

# 1 Barriers and Opportunities for Beneficial Reuse of Sediment to

## 2 Support Coastal Resilience

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## 19 Abstract

20 As urbanization and climate change alter sediment fluxes, relative sea level and coastal erosion around  
21 the world, management of sediment as a resource is increasingly important. Sediment is needed to  
22 enhance marsh accretion rates, raise the grade elevation of development, and build up beaches and  
23 dunes. Beneficial reuse of sediment refers to the repurposing of local sources of sediment for these  
24 applications, material typically available from dredging or sediment capture infrastructure, and represents  
25 a more sustainable approach compared to the status-quo involving transport to and from distant  
26 locations. However, in many locations, beneficial reuse remains a concept or is constrained to small-scale  
27 applications. In this paper, we draw on interviews with coastal sediment managers and regulators in  
28 Southern California to identify barriers to beneficial reuse and opportunities to overcome them.  
29 Interviewees reported numerous regulatory, technical, psychological, financial, and interorganizational  
30 barriers in their watersheds. By highlighting these barriers, we aim to identify systemic changes that would  
31 make beneficial reuse a realistic and accessible option for Southern California and elsewhere. Most  
32 prominently, a more flexible regulatory framework that allows sediment management practices to adapt  
33 over time, pilot studies to understand how beneficial reuse works in various settings, and educational  
34 programs for regulators and the public could make beneficial reuse a more widespread approach.

## 35 **1. Introduction**

36 Coastlines around the world are undergoing rapid change, with increasing migration to coastal regions,  
37 rapid urbanization, more frequent and intense storms and flooding, and sea level rise (Merkens et al.,  
38 2018, 2016; Neumann et al., 2015; Nicholls et al., 2018). Sediment is an important—yet often  
39 overlooked—dimension of how resilient coastlines can be to this change (Cappucci et al., 2011; Khalil et  
40 al., 2010; Morris, 2012). Humans have significantly altered terrestrial sediment fluxes through changing  
41 land use (Syvitski et al., 2005; Trimble, 1997; Warrick et al., 2013) and constructing dams and debris basins  
42 that trap sediment and alter streamflow (Kondolf et al., 2014; Syvitski et al., 2005; Willis and Griggs, 2003).  
43 In terms of coastline change, these changes have had mixed impacts with some shorelines eroding, some  
44 accreting, and some remaining stable (Luijendijk et al., 2018; Syvitski et al., 2005). Within estuarine and  
45 coastal embayments, excess sediment tends to degrade water quality and wetland habitat from reduced  
46 circulation, block ports and navigation, and increase flood risks due to reduced drainage capacity. On  
47 other hand, as the rate of sea level rise increases, there are increasing needs for sediment to nourish  
48 wetlands, restore beaches and dune ecosystems, and mitigate against erosion and flooding (Hamm et al.,  
49 2002; Hanley et al., 2014; Temmerman et al., 2013).

50 Given both a supply (e.g., from dredging) and demand for sediment at the same sites, there have been  
51 calls for beneficial reuse, or the site-based optimization of coastal sediment by recognizing that it is a  
52 valuable resource rather than a waste product (Ewing et al., 2008). Dredging—to address flood control,  
53 maintain existing navigation channels, and to construct new terminals, channels, and waterways—  
54 produces millions of cubic yards of dredge material each year in Southern California alone (Krause and  
55 McDonnell, 2000). The dredged material is typically shipped to offshore dredged material disposal sites,  
56 lost to any potential reuse, yet there is substantial demand for sediment for wetland restoration, beach  
57 nourishment, construction, and other goals (Devick, 2019). Beneficial reuse connects the supply and  
58 demand, such that sediment can serve a broad public purpose including reductions in the greenhouse gas  
59 emissions from the long-distance transport of sediment which promotes greater sustainability. More  
60 broadly, beneficial reuse responds to calls for more adaptive management of coastal sediment (Apitz,  
61 2008; Lillycrop et al., 2011).

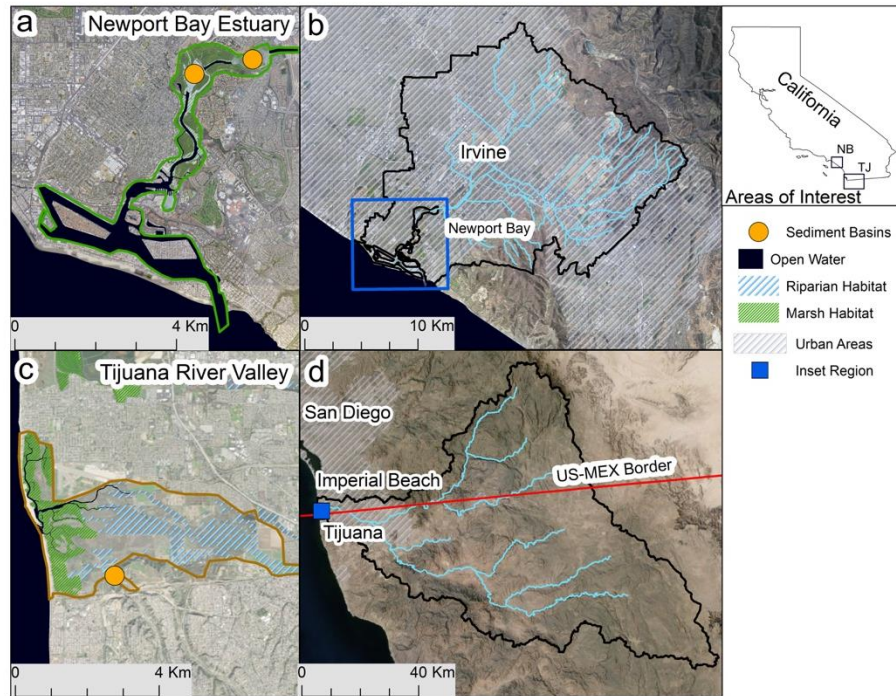
62 However, in many locations, beneficial reuse is an aspiration rather than an active practice (Devick, 2019).  
63 While collaboration to explore existing beneficial reuse standards and to coordinate source identification,  
64 movement, and placement efforts between restoration, flood control, and dredging communities is  
65 occurring regionally, many questions about implementing beneficial reuse still remain (Devick, 2019). In  
66 this paper, we aim to identify and report barriers to beneficial reuse of sediment and other adaptive  
67 approaches to management based on interviews with federal, state and local stakeholders involved in  
68 sediment management in Southern California. The overarching objective is to draw attention to the  
69 factors prohibiting more sustainable approaches for coastal resilience. We also report on the perceived  
70 strengths and weaknesses of existing approaches to sediment management, identify opportunities to  
71 overcome barriers to beneficial reuse, and discuss applicability of these approaches elsewhere.

