has the added benefit of allowing that sediment to dry before being reused. Some of this sediment may be temporarily stockpiled at locations closer to the removal reaches because of hauling restrictions set by local municipalities and the fast pace of sediment removal. In this scenario, sediment would be removed from the channel, placed into a truck, stored at the temporary stockpile, and then could be hauled to the final stockpile location at a later date (a truck carries approximately 12 CY). This has the benefit of meeting the munici-

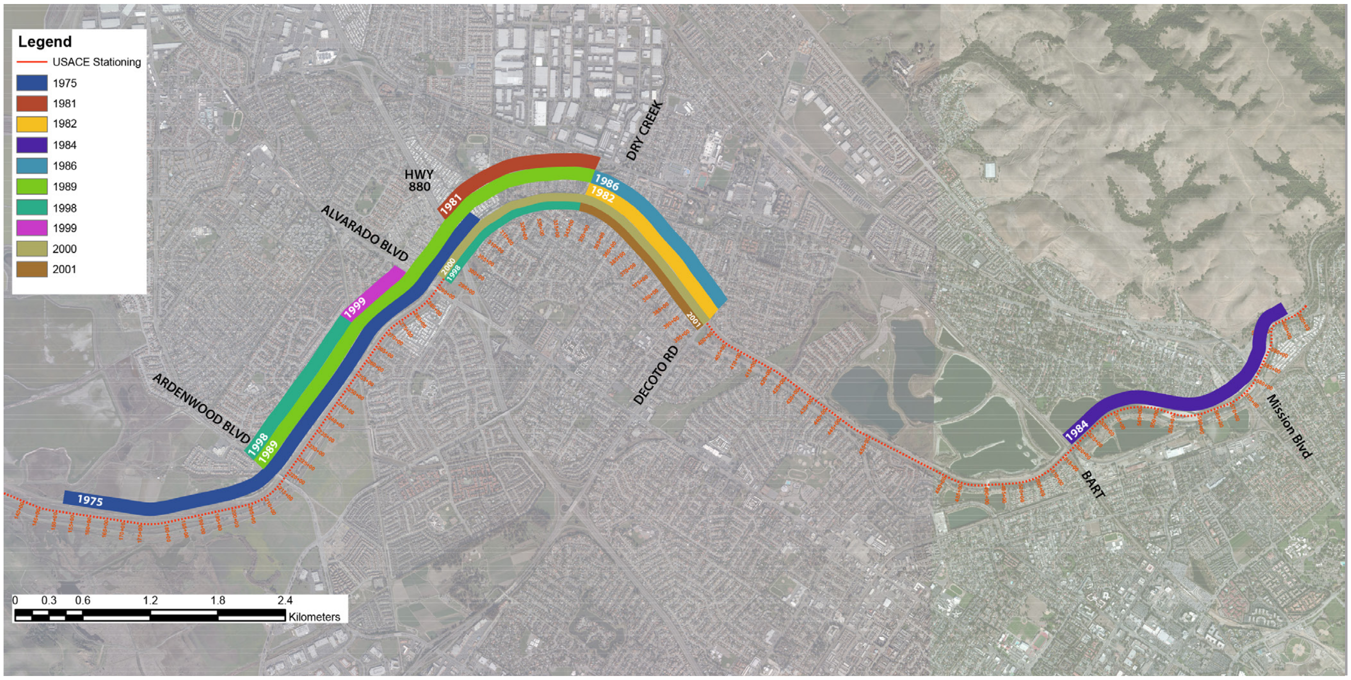


Figure 3: Desilting history of the Alameda Creek Flood Control Channel (Pearce and McKee, 2012 unpublished).

palities restrictions, allowing the sediment to dry before the longer trucking distance (reducing the total weight), but it also introduces the additional cost of handling the sediment.

Prior to developing removal plans, the District gathered information related to the bulk sediment grain size of material that will be removed (Pearce and McKee., 2009). In addition, ACFCWCD has conducted some preliminary contaminant testing on in-place sediment within the low-flow channel footprint; analysis for the standard suite of metals and common contaminants show that the sediment has passed standard tests for landfill disposal, with only low levels of contaminants present (H. Ackerman, pers comm 2023).

The project has been working with a number of regulatory agencies, including the U.S. Army Corps of Engineers, San Francisco Bay Regional Water Quality Control Board, California Department of Fish and Game, National Marine Fisheries Service and the U.S. Fish and Wildlife Service to gain the appropriate permits for this project. The project footprint is outside of the San Francisco Bay Conservation and Development Commission jurisdiction, so a formal permit is not required from this agency. Project partners noted that the agency staff have been very helpful and accommodating in this complex project during multiple consultations and project meetings.

During the planning phase, the project has faced several technical and regulatory challenges. Because the planned excavation is creating a new low flow channel that is 9 ft deep, the excavation will likely encounter the shallow groundwater table under the channel bed. The project will have to dewater the channel, either routing water around the excavation reach, or pumping it into local sanitary sewers. Turbidity restrictions of the project permit require that the return flow into the stream must have a turbidity that is no more than 10% higher than the incoming flow. This restriction is in place to protect downstream aquatic organisms from excess turbidity and fine grained sedimentation. Returning flow back to the channel will likely require settling tanks to reduce turbidity to appropriate levels, while pumping into the sanitary sewers would avoid this step. This would provide a benefit to the Union Sanitary District by providing additional flows to reduce equipment damage, and the levels of turbidity in the water are low enough to not cause deleterious effects.

