Appendix 3. Madera-Chowchilla Groundwater-Surface Water Simulation Model (MCSim) – First Model Update Report

Report | January 2025

Madera County

Sustainable Groundwater Management Act

Madera-Chowchilla Groundwater-Surface Water Simulation Model (MCSim) – First Model Update Report

Prepared For

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TABLE OF CONTENTS

1. INTRODUCTION 1
1.1. Background 1
1.2. Objectives and Approach 1
1.3. Report Organization 2
2. MODEL CODE AND PLATFORM 3
2.1. Integrated Water Flow Model 3
2.1.1. IWFM Demand Calculator 3
2.2. C2VSim-Fine Grid 3
3. GROUNDWATER FLOW MODEL DEVELOPMENT 5
3.1. MCSim_v2 – Historical Model 5
3.1.1. Model Configuration 5
3.1.2. Land Surface System 9
3.1.3. Surface Water System 12
3.1.4. Groundwater System 17
3.1.5. Small Watersheds 19
3.1.6. Initial Conditions 20
3.2. Model Calibration 20
3.3. MCSim – Projected Model 22
3.3.1. Projected Hydrology 22
3.3.2. Overview of Projected Scenarios 24
3.3.3. Land Surface System 25
3.3.4. Surface Water System 28
3.3.5. Groundwater System 48
3.3.6. Initial Conditions 49
4. GROUNDWATER FLOW MODEL RESULTS 50
4.1. Model Calibration Results 50
4.1.1. Statistical Measures of Model Fit 50
4.1.2. Groundwater Level Calibration 51
4.1.3. Subsidence Calibration 52
4.2. Aquifer Parameters 53
4.2.1. Hydraulic Conductivity 54
4.2.2. Storage Coefficients 56
4.2.3. Subsidence Parameters 57

4.3. Chowchilla Subbasin Model Results 59
4.3.1. Historical Period, WY 1989-2023 59
4.3.2. Projected Scenarios, WY 2024-2090 60
4.4. Madera Subbasin Model Results 67
4.4.1. Historical Period, WY 1989-2023 67
4.4.2. Projected Scenarios, WY 2024-2090 69
4.5. Model Results by GSA Area 77
4.5.1. Chowchilla Subbasin GSAs 77
4.5.2. Madera Subbasin GSAs 102
4.6. Additional Scenarios 137
4.6.1. Sensitivity – Projected with Projects Scenario 137
5. SENSITIVITY ANALYSIS AND MODEL UNCERTAINTY 142
5.1. Sensitivity Analysis 142
5.2. Model Uncertainty and Limitations 142
6. CONCLUSIONS AND RECOMMENDATIONS 144
6.1. Conclusions 144
6.2. Recommendations 144
7. REFERENCES 146

LIST OF TABLES

Table 3-1. MCSim Grid Characteristics 6
Table 3-2. Model Subregions within MCSim 6
Table 3-3. Average Thickness of MCSim_v2 Layers 8
Table 3-4. Weather Data Time Series Summary 10
Table 3-5. Summary of Historical Surface Water Inflows Development 13
Table 3-6. Summary of Historical Surface Water Diversions Development 14
Table 3-7. Summary of Historical Surface Water Bypasses Develop 16
Table 3-8. Summary of Small Watersheds 20
Table 3-9. Summary of Projected Water Years 23
Table 3-10. Summary of Projected Future Scenarios 25
Table 3-11. Development of Projected Future Land Surface Process Components 26
Table 3-12. Land Use Changes in the Projected with Projects Scenarios 28

TABLE OF CONTENTS

Table 3-13. Development of Projected Future Surface Water System Components 29

Table 3-14. Summary of Projected Projects by GSA 34

Table 4-1. Groundwater Level Calibration Statistics 52

Table 4-2. Summary of Aquifer Parameters End Member Values 53

Table 4-3. Summary of Zone Multipliers used to Calculate Aquifer Parameters 53

Table 4-4. Summary of MCSim_v2 Calibrated Hydraulic Conductivity 55

Table 4-5. Summary of MCSim_v2 Calibrated Storage Coefficients 56

Table 4-6. Summary of MCSim_v2 Calibrated Subsidence Parameters 58

Table 4-7. Chowchilla Subbasin GSP Historical Period Groundwater System Annual Water Budget Summary (acre-feet) 59

Table 4-8. Chowchilla Subbasin Calibrated Historical Period Groundwater System Annual Water Budget Summary (acre-feet) 60

Table 4-9. Chowchilla Subbasin Projected with Projects Implementation Period Groundwater System Annual Water Budget Summary (acre-feet) 61

Table 4-10. Chowchilla Subbasin Projected with Projects Sustainability Period Groundwater System Annual Water Budget Summary (acre-feet) 62

Table 4-11. Chowchilla Subbasin Projected with Projects and with Climate Change Implementation Period Groundwater System Annual Water Budget Summary (acre-feet) 63

Table 4-12. Chowchilla Subbasin Projected with Projects and with Climate Change Sustainability Period Groundwater System Annual Water Budget Summary (acre-feet) 64

Table 4-13. Chowchilla Subbasin Projected (No Action) Implementation Period Groundwater System Annual Water Budget Summary (acre-feet) 64

Table 4-14. Chowchilla Subbasin Projected (No Action) Sustainability Period Groundwater System Annual Water Budget Summary (acre-feet) 65

Table 4-15. Chowchilla Subbasin Projected (No Action) with Climate Change Implementation Period Groundwater System Annual Water Budget Summary (acre-feet) 66

Table 4-16. Chowchilla Subbasin Projected (No Action) with Climate Change Sustainability Period Groundwater System Annual Water Budget Summary (acre-feet) 67

Table 4-17. Madera Subbasin GSP Historical Period Groundwater System Annual Water Budget Summary (acre-feet) 68

Table 4-18. Madera Subbasin Calibrated Historical Period Groundwater System Annual Water Budget Summary (acre-feet) 69

Table 4-19. Madera Subbasin Projected with Projects Implementation Period Groundwater System Annual Water Budget Summary (acre-feet) 70

Table 4-20. Madera Subbasin Projected with Projects Sustainability Period Groundwater System Annual Water Budget Summary (acre-feet) 71
Table 4-21. Madera Subbasin Projected with Projects and with Climate Change Implementation Period Groundwater System Annual Water Budget Summary (acre-feet) 72
Table 4-22. Madera Subbasin Projected with Projects and with Climate Change Sustainability Period Groundwater System Annual Water Budget Summary (acre-feet) 73
Table 4-23. Madera Subbasin Projected (No Action) Implementation Period Groundwater System Annual Water Budget Summary (acre-feet) 74
Table 4-24. Madera Subbasin Projected (No Action) Sustainability Period Groundwater System Annual Water Budget Summary (acre-feet) 75
Table 4-25. Madera Subbasin Projected (No Action) with Climate Change Implementation Period Groundwater System Annual Water Budget Summary (acre-feet) 76
Table 4-26. Madera Subbasin Projected (No Action) with Climate Change Sustainability Period Groundwater System Annual Water Budget Summary (acre-feet) 77
Table 4-27. Chowchilla Water District GSA Historical Groundwater System Annual Water Budget Summary (acre-feet) 78
Table 4-28. Chowchilla Water District GSA Projected with Projects Groundwater System Annual Water Budget Summary (acre-feet) 79
Table 4-29. Chowchilla Water District GSA Projected with Projects and with Climate Change Groundwater System Annual Water Budget Summary (acre-feet) 80
Table 4-30. Chowchilla Water District GSA Projected (No Action) Groundwater System Annual Water Budget Summary (acre-feet) 81
Table 4-31. Chowchilla Water District GSA Projected (No Action) with Climate Change Groundwater System Annual Water Budget Summary (acre-feet) 82
Table 4-32. Madera County - East GSA Historical Groundwater System Annual Water Budget Summary (acre-feet) 83
Table 4-33. Madera County - East GSA Projected with Projects Groundwater System Annual Water Budget Summary (acre-feet) 84
Table 4-34. Madera County - East GSA Projected with Projects and with Climate Change Groundwater System Annual Water Budget Summary (acre-feet) 85
Table 4-35. Madera County - East GSA Projected (No Action) Groundwater System Annual Water Budget Summary (acre-feet) 86
Table 4-36. Madera County - East GSA Projected (No Action) with Climate Change Groundwater System Annual Water Budget Summary (acre-feet) 87
Table 4-37. Madera County - West GSA Historical Groundwater System Annual Water Budget Summary (acre-feet) 88

Table 4-38. Madera County - West GSA Projected with Projects Groundwater System Annual Water Budget Summary (acre-feet) 89
Table 4-39. Madera County - West GSA Projected with Projects and with Climate Change Groundwater System Annual Water Budget Summary (acre-feet) 90
Table 4-40. Madera County - West GSA Projected (No Action) Groundwater System Annual Water Budget Summary (acre-feet) 91
Table 4-41. Madera County - West GSA Projected (No Action) with Climate Change Groundwater System Annual Water Budget Summary (acre-feet) 92
Table 4-42. Triangle T Water District GSA Historical Groundwater System Annual Water Budget Summary (acre-feet) 93
Table 4-43. Triangle T Water District GSA Projected with Projects Groundwater System Annual Water Budget Summary (acre-feet) 94
Table 4-44. Triangle T Water District GSA Projected with Projects and with Climate Change Groundwater System Annual Water Budget Summary (acre-feet) 95
Table 4-45. Triangle T Water District GSA Projected (No Action) Groundwater System Annual Water Budget Summary (acre-feet) 96
Table 4-46. Triangle T Water District GSA Projected (No Action) with Climate Change Groundwater System Annual Water Budget Summary (acre-feet) 97
Table 4-47. Sierra Vista Mutual Water Company GSA Historical Groundwater System Annual Water Budget Summary (acre-feet) 98
Table 4-48. Sierra Vista Mutual Water Company GSA Projected with Projects Groundwater System Annual Water Budget Summary (acre-feet) 99
Table 4-49. Sierra Vista Mutual Water Company GSA Projected with Projects and with Climate Change Groundwater System Annual Water Budget Summary (acre-feet) 100
Table 4-50. Sierra Vista Mutual Water Company GSA Projected (No Action) Groundwater System Annual Water Budget Summary (acre-feet) 101
Table 4-51. Sierra Vista Mutual Water Company GSA Projected (No Action) with Climate Change Groundwater System Annual Water Budget Summary (acre-feet) 102
Table 4-52. City of Madera District GSA Historical Groundwater System Annual Water Budget Summary (acre-feet) 103
Table 4-53. City of Madera District GSA Projected with Projects Groundwater System Annual Water Budget Summary (acre-feet) 104
Table 4-54. City of Madera District GSA Projected with Projects and with Climate Change Groundwater System Annual Water Budget Summary (acre-feet) 105
Table 4-55. City of Madera District GSA Projected (No Action) Groundwater System Annual Water Budget Summary (acre-feet) 106

Table 4-56. City of Madera District GSA Projected (No Action) with Climate Change Groundwater System Annual Water Budget Summary (acre-feet) 107
Table 4-57. Madera County GSA Historical Groundwater System Annual Water Budget Summary (acre-feet) 108
Table 4-58. Madera County GSA Projected with Projects Groundwater System Annual Water Budget Summary (acre-feet) 109
Table 4-59. Madera County GSA Projected with Projects and with Climate Change Groundwater System Annual Water Budget Summary (acre-feet) 110
Table 4-60. Madera County GSA Projected (No Action) Groundwater System Annual Water Budget Summary (acre-feet) 111
Table 4-61. Madera County GSA Projected (No Action) with Climate Change Groundwater System Annual Water Budget Summary (acre-feet) 112
Table 4-62. Madera Irrigation District GSA Historical Groundwater System Annual Water Budget Summary (acre-feet) 113
Table 4-63. Madera Irrigation District GSA Projected with Projects Groundwater System Annual Water Budget Summary (acre-feet) 114
Table 4-64. Madera Irrigation District GSA Projected with Projects and with Climate Change Groundwater System Annual Water Budget Summary (acre-feet) 115
Table 4-65. Madera Irrigation District GSA Projected (No Action) Groundwater System Annual Water Budget Summary (acre-feet) 116
Table 4-66. Madera Irrigation District GSA Projected (No Action) with Climate Change Groundwater System Annual Water Budget Summary (acre-feet) 117
Table 4-67. Madera Water District GSA Historical Groundwater System Annual Water Budget Summary (acre-feet) 118
Table 4-68. Madera Water District GSA Projected with Projects Groundwater System Annual Water Budget Summary (acre-feet) 119
Table 4-69. Madera Water District GSA Projected with Projects and with Climate Change Groundwater System Annual Water Budget Summary (acre-feet) 120
Table 4-70. Madera Water District GSA Projected (No Action) Groundwater System Annual Water Budget Summary (acre-feet) 121
Table 4-83. Root Creek Water District GSA Projected with Projects Groundwater System Annual Water Budget Summary (acre-feet) 134
Table 4-84. Root Creek Water District GSA Projected with Projects and with Climate Change 135
Table 4-85. Root Creek Water District GSA Projected (No Action) Groundwater System Annual Water Budget Summary (acre-feet) 136
Table 4-86. Root Creek Water District GSA Projected (No Action) with Climate Change Groundwater System Annual Water Budget Summary (acre-feet) 137

Table 4-87. Madera Subbasin Sensitivity – Projected with Projects Groundwater System Annual Water Budget Summary (acre-feet) 138

Table 4-88. Madera Subbasin GSAs Sensitivity – Projected with Projects Implementation Period (Water Years 2024-2039) Groundwater System Annual Water Budget Summary (acre-feet) 140

Table 4-89. Madera Subbasin GSAs Sensitivity – Projected with Projects Sustainability Period (Water Years 2040-2090) Groundwater System Annual Water Budget Summary (acre-feet) 141

LIST OF FIGURES

Figures are available at the end of the report.

Figure 3-1 MCSim Model Domain

Figure 3-2 Modified Nodes and Elements in MCSim

Figure 3-3 Subregions in MCSim

Figure 3-4 MCSim Stream Network

Figure 3-5 Elevation of The Top of Layer 1

Figure 3-6 Elevation of The Top of the Layer 2 Aquitard (A-Clay)

Figure 3-7 Elevation of The Top of Layer 2

Figure 3-8 Elevation of The Top of the Layer 3 Aquitard (C-Clay)

Figure 3-9 Elevation of The Top of Layer 3

Figure 3-10 Elevation of The Top of the Layer 4 Aquitard (E-Clay)

Figure 3-11 Elevation of The Top of Layer 4

Figure 3-12 Elevation of The Top of Layer 5

Figure 3-13 Elevation of The Top of Layer 6

Figure 3-14 Elevation of The Top of Layer 7

Figure 3-15 Elevation of the Bottom of Layer 7

Figure 3-16 Thickness of Layer 1

Figure 3-17 Thickness of the Layer 2 Aquitard (A-Clay)

Figure 3-18 Thickness of Layer 2

Figure 3-19 Thickness of the Layer 3 Aquitard (C-Clay)

Figure 3-20 Thickness of Layer 3

Figure 3-21 Thickness of the Layer 4 Aquitard

Figure 3-22 Thickness of Layer 4

Figure 3-23 Thickness of Layer 5
Figure 3-24 Thickness of Layer 6
Figure 3-25 Thickness of Layer 7
Figure 3-26 MCSim Surface Water Inflow Locations
Figure 3-27 MCSim Historical Surface Water Diversion Locations
Figure 3-28 MCSim Historical Surface Water Bypass Locations
Figure 3-29 Percent Coarse – Layer 1
Figure 3-30 Percent Coarse – Layer 2
Figure 3-31 Percent Coarse – Layer 3
Figure 3-32 Percent Coarse – Layer 4
Figure 3-33 Percent Coarse – Layer 5
Figure 3-34 Percent Coarse – Layer 6
Figure 3-35 Percent Coarse – Layer 7
Figure 3-36 Groundwater Nodes with Boundary Conditions Specified in MCSim_v2
Figure 3-37 Vertical Distribution of Historical Agricultural Pumping - Layer 1
Figure 3-38 Vertical Distribution of Historical Agricultural Pumping - Layer 2
Figure 3-39 Vertical Distribution of Historical Agricultural Pumping - Layer 3
Figure 3-40 Vertical Distribution of Historical Agricultural Pumping - Layer 4
Figure 3-41 Vertical Distribution of Historical Agricultural Pumping - Layer 5
Figure 3-42 Vertical Distribution of Historical Agricultural Pumping - Layer 6
Figure 3-43 Vertical Distribution of Historical Agricultural Pumping - Layer 7
Figure 3-44 Vertical Distribution of Historical Urban Pumping - Layer 1
Figure 3-45 Vertical Distribution of Historical Urban Pumping - Layer 2
Figure 3-46 Vertical Distribution of Historical Urban Pumping - Layer 3
Figure 3-47 Vertical Distribution of Historical Urban Pumping - Layer 4
Figure 3-48 Vertical Distribution of Historical Urban Pumping - Layer 5
Figure 3-49 Vertical Distribution of Historical Urban Pumping - Layer 6
Figure 3-50 Vertical Distribution of Historical Urban Pumping - Layer 7
Figure 3-51 Nodes Receiving Small Watershed Contributions in MCSim_v2
Figure 3-52 Historical Initial Groundwater Heads - Layer 1
Figure 3-53 Historical Initial Groundwater Heads - Layer 2
Figure 3-54 Historical Initial Groundwater Heads - Layer 3
Figure 3-55 Historical Initial Groundwater Heads - Layer 4

Figure 3-56 Historical Initial Groundwater Heads - Layer 5
Figure 3-57 Historical Initial Groundwater Heads - Layer 6
Figure 3-58 Historical Initial Groundwater Heads - Layer 7
Figure 3-59 Map of Groundwater Level Calibration Wells
Figure 3-60 Map of Subsidence Calibration Stations
Figure 3-61 MCSim Projected Projects Surface Water Diversion Locations
Figure 3-62 Vertical Distribution of Projected Agricultural Pumping - Layer 1
Figure 3-63 Vertical Distribution of Projected Agricultural Pumping - Layer 2
Figure 3-64 Vertical Distribution of Projected Agricultural Pumping - Layer 3
Figure 3-65 Vertical Distribution of Projected Agricultural Pumping - Layer 4
Figure 3-66 Vertical Distribution of Projected Agricultural Pumping - Layer 5
Figure 3-67 Vertical Distribution of Projected Agricultural Pumping - Layer 6
Figure 3-68 Vertical Distribution of Projected Agricultural Pumping - Layer 7
Figure 3-69 Vertical Distribution of Projected Urban Pumping - Layer 1
Figure 3-70 Vertical Distribution of Projected Urban Pumping - Layer 2
Figure 3-71 Vertical Distribution of Projected Urban Pumping - Layer 3
Figure 3-72 Vertical Distribution of Projected Urban Pumping - Layer 4
Figure 3-73 Vertical Distribution of Projected Urban Pumping - Layer 5
Figure 3-74 Vertical Distribution of Projected Urban Pumping - Layer 6
Figure 3-75 Vertical Distribution of Projected Urban Pumping - Layer 7
Figure 3-76 Projected Initial Groundwater Heads - Layer 1
Figure 3-77 Projected Initial Groundwater Heads - Layer 2
Figure 3-78 Projected Initial Groundwater Heads - Layer 3
Figure 3-79 Projected Initial Groundwater Heads - Layer 4
Figure 3-80 Projected Initial Groundwater Heads - Layer 5
Figure 3-81 Projected Initial Groundwater Heads - Layer 6
Figure 3-82 Projected Initial Groundwater Heads - Layer 7
Figure 4-1 Histogram of Residual (Simulated minus Observed) Groundwater Elevations in MCSim_v2 for All Observations
Figure 4-2 Simulated vs. Observed Groundwater Elevations in MCSim_v2, By Layer
Figure 4-3 Average Residual Groundwater Elevation by Calibration Well
Figure 4-4 Average Residual Total Compaction by Subsidence Monitoring Station
Figure 4-5 Calibrated Horizontal Hydraulic Conductivity (Kh) - Layer 1

Figure 4-6 Calibrated Horizontal Hydraulic Conductivity (Kh) - Layer 2
Figure 4-7 Calibrated Horizontal Hydraulic Conductivity (Kh) - Layer 3
Figure 4-8 Calibrated Horizontal Hydraulic Conductivity (Kh) - Layer 4
Figure 4-9 Calibrated Horizontal Hydraulic Conductivity (Kh) - Layer 5
Figure 4-10 Calibrated Horizontal Hydraulic Conductivity (Kh) - Layer 6
Figure 4-11 Calibrated Horizontal Hydraulic Conductivity (Kh) - Layer 7
Figure 4-12 Calibrated Vertical Hydraulic Conductivity (Kv) - Layer 1
Figure 4-13 Calibrated Vertical Hydraulic Conductivity (Kv) - Layer 2 Aquitard
Figure 4-14 Calibrated Vertical Hydraulic Conductivity (Kv) - Layer 2
Figure 4-15 Calibrated Vertical Hydraulic Conductivity (Kv) - Layer 3 Aquitard
Figure 4-16 Calibrated Vertical Hydraulic Conductivity (Kv) - Layer 3
Figure 4-17 Calibrated Vertical Hydraulic Conductivity (Kv) - Layer 4 Aquitard
Figure 4-18 Calibrated Vertical Hydraulic Conductivity (Kv) - Layer 4
Figure 4-19 Calibrated Vertical Hydraulic Conductivity (Kv) - Layer 5
Figure 4-20 Calibrated Vertical Hydraulic Conductivity (Kv) - Layer 6
Figure 4-21 Calibrated Vertical Hydraulic Conductivity (Kv) - Layer 7
Figure 4-22 Calibrated Specific Yield (Sy) - Layer 1
Figure 4-23 Calibrated Specific Yield (Sy) - Layer 2
Figure 4-24 Calibrated Specific Yield (Sy) - Layer 3
Figure 4-25 Calibrated Specific Yield (Sy) - Layer 4
Figure 4-26 Calibrated Specific Yield (Sy) - Layer 5
Figure 4-27 Calibrated Specific Yield (Sy) - Layer 6
Figure 4-28 Calibrated Specific Yield (Sy) - Layer 7
Figure 4-29 Calibrated Specific Storage (SS) - Layer 1
Figure 4-30 Calibrated Specific Storage (SS) - Layer 2
Figure 4-31 Calibrated Specific Storage (SS) - Layer 3
Figure 4-32 Calibrated Specific Storage (SS) - Layer 4
Figure 4-33 Calibrated Specific Storage (SS) - Layer 5
Figure 4-34 Calibrated Specific Storage (SS) - Layer 6
Figure 4-35 Calibrated Specific Storage (SS) - Layer 7
Figure 4-36 Calibrated Inelastic Specific Storage (SCI) - Layer 1
Figure 4-37 Calibrated Inelastic Specific Storage (SCI) - Layer 2
Figure 4-38 Calibrated Inelastic Specific Storage (SCI) - Layer 3

Figure 4-39 Calibrated Inelastic Specific Storage (SCI) - Layer 4
Figure 4-40 Calibrated Inelastic Specific Storage (SCI) - Layer 5
Figure 4-41 Calibrated Inelastic Specific Storage (SCI) - Layer 6
Figure 4-42 Calibrated Inelastic Specific Storage (SCI) - the Layer 7
Figure 4-43 Calibrated Elastic Specific Storage (SCE) - Layer 1
Figure 4-44 Calibrated Elastic Specific Storage (SCE) - Layer 2
Figure 4-45 Calibrated Elastic Specific Storage (SCE) - Layer 3
Figure 4-46 Calibrated Elastic Specific Storage (SCE) - Layer 4
Figure 4-47 Calibrated Elastic Specific Storage (SCE) - Layer 5
Figure 4-48 Calibrated Elastic Specific Storage (SCE) - Layer 6
Figure 4-49 Calibrated Elastic Specific Storage (SCE) - Layer 7
Figure 4-50 Calibrated Interbed Vertical Hydraulic Conductivity - Layer 1
Figure 4-51 Calibrated Interbed Vertical Hydraulic Conductivity - Layer 2
Figure 4-52 Calibrated Interbed Vertical Hydraulic Conductivity - Layer 3
Figure 4-53 Calibrated Interbed Vertical Hydraulic Conductivity - Layer 4
Figure 4-54 Calibrated Interbed Vertical Hydraulic Conductivity - Layer 5
Figure 4-55 Calibrated Interbed Vertical Hydraulic Conductivity - Layer 6
Figure 4-56 Calibrated Interbed Vertical Hydraulic Conductivity - Layer 7
Figure 5-1 Composite Scaled Sensitivity of Simulated Groundwater Elevations to Model Parameter Values

APPENDICES

Appendix A Delivery Locations for Surface Water Diversions and Project Diversions
Appendix B Groundwater Elevation Calibration Hydrographs
Appendix C Subsidence Calibration Hydrographs
Appendix D Water Budget Results
- D.1 Chowchilla Subbasin Water Budget Results
  - D.1.a Chowchilla Water District GSA Water Budget Results
  - D.1.b Madera County - East GSA Water Budget Results
  - D.1.c Madera County - West GSA Water Budget Results
  - D.1.d Triangle T Water District GSA Water Budget Results
  - D.1.e Sierra Vista Mutual Water Company GSA Water Budget Results
- D.2 Madera Subbasin Water Budget Results
  - D.2.a City of Madera GSA Water Budget Results

D.2.b Madera County GSA Water Budget Results
D.2.c Madera Irrigation District GSA Water Budget Results
D.2.d Madera Water District GSA Water Budget Results
D.2.e Gravelly Ford Water District GSA Water Budget Results
D.2.f New Stone Water District GSA Water Budget Results
D.2.g Root Creek Water District GSA Water Budget Results

Appendix E Groundwater Elevation Hydrographs for RMS Wells
E.1 Chowchilla Subbasin RMS Groundwater Elevation Hydrographs
E.1.a Historical Scenario
E.1.b Projected with Projects Scenario
E.1.c Projected with Projects with Climate Change Scenario
E.1.d Projected (No Action) Scenario
E.1.e Projected (No Action) with Climate Change Scenario
E.2 Madera Subbasin RMS Groundwater Elevation Hydrographs
E.2.a Historical Scenario
E.2.b Projected with Projects Scenario
E.2.c Projected with Projects with Climate Change Scenario
E.2.d Projected (No Action) Scenario
E.2.e Projected (No Action) with Climate Change Scenario
E.2.f Sensitivity – Projected with Projects Scenario

Appendix F Subsidence Hydrographs for RMS Stations
F.1 Chowchilla Subbasin RMS Subsidence Hydrographs
F.1.a Historical Scenario
F.1.b Projected with Projects Scenario
F.1.c Projected with Projects with Climate Change Scenario
F.1.d Projected (No Action) Scenario
F.1.e Projected (No Action) with Climate Change Scenario
F.2 Madera Subbasin RMS Subsidence Hydrographs
F.2.a Historical Scenario
F.2.b Projected with Projects Scenario
F.2.c Projected with Projects with Climate Change Scenario
F.2.d Projected (No Action) Scenario
F.2.e Projected (No Action) with Climate Change Scenario
F.2.f Sensitivity – Projected with Projects Scenario

LIST OF ACRONYMS AND ABBREVIATIONS

Acronym	Meaning
3D	Three-Dimensional
AF	Acre-Feet
AN	Above Normal
BMP	Best Management Practice
BN	Below Normal
C	Critical
C2VSim	California Central Valley Groundwater-Surface Water Simulation Model
C2VSim-CG	California Central Valley Groundwater-Surface Water Simulation Model – Coarse Grid
C2VSim-FG Beta2	California Central Valley Groundwater-Surface Water Simulation Model – Fine Grid
CDEC	California Data Exchange Center
CIMIS	California Irrigation Management Information System
CVHM	Central Valley Hydrologic Model
CVP	Central Valley Project
CWD	Chowchilla Water District
D	Dry
DWR	California Department of Water Resources
ET	Evapotranspiration
ET_a	Actual ET
ET_c	Crop ET
ET_o	Grass Reference ET
ET_r	Alfalfa Reference ET
ET_{ref}	Reference Crop Evapotranspiration
eWRIMS	SWRCB Electronic Water Rights Information Management System
ft/d	Feet Per Day
GDE	Groundwater Dependent Ecosystem
GFWD	Gravelly Ford Water District
GSA	Groundwater Sustainability Agency
GSP	Groundwater Sustainability Plan
GWS	Groundwater System
HCM	Hydrogeologic Conceptual Model
IDC	Integrated Water Flow Model Demand Calculator
IWFM	Integrated Water Flow Model
Kh	Horizontal Hydraulic Conductivity
Kv	Vertical Hydraulic Conductivity
MA	Management Area
MC	Madera County
MCSim	Madera-Chowchilla Groundwater-Surface Water Simulation Model

Acronym	Meaning
MID	Madera Irrigation District
Model	Numerical Groundwater Flow Model
MWD	Madera Water District
NOAA NCEI	National Oceanic and Atmospheric Administration National Centers for Environmental Information
NRCS	United States Department of Agriculture Natural Resources Conservation Service
PM	Penman-Monteith
PRISM	Parameter Elevation Regression on Independent Slopes Model
RCWD	Root Creek Water District
SEBAL	Surface Energy Balance Algorithm for Land
SGMA	Sustainable Groundwater Management Act of 2014
SJRRP	San Joaquin River Restoration Program
SLDMWA	San Luis & Delta-Mendota Water Authority
SS	Specific Storage
SVMWC	Sierra Vista Mutual Water Company
SWP	State Water Project
SWRCB	State Water Resources Control Board
SWS	Surface Water System
Sy	Specific Yield
T-ProGS	Transition Probability Geostatistical Software
TTWD	Triangle T Water District
USACE	United States Army Corps of Engineers
USBR	United States Bureau of Reclamation
USGS	United States Geological Survey
W	Wet
WCR	Well Completion Report

1. INTRODUCTION

This report documents the first model update and re-calibration of the Madera-Chowchilla Groundwater-Surface Water Simulation Model (MCSim), a numerical groundwater flow model developed for the Madera and Chowchilla Subbasin areas to support preparation of Groundwater Sustainability Plans (GSPs) for both subbasins along with other future potential groundwater management and planning needs. This report includes a summary of the model platform, data sources, model development and calibration, and calibration results.

1.1. Background

To support preparation of GSPs for the Madera and Chowchilla Subbasins, four Groundwater Sustainability Agencies (GSAs) in the Madera Subbasin (Madera County, Madera Irrigation District, Madera Water District and City of Madera) and all GSAs in the Chowchilla Subbasin (Chowchilla Water District, Madera County, Triangle T Water District, and Sierra Vista Mutual Water Company) elected to pursue development of a numerical groundwater flow model to be able to satisfy GSP regulations requiring use of a numerical groundwater model, or equally effective approach, to evaluate projected water budget conditions and potential impacts to groundwater conditions and users from the GSP implementation. The development of the MCSim is intended to support groundwater resources management activities associated with GSP development and implementation. MCSim utilizes data and the hydrogeologic conceptualization that are presented and described in the GSPs for the Madera and Chowchilla Subbasins and also incorporates data assembled as part of Data Collection and Analysis Reports prepared for both subbasins (DE & LSCE, 2017a; and DE & LSCE, 2017b) to improve the understanding of hydrologic processes and their relationship to key sustainability metrics within the Chowchilla and Madera Subbasins. MCSim provides a platform to evaluate potential outcomes and impacts from future management actions, projects, and adaptive management strategies through predictive modeling scenarios.

1.2. Objectives and Approach

Numerical groundwater models are structured tools developed to represent the physical basin setting and simulate groundwater flow processes by integrating a multitude of data (e.g., lithology, groundwater levels, surface water features, groundwater pumping, etc.) that compose the conceptualization of the natural geologic and hydrogeologic environment. MCSim was developed in a manner consistent with the Modeling Best Management Practices (BMP) guidance document prepared by the California Department of Water Resources (DWR) (DWR, 2016). The objective of MCSim is to simulate hydrologic processes and effectively estimate historical and projected future hydrologic conditions in the Chowchilla and Madera Subbasins related to groundwater dependent ecosystems (GDEs) and SGMA sustainability indicators relevant to the Chowchilla and Madera Subbasins including:

1. Lowering of Groundwater Levels
2. Reduction of Groundwater Storage
3. Depletion of Interconnected Surface Water

The development of MCSim involved starting with and evaluating the beta version (released 5/1/2018) of DWR's fine-grid version of the California C[entral Valley Groundwater-Surface Water Flow Model (C2VSim-

FG Beta2) and eventually carving out a local model domain and conducting local refinements to the model structure (e.g., nodes, elements) and modifying or replacing inputs as needed to sufficiently and accurately simulate local conditions in the Madera and Chowchilla Subbasin areas within the model domain. C2VSim-FG Beta2 utilizes the most current version of the Integrated Water Flow Model (IWFM) code available at the time of the MCSim development. IWFM and C2VSim-FG Beta2 were selected as the modeling platform due to the versatility in simulating crop-water demands in the predominantly agricultural setting of the subbasins, groundwater surface-water interaction, the existing hydrologic inputs existing in the model for the time period through the end of water year 2015, and the ability to customize the existing C2VSim-FG Beta2 model to be more representative of local conditions in the area of the Madera and Chowchilla Subbasins. MCSim was refined from C2VSim-FG Beta2 and calibrated to a diverse set of available historical data using industry standard techniques. The version of the IWFM model code available at the time of initial MCSim development did not have the capability of directly simulating land subsidence or solute transport (groundwater quality), which are two additional sustainability indicators relevant to the Madera and Chowchilla Subbasins.

As part of the first Plan Amendment to the Madera Subbasin Joint GSP, MCSim was updated utilizing additional data gathered during GSP implementation and re-calibrated. The updated model, referred herein as MCSim_v2, utilizes the most up to date version of the IWFM code available at the time and now includes simulation of land subsidence. MCSim_v2 will be used to further the understanding of hydrologic processes in the Subbasins and evaluate and refine Sustainable Management Criteria (SMC) as needed.

1.3. Report Organization

This report is organized into the following sections:

- Section 2: Model Code and Platform
- Section 3: Groundwater Flow Model Development
- Section 4: Groundwater Flow Model Results
- Section 5: Sensitivity Analysis and Model Uncertainty
- Section 6: Conclusions and Recommendations
- Section 7: References

2. MODEL CODE AND PLATFORM

The modeling code and platform utilized for MCSim are described below. As required by GSP regulations, the selected model code is in the public domain. The decision to select the model codes for the MCSim was based on providing Madera County with a modeling tool that can be used for GSP development with sufficient representation of local conditions, while utilizing to the extent possible, previous modeling tools available, including regional models. With this objective in mind, the model tools and platforms described below were determined to be most suitable for adaptation for use in GSP analyses.

2.1. Integrated Water Flow Model

IWFM is a quasi-three-dimensional finite element modeling software that simulates groundwater, surface water, groundwater-surface water interaction, as well as other components of the hydrologic system (Dogrul et al., 2017). MCSim was developed using the IWFM Version 2015 (IWFM-2015) code, which couples a three-dimensional finite element groundwater simulation process with one-dimensional land surface, river, lake, unsaturated zone, and small-stream watershed processes (Brush et al., 2016). A key feature of IWFM-2015 is its capability to simulate the water demand as a function of different land use and crop types and compare it to the historical or projected amount of water supply (Dogrul et al., 2017). IWFM uses a model layering structure in which model layers represent aquifer zones that are assigned aquifer properties relating to both horizontal and vertical groundwater movement (e.g., horizontal and vertical hydraulic conductivity) and storage characteristics (e.g., specific yield, specific storage) with the option to associate an aquitard to each layer, although represented aquitards are assigned a more limited set of properties relating primarily to their role in vertical flow (e.g., vertical hydraulic conductivity).

MCSim_v2 utilizes version IWFM-2015.2.1443 of the IWFM-2015 source code. The IWFM-2015 source code and additional information and documentation relating to the IWFM-2015 code is available from DWR at the link below:

https://data.cnra.ca.gov/dataset/iwfm-integrated-water-flow-model/resource/311462d8-6cb5-4259-bd2c-c1e36a5475be

2.1.1. IWFM Demand Calculator

IWFM includes a stand-alone Integrated Water Flow Model Demand Calculator (IDC) that calculates water demands. Agricultural water demands are calculated in the IDC based on climate, land use, soil properties, and irrigation method whereas urban demands are calculated based on population and per-capita water use. MCSim utilizes IDC to simulate root zone processes and water demands. DWR developed and maintains the physically based IDC version 4.11.

2.2. C2VSim-Fine Grid

The C2VSim-FG Beta2 model utilizes the IWFM-2015 code and represents a refinement of the previous C2VSim-Coarse Grid (C2VSim-CG) model. Refinements made in the development of C2VSim-FG Beta2 include a finer horizontal discretization, an updated aquifer layering scheme, updated precipitation data, and an extended simulation period through water year 2015 (DWR, 2018). C2VSim-CG had an average element size of approximately 15 square miles, and the average element size for C2VSim-FG Beta2 was about 0.6 square miles. The C2VSim-FG Beta2 version available from DWR at the time of the initiation of modeling efforts to support GSP preparation in the Madera and Chowchilla, was not a calibrated model version. As of the date of the initial version of MCSim (August 2019), a calibrated version of C2VSim-FG was not available.

3. GROUNDWATER FLOW MODEL DEVELOPMENT

This section describes the spatial and temporal (time-series) structure of the model and the input data that was utilized for model development. The initial model development process utilized data and information that was available at the time of initial model development and is described in greater detail in the GSP and previous Data Collection and Analysis reports (DE & LSCE, 2017a for Chowchilla, and DE & LSCE, 2017b for Madera). The development of the updated version of the model (MCSim_v2) included additional data that had been developed and collected during GSP implementation.

3.1. MCSim_v2 – Historical Model

The initial version of the MCSim historical model simulated the period from October 1985 through September 2015 at a monthly time step, with a calibration period of October 1988 through September 2015. This simulation period was extended and calibrated through September 2023 as part of the MCSim_v2 update. The MCSim_v2 historical model simulates the period from October 1985 through September 2023 at a monthly time step, with a calibration period of October 1988 through September 2023. Annual model time periods are based on water years defined as October 1 through September 30. The historical calibration model period extends from water year 1989 through 2023. Water years 1986 through 1988 are not included as part of the historical calibration period but are simulated to allow the model some time to adjust to the specified initial conditions and spin-up prior to the calibration period starting in October 1988.

3.1.1. Model Configuration

The MCSim grid was carved out of the regional C2VSim-FG Beta2 model domain. While MCSim focuses on the Chowchilla and Madera Subbasins, the model domain was extended outside the two subbasins to incorporate a buffer zone an including area within the Merced, Delta-Mendota, and Kings Subbasins. The extent of the buffer zone was determined, using the C2VSim-FG Beta2 regional model, by simulating pumping wells along the boundary of the Chowchilla and Madera Subbasins to determine the distance to a one-foot drawdown of groundwater levels. This MCSim domain was delineated with consideration of these drawdown distances (typically 5-10 miles from Chowchilla and Madera Subbasin boundaries). The MCSim domain, shown in **Figure 3-1**, encompasses a total of 847,624 acres. All C2VSim-FG Beta2 model features (e.g., nodes, elements, streams, layers) within this domain were initially included in MCSim with subsequent modifications and refinements made within MCSim to these model components, as described in this report.

Nodes and Elements

The MCSim grid contains 2,458 nodes and 2,632 elements (**Figure 3-1**). The X-Y coordinates for node locations are presented in the UTM Zone 10N, NAD83 (meters) projected coordinate system. While the number of nodes and elements within the MCSim domain were not altered from C2VSim-FG Beta2, the locations of some nodes and elements were modified to more accurately align with subbasin boundaries and streams. **Figure 3-2** highlights the modified nodes and elements in MCSim. **Table 3-1** presents MCSim grid characteristics.

Table 3-1. MCSim Grid Characteristics	
Nodes	2,458
Elements	2,632
Average Element Size (acres)	322
Minimum Element Size (acres)	10
Maximum Element Size (acres)	1,486
Subregions	16
Aquifer Layers	7
Aquitard Layers	3

Model Subregions

Model elements are grouped into subregions to assist in the summarization of model results and development of water budgets. MCSim includes 16 subregions (listed in **Table 3-2**). Subregions were delineated by subbasin and also by GSA within the Chowchilla and Madera Subbasins. While subregions are used as the basis for summarizing model results, the model simulates hydrologic processes and conditions at the resolution of elements or nodes. **Figure 3-3** shows the delineation of subregions included within MCSim.

Table 3-2. Model Subregions within MCSim

Subregion	Subbasin	GSA
1	Chowchilla	Chowchilla Water District
2	Chowchilla	Madera County - East
3	Chowchilla	Madera County - West
4	Chowchilla	Sierra Vista MWC - Madera County
5	Chowchilla	Sierra Vista MWC - Merced County
6	Chowchilla	Triangle T Water District
7	Madera	City of Madera
8	Madera	Madera County
9	Madera	Gravelly Ford Water District
10	Madera	Madera Irrigation District
11	Madera	Madera Water District
12	Madera	New Stone Water District
13	Madera	Root Creek Water District
14	Merced	
15	Delta-Mendota	
16	Kings	

Streams

MCSim includes 35 stream reaches composed of 657 stream nodes. Streams that were adapted from existing streams simulated in C2VSim-FG Beta2 include Chowchilla River, Deadman's Creek, Eastside Bypass/Chowchilla Bypass, Fresno River, Fresno Slough, and San Joaquin River. Some of the stream nodes were shifted to better align with the actual stream configuration. Streams added to MCSim that were not included in C2VSim-FG Beta2 include Ash Slough, Berenda Creek, Berenda Slough, Cottonwood Creek, Dry Creek, Dutchman Creek, and Madera Canal. The stream network included in MCSim is shown in **Figure 34**.

Model Layers

A major modification in the adaptation of the C2VSim-FG Beta2 model for MCSim purposes was to refine the representation of the aquifer system through model layering. Within the MCSim domain, C2VSim-FG Beta2 delineates three aquifer layers and one aquitard layer; MCSim was refined to include seven aquifer layers and three aquitard layers corresponding with key hydrogeologic features identified in the Hydrogeologic Conceptual Model (HCM) for the subbasins. The aquifer system within MCSim is broken down into the Upper Aquifer (layers 1 through 3), the Lower Aquifer (layers 4 through 6), and a buffer layer (layer 7). The E-Clay unit (Corcoran Clay) of the Tulare Formation separates the Upper and Lower Aquifers, where present. Other less extensive clay units (e.g., A-Clay, C-Clay) of the Tulare Formation also exist in the area and were explicitly incorporated into the model as discrete model features (aquitard layers) or implicitly through assignment of hydraulic properties based on sediment texture as described below in **section 3.1.4.1**. **Table 3-3** presents the average thickness of each model layer in MCSim_v2.

The Upper Aquifer is generally unconfined, except where the A-Clay and/or C-Clay are present. The top of the aquifer system is defined by the land surface. In general, Layer 1 extends approximately 50 feet below ground surface, or to the top of the A-Clay, where present. The A-Clay is included as the Layer 2 aquitard overlying the Layer 2 aquifer. The Layer 2 aquifer extends from the base of the A-Clay, where present, to the top of the C-Clay (or other comparable shallow clays), where present. The C-Clay is included as the Layer 3 aquitard overlying the Layer 3 aquifer. The Layer 3 aquifer extends from the base of the C-Clay, where present, to the top of the E-Clay (Corcoran Clay), where present. Where aquitard(s) are not present in the Upper Aquifer, the remaining Upper Aquifer thickness below Layer 1 is divided evenly between Layers 2 and 3.

The Corcoran Clay is modeled as the Layer 4 aquitard. This aquitard layer separates the Upper Aquifer from the Lower Aquifer. The depth, thickness, and extent of the Corcoran Clay were refined as part of the MCSim_v2 update. During drilling of nested monitoring wells as part of the GSP implementation, the Corcoran Clay was observed in well CSB09, located outside of the Page (1986) extent. As a result, an effort was made to refine the extent of the Corcoran Clay within the Chowchilla and Madera subbasins.

In order to refine the Corcoran Clay extent, well completion reports (WCRs) in the surrounding area were reviewed for possible Corcoran Clay occurrences. A review of the CSB09 WCR and e-log shows the presence of the Corcoran Clay occurring from 135 to 160 feet below ground surface. Additionally, Mitten et al. (1970) describes the Corcoran Clay in the Madera area as “mostly clay, silty clay, or silt” and “gray, greenish gray, or bluish gray” and “plastic to friable.” WCRs were reviewed for clays described similarly to the description provided by Mitten et al. (1970) and within a similar depth zone (+/- approximately 50 feet) of the CSB09 observance.

WCRs with a possible Corcoran Clay observance were ranked based on the confidence of the WCR. This ranking was based on professional judgment, and included evaluation of the completeness of the WCR, the level of detail included in the geologic logging, and the drilling method used. WCRs that were ranked as High and Medium confidence were selected to refine the extent, depth, and thickness of the Corcoran Clay.

The WCRs identified as part of the refined Corcoran Clay extent were plotted in ArcGIS and surfaces were interpolated between these points to represent the refined extent, depth, and thickness of the Corcoran Clay.

The refined extent depth, and thickness of the Corcoran Clay was implemented within the MCSim_v2 model. Where the Corcoran Clay is not present, the below ground surface to the nearest occurrence of the Corcoran Clay was used to delineate the Upper and Lower aquifers.

The Lower Aquifer is confined where the Corcoran Clay is present and is considered semi-confined outside of the Corcoran Clay extent. The thicknesses of the Layer 4 aquifer and Layers 5, and 6 are delineated as equal percentages (approximately 33 percent) of the total Lower Aquifer thickness to the base of freshwater. The base of the Lower Aquifer was generally kept consistent with the base of the Lower Aquifer in C2VSim-FG Beta2 model, but some modifications were made in MCSim to better align the base of the Lower Aquifer with the base of freshwater (Page, 1973).

Layer 7 extends from the base of freshwater to the base of continental deposits (Williamson et al., 1989) and is considered a buffer layer. Though included in MCSim, Layer 7, although simulated in the model, is treated as a low-conductivity zone below the base of freshwater and below the zone of any groundwater pumping. Layer 7 was preserved in MCSim, with an overall model thickness equal to that of C2VSim-FG Beta2.

Table 3-3. Average Thickness of MCSim_v2 Layers

Model Layers	Average Thickness (feet)
Layer 1	49
A-Clay (where present)	15
Layer 2	99
C-Clay (where present)	13
Layer 3	90
Corcoran Clay (where present)	49
Layer 4	249
Layer 5	249
Layer 6	248
Layer 7	1,863

Elevations and thicknesses of MCSim aquifer and aquitard layers are shown in **Figures 3-5** through **3-25**.

3.1.2. Land Surface System

The IWFM Land Surface Process, which includes the IDC, calculates a water budget for four land use categories: non-ponded agricultural crops, ponded agricultural crops (i.e., rice), native and riparian vegetation, and urban areas. The Land Surface Process calculates water demand at the surface, allocates water to meet demands, and routes excess water through the root zone (Brush et al., 2016). The development of land surface system input files to simulate the Land Surface Process is explained in this section.

During initial MCSim development, a daily IDC application was first developed to calculate historical crop ET (ETc) and other water budget components in the Land Surface Process. A daily root zone water budget is a generally accepted and widely used method for land surface water budget development (ASCE, 2016 and ASABE, 2007). The daily IDC application was then adapted and calibrated to create the monthly IDC application within MCSim. The monthly IDC application within MCSim calculates various water budget components, including:

- ET of applied water
- ET of precipitation
- Infiltration of applied water
- Infiltration of precipitation
- Runoff of precipitation
- Change in root zone storage

Certain key MCSim inputs related to the Land Surface System are described below. Additional details regarding the development of the daily IDC application, including major inputs, are provided in GSP Appendix 2.F.

Precipitation

Monthly precipitation time series data was extracted from C2VSim-FG Beta2 (for water years 1922 through 2015) or directly from the Parameter Elevation Regression on Independent Slopes Model (PRISM; for water years 2016 through 2023), which was developed by the PRISM Climate Group at Oregon State University (PRISM Climate Group, 2024). Precipitation data within C2VSim-FG Beta2 is also based on PRISM data. PRISM quantifies spatial precipitation estimates, among other climate parameters, at a spatial resolution of four kilometers based on available weather station data and modeled spatial relationships with topography and other factors influencing weather and climate.

Monthly precipitation rates were downloaded for the coordinates nearest the centroid of each element and small watershed in MCSim. The monthly data sets were quality controlled and provided as model inputs for the nearest corresponding element or small watershed.

Evapotranspiration

Monthly evapotranspiration (ET) time series data was developed through the following processes, depending on available data during the historical period:

- For water years 1973 through 2015: ET rates were developed based on available weather data, reference crop ET (ET_{ref}), and crop coefficients.
- For water years 2016 through 2023: ET rates were developed using satellite-based remote sensing analyses and data available from OpenET.

These data sources and processes are described below. ET rates were developed for individual crop types and were refined based on available observation data, to the extent available.

Weather Data

Weather data was obtained from the California Irrigation Management Information System (CIMIS) and National Oceanic and Atmospheric Administration National Centers for Environmental Information (NOAA NCEI). **Table 3-4** lists the stations and periods of record used for each station through water year 2015. ET rates after water year 2015 are based on OpenET data, described below.

Table 3-4. Weather Data Time Series Summary

Weather Station	Station Type	Start Date	End Date	Comment
Fresno State	CIMIS	Oct. 2, 1988	May 12, 1998	Used before Madera CIMIS station was installed.
Madera	CIMIS	May 13, 1998	Apr. 2, 2013	Moved eastward 2 miles in 2013 and renamed “Madera II.”
Madera II	CIMIS	Apr. 3, 2013	Dec. 31, 2015	
Madera	NOAA NCEI	Jan. 1, 1928	Dec. 31, 2017	Used for developing ET_{ref} timeseries for water budget period when data gaps occurred, and before CIMIS station data was available.

Daily time series data was evaluated following the quality control procedures described in GSP Appendix 2.F. to develop daily reference crop evapotranspiration (ET_{ref}) for both the Chowchilla and Madera Subbasins during the historical and projected water budget periods.

Reference Evapotranspiration Development

Daily ET_{ref} was determined from available weather data (described above) following the widely accepted standardized Penman-Monteith (PM) method, as described by the ASCE Task Committee Report on the Standardized Reference Evapotranspiration Equation (ASCE-EWRI, 2005). The Task Committee Report standardizes the ASCE PM method for application to a full-cover alfalfa reference (ET_r) and to a clipped cool season grass reference (ET_o). ET_o is widely used throughout California and was selected as ET_{ref} for this application. Daily ET_o values were calculated and used to develop ET inputs for simulating crop consumptive use requirements through water year 2015. ET rates after water year 2015 are based on OpenET data, described below.

ET Development

Historical ET through water year 2015 was quantified for each land use in MCSim using the widely accepted reference ET-crop coefficient method (ASCE, 2016). In this method, ET_o is adjusted to estimate ET of other crops (ET_c) using a crop coefficient unique to the individual crop type, growth characteristics, health, and other local conditions. Crop coefficients for the MCSim domain were derived from actual ET (ET_a) estimated by the Surface Energy Balance Algorithm for Land (SEBAL) from available data in 2009. Remotely sensed energy balance ET results account for soil salinity, deficit irrigation, disease, poor plant stands, and other stress factors that affect crop ET. Studies by Bastiaanssen et al. (2005), Allen et al. (2007 and 2011), Thoreson et al. (2009) and others have found that when performed by an expert analyst, seasonal ET_a estimates produced by SEBAL are within plus or minus five percent of actual crop ET. Historical ET was computed through water year 2015 using the quality controlled ET_{ref} (described above) and these local, remote sensing derived crop coefficients.

For water years 2016 through 2023, ET inputs were developed for all land uses in MCSim using satellite-based remote sensing analyses available from OpenET. OpenET is a multi-agency web-based GIS utility that quantifies ET over time with a spatial resolution of 30 meters (m) x 30 m, or approximately 0.22 acres (OpenET Team, 2024). While OpenET is a new utility, the underlying methodologies to quantify ET apply a variety of well-established modeling approaches that are widely used in government and research applications. The OpenET modeling approaches are also similar to the SEBAL approach used to quantify ET through water year 2015 (described above). OpenET information was summarized from monthly raster coverages of the Chowchilla and Madera Subbasins in 2016 through 2023. ET inputs were then quantified on a monthly timestep as the average ET summarized for each land use in the MCSim domain (see below for information on how land use inputs were developed). ET inputs updated with OpenET information were compared with ET inputs estimated following the process used through water year 2015 to ensure their general consistency (within 5% difference for the primary irrigated agricultural crops in MCSim).

For all years, IDC parsed these ET estimates into the ET of applied water and ET of precipitation estimates used in the Chowchilla Subbasin and Madera Subbasin water budgets.

Land Use

Land use areas in the Chowchilla and Madera Subbasins were identified using the most recent and reliable spatial land use data in the region, depending on the time period. Data sources include:

- DWR county land use surveys for Madera County (1995, 2001, and 2011) and Merced County (1995, 2002, and 2012)
- Statewide crop mapping, available from the California Department of Water Resources through analyses by LandIQ (DWR) (DWR, 2024)
- CropScape Cropland Data Layer coverage, available from the United States Department of Agriculture (USDA, 2024).

For the historical period through 2015, land use areas were developed primarily from DWR county land use surveys statewide crop mapping in 2014, following the processes described in GSP Appendix 2.A.

For water years 2016 through 2023, land use areas were developed from DWR statewide crop mapping data and USDA CropScape data. Land use data from these sources were compiled into 30 m x 30 m annual coverages of the Chowchilla and Madera Subbasins. To prepare the MCSim inputs, DWR statewide crop mapping data (which includes extensive ground-truthing review of results) was preferentially used to identify agricultural land (including irrigated and non-irrigated lands) and urban areas, and then USDA CropScape data was utilized to back-fill gaps of non-irrigated, idle, and non-developed land. Local refinements were also applied, as needed, to account for local land use information, such as district crop reports. Comparisons were made to evaluate the consistency of the datasets with earlier land uses analyses through 2015 and found generally good correspondence for the major land use classes found in the Subbasin.

In addition to their application as MCSim inputs, land use areas were used together with ET-related information to develop crop coefficients and ET inputs for different land uses in MCSim (described above).

3.1.3. Surface Water System

The IWFM Surface Water System Process calculates a water budget along each stream reach between inflows and outflows, including stream-groundwater interactions (Brush et al., 2016). Time series inputs were developed to simulate Surface Water System processes during the historical model calibration period beginning October 1988. A steady-state average was used during earlier years of the MCSim simulation period to allow the model some time to adjust to the specified initial conditions and spin-up during water years 1985-1988, prior to the calibration period. Additional detail on the development of the Surface Water System model inputs is included in GSP Appendix 2.F.

Stream Characteristics

Stream bed parameters were taken from C2VSim-FG Beta2 for those stream nodes extracted from the C2VSim-FG Beta2 regional model. For additional stream nodes in MCSim, stream bed parameters were developed through review of soil properties and stream characteristics. Stream bed parameters, particularly stream bed conductivity and wetted perimeter, were further refined during the calibration process.

Inflows

Surface water inflows into the model domain are specified in MCSim for 10 stream reaches. Stream inflow locations are shown in **Figure 3-26**. Deadman’s Creek inflows were adapted from C2VSim-FG Beta2 inflow data. Fresno Slough inflows were generated in C2VSim-FG Beta2 by placing a stream flow hydrograph at the MCSim inflow node and using the resulting time series data for inflows to MCSim. Berenda Creek, Cottonwood Creek, Dry Creek, and Dutchman Creek inflows were based on available district data, including Madera Irrigation District (MID) Recorder data. and Chowchilla Water District (CWD) records. Chowchilla River, Fresno River, Madera Canal, and San Joaquin River inflows were based off of available records from the United States Army Corps of Engineers (USACE), United States Geological Survey (USGS) gage data, and district data, where applicable. More information regarding the development of surface inflow volumes is presented in **Table 3-5**.

Table 3-5. Summary of Historical Surface Water Inflows Development		
Waterway	**Calculation/Estimation Technique**	**Information Sources**
Berenda Creek	Calculated from MID recorder measurements adjusted upstream to the subbasin boundary for estimated seepage and evaporation	MID Recorder 13, USDA Natural Resources Conservation Service (NRCS) soil survey, Fresno State/Madera/Madera II CIMIS Stations
Chowchilla River	Reported Buchanan Dam irrigation and flood releases	United States Army Corps of Engineers (USACE) records, CWD records
Cottonwood Creek	Calculated from MID recorder measurements adjusted upstream to the subbasin boundary for estimated seepage and evaporation	MID Recorder 14, NRCS soil survey, Fresno State/Madera/Madera II CIMIS Stations
Deadman's Creek	n/a	From C2VSim-FG Beta2
Dry Creek	Estimated as equal to Berenda Creek recorder measurements adjusted upstream to the subbasin boundary for estimated seepage and evaporation	MID Recorder 13, NRCS soil survey, Fresno State/Madera/Madera II CIMIS Stations
Dutchman Creek	Estimated as equal to Received Legrand water reported by CWD	CWD monthly water supply reports
Fresno River	Estimated as equal to USGS measurement site along Fresno River below Hidden Dam	USGS Site 11258000 (FRESNO R BL HIDDEN DAM NR DAULTON CA)
Fresno Slough	Extracted streamflow hydrograph at inflow point from C2VSim-FG Beta2 regional model	From C2VSim-FG Beta2
Madera Canal	Estimated as equal to USGS measurement site along Madera Canal near Friant	USGS Site 11249500 (MADERA CN A FRIANT CA)
San Joaquin River	Estimated as equal to USGS measurement site along San Joaquin River below Friant Dam	USGS Site 11251000 (SAN JOAQUIN R BL FRIANT CA)

Surface Water Diversions and Deliveries

Surface water diversions and deliveries are simulated in the model as diversions from a stream node with an assigned delivery destination (element group). A total of 77 surface water diversions are included in the MCSim_v2 historical model, with 18 diversions adapted from C2VSim-FG Beta2 (primarily outside the Chowchilla and Madera Subbasins) and the remaining diversions added to MCSim. Diversions added to MCSim are used primarily to simulate agricultural diversions to districts and agricultural water users, riparian diversions to water users, and recharge efforts through water year 2023. Diversion locations are shown in **Figure 3-27**. Diversion volumes adapted from C2VSim-FG Beta2 were adjusted fractionally based on the percentage of the original C2VSim-FG Beta2 delivery location included within the MCSim domain. These diversions occur primarily outside of the Chowchilla and Madera Subbasins, but within the MCSim domain. Diversion volumes for the additional MCSim diversions were based on available data, including diversions reported from the United States Bureau of Reclamation (USBR), the State Water Resources Control Board (SWRCB), local district and GSA data sources. More information regarding the development of diversion volumes is presented in **Table 3-6**.

Losses associated with surface water deliveries are defined as fractions of each surface water diversion within MCSim and remain constant throughout the simulation period. Recoverable losses occur as seepage of water from the delivery system prior to arrival at the delivery destination. Accordingly, the fraction of recoverable loss represents water that recharges to the GWS from conveyance losses associated with surface water deliveries. Non-recoverable losses occur from evaporation associated with surface water deliveries. The fraction of non-recoverable loss represents water that does not recharge and occurs as an output from the SWS. The remaining percentage of surface water diversions (after subtraction of recoverable and non-recoverable losses) is considered the delivery fraction. The initial loss fractions used in the model were determined based on analyses of the average conveyance losses and evaporation associated with surface water deliveries within each GSA, as calculated in the SWS water budgets (GSP Appendix 2.F) performed outside the groundwater model. Fractional losses and deliveries were further refined during the calibration process.

In MCSim, surface water diversions are assigned to groups of elements for water delivery and recharge. Surface water delivery and recharge element groups were either adapted from C2VSim-FG Beta2 inputs or were defined to represent areas where surface water deliveries and/or recharge is known or expected to occur. The configuration and inputs associated with delivery and recharge groups adapted from C2VSim-FG Beta2 were not altered in MCSim. For refined surface water diversions and deliveries added into MCSim, delivery and recharge volumes were assigned to the entirety of the GSA receiving water, unless more specific data was available. Delivery groups for additional MCSim diversions were refined in CWD and MID based on delivery zone data provided for each GSA. Recharge groups were refined in CWD, GFWD, and MID based on locations of delivery conveyance systems. If a canal was present in a given element, recharge water was assigned to that element. Delivery locations for surface water deliveries are shown in **Appendix A**, **Figures A-1 through A-77** of this model report.

Table 3-6. Summary of Historical Surface Water Diversions Development

Diversion Number	Detailed Component	Calculation/Estimation Technique	Information Sources
DIV_1 - DIV_4, DIV_6 - DIV_19	C2VSim-FG Beta2 diversions data file	n/a	From C2VSim-FG Beta2
DIV_5	Diversions to RCWD	Reported by MID	MID delivery database

Table 3-6. Summary of Historical Surface Water Diversions Development

Diversion Number	Detailed Component	Calculation/Estimation Technique	Information Sources
DIV_20 - DIV_23	Chowchilla River and Berenda Slough Diversions to CWD	Sum of Buchanan Dam and Madera Canal irrigation releases diverted by CWD, plus additional flood releases diverted to meet reported CWD deliveries; apportioned to each waterway based on CWD delivery records, GIS analysis, and historical operations (18% from Chowchilla River, 82% from Berenda Slough)	USBR Central Valley Project (CVP) delivery records, USACE records, CWD delivery database, CWD monthly water supply reports
DIV_24	Flood Diversions to CWD for managed recharge	Reported deliveries during flood releases prior to the start of the irrigation season	CWD delivery database
DIV_25 - DIV_28	Diversions to GFWD	Reported by GFWD	Gravelly Ford WD reports
DIV_29, DIV_66	Dry Creek Diversions to MWD	Measured by MID, MWD	MID delivery database, MWD delivery records
DIV_30	Fresno River Diversions to MID	Closure of Fresno River Balance	USGS Site 11258000 (FRESNO R BL HIDDEN DAM NR DAULTON CA), USACE data, USBR CVP delivery records, IDC root zone water budget, NRCS soils characteristics, CIMIS precipitation data, MID recorders, and riparian deliveries.
DIV_31 - DIV_43	Madera Canal Diversions to MID	Reported in USBR CVP delivery records at Madera Canal Miles 6.1, 13.06, 22.23, 22.95, 24.1, 26.8, 27.5, 28.38, 28.39, 28.64, 30.4, 30.5, 32.2	USBR CVP delivery records
DIV_44 - DIV_59	Riparian Deliveries to MID, MC, and RCWD	Reported by historical water rights and statements of diversion, estimated from streamflow and crop ET when records not available	SWRCB Electronic Water Rights Information Management System (eWRIMS), Holding Contracts

Table 3-6. Summary of Historical Surface Water Diversions Development			
Diversion Number	**Detailed Component**	**Calculation/Estimation Technique**	**Information Sources**
DIV_60 - DIV_65	Water Rights Deliveries[1]	Reported riparian/appropriative/prescriptive water rights deliveries during flood releases and/or natural flood flows; estimated from streamflow and crop ET when records not available	CWD delivery records, eWRIMS, Fresno State/Madera/Madera II CIMIS Stations, land use data
DIV_67 - DIV_68	Purchased Water and Managed Recharge in TTWD	Reported by TTWD	TTWD reports
DIV_69 - DIV_77	Managed Recharge and Surface Water Diversions in MC, MID, and SVMWC	Reported diversions for recharge projects and additional surface water diversions (e.g., under the provisions of Executive Order N-4-23 in 2023)	District and county reports

[1] Includes riparian, appropriative, and prescriptive water rights deliveries during flood releases and/or natural flood flows along subbasin waterways.

Surface Water Bypasses

Surface water bypasses defined in the model simulate the movement of surface water between different waterways based on specified volumes or fractions. These bypasses can be used to simulate flood bypasses or water system operations. A total of eight surface water bypasses were included in MCSim. Two bypasses associated with moving surface water flows from the San Joaquin River into the Chowchilla Bypass and moving flows from the Chowchilla River into the Eastside Bypass were initially adapted from C2VSim-FG Beta2. Six additional bypasses were added to MCSim as a means to simulate the operations of MID and CWD surface water distribution systems. More information regarding the development of bypass volumes is presented in **Table 3-7**. Bypass locations are shown in **Figure 3-28**.

Table 3-7. Summary of Historical Surface Water Bypasses Develop			
Bypass Number	**Detailed Component**	**Calculation/Estimation Technique**	**Information Sources**
BYP_1	Chowchilla Bypass	Calculated from San Luis & Delta-Mendota Water Authority (SLDMWA) CBP station measurements adjusted downstream to the subbasin boundary for estimated seepage and evaporation	SLDMWA CBP station, NRCS soil survey, Fresno State/Madera/ Madera II CIMIS Stations

Table 3-7. Summary of Historical Surface Water Bypasses Develop			
Bypass Number	**Detailed Component**	**Calculation/Estimation Technique**	**Information Sources**
BYP_2	C2VSim-FG Beta2 diversions data file	N/A	From C2VSim-FG Beta2
BYP_3 - BYP_4	Madera Canal Diversions to CWD	Reported in USBR CVP delivery records at Madera Canal Miles 33.6 and 35.6	USBR CVP delivery records
BYP_5	MID Deliveries to CWD	Measured by MID, CWD	MID delivery database
BYP_6 - BYP_7	Chowchilla River and Berenda Slough Diversions to CWD	Sum of Buchanan Dam and Madera Canal irrigation releases diverted by CWD, plus additional flood releases diverted to meet reported CWD deliveries; apportioned to each waterway based on CWD delivery records, GIS analysis, and historical operations (18% from Chowchilla River, 82% from Berenda Slough)	USBR CVP delivery records, USACE records, CWD delivery database, CWD monthly water supply reports
BYP_8	Madera Canal Mile 18.8 Diversions to MID, Fresno River	Reported in USBR CVP delivery records at Madera Canal Mile 18.8	USBR CVP delivery records

[1] Includes riparian, appropriative, and prescriptive water rights deliveries during flood releases and/or natural flood flows along subbasin waterways.

3.1.4. Groundwater System

The IFWM Groundwater Flow Process balances subsurface inflows and outflows and manages groundwater storage within each element and layer (Brush et al., 2016). The development of groundwater system input files is explained in this section.

Aquifer Parameters

Because C2VSim-FG Beta2 was not a calibrated model and the basis for determining aquifer parameters in previous versions of C2VSim-CG were not characterized, aquifer parameters were defined in MCSim through subsurface lithologic textural analysis in conjunction with calibration of parameters based on texture. Aquifer parameters in MCSim are assigned to each node for each model layer and were developed to represent subsurface hydrogeologic characteristics.

Lithologic Texture Data

A significant refinement within MCSim_v2 was the implementation of a new textural model. A lithologic texture model was developed using borehole lithology data for 2,683 data points from DWR Airborne Electromagnetic Survey (AEM) data (Survey Area 5 and Survey Area 9 for Basin Characterization Pilot Study, available at https://data.cnra.ca.gov/dataset/aem) and an additional 120 Well Completion Reports (WCRs) located within the model domain. Lithology and texture data from the textural dataset developed for the US Geological Survey (USGS) Central Valley Hydrologic Model (CVHM) was used to fill spatial (lateral and vertical) gaps in the AEM and WCR textural dataset. For each dataset, the original texture description was simplified into a general texture class (gravel, sand, silt, clay). A binary percent coarse value was then assigned to each general texture classes, consistent with the methodology used by USGS in the development of the CVHM model (https://ca.water.usgs.gov/projects/central-valley/cvhm-texture-model.html). Gravels and sands were assigned a 1 while silts and clays were assigned a 0.

Translating the point textural dataset to a continuous textural model for use in MCSim_v2 was done by assigning values for the percent coarse at each textural borehole datapoint to each model layer penetrated by the borehole and then interpolating percent coarse by layer across the entire model domain. In this process, the intervals of fine and coarse-grained, textured sediments were calculated for model layers at each WCR location and the thickness-weighted percentage of coarse-grained materials within each model layer were estimated. Using values for percent coarse-grained materials by model layer at each borehole point, spatially continuous datasets representing the percentage of coarse-grained materials were developed for each model layer through point interpolation methods. Interpolation was performed using ordinary kriging interpolation tool in the ESRI ArcGIS software package, which applies a semivariogram approach. An appropriate semivariogram model was selected through exploration of the data. The resulting kriged spatial distribution of percent coarse by model layer is shown in **Figures 3-29 through 3-35**. During model development and calibration, aquifer parameters were assigned to model nodes and layers using parameter values specified for both the fine and coarse end members and relating these to the percent coarse values developed from the textural model. The process used to assign and calibrate aquifer parameters in the model based on the percent coarse values are described in the discussions of model calibration in Section 3.2 of this document.

Aquifer Parameter Zones

To better represent the geology within the MCSim domain, a set of aquifer parameter zones were developed to enable for more refined assignment of aquifer parameters based on the lithologic texture values, especially recognizing that aquifer properties for similar-textured materials (based on the textural model) may differ by geologic formation. Four zones (within Corcoran Clay (confined), within Corcoran Clay (semi-confined), outside Corcoran Clay/West of Highway 99, and East of Highway 99 were delineated for using multipliers applied to parameter values derived from the textural data. Depth decay factors are also applied to the multipliers within these zones, to represent the increased consolidation and induration that is believed to exist in older geologic units that are at greater depth and have undergone compression and compaction because of the geostatic load at greater depth.

A very low depth decay factor was applied to Layer 7 consistent with the greater depth of the layer and because the layer is below the depth at which groundwater pumping occurs in the area. Few or no wells penetrate to depths below the top of Layer 7 because it is below the base of freshwater. As a result, no groundwater pumping occurs at such great depths and little lithologic information is available so Layer 7 was represented with low aquifer properties to reduce any effect the layer may have on simulated conditions within the upper model layers where groundwater is actively used. Layer 7 was not considered in water budget estimates developed using the model.

A parameter overwrite was used to represent the occurrence of low-permeability materials associated with the basement complex within the MCSim model domain. Although the base of Layer 7 in the model was delineated to align with the base of continental deposits in many parts of the basin, because the contact between continental deposits and basement becomes steep along the eastern edge of the mode domain, in such areas MCSim simulated this contact through assignment of different aquifer parameters instead of through explicitly delineating this contact in the configuration of model layering. To achieve this, if a model layer was more than 50 percent below the mapped top of basement at a given model node, the node in that layer was designated as a basement complex node. Nodes designated as basement complex were assigned aquifer parameters associated with basement materials.

The discussion of the calibration of aquifer parameters using the parameter zones described above, and the results of the model calibration, are presented in **Sections 3.2 and 4.7** below.

Boundary Conditions

MCSim utilizes time-varying general head boundary conditions to simulate groundwater levels and fluxes at the extent of the model domain. A map of nodes where general head boundary conditions were specified in the model is presented in **Figure 3-36**. In specifying general head boundary conditions, hydraulic conductance was estimated at each boundary node by layer based on average horizontal hydraulic conductivity (Kh), cross-sectional area associated with each boundary node (product of distance between nodes and saturated layer thickness), and the distance from the model boundary (set as 1,000 feet). Transient historical water level boundary conditions were refined in MCSim_v2 by using the interpreted initial head conditions in 1985 and applying relative changes based on simulated water levels derived from the C2VSim-FG model for each model time step for the period 1985 to 2023. Some additional refinements were made to the boundary conditions after comparing modeled water levels to observed data.

Groundwater Pumping

Pumping within MCSim is determined by element based on land use characteristics and simulated demand and is calculated internally by the IDC to meet both agricultural and urban demands after available surface water deliveries have been accounted for. The vertical distribution of pumping by layer in MCSim was modified based on review of well construction information in DWR's database of Well Completion Reports (WCR) for wells within the model domain. Agricultural and urban pumping were distributed vertically based on well construction information data in DWR's WCR database for respective well types. The vertical distribution of pumping does not change over the historical simulation period. Maps of the vertical distribution of agricultural pumping by layer are presented in **Figures 3-37 through 3-43** and for urban pumping by layer in **Figures 3-44 through 3-50**.

3.1.5. Small Watersheds

A total of 44 small watersheds were included in MCSim from C2VSim-FG Beta2 (**Figure 3-51**). **Table 3-8** summarizes the contributions of small watersheds to modeled streams. Modifications were made to C2VSim-FG Beta2 small watersheds to properly route water through the additional streams modeled in MCSim. Additionally, minor edits to the contributing acreage of small watersheds were made to adjust to modifications of elements along model boundary.

Table 3-8. Summary of Small Watersheds		
Stream fed by Small Watersheds	**Count of Contributing Watersheds**	**Total Contributing Watershed Acreage**
Berenda Creek	3	4,694
Cottonwood Creek	3	12,710
Deadman's Creek	4	17,131
Dry Creek	3	15,820
Dutchman Creek	2	3,335
Fresno River	3	2,174
Madera Canal	16	31,814
San Joaquin River	10	42,899
TOTAL	**44**	**130,577**

3.1.6. Initial Conditions

Initial conditions were refined for MCSim_v2 and generated from mapped groundwater conditions based on observed groundwater levels and contour interpretation. Available historical groundwater level data were used to interpret groundwater elevations across the domain in Fall 1985 for use in the representation of initial model water level (head) conditions. Layers 1 through 3 were assigned initial head conditions representative of the Upper Aquifer and Layers 4 through 7 were assigned initial head conditions representative of the Lower Aquifer. Initial water level conditions used in the historical MCSim runs are shown in **Figures 3-52 through 3-58**.

Initial conditions for the unsaturated zone and small watersheds were defined from simulated C2VSim-FG Beta2 conditions.

3.2. Model Calibration

MCSim_v2 was calibrated using a trial and error approach in conjunction with utilization of automated calibration and parameter estimation techniques involving application of UCODE-2014, an inverse modeling computer code developed by the US Geological Survey. Automated techniques were used at stages during the calibration to explore model sensitivity and inform the trial and error calibration efforts. The calibration process focused on adjusting key model parameter values to improve the fit of simulated historical groundwater levels and subsidence to observed (measured) data. The key model parameters included in calibration were aquifer properties and subsidence properties.

Aquifer parameters were developed by assigning texture end member values to the percent coarse-grained materials in the textural model described in **Section 3.1.5.1.1** of this report. Texture end member values are the aquifer parameter values at the two ends of the percent coarse spectrum, either 100% (coarse) or 0% (fine). Aquifer parameters adjusted during calibration included horizontal hydraulic conductivity (Kh), vertical hydraulic conductivity (Kv), specific storage (Ss), specific yield (Sy), which were specified for aquifer parameter zones. The equations used to calculate the aquifer parameter values for each node and layer from the specified end-member values are presented below. For aquifer parameter zones where a multiplier was included in the calibration, the multiplier was applied to the parameter values resulting from calculations using these equations. The equations used for estimating aquifer parameters from textural model information are consistent with the methods used and described in development of the hydrogeologic conceptual model and model parameterization for C2VSim-FG (DWR, 2021).

Horizontal hydraulic conductivity (Kh) at each node and layer is calculated using the following equation:

$$Kh = (PCT * ({Kh_{C0}}^{pKh}) + (1 - PCT) * ({Kh_{F0}}^{pKh}))^{\frac{1}{pKh}}$$

Where: PCT is the percent coarse

Kh_{C0} is the Kh end member of coarse materials

Kh_{F0} is the Kh end member of fine materials

pKh is the power law empirical parameter for Kh

The vertical hydraulic conductivity (Kv) end member values are calculated through application of an anisotropy ratio (Kv / Kh) to the Kh endmember values. The Kv value at each node and layer is then calculated using the following equation:

$$Kv = (PCT * ({Kv_{C0}}^{pKv}) + (1 - PCT) * ({Kv_{F0}}^{pKv}))^{\frac{1}{pKv}}$$

Where: PCT is the percent coarse

Kv_{C0} is the Kv end member of coarse materials

Kv_{F0} is the Kv end member of fine materials

pKv is the power law empirical parameter for Kv

Specific storage (Ss) is calculated using the following equation:

$$SS = PCT * Ss_C + (1 - PCT) * Ss_F$$

Where: PCT is the percent coarse

Ss_C is the Ss end member of coarse materials

Ss_F is the Ss end member of fine materials

Specific yield (Sy) is calculated using the following equation:

$$Sy = PCT * Sy_C + (1 - PCT) * Sy_F$$

Where: PCT is the percent coarse

Sy_C is the Sy end member of coarse materials

Sy_F is the Sy end member of fine materials

Calibrated end member values are presented in **Section 4.2** of this report.

Observations used in the calibration of aquifer parameters included approximately 39,100 groundwater level observations from 401 wells across the model domain selected based on historical data record, well construction, and spatial representation (lateral and vertical distribution) (**Figure 3-59**).

Subsidence properties adjusted during the calibration included elastic specific storage (SCE), inelastic specific storage (SCI), and interbed vertical hydraulic conductivity (Kvi). SCE and SCI were assigned by applying a multiplier to the calculated SS value at each node for each layer. Multipliers were assigned using the same aquifer parameter zones described in **Section 3.1.5.1.2**. Kvi was initially assigned as the Kv value at each node and was subsequently adjusted during the calibration process.

Observations used in the calibration of the subsidence parameters included approximately 10,300 subsidence measurements from 37 subsidence monitoring stations (**Figure 3-60**).

The results of the model calibration are presented and discussed in **Section 4.1** below.

3.3. MCSim – Projected Model

The projected model simulations are intended to evaluate the effects of anticipated future conditions of hydrology, water supply availability, water demand, and projects and management actions within the Madera and Chowchilla Subbasins. The projected simulation period runs from WY 2024 through 2090 beginning on October 1, 2023, and ending September 30, 2090, at a monthly time step. Two distinct time periods exist in the future projected modeling: the implementation period (2024-2039), during which projects and management actions are enacted to bring the basin into sustainability, and the sustainability period (2040-2090), after which projects and management actions have been fully implemented. The projected model scenarios use hydrologic conditions representative of the most recent 50 years of hydrology in the Subbasins, with adjustments applied in scenarios for evaluating the water budget under climate change and/or altered water supply and demand conditions. The development of the projected future scenarios in MCSim is described in this section.

3.3.1. Projected Hydrology

Establishing a sequence of projected hydrology is key to the development of the projected model scenarios. Projected hydrology model inputs were developed based on review and consideration of the recent 50 years of hydrology for 1973-2023 and utilization of a hydrologic sequence that replicates the hydrologic patterns and trends over this period. During the implementation period, an average climatic period was simulated by repeating the observed average climatic period from 1999-2013 for the 2025 to 2039 period. During the sustainability period, the 50-year climatic period from 1973-2023 is repeated. The projected water year type and assigned surrogate water years for use developing the projected hydrology are shown in **Table 3-9**.

Table 3-9. Summary of Projected Water Years

WY	WY Type	WY Index	WY	Surrogate WY	WY Type	WY Index	WY	Surrogate WY	WY Type	WY Index
1989	C	1.96	2024	2018	BN	3.03	2059	1992	C	1.56
1990	C	1.51	2025	1999	AN	3.59	2060	1993	W	4.20
1991	C	1.96	2026	2000	AN	3.38	2061	1994	C	2.05
1992	C	1.56	2027	2001	D	2.20	2062	1995	W	5.95
1993	W	4.20	2028	2002	D	2.34	2063	1996	W	4.12
1994	C	2.05	2029	2003	BN	2.81	2064	1997	W	4.13
1995	W	5.95	2030	2004	D	2.21	2065	1998	W	5.65
1996	W	4.12	2031	2005	W	4.75	2066	1999	AN	3.59
1997	W	4.13	2032	2006	W	5.90	2067	2000	AN	3.38
1998	W	5.65	2033	2007	C	1.97	2068	2001	D	2.20
1999	AN	3.59	2034	2008	C	2.06	2069	2002	D	2.34
2000	AN	3.38	2035	2009	BN	2.72	2070	2003	BN	2.81
2001	D	2.20	2036	2010	AN	3.55	2071	2004	D	2.21
2002	D	2.34	2037	2011	W	5.58	2072	2005	W	4.75
2003	BN	2.81	2038	2012	D	2.18	2073	2006	W	5.90
2004	D	2.21	2039	2013	C	1.71	2074	2007	C	1.97
2005	W	4.75	2040	1973	AN	3.50	2075	2008	C	2.06
2006	W	5.90	2041	1974	W	3.90	2076	2009	BN	2.72
2007	C	1.97	2042	1975	W	3.85	2077	2010	AN	3.55
2008	C	2.06	2043	1976	C	1.57	2078	2011	W	5.58
2009	BN	2.72	2044	1977	C	0.84	2079	2012	D	2.18
2010	AN	3.55	2045	1978	W	4.58	2080	2013	C	1.71
2011	W	5.58	2046	1979	AN	3.67	2081	2014	C	1.16
2012	D	2.18	2047	1980	W	4.73	2082	2015	C	0.81
2013	C	1.71	2048	1981	D	2.44	2083	2016	D	2.35
2014	C	1.16	2049	1982	W	5.45	2084	2017	W	6.46
2015	C	0.81	2050	1983	W	7.22	2085	2018	BN	3.03
2016	D	2.35	2051	1984	AN	3.69	2086	2019	W	4.94
2017	W	6.46	2052	1985	D	2.40	2087	2020	D	2.35
2018	BN	3.03	2053	1986	W	4.31	2088	2021	C	1.32

Table 3-9. Summary of Projected Water Years

WY	WY Type	WY Index
2019	W	4.94
2020	D	2.35
2021	C	1.32
2022	C	1.56
2023	W	6.40

WY	Surrogate WY	WY Type	WY Index
2054	1987	C	1.86
2055	1988	C	1.48
2056	1989	C	1.96
2057	1990	C	1.51
2058	1991	C	1.96

WY	Surrogate WY	WY Type	WY Index
2089	2022	C	1.56
2090	2023	W	6.40

Note: Water Year Type is based on the San Joaquin Valley Water Year Index and is classified into five types:
W = Wet; AN = Above Normal; BN = Below Normal; D = Dry; C = Critical

Climate Change Adjustments

Climate change adjustments were also included in selected projected future scenarios to evaluate the potential influence of climate change on future conditions. The climate change factors applied to applicable MCSim inputs are from the DWR CalSim II simulated volume projections based on State Water Project (SWP) and Central Valley Project (CVP) operations under the 2030 mean climate change scenario (SGMA Data Viewer). For precipitation, evapotranspiration, and surface inflows for unimpaired waterways, historical data was adjusted by the CalSim II 2030 monthly streamflow change factors by water year type. For surface inflows for impaired waterways, the CalSim II projected reservoir outflows (assuming 2030 climate change) was used when available (1965-2003), or inflows were estimated as the average monthly CalSim II projected volume by water year type in other years (2004 and thereafter). For inflows to the San Joaquin River and other waterways stemming from it (i.e., Madera Canal), inflows were either derived from projected flows from a report on future supplies by the Friant Water Authority (Friant Water Authority, 2018), considering San Joaquin River Restoration Program (SJRRP) implementation and the CalSim II 2030 climate change projections (1965-2003), or inflows were estimated based on the average monthly projected volume by water year type (2004 and thereafter) included in the Friant Water Authority Report (Friant Water Authority, 2018). Additional information about climate change adjustments used in projected future scenarios is included in **Table 3-11** and **Table 3-13**.

3.3.2. Overview of Projected Scenarios

Four projected future scenarios were simulated to compare possible outcomes and evaluate the future sustainability of the Subbasins. These scenarios include: a Projected (No Action) scenario, a Projected (No Action) with Climate Change scenario, a Projected with Projects scenario, and a Projected with Projects and with Climate Change scenario. All four scenarios are simulated using the projected hydrology described in **Section 3.3.1** as a baseline. **Table 3-10** outlines the different model scenarios evaluated. The Projected (No Action) and Projected (No Action) with Climate Change scenarios use no flow boundary conditions, under which no subsurface flow is assumed to enter or exit the model domain along the model boundary. The Projected with Projects and Projected with Projects and with Climate Change scenarios use boundary conditions that assume adjacent basins are also implementing projects. The Projected with Climate Change and Projected with Projects and with Climate Change scenarios incorporate the 2030 mean climate change scenario adjustment for precipitation, ET, stream inflows, and surface water diversion volumes. All other model inputs are held constant across projected future scenarios.

The Projected with Projects scenario was chosen as the baseline future projected scenario. The Projected with Projects and with Climate Change, Projected (No Action), and Projected (No Action) with Climate Change model runs were chosen as sensitivity analysis scenarios.

Table 3-10. Summary of Projected Future Scenarios

Model Scenario Name/Description	Time Period (Water Years)	Boundary Conditions	Climate Change Adjustment	Projects and Management Actions
Projected with Projects	2024-2090	Adjacent Basins Implementing Projects	None	Yes
Projected with Projects and with Climate Change	2024-2090	Adjacent Basins Implementing Projects	2030 CT	Yes
Projected (No Action)	2024-2090	No Flow Assumed	None	No
Projected (No Action) with Climate Change	2024-2090	No Flow Assumed	2030 CT	No

3.3.3. Land Surface System

The development of land surface system datasets for projected future scenarios is described below.

Precipitation

For the projected scenarios, historical precipitation inputs from the appropriate surrogate water year were mapped to each projected water year through 2090 (**Table 3-9**). For scenarios with climate change adjustments, the historical precipitation inputs were adjusted using the appropriate CalSim II 2030 mean climate change scenario monthly water year type multiplier (see Section 3.3.1.1). Additional information about the development of projected precipitation rates is included in **Table 3-11**.

Table 3-11. Development of Projected Future Land Surface Process Components

Water Budget Component	Without Climate Change Adjustments		With Climate Change Adjustments	
	Implementation Period	Sustainability Period	Implementation Period	Sustainability Period
	(2024[1]-2039)	(2040-2090)	(2024[1]-2039)	(2040-2090)
Precipitation	2018, 1999-2013 historical data (2024 and 2025-2039)	1973-2023 historical data (2040-2090)	2018, 1999-2013 historical data (2024 and 2025-2039) adjusted by CalSim II 2030 monthly change factors by water year type	1973-2023 historical data (2040-2090) adjusted by CalSim II 2030 monthly change factors by water year type
Evapotranspiration	2018, 1999-2013 historical data (2024 and 2025-2039), assuming 2023 land use adjusted for projected urban area growth from 2024-2039	1973-2023 historical data (2040-2090), assuming 2023 land use adjusted for projected urban area growth from 2024-2070 (urban area constant from 2071-2090)	2018, 1999-2013 historical data (2024 and 2025-2039) adjusted by CalSim II 2030 monthly change factors by water year type, assuming 2023 land use adjusted for projected urban area growth from 2024-2039	1973-2023 historical data (2040-2090) adjusted by CalSim II 2030 monthly change factors by water year type, assuming 2023 land use adjusted for projected urban area growth from 2024-2070 (urban area constant from 2071-2090)

[1] Implementation period is from 2020-2039, although projected future MCSim updates have been refined to begin in 2024, following historical MCSim updates through 2023.

Evapotranspiration

ET inputs were also projected into the future by mapping historical ET inputs from the appropriate surrogate water year to each projected water year through 2090 (**Table 3-9**), with consideration of applicable projected changes in land use (described in **Section 3.3.3.3**). Additional information about the development of projected ET rates is included in **Table 3-11**.

Land Use

For all projected future scenarios, land use areas in the MCSim domain were adjusted starting from a baseline land use in 2023 (see Section 3.1.2.3). Specific land use area adjustments in each projected future scenario are summarized below.

No Action (Without Projects) Scenarios

Except in areas with urban growth, projected land use in the Projected No Action scenarios was based on the 2023 land use from the historical MCSim inputs. In areas with projected urban growth, simulated urban land use was gradually expanded over the 2024-2070 period, accompanied by commensurate decreases in agricultural and native vegetation land uses. Urban growth rates were developed through an analysis of urban growth trends from 1989 through 2023. These urban growth trends were also verified for general consistency with available urban water planning documents in the City of Madera, including the 2020 Urban Water Management Plan. Starting from 2023, urban land use was increased through 2070 using these urban growth percentages in elements where non-urban land was available for conversion. Any remaining non-urban land was distributed among the other land uses in the element based on each non-urban land use's percentage of total non-urban area in the element in 2023. After 2070, urban acreage was held constant through 2090.

In addition to urban land use expansion, projected urban population in the Projected No Action scenarios was developed based on review of observed population growth during water years 1989-2023. Projected urban population growth in the City of Chowchilla was estimated based on average 10-year population growth and projections for 2000-2040 from the City of Chowchilla Sphere of Influence Expansion & Municipal Service Review (Land Use Associates, 2011). Projected urban population growth in the City of Madera was estimated based on average 5-year population growth and review of the Madera Area Municipal Service Review and Sphere of Influence Update (Quad Knopf, 2018). Estimated urban population in water years 2071-2090 was held constant at the estimated population in 2070. The monthly projected urban per capita water use between water years 2024 and 2090 was estimated to be the same as water year 2018, a recent average year.

With Projects Scenarios

Land use in the Projected with Projects scenarios is based on land use in the Projected No Action scenarios, with modification to incorporate land use changes estimated to occur in association with projects and management actions (**Table 3-12**).

Madera County GSA is implementing a demand management program in both the Madera and Chowchilla Subbasins, which is expected to result in demand reduction to reach the sustainable yield for the Madera County GSA in each subbasin by 2040 (approximately 22,500 AFY in the Chowchilla Subbasin, and approximately 90,000 AFY in the Madera Subbasin), consistent with current planning efforts. Starting in water year 2024, irrigated agricultural land uses were gradually converted to fallow land uses in the Madera County GSA in each subbasin in order to meet anticipated annual demand reduction targets through 2040. Simulation of the demand management program is based on current plans for the program, although future updates may be warranted to the extent that program implementation or other assumptions change before 2040.

Land use was also modified to simulate gradual conversion of certain currently irrigated agricultural parcels to dedicated recharge basins within the MID GSA. Parcels anticipated to be converted in the future were transitioned from irrigated agriculture to recharge basins in MCSim according to their proposed extent and timeline (**Table 3-12**). These changes in land use and associated benefits to recharge in the

Subbasin may occur prior to 2040, depending on the MID GSA's implementation of projects and management actions.

Table 3-12. Land Use Changes in the Projected with Projects Scenarios

Subbasin	GSA	Change Year(s)	Project or Management Action	Land Use Changes
Chowchilla	Madera County	2024-2040	Demand management program	Annual conversion of irrigated agricultural land to fallow land in order to reach the GSA sustainable yield by 2040 (22,500 AFY), beginning with 10% reduction of transitional water in 2024-2025 and gradual reduction of remaining transitional water through 2040.
Madera	Madera County	2024-2040	Demand management program	Annual conversion of irrigated agricultural land to fallow land in order to reach the GSA sustainable yield by 2040 (90,000 AFY), beginning with 10% reduction of transitional water in 2024-2025 and gradual reduction of remaining transitional water through 2040.
Madera	Madera ID	2024-2028	Additional recharge basin conversions	Gradual conversion of 260 acres of irrigated agricultural land (as of 2023) to recharge basins (assuming orchards are converted).

3.3.4. Surface Water System

The development of surface water system datasets for projected future scenarios is described below.

Stream Inflows

For the projected scenarios, historical stream inflows from the appropriate surrogate water year were mapped to each projected water year through 2090 (**Table 3-9**), with the exception of inflows to the San Joaquin River and waterways stemming from the San Joaquin River (Madera Canal and Chowchilla Bypass), which were estimated from a report on future supplies by the Friant Water Authority (Friant Water Authority, 2018). For scenarios with climate change, a climate change adjustment was incorporated into the projections as described in Section 3.3.1.1. Additional information about the development of projected stream inflows is included in **Table 3-13**.

Table 3-13. Development of Projected Future Surface Water System Components				
Water Budget Component	Without Climate Change Adjustments		With Climate Change Adjustments	
	Implementation Period (2024[1]-2039)	Sustainability Period (2040-2090)	Implementation Period (2024[1]-2039)	Sustainability Period (2040-2090)
Surface Water Inflow - Unimpaired Streams	2018, 1999-2013 historical data (2024 and 2025-2039)	1973-2023 historical data (2040-2090)	2018, 1999-2013 historical data (2024 and 2025-2039) adjusted by CalSim II 2030 monthly streamflow change factors by water year type	1973-2023 historical data (2040-2090) adjusted by CalSim II 2030 monthly streamflow change factors by water year type
Surface Water Inflow - Chowchilla River (Buchanan Dam Releases)	2018, 1999-2013 historical data (2024 and 2025-2039)	1973-2023 historical data (2040-2090)	2018, 1999-2013 historical data (2024 and 2025-2039): 1999-2003 historical data adjusted by CalSim II 2030 climate change projections for Eastman Lake; 2004-2013 data estimated as the historical volume adjusted by the average monthly climate-adjusted volume by water year type	1973-2003 historical data (2040-2070) adjusted by CalSim II 2030 climate change projections for Eastman Lake; 2004-2023 data (2071-2090) estimated as the historical volume adjusted by the average monthly climate-adjusted volume by water year type
Surface Water Inflow - Fresno River (Hidden Dam Releases)	2018, 1999-2013 historical data (2024 and 2025-2039)	1973-2023 historical data (2040-2090)	2018, 1999-2013 historical data (2024 and 2025-2039): 1999-2003 historical data adjusted by CalSim II 2030 climate change projections for Hensley Lake; 2004-2013 data estimated as the historical volume adjusted by the average monthly climate-adjusted volume by water year type	1973-2003 historical data (2040-2070) adjusted by CalSim II 2030 climate change projections for Hensley Lake; 2004-2023 data (2071-2090) estimated as the historical volume adjusted by the average monthly climate-adjusted volume by water year type

Table 3-13. Development of Projected Future Surface Water System Components

Water Budget Component	Without Climate Change Adjustments		With Climate Change Adjustments	
	Implementation Period (2024[1]-2039)	Sustainability Period (2040-2090)	Implementation Period (2024[1]-2039)	Sustainability Period (2040-2090)
Surface Water Inflow - San Joaquin River (Friant Dam Releases)	Estimated based on the Friant Water Authority Report* (same as implementation period with climate change adjustments**, see right)	Estimated based on the Friant Water Authority Report* (same as implementation period with climate change adjustments**, see right)	2018, 1999-2013 historical data (2024 and 2025-2039): 1999-2003 data provided by Friant Water Authority Report*, considering the CalSim II 2030 climate change projections and implementation of the SJRRP; 2004-2013 data estimated as the historical volume adjusted by the average Friant Report volume by month and water year type	1973-2003 data (2040-2070) provided by Friant Water Authority Report*, considering the CalSim II 2030 climate change projections and implementation of the SJRRP; 2004-2023 data (2071-2090) estimated as the historical volume adjusted by the average Friant Report volume by month and water year type
Surface Water Inflow - Chowchilla Bypass	Estimated based on the historical monthly ratio of Chowchilla Bypass (CBP) and San Joaquin River (SJR) flows, with projected SJR inflow data provided by the Friant Water Authority Report* (same as the implementation period with climate change adjustments**, see right)	Estimated based on the historical monthly ratio of CBP and SJR flows, with projected SJR inflow data provided by the Friant Water Authority Report* (same as the implementation period with climate change adjustments**, see right)	2018, 1999-2013 historical data (2024 and 2025-2039): 1999-2003: estimated based on the historical monthly ratio of CBP and SJR flows by water year type, with projected SJR inflow data provided by the Friant Water Authority Report*, considering the CalSim II 2030 climate change projections and implementation of the SJRRP; 2004-2013: estimated based on the historical monthly ratio of CBP to SJR flows by water year	1973-2003 (2040-2070): estimated based on the historical monthly ratio of CBP to SJR flows by water year type, with projected SJR inflow data provided by the Friant Water Authority Report*, considering the CalSim II 2030 climate change projections and implementation of the SJRRP; 2004-2023 (2071-2090): estimated based on the historical monthly ratio of CBP to SJR flows by water year type, with

Table 3-13. Development of Projected Future Surface Water System Components				
Water Budget Component	Without Climate Change Adjustments		With Climate Change Adjustments	
	Implementation Period (2024[1]-2039)	Sustainability Period (2040-2090)	Implementation Period (2024[1]-2039)	Sustainability Period (2040-2090)
			type, with average projected SJR inflows calculated from 1921-2003 by month and water year type	average projected SJR inflows calculated by month and water year type
Diversions from Madera Canal	Estimated based on the Friant Water Authority Report* (same as implementation period with climate change adjustments**, see right)	Estimated based on the Friant Water Authority Report* (same as the implementation period with climate change adjustments**, see right)	2018, 1999-2013 historical data (2024 and 2025-2039): 1999-2003 data provided by Friant Water Authority Report*, considering the CalSim II 2030 climate change projections and implementation of the SJRRP; 2004-2013 data estimated as the historical volume adjusted by the average Friant Report climate change volume by month and water year type	1973-2003 data (2040-2070) provided by Friant Water Authority Report*, considering the CalSim II 2030 climate change projections and implementation of the SJRRP; 2004-2023 data (2071-2090) estimated as the historical volume adjusted by the average Friant Report climate change volume by month and water year type
Other Diversions/ Bypasses	2018, 1999-2013 historical data (2024 and 2025-2039)	1973-2023 historical data (2040-2090)	2018, 1999-2013 historical data (2024 and 2025-2039)***	1973-2023 historical data (2040-2090)***

[1] Implementation period is from 2020-2039, although projected future MCSim updates have been refined to begin in 2024, following historical MCSim updates through 2023.

* "Estimate of Future Friant Division Supplies for use in Groundwater Sustainability Plans, California," Friant Water Authority, 2018.

** Although the Friant Water Authority Report (or Friant Report) accounts for climate change, it is considered the best available estimate of projected Madera Canal deliveries under SJRRP. For comparison, projected Madera Canal deliveries under SJRRP were also estimated without account for climate change from the Steiner Report Kondolf Hydrograph (Steiner, 2005). These estimates were approximately equal to the Friant Report 2030 climate change adjusted deliveries. Thus, the Friant Report projections were used instead to maintain consistent assumptions in estimating Madera Canal deliveries across all projected simulations.

*** Historical volumes specified in the model to ensure that GSAs can use as much surface water as is available in a given time step up to the maximum historical surface water used.

Diversions

Surface water diversion volumes were projected into the future based on historical surface water diversions from the corresponding assigned water year (**Table 3-9**), with the exception of diversions from the Madera Canal which were estimated from a report on future supplies by the Friant Water Authority (Friant Water Authority, 2018). For scenarios with climate change, a climate change adjustment was incorporated into the projections as described in Section 3.3.1.1. Additional information on the development of projected surface water diversions is included in **Table 3-13**.

Projects

Three main types of projects or management actions were simulated in MCSim: direct recharge projects (e.g., projects that deliver flood water to recharge basins or fields to increase groundwater recharge); in-lieu recharge projects (e.g., projects that reduce groundwater pumping by encouraging growers to use surface water rather than groundwater, or by purchasing and importing additional surface water); and projects or management actions that lead to land use changes (e.g., demand management; simulated through land use changes, see Section 3.3.3.3). Estimates of direct and in-lieu recharge project configurations and recharge were developed in close collaboration with each GSA, as reported in the GSPs. The objective of the projects (and demand management in the case of the Madera County GSA) is to increase recharge or reduce groundwater pumping a sufficient volume so groundwater pumping does not exceed the sustainable yield. A summary of projected projects simulated in each GSA is presented in **Table 3-14**.

For recharge projects (e.g., recharge basins and flood managed aquifer recharge (flood-MAR) projects), diversion volumes were developed based on estimated project recharge benefits and typical anticipated project operations and water availability by water year type and month, consistent with project plans reported in the GSP. For in-lieu recharge projects (e.g., projects that purchase and import additional surface water), estimated diversion volumes were specified consistent with project plans reported in the GSP.

For recharge projects using flood water, diversions were specified in the model as the maximum volumes that could be diverted and used by the projects during years when flood water is anticipated to occur. This ensured that projects could take as much water as was available in a given time step up to the maximum capacity of each project. Because maximum volumes were specified for each project, no climate change adjustment was applied to projects in the Projected with Projects with Climate Change scenario.

Project diversion locations are provided in **Figure 3-61.**

Diversion points were located downstream of historical diversions in order to prioritize historical diversions over project diversions. Project diversions were delivered to the entirety of the appropriate GSA, unless more detailed delivery information was available for the project. Delivery locations for projects are shown in **Figures A-78 through A-158** of **Appendix A**.

Bypasses

Bypass volumes were generally projected into the future based on historical bypass flows from the corresponding assigned water year (**Table 3-9**). The inflows to the Chowchilla Bypass from the San Joaquin River were estimated based on the historical monthly ratio of Chowchilla Bypass USGS stream gage (CBP) and projected San Joaquin River flows provided by a report on future supplies by the Friant Water Authority (Friant Water Authority, 2018). For scenarios with climate change, a climate change adjustment was incorporated into the projections. Additional information about the development of projected bypass volumes is included in **Table 3-13**.

Table 3-14. Summary of Projected Projects by GSA											
Div ID	Subbasin	GSA/ Sub-region[1]	Project Description	Project Start	Simulated Benefits by WY Type (AFY)					Months with Benefits	Notes
					W	AN	BN	D	C		
67-68	Chowchilla	CWD	Road 13 Groundwater Recharge Basin (East and West)	2024	3,000	3,000	0	0	0	Jan-Apr	Average benefits (Road 13 East and West) distributed across typical months with recharge (based on 2023)
69	Chowchilla	CWD	City Groundwater Recharge Basin	2024	3,500	3,500	0	0	0	Jan-Apr	Average benefits distributed across typical months with recharge (based on 2023)
70	Chowchilla	CWD	Road 19 Groundwater Recharge Basin	2024	600	600	0	0	0	Jan-Apr	Average benefits distributed across typical months with recharge (based on 2023)
71	Chowchilla	CWD	Acconero Groundwater Recharge Basin	2024	1,900	1,900	0	0	0	Jan-Apr	Average benefits distributed across typical months with recharge (based on 2023)
72-73	Chowchilla	CWD	Wood Groundwater Recharge Basin (East and West)	2024	1,000	1,000	0	0	0	Jan-Apr	Average benefits (Wood East and West) distributed across typical months with recharge (based on 2023)
74	Chowchilla	CWD	Flood-MAR (Winter Recharge)	2024	15,000	8,000	0	0	0	Dec-Mar	Average benefits distributed across typical Flood-MAR period
75	Chowchilla	CWD	Additional Groundwater Recharge Basins	2028	25,000	6,000	0	0	0	Jan-Apr	Average anticipated benefits from GSP distributed across typical months with recharge at other CWD recharge basins

Table 3-14. Summary of Projected Projects by GSA

Div ID	Subbasin	GSA/ Sub-region[1]	Project Description	Project Start	Simulated Benefits by WY Type (AFY)					Months with Benefits	Notes
					W	AN	BN	D	C		
76	Chowchilla	CWD	Madera Canal Capacity Increase	N/A	0	0	0	0	0	N/A	No estimated benefits; project proposed in 2020 Initial GSP, but no longer considered as of 2024
77	Chowchilla	CWD	Merced-Chowchilla Intertie	2035	15,000	15,000	0	0	0	May-Aug	Average anticipated benefits from GSP distributed across typical peak irrigation season
78	Chowchilla	CWD	Buchanan Dam Capacity Increase	2040	24,800	0	0	0	0	May-Aug	Average anticipated benefits from GSP distributed across typical peak irrigation season
79	Chowchilla	CWD	Enhanced Management of Flood Releases for Recharge	2024	28,000	3,500	0	0	0	Dec-Mar	Average benefits distributed across typical flood release periods
80	Chowchilla	MC	Madera County East: Water Purchase	N/A	0	0	0	0	0	N/A	No estimated benefits; project proposed in 2020 Initial GSP, but funding for project is not currently available
81	Chowchilla	MC	Madera County East: Flood Flow Recharge	2024	1,400	0	0	0	0	Dec-Mar	Average anticipated recharge associated with SB122, based on benefits in 2023 distributed across typical flood water periods (assuming benefits increase by 5% in first three W years, then same benefits in all future W years)

Table 3-14. Summary of Projected Projects by GSA

Div ID	Subbasin	GSA/ Sub-region[1]	Project Description	Project Start	Simulated Benefits by WY Type (AFY)					Months with Benefits	Notes
					W	AN	BN	D	C		
82	Chowchilla	MC	Madera County East: Additional Water Rights Diversions for Ag	2024	400	0	0	0	0	May-Aug	Average anticipated diversions associated with SB122 and water rights use, based on benefits in 2023 distributed across typical peak irrigation season during flood water years
83	Chowchilla	MC	Madera County West: Chowchilla Bypass Flood Flow Recharge Phase 1	2026	8,300	0	0	0	0	Dec-Mar	Average anticipated recharge associated with Chowchilla Bypass Flood Flow Recharge Phase 1 (Project 1 in Chowchilla Subbasin), assuming construction finishes in 2025 and benefits are distributed across typical flood water periods
84	Chowchilla	MC	Madera County West: Chowchilla Bypass Flood Flow Recharge Phase 2	2026	4,000	0	0	0	0	Dec-Mar	Average anticipated recharge associated with Chowchilla Bypass Flood Flow Recharge Phase 2 (Project 2 in Chowchilla Subbasin, with refined location/design), assuming construction finishes in 2025 and benefits are distributed across typical flood water periods
85	Chowchilla	MC	Madera County West: Flood Flow Recharge	2024	33,000	0	0	0	0	Dec-Mar	Average anticipated recharge associated with SB122, based on benefits in 2023 distributed across typical flood water periods (assuming benefits increase by 5% in first three W years, then same benefits in all future W years)

Table 3-14. Summary of Projected Projects by GSA											
Div ID	Subbasin	GSA/ Sub-region[1]	Project Description	Project Start	Simulated Benefits by WY Type (AFY)					Months with Benefits	Notes
					W	AN	BN	D	C		
N/A	Chowchilla	MC	Demand Management	2024	--	--	--	--	--	--	Simulated through land use changes.
86	Chowchilla	MC	Madera County West: Additional Water Rights Diversions for Ag	2024	800	0	0	0	0	May-Aug	Average anticipated diversions associated with SB122 and water rights use, based on benefits in 2023 distributed across typical peak irrigation season during flood water years
87	Chowchilla	MC	Millerton Flood Release Imports	N/A	0	0	0	0	0	N/A	No estimated benefits; project proposed in 2020 Initial GSP, but funding for project is not currently available
88	Chowchilla	MC	Water Imports Purchase	N/A	0	0	0	0	0	N/A	No estimated benefits; project proposed in 2020 Initial GSP, but funding for project is not currently available
89	Chowchilla	SVMWC	SVMWC recharge basin	2024	5,000	3,000	0	0	0	Dec-Mar	Average anticipated benefits distributed across typical flood water periods; first year estimated from WY 2023 Annual Report
90	Chowchilla	SVMWC	Additional Water Rights Diversions for Ag	2024	2,200	0	0	0	0	May-Aug	Average anticipated diversions associated with SB122 and water rights use, based on benefits in 2023 distributed across typical peak irrigation season during flood water years

Table 3-14. Summary of Projected Projects by GSA

Div ID	Subbasin	GSA/ Sub-region[1]	Project Description	Project Start	Simulated Benefits by WY Type (AFY)					Months with Benefits	Notes
					W	AN	BN	D	C		
91	Chowchilla	TTWD	Poso Canal Pipeline and Columbia Canal Company Pipeline Projects	2024	8,000	8,000	8,000	7,500	7,000	May-Aug	Average additional water supply based on GSP and reported benefits through 2023, distributed across typical peak irrigation season
92	Chowchilla	TTWD	Poso Canal Pipeline Extension Project	2024	4,000	4,000	4,000	4,000	4,000	May-Aug	Average anticipated benefits distributed across typical peak irrigation season; first year estimated from WY 2023 Annual Report
93	Chowchilla	TTWD	Utilize Existing Recharge Basin	2024	14,000	4,000	0	0	0	Dec-Apr	Average recharge benefits based on GSP and reported benefits through 2023, distributed across typical flood water periods
94-95	Chowchilla	TTWD	Additional Recharge Basins to Capture Floodwater	2028	70,000	15,000	0	0	0	Dec-Apr	Average anticipated recharge based on GSP and distributed across typical flood water periods
96	Madera	CM	Berry Basin (with MID)	2024	221	30	10	0	0	Jan-Apr	Average benefits distributed across typical months with recharge; Partial benefit shown (50%, remainder of benefit assigned to MID)

Table 3-14. Summary of Projected Projects by GSA											
Div ID	Subbasin	GSA/ Sub-region[1]	Project Description	Project Start	Simulated Benefits by WY Type (AFY)					Months with Benefits	Notes
					W	AN	BN	D	C		
97	Madera	CM	Additional Recharge Basins with MID (Golf Course)	2024	51	25	0	0	0	Jan-Apr	Average benefits distributed across typical months with recharge (based on 2023); Partial benefit shown (50%, remainder of benefit assigned to MID)
98	Madera	CM	Additional Recharge Basins with MID (Absire)	2024	240	120	0	0	0	Jan-Apr	Average benefits distributed across typical months with recharge (based on 2023); Partial benefit shown (50%, remainder of benefit assigned to MID)
99	Madera	CM	Additional Recharge Basins with MID (Stadium)	2024	164	82	0	0	0	Jan-Apr	Average benefits distributed across typical months with recharge (based on 2023); Partial benefit shown (50%, remainder of benefit assigned to MID)
100	Madera	CM	Additional Recharge Basins with MID (Mitchell)	2024	88	44	0	0	0	Jan-Apr	Average benefits distributed across typical months with recharge (based on 2023); Partial benefit shown (50%, remainder of benefit assigned to MID)
101	Madera	CM	Additional Recharge Basins with MID (Mosesian)	2024	88	44	0	0	0	Jan-Apr	Average benefits distributed across typical months with recharge (based on 2023); Partial benefit shown (50%, remainder of benefit assigned to MID)

Table 3-14. Summary of Projected Projects by GSA											
Div ID	Subbasin	GSA/ Sub-region[1]	Project Description	Project Start	Simulated Benefits by WY Type (AFY)					Months with Benefits	Notes
					W	AN	BN	D	C		
102	Madera	CM	Meters and Volumetric Pricing	2024	3,350	3,350	3,350	3,350	3,350	Jan-Dec	Average benefits based on GSP
103	Madera	MC	Ellis Basin (with MID)	2024	275	150	150	0	0	Jan-Apr	Average benefits distributed across typical months with recharge; Partial benefit shown (50%, remainder of benefit assigned to MID)
104	Madera	MC	Water Imports Purchase	2025	0	5,000	7,000	9,000	2,500	May-Aug	Average anticipated benefits based on GSP and distributed across typical peak irrigation season; first year estimated from WY 2023 Annual Report
105	Madera	MC	Millerton Flood Release Imports	2025	22,000	0	0	0	0	Dec-Mar	Average anticipated benefits based on GSP and distributed across typical flood release periods; first year estimated from WY 2023 Annual Report
106	Madera	MC	Chowchilla Bypass Flood Flow Recharge Phase 1	2027	11,200	0	0	0	0	Dec-Mar	Average anticipated recharge associated with Chowchilla Bypass Flood Flow Recharge Phase 1 (Project 1, Option C in Madera Subbasin), assuming construction finishes in spring 2026 and benefits are distributed across typical flood water periods

Table 3-14. Summary of Projected Projects by GSA

Div ID	Subbasin	GSA/ Sub-region[1]	Project Description	Project Start	Simulated Benefits by WY Type (AFY)					Months with Benefits	Notes
					W	AN	BN	D	C		
107	Madera	MC	Chowchilla Bypass Flood Flow Recharge Phase 2	2030	49,600	0	0	0	0	Dec-Mar	Average anticipated recharge associated with Chowchilla Bypass Flood Flow Recharge Phase 2 (Projects 2-5, Option C in Madera Subbasin), assuming construction finishes by 2030 and benefits are distributed across typical flood water periods
108	Madera	MC	Flood Flow Recharge	2024	22,500	0	0	0	0	Dec-Mar	Average anticipated recharge associated with SB122, based on benefits in 2023 distributed across typical flood water periods (assuming benefits increase by 5% in first three W years, then same benefits in all future W years)
109	Madera	MC	Additional Water Rights Diversions for Ag	2024	19,600	0	0	0	0	May-Aug	Average anticipated diversions associated with SB122 and water rights use, based on benefits in 2023 distributed across typical peak irrigation season during flood water years
N/A	Chowchilla	MC	Demand Management	2024	--	--	--	--	--	--	Simulated through land use changes.
110	Madera	MID	Ellis Basin (with MC)	2024	275	150	150	0	0	Jan-Apr	Average benefits distributed across typical months with recharge; Partial benefit shown (50%, remainder of benefit assigned to MC)

Table 3-14. Summary of Projected Projects by GSA											
Div ID	Subbasin	GSA/ Sub-region[1]	Project Description	Project Start	Simulated Benefits by WY Type (AFY)					Months with Benefits	Notes
					W	AN	BN	D	C		
111	Madera	MID	Berry Basin (with CM)	2024	221	30	10	0	0	Jan-Apr	Average benefits distributed across typical months with recharge; Partial benefit shown (50%, remainder of benefit assigned to CM)
112	Madera	MID	Allende Basin	2024	5,000	1,300	400	0	0	Jan-Apr	Average benefits distributed across typical months with recharge (based on 2023)
113	Madera	MID	Additional Recharge Basins with CM (Golf Course)	2024	51	25	0	0	0	Jan-Apr	Average benefits distributed across typical months with recharge (based on 2023); Partial benefit shown (50%, remainder of benefit assigned to MID)
114	Madera	MID	Additional Recharge Basins with CM (Absire)	2024	240	120	0	0	0	Jan-Apr	Average benefits distributed across typical months with recharge (based on 2023); Partial benefit shown (50%, remainder of benefit assigned to MID)
115	Madera	MID	Additional Recharge Basins with CM (Stadium)	2024	164	82	0	0	0	Jan-Apr	Average benefits distributed across typical months with recharge (based on 2023); Partial benefit shown (50%, remainder of benefit assigned to MID)
116	Madera	MID	Additional Recharge Basins with CM (Mitchell)	2024	88	44	0	0	0	Jan-Apr	Average benefits distributed across typical months with recharge (based on 2023); Partial benefit shown (50%, remainder of benefit assigned to MID)

Table 3-14. Summary of Projected Projects by GSA											
Div ID	Subbasin	GSA/ Sub-region[1]	Project Description	Project Start	Simulated Benefits by WY Type (AFY)					Months with Benefits	Notes
					W	AN	BN	D	C		
117	Madera	MID	Additional Recharge Basins with CM (Mosesian)	2024	88	44	0	0	0	Jan-Apr	Average benefits distributed across typical months with recharge (based on 2023); Partial benefit shown (50%, remainder of benefit assigned to MID)
118	Madera	MID	Rehab Recharge Basins (MID Basin #1 - 32.2)	2024	1,560	780	585	0	0	Jan-Apr	Average benefits distributed across typical months with recharge (based on 2023)
119	Madera	MID	Rehab Recharge Basins (MID Basin #2 - Airport)	2024	4,920	2,460	1,845	0	0	Jan-Apr	Average benefits distributed across typical months with recharge (based on 2023)
120	Madera	MID	Rehab Recharge Basins (MID Basin #3 - Russell)	2024	2,040	1,020	765	0	0	Jan-Apr	Average benefits distributed across typical months with recharge (based on 2023)
121	Madera	MID	Rehab Recharge Basins (MID Basin #4 - Burgess)	2024	480	240	180	0	0	Jan-Apr	Average benefits distributed across typical months with recharge (based on 2023)
122	Madera	MID	Rehab Recharge Basins (MID Basin #5 - Beeman)	2024	2,760	1,380	1,035	0	0	Jan-Apr	Average benefits distributed across typical months with recharge (based on 2023)

Table 3-14. Summary of Projected Projects by GSA											
Div ID	Subbasin	GSA/ Sub-region[1]	Project Description	Project Start	Simulated Benefits by WY Type (AFY)					Months with Benefits	Notes
					W	AN	BN	D	C		
123	Madera	MID	Rehab Recharge Basins (MID Basin #6 - Madera Lake)	2024	240	120	90	0	0	Jan-Apr	Average benefits distributed across typical months with recharge (based on 2023)
124	Madera	MID	Additional Recharge Basins Phase 1 (MID Basin #8 - Campbell)	2024	7,540	3,770	1,044	0	0	Jan-Apr	Average benefits distributed across typical months with recharge (based on 2023)
125	Madera	MID	Additional Recharge Basins Phase 1 (MID Basin #9 - Basila)	2024	5,460	2,730	756	0	0	Jan-Apr	Average benefits distributed across typical months with recharge (based on 2023)
126	Madera	MID	Additional Recharge Basins Phase 2 (MID Basin #10)	2025	5,400	2,800	1,000	0	0	Jan-Apr	Average anticipated benefits of Phase 2 recharge basin on acquired parcel distributed across typical months with recharge, assuming recharge begins in 2025
127	Madera	MID	Additional Recharge Basins Phase 2 (Other New)	2035	48,600	25,200	9,000	0	0	Jan-Apr	Average anticipated benefits of remaining Phase 2 recharge basins planned in GSP distributed across typical months with recharge
128	Madera	MID	On-Farm Recharge Phase 1	2024	1,300	500	0	0	0	Dec-Mar	Average benefits distributed across typical on-farm recharge period

Table 3-14. Summary of Projected Projects by GSA

Div ID	Subbasin	GSA/ Sub-region[1]	Project Description	Project Start	Simulated Benefits by WY Type (AFY)					Months with Benefits	Notes
					W	AN	BN	D	C		
129	Madera	MID	On-Farm Recharge Phase 2	2025	4,000	3,000	0	0	0	Dec-Mar	Average anticipated benefits from GSP and distributed across typical on-farm recharge period
130	Madera	MID	MID Pipeline	2024	420	420	420	420	420	May-Aug	Average benefits based on GSP and distributed across typical peak irrigation season
131	Madera	MID	WaterSMART Pipeline	2024	880	880	880	880	880	May-Aug	Average benefits based on GSP and distributed across typical peak irrigation season
132	Madera	MID	WaterSMART SCADA	2024	1,230	1,230	1,230	1,230	1,230	May-Aug	Average benefits based on GSP and distributed across typical peak irrigation season
133	Madera	MID	Water Supply Partnerships	2025	3,990	3,990	3,990	3,990	3,990	May-Aug	Average benefits based on GSP and distributed across typical peak irrigation season
134	Madera	MID	Incentive Program	2024	5,010	5,010	5,010	5,010	5,010	May-Aug	Average benefits based on GSP and distributed across typical peak irrigation season
135	Madera	MWD	Expanded Surface Water Purchase	2024	6,000	6,000	1,500	0	0	May-Aug	Average benefits based on GSP and distributed across typical peak irrigation season; first year estimated from WY 2023 Annual Report
136	Madera	NSWD	Exercise of Appropriative Right	2024	15,700	0	0	0	0	Jan-Jun	Average benefits and timing estimated based on NSWD GSP and input from GSA technical team

Table 3-14. Summary of Projected Projects by GSA											
Div ID	Subbasin	GSA/ Sub-region[1]	Project Description	Project Start	Simulated Benefits by WY Type (AFY)					Months with Benefits	Notes
					W	AN	BN	D	C		
137	Madera	RCWD	1 - North WWTP ponds	2024	1,200	1,200	1,200	1,200	1,200	Jan-Dec	Average benefits and timing estimated based on RCWD GSP and input from GSA technical team
138	Madera	RCWD	2 - South WWTP ponds	2024	100	0	0	0	0	Jan-May	Average benefits and timing estimated based on RCWD GSP and input from GSA technical team
139	Madera	RCWD	3,4 - Flood MAR	2024	120	120	0	0	0	Dec-Mar	Average benefits and timing estimated based on RCWD GSP and input from GSA technical team
140	Madera	RCWD	5 - In-lieu Irrigation System	2024	4,155	4,155	0	0	0	May-Aug	Average benefits and timing estimated based on RCWD GSP and input from GSA technical team
141	Madera	RCWD	6,7,8 - Expanded in-lieu system	2027	1,845	1,845	0	0	0	May-Aug	Average benefits and timing estimated based on RCWD GSP and input from GSA technical team
142	Madera	RCWD	9 - Recharge basin	2030	4,500	4,500	0	0	0	Jan-Apr	Average benefits and timing estimated based on RCWD GSP and input from GSA technical team
143	Madera	RCWD	10 - Root Creek channel	2027	1,000	1,000	1,000	1,000	1,000	Jan-Apr	Average benefits and timing estimated based on RCWD GSP and input from GSA technical team
144	Madera	RCWD	11 - Riverstone Demand Reduction	2024-2035	2,000	2,000	2,000	2,000	2,000	May-Aug	Average benefits and timing estimated based on RCWD GSP and input from GSA technical team

Table 3-14. Summary of Projected Projects by GSA											
Div ID	Subbasin	GSA/ Sub-region[1]	Project Description	Project Start	Simulated Benefits by WY Type (AFY)					Months with Benefits	Notes
					W	AN	BN	D	C		
145	Madera	GFWD	Gravelly Ford Canal	2024	4,338	2,892	2,169	0	0	Feb-Jun	Average benefits and timing estimated based on GFWD GSP and input from GSA technical team
146	Madera	GFWD	Gravelly Ford Recharge Basin	2024	2,700	1,800	1,350	0	0	Feb-Jun	Average benefits and timing estimated based on GFWD GSP and input from GSA technical team
147	Madera	GFWD	Cottonwood Creek	2026	3,011	2,007	1,505	0	0	Feb-Jun	Average benefits and timing estimated based on GFWD GSP and input from GSA technical team

[1] CWD = Chowchilla Water District GSA; MC = Madera County GSA; SVMWC = Sierra Vista Mutual water Company GSA; TTWD = Triangle T Water District GSA; CM = City of Madera GSA; MID = Madera Irrigation District GSA; MWD = Madera Water District GSA; NSWD = New Stone Water District GSA; RCWD = Root Creek Water District GSA; GFWD = Gravelly Ford Water District GSA

3.3.5. Groundwater System

The development of groundwater system datasets for projected future scenarios is described below.

