Framing the Problem of Flood Risk and Flood Management in Metropolitan Los Angeles

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ABSTRACT: This paper develops the concept of flood problem framing to understand decision-makers' priorities in flood risk management in the Los Angeles Metropolitan Region in California (LA Metro). Problem frames shape an individual's preferences for particular management strategies and their future behaviors. While flooding is a complex, multifaceted problem, with multiple causes and multiple impacts, a decision-maker is most likely to manage only those dimensions of flooding about which they are aware or concerned. To evaluate flood decision-makers' primary concerns related to flood exposure, vulnerability, and management in the LA Metro, we draw on focus groups with flood control districts, city planners, nonprofit organizations, and other flood-related decision-makers. We identify numerous concerns, including concerns about specific types of floods (e.g., fluvial vs pluvial) and impacts to diverse infrastructure and communities. Our analyses demonstrate that flood concerns aggregate into three problem frames: one concerned with large fluvial floods exacerbated by climate change and their housing, economic, and infrastructure impacts; one concerned with pluvial nuisance flooding, pollution, and historic underinvestment in communities; and one concerned with coastal and fluvial flooding's ecosystem impacts. While each individual typically articulated concerns that overlapped with only one problem frame, each problem frame was discussed by numerous organization types, suggesting low barriers to cross-organizational coordination in flood planning and response. This paper also advances our understanding of flood risk perception in a region that does not face frequent large floods.

SIGNIFICANCE STATEMENT: This paper investigates the primary concerns that planners, flood managers, and other decision-makers have about flooding in Southern California. This is important because the way that decision-makers understand flooding shapes the way that they will plan for and respond to flood events. We find that some decision-makers are primarily concerned with large floods affecting large swaths of infrastructure and housing; others are concerned with frequent, small floods that mobilize pollution in low-income areas; and others are concerned with protecting coastal ecosystems during sea level rise. Our results also highlight key priorities for research and practice, including the need for flexible and accessible flood data and education about how to evacuate.

KEYWORDS: Decision-making; Emergency preparedness; Flood events; Planning; Societal impacts; Vulnerability

1. Introduction

Flooding is one of the most frequent and substantial natural hazards globally (Hanson et al. 2011; Hinkel et al. 2014; Jongman et al. 2012; Institute for Economics and Peace 2022; IPCC 2021). Between 2005 and 2015, flooding accounted for almost one-half of all weather-related disasters, affecting 2.3 billion people (Wahlstrom and Guha-Sapir 2015). In the United States, 90% of federally declared disasters involve flooding (FEMA 2021), and over 40 million people live in the 100-yr flood zone, the area with a 1% annual risk of flooding (Wing et al. 2017). In both the United States and globally, the number of people living in high-flood-risk areas is increasing due to rapid urban growth and expanded housing development in floodplains (Tellman et al. 2021; Climate Central 2019). Additionally, sea level rise (Hallegatte et al. 2013; Hauer et al. 2016; Kulp and Strauss 2017), projected increases in heavy precipitation events (Pachauri et al. 2014), and aging infrastructure (Powell 2021) each amplify future flood risks, with multiplicative impacts when occurring in compound.

While flooding is a multidimensional hazard, with multiple causes and multiple impacts, a decision-maker is most likely to manage only those dimensions of flooding about which they are aware or concerned. In other words, which dimensions of flooding decision-makers are thinking about and how they define the "problem" of flooding will shape what responses they take. We use "flood problem framing" to describe an individual's conceptualization of flooding and its impacts (Shön and Rein 1994; Elliott 2003). Research on problem framing has shown that the way a problem is conceptualized determines "which aspects of the problem are addressed, where managers seek relevant knowledge, and which solutions are considered

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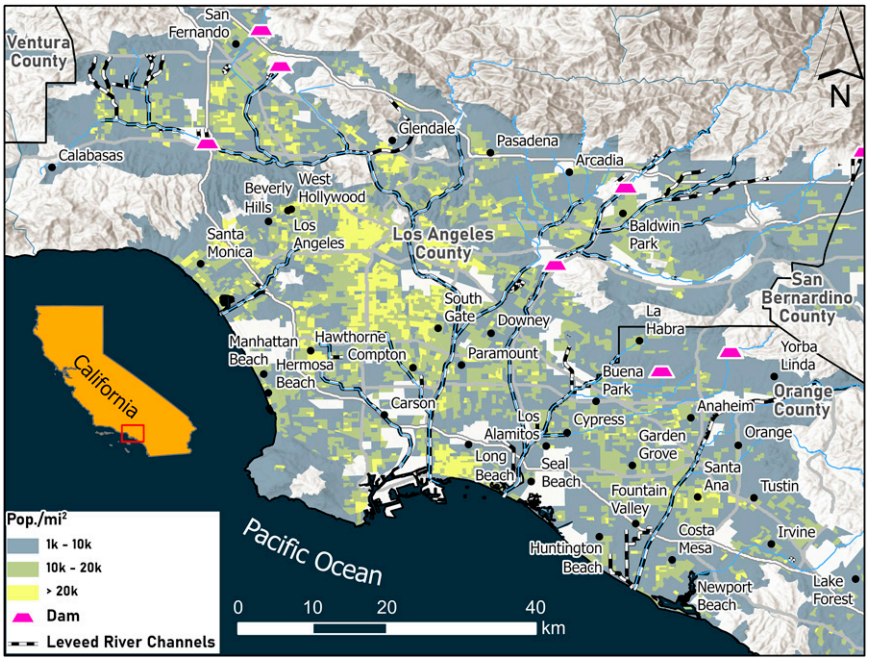

FIG. 1. The LA Metro study area including population density, flood channels, levees, and dams.

pertinent" (Cravens et al. 2021, p. 4; see also Hisschemöller and Hoppe 1995; Ulibarri et al. 2019). Problem frames shape an individual's preferences for particular management strategies and their future behaviors (Ives and Kendal 2014).

Existing flood management research has explored the ways that managers diagnose the problem of flooding and the mental models they hold about its causes and impacts (Morss et al. 2015; Crabbé et al. 2015; Wood et al. 2012)—concepts that closely overlap with our use of problem framing. In a study comparing the Netherlands and Belgium, Crabbé et al. (2015) explore the ways that policy makers "diagnose" the problems of flooding and climate change and find that communicating reduced frameworks helped stakeholders identify integrated policy approaches (Crabbé et al. 2015). Articulating an individual or organization's problem frames can also help to identify gaps in the types of risks and impacts currently considered and enable better communication across the many stakeholders responsible for managing flood risks. For instance, in a study following a large flood event in Boulder, Colorado, Morss et al. (2015) found that managers had many competing conceptions of flash flood risks, and that resolving these competing frames would enable development of clearer, more effective warning systems. Likewise, in a study comparing the mental models of flood risk management between experts and laypersons, Wood et al. (2012) identify gaps in how residents in flood-prone areas understand the role of flood control infrastructure, leading them to undervalue potential flood risks and not respond to evacuation orders.

