An Electric Vehicle Charging Station Siting Strategy for the South Coast:

Expanding Opportunities in Multi-unit Dwellings and Workplaces

UCLA Luskin Center for Innovation

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https://maps.scag.ca.gov/electric_vehicle/

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Cover photo: Workplace and visitor parking at UC Irvine (Photo Credit: Lucly Nicholson, Reuters)

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EXECUTIVE SUMMARY

The South Coast Air Quality Management District (South Coast AQMD) 2016 Air Quality Management Plan places a strong emphasis on accelerating the transition to zero and near-zero emission vehicles as a means to reduce emissions.[1] In support of this goal, the Mobile Source Air Pollution Reduction Review Committee (MSRC) is planning for the installation of electric vehicle service/charging equipment (EVSE) at two types of locations in the South Coast Air Basin: multi-unit dwellings (MUDs), such as apartments and condominiums, and workplaces.

These two types of locations have higher than usual hurdles for installing EVSE. Property owners and managers of MUDs and workplaces may not see the value of investing in electric vehicle (EV) charging because they do not necessarily drive plug-in electric vehicles (PEVs) themselves, nor is providing a PEV charging a core component of their business activities. However, some degree of participation from property owners and managers is necessary for EVSE installations to move forward. To compound the problem, PEV owners have little motivation to invest in equipment in such locations because it involves capital costs that they may not be able to recuperate. In order to overcome these motivational hurdles, financial incentives and technical assistance services are needed. Ensuring that these incentives and services actually reach likely PEV drivers is another challenge and requires robust and targeted outreach efforts.

This report seeks to support outreach efforts to property managers of MUDs and workplaces in the South Coast Air Basin where there is the greatest latent demand for charging. To that end, the report describes the development and use of two spatially resolved models, one of which ranks MUD properties according to the propensity of building occupants to purchase a PEV (assuming no barriers to charging), and the other of which ranks travel zones according to the additional electric miles that could be supported when plug-in hybrid vehicle (PHEV) drivers have access to workplace charging. The South Coast Air Basin, shown in **Figure 1**, is the largest region to which we have applied these models.

Figure 1. Study Region: The South Coast Air Basin[2]

[1] South Coast AQMD, 2017. Final 2016 Air Quality Management Plan. Accessed November 2019: http://www.aqmd.gov/home/air-quality/clean-air-plans/air-quality-mgt-plan
[2] South Coast AQMD, 2015 Notice of Completion of a Draft Environmental Assessment. Accessed March 2020: http://www.aqmd.gov/docs/default-source/ceqa/documents/aqmd-projects/2015/toxicrules-dea.pdf

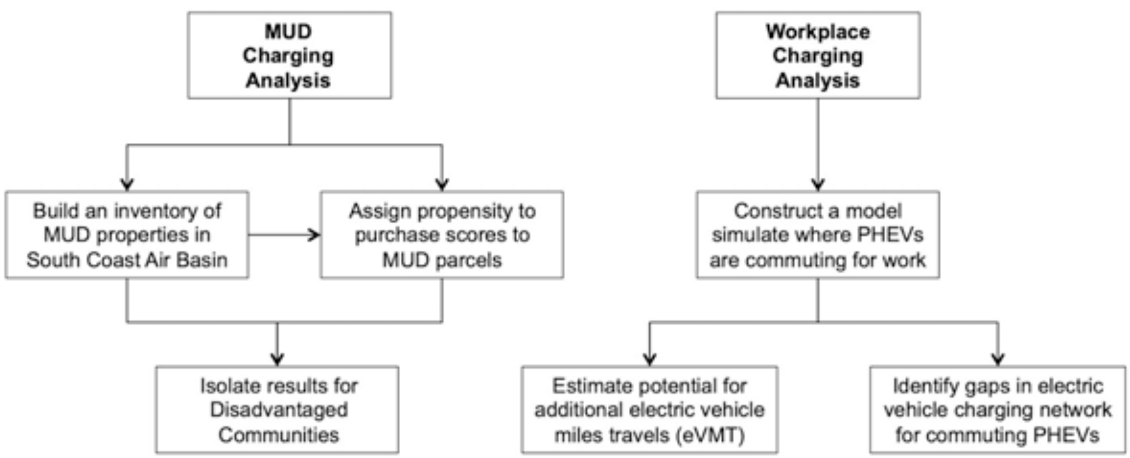
Methods

To identify opportunities where investments in EV charging infrastructure are most likely to address latent demand for charging, we analyzed opportunities at MUDs and workplaces, where PEV drivers often do not have a strong motivation nor ability to personally invest. The methods for identifying these opportunities relied upon a combination of exploratory mapping and probabilistic modeling techniques, which are summarized here (see **Figure 1** for a schematic overview), and described in more detail in the full report.

The MUD analysis consisted of three primary research activities. First, we used ArcGIS and tax assessor's property characteristics data to characterize the MUD portfolio of the South Coast Air Basin according to key variables that influence EV demand amongst MUD residents. Second, we estimated latent PEV demand for MUD residents by constructing a propensity-to-purchase score for each MUD parcel in the South Coast Air Basin. Third, we isolated results from the previous two activities for disadvantaged communities (DAC) boundaries, as identified by CalEnviroScreen 3.0.

The workplace analysis also consisted of three primary research activities. First, we developed a model that uses a spatial inventory of locations where light-duty PEVs reside and modeled regional travel patterns to simulate PEV commutes. Second, based on these modeled trips and the electric range of historical PEV purchases, we estimated how many additional electric miles could be supported if those vehicles charged at work before returning home. Third, we identified the gaps in the existing workplace charging network by looking at location data for large employment centers and the existing network of charging stations.

Figure 1. Summary of Methods



Findings from the MUD Analysis

Within the South Coast Air Basin, there are a total of 2,348,622 MUD housing units, which comprise 44% of the total housing stock in the region.[3] While there is no comprehensive inventory of which of these MUDs are home to EV charging infrastructure, we expect that the presence of charging infrastructure is low. According to survey data from the Clean Vehicle Rebate Project (CVRP), only 9% of PEV drivers who participated in the rebate program between 2012 and 2015, and who live in the four counties within the South Coast Air Basin, reside in an apartment building or condominium.[4] The low representation of MUD housing residents in the CVRP rebate pool suggests that there are significant barriers for these individuals to PEV adoption. The initial cost of PEV ownership is certainly a contributing factor, but with the emergence of a used PEV market, we expect lack of charging access to become an increasingly important deterrent.

There are a number of conditions that make investing in PEV charging infrastructure a more cost-effective proposition at some MUD locations compared to others. Newer MUDs are likely to have increased electrical capacity onsite, avoiding the need for potentially costly panel upgrades or service upgrades from the utility. The vast majority (79%) of MUD housing stock in the South Coast Air Basin, however, falls on the older side of the spectrum (older than 1970), and is likely not PEV ready in its current form.

Where costly panel and utility services are unavoidable, they are likely to be cheaper on a per-unit basis in larger MUDs with multiple charging installations. Thus, targeting large MUDs for technical and financial assistance programs will help maximize the amount of charging installations that can be supported by limited public dollars. Prioritizing large MUDs also helps narrow outreach efforts, as nearly 57% of all MUDs in the South Coast Air Basin are duplexes or triplexes. At these properties, MUD owners are often able to charge using available 110/220 volt outlets with portable Level 1 EVSE, so barriers to charging are less likely to be the cause of low-PEV penetration.

Investing in charging infrastructure at MUDs that are predominantly occupied by renters (i.e., apartment buildings) is also more likely to alleviate PEV adoption barriers than investments in MUDs that are occupied by owners (i.e., condominium complexes). For renters, the investment motivation is weak or nonexistent because they are unlikely to invest a significant sum of money in immobile equipment that they would leave behind upon moving. Alternatively, condominium owners are likely to view the charging equipment and electrical upgrades as a property improvement positively affecting the potential resale value of their particular unit. While the same upgrades will also enhance the property value of an apartment building, the owners of those buildings may not view charging equipment as a desirable amenity by which to attract tenants. In total, apartment units comprise about 78% of the total MUD housing stock in the South Coast Air Basin.

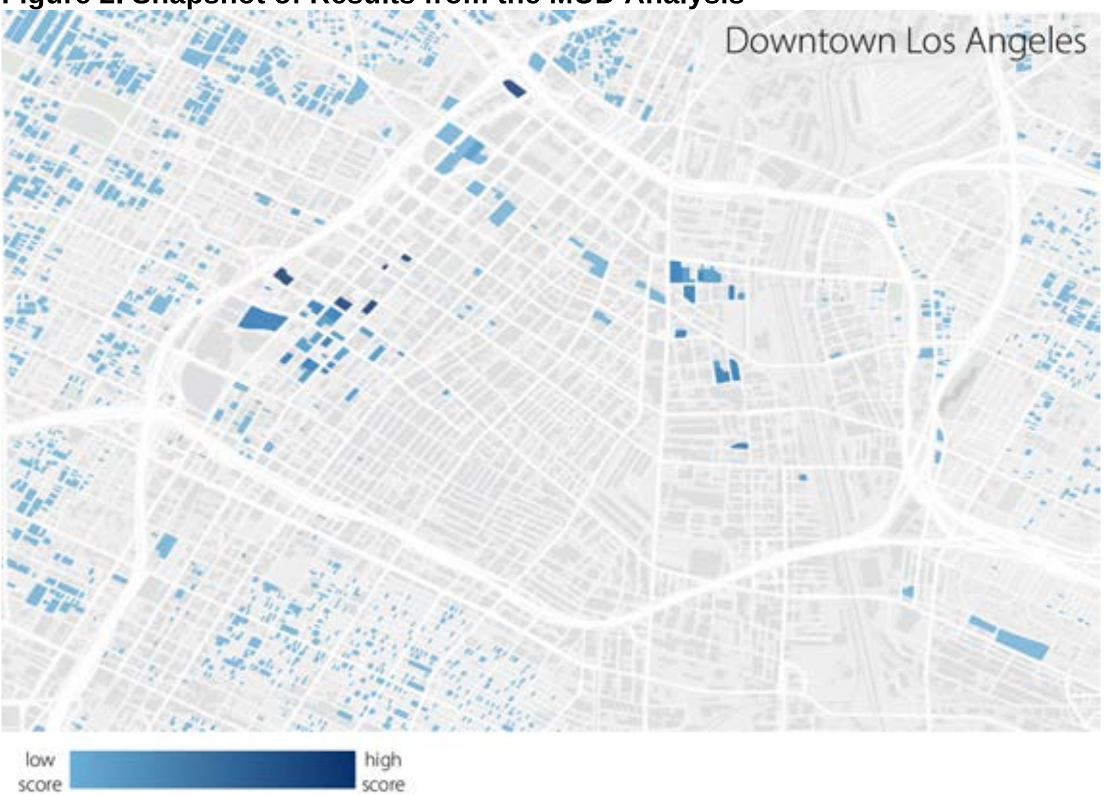
From a cost-effectiveness perspective, investing in charging infrastructure at MUD properties where occupants exhibit high latent demand for PEV ownership is likely to lead to greater reduction of gasoline-powered vehicle miles traveled (VMT). To assess latent demand, we calculated a propensity-to-purchase score for each MUD parcel in the South Coast Air

[3] Tax assessor’s data for Los Angeles County, Orange County, Riverside County, and San Bernardino County.
[4] Center for Sustainable Energy, 2019. California Air Resources Board Clean Vehicle Rebate Project, EV Consumer Survey Dataset. Retrieved from http://cleanvehiclerebate.org/eng/survey-dashboard/ev

Basin. The score accounts for the historical adoption rate of PEVs in each census tract, the likelihood that PEVs are to belong to households of different income groups, and the likelihood that those income groups are to live in a home of a certain value. These scores can be overlaid with the property characteristics previously discussed to further target investments where they may be most cost effective. For example, by targeting MUD units within the 90th percentile of propensity-to-purchase scores that are located in buildings with more than 50 units, the universe of MUD units within the South Coast Air Basin is constrained from 331.

To balance cost-effective and equity considerations, targeting MUDs in DACs will help ensure that charging resources are also spent in the neighborhoods that face the greatest air pollution burdens. About 40% of the total MUD units in the South Coast Air Basin are located in DACs. Outreach to MUDs in DACs should be two pronged, targeting both building owners and tenants. Assistance for building owners should be aimed at making their properties PEV ready. Meanwhile, assistance for renters should be aimed at reducing the cost of purchasing a PEV, which along with the charging challenge, is also likely to be a significant barrier for DAC residents to go electric. To support this effort, the California Air Resources Board (CARB) has launched several initiatives under its Low Carbon Transportation Program aimed at expanding PEV adoption among low- and moderate-income households.[5] Outreach to MUD residents in DACs should focus on making these programs more visible.

Figure 2. Snapshot of Results from the MUD Analysis



[5] CARB. 2015. "Low Carbon Transportation Light-Duty Project Projects that Benefit Disadvantaged Communities." Accessed on August 2017 from https://www.arb.ca.gov/msprog/aqip/ldv_pilots.htm

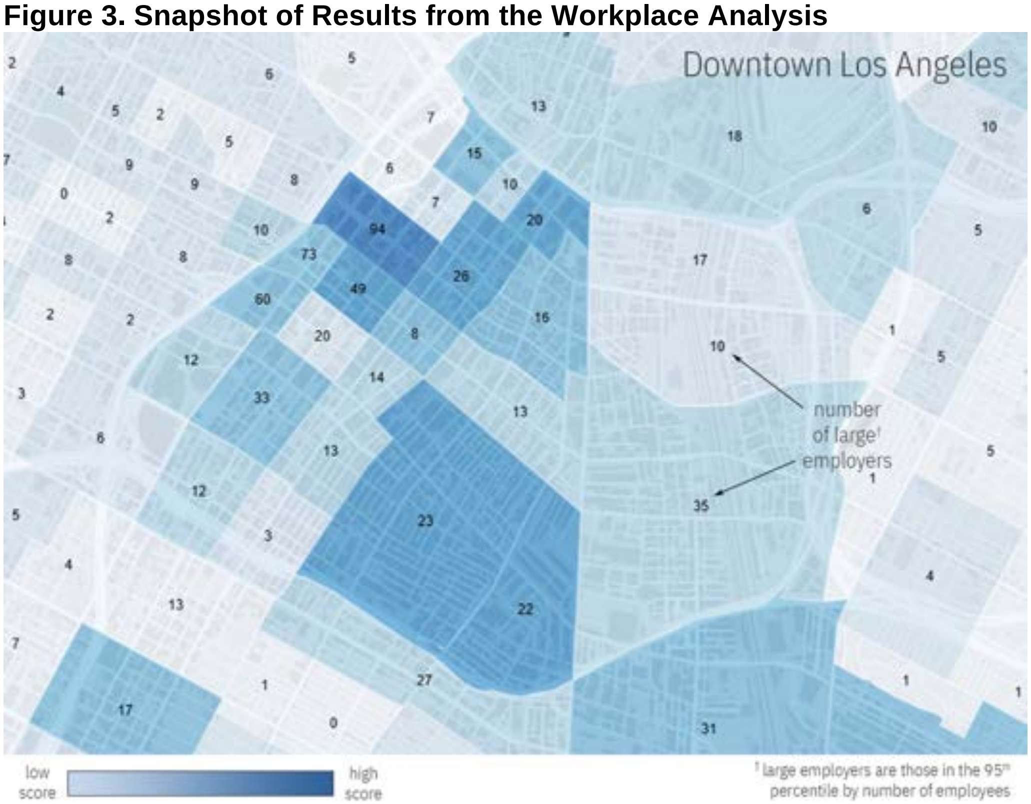
Findings from the Workplace Analysis

We estimate that there are 44,000 plug-in hybrids in the South Coast that are used for work commutes that exceed those vehicles' all-electric range. Such vehicles are underutilized resources. If given the opportunity to charge at work, they could yield as many as 480,000 additional electrically-driven commute miles (also referred to as additional electric vehicle miles traveled, or eVMT) per day without requiring any new vehicle purchases.

While some workplaces may already provide charging opportunities, we do not expect this to be the norm. According to CVRP survey data from the four counties that comprise the South Coast Air Basin, 44% of PHEV drivers report that they have charging at their workplace.[6]

Much of the expected potential to increase commute miles driven on electric power is concentrated in a few top zones. Over half of these potential miles could be supported by workplace charging stations in the top 15% of travel zones where PHEV commuters are driving for morning trips.[7] Targeting large employers within these travel zones will further enhance the likelihood that investments in EV charging equipment are used on a regular basis. The data products from this study can be used to target such investments. For instance, **Figure 3** shows an example of how the data from this study can be overlaid to inform siting decisions in downtown Los Angeles.

Figure 3. Snapshot of Results from the Workplace Analysis



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[6] Center for Sustainable Energy, 2019. California Air Resources Board Clean Vehicle Rebate Project, EV Consumer Survey Dataset. Retrieved from http://cleanvehiclerebate.org/eng/survey-dashboard/ev

[7] This study was conducted at the scale of transportation analysis zones (TAZs), which are geographic units built from census blocks. TAZs encompass areas of equal population or employment for use in travel demand forecast modeling.

Recommendations for Targeted Outreach

Outreach should be tailored to the level of PEV charging demand in the community. The propensity-to-purchase scores and additional eVMT estimates developed for this report can serve as helpful proxies for PEV charging demand. For properties where demand for PEV charging is expected to be high, too little engagement may slow the growth of PEV adoption and may lead to missed opportunities for charging. In contrast, for properties where demand for PEV charging is expected to be low, intensive outreach may not be a cost-effective use of funds if stakeholders do not follow through with installing charging equipment, or the equipment goes unused once installed. Outreach efforts can be conducted along a “ladder of engagement,” starting with more passive efforts that grow into more active projects:

Step 1: Informational support. To increase general literacy about PEVs and their charging requirements, local jurisdictions can provide information on vehicle types, potential cost savings from PEV driving, electrical service, and the charging equipment installation process through passive means such as a website, handouts from utilities and local building departments, direct mailings, and e-newsletters.

Step 2: Workshops. Local jurisdictions can host workshops for general or targeted audiences such as drivers, homeowner associations, property owners/managers, and renters for residential charging; or for employees, employers, or fleet managers for workplace charging.

Step 3: Targeted technical assistance. Planners may want to set up technical assistance programs for potential charging hosts who may be less aware of the physical or procedural aspects of installing charging or who may require more detailed decision support. Actively engaging property owners in the decision-making process or providing information specific to their needs can facilitate the installation of charging and use of PEVs at their site.

Step 4: Demonstration projects. Public agencies and utilities can partner to install charging equipment via demonstration projects at sites that have onsite staff to facilitate peer-to-peer learning opportunities.

Outreach and education should also vary by location type, as summarized in **Table 1**.

Table 1. Outreach Strategies by Location Type

	MUD Outreach	Workplace Outreach
What stakeholders should be targeted?	- Residential property owners - MUD residents - Developers of MUD properties	- Commercial property owners - Large employers - Parking management companies
What should outreach efforts address?	- Financial incentive programs - Charging rights for residents - Economies of scale opportunities - Cost recovery options	- Low-cost level 1 charging opportunities - Scheduling policies - Economies of scale opportunities - Cost recovery options

CHAPTER 1: Introduction

1.1 Problem Statement

Southern California's air quality has improved considerably since the mid-20th century, but the region still suffers from some of the worst air pollution in the nation. Seven of the top 10 air quality monitoring stations in the nation most frequently exceeding the 2015 National Ambient Air Quality Standards (NAAQS) for ozone were located within the South Coast Air Basin, a region which includes Orange County and the non-desert portions of Los Angeles, Riverside, and San Bernardino Counties.[8] That frequency translates to a sizable portion of the year. In 2015, one or more air monitoring stations in the South Coast Air Basin exceeded ozone NAAQS on a total of 113 days, or 40% of the year.[9]

The effect of air pollution on the health of Southern California residents is a major public health concern. Criteria air pollutants, such as ozone, nitrogen oxides (NOx), and particulate matter (PM), are directly linked to the onset and exacerbation of asthma, decreased lung function, and increased asthma-related hospitalizations and emergency department visits.[10] In Los Angeles County, it is estimated that 8% of all cases of childhood asthma were at least partly attributable to pollution associated with living within 75 meters of a major road.[11] Exposure to PM is also closely associated with cardiovascular disease.[12] In the South Coast Air Basin, it is estimated that 10% of coronary heart disease related deaths in 2008 were attributable to ambient regional particular matter less than 2.5µm (PM2.5).[13]

Improving Southern California's air quality is a particularly complex challenge. The unique topography and meteorology of the South Coast Air Basin lends itself to trapping air pollution from millions of vehicles that drive through the region on a daily basis. While stationary sources, such as industry and power generation facilities, also contribute to the region's air pollution, mobile sources are the dominant source. With respect to NOx emissions, a precursor to ozone formation, mobile sources contributed about 88% of the region's total NOx emissions in 2012.[14] Local and regional governments have limited authority to regulate mobile sources, but can help facilitate the transition to zero and near-zero emission vehicles, which once broadly adopted, will dramatically improve air quality in the South Coast Air Basin.

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[8] South Coast AQMD, 2017. *Final 2016 Air Quality Management Plan.* Accessed November 2019: http://www.aqmd.gov/home/air-quality/clean-air-plans/air-quality-mgt-plan
[9] South Coast AQMD, 2017. *Final 2016 Air Quality Management Plan.* Accessed November 2019: http://www.aqmd.gov/home/air-quality/clean-air-plans/air-quality-mgt-plan
[10] Guarnieri, M. & Balmes, J. R. Outdoor air pollution and asthma. The Lancet 383, 1581–1592 (2014)
[11] Perez, L., Lurmann, F., Wilson, J., Pastor, M., Brandt, S.J., Künzli N., McConnell, R., 2012. "Near-roadway pollution and childhood asthma: implications for developing 'win-win' compact urban development and clean vehicle strategies." *Environmental Health Perspective* 120(11): 1619-26.
[12] Lee, B.J., Kim, B., and Lee, K, 2014. "Air pollution exposure and cardiovascular disease." *Toxicological Research* 30(2): 71-75.
[13] Ghosh, R., Lurmann, F., Perez, L., Penfold, B., Brandt, S., WIlson, J., Milet, M., Künzli N., McConnell, R., 2016. "Near-roadway air pollution and coronary heart disease: burden of disease and potential impact of a greenhouse gas reduction strategy in Southern California." *Environmental Health* Perspective 124(2): 193-200.
[14] SCAQMD, 2017. *Final 2016 Air Quality Management Plan.* Accessed November 2019: http://www.aqmd.gov/home/air-quality/clean-air-plans/air-quality-mgt-plan

To help facilitate this transition, the Mobile Source Review Committee (MSRC) plans to direct funding towards developing the infrastructure needed to support zero and near-zero emissions vehicles.[15] Currently, there is an insufficient network of charging opportunities to support a fully-electrified passenger vehicle fleet. Unlike the mature market of readily available gasoline stations, the electric vehicle (EV) charging station market is still in the early stages of development. And unlike gasoline stations which fuel vehicles in minutes, charging an EV often takes several hours. Consequently, EV charging stations are generally located in parking areas where drivers will leave their vehicle for periods longer than one hour, such as at home or work.

For residents of multi-unit dwellings (MUDs), however, there are multiple barriers to charging at home. Foremost is the variable and often high cost of installing electric vehicle supply equipment (EVSE) at MUD sites, which often lack dedicated parking spaces with electrical outlets for all residents. In parking configurations without electrical outlets, an electrician will need to run wires from the electrical panel to the charge point. If the panel cannot produce adequate electricity or the utility service is not providing enough electricity to the property, then panel or service upgrades will be needed. For a sense of scale, the cost of installing Level 2 EVSE at a sample of 15 MUDs in the South Coast sub-region of Los Angeles County ranged from $1,800 to $17,800 per site, with an average of $5,400 per site (not including the cost of potential service capacity upgrades).[16] Whatever the total cost, renters or owners at MUD properties have low to nonexistent motivation to make such an investment in the absence of subsidies. Renters are unlikely to invest in significant property upgrades that they cannot take with them, and given the tight housing market, landlords do not need to provide EVSE in order to attract and retain tenants.

Charging at work is also not a straightforward proposition. Again, plug-in electric vehicle (PEV) drivers may not have a dedicated spot near an electrical outlet into which to charge their car on a predictable basis. To provide such an amenity would involve many of the cost considerations that exist for installing charging equipment at MUD locations. Additionally, the process of setting up charging at workplaces requires the cooperation of the parties that own and operate an employer's parking area. Some employers own their own building and dedicated parking areas, while others lease parking from commercial landlords, who may in turn contract with a parking management company to operate the lot or structure. No matter who owns the parking structure, the paying party must decide whether providing PEV charging is a worthy investment. And until the demand for workplace charging has a consequential effect on employee recruitment and retention, an employer's motivation to make such an investment is weak.

To reduce the financial and motivational barriers that thwart private investment in MUD and workplace charging, local planners and policymakers can provide funding and technical assistance to reduce some of the hard and soft costs of installation. Like all government programs, funds to assist property owners with charging installation are limited, and require planners and policymakers to think strategically about where they target investments and services to maximize public benefits. The section that follows describes some of the work that the UCLA Luskin Center for Innovation (LCI) has conducted to inform such efforts.

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[15] MSRC was established by AB 2766 to make recommendations to the South Coast Air Quality Management District Governing Board on how to use money collected by the Department of Motor Vehicles to support projects that reduce motor vehicle air pollution.
[16] UCLA Luskin Center for Innovation, 2016. *Overcoming Barriers to Electric Vehicle Charging in Multi-unit Dwellings: A South Bay Case Study.*

1.2 Previous Work to Support PEV Planning

Since the rollout of the first commercially available PEVs nearly a decade ago, LCI has developed a number of research products to help plan for vehicle electrification. Much of this work has been conducted in partnership with the Southern California Association of Governments (SCAG), a metropolitan planning organization responsible for regional transportation planning. Among the issues of chief concern to SCAG and its members are greenhouse gas (GHG) and air pollutant emissions from the passenger vehicle fleet. To address these concerns, SCAG partnered with the South Coast AQMD to fund LCI in authoring the *PEV Readiness Plan* (2012), a guidance document for rolling out EV charging infrastructure across a variety of land uses.[17] This plan was complemented by the *PEV Atlas* (2013), which mapped the neighborhoods in Southern California where PEVs are registered, as well as where these vehicles travel for morning and afternoon commutes.[18] To adjust for the dramatic increase in PEV adoption since the first atlas, LCI also released an updated atlas in 2017.[19]

Since the publication of the *PEV Readiness Plan* and *Atlas*, LCI has published several reports in partnership with SCAG to further support the siting of EV charging infrastructure at MUD locations. In *Overcoming Barriers to Charging in Multi-unit Dwellings: A South Bay Case Study* (2016), LCI developed the first iteration of its propensity-to-purchase model, which identifies MUDs where residents exhibit high latent demand to purchase a PEV but are restrained from doing so because of barriers to charging.[20] In this 2016 report, the model was applied to the South Bay sub-region of Los Angeles County.[21] One year later, LCI published a follow up report that focused on the Westside Cities sub-region of Los Angeles County. Since the publication of these two reports, LCI has worked to refine the propensity-to-purchase model to better relate MUD property values to expected rents and condominium ownership costs, two sensitive variables in the model that strongly influence the final propensity-to-purchase score assigned to MUD properties. The findings and maps presented here reflect the most up-to-date iteration of the model.

LCI has also developed a model to inform the siting of EV charging stations in workplace settings. In 2016, LCI organized a group of UCLA graduate students in the Department of Public Policy to assist SCAG in developing a strategy for prioritizing investments in workplace charging

[17] UCLA Luskin Center for Innovation, 2012. *Southern California Plug-in Electric Vehicle Readiness Plan.* Accessed November 2019: http://www.scag.ca.gov/programs/Pages/PEVReadinessPlan.aspx
[18] UCLA Luskin Center for Innovation, 2013. *Southern California Plug-in Electric Vehicle Atlas.* Accessed November 2019: http://www.scag.ca.gov/programs/Pages/PEVReadinessAtlas.aspx
[19] UCLA Luskin Center for Innovation, 2017. *Southern California Plug-in Electric Vehicle Readiness Atlas: 2017 Update.* Accessed November 2019: https://innovation.luskin.ucla.edu/wp-content/uploads/2019/03/Southern_CA_PEV_Readiness_Atlas.pdf
[20] UCLA Luskin Center for Innovation, 2016. *Overcoming Barriers to Charging in Multi-unit Dwellings: A South Bay Case Study.* Accessed November 2019: https://innovation.luskin.ucla.edu/wp-content/uploads/2019/03/Overcoming_Barriers_to_EV_Charging_in_MUDs-A_South_Bay_Case_Study.pdf
[21] UCLA Luskin Center for Innovation, 2017. *Overcoming Barriers to Charging in Multi-unit Dwellings: A Westside Case Study*. Accessed November 2019: https://innovation.luskin.ucla.edu/wp-content/uploads/2019/03/Overcoming_Barriers_to_EV_Charging_in_MUDs-A_Westside_Cities_Case_Study.pdf

for Los Angeles County.[22] To support that effort, LCI advised the graduate students in constructing a model the estimates the gasoline powered miles that plug-in hybrid electric vehicles (PHEVs) are likely driving in order to complete their roundtrip commute to work. Where those miles are greatest, investments in workplace charging should lead to the greatest emission reductions. For the workplace analysis presented in this document, LCI updated the model to take into account more recent PHEV registration data, a key input for determining the electric ranges of the existing PHEV fleet.

1.3 Purpose of this Report

This report is intended to support local and regional planners in expanding PEV charging opportunities at MUD and workplace locations across Southern California. The report accomplishes this aim by documenting the development and refinement of the spatial models described above, as well as providing summary results. Planners can use downscaled results from these models (which will be incorporated into SCAG's interactive PEV Atlas)[23] to perform targeted outreach to property managers of MUD and workplace locations where there is particularly high latent demand for PEV charging. At these locations, investments in charging infrastructure should most cost-effectively lead to an increase in zero-emission miles and a reduction in local air pollution.

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[22] Di Filippo, J., Moriyama, M., Terai, T., Trumbull, K., Zhang, J., 2018, "Prioritizing Workplace Electric Vehicle Charging Station Investments in Los Angeles County," *California Policy Options.* Accessed November 2019 from: https://innovation.luskin.ucla.edu/wp-content/uploads/2019/03/Prioritizing_Workplace_EV_Charging_Stations_Investments_in_LA.pdf

[23] SCAG's interactive PEV Atlas can be accessed here: http://maps.scag.ca.gov/electric_vehicle/index.html

CHAPTER 2: Methodology

To identify opportunities where investments in EV charging infrastructure are most likely to provide a public benefit, we analyzed opportunities at MUDs and workplaces, where PEV drivers often do not have a strong motivation to personally invest in charging infrastructure. The methods for identifying these opportunities relied upon a combination of descriptive mapping and techniques, which are documented in detail in this chapter, with supporting materials provided in the Appendix.

2.1 MUD Analysis

The MUD analysis consists of three primary research activities. The purpose of these activities was to better understand the composition of MUDs in the South Coast Air Basin and which MUD parcels represent promising opportunities to install charging infrastructure regarding air pollution reduction and equity goals. The three activities are outlined below.

I) Characterize the MUD Portfolio of the South Coast Air Basin

For each of the four counties within the South Coast Air Basin, we inventoried the MUD housing stock according to key variables that influence EV demand amongst MUD residents such as, building size, age, and average per unit value as well as ownership type (i.e., condominiums or rental units). The inventory is based on 2018 tax assessor parcel data obtained from the sources listed below.

- **Los Angeles County:** County of Los Angeles Open Data Portal – Published open data
- **Orange County:** Digital Maps Products – Private data product, available for fee
- **Riverside County:** Riverside County Innovation Center, Geographic Information Services – Public data, available upon request
- **San Bernardino County:** County of San Bernardino Geographic Information Services – Public data, available upon request

All parcel datasets had missing, contradictory, and erroneous data and required extensive cleaning to be made analysis ready. In order to carry out the PEV purchase propensity analysis, we required the following information/fields on each parcel: 1) land use type, 2) number of units, 3) assessed value, 4) assessed base year, and 5) location/address. Parcel records missing any of these values were removed from the dataset.

Information on land use type is necessary to identify whether or not a parcel is a MUD. All records without land use information were discarded which presumably removed at least some MUDs from the analysis dataset.

In some cases, unit count information directly contradicted land use type information. For example, a parcel listed as a quadplex might have had a unit count of seven. Virtual ground truthing using satellite imagery and Google Street View ® revealed land use type to be the more reliable field for establishing the number of units. Where land use type and unit count disagreed, and the land use typology contained specific information about the number of units on a parcel, we modified the unit field to agree with the land use type.

Parcel dataset quality varied greatly between counties. For example, Orange County's data lacked unit counts for a large portion of MUD parcels and subsequently has the largest share of excluded records. See **Table 2** for a breakdown of missing or erroneous data by county.

Table 2. Records Excluded for Missing or Erroneous Data.

County	Missing land use type	Missing/erroneous unit count, value and/or location information
Los Angeles	51	3,820
Orange	13,260	17,293
Riverside	0	607
San Bernardino	4,915	4,327

Excluding parcels from the analysis reduces the completeness of the final propensity-to-purchase inventory, however we took steps to mitigate the impact of error.

II) PEV Purchase Propensity Scoring Methodology

The propensity-to-purchase score is an indicator of *relative* demand for PEVs among MUD residents. The score is not a measure of the probability that any individual MUD household would or would not purchase a PEV. Instead, it is a comparative metric that indicates whether a household in a particular MUD is more or less likely to purchase a PEV than households in other MUDs. Moreover, the score is an indicator of potential or *latent* demand because MUD residents generally do not have access to onsite charging infrastructure—a significant barrier to PEV ownership. In other words, the score indicates the likelihood that a MUD resident household would purchase a PEV (relative to other MUDs), if home charging was made available to them.

The propensity-to-purchase score is a composite score of two interacted inputs: 1) an income-based numerical estimate of relative PEV purchase propensity at the parcel level, and 2) historic PEV adoption rates at the neighborhood-level (census tract). Both inputs are weighted equally in the final score. Regarding the first input to the score, prior research has demonstrated that income is a strong predictor of PEV adoption.[24] All else equal, this suggests that households with high incomes are more likely to purchase PEVs than those with lower incomes. With respect to the second input into the score, historical adoption rates at the census tract level are also an important predictor of PEV sales in that tract.[25] All else being equal, this suggests that residents of MUDs in areas with high rates of PEV adoption are more likely to purchase PEVs than those in areas with low rates of PEV adoption.

We aggregate the two scores multiplicatively to avoid the need to normalize either component score and to ensure that the composite scores respect proportionality (e.g. holding one score constant, a doubling of the other score will double the final score). Because parcels in the same

[24] Sheldon, L.T., and DeShazo, J.R., Carson, R.T., and Krumholz, S., 2017. *Factors Affecting Plug-in Electric Vehicles Sales in California.*

[25] We measure adoption rates as the number of PEVs registered per 1,000 residents in each census tract.

census tract will have the same adoption score, this means rank differences within census tracts will depend on parcel-level purchase propensities.

We estimate the first input by combining the historical distribution of PEV adoption by household income (from survey data) with an estimated probability distribution of household income at the parcel level. Household income data is not directly available at the parcel-level data, but can be estimated from housing costs, which can be in turn estimated from property values. Property values for individual parcels are available in tax assessor rolls. This cross-walking exercise ultimately yields an expected value estimate of the PEV adoption rate associated with a given MUD's probable household income.

As a simplified illustration of how the above calculation works, consider the following example for two income groups I and J that might reside in MUD X. About 75% of PEVs are purchased by group I and 25% are purchased by group J. The probability that MUD X's residents are either in group I or group J is 50-50. Combined, the purchase propensity of MUD X is 50% or, the sum of the products of 50% and 25%, and 50% and 75%.

The propensity-to-purchase model is constructed from a variety of data sources, including survey data from the Clean Vehicle Rebate Project (CVRP), census tract level socioeconomic data from the 2013–2017 American Community Survey (ACS), census tract level PEV registration data from IHS Markit, tax assessor's data on property characteristics for the four counties in the South Coast Air Basin, commercial rental property listing data from LoopNet, and Federal Housing Finance Agency (FHFA) data on home sales over time. The steps for constructing the propensity-to-purchase model are described below:

1. **Establish Relationship Between Income and Likelihood of PEV Purchase**

   First, we estimate the relationship of household income to relative purchase propensity. Unfortunately, reliable estimates of the direct relationship between income and PEV purchase propensity are not available at the individual level. As a second-best option, we use the distribution of PEV rebate uptake across household income groups as a proxy for the relative PEV purchase propensity of a household in a given income group, compared to households in other income groups. We assume that relative propensity to purchase a PEV for any given household income level is proportionate to the frequency at which a household of that income level is represented in PEV rebate survey responses. For example, if household income X accounts for 20% of PEV buyers and household income Y accounts for 10% of PEV buyers, a given household with X income is twice as likely to buy a PEV as a given household with Y income.

   The CVRP survey groups incomes into wide income buckets that do not match estimated income brackets made in future steps. To facilitate matching, we proportionally decompose the income brackets into $1,000 dollar increments.[26] For example, if 10% of respondents fall into an income bracket between $20,000 and $29,999, then we assume that 1% of respondents earn $20,000-20,999, 1% earn 21,000 - $21,999 and so on. This approach carries the implicit assumption that the distribution of incomes within brackets is flat.

[26] $1,000 brackets allow for flexibility and better matching while reducing computational requirements relative to smaller brackets.

2. Establish Relationship Between Income and MUD Property Values

Second, we estimate a probability distribution of household incomes at the parcel level. Because granular data on the incomes of residents of individual parcels is unavailable, we base income estimates on taxable parcel values which are public record. For rental properties we estimate rents based on the relationship between the value of a property and the rent it commands. For condominiums we estimate mortgage costs based on the value of the unit. That income estimate is then combined with ACS estimates of housing cost-to-income ratio distribution to create individualized income distributions for each parcel. The process for obtaining a probability distribution of household incomes at the parcel level is described in the following sub-steps:

2a. Correct Tax Assessor's Data for Market-rate Increases in Property Values

Tax assessor rolls provide public data on the value of individual parcels for the purposes of calculating property taxes. However, because of California's Proposition 13, a parcel's assessed value does not rise with market rates unless that property is sold. Instead, assessed values increase by at most 2% each year. This creates a challenge for our propensity-to-purchase model because in the real world, rents are related to current market values, not the value of the property when it was last sold.

