

Where Does California's Water Come From?

Land conservation and the watersheds that supply California's drinking water

The Nature Conservancy of California

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Version 1.1

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A Science *for* Conservation Technical Brief

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Cover maps: Surface drinking water sources for Fresno, Los Angeles, San Francisco and Inland Empire Cities. See Appendix A for full maps.

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Summary

Ninety-three percent of Californians rely on publicly supplied water to meet their domestic water needs.

Eighty-two percent of the water supplied by public water districts for domestic and other uses come from rivers, lakes, reservoirs, and other surface water sources (Kenny et al. 2009). The quality of the water flowing into these sources is directly affected by the condition of the land

in the surrounding watershed (Lenat and Crawford 1994, Gutman 2007). Better quality water generally translates to lower filtration and treatment costs for the utilities who deliver water to homes and businesses. Despite the importance of watershed conditions for California's drinking water supply, there is currently no comprehensive database that maps the full extent and condition of those watersheds.

Using public sources of data, we mapped the surface drinking water sources (rivers, reservoirs, lakes, etc.) in the state and the watersheds that supply water to those sources. We found that California's drinking water supply system relies on approximately 157 million acres of land spanning 8 states to collect, filter, and deliver water. Only 16% of this land is strictly protected from development and degradation (e.g., wilderness areas, national parks). Roughly half of the land (51%) has some level of protection but designated for multiple uses including significant landscape-disturbing activities like logging, road building, and mining. The remaining 33% is in private ownership with highly variable levels of protection from development and degradation. In fact, 7.7 million acres (5%) of the watersheds supplying California's drinking water have been converted to agricultural uses and an additional 3.2 million acres (2%) has been converted to urban and suburban development. The sizes of the watersheds supplying drinking water for individual cities range from 57,000 acres (San Bernardino) to 146,000,000 acres (Los Angeles). For some cities, the watersheds are very well protected (e.g., Fresno has 89% with some level of protection); while for other cities there are few known protections in place (e.g. Santa Rosa has 80% with no recorded protections). Mapping the watersheds that supply drinking water is important to highlight areas where more land-use protection and habitat restoration is needed. Increasing conservation action in unprotected watersheds could protect and in some cases improve drinking water quality, reducing the need for costly and energy intensive filtration and treatment facilities.

The Watersheds Supplying California's Drinking Water

Total land area (acres)	156,623,659
Land in public management	67%
Land in private ownership	33%
Land used for agriculture	5%
Land in urban/suburban development	2%

Introduction

A watershed is an area of land that contributes water to a given location, such as a reservoir, a confluence of two streams, or the ocean. Within a watershed, water from rain or snow flows down the slope, through the soil, or via groundwater flow – and usually by a combination of these routes – to reach the stream and contribute to the flow of the stream. Watersheds are important sources of drinking water, as well as a habitat for many aquatic species. Healthy watersheds with intact native vegetation and wetlands provide important functions such as water purification, flood control, nutrient recycling, and groundwater recharge. Such valuable functions are sometimes referred to as “ecosystem services” (Revenga et al. 1998).

Californians rely on both surface and ground water sources for their domestic water supply. Unfortunately, the watersheds that yield water to these sources face many sources of degradation including sedimentation and pollution from residential development, industrial runoff, timber harvests, agricultural production, land clearing, and mining (Revenga et al. 1998, Bolund and Hunhammar 1999). While these types of degradation will eventually affect both surface and groundwater, this report focuses on surface drinking water sources and watersheds. However, protecting and/or restoring native vegetation in these watersheds will also improve groundwater supply by maintaining or increasing groundwater recharge rates.

Mapping the watersheds that supply drinking water to people is a crucial first step to ensure they remain healthy and protected. Previous studies have listed sources or mapped a subset of the watersheds (e.g., the watersheds for one city), but none of these explicitly mapped all watersheds that supply drinking water to Californians¹. To fill this data gap, we have generated the most comprehensive map to date of surface water sources and the watersheds that supply California’s drinking water. In addition, we have analyzed the current land uses and protections in these watersheds. Finally, we identified which watersheds supply drinking water to 30 of the largest cities in the state. This document presents the results of this effort as well as a description of the methods we used.

Results

The watersheds that supply drinking water to Californians cover almost 157 million acres and span 8 states (Figure 1). These watersheds drain lands that include highly protected areas (e.g., wilderness areas) and those that have been developed (e.g., downtown Sacramento). From the

¹ The California Department of Forestry and Fire Protection (<http://frap.cdf.ca.gov/>) did map the watersheds for dams that supply drinking water, but this missed many drinking water sources that are not fed by major dams. The Water Education Foundation (<http://www.water-ed.org/watersources/>) provides detailed information about the water sources for individual cities, but it does not map the watersheds that supply the water.

map, it is clear that the Sierra Nevada mountains are an important source of water for the state of California, providing snowmelt for the many lakes and rivers that drain into the Sacramento and San Joaquin rivers. These rivers, in turn, supply water to the Sacramento-San Joaquin Delta, a water source that serves roughly 25 million Californians via the State Water Project. In addition, most southern California cities obtain some of their drinking water from the Colorado River, which originates in the mountains of Wyoming and Colorado, and then passes through and drains portions of Utah, New Mexico, Arizona, and Nevada until it reaches Lake Havasu, on the border between Arizona and California. There, it is diverted into the Metropolitan Water District's Colorado River Aqueduct which carries the water 242 miles to southern California.

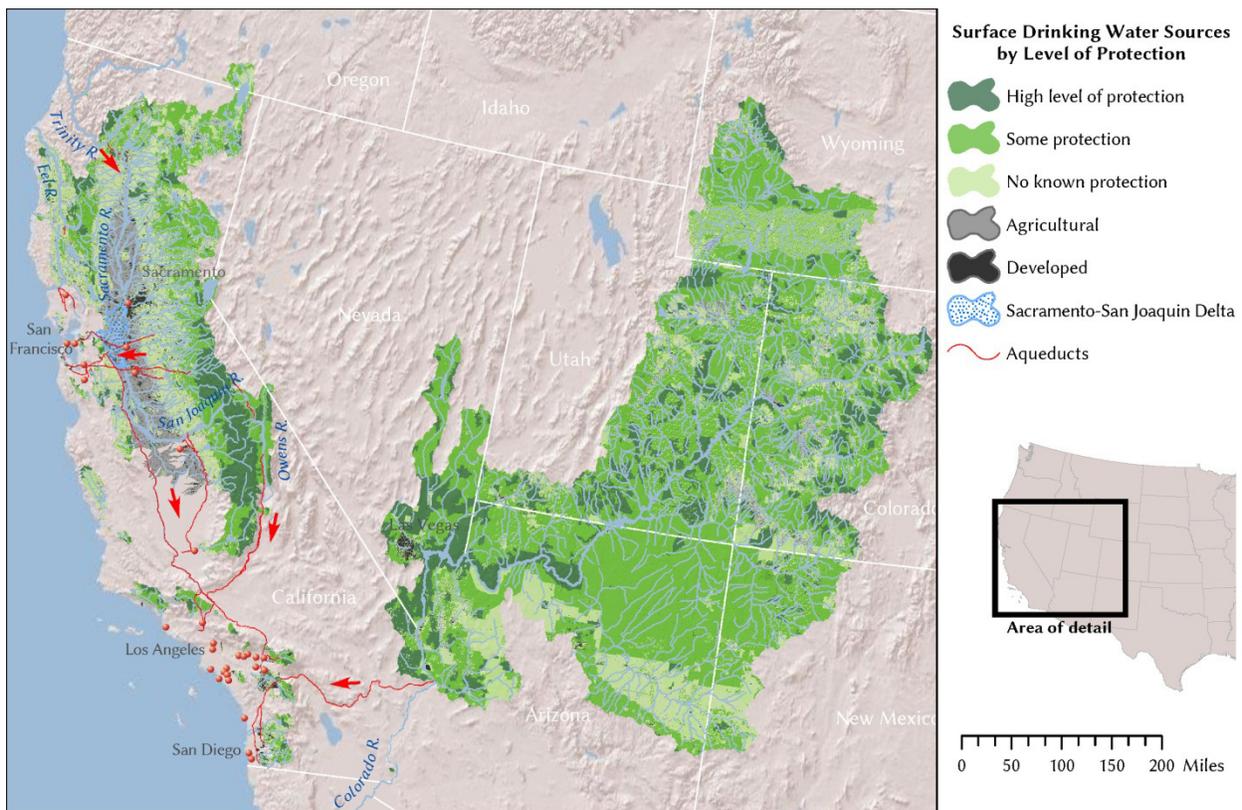


Figure 1: Map of all watersheds that supply drinking water to California residents. The 30 most populous (red dots) and the major aqueducts that supply these cities (red lines) are shown. A larger copy of this map is included in Appendix A.

Appendix A includes a series of maps that show the source watershed for the 30 most populous cities in the state. We calculated the total area of the watersheds that supply drinking water for each of those cities (Figure 2). Los Angeles depends on the largest area with contributing watersheds totaling 146 million acres -- approximately 1.5 times the size of California. Los Angeles is followed closely by the other southern California cities that get portions of their water from the Metropolitan Water District of Southern California (<http://www.mwdh2o.com/>),

which relies on water from both the Colorado River and the Sacramento-San Joaquin Delta. Bakersfield, San Jose, Santa Clarita, Fontana, Ontario, Rancho Cucamonga, and Fremont obtain water from the Sacramento-San Joaquin Delta and an array of other local streams and rivers, each city relying on almost 30 million acres to supply water. Sacramento gets its water from the Sacramento and American Rivers, draining just over 15 million acres. Fresno, San Francisco, Modesto, Stockton, Santa Rosa, Oakland and San Bernardino all rely on smaller watersheds that are less than 2 million acres. San Bernardino residents get most of their water from ground water, so they have one of the smallest surface water supply areas, 57,000 acres.

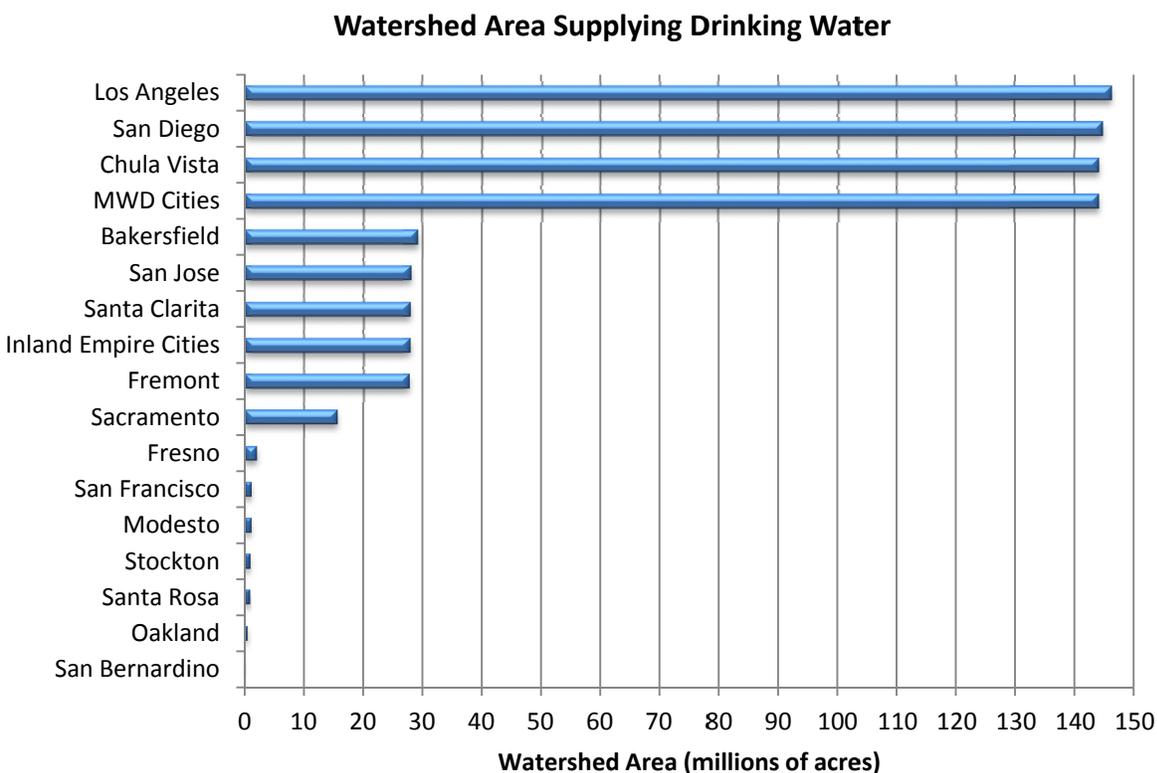


Figure 2: The watershed area each of the 30 largest cities relies on for drinking water. “MWD Cities” are served only by the Metropolitan Water District (MWD) of Southern California. These include Anaheim, Garden Grove, Glendale, Huntington Beach, Irvine, Long Beach, Moreno Valley, Oceanside, Oxnard, Pomona, Riverside and Santa Ana. Los Angeles, Chula Vista and San Diego also get water from MWD but they have additional surface water sources. “Inland Empire Cities” are served only by the Cucamonga Valley Water District. These include Fontana, Ontario and Rancho Cucamonga.

