JANUARY 2022

EAST BAY PLAIN SUBBASIN
GROUNDWATER SUSTAINABILITY PLAN
APPENDIX 6

PREPARED FOR

East Bay Municipal Utility District GSA and
City of Hayward GSA

PREPARED BY

Luhdorff & Scalmanini Consulting Engineers
Geosyntec
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APPENDIX 6. REFERENCES AND TECHNICAL STUDIES

Appendix 6.A. Interbasin and Coordination Agreements (as applicable) (Reg. Section 357)

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6.A. Interbasin and Coordination Agreements (as applicable) (Reg. Section 357) (None)

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6.B. Contact Information for Plan Manager and GSA Mailing Address (Reg. Section 354.6)

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PREPARED AS PART OF THE

EAST BAY PLAIN SUBBASIN GROUNDWATER SUSTAINABILITY PLAN

August 2021

GSP TEAM

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Plan Manager

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GSA Contact Information

Groundwater Sustainability Agency	Contact Person	Contact Title	Mailing Address	Phone Number	Email Address
East Bay Municipal Utility District	Brad Ledesma	Project Manager, East Bay Municipal Utility District	375 Eleventh Street, Oakland, CA 94607	(510) 287-0668	bradley.ledesma@ebmud.com
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APPENDIX 6. REFERENCES AND TECHNICAL STUDIES

6.C. List of Public Meetings (Reg. Section 354.10)

Appendix 6.C. List of Public Meetings

PREPARED AS PART OF THE

EAST BAY PLAIN SUBBASIN
GROUNDWATER SUSTAINABILITY PLAN

December 2021

LSCE TEAM

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List of Public Meetings

The following tables present the schedule of past and future GSA Board meetings related to development of the East Bay Plain (EBP) Subbasin Groundwater Sustainability Plan. Other public meetings are summarized in Appendix 2.B.c (Stakeholder Engagement Matrix). The GSA Board for EBMUD is the same as the EBMUD Board, and the Hayward GSA Board is the same as the City Council. Therefore, these Board meetings cover many topics unrelated to the EBP Subbasin GSP, and this appendix focuses on the Board meetings that included a GSP agenda item and/or some discussion related to the GSP.

Table 1 provides a summary of the typical GSA Board meeting schedules and locations for each GSA. All GSA Board meetings are open to the public. Additionally, recent GSA Board meeting agendas and minutes are available for public viewing on their respective websites.[1] The meetings listed in the table are based on the Boards' standing schedules and are subject to change. Please contact individual GSAs directly to confirm dates, times, and content of upcoming meetings (see GSA contact information in Appendix 6.B). Table 2 provides a chronological list of GSA Board meetings related to development of the EBP Subbasin GSP. Available meeting agendas are provided in Attachment 1 to this Appendix.

Table 1. GSA Board Meeting Schedules

GSA	GSA Meeting Schedule	GSA Meeting Location
East Bay Municipal Utility District	Second and Fourth Tuesdays of each month at 1:15 PM.	EBMUD Offices, 375 Eleventh Street, Oakland, CA 94607 (or via Zoom during pandemic)
City of Hayward	First, Third, and Fourth Tuesdays of each month at 7:00 PM.	Hayward City Hall, 777 B Street, Hayward, CA 94541

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[1] https://www.ebmud.com/about-us/board-directors/board-meetings/

Table 2. Chronological List of GSA Board Meetings

Date	Meeting Type	Time and Location	Meeting Purpose/Topics
3/28/2017	EBMUD: Board of Directors Special Meeting	9:30 AM Training Resource Center 375 Eleventh Street, Oakland, CA 94607	Long-Term Water Supply Workshop: Receive an update on the District's Water Conservation and Water Recycling Programs, information on the District's efforts to secure long-term water transfers, and to discuss regional partnerships and activities related to groundwater sustainability.
7/10/2017	Hayward: Council Sustainability Committee Meeting	4:30 pm City Hall, Conference Room 2A 777 B Street, Hayward, CA 94541	Update on groundwater sustainability activities.
7/18/2017	Hayward: City Council Special Meeting	7:00 PM Hayward City Hall Council Chambers 777 B Street, Hayward, CA 94541	Authorize the City Manager to execute a Memorandum of Understanding with the East Bay Municipal Utility District Regarding Joint Preparation of a Groundwater Sustainability Plan for the East Bay Plain Subbasin and Support for EBMUD's Grant Application.
7/25/2017	EBMUD: Board of Directors Regular Business Meeting	1:15 PM Board Room 375 Eleventh Street, Oakland, CA 94607	Authorize staff to execute a Memorandum of Understanding with the City of Hayward to jointly prepare a Groundwater Sustainability Plan for the East Bay Plain Sub-basin, a grant application, and a cooperating agreement.
3/12/2018	Hayward: Council Sustainability Committee Meeting	4:30 pm City Hall, Conference Room 2A 777 B Street, Hayward, CA 94541	Present Cooperating Agreement with East Bay Municipal Utility District to Jointly Develop a Groundwater Sustainability Plan for the East Bay Plain Subbasin.
5/22/2018	EBMUD: Board of Directors Regular Business Meeting	1:15 PM Board Room 375 Eleventh Street, Oakland, CA 94607	Authorize the execution of a Cooperating Agreement with the City of Hayward providing for the cooperative development and joint funding of a Groundwater Sustainability Plan for the East Bay Plain Subbasin.

Table 2. Chronological List of GSA Board Meetings

Date	Meeting Type	Time and Location	Meeting Purpose/Topics
5/22/18	Hayward: City Council Special Meeting	7:00 PM Hayward City Hall Council Chambers 777 B Street, Hayward, CA 94541	Authorize the City Manager to Negotiate a Cooperating Agreement with the East Bay Municipal Utility District for Preparation of a Groundwater Sustainability Plan for the East Bay Plain Subbasin.
6/5/2018	Hayward: City Council Regular Business Meeting	7:00 PM Hayward City Hall Council Chambers 777 B Street, Hayward, CA 94541	Authorize the City Manager to Execute a Cooperating Agreement with the East Bay Municipal Utility District for Preparation of a Groundwater Sustainability Plan for the East Bay Plain Subbasin.
9/11/2018	EBMUD: Board of Directors Planning Committee Meeting	9:30 AM Training Resource Center 375 Eleventh Street, Oakland, CA 94607	Sustainable Groundwater Management Act Update
1/29/2019	Hayward: City Council Special Meeting	7:00 PM Hayward City Hall Council Chambers 777 B Street, Hayward, CA 94541	Authorize the City Manager to Amend the Cooperating Agreement with the East Bay Municipal Utility District for Preparation of a Groundwater Sustainability Plan for the East Bay Plain Subbasin.
3/12/2019	EBMUD: Board of Directors Special Meeting	9:00 AM Training Resource Center 375 Eleventh Street, Oakland, CA 94607	Long-Term Water Supply Workshop: Overview on the District's current and planned activities to ensure water supply reliability; updates on the Water Conservation and Water Recycling programs, regional partnerships and activities related to groundwater sustainability; and information on the District's efforts to secure long-term water transfers.
2/25/2020	EBMUD: Board of Directors Special Meeting	9:00 AM Training Resource Center 375 Eleventh Street, Oakland, CA 94607	Long-Term Water Supply Workshop: Overview of the District's current and planned activities to ensure water supply reliability; including updates on water demand projections, the water conservation and water

Table 2. Chronological List of GSA Board Meetings

Date	Meeting Type	Time and Location	Meeting Purpose/Topics
			recycling programs, regional partnerships, and the 2020 Urban Water Management Plan.
10/6/2020	Hayward: City Council Special Meeting	7:00 PM Virtual Meeting	Authorize the City Manager to Execute an Amendment to the Cooperating Agreement with East Bay Municipal Utility District to Prepare a Groundwater Sustainability Plan for the East Bay Plain Subbasin.
10/27/2020	EBMUD: Board of Directors Regular Business Meeting	1:15 PM Virtual Meeting	District’s total cost-share for development of a Groundwater Sustainability Plan for the East Bay Plain Subbasin.
2/23/2021	EBMUD: Board of Directors Special Meeting	9:00 AM Virtual Meeting	Long-Term Water Supply Workshop: Session to receive an outline of the key challenges facing the District’s long-term water supplies and updates on the District’s strategy for improving resilience and sustainability within its water supply portfolio.
8/5/2021	EBMUD: Memo to the Board of Directors	N/A	Memo to the Board of Directors providing them with an update on the development East Bay Plain Subbasin Groundwater Sustainability Plan.
8/10/2021	EBMUD: Planning Committee Meeting	9:00 AM Virtual Meeting	Update on the development of the East Bay Plain Subbasin Groundwater Sustainability Plan.
11/8/2021	Hayward: Council Sustainability Committee Meeting	4:30 pm Virtual Meeting	Presentation on Draft East Bay Plain Subbasin Groundwater Sustainability Plan.
11/16/2021	Hayward: City Council Special Meeting	7:00 PM Hayward City Hall Council Chambers 777 B Street, Hayward, CA 94541, and Virtual Meeting	Authorize the City Manager to Execute an Amendment to the Cooperating Agreement with East Bay Municipal Utility District to Prepare a Groundwater Sustainability Plan for the East Bay Plain Subbasin.

APPENDIX 6. REFERENCES AND TECHNICAL STUDIES

6.D. Technical Appendices

APPENDIX 6D | SEPTEMBER 2021

SUMMARY OF CLIMATE CHANGE STUDIES AND GUIDANCE FOR EAST BAY PLAIN SUBBASIN

PREPARED FOR

EAST BAY MUNICIPAL UTILITY DISTRICT

CITY OF HAYWARD

PREPARED BY

LSCE
TEAM

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1. INTRODUCTION

Several key climate change studies and guidance documents relative to the San Francisco Bay Area and the East Bay Plain (EBP) Subbasin were reviewed to inform climate change considerations for the EBP Subbasin Groundwater Sustainability Plan (GSP) projected water budget. Following guidance from the Department of Water Resources (DWR), the climate change review evaluated sea level rise (SLR) and potential changes in precipitation, temperature and evapotranspiration (ET), and streamflow. This analysis provided input for developing future baseline and project scenarios for simulation with the EBP Subbasin groundwater model. A summary of these studies is provided below for two categories: Sea Level Rise and Precipitation, ET/Temperature, and Streamflow Change Factors.

2. SEA LEVEL RISE PROJECTIONS

A summary of projected SLR in the San Francisco Bay Area from several climate change studies reviewed for the EBP GSP is provided below, along with cited references for each study:

1. **DWR SGMA Guidance Document (DWR, July 2018)** – This study utilized SLR estimates from the National Research Council (NRC, 2012), which provided projections for 2030, 2050, and 2100 relative to 2000. DWR noted that NRC's projections had been adopted by the California Ocean Protection Council as guidance for planning and decision making in California. Based on the NRC study (2012), DWR provided SLR projections of 15 centimeters (0.5 feet) for 2030 and 45 centimeters (1.5 feet) for 2070.
2. **Hayward Regional Shoreline Master Plan (SCAPE, et.al., November 2019)** – This study documented various SLR projections for mapping inundation areas. These SLR projections included a range from 2.4 to 6.9 feet for the year 2100 and were based on the California Ocean Protection Council (2018) Study. Another cited reference is the California Coastal Commission (CCC) 2018 Guidance, which provides ranges of 0.5 (17% exceedance probability) to 0.8 feet (0.5% exceedance probability) for 2030 and 1.9 (17% exceedance probability) to 3.5 feet (0.5% exceedance probability) for 2070.
3. **City of Alameda (May et.al., September 2020)** – This study references various SLR scenarios mapped as part of the Adapting to Rising Tides program by Vandever et al., 2017. However, since the response of shallow groundwater to storm surges would likely be limited and temporary, the study cites SLR from 12 to 66 inches (1 to 5.5 feet) as being within the bounds of recent SLR studies conducted by others such as NRC 2012, Griggs, et al., 2017, and CCC, 2018. The study does not assign specific future years to predicted SLR.
4. **Griggs, et.al. (2017)** – This study provides median SLR projections of 0.4 feet for 2030, 0.9 feet for 2050, and 1.6 to 2.5 feet for 2100.
5. **Adapting to Rising Tides (BCDC, MTC, and ABAG, 2020)** – This study cited estimates from the Ocean Protection Council (2018), which included SLR estimates of 0.5 feet for 2030, 1.0 feet for 2050, 2.0 feet for 2070, and 3.4 feet for 2100.

Sea level rise estimates for the various studies reviewed are summarized in Table 1. The overall range in predicted sea level rise for 2070 ranges from 1.5 to 3.5 feet; considering all the studies listed, a typical value is approximately 2.0 feet. The estimates also indicate the average/typical anticipated sea level rise from current conditions derived from the various studies ranges from 0.5 feet in 2030 to 2.0 feet in 2070, which covers the range of years being simulated in various scenarios for the EBP Subbasin GSP.

Table 1. Summary of Sea Level Rise Estimates by Future Year (in feet)

Study	2030	2050	2070	2100
DWR, 2018	0.5		1.5	
Hayward Shoreline, 2019	0.5 – 0.8		1.9 – 3.5	2.4 – 6.9
City of Alameda, 2020	1 – 5.5			
Griggs/COPC, 2017	0.4	0.9		1.6 – 2.5
BCDC, 2020	0.5	1.0	2.0	3.4
All Studies – Minimum	0.4	0.9	1.5	1.6
All Studies - Maximum	0.8	1.0	3.5	6.9
All Studies – Typical Average	0.5	1.0	2.0	3.5

3. PRECIPITATION, ET/TEMPERATURE, AND STREAMFLOW CHANGE FACTORS

A summary of projected precipitation, ET/temperature, and streamflow changes in the San Francisco Bay Area from several climate change studies is provided below, along with cited references for each study:

1. **DWR SGMA Guidance Document (DWR, July 2018)** – DWR provides very specific guidance for change factors for precipitation, ET/temperature, and streamflow in the EBP Subbasin. DWR developed a set of change factors that can be applied to each month for a future scenario. These change factors for the EBP Subbasin for future years 2030 and 2070 were reviewed and are summarized below in Table 2.

Table 2. Summary of Average Precipitation, ET, and Streamflow Change Factors for EBP Subbasin (DWR, 2018)

Months	2030 Precipitation	2030 ET/ Temperature	2030 Streamflow	2070 Precipitation	2070 ET/ temperature	2070 Streamflow
December to March	1.09	1.02	1.11	1.17	1.07	1.24
Weighted Monthly Average	1.06	1.03	1.08	1.09	1.08	1.19

Approximately 70% of precipitation and most rainfall-related recharge occurs from December 1 to March 31, when the increase in precipitation is projected to be significantly more than the projected increase in ET (**Figure 6D-1**). Precipitation is generally projected to be less (than historical averages) in other months April 1 to November 30 (**Figure 6D-2**). Accounting for change factors in all months in proportion to the amount of monthly precipitation, the gap between projected increases in precipitation versus ET decreases but the projected precipitation increases are still slightly greater than projected ET increases. Streamflow change factors are similar to precipitation with greater increases for December through March (**Figure 6D-3**) compared to other months from April to November (**Figure 6D-4**).

2. **Hayward Regional Shoreline Master Plan (SCAPE, et.al., November 2019)** – Multiple studies were cited that ranged from a small imperceptible increase in precipitation (USGCRP, 2017; Ackerly, 2019) to a precipitation increase of 6 to 37% (atmospheric theory and climate models).
3. **DWR Climate Change Technical Advisory Group (DWR CCTAG,2015)** – This study provided two future greenhouse gas scenarios: Representative Concentration Pathway (RCP) 4.5 (low greenhouse gas emission scenario) and RCP 8.5 (high greenhouse gas emission scenario) simulations. The study evaluated a number of Global Climate Models (GCM) to compare projected changes in precipitation in California for 2070 to 2099 vs. 1961 to 1990. For the large ensemble of 31 GCMs, future precipitation ranged from 85 to 125 percent of the historical mean for the RCP 4.5 scenario and from 75 to 130 percent of historical mean for the RCP 8.5 scenario in the East of Sacramento Region. The most representative CGMs for California (10 in total), as selected by an expert panel, indicated future precipitation ranging from 88 to 125 percent of historical mean for the RCP 4.5 scenario, and from 89 to 130 percent of historical mean for the RCP 8.5 scenario. Review of charts for projected changes in precipitation from this study indicated a higher probability for a future increase in precipitation. Projected temperature increases for the RCP 4.5 scenario are 3.5 to 6 degrees Fahrenheit (F) for the 10 most representative GCMs and 3.5 to 6.5 degrees F for the entire 31 GCM ensemble, compared to projected temperature increases of 6.5 to 10 degrees F (10 representative GCMs) and 5.5 to 10.5 degrees F (31 GCM ensemble) for the RCP 8.5 scenario.
4. **EBMUD 2050 Demand Study (Hazen, July 2020)** – This study included a detailed review of the DWR CCTAG study (DWR, 2015) within the framework of developing a water demand model for estimating future water demands in the EBMUD service area. The study found that projected changes in rainfall were highly uncertain. Therefore, future rainfall forecasts from GCM models were not included in the 2050 Demand Study. EBMUD water demand forecasts incorporated predicted future increases in temperature for the higher greenhouse gas emission scenario (RCP 8.5), which amounted to a temperature increase of 6.2% for the portion of EBMUD service area that includes the EBP Subbasin.

The studies described above indicate that anticipated future increases in precipitation due to climate change are likely to exceed the projected future increases in evapotranspiration in the EBP Subbasin, especially in the Winter and early Spring seasons when most groundwater recharge occurs. These projected future changes in hydrology would tend to result in slight increases in groundwater recharge. Overall, the estimates described in these studies indicated that no change in the amount of recharge from rainfall and streamflow relative to historical values is a slightly conservative approach for a future scenario in EBP Subbasin (i.e., this approach possibly underestimates future recharge from rainfall and streamflow). The effect of these change factors is quite small regarding associated changes to basin recharge and remain highly uncertain.

4. CONCLUSIONS

Based on the review of key climate change studies/guidance documents, it is recommended that the amount of SLR for use in EBP Subbasin groundwater model scenarios be assigned as 2.0 feet (in 2070) for a typical average value. DWR's climate change guidance provides 1.5 feet as the SLR estimate for 2070, but a value of 2.0 feet is recommended due to slightly greater SLR amounts predicted in other local studies.

While significant uncertainty is associated with predictions, it is anticipated that there will be an overall increase in precipitation and streamflow with future climate change. ET is also expected to increase, as would be expected with expected increasing temperatures. The local change factors for the EBP Subbasin indicate greater increases in precipitation than in ET. Due to a greater likelihood of precipitation/streamflow increases (that offset projected future temperature/ET increases), it is anticipated that future groundwater recharge within EBP Subbasin will not change significantly. Using no change in precipitation recharge and streamflow infiltration in the future (versus increases forecasted by various studies) scenarios evaluated for the EBP Subbasin is more conservative (i.e., underpredict future recharge amounts).

5. LIST OF REFERENCES

Ackerly, D.J., *San Francisco Bay Area Summary Report*, University of California, Berkeley, 2019.

Adapting to Rising Tides 2020, *Adapting to Rising Tides, Bay Area: Regional Sea Level Rise Vulnerability and Adaptation Study*, Bay Conservation and Development Commission (BCDC) and Metropolitan Transportation commission/Association of Bay Area Governments (MTC/ABAG), San Francisco, CA, March 2020.

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May, C.L., Mohan, A.T, Mak, M., and Y. Badet, *The Response of the Shallow Groundwater Layer and Contaminants to Sea Level Rise*, Report by Silvestrum Climate Associates for the City of Alameda, California, September 2020.

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USGCRP, Climate Science Special Report: Fourth National Climate Assessment, Volume 1, Washington DC, 2017.

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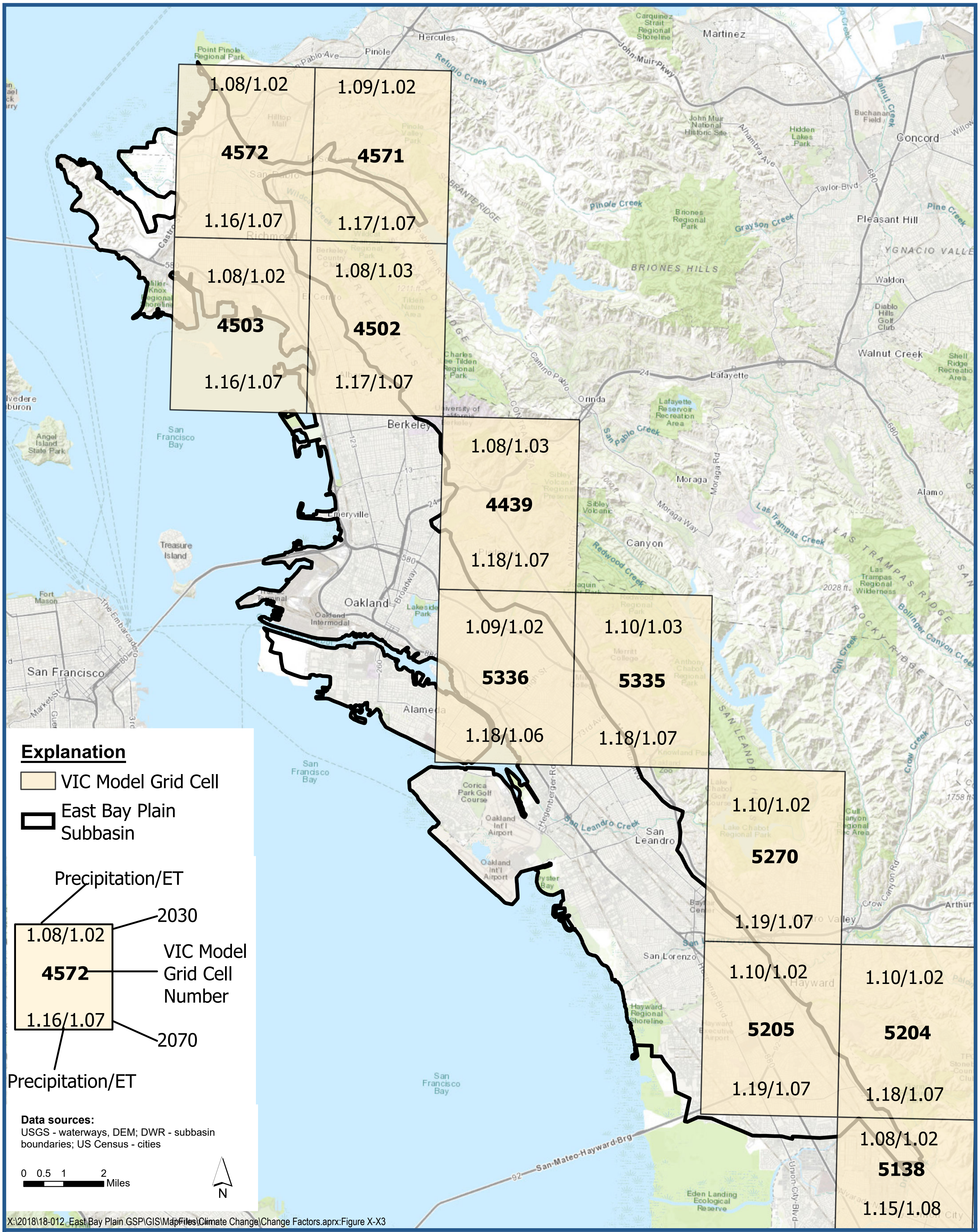


Data sources:
USGS - waterways, DEM; DWR - subbasin boundaries; US Census - cities

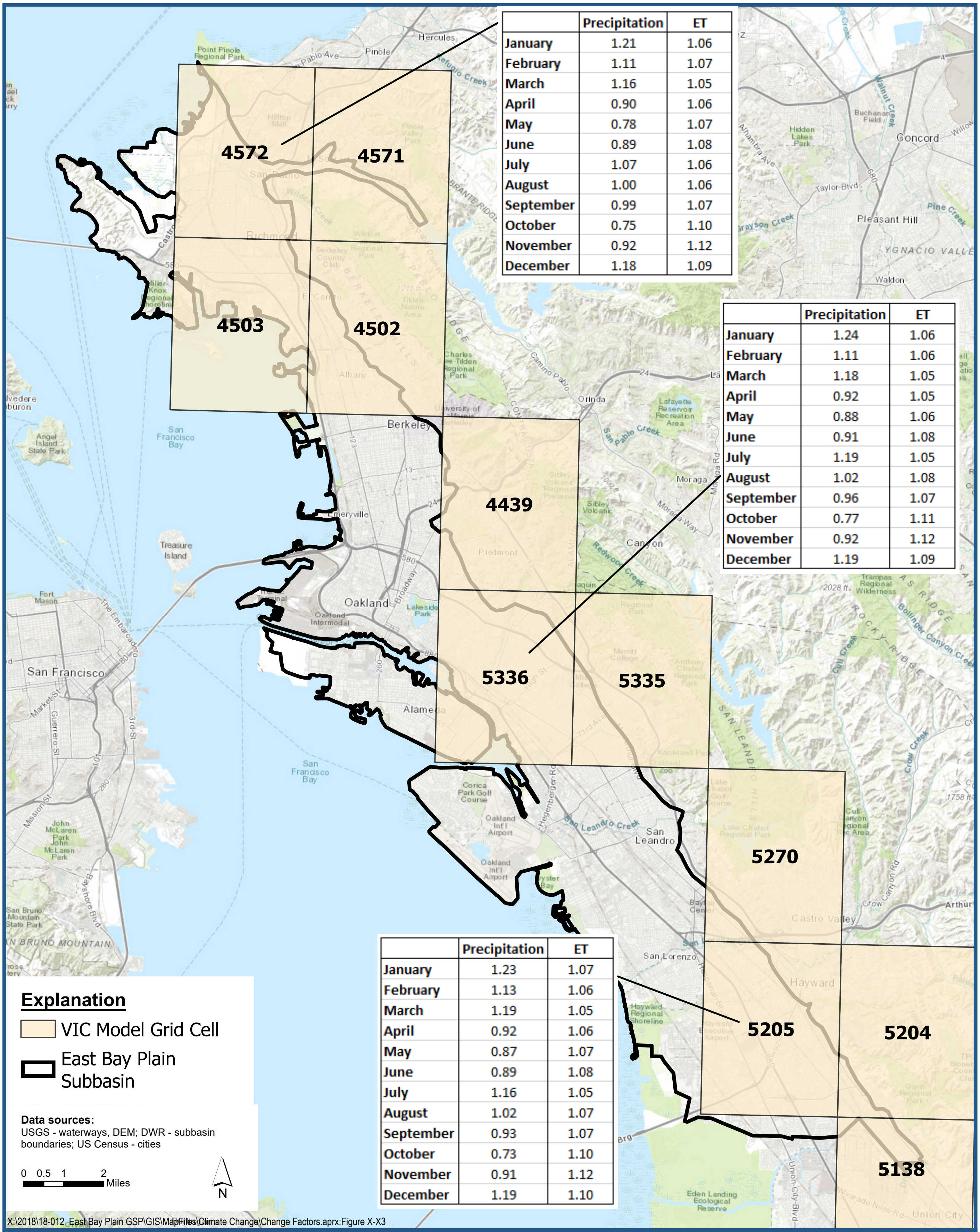
X:\2018\18-012_East Bay Plain GSP\GIS\MapFiles\Climate Change\Change Factors.aprx:Figure X-X3

LSCE TEAM

December-March Precipitation/ET Change Factors for 2030 and 2070

East Bay Plain Subbasin
Groundwater Sustainability Plan

Figure 6D-1



	Precipitation	ET
January	1.21	1.06
February	1.11	1.07
March	1.16	1.05
April	0.90	1.06
May	0.78	1.07
June	0.89	1.08
July	1.07	1.06
August	1.00	1.06
September	0.99	1.07
October	0.75	1.10
November	0.92	1.12
December	1.18	1.09

	Precipitation	ET
January	1.24	1.06
February	1.11	1.06
March	1.18	1.05
April	0.92	1.05
May	0.88	1.06
June	0.91	1.08
July	1.19	1.05
August	1.02	1.08
September	0.96	1.07
October	0.77	1.11
November	0.92	1.12
December	1.19	1.09

	Precipitation	ET
January	1.23	1.07
February	1.13	1.06
March	1.19	1.05
April	0.92	1.06
May	0.87	1.07
June	0.89	1.08
July	1.16	1.05
August	1.02	1.07
September	0.93	1.07
October	0.73	1.10
November	0.91	1.12
December	1.19	1.10

Data sources:
USGS - waterways, DEM; DWR - subbasin boundaries; US Census - cities

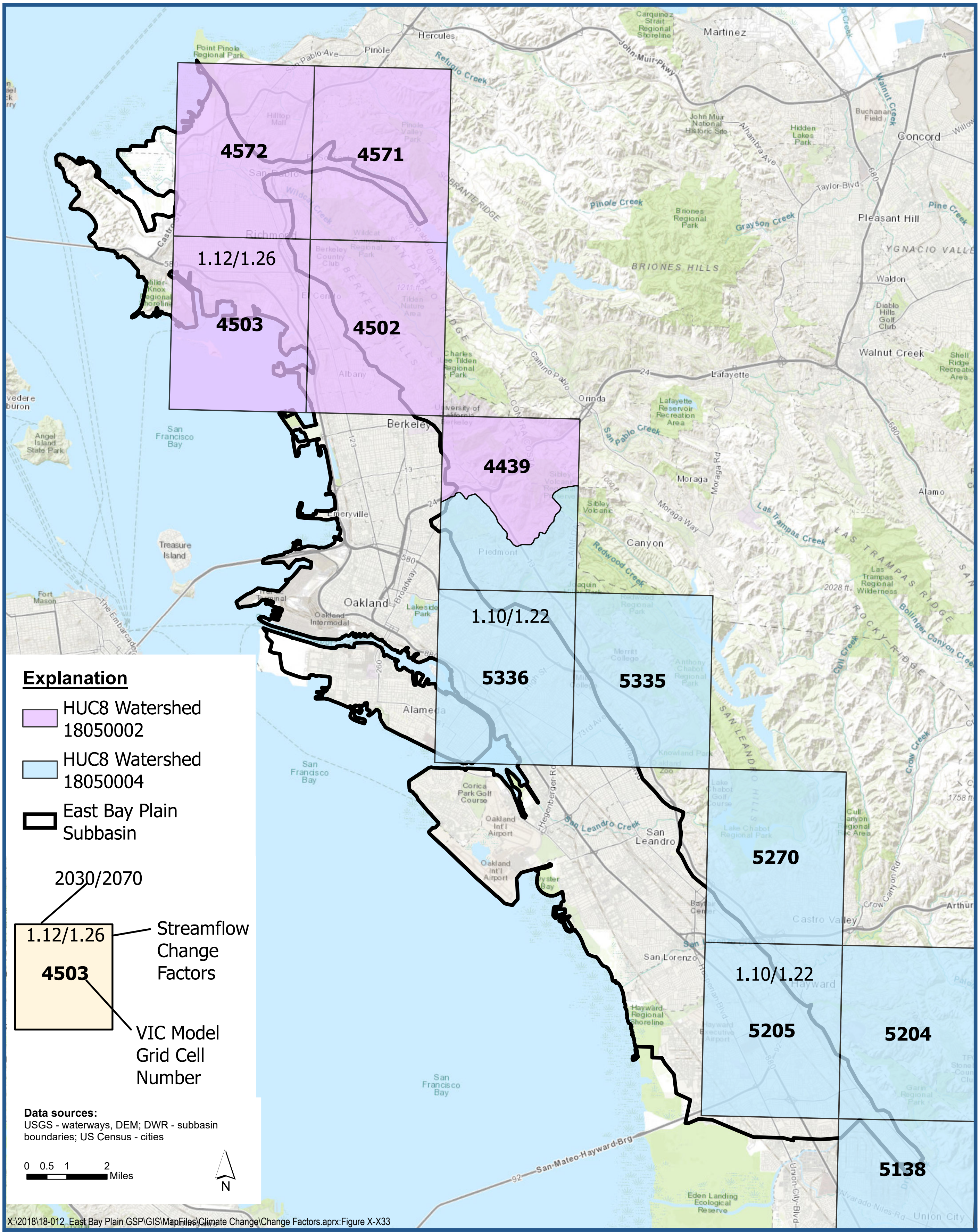
X:\2018\18-012_East Bay Plain GSP\GIS\MapFiles\Climate Change\Change Factors.aprx:Figure X-X3

LSCE TEAM

January-December Precipitation/ET Change Factors for 2070

East Bay Plain Subbasin
Groundwater Sustainability Plan

Figure 6D-2



Data sources:
USGS - waterways, DEM; DWR - subbasin boundaries; US Census - cities

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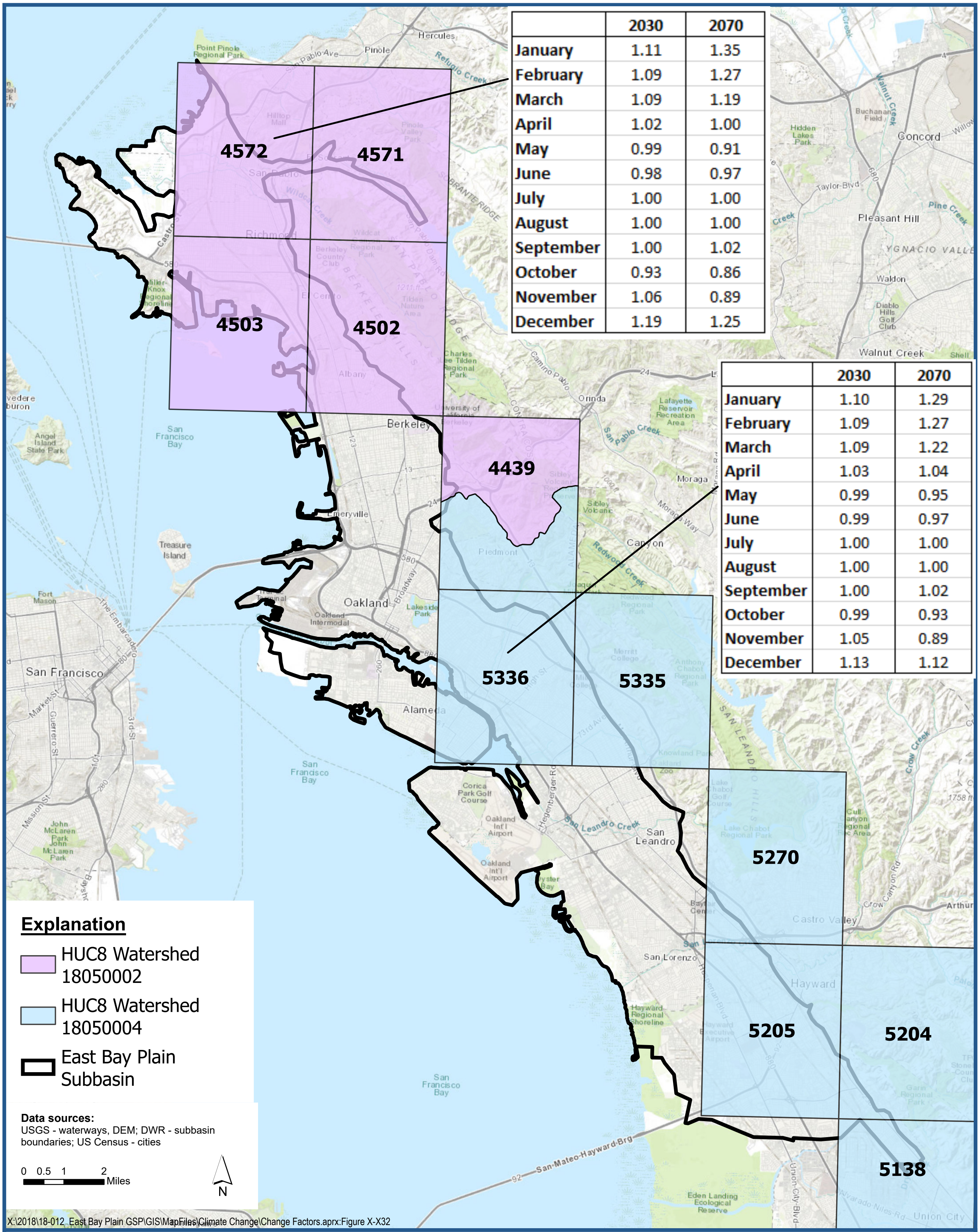
LSCE TEAM

December-March Average Streamflow Change Factors for 2030/2070 by Watershed

East Bay Plain Subbasin
Groundwater Sustainability Plan

Figure 6D-3



	2030	2070
January	1.11	1.35
February	1.09	1.27
March	1.09	1.19
April	1.02	1.00
May	0.99	0.91
June	0.98	0.97
July	1.00	1.00
August	1.00	1.00
September	1.00	1.02
October	0.93	0.86
November	1.06	0.89
December	1.19	1.25

	2030	2070
January	1.10	1.29
February	1.09	1.27
March	1.09	1.22
April	1.03	1.04
May	0.99	0.95
June	0.99	0.97
July	1.00	1.00
August	1.00	1.00
September	1.00	1.02
October	0.99	0.93
November	1.05	0.89
December	1.13	1.12

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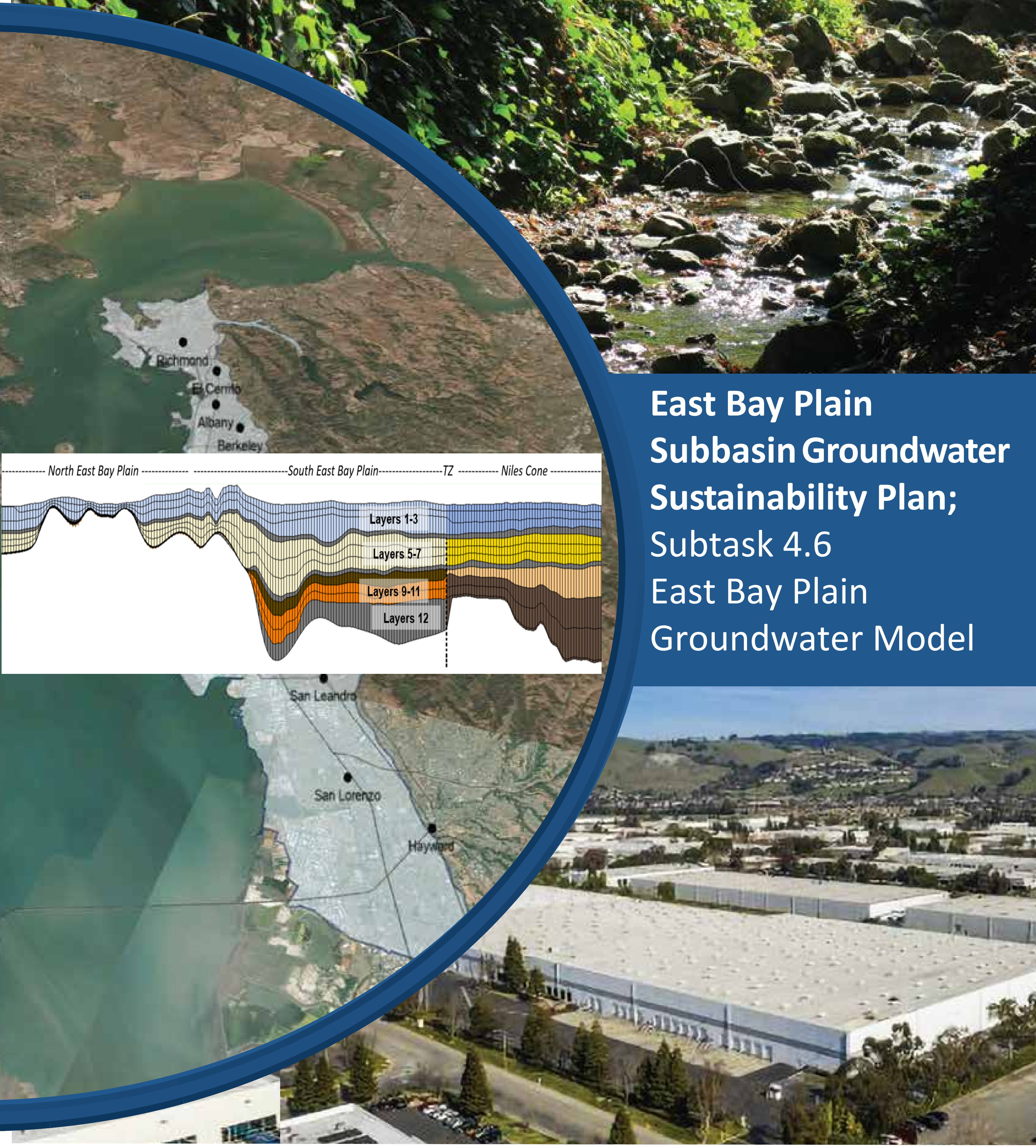
January-December Streamflow Change Factors for 2030 and 2070 by Watershed

East Bay Plain Subbasin
Groundwater Sustainability Plan

Figure 6D-4

APPENDIX 6. REFERENCES AND TECHNICAL STUDIES

6.E. Groundwater Model Documentation



East Bay Plain Subbasin Groundwater Sustainability Plan; Subtask 4.6 East Bay Plain Groundwater Model

EBMUD

HAYWARD

Prepared by

LSCE TEAM

November, 2021

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LIST OF ABBREVIATIONS & ACRONYMS

ACPWA	Alameda County Public Works Agency
ACWD	Alameda County Water District
AFY	acre-feet per year
AHGW	Arc Hydro Groundwater
ArcGIS	Geographical Information System maintained by the Environmental Systems Research Institute
bgs	below ground surface
BMP	Best Management Practices
DEM	digital elevation model
DWR	Department of Water Resources
EBMUD	East Bay Municipal Utility District
EBP	East Bay Plain
EBPGWM	East Bay Plain Groundwater Model
EKI	EKI Environment & Water
ft	feet
ft/d	feet per day
Fugro	Fugro West, Inc.
GAGE	gage package
GDEs	groundwater dependent ecosystems
Geosyntec	Geosyntec Consultants, Inc.
GHB	general head boundary
GHB1	General Head Boundary Package Version 1 for MODFLOW
GMS	Groundwater Modeling System
gpm	gallons per minute
GSA	Groundwater Sustainability Agency
GSP	groundwater sustainability plan
GUI	Graphical User Interface
Hayward	City of Hayward
HCM	Hydrogeologic Conceptual Model

HFB	Horizontal Flow Barrier
HFB6	Horizontal Flow Barrier Package Version 6 for MODFLOW
IGSM	Integrated Groundwater Surface Water Model
K	Hydraulic Conductivity
LSCE Team	LSCE, Geosyntec, and other subconsultants
LSCE	Luhdorff & Scalmanini Consulting Engineers
MAE	mean of the absolute error
ME	mean error
MODFLOW	United States Geological Survey Modular Finite-Difference Flow Model
NEBMODFLOW	Niles Cone and South East Bay Plain MODFLOW Model
NEBIGSM	Niles Cone and South East Bay Plain Integrated Groundwater and Surface Water Model
NOAA	National Oceanic and Atmospheric Administration
PEST	Parameter Estimation Code
R2	Coefficient of determination (statistics metric).
RCH1	Recharge Package Version 1 for MODFLOW
RMSE	root mean squared error
SFR2	Streamflow-Routing Package Version 2 for MODFLOW
SGMA	Sustainable Groundwater Management Act
SMPGWM	San Mateo Plain Groundwater Model
T	Transmissivity
TM	Technical Memorandum
USGS	United States Geological Survey
WEL1	Well Package Version 1 for MODFLOW

EXECUTIVE SUMMARY

California's Sustainable Groundwater Management Act (SGMA) requires sustainable management of the state's groundwater basins by local Groundwater Sustainability Agencies (GSAs) that have the authority to develop adopt and implement Groundwater Sustainability Plans (GSPs) for groundwater basins or sub-basins. Luhdorff & Scalmanini Consulting Engineers (LSCE) and a team of subconsultants (the LSCE Team)[1] are working with the East Bay Municipal Utility District (EBMUD) and the City of Hayward (Hayward) GSAs to develop a GSP for the East Bay Plain (EBP) Subbasin.

This Technical Memorandum (TM)[2] documents the development, calibration, and application of an updated numerical groundwater flow model of the EBP Subbasin (2021 EBPGWM) that is utilized as a tool in the development of the GSP in accordance with the SGMA guidelines (§352.4).

ES-1. Model Domain and Hydrogeologic Conceptual Model Overview

The domain of the updated EBP Groundwater Model (2021 EBPGWM) encompasses the entire EBP Subbasin (**Figure ES-1**) as defined by California Department of Water Resources (DWR) (2018). The model domain also includes the adjacent Niles Cone Subbasin on the south, and the Castro Valley Basin[3] north of Hayward, which is delineated as a separate groundwater basin by DWR. Although the DWR delineation of the EBP and Niles Cone Subbasins stops at the shoreline of the San Francisco Bay, the model domain extends to the west into the San Francisco Bay because the unconsolidated sedimentary units that comprise the subbasins extend beneath the San Francisco Bay (e.g., GSP Appendix 2.A.b). A geologic map of unconsolidated sedimentary deposits and the bedrock outcrops of the Franciscan Complex (Jennings et al., 1977) was used to constrain the eastern extent and inactive areas within the model domain. Most of the eastern margin of the model domain is approximately coincident with the Hayward Fault along the base of the East Bay Hills, which are dominantly consolidated rock of the Franciscan Complex (**Figure ES-1**).

Unconsolidated deposits that comprise the EBP Subbasin are up to at least 1,000 ft thick in the southern portion, but the maximum thickness in the northern portion is less than approximately 500 ft. Three depth interval zones are defined within the unconsolidated sedimentary deposits:

1. Shallow Aquifer Zone (ground surface to less than 200 ft below ground surface [bgs]),
2. Intermediate Aquifer Zone (200 to 400 ft bgs), and
3. Deep Aquifer Zone (over 400 ft bgs).

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[1] The LSCE Team includes Geosyntec Consultants, ESA, Brown and Caldwell, Jean Moran, Farallon Geographics, and Kearns & West.

[2] The LSCE Team prepared this TM under Subtask 4.6 of the GSP development work. Geosyntec Consultants led the development and calibration of the 2021 EBPGWM (Subtask 4.4), application of the 2021 EBPGWM to evaluate projections of Baseline and Alternative Management Scenarios (Subtask 4.5), and preparation of this TM with guidance and oversight by LSCE.

[3] DWR identifies the alluvial deposits in the Castro Valley as a separate groundwater basin from the EBP and NC, which are subbasins of the Santa Clara Valley Basin (e.g. DWR, https://gis.water.ca.gov/app/bbat/)

Relatively low permeability intervals are present within and between the three Aquifer Zones throughout the EBP Subbasin, which locally function as aquitards that limit the vertical hydraulic connection between the Aquifer Zones and create some impedance to vertical flow within Aquifer Zones.

The hydrogeologic conceptual model (HCM) of the EBP Subbasin is documented in detail by TM 4.2 (Appendix 2.A.b of the GSP). Coarse-grained permeable sediments in the Deep Aquifer Zone are most abundant and relatively continuous in the portion of the EBP Subbasin between southern San Leandro and Hayward (**Figure ES-1**).

The EBP Subbasin water budget comprises the following components:

- Inflows:
    - Recharge from precipitation, accounting for evapotranspiration;
    - Recharge from irrigation of large areas and residential parcels;
    - Recharge from leaking sewer lines and domestic water supply pipes;
    - Infiltration of surface water in streams to groundwater;
    - Inflow from the Niles Cone Subbasin; and
    - Inflow along the eastern margin of the EBP Subbasin (e.g., Castro Valley Basin and bedrock inflow).
- Outflows:
    - Groundwater pumping;
    - Groundwater discharge to the San Francisco Bay;
    - Outflow to the Niles Cone Subbasin; and
    - Discharge of groundwater to surface water in streams and sewer pipes.

For purposes of calibration and reporting the model results, an informal division is assigned between the northern and southern portions of the EBP Subbasin (**Figure ES-1)**[4]. The northern portion is less studied and north of Oakland the groundwater production potential is less because the unconsolidated sedimentary deposits are thinner and generally finer grained compared to the portion of the EBP Subbasin south of Oakland.

The hydrogeologic boundary between the EBP Subbasin and the main portion of the Niles Cone Subbasin occurs within a transition zone between the subbasins (LSCE, 2003; GSP Appendix 2.A.b). However, the current jurisdictional boundary between the EBP and Niles Cone Subbasins delineated by DWR in 2016 trends to the northwest of the transition zone toward the margin of the San Francisco Bay (**Figure ES-1**).

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[4] This designation of north and south portions of the EBP Subbasin is different than the north/south geographic division presented in the HCM TM (Figure 1-1 of GSP Appendix 2.A.b), which is in Oakland and extends into the San Francisco Bay along the Bay Bridge.

This delineation results in a northern appendage of the jurisdictional Niles Cone subbasin that is not consistent with the hydrogeologic boundary between the subbasins. Multiple lines of evidence indicate the presence of a partial barrier within the transition zone that impedes groundwater flow between the EBP Subbasin and the main portion of the Niles Cone Subbasin within the Deep and Intermediate Aquifer Zones. In addition, the relatively continuous coarse-grained units of the Niles Cone Newark Aquifer in the Shallow Zone are not present north of the transition zone.

ES-2. Model Design

Geosyntec developed the 2021 EBPGWM using MODFLOW[5], which is versatile and widely used public domain software for groundwater modeling that is supported by the United States Geological Survey (USGS) and is well-suited for simulating groundwater flow and interaction between surface water and groundwater in the EBP.

Most data used for construction and calibration of the model are presented in Section 2 of the GSP and the HCM TM (GSP Appendix 2.A.b), and include reported regional water budgets, precipitation data, regional geologic maps, geologic cross-sections, geophysical logs, aquifer test results, streamflow, and dam release data. In addition, lithologic and well construction data from 631 borings, and groundwater elevation records from approximately 100 wells were used in the construction and calibration of the 2021 EBPGWM. Previously developed groundwater flow models that overlap the domain of the 2021 EBPGWM[6] were also considered during the construction and calibration of the 2021 EBPGWM.

The seven layers of the 2013 NEBMODFLOW (EBMUD, 2013) model were used as a starting point for the design of the 2021 EBPGWM, which consists of 12 Layers. The additional layers in the 2021 EBPGWM improve the simulation of vertical hydraulic gradients, well screen intervals, and groundwater-surface water interaction. The 12 model layers correspond with the HCM as follows:

- Layers 1 through 3: Shallow Aquifer Zone;
- Layer 4: aquitard below the Shallow Aquifer Zone;
- Layers 5 through 7: Intermediate Aquifer Zone;
- Layer 8: aquitard below the Intermediate Aquifer Zone;
- Layers 9 through 11: Deep Aquifer Zone; and

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[5] USGS MODFLOW-NWT was the specific version of MODFLOW used (https://www.usgs.gov/software/modflow-nwt-a-newton-formulation-modflow-2005). MODFLOW-NWT is an update of MODFLOW-2005 to improve solving drying and rewetting nonlinearities of groundwater flow for unconfined conditions (Niswonger et al., 2011).

[6] TM 4.3 and the main body of this TM provide an overview of existing groundwater models of the NC and a portion of the East Bay Plain, which include the NEBIGSM, NEBMODFLOW, and other models in the general Bay Area vicinity that overlap with the EBP Subbasin.

- Layer 12: low permeability fine-grained sediments locally present between the Deep Aquifer Zone and bedrock in the southern portion of the EBP Subbasin.

The 2021 EBPGWM grid cells are all 1,000 by 1,000 ft, which provides sufficient resolution for the purposes of using the model as a regional tool for developing the GSP, representing large-scale variation in aquifer and aquitard geometry and hydraulic properties, boundary conditions, and hydraulic gradients, as well as managing and planning development of the groundwater resources.

The geometry of the 2021 EBPGWM layering is illustrated by a north-northwest to south-southeast cross-section (**Figure ES-2**), the location of which is shown by **Figure ES-1**. Refinements were made to the layering and hydraulic properties in the 2021 EBBGWM to improve the representation of documented hydrogeologic conditions in the vicinity of the transition zone between the EBP and Niles Cone subbasins. **Figure ES-2** includes a zoomed-in inset that illustrates the model layering detail near the transition zone. Layer geometry and hydraulic properties in the Niles Cone Subbasin portion of the 2021 EBPGWM is generally consistent with that of the 2013 NEBMODFLOW model[7], except for the added layers and adjustments in the vicinity of the transition zone.

Boundary conditions assigned to the 2021 EBPGWM are summarized in **Table ES-1**. Preliminary assignments to the 2021 EBPGWM of water budget components, such as recharge and inflow along the eastern margin, were based on data and estimates presented in the HCM TM (GSP Appendix 2.A.b).

Aquifer properties assigned to each grid cell in the 2021 EBPGWM include horizontal and vertical hydraulic conductivities, specific yield, and specific storage. Initial values were based on the previous models, the HCM, compilation of percent sand and gravel documented in boring logs, and professional judgement. The values were refined within zones during the model calibration.

ES-3. Model Calibration

The 2021 EBPGWM was calibrated using a combination of both manual and automated adjustment of model parameters to achieve an acceptable match between model-simulated results and observed data. Four different simulations were used for calibration: (1) steady-state representing recent average (baseline) 2000 – 2015 conditions, (2) historical transient that represents changing conditions each month between 1990 and 2015, (3&4) regional aquifer tests conducted in 2002 and 2010.

Because the 2021 EBPGWM is designed as a tool for the EBP GSP and evaluation of potential development of groundwater resources in the EBP subbasin, the calibration process focused on the EBP Subbasin. Model properties in the Niles Cone Subbasin were based on the 2019 update to the 2005 NEBIGSM model with some adjustments in the transition zone for the calibration to the two regional aquifer tests.

The calibration included comparison and optimization of model-simulated results to documented data or estimates for:

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[7] The 2013 NEBMODFLOW Model is based on the NEBIGSM Model.

- Approximately 100 well locations for calibration of the steady-state and historical transient versions of model,
- Water budget calculations for the EBP Subbasin presented in the HCM, and
- Stream flow data from six gages on Wildcat and San Lorenzo Creeks, and general conditions for the other creeks.

The calibration process included adjustment of values assigned to the following parameters to improve the match between model results and observed data:

- Horizontal conductivity (Kh) and vertical hydraulic conductivity (Kv) of active model cells,
- Specific yield (Sy) of active model cells in Layer 1,
- Specific storage (Ss) of active model cells in Layers 2 – 12,
- Groundwater recharge,
- Bedrock inflow rate at the eastern boundary of the model domain,
- Leakance through the Bay and salt pond floors,
- Leakance through the streambeds, and
- Conductance of the HFB, which is used in Layers 4 through 12 to represent a partial hydraulic barrier within the transition zone between the EBP Subbasin and the main part of the Niles Cone Subbasin.

Because most of the water supply in the EBP subbasin is imported, changes in pumping are minor during the historical transient period, so the calibration of that simulation does not include substantial changes in stresses to the aquifer system. Instead, the calibration to the simulations of a sequential pair of aquifer tests conducted in 2002 and an aquifer test conducted in 2010 provided the best constraints of aquifer properties and stresses of the aquifer system in the southern portion of the EBP, the transition zone, and northern portion of the Niles Cone Subbasin near the transition zone.

Calibration of the 2002 Aquifer Test Simulation (LSCE Test[8]) compared modeled and observed groundwater response to a sequential pair of aquifer tests conducted at City of Hayward Wells C and E. Well C is in the Niles Cone Subbasin, approximately 1.5 miles south of the horizontal flow barrier (HFB) that represents the partial hydraulic barrier in the transition zone, and Well E is in the EBP Subbasin within several hundred feet north of the HFB. Well C was pumped for two weeks at 3,300 gallons per minute (gpm). Then recovery was recorded for approximately one month before Well E was pumped at 2,200 gpm for two weeks, followed by more than another month of recording of recovery. Groundwater levels data for a total of 15 monitoring wells that were instrumented with pressure transducers and data loggers in both the southern portion of the EBP Subbasin and in the northern portion of the Niles Cone Subbasin were used for the calibration of the 2021 EBPGWM to the 2002 aquifer tests.

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[8] This test is also called the LSCE test because it was conducted and analyzed by LSCE for the City of Hayward, Alameda County Water District and EBMUD.

Calibration of the 2010 Aquifer Test Simulation (Fugro 2010 Test[9]) compared the modeled and observed groundwater response to an aquifer test conducted during the late summer of 2010 at the EBMUD Bayside Well. The Bayside well was pumped at 1,400 gpm for eight weeks and groundwater levels were recorded with pressure transducers and data loggers installed in a total of 35 monitoring wells in both the southern portion of the EBP Subbasin and the northern portion of the Niles Cone Subbasin before, during, and for approximately eight weeks after the pumping stopped. The Bayside Well is approximately 5 miles north of the HFB, between the EBP and the main portion of the Niles Cone Subbasins.

ES-3-1. Calibration of the Steady State Average Conditions Simulation

The automated parameter estimation software (PEST; Doherty, 2010), which is incorporated in the GMS software, was used to optimize the calibration of the steady-state baseline simulation that represents recent average conditions. A scatter plot of model-simulated versus observed groundwater levels (**Figure ES-3**) shows a generally good balance of model results that are both above and below the target values (average recorded target groundwater levels), and thus there is no evidence of significant bias in the model simulations relative to calibration targets. **Figure ES-3** also includes the groundwater elevation calibration statistics for the steady state baseline simulation for the entire model domain, Aquifer Zone subsets, and geographic subsets. The normalized root mean square error (RMSE)[10] is 6% of the range of the observed calibration targets and the R^2 value of a line fitted to the modeled and observed groundwater levels is 0.92.

The only groundwater level data subset with an RMSE that exceeds 10% of the range of the observed data is the Niles Cone Subbasin subset (15%). The lower model accuracy in the Niles Cone Subbasin is a consequence of less calibration effort in this portion of the 2021 EBPGWM because the intent was to preserve preexisting values of model properties in the Niles Cone Subbasin with only minor exceptions in the transition zone.

In addition to the quantitative metrics, qualitative assessments of the calibration are an important component of the calibration process. Qualitive comparisons of model-simulated and observed 2000 – 2015 average water level maps for the Shallow, Intermediate, and Deep Aquifer Zones show that the model-simulated average groundwater flow directions are generally representative of 2000 – 2015 average conditions based on measured data. Values of the water budget components for the steady-state baseline simulation are generally consistent with the calculated and estimated values for the EBP Subbasin presented in the HCM (GSP Appendix 2.A.b).

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[9] This test is also called the Fugro 2010 Test because it was conducted by Fugro for EBMUD.

[10] Although an RMSE less than 10% is commonly considered an indication of good calibration, note that RMSE as % range of observed groundwater levels is not a good indicator of the quality of calibration when the range of observed (target) groundwater levels is small.

ES-3-2. Calibration of the 1990 – 2015 Transient Simulation

Figure ES-4 presents a graph of observed versus simulated groundwater levels that shows a generally good balance between the model results being higher and lower than the target values (recorded historical data), and thus there is no evidence of significant model bias in the model-simulated values relative to calibration targets. The calibration statistic metrics for the calibration of the historical transient simulation are also included in **Figure ES-4**. Comparison of observed and model-simulated groundwater levels with time plotted as hydrographs show generally good agreement between historical (1990 – 2015) records of measured groundwater elevations and simulated groundwater elevations. Comparison of contour maps of model-simulated and measured data for groundwater elevations show that the model-simulated groundwater flow directions are generally representative of observed conditions.

Figure ES-5 shows the simulated water budget variation with time, and **Table ES-2** provides a comparison of the simulated water budget variation with time to the average estimated values of water budget components for the EBP Subbasin. The main water budget components do not vary significantly from year to year during the simulation period. Recharge varies somewhat with precipitation, with higher recharge on wetter years (e.g., 1998, 2005, 2006) and lower recharge in drier years (e.g., 1994, 2012-2015). Groundwater discharge to the San Francisco Bay increased between 1991 and 2000 and stabilized afterwards, consistent with recovery of the observed groundwater elevations in the Intermediate and Deep Aquifer Zones through the early 2000s. The average model-calculated water budget values are generally consistent with the estimated values presented in the HCM TM (GSP Appendix 2.A.b).

ES-3-3. Calibration of the 2002 Aquifer Testing Simulation

Figure ES-6 shows hydrographs that compare the observed and simulated changes in groundwater elevations during the two-week aquifer tests conducted in 2002 at Hayward Wells C and E. The hydrographs show generally good matches between the observed and simulated responses to the pumping and subsequent recovery for both the Well C and Well E tests.

Figure ES-7 is a scatter plot that compares the observed and simulated drawdown attained in response to the two weeks of pumping of each of the Hayward Wells C and E. **Figure ES-7** also provides the calibration statistics for the observed versus simulated drawdown for the simulation of the 2002 Aquifer Tests. Estimates of drawdown due to pumping from Wells C and E include corrections for the gradual regional decline in groundwater levels. One foot was used as a threshold for detected drawdown due to pumping from Wells C or E.

ES-3-4. Calibration of the 2010 Aquifer Test Simulation

Figure ES-8 shows hydrographs that compare the observed and simulated changes in groundwater elevations during the eight-week aquifer test conducted in 2010 at the EBMUD Bayside Well. The hydrographs show generally good matches between the observed and simulated responses to the pumping and subsequent recovery for the 2010 Bayside Well aquifer test.

A marked decrease in the response to pumping from the Bayside Well occurs within the transition zone between the southern portion of the EBP Subbasin and northern area of the main portion of the Niles Cone Subbasin.

Figure ES-9 is a scatter plot that compares the observed and simulated drawdown attained in response to the eight weeks of pumping from the Bayside Well. **Figure ES-9** provides the calibration statistics for the observed versus simulated drawdown for the simulation of the 2010 Aquifer Test, which indicate excellent agreement between the model results and the data recorded during the test. As with the 2002 Aquifer Tests, one foot was used as a threshold for detected drawdown due to pumping from the Bayside Well.

Figure ES-10 is a contour map of the model-simulated drawdown after eight weeks of pumping from the Bayside Well in the Deep Aquifer Zone with posted values of drawdown measured in the observation wells. As for the scatter plot, the contour map shows good agreement between the model simulation and the observed data. However, south of the HFB, the model-simulated drawdown is slightly (~1.5 ft) more than was observed in the northern area of the main portion of the Niles Cone Subbasin. This indicates that the actual impedance of the hydraulic connection between the northern portion of the main Niles Cone Subbasin and southern EBP Subbasin within the transition zone is likely slightly greater than represented with the HFB in the 2021 EBPGWM (i.e., the conductance assigned to the HFB in the 2021 EBPGWM is conservatively high). However, the calibrated HFB impedance provided the best overall fit when considering calibration to pumping of Hayward Wells C and E, and pumping of EBMUD Bayside well.

Calibration of the 2002 and 2010 aquifer test simulations provided important constraints and refinement of the values assigned to parameters in the 2021 EBPGWM in the southern portion of the EBP Subbasin and northern portion of the Niles Cone Subbasin, including the conductance of the partial hydraulic barrier in the transition zone between the EBP Subbasin and main portion of the Niles Cone Subbasin. The excellent calibration of the 2021 EBPGWM to the long-term 2010 Aquifer Test demonstrates that the model is a reliable tool to estimate sustainable yield and to simulate potential groundwater resources development projects and management actions for the EBP Subbasin.

ES-4. Parameter Sensitivity Analysis

Sensitivity of model parameters was evaluated using relative composite sensitivity calculated with PEST for the steady-state model simulation. In addition, qualitative observations were made during model calibration about the influence that adjusting certain model parameters has on the model's ability to simulate observed groundwater elevations and drawdowns, particularly for aquifer test simulations and historical pumping. The parameter sensitivity analysis of the steady-state model simulation indicates that the assigned parameter values are well constrained by calibration to steady-state calibration datasets.

The most sensitive parameters are

- Horizontal hydraulic conductivity of the Shallow Aquifer,

- Horizontal (and vertical) hydraulic conductivity of the aquitards between the Shallow and Intermediate Aquifers and between the Intermediate and Deep Aquifers,[11]
- Recharge, and
- Horizontal hydraulic conductivity of the Intermediate Aquifer.

In contrast, model-simulated steady-state groundwater elevations are relatively insensitive to change in hydraulic conductivity of the Deep Aquifer, horizontal to vertical hydraulic conductivity ratio of the Shallow, Intermediate, and Deep Aquifers and leakance through the Bay floor. Evaluation by geographic area of the most sensitive parameter groups is presented in the main body of this TM.

ES-5. Historical Pumping Evaluation

The calibrated steady-state model was used to evaluate the influence of increased rates of groundwater pumping in the EBP Subbasin that occurred in the 1950s to early 1960s. Estimated rates of historical pumping, which were used for industrial processes, irrigation, domestic uses, and municipal supply in Hayward, are as high as 35,000 to 50,000 acre-feet per year (AFY) (HCM, GSP Appendix 2.A.b). Most of this pumping likely occurred from the Intermediate and Deep Aquifer Zones in the southern portion of the Subbasin.

Pumping of approximately 23,000 AFY assigned to the steady-state model results in groundwater elevations consistent with the limited historical data, which are as low as approximately 100 feet below mean sea level in portions of the Intermediate and Deep Aquifers.

ES-6. Sustainable Yield and Future Groundwater Resource Development Simulations

Consistent with DWR Best Management Practices (BMP) guidance document for models developed for SGMA projects (DWR, 2016), the 2021 EBPGWM was used to estimate the sustainable yield of the EBP Subbasin, evaluate options for sustainable development of groundwater resources, and develop sustainable management criteria. A baseline transient simulation of future conditions with monthly time steps from Water Year 2016 through 2071 that assumes no additional groundwater resource development was compared to simulations of potential future additional development of groundwater resources in the EBP Subbasin.

Actual records were used for Water Years 2016 through 2021, and the 1991 to 2015 sequence used in the historical transient simulation was assigned twice sequentially to simulate future conditions for projected Water Years 2022 through 2071.

Projected sea level rise as a consequence of climate change was incorporated in the future baseline and the groundwater resources development simulations based on the climate change analysis presented in Appendix 6.D to the GSP. Two (2) feet of sea level rise over 50 years is represented by an incremental increase in the water level of the San Francisco Bay for each of the monthly time steps. The shoreline

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[11] The vertical hydraulic conductivity values are defined in terms of the ratio of vertical to horizontal hydraulic conductivity, so changes to horizontal hydraulic conductivity values affect vertical hydraulic conductivity values.

location was not altered, which is considered a reasonable assumption because seawalls and other infrastructure will likely be developed to mitigate inundation of most the EBP Subbasin.

For wells located in the EBP Subbasin, pumping rates from Water Year 2002, which are representative of current conditions, are assigned for each year for the 2022 – 2071 baseline simulation. For wells located in the Niles Cone Subbasin, pumping rates from Water Year 2015 are scaled so that the annual total is equal to the 2011 – 2020 average pumping and assigned for each year in the 2022 – 2071 baseline simulation.

A steady state simulation that approximates average future baseline conditions was also prepared using average values of the transient inputs for the period from Water Year 2022 to Water Year 2071 for recharge, streamflow, and groundwater pumping. The steady-state simulation of average future baseline conditions incorporates two (2) feet of sea level rise.

ES-6-1. Sustainable Yield Evaluation

The sustainable yield[12] of groundwater was evaluated for three areas of the EBP Subbasin: 1. North EBP (NEBP), 2. Middle EBP (MEBP), and 3. South EBP (SEBP). The MEBP and SEBP areas together are equivalent to the South EBP Subbasin defined in the HCM.

The following criteria were used in the determination of sustainable yield:

- **Water budget:** Maintain net outflow from the EBP Subbasin to the Niles Cone Subbasin, and from the EBP Subbasin to San Francisco Bay and to the aquifers underneath the Bay.
- **Water level to mitigate saltwater intrusion:** Maintain simulated water table along the Bay margin of the EBP Subbasin above the elevation of the San Francisco Bay.
- **Minimal depletion of surface water flows:** Qualitative assessment of the net decrease in simulated groundwater discharge to streams and in simulated streamflow in San Pablo, Wildcat, San Lorenzo and San Leandro Creeks.

Sustainable yield was evaluated using a steady state simulation of average future conditions with added hypothetical pumping wells regularly spaced on approximately 5,000-foot centers for most of the model domain. These hypothetical wells were screened in the Shallow Aquifer Zone in the NEBP, and in the Intermediate and Deep Aquifer Zones in the MEBP and SEBP. Based on multiple simulations using a range of pumping rates from the hypothetical wells, the maximum total pumping rate that meets the criteria for sustainability defined above is approximately 12,500 AFY.

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[12] Sustainable yield is defined by California Water Code Section 10721 as “the maximum quantity of water, calculated over a base period representative of long-term conditions in the basin and including any temporary surplus, that can be withdrawn annually from a groundwater supply without causing an undesirable result.”

ES-6-2. Groundwater Resources Development Simulation

A simulation was conducted with the 2021 EBPGWM to evaluate the feasibility and influence on groundwater and surface water conditions of a potential groundwater resources development scenario in the EBP Subbasin. The details of the scenario are presented in **Figure ES-11**.

The groundwater resources development scenario incorporates the following projects added to the baseline transient future simulation:

- The EBMUD Phase 1 well (Bayside Well) extracts 2 million gallons per day (mgd) between April 1 and September 30 during six water years in the 50-year future simulation that are classified as dry years. Extraction begins with the third consecutive dry year and continues during subsequent dry years within a drought cycle.
- The EBMUD Phase 1 Well injects 0.36 mgd of imported water between October 1 and March 31 during 12 water years in the 50-year simulation that are classified as wet years.
- Hayward Wells A, D, and E extract a combined total of 5.58 mgd between July 1 and August 31 to provide emergency water supply during seven water years in the 50-year simulation. The years during which Hayward emergency pumping are simulated represent a range of hydrologic year types, as this pumping is not associated with droughts but rather represents a potential action in response to an emergency disruption to Hayward's imported supplies (e.g., an earthquake).

This groundwater resources development scenario was also evaluated using a steady-state simulation with average pumping rates for the 50-year period (Water Year 2022 to 2071) that are listed below:

- EBMUD Phase 1 well: 76,800 gallons per day (86 AFY). Net of extraction minus injection
- Hayward Well A: 33,600 gallons per day (38 AFY)
- Hayward Well D: 23,800 gallons per day (27 AFY)
- Hayward Well E: 72,800 gallons per day (82 AFY)

Evaluation of the simulated transient and steady-state groundwater elevations and water budget for the groundwater resource development scenario compared to baseline simulations indicate that the sustainability criteria are met in the groundwater resources development scenario simulation:

- Groundwater resources development causes minimal change in the groundwater elevations in the Shallow Aquifer, and the simulated groundwater elevations in the Shallow Aquifer are maintained above the elevation of the Bay.
- Simulated drawdown induced by pumping at the Phase 1 Well and Hayward Wells A, D, and E recovers to baseline conditions within a few months.
- Net outflows are maintained from the NEBP, MEBP, and SEBP towards the Bay (including the aquifers beneath the Bay) and toward Niles Cone Subbasin every year during 50-year simulation of the groundwater resources development scenario.
- For 41 of 50 years, the groundwater resources development scenario simulation shows net flow from north to south across the HFB, which represents the impedance of hydraulic connection

within the transition zone between the Intermediate and Deep Aquifers in the EBP and Niles Cone Subbasins.

- The change in simulated streamflow between the baseline and groundwater resources development scenario simulations is negligible.

Based on consideration of five criteria within the Niles Cone Subbasin, which were previously defined for an Environmental Impact Report (EIR) for the EBMUD Phase 1 (Bayside) well (CH2M Hill, 2005), the potential influence of the EBP Groundwater Resources Development Scenario on the Niles Cone Subbasin is not significant (**Table ES-3).**

ES-7. Model Limitations and Recommendations for Future Updates

The 2021 EBPGWM is a robust and reliable tool to support the GSP and future development of groundwater resources in the EBP Subbasin. However, this model, like all numerical models, is a simplification of a complex hydrogeologic system and relies on approximations and assumptions regarding the physical system. Some limitations are listed below:

- Existing pumping (rates, locations, and depth intervals) within the EBP Subbasin are uncertain;
- The model does not provide robust estimates of surface water/groundwater interactions at the local scale because limited information is available regarding stream flows, stream bed properties, and shallow groundwater conditions near the streams;
- As is typical of regional groundwater models, large portions of model layers are assigned uniform values of hydraulic conductivity based on regional-scale calibration. Accordingly, while the model provides reasonable results at a large scale, actual conditions are expected to vary substantially on local scales that are not represented by the model;
- Similarly, a uniform value of specific yield is assigned within Layer 1 of the model domain, so the model is not capable of replicating small scale variations in fluctuation of the water table; and
- Limited groundwater elevation data are available after 2000 for the Intermediate and Deep Aquifers in the Oakland/Bayfarm area, and consequently the calibrated horizontal hydraulic conductivity values in this area are relatively poorly constrained.

Results of simulations with the 2021 EBPGWM that are reported as relative changes of groundwater conditions are more reliable than absolute results, which is generally the case with most groundwater models.

Recommendations for future updates of the 2021 EBPGWM include:

- Collection of stream flow data, shallow groundwater level data near the streams, and testing stream bed and Shallow Aquifer conditions near the streams to improve the calibration of the model properties that influence hydraulic connection between streams and groundwater;

- Collection of data to refine representation of the certain streams in the model, including Cerrito Creek, Codornices Creek, Lion Creek, and Sulphur Creek, which are currently represented as drains;
- Compilation of additional information on existing pumping in the EBP Subbasin;
- Refinement of the discretization of recharge/irrigation to better represent local groundwater flow for local applications of the model;
- Testing of the shallow aquifer and monitoring of shallow groundwater level data to refine estimates of the hydraulic conductivity and specific yield distribution in the Shallow Aquifer zone and recharge fluctuations; and
- Monitoring of chloride concentrations in groundwater and additional characterization of the Shallow Aquifer in Representative Monitoring Sites to improve the calibration of the model properties that influence hydraulic connection between the Bay and groundwater.

Tables and Figures in Executive Summary

Table ES-1: Model Boundary Conditions

East Bay Plain Groundwater Model
Groundwater Sustainability Plan

Location and Boundary Condition	Notes
Layer 1 grid cells beneath the SF Bay, and Salt Ponds south of San Mateo Bridge are General Head Boundaries (GHBs). Layers 2 – 12 at the western and northern margins of the model domain are No Flow Boundaries	Assigned head to Layer 1 beneath the Bay and Salt Ponds is one ft above mean sea level for baseline model. The GHBs include a conductance term that represents the vertical hydraulic conductivity and thickness of the bay floor. No flow boundaries for Layers 2 to 12 at the western and northern margins represent a groundwater divide and flow parallel to the margin, respectively, consistent with NEBIGSM.
Eastern Margin is a specified flow boundary.	Inflow to the model from the East Bay Hills is specified for 10 segments along this margin based on regional water budget and calibration.
Southern Margin is a no flow boundary.	Generally parallel to groundwater flow.
Internal boundary between the EBP and NC is a horizontal flow barrier (HFB).	HFB assigned along an east – west line in Layers 4 – 12 and represents a partial barrier to groundwater flow in the transition zone between the EBP and NC (**Figures ES-1, and ES-2**). The HFB includes a conductance term that represents the horizontal conductivity and thickness of a zone of impedance to groundwater flow.
San Pablo, Wildcat, San Leandro, San Lorenzo, and Old Alameda Creeks are represented with the MOFLOW Stream Package (SFR2). Cerrito, Codornices, Lion, and Sulphur Creeks are represented with the MODFLOW Drain Package (DRN).	Representation of these streams includes stage and flow rate, and conductance of the stream bed. Specified inflows are based on USGS gage records on Wildcat, San Lorenzo, and Old Alameda Creeks, and dam release volume records for the San Pablo and Lake Chabot reservoirs. The model simulates both inflow to the streams from groundwater and leakage of water from the streams to groundwater. The second set of creeks are represented as drains because they lack data on stream characteristics. Flow of groundwater into the drain (out of the model) occurs when the adjacent groundwater elevation exceeds the elevation of the drain. The flow rate into the drain is influenced by an assigned conductance for the drain.
Recharge is applied to Layer 1, except over the SF Bay because the GHB used for the Bay includes a reference elevation.	The assigned recharge represents precipitation, leakage from water and sewer pipes, and domestic and large-scale irrigation (e.g., golf courses and cemeteries). Different recharge rates are applied to 16 areas, based on sub-regions that are further subdivided based on soil properties as documented in the HCM (GSP Appendix 2.A.b). Recharge rates applied to the NC Subbasin are based on the 2013 NEBMODFLOW model. Assigned values of recharge vary monthly in the transient simulations. Recharge was adjusted as part of the model calibration.
The 2021 EBPGWM includes pumping from 505 “wells” in the EPB Subbasin that are active between 1990 and 2015. Injection wells are retained from previous models to represent recharge from the Quarry Lakes in the NC.	Locations of wells and pumping rates are based on the 2013 NEBMODFLOW model and the 2019 update to the 2005 NEBIGSM model. Seven additional wells are included based on information provided by EBMUD and stakeholders. 34 of the 505 wells represent actual wells, and 471 represent estimated pumping (by elemental cell) retained from the 2005 NEBIGSM model that was based on estimates of unmetered pumping to meet water demand for domestic use (355 “wells”) and irrigation (116 “wells”).

Table ES-2: Simulated Average Water Budget for EBP Subbasin

East Bay Plain Groundwater Model
Groundwater Sustainability Plan

		Simulated Average (1991 – 2015)	HCM Range
Inflow (AFY)			
	Recharge	14,400	8,000 to 23,500
	Bedrock Inflow	1,500	1,400 to 4,000
	Flow from Castro Valley	300	Not quantified
	Stream Recharge	2,500	1,500 to 5,000
	Flow from Niles Cone	1,000	Not quantified
	Total	**19,700**	**10,000 to 32,500**
Outflow (AFY)			
	Groundwater Pumping	-3,800	-2,000 to -4,000
	Discharge to Bay	-8,400	-8,000 to -17,000
	Stream Discharge	-3,000	-500 to -4,000
	Flow to Niles Cone	-2,300	Not quantified
	Total	**-17,500**	**-10,500 to -25,000**
Change in Storage (AFY)		2,200	Not applicable

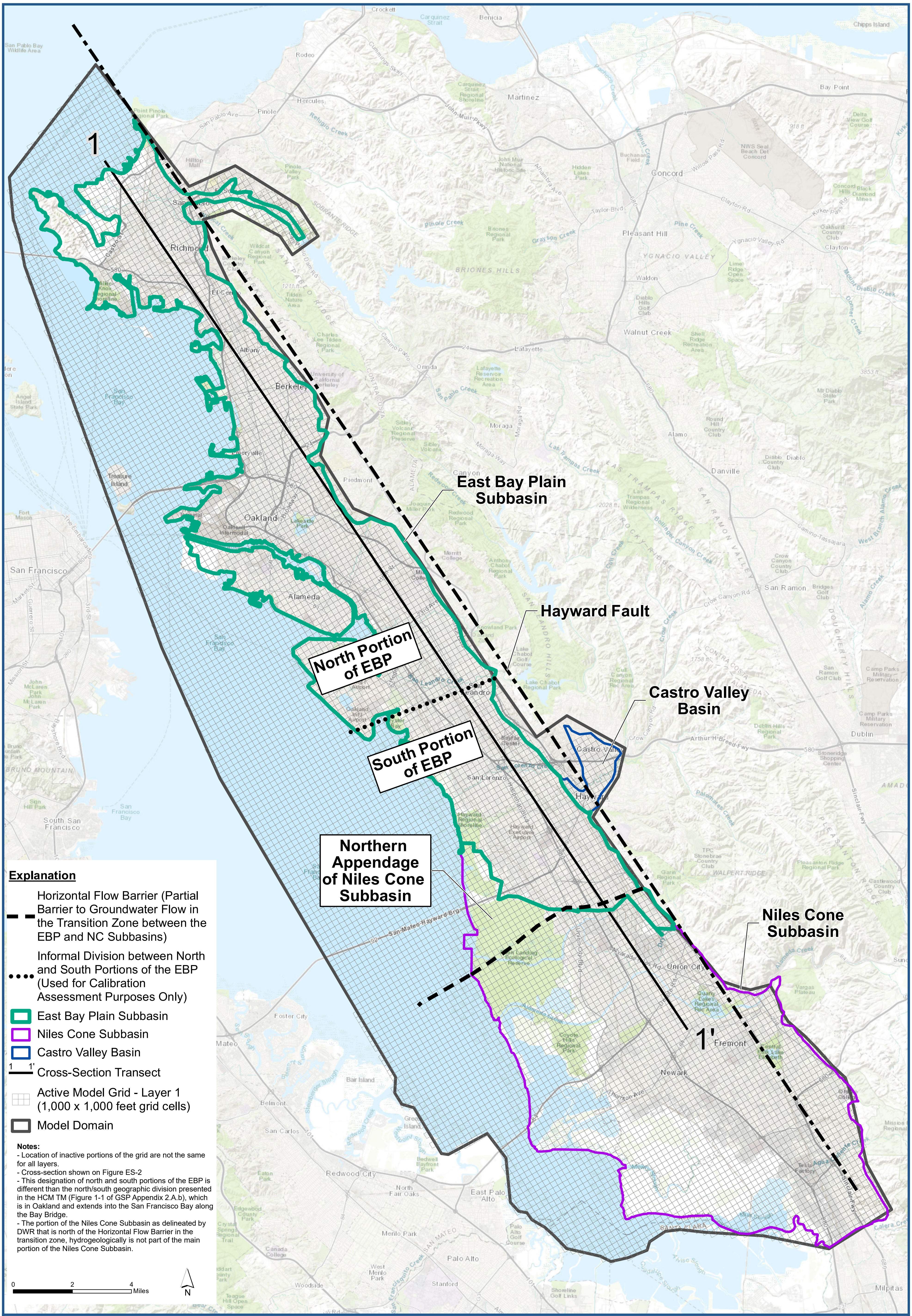
*Includes sewer pipe outflow as well

AFY = acre-feet per year

Table ES-3: Evaluation of Influence of the EBP Groundwater Resources Development Scenario on the NC Subbasin

East Bay Plain Groundwater Model
Groundwater Sustainability Plan

Criteria	Simulation Result
1. Change in water levels in the shallow Newark Aquifer	Minimal change (less than 0.5 feet) in simulated groundwater levels in the shallow Newark Aquifer in NC Subbasin between the baseline and the EBP groundwater resources development simulations. Thus, simulated impacts to the NC Newark Aquifer groundwater elevations (Criteria 1) are within the model noise and are considered negligible.
2. Decrease in outflow from the inland portion of the Newark Aquifer to the Newark Aquifer under the salt evaporator ponds adjacent to the Bay	Simulated outflows from the inland portion of the Newark Aquifer to the Newark Aquifer under the salt evaporator ponds adjacent to the Bay are nearly identical for the baseline and EBP groundwater resources development simulations: The simulated outflow decreases by less than 0.25% (< 35 AFY).
3. Change in downward vertical flow from the Newark Aquifer to the Centerville/Fremont and Deep Aquifers	The simulated downward flow increases by less than 0.5% (< 60 AFY) between the baseline and EBP groundwater resources development simulations.
4.Change in lateral movement of areas of groundwater with elevated chloride concentrations (chloride plumes) in the Newark, Centerville/Fremont, and Deep Aquifers	The area of elevated chloride (>250 mg/L) based on the ACWD 2019 Groundwater Monitoring Report (ACWD, 2020) for the Newark and Centerville/Freemont Aquifers was conservatively assumed the same in the Deep Aquifer. The simulated lateral flow does not change within the Newark and Centerville/Fremont Aquifers and increases by less than 10 AFY within the Deep Aquifer between the baseline and the EBP groundwater resources development simulations.
5. Drawdown in the Centerville/Fremont and Deep Aquifers	Simulated decrease in groundwater elevations in the Centerville/Fremont Aquifer in the NC Subbasin for the EBP Groundwater Resources Development Scenario is generally less than 2 feet in comparison to baseline simulation. Although transient simulations show decreases in the groundwater elevation in the Deep Aquifer in the NC Subbasin as much as ~15 feet near the HFB at the end of periods of sustained pumping in the EBP Subbasin, these drawdowns are short-lived and groundwater levels recover rapidly (in months). The steady state simulation of average conditions shows long-term average groundwater elevation decreases by less than 2 feet in the NC Deep Aquifer.



Notes:
- Location of inactive portions of the grid are not the same for all layers.
- Cross-section shown on Figure ES-2
- This designation of north and south portions of the EBP is different than the north/south geographic division presented in the HCM TM (Figure 1-1 of GSP Appendix 2.A.b), which is in Oakland and extends into the San Francisco Bay along the Bay Bridge.
- The portion of the Niles Cone Subbasin as delineated by DWR that is north of the Horizontal Flow Barrier in the transition zone, hydrogeologically is not part of the main portion of the Niles Cone Subbasin.