Boundary Conditions

Several different boundary head conditions were developed for use in evaluating potential future conditions in the projected future scenarios. Future boundary head conditions scenarios were developed for: 1) no subsurface flow boundary conditions, 2) continuation of the average historical trend in groundwater levels over the period 1989 to 2015, and 3) gradual ramping down of the average historical groundwater level trend over the implementation period (2020-2040) with long-term stable trends in groundwater levels from 2040 to 2070 and 2090. In developing the future groundwater head conditions, head conditions developed over the historical model base period from 1989 to 2015 were substituted based on similar water year types for the projected period. The relative changes in boundary head conditions from the base period were used to represent the appropriate trend in boundary head conditions to be represented at each boundary node. In scenarios in which the historical trend in boundary heads was ramped down over the implementation period and then set as stable for the sustainability period past 2040, adjustments were applied to achieve reductions in trend slopes in intervals of five years from 2020 to 2040 and then an adjustment to represent a zero long-term trend was applied for both the periods 2040 to 2070 and also 2070 to 2090.

In the future simulations, both the Projected (No Action) and Projected (No Action) with Climate Change scenarios assume no flow boundary conditions, under which no subsurface flow enters or exits the model domain along the model boundary. In the No Action scenarios, it is assumed that no subbasin is subject to SGMA, so levels continue to fall in neighboring subbasins also. In this situation, inflows probably remain about the same. To model this, a boundary condition of no subsurface inflow or outflow at the model boundary is assumed (approximately 5-10 miles outside Chowchilla and Madera Subbasin boundaries. The Projected with Projects and Projected with Projects and with Climate Change scenarios utilize general head boundary conditions with the assumption that adjacent basins are also implementing projects and experience ramping down of historical groundwater level trends with generally stable water level conditions after 2040. The same conductance values from the Historical simulation period are also used for the projected future general head boundary conditions.

Groundwater Pumping

The pumping specifications used for the historical simulation period were retained for the duration of all projected simulations (2024-2090) except in the Western Management Area (MA) of Chowchilla Subbasin. Due to the general need to reduce pumping from the Lower Aquifer in many parts of the Western MA to mitigate for potential subsidence impacts, in projected scenarios much of the pumping that occurred from the Lower Aquifer in the Western MA under the historical simulations was shifted into the Upper Aquifer model layers for the projected simulations. As a result, in the Western MA approximately 90 percent of projected pumping occurs in the Upper Aquifer and 10 percent is in the Lower Aquifer. Maps of the vertical distribution of projected agricultural pumping by layer are presented in **Figures 3-62 through 3-68** and for projected urban pumping by layer in **Figures 3-69 through 3-75**.

3.3.6. Initial Conditions

Initial conditions used for projected future simulations in 2024 utilized the final conditions from the historical simulation at the end of 2023. The initial conditions included used of the final conditions of the historical simulation period for the unsaturated zone, root zone, small watersheds, and groundwater levels. Initial groundwater levels are shown in **Figures 3-76 through 3-82**.

4. GROUNDWATER FLOW MODEL RESULTS

This section presents the results from simulations conducted with MCSim_v2. Results presented in this section include the results from model calibration, including calibrated aquifer parameters, and simulated Subbasin water budgets for various scenarios. The water budget results presented in this section are rounded to two significant digits consistent with the typical uncertainty associated with the methods and sources used in the analysis. Water budget component results may not sum to the totals presented because of rounding.

4.1. Model Calibration Results

Model calibration was achieved through comparison of observed groundwater levels and subsidence to model results. Observations used to constrain aquifer parameter values included approximately 39,100 groundwater level observations from 401 wells. Observations used to constrain subsidence parameters included approximately 10,300 subsidence measurements from 37 subsidence monitoring stations.

Calibration quality quantifies the ability of the groundwater model to simulate observed groundwater levels. These results are evaluated with respect to fit statistics outlined by Anderson and Woessner (2002). More qualitative measures of model fit are also commonly used to evaluate model calibration quality and included in the model results.

4.1.1. Statistical Measures of Model Fit

Model calibration was evaluated through five common residual error statistics used to characterize model fit. These include the mean of residual error (ME), mean of absolute residual error (MAE), root mean of squared residual error ($RMSE$), Normalized RMSE ($NRMSE$), and linear correlation coefficient (R). The residual error here is calculated by subtracting the observed value from the simulated value at a specific physical location and time.

The mean of residual error (ME) is a measure of the general model tendency to overestimate (+) or underestimate (-) measured values. In general, it is a quantification of the model bias given by:

$$ME = \frac{1}{N}\sum_{i=1}^{N}(y_i - \hat{y}_i)$$

Where: N is the total number of observations

y_i is the ith observed value

$\hat{y}_i$ is the ith simulated value of a model dependent variable

The mean absolute residual errors (MAE) is more robust to represent the goodness of fit as no individual errors will be canceled in the estimation as ME. The MAE estimates the average magnitude of the error between modeled and observed values and is defined as:

$$MAE = \frac{1}{N}\sum_{i=1}^{N}|(y_i - \hat{y}_i)|$$

The root mean of squared residual error ($RMSE$) is defined as the square root of the second moment of the differences between observed and simulated error. Since the error between each observed and simulated value is squared, larger errors tend to have a greater impact on the value of the $RMSE$, therefore RMSE is generally more sensitive to outliers than the MAE.

$$RMSE = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(y_i - \hat{y}_i)^{2}}$$

The normalized root mean squared error ($NRMSE$) is calculated to account for the scale dependency of the $RMSE$ and is a measure of the $RMSE$ divided by the range of observations (Anderson and Woessner, 2002).

The linear correlation coefficient (R) is defined in the following equations:

$$R = \frac{COV(y, \hat{y})}{\sigma_y . \sigma_{\hat{y}}}$$

Where: $COV(y, \hat{y}_i)$ is the covariance between the observed (y) and simulated ($\hat{y}$) values

σ_y is the standard deviation of the observed values

$\sigma_{\hat{y}}$ is the standard deviation of the simulated values

The value of R lies between 1 (perfect linear correlation) and -1 (perfect linear correlation in the opposite direction). Usually, simulated and observed quantity is plotted in a scatter diagram to represent the model calibration results graphically with associated linear correlation coefficient R.

There are no uniform calibration standards used to determine an acceptable calibration of a groundwater flow model (Anderson and Woessner, 2002; Anderson et al., 2015). Summary statistics, such as those discussed in this section, should be used to evaluate the fit of simulated values to observed data and to minimize the error between these values (Murray-Darling Basin Commission, 2001; ASTM, 2008). For the purposes of calibrating MCSim_v2, calibration targets were set to minimize the model error to within 10% of the range of observed values.

4.1.2. Groundwater Level Calibration

A subset of the approximately 2,400 wells that have observed groundwater levels in the study area was selected for model calibration. Wells were selected to provide a broad representation of the model domain based on the spatial distribution, availability of associated well construction information, depth zone of well completion, and period of record of available water level data. A total of 401 wells were selected to be used in calibration of MCSim_v2 with a total of 39,103 water level observations during the calibration period. Simulated and observed groundwater elevations were compared over the WY 1989 through 2023 calibration period.

Groundwater level calibration statistics are presented in **Table 4-1**. As stated in **Section 4.1.1**, the calibration targets for MCSim_v2 were set to minimize the model error to within 10% of the range of observed values. Observed groundwater level measurements used for calibration range from -183 to 339 feet, therefore an acceptable *RMSE* for MCSim_v2 would be 52.2 feet. The final calibrated *RMSE* was 25.6 feet, resulting in a *NRMSE* of 5%, well within acceptable limits (**Figure 4-1**). The calculated *ME* (-8.2 feet) and *MAE (*16.2 feet*)* indicate that the model tends to simulate higher groundwater levels than observed (over-predict). The relation between observed and simulated groundwater elevations is shown by layer in **Figure 4-2**. Points plotting above 1-to-1 correlation line represent observations where MCSim_v2 is simulating higher than observed groundwater elevations, while points plotting below the 1-to-1 correlation line represent observations where MCSim_v2 is simulating lower than observed groundwater elevations. In general, while points are plotting close to the 1-to-1 correlation line (R = 0.90), the model tends to over simulate water levels at lower observed groundwater elevations. The greatest residuals are generally observed in the Lower Aquifer, likely because of the thickness of layers 4, 5, and 6. Because the model can only produce one water level per model layer, it is hard to capture the nuance of water levels within a thicker model layers. The spatial distribution of residual errors in the simulated levels by well are presented in **Figure 4-3**. MCSim_v2 is generally well calibrated. Residuals tend to be randomly distributed, indicating no clear bias in the model.

Groundwater hydrographs of simulated and observed groundwater elevations used for model calibration are included in **Appendix B.**

Table 4-1. Groundwater Level Calibration Statistics

Calibration Statistic	Result	Target
Mean of Residual Error (ME)	-8.2 feet	-
Mean Absolute Residual Error (MAE)	16.2 feet	-
Root Mean of Squared Residual Error (RMSE)	25.6 feet	52.2 feet
Normalized Root Mean of Squared Residual Error (NRMSE)	5%	10%
Linear Correlation Coefficient (R)	0.90	1

4.1.3. Subsidence Calibration

Observed calibration measurements are generally unavailable during the early portion of the historical simulation period, with more subsidence monitoring beginning primarily in 2011. Observed subsidence measurements were compared to simulated compaction at 37 monitoring stations. Hydrographs of observed versus simulated subsidence are available in **Appendix C**. The spatial distribution of residual errors in the simulated subsidence by station are presented in **Figure 4-4**. In general, simulated subsidence is slightly greater than observed, but trends and rates generally match observed data where available.

4.2. Aquifer Parameters

Initial end member values assigned for each aquifer parameter were based on reported literature values. These values were further refined and adjusted during the calibration process. Final calibrated end member values for each of the aquifer parameters are presented in **Table 4**-2 and zone multipliers used to calculate aquifer parameters are presented in **Table 4-3**. These values were used to calculate aquifer parameter values for each model node in each model layer. The process for calculating aquifer parameters was previously described in **Section 3.1.4.1**.

Table 4-2. Summary of Aquifer Parameters End Member Values

Parameter	End Member Value
pKh (power law empirical parameter for Kh)	0.6
pKv (power law empirical parameter for KV)	-0.82
Kh_{C0} (Kh end member of coarse materials)	350
Kh_{F0} (Kh end member of fine materials)	0.5
VKA (Kv / Kh anisotropy ratio)	0.08
Ss_C (Ss end member of coarse materials)	1.00E-06
Ss_F (Ss end member of fine materials)	7.77E-06
Sy_C (Sy end member of coarse materials)	0.2393
Sy_F (Sy end member of fine materials)	0.03

Table 4-3. Summary of Zone Multipliers used to Calculate Aquifer Parameters

	Layer	Zone Multipliers			
		Horizontal Hydraulic Conductivity	Vertical Hydraulic Conductivity	Specific Yield	Specific Storage
Within Corcoran Clay (Confined)	1-3	1	1.1	1	1
	4	0.15	0.3	0.2	0.2
	5	0.25	0.6	0.2	0.2
	6	0.4	0.6	0.3	0.3
Within Corcoran Clay (Semi-unconfined)	1-3	1	1.1	1	1
	4	0.15	0.3	0.2	0.2
	5	0.35	0.6	0.2	0.2
	6	0.4	0.6	0.3	0.3
Outside of Corcoran Clay - West of Highway 99	1	0.25	0.5	1	1
	2	0.5	0.2	1	1
	3	0.7	0.7	1	1
	4	0.5	0.7	0.4	0.4

Table 4-3. Summary of Zone Multipliers used to Calculate Aquifer Parameters					
	Layer	Zone Multipliers			
		Horizontal Hydraulic Conductivity	Vertical Hydraulic Conductivity	Specific Yield	Specific Storage
	5	0.1	0.8	0.3	0.4
	6	0.3	0.4	0.6	0.6
Outside of Corcoran Clay - East of Highway 99	1	0.25	0.5	0.8	0.8
	2	0.35	0.35	0.8	0.8
	3	0.08	0.05	0.8	0.8
	4	0.05	0.3	0.3	0.4
	5	0.01	0.35	0.3	0.4
	6	0.6	0.6	0.65	0.6
Shallow Bedrock Zone	1	0.075	0.1	0.6	0.6
	2	0.085	0.085	0.6	0.6
	3	0.008	0.005	0.6	0.6
	4	0.005	0.03	0.1	0.2
	5	0.001	0.035	0.1	0.2
	6	0.06	0.06	0.45	0.4
Buffer Layer	7	0.001	0.001	0.001	0.001

4.2.1. Hydraulic Conductivity

The calibrated horizontal hydraulic conductivity (Kh) averages by layer are presented in **Table 4-4**. In the Chowchilla Subbasin, average Kh values range from 9.11 feet per day (ft/d) in layer 4 to 95.42 ft/d in layer 2. In the Madera Subbasin, average Kh values range from 7.78 ft/d in layer 5 to 68.30 ft/d in layer 2. Across the entire MCSim_v2 domain, average Kh values range from 10.30 ft/d in layer 5 to 87.92 ft/d in layer 2. The calibrated Kh values in MCSim_v2 are shown by model layer in **Figures 4-5 through 4-11**.

The calibrated vertical hydraulic conductivity (Kv) averages by layer are presented in **Table 4-4**. In the Chowchilla Subbasin, average Kv values range from 0.0206 ft/d in layer 4 to 0.0885 ft/d in layer 2. In the Madera Subbasin, average Kv values range from 0.0234 ft/d in layer 4 to 0.0585 ft/d in layer 1. Across the entire MCSim_v2 domain, average Kv values range from 0.0236 ft/d in layer 4 to 0.0797 ft/d in layer 1. The calibrated aquitard Kv averages by layer are also presented in **Table 4-4**. The aquitard layers simulated in the model (see **Section 3.1.1.4**) include the A-Clay (Layer 2), C-Clay (Layer 3), and E-Clay, or Corcoran Clay (Layer 4). The calibrated Kv values in MCSim_v2 are shown by model layer in **Figures 4-12 through 4-21**.

Table 4-4. Summary of MCSim_v2 Calibrated Hydraulic Conductivity			
Model Layer	AQUIFER PARAMETERS		
	Horizontal Hydraulic Conductivity (feet/day)	Vertical Hydraulic Conductivity (feet/day)	Aquitard Vertical Hydraulic Conductivity (feet/day)
CHOWCHILLA SUBBASIN			
1	82.19	0.0837	-
2	95.42	0.0885	0.0016
3	73.41	0.0742	0.0016
4	9.11	0.0206	0.0047
5	16.92	0.0379	-
6	11.11	0.0300	-
7	0.05	0.0001	-
Upper Aquifer	83.67	0.0821	-
Lower Aquifer	12.38	0.0295	-
MADERA SUBBASIN			
1	48.48	0.0585	-
2	68.30	0.0547	0.0034
3	55.68	0.0487	0.0034
4	11.31	0.0234	0.0030
5	7.78	0.0312	-
6	21.90	0.0273	-
7	0.01	0.0005	-
Upper Aquifer	57.49	0.0540	-
Lower Aquifer	13.66	0.0273	-
ENTIRE MODEL DOMAIN			
1	77.05	0.0797	-
2	87.92	0.0758	0.0024
3	71.96	0.0680	0.0024
4	11.95	0.0236	0.0039
5	10.30	0.0346	-
6	17.85	0.0298	-
7	0.04	0.0002	-
Upper Aquifer	78.98	0.0745	-
Lower Aquifer	13.37	0.0293	-

Note: Layers 1-3 are considered the Upper Aquifer, Layer 4-6 are considered the Lower Aquifer, and Layer 7 is considered a buffer layer.

4.2.2. Storage Coefficients

The calibrated specific storage (SS) averages by layer are presented in **Table 4-5**. In the Chowchilla Subbasin, average SS values range from 1.23E-06 feet^{-1} in layer 4 to 4.82E-06 feet^{-1} in layer 3. In the Madera Subbasin, average SS values range from 1.83E-06 feet^{-1} in layer 4 to 3.84E-06 feet^{-1} in layer 1. Across the entire MCSim_v2 domain, average SS values range from 1.51E-06 feet^{-1} in layer 4 to 4.23E-06 feet^{-1} in layer 3. The calibrated SS values in MCSim_v2 are shown by model layer in **Figures 4-22 through 4-28**.

The calibrated specific yield (Sy) averages by layer are presented in **Table 4-5**. In the Chowchilla Subbasin, average Sy values range from 0.02 in layers 4-6 to 0.13 in layer 2. In the Madera Subbasin, average Sy values range from 0.03 in layers 4-5 to 0.12 in layer 2. Across the entire MCSim_v2 domain, average Sy values range from 0.02 in layer 5 to 0.13 in layer 2. The calibrated Sy values in MCSim_v2 are shown by model layer in **Figures 4-29 through 4-35**.

Table 4-5. Summary of MCSim_v2 Calibrated Storage Coefficients

Model Layer	AQUIFER PARAMETERS	
	Specific Storage (feet^{-1})	Specifc Yield (-)
CHOWCHILLA SUBBASIN		
1	4.67E-06	0.12
2	4.45E-06	0.13
3	4.82E-06	0.11
4	1.23E-06	0.02
5	1.26E-06	0.02
6	2.13E-06	0.02
7	1.69E-07	1.73E-03
Upper Aquifer	4.65E-06	0.12
Lower Aquifer	1.54E-06	0.02
MADERA SUBBASIN		
1	3.84E-06	0.11
2	3.46E-06	0.12
3	3.64E-06	0.11
4	1.83E-06	0.03
5	1.84E-06	0.03
6	2.67E-06	0.04
7	2.44E-06	2.44E-02
Upper Aquifer	3.65E-06	0.11
Lower Aquifer	2.11E-06	0.03

Table 4-5. Summary of MCSim_v2 Calibrated Storage Coefficients		
Model Layer	AQUIFER PARAMETERS	
	Specific Storage (feet^{-1})	Specifc Yield (-)
ENTIRE MODEL DOMAIN		
1	4.11E-06	0.12
2	3.94E-06	0.13
3	4.23E-06	0.12
4	1.51E-06	0.03
5	1.55E-06	0.02
6	2.32E-06	0.04
7	9.55E-07	9.58E-03
Upper Aquifer	4.09E-06	0.12
Lower Aquifer	1.79E-06	0.03

Note: Layers 1-3 are considered the Upper Aquifer, Layer 4-6 are considered the Lower Aquifer, and Layer 7 is considered a buffer layer.

4.2.3. Subsidence Parameters

The calibrated inelastic specific storage (SCI) averages by layer are presented in **Table 4-6**. In the Chowchilla Subbasin, average SCI values range from 2.29E-05 feet^{-1} in layer 2 to 3.09E-05 feet^{-1} in layer 6. In the Madera Subbasin, average SCI values range from 1.85E-05 feet^{-1} in layer 2 to 2.28E-05 feet^{-1} in layer 6. Across the entire MCSim_v2 domain, average SCI values range from 2.00E-05 feet^{-1} in layer 2 to 2.62E-05 feet^{-1} in layer 6. The calibrated SCI values in MCSim_v2 are shown by model layer in **Figures 4-36 through 4-42**.

The calibrated elastic specific storage (SCE) averages by layer are presented in **Table 4-6**. In the Chowchilla Subbasin, average SCE values range from 1.56E-04 feet^{-1} in layer 2 to 2.23E-04 feet^{-1} in layer 6. In the Madera Subbasin, average SCE values range from 7.55E-05 feet^{-1} in layer 2 to 1.11E-04 feet^{-1} in layer 6. Across the entire MCSim_v2 domain, average SCE values range from 1.34E-04 feet^{-1} in layer 1 to 1.93E-04 feet^{-1} in layer 6. The calibrated SCE values in MCSim_v2 are shown by model layer in **Figures 4-43 through 4-49**.

The calibrated interbed vertical hydraulic conductivity (interbed Kv) averages by layer are presented in **Table 4-4**. In the Chowchilla Subbasin, average interbed Kv values range from 0.0234 ft/d in layer 4 to 0.1087 ft/d in layer 2. In the Madera Subbasin, average interbed Kv values range from 0.0257 ft/d in layer 4 to 0.0700 ft/d in layer 1. Across the entire MCSim_v2 domain, average interbed Kv values range from 0.0276 ft/d in layer 4 to 0.1013 ft/d in layer 1. The calibrated interbed Kv values in MCSim_v2 are shown by model layer in **Figures 4-50 through 4-56**.

Table 4-6. Summary of MCSim_v2 Calibrated Subsidence Parameters

Model Layer	SUBSIDENCE PARAMETERS		
	Inelastic Specific Storage (feet^{-1})	Elastic Specific Storage (feet^{-1})	Interbed Vertical Hydraulic Conductivity (feet/day)
CHOWCHILLA SUBBASIN			
1	2.40E-05	1.64E-04	0.1012
2	2.29E-05	1.56E-04	0.1087
3	2.48E-05	1.71E-04	0.0880
4	2.67E-05	1.84E-04	0.0234
5	2.70E-05	1.89E-04	0.0431
6	3.09E-05	2.23E-04	0.0317
7	2.77E-05	2.77E-04	0.0001
Upper Aquifer	2.39E-05	1.64E-04	0.0993
Lower Aquifer	2.82E-05	1.99E-04	0.0327
MADERA SUBBASIN			
1	2.06E-05	7.75E-05	0.0700
2	1.85E-05	7.55E-05	0.0685
3	1.97E-05	7.80E-05	0.0611
4	2.22E-05	9.53E-05	0.0257
5	2.11E-05	9.83E-05	0.0351
6	2.28E-05	1.11E-04	0.0293
7	1.29E-05	1.29E-04	0.0005
Upper Aquifer	1.96E-05	7.70E-05	0.0665
Lower Aquifer	2.20E-05	1.02E-04	0.0300
ENTIRE MODEL DOMAIN			
1	2.09E-05	1.34E-04	0.1013
2	2.00E-05	1.35E-04	0.0978
3	2.16E-05	1.46E-04	0.0859
4	2.45E-05	1.71E-04	0.0276
5	2.46E-05	1.78E-04	0.0395
6	2.62E-05	1.93E-04	0.0328
7	2.16E-05	2.16E-04	0.0002
Upper Aquifer	2.09E-05	1.38E-04	0.0950
Lower Aquifer	2.51E-05	1.81E-04	0.0333

Note: Layers 1-3 are considered the Upper Aquifer, Layer 4-6 are considered the Lower Aquifer, and Layer 7 is considered a buffer layer.

4.3. Chowchilla Subbasin Model Results

The following section summarizes the analyses and results for the Chowchilla Subbasin. Water budget results presented below reflect the complete groundwater system water budget. The surface water system water budget, as presented in the GSP, excludes subsurface flows and presents net recharge to groundwater using the net seepage, deep percolation, and groundwater pumping components.

4.3.1. Historical Period, WY 1989-2023

The water budget during the historical period simulation was calculated for the 1989-2023 water years spanning three different sub-time periods: the GSP historical period (WY 1989-2015), a transitional period (WY 2016-2019), and the GSP implementation period (WY 2020-2023). The water budgets presented in this section summarize results for the GSP historical period (WY 1989-2015) and the entire calibrated historical period (WY 1989-2023).

GSP Historical Period (WY 1989-2015)

Summarized results for major components of the GSP historical period water budget as they relate to the groundwater system (GWS) are presented in **Table 4-7**. The positive net seepage values (on average 53,000 AF per year) represent net stream seepage to groundwater. Deep percolation represents another large net inflow averaging about 120,000 AF per year. The positive net subsurface flows (on average 18,000 AF per year) represent the combined subsurface flows into the Subbasin from adjacent subbasins and upland areas. The positive subsidence value (on average 42,000 AF per year), while an inflow to the GWS water budget, represents active compaction within the Subbasin. Groundwater pumping (on average -260,000 AF per year) is a large outflow from the GWS. Overall, the water budget results for the 27-year historic period indicates a cumulative change in groundwater storage of about -770,000 AF, which equals an average annual change in groundwater storage of about -28,000 AF per year. These change in storage estimates equate to total decreases in storage in the Subbasin of about -5.27 AF per acre on average over the 27 years and an annual decrease of about -0.20 AF per acre across the entire Subbasin (approximately 146,000 acres).

Detailed results for each of the individual water budget components in the historical water budget are presented in **Appendix D.1**, simulated groundwater elevation hydrographs at select wells are presented in **Appendix E.1**, and simulated subsidence hydrographs are presented in **Appendix F.1**.

Table 4-7. Chowchilla Subbasin GSP Historical Period Groundwater System Annual Water Budget Summary (acre-feet)

Water Budget Component	Average Annual (WY 1989-2015)
Net Stream Seepage	53,000
Deep Percolation	120,000
Groundwater Extractions	-260,000
Subsidence	42,000

Net Subsurface Flows	18,000
Annual Change in Groundwater Storage	**-28,000**

Calibrated Historical Period (WY 1989-2023)

Summarized results for major components of the calibrated historical period water budget as they relate to the groundwater system (GWS) are presented in **Table 4-8**. The positive net seepage values (on average 59,000 AF per year) represent net stream seepage to groundwater. Deep percolation represents another large net inflow averaging about 120,000 AF per year. The positive net subsurface flows (on average 21,000 AF per year) represent the combined subsurface flows into the Subbasin from adjacent subbasins and upland areas. The positive subsidence value (on average 42,000 AF per year), while an inflow to the GWS water budget, represents active compaction within the Subbasin. Groundwater pumping (on average -270,000 AF per year) is a large outflow from the GWS. Overall, the water budget results for the 35-year historic period indicates a cumulative change in groundwater storage of about -700,000 AF, which equals an average annual change in groundwater storage of about -20,000 AF per year. These change in storage estimates equate to total decreases in storage in the Subbasin of about -4.81 AF per acre on average over the 35 years and an annual decrease of about -0.14 AF per acre across the entire Subbasin (approximately 146,000 acres).

Detailed results for each of the individual water budget components in the historical water budget are presented in **Appendix D.1**, simulated groundwater elevation hydrographs at select wells are presented in **Appendix E.1**, and simulated subsidence hydrographs are presented in **Appendix F.1**.

Table 4-8. Chowchilla Subbasin Calibrated Historical Period Groundwater System Annual Water Budget Summary (acre-feet)

Water Budget Component	Average Annual (WY 1989-2023)
Net Stream Seepage	59,000
Deep Percolation	120,000
Groundwater Extractions	-270,000
Subsidence	42,000
Net Subsurface Flows	21,000
Annual Change in Groundwater Storage	**-20,000**

4.3.2. Projected Scenarios, WY 2024-2090

The water budget during the projected scenarios was calculated for the 2024-2090 water years spanning two different sub-time periods: the GSP implementation period (WY 2024-2039) and the GSP sustainability period (WY 2040-2090).

Projected with Projects

Implementation Period, WY 2024-2039

Summarized results for major components of the Projected with Projects Implementation Period water budget as they relate to the groundwater system (GWS) are presented in **Table 4-9**. The positive net seepage values (on average 80,000 AF per year) represent net stream seepage to groundwater. Deep percolation represents another large net inflow averaging about 95,000 AF per year. The positive net subsurface flows (on average 24,000 AF per year) represent the combined subsurface flows into the Subbasin from adjacent subbasins and upland areas. The positive subsidence value (on average 8,600 AF per year), while an inflow to the GWS water budget, represents active compaction within the Subbasin. Groundwater pumping (on average -220,000 AF per year) is a large outflow from the GWS. Overall, the water budget results for the 16-year implementation period indicates a cumulative change in groundwater storage of about -200,000 AF, which equals an average annual change in groundwater storage of about -12,000 AF per year. These change in storage estimates equate to total decreases in storage in the Subbasin of about -1.36 AF per acre on average over the 16 years and an annual decrease of about -0.09 AF per acre across the entire Subbasin (approximately 146,000 acres).

Detailed results for each of the individual water budget components in the Projected with Projects water budget are presented in **Appendix D.1**, simulated groundwater elevation hydrographs at select wells are presented in **Appendix E.1**, and simulated subsidence hydrographs are presented in **Appendix F.1**.

Table 4-9. Chowchilla Subbasin Projected with Projects Implementation Period Groundwater System Annual Water Budget Summary (acre-feet)

Water Budget Component	Average Annual (2024-2039)
Net Stream Seepage	80,000
Deep Percolation	95,000
Groundwater Extractions	-220,000
Subsidence	8,600
Net Subsurface Flows	24,000
Annual Change in Groundwater Storage	**-12,000**

Sustainability Period, WY 2040-2090

Summarized results for major components of the Projected with Projects Sustainability Period water budget as they relate to the groundwater system (GWS) are presented in **Table 4-10**. The positive net seepage values (on average 90,000 AF per year) represent net stream seepage to groundwater. Deep percolation represents another large net inflow averaging about 98,000 AF per year. The positive net subsurface flows (on average 2,400 AF per year) represent the combined subsurface flows into the

Subbasin from adjacent subbasins and upland areas. The positive subsidence value (on average 310 AF per year), while an inflow to the GWS water budget, represents a small amount of active compaction within the Subbasin. Groundwater pumping (on average -190,000 AF per year) is a large outflow from the GWS. Overall, the water budget results for the 51-year historic period indicates a cumulative change in groundwater storage of about 300,000 AF, which equals an average annual change in groundwater storage of about 6,000 AF per year. These change in storage estimates equate to total increases in storage in the Subbasin of about 2.09 AF per acre on average over the 51 years and an annual increase of about 0.04 AF per acre across the entire Subbasin (approximately 146,000 acres).

Detailed results for each of the individual water budget components in the Projected with Projects water budget are presented in **Appendix D.1**, simulated groundwater elevation hydrographs at select wells are presented in **Appendix E.1**, and simulated subsidence hydrographs are presented in **Appendix F.1**.

Table 4-10. Chowchilla Subbasin Projected with Projects Sustainability Period Groundwater System Annual Water Budget Summary (acre-feet)

Water Budget Component	Average Annual (2040-2090)
Net Stream Seepage	90,000
Deep Percolation	98,000
Groundwater Extractions	-190,000
Subsidence	310
Net Subsurface Flows	2,400
Annual Change in Groundwater Storage	**6,000**

Projects with Projects and with Climate Change

Implementation Period, WY 2024-2039

Summarized results for major components of the Projected with Projects and with Climate Change Implementation Period water budget as they relate to the groundwater system (GWS) are presented in **Table 4-11**. The positive net seepage values (on average 69,000 AF per year) represent net stream seepage to groundwater. Deep percolation represents another large net inflow averaging about 90,000 AF per year. The positive net subsurface flows (on average 34,000 AF per year) represent the combined subsurface flows into the Subbasin from adjacent subbasins and upland areas. The positive subsidence value (on average 22,000 AF per year), while an inflow to the GWS water budget, represents active compaction within the Subbasin. Groundwater pumping (on average -240,000 AF per year) is a large outflow from the GWS. Overall, the water budget results for the 16-year implementation period indicates a cumulative change in groundwater storage of about -370,000 AF, which equals an average annual change in groundwater storage of about -23,000 AF per year. These change in storage estimates equate to total decreases in storage in the Subbasin of about -2.55 AF per acre on average over the 16 years and an annual decrease of about -0.16 AF per acre across the entire Subbasin (approximately 146,000 acres).

Detailed results for each of the individual water budget components in the Projected with Projects and with Climate Change water budget are presented in **Appendix D.1**, simulated groundwater elevation hydrographs at select wells are presented in **Appendix E.1**, and simulated subsidence hydrographs are presented in **Appendix F.1**.

Table 4-11. Chowchilla Subbasin Projected with Projects and with Climate Change Implementation Period Groundwater System Annual Water Budget Summary (acre-feet)

Water Budget Component	Average Annual (2024-2039)
Net Stream Seepage	69,000
Deep Percolation	90,000
Groundwater Extractions	-240,000
Subsidence	22,000
Net Subsurface Flows	34,000
Annual Change in Groundwater Storage	**-23,000**

Sustainability Period, WY 2040-2090

Summarized results for major components of the Projected with Projects and with Climate Change Sustainability Period water budget as they relate to the groundwater system (GWS) are presented in **Table 4-12**. The positive net seepage values (on average 84,000 AF per year) represent net stream seepage to groundwater. Deep percolation represents another large net inflow averaging about 94,000 AF per year. The positive net subsurface flows (on average 20,000 AF per year) represent the combined subsurface flows into the Subbasin from adjacent subbasins and upland areas. The positive subsidence value (on average 4,700 AF per year), while an inflow to the GWS water budget, represents active compaction within the Subbasin. Groundwater pumping (on average -200,000 AF per year) is a large outflow from the GWS. Overall, the water budget results for the 51-year historic period indicates a cumulative change in groundwater storage of about 85,000 AF, which equals an average annual change in groundwater storage of about 1,700 AF per year. These change in storage estimates equate to total increase in storage in the Subbasin of about 0.58 AF per acre on average over the 51 years and an annual increase of about 0.01 AF per acre across the entire Subbasin (approximately 146,000 acres).

Detailed results for each of the individual water budget components in the Projected with Projects and with Climate Change water budget are presented in **Appendix D.1**, simulated groundwater elevation hydrographs at select wells are presented in **Appendix E.1**, and simulated subsidence hydrographs are presented in **Appendix F.1**.

Table 4-12. Chowchilla Subbasin Projected with Projects and with Climate Change Sustainability Period Groundwater System Annual Water Budget Summary (acre-feet)	
Water Budget Component	**Average Annual (2040-2090)**
Net Stream Seepage	84,000
Deep Percolation	94,000
Groundwater Extractions	-200,000
Subsidence	4,700
Net Subsurface Flows	20,000
Annual Change in Groundwater Storage	**1,700**

Projected (No Action)

Implementation Period, WY 2024-2039

Summarized results for major components of the Projected (No Action) Implementation Period water budget as they relate to the groundwater system (GWS) are presented in **Table 4-13**. The positive net seepage values (on average 72,000 AF per year) represent net stream seepage to groundwater. Deep percolation represents another large net inflow averaging about 97,000 AF per year. The positive net subsurface flows (on average 32,000 AF per year) represent the combined subsurface flows into the Subbasin from adjacent subbasins and upland areas. The positive subsidence value (on average 20,000 AF per year), while an inflow to the GWS water budget, represents active compaction within the Subbasin. Groundwater pumping (on average -250,000 AF per year) is a large outflow from the GWS. Overall, the water budget results for the 16-year implementation period indicates a cumulative change in groundwater storage of about -490,000 AF, which equals an average annual change in groundwater storage of about -31,000 AF per year. These change in storage estimates equate to total decreases in storage in the Subbasin of about -3.37 AF per acre on average over the 16 years and an annual decrease of about -0.21 AF per acre across the entire Subbasin (approximately 146,000 acres).

Detailed results for each of the individual water budget components in the Projected (No Action) water budget are presented in **Appendix D.1**, simulated groundwater elevation hydrographs at select wells are presented in **Appendix E.1**, and simulated subsidence hydrographs are presented in **Appendix F.1**.

Table 4-13. Chowchilla Subbasin Projected (No Action) Implementation Period Groundwater System Annual Water Budget Summary (acre-feet)	
Water Budget Component	**Average Annual (2024-2039)**
Net Stream Seepage	72,000

Deep Percolation	97,000
Groundwater Extractions	-250,000
Subsidence	20,000
Net Subsurface Flows	32,000
Annual Change in Groundwater Storage	**-31,000**

Sustainability Period, WY 2040-2090

Summarized results for major components of the Projected (No Action) Sustainability Period water budget as they relate to the groundwater system (GWS) are presented in **Table 4-14**. The positive net seepage values (on average 77,000 AF per year) represent net stream seepage to groundwater. Deep percolation represents another large net inflow averaging about 110,000 AF per year. The positive net subsurface flows (on average 38,000 AF per year) represent the combined subsurface flows into the Subbasin from adjacent subbasins and upland areas. The positive subsidence value (on average 27,000 AF per year), while an inflow to the GWS water budget, represents active compaction within the Subbasin. Groundwater pumping (on average -260,000 AF per year) is a large outflow from the GWS. Overall, the water budget results for the 51-year historic period indicates a cumulative change in groundwater storage of about -620,000 AF, which equals an average annual change in groundwater storage of about -12,000 AF per year. These change in storage estimates equate to total decreases in storage in the Subbasin of about -4.28 AF per acre on average over the 51 years and an annual decrease of about -0.08 AF per acre across the entire Subbasin (approximately 146,000 acres).

Detailed results for each of the individual water budget components in the Projected (No Action) water budget are presented in **Appendix D.1**, simulated groundwater elevation hydrographs at select wells are presented in **Appendix E.1**, and simulated subsidence hydrographs are presented in **Appendix F.1**.

Table 4-14. Chowchilla Subbasin Projected (No Action) Sustainability Period Groundwater System Annual Water Budget Summary (acre-feet)

Water Budget Component	Average Annual (2040-2090)
Net Stream Seepage	77,000
Deep Percolation	110,000
Groundwater Extractions	-260,000
Subsidence	27,000
Net Subsurface Flows	38,000
Annual Change in Groundwater Storage	**-12,000**

Projected (No Action) with Climate Change

Implementation Period, WY 2024-2039

Summarized results for major components of the Projected (No Action) with Climate Change Implementation Period water budget as they relate to the groundwater system (GWS) are presented in **Table 4-15**. The positive net seepage values (on average 64,000 AF per year) represent net stream seepage to groundwater. Deep percolation represents another large net inflow averaging about 97,000 AF per year. The positive net subsurface flows (on average 47,000 AF per year) represent the combined subsurface flows into the Subbasin from adjacent subbasins and upland areas. The positive subsidence value (on average 36,000 AF per year), while an inflow to the GWS water budget, represents active compaction within the Subbasin. Groundwater pumping (on average -290,000 AF per year) is a large outflow from the GWS. Overall, the water budget results for the 16-year implementation period indicates a cumulative change in groundwater storage of about -670,000 AF, which equals an average annual change in groundwater storage of about -42,000 AF per year. These change in storage estimates equate to total decreases in storage in the Subbasin of about -4.59 AF per acre on average over the 16 years and an annual decrease of about -0.29 AF per acre across the entire Subbasin (approximately 146,000 acres).

Detailed results for each of the individual water budget components in the Projected (No Action) with Climate Change water budget are presented in **Appendix D.1**, simulated groundwater elevation hydrographs at select wells are presented in **Appendix E.1**, and simulated subsidence hydrographs are presented in **Appendix F.1**.

Table 4-15. Chowchilla Subbasin Projected (No Action) with Climate Change Implementation Period Groundwater System Annual Water Budget Summary (acre-feet)

Water Budget Component	Average Annual (2024-2039)
Net Stream Seepage	64,000
Deep Percolation	97,000
Groundwater Extractions	-290,000
Subsidence	36,000
Net Subsurface Flows	47,000
Annual Change in Groundwater Storage	**-42,000**

Sustainability Period, WY 2040-2090

Summarized results for major components of the Projected (No Action) with Climate Change Sustainability Period water budget as they relate to the groundwater system (GWS) are presented in **Table 4-16**. The positive net seepage values (on average 75,000 AF per year) represent net stream seepage to groundwater. Deep percolation represents another large net inflow averaging about 110,000 AF per year. The positive net subsurface flows (on average 56,000 AF per year) represent the combined subsurface flows into the Subbasin from adjacent subbasins and upland areas. The positive subsidence value (on average 33,000 AF per year), while an inflow to the GWS water budget, represents active compaction within the Subbasin. Groundwater pumping (on average -290,000 AF per year) is a large outflow from the GWS. Overall, the water budget results for the 51-year historic period indicates a cumulative change in groundwater storage of about -720,000 AF, which equals an average annual change in groundwater storage of about -14,000 AF per year. These change in storage estimates equate to total decreases in storage in the Subbasin of about -4.97 AF per acre on average over the 51 years and an annual decrease of about -0.10 AF per acre across the entire Subbasin (approximately 146,000 acres).

Detailed results for each of the individual water budget components in the Projected (No Action) with Climate Change water budget are presented in **Appendix D.1**, simulated groundwater elevation hydrographs at select wells are presented in **Appendix E.1**, and simulated subsidence hydrographs are presented in **Appendix F.1**.

Table 4-16. Chowchilla Subbasin Projected (No Action) with Climate Change Sustainability Period Groundwater System Annual Water Budget Summary (acre-feet)

Water Budget Component	Average Annual (2040-2090)
Net Stream Seepage	75,000
Deep Percolation	110,000
Groundwater Extractions	-290,000
Subsidence	33,000
Net Subsurface Flows	56,000
Annual Change in Groundwater Storage	**-14,000**

4.4. Madera Subbasin Model Results

The following section summarizes the analyses and results for the Madera Subbasin. Water budget results presented below reflect the complete groundwater system water budget. The surface water system water budget, as presented in the GSP, excludes subsurface flows and presents net recharge to groundwater using the net seepage, deep percolation, and groundwater pumping components.

4.4.1. Historical Period, WY 1989-2023

The water budget during the historical period simulation was calculated for the 1989-2023 water years spanning three different sub-time periods: the GSP historical period (WY 1989-2015), a transitional period (WY 2016-2019), and the GSP implementation period (WY 2020-2023). The water budgets presented in this section summarize results for the GSP historical period (WY 1989-2015) and the entire calibrated historical period (WY 1989-2023).

GSP Historical Period (WY 1989-2015)

Summarized results for major components of the GSP historical period water budget as they relate to the groundwater system (GWS) are presented in **Table 4-17**. The positive net seepage values (on average 130,000 AF per year) represent net stream seepage to groundwater. Deep percolation represents another large net inflow averaging about 230,000 AF per year. The positive net subsurface flows (on average 54,000 AF per year) represent the combined subsurface flows into the Subbasin from adjacent subbasins and upland areas. The positive subsidence value (on average 31,000 AF per year), while an inflow to the GWS water budget, represents active compaction within the Subbasin. Groundwater pumping (on average -490,000 AF per year) is a large outflow from the GWS. Overall, the water budget results for the 27-year historic period indicates a cumulative change in groundwater storage of about -1,200,000 AF, which equals an average annual change in groundwater storage of about -43,000 AF per year. These change in storage estimates equate to total decreases in storage in the Subbasin of about -3.33 AF per acre on average over the 27 years and an annual decrease of about -0.12 AF per acre across the entire Subbasin (approximately 349,000 acres).

Detailed results for each of the individual water budget components in the historical water budget are presented in **Appendix D.2**, simulated groundwater elevation hydrographs at select wells are presented in **Appendix E.2**, and simulated subsidence hydrographs are presented in **Appendix F.2**.

Table 4-17. Madera Subbasin GSP Historical Period Groundwater System Annual Water Budget Summary (acre-feet)

Water Budget Component	Average Annual (WY 1989-2015)
Net Stream Seepage	130,000
Deep Percolation	230,000
Groundwater Extractions	-490,000
Subsidence	31,000
Net Subsurface Flows	54,000
Annual Change in Groundwater Storage	**-43,000**

Calibrated Historical Period (WY 1989-2023)

Summarized results for major components of the calibrated historical period water budget as they relate to the groundwater system (GWS) are presented in **Table 4-18**. The positive net seepage values (on average 140,000 AF per year) represent net stream seepage to groundwater. Deep percolation represents another large net inflow averaging about 230,000 AF per year. The positive net subsurface flows (on average 59,000 AF per year) represent the combined subsurface flows into the Subbasin from adjacent subbasins and upland areas. The positive subsidence value (on average 34,000 AF per year), while an inflow to the GWS water budget, represents active compaction within the Subbasin. Groundwater pumping (on average -500,000 AF per year) is a large outflow from the GWS. Overall, the water budget results for the 35-year historic period indicates a cumulative change in groundwater storage of about -1,200,000 AF, which equals an average annual change in groundwater storage of about -36,000 AF per year. These change in storage estimates equate to total decreases in storage in the Subbasin of about -3.57 AF per acre on average over the 35 years and an annual decrease of about -0.10 AF per acre across the entire Subbasin (approximately 349,000 acres).

Detailed results for each of the individual water budget components in the historical water budget are presented in **Appendix D.2**, simulated groundwater elevation hydrographs at select wells are presented in **Appendix E.2**, and simulated subsidence hydrographs are presented in **Appendix F.2**.

Table 4-18. Madera Subbasin Calibrated Historical Period Groundwater System Annual Water Budget Summary (acre-feet)

Water Budget Component	Average Annual (WY 1989-2023)
Net Stream Seepage	140,000
Deep Percolation	230,000
Groundwater Extractions	-500,000
Subsidence	34,000
Net Subsurface Flows	59,000
Annual Change in Groundwater Storage	**-36,000**

4.4.2. Projected Scenarios, WY 2024-2090

The water budget during the projected scenarios was calculated for the 2024-2090 water years spanning two different sub-time periods: the GSP implementation period (WY 2024-2039) and the GSP sustainability period (WY 2040-2090).

Projected with Projects

Implementation Period, WY 2024-2039

Summarized results for major components of the Projected with Projects Implementation Period water budget as they relate to the groundwater system (GWS) are presented in **Table 4-19**. The positive net seepage values (on average 190,000 AF per year) represent net stream seepage to groundwater. Deep percolation represents another large net inflow averaging about 180,000 AF per year. The positive net subsurface flows (on average 64,000 AF per year) represent the combined subsurface flows into the Subbasin from adjacent subbasins and upland areas. The positive subsidence value (on average 7,300 AF per year), while an inflow to the GWS water budget, represents active compaction within the Subbasin. Groundwater pumping (on average -450,000 AF per year) is a large outflow from the GWS. Overall, the water budget results for the 16-year implementation period indicates a cumulative change in groundwater storage of about -120,000 AF, which equals an average annual change in groundwater storage of about -7,700 AF per year. These change in storage estimates equate to total decreases in storage in the Subbasin of about -0.36 AF per acre on average over the 16 years and an annual decrease of about -0.02 AF per acre across the entire Subbasin (approximately 349,000 acres).

Detailed results for each of the individual water budget components in the Projected with Projects water budget are presented in **Appendix D.2**, simulated groundwater elevation hydrographs at select wells are presented in **Appendix E.2**, and simulated subsidence hydrographs are presented in **Appendix F.2**.

Table 4-19. Madera Subbasin Projected with Projects Implementation Period Groundwater System Annual Water Budget Summary (acre-feet)

Water Budget Component	Average Annual (2024-2039)
Net Stream Seepage	190,000
Deep Percolation	180,000
Groundwater Extractions	-450,000
Subsidence	7,300
Net Subsurface Flows	64,000
Annual Change in Groundwater Storage	**-7,700**

Sustainability Period, WY 2040-2090

Summarized results for major components of the Projected with Projects Sustainability Period water budget as they relate to the groundwater system (GWS) are presented in **Table 4-20**. The positive net seepage values (on average 230,000 AF per year) represent net stream seepage to groundwater. Deep percolation represents another large net inflow averaging about 200,000 AF per year. The negative net subsurface flows (on average -5,600 AF per year) represent the combined subsurface flows out of the Subbasin to adjacent subbasins and into the Subbasin from upland areas. The negative subsidence value (on average -2,700 AF per year), while an outflow from the GWS water budget, represents a stop of active compaction within the Subbasin. Groundwater pumping (on average -390,000 AF per year) is a large outflow from the GWS. Overall, the water budget results for the 51-year historic period indicates a cumulative change in groundwater storage of about 1,200,000 AF, which equals an average annual change in groundwater storage of about 24,000 AF per year. These change in storage estimates equate to total increases in storage in the Subbasin of about 3.49 AF per acre on average over the 51 years and an annual increase of about 0.07 AF per acre across the entire Subbasin (approximately 349,000 acres).

Detailed results for each of the individual water budget components in the Projected with Projects water budget are presented in **Appendix D.2**, simulated groundwater elevation hydrographs at select wells are presented in **Appendix E.2**, and simulated subsidence hydrographs are presented in **Appendix F.2**.

Table 4-20. Madera Subbasin Projected with Projects Sustainability Period Groundwater System Annual Water Budget Summary (acre-feet)

Water Budget Component	Average Annual (2040-2090)
Net Stream Seepage	230,000
Deep Percolation	200,000
Groundwater Extractions	-390,000
Subsidence	-2,700
Net Subsurface Flows	-5,600
Annual Change in Groundwater Storage	**24,000**

Projects with Projects and with Climate Change

Implementation Period, WY 2024-2039

Summarized results for major components of the Projected with Projects and with Climate Change Implementation Period water budget as they relate to the groundwater system (GWS) are presented in **Table 4-21**. The positive net seepage values (on average 160,000 AF per year) represent net stream seepage to groundwater. Deep percolation represents another large net inflow averaging about 180,000 AF per year. The positive net subsurface flows (on average 75,000 AF per year) represent the combined subsurface flows into the Subbasin from adjacent subbasins and upland areas. The positive subsidence value (on average 19,000 AF per year), while an inflow to the GWS water budget, represents active compaction within the Subbasin. Groundwater pumping (on average -480,000 AF per year) is a large outflow from the GWS. Overall, the water budget results for the 16-year implementation period indicates a cumulative change in groundwater storage of about -760,000 AF, which equals an average annual change in groundwater storage of about -47,000 AF per year. These change in storage estimates equate to total decreases in storage in the Subbasin of about -2.17 AF per acre on average over the 16 years and an annual decrease of about -0.14 AF per acre across the entire Subbasin (approximately 349,000 acres).

Detailed results for each of the individual water budget components in the Projected with Projects and with Climate Change water budget are presented in **Appendix D.2**, simulated groundwater elevation hydrographs at select wells are presented in **Appendix E.2**, and simulated subsidence hydrographs are presented in **Appendix F.2**.

Table 4-21. Madera Subbasin Projected with Projects and with Climate Change Implementation Period Groundwater System Annual Water Budget Summary (acre-feet)

Water Budget Component	Average Annual (2024-2039)
Net Stream Seepage	160,000
Deep Percolation	180,000
Groundwater Extractions	-480,000
Subsidence	19,000
Net Subsurface Flows	75,000
Annual Change in Groundwater Storage	**-47,000**

Sustainability Period, WY 2040-2090

Summarized results for major components of the Projected with Projects and with Climate Change Sustainability Period water budget as they relate to the groundwater system (GWS) are presented in **Table 4-22**. The positive net seepage values (on average 180,000 AF per year) represent net stream seepage to groundwater. Deep percolation represents another large net inflow averaging about 200,000 AF per year. The positive net subsurface flows (on average 42,000 AF per year) represent the combined subsurface flows into the Subbasin from adjacent subbasins and upland areas. The positive subsidence value (on average 2,200 AF per year), while an inflow to the GWS water budget, represents active compaction within the Subbasin. Groundwater pumping (on average -420,000 AF per year) is a large outflow from the GWS. Overall, the water budget results for the 51-year historic period indicates a cumulative change in groundwater storage of about 480,000 AF, which equals an average annual change in groundwater storage of about 9,500 AF per year. These change in storage estimates equate to total increases in storage in the Subbasin of about 1.38 AF per acre on average over the 51 years and an annual increase of about 0.03 AF per acre across the entire Subbasin (approximately 349,000 acres).

Detailed results for each of the individual water budget components in the Projected with Projects and with Climate Change water budget are presented in **Appendix D.2**, simulated groundwater elevation hydrographs at select wells are presented in **Appendix E.2**, and simulated subsidence hydrographs are presented in **Appendix F.2**.

Table 4-22. Madera Subbasin Projected with Projects and with Climate Change Sustainability Period Groundwater System Annual Water Budget Summary (acre-feet)	
Water Budget Component	**Average Annual (2040-2090)**
Net Stream Seepage	180,000
Deep Percolation	200,000
Groundwater Extractions	-420,000
Subsidence	2,200
Net Subsurface Flows	42,000
Annual Change in Groundwater Storage	**9,500**

Projected (No Action)

Implementation Period, WY 2024-2039

Summarized results for major components of the Projected (No Action) Implementation Period water budget as they relate to the groundwater system (GWS) are presented in **Table 4-23**. The positive net seepage values (on average 140,000 AF per year) represent net stream seepage to groundwater. Deep percolation represents another large net inflow averaging about 190,000 AF per year. The positive net subsurface flows (on average 89,000 AF per year) represent the combined subsurface flows into the Subbasin from adjacent subbasins and upland areas. The positive subsidence value (on average 28,000 AF per year), while an inflow to the GWS water budget, represents active compaction within the Subbasin. Groundwater pumping (on average -520,000 AF per year) is a large outflow from the GWS. Overall, the water budget results for the 16-year implementation period indicates a cumulative change in groundwater storage of about -1,100,000 AF, which equals an average annual change in groundwater storage of about -69,000 AF per year. These change in storage estimates equate to total decreases in storage in the Subbasin of about -3.16 AF per acre on average over the 16 years and an annual decrease of about -0.20 AF per acre across the entire Subbasin (approximately 349,000 acres).

Detailed results for each of the individual water budget components in the Projected (No Action) water budget are presented in **Appendix D.2**, simulated groundwater elevation hydrographs at select wells are presented in **Appendix E.2**, and simulated subsidence hydrographs are presented in **Appendix F.2**.

Table 4-23. Madera Subbasin Projected (No Action) Implementation Period Groundwater System Annual Water Budget Summary (acre-feet)

Water Budget Component	Average Annual (2024-2039)
Net Stream Seepage	140,000
Deep Percolation	190,000
Groundwater Extractions	-520,000
Subsidence	28,000
Net Subsurface Flows	89,000
Annual Change in Groundwater Storage	**-69,000**

Sustainability Period, WY 2040-2090

Summarized results for major components of the Projected (No Action) Sustainability Period water budget as they relate to the groundwater system (GWS) are presented in **Table 4-24**. The positive net seepage values (on average 160,000 AF per year) represent net stream seepage to groundwater. Deep percolation represents another large net inflow averaging about 220,000 AF per year. The positive net subsurface flows (on average 100,000 AF per year) represent the combined subsurface flows into the Subbasin from adjacent subbasins and upland areas. The positive subsidence value (on average 26,000 AF per year), while an inflow to the GWS water budget, represents active compaction within the Subbasin. Groundwater pumping (on average -540,000 AF per year) is a large outflow from the GWS. Overall, the water budget results for the 51-year historic period indicates a cumulative change in groundwater storage of about -1,500,000 AF, which equals an average annual change in groundwater storage of about -29,000 AF per year. These change in storage estimates equate to total decreases in storage in the Subbasin of about -4.18 AF per acre on average over the 51 years and an annual decrease of about -0.08 AF per acre across the entire Subbasin (approximately 349,000 acres).

Detailed results for each of the individual water budget components in the Projected (No Action) water budget are presented in **Appendix D.2**, simulated groundwater elevation hydrographs at select wells are presented in **Appendix E.2**, and simulated subsidence hydrographs are presented in **Appendix F.2**.

Table 4-24. Madera Subbasin Projected (No Action) Sustainability Period Groundwater System Annual Water Budget Summary (acre-feet)	
Water Budget Component	**Average Annual (2040-2090)**
Net Stream Seepage	160,000
Deep Percolation	220,000
Groundwater Extractions	-540,000
Subsidence	26,000
Net Subsurface Flows	100,000
Annual Change in Groundwater Storage	**-29,000**

Projected (No Action) with Climate Change

Implementation Period, WY 2024-2039

Summarized results for major components of the Projected (No Action) with Climate Change Implementation Period water budget as they relate to the groundwater system (GWS) are presented in **Table 4-25**. The positive net seepage values (on average 130,000 AF per year) represent net stream seepage to groundwater. Deep percolation represents another large net inflow averaging about 190,000 AF per year. The positive net subsurface flows (on average 94,000 AF per year) represent the combined subsurface flows into the Subbasin from adjacent subbasins and upland areas. The positive subsidence value (on average 41,000 AF per year), while an inflow to the GWS water budget, represents active compaction within the Subbasin. Groundwater pumping (on average -550,000 AF per year) is a large outflow from the GWS. Overall, the water budget results for the 16-year implementation period indicates a cumulative change in groundwater storage of about -1,500,000 AF, which equals an average annual change in groundwater storage of about -96,000 AF per year. These change in storage estimates equate to total decreases in storage in the Subbasin of about -4.41 AF per acre on average over the 16 years and an annual decrease of about -0.28 AF per acre across the entire Subbasin (approximately 349,000 acres).

Detailed results for each of the individual water budget components in the Projected (No Action) with Climate Change water budget are presented in **Appendix D.2**, simulated groundwater elevation hydrographs at select wells are presented in **Appendix E.2**, and simulated subsidence hydrographs are presented in **Appendix F.2**.

Table 4-25. Madera Subbasin Projected (No Action) with Climate Change Implementation Period Groundwater System Annual Water Budget Summary (acre-feet)	
Water Budget Component	**Average Annual (2024-2039)**
Net Stream Seepage	130,000
Deep Percolation	190,000
Groundwater Extractions	-550,000
Subsidence	41,000
Net Subsurface Flows	94,000
Annual Change in Groundwater Storage	**-96,000**

Sustainability Period, WY 2040-2090

Summarized results for major components of the Projected (No Action) with Climate Change Sustainability Period water budget as they relate to the groundwater system (GWS) are presented in **Table 4-26**. The positive net seepage values (on average 150,000 AF per year) represent net stream seepage to groundwater. Deep percolation represents another large net inflow averaging about 220,000 AF per year. The positive net subsurface flows (on average 130,000 AF per year) represent the combined subsurface flows into the Subbasin from adjacent subbasins and upland areas. The positive subsidence value (on average 32,000 AF per year), while an inflow to the GWS water budget, represents active compaction within the Subbasin. Groundwater pumping (on average -560,000 AF per year) is a large outflow from the GWS. Overall, the water budget results for the 51-year historic period indicates a cumulative change in groundwater storage of about -1,700,000 AF, which equals an average annual change in groundwater storage of about -34,000 AF per year. These change in storage estimates equate to total decreases in storage in the Subbasin of about -4.96 AF per acre on average over the 51 years and an annual decrease of about -0.10 AF per acre across the entire Subbasin (approximately 349,000 acres).

Detailed results for each of the individual water budget components in the Projected (No Action) with Climate Change water budget are presented in **Appendix D.2**, simulated groundwater elevation hydrographs at select wells are presented in **Appendix E.2**, and simulated subsidence hydrographs are presented in **Appendix F.2**.

Table 4-26. Madera Subbasin Projected (No Action) with Climate Change Sustainability Period Groundwater System Annual Water Budget Summary (acre-feet)	
Water Budget Component	**Average Annual (2040-2090)**
Net Stream Seepage	150,000
Deep Percolation	220,000
Groundwater Extractions	-560,000
Subsidence	32,000
Net Subsurface Flows	130,000
Annual Change in Groundwater Storage	**-34,000**

4.5. Model Results by GSA Area

The following section summarizes the water budgets for the individual GSAs within Chowchilla and Madera Subbasins. Water budget results presented below reflect the complete groundwater system water budget. The surface water system water budget, as presented in the GSP, excludes subsurface flows and presents net recharge to groundwater using the net seepage, deep percolation, and groundwater pumping components.

4.5.1. Chowchilla Subbasin GSAs

There are five different GSAs within Chowchilla Subbasin: Chowchilla Water District GSA, Madera County GSA – East, Madera County GSA – West, Triangle T Water District GSA, and Sierra Vista Mutual Water Company GSA.

Chowchilla Water District GSA

The following section summarizes the analyses and results relating to the Chowchilla Water District GSA within Chowchilla Subbasin. Detailed results for each of the individual water budget components for each scenario are presented in **Appendix D.1.a**.

Historical

Summarized results for major components of the historical water budget as they relate to the GWS are presented in **Table 4-27**.

For the GSP historical period, inflows to the GWS include net stream seepage (on average 38,000 AF per year), deep percolation (on average 72,000 AF per year), and subsidence (on average 24,000 AF per year). Outflows from the GWS include groundwater extraction (on average -140,000 AF per year) and net subsurface flows (on average -17,000 AF per year). Overall, the water budget results for the 27-year historical period indicates a cumulative change in groundwater storage of about -580,000 AF, which equals an average annual change in groundwater storage of about -21,000 AF per year. These change in storage estimates equate to total decreases in storage in the GSA of about -6.73 AF per acre on average over the 27 years and an annual decrease of -0.24 AF per acre across the entire GSA (approximately 86,000 acres).

For the calibrated historical period, inflows to the GWS include net stream seepage (on average 38,000 AF per year), deep percolation (on average 71,000 AF per year), and subsidence (on average 24,000 AF per year). Outflows from the GWS include groundwater extraction (on average -140,000 AF per year) and net subsurface flows (on average -13,000 AF per year). Overall, the water budget results for the 35-year historical period indicates a cumulative change in groundwater storage of about -610,000 AF, which equals an average annual change in groundwater storage of about -18,000 AF per year. These change in storage estimates equate to total decreases in storage in the GSA of about -7.13 AF per acre on average over the 35 years and an annual decrease of -0.20 AF per acre across the entire GSA (approximately 86,000 acres).

Table 4-27. Chowchilla Water District GSA Historical Groundwater System Annual Water Budget Summary (acre-feet)

Water Budget Component	Average Annual GSP Historical Period (WY 1989-2015)	Average Annual Calibrated Historical Period (WY 1989-2023)
Net Stream Seepage	38,000	38,000
Deep Percolation	72,000	71,000
Groundwater Extractions	-140,000	-140,000
Subsidence	24,000	24,000
Net Subsurface Flows	-17,000	-13,000
Annual Change in Groundwater Storage	**-21,000**	**-18,000**

Projected with Projects

Summarized results for major components of the Projected with Projects water budget as they relate to the GWS are presented in **Table 4-28**.

For the Projected with Projects Implementation period, inflows to the GWS include net stream seepage (on average 50,000 AF per year), deep percolation (on average 59,000 AF per year), and subsidence (on average 7,000 AF per year). Outflows from the GWS include groundwater extraction (on average -120,000 AF per year) and net subsurface flows (on average -2,900 AF per year). Overall, the water budget results for the 16-year implementation period indicate a cumulative change in groundwater storage of about -91,000 AF, which equals an average annual change in groundwater storage of about -5,700 AF per year. These change in storage estimates equate to total decreases in storage in the GSA of about -1.06 AF per acre on average over the 16 years and an annual decrease of -0.07 AF per acre across the entire GSA (approximately 86,000 acres).

For the Projected with Projects Sustainability period, inflows to the GWS include net stream seepage (on average 56,000 AF per year), deep percolation (on average 64,000 AF per year), subsidence (on average 550 AF per year), and net subsurface flows (on average 6,100 AF per year). Outflows from the GWS include groundwater extraction (on average -120,000 AF per year). Overall, the water budget results for the 51-year sustainability period indicate a cumulative change in groundwater storage of about 120,000 AF, which equals an average annual change in groundwater storage of about 2,400 AF per year. These change in storage estimates equate to total increases in storage in the GSA of about 1.40 AF per acre on average over the 51 years and an annual increase of 0.03 AF per acre across the entire GSA (approximately 86,000 acres).

Table 4-28. Chowchilla Water District GSA Projected with Projects Groundwater System Annual Water Budget Summary (acre-feet)

Water Budget Component	Average Annual Implementation Period (WY 2024-2039)	Average Annual Sustainability Period (WY 2040-2090)
Net Stream Seepage	50,000	56,000
Deep Percolation	59,000	64,000
Groundwater Extractions	-120,000	-120,000
Subsidence	7,000	550
Net Subsurface Flows	-2,900	6,100
Annual Change in Groundwater Storage	**-5,700**	**2,400**

Summarized results for major components of the Projected with Projects and with Climate Change water budget as they relate to the GWS are presented in **Table 4-29**.

For the Projected with Projects and with Climate Change Implementation period, inflows to the GWS include net stream seepage (on average 39,000 AF per year), deep percolation (on average 58,000 AF per year), subsidence (on average 18,000 AF per year), and net subsurface flows (on average 20,000 AF per year). Outflows from the GWS include groundwater extraction (on average -150,000 AF per year). Overall, the water budget results for the 16-year implementation period indicate a cumulative change in groundwater storage of about -220,000 AF, which equals an average annual change in groundwater storage of about -14,000 AF per year. These change in storage estimates equate to total decreases in storage in the GSA of about -2.56 AF per acre on average over the 16 years and an annual decrease of -0.16 AF per acre across the entire GSA (approximately 86,000 acres).

For the Projected with Projects and with Climate Change Sustainability period, inflows to the GWS include net stream seepage (on average 45,000 AF per year), deep percolation (on average 64,000 AF per year), subsidence (on average 4,100 AF per year), and net subsurface flows (on average 41,000 AF per year). Outflows from the GWS include groundwater extraction (on average -160,000 AF per year). Overall, the water budget results for the 51-year sustainability period indicate a cumulative change in groundwater storage of about -33,000 AF, which equals an average annual change in groundwater storage of about -650 AF per year. These change in storage estimates equate to total decreases in storage in the GSA of about -0.38 AF per acre on average over the 51 years and an annual decrease of -0.01 AF per acre across the entire GSA (approximately 86,000 acres).

Table 4-29. Chowchilla Water District GSA Projected with Projects and with Climate Change Groundwater System Annual Water Budget Summary (acre-feet)

Water Budget Component	Average Annual Implementation Period (WY 2024-2039)	Average Annual Sustainability Period (WY 2040-2090)
Net Stream Seepage	39,000	45,000
Deep Percolation	58,000	64,000
Groundwater Extractions	-150,000	-160,000
Subsidence	18,000	4,100
Net Subsurface Flows	20,000	41,000
Annual Change in Groundwater Storage	**-14,000**	**-650**

Projected (No Action)

Summarized results for major components of the Projected (No Action) water budget as they relate to the GWS are presented in **Table 4-30**.

For the Projected (No Action) Implementation period, inflows to the GWS include net stream seepage (on average 43,000 AF per year), deep percolation (on average 59,000 AF per year), and subsidence (on average 13,000 AF per year). Outflows from the GWS include groundwater extraction (on average -120,000 AF per year) and net subsurface flows (on average -10,000 AF per year). Overall, the water budget results for the 16-year implementation period indicate a cumulative change in groundwater storage of about -230,000 AF, which equals an average annual change in groundwater storage of about -14,000 AF per year. These change in storage estimates equate to total decreases in storage in the GSA of about -2.65 AF per acre on average over the 16 years and an annual decrease of -0.17 AF per acre across the entire GSA (approximately 86,000 acres).

For the Projected (No Action) Sustainability period, inflows to the GWS include net stream seepage (on average 38,000 AF per year), deep percolation (on average 64,000 AF per year), subsidence (on average 18,000 AF per year), and net subsurface flows (on average 5,400 AF per year). Outflows from the GWS include groundwater extraction (on average -130,000 AF per year). Overall, the water budget results for the 51-year sustainability period indicate a cumulative change in groundwater storage of about -440,000 AF, which equals an average annual change in groundwater storage of about -8,600 AF per year. These change in storage estimates equate to total decreases in storage in the GSA of about -5.07 AF per acre on average over the 51 years and an annual decrease of -0.10 AF per acre across the entire GSA (approximately 86,000 acres).

Table 4-30. Chowchilla Water District GSA Projected (No Action) Groundwater System Annual Water Budget Summary (acre-feet)		
Water Budget Component	**Average Annual Implementation Period (WY 2024-2039)**	**Average Annual Sustainability Period (WY 2040-2090)**
Net Stream Seepage	43,000	38,000
Deep Percolation	59,000	64,000
Groundwater Extractions	-120,000	-130,000
Subsidence	13,000	18,000
Net Subsurface Flows	-10,000	5,400
Annual Change in Groundwater Storage	**-14,000**	**-8,600**

Summarized results for major components of the Projected (No Action) with Climate Change water budget as they relate to the GWS are presented in **Table 4-31**.

For the Projected (No Action) with Climate Change Implementation period, inflows to the GWS include net stream seepage (on average 33,000 AF per year), deep percolation (on average 59,000 AF per year), subsidence (on average 25,000 AF per year), and net subsurface flows (on average 10,000 AF per year). Outflows from the GWS include groundwater extraction (on average -150,000 AF per year). Overall, the water budget results for the 16-year implementation period indicate a cumulative change in groundwater storage of about -340,000 AF, which equals an average annual change in groundwater storage of about -21,000 AF per year. These change in storage estimates equate to total decreases in storage in the GSA of about -3.99 AF per acre on average over the 16 years and an annual decrease of -0.25 AF per acre across the entire GSA (approximately 86,000 acres).

For the Projected (No Action) with Climate Change Sustainability period, inflows to the GWS include net stream seepage (on average 32,000 AF per year), deep percolation (on average 64,000 AF per year), subsidence (on average 21,000 AF per year), and net subsurface flows (on average 29,000 AF per year). Outflows from the GWS include groundwater extraction (on average -160,000 AF per year). Overall, the water budget results for the 51-year sustainability period indicate a cumulative change in groundwater storage of about -500,000 AF, which equals an average annual change in groundwater storage of about -9,800 AF per year. These change in storage estimates equate to total decreases in storage in the GSA of about -5.79 AF per acre on average over the 51 years and an annual decrease of -0.11 AF per acre across the entire GSA (approximately 86,000 acres).

Table 4-31. Chowchilla Water District GSA Projected (No Action) with Climate Change Groundwater System Annual Water Budget Summary (acre-feet)

Water Budget Component	Average Annual Implementation Period (WY 2024-2039)	Average Annual Sustainability Period (WY 2040-2090)
Net Stream Seepage	33,000	32,000
Deep Percolation	59,000	64,000
Groundwater Extractions	-150,000	-160,000
Subsidence	25,000	21,000
Net Subsurface Flows	10,000	29,000
Annual Change in Groundwater Storage	**-21,000**	**-9,800**

Madera County GSA – East

The following section summarizes the analyses and results relating to the Madera County GSA – East within Chowchilla. Detailed results for each of the individual water budget components for each scenario are presented in **Appendix D.1.b**.

Historical

Summarized results for major components of the historical water budget as they relate to the GWS are presented in **Table 4-32**.

For the GSP historical period, inflows to the GWS include net stream seepage (on average 1,800 AF per year), deep percolation (on average 5,300 AF per year), subsidence (on average 2,500 AF per year), and net subsurface flows (on average 5,100 AF per year). Outflows from the GWS include groundwater extraction (on average -16,000 AF per year). Overall, the water budget results for the 27-year historical period indicates a cumulative change in groundwater storage of about -45,000 AF, which equals an average annual change in groundwater storage of about -1,700 AF per year. These change in storage estimates equate to total decreases in storage in the GSA of about -4.35 AF per acre on average over the 27 years and an annual decrease of -0.16 AF per acre across the entire GSA (approximately 10,000 acres).

For the calibrated historical period, inflows to the GWS include net stream seepage (on average 1,900 AF per year), deep percolation (on average 5,300 AF per year), subsidence (on average 2,600 AF per year), and net subsurface flows (on average 5,600 AF per year). Outflows from the GWS include groundwater extraction (on average -17,000 AF per year). Overall, the water budget results for the 35-year historical period indicates a cumulative change in groundwater storage of about -54,000 AF, which equals an average annual change in groundwater storage of about -1,500 AF per year. These change in storage estimates equate to total decreases in storage in the GSA of about -5.29 AF per acre on average over the 35 years and an annual increase of -0.15 AF per acre across the entire GSA (approximately 10,000 acres).

Table 4-32. Madera County - East GSA Historical Groundwater System Annual Water Budget Summary (acre-feet)		
Water Budget Component	**Average Annual GSP Historical Period (WY 1989-2015)**	**Average Annual Calibrated Historical Period (WY 1989-2023)**
Net Stream Seepage	1,800	1,900
Deep Percolation	5,300	5,300
Groundwater Extractions	-16,000	-17,000
Subsidence	2,500	2,600
Net Subsurface Flows	5,100	5,600
Annual Change in Groundwater Storage	**-1,700**	**-1,500**

Projected with Projects

Summarized results for major components of the Projected with Projects water budget as they relate to the GWS are presented in **Table 4-33**.

For the Projected with Projects Implementation period, inflows to the GWS include net stream seepage (on average 2,200 AF per year), deep percolation (on average 4,300 AF per year), subsidence (on average 980 AF per year), and net subsurface flows (on average 6,700 AF per year). Outflows from the GWS include groundwater extraction (on average -15,000 AF per year). Overall, the water budget results for the 16-year implementation period indicate a cumulative change in groundwater storage of about -19,000 AF, which equals an average annual change in groundwater storage of about -1,200 AF per year. These change in storage estimates equate to total decreases in storage in the GSA of about -1.83 AF per acre on average over the 16 years and an annual decrease of -0.11 AF per acre across the entire GSA (approximately 10,000 acres).

For the Projected with Projects Sustainability period, inflows to the GWS include net stream seepage (on average 2,200 AF per year), deep percolation (on average 3,400 AF per year), and net subsurface flows (on average 1,200 AF per year). Outflows from the GWS include groundwater extraction (on average -6,300 AF per year) and subsidence (on average -55 AF per year). Overall, the water budget results for the 51-year sustainability period indicate a cumulative change in groundwater storage of about 21,000 AF, which equals an average annual change in groundwater storage of about 420 AF per year. These change in storage estimates equate to total increases in storage in the GSA of about 2.07 AF per acre on average over the 51 years and an annual increase of 0.04 AF per acre across the entire GSA (approximately 10,000 acres).

Table 4-33. Madera County - East GSA Projected with Projects Groundwater System Annual Water Budget Summary (acre-feet)		
Water Budget Component	**Average Annual Implementation Period (WY 2024-2039)**	**Average Annual Sustainability Period (WY 2040-2090)**
Net Stream Seepage	2,200	2,200
Deep Percolation	4,300	3,400
Groundwater Extractions	-15,000	-6,300
Subsidence	980	-55
Net Subsurface Flows	6,700	1,200
Annual Change in Groundwater Storage	**-1,200**	**420**

Summarized results for major components of the Projected with Projects and with Climate Change water budget as they relate to the GWS are presented in **Table 4-34**.

For the Projected with Projects and with Climate Change Implementation period, inflows to the GWS include net stream seepage (on average 2,100 AF per year), deep percolation (on average 3,800 AF per year), subsidence (on average 1,300 AF per year), and net subsurface flows (on average 2,600 AF per year). Outflows from the GWS include groundwater extraction (on average -11,000 AF per year). Overall, the water budget results for the 16-year implementation period indicate a cumulative change in groundwater storage of about -23,000 AF, which equals an average annual change in groundwater storage of about -1,500 AF per year. These change in storage estimates equate to total decreases in storage in the GSA of about -2.27 AF per acre on average over the 16 years and an annual decrease of -0.14 AF per acre across the entire GSA (approximately 10,000 acres).

For the Projected with Projects and with Climate Change Sustainability period, inflows to the GWS include net stream seepage (on average 2,500 AF per year), deep percolation (on average 2,700 AF per year), and subsidence (on average 230 AF per year). Outflows from the GWS include groundwater extraction (on average -1,300 AF per year) and net subsurface flows (on average 4,100 AF per year). Overall, the water budget results for the 51-year sustainability period indicate a cumulative change in groundwater storage of about 2,600 AF, which equals an average annual change in groundwater storage of about 52 AF per year. These change in storage estimates equate to total increases in storage in the GSA of about 0.26 AF per acre on average over the 51 years and an annual increase of 0.01 AF per acre across the entire GSA (approximately 10,000 acres).

Table 4-34. Madera County - East GSA Projected with Projects and with Climate Change Groundwater System Annual Water Budget Summary (acre-feet)		
Water Budget Component	**Average Annual Implementation Period (WY 2024-2039)**	**Average Annual Sustainability Period (WY 2040-2090)**
Net Stream Seepage	2,100	2,500
Deep Percolation	3,800	2,700
Groundwater Extractions	-11,000	-1,300
Subsidence	1,300	230
Net Subsurface Flows	2,600	-4,100
Annual Change in Groundwater Storage	**-1,500**	**52**

Projected (No Action)

Summarized results for major components of the Projected (No Action) water budget as they relate to the GWS are presented in **Table 4-35**.

For the Projected (No Action) Implementation period, inflows to the GWS include net stream seepage (on average 2,200 AF per year), deep percolation (on average 4,800 AF per year), subsidence (on average 4,800 AF per year), and net subsurface flows (on average 9,000 AF per year). Outflows from the GWS include groundwater extraction (on average -20,000 AF per year). Overall, the water budget results for the 16-year implementation period indicate a cumulative change in groundwater storage of about -39,000 AF, which equals an average annual change in groundwater storage of about -2,500 AF per year. These change in storage estimates equate to total decreases in storage in the GSA of about -3.84 AF per acre on average over the 16 years and an annual decrease of -0.24 AF per acre across the entire GSA (approximately 10,000 acres).

For the Projected (No Action) Sustainability period, inflows to the GWS include net stream seepage (on average 2,100 AF per year), deep percolation (on average 4,800 AF per year), subsidence (on average 1,500 AF per year), and net subsurface flows (on average 9,500 AF per year). Outflows from the GWS include groundwater extraction (on average -19,000 AF per year). Overall, the water budget results for the 51-year sustainability period indicate a cumulative change in groundwater storage of about -67,000 AF, which equals an average annual change in groundwater storage of about -1,300 AF per year. These change in storage estimates equate to total decreases in storage in the GSA of about -6.57 AF per acre on average over the 51 years and an annual decrease of -0.13 AF per acre across the entire GSA (approximately 10,000 acres).

Table 4-35. Madera County - East GSA Projected (No Action) Groundwater System Annual Water Budget Summary (acre-feet)		
Water Budget Component	Average Annual Implementation Period (WY 2024-2039)	Average Annual Sustainability Period (WY 2040-2090)
Net Stream Seepage	2,200	2,100
Deep Percolation	4,800	4,800
Groundwater Extractions	-20,000	-19,000
Subsidence	4,800	1,500
Net Subsurface Flows	9,000	9,500
Annual Change in Groundwater Storage	**-2,500**	**-1,300**

Summarized results for major components of the Projected (No Action) with Climate Change water budget as they relate to the GWS are presented in **Table 4-36**.

For the Projected (No Action) with Climate Change Implementation period, inflows to the GWS include net stream seepage (on average 1,900 AF per year), deep percolation (on average 4,700 AF per year), subsidence (on average 2,400 AF per year), and net subsurface flows (on average 8,500 AF per year). Outflows from the GWS include groundwater extraction (on average -21,000 AF per year). Overall, the water budget results for the 16-year implementation period indicate a cumulative change in groundwater storage of about -51,000 AF, which equals an average annual change in groundwater storage of about -3,200 AF per year. These change in storage estimates equate to total decreases in storage in the GSA of about -4.94 AF per acre on average over the 16 years and an annual decrease of -0.31 AF per acre across the entire GSA (approximately 10,000 acres).

For the Projected (No Action) with Climate Change Sustainability period, inflows to the GWS include net stream seepage (on average 2,100 AF per year), deep percolation (on average 4,800 AF per year), subsidence (on average 1,700 AF per year), and net subsurface flows (on average 9,200 AF per year). Outflows from the GWS include groundwater extraction (on average -19,000 AF per year). Overall, the water budget results for the 51-year sustainability period indicate a cumulative change in groundwater storage of about -84,000 AF, which equals an average annual change in groundwater storage of about -1,600 AF per year. These change in storage estimates equate to total decreases in storage in the GSA of about -8.21 AF per acre on average over the 51 years and an annual decrease of -0.16 AF per acre across the entire GSA (approximately 10,000 acres).

Table 4-36. Madera County - East GSA Projected (No Action) with Climate Change Groundwater System Annual Water Budget Summary (acre-feet)		
Water Budget Component	**Average Annual Implementation Period (WY 2024-2039)**	**Average Annual Sustainability Period (WY 2040-2090)**
Net Stream Seepage	1,900	2,100
Deep Percolation	4,700	4,800
Groundwater Extractions	-21,000	-19,000
Subsidence	2,400	1,700
Net Subsurface Flows	8,500	9,200
Annual Change in Groundwater Storage	**-3,200**	**-1,600**

Madera County GSA – West

The following section summarizes the analyses and results relating to the Madera County GSA – West within Chowchilla Subbasin. Detailed results for each of the individual water budget components for each scenario are presented in **Appendix D.1.c**.

Historical

Summarized results for major components of the historical water budget as they relate to the GWS are presented in **Table 4-37**.

For the GSP historical period, inflows to the GWS include net stream seepage (on average 12,000 AF per year), deep percolation (on average 29,000 AF per year), subsidence (on average 9,900 AF per year), and net subsurface flows (on average 22,000 AF per year). Outflows from the GWS include groundwater extraction (on average -77,000 AF per year). Overall, the water budget results for the 27-year historical period indicates a cumulative change in groundwater storage of about -90,000 AF, which equals an average annual change in groundwater storage of about -3,300 AF per year. These change in storage estimates equate to total decreases in storage in the GSA of about -2.94 AF per acre on average over the 27 years and an annual decrease of -0.11 AF per acre across the entire GSA (approximately 31,000 acres).

For the calibrated historical period, inflows to the GWS include net stream seepage (on average 16,000 AF per year), deep percolation (on average 30,000 AF per year), subsidence (on average 9,400 AF per year), and net subsurface flows (on average 20,000 AF per year). Outflows from the GWS include groundwater extraction (on average -76,000 AF per year). Overall, the water budget results for the 35-year historical period indicates a cumulative change in groundwater storage of about -38,000 AF, which equals an average annual change in groundwater storage of about -1,100 AF per year. These change in storage estimates equate to total decreases in storage in the GSA of about -1.23 AF per acre on average over the 35 years and an annual decrease of -0.04 AF per acre across the entire GSA (approximately 31,000 acres).

Table 4-37. Madera County - West GSA Historical Groundwater System Annual Water Budget Summary (acre-feet)		
Water Budget Component	**Average Annual GSP Historical Period (WY 1989-2015)**	**Average Annual Calibrated Historical Period (WY 1989-2023)**
Net Stream Seepage	12,000	16,000
Deep Percolation	29,000	30,000
Groundwater Extractions	-77,000	-76,000
Subsidence	9,900	9,400
Net Subsurface Flows	22,000	20,000
Annual Change in Groundwater Storage	**-3,300**	**-1,100**

Projected with Projects

Summarized results for major components of the Projected with Projects water budget as they relate to the GWS are presented in **Table 4-38**.

For the Projected with Projects Implementation period, inflows to the GWS include net stream seepage (on average 24,000 AF per year), deep percolation (on average 18,000 AF per year), subsidence (on average 140 AF per year), and net subsurface flows (on average 4,600 AF per year). Outflows from the GWS include groundwater extraction (on average -49,000 AF per year). Overall, the water budget results for the 16-year implementation period indicate a cumulative change in groundwater storage of about -42,000 AF, which equals an average annual change in groundwater storage of about -2,600 AF per year. These change in storage estimates equate to total decreases in storage in the GSA of about -1.36 AF per acre on average over the 16 years and an annual decrease of -0.09 AF per acre across the entire GSA (approximately 31,000 acres).

For the Projected with Projects Sustainability period, inflows to the GWS include net stream seepage (on average 26,000 AF per year) and deep percolation (on average 13,000 AF per year. Outflows from the GWS include groundwater extraction (on average -20,000 AF per year), subsidence (on average -170 AF per year), and net subsurface flows (on average -17,000 AF per year). Overall, the water budget results for the 51-year sustainability period indicate a cumulative change in groundwater storage of about 110,000 AF, which equals an average annual change in groundwater storage of about 2,100 AF per year. These change in storage estimates equate to total increases in storage in the GSA of about 3.57 AF per acre on average over the 51 years and an annual increase of 0.07 AF per acre across the entire GSA (approximately 31,000 acres).

Table 4-38. Madera County - West GSA Projected with Projects Groundwater System Annual Water Budget Summary (acre-feet)		
Water Budget Component	**Average Annual Implementation Period (WY 2024-2039)**	**Average Annual Sustainability Period (WY 2040-2090)**
Net Stream Seepage	24,000	26,000
Deep Percolation	18,000	13,000
Groundwater Extractions	-49,000	-20,000
Subsidence	140	-170
Net Subsurface Flows	4,600	-17,000
Annual Change in Groundwater Storage	**-2,600**	**2,100**

Summarized results for major components of the Projected with Projects and with Climate Change water budget as they relate to the GWS are presented in **Table 4-39**.

For the Projected with Projects and with Climate Change Implementation period, inflows to the GWS include net stream seepage (on average 25,000 AF per year), deep percolation (on average 14,000 AF per year), and subsidence (on average 1,200 AF per year). Outflows from the GWS include groundwater extraction (on average -36,000 AF per year) and net subsurface flows (on average -9,100 AF per year). Overall, the water budget results for the 16-year implementation period indicate a cumulative change in groundwater storage of about -68,000 AF, which equals an average annual change in groundwater storage of about -4,300 AF per year. These change in storage estimates equate to total decreases in storage in the GSA of about -2.24 AF per acre on average over the 16 years and an annual decrease of -0.14 AF per acre across the entire GSA (approximately 31,000 acres).

For the Projected with Projects and with Climate Change Sustainability period, inflows to the GWS include net stream seepage (on average 32,000 AF per year), deep percolation (on average 10,000 AF per year), and subsidence (on average 110 AF per year). Outflows from the GWS include groundwater extraction (on average -4,100 AF per year) and net subsurface flows (on average -36,000 AF per year). Overall, the water budget results for the 51-year sustainability period indicate a cumulative change in groundwater storage of about 76,000 AF, which equals an average annual change in groundwater storage of about 1,500 AF per year. These change in storage estimates equate to total increases in storage in the GSA of about 2.49 AF per acre on average over the 51 years and an annual increase of 0.05 AF per acre across the entire GSA (approximately 31,000 acres).

Table 4-39. Madera County - West GSA Projected with Projects and with Climate Change Groundwater System Annual Water Budget Summary (acre-feet)		
Water Budget Component	**Average Annual Implementation Period (WY 2024-2039)**	**Average Annual Sustainability Period (WY 2040-2090)**
Net Stream Seepage	25,000	32,000
Deep Percolation	14,000	10,000
Groundwater Extractions	-36,000	-4,100
Subsidence	1,200	110
Net Subsurface Flows	-9,100	-36,000
Annual Change in Groundwater Storage	**-4,300**	**1,500**

Projected (No Action)

Summarized results for major components of the Projected (No Action) water budget as they relate to the GWS are presented in **Table 4-40**.

For the Projected (No Action) Implementation period, inflows to the GWS include net stream seepage (on average 25,000 AF per year), deep percolation (on average 20,000 AF per year), subsidence (on average 2,600 AF per year), and net subsurface flows (on average 8,100 AF per year). Outflows from the GWS include groundwater extraction (on average -64,000 AF per year). Overall, the water budget results for the 16-year implementation period indicate a cumulative change in groundwater storage of about -140,000 AF, which equals an average annual change in groundwater storage of about -8,700 AF per year. These change in storage estimates equate to total decreases in storage in the GSA of about -4.56 AF per acre on average over the 16 years and an annual decrease of -0.29 AF per acre across the entire GSA (approximately 31,000 acres).

For the Projected (No Action) Sustainability period, inflows to the GWS include net stream seepage (on average 34,000 AF per year), deep percolation (on average 23,000 AF per year), and subsidence (on average 5,400 AF per year). Outflows from the GWS include groundwater extraction (on average -64,000 AF per year) and net subsurface flows (on average -430 AF per year). Overall, the water budget results for the 51-year sustainability period indicate a cumulative change in groundwater storage of about -89,000 AF, which equals an average annual change in groundwater storage of about -1,800 AF per year. These change in storage estimates equate to total decreases in storage in the GSA of about -2.92 AF per acre on average over the 51 years and an annual decrease of -0.06 AF per acre across the entire GSA (approximately 31,000 acres).

Table 4-40. Madera County - West GSA Projected (No Action) Groundwater System Annual Water Budget Summary (acre-feet)

Water Budget Component	Average Annual Implementation Period (WY 2024-2039)	Average Annual Sustainability Period (WY 2040-2090)
Net Stream Seepage	25,000	34,000
Deep Percolation	20,000	23,000
Groundwater Extractions	-64,000	-64,000
Subsidence	2,600	5,400
Net Subsurface Flows	8,100	-430
Annual Change in Groundwater Storage	**-8,700**	**-1,800**

Summarized results for major components of the Projected (No Action) with Climate Change water budget as they relate to the GWS are presented in **Table 4-41**.

For the Projected (No Action) with Climate Change Implementation period, inflows to the GWS include net stream seepage (on average 27,000 AF per year), deep percolation (on average 20,000 AF per year), subsidence (on average 5,200 AF per year), and net subsurface flows (on average 3,000 AF per year). Outflows from the GWS include groundwater extraction (on average -66,000 AF per year). Overall, the water budget results for the 16-year implementation period indicate a cumulative change in groundwater storage of about -180,000 AF, which equals an average annual change in groundwater storage of about -11,000 AF per year. These change in storage estimates equate to total decreases in storage in the GSA of about -5.88 AF per acre on average over the 16 years and an annual decrease of -0.37 AF per acre across the entire GSA (approximately 31,000 acres).

For the Projected (No Action) with Climate Change Sustainability period, inflows to the GWS include net stream seepage (on average 38,000 AF per year), deep percolation (on average 23,000 AF per year), and subsidence (on average 7,500 AF per year). Outflows from the GWS include groundwater extraction (on average -66,000 AF per year) and net subsurface flows (on average -5,200 AF per year). Overall, the water budget results for the 51-year sustainability period indicate a cumulative change in groundwater storage of about -99,000 AF, which equals an average annual change in groundwater storage of about -1,900 AF per year. These change in storage estimates equate to total decreases in storage in the GSA of about -3.25 AF per acre on average over the 51 years and an annual decrease of -0.06 AF per acre across the entire GSA (approximately 31,000 acres).

Table 4-41. Madera County - West GSA Projected (No Action) with Climate Change Groundwater System Annual Water Budget Summary (acre-feet)		
Water Budget Component	**Average Annual Implementation Period (WY 2024-2039)**	**Average Annual Sustainability Period (WY 2040-2090)**
Net Stream Seepage	27,000	38,000
Deep Percolation	20,000	23,000
Groundwater Extractions	-66,000	-66,000
Subsidence	5,200	7,500
Net Subsurface Flows	3,000	-5,200
Annual Change in Groundwater Storage	**-11,000**	**-1,900**

Triangle T Water District GSA

The following section summarizes the analyses and results relating to the Triangle T Water District GSA (TTWD) within Chowchilla Subbasin. Detailed results for each of the individual water budget components for each scenario are presented in **Appendix D.1.d**.

<u>Historical</u>

Summarized results for major components of the historical water budget as they relate to the GWS are presented in **Table 4-42**.

For the GSP historical period, inflows to the GWS include net stream seepage (on average 680 AF per year), deep percolation (on average 10,000 AF per year), subsidence (on average 4,400 AF per year), and net subsurface flows (on average 4,000 AF per year). Outflows from the GWS include groundwater extraction (on average -21,000 AF per year). Overall, the water budget results for the 27-year historical period indicate a cumulative change in groundwater storage of about -42,000 AF, which equals an average annual change in groundwater storage of about -1,600 AF per year. These change in storage estimates equate to total decreases in storage in the GSA of about -2.84 AF per acre on average over the 27 years and an annual decrease of -0.11 AF per acre across the entire GSA (approximately 15,000 acres).

For the calibrated historical period, inflows to the GWS include net stream seepage (on average 2,300 AF per year), deep percolation (on average 12,000 AF per year), subsidence (on average 4,200 AF per year), and net subsurface flows (on average 4,800 AF per year). Outflows from the GWS include groundwater extraction (on average -23,000 AF per year). Overall, the water budget results for the 35-year historical period indicates a cumulative change in groundwater storage of about 16,000 AF, which equals an average annual change in groundwater storage of about 460 AF per year. These change in storage estimates equate to total increases in storage in the GSA of about 1.09 AF per acre on average over the 35 years and an annual increase of 0.03 AF per acre across the entire GSA (approximately 15,000 acres).

Table 4-42. Triangle T Water District GSA Historical Groundwater System Annual Water Budget Summary (acre-feet)		
Water Budget Component	**Average Annual GSP Historical Period (WY 1989-2015)**	**Average Annual Calibrated Historical Period (WY 1989-2023)**
Net Stream Seepage	680	2,300
Deep Percolation	10,000	12,000
Groundwater Extractions	-21,000	-23,000
Subsidence	4,400	4,200
Net Subsurface Flows	4,000	4,800
Annual Change in Groundwater Storage	**-1,600**	**460**

Projected with Projects

Summarized results for major components of the Projected with Projects water budget as they relate to the GWS are presented in **Table 4-43**.

For the Projected with Projects Implementation period, inflows to the GWS include net stream seepage (on average 3,100 AF per year), deep percolation (on average 9,500 AF per year), subsidence (on average 32 AF per year), and net subsurface flows (on average 13,000 AF per year). Outflows from the GWS include groundwater extraction (on average -28,000 AF per year). Overall, the water budget results for the 16-year implementation period indicate a cumulative change in groundwater storage of about -44,000 AF, which equals an average annual change in groundwater storage of about -2,700 AF per year. These change in storage estimates equate to total decreases in storage in the GSA of about -2.94 AF per acre on average over the 16 years and an annual decrease of -0.18 AF per acre across the entire GSA (approximately 15,000 acres).

For the Projected with Projects Sustainability period, inflows to the GWS include net stream seepage (on average 5,300 AF per year), deep percolation (on average 13,000 AF per year), and net subsurface flows (on average 8,900 AF per year). Outflows from the GWS include groundwater extraction (on average -26,000 AF per year) and subsidence (on average -70 AF per year). Overall, the water budget results for the 51-year sustainability period indicate a cumulative change in groundwater storage of about 49,000 AF, which equals an average annual change in groundwater storage of about 970 AF per year. These change in storage estimates equate to total increases in storage in the GSA of about 3.32 AF per acre on average over the 51 years and an annual increase of 0.07 AF per acre across the entire GSA (approximately 15,000 acres).

Table 4-43. Triangle T Water District GSA Projected with Projects Groundwater System Annual Water Budget Summary (acre-feet)		
Water Budget Component	Average Annual Implementation Period (WY 2024-2039)	Average Annual Sustainability Period (WY 2040-2090)
Net Stream Seepage	3,100	5,300
Deep Percolation	9,500	13,000
Groundwater Extractions	-28,000	-26,000
Subsidence	32	-70
Net Subsurface Flows	13,000	8,900
Annual Change in Groundwater Storage	**-2,700**	**970**

Summarized results for major components of the Projected with Projects and with Climate Change water budget as they relate to the GWS are presented in **Table 4-44**.

For the Projected with Projects and with Climate Change Implementation period, inflows to the GWS include net stream seepage (on average 2,600 AF per year), deep percolation (on average 9,100 AF per year), subsidence (on average 380 AF per year), and net subsurface flows (on average 18,000 AF per year). Outflows from the GWS include groundwater extraction (on average -33,000 AF per year). Overall, the water budget results for the 16-year implementation period indicate a cumulative change in groundwater storage of about -54,000 AF, which equals an average annual change in groundwater storage of about -3,400 AF per year. These change in storage estimates equate to total decreases in storage in the GSA of about -3.61 AF per acre on average over the 16 years and an annual decrease of -0.23 AF per acre across the entire GSA (approximately 15,000 acres).

For the Projected with Projects and with Climate Change Sustainability period, inflows to the GWS include net stream seepage (on average 4,600 AF per year), deep percolation (on average 13,000 AF per year), and net subsurface flows (on average 15,000 AF per year). Outflows from the GWS include groundwater extraction (on average -32,000 AF per year) and subsidence (on average -20 AF per year). Overall, the water budget results for the 51-year sustainability period indicate a cumulative change in groundwater storage of about 41,000 AF, which equals an average annual change in groundwater storage of about 810 AF per year. These change in storage estimates equate to total increases in storage in the GSA of about 2.79 AF per acre on average over the 51 years and an annual increase of 0.05 AF per acre across the entire GSA (approximately 15,000 acres).

Table 4-44. Triangle T Water District GSA Projected with Projects and with Climate Change Groundwater System Annual Water Budget Summary (acre-feet)		
Water Budget Component	Average Annual Implementation Period (WY 2024-2039)	Average Annual Sustainability Period (WY 2040-2090)
Net Stream Seepage	2,600	4,600
Deep Percolation	9,100	13,000
Groundwater Extractions	-33,000	-32,000
Subsidence	380	-20
Net Subsurface Flows	18,000	15,000
Annual Change in Groundwater Storage	**-3,400**	**810**

Projected (No Action)

Summarized results for major components of the Projected (No Action) water budget as they relate to the GWS are presented in **Table 4-45**.

For the Projected (No Action) Implementation period, inflows to the GWS include net stream seepage (on average 1,700 AF per year), deep percolation (on average 8,800 AF per year), subsidence (on average 1,300 AF per year), and net subsurface flows (on average 22,000 AF per year). Outflows from the GWS include groundwater extraction (on average -39,000 AF per year). Overall, the water budget results for the 16-year implementation period indicate a cumulative change in groundwater storage of about -78,000 AF, which equals an average annual change in groundwater storage of about -4,900 AF per year. These change in storage estimates equate to total decreases in storage in the GSA of about -5.28 AF per acre on average over the 16 years and an annual decrease of -0.33 AF per acre across the entire GSA (approximately 15,000 acres).

For the Projected (No Action) Sustainability period, inflows to the GWS include net stream seepage (on average 2,400 AF per year), deep percolation (on average 13,000 AF per year), subsidence (on average 1,800 AF per year), and net subsurface flows (on average 20,000 AF per year). Outflows from the GWS include groundwater extraction (on average -37,000 AF per year). Overall, the water budget results for the 51-year sustainability period indicate a cumulative change in groundwater storage of about -14,000 AF, which equals an average annual change in groundwater storage of about -270 AF per year. These change in storage estimates equate to total decreases in storage in the GSA of about -0.93 AF per acre on average over the 51 years and an annual decrease of -0.02 AF per acre across the entire GSA (approximately 15,000 acres).

Table 4-45. Triangle T Water District GSA Projected (No Action) Groundwater System Annual Water Budget Summary (acre-feet)		
Water Budget Component	Average Annual Implementation Period (WY 2024-2039)	Average Annual Sustainability Period (WY 2040-2090)
Net Stream Seepage	1,700	2,400
Deep Percolation	8,800	13,000
Groundwater Extractions	-39,000	-37,000
Subsidence	1,300	1,800
Net Subsurface Flows	22,000	20,000
Annual Change in Groundwater Storage	**-4,900**	**-270**

Summarized results for major components of the Projected (No Action) with Climate Change water budget as they relate to the GWS are presented in **Table 4-46**.

For the Projected (No Action) with Climate Change Implementation period, inflows to the GWS include net stream seepage (on average 2,000 AF per year), deep percolation (on average 8,700 AF per year), subsidence (on average 2,100 AF per year), and net subsurface flows (on average 22,000 AF per year). Outflows from the GWS include groundwater extraction (on average -41,000 AF per year). Overall, the water budget results for the 16-year implementation period indicate a cumulative change in groundwater storage of about -87,000 AF, which equals an average annual change in groundwater storage of about -5,400 AF per year. These change in storage estimates equate to total decreases in storage in the GSA of about -5.84 AF per acre on average over the 16 years and an annual decrease of -0.36 AF per acre across the entire GSA (approximately 15,000 acres).

For the Projected (No Action) with Climate Change Sustainability period, inflows to the GWS include net stream seepage (on average 3,000 AF per year), deep percolation (on average 13,000 AF per year), subsidence (on average 2,500 AF per year), and net subsurface flows (on average 20,000 AF per year). Outflows from the GWS include groundwater extraction (on average -39,000 AF per year). Overall, the water budget results for the 51-year sustainability period indicate a cumulative change in groundwater storage of about -23,000 AF, which equals an average annual change in groundwater storage of about -450 AF per year. These change in storage estimates equate to total decreases in storage in the GSA of about -1.55 AF per acre on average over the 51 years and an annual decrease of -0.03 AF per acre across the entire GSA (approximately 15,000 acres).

Table 4-46. Triangle T Water District GSA Projected (No Action) with Climate Change Groundwater System Annual Water Budget Summary (acre-feet)		
Water Budget Component	**Average Annual Implementation Period (WY 2024-2039)**	**Average Annual Sustainability Period (WY 2040-2090)**
Net Stream Seepage	2,000	3,000
Deep Percolation	8,700	13,000
Groundwater Extractions	-41,000	-39,000
Subsidence	2,100	2,500
Net Subsurface Flows	22,000	20,000
Annual Change in Groundwater Storage	**-5,400**	**-450**

Sierra Vista Mutual Water Company GSA

The following section summarizes the analyses and results relating to the Sierra Vista Mutual Water Company GSA (SVMWC) within Chowchilla Subbasin. Detailed results for each of the individual water budget components for each scenario are presented in **Appendix D.1.e**.

<u>Historical</u>

Summarized results for major components of the historical water budget as they relate to the GWS are presented in **Table 4-47**.

For the GSP historical period, inflows to the GWS include net stream seepage (on average 230 AF per year), deep percolation (on average 5,400 AF per year), subsidence (on average 1,300 AF per year), and net subsurface flows (on average 3,200 AF per year). Outflows from the GWS include groundwater extraction (on average -11,000 AF per year). Overall, the water budget results for the 27-year historical period indicate a cumulative change in groundwater storage of about -11,000 AF, which equals an average annual change in groundwater storage of about -390 AF per year. These change in storage estimates equate to total decreases in storage in the GSA of about -2.70 AF per acre on average over the 27 years and an annual decrease of -0.10 AF per acre across the entire GSA (approximately 4,000 acres).

