Southwest Climate Adaptation Science Center

Preventing Extreme Fire Events by Learning from Historical Fire Events, Weather, and Drought

DRI
Desert Research Institute

FINAL REPORT

Southwest Climate Adaptation Science Center

FINAL TECHNICAL REPORT

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PROJECT TITLE
Preventing Extreme Fire Events by Learning from Historical Fire Events, Weather, and Drought

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PURPOSE AND OBJECTIVES

This project is a combined effort from researchers at the USGS, Scripps Institution of Oceanography (SIO), and Desert Research Institute (DRI). At this time, the researchers at USGS and SIO have requested a no-cost-extension but the researchers at DRI have completed their portion of the research project and are presenting this final report in fulfillment of the USGS reporting requirements. The description of the project purpose below reflects this larger combined project, but the results section will focus on the aspects of the project completed as a part of the DRI statement of work and budget. We expect portions of this report will be included in a final technical summary as the balance of the research team completes their portions of the project in 2022. Additionally, a portion of this project focused on the technical advisory committee received additional support from the Southwest Climate Adaptation Science Center under a separate award in 2020 that will continue through 2022. These additional funds were to primarily support the collaboration with the Global Learning Exchange Network. Results presented here regarding the technical advisory committee are also reported under award G20AC00364.

Project **Purpose**

Understanding the multiple factors that cause extreme wildfire events is critical to short and long period forecasting and planning. The 2017 fire season was a wakeup call to fire scientists that managers throughout the western U.S. are in desperate need of scientific input on when and where to predict dangerous fire events that impact rural and suburban environments. Recent studies have shown that seasonal patterns of temperature and precipitation may explain substantial amounts of the variation in historical annual fire activity in western forests, but seasonal average conditions have proved to be of limited value on many non-forested landscapes. In this research, the research team investigated factors that may explain more of the variation in annual fire activity in forested and non-forested landscapes in California; these factors will include longer-term effects of extended droughts and shorter-term effects of intense heat spells and low relative humidity and extreme winds. Additionally, we investigated the synchrony of different ignition sources with long-term drought and fire-weather conditions.

Using the California Fire and Resource Assessment Program (FRAP) fire history database the research team extracted historical fire perimeter data to conduct separate analyses within climatically homogenous regions in California. For the point of ignition, we identified the associated local weather, including temperature, relative humidity and wind speed and direction for a three-day period beginning the day before the fire start, as well as ignition source (USGS). A new, high-resolution gridded historical wind (speed and direction) and humidity dataset was derived using the LOCA downscaling scheme (DRI/SIO), comparing 2km and 6km resolutions. This new vector wind and humidity data, along with gridded temperature, precipitation and derived hydrological measures will be used to diagnose the weather and climatic factors that contributed to larger and smaller fires in the dataset. Models of fire characteristics (area burned, fire severity) developed from the subsets of larger and smaller fires will be developed. The model performance was evaluated using a subset of historical small and large fires reserved from the model training set.

This project provides a better understanding of the longer and shorter period environmental factors that drive fire activity and provide the basis for a new set of predictive models of wildland fires using weather and drought measures for the major climate regions in the state. A key output will be to deliver better fire risk models that improve future management needs and diminish the likelihood of surprise events similar to those that caught some managers off guard in 2017. Originally, we planned to ensure that our research outputs help inform decision makers by collaborating with potential end users from state and federal management agencies throughout the project, as appropriate. As the project progressed, we identified several key challenges with extending this research from basic science to actionable science that directly informed decision making and adjusted accordingly. These changes are discussed below. As noted previously, the focus of this final report is the DRI statement of work deliverables. Specifically this is the extension of a Weather and Research Forecasting (WRF) numerical mesoscale model high-resolution gridded historical wind (speed and direction) and humidity hourly dataset at 2km spatial resolution for California and the technical advisory committee (TAC) process and how that has changed over the course of the project.

Weather and Research Forecasting (WRF) Numerical Mesoscale Model

In years 1 and 2, this project further developed a Weather and Research Forecasting (WRF) numerical mesoscale model high-resolution gridded historical wind (speed and direction) and humidity hourly dataset at 2km spatial resolution for California. The original dataset completed for CAL FIRE included the period 2004-2013. This was expanded in the current project by expanding the period to include 2002-2019. Outputs from the model runs (in particular, surface wind speed and direction) were provided to our project partners (Dan Cayan and Dave Pierce) at the Scripps Institution of Oceanography for use in the LOCA downscaling task of the project.

The WRF model is a well-supported and widely used non-hydrostatic model that includes a wide range of choices of physical parameterization schemes (Skamarock et al. 2008). DRI provides wildland fire and air quality agencies in California and Nevada operational fire weather forecasts under the auspices of the California and Nevada Smoke and Air Committee (CANSAC). As part of the CANSAC system, DRI is creating an hourly 2-km spatial gridded climatology for California-Nevada for the 41-year period 1980-2020. This is for the same domain as the operational 1.33-km twice daily runs. The Weather Research and Forecasting (WRF) model is being used to generate the climatology. The WRF configuration for this effort consists of three domains with grid spacings of 18 km (outer domain), 6 km (middle domain), and 2 km (inner domain) (Figure 1). The inner domain covers all of California. Outputs include a full 3-D volume of 32-levels. The initial state and lateral boundary conditions for the outer mesh are provided by the 6-hourly interval global reanalysis. The National Centers for Environmental Prediction (NCEP) FNL (Final) Operational Global Analysis data are available at 1 x 1-degree resolution every six hours and are being used for the 1999-2020 initializations. For the 1980-1998 initializations ECMWF ERA-Interim: 80 km (~.7 degrees) 6-hourly will be used. Model parameterizations are the same as for the established CANSAC WRF daily operational runs. Analysis nudging was employed for U and V wind components on all three domains, and on all sigma levels throughout the domain, except in the lowest levels of the PBL. Temperature and specific humidity are also nudged above the PBL (planetary boundary layer). Full details of CANSAC WRF operations and model configuration is available at https://cansac.dri.edu/cansac_output.php?model=WRF

RESULTS

Some basic correction of temperature, relative humidity, and wind speed was undertaken based on the quantile mapping method described in Brown et al. (2016). However, validation of the model output is being expanded as the dataset is being expanded (see below).

The model runs were undertaken at DRI, and the output data are stored on local servers. These data are publicly available, though requests will need to be made to project PI T. Brown as the full data volume is approximately 180TB.

This project further inspired expansion of the dataset. The California Energy Commission is supporting extension of the dataset to include the period 1980-2020. This will provide a high-resolution temporal (hourly) and spatial (2km) dataset of surface and upper-air fire weather for California and Nevada.

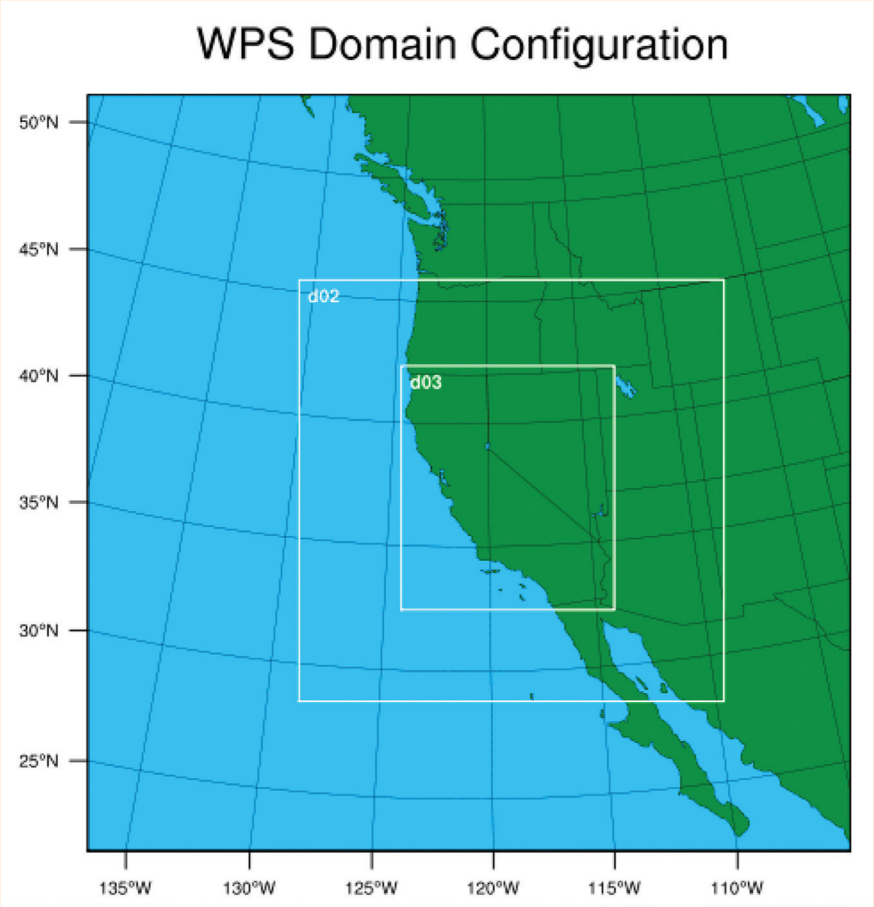

FIGURE 1 Spatial boundaries of WRF Post-processing System. The inner most high-resolution domain of 2km covers all of the California and Nevada.

