

Appendix 1: Potential subregion delineations for monitoring and assessing nutrients in the Delta

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1. Summary

The goal of this project element was to compile, review, and propose potential subregions for monitoring and assessing nutrients in the Delta.

How were potential nutrient subregions for the Delta identified?

The geographic area of interest is the Delta-Suisun Bay region. We reviewed existing approaches that have been used to break the Delta into subregions for water quality monitoring and assessment, hydrologic and water quality modeling, and ecosystem process-based habitat restoration.

Operational Landscape Units (OLUs) from SFEI are a proposed planning tool for landscape-scale ecosystem restoration in the Delta. The OLU delineations are based on ecosystem functions and physical drivers; therefore, there is a mechanistic linkage and scientific foundation for their use in the context of nutrient conditions and cycling. Nutrient subregions based on OLUs would facilitate the coordination of nutrient monitoring, assessment, and management with ecosystem restoration efforts. In addition, nutrient subregions based on OLUs would be compatible with DSM2-based modeling and are in reasonable agreement with water quality regions used by major monitoring programs. Therefore, subregions based on OLUs are the best option to serve as subregions for monitoring and assessing nutrients in the Delta.

The original OLUs are a draft product of an ongoing SFEI project and have not yet been finalized. A number of modifications were made to the draft OLUs to improve their use for the nutrient subregions. The modifications were based on a detailed review of the OLU boundaries in relation to hydrologic features, watershed boundaries, and DSM2 modeling requirements. The resulting subregions proposed here include the 6 modified OLU-based subregions and an additional subregion for Suisun Bay. There are considerable differences in land cover distribution among these subregions. Agriculture is the dominant land cover in most of the Delta regions, covering 56% of all Delta subregions combined, whereas wetlands are covering 86% of the Suisun Bay subregion.

How well are the proposed subregions covered by existing nutrient monitoring?

The IEP-EMP is the most important regional nutrient monitoring effort and its current monitoring network does not represent all proposed subregions. Additional programs measure nutrients and nutrient-associated variables across the Delta and expand the spatial coverage. However, these efforts are not coordinated with the IEP-EMP, and data collected by these programs cannot be readily integrated with IEP-EMP data for status and trends analyses. Modeling and advanced statistical analyses would be a useful next step to inform a regional monitoring design that would be stratified based on the proposed subregions.

What are the next steps to confirm or refine the proposed nutrient subregions of the Delta?

Modeling and advanced statistical analyses are a proposed next step to inform a regional monitoring design that would be stratified based on the proposed subregions.

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2. Glossary

BDCP	Bay-Delta Conservation Plan
DIN	dissolved inorganic nitrogen
DSM2	Delta Simulation Model 2
DWR	California Department of Water Resources
EMP	Environmental Monitoring Program
GAM	general additive modeling
HUC	Hydrologic Unit Code
HUC12	Subwatershed with a 12-digit HAC address
MeHg	methylmercury
NAWQA	National Water Quality Assessment Program
NH ₄	ammonium
NO ₃	nitrate
NPDES	National Pollutant Discharge Elimination System
OLUs	Operational landscape units
QUAL	DSM2 module that simulates fate and transport of water quality constituents
SFEI	San Francisco Estuary Institute
TMDL	total maximum daily loads
TN	total nitrogen
USGS	US Geological Survey
WRTDS	weighted regressions on temperature, discharge, and seasonality

3. Introduction

Nutrient concentrations in the Delta-Suisun Bay region are highly variable, in both time and space. The large variability is due to the physical heterogeneity and dynamics of this region. Suisun Bay is a shallow, turbid, low-salinity embayment incised by a remnant river channel. The Delta is primarily a freshwater system comprised of a complex channel network that is hydrologically strongly influenced by river flows, tidal exchange, and water exports. Natural fluctuations in freshwater flow, the interaction of flow with tides, and the active manipulation of flow volumes, timing, and paths result in highly variable hydrodynamics. The heterogeneity and dynamics of the system make it challenging to assess how nutrient management actions are affecting the Delta-Suisun Bay region as a whole.

Identifying representative subregions can be a useful tool to improve regional assessments.

Regionalization consists of dividing an area into approximately homogeneous subregions and can fulfill two important purposes: 1) comparing trends across subregions to gain a better understanding of spatial variability, and 2) providing more accurate region-wide estimates by stratifying the overall sampling frame and summing subregion estimates to produce Delta-wide estimates (Jassby et al., 2002).

Researchers have delineated subregions of the Delta for various purposes, but not yet specifically to inform the design of monitoring for nutrients. Therefore, the purpose of this review was to

1. Summarize and compare existing delineations that are potentially relevant for monitoring and assessing nutrients;
2. Based on this review, recommend potential subregion delineations for monitoring and assessing nutrients in the Delta

4. Approach

4.1. Scope of review

The geographic area of interest is the Delta-Suisun Bay region (Figure 1). We reviewed existing regionalization approaches used for water quality monitoring and assessment, hydrologic and water quality modeling, and ecosystem process-based habitat restoration.

4.2. Screening process

The review extended to existing regionalization approaches used for water quality monitoring and assessment, hydrologic and water quality modeling (delineations for DSM2), and ecosystem process-based habitat restoration (Table 1).

The screening process considered

- Spatial coverage
- Relevance to nutrient management
- Agreement with groupings of Delta monitoring stations based on statistical analysis of water quality data
- Utility for multiple purposes, e.g. modeling and monitoring
- Agreement with other existing delineations

Base on these considerations, potential operational landscape units (OLUs) were chosen. See Section 4.2 (Rationale for selecting OLU) for details.

4.3. Modifications

The OLUs are a draft product of an ongoing project and have not yet been finalized. A number of modifications were made to the draft OLU to improve their use for the regionalization of water quality data. The modifications were based on a detailed review of the OLU boundaries in relation to hydrologic features and watershed boundaries, as well as feedback from the DSM2 modeler (Marianne Guerin). The revisions included the redrawing of boundaries that overlapped, bisected important hydrologic features, excluded important features, or were inconsistent with hydrodynamic delineations.

4.4. Land cover analysis

Land cover provides a framework for assessing the risk of water pollution and can be a useful tool for the interpretation of differences in nutrient loads, concentrations, and effects across different areas. For example, field studies have shown that nitrogen and phosphorus export coefficients are significantly different across forest, agriculture, and urban land-cover types (Wickham et al., 2000). In this study, we used land cover analysis primarily to characterize and compare differences between proposed OLU-based subregions.

4.4.1. Land cover analysis for subregions

GIS data from A Delta Transformed (SFEI-ASC 2014) were used to quantify land cover for all of the Delta subregions. Wetland GIS data from the Bay Area Aquatic Resources Inventory version 2.0 GIS data (SFEI-ASC 2015) were used to quantify land cover for the Suisun Bay subregion. The “habitat_type” field in the GIS datasets was used to reduce the area into 6 simplified land cover classes: Agriculture, Grassland/Woodland, Water, Urban, Wetland/Riparian, and Unclassified. Unclassified areas were mostly locations within the subregion boundaries that fell outside of the extent of the two landcover datasets. In Suisun Bay, only wetlands and water features were included in the original BAARI mapping. However, since these two landcover types covered 89% of the subregion, it was determined that no additional land cover mapping was necessary for the general land cover characterization provided here. The total acreage and proportional coverage of the 6 land cover classes was summarized and calculated for each Delta subregion.

4.4.2. Land cover analysis for 100m buffer zone adjacent to water

To determine the total acreage and proportion of land cover classes adjacent to waterbodies, a 100-meter buffer was created around all water features in the land cover map. The land cover map was clipped to the buffer. Total acreage and proportional area for each Delta subregion was summarized and calculated.

5. Results

5.1. Existing regionalization approaches for the Delta

Existing regionalization approaches can be roughly divided into three groups: 1) subregions used for water quality monitoring and data analyses; 2) subregions used for modeling; and 3) subregions used for

ecosystem restoration planning. Table 1 provides an overview of all regionalization approaches reviewed. Short descriptions of each regionalization approach follow, organized into the three groups listed above.

5.1.1. Subregions used for water quality monitoring and data analyses

- 4.1.3.1. *Water quality regions (DWR 2012)*. The Department of Water Resources Environmental Monitoring Program (DWR-EMP) monitors water quality at 13 sampling sites representing 8 regions of the estuary (Figure 2). The eight regions include San Pablo Bay, Suisun Bay, and six Delta subregions.
- 4.1.3.2. *Water quality subregions (Jassby and Cloern 2002, Figure 3)*. In order to estimate mean Delta-wide productivity, biomass, and other water quality characteristics, Jassby and Cloern (2002) divided the Delta into eight approximately homogeneous subregions, to provide more accurate stratified sampling estimates of Delta-wide means.
- 4.1.3.3. *Regions of the upper estuary (Lehman 1996, Figure 4)*. These regions are described and used in the 1996 DWR-EMP water quality report. They were developed to group sampling stations and are based on individual and combined hierarchical cluster analysis of monthly data for 14 physical and chemical variables and chlorophyll *a* concentrations. They are similar to those developed for an independent analysis of phytoplankton community composition (Lehman & Smith 1991, Figure 5).
- 4.1.3.4. *Regions with similar phytoplankton communities by season (Lehman & Smith 1996, Figure 5)*. These geographical regions were developed to group sites that had similar phytoplankton communities over time.
- 4.1.3.5. *Benthic macrofaunal assemblages (Thompson et al. 2013, Figure 6)*. Hierarchical cluster analysis of macrobenthic species abundance data was used to identify the benthic assemblages that occur in the San Francisco Estuary and Delta.
- 4.1.3.6. *Hydrology-based delineation of subareas within the legal Delta and Yolo Bypass (Thompson et al. 2013, Figure 7)*. The methylmercury linkage and source analyses for the Delta methylmercury TMDL divide the Delta into eight subareas based on hydrologic characteristics and mixing of source waters.

5.1.2. Subregions used for modeling

- 4.1.3.7. *QUAL-Nutrient parameterization regions (Guerin 2015, Figure 8)*. Guerin (2015) defined 6 hydrodynamically homogeneous subregions of the Delta to parameterize output of the DSM2 and QUAL models. The model output was used to estimate losses of ammonium (NH₄) and total nitrogen (TN) in each of the subregions (Novick et al. 2015).

5.1.3. Subregions used for ecosystem restoration planning

- 4.1.3.8. *Habitat area specialization (Moyle et al. 2012, Figure 9)*. Moyle et al. (2012) divide the Delta regionally into five different ecosystem areas. Moyle et al. (2012) propose an aquatic ecosystem reconciliation strategy that would capitalize on the differences between these habitat areas.

- 4.1.3.9. *Conservation zones (DWR 2013, Figure 10).* The Bay-Delta Conservation Plan area was subdivided into 11 conservation zones to facilitate development of protection and restoration elements of the conservation strategy. Conservation zones were delineated primarily on the basis of landscape characteristics and logical geographic or landform divisions. Conservation zones were used as a planning tool to ensure that targets identified for natural communities and covered species' habitat are spatially distributed to help achieve biological goals and objectives.
- 4.1.3.10. *Potential operational landscape units (OLUs, Grenier & Grossinger 2013, Figure 11).* Draft OLU boundaries were developed to represent restoration opportunity areas based on an understanding of ecological functions, physical drivers, existing constraints, and elevation gradients.

5.2. Rationale for selecting OLUs

We selected the OLUs as the proposed regionalization approach based on the following considerations:

- *Spatial coverage.* The OLUs cover the entire Delta region without gaps. Delineations have been developed.
- *Relevance to nutrient management.* Nutrient management will need to be seamlessly integrated with ecosystem restoration efforts. The delineations are based on ecosystem functions and physical drivers; therefore, there is a mechanistic linkage and scientific foundation for their use in the context of nutrient conditions and cycling.
- *Agreement with monitoring results.* Regionalization based on OLU regions is generally consistent with the interpretation of spatial variability of measured nutrient concentrations in Novick et al. (2015).
- *Utility for multiple purposes.* The OLUs are similar to those developed for parameterizing DSM2 and QUAL model output for nutrient mass balance calculations. Therefore, use of OLUs would be compatible with DSM2-based modeling.
- *Similarity to other existing zonation approaches.* There is reasonable agreement with other approaches, such as the DSM2 zonation system, subregions assigned to IEP-EMP stations, or the MeHg TMDL subregions.