We attempt to correct the tax assessor's data for increases in market values by using the FHFA's housing price index (HPI), which is derived from data on single-family home sales. To account as specifically as possible for geospatial heterogeneity in housing price growth, we use the FHFA zip code index. Where the zip code level index had gaps (primarily in earlier years) we filled in values using the aggregate California HPI.

After adjustment using the HPI, we compared projected values with a sample of 976 real-world listings of MUD properties obtained from Loopnet.[27,28] This comparison revealed that the HPI based adjustment method systematically and significantly underestimates market values. We then correct for this systematic error by applying a correction factor[29] to each property based on the average error between real-world listing prices and projected property values. Unsurprisingly, the earlier a property was last sold, the larger the error between projected value and listing price becomes. To account for changing error rates over time, the correction factor scales up the further back in time the last transfer occurred based on the linear relationship between error and date of last assessment update.

2b. Establish a Relationship Between MUD Value and Gross Rent

The relationship between a building's value and the rent it earns is very strong. The simplest measure of this relationship is the gross rent multiplier (GRM) which is a ratio of rental income to property value. We leverage that relationship to estimate real rents for MUD parcels based on their individual property value.

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[27] Loopnet is a commercial and multifamily real estate listing company, accessible at: www.loopnet.com

[28] Data is a convenience sample of all MSRC region multifamily properties listed for sale on LoopNet at the time of data collection.

[29] We estimate the correction factor by fitting a linear regression model on the relationship between error rate and the base year of the property valuation. We use that linear model to predict and then correct for the error between HPI-estimated values and market price.

GRMs vary with geography and neighborhood characteristics, so accurately estimating rents from values requires a spatially resolved inventory of average GRMs. However, such spatially resolved data on GRM are not readily available. For the purposes of this study, we constructed an ad hoc GRM inventory from a sample of 729 current listings for MUD properties obtained from LoopNet in October and November of 2019. See **Appendix 1** for a map that visualizes the locations of these listings across the study region.

We aggregated listings by Public Use Microdata Area (PUMA) to create an average GRM to apply to all parcels within that PUMA.[30] Five PUMAs in the MSRC region did not contain any MUD listings. We created synthetic GRMs for those PUMAs using average neighbor spatial interpolation. See **Appendix 2** for a map that visualizes the average GRM per PUMA.

2c. Estimate Average Rents for MUDs

We then estimated the average rent per unit for all MUD apartment buildings in the South Coast Air Basin. This step took the GRM inventory from the previous step to calculate the unit gross rents for each MUD parcel based on the parcel's property value and the PUMA in which it is located. For example, a building worth $1,000,000 with a GRM of 10 would generate $100,000 per year in rent. If that building has four units, the average rent per unit would be $25,000 a year.

2d. Estimate Housing Cost Burdens for Condominium Owners

Unlike apartment buildings, condominiums are individually owned. While some condominiums are rented by their owners, most are owner-occupied. To simplify the analysis, we assume that condominiums are owner-occupied and that the owners are still paying a mortgage.

Unlike rental costs, which are most directly related to current market value, ownership costs are dominated by mortgage payments which are determined by initial loan principals and terms. To estimate likely ownership costs for condominium owners, we used a simple financial model that includes annual mortgage payments, home owner association (HOA) fees, and insurance premiums. Specifically, this model assumes the following: 1) mortgage payments are based on a 30-year loan with an 3.92%[31] annual percentage rate charged by the lender; 2) loan amounts are based on the sale price of the unit less a 19.7%[32] down payment; and 3) condominium owners pay $3,972[33] in HOA dues and $478[34] for insurance costs.

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[30] We used PUMA as a geographical unit because PUMAs were a convenient ready-made geographical unit that are both large enough to contain one or more listings, but small enough to respect geographic differences in GRM.

[31] ValuePenguin, "California Mortgage Rates for February 2020," available at: https://www.valuepenguin.com/mortgages/california-mortgage-rates

[32] ATTOM Data Solutions, "Median Down Payment for U.S. Homes Purchased in Q3 2017 Increases to a New High of $20,000," available at: https://www.attomdata.com/news/mortgage-and-finance/q3-2017-u-s-home-loan-origination-report/

[33] Guerra, T., 2018, "The Average Fees for a Condominium Association," SFGate, available at: https://homeguides.sfgate.com/average-fees-condominium-association-51757.html

[34] ValuePenguin, "Average Cost of Condo Insurance (2020)," available at: https://www.valuepenguin.com/average-cost-of-condo-insurance

2e. Estimate Income Frequency at the Parcel Level for All MUDs

We then estimate income frequency distributions by interacting rent/ownership costs with ACS data on housing cost-to-income ratios at the census tract level. The U.S. Census Bureau collects data on the distribution of housing-cost-to-income ratios at the census tract level for renters (Table B25070) and owners (Table B25091). We use this data to back out a distribution of likely household incomes for each multifamily parcel. For example, if the average annual rent for a unit in parcel A is $25,000 a year and 10% of households in the census tract spend 30-40% of their income on rent, then all else being equal, we would expect there to be a 10% chance that annual earnings for a household occupying that particular parcel would be between $62,500 (the income that corresponds with 40% cost burden) and $83,333 (the income that corresponds to a 30% cost burden). By repeating this estimation for all cost-to-income ratios, we estimate a full probability distribution of household income at the parcel level.

3. Assign Propensity Purchase Scores to MUD Parcels

Third, we estimate the relative propensity scores for each parcel based on income distributions. Because actual household incomes are uncertain, we estimate the expected value of the relative propensity to purchase score. Expected value is the average score of all represented income brackets weighted by the probability that a household would be in each bracket. For example, if there are two income brackets, X and Y which relate to relative propensities of 25% and 75%, and the household is equally likely to be in either income bracket, then the expected value of the propensity score is 50% or the sum of the product of 25% and 50% and 75% and 50%.

4. Incorporate Historical PEV Adoption Rates at the Census Tract Level

Fourth, we add weights to the above probabilities to account for geographic variation in PEV purchasing patterns. We do so by using new and used PEV registration data from IHS automotive for the period of October 2015 through September 2016. In effect, this step increases the final propensity-to-purchase scores assigned to MUDs according to the volume of PEV purchases in the census tract for which that MUD belongs. Here, we assume that the PEV market has not saturated and will continue to grow in each census tract. This final step yields the final propensity-to-purchase score.

III) Isolate Results for Disadvantaged Communities from Other Neighborhoods

Finally, we overlaid disadvantaged community (DAC) boundaries (defined by CalEnviroScreen 3.0) with the results described above. This overlay will help planners identify the DACs in which MUD charging investments are most likely to be used, and therefore lead to greater improvements in local air quality.

2.2 Workplace Analysis

The workplace analysis consisted of four primary research activities to identify where plug-in hybrid electric vehicles (PHEVs) are registered, where they are commuting, how many additional electric miles travel might be gained from supplying PHEVs with charging opportunities at work, and whether there are already opportunities for them to charge at work. The steps and assumptions that went into each of these research activities are as follows:

I) Construct PHEV Inventory

To understand where PHEVs are going, we first needed to understand from where PHEVs are coming. We used new and used PHEV registration data aggregated at the census tract level to construct a spatial inventory of where PHEVs reside at night. Because we only know where vehicles are registered at point of sale, we cannot account for non-sale changes in vehicle location (such as those that might occur when an owner moves homes). The registration data contains information on the individual PHEV makes, models, and years that occupy each census tract.

The model requires that the PHEV inventory be redistributed into travel analysis zones (TAZ). Like census tracts, TAZs are constructed from smaller census block groups geographies: however, TAZs and census tracts are not entirely contiguous. We use spatially-proportional allocation methods to interpolate TAZ PHEV populations from census tract populations. This method implicitly assumes that PHEVs are uniformly distributed across space. Because actual distribution of PHEVs is not likely to be uniform, some PHEVs will be misallocated to neighboring TAZs. However, because trip destinations from origins are spatially autocorrelated, small errors are unlikely to have significant impact on simulation results.

II) Estimate Trip Probabilities

To predict the trips that PHEVs would likely make from their home TAZ, we use SCAG's Regional Travel Demand Model (TDM).[35] The TDM is a forecast model that predicts a matrix of vehicle travel demand (measured in trips) to and from each TAZ within SCAG's territory. The trip counts modeled by the TDM can be thought of as probability distributions for trips leaving each origin. In other words, the more predicted trips from a particular origin that end in a particular destination, the more probable that destination will be the endpoint of any particular automobile trip.

III) Simulate PHEV Commuter Charge Deficits

We combine the PHEV inventory with the trip probability dataset to simulate the PHEV commutes on which to base estimates of additional electric vehicle miles travels (eVMT) that could be supported by workplace charging. Because the exact destination of any PHEV commute is uncertain, the simulation of potential eVMT gain is based on the concept of expected value, which is the product of the outcome and the probability that the outcome will occur. This simulation required the following three substeps:

1. Calculate Potential for Additional eVMT

The additional eVMT simulation is a simple algorithm that uses a decision rule based on commute distance and all-electric range to categorize each PHEV-commute pairing into one of the three below scenarios. To estimate commute distance, we calculated least-distance routes between each TAZ using OpenStreetMap road network centerlines and ArcGIS software. Electric range information was obtained from the vehicle fuel economy database hosted by the U.S. Department of Energy and Environmental Protection Agency (https://www.fueleconomy.gov/).

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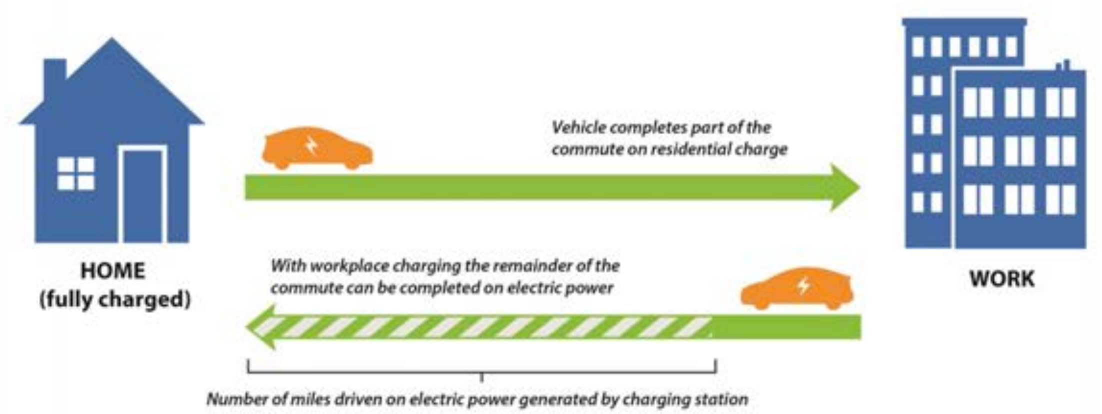
[35] SCAG. 2016. SCAG Regional Travel Demand Model and 2012 Model Validation. Accessed August 2017 from http://www.scag.ca.gov/Documents/SCAG_RTDM_2012ModelValidation.pdf

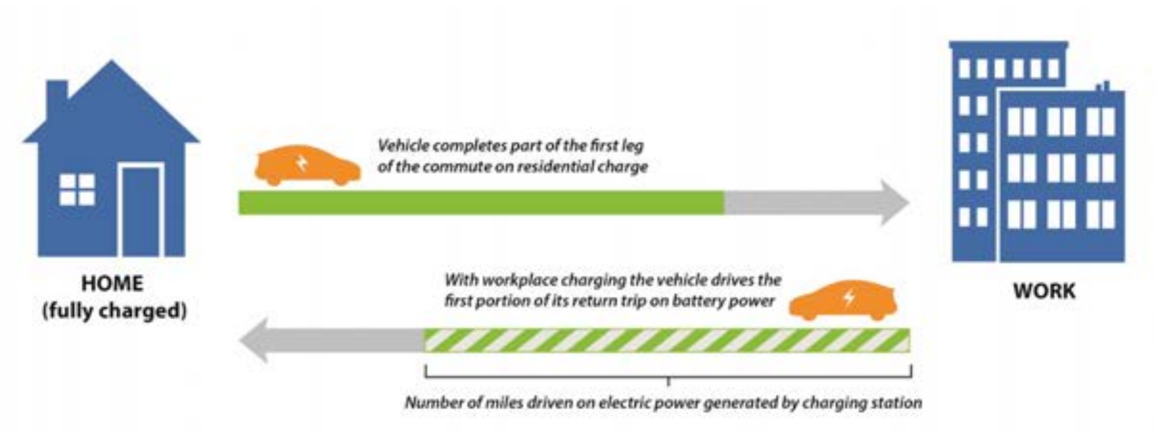
Scenario 1: If the commuting vehicle's all-electric range is greater than its one-way commute distance but less than its round trip commute distance, a workplace charge ensures that the entirety of its return trip can be completed on electric power. The number of eVMT gained is equal to the difference between the round-trip commute distance and the vehicle's all-electric range (**Figure 4**). In other words, the gain in eVMT is the portion of the round trip commute that was not already covered by the home-based charge.

Figure 4. Commute in which roundtrip distance exceeds all-electric range[36]



Scenario 2: If the commuting vehicle's one-way commute is longer than its all-electric range, the vehicle will exhaust its battery power prior to arriving at its destination, leaving no reserve for the return trip. Given the opportunity to recharge while at work, such vehicles are able to complete part of the return trip on electric power rather than gasoline combustion. In this scenario the number of eVMT gained is equal to the vehicle's all electric range (**Figure 5**). In other words, the commuting vehicle is able to use an additional full charge during its commute.

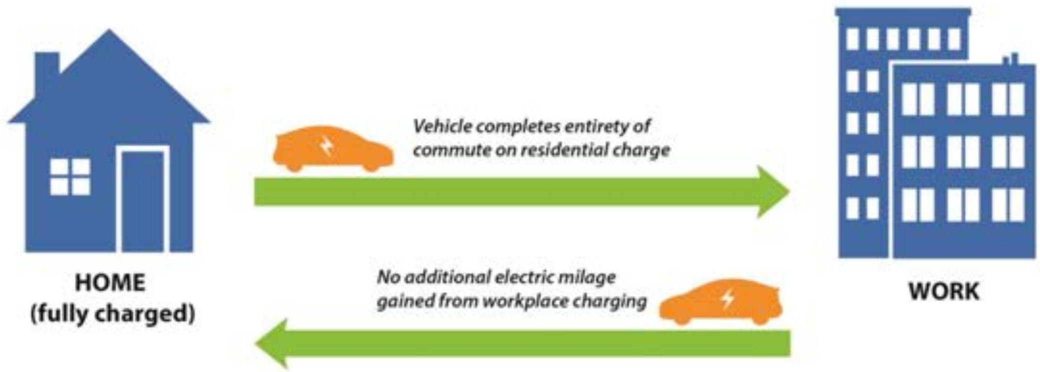
Figure 5. Commute in which departure distance exceeds all electric range[37]



[36] Di Filippo, J., Moriyama, M., Terai, T., Trumbull, K., Zhang, J., 2018, "Prioritizing Workplace Electric Vehicle Charging Station Investments in Los Angeles County," *California Policy Options.*
[37] Ibid.

Scenario 3: Where the round-trip commute distance is less than a commuter vehicle's all electric range, the vehicle can complete its trip to and from the workplace on the electric reserve from a single residential charge. In this scenario, charging at work will yield zero additional eVMT (**Figure 6**).

Figure 6. Round trip commute distance is less than all electric range[38]



2. **Map Additional eVMT onto Commute Probabilities**

   Simulated commutes are *probable* trips where the probability of whether a specific PHEV will travel to that TAZ is represented as a fraction. This fraction is applied to each eVMT estimate to calculate an expected value of eVMT for that specific PHEV trip. For example, if PHEV X commuting from origin A to destination B would gain five additional miles of eVMT by using workplace charging and the probability that PHEV X would commute to destination B is 20%, then the expected value of additional eVMT from PHEV X in destination B is 5 × 0.2 or, one eVMT. While this fractional eVMT value is not very useful on its own--in reality PHEV X can only commute to one destination--when this operation is iterated over the thousands of commuting PHEVs in the SCAG region, a picture of the on-average additional eVMT generatable by charging at each destination emerges.

3. **Account for Existing Stations**
   After summing the expected value of additional eVMT in each TAZ, that score must be adjusted for the availability of current charging stations, as based on location data provided by data provided by the Alternative Fuels Data Center (AFDC). Where charging stations already exist, a portion of the calculated eVMT is already supported. To account for existing charging opportunities, we subtract the amount of eVMT that current infrastructure can support from the TAZ eVMT total.[39] The resulting figures are the final eVMT scores for each TAZ.

IV) Identify Gaps in Existing Workplace Charging

The AFDC dataset contains insufficient data to specifically identify which workplaces do or do not have charging on site. In order to identify gaps in workplace charging, we identify

[38] Ibid
[39] To estimate currently supported VMT we assume that each charger is supporting one average commuter's VMT (i.e. the average per-vehicle additional eVMT score for that TAZ).

workplaces as either located or not located within ⅛ mile of a charging station reported in the AFDC dataset. Insofar as the AFDC data is reasonably complete, a ⅛ mile threshold is unlikely to incorrectly classify a workplace as having no charging when it does. However, it should be noted that those workplaces that are within ⅛ of a mile of a charging station may or may not be the host of those charging facilities. Thus employees at those workplaces do not necessarily have access to charging.

CHAPTER 3: MUD Charging Opportunities

The South Coast Air Basin is home to a total of 2,348,622 MUD housing units, which comprise 44% of the total housing stock in the region. MUD residents, however, are much less well represented among PEV drivers. According to 2012-2015 survey data from CVRP, only 9% of rebate recipients located in the four counties that comprise the South Coast Air Basin live in an apartment building or condominium[40]. While the cost of purchasing a PEV is certainly a limiting factor for many MUD residents, this financial hurdle is compounded by the high costs of installing charging infrastructure in MUD settings. Removing this cost barrier may require public investment, which in turn requires strategic planning to ensure investments are well-utilized.

This chapter provides an overview of the MUD portfolio in the South Coast Air Basin, including MUD characteristics that can influence the cost of installing EV charging infrastructure, and therefore the motivation of MUD property owners to invest. This chapter then provides an overview of where latent PEV demand among MUD residents is expected to be greatest due to the lack of at-home charging opportunities. City planners can review this chapter to understand the MUD composition of the sub-region at large, where installation costs may be relatively lower, and where motivations to charge may be relatively higher.

Caption: PEVs charging at Muir Commons, a townhouse community in the City of Davis (photo credit: Cool Davis)

[40] Center for Sustainable Energy, 2018. *Clean Vehicle Rebate Project, Final Report Fiscal Year 2015–2016.*

3.1 MUD Density

Understanding the density of MUD housing is particularly important for the purposes of utility planning. Where there are neighborhoods with high MUD density, transformers and distribution station upgrades may be needed prior to the mass roll out of charging stations in the garages of those buildings. Large scale investments in EV charging infrastructure at MUD locations, therefore, should be planned in coordination with local utilities to ensure that there is sufficient electrical capacity to accommodate the additional load.

Table 3.1 summarizes the number of MUD buildings and units in each county within the study area. **Appendix 3.1** provides maps that visualize the MUD density at the census tract level for each county in the study area.

Table 3.1. MUD Density of Counties in the South Coast Air Basin

	County	MUDs	MUDs / mi^2	MUD units	MUD units / mi^2
All MUDs	Los Angeles	256,864	93	1,784,414	647
	Orange	23,809	30	327,813	413
	Riverside	13,110	2	57,458	10
	San Bernardino	17,899	15	178,937	158
	Total	**311,676**	**29**	**2,348,622**	**219**
MUDs in DACs	Los Angeles	141,265	355	799,920	2,010
	Orange	4,357	97	45,029	1,000
	Riverside	4,556	10	13,856	29
	San Bernardino	9,281	39	82,422	345
	Total	**159,459**	**138**	**941,227**	**71**

3.2 MUD Building Size

Size is a consequential determinant of the likely physical barriers to deploying charging in an MUD. Like single family homes, duplexes (and to a lesser extent triplexes) often have enclosed garages, wired with preexisting 110 (and in some cases 220) volt circuits. These properties are likely to be able to support EV charging with little to no additional investment. Conversely, parking in MUDs with more units is typically restricted by space and building geometry to comparatively sparse parking stalls. If they have any electrical wiring, it is typically only for lighting. Adding charging to these buildings can require significant investment.

Furthermore, multiple PEVs charging at the same property may require investments in electrical panels and utility service upgrades to handle the additional electrical load. These costs, however, are relatively cheaper per parking space when they are shared among more MUD units.[41] Thus, the proposition of investing in charging infrastructure may be more appealing to owners of large MUDs compared to smaller MUDs where the cost per parking unit is higher.

MUDs within the South Coast Air Basin range greatly in size, but are mostly duplexes/triplexes. **Table 3.2** provides a count of MUDs by building size for each county within the basin. **Appendix 3.2** provides maps that visualize the median MUD size at the census tract level for each county.

Table 3.2. MUDs by Building Size in the South Coast Air Basin

	County	Duplex/ Triplex	4 to 9 Units	10 to 19 units	20 to 49 units	50+ units	Total MUDs
All MUDs	Los Angeles	144,097	76,595	19,993	12,102	4,077	256,864
	Orange	9,122	9,783	1,614	1,620	1,664	23,803
	Riverside	12,534	402	60	40	74	13,110
	San Bernardino	11,816	4,688	560	373	462	17,899
	Total	**177,569**	**91,468**	**22,227**	**14,135**	**6,277**	**311,676**
	% of Total	**57%**	**29%**	**7%**	**5%**	**2%**	**100%**
MUDs in DACs	Los Angeles	86,179	4,0079	8,702	4,909	1,400	141,265
	Orange	1,159	2,351	462	233	152	4,357
	Riverside	4,325	176	20	15	20	4,556
	San Bernardino	5,921	2,731	402	215	12	9,281
	Total	**97,584**	**45,337**	**9,586**	**5,372**	**1,584**	**159,459**
	% of Total	**61%**	**28%**	**6%**	**3%**	**1%**	**100%**

[41] UCLA Luskin Center for Innovation, 2017. Overcoming Barriers to Electric Vehicle Charging in Multiunit Dwellings: A Westside Cities Case Study.

3.3 MUD Vintage

The age of a building is often related to the cost of installing EV charging equipment. Specifically, new MUDs are likely to have increased electrical capacity onsite, avoiding the need for potentially costly panel upgrades or service upgrades from the utility. When panel upgrades are needed, replacement materials are likely easier to find and less expensive for newer buildings compared to older buildings. Older buildings, on the other hand, are more likely to need significant capacity upgrades to accommodate EV charging onsite, especially for multiple drivers. The motivation to invest in charging infrastructure at these sites, is therefore likely to be especially low. The financial and technical support of local governments will be especially important for these properties.

The vast majority of MUDs in the South Coast Air Basin were built before 1970. This suggests that the costs to install EVSE will be non-trivial at most properties within the region. **Table 3.3** provides the count of MUDs by vintage for each county within the study area. **Appendix 3.3** provides maps that visualize the median MUD vintage at the census tract level for each county in the study area.

Table 3.3. MUDs by Vintage in the South Coast Air Basin

	County	1970 and earlier	1970 to 1989	1990 to 1999	2000 to 2009	2010 and later	Total MUDs
All MUDs	Los Angeles	212,381	27,776	6,515	6,741	3,451	256,864
	Orange	13,843	7,725	741	885	609	23,803
	Riverside	8,275	2,957	718	1,011	149	13,110
	San Bernardino	12,720	3,970	375	699	135	17,899
	Total	**247,219**	**42,428**	**8,349**	**9,336**	**4,344**	**311,676**
	% of Total	**79%**	**14%**	**3%**	**3%**	**1%**	**100%**
MUDs in DACs	Los Angeles	123,820	10,233	2,689	2,773	1,750	141,265
	Orange	3,346	899	21	53	38	4,357
	Riverside	3,560	605	148	207	36	4,556
	San Bernardino	7,794	1,176	92	158	61	9,281
	Total	**138,520**	**12,913**	**2,950**	**3,191**	**1,885**	**159,459**
	% of Total	**87%**	**8%**	**2%**	**2%**	**1%**	**100%**

3.4 MUD Ownership Type

At a high-level, the MUD category can be broken down into two useful categories: income properties and condominiums. In the former, the vast majority of occupants are renters and in the latter, most occupants own their unit. This is a useful delineation in the context of EV charging infrastructure because ownership has a significant impact on which barriers to EVSE installation occupants face.

The first category includes properties in which multiple units are held in common on a single parcel. We term this category *income properties* because, aside from niche ownership sharing arrangements and the occasional owner-occupied unit, the overwhelming majority of units in this category are rentals. Apartment buildings are the archetype of this ownership type, though this category also includes duplexes, triplexes, bungalow courts and other multi-family building types.

Income properties are typically owned by an individual or company that rents units to tenants. Owners are responsible for amenities in common spaces, like parking stalls. Any structural changes to the building are paid for by the owner, who makes investment decisions based on expected returns from increased property value or rental income.

The second category is condominiums (condos) which are multi-unit properties where property ownership is structured so that each unit can be owned individually. As a result, condo ownership resembles that of single-family homes, where most occupants are owners who have financed their homes with traditional mortgages. However, it should be noted, a non-trivial number of condos are renter-occupied.

Most condo buildings physically resemble apartment buildings with common spaces and shared amenities. Non-unit decisions, such as managing common areas, are made collectively by an HOA governing board.

California law permits renters to install EVSE in rented parking stalls at their own expense. However, where property improvements such as panel upgrades or new wiring are required, motivation to do so is weak because renters are unlikely to invest significant sums of money into an improvement on property that they do not own. Moreover, apartment owners and management groups may not view charging equipment as a desirable amenity by which they can attract tenants, and thus are unlikely to be motivated to make such investments for the benefit of their tenants.

Alternatively--especially if the parking space is deeded to the property--condo owners are likely to view electrical upgrades as a property improvement which could positively affect the resale value of their unit. However, if upgrades to the building’s electrical system are needed, there may not be enough interest from other residents to approve such expenses. Thus, while more assistance may be necessary at income properties than at condo to overcome charging barriers, condos still present challenges for EV infrastructure adoption.

Table 3.5 provides a count of MUD units by ownership type for each county within the study area. **Appendix 3.5** provides maps that visualize the percentage of MUD units that are condos at the census tract level for each county in the study area.

Table 3.5. MUD Units by Ownership Type in the South Coast Air Basin

	County	Income Property Units	Condo Units	Total MUD Units
All MUDs	Los Angeles	303,921	1,480,493	1,784,414
	Orange	171,019	156,794	327,813
	Riverside	39,569	17,889	57,458
	San Bernardino	132,138	46,799	178,937
	Total	**646,647**	**1,701,975**	**2,348,622**
	% of Total	**28%**	**72%**	**100%**
MUDs in DACs	Los Angeles	734,300	64,494	799,920
	Orange	37,475	7,554	45,029
	Riverside	12,917	939	13,856
	San Bernardino	67,728	14,694	82,422
	Total	**852,420**	**87,681**	**941,227**
	% of Total	**91%**	**9%**	**100%**

3.5 MUD Unit Value

Early PEV sales indicate that high-income households are purchasing PEVS at higher rates than middle- and low-income households.[42] High-income households tend to purchase new vehicles at faster rates in general and also have more disposable income to spend on new technologies such as PEVs. Given this trend, the value of a MUD unit can serve as an indicator of latent PEV demand because high-income earners can also afford to live in higher-value properties. At these properties, barriers to charging, rather than the initial cost of purchasing a PEV, are likely to play a stronger role in limiting PEV adoption for high value MUD units. For this reason, the relationship between PEV adoption and income is one of the key inputs for the propensity-to-purchase scores that are discussed in **Section 3.6.**

Table 3.5 provides a count of MUDs by average unit value for each county within the study area. **Appendix 3.5** complements this data by visualizing the median MUD unit value at the census tract level for each county. These values are derived from tax assessor's parcel data and are adjusted to reflect the buildings current value rather than the assessed value. [43]

Table 3.5. MUD Units by Average Unit Value in the South Coast Air Basin[44]

	County	≤$49,999	$50,000-$249,999	$250,000-$499,999	$500,000-$999,999	≥$1 million	Total MUDs
All MUDs	Los Angeles	39,150	574,496	678,144	176,011	6,862	1,474,663
	Orange	10,966	106,976	83,418	41,155	17,133	259,648
	Riverside	140,626	38,272	93,419	5,627	13,597	291,541
	San Bernardino	1,985	38,933	98,676	3,612	6,584	149,790
	Total	**192,727**	**758,677**	**953,657**	**226,405**	**44,176**	**2,175,642**
	% of Total	**9%**	**35%**	**44%**	**10%**	**2%**	**100%**
MUDs in DACs	Los Angeles	14,216	182,517	386,506	22,777	3,975	609,991
	Orange	370	12,904	16,199	1,122	5,006	35,601
	Riverside	42,988	3,326	22,278	126	2,005	70,723
	San Bernardino	786	12,627	53,840	311	4,083	71,647
	Total	**58,360**	**211,374**	**478,823**	**24,336**	**15,069**	**787,962**
	% of Total	**7%**	**27%**	**61%**	**3%**	**2%**	**100%**

[42] Sheldon, Tamara L., J.R. DeShazo, Richard T. Carson, and Samuel Krumholz, 2016. *Factors Affecting Plug-in Electric Vehicle Sales in California.*
[43] See **Section 2.1** of **Chapter 2** for more information on the methodology employed here.
[44] Total number of units differs from table 3.1 due to missing value information for some MUD parcels.

3.6 Propensity-to-purchase Scores

To identify MUD households with the highest latent demand for PEVs, we calculated a propensity-to-purchase score for each MUD parcel in the South Coast Air Basin. The score is derived from the historical adoption rate of PEVs in each census tract, the likelihood that PEVs might be purchased by households based on their income, and the distribution of likely incomes for MUD resident households. Considering that a large share of PEVs are purchased by high-income individuals who are likely to live in high-value homes, the propensity to purchase model allocates a greater score to high-value homes.

From a cost-effectiveness perspective, investments in charging infrastructure at MUD properties with high propensity-to-purchase scores are more likely to induce PEV adoption, and result in a greater reduction of gasoline powered VMT. However, from an equity perspective, investing only in these properties could further stratify PEV ownership among low- and high-income households because income is such a sensitive variable in the model. To balance cost-effective and equity considerations, technical and financial assistance programs aimed at PEV adoption should be adjusted in intensity according to the relative strength of a MUD's propensity-to-purchase score.

Properties with lower propensity-to-purchase scores are likely to require more intensive outreach that couples technical and financial assistance for both building owners and renters. Assistance for building owners should be aimed at making their properties PEV-ready. Meanwhile, assistance for renters should be aimed at reducing the cost of purchasing a PEV. If renters live in a zip code that includes a DAC census tract, then they may be eligible for the Replace Your Ride program, which provides qualifying participants with up to $9,500 to scrap their old, high-polluting vehicle for a newer, more fuel-efficient one. [45]

Outreach and assistance to properties with higher propensity-to-purchase scores, on the other hand, can be scaled back in scope. Renters at these properties likely have the means to purchase a PEV, and so bringing down the sticker price of a PEV may do little to motivate them to go electric. Thus, outreach and assistance at these properties should be geared towards building owners to motivate them to invest in charging for their tenants.

Table 3.6 provides a count of MUD buildings within the top 5% of propensity-to-purchase scores for the South Coast Air Basin, broken out by building size. The scores assigned to MUD buildings reflect the score of an average unit within the MUD, so the score of the building is agnostic to the size of the building. Scores were not weighted by building size in order to preserve the variation in PEV latent demand among building occupants. In other words, if the scores were weighted by building size, large buildings (regardless of the latent PEV demand of individual occupants) would systematically score higher than smaller buildings that are home to households with exceptionally high latent PEV demand. Nonetheless, building size is an important factor to consider when investing in charging equipment because of cost-efficiencies associated with installing multiple chargers, as previously discussed. Thus, in the table below, we have grouped properties with high propensity-to-purchase scores into different tiers of building size to further assist with targeting outreach efforts.

Appendix 3.6 provides maps that visualize the number MUDs within the top 5% of propensity-to-purchase scores by census tract. Results are also isolated for DACs, such that the percentile

[45] The Replace Your Ride program can be accessed here: https://xappprod.aqmd.gov/RYR/Home

rankings of propensity-to-purchase scores are based only on the pool of DACs located in MUDs rather than the larger pool of all MUDs.

Table 3.6. MUDs in the 95th Percentile of Propensity-to-purchase Scores[46]

	County	4 to 9 Units	10 to 19 units	20 to 49 units	50+ units	Total MUDs
All MUDs	Los Angeles	3,773	690	371	183	**5,017**
	Orange	435	33	18	11	**497**
	Riverside	83	16	22	49	**170**
	San Bernardino	222	21	16	49	**308**
	Total	**4,513**	**760**	**427**	**292**	**5,992**
MUDs in DACs	Los Angeles	641	87	28	26	782
	Orange	65	9	1	2	77
	Riverside	15	3	1	8	27
	San Bernardino	78	13	7	18	116
	Total	**799**	**112**	**37**	**54**	**1,002**

[46] Duplexes and triplexes were not included in the propensity to purchase analysis. At these properties, residents are often able to charge using available 110/220 volt outlets with portable Level 1 EVSE, so barriers to charging are less likely to be the cause of low-PEV penetration.

CHAPTER 4: Workplace Charging Opportunities

While home charging is the most convenient solution for many PEV commuters, not all PEV drivers are maximizing the electric miles that they could be driving in their PEV. Specifically, PHEV drivers whose round-trip commutes exceed the all-electric range of their vehicles use gasoline to complete commute trips. When those drivers have the opportunity to charge at work, they can effectively increase their all-electric range by as much as double, enabling them to displace miles otherwise driven on their gasoline engines. In turn, displacing gasoline use reduces emissions and improves air quality.

This chapter provides a framework to help planners prioritize financial and technical assistance in support of enhancing workplace charging opportunities. Investing in workplace charging is a daunting task. According to data aggregated by InfoUSA, there are 592,985 workplaces in the South Coast Air Basin.[47] As this chapter details, some of these workplaces are more likely to employ PHEV drivers than others. Additionally, for workplaces that employ PHEV drivers, some of these drivers are more likely to need a charge than others, due to differences in commute lengths and electric ranges. These considerations help to simplify cost-effective decision-making.

Caption: EV charging stations at Sony Pictures Entertainment in Culver City (photo credit: Business Wire)

[47] InfoUSA.

4.1 PHEV Charging Productivity

One common sense strategy for siting EV charging stations is to locate them where PEVs are parked on a regular basis. Workplaces are a prime example of such a location. However, not all PEVs are equal in their need for a charge once arriving at work.

Pure BEVs have ranges of at least 70 miles, with most recent models exceeding 150 miles of range. Moreover, because BEV drivers do not have the option of driving on gasoline they will only commute to workplaces within their range. PHEVs by contrast typically have substantially shorter electric range which is supplemented by a gasoline engine. PHEV drivers can drive on either electricity or gasoline, and therefore can use their vehicles for commutes that exceed their all-electric range. Thus, in the context of workplace charging, it’s important to focus on where PHEVs are likely commuting from because they may not be able to support an entire trip from their home-based charge.

It is important to note that not all PHEVs will require the same level of charge when they arrive at work in order to return home without using gasoline. In fact, PHEVs commuting short distances for work may not need to charge at all. To prioritize workplaces where investments in charging will return the greatest additional eVMT and displace the most gasoline powered miles, planners should target workplace locations where PHEVs are leaving with the lowest state of charge.

Table 4.1 provides a sum of the additional eVMT that we estimated could be accrued for each county within the study area per day. **Appendix 4.1** provides four county level maps that visualize these results by TAZ.

Table 4.1. Additional eVMT Potential in the South Coast Air Basin Per Day

County	eVMT
Los Angeles	318,145
Orange	107,581
Riverside	25,986
San Bernardino	32,628
Total	**484,340**

4.2 Employer Size

It's important to note that our estimates for additional eVMT cannot be disaggregated by specific employment locations. This limitation stems from the regional travel demand model from which our analysis is built, which calculates trip counts at the TAZ level. In the absence of location specific results, employer size can be a helpful metric for determining which employers to target for outreach activities. From a simple probability perspective, a large employer will be more likely to host a PHEV driver in need of charging than a small employer. This probability increases when our estimates for additional eVMT potential are overlaid with employer size. Essentially, the workplace chargers mostly likely to displace gasoline-powered VMT are those located at large employment centers in TAZs that show high potential for additional eVMT.

Table 4.2 provides a count of employers by size for each county within the study area, including a subset of employers located in TAZs that show high potential for additional eVMT. **Appendix 4.2** provides four county level maps that visualize the number of employers that have greater than 25 employees for TAZs that show high potential for additional eVMT.

Table 4.2. Number of Employers by Size

		Number of Employees					
	County	1 to 10	11 to 25	26 to 50	51 to 100	>100	Total
All TAZs	Los Angeles	310,318	31,046	11,694	6,431	4,703	364,193
	Orange	115,669	12,374	4,666	2,612	1,851	137,172
	Riverside	48,404	5,273	2,022	1,101	896	57,696
	San Bernardino	43,607	5,538	2,198	1,165	818	53,326
	Total	**517,999**	**54,231**	**20,580**	**11,309**	**8,268**	**612,387**
	% of Total	**85%**	**9%**	**3%**	**2%**	**1%**	**100%**
TAZs with the top 5% eVMT improvement scores	Los Angeles	86,179	4,0079	8,702	4,909	1,400	141,265
	Orange	1,159	2,351	462	233	152	4,357
	Riverside	4,325	176	20	15	20	4,556
	San Bernardino	5,921	2,731	402	215	12	9,281
	Total	**97,584**	**45,337**	**9,586**	**5,372**	**1,584**	**159,459**
	% of Total	**61%**	**28%**	**6%**	**3%**	**1%**	**100%**

CHAPTER 5: Recommendations for Outreach

PEVs are gaining popularity among new car buyers, but still only make up a small percentage of total new car purchases. Over a five-year period from 2013 to 2018, PEVs rose from 2.5% to 7.8% of total new vehicles sales in California.[48] As discussed throughout this document, charging barriers are stymying consumer demand for PEVs, particularly for those who live in MUDs. Public investment in charging infrastructure is certainly needed to alleviate these barriers, but such investment should occur alongside a thoughtful outreach plan. Without such a plan, financial, and technical assistance programs for PEV charging installations may appear unpopular, and resources may go underutilized, as potential charging site hosts may not fully understand the economic value proposition of PEV charging.