Land use within a watershed can affect the quality of the surface water that flows from the watershed (Tong and Chen 2002). Watersheds with a high proportion of land covered by intact vegetation and wetlands filter and purify water, regulate seasonal flows, and minimize erosion (Postel and Thompson 2005). Alternatively, human conversion of natural watersheds through urbanization, timber harvesting, road construction, cultivation for agriculture, and mining can

increase sedimentation in rivers and stream, degrading the quality. Runoff from inadequately managed feedlots, golf courses, agricultural fields, and suburban lawns can pollute water bodies and contaminate drinking water sources (Foley et al. 2005).

To assess the susceptibility of water sources to pollution and contamination related to conversion or intensive management, we mapped land use types and level of protection for all watersheds according to the following land use and protection categories (Figure 3):

Land Use

- **Developed** – includes urban areas, suburban development, lawns, and golf courses.
- **Agriculture** – includes areas planted for annual crops, vineyards, orchards, and fields used for pasture and hay production. It does not include natural/semi-natural rangeland.

Protection

- **No Known Protection** – includes undeveloped land primarily in private ownership.
- **Some Level of Protection** – includes public and private lands that are protected from development but may support multiple uses, including resource extraction (forestry, mining, etc.)
- **Highest Level of Protection** – includes public and private areas managed for habitat conservation such as wilderness areas and national parks.

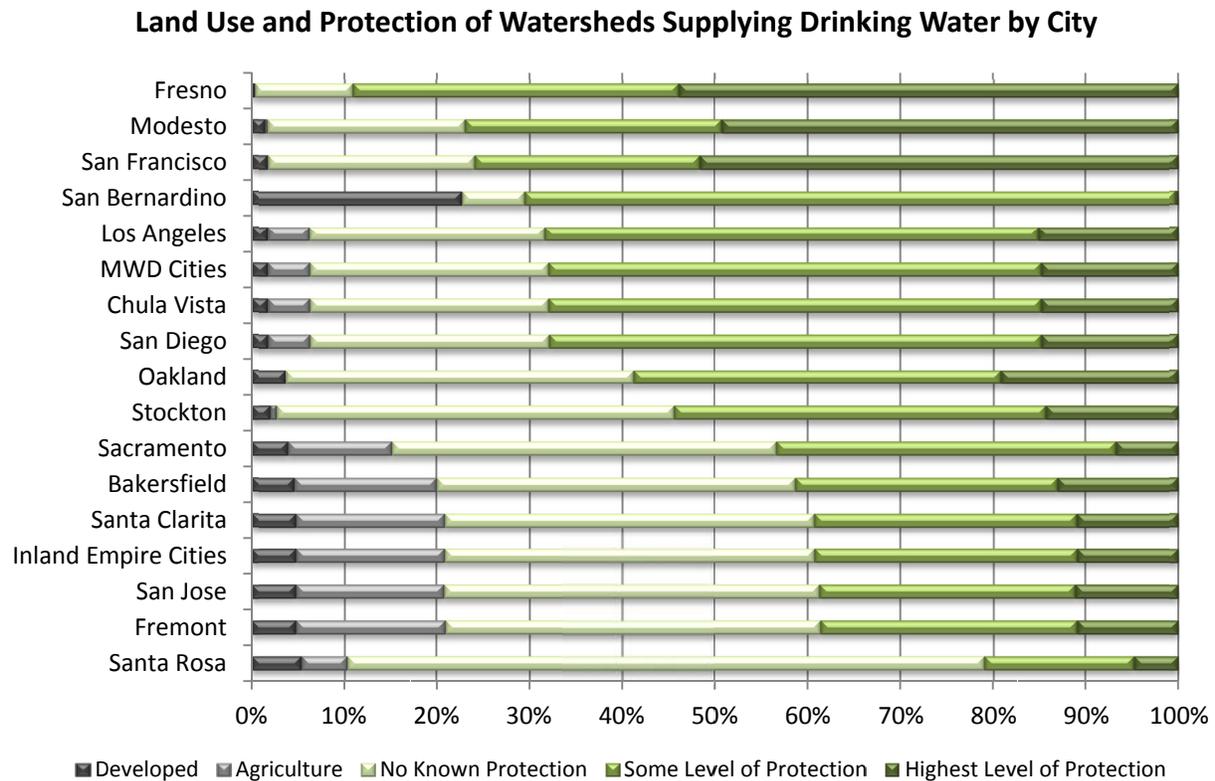


Figure 3: The land use and protection of the watershed each of the 30 largest cities relies on for drinking water. “MWD Cities” are served only by the Metropolitan Water District (MWD) of Southern California. These include Anaheim, Garden Grove, Glendale, Huntington Beach, Irvine, Long Beach, Moreno Valley, Oceanside, Oxnard, Pomona, Riverside and Santa Ana. Los Angeles, Chula Vista and San Diego also get water from MWD but they have additional surface water sources. “Inland Empire Cities” are served only by the Cucamonga Valley Water District. These include Fontana, Ontario and Rancho Cucamonga.

As shown in Figure 3, Fresno has the highest percentage (89%) of protected land in the watersheds that supply its drinking water, with 54% of the 2 million acres falling under the highest level of protection and 35% with some protection. The watersheds that supply Modesto and San Francisco also have high protection and minimal development, with over 75% protected. On the other hand, Santa Rosa gets its surface water from mostly private undeveloped land (69%) with only 21% having some level of known protection. San Bernardino has the highest amount of developed area in the 57,000 acre watershed that supplies its drinking water with 23% in low density development around Big Bear Lake (13,000 acres). All of the cities that rely on water from the Sacramento-San Joaquin Delta (Los Angeles, MWD cities, Chula Vista, San Diego, Santa Clarita, Fontana, Ontario, Rancho Cucamonga, Bakersfield, San Jose, and Fremont) use water that flows through California’s Central Valley, which is largely converted for urban and agricultural land uses.

Discussion

The people of California rely on an area that is 1.5 times the size of the state (157 million acres) to collect, filter, and deliver drinking water to their homes. In general, these watersheds are relatively well protected and support natural vegetation. Two thirds of the watersheds have some form of protection, while only 7% have been developed or converted to agriculture. However, this analysis highlights the following significant threats to drinking water quality and supply:

- **Land management.** Roughly half of the watersheds that supply drinking water are public lands that are designated for multiple uses, including intensive logging and mining. There are even fewer land use controls on private lands. Along the Sacramento, San Joaquin, and Russian rivers, people live, work, and grow crops directly adjacent to the rivers. If not managed correctly, these activities can pollute the drinking water for millions of Californians, increasing treatment costs that are then passed on to ratepayers.
- **Urban growth.** Only 2% of the watersheds that supply drinking water are currently developed for urban and suburban uses, but the population of California is expected to increase by 37% by 2050, with 13.8 million new people needing places to live (Pitkin and Myers 2012). Conversion of farmland and natural habitats to urban and suburban growth will increase impervious surfaces and reduce the ability of soils and plants to naturally filter the water.
- **Climate change.** All of the recent General Circulation Models (GCMs) that project future climate indicate significant increases in temperature, and many predict a drop in average annual precipitation, for the watersheds that supply California's drinking water (Christensen et al. 2007). The precipitation projections are especially dry for the Colorado River watershed and southern California (Seager et al. 2007, Seager and Vecchi 2010). In addition, recent studies indicate that a greater proportion of the rain that does fall will come in big events, increasing the probability of floods and decreasing the ability of water managers to store the water for drier times (Field et al. 2012).
- **Wildfires.** As the climate warms and gets potentially drier, the area burned by wildfires is predicted to increase (Westerling et al. 2011). These trends are already being observed throughout the western U.S. (Westerling et al. 2006, Williams et al. 2010). Intense wildfires can remove vegetation and increase sedimentation for years after the fire (George et al. 2004). If the fire is large enough and close to drinking water diversion infrastructure, this can cause significant damage by filling in reservoirs and clogging filtration systems.

Because of these threats, the future of California's drinking water supplies is in jeopardy. However, land conservation strategies like protection and management can reduce the impacts and severity of these threats. These strategies include:

- **Best management practices (BMPs).** By implementing pollution control and BMPs, economic activities like forestry, mining, and agriculture can have minimal impact on water quality and quantity. The U.S. Environmental Protection Agency's Source Water Protection program² provides a host of resources for identifying and implementing BMPs within drinking water watersheds.
- **Land use protections.** Local growth controls, zoning, urban growth boundaries, and conservation easements and acquisitions are all ways to protect natural habitats and minimize growth in key watersheds. The maps presented in this report can help communities and conservation organizations prioritize land use protections in watershed that supply drinking water.
- **Habitat restoration.** In places where natural habitat has already been removed, strategically located habitat restoration efforts can improve water quality (Osborne and Kovacic 1993, Fennessy and Cronk 1997). For example, restoration of riparian forests can intercept silt and other pollutants like nitrates before they enter the stream channel.
- **Greenhouse gas emissions controls.** In general, researchers predict less extreme changes in climate and less wildfire if global greenhouse gas emissions are reduced. The implementation of California Global Warming Solutions Act is an important step to demonstrate methods to reduce greenhouse gas emissions worldwide.
- **Forest management.** The intensity and location of a wildfire is a key determinant in its impacts on drinking water quality. The maps in this report can help forest managers prioritize thinning and prescribed burn actions in areas where an intense wildfire would be most troublesome (e.g. areas with erodible soils near a drinking water filtration facility).

All Californians benefit from clean, abundant, and inexpensive drinking water. By mapping and analyzing the protections and land uses in the watersheds that supply drinking water, this report highlights the connection between urban populations and the landscape. Lack of land use controls, inappropriate management, climate change, and wildfires all threaten the natural capacity of the watersheds to supply and filter drinking water. However, the conservation tools exist to minimize these threats and ensure a plentiful and inexpensive supply of drinking water for current and future generations of Californians.

² <http://water.epa.gov/infrastructure/drinkingwater/sourcewater/protection/index.cfm>

Methods

Definitions Used in this Section

- Diverter: the water company or municipality which is using (diverting) the water source; e.g. “San Francisco Regional Water System” or “Clearwater Mutual Water Company”
- Diversion: the surface water source of drinking water, including dams, canals, reservoirs and lakes; e.g. “Clear Lake” or “California Aqueduct”
- City: the incorporated (not metropolitan) area of a city

To create this database, we first compiled a list of water bodies Californian’s use for drinking water by systematically reviewing the water source assessments found on the California Department of Public Health’s Drinking Water Source Assessment and Protection Program (DWSAP) website (<http://swap.des.ucdavis.edu/TSinfo/TSsearch.asp>). We supplemented this database with information from reports available on the city and diverter webpages. We mapped the surface water sources by matching the names used in the DWSAP assessments with the names from GIS datasets and by researching information posted online by the diverters (see Appendix B for sources used).

We then determined which portions of the watershed drained into each diversion. To do this, we created a geometric network from the “flowlines” (e.g., rivers) from the National Hydrology Dataset Plus (<http://www.horizon-systems.com/nhdplus/>) using ArcGIS 10.0 software. We could then use the “trace upstream” tool which indicates which streams and rivers are upstream of the diversion. We selected the subwatersheds associated with the upstream rivers and added these to the database for every diversion.

To link individual cities to the surface sources of their drinking water, we selected the 30 most populous cities in California based on 2010 census data. We used spatial datasets of the service areas of the federal, state, and private water districts to relate each city to its diverter (https://projects.atlas.ca.gov/frs/?group_id=39&release_id=241). Using the tables in the database, we then linked each city to the watershed that supplies its drinking water (see Figure 4 for a generalized schematic of the information in the database).