## 72 **2. Methods**

### 73 **2.1. Case description**

74 Southern California contains a highly urbanized and energetic coastline with regions of both accretion and  
75 erosion under both human and natural influences (Flick, 1993; Hapke et al., 2006; Sanders and Grant,  
76 2020; Vitousek et al., 2017). The region's sediment is fed largely by flashy fluvial input, with the majority  
77 of riverine sediment movement occurring during occasional storms (Warrick et al., 2015; Warrick and  
78 Milliman, 2003) and both increases and decreases in fluxes as a result of stormwater infrastructure  
79 (Sanders and Grant, 2020). Many of the region's wide sandy beaches are the result of historical harbor  
80 dredging (Flick, 1993), and periodic beach nourishment projects are implemented to maintain beach  
81 widths for recreational, economic, and flood mitigation purposes (Flick, 1993; Patsch and Griggs, 2006).

82 This research uses a comparative case study design (Yin, 2017) to assess the barriers and opportunities to  
83 beneficial reuse for watersheds varying across a number of ecological, socioeconomic, and institutional  
84 factors. Two locations in Southern California were chosen as sites for the study: (1) Newport Bay Estuary  
85 (NBE) and (2) Tijuana River Valley (TRV) (Figure 1). Both sites share the same climate (warm dry summers  
86 and cool wet winters), fall within a coastal valley that is bordered by upland/mesa topography and at the  
87 terminus of a mountainous watershed, and contain significant natural wetland resources in the context  
88 of a highly developed Southern California (Sanders et al., 2020). However, the sites differ in several ways:  
89 First, wetland habitat mainly consists of tidal channels and salt marsh in NBE, while in addition to tidal  
90 channels and salt marsh, there is extensive riparian (freshwater) wetland habitat in TRV. Secondly, the  
91 coastal valley is highly urbanized in NBE, while the setting is rural in the TRV with land predominately  
92 managed as parks and open spaces. Third, the watershed is largely built-out in NBE, while in TRV the  
93 watershed is undergoing rapid development. Fourth, the NBE watershed is an order of magnitude smaller  
94 in area than TRV's watershed. Fifth, NBE is located in a much wealthier area, with median household  
95 incomes three times higher than TRV. And sixth, and most critical with respect to sediment management,  
96 NBE has a Total Maximum Daily Load (TMDL) for sediment whereas TRV does not, yet there is a  
97 collaborative group of representatives from regulatory agencies, landowners, and other stakeholders that  
98 coordinate environmental management. Hence, these two sites in many ways represent end-points for  
99 both land uses and management for coastal valleys and embayments of Southern California: one system  
100 that is largely built out with a history of regulation under a TMDL, and one system that is rapidly expanding  
101 with voluntary collaboration to address sediment management.



102

103 Figure 1. Map of the case study watersheds. (a) shows NBE, with shading to indicate open water and riparian and  
 104 marsh habitat and circles to indicate the location of the sediment collection basins. (b) shows the full San Diego  
 105 Creek watershed. (c) and (d) similarly shows the TRV and the full Tijuana River watershed.

106 **2.1.1. Case 1: San Diego Creek/Newport Bay Estuary**

107 The NBE site is at the terminus of the Newport Bay Watershed, which extends to the Santa Ana Mountains  
 108 to the east and the San Joaquin Hills to the west and southwest (US EPA, 2017). The majority of runoff  
 109 from the 394 km<sup>2</sup> watershed enters Newport Bay from San Diego Creek, with smaller contributions from  
 110 the Santa Ana Delhi and Bonita Canyon channels.

111 The watershed is highly urbanized (nine cities are partly or fully within the watershed) with some  
 112 agricultural use (US EPA, 2017). Development of this area has occurred mostly in the last 50 years with  
 113 growth slowing in recent years. The City of Newport Beach is among the most affluent cities in California;  
 114 in 2015, the median annual household income was \$113,071, compared with \$64,500 for California as a  
 115 whole (Sanders et al., 2020).