Outreach should be tailored to the level of PEV charging demand in the community. The propensity-to-purchase scores (see **Section 3.6**) and additional eVMT estimates (see **Section 4.2**) can serve as helpful proxies for PEV charging demand. For properties where demand for PEV charging is expected to be high, too little engagement may slow the growth of PEV adoption and may lead to missed opportunities for charging. In contrast, for properties where demand for PEV charging is expected to be low, intensive outreach may not be a cost-effective use of funds if stakeholders do not follow through with installing charging equipment, or the equipment goes unused once installed. Outreach efforts can be conducted along a “ladder of engagement” starting with more passive efforts that grow into more active projects:

Step 1: Informational support. To increase general literacy about PEVs and their charging requirements, local jurisdictions can provide information on vehicle types, potential cost savings from PEV driving, electrical service, and the charging equipment installation process through passive means such as a website, handouts from utilities and local building departments, direct mailings, and e-newsletters.

Step 2: Workshops. Local jurisdictions can host workshops for general or targeted audiences such as drivers, HOAs, property owners/managers, and renters for residential charging; or for employees, employers, or fleet managers for workplace charging.

Step 3: Targeted technical assistance. Planners may want to set up technical assistance programs for potential charging hosts who may be less aware of the physical or procedural aspects of installing charging or who may require more detailed decision support. Actively engaging property owners in the decision-making process or providing information specific to their needs can facilitate the installation of charging and use of PEVs at their site.

Step 4: Demonstration projects. Public agencies and utilities can partner to install charging equipment via demonstration projects at sites that have onsite staff to facilitate peer-to-peer learning opportunities.

Outreach and education should also vary by location type. Provided below is a list of recommendations for conducting outreach and education in MUD and workplace settings, which are the focus of this report because of the complexity involved with motivating property owners at these sites to independently invest in PEV charging.

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[48] As based on Auto Alliance and IHS Markit data provided at the following link: https://evadoption.com/ev-market-share/ev-market-share-california/

Outreach to MUD Sites

What stakeholders should be the target of outreach efforts?

- Property owners of residential MUDs include landlords and HOAs, whose cooperation is key in securing approval for MUD charging
- MUD residents include individual rental tenants and condo owners, who must understand their rights and responsibilities around PEV charging in MUDs
- Developers of MUD properties, who may consider installing chargers or PEV-ready wiring in exchange for density bonuses or other benefits

What should outreach efforts address?

- Charging rights for PEV drivers who live in MUDs. California law prohibits HOAs from unreasonably preventing the installation of PEV charging equipment.
- Incentives for charging equipment installation and special discounts on electricity used for charging in MUDs
- Economies of scale in MUD charging
- How MUD property owners might price charging services to recover costs

Outreach to Workplace Sites

What stakeholders should be the target of outreach efforts?

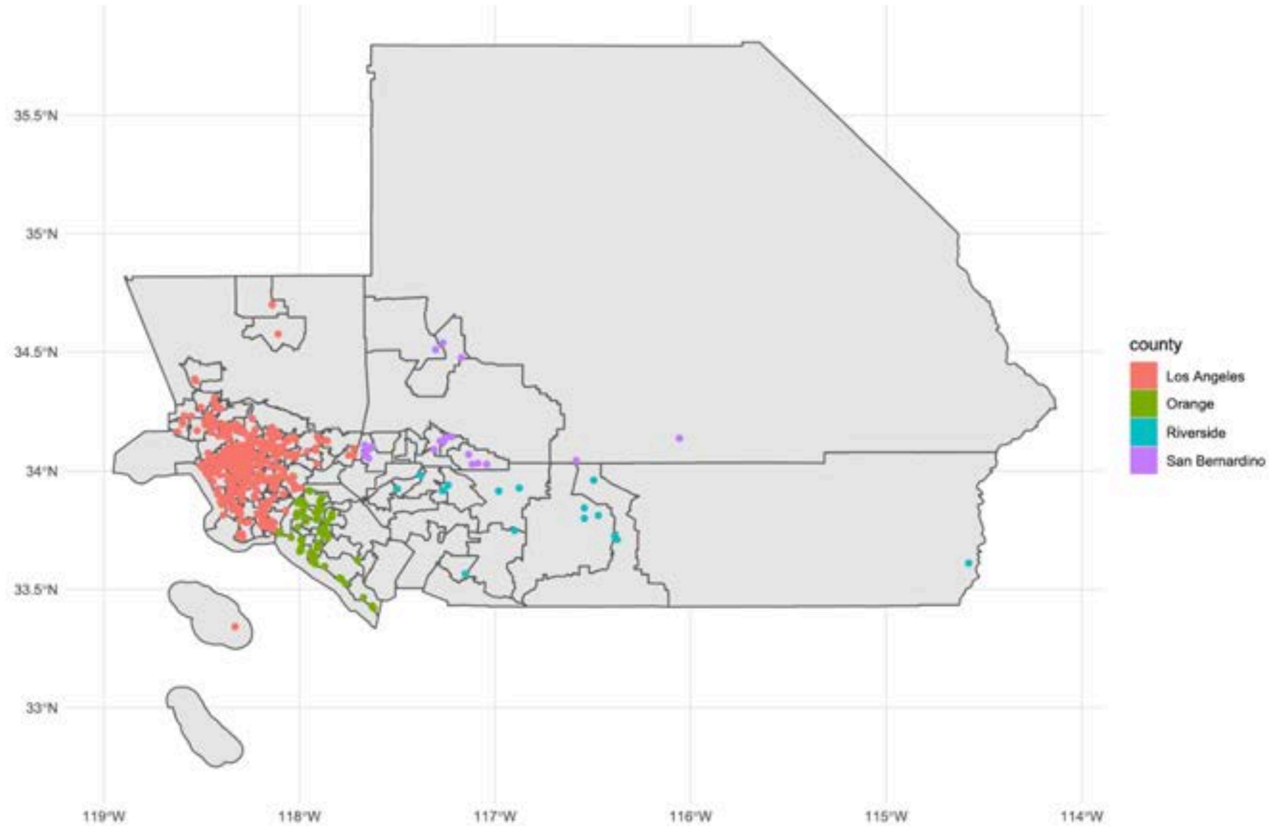
- Large employers
- Commercial property owners with employer tenants
- Parking management companies that operate workplace parking areas

What should outreach efforts address?

- Whether Level 1 or 2 charging can meet the needs of employee PEVs
- How employers or property owners might price charging services to recover costs
- Scheduling policies to maximize the use of charging equipment (e.g., powering fleet or public PEVs when not powering employee PEVs)
- Access control, especially when employee, fleet, and public vehicles need to share and coordinate limited charging resources

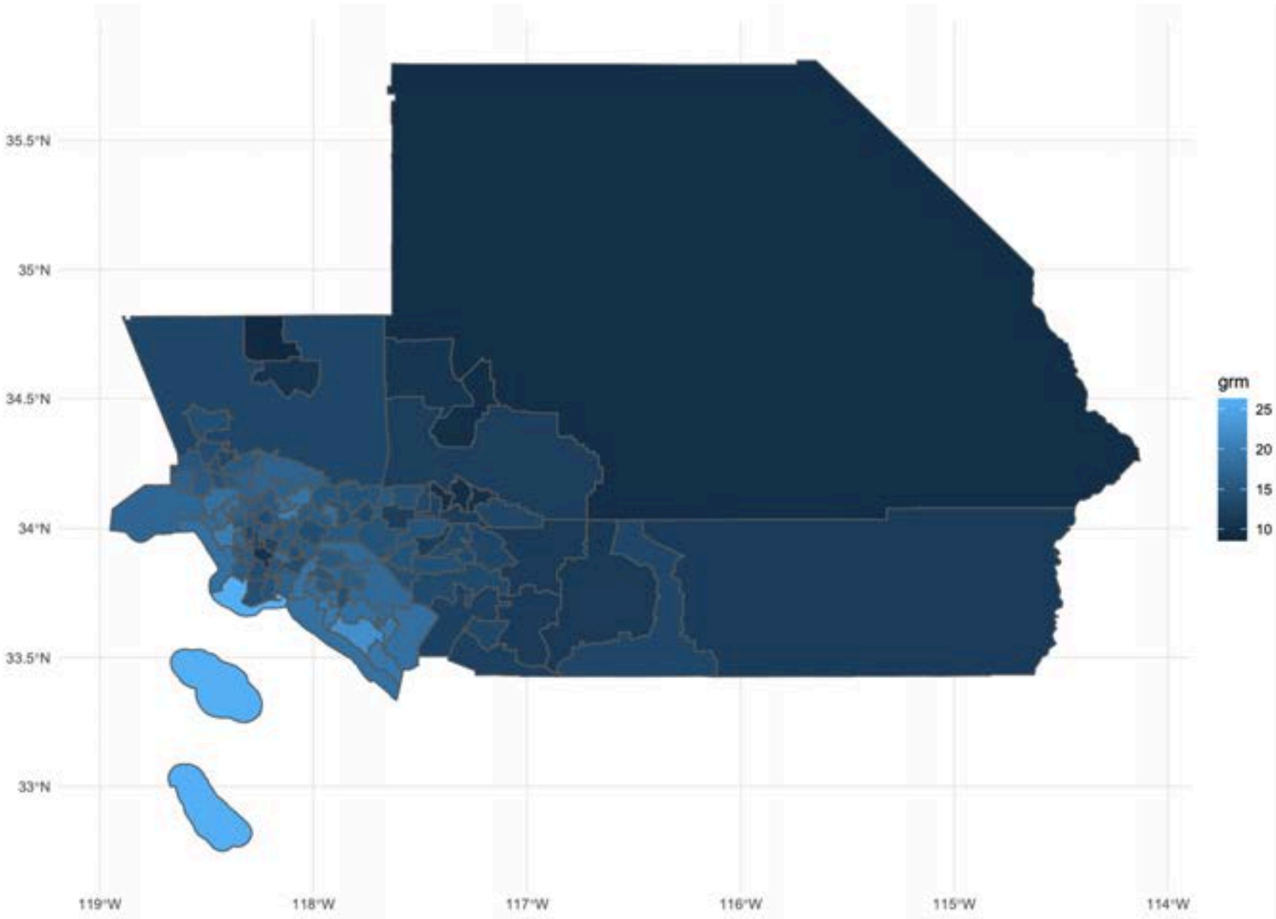
APPENDIX

Appendix 1 - Sample of Commercial Listings for Gross Rent Multiplier Analysis



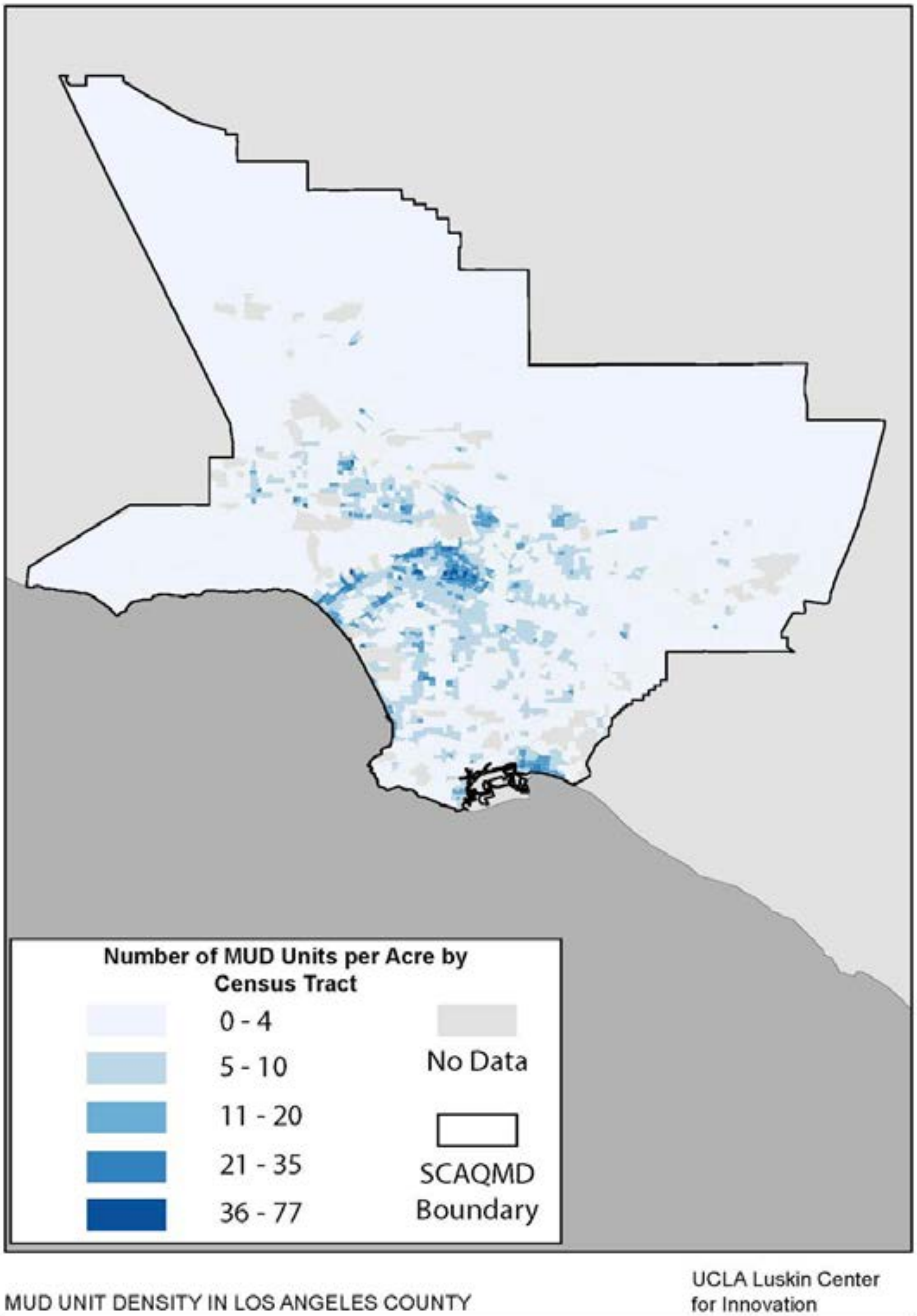
The geographic boundaries displayed here are Public Use Microdata Areas (PUMAs), which are statistical geographic areas defined by the U.S. Census for the dissemination of public use microdata. PUMAs are built along census tract and county lines and contain at least 100,000 people.

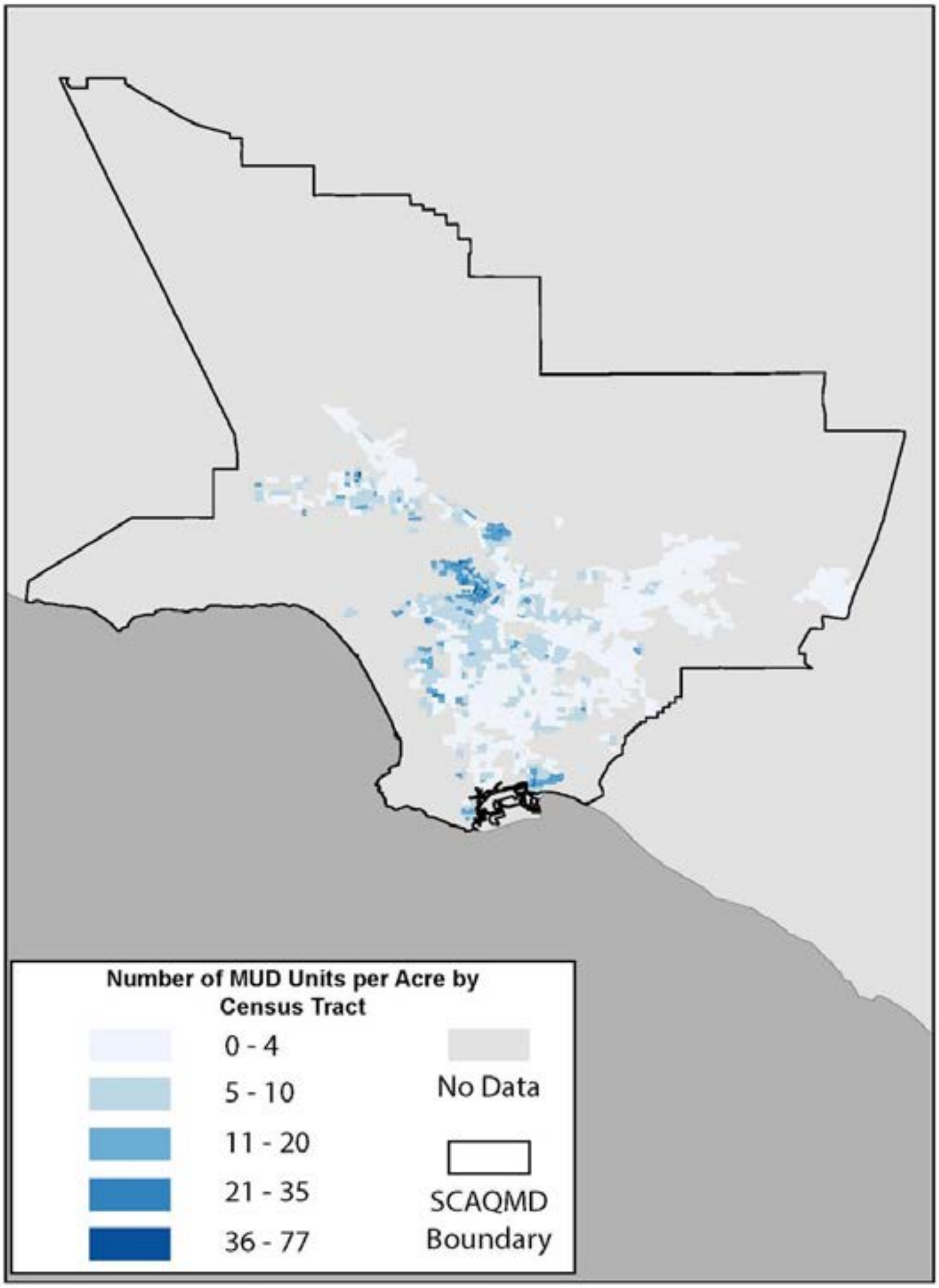
Appendix 2 - Average Gross Rent Multiplier per Public Use Microdata Area



The geographic boundaries displayed here are Public Use Microdata Areas (PUMAs), which are statistical geographic areas defined by the U.S. Census for the dissemination of public use microdata. PUMAs are built along census tract and county lines and contain at least 100,000 people.

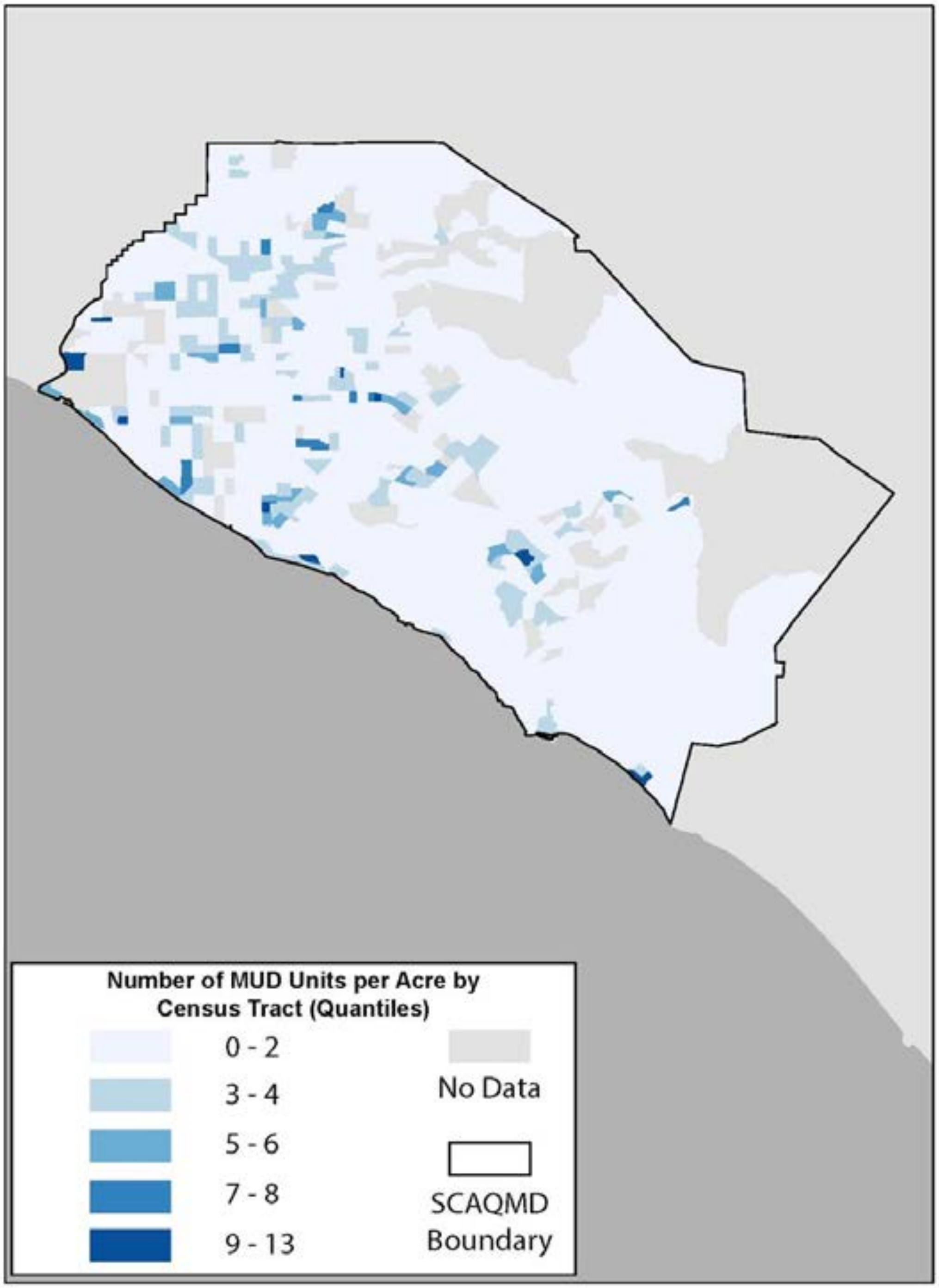
Appendix 3.1 - MUD Density by County - Maps





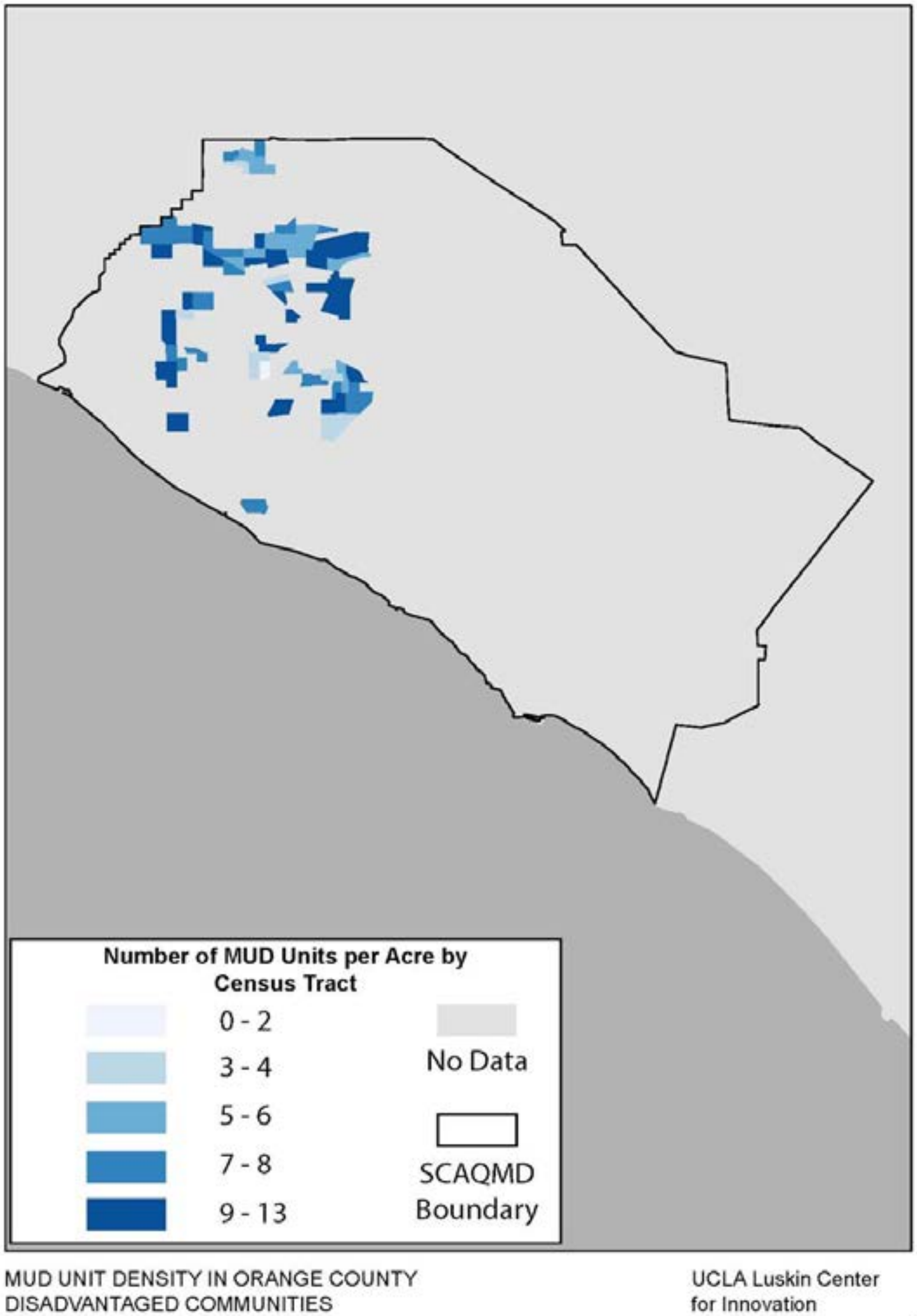
MUD UNIT DENSITY IN LOS ANGELES COUNTY DISADVANTAGED COMMUNITIES

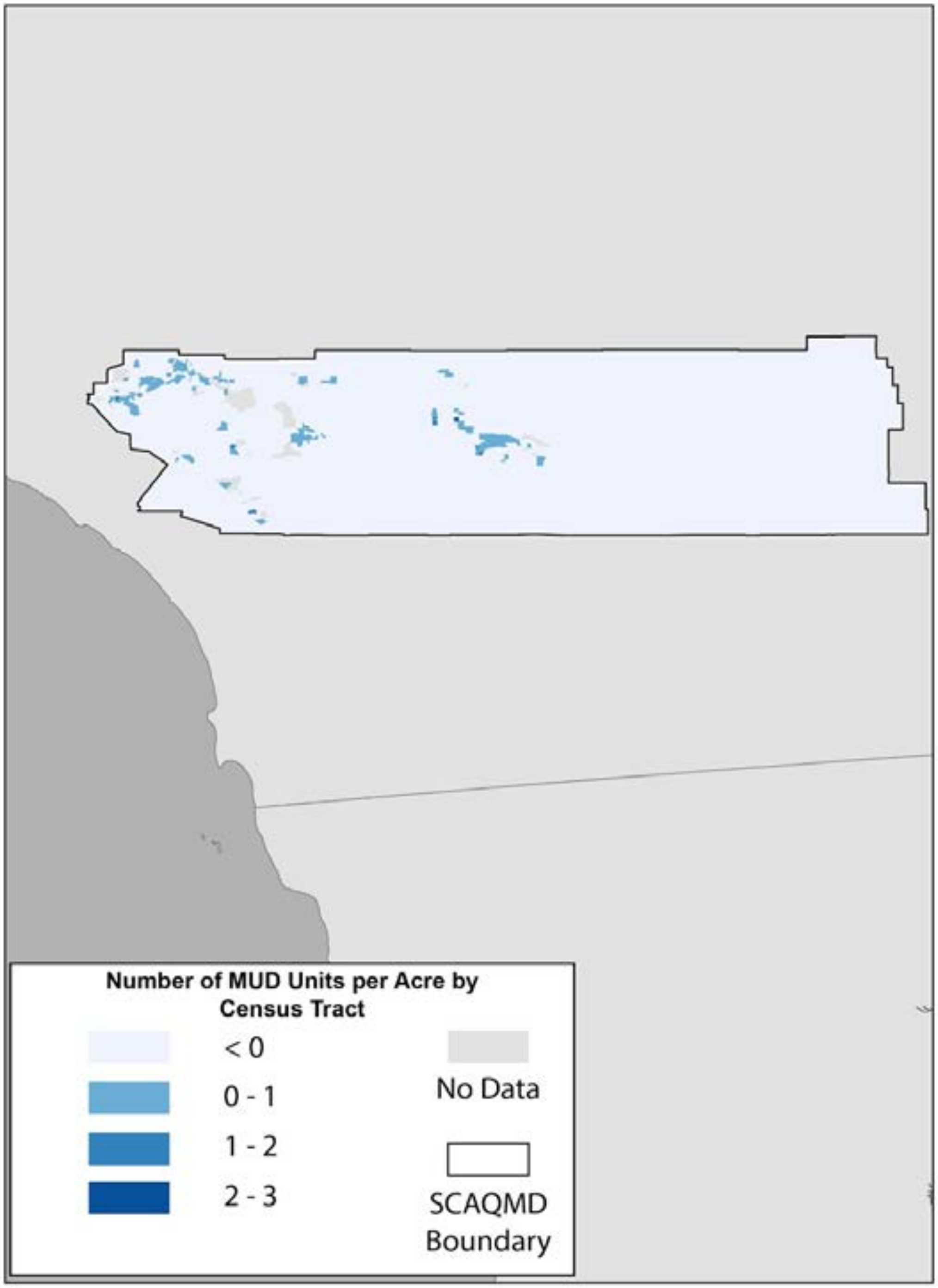
UCLA Luskin Center for Innovation



MUD UNIT DENSITY IN ORANGE COUNTY

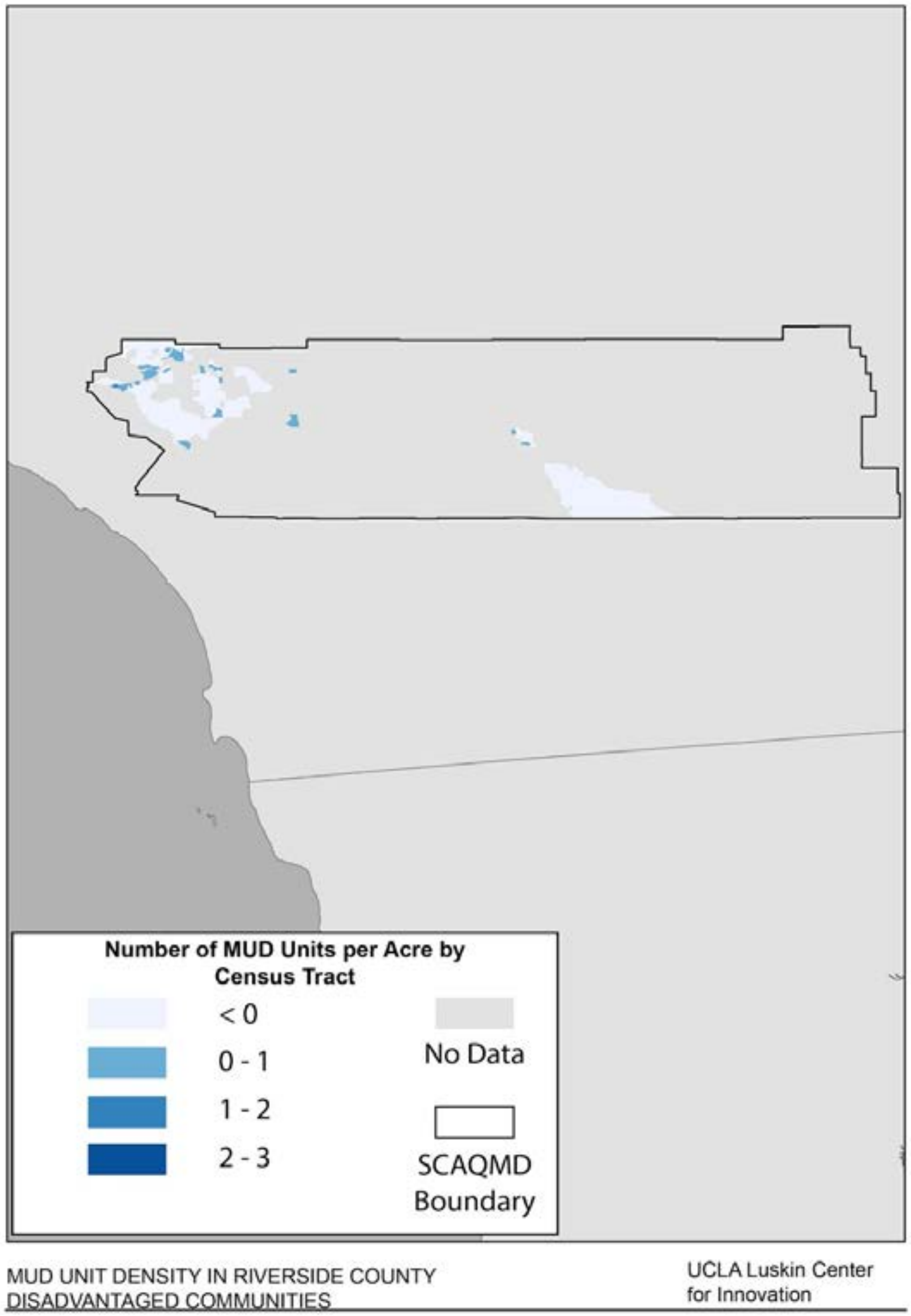
UCLA Luskin Center for Innovation


Number of MUD Units per Acre by Census Tract
0 - 2
3 - 4
5 - 6
7 - 8
9 - 13
No Data
SCAQMD Boundary
MUD UNIT DENSITY IN ORANGE COUNTY DISADVANTAGED COMMUNITIES
UCLA Luskin Center for Innovation



MUD UNIT DENSITY IN RIVERSIDE COUNTY

UCLA Luskin Center for Innovation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0 - 1
1 - 2
2 - 3
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SCAQMD Boundary
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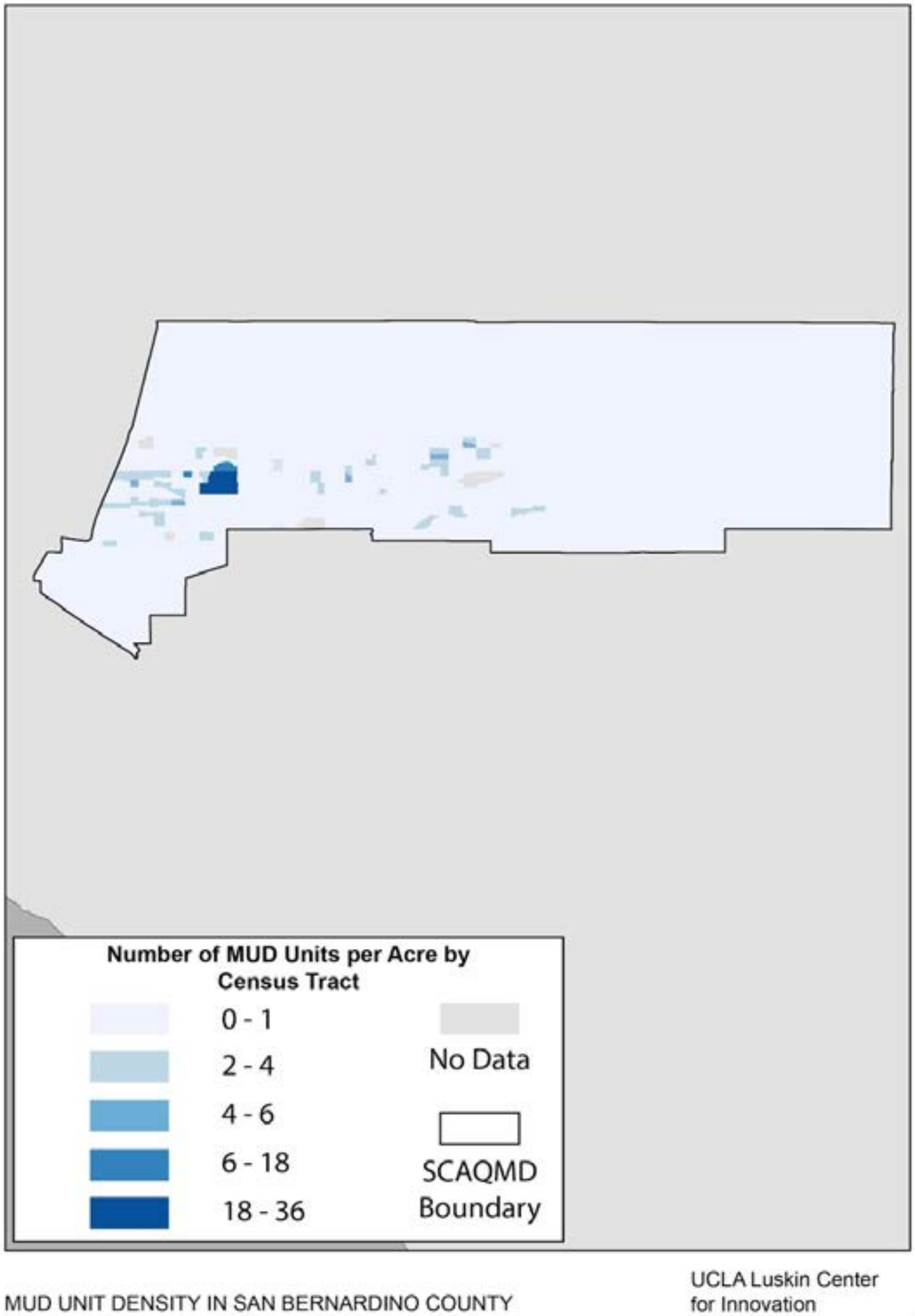
UCLA Luskin Center for Innovation