Stakeholder Advisory Committee—Challenges and Opportunities

Although much of the expected research products were projected to be technical in nature, we organized a key group of potential end-users to create a technical advisory committee (TAC) to help us validate and refine the developed model, i.e., are the results reasonable given their experience. The initial iteration of the TAC met informally in December 2018 for a one-day workshop in Sacramento to begin discussing the project and potential uses by fire management agencies and practitioners. The five participants included representatives from the United States Forest Service, National Park Service, and Cal Fire. The TAC also met virtually in 2019 to review initial research findings. At this time, members of the research team and the TAC began to realize that the results, while highly relevant in identifying gaps in knowledge and developing a path towards actionable research, were likely several key steps away from developing research for decision support by practitioners and fire managers. While there will be opportunities for the TAC to comment and advise on how what steps may need to be taken for this activity to occur in the future, deeply involving the TAC did not seem to be necessary for the balance of this project. To be respectful of members' time, we opted to extend the concept of a TAC in new directions that focused more fully on community wildfire resiliency in California and how to inform resiliency efforts in the State. To fulfill the original task with the TAC, lead PI Wall modified the original TAC to broaden participation to better understand the factors that impact community and ecosystem resiliency to wildfire, particularly impacts that are amplified by drought, such as the flammability of fuels and difficulty of fire containment in such environmental conditions. We scoped out a novel approach to the TAC concept that we are terming a "roundtable" and have begun work on the *California Roundtable on Wildfire Resiliency* in collaboration with the Global Learning Exchange Network (GLEN). We recruited three new members to invite to the roundtable and one member from the TAC also opted to participate. The participants included David Shrew (retired, Cal Fire), Kelly Martin (retired, National Park Service), Courtney Farrell (North State Planning and Development Collective, Center for Economic Development, Chico State) and Marti Witier (National Park Service). The research/engagement team for this effort included Dr. Tamara Wall (DRI), Dr. Gisela Wendling (GLEN), and David Sibbet (GLEN).

We held four virtual meetings during the past year, and developed a better understanding of the problem space, relevant sectors and perspectives to begin addressing community wildfire resilience, barriers and incentives to change, and identified key agencies and partners to move forward if funding is founded for an extended, expanded multi-year TAC process. The meetings and results are described below. Throughout this process, we began to think of this group as a pilot "design group" that was providing their insight into defining the problem space and identifying areas of opportunity. Below, we refer to this group as the roundtable design group.

RESULTS

MEETING 1: SHARED INTERESTS AND BEGINNING TO DEFINE THE PROBLEM SPACE

Overall Design Team Outcomes

- Develop a more refined/informed understanding of the problem space
- Identify the diverse stakeholder perspectives needed for an impactful roundtable outcome

Meeting Outcomes

- Build relationships
- Develop shared understanding of the work of this pilot group
- Share our interest and experience with the work of the wildfire community resilience roundtable
- Begin considering resilience as one of the key ideas for this project

Overview of Participants

The roundtable design group was deliberately small in number but optimized to bring a diverse set of expertise/perspectives and California regions. The group had experience working and living in the Sierras, North Bay, Southern California, and inland Northern California wildfire areas. These regions of areas have profoundly different wildfire regimes/ecosystems, cultural, and economic differences. This diverse set of drivers and conditions create the complex ecological and social system that makes addressing the wildfire challenge in California so very difficult.

A significant portion of our first call was spent providing an opportunity for the roundtable design group participants to get to know each other, build rapport, and understand what perspectives and expertise each was bringing to the process. This is detailed in Figure 2 on page 7. One participant, David Shrew, was joining the meeting from Napa, while several wildfires were burning nearby.

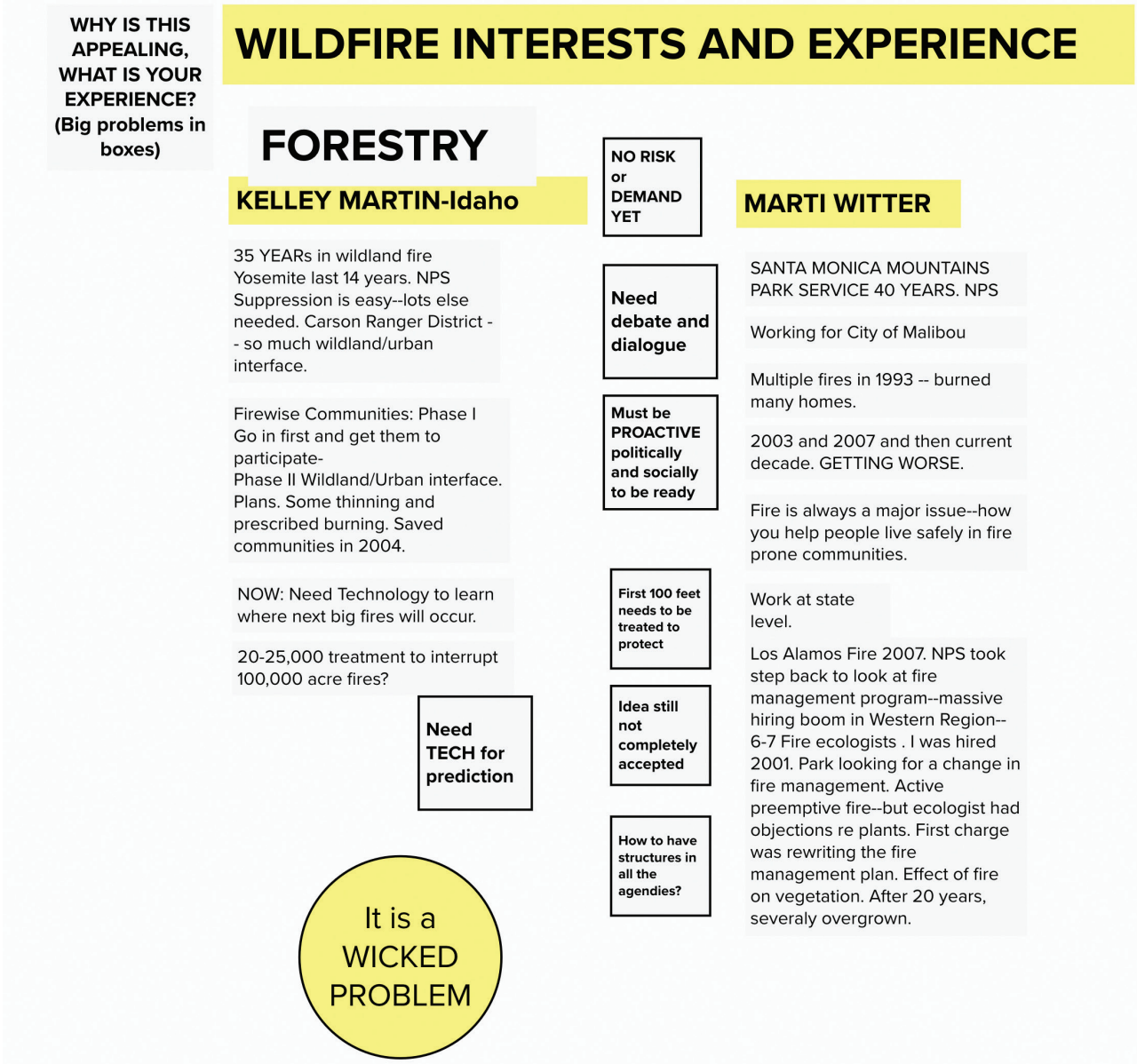

FIGURE 2 Wild fire interest and experience.