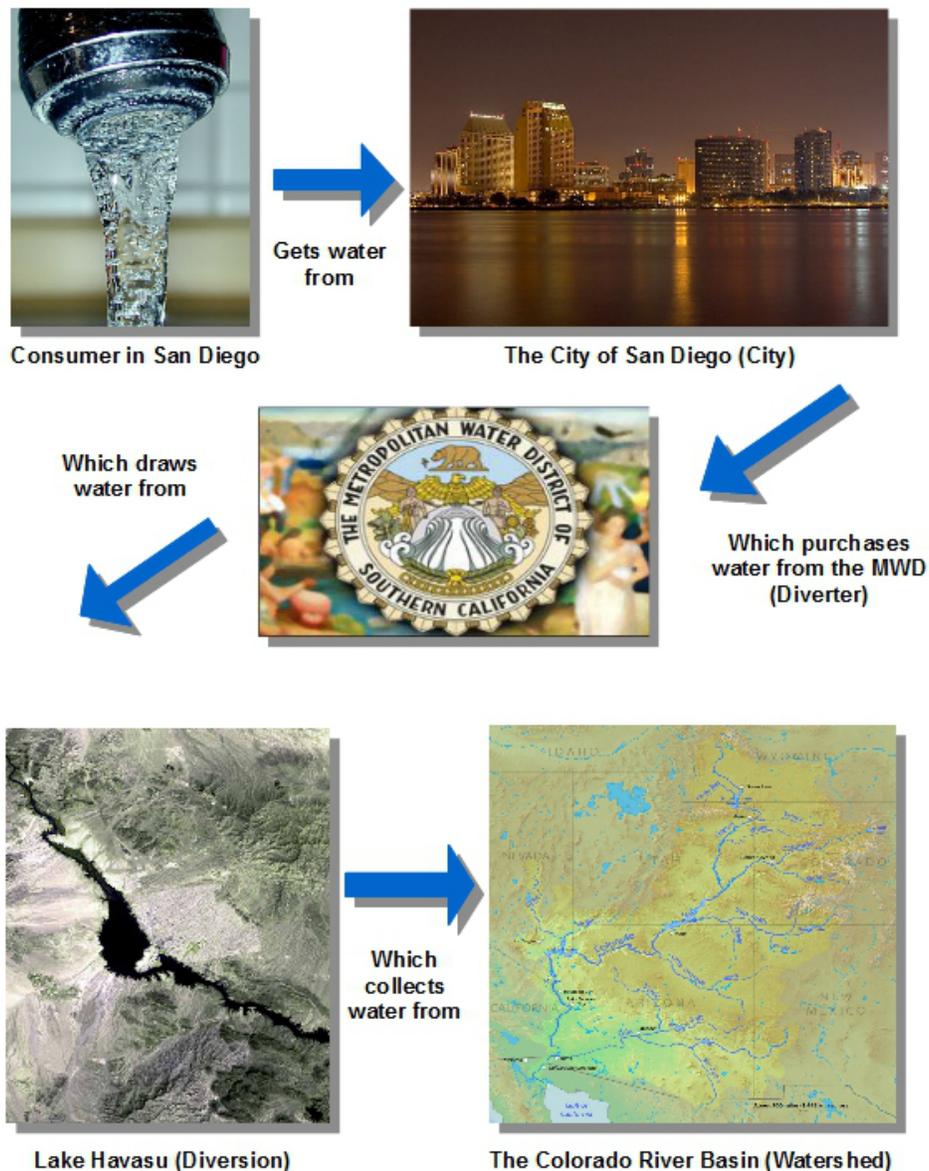


Figure 4. Schematic of terms used in this project and their relationship to one another. All images are in the public domain and were downloaded from <http://commons.wikimedia.org>.

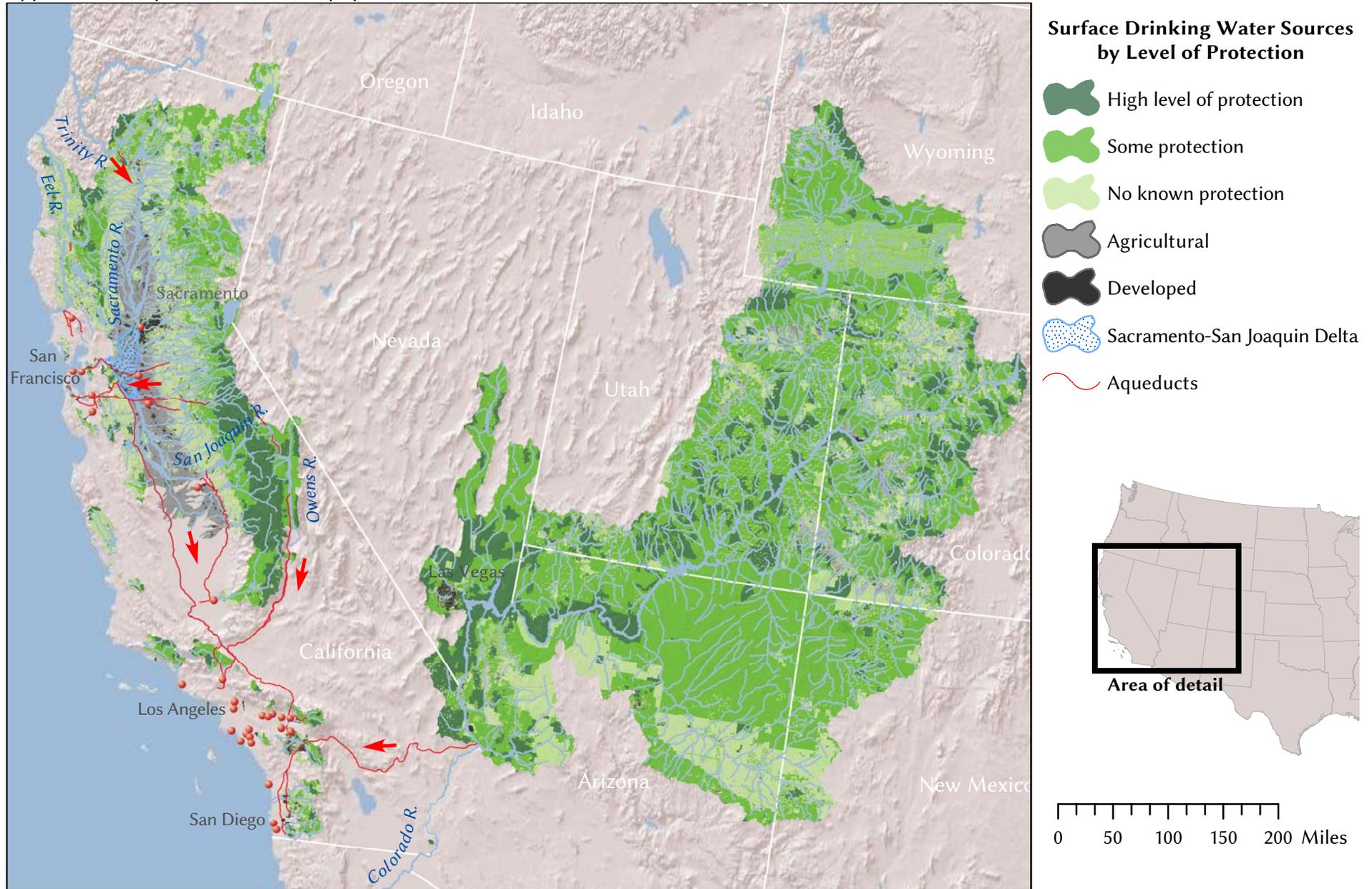
We calculated the percent of each watershed that is either protected or converted to human uses. The protected area information comes from the Protected Area Database of the United States (PADUS, <http://www.protectedlands.net/padus/>). In this database, the level of protection for each protected area is ranked on a scale of 1 to 4 with 1 having the highest protection and 4 the least. This scale is referred to as the “gap” status of the protected areas. We categorized areas with gap status 1 and 2 as having the “highest level of protection” and areas with gap

status of 3 as having “some level of protection”. Please note that this database does not include all public or private lands that have protections against development including many conservation easements on private land, so we categorized areas that are not included in the PADUS as having “no *known* protection.” We used the 2006 National Land Cover Dataset (<http://www.mrlc.gov/nlcd2006.php>) to calculate the percentage of the watersheds that are intensively managed for agriculture (planted/cultivated) or developed for other purposes, such as urban and suburban development.



View of creek and riparian habitat near Las Uvas Reservoir, a drinking water source for San José. © Avi Hesterman

Appendix A: Maps for the 30 most populous cities in California



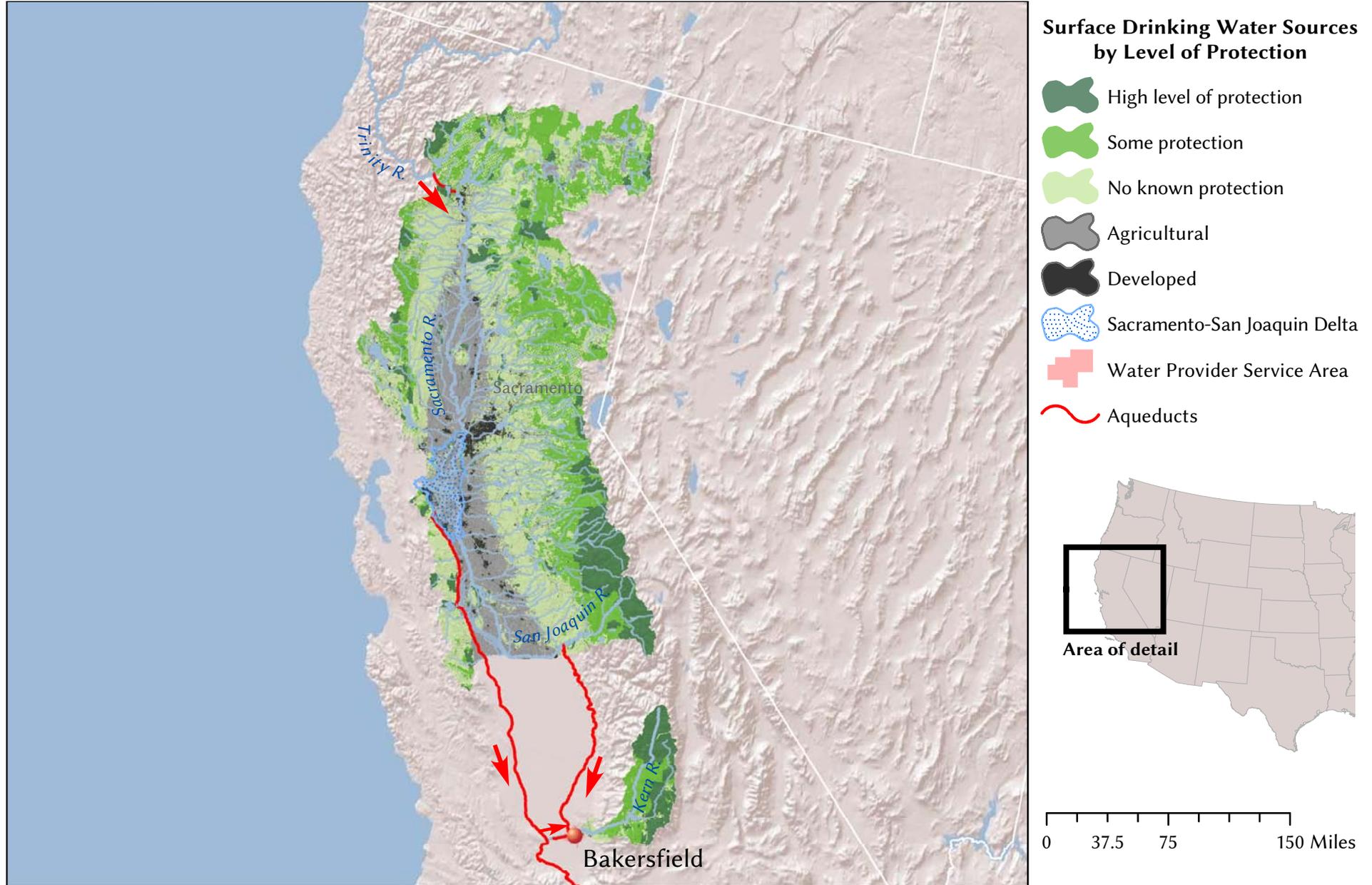
Surface Drinking Water Sources for the State of California

Map produced for The Nature Conservancy (TNC) 2012. TNC uses the most current and complete data available. GIS data and product accuracy may vary.

Areas delineated as having "No known protection" may include water district lands and easements on private lands.

Using GIS products for purposes other than those for which they were intended may yield inaccurate or misleading results.

Sources: Protected Areas Database of the U.S. 2010, USGS National Hydrography Dataset, National Land Cover Database 2006, TNC inferred and the website(s) of the utilities provider(s).