Number of MUD Units per Acre by Census Tract
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4 - 6
6 - 18
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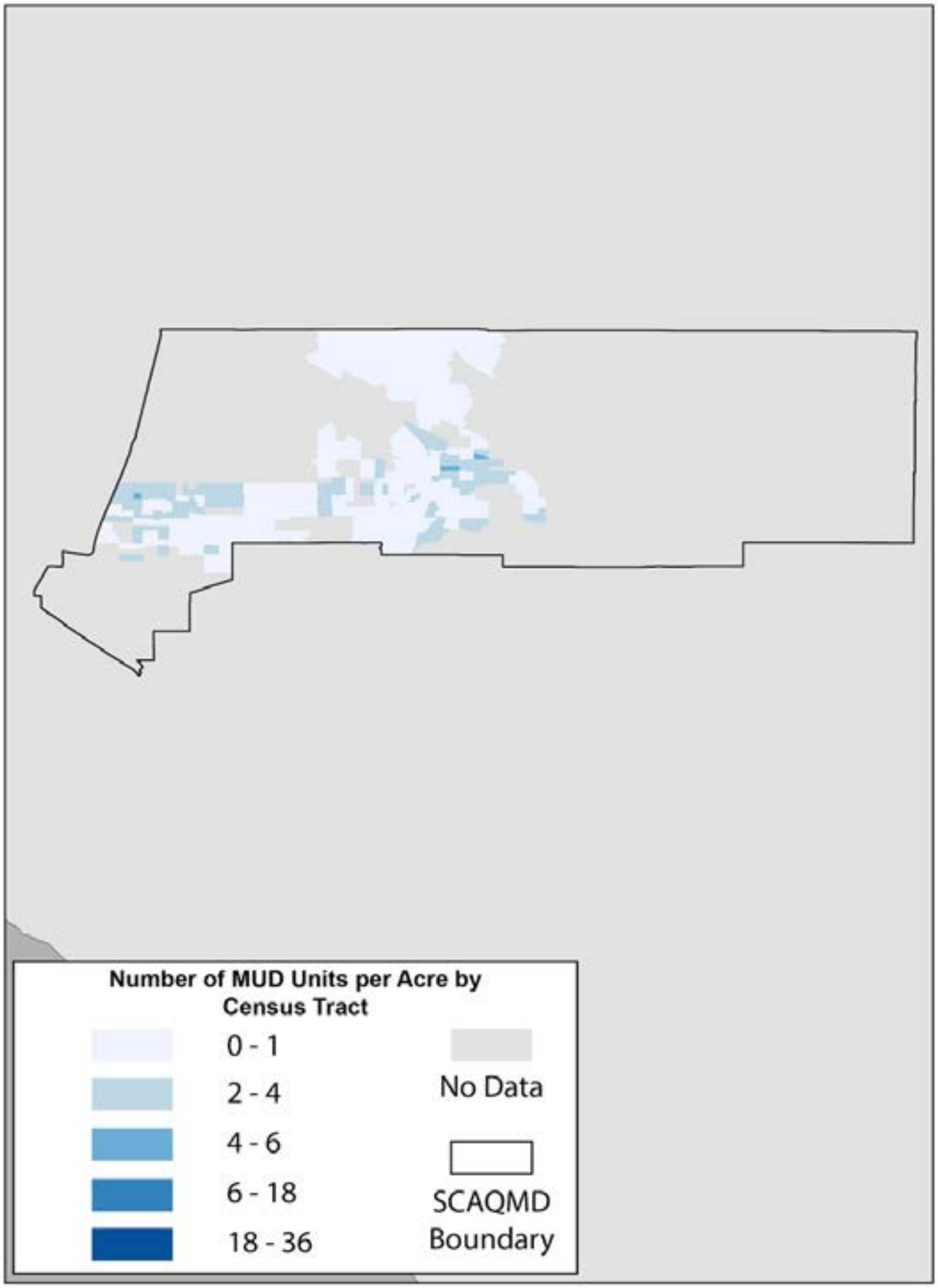
SCAQMD Boundary
MUD UNIT DENSITY IN SAN BERNARDINO COUNTY
UCLA Luskin Center for Innovation



MUD UNIT DENSITY IN SAN BERNARDINO COUNTY DISADVANTAGED COMMUNITIES

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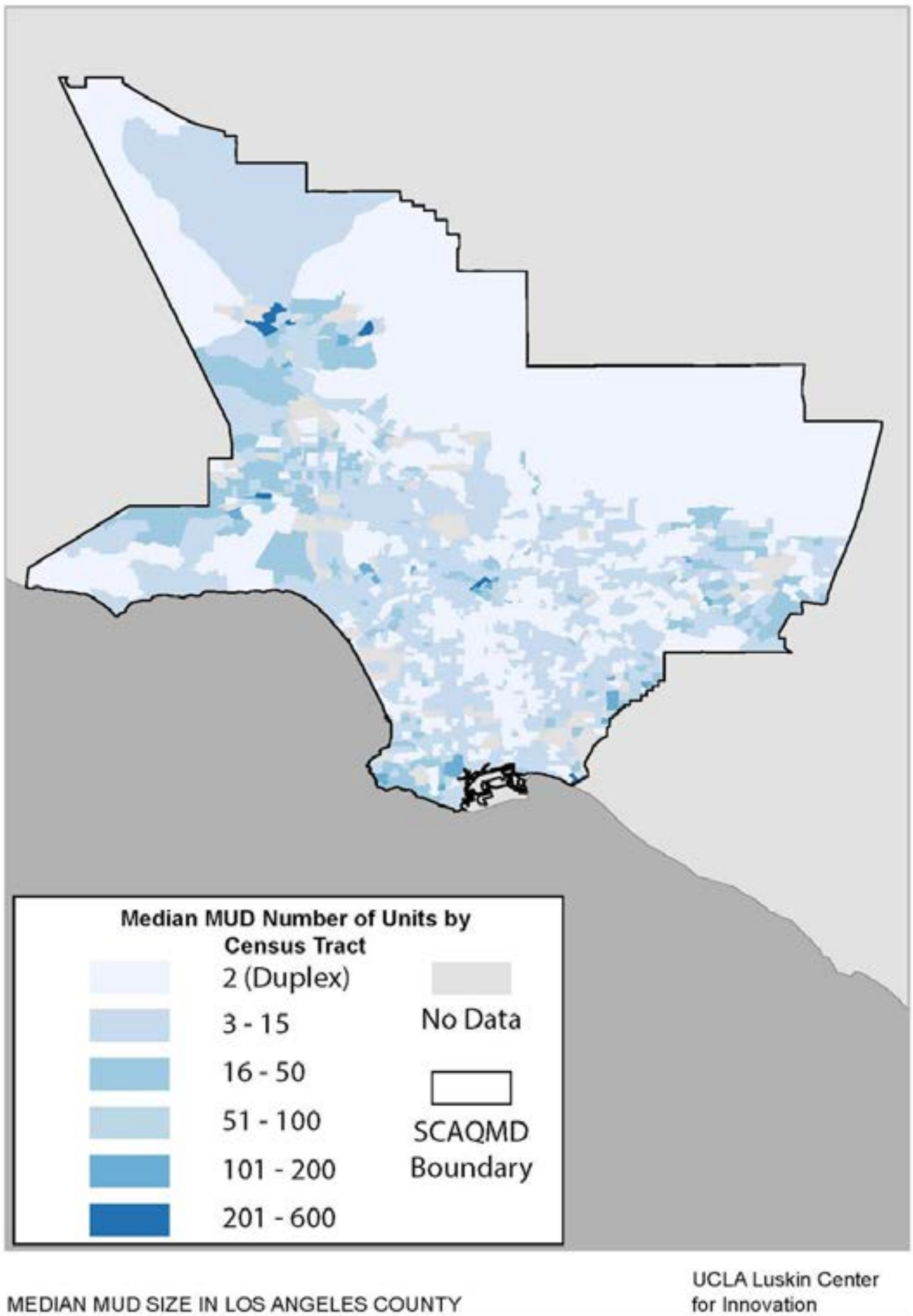
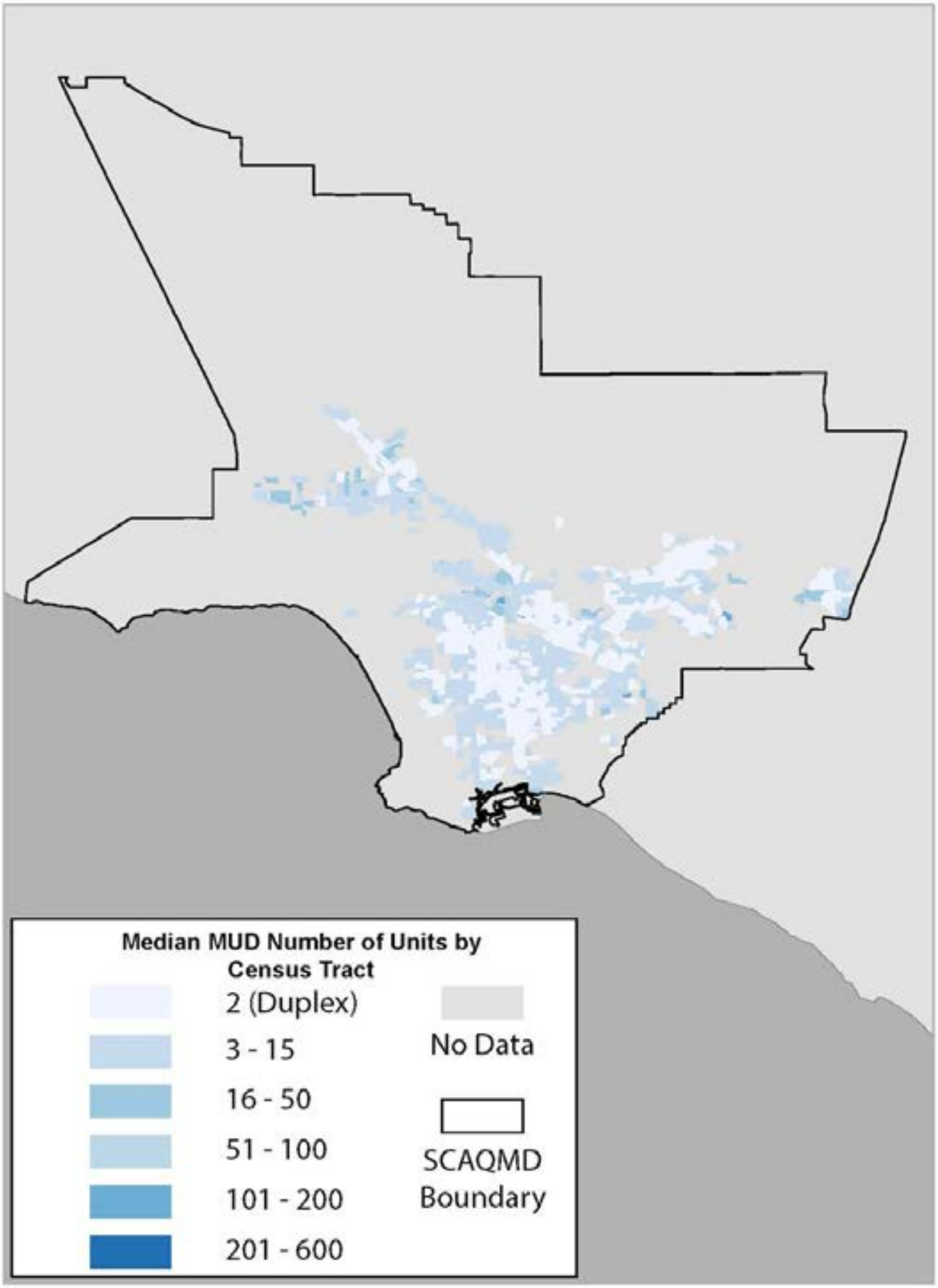
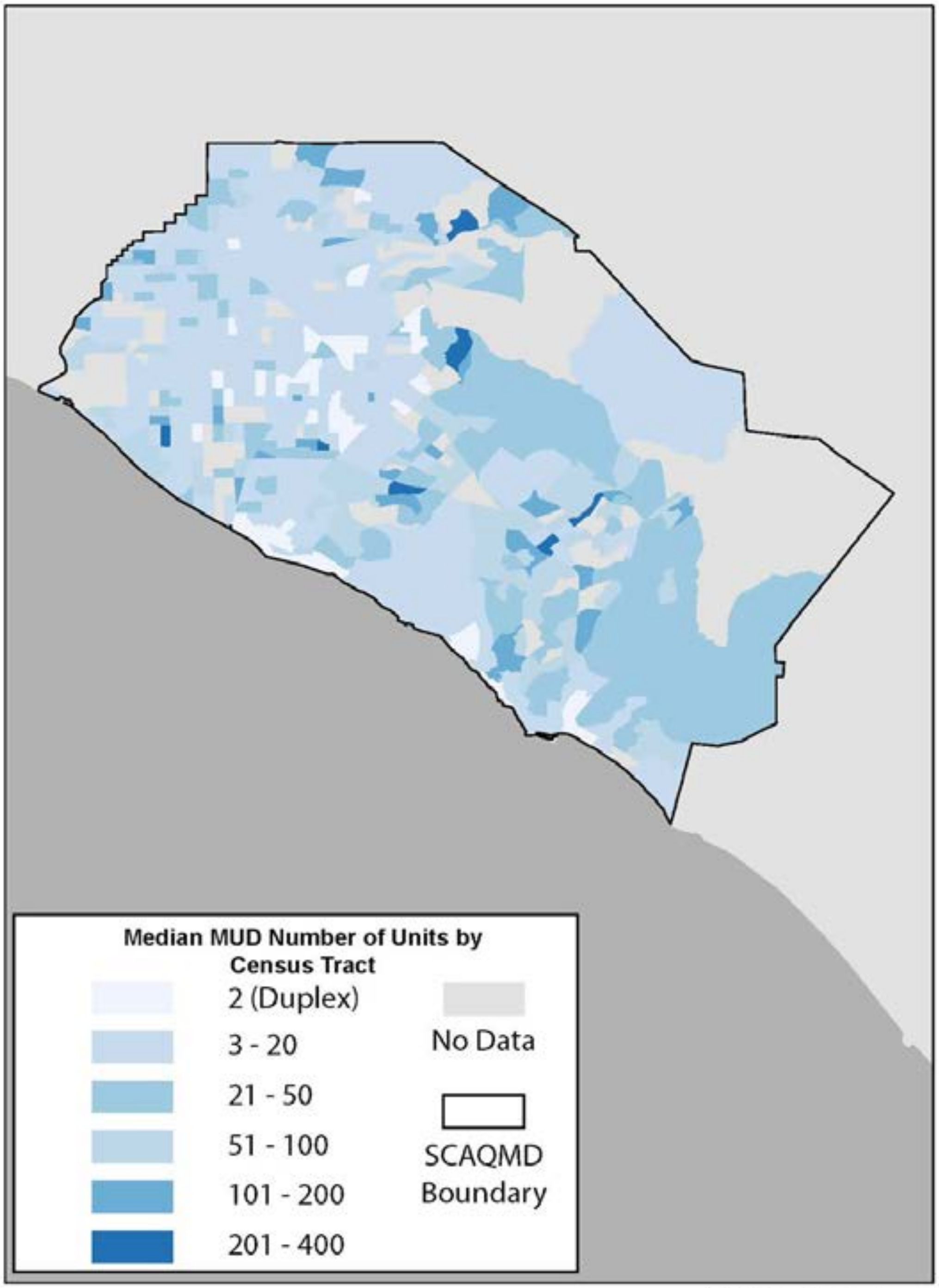
Appendix 3.2 - MUD Building Size - Maps





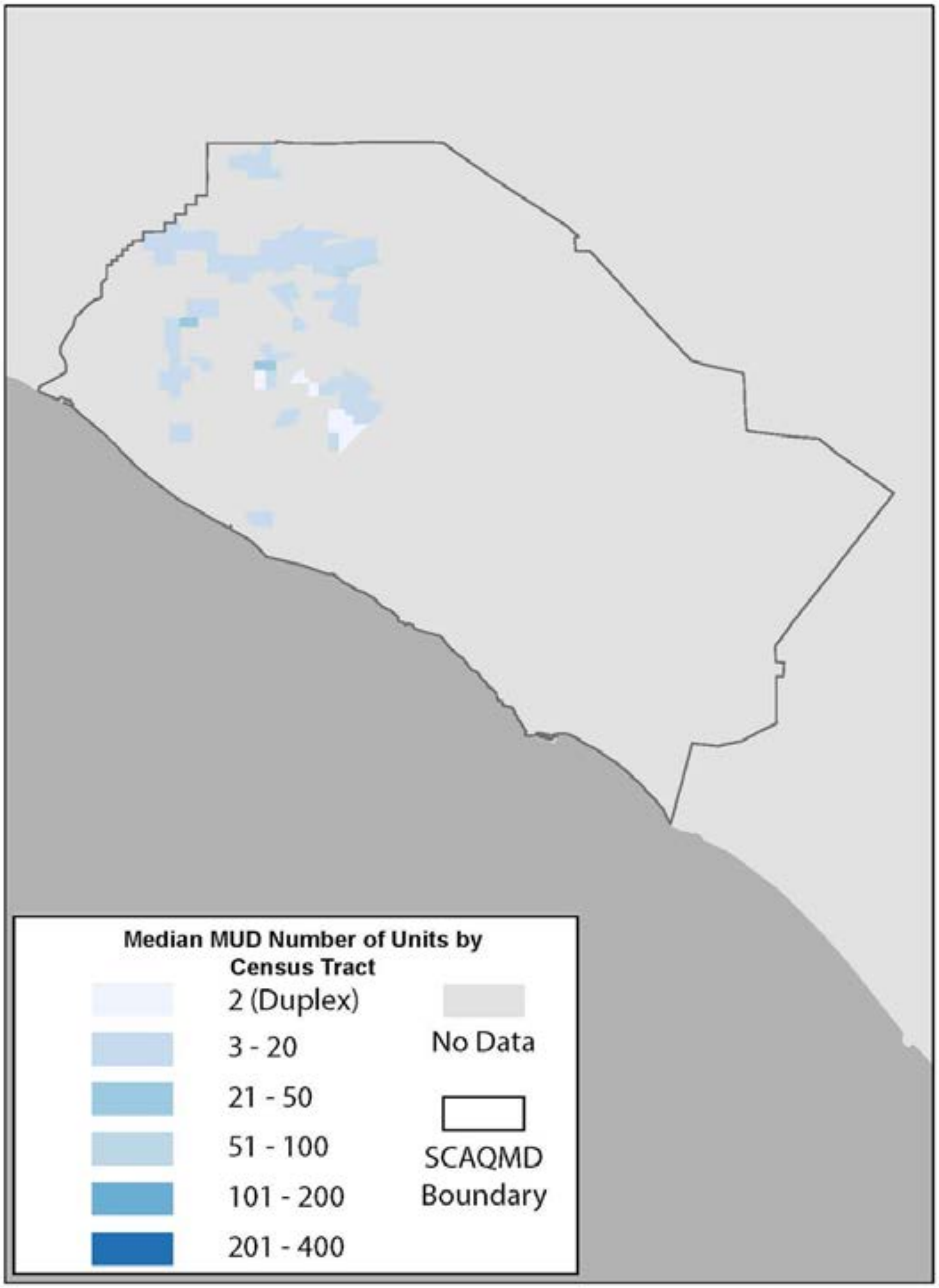
MEDIAN MUD SIZE IN LOS ANGELES COUNTY DISADVANTAGED COMMUNITIES

UCLA Luskin Center for Innovation



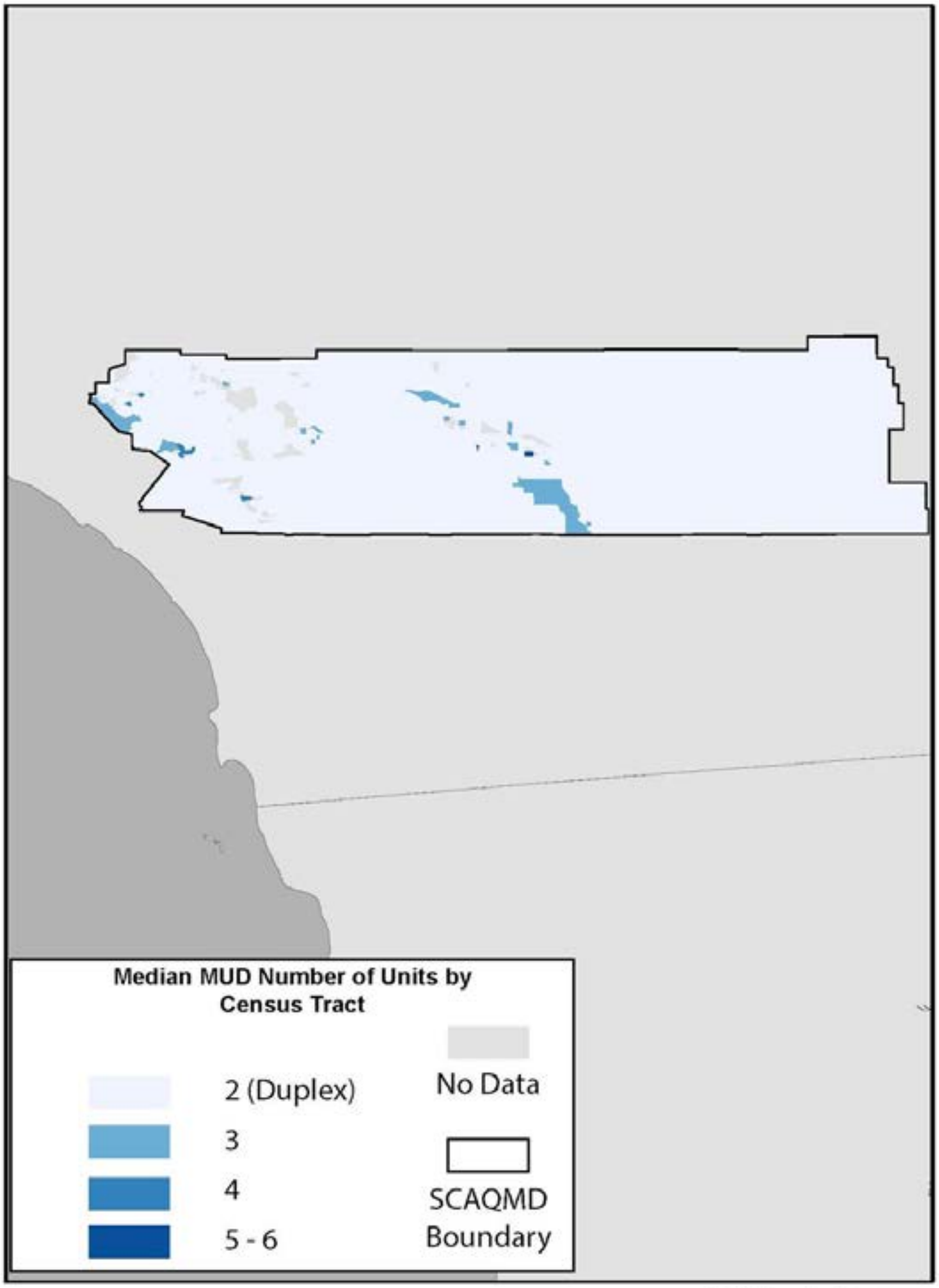
MEDIAN MUD SIZE IN ORANGE COUNTY

UCLA Luskin Center for Innovation



MEDIAN MUD SIZE IN ORANGE COUNTY DISADVANTAGED COMMUNITIES

UCLA Luskin Center for Innovation



MEDIAN MUD SIZE IN RIVERSIDE COUNTY

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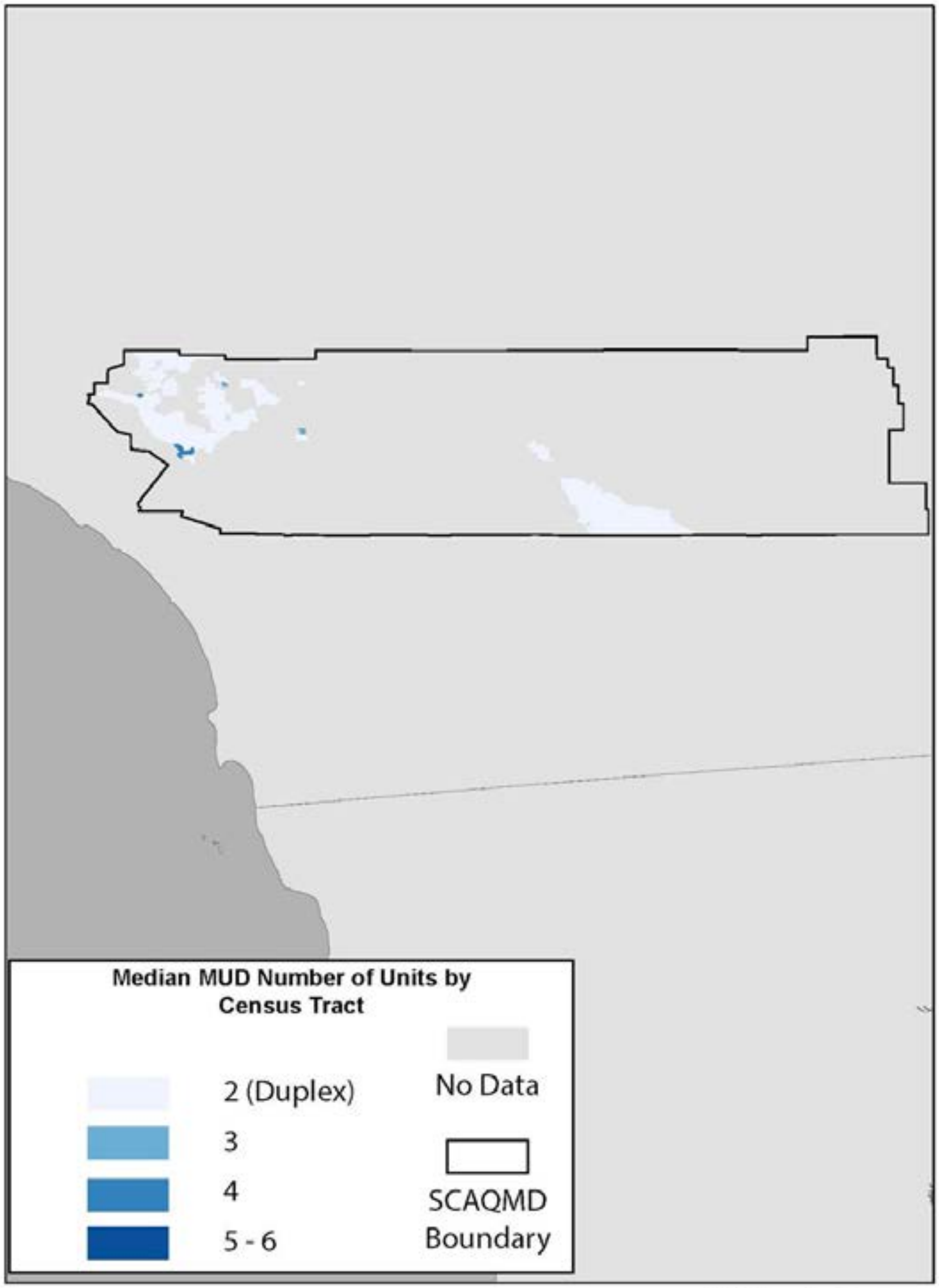
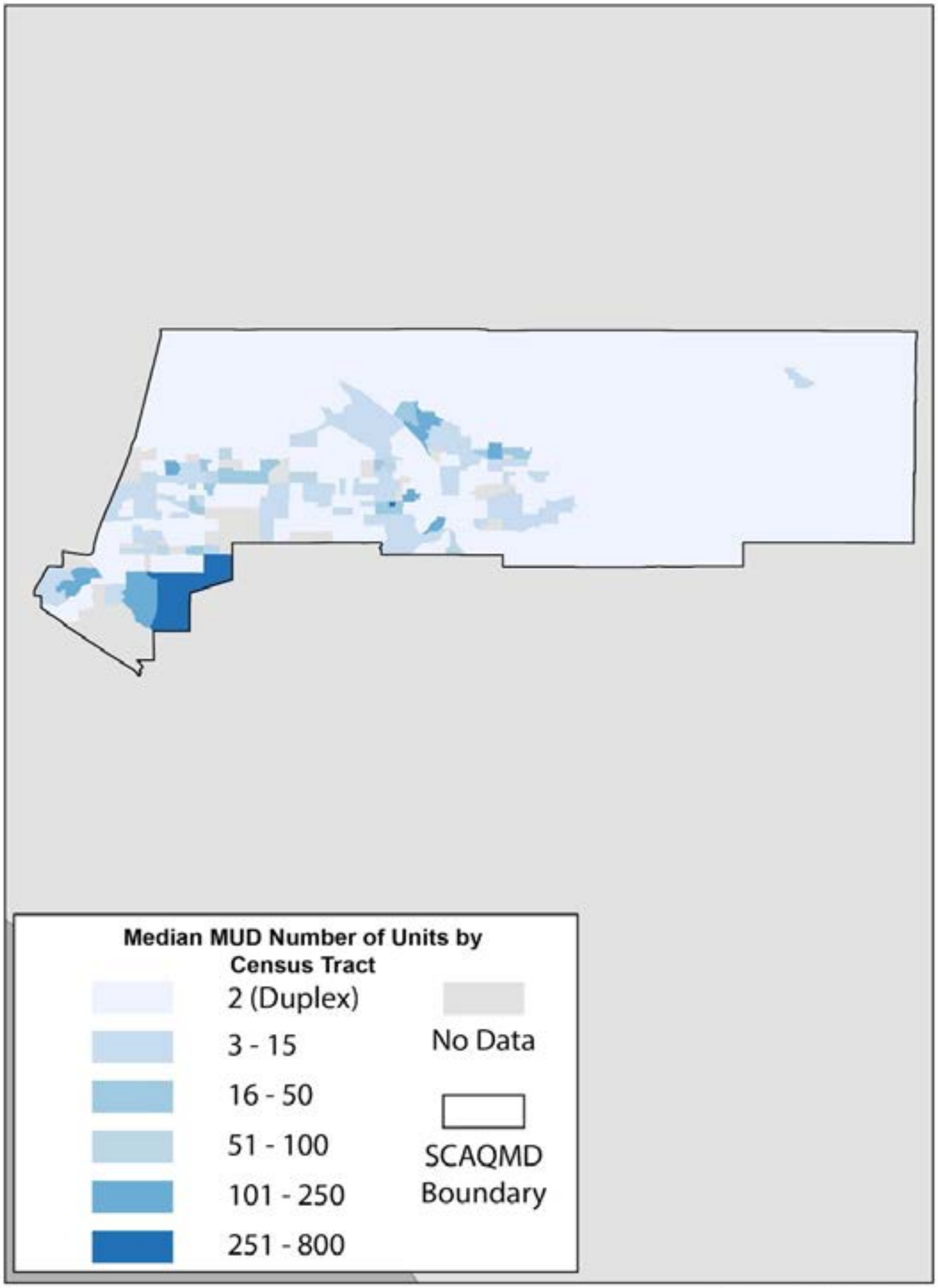
for Innovation



MEDIAN MUD SIZE IN RIVERSIDE COUNTY DISADVANTAGED COMMUNITIES

UCLA Luskin Center for Innovation



MEDIAN MUD SIZE IN SAN BERNARDINO COUNTY

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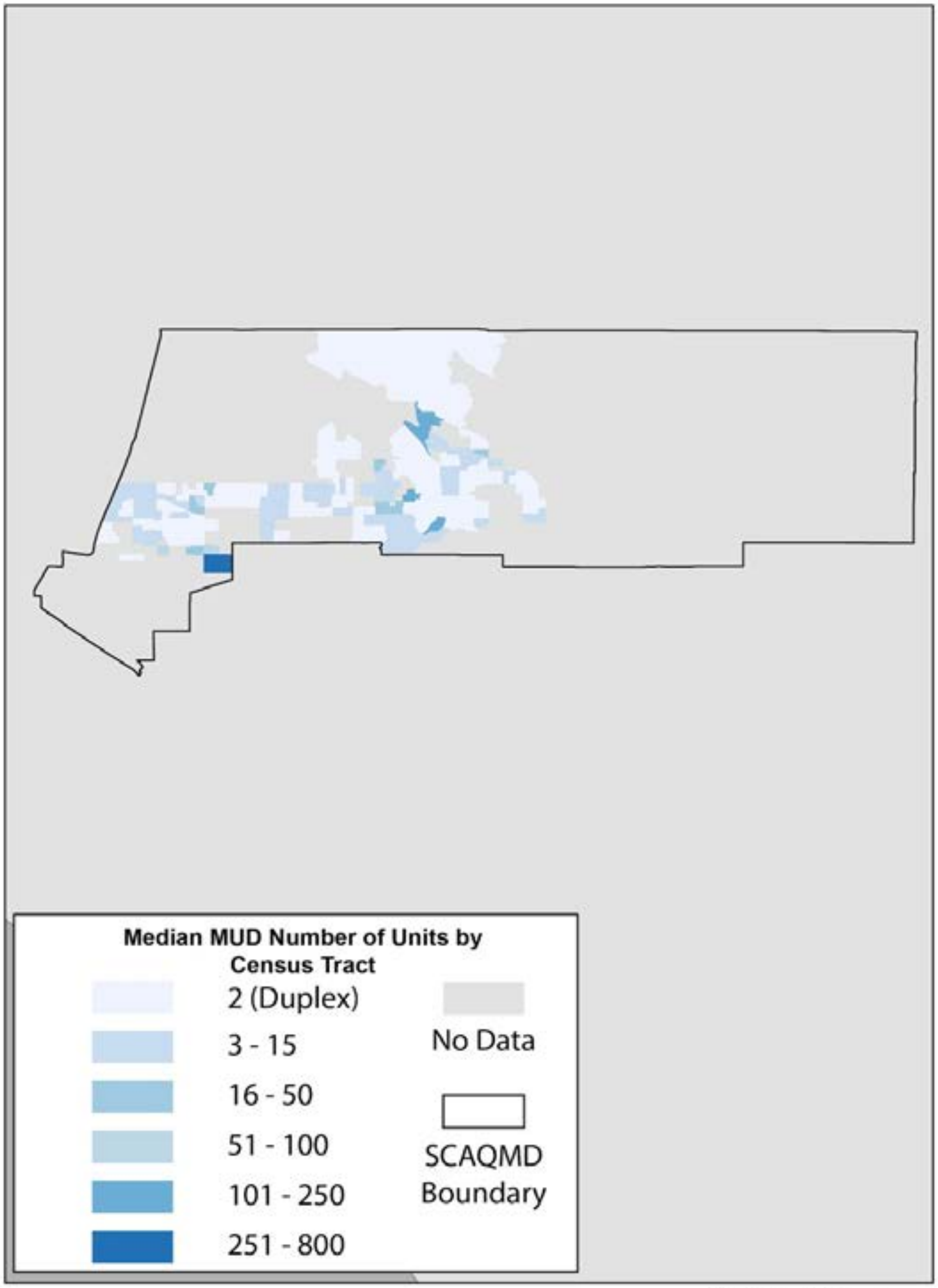

MEDIAN MUD SIZE IN SAN BERNARDINO COUNTY DISADVANTAGED COMMUNITIES

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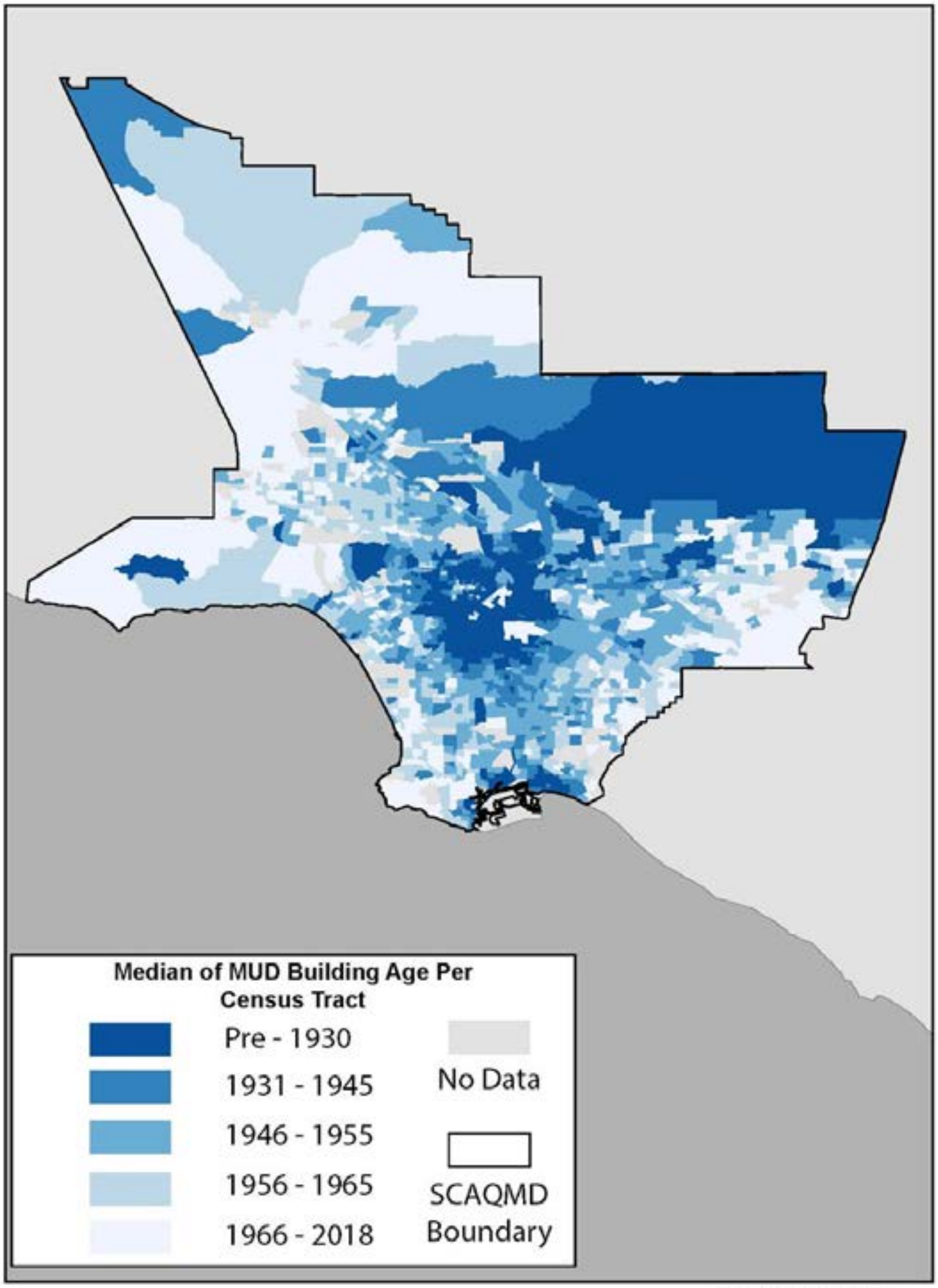
Appendix 3.3 - MUD Vintage - Maps