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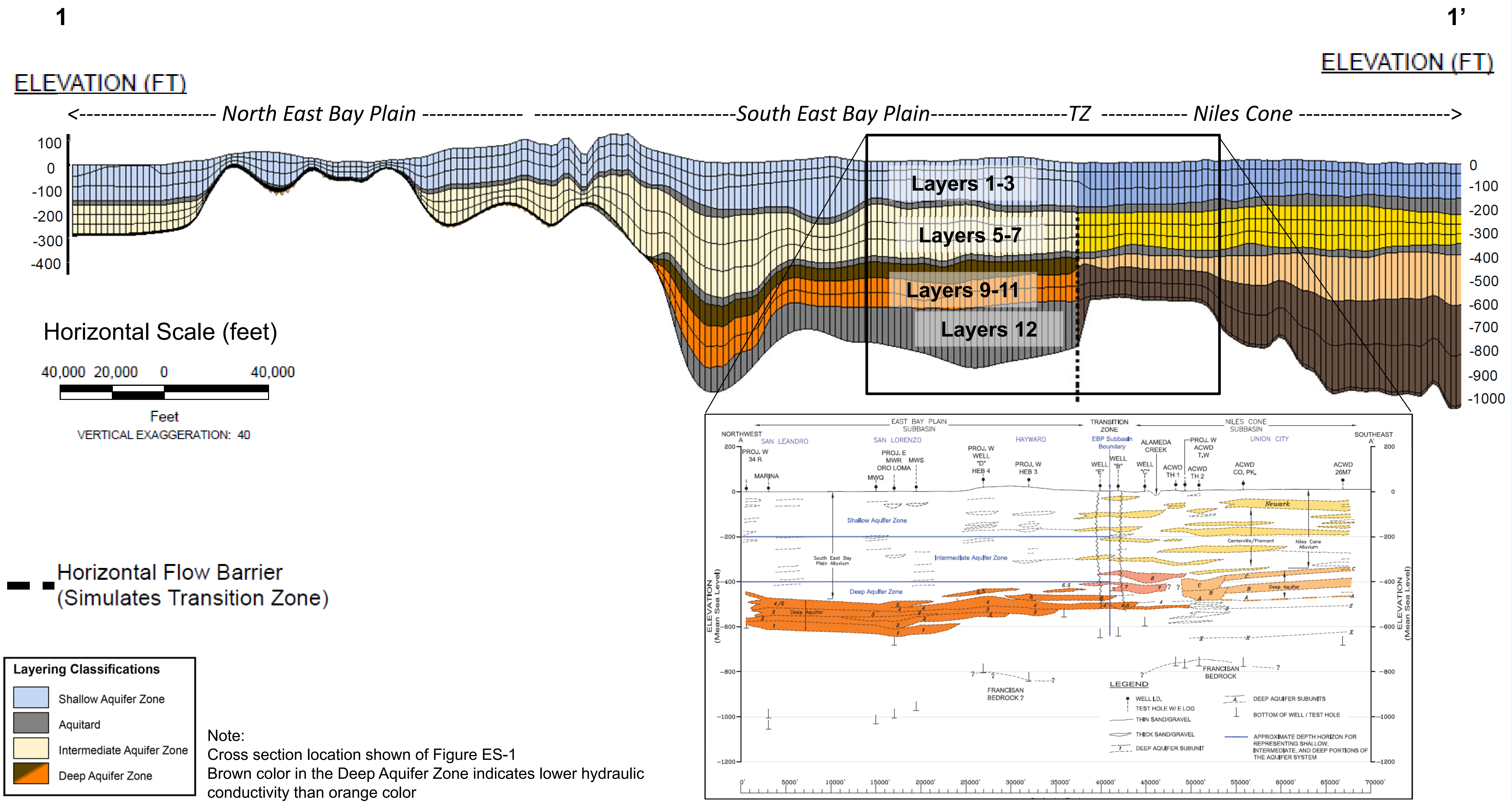
Model Domain and Grid

East Bay Plain Groundwater Model
Groundwater Sustainability Plan

Figure ES-1



Note:
Cross section location shown of Figure ES-1
Brown color in the Deep Aquifer Zone indicates lower hydraulic conductivity than orange color

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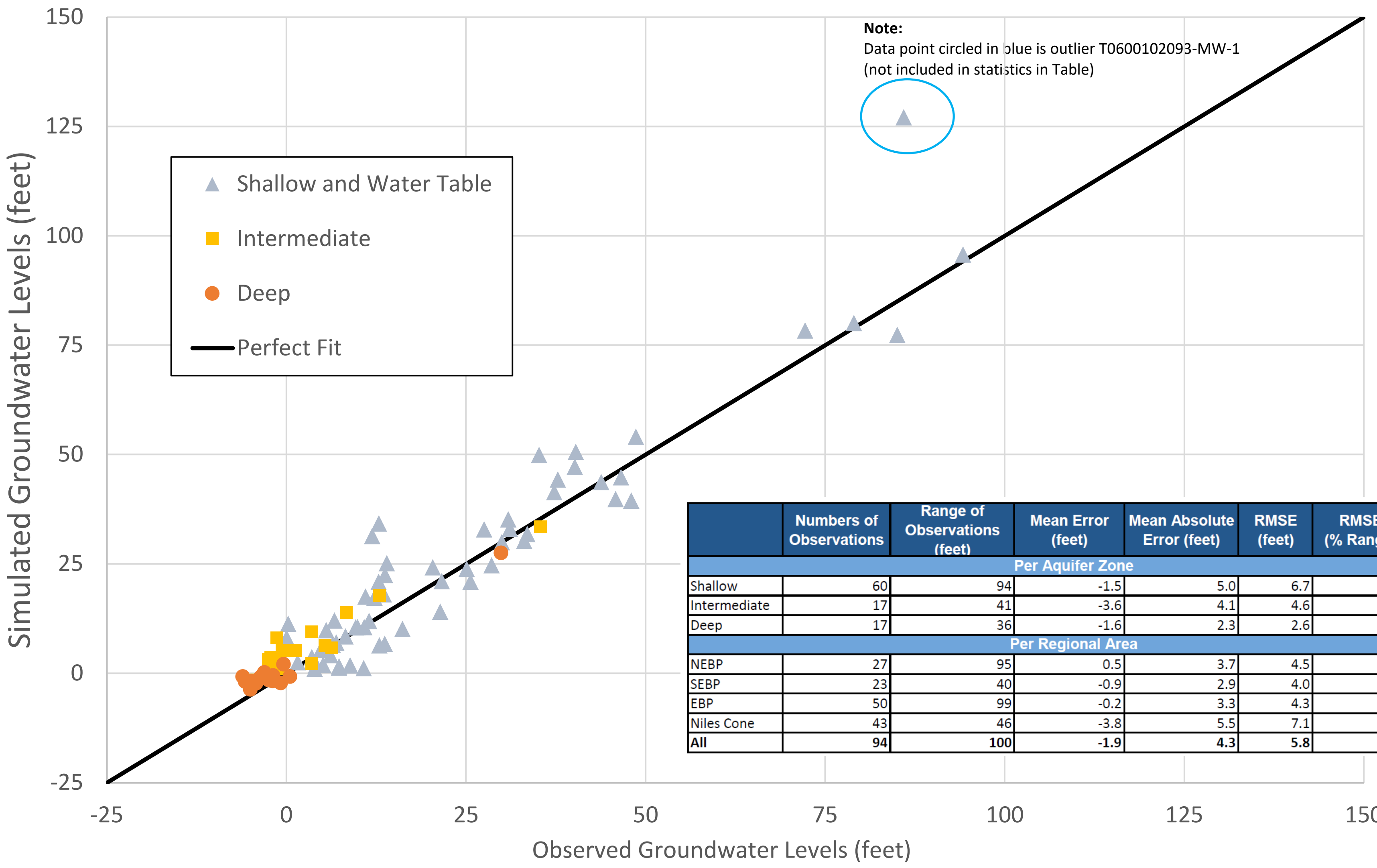
NNW – SSE Cross Section Showing Model Layers

Figure ES-2

East Bay Plain Groundwater Model
Groundwater Sustainability Plan



Note:
Data point circled in blue is outlier T0600102093-MW-1
(not included in statistics in Table)

	Numbers of Observations	Range of Observations (feet)	Mean Error (feet)	Mean Absolute Error (feet)	RMSE (feet)	RMSE (% Range)	R^2
Per Aquifer Zone							
Shallow	60	94	-1.5	5.0	6.7	7%	
Intermediate	17	41	-3.6	4.1	4.6	11%	
Deep	17	36	-1.6	2.3	2.6	7%	
Per Regional Area							
NEBP	27	95	0.5	3.7	4.5	5%	
SEBP	23	40	-0.9	2.9	4.0	10%	
EBP	50	99	-0.2	3.3	4.3	4%	
Niles Cone	43	46	-3.8	5.5	7.1	15%	
All	**94**	**100**	**-1.9**	**4.3**	**5.8**	**6%**	**0.92**

NEBP = Northern East Bay Plain
RMSE = root mean square error
R^2 = coefficient of determination
SEBP = Southern East Bay Plain

Simulated vs. Observed Groundwater Levels for Steady State Simulation

East Bay Plain Groundwater Model
Groundwater Sustainability Plan

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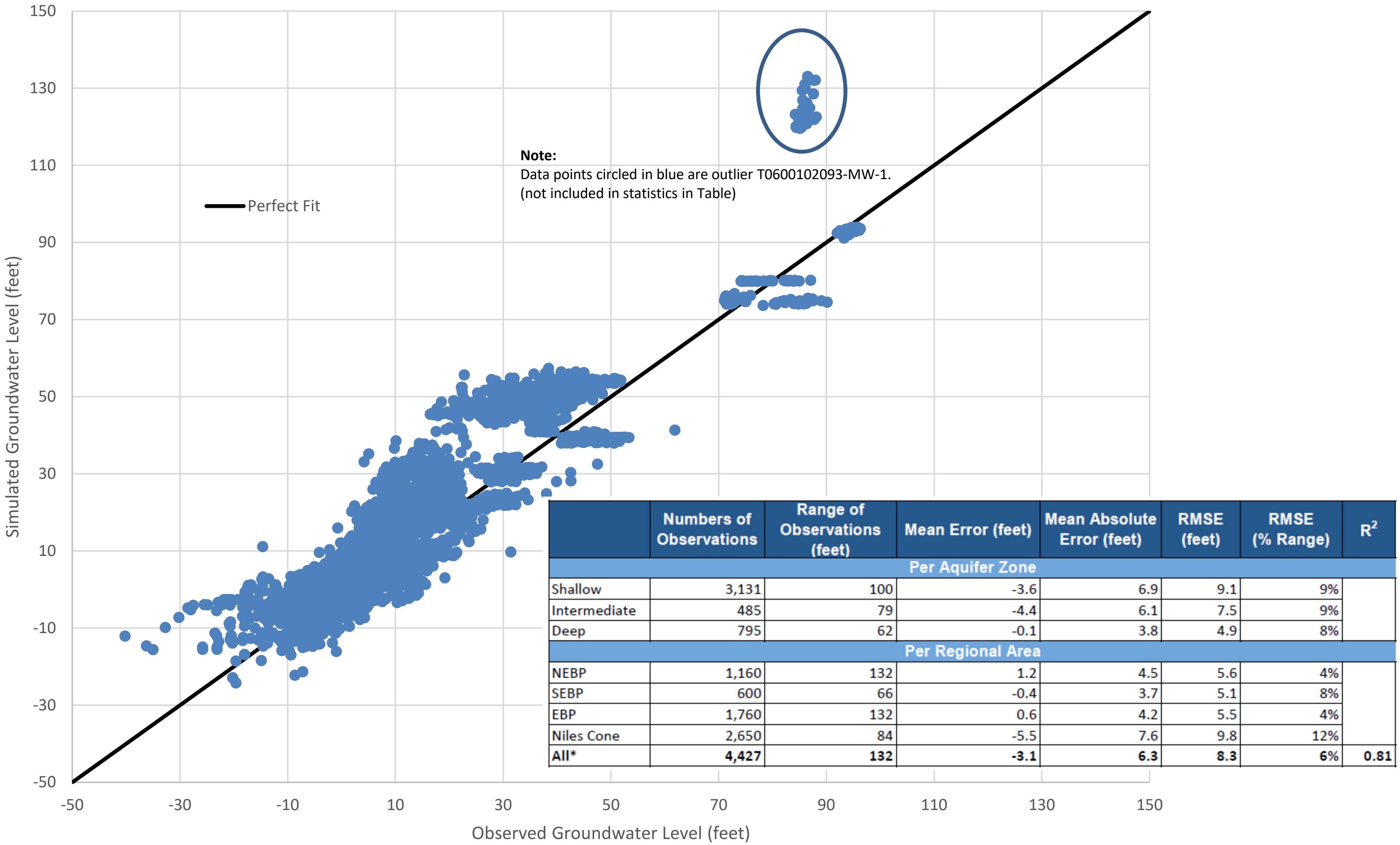
Figure ES-3



Note:
Data points circled in blue are outlier T0600102093-MW-1.
(not included in statistics in Table)

	Numbers of Observations	Range of Observations (feet)	Mean Error (feet)	Mean Absolute Error (feet)	RMSE (feet)	RMSE (% Range)	R^2
Per Aquifer Zone							
Shallow	3,131	100	-3.6	6.9	9.1	9%	
Intermediate	485	79	-4.4	6.1	7.5	9%	
Deep	795	62	-0.1	3.8	4.9	8%	
Per Regional Area							
NEBP	1,160	132	1.2	4.5	5.6	4%	
SEBP	600	66	-0.4	3.7	5.1	8%	
EBP	1,760	132	0.6	4.2	5.5	4%	
Niles Cone	2,650	84	-5.5	7.6	9.8	12%	
All*	**4,427**	**132**	**-3.1**	**6.3**	**8.3**	**6%**	**0.81**

NEBP = Northern East Bay Plain
RMSE = root mean square error
R^2 = coefficient of determination
SEBP = Southern East Bay Plain
* Also includes 17 measurements in Castro Valley that are not included in rows above

Observed vs Simulated Groundwater Levels for Transient Historical Model Simulation (1990 - 2015)

East Bay Plain Groundwater Model
Groundwater Sustainability Plan

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Figure

ES-4

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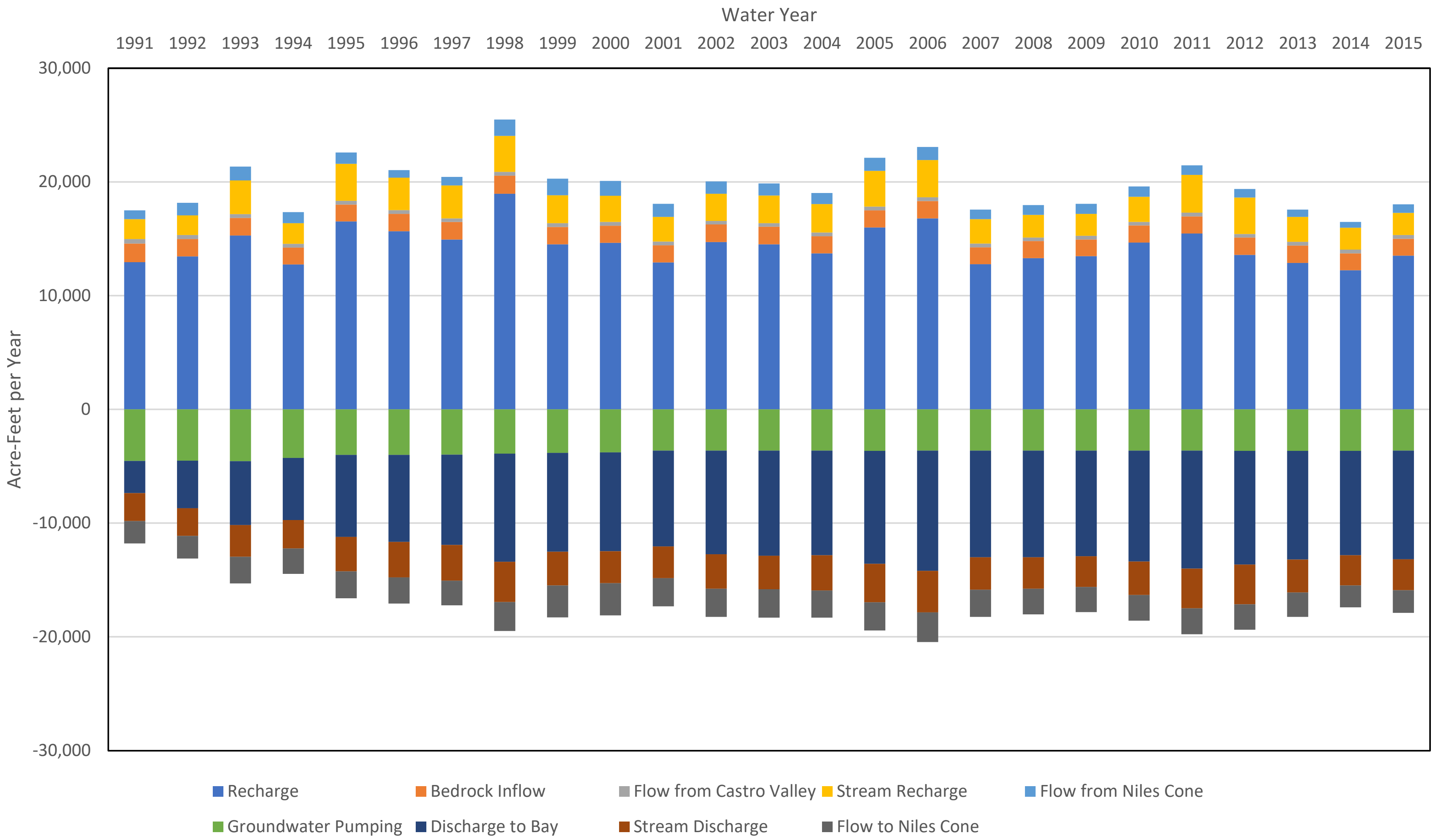

Annual Simulated Water Budget for the East Bay Plain Subbasin, 1990 - 2015

East Bay Plain Groundwater Model
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Figure

ES-5

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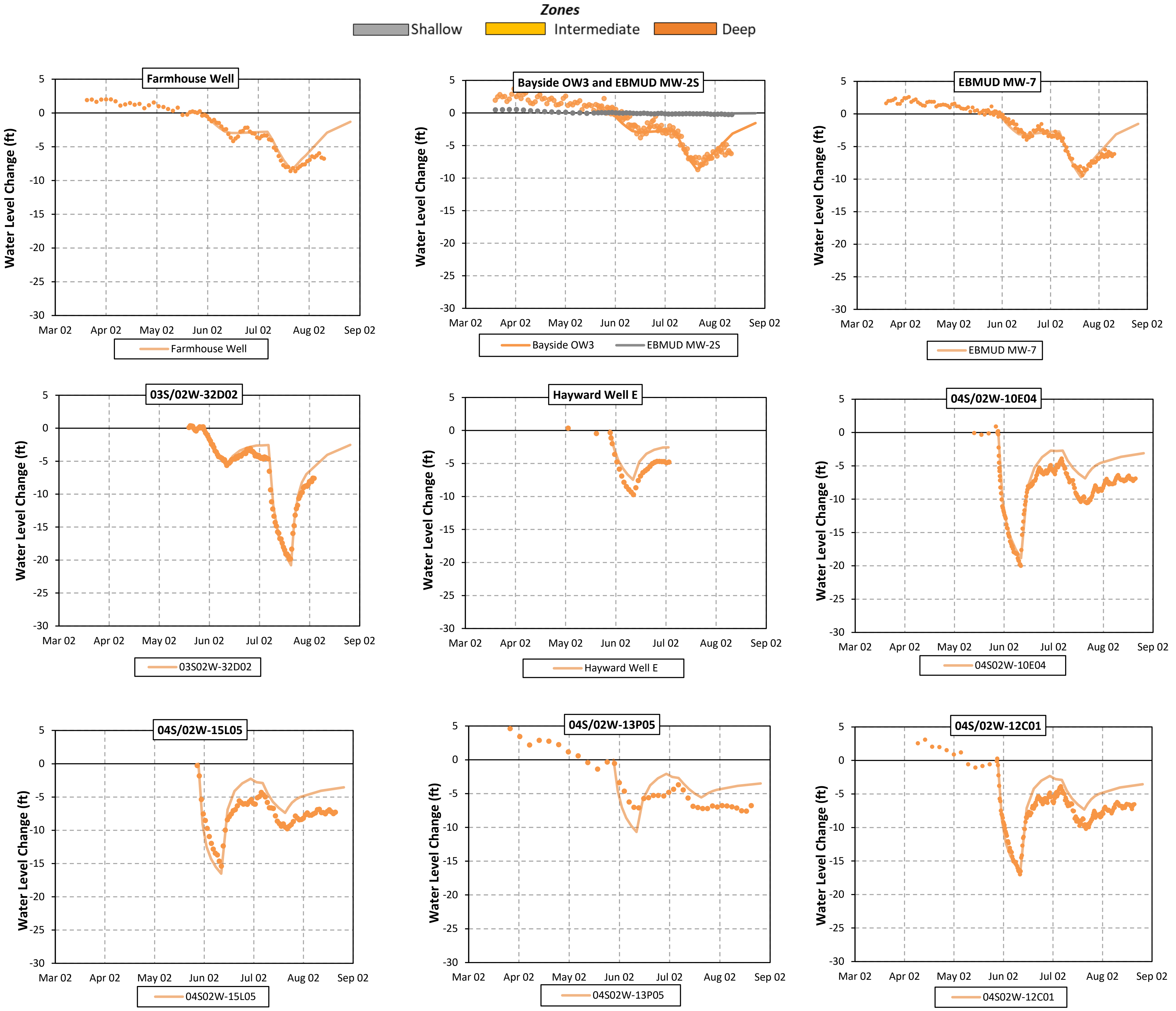

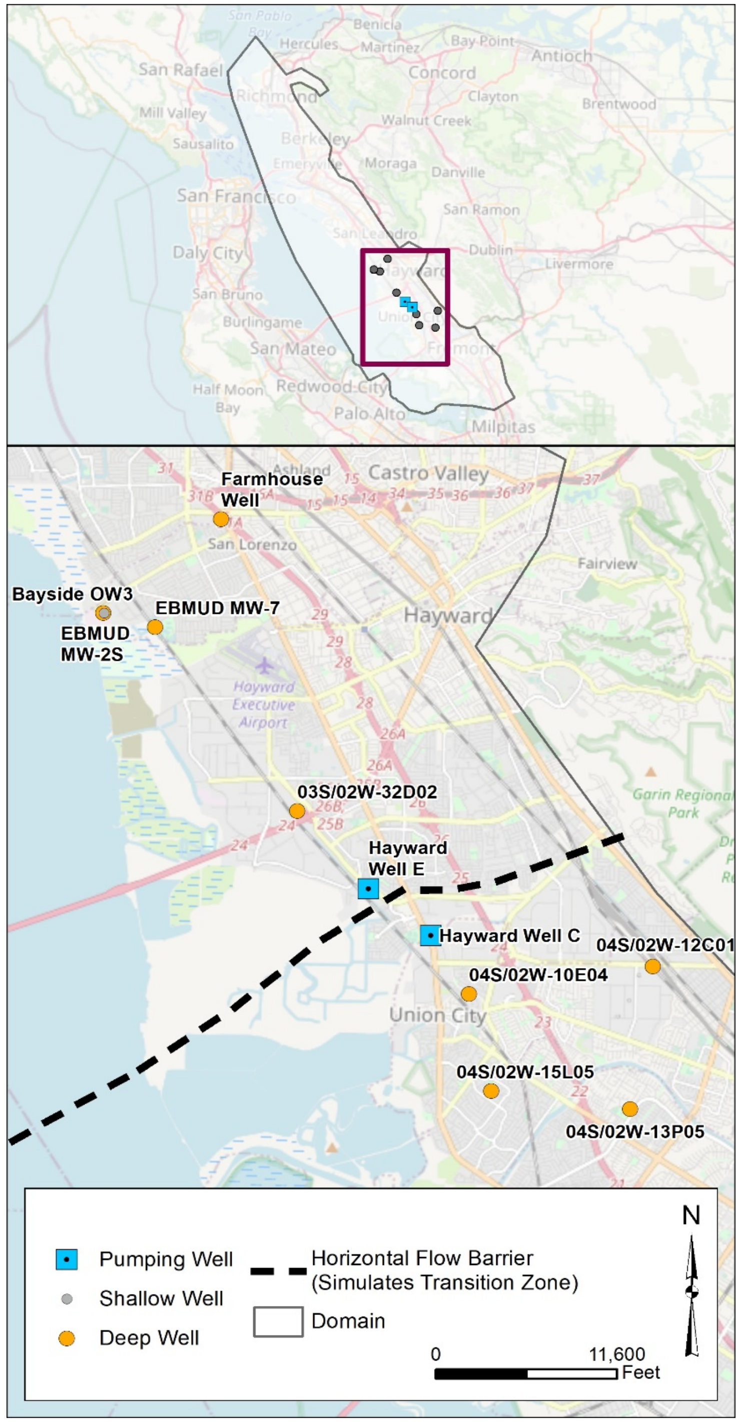

Notes:

ft = feet

Markers represent observed data, and lines represent simulated data for a given series.

Hydrographs of Modeled and Observed 2002 Aquifer Test Data

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November 2021

Figure ES-6

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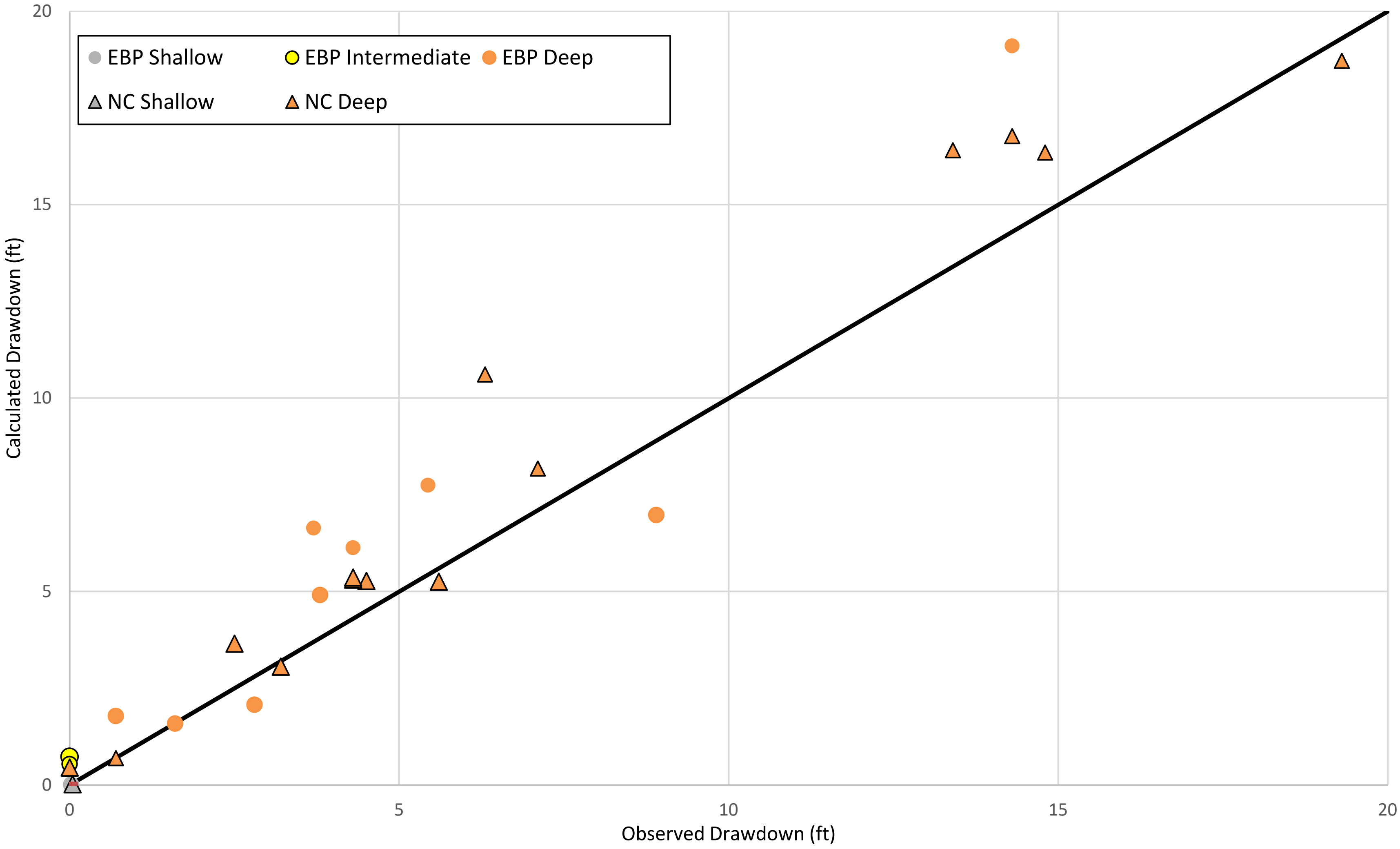

	Numbers of Observations	Range of Observations (feet)	Mean Error (feet)	Mean Absolute Error (feet)	RMSE (feet)	RMSE (% Range)	R^2
2002 Aquifer Test Simulation							
All	**29**	**19.3**	**-1.0**	**1.2**	**1.8**	**9%**	**0.89**
Well C Test	15	19.3	-0.8	1.2	1.7	N/A	
Well E Test	14	14.3	-1.2	1.3	1.8	N/A	

Observed vs Simulated Drawdown Attained for 2002 Aquifer Test

East Bay Plain Groundwater Model
Groundwater Sustainability Plan

LSCE TEAM

WR2668 November 2021

Figure

ES-7

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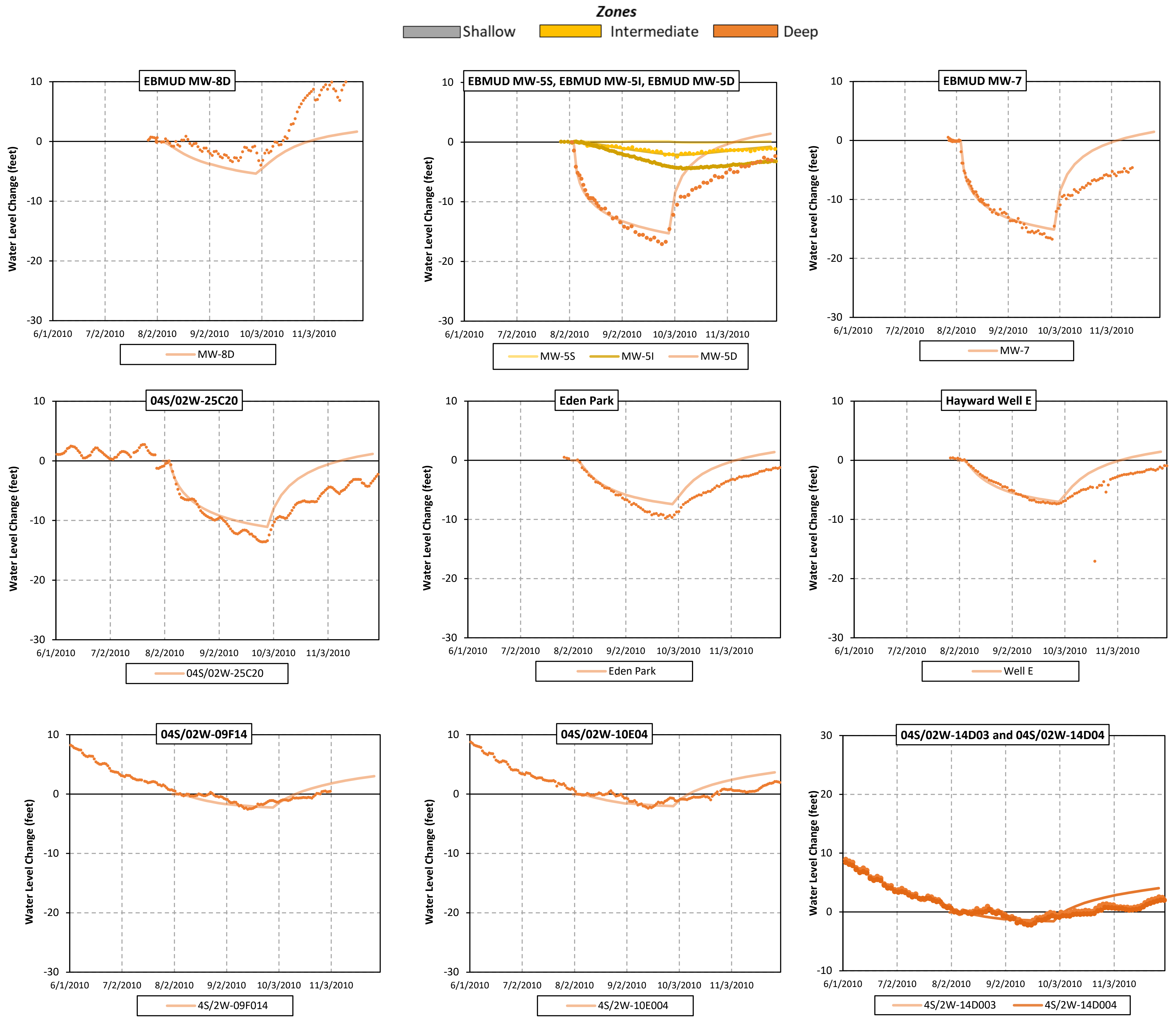

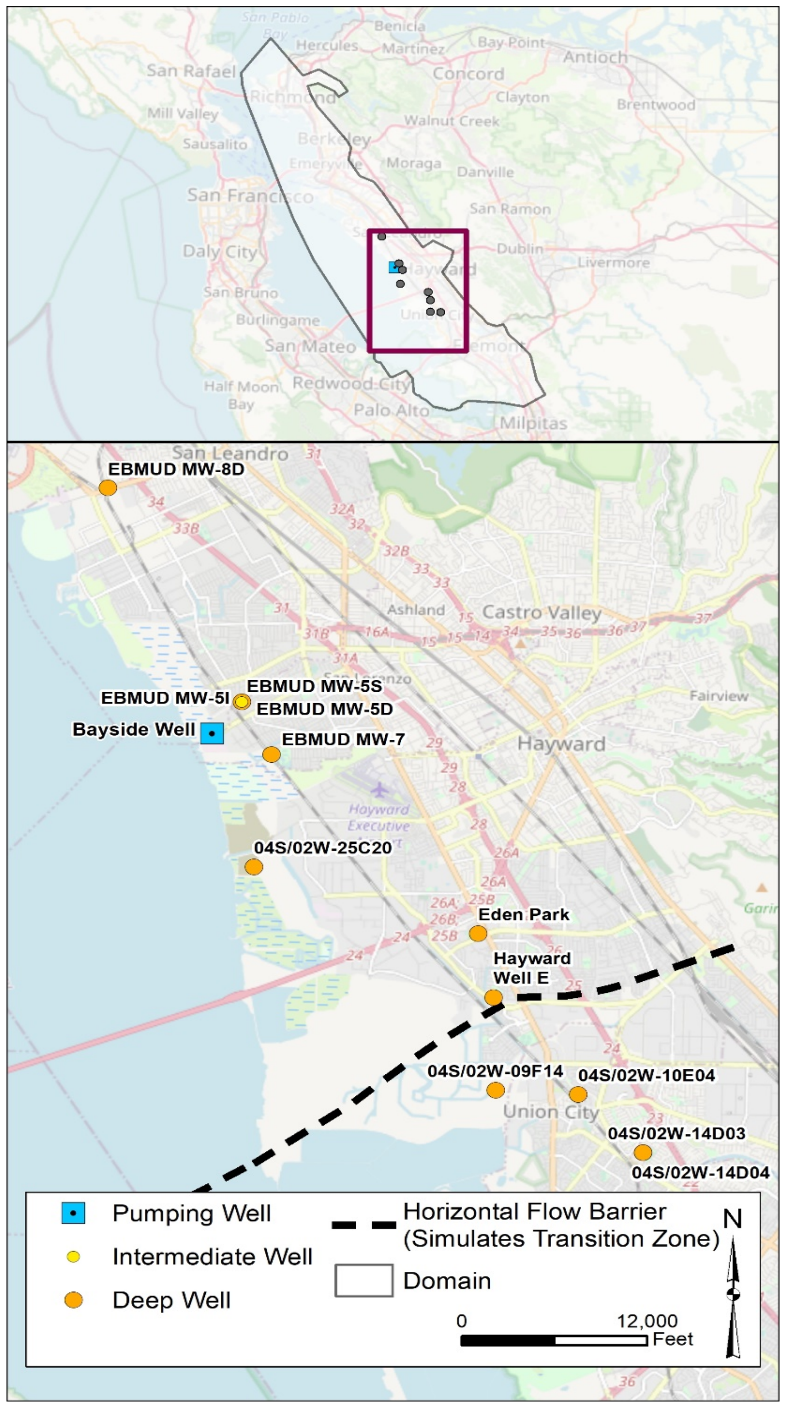

Notes:

Markers represent observed data, and lines represent simulated data for a given series.

Hydrographs of Modeled and Observed 2010 Aquifer Test Data

East Bay Plain Groundwater Model
Groundwater Sustainability Plan

LSCE TEAM

Figure

ES-8

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November 2021

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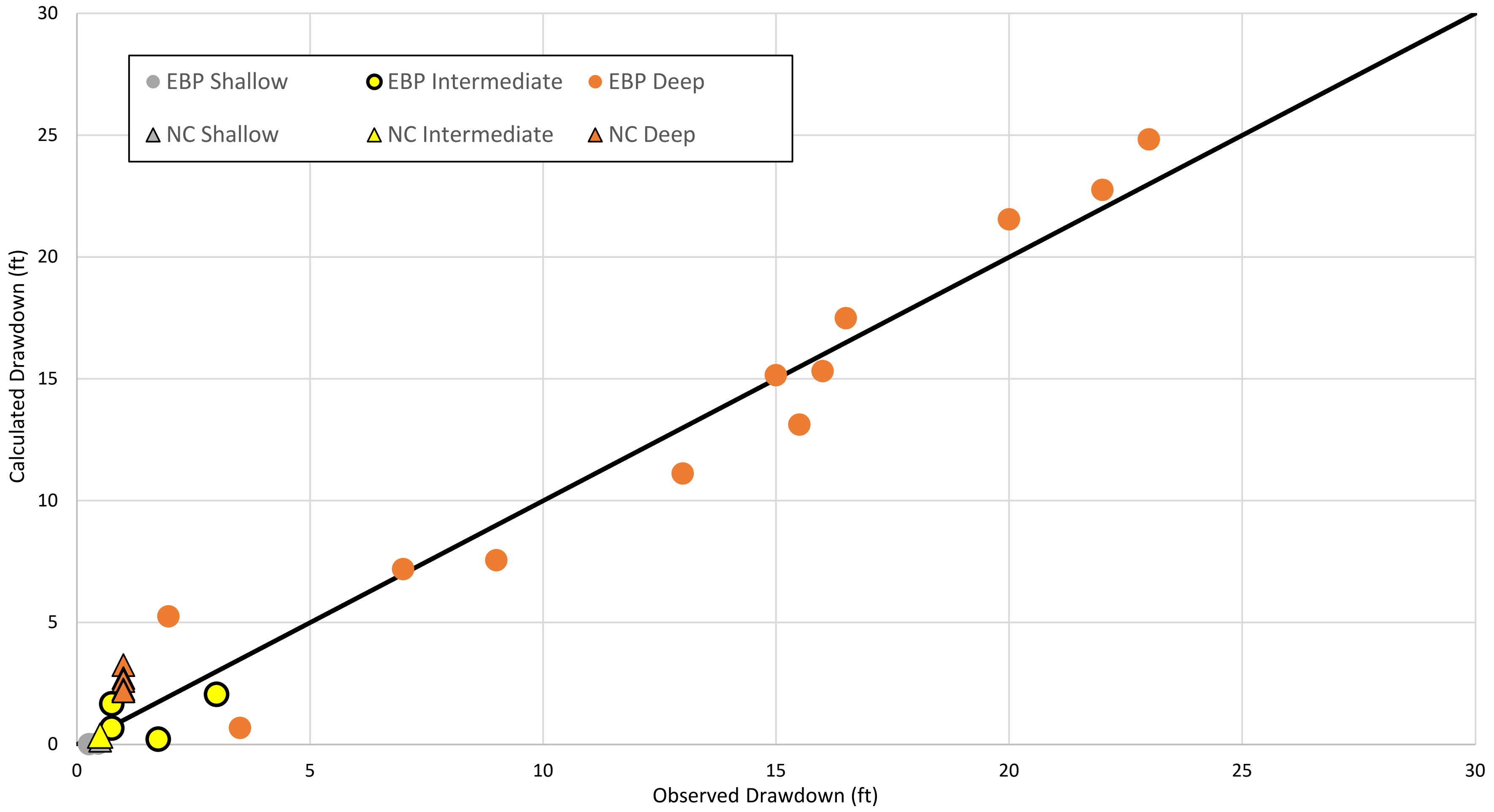

	Numbers of Observations	Range of Observations (feet)	Mean Error (feet)	Mean Absolute Error (feet)	RMSE (feet)	RMSE (% Range)	R2
2010 Aquifer Test Simulation							
All	**26**	**22.7**	**0.1**	**1.5**	**1.5**	**7%**	**0.96**
East Bay Plain							
Shallow	2	0.2	0.34	0.34	0.3	N/A	
Intermediate	4	2.3	0.42	0.87	1.0	N/A	
Deep	12	21.0	0.04	1.50	1.78	N/A	
Niles Cone							
Shallow	1	N/A	0.3	0.3	0.3	N/A	
Intermediate	1	N/A	0.1	0.1	0.1	N/A	
Deep	6	N/A	-1.5	1.5	1.6	N/A	

Observed vs Simulated Drawdown Attained for 2010 Aquifer Test

East Bay Plain Groundwater Model
Groundwater Sustainability Plan

LSCE TEAM

Figure

ES-9

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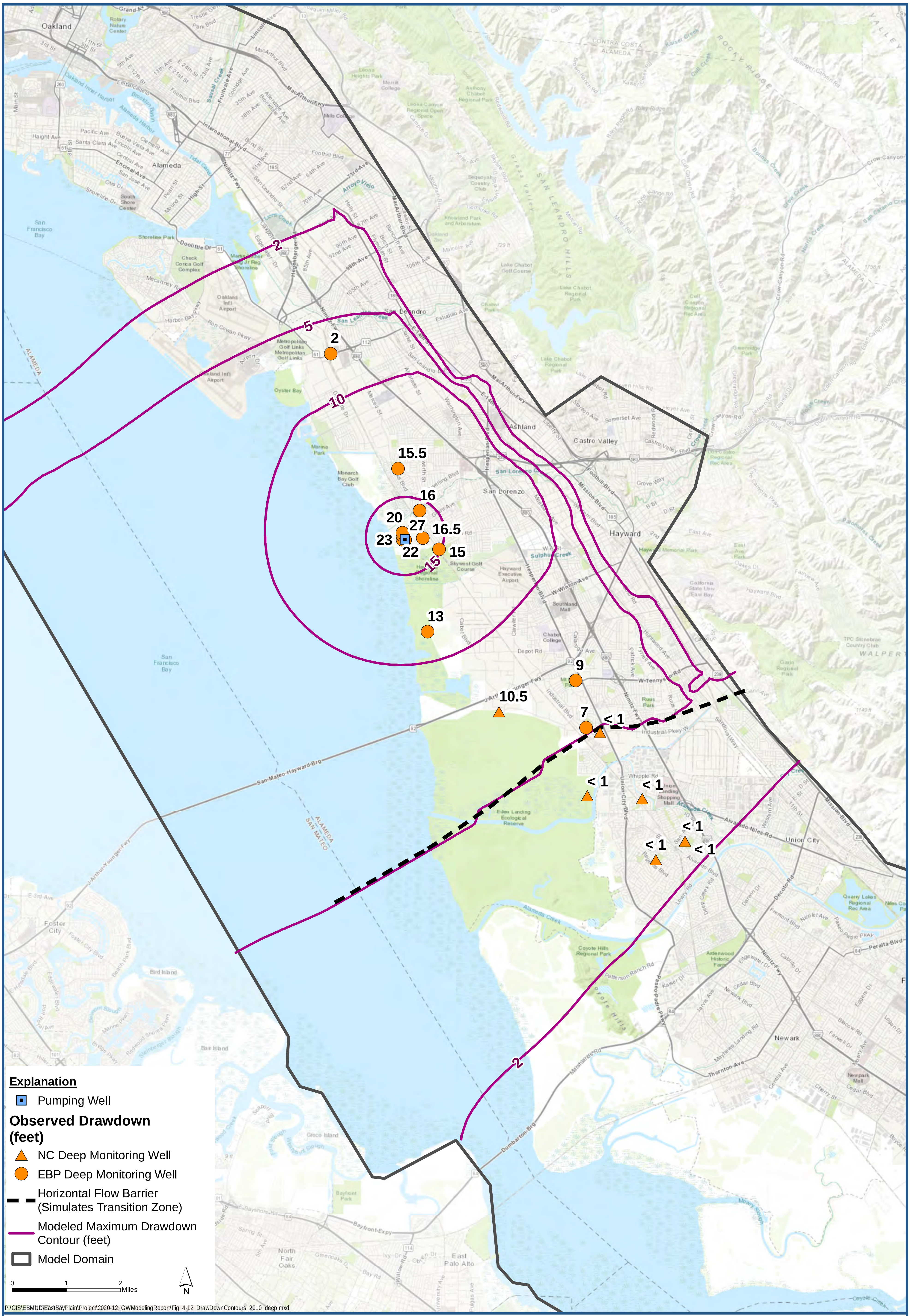
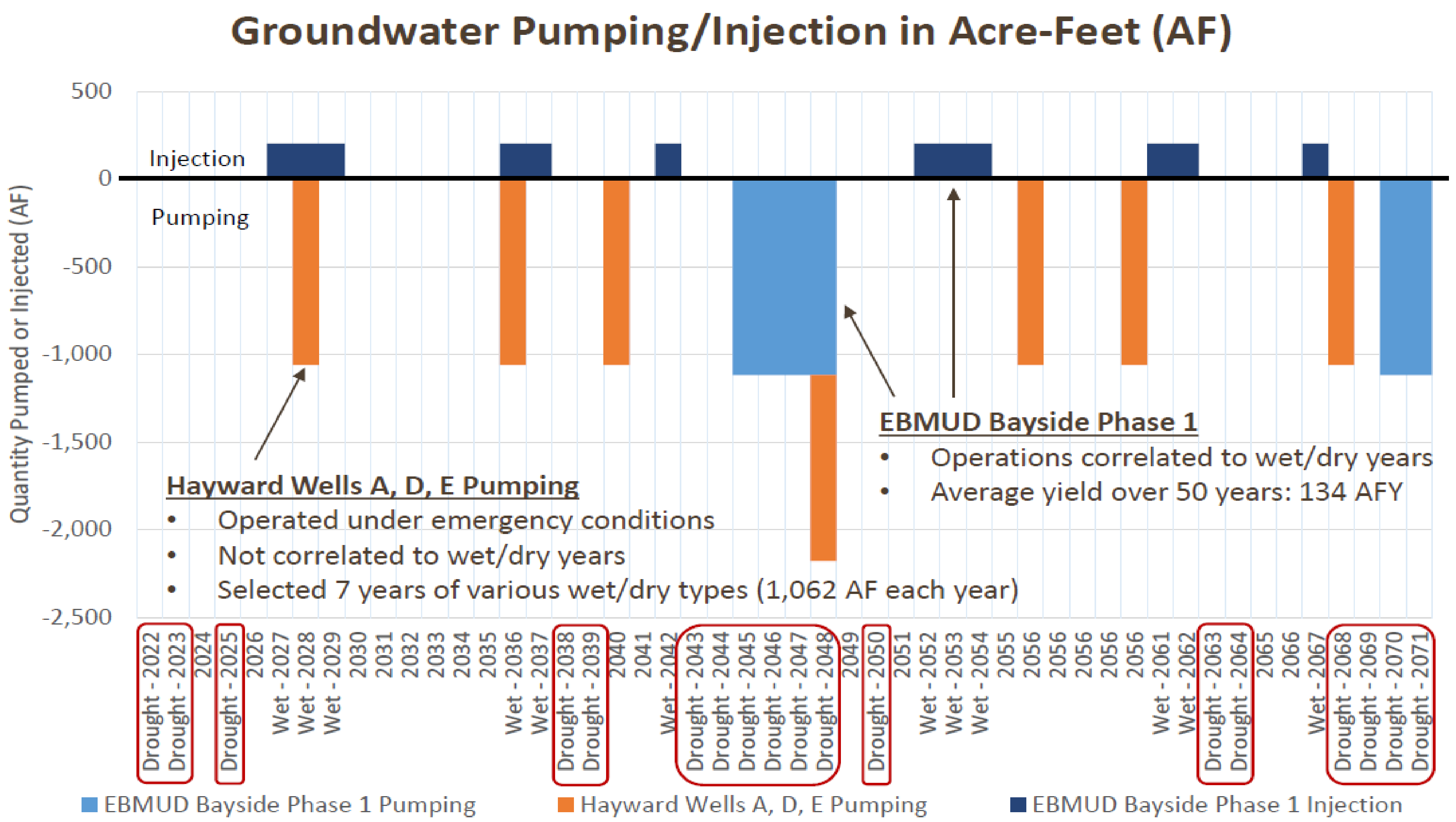
November 2021



Contour Map of Modeled Drawdown Attained during 2010 Aquifer Test with Observed Values Posted

East Bay Plain Groundwater Model
Groundwater Sustainability Plan

Figure ES-10



Pumping/Injection Sequence for Groundwater Resources Development Scenario

East Bay Plain Groundwater Model
Groundwater Sustainability Plan

LSCE TEAM

Figure

ES-11

WR2668

November 2021

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1 INTRODUCTION AND BACKGROUND

Luhdorff & Scalmanini Consulting Engineers (LSCE), Geosyntec Consultants, Inc. (Geosyntec), and other subconsultants (the LSCE Team) are working with the East Bay Municipal Utility District (EBMUD) and the City of Hayward (Hayward) to develop a groundwater sustainability plan (GSP) for the East Bay Plain (EBP) Subbasin, consistent with the requirements of the California Sustainable Groundwater Management Act (SGMA) and the GSP guidelines. The EBP Subbasin is shown in **Figure 1-1**. This report documents the development and calibration of an updated quantitative groundwater flow model of the EBP Subbasin (2021 EBPGWM), which served as a tool for the development of the GSP. Preparation of this report is a component of Subtask 4.6 (Document and Archive the 2021 EBPGWM), including documentation of Subtask 4.4 (Model Development and Calibration) and Subtask 4.5 (Baseline and Alternative Management Scenarios). In accordance with the terminology, this document is referred to as Technical Memorandum (TM) 4.6, TM 4.6, and 2021 EBPGWM TM.

1.1 Model Purpose

The 2021 EBPGWM is a tool to simulate groundwater flow and help with sustainable management of the EBP Subbasin water resources. In accordance with the Department of Water Resources Best Management Practices (BMP) guidance document (DWR, 2016) for models developed for SGMA projects, the 2021 EBPGWM provides an important framework that brings together conceptual understanding, available data, and science. In accordance with TM 4.3 (LSCE Team, 2020), the 2021 EBPGWM serves as a tool to address several components of the GSP, including:

- Quantifying annual water budgets and sustainable yield;
- Evaluating potential projects and management actions needed to maintain sustainability of the EBP Subbasin, including consideration of changing climate;
- Analyzing groundwater-surface water interactions, including recharge areas and groundwater dependent ecosystems (GDEs);
- Defining sustainable management criteria (particularly minimum thresholds and measurable objectives) to comply with GSP regulations for groundwater sustainability; and
- Supporting development of a monitoring network.

This report documents the development, construction, and calibration of the 2021 EBPGWM in Sections 2 to 4, and application of the 2021 EBPGWM for objectives outlined above in Sections 5 to 6.

1.2 Summary of Hydrogeologic Conceptual Model

A detailed description of the hydrogeologic conceptual model (HCM) prepared for the EBP Subbasin GSP is documented in the HCM TM (GSP Appendix 2.A.b). A summary is provided below.

The EBP Subbasin is bordered by the East Bay Hills to the east, San Francisco Bay to the west and north, and Niles Cone Subbasin to the south (**Figure 1-1**). The thickness of unconsolidated sedimentary deposits ranges from greater than 1,000 feet (ft) in southern portion of the EBP Subbasin to less than 500 ft in the north.

Three major depth zones are defined for the EBP Subbasin:

4. Shallow Aquifer Zone (ground surface to less than 200 ft below ground surface [bgs]),
5. Intermediate Aquifer Zone (200 to 400 ft bgs), and
6. Deep Aquifer Zone (over 400 ft bgs).

Coarse-grained sediments in the Deep Aquifer Zone are particularly well developed and continuous in the southern portion of the EBP Subbasin between southern San Leandro and Hayward (**Figure 1-2**). Several high-yield production wells have been developed within the Deep Aquifer Zone and lower portion of the Intermediate Aquifer Zone in the southern portion of the EBP Subbasin. The Shallow Aquifer Zone and upper to middle portions of the Intermediate Aquifer Zone tend to have more isolated lenses of coarse-grained deposits that result in lower yielding wells. Overall, the unconsolidated deposits have a significantly greater proportion of fine-grained sediments in all depth zones.

The shallower depth to bedrock and less frequent occurrence of coarse-grained units in the northern portion of the EBP Subbasin are illustrated in **Figure 1-3** for the Richmond area and in **Figures 1-4a through 1-4c** for the area around Berkeley, Emeryville, Oakland, and San Leandro. These four cross-sections also illustrate the occurrence of only the Shallow or Shallow/Intermediate Zones in the northern portion of the EBP Subbasin (northern Oakland to Richmond), as compared to the presence of all three depth zones over most of the southern portion of the EBP Subbasin (southern Oakland to San Leandro).

The hydrogeologic boundary between the EBP Subbasin and the main portion of the Niles Cone Subbasin occurs within a transition zone between the subbasins (LSCE, 2003; GSP Appendix 2.A.b). However, the current jurisdictional boundary between the EBP and Niles Cone Subbasins delineated by DWR in 2016, which is illustrated by **Figure 1-1**, trends to the northwest toward the margin of the San Francisco Bay. The location of this portion of the DWR jurisdictional boundary between the Niles Cone and EBP Subbasins is not consistent with the hydrogeologic boundary between the subbasins, which occurs within the transition zone.[13] The transition zone and boundary are addressed in detail in the HCM TM (Section 7 of GSP Appendix 2.A.b) based on available geologic data (e.g., cross-sections), hydraulic data (e.g., regional aquifer pumping tests), and isotopic data. Multiple lines of evidence indicate the presence of a partial barrier to groundwater flow between the EBP Subbasin and the main portion of the Niles Cone Subbasin within the Deep and Intermediate Aquifer systems in the transition zone. The partial barrier to

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[13] The northward deviation of the jurisdictional boundary between the EBP and Niles Cone Subbasins complicates discussion of the hydrogeology and groundwater model because although the representation in the 2021 EBPGWM of the hydrogeologic discontinuity within the transition zone is consistent with the data in the central portion of its extent, the northwest trend of the boundary toward the Bay is not. Accordingly, the alignment of the model representation of the hydraulic discontinuity with a partial barrier to horizontal flow in the transition zone results in an appendage of the Niles Cone Subbasin extending to the north of the hydrogeologic boundary (**Figure 1-1**). When discussing the hydrogeologic boundary and the 2021 NEBGWM, we refer to the main portion of the Niles Cone Subbasin, south of the hydrogeologic boundary as the main portion of the Niles Cone Subbasin.

groundwater flow that is represented in the 2021 EBPGWM occurs within transition zone (**Figure 1-2**). Constraints on the location and width of the transition zone have improved as more data have been obtained and evaluated. As documented in the HCM TM, the estimated location of the transition zone is within a swath that ranges in width from less than 1,500 ft, where it is well constrained between Hayward Wells E and Well B, to nearly a mile, where its location is less constrained (Figure 7-5 of the HCM TM, GSP Appendix 2.A.b).

1.3 Selected Software

Geosyntec used MODFLOW (MODFLOW-NWT)[14] for simulating groundwater flow and interaction between surface water and groundwater. MODFLOW and MODFLOW-NWT are public domain software supported by the United States Geological Survey (USGS). The term MODFLOW is used for subsequent reference herein to the model software used for the 2021 EBPGWM. MODFLOW is the most versatile and widely used software for groundwater modeling and is well-suited for simulating groundwater flow.

The Department of Defense Groundwater Modeling System (GMS, Aquaveo, 2018) and Arc Hydro Groundwater (AHGW, Jones and Strassberg, 2008) were used as the graphical user interface (GUI) for pre- and post-processing of MODFLOW files and storing the fundamental information that comprises the conceptual model, including databases of aquifer properties, groundwater levels[15], pumping rates, and sources (i.e., inflows) and sinks (i.e., outflows). GMS was used primarily for pre-and post-processing of data and AHGW was used for managing, visualizing, and storing groundwater data within a Geographical Information System maintained by the Environmental Systems Research Institute (ArcGIS) environment. Additional information on the selection of GMS and AHGW is provided in TM 4.3 (LSCE Team, 2020). Standard MODFLOW files will be provided and made available on the Groundwater Sustainability Agency (GSA)'s websites when the GSP is finalized.

1.4 Summary of Model Development Steps

Development of the 2021 EBPGWM included the following steps:

- Development of the model layering based on previous modeling efforts, additional data, and the HCM;
- Compilation of model input for the selected simulation period of 1990 through 2015;
- Compilation of model calibration data sets for a steady state model and a transient model that simulates changing water levels between 1990 and 2015 and aquifer response for two regional aquifer tests; and
- Model calibration, including adjustments to material properties and other model inputs to improve fit of available data.

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[14] The USGS MODFLOW-NWT (https://www.usgs.gov/software/modflow-nwt-a-newton-formulation-modflow-2005) is an option for MODFLOW-2005 to improve solution of unconfined groundwater flow problems. It is a standalone version of MODFLOW that is intended for solving problems involving drying and rewetting nonlinearities of the unconfined groundwater-flow equation (Niswonger et al., 2011).

[15] The terms "water levels" and "groundwater levels" are commonly used interchangeably in documentation and discussion of groundwater models.

2 SOURCES OF MODEL INPUT AND CALIBRATION DATA

The majority of data used for construction and calibration of the model are presented in the HCM TM (GSP Appendix 2.A.b), including groundwater elevations recorded within the basin, analysis of the geological boring log database compiled by the LSCE Team, review of previously published regional water budgets, precipitation data, regional geologic maps, geologic cross-sections produced by the LSCE Team and others, available geophysical logs, aquifer test results, and streamflow and dam release data.[16] Previously developed groundwater flow models that overlap the EBP Subbasin (Section 2.1) were also reviewed during construction and calibration of the 2021 EBPGWM.

2.1 Previously Developed Groundwater Flow Models

Previously developed groundwater models that overlap or partially overlap the EBP Subbasin area include:

1. The 2005 Niles Cone and South East Bay Plain Integrated Groundwater and Surface Water Model (NEBIGSM, WRIME, 2005), including 2019 updates;
2. The 2013 Niles Cone and South East Bay Plain MODFLOW Model (NEBMODFLOW, West Yost, 2013); and
3. The San Mateo Plain Groundwater Model (SMPGWM, EKI Environment & Water [EKI] et al., 2018), which uses MODFLOW.

Figure 2-1a shows the extent of the domains for these three models and the 2021 EBPGWM. **Figure 2-1b** shows the extent of two additional regional models in the San Francisco Bay Region that are also used as tools for management of groundwater resources: Westside Basin MODFLOW model and Santa Clara Valley MODFLOW Model. **Table 2-1** provides a summary of the software used for each basin and the objectives of the models. An overview of the models is provided in TM 4.3 (LSCE Team, 2020), and a more detailed discussion of NEBIGSM and NEBMODFLOW is provided below.

2.1.1 2005 NEBIGSM and 2019 Updates

In 2004/2005, Alameda County Water District (ACWD), EBMUD, and Hayward developed a model for the South EBP and Niles Cone groundwater basins in the southeastern portion of the San Francisco Bay Area (WRIME, Inc., 2005). This model was based on previous models developed by ACWD and EBMUD for the southern portion of the EBP and the Niles Cone Subbasins. The NEBIGSM was developed using Version 6 of the Integrated Groundwater Surface Water Model (IGSM) software. IGSM is a proprietary, finite element-based groundwater modeling software developed in the 1970s (Montgomery Watson, 1995; LaBolle et al., 2002). The NEBIGSM consists of four layers representing the four main aquifers[17] and indirectly simulates intervening aquitards. The IGSM is still used by ACWD as a tool for groundwater

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[16] Additional data obtained from EBMUD on monthly releases between 1992 and 2020 at Chabot and San Pablo reservoirs to San Leandro and San Pablo creeks, respectively, that were not documented in the HCM TM (GSP Appendix 2.A.b), were used for the model construction. These data are included in GSP Appendix 2.A.c.

[17] In the NEBIGSM, Layer 1 represents the Newark Aquifer or equivalent depth interval, Layers 2 and 3 of the NEBIGSM represent the Intermediate Aquifer in the EBP and the Centerville/Fremont Aquifers in the Niles Cone Subbasin, which are often referred to as one single layer, known as the Centerville/Fremont Aquifer because of their high degree of interconnection, and Layer 4 represents the Deep Aquifer (WRIME, Inc., 2005).

resources management. In May 2019, ACWD provided EBMUD an updated version of NEBIGSM model files, which included input files from October 1964 through December 2020. The input data between late 2018 and December 2020 were provisional data or projected.

2.1.2 2013 NEBMODFLOW

In 2013, EBMUD had the NEBIGSM converted from the IGSM modeling code to the public-domain MODFLOW modeling code. Like the NEBIGSM, the NEBMODFLOW model represents three primary hydrogeologic units:

- Shallow Aquifer Zone (from the ground surface to depths ranging up to approximately 200 ft);
- Intermediate Aquifer Zone (at depths ranging from approximately 200 to as much as 500 ft bgs), single layer representing the Centerville/Fremont Aquifer in Niles Cone Subbasin; and
- Deep Aquifer Zone (at depths ranging from approximately from 400 to 500 feet to more than 660 ft bgs).

The NEBMODFLOW model consists of seven layers that represent these aquifers and intervening aquitards, and it includes some refinement of layering and hydraulic properties compared to 2005 NEBIGSM in the southern portion of the EBP Subbasin based on additional data (EBMUD, 2013). All input data from the NEBMODFLOW model was evaluated and refined during the development of the 2021 EBPGWM.

2.2 Data

Development and calibration of the 2021 EBPGWM utilized information and data collected from various sources, most of which are presented in detail in the HCM TM (GSP Appendix 2.A.b). Specific sources of model input and calibration data are referenced in the appropriate sections of this report. The following summary provides an overview of the data sources.

2.2.1 Groundwater Elevation Database

As described in TM 4.1 (GSP Appendix 2.A.a), 823,504 groundwater level measurements from 7,495 wells were gathered from available sources and compiled in a Microsoft Access Water Level Database. The sources of the groundwater elevation data include Alameda County Public Works Agency (ACPWA), ACWD, DWR, EBMUD, Port of Oakland, USGS, previous studies, and LSCE files for the City of Hayward. Data were provided as periodic water level measurements and transducer measurements recorded with dataloggers. These data also include historical data from previous studies in the EBP and Niles Cone Subbasin.

Figure 2-2 shows potentiometric surface contour maps based on average groundwater level measurements between 2000 and 2015. A subset of water level measurements from the Water Level Database was used as targets for the calibration of the 2021 EBPGWM, as described in Section 4.1. Selected hydrographs comprising monitoring well data used as calibration targets are displayed in **Figures 2-3a and 2-3b**.

2.2.2 Additional Groundwater Level Data

Groundwater level data recorded with transducers and dataloggers that were not included in the Water Level Database were also used as targets during calibration of the 2021 EBPGWM. Specifically, groundwater level records were obtained from ACWD for regional groundwater aquifer tests conducted by LSCE in 2002 and by Fugro West, Inc. (Fugro) in 2010 (LSCE, 2003; Fugro, 2011).

2.2.3 Boring Log Database

Geologic data from DWR well completion reports were compiled for 631 boreholes and tabulated in an Excel file, as described in the HCM TM (GSP Appendix 2.A.b).

A review of the boring logs indicated the use of 15 different material categories (e.g., gravel, clay) was sufficient. These 15 material categories were assigned to seven hydrogeological categories developed based on relative hydraulic conductivity estimated from typical literature values. **Table 2-2** shows the assignment of the 15 material categories to the seven hydrogeological categories and **Table 2-3** presents the basis for the seven hydrogeological categories. Hydrogeological categories assigned to depth intervals within each model layer at the 631 borehole locations were used to inform layer aquifer parameters, as described in Section 3.3.3.

2.2.4 Water Budget Data

A preliminary water budget for the EBP Subbasin is presented in the HCM TM (GSP Appendix 2.A.b). Values within the ranges presented in the HCM TM were used for initial values assigned to the EBP portion of the 2021 EBPGWM. The preliminary EBP water budget values from the HCM TM and initial values assigned to the model are tabulated in **Table 2-4**.

The EBP Subbasin water budget comprises the following components of inflows and outflows:

Inflows:

- Recharge from precipitation, accounting for evapotranspiration;
- Recharge from irrigation of large areas and residential parcels;
- Recharge from leaking sewer lines and domestic water supply pipes;
- Infiltration of surface water in streams to groundwater; and
- Inflow along the eastern margin of the EBP Subbasin.

Outflows:

- Groundwater pumping;
- Groundwater discharge to the San Francisco Bay; and
- Discharge of groundwater to surface water in streams and sewer pipes.

Section 4 presents the final model inputs for sources (recharge and inflow along the eastern margin) and sinks (groundwater pumping) for the calibrated groundwater model and resulting modeled water budget.

2.2.5 Precipitation Data

Recharge assigned to the 2021 EBPGWM associated with precipitation is based on records from four National Oceanic Atmospheric Administration (NOAA) stations in the model domain (USC00047414 in Richmond, USC00040693 in Berkeley, USC00049185 in Upper San Leandro Filters, and USC00046144 in Newark), the locations of which are shown on Figure 6-2 of TM 4.2 (GSP Appendix 2.A.b). As described in Section 3.3.2.2, the recharge from precipitation assigned to the model was based on precipitation records that were combined with a contour map of average annual precipitation across the East Bay (Alameda County Flood Control and Water Conservation District, 1988) to obtain an estimate of average annual precipitation in the subregions within the EBP Subbasin. The water budget data described in Section 2.2.4 (above) were also used to develop the recharge inputs that were not related to precipitation (i.e., pipe leakage and irrigation).

2.2.6 Geologic Maps

Locations of unconsolidated sedimentary deposits and the bedrock outcrops of the Franciscan Complex shown on a surficial geologic map of the EBP Subbasin (Jennings et al., 1977) were used to inform the eastern extent and inactive areas within the model domain. Most of the eastern margin of the model domain is approximately coincident with the Hayward Fault along the base of the East Bay Hills (**Figure 1-1**). A contour map of estimated bedrock elevation in the East Bay (Norfleet Consultants, 1998) was used to constrain the base of the model, as described in Section 3.2.2.

2.2.7 Geologic Cross-Sections Prepared by Others

Geologic cross-sections of the EBP Subbasin prepared by others and presented in Appendix C of the HCM TM (GSP Appendix 2.A.b) were also used to inform model layering and base of the model, as described in Section 3.2.2.

2.2.8 Geophysical Logs

Geophysical logs of borings in the EBP Subbasin compiled for HCM TM (GSP Appendix 2.A.b), which are a fundamental basis for geologic cross-sections (e.g., LSCE, 2003; GSP Appendix 2.A.b) were also used to constrain the geometry of the model layers.

2.2.9 Aquifer Test Results

Reported estimates of aquifer properties based on regional aquifer tests (also called pumping tests or pump tests) conducted in 2002 and 2010 (Fugro, 2011; LCSE, 2003; GSP Appendix 2.A.b) were used to guide assignment of initial values and ranges of values for aquifer properties during development and calibration of the 2021 EBPGWM. The 2002 aquifer test was comprised of sequential two-week pumping tests at two wells with recovery between, and is referred to herein as the LSCE 2002 Test. The 2010 aquifer test was an eight-week pumping test and is referred to as the Fugro 2010 Test. Both the 2002 LSCE and 2010 Fugro aquifer tests included records of response during and after pumping at several observation wells (Fugro, 2011; LCSE, 2003, and Sections 4.3.3 and 4.3.4 below).

2.2.10 Streamflow and Reservoir Release Data

Discharge data from eight USGS stream gauging stations on Alameda Creek, San Lorenzo Creek, and Wildcat Creek and water release data from San Pablo and Chabot reservoirs were used to define streamflow model inputs, as described in Section 3.3.2.1.

3 NUMERICAL MODEL DEVELOPMENT

3.1 Computer Code

MODFLOW-NWT (Niswonger et al., 2011) was used for the 2021 EBPGWM and is referred to herein as MODFLOW. MODFLOW uses a finite-difference method to solve the governing groundwater flow equation. This method calculates water levels[18] and flux to and from a network of finite difference grid cells. The size of the finite-difference grid cells controls the resolution of hydraulic properties and hydraulic head and influences practical aspects, including size of model files and computational run time.

MODFLOW can simulate a series of transient (time-varying) conditions where inflow and outflow components of the groundwater system change with time resulting in varying simulated water levels, or steady-state (equilibrium) conditions for which inflow and outflow components are in balance so there is no change in storage and groundwater levels are constant. Both steady-state and transient model simulations were used in developing and calibrating the 2021 EBPGWM.

MODFLOW includes several optional specialized "packages" to simulate different processes and features. The packages used in the 2021 EBPGWM include the recharge package (RCH1) (Harbaugh, 2005), the general head boundary package (GHB1) (Harbaugh, 2005), the well package (WEL1) (Niswonger et al., 2011), the horizontal flow barrier package (HFB6) (Harbaugh, 2005), the streamflow-routing package (SFR2) (Niswonger and Prudic, 2005), the drain package (DRN) (Harbaugh, 2005), and the gage package (GAGE) (Niswonger and Prudic, 2005).

Automated Parameter Estimation (PEST) software (Doherty, 2010; Doherty and Hunt, 2010) was used to support model calibration. PEST is a program that accepts a number of parameters with specified lower and upper bounds, and then repeatedly runs the model with varying parameter values with the goal of minimizing the objective function, defined as the sum of weighted squared residuals. The result is a model with outputs that closely match measured data.

3.2 Model Domain, Grid, and Layering

3.2.1 Model Domain

The domain of the 2021 EBPGWM, which is shown in **Figure 3-1,** encompasses the entire EBP Subbasin as defined by DWR (2018). It also includes all of the adjacent Niles Cone Subbasin on the south, and the Castro Valley Basin north of Hayward, which DWR has delineated as a separate groundwater basin adjacent to the EBP Subbasin. Although the DWR delineation of the EBP and Niles Cone Subbasins stops at the shoreline of the San Francisco Bay, the model domain extends to the west into the San Francisco Bay because the unconsolidated sedimentary units that comprise the Subbasins generally extend beneath the San Francisco Bay (e.g., GSP Appendix 2.A.b).

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[18] The terms "water levels" and "groundwater levels" are commonly used interchangeably in documentation and discussion of groundwater models.

For purposes of calibration and reporting model results, an informal division is used herein between the northern and southern modeled portions of the EBP Subbasin,[19] which is shown in **Figure 3-1**. The northern modeled portion of the EBP Subbasin generally includes areas from Richmond to San Leandro, and the southern modeled portion includes areas from San Leandro to the border with Niles Cone Subbasin in Hayward. Unconsolidated deposits extend to depths of 1,000 ft or more in the southern EBP Subbasin, 500 to 1000 ft between San Leandro and Oakland, and are generally less than 500 ft thick north of Oakland.

3.2.2 Model Grid

The model grid cells are all 1,000 by 1,000 ft, which provides sufficient resolution for the purposes of using the model as a regional tool for developing the GSP, managing the groundwater resources, and representing large-scale variation in aquifer and aquitard geometry and hydraulic properties, boundary conditions, and hydraulic gradients. The grid is rotated approximately 30 degrees west of north to generally align with the predominant direction of groundwater flow for natural conditions (from the East Bay Hills at eastern margin to San Francisco Bay), which is generally perpendicular to the San Francisco Bay margin.

3.2.3 Model Layering

The seven layers of the 2013 NEBMODFLOW model were used as a starting point for the construction of the layering in the 2021 EBPGWM. Layer 1 of the 2013 NEBMODFLOW model, which represents the Shallow Aquifer Zone, was split into three layers (Layers 1 through 3) to accommodate vertical hydraulic gradients within the Shallow Aquifer Zone and improve representation of groundwater-surface water interaction. The Intermediate Aquifer Zone, represented by Layer 3 of the 2013 NEBMODFLOW model, was also split into three layers (Layers 5 through 7) to accommodate vertical hydraulic gradients within the Intermediate Aquifer Zone and represent pumping from discrete depth intervals. The Deep Aquifer Zone, which is Layers 5 through 7 in the 2013 NEBMODFLOW model, is represented by Layers 9 through 11 in the 2021 EBPGWM. In addition, Layer 12 was added to represent the predominantly fine-grained unconsolidated materials that are locally present between the base of the Deep Aquifer Zone and bedrock. Layer 12 has negligible thickness in the main portion of the Niles Cone Subbasin. The model layers described above correspond with the HCM in the following manner:

- Layers 1 through 3 represent the Shallow Aquifer Zone;
- Layer 4 represents the aquitard below the Shallow Aquifer Zone;
- Layers 5 through 7 represent the Intermediate Aquifer Zone;
- Layer 8 represents the aquitard below the Intermediate Aquifer Zone;

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[19] This designation of north and south portions of the EBP Subbasin is different than the north/south geographic division presented in the HCM TM (Figure 1-1 of GSP Appendix 2.A.b), which is in Oakland and extends into the San Francisco Bay along the Bay Bridge.

- Layers 9 through 11 represent the Deep Aquifer Zone;[20] and
- Layer 12 represents the generally low permeability fine-grained sediments that are locally present between the Deep Aquifer Zone and bedrock in the southern portion of the EBP Subbasin.

The geometry of the model layering described above for 2021 EBPGWM is illustrated by three cross-sections, the locations of which are shown in **Figure 3-1**. **Figure 3-2a** shows a north-northwest to south-southeast cross-section (1-1’) through the 2021 EBPGWM domain, roughly parallel to the San Francisco Bay Margin and Hayward Fault. **Figure 3-2b** shows two west-southwest to east-northeast cross-sections (2-2’ and 3-3’) transverse to the cross-section illustrated on **Figure 3-2a**.

Figures 3-3a through **3-3l** present contour maps of the top elevation for selected layers, and contour maps of the thicknesses (isopach maps) of the aquifer and aquitard units. **Figure 3-3m** is a contour map of the bottom elevation of Layer 12, which is the base of the model.

Additionally, because model layers in MODFLOW must extend through the entire MODFLOW domain, the thicknesses of model layers that represent the Deep Aquifer Zone, the underlying fine-grained sediments, and in some areas the Intermediate Aquifer Zone are of negligible thickness where the depth to bedrock decreases, such as in northern and eastern portions of the EBP Subbasin. This aspect of the model layer geometry is illustrated by the cross-sections (**Figures 3-2a** through **3-2b**) and the model layer isopach maps (e.g., **Figures 3-3f** and **3-3j**).

In addition to the model layer modifications described above, several other refinements were made to improve the representation of the hydrostratigraphy in the 2021 EBPGWM in general accordance with the HCM TM (GSP Appendix 2.A.b). The elevation of the top of Layer 1, which is the top of the model and approximates the ground surface, was interpolated to the model domain from a digital elevation model (DEM) with data points at 30 ft intervals (USGS, 2013; USGS, 2019). **Figure 3-3a** is a contour map of the elevation of the top of Layer 1. In the area of the model covered by the San Francisco Bay, a bathymetric DEM (Fregoso et al., 2017) was used as the top of Layer 2.

In the main portion of the Niles Cone Subbasin, the elevation of the base of the 2013 NEBMODFLOW model was retained as the base of the 2021 EBPGWM (the bottom of Layer 12). The elevation of the bottom of Layer 12 in the EBP Subbasin, which is represented by the contour map shown in **Figure 3-3m**, was interpolated from data points for the elevation of the top of bedrock in the borehole log database, excluding logs with poor data quality (e.g. the log recorded bedrock as occurring above unconsolidated deposits). The interpolated top of bedrock surface, which is the base of the 2021 EBPGWM, was adjusted based on information from existing cross-sections (GSP Appendix 2.A.b) and a map of surficial geology (Jennings, 1977).

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[20] Layer 9 generally represents the least transmissive part of the Deep Aquifer Zone in the southern portion of the EBP Subbasin and the most transmissive part of the Deep Aquifer Zone in the northern portion of the main Niles Cone Subbasin. Layers 10 and 11 represent the most transmissive part of the Deep Aquifer Zone in the southern portion of the EBP Subbasin and the least transmissive part of the Deep Aquifer Zone in the northern portion of the main Niles Cone Subbasin.

The base of the 2021 EBPGWM was checked against geophysical logs compiled during the development of the HCM TM (GSP Appendix 2.A.b), and it was found to be generally consistent with geophysical logs. In addition, the base of the 2021 EBPGWM was compared to a regional contour map of bedrock elevation (Norfleet Consultants, 1998), and the two were found to be generally consistent, except for an area in the northernmost EBP Subbasin where the bedrock contour map shows a valley bedrock surface that is not reflected by the borehole logs. The interpolated model base was not revised based on the map of bedrock elevation.

Minor adjustments to the elevation of model layers in the EBP Subbasin were made based on review of lithology in the borehole log database. At locations where boring logs recorded long, uninterrupted intervals of sand and gravel, model layering was adjusted so that model layers did not intersect these intervals, where feasible.

Close to the transition zone, several model adjustments were made to improve the model layering's representation of previously prepared cross-sections. In the main portion of the Niles Cone Subbasin, the elevation of Layer 4 was moved upwards so that a continuous coarse-grained interval mapped in the Intermediate Aquifer Zone would be included in model Layer 5. Additionally, the elevation of model Layer 8 was moved upwards in the main portion of the Niles Cone so that a continuous coarse-grained interval mapped in the Deep Aquifer Zone would be included in model Layer 9. In the main portion of the Niles Cone Subbasin, the bottom of model Layer 9 was also moved upwards so the total thickness of the layer was less within approximately 1.5 miles of the transition zone, based on boring logs and information in the vicinity of the transition zone. In the EBP Subbasin, the top of Layer 10 was adjusted to align more closely with the top of mapped coarse-grained Deep Aquifer Zone intervals, and the bottom of Layer 11 was also adjusted to align more closely with the bottom of coarse-grained Deep Aquifer Zone intervals. The model layering in the vicinity of the transition zone is illustrated in **Figure 3-2a**.

Layering in the Niles Cone Subbasin portion of the model domain is consistent with that of the 2013 NEBMODFLOW model, except for the division of layers described above (e.g., Shallow Aquifer Zone represented by layers 1 through 3), and minor adjustments in the vicinity of the transition zone.

3.3 Boundary Conditions, Stresses and Aquifer Properties

3.3.1 Boundary Conditions

There are four boundaries to the lateral extent of the 2021 EBPGWM domain: (1) San Francisco Bay; (2) Eastern Margin; (3) Southern Margin; and (4) Western Margin. In addition, the transition zone between the EBP Subbasin and the main portion of the Niles Cone Subbasin constitutes a partial internal boundary. Each is described below.

3.3.1.1 San Francisco Bay

The San Francisco Bay and the salt ponds south of the San Mateo Bridge are represented using general heads assigned to portions of Layer 1 area, as shown in **Figure 3-4**. The bottom elevation of Layer 1 in San Francisco Bay and the salt ponds is set to the average elevation of the bottom of San Francisco Bay and the salt ponds. The head stage is 1 ft above mean sea level, and the conductance per square foot (ft^2) of the bay and salt pond polygons range from 10^{-6} to 0.095 day^{-1}. The conductance of the bay and salt ponds can be converted to an assumed thickness (b) and vertical hydraulic conductivity (Kv) of sediments on the bay floor with the following equation:

Conductance per unit area (leakance) of the Bay Floor =

$$(Kv)(A)/(b)(A) = (0.475\ ft/d)(1ft^2) / ((5\ ft)(1ft^2)) = 0.095\ [1/d]$$

Where:
Kv (feet per day [ft/d]) is the vertical hydraulic conductivity of the sediments on the bay floor;
A is the unit area; and
b (ft) is the thickness of the sediments on the bay floor.

The conductance per unit area of the floor of the salt ponds varies between 0.0186 and 10^{-6} day^{-1}, consistent with the NEBIGSM model, which is lower than that of the floor of the San Francisco Bay.

This approach to modeling the bay is consistent with that used by the USGS Santa Clara Valley Regional Groundwater/Surface water flow model, which also uses a general head boundary to represent the San Francisco Bay (Hanson et al., 2004). The conductance of the San Francisco Bay and salt ponds in the 2021 EBPGWM is also consistent with the conductance of the bay floor used in other regional groundwater models. For example, although the 2013 NEBMODFLOW model uses the MODFLOW Lake Package instead of the GHB package to model the bay, the conductance per unit area, or leakance (Kv/b) of the lake bottom is set at 0.1 (ft/d)(1/ft) or 0.1 day^{-1}.

The San Mateo Plain Groundwater Model (SMPGWM, EKI et al., 2018) and Westside Basin Groundwater Models (Hydrofocus, 2017) use constant heads for the San Francisco Bay and Pacific Ocean. With this approach the Kv of the uppermost layer beneath the bay controls the hydraulic communication with the water body. A Kv of 0.01 ft/d is assigned to the Bay Muds in the Westside Basins Groundwater Model (Table 2 in Hydrofocus, 2017). Kv for shallow layers in the SMPGWM are reported to range from 0.06 to 0.0009 ft/d. A Kv of 0.01 ft/d, which is in the middle of the reported range, and an assumed thickness of 5 feet for the Bay floor sediments, equates to a leakance of 0.002 day^{-1}, which is lower than the values used for used for EBP, Niles Cone, and Santa Clara Models.

3.3.1.2 Eastern Margin

The eastern margin of the 2021 EBPGWM is a specified flow boundary (also known as a specified flux boundary) that is divided into 10 segments. The inflow occurs in all layers in each of these segments. The inflow value was based on the regional water budget as described in the HCM TM (GSP Appendix 2.A.b), and was refined as part of the model calibration. **Table 3-1** lists the initial flow values defined for each segment, as well as the final value. **Figure 3-4** delineates the 10 inflow segments.

3.3.1.3 Southern Margin

This location and alignment of the southern margin of the 2021 EBPGWM has been updated to coincide with the DWR delineation of southern boundary of the Niles Cone Subbasin. In the 2021 EBPGWM, it is a no-flow boundary, which is appropriate because the predominant natural groundwater flow direction in the vicinity is generally parallel to the southern boundary.

3.3.1.4 Western Margin

Beneath the GHB boundary in Layer 1, the western margins of the underlying layers are no-flow boundaries, which is consistent with previous models (NEBIGSM and NEBMODFLOW), and is generally consistent with a conceptual model of upward discharge to the San Francisco Bay from the deeper aquifers, and a potential groundwater divide under the San Francisco Bay within deep aquifers that may extend beneath the San Francisco Bay and under Santa Clara, San Mateo, San Francisco, and Marin Counties. In addition, the western margin of the model domain is sufficiently far from existing and potential pumping locations and recharge application zones to have negligible influence on groundwater elevations and flow in the portions of the EBP Subbasin that are pertinent to the GSP development and groundwater resources management.

3.3.1.5 Horizontal Flow Barriers (HFB)

The Horizontal Flow Barrier (HFB) Package in MODFLOW is used to represent the partial barrier to groundwater flow within the transition zone between the EBP Subbasin and the main portion of the Niles Cone Subbasin. The HFB controls the hydraulic connection between adjacent model grid cells independently of the hydraulic properties assigned to the grid cells. The location and hydraulic properties of the HFB can be easily revised and varied.

The properties assigned to the HFB were calibrated based on groundwater elevation responses to aquifer pumping tests on both sides of the HFB. The HFB is assigned to Layers 4 through 12 of the 2021 EBPGWM in the location shown in **Figure 3-4**; it is not included in the Shallow Aquifer Zone (Layers 1 – 3). The location and geological and hydrogeological characterization of the transition zone are discussed in detail in the HCM TM (GSP Appendix 2.A.b). The location and function of the HFB in the transition zone between the main portion of the Niles Cone Subbasin and the EBP Subbasin in the 2021 EBPGWM are consistent with characterization of the partial hydraulic barrier in the transition zone presented in the HCM TM (GSP Appendix 2.A.b). Specifically, the HFB is located between Hayward Wells B and E, and its orientation follows the transition zone boundary defined based on multiple lines of evidence in the HCM TM (GSP Appendix 2.A.b). The HFB extends from the eastern margin of the model, corresponding to the eastern margin of the groundwater basin, to approximately the middle of San Francisco Bay. The western extent is uncertain; however, it is consistent with a concealed bedrock fault delineated by DWR (1967) parallel to the transition zone and extending into San Francisco Bay. In addition, the extent of the HFB was refined based on model calibration, and the final extent used in the 2021 EBPGWM provided the best overall calibration of simulations to the long-term aquifer pumping tests conducted at the City of Hayward Wells C and E (LSCE, 2003), and the EBMUD Bayside Well (Fugro, 2010).

An HFB is also used to represent the partial barrier to groundwater flow along the Hayward fault in a portion of the Niles Cone Subbasin where the eastern margin of the model extends beyond the Hayward Fault. In the NEBIGSM model (WRIME, 2005) this area along the Hayward Fault in the Niles Cone Subbasin is assigned a low hydraulic conductivity (0.01 ft/d). In the 2021 EBPGWM the HFB that represents impedance of groundwater flow across the Hayward Fault is assigned to Layers 1 through 12 in the location shown in **Figure 3-4.** The HFB is assigned a leakance value of 0.05 day^{-1}, which is equivalent to a hydraulic conductivity of 0.5 ft/d for a thickness of 10 ft.

3.3.2 Stresses

There are four stresses represented in the 2021 EBPGWM: (1) surface water / groundwater interactions along creeks; (2) recharge; (3) groundwater pumping; and (4) artificial recharge. Each is described below.

3.3.2.1 Creeks

The creeks that are simulated in the 2021 EBPGWM are shown in **Figure 3-4**. The major creeks (San Pablo Creek, Wildcat Creek, San Leandro Creek, San Lorenzo Creek, and Old Alameda Creek) were simulated with the MODFLOW Stream (SFR2) Package. In addition, four minor creeks, that lack detailed data on stream characteristics, were simulated with the MODFLOW drain (DRN) package: Cerrito Creek, Codornices Creek, Lion Creek, and Sulphur Creek.

San Leandro Creek, San Lorenzo Creek, and Old Alameda Creek were represented in the 2013 NEBMODFLOW model and their locations and properties were imported into the 2021 EBPGWM as a starting point prior to model calibration. Assumptions about which portions of these three creeks are concrete-lined were based on the HCM TM (GSP Appendix 2.A.b) and further evaluated using recent Google Earth imagery. Streambed conductance values were updated accordingly.

For creeks not previously delineated in the 2013 NEBMODFLOW model, creek traces were delineated using the National Hydrography Dataset (DWR, 2020). Streambed elevations at nodes along each stream were set using a DEM (USGS, 2013; USGS, 2019), and linearly interpolated between nodes. Similar streambed conductance values to those of San Leandro, San Lorenzo, and Old Alameda Creek were used as initial values prior to model calibration.

The headwaters of many creeks in the model are outside the model domain. Inflows at the most upstream point of these creeks was compiled from USGS gage records on Wildcat, San Lorenzo, and Old Alameda Creeks, and dam release volume records for the San Pablo and Lake Chabot reservoirs for San Pablo and San Leandro Creeks, respectively.

3.3.2.2 Recharge

Recharge is applied to model Layer 1, except over the San Francisco Bay where it would have no effect because the GHB boundary used for the bay includes a reference elevation. Assigned values of recharge vary monthly in the transient simulations, and an average value is used in the steady state simulation. Different recharge rates are applied to 16 recharge zones,[21] tabulated in **Table 3-2**. The recharge polygons

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[21] Within each recharge zone, recharge is applied uniformly.

are based on sub-regions defined by Muir (1994) and presented in the HCM TM (GSP Appendix 2.A.b). These polygons were further subdivided based on soil properties presented in the HCM TM (GSP Appendix 2.A.b). Recharge was adjusted as part of model calibration, and **Table A-3 in Appendix A** lists the lower and upper bounds for average recharge in the EBP Subbasin used during calibration, as well as the final average value. **Figure 3-5** shows the boundaries of the 16 recharge zones.

The 2013 NEBMODFLOW model was used as the basis for initial recharge rates applied to the Niles Cone Subbasin and all areas that contain salt ponds.[22] The components and basis for the initial recharge rates applied to the EBP Subbasin are described in detail in the HCM TM (GSP Appendix 2.A.b). These components include recharge from precipitation, recharge from water and sewer pipe leakage, and recharge from domestic and large-scale irrigation (i.e., golf courses and cemeteries).

Recharge from pipe leakage and irrigation was applied to recharge zones in the 2021 EBPGWM according to the water budget data presented in the HCM TM with no monthly variation. Average annual recharge from irrigation of both large irrigated parcels and residential parcels in acre-feet per year (AFY) is listed for each recharge polygon in the HCM TM. Although the majority of irrigation occurs during the summer and early autumn months, the estimated annual recharge volumes associated with irrigation were divided by 12 and applied to the appropriate recharge polygon each month in the EBP Subbasin portion of the model[23]. Average annual recharge from leaking water and sewer pipes in the entire EBP Subbasin is also presented in the HCM TM. These annual recharge volumes were also divided by 12 and applied evenly to each recharge polygon on a monthly basis in the EBP Subbasin portion of the 2021 EBPGWM.

Recharge from precipitation was applied to each recharge zone in the EBP Subbasin by compiling monthly precipitation from the nearest USGS station, scaling the station's records by a factor so that the average value was consistent with average precipitation estimates for the recharge zone from regional precipitation mapping (Alameda County Flood Control and Water Conservation District, 1988), and then multiplying the monthly records by the percentage of precipitation that recharges groundwater presented in the HCM TM (GSP Appendix 2.A.b). The equation below summarizes this calculation.

Recharge = [Precipitation] x [Scaling coefficient] x [Recharge factor]

Table 3-3 lists the average precipitation, the scaling coefficient, and the recharge factor for each of the recharge polygons. The recharge from precipitation was varied on a monthly basis based on monthly precipitation.

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[22] Because the Salt Ponds are represented in the 2021 EBPGWM as general head boundaries, the assigned recharge, which has been retained from the 2013 NEBMODFLOW model, has negligible influence on the simulated groundwater levels.

[23] For long-term regional groundwater model simulations, constant recharge associated with irrigation is acceptable, but refinement to include seasonal variation of recharge associated with irrigation is recommended for local short-term applications of the 2021 EBPGWM.

3.3.2.3 Groundwater Pumping

The 2021 EBPGWM includes approximately 163 pumping wells that are active between 1990 and 2015, which are listed in **Tables A-1 of Appendix A**, 34 of which are located in the EBP Subbasin**.** The locations and pumping rates of these wells are based on the 2013 NEBMODFLOW groundwater flow model and the 2019 update to the 2005 NEBIGSM model. Seven additional wells in the EBP Subbasin are included based on information provided by EBMUD and stakeholders on additional groundwater users and estimated pumpage. In addition, unmetered irrigation and domestic pumping as estimated in the 2005 NEBIGSM is represented with 471 wells. For all wells in EBP Subbasin, 2002 monthly pumping rates are used for the 2003-2015 time period, consistent with previous estimates that pumping rates have not varied significantly since the 2000s (EBMUD, 2013).

Some of the wells in the 2013 NEBMODFLOW model and/or 2019 update to the 2005 NEBIGSM model have specific defined screen intervals, while the depth interval of pumping for others are defined only by model layer. The wells with screened intervals defined only by model layer were updated in the 2021 EBPGWM so that the screened interval intersects the appropriate aquifer zone.

Pumping from wells is represented in the 2021 EBPGWM using the MODFLOW Well (WEL) package, with specified top and bottom elevations of the screened interval and assigned pumping rate schedules. If the screened interval intersects more than one model layer, then GMS distributes the pumping rate across the intersected layers proportionally to the transmissivity of the layers.

3.3.2.4 Injection Wells/Artificial Recharge

There are injection wells assigned in 2021 EBPGWM that represent artificial recharge from ponds such as the Quarry Lakes recharge ponds in the Niles Cone area between 1990 and 2015. The location and injection rates of these wells are based on the 2013 NEBMODFLOW model and the 2019 update to the 2005 NEBIGSM model.

3.3.3 Aquifer Properties

Aquifer properties assigned to each grid cell in the 2021 EBPGWM include horizontal and vertical hydraulic conductivities, specific yield, and specific storage. As described in Section 4, the calibration process for the 2021 EBPGWM included adjusting values of input parameters until the model simulation closely matched observations. The distribution of the hydraulic properties is the end-product of the calibration process.

Figure 3-6a through **3-6l** show the post-calibration distribution of horizontal and vertical hydraulic conductivity and specific yield or specific storage assigned to each layer of the 2021 EBPGWM. All horizontal hydraulic conductivity assignments are isotropic, i.e., the same in all horizontal directions. All vertical hydraulic conductivity values were defined using a vertical anisotropy ratio.

3.3.3.1 Hydraulic Conductivity

The pre-calibration values of horizontal and vertical hydraulic conductivity were generally based on the 2013 NEBMODFLOW model. The values were refined using geographic calibration zones. The calibration zones were delineated using data from the boring log database using the process described below:

- For each boring log in the model domain, the percentage of the log consisting primarily of sand and gravel (hydrogeological category 1, 2, 2a, or 2b; see **Table 2-3**) was calculated for the length of the log intersecting each layer;
- Zones of similar percent sand and gravel were delineated in each model layer using maps with the percentage sand and gravel by layer for each boring log location; and
- Initial values and ranges were established for each calibration zone based on all available hydrogeological data.

Figures 3-6a through **3-6l** show the calibrated aquifer properties by layer. Appendix B provides more details about the calibration zone delineation.

3.3.3.2 Specific Storage and Specific Yield

The specific storage values assigned to model cells are calibrated parameters. The values were calibrated using the 2002 and 2010 pumping test simulations and the historical transient simulation. Refinement of the parameter values during calibration was conducted using the same geographic zones as for the horizontal and vertical hydraulic conductivities. A specific yield value of 0.06 was assigned over the entire model domain, consistent with estimates used by DWR in previous storage calculations in EBP Subbasin (DWR, 1994).

4 MODEL CALIBRATION AND PARAMETER SENSITIVITY

Model calibration is the process of adjusting values of model parameters such as hydraulic parameters and water balance inputs to reduce the difference between the simulated and measured data. Model calibration can be accomplished manually by reviewing initial model output, adjusting parameters based on the review, and then rerunning the model. It can also be accomplished in an automated fashion using software such as PEST (Doherty, 2010; Doherty and Hunt, 2010), by setting up ranges of values for selected parameters and using the software to automatically run many model versions with different parameter values with the objective of minimizing the sum of the squared residuals between simulated response and measured data. The 2021 EBPGWM was calibrated using a combination of both manual and automated calibration. Following are a description of the simulation periods used for calibration (Section 4.1), a summary of the simulation setup and calibration datasets (Sections 4.2 through 4.5) discussions of the calibration process and metrics (Section 4.6) and calibration results (Section 4.7), and parameter sensitivity observations that were made during calibration (Section 4.8).

4.1 Simulation Periods used for Calibration

The following groundwater model simulations were used to calibrate the 2021 EBPGWM:

- Steady state based on recent average conditions;
- Historical transient from 1990 to 2015;
- 2002 Aquifer Test; and
- 2010 Aquifer Test.

Each is discussed below in more detail.

4.2 Steady State based on Recent Average Conditions

4.2.1 Steady State Simulation Setup

A steady state simulation that approximates recent average (baseline) conditions was designed using average values for recharge, streamflow, and groundwater pumping for the period from 2000 to 2015. The 2000 to 2015 time period was selected in place of the 1990 to 2015 time period that is used for the historical transient model discussed below, because historical water level records in the Intermediate and Deep Aquifer Zones[24] show that many wells were still recovering in the 1990s from past historical pumping, and therefore are not appropriate for approximation of recent average conditions. Available historical data indicate that water levels have recovered to approximate recent levels by 2000.

The steady state model simulation was calibrated using average groundwater elevation data recorded between 2000 and 2015 for a selection of observation wells. The results of the steady state model

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[24] Recovery from historical pumping in the southern portion of the EBP Subbasin likely continued after 1990 in portions of the Deep Aquifer as well as the Intermediate Aquifer, but there is a paucity of groundwater elevation data for the Deep Aquifer in the relevant timeframe.

simulation were used for calibration of the aquifer parameters and of the water budget components (e.g., adjustments of recharge inflows within estimated range [Table 2-4], comparison of simulated discharge to San Francisco Bay with estimated range [Table 2-4]), and the simulated groundwater elevations were used as the starting heads for portions of the historical model simulation, as explained further below.

4.2.2 Steady State Calibration Data

Average groundwater elevations between 2000 and 2015 were used as calibration targets for the steady state simulation, which approximates average recent conditions. Measurements recorded between 1990 and 2000 that were included for calibration of the transient historical simulation, discussed above, were excluded because groundwater levels recorded between 1990 and 2000 in observation wells screened in the Intermediate and Deep Aquifer Zones show systematic recovery from drawdown due to pumping earlier in the century and therefore are not representative of average recent conditions. 101 of the 108 wells used as calibration targets for the historical transient model simulations were also used in the calibration of the steady state groundwater flow model. Three wells not used for calibration of the historical simulation were used in the steady state simulation.[25] The locations of the target observation wells are shown in **Figure 4-1a** and the wells are listed in **Table A-2 of Appendix A**.

Flow budget components for the EBP Subbasin presented in the HCM TM (GSP Appendix 2.A.b), which are also described in Section 2.2.4 and documented in **Table 2-4**, were also used as general guidelines during the calibration of the steady state model that represents average recent conditions.

Average flow data between 2000 and 2015 from six USGS gages on Wildcat Creek and San Lorenzo Creek were also used as general guidelines for streamflow during the calibration of the steady state simulation of recent conditions. As part of the calibration effort, the model properties were adjusted to improve the match between simulated and recorded flows in Wildcat and San Lorenzo Creeks, but the model properties were not adjusted for the vicinity of Old Alameda Creek, because it is in the Niles Cone Subbasin. The locations of the gages are shown in **Figure 4-1a**.

4.3 Historical Simulation

4.3.1 Historical Simulation Setup

The historical model simulation is a transient run that simulates changing conditions for the period of 1990 through 2015. The model simulation has a total of 309 month-long stress periods, corresponding to nine months of simulation from January 1990 to September 1990, and 25 Water Years between October 1990 and September 2015. Each stress period incorporates monthly inputs from 1990 through 2015 for recharge, streamflow, and groundwater pumping. The historical model simulation was calibrated to hydrographs for a selection of monitoring well locations.

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[25] Wells that were used as historical simulation targets, but not as steady state targets, were excluded because they did not have any measurements recorded between 2000 and 2015.

Because of the long recovery period in parts of the Intermediate and Deep Aquifer Zones, the steady state solution does not reflect initial conditions for the transient model. Therefore, initial conditions for the transient model were interpolated from historical groundwater levels recorded in the 1990s for portions of the Intermediate and Deep Aquifer Zones, while the steady state solution was used for the starting heads for the rest of the model domain.

4.3.2 Historical Calibration Data

Groundwater elevation measurements recorded between 1990 and 2015 from 108 wells were used as targets in the calibration of the historical groundwater flow model simulation. The 108 wells were selected from the 7,495 wells with data available in the groundwater level database described in Section 2.2.1 based on the following criteria:

- Large number of measurements between 1990 and 2015;
- Spatial distribution across the model domain;
- Similar number of observations in each aquifer zone; and
- Locations with wells screened across multiple aquifers, to provide data on vertical gradients.

The locations of the target observation wells are shown in **Figure 4-1a** and the wells are listed in **Table A-2 of Appendix A**. Because fewer groundwater level records are available for the Intermediate and Deep Aquifer Zones, the distribution of targets in these aquifer zones is not as uniform as in the Shallow Aquifer Zone.

Components of the flow budget for the EBP Subbasin presented in the HCM TM (GSP Appendix 2.A.b) and described in Section 2.2.4 were used as general guidelines in the calibration of the historical groundwater flow model simulation. The estimated ranges of average inflows/outflows reported in the HCM TM are listed in **Table 2-4**.

Monthly average flow data from six USGS gages on Wildcat Creek, San Lorenzo Creek, and Old Alameda Creek were used as general guidelines for calibration of streamflow. As part of the calibration, the model properties were adjusted to improve the match between simulated and recorded flows in Wildcat and San Lorenzo Creeks, but the model properties were not adjusted for the vicinity of Old Alameda Creek, because it is in the Niles Cone Subbasin. The locations of the gages are shown in **Figure 4-1a**.

4.4 2002 Aquifer Test Simulation (LSCE Test)

4.4.1 2002 Aquifer Test Simulation Setup

The 2002 Aquifer Test Simulation (LSCE Test) compares modeled and observed groundwater response to a sequential pair of aquifer tests (also called pumping tests) conducted during the late spring and summer of 2002 at City of Hayward (Hayward) Wells C and E. This test is also called the LSCE test because it was conducted and analyzed by LSCE for the City of Hayward, ACWD and EBMUD. Groundwater levels were recorded with pressure transducers and data loggers installed in several monitoring wells in both the southern portion of the EBP Subbasin and in the northern portion of Niles Cone Subbasin (**Figure 4-1b**).

The simulation period for the LSCE Test is from May 27, 2002 to September 30, 2002, using nine stress periods that ranged between 2.3 and 60 days to reflect groundwater extraction and recovery. Well C is in the Niles Cone Subbasin, approximately 1.5 miles south of the partial hydraulic barrier in the transition zone, and Well E is in EBP Subbasin within several hundred feet of the partial hydraulic barrier. Well C was pumped for two weeks at 3,300 gallons per minute (gpm). Then recovery was recorded for approximately one month before Well E was pumped at 2,200 gpm for two weeks, followed by more than another month of recording the recovery of groundwater levels after pumping from Well E stopped.

The model simulation begins on May 27, 2002, two days before groundwater pumping began at Well C on May 29,[26] and ends September 30, 2002, approximately two months after pumping from Well E stopped on July 22, 2002. Calibration of the 2002 aquifer test simulation to recorded groundwater levels refined the values of horizontal and vertical hydraulic conductivity of the deep and intermediate aquifers and intervening aquitard in the northern portion of the Niles Cone Subbasin and the southern portion of the EBP Subbasin, and the conductance of the partial hydraulic barrier in the transition zone between the EBP and main portion of the Niles Cone Subbasins.

4.4.2 2002 Aquifer Test Calibration Data

During the 2002 aquifer pumping test of Hayward Wells C and E, water levels were recorded at rapid intervals with transducers and data loggers installed in 17 observation wells as well as in Hayward Wells C and E. The locations of the instrumented wells are shown in **Figure 4-1b**. The maximum decrease in groundwater levels caused by the pumping, which is commonly called drawdown, that was recorded in each of the observation wells was used as calibration targets for the model simulation of the 2002 Aquifer Test. The water level data recorded during the 2002 Aquifer Test were also compiled as hydrographs for comparison to the groundwater levels generated by the model simulation of the 2002 Aquifer Test for the calibration.

4.5 2010 Aquifer Test Simulation (Fugro 2010 Test)

4.5.1 2010 Aquifer Test Simulation Setup

The 2010 Aquifer Test Simulation (Fugro 2010 Test) compares the modeled and observed groundwater response to an aquifer test conducted during the late summer of 2010 at the EBMUD Bayside Well. The Bayside well was pumped at 1,400 gpm for eight weeks and groundwater levels were recorded with pressure transducers and data loggers installed in a total of 35 monitoring wells in both the southern portion of the EBP Subbasin and in the northern portion of the Niles Cone (**Figure 4-1a and 4-1b**) before, during, and for approximately eight weeks after the pumping stopped. The Bayside Well is approximately 5 miles north of the Horizontal Flow Barrier (see discussion in Section 3.3.1.5), which represents the partial

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[26] The model simulation of the 2002 aquifer test starts two days before pumping began at Hayward Well C, but as the hydrographs show (**Figure 4-10**), the recorded data started many days or weeks before the pumping started.

barrier to groundwater flow within the transition zone between the EBP and the main portion of the Niles Cone Subbasins. This test is also called the Fugro 2010 Test because it was conducted by Fugro for EBMUD.

The Fugro 2010 Test simulation period begins on July 27, 2010, about a week before groundwater pumping at the Bayside Well began on August 4, 2010, and ends November 28, 2010, about two months after pumping from the Bayside Well terminated, and is divided into six stress periods that ranged between 3.4 to 60 days.

Calibration of the 2010 aquifer test simulation to recorded groundwater levels refined the values of horizontal and vertical hydraulic conductivity of the Deep and Intermediate Aquifers and intervening aquitard in the southern portion of the EBP Subbasin and the conductance of the partial hydraulic barrier in the transition zone between the EBP Subbasin and main portion of the Niles Cone Subbasin.

4.5.2 2010 Aquifer Test Calibration Data

Water levels recorded at frequent intervals during the aquifer testing of the EBMUD Bayside Well with transducers and data loggers installed in 26 observation wells were used for the calibration. The locations of these wells are shown in **Figure 4-1b**. The maximum drawdown recorded in each of the observation wells was used as calibration targets for the model simulation of pumping from the Bayside Well (the 2010 Aquifer Test)[27]. The water level data recorded during the 2010 Aquifer Test were also compiled as hydrographs for comparison to the groundwater levels generated by the model simulation of the 2010 Aquifer Test for the calibration.

4.6 Calibration Parameters and Approach

The following parameters were varied to improve the match between model results and observed data (model calibration):

- Horizontal conductivity (Kh) and vertical hydraulic conductivity (Kv) of active model cells;
- Specific yield (Sy) of active model cells in Layer 1;
- Specific storage (Ss) of active model cells in Layers 2 – 12;
- Groundwater recharge applied to Layer 1;
- Bedrock inflow rate at the eastern boundary of the model domain;
- Leakance of the Bay and salt pond floors, represented in the model with general head boundaries (GHB) in portions of Layer 1;
- Leakance of the streambeds; and
- Conductance of the HFB, which is used in Layers 4 through 12 to represent a partial hydraulic barrier within the transition zone between the EBP Subbasin and the main part of the Niles Cone Subbasin.

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[27] Observation wells located in the same grid cell as the Bayside Well were not used for calibration.

Table A-3 in Appendix A provides the range of values used for the parameters listed above during the model calibration process.