Surface Drinking Water Sources for Bakersfield, CA

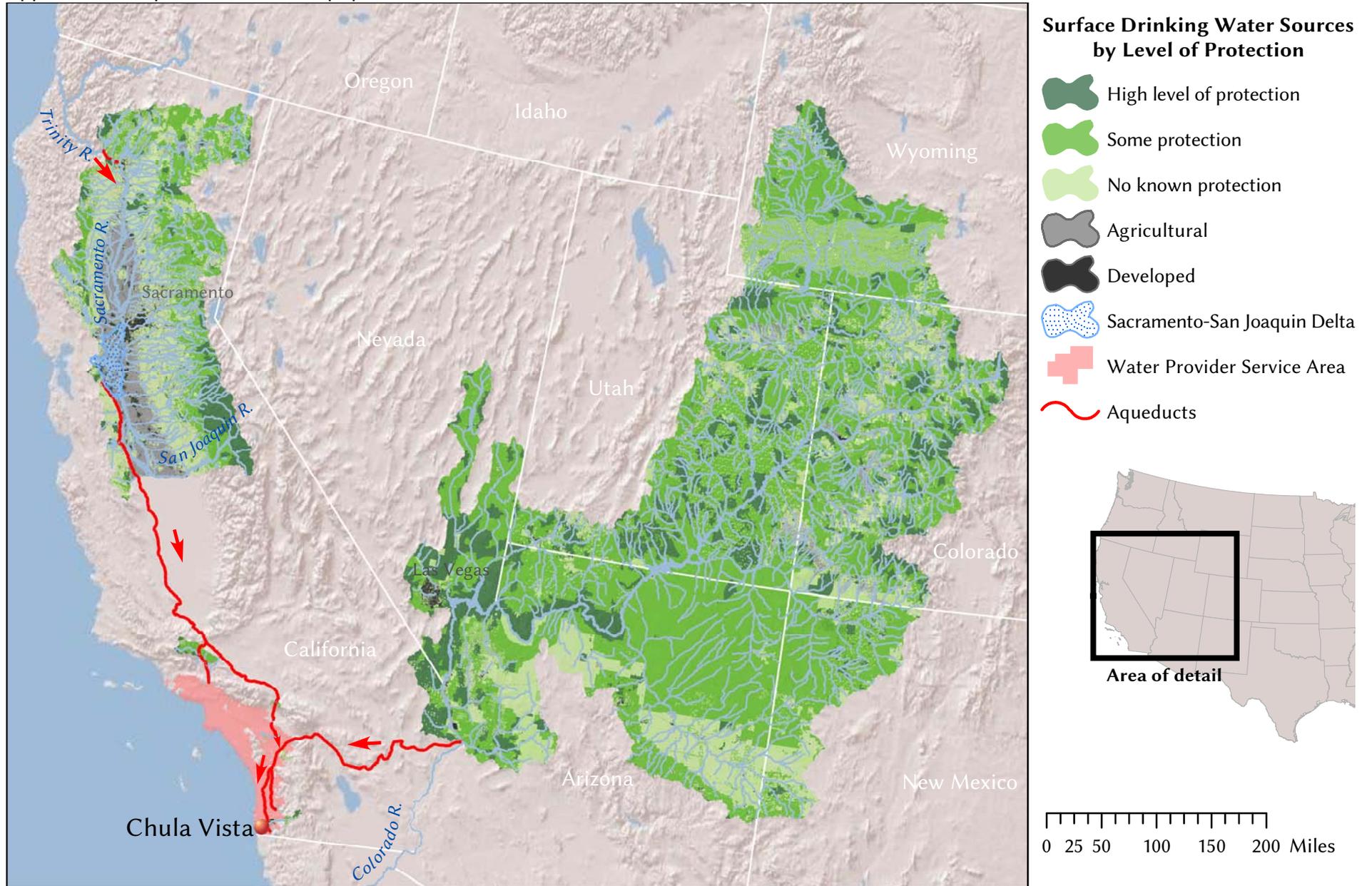
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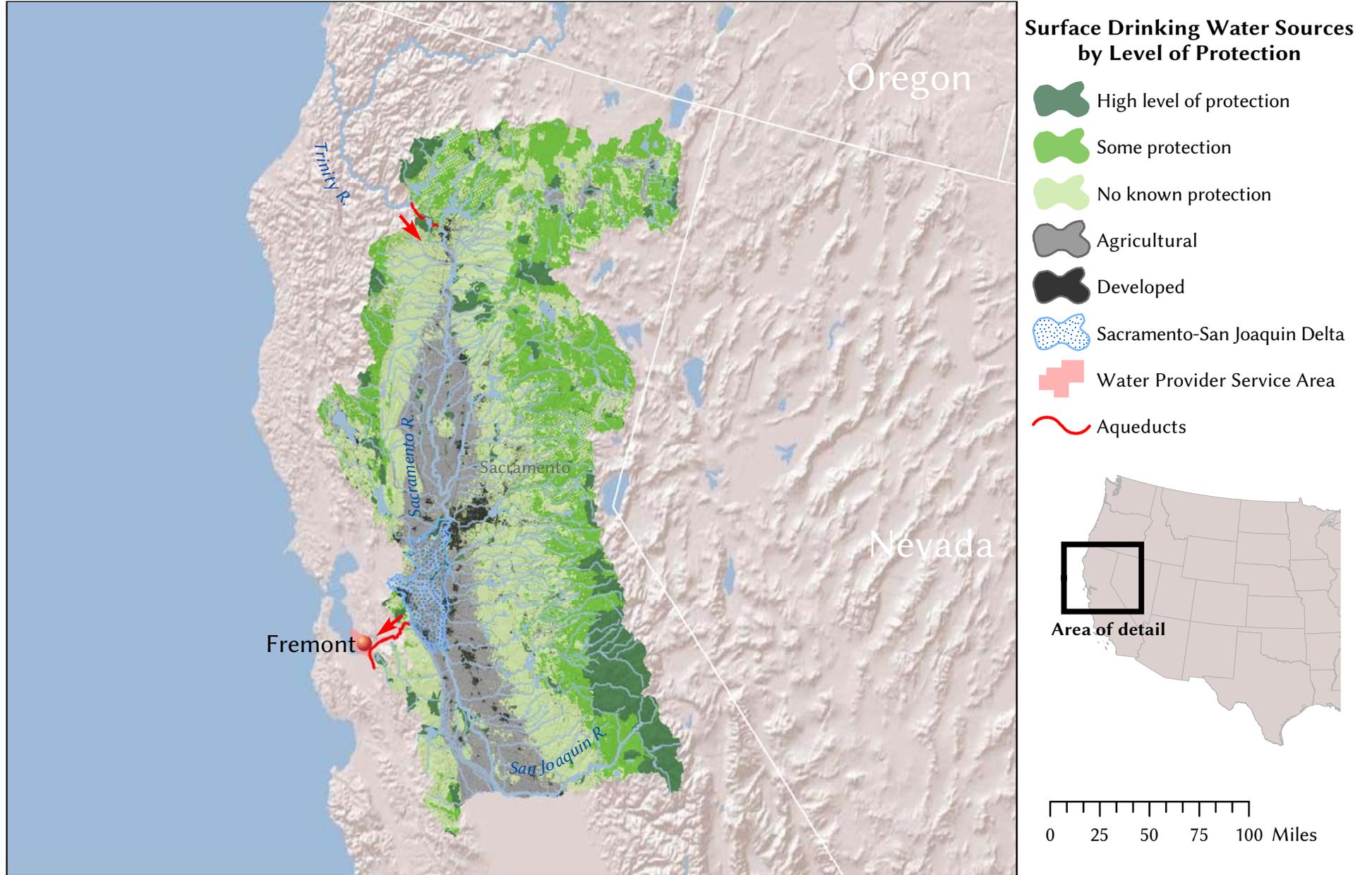
Surface Drinking Water Sources for Chula Vista, CA

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Surface Drinking Water Sources for Fremont, CA

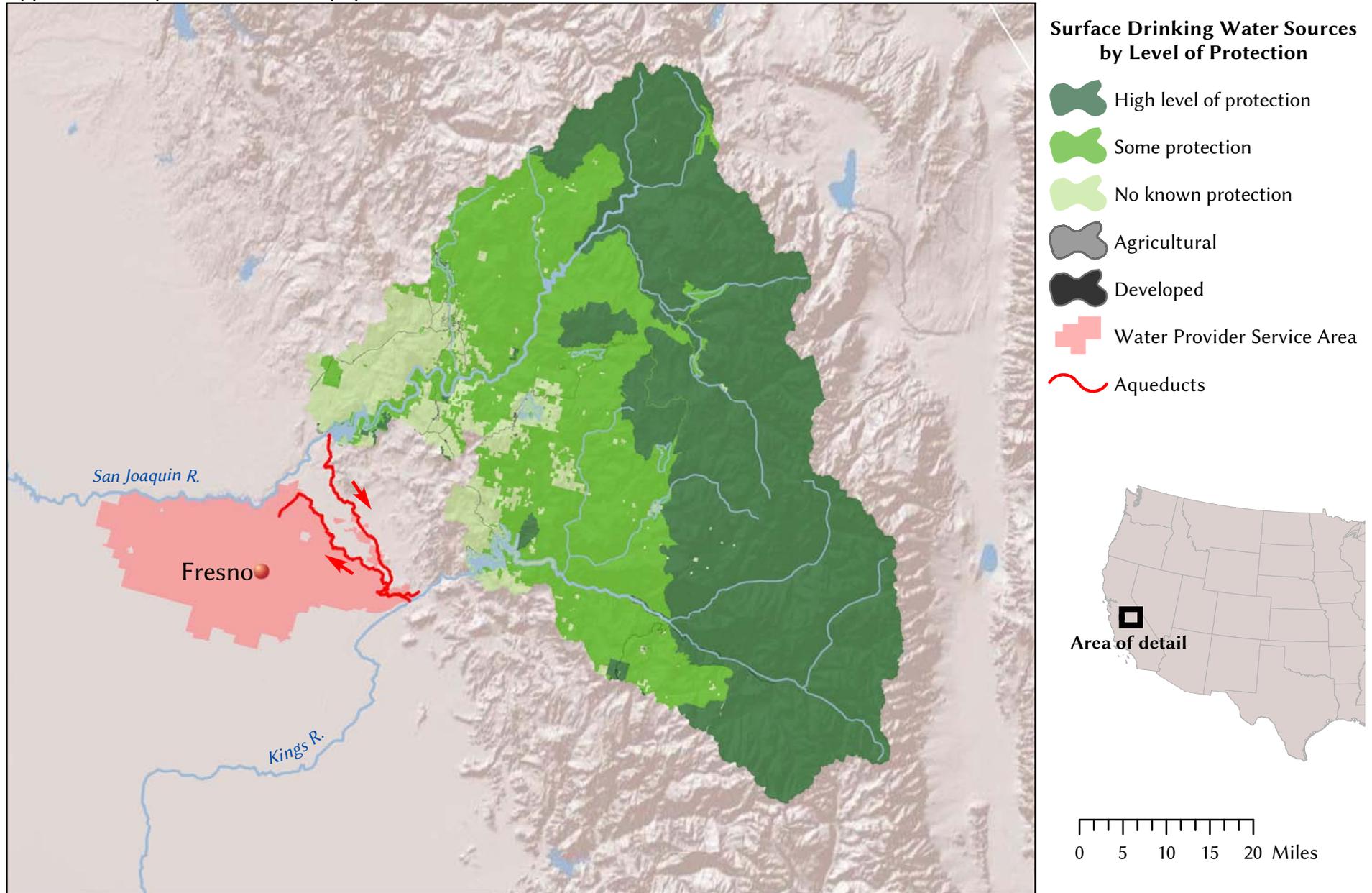
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Surface Drinking Water Sources for Fresno, CA

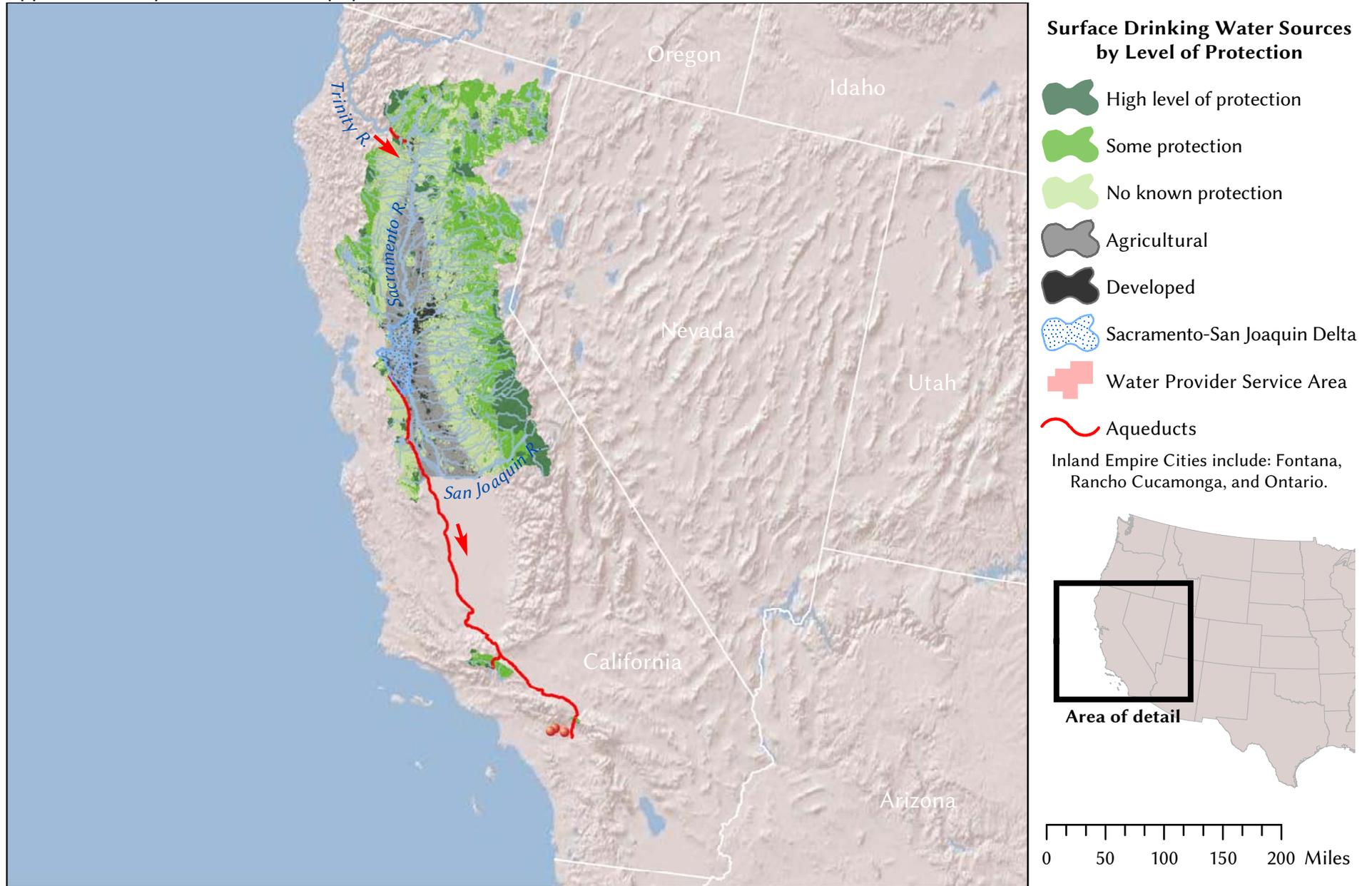
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Surface Drinking Water Sources for Inland Empire Cities

