Technical Memorandum

Date: 03/01/2023
To: Madera Subbasin Joint GSP GSAs
From: Davids Engineering, Inc.
Topic: Madera Subbasin Infrastructure Assessment

1 Introduction

This Infrastructure Assessment (Assessment) is intended to document insights about the characteristics of critical infrastructure in the Madera Subbasin, including the proximity, orientation, and relative vulnerability of infrastructure to adverse effects of land subsidence (referred to herein as "subsidence"). The assessment considers critical infrastructure and historical subsidence[1] throughout the entire Madera Subbasin, although the Assessment was prepared specifically to support development of the Madera Subbasin Revised Joint Groundwater Sustainability Plan (GSP). This information has been used by the Madera Subbasin Joint GSP Groundwater Sustainability Agencies (GSAs) to design subsidence-related Sustainable Management Criteria (SMC) with the goal of protecting this critical infrastructure from Undesirable Results (URs) of groundwater conditions during implementation of the Revised Joint GSP.

This Assessment first identifies the location and characteristics of critical infrastructure that must be considered when developing SMC in the Madera Subbasin, and then identifies recent subsidence conditions in areas of the Madera Subbasin that may create risks of adverse impacts to the beneficial uses and users of those critical infrastructure.

Critical infrastructure in the Madera Subbasin that were considered in this Assessment include:

- Roads and highway infrastructure
- Railroad infrastructure
- Waterways and surface water conveyance infrastructure
- Groundwater wells, including agricultural wells, domestic wells, and public supply wells
- Wastewater infrastructure

The Assessment considers how communities in and around the Madera Subbasin access and use critical infrastructure, how subsidence has or could affect those uses and users, and

[1] This assessment reviews historical subsidence conditions from 2015-2022. However, the GSAs recognize that residual subsidence has been observed in many areas of the San Joaquin Valley and is likely to occur to some extent in the Madera Subbasin in areas where historical subsidence was observed. Residual subsidence is associated with delayed compaction that occurs after groundwater levels have declined to a low point (the preconsolidation head), following a lag time of several years to decades in some cases.

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identifies areas where subsidence has recently occurred and where critical infrastructure may be vulnerable to URs from subsidence in the future.

This Assessment has been developed based on the information available during the GSP revisions process in 2022-2023. However, the GSAs have developed a work plan to fill subsidence-related data gaps between 2023-2026. The work plan is discussed in Section 2.2.2.7 of the Madera Subbasin Revised Joint GSP. The GSAs are pursuing proposition 68 grant funds through the California Department of Water Resources (DWR) Sustainable Groundwater Management (SGM) Grant Program that would help to support implementation of the work plan. As the GSAs implement the work plan and more is learned about subsidence conditions in the Madera Subbasin, those findings and implications for critical infrastructure will be documented in Annual Reports and GSP updates.

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2 Overview of Critical Infrastructure in the Madera Subbasin

This section provides a brief overview of critical infrastructure categories that were considered when establishing subsidence-related SMC in the Madera Subbasin. The locations of all critical infrastructure categories were considered with respect to the Madera Subbasin boundaries and the GSAs' boundaries (**Figure 1**). The orientation of all critical infrastructure categories was also considered with respect to the overall topography of the Madera Subbasin (**Figure 2**), where the ground surface elevation generally slopes downward from northeast (highest elevation) to southwest (lowest elevation).

Each subsection below generally summarizes what is encompassed in each critical infrastructure category, the general location and characteristics of that critical infrastructure (including its structure and orientation), and other core considerations for the beneficial uses and users of that infrastructure. Maps referenced in these subsections are provided at the end of the Assessment.

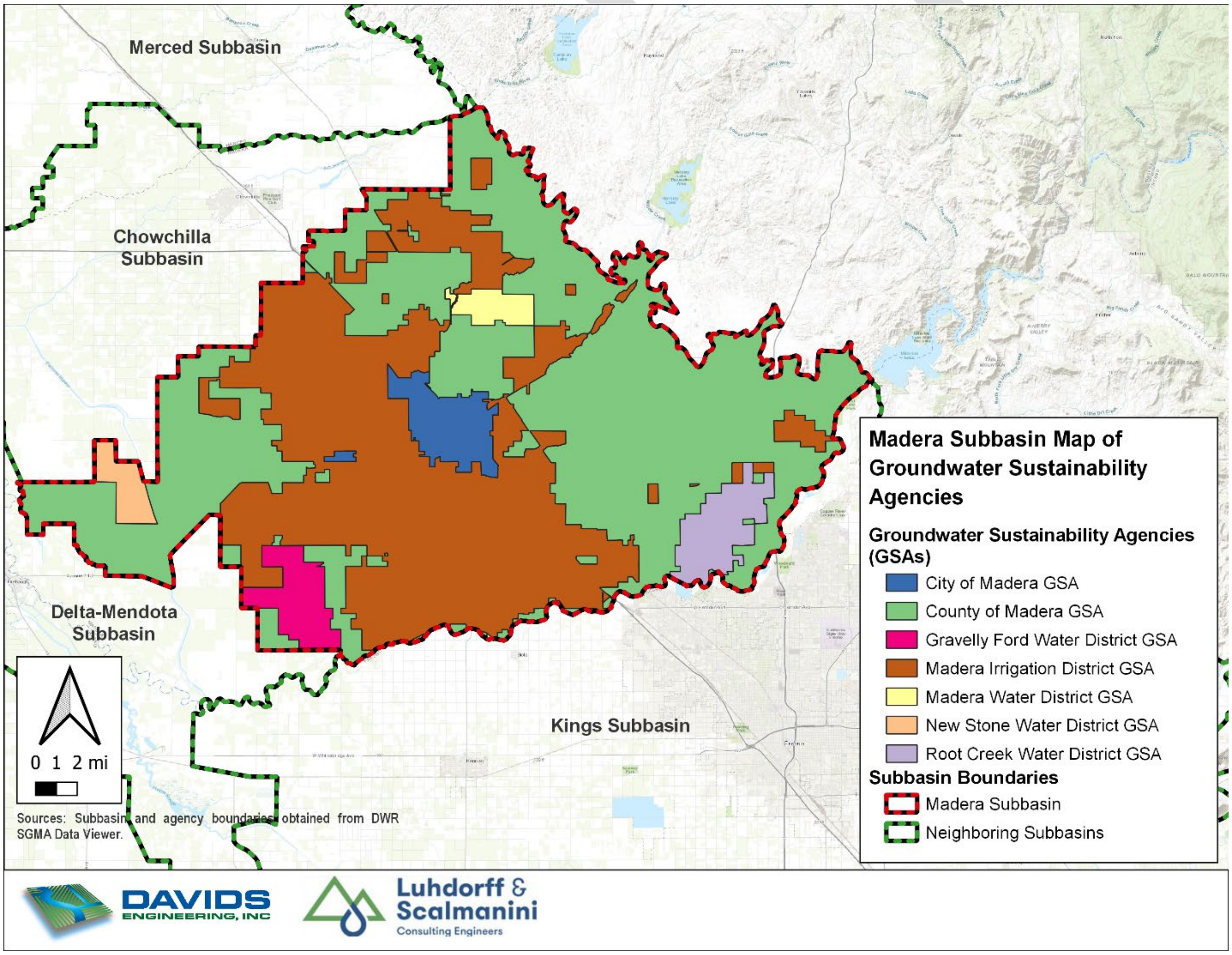

Figure 1. Map of Groundwater Sustainability Agencies in the Madera Subbasin.

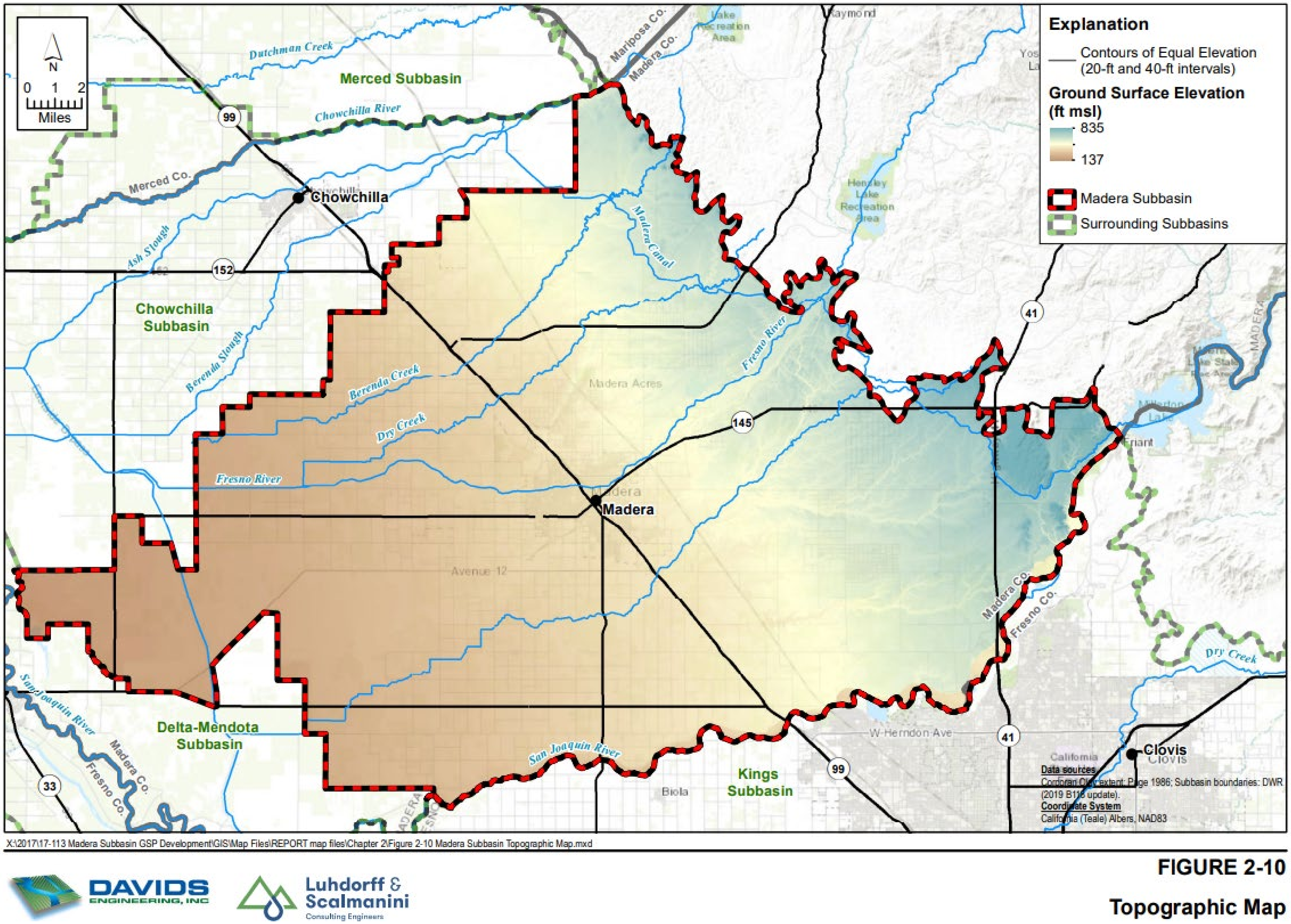

Figure 2. Madera Subbasin Topographic Map (Source: Madera Subbasin Revised Joint GSP, Figure 2-10).

2.1 Roads and Highway Infrastructure

Road and highway infrastructure considered when setting subsidence-related SMC in the Madera Subbasin primarily includes roadways and bridges within the boundaries of the Madera Subbasin. Maintaining the integrity of road and highway infrastructure is important for securing transportation and freight corridors within and through the Madera Subbasin.

Figure 3 shows the locations of major highways and highway bridges in the Madera Subbasin, and **Figure 4** shows the annual average daily traffic volumes on those major highways. The largest highway corridors in the Madera Subbasin include California State Routes (SR) 99, 145, and 41. SR 99 crosses the center of the Madera Subbasin, passing through the City of Madera following a northwest-southeast path. SR 145 follows a north-south path to the south of the City of Madera, and follows a southwest-northeast path to the east of the City of Madera until it connects to SR 41 near the eastern edge of the Madera Subbasin. SR 41 crosses the eastern portion of the Madera Subbasin in a north-south path. Other smaller, local roadways are generally located in the City of Madera or traverse rural areas of the Madera Subbasin.

