Bay Area Urban Areas Security Initiative

Supply Chain Resilience Playbook

Making Time and Space for Flow

September 1, 2023

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BACKGROUND

The Bay Area UASI has been awarded funds via the Department of Homeland Security's Fiscal Year 2021 Regional Catastrophic Preparedness Grant Program (RCPGP) to build capability by ensuring the whole community is engaged in strengthening Bay Area supply chain resilience. To prepare for future incidents, Bay Area jurisdictions are eager to coordinate with the whole community in planning to resolve supply chain issues to ensure impacted communities can access essential commodities. To improve supply chain resilience in the Bay Area, a project was designed with progressive and complimentary components outlined in the introduction. Composition of this report began with stakeholder engagement, incorporating feedback and lessons learned from a series of nine seminars, which shaped the purpose and content.

PURPOSE

The Bay Area Urban Areas Security Initiative (UASI) Supply Chain Resilience Playbook (herein referred to as the Playbook) is intended to support preparation for, response to, and recovery from incidents impacting food and water supply chains in the San Francisco Bay Area region with the goals of saving and sustaining lives, stabilizing incidents, and recovering as rapidly as is reasonable. It also provides guidance on decision-making to improve coordination, information sharing, and resource allocation within and across the region with the aims of deploying regional assets in a timely manner, minimizing duplication of efforts, and maximizing regional resources. The following sections summarize the approach to achieve these goals.

FOUNDATIONAL KNOWLEDGE AND REGIONAL CONTEXT

Fundamentals of supply chain resilience are presented to establish foundational understanding of supply chains in general with a concentration on food and water supply chains. Key concepts are introduced and built upon in subsequent sections. Particular attention is paid to supply and demand dynamics – demand pulls supply while supply pushes toward demand. The overarching goal is continuous flow as commodities largely move from upstream (e.g., sourcing, packaging) to midstream (e.g., storing, distributing) to downstream (e.g., stocking, retailing) and demand is signaled from downstream to upstream (largely through electronic payment cards). Planned bottlenecks are also emphasized as they are at risk of turning into chokepoints in disasters. Roles of key players are categorized by upstream, midstream, and downstream with primary contributions summarized by originating push, leveraging push to fulfill pull, and facilitating flows and fixing problems, respectively.

Supply chain dynamics specific to the Bay Area are presented. High-level information on the most critical water and food flows as informed and validated by water and private sector stakeholders are described.

Analytic results and maps, tables, and figures that contribute to the regional profile of food and water supply chains are organized in appendices for quick reference.

RISK

Risk is presented as a function of compounding factors that include threat, vulnerability, and consequences. Supply chain resilience is often challenged by simultaneous and diverse threats and vulnerabilities, including complications, disruptions, contamination, vulnerable populations, destruction, and too much force-on-target, as well as unfolding catastrophic consequences. Complications are expected, recurring, and innate to any supply chain and are usually addressed by experienced personnel. Disruptions are usually perceived as having an external source that cannot be reliably predicted. As the name suggests, the event ruptures preexisting expectations and flows. Contamination events are frequent in both food and water across the nation. Early containment is fundamental to many effective risk management strategies. Vulnerable populations can be categorized as preexisting or new. Preexisting vulnerabilities related to food and water will drive higher-scaled consequences from any disruption of food or water supply chains. Knowing where preexisting vulnerable populations are located will enhance validity and speed of post-event risk assessments, mitigation measures, and strategic interventions. Having preexisting relationships of trust and operational preparedness with related stakeholders can effectively reduce the vulnerability multiplier. For the most serious threats, there can be tens of thousands of newly vulnerable individuals, such as in the case of sudden onset food deserts. Destruction is anticipated with any major disaster. Planned bottlenecks can become chokepoints, especially when and where any crucial components of supply chains are destroyed – when and where concentrated pull or push capacity is displaced. Force-on-target increases as the number of simultaneous threats and vulnerabilities increases. Catastrophic-scale events do not often unfold, but when they do, supply chain resilience requires atypical collaboration among everyday competitors and between private and public sectors. As risk increases due to combinations of these variables, so too does the level of involvement required of emergency management.

ACTION

Activities that emergency management can execute to improve resilience are described as sets of actions that prepare for, respond to, and recover from incidents impacting supply chains. Detailed descriptions and examples are provided in the text and templates are provided for quick reference in the appendices. In general, actions can be summarized by the following.

> Preparedness actions tend to be gradual and work to anticipate troubled flow. They are mostly focused on 1) understanding the capacity, structure, and typical behavior of current demand and supply networks; 2) establishing relationships with those who operate current demand and supply networks; and 3) exploring effective responses to potential disruption and destruction scenarios.

Response actions are urgent, on-the-ground, and action-packed to serve survivors. They are specific actions that emergency management can take to facilitate flows under duress and better ensure vulnerable people are served. These plays mostly involve 1) identifying where and how preexisting flows have been impacted; 2) taking steps to remove constraints on preexisting flows; and 3) taking steps to increase time and space available for surviving flows.

Recovery actions are often variations of preparedness and response plays that gradually wind down response actions as preexisting flows are recovered. They can include gap-filling measures given the sometimes-volatile situation on the boundary between response and recovery. Response actions increase space and time available to make and move commodities. As the response actions achieve this purpose, more volume can flow at greater velocity until the needs and even wants of survivors are mostly fulfilled. Recovery actions are often aimed at more specific targeting of this velocity. Reduced volatility during this transition is the goal.

COLLABORATION

Successful execution of these actions requires local adaptions that are built through considerable co-development with the private sector along with tabletop exercises and trial-and-error learning in actual disasters. Region-wide disruption and destruction requires local know-how and, especially, local emergency management expertise to facilitate flows under severe duress. Local to regional (i.e., bottom-up) supply chain resilience collaboration is needed to prepare together and thereby be ready to respond and recover together. Further, multi-agency coordination groups can be pivotal in achieving these goals. An example structure aimed at improving collaborations to improve supply chain resilience is provided from which the Bay Area can model a customized, local structure.

INTRODUCTION

The Bay Area UASI has been awarded funds via the Department of Homeland Security's Fiscal Year 2021 Regional Catastrophic Preparedness Grant Program (RCPGP) to build capability by ensuring the whole community is engaged in strengthening Bay Area supply chain resilience. The Bay Area, like much of the globe, suffered from supply chain interruptions during COVID-19. To prepare for future pandemics, Bay Area jurisdictions are eager to coordinate with the whole community in planning to resolve supply chain issues to ensure impacted communities can access essential commodities. Lessons learned from COVID-19 indicate that to be most successful in future emergencies, the region needs to build capacity across the functional areas of supply chain restoration, private resources, resource delivery, and access to community staples. Challenges identified during the COVID-19 pandemic response, as well as findings from previous UASI- and RCPGP-funded projects, show that the key to closing gaps in these functional areas is building successful relationships between the private and the public sectors.

To improve supply chain resilience in the Bay Area, a project was designed with progressive and complimentary components including: 1) a series of nine seminars on supply chains, 2) analysis of Bay Area food and water supply chains, 3) this Supply Chain Resilience Playbook, 4) a report on supply chain considerations for people with disabilities and access and functional needs, 5) a report on the feasibility of and recommendations for developing a Regional Community Lifelines Council, 6) a series of six table-top exercises, and 7) a summary report with recommendations for the future. Composition of this report began with stakeholder engagement, incorporating feedback and lessons learned from the seminar series to shape the purpose and content.

PURPOSE

The Bay Area Urban Areas Security Initiative (UASI) Supply Chain Resilience Playbook (herein referred to as the Playbook) is **intended to support preparation for, response to, and recovery from incidents** impacting food and water supply chains in the San Francisco Bay Area region with the goals of saving and sustaining lives, stabilizing incidents, and recovering as rapidly as is reasonable. It also provides content on decision-making **improve coordination, information sharing, and resource allocation** within and across the region with the aims of deploying regional assets in a timely manner, minimizing duplication of efforts, and maximizing regional resources. This is achieved by 1) providing an overview of supply chain dynamics in general and specific to the Bay Area including high-level information on the most critical water and food flows as informed and validated by water and private sector stakeholders; 2). describing key modes by which incidents impact supply chains; 3) outlining sets of actions that can be taken to prepare for, respond to, and recover from incidents impacting supply chains; and 4) providing an example structure aimed at improving collaborations to improve supply chain resilience.

SCOPE

The geographic scope of this plan is composed of the following California jurisdictions (Figure 1):

- Alameda County
- Contra Costa County
- Marin County
- Monterey County
- Napa County
- San Benito County
- San Mateo County
- Santa Clara County
- Santa Cruz County
- Solano County
- Sonoma County
- City of San Francisco

Figure 1. Jurisdictions in California's Bay Area Urban Areas Security Initiative region and the cities of Oakland and San Jose highlighted.

This Playbook is written for Emergency Managers and stakeholders of the regional food and water supply chains. It may be generally applied in any type of incident impacting the food and water supply chains of the region. The Playbook provides guidance only. It is intended to serve as a framework for additional development of incident response procedures specific to the Bay Area region. Actual responses will depend upon the complexity of the incidents.

DEFINITIONS

A supply chain is the sequence of processes involved in the production and distribution of a commodity. This includes local, regional, and/or global networks used to move commodities from the point of sourcing raw materials to end users.

Supply chain resilience is the capacity for a supply chain to resist and recover from disruptions while limiting the impacts of disruptions.

This Playbook uses select terminology analogous to a sports playbook. Historically, playbooks have helped athletic teams conceptualize, practice, and execute complicated plays. The term *playbook* has been used increasingly in business, political, and other contexts to reference a set of shared strategies and tactics to be deployed across an enterprise or campaign. This playbook adopts the term ***players*** to refer to Emergency Managers and stakeholders supporting supply chain resilience. The term ***plays*** refers to sets of actions that can be executed to improve preparedness for, response to, and recovery from incidents impacting supply chains.

ASSUMPTIONS AND LIMITATIONS

The following assumptions were made in development of this Playbook:

- This Playbook is not authoritative; no individual or jurisdiction is bound by the guidelines contained herein.
- Each jurisdiction is responsible for making decisions and executing individual responses and retains control and authority over response management even when the response is supported by regional, state, or federal assets/entities.
- Responses may vary across political boundaries.
- This Playbook is not intended to replace other plans.
- Incidents will occur that will impact supply chains and may be the result of natural or manmade hazards or a combination of both.
- Incidents are not limited by space or time – they may originate within or outside regional boundaries and occur at any time.
- Incidents will vary in complexity with distinct impacts on sectors and jurisdictions.
- More complex incidents may require support originating outside of directly impacted jurisdictions.
- Responses may be hindered by compounding incidents.
- Incidents highlighted in this Playbook do not represent an exhaustive list.

FUNDAMENTALS OF SUPPLY CHAIN RESILIENCE

Human need for water and food stimulates *supply* of both. Where consumers have value to exchange for water, food, and more, this *demand* motivates supply. Where demand pulls, supply (in the form of production, processing, distribution) tries to push. When local demand exceeds local supply, connections emerge to push what is wanted over longer distances. These higher-volume, higher-velocity connections tend to spawn concentrations of *flow*, or movements from supply to demand. Suppliers who can regularly deliver what is wanted at lower costs will usually claim an increasing proportion of total flows.

For more than a half-century, the most cost-effective way to serve these increasing flows has been physical and/or functional concentration of production and distribution capacity. Now, fewer refineries produce more fuel. Fewer slaughterhouses produce more meat. Fewer water treatment plants serve many more customers. A higher proportion of grocery customers are served by a smaller number of grocery distributors. Sourcing and treatment of raw water is often widely distributed but proportional flow capacity is highly concentrated.

While economies of scale often provide better quality and more volume at lower costs, concentrated capacity increases systemic risk. As connections and flow capacity are more proportionally, physically and/or functionally concentrated, even modest complications can quickly multiply across supply networks and disturb velocity (speed and direction) of flows. In most high-volume, wide-area networks, these challenges are constant and receive ongoing attention aimed at mitigating potential system-wide slowdowns. While bottlenecks can and do become chokepoints and supply may be delayed, supply has typically proven to be very resilient even to extraordinary disruptions so long as demand persists. However, destruction is an entirely different risk category.

Given the typical concentration of capacity serving dense urban populations, if principal connections and/or high-volume production/distribution facilities are removed from the network, push can suddenly dwindle to far less than pull is working to attract. In the case of water and food (or pharmaceuticals, fuel, and other essential flows) this loss can have quick and life-threatening consequences. The longer flows of water and food are stopped, the more likely consequences will be catastrophic for people trying to pull what they need.

The goal of supply chain resilience is to facilitate persistent flows under severe duress, to make time and space for flow. Following are core concepts of supply chain resilience centered around making time and space for flow.

> *Goal*: Feed and hydrate survivors of major disasters. Fulfill large-scale demand for water, food, and those products and services that water and food depend upon.
>
> *Operating Context:* Scope reflects local, regional, super-regional, national, and global demand and supply networks.
>
> *Operational Assets*: Assets include private sector resources, including industry groups and partners, and several, mostly independent, emergency management functions, including Emergency Support Functions. These functions engage a chaotic combination of natural, accidental, and intentional complications, contamination, disruptions, and destruction.
>
> *Operational Objectives*: Flow-friendly emergency management functions can focus on maintaining, reopening, or replicating connections to surviving or recoverable concentrations that produce, distribute, and deliver food and water. Depending on the disruption, operational objectives may focus different stages of the supply chain.
>
> *Measuring Success*: Survivors of a potential catastrophe receive adequate and quality water and food in a timely manner.
>
> *Duration*: Preparedness starts today (or is already underway). Plays continue with response activities as long as it takes to ensure sufficient flow to survivors and full recovery of flow capacity.
>
> *Recurring Plays*: Maintain, reopen, or replicate connections to surviving or recoverable concentrations. Overcome complications slowing or stopping flow. Communicate flow possibilities. Target places and people needing flow. Supplement insufficient flows. Shape context, channels, and even chaos.

OVERVIEW OF FOOD AND WATER SUPPLY CHAINS

Modern, high-volume, high-velocity systems work well most of the time - push fulfills pull. This is true for both water and food supply chains that seek to balance push and pull by organizing around demand. The grocery supply chain is a mostly open system pulling and pushing toward a desired (if seldom achieved) state of constant, stable flows. Figure 2 illustrates the stages of the food supply chain and the nodes within each stage. While there are exceptions, flows generally move left to right. The first stage is sourcing and harvesting of raw materials such as grains, fish, and livestock. Those raw materials are then transported to processing facilities that turn them into finished products. The processed food is sent to wholesalers and distributors that supply food to retail facilities. The focus of wholesalers and distributors can vary. For example, some wholesalers may specialize in a single food product while large distribution centers may collect food from numerous processors and serve specific grocery brands. Additionally, distribution centers that serve the food service industry specialize in distributing to restaurants and cafeterias. These products are often packaged in larger sizes by commercial processors. The result is parallel channels in the supply chain. At the retail stage, grocery and convenience stores create opportunities for end users to acquire food onsite or have food delivered to their homes. Parallel channels include restaurants, cafeterias, food assistance locations, and others.

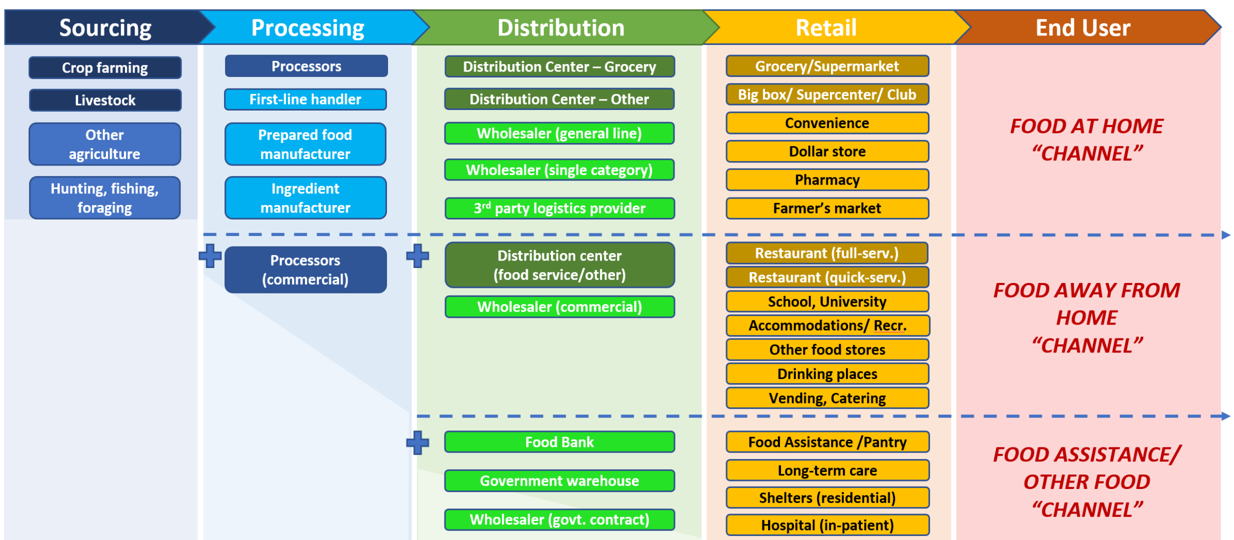

Figure 2. The food supply chain stages and nodes.