MEDIAN MUD AGE IN LOS ANGELES COUNTY

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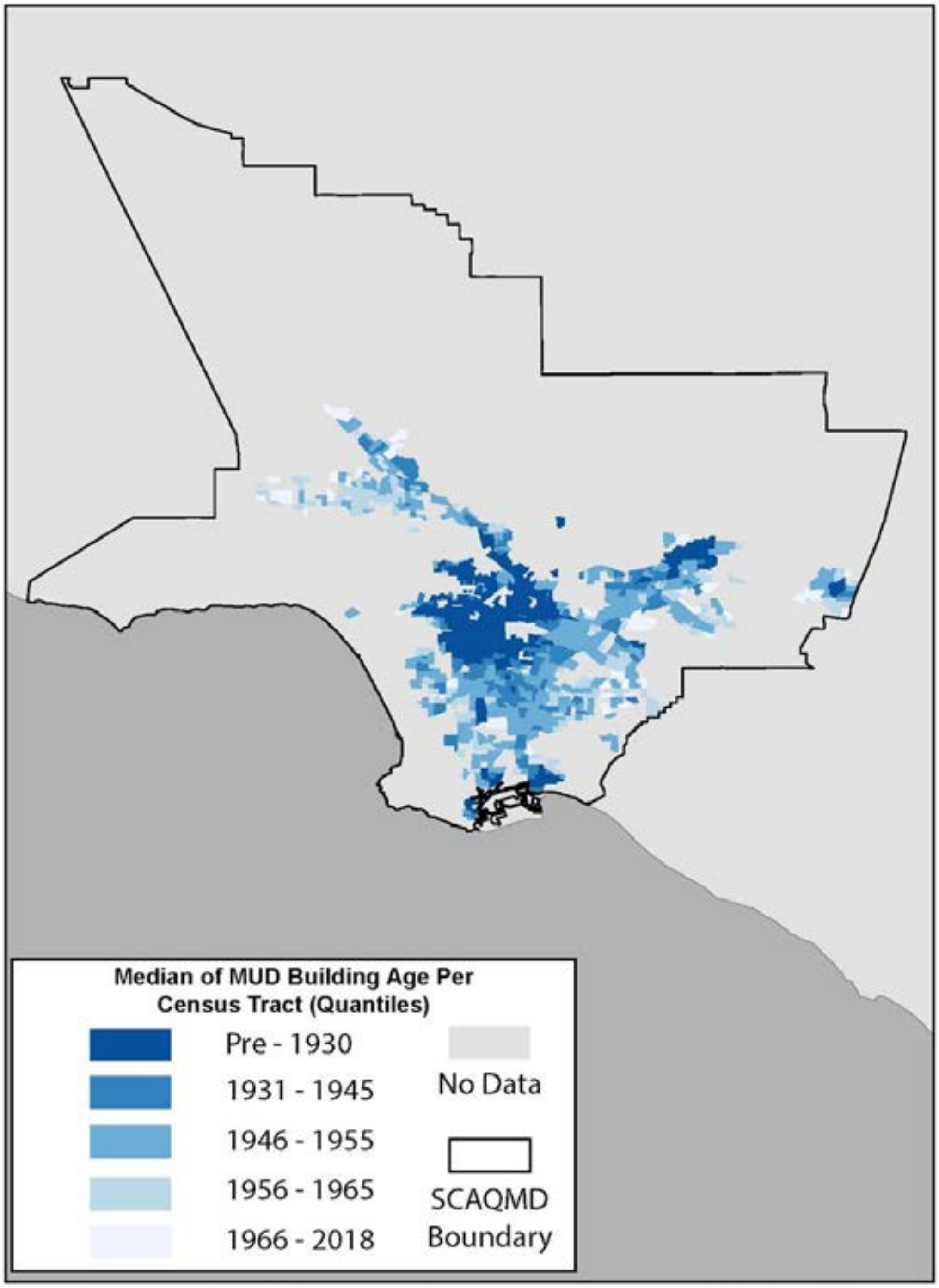
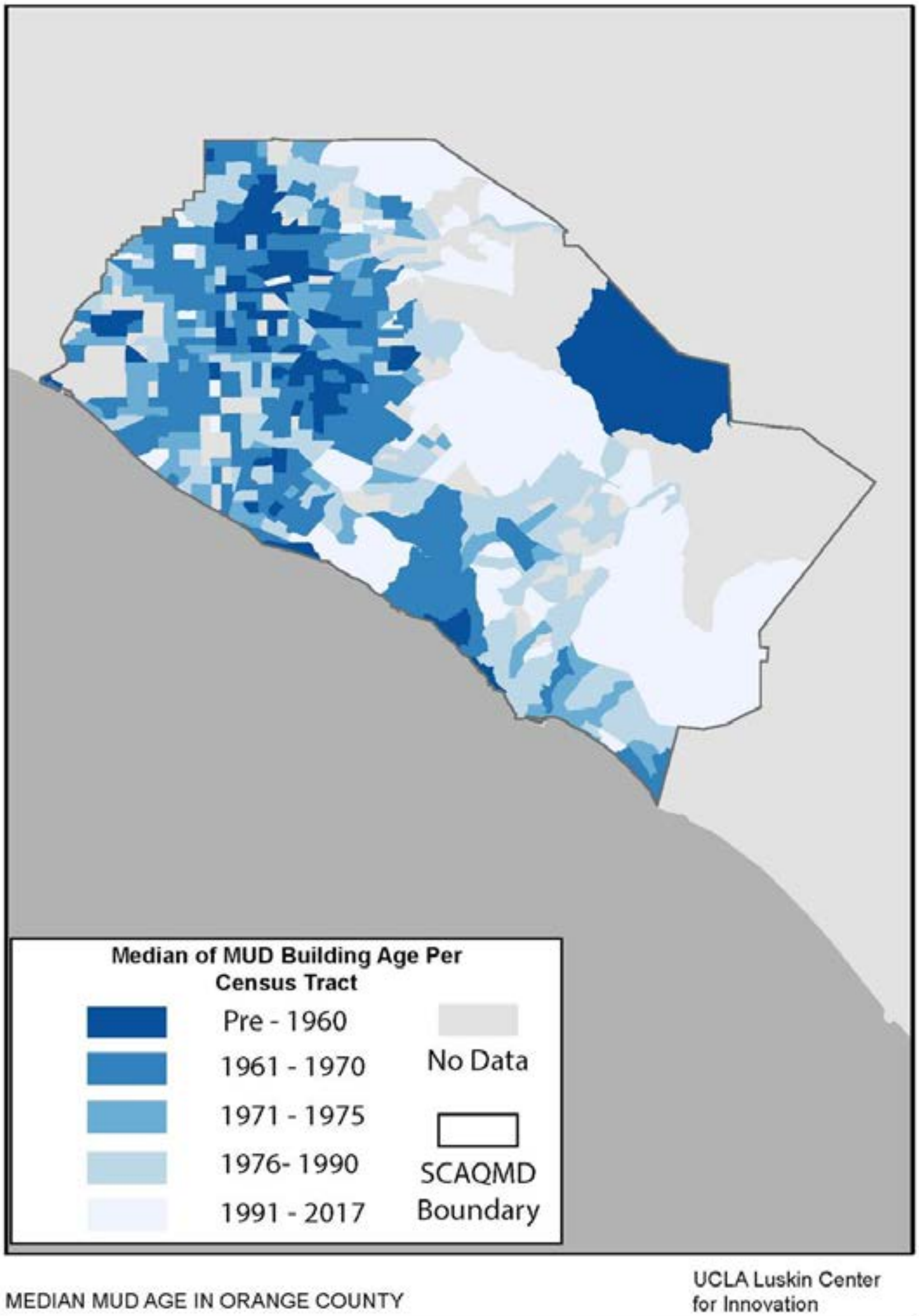


MEDIAN MUD AGE IN LOS ANGELES COUNTY DISADVANTAGED COMMUNITIES

UCLA Luskin Center for Innovation


Median of MUD Building Age Per Census Tract
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1971 - 1975
1976- 1990
1991 - 2017
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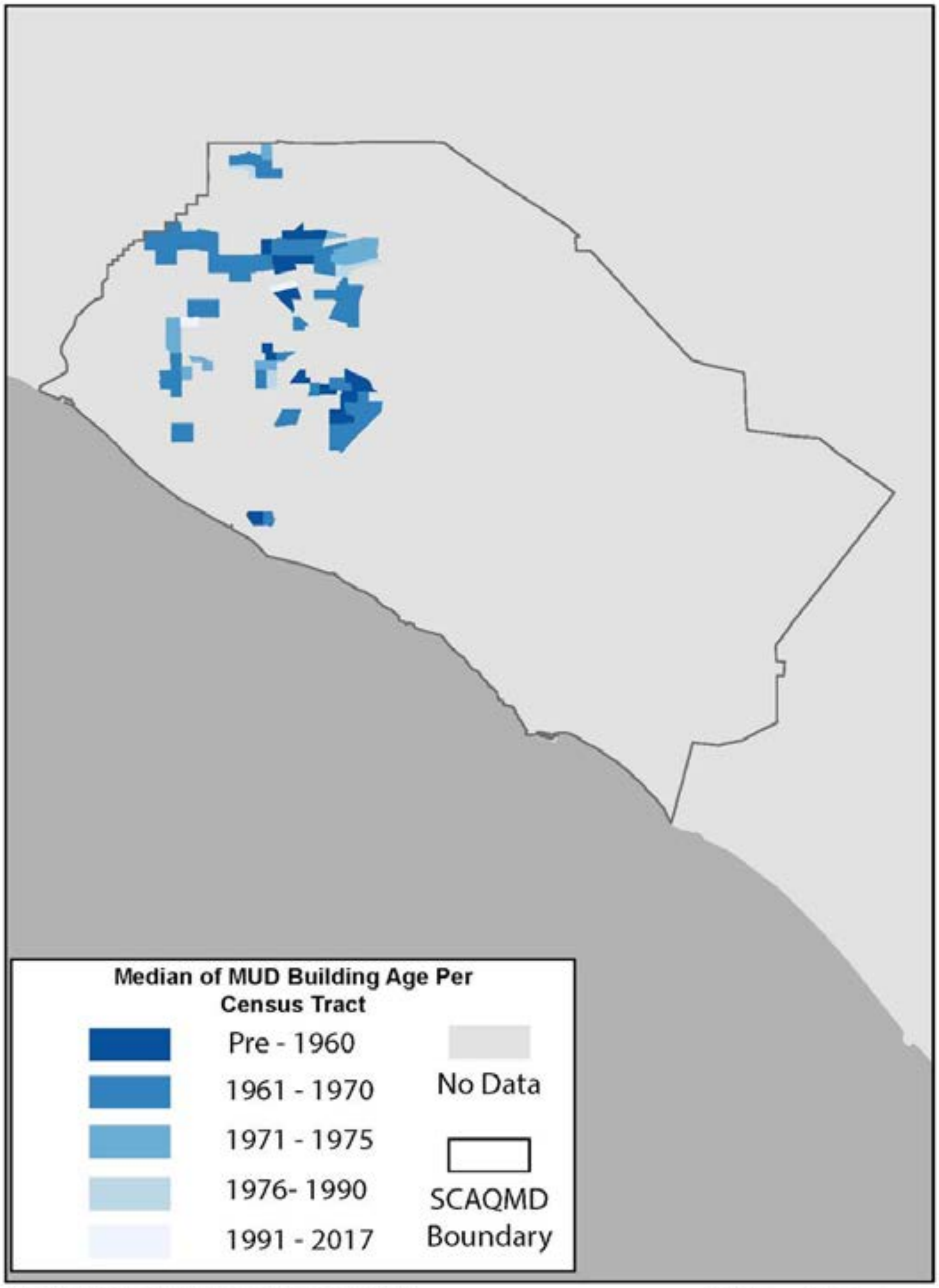
SCAQMD Boundary
MEDIAN MUD AGE IN ORANGE COUNTY
UCLA Luskin Center for Innovation



MEDIAN MUD AGE IN ORANGE COUNTY DISADVANTAGED COMMUNITIES

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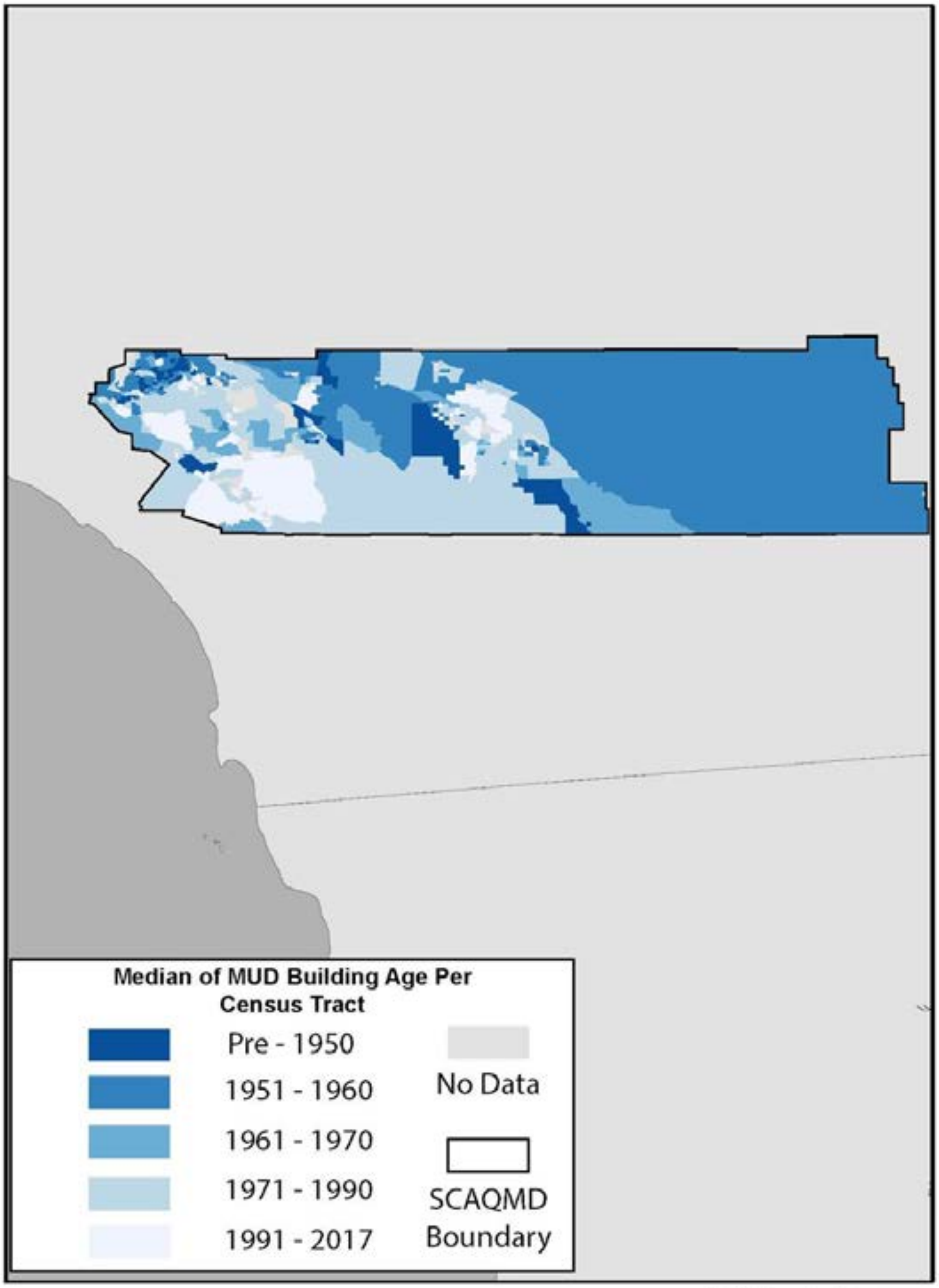

MEDIAN MUD AGE IN RIVERSIDE COUNTY

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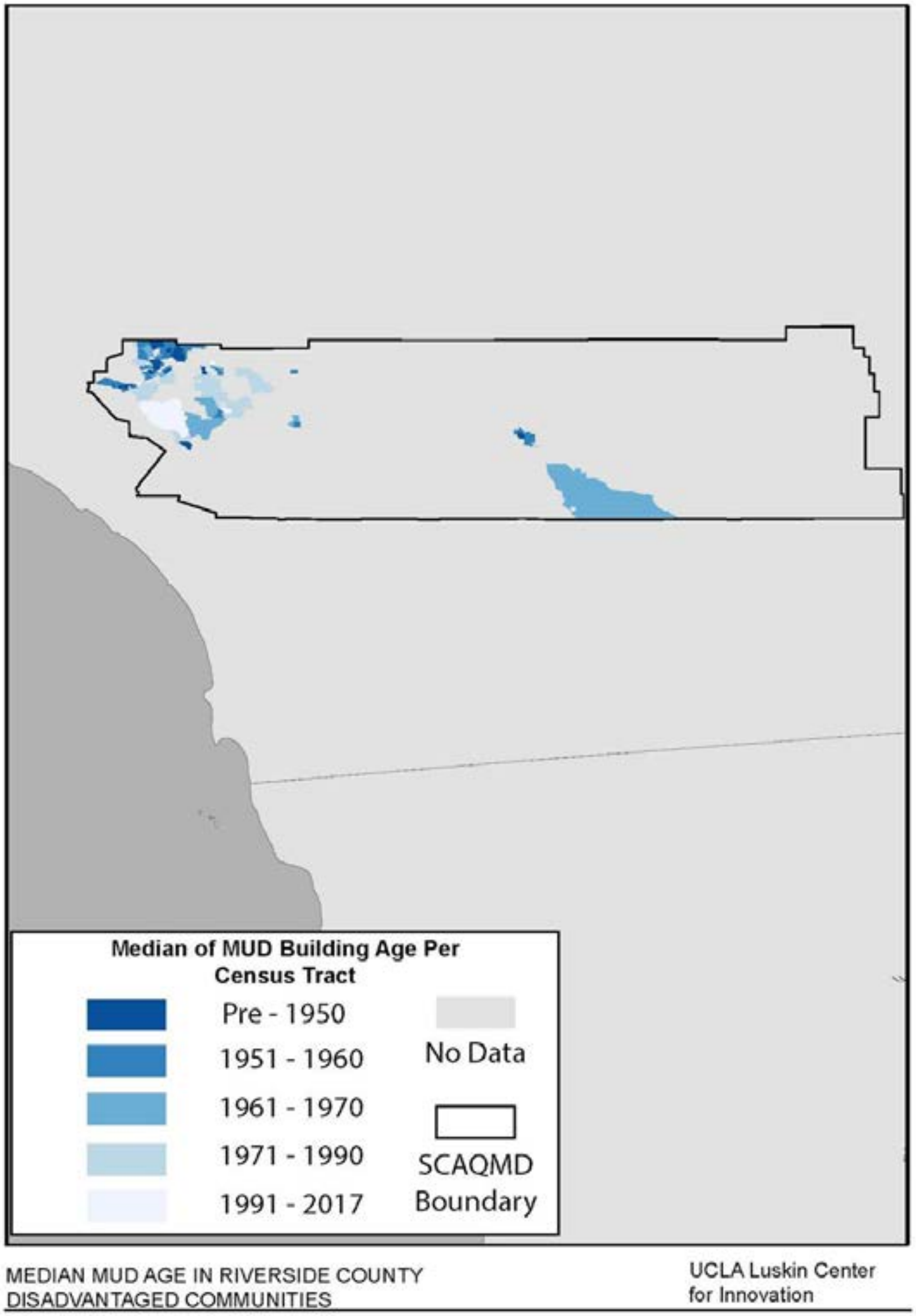
Median of MUD Building Age Per Census Tract
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1951 - 1960
1961 - 1970
1971 - 1990
1991 - 2017
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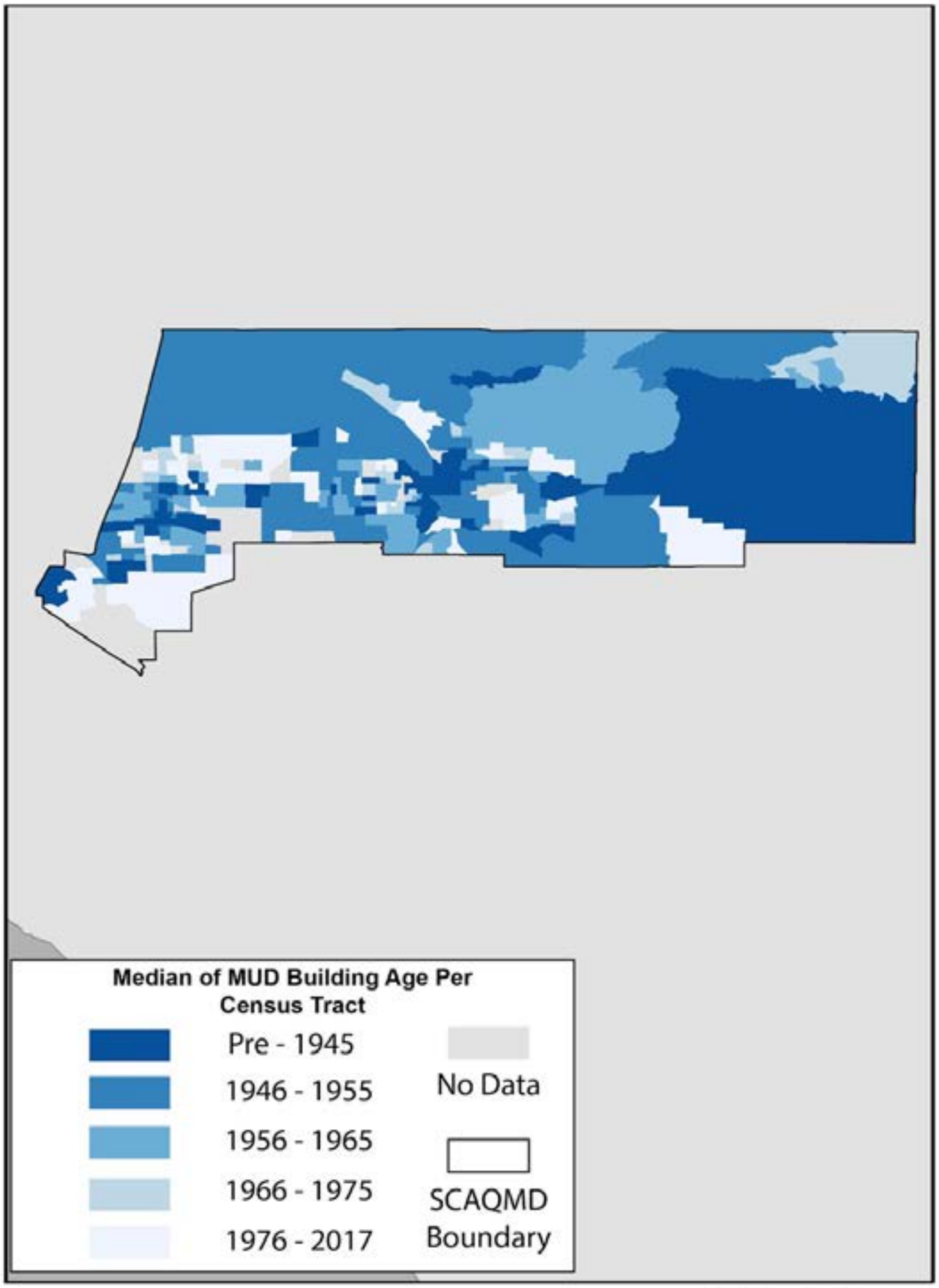
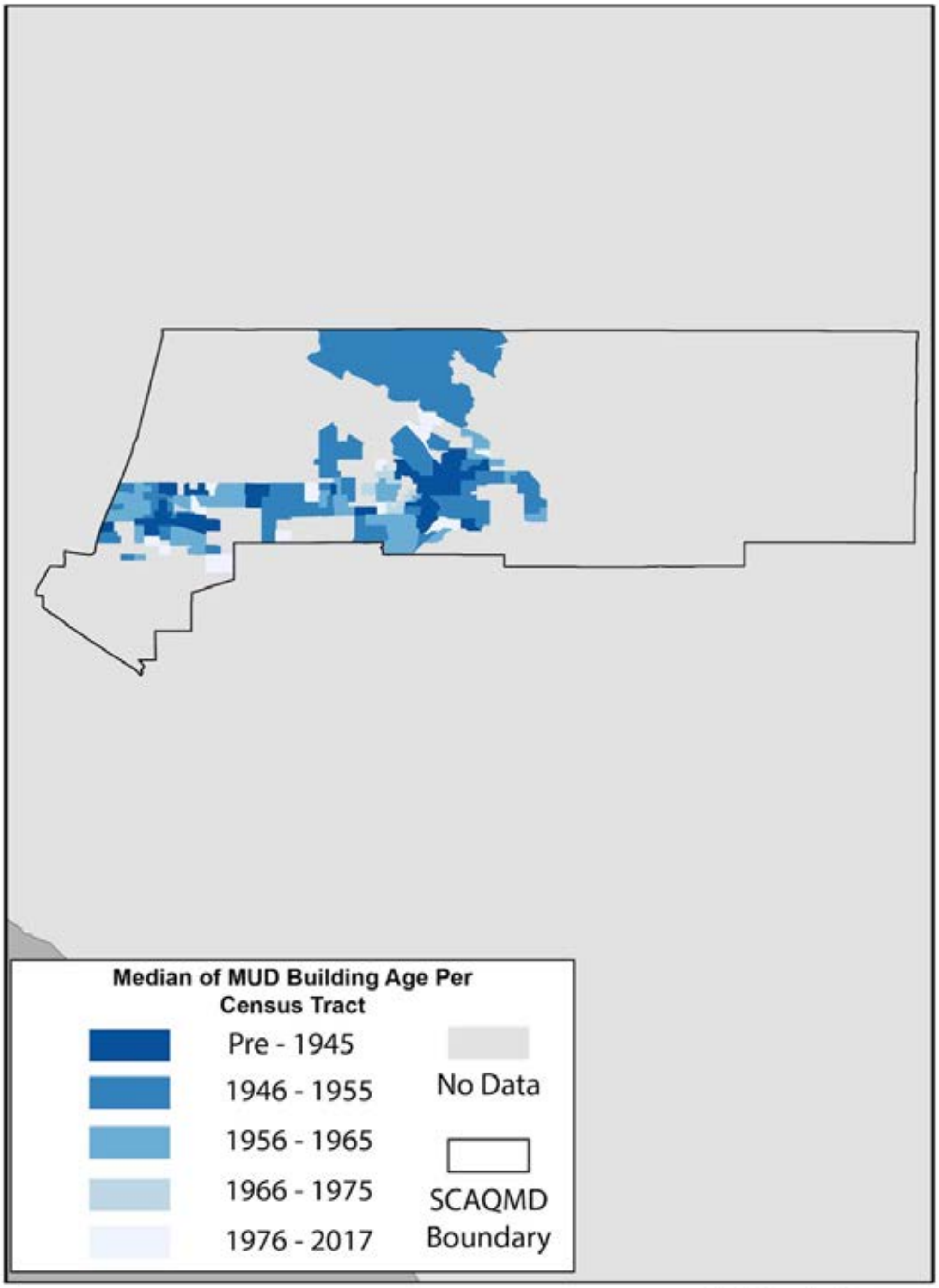
SCAQMD Boundary
MEDIAN MUD AGE IN RIVERSIDE COUNTY DISADVANTAGED COMMUNITIES
UCLA Luskin Center for Innovation



MEDIAN MUD AGE IN SAN BERNARDINO COUNTY

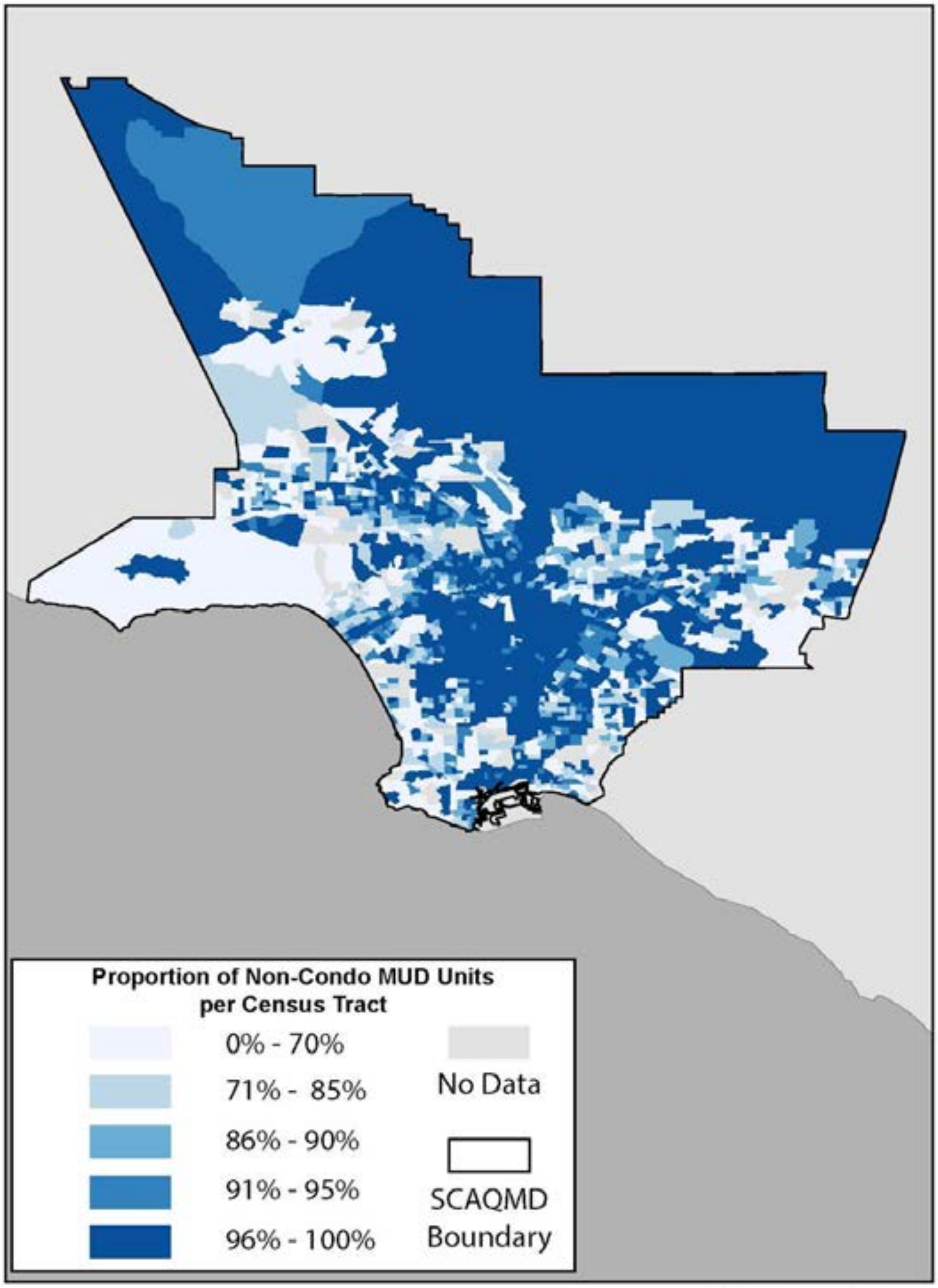
UCLA Luskin Center for Innovation



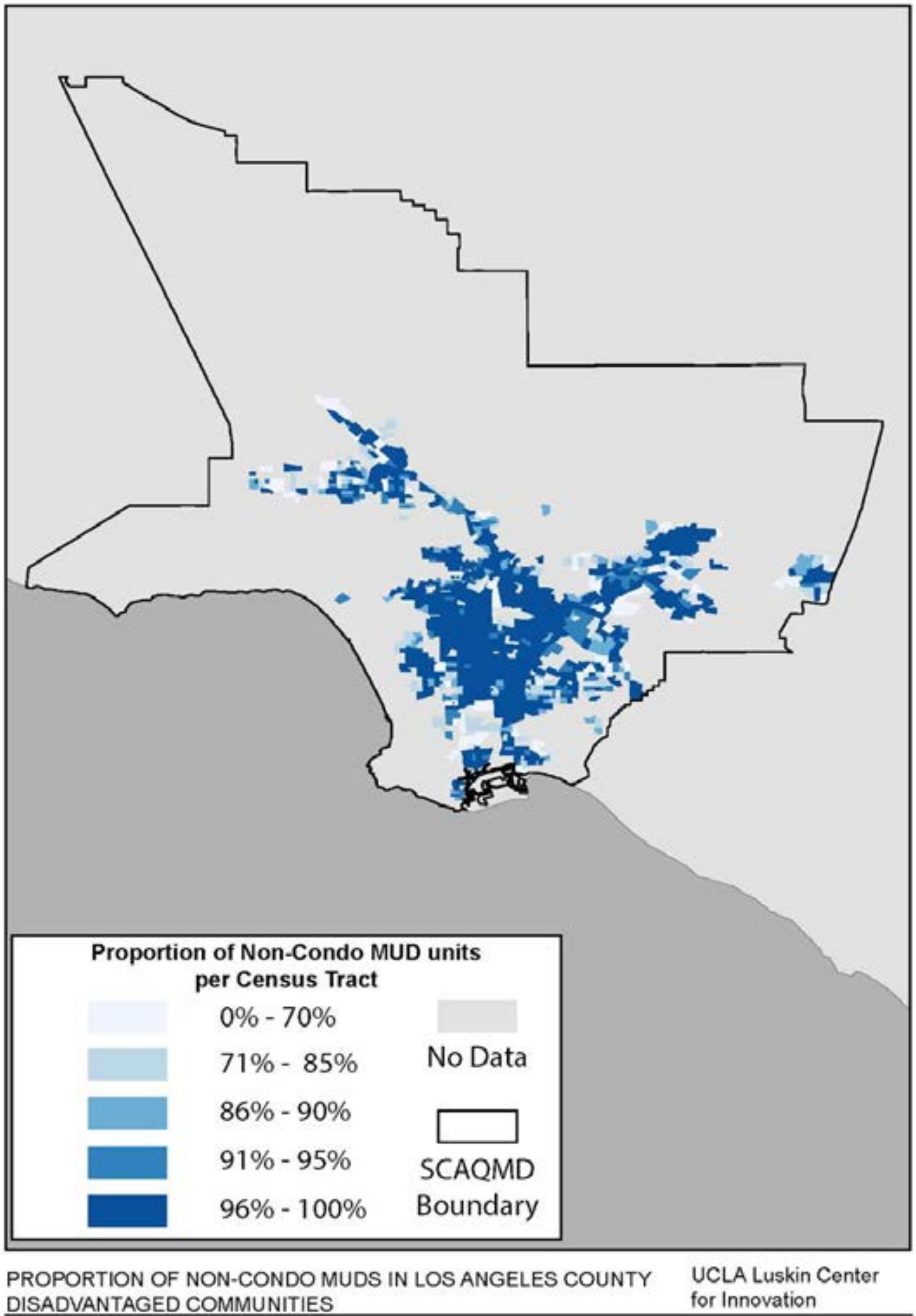
MEDIAN MUD AGE IN SAN BERNARDINO COUNTY DISADVANTAGED COMMUNITIES

UCLA Luskin Center for Innovation

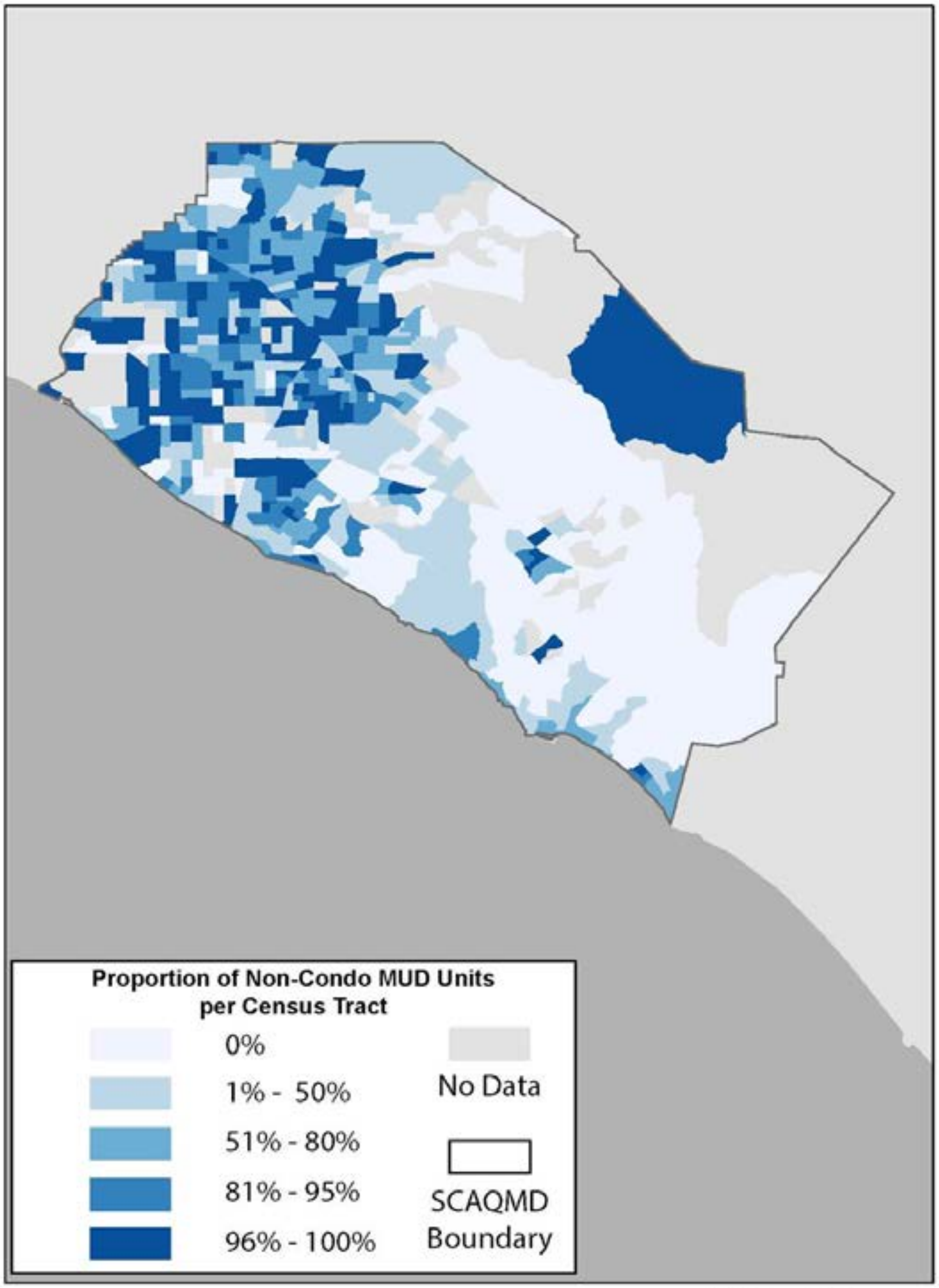
Appendix 3.4 - MUD Ownership Type - Maps