According to data available from the California Department of Transportation (Caltrans), SR 99 features the majority of highway bridges in the Madera Subbasin (29 of 43), and also experiences the majority of traffic (typically serving more than 40,000 vehicles per day, on average). Off of SR 99, traffic on SR 145 ranges from approximately 7,000-15,000 vehicles per day, on average, with higher volumes nearer to the City of Madera. On the eastern side of the Madera Subbasin, traffic on SR 41 ranges from approximately 16,000-18,000 vehicles per day.

2.2 Railroad Infrastructure

Railroad infrastructure was also considered in setting subsidence-related SMC in the Madera Subbasin. Like road and highway infrastructure, maintaining the integrity of railroad infrastructure is important for securing transportation and freight corridors through the Madera Subbasin. **Figure 5** shows the location of railroad infrastructure in the Madera Subbasin summarized from available Caltrans data. The Madera Subbasin contains two main railways: one that crosses the central portion of the Madera Subbasin and passes through the City of Madera following a northwest-southeast path, and the second following a roughly parallel path to the northeast of the first. A third short railway, the North Madera Industrial Lead, also branches off from the first railway within the City of Madera, following a short southwest-northeast path.

2.3 Waterways and Surface Water Conveyance Infrastructure

Waterways and surface water conveyance infrastructure considered when setting subsidence-related SMC in the Madera Subbasin are shown in **Figure 6**. Maintaining the integrity of waterways and surface water conveyance infrastructure is important for flood protection, irrigation, recharge, and other beneficial uses and users of surface water in and around the Madera Subbasin. More specific considerations for waterways and surface water conveyance infrastructure are described below.

2.3.1 General Flow Characteristics

Most waterways that flow into and through the Madera Subbasin begin in upslope lands east and northeast of the Madera Subbasin and flow downslope in a westerly direction. Besides the San Joaquin River, which flows along the southern edge of the Subbasin, waterways in the Madera Subbasin are considered intermittent or ephemeral streams, and have historically remained dry for at least several months each year.

The Madera Canal and reaches of the Fresno River, Berenda Creek, Cottonwood Creek, and Dry Creek within the Madera Subbasin are used for conveyance of surface water (generally in March-October at times when surface water supplies are available). Virtually all surface water flows on these waterways originate from either Hensley Lake releases at Hidden Dam or from Millerton Reservoir releases at Friant Dam that are delivered via the Madera Canal. These waterways are typically dry during the non-irrigation season except during storm runoff events and during periods when flood releases occur from the upstream reservoirs.

Flows on the San Joaquin River along the southern boundary of the Madera Subbasin originate from various upstream sources, including Millerton Reservoir releases at Friant Dam. Streamgage data from the United States Geological Survey (USGS)[2] shows flows along the San Joaquin River during most times of year, with greater flows typically occurring during spring months of wet water years.

2.3.2 Waterways within the Purview of the Central Valley Flood Protection Board

Core considerations for waterways within the purview of the Central Valley Flood Protection Board (CVFPB) are the freeboard and design profile, as defined in the corresponding Federal and State Operation and Maintenance Manuals (O&M Manuals).

In their comments to the Madera Subbasin GSAs, the CVFPB noted that any reduction in the freeboard or change to design profile, beyond the design criteria given in the O&M Manuals, may lead to increased flood risk and damage to Federal-State flood control facilities, and is considered unlawful for waterways in their purview.

The GSAs have recognized and considered the following design criteria of waterway reaches in the Madera Subbasin when establishing the subsidence-related SMC for the Madera Subbasin:

- Fresno River:
  - Bank levees freeboard of 3 feet
  - Design flows of 5,000 cubic feet per second (cfs)
- San Joaquin River:
  - Bank levees freeboard of 3 feet
  - Design flows of 8,000 cfs
- Chowchilla Bypass:
  - Bank levees freeboard of 4 feet

[2] USGS 11251000 SAN JOAQUIN R BL FRIANT CA. https://waterdata.usgs.gov/nwis/uv?site_no=11251000.

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- Design flows of 5,500 cfs

2.4 Groundwater Wells

Groundwater well infrastructure in the Madera Subbasin encompasses the infrastructure of multiple types of wells, including agricultural wells, domestic wells, and public supply wells. Sustaining access to groundwater is crucial to upholding the Human Right to Water (as set forth in California Water Code § 106.3) and is also important to maintaining the economic vitality of the Madera Subbasin.

Figure 7 through **Figure 9** show the general locations of groundwater wells of each type (agricultural, domestic, and public supply), aggregated by section from Well Completion Report (WCR) data available from the California Department of Water Resources (DWR). WCR data includes only wells with well completion reports that have been submitted to DWR since 1970, and thus typically underestimates the total number of wells in each section. However, the data is expected to provide a reasonably accurate understanding of the relative location and distribution of wells in the Madera Subbasin. Agricultural wells are the most uniformly distributed across the entire Madera Subbasin, while domestic wells and public supply wells are distributed most densely in a strip generally following SR 99, especially in sections surrounding the City of Madera, and in sections around Bonadelle Ranchos-Madera Ranchos. Agricultural wells in the Madera Subbasin are typically deeper than domestic and public supply wells (see the Madera Subbasin Revised Joint GSP Figures 2-44 through 2-46).

2.5 Wastewater Infrastructure

Wastewater infrastructure in the Madera Subbasin primarily includes the wastewater treatment plant operated within the City of Madera. Like other municipal infrastructure, maintaining the integrity of wastewater infrastructure is important to maintaining sanitary conditions in urban communities. The importance of functional wastewater infrastructure is closely tied to the Human Right to Water.

3 Relationship between Subsidence Conditions and Infrastructure Concerns

This section summarizes the potential URs to critical infrastructure that may result from subsidence, and then evaluates the relationship between recent historical subsidence that has occurred in the Madera Subbasin and the potential vulnerability of critical infrastructure in the Madera Subbasin. Maps referenced in these subsections are provided at the end of the Assessment. It is noted that the Joint GSP GSAs have set the subsidence minimum thresholds (MTs) at 0.00 feet/year in 2040. Subsidence conditions at 2040 are not expected to trigger undesirable results for any of the critical infrastructure.

Figure 3 through **Figure 9** show the location of critical infrastructure and the historical cumulative subsidence between 2015-2020 in the Madera Subbasin. These figures show cumulative subsidence conditions (reported as total vertical displacement from InSAR[3] data) starting with the first available InSAR data (June 2015) and extending through June 2020. **Figure 10** through **Figure 16** similarly show the location of critical infrastructure and the historical cumulative subsidence between 2015-2022 in the Madera Subbasin, extending the summary of subsidence conditions through the most recently available InSAR data available at the time of this analysis (through June 2022). The subsections below summarize relevant findings related to each figure, in addition to other pertinent findings from other studies and surveys of subsidence impacts in the Madera Subbasin.

3.1 Roads and Highway Infrastructure

In general, subsidence has the potential to cause URs to users of road and highway infrastructure by causing deterioration or loss of access and use of that infrastructure through fractures, unevenness, or other issues with structural integrity.

There is currently no known subsidence-related issue that has resulted in loss of access and use of road and highway infrastructure in the Madera Subbasin. As shown in **Figure 3, Figure 4**, **Figure 10**, and **Figure 11**, SR 99 – the roadway with the greatest number of bridges and the highest volume of traffic in the Madera Subbasin – is located in the central and eastern portion of the Madera Subbasin where subsidence rates have generally been lower. Between 2015-2020, the total cumulative subsidence along SR 99 ranged from virtually zero subsidence (southeast of the City of Madera) to, at most, approximately 2 feet of total cumulative subsidence (less than approximately 0.4 feet per year over approximately five years). Along SR 145, the total cumulative subsidence from 2015-2020 was less than 1 foot (approximately 0.2 feet per year over approximately five years). Along SR 41, the total cumulative subsidence from 2015-2020 was less than approximately 0.5 feet (.1 feet per year over approximately five years).

As described in Section 3.4.3 of the Madera Subbasin Revised Joint GSP, the GSAs are planning to mitigate subsidence, as needed, in the Madera Subbasin and do not expect residual subsidence conditions to cause URs to beneficial uses and users of roads and highway infrastructure. However, the GSAs will continue to monitor conditions and will adapt GSP implementation if URs are found to occur. Future findings and adaptations to GSP implementation will be described in Annual Reports, as applicable.

3.2 Railroad Infrastructure

Similar to roads and highways, subsidence has the potential to cause URs to users of railroads by causing deterioration or loss of access and use of railways and related infrastructure through fractures, unevenness, or other issues with structural integrity.

[3] Interferometric Synthetic Aperture Radar (InSAR) data provides measurements of vertical ground surface displacement, and is available from the California Department of Water Resources (DWR) beginning in June 2015. https://data.cnra.ca.gov/dataset/tre-altamira-insar-subsidence.

There is currently no known subsidence-related issue that has resulted in loss of access and use of railroad infrastructure in the Madera Subbasin. As shown in **Figure 5** and **Figure 12**, railroads in the Madera Subbasin are located in the northern and eastern portions of the Madera Subbasin where the cumulative subsidence from 2015-2020 was between 0.0 to 2 feet (approximately 0.0 to 0.4 feet per year over approximately five years). As described in Section 3.4.3 of the Madera Subbasin Revised Joint GSP, the GSAs are planning to mitigate subsidence, as needed, in the Madera Subbasin and do not expect residual subsidence conditions to cause URs to beneficial uses and users of railroad infrastructure. However, the GSAs will continue to monitor conditions and will adapt GSP implementation if URs are found to occur. Future findings and adaptations to GSP implementation will be described in Annual Reports, as applicable.

3.3 Waterways and Conveyance Infrastructure

Subsidence in the Madera Subbasin has the potential to cause URs to uses and users of waterways and conveyance infrastructure by potentially causing changes in the design profile and slope of gravity flow channels, affecting freeboard and channel capacity. Changes that reduce capacity can impact the ability of surface water suppliers to use those conveyance channels to meet demands. Changes that reduce capacity and diminish freeboard can also cause flooding along waterways during times of peak flow. The GSAs considered potential impacts to waterways in the Madera Subbasin resulting from subsidence in relation to the channel design criteria described in the respective O&M Manuals, including the channel freeboard and design profile.

3.3.1 East-West Oriented Waterways

As shown in **Figure 6** and **Figure 13**, the majority of waterways in the Madera Subbasin flow generally from east to west, in the same general direction as the cumulative "subsidence gradient" that has historically occurred in the Madera Subbasin. Along these "east-west" oriented waterways – including the Fresno River, Berenda Creek, Cottonwood Creek, and Dry Creek – higher subsidence rates in the western portion of the Madera Subbasin have increased the existing slope of the ground surface (**Figure 2**), functionally increasing the capacity of those channels. Thus, despite there being higher rates of subsidence in the western portion of the Madera Subbasin where these waterways flow – as much as 3.0 feet in some areas between 2015-2020 (approximately 0.6 feet per year) and as much as 4.5 feet in some areas along the Chowchilla Subbasin boundary between 2015-2022 (approximately 0.9 feet per year) – the GSAs do not anticipate that subsidence conditions will cause URs to beneficial uses and users of these east-west oriented waterways in the Madera Subbasin in the near future.

For subsidence to substantially impact the freeboard and design profile of those east-west oriented waterways in opposition to the O&M Manuals, subsidence rates in the eastern portion of the Madera Subbasin would need to significantly increase relative to the western portion of the Madera Subbasin and reduce the existing ground surface slope. Considering historical subsidence conditions and differences in the underlying geologic structure of the Madera Subbasin from east-to-west, the GSAs consider URs to beneficial uses and users of the east-west oriented waterways to be unlikely. Nevertheless, as described in Section 3.4.3 of the Madera Subbasin Revised Joint GSP, the GSAs will continue to monitor conditions and will adapt GSP implementation if URs are found to occur. Future findings and adaptations to GSP implementation will be described in Annual Reports, as applicable.