Relative to the food supply chain, the public water system "supply chain" is a much more engineered system, relying on infrastructure to move the water in a system of pipes between nodes (as opposed to trucks). But the system can still be organized into functional stages, as illustrated in Figure 3. Our water supply begins with precipitation which collects in surface water streams and lakes or soaks into the ground to accumulate in groundwater aquifers. Public water systems collect groundwater through wells or pump surface water collected from intakes. After acquisition from the source, water can be pumped to a water treatment plant to be treated to meet potable water standards. Water treatment plants use chemical, physical, and biologic methods to treat water. Once treated, water is pumped through transmission mains to be stored in ground-level tanks or water towers that generally serve distinct pressure zones. Pressure is generated by gravity or pumps. Note that, at this stage, water systems may purchase and receive water from other water systems through transmission pipelines or direct interconnections. The distribution stage is dependent on a network of underground pipes to provide water to end users. This network also includes valves to shut off water, pumps or pressure-reducing valves to regulate pressure, and fire hydrants to support firefighting. End users connect to the distribution system through a small pipe referred to as a lateral or service connection, with their water usage tracked by a water meter. Though not shown here, the wastewater system operates in reverse. Wastewater is collected from end users in sewer laterals which connect to a collection system, which concentrates flow and uses lift stations (i.e., wastewater pump stations) to move the water to wastewater treatment plants where it is treated and released back into the environment as effluent. In some cases, the treated wastewater is returned to surface water or groundwater sources, used in non-potable applications, or even treated to potable standards as part of water reuse or water recycling.

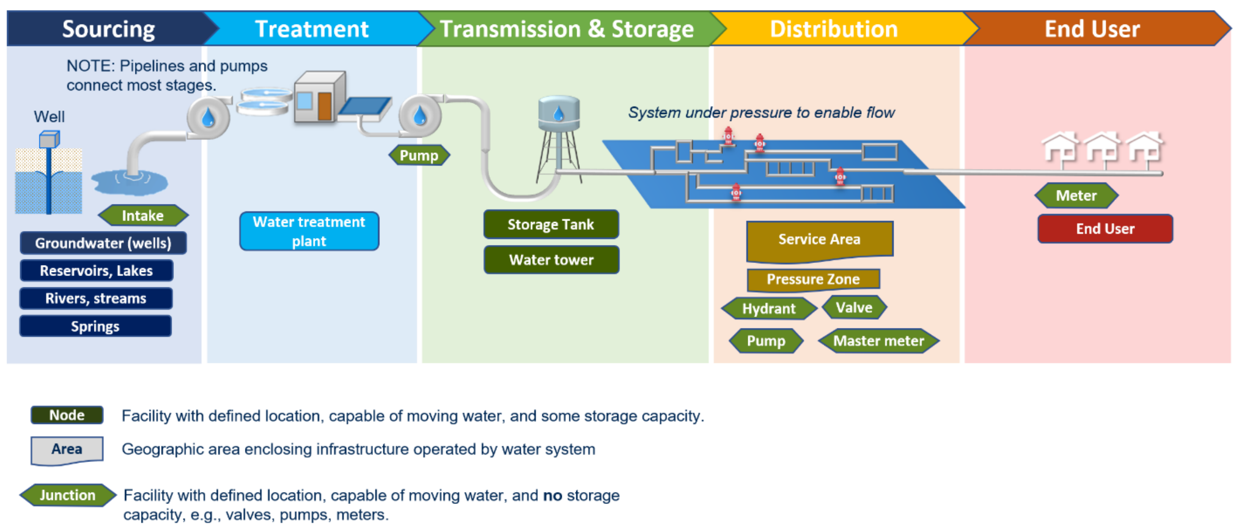

Figure 3. The water supply system stages and nodes.

DEMAND AND SUPPLY (PULL AND PUSH): HOW FLOW STARTS

The last 50 years have seen an increase in the demand for goods and a concentration of people in urban areas. This has led to supply chains being radically transformed and they continue to adapt to increasing volume, velocity, and density of demand. Further, an exponential growth in digital demand has had big implications for delivery efficiency. Compared to the 1970s, US supply chains deliver much more volume at reduced costs per unit consumed with much less waste. Goods are mostly delivered when and where there is near-term demand for what is delivered. Sourcing, processing, packaging, distribution, and retail capacity are organized around consumer patterns: when, where, and how dollars are spent. Supply is pulled toward demand by financial signals communicated mostly by digital means. In response to these financial signals, sourcing, processing, packaging, distribution, and retail capacity is developed and managed to push what is wanted when, where, and how consumers want to buy it.

When demand and supply are close to equilibrium, the result is continuous, mostly predictable flows of financial information pulling goods and services. In turn, goods and services are pushed out with a volume and velocity that accurately reflects pull. These continuous flows depend on a wide array of factors working in tandem and there are constant complications that require quick fixes to avoid flow problems.

Bay Area Characteristics: Demand and Supply

In the Bay Area, we calculated food demand for each jurisdiction using equation *(1)*

$$D = \frac{PC}{(1-W)} \tag{1}$$

where *D* is demand in pounds per day, *P* is the estimated population [1], *C* is the weight in pounds of food consumed per person per day (5.03 lbs; [2]), and *W* is estimated food waste rate (40 %; [3, 4]). Results indicate that the Bay Area region requires a minimum of 72 million pounds of food per day. Figure B.1 shows total food demand (assuming constant demand and waste rates) across Bay Area counties, with highest demand in the highest population counties: Contra Costa, Alameda, and Santa Clara. The source for the food commodities that satisfy that demand is largely within the state of California (35% and 30% sourced from within the Bay Area region and within California, respectively; Figure B.2) [5] though the Pacific Northwest, Midwest, and other regions are important contributors (Figure B.3) [5].

Food processors tend to be geographically concentrated near agricultural areas, population centers, or transportation access. Figure B.4 shows the geographic distribution of processors identified by North American Industry Classification System (NAICS) code commodity groupings [6]. Relatedly, Figure B.5 reveals a pattern of distribution centers and wholesalers that is comparable to that of food processors with respect to the food commodity types handled, breakdown by revenue categories, and geographic concentrations. However, several large produce wholesalers/distributors are located in the south [6]. It is also important to note that larger wholesalers, and in particular, distribution centers tend to be concentrated together.

In the Bay Area, 95 % of the population receives water from public water systems, with about 5% supplied with their own groundwater wells [7, 8]. As with food demand, the highest population counties of Santa Clara, Alameda, and Contra Cosa have the highest total demand for public water supply (Figure C.1) [7, 8]. The percentage of the population served by public water is highest in central jurisdictions that are the most urban (Figure C.2). Several major water districts are the key players in the region that operate and manage many of the sources and transmission to ultimately sell untreated water to local retail public water supply systems. Some of these water districts, such as San Francisco Public Utilities Commission and East Bay Municipal Utility District, also have retail service areas where they operate treatment and the distribution system and sell directly to water users [8, 9]. Figure C.3 provides an overview of the geographic areas served by 11 major districts (and similar key players) in the region, and the retail service areas they help supply.

The region's water providers rely on a variety of sources including surface water imported via canal or pipeline by the major water districts, local surface water sources, groundwater, and reused (or recycled or reclaimed water). Figure C.4 shows the water systems in the region mapped by their primary water source, and population. Dependence on groundwater sources for water supply is higher in the northern and southern portions of the region. Note that many of the systems in the core of the region show their primary source as "Surface Water Purchased," which usually indicates they are receiving the majority of their supply from imported water. Figure C.5 goes one step further and breaks down the percentage of supply coming from imported water (panel A), local surface water (panel B), local groundwater (panel C), and reused water (panel D) [8, 9]. A large portion of the region relies on surface water sourced from reservoirs outside the region and imported via large surface water transmission projects, which can be owned and operated by federal, state, or local agencies.

CONNECTIONS, CHANNELS, FUNCTIONS, AND CYCLE TIME

Persistent pull and push prompts emergence of preferred connections between demand and supply. Better roads and air cargo speed supply. Bridges reduce distance traveled. Rail and maritime channels usually push larger volumes. Functional innovations, such as standardized shipping containers, improve loading and unloading speed. Multimodal facilities seek to streamline speedy volumes as goods move between modes of transport. Distance between demand and supply may stay the same, but connections are developed that reduce time, cost, and guesswork required to cross that distance.

Depending on the cost of local sourcing and production, cost-efficient connections can result in local sources being displaced by those farther away. Historically, time and cost involved in shipping often gave local sourcing and production a cost advantage. In the last half-century, some of these advantages have dissipated, especially for more expensive and less bulky products. In contrast, heavier products such as water still tend to be locally sourced or have low-cost long-distance connections. Utilization of pipelines achieves these low-cost connections for water systems as well as major elements of fuel production and distribution.

Roads, bridges, pipelines, and such are often categorized as "critical infrastructure." This is accurate but tends to emphasize form over function and sometimes ignores flow. Supply chain resilience engages connections as key parts of whole networks. For example, roads that connect a grocery distribution center to retail outlets are critical. Criticality extends to trucks, vans, drivers, truck stops, fuel racks, gasoline and diesel tanker trucks, Global Positioning System mapping systems, routing software, and more. All are connected. Connections are as important to pull as they are to push.

Cycle time (or lead time) is the amount of time that is required to fulfill a consumer's pull for food or water given distance, available inventory, and available connections. Pull signals are necessary to minimize cycle time. In the United States a bit more than two-fifths of groceries are purchased using a debit card, about one-third of grocery purchases are made with a credit card [10, 11]. Most SNAP (Supplemental Nutrition Assistance Program) beneficiaries use an EBT (Electronic Benefit Transfer) card similar to a debit card.

More than one-tenth of US grocery purchases is made using SNAP benefits [12]. These crucial pull signals require Point-of-Sale (POS) devices, electricity, telecommunications, computing, financial transaction agreements with processes, and plenty of other connections. In a crisis, efforts are made to reduce cycle time and must find workarounds when pull signals are lost.

Bay Area Characteristics: Connections and Channels

While precise data on grocery flows are difficult to generate due to the dynamic nature of grocery sales, published sources and interviews indicate that a small number of players are responsible for the great majority of total supply in the region. Table B.1. summarizes results for two analyses of grocery market share in the Bay Area: estimates of market share for a 2019 Bay Area UASI study [13] and this project are comparable, indicating 5 – 7 key players make up at least 75 % of the grocery market share. Using brand name and retail sales information from USDA and business reference databases as sources, and independent research and interviews with grocery distributors (personal communications, October 2022) to establish connectivity, we were able to identify locations for each store and their distribution centers [6, 14].

We performed routing analysis to determine the routes with minimum trucking time from distribution centers to all stores served by that distribution center, and then aggregated the flows along each route for all brands. We mapped the aggregate concentration of grocery truck flows as a percent of total market share served along distinct routes. Our results reveal two major areas of concentration for distribution centers that are located outside of the Bay Area region – Tracy-Stockton and Sacramento (Figure B.6). As a result, flows concentrate on a few key truck routes into the area. Coming from the distribution centers in the Tracy-Stockton area, Interstate-580 represents the most important food freight route into the Bay Area representing approximately half of the flow into the region. Interstate-680 appears to be an important connector for San Jose and Interstate-880 for Oakland. Further, there are four major bridges that are important for food freight, carrying a combined 17 % of the grocery market share. Coming from the supply sources in Sacramento region, I-80 is an important route for inbound food, especially serving the northern counties in the region.

For water, sources of imported water can be far from the Bay Area. California's Central Valley Project (CVP) and State Water Project (SWP) supplies water to millions of people throughout California. The CVP is a "multi-purpose network of dams, reservoirs, canals, hydroelectric powerplants and other facilities," primarily supplying water to the Greater Sacramento and San Francisco Bay areas. The SWP "is a multi-purpose water storage and delivery system that extends more than 705 miles" and consists of a "collection of canals, pipelines, reservoirs, and hydroelectric power facilities." The California Aqueduct (SWP) and Delta Mendota Canal (CVP) are the major transmission links for water moving into the Bay Area, and South of the Bay-Delta to water users in the Southern portion of the Central Valley and Southern California.

The major sources and transmission routes used by the key players to move water into and within the Bay Area are summarized in Figure C.6 [15, 16, 17, 18]. Water flows from the SWP's North Bay Aqueduct, and a US Bureau of Reclamation funded system called the Solano Project to City of Napa and Solano County Water Authority. The SWP's South Bay Aqueduct enables flow to the Alameda County Water District (ACWD), Santa Clara Valley Water District (SCVWD), and Zone 7 Water Agency. The CVP operates two canals that deliver water to the region including the Contra Costa Canal, which delivers water to Contra Costa Water District, and the CVP's Delta-Mendota canal, which provides water to the San Luis reservoir. From the San Luis reservoir, a system of conduits (Pacheco, Hollister, Santa Clara) provide water to SCVWD and San Benito County WD. The Hetch-Hetchy Aqueduct is operated by SFPUC and sells water to the Bay Area Water Supply and Conservation Authority as well as all the systems served by the South Bay Aqueduct (ACWD, SCVWD, Zone 7). The Mokelumne is owned by East Bay MUD. Note that the Hetch Hetchy and Mokelumne projects are somewhat different in that they are owned and operated by local water districts, so are counted as local sources in Figure C.5. The Russian River project supplies Sonoma County Water District and Marin Metropolitan Water District.

The major raw water projects are not the only means of moving water through the region. Individual public water systems can also move water through direct pipe interconnections allowing water to be sold between neighboring utilities on an everyday basis or during emergencies. Figure C.7 shows the main interconnections in the Central part of region, which reflect the buyer-seller relationships between the major water districts and their retail customers (Figure C.3), though not the actual physical path of the connection pipes.

In summary, the major water systems in the core of the Bay Area region rely more heavily on imported sources (Figure C.5) [9, 19] and may have more source diversity and have more interconnections (Figure C.7) [8, 9]. Further, water systems in the northern and southern parts of the region have more local sourcing but fewer options for emergency or alternative sourcing.

CONCENTRATIONS: CAPACITY, PLANNED BOTTLENECKS, AND EMERGENT CHOKEPOINTS

Supplies tend to flow faster at higher volumes when demand is concentrated. As connections are made to improve volume and velocity, flows become further concentrated. The fact that most of the San Francisco-Oakland-San Jose metro area's groceries move west along Interstate-580 (Figure B.6) serves as a primary example of this concentration. Typically, these concentrated corridors emerge from concentrated clusters of distribution and, sometimes, production facilities surrounded by related freight, fuel, and maintenance operations. Developing distribution capacity integrated into high-volume, high-velocity connections can reduce time to deliver and the related costs. Expensive distribution capacity is purpose-built to serve projected pull over a large, loosely defined area for an extended number of years.

Flow capacity creates planned bottlenecks and consists of inbound lead times, shelf space, inventory, selector numbers, van space, drivers, delivery locations, distance, and more. The neck of this bottle is designed to improve the speed and accuracy of what flows (like a wine bottle's pour). Most of the time, flow is broadly predictable per population, economic conditions, place, and season. Small complications are constant, but quick fixes are usually possible. Buffer stocks are often available, though quantity may vary by company. In some cases, however, a bottleneck can become a chokepoint.

Given the proportional concentrations of capacity that have emerged over the last half-century, the extended loss of any top-five source of capacity will often result in the loss of double-digit flow percentages. Further, given the tendency of capacity sources to cluster near each other and with major connections, chokepoint potential is often shared across the cluster, amplifying network-wide risks.

Bay Area Characteristics: Concentrations

As outlined previously, Bay Area demand, supply, and connections tend to be geographically and functionally concentrated. Water, food, and fuel serving the Bay Area all depend on a handful of high-capacity upstream nodes that flow through innately rate-limiting channels toward concentrations of people. The capacity to receive and distribute food is clustered in a handful of places east of the Bay Area; resulting food freight flows by truck are concentrated, especially on a few Interstates and bridges (Figure B.6). Importantly, the capacity to produce fuel needed for trucking and logistics depends principally on refining facilities. These are also clustered, specifically in the North Bay (Figure 4) [20, 21, 22]. Importantly, there is no existing ability to move fuel into the Region from other refineries via pipeline if these nodes fail. Transport would have to occur by ship or truck, and it would be very difficult to match the capacity of the Bay Area refineries.

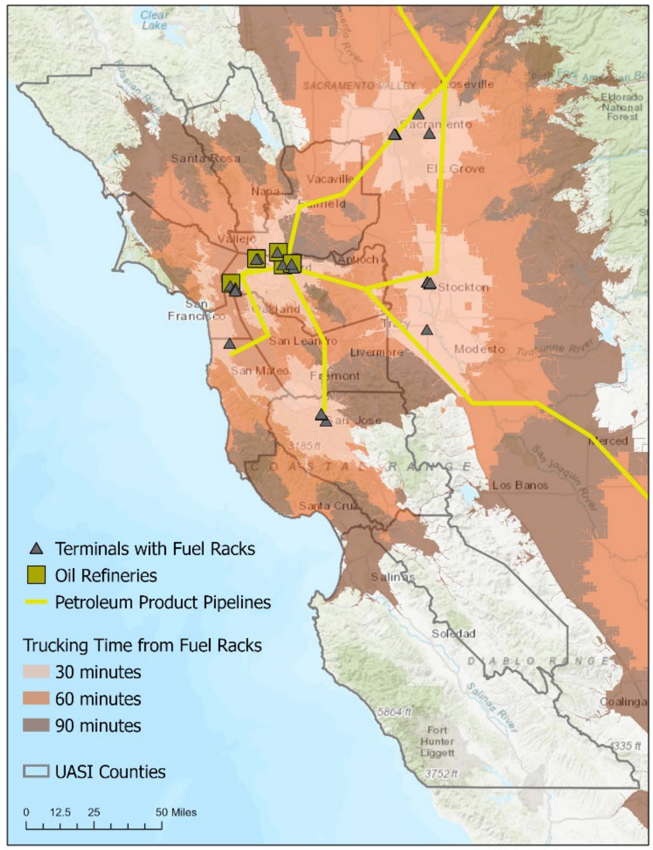

Figure 4. Fuel terminals with fuel racks, oil refineries, petroleum produce pipelines, and trucking time from fuel racks in the Bay Area and surrounding regions.