DISCUSSION SUMMARY AND SYNTHESIS

Our initial conversation focused on identifying the big themes around wildfire and resilience that came out for this group, and their thoughts on the current agency response to wildfires, and most importantly, how to move forward and change the outcomes in these communities after a wildfire. These themes included (Figure 3):

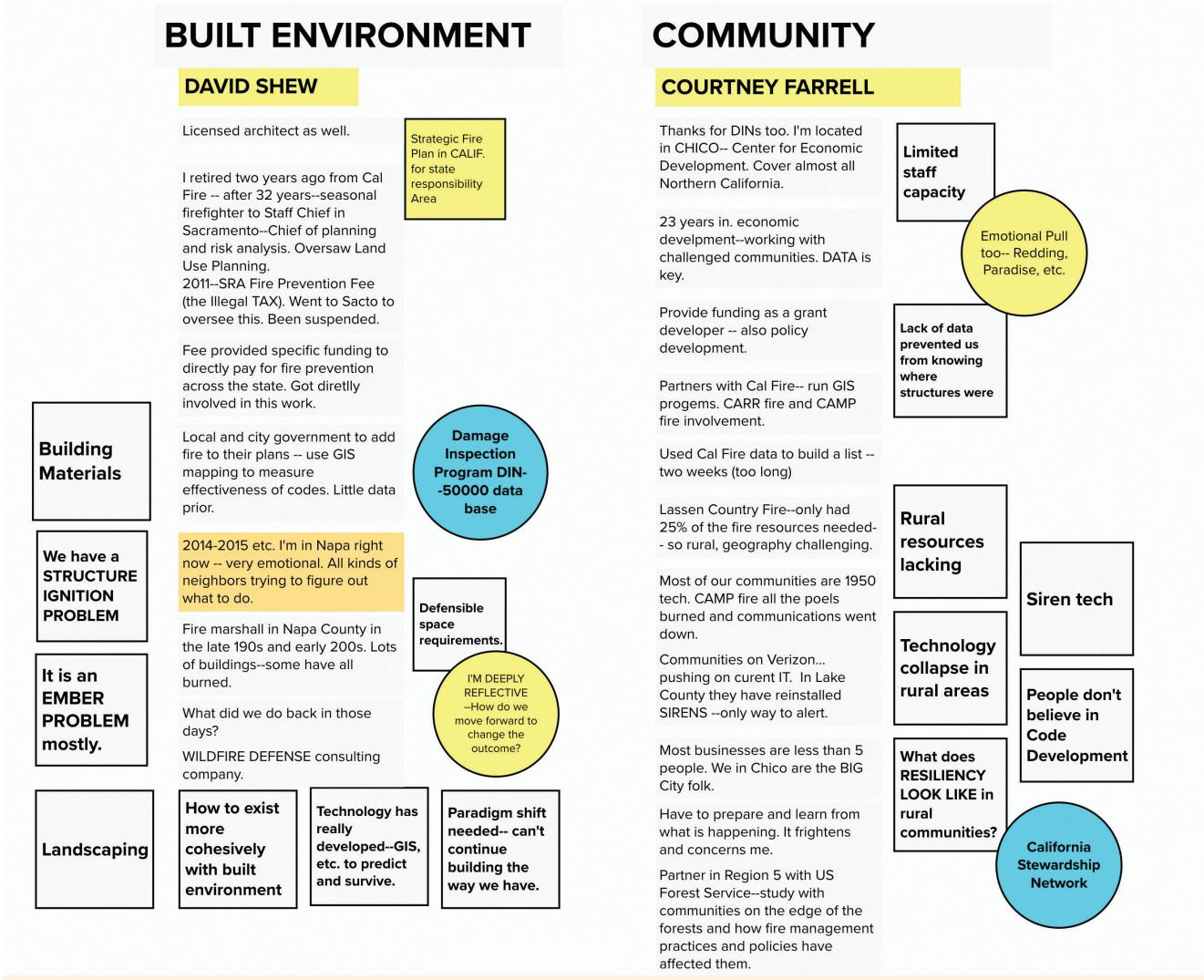

FIGURE 3 Built environment and community themes.

- Wildfire potential is exponential in scale
- Using fire as a tool is not sufficiently utilized
- Agency response is always reactionary—how to move to proactive?
- Wildfire responders are exhausted and overwhelmed with the severity and duration of recent wildfire seasons
- A need to get “out in front” of the problem
- Need a demand for change from communities to drive policy

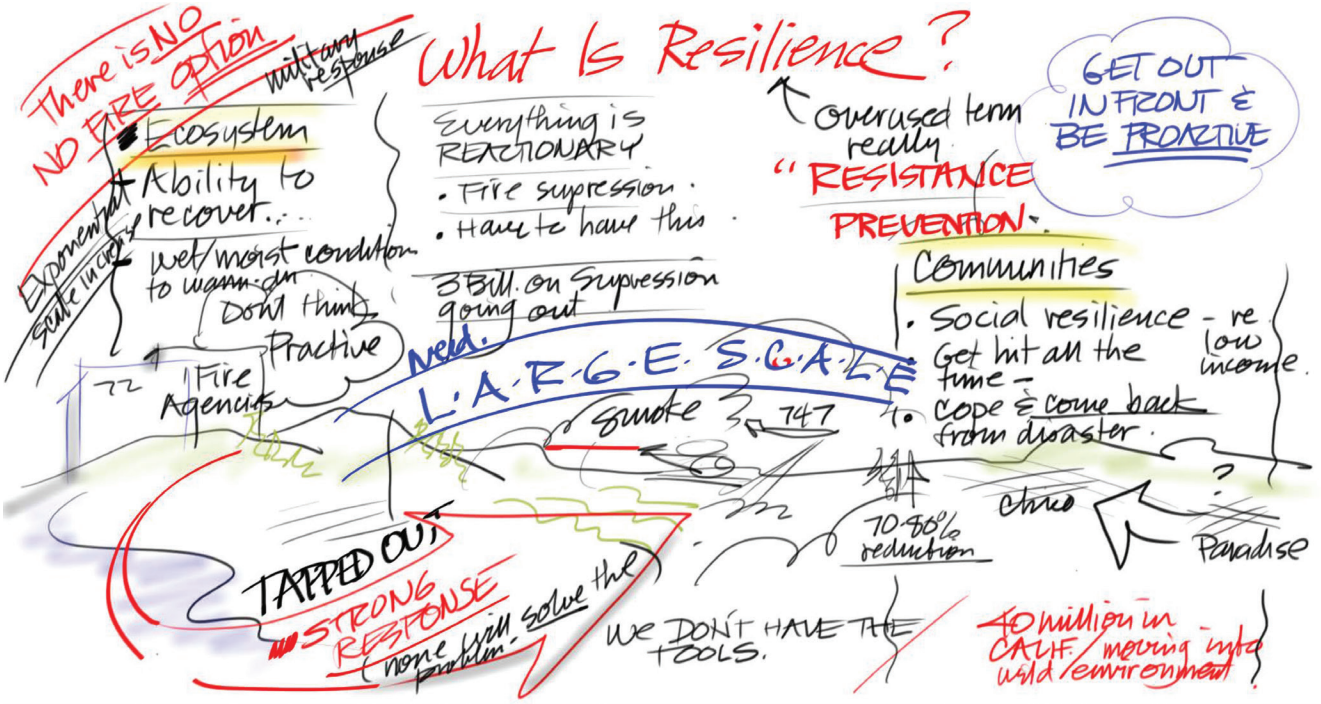

FIGURE 4A What is resilience?

Numerous questions came out of the discussion, including (Figure 4A and 4B):

- How will watersheds respond to large scale wildfires in these regions?
- Is big fire helping or depleting need to assess severity?
- How do we apply the concept of resilience to these communities?
- What are the impacts on neighbors, fire fighters in mass casualty events?
- How can this group evolve the problem definition?