The regulatory agencies have also required mitigation for the impacts of this sediment removal. In addition to the temporary impacts due to the removal, the project will also cause some permanent impact at three bridge locations. With the project excavating a 9 ft deep low-flow channel, there is potential to impact bridge structure for the three bridges within the project footprint. To prevent destabilization, the project will install vertical sheetpile walls and place grouted riprap across the channel underneath each bridge, permanently impacting <2 acres of channel habitat. Together, these impacts are required to be mitigated at a 3:1 ratio. ACFCWCD will concurrently complete the mitigation on the 5-acre parcel owned by the District along the tidal reaches of Alameda Creek, the same parcel that is currently used for agriculture and for sediment stockpiling. The project will create new area of tidal marsh by lowering the elevation of current upland (a portion of the current agricultural area) 1.5 to 2 ft, disposing of that sediment at the stockpile, and grade new pilot tidal channels, so that the area receives tidal action. Ironically, this new marsh area will likely be dependent upon sediment supplied by Alameda Creek in the future to maintain its elevation in the face of sea level rise. When considering a sediment removal project, many forget about the mitigation requirements associated with the removal, which due to the costs, can delay the removal or reduce the total volume removed. Although mitigation adds an additional component and cost to a sediment removal project, this particular mitigation is relatively straightforward in that the District has an appropriate location for the mitigation to occur and the habitat improvements are simple to implement. Due to the multiple challenges of removing the sediment, the transport costs, and the potential double-handling of the sediment before it is placed at the stockpile location, ACFCWCD is anticipating a total cost between $130 and $150 per CY of sediment removed. For comparison, SFEI's Flood Control 2.0 Project (SFEI, 2016) gathered data on previous (1958-2013) sediment removals from flood control channels around the Bay Area, and costs per CY of sediment for these projects ranged between $2 and $86/CY (although many removals occurred in the 1970s and 1980s, and costs are not adjusted for inflation). This relatively higher cost for removal is anticipated to be balanced by reduced long-term maintenance and sediment removal costs.

ACFCWCD removing and hauling the sediment to the stockpile location is only half of the equation of beneficial reuse. The Lower Alameda Project has found a potential reuse partner in the SBSPRP. This project aims to restore 15,100 acres (in total across multiple locations within the project) of previous salt ponds to tidal marsh and other habitat types. Much of the restoration involves using imported sediment to construct habitat transition zones and island habitat, and to raise and widen existing berms and levees because these actions must occur before the levee is ultimately breached. In the future, the project aims to use additional sediment to raise the elevation of previous subsided salt pond beds and allow new salt marsh habitat to develop. This type of restoration requires large volumes of sediment that meets strict regulatory contaminant thresholds, is of the appropriate grain size, and is available within time windows that match restoration project phase timing. The Eden Landing Ecological Reserve portion of the SBSPRP is directly adjacent to ACFCWCD property along Old Alameda Creek, north of Lower Alameda Creek. The District operates a second stockpile on their property here, just on the east side of Old Alameda Creek, which is closer to where the SBSPRP would ultimately use the Lower Alameda Creek sediment. Hank Ackerman, director of ACFCWCD, and Dave Halsing, Executive Project Manager for SBSPRP, have developed a relationship based upon the long-term interactions of their organizations' past and current projects in this area. During regular meetings, the District has informed the SBSPRP of this upcoming project, and that the resulting sediment would be stockpiled adjacent to the lower reaches of Alameda Creek, and would be available for use by SBSPRP at no cost for the material itself. This offer for potential future reuse came about because of this ongoing collaboration and the relative proximity of the stockpile location to the likely future reuse location. Neither a middleman, a sediment broker, or SediMatch was used. At this point, the potential reuse exists as an offer, with no official agreement or contract in place.

SBSPRP regularly receives sediment – most commonly excavated upland fill – at no cost to the project, so the opportunity to receive Alameda Creek sediment for no cost is welcome and helpful but not exceptional. The 203,000 CY of sediment that will be produced in Phases 1 and 2 represents a comparable amount of sediment that they have received previously from "moderate- to large-" sized projects. SPSPRP is very much interested in this sediment, and it represents an opportunity for reuse for a few primary reasons: the relative proximity to


PHOTOGRAPH COURTESY OF SYD TEMPLE

the final placement location, the overall total volume, the known location and timing of removal, and the flexibility in timing for that sediment to be reused because it is stockpiled. But it is not certain that some or all of the removed sediment will be beneficially reused for a few reasons. First, as a condition of the Quality Assurance Program Plan for the Beneficial Reuse of Material (QAPP), the location and source of the sediment must be known, so potential contaminants associated with land uses within the watershed can be considered. This requires that the sediment from this low-flow channel project be stored separately from any existing stockpiles, since the source of that material is from multiple channels. Next, the stockpile will be assessed for overall total volume, and sampled for grain size distribution. Bayland projects primarily need finer grained sediment, such as silts and muds rather than gravels and sands, because the material must be able to be compacted to the required specifications to be used in building and enhancing berms and levees, to eliminate seepage through the levee. This does not mean that coarser material cannot be used, but instead, these materials are typically only used for specific purposes (e.g., graveling levee tops to make them drivable, or island topping [surface treatment to prevent excess vegetation growth]) and used in much smaller quantities. And finally, the cleanliness of the sediment will be assessed based on SBSPRP's QAPP requirements. The SBSPRP has existing permits in place for the placement of sediment as it becomes available, but that sediment must be extensively tested for contaminants, and must meet the strict thresholds set by the regulatory agencies for placement within a wetland. Because these standards are so stringent, sediment sourced from urban channels may not meet the thresholds simply due to common contaminants that run off from the urban environment, even for foundation or non-cover uses within restoration projects, which have more lenient thresholds for contaminants. Sediment from other sources that has been delivered to the SBSPRP has been tested by a material provider or a dirt broker (private entities that excavate and haul primarily construction-related sediment from terrestrial areas) or their consultants before delivery. In the past, the SBSPRP has not taken on the responsibility of contaminant testing before accepting the sediment. Because the sediment would be used within the Eden Landing SBSPRP, the testing requirements would likely be similar to those outlined in the Don Edwards San

Francisco Bay National Wildlife Refuge Master QAPP (Gavin Archbald, H.T. Harvey, pers. comm. 2023). The QAPP bases contaminant sampling requirements on surface area (if the sediment is in-situ) or on volume (if the sediment is in a stockpile), using the Department of Toxic Substance Control sample size recommendations. For Phases 1 and 2 of the project, these guidelines suggest that approximately 8 samples will be required, however this number would likely increase after initial sampling (perhaps up to 15-20 samples) so as to better quantify any hotspots that were identified. A rough ballpark estimate for this in-situ contaminant sampling is approximately \$50,000-\$60,000. However, if the sediment is tested while it is in stockpile, the recommendations could require up to 210 samples for the 203,000 CY of sediment, for a cost of approximately \$420,000. The total number of samples would likely be negotiated, and potentially could be reduced with a custom sample plan development. Of course, these are rough estimates of sample quantities and costs, and the actual number and cost would be determined by the project proponents and the regulators.