5.3. Revised OLU-based subregions

Even though we considered the OLUs the best available option for Delta regionalization, a number of adaptations were needed. Figure 12 illustrates the revisions that were made to OLU delineations. Figure 13 shows the final product. Revisions to the original OLU boundaries addressed the following issues:

- *Overlapping boundaries.* Selected one or the other edge based on hydrology.
- *Bisected waterbodies.* Adjusted delineations that arbitrarily bisected water bodies. Revisions were based on knowledge of hydrology.
- *Drainage divides.* The North Delta OLU was modified based on watershed boundaries to not include sloughs that drain to Suisun Bay.
- *Adding a subregion for Suisun Bay.* The OLUs were developed for the Delta and do not include an outline for Suisun Bay. A boundary for Suisun Bay was created based on the HUC12 shapefile.
- *Extending eastern boundary of Confluence region to Chipps Island.* The need for this revision was identified during the DSM2-based water fate and age simulations using the new subregions.

The eastward extension is consistent with the official boundary between the Delta and Suisun Bay and improves modeling results.

5.4. Description of OLUs

The revised subregions used here include the 6 modified OLU-based subregions and an additional subregion for Suisun Bay. The Suisun Bay subregion is not an OLU and therefore not described here. (Suisun Bay defined by the hydrologic unit delineation for the HUC12 Suisun Bay watershed.) The original draft OLU boundaries consider ecological functions, physical drivers, opportunity areas, major constraints, and elevation gradients. The following short subsections summarize key features of the OLUs that served as a template for the proposed subregions.

5.4.1. North Delta

The North Delta (originally North West OLU) includes the Yolo Bypass, Liberty Island/Cache Slough Complex, and the Sacramento Deep Water Ship Channel. The main hydrological influences in the North Delta are the watersheds of the Sacramento River (flood basin link), Putah Creek, Cache Creek, and Lindsey slough.

5.4.2. Sacramento River

The Sacramento River subregion (originally North Central OLU) includes large urban areas within its boundaries. Both riparian and watershed processes are important in this OLU, which provides opportunities to connect riparian lined channels.

5.4.3. Eastside

The Eastside (originally North East OLU) includes the lower Mokelumne, and Cosumnes rivers and Stone Lakes. Important physical processes include fluvial processes/undammed rivers, Sacramento River overflow and lowered groundwater.

5.4.4. Central Delta

The Central Delta (originally East Central OLU) is characterized as a transition zone with drowned islands, tidal influence, and multiple peripheral influences.

5.4.5. South Delta

The main hydrological influence in the South Delta (originally South OLU) are the San Joaquin watershed, the Central Delta, and the pumps of the Federal and State water projects.

5.4.6. Confluence

The key feature in the Confluence (originally West Central OLU) is the tidal influence.

5.5. Land cover analysis

GIS-based land cover analysis was applied to compare subregions with each other (Table 2, Figure 14). The importance of all land cover types varies considerably across subregions. Overall, the Delta is mostly an agricultural region. However, the portion of agricultural land in Delta subregions ranges from 70% in

the Central Delta to 24% in the Confluence subregion. There is no agriculture in the Suisun Bay subregion (0%). Confluence (30%) and Suisun Bay (29%) have the largest portions of open water. Suisun Bay has by far the largest proportion of wetland areas (60%). Urban areas cover relatively large portions of the Sacramento River (15%), South Delta (14%), and Eastside (13%) subregions (Figure 15).

Agriculture also dominates the 100-m buffer zone adjacent to open water channels in most Delta subregions (Figure 15). Agricultural lands account for 56% of the total land cover in the 100-m buffer zone in Delta subregions. The portion of agricultural land in the 100m-buffer zone in individual Delta subregions is 63% (Sacramento River and South Delta), 60% (Central Delta), 59% (North Delta), 45% (Eastside), and 25% (Confluence). The proportion of urban land use in the 100-m buffer is relatively high in the Central Delta region (15%). Wetlands and riparian areas make up the largest part of the buffer zone in Suisun Bay (86%) and the Confluence (51%). Their relative importance in other subregions is 37% (Eastside), 29% (North Delta) 21% (Central Delta and South Delta), and 16% (Sacramento River).

6. Discussion

We propose the OLU-based subregions as a useful, forward-looking zonation system for monitoring and assessing nutrients in the Delta. The OLU-based subregions consider ecosystem functions, physical processes, and ecosystem restoration opportunities. These factors are highly relevant to nutrient management. In the following sections, we briefly discuss the coverage of OLU-based subregions by the existing monitoring network, how nutrient observations in different subregions compare to each other, and potential next steps for validating and further refining the OLU-based subregions

6.1. What is the coverage of OLU-based subregions by the existing nutrient monitoring network?

The current DWR-EMP monitoring network does not represent all proposed subregions. The active DWR-EMP sampling sites are located in the Sacramento River, Central Delta, South Delta, Confluence, and Suisun Bay subregions (Figure 16). There are five active stations in the Central Delta, three in Suisun Bay, and one each in the Confluence, Sacramento River, and South Delta subregions. There are no active stations in the Eastside and North Delta subregions. High-frequency nutrient sensors maintained by USGS provide limited spatial coverage and are located in the North Delta, Sacramento River and Confluence subregions (Figure 17). Additional programs measure nutrients and nutrient-associated variables across the Delta and expand the spatial coverage (Figure 18). However, these efforts are not coordinated with the DWR-EMP or USGS sensor network, and data collected by these programs cannot be readily integrated with DWR-EMP data for status and trends analyses.

6.2. How do nutrient observations in OLU-based subregions compare to each other?

Results from a recently completed project (Novick et al. 2015) provide some initial insights and suggest that nutrients and nutrient-related variables display a range of seasonal patterns across subregions (Figure 19). Generally, Central Delta, Confluence, and Suisun Bay stations tend to have typical summertime dissolved inorganic nitrogen (DIN) depletion, whereas seasonal variability at active upstream stations in the Sacramento River and South Delta regions does not follow this pattern because it is more affected by upstream loadings and local sources. There are data gaps for the North Delta and Eastside subregions.

6.3. Potential next steps for improving monitoring of OLU-based subregions

The subregions are further evaluated in subsequent sections of this report, which investigate important factors affecting nutrient concentrations relative to the OLU-based subregions, and further evaluate whether different subregions are adequately monitored to assess status and trends in nutrient concentrations. Advanced statistical analyses such as weighted regressions on temperature, discharge, and seasonality (WRTDS) and general additive modeling (GAM) can provide additional insights into the relative importance of drivers across subregions and an additional mechanistic basis for evaluating data gaps. Modeling (e.g. DMS2-based) can help identify the necessary sampling network to fill these gaps.

7. Conclusions

OLU-based subregions provide a conceptually sound, useful, and forward-looking zonation system for monitoring and assessing nutrients in the Delta. The subregions can be applied to interpret the results of prior data analyses. Modeling (e.g., DMS2-based) and advanced statistical analyses (WRTDS, GAM) can be a useful next step to inform a regional monitoring design that would be stratified based on the proposed subregions.

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9. Tables

Table 1. List of reviewed subregions of the Delta.

Regionalization	Summary	Source	Map
Water quality regions	DWR-EMP water quality sampling sites represent eight regions of the Bay-Delta system. The eight regions include San Pablo Bay, Suisun Bay, and six Delta subregions.	DWR (2012)	Figure 2
Water quality subregions	In order to estimate mean Delta-wide productivity, biomass, and other water quality characteristics, Jassby and Cloern (2000) divided the Delta into eight approximately homogeneous subregions	Jassby & Cloern (2000)	Figure 3
Regions of the upper estuary	Regions based on individual and combined hierarchical cluster analysis of monthly data for 14 physical and chemical variables and chlorophyll <i>a</i> concentrations	Lehman (1996)	Figure 4
Regions with similar phytoplankton communities by season	Grouping of monitoring sites into geographic regions, which had similar phytoplankton communities over time. Sites with similar communities were determined with cluster analysis of site-year data.	Lehman & Smith (1991)	Figures 5 (a) and (b)
Benthic macrofaunal assemblages	Hierarchical cluster analysis of macrobenthic species abundance data was used to identify the benthic assemblages that occur in the San Francisco Estuary and Delta	Thompson et al. (2013)	Figure 6
Hydrology-based delineation of subareas within the legal Delta and Yolo Bypass	The methylmercury source analysis and linkage analysis for the Delta MeHg TMDL divided the Delta into eight regions based on hydrologic characteristics and mixing of source waters	Wood et al. (2010)	Figure 7
QUAL-Nutrient parameterization regions	The region boundaries are set to define hydrodynamically similar areas in the Delta.	Guerin (2015)	Figure 8
Habitat area specialization	Ecosystem areas as regions for a reconciled Delta	Moyle et al. (2012)	Figure 9
Conservation zones	Conservations zones are geographic areas defined by the biological needs of the species covered under the Bay-Delta Conservation Plan.	DWR (2013)	Figure 10

	Conservation zones were identified based on landscape characteristics, land elevations, particular land features likely to be present at specific elevations, and land uses.		
Potential operational landscape units (OLUs)	Draft OLU boundaries were developed to represent restoration opportunity areas based on an understanding of ecological functions, physical drivers, existing constraints, and elevation gradients.	Grenier & Grossinger (2013)	Figure 11

Table 2. Land cover summary table.

Land Cover	Subregions (Land cover in acres and percent)						
	Central Delta	Confluence	Eastside	North Delta	Sacramento River	South Delta	Suisun Bay
Agriculture	221,944 (70%)	15,094 (24%)	40,581 (45%)	116,270 (53%)	74,632 (57%)	65,706 (56%)	0 (0%)
Grassland/Woodland	7,977 (3%)	3,455 (6%)	6,002 (7%)	10,365 (5%)	1,096 (1%)	1,805 (2%)	0 (0%)
Urban	30,219 (9%)	2,674 (4%)	12,031 (13%)	6,526 (3%)	19,719 (15%)	16,595 (14%)	0 (0%)
Water	28,042 (9%)	18,682 (30%)	2,362 (3%)	11,246 (5%)	5,777 (4%)	3,558 (3%)	27,471 (29%)
Wetland/Riparian	14,960 (5%)	6,842 (11%)	8,347 (9%)	30,278 (14%)	3,008 (2%)	2,861 (2%)	57,914 (60%)
Unclassified*	15,068 (5%)	15,803 (25%)	20,543 (23%)	42,753 (20%)	27,554 (21%)	26,009 (22%)	10,818 (11%)
Total	318,210 (100%)	62,550 (100%)	89,866 (100%)	217,337 (100%)	131,517 (100%)	116,533 (100%)	96,204 (100%)

*Large unclassified areas are the result of the extension of subarea boundaries beyond the area included in the Delta habitat mapping effort that was used as the basis for the land cover analysis.