For the calibrated historical period, inflows to the GWS include net stream seepage (on average 220 AF per year), deep percolation (on average 5,400 AF per year), subsidence (on average 1,400 AF per year), and net subsurface flows (on average 3,300 AF per year). Outflows from the GWS include groundwater extraction (on average -11,000 AF per year). Overall, the water budget results for the 35-year historical period indicate a cumulative change in groundwater storage of about -11,000 AF, which equals an average annual change in groundwater storage of about -320 AF per year. These change in storage estimates equate to total decreases in storage in the GSA of about -2.83 AF per acre on average over the 35 years and an annual decrease of -0.08 AF per acre across the entire GSA (approximately 4,000 acres).

Table 4-47. Sierra Vista Mutual Water Company GSA Historical Groundwater System Annual Water Budget Summary (acre-feet)		
Water Budget Component	**Average Annual GSP Historical Period (WY 1989-2015)**	**Average Annual Calibrated Historical Period (WY 1989-2023)**
Net Stream Seepage	230	220
Deep Percolation	5,400	5,400
Groundwater Extractions	-11,000	-11,000
Subsidence	1,300	1,400
Net Subsurface Flows	3,200	3,300
Annual Change in Groundwater Storage	**-390**	**-320**

Projected with Projects

Summarized results for major components of the Projected with Projects water budget as they relate to the GWS are presented in **Table 4-48**.

For the Projected with Projects Implementation period, inflows to the GWS include net stream seepage (on average 850 AF per year), deep percolation (on average 4,500 AF per year), subsidence (on average 450 AF per year), and net subsurface flows (on average 3,000 AF per year). Outflows from the GWS include groundwater extraction (on average -9,000 AF per year). Overall, the water budget results for the 16-year implementation period indicate a cumulative change in groundwater storage of about -2,800 AF, which equals an average annual change in groundwater storage of about -180 AF per year. These change in storage estimates equate to total decreases in storage in the GSA of about -0.72 AF per acre on average over the 16 years and an annual decrease of -0.05 AF per acre across the entire GSA (approximately 4,000 acres).

For the Projected with Projects Sustainability period, inflows to the GWS include net stream seepage (on average 1,200 AF per year), deep percolation (on average 4,700 AF per year), subsidence (on average 58 AF per year), and net subsurface flows (on average 2,800 AF per year). Outflows from the GWS include groundwater extraction (on average -8,600 AF per year). Overall, the water budget results for the 51-year sustainability period indicate a cumulative change in groundwater storage of about 4,300 AF, which equals an average annual change in groundwater storage of about 84 AF per year. These change in storage estimates equate to total increases in storage in the GSA of about 1.10 AF per acre on average over the 51 years and an annual increase of 0.02 AF per acre across the entire GSA (approximately 4,000 acres).

Table 4-48. Sierra Vista Mutual Water Company GSA Projected with Projects Groundwater System Annual Water Budget Summary (acre-feet)		
Water Budget Component	**Average Annual Implementation Period (WY 2024-2039)**	**Average Annual Sustainability Period (WY 2040-2090)**
Net Stream Seepage	850	1,200
Deep Percolation	4,500	4,700
Groundwater Extractions	-9,000	-8,600
Subsidence	450	58
Net Subsurface Flows	3,000	2,800
Annual Change in Groundwater Storage	**-180**	**84**

Summarized results for major components of the Projected with Projects and with Climate Change water budget as they relate to the GWS are presented in **Table 4-49**.

For the Projected with Projects and with Climate Change Implementation period, inflows to the GWS include net stream seepage (on average 220 AF per year), deep percolation (on average 4,500 AF per year), subsidence (on average 930 AF per year), and net subsurface flows (on average 3,500 AF per year). Outflows from the GWS include groundwater extraction (on average -9,600 AF per year). Overall, the water budget results for the 16-year implementation period indicate a cumulative change in groundwater storage of about -6,100 AF, which equals an average annual change in groundwater storage of about -390 AF per year. These change in storage estimates equate to total decreases in storage in the GSA of about -1.57 AF per acre on average over the 16 years and an annual decrease of -0.10 AF per acre across the entire GSA (approximately 4,000 acres).

For the Projected with Projects and with Climate Change Sustainability period, inflows to the GWS include net stream seepage (on average 230 AF per year), deep percolation (on average 4,800 AF per year), subsidence (on average 260 AF per year), and net subsurface flows (on average 4,300 AF per year). Outflows from the GWS include groundwater extraction (on average -9,600 AF per year). Overall, the water budget results for the 51-year sustainability period indicate a cumulative change in groundwater storage of about -0.62 AF, which equals an average annual change in groundwater storage of about -48 AF per year. These change in storage estimates equate to total decreases in storage in the GSA of about -0.62 AF per acre on average over the 51 years and an annual decrease of -0.01 AF per acre across the entire GSA (approximately 4,000 acres).

Table 4-49. Sierra Vista Mutual Water Company GSA Projected with Projects and with Climate Change Groundwater System Annual Water Budget Summary (acre-feet)		
Water Budget Component	**Average Annual Implementation Period (WY 2024-2039)**	**Average Annual Sustainability Period (WY 2040-2090)**
Net Stream Seepage	220	230
Deep Percolation	4,500	4,800
Groundwater Extractions	-9,600	-9,600
Subsidence	930	260
Net Subsurface Flows	3,500	4,300
Annual Change in Groundwater Storage	**-390**	**-48**

Projected (No Action)

Summarized results for major components of the Projected (No Action) water budget as they relate to the GWS are presented in **Table 4-50**.

For the Projected (No Action) Implementation period, inflows to the GWS include net stream seepage (on average 230 AF per year), deep percolation (on average 4,500 AF per year), subsidence (on average 750 AF per year), and net subsurface flows (on average 3,500 AF per year). Outflows from the GWS include groundwater extraction (on average -9,400 AF per year). Overall, the water budget results for the 16-year implementation period indicate a cumulative change in groundwater storage of about -5,800 AF, which equals an average annual change in groundwater storage of about -370 AF per year. These change in storage estimates equate to total decreases in storage in the GSA of about -1.49 AF per acre on average over the 16 years and an annual decrease of -0.09 AF per acre across the entire GSA (approximately 4,000 acres).

For the Projected (No Action) Sustainability period, inflows to the GWS include net stream seepage (on average 230 AF per year), deep percolation (on average 4,600 AF per year), subsidence (on average 880 AF per year), and net subsurface flows (on average 3,300 AF per year). Outflows from the GWS include groundwater extraction (on average -9,300 AF per year). Overall, the water budget results for the 51-year sustainability period indicate a cumulative change in groundwater storage of about -16,000 AF, which equals an average annual change in groundwater storage of about -320 AF per year. These change in storage estimates equate to total decreases in storage in the GSA of about -4.16 AF per acre on average over the 51 years and an annual decrease of -0.08 AF per acre across the entire GSA (approximately 4,000 acres).

Table 4-50. Sierra Vista Mutual Water Company GSA Projected (No Action) Groundwater System Annual Water Budget Summary (acre-feet)		
Water Budget Component	Average Annual Implementation Period (WY 2024-2039)	Average Annual Sustainability Period (WY 2040-2090)
Net Stream Seepage	230	230
Deep Percolation	4,500	4,600
Groundwater Extractions	-9,400	-9,300
Subsidence	750	880
Net Subsurface Flows	3,500	3,300
Annual Change in Groundwater Storage	**-370**	**-320**

Summarized results for major components of the Projected (No Action) with Climate Change water budget as they relate to the GWS are presented in **Table 4-51**.

For the Projected (No Action) with Climate Change Implementation period, inflows to the GWS include net stream seepage (on average 220 AF per year), deep percolation (on average 4,500 AF per year), subsidence (on average 1,300 AF per year), and net subsurface flows (on average 3,100 AF per year). Outflows from the GWS include groundwater extraction (on average -9,700 AF per year). Overall, the water budget results for the 16-year implementation period indicate a cumulative change in groundwater storage of about -8,700 AF, which equals an average annual change in groundwater storage of about -540 AF per year. These change in storage estimates equate to total decreases in storage in the GSA of about -2.22 AF per acre on average over the 16 years and an annual decrease of -0.14 AF per acre across the entire GSA (approximately 4,000 acres).

For the Projected (No Action) with Climate Change Sustainability period, inflows to the GWS include net stream seepage (on average 230 AF per year), deep percolation (on average 4,500 AF per year), subsidence (on average 1,000 AF per year), and net subsurface flows (on average 3,300 AF per year). Outflows from the GWS include groundwater extraction (on average -9,500 AF per year). Overall, the water budget results for the 51-year sustainability period indicate a cumulative change in groundwater storage of about -20,000 AF, which equals an average annual change in groundwater storage of about -390 AF per year. These change in storage estimates equate to total decreases in storage in the GSA of about -5.13 AF per acre on average over the 51 years and an annual decrease of -0.10 AF per acre across the entire GSA (approximately 4,000 acres).

Table 4-51. Sierra Vista Mutual Water Company GSA Projected (No Action) with Climate Change Groundwater System Annual Water Budget Summary (acre-feet)		
Water Budget Component	**Average Annual Implementation Period (WY 2024-2039)**	**Average Annual Sustainability Period (WY 2040-2090)**
Net Stream Seepage	220	230
Deep Percolation	4,500	4,500
Groundwater Extractions	-9,700	-9,500
Subsidence	1,300	1,000
Net Subsurface Flows	3,100	3,300
Annual Change in Groundwater Storage	**-540**	**-390**

4.5.2. Madera Subbasin GSAs

There are four different GSAs within Madera Subbasin that are part of the Joint GSP: City of Madera GSA, Madera County GSA, Madera Irrigation District GSA, and Madera Water District GSA. There are an additional three GSAs who prepared individual GSPs within Madera Subbasin: Gravelly Ford Water District GSA, New Stone Water District GSA, and Root Creek Water District GSA.

Joint GSP GSAs

City of Madera GSA

The following section summarizes the analyses and results relating to the City of Madera District GSA within Madera Subbasin. Detailed results for each of the individual water budget components for each scenario are presented in **Appendix D.2.a**.

Historical

Summarized results for major components of the historical water budget as they relate to the GWS are presented in **Table 4-52**.

For the GSP historical period, inflows to the GWS include net stream seepage (on average 2,100 AF per year), deep percolation (on average 3,900 AF per year), subsidence (on average 880 AF per year), and net subsurface flows (on average 1,000 AF per year). Outflows from the GWS include groundwater extraction (on average -9,400 AF per year). Overall, the water budget results for the 27-year historical period indicates a cumulative change in groundwater storage of about -40,000 AF, which equals an average annual change in groundwater storage of about -1,500 AF per year. These change in storage estimates equate to total decreases in storage in the GSA of about -4.48 AF per acre on average over the 27 years and an annual decrease of -0.17 AF per acre across the entire GSA (approximately 8,900 acres).

For the calibrated historical period, inflows to the GWS include net stream seepage (on average 2,300 AF per year), deep percolation (on average 3,800 AF per year), subsidence (on average 1,100 AF per year), and net subsurface flows (on average 720 AF per year). Outflows from the GWS include groundwater extraction (on average -9,400 AF per year). Overall, the water budget results for the 35-year historical period indicates a cumulative change in groundwater storage of about -54,000 AF, which equals an average annual change in groundwater storage of about -1,500 AF per year. These change in storage estimates equate to total decreases in storage in the GSA of about -6.07 AF per acre on average over the 35 years and an annual decrease of -0.17 AF per acre across the entire GSA (approximately 8,900 acres).

Table 4-52. City of Madera District GSA Historical Groundwater System Annual Water Budget Summary (acre-feet)

Water Budget Component	Average Annual GSP Historical Period (WY 1989-2015)	Average Annual Calibrated Historical Period (WY 1989-2023)
Net Stream Seepage	2,100	2,300
Deep Percolation	3,900	3,800
Groundwater Extractions	-9,400	-9,400
Subsidence	880	1,100
Net Subsurface Flows	1,000	720
Annual Change in Groundwater Storage	**-1,500**	**-1,500**

Projected with Projects

Summarized results for major components of the Projected with Projects water budget as they relate to the GWS are presented in **Table 4-53**.

For the Projected with Projects Implementation period, inflows to the GWS include net stream seepage (on average 6,100 AF per year), deep percolation (on average 3,300 AF per year), subsidence (on average 230 AF per year), and net subsurface flows (on average 500 AF per year). Outflows from the GWS include groundwater extraction (on average -9,500 AF per year). Overall, the water budget results for the 16-year implementation period indicate a cumulative change in groundwater storage of about 9,800 AF, which equals an average annual change in groundwater storage of about 610 AF per year. These change in storage estimates equate to total increases in storage in the GSA of about 1.10 AF per acre on average over the 16 years and an annual increase of 0.07 AF per acre across the entire GSA (approximately 8,900 acres).

For the Projected with Projects Sustainability period, inflows to the GWS include net stream seepage (on average 7,900 AF per year), deep percolation (on average 4,700 AF per year), and net subsurface flows (on average 590 AF per year). Outflows from the GWS include groundwater extraction (on average -12,000 AF per year) and subsidence (on average -100 AF per year). Overall, the water budget results for the 51-year sustainability period indicate a cumulative change in groundwater storage of about 31,000 AF, which equals an average annual change in groundwater storage of about 610 AF per year. These change in storage estimates equate to total increases in storage in the GSA of about 3.49 AF per acre on average over the 51 years and an annual increase of 0.07 AF per acre across the entire GSA (approximately 8,900 acres).

Table 4-53. City of Madera District GSA Projected with Projects Groundwater System Annual Water Budget Summary (acre-feet)		
Water Budget Component	Average Annual Implementation Period (WY 2024-2039)	Average Annual Sustainability Period (WY 2040-2090)
Net Stream Seepage	6,100	7,900
Deep Percolation	3,300	4,700
Groundwater Extractions	-9,500	-12,000
Subsidence	230	-100
Net Subsurface Flows	500	590
Annual Change in Groundwater Storage	**610**	**610**

Summarized results for major components of the Projected with Projects and with Climate Change water budget as they relate to the GWS are presented in **Table 4-54**.

For the Projected with Projects and with Climate Change Implementation period, inflows to the GWS include net stream seepage (on average 6,100 AF per year), deep percolation (on average 3,100 AF per year), and subsidence (on average 660 AF per year). Outflows from the GWS include groundwater extraction (on average -9,600 AF per year) and net subsurface flows (on average -850 AF per year). Overall, the water budget results for the 16-year implementation period indicate a cumulative change in groundwater storage of about -8,300 AF, which equals an average annual change in groundwater storage of about -520 AF per year. These change in storage estimates equate to total decreases in storage in the GSA of about -0.93 AF per acre on average over the 16 years and an annual decrease of -0.06 AF per acre across the entire GSA (approximately 8,900 acres).

For the Projected with Projects and with Climate Change Sustainability period, inflows to the GWS include net stream seepage (on average 8,200 AF per year), deep percolation (on average 4,600 AF per year), and subsidence (on average 130 AF per year). Outflows from the GWS include groundwater extraction (on average -12,000 AF per year) and net subsurface flows (on average -260 AF per year). Overall, the water budget results for the 51-year sustainability period indicate a cumulative change in groundwater storage of about 8,400 AF, which equals an average annual change in groundwater storage of about 160 AF per year. These change in storage estimates equate to total increases in storage in the GSA of about 0.94 AF per acre on average over the 51 years and an annual increase of 0.02 AF per acre across the entire GSA (approximately 8,900 acres).

Table 4-54. City of Madera District GSA Projected with Projects and with Climate Change Groundwater System Annual Water Budget Summary (acre-feet)		
Water Budget Component	**Average Annual Implementation Period (WY 2024-2039)**	**Average Annual Sustainability Period (WY 2040-2090)**
Net Stream Seepage	6,100	8,200
Deep Percolation	3,100	4,600
Groundwater Extractions	-9,600	-12,000
Subsidence	660	130
Net Subsurface Flows	-850	-260
Annual Change in Groundwater Storage	**-520**	**160**

<u>Projected (No Action)</u>

Summarized results for major components of the Projected (No Action) water budget as they relate to the GWS are presented in **Table 4-55**.

For the Projected (No Action) Implementation period, inflows to the GWS include net stream seepage (on average 1,700 AF per year), deep percolation (on average 3,400 AF per year), subsidence (on average 940 AF per year), and net subsurface flows (on average 2,200 AF per year). Outflows from the GWS include groundwater extraction (on average -10,000 AF per year). Overall, the water budget results for the 16-year implementation period indicate a cumulative change in groundwater storage of about -30,000 AF, which equals an average annual change in groundwater storage of about -1,900 AF per year. These change in storage estimates equate to total decreases in storage in the GSA of about -3.35 AF per acre on average over the 16 years and an annual decrease of -0.21 AF per acre across the entire GSA (approximately 8,900 acres).

For the Projected (No Action) Sustainability period, inflows to the GWS include net stream seepage (on average 2,400 AF per year), deep percolation (on average 6,000 AF per year), subsidence (on average 910 AF per year), and net subsurface flows (on average 5,700 AF per year). Outflows from the GWS include groundwater extraction (on average -16,000 AF per year). Overall, the water budget results for the 51-year sustainability period indicate a cumulative change in groundwater storage of about -39,000 AF, which equals an average annual change in groundwater storage of about -770 AF per year. These change in storage estimates equate to total decreases in storage in the GSA of about -4.42 AF per acre on average over the 51 years and an annual decrease of -0.09 AF per acre across the entire GSA (approximately 8,900 acres).

Table 4-55. City of Madera District GSA Projected (No Action) Groundwater System Annual Water Budget Summary (acre-feet)		
Water Budget Component	**Average Annual Implementation Period (WY 2024-2039)**	**Average Annual Sustainability Period (WY 2040-2090)**
Net Stream Seepage	1,700	2,400
Deep Percolation	3,400	6,000
Groundwater Extractions	-10,000	-16,000
Subsidence	940	910
Net Subsurface Flows	2,200	5,700
Annual Change in Groundwater Storage	**-1,900**	**-770**

Summarized results for major components of the Projected (No Action) with Climate Change water budget as they relate to the GWS are presented in **Table 4-56**.

For the Projected (No Action) with Climate Change Implementation period, inflows to the GWS include net stream seepage (on average 1,700 AF per year), deep percolation (on average 3,200 AF per year), subsidence (on average 1,400 AF per year), and net subsurface flows (on average 1,100 AF per year). Outflows from the GWS include groundwater extraction (on average -10,000 AF per year). Overall, the water budget results for the 16-year implementation period indicate a cumulative change in groundwater storage of about -44,000 AF, which equals an average annual change in groundwater storage of about -2,800 AF per year. These change in storage estimates equate to total decreases in storage in the GSA of about -4.96 AF per acre on average over the 16 years and an annual decrease of -0.31 AF per acre across the entire GSA (approximately 8,900 acres).

For the Projected (No Action) with Climate Change Sustainability period, inflows to the GWS include net stream seepage (on average 2,600 AF per year), deep percolation (on average 5,900 AF per year), subsidence (on average 1,100 AF per year), and net subsurface flows (on average 5,200 AF per year). Outflows from the GWS include groundwater extraction (on average -16,000 AF per year). Overall, the water budget results for the 51-year sustainability period indicate a cumulative change in groundwater storage of about -52,000 AF, which equals an average annual change in groundwater storage of about -1,000 AF per year. These change in storage estimates equate to total decreases in storage in the GSA of about -5.85 AF per acre on average over the 51 years and an annual decrease of -0.11 AF per acre across the entire GSA (approximately 8,900 acres).

Table 4-56. City of Madera District GSA Projected (No Action) with Climate Change Groundwater System Annual Water Budget Summary (acre-feet)		
Water Budget Component	**Average Annual Implementation Period (WY 2024-2039)**	**Average Annual Sustainability Period (WY 2040-2090)**
Net Stream Seepage	1,700	2,600
Deep Percolation	3,200	5,900
Groundwater Extractions	-10,000	-16,000
Subsidence	1,400	1,100
Net Subsurface Flows	1,100	5,200
Annual Change in Groundwater Storage	**-2,800**	**-1,000**

Madera County GSA

The following section summarizes the analyses and results relating to the Madera County GSA within Madera Subbasin. Detailed results for each of the individual water budget components for each scenario are presented in **Appendix D.2.b**.

Historical

Summarized results for major components of the historical water budget as they relate to the GWS are presented in **Table 4-57**.

For the GSP historical period, inflows to the GWS include net stream seepage (on average 36,000 AF per year), deep percolation (on average 98,000 AF per year), subsidence (on average 17,000 AF per year), and net subsurface flows (on average 50,000 AF per year). Outflows from the GWS include groundwater extraction (on average -220,000 AF per year). Overall, the water budget results for the 27-year historical period indicates a cumulative change in groundwater storage of about -360,000 AF, which equals an average annual change in groundwater storage of about -13,000 AF per year. These change in storage estimates equate to total decreases in storage in the GSA of about -2.68 AF per acre on average over the 27 years and an annual decrease of -0.10 AF per acre across the entire GSA (approximately 180,000 acres).

For the calibrated historical period, inflows to the GWS include net stream seepage (on average 40,000 AF per year), deep percolation (on average 99,000 AF per year), subsidence (on average 17,000 AF per year), and net subsurface flows (on average 52,000 AF per year). Outflows from the GWS include groundwater extraction (on average -220,000 AF per year). Overall, the water budget results for the 35-year historical period indicates a cumulative change in groundwater storage of about -390,000 AF, which equals an average annual change in groundwater storage of about -11,000 AF per year. These change in storage estimates equate to total decreases in storage in the GSA of about -2.84 AF per acre on average over the 35 years and an annual decrease of -0.08 AF per acre across the entire GSA (approximately 180,000 acres).

Table 4-57. Madera County GSA Historical Groundwater System Annual Water Budget Summary (acre-feet)

Water Budget Component	Average Annual GSP Historical Period (WY 1989-2015)	Average Annual Calibrated Historical Period (WY 1989-2023)
Net Stream Seepage	36,000	40,000
Deep Percolation	98,000	99,000
Groundwater Extractions	-220,000	-220,000
Subsidence	17,000	17,000
Net Subsurface Flows	50,000	52,000
Annual Change in Groundwater Storage	**-13,000**	**-11,000**

Projected with Projects

Summarized results for major components of the Projected with Projects water budget as they relate to the GWS are presented in **Table 4-58**.

For the Projected with Projects Implementation period, inflows to the GWS include net stream seepage (on average 51,000 AF per year), deep percolation (on average 76,000 AF per year), subsidence (on average 2,900 AF per year), and net subsurface flows (on average 44,000 AF per year). Outflows from the GWS include groundwater extraction (on average -170,000 AF per year). Overall, the water budget results for the 16-year implementation period indicate a cumulative change in groundwater storage of about 13,000 AF, which equals an average annual change in groundwater storage of about 810 AF per year. These change in storage estimates equate to total increases in storage in the GSA of about 0.10 AF per acre on average over the 16 years and an annual increase of 0.01 AF per acre across the entire GSA (approximately 180,000 acres).

For the Projected with Projects Sustainability period, inflows to the GWS include net stream seepage (on average 63,000 AF per year) and deep percolation (on average 75,000 AF per year). Outflows from the GWS include groundwater extraction (on average -110,000 AF per year), subsidence (on average -1,500 AF per year), and net subsurface flows (on average -17,000 AF per year). Overall, the water budget results for the 51-year sustainability period indicate a cumulative change in groundwater storage of about 590,000 AF, which equals an average annual change in groundwater storage of about 12,000 AF per year. These change in storage estimates equate to total increases in storage in the GSA of about 4.35 AF per acre on average over the 51 years and an annual increase of 0.09 AF per acre across the entire GSA (approximately 180,000 acres).

Table 4-58. Madera County GSA Projected with Projects Groundwater System Annual Water Budget Summary (acre-feet)

Water Budget Component	Average Annual Implementation Period (WY 2024-2039)	Average Annual Sustainability Period (WY 2040-2090)
Net Stream Seepage	51,000	63,000
Deep Percolation	76,000	75,000
Groundwater Extractions	-170,000	-110,000
Subsidence	2,900	-1,500
Net Subsurface Flows	44,000	-17,000
Annual Change in Groundwater Storage	**810**	**12,000**

Summarized results for major components of the Projected with Projects and with Climate Change water budget as they relate to the GWS are presented in **Table 4-59**.

For the Projected with Projects and with Climate Change Implementation period, inflows to the GWS include net stream seepage (on average 45,000 AF per year), deep percolation (on average 73,000 AF per year), subsidence (on average 7,800 AF per year), and net subsurface flows (on average 34,000 AF per year). Outflows from the GWS include groundwater extraction (on average -180,000 AF per year). Overall, the water budget results for the 16-year implementation period indicate a cumulative change in groundwater storage of about -240,000 AF, which equals an average annual change in groundwater storage of about -15,000 AF per year. These change in storage estimates equate to total decreases in storage in the GSA of about -1.73 AF per acre on average over the 16 years and an annual decrease of -0.11 AF per acre across the entire GSA (approximately 180,000 acres).

For the Projected with Projects and with Climate Change Sustainability period, inflows to the GWS include net stream seepage (on average 57,000 AF per year), deep percolation (on average 75,000 AF per year), and subsidence (on average 590 AF per year). Outflows from the GWS include groundwater extraction (on average -110,000 AF per year) and net subsurface flows (on average -14,000 AF per year). Overall, the water budget results for the 51-year sustainability period indicate a cumulative change in groundwater storage of about 260,000 AF, which equals an average annual change in groundwater storage of about 5,100 AF per year. These change in storage estimates equate to total increases in storage in the GSA of about 1.93 AF per acre on average over the 51 years and an annual increase of 0.04 AF per acre across the entire GSA (approximately 180,000 acres).

Table 4-59. Madera County GSA Projected with Projects and with Climate Change Groundwater System Annual Water Budget Summary (acre-feet)

Water Budget Component	Average Annual Implementation Period (WY 2024-2039)	Average Annual Sustainability Period (WY 2040-2090)
Net Stream Seepage	45,000	57,000
Deep Percolation	73,000	75,000
Groundwater Extractions	-180,000	-110,000
Subsidence	7,800	590
Net Subsurface Flows	34,000	-14,000
Annual Change in Groundwater Storage	**-15,000**	**5,100**

<u>Projected (No Action)</u>

Summarized results for major components of the Projected (No Action) water budget as they relate to the GWS are presented in **Table 4-60**.

For the Projected (No Action) Implementation period, inflows to the GWS include net stream seepage (on average 44,000 AF per year), deep percolation (on average 82,000 AF per year), subsidence (on average 14,000 AF per year), and net subsurface flows (on average 68,000 AF per year). Outflows from the GWS include groundwater extraction (on average -240,000 AF per year). Overall, the water budget results for the 16-year implementation period indicate a cumulative change in groundwater storage of about -450,000 AF, which equals an average annual change in groundwater storage of about -28,000 AF per year. These change in storage estimates equate to total decreases in storage in the GSA of about -3.33 AF per acre on average over the 16 years and an annual decrease of -0.21 AF per acre across the entire GSA (approximately 180,000 acres).

For the Projected (No Action) Sustainability period, inflows to the GWS include net stream seepage (on average 54,000 AF per year), deep percolation (on average 94,000 AF per year), subsidence (on average 12,000 AF per year), and net subsurface flows (on average 69,000 AF per year). Outflows from the GWS include groundwater extraction (on average -240,000 AF per year). Overall, the water budget results for the 51-year sustainability period indicate a cumulative change in groundwater storage of about -570,000 AF, which equals an average annual change in groundwater storage of about -11,000 AF per year. These change in storage estimates equate to total decreases in storage in the GSA of about -4.18 AF per acre on average over the 51 years and an annual decrease of -0.08 AF per acre across the entire GSA (approximately 180,000 acres).

Table 4-60. Madera County GSA Projected (No Action) Groundwater System Annual Water Budget Summary (acre-feet)		
Water Budget Component	**Average Annual Implementation Period (WY 2024-2039)**	**Average Annual Sustainability Period (WY 2040-2090)**
Net Stream Seepage	44,000	54,000
Deep Percolation	82,000	94,000
Groundwater Extractions	-240,000	-240,000
Subsidence	14,000	12,000
Net Subsurface Flows	68,000	69,000
Annual Change in Groundwater Storage	**-28,000**	**-11,000**

Summarized results for major components of the Projected (No Action) with Climate Change water budget as they relate to the GWS are presented in **Table 4-61**.

For the Projected (No Action) with Climate Change Implementation period, inflows to the GWS include net stream seepage (on average 44,000 AF per year), deep percolation (on average 81,000 AF per year), subsidence (on average 20,000 AF per year), and net subsurface flows (on average 60,000 AF per year). Outflows from the GWS include groundwater extraction (on average -240,000 AF per year). Overall, the water budget results for the 16-year implementation period indicate a cumulative change in groundwater storage of about -610,000 AF, which equals an average annual change in groundwater storage of about -38,000 AF per year. These change in storage estimates equate to total decreases in storage in the GSA of about -4.49 AF per acre on average over the 16 years and an annual decrease of -0.28 AF per acre across the entire GSA (approximately 180,000 acres).

For the Projected (No Action) with Climate Change Sustainability period, inflows to the GWS include net stream seepage (on average 55,000 AF per year), deep percolation (on average 95,000 AF per year), subsidence (on average 15,000 AF per year), and net subsurface flows (on average 68,000 AF per year). Outflows from the GWS include groundwater extraction (on average -240,000 AF per year). Overall, the water budget results for the 51-year sustainability period indicate a cumulative change in groundwater storage of about -670,000 AF, which equals an average annual change in groundwater storage of about -13,000 AF per year. These change in storage estimates equate to total decreases in storage in the GSA of about -4.96 AF per acre on average over the 51 years and an annual decrease of -0.10 AF per acre across the entire GSA (approximately 180,000 acres).

Table 4-61. Madera County GSA Projected (No Action) with Climate Change Groundwater System Annual Water Budget Summary (acre-feet)

Water Budget Component	Average Annual Implementation Period (WY 2024-2039)	Average Annual Sustainability Period (WY 2040-2090)
Net Stream Seepage	44,000	55,000
Deep Percolation	81,000	95,000
Groundwater Extractions	-240,000	-240,000
Subsidence	20,000	15,000
Net Subsurface Flows	60,000	68,000
Annual Change in Groundwater Storage	**-38,000**	**-13,000**

Madera Irrigation District GSA

The following section summarizes the analyses and results relating to the Madera Irrigation District GSA (MID) within Madera Subbasin. Detailed results for each of the individual water budget components for each scenario are presented in **Appendix D.2.c**.

Historical

Summarized results for major components of the historical water budget as they relate to the GWS are presented in **Table 4-62**.

For the GSP historical period, inflows to the GWS include net stream seepage (on average 80,000 AF per year), deep percolation (on average 100,000 AF per year), and subsidence (on average 12,000 AF per year). Outflows from the GWS include groundwater extraction (on average -200,000 AF per year) and net subsurface flows (on average -18,000 AF per year). Overall, the water budget results for the 27-year historical period indicates a cumulative change in groundwater storage of about -700,000 AF, which equals an average annual change in groundwater storage of about -26,000 AF per year. These change in storage estimates equate to total decreases in storage in the GSA of about -5.24 AF per acre on average over the 27 years and an annual decrease of -0.19 AF per acre across the entire GSA (approximately 130,000 acres).

For the calibrated historical period, inflows to the GWS include net stream seepage (on average 82,000 AF per year), deep percolation (on average 110,000 AF per year), and subsidence (on average 13,000 AF per year). Outflows from the GWS include groundwater extraction (on average -210,000 AF per year) and net subsurface flows (on average -14,000 AF per year). Overall, the water budget results for the 35-year historical period indicates a cumulative change in groundwater storage of about -760,000 AF, which equals an average annual change in groundwater storage of about -22,000 AF per year. These change in storage estimates equate to total decreases in storage in the GSA of about -5.64 AF per acre on average over the 35 years and an annual decrease of -0.16 AF per acre across the entire GSA (approximately 130,000 acres).

Table 4-62. Madera Irrigation District GSA Historical Groundwater System Annual Water Budget Summary (acre-feet)		
Water Budget Component	Average Annual GSP Historical Period (WY 1989-2015)	Average Annual Calibrated Historical Period (WY 1989-2023)
Net Stream Seepage	80,000	82,000
Deep Percolation	100,000	110,000
Groundwater Extractions	-200,000	-210,000
Subsidence	12,000	13,000
Net Subsurface Flows	-18,000	-14,000
Annual Change in Groundwater Storage	**-26,000**	**-22,000**

Projected with Projects

Summarized results for major components of the Projected with Projects water budget as they relate to the GWS are presented in **Table 4-63**.

For the Projected with Projects Implementation period, inflows to the GWS include net stream seepage (on average 110,000 AF per year), deep percolation (on average 87,000 AF per year), subsidence (on average 3,400 AF per year), and net subsurface flows (on average 9,800 AF per year). Outflows from the GWS include groundwater extraction (on average -220,000 AF per year). Overall, the water budget results for the 16-year implementation period indicate a cumulative change in groundwater storage of about -140,000 AF, which equals an average annual change in groundwater storage of about -8,700 AF per year. These change in storage estimates equate to total decreases in storage in the GSA of about -1.04 AF per acre on average over the 16 years and an annual decrease of -0.06 AF per acre across the entire GSA (approximately 130,000 acres).

For the Projected with Projects Sustainability period, inflows to the GWS include net stream seepage (on average 130,000 AF per year), deep percolation (on average 99,000 AF per year), and net subsurface flows (on average 2,600 AF per year). Outflows from the GWS include groundwater extraction (on average -220,000 AF per year) and subsidence (on average -1,000 AF per year). Overall, the water budget results for the 51-year sustainability period indicate a cumulative change in groundwater storage of about 500,000 AF, which equals an average annual change in groundwater storage of about 9,800 AF per year. These change in storage estimates equate to total increases in storage in the GSA of about 3.70 AF per acre on average over the 51 years and an annual increase of 0.07 AF per acre across the entire GSA (approximately 130,000 acres).

Table 4-63. Madera Irrigation District GSA Projected with Projects Groundwater System Annual Water Budget Summary (acre-feet)		
Water Budget Component	**Average Annual Implementation Period (WY 2024-2039)**	**Average Annual Sustainability Period (WY 2040-2090)**
Net Stream Seepage	110,000	130,000
Deep Percolation	87,000	99,000
Groundwater Extractions	-220,000	-220,000
Subsidence	3,400	-1,000
Net Subsurface Flows	9,800	2,600
Annual Change in Groundwater Storage	**-8,700**	**9,800**

Summarized results for major components of the Projected with Projects and with Climate Change water budget as they relate to the GWS are presented in **Table 4-64**.

For the Projected with Projects and with Climate Change Implementation period, inflows to the GWS include net stream seepage (on average 88,000 AF per year), deep percolation (on average 85,000 AF per year), subsidence (on average 9,400 AF per year), and net subsurface flows (on average 29,000 AF per year). Outflows from the GWS include groundwater extraction (on average -240,000 AF per year). Overall, the water budget results for the 16-year implementation period indicate a cumulative change in groundwater storage of about -470,000 AF, which equals an average annual change in groundwater storage of about -29,000 AF per year. These change in storage estimates equate to total decreases in storage in the GSA of about -3.46 AF per acre on average over the 16 years and an annual decrease of -0.22 AF per acre across the entire GSA (approximately 130,000 acres).

For the Projected with Projects and with Climate Change Sustainability period, inflows to the GWS include net stream seepage (on average 98,000 AF per year), deep percolation (on average 99,000 AF per year), subsidence (on average 1,400 AF per year), and net subsurface flows (on average 45,000 AF per year). Outflows from the GWS include groundwater extraction (on average -240,000 AF per year). Overall, the water budget results for the 51-year sustainability period indicate a cumulative change in groundwater storage of about 160,000 AF, which equals an average annual change in groundwater storage of about 3,100 AF per year. These change in storage estimates equate to total increases in storage in the GSA of about 1.16 AF per acre on average over the 51 years and an annual increase of 0.02 AF per acre across the entire GSA (approximately 130,000 acres).

Table 4-64. Madera Irrigation District GSA Projected with Projects and with Climate Change Groundwater System Annual Water Budget Summary (acre-feet)		
Water Budget Component	Average Annual Implementation Period (WY 2024-2039)	Average Annual Sustainability Period (WY 2040-2090)
Net Stream Seepage	88,000	98,000
Deep Percolation	85,000	99,000
Groundwater Extractions	-240,000	-240,000
Subsidence	9,400	1,400
Net Subsurface Flows	29,000	45,000
Annual Change in Groundwater Storage	**-29,000**	**3,100**

Projected (No Action)

Summarized results for major components of the Projected (No Action) water budget as they relate to the GWS are presented in **Table 4-65**.

For the Projected (No Action) Implementation period, inflows to the GWS include net stream seepage (on average 86,000 AF per year), deep percolation (on average 87,000 AF per year), subsidence (on average 11,000 AF per year), and net subsurface flows (on average 3,400 AF per year). Outflows from the GWS include groundwater extraction (on average -220,000 AF per year). Overall, the water budget results for the 16-year implementation period indicate a cumulative change in groundwater storage of about -520,000 AF, which equals an average annual change in groundwater storage of about -33,000 AF per year. These change in storage estimates equate to total decreases in storage in the GSA of about -3.91 AF per acre on average over the 16 years and an annual decrease of -0.24 AF per acre across the entire GSA (approximately 130,000 acres).

For the Projected (No Action) Sustainability period, inflows to the GWS include net stream seepage (on average 88,000 AF per year), deep percolation (on average 100,000 AF per year), subsidence (on average 11,000 AF per year), and net subsurface flows (on average 14,000 AF per year). Outflows from the GWS include groundwater extraction (on average -230,000 AF per year). Overall, the water budget results for the 51-year sustainability period indicate a cumulative change in groundwater storage of about -740,000 AF, which equals an average annual change in groundwater storage of about -15,000 AF per year. These change in storage estimates equate to total decreases in storage in the GSA of about -5.53 AF per acre on average over the 51 years and an annual decrease of -0.11 AF per acre across the entire GSA (approximately 130,000 acres).

Table 4-65. Madera Irrigation District GSA Projected (No Action) Groundwater System Annual Water Budget Summary (acre-feet)

Water Budget Component	Average Annual Implementation Period (WY 2024-2039)	Average Annual Sustainability Period (WY 2040-2090)
Net Stream Seepage	86,000	88,000
Deep Percolation	87,000	100,000
Groundwater Extractions	-220,000	-230,000
Subsidence	11,000	11,000
Net Subsurface Flows	3,400	14,000
Annual Change in Groundwater Storage	**-33,000**	**-15,000**

Summarized results for major components of the Projected (No Action) with Climate Change water budget as they relate to the GWS are presented in **Table 4-66**.

For the Projected (No Action) with Climate Change Implementation period, inflows to the GWS include net stream seepage (on average 74,000 AF per year), deep percolation (on average 85,000 AF per year), subsidence (on average 17,000 AF per year), and net subsurface flows (on average 18,000 AF per year). Outflows from the GWS include groundwater extraction (on average -240,000 AF per year). Overall, the water budget results for the 16-year implementation period indicate a cumulative change in groundwater storage of about -770,000 AF, which equals an average annual change in groundwater storage of about -48,000 AF per year. These change in storage estimates equate to total decreases in storage in the GSA of about -5.72 AF per acre on average over the 16 years and an annual decrease of -0.36 AF per acre across the entire GSA (approximately 130,000 acres).

For the Projected (No Action) with Climate Change Sustainability period, inflows to the GWS include net stream seepage (on average 79,000 AF per year), deep percolation (on average 100,000 AF per year), subsidence (on average 14,000 AF per year), and net subsurface flows (on average 37,000 AF per year). Outflows from the GWS include groundwater extraction (on average -250,000 AF per year). Overall, the water budget results for the 51-year sustainability period indicate a cumulative change in groundwater storage of about -870,000 AF, which equals an average annual change in groundwater storage of about -17,000 AF per year. These change in storage estimates equate to total decreases in storage in the GSA of about -6.47 AF per acre on average over the 51 years and an annual decrease of -0.13 AF per acre across the entire GSA (approximately 130,000 acres).

Table 4-66. Madera Irrigation District GSA Projected (No Action) with Climate Change Groundwater System Annual Water Budget Summary (acre-feet)		
Water Budget Component	Average Annual Implementation Period (WY 2024-2039)	Average Annual Sustainability Period (WY 2040-2090)
Net Stream Seepage	74,000	79,000
Deep Percolation	85,000	100,000
Groundwater Extractions	-240,000	-250,000
Subsidence	17,000	14,000
Net Subsurface Flows	18,000	37,000
Annual Change in Groundwater Storage	**-48,000**	**-17,000**

Madera Water District GSA

The following section summarizes the analyses and results relating to the Madera Water District GSA (MWD) within Madera Subbasin. Detailed results for each of the individual water budget components for each scenario are presented in **Appendix D.2.d**.

Historical

Summarized results for major components of the historical water budget as they relate to the GWS are presented in **Table 4-67**.

For the GSP historical period, inflows to the GWS include net stream seepage (on average 120 AF per year), deep percolation (on average 3,500 AF per year), subsidence (on average 510 AF per year), and net subsurface flows (on average 3,000 AF per year). Outflows from the GWS include groundwater extraction (on average -7,900 AF per year). Overall, the water budget results for the 27-year historical period indicates a cumulative change in groundwater storage of about -18,000 AF, which equals an average annual change in groundwater storage of about -650 AF per year. These change in storage estimates equate to total decreases in storage in the GSA of about -5.23 AF per acre on average over the 27 years and an annual decrease of -0.19 AF per acre across the entire GSA (approximately 3,400 acres).

For the calibrated historical period, inflows to the GWS include net stream seepage (on average 120 AF per year), deep percolation (on average 3,400 AF per year), subsidence (on average 500 AF per year), and net subsurface flows (on average 2,500 AF per year). Outflows from the GWS include groundwater extraction (on average -7,000 AF per year). Overall, the water budget results for the 35-year historical period indicates a cumulative change in groundwater storage of about -18,000 AF, which equals an average annual change in groundwater storage of about -530 AF per year. These change in storage estimates equate to total decreases in storage in the GSA of about -5.44 AF per acre on average over the 35 years and an annual decrease of -0.16 AF per acre across the entire GSA (approximately 3,400 acres).

Table 4-67. Madera Water District GSA Historical Groundwater System Annual Water Budget Summary (acre-feet)

Water Budget Component	Average Annual GSP Historical Period (WY 1989-2015)	Average Annual Calibrated Historical Period (WY 1989-2023)
Net Stream Seepage	120	120
Deep Percolation	3,500	3,400
Groundwater Extractions	-7,900	-7,000
Subsidence	510	500
Net Subsurface Flows	3,000	2,500
Annual Change in Groundwater Storage	**-650**	**-530**

Projected with Projects

Summarized results for major components of the Projected with Projects water budget as they relate to the GWS are presented in **Table 4-68**.

For the Projected with Projects Implementation period, inflows to the GWS include net stream seepage (on average 2,500 AF per year), deep percolation (on average 2,400 AF per year), subsidence (on average 190 AF per year), and net subsurface flows (on average 1,100 AF per year). Outflows from the GWS include groundwater extraction (on average -6,100 AF per year). Overall, the water budget results for the 16-year implementation period indicate a cumulative change in groundwater storage of about 2,000 AF, which equals an average annual change in groundwater storage of about 120 AF per year. These change in storage estimates equate to total increases in storage in the GSA of about 0.58 AF per acre on average over the 16 years and an annual increase of 0.04 AF per acre across the entire GSA (approximately 3,400 acres).

For the Projected with Projects Sustainability period, inflows to the GWS include net stream seepage (on average 3,100 AF per year), deep percolation (on average 2,700 AF per year), and net subsurface flows (on average 1,100 AF per year). Outflows from the GWS include groundwater extraction (on average -6,400 AF per year) and subsidence (on average -59 AF per year). Overall, the water budget results for the 51-year sustainability period indicate a cumulative change in groundwater storage of about 21,000 AF, which equals an average annual change in groundwater storage of about 410 AF per year. These change in storage estimates equate to total increases in storage in the GSA of about 6.19 AF per acre on average over the 51 years and an annual increase of 0.12 AF per acre across the entire GSA (approximately 3,400 acres).

Table 4-68. Madera Water District GSA Projected with Projects Groundwater System Annual Water Budget Summary (acre-feet)		
Water Budget Component	**Average Annual Implementation Period (WY 2024-2039)**	**Average Annual Sustainability Period (WY 2040-2090)**
Net Stream Seepage	2,500	3,100
Deep Percolation	2,400	2,700
Groundwater Extractions	-6,100	-6,400
Subsidence	190	-59
Net Subsurface Flows	1,100	1,100
Annual Change in Groundwater Storage	**120**	**410**

Summarized results for major components of the Projected with Projects and with Climate Change water budget as they relate to the GWS are presented in **Table 4-69**.

For the Projected with Projects and with Climate Change Implementation period, inflows to the GWS include net stream seepage (on average 100 AF per year), deep percolation (on average 2,500 AF per year), subsidence (on average 370 AF per year), and net subsurface flows (on average 2,800 AF per year). Outflows from the GWS include groundwater extraction (on average -6,500 AF per year). Overall, the water budget results for the 16-year implementation period indicate a cumulative change in groundwater storage of about -12,000 AF, which equals an average annual change in groundwater storage of about -760 AF per year. These change in storage estimates equate to total decreases in storage in the GSA of about -3.59 AF per acre on average over the 16 years and an annual decrease of -0.22 AF per acre across the entire GSA (approximately 3,400 acres).

For the Projected with Projects and with Climate Change Sustainability period, inflows to the GWS include net stream seepage (on average 170 AF per year), deep percolation (on average 2,700 AF per year), subsidence (on average 55 AF per year), and net subsurface flows (on average 4,000 AF per year). Outflows from the GWS include groundwater extraction (on average -6,700 AF per year). Overall, the water budget results for the 51-year sustainability period indicate a cumulative change in groundwater storage of about 8,400 AF, which equals an average annual change in groundwater storage of about 170 AF per year. These change in storage estimates equate to total increases in storage in the GSA of about 2.50 AF per acre on average over the 51 years and an annual increase of 0.05 AF per acre across the entire GSA (approximately 3,400 acres).

Table 4-69. Madera Water District GSA Projected with Projects and with Climate Change Groundwater System Annual Water Budget Summary (acre-feet)

Water Budget Component	Average Annual Implementation Period (WY 2024-2039)	Average Annual Sustainability Period (WY 2040-2090)
Net Stream Seepage	100	170
Deep Percolation	2,500	2,700
Groundwater Extractions	-6,500	-6,700
Subsidence	370	55
Net Subsurface Flows	2,800	4,000
Annual Change in Groundwater Storage	**-760**	**170**

Projected (No Action)

Summarized results for major components of the Projected (No Action) water budget as they relate to the GWS are presented in **Table 4-70**.

For the Projected (No Action) Implementation period, inflows to the GWS include net stream seepage (on average 100 AF per year), deep percolation (on average 2,400 AF per year), subsidence (on average 460 AF per year), and net subsurface flows (on average 2,100 AF per year). Outflows from the GWS include groundwater extraction (on average -6,100 AF per year). Overall, the water budget results for the 16-year implementation period indicate a cumulative change in groundwater storage of about -17,000 AF, which equals an average annual change in groundwater storage of about -1,000 AF per year. These change in storage estimates equate to total decreases in storage in the GSA of about -4.90 AF per acre on average over the 16 years and an annual decrease of -0.31 AF per acre across the entire GSA (approximately 3,400 acres).

For the Projected (No Action) Sustainability period, inflows to the GWS include net stream seepage (on average 160 AF per year), deep percolation (on average 2,700 AF per year), subsidence (on average 390 AF per year), and net subsurface flows (on average 2,800 AF per year). Outflows from the GWS include groundwater extraction (on average -6,400 AF per year). Overall, the water budget results for the 51-year sustainability period indicate a cumulative change in groundwater storage of about -23,000 AF, which equals an average annual change in groundwater storage of about -450 AF per year. These change in storage estimates equate to total decreases in storage in the GSA of about -6.75 AF per acre on average over the 51 years and an annual decrease of -0.13 AF per acre across the entire GSA (approximately 3,400 acres).

Table 4-70. Madera Water District GSA Projected (No Action) Groundwater System Annual Water Budget Summary (acre-feet)

Water Budget Component	Average Annual Implementation Period (WY 2024-2039)	Average Annual Sustainability Period (WY 2040-2090)
Net Stream Seepage	100	160
Deep Percolation	2,400	2,700
Groundwater Extractions	-6,100	-6,400
Subsidence	460	390
Net Subsurface Flows	2,100	2,800
Annual Change in Groundwater Storage	**-1,000**	**-450**

Summarized results for major components of the Projected (No Action) with Climate Change water budget as they relate to the GWS are presented in **Table 4-71**.

For the Projected (No Action) with Climate Change Implementation period, inflows to the GWS include net stream seepage (on average 100 AF per year), deep percolation (on average 2,500 AF per year), subsidence (on average 580 AF per year), and net subsurface flows (on average 2,000 AF per year). Outflows from the GWS include groundwater extraction (on average -6,500 AF per year). Overall, the water budget results for the 16-year implementation period indicate a cumulative change in groundwater storage of about -21,000 AF, which equals an average annual change in groundwater storage of about -1,300 AF per year. These change in storage estimates equate to total decreases in storage in the GSA of about -6.25 AF per acre on average over the 16 years and an annual decrease of -0.39 AF per acre across the entire GSA (approximately 3,400 acres).

For the Projected (No Action) with Climate Change Sustainability period, inflows to the GWS include net stream seepage (on average 160 AF per year), deep percolation (on average 2,700 AF per year), subsidence (on average 490 AF per year), and net subsurface flows (on average 2,700 AF per year). Outflows from the GWS include groundwater extraction (on average -6,700 AF per year). Overall, the water budget results for the 51-year sustainability period indicate a cumulative change in groundwater storage of about -34,000 AF, which equals an average annual change in groundwater storage of about -670 AF per year. These change in storage estimates equate to total decreases in storage in the GSA of about -10.14 AF per acre on average over the 51 years and an annual decrease of -0.20 AF per acre across the entire GSA (approximately 3,400 acres).

Table 4-71. Madera Water District GSA Projected (No Action) with Climate Change Groundwater System Annual Water Budget Summary (acre-feet)		
Water Budget Component	Average Annual Implementation Period (WY 2024-2039)	Average Annual Sustainability Period (WY 2040-2090)
Net Stream Seepage	100	160
Deep Percolation	2,500	2,700
Groundwater Extractions	-6,500	-6,700
Subsidence	580	490
Net Subsurface Flows	2,000	2,700
Annual Change in Groundwater Storage	**-1,300**	**-670**

Other GSP GSAs

Gravelly Ford Water District GSA

The following section summarizes the analyses and results relating to the Gravelly Ford Water District GSA (GFWD) within Madera Subbasin. Detailed results for each of the individual water budget components for each scenario are presented in **Appendix D.2.e**.

<u>Historical</u>

Summarized results for major components of the historical water budget as they relate to the GWS are presented in **Table 4-72**.

For the GSP historical period, inflows to the GWS include net stream seepage (on average 5,800 AF per year), deep percolation (on average 9,100 AF per year), and subsidence (on average 570 AF per year). Outflows from the GWS include groundwater extraction (on average -16,000 AF per year) and net subsurface flows (on average -980 AF per year). Overall, the water budget results for the 27-year historical period indicates a cumulative change in groundwater storage of about -33,000 AF, which equals an average annual change in groundwater storage of about -1,200 AF per year. These change in storage estimates equate to total decreases in storage in the GSA of about -4.14 AF per acre on average over the 27 years and an annual decrease of -0.15 AF per acre across the entire GSA (approximately 7,900 acres).

For the calibrated historical period, inflows to the GWS include net stream seepage (on average 5,700 AF per year), deep percolation (on average 9,200 AF per year), and subsidence (on average 680 AF per year). Outflows from the GWS include groundwater extraction (on average -16,000 AF per year) and net subsurface flows (on average -320 AF per year). Overall, the water budget results for the 35-year historical period indicates a cumulative change in groundwater storage of about -32,000 AF, which equals an average annual change in groundwater storage of about -910 AF per year. These change in storage estimates equate to total decreases in storage in the GSA of about -4.03 AF per acre on average over the 35 years and an annual decrease of -0.12 AF per acre across the entire GSA (approximately 7,900 acres).

Table 4-72. Gravelly Ford Water District GSA Historical Groundwater System Annual Water Budget Summary (acre-feet)		
Water Budget Component	**Average Annual GSP Historical Period (WY 1989-2015)**	**Average Annual Calibrated Historical Period (WY 1989-2023)**
Net Stream Seepage	5,800	5,700
Deep Percolation	9,100	9,200
Groundwater Extractions	-16,000	-16,000
Subsidence	570	680
Net Subsurface Flows	-980	-320
Annual Change in Groundwater Storage	**-1,200**	**-910**

Projected with Projects

Summarized results for major components of the Projected with Projects water budget as they relate to the GWS are presented in **Table 4-73**.

For the Projected with Projects Implementation period, inflows to the GWS include net stream seepage (on average 8,900 AF per year), deep percolation (on average 7,400 AF per year), and subsidence (on average 210 AF per year). Outflows from the GWS include groundwater extraction (on average -16,000 AF per year) and net subsurface flows (on average -1,300 AF per year). Overall, the water budget results for the 16-year implementation period indicate a cumulative change in groundwater storage of about -19,000 AF, which equals an average annual change in groundwater storage of about -1,200 AF per year. These change in storage estimates equate to total decreases in storage in the GSA of about -2.41 AF per acre on average over the 16 years and an annual decrease of -0.15 AF per acre across the entire GSA (approximately 7,900 acres).

For the Projected with Projects Sustainability period, inflows to the GWS include net stream seepage (on average 11,000 AF per year) and deep percolation (on average 8,500 AF per year). Outflows from the GWS include groundwater extraction (on average -16,000 AF per year), subsidence (on average -8 AF per year), and net subsurface flows (on average -2,800 AF per year). Overall, the water budget results for the 51-year sustainability period indicate a cumulative change in groundwater storage of about 34,000 AF, which equals an average annual change in groundwater storage of about 670 AF per year. These change in storage estimates equate to total increases in storage in the GSA of about 4.30 AF per acre on average over the 51 years and an annual increase of 0.08 AF per acre across the entire GSA (approximately 7,900 acres).

Table 4-73. Gravelly Ford Water District GSA Projected with Projects Groundwater System Annual Water Budget Summary (acre-feet)

Water Budget Component	Average Annual Implementation Period (WY 2024-2039)	Average Annual Sustainability Period (WY 2040-2090)
Net Stream Seepage	8,900	11,000
Deep Percolation	7,400	8,500
Groundwater Extractions	-16,000	-16,000
Subsidence	210	-8
Net Subsurface Flows	-1,300	-2,800
Annual Change in Groundwater Storage	**-1,200**	**670**

Summarized results for major components of the Projected with Projects and with Climate Change water budget as they relate to the GWS are presented in **Table 4-74**.

For the Projected with Projects and with Climate Change Implementation period, inflows to the GWS include net stream seepage (on average 8,000 AF per year), deep percolation (on average 7,400 AF per year), and subsidence (on average 450 AF per year). Outflows from the GWS include groundwater extraction (on average -17,000 AF per year) and net subsurface flows (on average -620 AF per year). Overall, the water budget results for the 16-year implementation period indicate a cumulative change in groundwater storage of about -29,000 AF, which equals an average annual change in groundwater storage of about -1,800 AF per year. These change in storage estimates equate to total decreases in storage in the GSA of about -3.66 AF per acre on average over the 16 years and an annual decrease of -0.23 AF per acre across the entire GSA (approximately 7,900 acres).

For the Projected with Projects and with Climate Change Sustainability period, inflows to the GWS include net stream seepage (on average 9,500 AF per year), deep percolation (on average 8,500 AF per year), and subsidence (on average 50 AF per year). Outflows from the GWS include groundwater extraction (on average -16,000 AF per year) and net subsurface flows (on average -1,200 AF per year). Overall, the water budget results for the 51-year sustainability period indicate a cumulative change in groundwater storage of about 21,000 AF, which equals an average annual change in groundwater storage of about 410 AF per year. These change in storage estimates equate to total increases in storage in the GSA of about 2.68 AF per acre on average over the 51 years and an annual increase of 0.05 AF per acre across the entire GSA (approximately 7,900 acres).

Table 4-74. Gravelly Ford Water District GSA Projected with Projects and with Climate Change Groundwater System Annual Water Budget Summary (acre-feet)		
Water Budget Component	**Average Annual Implementation Period (WY 2024-2039)**	**Average Annual Sustainability Period (WY 2040-2090)**
Net Stream Seepage	8,000	9,500
Deep Percolation	7,400	8,500
Groundwater Extractions	-17,000	-16,000
Subsidence	450	50
Net Subsurface Flows	-620	-1,200
Annual Change in Groundwater Storage	**-1,800**	**410**

Projected (No Action)

Summarized results for major components of the Projected (No Action) water budget as they relate to the GWS are presented in **Table 4-75**.

For the Projected (No Action) Implementation period, inflows to the GWS include net stream seepage (on average 5,100 AF per year), deep percolation (on average 7,400 AF per year), subsidence (on average 580 AF per year), and net subsurface flows (on average 1,100 AF per year). Outflows from the GWS include groundwater extraction (on average -16,000 AF per year). Overall, the water budget results for the 16-year implementation period indicate a cumulative change in groundwater storage of about -34,000 AF, which equals an average annual change in groundwater storage of about -2,100 AF per year. These change in storage estimates equate to total decreases in storage in the GSA of about -4.29 AF per acre on average over the 16 years and an annual decrease of -0.27 AF per acre across the entire GSA (approximately 7,900 acres).

For the Projected (No Action) Sustainability period, inflows to the GWS include net stream seepage (on average 6,200 AF per year), deep percolation (on average 8,400 AF per year), subsidence (on average 420 AF per year), and net subsurface flows (on average 410 AF per year). Outflows from the GWS include groundwater extraction (on average -16,000 AF per year). Overall, the water budget results for the 51-year sustainability period indicate a cumulative change in groundwater storage of about -22,000 AF, which equals an average annual change in groundwater storage of about -430 AF per year. These change in storage estimates equate to total decreases in storage in the GSA of about -2.79 AF per acre on average over the 51 years and an annual decrease of -0.05 AF per acre across the entire GSA (approximately 7,900 acres).

Table 4-75. Gravelly Ford Water District GSA Projected (No Action) Groundwater System Annual Water Budget Summary (acre-feet)

Water Budget Component	Average Annual Implementation Period (WY 2024-2039)	Average Annual Sustainability Period (WY 2040-2090)
Net Stream Seepage	5,100	6,200
Deep Percolation	7,400	8,400
Groundwater Extractions	-16,000	-16,000
Subsidence	580	420
Net Subsurface Flows	1,100	410
Annual Change in Groundwater Storage	**-2,100**	**-430**

Summarized results for major components of the Projected (No Action) with Climate Change water budget as they relate to the GWS are presented in **Table 4-76**.

For the Projected (No Action) with Climate Change Implementation period, inflows to the GWS include net stream seepage (on average 5,100 AF per year), deep percolation (on average 7,400 AF per year), subsidence (on average 790 AF per year), and net subsurface flows (on average 1,100 AF per year). Outflows from the GWS include groundwater extraction (on average 17,000 AF per year). Overall, the water budget results for the 16-year implementation period indicate a cumulative change in groundwater storage of about -41,000 AF, which equals an average annual change in groundwater storage of about -2,600 AF per year. These change in storage estimates equate to total decreases in storage in the GSA of about -5.19 AF per acre on average over the 16 years and an annual decrease of -0.32 AF per acre across the entire GSA (approximately 7,900 acres).

For the Projected (No Action) with Climate Change Sustainability period, inflows to the GWS include net stream seepage (on average 6,200 AF per year), deep percolation (on average 8,500 AF per year), subsidence (on average 520 AF per year), and net subsurface flows (on average 550 AF per year). Outflows from the GWS include groundwater extraction (on average -16,000 AF per year). Overall, the water budget results for the 51-year sustainability period indicate a cumulative change in groundwater storage of about -31,000 AF, which equals an average annual change in groundwater storage of about -610 AF per year. These change in storage estimates equate to total decreases in storage in the GSA of about -3.93 AF per acre on average over the 51 years and an annual decrease of -0.08 AF per acre across the entire GSA (approximately 7,900 acres).

Table 4-76. Gravelly Ford Water District GSA Projected (No Action) with Climate Change Groundwater System Annual Water Budget Summary (acre-feet)		
Water Budget Component	**Average Annual Implementation Period (WY 2024-2039)**	**Average Annual Sustainability Period (WY 2040-2090)**
Net Stream Seepage	5,100	6,200
Deep Percolation	7,400	8,500
Groundwater Extractions	-17,000	-16,000
Subsidence	790	520
Net Subsurface Flows	1,100	550
Annual Change in Groundwater Storage	**-2,600**	**-610**

New Stone Water District GSA

The following section summarizes the analyses and results relating to the New Stone Water District GSA (NSWD) within Madera Subbasin. Detailed results for each of the individual water budget components for each scenario are presented in **Appendix D.2.f**.

Historical

Summarized results for major components of the historical water budget as they relate to the GWS are presented in **Table 4-77**.

For the GSP historical period, inflows to the GWS include net stream seepage (on average 3,400 AF per year), deep percolation (on average 3,900 AF per year), subsidence (on average 540 AF per year), and net subsurface flows (on average 2,300 AF per year). Outflows from the GWS include groundwater extraction (on average -10,000 AF per year). Overall, the water budget results for the 27-year historical period indicates a cumulative change in groundwater storage of about -6,900 AF, which equals an average annual change in groundwater storage of about -260 AF per year. These change in storage estimates equate to total decreases in storage in the GSA of about -1.65 AF per acre on average over the 27 years and an annual decrease of -0.06 AF per acre across the entire GSA (approximately 4,200 acres).

For the calibrated historical period, inflows to the GWS include net stream seepage (on average 3,800 AF per year), deep percolation (on average 3,800 AF per year), subsidence (on average 630 AF per year), and net subsurface flows (on average 2,000 AF per year). Outflows from the GWS include groundwater extraction (on average -10,000 AF per year). Overall, the water budget results for the 35-year historical period indicates a cumulative change in groundwater storage of about 870 AF, which equals an average annual change in groundwater storage of about 25 AF per year. These change in storage estimates equate to total increases in storage in the GSA of about 0.21 AF per acre on average over the 35 years and an annual increase of 0.01 AF per acre across the entire GSA (approximately 4,200 acres).

Table 4-77. New Stone Water District GSA Historical Groundwater System Annual Water Budget Summary (acre-feet)		
Water Budget Component	**Average Annual GSP Historical Period (WY 1989-2015)**	**Average Annual Calibrated Historical Period (WY 1989-2023)**
Net Stream Seepage	3,400	3,800
Deep Percolation	3,900	3,800
Groundwater Extractions	-10,000	-10,000
Subsidence	540	630
Net Subsurface Flows	2,300	2,000
Annual Change in Groundwater Storage	**-260**	**25**

Projected with Projects

Summarized results for major components of the Projected with Projects water budget as they relate to the GWS are presented in **Table 4-78**.

For the Projected with Projects Implementation period, inflows to the GWS include net stream seepage (on average 3,700 AF per year), deep percolation (on average 3,300 AF per year), subsidence (on average 190 AF per year), and net subsurface flows (on average 510 AF per year). Outflows from the GWS include groundwater extraction (on average -7,900 AF per year). Overall, the water budget results for the 16-year implementation period indicate a cumulative change in groundwater storage of about -3,300 AF, which equals an average annual change in groundwater storage of about -210 AF per year. These change in storage estimates equate to total decreases in storage in the GSA of about -0.80 AF per acre on average over the 16 years and an annual decrease of -0.05 AF per acre across the entire GSA (approximately 4,200 acres).

For the Projected with Projects Sustainability period, inflows to the GWS include net stream seepage (on average 3,600 AF per year), deep percolation (on average 4,800 AF per year), and net subsurface flows (on average 150 AF per year). Outflows from the GWS include groundwater extraction (on average -8,000 AF per year) and subsidence (on average -34 AF per year). Overall, the water budget results for the 51-year sustainability period indicate a cumulative change in groundwater storage of about 24,000 AF, which equals an average annual change in groundwater storage of about 470 AF per year. These change in storage estimates equate to total increases in storage in the GSA of about 5.76 AF per acre on average over the 51 years and an annual increase of 0.11 AF per acre across the entire GSA (approximately 4,200 acres).

Table 4-78. New Stone Water District GSA Projected with Projects Groundwater System Annual Water Budget Summary (acre-feet)		
Water Budget Component	**Average Annual Implementation Period (WY 2024-2039)**	**Average Annual Sustainability Period (WY 2040-2090)**
Net Stream Seepage	3,700	3,600
Deep Percolation	3,300	4,800
Groundwater Extractions	-7,900	-8,000
Subsidence	190	-34
Net Subsurface Flows	510	150
Annual Change in Groundwater Storage	**-210**	**470**

Summarized results for major components of the Projected with Projects and with Climate Change water budget as they relate to the GWS are presented in **Table 4-79**.

For the Projected with Projects and with Climate Change Implementation period, inflows to the GWS include net stream seepage (on average 3,900 AF per year), deep percolation (on average 3,200 AF per year), subsidence (on average 290 AF per year), and net subsurface flows (on average 230 AF per year). Outflows from the GWS include groundwater extraction (on average -8,100 AF per year). Overall, the water budget results for the 16-year implementation period indicate a cumulative change in groundwater storage of about -7,600 AF, which equals an average annual change in groundwater storage of about -470 AF per year. These change in storage estimates equate to total decreases in storage in the GSA of -1.81 AF per acre on average over the 16 years and an annual decrease of -0.11 AF per acre across the entire GSA (approximately 4,200 acres).

For the Projected with Projects and with Climate Change Sustainability period, inflows to the GWS include net stream seepage (on average 5,400 AF per year) and deep percolation (on average 4,800 AF per year). Outflows from the GWS include groundwater extraction (on average -8,100 AF per year), subsidence (on average -18 AF per year), and net subsurface flows (on average -1,600 AF per year). Overall, the water budget results for the 51-year sustainability period indicate a cumulative change in groundwater storage of about 22,000 AF, which equals an average annual change in groundwater storage of about 430 AF per year. These change in storage estimates equate to total increases in storage in the GSA of about 5.31 AF per acre on average over the 51 years and an annual increase of 0.10 AF per acre across the entire GSA (approximately 4,200 acres).

Table 4-79. New Stone Water District GSA Projected with Projects and with Climate Change Groundwater System Annual Water Budget Summary (acre-feet)

Water Budget Component	Average Annual Implementation Period (WY 2024-2039)	Average Annual Sustainability Period (WY 2040-2090)
Net Stream Seepage	3,900	5,400
Deep Percolation	3,200	4,800
Groundwater Extractions	-8,100	-8,100
Subsidence	290	-18
Net Subsurface Flows	230	-1,600
Annual Change in Groundwater Storage	**-470**	**430**

Projected (No Action)

Summarized results for major components of the Projected (No Action) water budget as they relate to the GWS are presented in **Table 4-80**.

For the Projected (No Action) Implementation period, inflows to the GWS include net stream seepage (on average 3,600 AF per year), deep percolation (on average 2,500 AF per year), subsidence (on average 690 AF per year), and net subsurface flows (on average 250 AF per year). Outflows from the GWS include groundwater extraction (on average -8,300 AF per year). Overall, the water budget results for the 16-year implementation period indicate a cumulative change in groundwater storage of about -19,000 AF, which equals an average annual change in groundwater storage of about -1,200 AF per year. These change in storage estimates equate to total decreases in storage in the GSA of about -4.58 AF per acre on average over the 16 years and an annual decrease of -0.29 AF per acre across the entire GSA (approximately 4,200 acres).

For the Projected (No Action) Sustainability period, inflows to the GWS include net stream seepage (on average 5,800 AF per year), deep percolation (on average 2,900 AF per year), and subsidence (on average 470 AF per year). Outflows from the GWS include groundwater extraction (on average -8,500 AF per year) and net subsurface flows (on average -710 AF per year). Overall, the water budget results for the 51-year sustainability period indicate a cumulative change in groundwater storage of about -5,400 AF, which equals an average annual change in groundwater storage of about -110 AF per year. These change in storage estimates equate to total decreases in storage in the GSA of about -1.29 AF per acre on average over the 51 years and an annual decrease of -0.03 AF per acre across the entire GSA (approximately 4,200 acres).

Table 4-80. New Stone Water District GSA Projected (No Action) Groundwater System Annual Water Budget Summary (acre-feet)		
Water Budget Component	**Average Annual Implementation Period (WY 2024-2039)**	**Average Annual Sustainability Period (WY 2040-2090)**
Net Stream Seepage	3,600	5,800
Deep Percolation	2,500	2,900
Groundwater Extractions	-8,300	-8,500
Subsidence	690	470
Net Subsurface Flows	250	-710
Annual Change in Groundwater Storage	**-1,200**	**-110**

Summarized results for major components of the Projected (No Action) with Climate Change water budget as they relate to the GWS are presented in **Table 4-81**.

For the Projected (No Action) with Climate Change Implementation period, inflows to the GWS include net stream seepage (on average 3,700 AF per year), deep percolation (on average 2,600 AF per year), and subsidence (on average 940 AF per year). Outflows from the GWS include groundwater extraction (on average -8,500 AF per year) and net subsurface flows (on average -33 AF per year). Overall, the water budget results for the 16-year implementation period indicate a cumulative change in groundwater storage of about -22,000 AF, which equals an average annual change in groundwater storage of -1,400 AF per year. These change in storage estimates equate to total decreases in storage in the GSA of about -5.36 AF per acre on average over the 16 years and an annual decrease of -0.33 AF per acre across the entire GSA (approximately 4,200 acres).

For the Projected (No Action) with Climate Change Sustainability period, inflows to the GWS include net stream seepage (on average 6,000 AF per year), deep percolation (on average 2,900 AF per year), and subsidence (on average 650 AF per year). Outflows from the GWS include groundwater extraction (on average -8,800 AF per year) and net subsurface flows (on average -930 AF per year). Overall, the water budget results for the 51-year sustainability period indicate a cumulative change in groundwater storage of about -9,500 AF, which equals an average annual change in groundwater storage of about -190 AF per year. These change in storage estimates equate to total decreases in storage in the GSA of about -2.29 AF per acre on average over the 51 years and an annual decrease of -0.04 AF per acre across the entire GSA (approximately 4,200 acres).

Table 4-81. New Stone Water District GSA Projected (No Action) with Climate Change Groundwater System Annual Water Budget Summary (acre-feet)

Water Budget Component	Average Annual Implementation Period (WY 2024-2039)	Average Annual Sustainability Period (WY 2040-2090)
Net Stream Seepage	3,700	6,000
Deep Percolation	2,600	2,900
Groundwater Extractions	-8,500	-8,800
Subsidence	940	650
Net Subsurface Flows	-33	-930
Annual Change in Groundwater Storage	**-1,400**	**-190**

Root Creek Water District GSA

The following section summarizes the analyses and results relating to the Root Creek Water District GSA (RCWD) within Madera Subbasin. Detailed results for each of the individual water budget components for each scenario are presented in **Appendix D.2.g**.

Historical

Summarized results for major components of the historical water budget as they relate to the GWS are presented in **Table 4-82**.

For the GSP historical period, inflows to the GWS include net stream seepage (on average 2,000 AF per year), deep percolation (on average 8,600 AF per year), subsidence (on average 460 AF per year), and net subsurface flows (on average 14,000 AF per year). Outflows from the GWS include groundwater extraction (on average -25,000 AF per year). Overall, the water budget results for the 27-year historical period indicates a cumulative change in groundwater storage of about 1,200 AF, which equals an average annual change in groundwater storage of about 46 AF per year. These change in storage estimates equate to total increases in storage in the GSA of about 0.12 AF per acre on average over the 27 years and an annual increase of less than 0.01 AF per acre across the entire GSA (approximately 10,000 acres).

For the calibrated historical period, inflows to the GWS include net stream seepage (on average 2,300 AF per year), deep percolation (on average 8,200 AF per year), subsidence (on average 470 AF per year), and net subsurface flows (on average 13,000 AF per year). Outflows from the GWS include groundwater extraction (on average -24,000 AF per year). Overall, the water budget results for the 35-year historical period indicates a cumulative change in groundwater storage of about -580 AF, which equals an average annual change in groundwater storage of about -17 AF per year. These change in storage estimates equate to total decreases in storage in the GSA of about -0.06 AF per acre on average over the 35 years and an annual decrease of less than -0.01 AF per acre across the entire GSA (approximately 10,000 acres).

Table 4-82. Root Creek Water District GSA Historical Groundwater System Annual Water Budget Summary (acre-feet)		
Water Budget Component	**Average Annual GSP Historical Period (WY 1989-2015)**	**Average Annual Calibrated Historical Period (WY 1989-2023)**
Net Stream Seepage	2,000	2,300
Deep Percolation	8,600	8,200
Groundwater Extractions	-25,000	-24,000
Subsidence	460	470
Net Subsurface Flows	14,000	13,000
Annual Change in Groundwater Storage	**46**	**-17**

Projected with Projects

Summarized results for major components of the Projected with Projects water budget as they relate to the GWS are presented in **Table 4-83**.

For the Projected with Projects Implementation period, inflows to the GWS include net stream seepage (on average 7,800 AF per year), deep percolation (on average 5,600 AF per year), subsidence (on average 46 AF per year), and net subsurface flows (on average 7,800 AF per year). Outflows from the GWS include groundwater extraction (on average -21,000 AF per year). Overall, the water budget results for the 16-year implementation period indicate a cumulative change in groundwater storage of about 13,000 AF, which equals an average annual change in groundwater storage of about 830 AF per year. These change in storage estimates equate to total increases in storage in the GSA of about 1.32 AF per acre on average over the 16 years and an annual increase of 0.08 AF per acre across the entire GSA (approximately 10,000 acres).

For the Projected with Projects Sustainability period, inflows to the GWS include net stream seepage (on average 7,400 AF per year), deep percolation (on average 6,100 AF per year), and net subsurface flows (on average 6,700 AF per year). Outflows from the GWS include groundwater extraction (on average -20,000 AF per year) and subsidence (on average -34 AF per year). Overall, the water budget results for the 51-year sustainability period indicate a cumulative change in groundwater storage of about 20,000 AF, which equals an average annual change in groundwater storage of about 390 AF per year. These change in storage estimates equate to total increases in storage in the GSA of about 1.96 AF per acre on average over the 51 years and an annual increase of 0.04 AF per acre across the entire GSA (approximately 10,000 acres).

Table 4-83. Root Creek Water District GSA Projected with Projects Groundwater System Annual Water Budget Summary (acre-feet)

Water Budget Component	Average Annual Implementation Period (WY 2024-2039)	Average Annual Sustainability Period (WY 2040-2090)
Net Stream Seepage	7,800	7,400
Deep Percolation	5,600	6,100
Groundwater Extractions	-21,000	-20,000
Subsidence	46	-34
Net Subsurface Flows	7,800	6,700
Annual Change in Groundwater Storage	**830**	**390**

Summarized results for major components of the Projected with Projects and with Climate Change water budget as they relate to the GWS are presented in **Table 4-84**.

For the Projected with Projects and with Climate Change Implementation period, inflows to the GWS include net stream seepage (on average 6,900 AF per year), deep percolation (on average 5,600 AF per year), subsidence (on average 170 AF per year), and net subsurface flows (on average 8,500 AF per year). Outflows from the GWS include groundwater extraction (on average -21,000 AF per year). Overall, the water budget results for the 16-year implementation period indicate a cumulative change in groundwater storage of about -1,900 AF, which equals an average annual change in groundwater storage of -120 AF per year. These change in storage estimates equate to total decreases in storage in the GSA of about -0.18 AF per acre on average over the 16 years and an annual decrease of -0.01 AF per acre across the entire GSA (approximately 10,000 acres).

For the Projected with Projects and with Climate Change Sustainability period, inflows to the GWS include net stream seepage (on average 6,000 AF per year), deep percolation (on average 6,100 AF per year), subsidence (on average 12 AF per year), and net subsurface flows (on average 8,300 AF per year). Outflows from the GWS include groundwater extraction (on average -20,000 AF per year). Overall, the water budget results for the 51-year sustainability period indicate a cumulative change in groundwater storage of about 4,900 AF, which equals an average annual change in groundwater storage of about 97 AF per year. These change in storage estimates equate to total increases in storage in the GSA of about 0.49 AF per acre on average over the 51 years and an annual increase of 0.01 AF per acre across the entire GSA (approximately 10,000 acres).

Table 4-84. Root Creek Water District GSA Projected with Projects and with Climate Change		
Water Budget Component	**Average Annual Implementation Period (WY 2024-2039)**	**Average Annual Sustainability Period (WY 2040-2090)**
Net Stream Seepage	6,900	6,000
Deep Percolation	5,600	6,100
Groundwater Extractions	-21,000	-20,000
Subsidence	170	12
Net Subsurface Flows	8,500	8,300
Annual Change in Groundwater Storage	**-120**	**97**

Projected (No Action)

Summarized results for major components of the Projected (No Action) water budget as they relate to the GWS are presented in **Table 4-85**.

For the Projected (No Action) Implementation period, inflows to the GWS include net stream seepage (on average 3,200 AF per year), deep percolation (on average 5,700 AF per year), subsidence (on average 540 AF per year), and net subsurface flows (on average 10,000 AF per year). Outflows from the GWS include groundwater extraction (on average -21,000 AF per year). Overall, the water budget results for the 16-year implementation period indicate a cumulative change in groundwater storage of about -29,000 AF, which equals an average annual change in groundwater storage of about -1,800 AF per year. These change in storage estimates equate to total decreases in storage in the GSA of about -2.85 AF per acre on average over the 16 years and an annual decrease of -0.18 AF per acre across the entire GSA (approximately 10,000 acres).

For the Projected (No Action) Sustainability period, inflows to the GWS include net stream seepage (on average 3,400 AF per year), deep percolation (on average 6,400 AF per year), subsidence (on average 490 AF per year), and net subsurface flows (on average 9,700 AF per year). Outflows from the GWS include groundwater extraction (on average -21,000 AF per year). Overall, the water budget results for the 51-year sustainability period indicate a cumulative change in groundwater storage of about -58,000 AF, which equals an average annual change in groundwater storage of about -1,100 AF per year. These change in storage estimates equate to total decreases in storage in the GSA of about -5.76 AF per acre on average over the 51 years and an annual decrease of -0.11 AF per acre across the entire GSA (approximately 10,000 acres).

Table 4-85. Root Creek Water District GSA Projected (No Action) Groundwater System Annual Water Budget Summary (acre-feet)		
Water Budget Component	**Average Annual Implementation Period (WY 2024-2039)**	**Average Annual Sustainability Period (WY 2040-2090)**
Net Stream Seepage	3,200	3,400
Deep Percolation	5,700	6,400
Groundwater Extractions	-21,000	-21,000
Subsidence	540	490
Net Subsurface Flows	10,000	9,700
Annual Change in Groundwater Storage	**-1,800**	**-1,100**

Summarized results for major components of the Projected (No Action) with Climate Change water budget as they relate to the GWS are presented in **Table 4-86**.

For the Projected (No Action) with Climate Change Implementation period, inflows to the GWS include net stream seepage (on average 3,300 AF per year), deep percolation (on average 5,700 AF per year), subsidence (on average 650 AF per year), and net subsurface flows (on average 10,000 AF per year). Outflows from the GWS include groundwater extraction (on average -22,000 AF per year). Overall, the water budget results for the 16-year implementation period indicate a cumulative change in groundwater storage of about -34,000 AF, which equals an average annual change in groundwater storage of about -2,100 AF per year. These change in storage estimates equate to total decreases in storage in the GSA of about -3.39 AF per acre on average over the 16 years and an annual decrease of -0.21 AF per acre across the entire GSA (approximately 10,000 acres).

For the Projected (No Action) with Climate Change Sustainability period, inflows to the GWS include net stream seepage (on average 3,500 AF per year), deep percolation (on average 6,400 AF per year), subsidence (on average 530 AF per year), and net subsurface flows (on average 10,000 AF per year). Outflows from the GWS include groundwater extraction (on average -22,000 AF per year). Overall, the water budget results for the 51-year sustainability period indicate a cumulative change in groundwater storage of about -60,000 AF, which equals an average annual change in groundwater storage of about -1,200 AF per year. These change in storage estimates equate to total decreases in storage in the GSA of about -6.00 AF per acre on average over the 51 years and an annual decrease of -0.12 AF per acre across the entire GSA (approximately 10,000 acres).

Table 4-86. Root Creek Water District GSA Projected (No Action) with Climate Change Groundwater System Annual Water Budget Summary (acre-feet)		
Water Budget Component	**Average Annual Implementation Period (WY 2024-2039)**	**Average Annual Sustainability Period (WY 2040-2090)**
Net Stream Seepage	3,300	3,500
Deep Percolation	5,700	6,400
Groundwater Extractions	-22,000	-22,000
Subsidence	650	530
Net Subsurface Flows	10,000	10,000
Annual Change in Groundwater Storage	**-2,100**	**-1,200**

4.6. Additional Scenarios

As a GSP implementation tool, MCSim is intended to evaluate a range of potential scenarios and outcomes within the Chowchilla and Madera Subbasins.

4.6.1. Sensitivity – Projected with Projects Scenario

A sensitivity scenario was developed based on the Projected with Projects Scenario described above. In this scenario, the projects implementation within Madera Subbasin is scaled back to a less aggressive approach. This scaled back approach was applied specifically to the Madera County GSA.

Madera Subbasin Model Results

Summarized results for major components of the Sensitivity – Projected with Projects water budget as they relate to the GWS are presented in **Table 4-87**.

For the Sensitivity – Projected with Projects Implementation period, inflows to the GWS include net stream seepage (on average 190,000 AF per year), deep percolation (on average 190,000 AF per year), subsidence (on average 12,000 AF per year), and net subsurface flows (on average 73,000 AF per year). Outflows from the GWS include groundwater extraction (on average -480,000 AF per year). Overall, the water budget results for the 16-year implementation period indicate a cumulative change in groundwater storage of about -310,000 AF, which equals an average annual change in groundwater storage of about -19,000 AF per year. These change in storage estimates equate to total decreases in storage in the Subbasin of about -0.88 AF per acre on average over the 16 years and an annual decrease of -0.06 AF per acre across the entire Subbasin (approximately 349,000 acres).

For the Sensitivity – Projected with Projects Sustainability period, inflows to the GWS include net stream seepage (on average 230,000 AF per year), deep percolation (on average 210,000 AF per year), and net subsurface flows (on average 18,000 AF per year). Outflows from the GWS include groundwater extraction (on average -430,000 AF per year) and subsidence (on average -1,200 AF per year). Overall, the water budget results for the 51-year sustainability period indicate a cumulative change in groundwater storage of about 970,000 AF, which equals an average annual change in groundwater storage of about 19,000 AF per year. These change in storage estimates equate to total increases in storage in the Subbasin of about 2.78 AF per acre on average over the 51 years and an annual increase of 0.05 AF per acre across the entire Subbasin (approximately 349,000 acres).

Detailed results for each of the individual water budget components in the Sensitivity – Projected with Projects water budget are presented in **Appendix D.2**, simulated groundwater elevation hydrographs at select wells are presented in **Appendix E.2.f**, and simulated subsidence hydrographs are presented in **Appendix F.2.f**.

Table 4-87. Madera Subbasin Sensitivity – Projected with Projects Groundwater System Annual Water Budget Summary (acre-feet)

Water Budget Component	Average Annual Implementation Period (WY 2024-2039)	Average Annual Sustainability Period (WY 2040-2090)
Net Stream Seepage	190,000	230,000
Deep Percolation	190,000	210,000
Groundwater Extractions	-480,000	-430,000
Subsidence	12,000	-1,200
Net Subsurface Flows	73,000	18,000
Annual Change in Groundwater Storage	**-19,000**	**19,000**

By GSA Model Results

Summarized results for major components of the Sensitivity – Projected with Projects Implementation Period water budget as they relate to the GWS are presented in **Table 4-88**.

On average, the annual change in storage for the City of Madera GSA is 410 AF per year. Inflows include net stream seepage (on average 6,100 AF per year), deep percolation (on average 3,300 AF per year), subsidence (on average 380 AF per year), and net subsurface flows (on average 160 AF per year). Outflows include groundwater extraction (on average -9,500 AF per year). Detailed results for the City of Madera GSA are presented in **Appendix D.2.a**.

On average, the annual change in storage for the Madera County GSA is -5,600 AF per year. Inflows include net stream seepage (on average 51,000 AF per year), deep percolation (on average 79,000 AF per year), subsidence (on average 5,800AF per year), and net subsurface flows (on average 60,000 AF per year). Outflows include groundwater extraction (on average -210,000 AF per year). Detailed results for the Madera County GSA are presented in **Appendix D.2.b**.

On average, the annual change in storage for the Madera Irrigation District GSA is -13,000 AF per year. Inflows include net stream seepage (on average 110,000 AF per year), deep percolation (on average 87,000 AF per year), subsidence (on average 5,100 AF per year), and net subsurface flows (on average

4,200 AF per year). Outflows include groundwater extraction (on average -220,000 AF per year). Detailed results for the Madera Irrigation District GSA are presented in **Appendix D.2.c**.

On average, the annual change in storage for the Madera Water District GSA is -53 AF per year. Inflows include net stream seepage (on average 2,500 AF per year), deep percolation (on average 2,400 AF per year), subsidence (on average 260 AF per year), and net subsurface flows (on average 840 AF per year). Outflows include groundwater extraction (on average -6,100AF per year). Detailed results for the Madera Water District GSA are presented in **Appendix D.2.d**.

On average, the annual change in storage for the Gravelly Ford Water District GSA is -1,400 AF per year. Inflows include net stream seepage (on average 8,900 AF per year), deep percolation (on average 7,400 AF per year), and subsidence (on average 280 AF per year). Outflows include groundwater extraction (on average -16,000 AF per year) and net subsurface flows (on average -1,600 AF per year). Detailed results for the Gravelly Ford Water District GSA are presented in **Appendix D.2.e**.

On average, the annual change in storage for the New Stone Water District GSA is -410 AF per year. Inflows include net stream seepage (on average 3,800 AF per year), deep percolation (on average 3,200 AF per year), subsidence (on average 280 AF per year), and net subsurface flows (on average 140 AF per year). Outflows include groundwater extraction (on average -7,900 AF per year). Detailed results for the New Stone Water District GSA are presented in **Appendix D.2.f**.

On average, the annual change in storage for the Root Creek Water District GSA is 520 AF per year. Inflows include net stream seepage (on average 7,900 AF per year), deep percolation (on average 5,600 AF per year), subsidence (on average 140 AF per year), and net subsurface flows (on average 7,400 AF per year). Outflows include groundwater extraction (on average -21,000 AF per year). Detailed results for the Root Creek Water District GSA are presented in **Appendix D.2.g**.

Table 4-88. Madera Subbasin GSAs Sensitivity – Projected with Projects Implementation Period (Water Years 2024-2039) Groundwater System Annual Water Budget Summary (acre-feet)							
Water Budget Component	City of Madera GSA	Madera County GSA	Madera Irrigation District GSA	Madera Water District GSA	Gravelly Ford Water District GSA	New Stone Water District GSA	Root Creek Water District GSA
Net Stream Seepage	6,100	51,000	110,000	2,500	8,900	3,800	7,900
Deep Percolation	3,300	79,000	87,000	2,400	7,400	3,200	5,600
Groundwater Extractions	-9,500	-210,000	-220,000	-6,100	-16,000	-7,900	-21,000
Subsidence	380	5,800	5,100	260	280	280	140
Net Subsurface Flows	160	60,000	4,200	840	-1,600	140	7,400
Annual Change in Groundwater Storage	**410**	**-5,600**	**-13,000**	**-53**	**-1,400**	**-410**	**520**

Summarized results for major components of the Sensitivity – Projected with Projects Sustainability Period water budget as they relate to the GWS are presented in **Table 4-89**.

On average, the annual change in storage for the City of Madera GSA is 440 AF per year. Inflows include net stream seepage (on average 7,900 AF per year), deep percolation (on average 4,700 AF per year), and net subsurface flows (on average 360 AF per year). Outflows include groundwater extraction (on average -12,000 AF per year) and subsidence (on average -39 AF per year). Detailed results for the City of Madera GSA are presented in **Appendix D.2.a**.

On average, the annual change in storage for the Madera County GSA is 9,300 AF per year. Inflows include net stream seepage (on average 61,000 AF per year), deep percolation (on average 82,000 AF per year), and net subsurface flows (on average 12,000 AF per year). Outflows include groundwater extraction (on average -150,000 AF per year) and subsidence (on average -710 AF per year). Detailed results for the Madera County GSA are presented in **Appendix D.2.b**.

On average, the annual change in storage for the Madera Irrigation District GSA is 7,600 AF per year. Inflows include net stream seepage (on average 130,000 AF per year) and deep percolation (on average 99,000 AF per year). Outflows include groundwater extraction (on average -220,000 AF per year), subsidence (on average -370 AF per year), and net subsurface flows (on average -970 AF per year). Detailed results for the Madera Irrigation District GSA are presented in **Appendix D.2.c**.

On average, the annual change in storage for the Madera Water District GSA is 350 AF per year. Inflows include net stream seepage (on average 3,100 AF per year), deep percolation (on average 2,700 AF per year), and net subsurface flows (on average 1,000 AF per year). Outflows include groundwater extraction (on average -6,400 AF per year) and subsidence (on average -27 AF per year). Detailed results for the Madera Water District GSA are presented in **Appendix D.2.d**.

On average, the annual change in storage for the Gravelly Ford Water District GSA is 600 AF per year. Inflows include net stream seepage (on average 11,000 AF per year), deep percolation (on average 8,500 AF per year), and subsidence (on average 9 AF per year). Outflows include groundwater extraction (on average -16,000 AF per year) and net subsurface flows (on average -2,900 AF per year) Detailed results for the Gravelly Ford Water District GSA are presented in **Appendix D.2.e**.

On average, the annual change in storage for the New Stone Water District GSA is 480 AF per year. Inflows include net stream seepage (on average 4,800 AF per year) and deep percolation (on average 4,800 AF per year). Outflows include groundwater extraction (on average -8,900 AF per year), subsidence (on average -29 AF per year), and net subsurface flows (on average -1,100 AF per year). Detailed results for the New Stone Water District GSA are presented in **Appendix D.2.f**.

On average, the annual change in storage for the Root Creek Water District GSA is 280 AF per year. Inflows include net stream seepage (on average 7,500 AF per year), deep percolation (on average 6,100 AF per year), and net subsurface flows (on average 6,500 AF per year). Outflows include groundwater extraction (on average-20,000 AF per year) and subsidence (on average -17 AF per year). Detailed results for the Root Creek Water District GSA are presented in **Appendix D.2.g**.

Table 4-89. Madera Subbasin GSAs Sensitivity – Projected with Projects Sustainability Period (Water Years 2040-2090) Groundwater System Annual Water Budget Summary (acre-feet)

Water Budget Component	City of Madera GSA	Madera County GSA	Madera Irrigation District GSA	Madera Water District GSA	Gravelly Ford Water District GSA	New Stone Water District GSA	Root Creek Water District GSA
Net Stream Seepage	7,900	27,000	34,000	61,000	130,000	3,100	11,000
Deep Percolation	4,700	56,000	26,000	82,000	99,000	2,700	8,500
Groundwater Extractions	-12,000	-94,000	-51,000	-150,000	-220,000	-6,400	-16,000
Subsidence	-39	-580	-130	-710	-370	-27	9
Net Subsurface Flows	360	17,000	-4,700	12,000	-970	1,000	-2,900
Annual Change in Groundwater Storage	**440**	**5,700**	**3,600**	**9,300**	**7,600**	**350**	**600**

5. SENSITIVITY ANALYSIS AND MODEL UNCERTAINTY

5.1. Sensitivity Analysis

A model response or prediction depends on the governing equations it solves, the mechanisms and structure of the model, and the values of the model parameters. Sensitivity analysis is a means of evaluating model uncertainty due to parameter estimates by systematically altering one of the model parameters and examining the associated change in the model response. After the groundwater model was calibrated, a quantitative sensitivity analysis was performed using the model parameters that were most uncertain and likely to affect the simulation results. The calibrated flow was used as the baseline simulation and sensitivity simulations were compared with those of the baseline simulation at all observation points. Model sensitivity was evaluated for model parameters using UCODE- 2014. The basis of a model parameter's sensitivity was based on groundwater elevation observations given a 1% parameter value perturbation. Sensitivity was evaluated through the Composite Scaled Sensitivity (CSS) statistic described by Hill and Tiedman (2007).

Sensitivity of simulated groundwater elevations to parameter perturbations are presented in **Figure 5-1**. The CSS statistic shows the model is most sensitive to the Anisotropy Ratio (VKA) and Horizontal Hydraulic Conductivity of Fine Materials (KHF) parameters within the aquifer system defined in **Table 4-4**. The Anisotropy Ratio parameter is applied to the horizontal hydraulic conductivity values at each node and layer to estimate vertical hydraulic conductivity. Therefore, the high sensitivity to the Anisotropy Ratio suggests a sensitivity to the vertical hydraulic conductivity of the model. The model is less sensitive to specific yield and specific storage parameters.

5.2. Model Uncertainty and Limitations

All groundwater flow models are a simplification of the natural environment, and therefore have uncertainty and limitations that are important to recognize. For this reason, uncertainty exists in the ability of any numerical model to completely represent groundwater flow. Some of the uncertainty is associated with limitations in available data. Considerable effort was made to reduce model uncertainty by using measured values as model inputs whenever available, and by conducting quality assurance and quality control assessments of data that were obtained. Where limited data exist to develop input values for parameters or other inputs with high uncertainty, a conservative approach to assigning input values was followed.

Uncertainty associated with water budget results estimated using MCSim_v2 depends in part on the model inputs relating to the surface water system with additional sources of uncertainty associated with model inputs relating to the groundwater system, including aquifer and streambed properties, specification of boundary conditions, and other factors. The uncertainty estimates associated with surface water system water budget components that are also inputs or outputs of the groundwater system water budget are discussed in Section 2.2.3 of the GSP. Recognizing the uncertainty of the surface water system water budget components, the overall uncertainty of other water budget components simulated for the groundwater system, including subsurface flows, groundwater discharging to surface water, and change in groundwater storage are estimated to be in the range of 10 to 30 percent. These groundwater system water budget components are subject to slightly higher uncertainty as they incorporate uncertainty in the surface water system water inflows and outflows with additional uncertainty resulting from limitations in available input data and simplification required in modeling of the subsurface heterogeneity. However, the uncertainty in the groundwater system water budget derived from a numerical model such as MCSim_v2 depends to a considerable degree on the calibration of the model and can vary by location and depth within the model domain. MCSim_v2 is a product of local refinement and improvements made to the C2VSimFG model. MCSim_v2 simulates the integrated groundwater and surface water systems and metrics relating to the calibration of the model indicate the model is reasonably well calibrated in accordance with generally accepted professional guidelines and is sufficient for GSP-related applications. The finding and conclusions of this study are focused on a regional scale and use of the model for site specific analysis should be conducted with an understanding that representation of local site-specific conditions may be approximate and should be verified with local site-specific investigations. The flow model was developed in a manner consistent with the level of care and skill normally exercised by professionals practicing under similar conditions in the area. There is no warranty, expressed or implied that this modeling study has considered or addresses all hydrogeological, hydrological, environmental, geotechnical or other characteristics and properties associated with the subject model domain and the simulated system.

6. CONCLUSIONS AND RECOMMENDATIONS

Based on the calibration of MCSim_v2 to historical conditions for the calibration period from water year 1989 to 2023 and accompanying assessment of model sensitivity, the MCSim groundwater flow model is suitable for use as a tool to support management of water resources within the Madera and Chowchilla Subbasins.

6.1. Conclusions

MCSim_v2 provides a useful tool for evaluating a wide variety of future scenarios and informing the decision-making process to achieve and maintain sustainable groundwater management in both the Madera and Chowchilla Subbasins. A numerical model can be a convenient and cost-efficient tool for providing insights into groundwater responses to various perturbations including natural variability and change, and also changes associated with management decisions or other humanmade conditions. However, as with any other modeling tool, information obtained from a numerical model also has a level of uncertainty, especially for long-term predictions or forecasts. The level of uncertainty associated with model simulations are likely to increase the more the scenarios extend beyond the range of historical conditions and processes over which the model was calibrated, such as for long-term predictive scenarios or predictive scenarios with extreme alterations to the hydrologic conditions.

6.2. Recommendations

Future and ongoing updates to MCSim_v2 will be valuable for improving the model performance and verifying the accuracy of the model predictions. Using data from the ongoing monitoring efforts and forthcoming GSP monitoring, MCSim_v2 should be updated periodically, including through extending of the model period and associated inputs. Although the frequency of conducting model updates may depend on a variety of factors, including evaluation of the model performance in predicting future conditions, such an update could initially be considered every five years. This frequency of model update should be adequate and cost effective to test and improve MCSim_v2 periodically with new site specific and monitoring information. Groundwater elevations, groundwater pumping, subsidence measurements, rainfall, and stream discharge should be collected on an ongoing basis, to the extent possible, at intervals of at least monthly for pumpage, rainfall, and streamflow, and less frequently (semi-annually at least) for groundwater levels and subsidence. The new groundwater data should be compared with the respective model simulation results so that the flow model can be verified in the future. If the differences between the measured groundwater data and MCSim_v2's predicted results are significant, adjustment and modification may be applied to the model input parameters.

MCSim has been calibrated and verified. It adheres closely to site-specific observed data so that model input parameters are reasonable and appropriate especially within the Chowchilla and Madera Subbasins. Additional model revisions should be conducted in areas outside the Chowchilla and Madera Subbasins as that data is obtained from adjacent GSAs.

Further refinement to MCSim_v2 should be made by addressing key data gaps. Upon release of DWR's Guidance Document on Interconnected Surface Water, an evaluation should be done to incorporate any relevant aspects of the model into MCSim, as appropriate and necessary. Through upcoming GSP-related monitoring, additional groundwater level data can be used to refine boundary condition water levels and improve model calibration. Additional improvements to model calibration can be made by the potential linking of additional well construction information to calibration wells, development and incorporation of longer periods of record for subsidence monitoring stations, incorporation of additional stream flow data on ungaged streams, and refinements to the simulation of surface water distribution systems. Further refinements to MCSim can be made by extending the historical base period and ongoing updating of model calibration in preparation for 5-year GSP Plan Amendments and/or Periodic Evaluations.