Water storage is concentrated in a few key reservoirs, and flow in canals, and pipelines that allow distant water to flow toward demand. For example, the Hetch-Hetchy reservoir is located on the Tuolumne River in Yosemite National Park. From this reservoir that stores Sierra Nevada snowmelt, the transmission system composed of canals, pipelines, and storage allows the water to travel 160 miles to the San Francisco Bay Area entirely by gravity flow. This system provides 85% of the water used by the Bay Area Water Supply and Conservation Agency's utility members in San Francisco, Santa Clara, Alameda, and San Mateo counties [23].

The Bay-Delta Estuary (approximately on the border between Solano and Contra Costa counties) is a significant hydrologic bottleneck for both natural flows and human-built water projects and systems. The estuary is the convergence point for the Sacramento and San Joaquin rivers, which drain the water flowing from the Western slope of the Sierra Nevada and the Central Valley to the North and South of the Bay Area, respectively. Since rivers flow by gravity, the estuary is a natural low point, and the major water projects (SWP and CVP) move water from North of the estuary to points South, requiring major pumping, transmission, and storage in the Bay-Delta Estuary. This area is also prone to liquefaction in a large earthquake, so there is a significant risk that the infrastructure may fail, which is one driver of the interest in DWR's proposed Delta Conveyance Project [24]. Whether or not the project is built, the infrastructure in the area is crucial for feeding major canals such as the North Bay Aqueduct, Contra Costa Canal, California Aqueduct, and South Bay Aqueduct, among others. The San Luis Reservoir (see Figure C.6) is also a major bottleneck, where flow from the North in the California Aqueduct and Delta-Mendota Canal is collected, and then redistributed to SCVWD and San Benito County WD through the San Luis and San Felipe system (Pacheco, Hollister, Santa Clara conduits), or redirected further south through the Delta-Mendota Canal, and southern section of the California Aqueduct, called the San Luis Canal.

FLOW: VOLUME AND VELOCITY

For the purposes of supply chain resilience, flow is the aggregated volume of supplies being pushed at certain speeds in particular directions in response to the various pulls in a defined space. In technical terms, flow is measured by the amount of volume passing a given point in defined amount of time. Whenever and wherever possible, those pushing will try to improve the velocity of flow (speed and direction) so that increased volumes are delivered at lower costs per unit. During the 21st Century, supply velocity has become increasingly important for responding to or anticipating shifts in consumer behavior. Many consumers now expect speedy, customized delivery, whether it is to retail locations or otherwise (e.g., home delivery, 3rd party gig economy shops, curbside pick-up). Many urban grocery supply chains are being organized to deliver this competitive advantage.

A velocity-focused supply chain strategy depends on reliable connections and related interdependencies. To achieve cost-containment goals, an essentially fixed number of drivers and trucks are required to traverse defined distances to specific receiving locations on a specific schedule. Any sustained loss of drivers or trucks or accessible routes will quickly and seriously reduce velocity, volume, and the proportion of pull that is possible to fulfill. These same fixed variables constrain the system's ability to respond to any sudden, substantial increase in demand. For high-volume flows, there is often sufficient buffer stock in the system to support short-term spikes (perhaps of up to two or three weeks) of between one-tenth to one-fifth of ordinary demand. Beyond these buffers, fulfilling demand depends on upstream capacity and lead-time.

Direction, or targeting, has become as or even more important in recent decades. Targeting depends on accurate pull signals in the form of financial and other feedback that communicates demand velocity. As mentioned above, this is almost always signaled by a digital transaction. Without receiving that digital signal, contemporary supply chains are unable to hear or see, which compromises decision-making.

BAY AREA CHARACTERISTICS: VOLUME

Extending equation *(1)*, we calculated minimum daily truck trips to serve baseline food demand of the Bay Area population using equation *(2)*

$$F = \frac{D}{T} \tag{2}$$

where *F* is total freight capacity needs in truck trips per day, *D* is food demand in pounds per day, and *T* is loaded weight in pounds per truck trailer (44, 000 lbs) [25]. Results indicate that the Bay Area requires a minimum of 1650 truck trips per day with the most daily truck trips need to meet the needs of centrally-located jurisdictions – Alameda, Santa Clara, Contra Costa, San Francisco, and San Mateo (Figure B.7).

The Bay Area population uses an average of 60-70 gallons per day per person for household use, which is less than the California average of 80-90 per capita per day. When all users and end uses are taken into account, the total amounts to roughly 135 gallons per capita per day for all public supply usage, and a total usage of roughly 4.8 billion gallons per day [7]. After analyzing the total use from 2020 Urban Water Management Plans [19], we found that 58% of the usage is residential, 12% is commercial, and 9% is for outdoor usage. Up to 13% of water is lost to leakage. Figure C.8 shows a full breakdown by end use.

KEY PLAYERS: UPSTREAM, MIDSTREAM, DOWNSTREAM

The shared objective in supply chain resilience is to make time and space for flows of water and food to persist, recover, and arrive where needed. Upstream players make water and food. The whole system moves water and food, but the midstream players tend to move at the highest volumes and very high velocities. Downstream is where flow is consumed, creating a pull on upstream supply. Downstream players facilitate upstream and midstream functions while opening time and space for flow through complications, contamination disruptions, and destruction. Key players in Bay Area are summarized by sector in Table D.1.

UPSTREAM: WHERE PUSH ORIGINATES

Upstream food capacity is generated by a diverse array of players – farmers, ranchers, gardeners, dairies, egg laying and packaging facilities, slaughterhouses, bakeries, canning operations, Consumer-Packaged-Goods (CPG) companies, small and large food processors, and others. The distance between these players and end users can vary greatly depending on where demand is located. Not surprisingly, Honolulu depends heavily on seaborne food flows 2400 miles away from Oakland and 2600 miles away from Los Angeles/Long Beach [26]. However, food can also travel thousands of miles within the continental US to reach end users. For example, one study found that lettuce consumed in Chicago traveled an average of over 2000 miles. In contrast, lettuce travels barely 100 miles to many San Francisco Bay Area grocery stores [27]. In general, most US urban areas depend heavily on distant sources, suppliers, and packagers for local food flows. It is also important to note that smaller food processors tend to promise local sources. Finding and knowing which food-makers supply especially large proportions of total local flow is important to supply chain resilience.

This is also true for water in California. Due to water's weight, there is a strong incentive in most places to acquire and develop water sources close to the communities that use it. But hydrologic conditions and the history of Western development have resulted in major movements of water from non-local sources. The most powerful upstream water players are almost always public water systems, and occasionally, state and federal water project operators, water districts, and river or groundwater authorities. Even when, as in California, a big proportion of water may be sourced outside immediate local areas, local owners/operators have considerable knowledge and authority regarding flows. These large water players can usually be easily found and are often already in communication with emergency management agencies.

While proportions that are locally sourced may be the most reliable and less prone to transmission interruptions, more distant sources may be the most likely to survive a catastrophe depending on the complication, disruption, or destruction involved. So, a wider, risk-informed view is beneficial. In the case of both water and food, those who make and move the highest proportion of total flows – or sometimes *survivable* flows – will be especially important to find and know. Understanding connections and interdependencies between upstream and midstream can be crucial when push requires a shove.

MIDSTREAM: WHERE AND HOW PUSH FULFILLS PULL

Individual upstream flows may be significant, but as individual flows are aggregated in midstream channels and nodes, volumes multiply fast, as can the velocity of flows. Midstream tends to emphasize maximizing the potential for both volume and velocity (speed in a specific direction, such as to a consumer with money to spend).

In the food sector, some midstream players specialize in specific higher-margin product categories, such as seafood or fresh produce. However, most of the highest volume midstream movers are aggregators of a wide range of products: dairy, eggs, meat, bread, produce, and others. In either case, various fast- and slow-moving products are delivered to a distribution center that is positioned to serve demand at high velocity. Each midstream mover is specialized in receiving multiple inbound flows from several upstream sources, efficiently organizing the combined flows in their distribution center, and selecting customized product combinations that are usually palletized and loaded into "dry vans" or refrigerated vans ("reefers"). Each outbound van is loaded to reflect the specific pull of specific places. Then a truck can be regularly and efficiently routed to push what is needed to downstream retail nodes, very close to when it is needed to satisfy each source of pull.

Public water systems also depend on their own version of midstream capacity. Water flow is a function of water pressure and pipe size. The key midstream nodes in water systems after water treatment are storage reservoirs, pumping stations, and where necessary, pressure reducing stations. These are roughly analogous to production warehouses, distribution centers, and demand management tactics for food flows. Typically, large diameter pipelines serve as the high flow, high velocity links that pumps or gravity move water through to reach the storage reservoirs or water towers that feed the downstream distribution system. The goal is continuous fulfillment of demand for each flow.

DOWNSTREAM: FACILITATION FLOWS AND FIXING PROBLEMS

Those who make (upstream players) and move (midstream players) products everyday have deep experience developing workarounds for short-term, recurring impediments. These players facilitate flows and fix problems that complicate timely delivery of push to pull every day. The same is true downstream, where demand pulls upstream supply toward it.

Grocery stores, other retail outlets, water networks, and fuel racks may choose to develop plans and capabilities and may have the experience to stay open longer and reopen sooner in the face of recurring extreme weather and many other impediments. But in some cases, these consumer-facing locations are damaged or inaccessible. When the downstream workforce is directly impacted by disruption or destruction, early identification of surviving retail nodes and their current capacity is key to assessing response and recovery requirements.

It is important to know which retail nodes serve a disproportionate share of overall consumer demand. In many grocery markets it is not unusual for up to eighty percent of grocery transactions to occur at fewer than twenty percent of local grocery outlets. Losing one or more of these high-volume retail nodes can have significant impacts. Further, losing just one grocery store in many non-urban locations can seriously reduce the ability to fulfill demand, effectively creating a “food desert”.

It is also important to understand the relationship between retail nodes and vulnerable populations Knowing which retail nodes serve disproportionate shares of demand by preexisting vulnerable populations before a disruption or destruction can minimize impacts when these very local flows are lost for an extended period. Anticipating the need to restore and replicate these high priority nodes and preserve flows to the preexisting vulnerable population is a key element of supply chain resilience.

Even when vital downstream nodes are lost, water, food, fuel, and other crucial freight can often be delivered in sufficient quantity to minimally fulfill demand if midstream and upstream capacity has survived. However, upstream and midstream players are very averse to being trapped – or worse: workers are hurt – by a risky situation they cannot independently evaluate. The more uncertain the context, the more likely upstream and midstream players will pause making or, especially, moving. When stores are disrupted, pull signals are lost, connections are bad, and physical danger is possible, most players will pull back until they have some confidence that taking a risk is worth it. As this suggests, many of the most important plays that emergency management can execute involve keeping upstream makers and midstream movers accurately informed of unfolding conditions between them and downstream.

Information can empower creative problem-solving by the players themselves. In worst-case-scenarios, bridges are down, roads are buried, the grid is gone, and tens of thousands of survivors still want to pull food and water but have been effectively silenced through the loss of the demand signal. In such a context, updated and accurate information and practical downstream problem-solving to minimize the impact on flows are crucial. Emergency management agencies and professionals that know how, when, and where to help most will facilitate potential flows. These crucial downstream players can come from a wide variety of functional areas, agencies, and places. The collaboration and coordination roles of emergency management professionals and agencies are often vital to deploying the right help at the right time to the right place.

EMERGENCY MANAGEMENT BLOCKS A POTENTIAL INFORMATION IMPEDIMENT

In late March 2020, the risk of covid in the New York City area was obvious. Hospitalizations and deaths had suddenly spiked. Potential risks to truck drivers delivering food into the city were, however, less obvious. At this point in the pandemic viral transmission was not fully understood and what was known was even less well communicated. When senior federal officials suggested travel to New York City be avoided and a travel ban was discussed, truckers who served the metro area from Eastern Pennsylvania, New Jersey, and Connecticut noticed. Rumors of heightened personal risk ricocheted from grocery stores to truck stops to distribution centers. FEMA officials asked for expert clarification. Information on health risks were communicated. Real risks of empty shelves serving millions were outlined. Federal, state, and local emergency managers reached-out to trucking firms and trucker networks. Pull for groceries had spiked. Most truckers decided that the public risk of not delivering was worse than the personal risk of continuing to deliver food into the metro area. Push continued to *mostly* fulfill pull.

THREATS, VULNERABILITIES, CONSEQUENCES, AND RISK

Risk is determined by a combination of threats, vulnerabilities, and consequences. Threats can range from simple complications to contamination and disruptions. Vulnerabilities vary depending on duration, spatial extent, and adaptability of individuals/communities. Consequences can include destruction, and complex catastrophes. Combinations of risk variables can compound forces on a single target.

While emergency management mostly gets involved when flow between midstream and downstream is threatened, involvement increases as any threat's scope and scale increases. There is a tendency for the worst supply chain risks to be multidimensional. Different threat categories occur coincidentally and even exponentially. Instead of confronting one threat, supply chain resilience is often simultaneously facing diverse threats and several vulnerabilities, such as complications, disruptions, contamination, vulnerable populations, destruction, too much force-on-target, and unfolding catastrophic consequences.

COMPLICATIONS

Complications are inevitable. Employees don't show up. You can't hire everyone you need. An inbound truck does not arrive. Traffic congestion delays outbound deliveries. A pallet falls apart spilling contents everywhere. A shelf falls over. A popular new recipe wipes out stock expected to last for weeks. Off-season freezing spoils the supply scheduled to serve you and your customers. Life happens.

Complications are expected, recurring, and innate to any supply chain. They are usually addressed by experienced personnel who recognize the problem, know their options for fixing or minimizing, and have the resources – internal to the supply chain – to fix, mitigate, or replicate lost flows. Upstream makers may call on midstream movers for help or vice-versa. On rare occasions the makers and movers may call for public sector help resolving a complication. For example, a fire inside a facility will almost always involve one or more flow facilitation specialty teams (e.g., fire suppression, police, food safety inspectors).

On most days roughly five percent of grocery stocks are missing in action [28] because of some sort of everyday complication. While constant and usually containable, it is a mistake to underestimate the risk presented by complications – especially accumulating complications. For example, simultaneous fires in five retail facilities would have amplified network effects. A network designed for constant flow can react very badly whenever flow is unexpectedly constrained.

DISRUPTIONS

There can be a fine line between innate complications and disruptions. Disruptions are usually perceived (accurately or not) as having an external source that cannot be reliably predicted. As the name suggests, the event ruptures preexisting expectations and flows. The more time-extended and geographically-distributed the disruption, the more likely that a reduction in flows will accumulate. This reflects the interdependencies of most high-volume, high-velocity demand and supply networks. For example, a grid outage that lasts two hours may disrupt retail sales while having little or no impact on upstream production or flow. Delivery trucks may be slowed by the loss of some traffic lights, but deliveries will continue if retail locations can receive flow. In contrast, effects may be amplified by factors including surprise, longer durations of the power outage, expansive geographic scope affected by the power outage, and the lack of established procedures for assessing the ability of destinations to receive deliveries.

EFFECTS OF GRID LOSS ARE AMPLIFIED

In June 2012 sustained straight-line winds of nearly 90 miles per hour moved between the Upper Midwest and mid-Atlantic. In one metropolitan area grid power was lost shortly before sundown and incompletely restored overnight. Many grocery retailers were unable to receive deliveries, shelves were emptied, full truckloads returned to distribution centers needing to be unloaded, and deliveries to retail locations with power and the ability to receive were seriously delayed. Overall flows were reduced by at least one-fifth, and it took almost two weeks for full flow capacity to be recovered.

In most of the United States the profession of supply chain management has emerged when and where it has been reasonable to anticipate very brief grid outages. However, there have been exceptions and the scope and scale of recurring exceptions are expanding. For example, in 2019 some California electric utilities initiated short-notice Public Safety Power Shutoffs to reduce the risk of electrical equipment initiating wildfires during high-wind events. Recurring implementation of Public Safety Power Shutoffs has prompted increased adoption of emergency power generation and related procedures by California food, fuel, and other commercial operators.

SCOPE AND SCALE EXPANDING

During the last twenty years Puerto Rico power customers have regularly experienced five or more multi-day grid outages per year, mostly associated with hurricanes. As a result, there is widespread use of emergency power generation. In hurricane-prone Texas and Florida major grocery chains compete to provide continuity of food flows when the grid is gone.

Discontinuities related to electrical power are certainly not the only source of disruption. Flooding, lack of clean water, extreme temperatures, traffic disruptions, and many other disruptions present supply chain resilience challenges, each with preparedness, response, and recovery implications. Depending on duration, geographic scope, and recurrence, a complication can become a disruption. Depending on adaptive responses, a disruption can also evolve into a complication.

CONTAMINATION

Food and water networks try to avoid contamination. Ongoing technical and management processes are used to prevent, monitor, and mitigate contamination potential. Early containment is fundamental to many effective risk management strategies and, when successful, contamination is nothing more than a complication. When prevention and early containment fail, contamination can quickly cause human harm, increase systemic stress, and disrupt effective supply chain flows and consumer confidence.