3.3.2 Madera Canal

Besides those east-west oriented waterways that are used for conveyance of surface water supplies (Fresno River, Berenda Creek, Cottonwood Creek, Dry Creek), the primary conveyance infrastructure in the Madera Subbasin is the Madera Canal.

The Madera Canal flows along the far northeastern portion of the Madera Subbasin where the cumulative subsidence from 2015-2022 remained less than 0.5 feet in total (less than 0.1 feet per year). There is currently no known subsidence-related issue with capacity or flows along Madera Canal in the Madera Subbasin. The GSAs consider any future URs to the Madera Canal to be highly unlikely in view of the Madera Subbasin's topography and the location of the Madera Canal relative to where subsidence has historically occurred.

3.3.3 Chowchilla Bypass and San Joaquin River

During development of the Madera Subbasin GSPs and the Revised GSPs, the Madera Subbasin GSAs reviewed past analyses of subsidence-related capacity concerns conducted by DWR in May 2018 for the San Joaquin River Restoration Program (SJRRP). These analyses are documented in a report titled "Evaluation of the Effect of Subsidence on Flow Capacity in the Chowchilla and Eastside Bypasses, and Reach 4A of the San Joaquin River" (DWR, 2018). The analyses were conducted to evaluate the subsidence-related impacts to the flow capacity of the Chowchilla Bypass, the Eastside Bypass, and the San Joaquin River under recent historical subsidence conditions (as of 2016) and projected future subsidence conditions through 2026. Flows under the different subsidence-related topography changes were simulated using HEC-RAS[4] with consideration for the channel design criteria in the O&M Manuals (described in Section 2.3.2, above).

Table 3 of the analysis (shown in **Table 1**, below) summarizes the estimated flow capacity in:

- Chowchilla Bypass (segment from the bifurcation structure at the San Joaquin River to the Fresno River; this segment flows primarily within the Madera Subbasin),
- Eastside Bypass (four segments from the end of the Chowchilla Bypass to the Mariposa Bypass; these segments primarily flow outside the Madera Subbasin)
- San Joaquin River (Reach 4A, which flows along the boundaries of the Chowchilla Subbasin, and the San Slough Connector Channel; these segments primarily flow outside the Madera Subbasin)

[4] United States Army Corps of Engineers Hydrologic Engineering Center's River Analysis System (HEC-RAS). Available at: https://www.hec.usace.army.mil/software/hec-ras/.

Results of the analysis were calculated assuming a fixed freeboard set according to the design criteria in the O&M Manuals. The extent of each reach considered in the analysis is shown in **Figure 17**, below. These analyses found that:

- Flow capacity in all reaches of the Chowchilla Bypass (within the Madera Subbasin) and two reaches of the Eastside Bypass (from Fresno River to Ash Slough, directly downstream of the Madera Subbasin) were within design flows in all historical and projected scenarios considered.
- Flow capacity in the San Joaquin River Reach 4A (outside the Madera Subbasin) and in the Eastside Bypass from Ash Slough to Sand Slough (outside the Madera Subbasin) were already considered to be below the design capacity beginning in the scenario considering historical subsidence conditions as of 2016.

These findings suggest that:

- The design profile and freeboard of the Chowchilla Bypass (within the Madera Subbasin) and upstream reaches of the Eastside Bypass (directly downstream of the Madera Subbasin) were not adversely impacted by subsidence conditions as of 2016, and were not anticipated to be impacted by future subsidence through 2026 (under the assumptions given below).
- The design profile and freeboard of the San Joaquin River Reach 4A (outside the Madera Subbasin) and the Eastside Bypass from Ash Slough to Sand Slough (outside the Madera Subbasin) were already impaired relative to the design criteria given in the O&M Manuals as of 2016. These impairments are far outside the boundaries of the Madera Subbasin and are not understood to be directly impacted by subsidence conditions within the Madera Subbasin. Additionally, these impairments precede the formation of the GSAs and the GSP implementation period in both the Madera Subbasin and neighboring subbasins.

The GSAs do recognize certain assumptions and limitations given for these analyses (DWR, 2018), mainly:

- Flows were modeled using HEC-RAS, and were validated by flows in 2017 (assuming that those flows were close to design flows). Flow capacities were evaluated for two conditions: a run-of-the-river condition in which there were no concurrent tributary flows, and a backwater condition in which there were concurrent flows in tributary channels that added to downstream flows. Tributary flows to the Chowchilla/Eastside Bypass from Ash Slough, Berenda Slough, and other waterways were assumed to concurrently reach their design flows (per the O&M Manuals) in backwater model scenarios. The GSAs cannot be sure of the validity of the model or these assumptions.
- Projected future subsidence rates through 2026 were estimated using the average annual subsidence rates reported by the United States Bureau of Reclamation from 2011 to 2017. Those subsidence rates may not accurately reflect the actual rates observed from InSAR data in 2017-2020 in the Madera Subbasin and neighboring areas of the Chowchilla Subbasin. For instance, certain landowners in the southwestern portion of the Chowchilla Subbasin (near the Madera and Delta-Mendota Subbasins)

entered into a Subsidence Control Measures Agreement in 2017 and have since made significant progress to reduce subsidence by reducing pumping from the Lower Aquifer. Those efforts have resulted in significantly reduced subsidence rates in the vicinity of the Chowchilla Bypass, Eastside Bypass, and the San Joaquin River, as compared to rates prior to 2017 (see Section 3.3.3 of the Chowchilla Subbasin Revised GSP).

- The conclusions of DWR's study are planning-level modeled estimates that do not consider factors besides subsidence (e.g., sediment transport). Sediment deposition is another factor that affects capacity, although sediment management and maintenance of the Chowchilla Bypass, Eastside Bypass, and the San Joaquin River is not the responsibility of the GSAs.

Considering these findings, the GSAs do not expect that subsidence conditions in the Madera Subbasin will impair the design profile or freeboard of the Chowchilla Bypass in the Madera Subbasin during the GSP implementation period. The GSAs also do not expect subsidence conditions in the Madera Subbasin to impair the design profile or freeboard of the Eastside Bypass or the San Joaquin River directly downstream of the Madera Subbasin beyond what conditions were already present prior to 2016.

Nevertheless, as described in Section 3.4.3 of the Madera Subbasin Revised Joint GSP, the GSAs will continue to monitor conditions and will adapt GSP implementation if URs are found to occur. Future findings and adaptations to GSP implementation will be described in Annual Reports, as applicable.

3.4 Groundwater Wells

In general, subsidence has the potential to cause URs to users of groundwater well infrastructure by causing deterioration or loss of access and use of that infrastructure through casing damage, collapse, or other issues with structural integrity. These potential issues are also affected or exacerbated by other factors besides subsidence, such as well age, construction, and materials.

As shown in **Figure 7** and **Figure 14**, agricultural wells are generally distributed evenly throughout the Madera Subbasin, in areas where both higher and lower rates of subsidence have occurred. A survey of agricultural well owners in portions of Madera County in spring 2022 found that wells near the Madera/Chowchilla Subbasin border were beginning to collapse, particularly in areas that have experienced approximately 3 feet of subsidence or more. However, the agricultural well owners that were surveyed also indicated that these effects and the costs of well deepening and replacement were considered a necessary side effect of maintaining the economic viability of their businesses during the current drought and early GSP implementation efforts, while projects and management actions – including demand management – ramp up. Those agricultural well owners surveyed did not consider these effects to be "undesirable results." The GSAs will continue to monitor conditions and engage with stakeholders, and will adapt GSP implementation if URs are found to occur. Future findings and adaptations to GSP implementation will be described in Annual Reports, as applicable.

As shown in **Figure 8**, **Figure 9**, **Figure 15**, and **Figure 16**, domestic wells and public supply wells in the Madera Subbasin are distributed most densely in the vicinity of SR 99, especially in sections surrounding the City of Madera, and in sections around Bonadelle Ranchos-Madera Ranchos. While these areas of the Madera Subbasin have historically experienced lower rates of subsidence, domestic wells in various parts of the Madera Subbasin have already experienced URs from loss of access to groundwater. SMC and GSP implementation efforts have been designed to directly address these issues and preserve the Human Right to Water, as described in Section 3.4.3 of the Madera Subbasin Revised Joint GSP.

Discussions and stakeholder input during public GSP development meetings indicated a clear desire to balance the water supply needs of all beneficial uses and users of groundwater to the greatest extent practicable. Stakeholders expressed clear intent to protect domestic well users that rely on groundwater, but also expressed a desire to protect the local agricultural economy – the economic lifeblood of the region – while GSP implementation ramps up. The GSAs considered many groundwater management approaches to achieve these goals of balancing diverse beneficial user interests. The minimum thresholds (MTs) established for groundwater levels in the Madera Subbasin reflect the outcome of this balanced approach, allowing groundwater use for agricultural production to continue, albeit at a gradually reducing rate, while GSP implementation ramps up, and recognizing that this would likely result in lowered groundwater levels impacting some well users in the Madera Subbasin. This approach was considered preferable to alternatives that would require immediate and substantial cutbacks in agricultural groundwater pumping in order to avoid significant and unreasonable adverse impacts on well users, especially domestic wells. Such an alternative would result in major economic impacts to the local communities and all stakeholders in the Madera Subbasin, including domestic well users and disadvantaged communities. The GSAs re-evaluated the economic tradeoffs of these alternatives in 2022 (Appendix 3.D of the Madera Subbasin Revised Joint GSP), and determined that the avoided costs resulting from immediate demand reduction (i.e., fewer domestic wells requiring replacement) would be comparatively small ($38.64 million) relative to the additional lost agricultural net return ($251.98 million) in the Madera Subbasin, even after accounting for the pumping cost savings ($92.52 million). These analyses considered the impacts of immediate demand reduction only on agricultural net return, but in reality the economic impacts would spread to other county businesses and industries, significantly increasing the net effect on all beneficial uses and users of groundwater in the Madera Subbasin, including domestic well owners.

With these findings, the GSAs determined that implementing a Domestic Well Mitigation Program would provide the best and most economically reasonable outcome for beneficial uses and users of groundwater in the Madera Subbasin by preserving the local economy and protecting domestic well users' access to groundwater. For this reason, the GSAs have elected to mitigate for potential impacts to domestic well users during the GSP implementation period or until groundwater sustainability is achieved. Implementation of the Domestic Well Mitigation

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Program will allow the GSAs to establish lower MTs that avoid URs to other groundwater users, while still preserving access to critical water supplies for domestic well users.

The GSAs have expressed and formalized their clear commitment to fund and implement the Program beginning no later than January 1, 2024. GSA staff and representatives have already made substantial and material progress toward Program development and implementation by creating and executing a Domestic Well Mitigation Program Memorandum of Understanding (MOU).

3.5 Wastewater Infrastructure

Subsidence has the potential to cause URs to users of wastewater infrastructure by causing deterioration or loss of functionality of the gravity flow characteristics of those systems and by causing other issues with structural integrity.

There is currently no known subsidence-related issue that has resulted in loss of functionality of wastewater infrastructure in the Madera Subbasin. The cumulative subsidence in the City of Madera service area (**Figure 1**) was approximately 1.5 feet or less between 2015-2022 (approximately 0.2 feet per year or less over approximately seven years). As described in Section 3.4.3 of the Madera Subbasin Revised Joint GSP, the GSAs are planning to mitigate subsidence, as needed, in the Madera Subbasin and do not expect residual subsidence conditions to cause URs to beneficial uses and users of wastewater infrastructure. However, the GSAs will continue to monitor conditions and will adapt GSP implementation if URs are found to occur. Future findings and adaptations to GSP implementation will be described in Annual Reports, as applicable.

4 References

DWR. 2018. Evaluation of the Effect of Subsidence on Flow Capacity in the Chowchilla and Eastside Bypasses, and Reach 4A of the San Joaquin River. May 2018. In Technical Memorandum: Channel Capacity Report 2018 Restoration Year. San Joaquin River Restoration Program. January 2019.