10.Figures

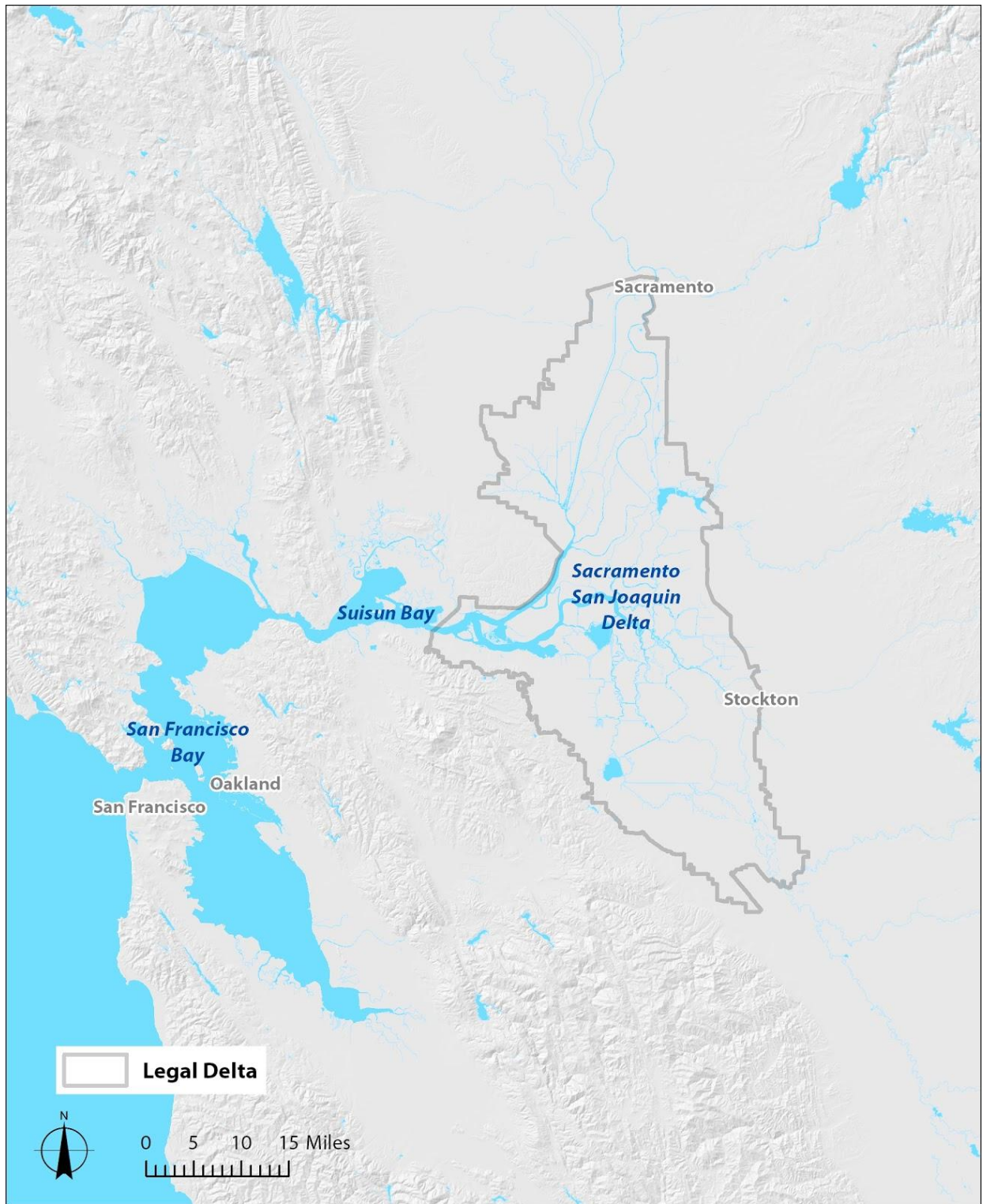


Figure 1. The Sacramento-San Joaquin Delta.

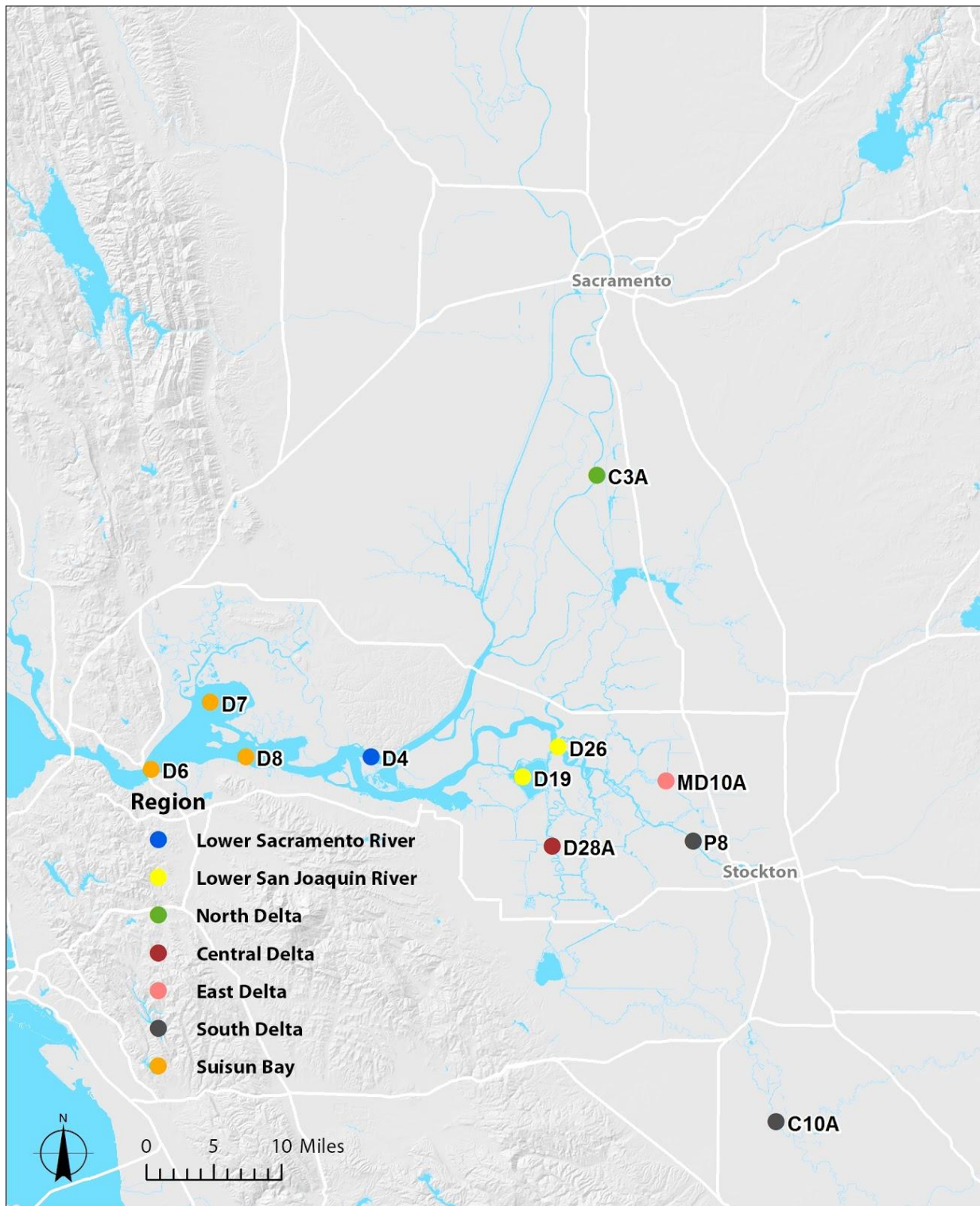


Figure 2. DWR-EMP water quality sampling sites and regions.

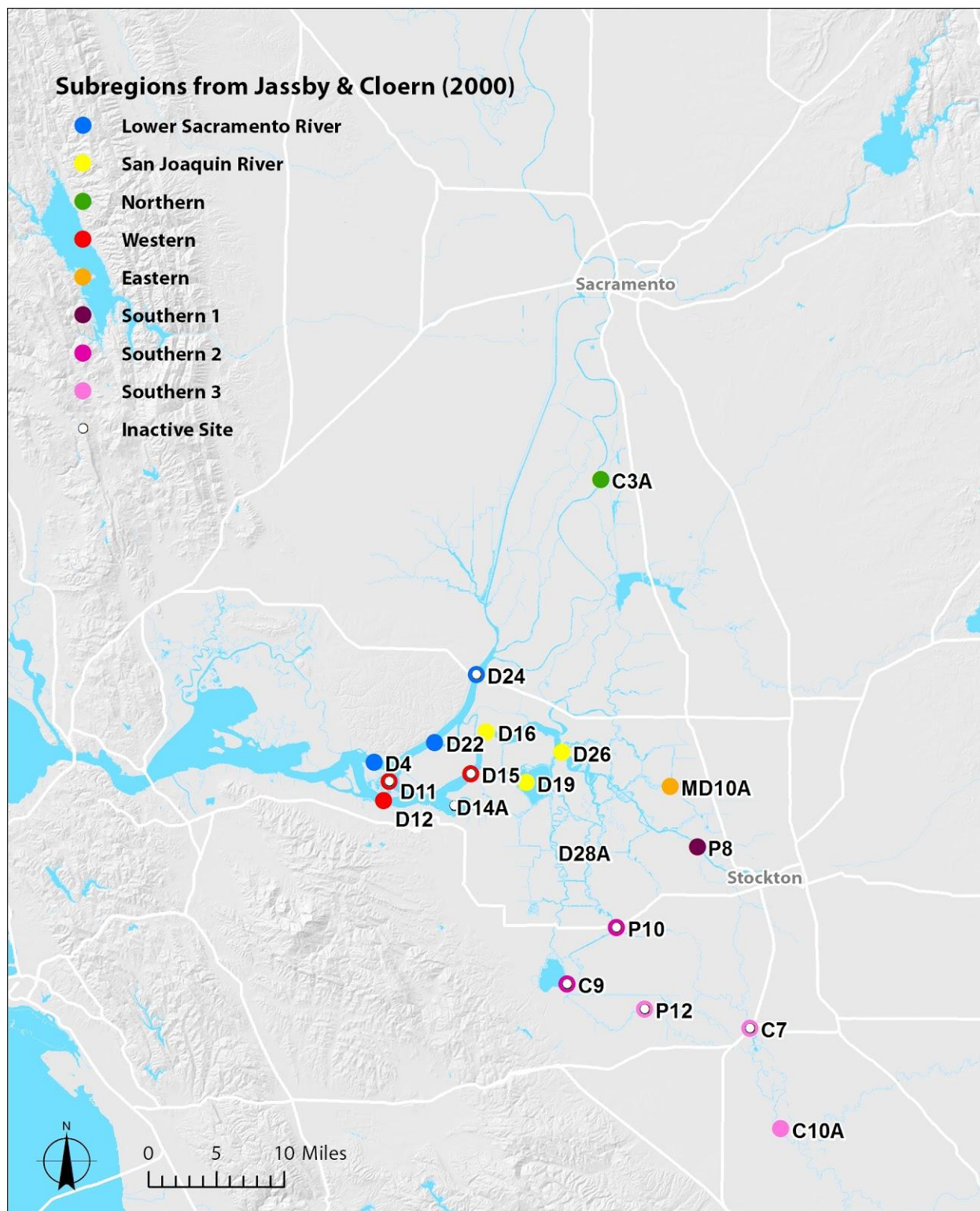


Figure 3. Water quality subregions of the Delta and associated sampling stations, according to Jassby & Cloern (2000). Open circles represent discontinued stations.

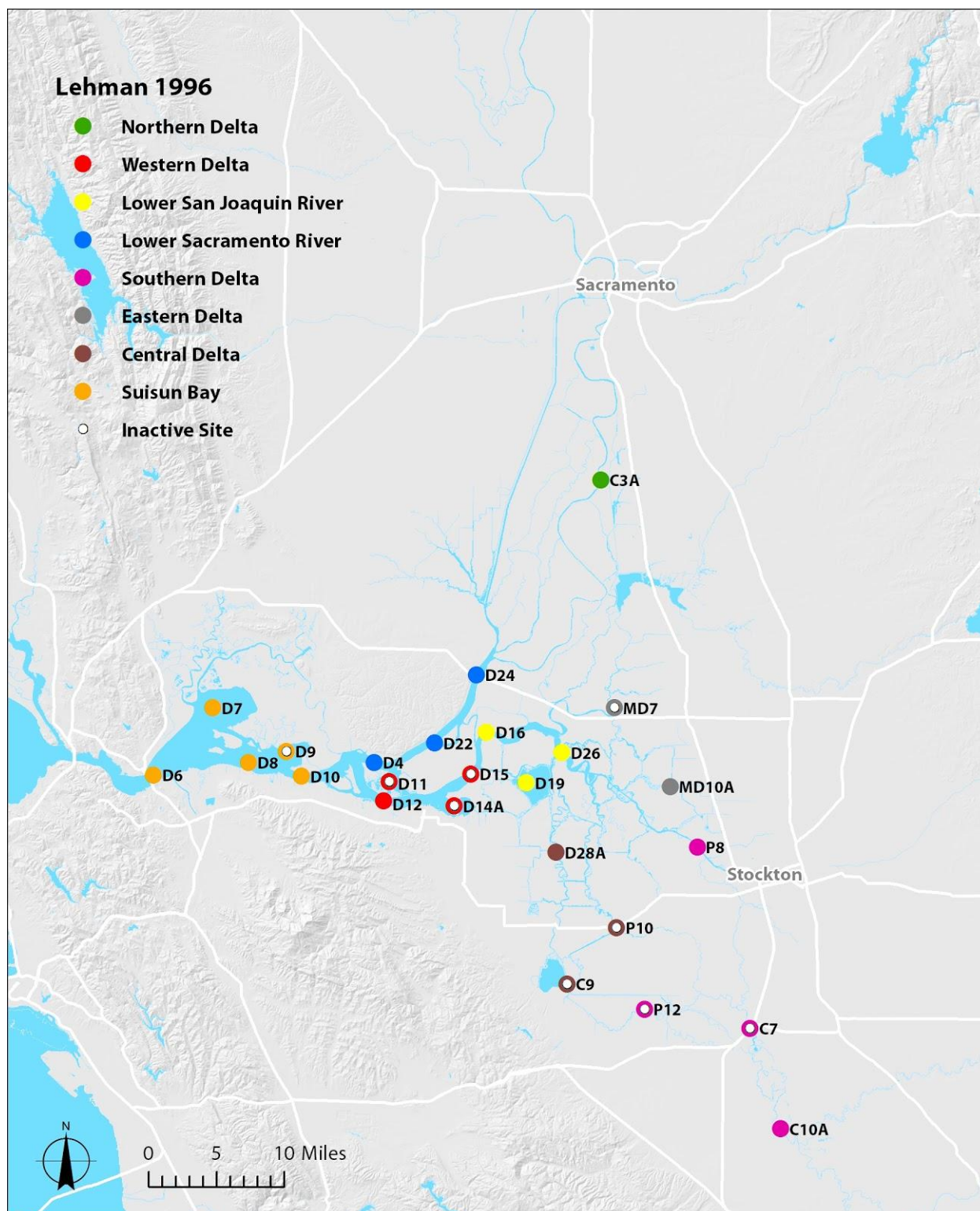


Figure 5(a).