The following approaches were used to calibrate the 2021 EBPGWM using the specific model simulations:

- Steady State Simulation Representing Average Recent Conditions (2000 – 2015):
    - Constrained horizontal and vertical hydraulic conductivities of aquifers and aquitards so that error between measured and observed water levels was minimized;
    - Refined recharge and inflow at the eastern model margin so that error between measured and observed water levels was minimized and groundwater sources were within the range of estimated water budget values documented by HCM TM;
    - Refined the leakance values associated with the GHB boundaries with consideration of estimated amounts of groundwater discharge to San Francisco Bay documented by the HCM TM and summarized in **Table 2-4**; and
    - Refined streambed leakance values to improve match between model results and estimated average flows based on data from USGS gage stations, and compared simulated stream recharge/discharge with estimated amounts documented by the HCM TM and summarized in **Table 2-4**.
- Historical Transient Simulation (1990 – 2015):
    - Constrained horizontal and vertical hydraulic conductivities of aquifers and aquitards so that the error between measured and observed water levels was minimized;
    - Constrained specific yield and specific storage so that modeled responses to transient recharge and pumping matched observed water level fluctuations;
    - Refined recharge and inflow at the eastern margin so that the error between measured and observed water levels was minimized and groundwater sources were within the range of the HCM TM water budget inputs; and
    - Refined GHB leakance parameter based on estimated discharge to San Francisco Bay (**Table 2-4**);
- 2002 and 2010 Aquifer Test Simulations:
    - Constrained the horizontal and vertical transmissivity in the Deep Aquifer Zone, Intermediate Aquifer Zone, and intervening aquitard based on calibration of the simulated response to pumping to the observed response;
    - Constrained the specific storage in the deep zone based on calibration of the modeled response to pumping to the recorded response in several observation wells; and
    - Constrained the conductance of the HFB based on calibration of the modeled response to pumping to the recorded response in several observation wells located north and south of the HFB.

The 2021 EBPGWM was developed to support the EBP Subbasin GSP, therefore the calibration process outlined above focused on adjusting boundary conditions, stresses, and material properties within the East Bay Plain Subbasin, while the model properties in the Niles Cone Subbasin were based on previous estimates, specifically the 2019 update to the 2005 NEBIGSM model with some exceptions in the transition zone.

The calibration results for the 2021 EBPGWM are presented and discussed below.

4.7 Calibration Assessment

Several metrics, both quantitative and qualitative, were used to assess the calibration and inform the selection of final values assigned to the model parameters in the 2021 EBPGWM.

Calibration metrics used to quantitatively assess the goodness of fit of the model simulation results to the groundwater elevation targets include the mean error (ME), the mean of the absolute error (MAE), the root mean squared error (RMSE), the root mean squared error normalized by the range of the observed data (RMSE as % of Observed Range), and the coefficient of determination (R^2).

The mean error reported herein for the 2021 EBPGWM is the mean of the difference between the simulated and observed water level at each calibration target.

$$ME = \frac{1}{m}\sum_{n=1}^{m}(obs_{\mathrm{n}} - sim_{\mathrm{n}})$$

where:
ME = mean error
obs_n = nth observed value
sim_n = nth simulated value

The ME value can be positive or negative, depending on whether the simulation over- or underestimates the water level at the target. Some assessments of model calibration calculate the errors using simulated minus observed $(sim_{\mathrm{n}} - obs_{\mathrm{n}})$ rather than observed minus simulated $(obs_{\mathrm{n}} - sim_{\mathrm{n}})$ as is used herein.

The mean of the absolute error is the mean of the absolute value of the difference between the simulated and observed water level at each calibration target, and the value is therefore always positive.

$$MAE = \frac{1}{m}\sum_{n=1}^{m} abs(obs_{\mathrm{n}} - sim_{\mathrm{n}})$$

where:
MAE = mean absolute error
obs_n = nth observed value
sim_n = nth simulated value

The root mean square error is the square root of the mean of the squared errors. Because the square of the error is a positive value, the RMSE is also always positive.

$$RMSE = sqrt(\frac{1}{m}\sum_{n=1}^{m}(obs_{\mathrm{n}} - sim_{\mathrm{n}})^2)$$

where:
RMSE = root mean squared error
obs_n = nth observed value
sim_n = nth simulated value

The RMSE normalized by the range of observed data can be a useful metric because it puts the RMSE in context with the range of water levels that the model simulates. It is commonly presented as a percent and is referred to as RMSE as % Range (or normalized RMSE) in portions of this document. However, the RMSE as % Range of the observed data is sensitive to the data set and can be a misleading indicator of the quality of the model calibration. For example, if the calibration data set has a small range of measured values, such as groundwater levels with little variation in elevation, the RMSE can be a large percentage of the range of target values even if the errors are small. Accordingly, the calibration data set, the groundwater conditions, and the purpose of the model need to be considered to determine if the RMSE as % Range is useful in assessing the quality of the model calibration. The RMSE as % Range is therefore only reported herein for some of the calibration subsets.

The coefficient of determination, commonly called the R^2, value is a statistical measure of how close data points are to a fitted regression line, or how well a line fits the data. A set of X, Y (observed, simulated) points could closely fit a line and thus the line fitted to the points would have a high R^2 value, but the set of points could be a poor match to the line defined by X=Y, which is the target for a model calibration. The R^2 value relevant to a model calibration must be for an X=Y line.

$$R^2 = 1 - \sum_{n=1}^{m}\frac{\sum_{n=1}^{m}(obs_{\mathrm{n}} - sim_{\mathrm{n}})^2}{\sum_{n=1}^{m}(obs_{\mathrm{n}} - mean\ obs)^2}$$

where:
obs_n = nth observed value
sim_n = nth simulated value
mean obs = mean of the observed values.

A perfect match between a line or target function and a set of data points, or in the case of a model calibration, perfect match between observed and simulated values, is an R^2 value of 1. For assessment of model calibrations, commonly an R^2 value greater than 0.9 is considered an excellent match between the points and the ideal perfect match (e.g., Modeling Best Management Practice Guidelines for Sustainable Management of Groundwater [DWR, 2016]).

The calibration metrics used, which differ for the specific simulations used in developing and calibrating the 2021 EBPGWM, are described below.

4.7.1 Steady State (Average Recent Conditions 2000 – 2015)

Table 4-1 lists the groundwater elevation calibration statistics for the steady state simulation, which include ME, MAE, RMSE, and RMSE normalized by the range of observed values, and R^2. A goal of the calibration of the steady state simulation, which represents recent average conditions, was to minimize the normalized RMSE, ideally below 10% of the range of the observed data, and maximize that R^2, ideally above 0.9. As **Table 4-1** shows, for the entire data set the normalized RMSE is 6% of the range of the observed calibration targets and the R^2 value defined by the results compared to that of perfect agreement between the observed and simulated values is 0.92[28].

Table 4-1 also lists the calibration statistics for two subsets of the observed data vs simulated results. The first subset is based on depth interval and includes calibration statistics for the Shallow, Intermediate, and Deep Aquifer Zones. The second subset is based on geographic area and includes the northern portion of the EBP Subbasin, the southern portion the EBP Subbasin, the entire EBP Subbasin, and the Niles Cone Subbasin areas.

The values of RMSE as a percent of the range of target groundwater elevations are largest for the Intermediate Aquifer Zone and the Niles Cone Subbasin. The apparent indication of lower model accuracy in the Intermediate Aquifer Zone is likely due to recovery from prior pumping continuing at some observation wells in the 1990s and into the current century. Further evaluation to exclude wells with water level records that show continued recovery after 2000 would improve the calibration statistics, but as is, the steady state model based on average conditions between 2000 and 2015 provides useful baseline results that are representative of recent groundwater average conditions in the EBP Subbasin.

The only subset with an RMSE that exceeds 10% of the range of the observed data is the Niles Cone Subbasin subset, which is 15% of the range of the observed groundwater elevations. The lower accuracy in the Niles Cone Subbasin is a consequence of less calibration effort in this portion of the 2021 EBPGWM because the intent was to preserve preexisting values of model properties in the Niles Cone Subbasin with some exceptions in the transition zone. In addition, as discussed above, the RMSE as % range of observed groundwater levels is not a good indicator of the quality of calibration when the range of observed (target) groundwater levels is small.

The following data were removed prior to calculation of the calibration statistics for the steady state simulation that are presented in **Table 4-1**:

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[28] As discussed in the previous section, the R^2 value for a perfect match between the trend of the simulated and observed results would be 1.0.

- All targets with observed groundwater elevations higher 150 ft above mean sea level (T0600100274-MW-1, T0600194038-MW-1, T0600102279-MW-5, T0600100324-MW-1, T0600101262-S-10, and T0600101262-S-6);
- The outlier T0600102093-MW-1; and
- Observation wells with groundwater level data that exhibit evidence of ongoing recovery beyond 2000 from prior pumping (02S03W-19Q01, 01S04W-04R01, 02S03W-22P03, and 02S03W-28G01).

The removal of these outliers does not decrease the overall normalized RMSE metric, because although these targets are outliers with large errors, they also increase the range of observed data. Groundwater elevations classified as outliers are in the hills near the eastern margin of the model, and were excluded in the calculation of calibration metrics for two reasons:

1. The outliers are in areas where the model is relatively thin so as a consequence of the lower transmissivity, the flux between these areas and the rest of the model is relatively minor, and
2. The outliers are in the areas with steep hydraulic (and ground surface) gradients near the East Bay Hills. The 2021 EBPGWM is a regional model that calculates a single value for groundwater elevation in each of the 1,000 x 1,000-ft grid cells. Accordingly, the 2021 EBPGWM provides large-scale approximations of the actual groundwater elevations, but it was not designed for precise resolution of groundwater levels where actual levels vary significantly over distances of less than 1,000 ft.

In addition to the quantitative metrics, qualitative assessments of the calibration are an important component of the calibration process, including evaluation of graphical comparisons of the model-simulated and observed data. **Figure 4-2** presents a graph of observed versus simulated groundwater levels (also called a scatter plot) that illustrates the distribution of model errors with respect to elevation (differences between the simulated and observed groundwater levels for the steady state baseline simulation of recent average conditions). Each point on the scatter plot represents an observed and model-simulated groundwater level at each calibration target location. The scatter plot can help in detecting model bias. For example, if most of the points plot above or below the heavy black line, where X=Y (observed = simulated), the model would be systematically calculating results that are too high or too low relative to observed conditions, respectively.

The scatter plot of model-simulated versus observed groundwater levels (**Figure 4-2**) for the steady state model simulation of recent (2000 – 2015) average conditions shows a generally good balance of model results that are both above and below the target values (average recorded target groundwater levels), and thus there is no evidence of significant bias in the model simulations relative to calibration targets. **Figure 4-3** is a graph that shows the observed groundwater elevations versus the residuals (differences between the target and simulated values) for the steady state model simulation. **Figure 4-4** is a map that shows the groundwater elevation residuals for the steady state model simulation. **Figures 4-2, 4-3, and 4-4** show some general bias of the model simulated groundwater elevations in the Intermediate and Deep Aquifer Zones being higher than the steady state targets. However, as discussed above, this bias is influenced by recovery from higher historical pumping in the EBP Subbasin continuing beyond the year 2000, so although the observation targets with the most obvious ongoing recovery are not included in the calculation of the calibration metrics, the average groundwater elevations for some observation wells (particularly in the intermediate zone) are lower than simulated steady state groundwater levels that represent average recent conditions.

Qualitive comparisons of model-simulated and observed 2000 – 2015 average water level maps for the Shallow, Intermediate, and Deep Aquifer Zones (**Figure 4-5**) show that the model-simulated average groundwater flow directions are generally representative of 2000 – 2015 average conditions based on measured data.

Table 4-2 provides a comparison of the values of the water budget components for the steady state baseline simulation compared with the estimated values of water budget components for the EBP Subbasin presented in the HCM TM (GSP Appendix 2.A.b). The values from steady state baseline simulation are generally consistent with the estimated values presented in the HCM TM. For calibration of the steady state simulations, lower values of inflow at the specific flux boundary are required for a reasonable steady state (equilibrium) solution for portions of the eastern margin of the model. However, the simulated values for all water budget components are within the estimated ranges presented in the HCM TM (GSP Appendix 2.A.b), including the estimates of bedrock inflow, which also includes estimated inflow from the adjacent Castro Valley Basin to the EBP Subbasin.

Assessment and calibration of simulated stream flow were also conducted for the steady state simulations. **Table 4-3** compares simulated flow rates with observed average flows at USGS gaging stations on Wildcat Creek, San Lorenzo Creek, and Old Alameda Creek. However, no refinements were made to improve the calibration of the model-simulated stream flows with the gage data for Alameda Creek, which is in the Niles Cone Subbasin. The values of model properties for the Niles Cone Subbasin were retained from the 2013 NEBMODFLOW model with some exceptions in the transition zone.

Simulated steady state flow at San Lorenzo Creek Gage Station 11181000 correlates well with observed average flows. However, simulated flows downstream at San Lorenzo Creek Gage Station 11181040 are substantially lower than recorded average flows. Because most of San Lorenzo Creek between these two gage stations is concrete-lined, the likely cause of the discrepancy is inflows to the lined channel from storm sewers that are not represented in the model. However, because San Lorenzo Creek has minimal interaction with groundwater in this area where it is mostly concrete lined, the discrepancy between gaged and simulated flows is not significant to the groundwater levels and flow budget simulations with the 2021 EBPGWM.

The similarity between observed average flows on Wildcat Creek at the upstream and downstream gages (11181390 and 11181400, respectively) indicates little net change in streamflow due to interaction between groundwater and surface water. The simulated steady state flows in Wildcat Creek also indicate limited net change in streamflow due to groundwater-surface water interaction.

4.7.2 Historical Transient Simulation (1990 – 2015)

The same statistical metrics used to evaluate the steady state calibration were used to evaluate the calibration of the historical transient simulation: ME, MAE, RMSE, and RMSE normalized by the range of observed values, and R^2. The calibration statistics listed in **Table 4-4** which reflect removal of the same outliers as for the steady state simulation, discussed above, with the exception of data sets for observation wells that exhibit evidence of ongoing recovery of groundwater elevations beyond 2000 from prior pumping (02S03W-19Q01, 01S04W-04R01, 02S03W-22P03, and 02S03W-28G01), which are included as calibration targets for the historical transient simulation.

As for the steady state simulation of recent average conditions, a goal of the calibration of the historical transient simulation was to minimize RMSE, ideally below 10% of the range of the observed data, and maximize R^2, ideally above 0.9. As **Table 4-4** shows, for the entire data set, RMSE is 6% of the range of the observed calibration targets and the R^2 value for the results compared to a perfect match between the observed and simulated values is 0.81. However, the RMSE is a better metric to assess the overall model calibration.

Table 4-4 also lists the RMSE as a percentage of the range for the same two subsets of the calibration targets as for the steady state average conditions simulation: (1) aquifer zone intervals of the screened intervals (Shallow, Intermediate, and Deep Aquifer Zones), and (2) geographic location (northern portion of the EBP Subbasin, southern portion of the EBP Subbasin, the entire EBP Subbasin and the Niles Cone Subbasin areas). The only subset that has an RMSE that exceeds 10% of the range of the observed data is the Niles Cone Subbasin subset. As discussed above, the lower accuracy in the Niles Cone Subbasin is a consequence of less calibration effort in the Niles Cone Subbasin portion of the 2021 EBPGWM.

Figure 4-6 presents a graph of observed versus simulated groundwater levels. Each point on the scatter plot represents an observed and model-simulated groundwater level at each calibration target location, for each time step, for which there is an observed value. The scatter plot (**Figure 4-6**) illustrates the calibration of groundwater elevations for the transient historical model simulation and shows a generally good balance of model results being higher and lower than the target values (recorded historical data), and thus there is no evidence of significant model bias in the model-simulated values relative to calibration targets.

Comparison of observed and model-simulated groundwater levels with time plotted as hydrographs is also an important graphical qualitative assessment of the model calibration. Comparison of observed and simulated water levels shown by the hydrographs presented in **Figures 4-7a** through **4-7j** show generally good agreement between historical (1990 – 2015) records of measured groundwater elevations and groundwater elevations simulated for the same time period with 2021 EBPGWM, including:

- Long term trends in observed groundwater elevation such as the recovery of groundwater elevations in the Intermediate and Deep Aquifer Zones shown in Figure 4-7d;
- Vertical hydraulic gradients between groundwater elevations at different depths such as the vertical gradients shown in Figure 4-7j; and

- Seasonal variations in groundwater elevations such as shown in Figure 4-7h.

Comparison of model-simulated and measured data for groundwater elevations is also illustrated by contour maps (**Figure 4-8** and **4-9)** that show observed (left pane) and modeled (right pane) groundwater contours during 1995 and 2011. The contour maps show that the model-simulated groundwater flow directions are generally representative of observed conditions.

Figure 4-10 shows the simulated water budget variation with time, and **Table 4-5** provides a comparison of the simulated water budget variation with time to the average estimated values of water budget components for the EBP Subbasin. The main water budget components do not vary significantly from year to year during the simulation period. Recharge varies with varying precipitation, with higher recharge on wetter years (e.g., 1998, 2005, 2006) and lower recharge in dry years (e.g., 1994, 2012-2015). Groundwater discharge to the San Francisco Bay has increased between 1991 and 2000 and stabilized afterwards, consistent with the observed groundwater elevation recovery in Intermediate and Deep Aquifer Zones through the early 2000s. The average water budget values, which are also discussed in Section 4.3.1 above, are generally consistent with the estimated values presented in the HCM TM.

4.7.3 2002 Aquifer Test Simulation

Figures 4-11a and **4-11b** each present hydrographs that compare the recorded and simulated changes in groundwater elevations during the two-week aquifer tests conducted in 2002 at Hayward Wells C and E (Section 3.3.1.3, above). These figures also include maps that show the locations of the wells with the displayed hydrographs. The hydrographs show generally good matches between the recorded and simulated responses to the pumping and subsequent recovery for both the Well C and Well E tests.

A gradual regional decline in groundwater levels and variations due to pumping from other production wells in the main portion of the Niles Cone Subbasin makes detection of small changes due to pumping from Wells C and E difficult, particularly in the main portion of the Niles Cone Subbasin where most of the other pumping occurred. Estimates of drawdown due to pumping from Wells C and E include corrections for the gradual regional decline in groundwater levels. One foot was used as a threshold for detected drawdown due to pumping from Wells C or E.

Figures 4-12 presents a scatter plot that compares the observed versus simulated drawdown attained in response to the two-weeks of pumping for both the Hayward Well C and Well E aquifer pumping tests. A table that provides the calibrations statistics for the observed versus simulated drawdown is included In **Figure 4-12**. The RMSE as a percent of the range of observed drawdown is 9%, and the R^2 value is 0.89, for the calibration of 2021 EBPGWM to the recorded drawdown of groundwater levels in response to the Well C and Well E aquifer pumping tests combined.

The 2002 Aquifer Tests provided important data for calibrating the 2021 EBPGWM because Hayward Wells C and E are on opposite sides of the HFB, which represents the partial barrier within the transition zone. Calibration of the model response to the changes in groundwater levels in 14 and 15 observation wells for the Well C and E tests, respectively, constrained the aquifer properties in the southern portion of the EBP

Subbasin and northern area of the main portion of the Niles Cone Subbasin and the conductance of the HFB, which controls the impedance of the hydraulic continuity within the transition zone.

4.7.4 2010 Aquifer Test Simulation

Figures 4-13a and **4-13b** each present hydrographs that compare the recorded and simulated changes in groundwater elevations before, during, and after the eight-week aquifer test conducted in 2010 at the EBMUD Bayside Well (Section 3.3.1.4 above), which is in the southern portion of the EBP Subbasin approximately 5 miles north of the HFB (partial hydraulic barrier) within the transition zone. These figures also include maps that show the locations of the wells with the displayed hydrographs. The hydrographs show generally good matches between the recorded and simulated responses to the pumping and subsequent recovery associated with the Bayside Well aquifer pumping test.

A marked decrease in the response to pumping from the Bayside Well occurs within the transition zone between the southern portion of the EBP Subbasin and northern area of the main portion of the Niles Cone Subbasin. Resolution of small responses to pumping from the Bayside Well is difficult, particularly in observation wells in the Niles Cone Subbasin where groundwater levels were influenced by changes in pumping from other wells in the main portion of the Niles Cone Subbasin. For comparison of the model results to observed drawdown, one foot was used as a threshold for detected drawdown due to pumping from the Bayside Well.

Figure 4-14 presents a scatter plot that compares the observed to simulated drawdown in response to eight weeks of pumping from the Bayside Well in 26 observation wells. A table is included in **Figure 4-14** the provides the calibration statistics for calibration to the 2010 aquifer test. The RMSE as a percent of the range of observed drawdown is 7%, and the R^2 value is 0.96 for the calibration of 2021 EBPGWM to the recorded drawdown of groundwater levels in response to the Bayside Well aquifer pumping test. These calibration metrics indicate the model simulation of the aquifer test is in excellent agreement with the data recorded during the test.

Figure 4-14 is a map with contours of the model-simulated drawdown after eight weeks of pumping from the Bayside Well in the Deep Aquifer Zone and posted values of drawdown recorded in all the observation wells (in all three depth zones). As for the scatter plot, this map shows good agreement between the model simulation and the observed data. However, south of the HFB, the model-simulated drawdown is slightly (~ 1.5 ft) more than was observed in the western area of the main portion of the Niles Cone Subbasin (south of the HFB). This indicates that the actual impedance of the hydraulic connection between the northern portion of the main Niles Cone Subbasin and southern EBP Subbasin within the transition zone may be slightly more than currently represented with the HFB in the 2021 EBPGWM (i.e., the conductance assigned to the HFB high in the 2021 EBPGWM is conservatively high). However, the calibrated HFB impedance provided the best overall fit when considering calibration to pumping of Hayward Wells C and E, and pumping of EBMUD Bayside well.

Like the 2002 Aquifer Test conducted by LSCE (2003) for the City of Hayward, the 2010 Aquifer Test conducted by Fugro (2011) for EBMUD provided important data for calibrating the 2021 EBPGWM. Both the 2002 and 2010 aquifer tests constrained the conductance of HFB in the model, which controls the impedance of the hydraulic continuity in the transition zone between the southern portion of the EBP Subbasin and northern area of the main portion of the Niles Cone Subbasin. In addition, the 2010 Bayside Aquifer Test, which included continuous pumping for eight weeks from the Deep Aquifer approximately 5 miles north of the transition zone, provided valuable data for calibration of the aquifer properties in the southern portion of the EBP Subbasin. The excellent calibration of the 2021 EBPGWM to the long-term 2010 Aquifer Test demonstrates that the model is a reliable tool to estimate sustainable yield and to simulate potential projects and management actions for the EBP Subbasin.

4.8 Parameter Sensitivity

Model sensitivity analyses evaluate the effects of changing assigned values of model parameters or model design components on the outputs or performance of the model (e.g., simulated groundwater elevations and calibration metrics). Sensitivity of model parameters was evaluated using relative composite sensitivity calculated with PEST for the steady-state model simulation. In addition, qualitative observations were made during model calibration about the influence that adjusting certain model parameters has on the model's ability to simulate observed groundwater elevations and drawdowns, particularly for aquifer test simulations and historical pumping. The model calibration sensitivity to change in model parameter input values is discussed below.

The parameters included for the composite sensitivity analysis conducted with PEST are provided in **Table A-3** of **Appendix A**. The sensitivity was evaluated first by grouping parameters: e.g., sensitivity to varying the horizontal hydraulic conductivity values of all zones within the Shallow Aquifer. PEST was also used to identify sensitive parameters within each grouping: e.g., sensitivity to varying the horizontal hydraulic conductivity values assigned to each geographic calibration zone was evaluated individually. The model-calculated sensitivity to input parameters is illustrated in **Figure 4-16**.

The most sensitive parameters, in order of decreasing sensitivity, are:

- Horizontal hydraulic conductivity of the Shallow Aquifer;
- Horizontal (and vertical) hydraulic conductivity of the aquitards between the Shallow and Intermediate Aquifers and between the Intermediate and Deep Aquifers;[29]
- Recharge; and
- Horizontal hydraulic conductivity of the Intermediate Aquifer.

The steady-state model calibration simulation is also sensitive to the horizontal to vertical hydraulic conductivity ratio of the aquitards between the Shallow and Intermediate Aquifers and between the Intermediate and Deep Aquifers. In contrast, model-simulated steady-state groundwater elevations are relatively insensitive to change in hydraulic conductivity of the Deep Aquifer, horizontal to vertical

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[29] The vertical hydraulic conductivity values are defined in terms of the ratio of vertical to horizontal hydraulic conductivity, so changes to horizontal hydraulic conductivity values affect vertical hydraulic conductivity values.

hydraulic conductivity ratio of the Shallow, Intermediate, and Deep Aquifers and leakance of the Bay floor. Within the most sensitive parameter groups, the parameter sensitivity varies as follows:

- Horizontal hydraulic conductivity in the Shallow Aquifer: parameters are most sensitive in San Pablo Cone, Hayward, San Lorenzo Cone, and Berkeley areas (**Figure B-1** in **Appendix B**);
- Hydraulic (and vertical) conductivity in the Shallow/Intermediate Aquitard: parameters are most sensitive in mountain front, Hayward and Oakland/San Leandro areas (**Figure B-2** in **Appendix B**);
- Hydraulic (and vertical) conductivity in the Intermediate/Deep Aquitard: parameters are most sensitive in Hayward and Oakland/San Leandro areas (**Figure B-4** in **Appendix B**);
- Horizontal hydraulic conductivity in the Intermediate Aquifer: parameters are most sensitive in Berkeley, Oakland/San Leandro, and Merritt Sand areas (**Figure B-3** in **Appendix B**); and
- Recharge parameters are most sensitive in Berkeley, Oakland, San Leandro Cone and San Lorenzo Cone areas (**Figure 3-5**).

The parameter sensitivity to the steady-state model simulation indicates that these parameter calibrated values are well constrained by calibration to steady-state calibration datasets, and changes to parameter values would result in a change in simulated groundwater elevations and calibration metrics.

The following observations about model sensitivity were made during model calibration to multiple datasets:

- Simulated drawdowns were highly sensitive to change in the horizontal hydraulic conductivity and specific storage of the Deep and Intermediate Aquifers and intervening aquitard in the southern portion of the EBP Subbasin and in the conductance of the partial hydraulic barrier in the transition zone between the EBP Subbasin and main portion of the Niles Cone Subbasin. Those parameters are therefore well constrained by the calibration;
- Simulated groundwater elevation recovery in the Intermediate Aquifer in 1990 – 2000 (**Figure 4-7b** through **4-7d**) is sensitive to change in the specific storage of the Intermediate Aquifer; and
- Simulated historical groundwater elevations in the Shallow Aquifer are sensitive to change in specific yield and monthly fluctuations in recharge rates, however the time discretization of the observed water levels is not sufficient to refine the model parameters. Additional water level data in the Shallow Aquifer at short time intervals could be used to refine those parameters.

5 HISTORICAL (1950-1960S) PUMPING EVALUATION

The calibrated steady-state model was used to evaluate the impacts of greater amounts of groundwater pumping that occurred in the EBP Subbasin in the 1950s to early 1960s. Historical pumping rates in the EBP Subbasin are estimated to have been as high as 35,000 to 50,000 AFY, with pumping occurring for municipal (Hayward), industrial, irrigation, and domestic uses. The majority of this pumping is assumed to have occurred in the southern portion of the Subbasin (GSP Appendix 2.A.b).

The calibrated steady-state model described in Section 4.2 was revised to simulate estimated historical (1950s – 1960s) conditions in the EBP Subbasin and to simulate the historical observed drawdown observed in the 1950s and 1960s in the Intermediate and Deep Aquifers in the EBP Subbasin. Revisions to the model to represent historical pumping included:

- Assigning wells to represent estimated locations of historical (1950s – 1960s) pumping:
  - Historical production well locations are based on active wells defined in the 2019 update to the 2005 NEBIGSM model in Water Year 1965 (those locations included both some of the wells used in the historical 1990-2015 simulation and additional wells);
  - Hayward wells 4, 8, and 9, which were known to provide groundwater to City of Hayward in 1950s – 1960s; and
  - Six production wells in the Intermediate Aquifer in the southern portion of the East Bay Plain Subbasin (east and south of Bayfarm) based on observed drawdown in this vicinity in the Intermediate Aquifer in 1950s-1960s (GSP Appendix 2.A.b).
- Assigning pumping rates to represent estimated locations of historical (1950s – 1960s) pumping:
  - At wells based on Water Year 1965 in the 2019 update to the 2005 NEBIGSM model:
    - equal to rates for Water Year 1965 in the 2019 update to the 2005 NEBIGSM model for the Niles Cone Subbasin; and
    - a factor of two greater than the rates for Water Year 1965 in the 2019 update to the 2005 NEBIGSM model for the East Bay Subbasin. This factor of two was used to better reproduce the observed drawdown;
  - At Hayward wells 4, 8 and 9:
    - Total production rate of approximately 2,000 AFY based on City of Hayward historical consumption
  - At the six production wells located east and south of Bayfarm:
    - total production rate of approximately 7,500 AFY, to better reproduce the observed drawdown in the Intermediate Aquifer in 1950s-1960s (GSP Appendix 2.A.b).

With these changes, the total groundwater extraction rate from East Bay Plain Subbasin is approximately 23,000 AFY. Simulation with the steady-state model with this additional pumping included approximates the historical groundwater elevations observed in the 1950s and 1960s in the Intermediate and Deep Aquifers in the EBP Subbasin (Figures 5-23 through 5-26, 5-36 and 5-37 of GSP Appendix 2.A.b.

The steady-state simulated groundwater elevation contours for historical pumping of approximately 23,000 AFY in EBP Subbasin are shown in **Figure 5-1**. The simulated groundwater elevations in portions of the Intermediate and Deep Aquifers, where historical pumping occurred, are as low as approximately -100 feet mean sea level, which is consistent with observed groundwater elevations during this time period (GSP Appendix 2.A.b). The simulated groundwater elevations in the Shallow Aquifer are likely lower than actual condition because the steady-state simulation results in greater influence of pumping particularly for the shallower aquifers than is expected under transient conditions.

Table 5-1 compares the water budget of the steady-state average recent conditions simulation and the historical (1950s – 1960s) pumping simulation. **Table 5-2** compares simulated streamflow at San Pablo, Wildcat, San Leandro, and San Lorenzo Creeks for the steady-state average recent conditions simulation and the historical (1950s – 1960s) pumping simulation. Due to both the limited data available for streamflow in the four major creeks of the EBP Subbasin, and the highly variable seasonal flows in the creeks, the simulated streamflow values are uncertain. However, those values provide useful metrics for comparison with sustainable yield and alternative scenario simulations (Section 6).

6 FUTURE GROUNDWATER RESOURCE DEVELOPMENT SCENARIO EVALUATION

SGMA sustainability criteria include a sustainability goal, and quantitatively defined undesirable results, minimum thresholds, and measurable objectives. Consistent with DWR BMP guidance document for models developed for SGMA projects (DWR, 2016), the 2021 EBPGWM is used to help inform development and quantification of sustainable management criteria, estimate the sustainable yield of the EBP Subbasin, and evaluate feasibility and potential effects of potential projects and management actions.

The 2021 EBPGWM was used to evaluate potential future conditions in the EBP Subbasin. A baseline simulation of future conditions was developed with the 2021 EBPGWM that assumes no additional groundwater resource development. The baseline simulation was used to compare to simulations of potential future development of groundwater resources in the EBP Subbasin. In addition to a simulation to estimate the sustainable yield of the EBP Subbasin, a simulation was run of a future scenario that includes potential groundwater resources development by both the City of Hayward and EBMUD. The details of the evaluation of these future scenarios are described in this section. The computer code, model domain, grid, layering, and aquifer properties of the 2021 EBPGWM were not altered for these simulations, but some model inputs related to climatic conditions and future groundwater pumping and injection were updated to represent hypothetical future conditions.

6.1 Baseline Groundwater Flow Simulation

Baseline groundwater flow simulations encompassing Water Years 2016 through 2071 were conducted to compare to the simulations to evaluate sustainable yield and a potential groundwater resources development scenario. Both a transient simulation with inputs that vary monthly, and a steady state simulation that represents average future baseline conditions were established. The subsections below describe the transient and steady state simulation inputs for the baseline future conditions.

6.1.1 Simulation Periods

6.1.1.1 Transient

The baseline future transient simulation represents changing conditions for the period of October 1, 2015 through September 30, 2071. The model simulation has a total of 672 one-month stress periods, corresponding to 56 Water Years between October 2015 and September 2071. Each stress period incorporates monthly inputs for recharge, streamflow, and groundwater pumping. Actual records were used for Water Years 2016 through 2021, and the 1991 to 2015 sequence used in the historical transient simulation was assigned twice sequentially to simulate future conditions for projected Water Years 2022 through 2071. **Table 6-1** lists the simulated future years, along with the historical years on which inputs are based. The head solution from the September 2015 stress period of the historical transient simulation was used as the starting head conditions for the baseline future transient simulation.

6.1.1.2 Steady State

A steady state simulation that approximates average future baseline conditions was designed using average values of the transient inputs for the period from Water Year 2022 to Water Year 2071 for recharge, streamflow, and groundwater pumping.

6.1.2 Climate Change

Climate change (including sea level rise) was incorporated in future baseline and the groundwater resources development scenario simulations per the climate change analysis that is included as Appendix 6.D to the GSP.

6.1.3 Changes to Boundary Conditions, Recharge, Applied Stresses

Using the historical transient simulation with the updated stress periods described above as a baseline, the changes in recharge and applied stresses were assigned to simulate anticipated baseline future conditions in the EBP Subbasin.

Creek inflow at the upstream extent of creeks and aerial recharge assigned to the model are based on available data that were applied to stress periods between October 1, 2015 and September 30, 2021. For the months in 2021 that do not have observed data, estimated values were applied. Inputs were calculated using the same methods and data sources as for recharge and creek inflow in the historical transient simulation (Section 3.3.2.1). For stress periods between October 1, 2021 and September 30, 2071, the 25-year sequence of inputs from October 1, 1990 through September 30, 2015 from the historical transient simulation were assigned twice. This data record is considered representative of average basin conditions and encompasses both multiple-year drought conditions and multiple-year wet year conditions (**Table 6-1**).

The baseline future simulation and the groundwater resources development scenario both include two feet of sea level rise over 50 years, which is represented in the model by an incremental increase in the water level of the San Francisco Bay for each of the monthly time steps. The steady state simulation of average future baseline conditions incorporates two feet of sea level rise. The shoreline location was not altered, which is considered a reasonable assumption because most of the EBP Subbasin is developed and seawalls and other infrastructure will likely be developed to mitigate inundation.

The set of active wells from the historical transient simulation was used as a starting point for the groundwater pumping and injection wells[30] for the simulations of future conditions. For wells located in the EBP Subbasin, pumping rates from Water Year 2002 are assigned for each year in the 2021 – 2071 baseline simulation. The pumping rates from Water Year 2002 are considered representative of pumping since 2000s in EBP Subbasin based on previous estimates that pumping rates have not varied significantly since 2000s (EBMUD, 2013; Section 3.3.2.3). For wells located in the Niles Cone Subbasin, pumping rates from Water Year 2015 are scaled so that the annual total is equal to the 2011 – 2020 average pumping and assigned for each year for the 2021 – 2071 baseline simulation.

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[30] Injection wells are retained in the 2021 EBPGWM from the 2019 update to the 2005 NEBIGSM model to represent artificial recharge in the Niles Cone Subbasin such as the quarry lakes (Section 3.3.2.4).

6.2 Evaluation of Sustainable Yield

6.2.1 Sustainable Yield Evaluation Criteria

The sustainable yield of groundwater from the EBP Subbasin was evaluated using several criteria, as described in this section. Sustainable yield is defined by California Water Code Section 10721 as "the maximum quantity of water, calculated over a base period representative of long-term conditions in the basin and including any temporary surplus, that can be withdrawn annually from a groundwater supply without causing an undesirable result." The EBP Subbasin was divided into three areas for this evaluation (**Figure 6-1**): North EBP (NEBP), Middle EBP (MEBP), and South EBP (SEBP). The MEBP and SEBP areas together are equivalent to the South EBP Subbasin defined in the hydrogeologic conceptual model discussion in Section 2 of the GSP. This added subdivision of the South EBP Subbasin for the groundwater model provides a more refined evaluation of sustainable yield. Sustainable yield was quantified for the EBP Subbasin with the 2021 EBPGWM simulations and the following SGMA sustainability indicators:

- Water budget criteria:
    - Maintain net outflow from the EBP Subbasin to the Niles Cone Subbasin.
    - Maintain net outflow from the EBP Subbasin to San Francisco Bay and to the aquifers underneath the Bay. Net outflow was evaluated separately in the NEBP, the MEBP, and the SEBP.
- Water level criteria to evaluate potential for saltwater intrusion:
    - Maintain simulated water table in the EBP Subbasin along the Bay margins above the elevation of the San Francisco Bay.
- Surface water criteria to evaluate potential for depletion of surface water resulting from increased groundwater pumping:
    - Evaluate the net decrease in simulated groundwater discharge to streams and in simulated streamflow in the four major creeks (San Pablo, Wildcat, San Lorenzo and San Leandro). Because of the limited data available in the EBP Subbasin for stream flow, the assessment was only qualitative.

6.2.2 Sustainable Yield Simulation Setup

Sustainable yield in the EBP Subbasin was evaluated using the steady state average future conditions simulation described in Section 6.1.1.2. Hypothetical pumping wells regularly spaced on approximately 5,000-foot centers were added for this simulation, as shown in **Figure 6-1**. These hypothetical wells were screened in the Shallow Aquifer Zone in the NEBP, and in the Intermediate and Deep Aquifer Zones in the MEBP and SEBP. Multiple simulations were run to evaluate a range of pumping rates from the hypothetical wells and define the sustainable yield that meet the criteria outlined above.

6.2.3 Sustainable Yield Simulation Results

The maximum sustainable yield obtainable using the criteria described in section 6.2.1 is approximately 12,500 AFY. **Figure 6-2** shows the simulated decrease (drawdown) in groundwater elevations for the sustainable yield simulation compared to the baseline steady state simulation. **Figure 6-2** demonstrates that the sustainable yield simulation meets the water level criteria for sustainable yield outlined in Section 6.2.1 because there is minimal change in groundwater elevation in the Shallow Aquifer along the Bay margins.

Table 6-2 compares the water budget of the average future baseline simulation with the sustainable yield simulation. As summarized in **Table 6-2,** the sustainable yield simulation meets the water budget criteria for sustainable yield outlined in Section 6.2.1 because outflow from the NEBP, MEBP, and total EBP Subbasin towards the Bay (including the aquifers beneath the Bay) is maintained, and there is net combined outflow from the SEBP to the Niles Cone Subbasin and towards the Bay (including the aquifers beneath the Bay).

Figure 6-3 shows the simulated groundwater elevation in Layer 1 of the Shallow Aquifer for the baseline simulation (left panel) and the sustainable yield simulation (right panel). Areas where the groundwater elevation drops below sea level (i.e. below 3 feet mean sea level, accounting for sea level rise) are shown shaded. This figure demonstrates that the sustainable yield simulation meets the water level criteria to minimize potential for saltwater intrusion.

Table 6-3 compares streamflow metrics in the future baseline scenario and the maximum sustainable yield scenario. The metrics listed include the simulated streamflow and the simulated discharge of groundwater to streams in San Pablo, Wildcat, San Leandro, and San Lorenzo Creeks. As summarized in the table, both the change in streamflow and the change in simulated discharge of groundwater to streams between the baseline and maximum sustainable yield simulation is de minimis. Due to both the limited data available on streamflow for the four major creeks of the EBP Subbasin, and the highly variable seasonal flows in the creeks, it should be noted that the change in simulated streamflow and net groundwater discharge for the streams are more meaningful than the simulated actual values of streamflow and net groundwater discharge.

6.3 Potential Groundwater Resources Development Scenario

A simulation was conducted to evaluate the feasibility and influence on groundwater and surface water conditions of potential future groundwater resources development projects in the EBP Subbasin. The details of the scenario are presented in **Table 6-1** and **Figure 6-4a** and described in the sections below. **Figure 6-4b** shows the features of the Groundwater Resources Development Scenario.

6.3.1 Groundwater Resources Development Scenario Setup

The groundwater resources development scenario incorporates the following projects added to the baseline transient future simulation:

- The EBMUD Phase 1 well (i.e. the Bayside Well) extracts 2 million gallons per day of groundwater between April 1 and September 30 during the following six water years, which are classified as dry years. Extraction begins with the third consecutive dry year and continues during subsequent dry years within a drought cycle (**Table 6-1** and **Figure 6-4a**):
    - 2045-2048

    - 2070-2071
- The EBMUD Phase 1 well (i.e. the Bayside Well) injects 0.36 million gallons per day of groundwater between October 1 and March 31 during the following 12 water years, which are classified as wet years:
    - 2027-2029
    - 2036-2037
    - 2042
    - 2052-2054
    - 2061-2062
    - 2067
- Hayward Wells A, D, and E extract a combined total of 5.58 million gallons per day of groundwater between July 1 and August 31 to provide emergency water supply during the following seven water years:
    - 2028: a wet year in the middle of a three wet-year cycle;
    - 2036: a wet year after a short dry period;
    - 2040: a below normal year after a short dry period;
    - 2048: a critical year at the end of a dry/critical six-year cycle;
    - 2056: an above normal year at the end of a wet period;
    - 2060: a dry year at the end of a short dry period; and
    - 2068: a dry year at the beginning of a dry period.

A steady state simulation was also used for evaluating this scenario (Section 6.1.1.2). The scenario extraction rates for the steady state simulation are based on the average pumping from Water Year 2022 to Water Year 2071 and listed below:

- EBMUD Phase 1 well: 76,800 gallons per day (86 AFY) – net of extraction minus injection
- Hayward Well A: 33,600 gallons per day (38 AFY)
- Hayward Well D: 23,800 gallons per day (27 AFY)
- Hayward Well E: 72,800 gallons per day (82 AFY)

6.3.2 EBP Subbasin Results and Comparison to Baseline

This section presents the results of the simulation of the groundwater resources development scenario, comparison to baseline conditions simulation, and evaluation of the scenario with respect to sustainability criteria as defined in Section 6.2.1.

Figures 6-5a through **6-5e** show contours of simulated groundwater elevations for the simulation of the groundwater resources development scenario for a selection of future dates and for average conditions:

- 9/1/2048 (Model Year 27, **Figure 6-5a**): after 4 years of dry season with extraction from the EBMUD Phase 1 Well and 2 months of emergency supply extraction from Hayward Wells A, D, and E;

- 9/1/2060 (Model Year 39, **Figure 6-5b**): after 2 months of emergency supply extraction from Hayward Wells A, D, and E;
- 10/1/2066 (Model Year 45, **Figure 6-5c**): after 4 years without injection or extraction at the EBMUD Phase 1 Well and Hayward Wells A, D, and E;
- 10/1/2071 (Model Year 50, **Figure 6-5d**): after 2 years of dry season extraction from the EBMUD Phase 1 Well; and
- Steady state: average conditions and average of simulated extraction and injection rates over the 50-year scenario at the EBMUD Phase 1 Well and Hayward Wells A, D, and E.

Figures 6-6a through **6-6e** show contours of the differences between groundwater elevations for the baseline simulation and the groundwater resources development scenario simulation, which is commonly called drawdown, for the same dates listed above. These figures show that the simulation of groundwater resources development causes minimal change in the groundwater elevations in the Shallow Aquifer, and that simulated groundwater elevations in the Shallow Aquifer are maintained above the elevation of the Bay. Accordingly, the groundwater resources development scenario simulation is not anticipated to result in saltwater intrusion in accordance with the sustainability criteria defined in Section 6.2.1

Hydrographs shown in **Figures 6-7a** through **6-7j** further support that the sustainability criteria for groundwater elevations are met in the groundwater resources development scenario simulation. These figures additionally demonstrate that the simulated drawdown induced by pumping at the Phase 1 Well and Hayward wells A, D, and E recovers to baseline conditions on a scale of a few months.

Table 6-4 lists the average water budget information for the baseline and the groundwater resources development scenario simulations. **Figures 6-8a** and **6-8b** show the water budget over time for the baseline and the groundwater resources development scenario simulations, respectively. The water budget information provided in **Table 6-4** shows that on average, net outflows are maintained from the NEBP, MEBP, and SEBP towards the Bay (including the aquifers beneath the Bay). **Figure 6-8b** shows that there is a significant net outflow from the EBP Subbasin towards the Bay (including the aquifers beneath the Bay) as well as net outflow from the EBP Subbasin to the Niles Cone Subbasin every year during 50-year simulation of the groundwater resources development scenario. **Figure 6-9** shows the detail with time of the simulated annual flow from the EBP Subbasin to the Niles Cone Subbasin. **Figure 6-10** shows that 41 out of 50 years, there is net flow from the northern side of the HFB to the southern side of the HFB, which represents the impedance of horizontal hydraulic connection within the transition zone between the Intermediate and Deep Aquifers in the EBP and Niles Cone Subbasins.

Table 6-5 lists average simulated streamflow for the four major creeks in the EBP Subbasin (San Pablo, Wildcat, San Leandro, and San Lorenzo) based on the steady state simulations of the baseline and groundwater resources development scenario. The change in simulated streamflow between the baseline and groundwater resources development scenario simulations is negligible. Thus, the simulations with the 2021 EBPGWM indicate that the groundwater resources development scenario poses de minimis risk of surface water depletion.

The model was also used to evaluate change in connectivity of stream and groundwater for the groundwater resources development scenario compared to the baseline simulation. The stream connectivity at each model grid cell containing a stream boundary condition (SFR package) was assessed as follows:

- Cells where groundwater is discharging into the stream are classified as connected and gaining;
- Cells where groundwater level is below the stream stage but above the stream bed elevation are classified as connected and losing; and
- Cells where groundwater level is below the stream bed elevation are classified as not connected.

Table 6-6 provides a comparison of connectivity for the baseline and groundwater resources development scenario simulations for the four major creeks in the EBP Subbasin. The model simulations show no difference in simulated stream connectivity between the baseline and the groundwater resources development scenario steady state simulations. De minimis influence of the groundwater resources development scenario on stream flow is a consequence of the project pumping being assigned to the Intermediate and Deep Aquifers, which are confined and thus have little hydraulic connection to the shallow aquifer and creeks.

Note that limited data in the EBP Subbasin are available for stream flow and shallow groundwater levels near the streams. Consequently, collection of stream flow data, shallow groundwater level data near the streams, testing shallow aquifer conditions near the streams, and improvement of calibration of the model properties that influence hydraulic connection between streams and groundwater is a high priority. As more data become available future refinements to the model properties can be implemented that will improve the simulation of interaction between streams and groundwater.

6.3.3 Adjacent Basin Evaluation

The 2021 EBPGWM was also used to evaluate the potential influence from development of groundwater resources in the EBP Subbasin on the adjacent Niles Cone Subbasin. Five criteria within the Niles Cone Subbasin were considered, consistent with a previous evaluation performed as a part of the Environmental Impact Report (EIR) for the EBMUD Phase 1 (Bayside) well (CH2M Hill, 2005):

1. Change in water levels in the shallow Newark Aquifer;
2. Decrease in outflow from the inland portion of the Newark Aquifer to the Newark Aquifer under the salt evaporator ponds adjacent to the Bay;
3. Change in downward vertical flow from the Newark Aquifer to the Centerville/Fremont and Deep Aquifers;
4. Change in lateral movement of areas of groundwater with elevated chloride concentrations (chloride plumes) in the Newark, Centerville/Fremont, and Deep Aquifers; and
5. Drawdown in the Centerville/Fremont and Deep Aquifers.

6.3.3.1 Criteria 1 - Change in Water Levels in the Shallow Newark Aquifer

Figures 6-6a through **6-6e** and **6-7h** through **6-7j** show minimal change (less than 0.5 feet) in simulated groundwater levels in the shallow Newark Aquifer in Niles Cone Subbasin between the baseline and the groundwater resources development scenario simulations. Thus, simulated impacts to the Niles Cone Newark Aquifer groundwater elevations (Criteria 1) are within the model noise and are considered negligible.

6.3.3.2 Criteria 2 - Decrease in Outflow from the Inland Portion of The Newark Aquifer to the Newark Aquifer under the Salt Evaporator Ponds Adjacent to the Bay

The flow budgets of the transient simulations were used to evaluate change in simulated outflows from the inland portion of the Newark Aquifer to the Newark Aquifer under the salt evaporator ponds adjacent to the Bay to evaluate Criteria 2 (salt evaporator pond locations shown in **Figure 6-1**). **Figure 6-11** shows a comparison for the baseline and groundwater development scenarios of the annual simulated outflows from the inland portion of the Newark Aquifer to the Newark Aquifer under the salt evaporator ponds adjacent to the Bay, and the average simulated flows are summarized in **Table 6-7**. They are nearly identical; the simulated outflow decreases by less than 0.25% (< 35 AFY).

6.3.3.3 Criteria 3 - Change in Vertical Flow from the Newark Aquifer to the Centerville/Fremont and Deep Aquifers

The flow budgets of the transient simulations were used to evaluate change in simulated downward vertical flows from the Newark Aquifer to the Centerville/Fremont and Deep Aquifers in Niles Cone Subbasin (Criteria 3). The simulated vertical flow increases by less than 0.5% (< 60 AFY) between the baseline and groundwater resources development scenario simulations. **Figure 6-12** shows the simulated vertical flow from the Newark Aquifer to the Centerville/Fremont and Deep Aquifers in the Niles Cone Subbasin, and the average simulated flows are summarized in **Table 6-7**.

6.3.3.4 Criteria 4 - Change in Lateral Movement of Elevated Chloride in the Newark, Centerville/Fremont, and Deep Aquifers

The 2021 EBPGWM were used to evaluate change in lateral movement of groundwater with chloride concentrations > 250 milligrams per liter in the three aquifer intervals in the Niles Cone Subbasin for the baseline and groundwater resources development scenario simulations. Change in lateral movement was evaluated using the simulated lateral flow from the areas with elevated chloride concentrations. Within the Newark and Centerville/Fremont Aquifers, the area of elevated chloride is based on chloride concentration contours in ACWD 2019 Groundwater Monitoring Report (ACWD, 2020). For the Deep Aquifer, the estimated elevated chloride distribution was not available, so the conservative assumption was used that it is similar to the distribution within the Centerville/Fremont Aquifer.

The average simulated flows are summarized in **Table 6-7;** the simulated lateral flow does not change within the Newark and Centerville/Fremont Aquifers and increases by less than 10 AFY within the Deep Aquifer between the baseline and groundwater resources development scenario simulations.

6.3.3.5 Criteria 5 - Drawdown in the Centerville/Fremont and Deep Aquifers

Figures 6-6a through **6-6e** and **6-7h** through **6-7j** show contours of the simulated decrease in groundwater elevations in the Centerville/Fremont Aquifer in the Niles Cone and illustrate that the drawdown of groundwater levels simulated for the groundwater resources development scenario is generally less than 2 feet in comparison to baseline simulation. These figures also show that although the decrease in the groundwater elevation in the Deep Aquifer in the Niles Cone is estimated to be as much as approximately 15 feet near the HFB (but considerably less drawdown further south into Niles Cone Subbasin) at the end of periods of sustained pumping in the EBP Subbasin, these drawdowns are short-lived and groundwater levels recover rapidly (in months). The steady state simulation of average conditions shows long-term average groundwater elevation decreases by less than 2 feet in the Niles Cone Deep Aquifer (**Figure 6-6e**).

7 MODEL LIMITATIONS AND RECOMMENDATIONS FOR FUTURE UPDATES

This section provides a summary of the model limitations, and recommendations for future updates of the model.

7.1 Model Limitations

The 2021 EBPGWM has been developed through a detailed process of data compilation and review, conceptual model refinements, and model construction and calibration to multiple datasets. Accordingly, the model is a viable and reliable tool to use to support development of the GSP and future development of groundwater resources in the EBP Subbasin. However, this model, like all numerical models, is a simplification of a complex hydrogeologic system and relies on approximations and assumptions regarding the physical system. The main limitations are listed below:

- Existing pumping (rates, locations and depth intervals) within the EBP Subbasin are uncertain and actual total pumping in the EBP Subbasin may be over- or underestimated in the model simulations;
- Limited information was available on surface water/groundwater interactions, such as measured stream flows, shallow groundwater elevations near the streams, and variation in properties of the stream beds, therefore the model does not provide robust estimates of surface water/groundwater interactions at the local scale;
- The distribution of hydraulic conductivity varies significantly on a small scale in the alluvial sediments of the EBP Subbasin, however as is typical of regional groundwater models, large portions of model layers are assigned uniform values of hydraulic conductivity based on regional-scale calibration to groundwater levels. Accordingly, while the model provides reasonable results on average at a large scale, actual conditions are expected to vary substantially on a local scale;
- The specific yield is defined uniformly across the model domain, and detailed (discrete) water level fluctuations in the Shallow Aquifer are not available to refine the regional distribution; and
- Limited data are available on groundwater elevations in the Intermediate and Deep Aquifers in the Oakland/Bayfarm area after 2000, and consequently the calibrated horizontal hydraulic conductivity values in this area are relatively poorly constrained.

As indicated in Section 6, future modeling analyses, interpretations, and conclusions should not be viewed as absolute results and are best assessed considering relative changes, which is generally the case with most groundwater models.

7.2 Recommendations for Future Updates of the Model

Recommendations for future updates of the model follow:

- Collection of stream flow data, shallow groundwater level data near the streams, and testing stream bed and shallow aquifer conditions near the streams to improve the calibration of the model properties that influence hydraulic connection between streams and groundwater. As more data become available future refinements to the model properties can be implemented that will improve the simulation of interaction between streams and groundwater;

- Collection of data (e.g., stream width, streambed thickness, cross-section surveys) to refine representation of the streams in the model, including the four creeks represented as drain boundary conditions (Cerrito Creek, Codornices Creek, Lion Creek, and Sulphur Creek);
- Additional information on existing pumping in the EBP Subbasin to refine representation of current and anticipated future conditions;
- Additional discretization of recharge/irrigation to better represent local groundwater flow for local applications of the model;
- Collection of shallow groundwater level data in the EBP Subbasin to refine estimate of specific yield and recharge fluctuations; and
- Collection of chloride concentration data and additional characterization of the Shallow Aquifer in Representative Monitoring Sites to improve the calibration of the model properties that influence hydraulic connection between the Bay and groundwater. Future updates may include development of a transport model to simulate chloride migration.

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WRIME, Inc., 2005, Niles Cone and South East Bay Plain Integrated Groundwater and Surface Water Model (NEBIGSM). March.

Tables

Table 2-1: Summary of Groundwater Models in the Project Vicinity

East Bay Plain Groundwater Model
Groundwater Sustainability Plan

Software	Locations	Year	Key Objectives
IGSM	Niles Cone; southern East Bay Plain	1991; 2005	Primarily for management of Niles Cone Groundwater Basin; secondary purpose for application to EBMUD Bayside ASR Well EIR.
MODFLOW	Southern East Bay Plain	2001	Used for evaluation of EBMUD Bayside ASR project
MODFLOW	San Mateo Plain	2018	General basin management
MODFLOW	Santa Clara Valley	1990s; periodically updated	General basin management
MODFLOW	Westside Basin - San Francisco/San Mateo Counties	2007; periodically updated	General basin management

ASR = Aquifer Storage Recovery
EBMUD = East Bay Municipal Water District
EIR = Environmental Impact Report

Table 2-2: Material Categories for 3-D Geologic Model

East Bay Plain Groundwater Model
Groundwater Sustainability Plan

Material Categories	Hydrogeologic Category*
Impermeable Surface Cover	4
Topsoil	1, 2, 2a, 2b, 3
Hardpan	4
Fill	2
Clay	3
Silt	3
Clayey/Silty Sand	2, 2a, 2b
Gravel with fins	2a, 2b
Sand	1
Sand Gravel	1
Gravel	1
No Returns	NA, 1, 3, 4
Shale	5
Cemented Geologic Materials	4
Bedrock	5

Note:

*The hydrogeological categories are defined in Table 2-3. Some material categories are assigned to multiple hydrogeologic categories. For these material categories, hydrogeological categories were assigned based on the full geologic description of the material, the geologic description of over- and underlying materials, and professional judgement.

Table 2-3: Hydrogeological Categories for 3-D Geologic Model

East Bay Plain Groundwater Model
Groundwater Sustainability Plan

Hydrogeological Category	Definition
1	>100 ft/d High K (dominantly sand and/or gravel)
2	(1 to 100 ft/d) Moderate K (mixture of gravel and/or sand, with silt and/or clay without enough detail in boring logs to refine)
2a	(10 to 100 ft/d) Moderate to High K (gravel and/or sand that includes some silt and/or clay)
2b	(1 to 10 ft/d) Moderate to Low K (silt and/or clay that includes some sand and/or gravel)
3	(0.1 to 1 ft/d) Low K (predominantly silt or clay)
4	(<0.1 ft/d) Very low K (for example well-developed clay)
5	(<0.1 ft/d) Very low K (Bedrock only)

ft/d = feet per day
K = hydraulic conductivity

Table 2-4: Preliminary Water Budget for the East Bay Plain Subbasin

East Bay Plain Groundwater Model
Groundwater Sustainability Plan

Inflows	**Average Annual (AFY)**	**Potential Range (AFY)**
Precipitation Recharge	4,800	3,000 to 8,000
Excess Irrigation Recharge - Large Parcels	750	500 to 1,000
Excess Irrigation Recharge - Residential Parcels	1,600	1,000 to 2,000
Water Pipe Leaks	4,350	2,000 to 7,500
Sewer Pipe Leaks	3,000	1,500 to 5,000
Stream Infiltration	2,350	1,000 to 5,000
Bedrock Inflow	2,600	1,000 to 4,000
Recharge Totals	**19,450**	**10,000 to 32,500**
Outflows		
Groundwater Pumping	-3,150	-2,000 to -4,000
Subsurface Outflow to San Francisco Bay	-13,500	-8,000 to -17,000
Stream Discharge and Sewer Pipe Outflow	-2,800	-500 to -4,000
Discharge Totals	**-19,450**	**-10,500 to -25,000**

AFY = acre-feet per year

Additional information on the preliminary water budget can be found in HCM TM 4.2 (GSP Appendix 2.A.b)

Table 3-1: Inflow to Eastern Margin of the Model

East Bay Plain Groundwater Model
Groundwater Sustainability Plan

Arc ID	Layers	Initial Inflow (AFY)	Final Calibrated Inflow (AFY)	Range (AFY) Based on Table 2-4
1050	1 through 12	260	409	-
1051	1 through 12	260	25	-
1052	1 through 12	260	168	-
1053	1 through 12	260	84	-
1054	1 through 12	260	84	-
1055	1 through 12	260	242	-
1056	1 through 12	260	242	-
1057	1 through 12	260	242	-
1058	1 through 12	260	242	-
1059	1 through 12	260	242	-
Total	**1 through 12**	**2,600**	**1,978**	**1,000 to 4,000**

AFY = acre-feet per year

Arc IDs are shown in Figure 3-3.

Initial inflow based on average annual estimate (Table 2-4) divided by 10.

Table 3-2: Initial and Calibrated Recharge Inputs

East Bay Plain Groundwater Model
Groundwater Sustainability Plan

Recharge Polygon	Polygon ID	Initial Average Recharge Input (in/yr)	Calibrated Final Average Recharge Input (in/yr)
Northern EBP/Richmond	1021	2.0	2.0
San Pablo Uplands	San Pablo Uplands	2.0	2.6
Berkeley Alluvial Plain	1022	2.5	2.8
Berkeley Hills	Berkeley Hills	2.5	0.0
Oakland Upland and Alluvial Plain	1023	2.7	3.1
Oakland Hills	Oakland Hills	2.7	0.0
Merritt Sand Outcrop Oakland	1024	2.7	2.2
Merritt Sand Outcrop Alameda Island	1025	2.7	2.7
San Leandro Cone	1026	1.8	1.8
San Lorenzo Cone	1027	2.1	2.1
Castro Valley	1028	2.1	0.7
Fremont Salt Pond	1029	0.0	0.0
Hayward Salt Pond	1030	0.0	0.0
Fremont Area - Below Hayward Fault	1031	3.4	3.4
Fremont Area - above Hayward fault	1032	2.6	2.6
Richmond South	Richmond South	2.0	2.6

in/yr = inches per year

Table 3-3: Precipitation Recharge Inputs

East Bay Plain Groundwater Model
Groundwater Sustainability Plan

Recharge Polygon	Average Precipitation (in/yr)	Scaling Coefficient	Recharge Factor
Fremont Area - above Hayward fault	NA	NA	NA
Fremont - Below Hayward Fault	NA	NA	NA
Berkeley Alluvial Plain	24.5	0.94	0.076
Northern EBP/Richmond	22.7	1.06	0.054
San Lorenzo Cone	24.9	0.76	0.054
Oakland Upland and Alluvial Plain	24.9	0.96	0.083
Castro Valley	24.9	0.76[a]	0.054[b]
Fremont Salt Pond	NA	NA	NA
Hayward Salt Pond	NA	NA	NA
San Leandro Cone	24.9	0.72	0.054
Merritt Sand Outcrop Alameda Island	24.9	0.80	0.054
Merritt Sand Outcrop Oakland	24.9	0.80	0.054
San Pablo Uplands	22.7	1.06	0.054
Berkeley Hills	24.5	0.94	0.076
Oakland Hills	24.9	0.96	0.083
Richmond South	22.7	1.06	0.054

a: Average precipitation for the Castro Valley was not included in Muir (1994), so San Lorenzo values were used.
b: Recharge factor for the Castro Valley was not reported in the HCM Report (LSCE Team, 2021), so San Lorenzo values were used.

EPB = East Bay Plain

HCM = hydrogeological conceptual model

in/yr = inches per year

NA = not applicable; values not estimated as part of this work

Table 4-1: Calibration Statistics for the Steady State Baseline Simulation

East Bay Plain Groundwater Model
Groundwater Sustainability Plan

	Numbers of Observations	Range of Observations (feet)	Mean Error (feet)	Mean Absolute Error (feet)	RMSE (feet)	RMSE (% Range)	R^2
Per Aquifer Zone							
Shallow	60	94	-1.5	5.0	6.7	7%	
Intermediate	17	41	-3.6	4.1	4.6	11%	
Deep	17	36	-1.6	2.3	2.6	7%	
Per Regional Area							
NEBP	27	95	0.5	3.7	4.5	5%	
SEBP	23	40	-0.9	2.9	4.0	10%	
EBP	50	99	-0.2	3.3	4.3	4%	
Niles Cone	43	46	-3.8	5.5	7.1	15%	
All	**94**	**100**	**-1.9**	**4.3**	**5.8**	**6%**	**0.92**

NEBP = Northern East Bay Plain
RMSE = root mean square error
R^2 = coefficient of determination
SEBP = Southern East Bay Plain
Outlier T0600102093-MW-1 not included in statistics.

Table 4-2: Steady State Water Budget for the East Bay Plain Subbasin

East Bay Plain Groundwater Model
Groundwater Sustainability Plan

Model Component	Average (AFY)	HCM Range (AFY)
Inflows		
Precipitation Recharge	14,397	3,000 to 8,000
Pipe Leakage Recharge		3,500 to 12,500
Irrigation Recharge		1,500 to 3,000
Bedrock Inflow	1,484	1,000 to 4,000
Flow from Castro Valley	307	Not Quantified
Stream Recharge	3,698	1,000 to 5,000
Flow from Niles Cone	883	Not Quantified
Outflows		
Groundwater Pumping	-3,645	-2,000 to -4,000
Discharge to Bay	-10,833	-8,000 to -17,000
Stream Discharge	-3,955	-500 to -4,000*
Flow to Niles Cone	-2,337	Not Quantified
Total Inflow	20,769	10,000 to 32,500
Total Outflow	-20,769	-10,500 to -25,000

*Includes sewer pipe outflow as well

AFY = acre-feet per year

HCM = Hydrogeological Conceptual Model

Table 4-3: Observed versus Modeled Average Streamflow

East Bay Plain Groundwater Model
Groundwater Sustainability Plan

Stream	Gage Station	Average Flow (ft^3/d)	Modeled Average Flow (ft^3/d)
Alameda Creek (upstream)	11179100	8,714,900	11,531,000
Alameda Creek (downstream)	11180700	9,670,600	12,199,000
San Lorenzo Creek (upstream)	11181000	1,307,000	1,231,000
San Lorenzo Creek (downstream)	11181040	2,098,000	1,229,000
Wildcat Creek (upstream)	11181390	453,100	383,000
Wildcat Creek (downstream)	11181400	442,000	378,000

ft^3/d = cubic feet per day

Table 4-4: Calibration Statistics for the Historical Simulation

East Bay Plain Groundwater Model
Groundwater Sustainability Plan

	Numbers of Observations	Range of Observations (feet)	Mean Error (feet)	Mean Absolute Error (feet)	RMSE (feet)	RMSE (% Range)	R^2
Per Aquifer Zone							
Shallow	3,131	100	-3.6	6.9	9.1	9%	
Intermediate	485	79	-4.4	6.1	7.5	9%	
Deep	795	62	-0.1	3.8	4.9	8%	
Per Regional Area							
NEBP	1,160	132	1.2	4.5	5.6	4%	
SEBP	600	66	-0.4	3.7	5.1	8%	
EBP	1,760	132	0.6	4.2	5.5	4%	
Niles Cone	2,650	84	-5.5	7.6	9.8	12%	
All*	**4,427**	**132**	**-3.1**	**6.3**	**8.3**	**6%**	**0.81**

NEBP = Northern East Bay Plain

RMSE = root mean square error

R^2 = coefficient of determination

SEBP = Southern East Bay Plain

Outlier T0600102093-MW-1 not included in statistics.

* Also includes 17 measurements in Castro Valley that are not included in rows above

Table 4-5: Simulated Annual Water Budget for the East Bay Plain Subbasin, 1990-2015

East Bay Plain Groundwater Model
Groundwater Sustainability Plan

Water Year	Inflows (AFY)					Outflows (AFY)				Total		
	Recharge	Bedrock Inflow	Flow from Castro Valley	Stream Recharge	Flow from Niles Cone	Groundwater Pumping	Discharge to Bay	Stream Discharge	Flow to Niles Cone	Inflow	Outflow	Change in Storage
1991	12,943	1,643	389	1,742	786	-4,533	-2,825	-2,464	-1,958	17,503	-11,780	5,724
1992	13,448	1,537	350	1,714	1,107	-4,501	-4,197	-2,417	-1,994	18,156	-13,108	5,048
1993	15,293	1,545	337	2,961	1,209	-4,544	-5,615	-2,788	-2,363	21,344	-15,311	6,033
1994	12,746	1,476	330	1,814	990	-4,268	-5,468	-2,485	-2,235	17,355	-14,456	2,900
1995	16,536	1,479	327	3,247	992	-3,999	-7,202	-3,034	-2,375	22,581	-16,610	5,971
1996	15,658	1,544	328	2,853	649	-4,003	-7,650	-3,122	-2,302	21,031	-17,077	3,954
1997	14,934	1,540	325	2,888	751	-3,969	-7,942	-3,148	-2,174	20,438	-17,232	3,206
1998	18,951	1,606	325	3,159	1,450	-3,888	-9,511	-3,534	-2,541	25,491	-19,474	6,017
1999	14,512	1,529	325	2,452	1,460	-3,825	-8,681	-2,975	-2,804	20,278	-18,285	1,993
2000	14,645	1,508	326	2,304	1,295	-3,785	-8,694	-2,808	-2,821	20,078	-18,109	1,969
2001	12,912	1,516	323	2,163	1,162	-3,627	-8,431	-2,774	-2,487	18,077	-17,318	758
2002	14,722	1,532	323	2,389	1,076	-3,627	-9,109	-3,035	-2,476	20,042	-18,247	1,796
2003	14,513	1,544	325	2,420	1,058	-3,627	-9,239	-2,952	-2,481	19,860	-18,300	1,560
2004	13,708	1,519	325	2,504	973	-3,631	-9,196	-3,100	-2,381	19,029	-18,308	721
2005	16,006	1,498	325	3,140	1,156	-3,636	-9,950	-3,372	-2,488	22,125	-19,445	2,680
2006	16,799	1,530	327	3,257	1,164	-3,630	-10,569	-3,641	-2,618	23,077	-20,459	2,618
2007	12,776	1,481	326	2,139	845	-3,627	-9,375	-2,862	-2,386	17,568	-18,250	-682
2008	13,294	1,497	326	1,984	860	-3,631	-9,368	-2,775	-2,253	17,961	-18,028	-67
2009	13,467	1,472	325	1,917	891	-3,627	-9,279	-2,698	-2,214	18,072	-17,818	254
2010	14,662	1,506	326	2,210	892	-3,627	-9,751	-2,951	-2,243	19,596	-18,572	1,024
2011	15,456	1,522	328	3,312	851	-3,627	-10,373	-3,496	-2,273	21,468	-19,768	1,699
2012	13,594	1,509	329	3,191	747	-3,642	-10,006	-3,493	-2,226	19,369	-19,368	1
2013	12,886	1,517	328	2,198	643	-3,642	-9,560	-2,905	-2,135	17,571	-18,242	-671
2014	12,246	1,473	327	1,920	514	-3,639	-9,176	-2,659	-1,930	16,479	-17,403	-924
2015	13,519	1,491	327	1,945	741	-3,627	-9,543	-2,724	-1,991	18,023	-17,885	138
Average 1991-2015	**14,409**	**1,521**	**330**	**2,473**	**970**	**-3,831**	**-8,428**	**-2,968**	**-2,326**	**19,703**	**-17,554**	**2,149**
HCM Range (AFY)	**8,000 to 23,500**	**1,000 to 4,000**	**Not Quantified**	**1,000 to 5,000**	**Not Quantified**	**-2,000 to -4,000**	**-8,000 to -17,000**	**-500 to -4,000***	**Not Quantified**	**10,000 to 32,500**	**-10,500 to -25,000**	**Not Applicable**

*Includes sewer pipe outflow as well

AFY = acre-feet per year

HCM = Hydrogeological Conceptual Model

Table 5-1: Steady-State Water Budget for Average Recent Conditions and Historical Pumping Simulations

East Bay Plain Groundwater Model
Groundwater Sustainability Plan

	Inflow		Outflow			
	Recharge, Bedrock Inflow, and Castro Valley Inflow	Stream Recharge	Groundwater Pumping	Stream Discharge	Net Flow to Niles Cone Subbasin	Discharge to Bay
Steady-State Historical Pumping Simulation						
EBP Subbasin	16,200	5,000	22,800	3,000	-2,500[a]	-2,200[b]
Steady-State Average Recent Conditions Simulation						
EBP Subbasin	16,200	3,700	3,600	4,000	1,500	10,800

AFY = acre-feet per year

EBP = East Bay Plain

a. Negative number means this is an inflow (inflow from Niles Cone Subbasin to EBP Subbasin)

b. Negative number means this is an inflow (inflow from Bay/aquifers underneath the Bay to EBP Subbasin)

Table 5-2: Streamflow for Average Recent Conditions and Historical Pumping Simulations

East Bay Plain Groundwater Model
Groundwater Sustainability Plan

Stream:	**San Pablo**	**Wildcat**	**San Leandro**	**San Lorenzo**
Steady-State Average Recent Conditions Simulation (cfs)	5.8	4.2	8.4	15.2
Steady-State Historical Pumping Simulation (cfs)	5.5	4.1	6.9	14.6
Decrease (cfs)	0.3	0.0	1.5	0.6
Decrease (%)	5%	1%	18%	4%

cfs = cubic feet per second

Table 6-1: Details of the Transient 2021 EBPGWM Future Simulation

East Bay Plain Groundwater Model
Groundwater Sustainability Plan

Simulated Future Water Year	Historical Water Year Model Inputs Are Based on	Mokelumne River Water Year Type[1]	San Joaquin Valley Water Year Type[2]	Alternative Scenario Water Use	
				EBMUD Phase 1 Well	Hayward Wells A, D, and E
2016	2016	Below Normal	Below Normal		
2017	2017	Normal and Above	Wet		
2018	2018	Below Normal	Below Normal		
2019	2019	Normal and Above	Wet		
2020	2020	Dry	Dry		
2021	2021	--	--		
2022	1991	Dry	Critical		
2023	1992	Critical	Critical		
2024	1993	Normal and Above	Wet		
2025	1994	Critical	Critical		
2026	1995	Normal and Above	Wet		
2027	1996	Normal and Above	Wet	injection	
2028	1997	Normal and Above	Wet	injection	extraction
2029	1998	Normal and Above	Wet	injection	
2030	1999	Below Normal	Above Normal		
2031	2000	Below Normal	Above Normal		
2032	2001	Dry	Dry		
2033	2002	Below Normal	Dry		
2034	2003	Below Normal	Below Normal		
2035	2004	Below Normal	Dry		
2036	2005	Normal and Above	Wet	injection	extraction
2037	2006	Normal and Above	Wet	injection	
2038	2007	Dry	Critical		
2039	2008	Dry	Critical		
2040	2009	Below Normal	Below Normal		extraction
2041	2010	Below Normal	Above Normal		
2042	2011	Normal and Above	Wet	injection	
2043	2012	Dry	Dry		
2044	2013	Dry	Critical		
2045	2014	Critical	Critical	extraction	
2046	2015	Critical	Critical	extraction	
2047	1991	Dry	Critical	extraction	
2048	1992	Critical	Critical	extraction	extraction
2049	1993	Normal and Above	Wet		
2050	1994	Critical	Critical		
2051	1995	Normal and Above	Wet		
2052	1996	Normal and Above	Wet	injection	
2053	1997	Normal and Above	Wet	injection	
2054	1998	Normal and Above	Wet	injection	
2055	1999	Below Normal	Above Normal		
2056	2000	Below Normal	Above Normal		extraction
2057	2001	Dry	Dry		
2058	2002	Below Normal	Dry		
2059	2003	Below Normal	Below Normal		
2060	2004	Below Normal	Dry		extraction
2061	2005	Normal and Above	Wet	injection	
2062	2006	Normal and Above	Wet	injection	
2063	2007	Dry	Critical		
2064	2008	Dry	Critical		
2065	2009	Below Normal	Below Normal		
2066	2010	Below Normal	Above Normal		

Table 6-1: Details of the Transient 2021 EBPGWM Future Simulation

East Bay Plain Groundwater Model
Groundwater Sustainability Plan

Simulated Future Water Year	Historical Water Year Model Inputs Are Based on	Mokelumne River Water Year Type[1]	San Joaquin Valley Water Year Type[2]	Alternative Scenario Water Use	
				EBMUD Phase 1 Well	Hayward Wells A, D, and E
2067	2011	Normal and Above	Wet	injection	
2068	2012	Dry	Dry		extraction
2069	2013	Dry	Critical		
2070	2014	Critical	Critical	extraction	
2071	2015	Critical	Critical	extraction	

EBMUD = East Bay Municipal Utility District

1. East Bay Municipal Utility District
2. https://cdec.water.ca.gov/reportapp/javareports?name=WSIHIST

Table 6-2: Water Budget for Baseline and Sustainable Yield Steady-State Simulations

East Bay Plain Groundwater Model
Groundwater Sustainability Plan

	AFY			
Future Baseline	**North**	**Middle**	**South**	**Total**
Discharge to Bay plus Flow to Niles Cone Subbasin	4,856	4,889	956	10,702
Net Flow to Niles Cone Subbasin	0	0	1,270	1,270
Groundwater Pumping	246	1,544	1,846	3,636
Sustainable Yield Simulation (12,500 AFY pumping)				
Discharge to Bay plus Flow to Niles Cone Subbasin	2,928	227	3	3,158
Net Flow to Niles Cone Subbasin	0	0	558	558
Groundwater Pumping	3,306	6,216	2,979	12,501
Decrease from Baseline				
Discharge to Bay plus Flow to Niles Cone Subbasin	1,928	4,662	953	7,544
Net Flow to Niles Cone Subbasin	0	0	713	713
Groundwater Pumping	-3,060	-4,672	-1,133	-8,865

AFY = acre-feet per year

Table 6-3: Streamflow and Stream-Groundwater Interaction for Baseline and Sustainable Yield Steady-State Simulations

East Bay Plain Groundwater Model
Groundwater Sustainability Plan

	San Pablo	Wildcat	San Leandro	San Lorenzo
Simulated Streamflow (cfs)				
Future Baseline	6.5	4.4	8.8	15.7
Sustainable Yield	5.9	4.1	8.4	15.7
Decrease from Baseline to Sustainable Yield	0.6	0.3	0.4	0.0
Simulated Stream Recharge to Groundwater (cfs)				
Future Baseline	4.6			
Sustainable Yield	5.6			
Simulated Groundwater Discharge to Streams (cfs)				
Future Baseline	5.1			
Sustainable Yield	4.8			
Simulated Net Groundwater Discharge to Streams (cfs)				
Future Baseline	0.5			
Sustainable Yield	-0.7			

cfs = cubic feet per second

Table 6-4: Average Annual Water Budget for Transient Baseline and Groundwater Resources Development Scenario Simulations

East Bay Plain Groundwater Model
Groundwater Sustainability Plan

	Inflow			Outflow				Change in Storage
Average WY 2022-2071 (AFY)	Recharge and Bedrock Inflow	Stream Recharge	Injection	Groundwater Pumping	Stream Discharge	Net Flow to Niles Cone Subbasin	Discharge to Bay	
Groundwater Resources Development Scenario Simulation								
EBP Subbasin	16,200	2,420	50	3,910	3,620	1,250	9,700	200
North EBP	5,190	2,260	0	250	1,980	0	4,980	50
Middle EBP	6,660	160	0	1,540	490	0	4,850	130
South EBP	4,350	0	50	2,120	1,140	1,250	-130	20
Future Baseline Simulation								
EBP Subbasin	16,200	2,420	0	3,630	3,620	1,370	9,780	230
North EBP	5,190	2,260	0	250	1,980	0	4,980	50
Middle EBP	6,660	160	0	1,540	490	0	4,870	140
South EBP	4,350	0	0	1,840	1,150	1,370	-70	40

AFY = acre-feet per year
EBP = East Bay Plain
WY = water year

Table 6-5: Streamflow for Baseline and Groundwater Resources Development Scenario Steady-State Simulations

East Bay Plain Groundwater Model
Groundwater Sustainability Plan

	San Pablo	Wildcat	San Leandro	San Lorenzo
Future Baseline Steady State Simulation (cfs)	6.5	4.4	8.8	15.7
Groundwater Resources Development Scenario Steady-State Simulation (cfs)	6.5	4.4	8.8	15.7
Decrease (cfs)	0.0	0.0	0.0	0.0
Decrease (%)	0%	0%	0%	0%

cfs = cubic feet per second

Table 6-6: Stream Connectivity for Baseline and Groundwater Resources Development Scenario Steady-State Simulations

East Bay Plain Groundwater Model
Groundwater Sustainability Plan

Future Baseline Steady-State Simulation	Total Cells Intersecting Stream	Connected Cells	% Connected Cells	Gaining Cells	% Gaining Cells
Wildcat	28	21	75%	8	29%
San Pablo	63	63	100%	40	63%
San Leandro	34	34	100%	18	53%
San Lorenzo	49	30	61%	21	43%
Groundwater Resources Development Scenario Steady-State Simulation	**Total Cells Intersecting Stream**	**Connected Cells**	**% Connected Cells**	**Gaining Cells**	**% Gaining Cells**
Wildcat	28	21	75%	8	29%
San Pablo	63	63	100%	40	63%
San Leandro	34	34	100%	18	53%
San Lorenzo	49	30	61%	21	43%

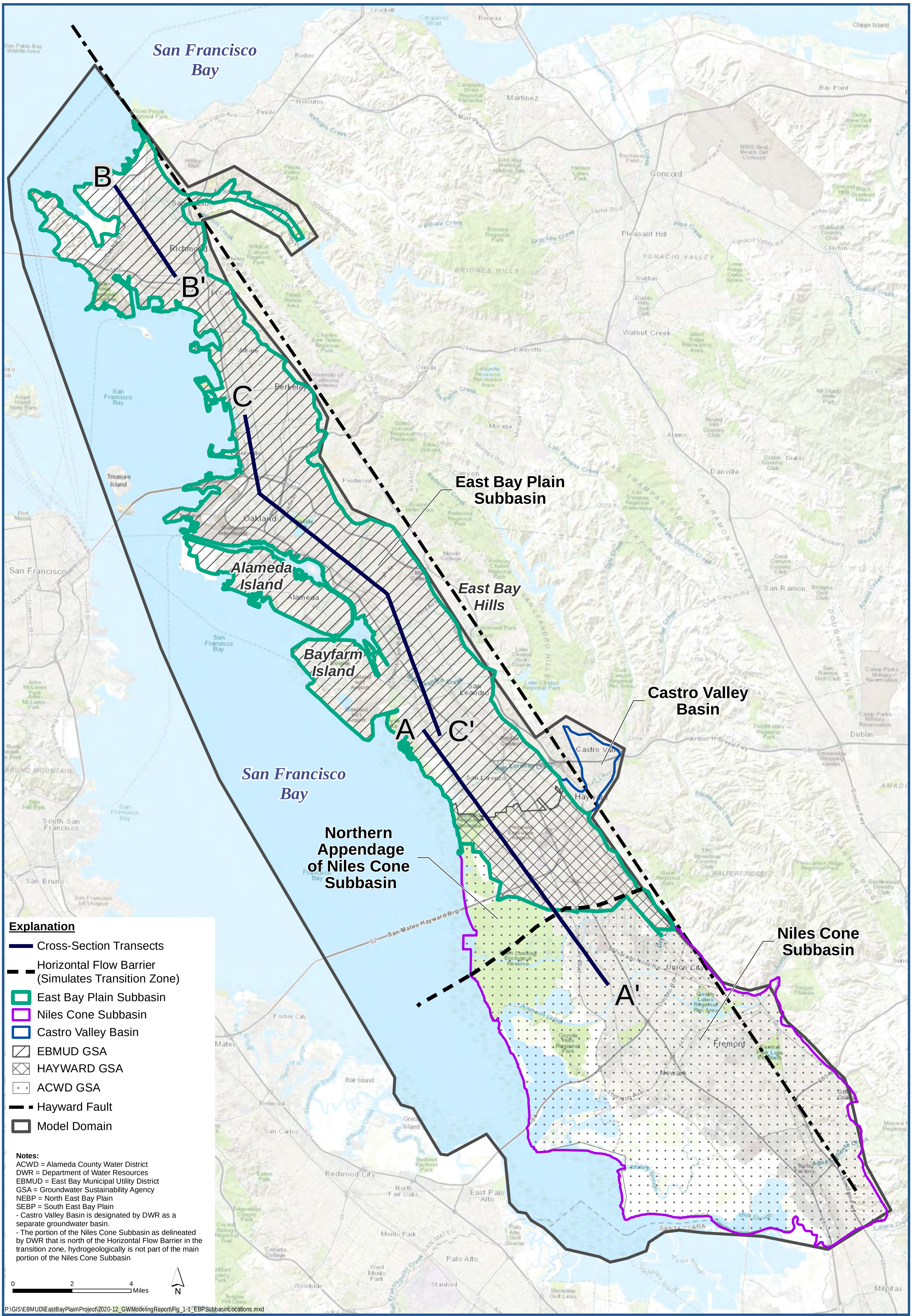
Table 6-7: Niles Cone Subbasin Flow Budget for Transient Baseline and Groundwater Resources Development Scenario Simulations

East Bay Plain Groundwater Model
Groundwater Sustainability Plan

	Average WY 2022-2071 (AFY)				
	Outflow from the Inland Portion of The Newark Aquifer to the Newark Aquifer under the Salt Evaporator Ponds Adjacent to the Bay	Vertical Flow from the Newark Aquifer to the Centerville/Fremont and Deep Aquifers	Lateral Movement of Elevated Chloride		
			Newark Aquifer	Centerville / Fremont Aquifer	Deep Aquifer
Future Baseline	15,380	12,370	1,690	2,360	50
Groundwater Resources Development Scenario	15,350	12,430	1,690	2,360	60
Decrease from Baseline to Scenario	30	-60	0	0	-10

AFY = acre-feet per year
WY = water year

Figures



Notes:
ACWD = Alameda County Water District
DWR = Department of Water Resources
EBMUD = East Bay Municipal Utility District
GSA = Groundwater Sustainability Agency
NEBP = North East Bay Plain
SEBP = South East Bay Plain
- Castro Valley Basin is designated by DWR as a separate groundwater basin.
- The portion of the Niles Cone Subbasin as delineated by DWR that is north of the Horizontal Flow Barrier in the transition zone, hydrogeologically is not part of the main portion of the Niles Cone Subbasin

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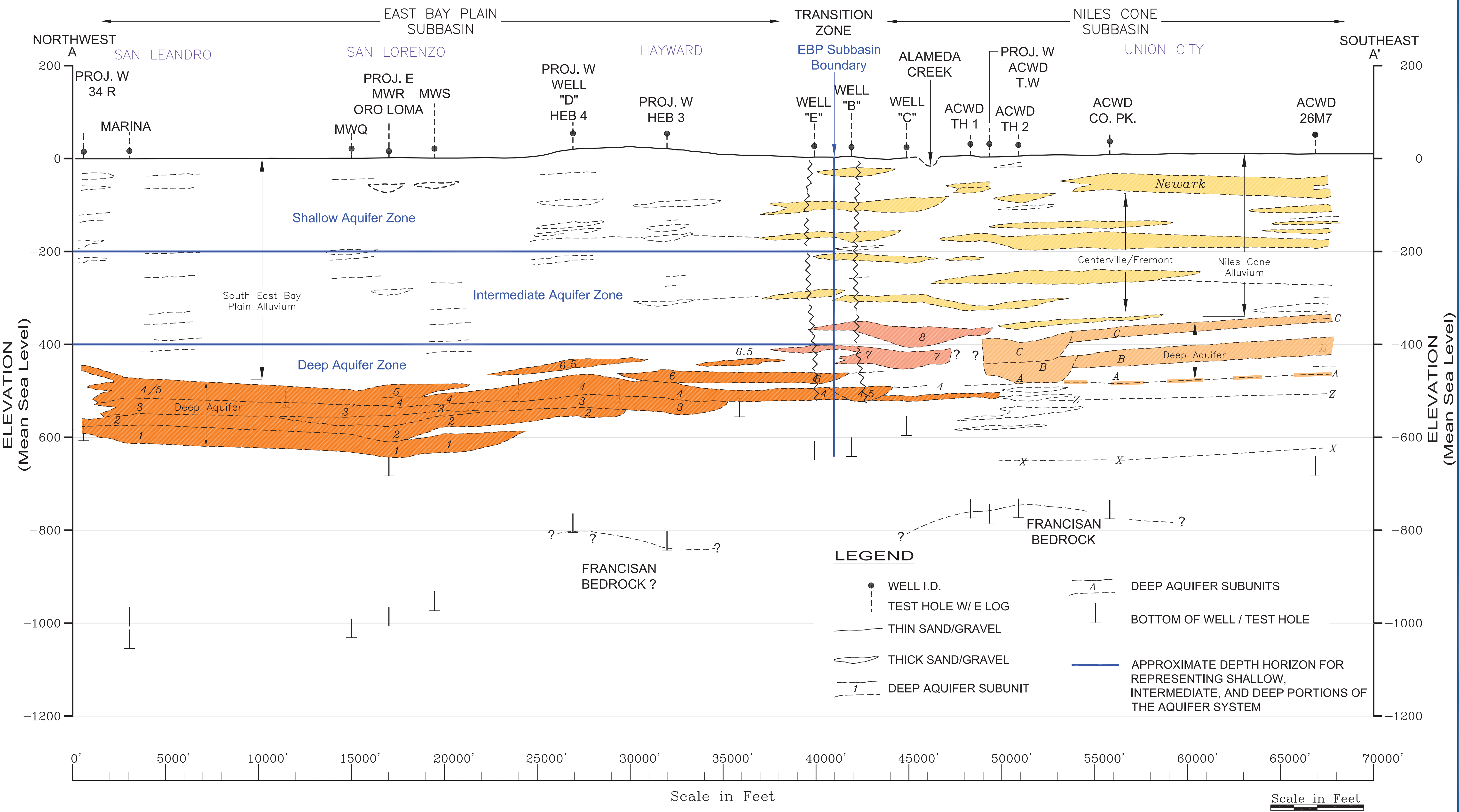
East Bay Plain Subbasin Location

East Bay Plain Subbasin
Groundwater Modeling Report

Figure 1-1



Note:
Figure modified from Figure 18; LSCE, 2003.