PROPORTION OF NON-CONDO MUDS IN LOS ANGELES COUNTY
UCLA Luskin Center for Innovation

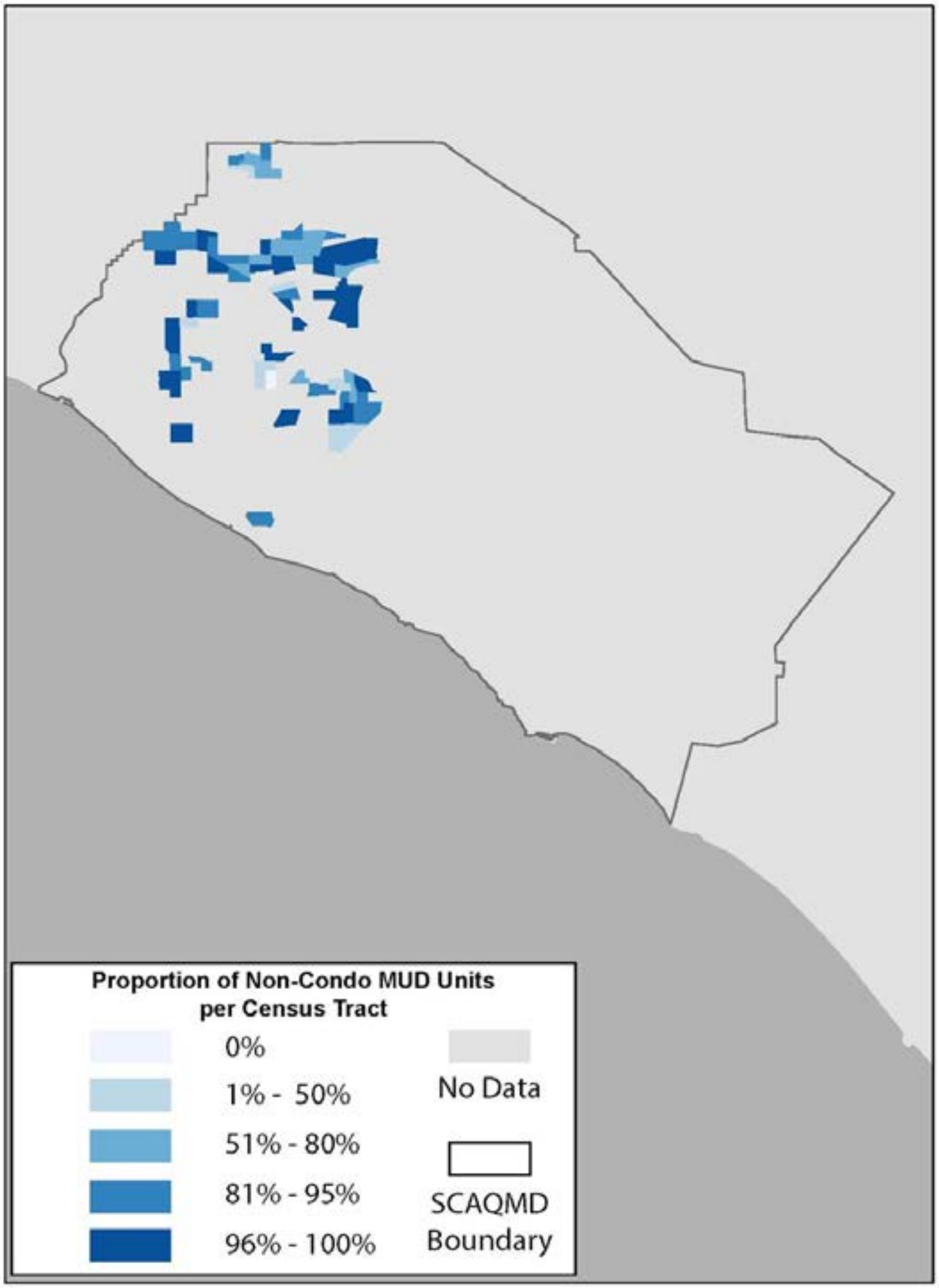


PROPORTION OF NON-CONDO MUDS IN LOS ANGELES COUNTY DISADVANTAGED COMMUNITIES



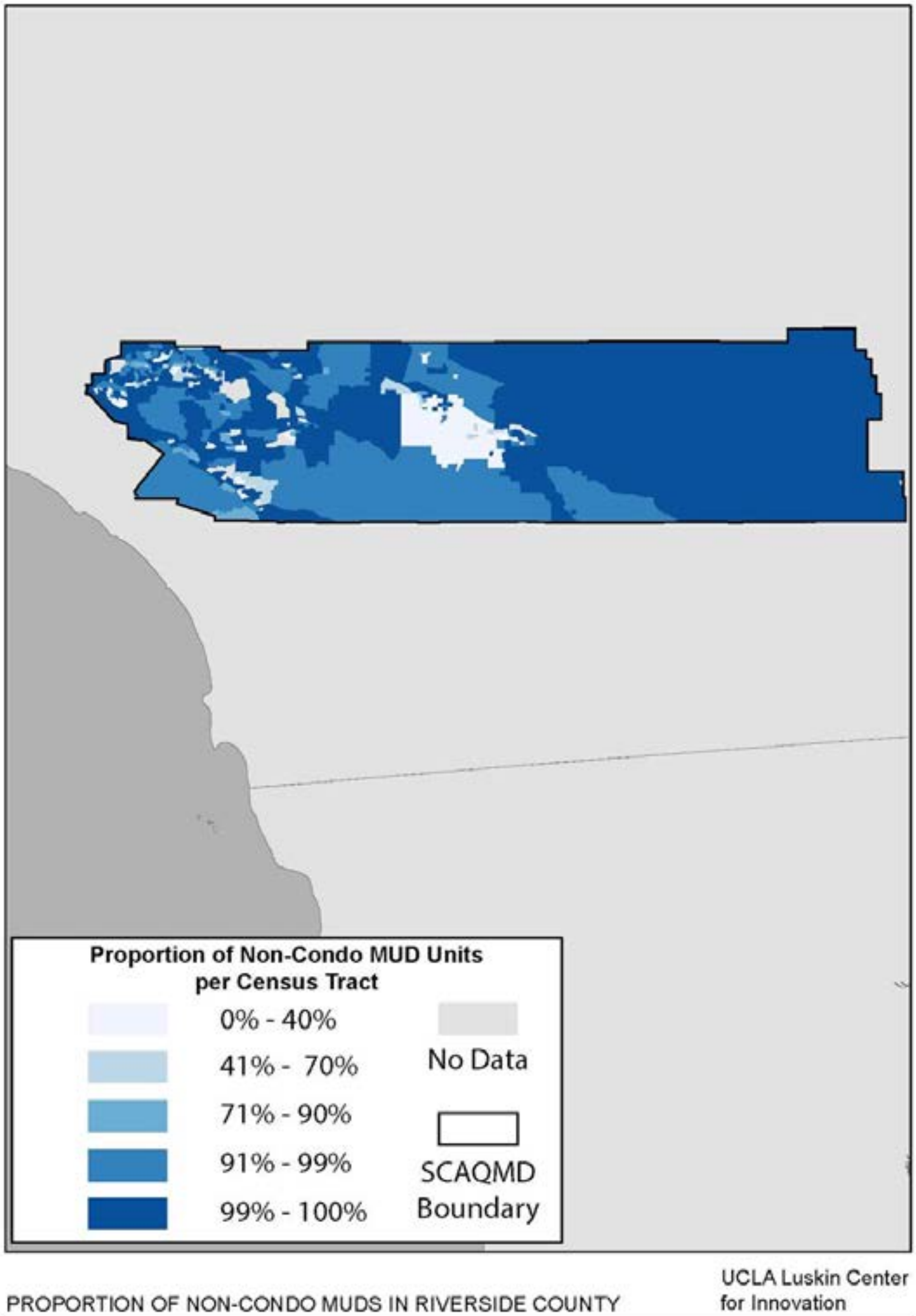
PROPORTION OF NON-CONDO MUDS IN ORANGE COUNTY

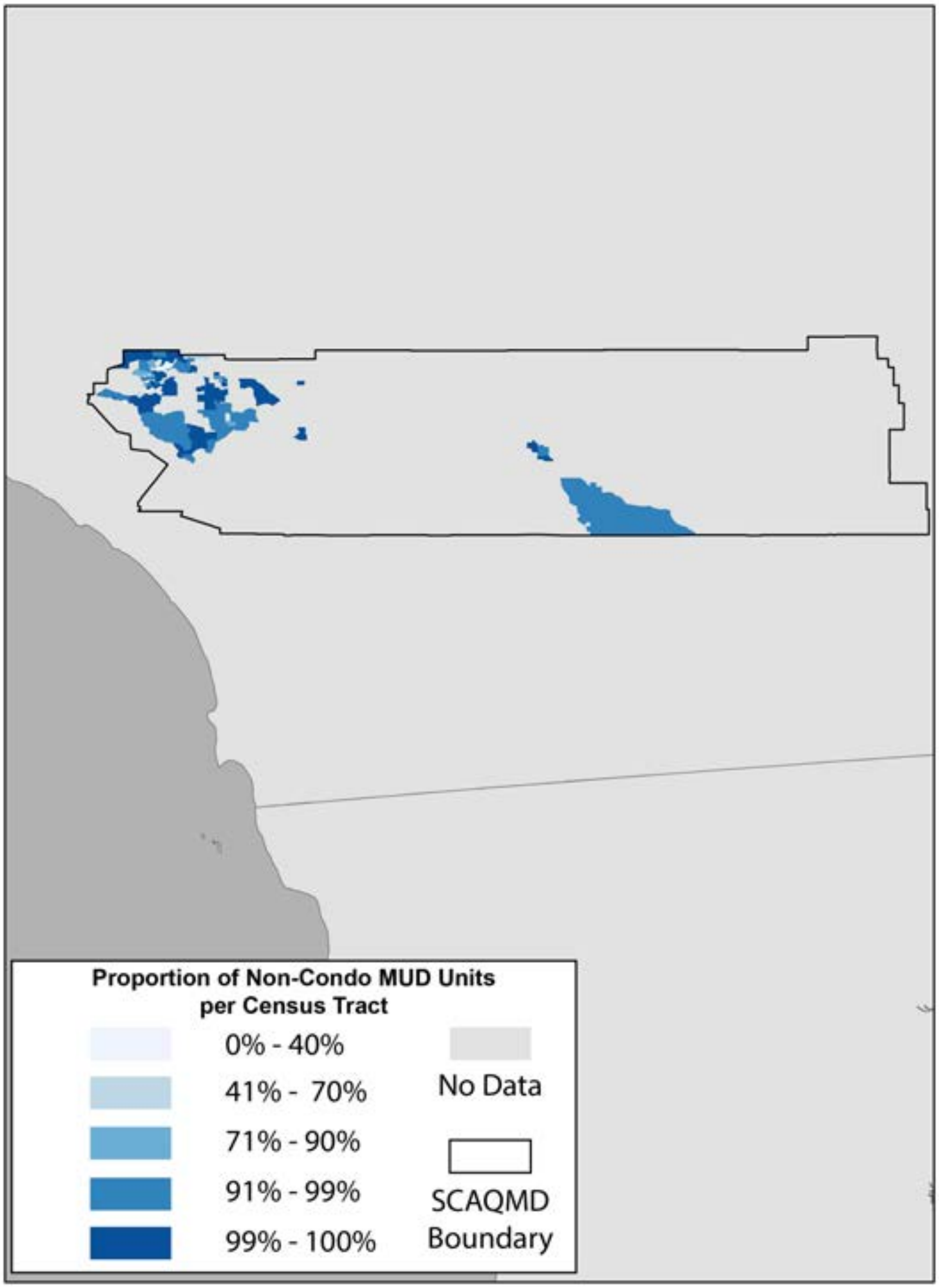
UCLA Luskin Center
for Innovation



PROPORTION OF NON-CONDO MUDS IN ORANGE COUNTY DISADVANTAGED COMMUNITIES

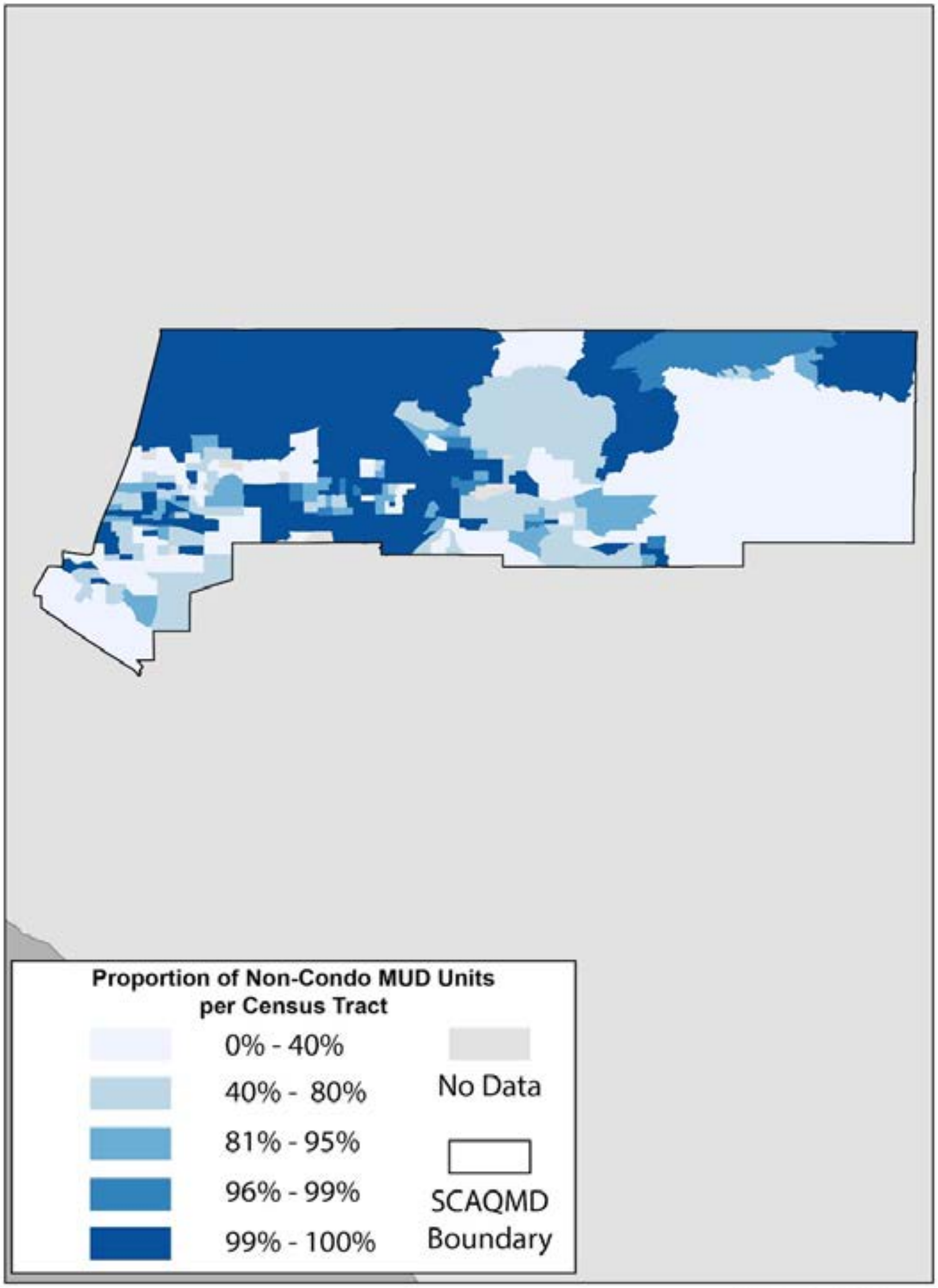
UCLA Luskin Center for Innovation


Proportion of Non-Condo MUD Units per Census Tract
0% - 40%
41% - 70%
71% - 90%
91% - 99%
99% - 100%
No Data
SCAQMD Boundary
PROPORTION OF NON-CONDO MUDS IN RIVERSIDE COUNTY
UCLA Luskin Center for Innovation

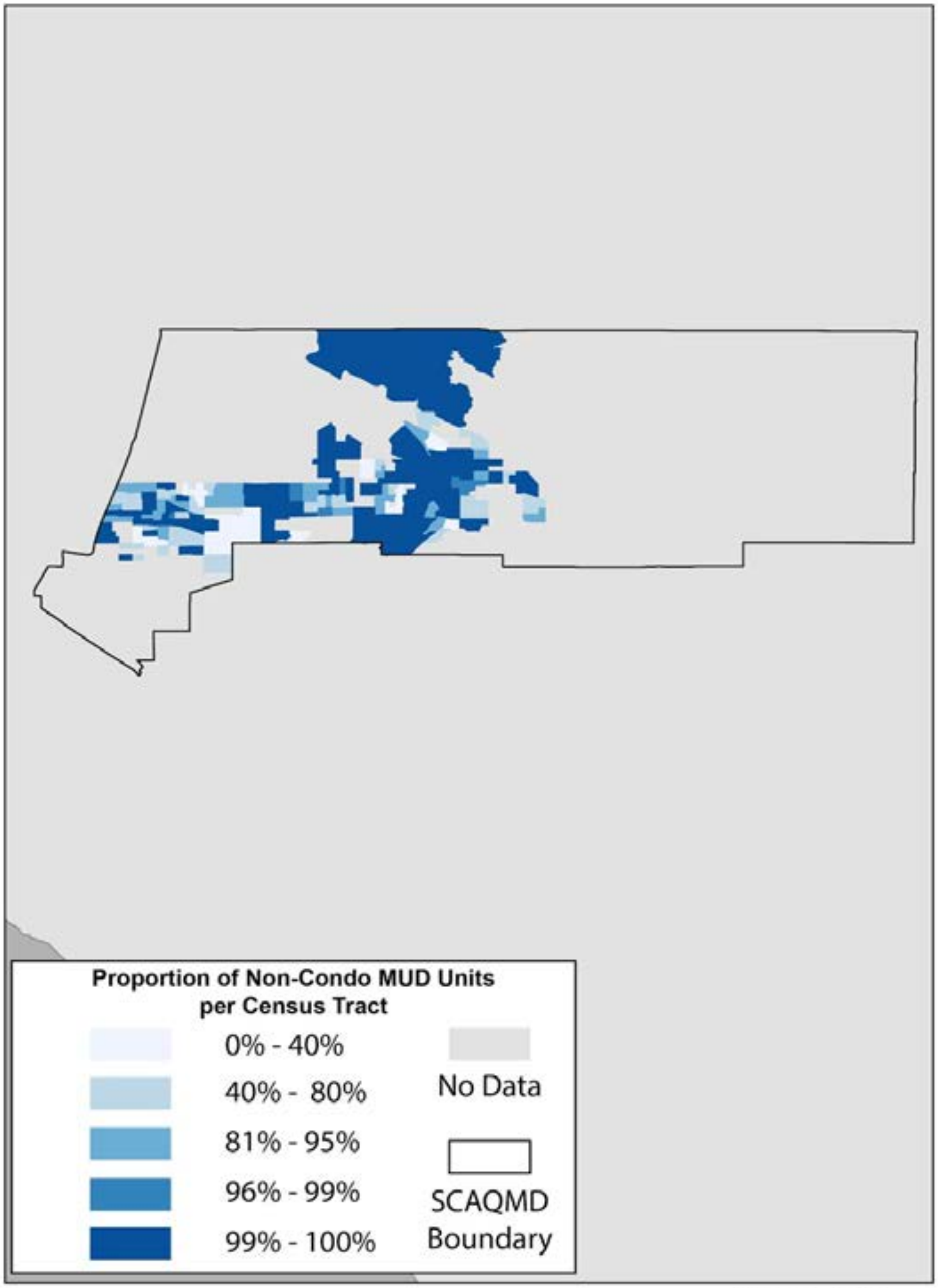


PROPORTION OF NON-CONDO MUDS IN RIVERSIDE COUNTY DISADVANTAGED COMMUNITIES

UCLA Luskin Center for Innovation



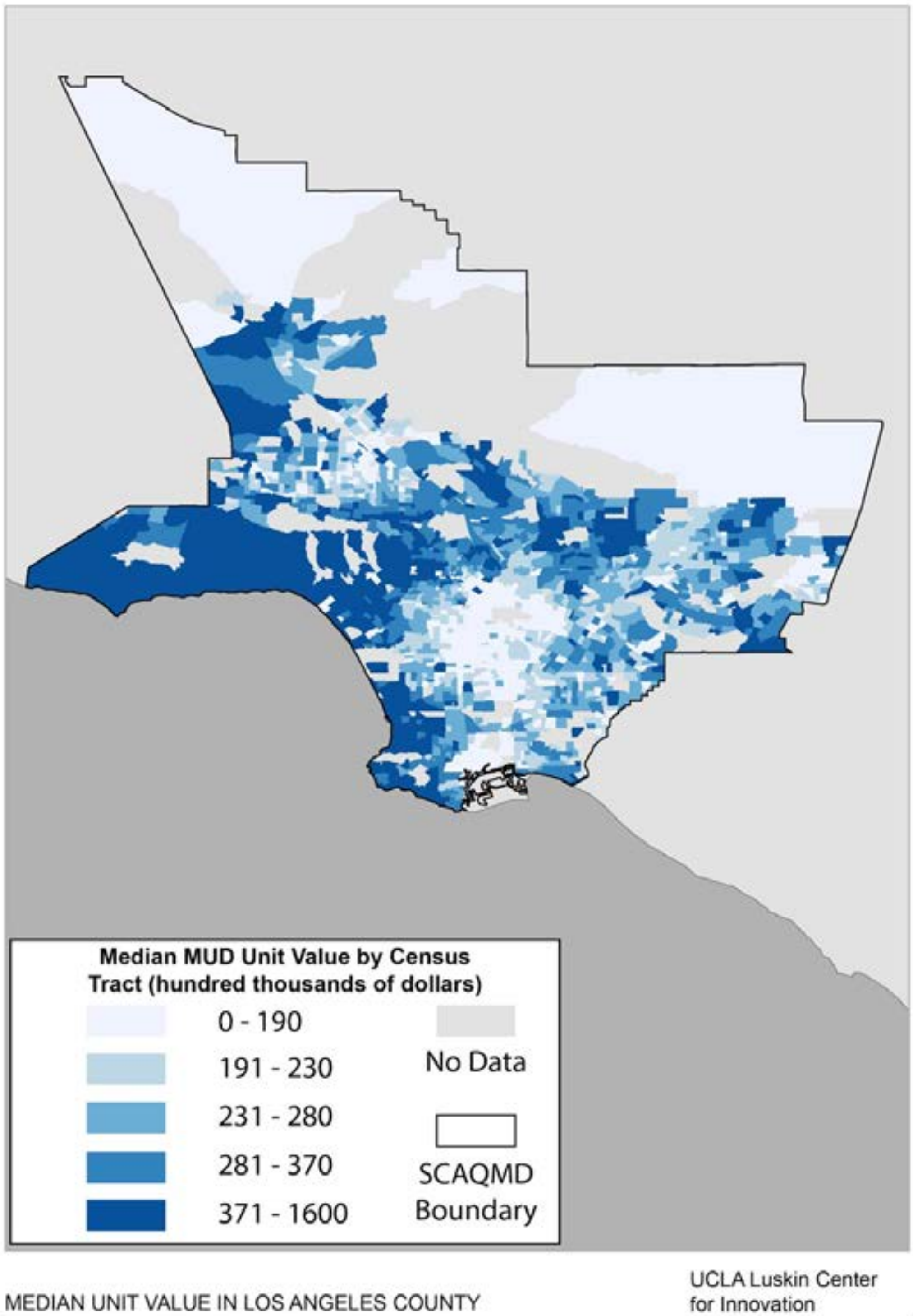
PROPORTION OF NON-CONDO MUDS IN SAN BERNARDINO COUNTY UCLA Luskin Center for Innovation

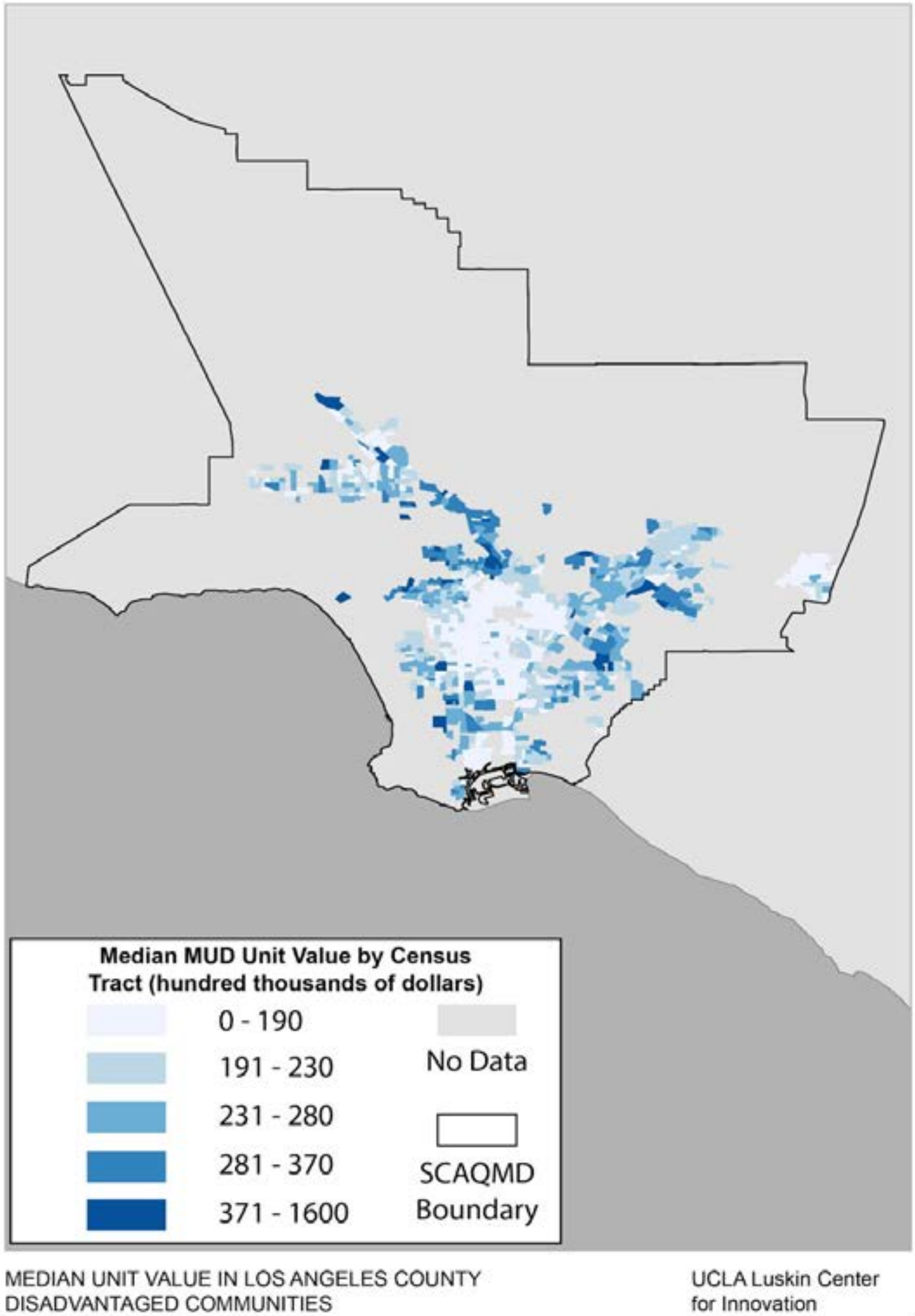


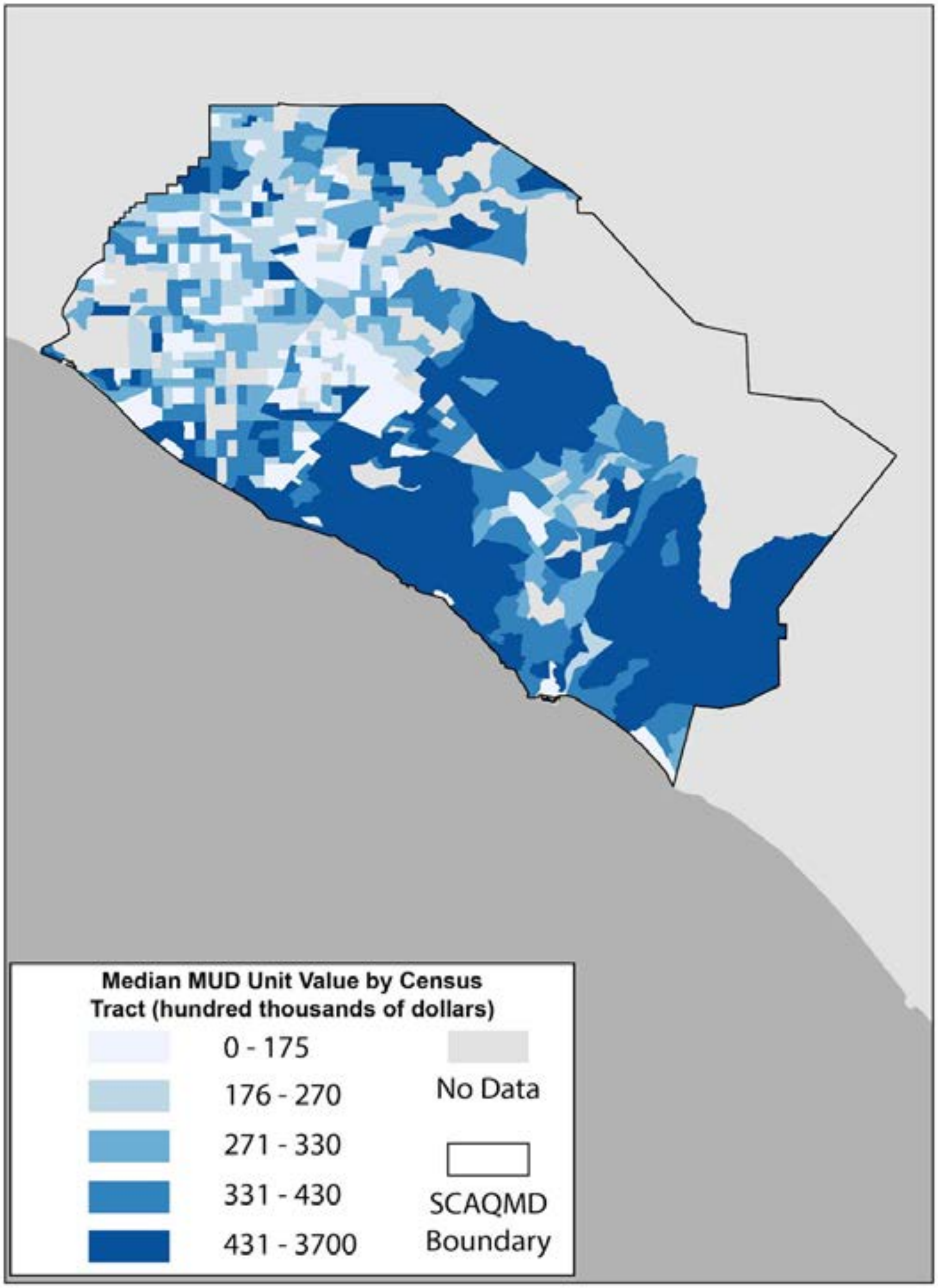
PROPORTION OF NON-CONDO MUDS IN SAN BERNARDINO COUNTY DISADVANTAGED COMMUNITIES

UCLA Luskin Center for Innovation

Appendix 3.5 - MUD Unit Value - Maps

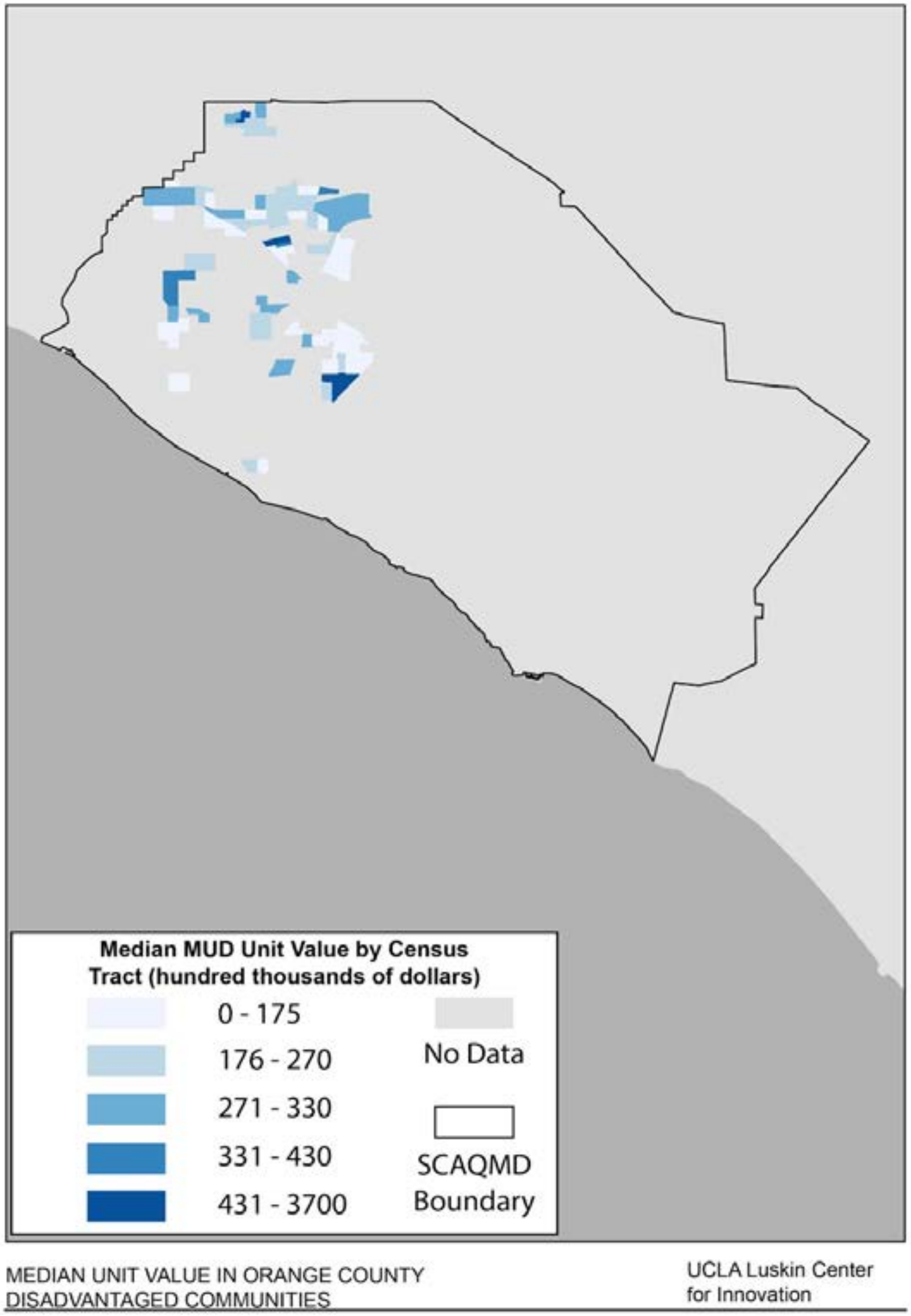


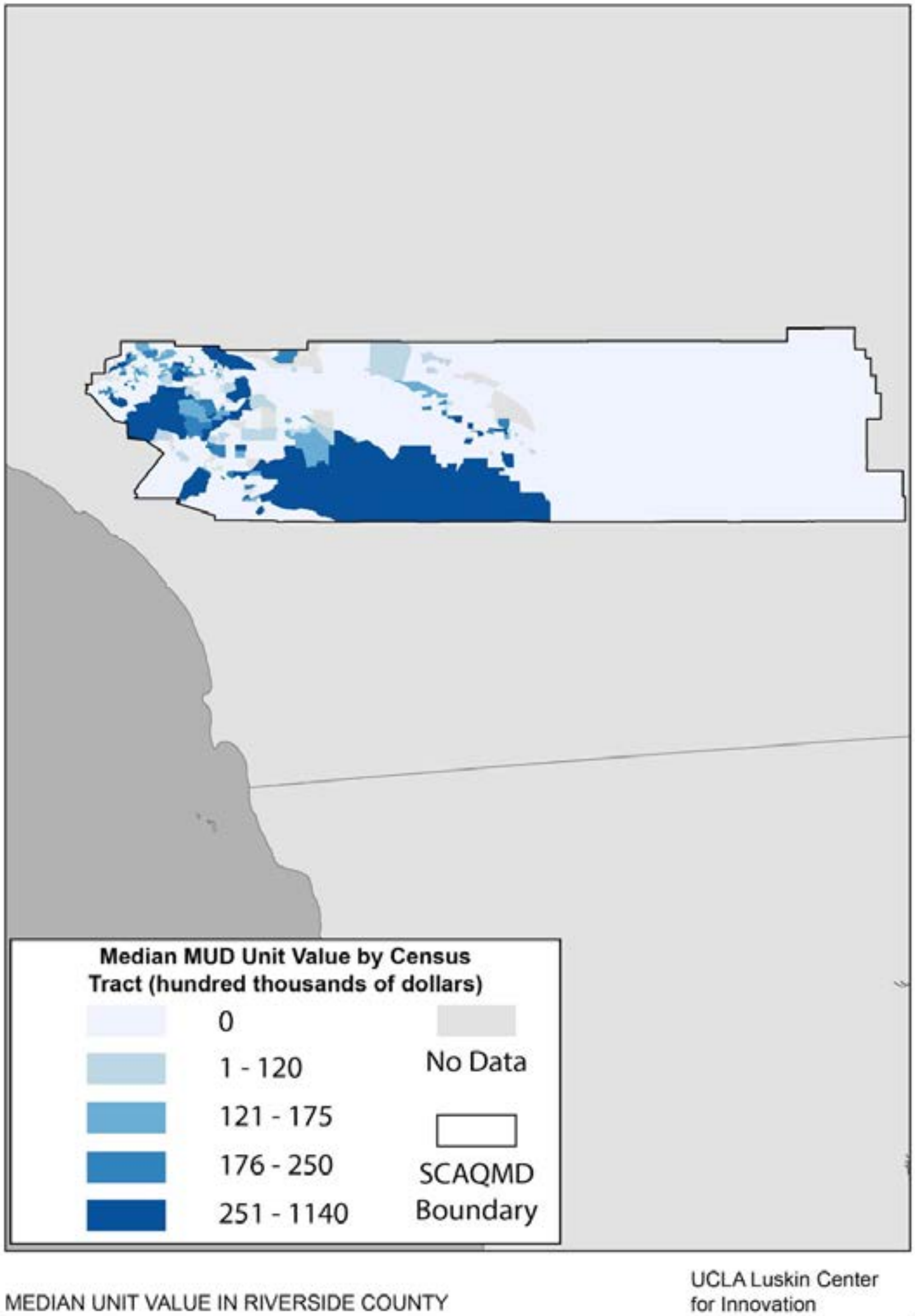

Median MUD Unit Value by Census Tract (hundred thousands of dollars)
0 - 190
191 - 230
231 - 280
281 - 370
371 - 1600
No Data
SCAQMD Boundary
MEDIAN UNIT VALUE IN LOS ANGELES COUNTY DISADVANTAGED COMMUNITIES
UCLA Luskin Center for Innovation