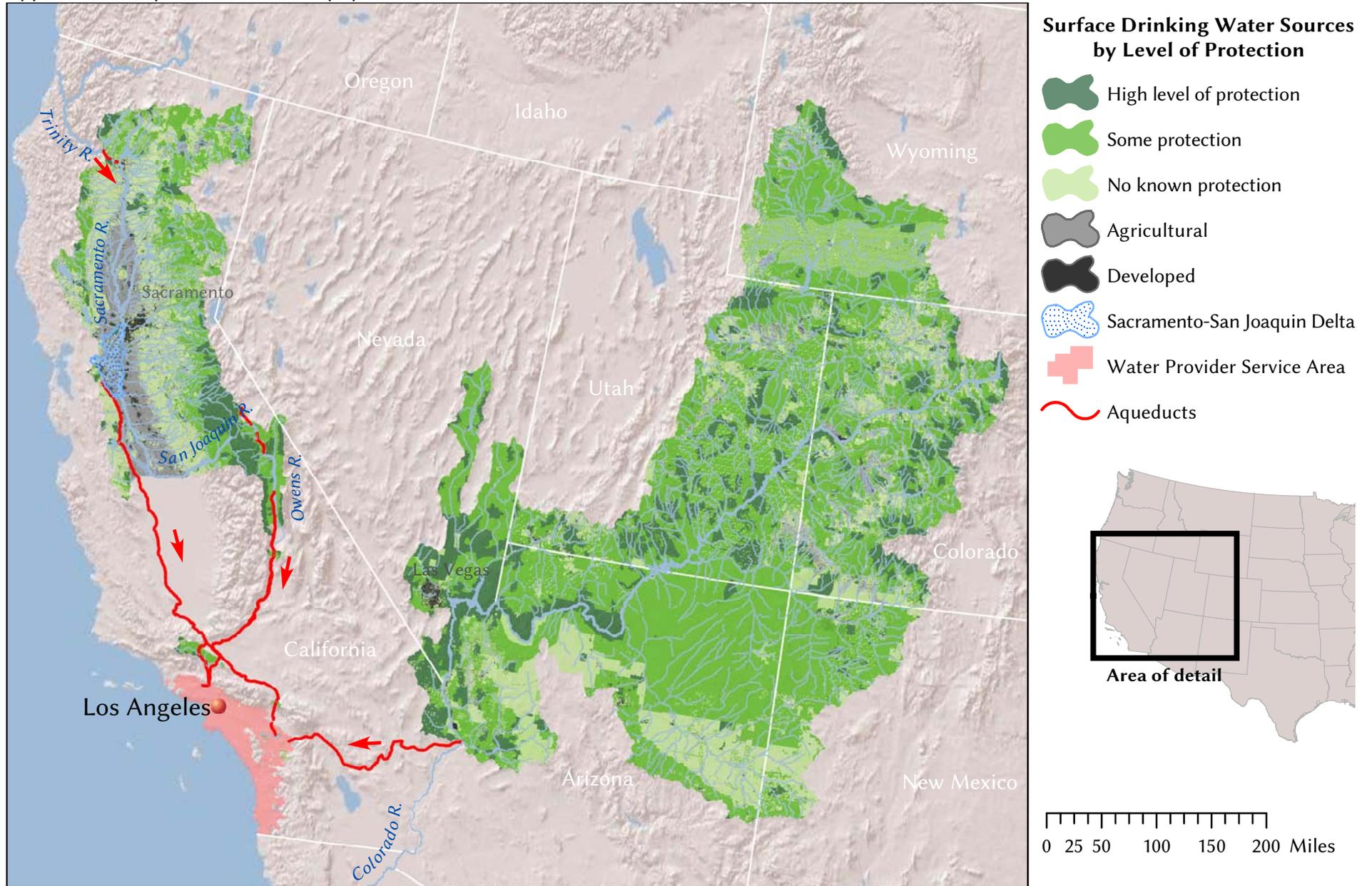
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Appendix A: Maps for the 30 most populous cities in California



Surface Drinking Water Sources for Los Angeles, CA

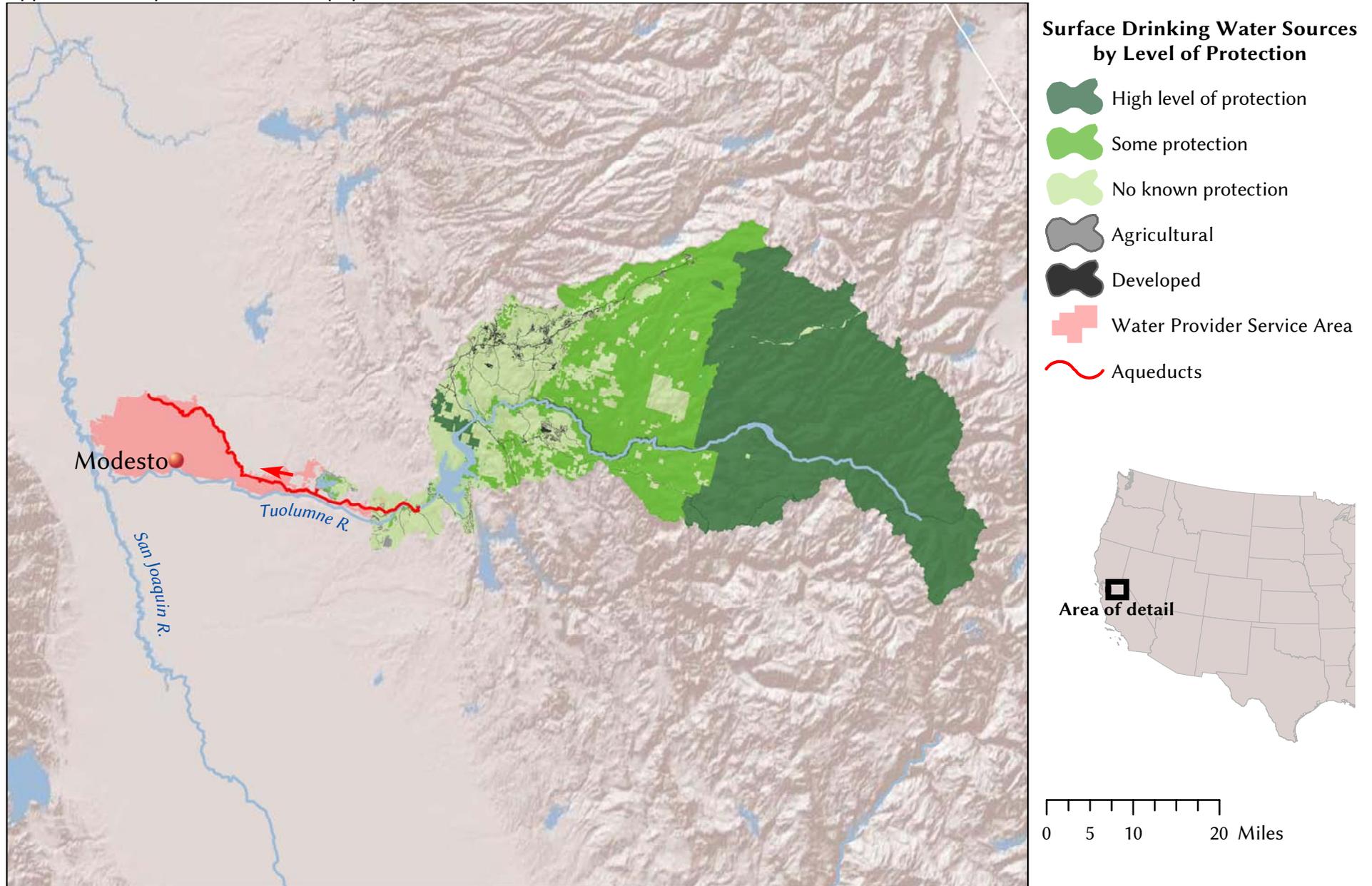
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Appendix A: Maps for the 30 most populous cities in California



Surface Drinking Water Sources for Modesto, CA

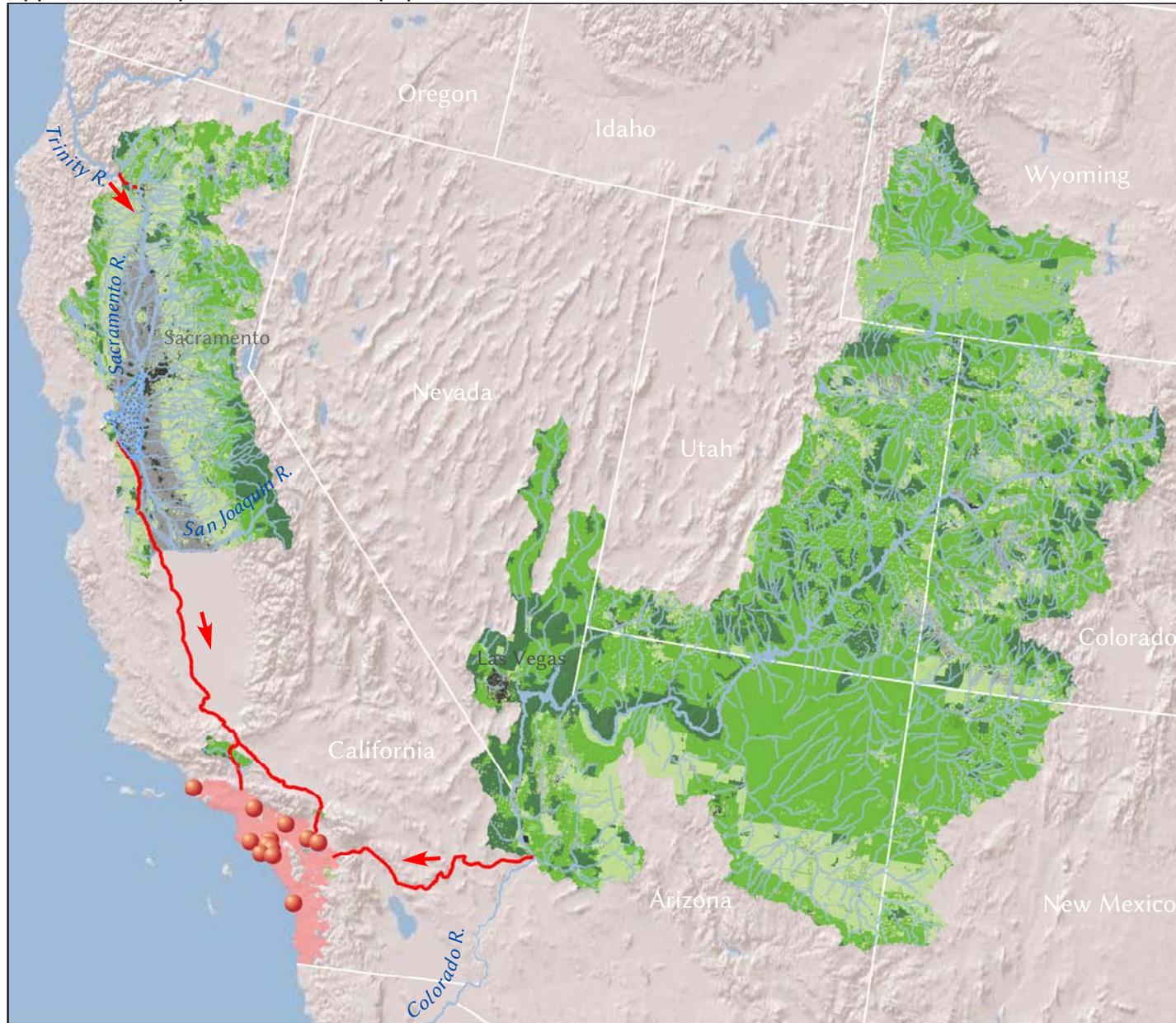
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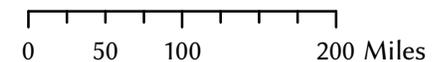
Appendix A: Maps for the 30 most populous cities in California



Surface Drinking Water Sources by Level of Protection

-  High level of protection
-  Some protection
-  No known protection
-  Agricultural
-  Developed
-  Sacramento-San Joaquin Delta
-  Water Provider Service Area
-  Aqueducts

MWDSC Cities include: Anaheim, Garden Grove, Glendale, Huntington Beach, Irvine, Long Beach, Moreno Valley, Oceanside, Oxnard, Pomona, Riverside and Santa Ana.