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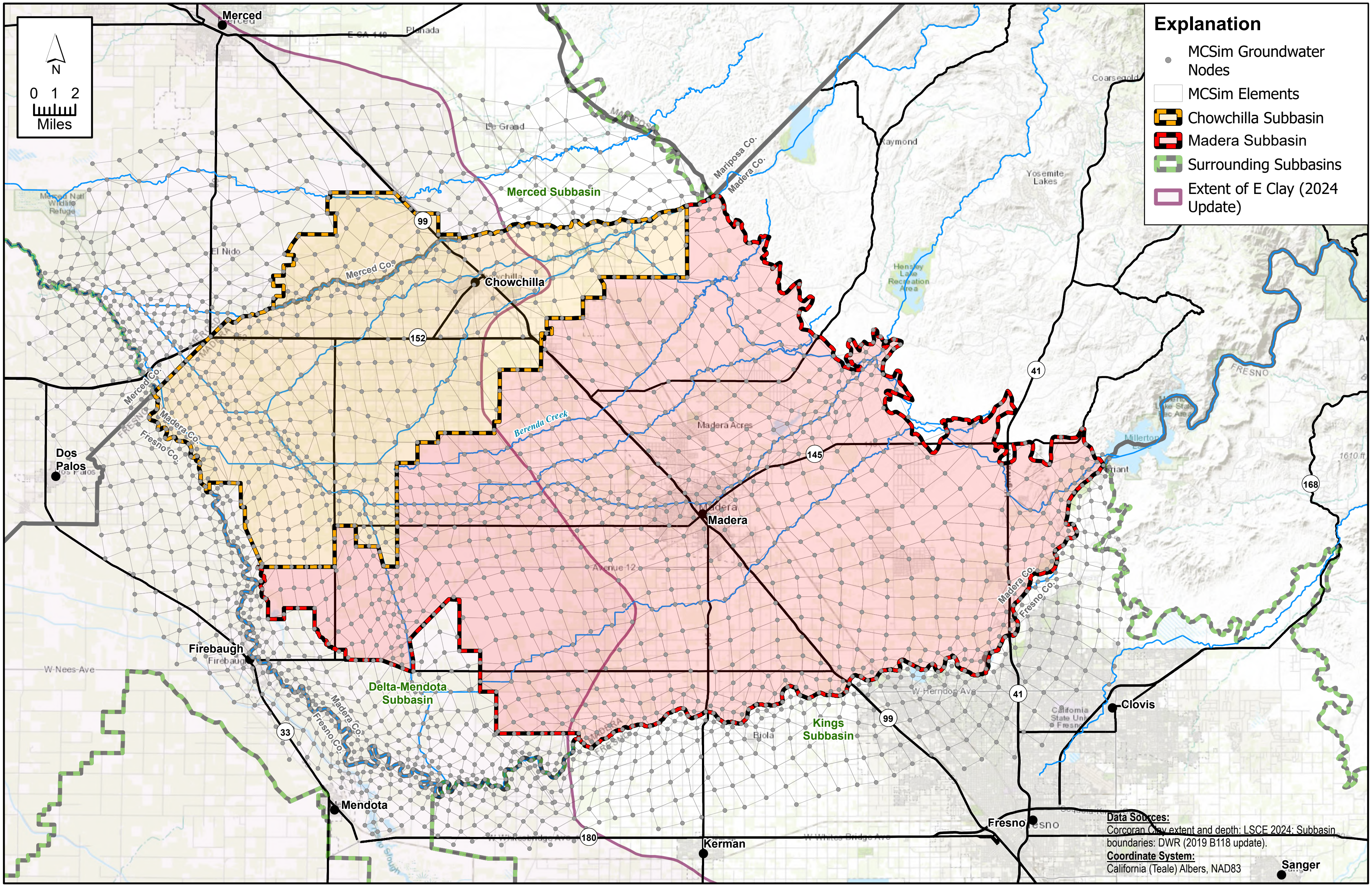

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FIGURE 3-1

MCSim Model Domain

Madera-Chowchilla Groundwater-Surface Water Simulation Model (MCSim) - First Model Update

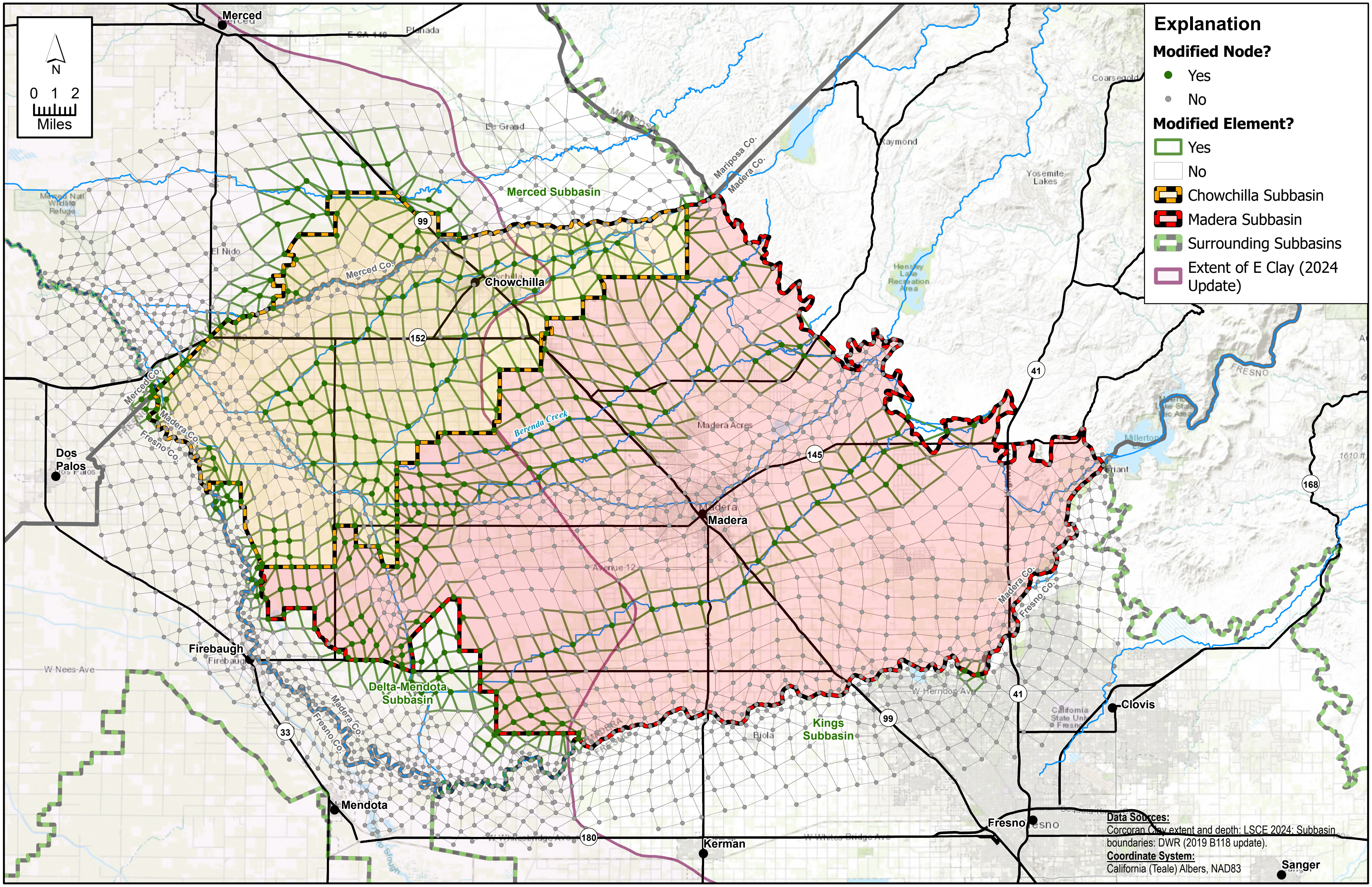

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FIGURE 3-2

Modified Nodes and Elements in MCSim

Madera-Chowchilla Groundwater-Surface Water Simulation Model (MCSim) - First Model Update

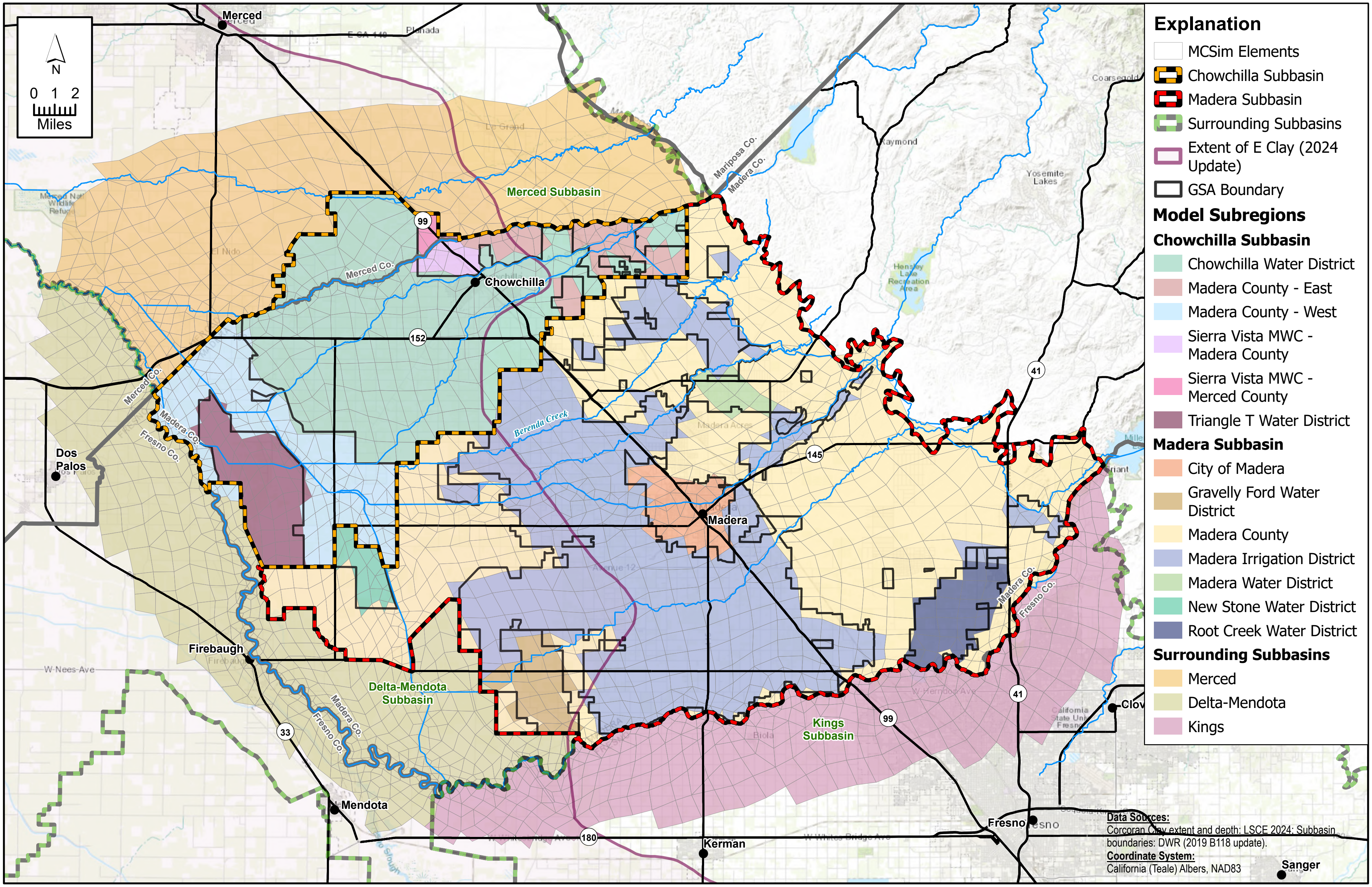

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FIGURE 3-3

Subregions in MCSim

Madera-Chowchilla Groundwater-Surface Water Simulation Model (MCSim) - First Model Update

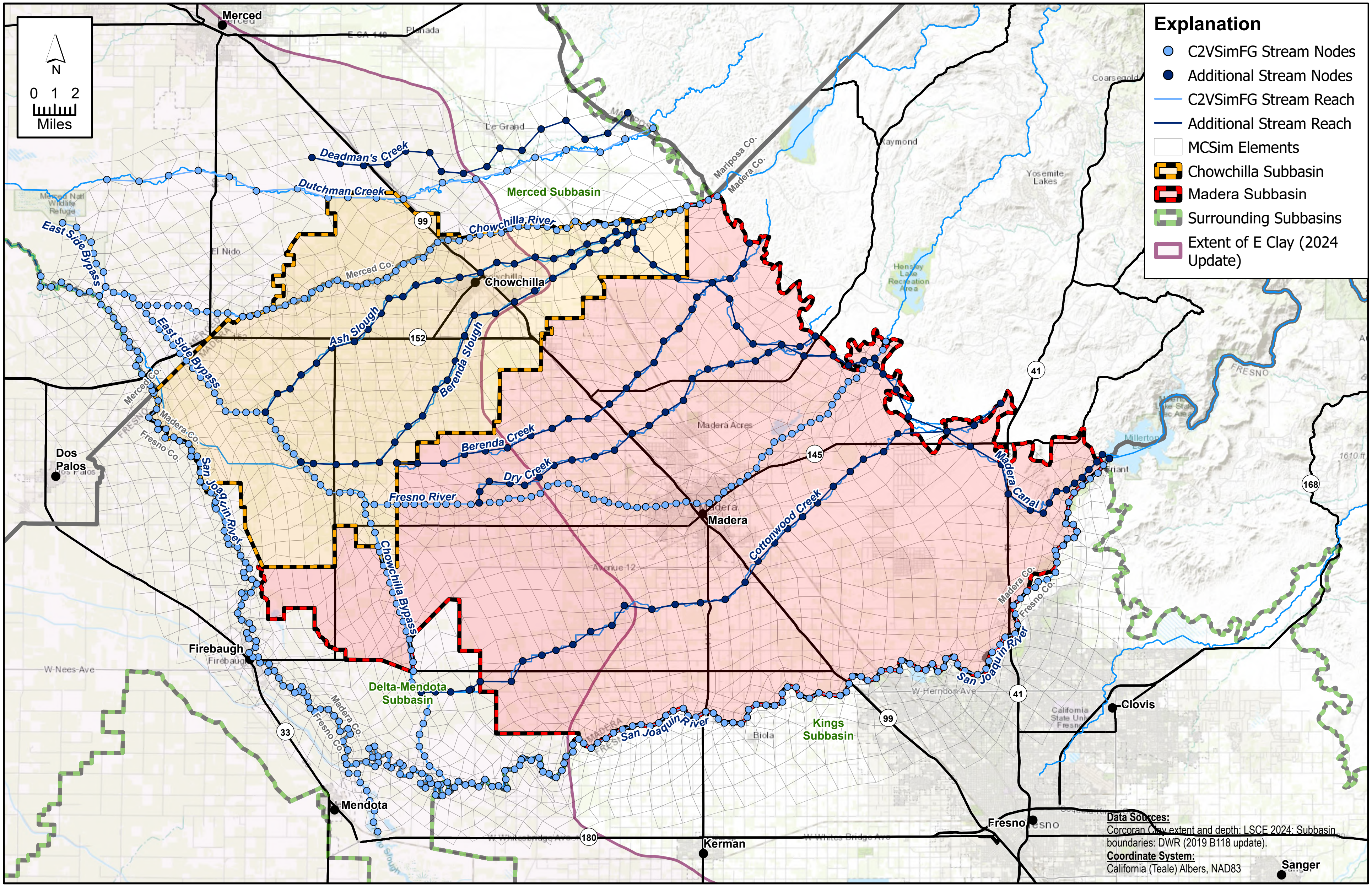

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FIGURE 3-4

MCSim Stream Network

Madera-Chowchilla Groundwater-Surface Water Simulation Model (MCSim) - First Model Update

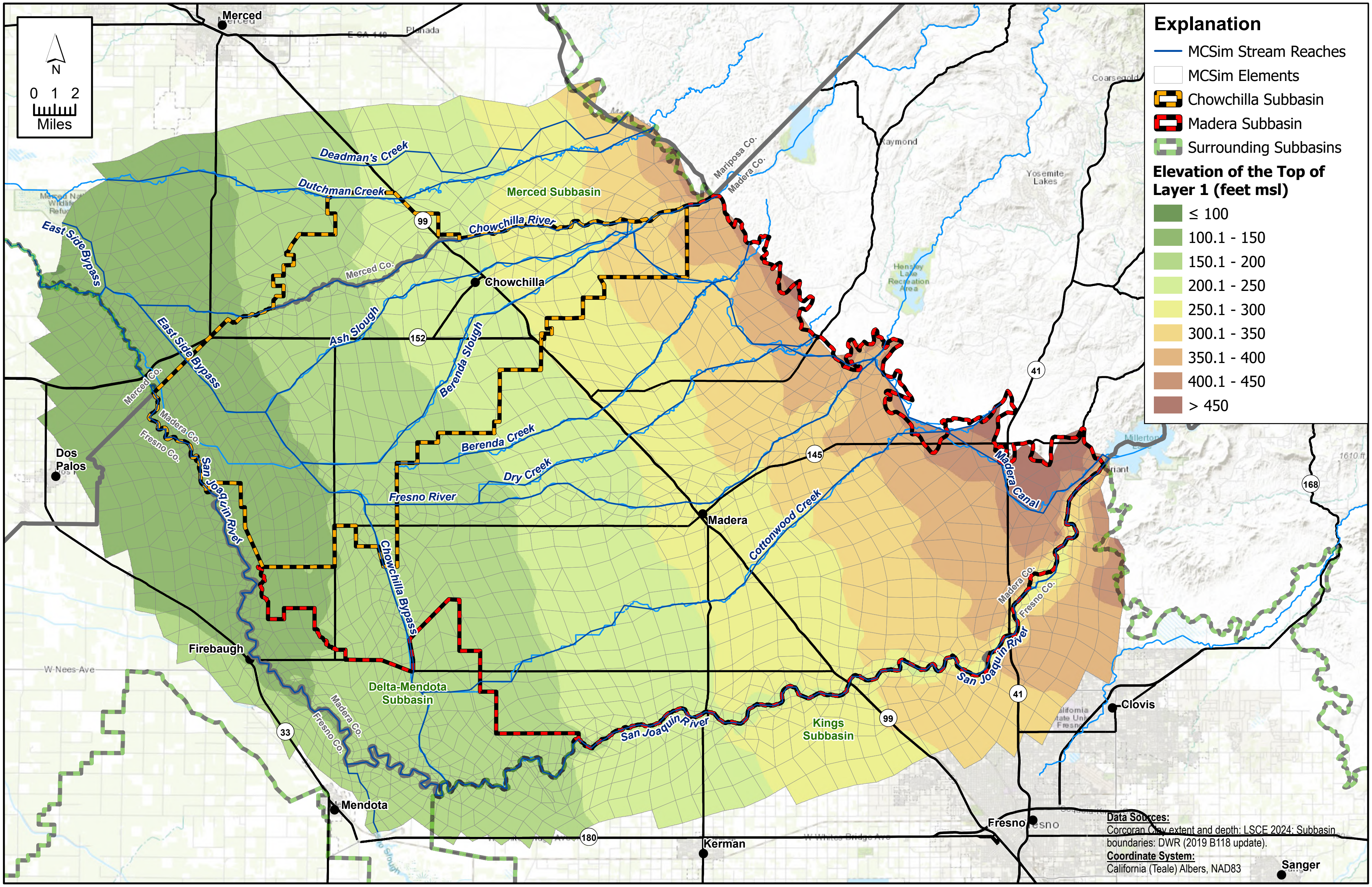

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FIGURE 3-5

Elevation of the Top of the Layer 1

Madera-Chowchilla Groundwater-Surface Water Simulation Model (MCSim) - First Model Update

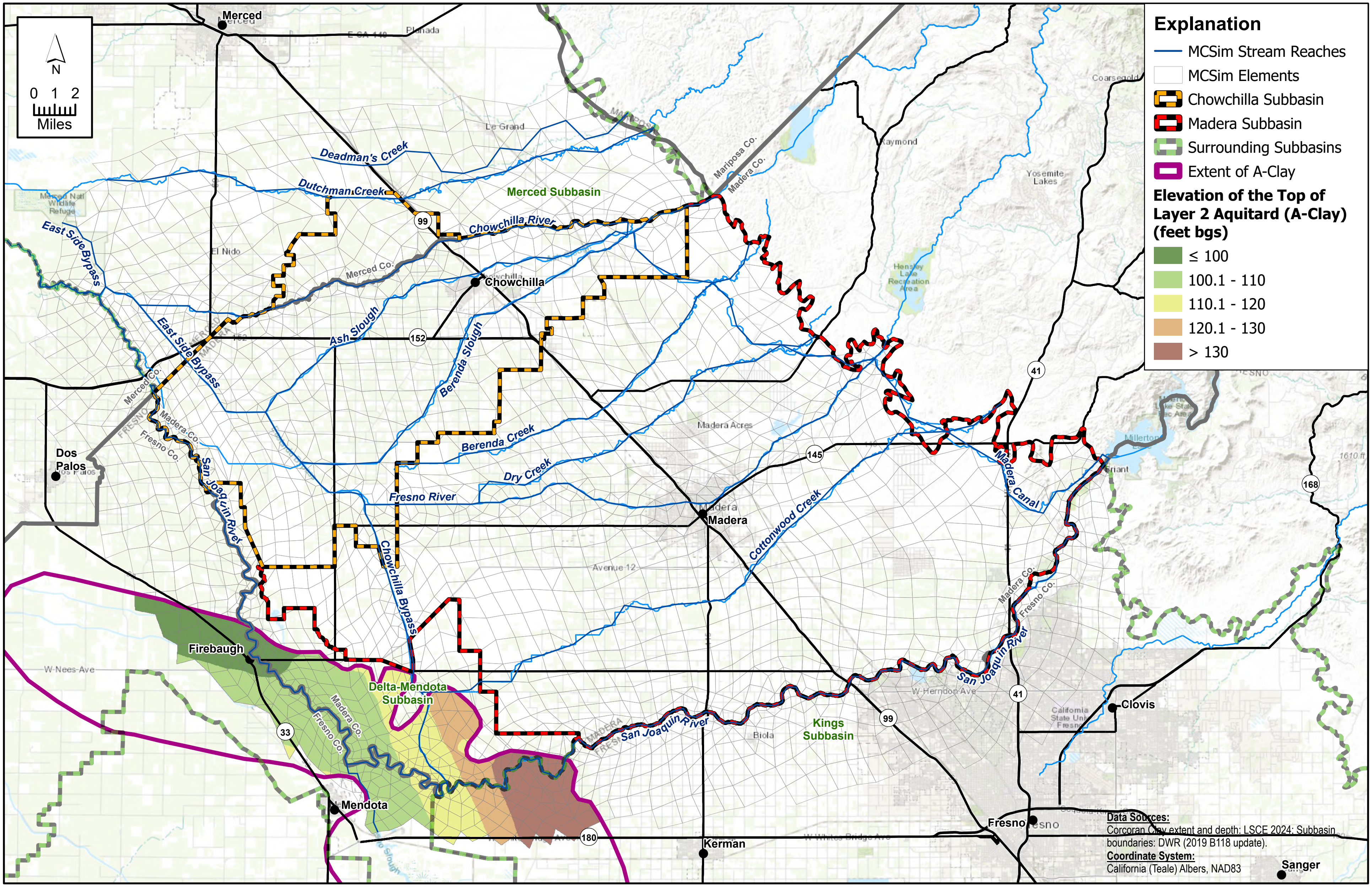

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FIGURE 3-6

Elevation of the Top of the Layer 2 Aquitard (A-Clay)

Madera-Chowchilla Groundwater-Surface Water Simulation Model (MCSim) - First Model Update

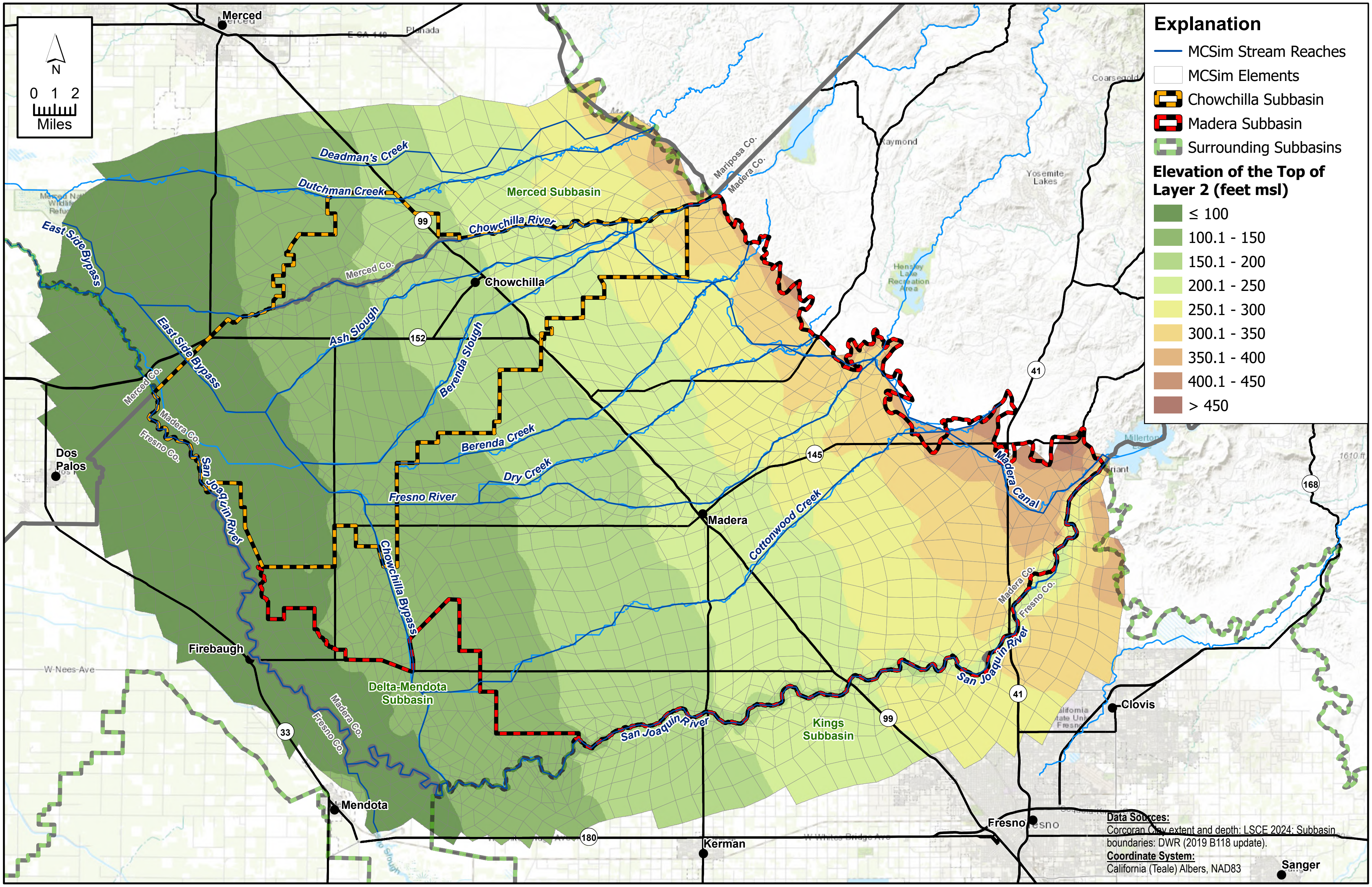

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FIGURE 3-7

Elevation of the Top of the Layer 2

Madera-Chowchilla Groundwater-Surface Water Simulation Model (MCSim) - First Model Update

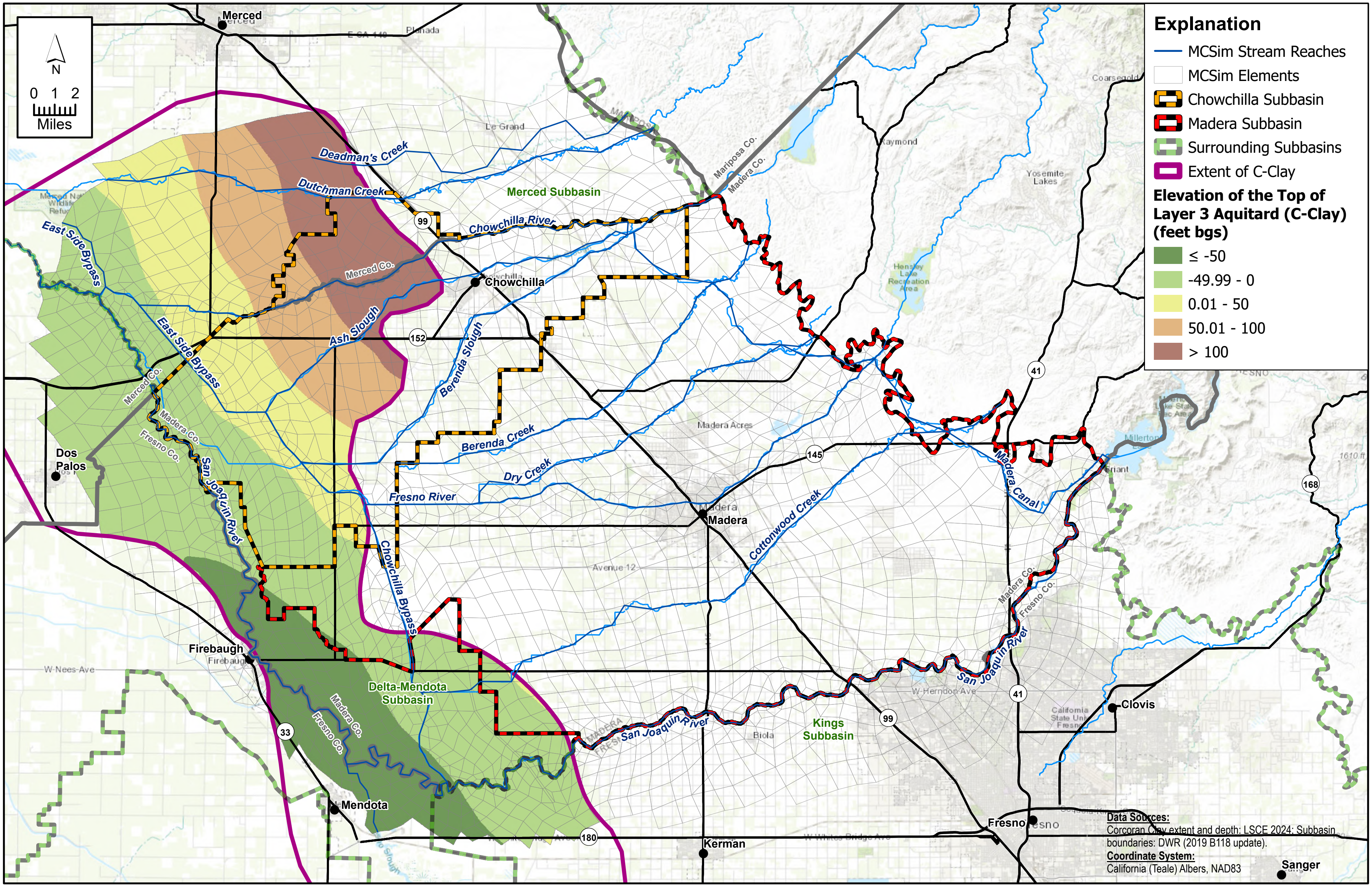

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FIGURE 3-8

Elevation of the Top of the Layer 3 Aquitard (C-Clay)

Madera-Chowchilla Groundwater-Surface Water Simulation Model (MCSim) - First Model Update

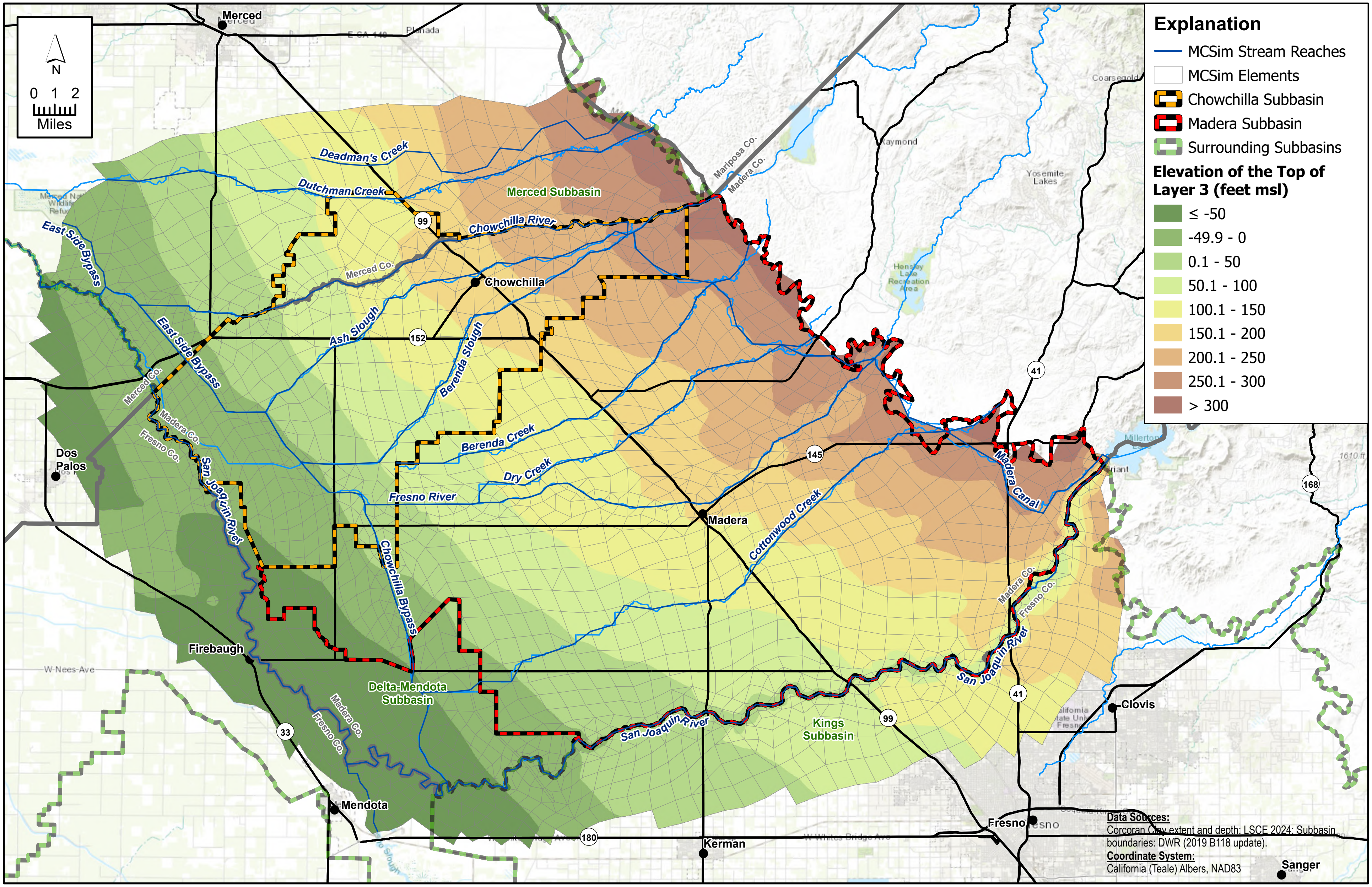

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FIGURE 3-9

Elevation of the Top of the Layer 3

Madera-Chowchilla Groundwater-Surface Water Simulation Model (MCSim) - First Model Update

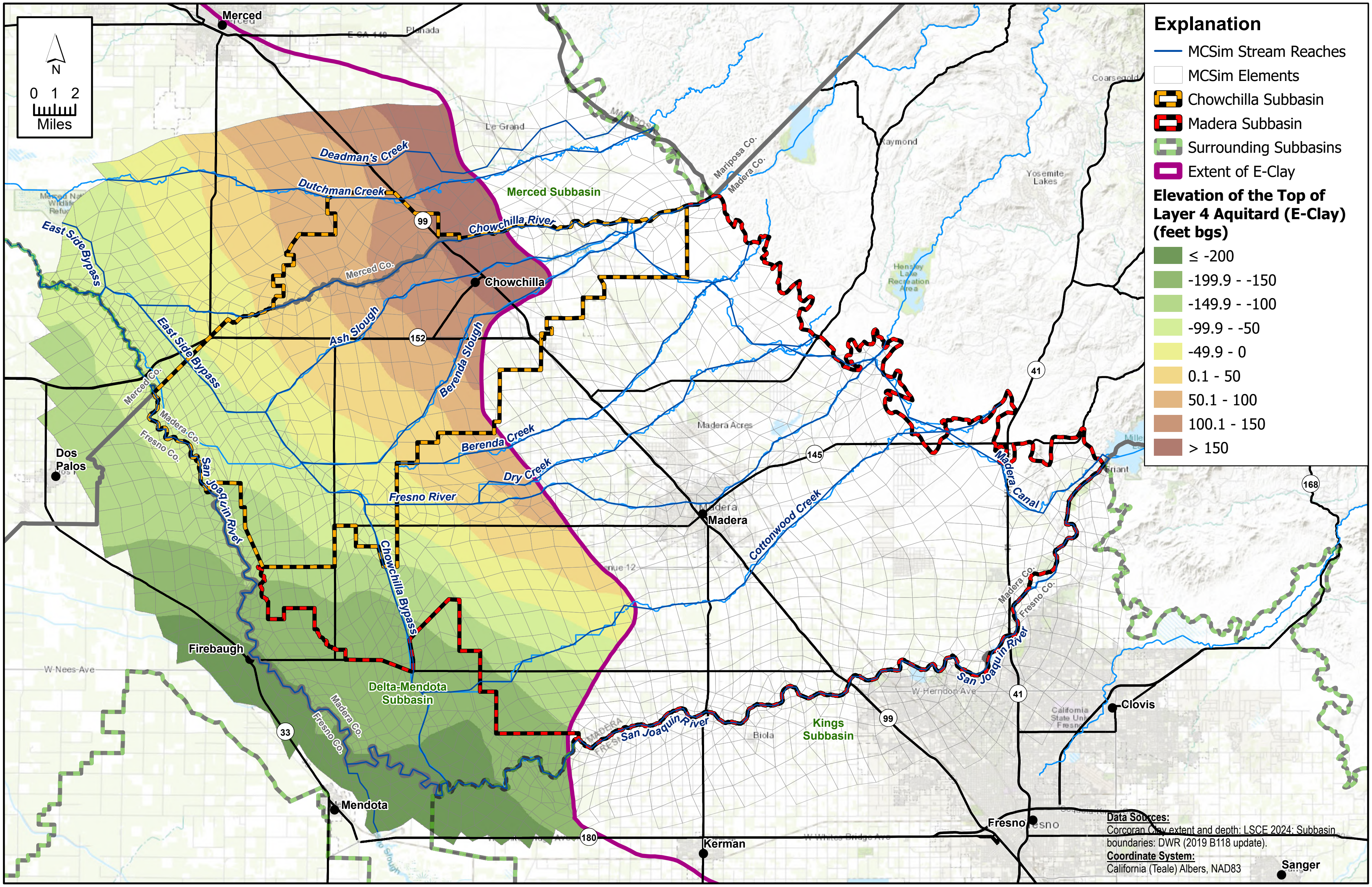

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FIGURE 3-10

Elevation of the Top of the Layer 4 Aquitard (E-Clay)

Madera-Chowchilla Groundwater-Surface Water Simulation Model (MCSim) - First Model Update

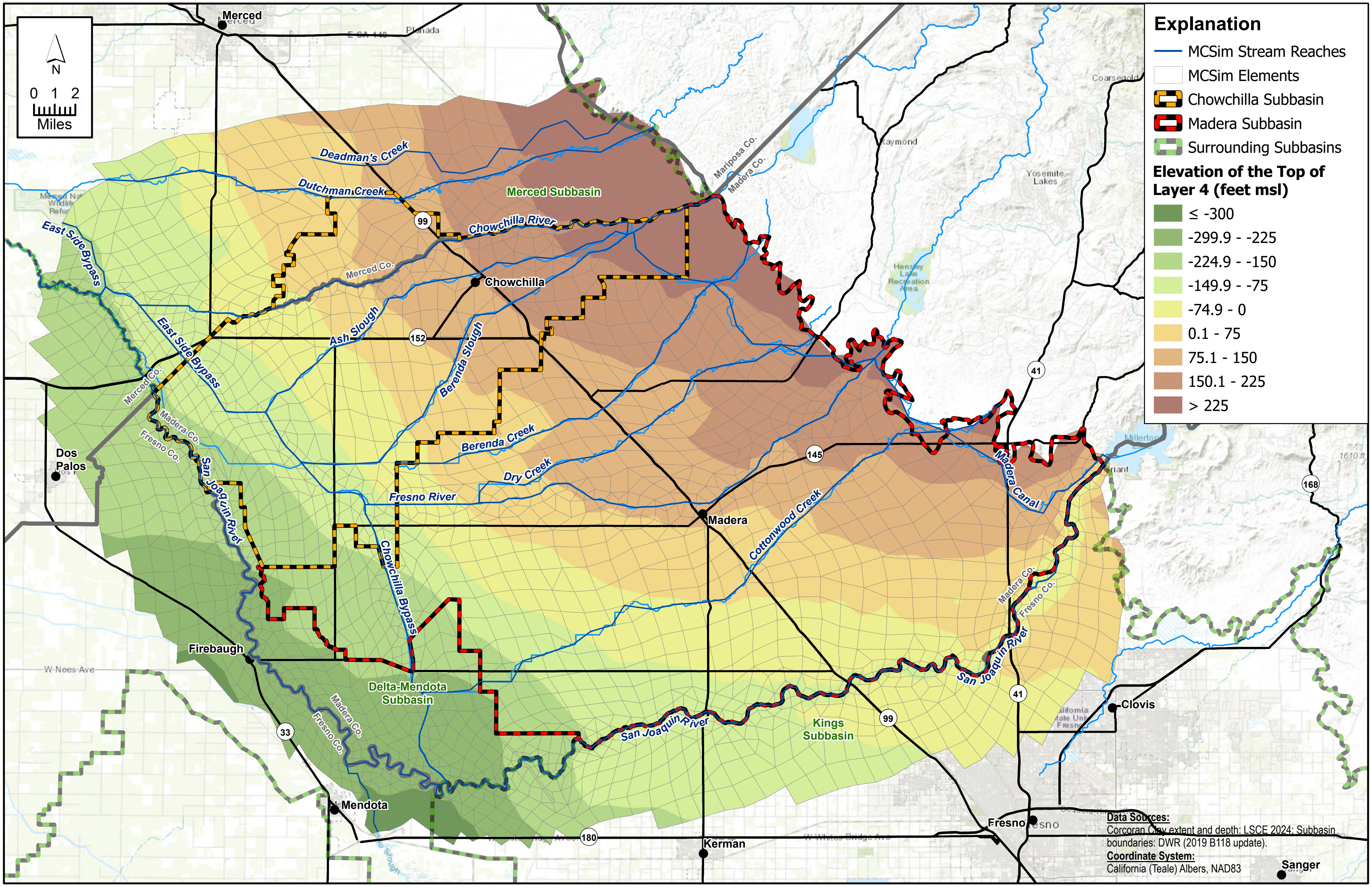

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FIGURE 3-11

Elevation of the Top of the Layer 4

Madera-Chowchilla Groundwater-Surface Water Simulation Model (MCSim) - First Model Update

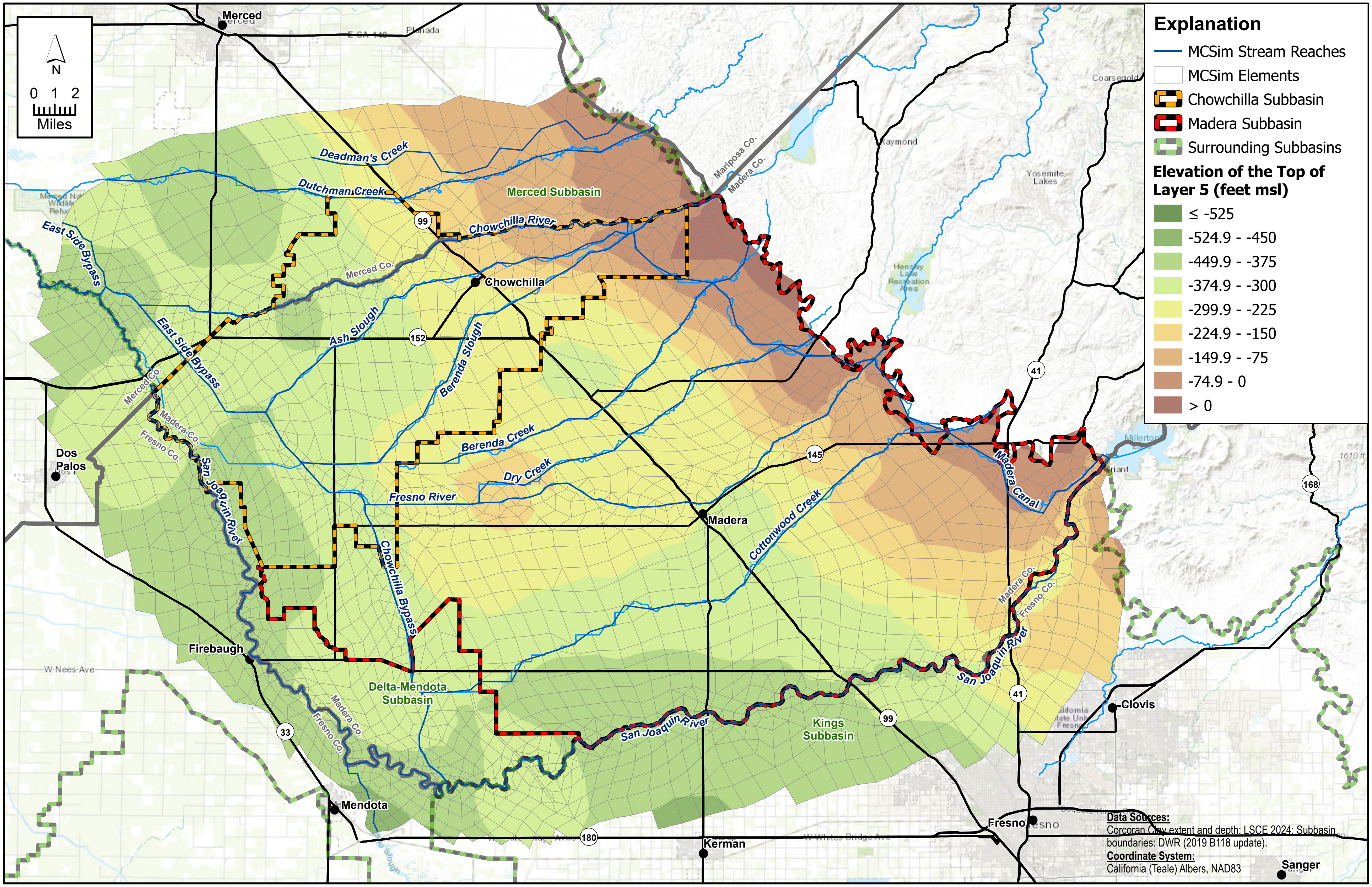

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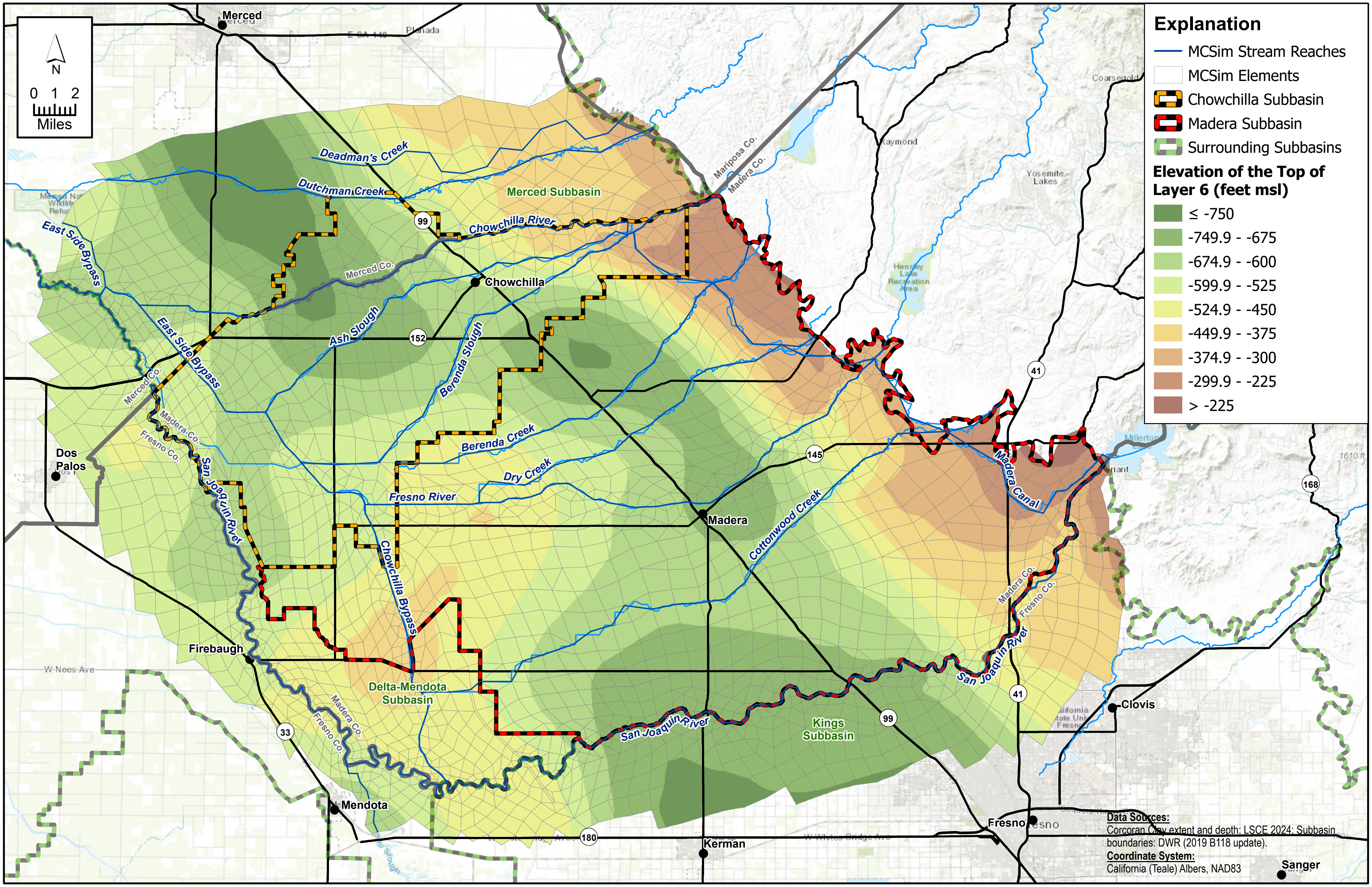
FIGURE 3-12

Elevation of the Top of the Layer 5

Madera-Chowchilla Groundwater-Surface Water Simulation Model (MCSim) - First Model Update

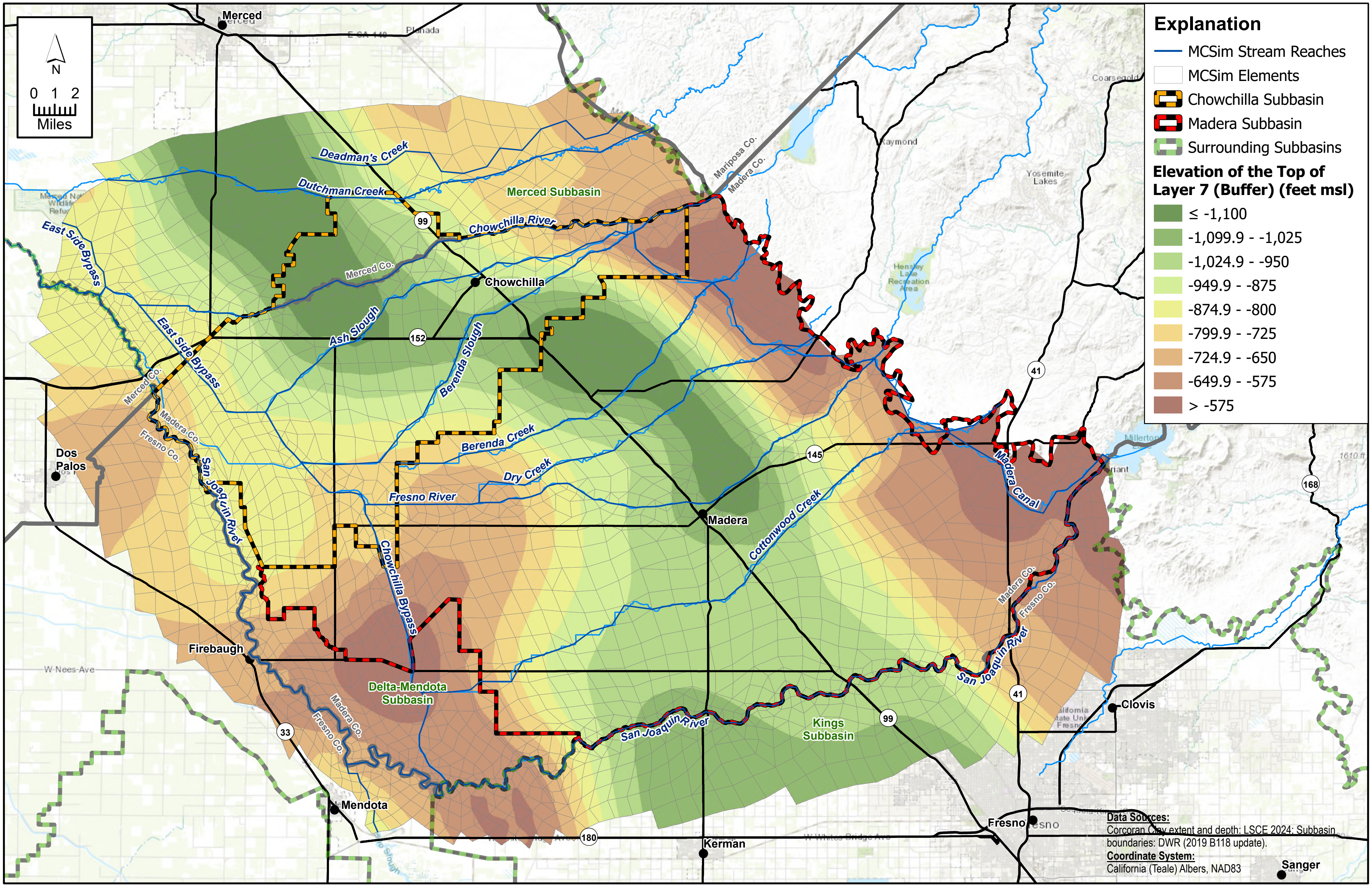


X:\2024\24-010 (1) Davids Eng. - Madera Subbasin 5-Year GSP Update\MODEL\MCSim_v2_GIS_20231101\MCSim_v2_20231101.aprx; STRAT_Layering_Elevation

FIGURE 3-13

Elevation of the Top of the Layer 6

Madera-Chowchilla Groundwater-Surface Water Simulation Model (MCSim) - First Model Update



X:\2024\24-010 (1) Davids Eng. - Madera Subbasin 5-Year GSP Update\MODEL\MCSim_v2_GIS_20231101\MCSim_v2_20231101.aprx; STRAT_Layering_Elevation

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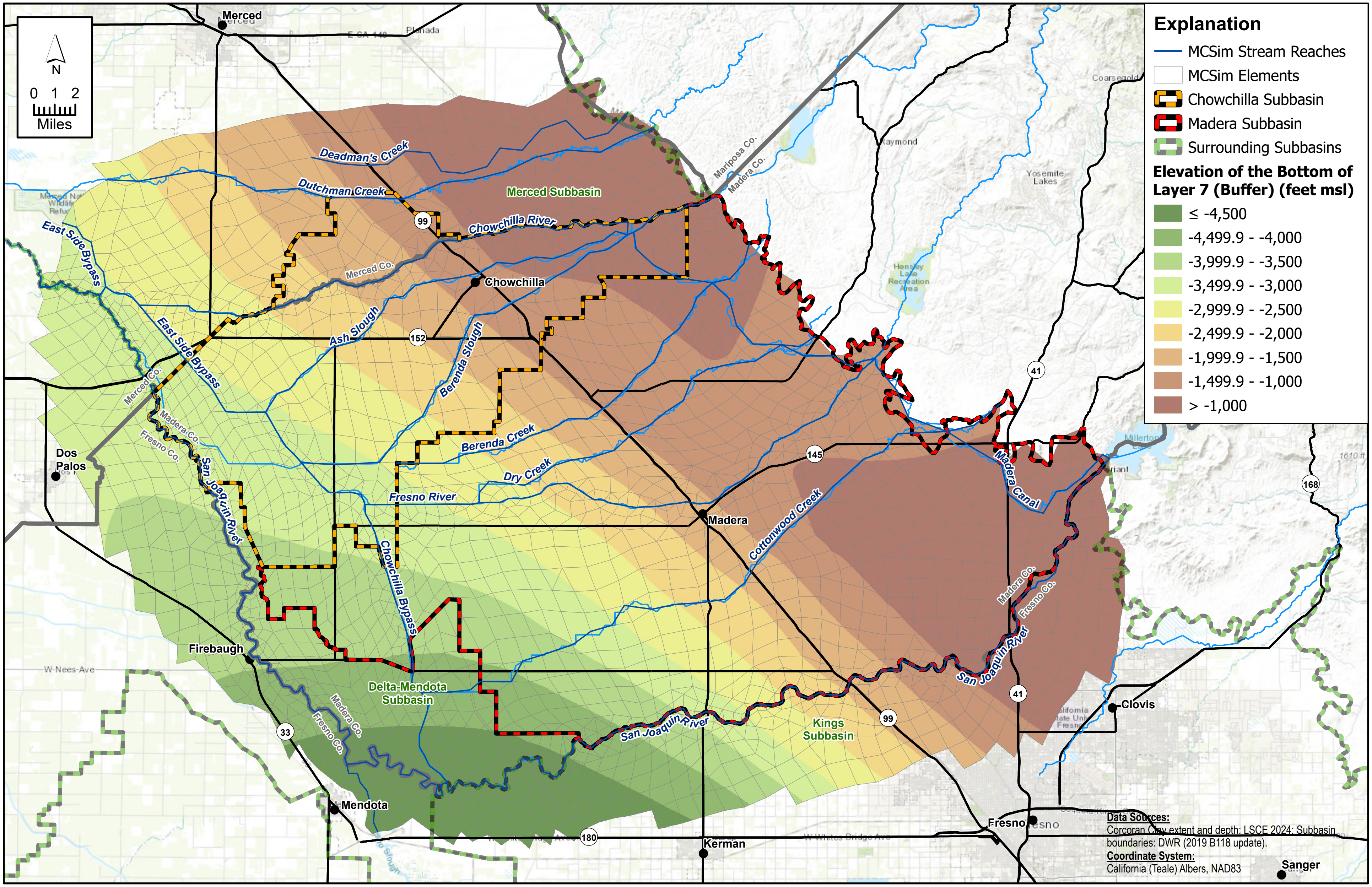
FIGURE 3-14

Elevation of the Top of the Layer 7

Madera-Chowchilla Groundwater-Surface Water Simulation Model (MCSim) - First Model Update



X:\2024\24-010 (1) Davids Eng. - Madera Subbasin 5-Year GSP Update\MODEL\MCSim_v2_GIS_20231101\MCSim_v2_20231101.aprx; STRAT_Layering_Elevation

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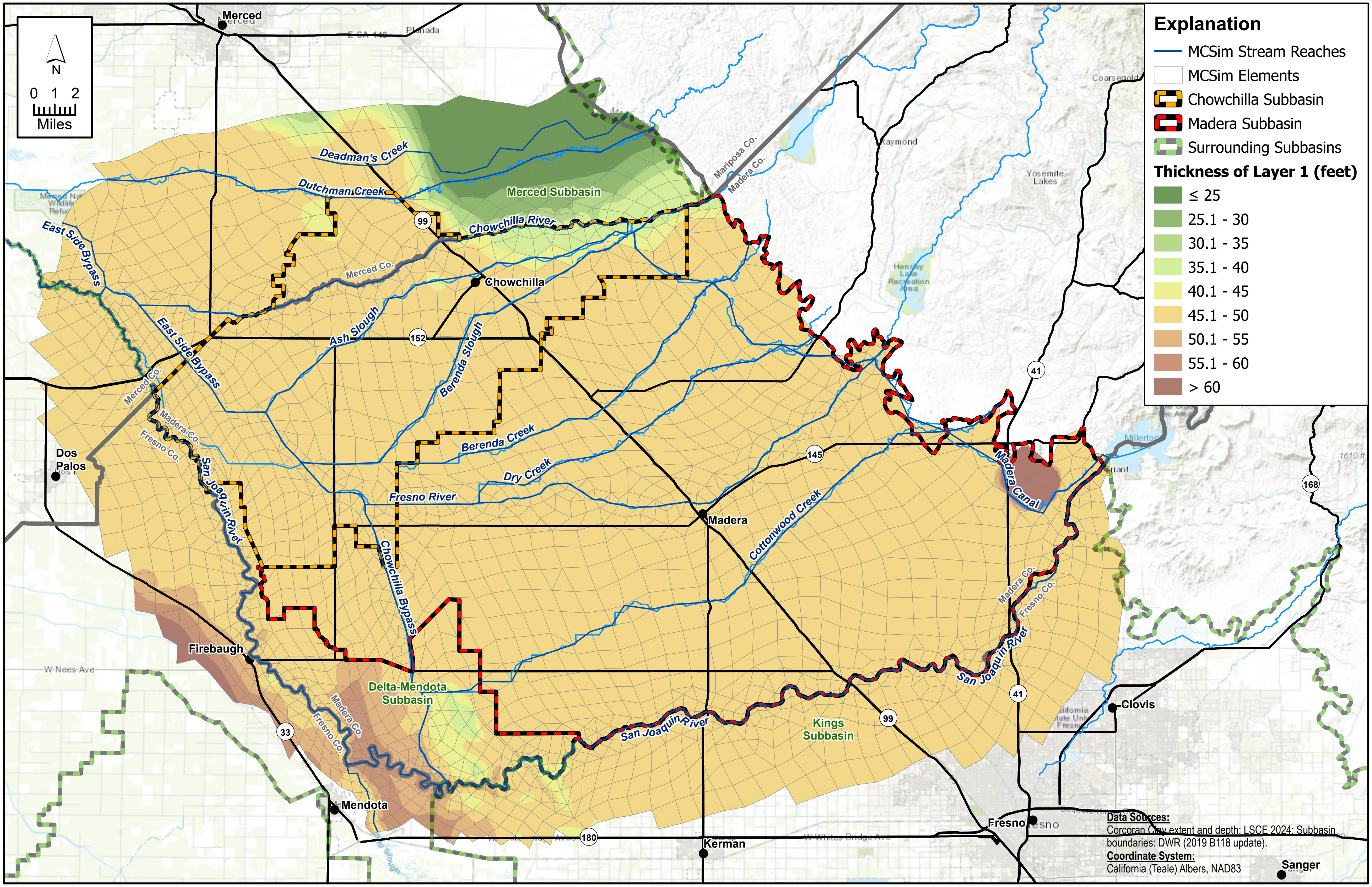
FIGURE 3-15

Elevation of the Bottom of the Layer 7

Madera-Chowchilla Groundwater-Surface Water Simulation Model (MCSim) - First Model Update



X:\2024\24-010 (1) Davids Eng. - Madera Subbasin 5-Year GSP Update\MODEL\MCSim_v2_GIS_20231101\MCSim_v2_20231101.aprx; STRAT_Layering_Thickness

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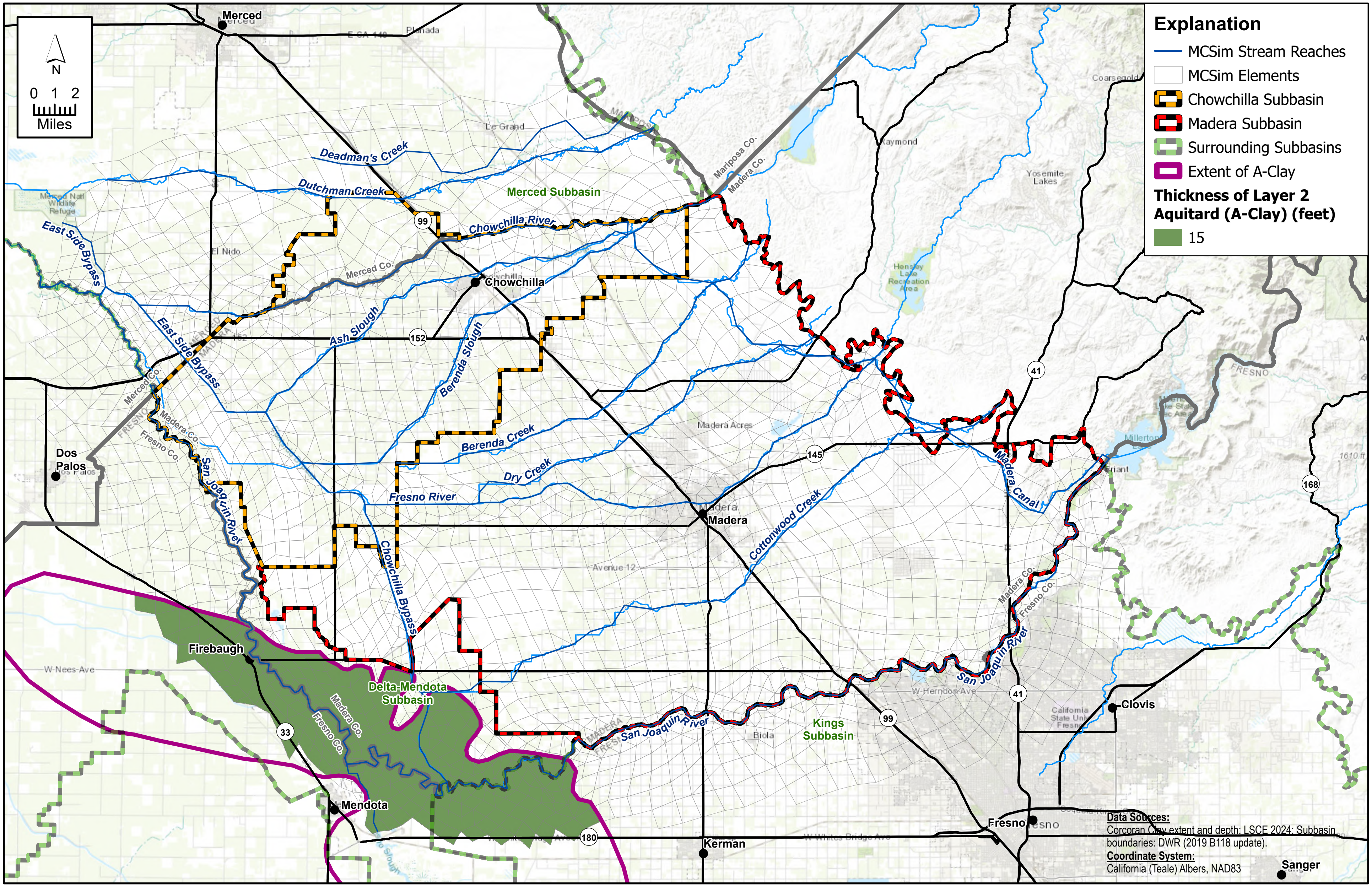
FIGURE 3-16

Thickness of Layer 1

Madera-Chowchilla Groundwater-Surface Water Simulation Model (MCSim) - First Model Update



X:\2024\24-010 (1) Davids Eng. - Madera Subbasin 5-Year GSP Update\MODEL\MCSim_v2_GIS_20231101\MCSim_v2_20231101.aprx; STRAT_Layering_Thickness

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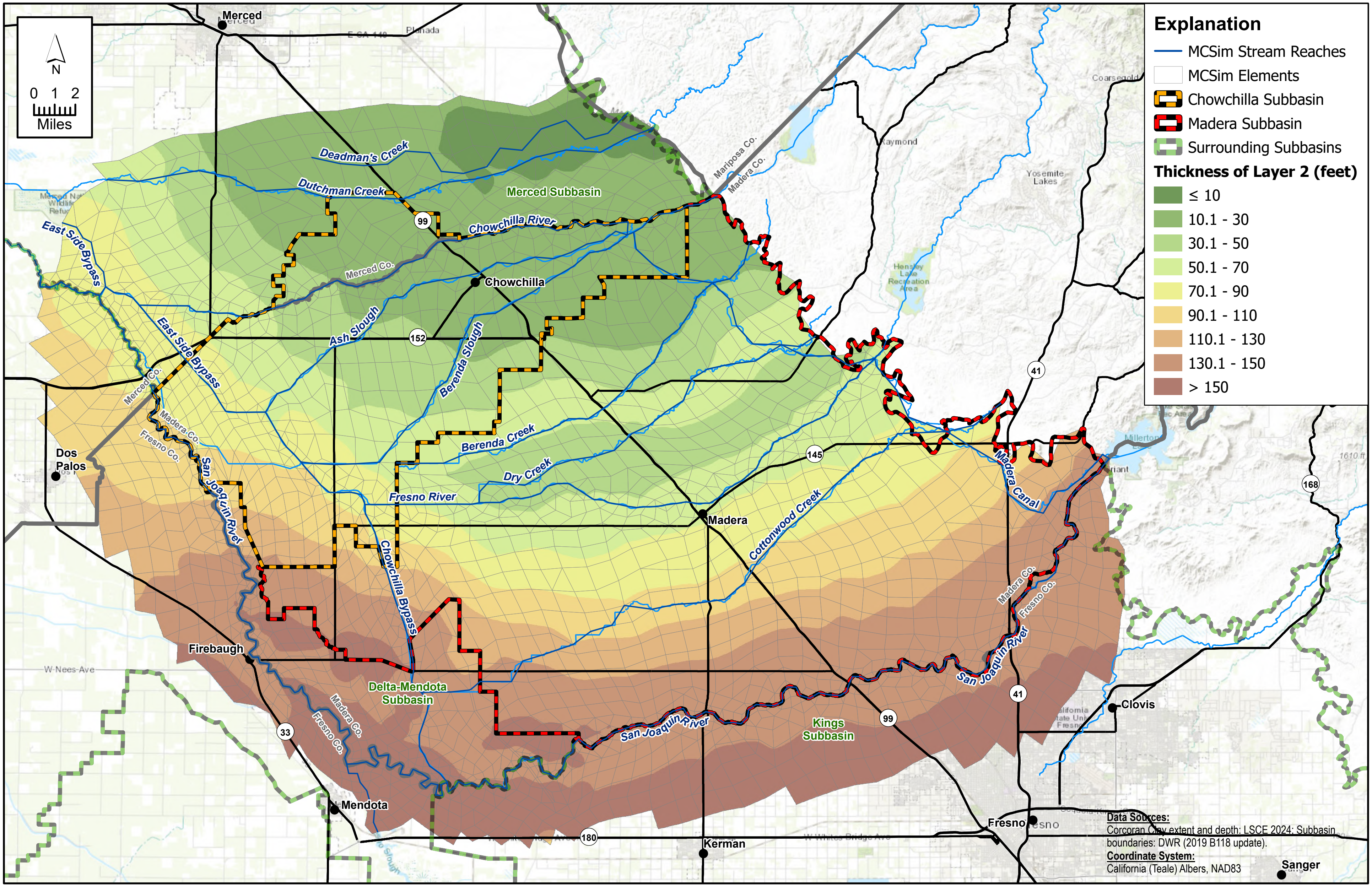
FIGURE 3-17

Thickness of the Layer 2 Aquitard (A-Clay)

Madera-Chowchilla Groundwater-Surface Water Simulation Model (MCSim) - First Model Update



X:\2024\24-010 (1) Davids Eng. - Madera Subbasin 5-Year GSP Update\MODEL\MCSim_v2_GIS_20231101\MCSim_v2_20231101.aprx; STRAT_Layering_Thickness

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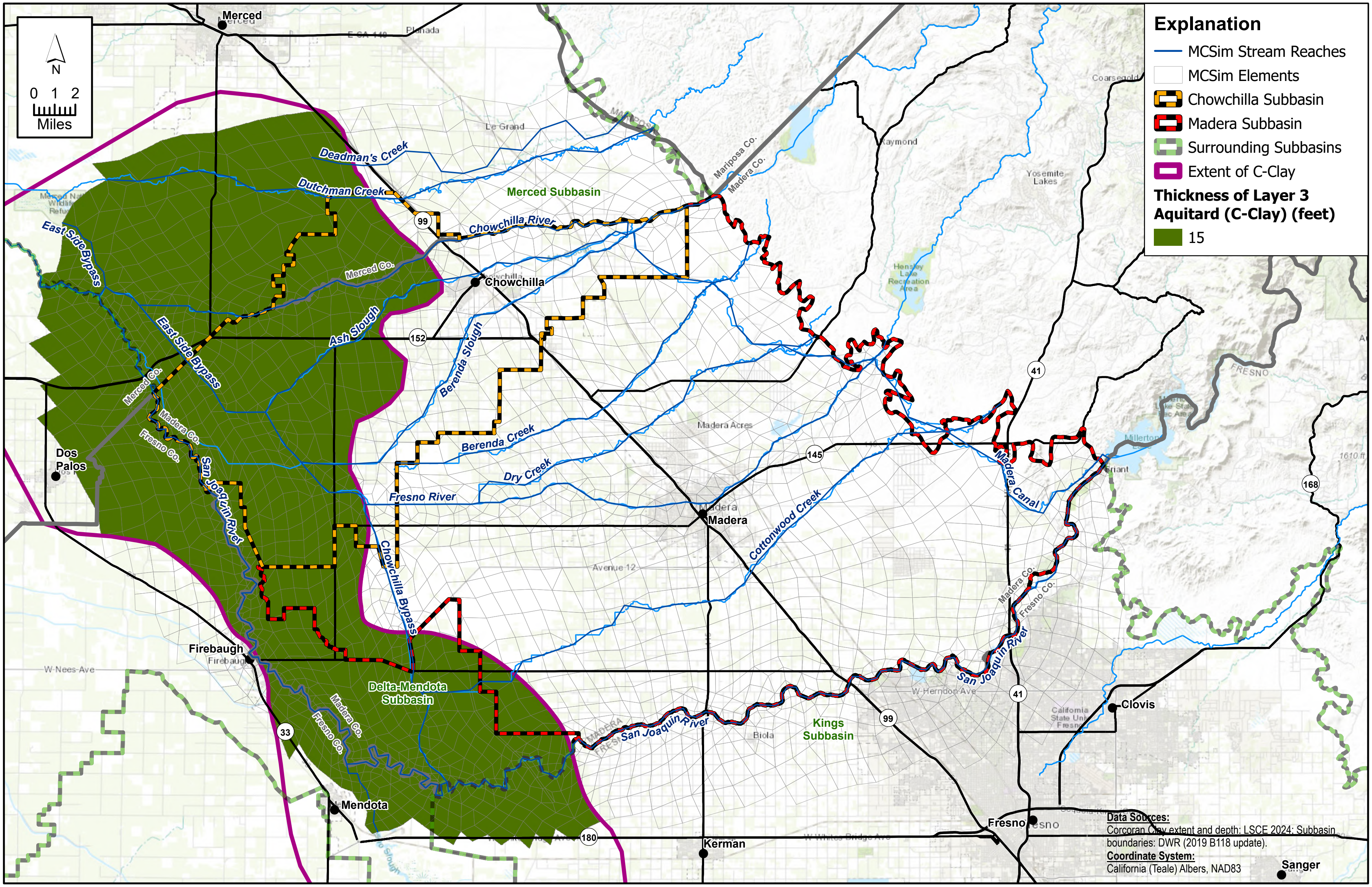
FIGURE 3-18

Thickness of Layer 2

Madera-Chowchilla Groundwater-Surface Water Simulation Model (MCSim) - First Model Update



X:\2024\24-010 (1) Davids Eng. - Madera Subbasin 5-Year GSP Update\MODEL\MCSim_v2_GIS_20231101\MCSim_v2_20231101.aprx; STRAT_Layering_Thickness

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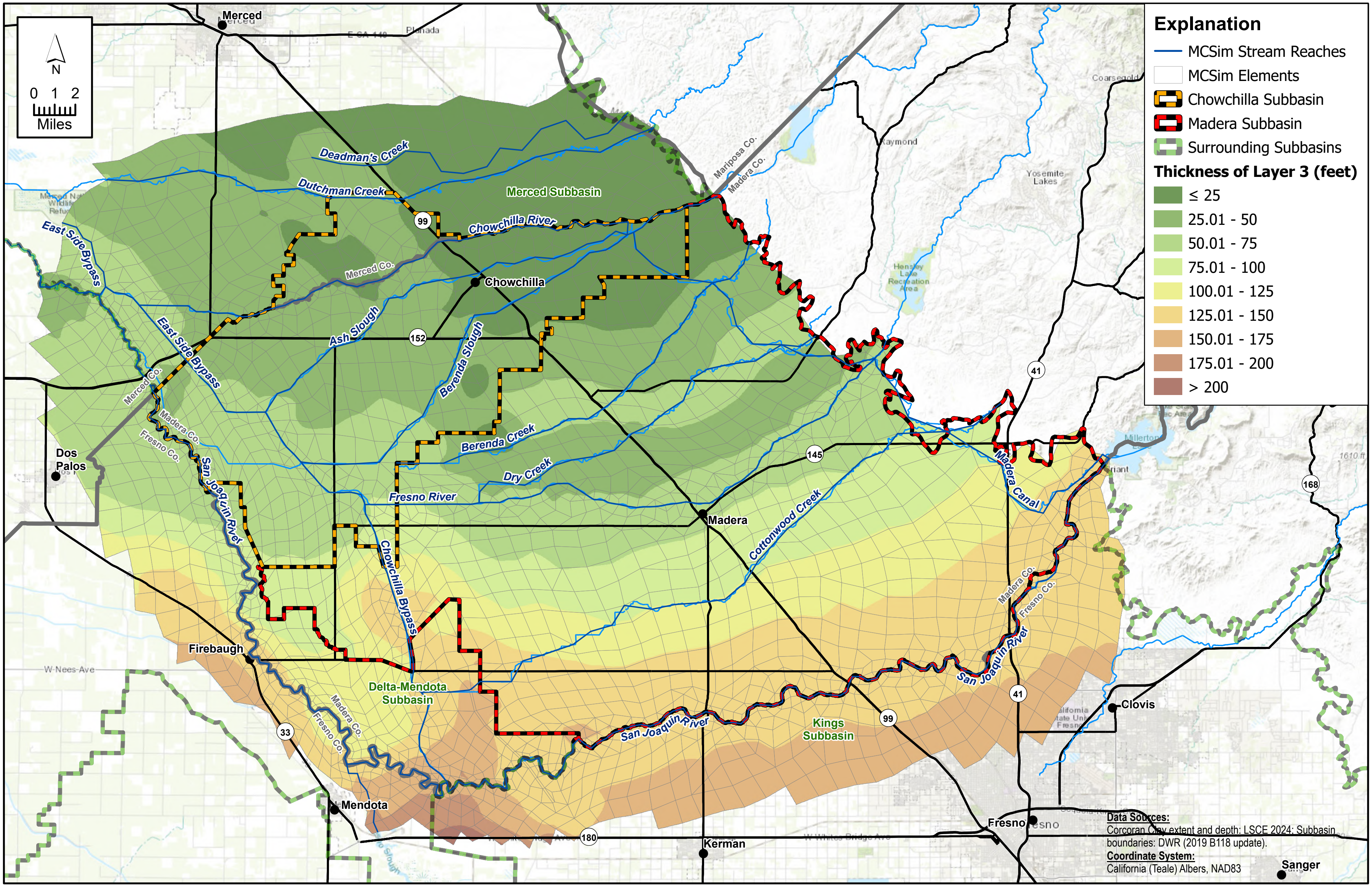
FIGURE 3-19

Thickness of the Layer 3 Aquitard (C-Clay)

Madera-Chowchilla Groundwater-Surface Water Simulation Model (MCSim) - First Model Update



X:\2024\24-010 (1) Davids Eng. - Madera Subbasin 5-Year GSP Update\MODEL\MCSim_v2_GIS_20231101\MCSim_v2_20231101.aprx; STRAT_Layering_Thickness

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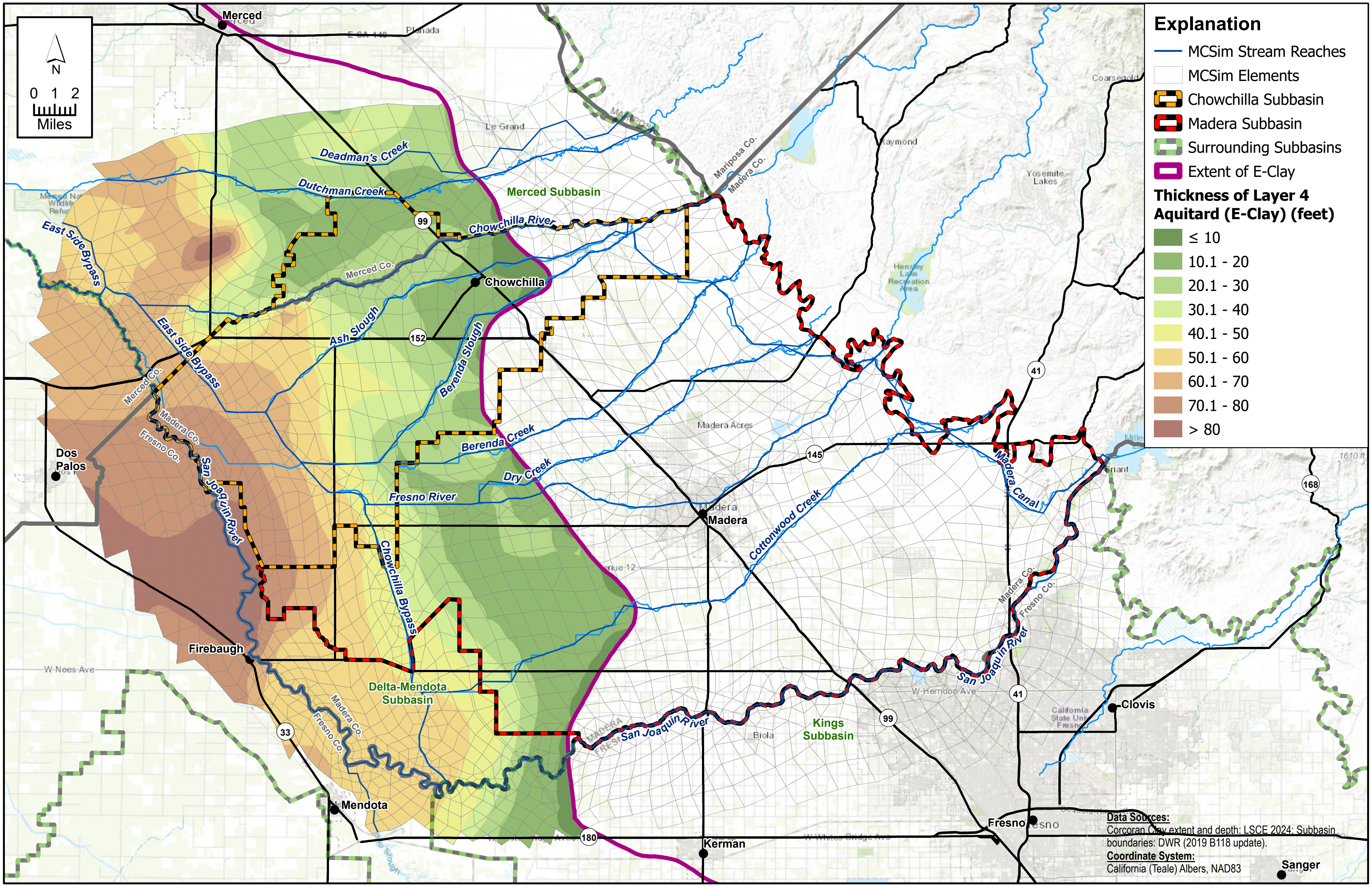
FIGURE 3-20

Thickness of Layer 3

Madera-Chowchilla Groundwater-Surface Water Simulation Model (MCSim) - First Model Update



X:\2024\24-010 (1) Davids Eng. - Madera Subbasin 5-Year GSP Update\MODEL\MCSim_v2_GIS_20231101\MCSim_v2_20231101.aprx; STRAT_Layering_Thickness

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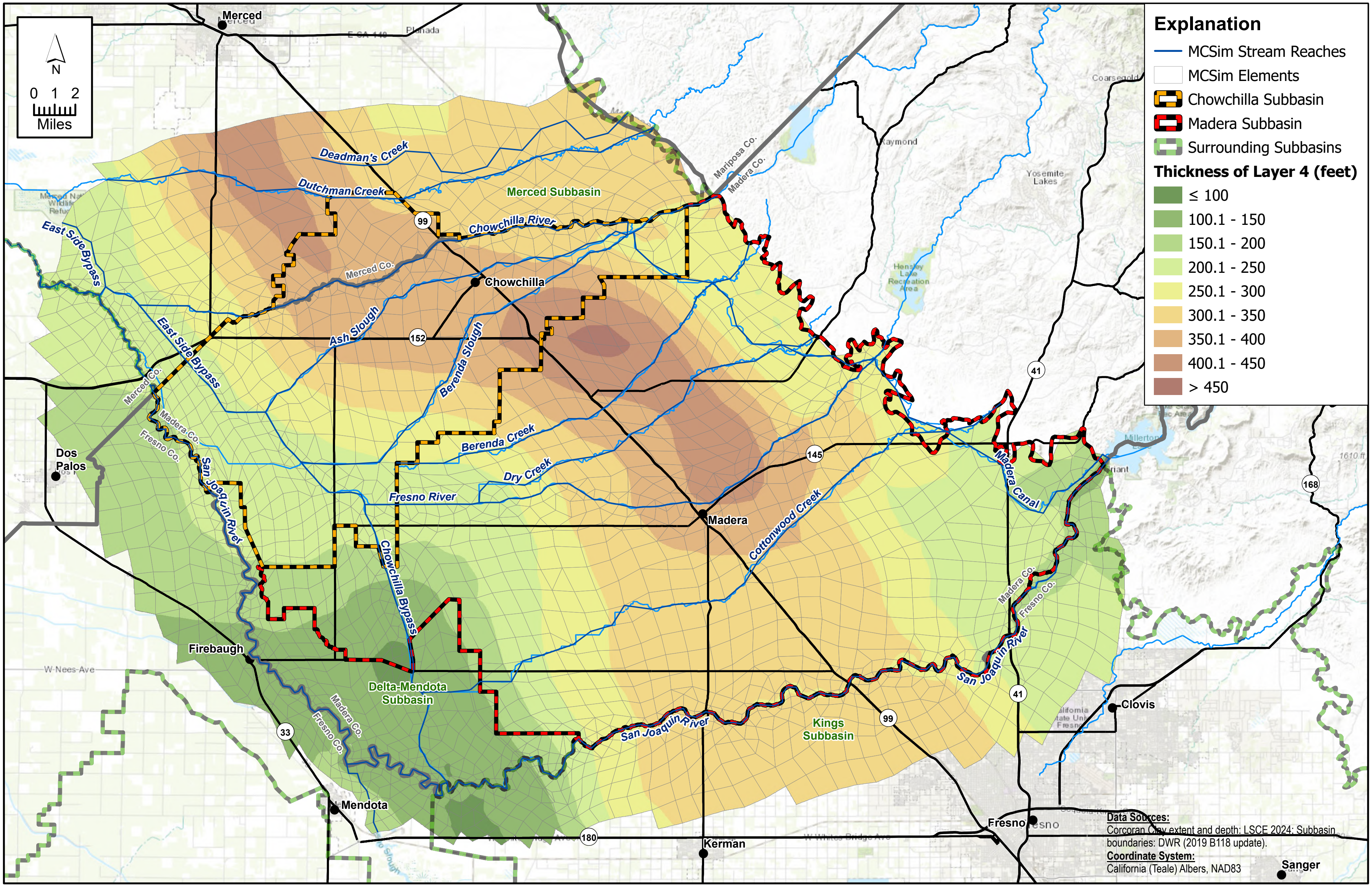
FIGURE 3-21

Thickness of the Layer 4 Aquitard (E-Clay)

Madera-Chowchilla Groundwater-Surface Water Simulation Model (MCSim) - First Model Update



X:\2024\24-010 (1) Davids Eng. - Madera Subbasin 5-Year GSP Update\MODEL\MCSim_v2_GIS_20231101\MCSim_v2_20231101.aprx; STRAT_Layering_Thickness

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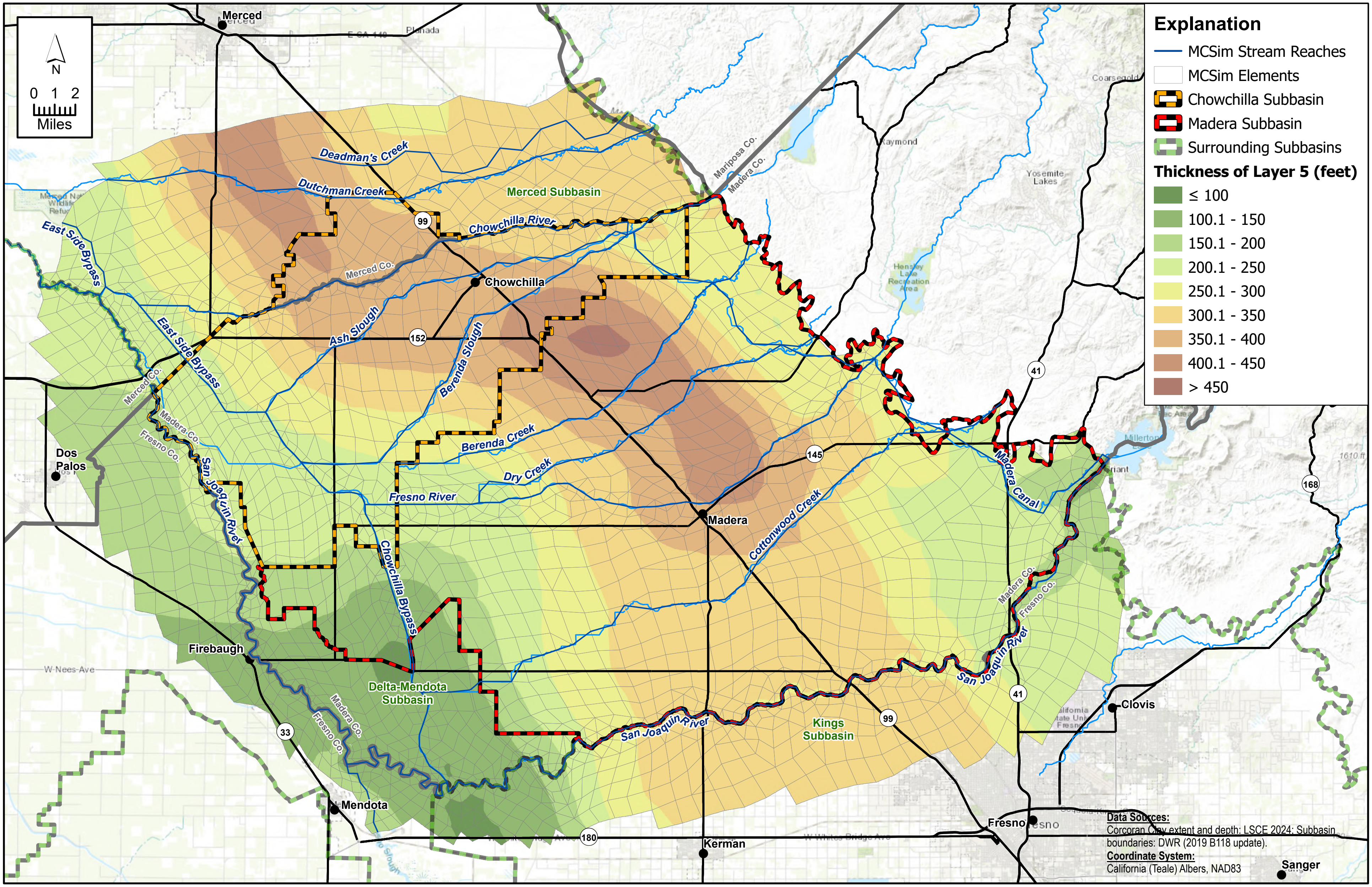
FIGURE 3-22

Thickness of Layer 4

Madera-Chowchilla Groundwater-Surface Water Simulation Model (MCSim) - First Model Update



X:\2024\24-010 (1) Davids Eng. - Madera Subbasin 5-Year GSP Update\MODEL\MCSim_v2_GIS_20231101\MCSim_v2_20231101.aprx; STRAT_Layering_Thickness

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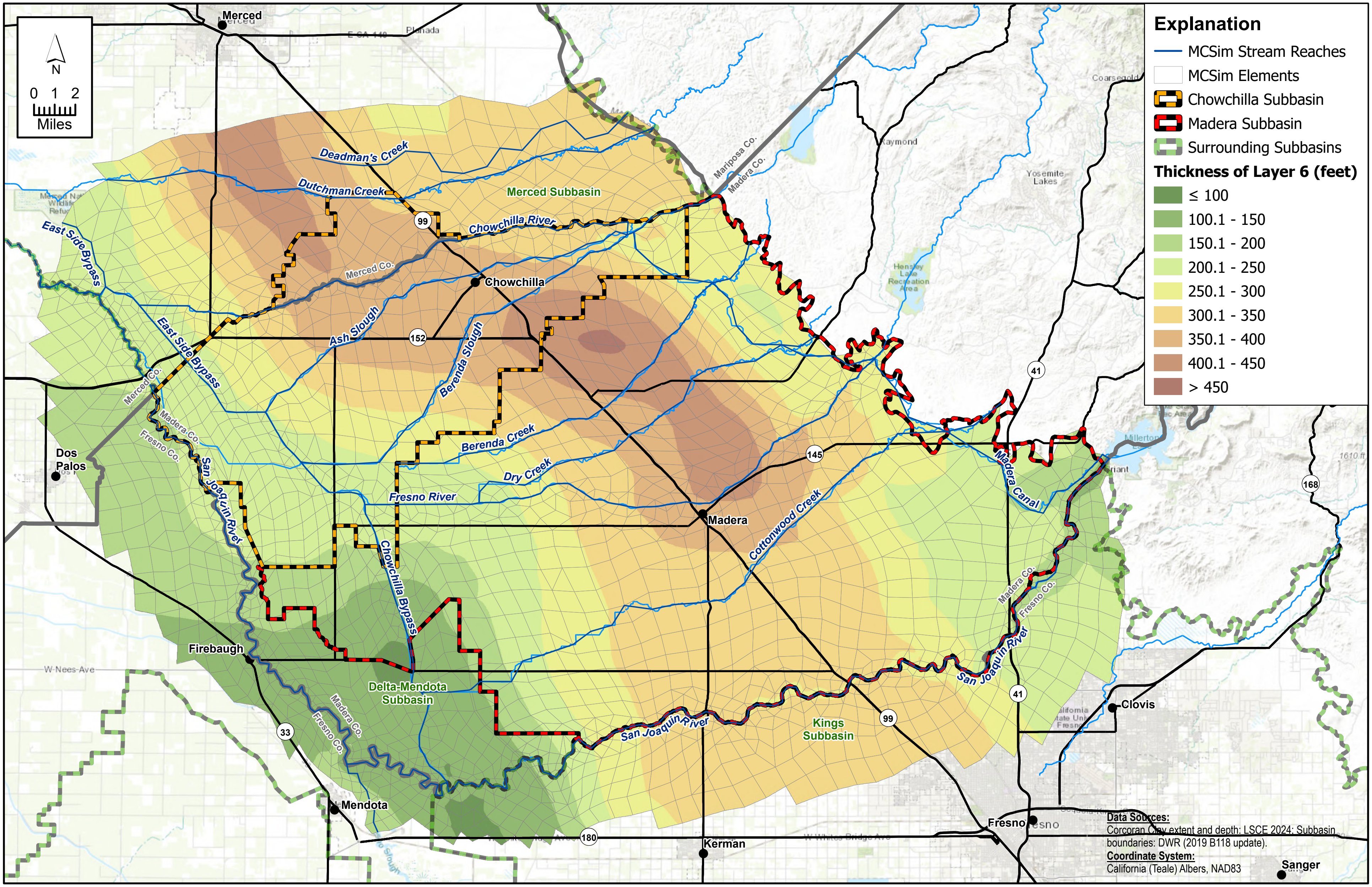
FIGURE 3-23

Thickness of Layer 5

Madera-Chowchilla Groundwater-Surface Water Simulation Model (MCSim) - First Model Update



X:\2024\24-010 (1) Davids Eng. - Madera Subbasin 5-Year GSP Update\MODEL\MCSim_v2_GIS_20231101\MCSim_v2_20231101.aprx; STRAT_Layering_Thickness

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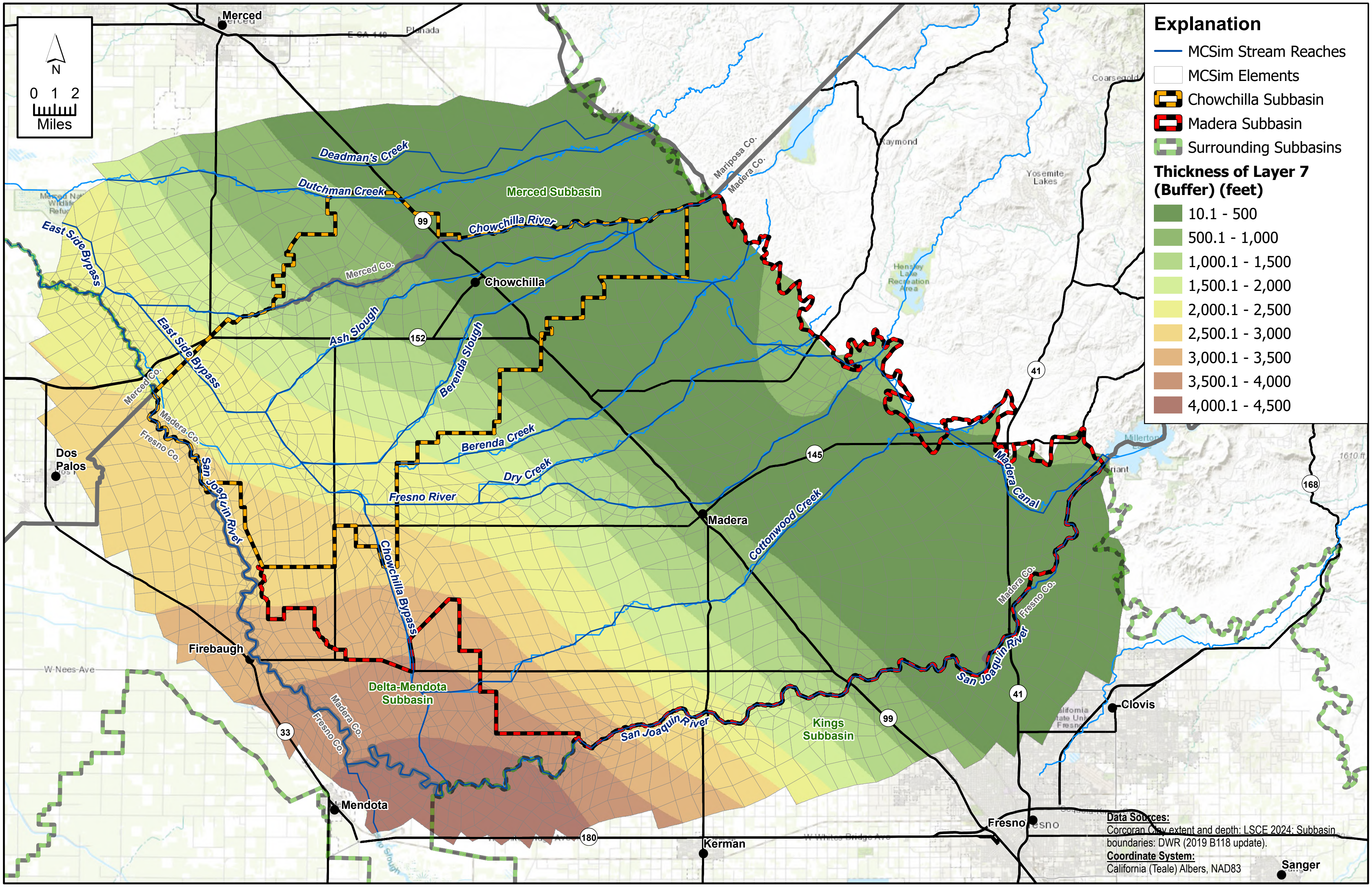
FIGURE 3-24

Thickness of Layer 6

Madera-Chowchilla Groundwater-Surface Water Simulation Model (MCSim) - First Model Update



X:\2024\24-010 (1) Davids Eng. - Madera Subbasin 5-Year GSP Update\MODEL\MCSim_v2_GIS_20231101\MCSim_v2_20231101.aprx; STRAT_Layering_Thickness

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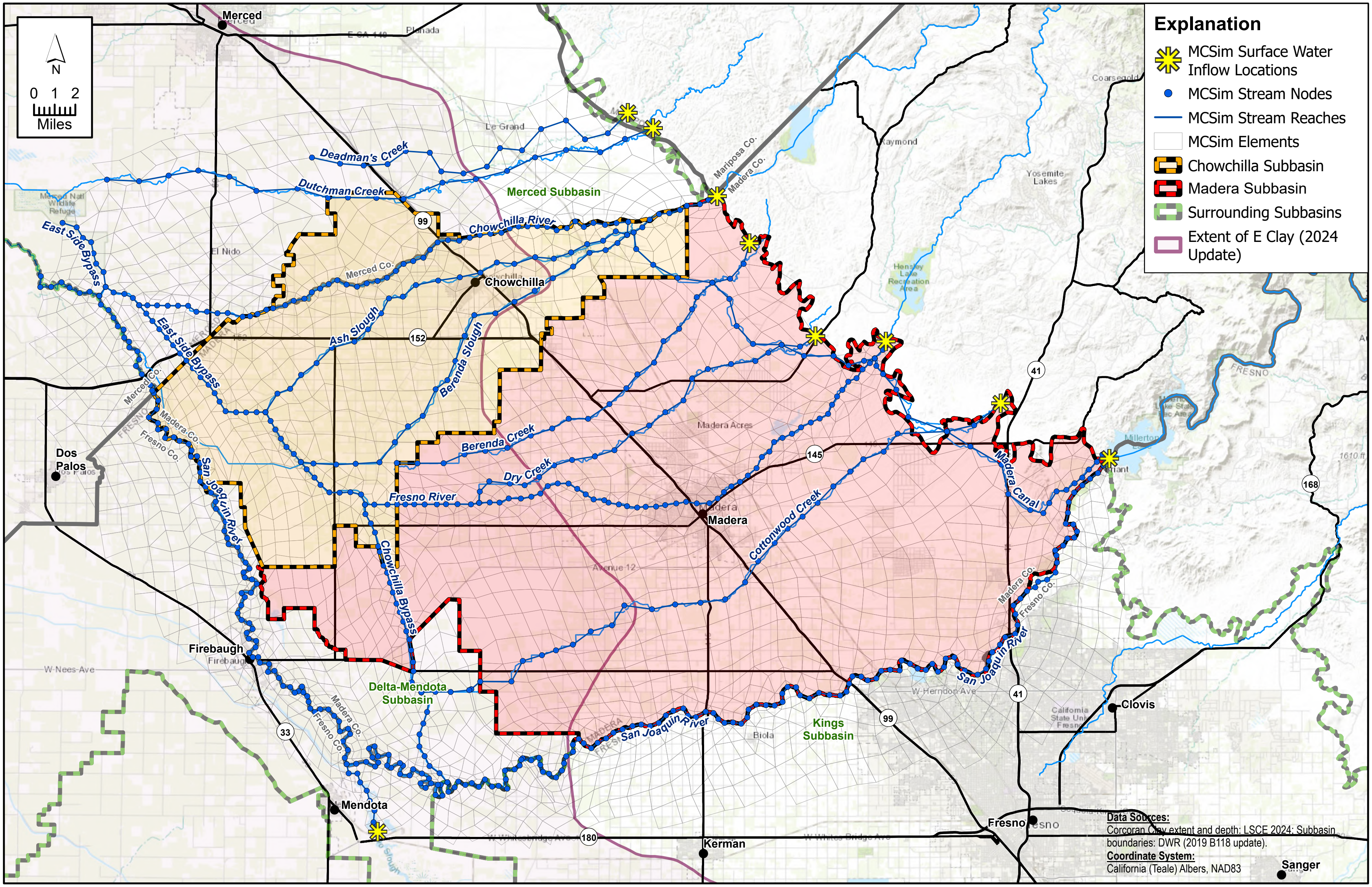
FIGURE 3-25

Thickness of Layer 7

Madera-Chowchilla Groundwater-Surface Water Simulation Model (MCSim) - First Model Update



X:\2024\24-010 (1) Davids Eng. - Madera Subbasin 5-Year GSP Update\MODEL\MCSim_v2_GIS_20231101\MCSim_v2_20231101.aprx; Fig3-26_Surface Water Inflows

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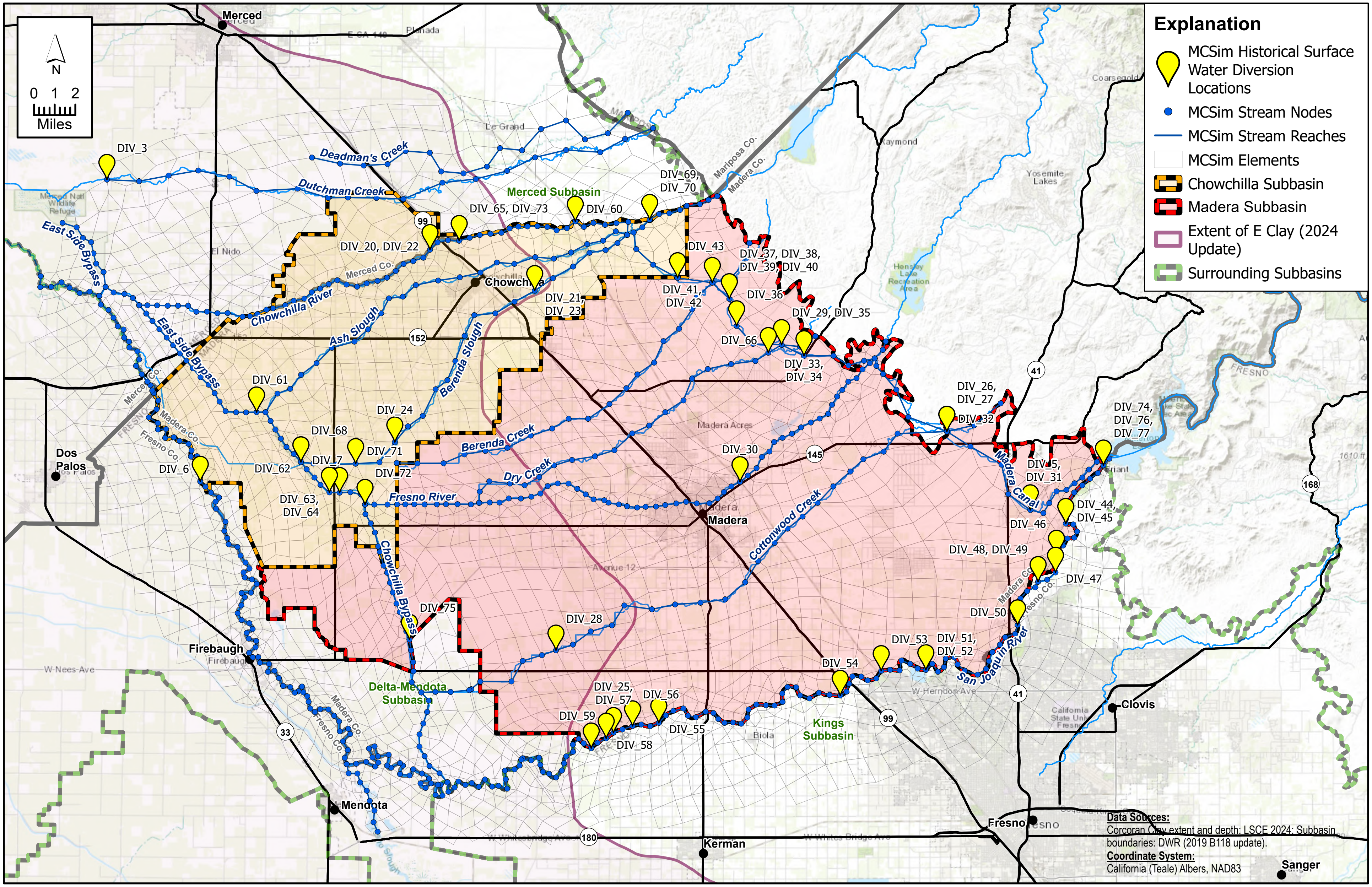
FIGURE 3-26

MCSim Surface Water Inflow Locations

Madera-Chowchilla Groundwater-Surface Water Simulation Model (MCSim) - First Model Update



X:\2024\24-010 (1) Davids Eng. - Madera Subbasin 5-Year GSP Update\MODEL\MCSim_v2_GIS_20231101\MCSim_v2_20231101.aprx; Fig3-27_Historical Surface Water Diversions

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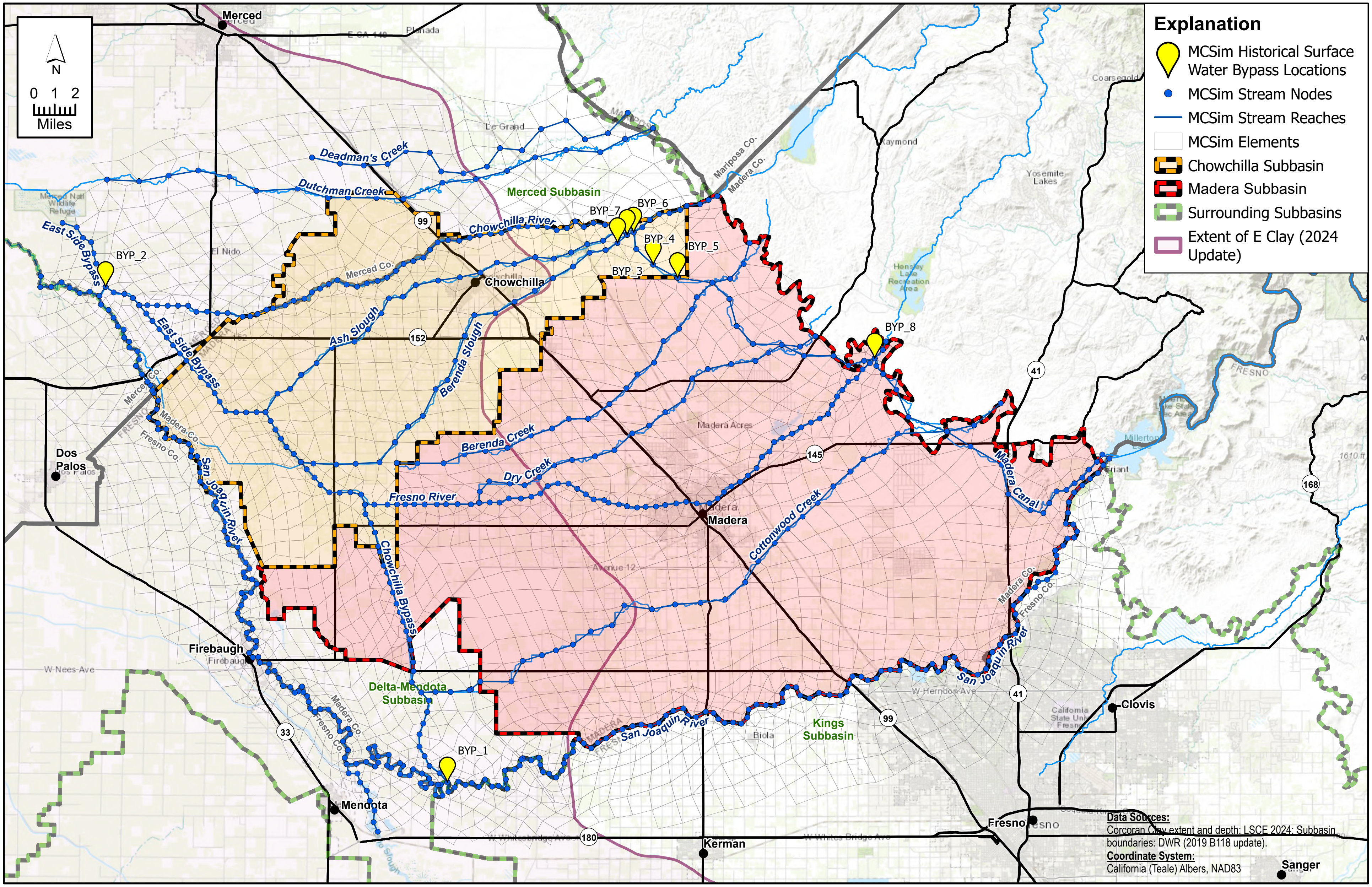
FIGURE 3-27

MCSim Historical Surface Water Diversions Locations

Madera-Chowchilla Groundwater-Surface Water Simulation Model (MCSim) - First Model Update



X:\2024\24-010 (1) Davids Eng. - Madera Subbasin 5-Year GSP Update\MODEL\MCSim_v2_GIS_20231101\MCSim_v2_20231101.aprx; Fig3-28_Historical Surface Water Bypasses

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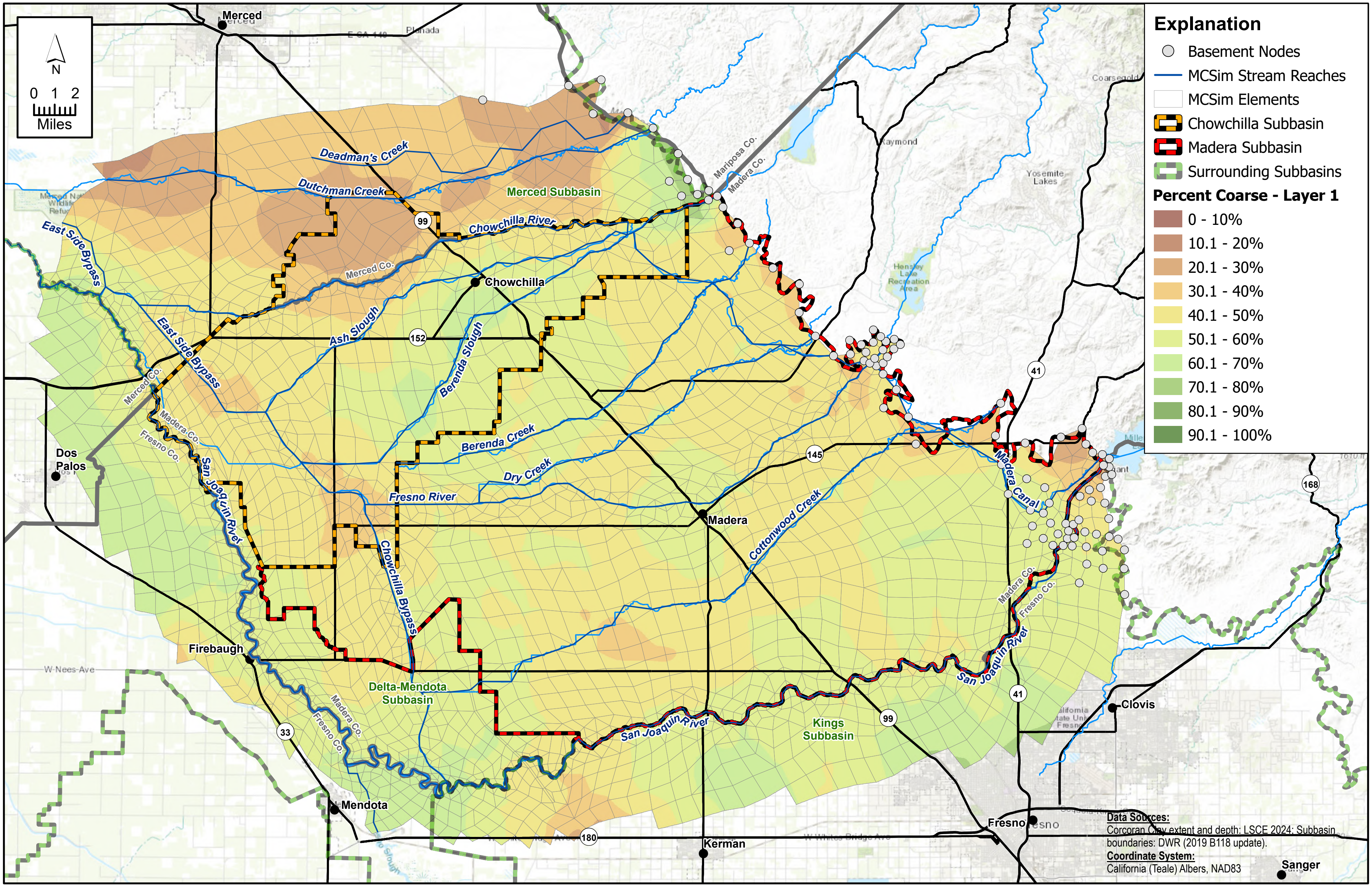
FIGURE 3-28

MCSim Historical Surface Water Bypass Locations

Madera-Chowchilla Groundwater-Surface Water Simulation Model (MCSim) - First Model Update



X:\2024\24-010 (1) Davids Eng. - Madera Subbasin 5-Year GSP Update\MODEL\MCSim_v2_GIS_20231101\MCSim_v2_20231101.aprx; TEXTURE_Percent_Coarse

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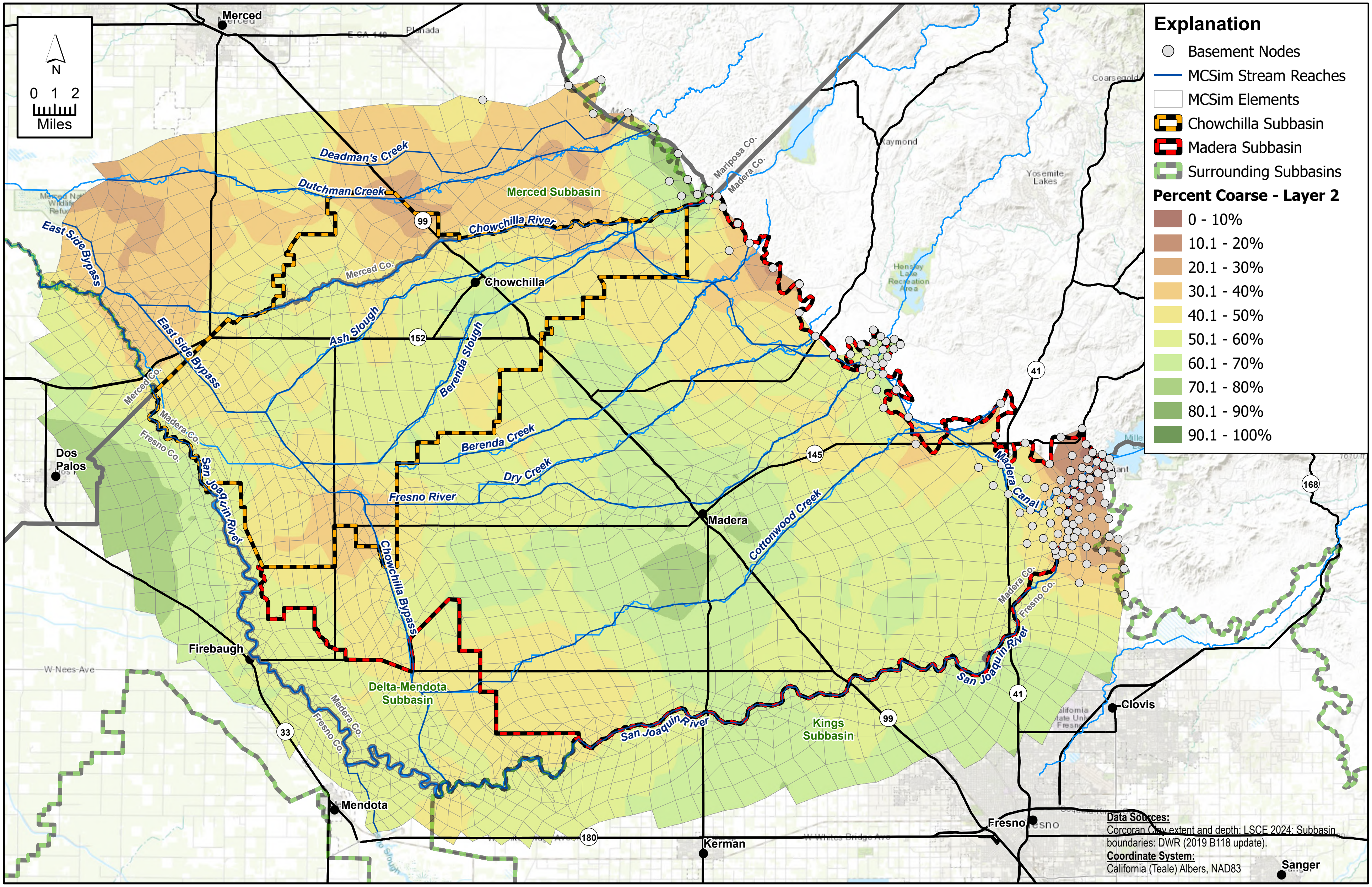
FIGURE 3-29

Percent Coarse - Layer 1

Madera-Chowchilla Groundwater-Surface Water Simulation Model (MCSim) - First Model Update



X:\2024\24-010 (1) Davids Eng. - Madera Subbasin 5-Year GSP Update\MODEL\MCSim_v2_GIS_20231101\MCSim_v2_20231101.aprx; TEXTURE_Percent_Coarse

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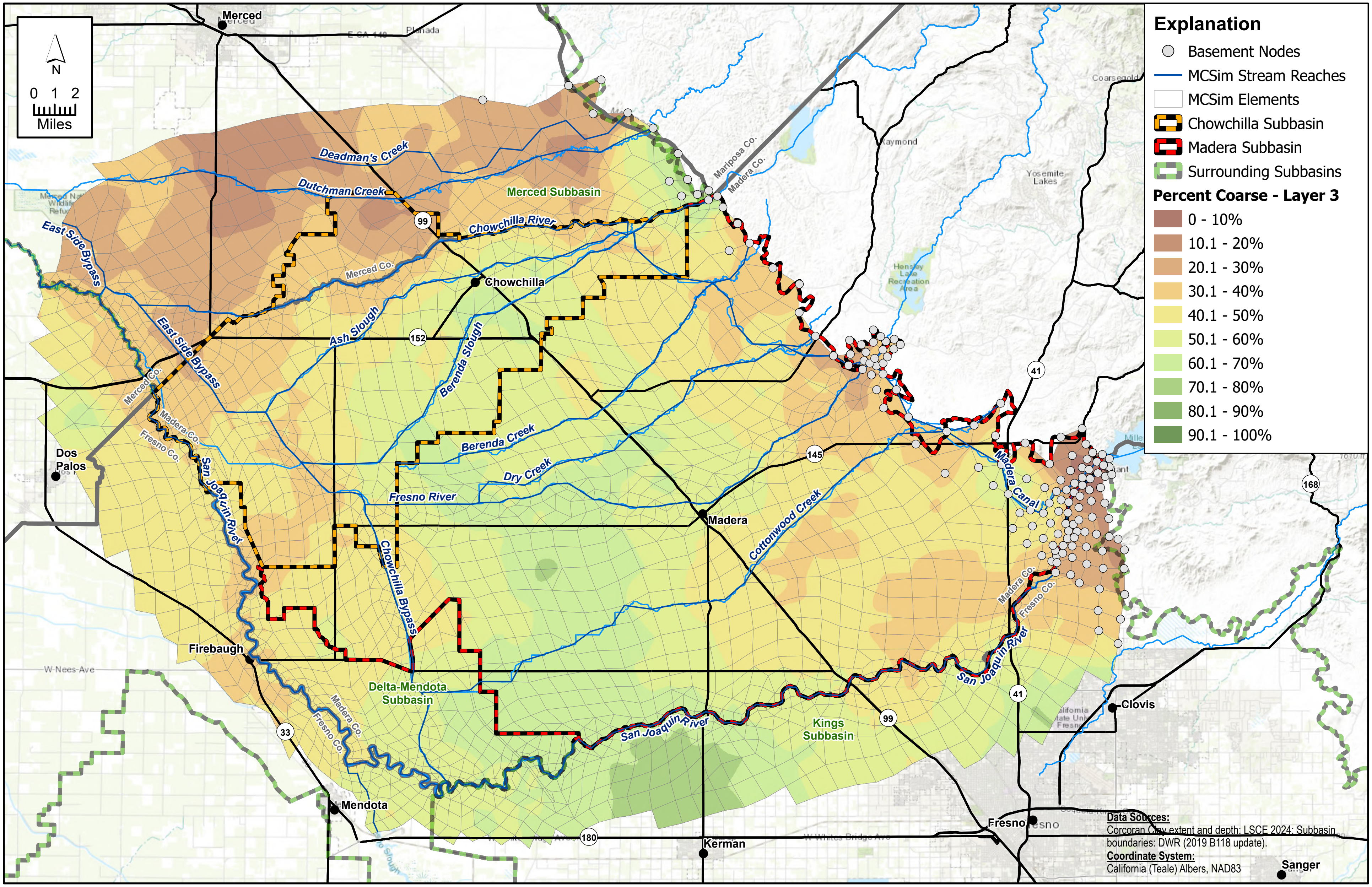
FIGURE 3-30