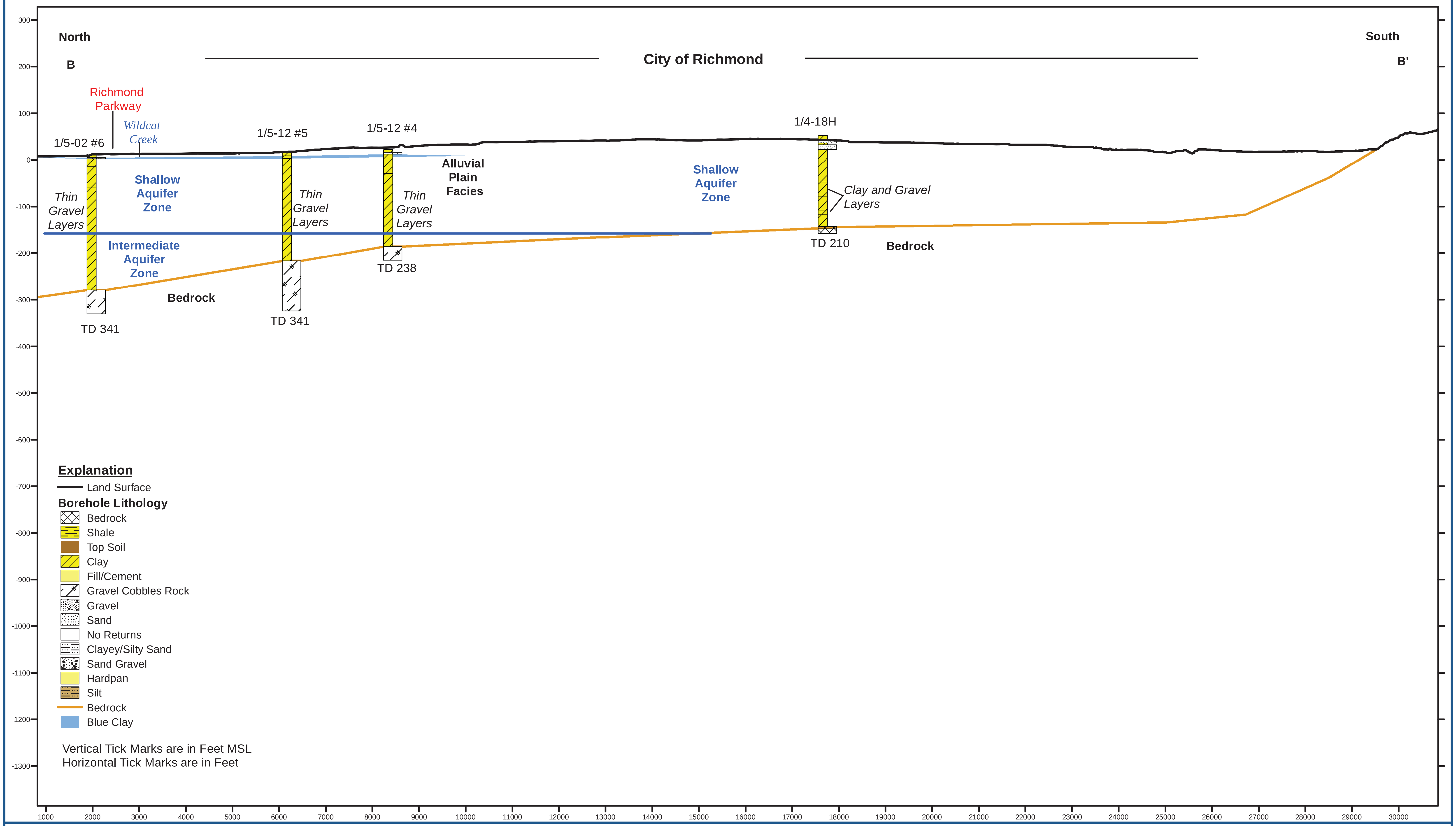
CAD FILE: D:\LS_ACAD_Dropbox\Projects\Alameda_County_Water_District\18-1-012\ShallowAquiferZone_20210202.dwg DATE: 2/2/2021 12:43 PM

LSCE TEAM

Hydrostratigraphic Cross Section A-A'

Figure 1-2

East Bay Plain Groundwater Model
Groundwater Sustainability Plan

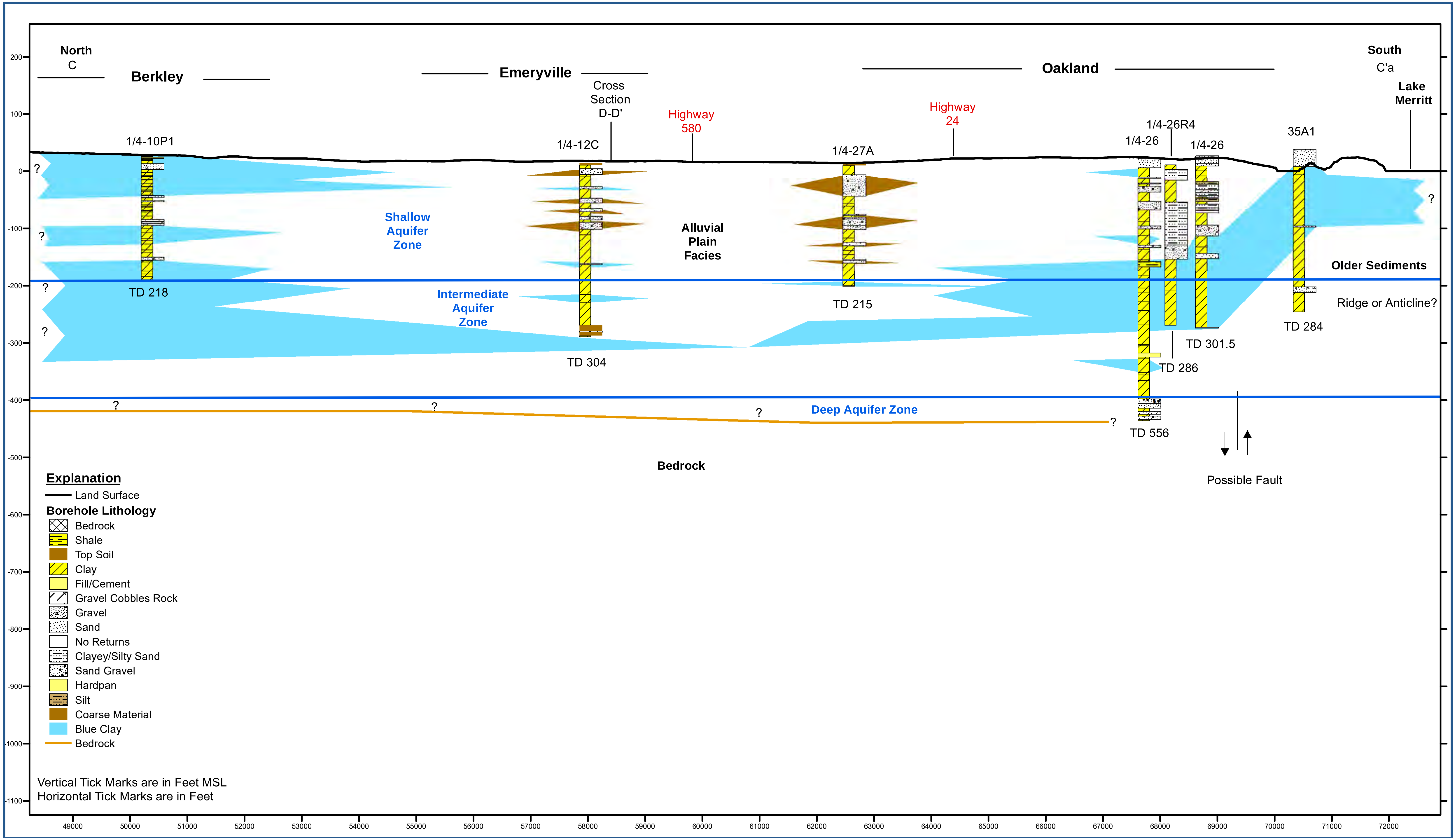


LSCE TEAM

Hydrostratigraphic Cross Section B-B'

East Bay Plain Groundwater Model
Groundwater Sustainability Plan

Figure 1-3

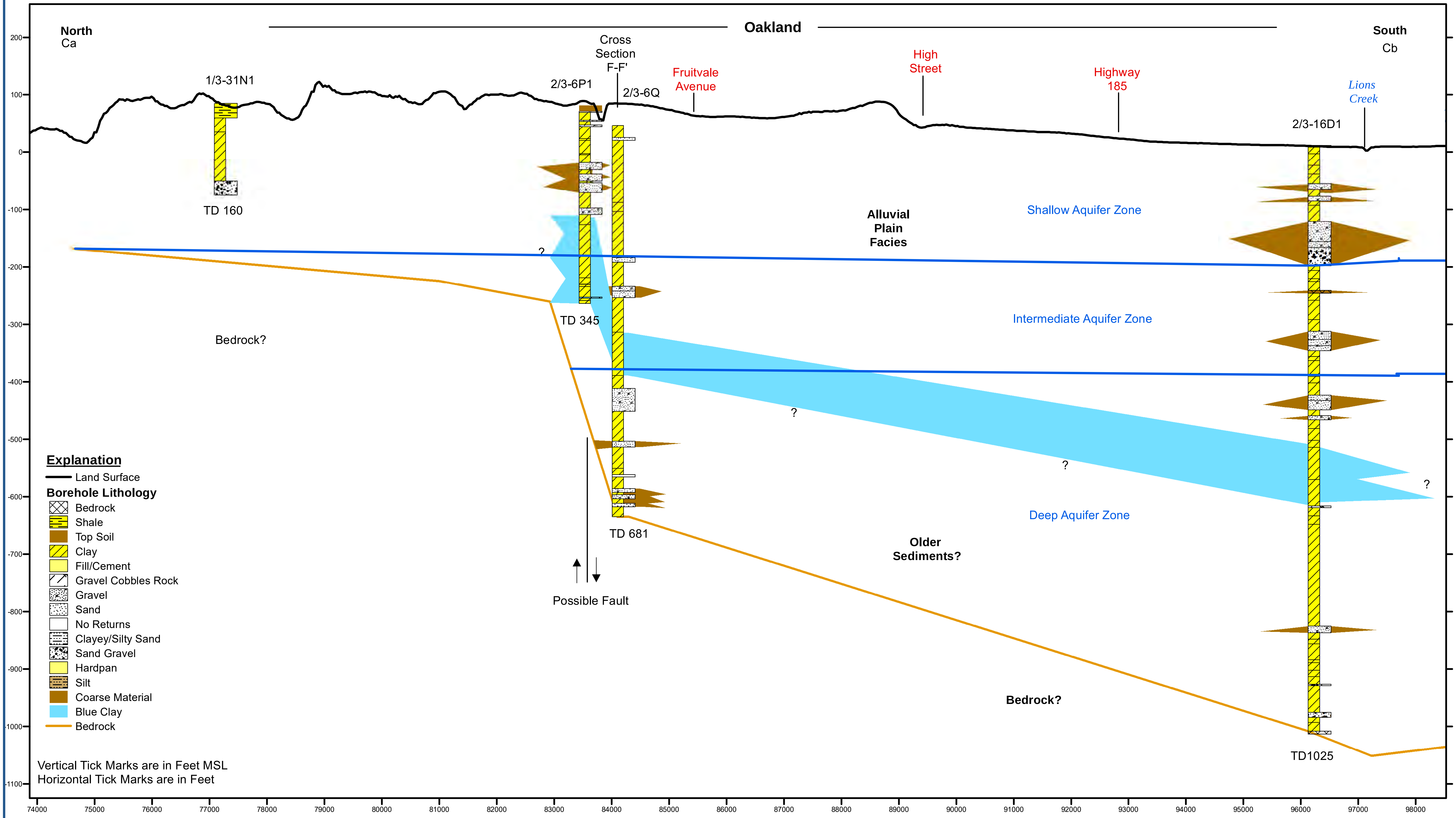


LSCE TEAM

Hydrostratigraphic Cross Section C-C'a

East Bay Plain Groundwater Model
Groundwater Sustainability Plan

Figure 1-4a

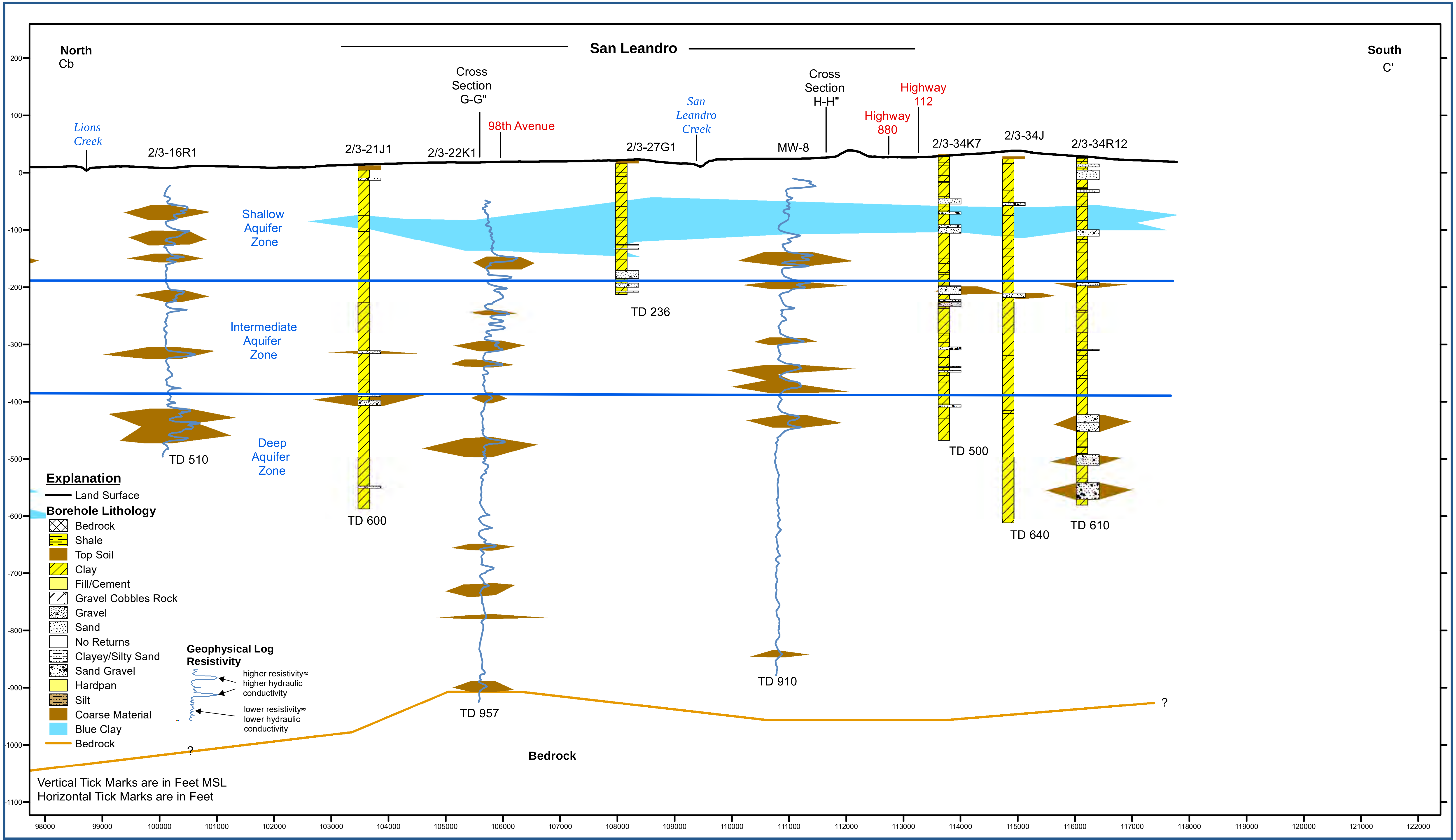


LSCE TEAM

Hydrostratigraphic Cross Section C-C'b

East Bay Plain Groundwater Model
Groundwater Sustainability Plan

Figure 1-4b

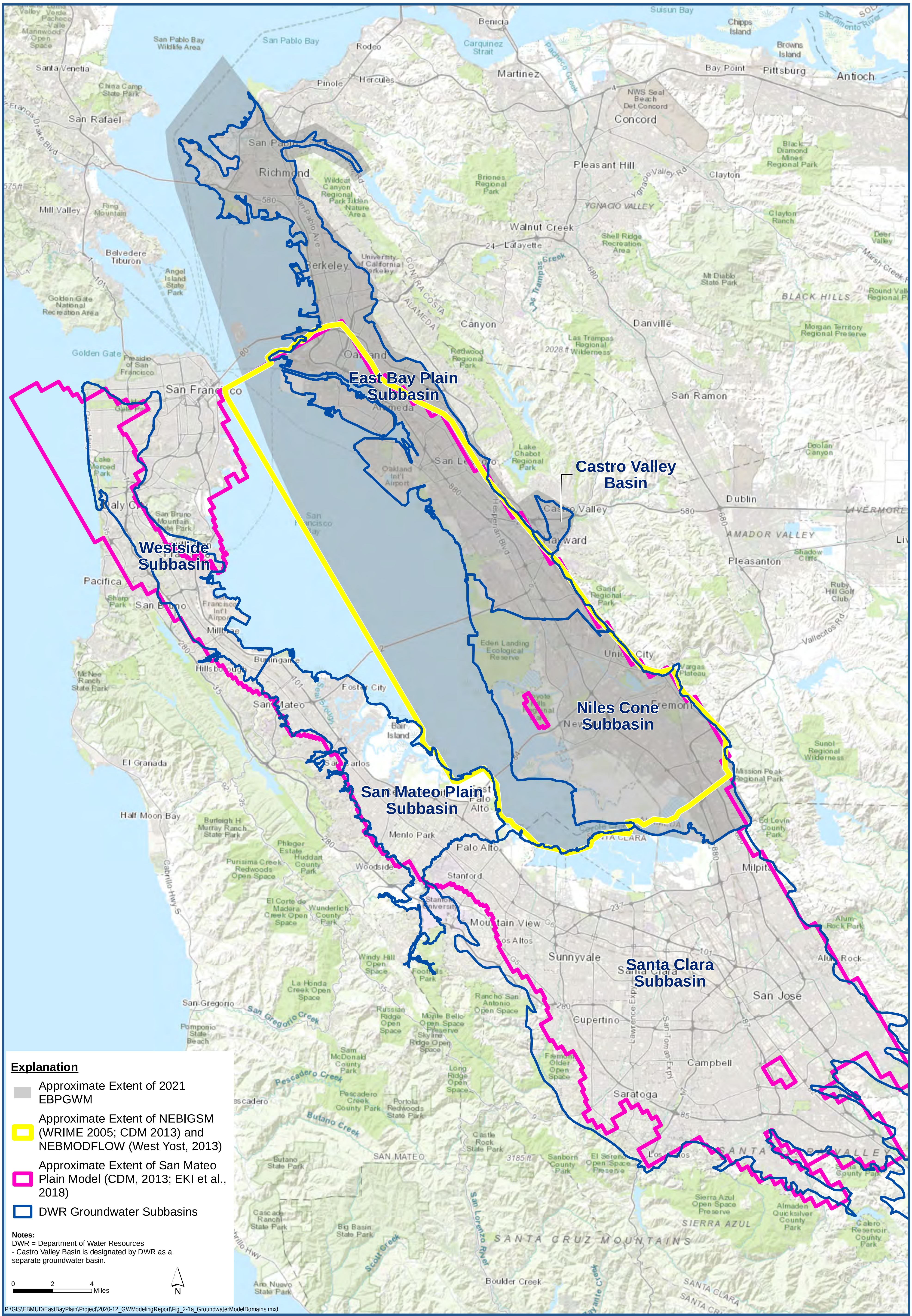


LSCE TEAM

Hydrostratigraphic Cross Section C-C'c

East Bay Plain Groundwater Model
Groundwater Sustainability Plan

Figure 1-4c

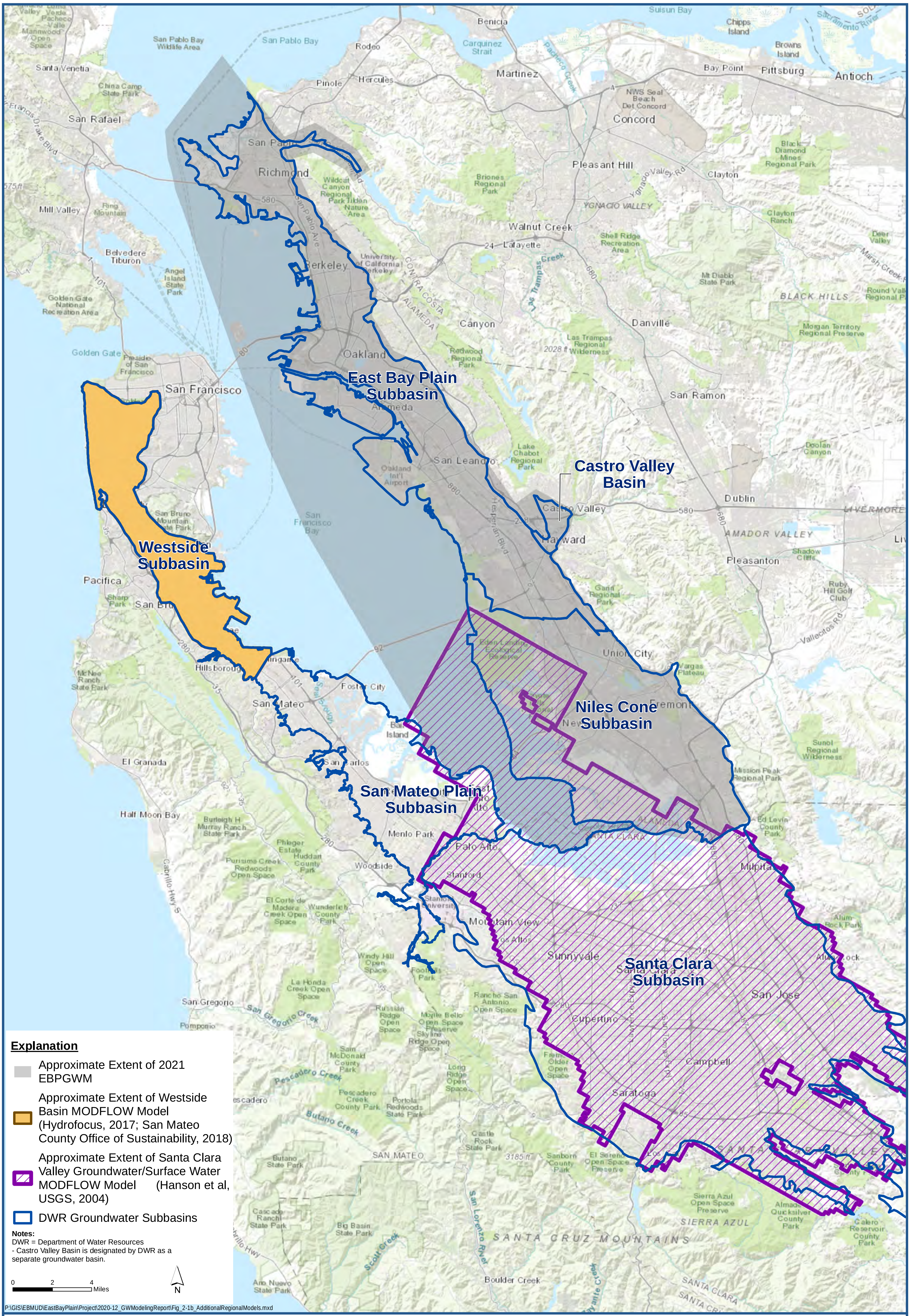


Notes:
DWR = Department of Water Resources
- Castro Valley Basin is designated by DWR as a separate groundwater basin.

P:\GIS\EBMUD\EastBayPlain\Project\2020-12_GWModelingReport\Fig_2-1a_GroundwaterModelDomains.mxd

Groundwater Model Domains that Include the East Bay Plain

Figure 2-1a



Notes:
DWR = Department of Water Resources
- Castro Valley Basin is designated by DWR as a separate groundwater basin.

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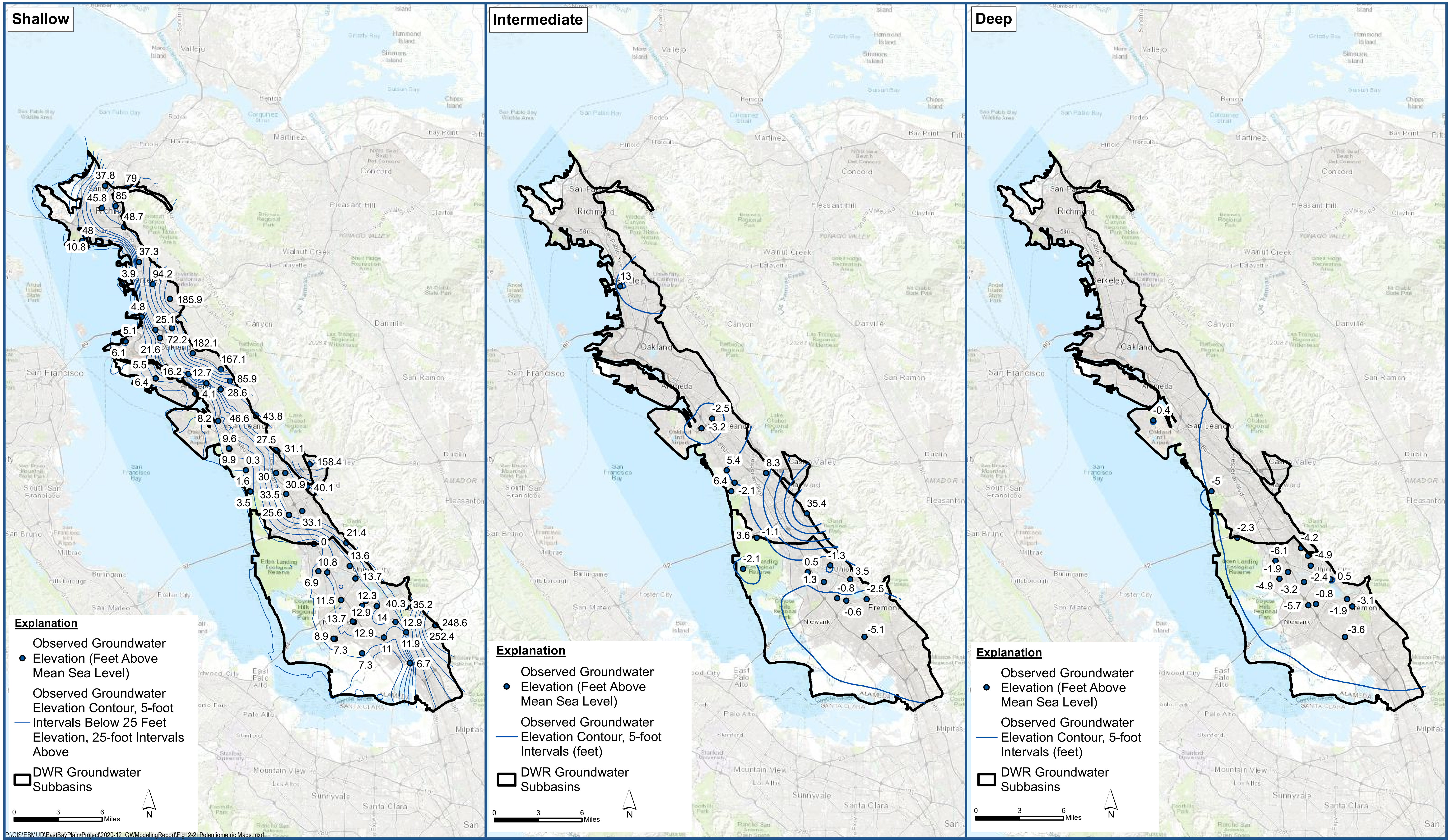
Additional Regional Models in the San Francisco Bay Area

East Bay Plain Groundwater Model
Groundwater Sustainability Plan

Figure 2-1b



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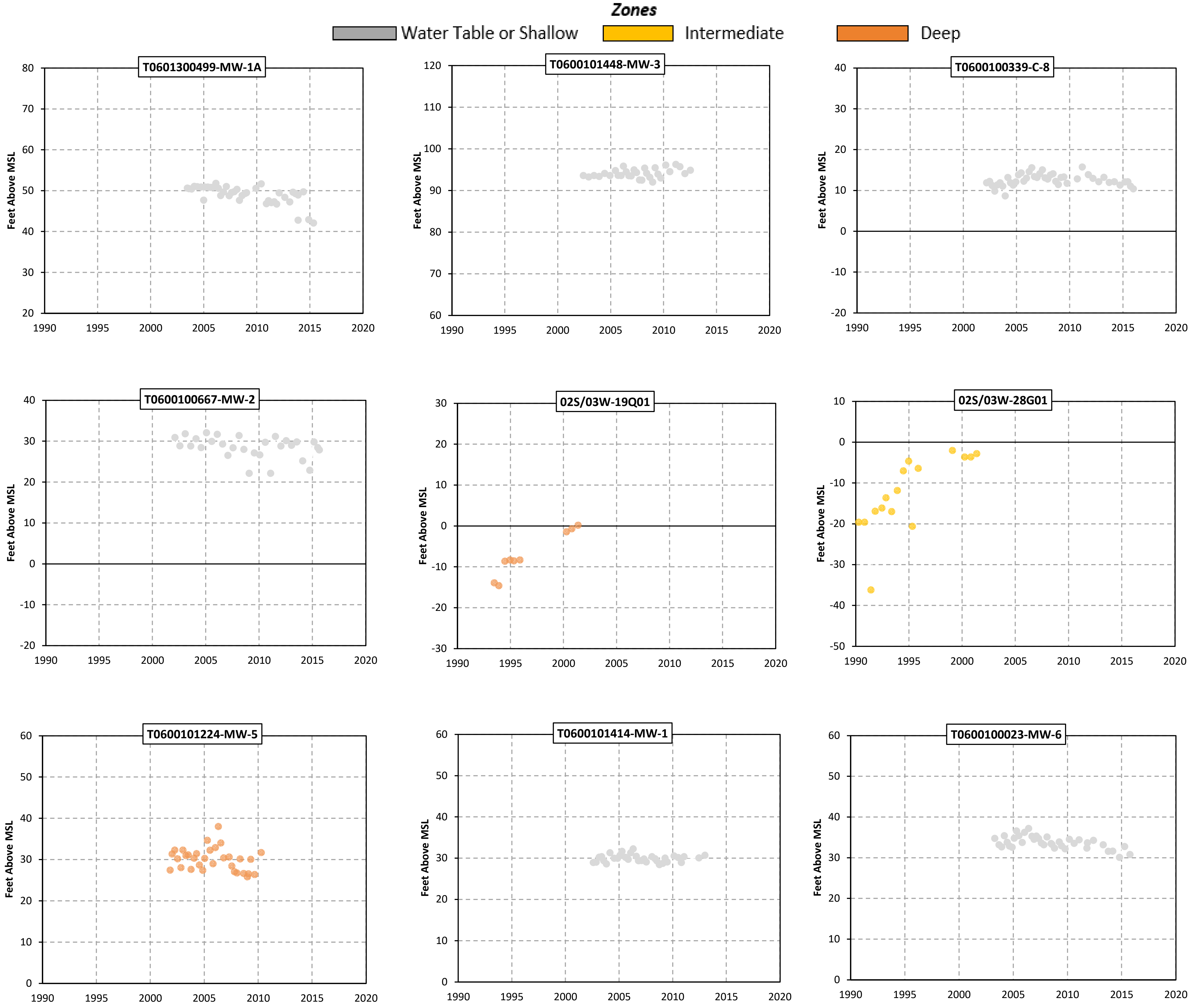
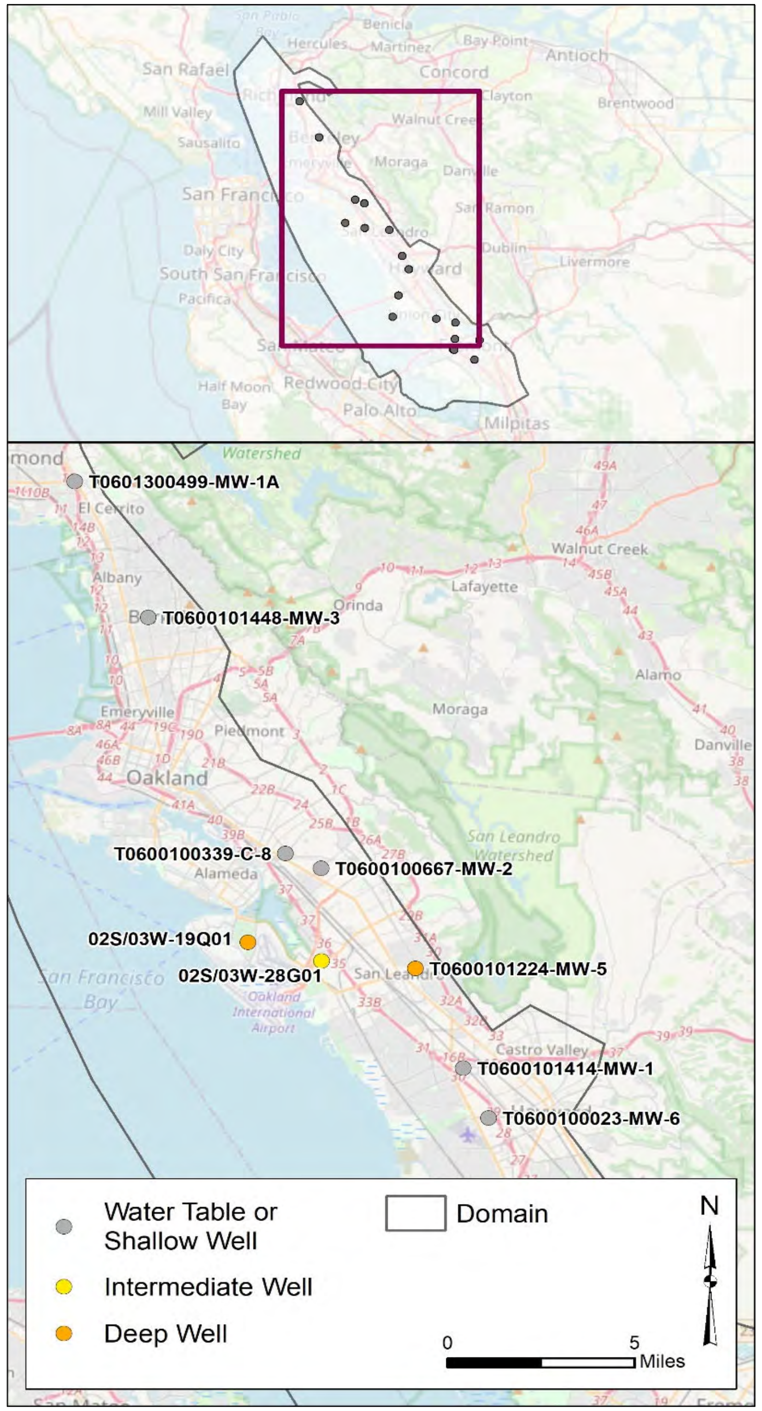
Potentiometric Maps Based on Averages of Observed Data Between 2000 and 2015

East Bay Plain Groundwater Model
Groundwater Sustainability Plan

Figure 2-2





Notes:
MSL = mean sea level

Hydrographs at Selected Monitoring Wells (North)

East Bay Plain Groundwater Model
Groundwater Sustainability Plan

LSCE TEAM

WR2668	March 2021

Figure
2-3a

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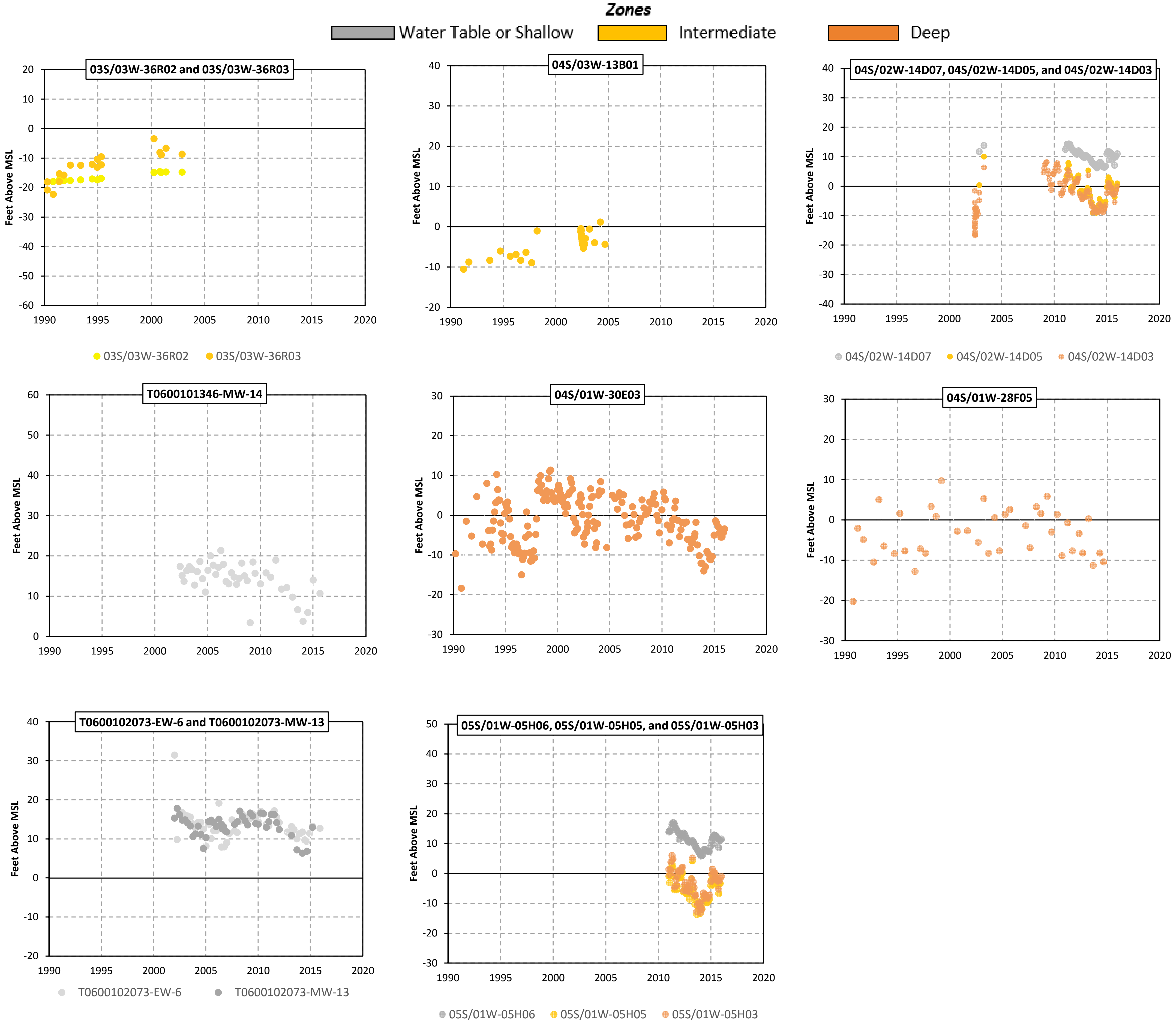
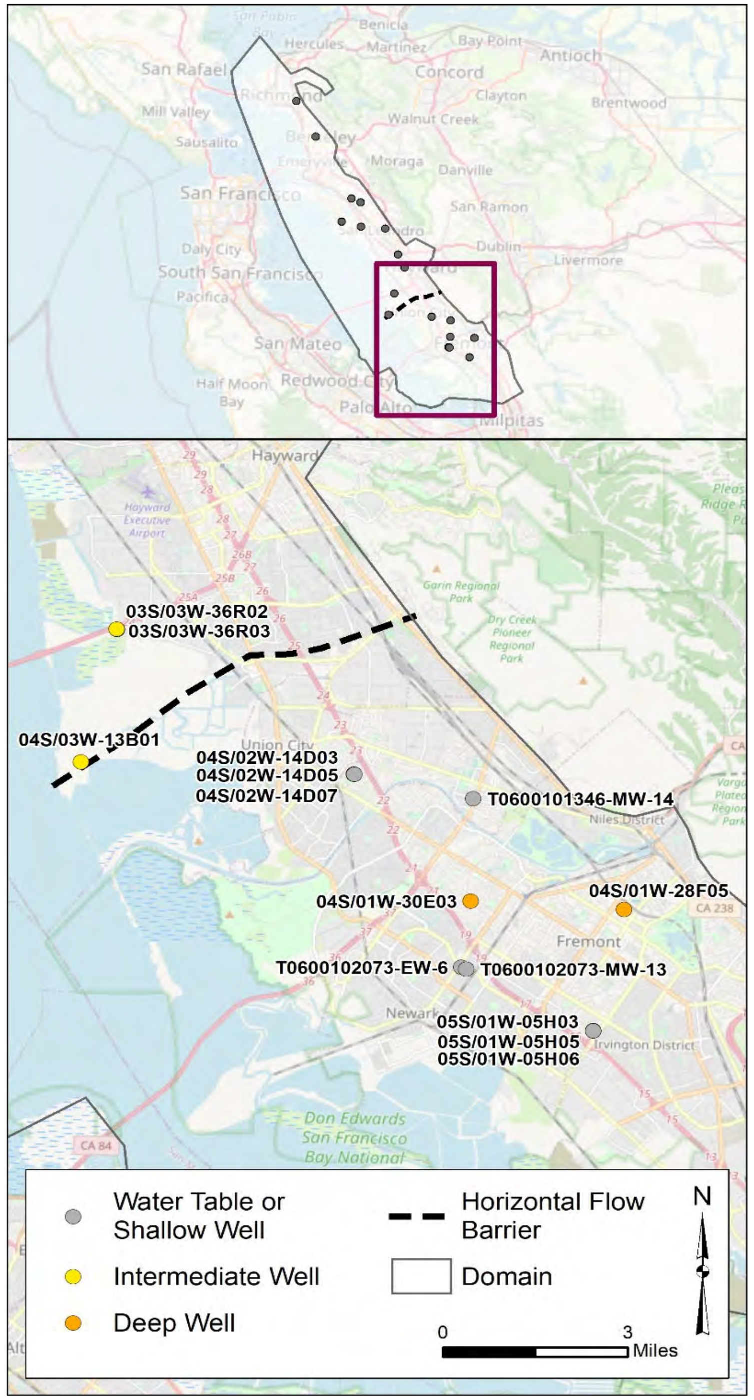




Notes:
MSL = mean sea level

Hydrographs at Selected Monitoring Wells (South)

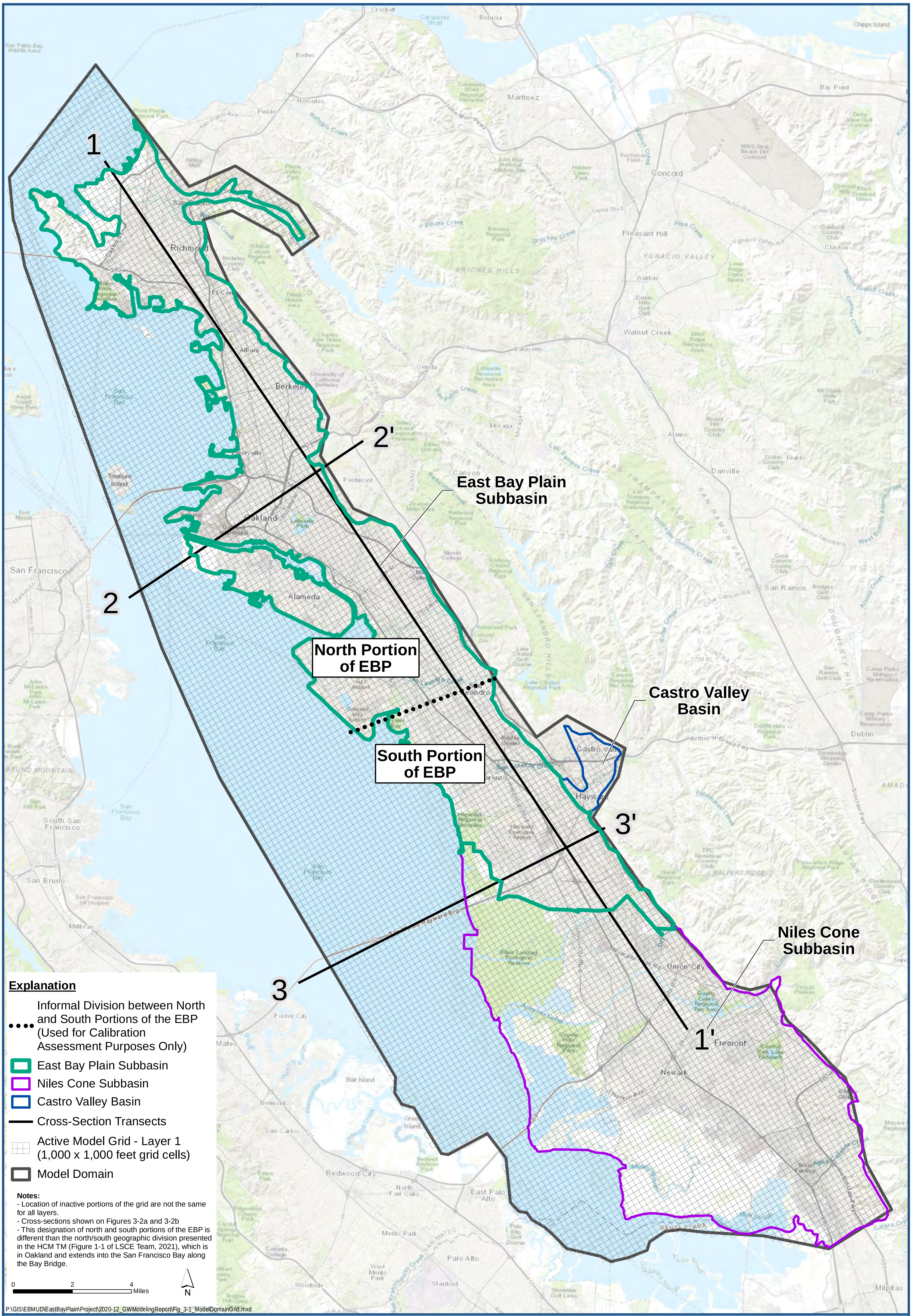
East Bay Plain Groundwater Model
Groundwater Sustainability Plan

LSCE TEAM

WR2668	March 2021

Figure

2-3b



Explanation

●●●● Informal Division between North and South Portions of the EBP (Used for Calibration Assessment Purposes Only)

🟩 East Bay Plain Subbasin

🟪 Niles Cone Subbasin

🟦 Castro Valley Basin

— Cross-Section Transects

▦ Active Model Grid - Layer 1 (1,000 x 1,000 feet grid cells)

▢ Model Domain

Notes:
- Location of inactive portions of the grid are not the same for all layers.
- Cross-sections shown on Figures 3-2a and 3-2b
- This designation of north and south portions of the EBP is different than the north/south geographic division presented in the HCM TM (Figure 1-1 of LSCE Team, 2021), which is in Oakland and extends into the San Francisco Bay along the Bay Bridge.

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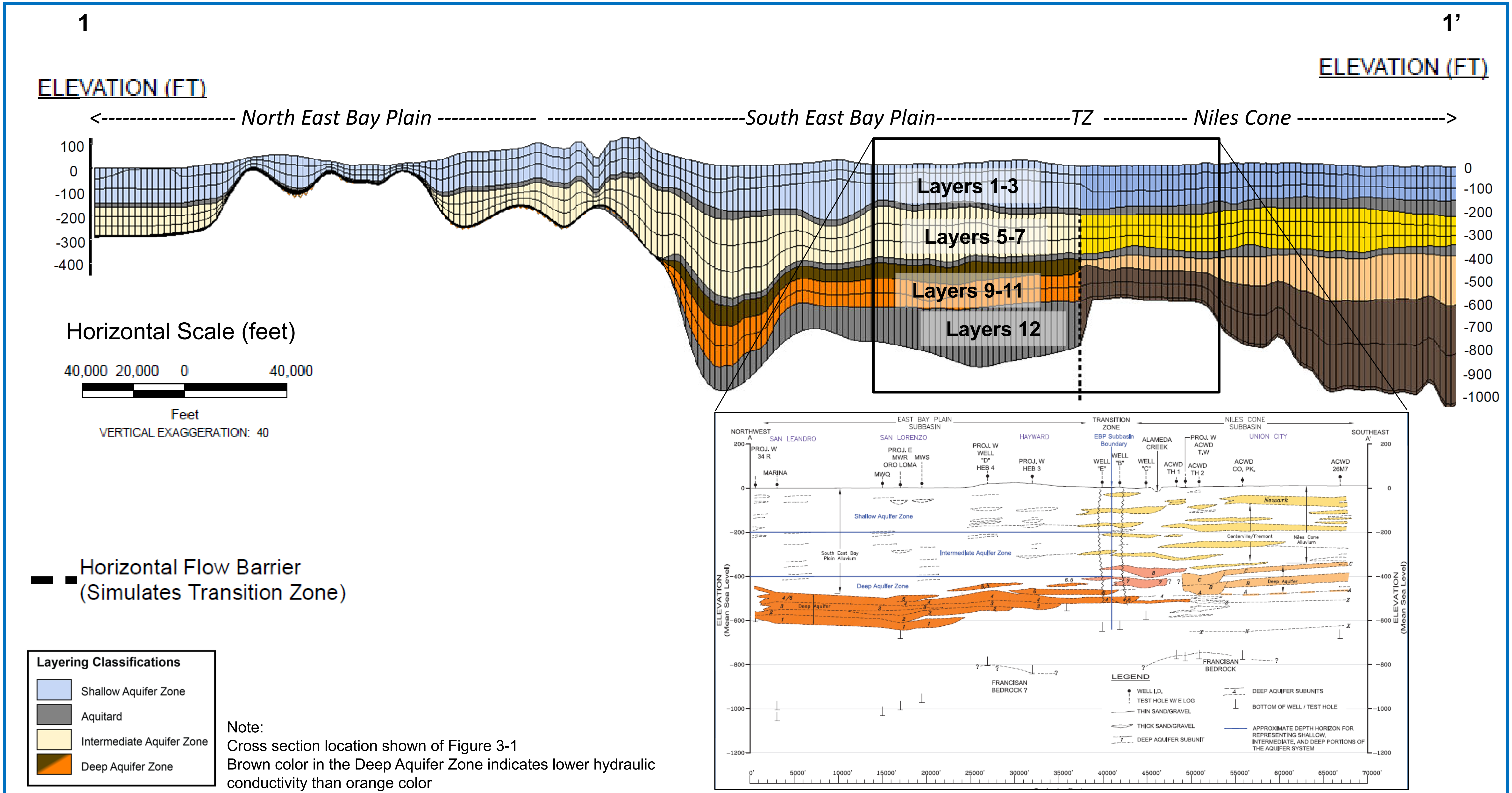
LSCE TEAM

Model Domain and Grid

East Bay Plain Groundwater Model
Groundwater Sustainability Plan

Figure 3-1



Note:
Cross section location shown of Figure 3-1
Brown color in the Deep Aquifer Zone indicates lower hydraulic conductivity than orange color

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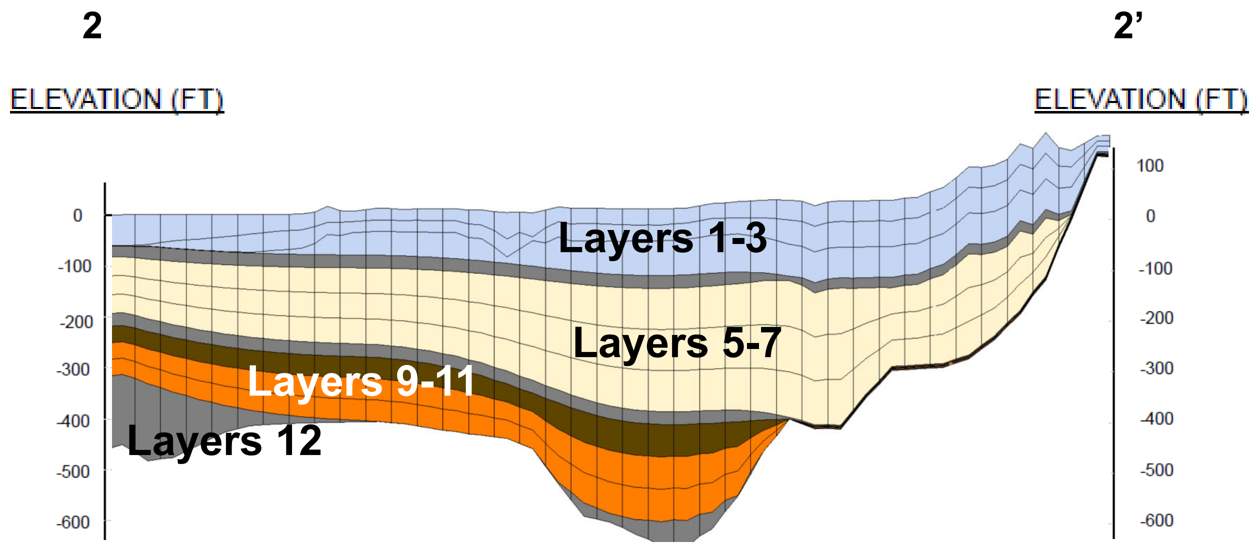
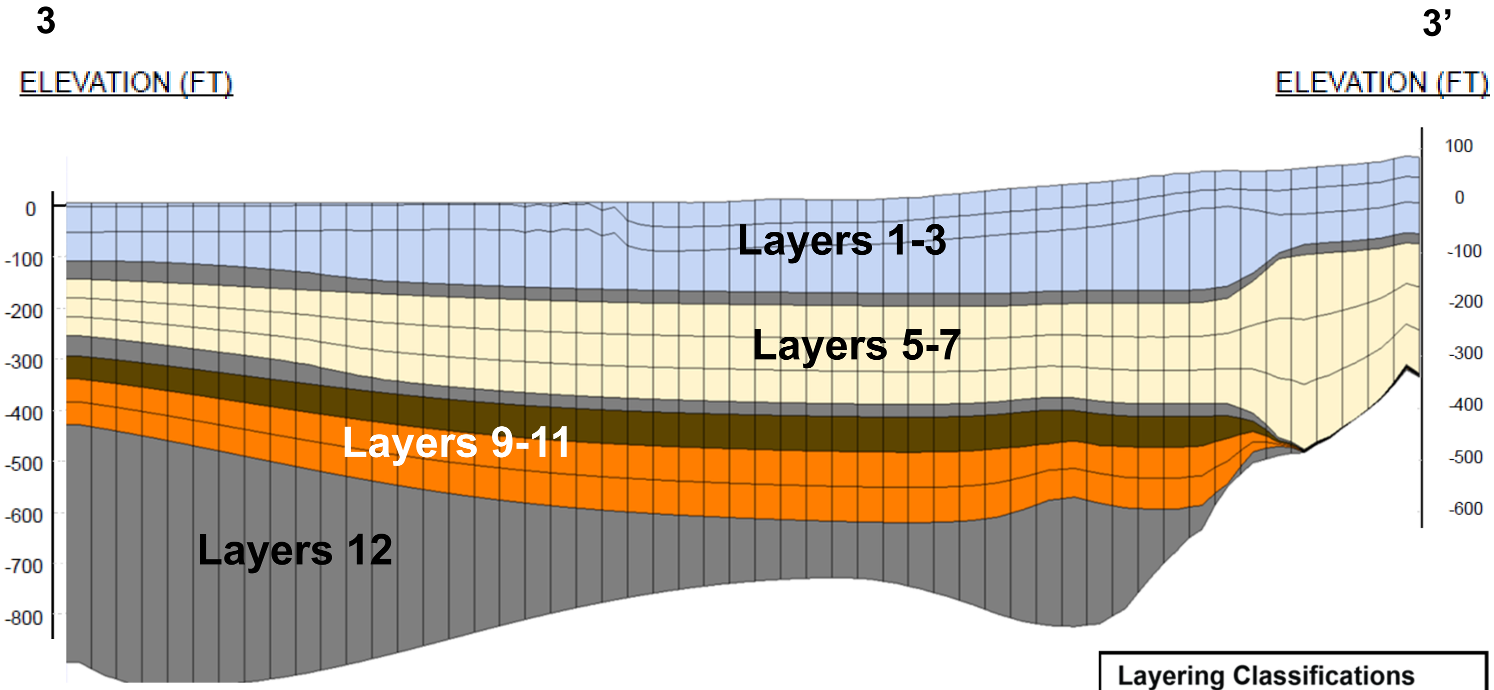
NNW – SSE Cross Section Showing Model Layers

Figure 3-2a

East Bay Plain Groundwater Model
Groundwater Sustainability Plan





Layering Classifications

- 🟦 Shallow Aquifer Zone
- ⬛ Aquitard
- 🟨 Intermediate Aquifer Zone
- 🟧 Deep Aquifer Zone

Horizontal Scale (feet)

4,000 2,000 0 4,000

Feet

VERTICAL EXAGGERATION: 20

Note:
Cross section location shown of Figure 3-1
Brown color in the Deep Aquifer Zone indicates lower hydraulic conductivity than orange color

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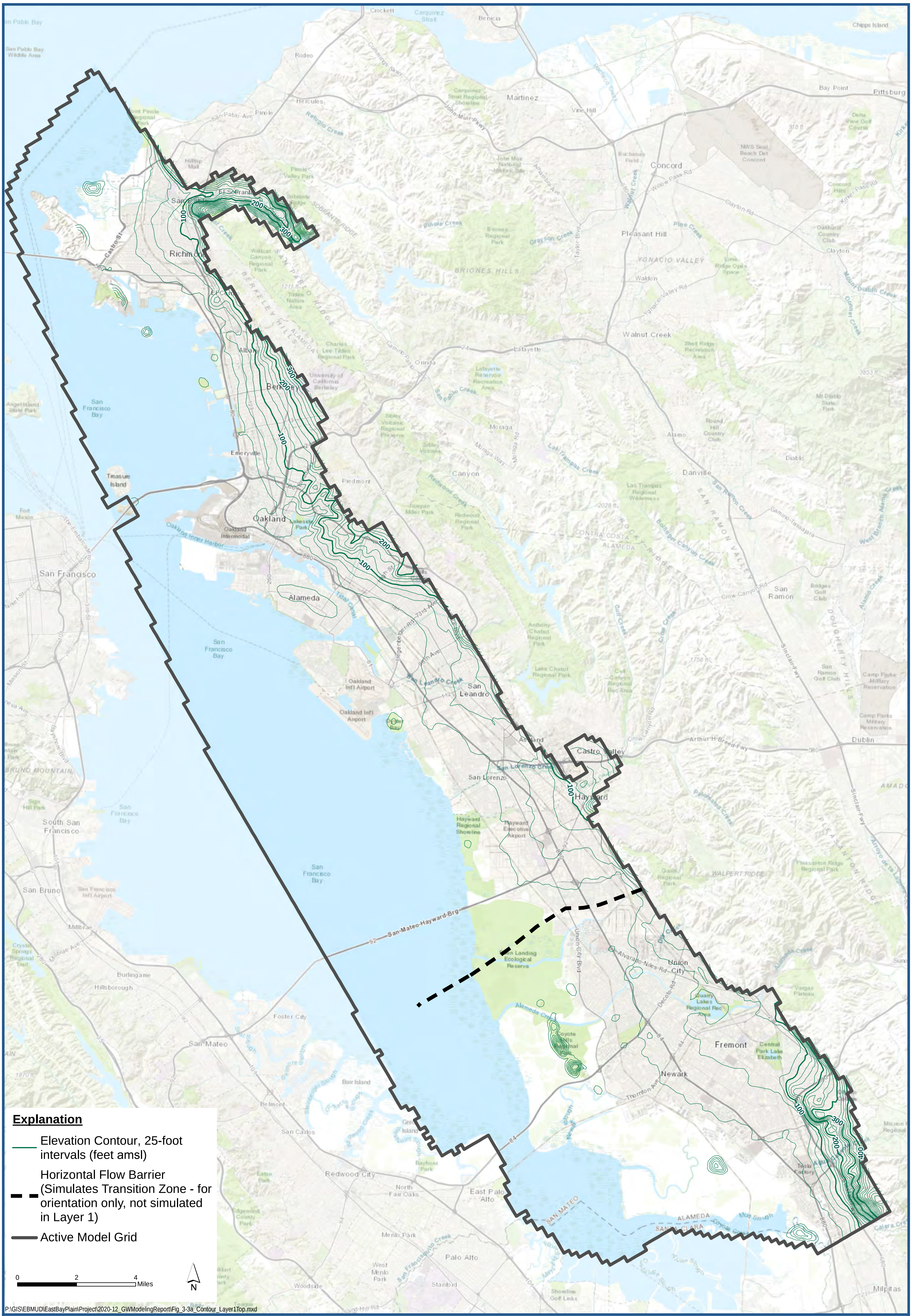
Two WSW – ENE Cross Sections Showing Model Layers

Figure 3-2b

East Bay Plain Groundwater Model
Groundwater Sustainability Plan



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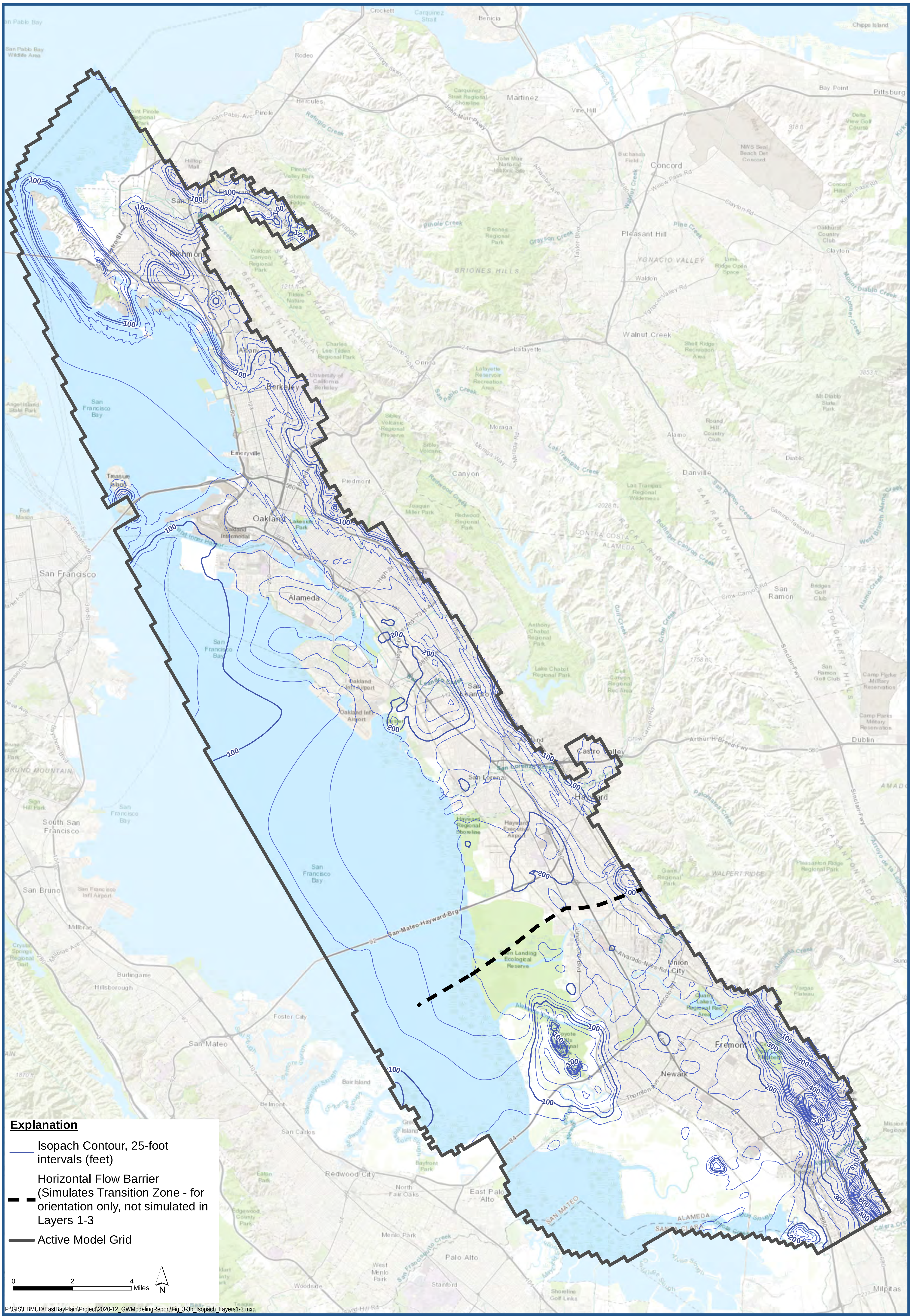
Contour Map of Top of Layer 1 Elevation

East Bay Plain Groundwater Model
Groundwater Sustainability Plan

Figure 3-3a

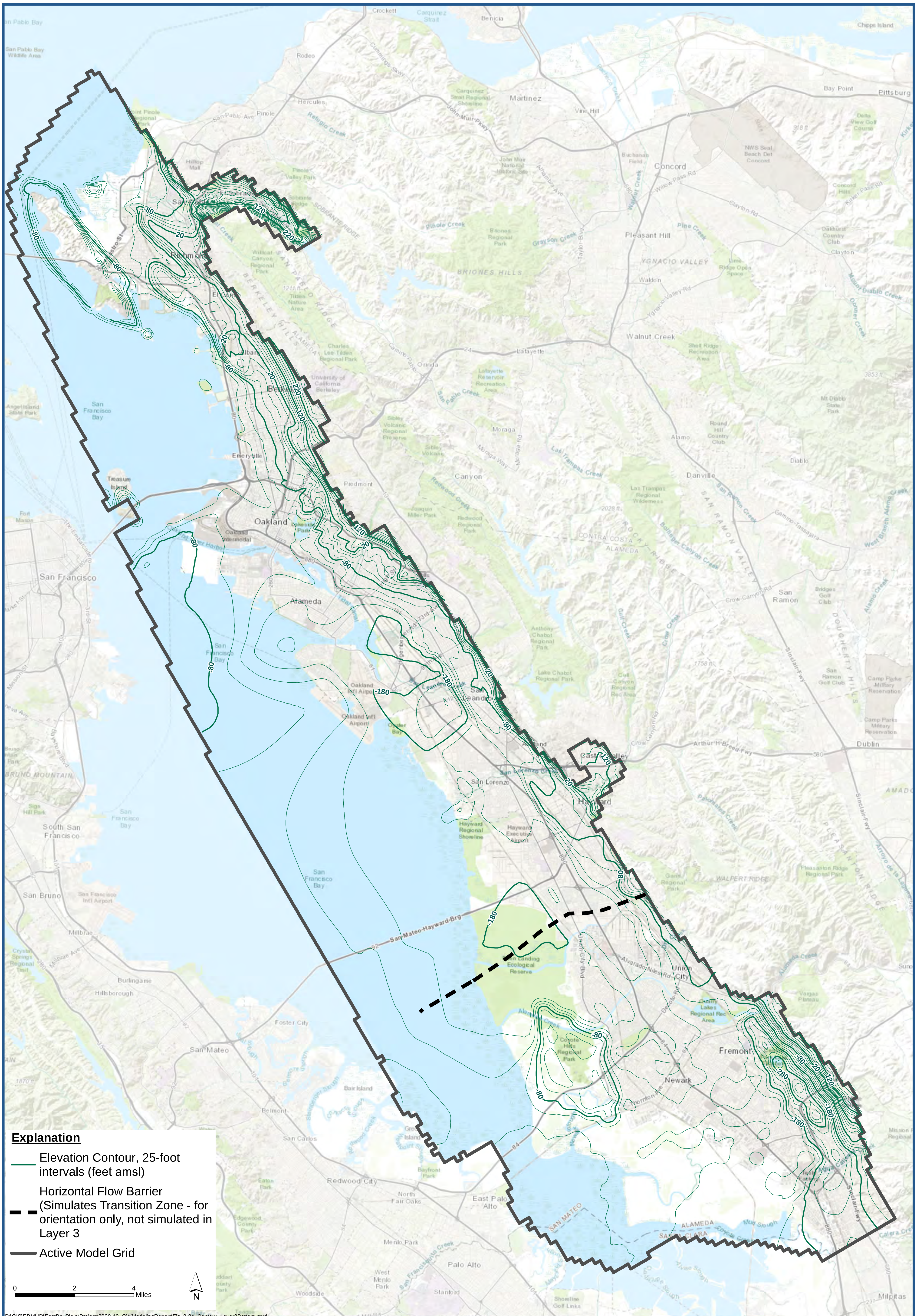


Isopach Map of Shallow Aquifer Zone (Layers 1-3)

East Bay Plain Groundwater Model
Groundwater Sustainability Plan

Figure 3-3b

LSCE TEAM



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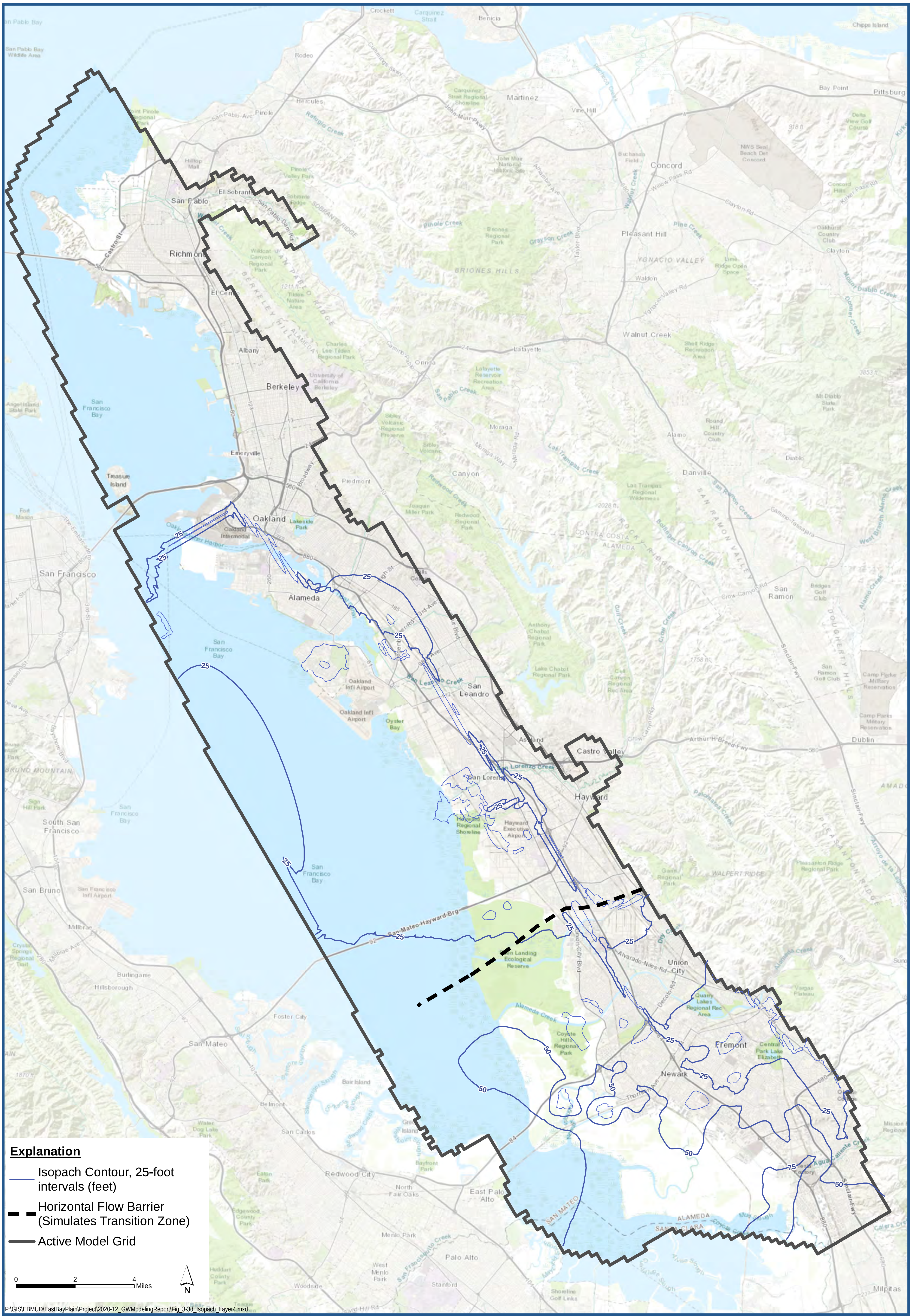
Contour Map of Bottom of Layer 3 Elevation

East Bay Plain Groundwater Model
Groundwater Sustainability Plan

Figure 3-3c



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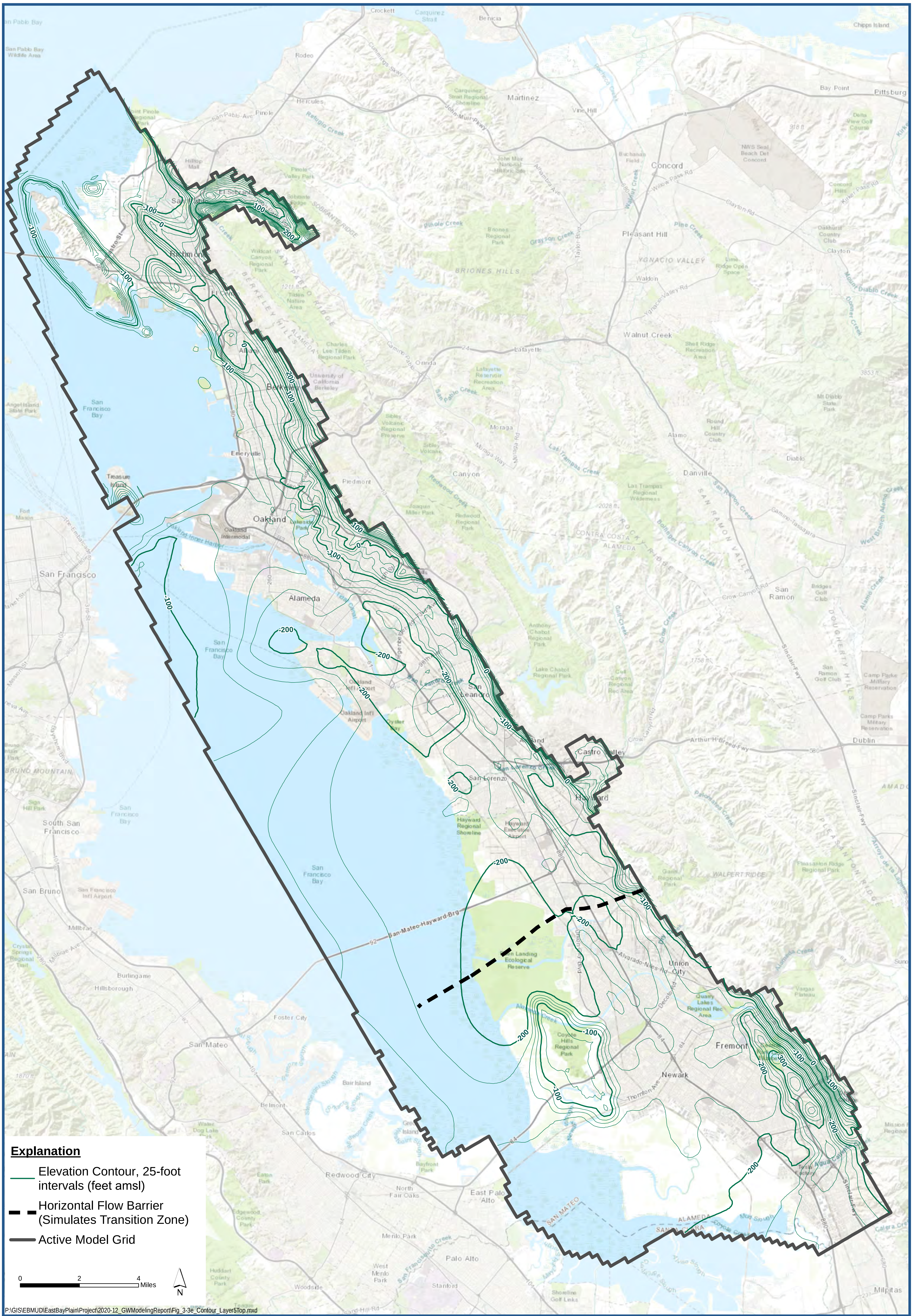
Isopach Map of Aquitard between Shallow and Intermediate Aquifer Zones (Layer 4)

East Bay Plain Groundwater Model
Groundwater Sustainability Plan

Figure 3-3d



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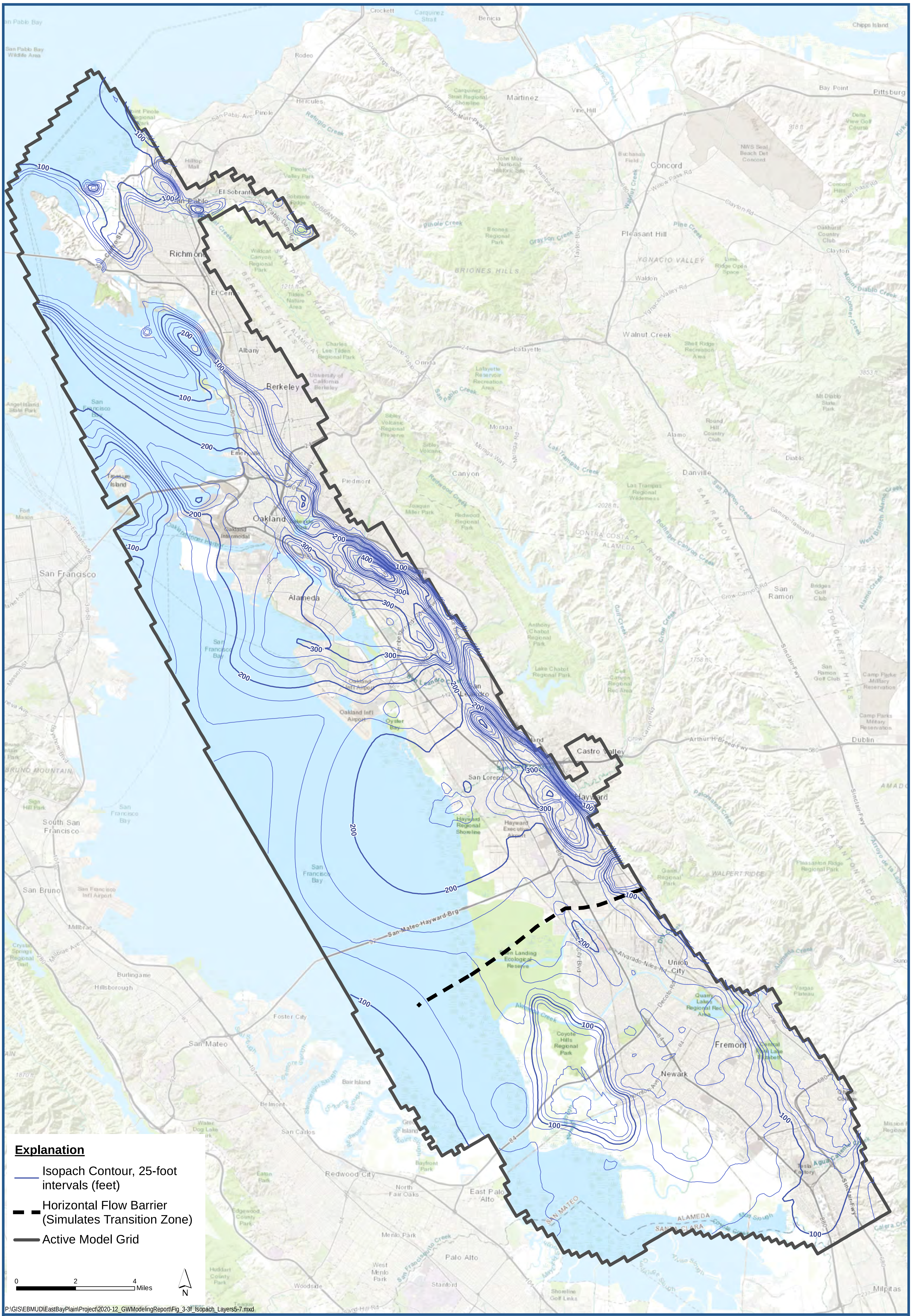
Contour Map of Top of Layer 5 Elevation

East Bay Plain Groundwater Model
Groundwater Sustainability Plan

Figure 3-3e



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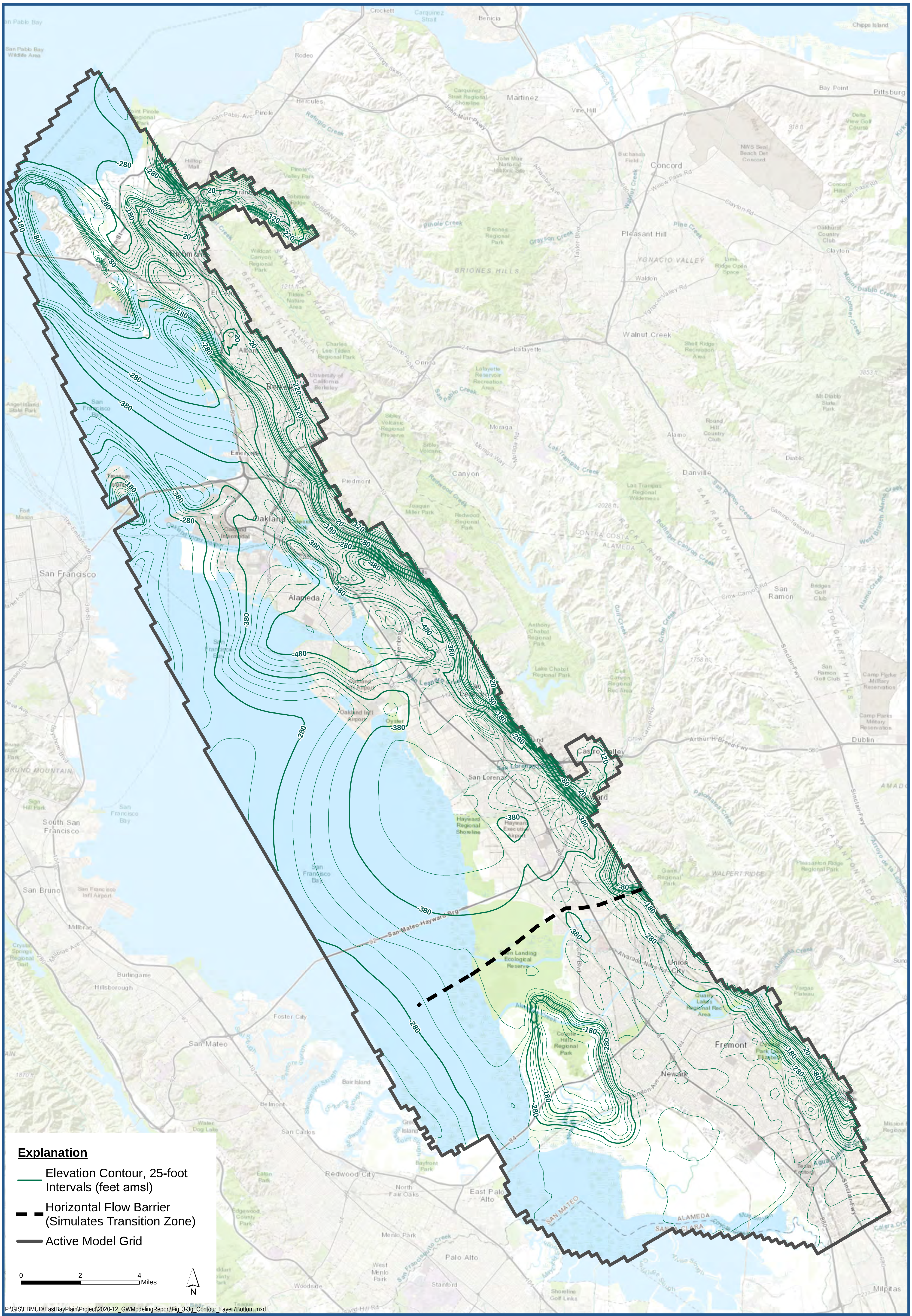
LSCE TEAM

Isopach Map of Intermediate Aquifer Zone (Layers 5-7)

East Bay Plain Groundwater Model
Groundwater Sustainability Plan

Figure 3-3f

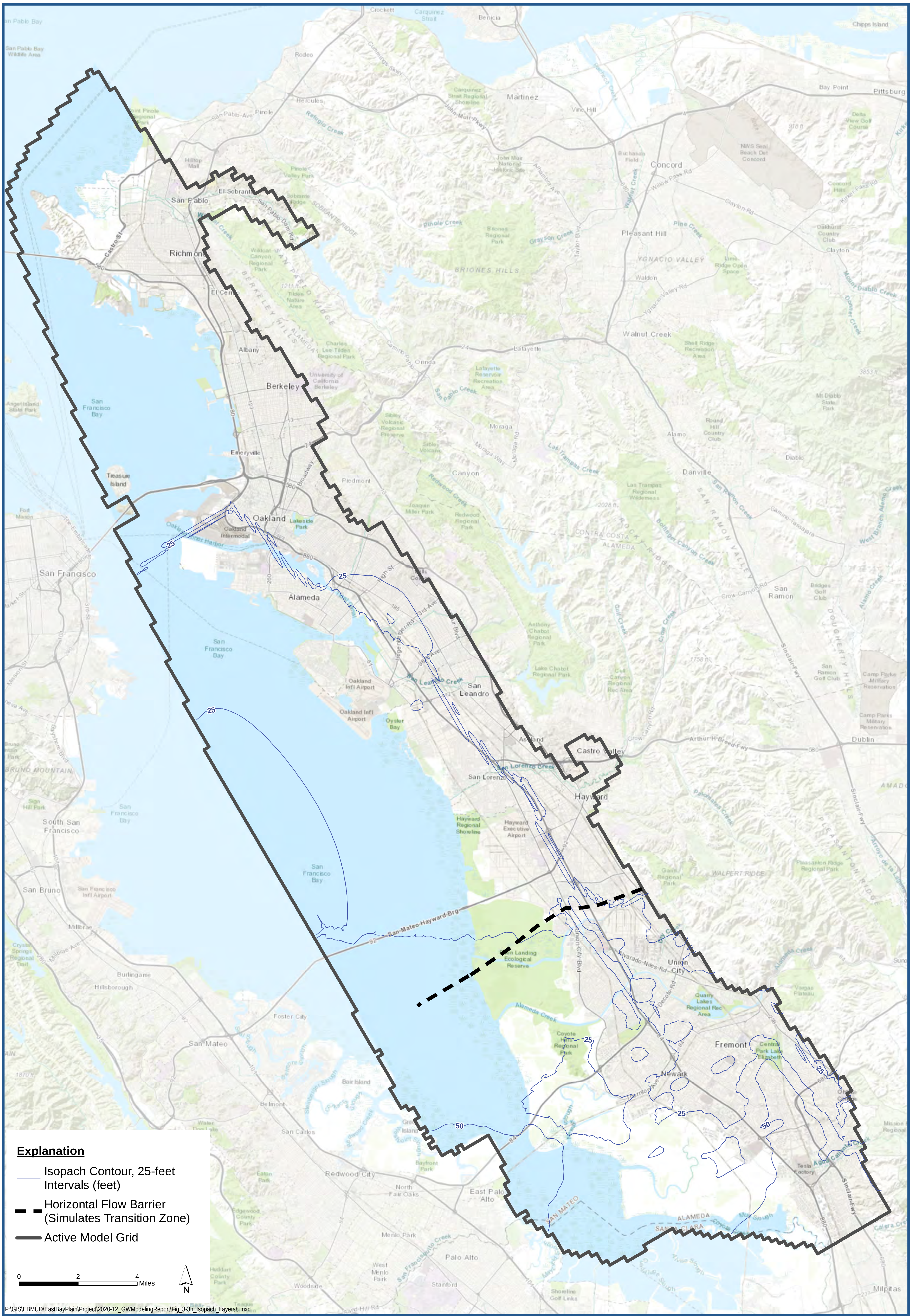


LSCE TEAM

Contour Map of Bottom of Layer 7 Elevation

East Bay Plain Groundwater Model
Groundwater Sustainability Plan

Figure 3-3g



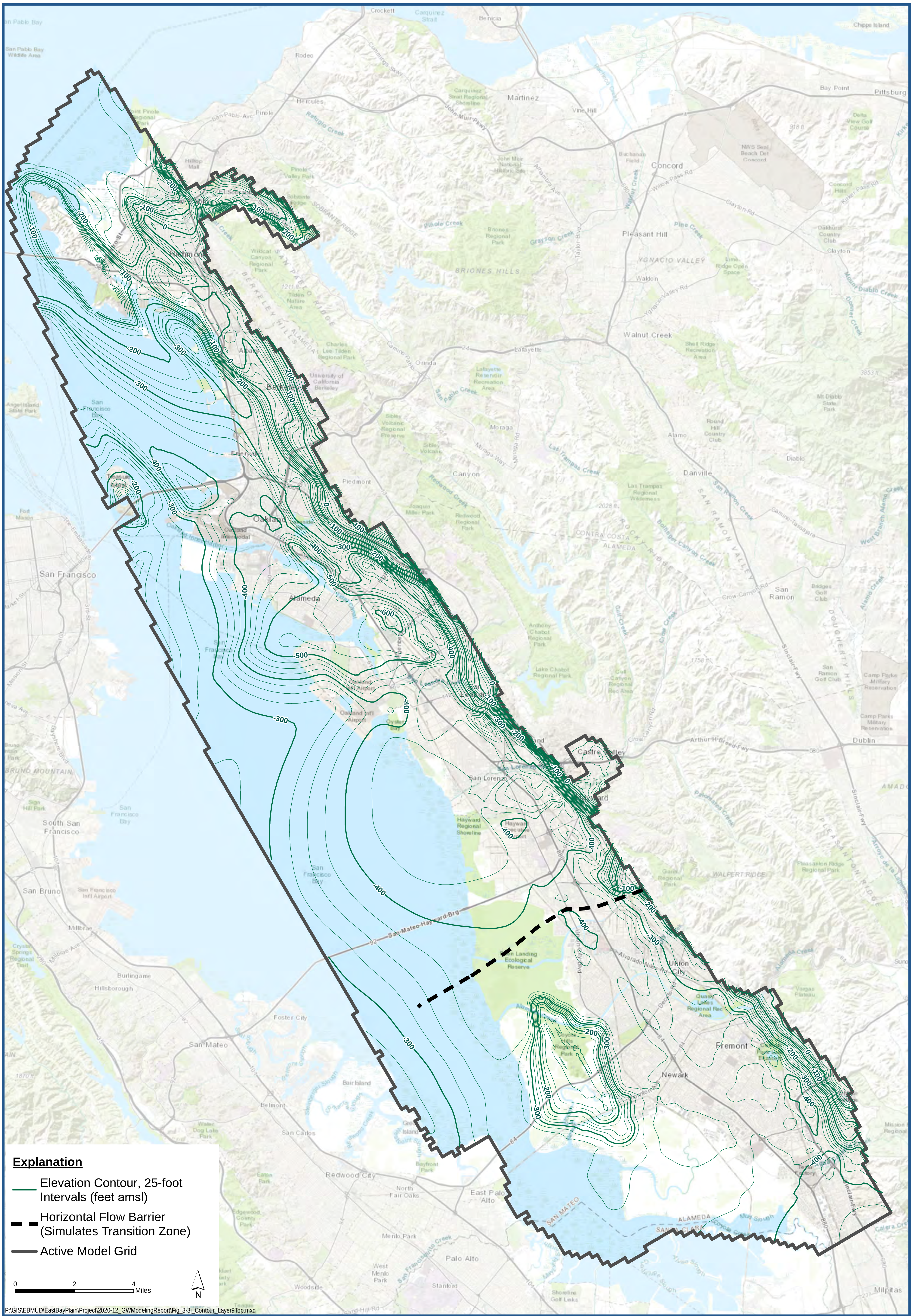
P:\GIS\EBMUD\EastBayPlain\Project\2020-12_GWModelingReport\Fig_3-3h_Isopach_Layers8.mxd

LSCE TEAM

Isopach Map of Aquitard between Intermediate and Deep Aquifer Zones (Layers 8)

East Bay Plain Groundwater Model
Groundwater Sustainability Plan

Figure 3-3h



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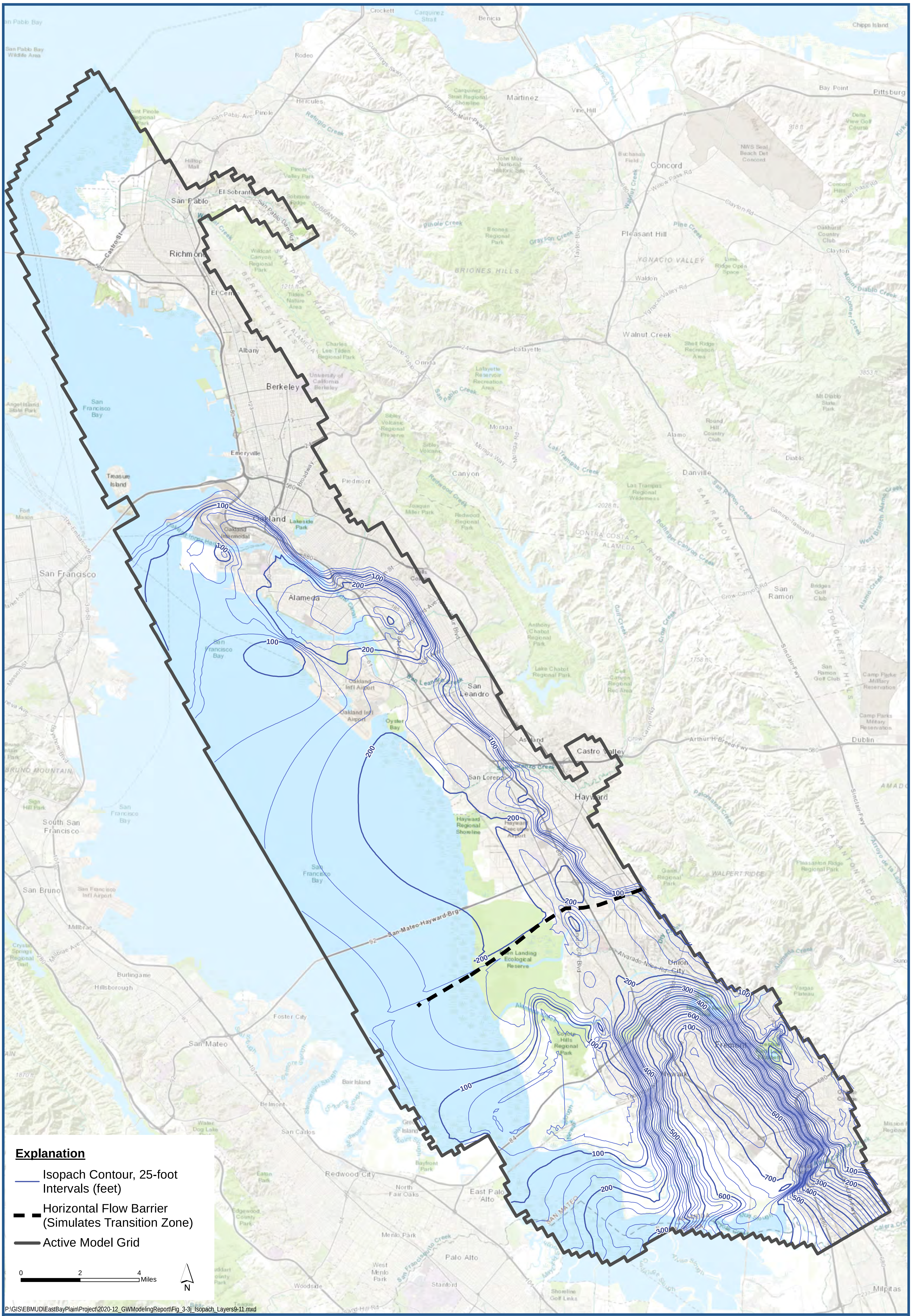
LSCE TEAM

Contour Map of Top of Layer 9 Elevation

East Bay Plain Groundwater Model
Groundwater Sustainability Plan

Figure 3-3i

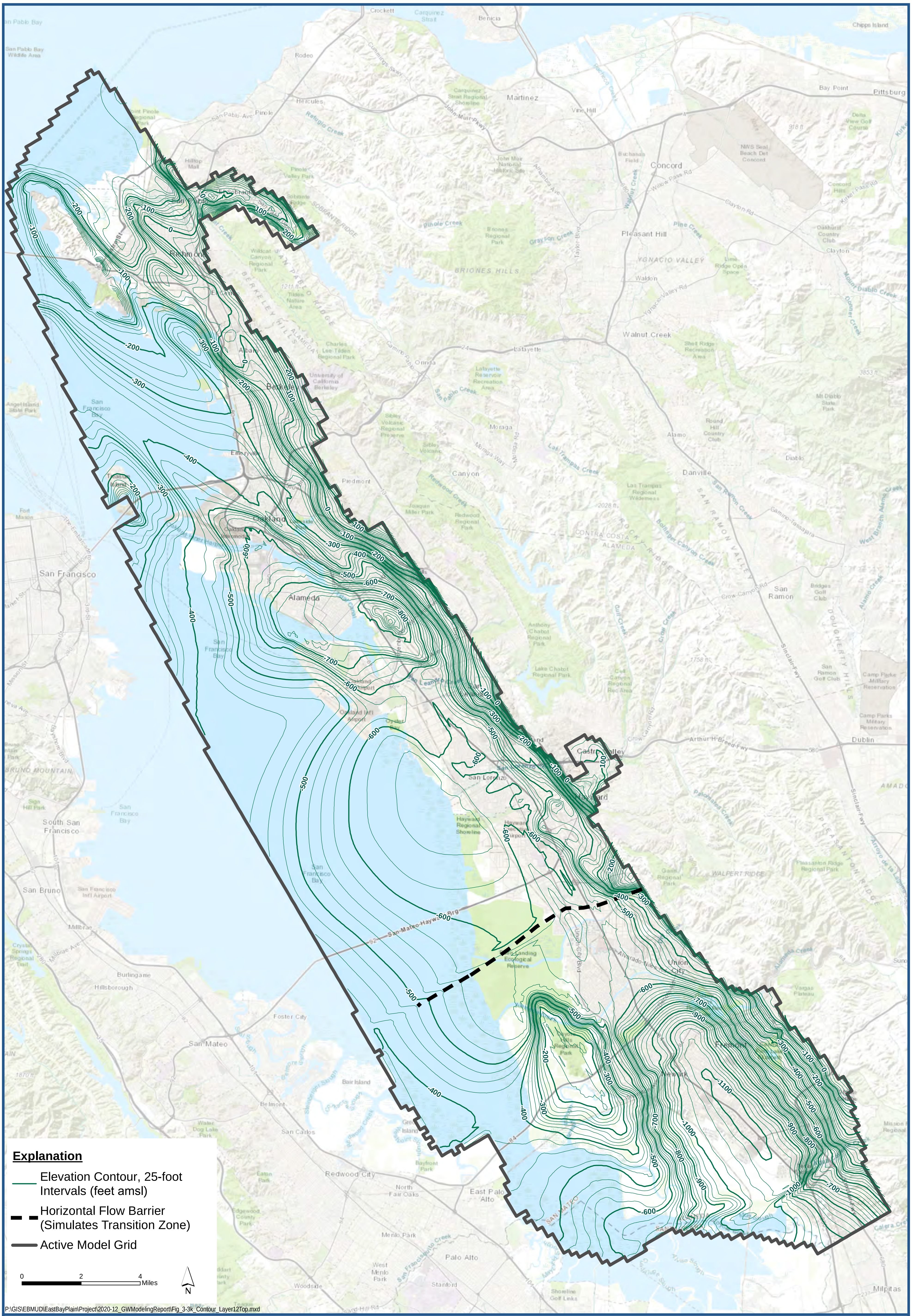


LSCE TEAM

Isopach Map of Deep Aquifer Zone (Layers 9-11)

East Bay Plain Groundwater Model
Groundwater Sustainability Plan

Figure 3-3j



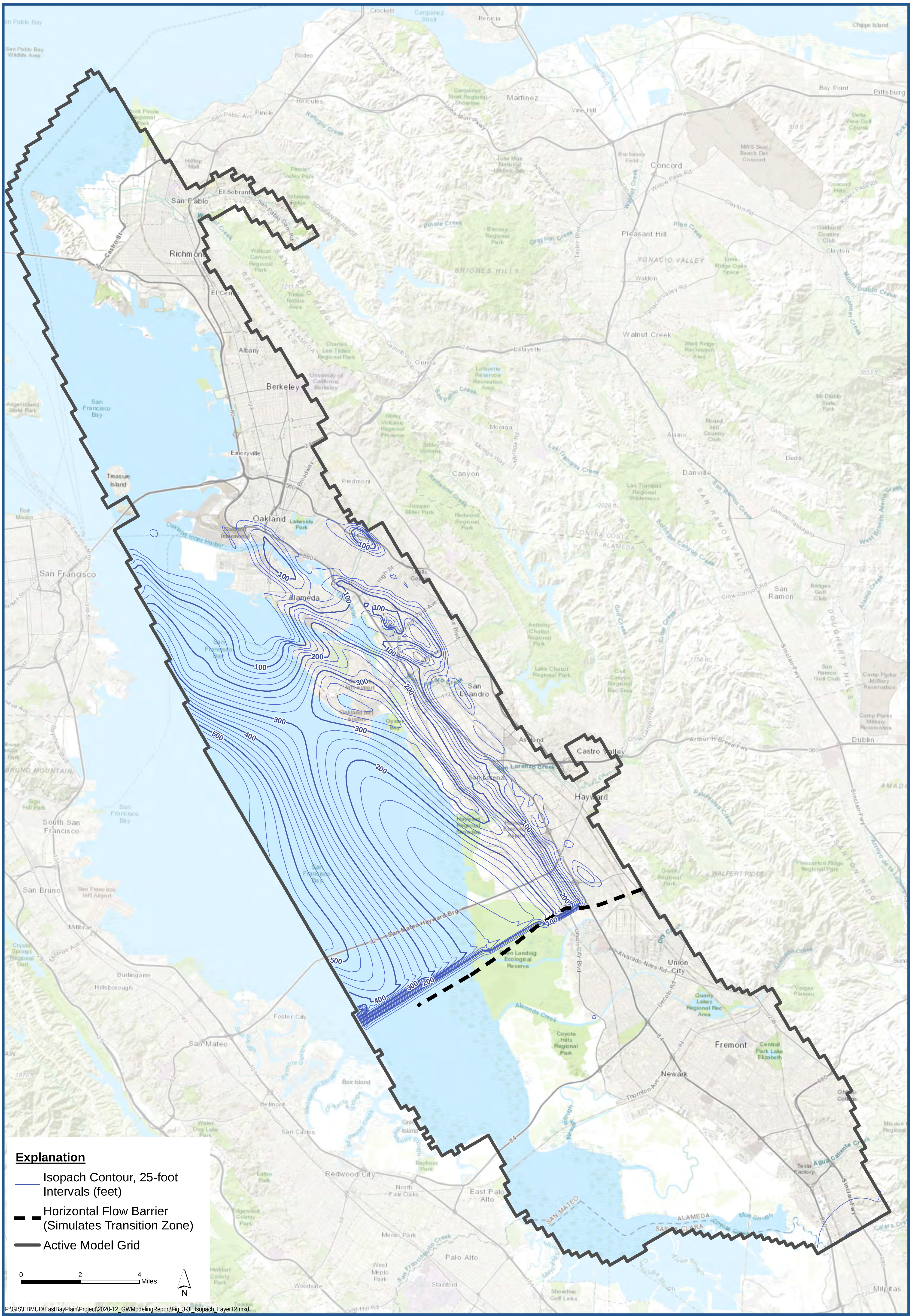
P:\GIS\EBMUD\EastBayPlain\Project\2020-12_GWModelingReport\Fig_3-3k_Contour_Layer12Top.mxd