Contamination events are frequent in both food and water across the nation. In the public water sector, well-known water contamination examples include Flint, Michigan; Charleston, West Virginia; and Jackson, Mississippi; there are many more. Water main breaks are frequent, occurring every two minutes across the US, and results in approximately 6 billion gallons of treated water loss every day [29]. These disruptions in flow almost always increase the chance of contamination, contributing to 7,000 deaths, 120,000 hospitalizations, 7 million illnesses, and $3 billion in healthcare costs originating from waterborne pathogens every year in the US [30]. Mitigation measures include Boil-Water, Do-Not-Drink, and Do-Not-Use advisories. Recent examples of food sector contamination events include baby formula manufacturing safety violations (and related product shortages) and recurring listeria outbreaks in various fresh foods. Each year in the US, foodborne diseases cause 48 million people to become ill, 128,000 to be hospitalized, and 3,000 to pass away [31]. Over the last decade, there have been more than 6000 Food and Drug Administration recalls related to the food and cosmetics category [32]. The recall of a product is perhaps the most serious mitigation measure the US Food and Drug Administration can take.

Risks to supply chains related to contamination extend beyond direct contamination of food and water. From a supply chain perspective, the coronavirus pandemic can be characterized as a wide-area, time-extended contamination event. Even the prospect of contamination can potentially disrupt supply chains. Further, lack of consensus regarding virulence is a frequent outcome of contamination events that cannot be quickly and credibly contained. Finally, contamination consequences are often amplified by capacity concentrations in public water, processed food, and other networks. As an example, nearly one year after 2022 baby formula contamination concerns had been resolved, Bloomberg reported that competitors of Sturgis, which made approximately 20 percent of infant formula in the US including Similac, couldn't compensate for the shortfall in product when their factory closed. They went on to emphasize that consolidation in the market needs to be addressed [33].

An increased frequency of boil-water-advisories and food safety recalls may signal systemic stresses such as aging infrastructure, insufficient maintenance, and uneven safety measures. As stresses persist and accumulate, vulnerability to disruptive shocks increase. It is often a shock event that results in emergency management professionals being mobilized to address the consequences of both an acute shock and chronic stress. The context of the stress can complicate resolution of shock consequences. In some cases, the acute problems cannot be fixed without significant mitigation of accumulated stress: physical, social, economic, and otherwise. The stress-shock connection characterizes a wide array of short-term, small-scale complications that can evolve into longer-term, larger-scale disruptions.

PERSISTENT, ACCUMULATING STRESSES INCREASE VULNERABILITY TO DISRUPTIVE SHOCKS

Reporting on the Jackson, Mississippi water crisis the Washington Post found, "Over time, inspection records show, the state found 55 cracks per every 100 miles of pipe — almost four times higher than the Environmental Protection Agency's acceptable standard. In sum: The city's water system was potentially dangerous, unsanitary, and inefficient — as much as 50 percent of water was lost when it flowed through Jackson's leaking pipes." As a result, when Jackson experienced serious flooding in August 2022, an already seriously stressed system suffered amplified consequences from the sudden shock.

The context around contamination can be unusually complex given the threat multiplier of uncertainty and fear. The presence or virulence of contamination is often ambiguous. Confirming or denying contamination is often delayed and contentious. For some people, uncertainty alone is considered threatening. When containment of contamination is perceived as uncertain or failed, regardless of whether the perception is accurate, the perceived risk of contamination will influence consumer behavior and demand and push patterns. This is especially true when a contamination shock occurs in a network and population that has experienced chronic stress, directly related to the source of contamination or not.

VULNERABLE POPULATIONS

A widely used conceptual relationship defines risk by the compounding impacts of threats, vulnerabilities, and consequences:

Risk = Threat x Vulnerability x Consequence.

Many natural threats (e.g., fires, floods, hurricanes, earthquakes, pandemics) persist and recur but not every place or person is equally vulnerable to every threat or every consequence. Vulnerability depends on factors including time, space, and personal/community adaptability. The differences in vulnerability influence whether consequences from grid failure, for example, are complications, disruptions, or something much worse. For most, a localized, short-term grid failure will be an inconvenient complication, a very minor consequence. For dialysis patients (low adaptability), a widespread (increased space) grid failure impacting their residence and regional dialysis centers can increase consequences, becoming more life-threatening with each passing day (increased time). Dialysis patients who have access to at-home dialysis and emergency power (increased adaptability) reduce their vulnerability and consequences while the threat stays the same.

Preexisting vulnerabilities related to food and water will drive higher-scaled consequences from any disruption of food or water supply chains. A household dependent on SNAP benefits and food pantry visits for daily nutrition will almost certainly be vulnerable to any extended loss of food access caused by inability to use their SNAP EBT card and/or loss of upstream food flows. Consequence can especially shift as the disruption extends over time. Further, this food access vulnerability is likely to increase the farther this household’s physical distance from where food flows continue to be discharged and/or where they can use SNAP benefits to purchase food.

Vulnerabilities are often considered to be more heavily weighted in the conceptual risk relationship introduced above and should be effectively scouted. Knowing where preexisting vulnerable populations are located – such as skilled nursing homes, assisted living facilities, schools, food deserts, high-poverty neighborhoods – will enhance validity and speed of post-event risk assessments, mitigation measures, and strategic interventions. Having preexisting relationships of trust and operational preparedness with related civic organizations, faith communities, grocery stores, food pantries, and other stakeholders can effectively reduce the vulnerability multiplier.

For the most serious threats – catastrophic hurricanes, earthquakes, long-term grid outages, and more – there can be tens of thousands of newly vulnerable individuals. These households will be as unable to use their bank cards as the preexisting vulnerable are unable to use their SNAP EBT cards. Neighborhoods with abundant pre-event options for groceries will become sudden-onset food deserts. Households accustomed to quick food delivery may be reduced to daydreams featuring hard-to-get peanut butter, canned chicken, and crackers. In this context, well-managed chronic conditions, such as hypertension or asthma, can suddenly become acute. Vulnerability is, arguably, the risk factor that is most influential and, at least potentially, the most able to be influenced by pre-disaster choices.

Supply chain resilience confronts this crucial risk factor by working to effectively engage known and anticipated vulnerabilities before threats are consequential. The Rockefeller Foundation has suggested, "[Resilience] moves away from traditional disaster risk management, which is founded on risk assessments that relate to specific hazards. Instead, it accepts the possibility that a wide range of disruptive events – both stresses and shocks – may occur but are not necessarily predictable. Resilience focuses on enhancing the performance of a system in the face of multiple hazards, rather than preventing or mitigating the loss of assets due to specific events" [34].

DESTRUCTION

Resilience as adaptability more than loss-prevention or survival can be especially helpful for anticipating the most seriously destructive threats. We are almost certain there will be major moves in the Cascadia, San Andreas, and other seismic faults. But these could happen tomorrow or many years from now. We can be as sure of annual hurricanes, but where the worst will hit hardest can be tough to forecast even 48 hours before landfall. This time and space ambiguity (especially for the most destructive events), scorns prediction, complicates planning, and rewards investments in resilience.

As outlined above, we know that high-volume, high-velocity supply chains are organized around capacity clusters and other concentrations. Beautiful bottlenecks can become deadly chokepoints, especially when and where any of these crucial nodes and channels are destroyed – when and where concentrated pull or push capacity is displaced.

Consider a scenario where a major earthquake results in roads to two of five major distribution centers are cut-off for weeks and at least two of the remaining distribution centers are destroyed, leaving only one distribution center standing. As a result, roughly twenty percent of the preexisting capacity may survive. How can this surviving capacity be maximized and most effectively supplemented? How can the food supply chain adapt to such sudden loss of this much capacity? Can any significant capacity be quickly clawed-back? Can alternative sources of capacity for volume and velocity be conceived and prepared? What does a post-catastrophe food supply chain look like? How does it behave? What needs to be done now to facilitate resilience then?

There are possibilities. None are easy.

All the adaptations involve myriad complications, disruptions, and risks of food contamination when and where the number of vulnerable people has suddenly skyrocketed. But because it is possible to roughly map and model preexisting capacity, it is possible to conceive resilient potential. It is possible to cultivate network resilience – if destructive potential is accepted, scouted, and specifically appropriate plays are well-executed when destruction shows up. In some places, destruction is anticipated and even estimated. But too often such recognized risks are so intimidating that very little is practically undertaken to advance supply chain resilience. The worst case is, however, precisely when prior investments will pay off the most for survivors.

FORCE-ON-TARGET

Supply chains will often face several simultaneous threats and vulnerabilities – forces-on-targets. On rare occasions, complications, disruptions, contamination, vulnerable populations, and destruction will all show up at the same time and place. How much force on which target(s) is a crucial factor in supply chain resilience.

US national food, fuel, and freight capacity is more than the sum of each region's capacity. For example, food processed in the Mid-Atlantic and Upper Midwest serves national markets, including California. Grocery stores nationwide depend on fresh vegetables and fruit that are grown, processed, and packaged in California. The diversity and geographic distribution of this national capacity enhances resilience, effective response, and rapid recovery in case of local disasters. But distance between demand and supply still matters.

SURVIVAL OF CAPACITY CONCENTRATIONS

In 2022 some forecasts had Hurricane Ian making landfall at Tampa Bay as a strong Category 4 storm and continuing northeast along the Interstate-4 corridor thick with grocery distribution centers, trucking capacity, and fuel infrastructure serving most of central and even south Florida. Forty to forty-five percent of fuel consumed in Florida is barged into Tampa Bay. If this capacity concentration or the Central Florida Pipeline is taken down, there is no effective near-term alternative. Similar constraints on food flows are possible if sufficient force hits specific targets along Interstate 4 between Tampa to Orlando.

Instead, Hurricane Ian made landfall in Lee County about 100 miles southeast of Tampa Bay. It was still a Category 4 hurricane. It was still the deadliest Florida hurricane since 1935. More than 52,000 structures were damaged and more than 5000 were destroyed. But just because of location, impacts on supply chain capacity were modest and mostly local. The Interstate-4 corridor's surviving fuel and food capacity was fundamental to effective response and recovery in Fort Meyers, Cape Coral, and nearby.

If regional capacity concentrations are seriously disrupted or destroyed, there will be negative consequences for fulfilling demand for food, fuel, and freight – especially where regional capacity is less connected with national capacity or non-operating planned bottlenecks encompass such a high proportion of total flows that practical alternatives barely exist. When capacity concentrations survive hurricanes, earthquakes, or other worst cases, strategic options and tactical capabilities available to the private sector and emergency management will be significant. If these sorts of capacity concentrations experience long-term disruption, survivors and emergency managers will be much more hard-pressed.

COMPLEXITY AND POTENTIAL CATASTROPHE

It is worth highlighting that on most days, flow is abundant. Complications are quickly solved. Disruptions are effectively mitigated. Contamination is prevented or contained. Even the most vulnerable are minimally served. Destruction sleeps (soundly or not).

Threats can be persistent but are often inconsistent, even radically random. Our greatest strengths are often where we are also most vulnerable. But unless our vulnerabilities seriously unravel, we retain our strengths. Huge volumes flow at amazing speed and with increasing accuracy.

Still, there are occasions when all the threats descend at exactly the wrong place and time. Maybe complications accumulate into more frequent disruptions. Maybe recurring contaminations undermine the resilience of pull and push, especially where already vulnerable people are concentrated. Maybe an especially hard hit on the grid and/or roads and/or water systems and/or most regional capacity clusters create a cascade of problems that overwhelm ordinary patterns of push and pull. Catastrophic threats of particular concern in the Bay Area region include seismic activity and atmospheric rivers, each with the potential to cause impacts such as grid outage, road damage, pipeline ruptures, flooding. Further, long-term grid failure is a risk commonly resulting from natural hazards, intentional attacks, and excess demand.

Catastrophic-scale events do not often unfold, but when they do, supply chain resilience requires atypical collaboration among everyday competitors and between private and public sectors. Stay out of their way and many upstream movers will make much more than is needed. Stay out of their way and many midstream movers will run full and faster to give consumers all they want, when and where they want it – and in doing so, motivate wanting even more. This is when superstar makers and movers need help and protection. This is when shared strategies are needed. This is when new realities need to be well-understood by all and a series of well-conceived plays can be quickly executed by a well-calibrated team.

IMPACTS CASCADE

In the 2011 Triple Disaster in Japan, a 9.0 plus magnitude mega-thrust spawns a tsunami, exceeding 130 feet high in some places, and more than a thousand aftershocks. The combination of seismic and tsunami effects cut grid power and destroyed emergency power generators at the Fukushima nuclear power station resulting in radiation leaks and a wide range of potential and realized catastrophic consequences. Transportation routes, water systems, and fuel networks were seriously damaged, disrupted, and sometimes destroyed. Almost 20,000 were killed, over 6000 were injured, roughly a million structures were damaged, and more than 120,000 buildings were destroyed. Over 4.4 million households were left without electricity. More than 1.5 million households lost water network connections. Almost a half-million people were left without their homes.

THE PLAYS: COLLABORATE TO MAKE TIME AND SPACE FOR FLOW

Every day, push responds to pull. Every day, the makers and movers compete against complications, contamination, disruptions, and each other with little or no direct assistance from emergency management. Upstream flows aggregate toward midstream and cascade downstream. Clean water emerges from taps. Food, fuel, and other commodities are sold. However, when complications, contamination, and/or disruptions show up at or near the same time and in a shared space, even the strongest flows will need help. When destruction is also involved, emergency management's strength, agility, and creativity is essential to facilitate continued flows of food, water, fuel, and freight to vulnerable populations.

When upstream or midstream capacity is significantly displaced, emergency management is fundamental to maximizing the push that can be generated by the remaining capacity and to support upstream makers and midstream movers do what they always do. To successfully execute the most powerful plays on the worst days, emergency management must be able to prepare with the private sector, effectively respond in real-time, and support recovery over time.

> Preparedness Plays tend to be gradual and work to anticipate troubled flow. They are mostly focused on 1) understanding the capacity, structure, and typical behavior of current demand and supply networks; 2) establishing relationships with those who operate current demand and supply networks; and 3) exploring effective responses to potential disruption and destruction scenarios.
>
> Response Plays are urgent, on-the-ground, and action-packed to serve survivors. They are specific actions that emergency management can take to facilitate flows under duress and better ensure vulnerable people are served. These plays mostly involve 1) identifying where and how preexisting flows have been impacted; 2) taking steps to remove constraints on preexisting flows; and 3) taking steps to increase time and space available for surviving flows.
>
> Recovery Plays are often variations of preparedness and response plays that gradually wind down response actions as preexisting flows are recovered. They can include gap-filling measures given the sometimes-volatile situation on the boundary between response and recovery. Response plays increase space and time available to make and move. As the response plays achieve this purpose, more volume can flow at greater velocity until the needs and even wants of survivors are mostly fulfilled. Recovery plays are often aimed at more specific targeting of this velocity. Reduced volatility during this transition is the goal.

New plays and variations are always possible. The best plays will usually reflect specific local conditions, emergency management capabilities, collaborative capacity, and realities of specific risks. While the specifics of plays will vary, the following objectives are consistently essential for success:

1. Find the top (usually five) high-capacity sources for flows of water, food, fuel, and other crucial freight for your community.
2. Find the most concentrated physical and functional flows for moving water, food, fuel, and other crucial freight to your community.
3. Find where and how your community receives and consumes water, food, fuel, and other crucial freight.
4. Establish meaningful and sustainable collaborative relationships with the highest-capacity people, places, and enterprises providing water, food, fuel, and other freight crucial to your community.
5. Talk, think, and realistically prepare for disruptions and destruction that could seriously impede flows of water, food, fuel, and other crucial freight to your community.

PREPAREDNESS PLAYS

IDENTIFY PREEXISTING VULNERABILITIES

Action(s): Identify people and locations at highest risk of being separated from flows. Understand local resources and build relationships with local stakeholders.

Knowing where people are likely to become (or already are) food/water insecure facilitates keeping flows moving where and when they are needed most. Mapping where there are people with preexisting financial vulnerability or places (and people) physically vulnerable to being separated from flows helps size risk and focus risk mitigation. Use census, flood, seismic, and other maps to find potential weak spots. Explore these weak spots, getting to know local resources, and developing local relationships. Give particular attention to continuity of POS technologies for financial transactions, including back-up POS methodologies.

IDENTIFY PREEXISTING FLOWS

Action(s): Identify flow routes and modes (e.g., truck, rail) at highest risk of being impacted. Understand local resources and build relationships with local stakeholders.

Identifying origins and channels of major flows supports working together to maintain flows, redirect flows, or recognize where flows will *not* be rapidly restored. Mapping preexisting proportional flows helps recognize existing vulnerabilities and mitigation opportunities. Use census, flood, seismic, and other maps to find potential weak spots. Explore weak spots, get to know local resources, and develop local relationships.

CONFIRM FLOWS WITH PRIVATE SECTOR

Action(s): Work with local stakeholders to confirm identified flow routes and modes of transport.

The two prior plays should be quickly followed by reviewing with operators that that make and move these flows every day. This vetting will confirm, clarify, or correct the data-informed sources and is often a constructive way to initiate meaningful, practical relationships between private and public sectors.

CONDUCT SITE VISITS TO KEY NODES AND CHANNELS

Action(s): Conduct regular visits with the top sources of water, food, and fuel to share information related to the Supply Chain and build relationships.