Percent Coarse - Layer 2

Madera-Chowchilla Groundwater-Surface Water Simulation Model (MCSim) - First Model Update



X:\2024\24-010 (1) Davids Eng. - Madera Subbasin 5-Year GSP Update\MODEL\MCSim_v2_GIS_20231101\MCSim_v2_20231101.aprx; TEXTURE_Percent_Coarse

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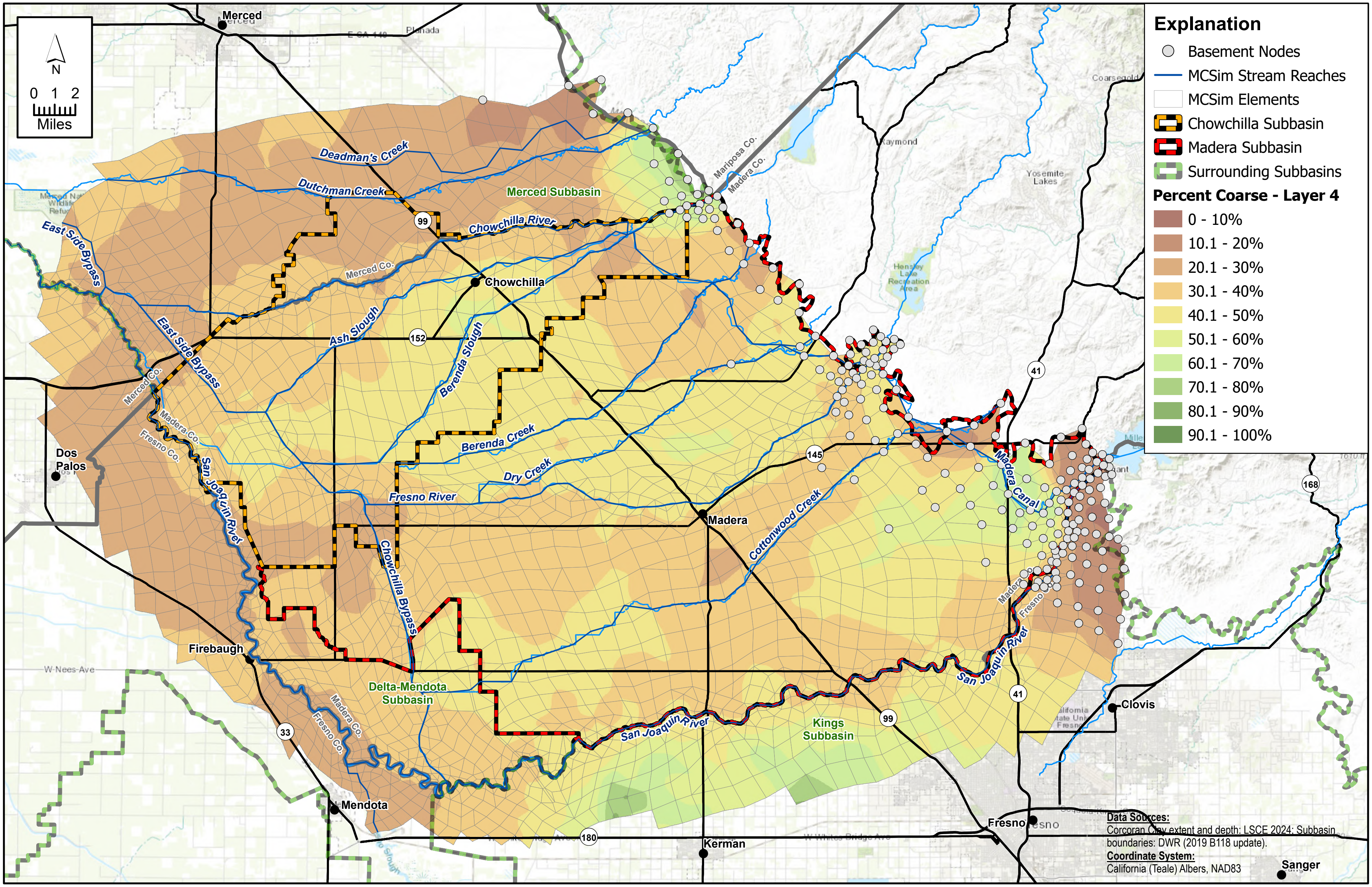
FIGURE 3-31

Percent Coarse - Layer 3

Madera-Chowchilla Groundwater-Surface Water Simulation Model (MCSim) - First Model Update



X:\2024\24-010 (1) Davids Eng. - Madera Subbasin 5-Year GSP Update\MODEL\MCSim_v2_GIS_20231101\MCSim_v2_20231101.aprx; TEXTURE_Percent_Coarse

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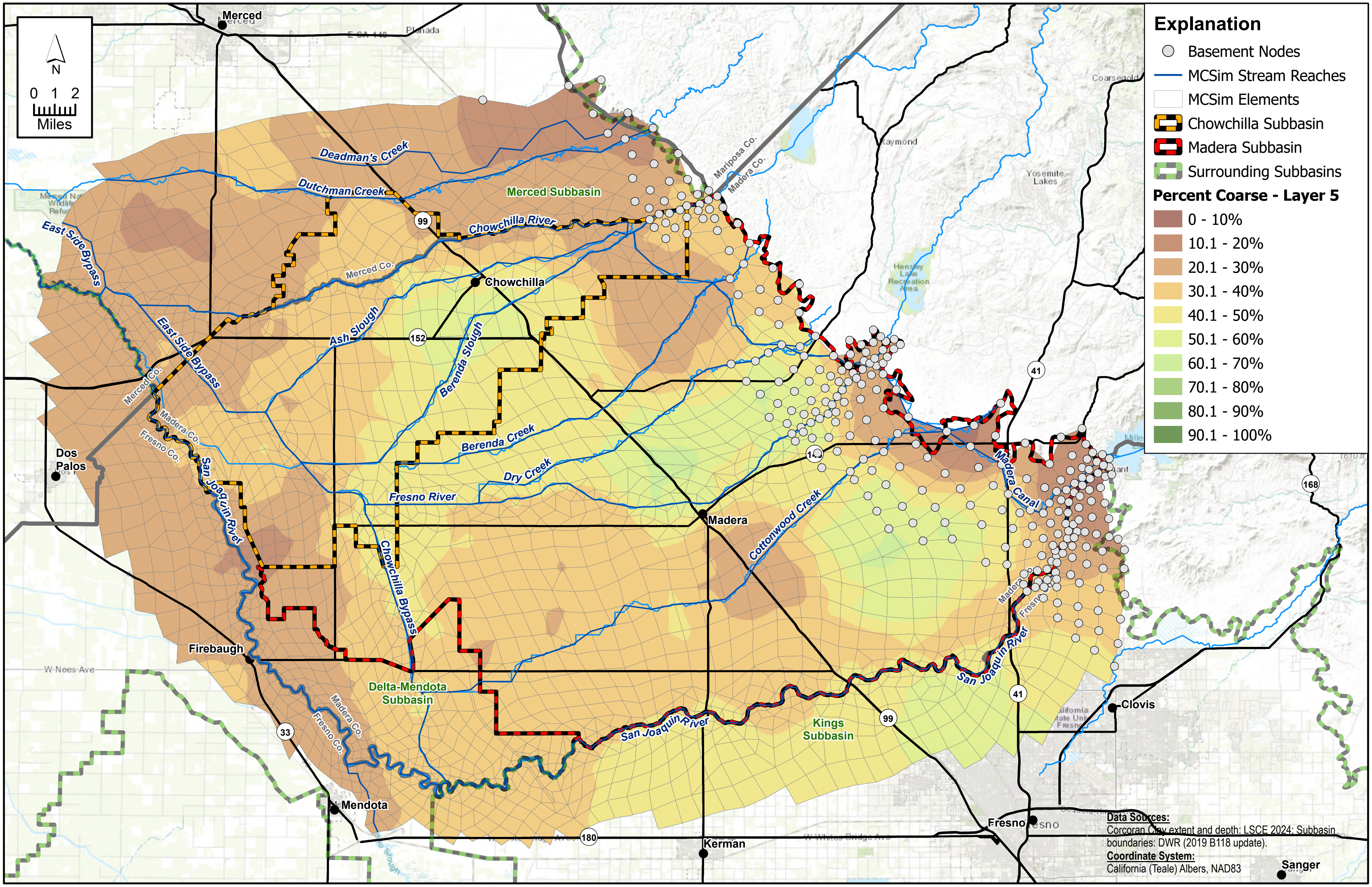
FIGURE 3-32

Percent Coarse - Layer 4

Madera-Chowchilla Groundwater-Surface Water Simulation Model (MCSim) - First Model Update



X:\2024\24-010 (1) Davids Eng. - Madera Subbasin 5-Year GSP Update\MODEL\MCSim_v2_GIS_20231101\MCSim_v2_20231101.aprx; TEXTURE_Percent_Coarse

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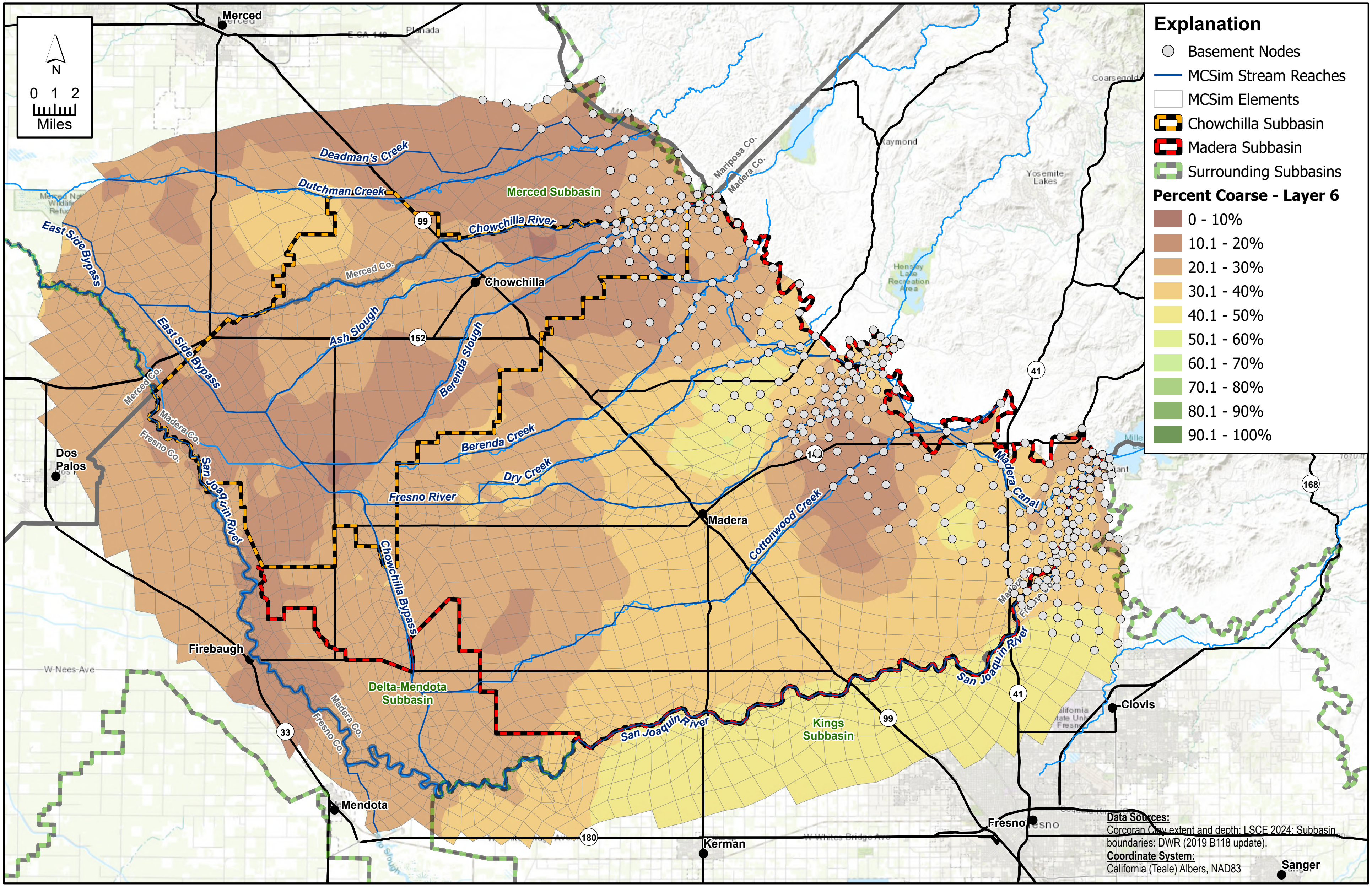
FIGURE 3-33

Percent Coarse - Layer 5

Madera-Chowchilla Groundwater-Surface Water Simulation Model (MCSim) - First Model Update



X:\2024\24-010 (1) Davids Eng. - Madera Subbasin 5-Year GSP Update\MODEL\MCSim_v2_GIS_20231101\MCSim_v2_20231101.aprx; TEXTURE_Percent_Coarse

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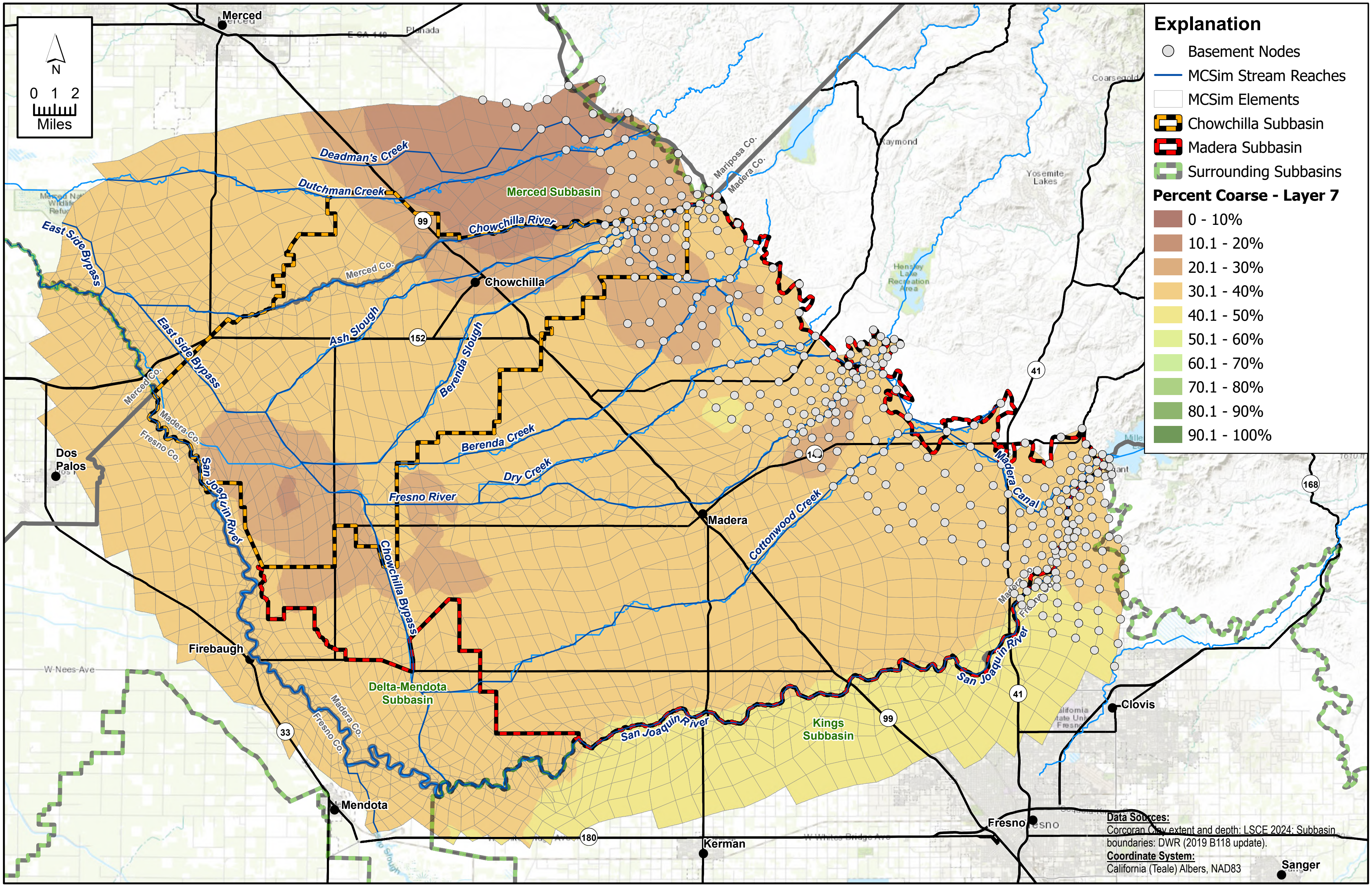
FIGURE 3-34

Percent Coarse - Layer 6

Madera-Chowchilla Groundwater-Surface Water Simulation Model (MCSim) - First Model Update



X:\2024\24-010 (1) Davids Eng. - Madera Subbasin 5-Year GSP Update\MODEL\MCSim_v2_GIS_20231101\MCSim_v2_20231101.aprx; TEXTURE_Percent_Coarse

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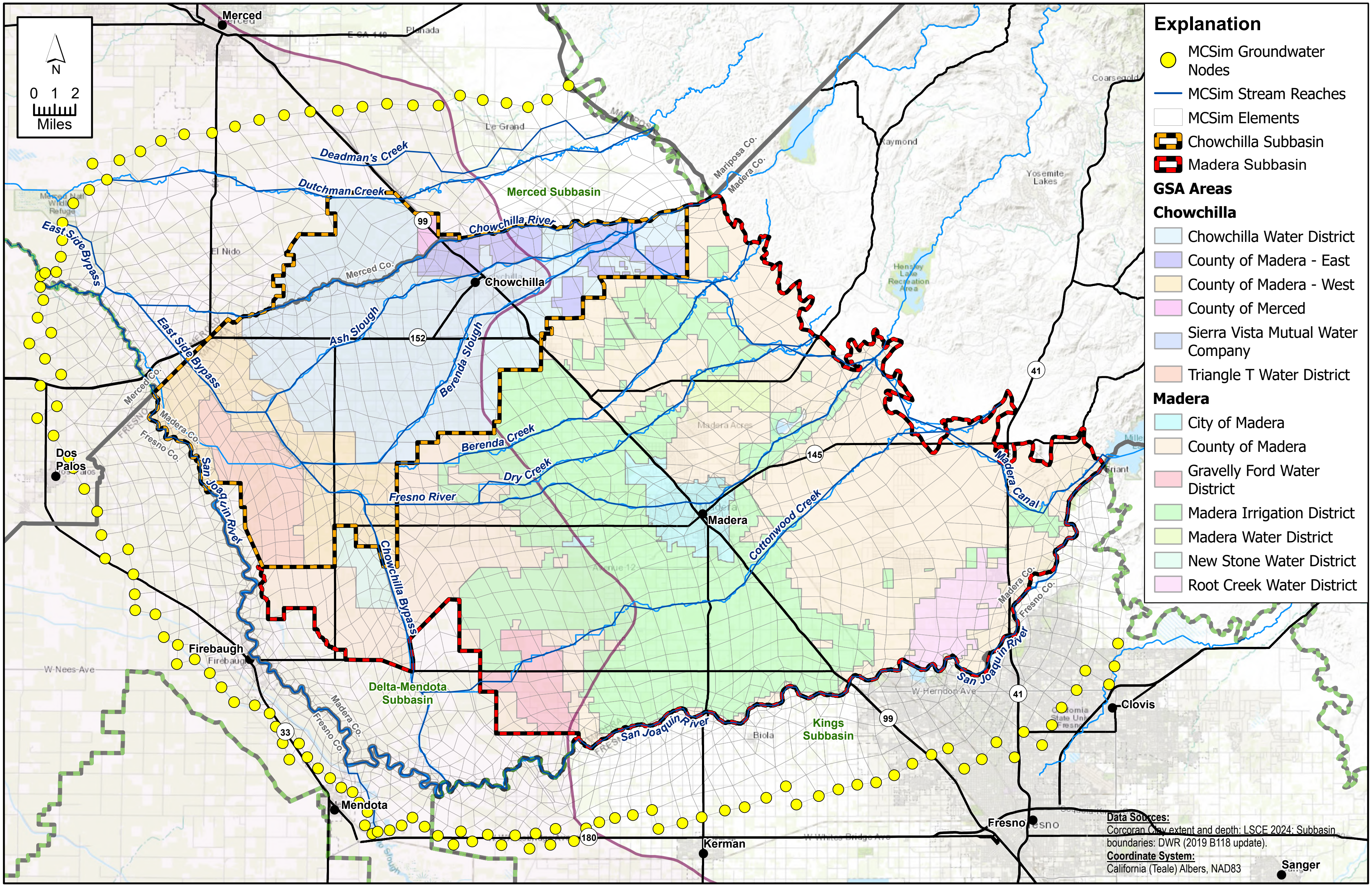
FIGURE 3-35

Percent Coarse - Layer 7

Madera-Chowchilla Groundwater-Surface Water Simulation Model (MCSim) - First Model Update

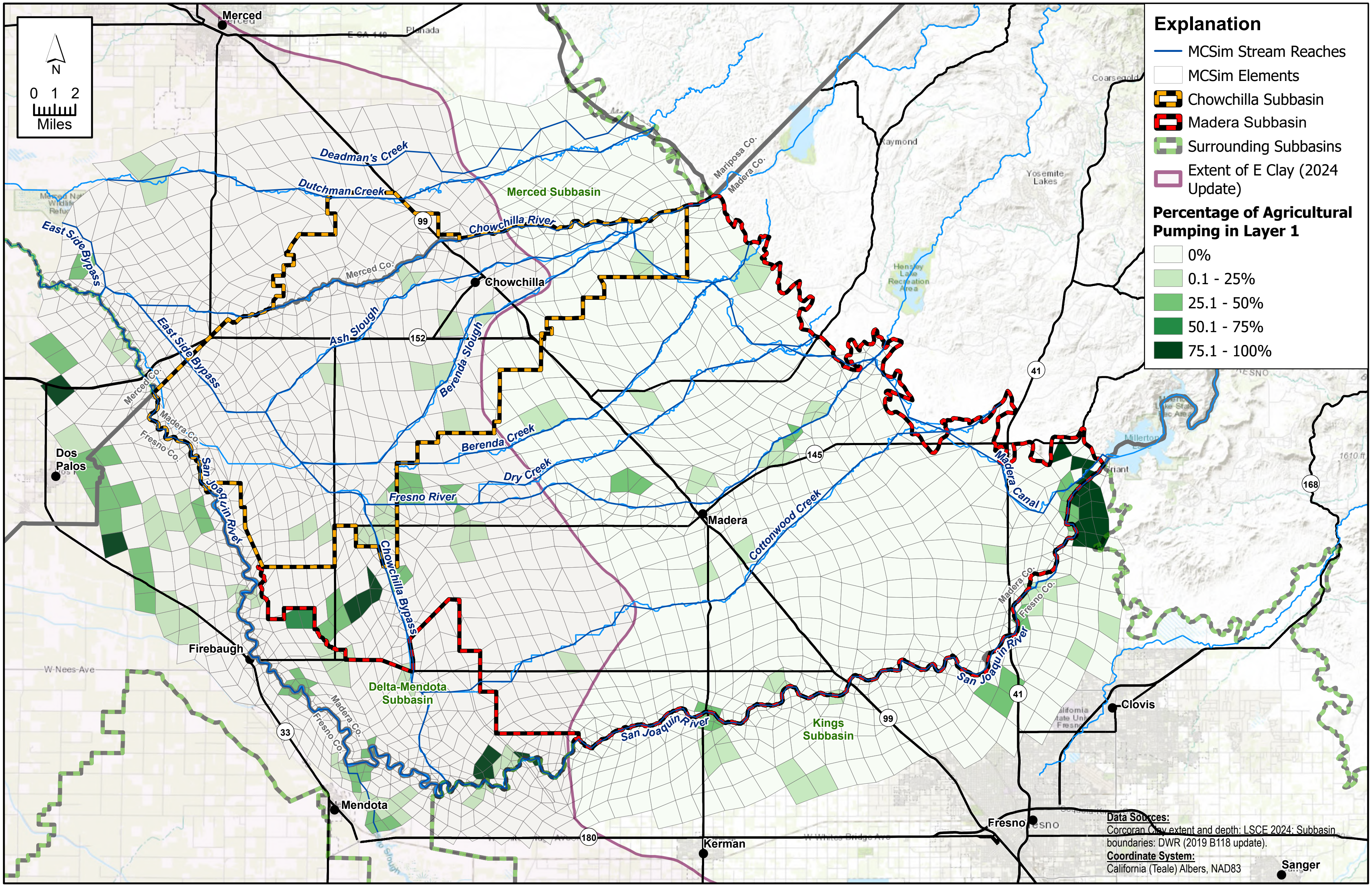


X:\2024\24-010 (1) Davids Eng. - Madera Subbasin 5-Year GSP Update\MODEL\MCSim_v2_GIS_20231101\MCSim_v2_20231101.aprx; Boundary Conditions

FIGURE 3-36

Groundwater Nodes with Boundary Conditions Specified in MCSim_v2

Madera-Chowchilla Groundwater-Surface Water Simulation Model (MCSim) - First Model Update



X:\2024\24-010 (1) Davids Eng. - Madera Subbasin 5-Year GSP Update\MODEL\MCSim_v2_GIS_20231101\MCSim_v2_20231101.aprx; GW_ELEM_PUMP_AG

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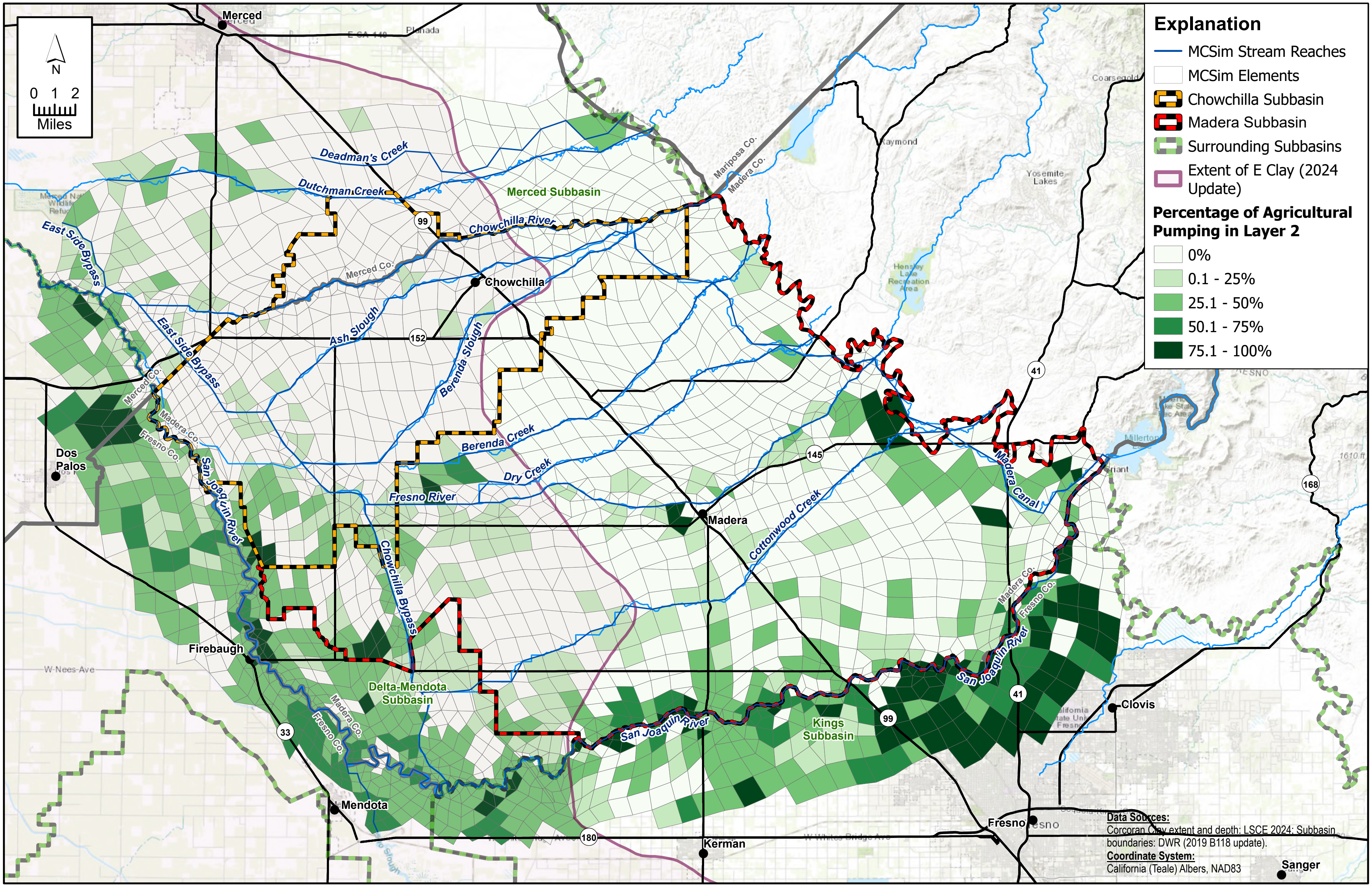
FIGURE 3-37

Vertical Distribution of Historical Agricultural Pumping - Layer 1

Madera-Chowchilla Groundwater-Surface Water Simulation Model (MCSim) - First Model Update



X:\2024\24-010 (1) Davids Eng. - Madera Subbasin 5-Year GSP Update\MODEL\MCSim_v2_GIS_20231101\MCSim_v2_20231101.aprx; GW_ELEM_PUMP_AG

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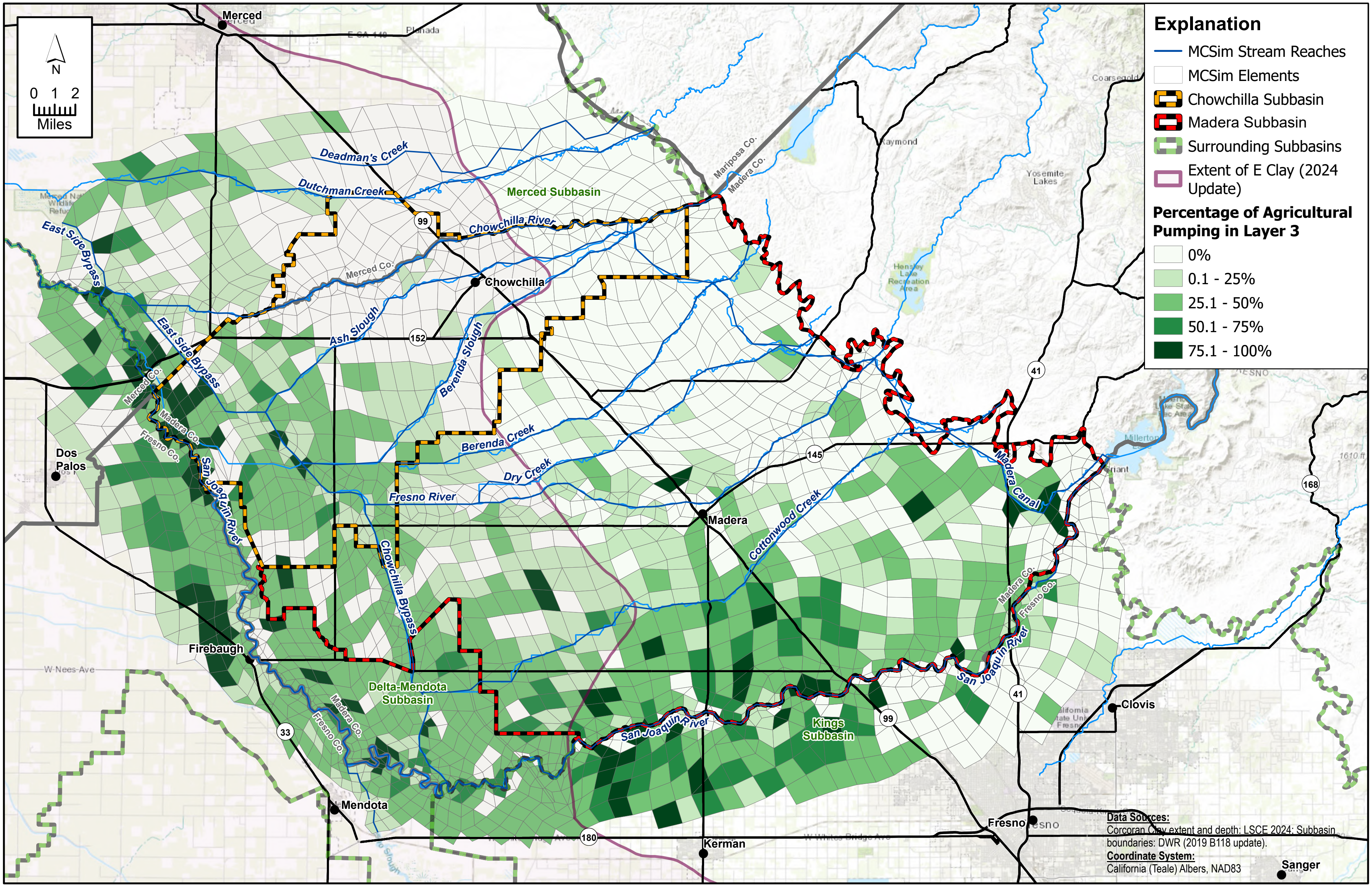
FIGURE 3-38

Vertical Distribution of Historical Agricultural Pumping - Layer 2

Madera-Chowchilla Groundwater-Surface Water Simulation Model (MCSim) - First Model Update



X:\2024\24-010 (1) Davids Eng. - Madera Subbasin 5-Year GSP Update\MODEL\MCSim_v2_GIS_20231101\MCSim_v2_20231101.aprx; GW_ELEM_PUMP_AG

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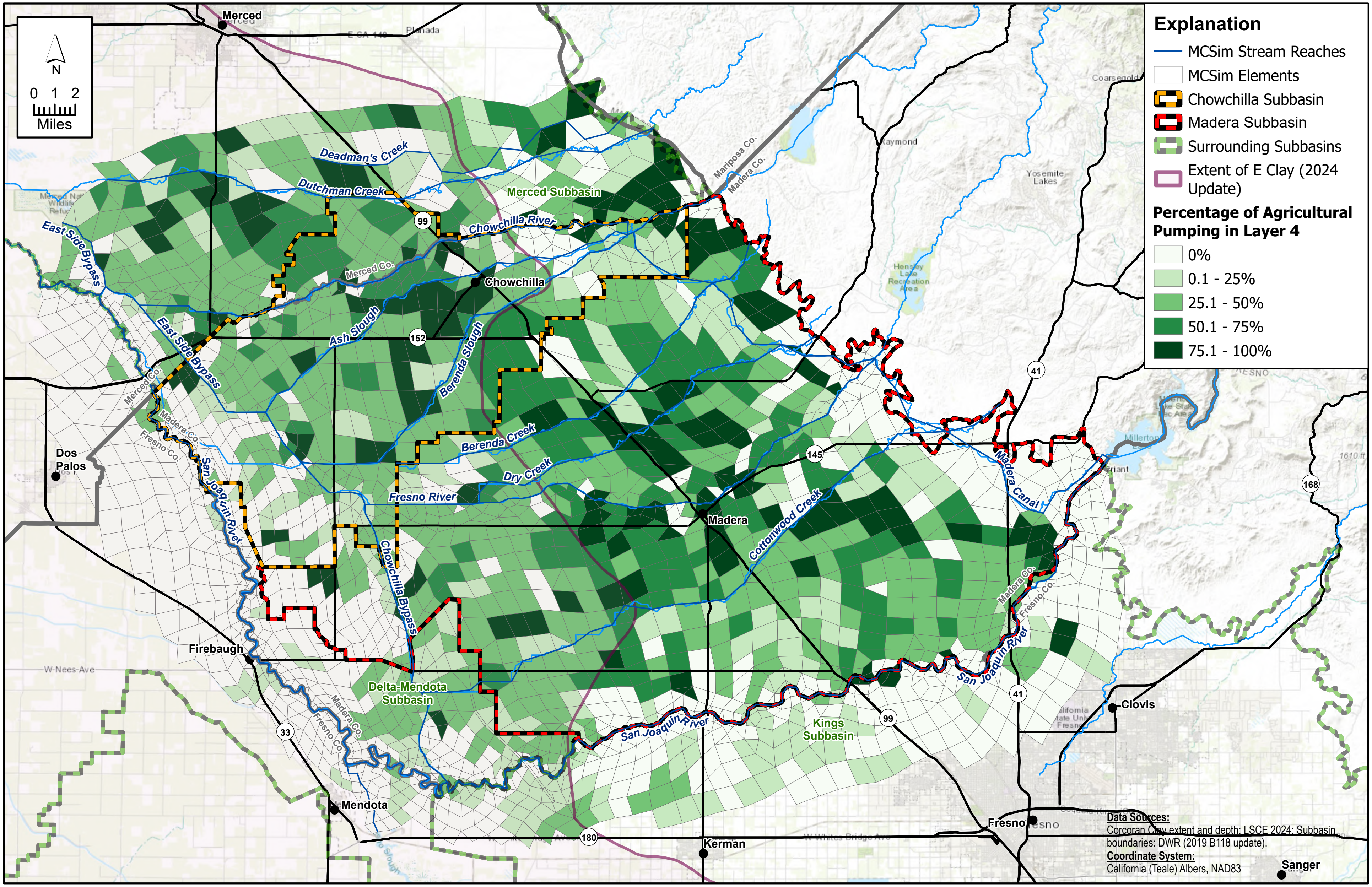
FIGURE 3-39

Vertical Distribution of Historical Agricultural Pumping - Layer 3

Madera-Chowchilla Groundwater-Surface Water Simulation Model (MCSim) - First Model Update



X:\2024\24-010 (1) Davids Eng. - Madera Subbasin 5-Year GSP Update\MODEL\MCSim_v2_GIS_20231101\MCSim_v2_20231101.aprx; GW_ELEM_PUMP_AG

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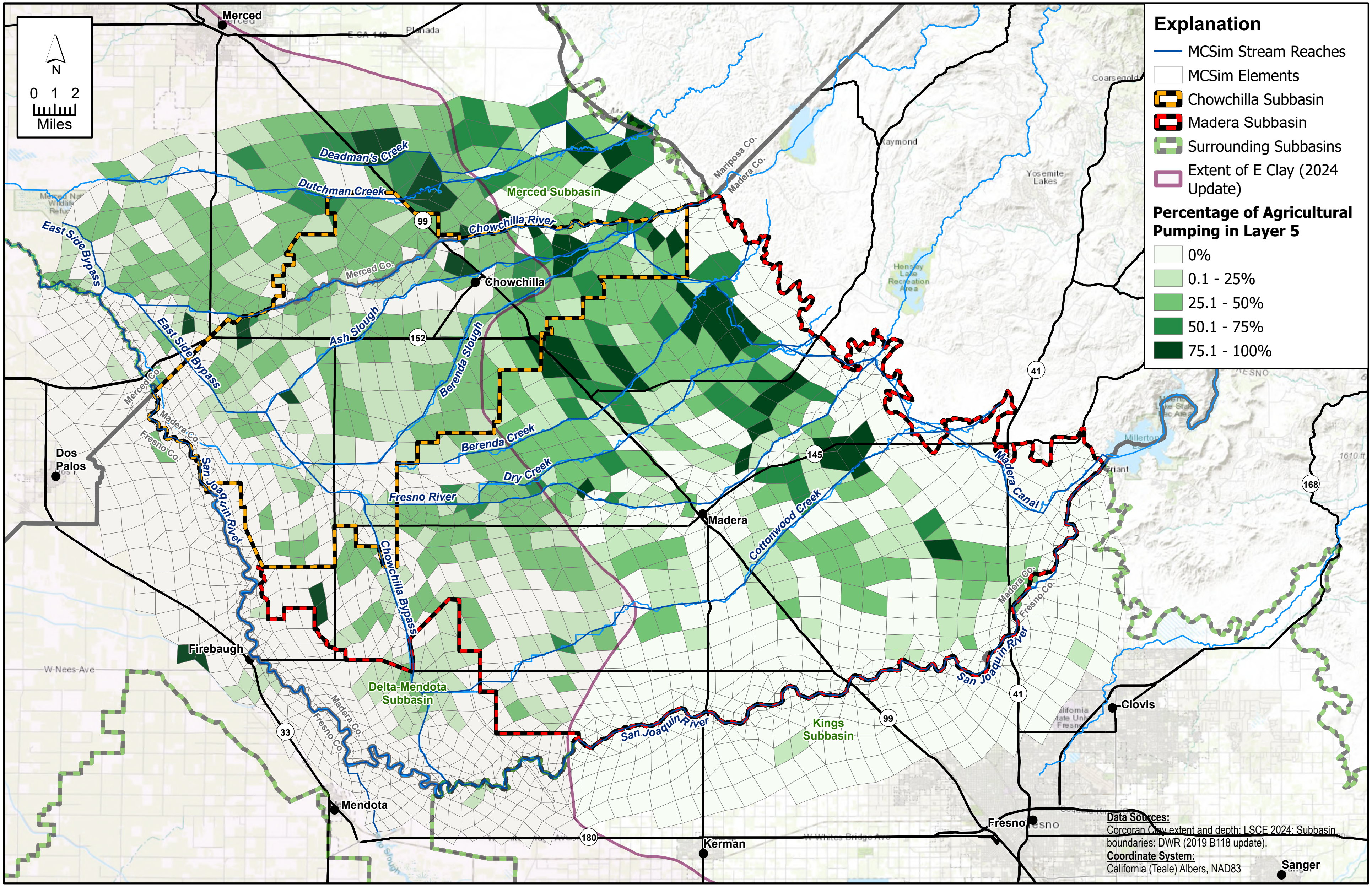
FIGURE 3-40

Vertical Distribution of Historical Agricultural Pumping - Layer 4

Madera-Chowchilla Groundwater-Surface Water Simulation Model (MCSim) - First Model Update



X:\2024\24-010 (1) Davids Eng. - Madera Subbasin 5-Year GSP Update\MODEL\MCSim_v2_GIS_20231101\MCSim_v2_20231101.aprx; GW_ELEM_PUMP_AG

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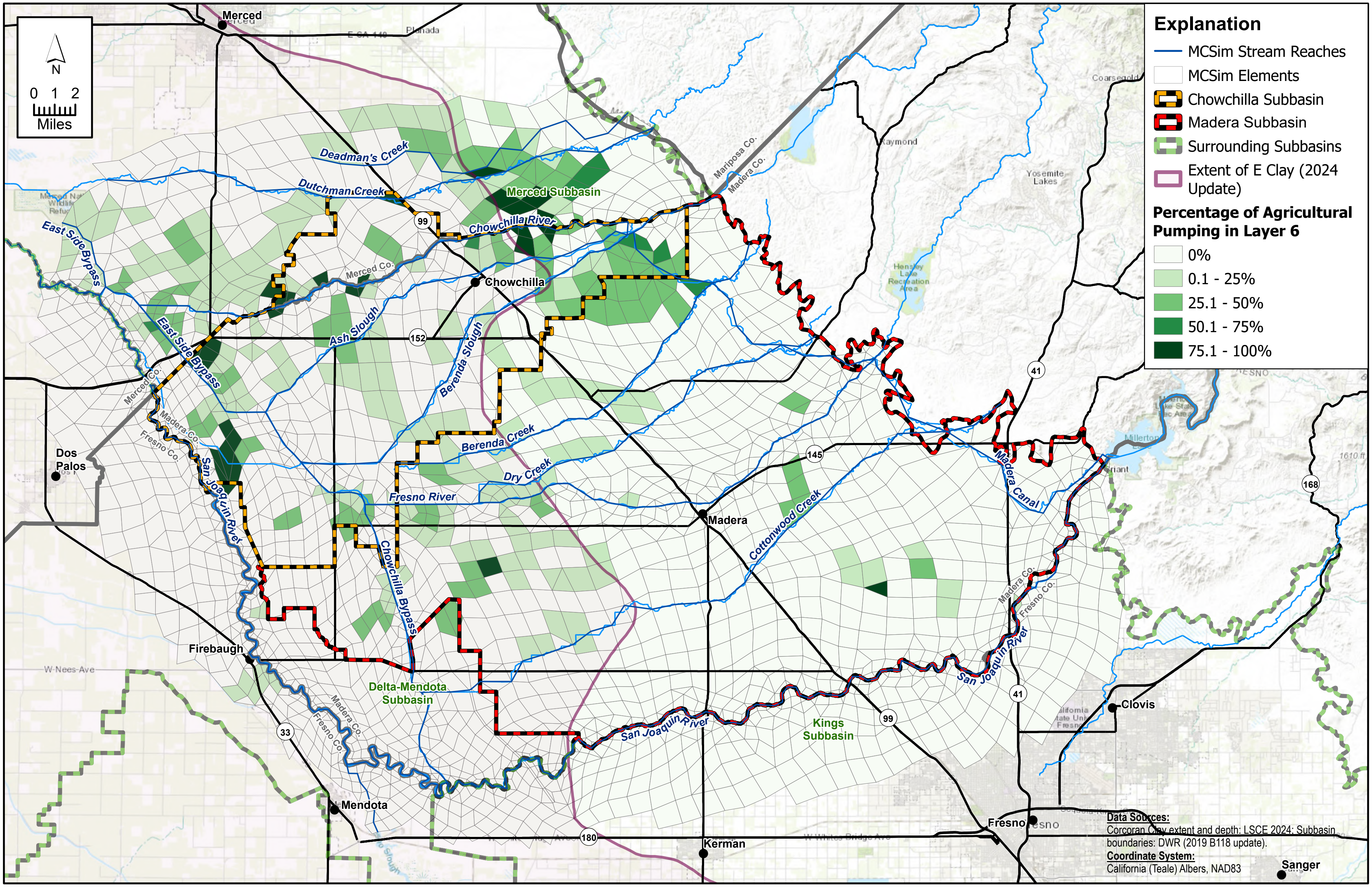
FIGURE 3-41

Vertical Distribution of Historical Agricultural Pumping - Layer 5

Madera-Chowchilla Groundwater-Surface Water Simulation Model (MCSim) - First Model Update



X:\2024\24-010 (1) Davids Eng. - Madera Subbasin 5-Year GSP Update\MODEL\MCSim_v2_GIS_20231101\MCSim_v2_20231101.aprx; GW_ELEM_PUMP_AG

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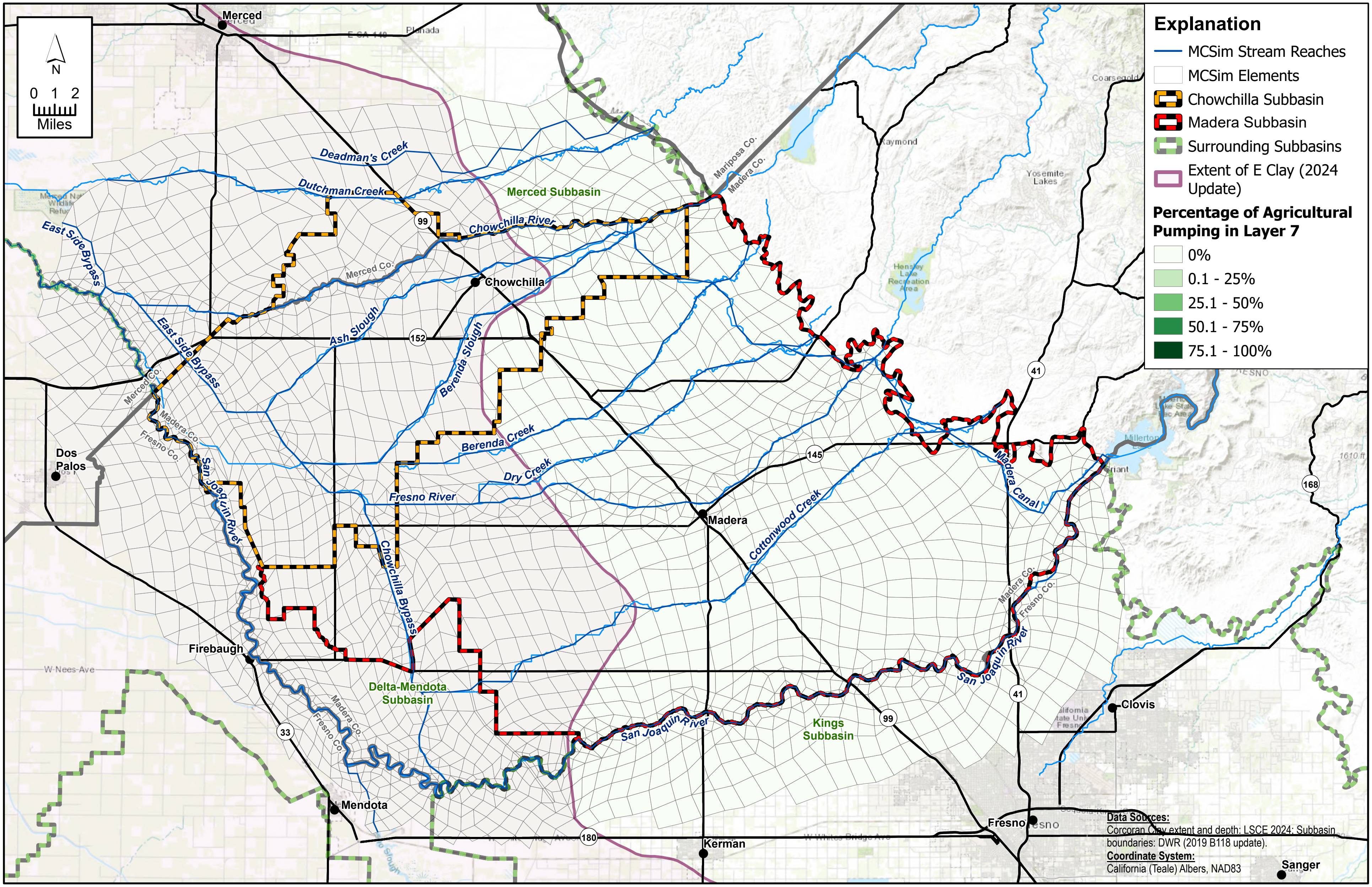
FIGURE 3-42

Vertical Distribution of Historical Agricultural Pumping - Layer 6

Madera-Chowchilla Groundwater-Surface Water Simulation Model (MCSim) - First Model Update



X:\2024\24-010 (1) Davids Eng. - Madera Subbasin 5-Year GSP Update\MODEL\MCSim_v2_GIS_20231101\MCSim_v2_20231101.aprx; GW_ELEM_PUMP_AG

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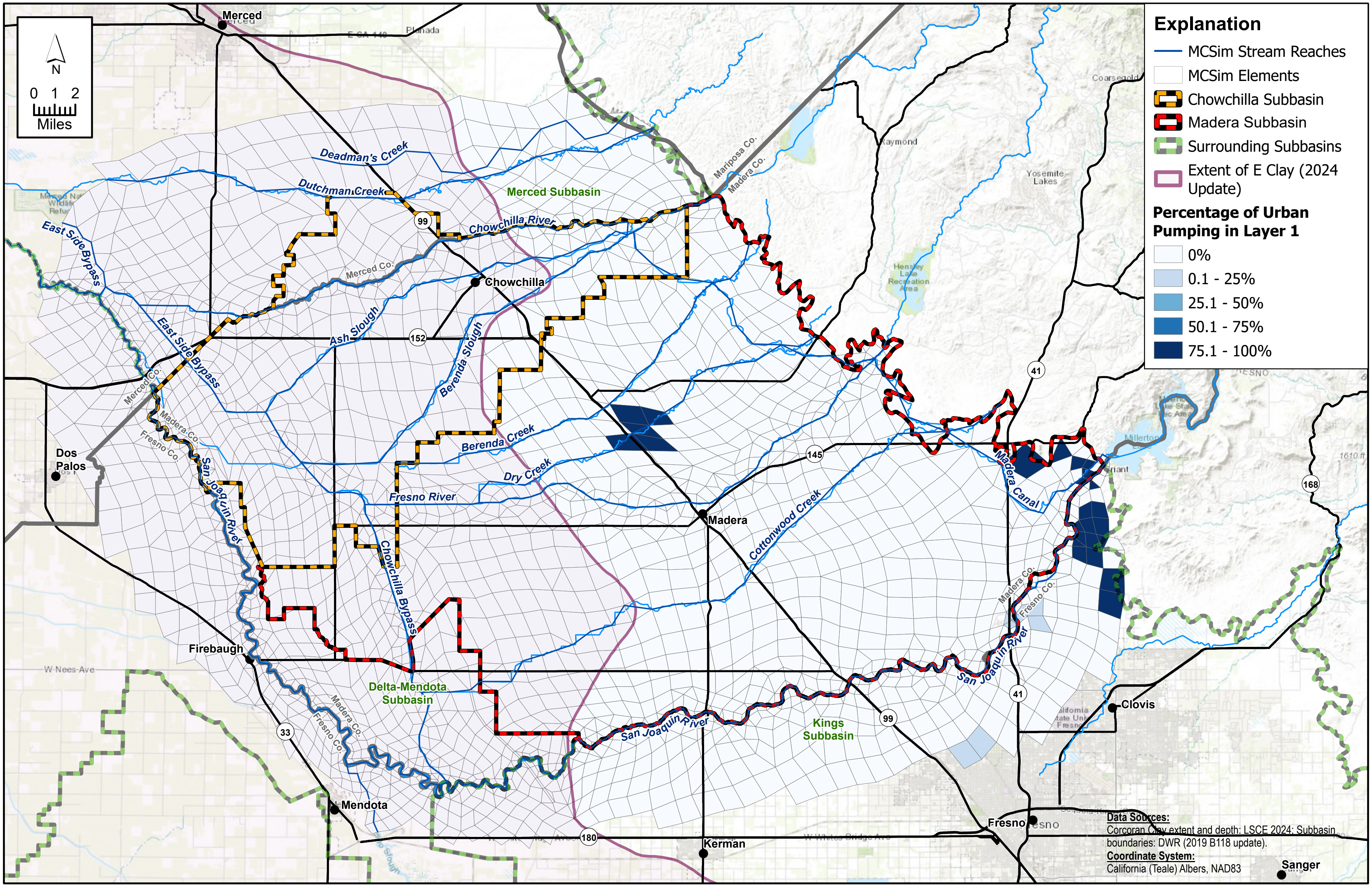
FIGURE 3-43

Vertical Distribution of Historical Agricultural Pumping - Layer 7

Madera-Chowchilla Groundwater-Surface Water Simulation Model (MCSim) - First Model Update



X:\2024\24-010 (1) Davids Eng. - Madera Subbasin 5-Year GSP Update\MODEL\MCSim_v2_GIS_20231101\MCSim_v2_20231101.aprx; GW_ELEM_PUMP_URBAN

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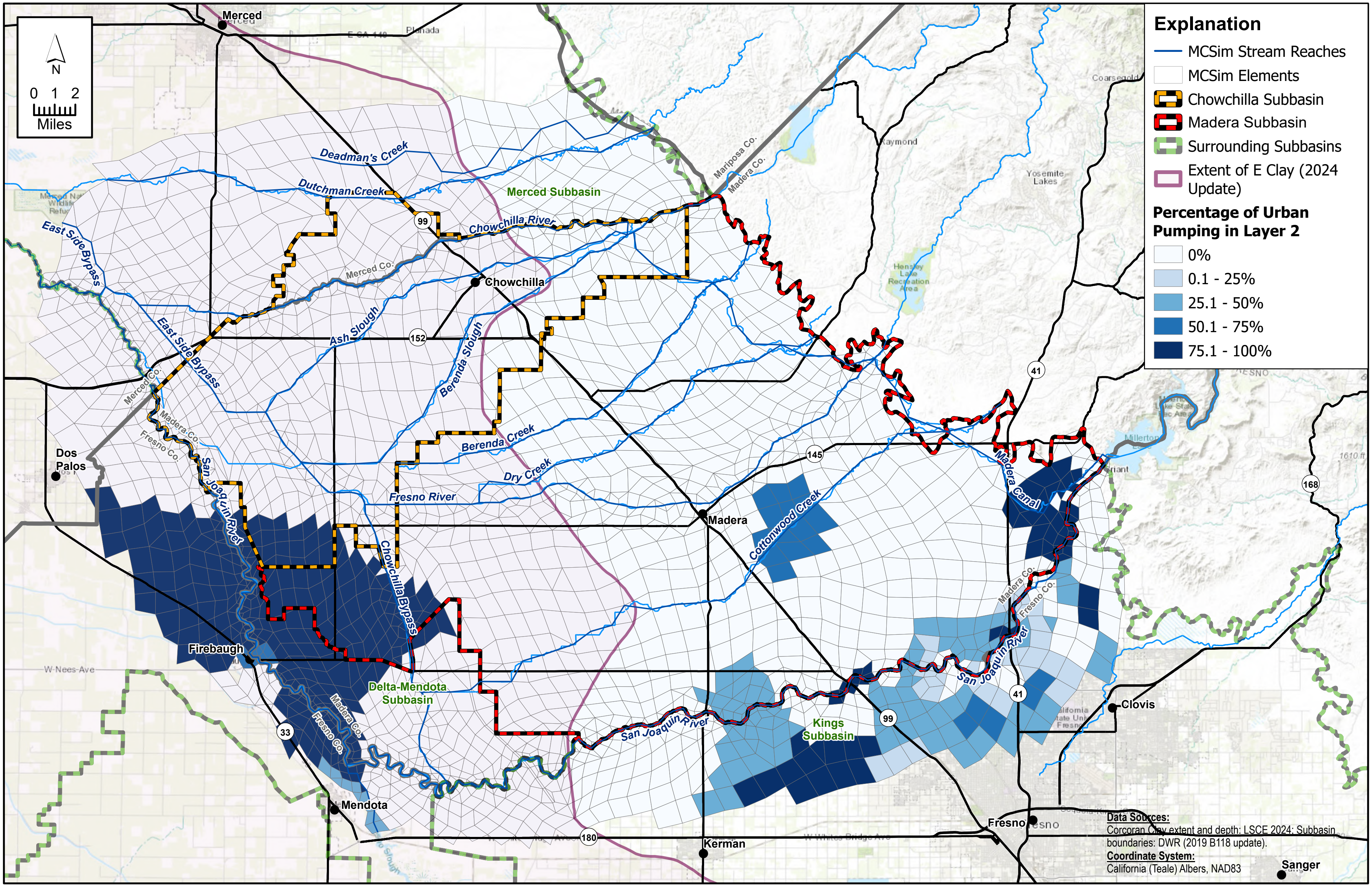
FIGURE 3-44

Vertical Distribution of Historical Urban Pumping - Layer 1

Madera-Chowchilla Groundwater-Surface Water Simulation Model (MCSim) - First Model Update



X:\2024\24-010 (1) Davids Eng. - Madera Subbasin 5-Year GSP Update\MODEL\MCSim_v2_GIS_20231101\MCSim_v2_20231101.aprx; GW_ELEM_PUMP_URBAN

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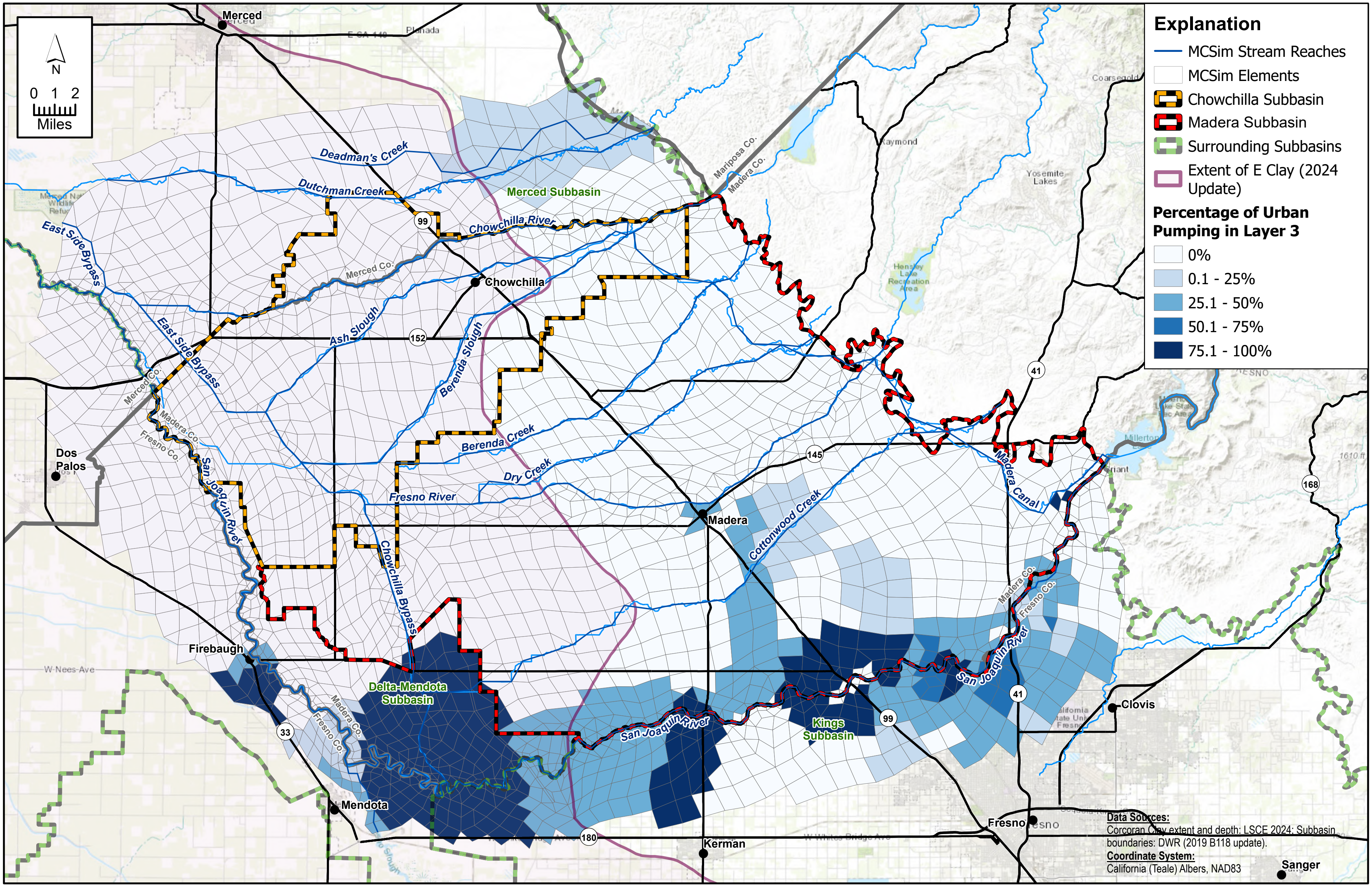
FIGURE 3-45

Vertical Distribution of Historical Urban Pumping - Layer 2

Madera-Chowchilla Groundwater-Surface Water Simulation Model (MCSim) - First Model Update



X:\2024\24-010 (1) Davids Eng. - Madera Subbasin 5-Year GSP Update\MODEL\MCSim_v2_GIS_20231101\MCSim_v2_20231101.aprx; GW_ELEM_PUMP_URBAN

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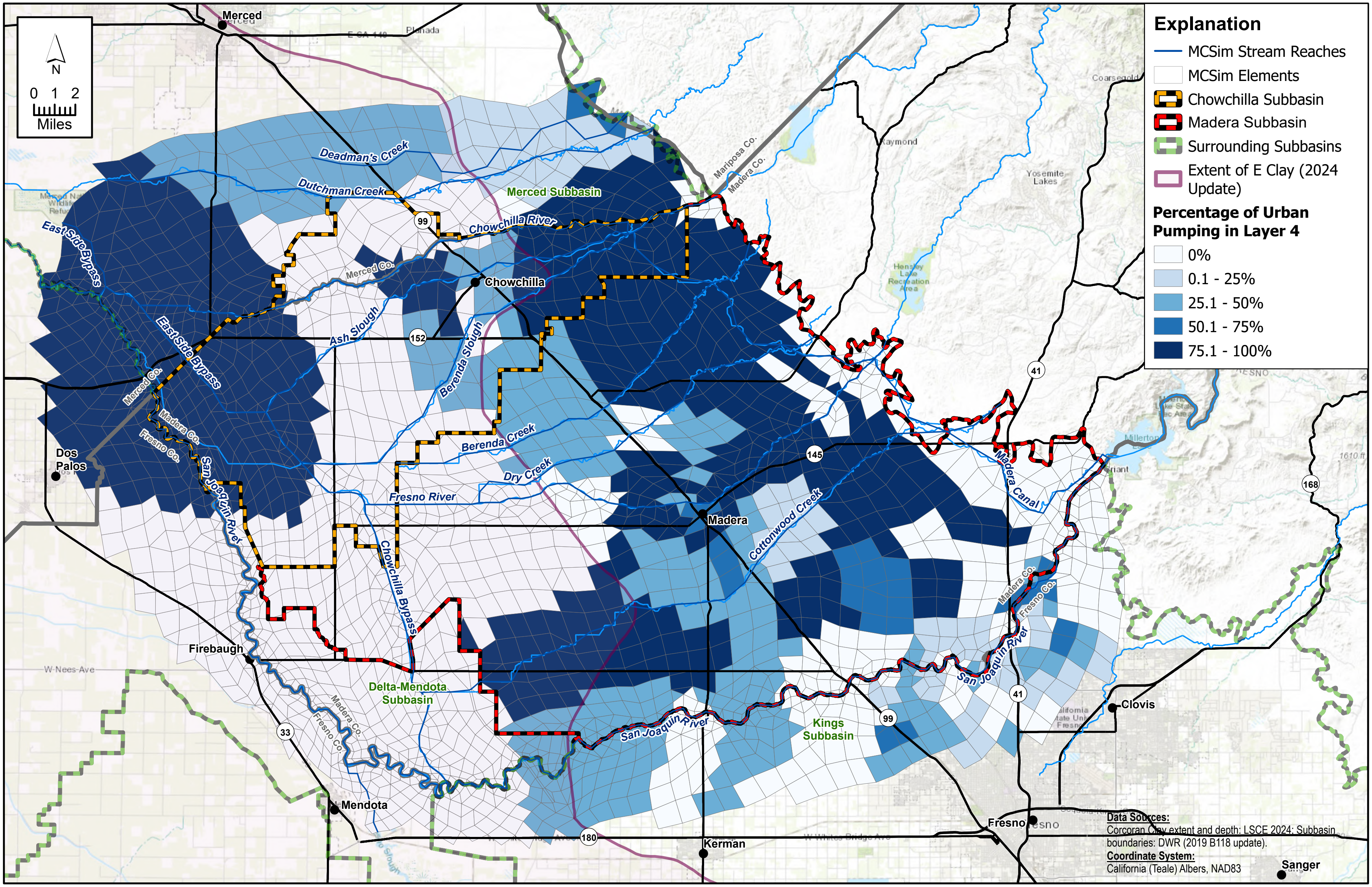
FIGURE 3-46

Vertical Distribution of Historical Urban Pumping - Layer 3

Madera-Chowchilla Groundwater-Surface Water Simulation Model (MCSim) - First Model Update



X:\2024\24-010 (1) Davids Eng. - Madera Subbasin 5-Year GSP Update\MODEL\MCSim_v2_GIS_20231101\MCSim_v2_20231101.aprx; GW_ELEM_PUMP_URBAN

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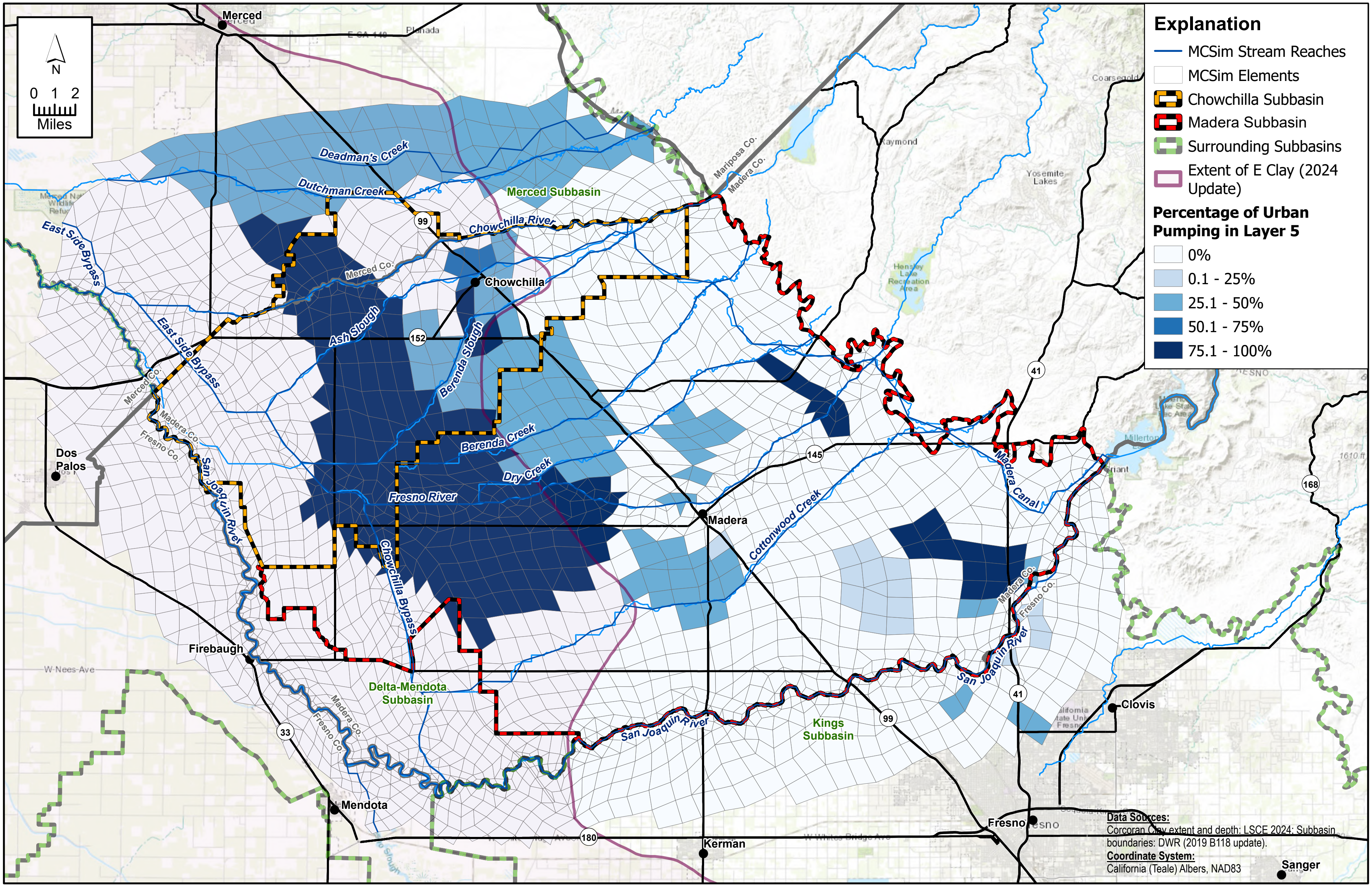
FIGURE 3-47

Vertical Distribution of Historical Urban Pumping - Layer 4

Madera-Chowchilla Groundwater-Surface Water Simulation Model (MCSim) - First Model Update



X:\2024\24-010 (1) Davids Eng. - Madera Subbasin 5-Year GSP Update\MODEL\MCSim_v2_GIS_20231101\MCSim_v2_20231101.aprx; GW_ELEM_PUMP_URBAN

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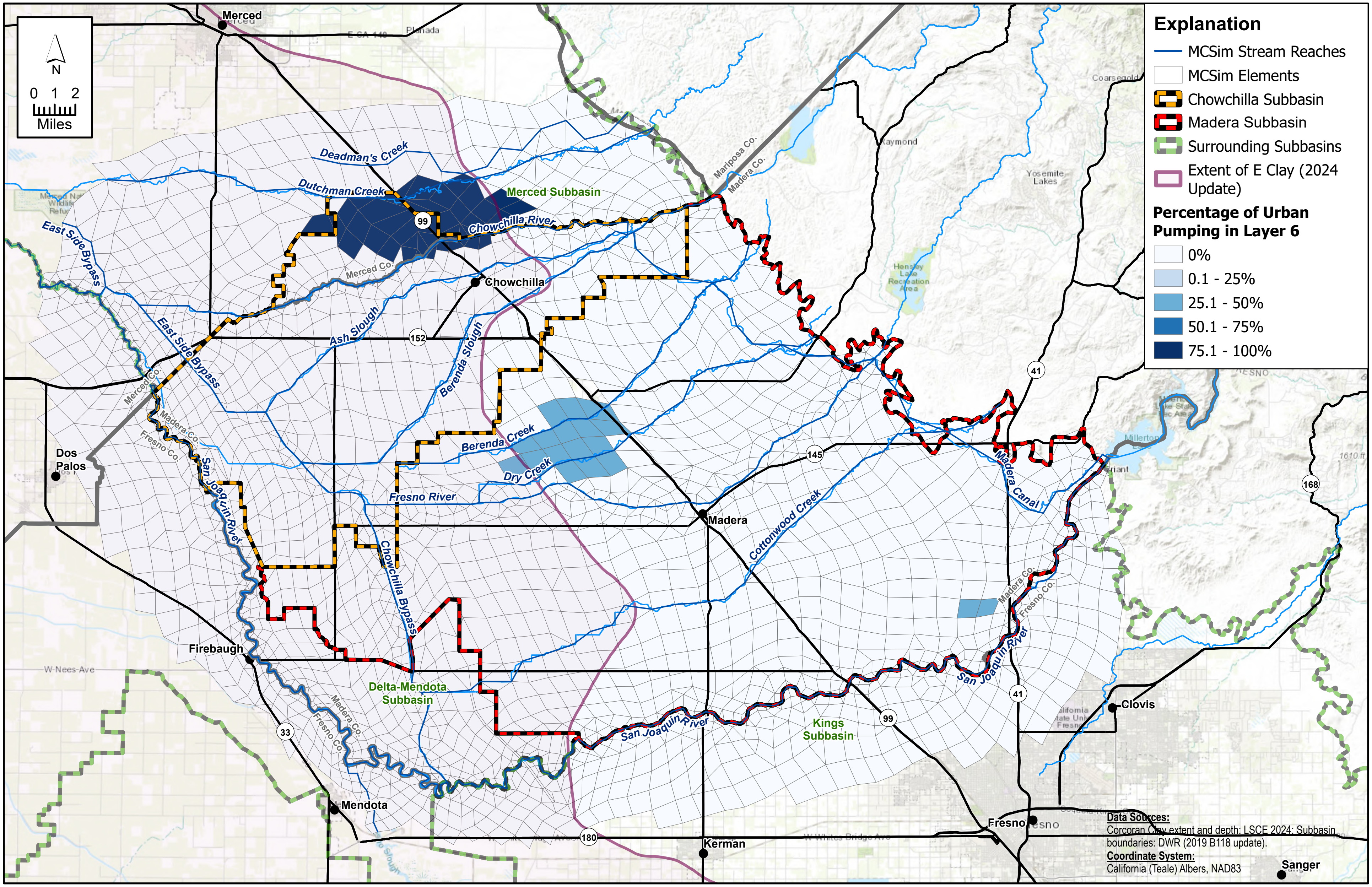
FIGURE 3-48

Vertical Distribution of Historical Urban Pumping - Layer 5

Madera-Chowchilla Groundwater-Surface Water Simulation Model (MCSim) - First Model Update



X:\2024\24-010 (1) Davids Eng. - Madera Subbasin 5-Year GSP Update\MODEL\MCSim_v2_GIS_20231101\MCSim_v2_20231101.aprx; GW_ELEM_PUMP_URBAN

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FIGURE 3-49

Vertical Distribution of Historical Urban Pumping - Layer 6

Madera-Chowchilla Groundwater-Surface Water Simulation Model (MCSim) - First Model Update

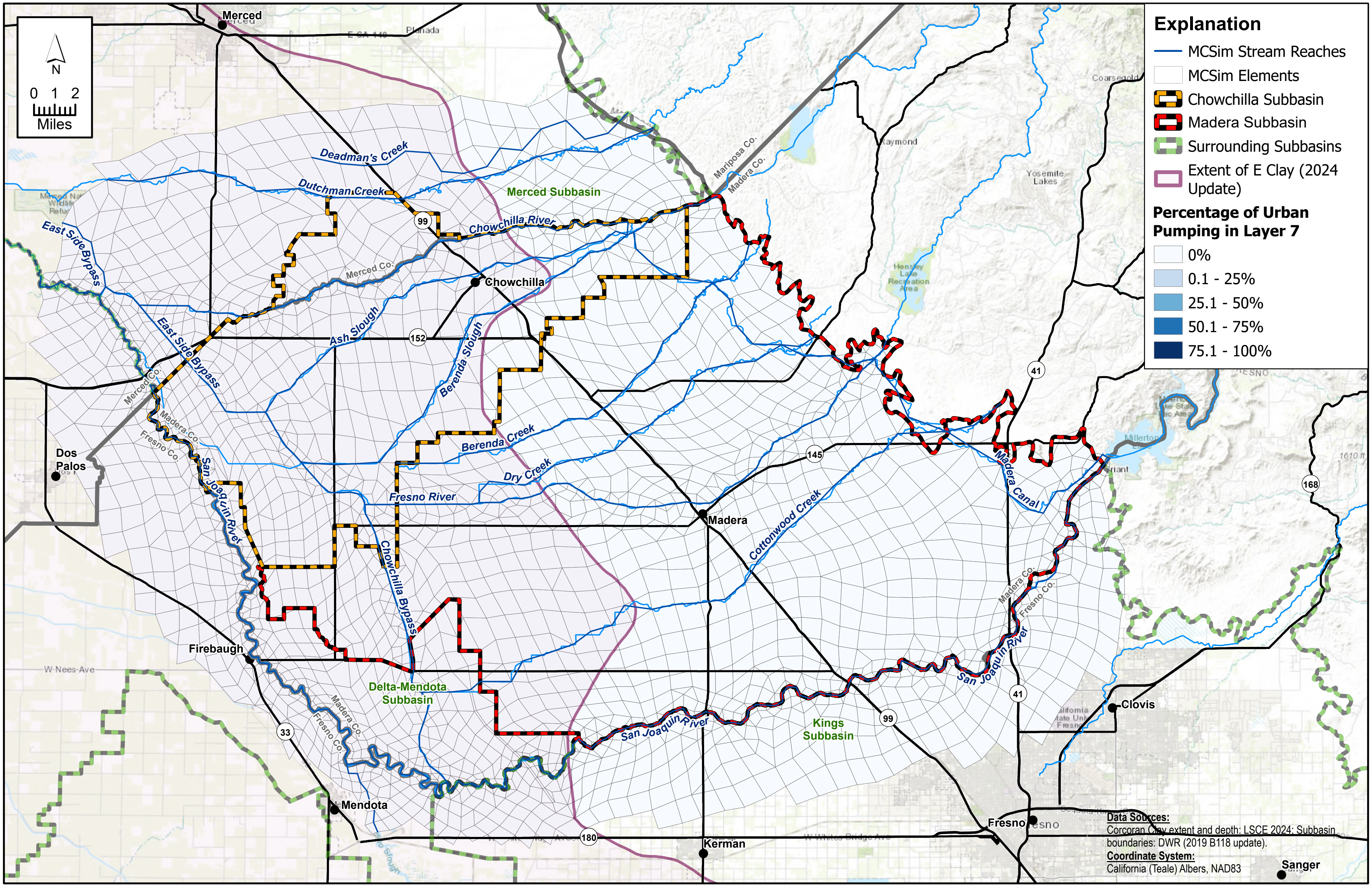

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FIGURE 3-50

Vertical Distribution of Historical Urban Pumping - Layer 7

Madera-Chowchilla Groundwater-Surface Water Simulation Model (MCSim) - First Model Update

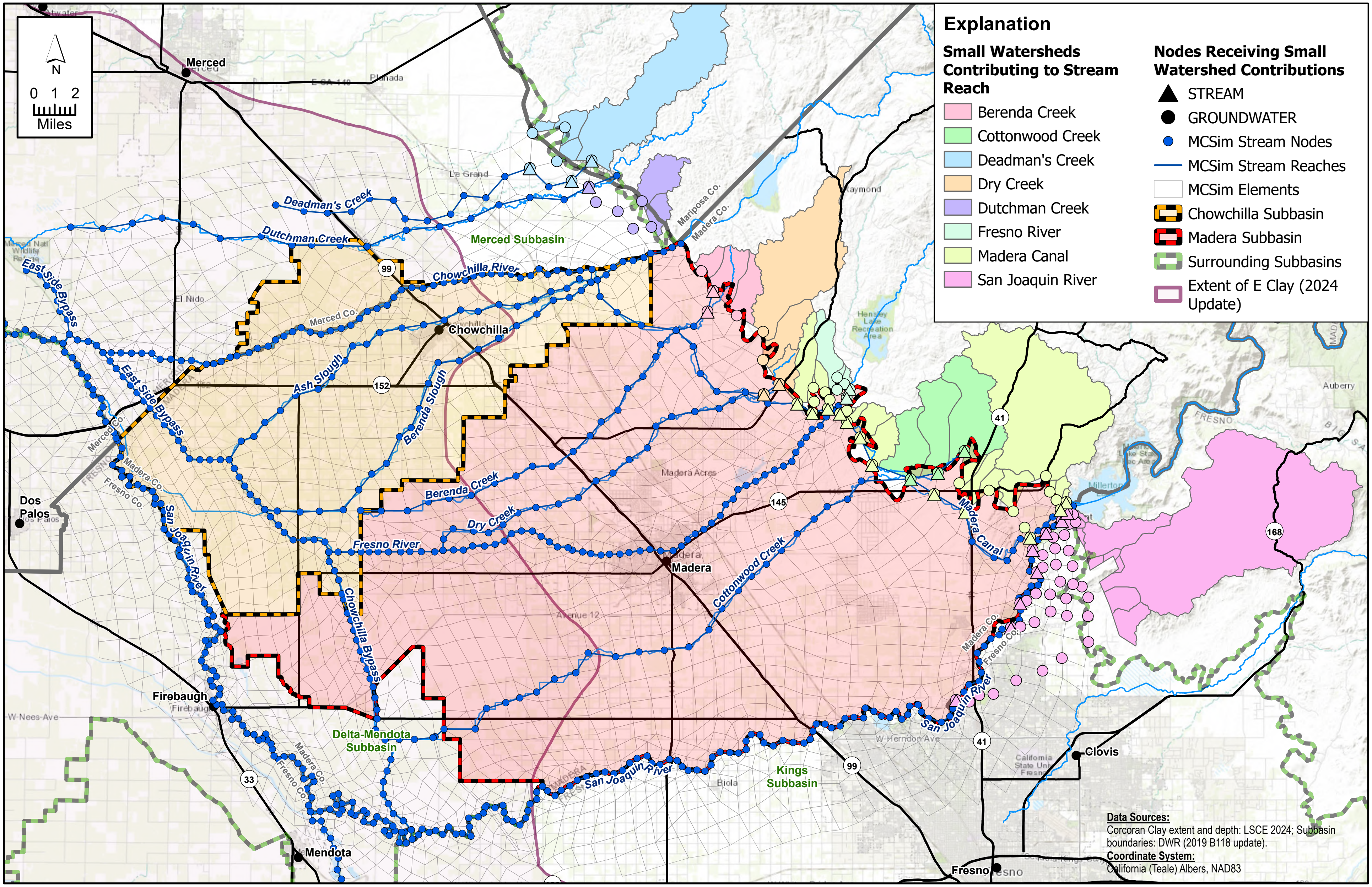

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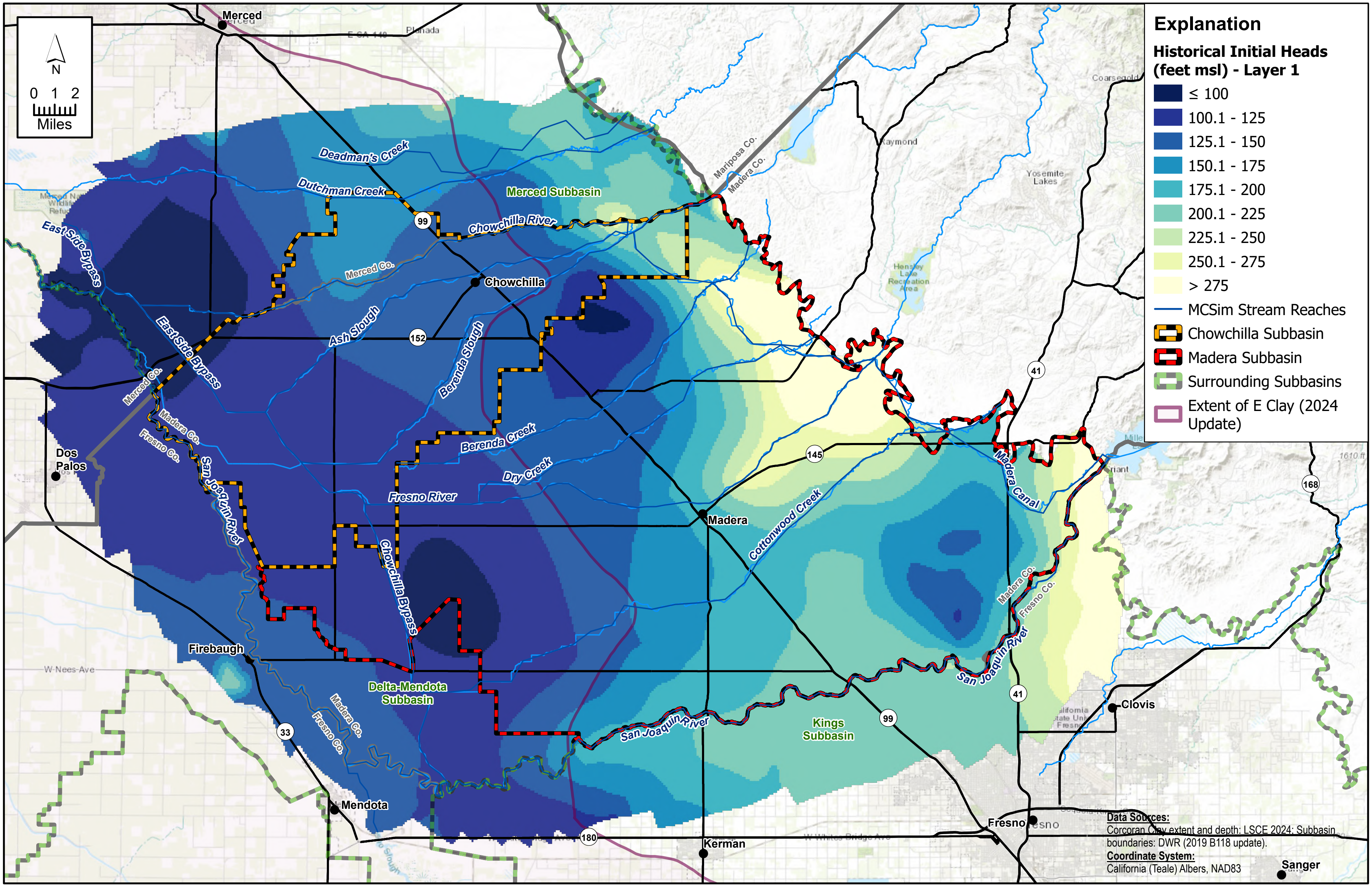
FIGURE 3-51

Nodes Receiving Small Watershed Contributions in MCSim_v2

Madera-Chowchilla Groundwater-Surface Water Simulation Model (MCSim) - First Model Update



X:\2024\24-010 (1) Davids Eng. - Madera Subbasin 5-Year GSP Update\MODEL\MCSim_v2_GIS_20231101\MCSim_v2_20231101.aprx; InCond_HIST_20241029_3

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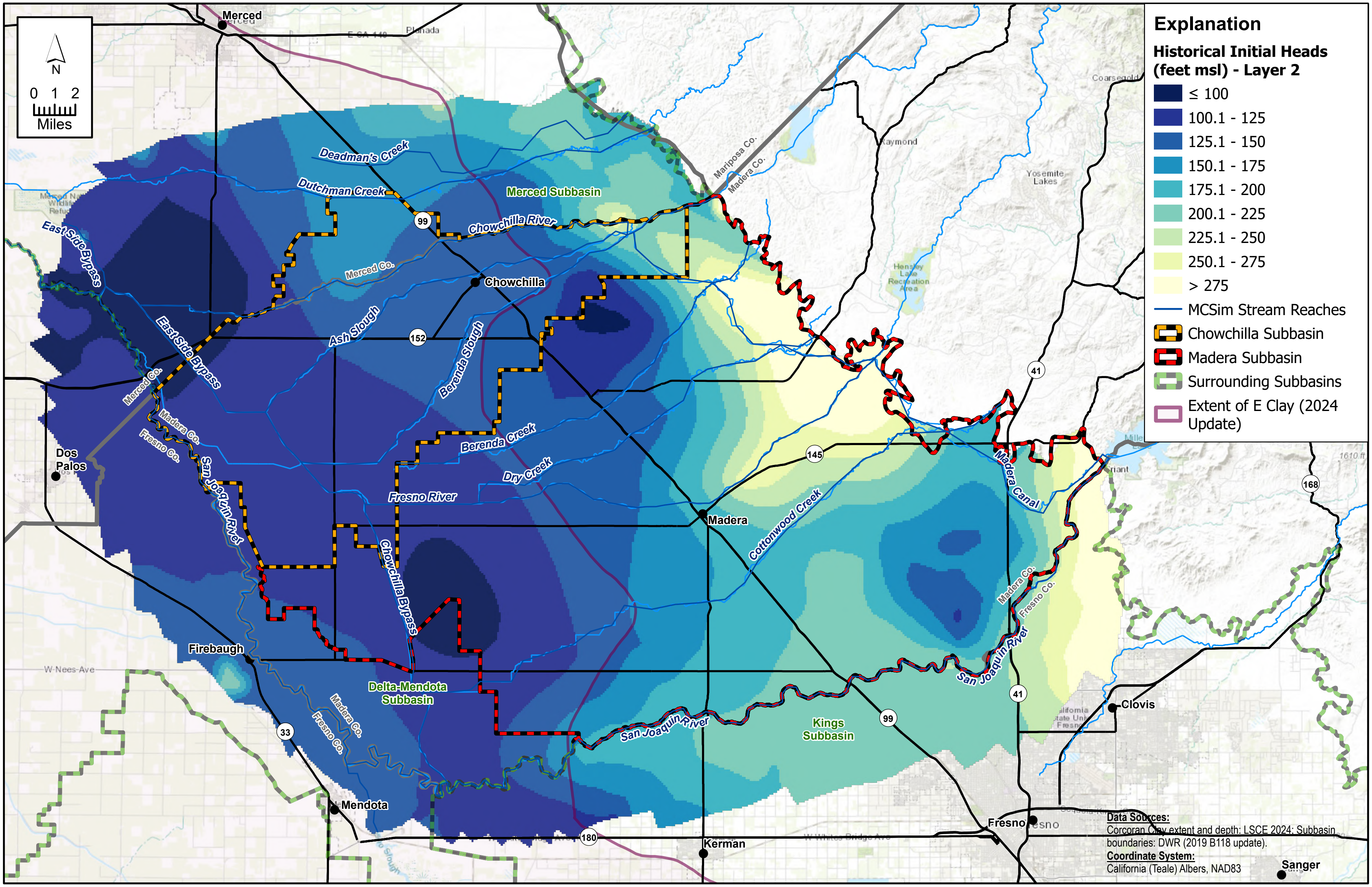
FIGURE 3-52

Historical Initial Groundwater Heads - Layer 1

Madera-Chowchilla Groundwater-Surface Water Simulation Model (MCSim) - First Model Update



X:\2024\24-010 (1) Davids Eng. - Madera Subbasin 5-Year GSP Update\MODEL\MCSim_v2_GIS_20231101\MCSim_v2_20231101.aprx; InCond_HIST_20241029_3

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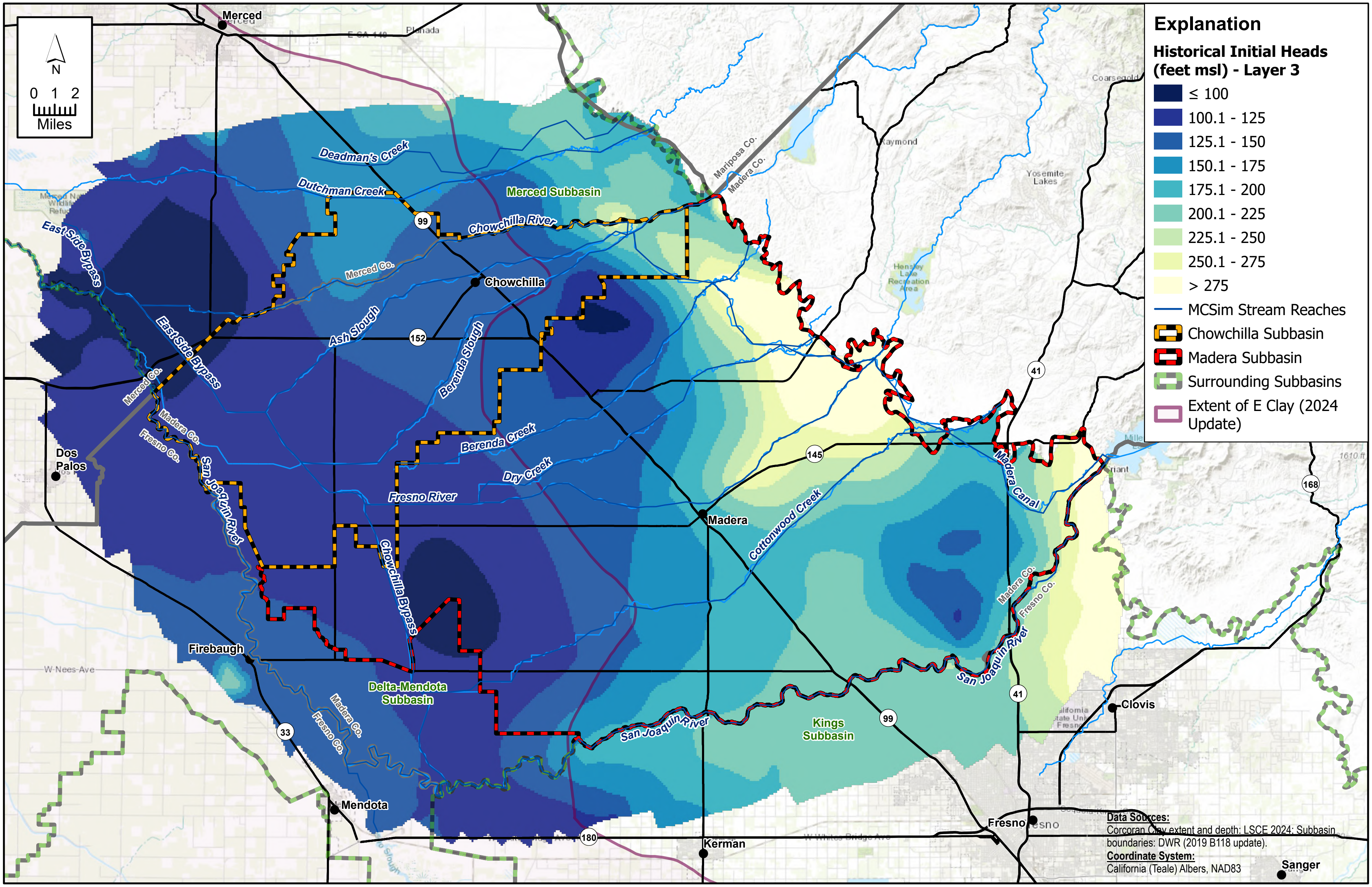
FIGURE 3-53

Historical Initial Groundwater Heads - Layer 2

Madera-Chowchilla Groundwater-Surface Water Simulation Model (MCSim) - First Model Update



X:\2024\24-010 (1) Davids Eng. - Madera Subbasin 5-Year GSP Update\MODEL\MCSim_v2_GIS_20231101\MCSim_v2_20231101.aprx; InCond_HIST_20241029_3

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FIGURE 3-54

Historical Initial Groundwater Heads - Layer 3

Madera-Chowchilla Groundwater-Surface Water Simulation Model (MCSim) - First Model Update

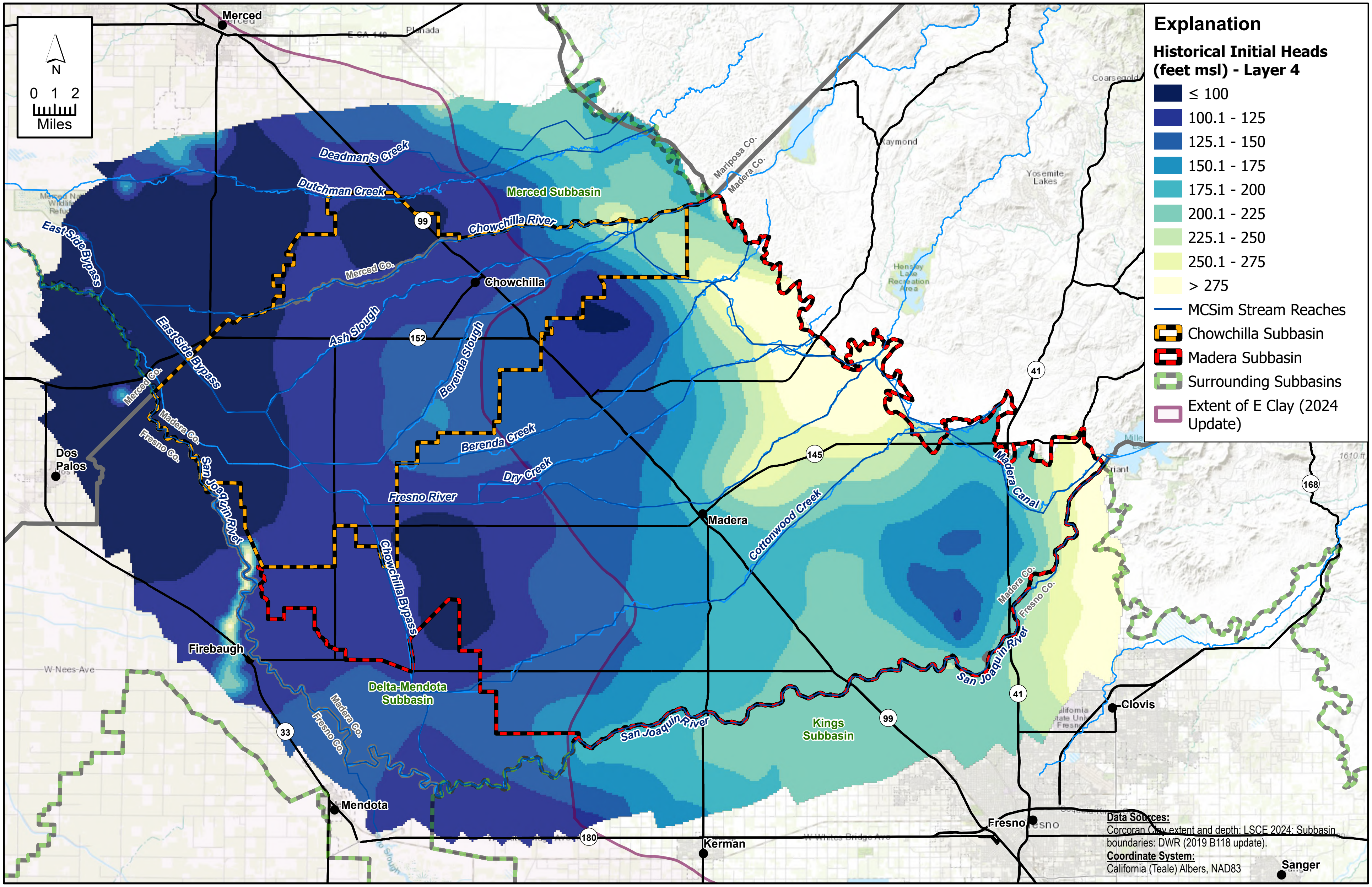

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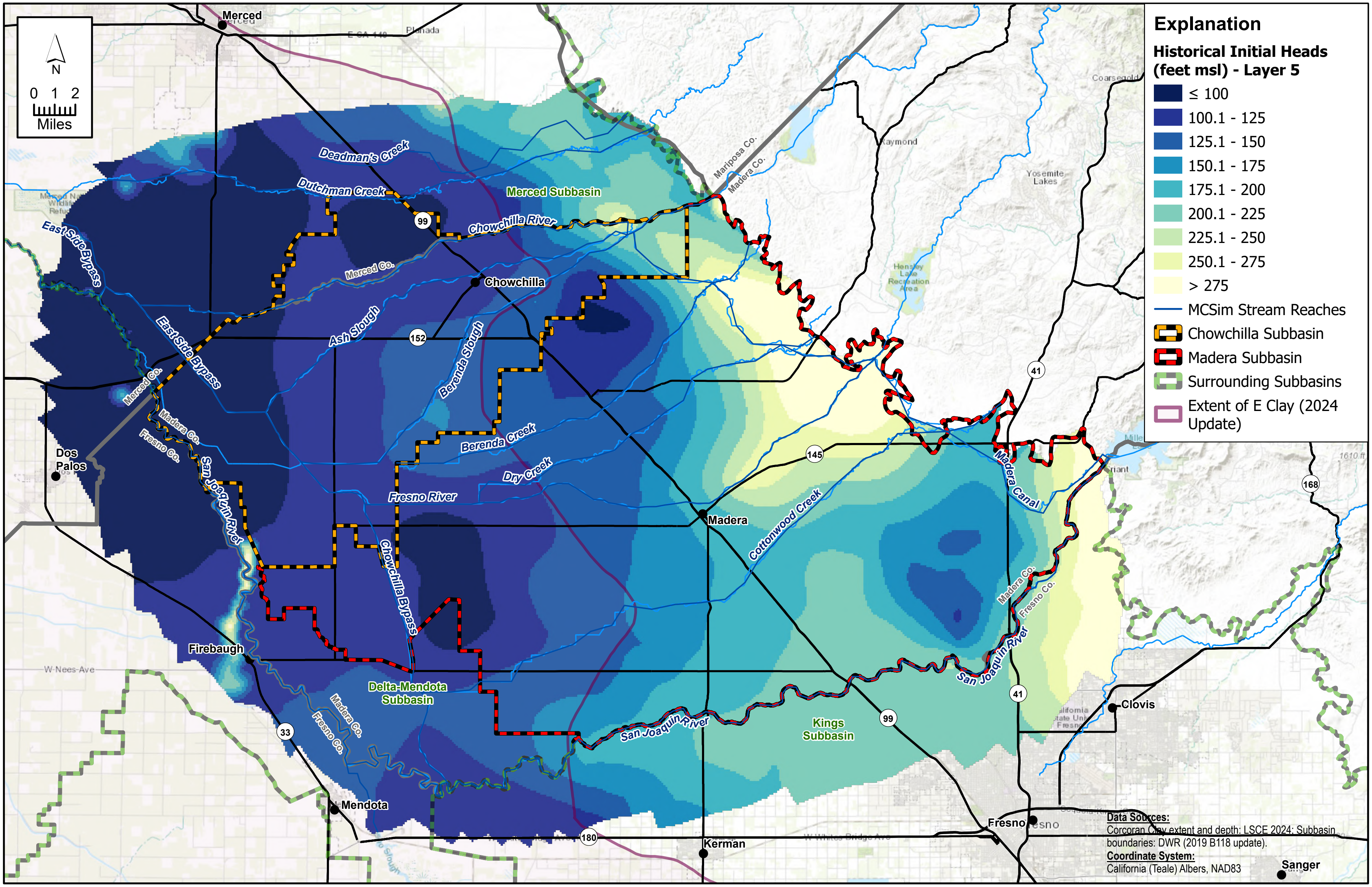
FIGURE 3-55

Historical Initial Groundwater Heads - Layer 4

Madera-Chowchilla Groundwater-Surface Water Simulation Model (MCSim) - First Model Update



X:\2024\24-010 (1) Davids Eng. - Madera Subbasin 5-Year GSP Update\MODEL\MCSim_v2_GIS_20231101\MCSim_v2_20231101.aprx; InCond_HIST_20241029_3

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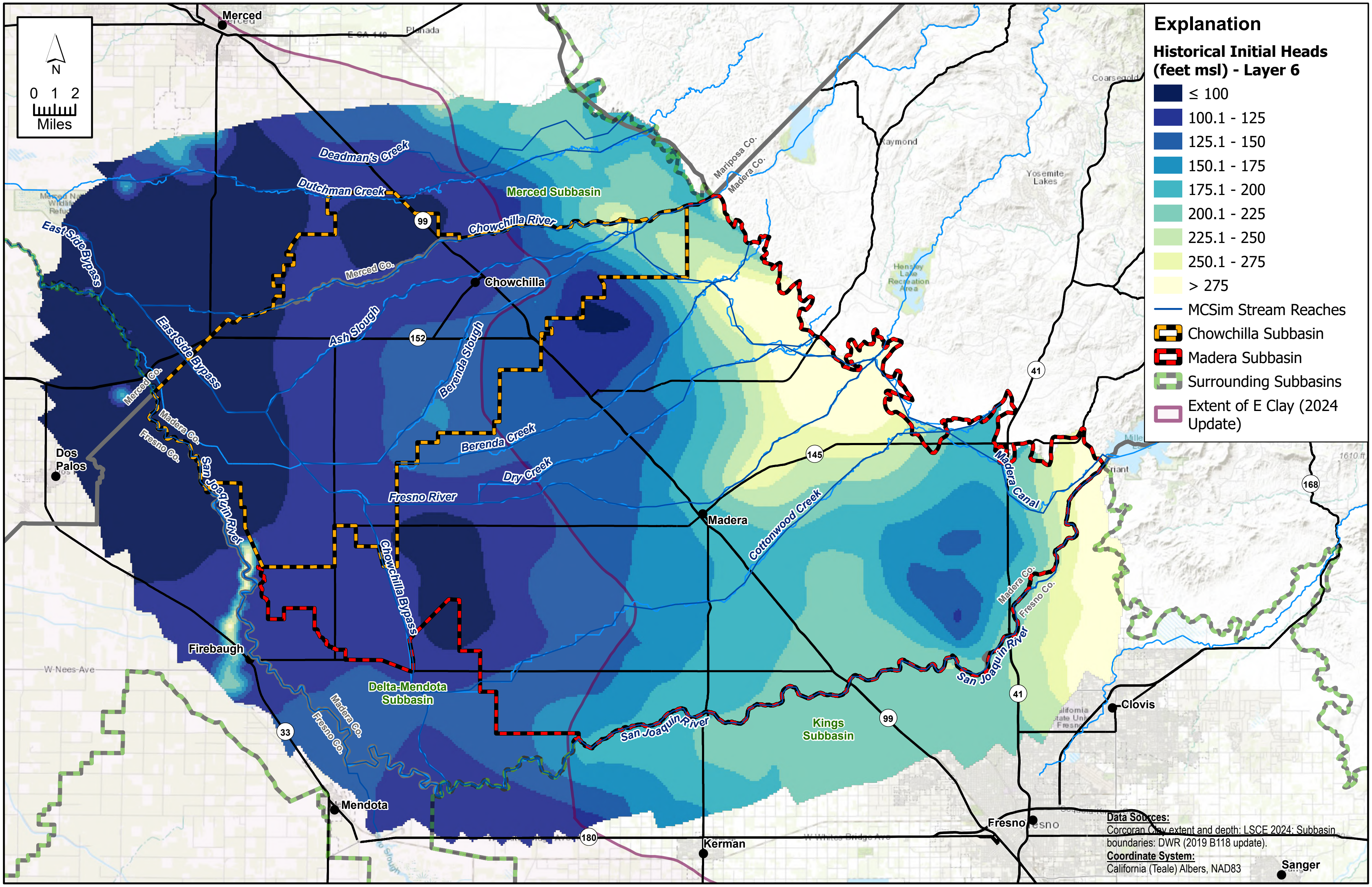
FIGURE 3-56

Historical Initial Groundwater Heads - Layer 5

Madera-Chowchilla Groundwater-Surface Water Simulation Model (MCSim) - First Model Update



X:\2024\24-010 (1) Davids Eng. - Madera Subbasin 5-Year GSP Update\MODEL\MCSim_v2_GIS_20231101\MCSim_v2_20231101.aprx; InCond_HIST_20241029_3

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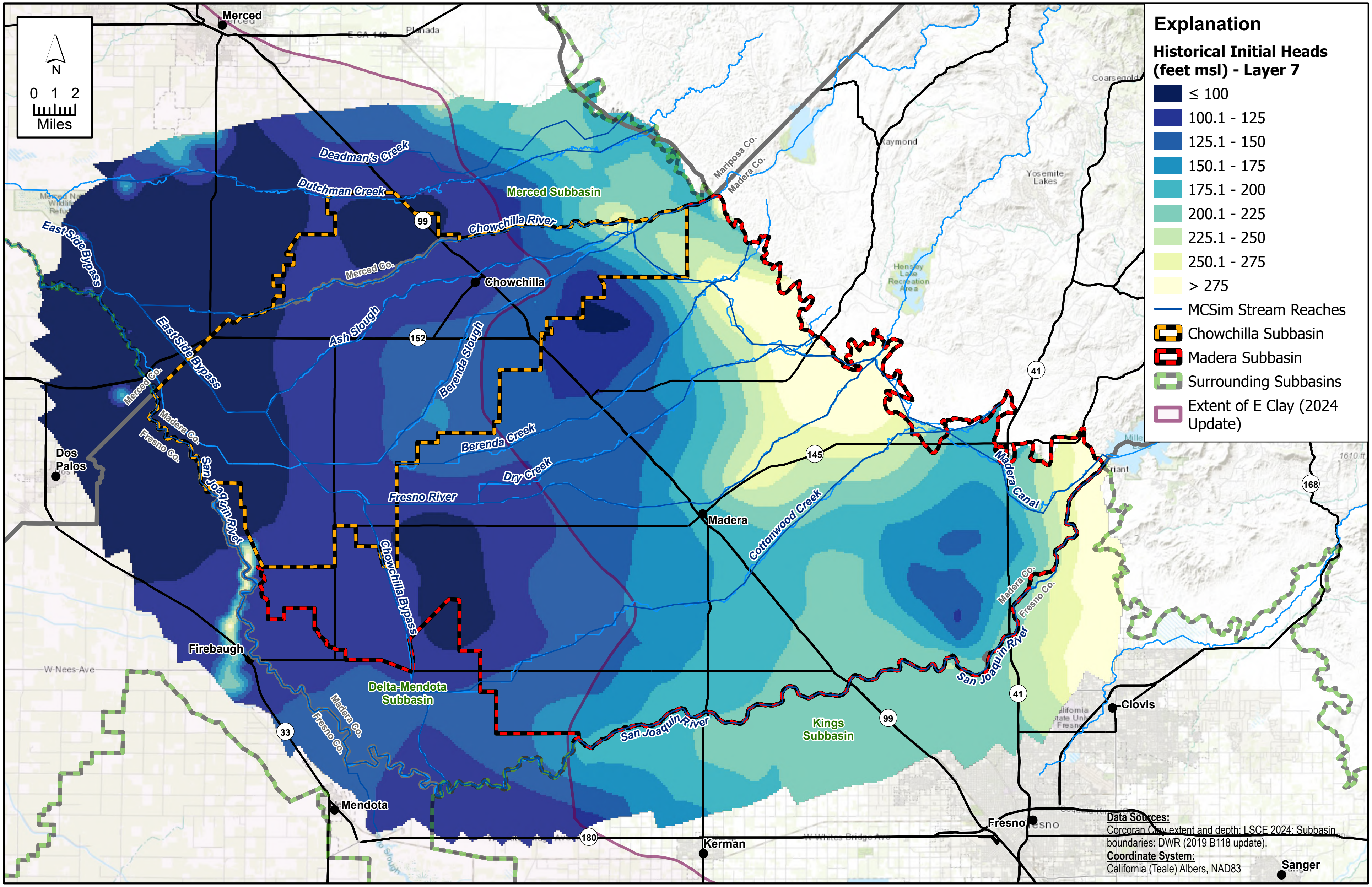
FIGURE 3-57