LSCE TEAM

Contour Map of Top of Layer 12 Elevation

East Bay Plain Groundwater Model
Groundwater Sustainability Plan

Figure 3-3k



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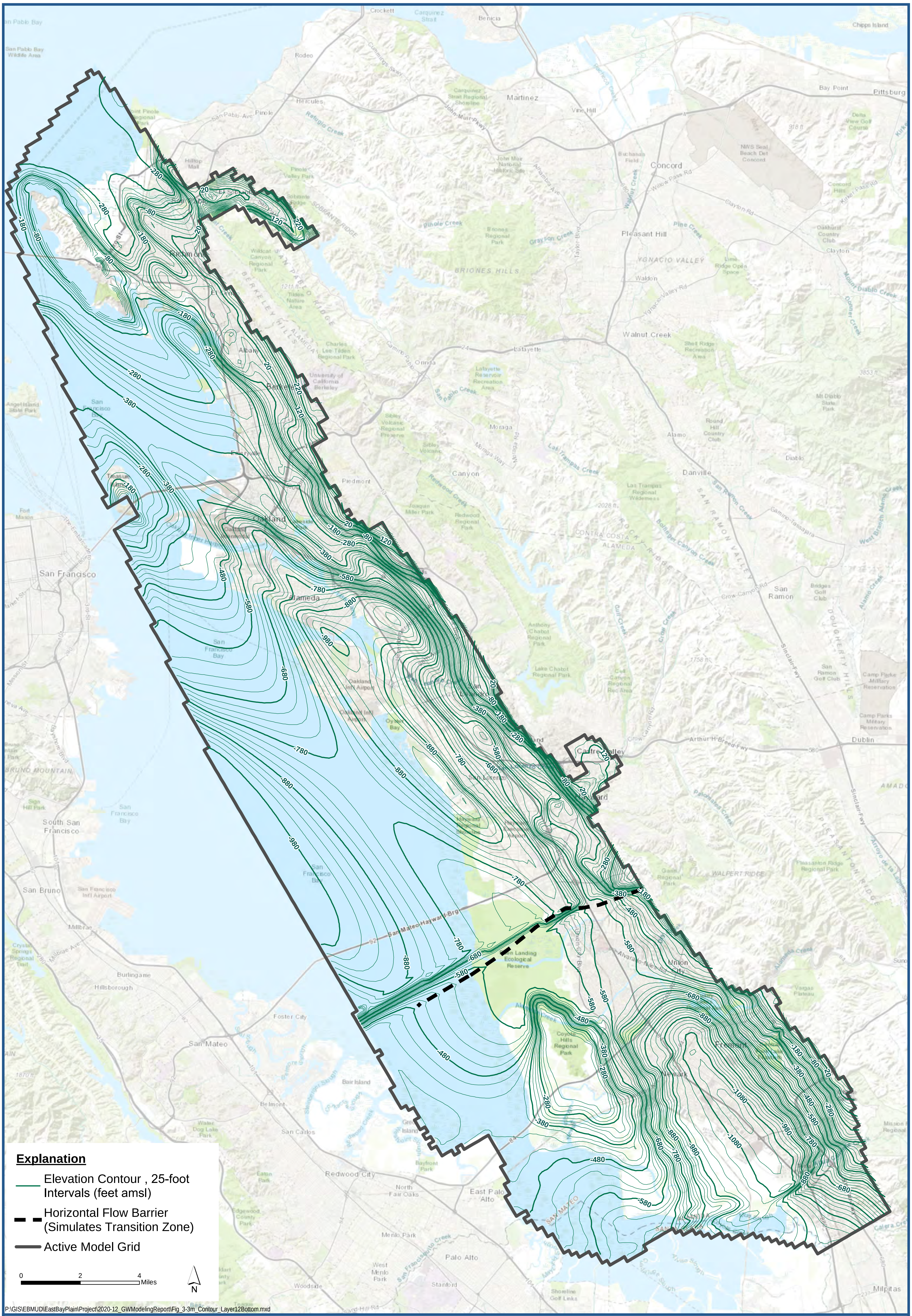
LSCE TEAM

Isopach Map of Layer 12

East Bay Plain Groundwater Model
Groundwater Sustainability Plan

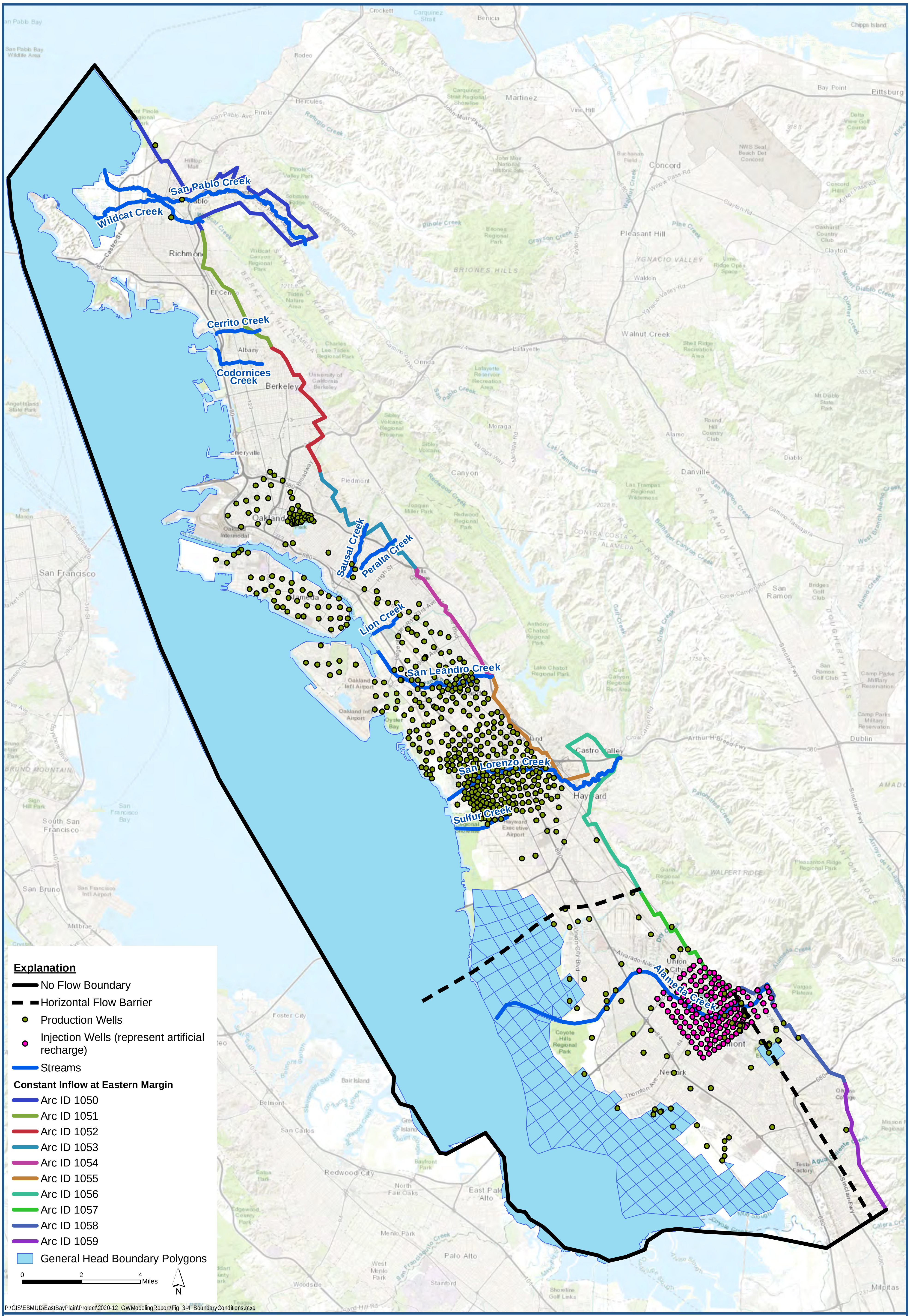
Figure 3-3l



Contour Map of Base of Layer 12 Elevation (Bottom of Model)

East Bay Plain Groundwater Model
Groundwater Sustainability Plan

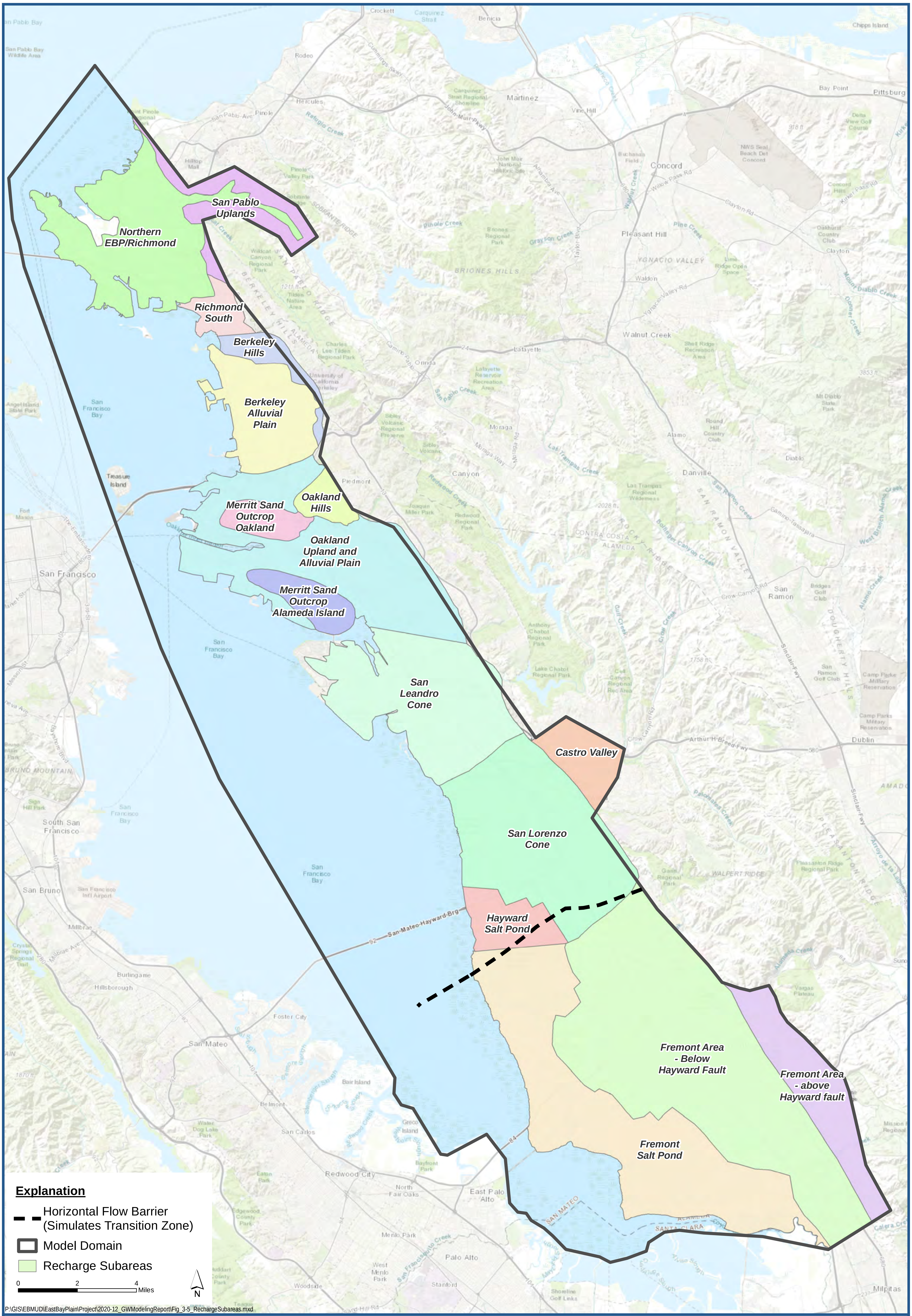
Figure 3-3m



Boundary Conditions

East Bay Plain Groundwater Model
Groundwater Sustainability Plan

Figure 3-4

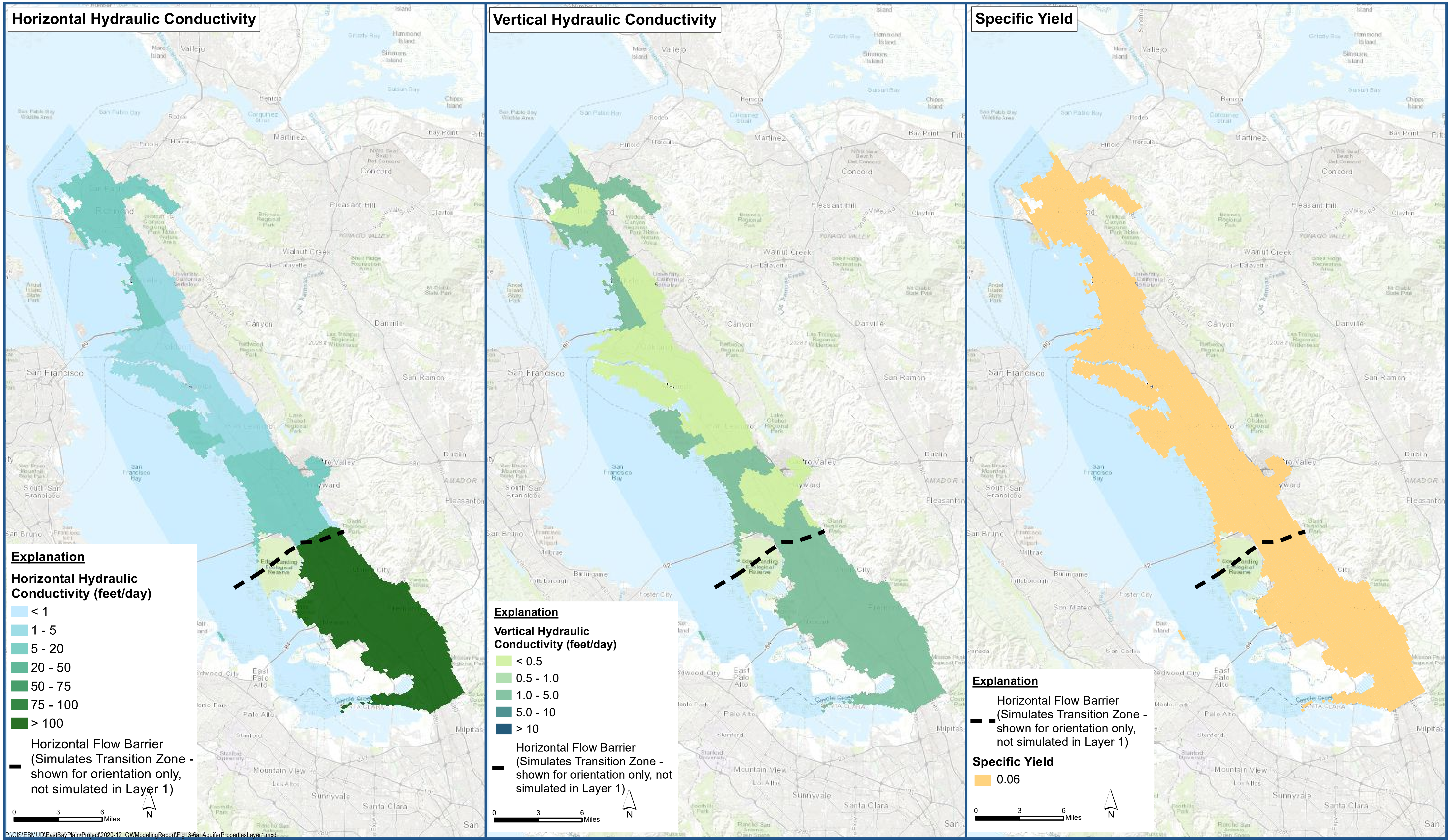


LSCE TEAM

Recharge Subareas

East Bay Plain Groundwater Model
Groundwater Sustainability Plan

Figure 3-5

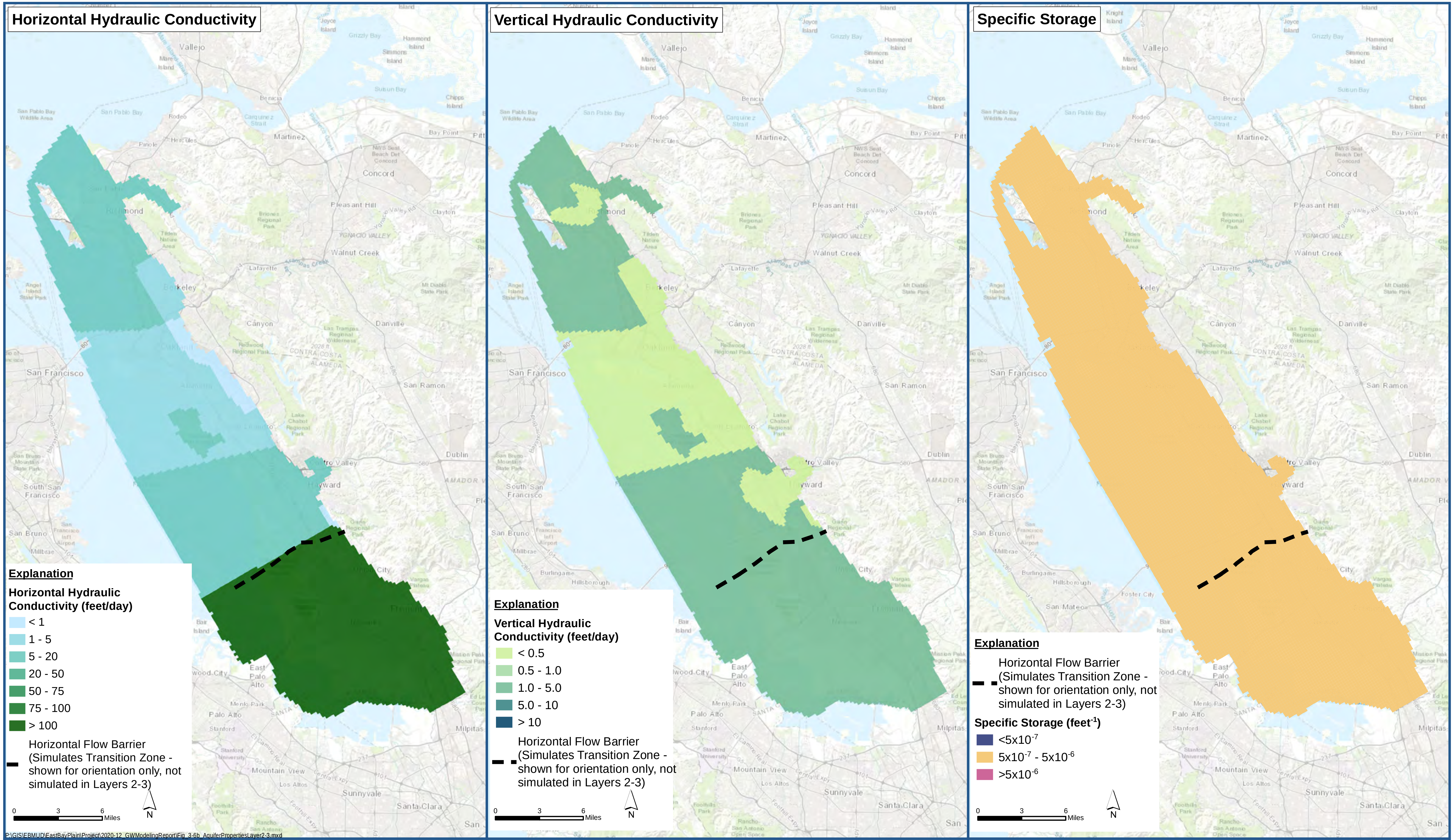


LSCE TEAM

Aquifer Properties - Layer 1

East Bay Plain Groundwater Model
Groundwater Sustainability Plan

Figure 3-6a

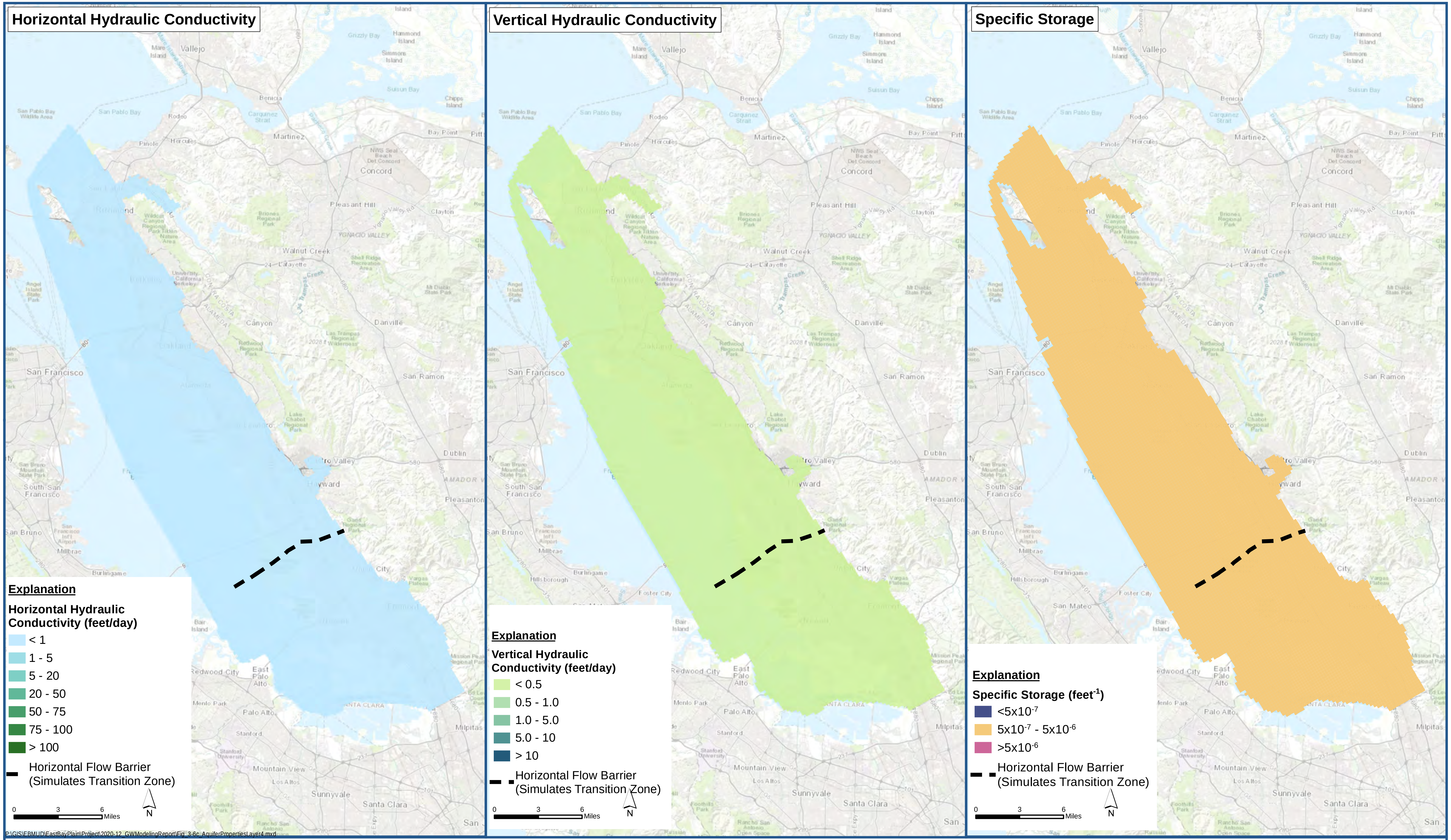


LSCE TEAM

Aquifer Properties - Layer 2 and 3

East Bay Plain Groundwater Model
Groundwater Sustainability Plan

Figure 3-6b

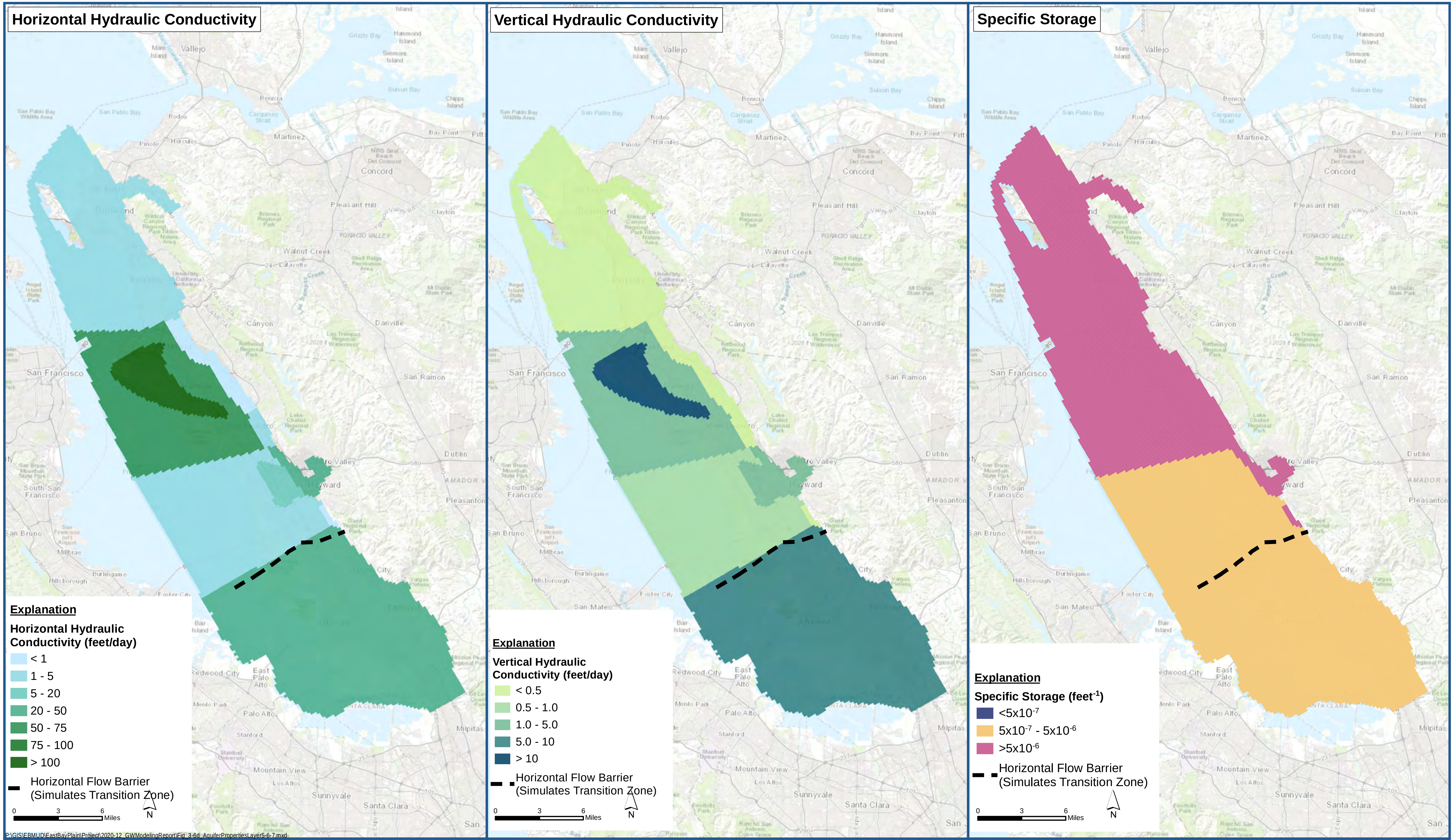


LSCE TEAM

Aquifer Properties - Layer 4

East Bay Plain Groundwater Model
Groundwater Sustainability Plan

Figure 3-6c

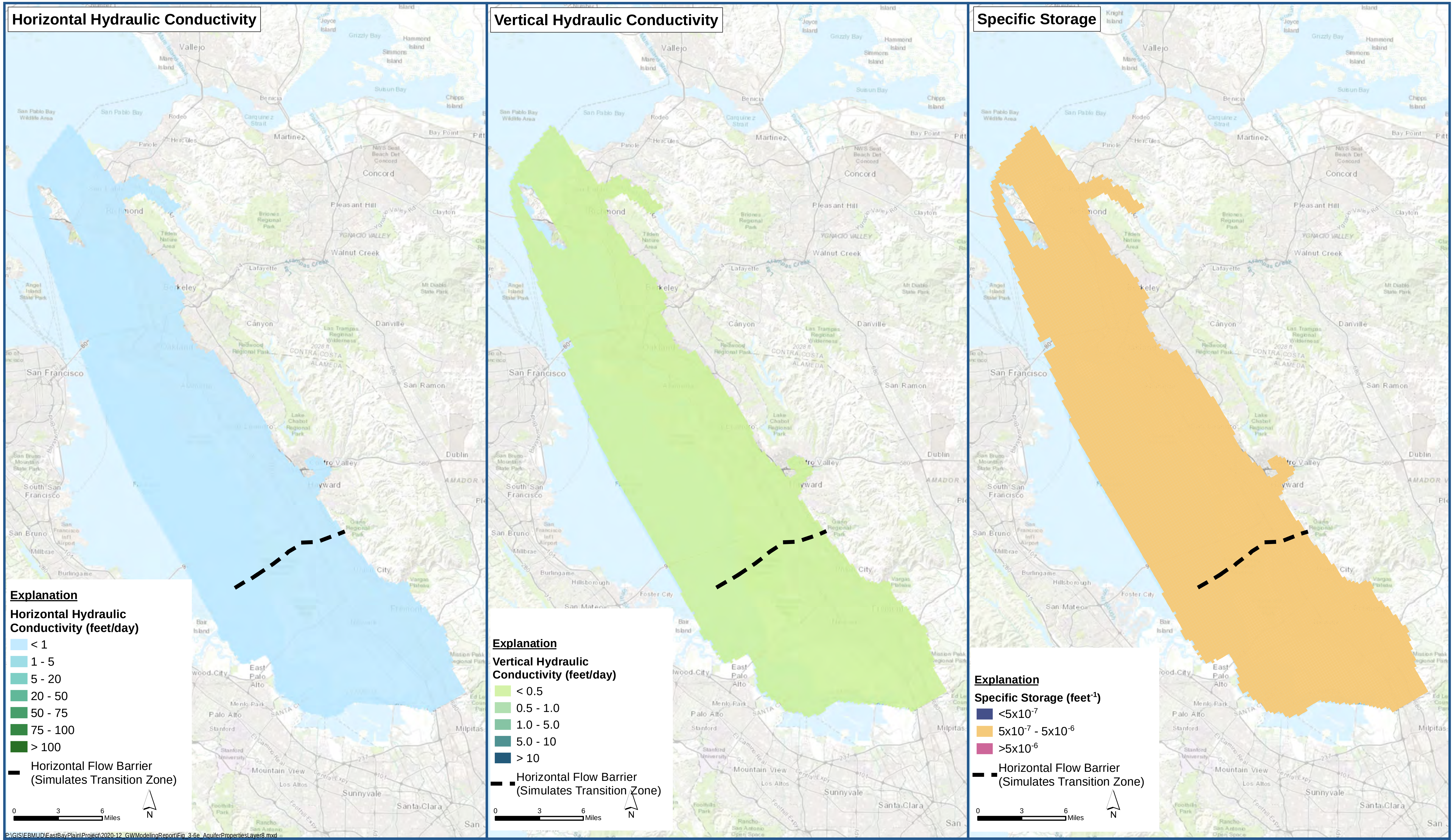


LSCE TEAM

Aquifer Properties - Layer 5, 6, and 7

East Bay Plain Groundwater Model
Groundwater Sustainability Plan

Figure 3-6d

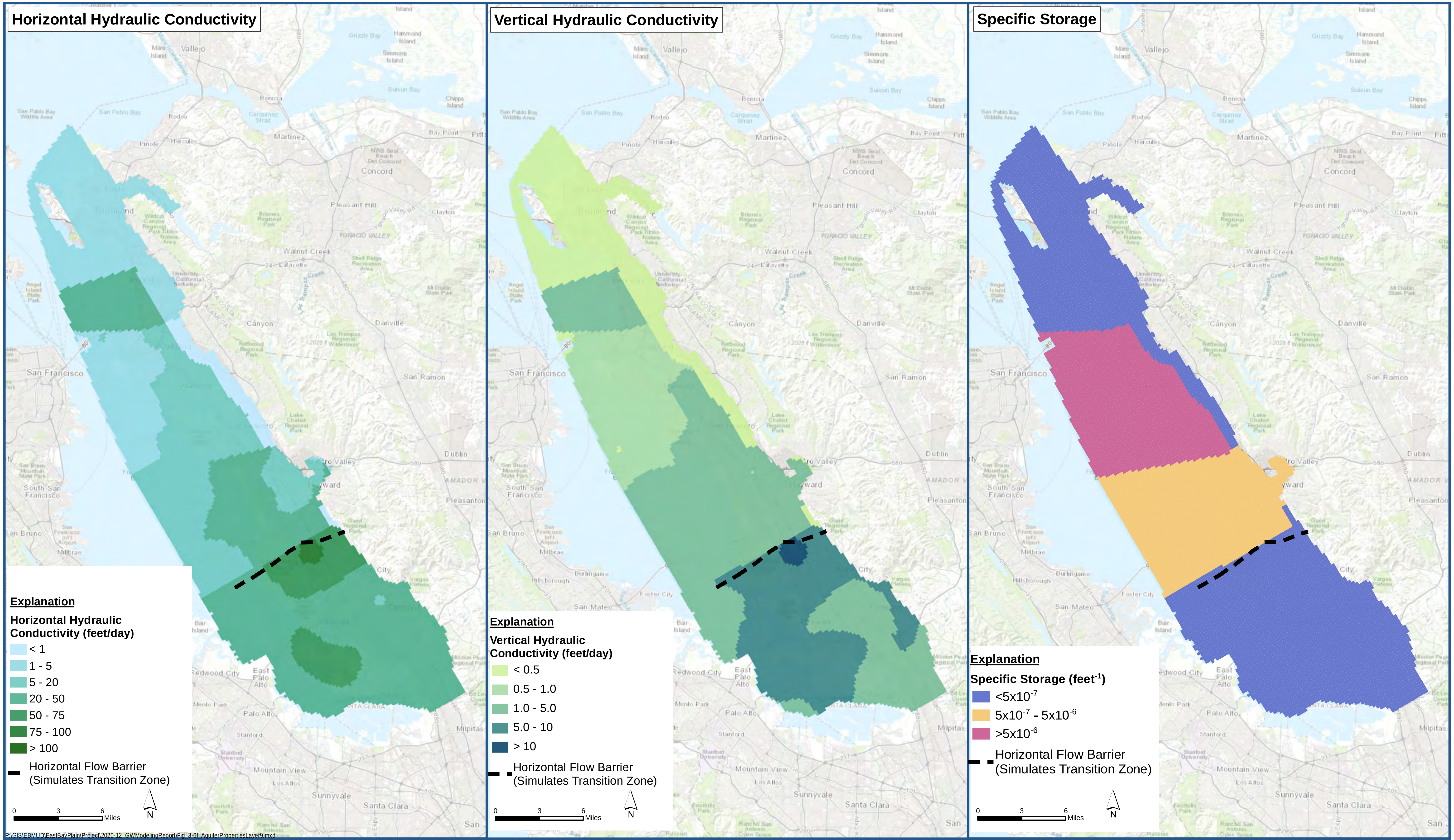


LSCE TEAM

Aquifer Properties - Layer 8

East Bay Plain Groundwater Model
Groundwater Sustainability Plan

Figure 3-6e



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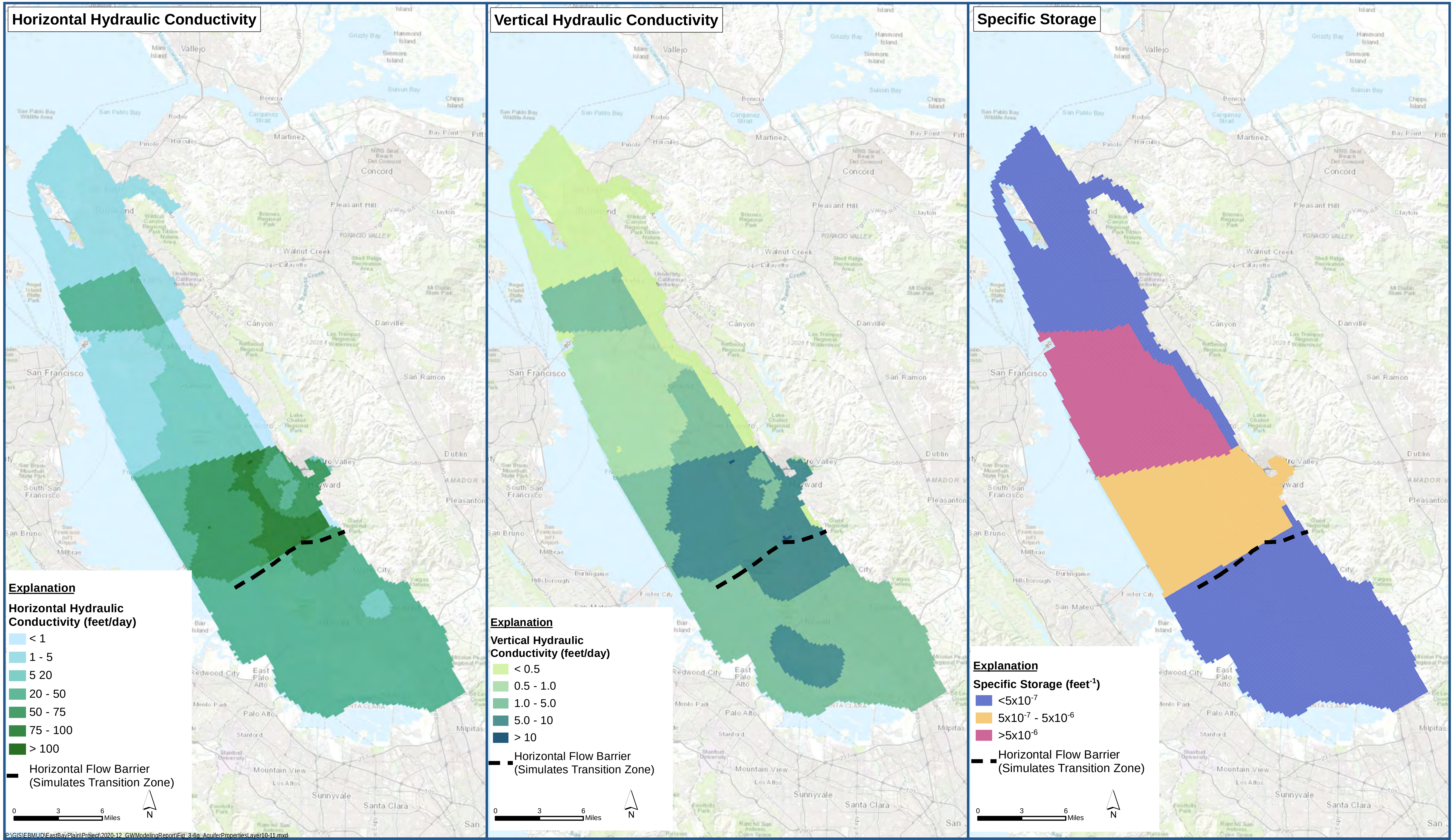
LSCE TEAM

Aquifer Properties - Layer 9

2021 East Bay Plain Groundwater Model
Groundwater Sustainability Plan

Figure 3-6f

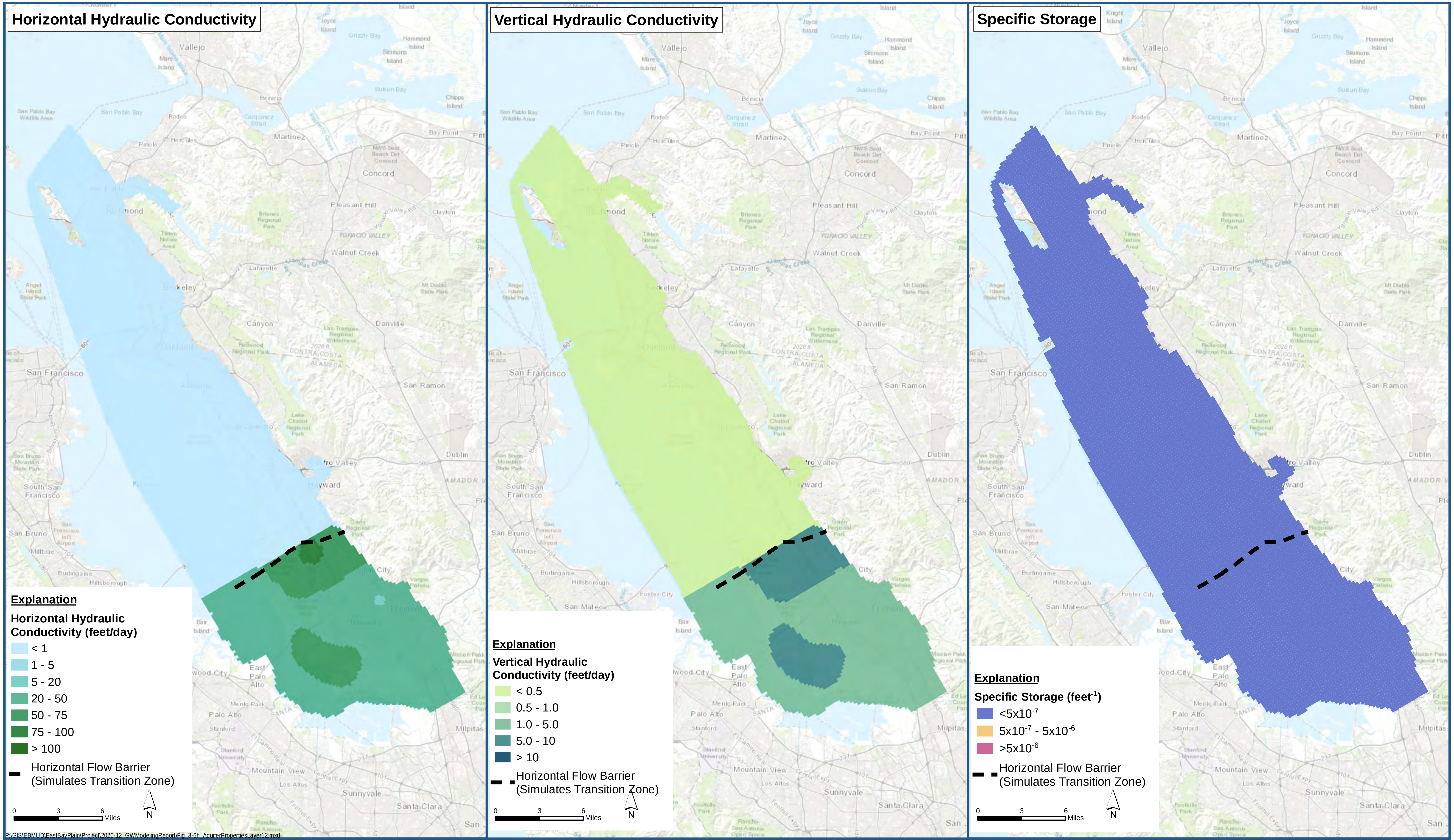


LSCE TEAM

Aquifer Properties - Layer 10 - 11

East Bay Plain Groundwater Model
Groundwater Sustainability Plan

Figure 3-6g



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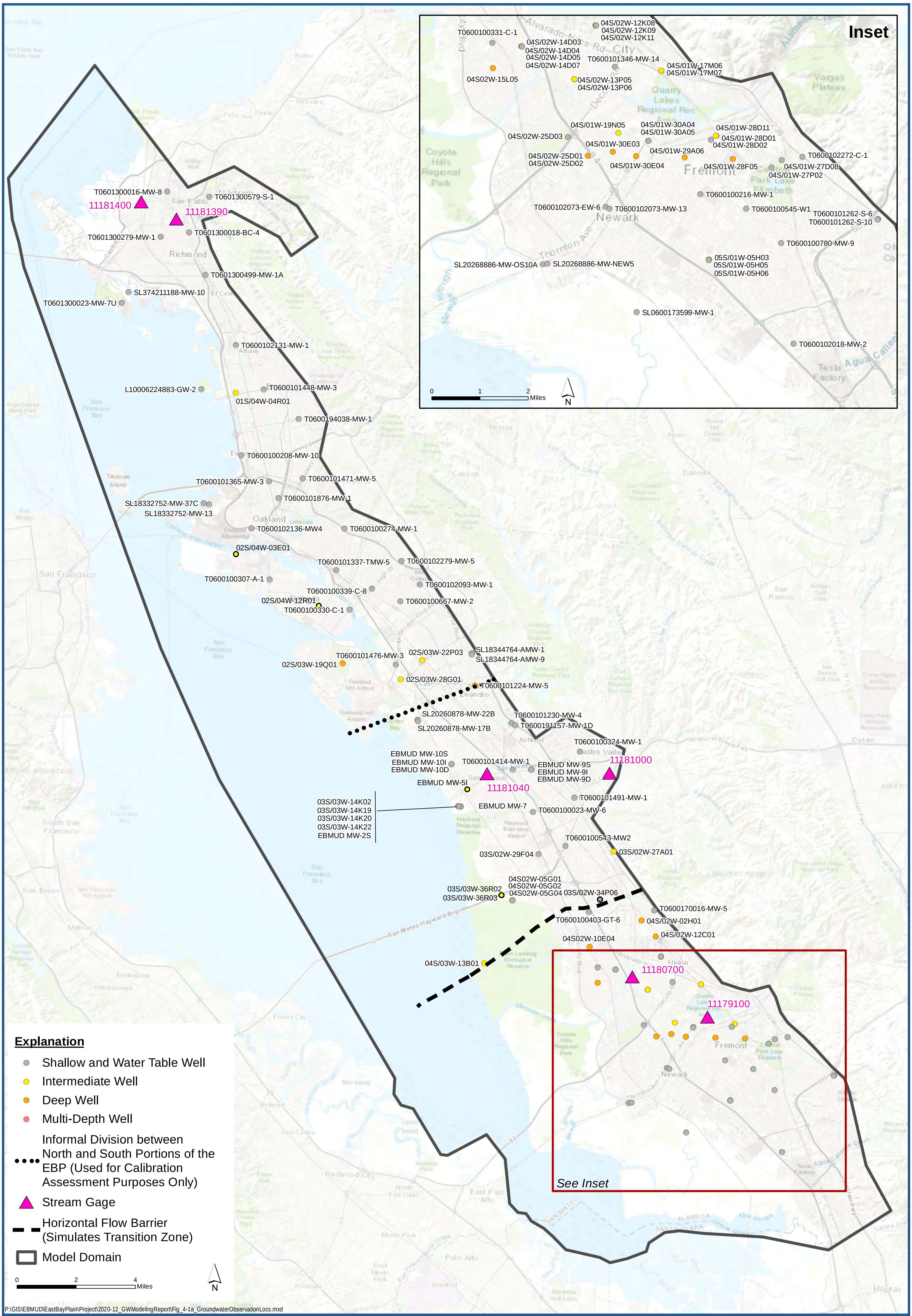
LSCE TEAM

Aquifer Properties - Layer 12

East Bay Plain Groundwater Model
Groundwater Sustainability Plan

Figure 3-6h



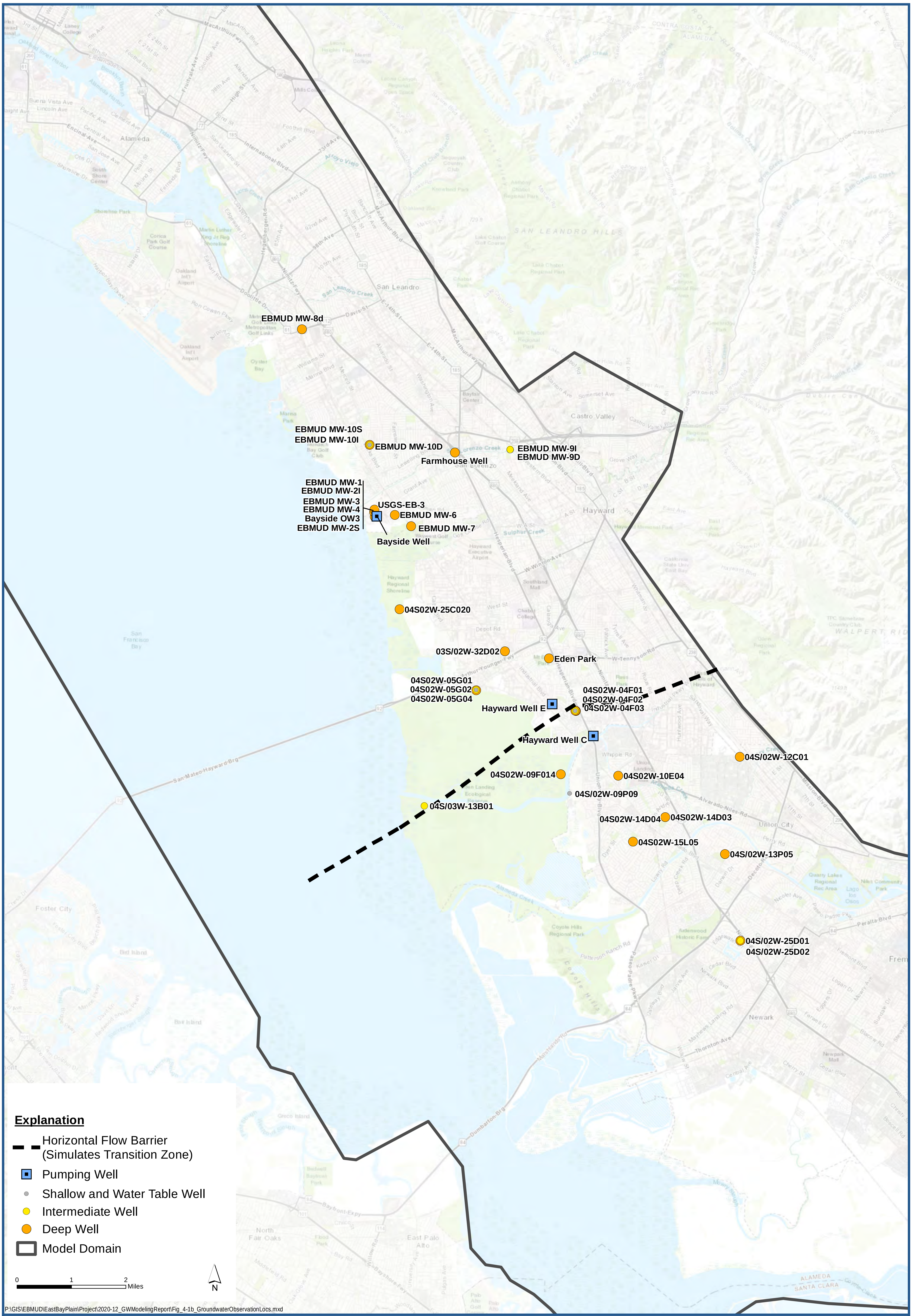
P:\GIS\EBMUD\EastBayPlain\Project\2020-12_GWModelingReport\Fig_4-1a_GroundwaterObservationLocs.mxd

LSCE TEAM

Groundwater Level Observation Locations - For Historical and Steady-State Simulations

East Bay Plain Groundwater Model
Groundwater Sustainability Plan

Figure 4-1a

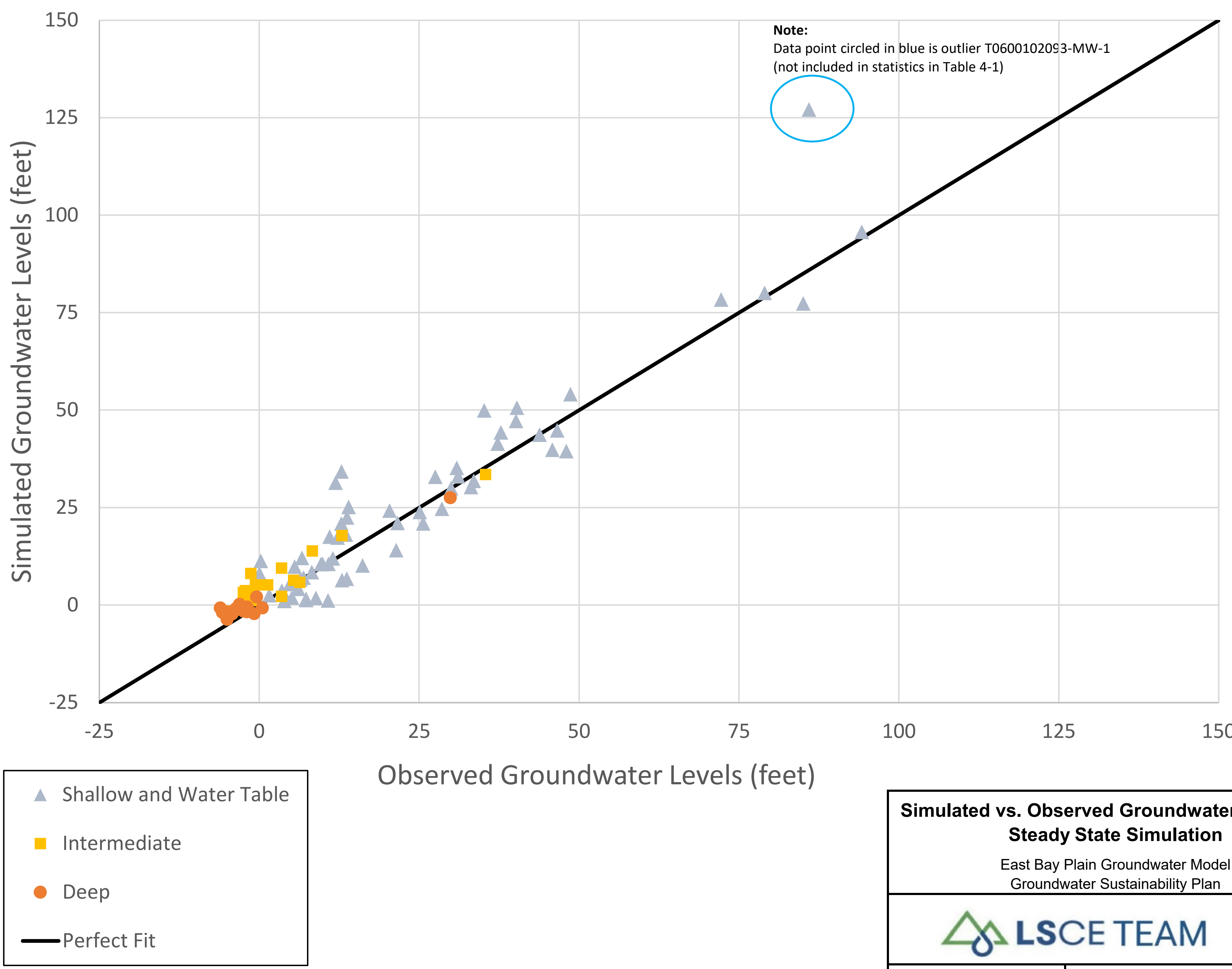


LSCE TEAM

Groundwater Level Observation Locations - For 2002 and 2010 Aquifer Test Simulations

Figure 4-1b

East Bay Plain Groundwater Model
Groundwater Sustainability Plan



Note:
Data point circled in blue is outlier T0600102093-MW-1
(not included in statistics in Table 4-1)

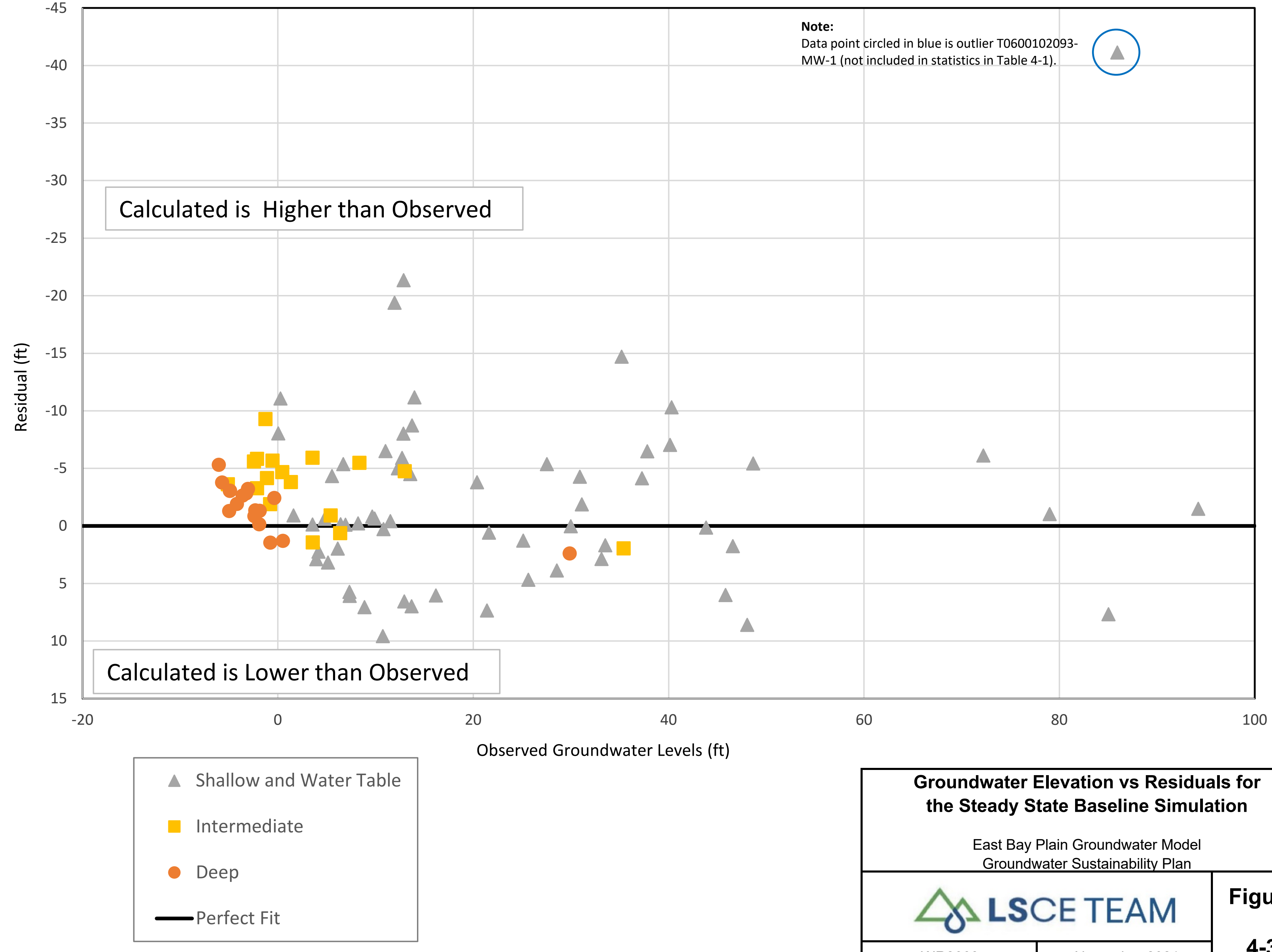
Simulated vs. Observed Groundwater Levels for Steady State Simulation

East Bay Plain Groundwater Model
Groundwater Sustainability Plan

LSCE TEAM

WR2668	November 2021	**Figure 4-2**

\\Oakland-01\data\PRJ2003REM\East Bay Plain GSP\06. Deliverables\Working Versions-Delete when finalized\4.6 Groundwater Modeling Memo\Figures\[Fig_4-7_Master2_SS.xlsx]



Note:
Data point circled in blue is outlier T0600102093-MW-1 (not included in statistics in Table 4-1).

Groundwater Elevation vs Residuals for the Steady State Baseline Simulation

East Bay Plain Groundwater Model
Groundwater Sustainability Plan

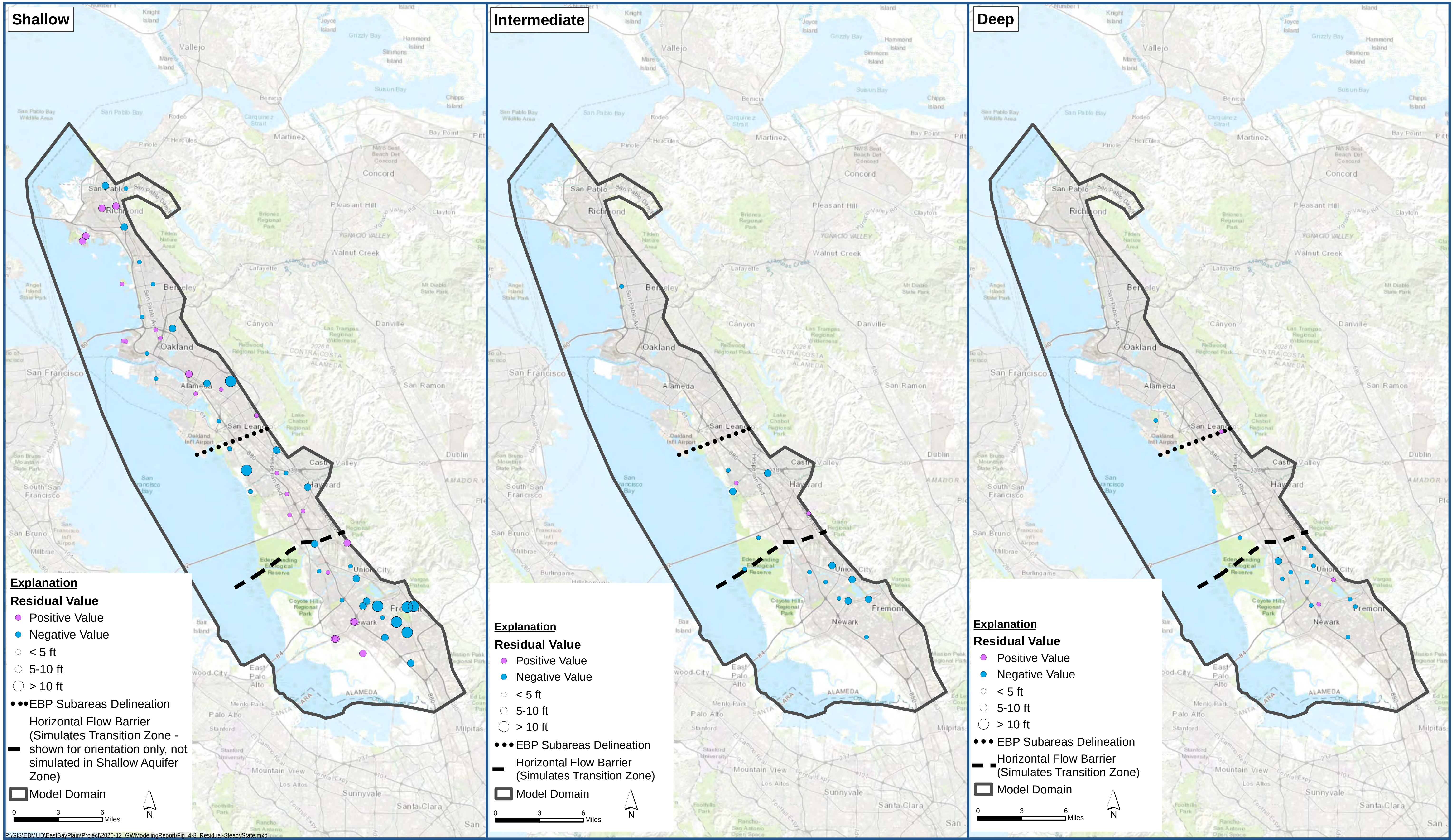
LSCE TEAM

WR2668	November 2021

Figure

4-3

\\Oakland-01\data\PRJ2003REM\East Bay Plain GSP\06. Deliverables\Working Versions-Delete when finalized\4.6 Groundwater Modeling Memo\Figures\[Fig_4-7_4-8_Master2_SS.xlsx]



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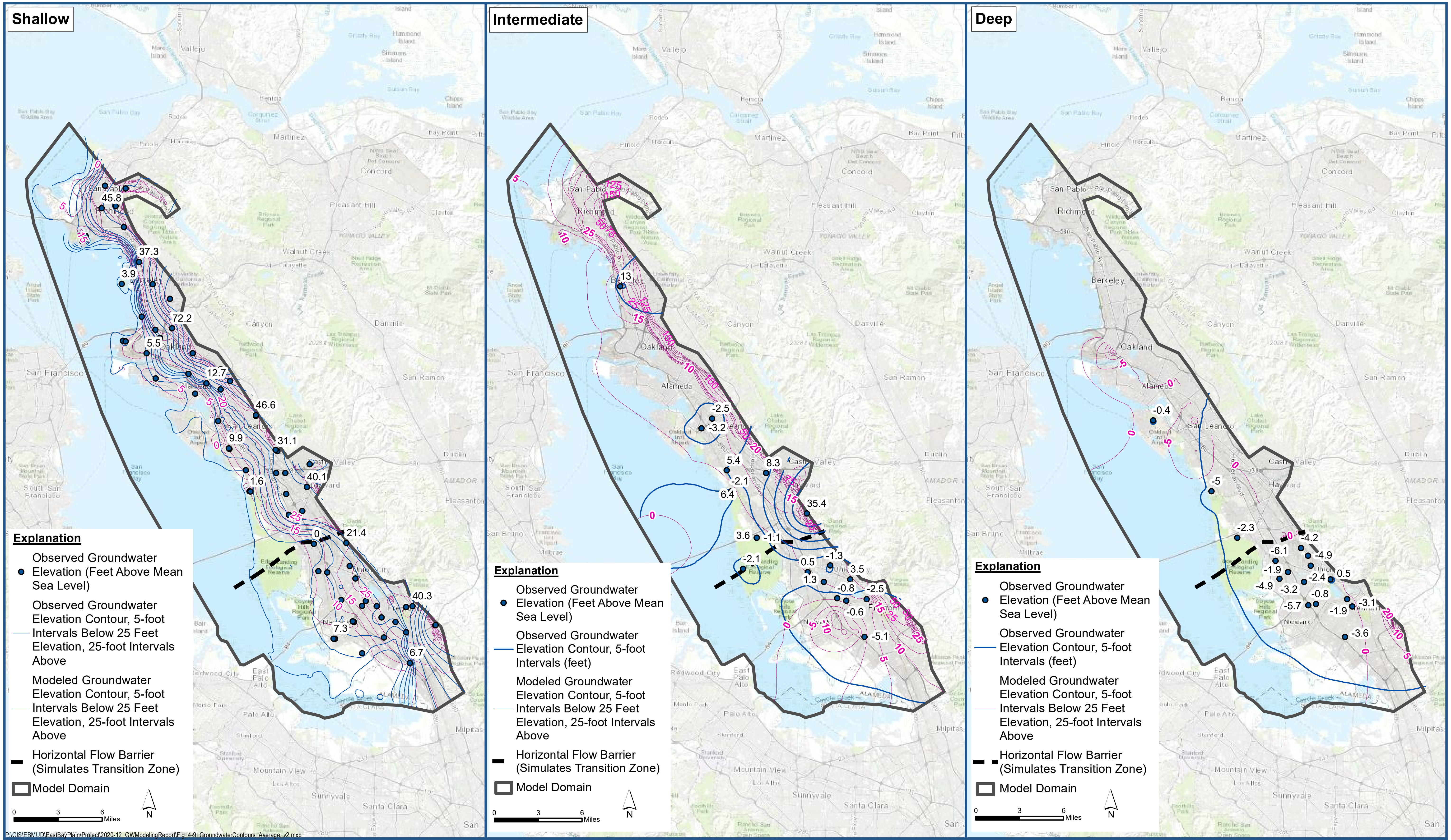
Maps Showing Distribution of Residuals for the Steady State Baseline Simulation

East Bay Plain Groundwater Model
Groundwater Sustainability Plan

Figure 4-4



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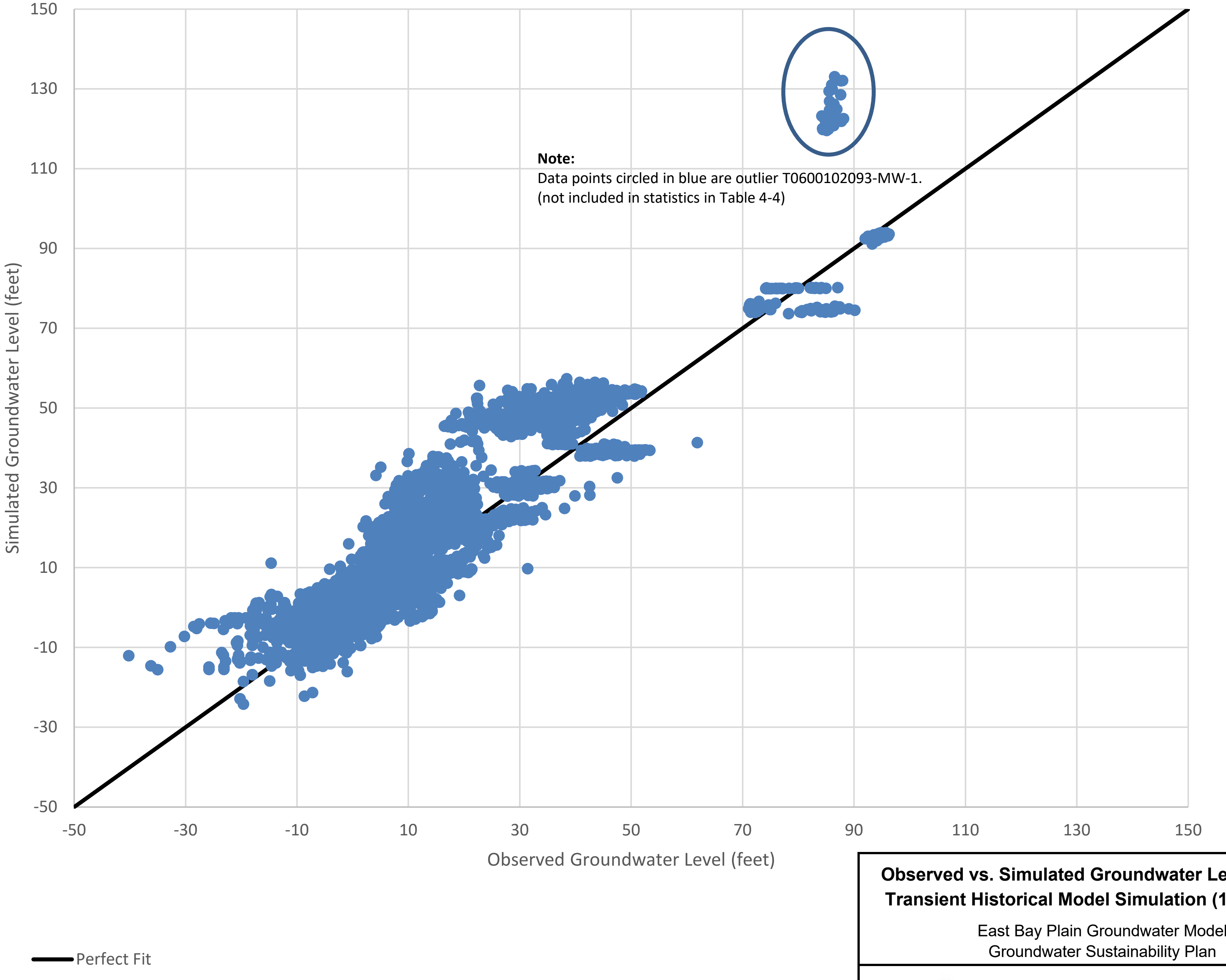
Modeled and Observed Average Groundwater Contours in the Shallow, Intermediate, and Deep Aquifer Zones, Steady-State Baseline Simulation

East Bay Plain Groundwater Model
Groundwater Sustainability Plan

Figure 4-5



Note:
Data points circled in blue are outlier T0600102093-MW-1.
(not included in statistics in Table 4-4)

Observed vs. Simulated Groundwater Levels for the Transient Historical Model Simulation (1990 - 2015)

East Bay Plain Groundwater Model
Groundwater Sustainability Plan

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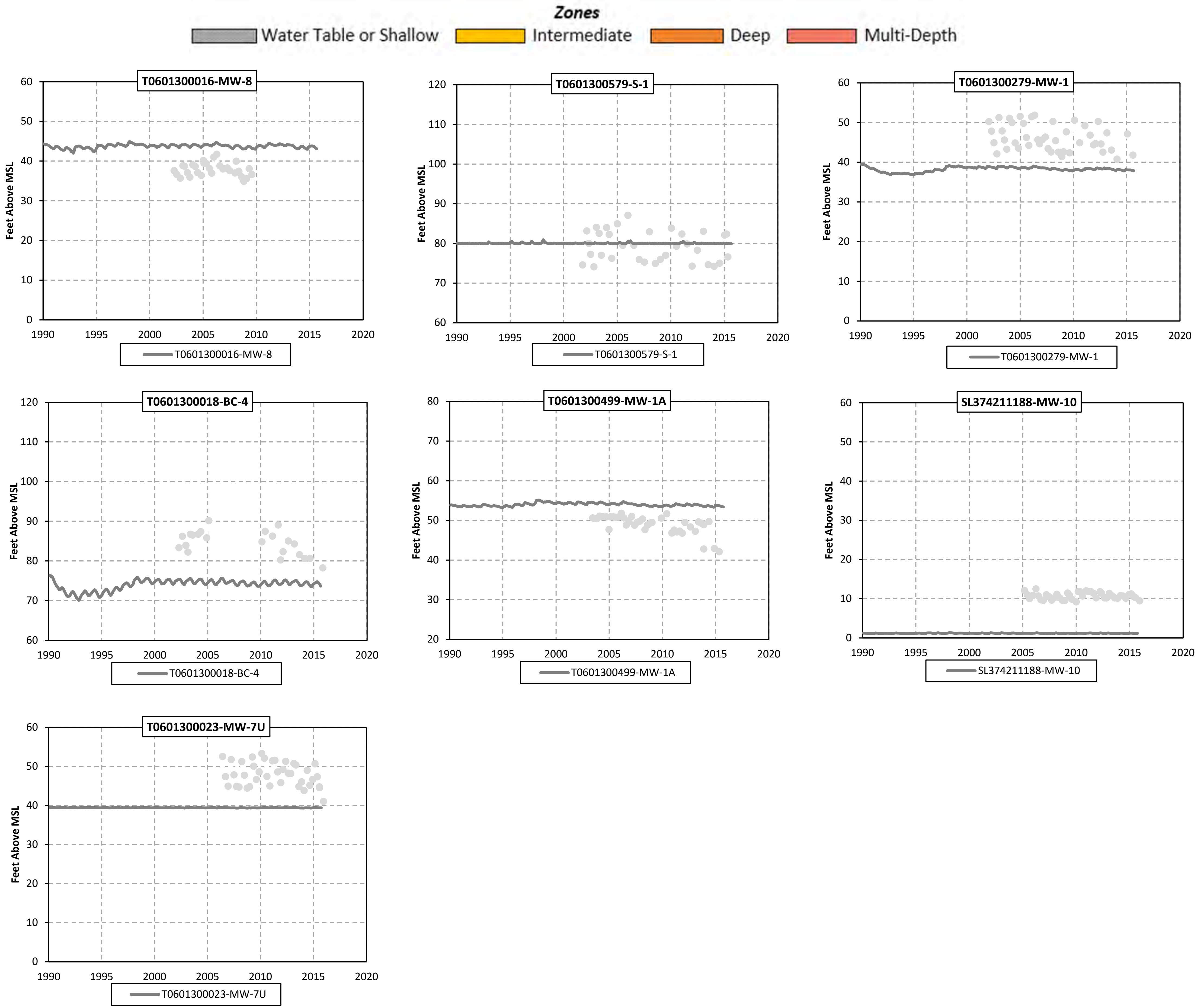
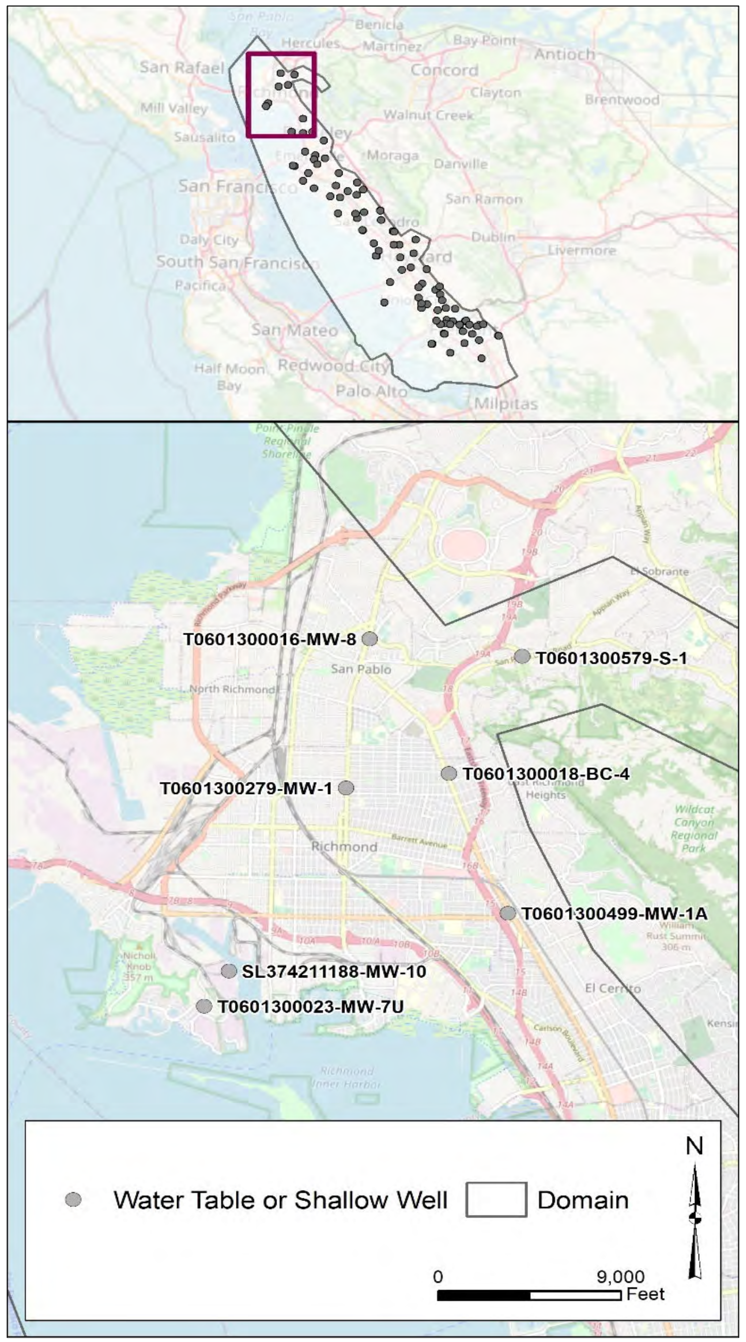
WR2668

November 2021

Figure

4-6





Notes:
MSL = mean sea level
Markers represent observed data, and lines represent simulated data for a given series.

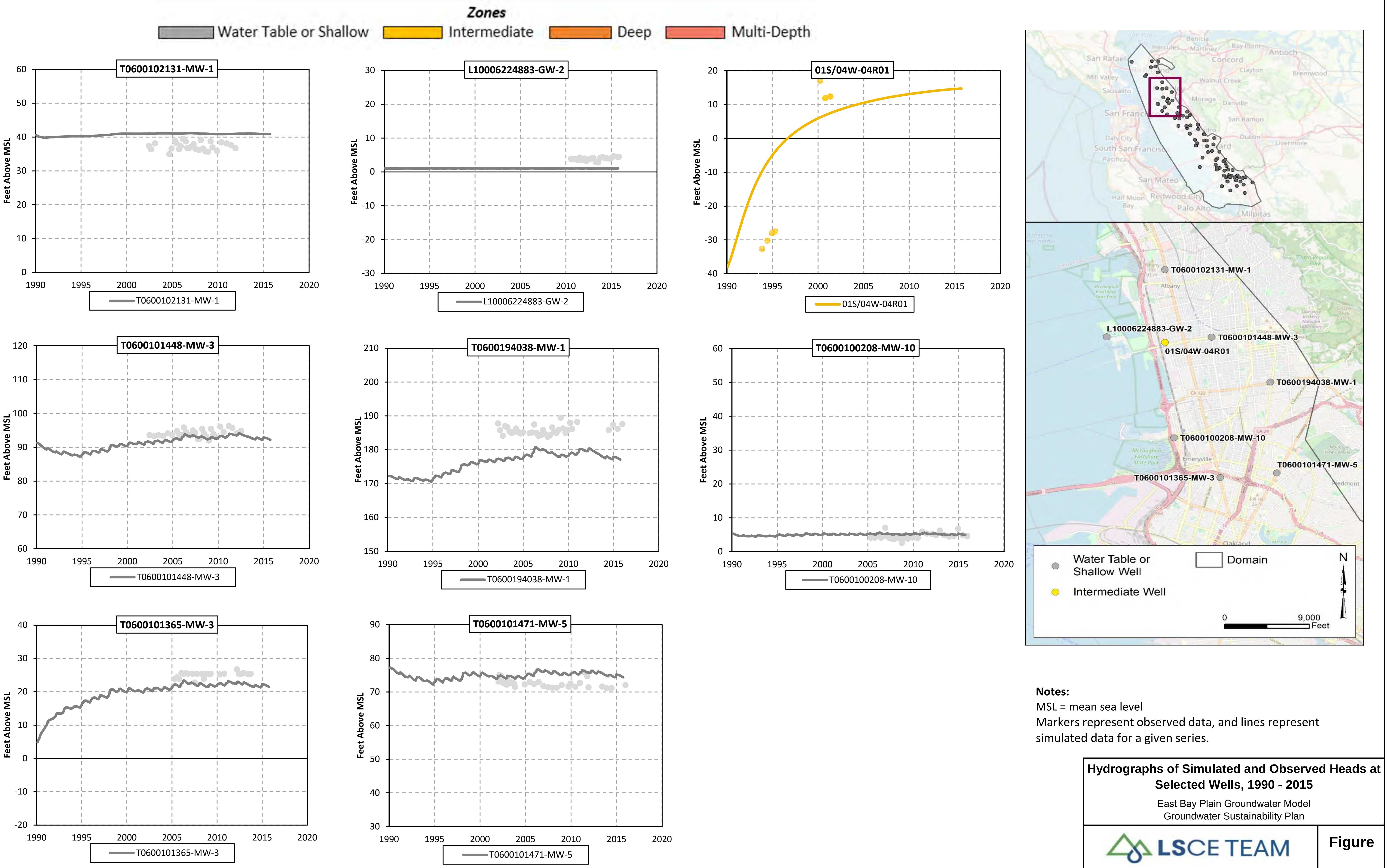
Hydrographs of Simulated and Observed Heads at Selected Wells, 1990 - 2015

East Bay Plain Groundwater Model
Groundwater Sustainability Plan

LSCE TEAM

WR2668
November 2021

Figure
4-7a



Notes:
MSL = mean sea level
Markers represent observed data, and lines represent simulated data for a given series.

Hydrographs of Simulated and Observed Heads at Selected Wells, 1990 - 2015

East Bay Plain Groundwater Model
Groundwater Sustainability Plan

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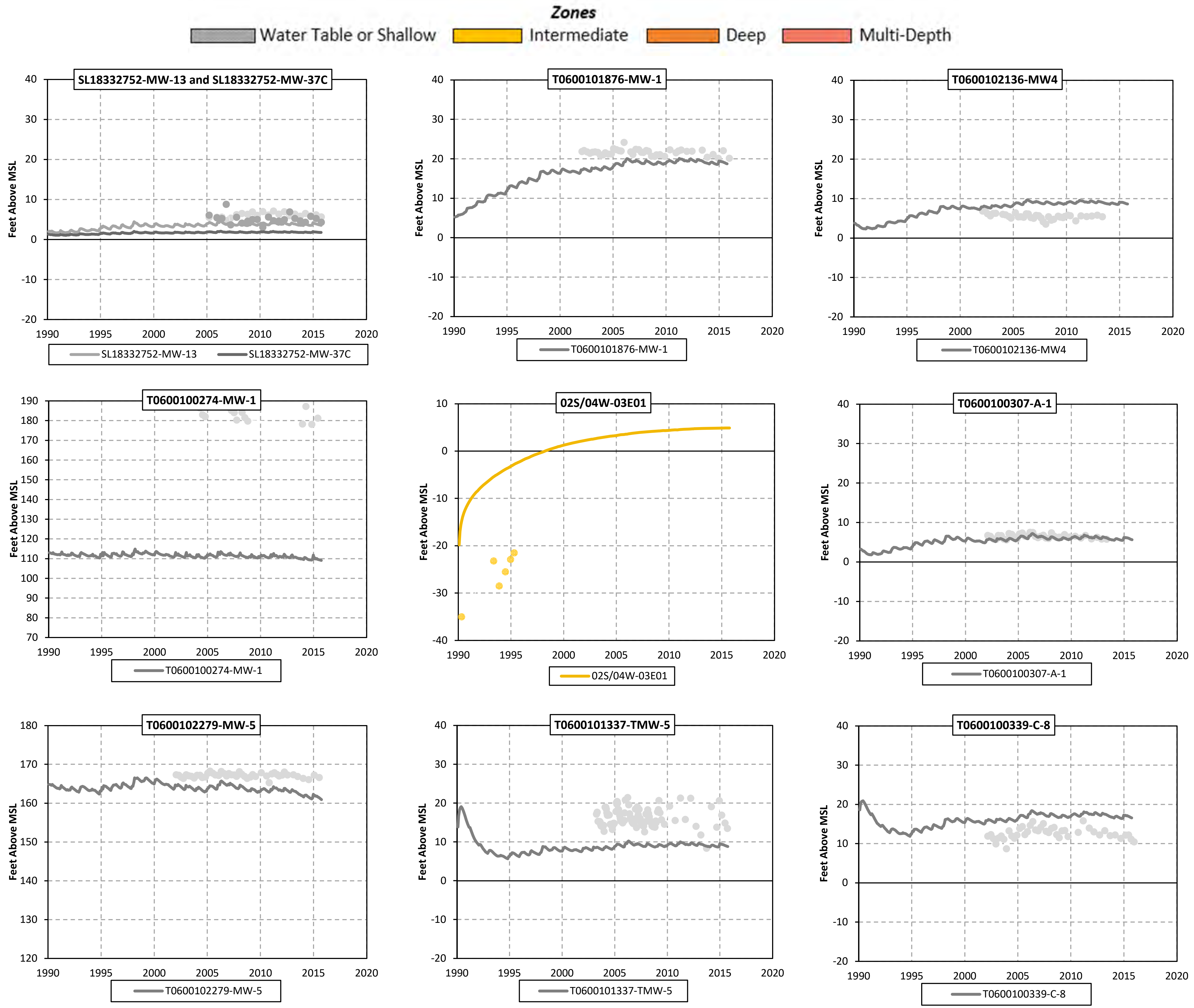
WR2668

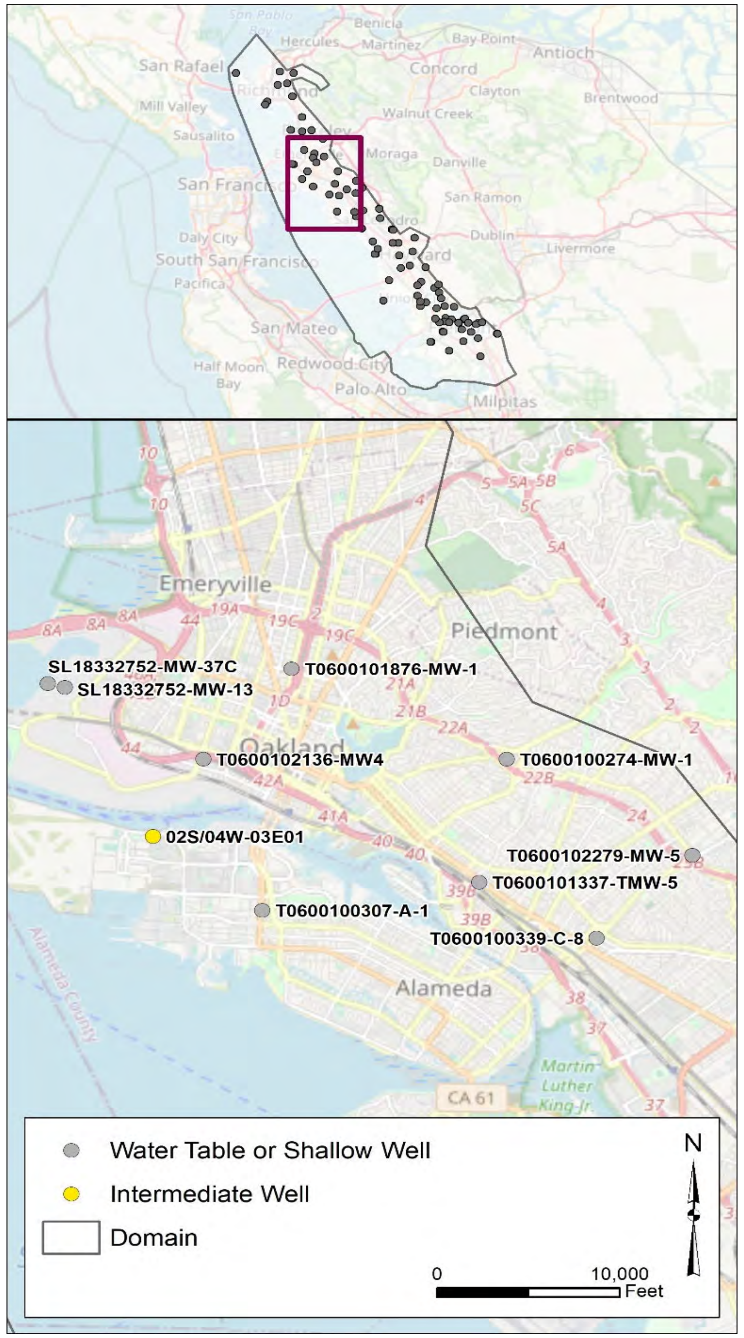
November 2021

Figure

4-7b

\\Oakland-01\data\PRJ2003REM\East Bay Plain GSP\06. Deliverables\Working Versions-Delete when finalized\4.6 Groundwater Modeling Memo\Figures\[Fig_4-2_4-3_EBP_Hydrographs_Master1_sens2.xlsx]





Notes:

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Markers represent observed data, and lines represent simulated data for a given series.

Hydrographs of Simulated and Observed Heads at Selected Wells, 1990 - 2015

East Bay Plain Groundwater Model
Groundwater Sustainability Plan

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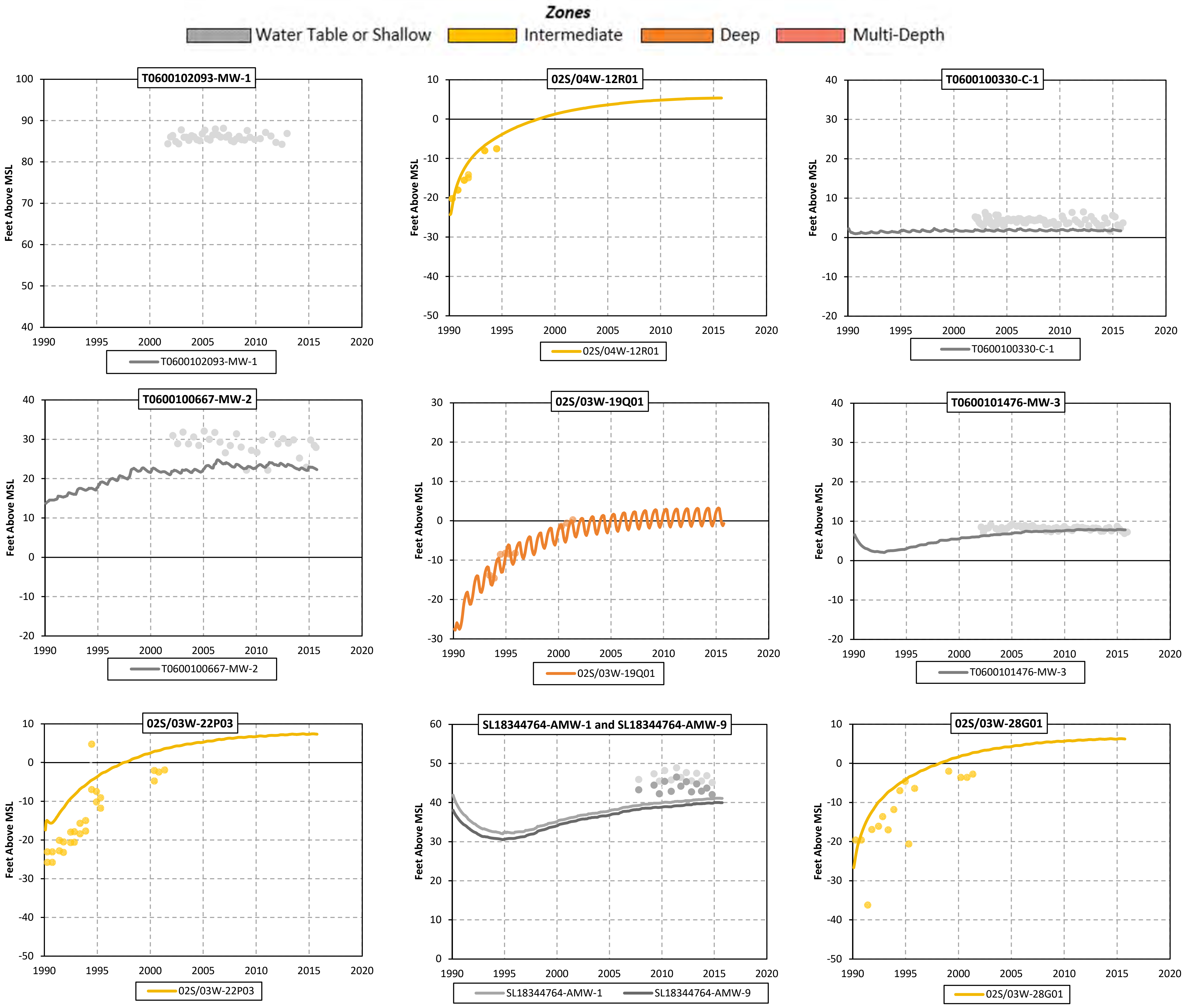
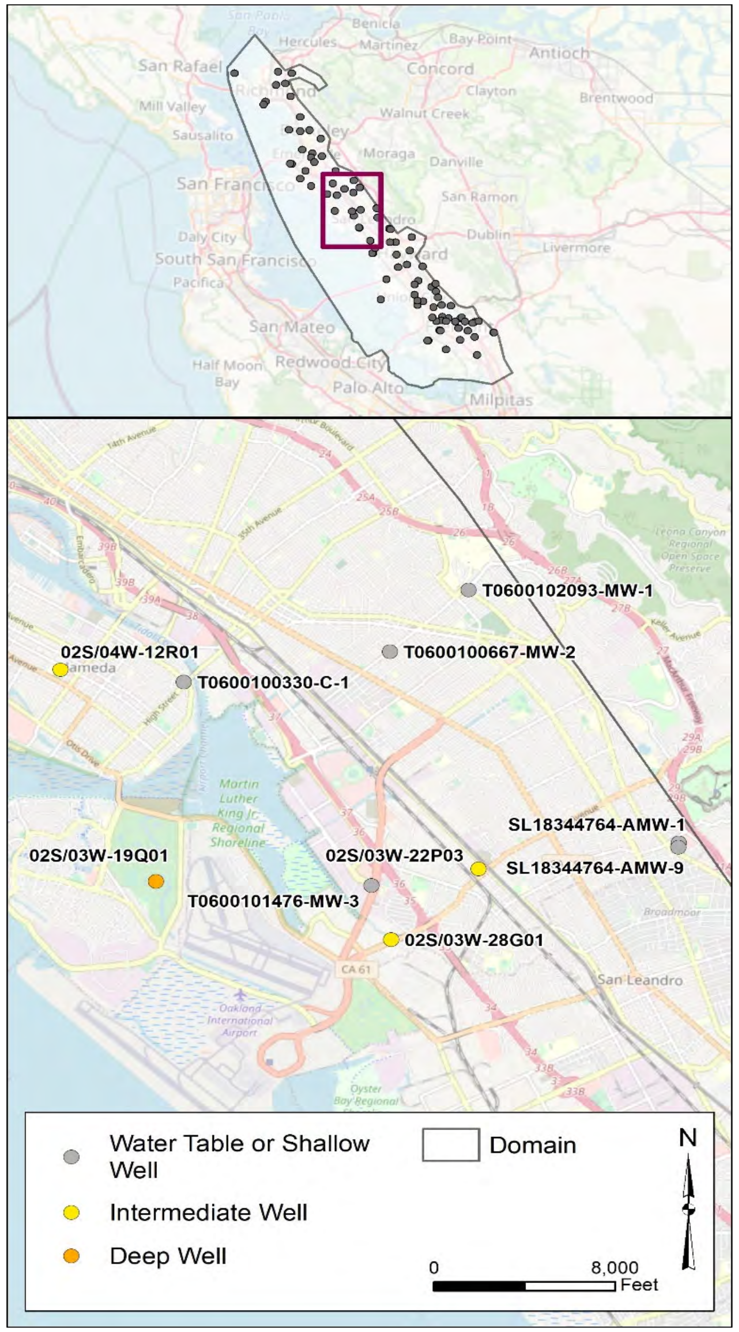
WR2668	November 2021	Figure 4-7c





Notes:
MSL = mean sea level
Markers represent observed data, and lines represent simulated data for a given series.