Sharing information on threats, vulnerabilities, the current operating environment, and how regular flows are being impacted is one of the most important plays that can be called. This play is called during "blue-sky" periods by making site visits to key nodes (see above) to meet owners/operators. These informal, usually one-on-one conversations focused on supply chain resilience can advance information-sharing, trust-building, and collaborative actions. One-hour site visits, once each year for each top-five source of water, food, and fuel will be foundational for every other play.

CONDUCT PRIVATE-PUBLIC GROUP ACTIVITIES

Action(s): Refine plays and processes through regular scenario-based activities.

This Play is called during "blue-sky" by conducting exercises, workshops, or other scenario-based problem discovery processes: If X happens, what would you do? If upstream makers do A and midstream movers do B, what does that mean emergency management should do? Response and recovery plays are injected into the scenarios to assess potential positive and negative outcomes. Based on the results, plays and processes are refined.

RESPONSE PLAYS

ASSESS HIGH-CAPACITY NODES AND CHANNELS

Action(s): Assess surviving capacity and flow and the implications of lost capacity and flow. Communicate response priorities to stakeholders.

Focusing assessments on the highest capacity nodes and channels (e.g., distribution centers, fuel racks, bridges and similar) will facilitate more accurate estimates of surviving flow and identify the most effective priority actions for restoring and/or growing flow. In the immediate aftermath of disasters, use the results of preparedness plays to assess surviving capacity and flow options to the needs of places and people. Which nodes have survived? Which have not? What are the flow implications? Same for channels. Communicate related response priorities through processes established by the preparedness activities.

FOCUS ON VULNERABLE PEOPLE AND PLACES

Action(s): Assess continuing and novel needs of vulnerable places and people. Communicate response priorities to stakeholders.

Early post-disaster assessments of flow serving preexisting vulnerable populations will, when necessary, facilitate best-possible flow restoration for places and people for whom any extended delay in flows of water, food, fuel, or other crucial freight is especially threatening. In the immediate aftermath of disasters, use results of preparedness plays to assess continuing and new needs of especially vulnerable places and people. Communicate the resulting response priorities through processes established by the preparedness plays.

RESTORE GRID POWER TO HIGH-CAPACITY CONCENTRATIONS

Action(s): Assess electric grid outages that have significant impacts on water, food, fuel, and/or freight movement. Communicate response priorities to stakeholders.

Restoring grid power is fundamental to several supply chain functions. Calibrating grid restoration schedules (and mitigation investments) with identified high-capacity nodes and channels of flow is more likely to restore (and grow) flows to principal concentrations of survivors. In the immediate aftermath of disasters, use knowledge gained from mapping and other preparedness activities to identify any grid outages that are especially disruptive to water, food, fuel, or other essential freight movements. Communicate grid restoration priorities resulting from preparedness research, exercises, and workshops – and post-disaster observations.

RELEASE DISASTER-SNAP FUNDING (AND SIMILAR)

Action(s): Supplement financial ability of impacted populations to purchase necessary food and other supplies.

SNAP is fundamental to fulfilling the food requirements of many preexisting vulnerable populations. Taking whatever action is possible to facilitate the ability of these people to signal their needs/demands is the best way to energize supply chains to effectively respond.

ENSURE EFFECTIVE POINT-OF-SALE TECHNOLOGY IS AVAILABLE

Action(s): Deploy POS technology.

POS devices and processes pull supplies when, where, and in the volumes needed. Being prepared to reactivate or replicate POS digital transactions is, where possible, a crucial step in restoring flow. In the immediate aftermath of disasters, use results of preparedness activities to deploy alternative POS transaction devices and processes at key retail nodes to signal/target volume and velocity of demand for at-risk neighborhoods and other places. While each approach has its limitations, options such as POS receiver communications via satellite linkage, deployment of mobile broadband solutions or microwave transmitter trucks, and even manual credit card imprinters may all represent opportunities to support these recovery efforts, depending on power availability (including generators) and other incident-specific circumstances.

ENSURE ESSENTIAL TARGETING AND SIZING OF FLOWS

Action(s): Deploy non-traditional purchasing measures.

Where and when it is not possible or ineffective to deploy POS technology, deploy non-traditional consumer purchasing measures to restore demand signaling needed to fulfill fundamental needs for food, fuel, and other essential freight. Examples of non-traditional consumer purchases include providing government script to consumers to be used instead of unusable EBT, credit, and debit cards or offering temporary take now/pay later processes guaranteed by disaster funding.

SHARE STRATEGIC CONTEXT AND SITUATIONAL AWARENESS IN ADVANCE

Action(s): Share information with stakeholders early.

When an emerging threat allows (e.g., hurricane or blizzard or pandemic), distribute information and establish information-sharing rhythm to facilitate rapid, agile, well-calibrated collaborative action even before the threat fully forms. When a notice-event is emerging, pull typically starts to surge several days before impact. Facilitating the surge in demand (and flow) as early as possible will enhance population and system resilience *after* receiving the toughest hits.

SHARE STRATEGIC CONTEXT AND SITUATIONAL AWARENESS IN REAL-TIME

Action(s): Share real-time information with stakeholders throughout the response.

Distribute information on grid status, road closures, communications status, travel bans, waivers, store status, and other real-time outcomes that could constrain or de-constrain push fulfilling pull: delivering water, food, fuel, and other critical freight to survivors of the disaster. Deliver concise, relevant, when possible pre-scripted methods (developed through preparedness plays) that are updated often.

MOVE MORE VOLUMES FASTER BY WAIVING WEIGHT RESTRICTIONS

Action(s): Advocate for, facilitate, and communicate to stakeholders the issuance of truck weight waivers.

Volume is fundamental to effective flows and, given the crucial role of trucking in most flows, allowing for maximum weight can be very helpful to maintaining and/or increasing volumes. Advocate, facilitate, and communicate issuance of truck weight waivers. Develop plays for 1) intra-state purposes and 2) interstate purposes executed through state-by-state action or by the Federal Motor Carrier Safety Administration.

MOVE MORE VOLUMES FASTER BY WAIVING HOURS-OF-SERVICE RESTRICTIONS

Action(s): Advocate for, facilitate, and communicate to stakeholders the issuance of waivers for Hours-Of-Service regulations for truckers.

Velocity is fundamental to effective flows and, given the crucial role of trucking in most flows, allowing for maximum Hours-Of-Service can help maintain and/or increase volumes. Advocate, facilitate, and communicate issuance of waivers for Hours-Of-Service regulations for truckers. Develop plays for 1) intra-state purposes, 2) interstate purposes that can be executed state-by-state or through action by the Federal Motor Carrier Safety Administration, and 3) waiving delivery curfew restrictions.

ENSURE FLOW ACCESS TO HIGH-CAPACITY NODES AND CHANNELS

Action(s): Assess debris clearance and road restoration needs that have significant impacts on water, food, fuel, and/or freight movement. Communicate clearing and restoration priorities to stakeholders.

Flows tend to concentrate along specific roads, bridges, and similar engineered structures. Any impediments, such as landslides and downed trees or powerlines, will reduce velocity and therefore volume. Focusing debris clearance and similar actions where the most flow originates and usually moves will increase the number of survivors who can be served with water, food, and other crucial freight. In the immediate aftermath of disasters, use results of preparedness plays to assess debris clearance or road restoration needs relevant to high-capacity nodes and channels. Communicate and actuate these priorities through processes established by preparedness activities.

ORGANIZE TRAFFIC CONTROL TO EXPEDITE FLOWS

Action(s): Increase velocity and volumes available to survivors via queue management techniques.

When surging demand prompts supply chains to also surge, congestion at high-capacity nodes and channels can cause significant reductions in flow velocity. This is especially common at fuel racks but can happen at many places when pull exceeds anticipated flow capacity. Queue management techniques can mitigate the worst delays and often effectively expedite discharge with common traffic management methods, especially if pre-planned with site managers. Depending on specific local conditions, different techniques may be appropriate, including but not limited to organizing police-escorted convoys, identifying truck-only routes, organizing police escorts for individual delivery trucks, expediting truck flows near distribution centers, and decongesting the queue for fuel racks.

TROUBLESHOOT AND FACILITATE FUEL ACCESS BY CRITICAL NODES, CHANNELS, AND MODES

Action(s): Assess fuel access impacting water, food, fuel, and/or freight movement. Communicate response priorities to stakeholders.

Jurisdictions have varied policies, authorities, and plans for prioritized fuel access. Ensuring that crucial upstream and midstream sources and freight modalities are included in these priorities will facilitate continuity, restoration, and maximization of water, food, and other essential flows. In the immediate aftermath of disasters, use results of preparedness plays to assess fuel access relevant to high-capacity nodes, channels, and modes (especially trucking). Communicate and actuate these priorities through processes established by preparedness Plays.

PROVIDE SECURITY FOR COMMODITIES IN TRANSIT

Action(s): Provide police escorts for trucks delivering commodities (particularly, fuel trucks).

Police escorts may be needed to facilitate delivery of key commodities, including fuel. Police support may also include traffic control around delivery destinations such as retail fuel stations to ensure access.

INCREASE AVAILABLE INVENTORIES

Action(s): Identify and bolster inventories of high-demand products.

In blizzard and hurricane prone regions the private sector increases stocks of high-demand products for pre-event and post-event distribution. Using preparedness plays to anticipate, can similar capacity enhancement be practically undertaken for no-notice events? Is there a role for public sector-funded Virtual Managed Inventory and other non-traditional stock-building?

PROTECT HIGH-CAPACITY NODES AND CHANNELS

Action(s): Monitor, identify, and prevent threats (e.g., civil unrest) to high-capacity nodes and channels.

The presence of additional security and related measures at key upstream, midstream, and downstream nodes can preempt possible disruption of supply chain functions and flows. Where assessments find a credible threat of civil unrest or other population behavior disruptive of fundamental flows, deploy law enforcement, National Guard, or similar resources to key retail nodes to deter disruption or restore flows.

EMERGENCY MANAGEMENT RESOLVES ANOTHER FREIGHT FLOW IMPEDIMENT

In early September 2017, Hurricane Irma knocked out power along Florida's entire Interstate-95 corridor. A significant proportion of the trucking fleet involved in supplying South Florida had evacuated to Jacksonville, Florida – out of harm's way to quickly resupply metro Miami after Irma passed. But pre-storm evacuations had drained much of the fuel between Jacksonville and Miami. Without grid power, most of the truck stops could not pump remaining fuel. Most of the trucking fleet could complete their initial delivery with fuel already in their tanks, but in some cases, grocery trucks would not have enough fuel to return to distribution centers for reloading and the next round of deliveries. In consultation with the private sector, key refueling locations were identified and prioritized for grid restoration and tanker truck refueling. Starting at dawn on the morning after Irma's hard hits, enough truck stops were refueled and reenergized to support delivery of continuous freight flows into South Florida.

SUCCESSFULLY REPLICATE LOST NODES AND CHANNELS

Action(s): Leverage elements of surviving network capacity to replicate lost nodes and/or channels.

Where early assessments find that nodes and/or channels will experience long-term disruption, have preparedness plays identified alternative locations to receive and turn inbound flows? Replication is different from replacement. Replication almost always involves using significant elements of surviving network capacity. These and similar options require serious and detailed private-public preparedness collaboration.

DECONFLICT AND ACCELERATE DISRUPTED NODES AND CHANNELS

Action(s): Identify opportunities for and expedite staging and dropping of inbound loads.

Are there staging places and options where inbound loads could be dropped for unloading and redistribution, thereby speeding cycle-times? These and similar options require serious preparedness activities.

EXPEDITIONARY CROSS-DOCKING

Action(s): Identify opportunities for and expedite cross-docking of inbound loads.

A variation of staging and dropping, this play anticipates rapid unloading of large loads on the edge of the disaster zone for redistribution to smaller vehicles that will be more agile moving through disaster zones and toward isolated populations of survivors.

CARE FOR TRUCKERS AND OTHER PEOPLE ON WHOM PUSH DEPENDS

Action(s): Provide support for essential workers.

Truck drivers involved in novel response plays need to be fed, watered, and otherwise supported physically, financially, technologically, and psycho-socially.

REPLICATE FULFILLMENT OF DEMAND SIGNALS WHERE THEY HAVE BEEN LOST

Action(s): Size, mix, target, and deliver government-procured water, food, or freight to address what survivors would pull if POS and other traditional means of demand signaling had survived or could be restored.

Where there are people and places that are unable to effectively express demand, public sector agencies deploy non-traditional procurement activities to incentivize, encourage, and stimulate flows of water, food, fuel, or other essential freight.

DEPLOY COMMUNITY POINTS OF DISTRIBUTION AND OTHER REPLACEMENT TACTICS)

Action(s): Identify where prior inputs have failed and deploy Community Points of Distribution, congregant feeding, emergency water and food distribution and related services as needed to these places.

Where ongoing assessments find that preexisting flows of water, food, fuel, and other essential freight have been cut-off from vulnerable people and places and the prior plays are unsuccessful in prompting new flows, Community Points of Distribution and other flow replacement tactics are deployed by the public and not-for-profit sectors.

RECOVERY PLAYS

FOCUS ON VULNERABLE PEOPLE AND PLACES

Action(s): Continue assessments to identify people and places that remain vulnerable to impacts.
Communicate response priorities to stakeholders.
As the response plays are executed, ongoing assessment of demand and supply works to find where there is persistent disequilibrium. Problem areas are communicated to everyone involved.

ENSURE ESSENTIAL TARGETING AND SIZING OF FLOWS

Action(s): Identify how much is needed where and when. Give particular focus to restoring functionality of POS technologies or alternatives to serve this end.

Based on results of ongoing assessments and available resources, recovery priorities and places are identified. Recovery plays are more tightly targeted than response plays and usually less time-extended but can still involve the full range of non-traditional measures to facilitate the effectual expression of demand including deploying POS technology or non-traditional consumer purchases or procurements.

ENSURE PUSH MOVES TOWARD PULL

Action(s): Leverage non-traditional measures as needed to satisfy demand.

Based on results of ongoing assessments, deploy full range of non-traditional measures to facilitate the delivery of supplies to where there is unfulfilled demand. (e.g., weight waivers, Hour of Service waivers, staging and dropping, cross-docking, queue management, protecting, etc.)

DEPLOY COMMUNITY POINTS OF DISTRIBUTION AND OTHER REPLACEMENT TACTICS

Action(s): Identify the need for and deploy gap-filling measures.

When and where every other tool fails to provide enough food and water to serve survivors, deploy Community Points of Distribution and other gap-filling measures as necessary.

PRIORITIZE AND EXPEDITE SAFETY INSPECTIONS

Action(s): Prioritize and expedite safety inspections.

As destruction and disruptions are minimized, contamination can become a particular concern. Food safety, water quality, and other quality assurance checks are especially important. Sequencing checks to facilitate flow volumes and velocity to serve vulnerable populations is an important aspect of the recovery period.

SHARE CHANGES IN STRATEGIC CONTEXT

Action(s): Collaborate with the private sector to share accurate information with the general public.

The transition from response to recovery is typically uneven and can be treacherous. But by utilizing the results of ongoing network assessments the gradual recovery of preexisting flows can be observed and confirmed. Constantly sharing meaningful measures of flow will prioritize behavior and increase the confidence of makers and movers, increasing the volume/ velocity of overall flows. In collaboration with the private sector share accurate information with the general public to facilitate improved demand management.

INFORM OF IMPENDING CHANGES IN PUBLIC SECTOR BEHAVIOR

Action(s): Communicate discontinuation of response plays with stakeholders.

When response plays are going to be discontinued – such as weight or hour waivers – consult with and provide appropriate warning to the makers and movers so that sudden changes do not unnecessarily complicate flows. For example, if delivery curfews are to begin again this will require much tighter private sector trucking schedules.

CONDUCT AFTER-ACTIONS AND DEVELOP LESSONS-TO-BE-LEARNED

Action(s): Collect, analyze, and share data on the effectiveness of responses and plays.

The recovery period is an important opportunity to gather information on the comparative effectiveness of preparedness and response plays. What worked? What did not work? What new flow facilitation tactics were developed? Who and where did not receive sufficient flows and why? Publish and socialize lessons-to-be-learned, integrate outcomes into future preparedness plays.

CELEBRATE SUCCESS

Action(s): Recognize and celebrate people and actions contributing to success. Leverage successes to strengthen relationships and further improve resilience.

Highlight effective plays. Recognize key contributions. Express appreciation. Celebrate each win. Gather the whole private-public supply chain resilience team, learn from each other, appreciate each other, and be better prepared for next time.

LOCAL AUTHORITIES MITIGATE GLOBAL FREIGHT FLOW IMPEDIMENT

In October 2021, many maritime ports world-wide were overwhelmed by inbound container flows. At the Port of Long Beach, California over seventy ships were lined up in San Pedro Bay waiting to offload. Among several contributing causes, the "dock density" of already delivered containers left little room for stacking additional offloaded containers. In compliance with a city ordinance, containers were stacked no more than two-high. In response the City of Long Beach decided to "temporarily waive enforcement of current shipping container stacking and height limits for a period of 90 days from October 22, 2021. During this period, affected operations will be allowed to stack up to four shipping containers without being cited for a Code violation." In combination with a variety of other measures this measure opened more space, reducing offloading time, and increasing flow velocity.

ORGANIZING LOCAL SUPPLY CHAIN RESILIENCE COLLABORATIONS

Most emergency management agencies in the United States have little to no prior experience with supply chain resilience. Most of the plays identified above have seldom been executed. In the rare instances of execution, an individual play has usually been executed as a one-off rather than one of several steps in a sustained strategic effort. Successful execution of these plays will require considerable co-development with the private sector along with tabletop exercises and trial-and-error learning in actual disasters.