116 NBE comprises two geographic areas: (1) the upper region of the bay is a nature preserve characterized  
 117 by an intertidal marsh that provides habitat for several threatened and endangered species and (2) the  
 118 lower region (Newport Harbor) falls within the City of Newport Beach and is developed with waterfront  
 119 homes, marinas for boating and commercial areas; both areas support numerous recreational activities  
 120 (Sanders et al., 2020). Newport Harbor was developed over the first half of the 20th century on sand dunes  
 121 and marshlands formed by the interaction of the Santa Ana River with the tides and waves of the Pacific  
 122 Ocean (Sanders et al., 2020). Sediment has been managed at this site by the Environmental Protection  
 123 Agency's (EPA) regulatory mechanism of a TMDL since 1999 through investment in infrastructure such as

124 sedimentation basins (Orange County Public Works, 2020). The sediment basins are located underwater  
125 at the head of Upper Newport Bay, and thus rely on gravitational settling during storm events. Excessive  
126 sedimentation in NBE initially occurred with the construction and erosion of soft-bottom drainage  
127 channels (Trimble, 1997), and thus source control in the watershed emphasizes channel armoring.

### 128 **2.1.2. Case 2: Tijuana River Valley**

129 Geographically, the Tijuana River Watershed is an approximately 4530 km<sup>2</sup> binational area that includes  
130 a diverse and complex drainage system ranging from 1800 m pine forest-covered mountains to the tidal  
131 saltwater estuary at the mouth of the Tijuana River in the United States, with the Tijuana River  
132 originating at the confluence of Arroyo Alamar and Río de las Palmas in Mexico (Tijuana River Valley  
133 Recovery Team, 2012). A wide variety of land uses are present in the watershed, from largely  
134 undeveloped open space in the upper watershed to highly urbanized<sup>1</sup>, residential, commercial, military,  
135 industrial, and agricultural areas in the lower watershed. The Tijuana River Valley was determined to be  
136 an area with 'lowest access to opportunity' within the City of San Diego (City of San Diego, 2019), and  
137 Imperial Beach is among the least affluent stretches of the Southern California coastline (Sanders et al.,  
138 2020). The 2015 median annual household income in Imperial Beach was \$46,659 (US Census Bureau,  
139 2020).

140 Nearly three-quarters of the watershed is located in Mexico, but the Tijuana River drains to the Pacific  
141 Ocean through an approximately 8-square mile area called the Tijuana River Valley (TRV) that is located  
142 immediately north of the border and contains the largest intact coastal wetland system in Southern  
143 California (Goodrich et al., 2019). Proximity to the rapidly developing and erosive canyon hillsides in  
144 Tijuana, particularly the Los Laureles Canyon (LLC) sub-drainage, presents sedimentation and burial risk  
145 to the wetlands downstream during rain events (Biggs et al., 2010; Goodrich et al., 2020). Sediment basins  
146 on Mexican and U.S. sides of the border intercept sediment and debris flows; unlike in NBE, TRV's  
147 sediment basins are located within riparian wetland (or arroyo) habitat.

148 In the TRV, there is no TMDL for sediment. Environmental management including sediment and debris  
149 challenges are addressed in part by the Tijuana River Valley Recovery Team, a collaborative group  
150 including regulatory agencies, landowners, and other stakeholders (Tijuana River Valley Recovery Team,  
151 2012). Additionally, Minute 320, an agreement developed by the International Boundary and Water  
152 Commission, guides cross-border collaboration and activities through its conceptual framework  
153 (International Boundary and Water Commission, 2015).

## 154 **2.2. Data and methods**

155 This research uses an inductive, qualitative approach to elicit information on sediment reuse from  
156 individuals who are experts on sediment management in Southern California. Our aim is to identify  
157 barriers to beneficial reuse—the “cause of an effect” rather than the “effect of a cause” (Smith, 2014)—

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<sup>1</sup> In 2010, the population of the San Diego-Tijuana border region was 4.8 million, making it the largest bi-national metropolitan area shared between the United States and Mexico (Al-Delaimy et al., 2014).

158 and a qualitative approach enables the researcher to assemble a causal framework when categories are  
 159 not known *a priori* (Moon and Blackman, 2014; Yin, 2017).

160 Twenty-two in-depth, semi-structured interviews were conducted with stakeholders on the current state  
 161 of sediment management in Southern California, discussing topics such as economics, policies and  
 162 regulations, extreme events and climate change impacts, and preferred future policy and management  
 163 interventions. Interviewees were sediment managers, defined as individuals who played a role (e.g.,  
 164 regulatory, programmatic, land management, advocacy) in NBE or TRV, as well as federal and state agency  
 165 actors who work at the regional or state level. Interviewees represented city and county governments  
 166 (n=7), state agencies (n=6), federal agencies (n=6), and NGOs (n=3) (Table 1). The initial list of interviewees  
 167 included key players in the sediment management system who were either prior contacts to the research  
 168 team or names obtained upon contacting organizations known to engage in sediment management or  
 169 regulation. To obtain coverage of organizational perspectives that our initial sample missed, additional  
 170 interviews were obtained through snowball sampling (Parker et al., 2020; van Rijnsoever, 2017), asking  
 171 interviewees to recommend additional individuals to speak with. The same interviewer was present at all  
 172 interviews, with one or two additional interviewers present. Interviews lasted approximately one hour.