These existing studies focus on locations that regularly or recently faced large floods. However, in many arid cities, floods occur infrequently, and flood-control infrastructure has more-or-less eliminated floods from recent memory, which could impact the problem frames managers hold and the flood-related actions they take. The present study applies the problem framing concept to flood-related decision-making in one arid megacity: the Los Angeles Metropolitan Region in California (LA Metro), which new research shows has far larger potential flood risks than was previously believed (Sanders et al. 2022). Drawing on focus groups with flood control districts, city planners, nonprofit organizations, and other flood-related decision-makers, we ask the following questions: How do local governments and community-based organizations frame the problem of flooding in greater Los Angeles? Specifically, what types of flood exposure and flood vulnerabilities are they most concerned about, and how do they assess the region's ability to cope with future flood events?

The paper begins with an overview of flood risks in the LA Metro, then describes our data collection and analyses. We then present specific flood-related concerns raised by focus group participants, describing concerns related to characteristics of the flood event, the impacts it has on people, infrastructure, and the environment, and the region's capacity to respond. We then assess the types of organizations who articulated each concern and aggregate the flood concerns into three overarching problem frames. We conclude with a brief discussion.

2. Case background

The LA Metro is the second largest metropolitan area in the United States and 30th globally and has the third largest municipal GDP globally. We focus on the portion of the LA Metro encompassing Los Angeles and Orange County (Fig. 1), which has a population of 13.2 million and covers 4850 mi^2 (~12 560 km^2), making it the most densely populated urban area in the country.

TABLE 1. Overview of attendees at the focus groups.

Date	Target audience	Total attendees	Active participants[a] by organization type
8 Apr 2021	Planning and policy organizations	48	28 participants: city planning departments (n = 6), nonprofits (n = 7), consulting firms (n = 5), universities (n = 6), and special districts (e.g., resource conservation or transportation; n = 4)
24 May 2021	Community-based organizations	12	7 participants: nonprofits (n = 4), state agency (n = 1), university (n = 1), and city planning department (n = 1)
9 Jun 2021	State and federal agencies	17	3 participants: California Department of Water Resources (n = 2) and universities (n = 1)
21 Jul 2021	Flood control districts	15	5 participants: Los Angeles county (n = 3) and Orange County (n = 2)

[a] Count of participants who spoke or wrote in the Zoom chat during the focus groups.

The population is diverse: 56% white, 18% Asian, 8% Black, 2% American Indian, 0.6% Native Hawaiians/Pacific Islanders (NHPI), and 23% some other race[1]; 45% of the population identifies as Hispanic (U.S. Census Bureau 2022).

Southern California is famous for sunny weather; concerns about droughts, earthquakes, and fires typically receive public attention. However, the region is exposed to several different types of flooding including fluvial flooding associated with multiday atmospheric river events (Jones 2019; Porter et al. 2011), coastal flooding from storm tides, waves, and rising groundwater (Gallien et al. 2018), pluvial flooding from expansive hardening of the land surface, where even small storms create localized street flooding (National Academies of Sciences, Engineering, and Medicine 2019), and mud and debris flows from the surrounding mountains (Kean and Staley 2021).

Major infrastructure investments including construction of dams, flood channels, and levees have been made for protection (Fig. 1) but are unlikely to contain an extreme event comparable to a 100-yr flood, and extensive damages and fatalities can be expected (Sanders and Grant 2020; Porter et al. 2011; Sanders et al. 2022). Substantial economic impacts stem from the region's population, economic stature, and role in global and U.S. trade (Wing et al. 2016). The potential for high fatalities is linked to population density, exposure to ultrahazardous flooding with high concentrations of sediment and debris, and unpredictable flow paths carved through developed areas (Sanders and Grant 2020). Furthermore, recent research suggests that the cumulative risk of frequent nuisance flooding can be comparable to rare extreme events (Moftakhari et al. 2017a).

In summary, the LA Metro faces a wide range of flooding challenges, from catastrophic events that overwhelm infrastructure and send high velocity floodwaters with mud and debris through communities to more chronic problems with standing water from high tides and seasonal rainfall events. But how the problem of flooding is framed across the region and by those responsible for managing infrastructure and resources to address flooding, is poorly understood.

[1] Percentages sum to over 100 because individuals who selected two or more races (7%) are counted twice.

3. Methods

This research is embedded in a larger interdisciplinary project modeling flood risk in the LA Metro, which entailed the application of an innovative, fine-resolution flood model that captures flood distributions at the metropolitan scale, overlaying socioeconomic indicators to understand the types of communities affected by flooding, and developing interactive, online visualizations (i.e., maps) for exploration and discussion of flood risks (Sanders et al. 2022). As part of the project, we conducted four focus groups with flood-related decision-makers in the LA Metro, which form the data for this article. We define flood decision-makers as individuals who work for an organization whose actions shape the magnitude of flooding (e.g., via land use or infrastructure decisions) or who work in flood risk communication, climate adaptation, or response and recovery of flood-affected communities; these include local, state, and federal agencies, nonprofit organizations, and businesses.

Focus groups are a relatively efficient way to generate diverse qualitative insights from many individuals. Relative to individual interviews, focus groups have been shown to generate the same number and range of concepts or issues as a series of individual interviews (Guest et al. 2017; Namey et al. 2016). Focus groups also benefit from the group setting, as participants can build on and/or contradict one another's responses (Guest et al. 2017; Krueger 2014; Kidd and Parshall 2000). However, focus groups do not allow as much depth of response from each individual participant as a semistructured interview, so our data are limited in that we do not have a lot of details from each participant.