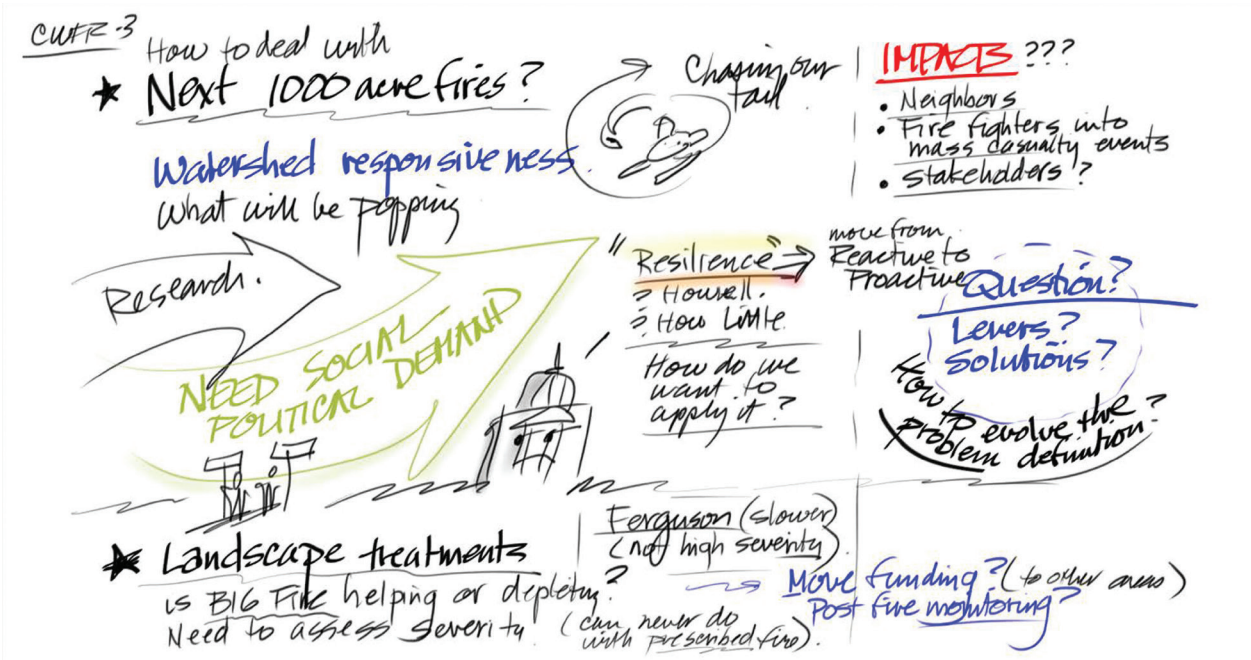

FIGURE 4B What is resilience?

The first meeting of the pilot design group was focused on building a sense of relationship, shared experiences, and trust between the participants and with the leadership team (Figure 5). In summary, the pilot design group opted to focus their efforts on elaborating the problem space further, identify a set of key stakeholders to participate in a full roundtable process, and asked the facilitation team to identify one possible additional person to add to the pilot design group. The facilitation group met to debrief after the meeting and begin the process of designing the second meeting, which we focused on further eliciting a definition of the problem space.

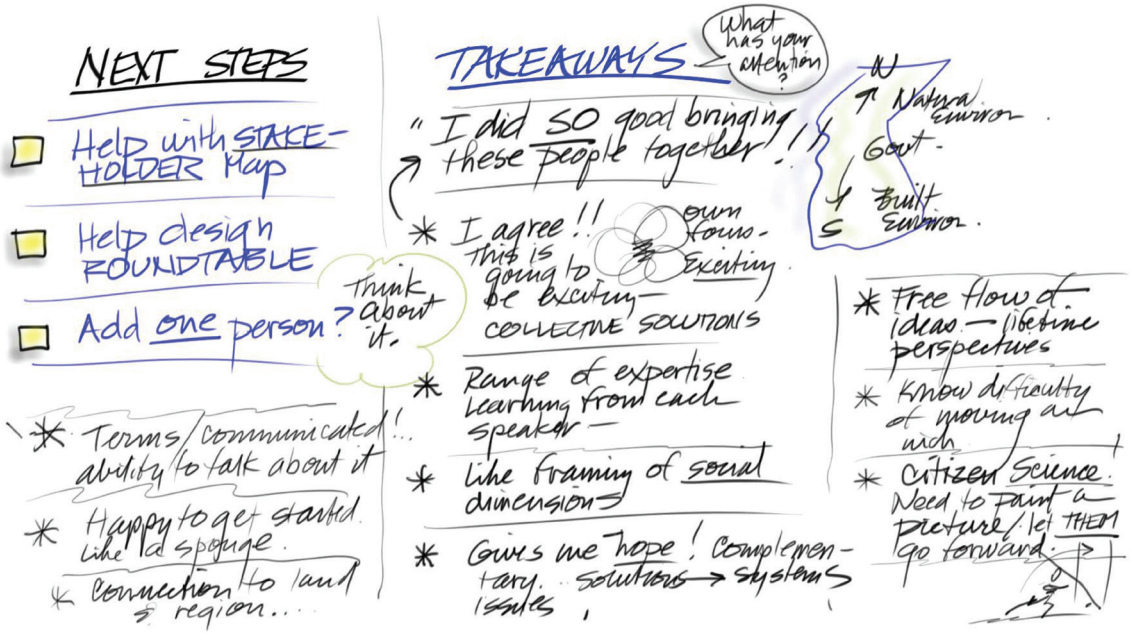

FIGURE 5 Next steps and takeaways.

MEETING 2: ELICITING THE DRIVERS OF WILDFIRE RISK TO COMMUNITIES

The facilitation team opted to focus Meeting 2 on better understanding and eliciting the drivers of community wildfire vulnerability, the barriers to change, and incentives to changing the current situation. To do this, we opted to use a "force field analysis" approach which uses a straightforward graphic design and process.

This activity is an opportunity to begin understanding the problem space by exploring the forces that help and hinder mitigating and reducing the impact of wildfires in California. It also helps us begin to develop a systemic picture of what is going on, how intervening in that system might make sense, and what kinds of options to explore further.

FORCE FIELD ANALYSIS STEPS

1. **Introduce how a Force Field Analysis works using a visual** *(3 min)*
   a. Helping forces
   b. Hindering forces
   c. Shift current state to desired future state
2. **Brainstorm Current State, i.e.,** *(5 min)*
   a. Increasing amount of fire
   b. High casualty rates
   c. High cost…
   d. Brainstorm just enough to have a basic picture
3. **Brainstorm Future State, i.e.,** *(5 min)*
   a. Fewer fires
   b. Better management
   c. Fewer people die
   d. Fewer homes burn
   e. Fewer economic components are destroyed
4. **Helping and Hindering Forces**
   a. Silent reflection and journaling amongst the participants (5 min)
   b. Go-around to collect helping forces (15 min)
   c. Go-around to collect hindering forces (15 min)
   d. Allow for discussion and clarification of what the participants have contributed and add additional forces as they come up
5. **Dot Voting to identify top helping and hindering forces** *(10 min)*

Overall Roundtable Design Team Outcomes

- Develop a more refined/informed understanding of the problem space
- Identify the diverse stakeholder perspective needed for impactful roundtable outcome

Meeting Outcomes

- Continue to build relationships
- Using a simple force field analysis approach, explore ways to mitigate and reduce the impact of wildfire on California's Communities
- Identify the helping and hindering forces that are part of making shift from the current state to a desired future state
- Consider what this says about the problem space that we want to explore though a multi-year roundtable process