173 **Table 1. Interviewees by Watershed and Organization Type**

Organization Type	NBE	TRV	Regional or State
City or County	City of Newport Beach, County of Orange (2), Orange County Parks	City of Imperial Beach, City of San Diego	
State Government	CA Department of Fish and Wildlife, Santa Ana Regional Water Quality Control Board	CA State Parks, San Diego Regional Water Quality Control Board	Bay Conservation and Development Commission, CA Coastal Commission, CA Coastal Conservancy
Federal Government		International Boundary and Water Commission, US Fish and Wildlife Service, Tijuana River National Estuarine Research Reserve (TRNERR) <sup>a</sup>	Environmental Protection Agency (Region 9) (2), US Army Corps of Engineers (Los Angeles District)
NGO	Orange County Coastkeeper	Surfrider Foundation, WiLDcoast	

174 *Note: In reporting interview quotes, we refer solely to organization type (rather than name) to preserve anonymity.*  
 175 <sup>a</sup>TRNERR is a federal-state-NGO partnership.

176 Interview questions were designed to: (1) identify how managers understand the coupled human natural  
 177 system they work within; (2) to produce a causal mental map from the vantage point of a sediment

178 manager of how their system — and decision-making related to sediment management in their system —  
179 works; and (3) to identify key threats, opportunities, challenges and possible innovations (Goodrich et al.,  
180 2019). Importantly, none of the interview questions focused specifically on beneficial reuse; the topic  
181 rather emerged when interviewees were asked about their goals for sediment management, current  
182 management approaches, and/or their desired innovations. Interviews were recorded and transcribed.

183 Using a modified grounded theory approach (Corbin and Strauss, 2007), iterative coding was used to  
184 identify emergent themes and patterns in the interviews. We began with broad categories based on the  
185 interview guide, such as “regulation” to capture any time a respondent discussed existing or proposed  
186 regulations or “movement” to capture discussions of sediment transport. These categories were  
187 iteratively refined to better match the terminology used by interviewees, and new categories were added  
188 when a topic was introduced that didn’t fit neatly into an existing category. Subcategories were added to  
189 capture detail (e.g., “dredging” added as a subcategory of “management approaches”, and  
190 “contaminants” added as a subcategory of “challenges”). For analysis, we focused on categories that were  
191 discussed by multiple interviewees. We then assessed which organization types had raised each topic,  
192 which watershed they were located in, and how discussion of these categories varied by watershed and  
193 by organization type. In the text, we provide quotes that are representative of perspectives raised by  
194 multiple organizations.

## 195 **3. Results**

### 196 **3.1. Perceived strengths and weaknesses of current approaches to sediment** 197 **management**

198 Current management approaches, as described in Section 2.1, are seen at a minimum to work in that they  
199 keep excess sediment out of the estuaries. Interviewees note that in Tijuana, for instance, it is far easier  
200 to manage excess sediment coming from the canyons that have retention basins than those that don’t  
201 (Federal). Likewise, NBE’s TMDL was seen as a pioneering approach to sediment management when it  
202 was implemented: “It was the first TMDL for sediment in California... A lot of other agencies look[ed] at  
203 ours and copied our approach” (State). The TMDL was also the first attempt to address sediment  
204 considerations from a watershed approach.

205 There were also many perceived weaknesses of the current approaches in both watersheds, which were  
206 described by one interviewee as “inelegant [and] ham-handed” (Federal). First, interviewees noted that  
207 the current approach of capture, dredge, and dump is expensive and inefficient. Dredging is “arduous and  
208 hard and long and expensive” (City/County), as is trucking sediment off site (Federal, City/County) and  
209 maintaining the sediment channels (City/County). Second, the regulatory regime underlying the approach  
210 is viewed as complex and at times burdensome. Permits for dredging or construction can take years to  
211 get: “If you don’t have an ongoing operation and maintenance program that gets implemented  
212 consistently, then you’ve got to jump through all the regulatory and permitting hoops from the very  
213 beginning” (City/County). In both watersheds, the permitting process is complicated by endangered  
214 species considerations. When sediment is not cleared from the channels or basins at regular intervals,  
215 plants take root and create habitat for protected species; as a result, when the sediment managers need  
216 to clean the channels or dredge, additional consultations for federal and state endangered species

217 protections are needed: “Since sediments have been there for so long, we have a lot of ESA issues; I mean  
 218 our basins are full of... all kinds of threatened and endangered species” (Federal, also City/County). This  
 219 incentivizes the need to dredge in order to ‘prevent’ sensitive habitats from developing, which in turn  
 220 hinders objectives of wildlife protection programs and regulations. Lastly, multiple interviewees stated  
 221 that shipping sediment to a landfill was wasteful: “the worst thing is probably put it in a landfill, but... that  
 222 happens too” (Federal, State).