Hydrographs of Simulated and Observed Heads at Selected Wells, 1990 - 2015

East Bay Plain Groundwater Model
Groundwater Sustainability Plan

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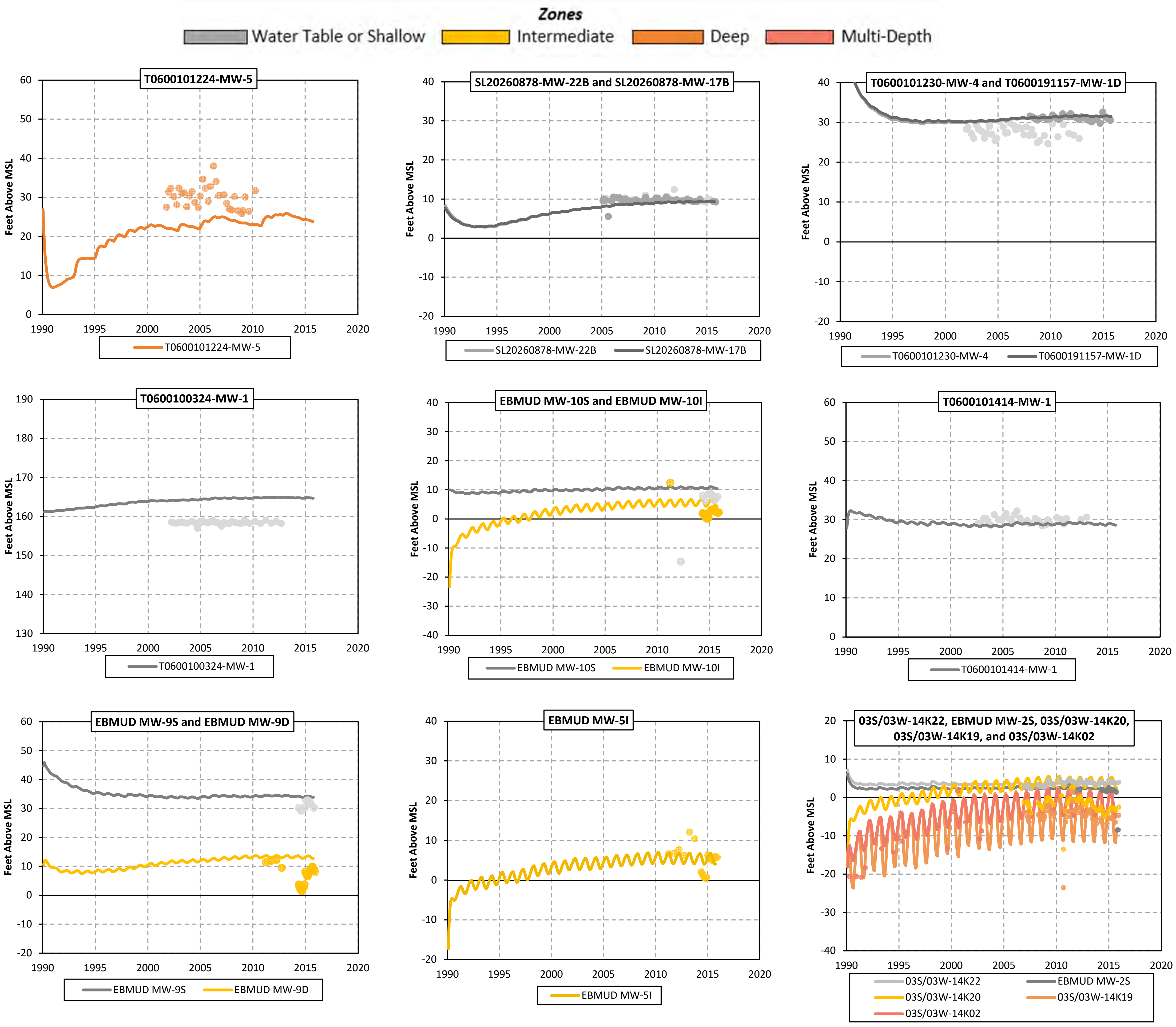
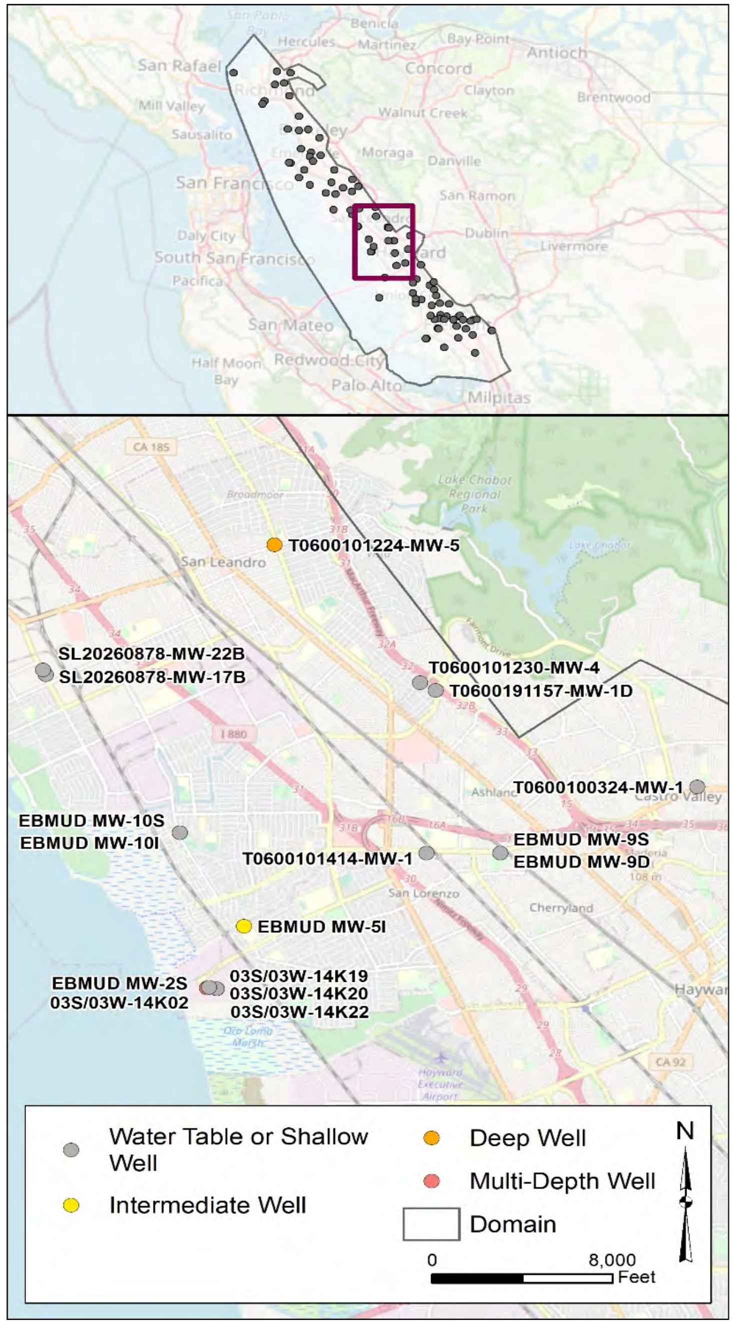
November 2021

Figure

4-7d

\\Oakland-01\data\PRJ2003REM\East Bay Plain GSP\06. Deliverables\Working Versions-Delete when finalized\4.6 Groundwater Modeling Memo\Figures\[Fig_4-2_4-3_EBP_Hydrographs_Master1_sens2.xlsx]





Notes:

MSL = mean sea level

Markers represent observed data, and lines represent simulated data for a given series.

Hydrographs of Simulated and Observed Heads at Selected Wells, 1990 - 2015

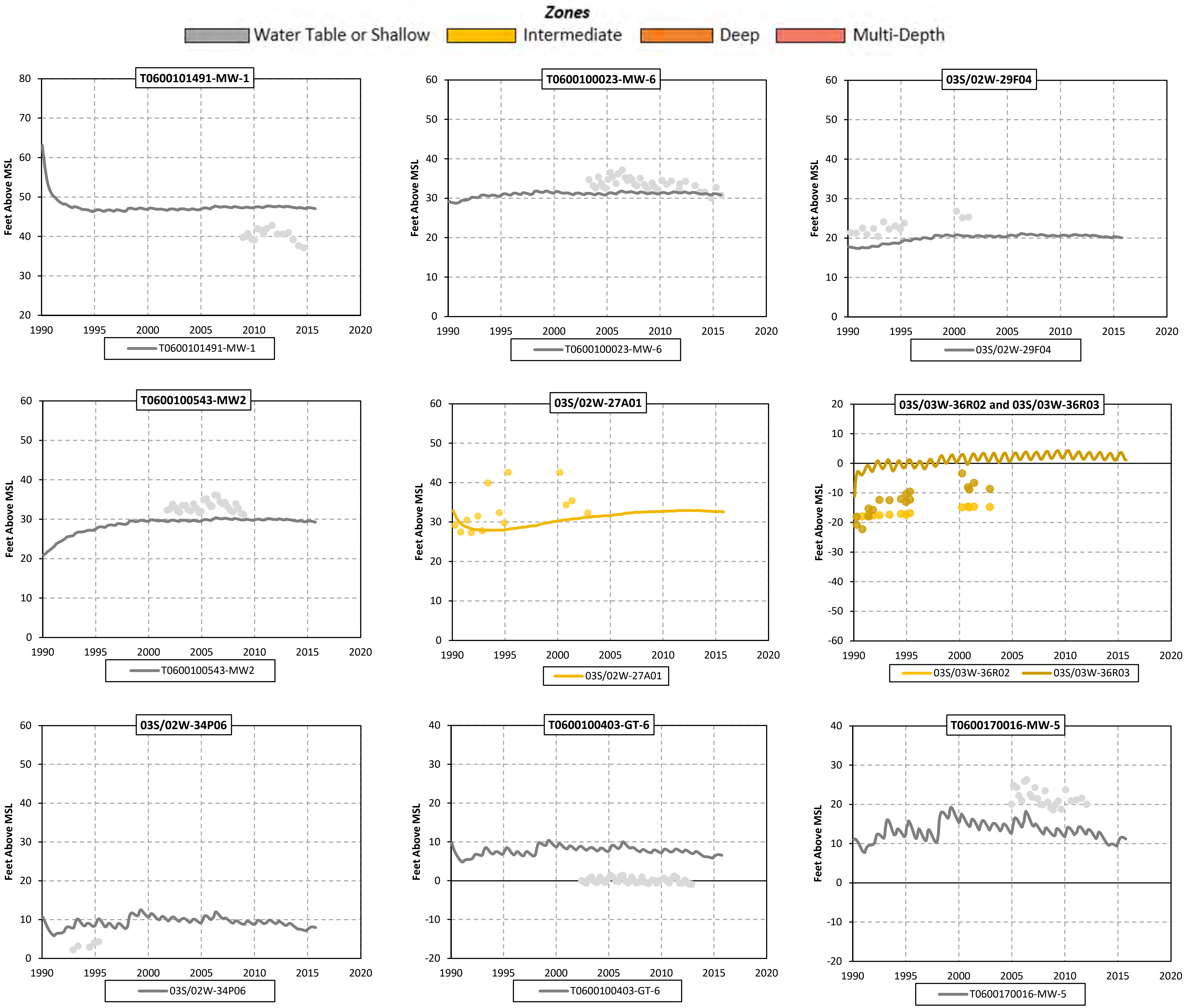
East Bay Plain Groundwater Model
Groundwater Sustainability Plan

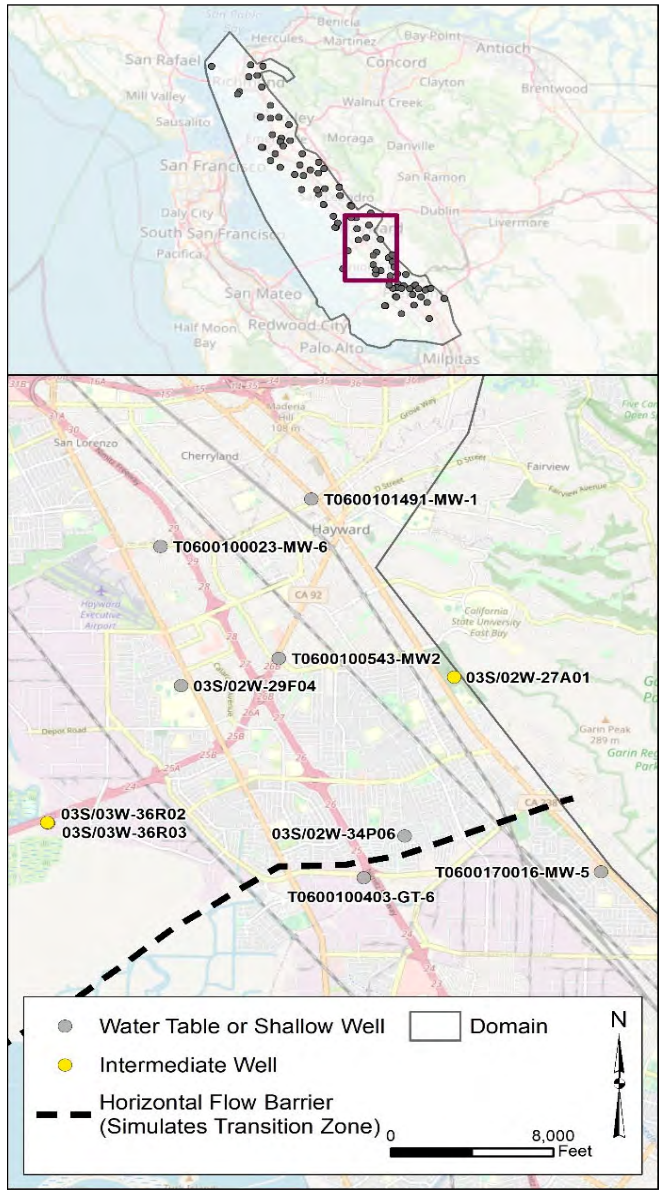
LSCE TEAM

WR2668

November 2021

Figure 4-7e





Notes:
MSL = mean sea level
Markers represent observed data, and lines represent simulated data for a given series.

Hydrographs of Simulated and Observed Heads at Selected Wells, 1990 - 2015

East Bay Plain Groundwater Model
Groundwater Sustainability Plan

LSCE TEAM

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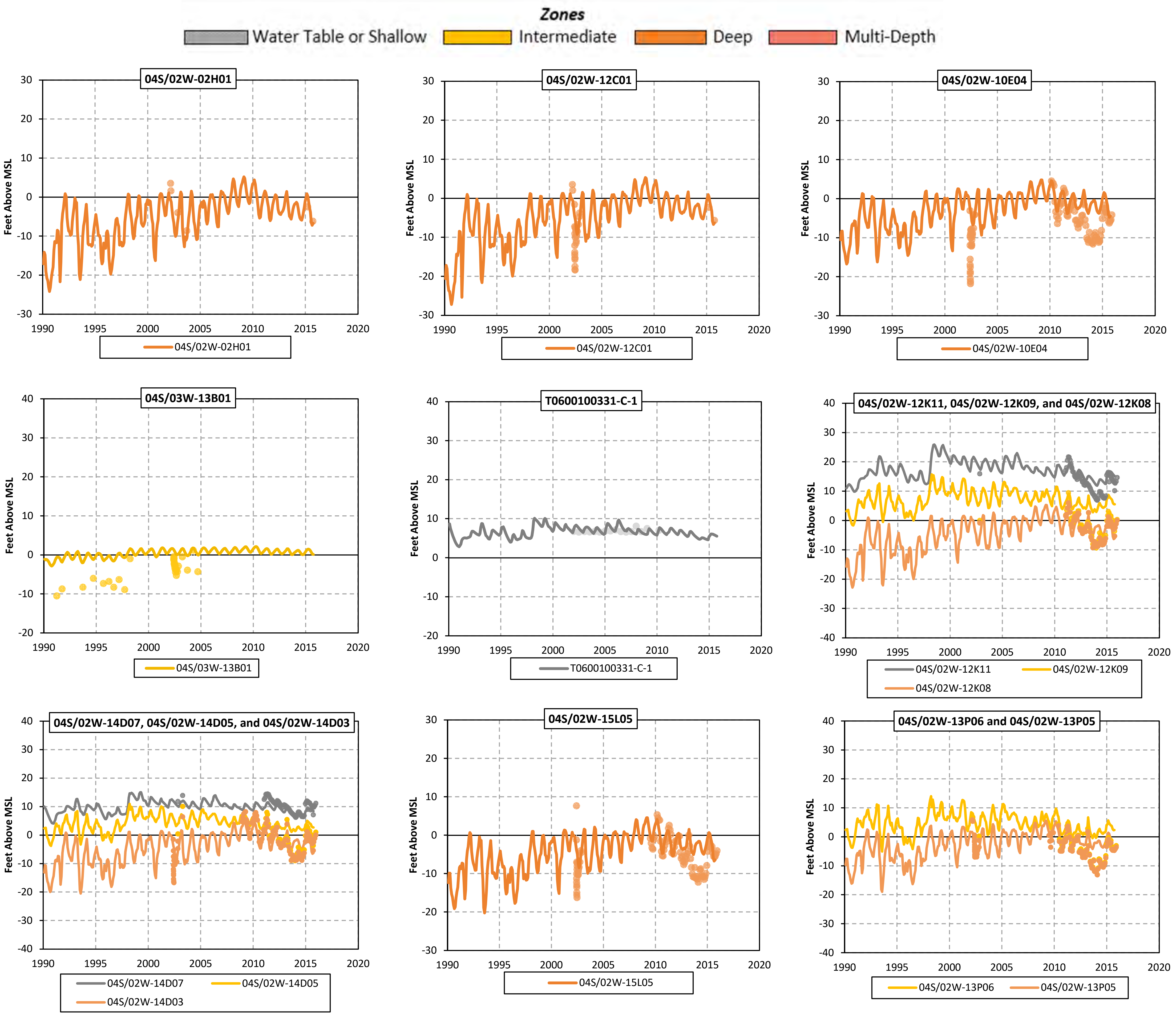
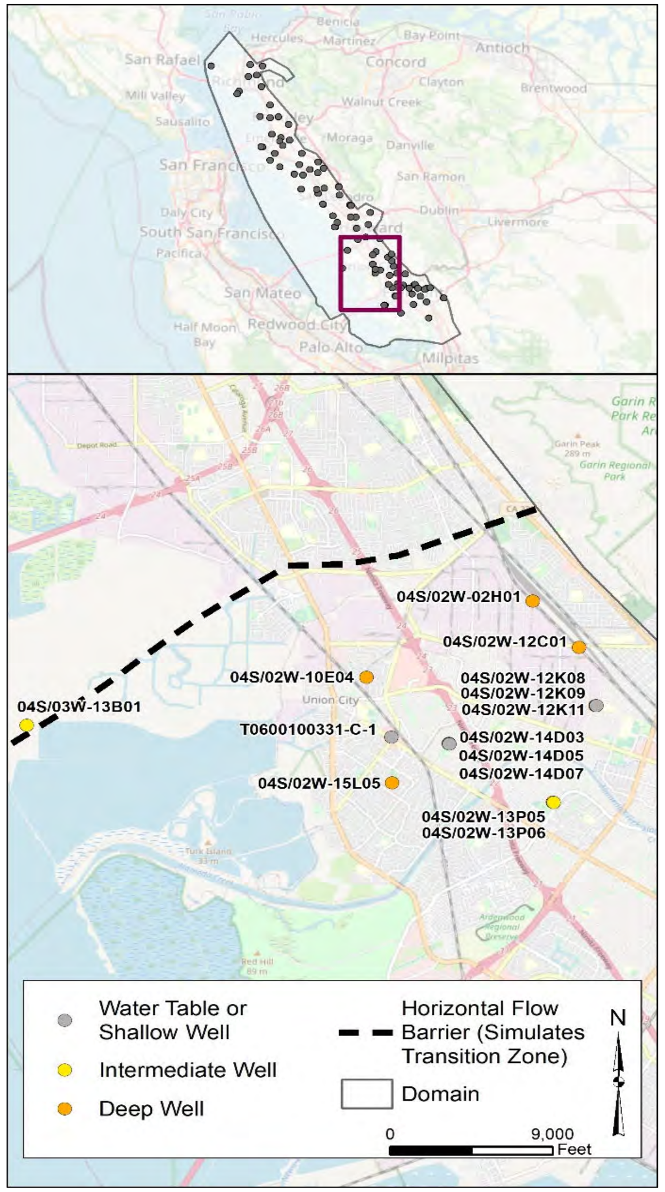
November 2021

Figure

4-7f

\\Oakland-01\data\PRJ2003REM\East Bay Plain GSP\06. Deliverables\Working Versions-Delete when finalized\4.6 Groundwater Modeling Memo\Figures\[Fig_4-2_4-3_EBP_Hydrographs_Master1_sens2.xlsx]





Notes:
MSL = mean sea level
Markers represent observed data, and lines represent simulated data for a given series.

Hydrographs of Simulated and Observed Heads at Selected Wells, 1990 - 2015

East Bay Plain Groundwater Model
Groundwater Sustainability Plan

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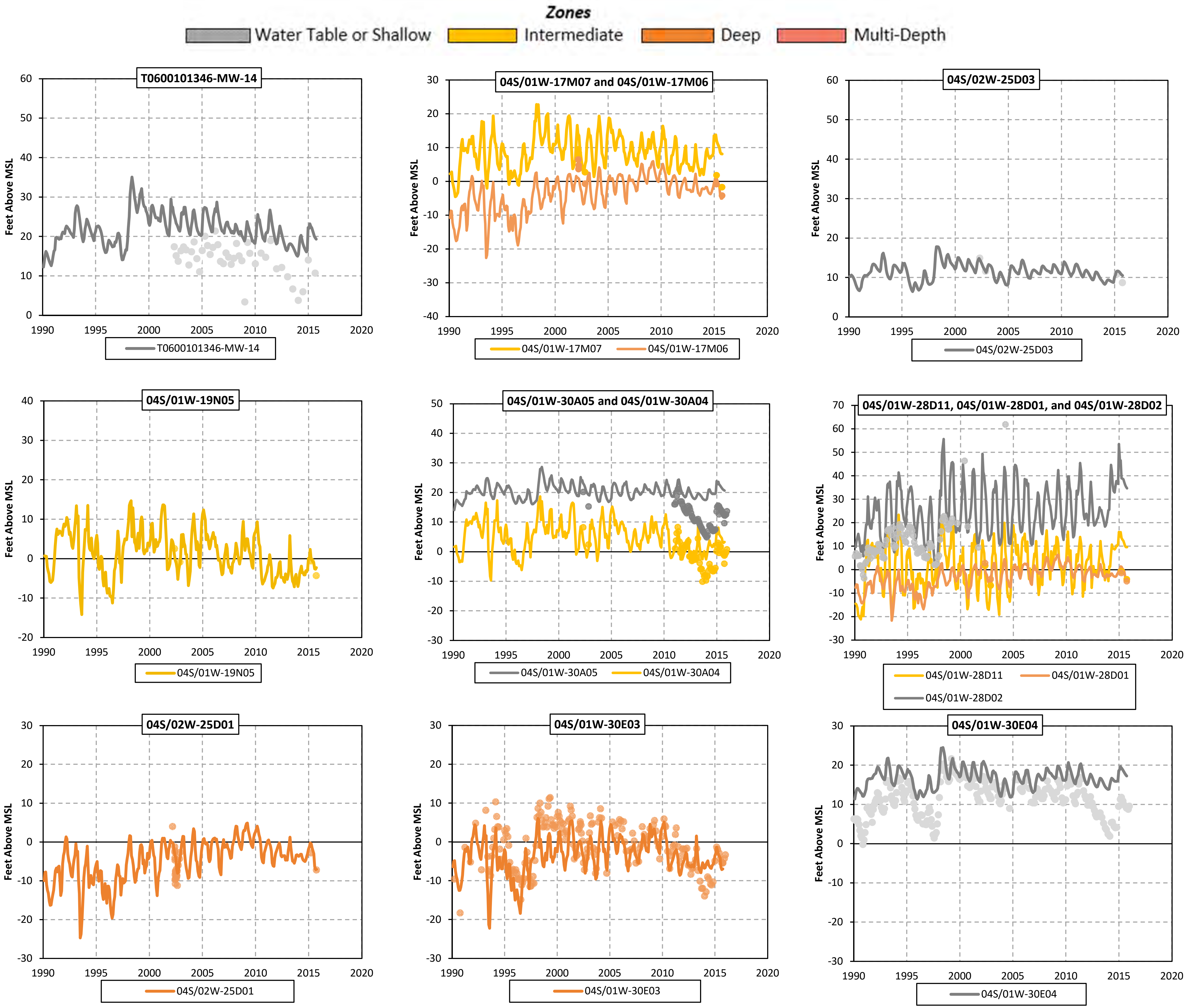
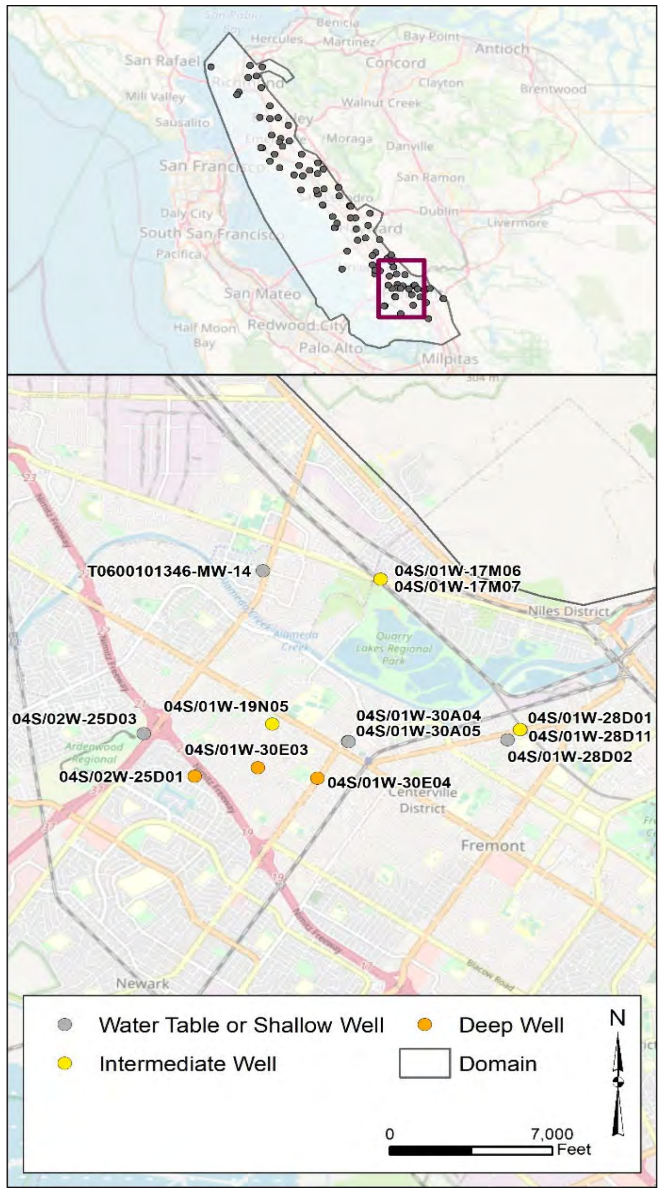
November 2021

Figure

4-7g

\\Oakland-01\data\PRJ2003REM\East Bay Plain GSP\06. Deliverables\Working Versions-Delete when finalized\4.6 Groundwater Modeling Memo\Figures\[Fig_4-2_4-3_EBP_Hydrographs_Master1_sens2.xlsx]





Notes:
MSL = mean sea level
Markers represent observed data, and lines represent simulated data for a given series.

Hydrographs of Simulated and Observed Heads at Selected Wells, 1990 - 2015

East Bay Plain Groundwater Model
Groundwater Sustainability Plan

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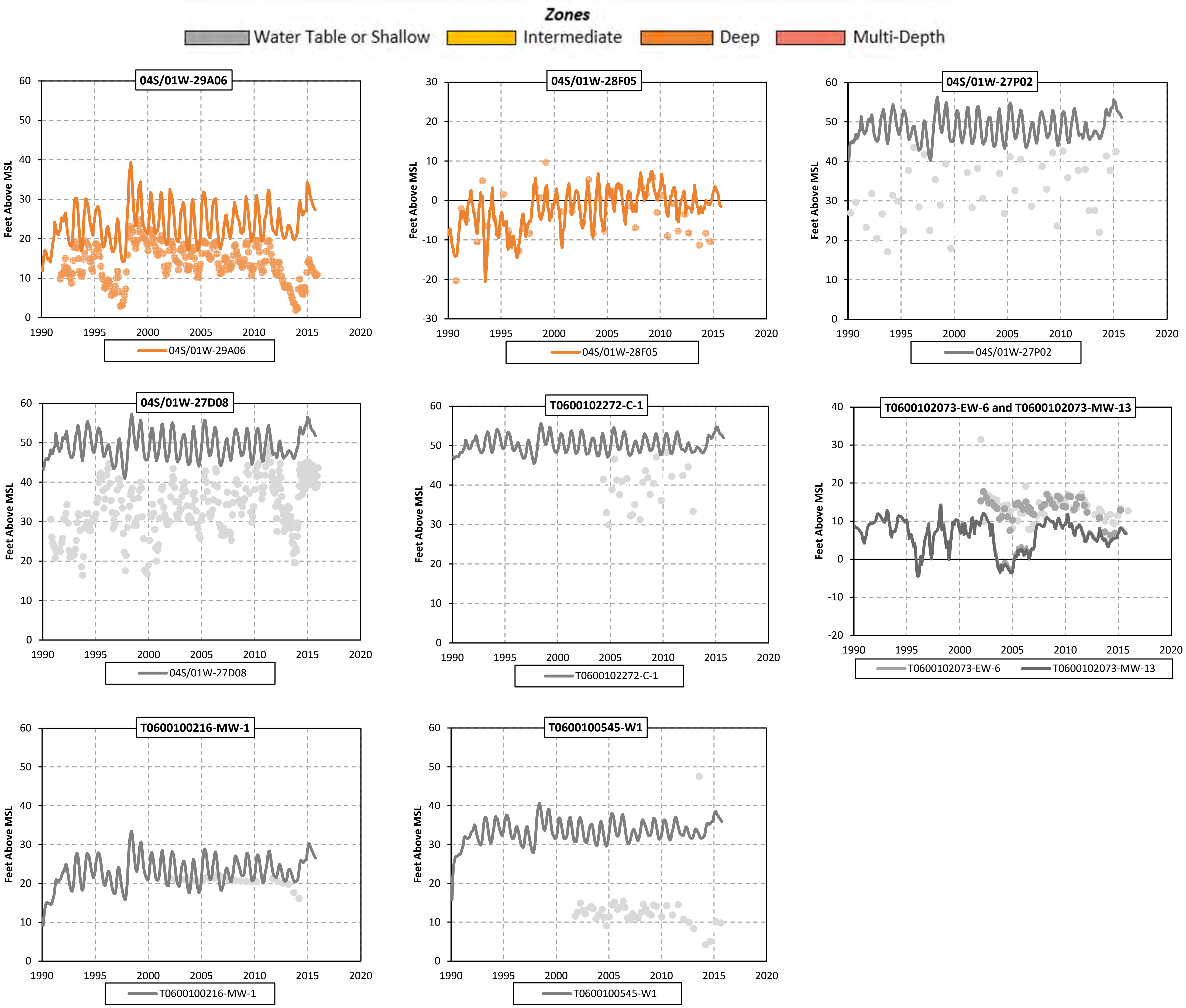
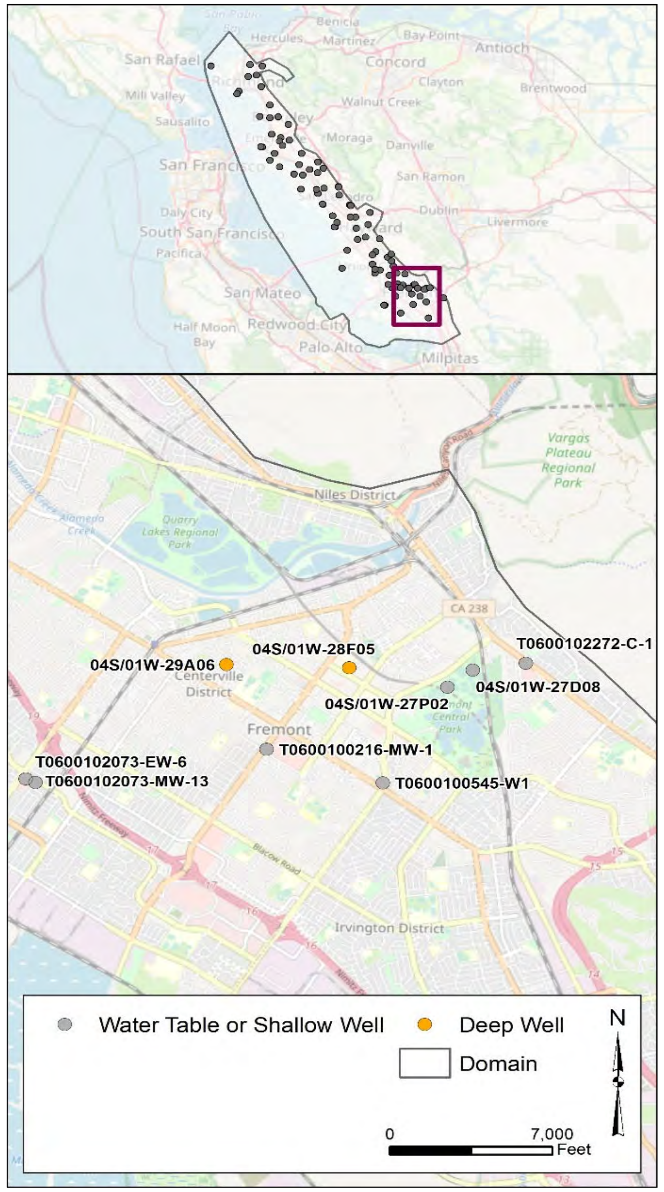
WR2668

November 2021

Figure

4-7h





Notes:
MSL = mean sea level
Markers represent observed data, and lines represent simulated data for a given series.

Hydrographs of Simulated and Observed Heads at Selected Wells, 1990 - 2015

East Bay Plain Groundwater Model
Groundwater Sustainability Plan

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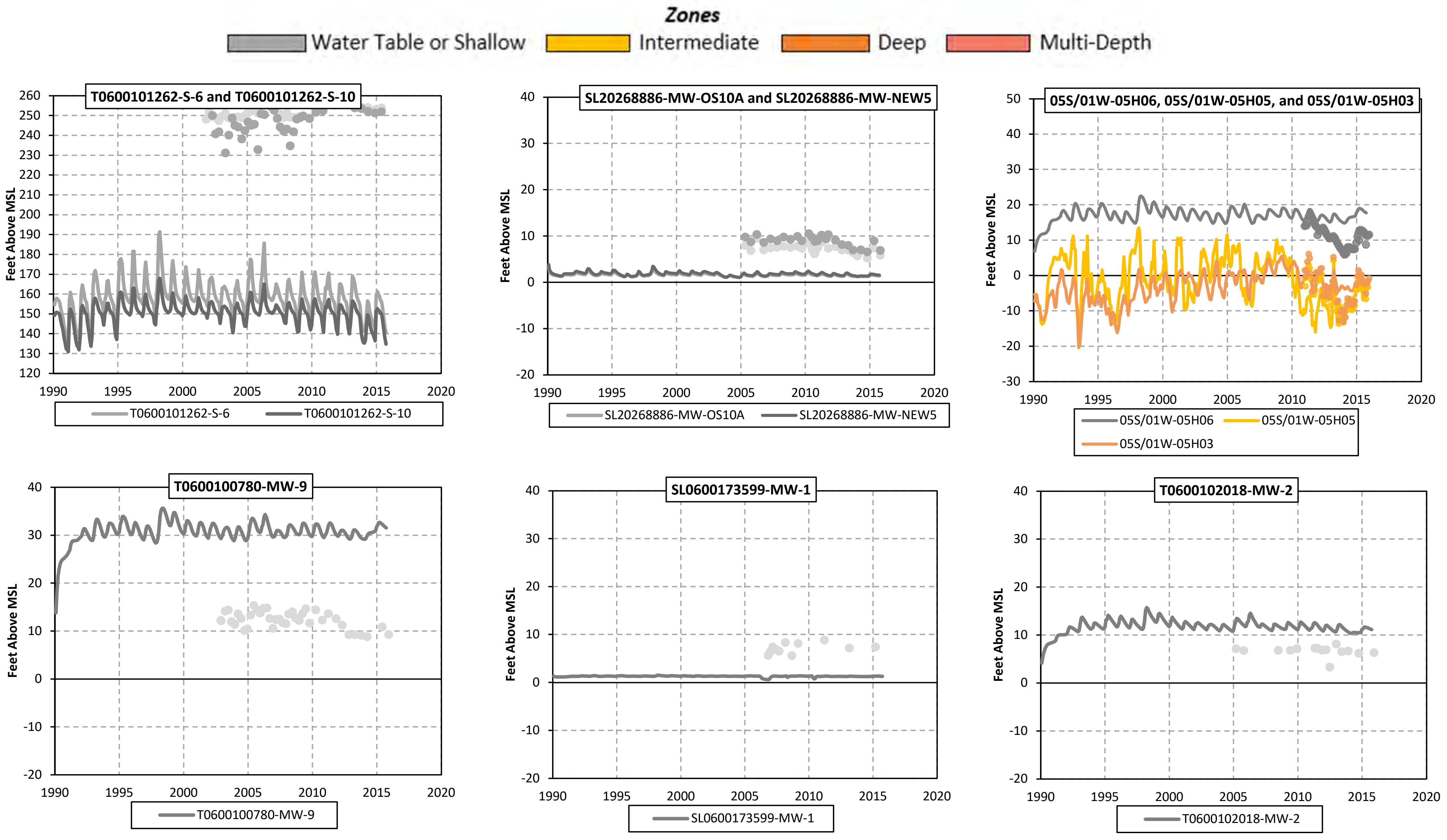
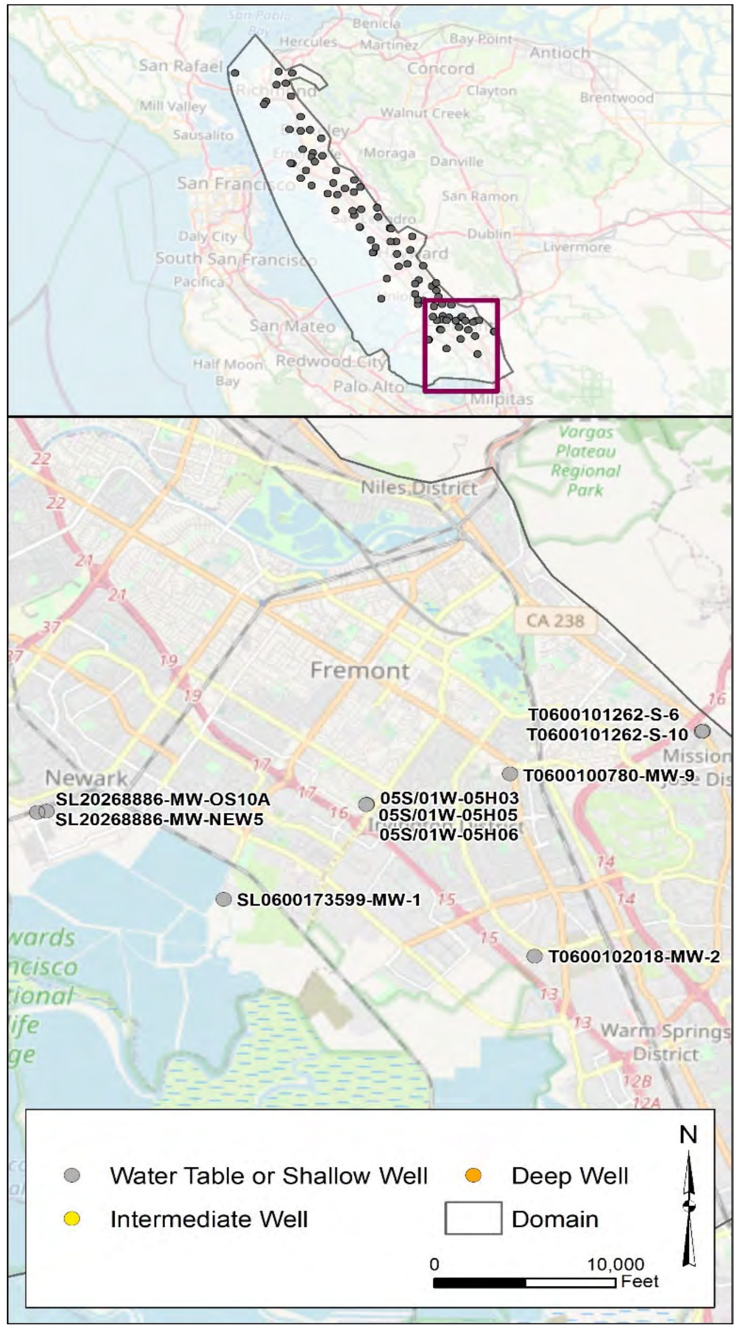
Figure
4-7i





Notes:
MSL = mean sea level
Markers represent observed data, and lines represent simulated data for a given series.

Hydrographs of Simulated and Observed Heads at Selected Wells, 1990 - 2015

East Bay Plain Groundwater Model
Groundwater Sustainability Plan

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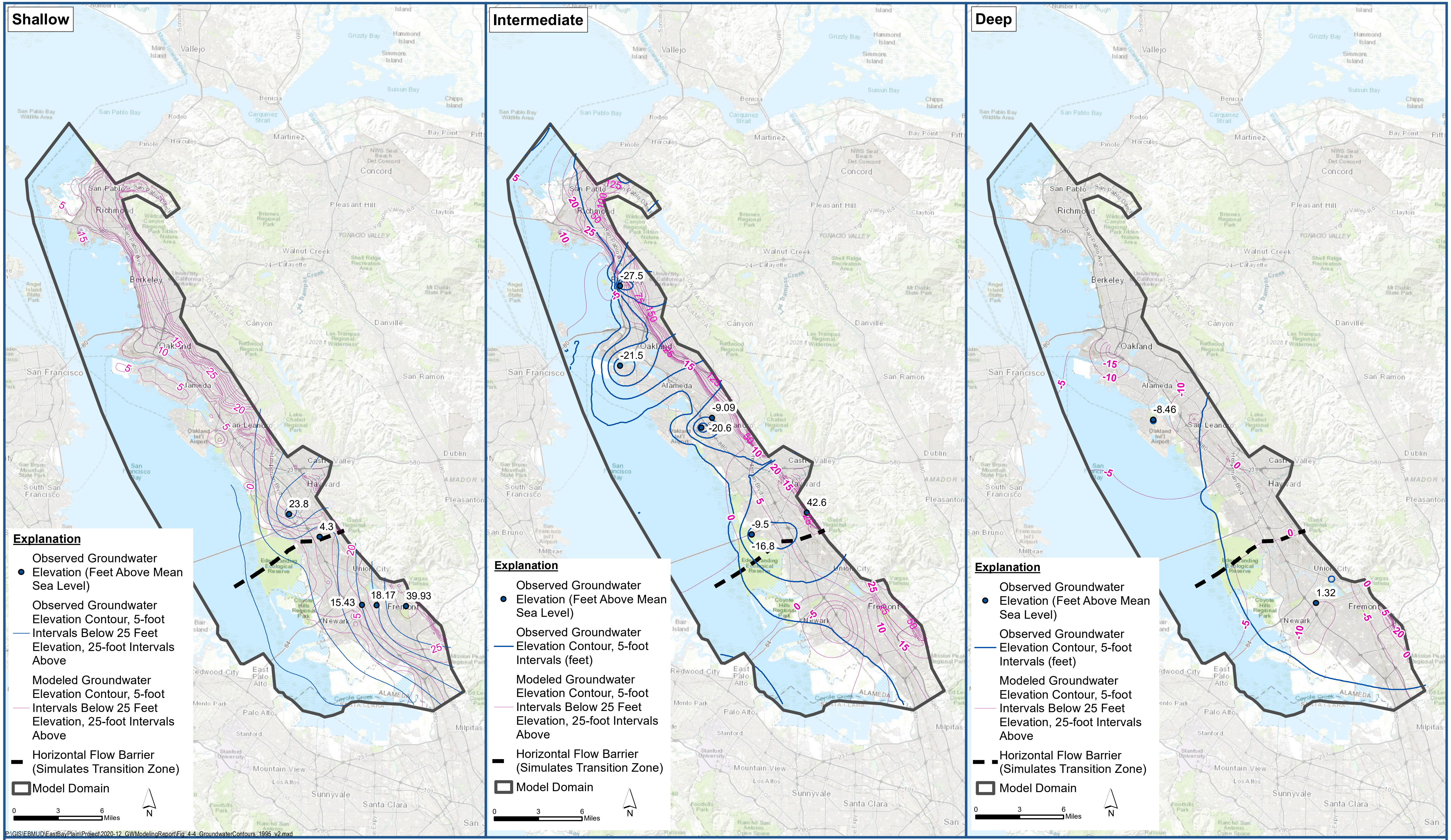
WR2668

November 2021

Figure

4-7j



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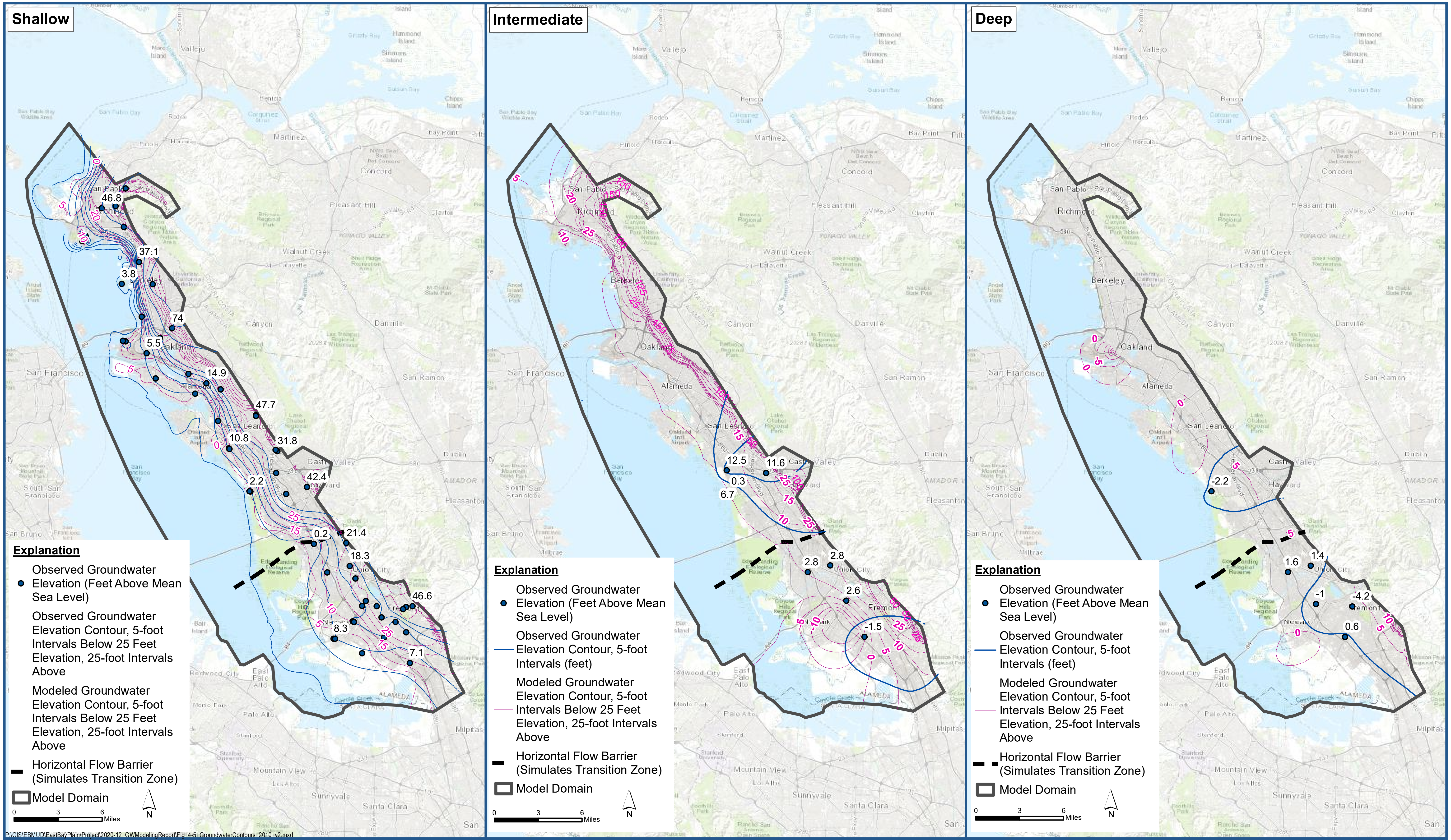
Modeled and Observed Groundwater Contours in the Shallow, Intermediate, and Deep Aquifer Zones - 1995

East Bay Plain Groundwater Model
Groundwater Sustainability Plan

Figure 4-8

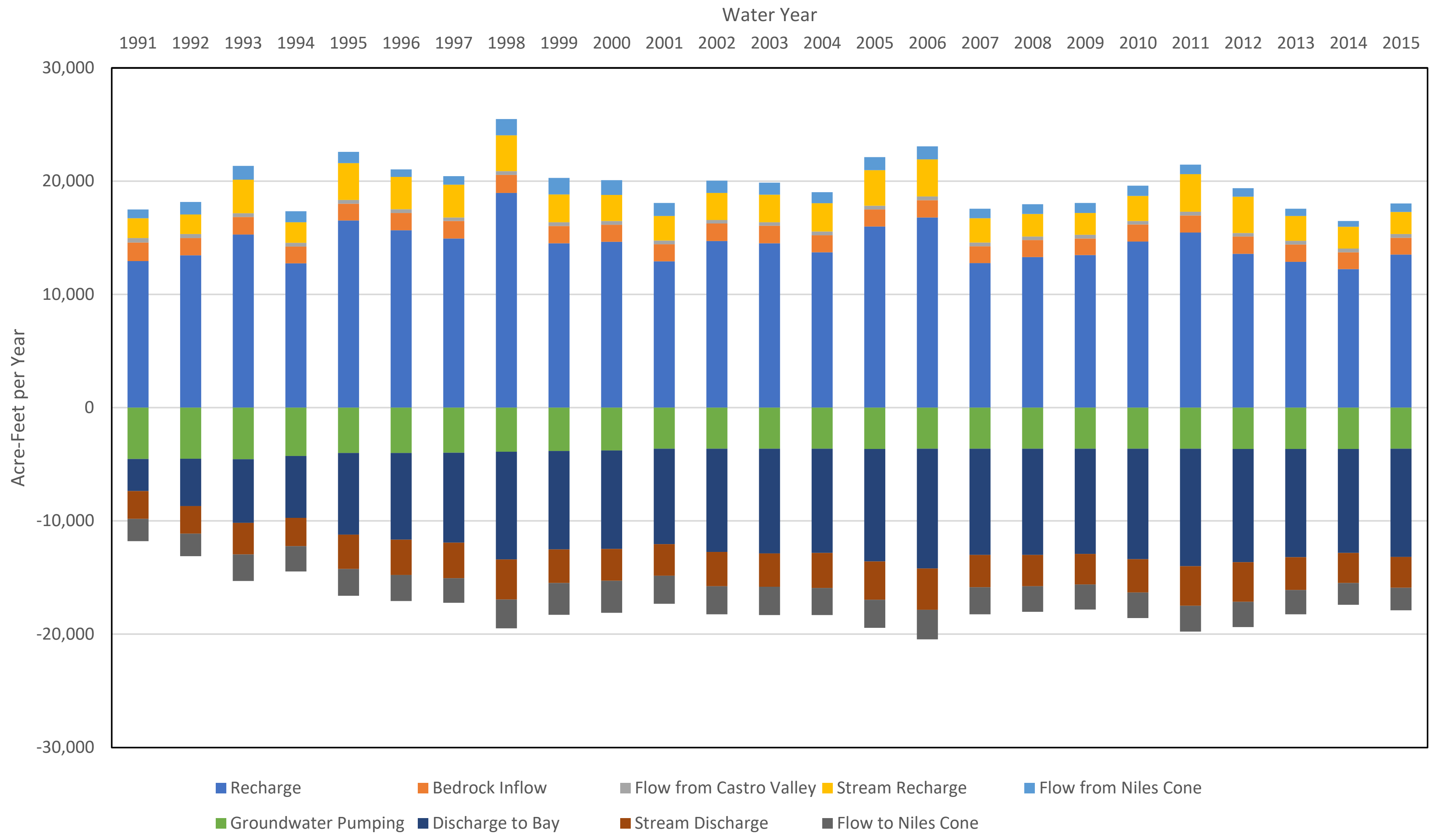


LSCE TEAM

Modeled and Observed Groundwater Contours in the Shallow, Intermediate, and Deep Aquifer Zones - 2011

East Bay Plain Groundwater Model
Groundwater Sustainability Plan

Figure 4-9



Annual Simulated Water Budget for the East Bay Plain Subbasin, 1990 - 2015

East Bay Plain Groundwater Model
Groundwater Sustainability Plan

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Figure

4-10

WR2668

November 2021

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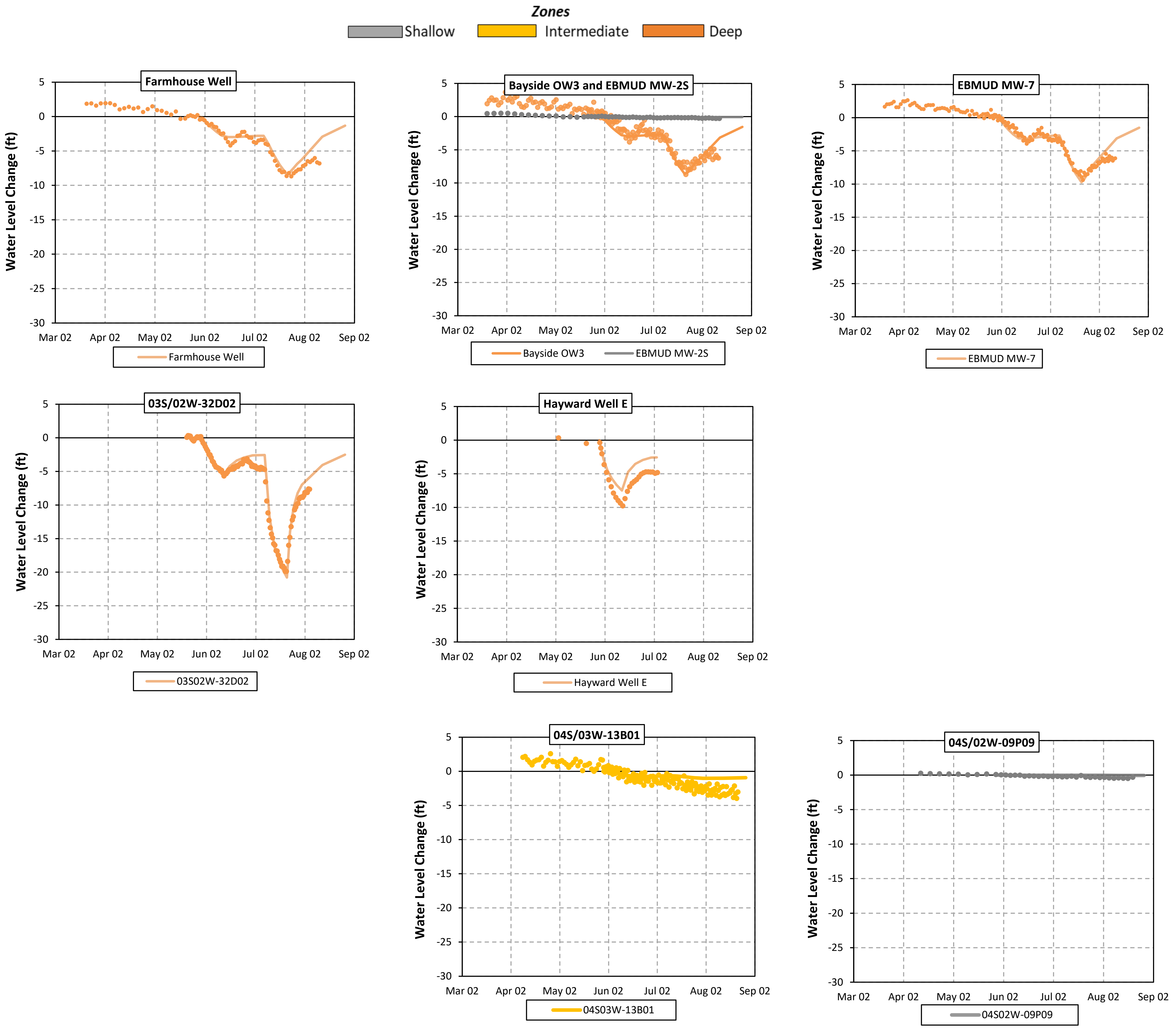
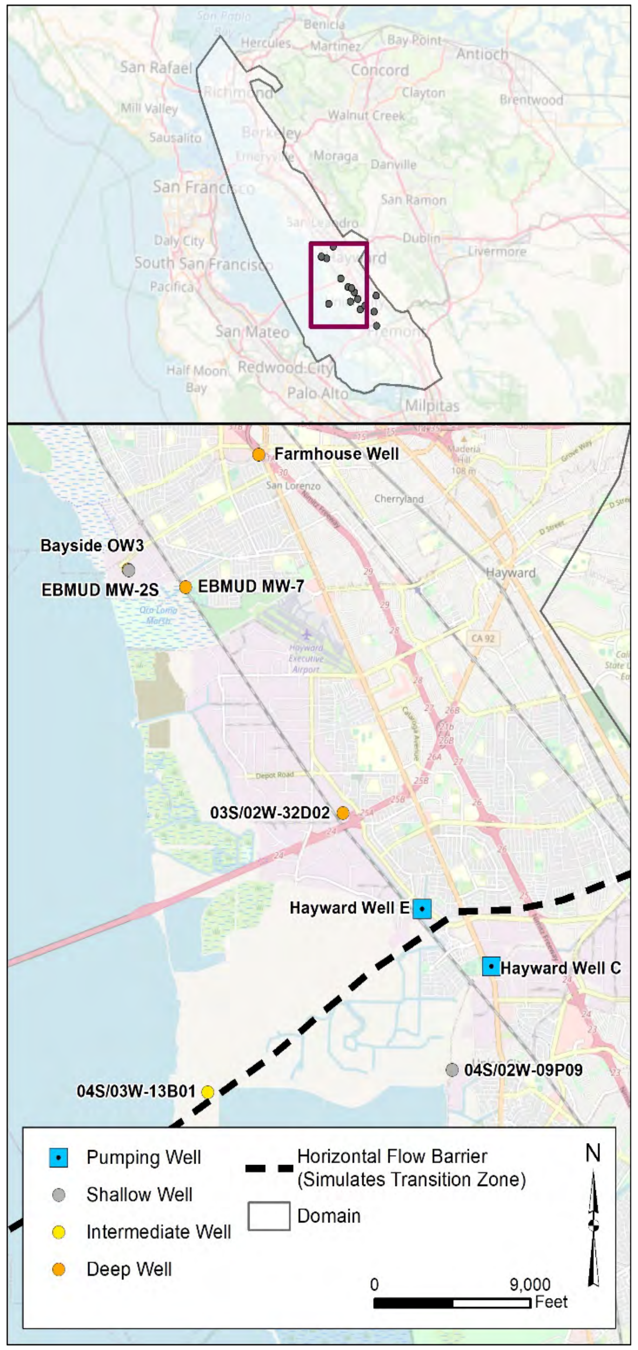




Notes:
ft = feet
Markers represent observed data, and lines represent simulated data for a given series.

Hydrographs of Modeled and Observed 2002 Aquifer Test Data (north)

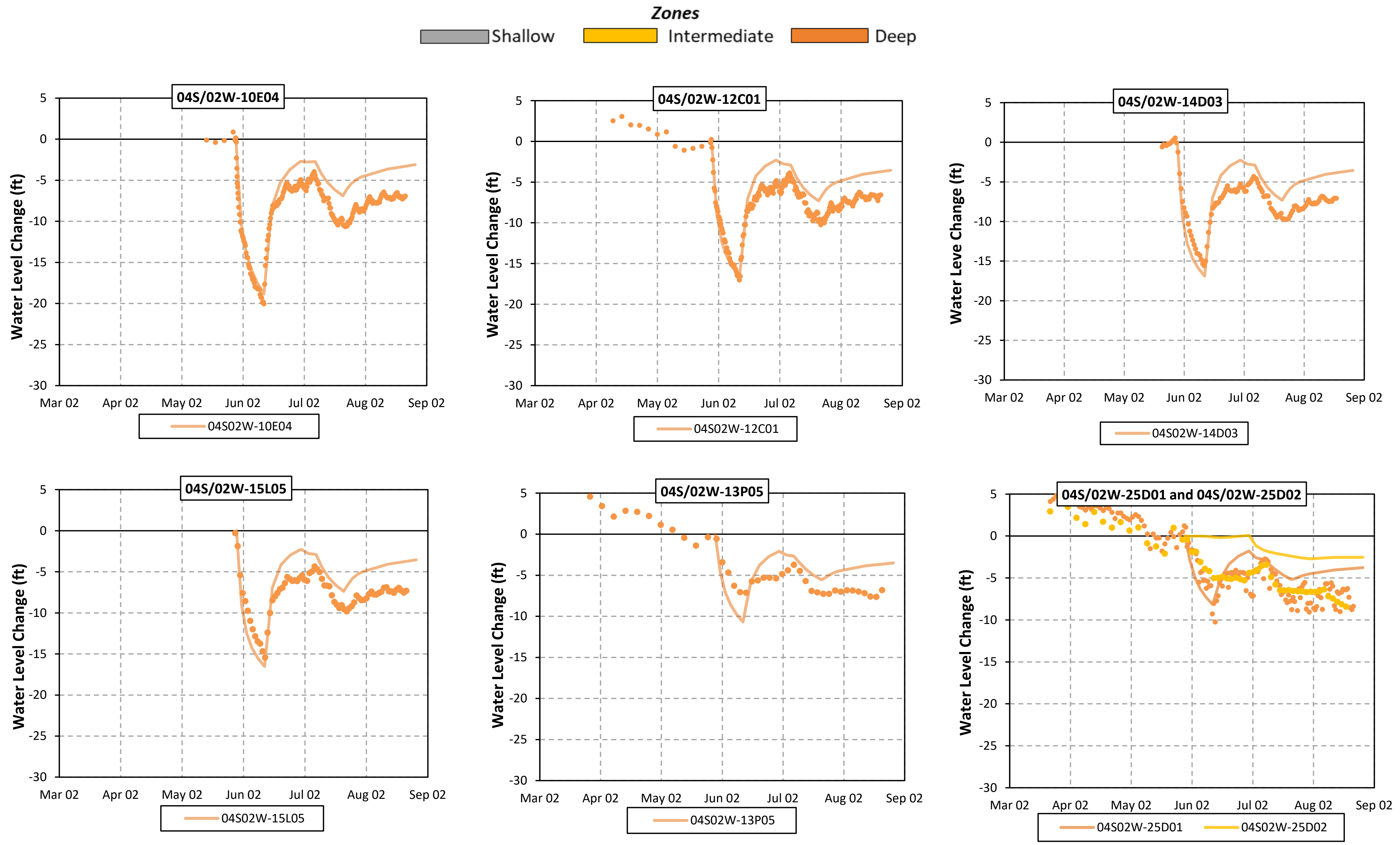
East Bay Plain Groundwater Model
Groundwater Sustainability Plan

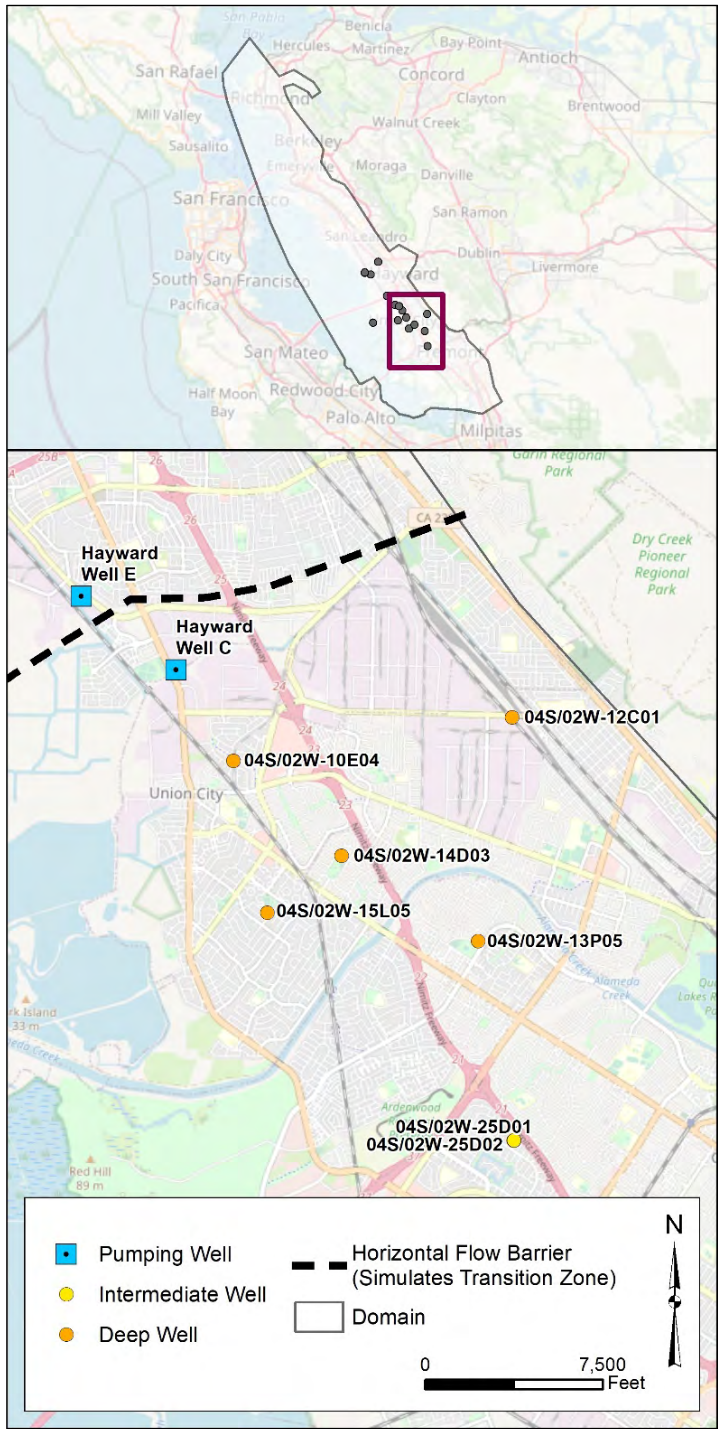
LSCE TEAM

WR2668

March 2021

Figure 4-11a





Notes:
ft = feet
Markers represent observed data, and lines represent simulated data for a given series.

Hydrographs of Modeled and Observed 2002 Aquifer Test Data (south)

East Bay Plain Groundwater Model
Groundwater Sustainability Plan

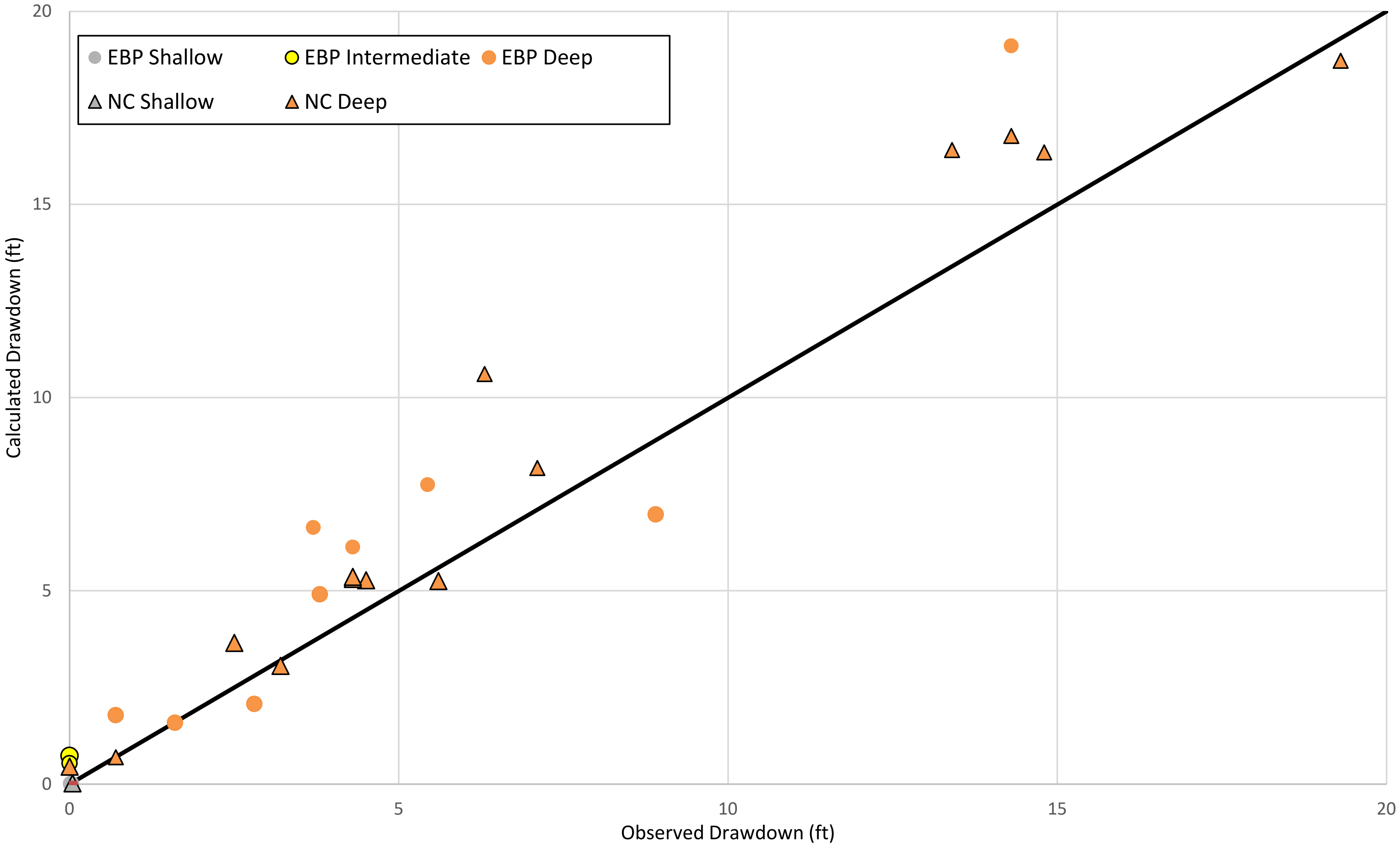
LSCE TEAM

WR2668

March 2021

Figure

4-11b



	Numbers of Observations	Range of Observations (feet)	Mean Error (feet)	Mean Absolute Error (feet)	RMSE (feet)	RMSE (% Range)	R^2
2002 Aquifer Test Simulation							
All	**29**	**19.3**	**-1.0**	**1.2**	**1.8**	**9%**	**0.89**
Well C Test	15	19.3	-0.8	1.2	1.7	N/A	
Well E Test	14	14.3	-1.2	1.3	1.8	N/A	

Observed vs Simulated Drawdown Attained for 2002 Aquifer Test

East Bay Plain Groundwater Model
Groundwater Sustainability Plan

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Figure

4-12

WR2668

March 2021

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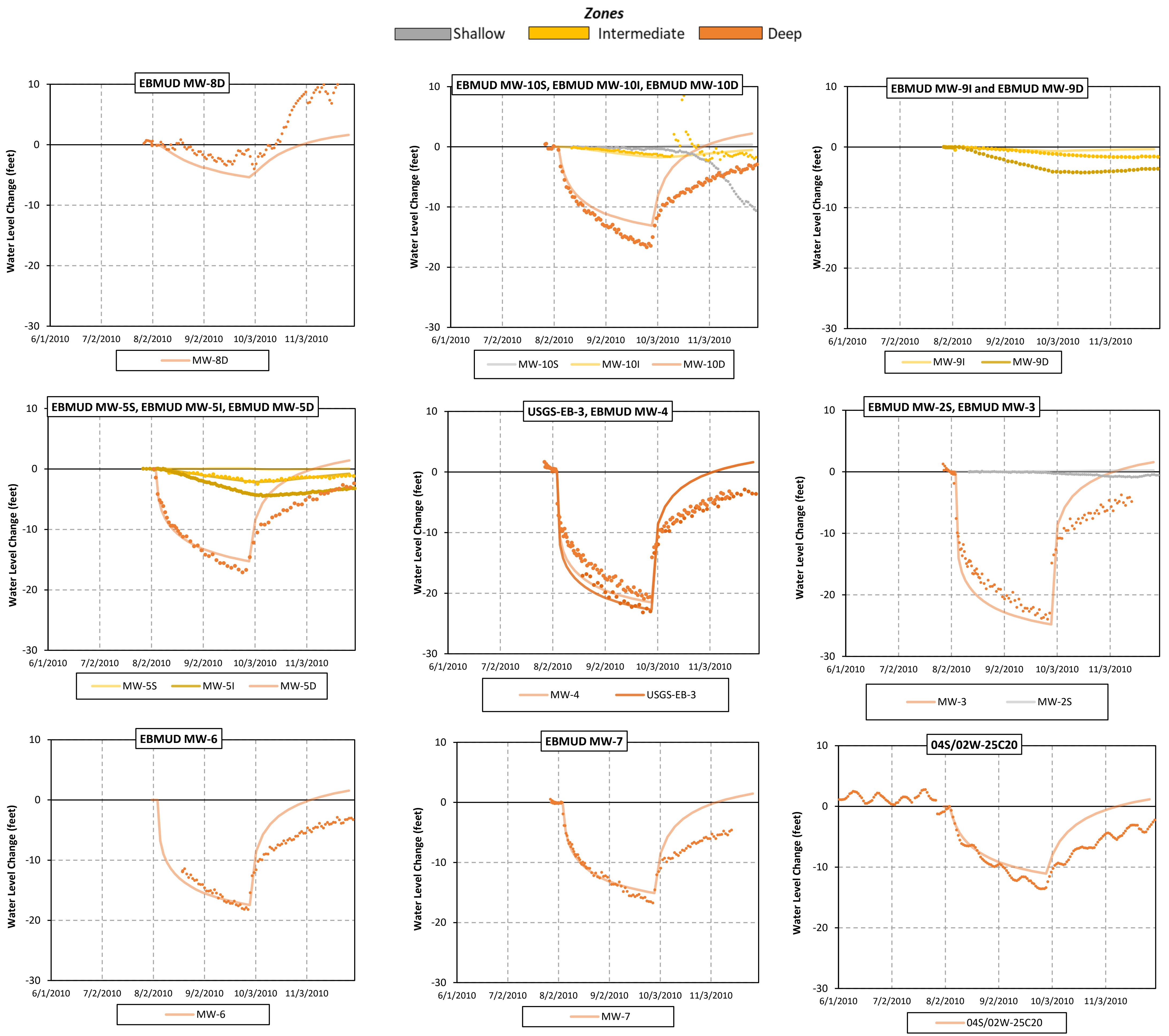

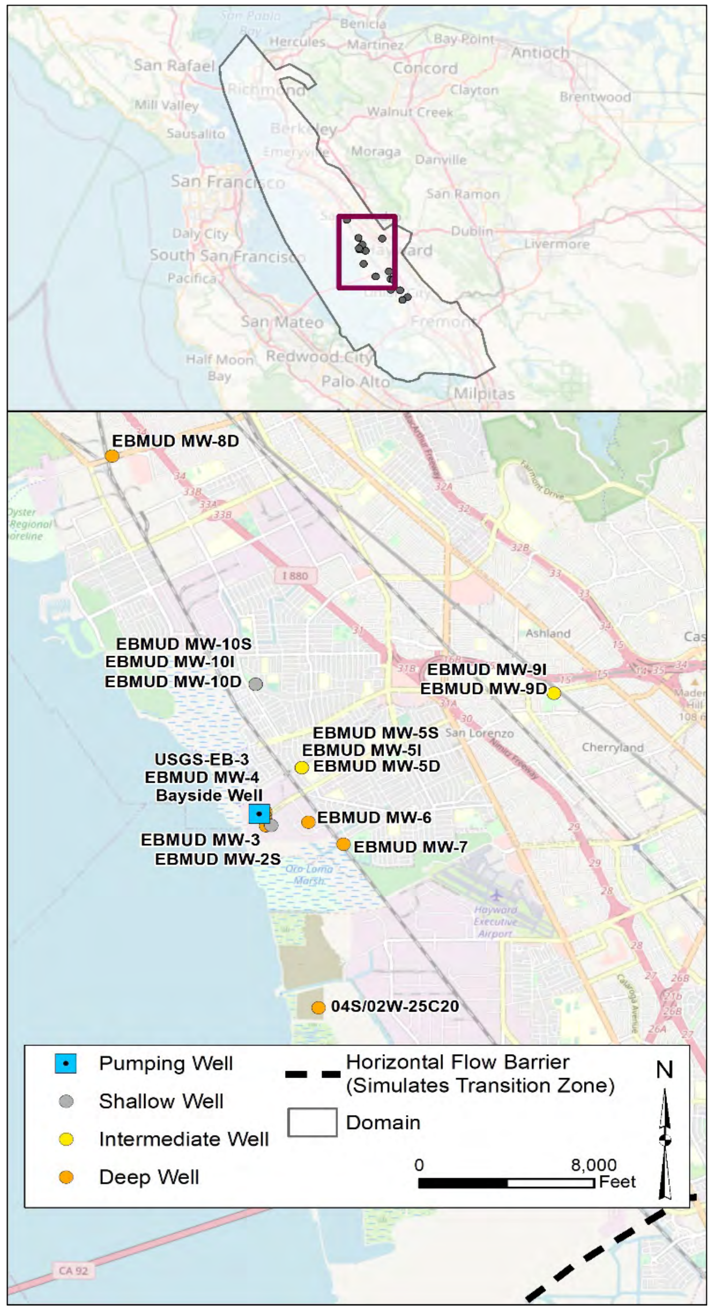

Notes:
Markers represent observed data, and lines represent simulated data for a given series.

Hydrographs of Modeled and Observed 2010 Aquifer Test Data (north)

East Bay Plain Groundwater Model
Groundwater Sustainability Plan

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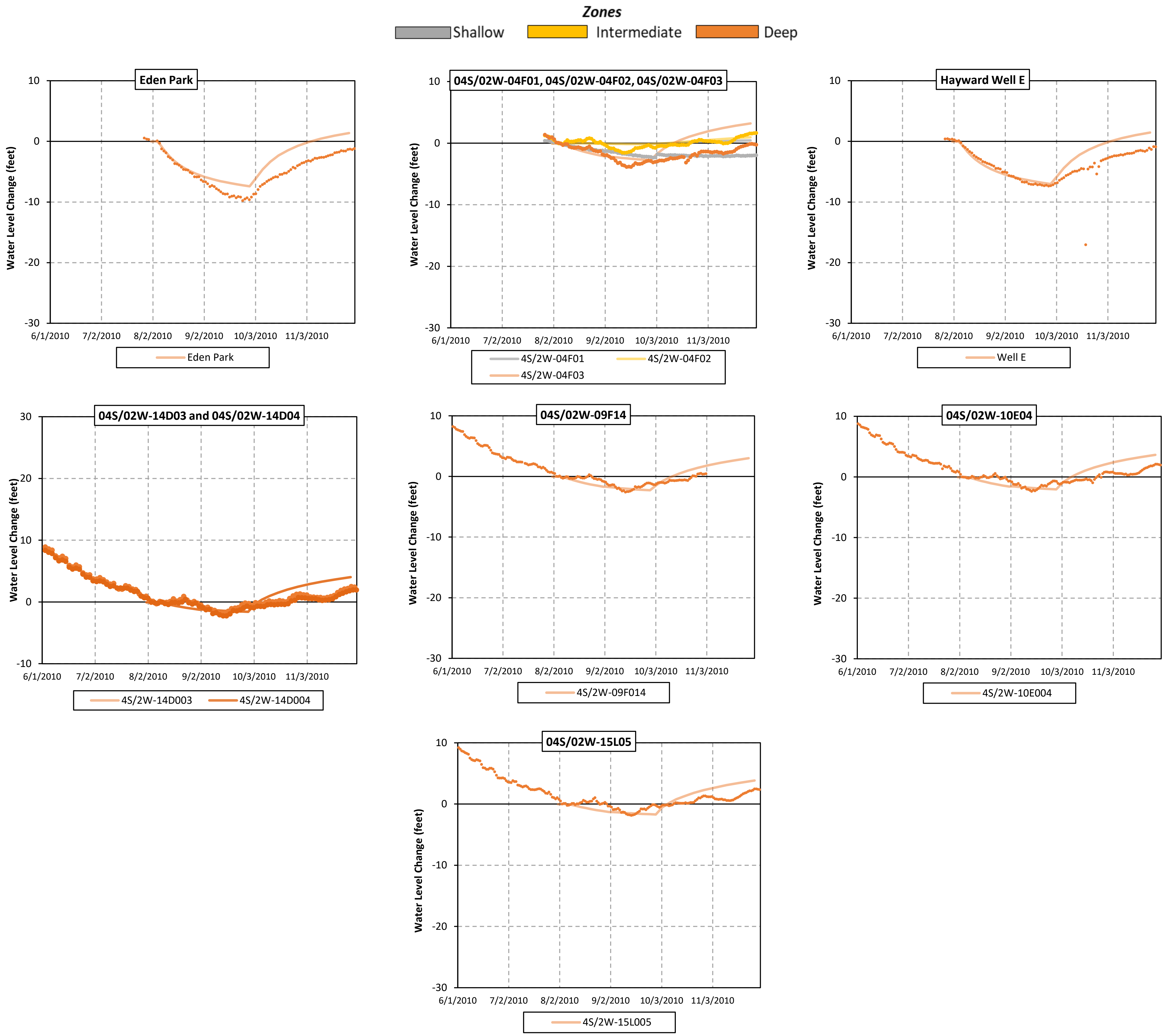
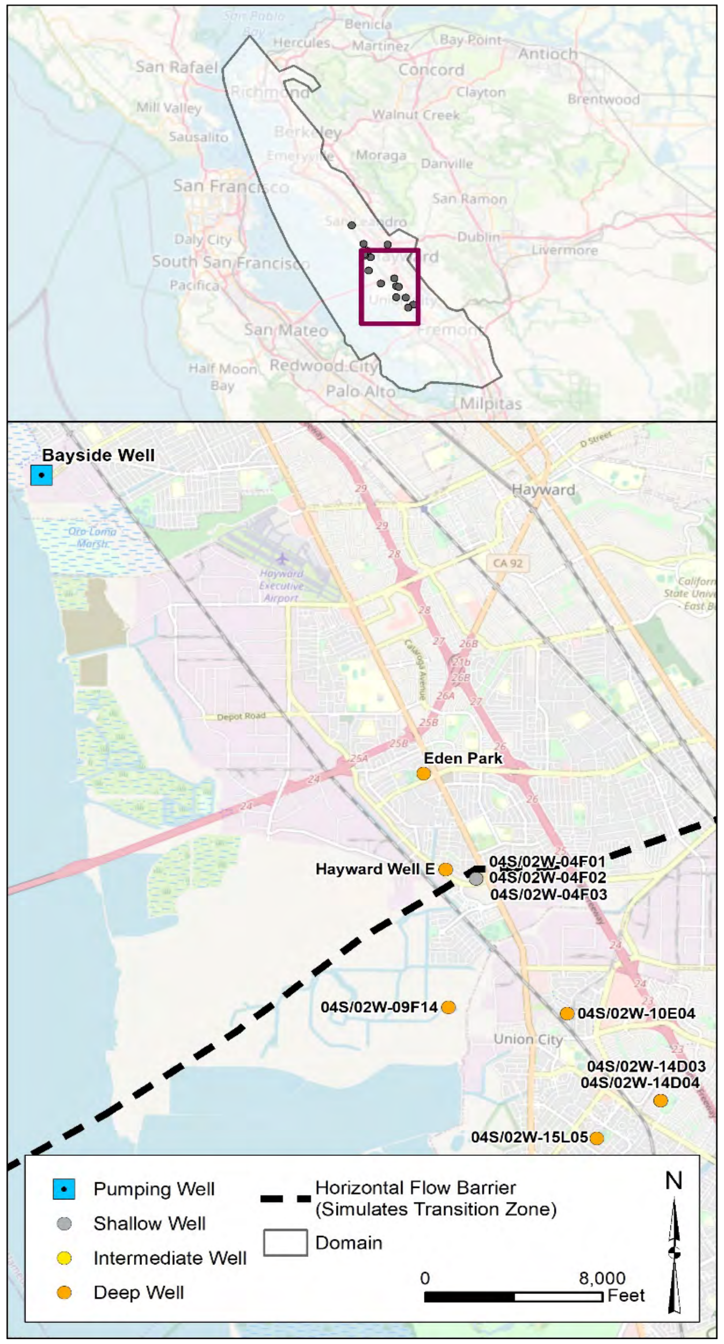
Figure

4-13a

WR2668

March 2021





Notes:

MSL = mean sea level

Markers represent observed data, and lines represent simulated data for a given series.