Between April and July 2021, we held four 90-min focus groups, each targeting a slightly different group of flood-related stakeholders (Table 1). The April and June focus groups were presented as part of two ongoing workshop series for practitioners, with invitations distributed to each workshops' email listserv. The April focus group was presented via the LA Regional Collaborative, a convening body for government and nonprofit dialogues about climate resilience in Los Angeles. The June focus group was presented via the University of California (UC) FloodHub, which coordinates monthly dialogues between academic researchers and flood-adjacent

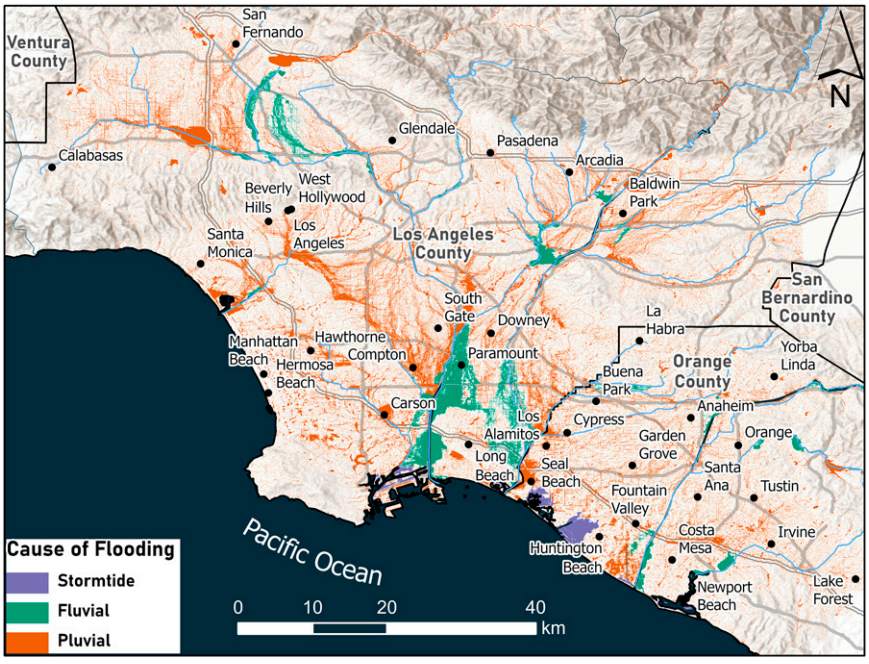

FIG. 2. Regional, fine-resolution model of areas at risk of flooding from different flood drivers including 100-yr storm tides (purple), 100-yr flood peaks that are not contained by flood channels (fluvial; green), and 100-yr rainfall (pluvial; orange) (Sanders et al. 2022). An online version of the data was presented to focus groups to explore the overlay between flood hazards and community vulnerability and stimulate discussion.

state agencies. For the May and July focus groups (targeting community-based organizations and flood control districts, respectively), the research team identified appropriate organizations from internet searches and recommendations from our networks and invited potential participants via email.

As the research was conducted during the COVID-19 pandemic, all focus groups were virtual, using the Zoom video conference platform. All invited participants work in settings where virtual meetings have become commonplace during the pandemic, so we assume a relatively high familiarity with video conferencing applications. However, to support as inclusive a conversation as possible, we followed best practices for online focus groups, including inviting participants to change their name to an anonymous handle, allowing use of the phone for meeting access, careful facilitation to ensure everyone had a chance to respond, and monitoring connectivity issues to bring dropped participants back up to speed (Lobe 2017). Meetings were also kept to 90 min to help to maintain attention and reduce "Zoom fatigue."

All four focus groups followed the same structure. First, as part of their introductions, participants were asked to write (in the Zoom chat) their top concern related to flooding in the region and to note where flooding stands on the list of policy issues they manage. Second, as a primary objective of the focus groups was to receive feedback on the realism of flooding depicted by the regional model, the research team presented in-progress visualizations of flood hazard areas and community vulnerability (e.g., Fig. 2), followed by a brief question-and-answer session focusing on flood model development, implementation, and validation. Third, participants were facilitated in a 30-min discussion around opportunities to enhance flood risk management in the region. The discussions followed a semistructured approach, which allows for participants to share their views and experiences on a predefined set of questions, but also provide space for new themes or understandings to emerge via impromptu follow-up questions (Stewart and Shamdasani 2014). Each discussion covered three themes: 1) participants' current flood awareness and concerns, 2) their reaction to the flood models, and 3) their views on social disadvantage and flood risk in LA. The interview guide is provided in the appendix. The discussions were facilitated by the author team. The focus groups were recorded and automatically transcribed via Zoom.

Overall attendance varied from 12 to 48. However, some participants only attended the presentation of the flood maps but did not stay for the facilitated discussion. Attendees in the facilitated discussions ("active participants" in Table 1) ranged from 3 to 28 per focus group (the latter broken into three groups of 8–10 participants).

The focus group transcripts and Zoom chat records were analyzed in NVivo qualitative analysis software. We used a modified grounded theory coding approach (Corbin and Strauss 2008; Maxwell 2012; Creswell and Poth 2016), wherein stated concerns about flooding and flood management were categorized into themes inductively from the data themselves. The first two authors conducted three rounds of coding. A

first round of open coding identified repeated topics (e.g., types of flooding or impacts on particular types of infrastructure), which we used to generate our coding scheme. The second and third rounds were conducted to refine the coding scheme, ensure that codes were applied consistently, and apply emergent codes to all focus groups. Individual codes were then organized into larger themes reflecting codes pertaining to qualities of the flood itself, the impacts the flood has, and the ability to respond to the impacts–these themes form the structure for the results section.

To understand which types of organization hold each problem frame, we attributed each statement or chat entry to an individual speaker (and affiliated organization type) and then compared how many times each code was mentioned by an individual from each organization type. To observe overlaps between exposure, vulnerability, and resilience, we cross tabulated mentions of each type of flood exposure with each type of vulnerability. Finally, to condense the numerous flood concerns into underlying problem frames, we conducted a principal components analysis (PCA). PCA is a statistical approach that reduces a large set of variables to a smaller number of components, while still explaining overall variance in individual responses. Our PCA reduced the flood concerns mentioned by each individual into three[2] components that together explained 43% of overall variance. PCA was completed using the *FactoMineR* package in the R software (Lê et al. 2008).