223 Perhaps more importantly, the current approach was not perceived as adaptive to either social or  
 224 environmental changes. In both watersheds, development patterns are changing, altering sediment loads.  
 225 Both systems face increasing inundation and growing flood risks with sea level rise (Luke et al., 2018;  
 226 Sanders et al., 2020; Thorne et al., 2018), and managers did not feel that the current approach would help  
 227 coastal wetlands keep pace with sea-level rise. In NBE, development has slowed and the watershed has  
 228 reached close to full urbanization, so less sediment is coming into the drainage basins (City/County).  
 229 Managers worried that they might “control the sediment input into the bay to a degree where it becomes  
 230 sediment deficient, [such that] sea level rise will cause habitat loss” (City/County). As an added challenge  
 231 in NBE, the estuary is surrounded by bluffs, so managers worry that habitat cannot migrate to higher  
 232 elevations. In TRV, development is increasing and was viewed as “uncontrollable” (City/County) because  
 233 it happens across the border in Mexico. Managers thus have to prepare for larger than expected volumes  
 234 of sediment compared to natural or fully-urbanized watersheds, and there is acknowledgement that  
 235 changes in land use practices in Tijuana may trigger a different management scenario (Boudreau et al.,  
 236 2017). TRV managers felt that they currently had enough sediment that “we’re going to be fine in terms  
 237 of salt marsh habitat and sea level rise” (State), but that with more active management they could  
 238 maintain healthy habitats and recreational spaces as the system shifts.

239 Finally, managers do not feel that the current regulations and infrastructure are flexible enough to deal  
 240 with these changes. For instance, regarding the TMDL, an interviewee noted, “What’s frustrating is that it  
 241 was so prescribed. They didn’t allow it to be flexible, and ... what we’re looking for is to allow adaptive  
 242 management.” (City/County, also State). Another said, “We need flexibility... [T]hose hard prescriptive  
 243 requirements in the bay and looking at the bay as a static [isn’t flexible]” (City/County).

### 244 **3.2. Opportunities for beneficial reuse**

245 Given the challenges with the current approach, many of the interviewees discussed the desire to make  
 246 the sediment system more resilient and sustainable. Approaches discussed include both reusing dredge  
 247 material to nourish beaches or provide ecological benefits and (in NBE) directly reconnecting the upper  
 248 watershed (sediment sources) with downstream wetlands and beaches. (“We are beneficially reusing  
 249 sediment, putting it down drift where it would have gone if ... it hadn’t been trapped in harbors” (Federal);  
 250 We need to ensure “that sediment is present to allow wetlands to keep pace with sea level rise” (Federal,  
 251 also NGO).) These approaches are seen to both enable adaptation to SLR and changes in development  
 252 patterns, but also to potentially reduce dredging costs.

253 In TRV, several projects are completed and underway to explore alternatives to the current practice of  
 254 disposing of sediment excavated from sediment basins in landfills. One such alternative is nearshore  
 255 placement; the United States Geological Survey (USGS) conducted a pilot project from 2008-2009 at the



256 Tijuana River National Estuarine Research Reserve involving the placement of 45,000 cubic yards of  
257 sediment with approximately 40% fine-grained material in the coastal nearshore, and monitoring the  
258 processes of fine-sediment transport (Warrick, 2013). Results indicated that the fine-grained sediment  
259 was winnowed from the coarse material at the placement site. As a result, coarse material stayed in the  
260 nearshore where it could contribute to littoral sediment budgets and the fine material was carried  
261 offshore, distributed over long distances, and settled into deeper water where fine sediment makes up  
262 the majority of the existing substrate (Farnsworth and Warrick, 2007; Warrick, 2013). The sediment  
263 volume was an order of magnitude smaller than the sediment volume associated with an annual river  
264 discharge, suggesting that it would take ten such nearshore placement events per year to equal the annual  
265 river discharge contribution to the coastal sediment budget. Additionally, no impacts to nearby biological  
266 communities were detected (Everest International Consultants, Inc. and Nordby Biological Consulting,  
267 2017). Results from this study were discussed between managers and regulators in focus groups to  
268 explore opportunities for future permitting of nearshore placement of dredged sediment, a more  
269 beneficial alternative in TRV and the region than disposing of sediment in landfills (Goodrich and Warrick,  
270 2015).

271 Stakeholders in the TRV region also received funding from the state to plan for the reuse of excavated  
272 sediment to restore the Nelson Sloan Quarry, a former sand and gravel quarry in the watershed. This  
273 project is in planning phases, and interviewees articulated their aspirations for it: “The hope is that we  
274 will be able to take the sediment that we're digging out of the sediment basins, ... out of other flood  
275 control channels in the river valley, and from our salt marsh restoration projects and take them to this  
276 abandoned quarry and restore that quarry back to natural hillside. That's a cheaper way to manage  
277 sediment, because of the proximity. An example...that would not only be economically more viable, but  
278 it would have a secondary environmental benefit.” (State).

279 While NBE had not begun any specific projects for beneficial reuse, interviewees also discussed wanting  
280 to use thin layer augmentation to restore habitat in the upper bay and nearshore placement to nourish  
281 beaches and more cost effectively dispose of dredge material: “We're looking at putting sediment on the  
282 habitat to see if the plants can grow up through it, which would allow us to be able to do that in places  
283 where we would actually increase the elevation” (Federal). They are currently looking to other areas for  
284 guidance. Regarding thin-layer placement, one manager told us of their goal to find a demonstration  
285 project elsewhere:

286 “[In] Upper Newport Bay, it seems like we're a little bit more sediment-starved now. It's been kind  
287 of a surprising outcome because for so long, we were so hyper-focused on removing sediment,  
288 that now we kind of want it. We're wondering, how are we going to maintain these habitats? We  
289 kind of look to Seal Beach Wildlife Refuge [in north Orange County]. They did a lot of the  
290 augmentation in their marsh areas because they don't have any sediment inputs. I think the first  
291 project failed. I don't know if they're going to attempt it again, because it was pretty expensive.  
292 We're sort of kind of looking around to see, okay, well, who's augmenting their habitat [so that  
293 we can learn to make it work].” (State)

294 In NBE, there is also interest in modifying the capture of sediment from upstream portions of the  
 295 watershed, for instance through less frequent or extensive dredging, to allow more sediment to enter the  
 296 bay.