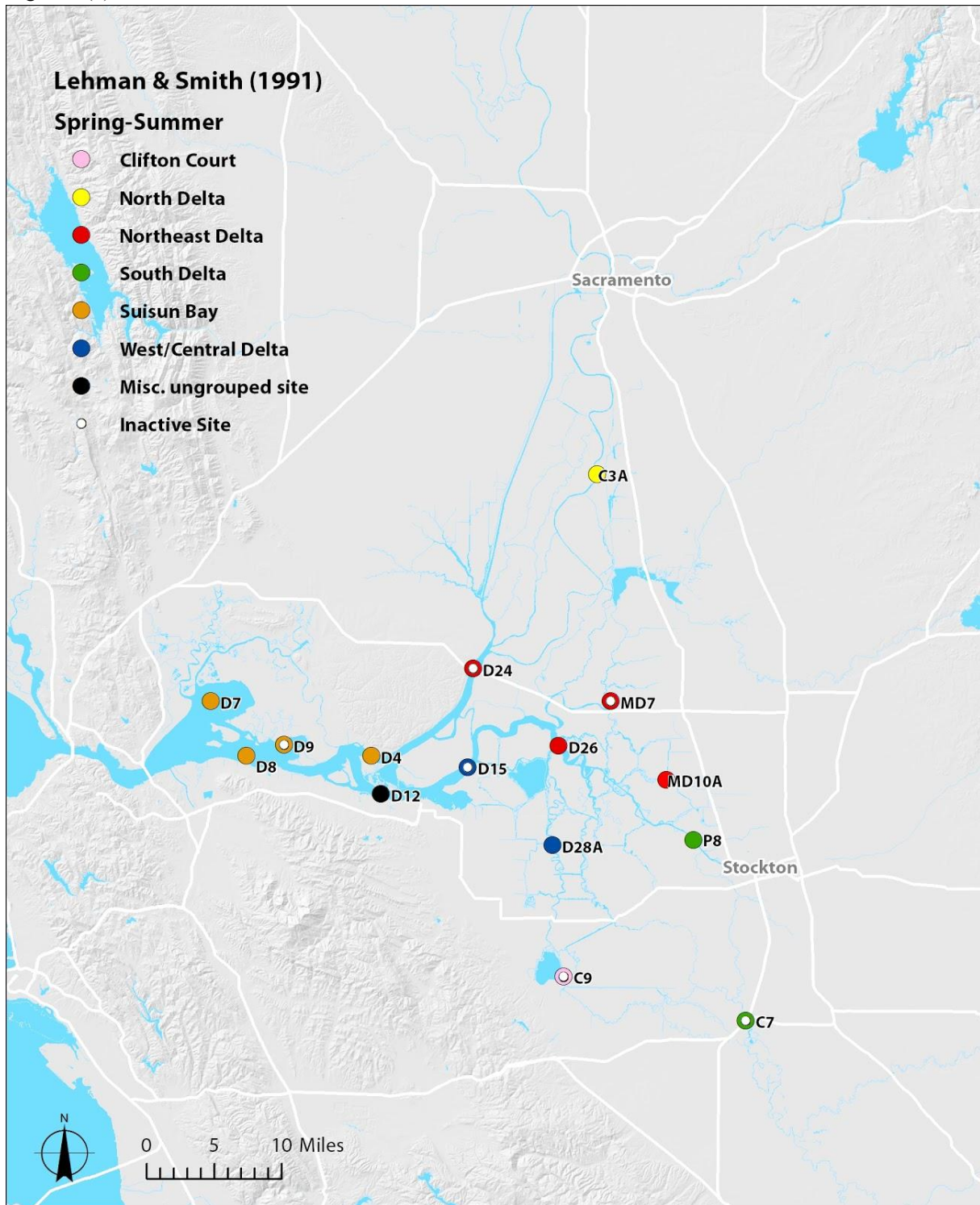


Figure 5(b).

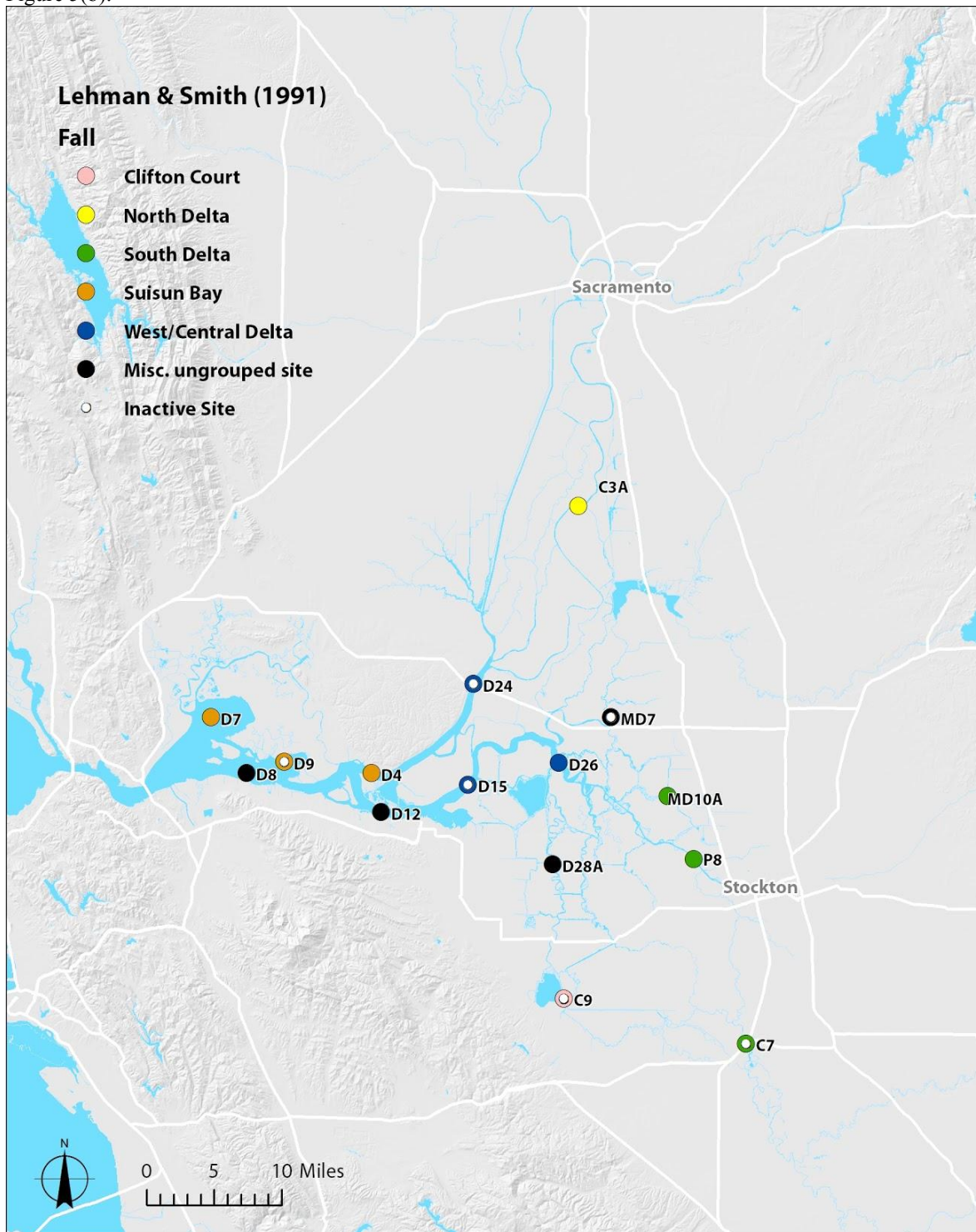


Figure 5. Association of sampling sites into regions with similar phytoplankton communities by season (Lehman and Smith 1991): (a) spring/summer, (b) fall.

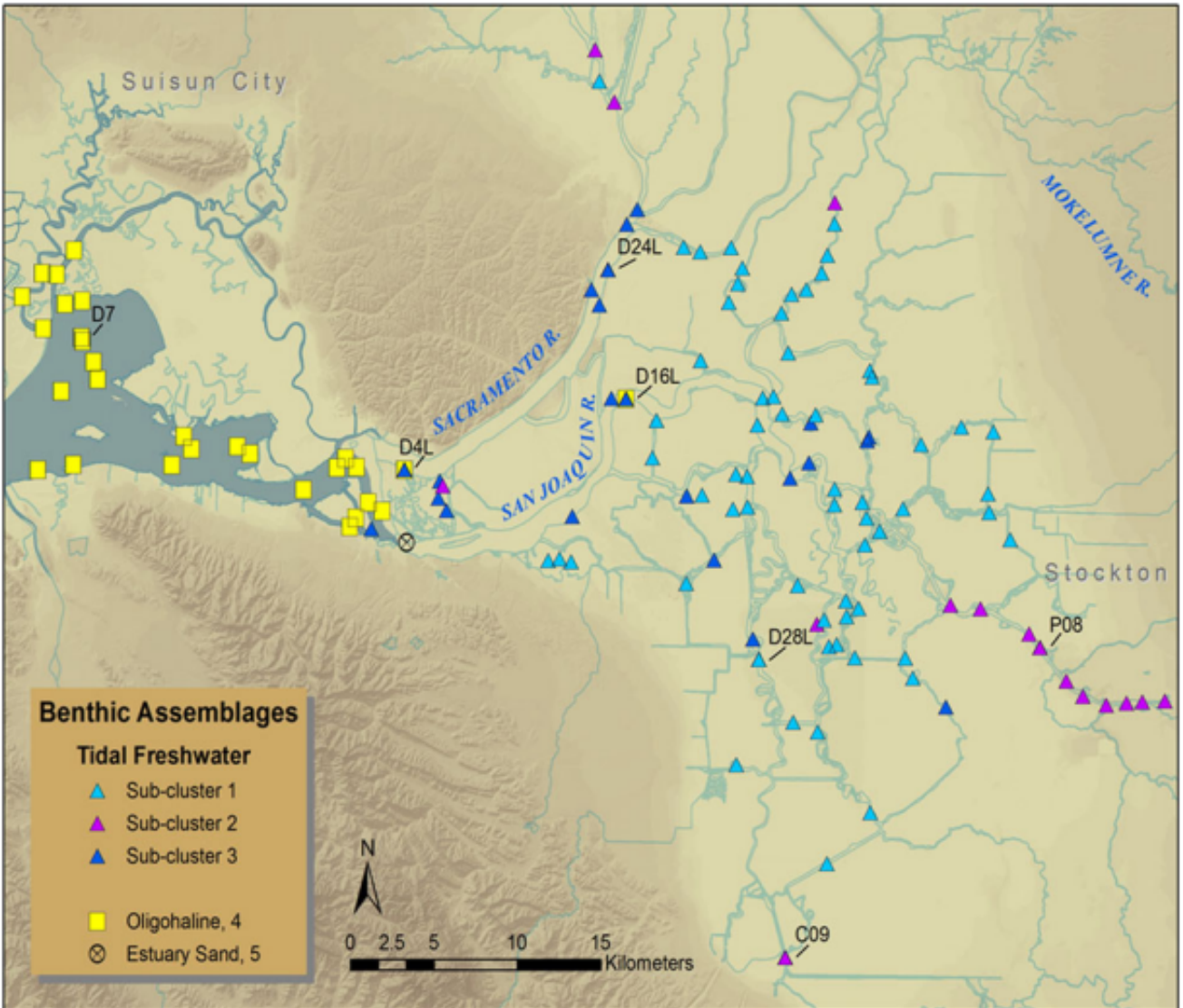


Figure 6. Association of sampling sites into clusters based on benthic macrofaunal assemblages (Thompson et al. 2013).