**Surface Drinking Water Sources for Cities Served by
The Metropolitan Water District of Southern California (MWDSC)**

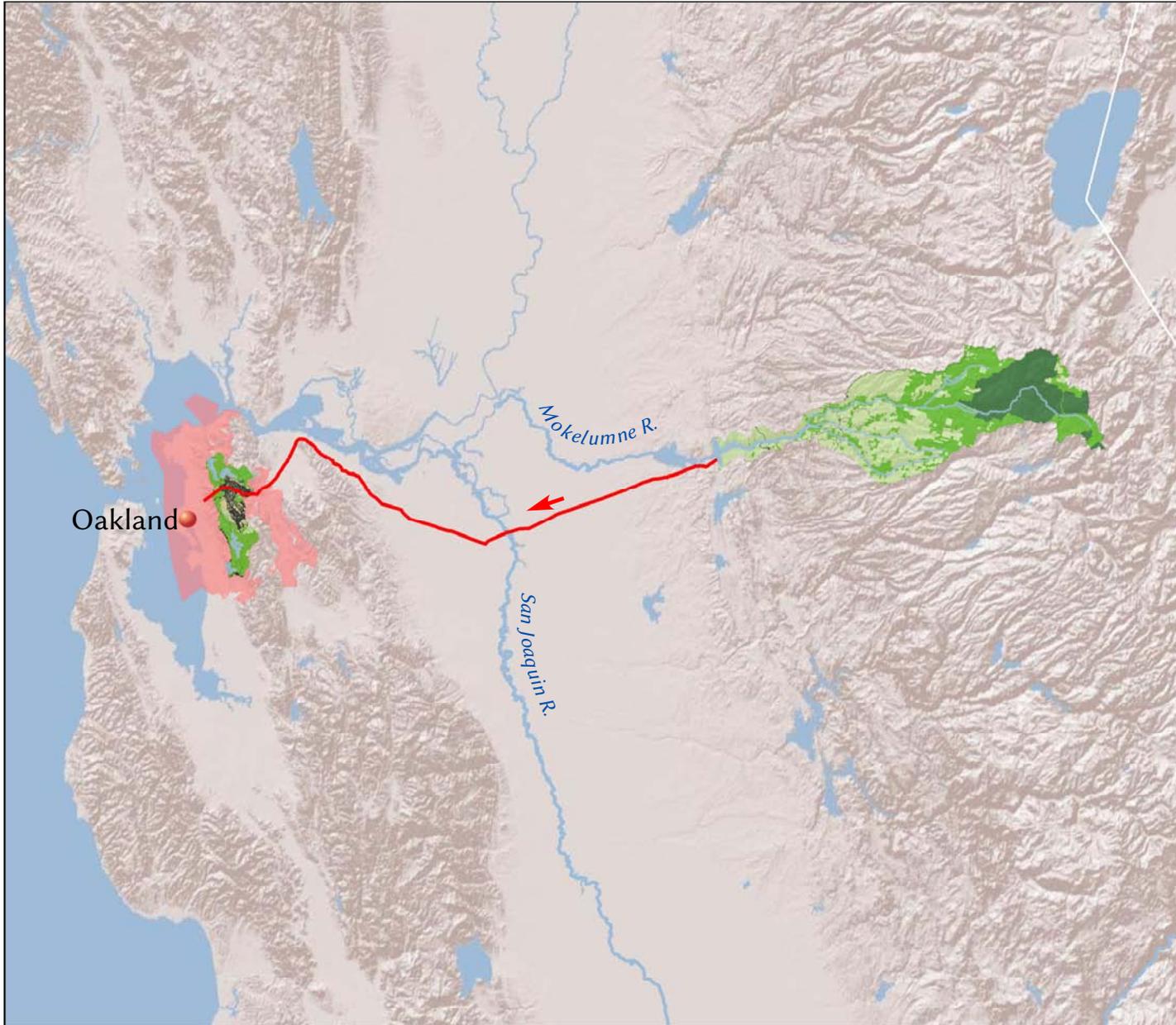
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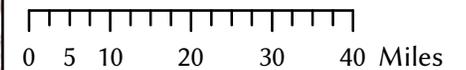
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-  Some protection
-  No known protection
-  Agricultural
-  Developed
-  Water Provider Service Area
-  Aqueducts



Surface Drinking Water Sources for Oakland, CA

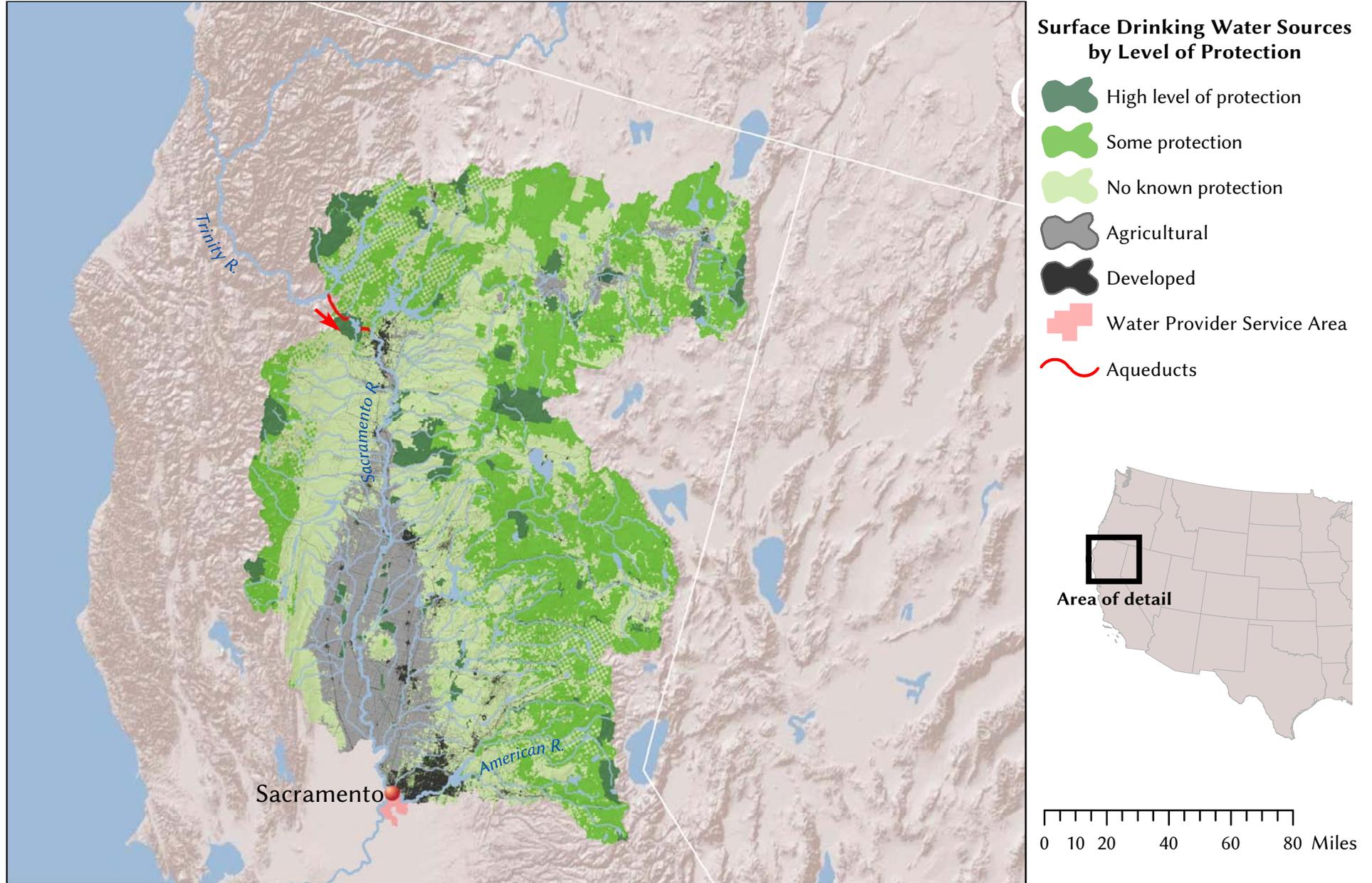
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Surface Drinking Water Sources for Sacramento, CA

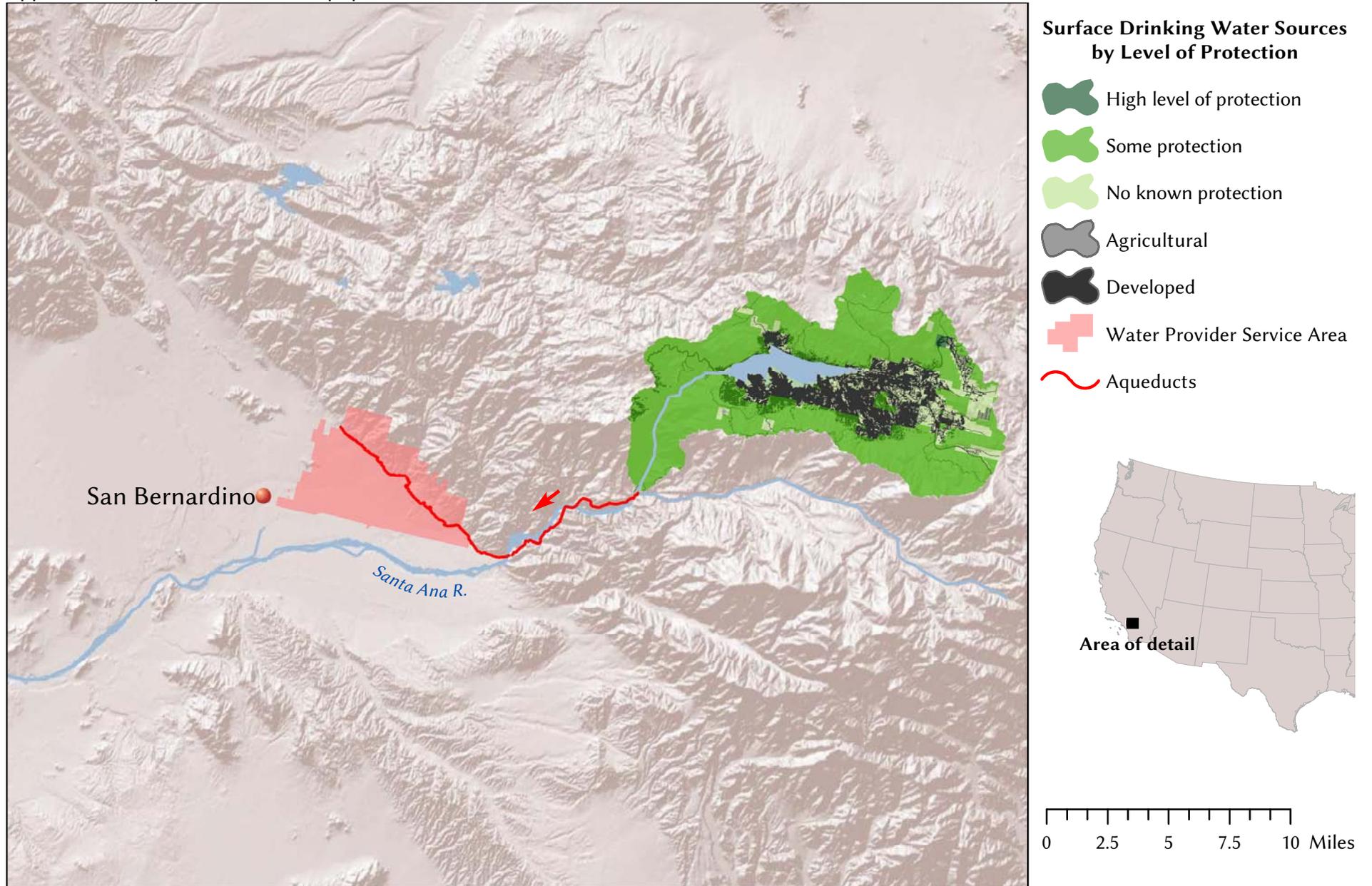
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Surface Drinking Water Sources for San Bernardino, CA