297 Interviewees saw a shift in mindset as being one of the key enablers of this new thinking: “10 years ago  
 298 we didn’t have this conversation about thin layer placement” (Federal). For instance, regulators were  
 299 perceived as being less rigid regarding the implementation of the TMDL (City/County), which permitted  
 300 some flexibility around developing pilot projects that meant leaving sediment in Newport Bay.

### 301 **3.3. Barriers to beneficial reuse**

#### 302 **3.3.1. Regulatory barriers**

303 There were numerous perceived barriers to beneficial reuse or other changes that would enable a more  
 304 sustainable system. First, regulatory inflexibility was seen as a major barrier. In a general sense, the  
 305 permitting regime was seen as a barrier, as “what any one agency needs to permit [beneficial reuse] and  
 306 what monitoring they want, and the specific conditions of the permit, that’s where things can get jumbled  
 307 up” (Federal). Interviewees noted that as soon as you add multiple agencies, those permits requirements  
 308 can conflict with each other and slow down the process (City/County). And existing regulations, like the  
 309 California Coastal Act, were seen not to match current needs and understandings of natural infrastructure:

310 “There’s an understanding, in general, about how resilient coastlines include things like healthy  
 311 marshes and different natural infrastructure that can be protective of development behind it,  
 312 potentially. I think there is a definite openness to innovative approaches. Our challenge,  
 313 sometimes, is finding how to get those projects, how to get them to a place where it’s consistent  
 314 with the Coastal Act, which hasn’t been updated since 1973. That’s the challenge.” (State)

315 Likewise, while USACE does some sand sorting to make dredged material more easily reusable, they can’t  
 316 keep the sediment for too long because that triggers regulations that “restrict... selling federal property  
 317 for beneficial reuse” (Federal).

318 These regulatory challenges have definitely limited change in both watersheds. The current innovations  
 319 in TRV, like Nelson Sloan Quarry, were perceived to be “held up” in bureaucratic processes (City/County,  
 320 State), despite stakeholders having funding to implement them. For instance, after receiving a grant from  
 321 the state, the City of Imperial Beach was told they could not maintain the Quarry on their own, but would  
 322 need jurisdictional agreements from the State Park and San Diego County. Likewise, stakeholders in NBE  
 323 felt constrained by the TMDL. As one interviewee said, “We’ve done our job, we’ve met our objectives [of  
 324 reducing sediment loads]. We want out... [but] Once you’re in the TMDL hotel, you’re never checking out”  
 325 (City/County).

#### 326 **3.3.2. Technical barriers**

327 Second, reusing sediment faced several technical challenges. Contaminated sediments were a concern in  
 328 both watersheds, with selenium (in NBE), trash, and sewage all mentioned. In both watersheds,  
 329 stakeholders also raised the need to match the grain size of available sediment to its use. For instance, in  
 330 doing their nearshore placement experiment, TRV stakeholders discovered the importance of grain size:

331 “It ended up being that the sand was really coarse. Well, the science at the time said use coarse sand  
332 [because] it sticks around longer... One of the consequences of having coarse sand is then you had more  
333 water flowing in through it and we had some inundation problems with, somehow, water washing up on  
334 the back beach soaking into the sand. Instead of draining back out towards the ocean, [it] drained back  
335 out towards the estuary.” (City/County). Another interviewee noted that conversations can stall because  
336 people get hung up on grain size (Federal), underscoring its importance. And lastly, interviewees noted  
337 that there are still many uncertainties about how to do placement effectively (NGO). The uncertainties  
338 are compounded by the fact that much of what managers do know comes from a few pilot projects in the  
339 region and elsewhere: “I think you have to think very hard about what you’re intending to scale up... You  
340 just can’t get around the site-specific nature of all of our estuaries and bays. That is just how it is. If you  
341 try too hard to take an approach and fit it exactly into a different—you just increase the chance of failure.”  
342 (State).

343 Interviewees also felt that the scalability challenge interacted with regulatory inflexibility, as pilot projects  
344 didn’t serve as a strong enough basis to update regulations: “I think changing policies on any one pilot is  
345 hard. If there were several pilots, say, along the coast ... and we found consistent results and this and this  
346 is—then that starts being like, “Okay, we have a basis for making decisions.” (Federal, also State).

347 A final technical challenge related to the timing of placements. Sediment placement had to coincide with  
348 optimal hydrological conditions: “We would do a placement activity potentially when the river’s flowing,  
349 and it would be just a blip in the radar compared to what’s coming down through the system naturally”  
350 (Federal). Given Southern California’s infrequent but large rainstorms, this could be challenging. And  
351 specifically for beneficial reuse, the sediment had to be available at the same time as its designated use:  
352 “It’s really hard to logistically match up a restoration project with a dredging project. It’s just the timing  
353 and the access. They’ve got to be dredging exactly when you need the sediment because they don’t want  
354 to stockpile it, and [it] can’t sit on the boat.” (Federal).