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5 Figures and Tables

Figure 3 through **Figure 17** and **Table 1** are provided below.

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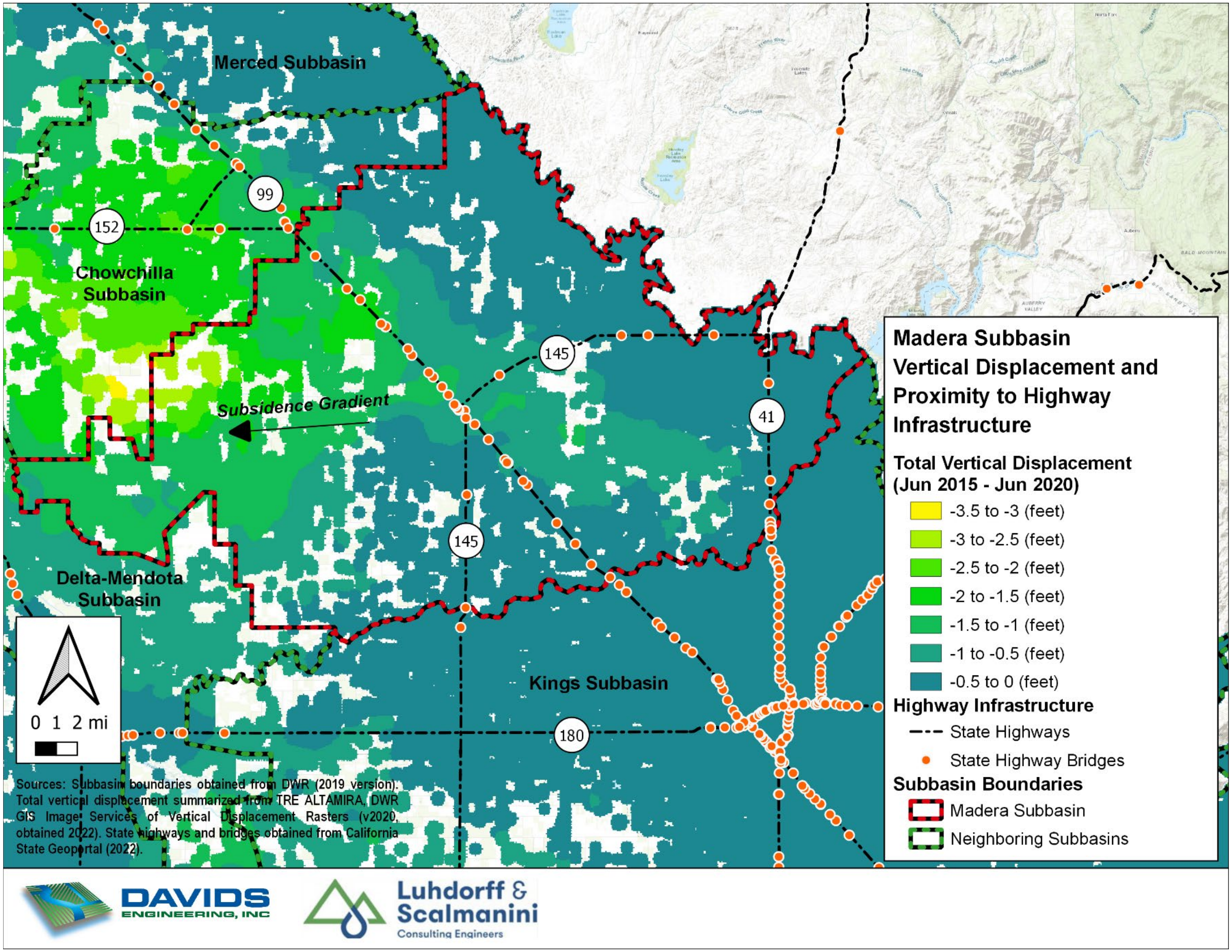

Figure 3. Vertical Displacement (June 2015 - June 2020) and Proximity to Highway Infrastructure.

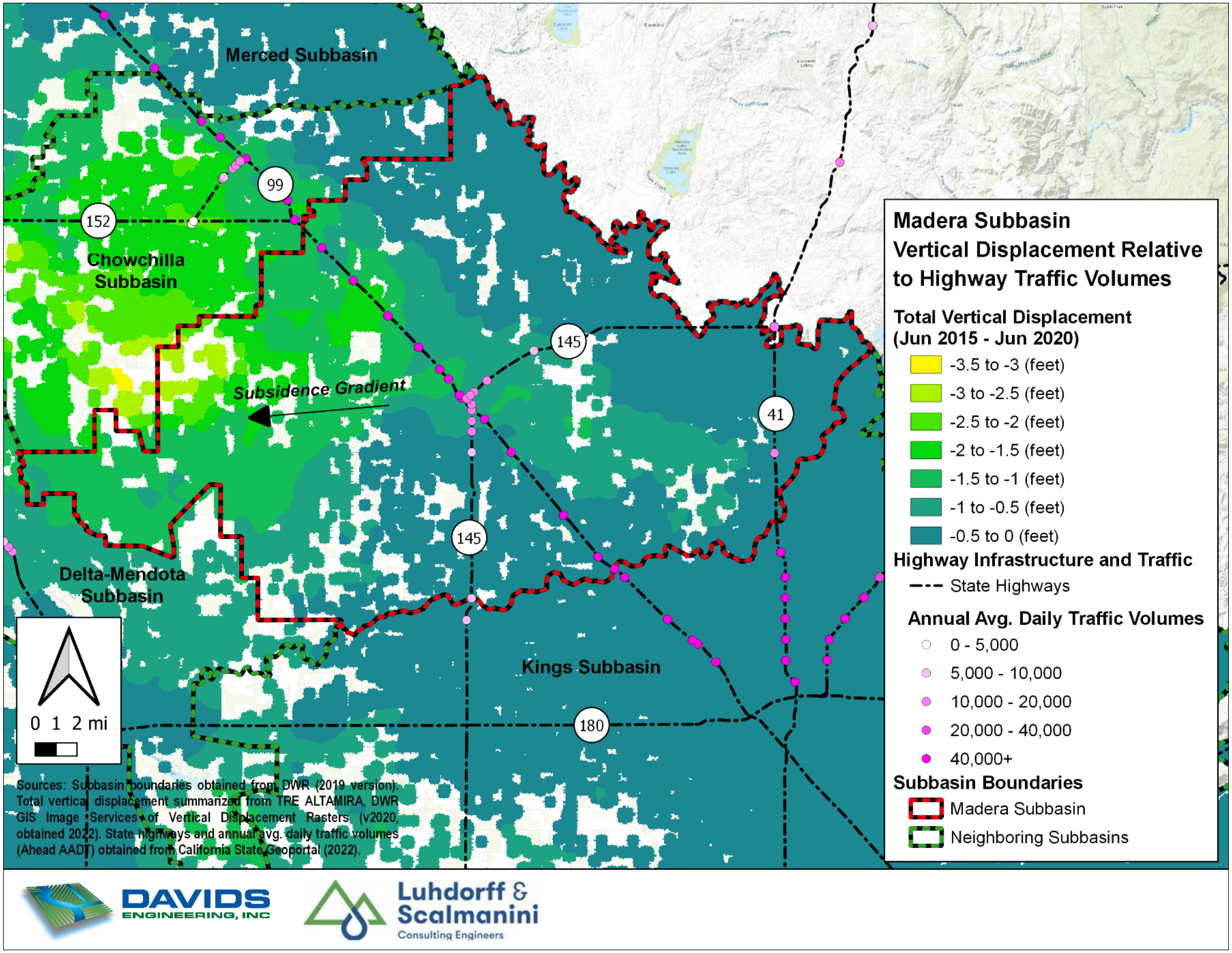

Figure 4. Vertical Displacement (June 2015 - June 2020) Relative to Highway Traffic Volumes.

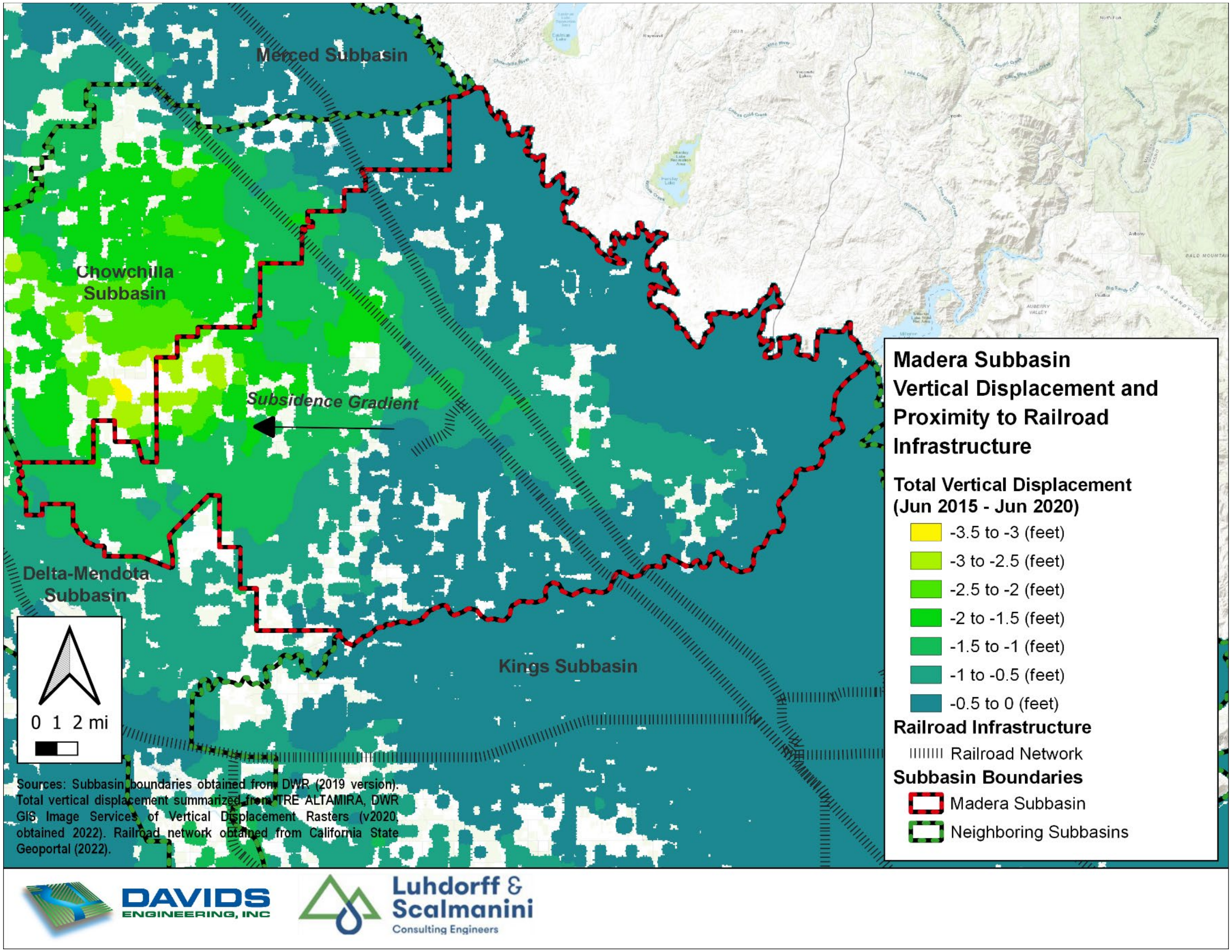

Figure 5. Vertical Displacement (June 2015 - June 2020) and Proximity to Railroad Infrastructure.