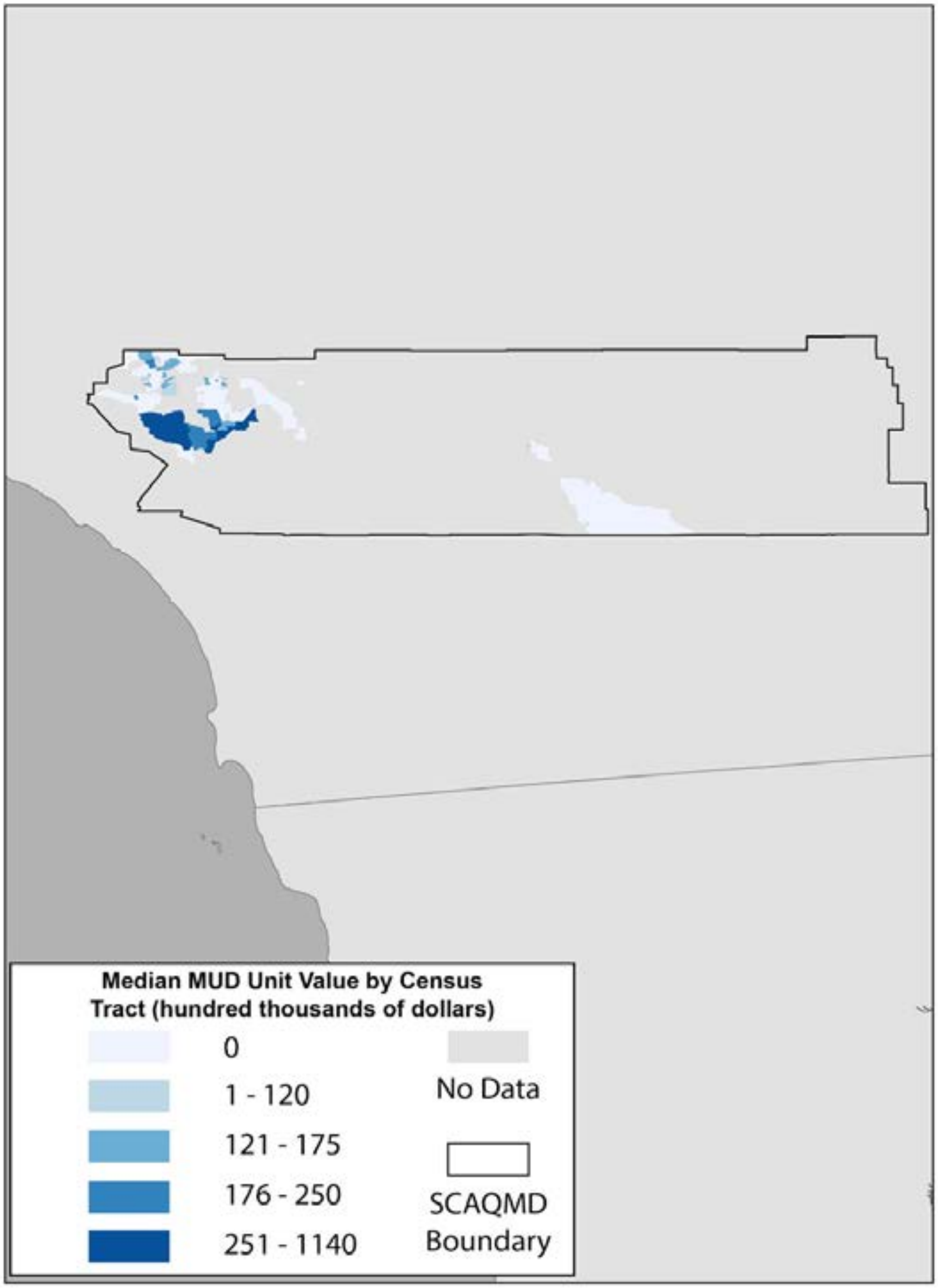


MEDIAN UNIT VALUE IN ORANGE COUNTY

UCLA Luskin Center
for Innovation

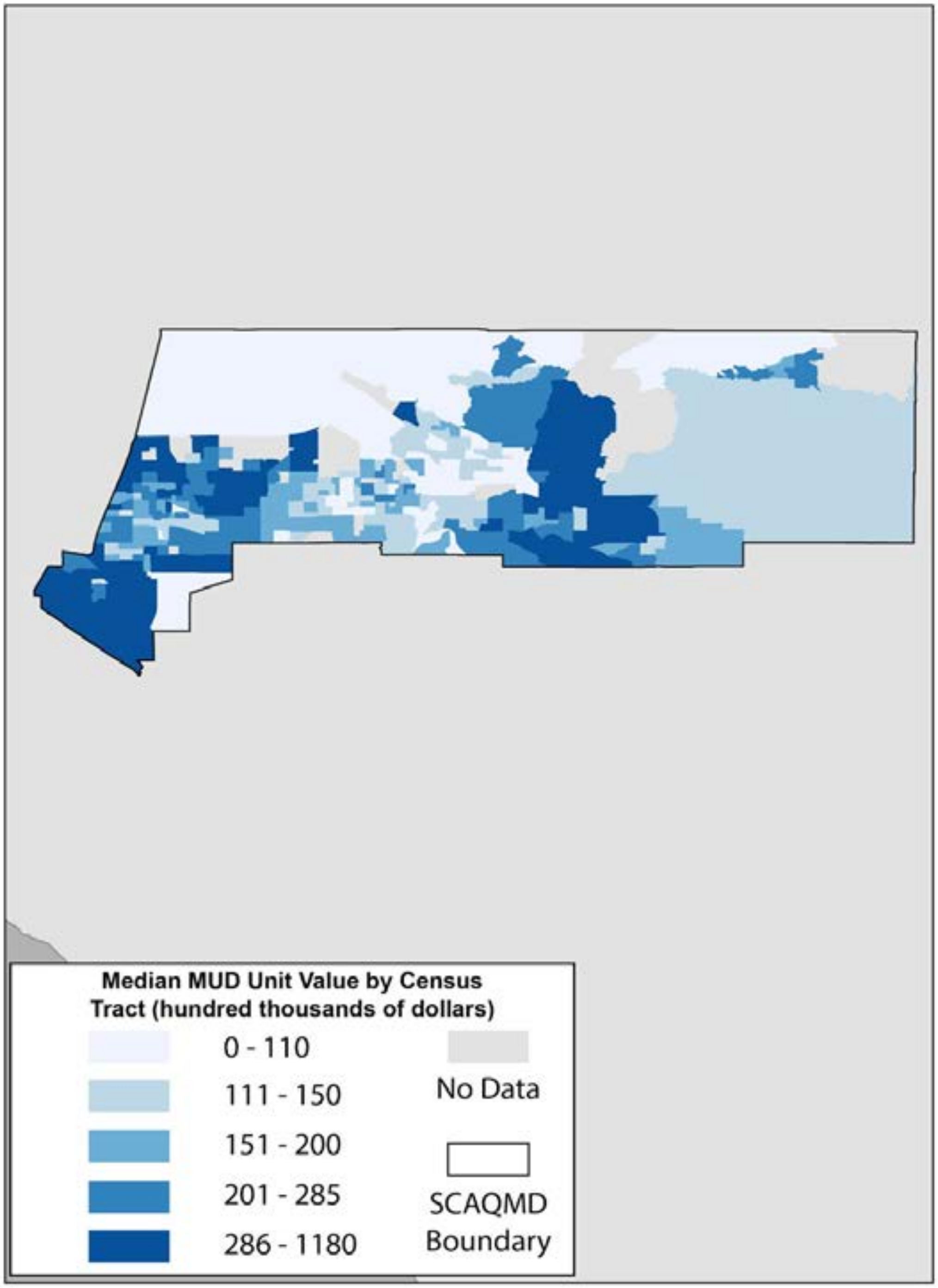

Median MUD Unit Value by Census Tract (hundred thousands of dollars)
0 - 175
176 - 270
271 - 330
331 - 430
431 - 3700
No Data
SCAQMD Boundary
MEDIAN UNIT VALUE IN ORANGE COUNTY DISADVANTAGED COMMUNITIES
UCLA Luskin Center for Innovation


Median MUD Unit Value by Census Tract (hundred thousands of dollars)
0
1 - 120
121 - 175
176 - 250
251 - 1140
No Data
SCAQMD Boundary
MEDIAN UNIT VALUE IN RIVERSIDE COUNTY
UCLA Luskin Center for Innovation