Historical Initial Groundwater Heads - Layer 6

Madera-Chowchilla Groundwater-Surface Water Simulation Model (MCSim) - First Model Update



X:\2024\24-010 (1) Davids Eng. - Madera Subbasin 5-Year GSP Update\MODEL\MCSim_v2_GIS_20231101\MCSim_v2_20231101.aprx; InCond_HIST_20241029_3

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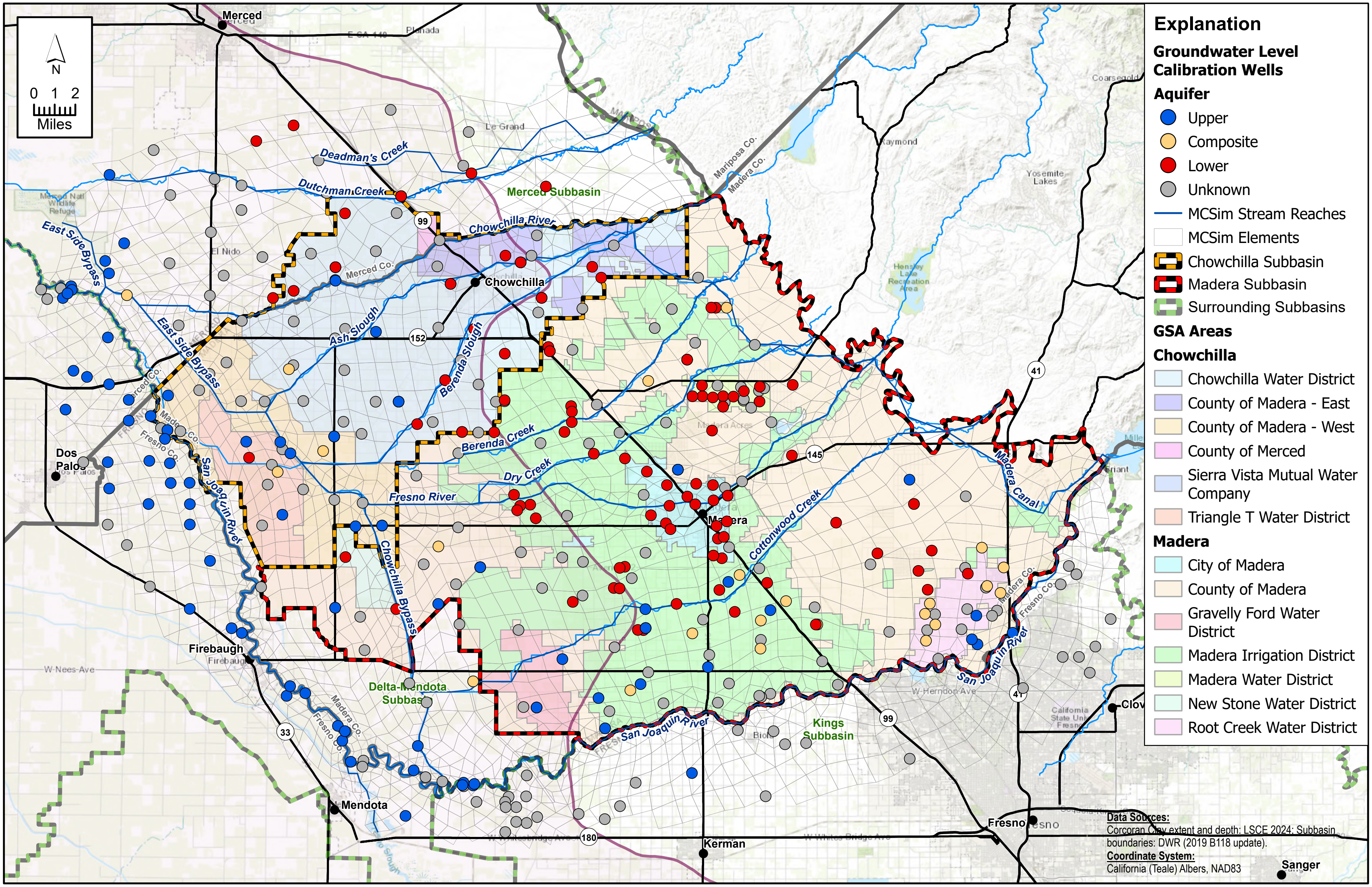
FIGURE 3-58

Historical Initial Groundwater Heads - Layer 7

Madera-Chowchilla Groundwater-Surface Water Simulation Model (MCSim) - First Model Update



X:\2024\24-010 (1) Davids Eng. - Madera Subbasin 5-Year GSP Update\MODEL\MCSim_v2_GIS_20231101\MCSim_v2_20231101.aprx; Calibration Points

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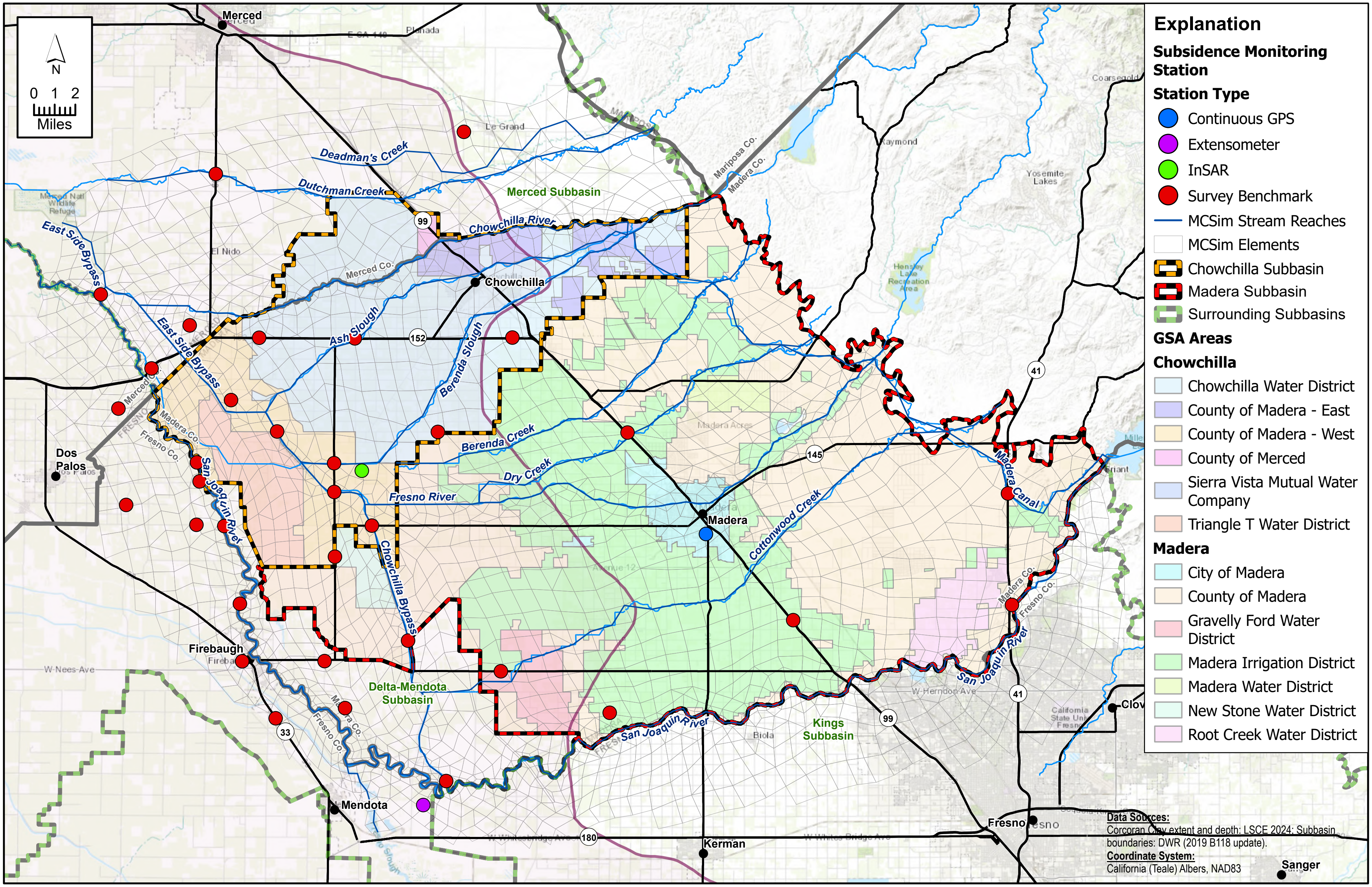
FIGURE 3-59

Map of Groundwater Level Calibration Wells

Madera-Chowchilla Groundwater-Surface Water Simulation Model (MCSim) - First Model Update



X:\2024\24-010 (1) Davids Eng. - Madera Subbasin 5-Year GSP Update\MODEL\MCSim_v2_GIS_20231101\MCSim_v2_20231101.aprx; Calibration Points

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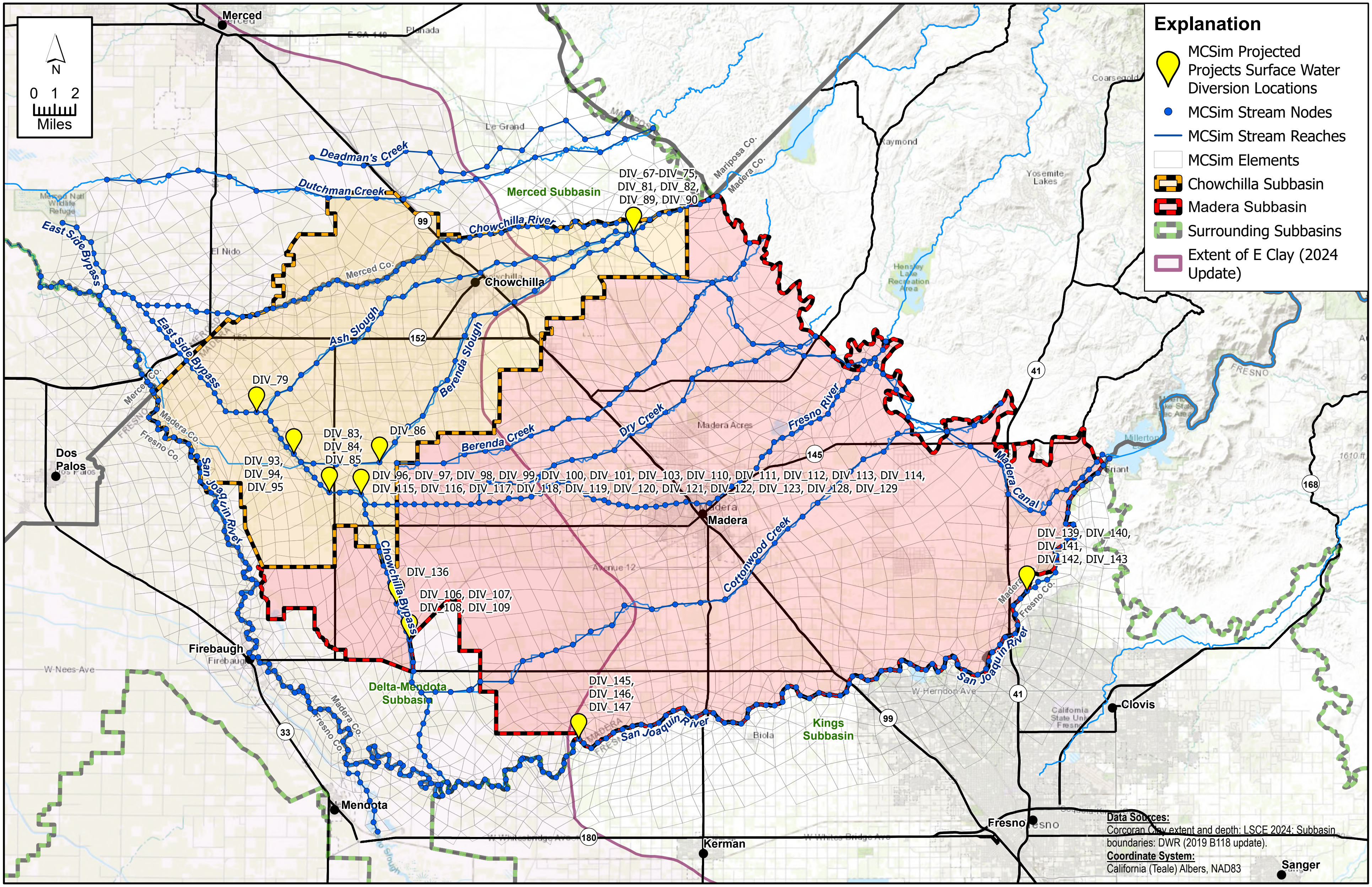
FIGURE 3-60

Map of Subsidence Calibration Stations

Madera-Chowchilla Groundwater-Surface Water Simulation Model (MCSim) - First Model Update

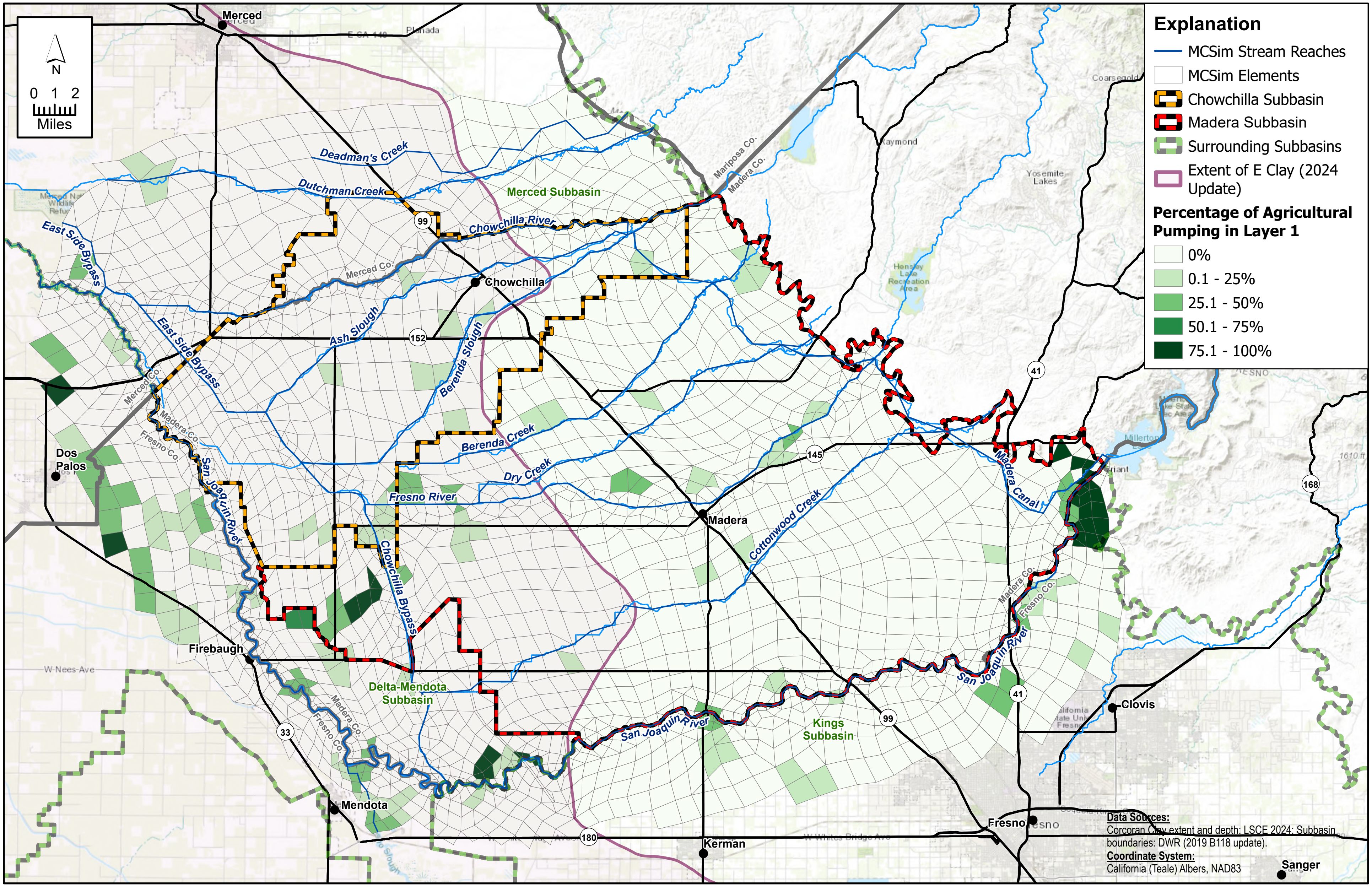


X:\2024\24-010 (1) Davids Eng. - Madera Subbasin 5-Year GSP Update\MODEL\MCSim_v2_GIS_20231101\MCSim_v2_20231101.aprx; Fig3-61_Projected Surface Water Diversions

FIGURE 3-61

MCSim Projected Projects Surface Water Diversions Locations

Madera-Chowchilla Groundwater-Surface Water Simulation Model (MCSim) - First Model Update



X:\2024\24-010 (1) Davids Eng. - Madera Subbasin 5-Year GSP Update\MODEL\MCSim_v2_GIS_20231101\MCSim_v2_20231101.aprx; GW_PROJ_ELEM_PUMP_AG

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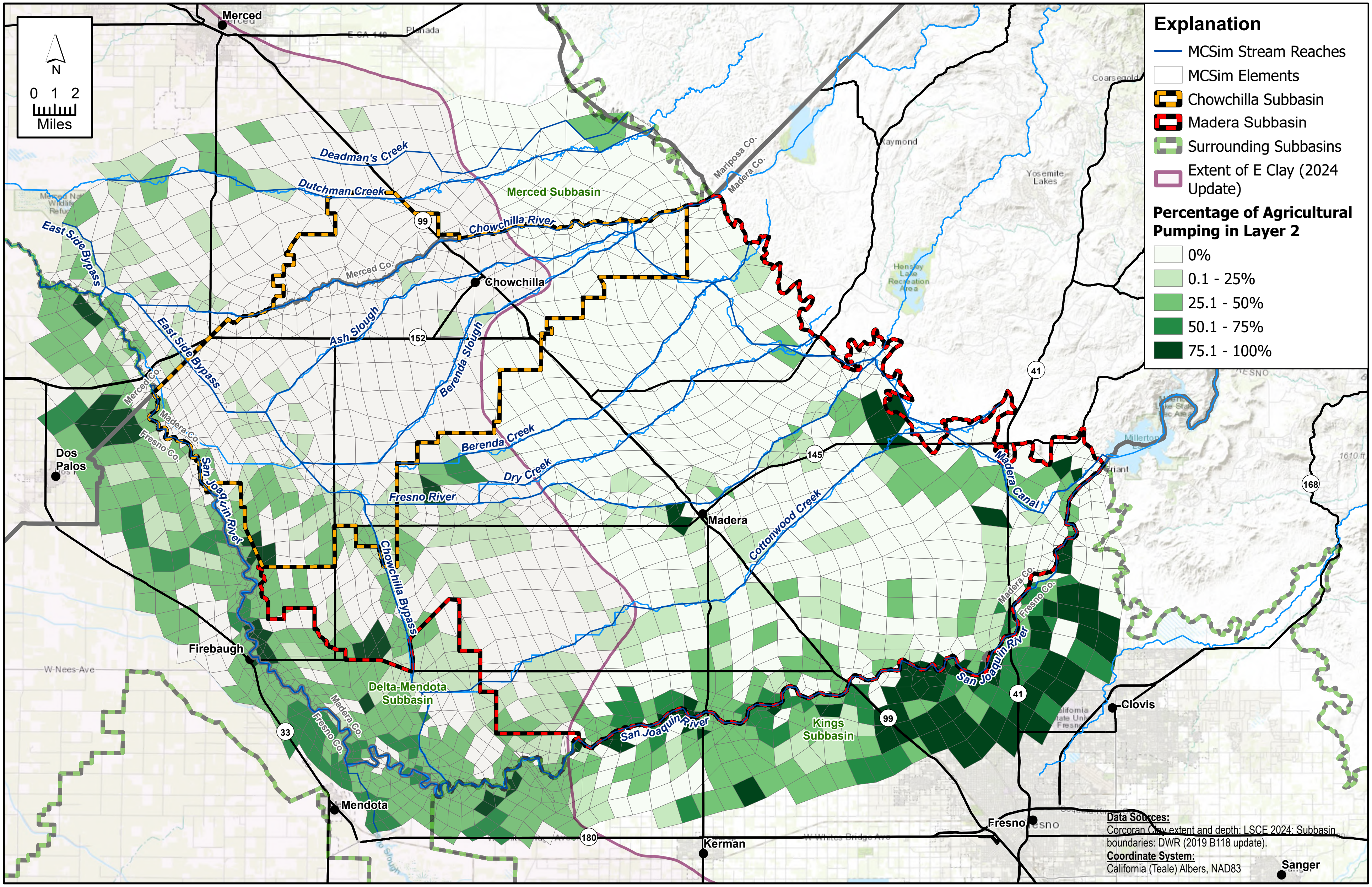
FIGURE 3-62

Vertical Distribution of Projected Agricultural Pumping - Layer 1

Madera-Chowchilla Groundwater-Surface Water Simulation Model (MCSim) - First Model Update



X:\2024\24-010 (1) Davids Eng. - Madera Subbasin 5-Year GSP Update\MODEL\MCSim_v2_GIS_20231101\MCSim_v2_20231101.aprx; GW_PROJ_ELEM_PUMP_AG

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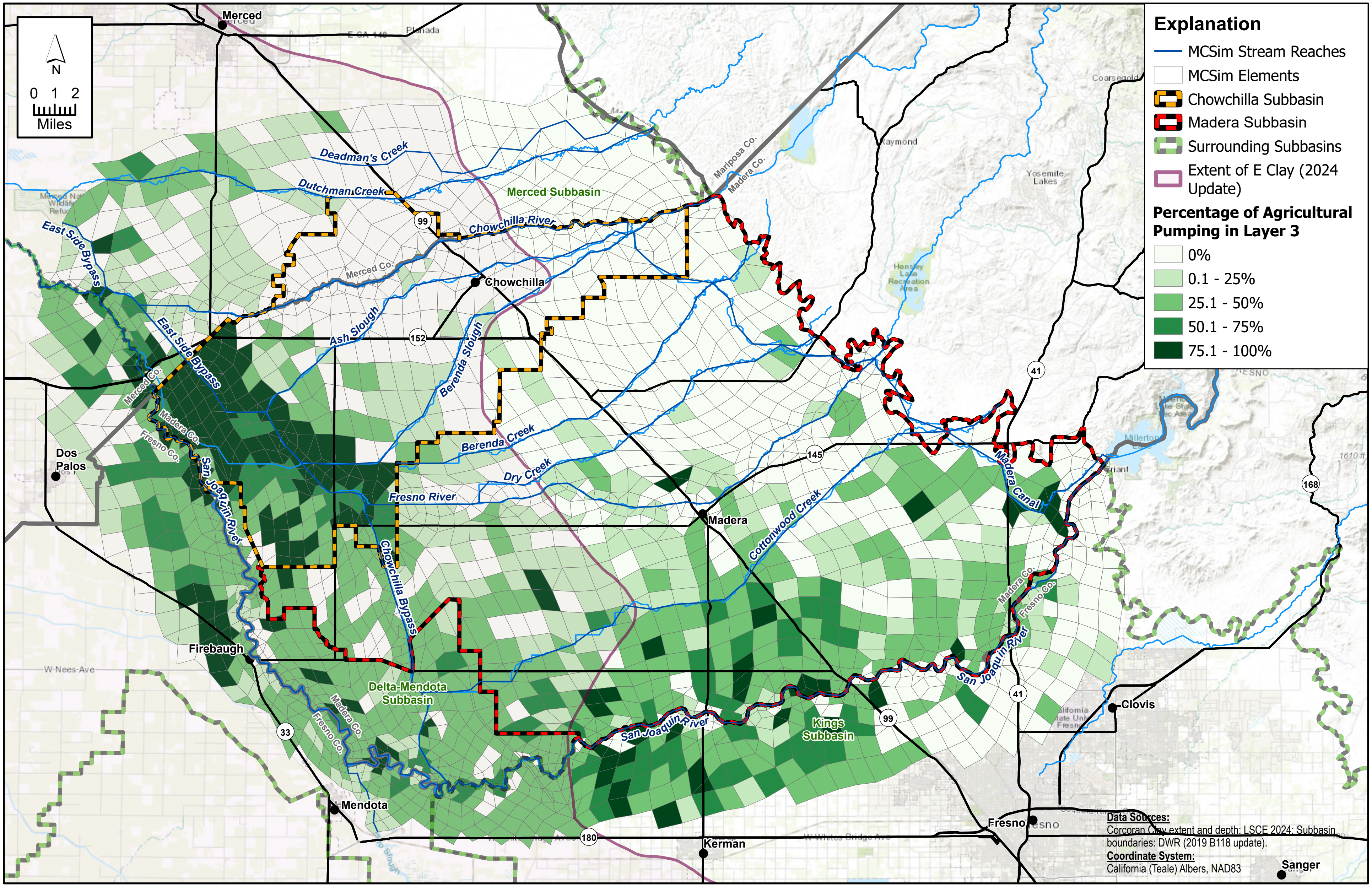
FIGURE 3-63

Vertical Distribution of Projected Agricultural Pumping - Layer 2

Madera-Chowchilla Groundwater-Surface Water Simulation Model (MCSim) - First Model Update



X:\2024\24-010 (1) Davids Eng. - Madera Subbasin 5-Year GSP Update\MODEL\MCSim_v2_GIS_20231101\MCSim_v2_20231101.aprx; GW_PROJ_ELEM_PUMP_AG

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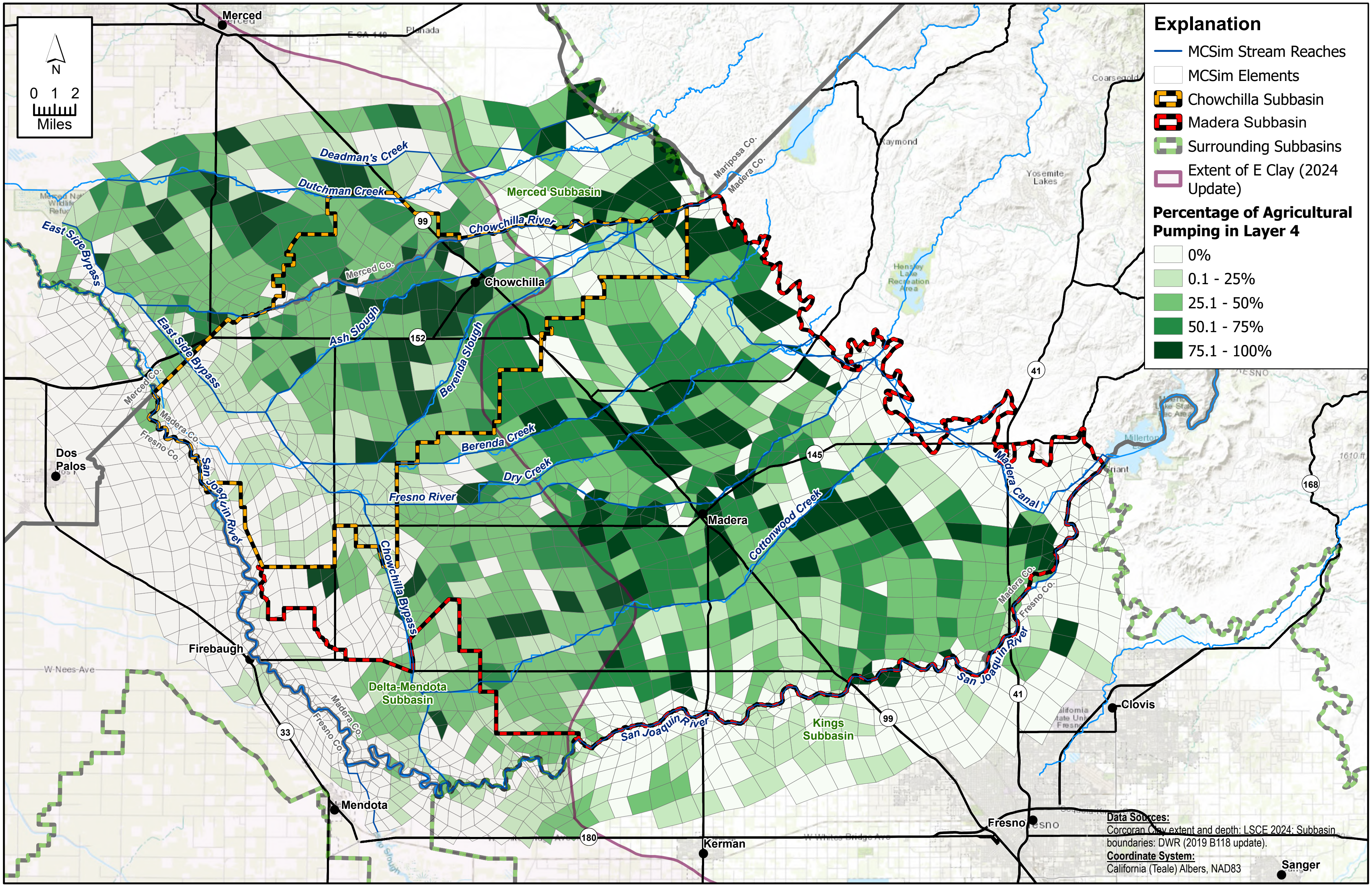
FIGURE 3-64

Vertical Distribution of Projected Agricultural Pumping - Layer 3

Madera-Chowchilla Groundwater-Surface Water Simulation Model (MCSim) - First Model Update



X:\2024\24-010 (1) Davids Eng. - Madera Subbasin 5-Year GSP Update\MODEL\MCSim_v2_GIS_20231101\MCSim_v2_20231101.aprx; GW_PROJ_ELEM_PUMP_AG

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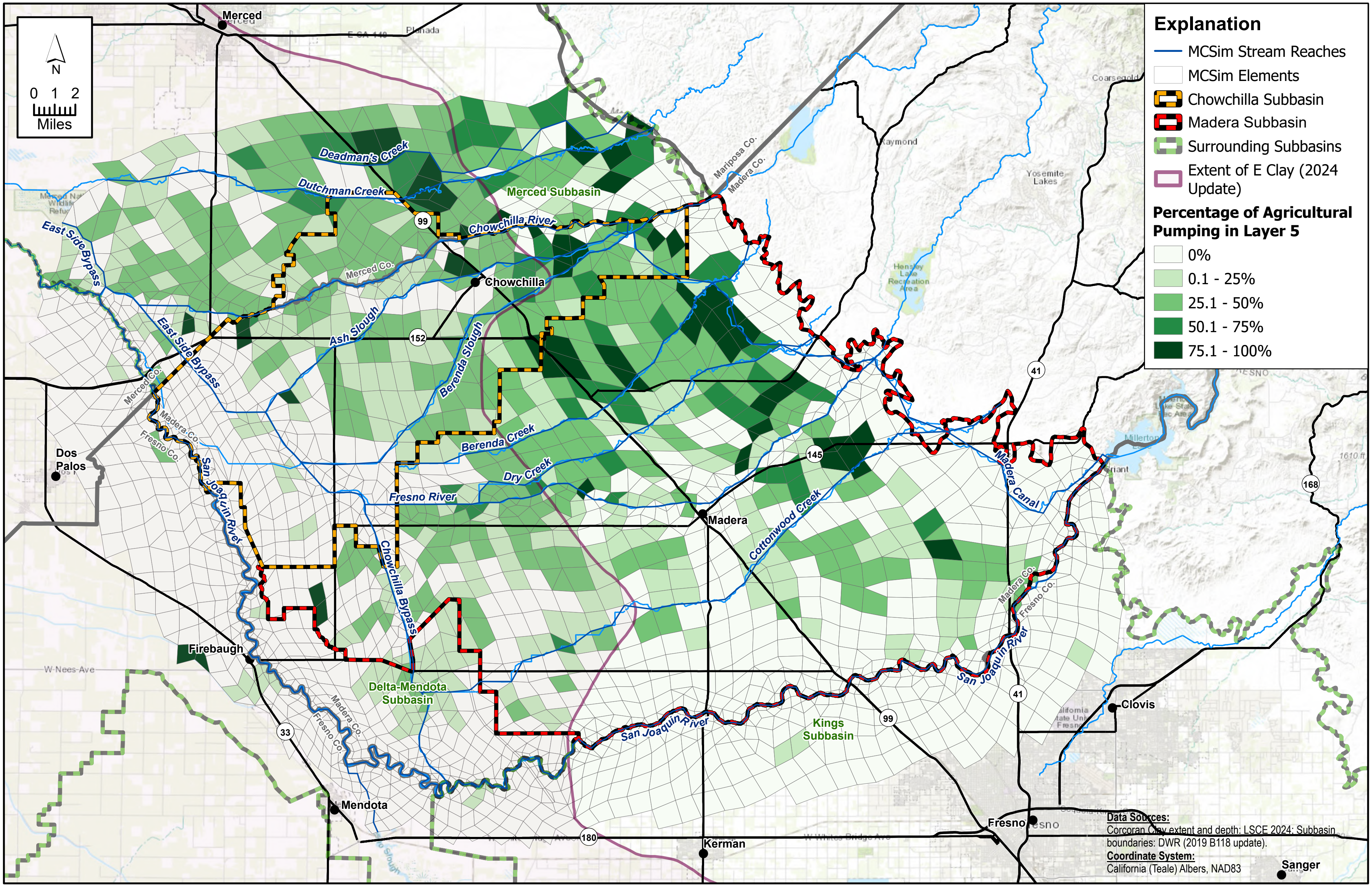
FIGURE 3-65

Vertical Distribution of Projected Agricultural Pumping - Layer 4

Madera-Chowchilla Groundwater-Surface Water Simulation Model (MCSim) - First Model Update



X:\2024\24-010 (1) Davids Eng. - Madera Subbasin 5-Year GSP Update\MODEL\MCSim_v2_GIS_20231101\MCSim_v2_20231101.aprx; GW_PROJ_ELEM_PUMP_AG

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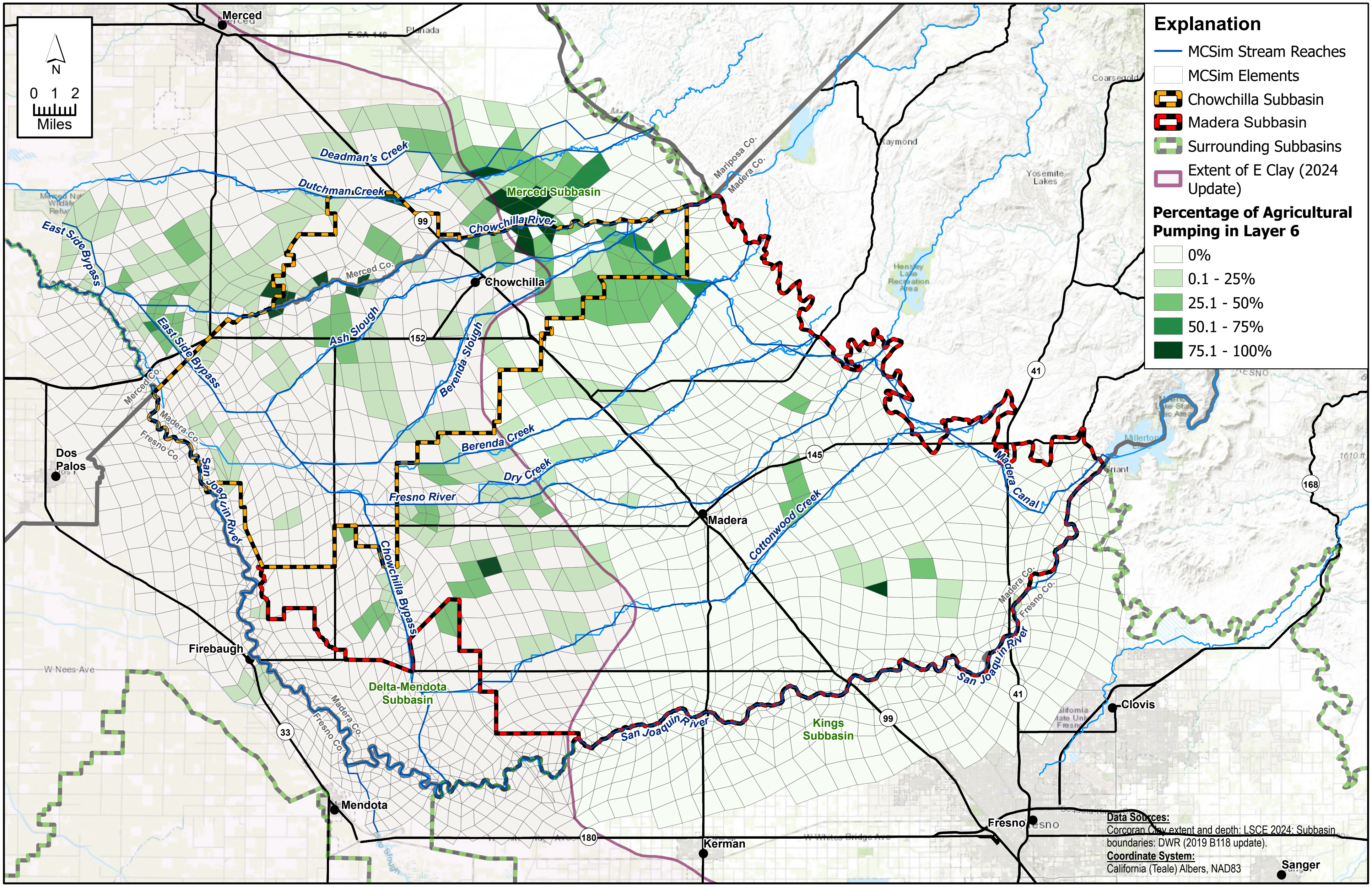
FIGURE 3-66

Vertical Distribution of Projected Agricultural Pumping - Layer 5

Madera-Chowchilla Groundwater-Surface Water Simulation Model (MCSim) - First Model Update



X:\2024\24-010 (1) Davids Eng. - Madera Subbasin 5-Year GSP Update\MODEL\MCSim_v2_GIS_20231101\MCSim_v2_20231101.aprx; GW_PROJ_ELEM_PUMP_AG

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FIGURE 3-67

Vertical Distribution of Projected Agricultural Pumping - Layer 6

Madera-Chowchilla Groundwater-Surface Water Simulation Model (MCSim) - First Model Update

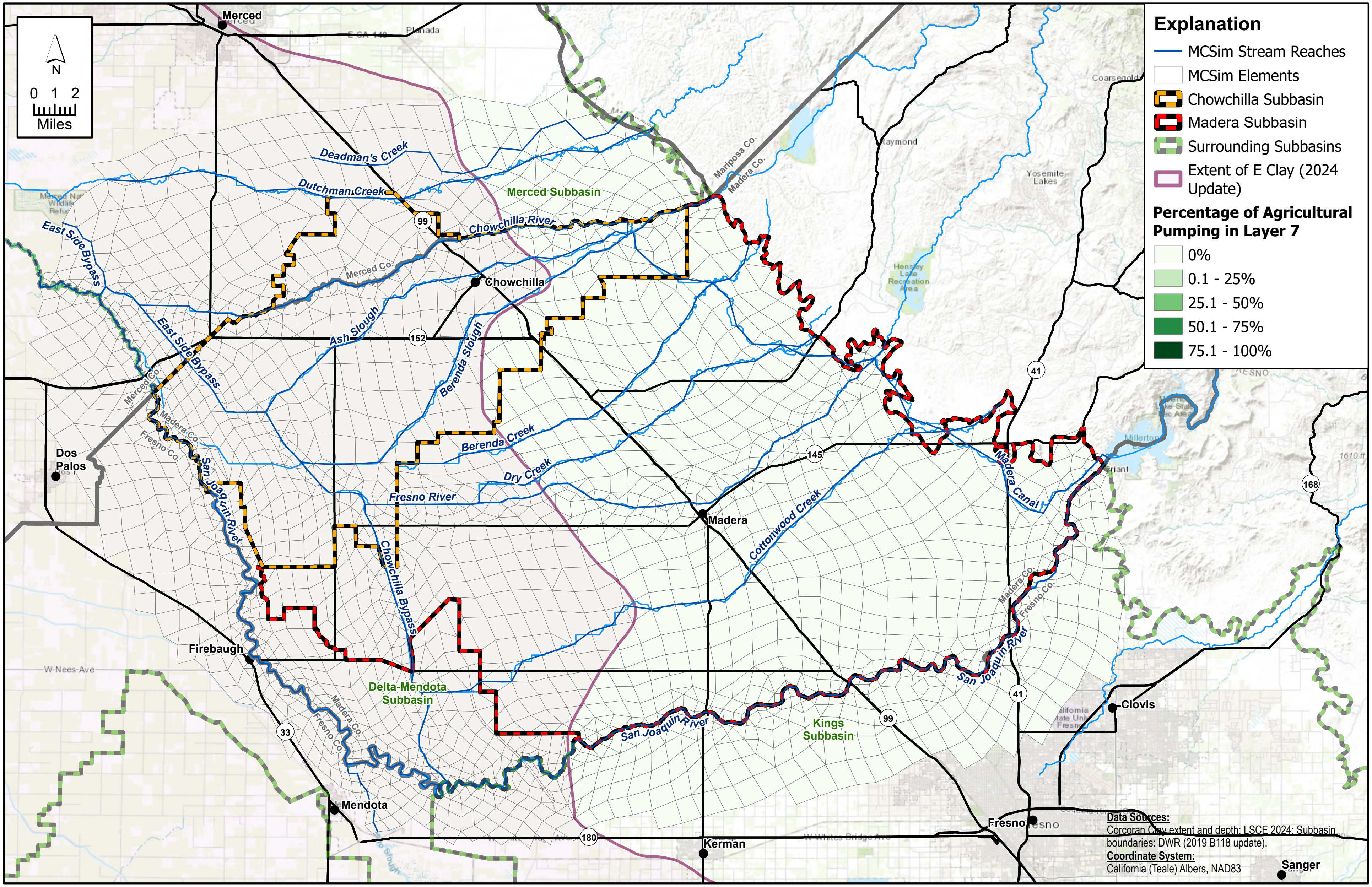

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FIGURE 3-68

Vertical Distribution of Projected Agricultural Pumping - Layer 7

Madera-Chowchilla Groundwater-Surface Water Simulation Model (MCSim) - First Model Update

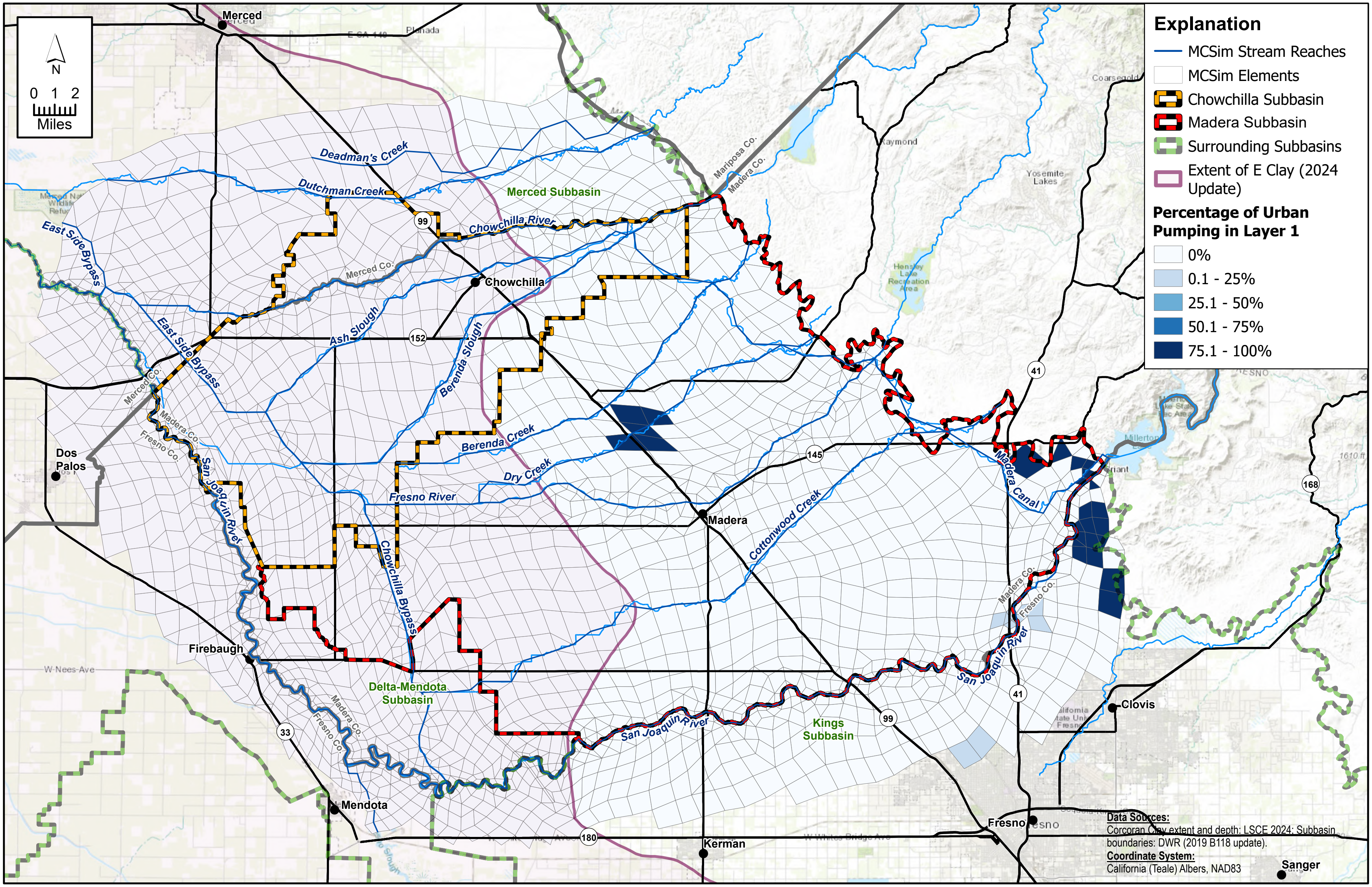

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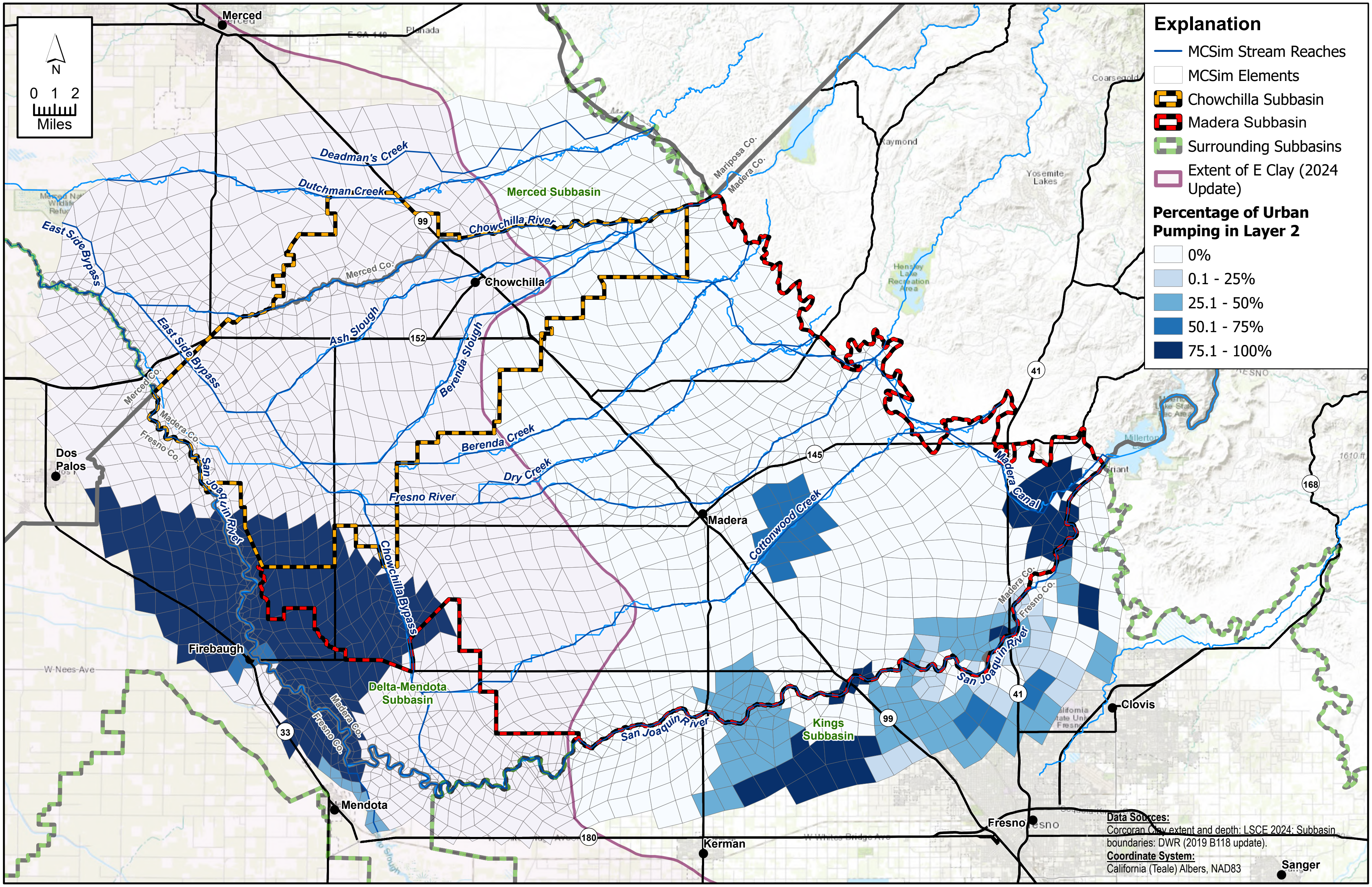
FIGURE 3-69

Vertical Distribution of Projected Urban Pumping - Layer 1

Madera-Chowchilla Groundwater-Surface Water Simulation Model (MCSim) - First Model Update



X:\2024\24-010 (1) Davids Eng. - Madera Subbasin 5-Year GSP Update\MODEL\MCSim_v2_GIS_20231101\MCSim_v2_20231101.aprx; GW_PROJ_ELEM_PUMP_URBAN

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FIGURE 3-70

Vertical Distribution of Projected Urban Pumping - Layer 2

Madera-Chowchilla Groundwater-Surface Water Simulation Model (MCSim) - First Model Update

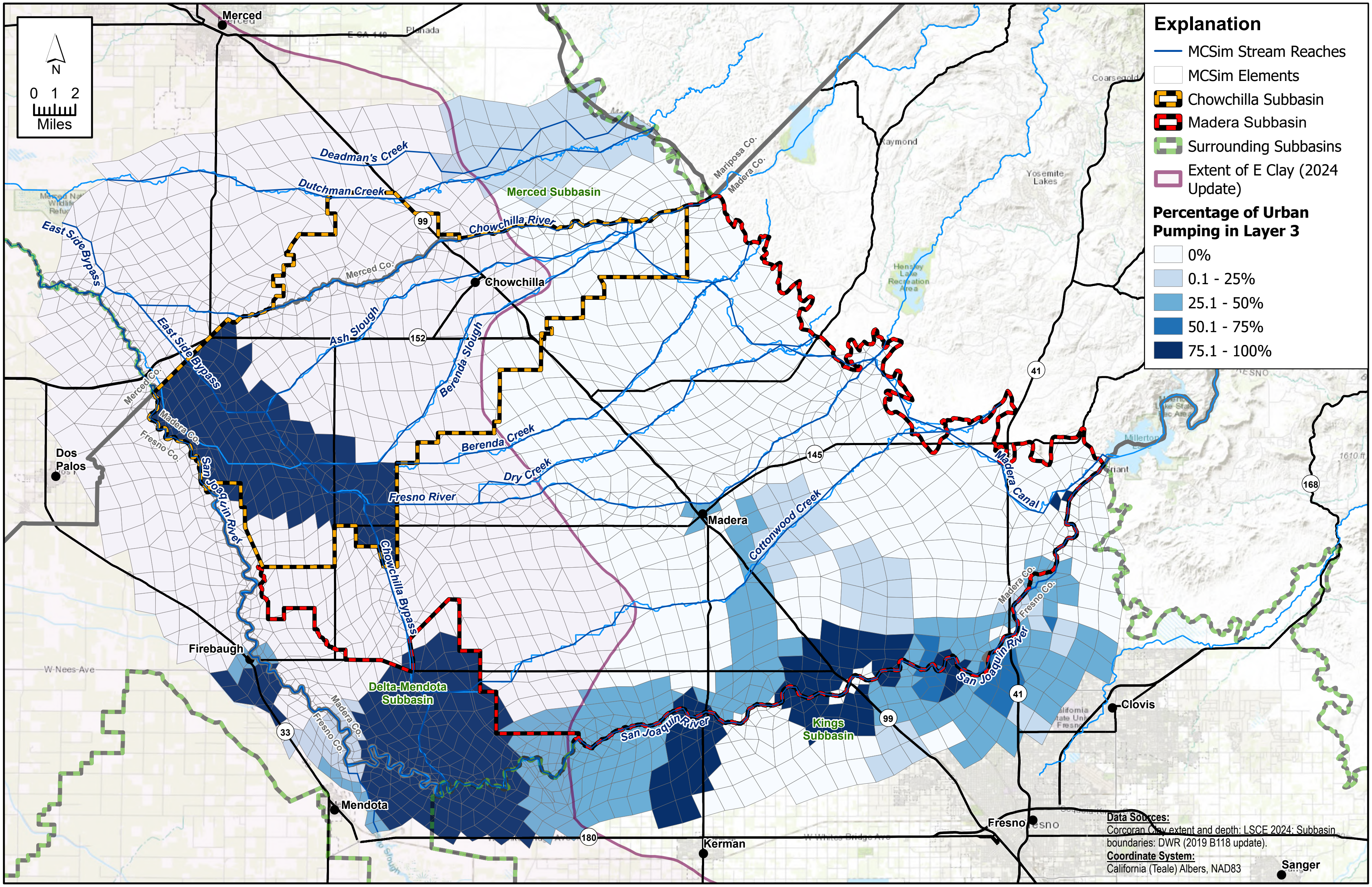

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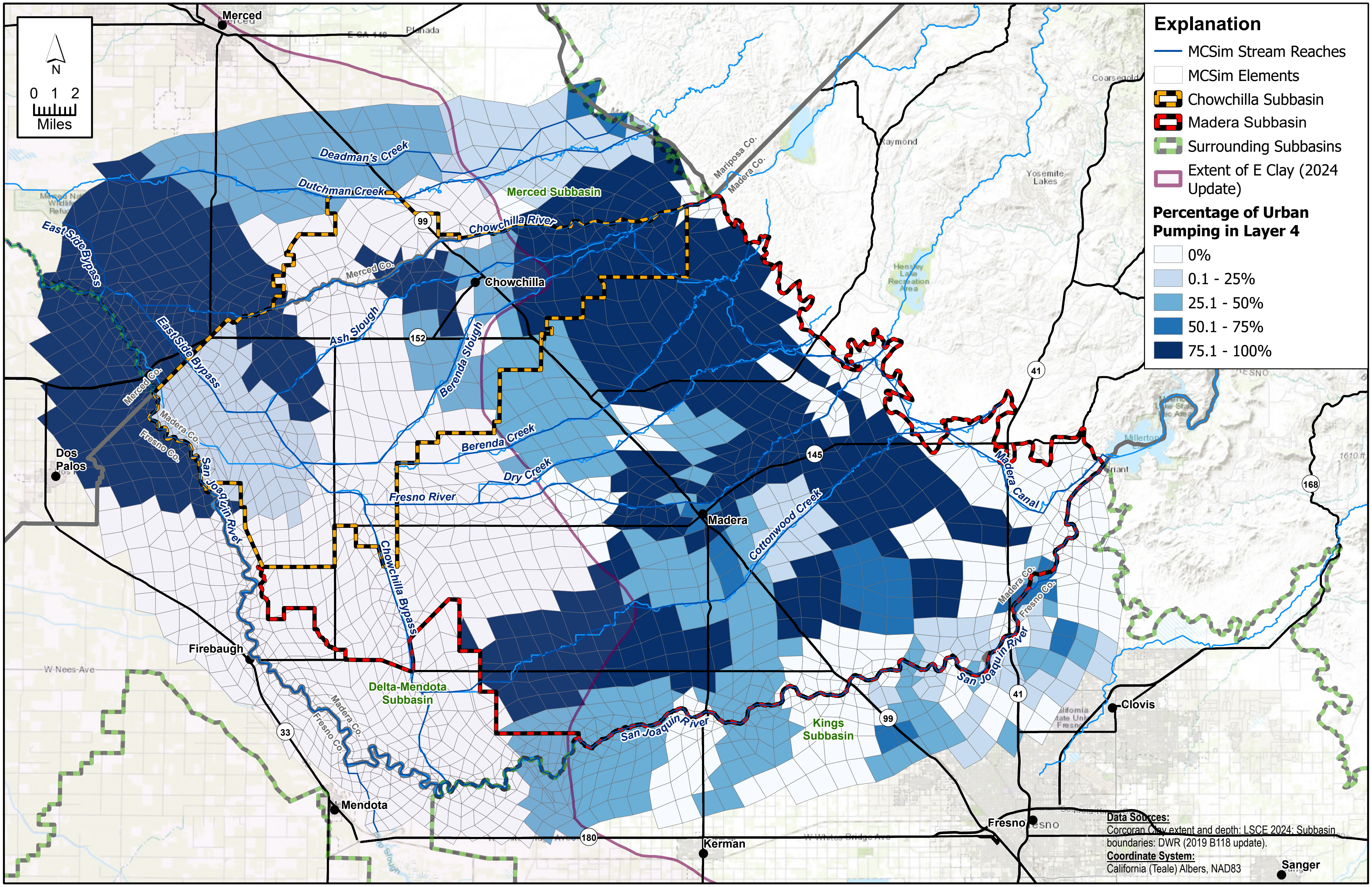
FIGURE 3-71

Vertical Distribution of Projected Urban Pumping - Layer 3

Madera-Chowchilla Groundwater-Surface Water Simulation Model (MCSim) - First Model Update



X:\2024\24-010 (1) Davids Eng. - Madera Subbasin 5-Year GSP Update\MODEL\MCSim_v2_GIS_20231101\MCSim_v2_20231101.aprx; GW_PROJ_ELEM_PUMP_URBAN

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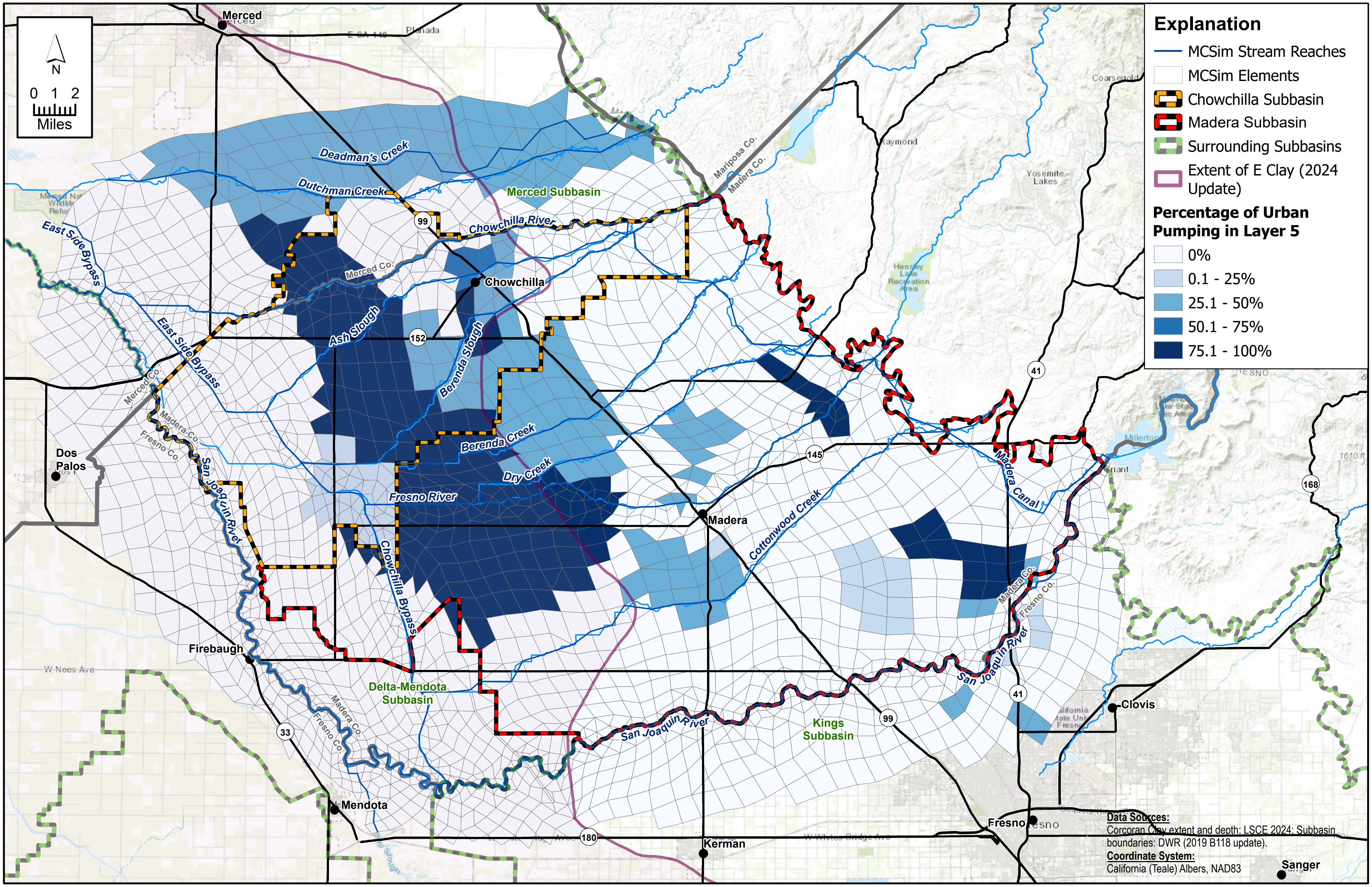
FIGURE 3-72

Vertical Distribution of Projected Urban Pumping - Layer 4

Madera-Chowchilla Groundwater-Surface Water Simulation Model (MCSim) - First Model Update



X:\2024\24-010 (1) Davids Eng. - Madera Subbasin 5-Year GSP Update\MODEL\MCSim_v2_GIS_20231101\MCSim_v2_20231101.aprx; GW_PROJ_ELEM_PUMP_URBAN

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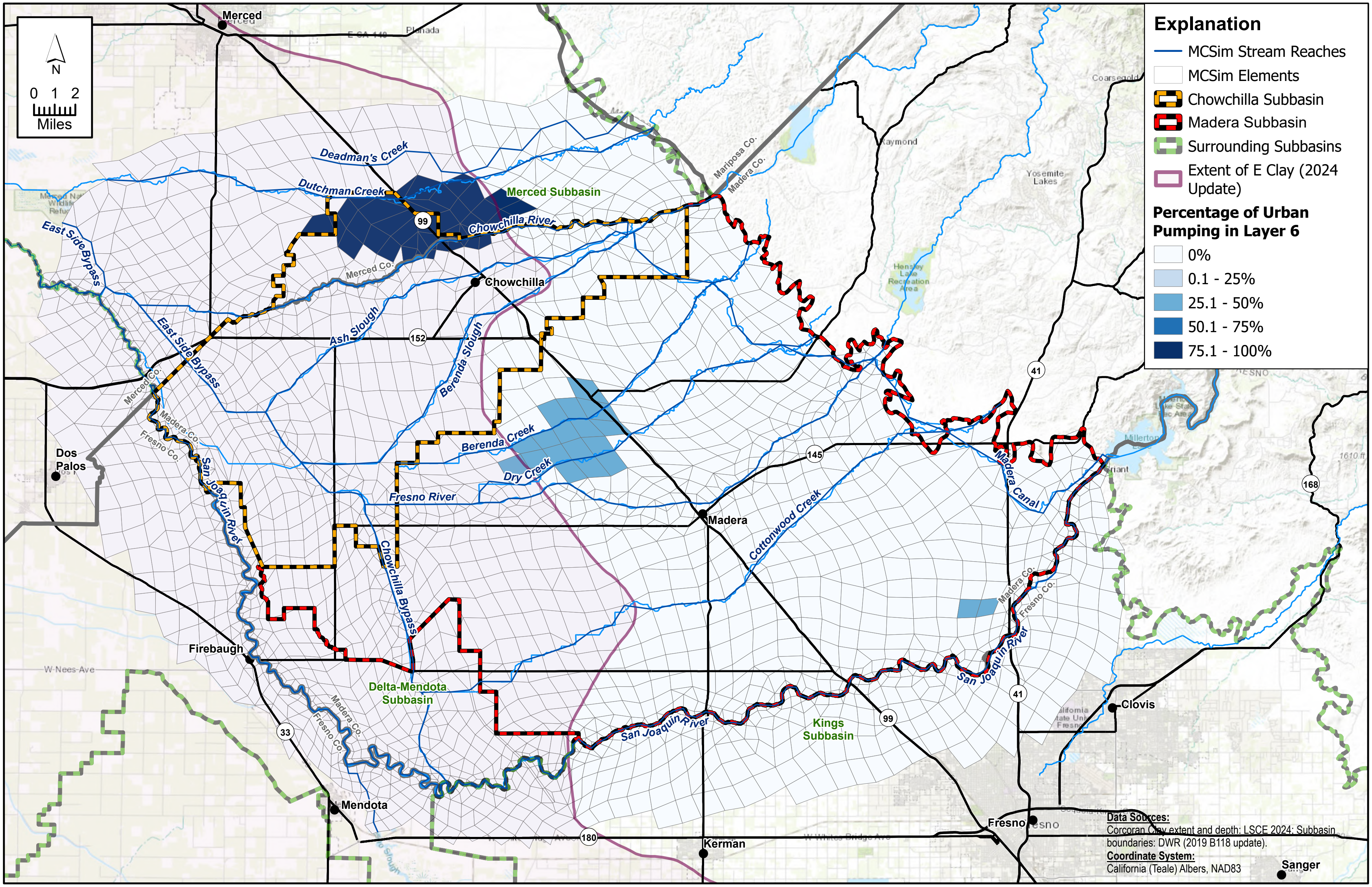
FIGURE 3-73

Vertical Distribution of Projected Urban Pumping - Layer 5

Madera-Chowchilla Groundwater-Surface Water Simulation Model (MCSim) - First Model Update



X:\2024\24-010 (1) Davids Eng. - Madera Subbasin 5-Year GSP Update\MODEL\MCSim_v2_GIS_20231101\MCSim_v2_20231101.aprx; GW_PROJ_ELEM_PUMP_URBAN

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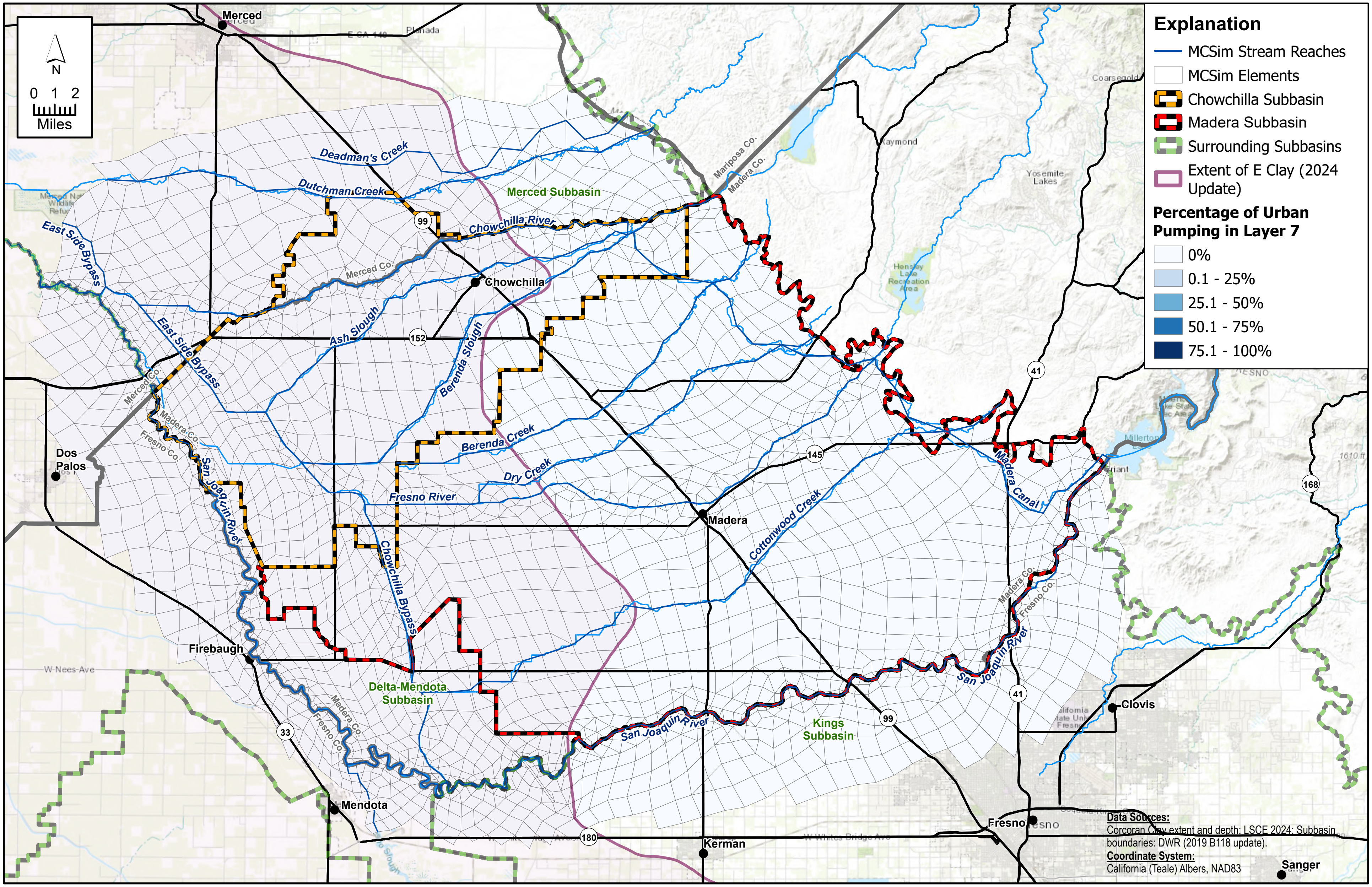
FIGURE 3-74

Vertical Distribution of Projected Urban Pumping - Layer 6

Madera-Chowchilla Groundwater-Surface Water Simulation Model (MCSim) - First Model Update



X:\2024\24-010 (1) Davids Eng. - Madera Subbasin 5-Year GSP Update\MODEL\MCSim_v2_GIS_20231101\MCSim_v2_20231101.aprx; GW_PROJ_ELEM_PUMP_URBAN

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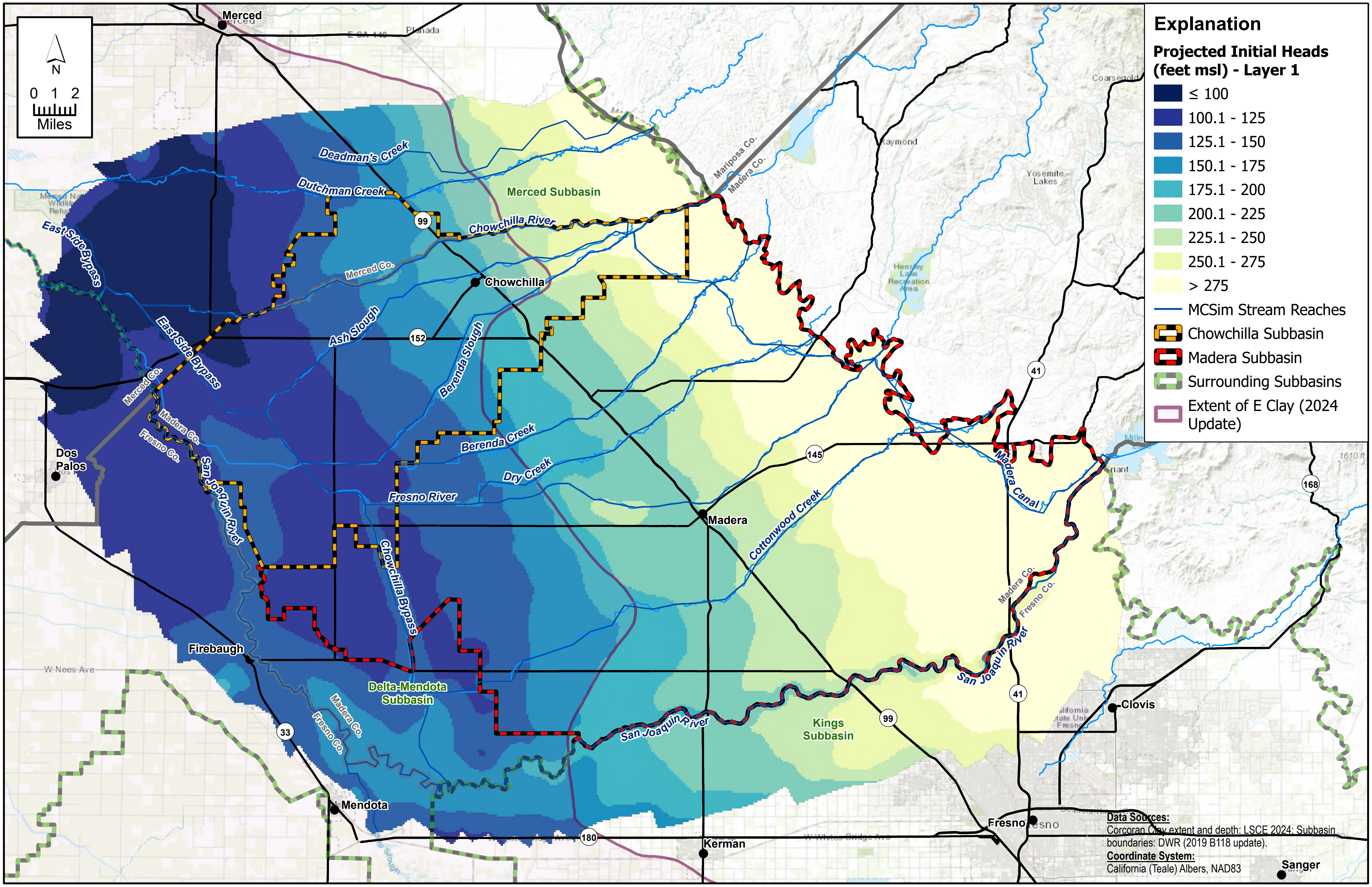
FIGURE 3-75

Vertical Distribution of Projected Urban Pumping - Layer 7

Madera-Chowchilla Groundwater-Surface Water Simulation Model (MCSim) - First Model Update



X:\2024\24-010 (1) Davids Eng. - Madera Subbasin 5-Year GSP Update\MODEL\MCSim_v2_GIS_20231101\MCSim_v2_20231101.aprx; InCond_PROJ_20241029_1

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FIGURE 3-76

Projected Initial Groundwater Heads - Layer 1

Madera-Chowchilla Groundwater-Surface Water Simulation Model (MCSim) - First Model Update

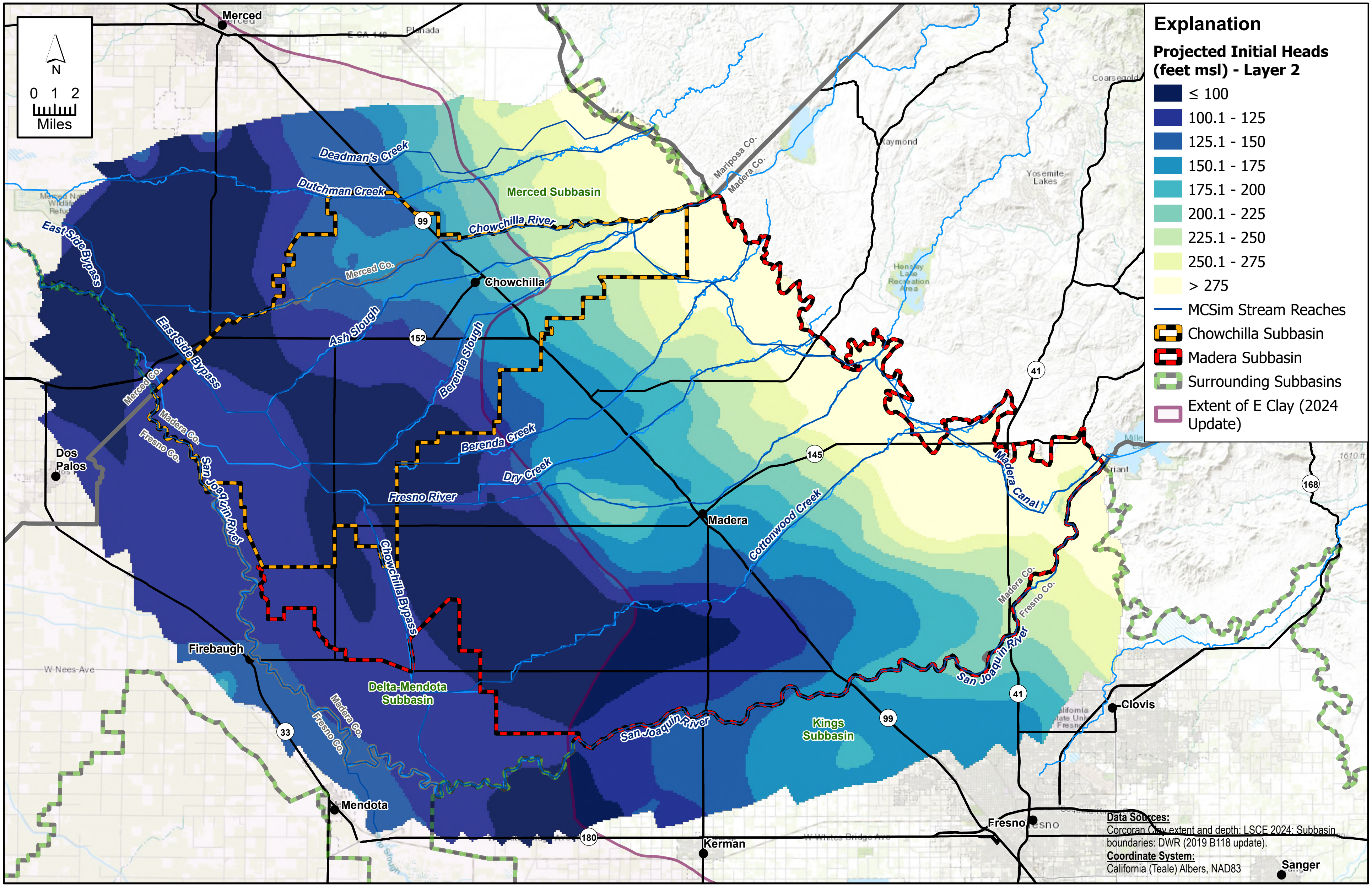

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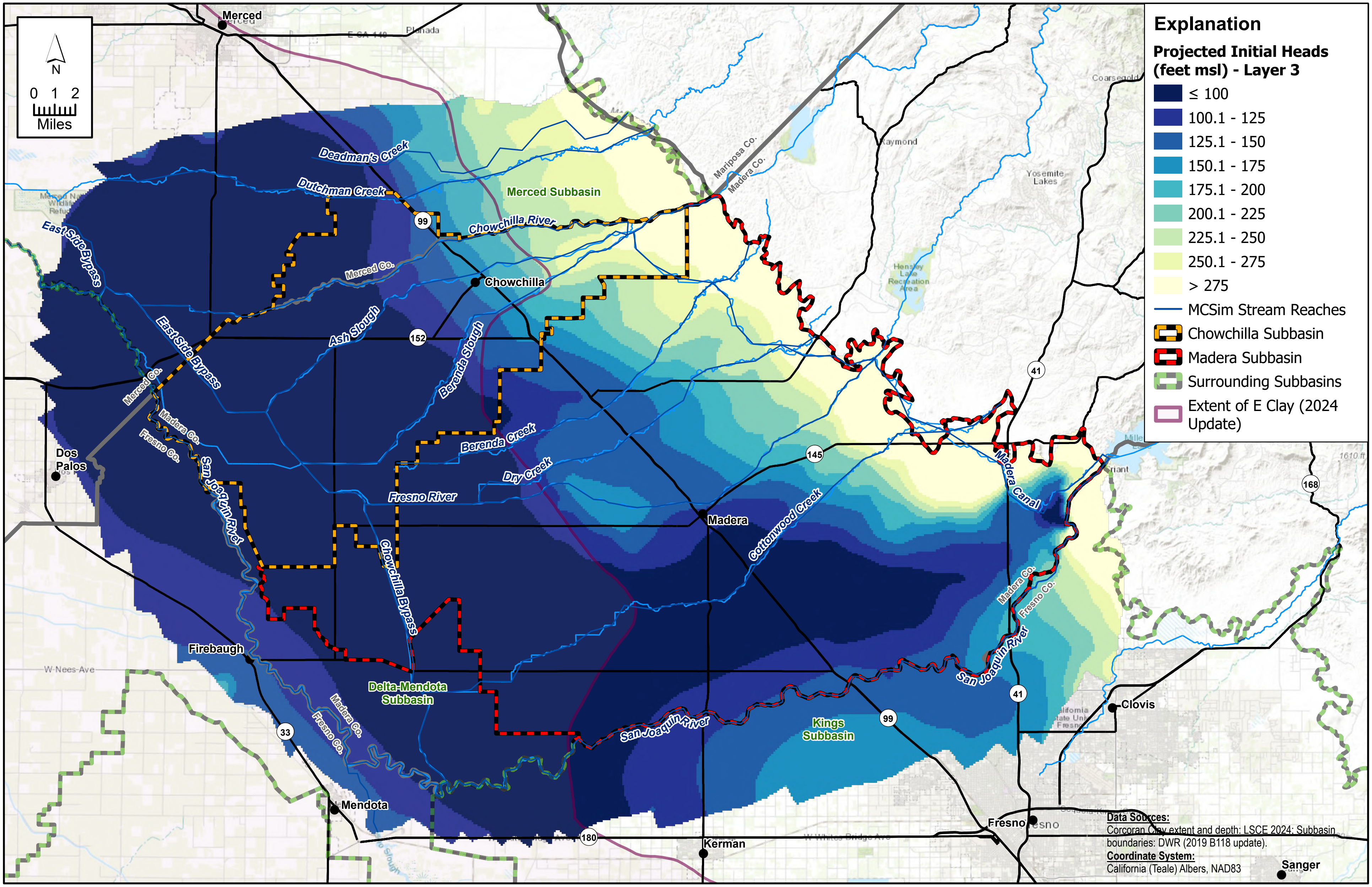
FIGURE 3-77

Projected Initial Groundwater Heads - Layer 2

Madera-Chowchilla Groundwater-Surface Water Simulation Model (MCSim) - First Model Update



X:\2024\24-010 (1) Davids Eng. - Madera Subbasin 5-Year GSP Update\MODEL\MCSim_v2_GIS_20231101\MCSim_v2_20231101.aprx; InCond_PROJ_20241029_1

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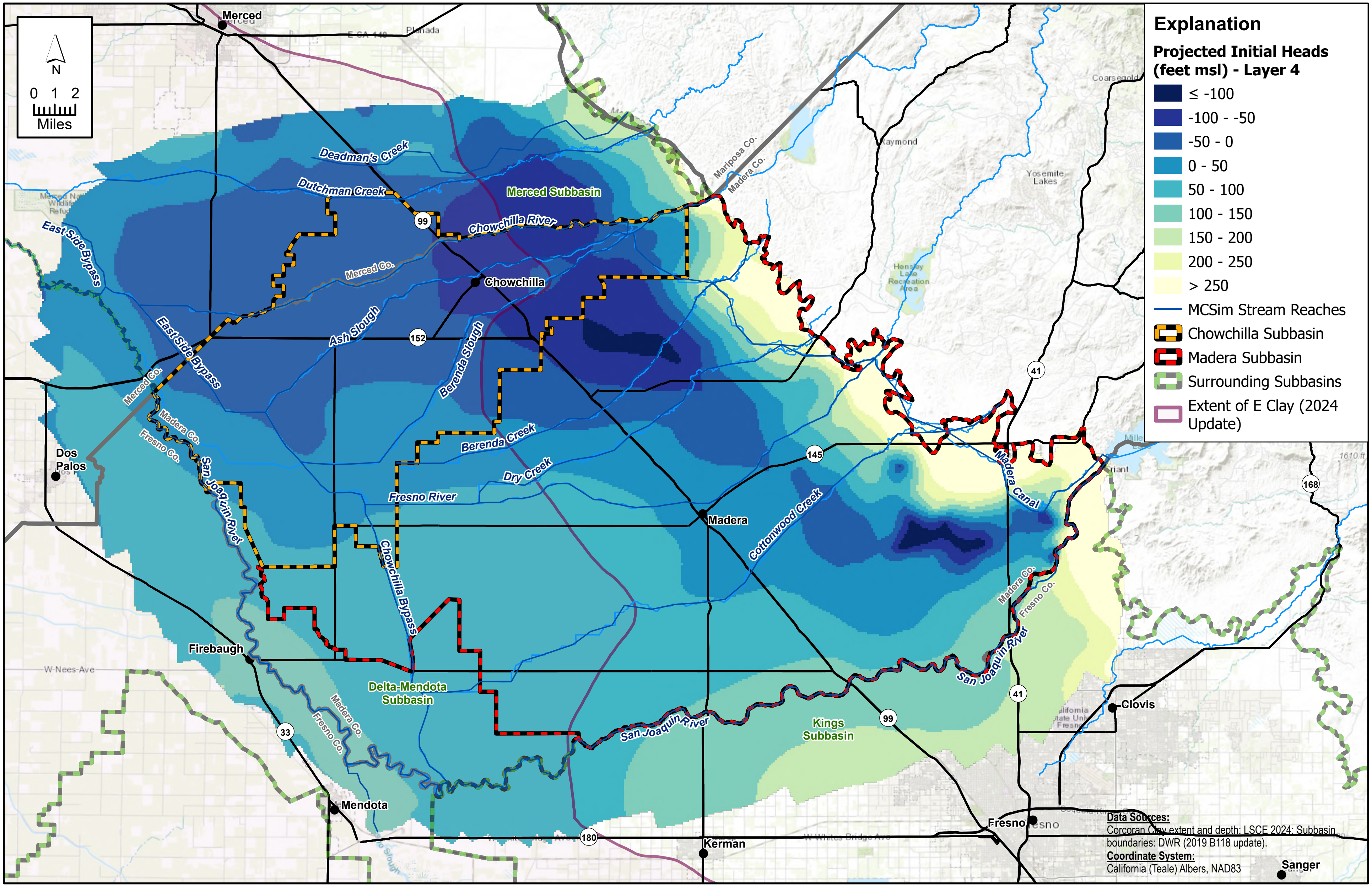
FIGURE 3-78

Projected Initial Groundwater Heads - Layer 3

Madera-Chowchilla Groundwater-Surface Water Simulation Model (MCSim) - First Model Update



X:\2024\24-010 (1) Davids Eng. - Madera Subbasin 5-Year GSP Update\MODEL\MCSim_v2_GIS_20231101\MCSim_v2_20231101.aprx; InCond_PROJ_20241029_1

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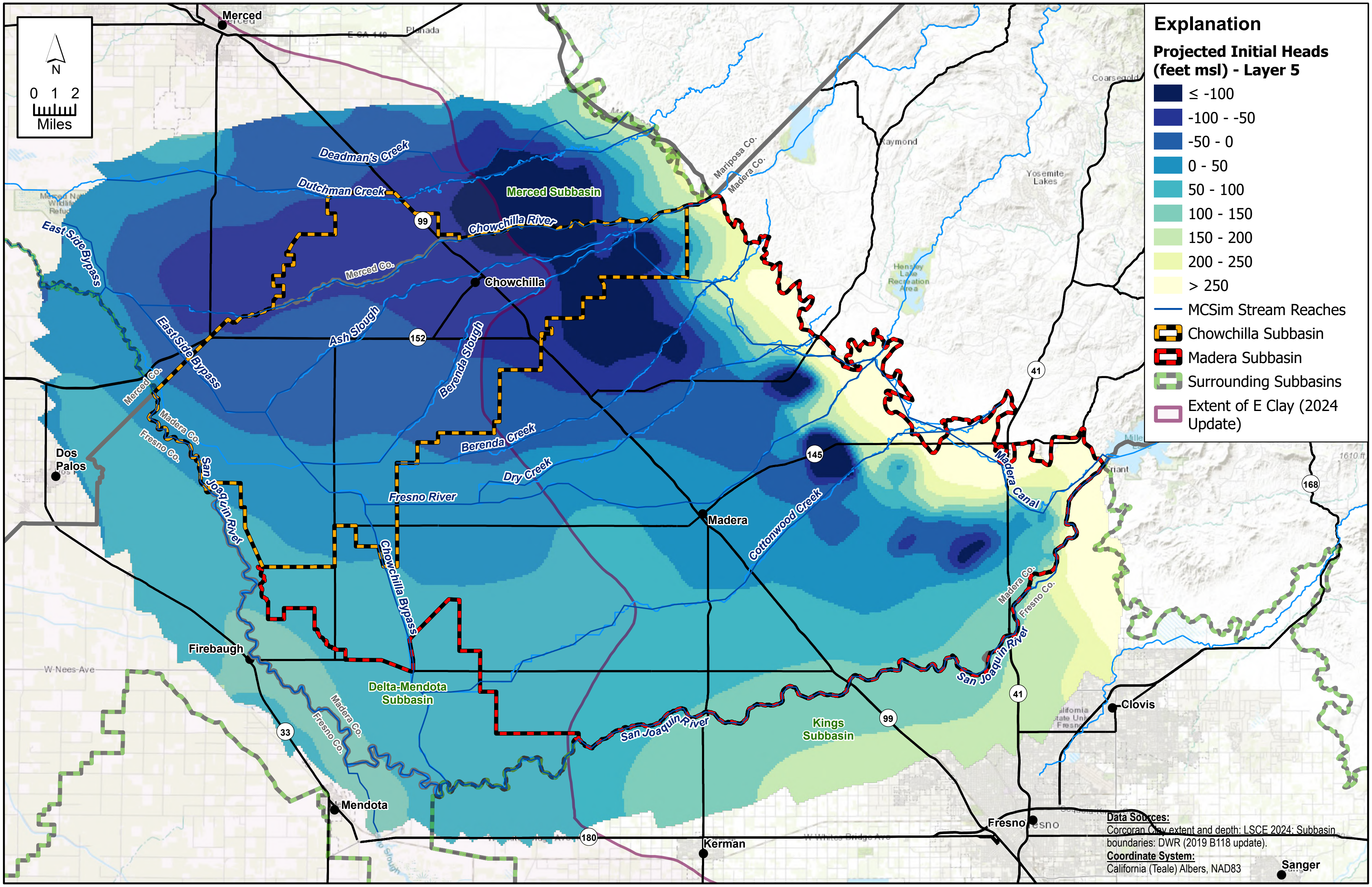
FIGURE 3-79

Projected Initial Groundwater Heads - Layer 4

Madera-Chowchilla Groundwater-Surface Water Simulation Model (MCSim) - First Model Update



X:\2024\24-010 (1) Davids Eng. - Madera Subbasin 5-Year GSP Update\MODEL\MCSim_v2_GIS_20231101\MCSim_v2_20231101.aprx; InCond_PROJ_20241029_1

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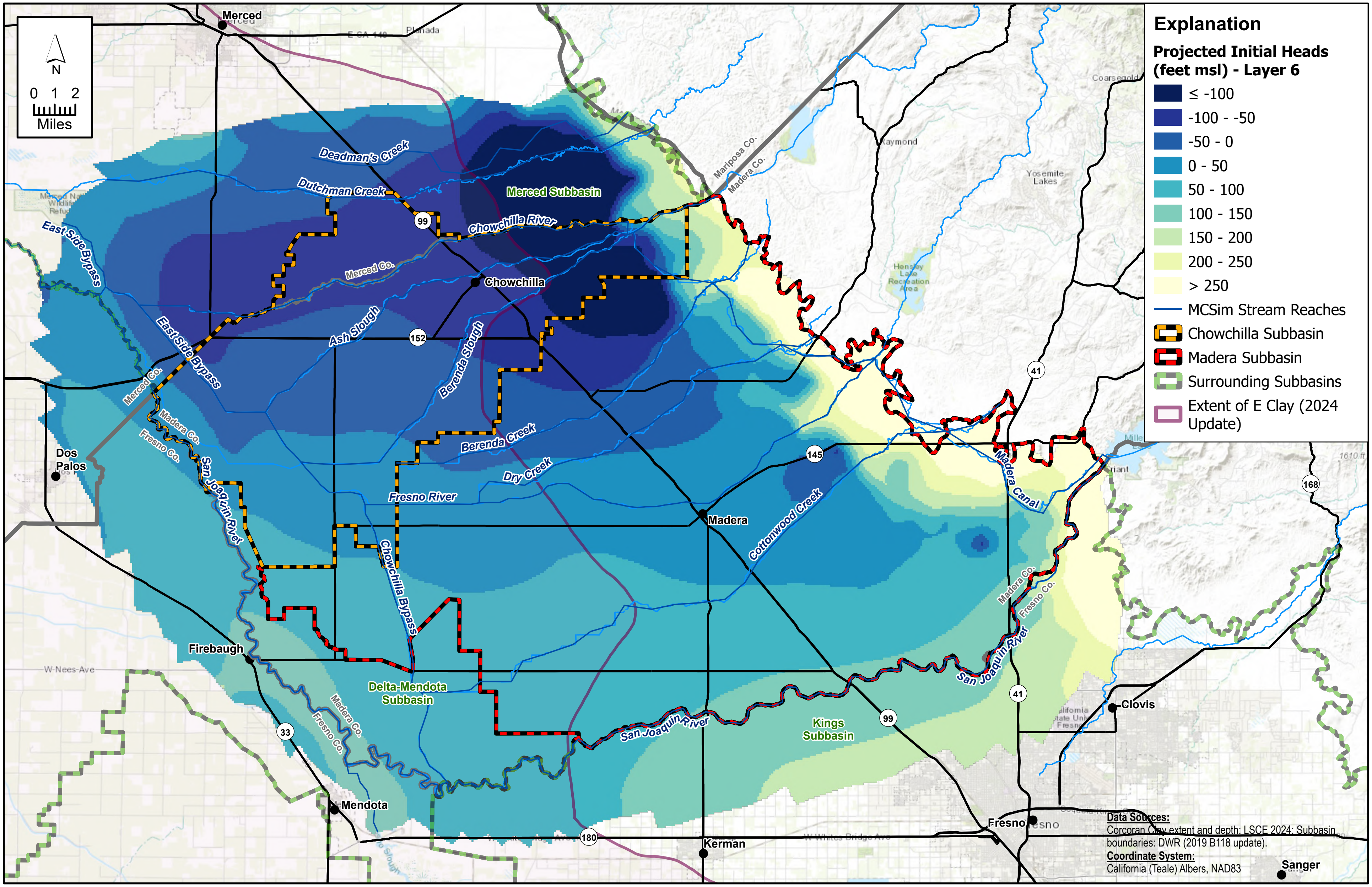
FIGURE 3-80

Projected Initial Groundwater Heads - Layer 5

Madera-Chowchilla Groundwater-Surface Water Simulation Model (MCSim) - First Model Update



X:\2024\24-010 (1) Davids Eng. - Madera Subbasin 5-Year GSP Update\MODEL\MCSim_v2_GIS_20231101\MCSim_v2_20231101.aprx; InCond_PROJ_20241029_1

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FIGURE 3-81

Projected Initial Groundwater Heads - Layer 6

Madera-Chowchilla Groundwater-Surface Water Simulation Model (MCSim) - First Model Update

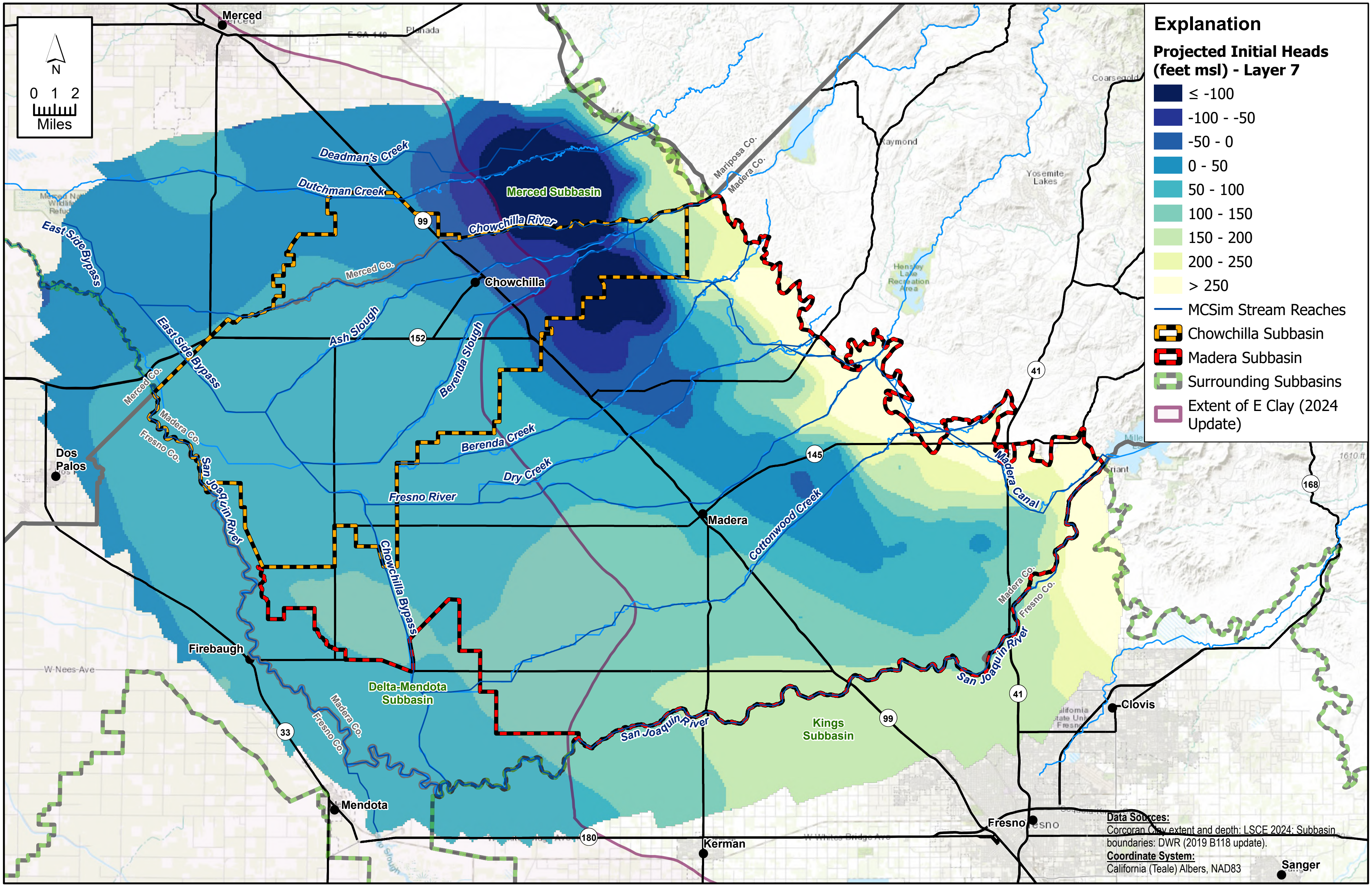

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FIGURE 3-82

Projected Initial Groundwater Heads - Layer 7

Madera-Chowchilla Groundwater-Surface Water Simulation Model (MCSim) - First Model Update

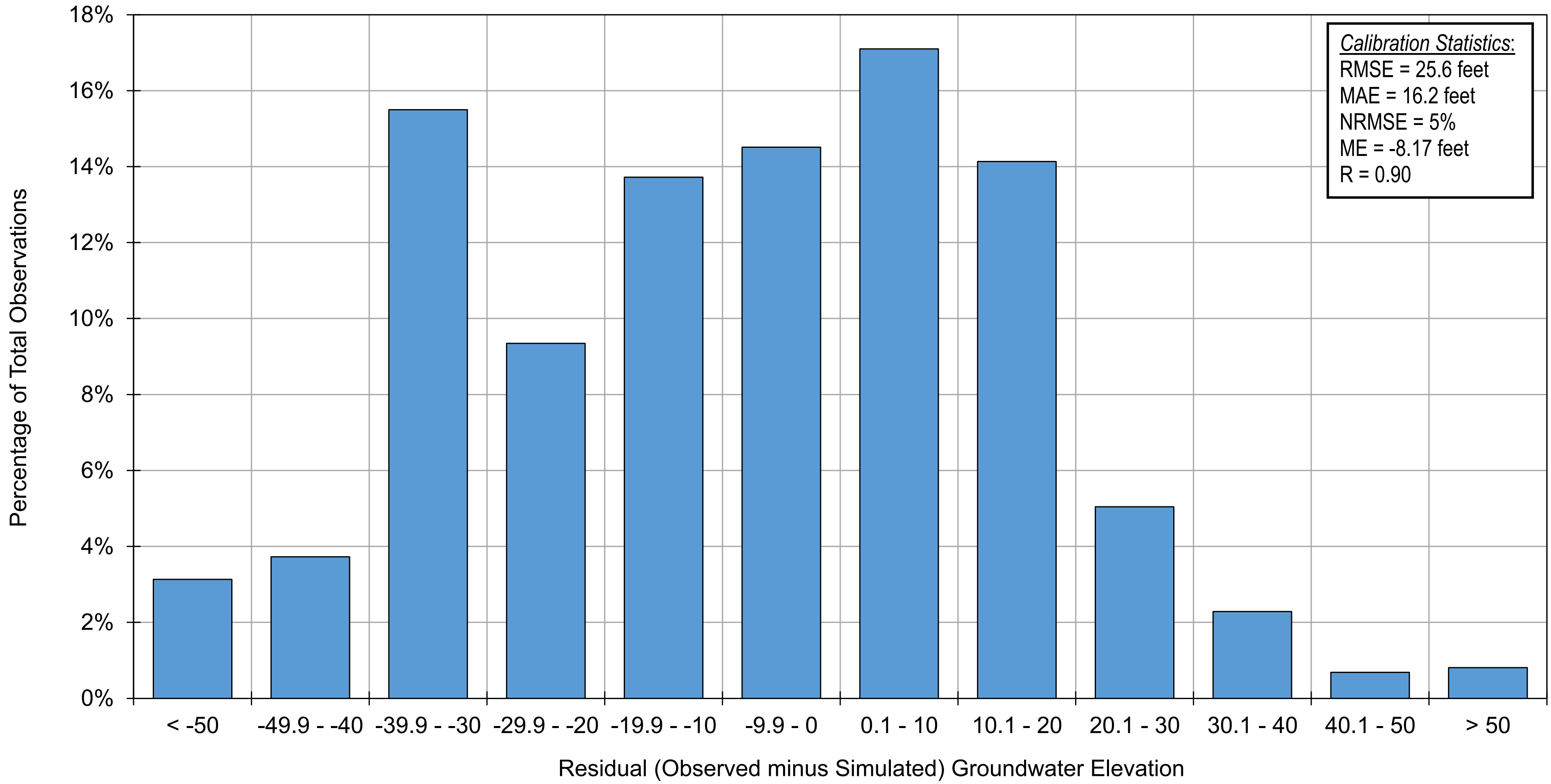

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FIGURE 4-1

Histogram of Residual (Simulated minus Observed) Groundwater Elevations in MCSim_v2 for All Observations

Madera-Chowchilla Groundwater-Surface Water Simulation Model (MCSim) - First Model Update

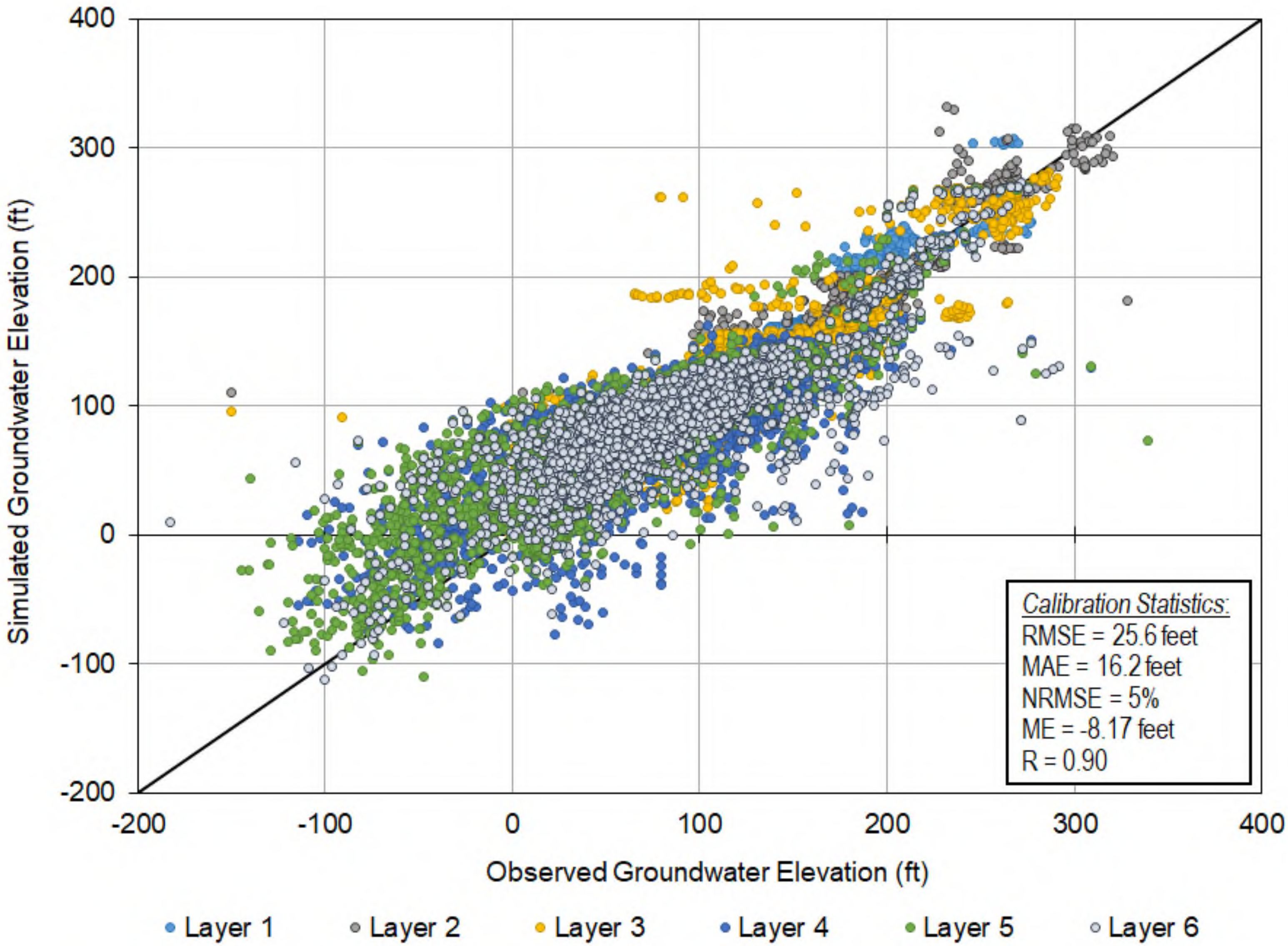

FIGURE 4-2
Simulated vs. Observed Groundwater Elevations in MCSim_v2, By Layer

Madera-Chowchilla Groundwater-Surface Water Simulation Model (MCSim) - First Model Update