4. Results

In this section, we first describe the different problems focus group participants articulated about flooding in the LA Metro region. We organize the concerns into four sections: hazard (concerns about specific types of floods), exposure and vulnerability (concerns about specific impacts from floods on people, infrastructure, housing, and other human and natural assets), management (concerns about the region's current flood management), and proposed solutions. This grouping reflects the common understanding that a hazards' impacts depend on exposure to the hazard, vulnerability of exposed people, infrastructure, and environments, and the capacity of the system to plan for or respond to the hazard (Cardona et al. 2012; Masterson et al. 2014). Within each section, concerns are listed by order of frequency, with concerns mentioned by more individuals presented first. In section 4e, we then evaluate overlap between concerns, to identify the types of organizations who articulated them and how specific hazards relate to particular vulnerabilities or adaptive capacity.

a. Hazard: Concerns about types and causes of flooding

1) TYPES OF FLOODS

As a coastal region, Los Angeles faces pluvial, fluvial, and coastal flood risks, each of which was highlighted in the presentation of the flood visualizations (see Fig. 2). In discussing their key flooding concerns, participants mentioned all three types of flooding, with coastal and pluvial flooding being most prominent. Many participants listed coastal flooding as their number one flood concern: "I think our key concern . . . is sea level rise-induced flooding storm surge." Others were concerned about rain given a lack of stormwater infrastructure in some communities: "With regard to flooding from precipitation events and even water main breaks, there is a critical need for improved stormwater management and mitigation efforts to store this water while also reducing damage from the floods." Concerns about river flooding were less frequent; many mentions of riverine flooding suggested that it was mostly a managed problem: "I think it's interesting, the idea of the concern about river flooding within Los Angeles. From a planning perspective, I feel like a lot of our focus is on the de-channelization of the rivers and kind of like what that next step looks like." Last, despite compound floods being a real risk in Los Angeles (Wahl et al. 2015), most participants discussed only a single type of flooding; only two individuals mentioned multiple sources (coastal and riverine flooding in both cases).

2) CLIMATE CHANGE

A number of participants discussed expected increases in flooding because of climate change, with individuals who discussed coastal flooding being most likely to also mention climate change (specifically sea level rise). For instance, a "high priority" concern for one participant was "how flooding, sea-level rise, climate change and gray infrastructure responses threaten critical coastal habitat." This sentiment that climate impacts on flooding are primarily a coastal issue has also been documented in places like Belgium (Crabbé et al. 2015) and across Oceania (Cuthbertson et al. 2019).

Interestingly, participants who were concerned about rain-driven flooding saw climate change as more of a secondary concern, needed once current flooding problems are addressed:

> My take on your question . . . is that I think it'd be useful to add climate change after you identify today's problems. Right? And how the solution to the problems we have now could be constructed in such a way that they would also encompass what will be added to them by climate. The reason why I think doing it that way is valuable is because there are places who have been invested in the past, who will become vulnerable and very easily their resources can be drawn to them because they have more power. And the places that have been underinvested in today and have challenges today won't be the first in line for a climate response when they need to be in line now for a now response.

This quote highlights a concern that a future-oriented focus on climate change will divert resources from communities that already are facing flooding, and which historically have received less attention. Additionally, it highlights the need to ensure that new infrastructure in these communities is adequate for a new climate future.

3) NUISANCE FLOODING

Nuisance flooding, or small-scale flood events that cause street-level problems such as storm drain overflow (Moftakhari et al. 2018), was a central concern to many participants. As noted

[2] We selected components that explained more than 10% of the variation in individual responses, which in this case was the top three.

by one, "I understand that the larger scale events overwhelm the entire system, but people live their lives on a daily basis, not just an extreme event basis and they're burdened by these daily disinvestment policies." In several instances, the interviewees pointed to specific streets that experience severe flooding due to a lack of stormwater infrastructure or to clogged drains, which then affect pedestrians who cannot access their bus stops due to water overflow. Furthermore, prolonged periods of street-level flooding can have severe consequences for the people who rely on public transportation and who risk their employment if they miss several days of work because they cannot access the bus. To the study participants, nuisance flooding indicates a lack of investment in certain communities since this type of flooding often can be prevented if storm drains were cleaned more often. In addition, if information were available on which streets were prone to nuisance flooding, planners would be better able to target their investments in these communities, "creating green streets and incorporating features that can capture more water and reduce that flooding."

4) BIG FLOODS

Concerns over big floods focused particularly on the region's ability to respond to these floods and recovery postflood. For instance, it was noted that vertical evacuation is difficult when debris is flowing and someone's shelter is compromised by the amount and intensity of water flow. The impacts of a big flood on critical infrastructure such as water treatment facilities and power plants and on the communities that live adjacent to this type of infrastructure were also discussed, as was the unequal distribution of resources to help with recovery postflood.

Despite participants' concerns related to big floods, one participant felt it was an underaddressed area:

> Oh my God. [A big flood's impacts] is the most important thing that we have the least information on, but it's actually contemporary and relevant. And there's been incredible resistance to developing that information. It's, like I said in my comment that keeps me up at night and has-has ever since, ever since the ARkStorm scenario report[3] was released.

b. *Exposure and vulnerability: Concerns about specific impacts from floods*

1) INFRASTRUCTURE

Flood impacts on transportation infrastructure were discussed in a very localized context, for example, creating sinkholes in neighborhoods or blocking intersections and sidewalks. These localized impacts have disproportionate impacts on vulnerable populations since they often rely on sidewalks and public transportation to move around the city. If this infrastructure is impeded by water, people are not able to access their everyday routes to their jobs and other critical destinations:

> Everybody in the communities I work with is going to be vulnerable to this because they don't drive. They tend to walk everywhere. They take public transit everywhere. They are extremely disadvantaged communities.

Besides transportation infrastructure, concerns over the potential impacts on energy, communications, water treatment facilities, and food systems were mentioned. Participants noted that if these critical infrastructures fail, the long-term effects could be catastrophic: "if you prepare and evacuate and respond, and yet that water treatment plant or that power plant or that other piece of critical infrastructure goes out . . . I lose sleep over this every day." One study participant noted the importance of highlighting which facilities are in high flood risk zones to ensure that emergency managers have a plan to prepare, respond, and evacuate, while also taking into consideration that the infrastructure they may rely on to execute their plan may go out.

2) HOUSING

The impact on housing was a major concern for participants, particularly as it relates to disparate impacts in wealthy versus lower income communities and identifying locations to build affordable housing. As one participant stated, "There's just so many [worries], if you live in a flooding area, you've got to think about, will your house survive, will you have somewhere to go, will you be able to come back to that house?" Others emphasized that these questions are more challenging to address for people who live in temporary housing or are unhoused.

Several participants pointed out that many of the sites proposed for affordable housing projects are areas at high risk to flooding. Many of these projects are being proposed as short-term or temporary in nature, meaning that flooding is not expected to be an issue in the next couple of years. However, as one participant noted, these flood projections are not always accurate and do not reflect the reality of flood risk in the near future.

> Even in Venice today, we're looking at these sites that have been screened for affordable housing or permanent supportive housing. And while some of these projects are more temporary in nature where there are only plans the next two to four years, if we're thinking long range about introducing these housing projects in areas that have a high risk to flooding, well, what's the plan when that building eventually does falter, when people have to be moved, and how do we prioritize these populations? If we're responding to some of these risks by saying the best use right now for this land is housing, that might not be the best use in 20 or 30 years.