355 Interestingly, some of the technical uncertainties raised may be more perceived than real. Regarding  
356 grainsize, a commonly cited regulation was the “80/20 rule”, which prohibits the use of material  
357 containing more than 20% fines for beach nourishment purposes. However, interviewees disagreed  
358 whether this was a hard-and-fast regulation (Federal) or simply a “rule of thumb” that could be treated  
359 more as a guideline (State). During a focus group held in 2014, where the implications of the 80/20 rule  
360 were discussed by sediment and coastal managers, it was clarified that regulatory agencies rely more on  
361 site information (i.e., appropriate grain size) when making decisions, rather than considering this as an  
362 exclusionary rule of thumb (Goodrich and Warrick, 2015; see also California Coastal Sediment  
363 Management Workgroup, 2005).

364 Similarly, regarding contamination, interviewees in TRV disagreed whether they had clean sediment if all  
365 of the trash and debris was removed. For instance, one interviewee said, “mostly in the sediment in the  
366 valley itself, the sediment has been pretty clean. There’s been some residual pesticides. It’s actually really  
367 high-quality beach sand” (State). From another perspective, “We have no idea what’s in the sediment.  
368 There’s a very strong suspicion that there’s something well beyond just sewage. We’re talking about  
369 suspected chemicals in heavy metals.” (NGO).

**370 3.3.3. Psychological barriers**

371 Third, interviewees recognized that there were psychological barriers that would have to be overcome in  
372 order to implement beneficial reuse. For instance, in NBE, beach visitors have complained that placed  
373 sediment is polluted because it looks different than the white beaches they're used to (City/County). And  
374 in TRV, there is a perception that reconnecting the system would introduce trash from the Mexican side  
375 of the border (State). More broadly, long held assumptions about 'effective' management would have to  
376 change in both watersheds. For instance, among environmentalists, many are uncomfortable with  
377 managed restoration, thinking that work with machines can't be "natural": "We've received so many calls  
378 from people like, 'There's a bulldozer in the estuary. Oh my God. What are you guys going to do? Are you  
379 going to go chain yourselves to it?' We're like, 'No. We actually want it in there.'" (NGO). Similarly,  
380 environmental agencies felt that many engineers and regulators are more supportive of hard structures  
381 because they provide more certain performance (State). Interviewees described the need to change these  
382 assumptions as affecting many different individuals, from educating visitors to the beach to needing to  
383 convince the "chain of management" that a new approach is better (Federal).

**384 3.3.4. Financial barriers**

385 The fourth set of barriers were financial. Stakeholders in both watersheds raised concerns about the  
386 monetary costs associated with getting the sediment, transporting the sediment, and changing the  
387 regulations (e.g., the TMDL) to allow reuse. Nourishment would still require the dredging of sediment, but  
388 with potentially increased transportation costs: "we can barely get enough money to just take that  
389 material, dredge it, and put it right down coast" as opposed to move it the longer distances potentially  
390 needed for beneficial reuse projects (Federal, also City/County). For projects under US Army Corps of  
391 Engineers (USACE) authority<sup>2</sup>, this is a major barrier, as they are required to choose the least-cost option,  
392 even if that option does not provide as many benefits; most dredging projects require USACE  
393 authorization. Other financial concerns revolved around the costs of restoration (State), reconnecting the  
394 upper watershed to the lower estuary to enable sediment to move through (State), and even paying to  
395 update the TMDL technical report (City/County).

**396 3.3.5. Inter-organizational barriers**

397 The final challenge relates to collaboration and coordination between organizations. Because there are  
398 many players and jurisdictions engaged in sediment management, individuals have to work across  
399 organizational boundaries, but it's hard to initiate and maintain collaboration. Working between agencies  
400 is difficult because each organization has different goals: "Having multiple agencies make it even more  
401 difficult because here we've got to deal with the federal government. We've got to deal with the Coastal  
402 Commission and all the state regulatory agencies and they don't always agree among themselves"  
403 (City/County). In instances where there is coordination, a lack of leadership still hinders progress: "We go  
404 to meetings, but we don't have any follow-up actions because there's no one championing this"  
405 (City/County). And in other cases, collaborations that were once perceived as successful are now "shutting  
406 down". For instance, regarding the cross-border collaboration created by Minute 320, one interviewee

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<sup>2</sup> USACE is the primary federal regulator of sediment under §404 of the Clean Water Act (Ulibarri and Tao, 2019).

407 said, “Now because it's turned into a legal issue, certain people are not coming to the table anymore,  
 408 because that's the advice that their counsel [gives]” (State).

409 **4. Discussion**

410 In both NBE and TRV, interviewees articulated clear goals for what they envision as sustainable coastal  
 411 sediment management to entail, particularly relating to beneficial reuse of sediment. Indeed, they were  
 412 enthusiastic for the possibilities that beneficial reuse raises for their watersheds. And in both cases,  
 413 though more prominently in TRV, stakeholders are actively making changes via pilot projects and  
 414 infrastructure development to become more sustainable. However, we found that managers face  
 415 substantial constraints to changing the system, including regulatory inflexibility, technical difficulties,  
 416 psychological barriers, financial constraints, and inter-organizational collaboration and coordination  
 417 challenges. These barriers pose a problem for long term resilience, given that both watersheds have  
 418 already-degraded ecosystems and face future changes from sea-level rise and altered urbanization  
 419 patterns.

420 Table 2 summarizes the perceived barriers to beneficial reuse of sediment, along with which types of  
 421 organizations mentioned them. All of the barriers were mentioned by interviewees in both watersheds,  
 422 although the exact characteristics varied. Table 2 also shows that all of the barriers were cross-cutting by  
 423 organization type, with all mentioned by multiple organization types and all but inter-organizational  
 424 collaboration mentioned by all organization types. This suggests that these are widespread challenges  
 425 that are not unique to a single agency or organization.