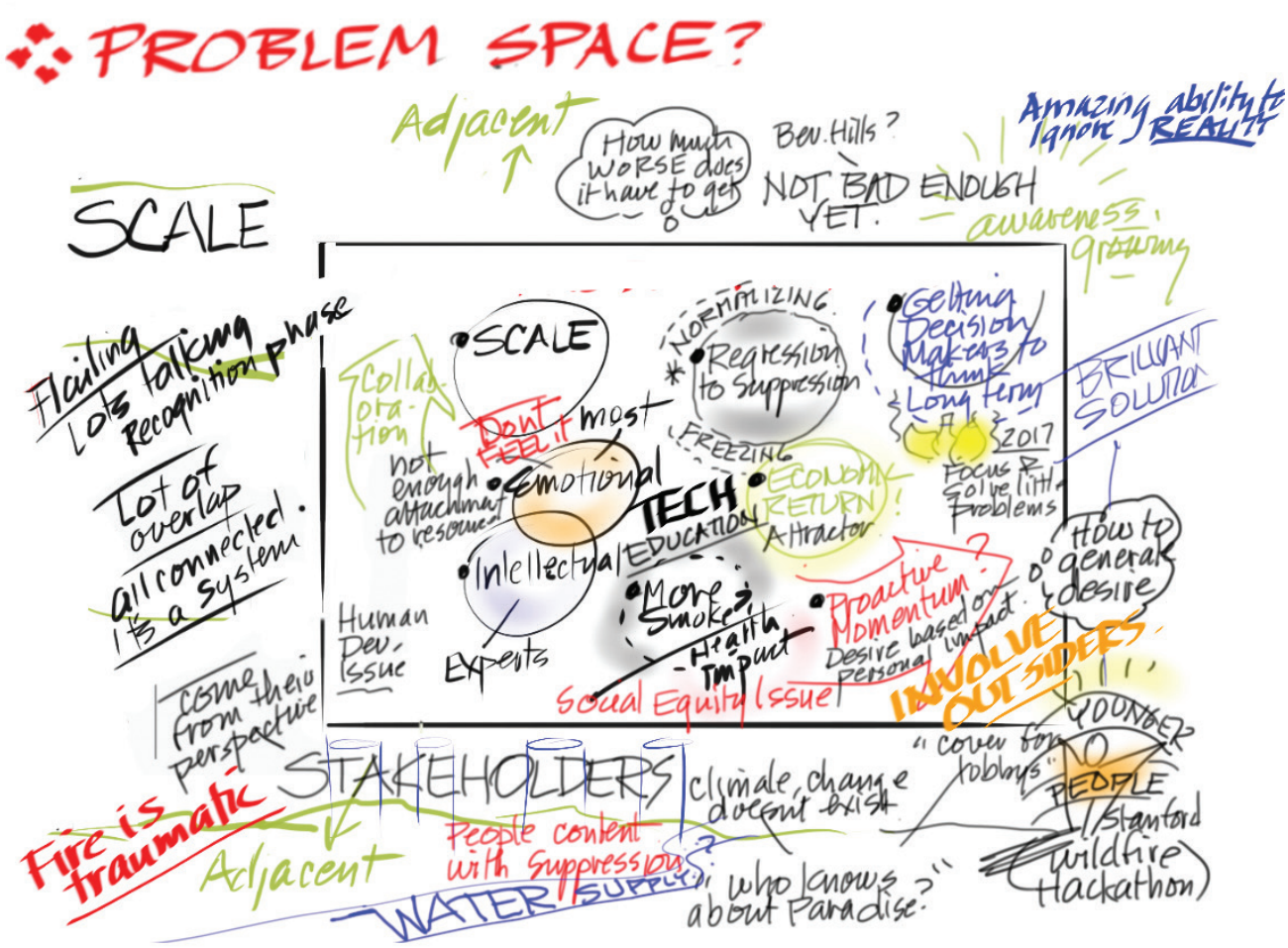

FIGURE 6 Force field analysis.

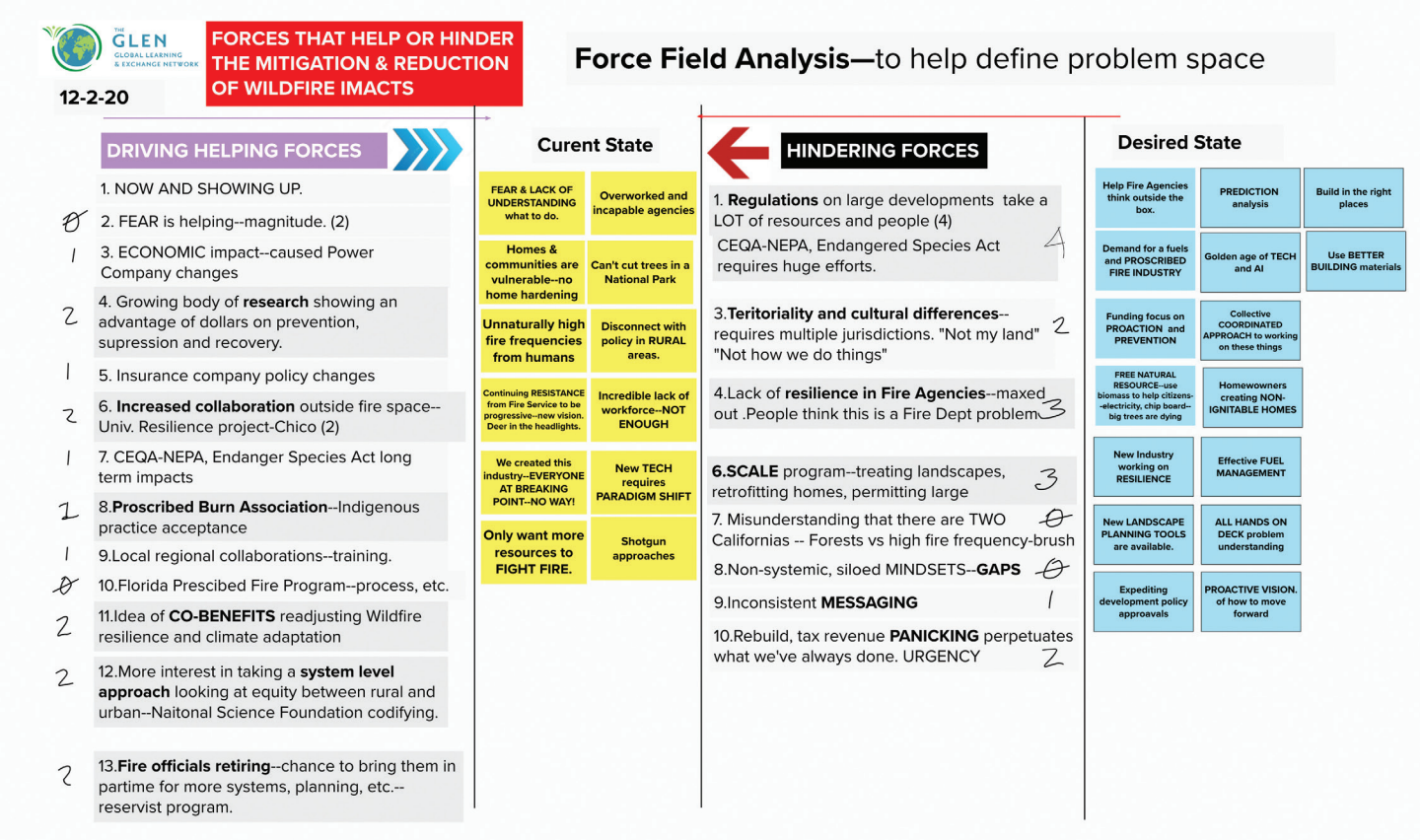

FIGURE 6 Force field analysis.

DISCUSSION SUMMARY AND SYNTHESIS

Examining the resiliency of communities to wildfire from a systems perspective, the set of circumstances and properties involved create a complex adaptative system, where the properties are often emergent and arising from the interaction of the different parts (i.e., the fuels, weather, climate conditions in combination with the built environment and social/cultural environment). While these emergent qualities are distinct from the properties of these parts, to understand and conceptualize the system, we need to understand both the properties of the parts and the emergent qualities created by the interaction of these parts, *while they are evolving* (Hassan 2014). In Meeting 2, our efforts focused on beginning to define the parts and the interactions between the parts as driving *helping forces* and *hindering forces*, in the context of defining the (undesirable) current state and visualizing a desired future state.

Key driving forces, from the perspective of the pilot design group in *helping forces* cluster around leveraging/system forces—co-benefits, equity between rural and urban systems, utilizing the experience and social capital of retiring fire practitioners, increasing collaboration *outside* the fire space. Hindering forces clustered around the impacts of regulations, even well-intentioned regulations, on slowing down change and mitigation efforts; the lack of social capital in fire management agencies and a systems perspective; and the scale of the problem (the unrealized knowledge that this is a complex adaptative system challenge, as are most problems with multiple sectors that need to be addressed). While the current state is largely characterized by business as usual (BAU) themes—lack of vision, continuing to perform the same actions, the desired future state is characterized by innovation and movement away from BAU—thinking outside of the box, new tools, proactive approaches. Notably, no one thought the problem was going away, or the solution was to abandon these landscapes. Instead, the focus was new ways to create safe spaces and community resiliency across multiple vulnerabilities.

Next steps for the group included setting the preliminary focus of the third meeting on refining the group's understanding of the problem space and begin tackling the stakeholder perspectives necessary for an impactful roundtable outcome. Previous to the third call, the facilitation team met to build the agenda focus, design the meeting, and create the visual graphics that would ground the discussion. Looking through the notes and visual from the first two meetings, we created a graphic that would help organize and focus our discussion around four dimensions of the problem space: mindsets, political/social, physical, and technological properties (Figure 6).