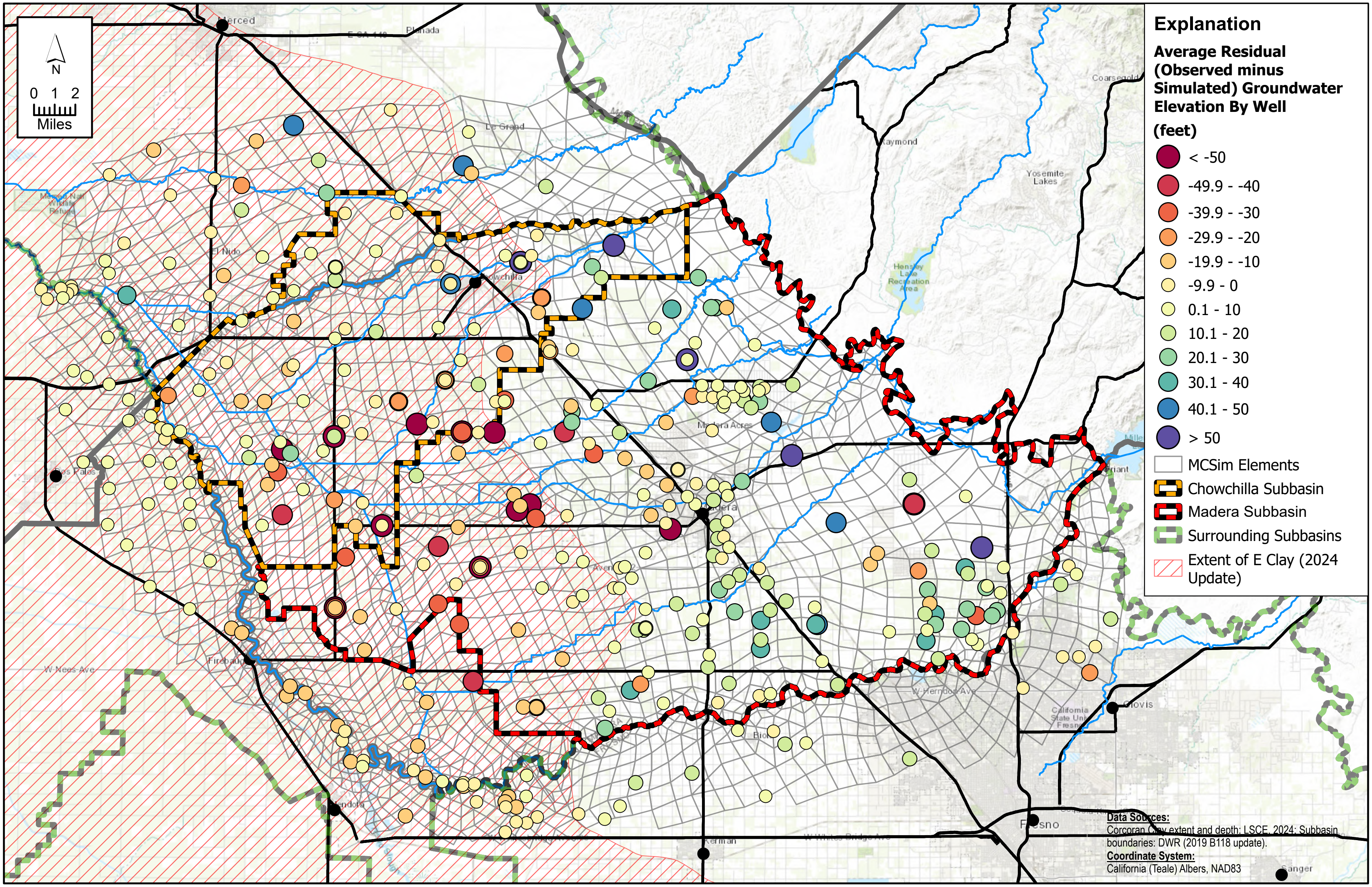

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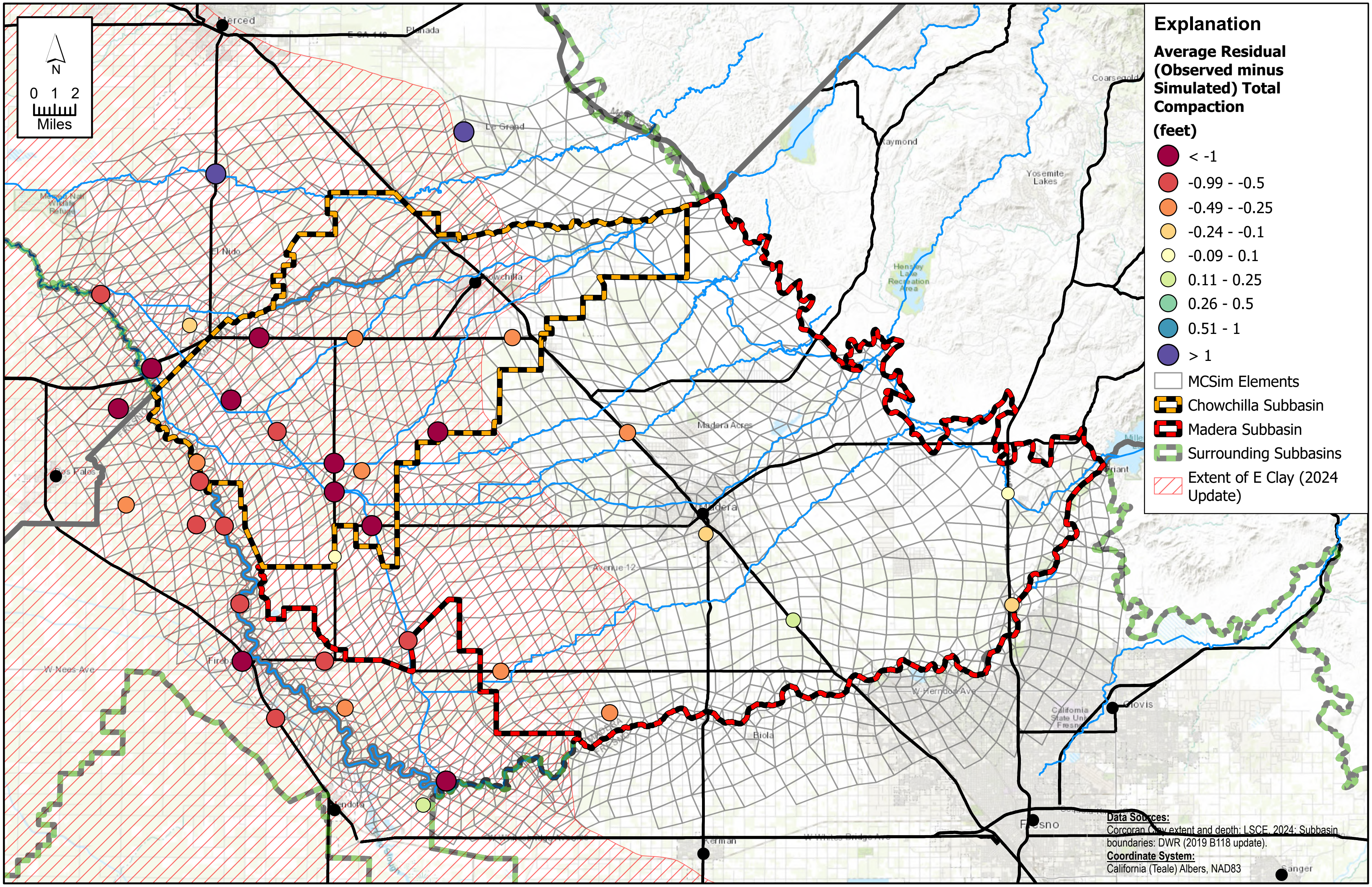
FIGURE 4-3

Average Residual Groundwater Elevation by Calibration Well

Madera-Chowchilla Groundwater-Surface Water Simulation Model (MCSim) - First Model Update



X:\2024\24-010 (1) Davids Eng. - Madera Subbasin 5-Year GSP Update\MODEL\MCSim_v2_GIS_20231101\MCSim_v2_20231101.aprx; CALIB_SUBS_working

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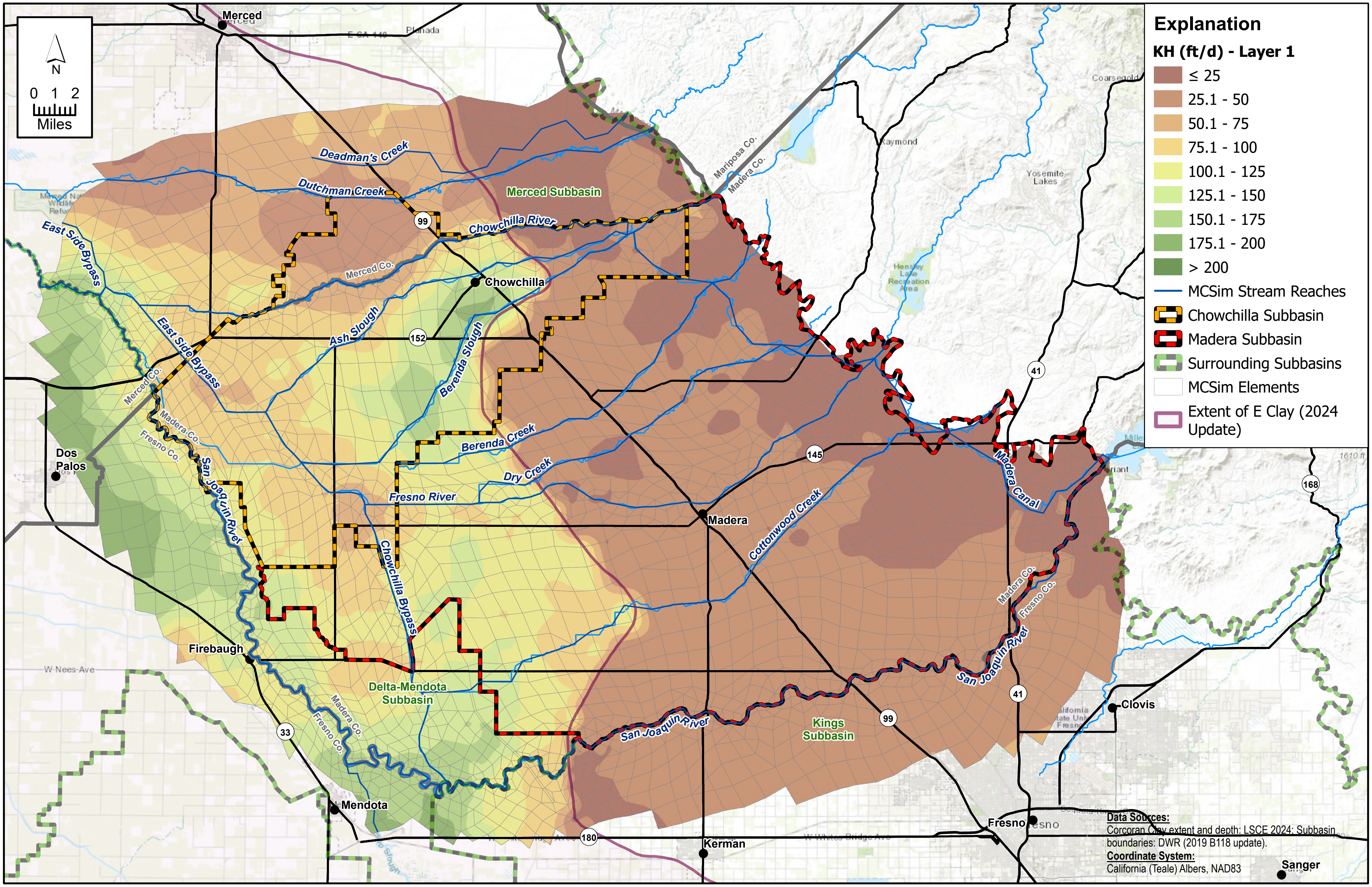
FIGURE 4-4

Average Residual Total Compaction by Subsidence Monitoring Station

Madera-Chowchilla Groundwater-Surface Water Simulation Model (MCSim) - First Model Update



X:\2024\24-010 (1) Davids Eng. - Madera Subbasin 5-Year GSP Update\MODEL\MCSim_v2_GIS_20231101\MCSim_v2_20231101.aprx; AQ_PARAM_KH

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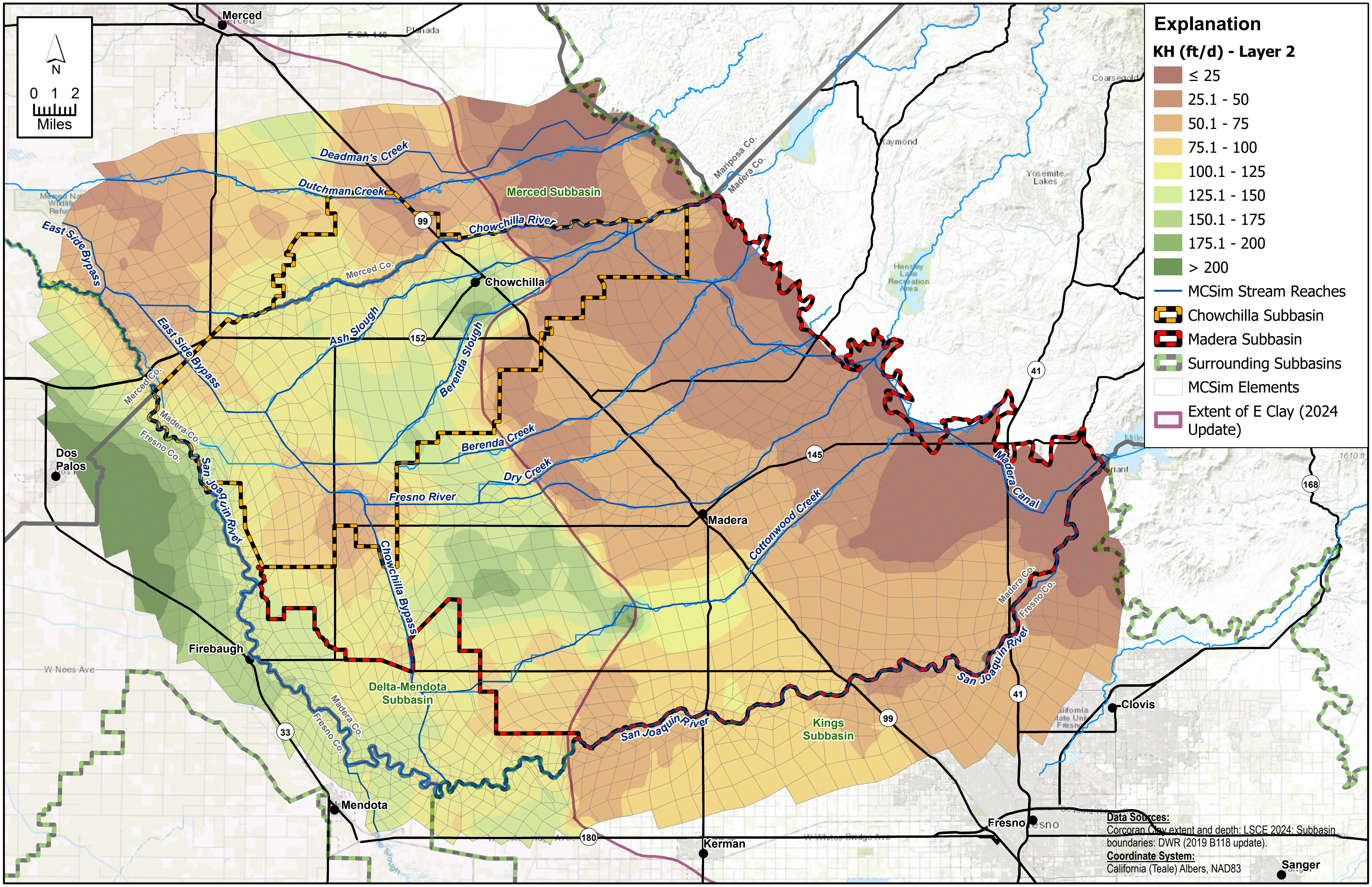
FIGURE 4-5

Calibrated Horizontal Hydraulic Conductivity (Kh) - Layer 1

Madera-Chowchilla Groundwater-Surface Water Simulation Model (MCSim) - First Model Update



X:\2024\24-010 (1) Davids Eng. - Madera Subbasin 5-Year GSP Update\MODEL\MCSim_v2_GIS_20231101\MCSim_v2_20231101.aprx; AQ_PARAM_KH

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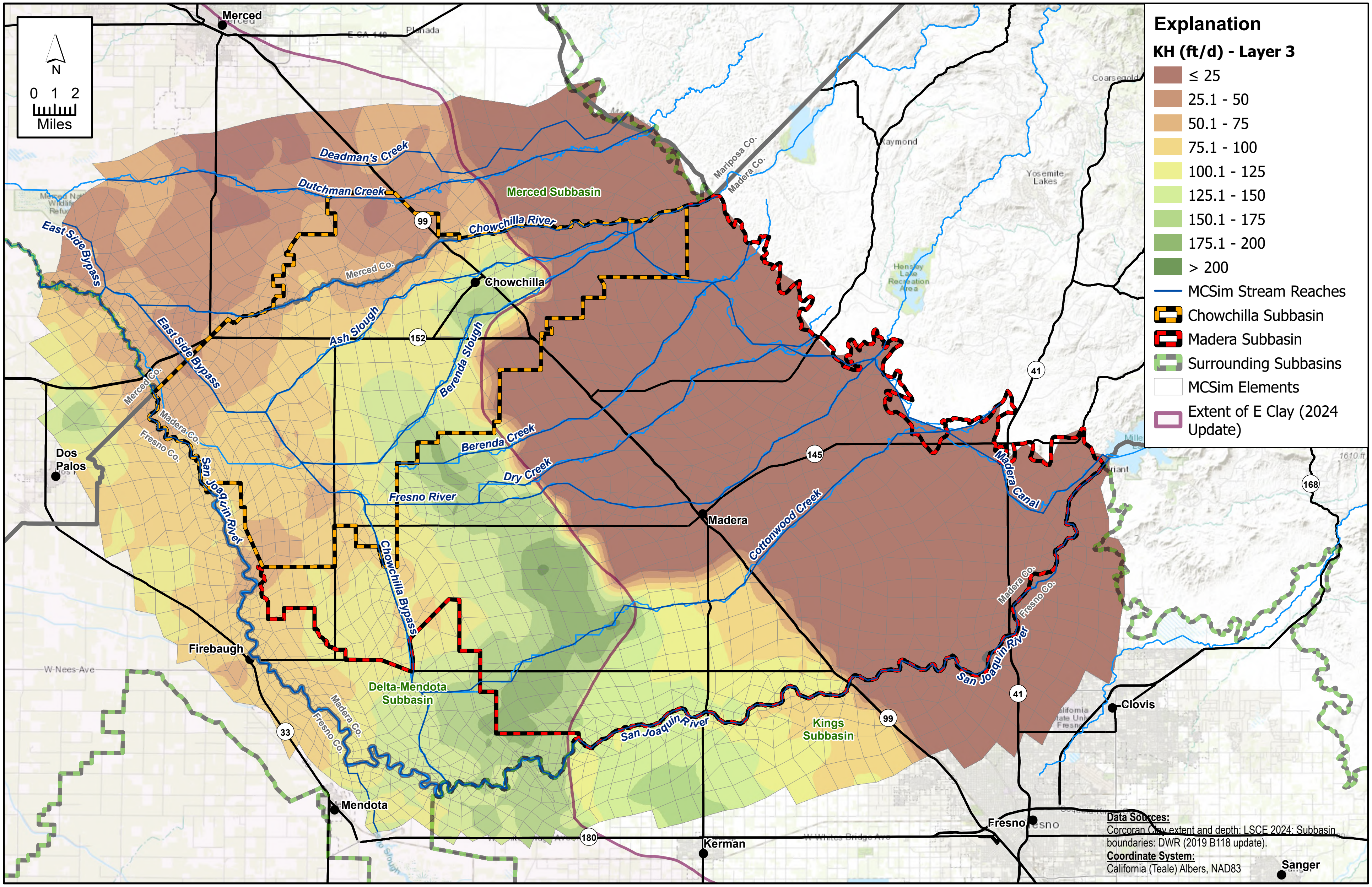
FIGURE 4-6

Calibrated Horizontal Hydraulic Conductivity (Kh) - Layer 2

Madera-Chowchilla Groundwater-Surface Water Simulation Model (MCSim) - First Model Update



X:\2024\24-010 (1) Davids Eng. - Madera Subbasin 5-Year GSP Update\MODEL\MCSim_v2_GIS_20231101\MCSim_v2_20231101.aprx; AQ_PARAM_KH

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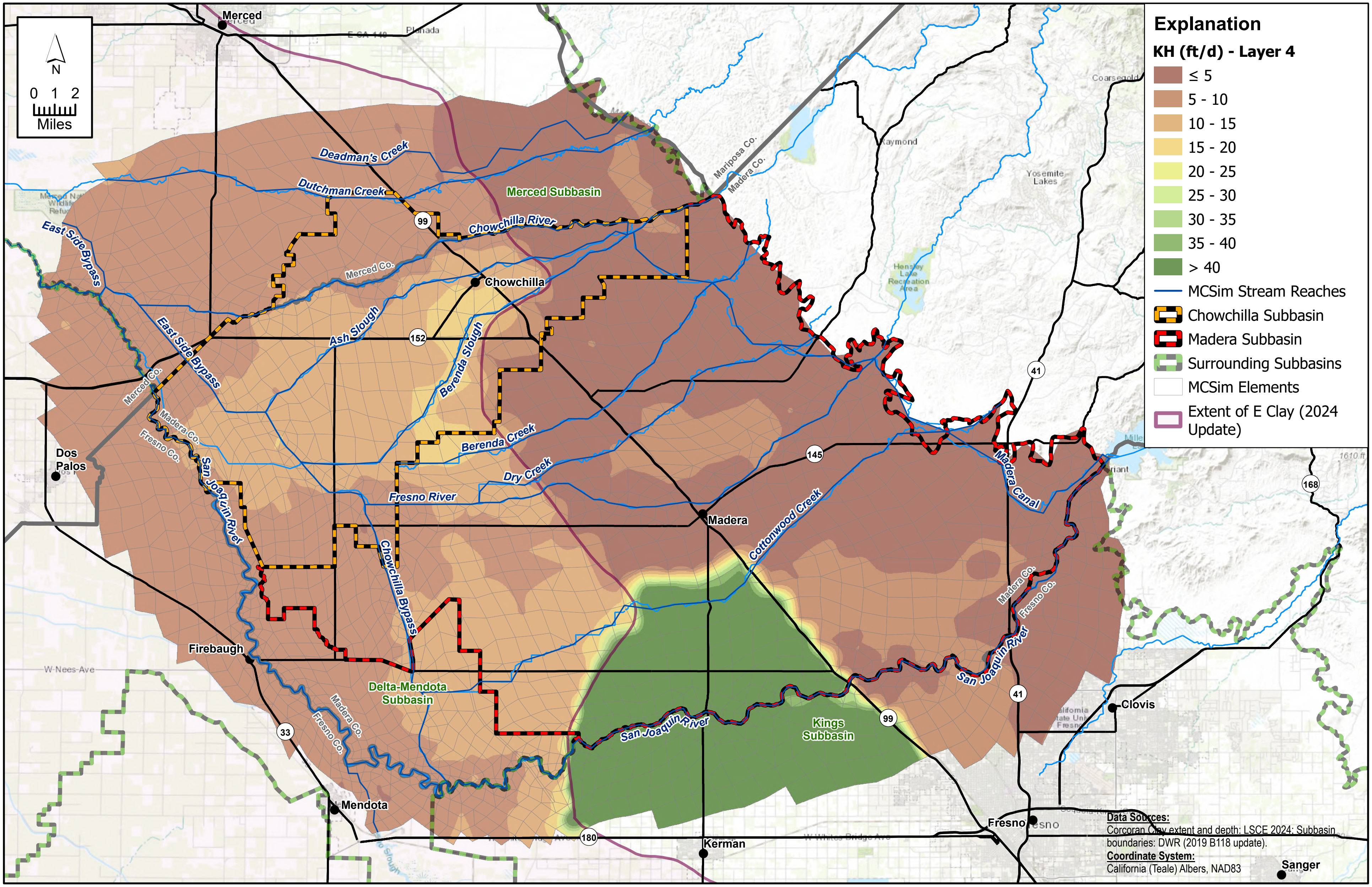
FIGURE 4-7

Calibrated Horizontal Hydraulic Conductivity (Kh) - Layer 3

Madera-Chowchilla Groundwater-Surface Water Simulation Model (MCSim) - First Model Update



X:\2024\24-010 (1) Davids Eng. - Madera Subbasin 5-Year GSP Update\MODEL\MCSim_v2_GIS_20231101\MCSim_v2_20231101.aprx; AQ_PARAM_KH

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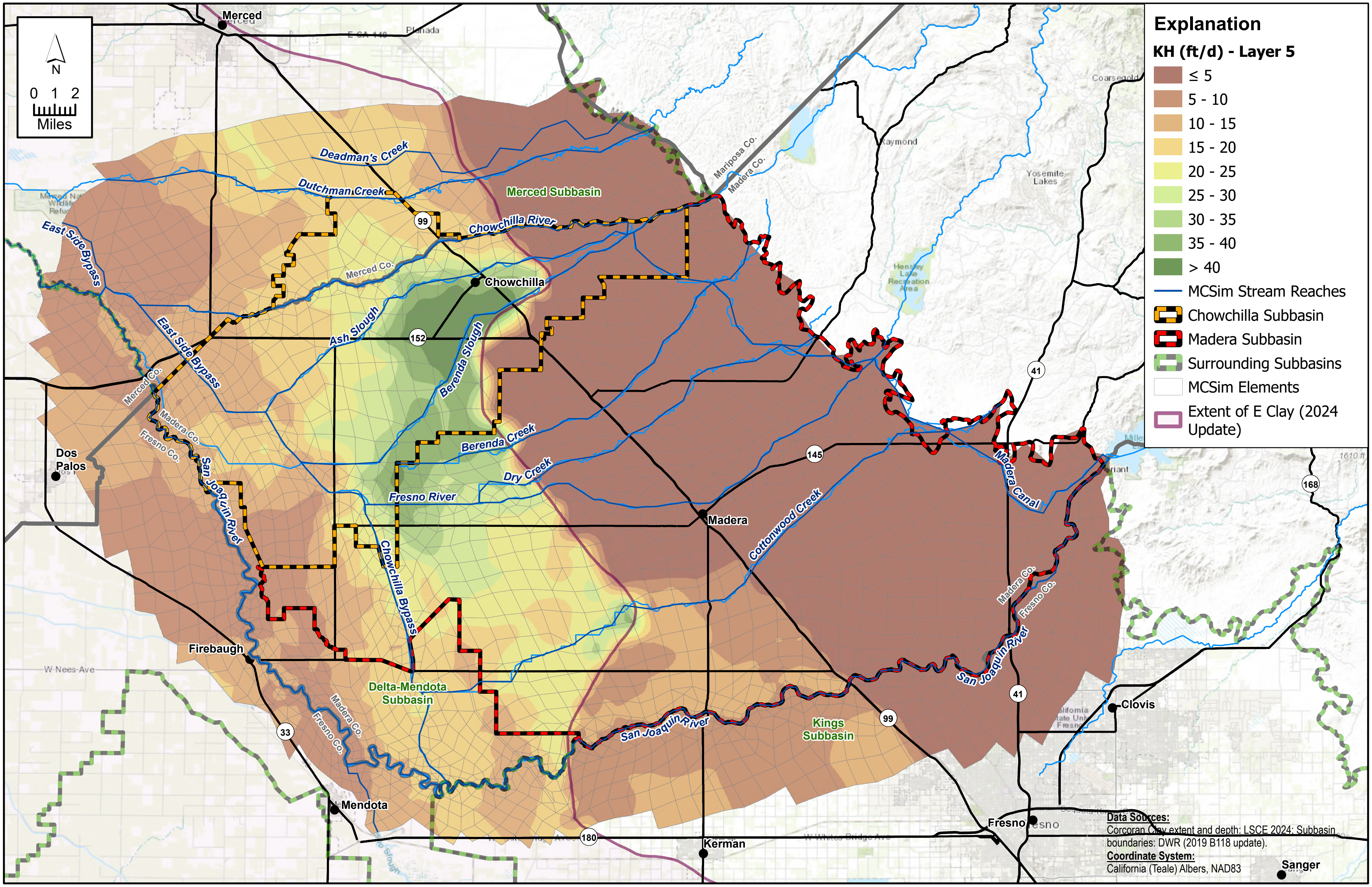
FIGURE 4-8

Calibrated Horizontal Hydraulic Conductivity (Kh) - Layer 4

Madera-Chowchilla Groundwater-Surface Water Simulation Model (MCSim) - First Model Update



X:\2024\24-010 (1) Davids Eng. - Madera Subbasin 5-Year GSP Update\MODEL\MCSim_v2_GIS_20231101\MCSim_v2_20231101.aprx; AQ_PARAM_KH

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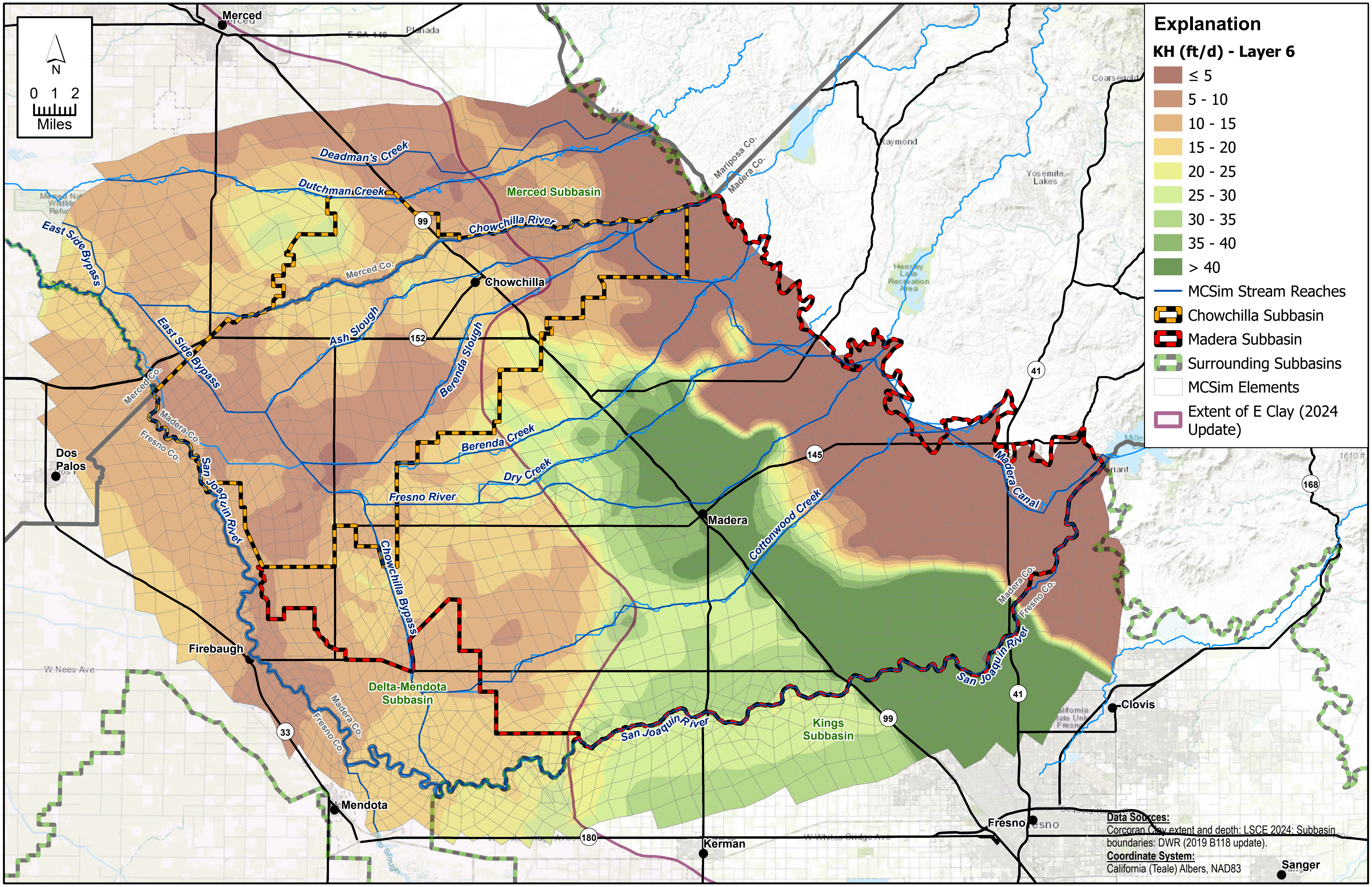
FIGURE 4-9

Calibrated Horizontal Hydraulic Conductivity (Kh) - Layer 5

Madera-Chowchilla Groundwater-Surface Water Simulation Model (MCSim) - First Model Update



X:\2024\24-010 (1) Davids Eng. - Madera Subbasin 5-Year GSP Update\MODEL\MCSim_v2_GIS_20231101\MCSim_v2_20231101.aprx; AQ_PARAM_KH

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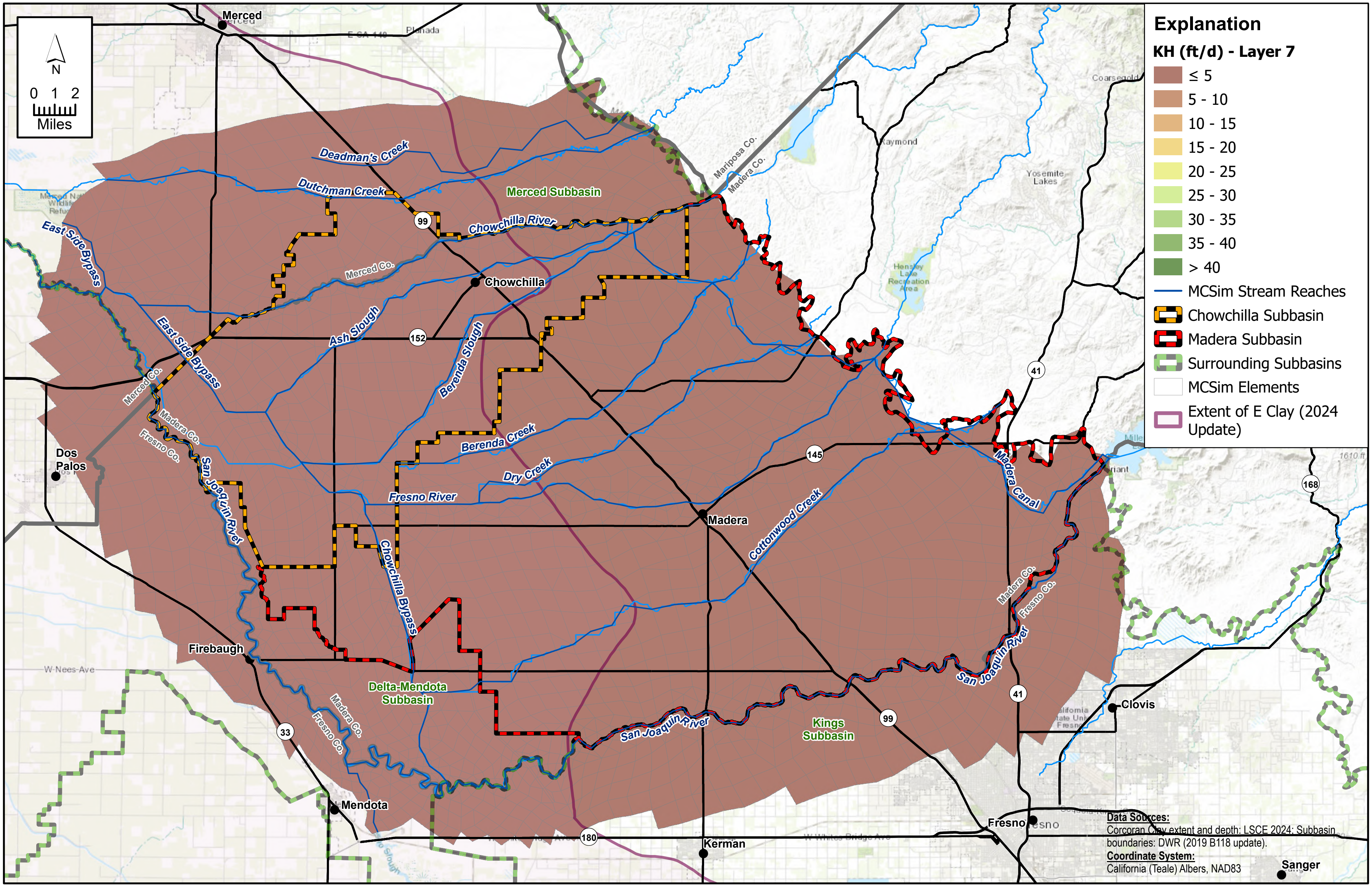
FIGURE 4-10

Calibrated Horizontal Hydraulic Conductivity (Kh) - Layer 6

Madera-Chowchilla Groundwater-Surface Water Simulation Model (MCSim) - First Model Update



X:\2024\24-010 (1) Davids Eng. - Madera Subbasin 5-Year GSP Update\MODEL\MCSim_v2_GIS_20231101\MCSim_v2_20231101.aprx; AQ_PARAM_KH

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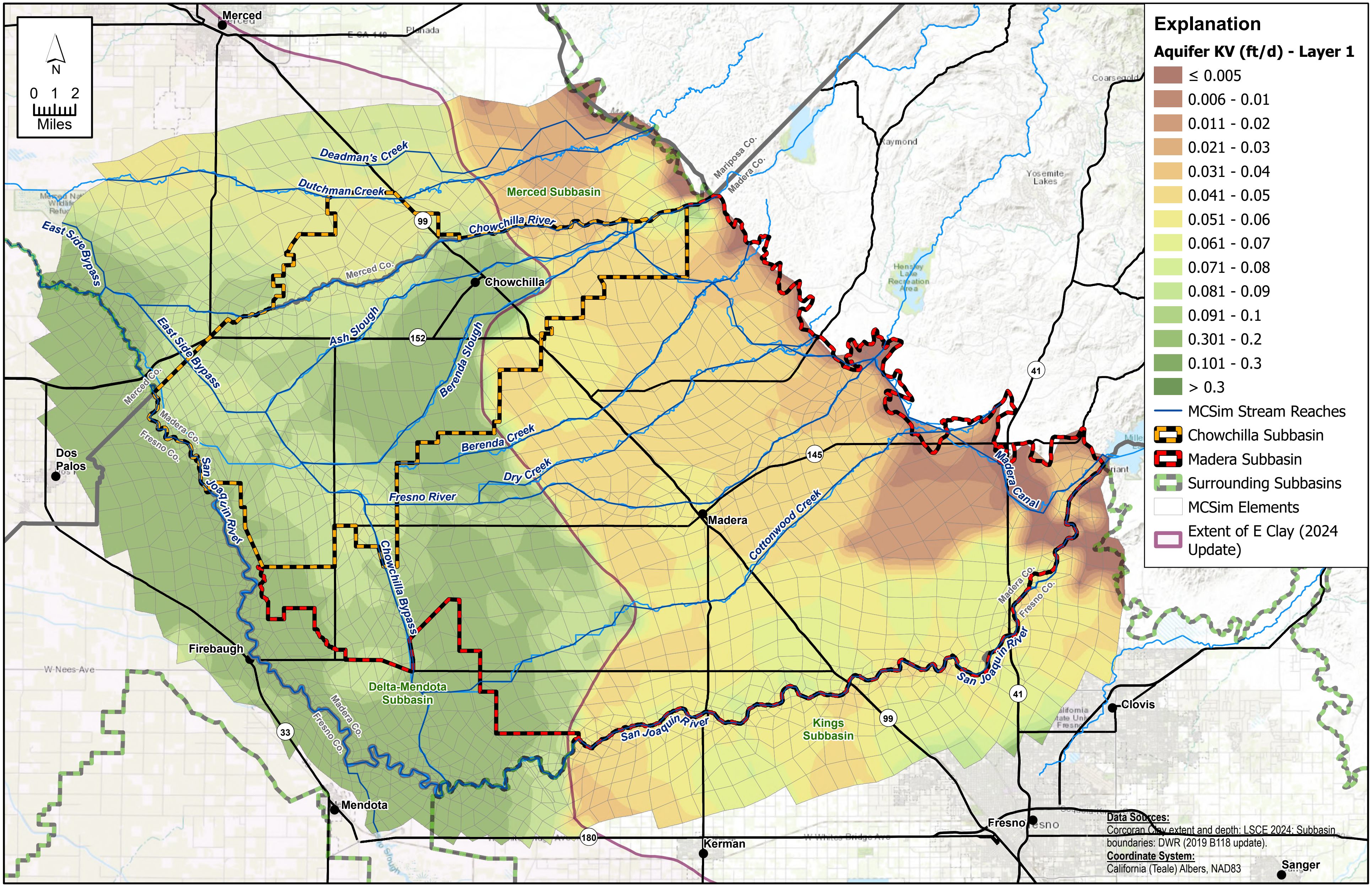
FIGURE 4-11

Calibrated Horizontal Hydraulic Conductivity (Kh) - Layer 7

Madera-Chowchilla Groundwater-Surface Water Simulation Model (MCSim) - First Model Update



X:\2024\24-010 (1) Davids Eng. - Madera Subbasin 5-Year GSP Update\MODEL\MCSim_v2_GIS_20231101\MCSim_v2_20231101.aprx; AQ_PARAM_AQFR_KV

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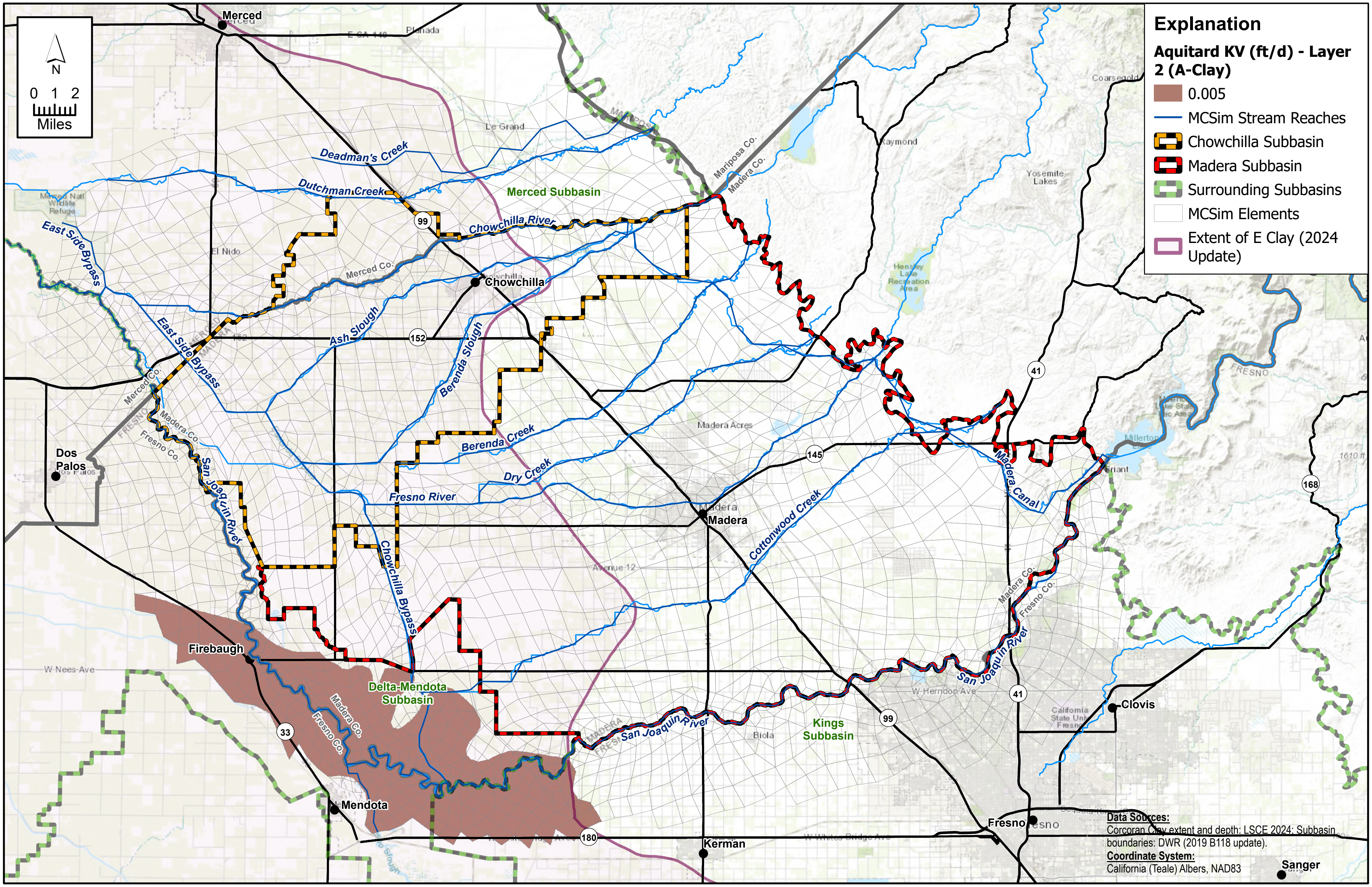
FIGURE 4-12

Calibrated Vertical Hydraulic Conductivity (Kv) - Layer 1

Madera-Chowchilla Groundwater-Surface Water Simulation Model (MCSim) - First Model Update



X:\2024\24-010 (1) Davids Eng. - Madera Subbasin 5-Year GSP Update\MODEL\MCSim_v2_GIS_20231101\MCSim_v2_20231101.aprx; AQ_PARAM_AQTD_KV

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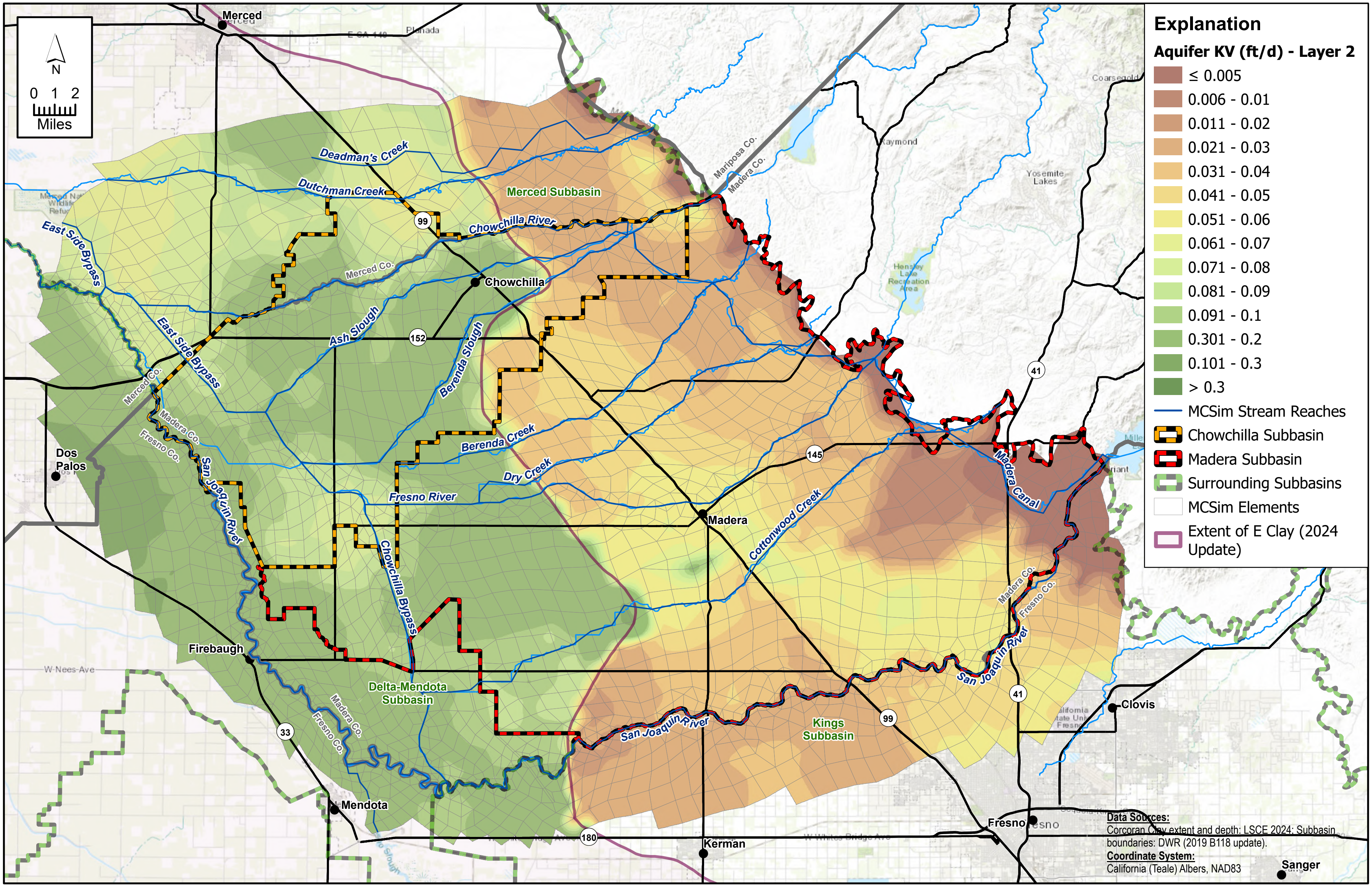
FIGURE 4-13

Calibrated Vertical Hydraulic Conductivity (Kv) - Layer 2 Aquitard

Madera-Chowchilla Groundwater-Surface Water Simulation Model (MCSim) - First Model Update



X:\2024\24-010 (1) Davids Eng. - Madera Subbasin 5-Year GSP Update\MODEL\MCSim_v2_GIS_20231101\MCSim_v2_20231101.aprx; AQ_PARAM_AQFR_KV

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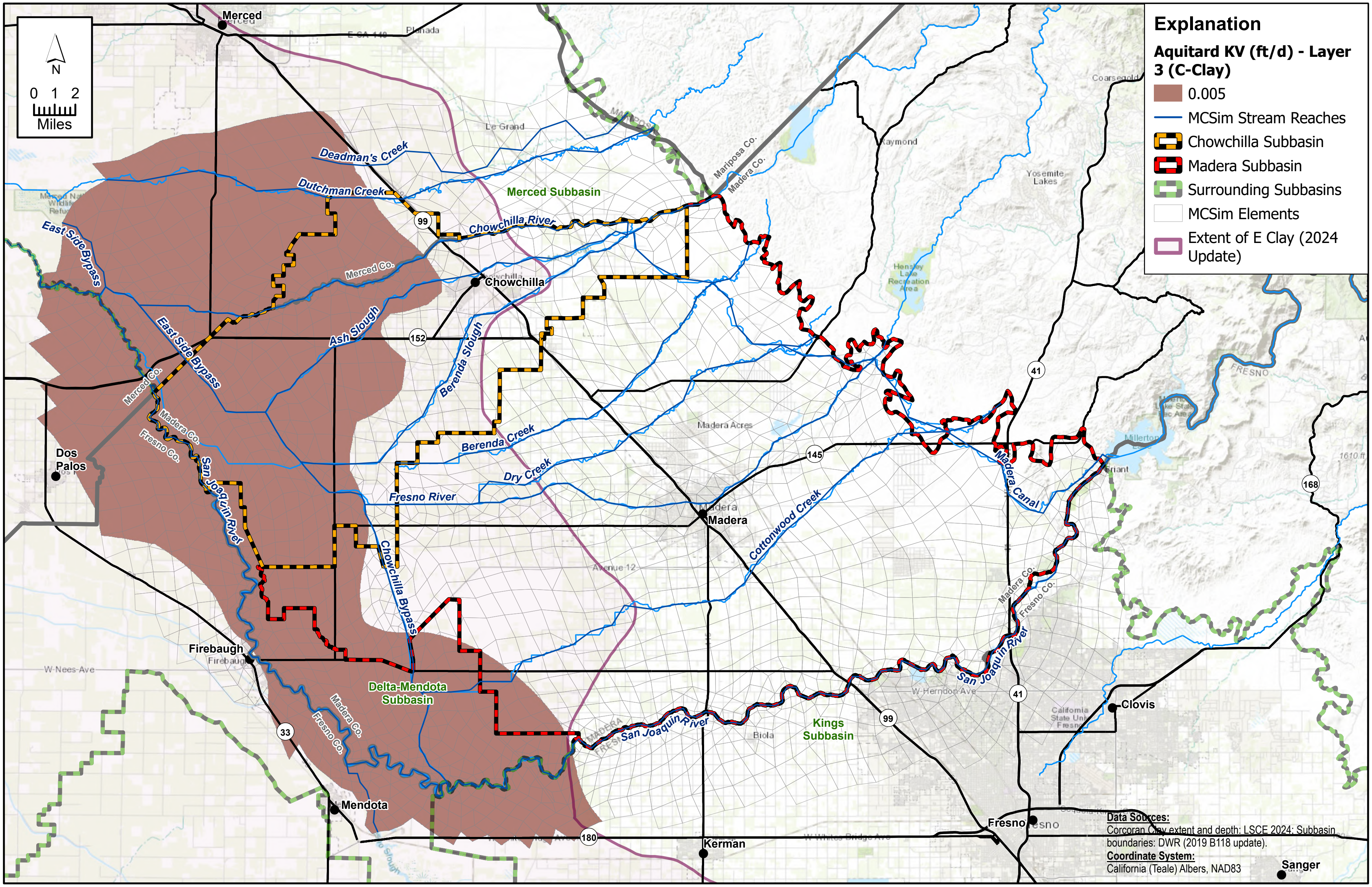
FIGURE 4-14

Calibrated Vertical Hydraulic Conductivity (Kv) - Layer 2

Madera-Chowchilla Groundwater-Surface Water Simulation Model (MCSim) - First Model Update



X:\2024\24-010 (1) Davids Eng. - Madera Subbasin 5-Year GSP Update\MODEL\MCSim_v2_GIS_20231101\MCSim_v2_20231101.aprx; AQ_PARAM_AQTD_KV

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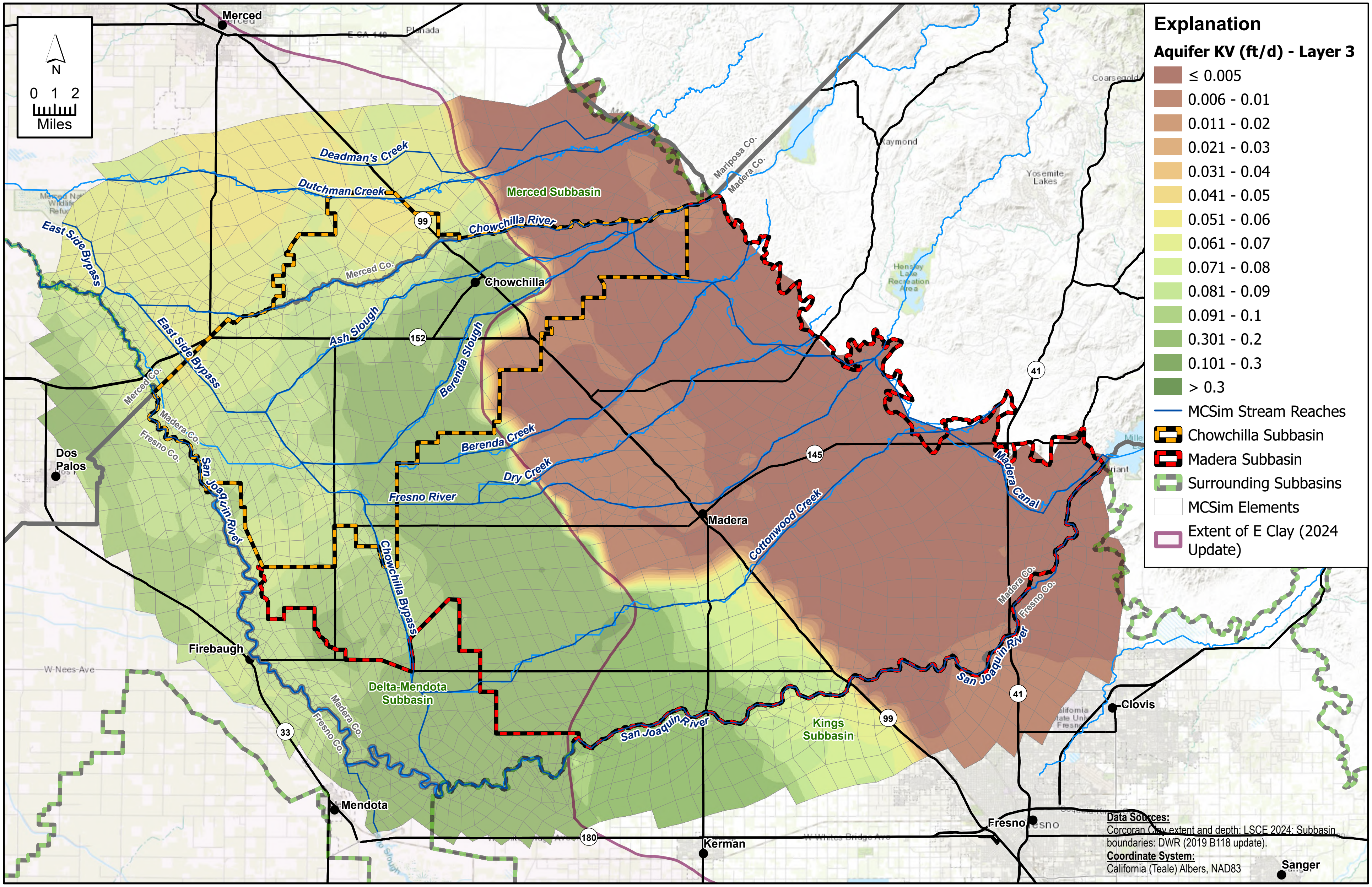
FIGURE 4-15

Calibrated Vertical Hydraulic Conductivity (Kv) - Layer 3 Aquitard

Madera-Chowchilla Groundwater-Surface Water Simulation Model (MCSim) - First Model Update



X:\2024\24-010 (1) Davids Eng. - Madera Subbasin 5-Year GSP Update\MODEL\MCSim_v2_GIS_20231101\MCSim_v2_20231101.aprx; AQ_PARAM_AQFR_KV

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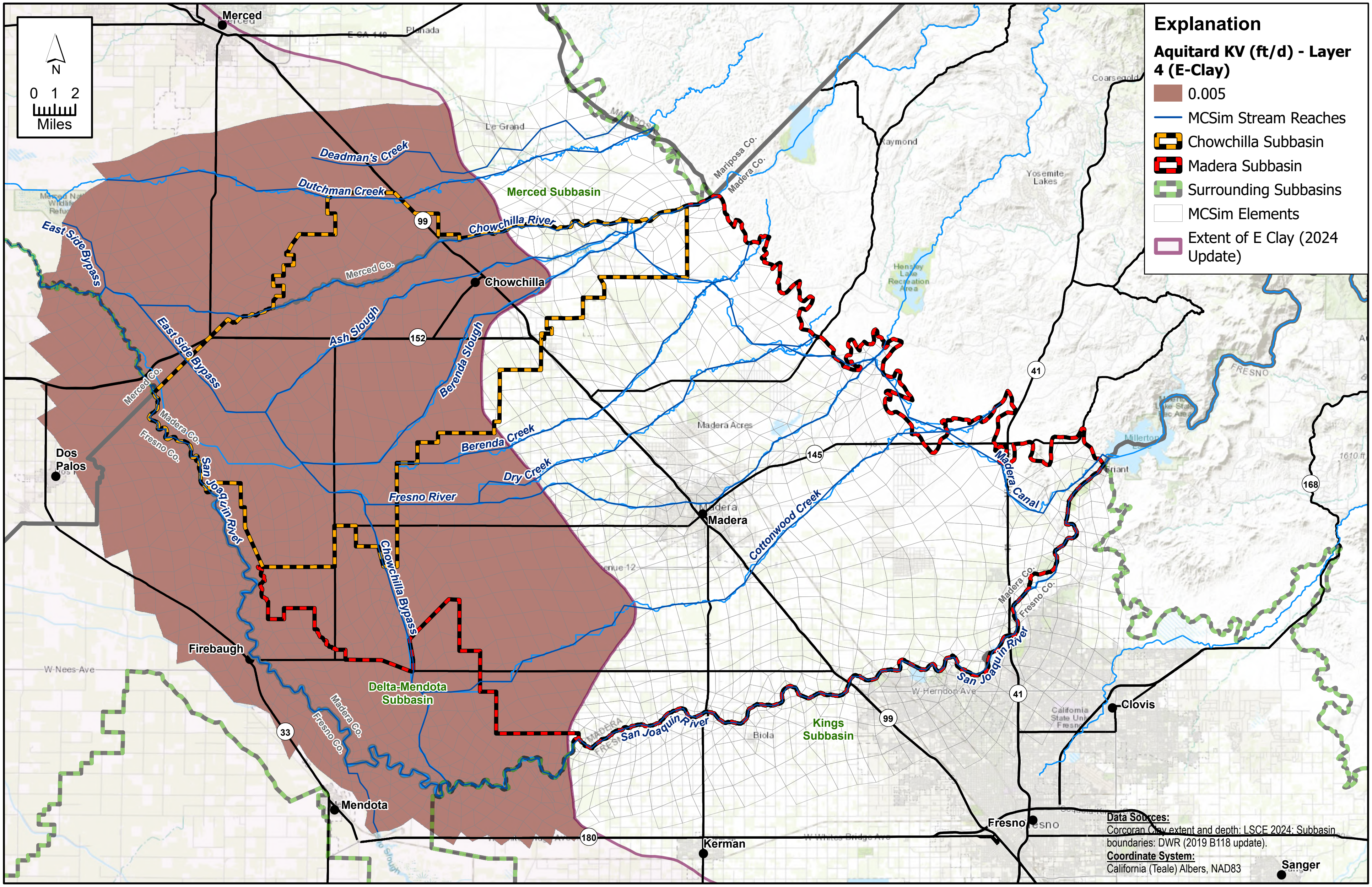
FIGURE 4-16

Calibrated Vertical Hydraulic Conductivity (Kv) - Layer 3

Madera-Chowchilla Groundwater-Surface Water Simulation Model (MCSim) - First Model Update



X:\2024\24-010 (1) Davids Eng. - Madera Subbasin 5-Year GSP Update\MODEL\MCSim_v2_GIS_20231101\MCSim_v2_20231101.aprx; AQ_PARAM_AQTD_KV

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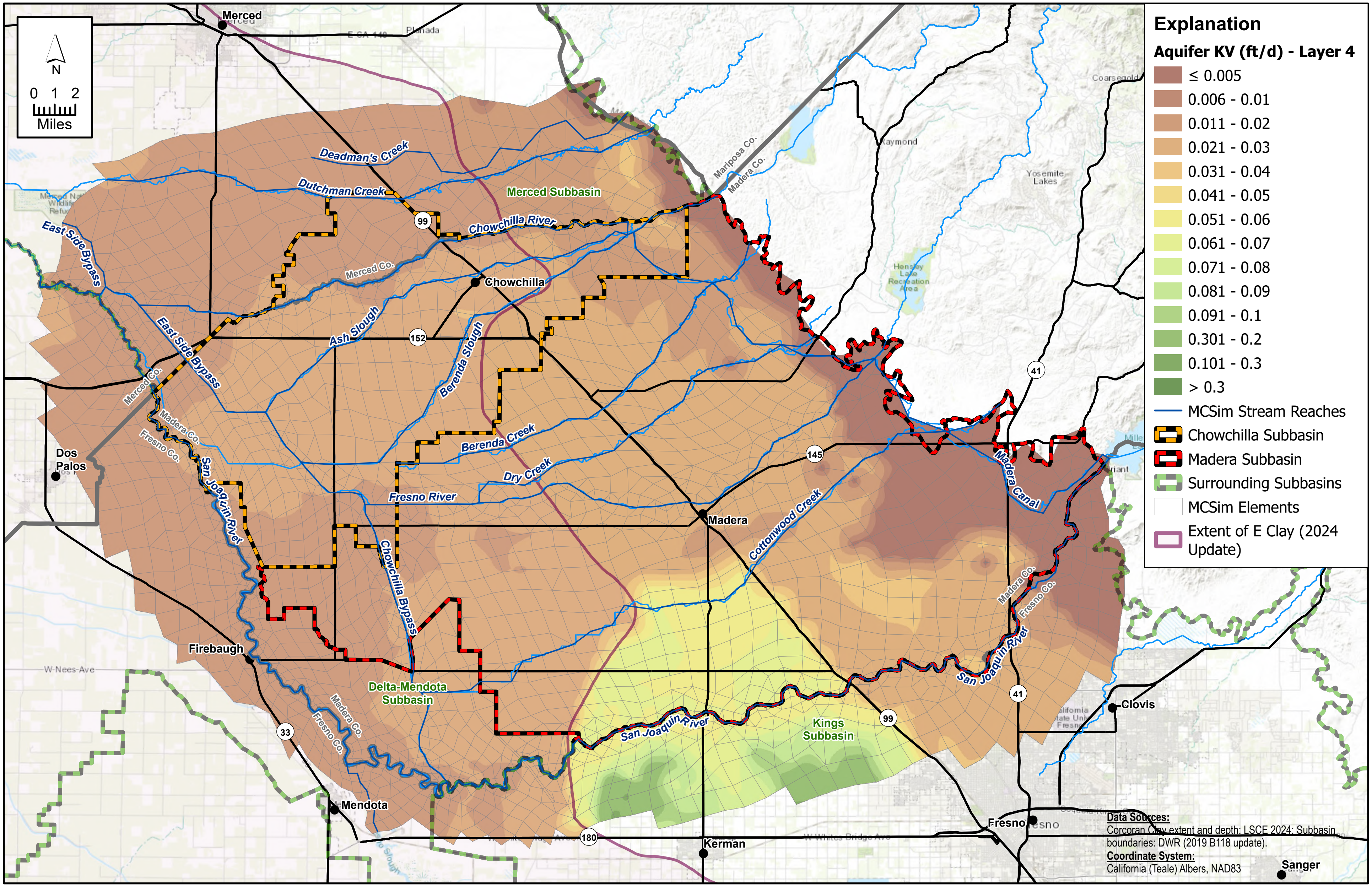
FIGURE 4-17

Calibrated Vertical Hydraulic Conductivity (Kv) - Layer 4 Aquitard

Madera-Chowchilla Groundwater-Surface Water Simulation Model (MCSim) - First Model Update



X:\2024\24-010 (1) Davids Eng. - Madera Subbasin 5-Year GSP Update\MODEL\MCSim_v2_GIS_20231101\MCSim_v2_20231101.aprx; AQ_PARAM_AQFR_KV

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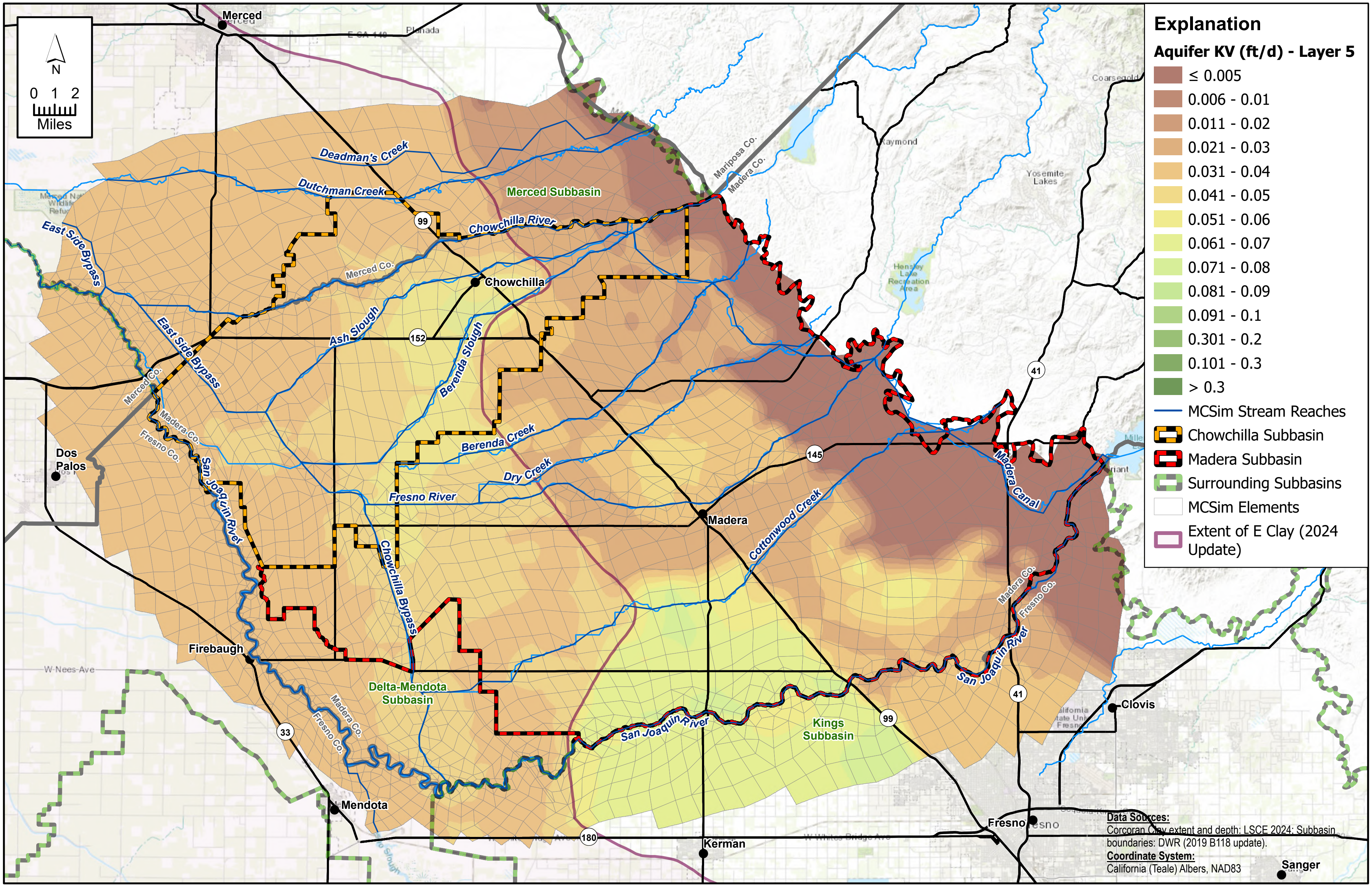
FIGURE 4-18

Calibrated Vertical Hydraulic Conductivity (Kv) - Layer 4

Madera-Chowchilla Groundwater-Surface Water Simulation Model (MCSim) - First Model Update



X:\2024\24-010 (1) Davids Eng. - Madera Subbasin 5-Year GSP Update\MODEL\MCSim_v2_GIS_20231101\MCSim_v2_20231101.aprx; AQ_PARAM_AQFR_KV

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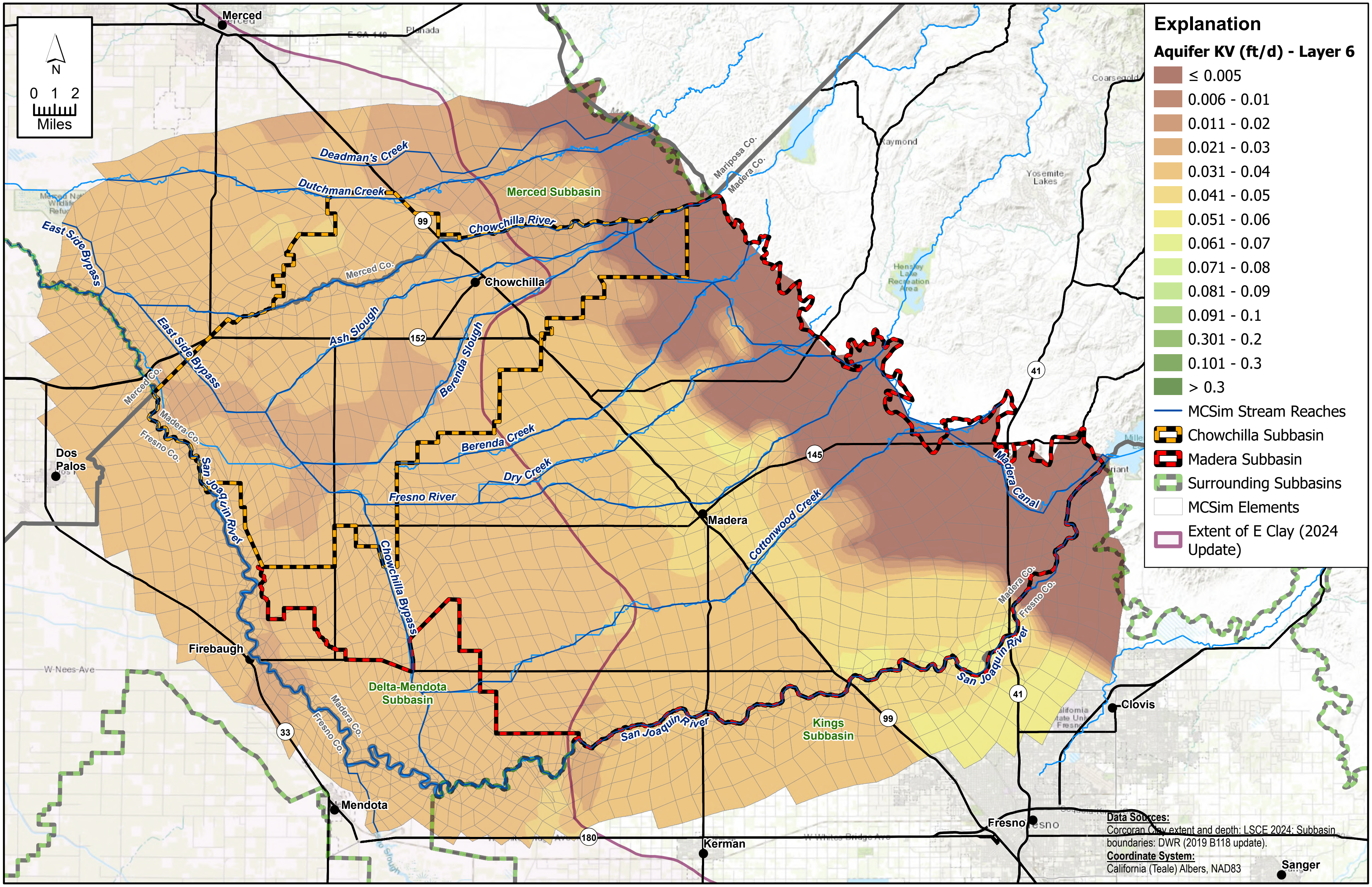
FIGURE 4-19

Calibrated Vertical Hydraulic Conductivity (Kv) - Layer 5

Madera-Chowchilla Groundwater-Surface Water Simulation Model (MCSim) - First Model Update



X:\2024\24-010 (1) Davids Eng. - Madera Subbasin 5-Year GSP Update\MODEL\MCSim_v2_GIS_20231101\MCSim_v2_20231101.aprx; AQ_PARAM_AQFR_KV

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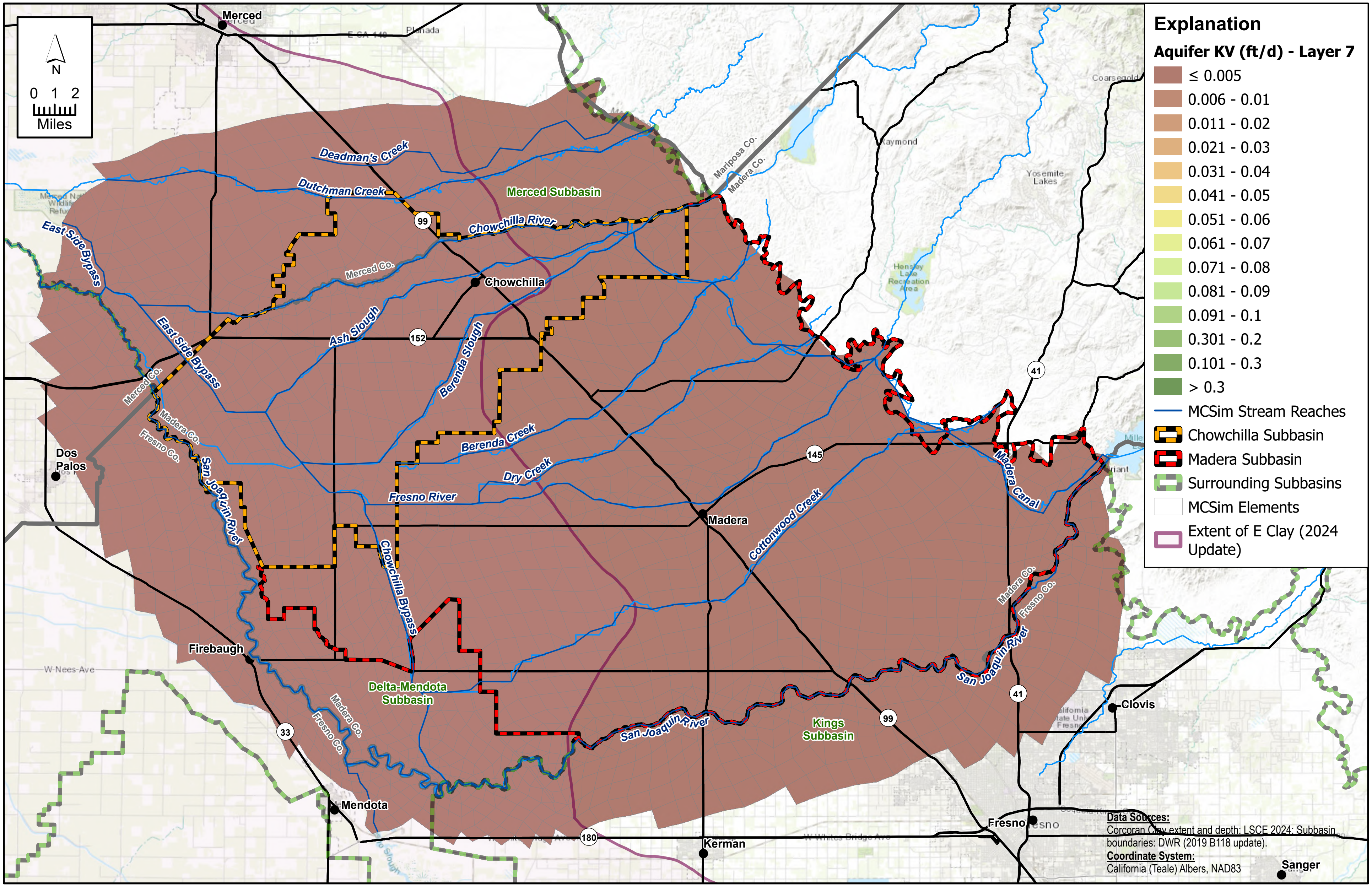
FIGURE 4-20

Calibrated Vertical Hydraulic Conductivity (Kv) - Layer 6

Madera-Chowchilla Groundwater-Surface Water Simulation Model (MCSim) - First Model Update



X:\2024\24-010 (1) Davids Eng. - Madera Subbasin 5-Year GSP Update\MODEL\MCSim_v2_GIS_20231101\MCSim_v2_20231101.aprx; AQ_PARAM_AQFR_KV

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FIGURE 4-21

Calibrated Vertical Hydraulic Conductivity (Kv) - Layer 7

Madera-Chowchilla Groundwater-Surface Water Simulation Model (MCSim) - First Model Update

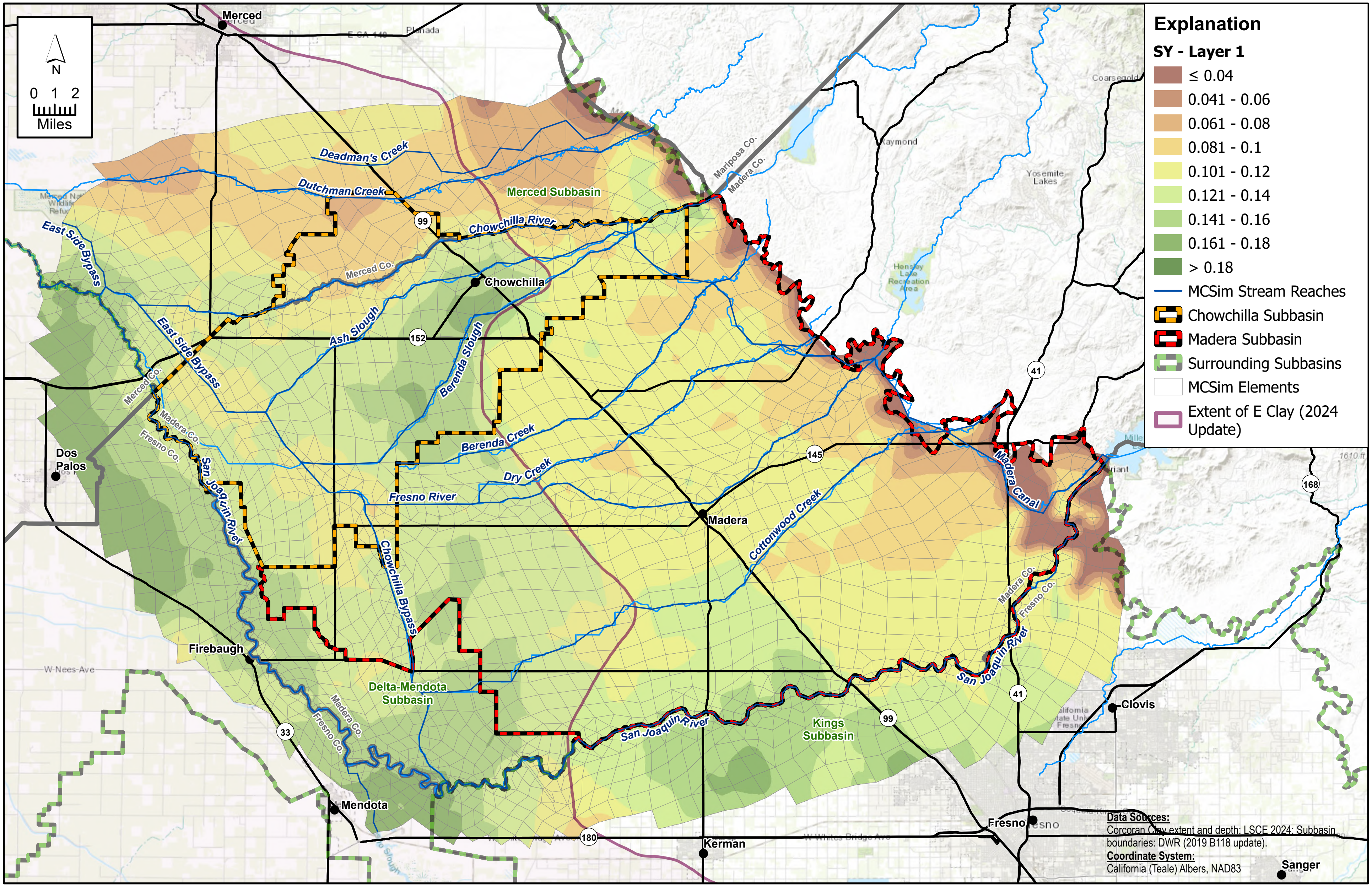

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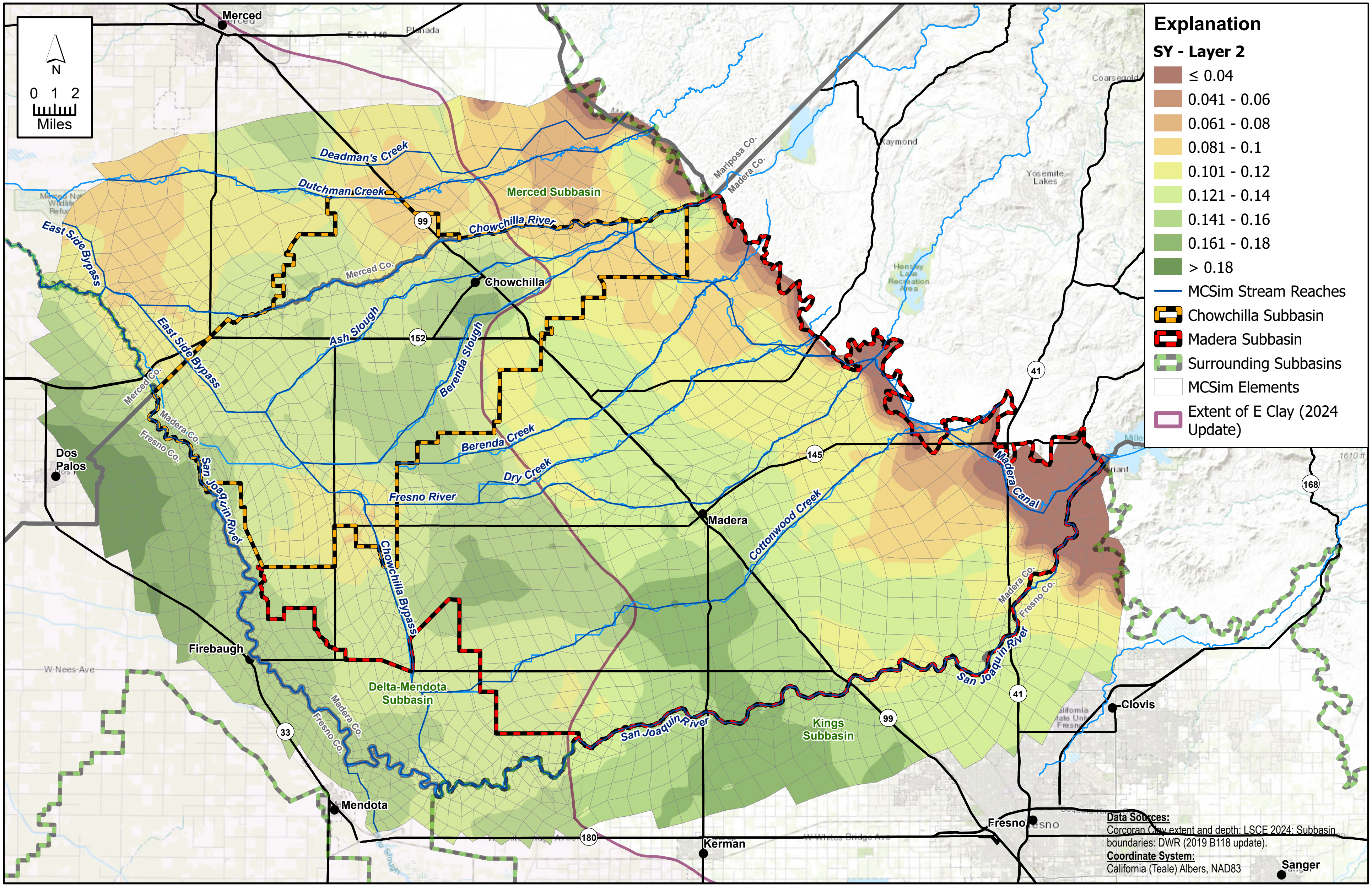
FIGURE 4-22

Calibrated Specific Yield (Sy) - Layer 1

Madera-Chowchilla Groundwater-Surface Water Simulation Model (MCSim) - First Model Update



X:\2024\24-010 (1) Davids Eng. - Madera Subbasin 5-Year GSP Update\MODEL\MCSim_v2_GIS_20231101\MCSim_v2_20231101.aprx; AQ_PARAM_SY

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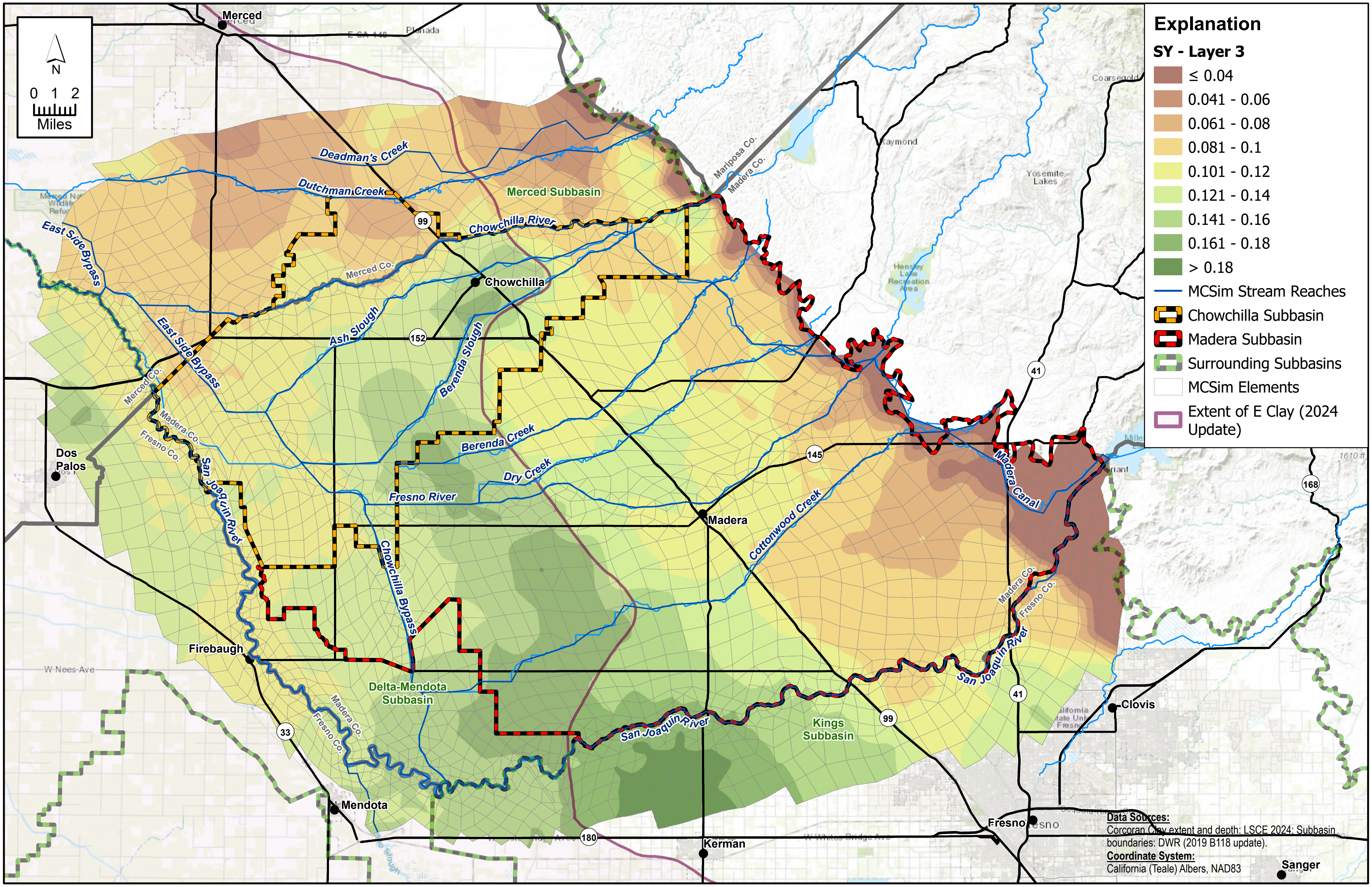
FIGURE 4-23

Calibrated Specific Yield (Sy) - Layer 2

Madera-Chowchilla Groundwater-Surface Water Simulation Model (MCSim) - First Model Update



X:\2024\24-010 (1) Davids Eng. - Madera Subbasin 5-Year GSP Update\MODEL\MCSim_v2_GIS_20231101\MCSim_v2_20231101.aprx; AQ_PARAM_SY

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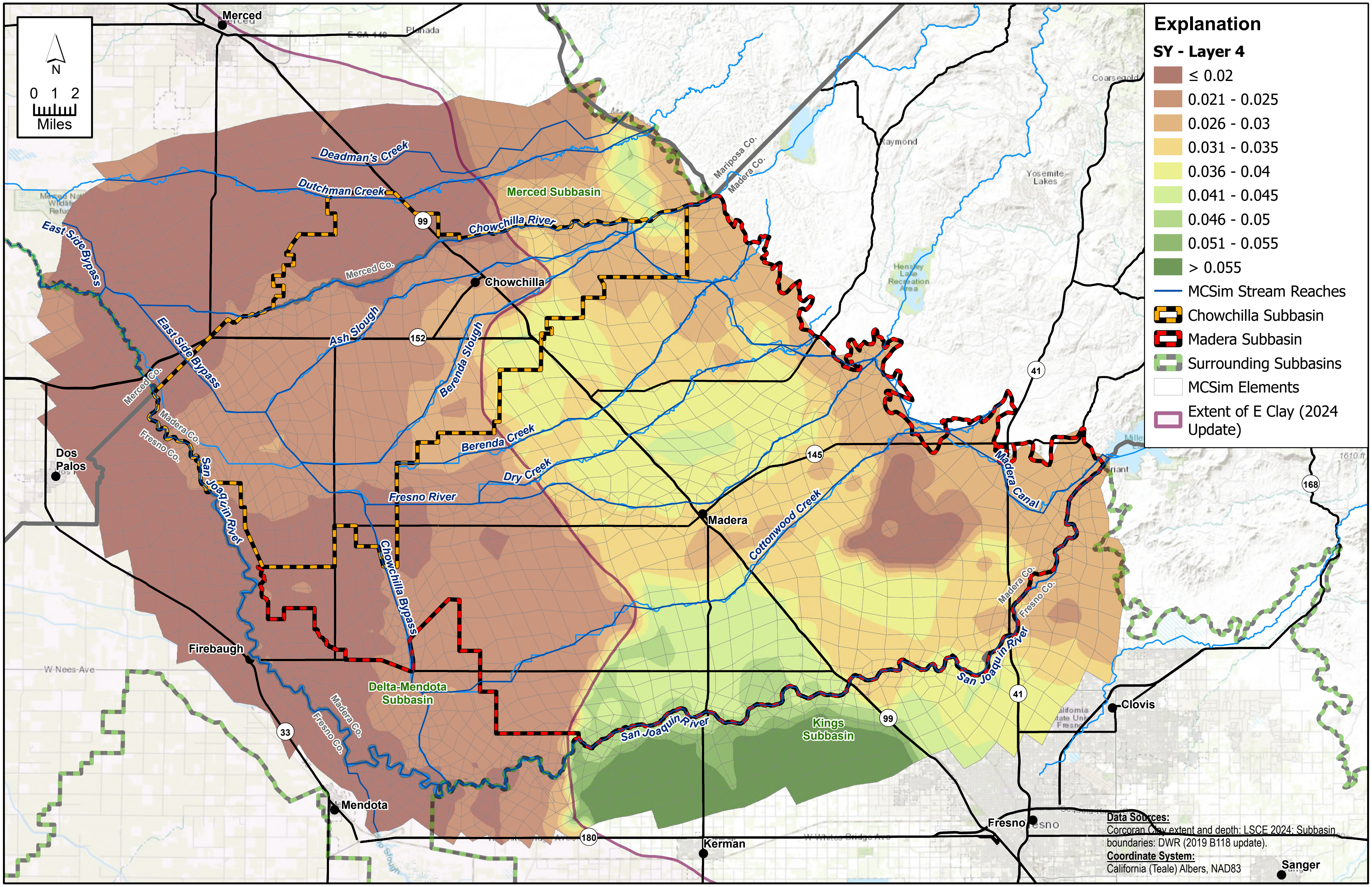
FIGURE 4-24

Calibrated Specific Yield (Sy) - Layer 3

Madera-Chowchilla Groundwater-Surface Water Simulation Model (MCSim) - First Model Update



X:\2024\24-010 (1) Davids Eng. - Madera Subbasin 5-Year GSP Update\MODEL\MCSim_v2_GIS_20231101\MCSim_v2_20231101.aprx; AQ_PARAM_SY

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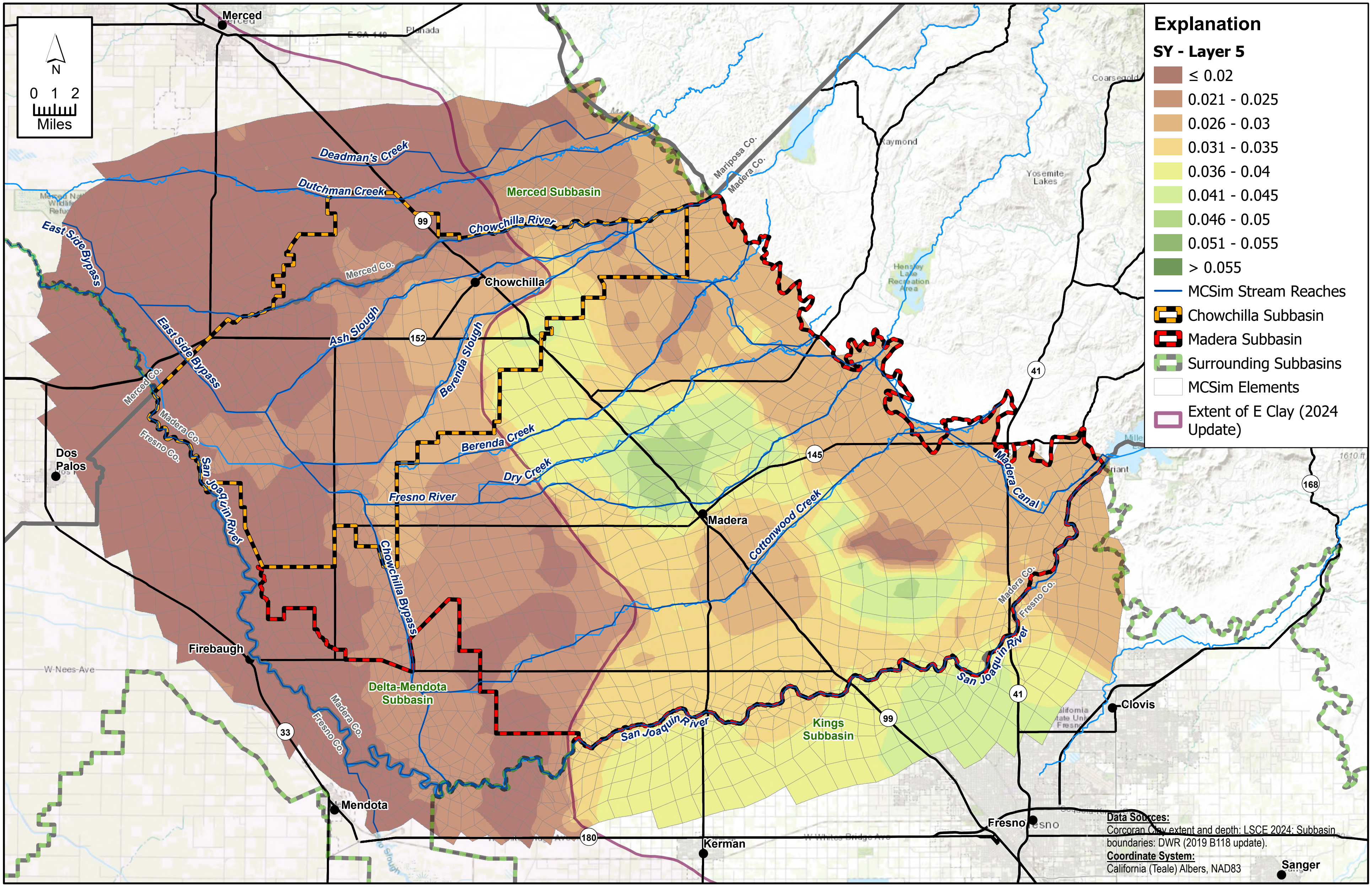
FIGURE 4-25

Calibrated Specific Yield (Sy) - Layer 4

Madera-Chowchilla Groundwater-Surface Water Simulation Model (MCSim) - First Model Update



X:\2024\24-010 (1) Davids Eng. - Madera Subbasin 5-Year GSP Update\MODEL\MCSim_v2_GIS_20231101\MCSim_v2_20231101.aprx; AQ_PARAM_SY

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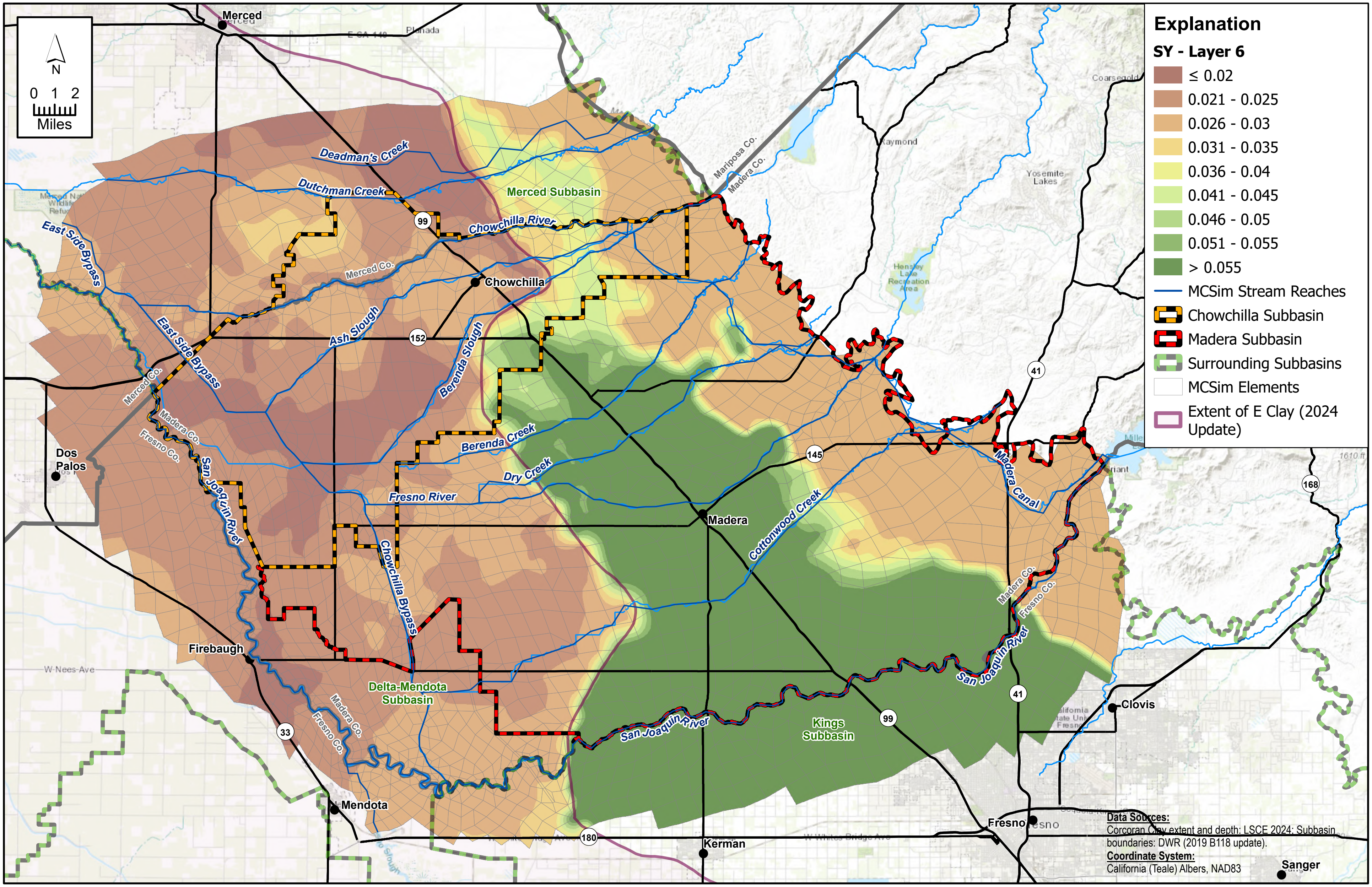
FIGURE 4-26

Calibrated Specific Yield (Sy) - Layer 5

Madera-Chowchilla Groundwater-Surface Water Simulation Model (MCSim) - First Model Update



X:\2024\24-010 (1) Davids Eng. - Madera Subbasin 5-Year GSP Update\MODEL\MCSim_v2_GIS_20231101\MCSim_v2_20231101.aprx; AQ_PARAM_SY

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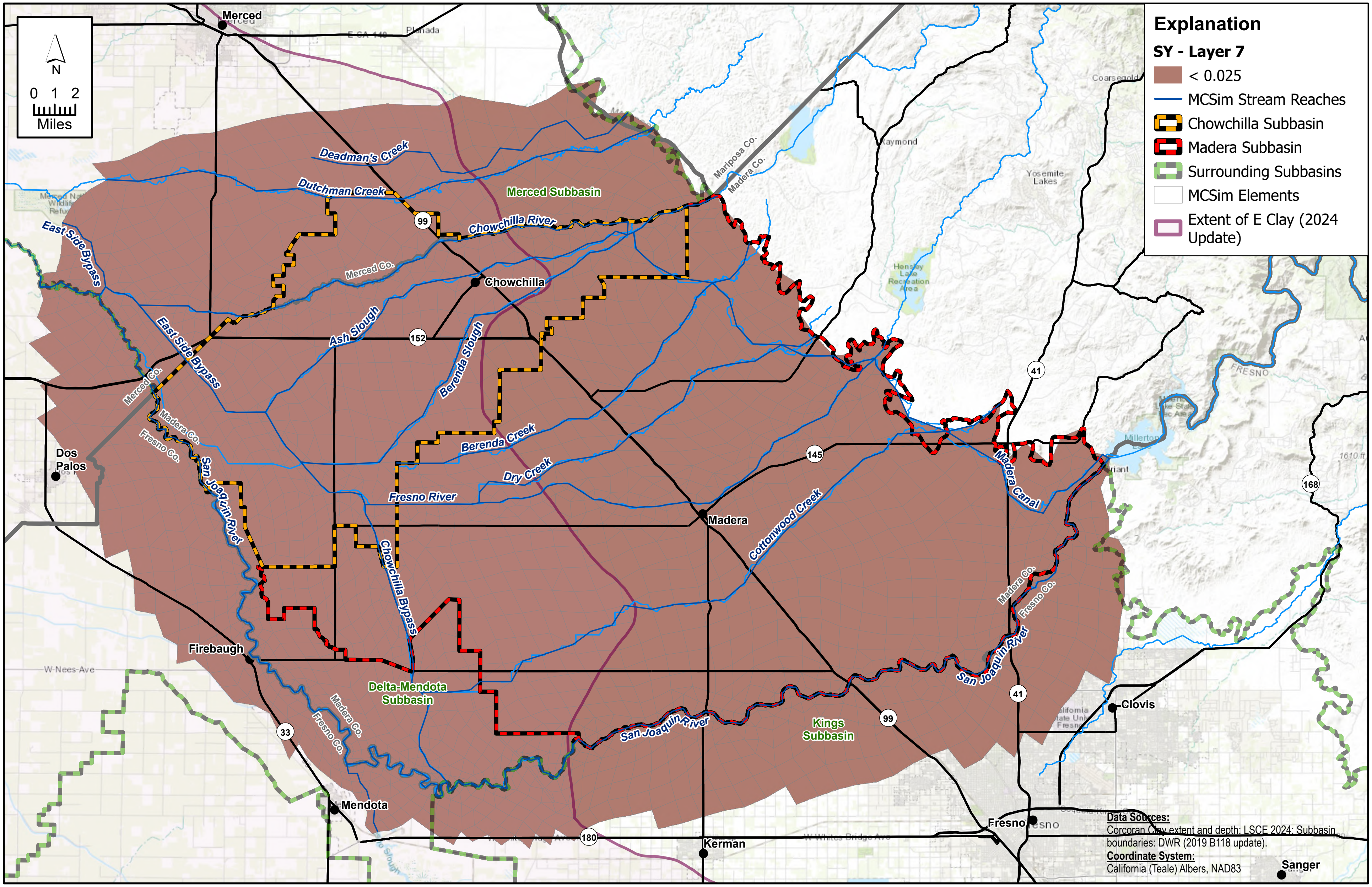
FIGURE 4-27

Calibrated Specific Yield (Sy) - Layer 6

Madera-Chowchilla Groundwater-Surface Water Simulation Model (MCSim) - First Model Update



X:\2024\24-010 (1) Davids Eng. - Madera Subbasin 5-Year GSP Update\MODEL\MCSim_v2_GIS_20231101\MCSim_v2_20231101.aprx; AQ_PARAM_SY

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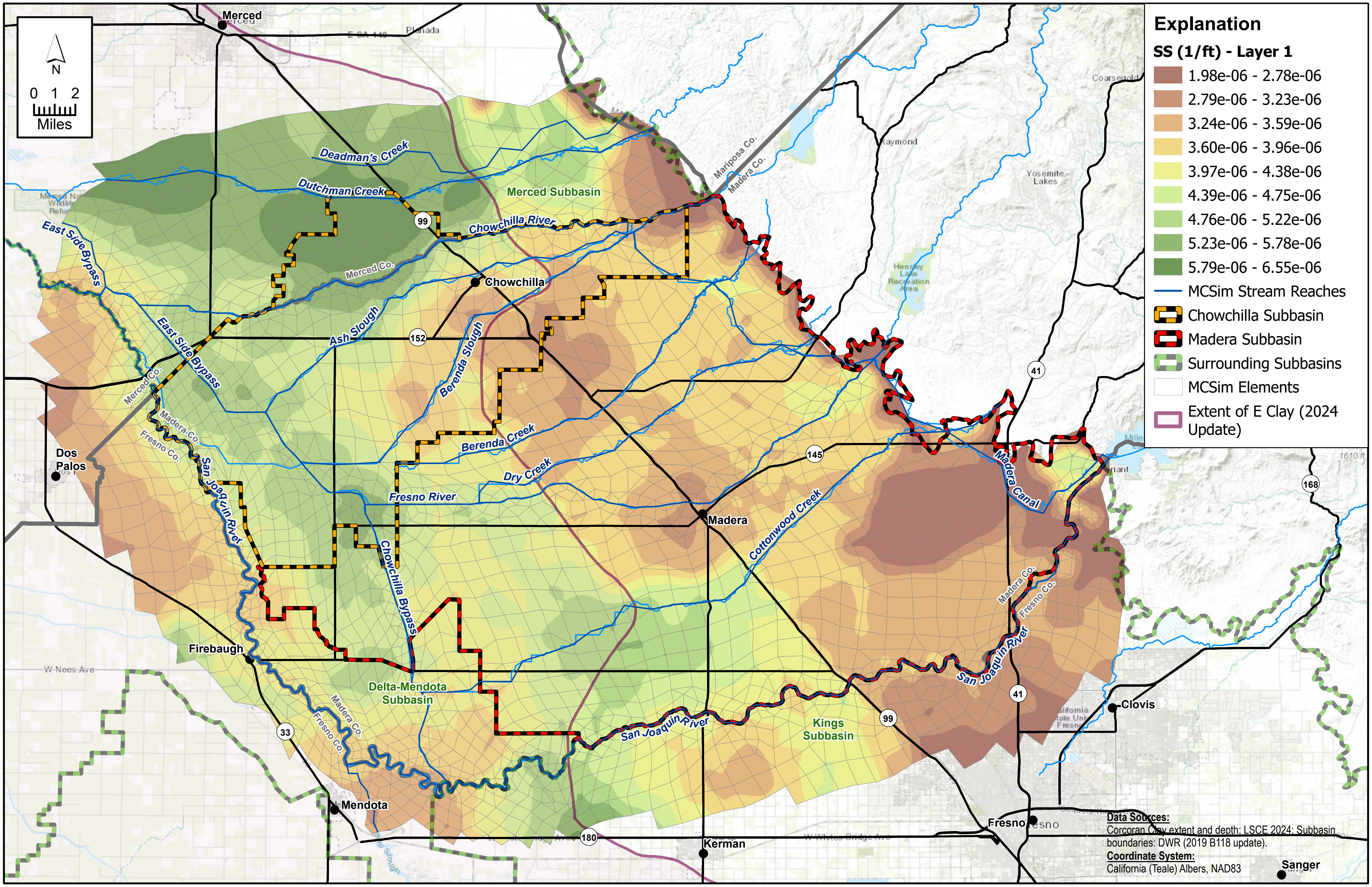
FIGURE 4-28

Calibrated Specific Yield (Sy) - Layer 7

Madera-Chowchilla Groundwater-Surface Water Simulation Model (MCSim) - First Model Update



X:\2024\24-010 (1) Davids Eng. - Madera Subbasin 5-Year GSP Update\MODEL\MCSim_v2_GIS_20231101\MCSim_v2_20231101.aprx; AQ_PARAM_SS