Assuming that these requirements are met, SBSPRP would be able to use this sediment in a portion of the Eden Landing project. The SBSPRP would assume the cost of moving the sediment from the stockpile to the appropriate location within the project, at a roughly estimated cost of \$15/CY for hauling, placement and grading if the stockpile location is at Old Alameda Creek. If the stockpile location is adjacent to Lower Alameda Creek the hauling cost would likely be \$40 to \$50/CY for the greater distance and extra considerations (sediment may have to be hauled on city streets, with street sweeping, traffic control, time of day, and route constraints). This extra cost could affect the viability of using this sediment. In total, between removal, hauling to the final stockpile location, contaminant testing, hauling to the project location, and the final placement and grading, the beneficial reuse of this sediment (excluding mitigation costs) will likely cost approximately \$147 to \$204/CY.

PHOTOGRAPH COURTESY OF SARAH PEARCE

Lessons Learned and Future Opportunities

The Lower Alameda Creek low flow channel modification project is representative of one of the most common scenarios envisioned by the beneficial sediment reuse community (including entities producing sediment such as water districts and flood control districts, dredgers, and construction companies; entities using sediment such as restoration or mitigation projects; and regulatory agencies such as the USACE, the State Water Quality Control Board, the Regional Water Quality Control Boards, BCDC, USFWS, etc). That is, in an ideal situation, a relatively large volume of sediment removed from a channel could be reused locally, in the baylands downstream of the channel, and would be financially viable for both the agency completing the removal and the project that is using the sediment. Although sediment removed from channels will not provide the volumes needed for all of the bayland restoration that is planned, in progress, or called for, it does represent the most common type of reuse. Sediment that historically was delivered to the bay but is now trapped can again be provided to those wetlands and habitats within the immediate vicinity.

This case study builds on those previous efforts by documenting a particular case that illustrates a ***specific*** set of challenges encountered, as well as the opportunities for reuse success within this particular project. Specifically, to-date this project has faced these challenges

- Requirements and restrictions around channel dewatering and turbidity during the desilting process;
- A potential mismatch between the grain sizes removed and the grain sizes needed by the SBSPRP;
- Restrictions on trucks hauling the sediment to the stockpile location (e.g., time of day, routes);
- A potential mismatch between the pace at which sediment will be removed and the number of trucks that are allowed to utilize the hauling route, potentially causing the need for temporary stockpile locations and double-handling of the sediment; and
- The overall expense per CY of removing, hauling, placing and grading the sediment, which may require double or even triple handling.

However, the project also has a number of factors and reasons why this reuse could be a success, including:

- The funding for the channel modification project (and thus, sediment removal) has already been secured through state-level grants and district funds;
- Individual regulators from each agency that have been helpful in permitting the project;
- A potential discharge location alternative for dewatering the channel that could benefit the local city storm drain system;
- Existing relationship between ACFCWCD and SBSPRP so that this potential match could be made, and sediment could be made available to SBSPRP for only transportation costs;
- The existence of a stockpile location that is near the reuse location and a project that needs sediment;
- The stockpile location is owned by ACFCWCD, which allows the District to place the sediment there at little or no cost, as opposed to having to pay a fee for landfill disposal;
- ACFCWCD owns property that is suitable for the required mitigation, so that they do not have to find other mitigation opportunities to mitigate for the removal project;

- The sediment is from a known location, allowing the regulators to carefully assess the potential for contamination based upon the land use history within the watershed; and
- Sediment from the stockpile location will have had the opportunity to fully dry before it is reused, and can be placed and graded when the timing is appropriate.

In addition to the challenges and opportunities listed above, the project has also been working with the regulatory agencies on meeting the required mitigation for temporary and permanent impacts to the channel and the future reuse component of this project will need to ensure that the sediment meets the stringent contamination thresholds for sediment reuse in wetland environments. These two topics are not unique to the Lower Alameda Creek project, and have been previously discussed in earlier reports. However, there is an entirely different set of challenges that nearly every project faces that are not as well known except to those that regularly implement restoration projects. These challenges are important to bring to light here, and to discuss separately from those challenges described above, because to-date they have not really been discussed, and they have the potential to significantly slow or even halt a project's progress. These challenges can be categorized as "logistical challenges" and "status quo challenges".

Firstly, the "logistical challenges" include negotiating right-of-way easements with properties that are directly affected by the restoration effort. The timing of material reuse is also important, as there are seasonal work windows (to protect certain sensitive wildlife species) in some months and challenges with winter rains in others. Most restoration projects are at least partly grant-funded, so material being available at the right time (i.e., within the grants' performance periods) is critical for the no-cost reuse approach described here to be feasible. These types of "logistical challenges" are not scientific challenges, but instead are organizational, political and legal challenges, which unfortunately can have a larger negative effect on material reuse in a restoration project compared to scientific and technical challenges. Without agreement from all of the parties involved to work towards the greater goal, sometimes a seemingly minor hurdle can result in a project not moving forward at all.

Secondly, the "status quo challenges" involve getting local cities, jurisdictions, consultants, regulators, and material providers to step out of "status quo" operations and be willing to explore new potential solutions to increase the beneficial reuse of large volumes of sediment, working towards meeting the large-scale restoration goals of the Bay Area. This could include changing the way things are typically done, or adding in a new component or step within the normal process that provides a benefit to the project or the region. For example, ACFCWCD chose to stockpile the removed sediment so that it opened the opportunity for future reuse, rather than planning to take it directly to landfill. As another theoretical example, early discussions between the sediment producer and the receiving project might find cost efficiencies in the transport; if the producer is already hauling sediment to a stockpile, perhaps the receiving project could contribute additional funds that would allow transport to the final use location instead. We encourage everyone in the reuse community to find novel solutions that will solve one (or many) challenges. The first project to tackle some of the difficult issues will likely bear the greatest burden (including a likely longer time period and greater cost to that project), but subsequent reuse efforts will likely benefit from those who tackle these issues first.