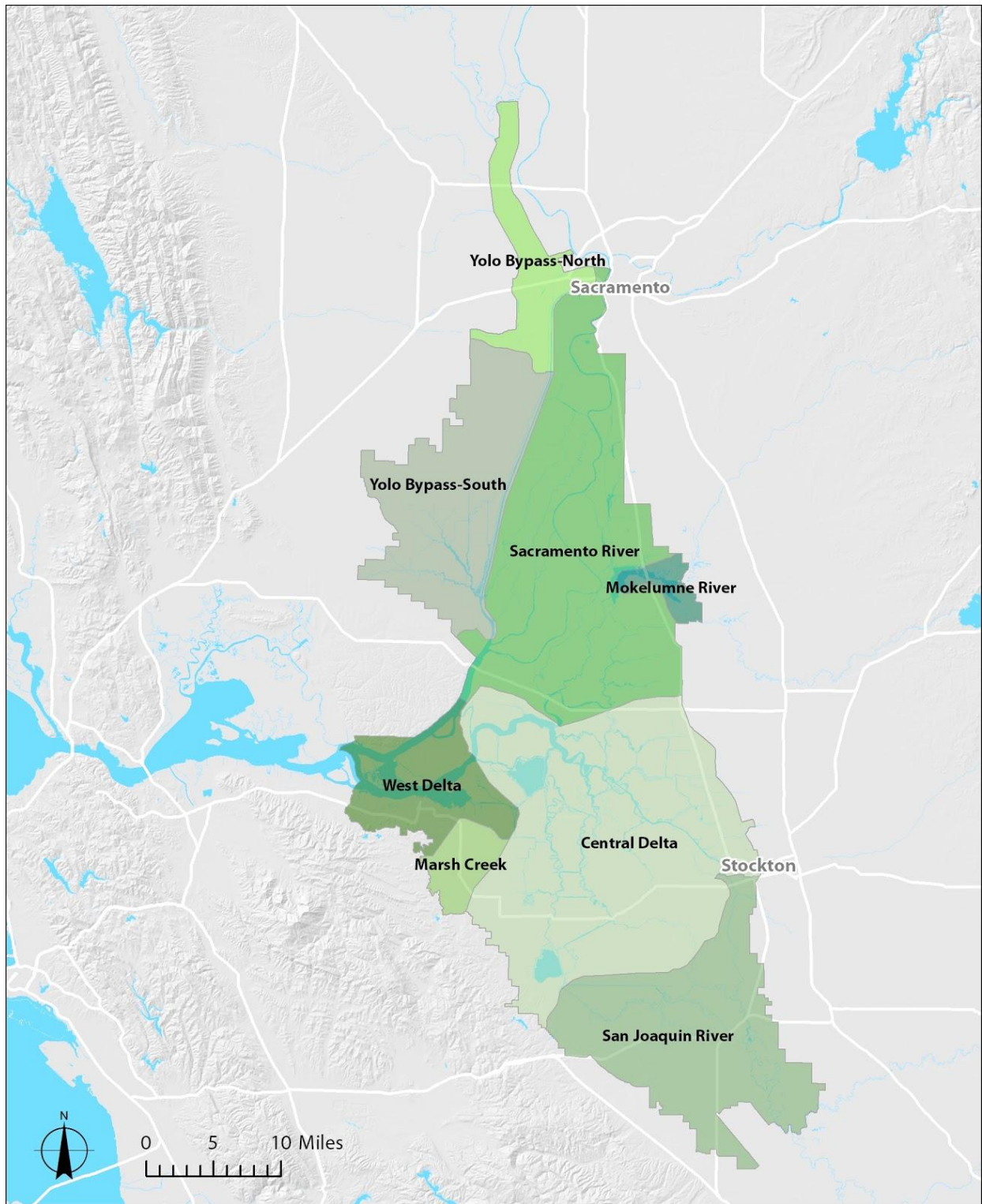


Figure 7. Delta subregions for Delta MeHg TMDL (Wood et al. 2010).

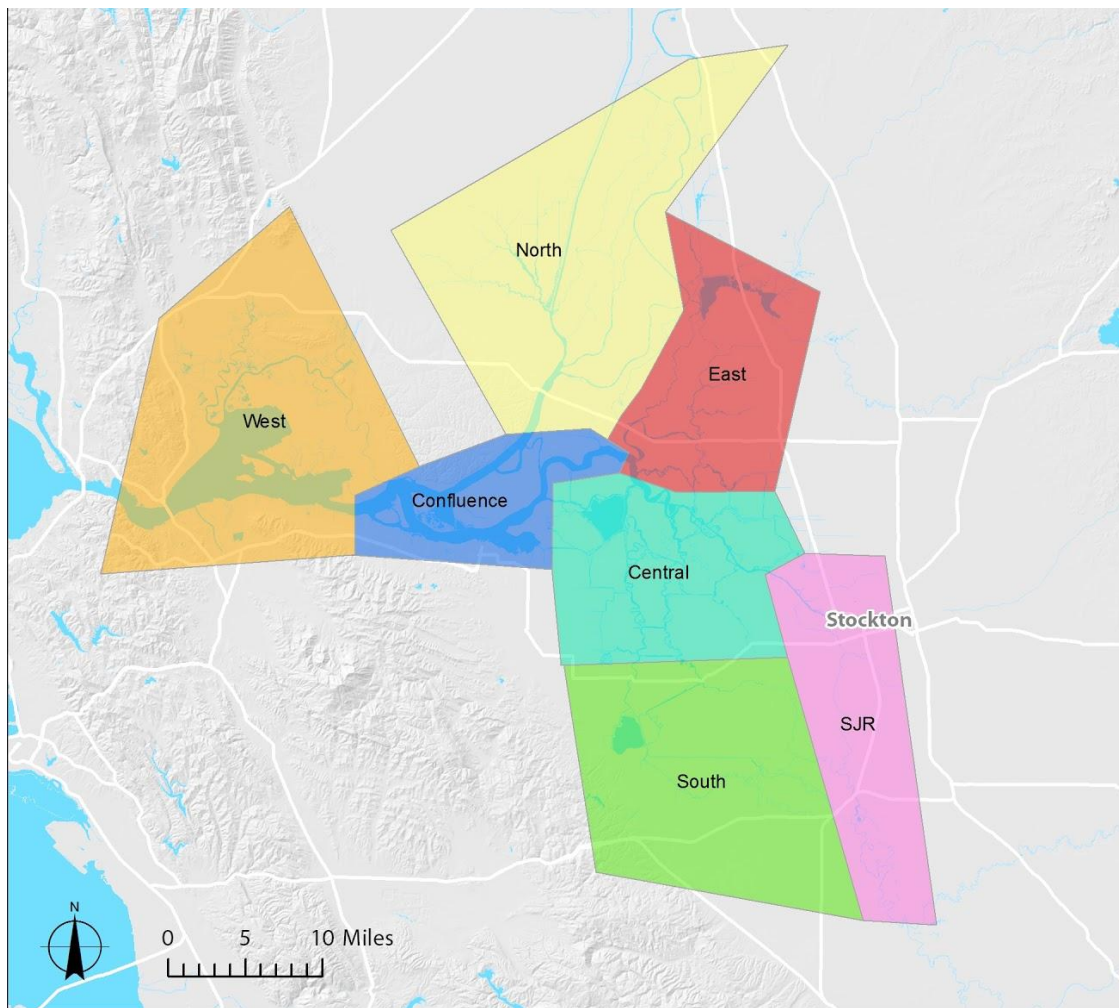


Figure 8. QUAL-Nutrient parameterization regions.

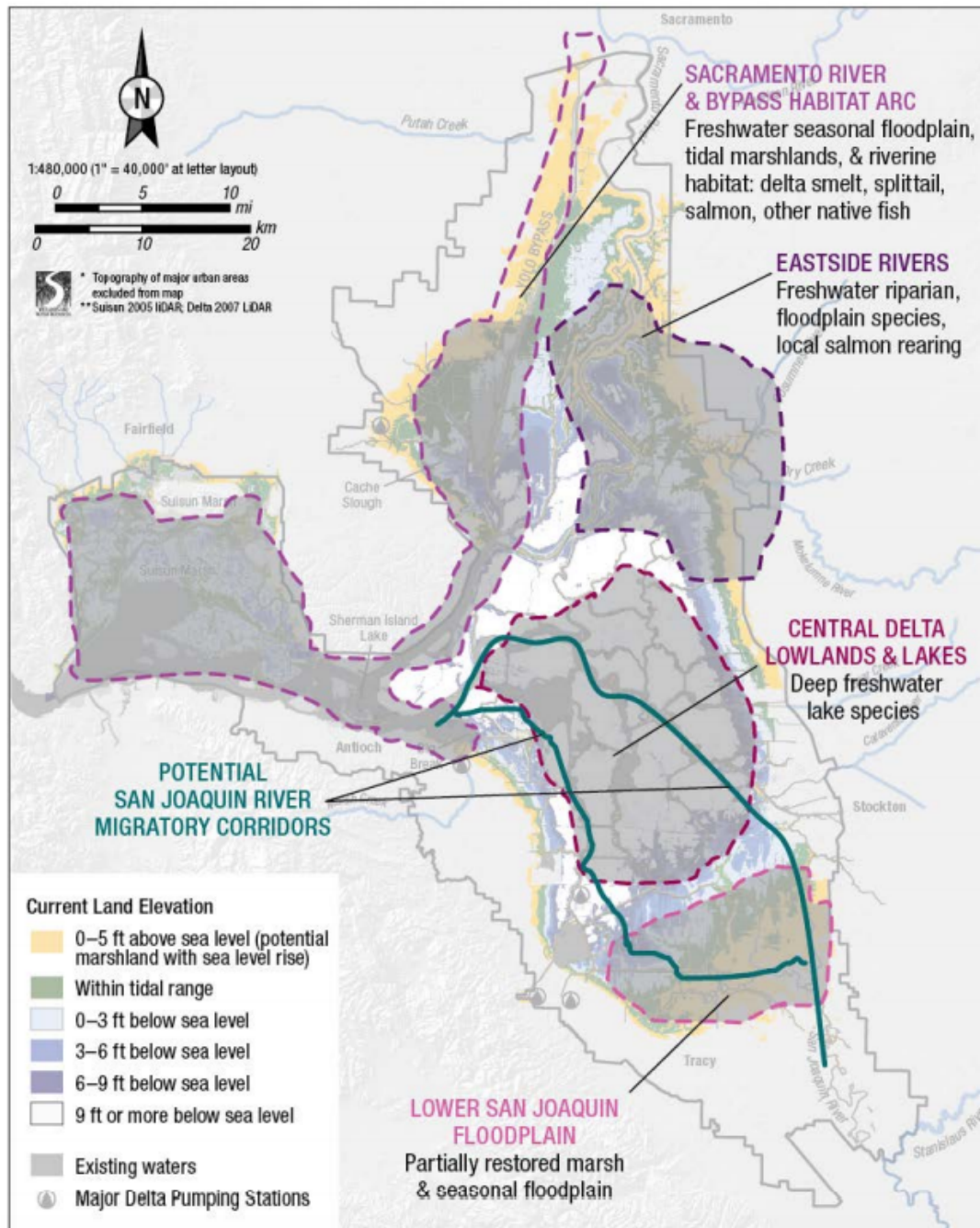


Figure 9. Ecosystem areas as regions (from Moyle et al. 2012). The authors describe proposed ecosystem areas that are based on regional habitat differences. The authors propose an aquatic ecosystem reconciliation strategy that would capitalize on these differences for habitat area specialization.