Local adaptations of these plays are a crucial investment in the process. Very local disruption and even destruction will seldom seriously challenge the ability of high-volume, high-velocity supply chains to deliver what is needed to survivors. Yet, region-wide disruption and destruction requires local know-how and, especially, local emergency management expertise to facilitate flows under severe duress. Local to regional (i.e., bottom-up) supply chain resilience collaboration is needed to prepare together and thereby be ready to respond and recover together. Multi-agency coordination groups can be pivotal in achieving these goals.

REGIONAL SUPPLY CHAIN RESILIENCE COLLABORATION FRAMEWORK EXAMPLE

The following is how one regionwide private-public supply chain resilience "co-laboratory" framed their opportunity and process.

Vision

Demand and supply networks for food and related critical freight will continue to flow with best possible volume and velocity even on worst days.

Mission

- Facilitate private-private and private-public collaboration to achieve the vision.
- Prepare and mitigate before the worst day to better achieve the vision on the worst day.
- Identify and serve significant shifts in demand caused by extreme events.
- Remove and mitigate physical, regulatory, and other impediments to flow.
- Prioritize restoring electric power, road access, fuel availability, communications, and other essential services needed to achieve vision.

Purposes

- Host and facilitate recurring processes to encourage public sector coordination of policies, plans, and practice to achieve vision and mission in the region.
- Host and facilitate recurring processes to encourage private sector collaboration to anticipate, cooperate, and effectively adapt to achieve vision and mission in the region.
- Meaningfully sustain shared vision and mission over time as personnel change and risks evolve.

In this example three large metro-areas came together when they recognized that they share many of the same sources of food, depend on the same transportation corridors, and are susceptible to many of the same risks of disruption and destruction.

RELATIONSHIP-BUILDING

Initial conversations between the three jurisdictions were prompted by a recognition of shared risk which stems from the following circumstances: Two of the three metro areas have a common border but are in separate states. The third jurisdiction is separated from the other two by 140 miles and about 100 miles. These are huge distances for local public-public collaboration (especially across state lines). However, each jurisdiction shares the same sources for 40–60 percent of food consumed (depending on what is counted). Only seven grocery distributors account for more than 80 percent of related flows inside a common transportation corridor connecting the three jurisdictions. All three jurisdictions have active food security and supply chain resilience efforts underway. Relatedly, each jurisdiction has attracted grant-funding for related work.

As is common in many regions, dynamics vary in the relationships within and between the public and private sectors in these metro areas. For both public-public and private-private relationships, a recognition of shared dependencies equates to shared risks and, therefore, shared opportunities for risk mitigation. A distinction in these relationships is that, where the public sector sees shared food flows, the private sector is more likely to see their biggest competitors. Nevertheless, it is in everyone's best interest to support more volume and velocity of flows. In the private-public relationships, friction can be caused by very different and sometimes contradictory jurisdictional policies and practices. These relationships are complicated by different organizational cultures, competing priorities, and widely shared tendencies to discount the worst risks of disruption and destruction – where supply chain resilience generates most of its pay-off.

Understanding these dynamics and addressing areas of known friction supports building and strengthening relationships. Relatedly, leveraging areas of mutual self-interest works toward win-win situations. For example, minimizing variability in public sector behaviors and keeping track of and communicating road closures can support the shared goal of increasing volume and velocity of flows.

COLLABORATION AND COOPERATION

This mutual self-interest is achieved when flows persist even when threatened by disruption and destruction. When the upstream makers and midstream movers can continue to operate at close to full capacity, the private-public relationship fulfills its purpose. The more disruption and destruction: the more insightful, agile, creative, and effective emergency management is needed.

The movers and makers want and need to persist. They are experts at continuing through complications, contamination, and significant disruption. However, as more disruptions and, especially, destruction emerge, emergency management will often be needed to open space and time for flow. Emergency management must 1) know when, where, and how to open space and time for flow, 2) communicate to the makers and movers when and where flow openings are being created, and 3) facilitate more opportunities for flow through space and time until disruption and destruction are minimized.

Working toward these goals, the three metro areas that crafted private-public collaboration around food flows chose to organize private-public tabletop exercises. Each year a total of four sessions are conducted: one for each of the three jurisdiction’s food supply chain resilience and a fourth featuring a regional tabletop exercise involving all three metropolitan regions. There are usually less than twenty people directly involved in each tabletop, including representatives from five to seven grocery distributors representing three-quarters of total grocery flows. Each tabletop is designed to be realistic, interesting, intimate, informal, low-cost (in terms of time and funds), and even a fun four hours. The tabletops focus on exploring scenario-based problems. Substantively, this helps emergency management recognize when and where they can do the most good. The recurring exercise calendar also keeps private-public relationships fresh between real threat activations. As a result, the entire supply chain resilience effort is better prepared when disruptions and destruction show up and pile on.

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APPENDIX A: OTHER RESOURCES ON SUPPLY CHAIN RESILIENCE

GENERAL RESOURCES

- National Academies of Sciences, Engineering, and Medicine, *Strengthening Post-Hurricane Supply Chain Resilience: Observations from Hurricanes Harvey, Irma, and Maria* (2020)
- National Academies of Sciences, Engineering, and Medicine, Freight Transportation Resilience in Response to Supply Chain Disruptions (2019)
- FEMA, Department of Homeland Security, Supply Chain Resilience Guide (2020)
- Brian Eastwood, Supply Chain Resilience in a State of Steady Disruption, MIT/Sloan (2022)
- Yossi Sheffi, The New (Ab)normal, MIT/CTL (2020)
- Jarrod Goentzel, Humanitarian Supply Chains, MIT edX (2023)
- Center for Homeland Defense and Security, Self-Study Course on Supply Chain Resilience (2021)
- Philip J. Palin, A Case Study in Private-Public Collaboration to Facilitate Flows, CNA/Institute for Public Research (2022) (Specifically relevant to Green Push Vet)
- Philip J. Palin, The Role of Groceries in Response to Catastrophes, CNA/Institute for Public Research (includes attention to potential role of Virtual Managed Inventory) (2017)
- California Resiliency Alliance, Supply Chain Quick links
- San Francisco Bay Area Goods Movement Plan

OPEN-SOURCE SUPPLY CHAIN INFORMATION

General

- US DOT Supply Chain Indicators
- FreightWaves
- Wall Street Journal Logistics Report
- Demographic and other data by area
- Food, energy, water flows by area (FEWSION); Freight Analysis Framework v5
- Homeland Infrastructure Foundation-Level Data

Food Commodities

- USDA Agricultural Marketing Service Reports
    - Fruit and Vegetable Truck Rate Report
    - Dairy Market News Weekly Reports
- CalFresh Data Dashboard - California Department of Social Services
- SABER
- Walmart Emergency Management Hub

Water

- California Reservoirs
- Dry Well Reporting System Data

- Licensed Water Haulers

Fuel

- GasBuddy Outage Tracker
- US Energy Information Administration – This Week in Petroleum
- California Energy Commission Weekly Fuels Watch
    - Refinery Inputs and Production
    - Weekly Fuels Watch - Refinery Stocks
    - Monthly Petroleum Watch

Healthcare / Pharmaceuticals

- FDA Drug Shortage Database
- RX Open

Transportation Mode Specific - Aviation

- Avia National Airspace System Status
- FAA - Temporary Flight Restrictions
- Flight Radar
- Flight Radar – Statistics

Transportation Mode Specific - Marine

- Marine Traffic
- Marine Traffic – Port Pages (Port of Oakland)
- DHL Ocean Freight Market Update

Transportation Mode Specific - Rail

- Union Pacific Customer News
- BNSF Customer Notifications

Transportation Mode Specific – Mail / Package Delivery

- USPS Service Alerts
- FedEx Service Alerts
- UPS Service Alerts

Transportation – Freight

- Freight Analysis Framework

Waivers, Permits, Exemptions

- US DOT
- California Department of Education (food waivers for schools)

APPENDIX B: FOOD SECTOR TABLES AND FIGURES

Table B.1. Grocery market share estimates for the Bay Area region by brand, including wholesalers (*) that often serve smaller grocery banners, independents, and provide food products to some mass market retailers. Values are derived from Palin 2019 [13] and analysis for this project.

Brand / Wholesale Supplier*	Approximate No. Locations Served	Grocery Market Share (%)	
		Palin (2019)	Current Project (2022)
Albertson's (Safeway)	183	24-26	26
Super Store Industries (Lucky, FoodMaxx, Save Mart)	89	21-23	10
C&S Wholesale Grocers*	129	11-13	5
UNFI*	70	11-13	13
Walmart	40	10-12	5
Raley's, Nob Hill	36		4
Costco	30		7
Trader Joe's	55		5
TOTAL:	**632**	**77-87%**	**75%**

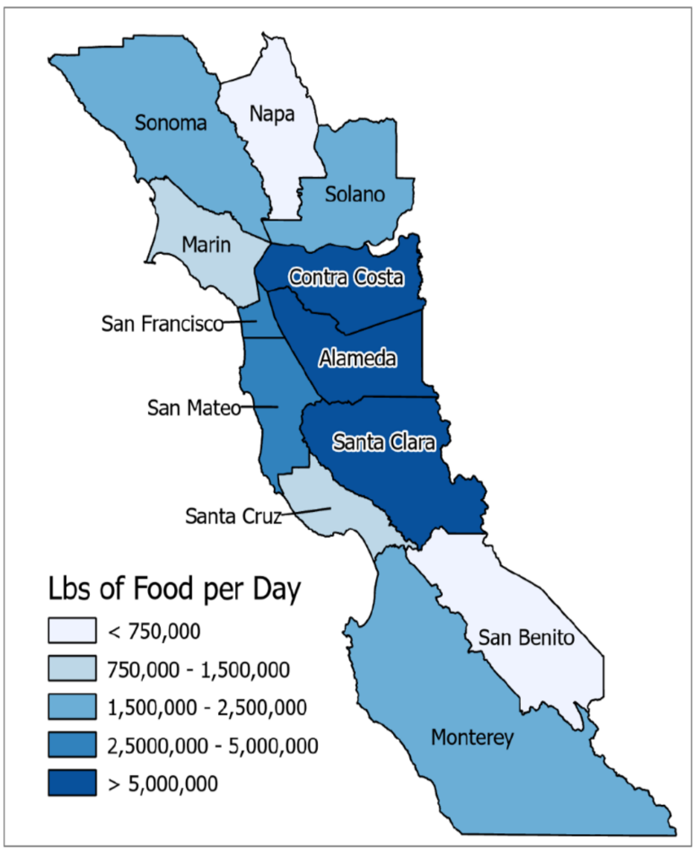

Figure B.1. Food demand (lbs day^{-1}) in the California Bay Area region.

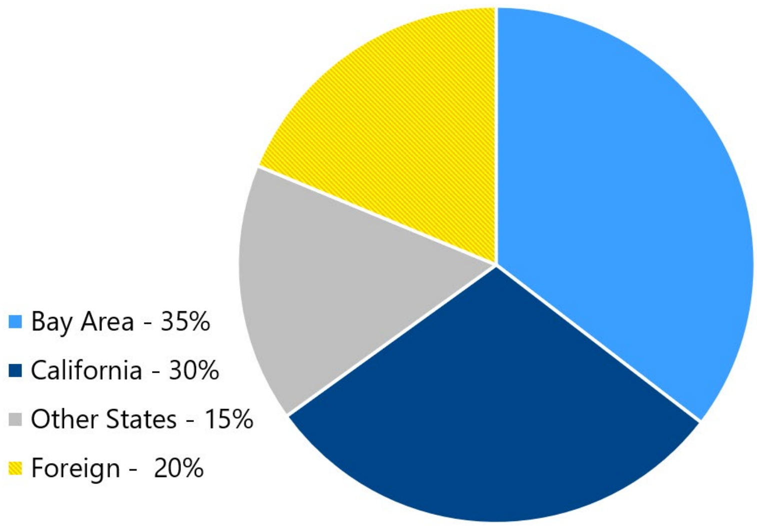

Figure B.2. Percentage of inbound flow to the California Bay Area region of food commodities by geographic source.

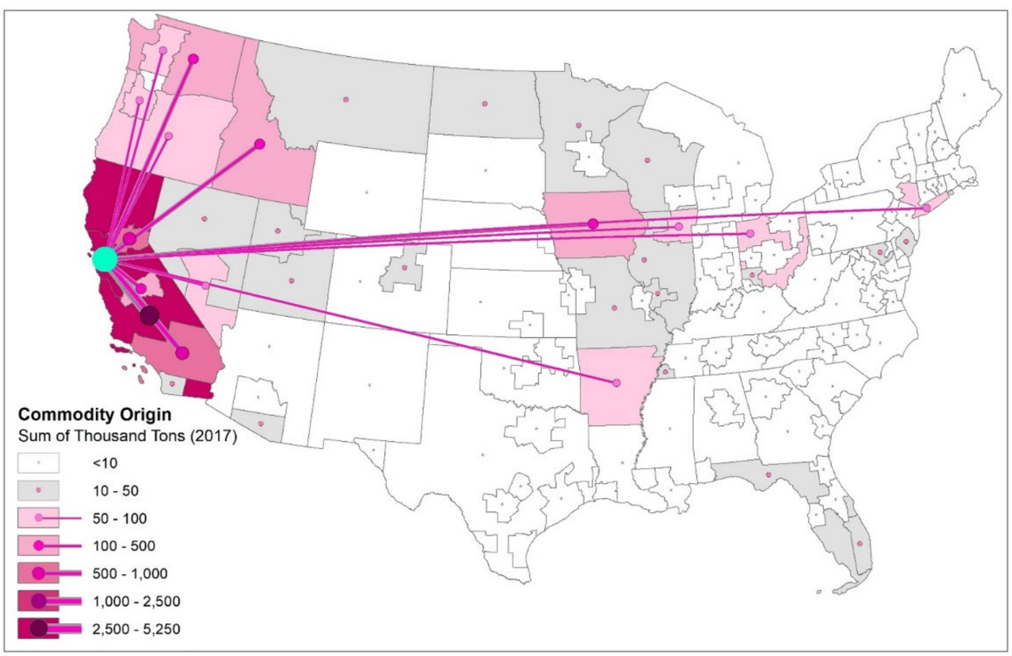

Figure B.3.Domestic food commodity inbound flows (thousand tons) to California Bay Area.

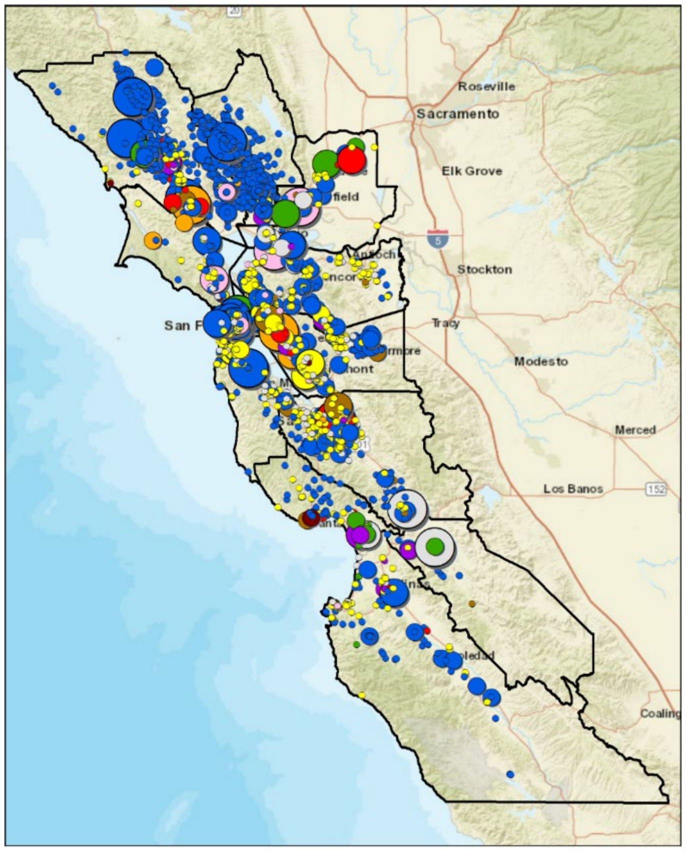

Figure B.4. Bay Area region food processors. Larger size indicates higher revenue.