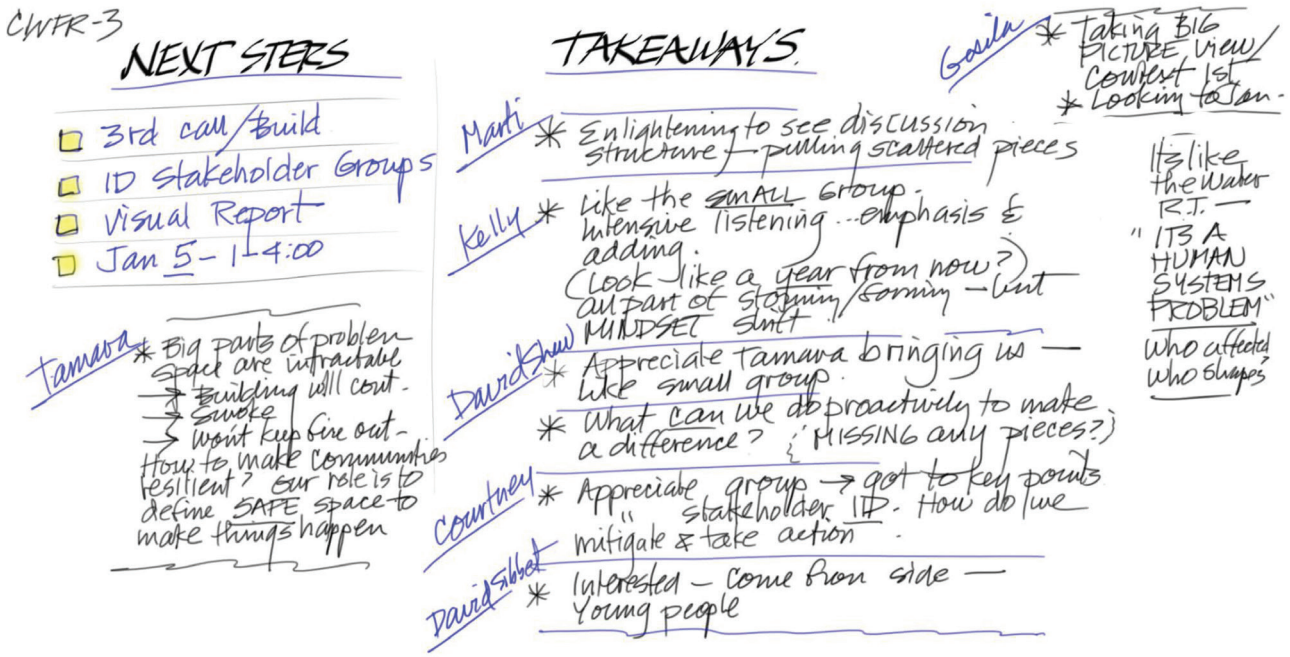

FIGURE 7 Next steps and takeaways.

MEETING 3: DIGGING DEEPER: REFINING THE DIMENSIONS OF THE PROBLEM SPACE

Overall Design Team Outcomes

- Develop a more refined/informed understanding of the problem space
- Identify the diverse stakeholder perspectives needed for an impactful roundtable outcome

Meeting Outcomes

- Continue to build relationships
- Review and evolve initial problem space graphic depicting several overarching dimensions with subthemes

DISCUSSION SUMMARY AND SYNTHESIS

For this meeting, the facilitation team developed an initial graphic in advance of the meeting and introduced the graphic at the start of the meeting, drawing from previous discussions in Meeting 1 and 2. Once the pilot design group was familiar with the graphic contents, we focused on building out these elements to refine the four dimensions we wanted to explore: mindsets impacting wildfire response, technological, political and social, and the physical environment/context (Figure 8A and 8B).

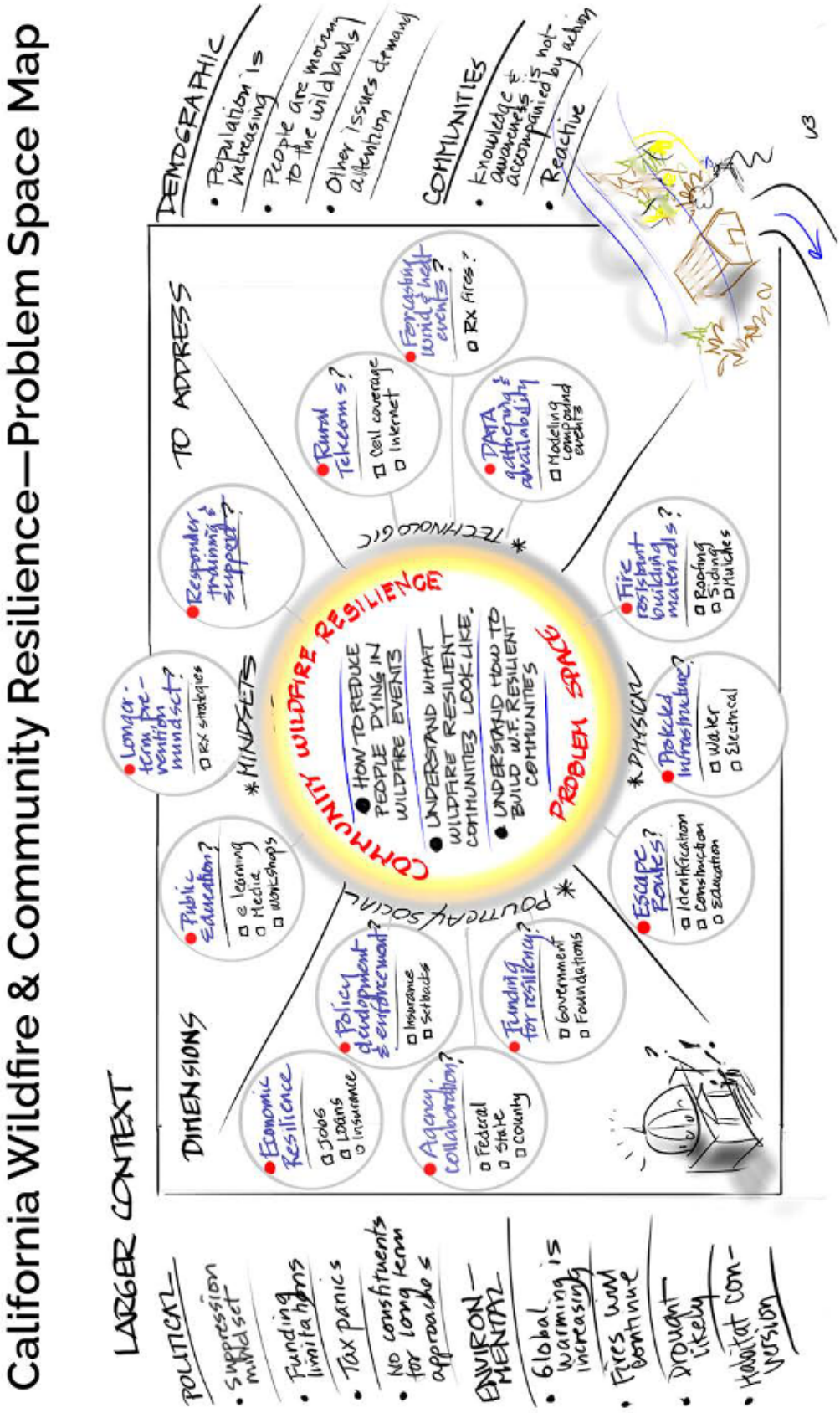

FIGURE 8A California wildfire & community resilience—problem space map.