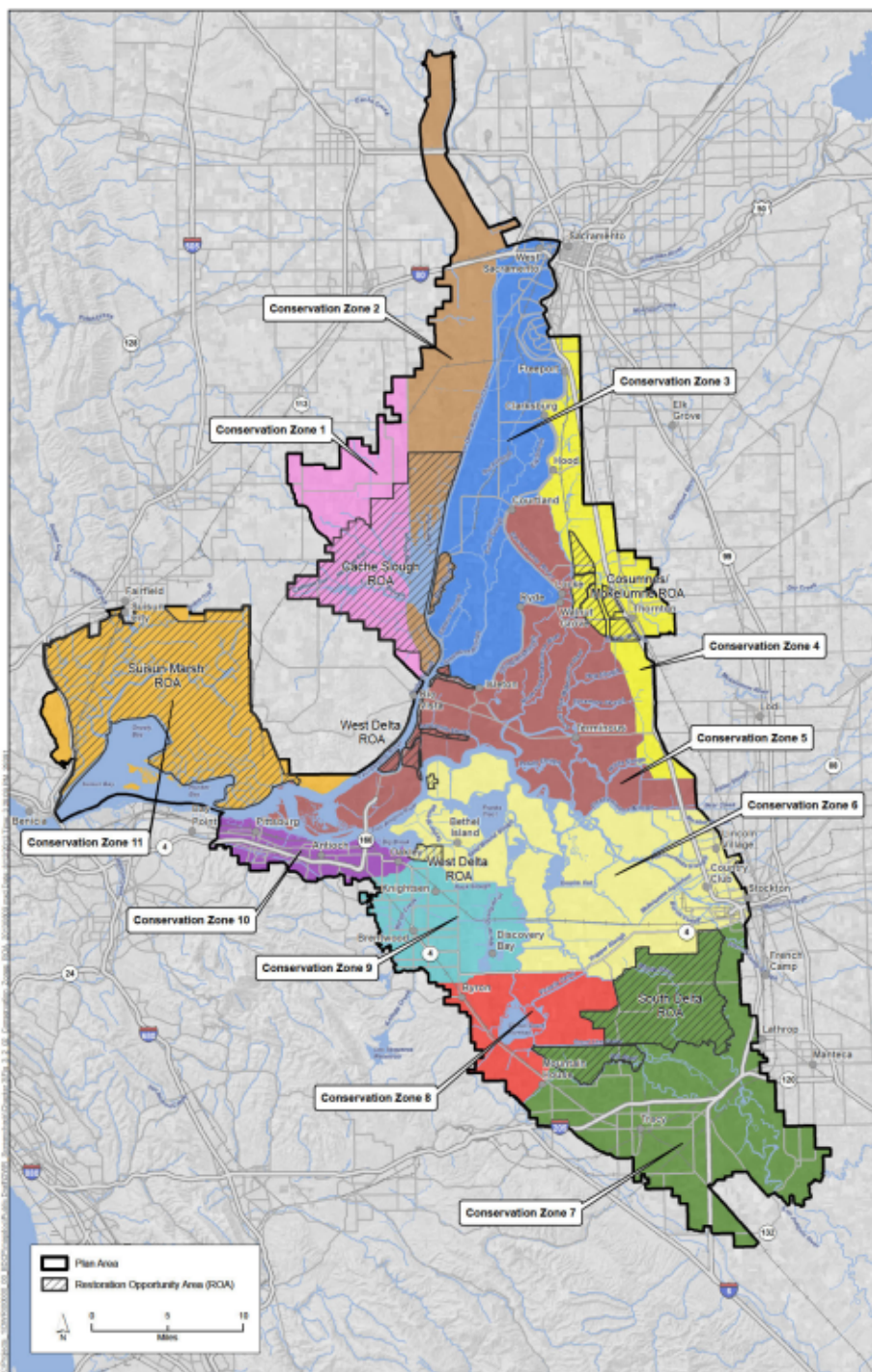


Figure 10. Conservation zones (BDGP 2015). Conservation zones are geographic areas defined by the biological needs of the species covered under the BDGP. Conservation zones were identified based on landscape characteristics, land elevations, particular land features likely to be present at specific elevations, and land uses.

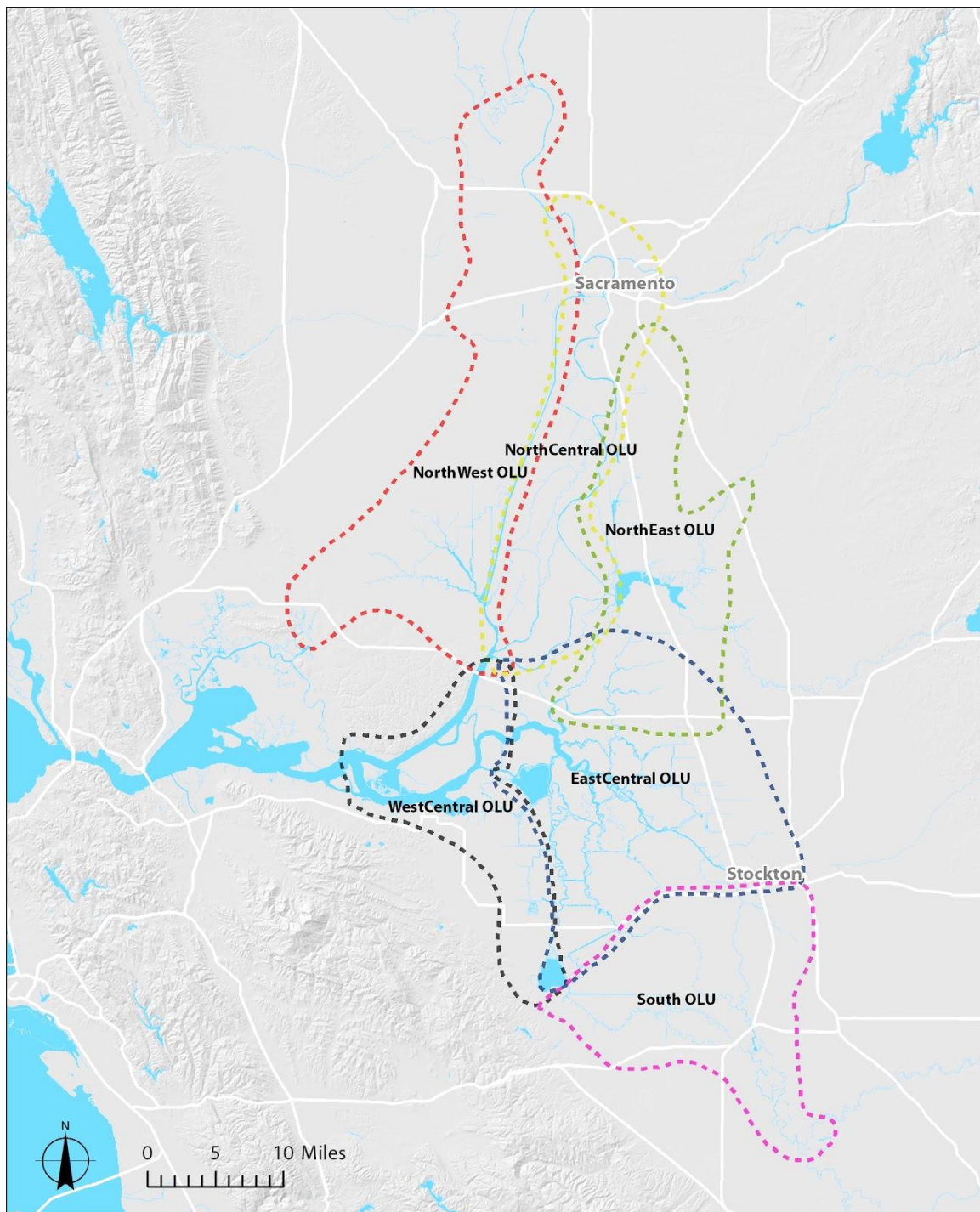


Figure 11. Potential operational landscape units (OLUs). Draft OLU boundaries were developed to represent restoration opportunity areas based on an understanding of ecological functions, physical drivers, existing constraints, and elevation gradients.

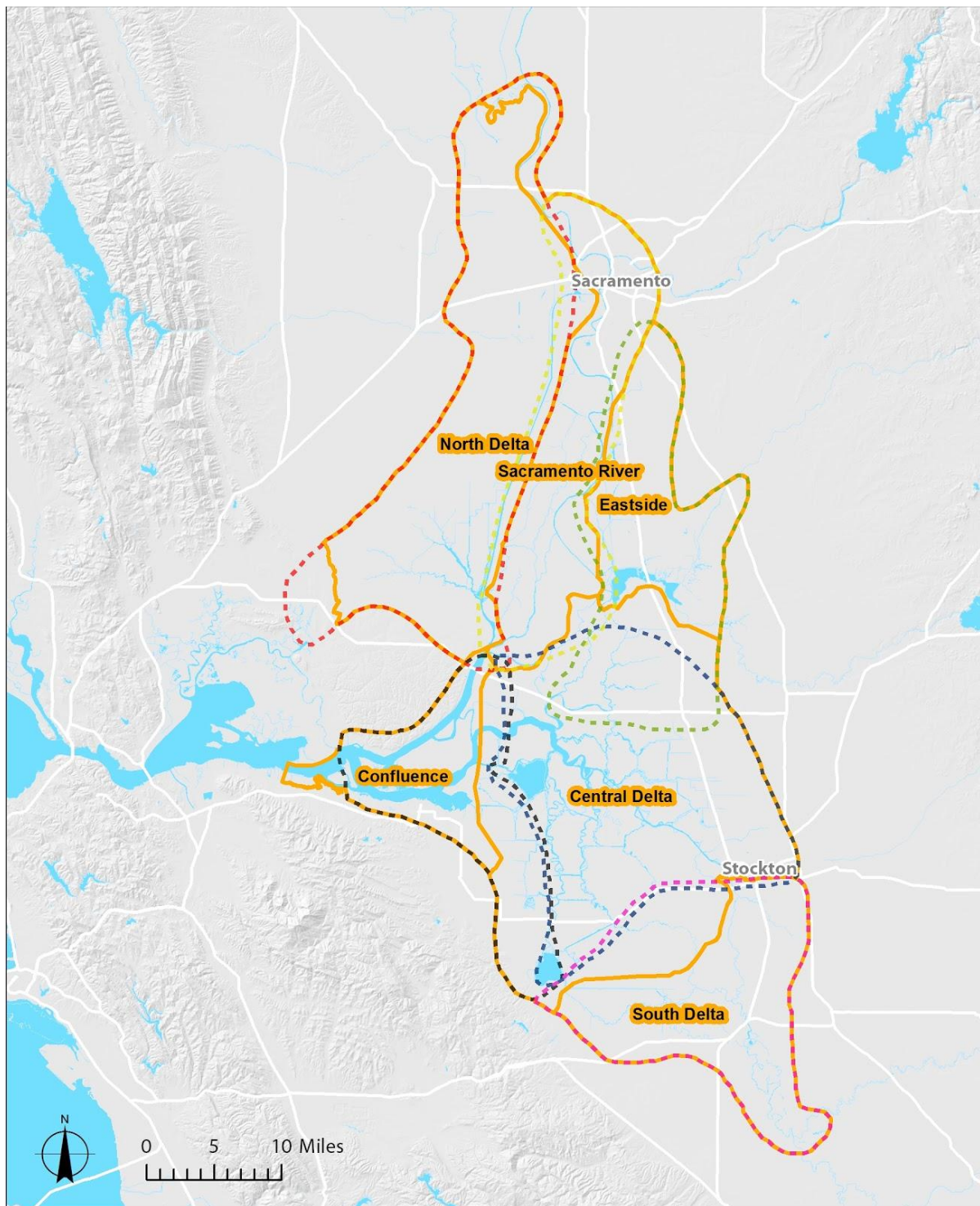


Figure 12. This map illustrates the modifications that were made to the original OLU boundaries. The dashed lines represent the original regional boundaries and the solid lines represent the modified boundaries.