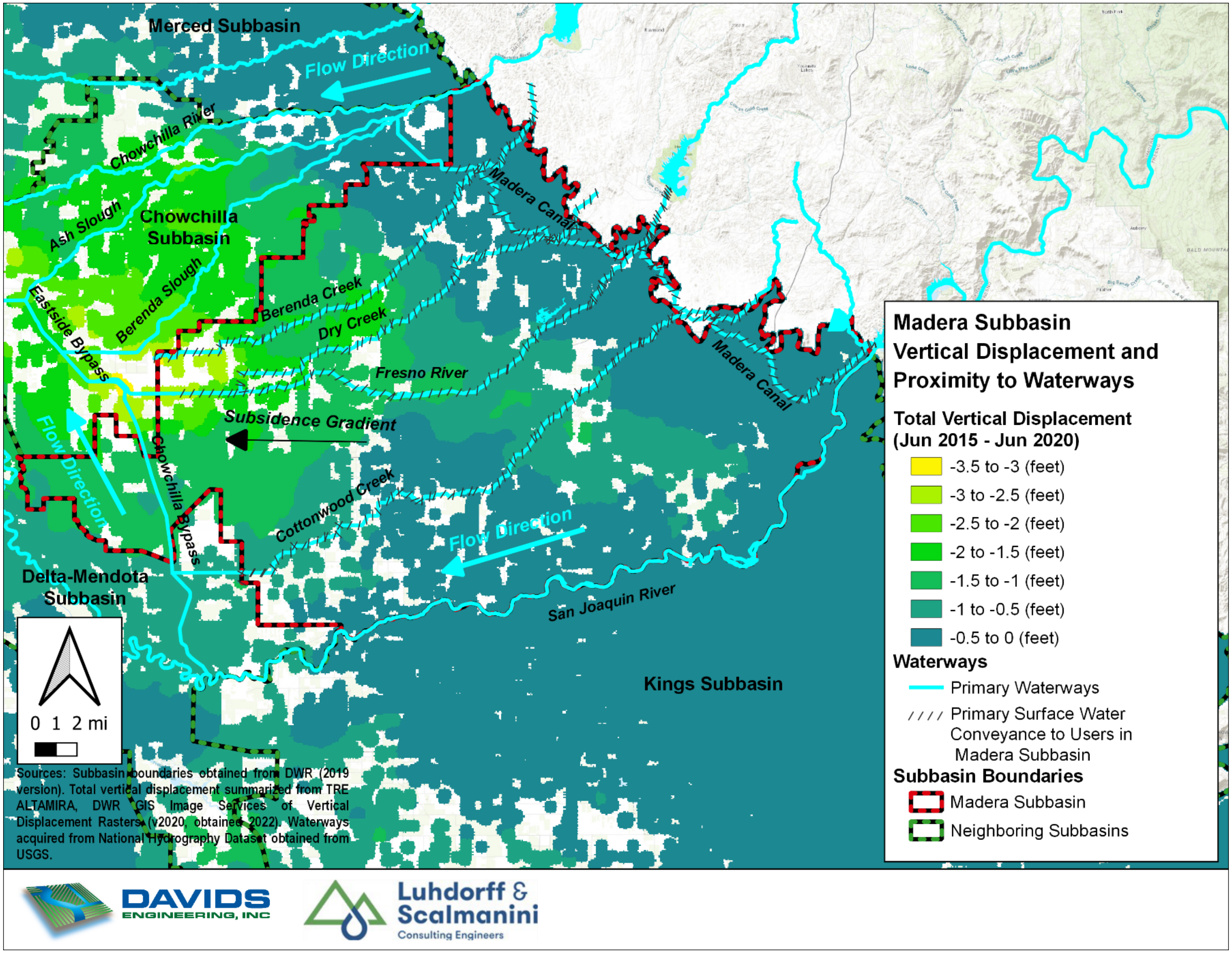

Figure 6. Vertical Displacement (June 2015 - June 2020) and Proximity to Waterways and Surface Water Conveyance Infrastructure.

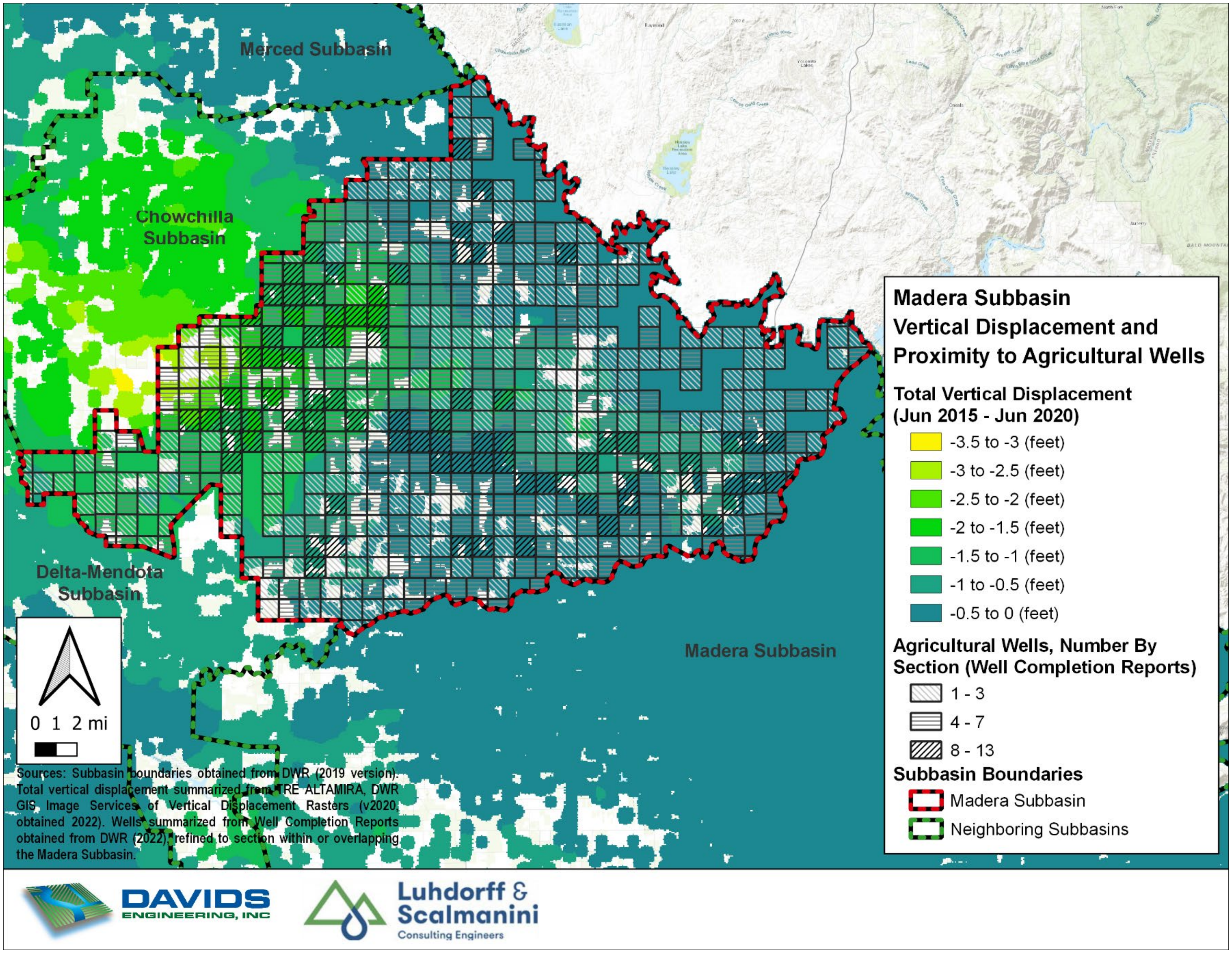

Figure 7. Vertical Displacement (June 2015 – June 2020) and Proximity to Agricultural Wells.

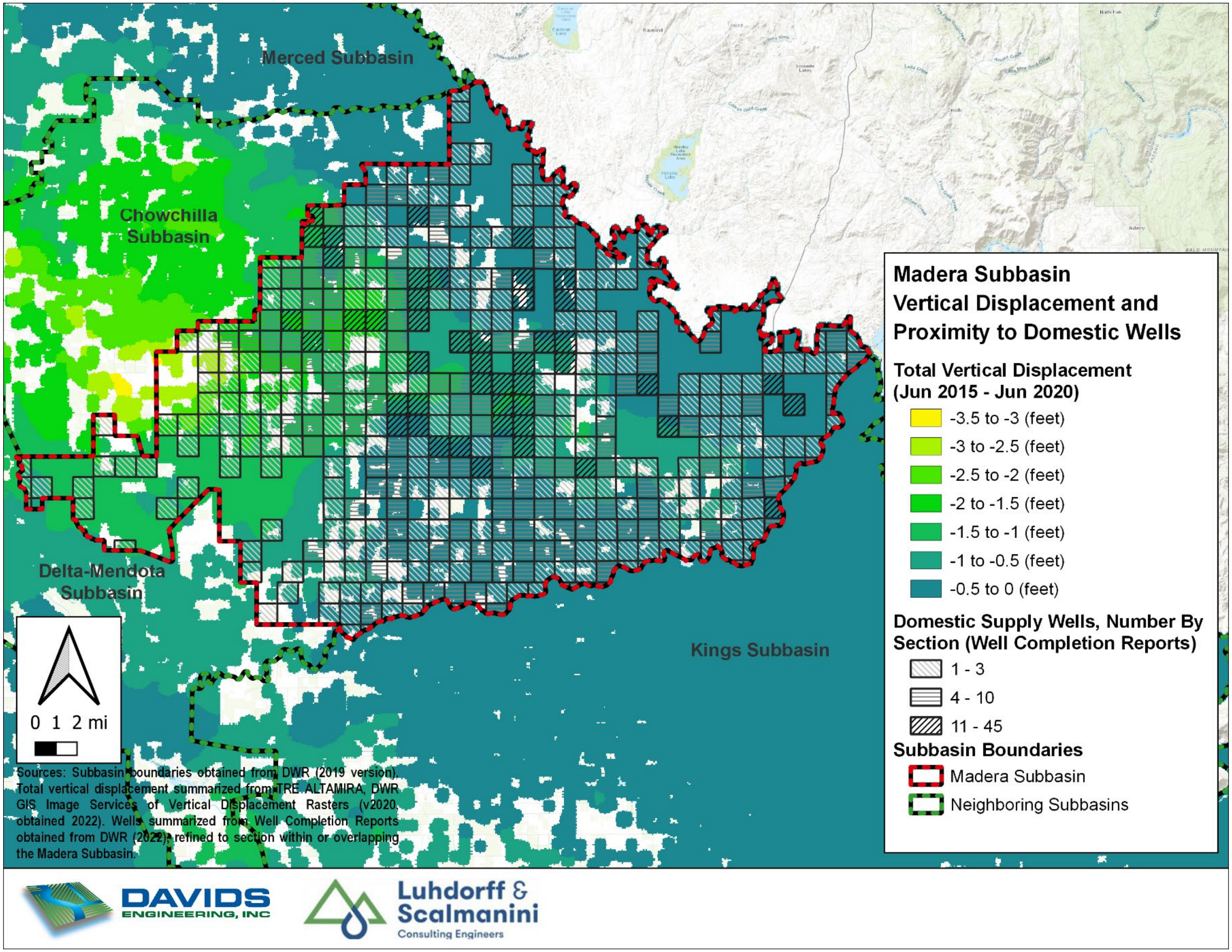

Figure 8. Vertical Displacement (June 2015 – June 2020) and Proximity to Domestic Wells.