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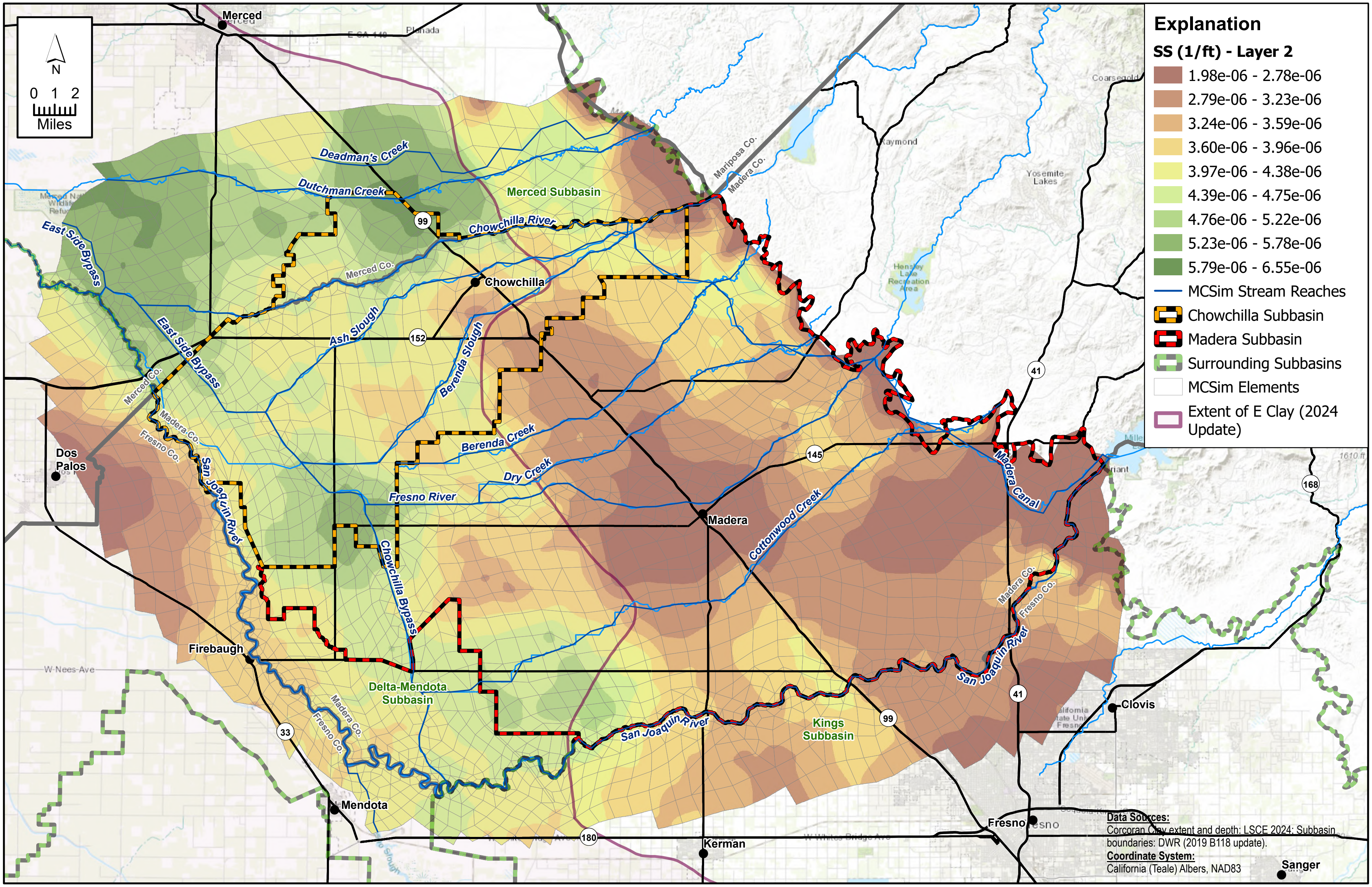
FIGURE 4-29

Calibrated Specific Storage (SS) - Layer 1

Madera-Chowchilla Groundwater-Surface Water Simulation Model (MCSim) - First Model Update



X:\2024\24-010 (1) Davids Eng. - Madera Subbasin 5-Year GSP Update\MODEL\MCSim_v2_GIS_20231101\MCSim_v2_20231101.aprx; AQ_PARAM_SS

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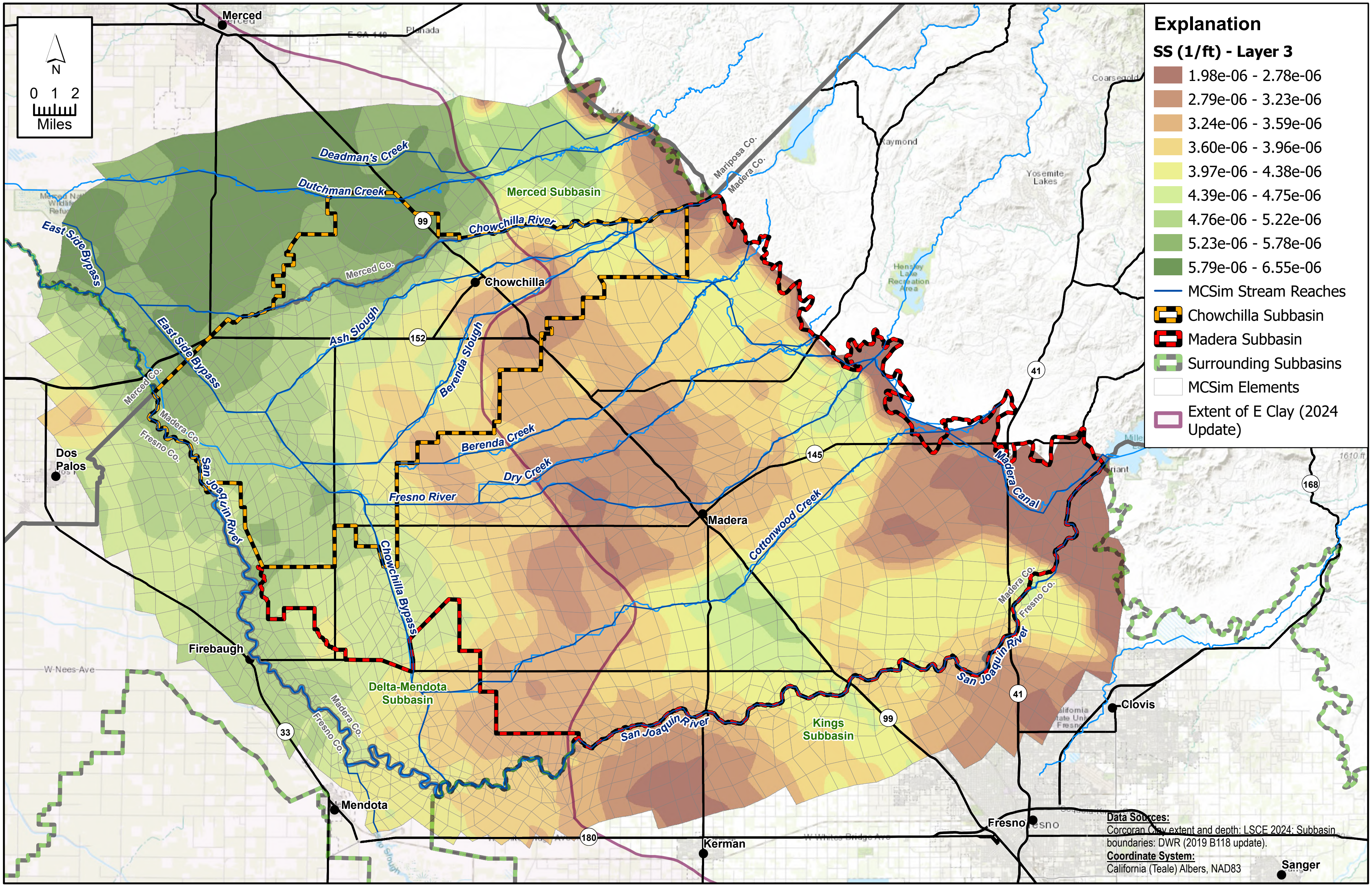
FIGURE 4-30

Calibrated Specific Storage (SS) - Layer 2

Madera-Chowchilla Groundwater-Surface Water Simulation Model (MCSim) - First Model Update



X:\2024\24-010 (1) Davids Eng. - Madera Subbasin 5-Year GSP Update\MODEL\MCSim_v2_GIS_20231101\MCSim_v2_20231101.aprx; AQ_PARAM_SS

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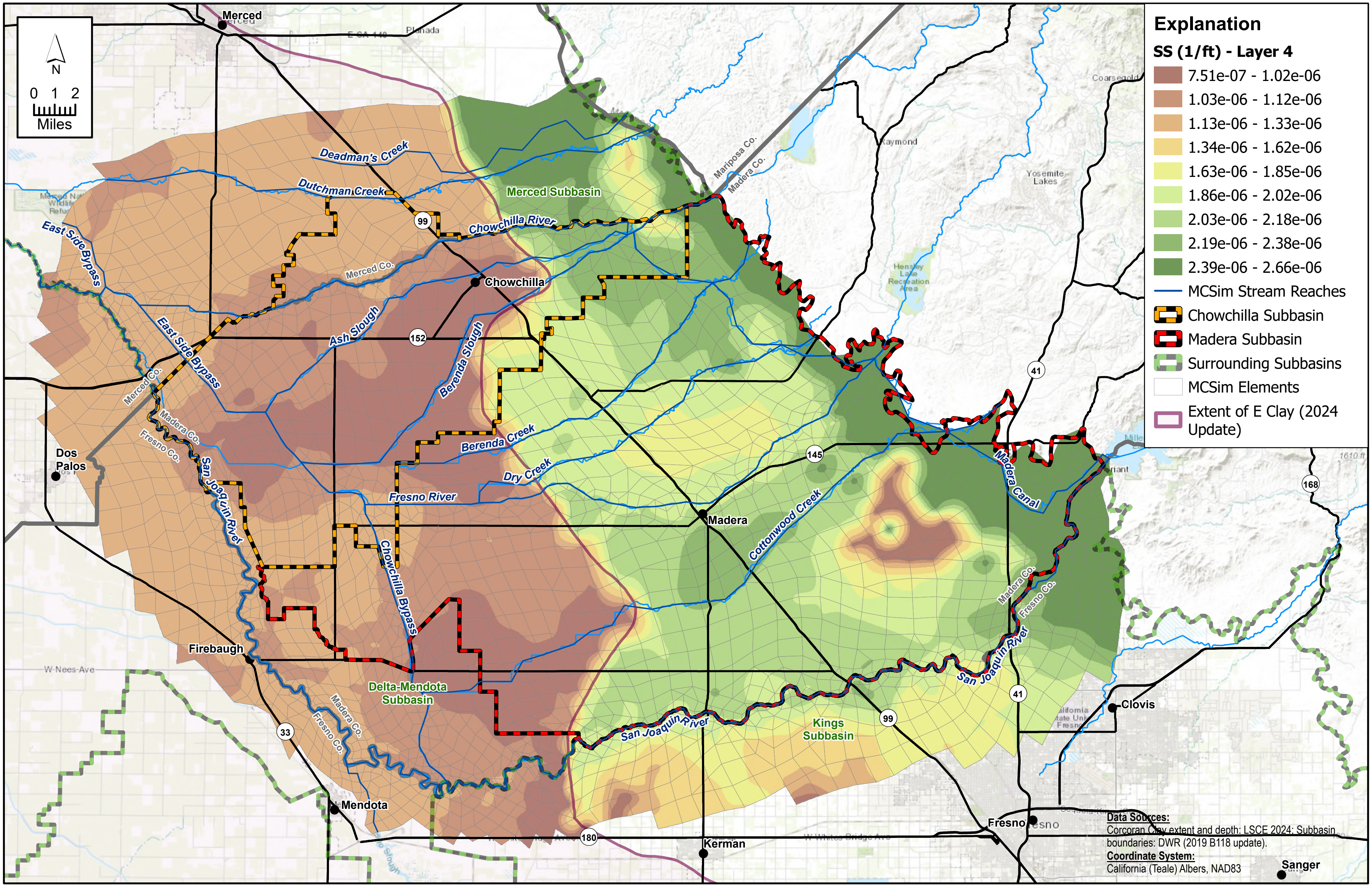
FIGURE 4-31

Calibrated Specific Storage (SS) - Layer 3

Madera-Chowchilla Groundwater-Surface Water Simulation Model (MCSim) - First Model Update



X:\2024\24-010 (1) Davids Eng. - Madera Subbasin 5-Year GSP Update\MODEL\MCSim_v2_GIS_20231101\MCSim_v2_20231101.aprx; AQ_PARAM_SS

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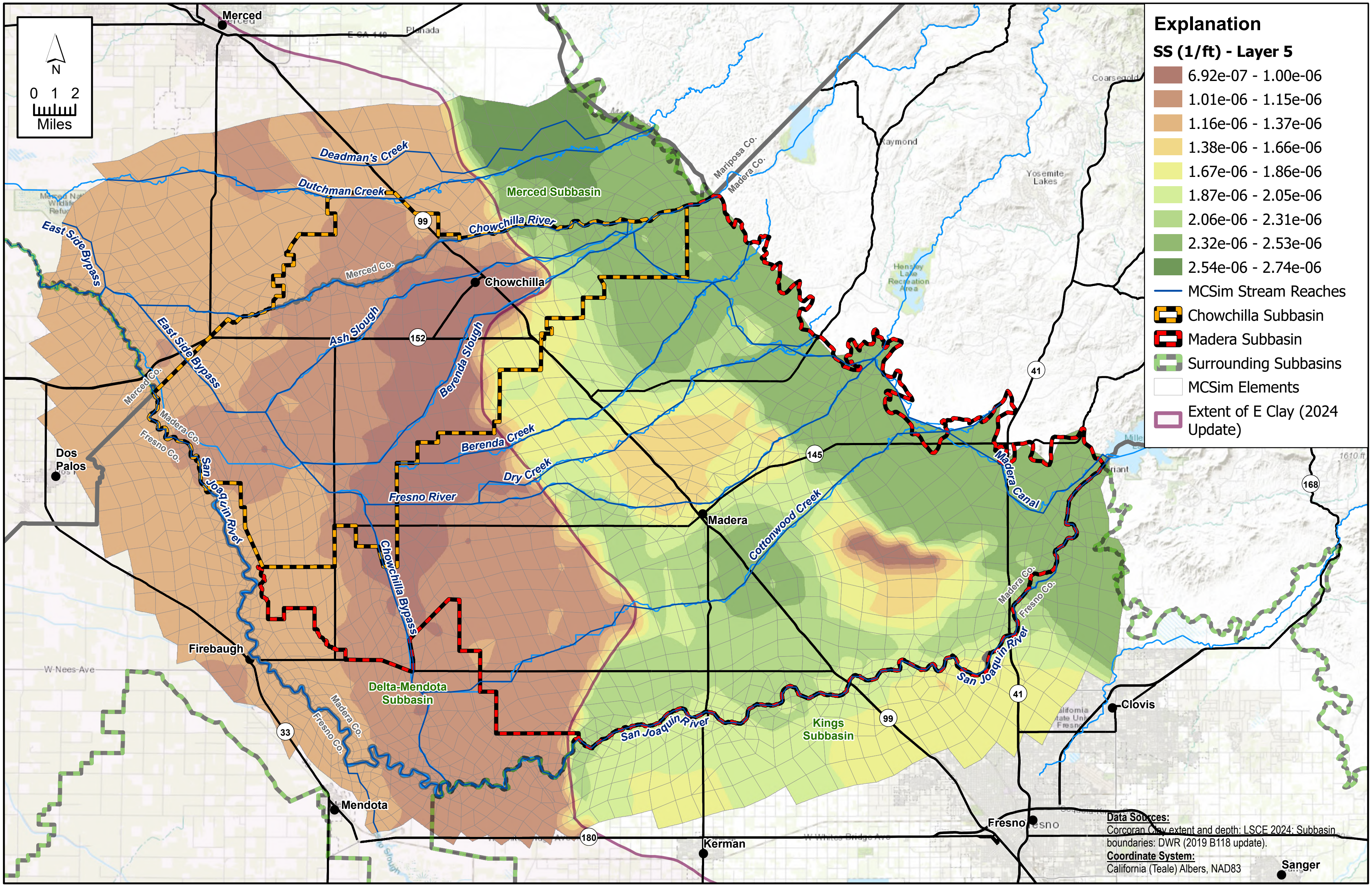
FIGURE 4-32

Calibrated Specific Storage (SS) - Layer 4

Madera-Chowchilla Groundwater-Surface Water Simulation Model (MCSim) - First Model Update



X:\2024\24-010 (1) Davids Eng. - Madera Subbasin 5-Year GSP Update\MODEL\MCSim_v2_GIS_20231101\MCSim_v2_20231101.aprx; AQ_PARAM_SS

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FIGURE 4-33

Calibrated Specific Storage (SS) - Layer 5

Madera-Chowchilla Groundwater-Surface Water Simulation Model (MCSim) - First Model Update

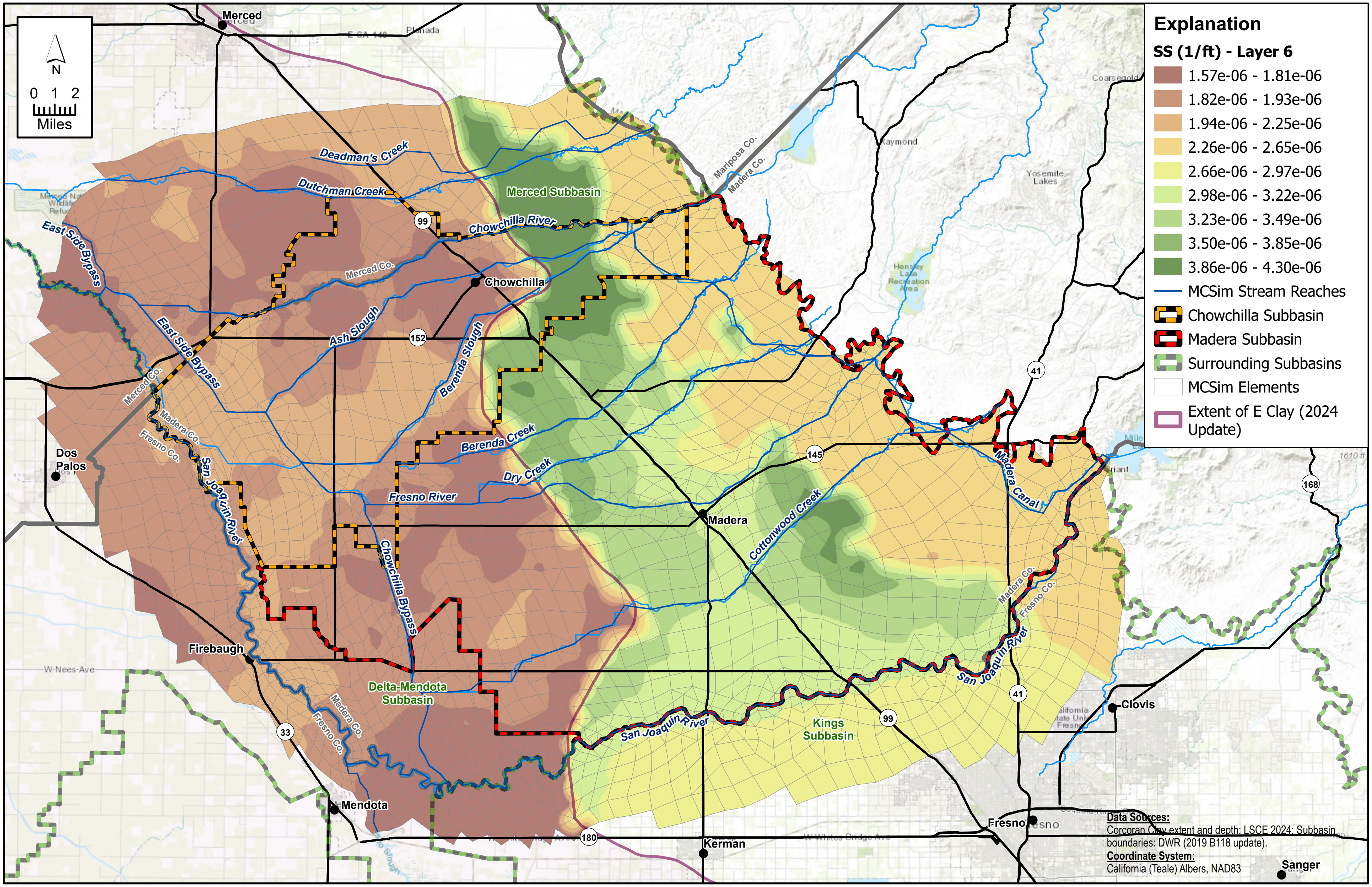

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FIGURE 4-34

Calibrated Specific Storage (SS) - Layer 6

Madera-Chowchilla Groundwater-Surface Water Simulation Model (MCSim) - First Model Update

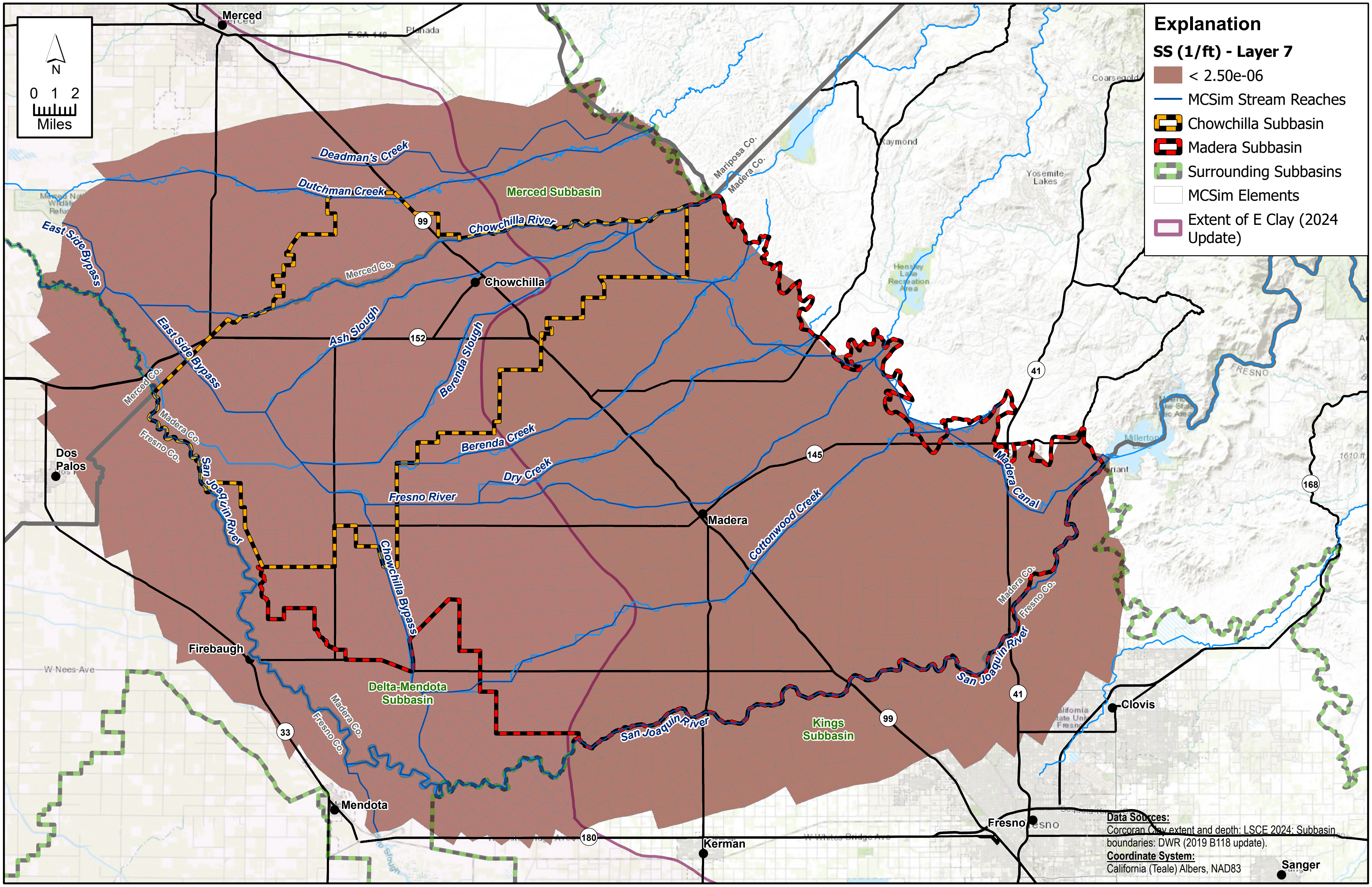

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FIGURE 4-35

Calibrated Specific Storage (SS) - Layer 7

Madera-Chowchilla Groundwater-Surface Water Simulation Model (MCSim) - First Model Update

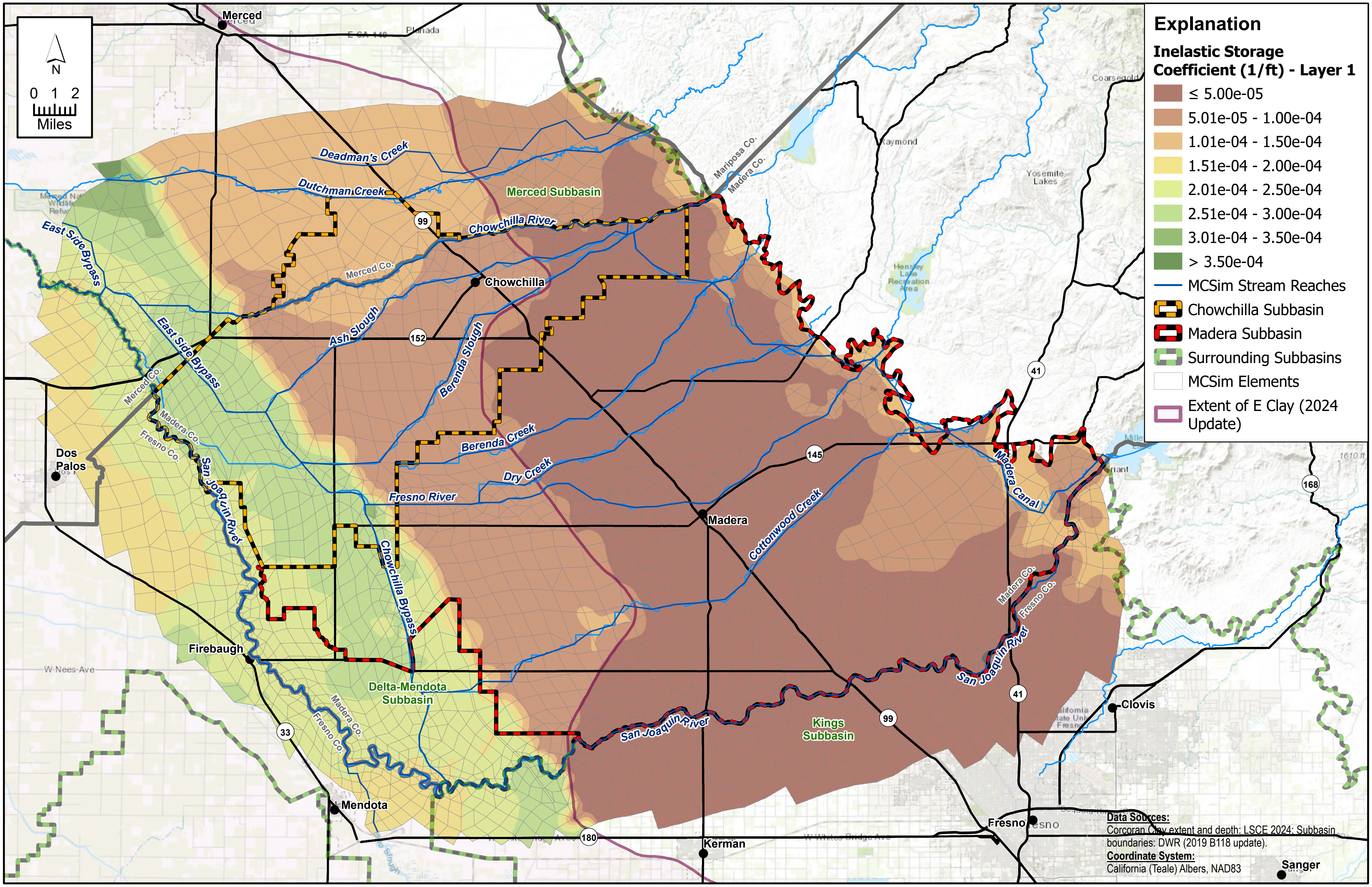

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FIGURE 4-36

Calibrated Inelastic Specific Storage (SCI)- Layer 1

Madera-Chowchilla Groundwater-Surface Water Simulation Model (MCSim) - First Model Update

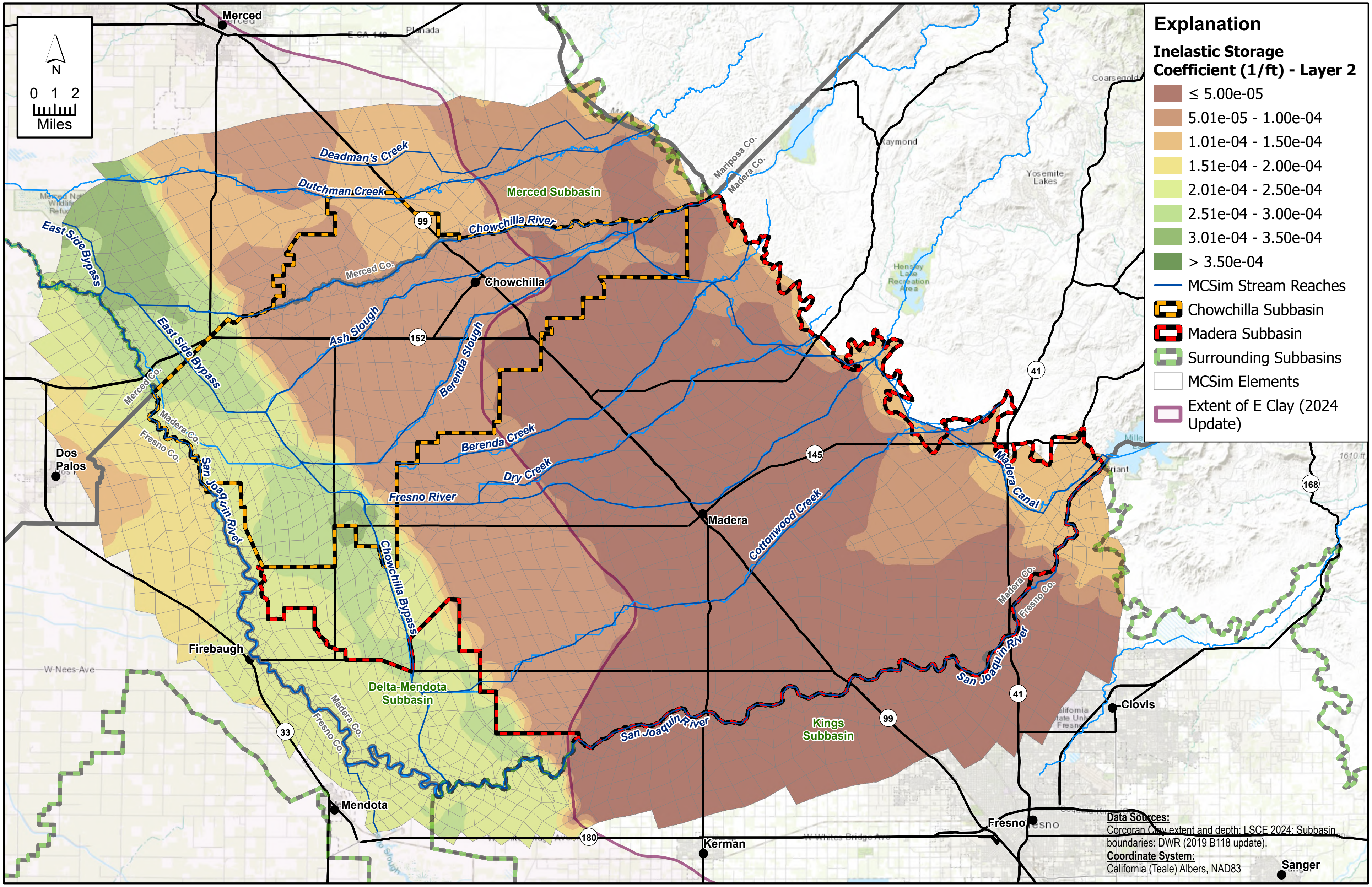

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FIGURE 4-37

Calibrated Inelastic Specific Storage (SCI)- Layer 2

Madera-Chowchilla Groundwater-Surface Water Simulation Model (MCSim) - First Model Update

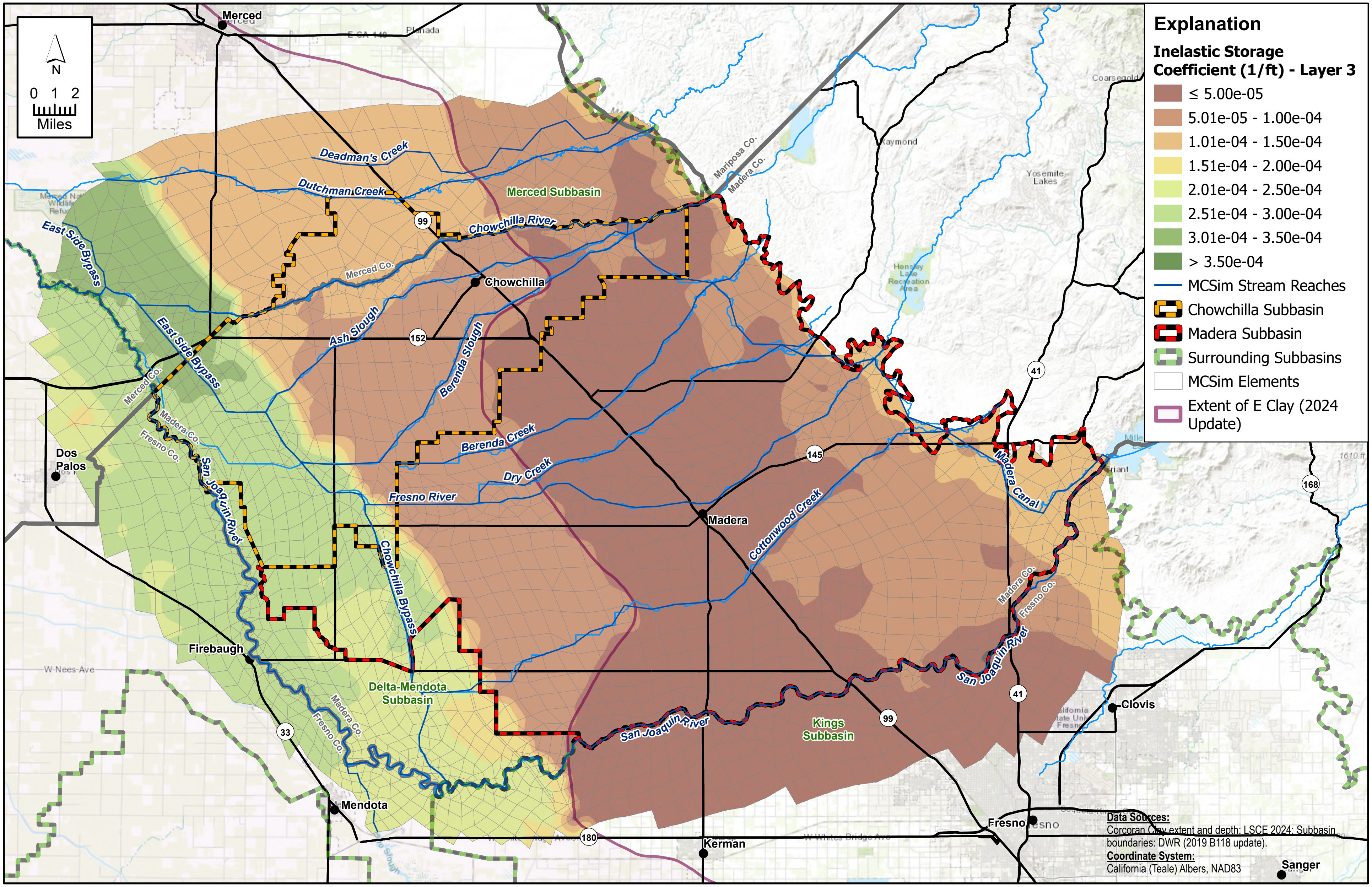

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FIGURE 4-38

Calibrated Inelastic Specific Storage (SCI)- Layer 3

Madera-Chowchilla Groundwater-Surface Water Simulation Model (MCSim) - First Model Update

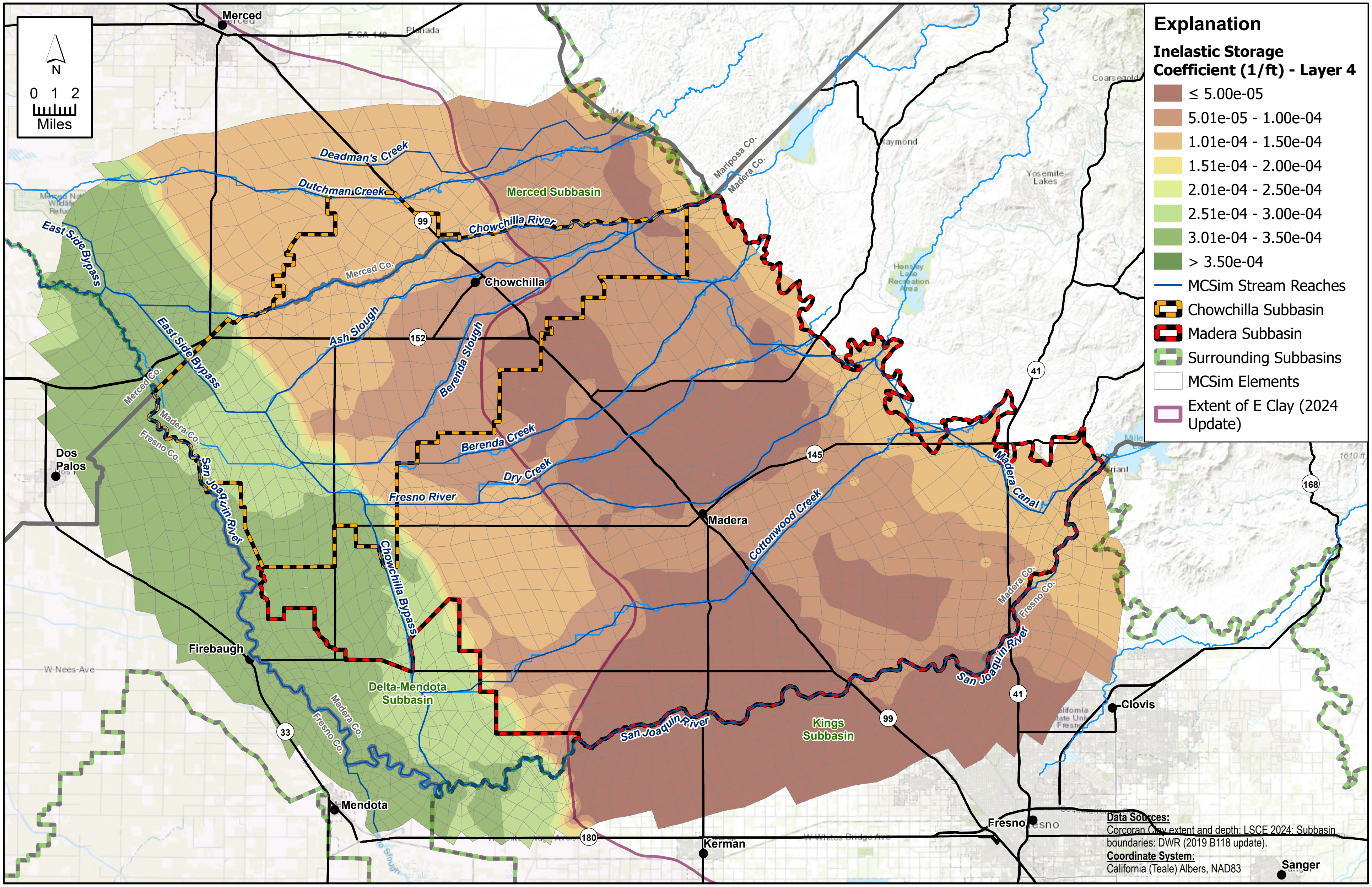

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FIGURE 4-39

Calibrated Inelastic Specific Storage (SCI)- Layer 4

Madera-Chowchilla Groundwater-Surface Water Simulation Model (MCSim) - First Model Update

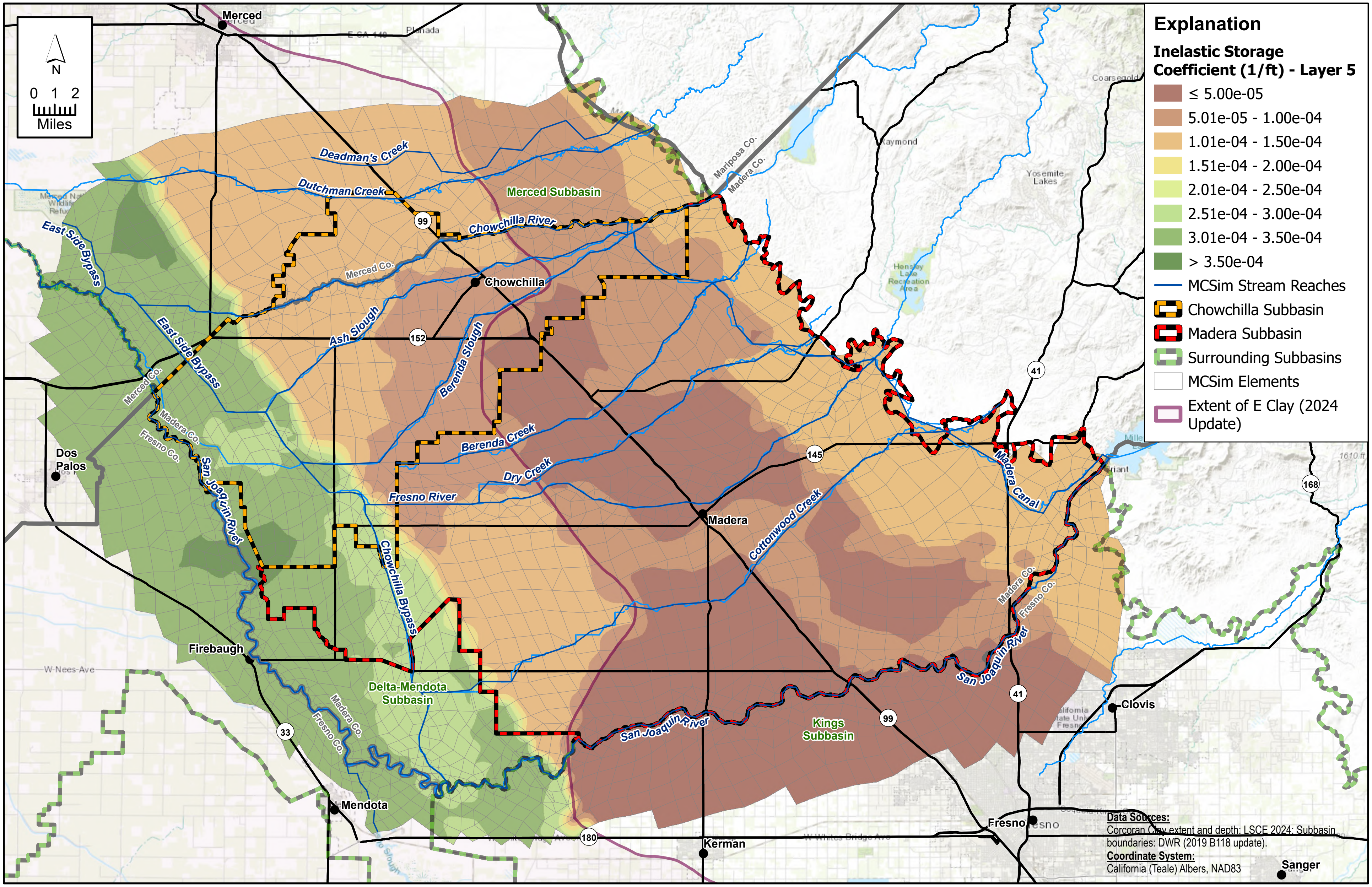

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FIGURE 4-40

Calibrated Inelastic Specific Storage (SCI)- Layer 5

Madera-Chowchilla Groundwater-Surface Water Simulation Model (MCSim) - First Model Update

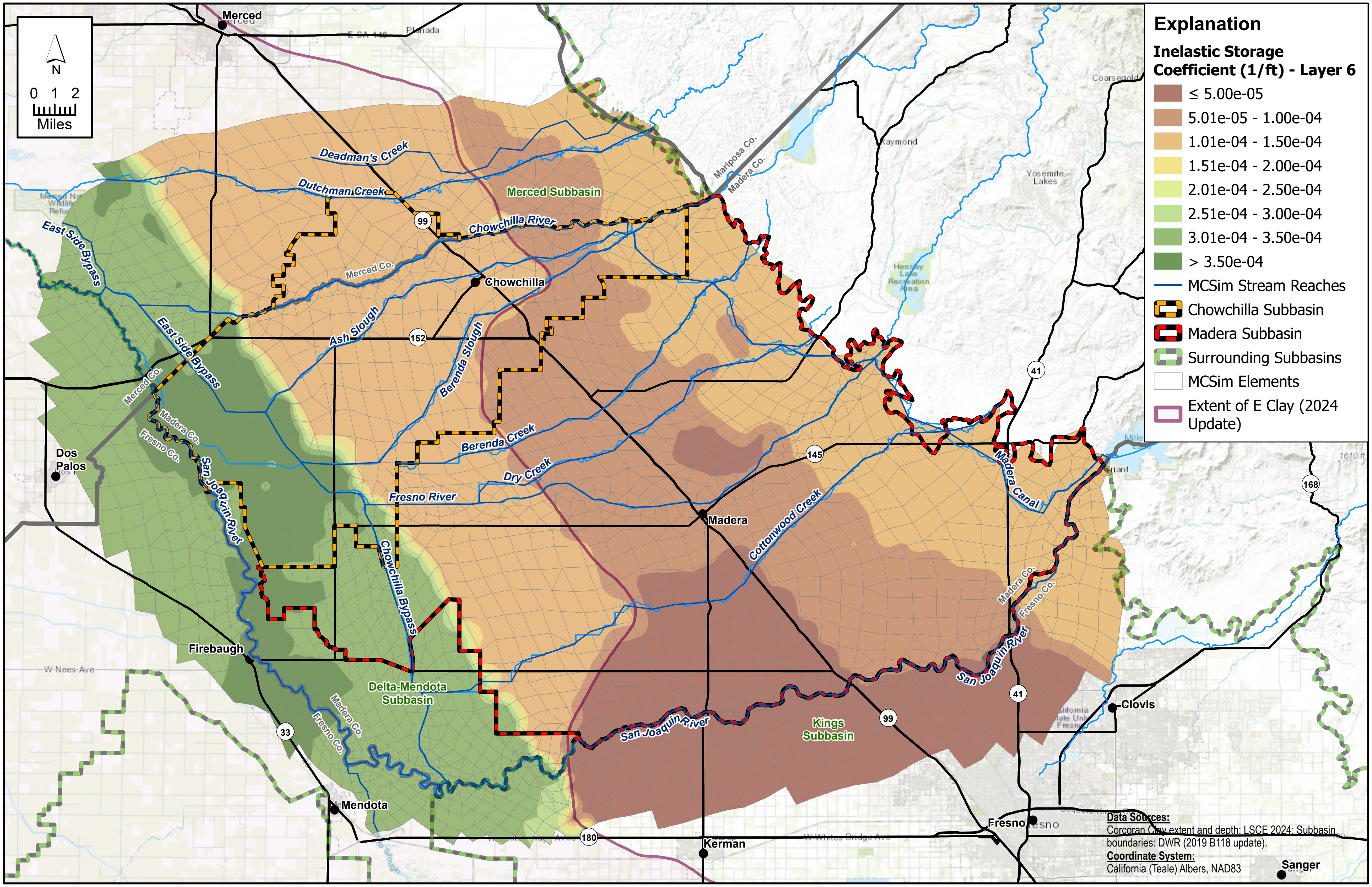

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FIGURE 4-41

Calibrated Inelastic Specific Storage (SCI)- Layer 6

Madera-Chowchilla Groundwater-Surface Water Simulation Model (MCSim) - First Model Update

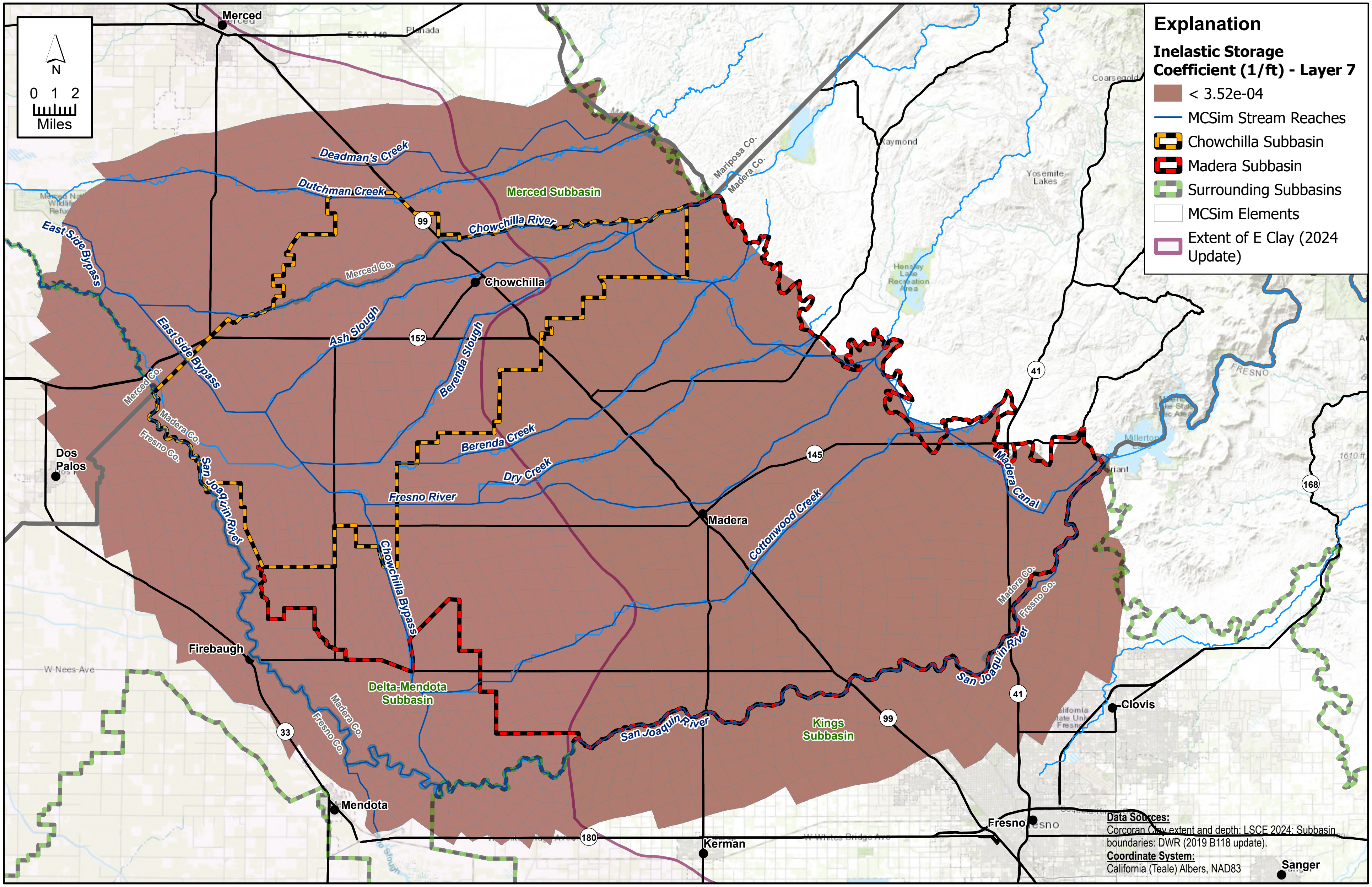

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FIGURE 4-42

Calibrated Inelastic Specific Storage (SCI)- Layer 7

Madera-Chowchilla Groundwater-Surface Water Simulation Model (MCSim) - First Model Update

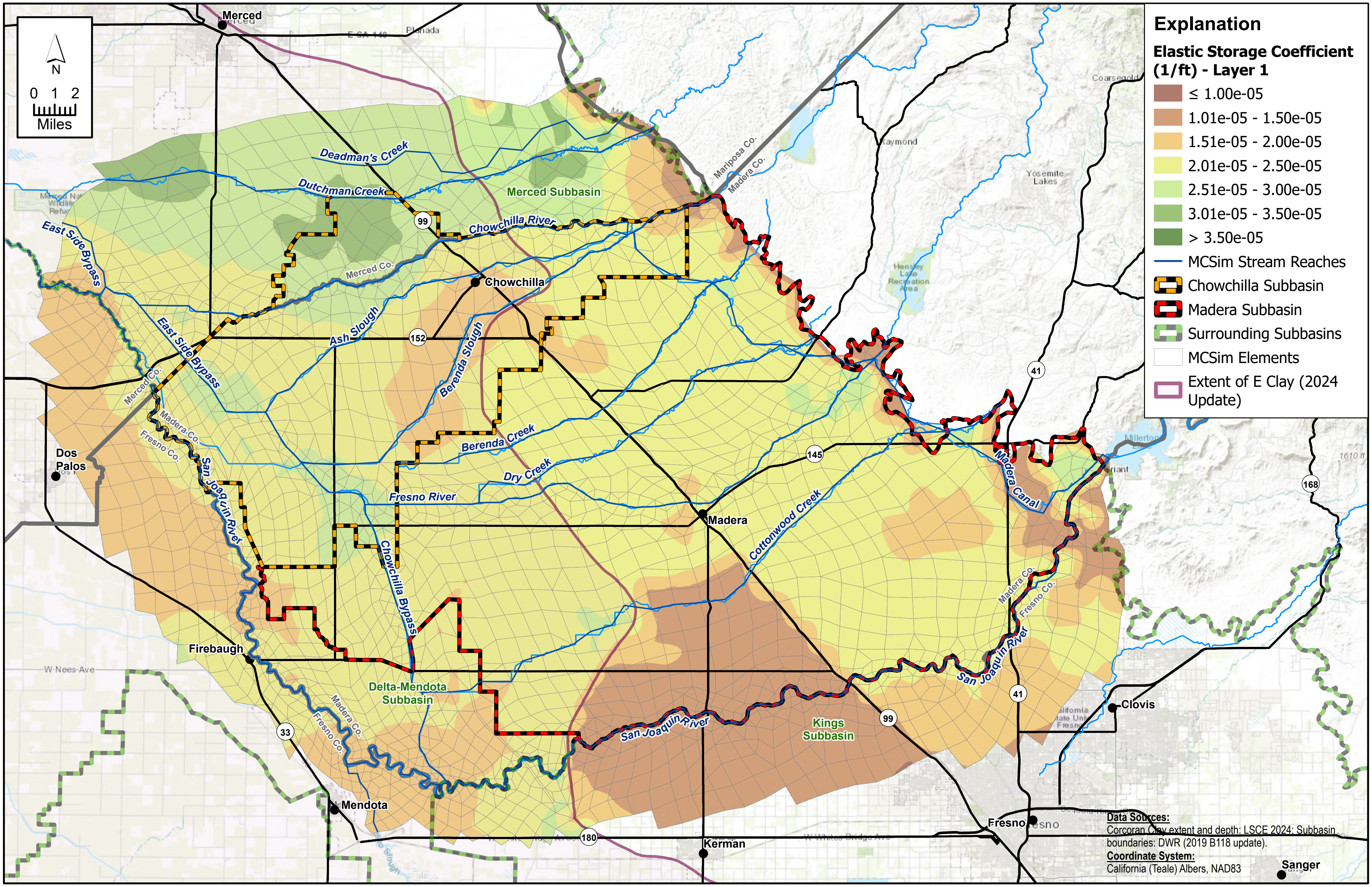

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FIGURE 4-43

Calibrated Elastic Specific Storage (SCE)- Layer 1

Madera-Chowchilla Groundwater-Surface Water Simulation Model (MCSim) - First Model Update

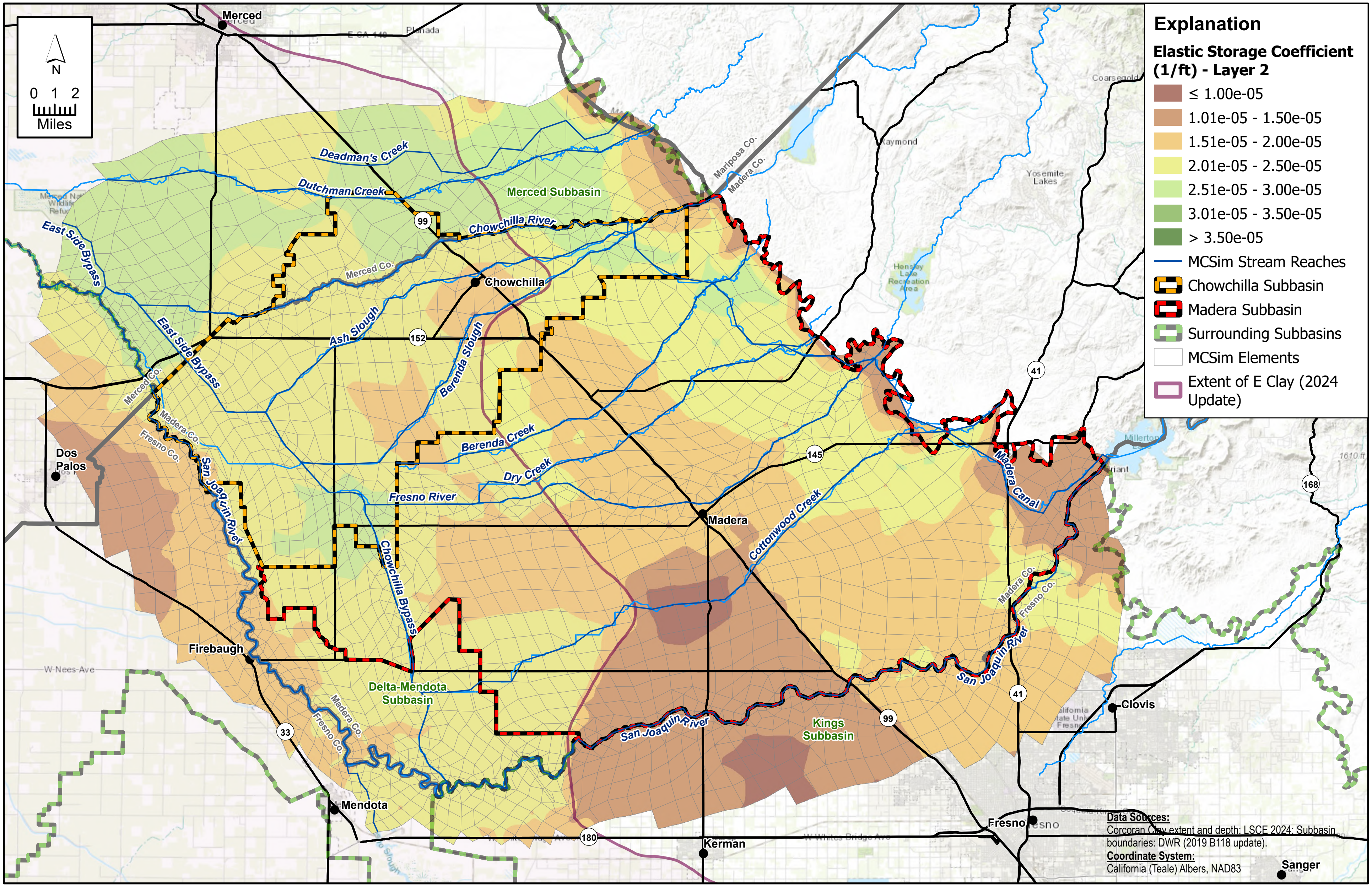

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FIGURE 4-44

Calibrated Elastic Specific Storage (SCE)- Layer 2

Madera-Chowchilla Groundwater-Surface Water Simulation Model (MCSim) - First Model Update

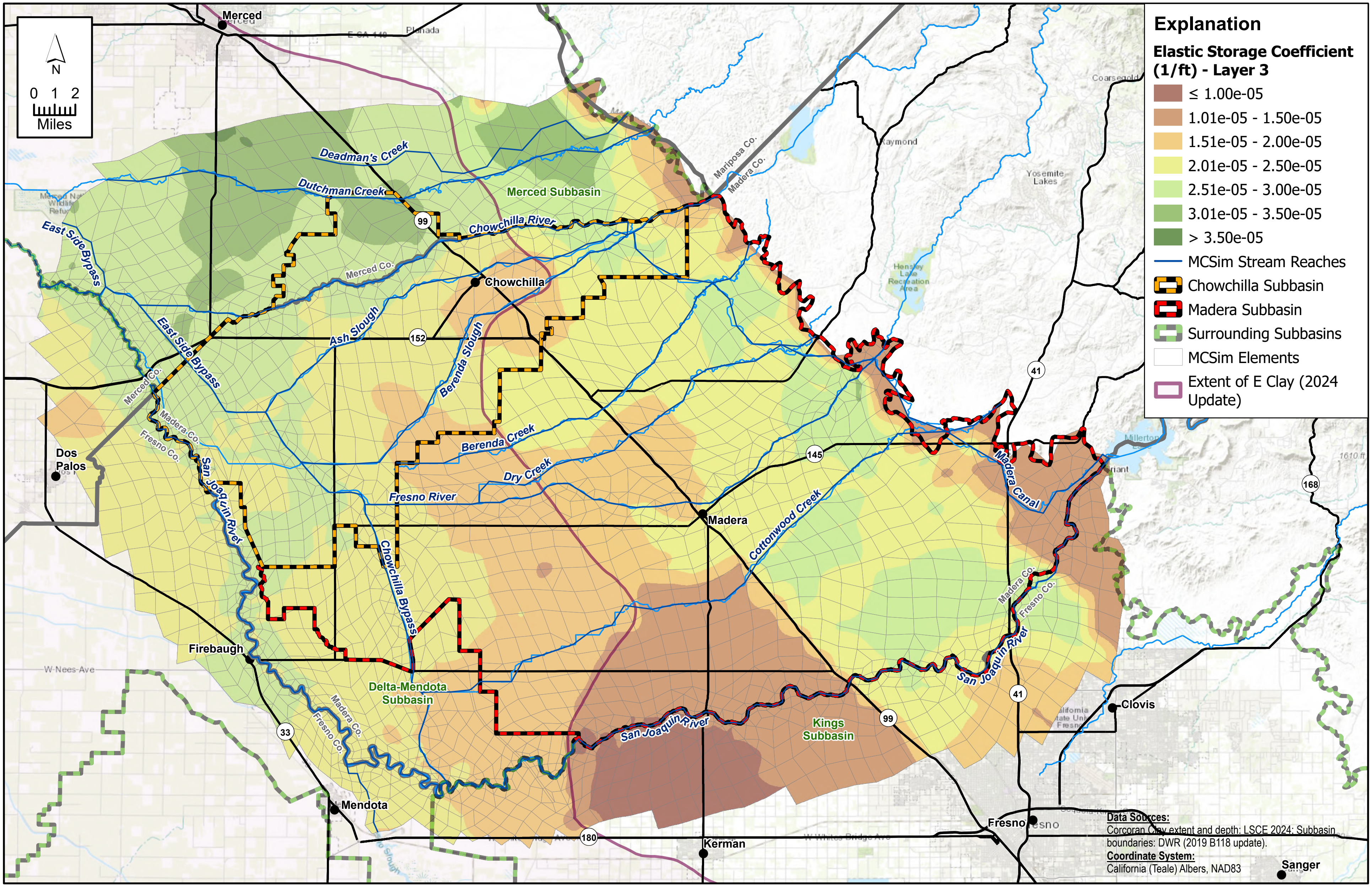

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FIGURE 4-45

Calibrated Elastic Specific Storage (SCE)- Layer 3

Madera-Chowchilla Groundwater-Surface Water Simulation Model (MCSim) - First Model Update

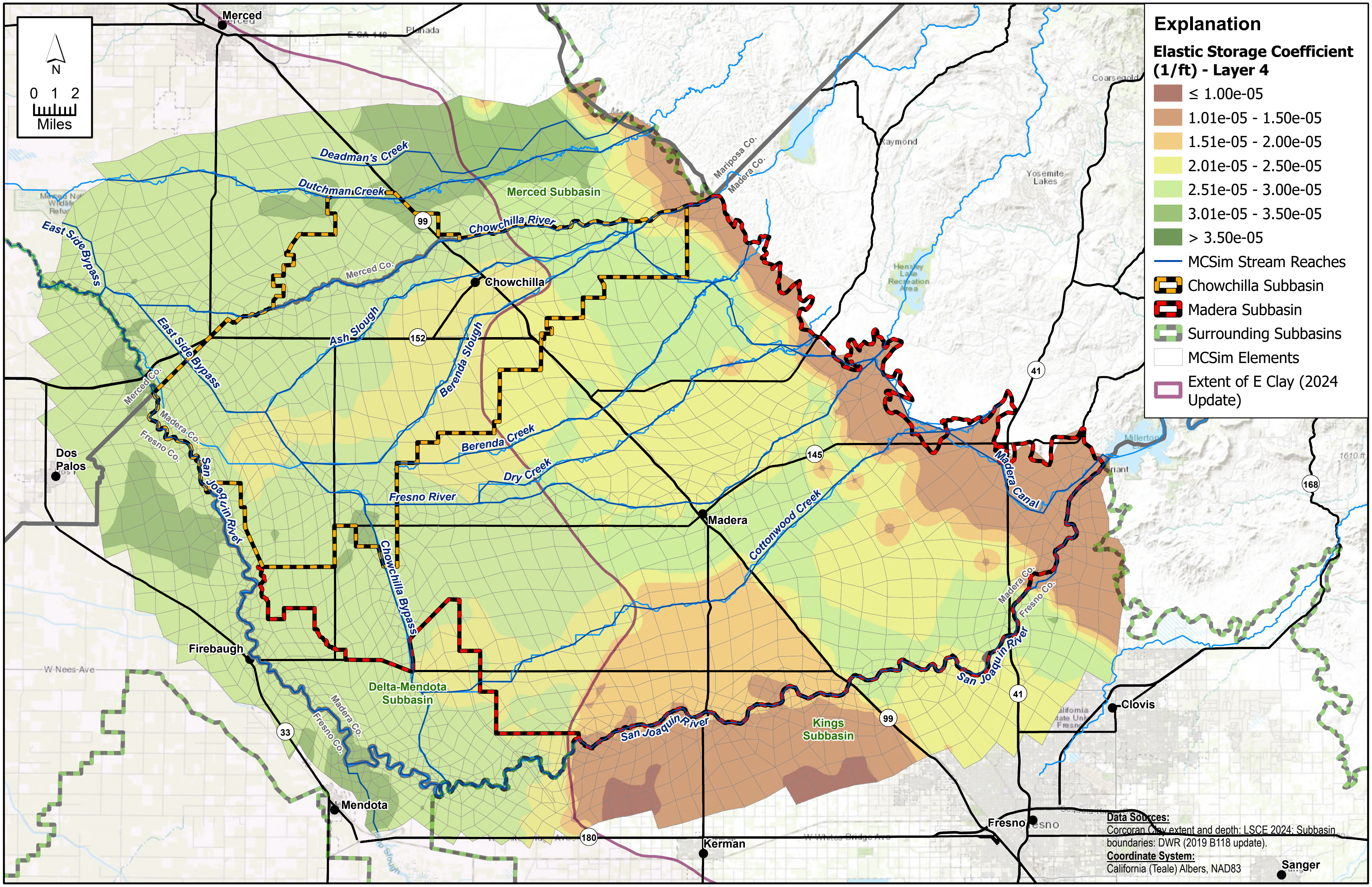

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FIGURE 4-46

Calibrated Elastic Specific Storage (SCE)- Layer 4

Madera-Chowchilla Groundwater-Surface Water Simulation Model (MCSim) - First Model Update

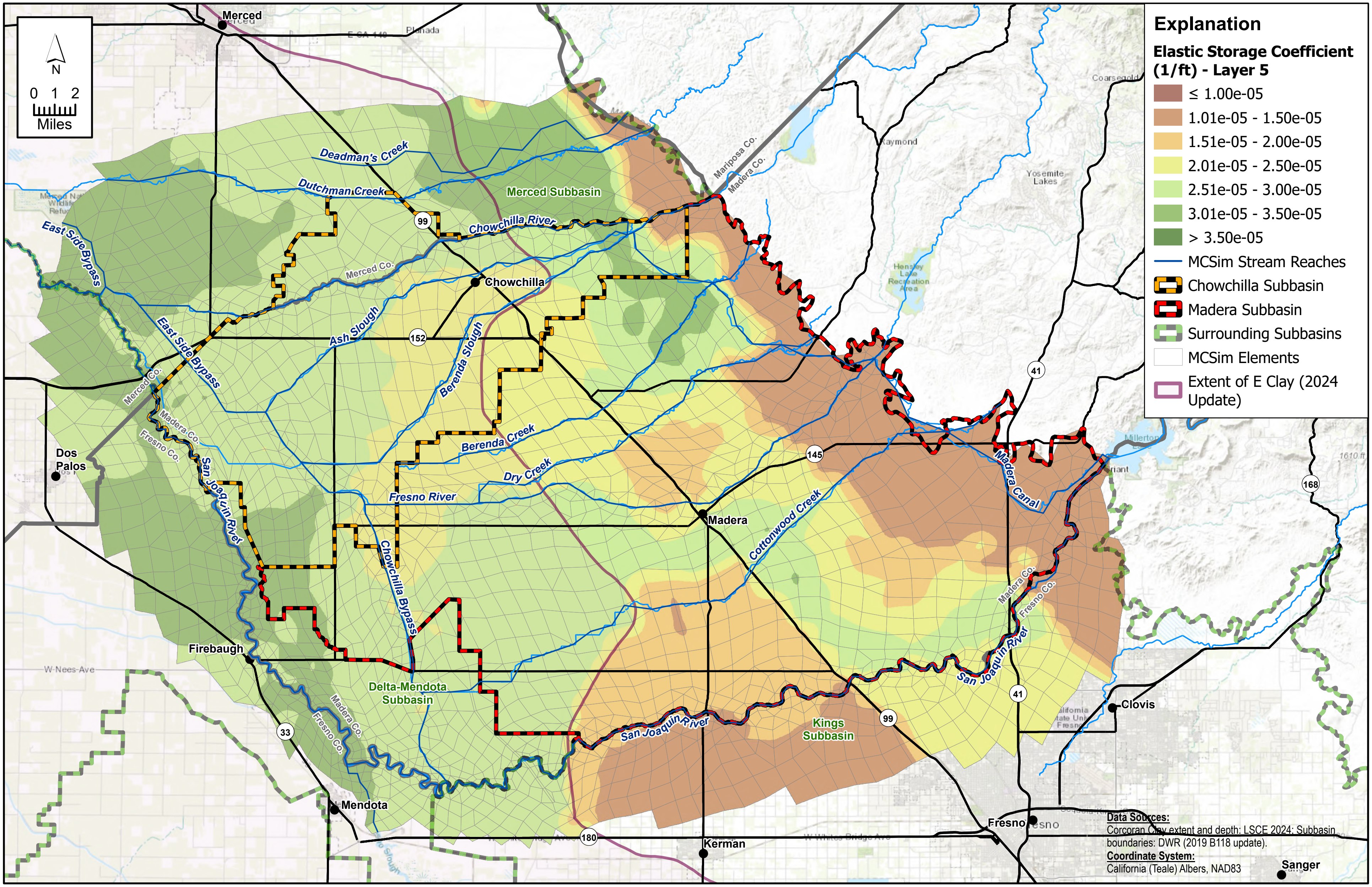

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FIGURE 4-47

Calibrated Elastic Specific Storage (SCE)- Layer 5

Madera-Chowchilla Groundwater-Surface Water Simulation Model (MCSim) - First Model Update

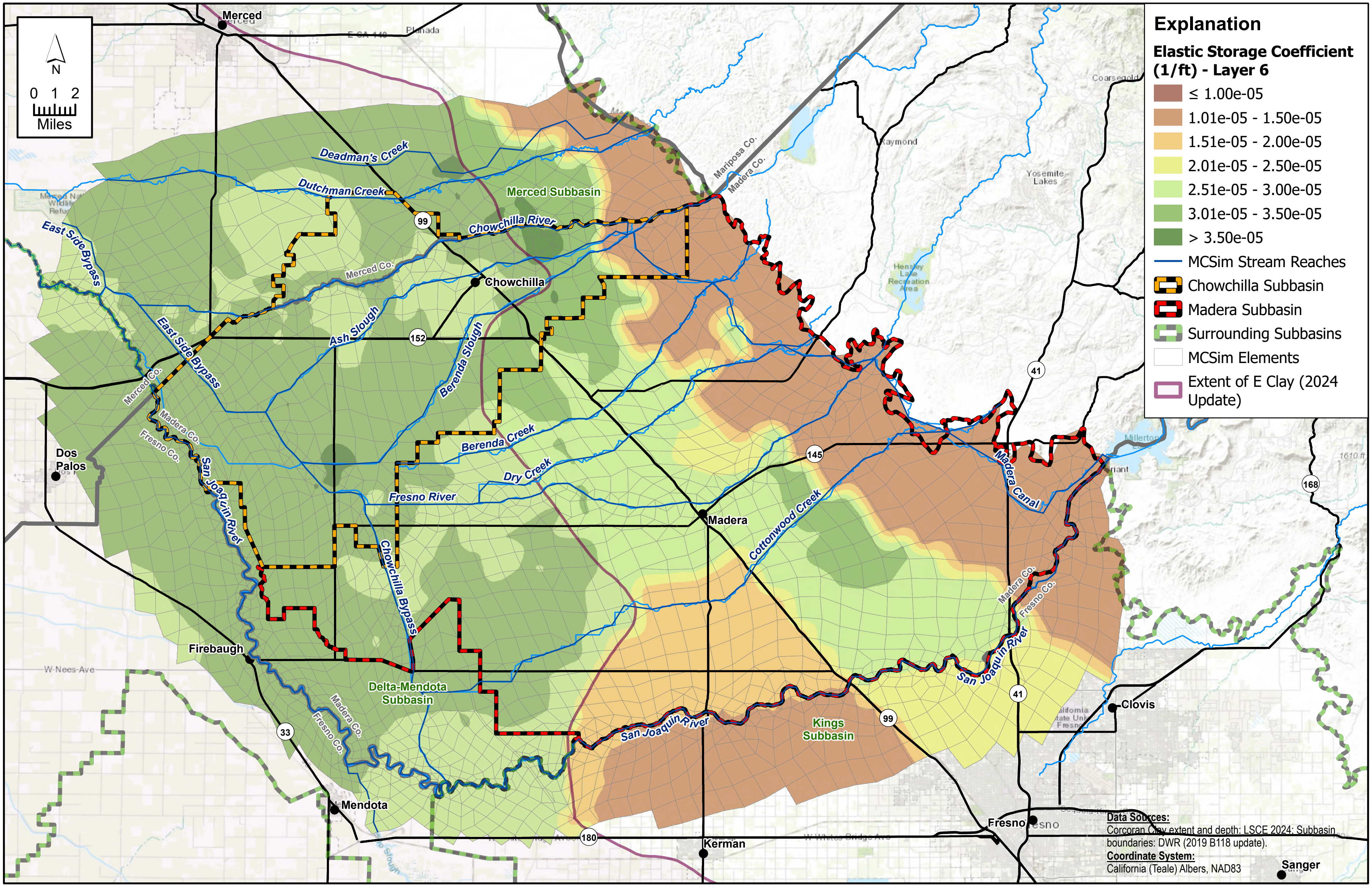

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FIGURE 4-48

Calibrated Elastic Specific Storage (SCE)- Layer 6

Madera-Chowchilla Groundwater-Surface Water Simulation Model (MCSim) - First Model Update

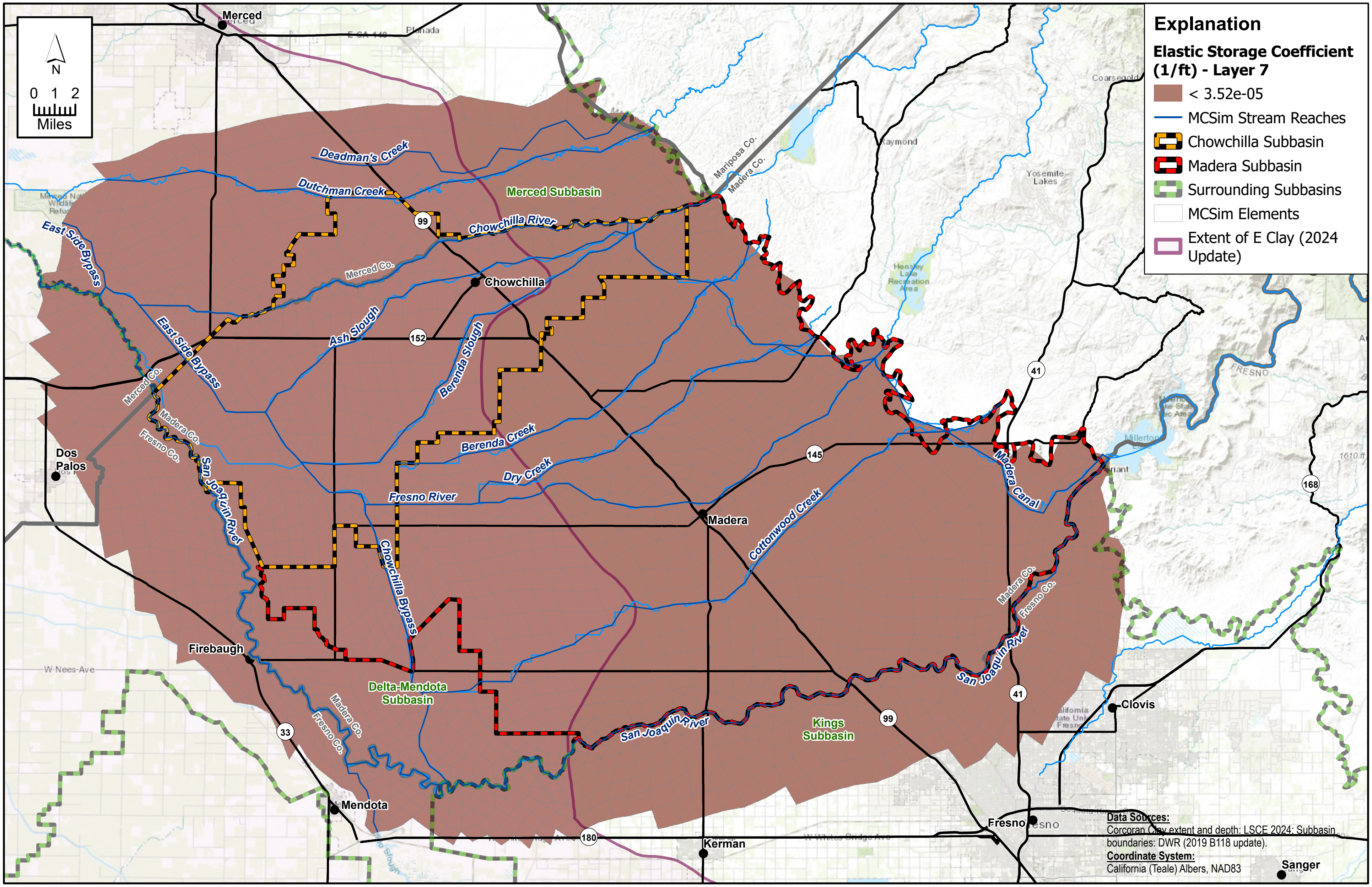

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FIGURE 4-49

Calibrated Elastic Specific Storage (SCE)- Layer 7

Madera-Chowchilla Groundwater-Surface Water Simulation Model (MCSim) - First Model Update

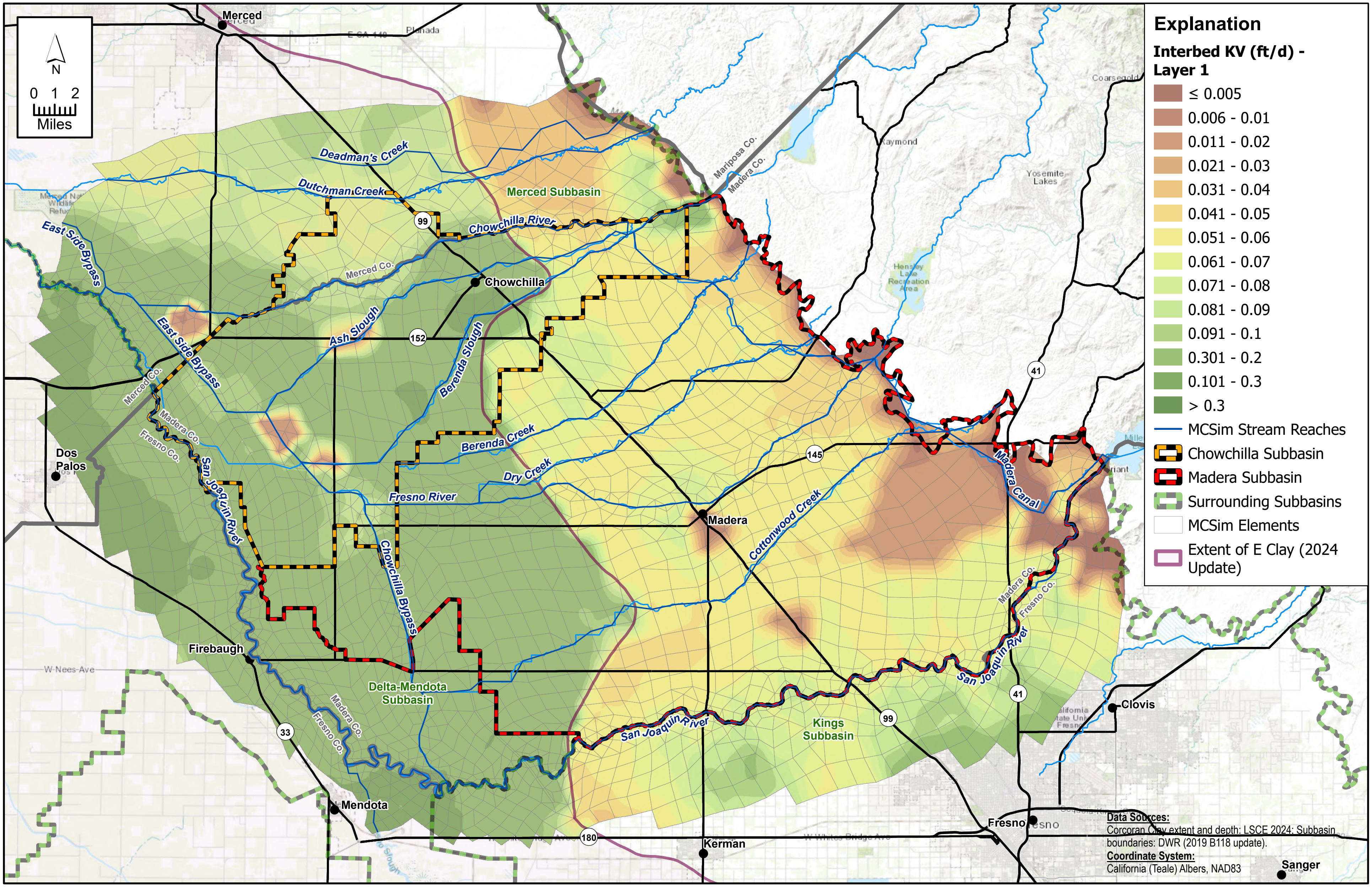

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FIGURE 4-50

Calibrated Interbed Vertical Hydraulic Conductivity- Layer 1

Madera-Chowchilla Groundwater-Surface Water Simulation Model (MCSim) - First Model Update

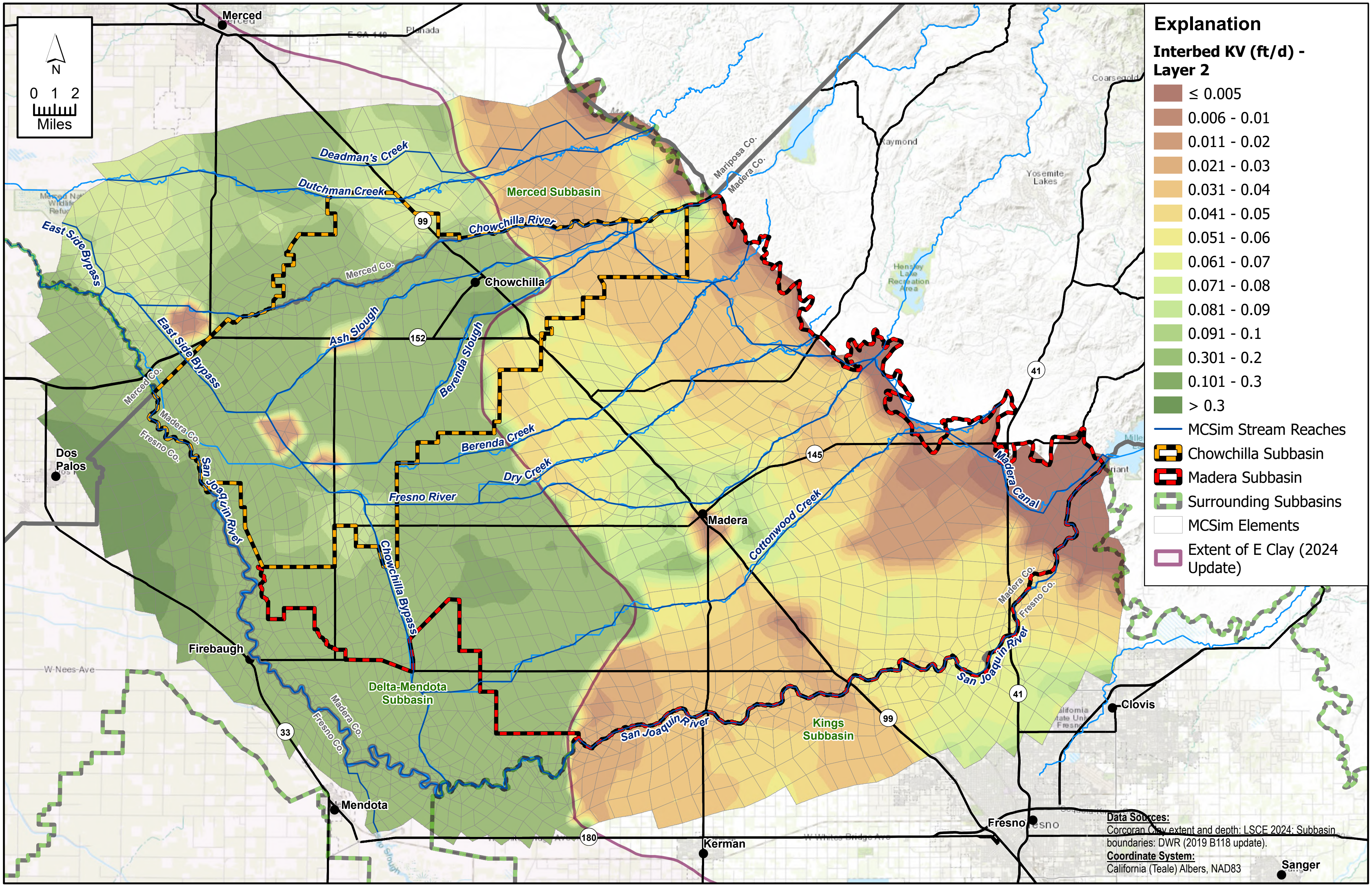

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FIGURE 4-51

Calibrated Interbed Vertical Hydraulic Conductivity- Layer 2

Madera-Chowchilla Groundwater-Surface Water Simulation Model (MCSim) - First Model Update

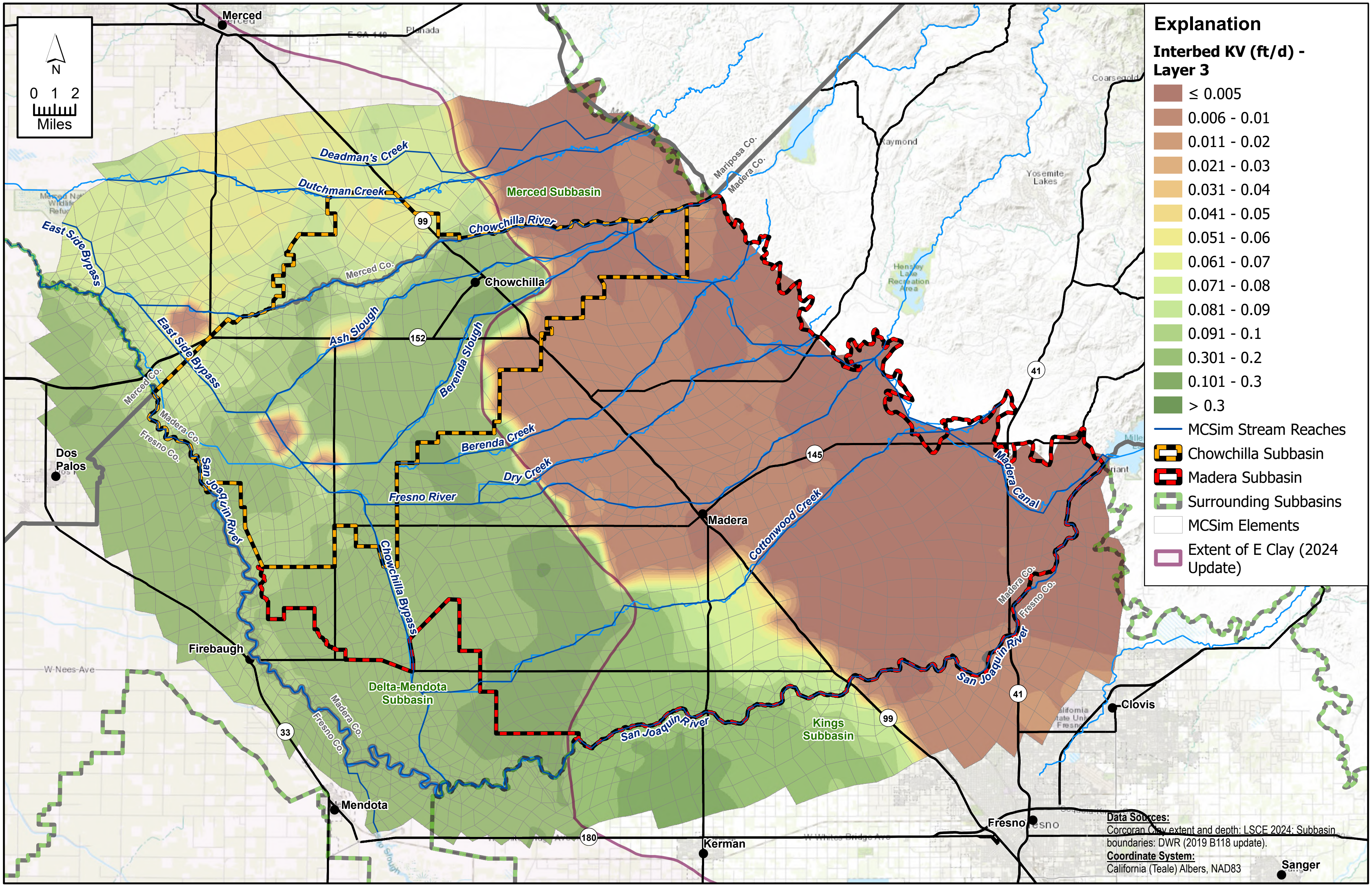

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FIGURE 4-52

Calibrated Interbed Vertical Hydraulic Conductivity- Layer 3

Madera-Chowchilla Groundwater-Surface Water Simulation Model (MCSim) - First Model Update

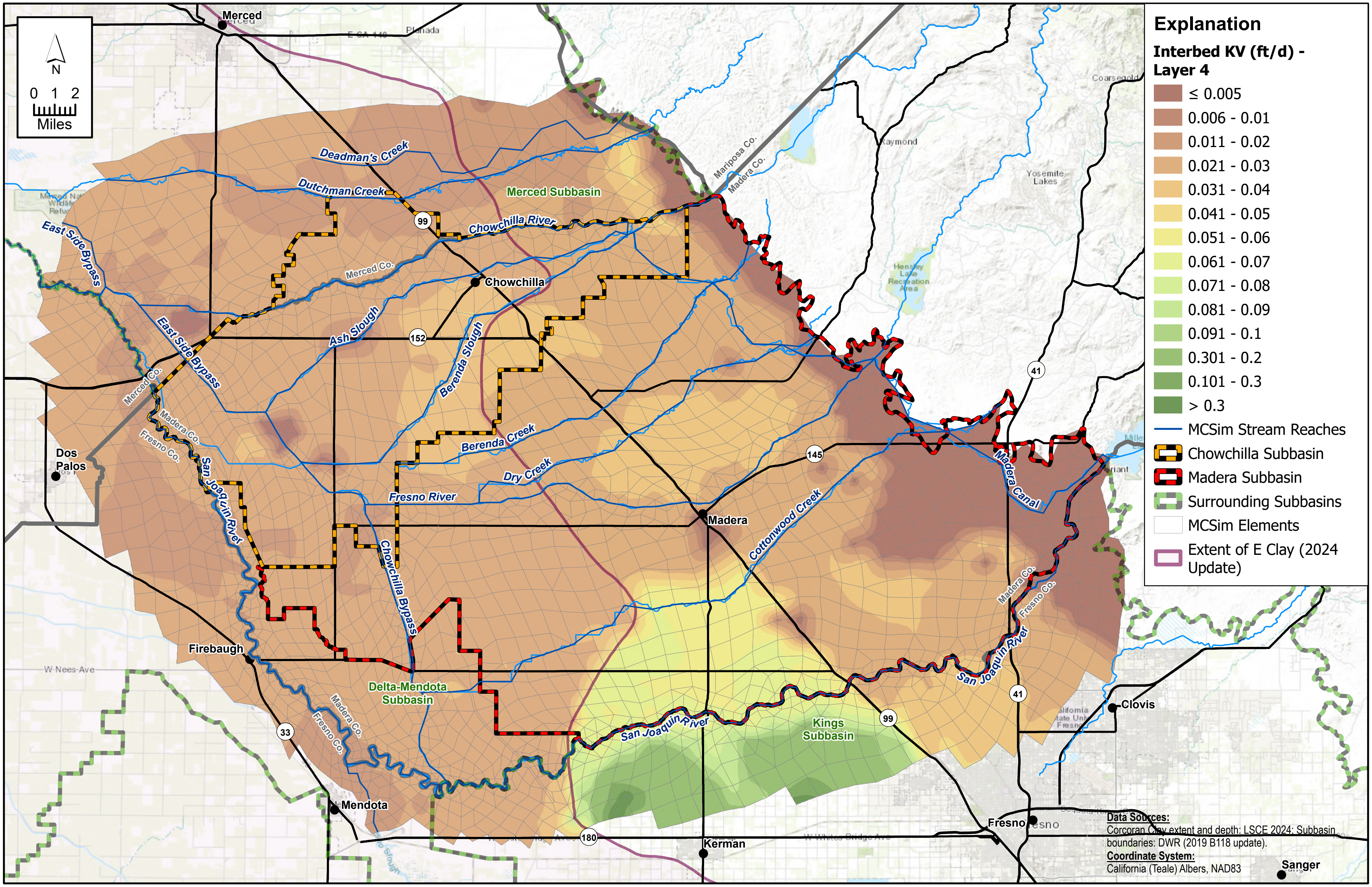

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FIGURE 4-53

Calibrated Interbed Vertical Hydraulic Conductivity- Layer 4

Madera-Chowchilla Groundwater-Surface Water Simulation Model (MCSim) - First Model Update

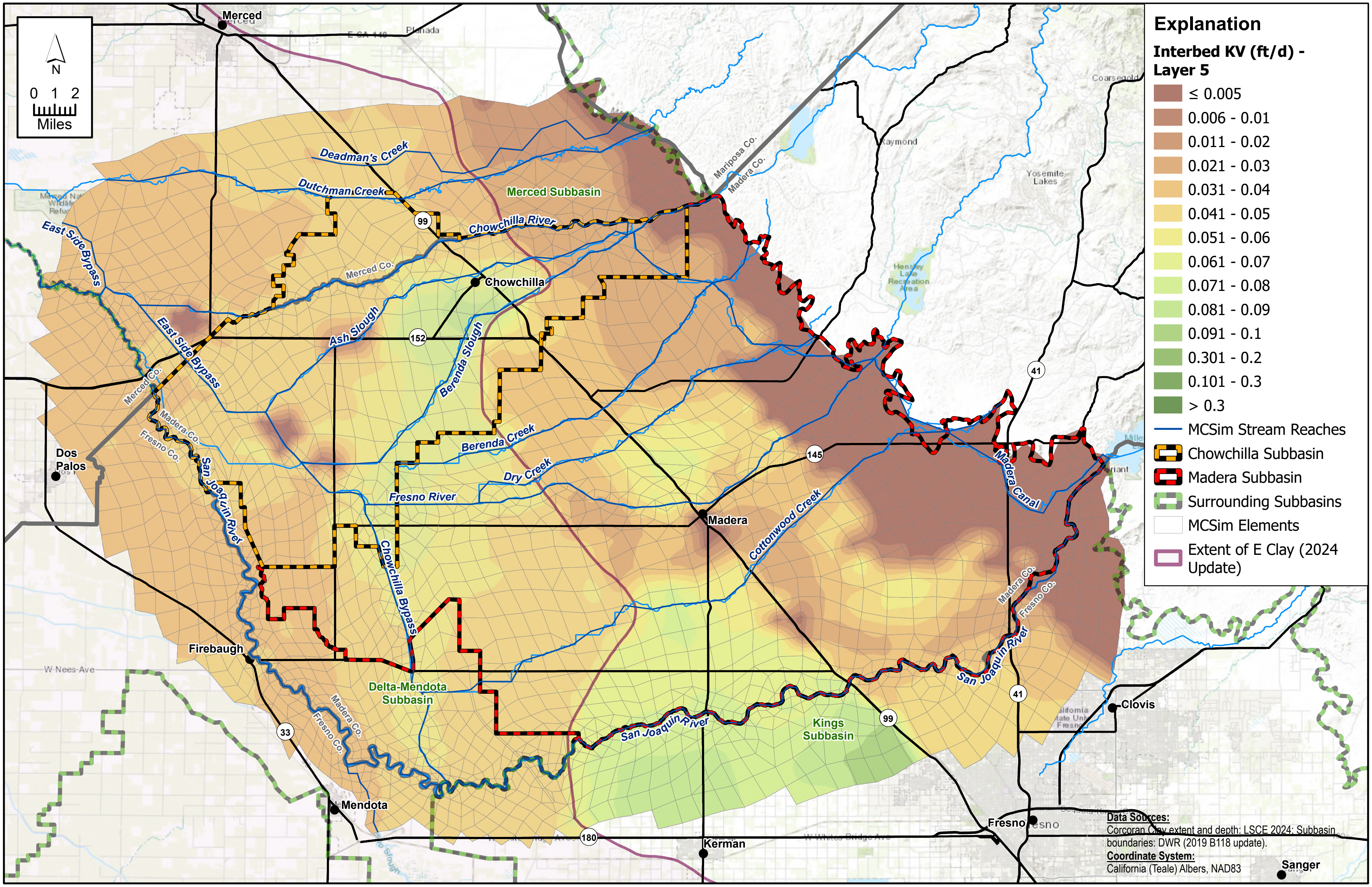

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FIGURE 4-54

Calibrated Interbed Vertical Hydraulic Conductivity- Layer 5

Madera-Chowchilla Groundwater-Surface Water Simulation Model (MCSim) - First Model Update

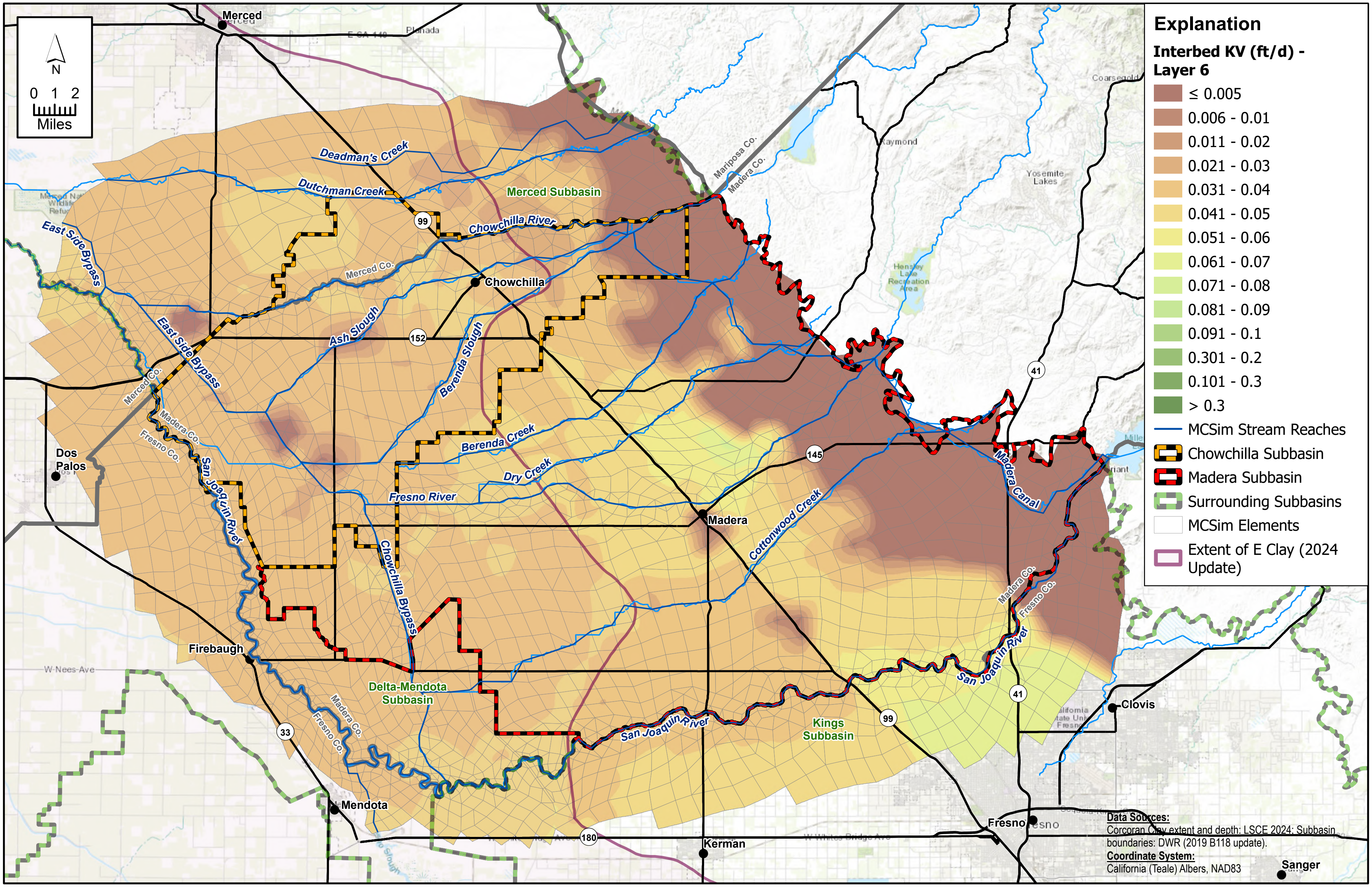

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FIGURE 4-55

Calibrated Interbed Vertical Hydraulic Conductivity- Layer 6

Madera-Chowchilla Groundwater-Surface Water Simulation Model (MCSim) - First Model Update

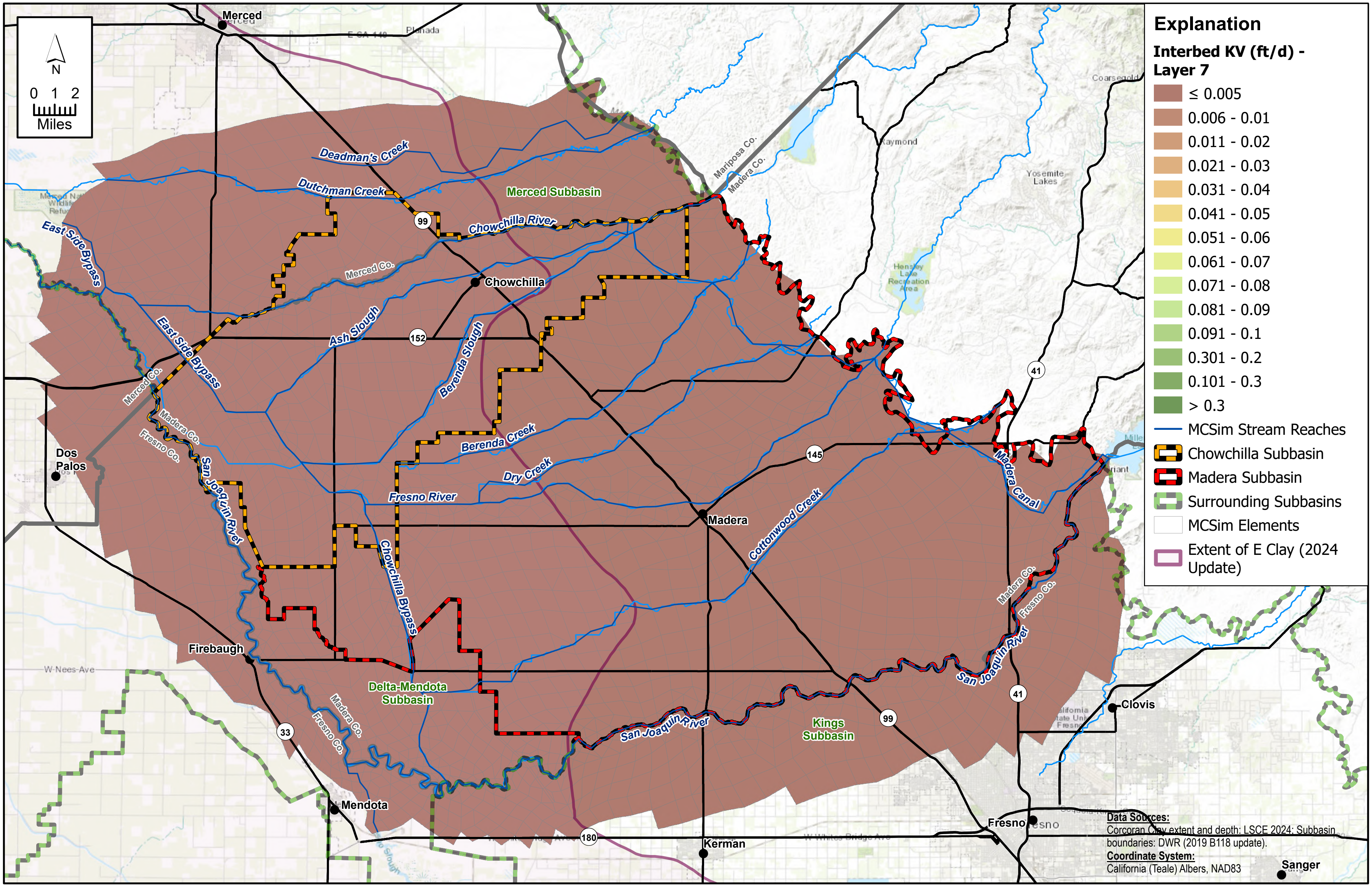

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FIGURE 4-56

Calibrated Interbed Vertical Hydraulic Conductivity- Layer 7

Madera-Chowchilla Groundwater-Surface Water Simulation Model (MCSim) - First Model Update

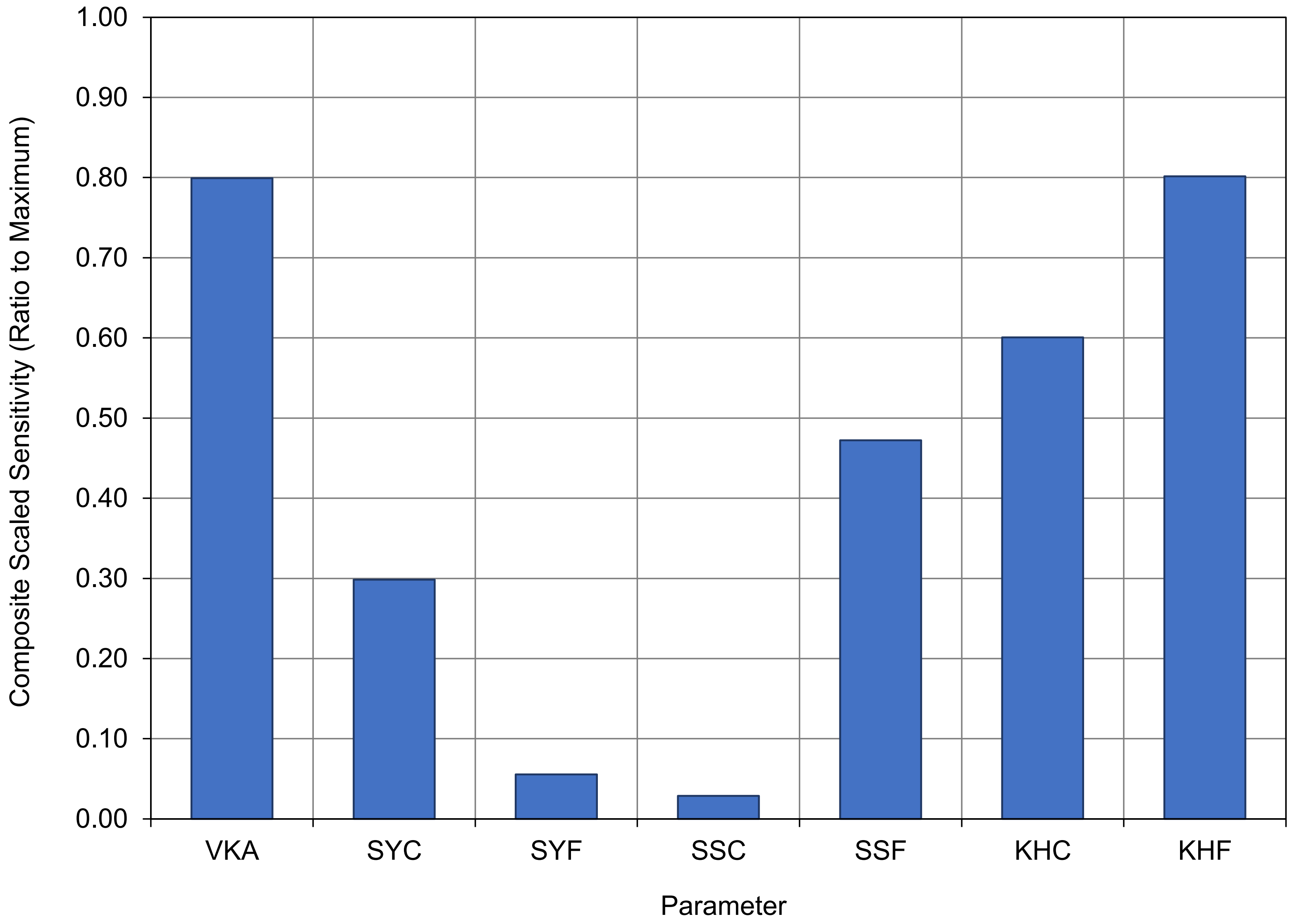

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FIGURE 5-1
Composite Scaled Sensitivity of Simulated Groundwater Elevations to Model Parameter Values

Madera-Chowchilla Groundwater-Surface Water Simulation Model (MCSim) - First Model Update

All appendices to this report are included in the Joint GSP 2025 Plan Amendment.

Please see Appendix 6.D of the Joint GSP 2025 Plan Amendment.