The challenges for sediment reuse faced by this project likely will not be solved before the project begins dredging in the summer of 2024. However, perhaps bringing this set of challenges as well as opportunities and successes forward can spur discussion and problem solving for future projects.

PHOTOGRAPH COURTESY OF DUCKS UNLIMITED, INC.

CASE STUDY #2:
Eden Landing sediment reuse by Ducks Unlimited

Project Description

Eden Landing Ecological Reserve is located near Hayward, CA (Fig. 4). Extensive restoration has occurred on northern Eden Landing as part of SBSPRP Phase 1, which was completed in 2016. During Phase 2, the southern portion between Old Alameda Creek and the Alameda Creek Flood Control Channel will be transformed from abandoned salt ponds into enhanced intertidal , and upland habitat through a partnership between the California Department of Fish and Wildlife, California State Coastal Conservancy, and numerous other partners. Ducks Unlimited, Inc. (DU) works as a partner with the SBSPRP to plan and implement projects, including habitat creation and restoration. Habitat restoration and enhancement includes construction of wetlands, foraging mounds, swales, gravel beaches, islands used as nesting habitat, and ecotone slopes.

The Eden Landing project needed approximately 3,000 CY of gravel, with a median grain size of about 8 mm and no grains smaller than 2 mm, to use for the construction of the beach and berm habitat. These stringent specifications for the size classification were based on the modeling conducted for the design of the beach berm design. Renee Spenst of DU was in contact with Zone 7 about potentially obtaining sediment that had been removed from a channel in Livermore. This match would have provided a location for Zone 7 to beneficially reuse their sediment, rather than using it locally for purposes such as resurfacing maintenance roads. Unfortunately, after grain size analysis, it was found that the sediment was too coarse and contained too wide a gradation of grain sizes, and would be unsuitable for this specific habitat use.

As a potential solution, Zone 7 worked with the Vulcan Materials company in Pleasanton to donate 3,000 CY of pea gravel (approximately 9 mm or 0.37 in in diameter) that was stockpiled in Pleasanton and unable to be used by the company. DU was very interested in this sediment for the beach and berm habitat, but while it was a consistent gradation, it was also the wrong grain size. However, it was appropriate for use in resurfacing the island habitat, as coarse and unvegetated sediment is needed for nesting habitat for birds. Vulcan offered to donate an even larger quantity of approximately 20,000 CY (30,000 tons) for this purpose.

The project ultimately elected to accept the donated sediment, as it was available free of charge, and the project would otherwise bear the cost of both the material and the transport, with no other nearby sources of material. The project spent approximately $440,000 to transport the sediment via trucks from Pleasanton to Eden Landing (approximately 25 miles) over four months in 2022, equating to approximately $21/CY (for transport alone, not sourcing sediment). This sediment was offloaded into a stockpile location, and will be placed (pending final permitting) into the project during 2023. This double-handling of the sediment will cost approximately $10/CY for transport from the stockpile to the placement location and for final grading. The project team is also planning to use upland sediment sourced by a dirt broker for constructing gentle habitat transition zone slopes because this sediment is available to the project free of charge, including contaminant testing, transport, and placement by the broker company.

Figure 4: Eden Landing Ecological Reserve (yellow boundary).

The beach and berm habitat constructed at Eden Landing are among the first of their kind within the Bay Area and are being constructed in an extremely high energy tidal and wave environment. There are no previous comparable projects to provide data or experience as guidance. However, because the sediment imported was gravel, the San Francisco Regional Water Quality Control Board (Regional Board) did not require the sediment to be tested for contaminants, as is required for finer sediments.

Lessons Learned and Future Opportunities

The Eden Landing project represents a restoration project that was eager to explore opportunities for beneficial sediment reuse, but had very specific needs in terms of the sediment grain size. While a potential partnership was forged, ultimately the sediment that was available did not meet the specifications of what was needed and was already designed for the project. This illustrates the challenge of projects in the design phase ensuring that suitable sediment is available, as well as the challenge of matching removal projects with restoration projects, and the detailed communication that must be a part of that matching process to ensure the needs of the restoration project are met.

Although a second match was made, and this sediment was available free of charge, the Eden Landing project still had to pay for the hauling of the sediment. Due to the distance, the total cost was fairly high, illustrating the need for a spatial match between removal and restoration projects to keep costs low. In addition, the availability of the sediment did not quite match the timing of the restoration project, requiring double-handling of the sediment, and another cost for the project. Fortunately, the restoration project had an area available for stockpiling the sediment, otherwise this reuse may not have been viable.

Through this process, DU staff recommend that future matching of projects should be commenced as soon as possible, with prioritization for matching the characteristics of the available sediment (e.g., grain size, total volume, contaminant level) along with the spatial location of the sediment relative to the reuse location. Collectively, the reuse and regulatory community must address the many challenges so that larger amounts of sediment can be beneficially reused at a faster pace. The community should improve the coordination and communication around matching projects geographically and by sediment availability, and the need to implement sediment reuse. Ultimately, one potential way to facilitate importing sediment to subsided bayland restoration projects that need it would be a programmatic approach, with the involvement of agencies such as the US Army Corps of Engineers, Bay Conservation and Development Commission, and the Regional Board, among others, to develop regional permits for placement of sediment in subsided baylands for habitat restoration and enhancement purposes beyond or in advance project permits.