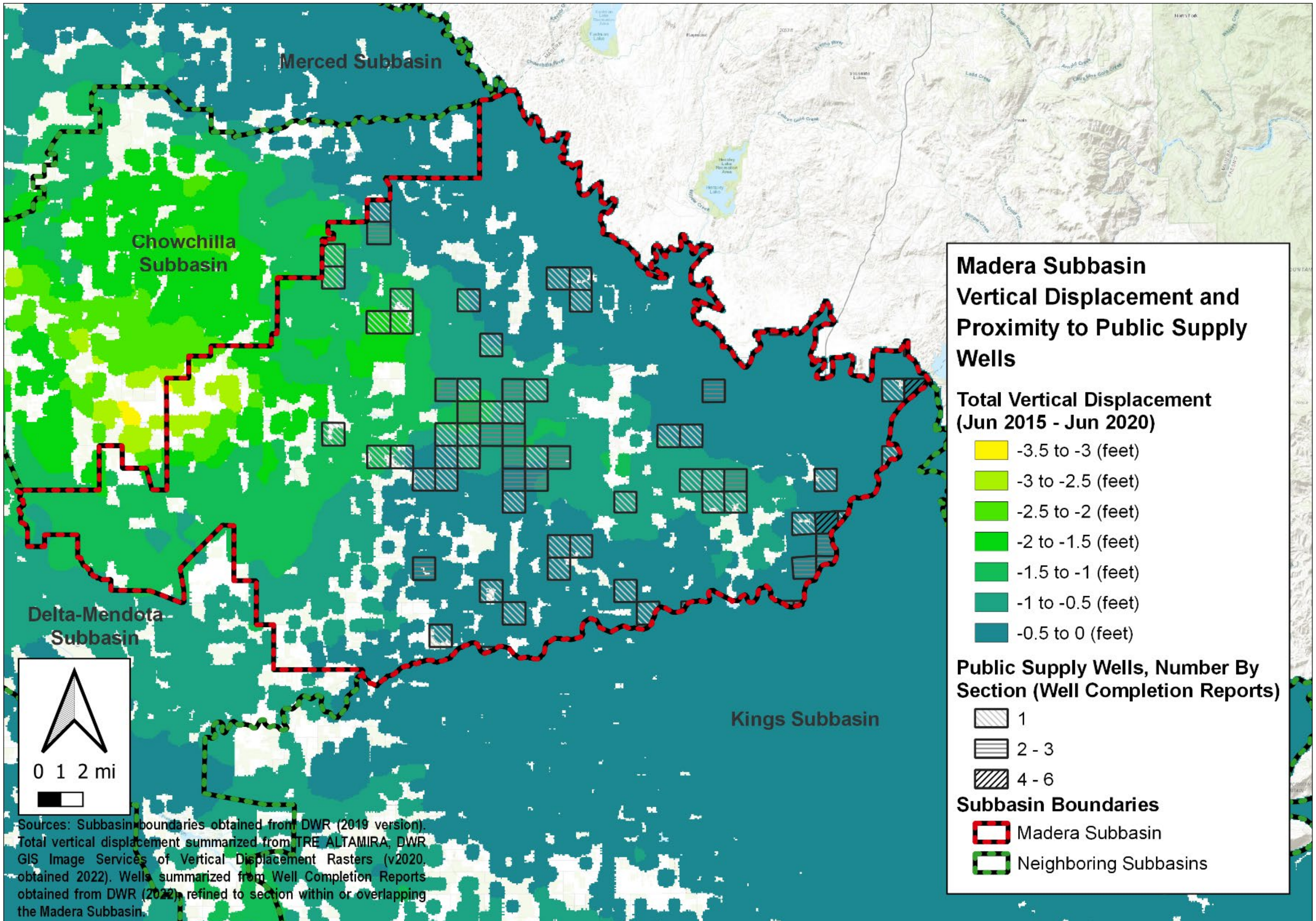

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Figure 9. Vertical Displacement (June 2015 – June 2020) and Proximity to Public Supply Wells.

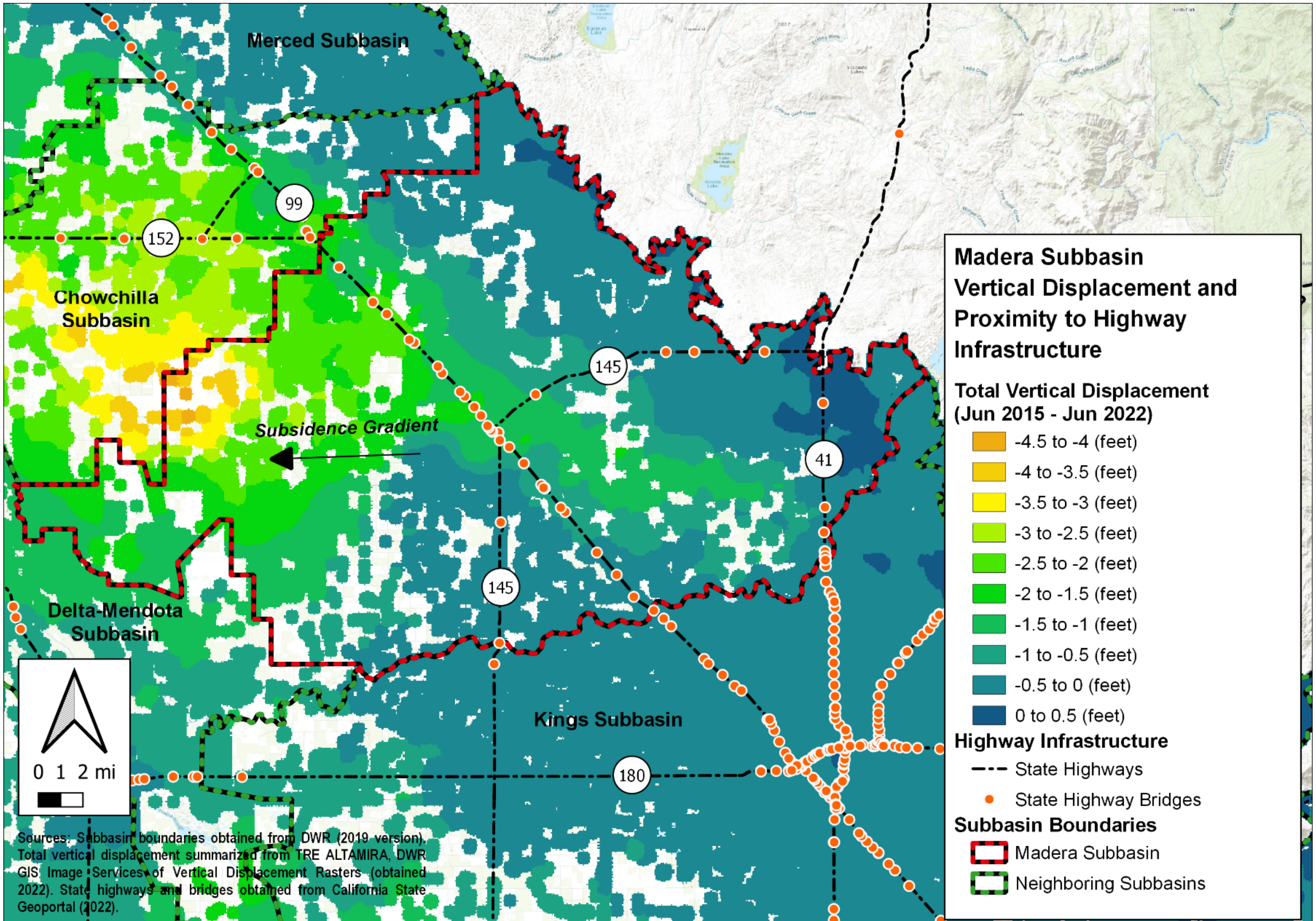

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Figure 10. Vertical Displacement (June 2015 – June 2022) and Proximity to Highway Infrastructure.

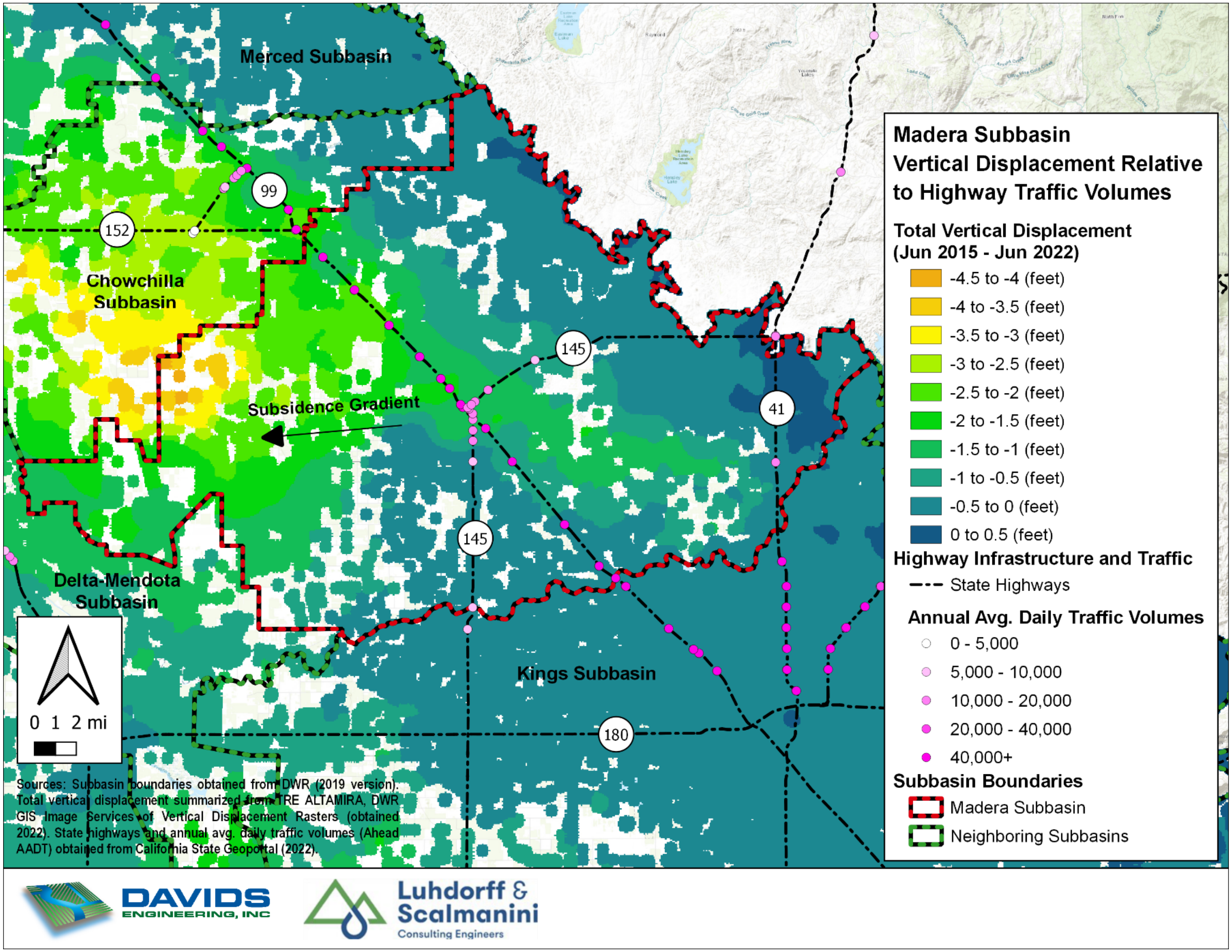

Figure 11. Vertical Displacement (June 2015 – June 2022) Relative to Highway Traffic Volumes.