Hydrographs of Modeled and Observed 2010 Aquifer Test Data (south)

East Bay Plain Groundwater Model
Groundwater Sustainability Plan

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Figure 4-13b

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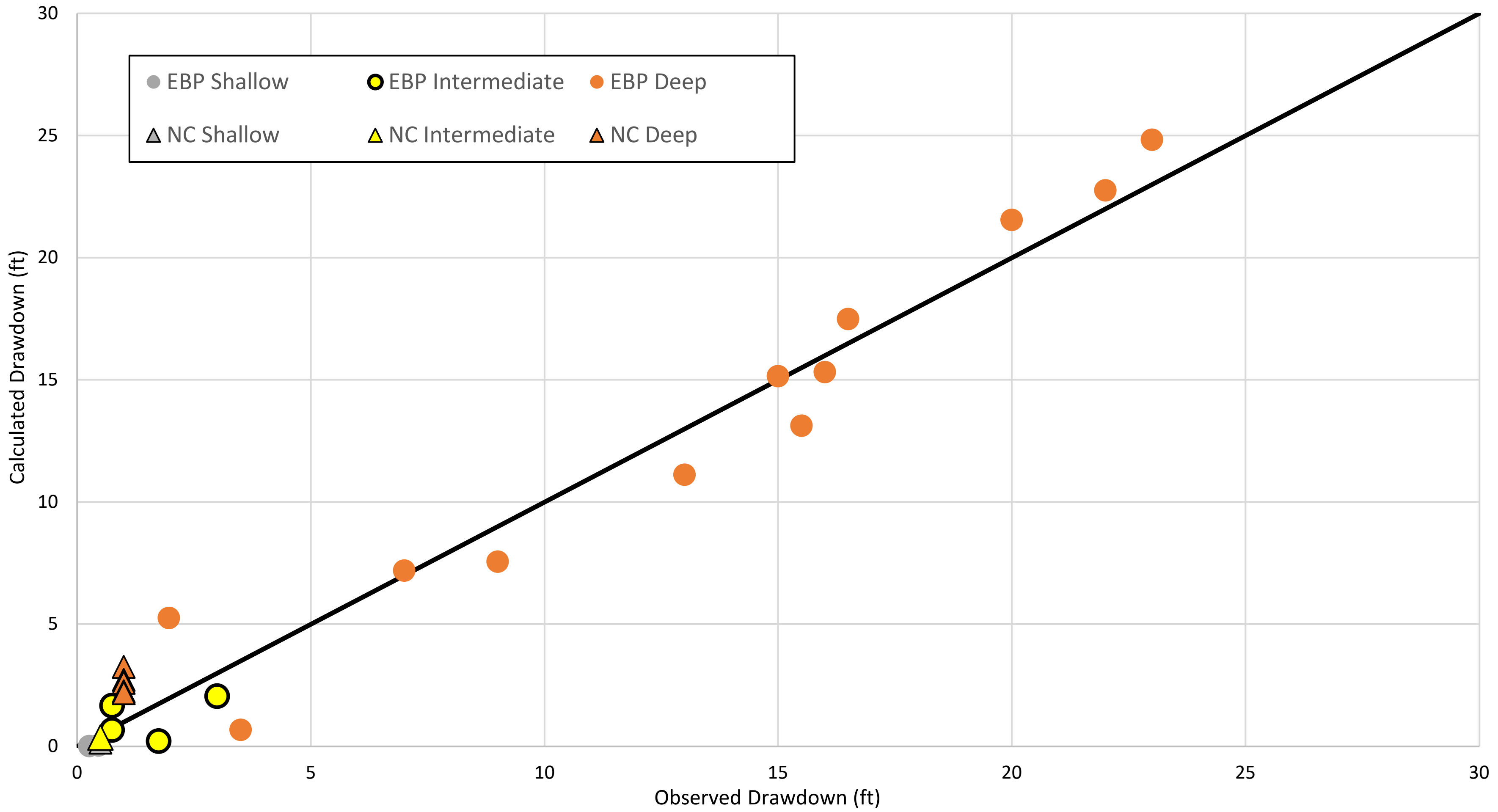
March 2021



	Numbers of Observations	Range of Observations (feet)	Mean Error (feet)	Mean Absolute Error (feet)	RMSE (feet)	RMSE (% Range)	R2
2010 Aquifer Test Simulation							
All	**26**	**22.7**	**0.1**	**1.5**	**1.5**	**7%**	**0.96**
East Bay Plain							
Shallow	2	0.2	0.34	0.34	0.3	N/A	
Intermediate	4	2.3	0.42	0.87	1.0	N/A	
Deep	12	21.0	0.04	1.50	1.78	N/A	
Niles Cone							
Shallow	1	N/A	0.3	0.3	0.3	N/A	
Intermediate	1	N/A	0.1	0.1	0.1	N/A	
Deep	6	N/A	-1.5	1.5	1.6	N/A	

Observed vs Simulated Drawdown Attained for 2010 Aquifer Test

East Bay Plain Groundwater Model
Groundwater Sustainability Plan

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Figure 4-14

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March 2021

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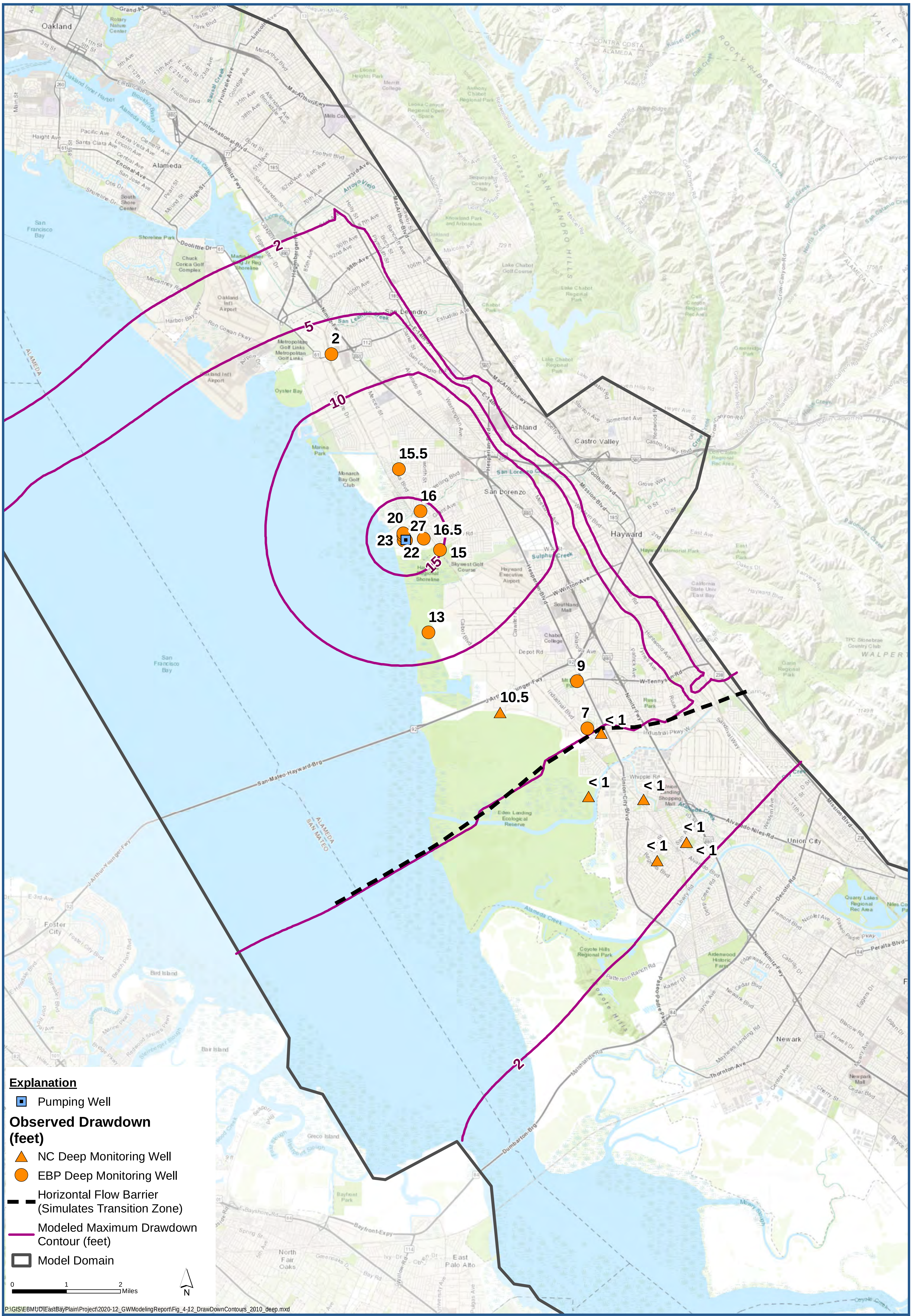

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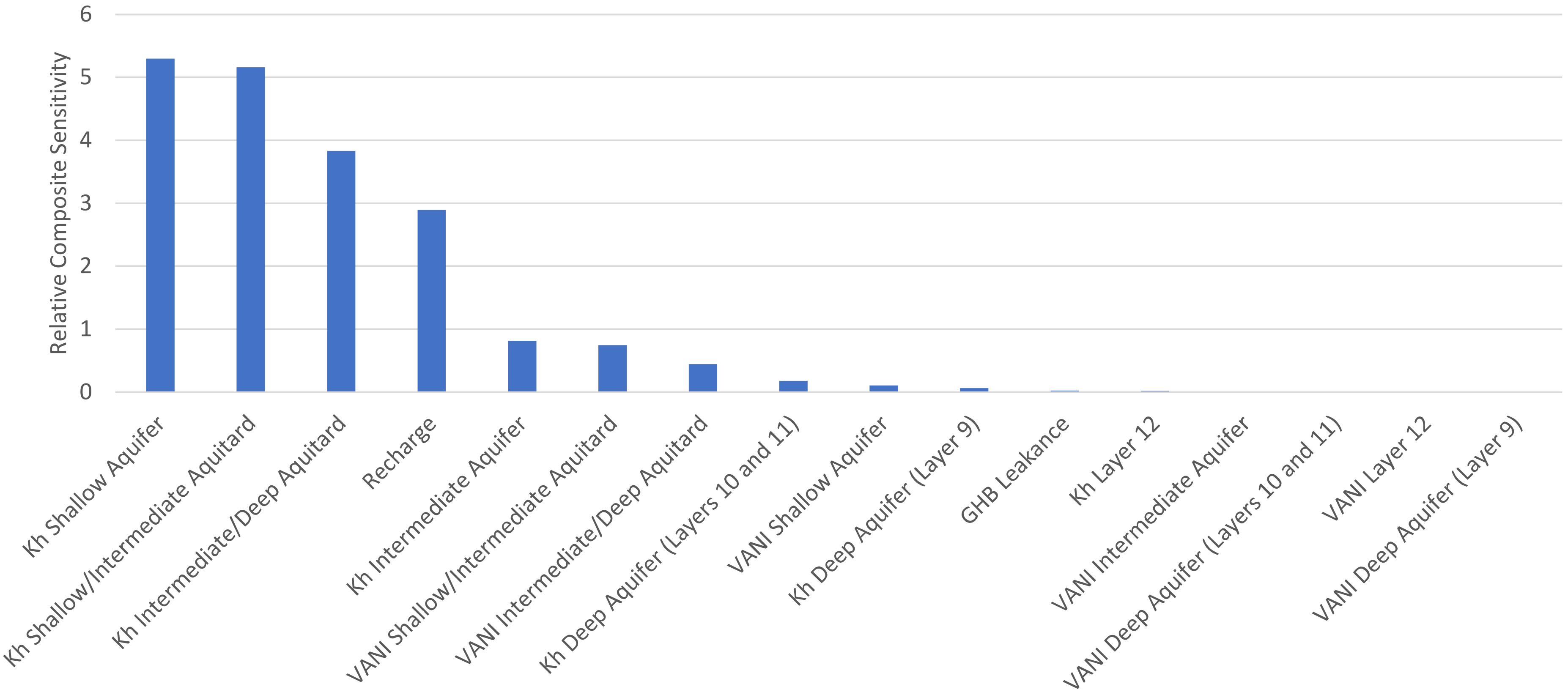
Contour Map of Modeled Drawdown Attained during 2010 Aquifer Test with Observed Values Posted

East Bay Plain Groundwater Model
Groundwater Sustainability Plan

Figure 4-15



Kh = Horizontal Hydraulic Conductivity
VANI = Vertical Hydraulic Conductivity Anisotropy Ratio
GHB = General Head Boundary

Model-Calculated Sensitivity to Input Parameters for Steady-State Simulation

East Bay Plain Groundwater Model
Groundwater Sustainability Plan

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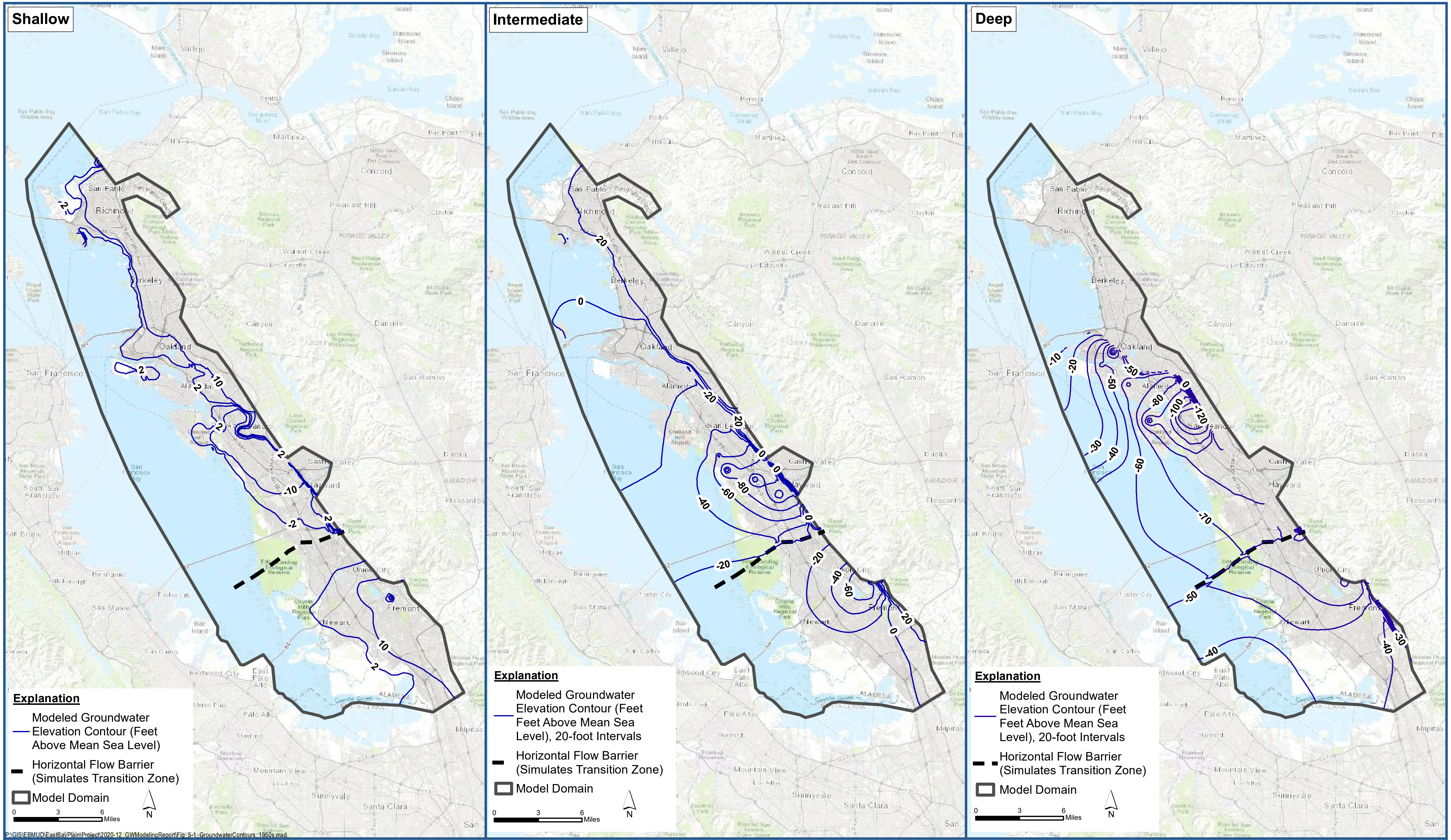
Figure 4-16



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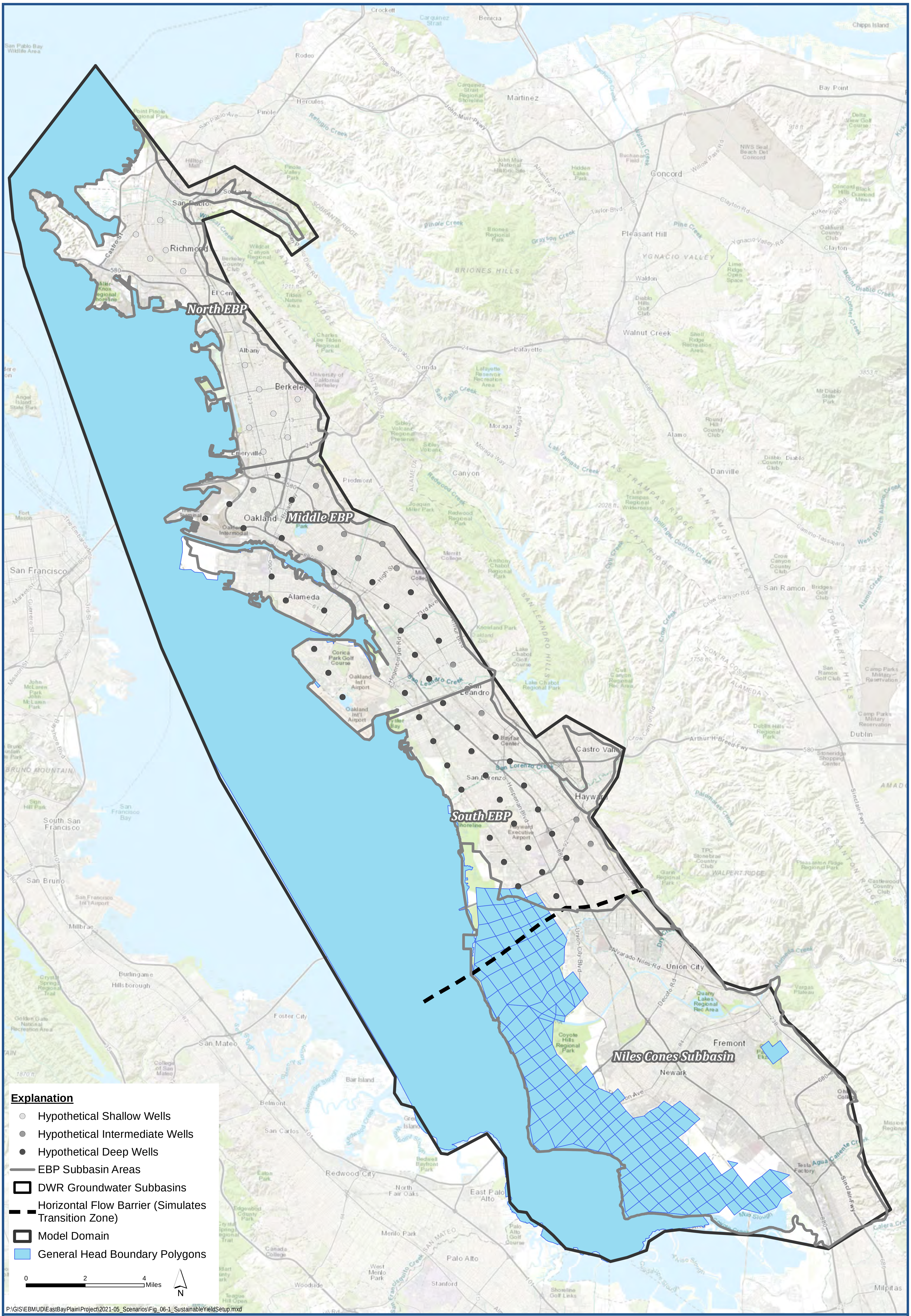
Modeled Groundwater Contours in the Shallow, Intermediate, and Deep Aquifer Zones - Historical (1950s/1960s) Pumping

East Bay Plain Groundwater Model
Groundwater Sustainability Plan

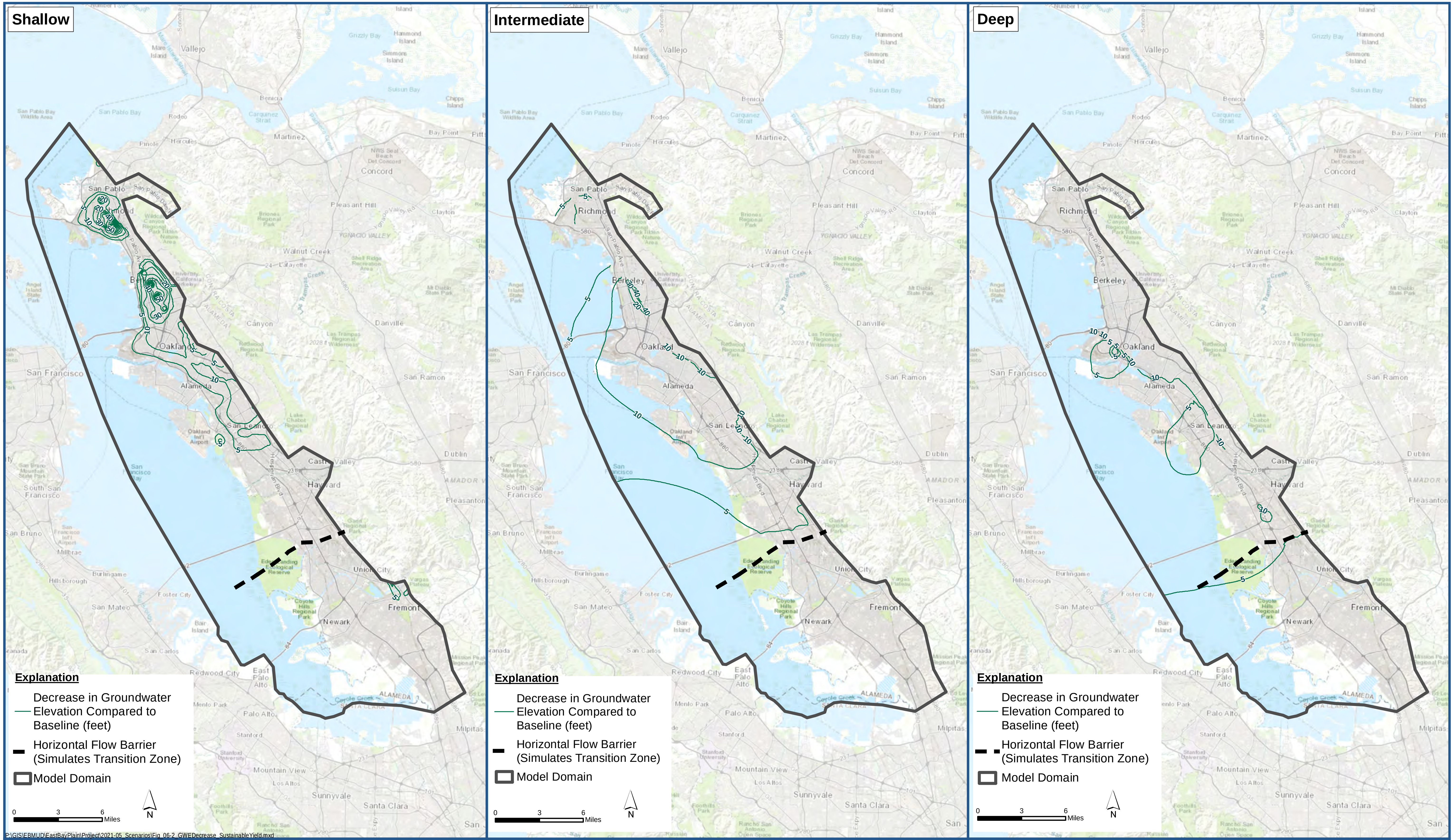
Figure 5-1



Sustainable Yield Evaluation

East Bay Plain Groundwater Model
Groundwater Sustainability Plan

Figure 6-1



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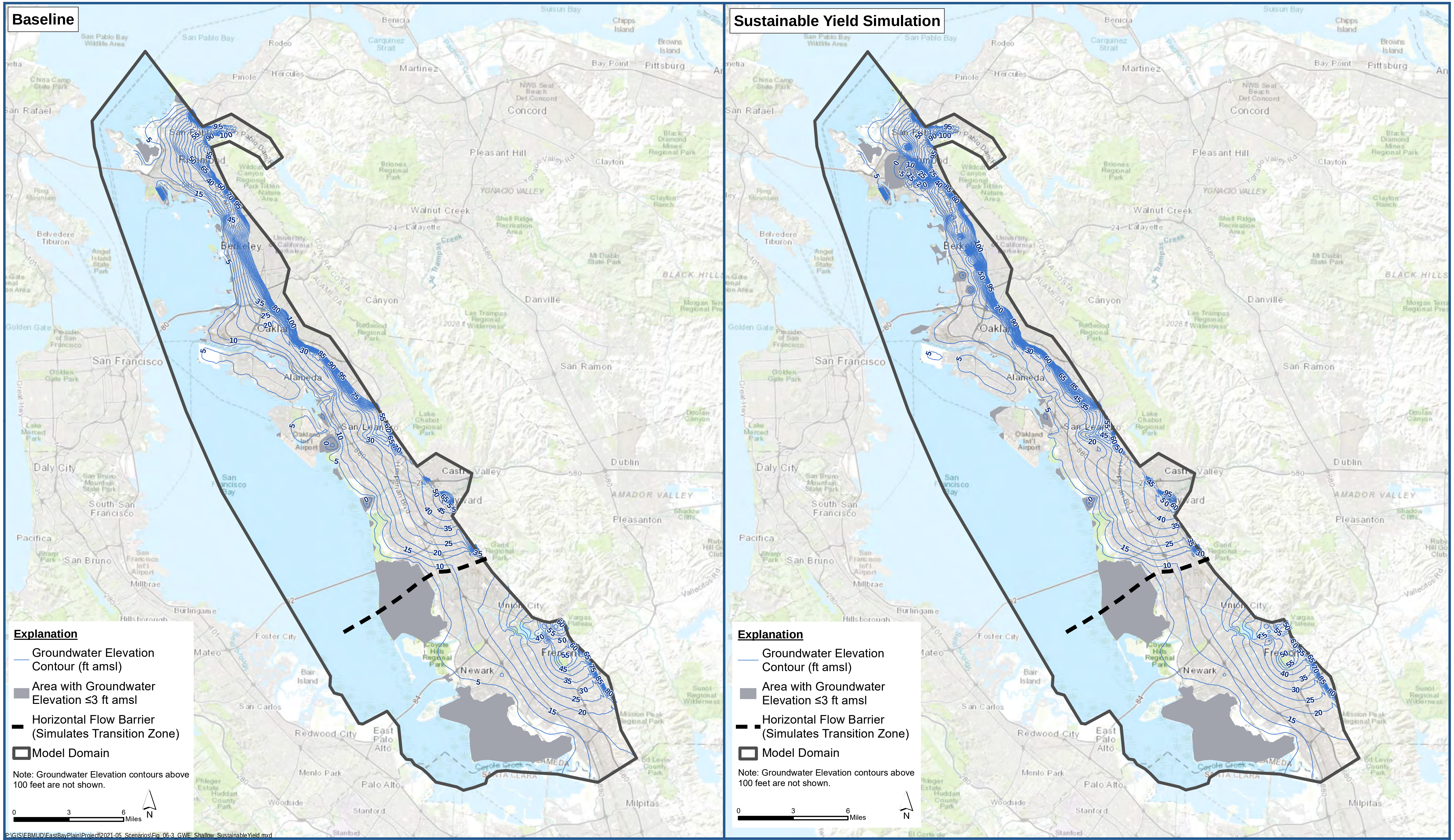
Groundwater Elevation Decrease in Sustainable Yield Simulation Compared to Baseline

Figure 6-2

East Bay Plain Groundwater Model
Groundwater Sustainability Plan



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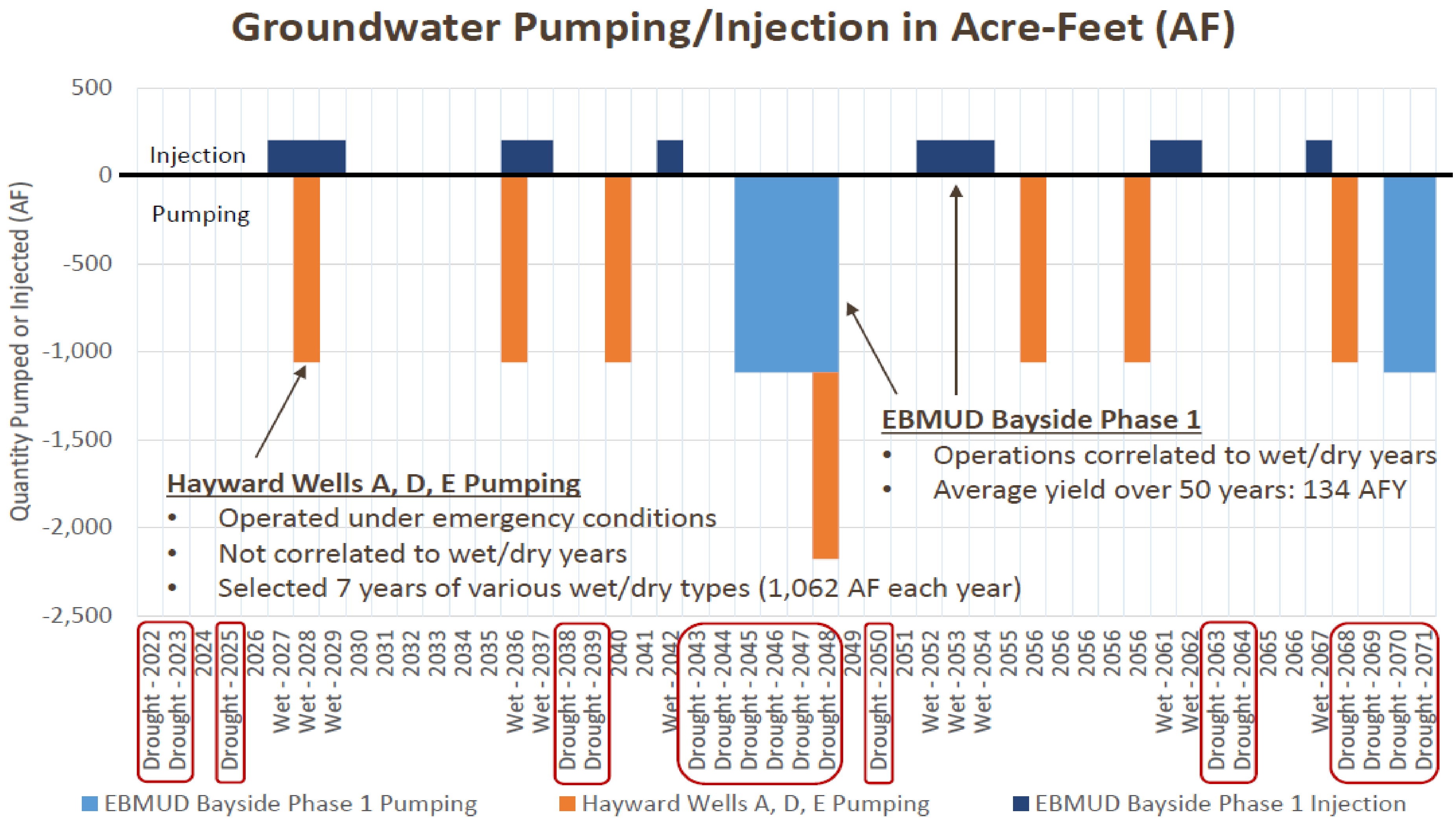
Groundwater Elevation in Shallow Aquifer in Sustainable Yield Simulation (Model Layer 1)

East Bay Plain Groundwater Model
Groundwater Sustainability Plan

Figure 6-3



Hayward Wells A, D, E Pumping

- Operated under emergency conditions
- Not correlated to wet/dry years
- Selected 7 years of various wet/dry types (1,062 AF each year)

EBMUD Bayside Phase 1

- Operations correlated to wet/dry years
- Average yield over 50 years: 134 AFY

Pumping/Injection Sequence for Groundwater Resources Development Scenario

East Bay Plain Groundwater Model
Groundwater Sustainability Plan

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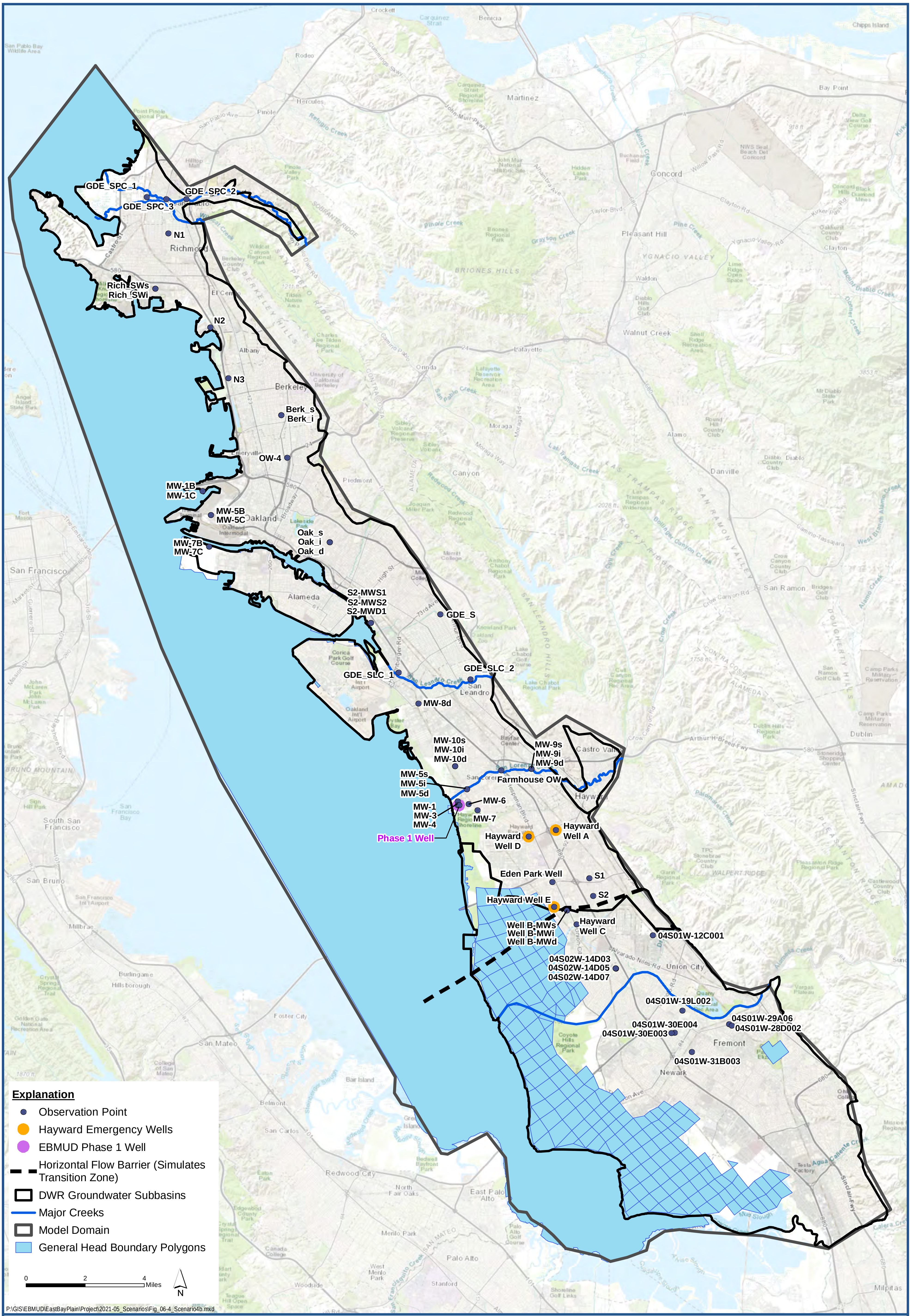
WR2668	November 2021	**Figure 6-4a**

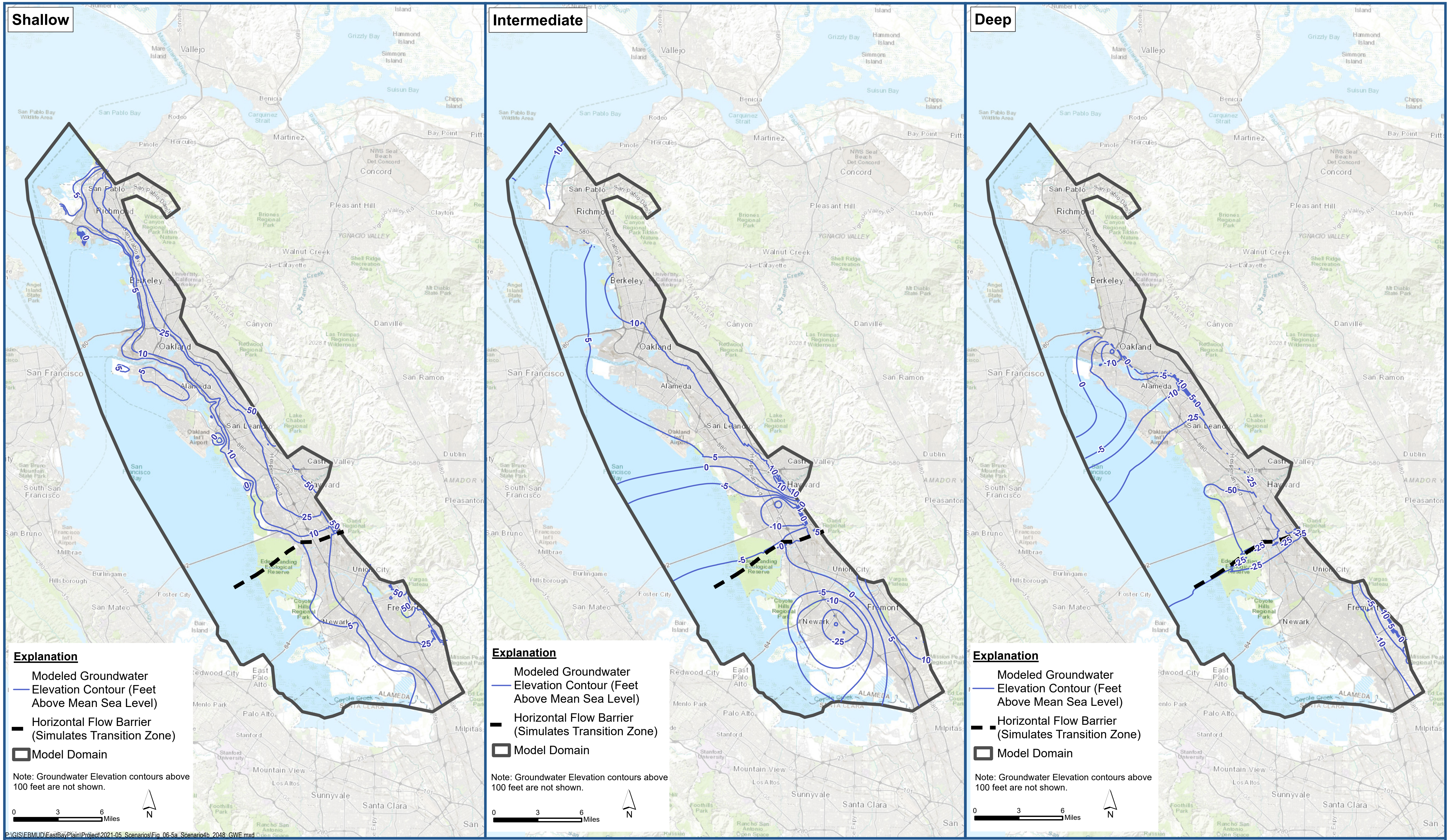
\\Oakland-01\data\PRJ2003REM\East Bay Plain GSP\06. Deliverables\Working Versions-Delete when finalized\4.6 Groundwater Modeling Memo\Figures\[figure6-4a.xlsx]



Features for Groundwater Resources Development Scenario

East Bay Plain Groundwater Model
Groundwater Sustainability Plan

Figure 6-4b



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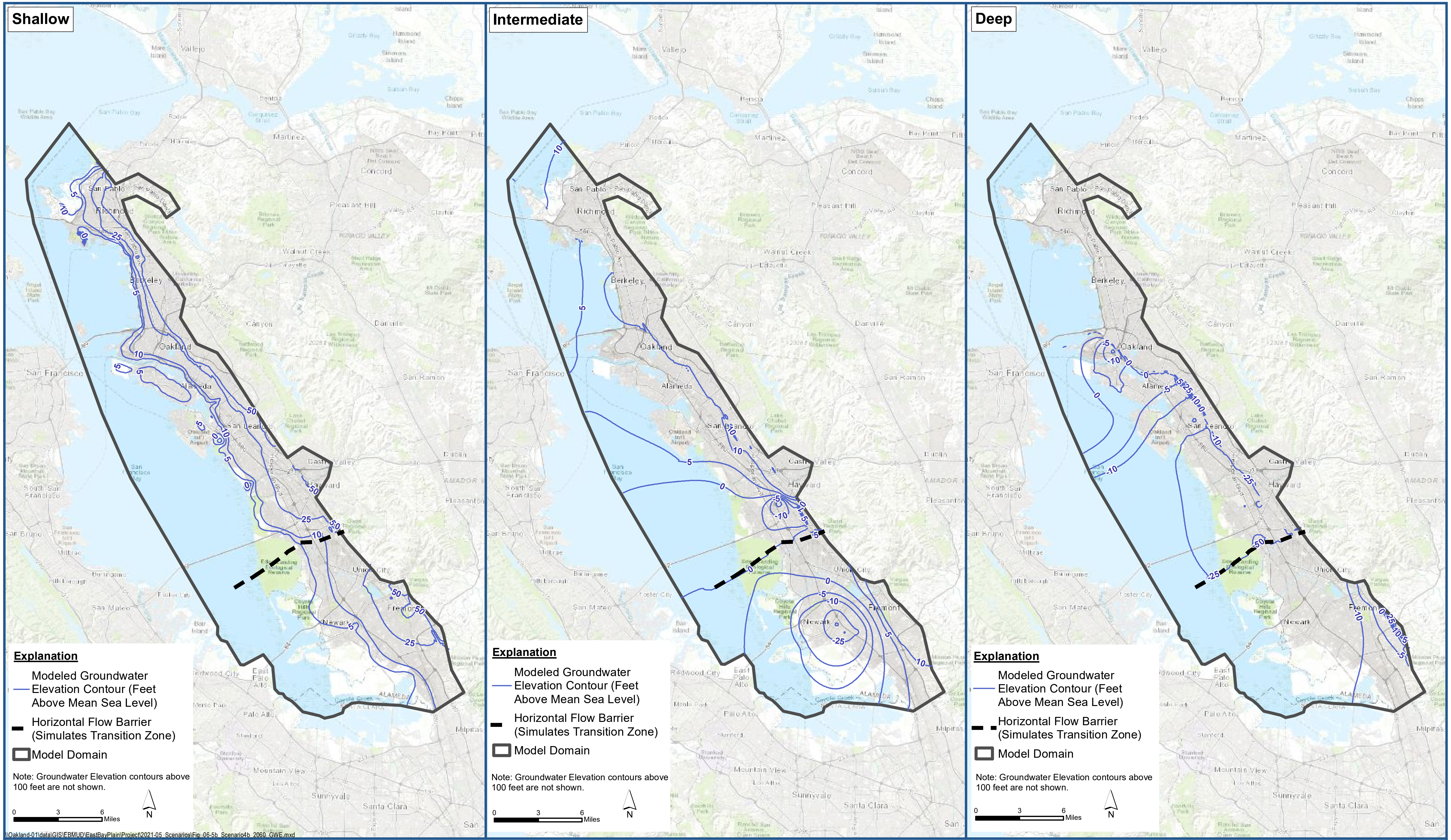
Modeled Groundwater Elevation Contours in the Shallow, Intermediate, and Deep Aquifers
August 2048 (Model Year 27)

East Bay Plain Groundwater Model
Groundwater Sustainability Plan

Figure 6-5a



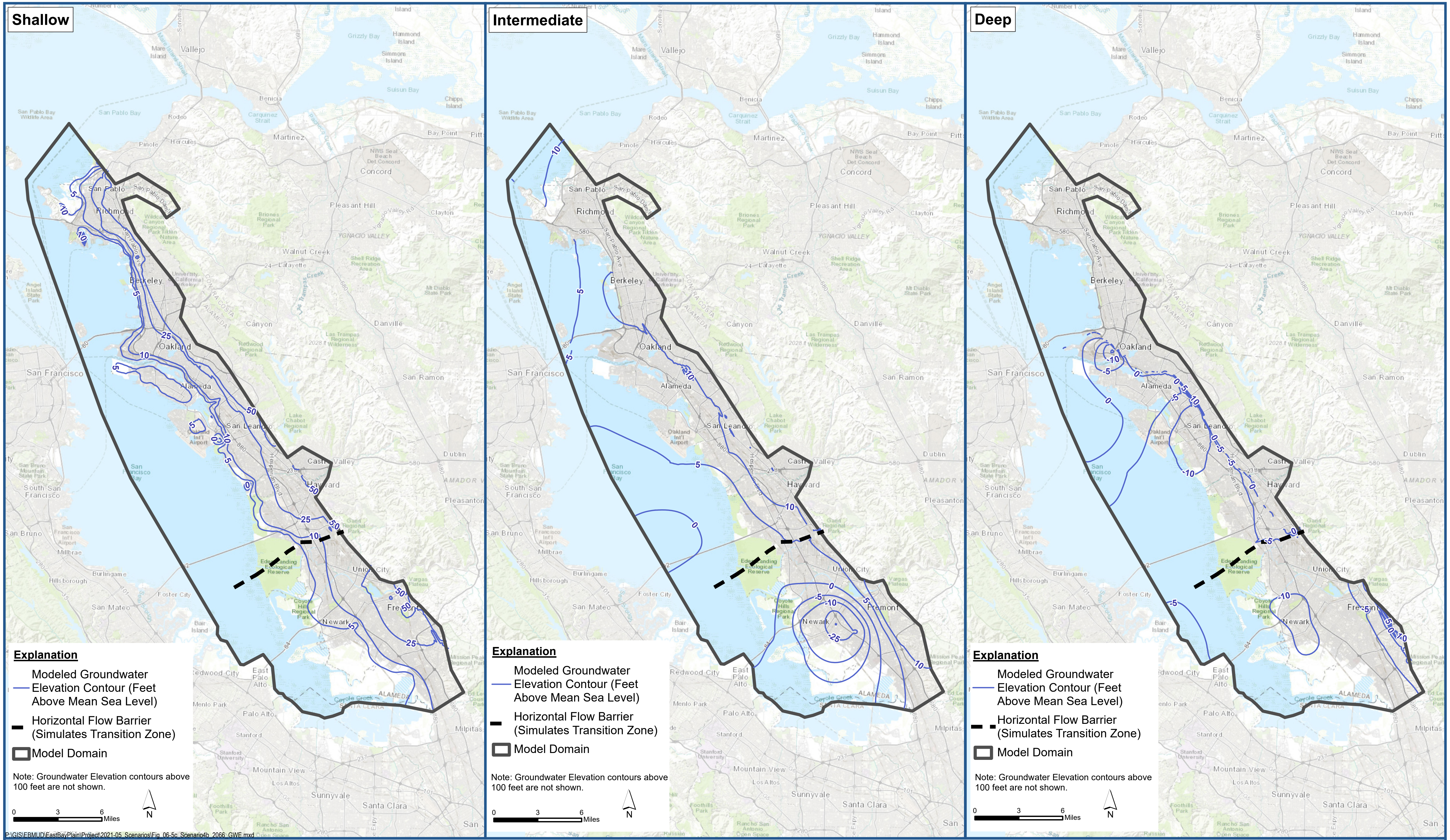
\\Oakland-01\data\GIS\EBMUD\EastBayPlain\Project\2021-05_Scenarios\Fig_06-5b_Scenario4b_2060_GWE.mxd

LSCE TEAM

Modeled Groundwater Elevation Contours in the Shallow, Intermediate, and Deep Aquifers
August 2060 (Model Year 39)

East Bay Plain Groundwater Model
Groundwater Sustainability Plan

Figure 6-5b



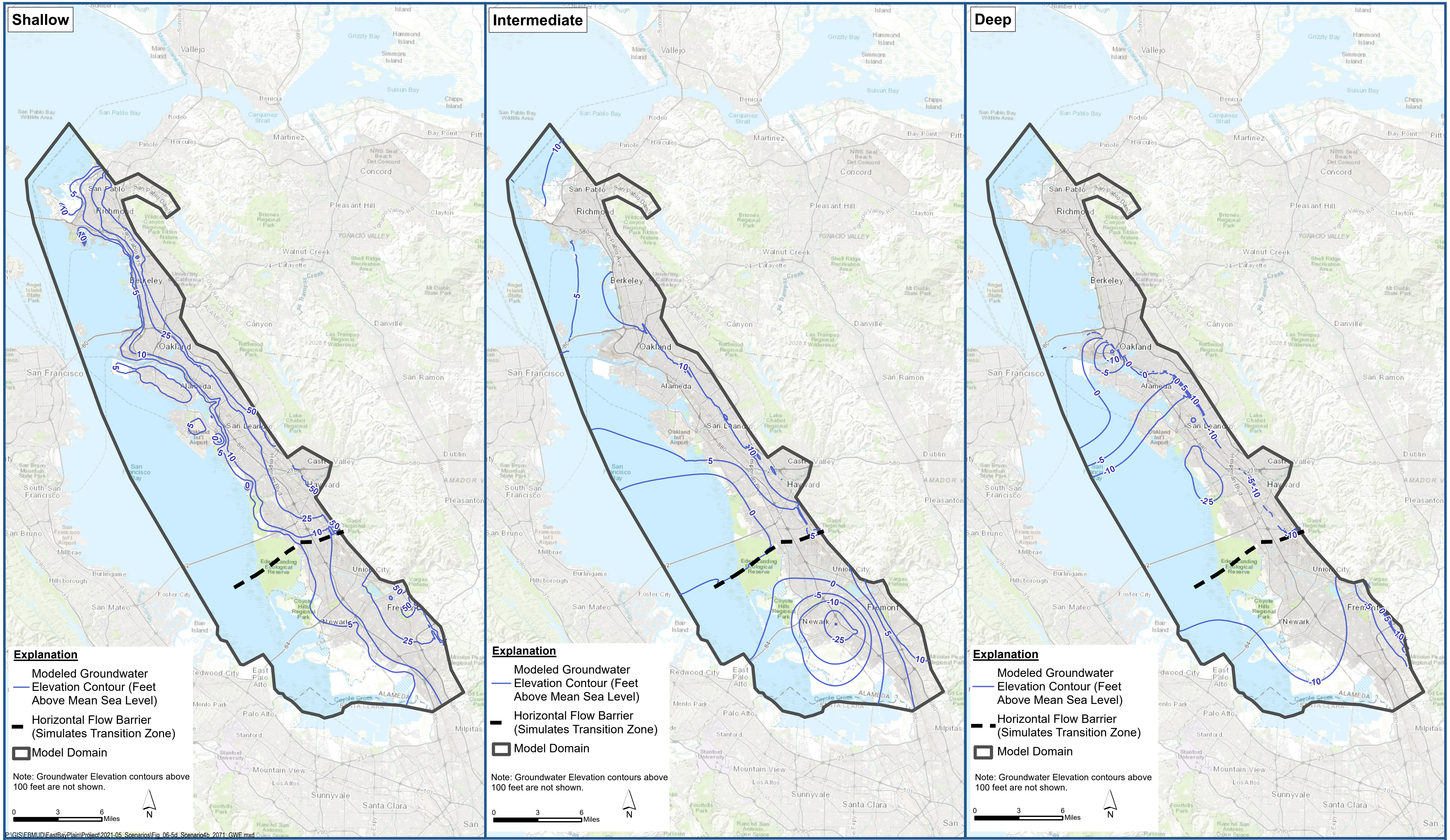
Note: Groundwater Elevation contours above 100 feet are not shown.

LSCE TEAM

Modeled Groundwater Elevation Contours in the Shallow, Intermediate, and Deep Aquifers
September 2066 (Model Year 45)

East Bay Plain Groundwater Model
Groundwater Sustainability Plan

Figure 6-5c

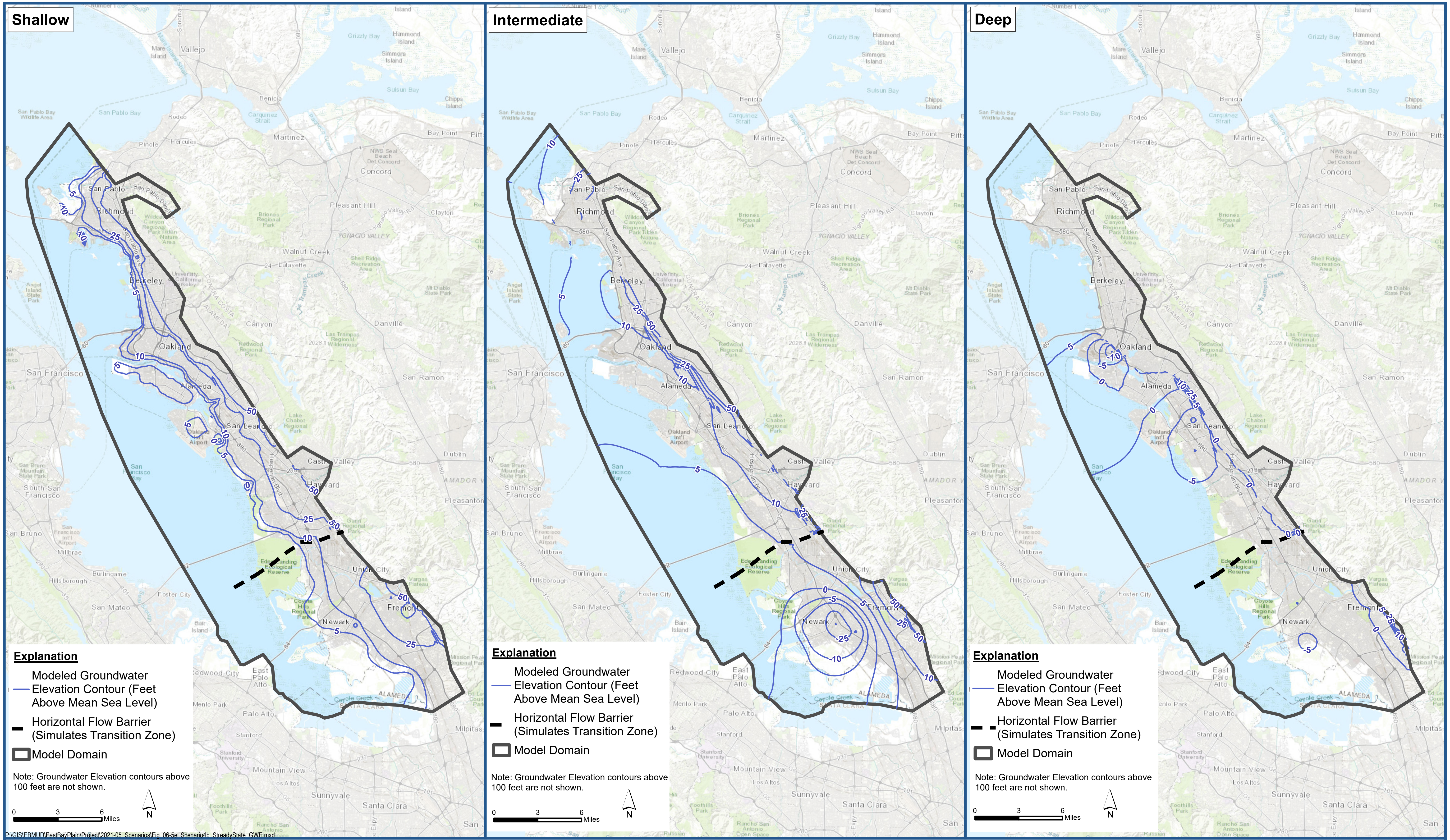


LSCE TEAM

Modeled Groundwater Elevation Contours in the Shallow, Intermediate, and Deep Aquifers September 2071 (Model Year 50)

East Bay Plain Groundwater Model
Groundwater Sustainability Plan

Figure 6-5d

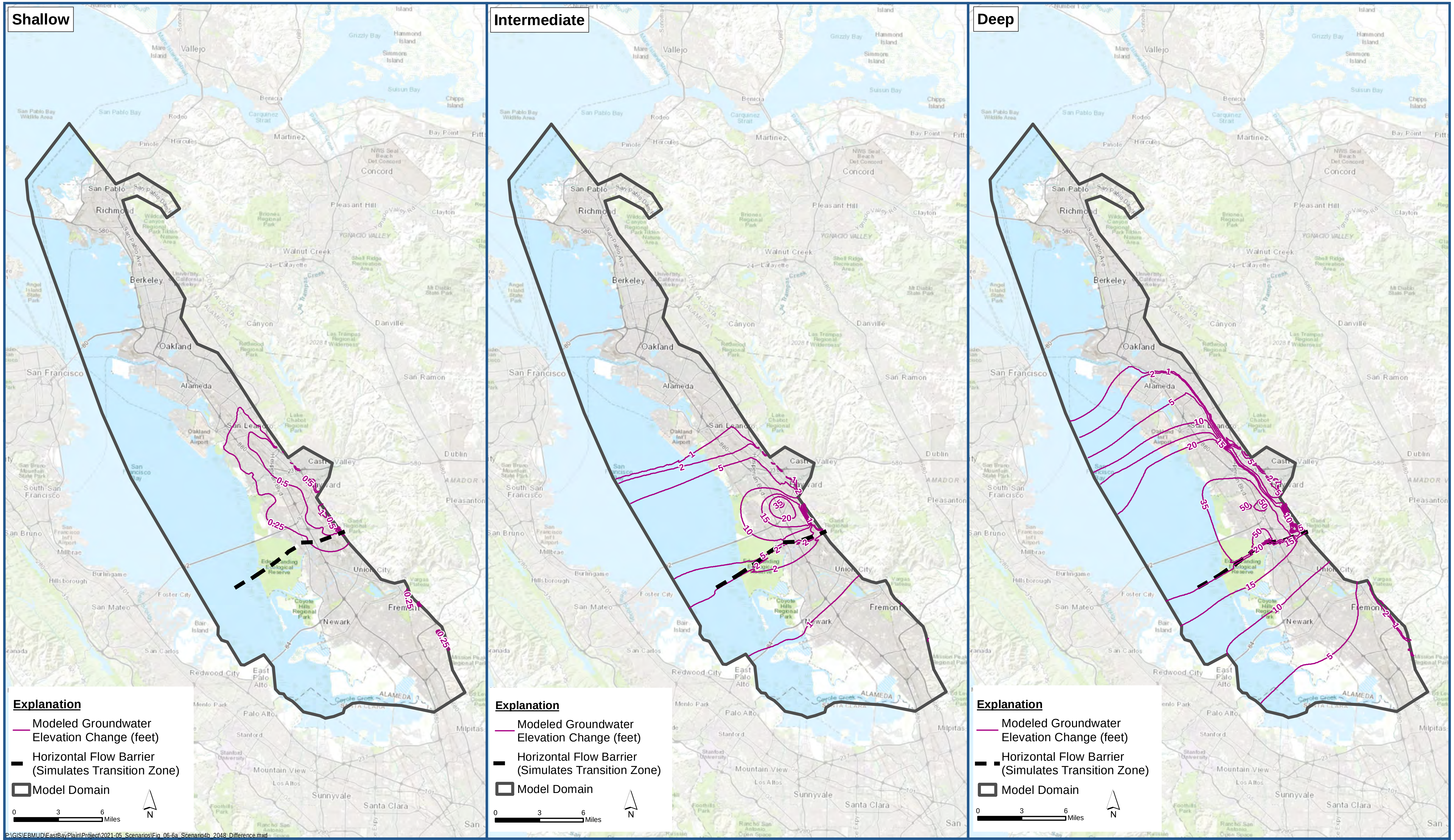


LSCE TEAM

Modeled Groundwater Elevation Contours in the Shallow, Intermediate, and Deep Aquifers (Steady State)

East Bay Plain Groundwater Model
Groundwater Sustainability Plan

Figure 6-5e



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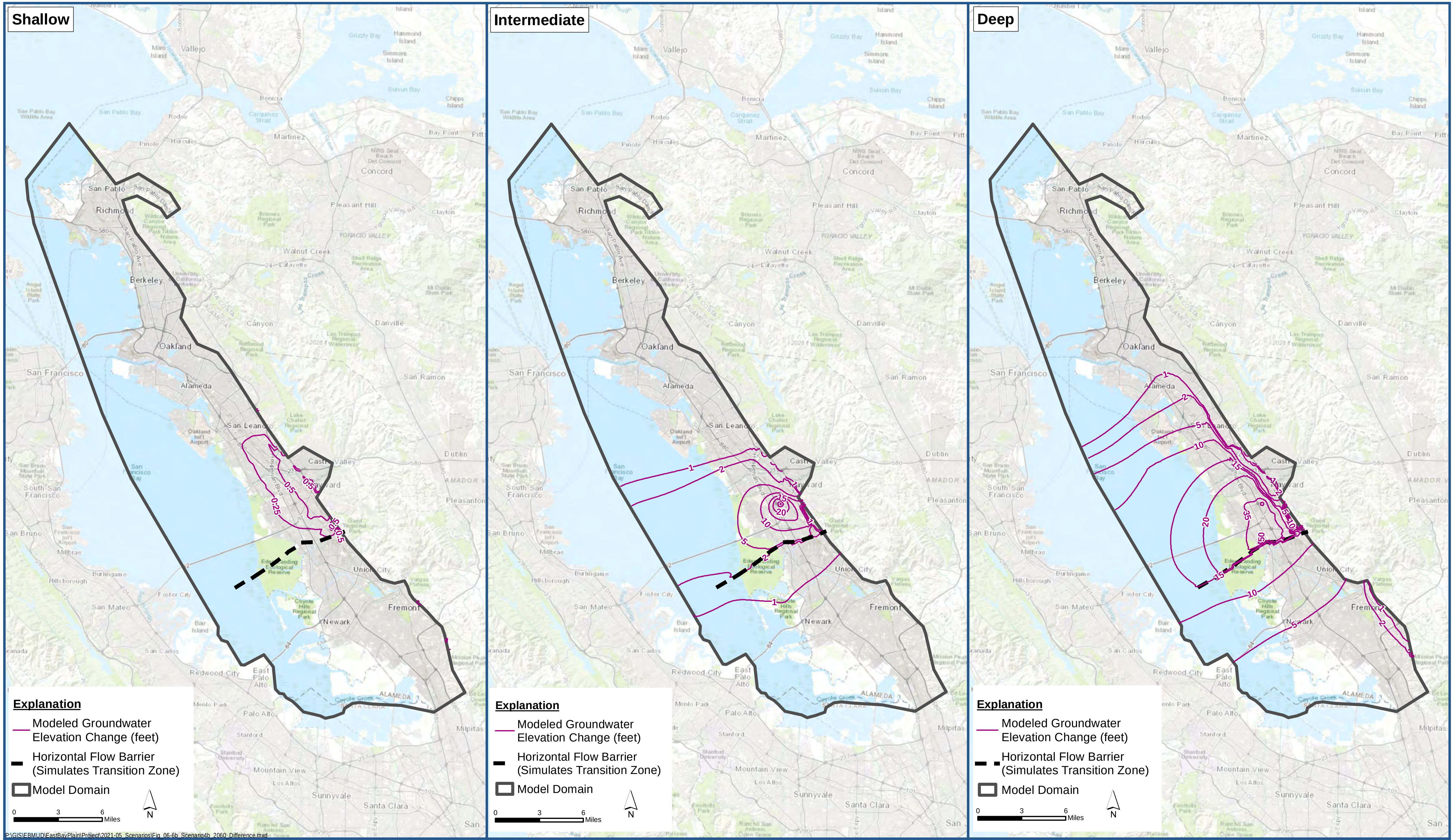
Decrease in Groundwater Elevations in the Shallow, Intermediate, and Deep Aquifers Compared to Baseline August 2048 (Model Year 27)

Figure 6-6a

East Bay Plain Groundwater Model
Groundwater Sustainability Plan



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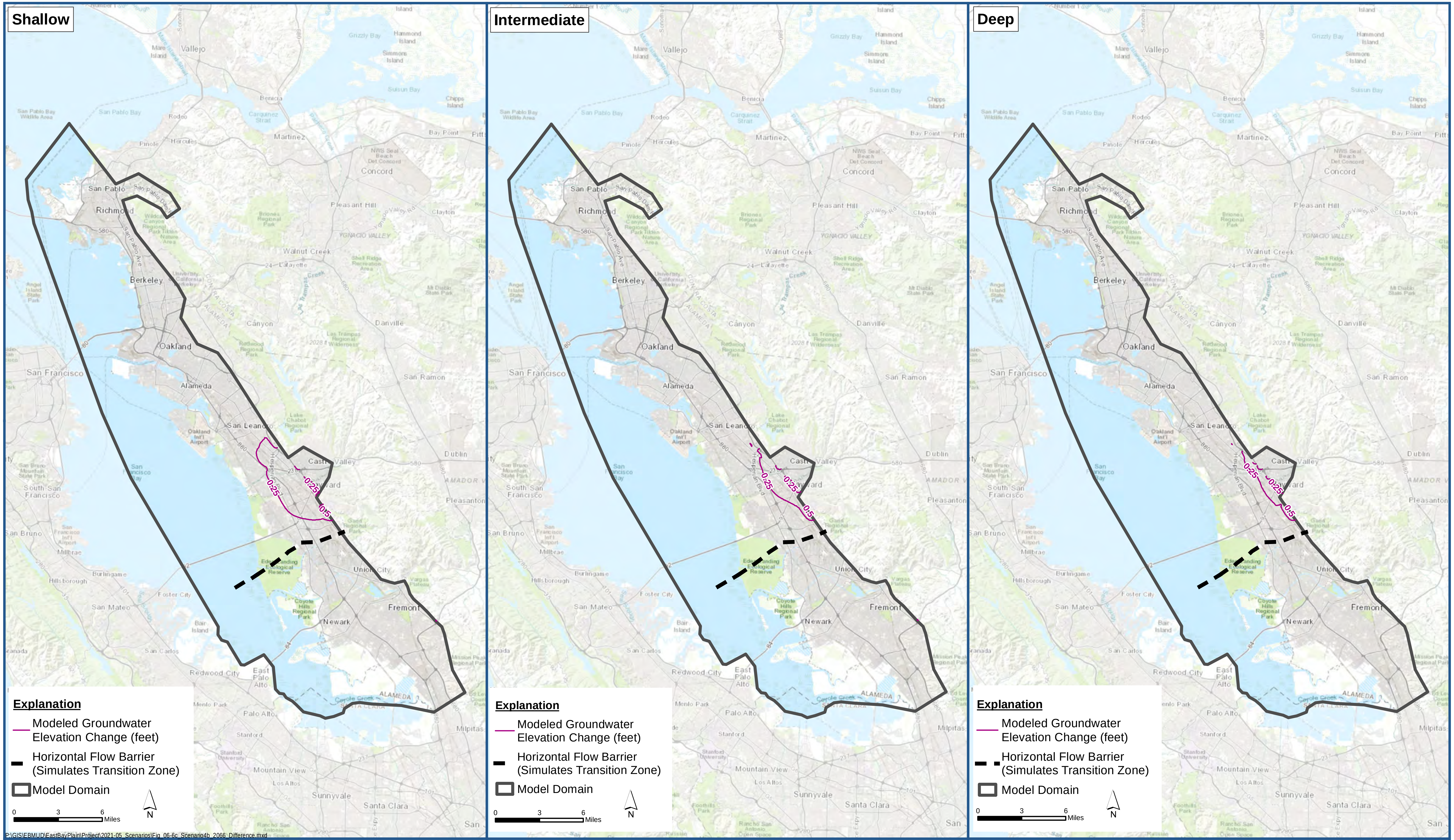
LSCE TEAM

Decrease in Groundwater Elevations in the Shallow, Intermediate, and Deep Aquifers Compared to Baseline August 2060 (Model Year 39)

East Bay Plain Groundwater Model
Groundwater Sustainability Plan

Figure 6-6b

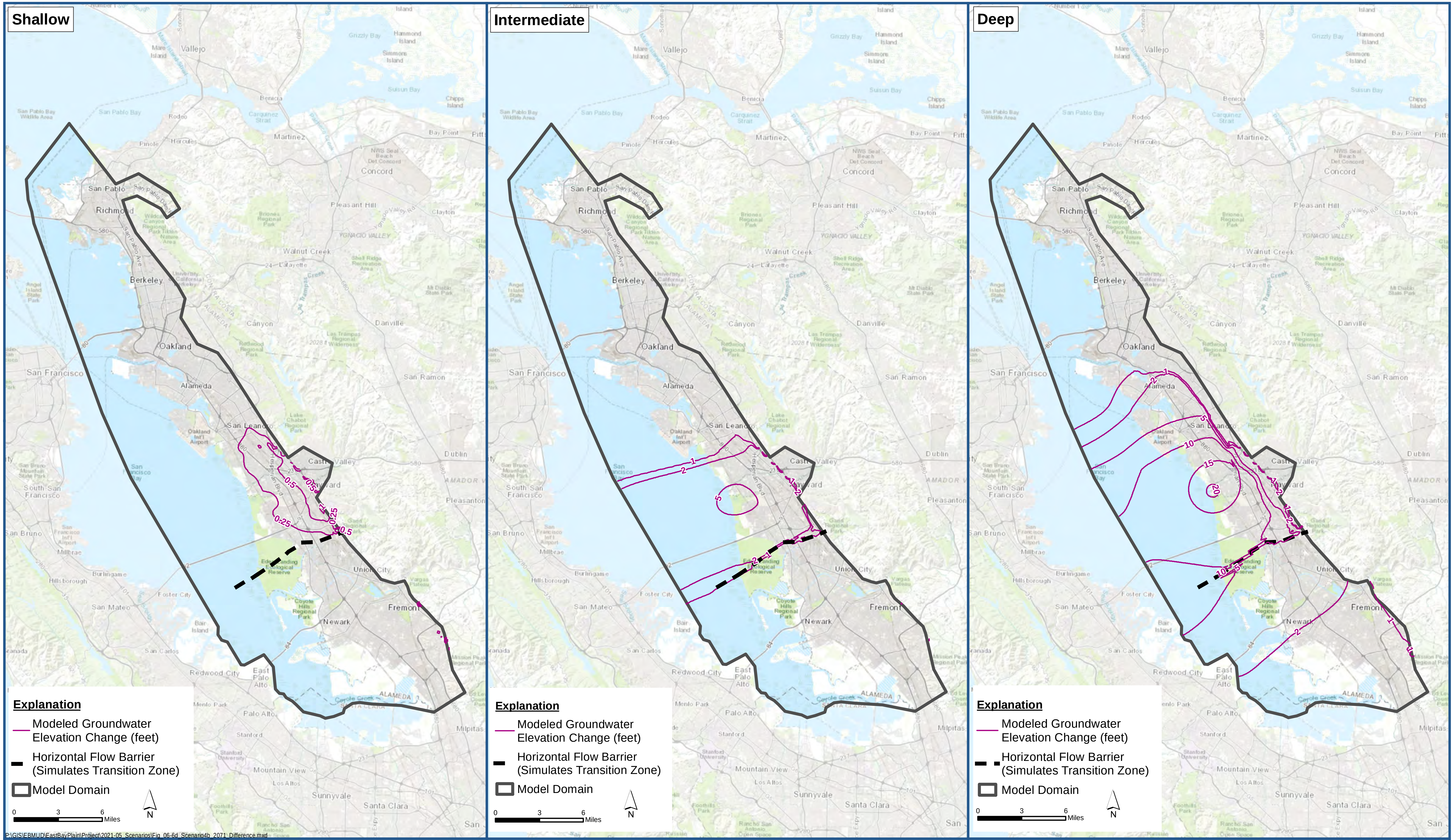


LSCE TEAM

Decrease in Groundwater Elevations in the Shallow, Intermediate, and Deep Aquifers Compared to Baseline September 2066 (Model Year 45)

East Bay Plain Groundwater Model
Groundwater Sustainability Plan

Figure 6-6c



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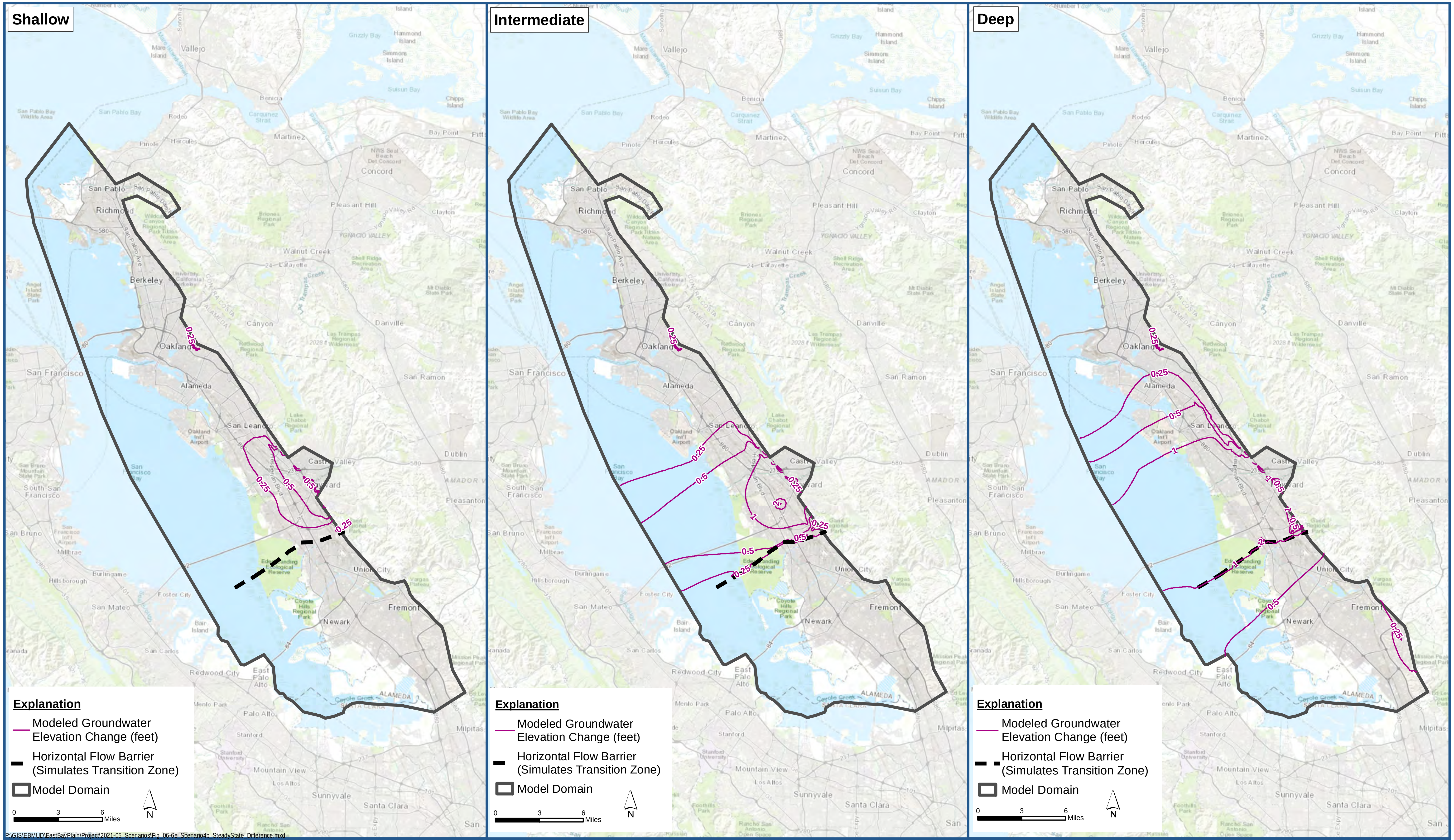
Decrease in Groundwater Elevations in the Shallow, Intermediate, and Deep Aquifers Compared to Baseline September 2071 (Model Year 50)

Figure 6-6d

East Bay Plain Groundwater Model
Groundwater Sustainability Plan

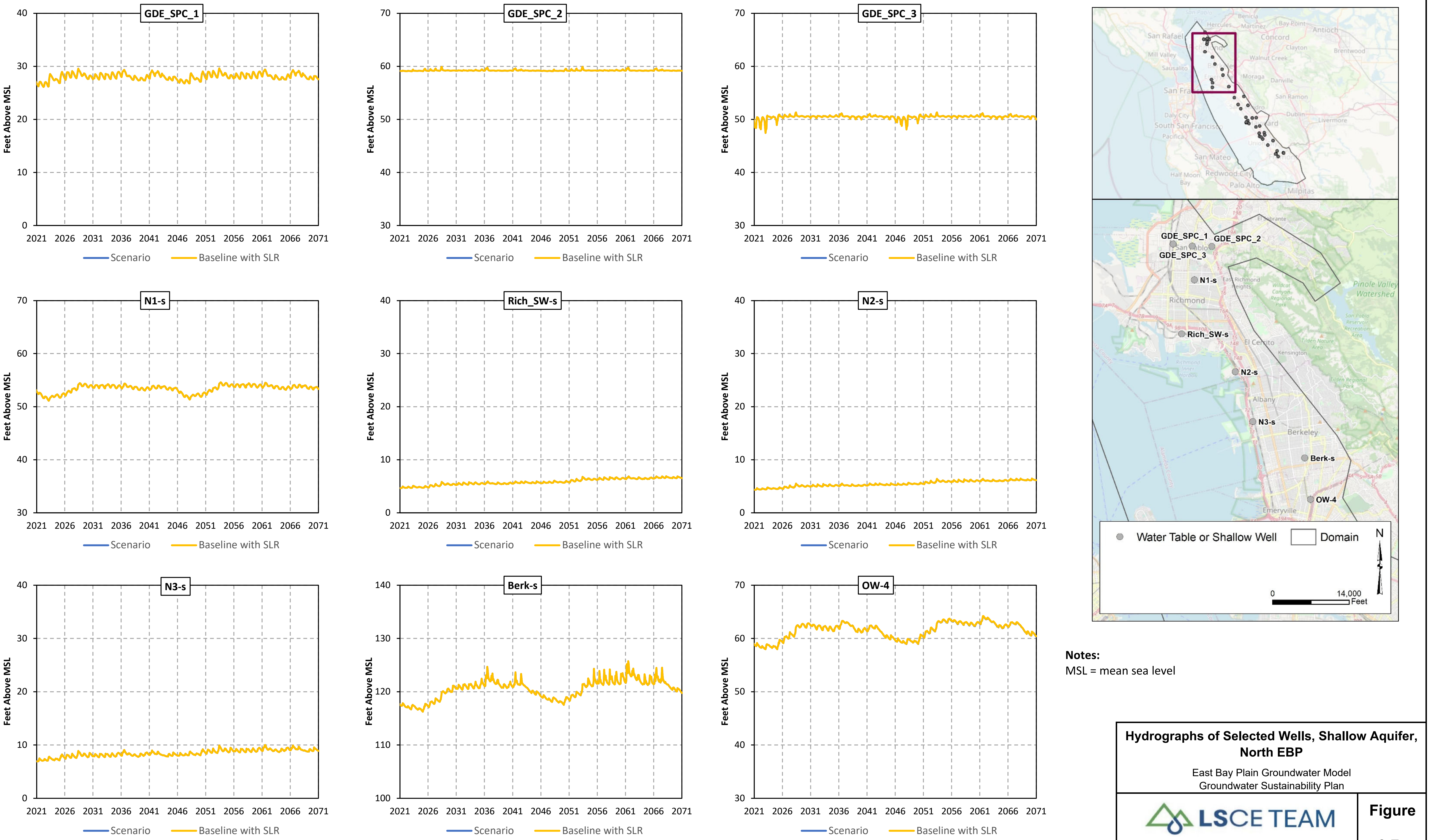


LSCE TEAM

Decrease in Groundwater Elevations in the Shallow, Intermediate, and Deep Aquifers Compared to Baseline (Steady State)

East Bay Plain Groundwater Model
Groundwater Sustainability Plan

Figure 6-6e



Notes:
MSL = mean sea level

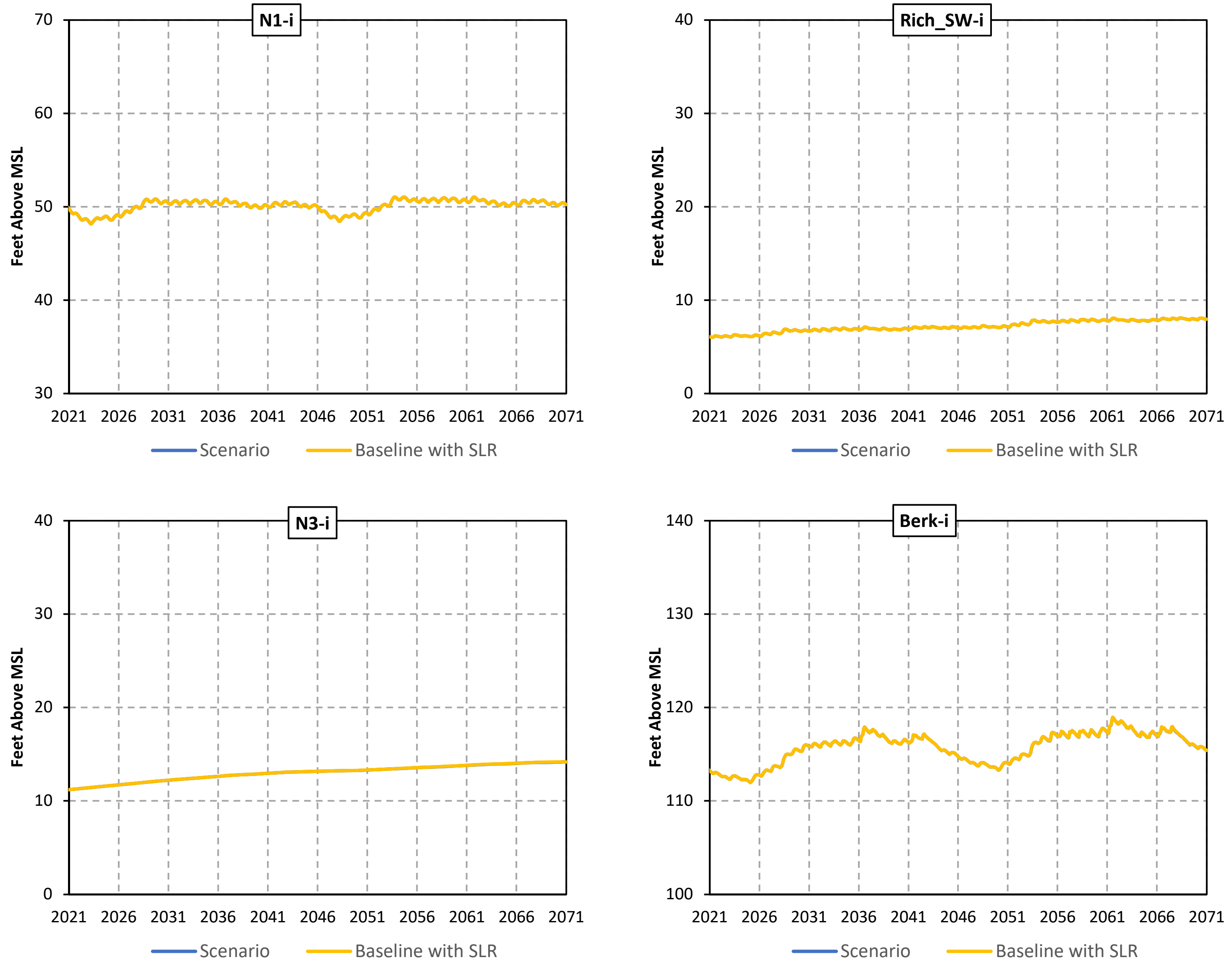
Hydrographs of Selected Wells, Shallow Aquifer, North EBP

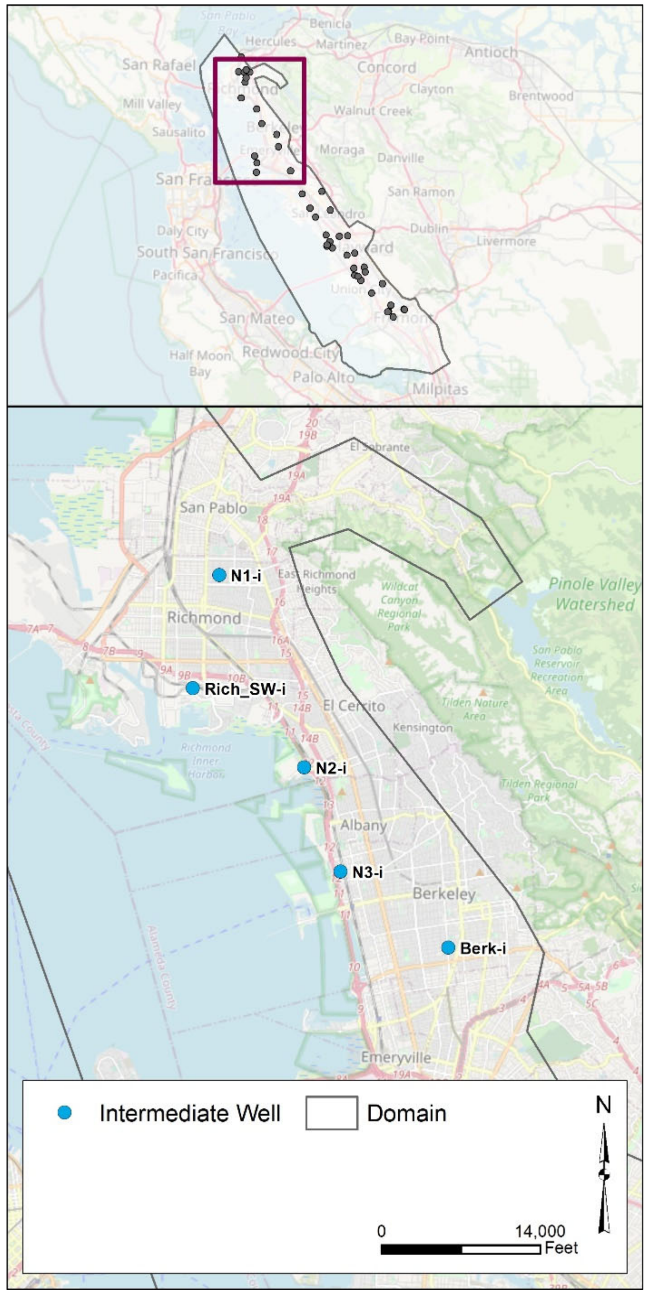
East Bay Plain Groundwater Model
Groundwater Sustainability Plan

LSCE TEAM

WR2668	November 2021	Figure 6-7a

P:\GIS\EBMUD\EastBayPlain\PDF\2021-05_scenarios\[Fig_06-07_Simulated_Heads_Obs_WY2016-2071_Scenario4b.xlsx]





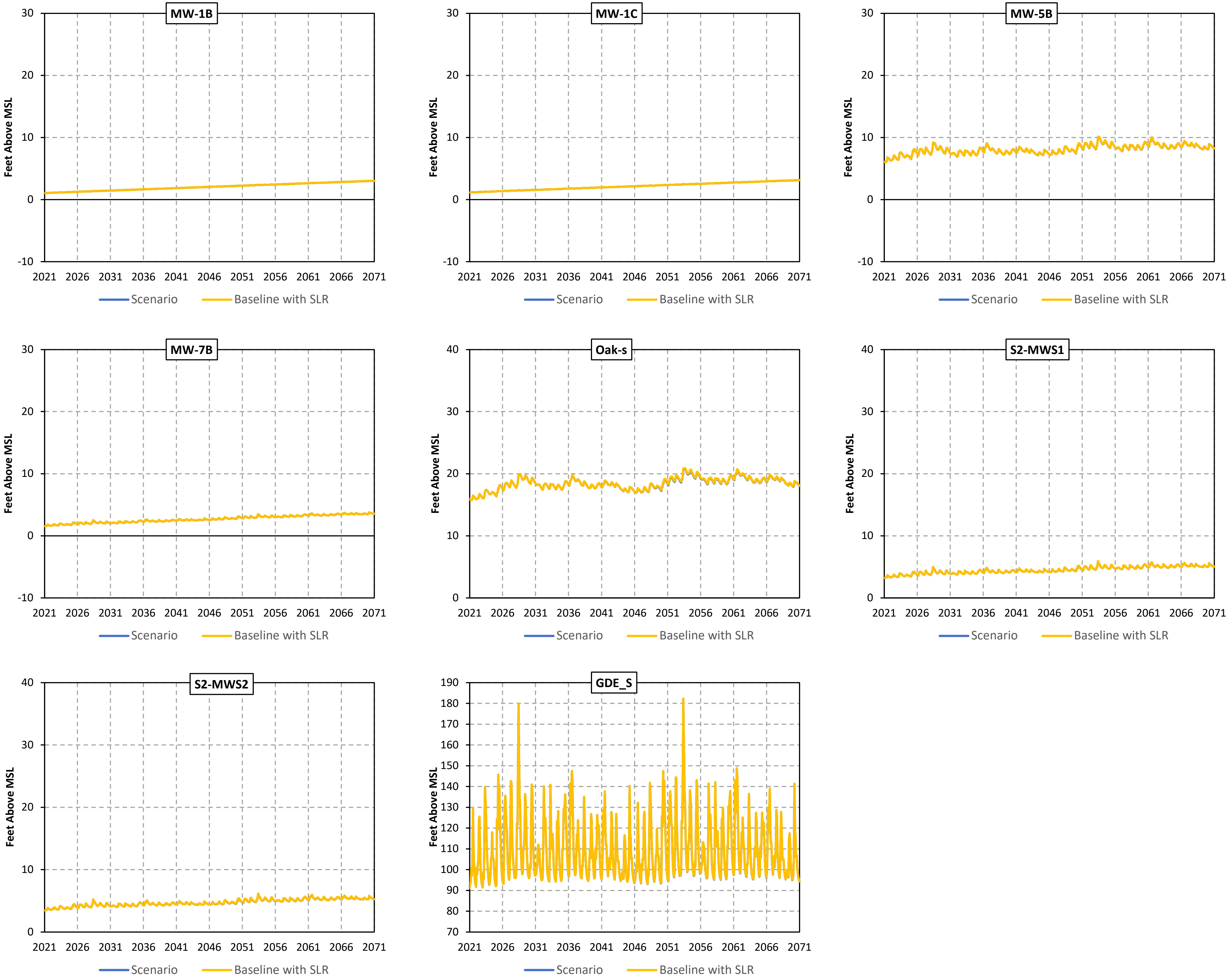
Notes:
MSL = mean sea level

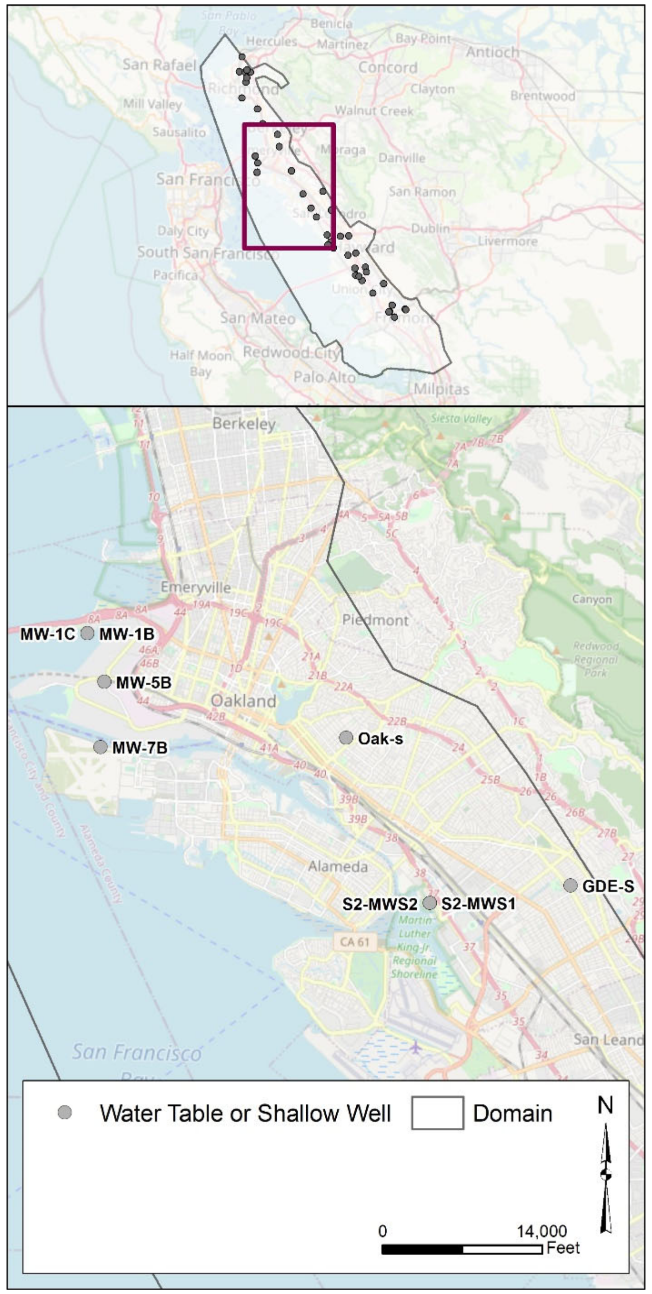
Hydrographs of Selected Wells, Intermediate Aquifer, North EBP

East Bay Plain Groundwater Model
Groundwater Sustainability Plan

LSCE TEAM

WR2668	November 2021	Figure 6-7b





Notes:
MSL = mean sea level

Hydrographs of Selected Wells, Shallow Aquifer, Middle EBP

East Bay Plain Groundwater Model
Groundwater Sustainability Plan

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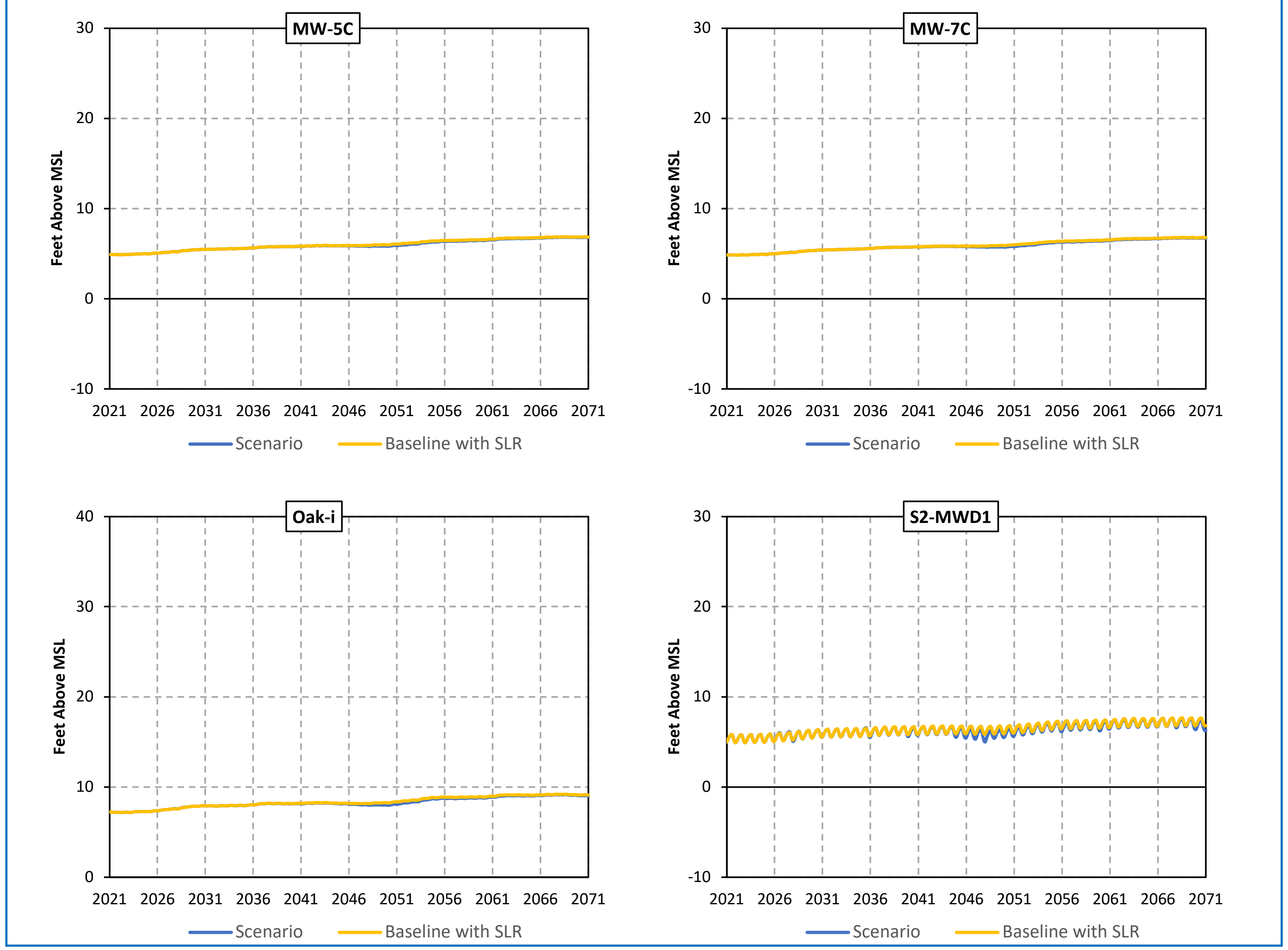
November 2021

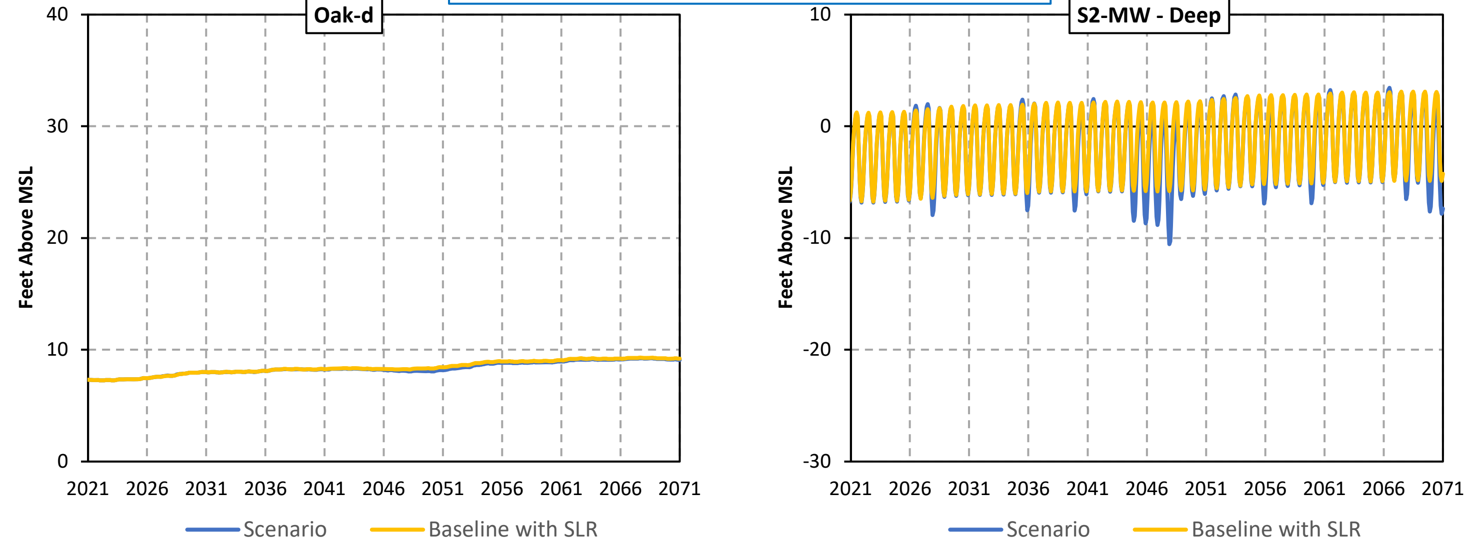
Figure
6-7c

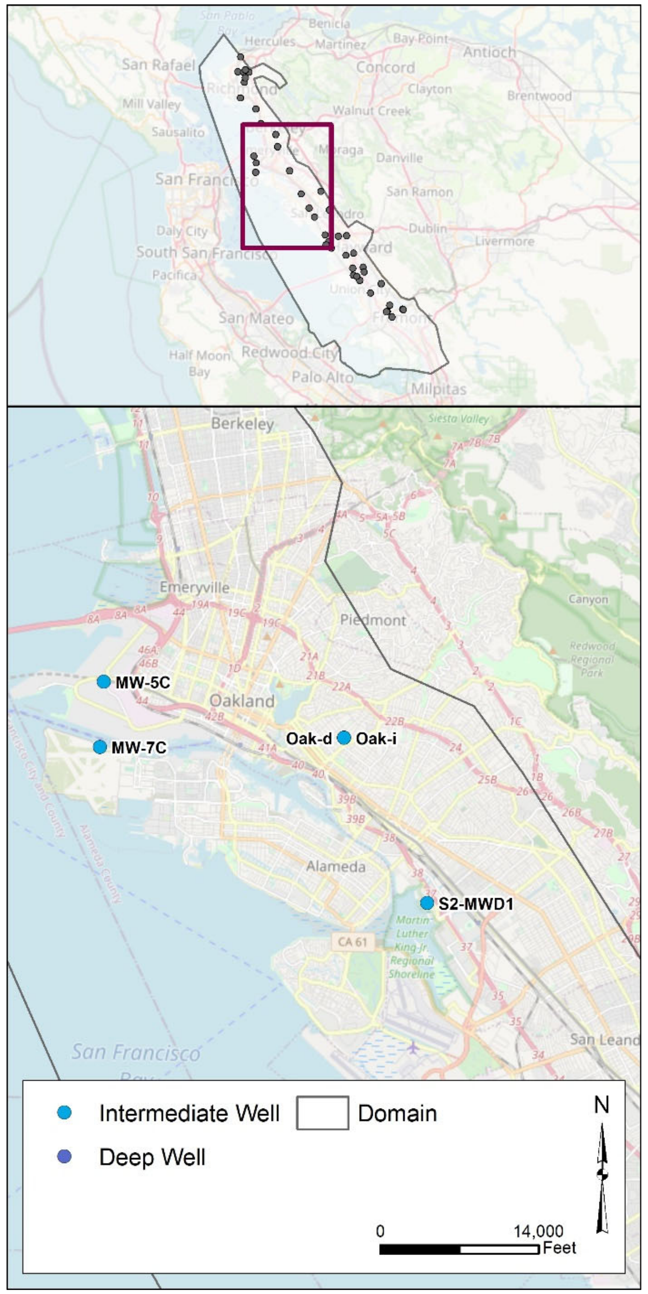
P:\GIS\EBMUD\EastBayPlain\PDF\2021-05_scenarios\[Fig_06-07_Simulated_Heads_Obs_WY2016-2071_Scenario4b.xlsx]

Intermediate Aquifer



Deep Aquifer





Notes:
MSL = mean sea level

Hydrographs of Selected Wells, Intermediate and Deep Aquifers, Middle EBP

East Bay Plain Groundwater Model
Groundwater Sustainability Plan

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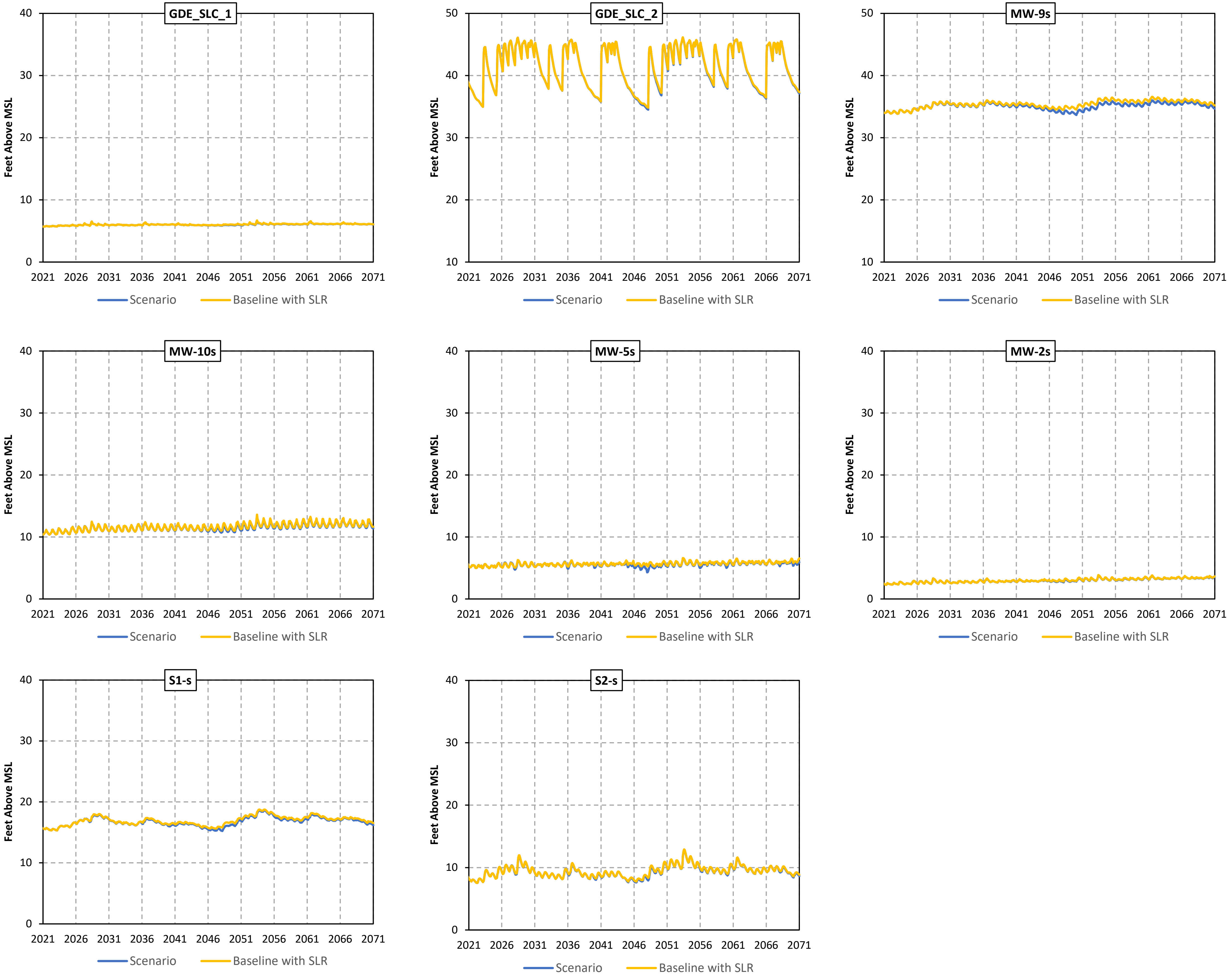
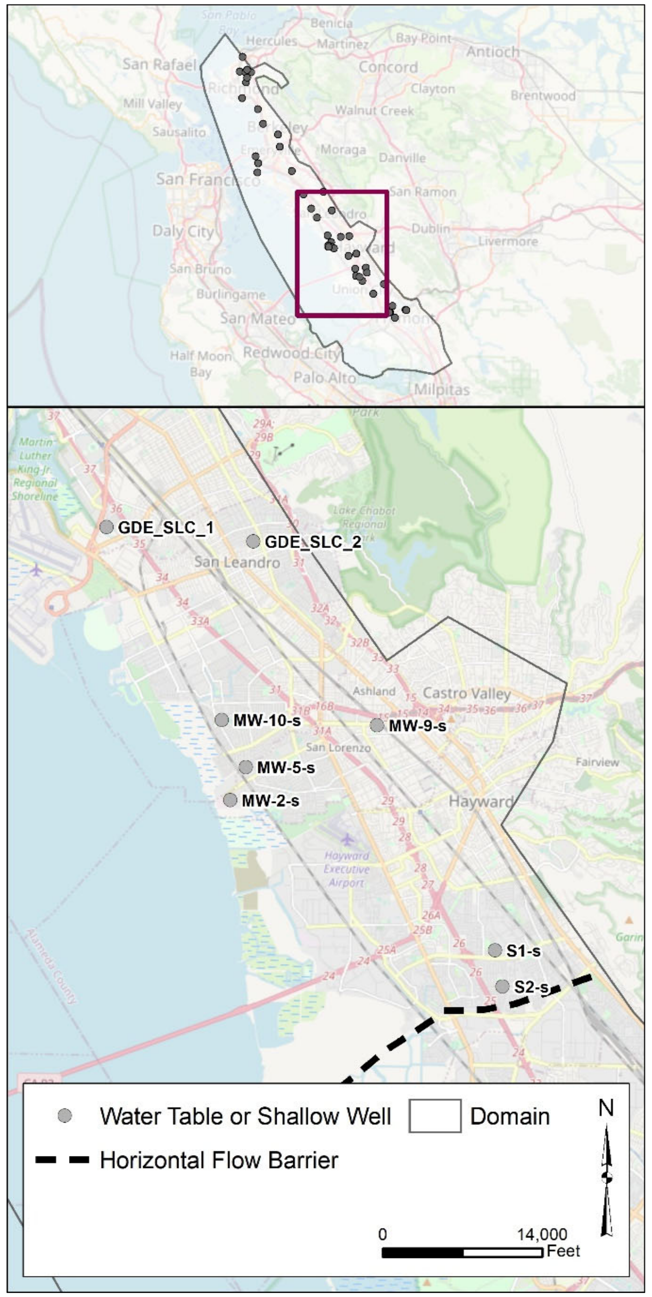
Figure
6-7d