CASE STUDY #3:

Don Castro reservoir sediment slurry pipeline

Project Description

The Don Castro Reservoir, in the San Lorenzo Creek watershed, was constructed in 1964 for recreation, with the added benefits of flood control, water supply (for firefighting), and as a sediment basin (Fig. 5). As expected, the reservoir has been trapping sediment supplied from the upstream watershed since construction. The upstream drainage area is 50.6 km^2, with an estimated mean sediment yield between 421 to 493 tonnes/km^2/yr (Bigelow et. al., 2012). However, previous studies (Bigelow et al., 2012) have shown that 50% of the sediment delivered to

Figure 5: Route of Don Castro Proposed Pipeline. The route follows the original route proposed by Wood Rodgers, 2013.

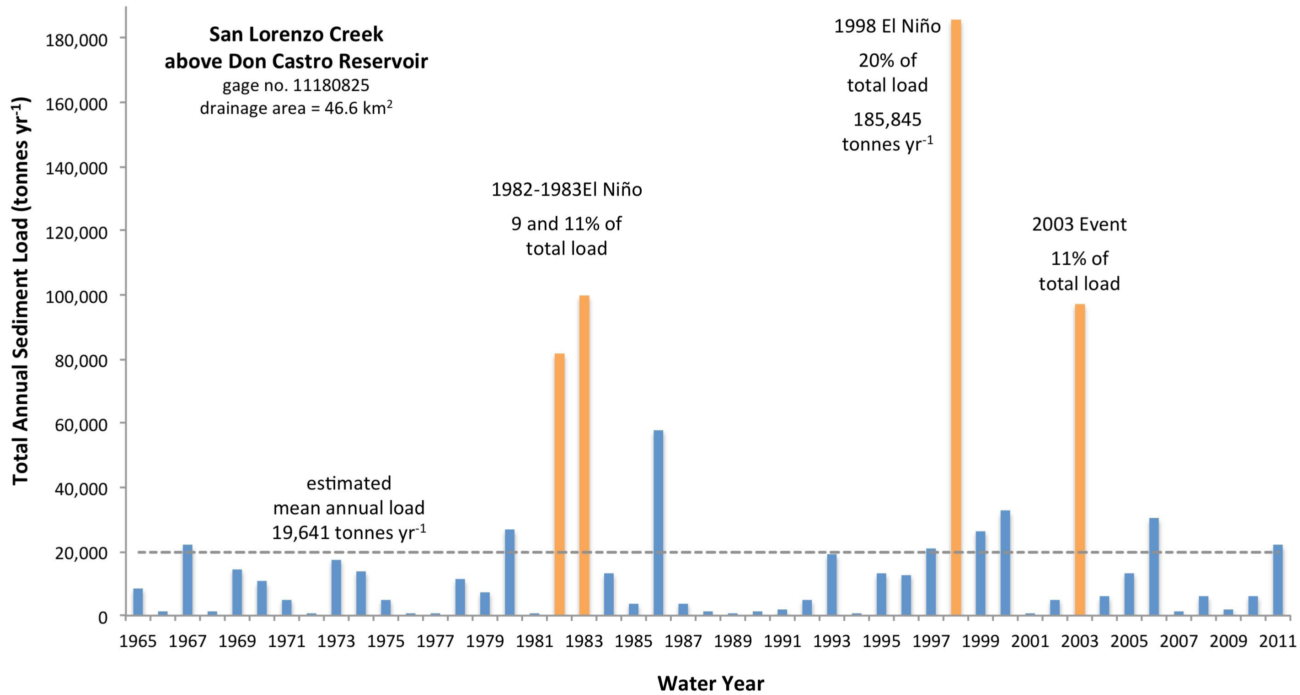


Figure 6. Estimated annual sediment load at the gauge just above Don Castro Reservoir (USGS gauge 11180825). The four highest years that comprise 50% of the 47-year total load are shown in orange, most of which occurs over a few days during those years. USGS collected sediment flux data for water years 1981-1995 and 1998-2003, other years are extrapolated using rating curves. From Bigelow et al., 2012.

the reservoir during the time period 1965-2011 occurred during flood events that occurred over just 14 days during four discrete water years (Fig. 6). The sediment trapped behind the reservoir affects reservoir capacity and future management scenarios (e.g. managing water levels, vegetation growth, and recreation opportunities). As of 2012, approximately 573,275 CY of sediment is trapped in the reservoir, resulting in a 94% reduction in as-built capacity (Bigelow et al., 2012). Recent wet years (e.g., 2017, 2019, and 2023) have likely further reduced the capacity of the reservoir. Between 1980 and 2000 five desilting events removed an additional 193,000 CY of sediment from the reservoir.

Due to the significantly reduced capacity, ACFCWCD staff began investigating how to remove sediment from the reservoir outside of traditional dredge and haul methods. They suggested possibility of removing sediment from the reservoir and transporting it downstream via slurry in a pipeline (Fig. 5). The Wood Rodgers 2013 technical memo that was developed describes 12.4 miles of 18 to 24" pipe that could be installed following an easement along the San Lorenzo Flood Control Channel to the San Francisco Bay and then south, delivering sediment to Eden Landing.

According to the preliminary design, several pipe diameters and sediment concentrations were considered, but ultimately the accepted configuration includes 1.5% sediment concentration flowing at 10.4 cubic feet per second. Several pumps would be required along the route to maintain the required head gradient for the full 12.4 mile journey. A water source for the project is not specified, but one possible candidate includes sourcing wastewater effluent from the San Ramon Treatment Plant (Wood Rodgers, 2013). The total estimated sediment volume that could be removed from the reservoir was 450,000 CY in 2013, which represents a significant volume of sediment for a bayland restoration project.

The estimated costs of design and construction of a pipeline ($9.4M) were comparable to trucking costs ($9.5M), equating to a cost of about $21/CY of sediment for the 450,000 CY of sediment estimated to be stored in the reservoir (Wood Rodgers, 2013). Note that these costs are simply for the *transport* of the sediment, and does not include the actual removal from the reservoir, or placement in the final project location. However, the pipeline has the added benefit of continued future use to regularly supply sediment slurries downstream to sediment-starved locations in the East Bay. Crucially, the estimated costs are now out-of-date; conversations with ACFCWCD and Wood Rodgers reveal that the estimated cost today would be roughly 5 - 10 times the 2013 figure due to higher material and labor costs, as well as some increase due to inflation (H. Ackerman and D. Matthies, pers. comm. 2023). This increase in costs equates to approximately $104/CY to $211/CY of sediment.