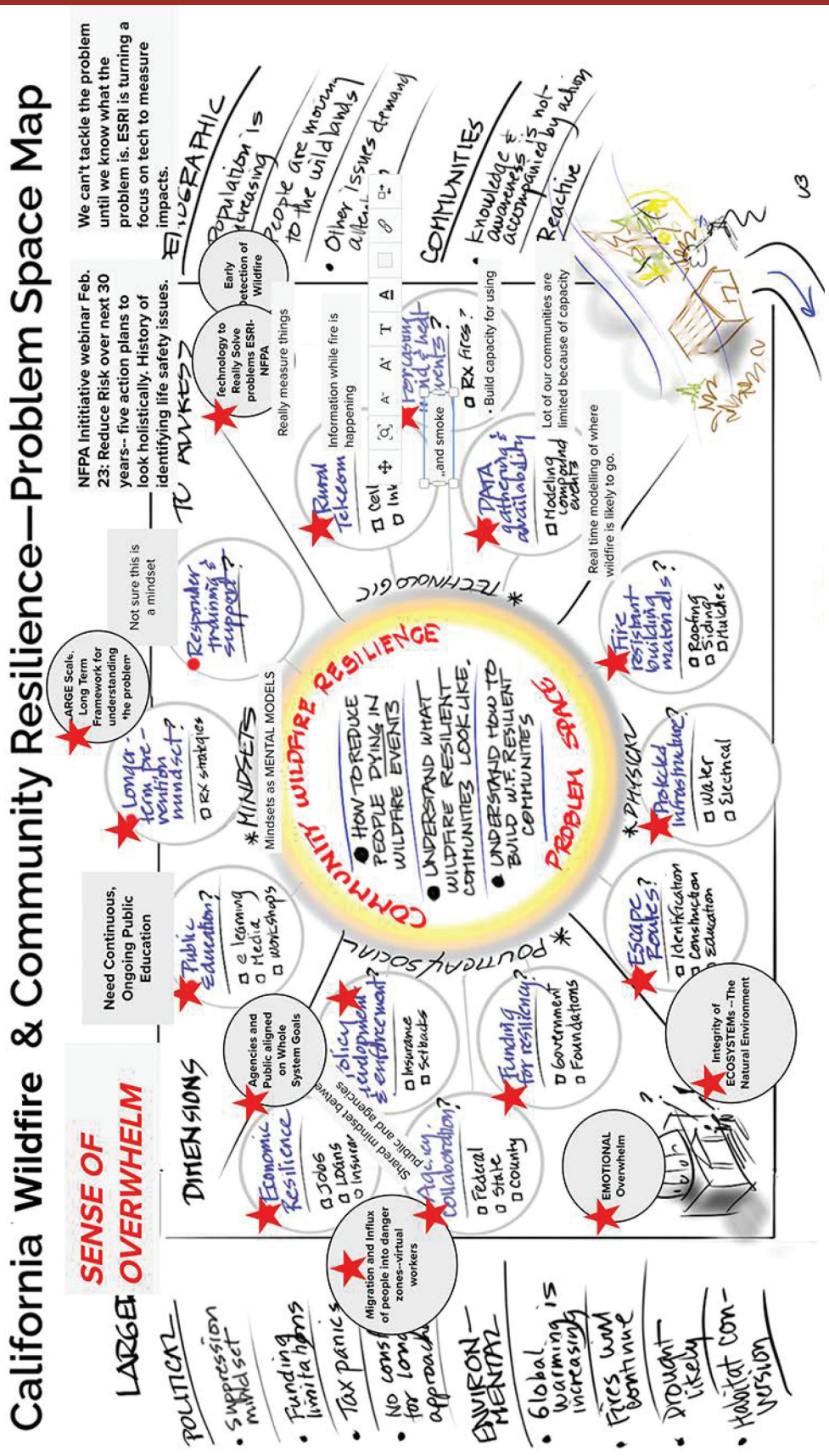

FIGURE 8B California wildfire & community resilience—problem space map.

DISCUSSION SUMMARY AND SYNTHESIS

This meeting added key additions to the visual problem definition graphic were 1) the limitations of some communities to respond to both opportunities to increase resiliency and threats that reduced community resiliency, 2) the need for the public and agencies to begin entraining a system-wide focus and set of goals to address what is a large scale, long term problem, and 3) the need for systematic and robust forms of communication between agencies and the communities at risk, as a wildfire starts and throughout the life cycle of the event.

The second portion of the Meeting 3 focused on beginning to identify a stakeholder map, i.e, a map of what interests, perspectives, and/or sectors would be ideal to have participate in a full roundtable process for the greatest potential diversity and opportunities to create innovative or "out of the box" thinking and disrupt habitual BAU planning approaches. While many of the perspectives were expected, the inclusion of several were unanticipated (Figure 9), as was the focus on fiscal perspectives and affordable housing.

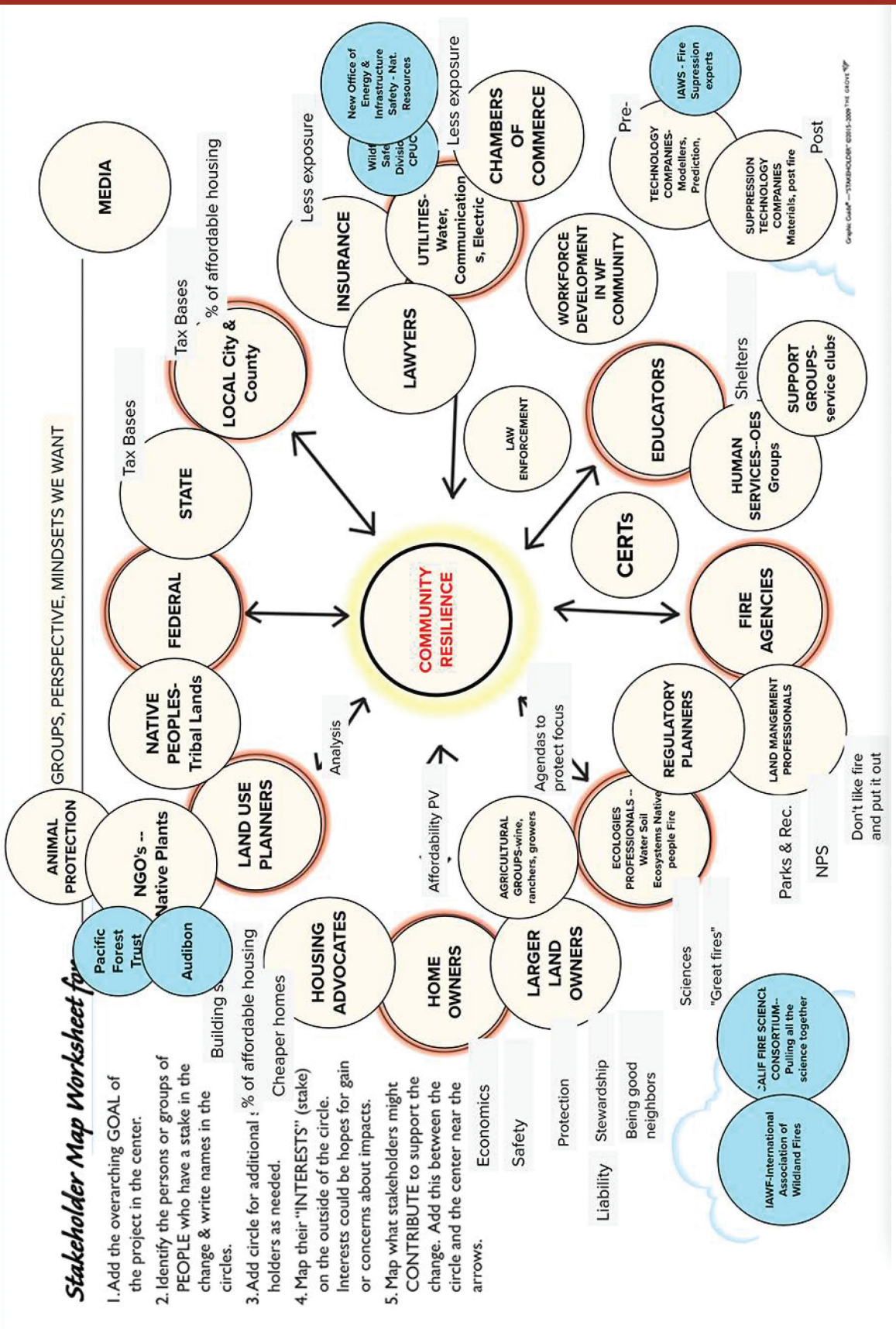

FIGURE 9 Stakeholder map worksheet.

Next Steps are detailed in Figure 10, but a key theme emerging was the need to coordinate or collaborate with other ongoing efforts in this area, or possibly merge this effort into another effort, if most effective and have impact going forward—what does that look like, what can this effort achieve?