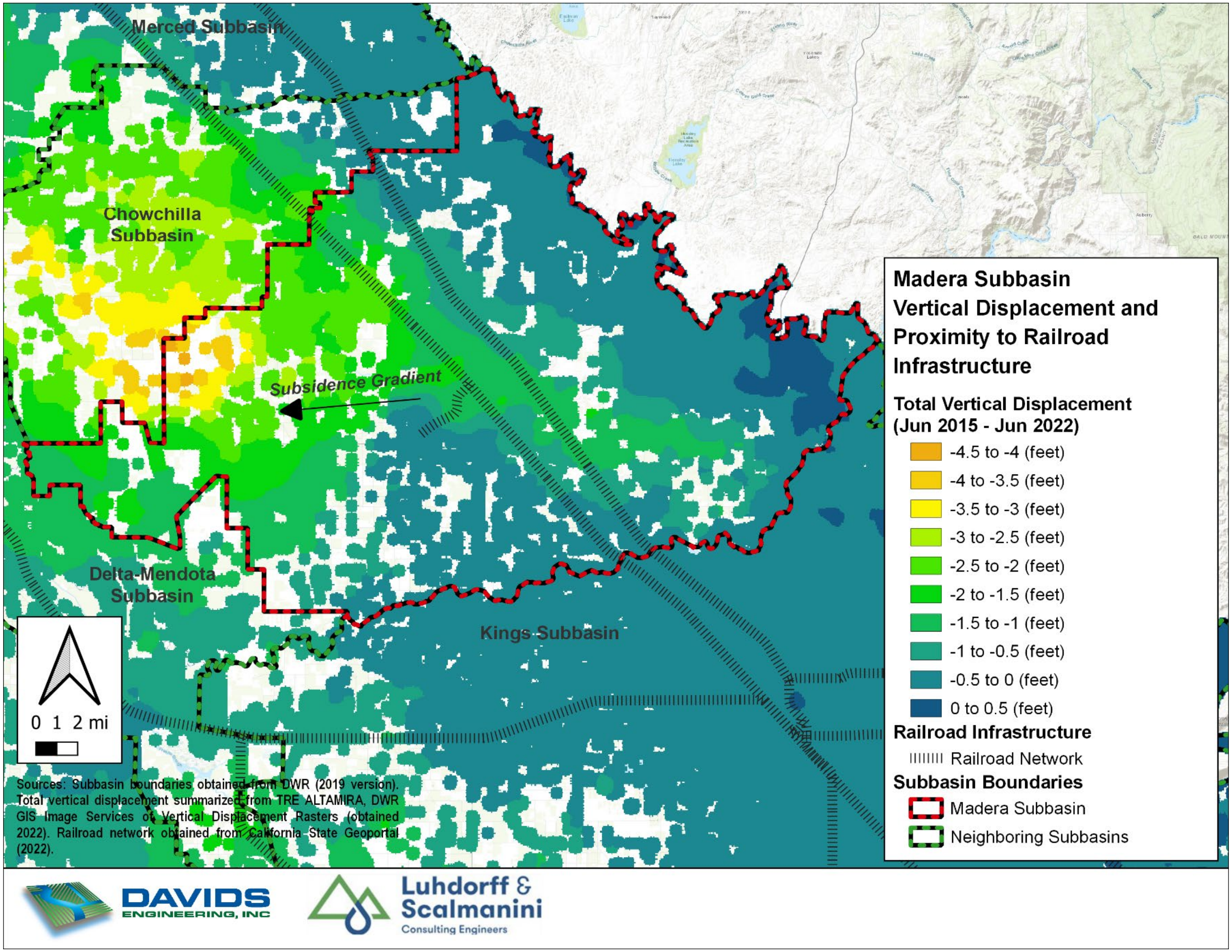

Figure 12. Vertical Displacement (June 2015 – June 2022) and Proximity to Railroad Infrastructure.

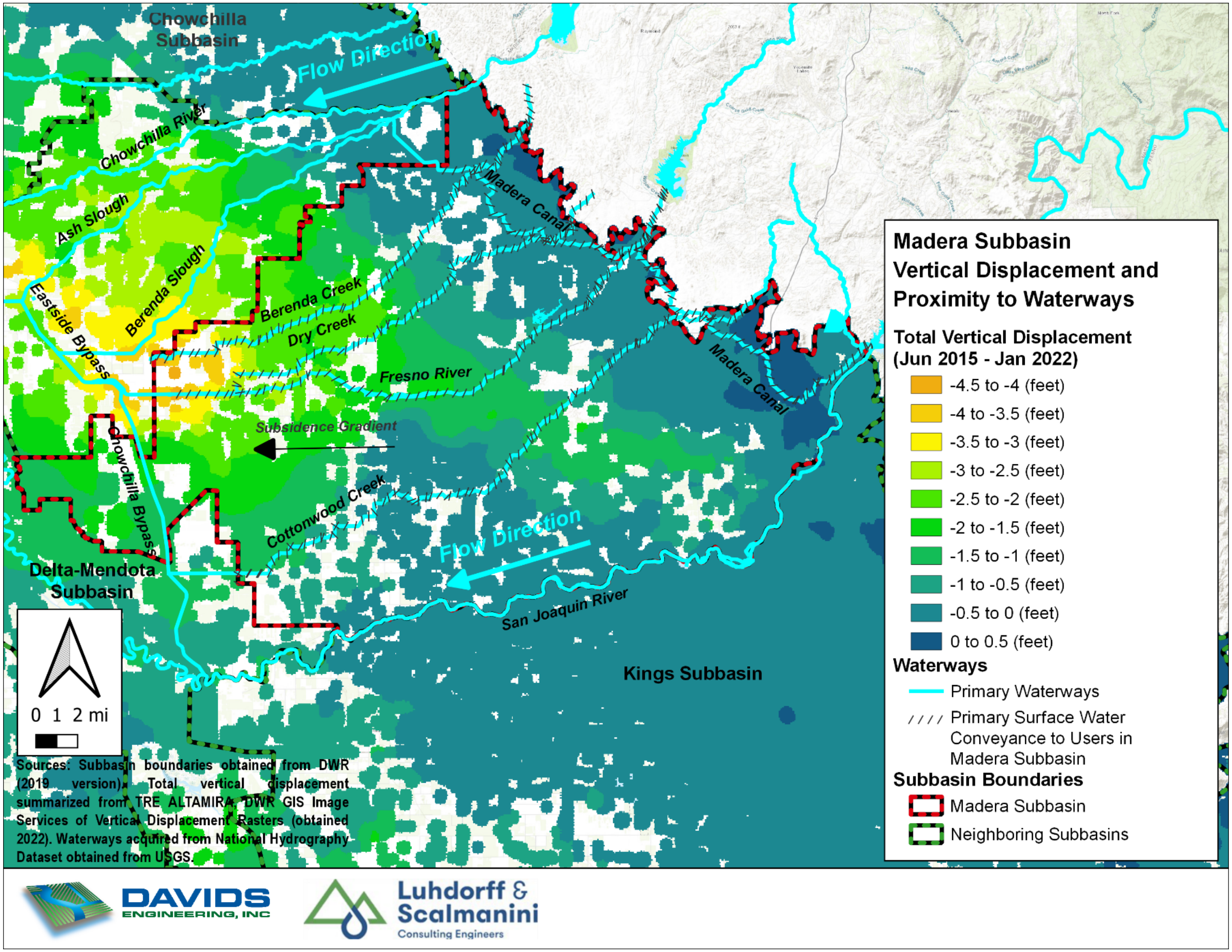

Figure 13. Vertical Displacement (June 2015 – June 2022) and Proximity to Waterways and Surface Water Conveyance Infrastructure.

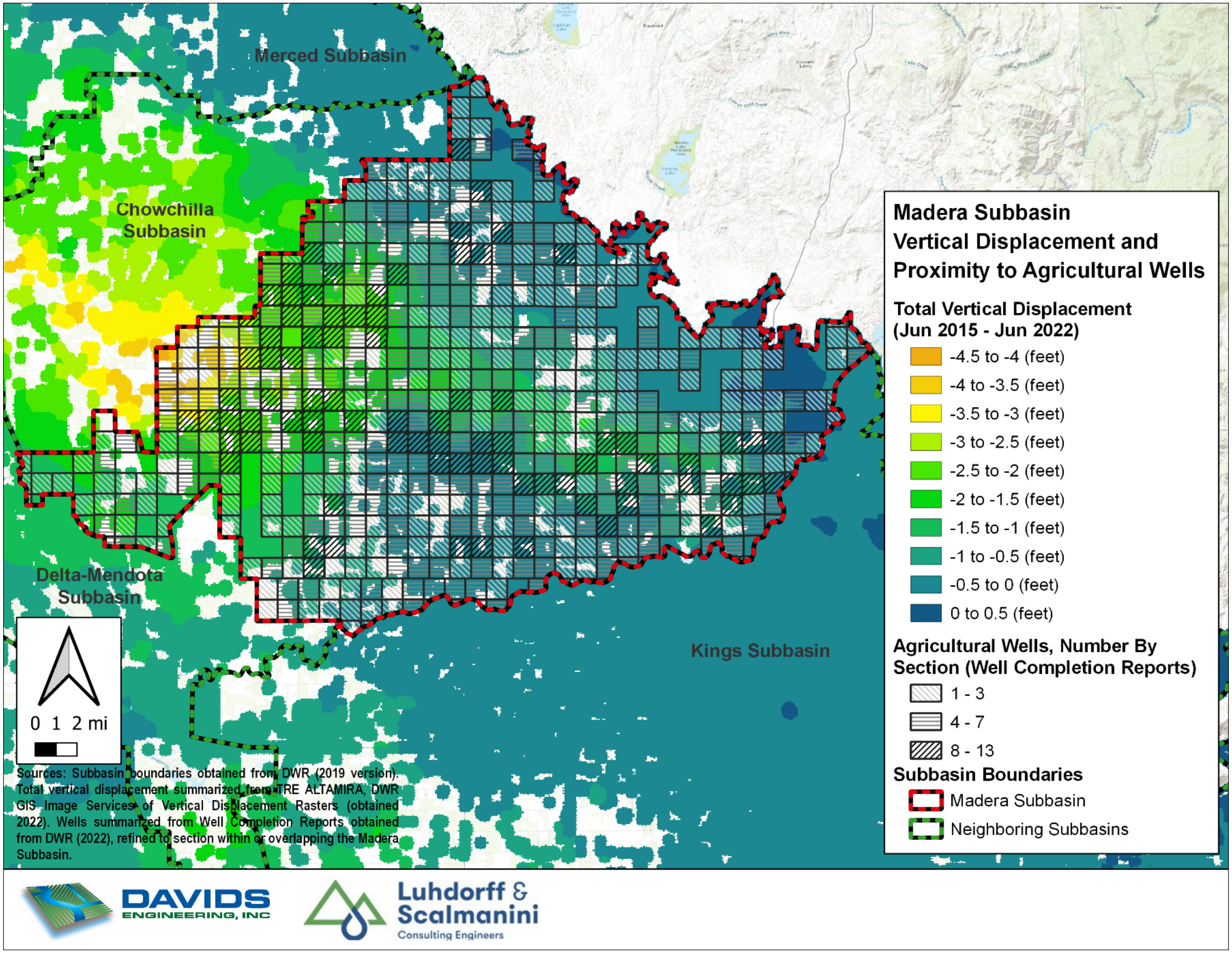

Figure 14. Vertical Displacement (June 2015 - June 2022) and Proximity to Agricultural Wells.