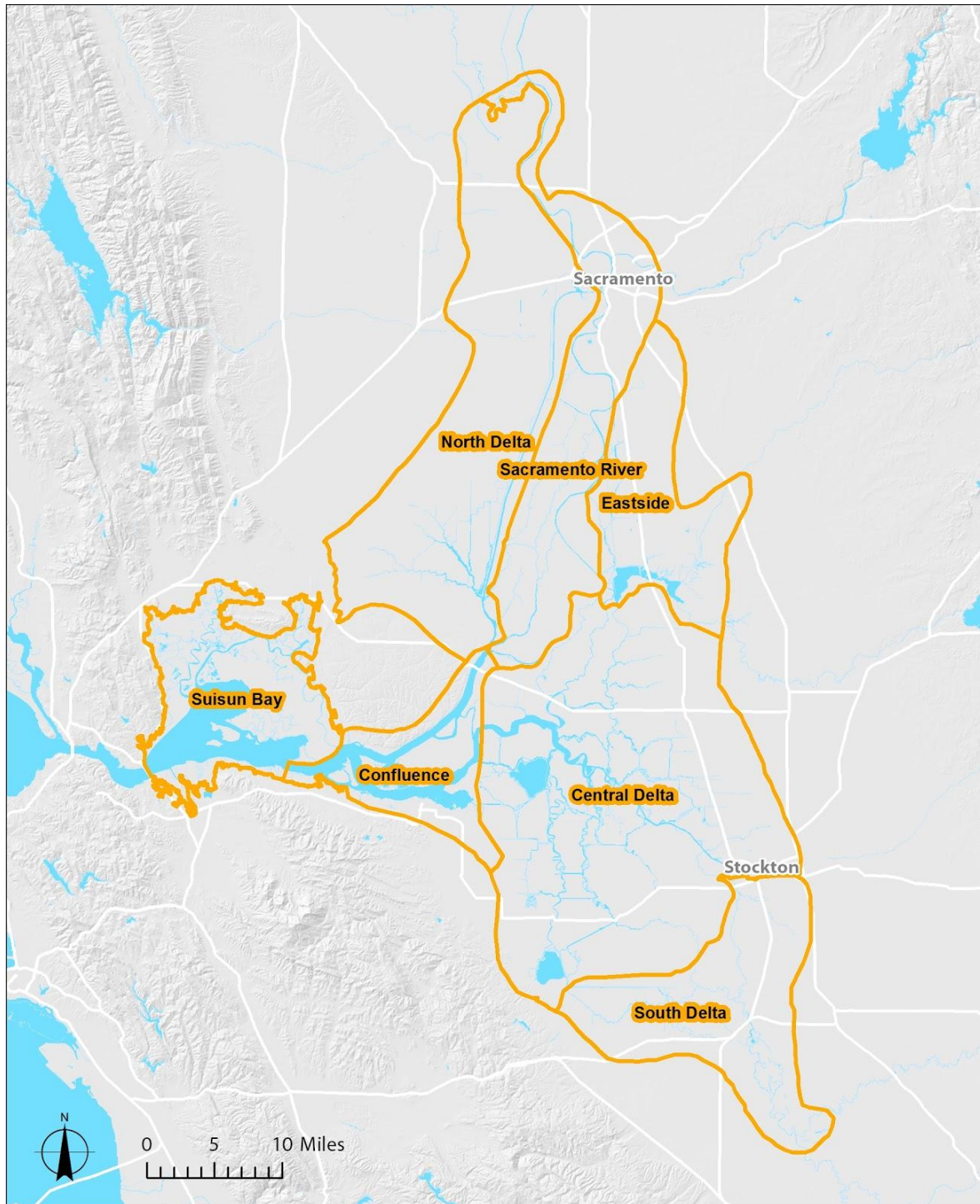
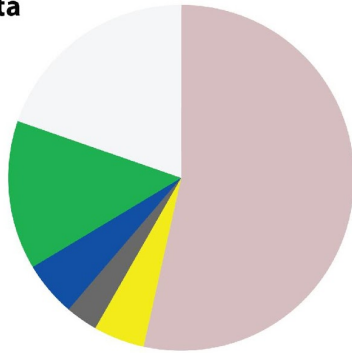
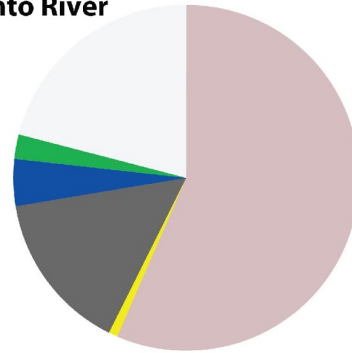


Figure 13. Proposed subregions for nutrient analyses, derived from potential OLUs.

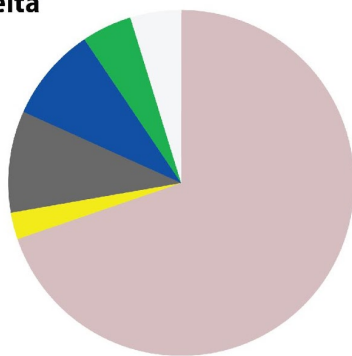
North Delta



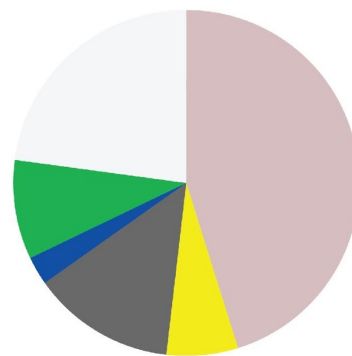
Sacramento River



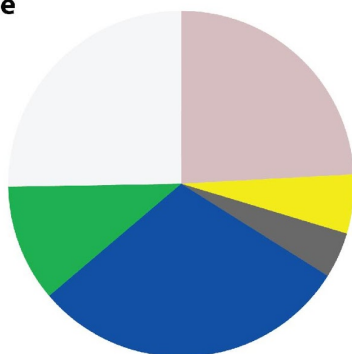
Central Delta



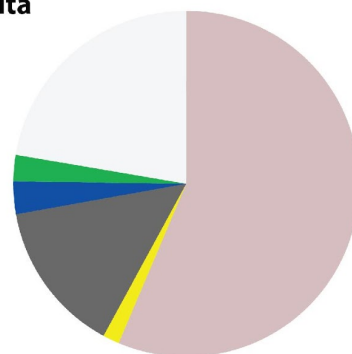
Eastside



Confluence



South Delta



Suisun Bay



Figure 14. Land cover distribution by subregion.

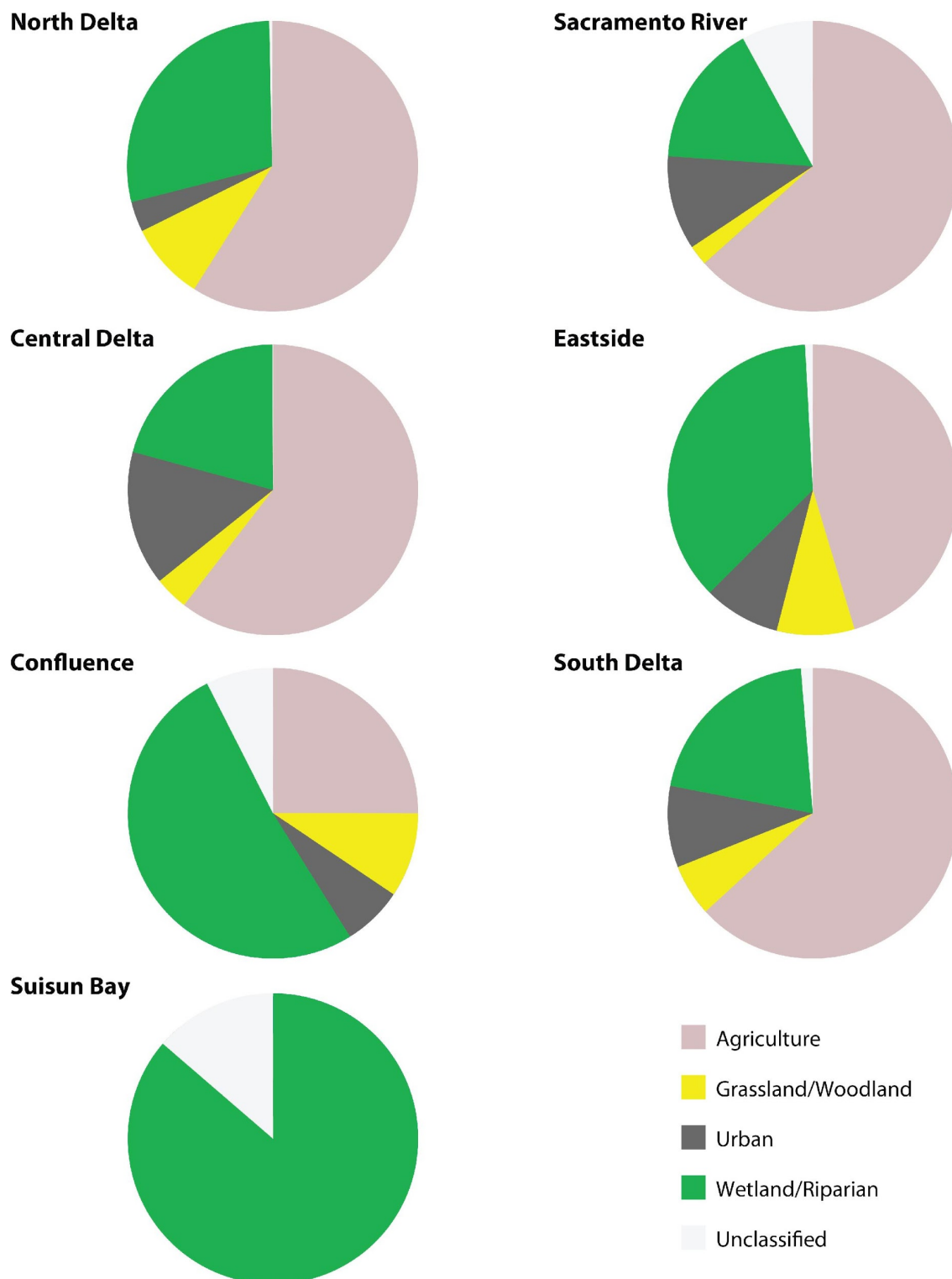


Figure 15. Land cover distribution by subregion, 100-m-buffer zone.

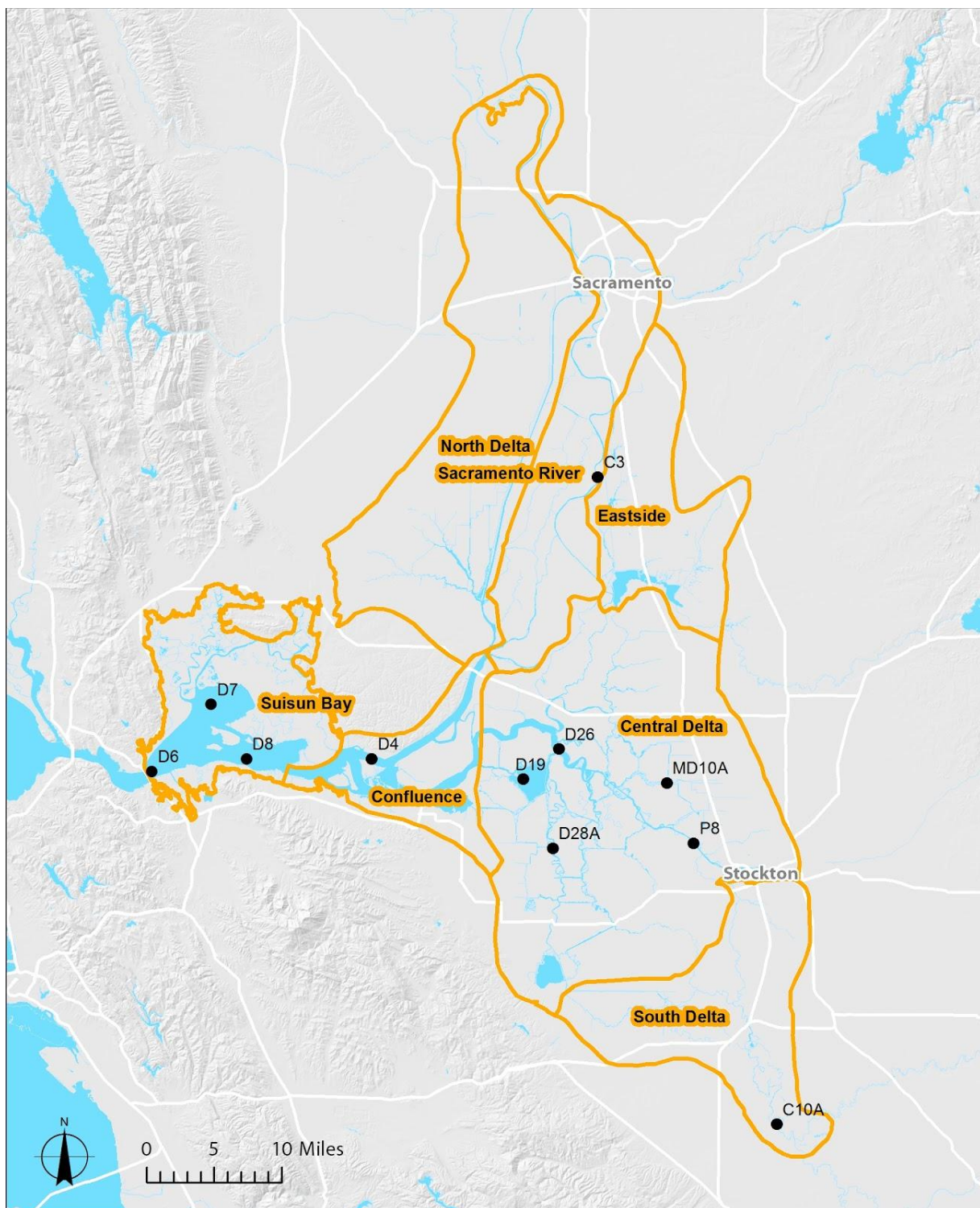


Figure 16. Location of DWR-EMP discrete water quality monitoring sites relative to OLU-based Delta subregions.