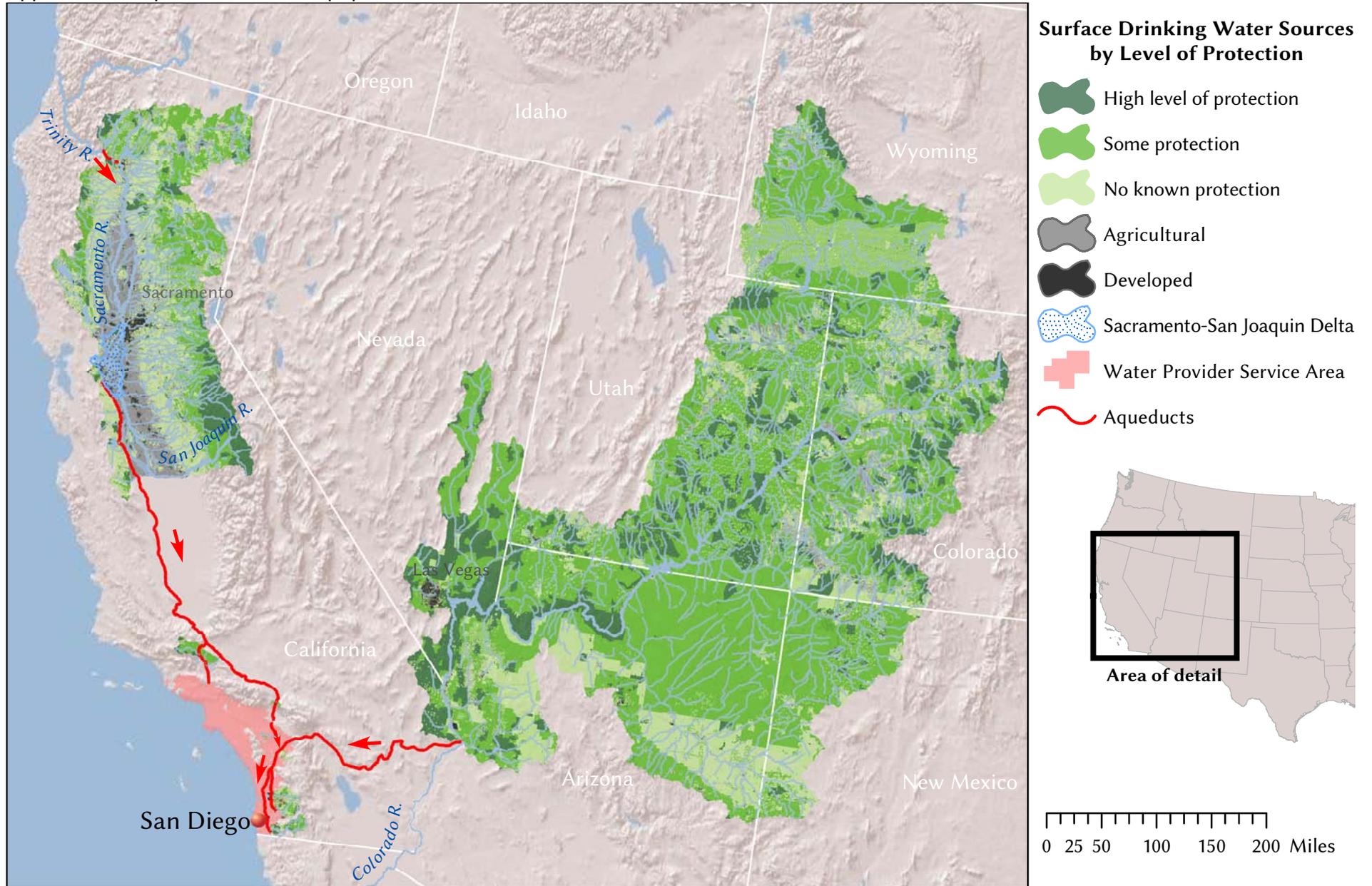
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Sources: Protected Areas Database of the U.S. 2010, USGS National Hydrography Dataset, National Land Cover Database 2006, TNC inferred and the website(s) of the utilities provider(s).

Appendix A: Maps for the 30 most populous cities in California



Surface Drinking Water Sources for San Diego, CA

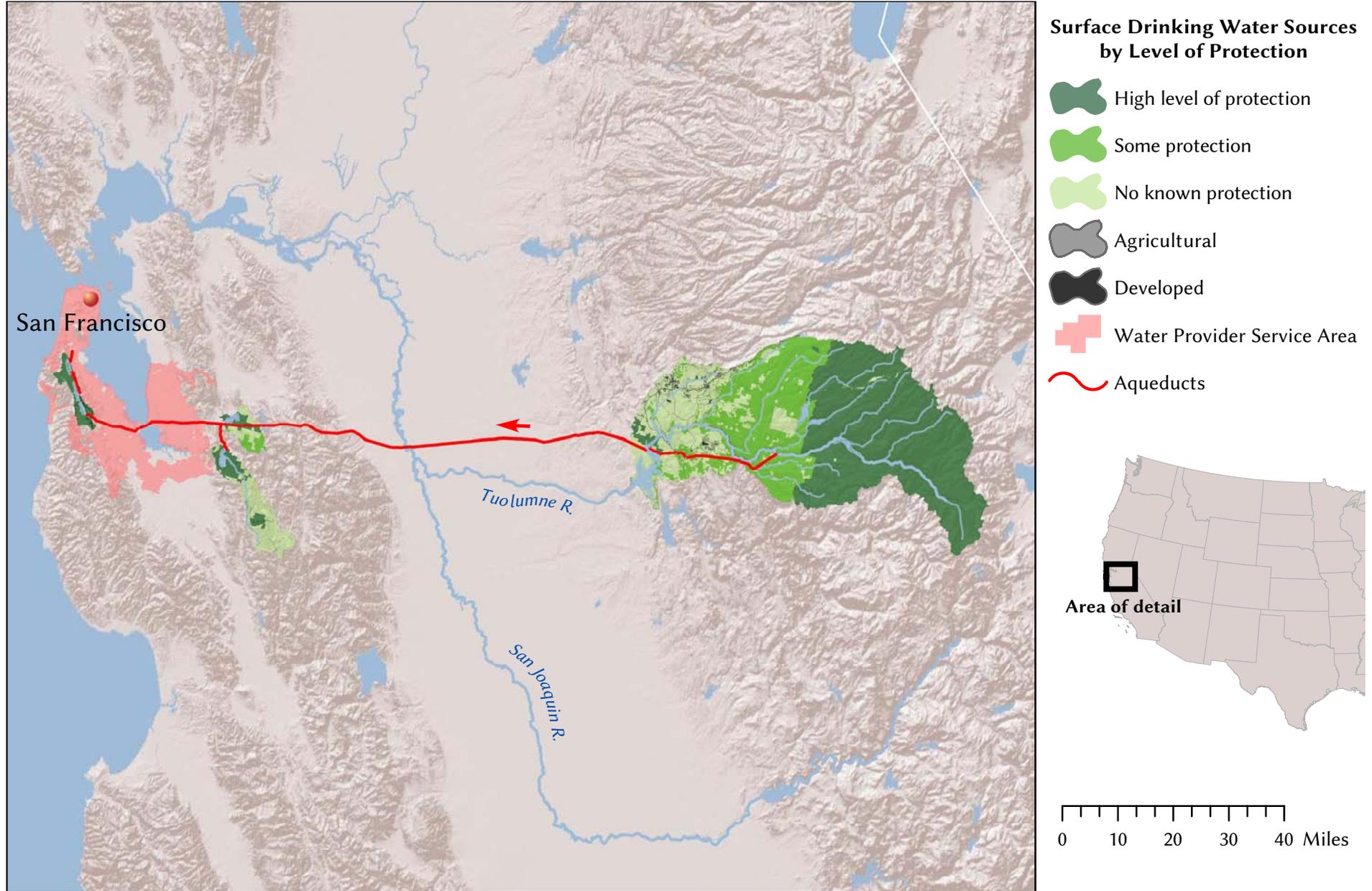
Map produced for The Nature Conservancy (TNC) 2012. TNC uses the most current and complete data available. GIS data and product accuracy may vary.

Areas delineated as having "No known protection" may include water district lands and easements on private lands.

Using GIS products for purposes other than those for which they were intended may yield inaccurate or misleading results.

Sources: Protected Areas Database of the U.S. 2010, USGS National Hydrography Dataset, National Land Cover Database 2006, and the website(s) of the utilities provider(s).

Appendix A: Maps for the 30 most populous cities in California



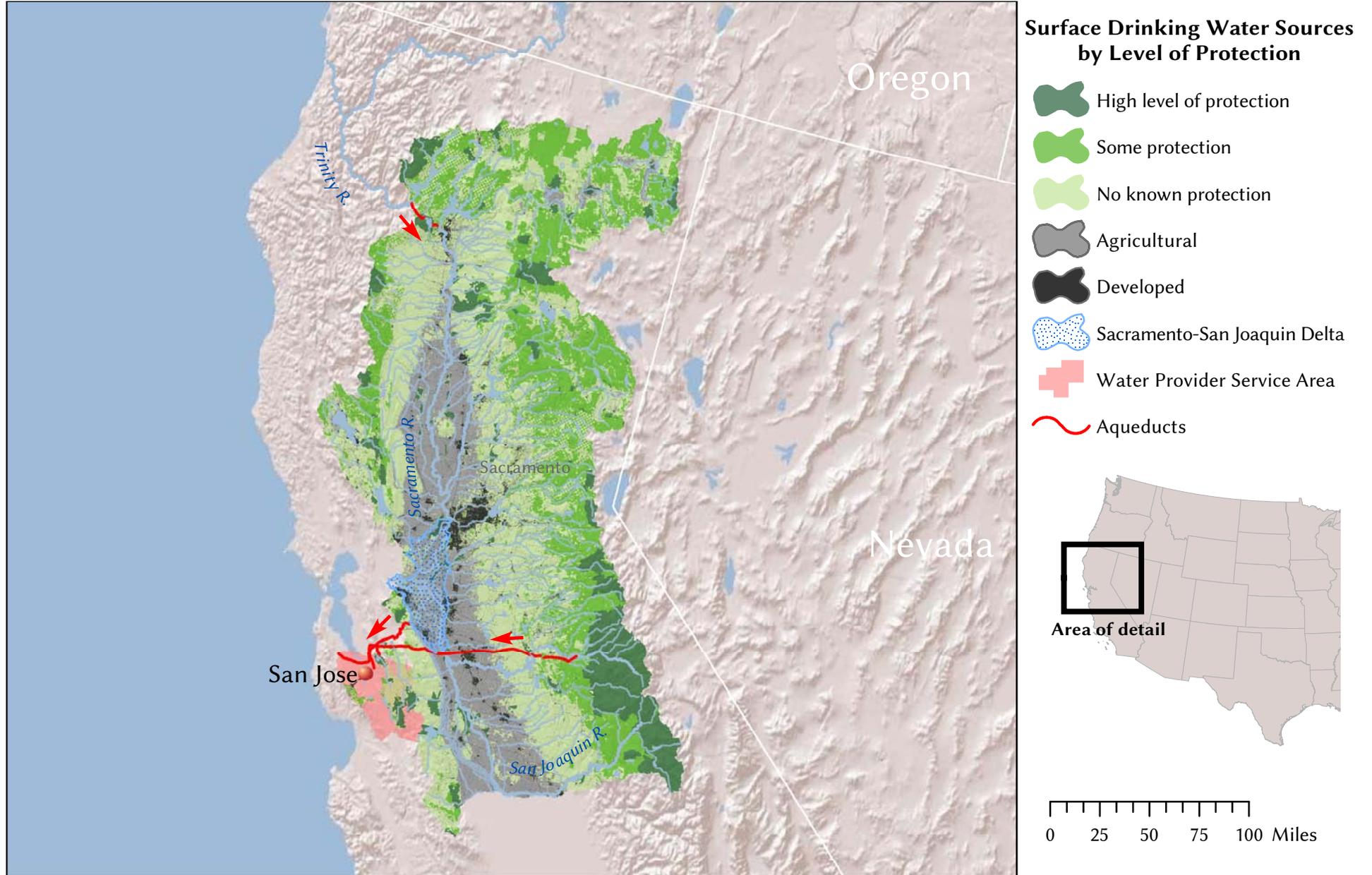
Surface Drinking Water Sources for San Francisco, CA

Map produced for The Nature Conservancy (TNC) 2012. TNC uses the most current and complete data available. GIS data and product accuracy may vary.

Areas delineated as having "No known protection" may include water district lands and easements on private lands.

Using GIS products for purposes other than those for which they were intended may yield inaccurate or misleading results.

Sources: Protected Areas Database of the U.S. 2010, USGS National Hydrography Dataset, National Land Cover Database 2006, TNC inferred and the website(s) of the utilities provider(s).



Surface Drinking Water Sources for San Jose, CA

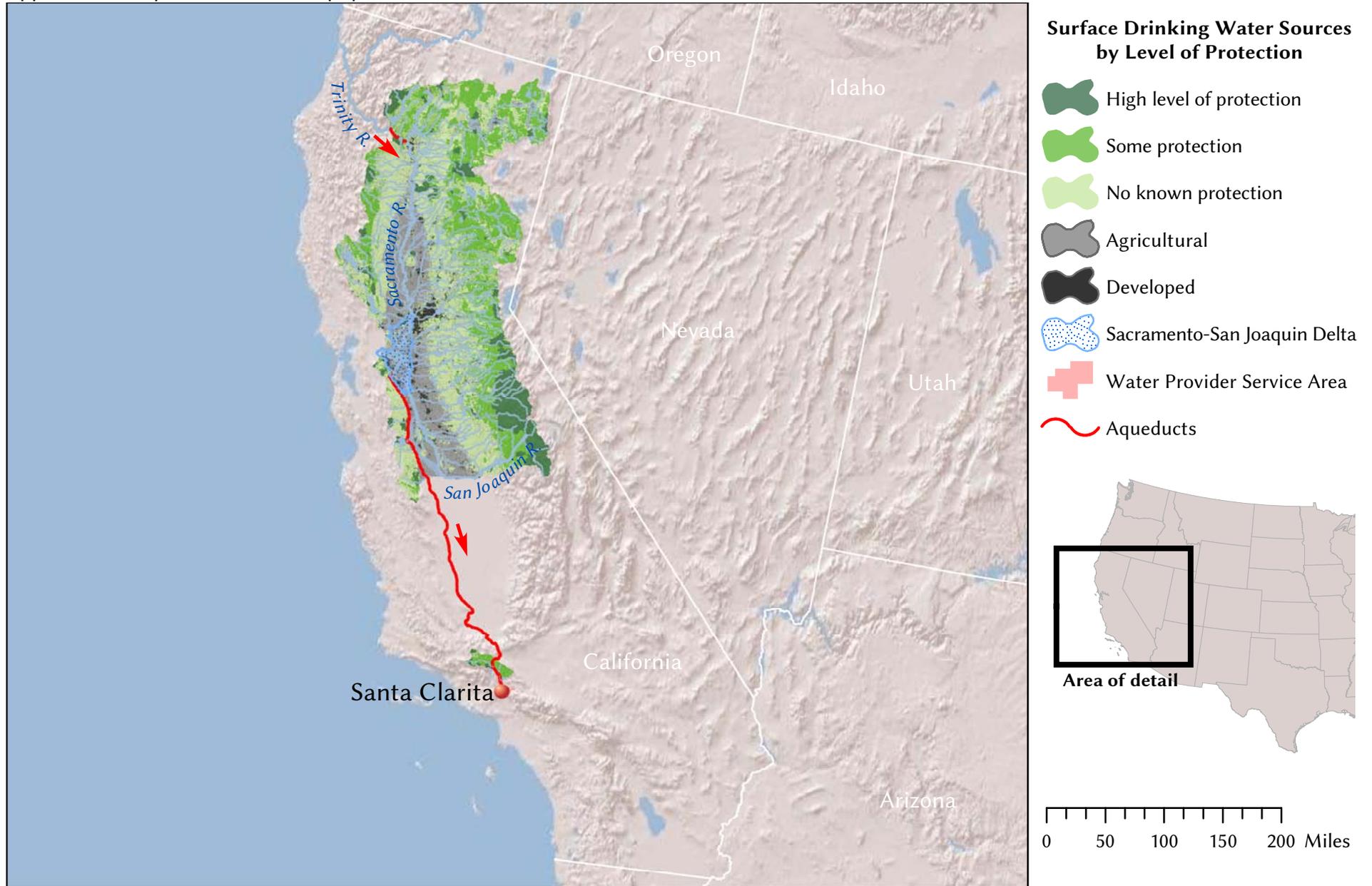
Map produced for The Nature Conservancy (TNC) 2012. TNC uses the most current and complete data available. GIS data and product accuracy may vary.