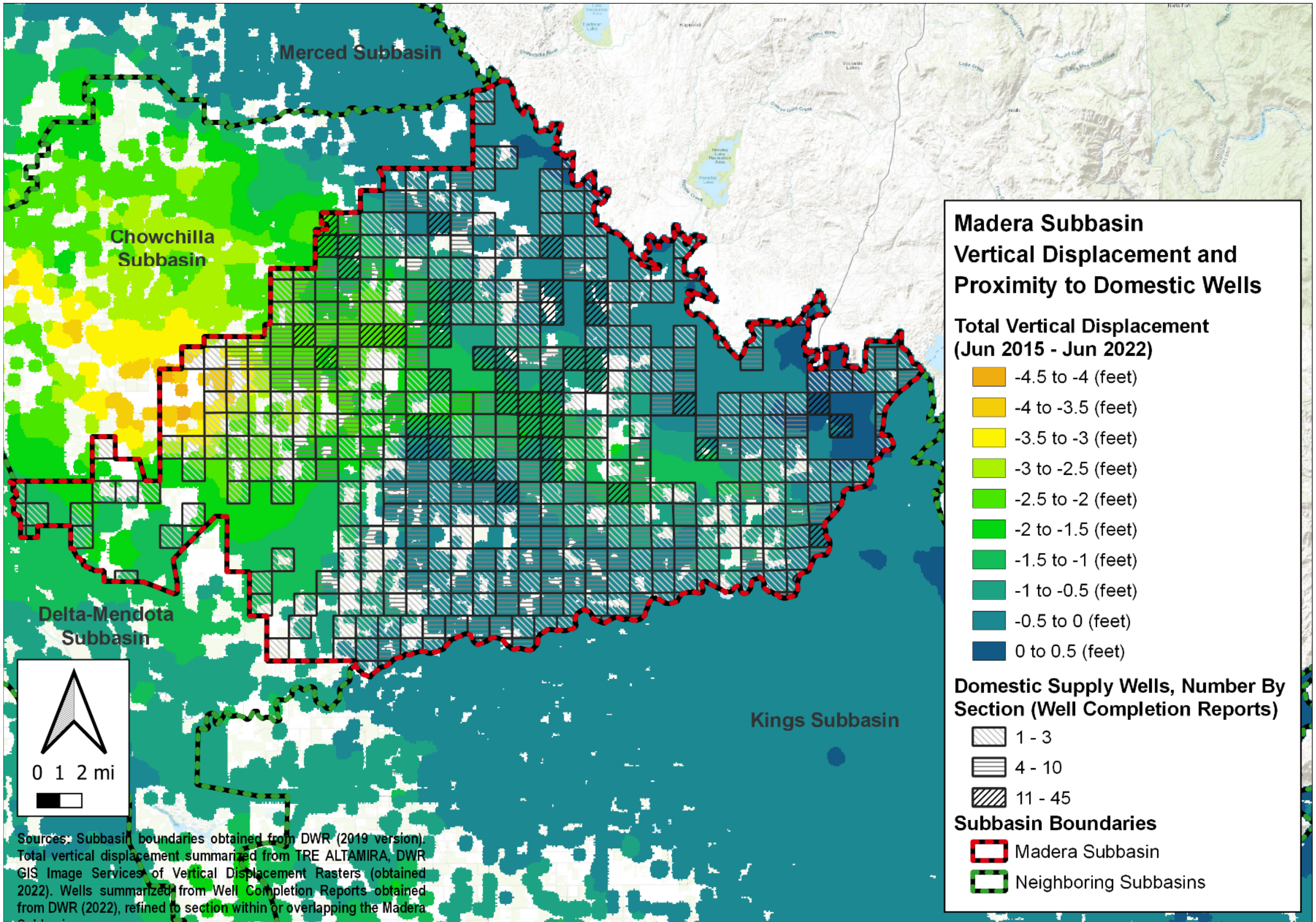

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Figure 15. Vertical Displacement (June 2015 - June 2022) and Proximity to Domestic Wells.

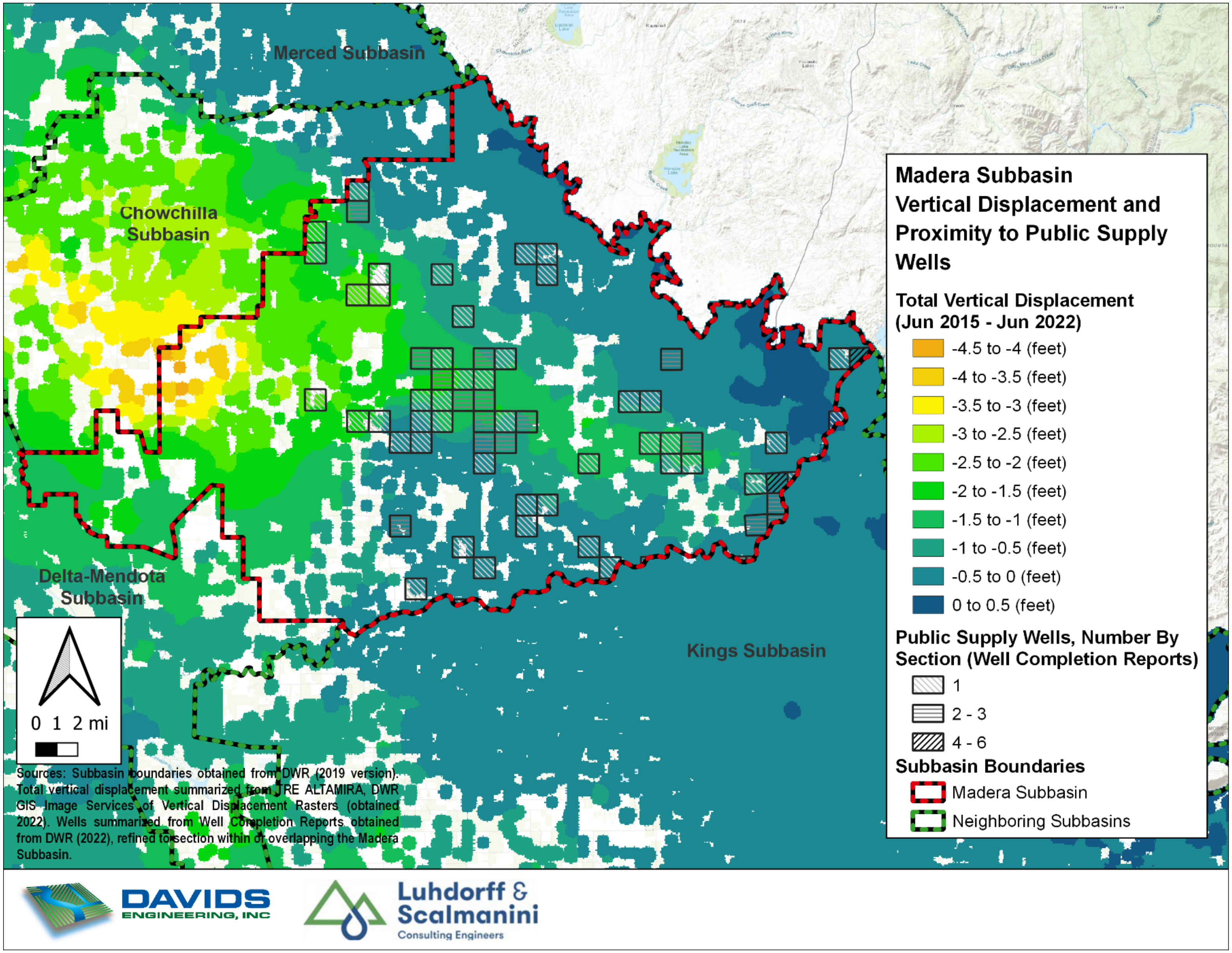

Figure 16. Vertical Displacement (June 2015 - June 2022) and Proximity to Public Supply Wells.

Figure 1 Study Area

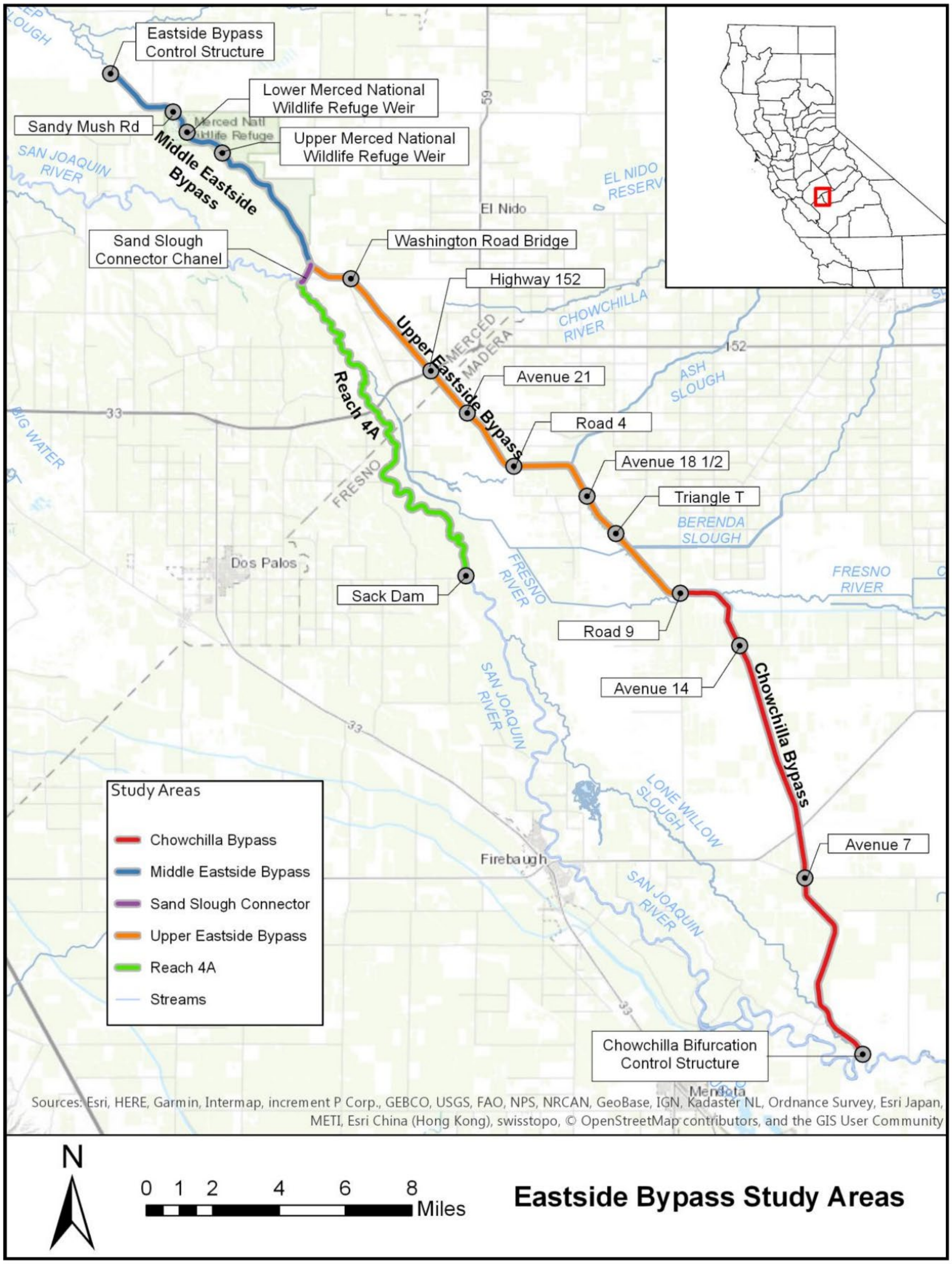

Figure 17. DWR Analysis Study Area, from "Evaluation of the Effect of Subsidence on Flow Capacity in the Chowchilla and Eastside Bypasses, and Reach 4A of the San Joaquin River" (DWR, 2018). A section of the Chowchilla Bypass flows through the eastern reach of the Madera Subbasin.

Table 1. DWR Analysis Results, from "Evaluation of the Effect of Subsidence on Flow Capacity in the Chowchilla and Eastside Bypasses, and Reach 4A of the San Joaquin River" (DWR, 2018). A portion of the Chowchilla Bypass flows through the eastern reach of the Madera Subbasin.

Table 3 Estimated Flow Capacity in Reach 4A and the Chowchilla and Eastside Bypasses based on Freeboard Criteria (in cfs)

Channel Segment	Flood Design Flow[a]	2008[b]	2011[b]	2016	2026
Chowchilla Bypass					
Bifurcation Structure to Fresno River	5,500	>5,500	>5,500	>5,500	>5,500
Eastside Bypass					
Fresno River to Berenda Slough	10,000	>10,000	>10,000	>10,000	>10,000
Berenda Slough to Ash Slough	12,000	>12,000	>12,000	>12,000	>12,000
Ash Slough to Sand Slough	17,500	9,500[c] – 12,500	7,500[c] – 11,500	5,700[c] – 9,500	3,400[c] - 7,500
Sand Slough to Mariposa Bypass[d]	16,500	16,000	14,500	12,500	9,800
San Joaquin River					
Reach 4A	4,500	ND	ND	3,700[e] – 4,300	2,500[e] – 3,800
Sand Slough Connector Channel	ND	ND	ND	2,100[e] – > 4,500	0[e] – > 4,500

Notes: cfs = cubic feet per second, ND = not determined as part of this study

[a] Referenced from the Lower San Joaquin River Flood Control Project Operation and Maintenance Manual.

[b] Results obtained from a previous study done by DWR in 2013.

[c] Reduced capacity assumes contribution of 4,500 cfs from Reach 4A of the San Joaquin River (creating backwater conditions).

[d] Capacity assumes diversions into the Mariposa Bypass based on the O&M Manual operating rules.

[e] Reduced capacity assumes contribution of 12,000 cfs through the Bypass Channel (creating backwater conditions).