Lessons Learned and Future Opportunities

The Don Castro Reservoir pipeline concept is an example of creative thinking about non-trucking solutions for sediment removal, transport, and reuse. Transport via slurry has the potential to reduce greenhouse gas emissions as compared to those produced by trucking the sediment to the baylands, and avoid route and time-of-day restrictions placed on trucks by the cities. Another significant potential benefit of a pipeline is the ability to repeatedly use the pipeline, especially in erosive watersheds similar to San Lorenzo, as the watershed geologic lithologies will continue to produce excessive sediment, with sediment loads that are likely to increase under future climate scenarios (Bigelow et. al., 2012). However this option also includes many logistical constraints such as finalizing the route along city streets and county right-of-ways, pipeline construction and maintenance, the need for a water source to create the slurry, and the need for a number of pumps along the way to transport the slurry southward along the Bay margin to the Eden Landing area.

Despite the potential benefits, this case study illustrates the large expense of sediment removal and transportation. Solutions that are able to reduce the overall costs, or share costs between agencies that remove the sediment and projects that need the sediment could help ensure that a larger volume of sediment is beneficially reused in the future. In addition to the costs, the project partners should consider the cost of "no action", that is, if the sediment is not removed, which potentially could have a larger long-term cost than the project itself. And finally, perhaps another solution could provide regulatory incentives for a project that chooses to beneficially reuse their sediment, even if the total cost isn't significantly different than a non-reuse option.

CASE STUDY #4:
Sediment removal at Holmes Street Bridge

Project Description

Arroyo Mocho flows northward out of the Diablo Range and across its historical alluvial fan into the Livermore-Amador Valley through the cities of Livermore and Pleasanton. Due to the underlying geology, the watershed produces relatively coarse sediment, including cobble, gravel and sand which is transported downstream during larger flood events. Historically the Arroyo was a distributary channel - flows spread across the alluvial fan, and its sediment load was deposited. Although the Arroyo was channelized in its lower reaches and connected downstream to the Arroyo de la Laguna in 1889 (Beagle et. al., 2014), these processes persist. Deposition still occurs due to a decrease in gradient (and associated stream power) along its longitudinal profile, particularly in the non-engineered sections of the channel.

The Holmes Street bridge is located near the historical terminus of the defined Arroyo Mocho channel, and is currently the location of regular deposition of sediment due to both its location along the longitudinal profile, and the hydraulic constriction associated with the bridge structure (Fig. 7). The City of Livermore (City) is responsible for maintaining hydraulic conveyance under the bridge to protect the road and adjacent neighborhood areas from flooding. The chronic deposition of sediment has caused the City to repeatedly remove sediment from underneath the bridge and from areas upstream of the bridge. Sediment deposition typically occurs during larger storm events. If a large flow occurs during the winter, sediment is typically removed the following summer/fall season.

Records gathered from the City for previous projects reveal that between Water Years 2005 and 2022 a total of 19,943 CY of sediment was removed from the Holmes Street bridge site. Annual removal volumes ranged from 0 CY (in 2013, 2015, 2016, 2019, 2021 and 2022) to 8,900 CY in 2017. A total of 12 annual removals occurred during these 18 years,

Figure 7: Holmes Street Removal Location.

meaning that with the exception of very dry years sediment tends to be removed every couple of years. Records are incomplete and the cost per CY is unable to be reported. However, cost estimates for hauling alone were gathered in 2021, and are roughly $8-10/CY for a 60-minute trip (estimate based upon time, not mileage), not including the excavation or loading of the sediment. Sediment was not removed in 2022 due to the low flows of the prior wet season, but due to the large New Year's storm of 2022/2023, a removal is tentatively planned for the summer/fall of 2023, and will likely be similar in total volume to the 2017 removal. A plan is not yet in place for the reuse of this sediment, so it will just be taken to an existing stockpile location in the Zone 7 area (e.g., at the Chain of Lakes, at the El Charro Road stockpile, at the Vulcan Materials property) for future use, as has been typically done in the past few years.

The records do not generally describe the fate of the removed Holmes Street bridge site sediment. Discussion with Drew Engstrom (Alameda County Resource Conservation District), who works directly with the City for their Stream Maintenance Program, indicated that the City previously disposed of removed sediment at an appropriate landfill. However, these practices have been changing recently, and the City has been looking to find reuse partners. For example, some sediment has been used for resurfacing parking lot areas, while other sediment has been used in adjacent channel reaches to fill in excessive scour of the channel bed. Although this local reuse is not contributing to larger Bay Area habitat goals, it does save on fuel costs for transport and greenhouse gas emissions, and may provide some public benefit. This type of reuse requires testing for contaminants, but is generally easily accepted by many in the regulatory community, and often does not require testing for invasive species if the reuse occurs within the same watershed. In addition to reusing the sediment locally for City or for Zone 7 projects, the City was also exploring a partnership with a local construction company, based upon previous interactions between Zone 7 and the company. In this potential partnership the City would conduct the removal, but the company would haul the sediment away and use it in their construction projects. While the potential partnership was promising initially, it has currently stalled due to the company's waning interest because of the present economy. In the absence of a dedicated reuse partner, sediment from multiple removal locations has been transported to the Chain of Lakes area or to a local Water Resources Division maintenance yard, and placed in stockpiles.

Sediment removal at the Holmes Street bridge site is costly, and must be conducted fairly regularly, making it a continual issue for the City staff. Chief among these costs are disturbances to the in-channel habitat, which require significant mitigation. During the 2017 removal, it was determined that 80,000 sq ft of in-channel habitat had been disturbed, requiring 88,000 sq ft of habitat enhancement mitigation (the City is required to mitigate at the same rate as developers). The 2018 removal had similar requirements; roughly 24,000 sq ft of disturbance was mitigated through 26,000 sq ft of habitat enhancement. Local mitigation is difficult in these highly urban settings and requires creative solutions. As a result, the City typically conducts much of their mitigation at dedicated off-site mitigation sites. In this example, the City owns property in the channel corridor upstream of Holmes Street at Robertson Park, and is able to conduct mitigation here, including planting native riparian species to enhance the riparian corridor and creating and improving California red-legged frog (*Rana draytonii*). To date, habitat restoration at Robertson Park alone has cost roughly $300,000, with a majority of the cost directly related to mitigation for impacts at Holmes Street. Another $100,000 of mitigation credits was purchased from an offsite mitigation bank as incidental coverage during project activities.