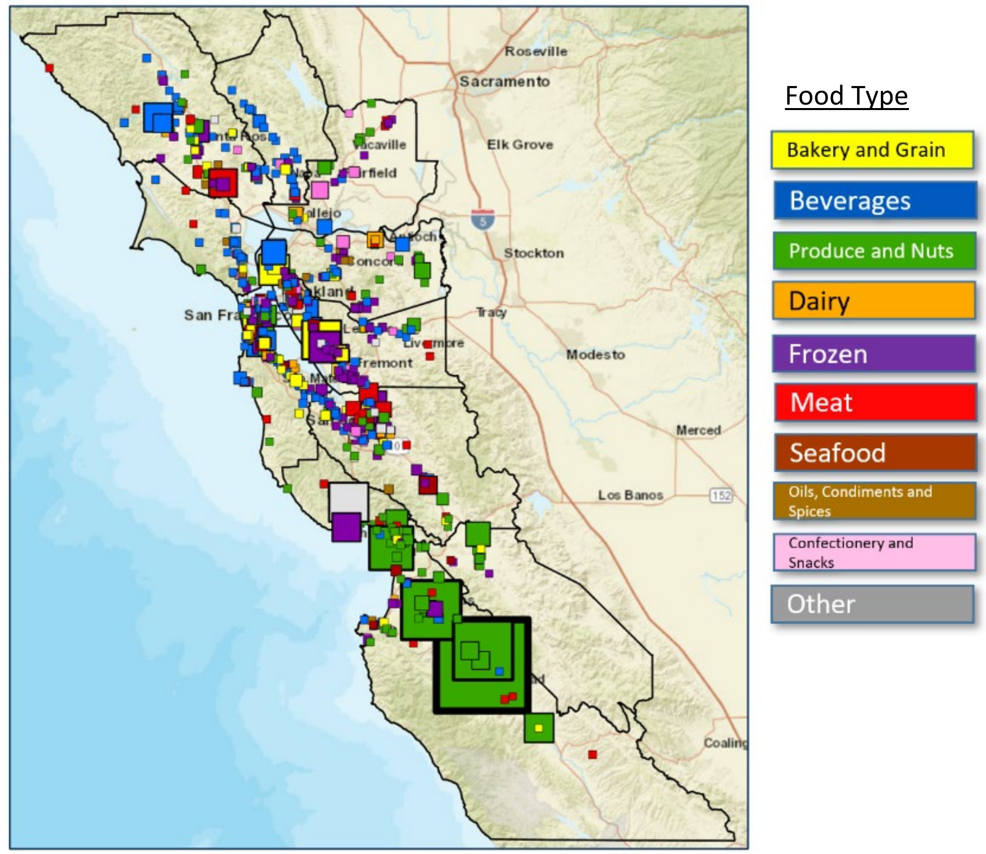

Figure B.5. Bay Area region wholesalers and distributors. Larger size indicates higher revenue.

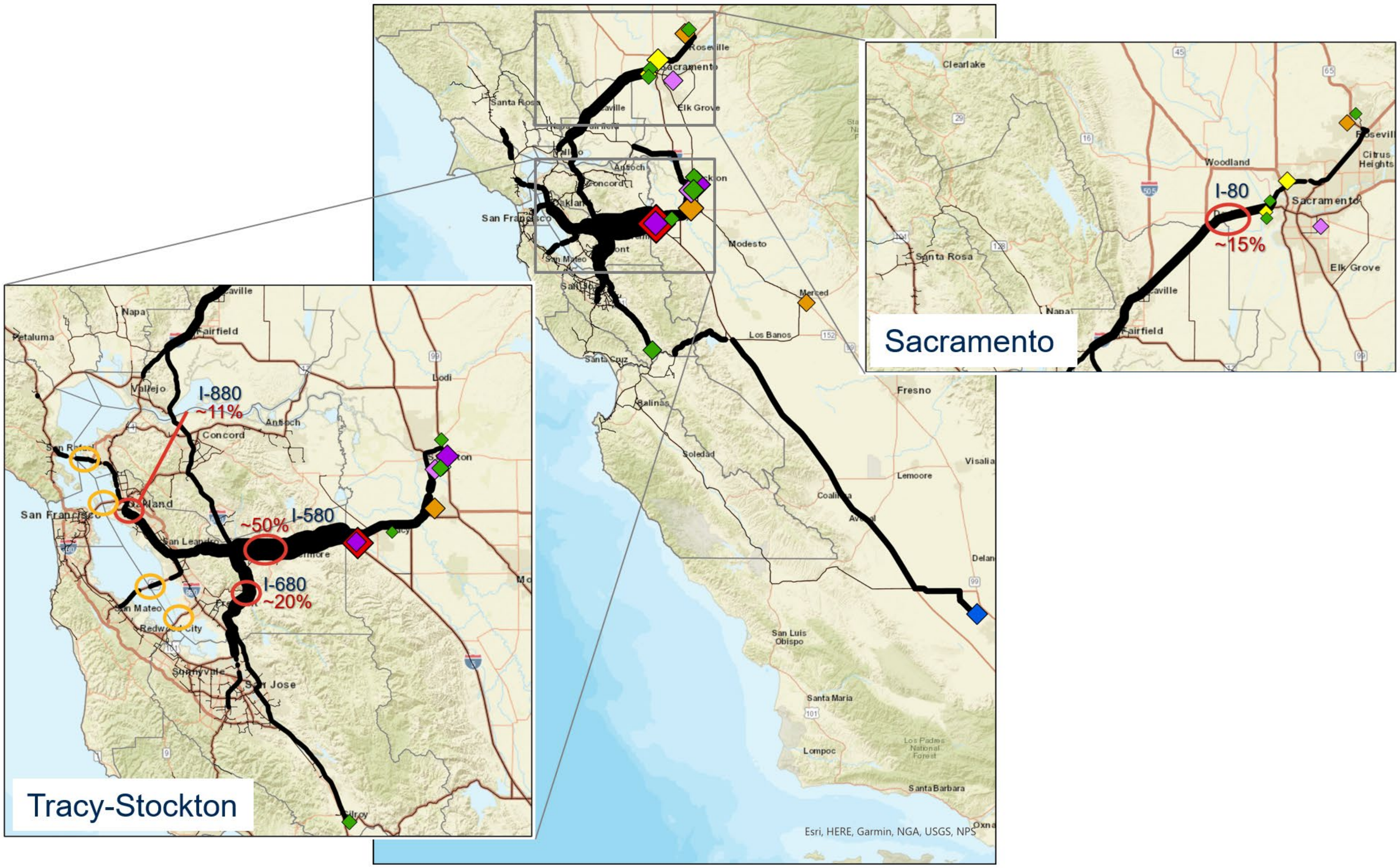

Figure B.6. Food distribution truck flow from distribution centers to retail locations in the Bay Area region with Sacramento and Tracy-Stockton regions detailed. Relatively thicker lines represent roadways with higher truck traffic. Approximate shares of modeled truck flows (percent) into the Bay Area Region are indicated in red text for major routes, which are indicated by red circles. Orange circles highlight important bridges.

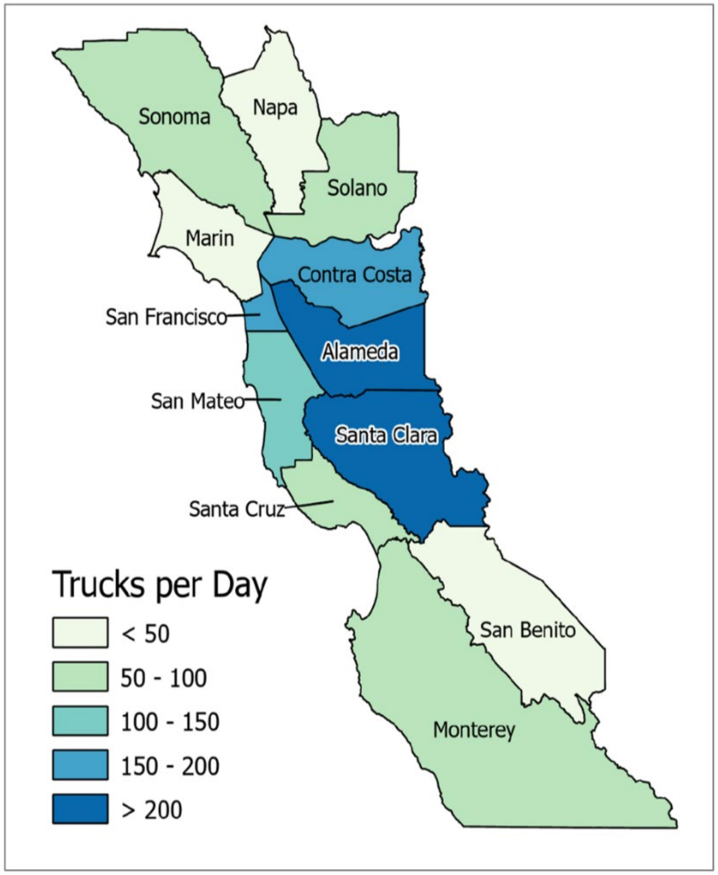

Figure B.7. Total number of truck trips needed per day at minimum to satisfy food demand in the Bay Area region.

APPENDIX C: WATER SECTOR TABLES AND FIGURES

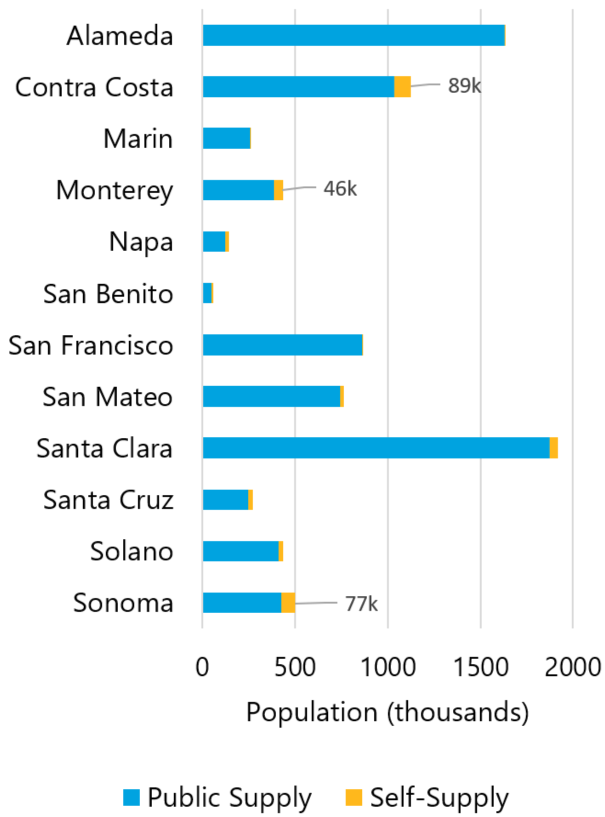

Figure C.1. Population (thousands) acquiring water from public water supply versus self-supply in the Bay Area region.

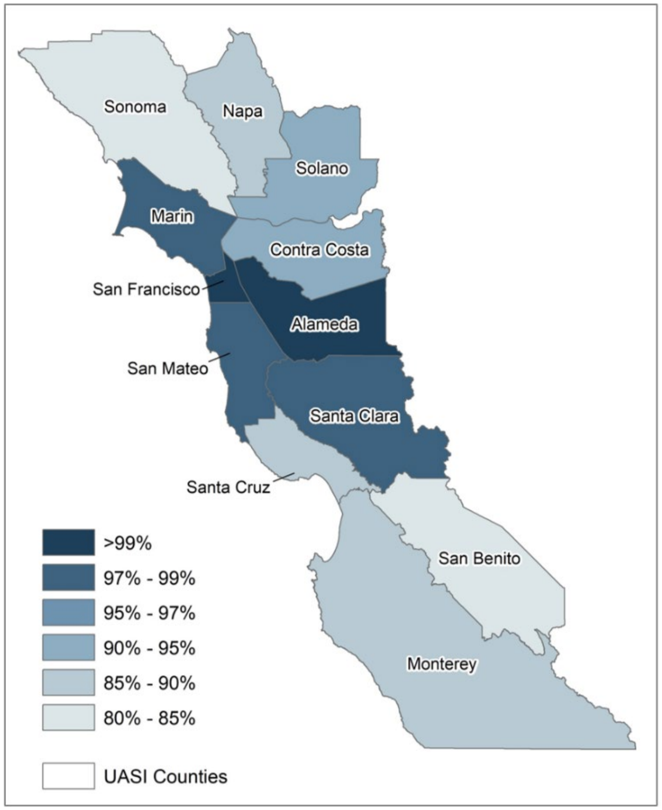

Figure C.2. Percentage of population served by public water supply in the Bay Area region.

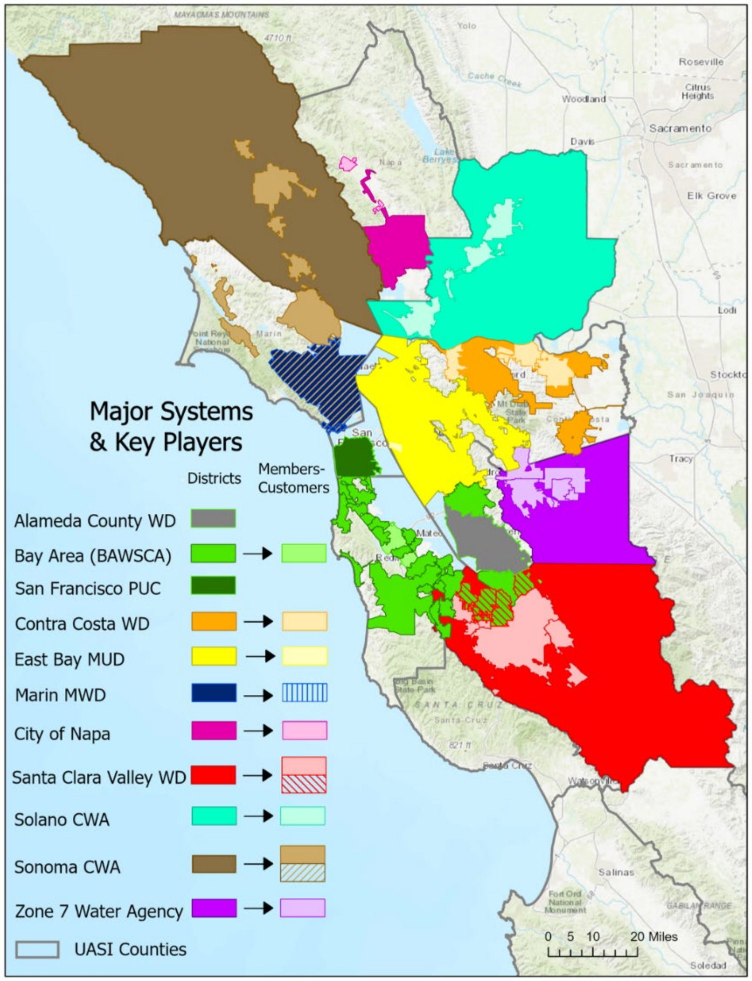

Figure C.3. Major water systems and key players in the Bay Area region.

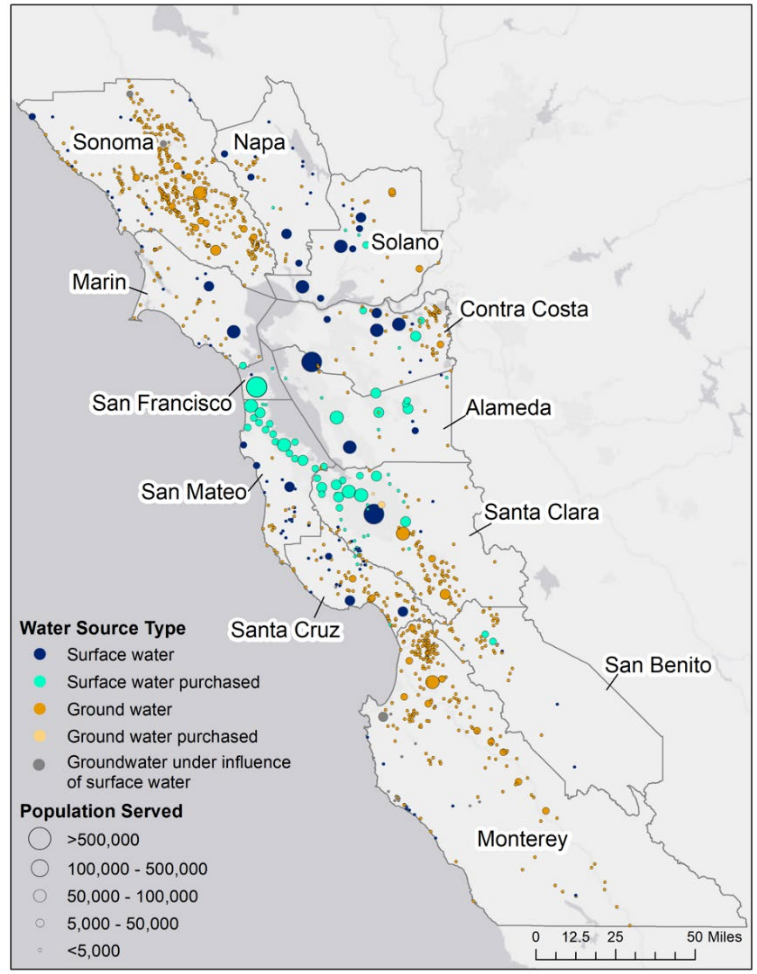

Figure C.4. Water systems by primary source type and size (population served) in the Bay Area region.