For those housing projects that are more permanent, there are concerns over how to respond when an extreme flood does occur. Participants called for the need to have a plan in place that is tailored to the vulnerabilities that exist in these neighborhoods and prioritizes the residents who would need to be evacuated immediately because their homes are at the center of a flood zone.

[3] ARKStorm is a model scenario of a scientifically plausible megastorm, patterned after the 1861–62 historical storm events that devastated California (Porter et al. 2011). Storms of similar magnitudes are projected to become more frequent and intense because of climate change.

3) ECOSYSTEMS

The impacts a severe flood would have on ecosystems was shared by several participants. As one put it, "We're also obviously very concerned about the loss of coastal dune and wetland habitat, especially in LA, where we have hardly any left." Every mention of ecosystem-related impacts focused on coastal systems, which face dual flood risks from sea level rise and inland storms.

4) MOBILIZATION OF POLLUTION

Pollution being mobilized by precipitation was a major concern since it could impact water quality and public health, reflecting concerns documented among water managers in Europe (Crabbé et al. 2015; Lara et al. 2010). Participants noted that many densely populated communities are located near pollution sources such as auto wrecking yards. For neighborhoods where flooding gets ankle deep, residents find themselves having to walk through heavily polluted water:

> The amount of pollutants that are released and washed through this entire neighborhood is pretty severe, and with just any seasonal rain it definitely will get ankle deep . . . That major corridor . . . definitely gets flooded throughout and as the diesels are moving from all of the industry right there on the right-hand side; there's huge potholes caused from the water damage and heavy traffic.

Participants further noted that mobilized waste often stays in neighborhoods because cleanup efforts are delayed.

5) ECONOMIC

The concerns study participants expressed over the economy were mainly related to impacts on employment. One participant highlighted the impact of flooding in coastal areas, which "support a great deal of economic activity and provision of services." Individuals who do not live in flood hazard zones may rely on jobs located in these areas, as noted by one participant:

> What are the ripple effects of their potential movement and responses to risk? Thinking about the people who don't reside in these flood risk zones but are potentially really affected, people who work in these households, people who work in businesses that are affected . . . People who are working in these areas, like wealthier homes, but are kind of invisible in terms of the impact on them.

For communities already at "the very maximum of like the economic risks they're facing, the health risks and all these other, other vulnerabilities" as stated by one participant, a flood would only further exacerbate the conditions they live under.

This finding on the implications of flooding on economic activity expands on previous studies (Crabbé et al. 2015) by specifying the impacts on people relying on employment and economic activity located in coastal cities, but who do not necessarily live in those areas. The participants in this study understand economic implications as going beyond the impacts on things like tourism and recreation, focusing more on the livelihoods of those who depend on such activities.

c. Management: Concerns about current flood management and response

1) LACK OF ACTIONABLE DATA

Numerous participants lamented a lack of access to accurate and granular data on flood hazards or impacts, which they rely on to inform land use policy and infrastructure investments. Participants felt that available data either downplayed actual flood risks or displayed the whole region as underwater, making neighborhood-scale decision-making impossible. As noted by one participant, floods are often localized and the methods to communicate and address these risks vary depending on the community the participant is engaging with. Available data sources also tended to use 100-yr flood returns, when many of the participants expressed their preference for data that looks at 1- or 5-yr returns to better understand recurring nuisance flood events (a preference also documented in Morss et al. 2015). Some participants felt that governments, especially the city and county of Los Angeles, were reluctant to produce this data and make it publicly available.

2) EVACUATION CONCERNS

Participants raised concerns that managers do not effectively share evacuation information with those potentially affected by floods. As one participant said,

> We continue to exacerbate flood risks and we continue to pretend it's not a problem. But emergency managers need to be able to undertake . . . a climate informed risk informed emergency exercise . . . It's very important to ensure that community members have the information they need to evacuate and protect themselves and prepare and respond.

Both emergency managers and residents have a role in preparing and responding during a flood event, but for residents to properly plan, they have to be informed and spreading that information is the task emergency managers have to undertake.

The adequate and trustworthy explanation of flood hazards has been previously found to impact the public's trust in the system that is responsible for making decisions on protective measures like sirens and evacuation orders (Morss et al. 2015). Additionally, residents are more willing to accept mandatory evacuation orders when clearly explained about the risk of hazardous flooding (Rasid and Haider 2002). During a severe flood, quickly sharing information on evacuations can help avoid adverse consequences such as loss of life (Wood et al. 2012; Morss et al. 2015).

Another participant also highlighted how evacuation challenges vary depending on the type of flooding and density of housing. For instance, evacuation looks different during more nuisance flooding that is ankle deep versus a bigger flood where there is debris flowing, building structures are compromised, and a person may incur more losses trying to reach their vehicle. Housing density adds to the challenge of evacuation, especially during bigger floods or when vertical evacuation is needed.

3) Low flood awareness

Participants noted that given California's dry climate, many Angelenos are generally not concerned or aware of flooding as a potential hazard, a concern because people with little knowledge about floods are less likely to perceive them as a serious issue (Lara et al. 2010; Lawrence et al. 2014). According to one participant, the public assumes that Los Angeles is flat and therefore excess water via high precipitation or sea level rise would not cause flooding. The flood maps presented by the research team proved otherwise by telling the story "of how incredibly unflat we are." Participants believed that emergency managers could do a better job of using these types of maps to improve messaging and promote flood awareness, as well as help inform the public about the constraints managers face when weighing mitigation options. Lack of awareness over flood hazards was also attributed to the challenge of communicating this information to the communities that will be most affected. Participants emphasized that many of these groups have to be reached via in-person meetings, noting that it is difficult for communities to learn about hazards if the information is being shared through a Zoom call and they do not have access to a computer, let alone internet.

4) Translating flood information

Participants also lamented a lack of flood-related information that nontechnicians can understand:

> In the communities we work with, there is very little accessible information on all climate risks and the information that is available might be available to somebody like me where I can understand it, but it is not accessible to the communities that we work with. It needs to be bilingual and it needs to be written for the general public and not a more scientific audience.

Information on flood risk is often difficult to digest. Participants noted that, for those working more than one job and living paycheck to paycheck, finding time to comprehend this information and plan accordingly is a challenge. Planners and engineers have previously expressed the need for more public education, citing misunderstanding of common flood terminology like "hundred-year flood" (Wood et al. 2012), but our participants highlighted that simply translating terminology may not be enough when working with lower income or non-English-speaking communities.