426 **Table 2. Organization Types Mentioning Perceived Barriers to Beneficial Reuse of Sediment**

427

Barrier	City	County	State	Federal	NGO
Regulatory	X	X	X	X	
Technical		X		X	X
Psychological		X	X	X	X
Financial	X	X	X	X	
Inter-organizational	X		X		

428

429 At the same time, this study suggests several promising dimensions of sediment management. First, while  
 430 this study was framed as a comparative case study given the strong differences in context, both  
 431 watersheds actually faced very similar opportunities and barriers. Despite the watersheds’ drastically  
 432 different sizes, financial setting, trends in development (TRV’s rapid urbanization versus NBE’s slowing  
 433 development), and overall level of infrastructure development, interviewees in both watersheds  
 434 articulated the same desire to see increased beneficial reuse and the same set of challenges. The only  
 435 exceptionally distinct difference was the binational setting in TRV, which made for a much more  
 436 complicated governance setting. However, the same challenges of working across organizational and

437 jurisdictional settings was articulated by NBE interviewees. This suggests that perhaps the categories of  
 438 barriers to beneficial reuse that we identified are fairly universal across different physical and  
 439 socioeconomic settings.

440 Additionally, many of the interviewees pointed to other locations, for example elsewhere in California and  
 441 on the East Coast, for possible options for sediment management. This shows a willingness to change and  
 442 innovate, which is quite different than other sectors (like water) where managers tend to be conservative  
 443 and resistant to innovation (Lach et al., 2005). This also suggests that any barriers to innovation are not  
 444 due to a lack of awareness or knowledge about potential options.

## 445 **5. Recommendations**

446 As beneficial reuse of sediment has the potential to bolster coastlines against sea level rise, finding ways  
 447 to implement it more effectively and efficiently is critical. In this study, we found that despite a common  
 448 desire to incorporate beneficial reuse more prominently as a management approach in both case study  
 449 watersheds, regulatory inflexibility, technical difficulties, psychological barriers, financial constraints, and  
 450 inter-organizational collaboration and coordination challenges limited the ability of stakeholders to do so.

451 While we have focused on identifying barriers, each barrier also highlights opportunities that would help  
 452 make beneficial reuse an achievable approach for Southern California, and likely for other regions.

453 Regulatory:

- 454 ● Create streamlined permitting approaches for beneficial reuse projects meeting certain  
 455 predefined criteria.
- 456 ● Consider benefits of sediment to the coast during when issuing or updating a sediment TMDL.  
 457 Clarify expectations around the 80/20 rule—that it is a rule, not a regulation—for project  
 458 proponents with projects that involve fine grained sediment.

459 Technical:

- 460 ● Support additional studies, modeling, and pilot projects to advance the practice of beneficial  
 461 reuse. In particular, consider projects that advance knowledge about scaling up or translating  
 462 results between locations. This includes the optimal frequency (or triggers) for implementing  
 463 reuse.

464 Psychological:

- 465 ● Educate the public about the benefits and hazards of sediment placement, especially for beaches  
 466 or recreational areas.
- 467 ● Engage in pilot projects to reassure skeptical managers and publics about its effectiveness.

468 Financial:

- 469 ● Relax the requirement for governments to use the lowest-cost option when an alternative meets  
 470 diverse social or environmental needs.

- 471 ● Provide funding for both pilot and large-scale projects (especially those that provide insight that  
 472 can apply to other regions or coastlines).  
 473 ● Allow for credit trading with potential users of sediment to reduce dredging cost.  
 474 ● Allow the benefit of sediment delivery to coastal environments to be considered in benefit-cost  
 475 analysis.

476 Inter-organizational:

- 477 ● Provide facilitation and incentives for interorganizational coordination and innovation.  
 478 ● Support organizations to act as leaders in regional sediment management via funding.  
 479 ● Support existing interagency sediment management workgroups to better coordinate activities.  
 480 ● Explore opportunities to “match” entities with excess sediment from projects to entities that need  
 481 sediment for restoration projects.

482 Many of these recommendations are most relevant for federal and state agencies, as they hold regulatory  
 483 authority and have the most resources to support new studies and coordination approaches. However,  
 484 addressing technical, psychological, and inter-organizational barriers can be more effective if all  
 485 organization types (cities, counties, and NGOs) are engaged, since these organizations have strong local  
 486 knowledge and connections with the affected public.

487 Although these recommendations are specific to Southern California, we anticipate that similar  
 488 recommendations would apply elsewhere. The two watersheds have very different socioenvironmental  
 489 contexts, but the barriers we identified were cross cutting: they were raised by a diversity of organization  
 490 types and by interviewees in both watersheds, suggesting more widespread applicability. For instance,  
 491 while NBE’s TMDL was developed specifically for that watershed’s sediment and land use context, it is  
 492 likely that other locations have rigid regulations that may constrain future innovation. Thus, providing  
 493 financial incentives, making regulations more flexible, conducting pilot studies and building models to  
 494 grow knowledge about beneficial reuse in a particular context (or under various scenarios), educating the  
 495 public and decision-makers, and providing support for interorganizational coordination will likely pave the  
 496 way for more implementation of beneficial reuse around the world.

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