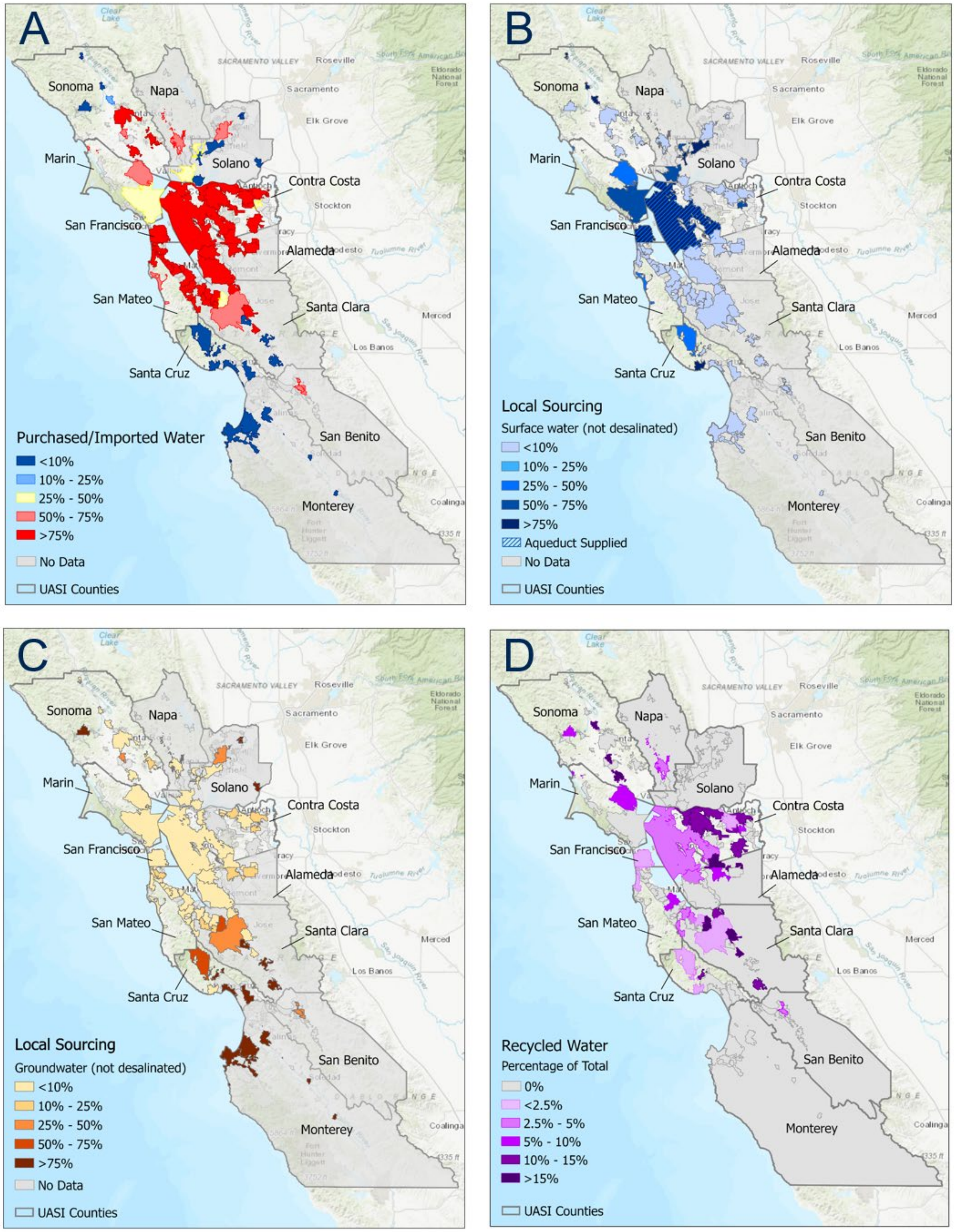

Figure C.5. Sourcing of Bay Area region water supply systems, percentage of supply from: A) purchased/imported water; B) locally controlled surface water; C) local groundwater; and D) recycled water. Note: On panel B, SFPUC and EBMUD control their sources and aqueducts, so the sourcing is counted as locally controlled, but hashing denotes the movement by aqueduct.

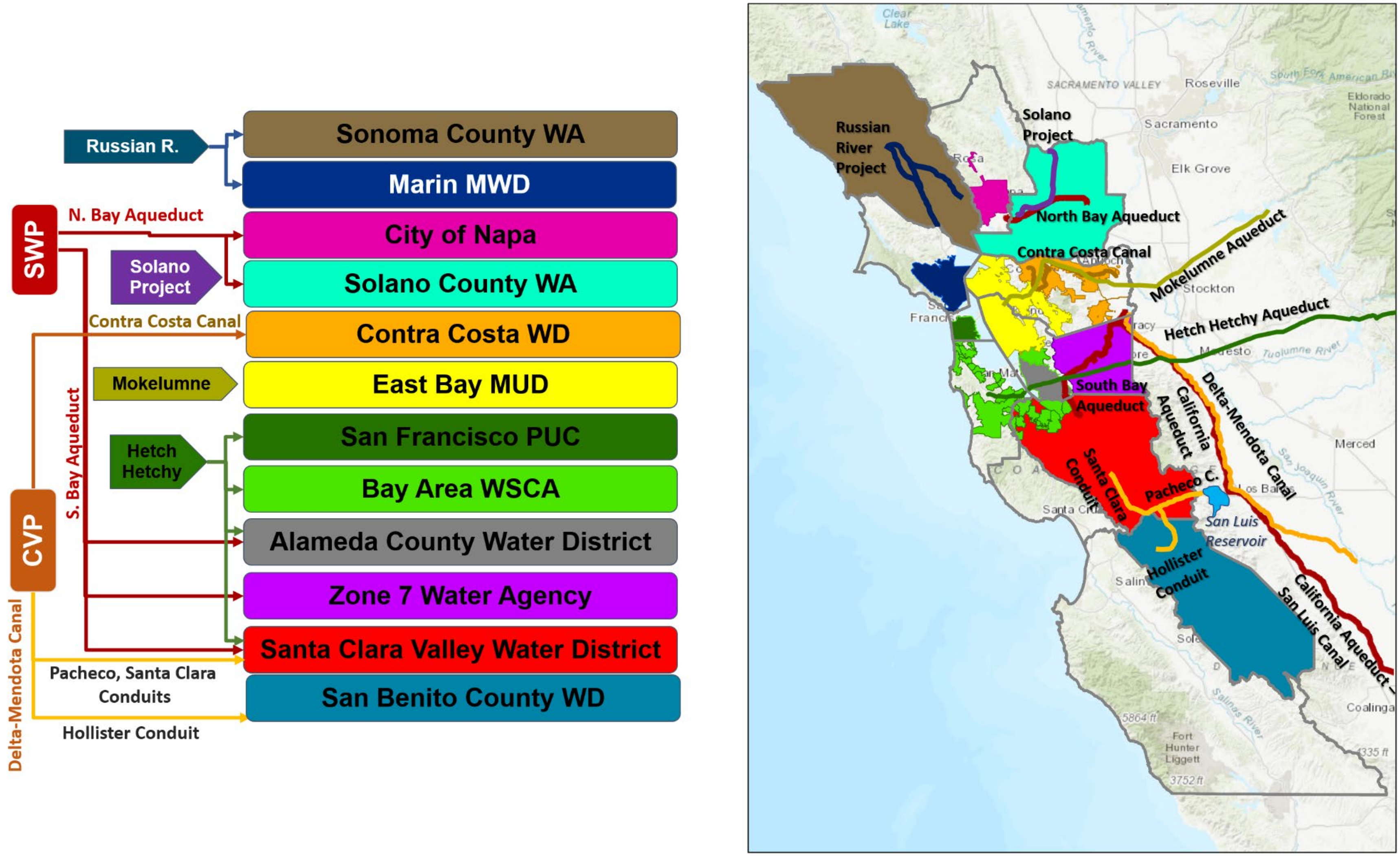

Figure C.6. Sourcing and transmission of major water systems and key players in the Bay Area region.

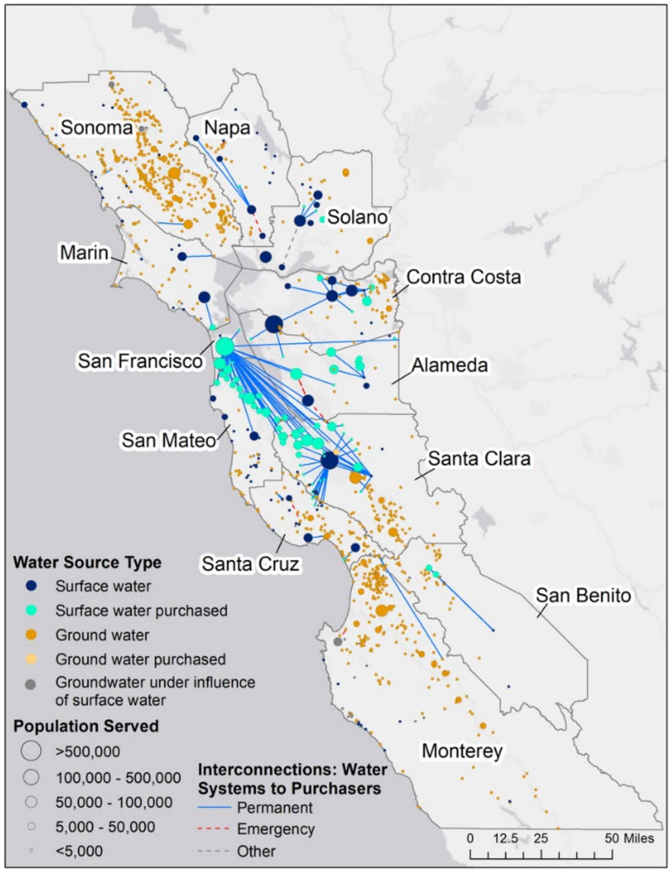

Figure C.7. Interconnections and types of water sources sized by population served in the Bay Area region.

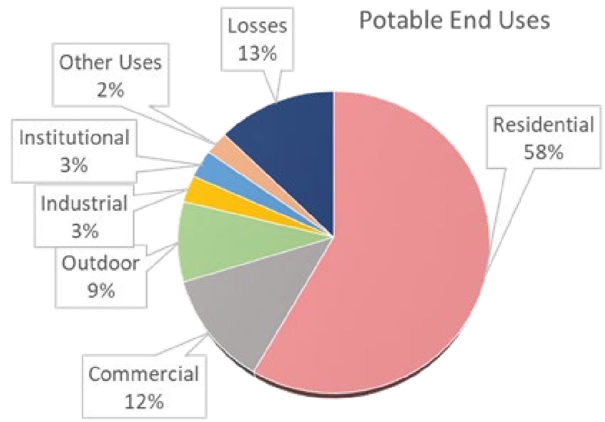

Figure C.8. Potable water end uses by sector for Bay Area region in 2020. Represents aggregation of all water systems with end use data in 2020 Urban Water management plans.

APPENDIX D: KEY PLAYERS IN BAY AREA SUPPLY CHAINS

Table D.1. Key players in the Bay Area region summarized by sector.

Sector	Organization (Player)
Airports / Seaport	Marine Exchange of the San Francisco Bay Area Region
	Oakland International Airport (OAK)
	Port of Oakland
	San Francisco International Airport (SFO)
Communications	AT&T
	Google
	Verizon
Electric Power and Natural Gas	Pacific Gas and Electric (PG&E)
Emergency Management	1 representative from each hub (total of 4)
	Alameda County Fire Department
	Army National Guard
	Bay Area Urban Areas Security Initiative
	California Governor's Office of Emergency Services (Cal OES)
	California Highway Patrol
	County of Santa Clara Office of Emergency Management
	California Resiliency Alliance (CRA)
	San Francisco Department of Emergency Management
Finance	Federal Reserve Bank of San Francisco
Food	Albertsons
	Anheuser-Busch
	Blue Apron
	C&S Wholesale Grocers
	California Grocers Association
	Clif Bar
	Coca-Cola
	Costco Wholesale
	Del Monte
	General Mills
	Ghirardelli
	Mendelez International
	Nestle
	Pepsico
	Regional food banks
	Smuckers
	Super Store Industries (SSI)
	United Natural Foods Inc. (UNFI)
	Walmart

Table D.1. Key players in the Bay Area region summarized by sector. Continued.

Sector	Organization (Player)
Fuel	Kinder Morgan
	California Fuels & Convenience Alliance (CFCA)
	Regional Refineries
Health	Association of Bay Area Health Officers (ABAHO)
Solid Waste Management	Recology
	Waste Management
Transportation	Bay Area Rapid Transit (BART)
	Caltrans Region 4 (Bay Area Region)
	Metropolitan Transportation Commission (MTC)
Water/Wastewater	Bay area Water Supply and Conservation Agency
	East Bay Municipal Utility District (EBMUD)
	Hetch Hetchy Aqueduct
	San Francisco Water
	San Francisco Water Power Sewer
	San Jose Water Company
	Sonoma Water
	Valley Water

APPENDIX E: PLAY EXECUTION SUPPORT MATERIALS

Preparedness Plays Template

PREPAREDNESS PLAYS		Staff Completing This Template:	
STATUS (Not Started, Ongoing, Completed, N/A)	**THE PLAY**	**ACTION(S)**	**NOTES**
	Identify Preexisting Vulnerabilities	Identify people and locations at highest risk of being separated from flows. Understand local resources and build relationships with local stakeholders.	
	Identify Preexisting Flows	Identify flow routes and modes (e.g., truck, rail) at highest risk of being impacted. Understand local resources and build relationships with local stakeholders.	
	Confirm Flow with Private Sector	Work with local stakeholders to confirm identified flow routes and modes of transport.	
	Conduct Site Visits to Key Nodes and Channels	Conduct regular visits with the top sources of water, food, and fuel to share information related to the Supply Chain and build relationships.	
	Conduct Private-Public Group Activities	Refine plays and processes through regular scenario-based activities.	

Response Plays Template

RESPONSE PLAYS		Staff Completing This Template:	Incident Start Date:
Jurisdiction(s) Impacted:		Incident Description:	
STATUS (Not Started, Ongoing, Completed, N/A)	**THE PLAY**	**ACTION(S)**	**NOTES**
	Assess High-Capacity Nodes and Channels	Assess surviving capacity and flow and the implications of lost capacity and flow. Communicate response priorities to stakeholders.	
	Focus on Vulnerable People and Places	Assess continuing and novel needs of vulnerable places and people. Communicate response priorities to stakeholders.	
	Restore Grid Power to High-Capacity Concentrations	Assess electric grid outages that have significant impacts on water, food, fuel, and/or freight movement. Communicate response priorities to stakeholders.	
	Release Disaster-SNAP Funding (and/or Similar Funding Sources)	Supplement financial ability of impacted populations to purchase necessary food and other supplies.	
	Ensure Effective POS Technology is Available	Deploy alternatives to traditional POS technology.	
	Ensure Essential Targeting and Sizing of Flows	Deploy non-traditional purchasing measures.	
	Share Strategic Context and Situational Awareness in Advance	Share information with stakeholders early.	
	Share Strategic Context and Situational Awareness in Real-Time	Share real-time information with stakeholders throughout the response.	
	Move More Volumes Faster by Waiving Weight Restrictions	Advocate for, facilitate, and communicate to stakeholders issuance of truck weight waivers.	
	Move More Volumes Faster by waiving Hours-Of-Service Restrictions	Advocate for, facilitate, and communicate to stakeholders issuance of waivers for Hours-Of-Service (HOS) regulations for truckers.	

RESPONSE PLAYS (cont'd)			
STATUS (Not Started, Ongoing, Completed, N/A)	**THE PLAY**	**ACTION(S)**	**NOTES**
	Ensure Flow Access to High-Capacity Nodes and Channels	Assess debris clearance and road restoration needs that have significant impacts on water, food, fuel, and/or freight movement. Communicate clearing and restoration priorities to stakeholders.	
	Organize Traffic Control to Expedite Flows	Increase velocity and volumes available to survivors via queue management techniques.	
	Troubleshoot and Facilitate Fuel Access by Critical Nodes, Channels, and Modes	Assess fuel access impacting water, food, fuel, and/or freight movement. Communicate response priorities to stakeholders.	
	Provide Security for Commodities in Transit	Provide police escorts for trucks delivering commodities (particularly, fuel trucks). Provide traffic control around delivery destinations.	
	Increase Available Inventories	Identify and bolster inventories of high-demand products.	
	Protect High-Capacity Nodes and Channels	Monitor, identify, and prevent threats (e.g., civil unrest) to high-capacity nodes and channels.	
	Replicate Lost Nodes and Channels	Leverage elements of surviving network capacity to replicate lost nodes and/or channels.	
	Deconflict and Accelerate Disrupted Nodes and Channels	Identify opportunities for and execute staging and dropping of inbound loads.	
	Expedite Cross-Docking	Identify opportunities for and expedite cross-docking of inbound loads.	
	Care for People on Whom Push Depends	Provide support for essential workers.	
	Replicate Demand Signals Where They Have Been Lost	Size, mix, target, and deliver government-procured water, food, or freight to address what survivors would pull if POS and other traditional means of demand signaling had survived or could be restored.	
	Deploy C-PODs and Other Replacement Tactics	Identify where prior inputs have failed and deploy CPODs, congregant feeding, emergency water and food distribution and related services as needed to these places.	

Recovery Plays Template

RECOVERY PLAYS		Staff Completing This Template:	Recovery Start Date:
Jurisdiction(s) Impacted:		Incident Description:	
STATUS (Not Started, Ongoing, Completed, N/A)	**THE PLAY**	**ACTION(S)**	**NOTES**
	Focus on Vulnerable People and Places	Continue assessments to identify people and places that remain vulnerable to impacts. Communicate response priorities to stakeholders.	
	Ensure Essential Targeting and Sizing of Flows	Identify how much is needed where and when. Give particular focus to restoring functionality of POS technologies or alternatives to serve this end.	
	Ensure Push Moves Toward Pull	Leverage non-traditional measures as needed to satisfy demand.	
	Deploy C-PODs and other Replacement Tactics	Identify the need for and deploy gap-filling measures.	
	Prioritize and Expedite Safety Inspections	Prioritize and expedite safety inspections.	
	Share Changes in Strategic Context	Collaborate with the private sector to share accurate information with the general public.	
	Inform of Impending Changes in Public Sector Behavior	Communicate discontinuation of response plays with stakeholders	
	Conduct After-Actions and Identify Lessons Learned	Collect, analyze, and share data on the effectiveness of responses and executed plays.	
	Celebrate Success	Recognize and celebrate people and actions contributing to success. Leverage successes to strengthen relationships and further improve resilience.	