5) Recovery concerns

Participants discussed deficiencies in the way Los Angeles coordinates long-term recovery, highlighting the city's "low capacity for resiliency and flood adaptation measures." As one participant noted: "I'm really concerned. I think the pandemic was a really great indicator for recovery initiatives and systems we don't have in place well." However, details about specific initiatives or coordination approaches were not provided.

6) Flood insurance

The flood insurance industry was criticized by several participants, especially for not providing transparent data to property owners so they can understand their flood risks and the requirements for flood insurance. For people who are buying or currently own properties, they "need to have a much more realistic set of information about what risks they're facing." According to participants, property owners and purchasers cannot prepare and be resilient if they do not know the risks they are incurring. Additionally, some people may not know that they live in high flood risk areas and whether they are required to have flood insurance. Some property owners find themselves in positions where they have owned their property for a long period of time and "the requirement to maintain flood insurance gets lost along the way." Therefore, assuming that property owners know about and carry flood insurance is naive, and more efforts need to be made in communicating flood insurance information.

Participants also discussed unequal access to flood insurance for homeowners, which substantially reduces costs to rebuild relative to other federal assistance. Study participants noted the challenge of purchasing insurance due to its high cost and how some homeowners are in the position where they have to decide between protecting their homes or feeding their families:

> That is a huge expense for a low to moderate income homeowner, especially when they're having to make their mortgage and put food on the table and possibly try to set aside a little for the kids' education . . . If you have low to moderate income homeowners, and let's say that they inherited their house from their parents . . . they don't have a mandate for flood insurance, great that's one less expense I'm going to have, but if some sort of flood disaster does occur, because they don't have flood insurance their access to federal disaster assistance or the amount of assistance they're going to get from the feds, is considerably lower than what they can get with flood insurance. A flood disaster can be especially devastating for those neighborhoods and those particular homeowners.

Participants also pointed to the equity implications of making insurance a requirement for property owners. Mandating insurance in communities that were not previously considered flood zones introduces a significant expenditure for which these residents were not prepared.

7) Historically underinvested communities

While Los Angeles is a big political entity with access to a lot of resources, participants emphasized that infrastructure investment is not distributed equally. They noted that larger municipalities within the region are often better positioned to organize and invest the resources they are granted in infrastructure needed to mitigate floods. In contrast, unincorporated or rural communities often have less political power and therefore less access to resources that can be used to fund basic flood solutions like installing storm drains. Participants felt that in the event of a big flood, the communities that have been historically invested in will be better positioned to respond to and recover from the flood as opposed to the communities with fewer resources (echoing Raikes et al. 2022).

Some residents turned disinvestment in their communities into an opportunity for self-reliance. People's decision to take responsibility for their own safety can prove to be critical for

spatially complex, rapid-onset hazards like floods (Morss et al. 2015). However, the focus groups suggested that these self-reliant actions could be maladaptive, causing new problems to arise. One study participant shared an experience with a community who resolved flooding in a busy street by installing their own piping system without the approval of their local planning authority:

> I bring this community up because when you talk about just about any neighborhood being vulnerable they're definitely vulnerable. They hit everything from every public, every social determinant of health to economics, homelessness, coming out of the prison system, all of them. And then, it is right where all these industries are . . . When you drive down through this neighborhood you will see that they've dug their own piping system so that they won't flood directly, and they will release, they'll discharge [wastewater] directly from their facility onto these major streets . . . Illegally, of course, you can totally tell that this was done on their own. The amounts of pollutants that are released and washed through this entire neighborhood are pretty severe, and with any seasonal rain it definitely will get ankle deep.

In this case, the lack of infrastructure means that local industries discharge waste directly into the street, and now there are substantial pollution concerns when rainstorms happen.

d. *Proposed solutions: Multibenefit projects and community engagement*

While the participants did not downplay the need for better flood management practices, they did note that managers in the region are starting to implement policies and build infrastructure that meets multiple purposes including flooding. These multiple benefit flood-control projects maximize use of space, establish green spaces, promote equity, and tackle other contemporary problems. As one participant put it, there is too much need in Los Angeles to only focus efforts on flooding:

> [We] have so much need and LA County for other things that we're really as an agency looking towards how to use our infrastructure, how it primarily needed to be used, which is flood risk mitigation and water conservation, but our communities are asking for much, much more.

Another participant noted the need to use existing and new infrastructure in a more contemporary way that meets the region's multiple land use goals. Multiple benefit projects were seen to be the best value and provide the most benefit for communities in Los Angeles and the region's push for climate adaptation and mitigation strategies.

Nature-based solutions, such as replacing concrete parking lots with public parks, were a particularly popular form of multibenefit project, especially among participants concerned with ecosystem impacts: "[Nature based solutions make] communities more flood resistant. As the state restores the Ballona wetlands, it will reduce the flood risk on the surrounding community." Crabbé et al. (2015) found that Belgian policy makers also preferred investing in green infrastructure with functional and well-balanced biodiversity to mitigate flooding in a changing climate. They argued that green infrastructure can deliver protection against flooding, natural water sanitation, and recreation in nature, all while requiring little technology and low-maintenance (see also Lara et al. 2010).

Participants also noted general benefits in using community engagement while building these multibenefit projects. Several participants discussed using community member testimonies to express what they want to see in their neighborhoods and other project priorities. For the participants who have taken this community engagement approach, they were able to overlap testimonies with other data sources, such as the state's CalEnviroScreen tool [California Office of Environmental Health Hazard Assessment (OEHHA) 2021] and recommend projects that address critical issues that were brought up by residents. Not only does community engagement help these participants justify why they propose certain projects, but the projects are tailored to meet the unique needs of each community:

> We had to show [community members] all the different factors to try to narrow down areas with need. For example, if you wanted to do a project, we said okay, we heard you community, and then we went and we looked at the data showing scientifically what's happening in your community, and then we heard from you what your needs are, and then we put those together and we graphically showed them, if you want a project here, we recommend these different projects and these locations.

Community engagement also allows managers to identify the impacts of issues on different communities. The example given was the 51-mile Los Angeles River. As one participant put it, "the answer to how to address a flood question [related to the river] was different depending where you were." The impacts of and solutions to water overflow in one community may differ from another. In some areas, there is more open space to implement a land use solution and in others, public health was more of a priority.