The City removed sediment from the same area of the Holmes Street bridge site during 2017, 2018 and 2020 completing required mitigation after each removal. Because the City completed the required mitigation for disturbing the channel after the three removals, the San Francisco Bay Regional Water Quality Control Board determined that their actions met the Board's established criteria, and they no longer needed to mitigate for additional removals in that same location. However, sediment removals do still require mitigation for the disturbance of endangered species habitat (such as California red-legged frog), and will continue to be required into the future. The upcoming 2023 removal will likely limit the total area of removal, so as to reduce the area impacted and thus the mitigation that is required.

The City of Livermore is actively researching long-term geomorphic solutions to the sedimentation issues to reduce their sediment removal and mitigation costs including considering the addition of sediment basins or upstream channel re-design reduce the overall volume of sedimentation that occurs at the Holmes Street bridge. The City is interested in reuse opportunities, but they face challenges such as the distance between Livermore and most restoration project locations, and the wide range of grain sizes in the sediment that is removed. The cost of hauling sediment long distances typically makes it difficult financially to reuse the sediment in bayland habitat projects. In addition, sites like Holmes Street bridge produce fairly small volumes of sediment on an annual basis, much of which is only appropriate for specialty uses, such as the creation of beaches or berms. As described in the case studies above, these habitat features typically require a very specific grain size of sediment, again potentially limiting the reuse for specific bayland purposes.

PHOTOGRAPH COURTESY OF DREW ENGSTROM

Lessons Learned and Future Opportunities

Sediment removal from the Holmes Street bridge site is representative of many locations around the Bay Area, where chronic sediment deposition is an issue, requiring regular removal of small total volumes of sediment. At the Holmes Street bridge site, the City has prioritized finding reuse partners to help reduce the cost of hauling and disposal, and has also adjusted the removal footprint so as to reduce the cost of mitigation. But these actions have yet to solve the problem for this location. This case study has illustrated a number of ***specific*** challenges encountered at Holmes Street, but has also highlighted opportunities for reuse success. Specifically, the Holmes Street bridge site faces these challenges:

- The need for continual removal due to natural geomorphic processes;
- Sediment removals are relatively small in size, producing volumes of sediment that are not very useful for large restoration projects;
- The sediment removed is coarse, and with a range of grain sizes, reducing the total number of potential uses;
- The need for contaminant testing before the removed sediment could potentially be used in a restoration project;
- The distance from the baylands makes reuse for wetland projects very expense due to the cost of hauling;
- The mitigation ratio that the City is required to mitigate at (for species impacts) for this necessary flood risk reduction is high, and is similar to the rate for developers;
- The cost of mitigation and the limited number of locations to conduct mitigation;
- The cost of mitigation has caused the City to reduce the total area of sediment removal. However, if a project required a larger volume of sediment with the grain size distribution that is present at Holmes Street, the City might consider removing a larger volume. The sediment is present and ready for removal, and would just require the appropriate financials to cover the increased mitigation that would be required; and
- Some of the local reuse, such as spreading at the rodeo grounds or resurfacing maintenance roads, are not contributing to increased or improved habitat, meaning that it is sediment reuse, but perhaps not beneficial sediment reuse.

However, there are also a number of reasons why reuse could be a success for sediment from Holmes Street, including:

- Local reuses have a lower cost for hauling, reduced greenhouse gas emissions, and still have a public benefit despite not contributing to regional baylands goals;
- Previous contaminant sampling has shown this sediment to be fairly “clean”, or free of contaminants;
- The opportunity exists for local reuse for in-channel projects, such as filling in areas of excessive scour, or perhaps providing sediment for degraded areas downstream of dams;
- Minimal regulatory resistance to reuse within the same watershed; and
- The existence of local stockpile locations, so that if a partner is not found, the City can at least store the sediment in a stockpile for potential future reuse.

Summary of reuse challenges and successes

These four case studies illustrate the constellation of factors that must align in order for sediment removed from flood control channels or from behind reservoirs to be beneficially reused. Within each case study there are a number of challenges that are faced by the project, some of which are readily addressed and just require a little creativity, and others that represent programmatic level challenges that will require the entire reuse community to engage together to find a solution and change the status quo.

The challenges observed include:

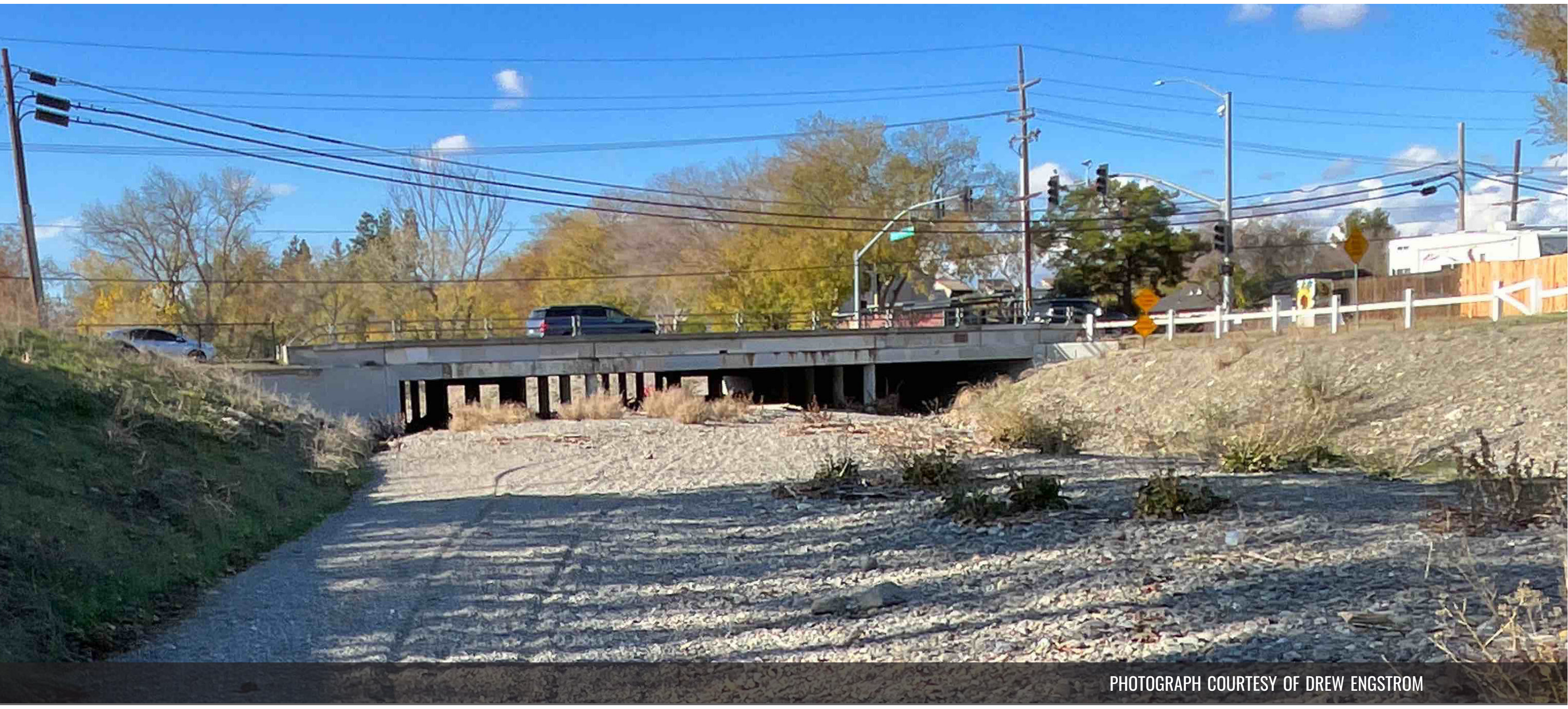
- **Geomorphic issues** such as chronic sedimentation that requires frequent but small removals, sediment that is not well graded (i.e., has a variety of grain sizes) which limits potential for reuse, and specific specifications for grain size needed by restoration projects.
- **Logistical issues** such as mismatches between the pace of sediment removal and the pace of hauling, mismatches in timing between when sediment is removed and when it can be used, mismatches in volumes (small volumes are not very practical for large restoration projects), and total volumes of removals that are affected by regulatory or logistical constraints.
- **Transport issues** such as restrictions on hauling placed by cities/counties (e.g. time of day, routes, number of trucks, etc), and the overall distance of hauling between removal and reuse locations (hauling costs, diesel, greenhouse gasses) Cost issues such as the overall high total cost of removal, hauling, placing and grading sediment in reuse projects, the cost of hauling long distances, and the cost of having to double (or sometimes triple) handle the sediment between removal, stockpile, and final locations.
- **Administrative issues** such as the low success to date of matching removal projects with restoration projects, effectively communicating project goals and needs between producer, user and regulatory agencies, and project-specific issues such as obtaining easement and access approvals.
- **Regulatory issues** such as requirements during removal (e.g. dewatering, turbidity thresholds), contaminant requirements and thresholds that have been established for wetland environments, and mitigation requirements (total amount, ratios similar to developers, for temporary and permanent impacts, high overall cost, limited number of appropriate locations to conduct mitigation, potential effects on project scope in an effort to limit the amount of mitigation required). This follows from a recommendation made in Pearce et al. 2021 that recommended updating regulatory policies so that additional volumes of sediment could be beneficially reused across the Bay Area.

There are also a number of factors that made/will make the reuse more likely to occur. Here these factors are referred to as 'successes' because they are beneficial characteristics or components that have helped the project. Previous studies have not necessarily focused on these successes, but they are equally as important to understand as the challenges, especially as the region tries to increase the total volume of sediment that is reused.

Successes observed include:

- Regulatory agency staff that are engaged and helpful in moving the project forward. Regulatory co-operation around sediment testing requirements, especially when being reused in the same channel reach, and limiting repeated in-channel mitigation for removal.

- Ability to secure funds from state grant programs to conduct channel projects that will produce sediment as a side benefit.
- Building upon existing relationships and conducting outreach to nearby partners to discuss potential reuse and find common goals and mutual benefits.
- A change in management practices of the sediment producers, where they are actively looking for reuse partners instead of only considering placement in the landfill. Sediment reuse has become the first option, with disposal at landfills becoming a least preferred option, due to better understanding of the regional value of sediment and the potential for reduced disposal costs.
- Stockpiles that are owned by project partners, that can accept and provide sediment when needed, that doesn't charge a fee for placement, that provide an opportunity for the sediment to dry, and are located fairly close to reuse project locations. Also, the ability for sediment in stockpiles to remain separate from sediment generated from other locations/time periods to assist with regulatory assessment for potential contamination before reuse.
- Acknowledgment that distance matters, and the associated costs of transporting sediment over a long distance is a critical aspect of the success of the project. These include explicit costs (time and fuel) but also other costs such as emissions, noise, and road damage.
- Partners that are able to offer sediment to reuse projects free of charge for the material itself.
- Partners that own land that is appropriate for mitigation, so as to reduce total mitigation costs.
- Creative thinking around challenges, including partnering with the City to discharge creek flows into the sanitary sewer system to increase flows during low flow time periods to reduce wear on their machinery reuse in local in-channel projects; transport of sediment via slurry (however there are no recent completed Bay Area examples to draw knowledge from, although Searsville Dam on San Francisquito Creek is exploring ideas on how to best transport sediment that is currently trapped behind the dam.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