Areas delineated as having "No known protection" may include water district lands and easements on private lands.

Using GIS products for purposes other than those for which they were intended may yield inaccurate or misleading results.

Sources: Protected Areas Database of the U.S. 2010, USGS National Hydrography Dataset, National Land Cover Database 2006, TNC inferred and the website(s) of the utilities provider(s).

Appendix A: Maps for the 30 most populous cities in California



Surface Drinking Water Sources for Santa Clarita, CA

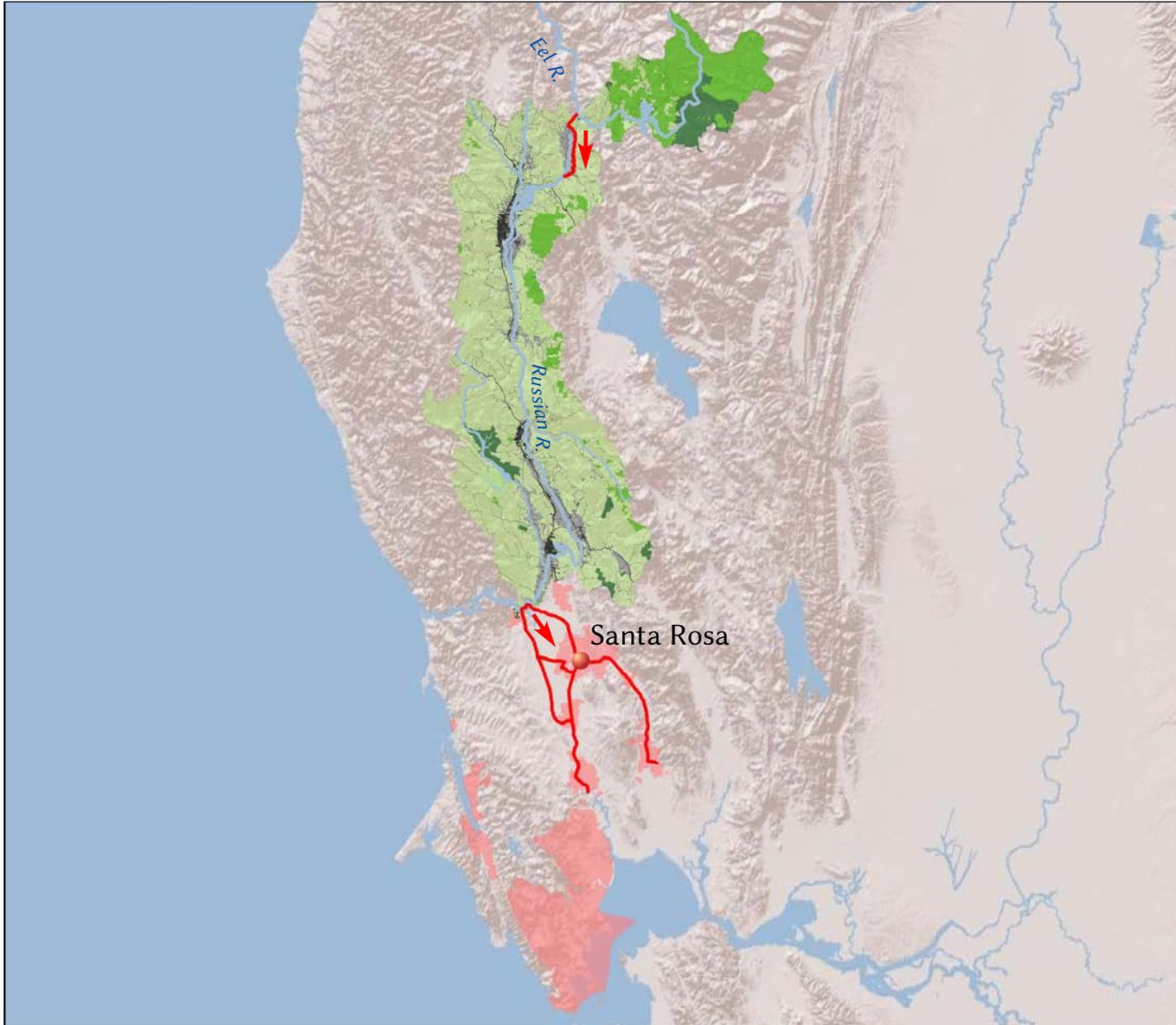
Map produced for The Nature Conservancy (TNC) 2012. TNC uses the most current and complete data available. GIS data and product accuracy may vary.

Areas delineated as having "No known protection" may include water district lands and easements on private lands.

Using GIS products for purposes other than those for which they were intended may yield inaccurate or misleading results.

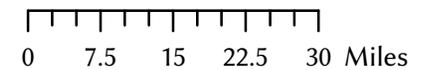
Sources: Protected Areas Database of the U.S. 2010, USGS National Hydrography Dataset, National Land Cover Database 2006, TNC inferred and the website(s) of the utilities provider(s).

Appendix A: Maps for the 30 most populous cities in California



Surface Drinking Water Sources by Level of Protection

- High level of protection
- Some protection
- No known protection
- Agricultural
- Developed
- Water Provider Service Area
- Aqueducts



Surface Drinking Water Sources for Santa Rosa, CA

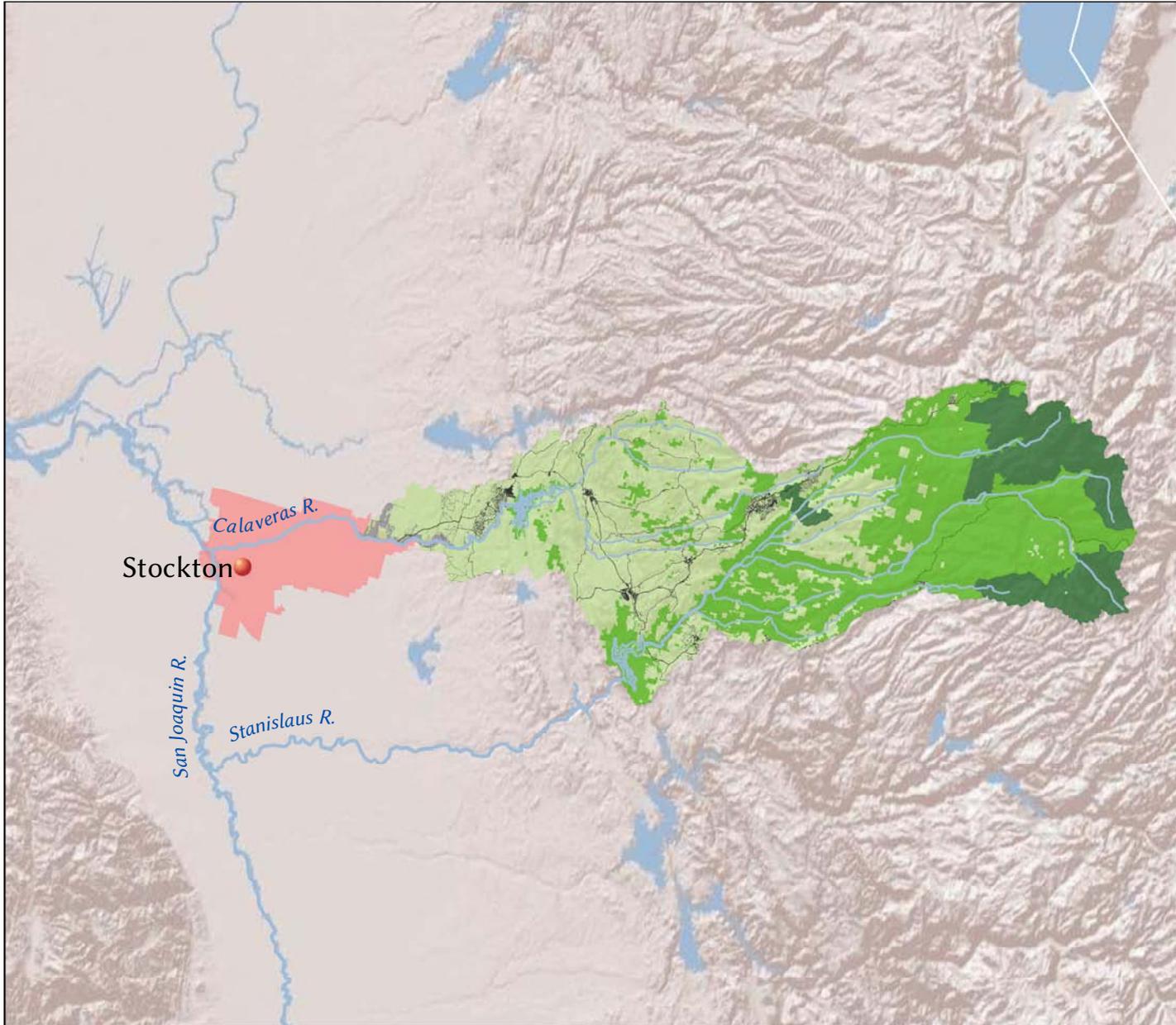
Map produced for The Nature Conservancy (TNC) 2012. TNC uses the most current and complete data available. GIS data and product accuracy may vary.

Areas delineated as having "No known protection" may include water district lands and easements on private lands.

Using GIS products for purposes other than those for which they were intended may yield inaccurate or misleading results.

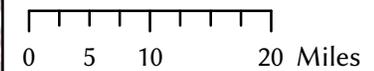
Sources: Protected Areas Database of the U.S. 2010, USGS National Hydrography Dataset, National Land Cover Database 2006, TNC inferred and the website(s) of the utilities provider(s).

Appendix A: Maps for the 30 most populous cities in California



Surface Drinking Water Sources by Level of Protection

- High level of protection
- Some protection
- No known protection
- Agricultural
- Developed
- Water Provider Service Area



Surface Drinking Water Sources for Stockton, CA

Map produced for The Nature Conservancy (TNC) 2012. TNC uses the most current and complete data available. GIS data and product accuracy may vary.

Areas delineated as having "No known protection" may include water district lands and easements on private lands.

Using GIS products for purposes other than those for which they were intended may yield inaccurate or misleading results.

Sources: Protected Areas Database of the U.S. 2010, USGS National Hydrography Dataset, National Land Cover Database 2006, and the website(s) of the utilities provider(s).



APPENDIX B

Source Data

- CA fish passage assessment database: June 2011
 - Sometimes gave locations for dams, sloughs, and pumps
 - <http://www.calfish.org/DataandMaps/CalFishDataDownloads/tabid/93/Default.aspx>
- National Hydrography Dataset Plus (100K)
 - Main source of reservoir, stream, and watershed data
 - <http://www.horizon-systems.com/nhdplus/HSC-wth18.php>
- National Hydrography Dataset (24K)
 - Secondary source of stream and reservoir data, especially for smaller features
 - <ftp://nhdftp.usgs.gov/DataSets/Staged/States/FileGDB/HighResolution/>
- HUC 12 – Watershed Boundary Dataset
 - Delineation of watershed used for large diversions
 - <http://datagateway.nrcs.usda.gov/GDGOrder.aspx>
- Federal Water Users
 - Used to determine whether a city used a federal source of water
 - https://projects.atlas.ca.gov/frs/?group_id=39&release_id=241
- State water districts
 - Used to determine whether a city used a state source of water
 - https://projects.atlas.ca.gov/frs/?group_id=39&release_id=241
- Private water districts
 - Used to determine whether a city used a private water company
 - https://projects.atlas.ca.gov/frs/?group_id=39&release_id=241

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