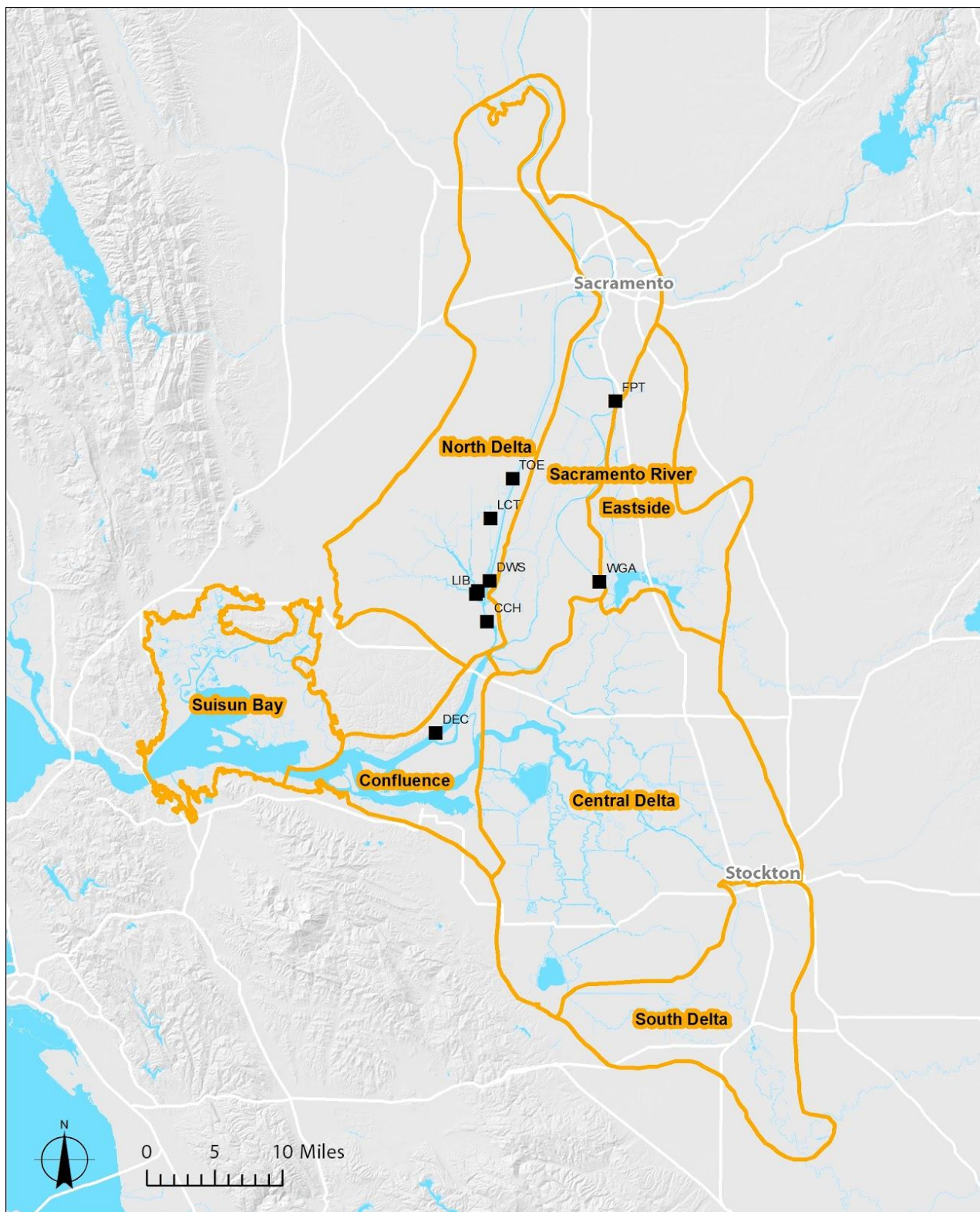


Figure 17. Location of USGS high-frequency nutrient sensors relative to OLU-based Delta subregions.

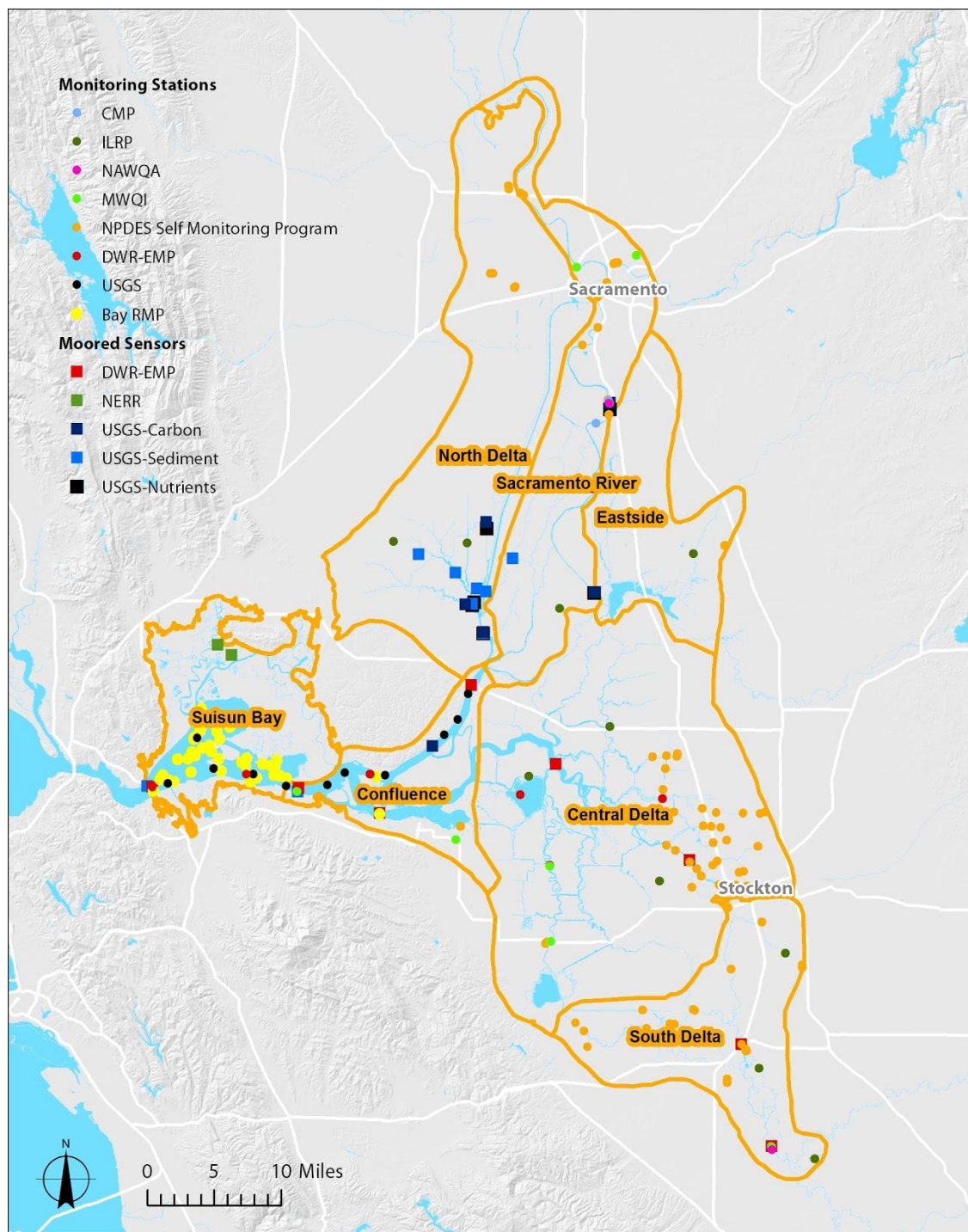


Figure 18. Location of additional monitoring stations relative to OLU-based subregions, including receiving water compliance monitoring sites (NPDES, Irrigated Lands Regulatory Program, Stormwater), DWR and US Bureau of Reclamation continuous recorders, and USGS NAWQA sites.

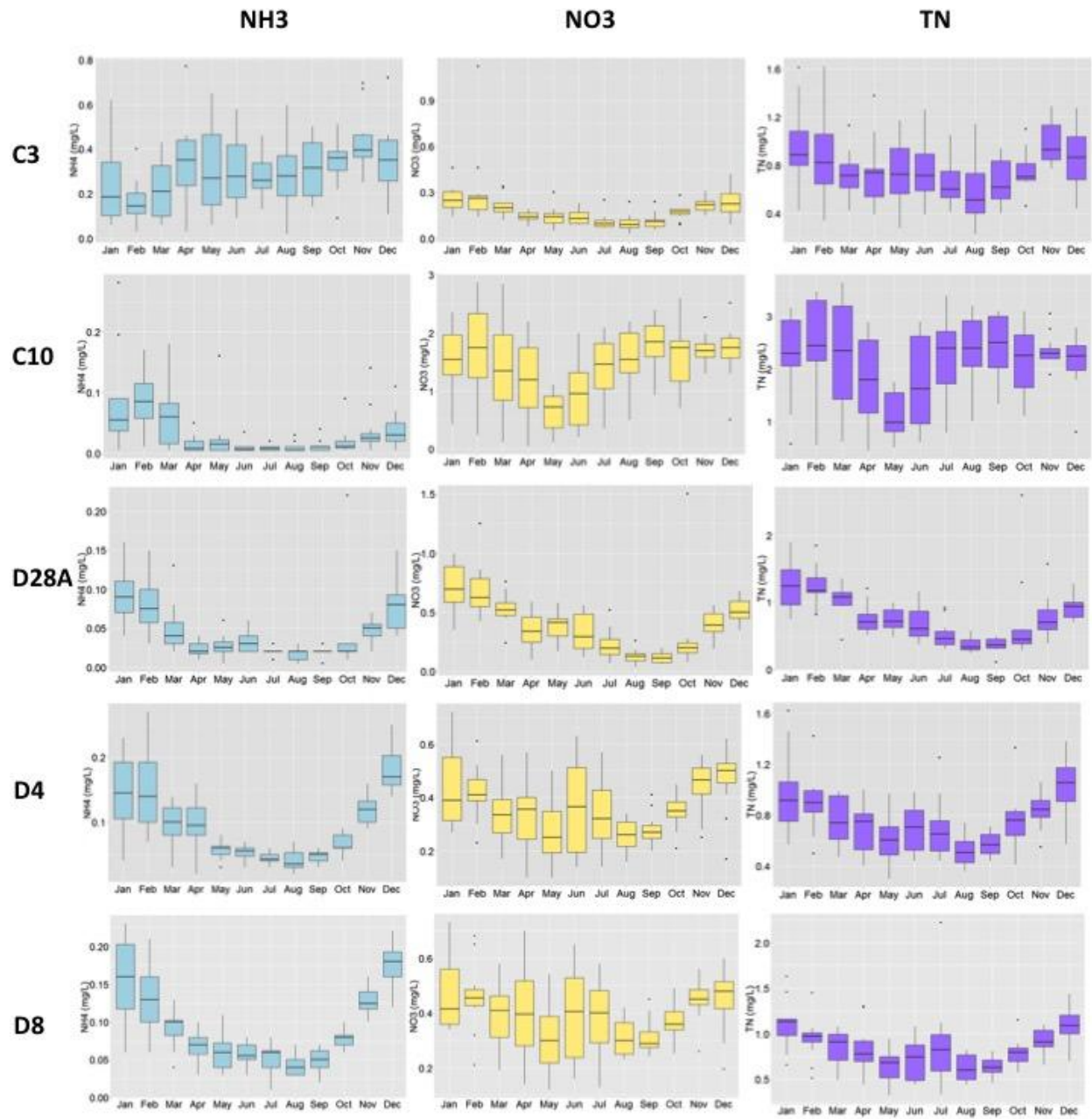


Figure 19. Boxplots on NH_4 , NO_3 , DIN and TN concentrations at a subset of DWR-EMP stations representative of different OLC-subregions for the period 2000-2011: Sacramento River (C3), South Delta (C10), Central Delta (D28A), Confluence (D4), and Suisun Bay (D8).