The benefits of community engagement for flood management are not unique to LA (Wood et al. 2012; Morss et al. 2015). Encouraging dialogue between communities and public agencies during the planning process is essential for issues where there is a lot of uncertainty and changing outcomes, like floods (Lawrence et al. 2014), and collaborating with communities helps ensure plans are local and relevant, thus further preparing local residents to respond to natural disasters (Cuthbertson et al. 2019).

e. *Flood problem framings*

This section reanalyzes the specific flood concerns presented in sections 4a–4c to understand 1) which types of organizations held each concern and 2) which concerns were held in tandem (i.e., were part of the same problem frame). Figure 3 shows the number of participants who mentioned each flood-related concern, grouped by type of organization. Here, we see that most concerns were raised by almost every participating organization type. The exceptions are big floods (discussed by nonprofits and state governments), ecosystems (nonprofits and local government), pollution (nonprofits, academics, and state governments), economic concerns (discussed by nonprofits, academics, and consultants), and awareness of flooding (nonprofits, local governments, and consulting firms).

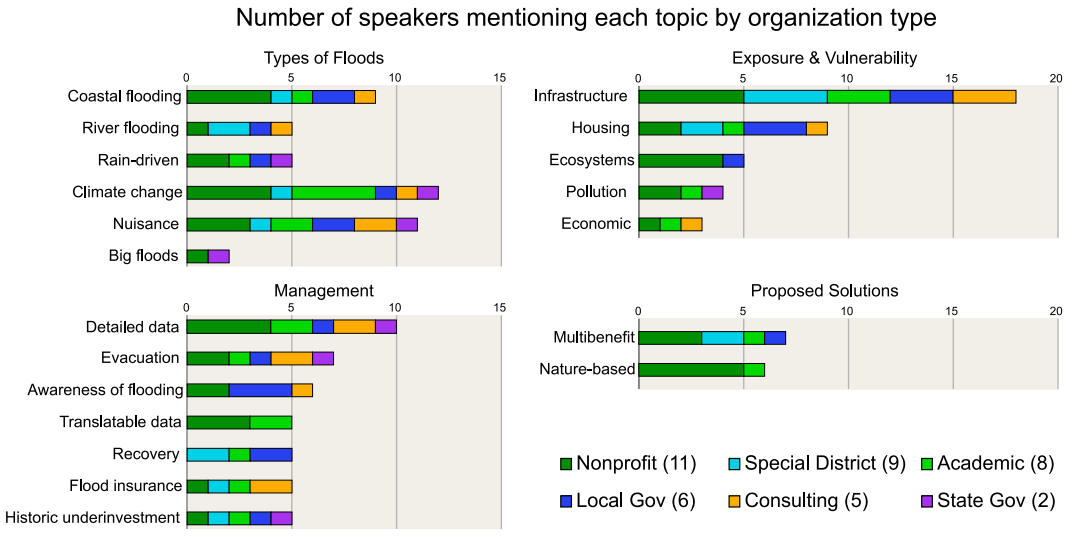

FIG. 3. Number of speakers mentioning each topic, colored by organization type. The overall count of speakers by organization type is in parentheses in the legend.

This suggests that most organizations see flooding as a multidimensional issue, rather than focusing only on particular dimensions of it.

While there was not a clear organizational divide, certain flood concerns tended to be discussed in tandem. To observe the ways different flood concerns cluster together, Table 2 shows correlations between each flood concern and the three primary components derived from a principal components analysis. To interpret the PCA, an individual who discussed fluvial flooding was also likely to articulate concerns related to infrastructure, housing, and flood insurance, while an individual who discussed pluvial flooding likely also discussed pollution and historic underinvestment (and not coastal flooding).

The PCA suggests that participants' flood concerns orient around three problem frames. Component 1 signals a frame about climate change's impacts on large fluvial floods and their impacts on housing, infrastructure, and the economy. Component 2 signals a frame about nuisance pluvial flooding, pollution, and historic underinvestment in communities; this frame does not talk about economic impacts, coastal flooding,

TABLE 2. Correlations between individual variables and each component. Boldface type indicates a significant correlation, with added italics indicating that the significant correlation is negative. An asterisk indicates a significance level $p < 0.05$.

Variable	Component 1	Component 2	Component 3
Types of floods			
Coastal flooding	0.130	***−0.432****	**0.491***
River flooding	**0.426***	0.277	**0.671***
Rain-driven flooding	0.069	**0.615***	***−0.363****
Climate change	**0.470***	−0.075	***−0.329****
Nuisance floods	−0.101	**0.643***	0.177
Big floods	**0.546***	0.295	−0.099
Exposure and vulnerability			
Infrastructure	**0.418***	0.084	0.268
Housing	**0.753***	−0.031	0.051
Ecosystems	0.033	***−0.444****	**0.405**
Pollution	−0.259	**0.540**	−0.275
Economic	**0.450***	***−0.345****	***−0.336****
Management			
Detailed data	0.244	**0.373***	−0.056
Evacuation	**0.738***	0.003	***−0.408****
Awareness of flooding	0.317	0.317	**0.554***
Translatable data	0.218	−0.229	***−0.514****
Recovery	0.268	−0.129	−0.039
Flood insurance	**0.517***	**0.392***	0.151
Historic underinvestment	−0.287	**0.631***	−0.006

TABLE 3. Flood problem frames.

Problem frame	Flood concerns	Impact concerns	Management concerns
Climate change and large floods	Big floods, climate change, and fluvial	Housing, economic, and infrastructure	Evacuation and flood insurance
Environmental justice	Pluvial and nuisance	Pollution	Historic underinvestment, flood insurance, and detailed data
Ecosystems	Coastal and fluvial	Ecosystems	Awareness of flooding

or ecosystems. Component 3 signals a frame about fluvial and coastal flooding and their ecosystem impacts; this frame does not discuss economic impacts. Table 3 summarizes the key features of these problem frames.

As an example of how the problem frames manifest, we note that individuals in the first two groups talked specifically about how flooding differentially impacts low-income, minority, and other more vulnerable communities. However, this focus manifested differently across the problem frames. For individuals holding the "climate change and large floods" frame, environmental justice focused on the distributional impacts of flood recovery, for example, the high costs of flood insurance for low-income homeowners, the challenges of evacuating households that do not own cars, and disruption to public transportation during storm events. In contrast, individuals holding the "environmental justice" frame were more likely to highlight the structural and historical features that led to distributional inequities, for instance the history of redlining and historic underinvestment in communities. They were also more likely to raise the compound risks of flooding occurring in neighborhoods that also have higher levels of pollution from industrial activities. Last, individuals concerned with ecosystems were unlikely to discuss human impacts.

5. Discussion

This paper 1) analyzed concerns related to flood risk, impacts, and adaptive capacity articulated by flood-related decision-makers in the LA Metro region; and 2) assessed which concerns were raised in tandem to identify overarching problem frames. This paper uniquely develops the concept of problem frames for flood-related research and studies flood risk perception in a region that does not regularly face large floods.