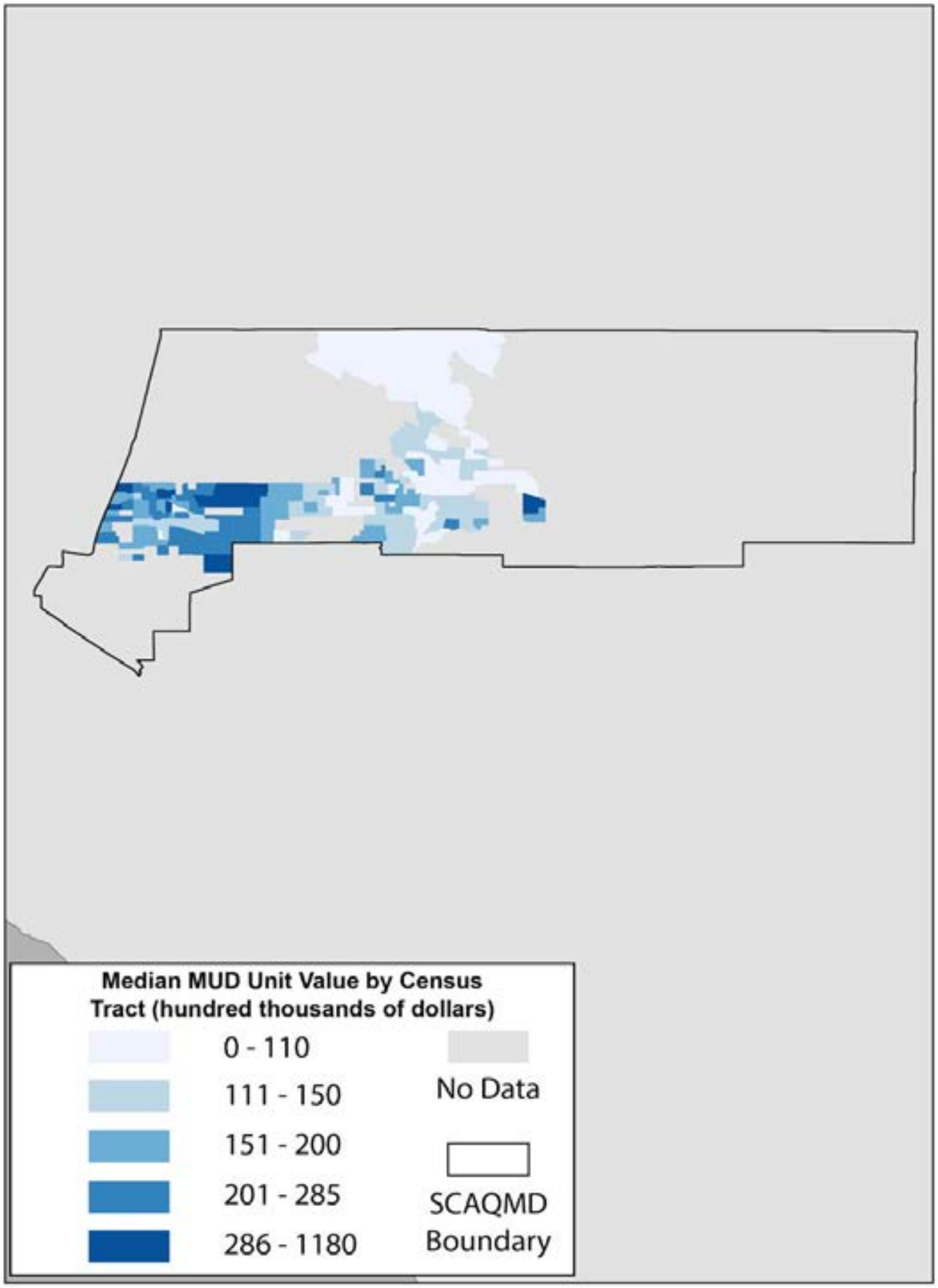
MEDIAN UNIT VALUE IN RIVERSIDE COUNTY DISADVANTAGED COMMUNITIES

UCLA Luskin Center for Innovation



MEDIAN UNIT VALUE IN SAN BERNARDINO COUNTY

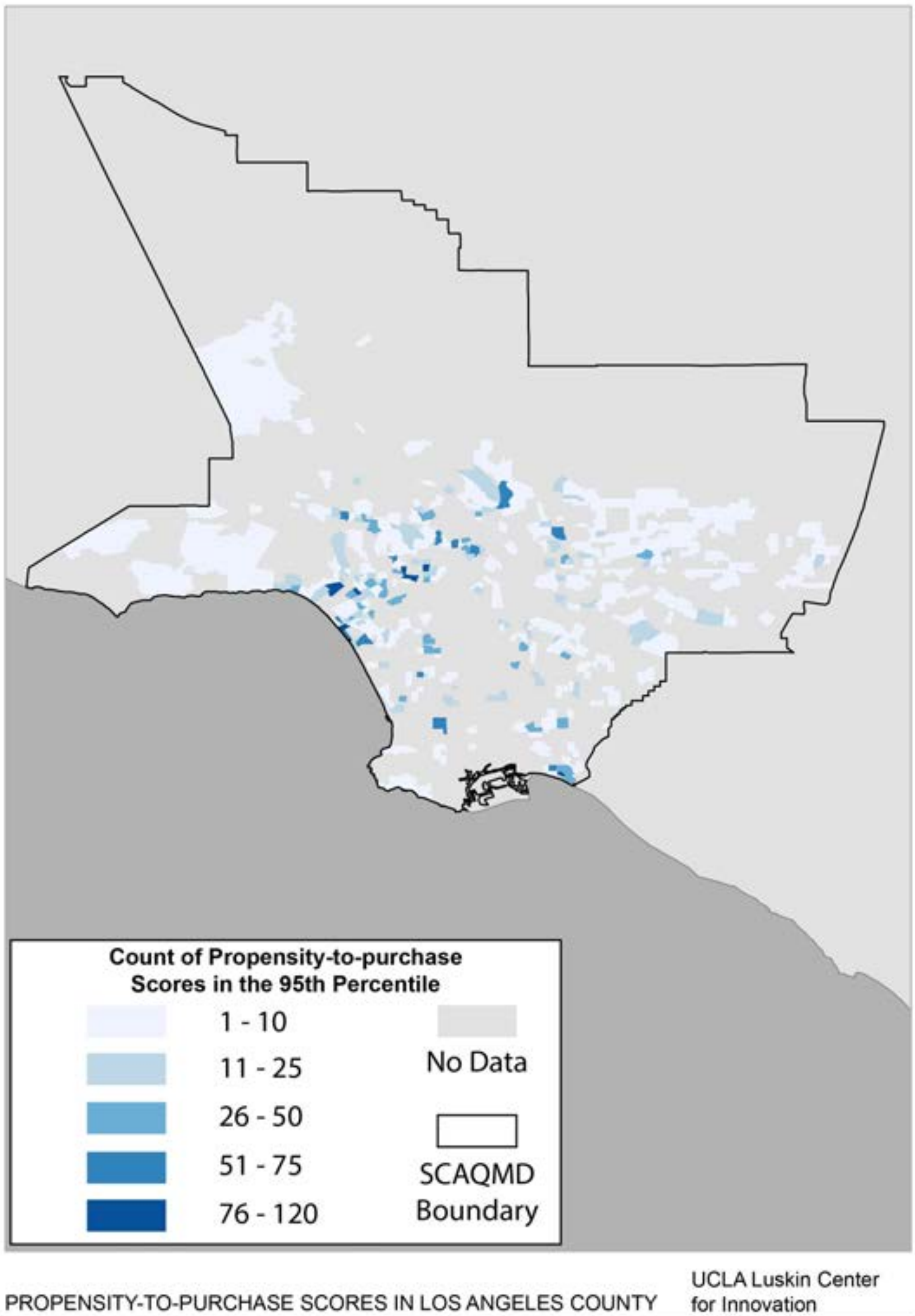
UCLA Luskin Center for Innovation

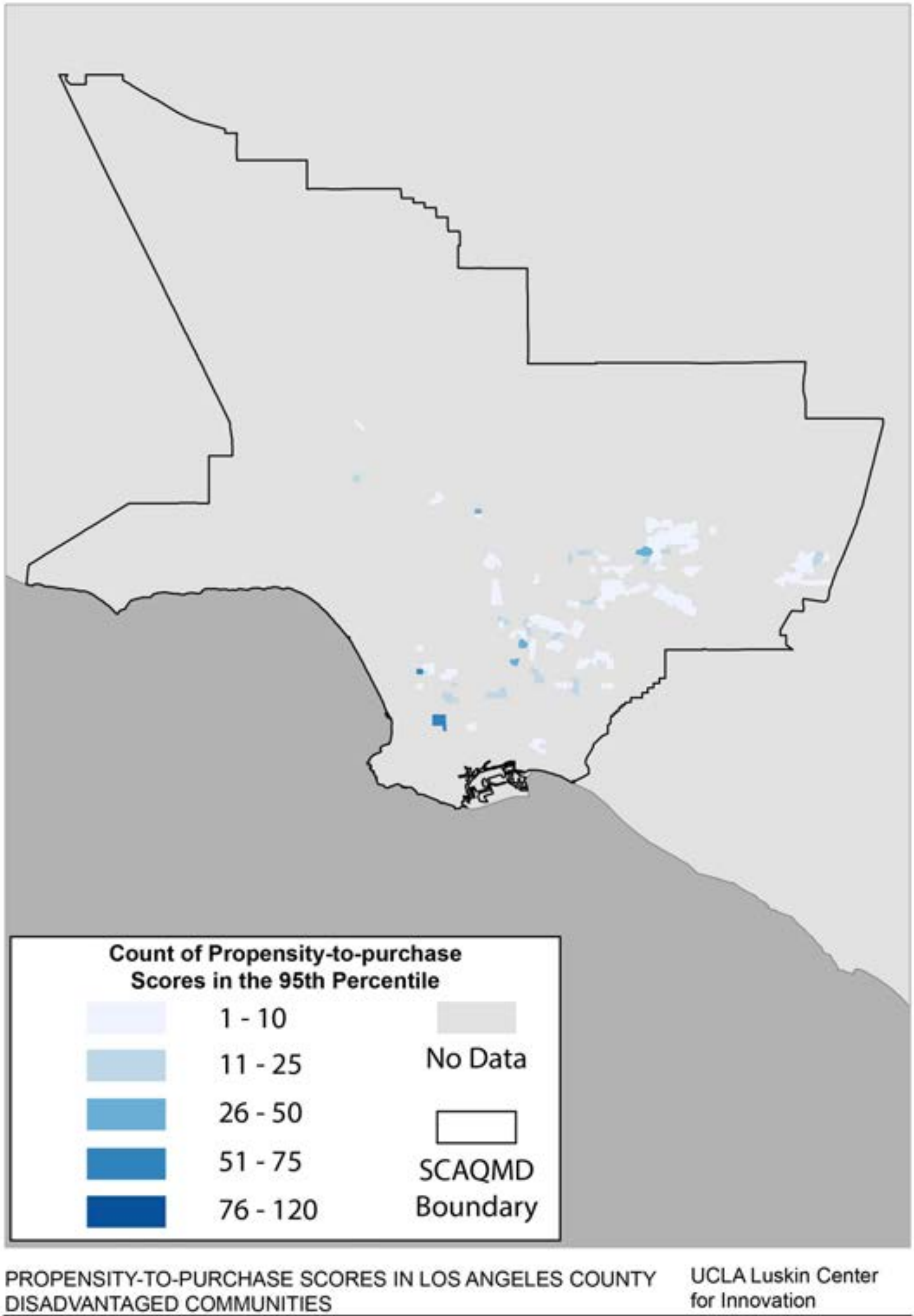


MEDIAN UNIT VALUE IN SAN BERNARDINO COUNTY DISADVANTAGED COMMUNITIES

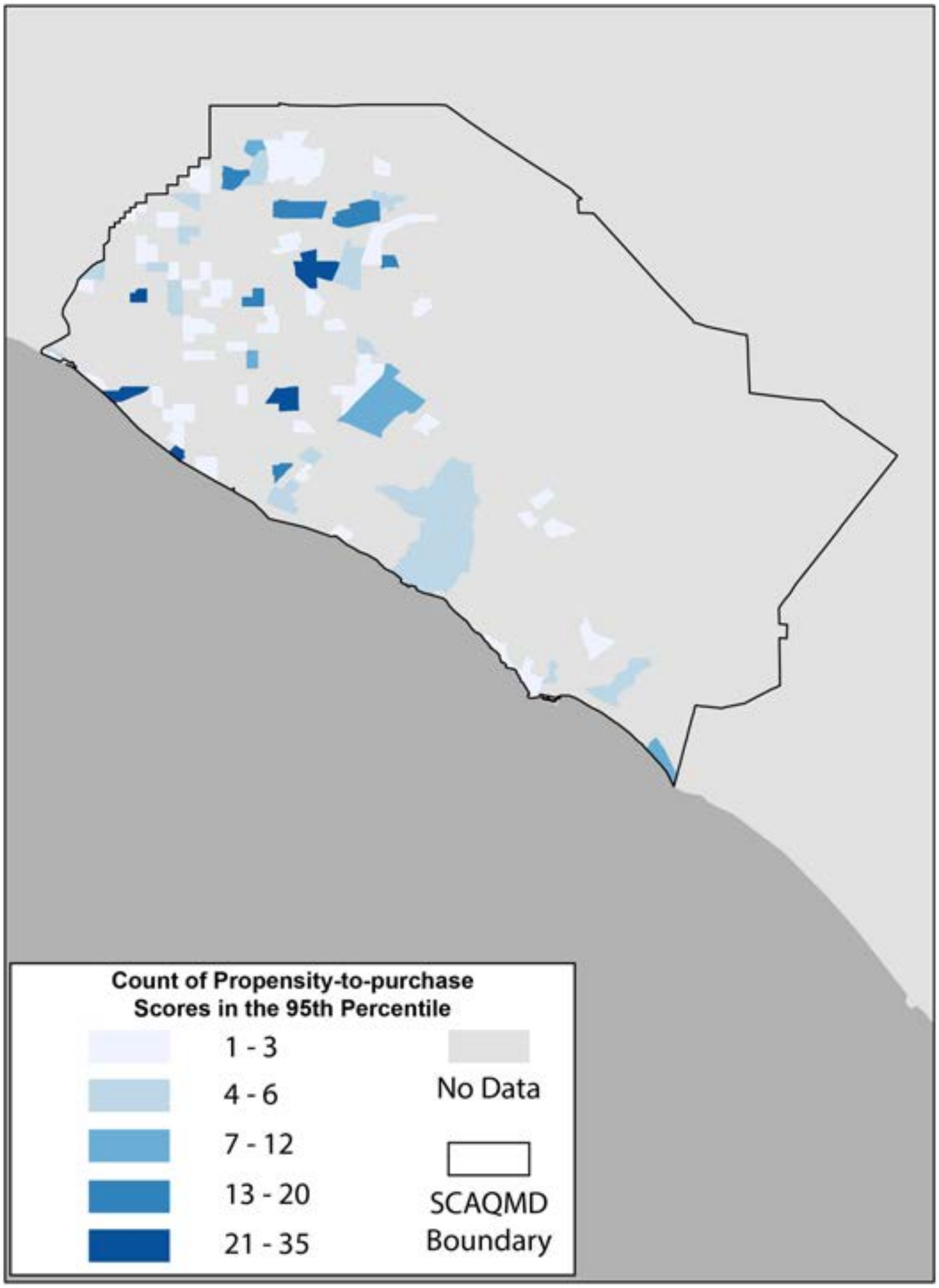
UCLA Luskin Center for Innovation

Appendix 3.6 – Propensity-to-purchase Scores - Maps



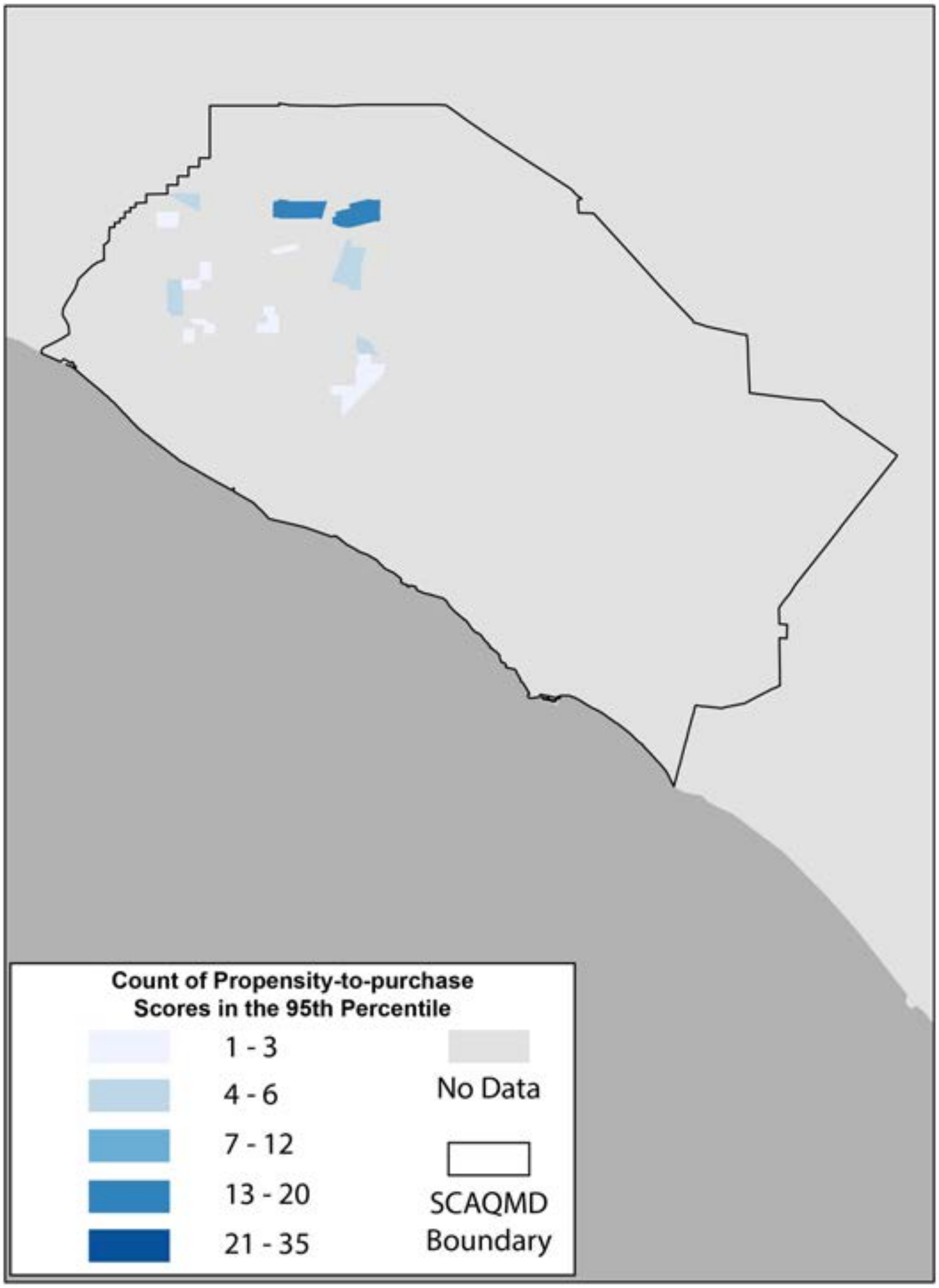


PROPENSITY-TO-PURCHASE SCORES IN LOS ANGELES COUNTY DISADVANTAGED COMMUNITIES



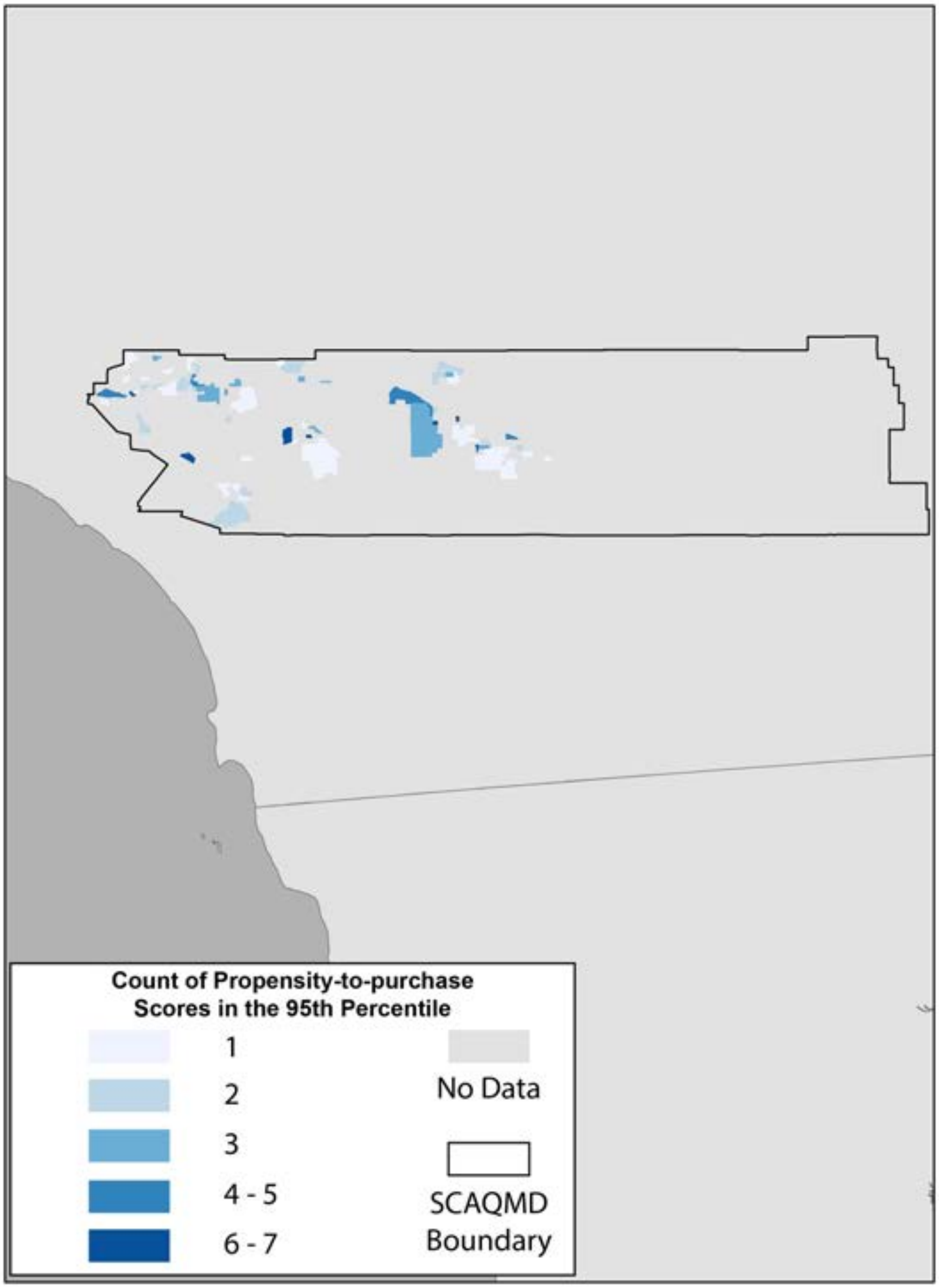
PROPENSITY-TO-PURCHASE SCORES IN ORANGE COUNTY

UCLA Luskin Center for Innovation



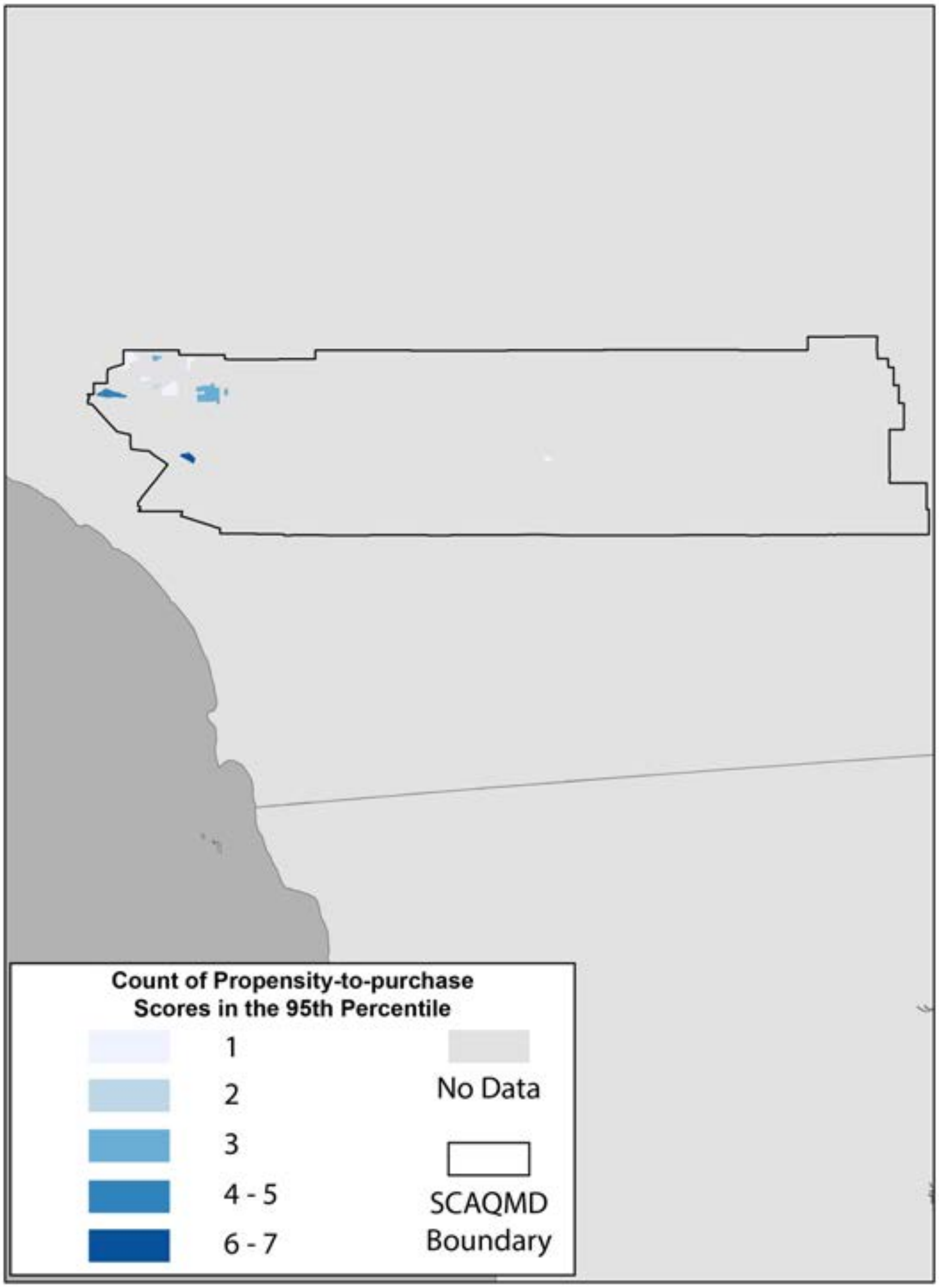
PROPENSITY-TO-PURCHASE SCORES IN ORANGE COUNTY DISADVANTAGED COMMUNITIES

UCLA Luskin Center for Innovation



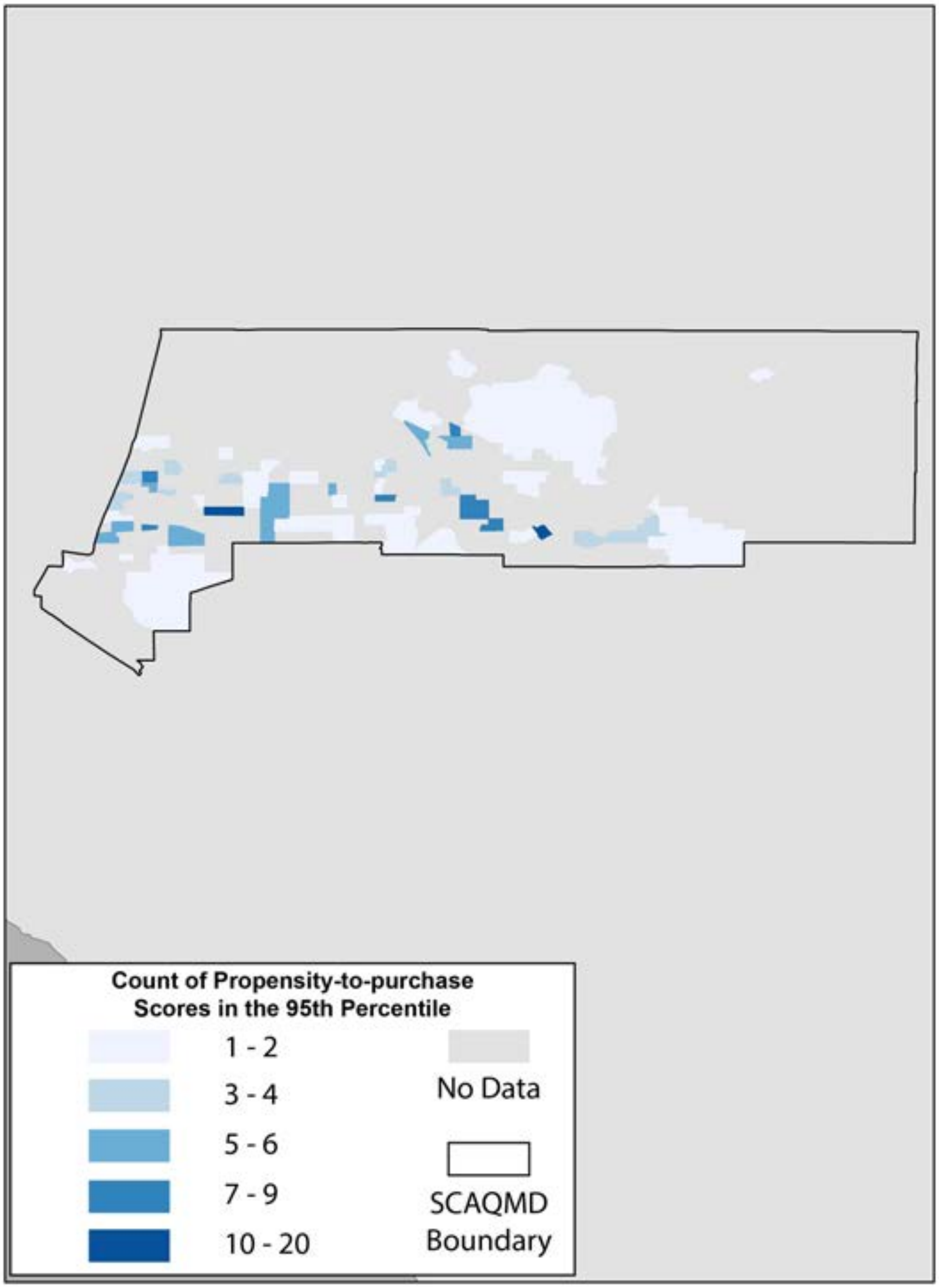
PROPENSITY-TO-PURCHASE SCORES IN RIVERSIDE COUNTY

UCLA Luskin Center
for Innovation



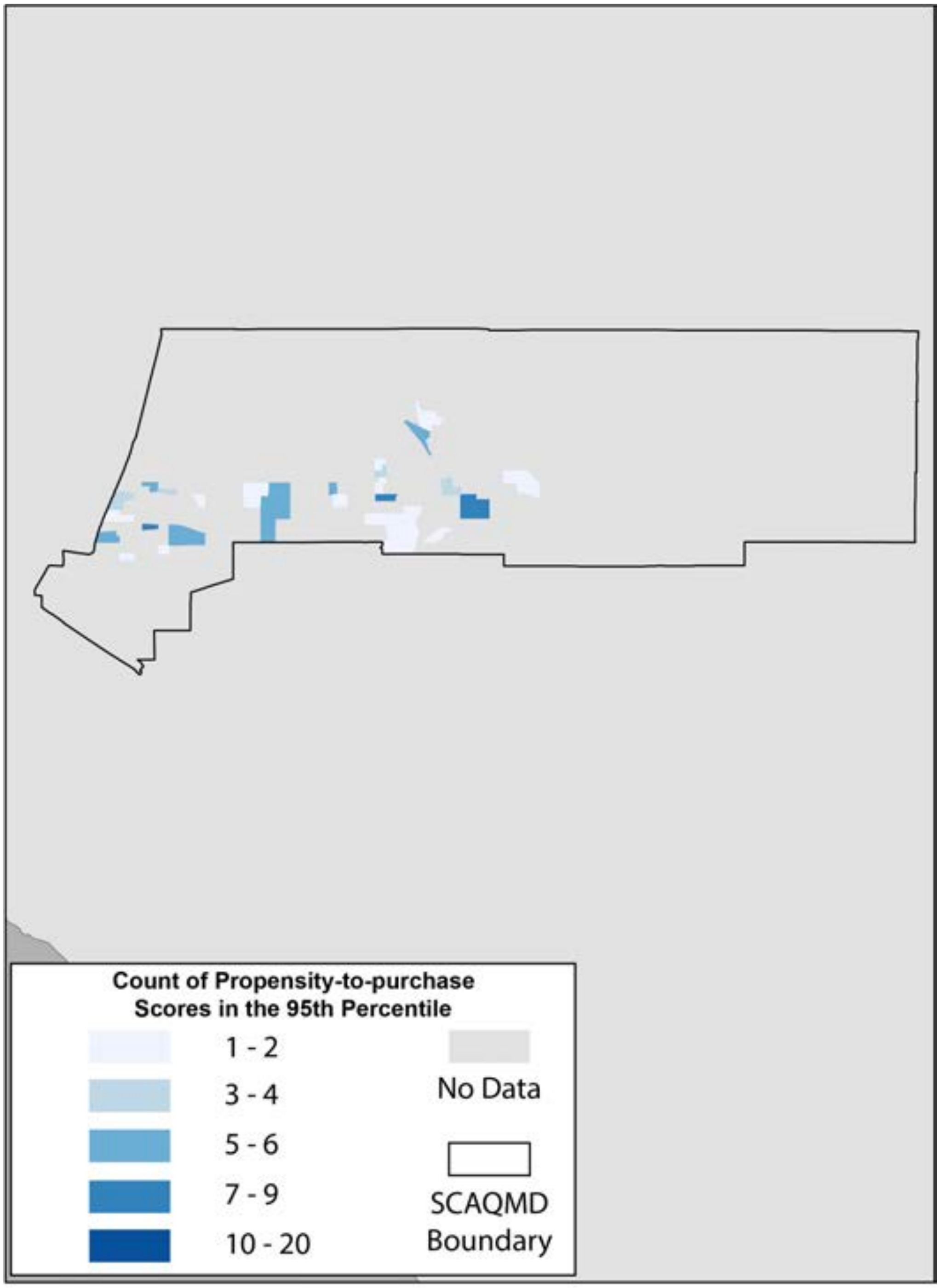
PROPENSITY-TO-PURCHASE SCORES IN RIVERSIDE COUNTY DISADVANTAGED COMMUNITIES

UCLA Luskin Center for Innovation



PROPENSITY-TO-PURCHASE SCORES IN SAN BERNARDINO COUNTY

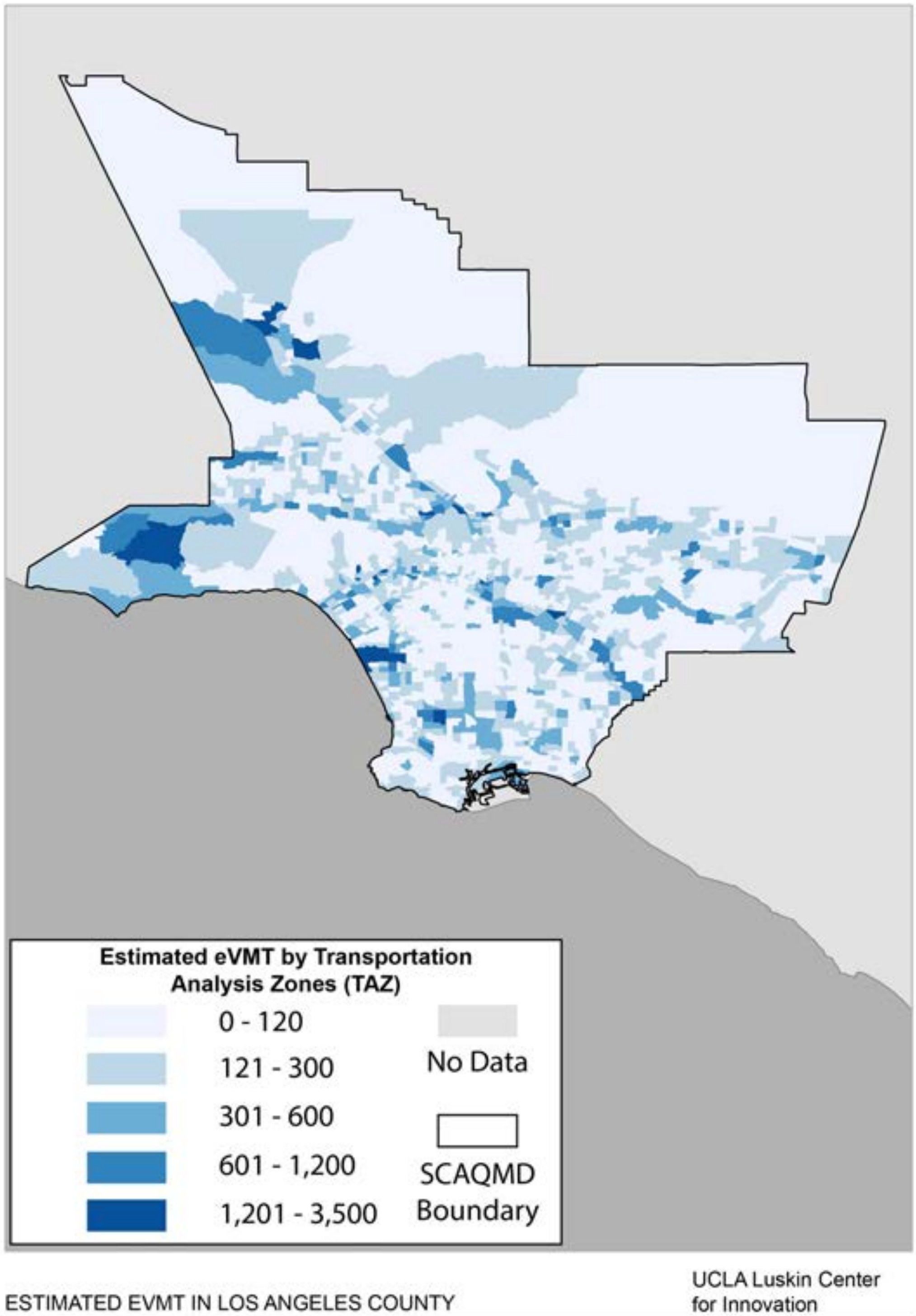
UCLA Luskin Center for Innovation

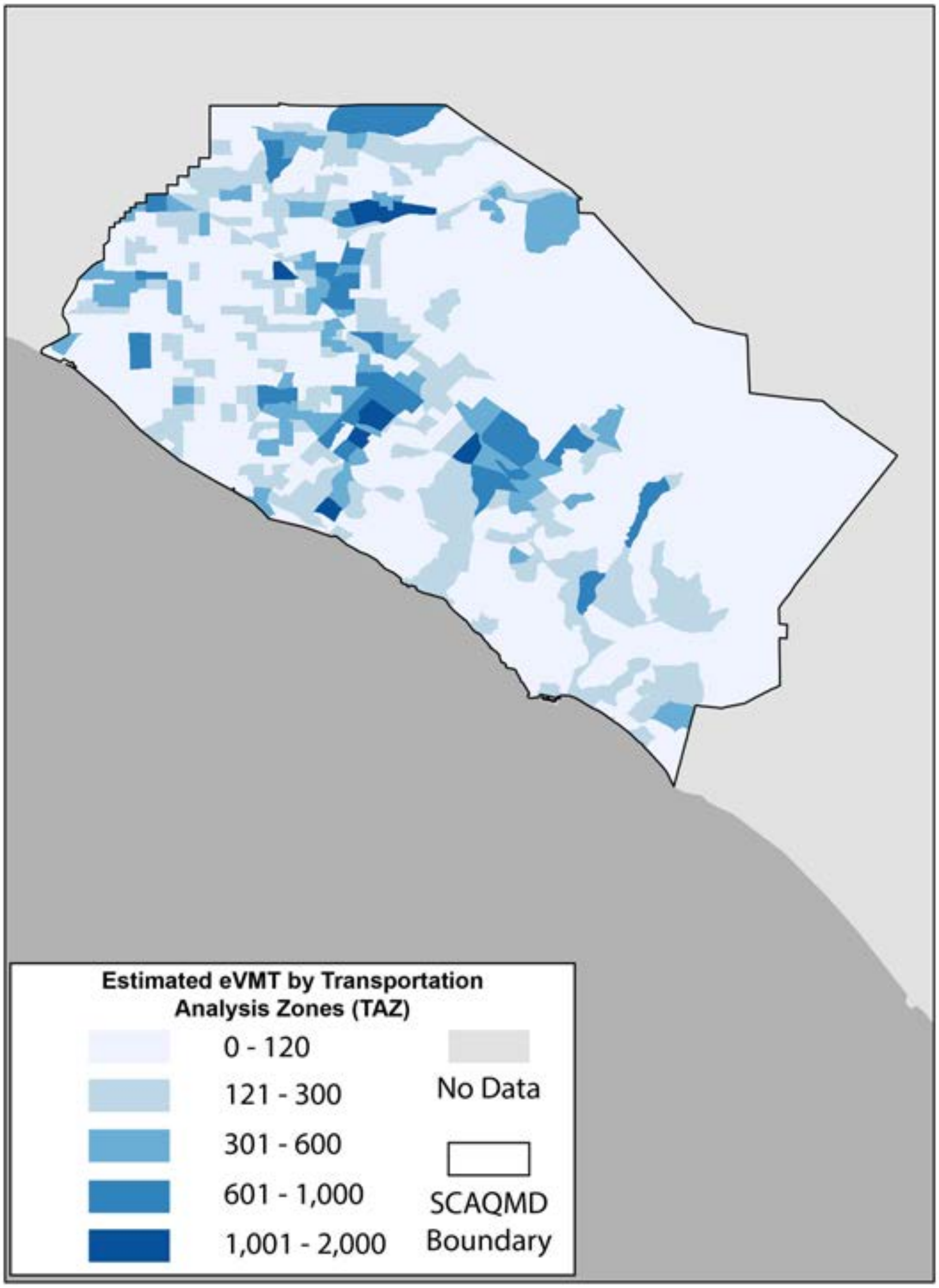


PROPENSITY-TO-PURCHASE SCORES IN SAN BERNARDINO COUNTY -- DISADVANTAGED COMMUNITIES

UCLA Luskin Center for Innovation

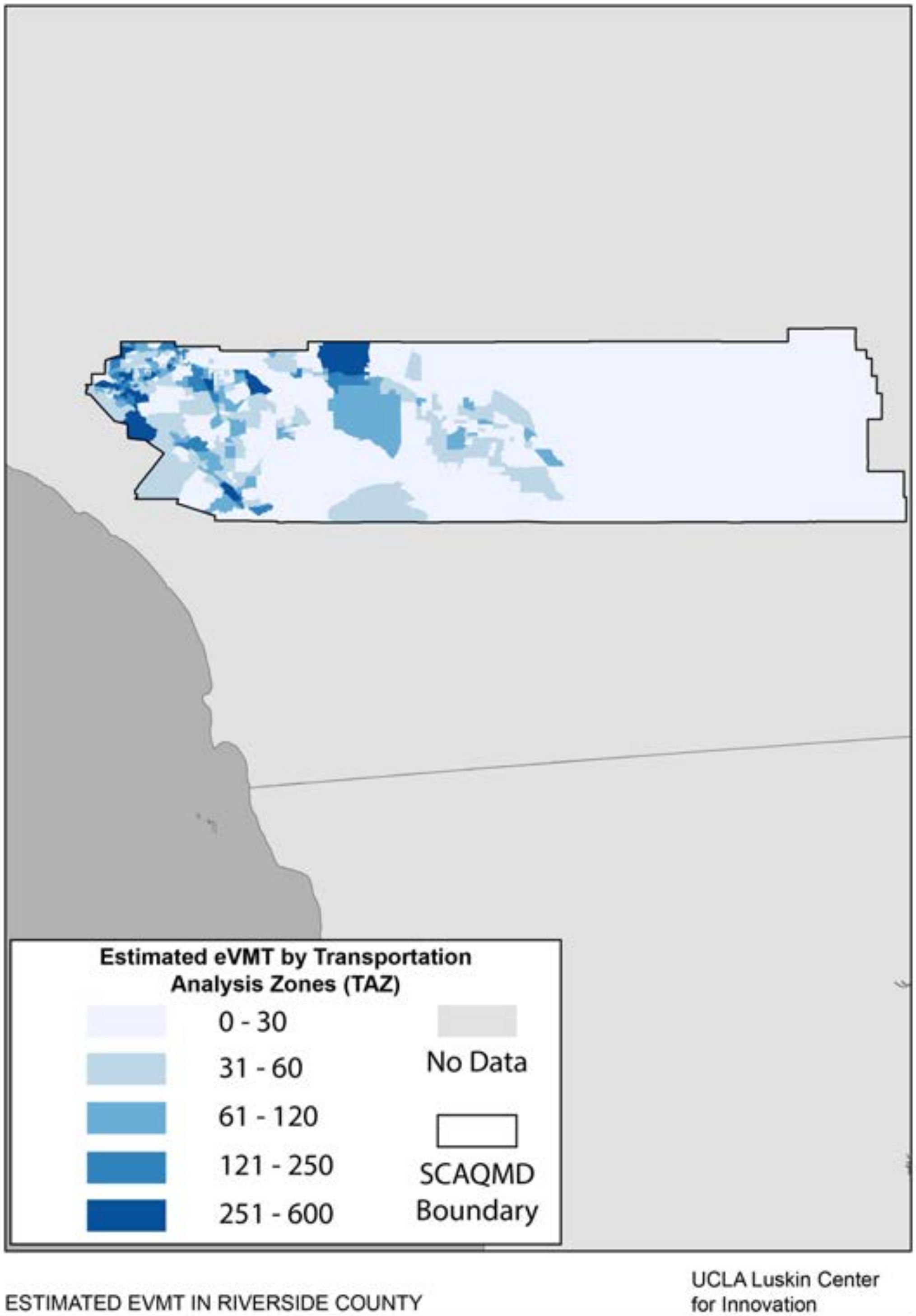
Appendix 4.1 - Workplace Charging Productivity – Maps

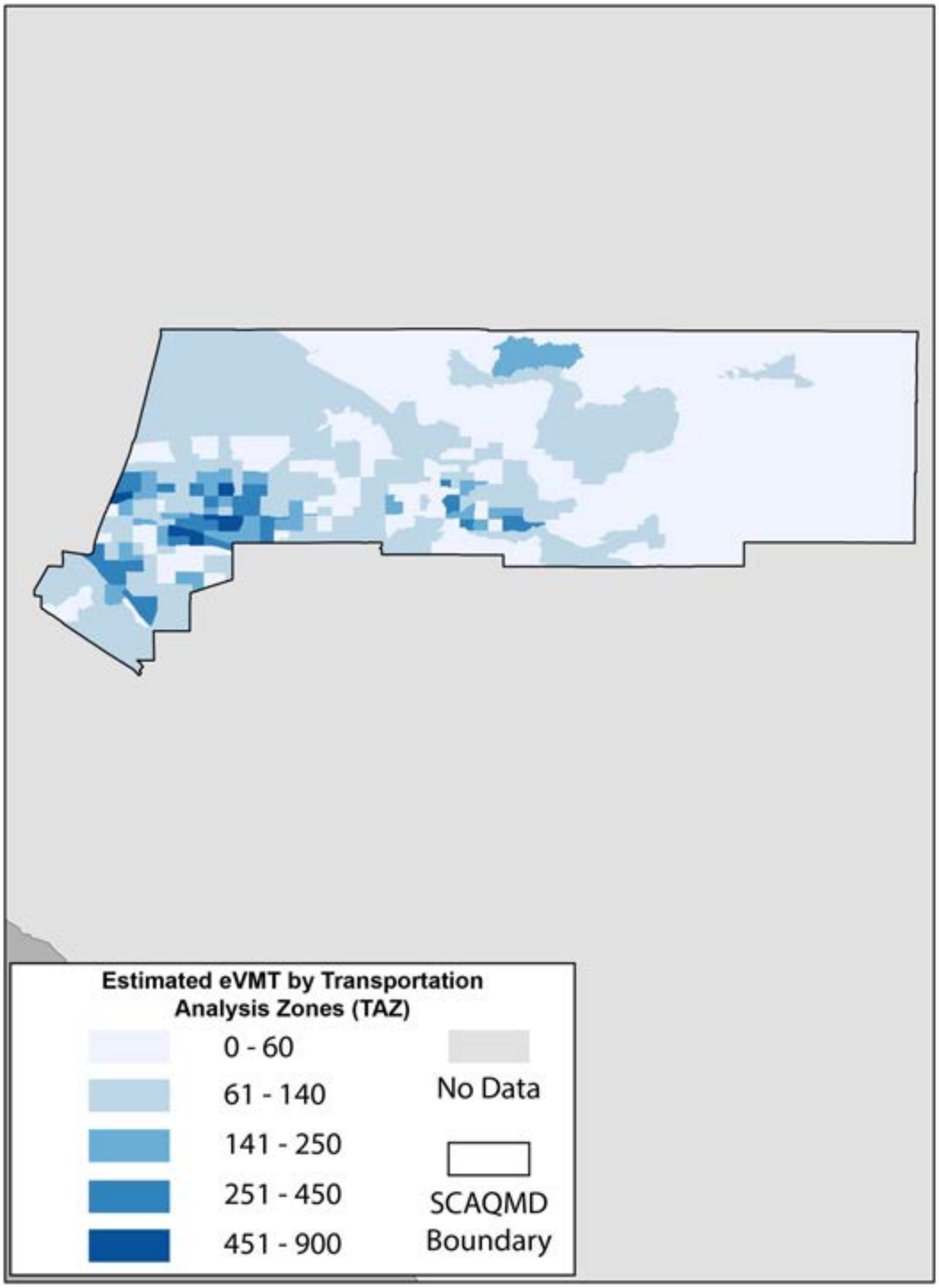




ESTIMATED EVMT IN ORANGE COUNTY

UCLA Luskin Center for Innovation

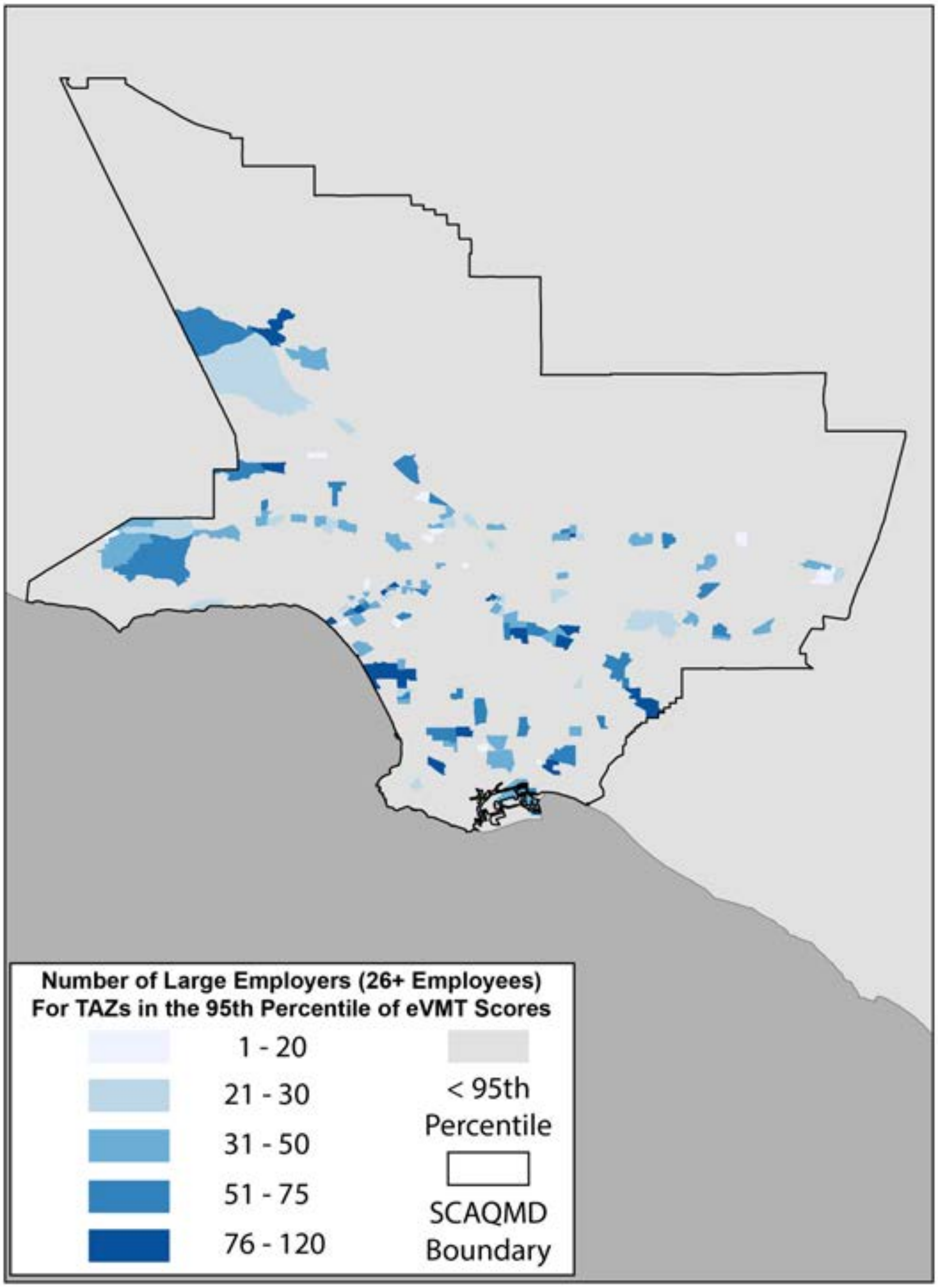

Estimated eVMT by Transportation Analysis Zones (TAZ)
0 - 30
31 - 60
61 - 120
121 - 250
251 - 600
No Data
SCAQMD Boundary
ESTIMATED EVMT IN RIVERSIDE COUNTY
UCLA Luskin Center for Innovation



ESTIMATED EVMT IN SAN BERNARDINO COUNTY

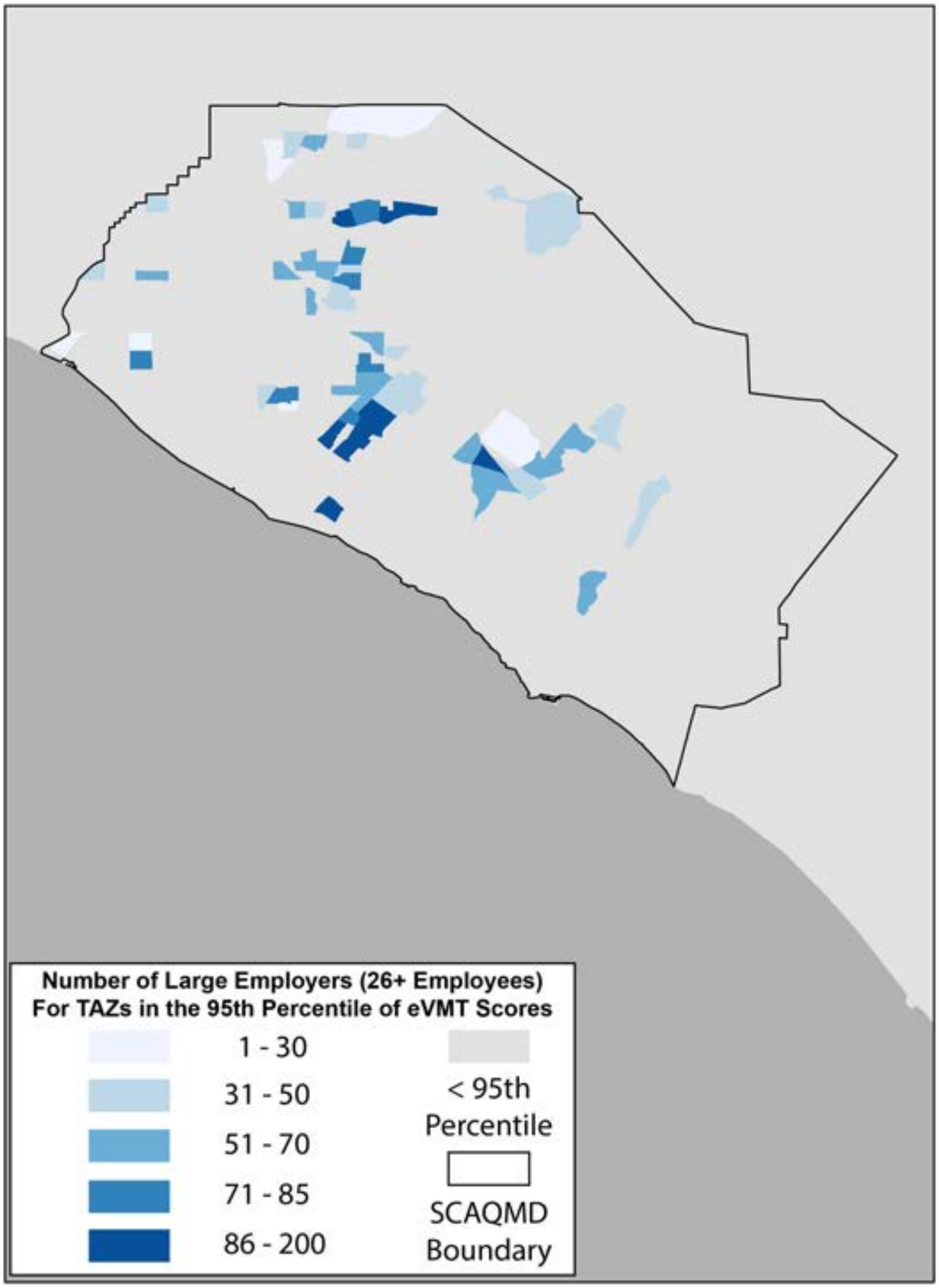
UCLA Luskin Center for Innovation

Appendix 4.2 – Large Employers – Maps



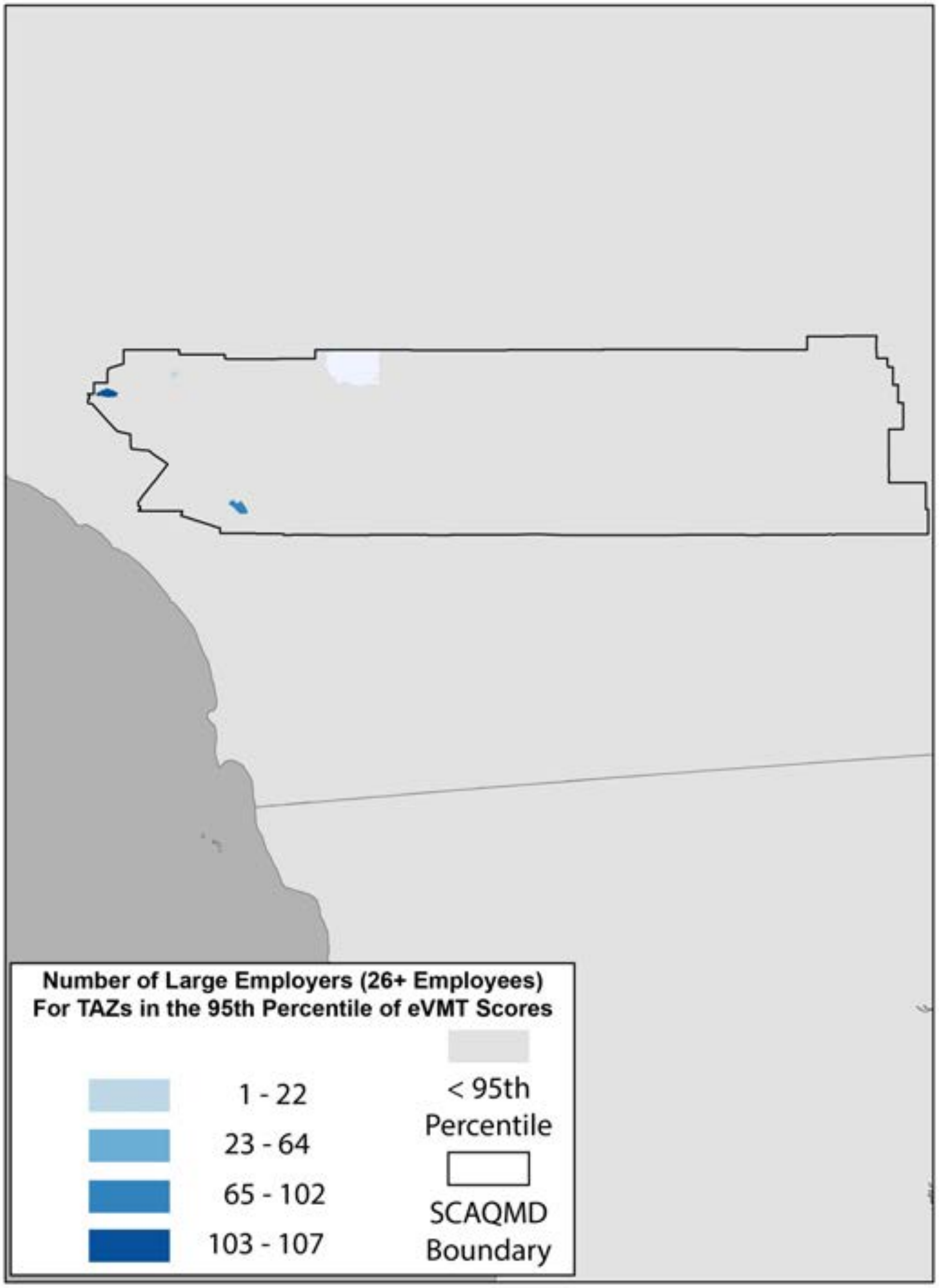
LARGE EMPLOYERS IN LOS ANGELES COUNTY

UCLA Luskin Center for Innovation



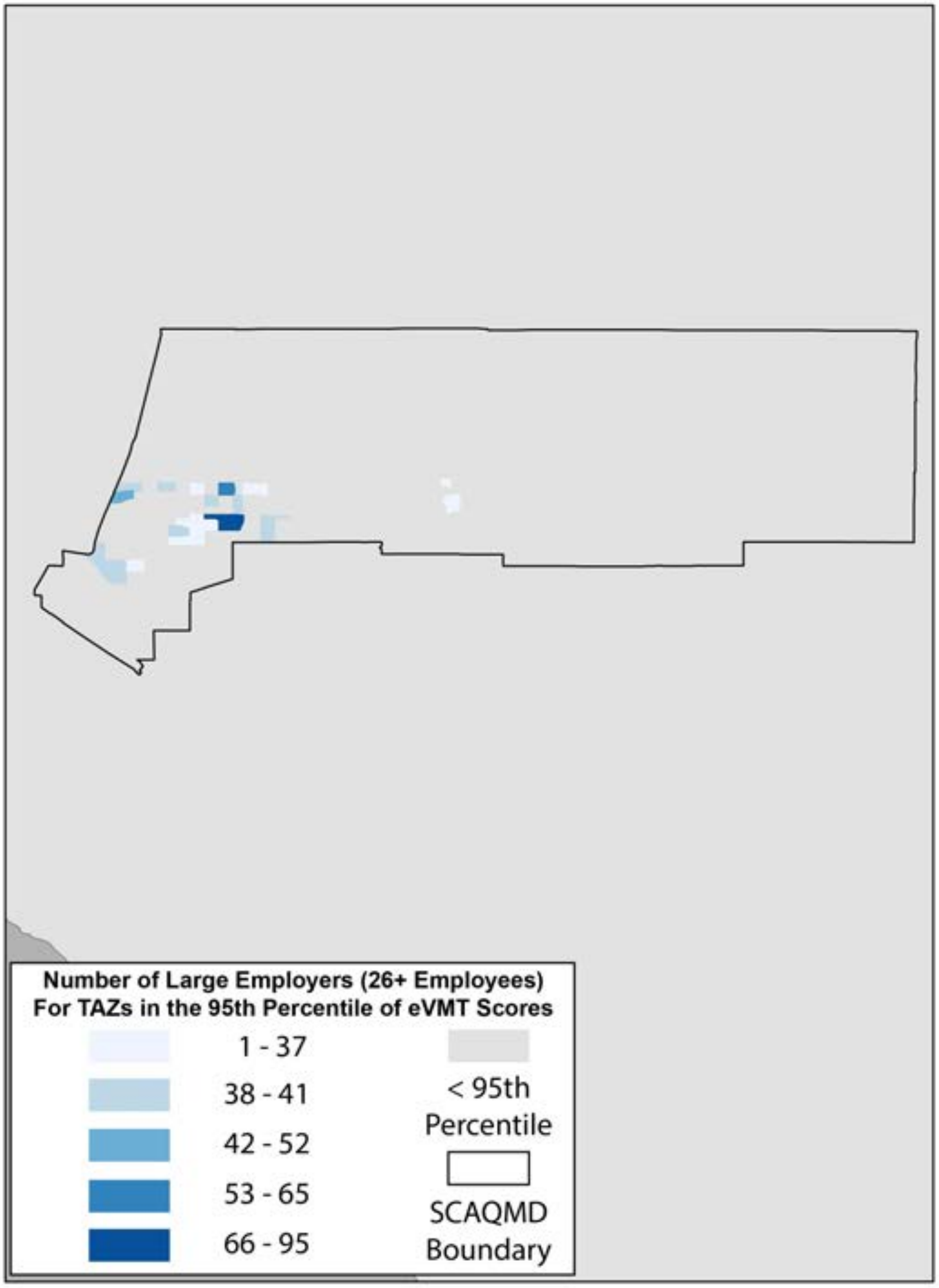
LARGE EMPLOYERS IN ORANGE COUNTY

UCLA Luskin Center for Innovation



LARGE EMPLOYERS IN RIVERSIDE COUNTY

UCLA Luskin Center for Innovation



LARGE EMPLOYERS IN SAN BERNARDINO COUNTY

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