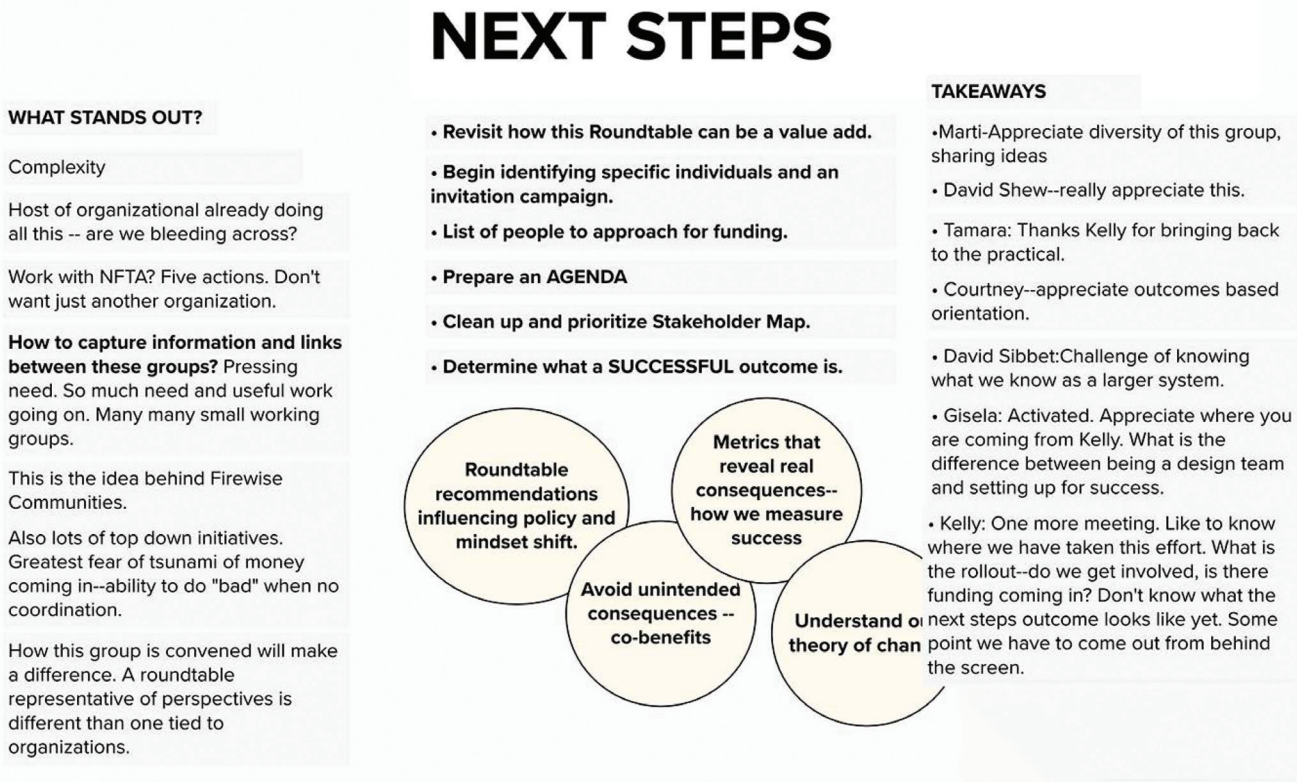

FIGURE 10 Next steps and takeaways.

MEETING 4: CREATING A STAKEHOLDER MAP AND PRIORITIZING ACTIONS

Overall Design Team Outcomes

- Identify stakeholder groups/perspectives needed to systemically explore and develop recommendations for supporting resilience for communities impacted by wildfires
- Wrap up pilot round table discussion and discuss next steps

Meeting Outcomes

- Overview of what we have learned so far
- Create a Stakeholder map based on the Problem Scope we identified
- Identify opportunities where we can really make a difference—where something isn't happening or where we can have impact. (HiLo Matrix)
- Wrap up this initial phase of the work
- Talk about the next phase for the project

DISSCUSSION SUMMARY AND SYNTHESIS

The first part of Meeting 4 focused on populating a stakeholder worksheet (based on areas identified in Meeting 3), to identify a preliminary list of possible names, agencies, and organizations to invite to a full 1 or 2 year roundtable process to systemically explore and develop recommendations for supporting resilience for communities impacted by wildfires (Figure 11).

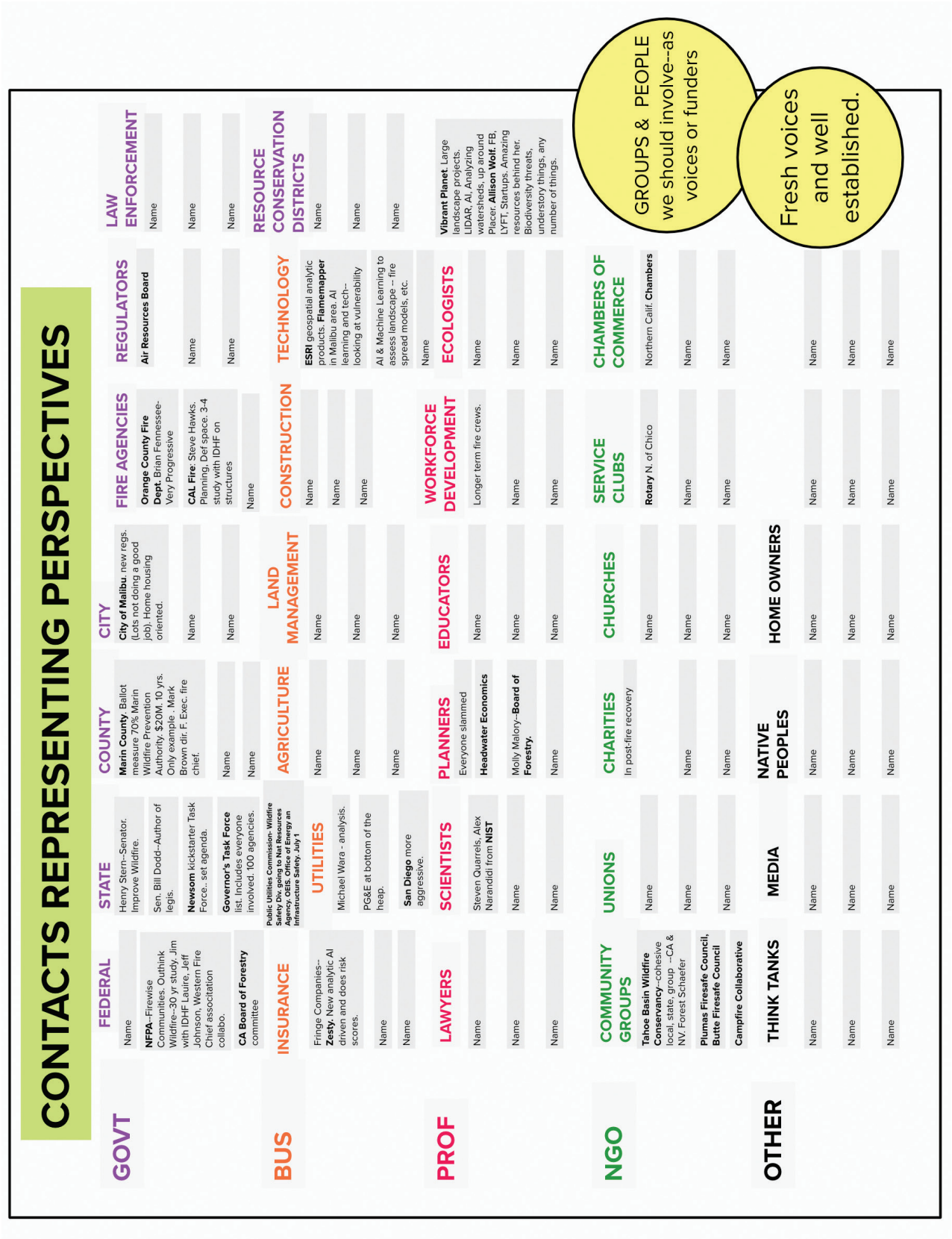

FIGURE 11 Contacts representing perspectives.

The second half the meeting focused on a high-low exercise to identify areas where the pilot design team felt a difference could be made in enhancing community resilience to wildfire in the short-term (Figure 12).

FIGURE 12 High-low priorities.

Conclusion

The pilot design group and facilitators spent some time reflecting on the four meetings we had, what we all learned from the process, and what we hoped for moving forward. Overall, the pilot design group felt that it was vital to include diverse, new voices and leaders in a roundtable focused on mitigating and adapting to wildfire risk in communities. The wildfire risk and resiliency problem space is enormously complex. A recommendation from the pilot design group is that the roundtable process should focus on one aspect of this problem space to have the best chance of developing recommendations that will create change and enhance community wildfire resilience. Figure 12 suggests that in looking at areas with the potential for impact, a focus on infrastructure changes at different points in the system in combination with new awareness programs and incentives (also cross-system) could offer the best opportunity to reduce wildfire risk to communities in the short term. Systematically exploring this aspect of the complex wildfire risk and resiliency problem space through a multi-perspective roundtable process would potentially produce actionable recommendations for programs and policy initiatives to address one aspect of risk to communities from wildfire.

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