Focus group participants articulated diverse types of flood concerns, including concerns about specific types of floods (e.g., fluvial vs pluvial) and impacts to diverse infrastructure and communities. While many of the concerns reflect decision-maker perceptions that have been documented in other flood-prone areas (as discussed throughout the results), our participants were highly inclined to link flood impacts directly to impacts on environmental justice communities. Across the United States, low-income and historically marginalized communities are particularly vulnerable to flooding. Historic practices like redlining (Linscott et al. 2021) and underinvestment in infrastructure make some low-income and minority neighborhoods more prone to flooding (Zahran et al. 2008; Smiley 2020). Historically marginalized communities may also lack information, resources, or capacity to evacuate during a flood or rebuild quickly (Wisner et al. 2004; Macias et al. 2021; Maldonado et al. 2016), making response and recovery more difficult. Finally, these communities are often excluded from flood-related planning and decision-making processes (Lebel et al. 2006), and recovery aid can disproportionately flow to higher-income communities given the government's emphasis on compensation for property damage (Allaire 2018). Each of these concerns was raised in our focus groups, emphasizing their importance for the LA Metro.

Participants' views on the region's resilience highlight several concerns that are widespread for flood risk reduction and provide concrete policy suggestions. For instance, development of high-resolution flood models at a variety of flood returns would provide useful data for longer term infrastructure planning and could serve as fodder for communities seeking restoration for historic underinvestment; such data need to be publicly available and easily interpretable. Likewise, better education about evacuation, including coordination with non-emergency response teams, could help avert concerns that communities are not prepared to mobilize quickly in the event of a large flood.

Participants' concerns oriented around three problem frames (Table 3). Because an individual's framing of a problem shapes the concerns they view as relevant to flooding and the types of solutions they are likely to promote (Cravens et al. 2021; Hisschemöller and Hoppe 1995; Ulibarri et al. 2019), understanding these frames provides insight into opportunities and challenges for better flood management. For example, compound flooding—when multiple flood drivers occur simultaneously—has been shown to occur regularly in Los Angeles (Wahl et al. 2015) and be likely to increase with sea level rise (Moftakhari et al. 2017b). However, only the "ecosystems" problem frame encompassed multiple types of floods, and only two participants discussed more than one type of flooding (in both cases, tidal and river flooding). This suggests that managers may worry primarily about (and therefore manage for) one flood type. To the extent that compound flooding increases flood risk, flood managers may be underprepared for future compound flood events. Likewise, only individuals who discussed coastal flooding mentioned any negative impacts to the environment; the other frames focused almost exclusively on human impacts. This highlights a potential lack of attention to environmental impacts arising from pluvial or fluvial events.

It is important to emphasize that, given the open-ended nature of the focus group discussions, not mentioning a specific concern does not mean that individual definitively does not

think about that particular flood concern. However, the things an individual thinks about first are likely the most important or salient; we presume that these are the topics they were most likely to raise in the discussions. Additionally, our presentation of the flood maps prior to the focus group discussions served to remind participants about the basic facts about flooding in the region (where it occurs, what causes it, etc.). Following the presentation, an individual should have been primed to talk equally about coastal, riverine, and fluvial flooding, yet they each chose to focus on specific concerns, suggesting that is what they care most about.

One promising finding is the lack of siloing by organization type: almost all flood concerns were discussed by individuals representing many organization types, and individuals from at least five of the six organization types were highly correlated with each of the three problem frames. This suggests that managing flooding may have less of a coordination problem in the LA Metro relative to other locations or problems. A lack of cross-sectoral coordination has been shown to undermine effective disaster planning and response (Nolte et al. 2012; Hossain and Kuti 2010; Comfort et al. 2004; Comfort 2007; Kapucu 2006). Because organizations are more likely to coordinate when they share beliefs about the nature of a problem (Berardo and Scholz 2010), the fact that so many organization types hold overlapping flood problem frames in our study area bodes well for self-organized coordination around flooding.

This research is subject to several important limitations. First, to get coverage across participants and topics, we sacrificed the ability to dive deeply into any individual component. Our research enables us to understand the many different flood concerns that exist across LA and which are most common across diverse expert organizations and individuals, but we lack detailed mental models on how flood risks and flood concerns interact for any individual (in contrast with Morss et al. 2015). Second, we focus on experts, that is, people who think about flooding somewhat regularly in their jobs. However, decisions that impact overall flood risk and recovery are also made across sectors, many of which may never think about flooding. Because we are working in an arid region where risks from flooding are less visible, selecting the most potentially knowledgeable individuals ensured that participants had a base of knowledge to contribute and a preexisting flood problem frame. Exploring problem frames held by flood-adjacent individuals is important for understanding overall management implications. Third, the quantitative analysis used to generate the problem frames generally assumes independence of observations. However, given the group nature of focus groups, each individual's statements were influenced by the specific conversation they were embedded in. Nonetheless, each focus group contained individuals whose statements associated them with different problem frames, suggesting that the topics one discussed were not predetermined by which focus group was attended.

This research explored decision-makers' major concerns relating to flooding, its impacts, and its management in Metropolitan Los Angeles. By applying the concept of problem frames to the challenge of flooding, we are able to identify specific synergies and gaps in how decision-makers plan for and respond to flooding. Studying a single region means our concerns may be unique to Southern California, but the problem frame concept can provide a template to compare flood risks and management over time or across regions.

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Data availability statement. Because of privacy and ethical concerns, focus group data cannot be made available.

APPENDIX

Focus Group Discussion Guide

Topic 1—Current flood awareness:

- What do you see as the biggest flood risks in your city/neighborhood?
- Do you feel that you have adequate knowledge about flood risks in SoCal?
- What information or resources could help you plan for future flood events?
- What information or resources could help with recovery after flooding?

Topic 2—Reaction to FloodBRIDGE flood models:

- Was there anything that stood out to you about the flooding maps we presented?
- As we presented earlier, our flood model is very high resolution, capturing street-level and house-level flood hazard information (e.g., flood depth, flood velocity, flood force). This is a different approach than the standard flood hazard zones (e.g., FEMA maps). Is a high resolution model like ours helpful for your organization's decision-making? Why or why not?

Topic 3—Reaction to social disadvantage work:

- What groups or types of people are most vulnerable to floods in the areas where you work? Why?
- Do our disadvantage metrics capture these groups? Do you think they are helpful? Why or why not?
- Is it helpful to your organization's decision-making to have vulnerability data at the block group level versus the census tract or county level? Why or why not?

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