Notes:
MSL = mean sea level

Hydrographs of Selected Wells, Shallow Aquifer, South EBP

East Bay Plain Groundwater Model
Groundwater Sustainability Plan

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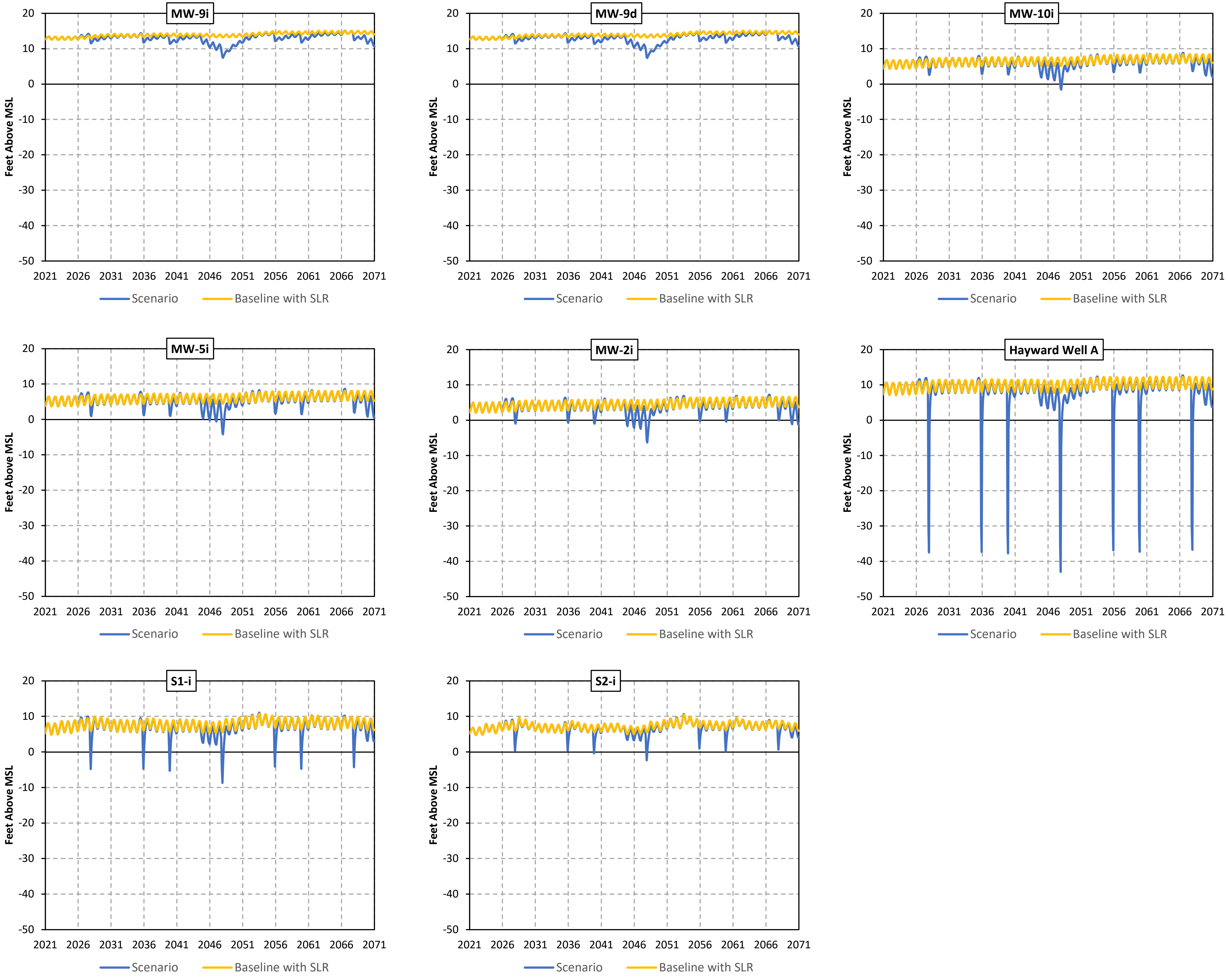
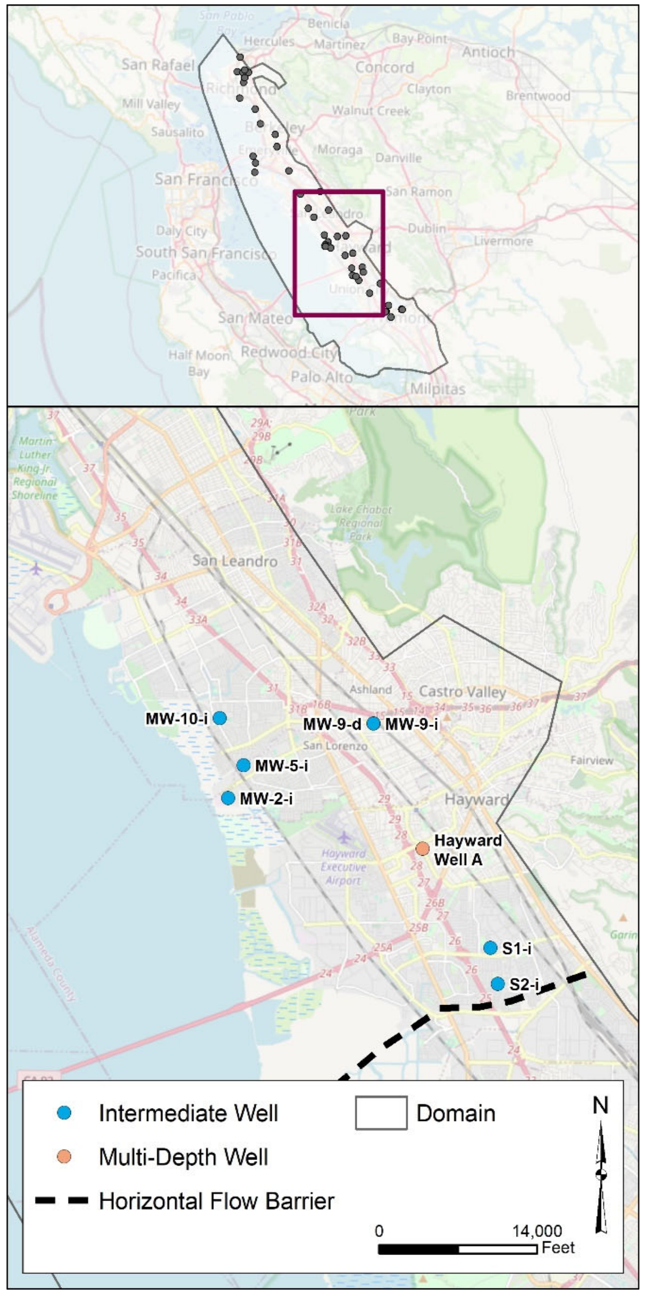
November 2021

Figure
6-7e

P:\GIS\EBMUD\EastBayPlain\PDF\2021-05_scenarios\[Fig_06-07_Simulated_Heads_Obs_WY2016-2071_Scenario4b.xlsx]





Notes:
MSL = mean sea level
Hayward Well A is also screened in Deep Aquifer

Hydrographs of Selected Wells, Intermediate Aquifer, South EBP

East Bay Plain Groundwater Model
Groundwater Sustainability Plan

LSCE TEAM

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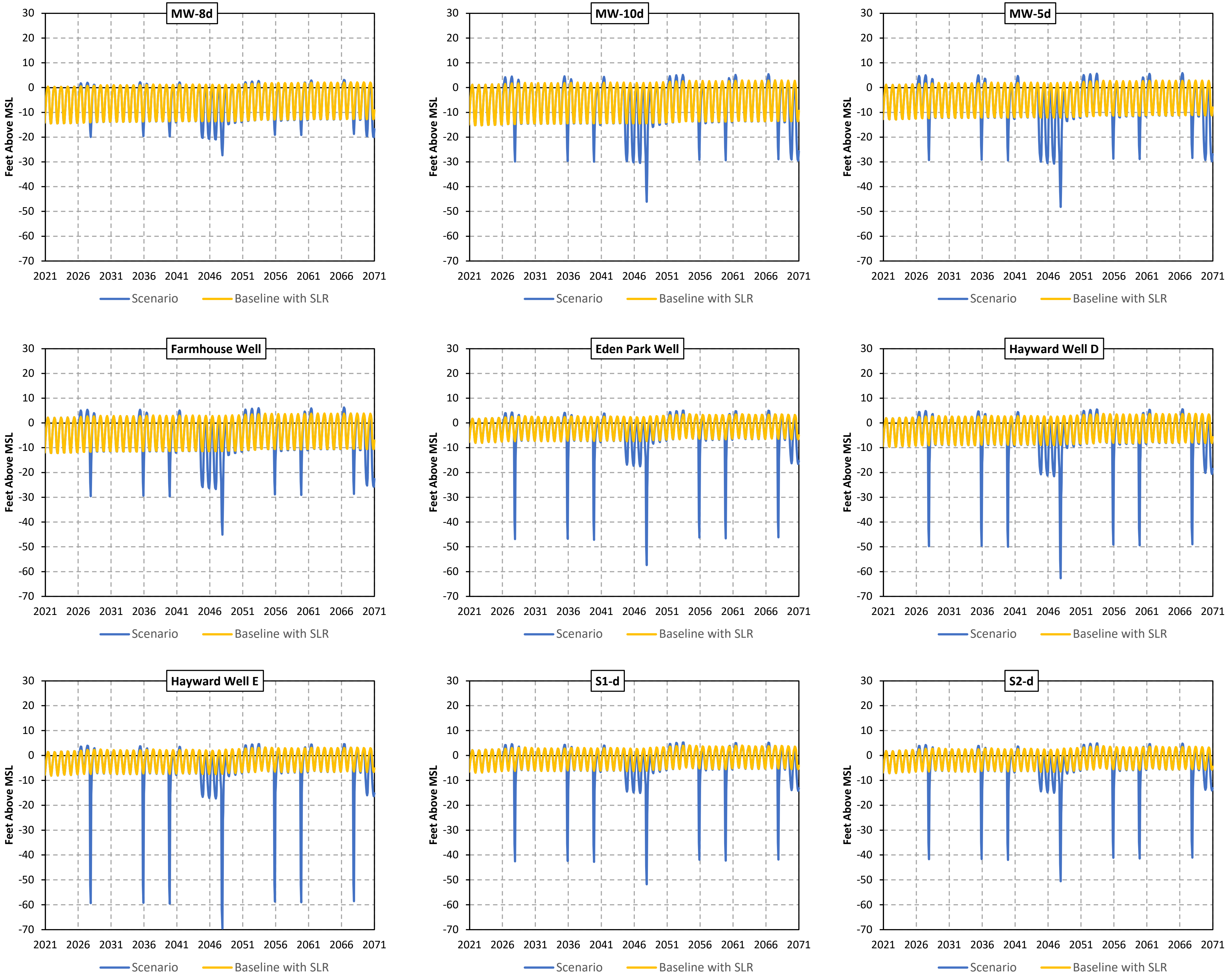
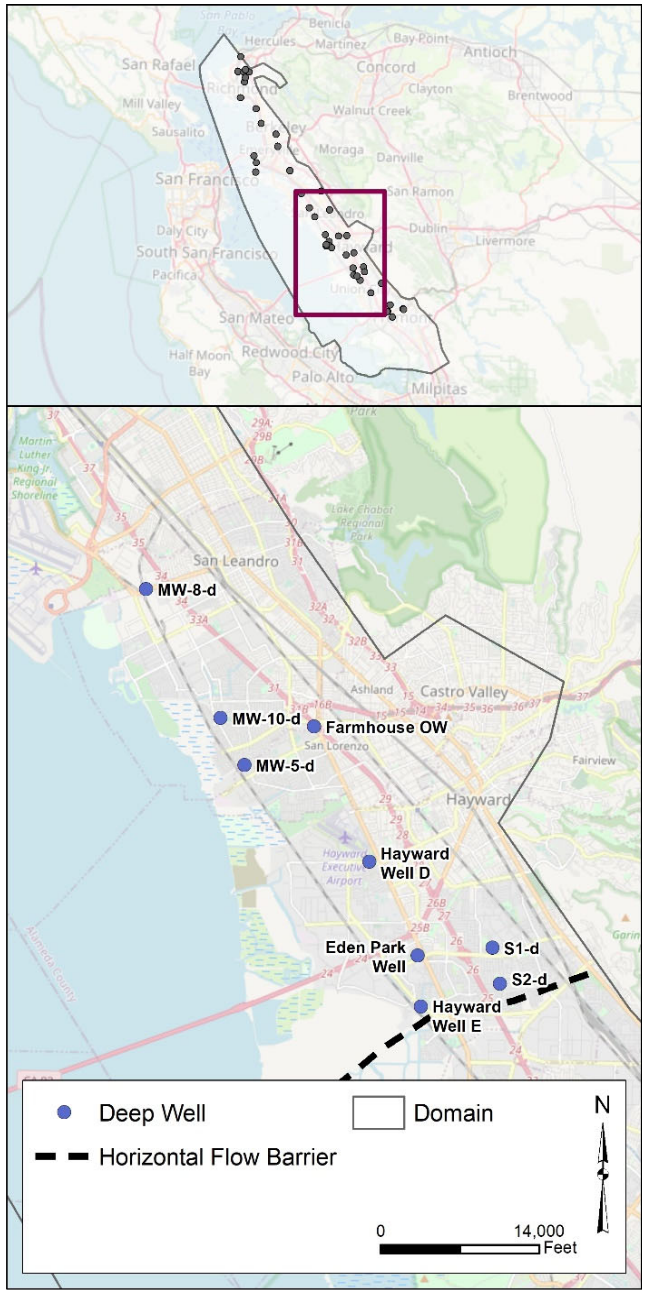
Figure

6-7f





Notes:
MSL = mean sea level

Hydrographs of Selected Wells, Deep Aquifer, South EBP

East Bay Plain Groundwater Model
Groundwater Sustainability Plan

LSCE TEAM

Figure

6-7g

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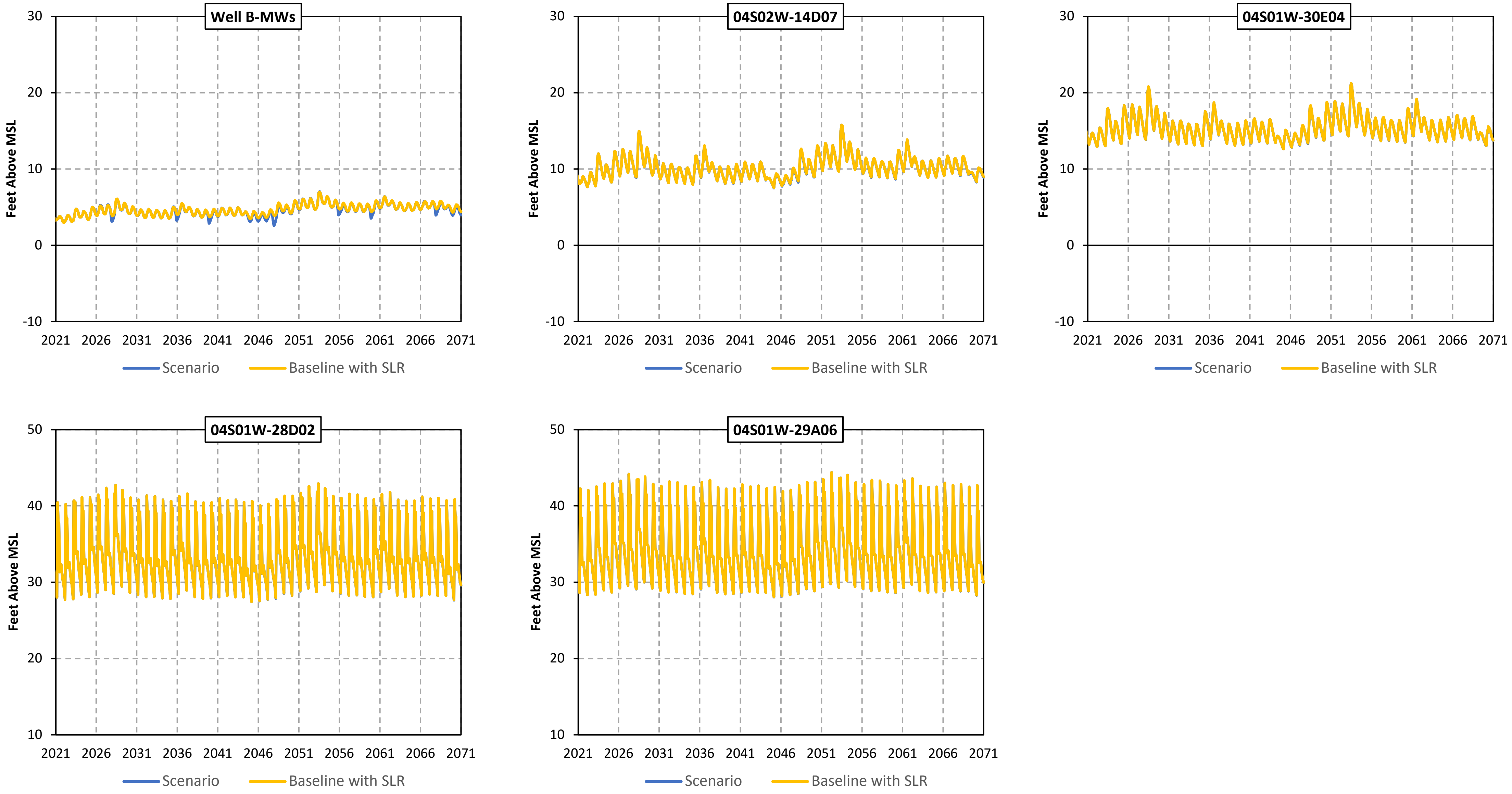
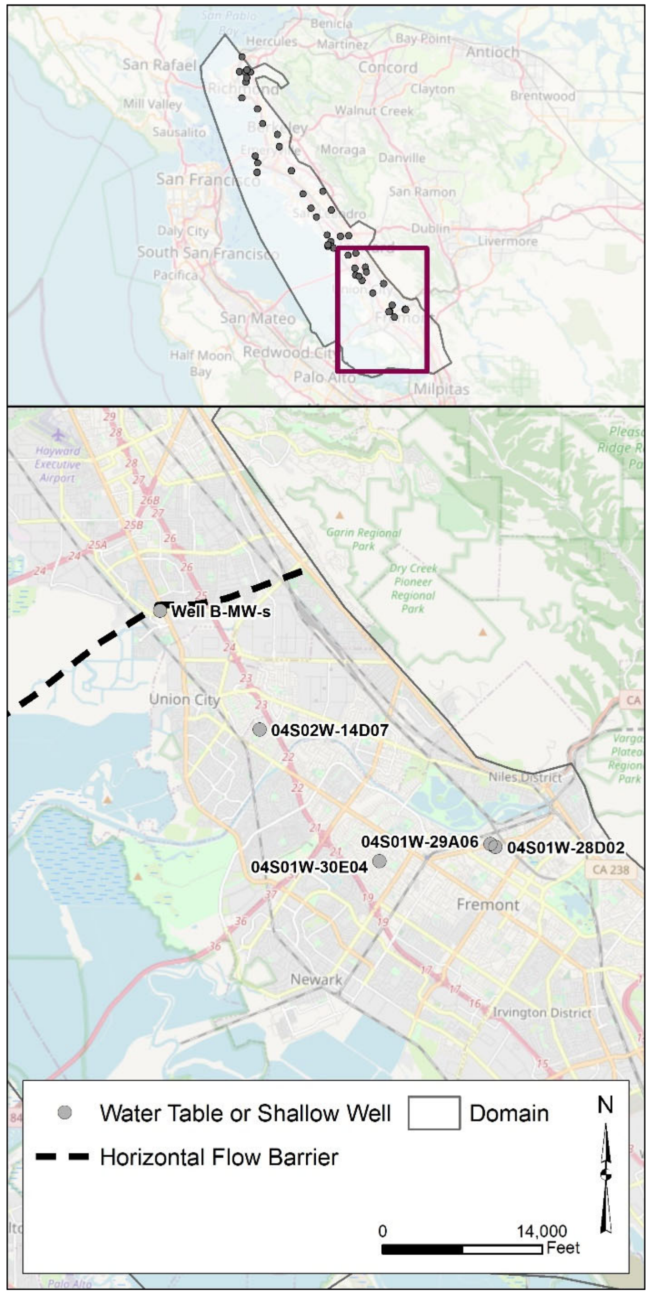




Notes:
MSL = mean sea level

Hydrographs of Selected Wells, Shallow Aquifer, Niles Cone

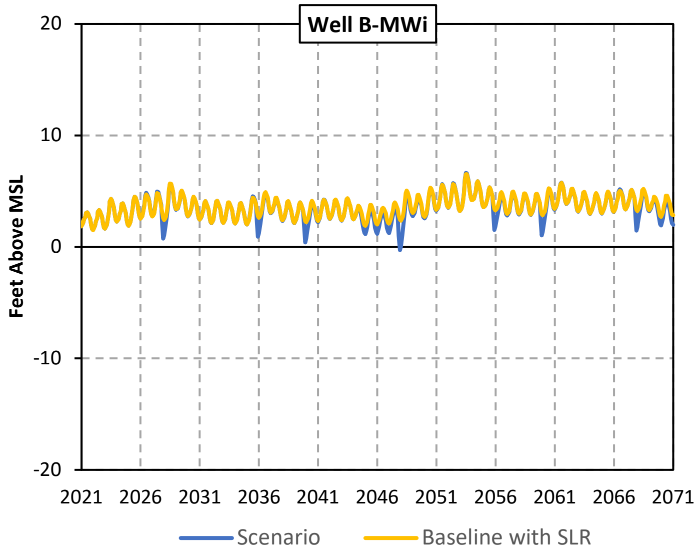
East Bay Plain Groundwater Model
Groundwater Sustainability Plan

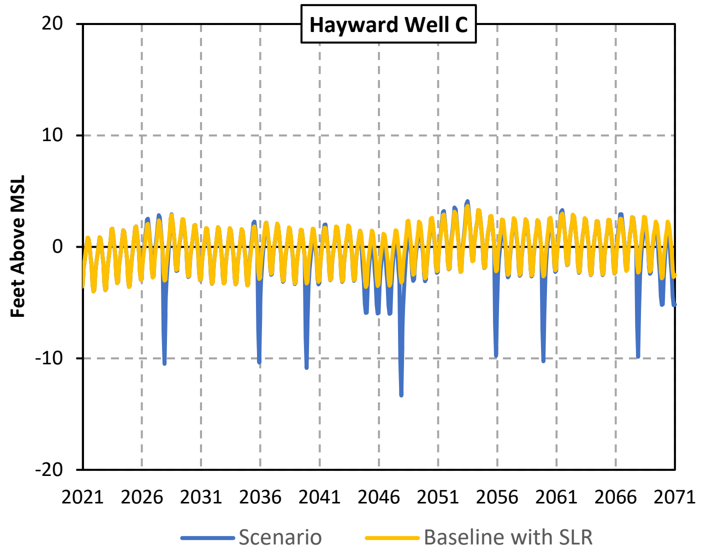
LSCE TEAM

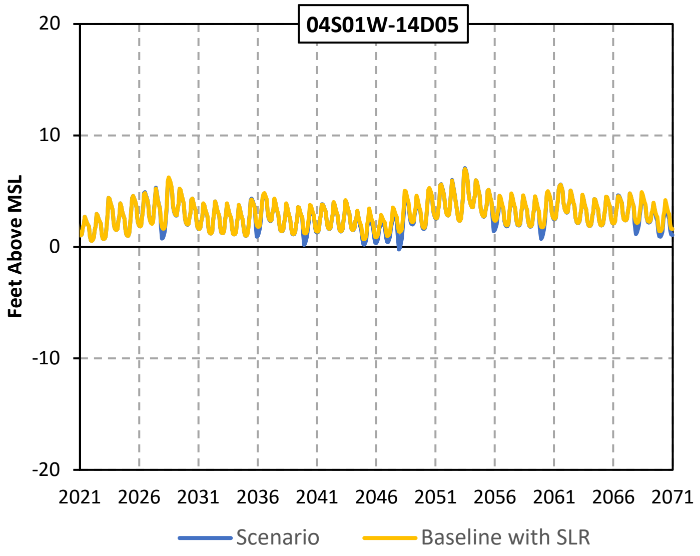
WR2668

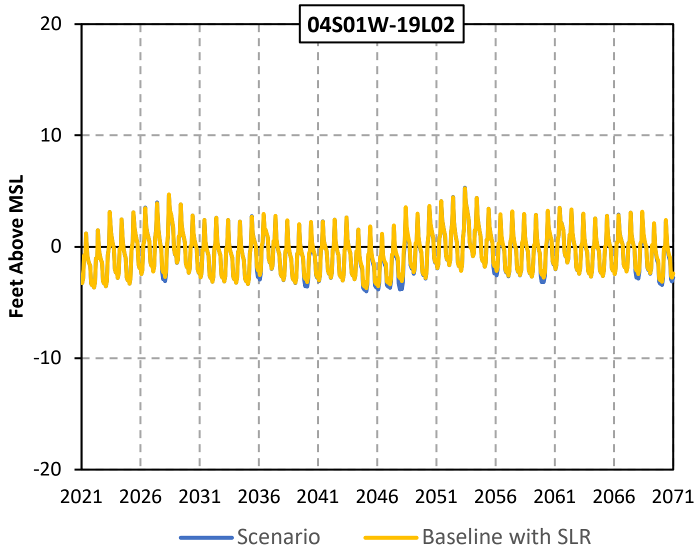
November 2021

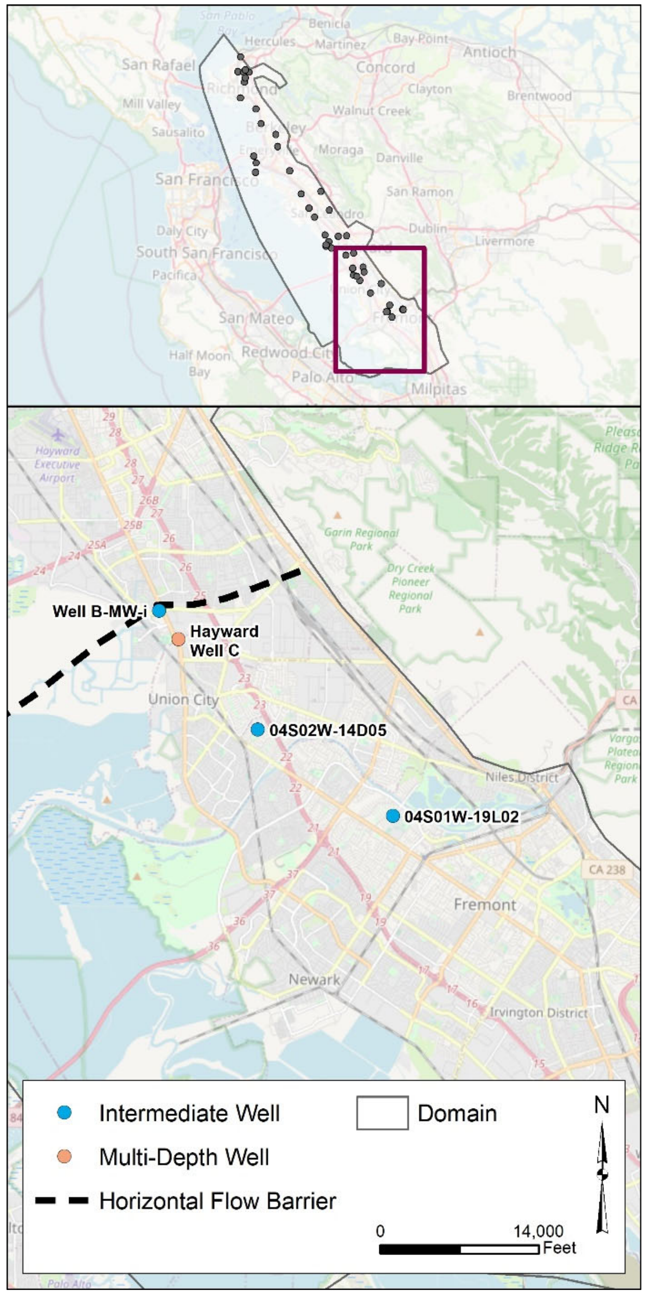
Figure
6-7h











Notes:
MSL = mean sea level
Hayward Well C is also screened in Deep Aquifer

Hydrographs of Selected Wells, Intermediate Aquifer, Niles Cone

East Bay Plain Groundwater Model
Groundwater Sustainability Plan

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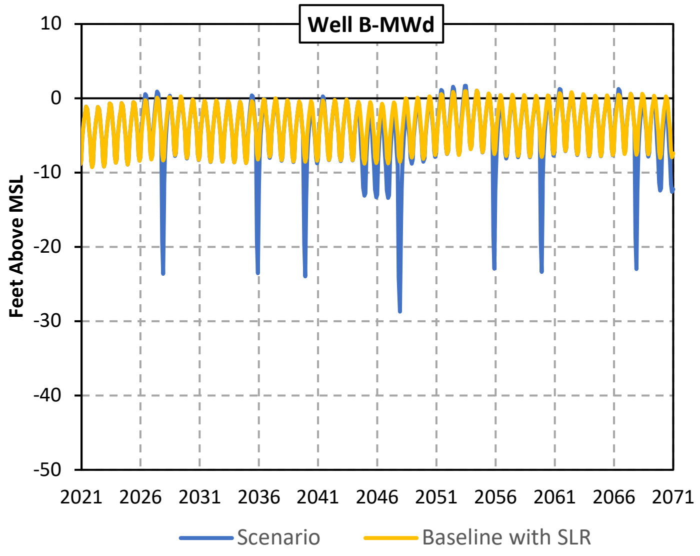
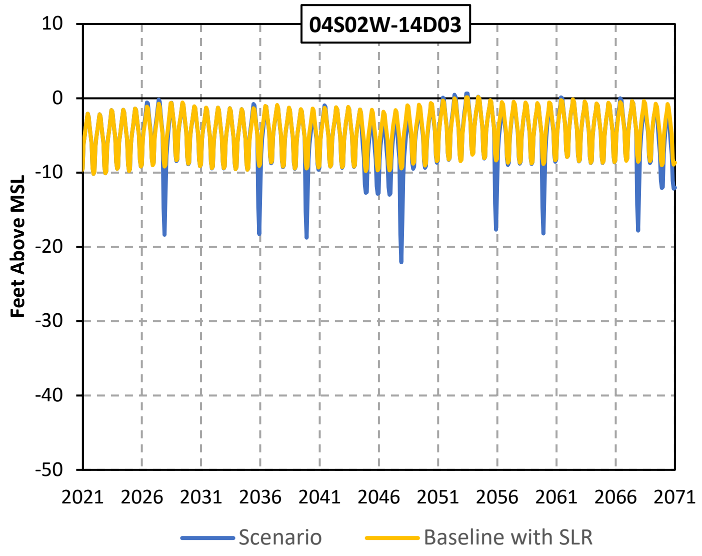
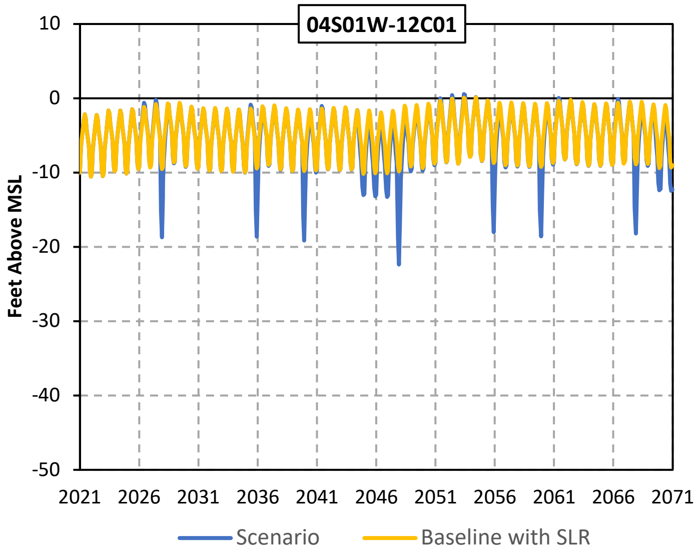
WR2668 | November 2021

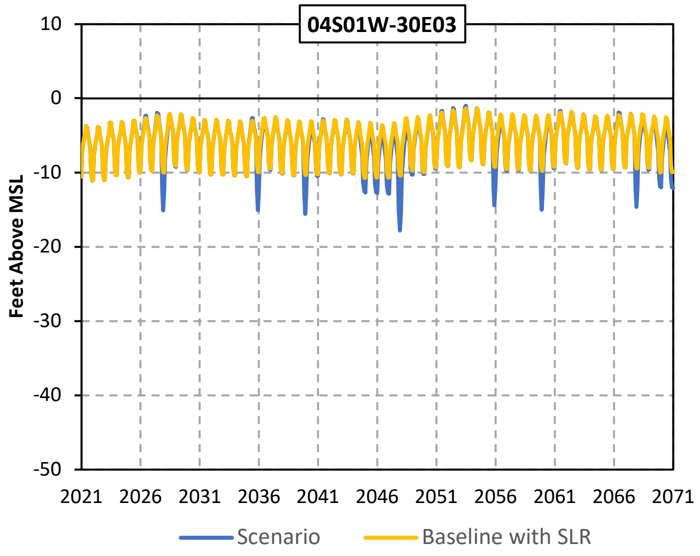
Figure
6-7i

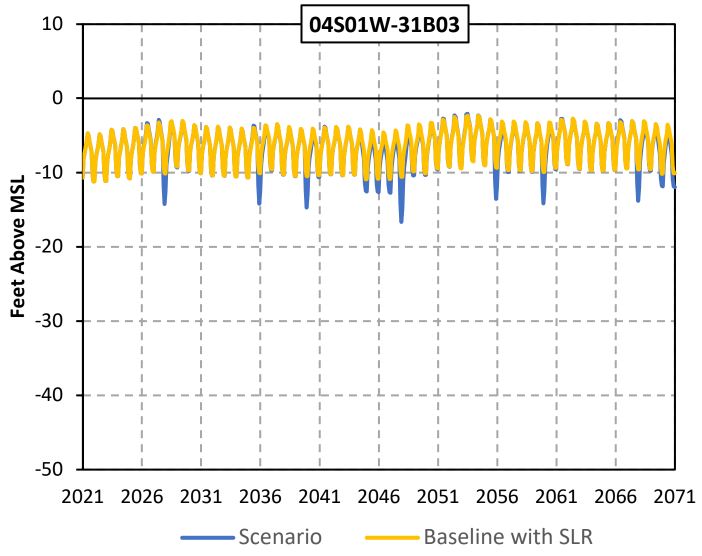
P:\GIS\EBMUD\EastBayPlain\PDF\2021-05_scenarios\[Fig_06-07_Simulated_Heads_Obs_WY2016-2071_Scenario4b.xlsx]

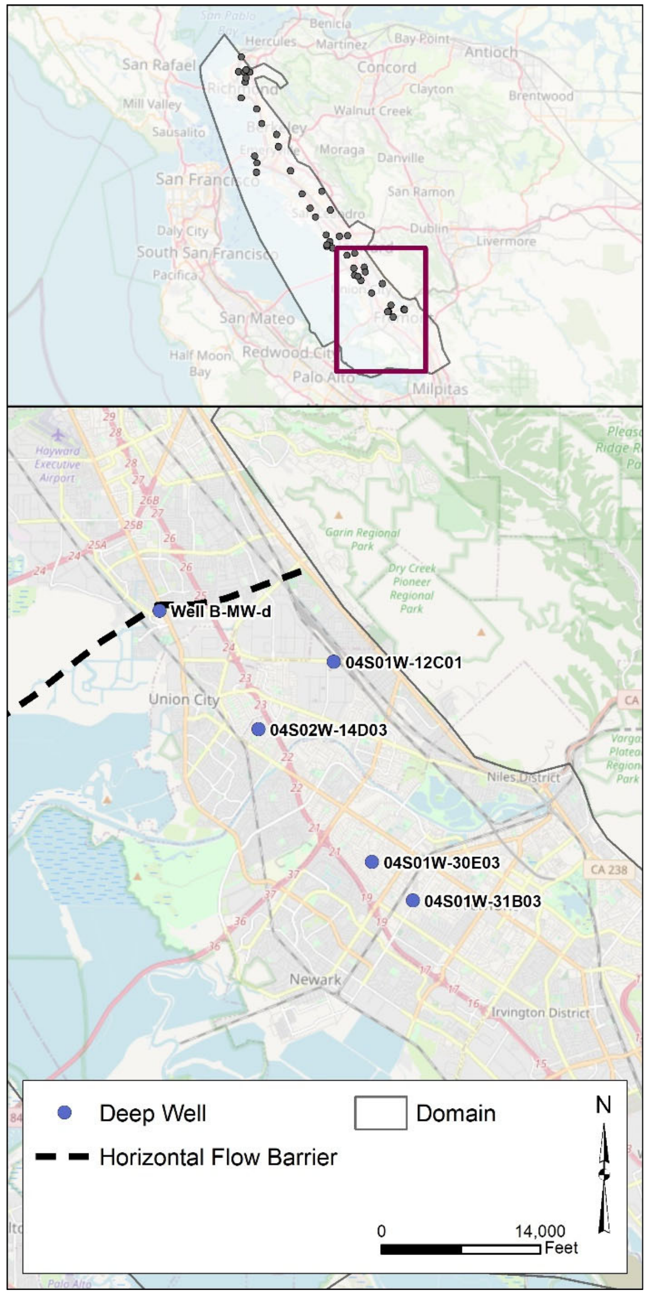












Notes:
MSL = mean sea level

Hydrographs of Selected Wells, Deep Aquifer, Niles Cone

East Bay Plain Groundwater Model
Groundwater Sustainability Plan

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Figure

6-7j

WR2668

November 2021

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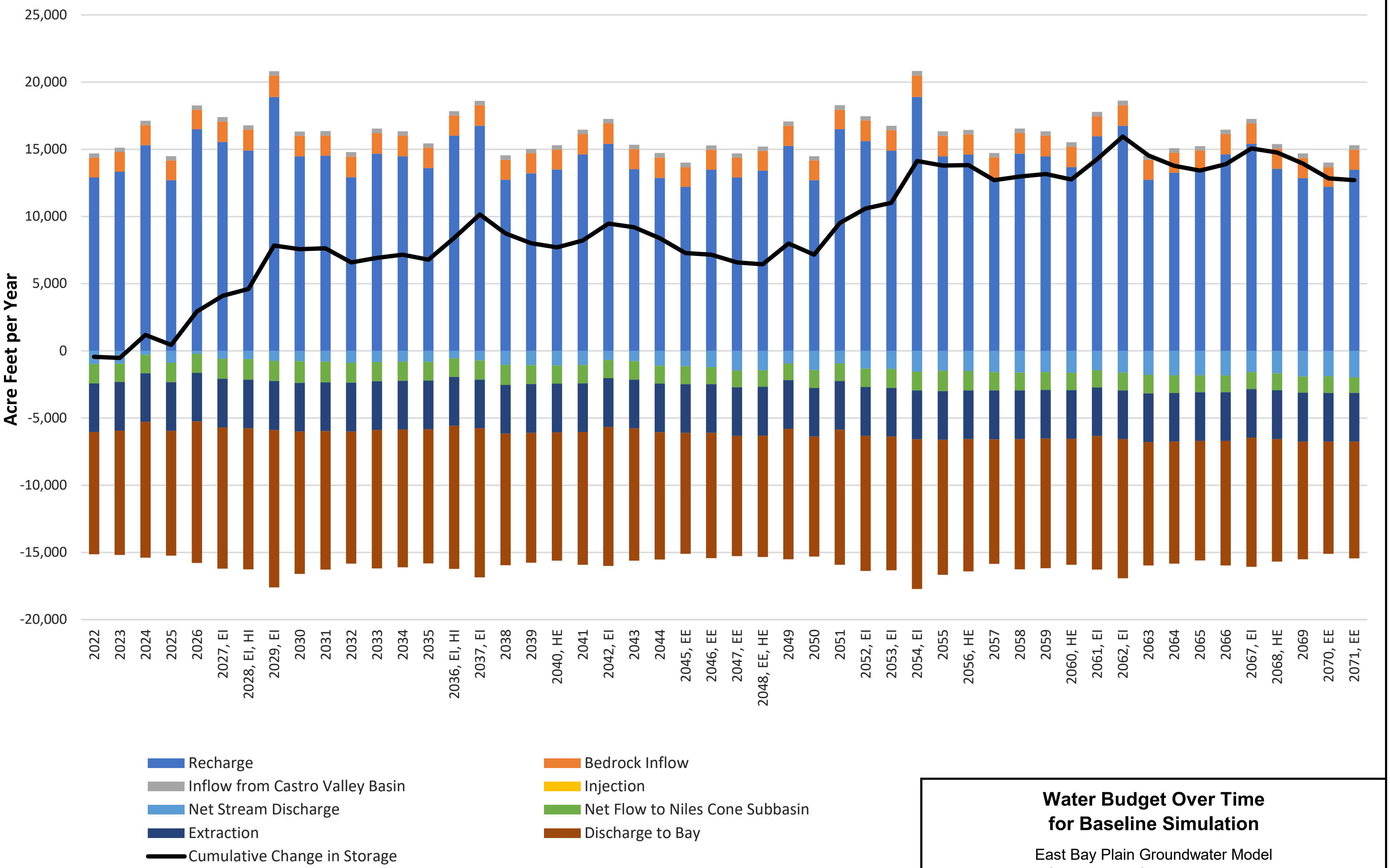

Notes:

EE = EBMUD Extraction

EI = EBMUD Injection

HE = City of Hayward Extraction

Water Budget Over Time for Baseline Simulation

East Bay Plain Groundwater Model
Groundwater Sustainability Plan

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Figure

6-8a

WR2668

November 2021

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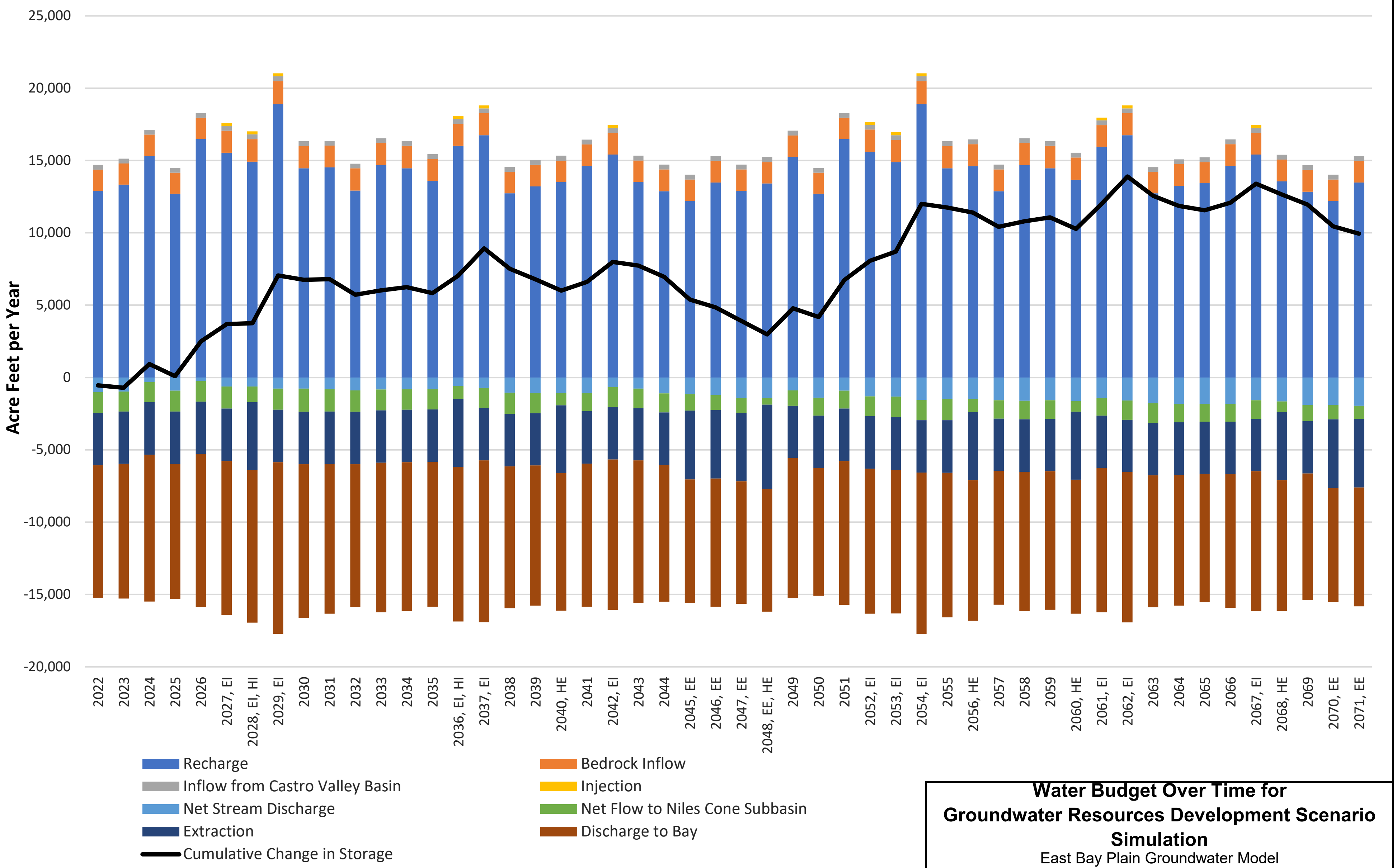

Notes:
EE = EBMUD Extraction
EI = EBMUD Injection
HE = City of Hayward Extraction

Water Budget Over Time for Groundwater Resources Development Scenario Simulation

East Bay Plain Groundwater Model
Groundwater Sustainability Plan

LSCE TEAM

Figure

6-8b

WR2668

November 2021

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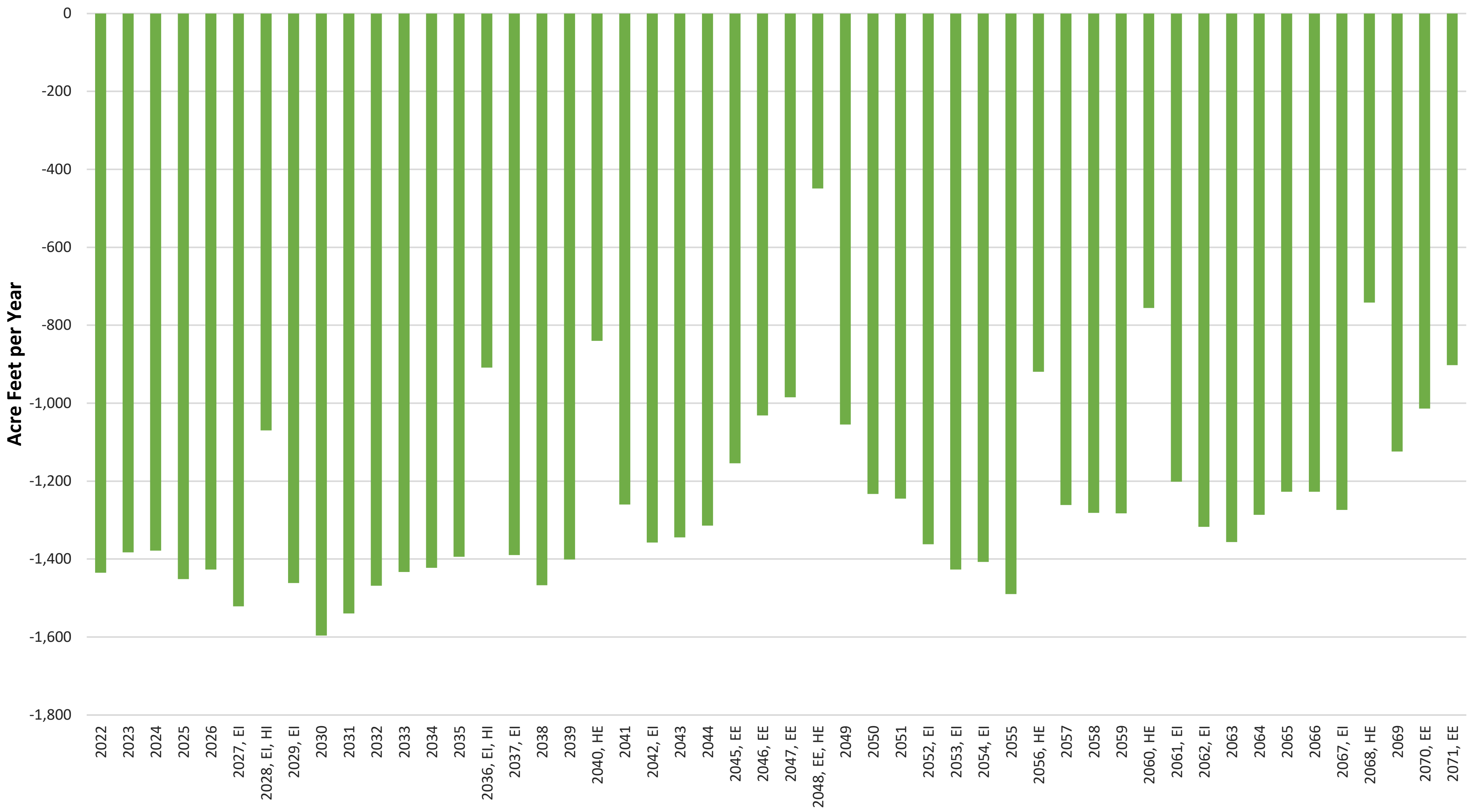


Notes:
EE = EBMUD Extraction
EI = EBMUD Injection
HE = City of Hayward Extraction

Negative numbers mean flow from East Bay Plain Subbasin to Niles Cone Subbasin

Simulated Net Inflow from Niles Cone Subbasin to East Bay Plain Subbasin

East Bay Plain Groundwater Model
Groundwater Sustainability Plan

LSCE TEAM

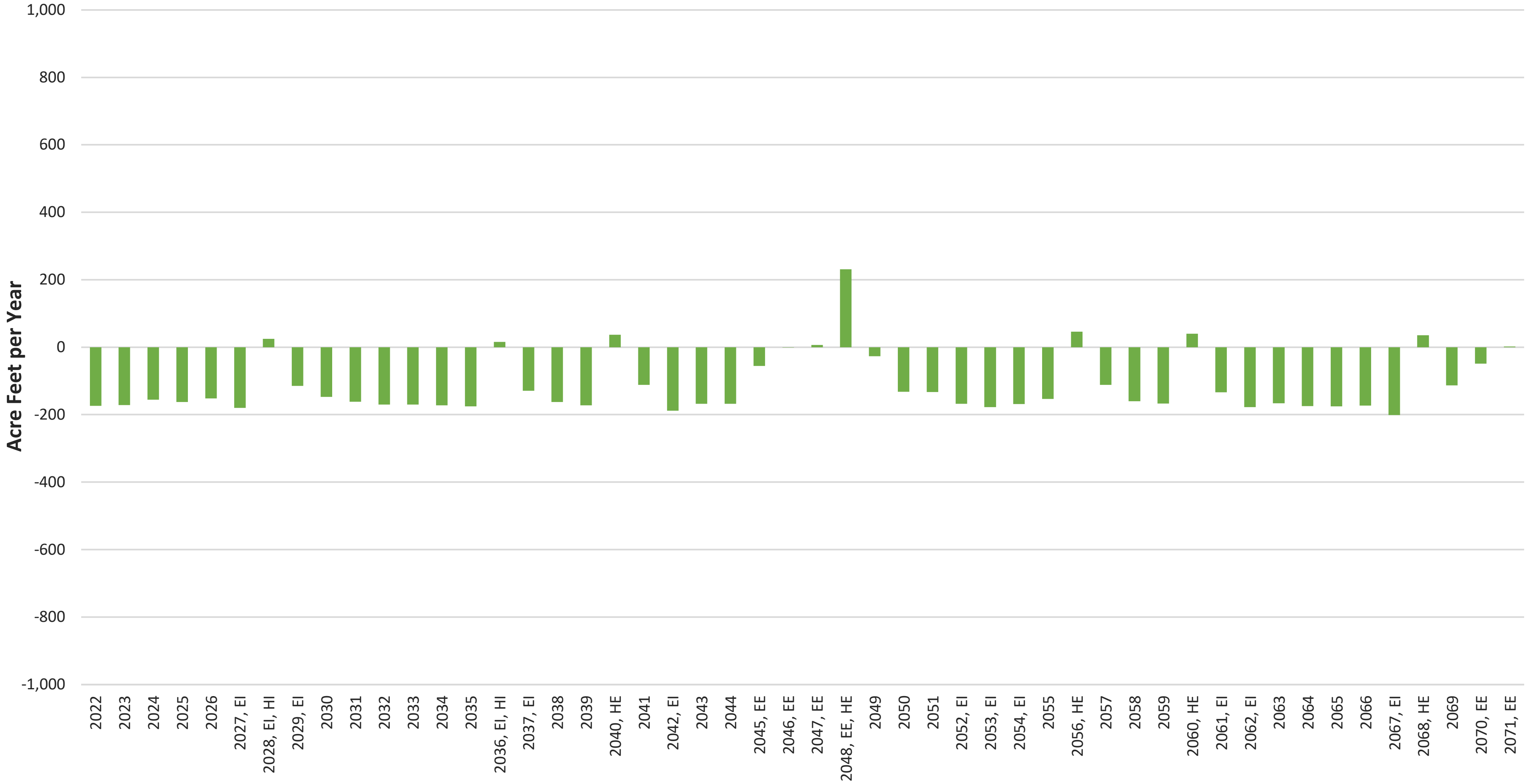
Figure

6-9

WR2668

November 2021

\\Oakland-01\data\PRJ2003REM\East Bay Plain GSP\04. Technical\Technical Analyses\GMS\GMS_outputs\flow budget\Scenarios\[Flow_Budget_WY2016-2071_Scenario4b.xlsx]



Notes:
EE = EBMUD Extraction
EI = EBMUD Injection
HE = City of Hayward Extraction

Simulated flow through Intermediate and Deep Aquifers
Negative numbers mean flow from East Bay Plain Subbasin to Niles Cone Subbasin

Simulated Net Inflow Across Horizontal Flow Barrier (Transition Zone)

East Bay Plain Groundwater Model
Groundwater Sustainability Plan

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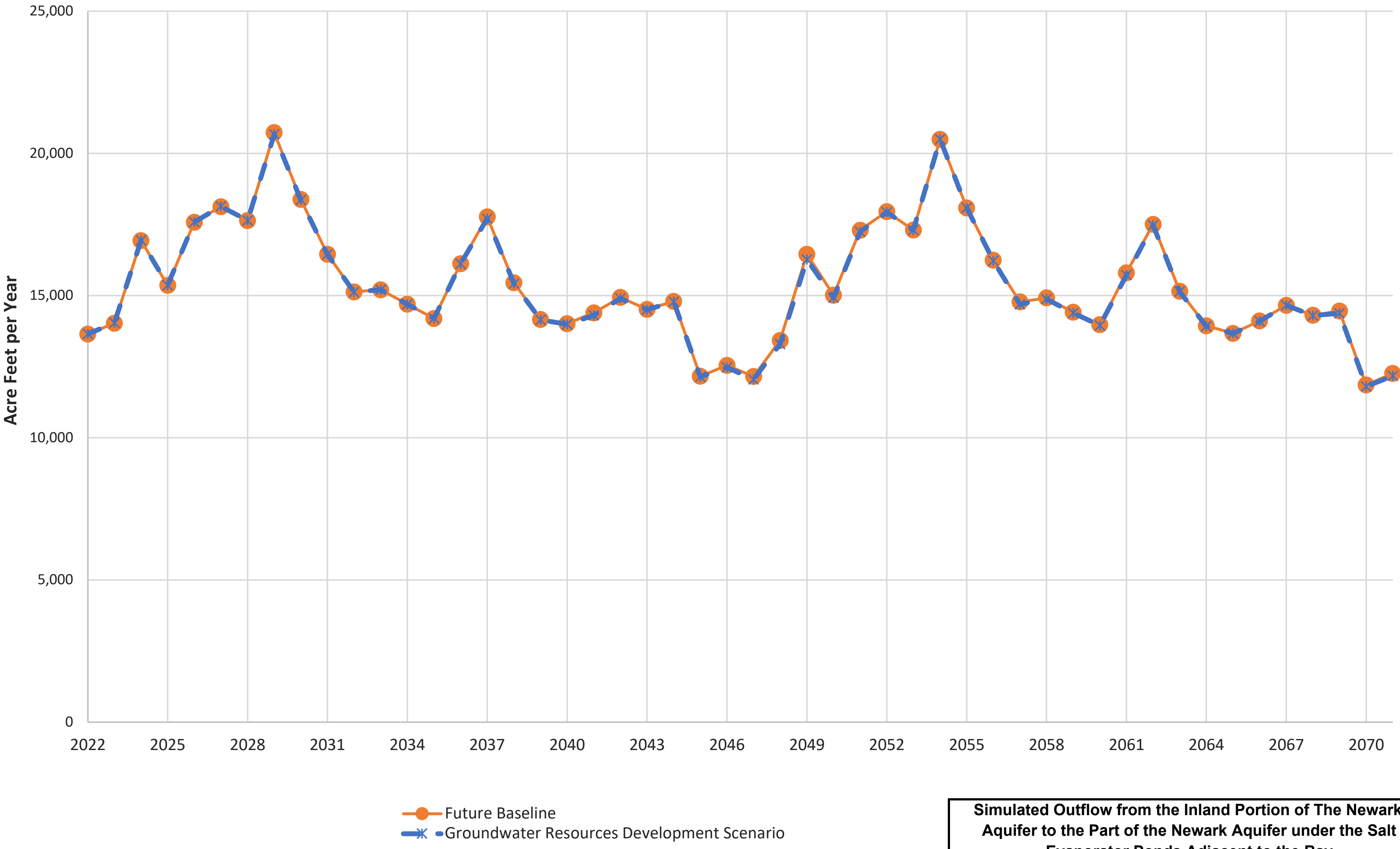
Figure

6-10

WR2668

November 2021

\\Oakland-01\data\PRJ2003REM\East Bay Plain GSP\04. Technical\Technical Analyses\GMS\GMS_outputs\flow budget\Scenarios\[Flow_Budget_WY2016-2071_Scenario4b_HFB Zones.xlsx]



Note: The results presented on this graph for the groundwater development scenario and baseline simulations are nearly identical, so the groundwater development scenario series mostly covers the baseline series.

Simulated Outflow from the Inland Portion of The Newark Aquifer to the Part of the Newark Aquifer under the Salt Evaporator Ponds Adjacent to the Bay

East Bay Plain Groundwater Model
Groundwater Sustainability Plan

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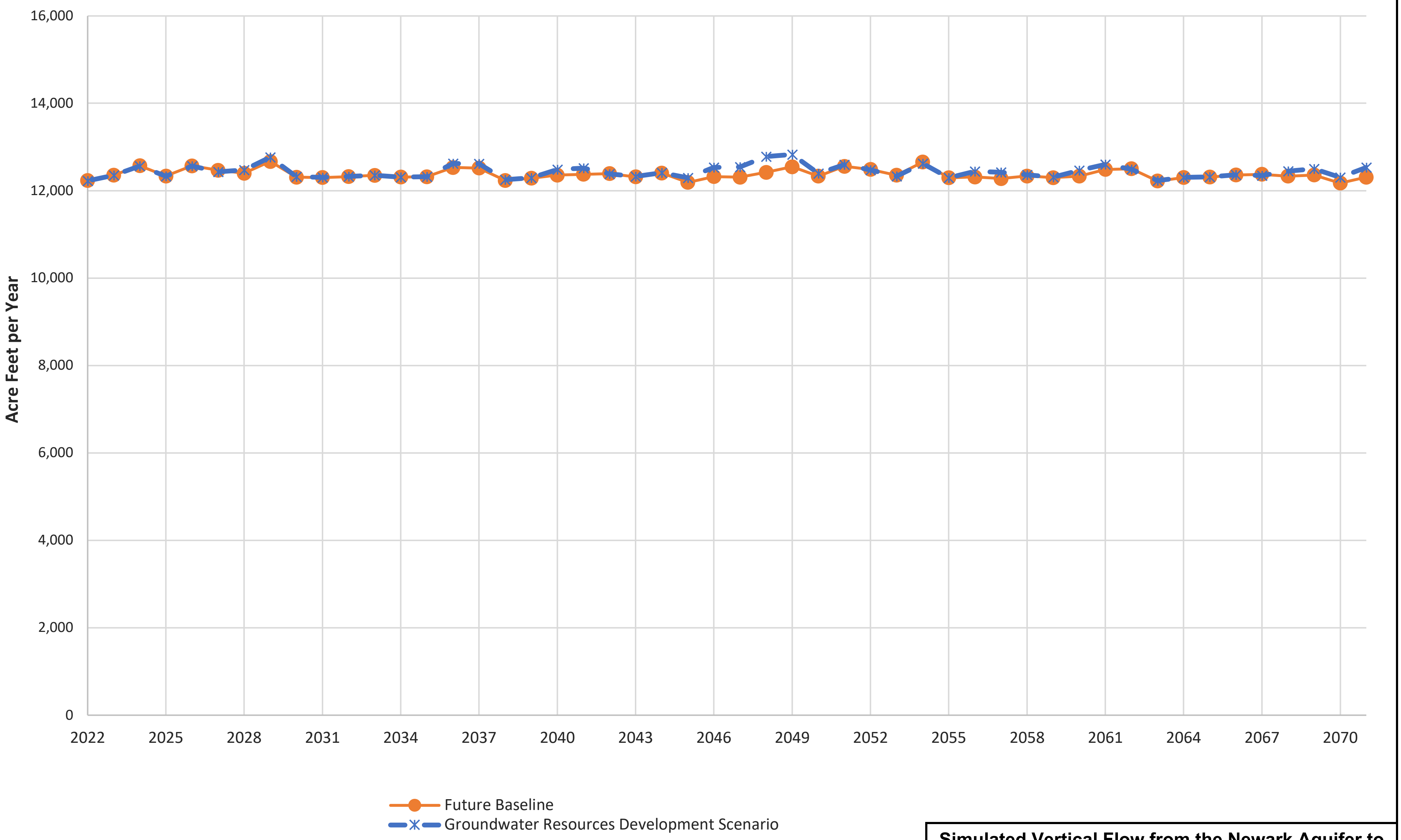
Figure

6-11

WR2668

November 2021

\\Oakland-01\data\PRJ2003REM\East Bay Plain GSP\04. Technical\Technical Analyses\GMS\GMS_outputs\flow budget\Scenarios\[Flow_Budget_WY2016-2071_Scenario4b_NC.xlsx]



Simulated Vertical Flow from the Newark Aquifer to the Centerville/Fremont and Deep Aquifers

East Bay Plain Groundwater Model
Groundwater Sustainability Plan

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Figure

6-12

WR2668

November 2021

\\Oakland-01\data\PRJ2003REM\East Bay Plain GSP\04. Technical\Technical Analyses\GMS\GMS_outputs\flow budget\Scenarios\[Flow_Budget_WY2016-2071_Scenario4b_NC.xlsx]

Appendices

Appendix A. Additional Tables

Table A-1. Pumping Wells

Table A-2. Observation Wells

Table A-3. Range of Parameters for Calibration Analysis

Table A-1: Pumping Wells

East Bay Plain Groundwater Model
Groundwater Sustainability Plan

Well ID	E	N	Top of Screen (ft bgs)	Bottom of Screen (ft bgs)	Average Pumping Rate (2000-2015)		Note
					AFY	gpm	
4	6121946	2044057	58	129	156	96.8	1
5	6120626	2042737	179	289	32	19.5	1
50	6140426	2030857	5	13	7	4.2	1
60	6136466	2028217	59	309	0	0	1
77	6135146	2029537	57	309	55	33.9	1
90	6135146	2025577	59	230	0	0	1
100	6102146	2048017	203	363	2	1.3	1
107	6108746	2045377	413	551	0	0	1
110	6114027	2046697	390	512	0	0	1
111	6114027	2046697	390	512	142	88.2	1
124	6116666	2041417	58	161	0	0	1
125	6116666	2041417	210	346	4	2.6	1
131	6111386	2041417	225	380	2	0.9	1
142	6104786	2038777	218	345	15	9.1	1
153	6103466	2033497	219	349	36	22.2	1
155	6108566	2036107	221	366	0.1	0.04	1
188	6110066	2025578	60	146	0	0	1
196	6136466	2016337	60	146	5	2.9	1
209	6120626	2012378	183	350	0	0.0	1
230	6129866	2008418	204	346	2	0.9	1
231	6129866	2007098	203	341	18	11.2	1
232	6129866	2007098	203	341	1	0.6	1
249	6120576	2039817	62	130	0	0	1
250	6135206	2032837	65	212	0	0	1
251	6139526	2027727	74	234	1	0.5	1
257	6110656	2015648	61	92	31	19.4	1
264	6104786	2021808	12	28	33	20.7	1
265	6127356	2027867	58	164	0	0	1
267	6130236	2032497	60	158	0	0	1
268	6139106	2029867	66	122	0.4	0.2	1
269	6123006	2024197	62	163	0	0	1
270	6117746	2043107	65	166	0	0	1
274	6082037	2069966	175	405	18	11.2	1
275	6129416	2006308	202	336	14	8.8	1
277	6132826	2034477	55	153	7	4.4	1
281	6071457	2100038	632	788	31	19.2	1
282	6042858	2115048	416	576	32	19.8	1
285	6106935	2063541	333	370	64	39.9	1
287	6052298	2108105	564	723	1	0.5	1
288	6084429	2078406	493	614	23	14.2	1
291	6076296	2096189	544	724	212	131.5	1
292	6047666	2108292	526	668	7	4.3	1
293	6076840	2084123	454	609	161	99.8	1
294	6075687	2095504	539	719	0	0	1
296	6083748	2085719	502	560	0	0	1
297	6076547	2085413	458	617	0	0	1
298	6075244	2079966	504	637	399	247.2	1
299	6113359	2054152	279	381	81	50.0	1
300	6093580	2060274	489	594	74	45.7	1
301	6075239	2088145	450	604	43	26.7	1
302	6067813	2106709	568	813	4	2.4	1
307	6071830	2104701	562	812	0	0	1
308	6071887	2092233	448	599	32	19.9	1
309	6046350	2120105	433	583	240	148.7	1
310	6073856	2100740	545	785	37	22.8	1
311	6078282	2087293	473	617	20	12.3	1
312	6092464	2076459	500	575	31	19.2	1
313	6086647	2068945	496	624	8	4.7	1
314	6083064	2071045	505	647	0	0	1
315	6082546	2090871	302	422	18	11.3	1
322	6076119	2096069	537	717	7	4.5	1
323	6099297	2048542	60	172	3	2.0	1
324	6136522	2027498	58	308	6	3.5	1
325	6134540	2022922	60	174	2	1.0	1
327	6120406	2048069	15	83	6	3.8	1
330	6137809	2027216	59	266	6	3.9	1
331	6130624	2010452	60	133	38	23.7	1
Contra Costa College	6031009	2179805	40	89	92	56.8	1
Metropolitan Golf Course	6071334	2088432	51	170	440	272.8	1
Richmond Country Club	6028000	2187800	40	90	264	163.7	1
Salesian High school	6030853	2174946	40	90	26	15.9	1

Table A-1: Pumping Wells (continued)

East Bay Plain Groundwater Model
Groundwater Sustainability Plan

Well ID	E	N	Top of Screen (ft bgs)	Bottom of Screen (ft bgs)	Average Pumping Rate (2000-2015)		Note
					AFY	gpm	
St. Joseph Cemetery	6032782	2178120	42	116	128	79.6	1
Chabot College	6096000	2060842	26	162	110	68.2	1
Kennedy Park	6091918	2070000	28	132	51	31.8	1
3	6123266	2044057	334	374	0.03	0.02	2
6	6121946	2042737	446	466	0	0	2
19	6124586	2036137	280	355	43	26.8	2
20	6129866	2036137	118	183	16	9.8	2
21	6129866	2036137	147	322	0	0.2	2
27	6129866	2032177	4	14	1	0.5	2
29	6133506	2032177	67	184	740	458.2	2
30	6133506	2032177	73	188	968	600.0	2
31	6133506	2032177	78	175	852	527.8	2
32	6133506	2032177	71	178	1,024	634.3	2
33	6133506	2032177	55	182	690	427.5	2
34	6133506	2032177	83	183	1,101	682.1	2
35	6133506	2032177	53	185	1,076	666.4	2
36	6133506	2032177	119	214	1,179	730.4	2
46	6143066	2028217	62	95	3	2.0	2
59	6139106	2029537	100	170	127	78.5	2
61	6137786	2026897	64	157	58	35.8	2
62	6137786	2026897	104	215	28	17.4	2
64	6132806	2030397	121	181	406	251.8	2
66	6132666	2030417	188	454	787	487.6	2
67	6132596	2030537	197	305	1,415	876.7	2
68	6132906	2030647	56	184	1,237	766.4	2
69	6132966	2030657	226	320	0	0.0	2
70	6132896	2030447	220	300	566	350.6	2
71	6132856	2030637	220	300	848	525.6	2
72	6131186	2030857	172	278	0.3	0.2	2
73	6131186	2030857	163	188	0	0	2
74	6132506	2029537	439	487	5	3.2	2
81	6129866	2028217	191	224	8	4.8	2
85	6123266	2025577	375	421	14	8.6	2
86	6123266	2025577	197	311	197	122.0	2
87	6120776	2022007	173	233	1,616	1,000.9	2
88	6120776	2022007	40	100	1,259	779.9	2
89	6129866	2025577	30	56	0	0	2
92	6137786	2025577	76	133	606	375.7	2
112	6112706	2045377	305	326	0	0	2
114	6111386	2044057	262	302	0	0	2
116	6112706	2042737	299	304	0	0	2
119	6116667	2046697	393	470	0.3	0.2	2
127	6119306	2040097	93	247	22	13.7	2
135	6110366	2036717	46	108	18	11.1	2
145	6102146	2038777	163	225	0.03	0.02	2
151	6102146	2034817	222	261	0.06	0.04	2
157	6108746	2034817	180	245	0.2	0.1	2
158	6108746	2033497	235	326	2	1.4	2
162	6106106	2032177	226	250	0	0	2
163	6106106	2032177	231	338	1	0.9	2
165	6111386	2034817	245	278	7	4.6	2
170	6115346	2036137	109	415	0	0	2
171	6119306	2034817	74	302	0	0	2
172	6119306	2034817	282	302	0	0	2
173	6116666	2033497	190	208	16	10.0	2
175	6116666	2029537	161	247	82	50.5	2
183	6107426	2030857	453	510	0	0	2
185	6106106	2028217	213	246	20	12.4	2
186	6106106	2028217	205	275	0.03	0.02	2
191	6119506	2024977	49	91	801	496.3	2
192	6119506	2024977	197	327	2,204	1,365.5	2
193	6115346	2025577	83	438	22	13.6	2
198	6131186	2017657	435	474	0	0	2
199	6127346	2019257	200	242	1,338	828.6	2
201	6123716	2019138	194	266	1,365	845.8	2
203	6120246	2015608	52	100	121	74.7	2
208	6124866	2012608	24	77	189	117.3	2
213	6127226	2011058	209	364	0	0	2
214	6139106	2012377	38	162	0	0	2
217	6147026	2005777	196	296	0	0	2
228	6129866	2009738	232	245	1	0.9	2

Table A-1: Pumping Wells (continued)

East Bay Plain Groundwater Model
Groundwater Sustainability Plan

Well ID	E	N	Top of Screen (ft bgs)	Bottom of Screen (ft bgs)	Average Pumping Rate (2000-2015)		Note
					AFY	gpm	
235	6115346	2016338	205	427	0	0	2
241	6117986	2015018	190	418	0	0	2
245	6117114	2014597	360	473	133	82.7	2
246	6117146	2014558	360	483	67	41.4	2
247	6116666	2015018	318	464	0	0	2
252	6114467	2049807	423	453	0	0.1	2
253	6105627	2049527	361	436	110	67.9	2
254	6113516	2028957	476	496	123	76.3	2
255	6126666	2008908	440	488	0.06	0.04	2
258	6117596	2015448	380	493	0	0	2
259	6132946	2030457	100	180	966	598.6	2
260	6132616	2030447	119	179	703	435.5	2
263	6118526	2015068	380	443	149	92.3	2
271	6138326	2012267	232	292	20	12.1	2
272	6101317	2051307	352	518	22	13.8	2
276	6117406	2015478	310	353	53	32.7	2
278	6103576	2049037	368	464	17	10.4	2
280	6139423	2027812	374	474	79	48.7	2
328	6118339	2014963	380	442	189	117.1	2
329	6151603	2011825	59	219	1	0.7	2

Notes and Abbreviations:

1 = Screened interval based on Layer Elevation
2 = Screened interval based on known screen elevation
E = Easting (feet)
N - Northing (feet)
Coordinates in State Plane California NAD 83 Zone 3

AFY = acre-feet per year
gpm = gallons per minutes
ft msl = feet mean sea level
ft bgs = feet below ground surface

Table A-2: Observation Wells (continued)

East Bay Plain Groundwater Model
Groundwater Sustainability Plan

Calibration Dataset	Well ID	E	N	Top of Screen (ft msl)	Bottom of Screen (ft msl)	Aquifer Zone
2010 Aquifer Pump Test	EBMUD MW-2S	6082097	2069940	-30	-50	Shallow
2010 Aquifer Pump Test	EBMUD MW-3	6081842	2069940	-511	-641	Deep
2010 Aquifer Pump Test	USGS-EB-3	6081796	2070406	-500	-600	Deep
2010 Aquifer Pump Test	EBMUD MW-4	6081803	2070628	-511	-641	Deep
2010 Aquifer Pump Test	EBMUD MW-6	6083784	2070120	-471	-641	Deep
2010 Aquifer Pump Test	EBMUD MW-5s	6083469	2072797	-187	-197	Intermediate
2010 Aquifer Pump Test	EBMUD MW-5i	6083469	2072797	-302	-312	Intermediate
2010 Aquifer Pump Test	EBMUD MW-5d	6083469	2072797	-487	-617	Deep
2010 Aquifer Pump Test	EBMUD MW-7	6085379	2069033	-503	-623	Deep
2010 Aquifer Pump Test	EBMUD MW-10s	6081364	2076905	-89	-109	Shallow
2010 Aquifer Pump Test	EBMUD MW-10i	6081364	2076905	-329	-349	Intermediate
2010 Aquifer Pump Test	EBMUD MW-10d	6081364	2076905	-579	-599	Deep
2010 Aquifer Pump Test	4S/2W-25C020	6084247	2060974	-469	-509	Deep
2010 Aquifer Pump Test	EBMUD MW-9i	6094992	2076460	-146	-156	Intermediate
2010 Aquifer Pump Test	EBMUD MW-9d	6094992	2076460	-271	-281	Deep
2010 Aquifer Pump Test	EBMUD MW-8d	6074793	2088139	-401	-461	Deep
2010 Aquifer Pump Test	Eden Park	6098741	2056203	-431	-501	Deep
2010 Aquifer Pump Test	Hayward Well E	6099037	2051756	-462	-517	Deep
2010 Aquifer Pump Test	04S/02W-04F01	6101106	2051140	-159	-209	Shallow
2010 Aquifer Pump Test	04S/02W-04F03	6101108	2051142	-289	-359	Intermediate
2010 Aquifer Pump Test	04S/02W-04F02	6101106	2051140	-427	-512	Deep
2010 Aquifer Pump Test	4S/2W-09F014	6099870	2044972	-385	-445	Deep
2010 Aquifer Pump Test	4S/2W-10E04	6105219	2044667	-419	-459	Deep
2010 Aquifer Pump Test	4S/2W-15L05	6106553	2038690	-389	-439	Deep
2010 Aquifer Pump Test	4S/2W-14D03	6110017	2040814	-383	-433	Deep
2010 Aquifer Pump Test	4S/2W-14D04	6109425	2040497	-454	-494	Deep
2002 Aquifer Pump Test	Hayward Well E	6099037	2051756	-462	-517	Deep
2002 Aquifer Pump Test	04S/02W-12C01	6117232	2046651	-341	-418	Deep
2002 Aquifer Pump Test	04S/02W-15L05	6106890	2038417	-418	-458	Deep
2002 Aquifer Pump Test	04S/02W-14D03	6110017	2040814	-383	-433	Deep
2002 Aquifer Pump Test	04S/02W-13P05	6115798	2037217	-371	-391	Deep
2002 Aquifer Pump Test	04S/02W-10E04	6105460	2044824	-386	-426	Deep
2002 Aquifer Pump Test	04S/02W-25D01	6117302	2028823	-454	-484	Deep
2002 Aquifer Pump Test	04S/03W-13B01	6086670	2041905	-304	-351	Intermediate
2002 Aquifer Pump Test	04S/02W-09P09	6100752	2043096	-56	-96	Shallow
2002 Aquifer Pump Test	03S/02W-32D02	6094465	2056905	-408	-527	Deep
2002 Aquifer Pump Test	Farmhouse Well	6089607	2076176	-464	-494	Deep
2002 Aquifer Pump Test	04S/02W-25D02	6117302	2028823	-242	-282	Intermediate
2002 Aquifer Pump Test	EBMUD MW-2S	6082097	2069940	-30	-50	Shallow
2002 Aquifer Pump Test	Bayside OW3	6082051	2069980	-516	-646	Deep
2002 Aquifer Pump Test	EBMUD MW-7	6085382	2069045	-499	-619	Deep
Historical	02S/03W-22P03	6075585	2096024	-252	-272	Intermediate
Historical	02S/03W-28G01	6071735	2092597	-219	-239	Intermediate
Historical and Steady State	03S/02W-29F04	6096305	2061391	-45	-65	Shallow
Historical and Steady State	03S/02W-27A01	6109719	2061856	-184	-204	Intermediate
Historical and Steady State	04S/01W-30E03	6120018	2029239	-337	-357	Deep
Historical and Steady State	04S/01W-30E04	6120571	2029300	-50	-60	Shallow
Historical and Steady State	04S/01W-28F05	6133174	2028457	-353	-373	Deep
Historical and Steady State	04S/01W-27D08	6136242	2030907	-24	-44	Shallow
Historical	03S/03W-14K02	6082006	2069907	-153	-981	Multi-Aquifer
Historical and Steady State	04S/03W-13B01	6086666	2041907	-300	-347	Intermediate
Historical and Steady State	04S/01W-29A06	6130326	2030797	-40	-50	Shallow
Historical and Steady State	01S/04W-04R01	6042318	2143732	-196	-296	Intermediate
Historical and Steady State	02S/03W-19Q01	6061345	2095409	-491	-511	Deep
Historical and Steady State	T0601300579-S-1	6037569	2178746	94	74	Shallow
Historical and Steady State	T0600102093-MW-1	6075139	2109532	47	27	Shallow
Historical and Steady State	T0600101224-MW-5	6084991	2091483	-112	-132	Deep
Historical and Steady State	T0600100543-MW2	6101104	2062864	37	22	Shallow
Historical and Steady State	T0600100216-MW-1	6129612	2024596	33	13	Shallow
Historical and Steady State	T0600100545-W1	6134617	2023008	13	3	Shallow
Historical	T0600101262-S-6	6149073	2021881	246	226	Shallow
Historical and Steady State	T0600101230-MW-4	6091443	2084757	41	21	Shallow
Historical and Steady State	T0601300016-MW-8	6030058	2179684	35	25	Shallow
Historical and Steady State	T0601300279-MW-1	6028909	2171612	60	40	Shallow
Historical and Steady State	T0601300018-BC-4	6033959	2172403	54	39	Shallow
Historical and Steady State	T0600102131-MW-1	6042305	2152266	49	29	Shallow
Historical and Steady State	T0600101448-MW-3	6047282	2144359	97	77	Shallow
Historical	T0600194038-MW-1	6053522	2139105	203	183	Shallow
Historical and Steady State	T0600101471-MW-5	6054215	2128481	83	68	Shallow
Historical and Steady State	T0600101876-MW-1	6049918	2124963	32	23	Shallow
Historical and Steady State	T0600102136-MW4	6045081	2119532	27	7	Shallow
Historical and Steady State	T0600100307-A-1	6048314	2110431	28	8	Shallow

Table A-2: Observation Wells (continued)

East Bay Plain Groundwater Model
Groundwater Sustainability Plan

Calibration Dataset	Well ID	E	N	Top of Screen (ft msl)	Bottom of Screen (ft msl)	Aquifer Zone
Historical	T0600102279-MW-5	6071856	2113753	179	159	Shallow
Historical and Steady State	T0600100339-C-8	6066598	2108770	6	-14	Shallow
Historical and Steady State	T0600100330-C-1	6062570	2105045	20	0	Shallow
Historical and Steady State	T0600100667-MW-2	6071672	2106540	27	7	Shallow
Historical and Steady State	T0600101476-MW-3	6070857	2095209	11	-1	Shallow
Historical	T0600100324-MW-1	6103729	2079688	170	150	Shallow
Historical and Steady State	T0600101414-MW-1	6091724	2076464	36	16	Shallow
Historical and Steady State	T0600100403-GT-6	6105280	2051005	6	-14	Shallow
Historical and Steady State	04S/02W-02H01	6114660	2049477	-413	-433	Deep
Historical and Steady State	04S/02W-12C01	6117229	2046653	-345	-422	Deep
Historical and Steady State	04S/02W-10E04	6105456	2044826	-387	-427	Deep
Historical and Steady State	T0600100331-C-1	6106847	2041185	22	2	Shallow
Historical and Steady State	04S/02W-15L05	6106886	2038419	-420	-460	Deep
Historical and Steady State	T0600101346-MW-14	6120233	2038563	18	-2	Shallow
Historical and Steady State	04S/02W-25D03	6115101	2030847	-101	-121	Shallow
Historical and Steady State	04S/01W-19N05	6120641	2031303	-163	-183	Intermediate
Historical and Steady State	04S/01W-28D11	6131322	2031030	-192	-212	Intermediate
Historical and Steady State	04S/02W-25D01	6117298	2028825	-356	-376	Deep
Historical and Steady State	T0600100780-MW-9	6138444	2019263	39	19	Shallow
Historical	T0600101262-S-10	6149007	2021821	206	186	Shallow
Historical and Steady State	04S/02W-12K11	6118192	2043109	-56	-96	Shallow
Historical and Steady State	04S/02W-12K09	6118162	2043109	-246	-256	Intermediate
Historical and Steady State	04S/02W-12K08	6118147	2043109	-416	-456	Deep
Historical and Steady State	04S/02W-14D07	6110055	2040770	-52	-92	Shallow
Historical and Steady State	04S/02W-14D05	6110034	2040791	-242	-262	Intermediate
Historical and Steady State	04S/02W-14D03	6110017	2040814	-383	-433	Deep
Historical and Steady State	04S/02W-13P06	6115818	2037218	-305	-325	Intermediate
Historical and Steady State	04S/02W-13P05	6115794	2037219	-367	-387	Deep
Historical and Steady State	04S/01W-17M07	6125309	2038156	-184	-204	Intermediate
Historical and Steady State	04S/01W-17M06	6125317	2038156	-384	-404	Deep
Historical and Steady State	04S/01W-30A05	6123929	2030461	-57	-97	Shallow
Historical and Steady State	04S/01W-30A04	6123909	2030477	-147	-177	Intermediate
Historical and Steady State	04S/01W-28D01	6131338	2031030	-357	-377	Deep
Historical and Steady State	T0600102073-EW-6	6119224	2023204	32	12	Shallow
Historical and Steady State	T0600102073-MW-13	6119653	2023026	1	-19	Shallow
Historical and Steady State	T0601300499-MW-1A	6036864	2164827	81	61	Shallow
Historical and Steady State	T0600101337-TMW-5	6060176	2112120	36	16	Shallow
Historical and Steady State	T0600100023-MW-6	6095289	2068910	40	25	Shallow
Historical	T0600100274-MW-1	6061693	2119527	181	168	Shallow
Historical and Steady State	T0600170016-MW-5	6116937	2051339	29	14	Shallow
Historical and Steady State	T0600102272-C-1	6140770	2028677	51	31	Shallow
Historical and Steady State	SL374211188-MW-10	6023151	2161719	23	3	Shallow
Historical and Steady State	T0600100208-MW-10	6043279	2132597	4	-6	Shallow
Historical and Steady State	T0600101365-MW-3	6048200	2127930	8	-12	Shallow
Historical and Steady State	T0600102018-MW-2	6139784	2008216	8	-2	Shallow
Historical and Steady State	SL20268886-MW-OS10A	6112355	2016935	4	-6	Shallow
Historical and Steady State	SL20268886-MW-NEW5	6112867	2017010	-37	-47	Shallow
Historical and Steady State	SL18332752-MW-13	6037498	2123827	7	-6	Shallow
Historical and Steady State	SL18332752-MW-37C	6036574	2124052	-51	-56	Shallow
Historical and Steady State	SL20260878-MW-22B	6074721	2085373	11	-1	Shallow
Historical and Steady State	SL20260878-MW-17B	6074845	2085138	-36	-46	Shallow
Historical and Steady State	T0601300023-MW-7U	6021918	2159822	58	33	Shallow
Historical and Steady State	SL0600173599-MW-1	6122633	2011681	12	2	Shallow
Historical and Steady State	03S/03W-14K22	6082425	2069870	-9	-29	Shallow
Historical and Steady State	03S/03W-14K20	6082425	2069870	-282	-302	Intermediate
Historical and Steady State	03S/03W-14K19	6082425	2069870	-604	-624	Deep
Historical and Steady State	SL18344764-AMW-1	6084421	2097287	53	33	Shallow
Historical and Steady State	SL18344764-AMW-9	6084407	2097064	33	13	Shallow
Historical and Steady State	T0600101491-MW-1	6102705	2071479	50	30	Shallow
Historical and Steady State	T0600191157-MW-1D	6092128	2084371	21	6	Shallow
Historical and Steady State	L10006224883-GW-2	6036128	2144404	-7	-27	Shallow
Historical and Steady State	EBMUD MW-5I	6083642	2072908	-299	-309	Intermediate
Historical and Steady State	05S/01W-05H06	6130510	2017403	-12	-42	Shallow
Historical and Steady State	05S/01W-05H05	6130522	2017420	-192	-222	Intermediate
Historical and Steady State	05S/01W-05H03	6130533	2017436	-412	-442	Deep
Historical and Steady State	EBMUD MW-10I	6080796	2077471	-327	-347	Intermediate
Historical and Steady State	EBMUD MW-9D	6094992	2076460	-272	-282	Intermediate
Historical and Steady State	EBMUD MW-2S	6082093	2069942	-29	-49	Shallow
Historical and Steady State	EBMUD MW-10S	6080796	2077471	-87	-107	Shallow
Historical and Steady State	EBMUD MW-9S	6094992	2076460	-57	-67	Shallow
Steady State	04S/02W-05G01	6091679	2053130	-306	-356	Intermediate
Steady State	04S/02W-05G02	6091677	2053118	-391	-431	Deep

Table A-2: Observation Wells (continued)

East Bay Plain Groundwater Model
Groundwater Sustainability Plan

Calibration Dataset	Well ID	E	N	Top of Screen (ft msl)	Bottom of Screen (ft msl)	Aquifer Zone
Steady State	04S/02W-05G04	6091681	2053144	-186	-211	Intermediate
Historical	03S/03W-36R02	6089747	2053966	-230	-250	Intermediate
Historical	03S/03W-36R03	6089719	2054003	-293	-317	Intermediate
Historical	04S/01W-27P02	6137403	2027537	-110	-120	Intermediate
Historical	04S/01W-28D02	6130766	2030557	21	-48	Shallow
Historical	02S/04W-03E01	6042341	2114887	-261	-337	Intermediate
Historical	02S/04W-12R01	6057140	2105648	-267	-287	Intermediate
Historical	03S/02W-34P06	6107288	2053266	-19	-70	Shallow

Notes and Abbreviations:

E = Easting (feet)

ft msl = feet mean sea level

N - Northing (feet)

Coordinates in State Plane California NAD 83 Zone 3; vertical datum NAVD88

Table A-3: Range of Parameters for Calibration Analysis (continued)

East Bay Plain Groundwater Model
Groundwater Sustainability Plan

Name	Area Description	Value	Range Minimum	Range Maximum	Qualitative Hydraulic Conductivity Category Based on Borehole Log Data	Layer/Aquifer Zone
Hydraulic Conductivity Parameters						
Horizontal Hydraulic Conductivity (feet per day)						
HK_1001	San Pablo Cone Region	18.0	0.5	50	Low	Layers 1-3; Shallow Aquifer Zone
HK_1002	San Pablo Cone	18.0	0.5	50	Medium	Layers 1-3; Shallow Aquifer Zone
HK_1003	Berkeley Region	7.00	0.5	50	Medium	Layers 1-3; Shallow Aquifer Zone
HK_1004	Merritt Sand Region	5.00	0.5	50	Medium	Layers 1-3; Shallow Aquifer Zone
HK_1005	Oakland Uplands	5.00	0.5	50	Low	Layers 1-3; Shallow Aquifer Zone
HK_1007	San Leandro Region	1.50	0.5	50	Medium	Layers 1-3; Shallow Aquifer Zone
HK_1008	San Lorenzo Cone	8.61	0.5	50	Medium	Layers 1-3; Shallow Aquifer Zone
HK_1009	Hayward Region	6.00	0.5	50	Medium	Layers 1-3; Shallow Aquifer Zone
HK_1010	Niles Cone Region	121	10	1000	High	Layers 1-3; Shallow Aquifer Zone
HK_1011	MF Berkeley Region	1.50	0.5	50	Low	Layers 1-3; Shallow Aquifer Zone
HK_1012	MF Oakland	0.30	0.1	50	Low	Layers 1-3; Shallow Aquifer Zone
HK_1013	MF San Leandro	2.00	0.5	50	Low	Layers 1-3; Shallow Aquifer Zone
HK_1014	MF Hayward	0.85	0.5	50	Low	Layers 1-3; Shallow Aquifer Zone
HK_1016	Bayfarm High Percolation Region	18.7	0.5	50	Medium	Layers 1-3; Shallow Aquifer Zone
HK_4001	San Pablo Cone Region	1.00E-03	1.00E-04	5.00E-01	Aquitard	Layer 4; Upper Aquitard
HK_4003	Berkeley Region	2.47E-03	1.00E-04	1.00E-02	Aquitard	Layer 4; Upper Aquitard
HK_4006	Oakland and San Leandro Region	2.50E-02	1.00E-04	5.00E-01	Aquitard	Layer 4; Upper Aquitard
HK_4008	San Lorenzo Cone	5.00E-04	1.00E-04	1.00E-02	Aquitard	Layer 4; Upper Aquitard
HK_4009	Hayward Region	5.00E-03	1.00E-04	1.00E-02	Aquitard	Layer 4; Upper Aquitard
HK_4010	Niles Cone Region	4.54E-03	1.00E-04	1.00E-01	Aquitard	Layer 4; Upper Aquitard
HK_4011	MF Berkeley Region	6.35E-04	1.00E-04	1.00E-02	Aquitard	Layer 4; Upper Aquitard
HK_4012	MF Oakland	2.65E-04	1.00E-04	1.00E-02	Aquitard	Layer 4; Upper Aquitard
HK_4013	MF San Leandro	4.00E-03	1.00E-04	1.00E-02	Aquitard	Layer 4; Upper Aquitard
HK_4014	MF Hayward	5.00E-01	1.00E-04	5.00E-01	Aquitard	Layer 4; Upper Aquitard
HK_5001	San Pablo Cone Region	2.91	2	200	Medium	Layers 5-7; Intermediate Aquifer Zone
HK_5003	Berkeley Region	3.24	2	200	Medium	Layers 5-7; Intermediate Aquifer Zone
HK_5004	Merritt Sand Region	201	2	250	High	Layers 5-7; Intermediate Aquifer Zone
HK_5006	Oakland and San Leandro Region	52.5	2	200	Medium	Layers 5-7; Intermediate Aquifer Zone
HK_5008	San Lorenzo Cone	5.02	2.5	250	High	Layers 5-7; Intermediate Aquifer Zone
HK_5009	Hayward Region	4.96	2	200	Medium	Layers 5-7; Intermediate Aquifer Zone
HK_5010	Niles Cone Region	50	25	500	High	Layers 5-7; Intermediate Aquifer Zone
HK_5011	MF Berkeley Region	1.49	0.02	20	Low	Layers 5-7; Intermediate Aquifer Zone
HK_5012	MF Oakland	0.30	0.05	5	Low	Layers 5-7; Intermediate Aquifer Zone
HK_5013	MF San Leandro	2.14	0.1	10	Low	Layers 5-7; Intermediate Aquifer Zone
HK_5014	MF Hayward	0.31	0.2	20	Low	Layers 5-7; Intermediate Aquifer Zone
HK_5015	Castro Valley	32.8	5	500	Medium	Layers 5-7; Intermediate Aquifer Zone
HK_6001	San Pablo Cone Region	1.73E-04	1.00E-05	1.00E-03	Aquitard	Layer 8; Lower Aquitard
HK_6003	Berkeley Region	1.60E-05	1.00E-05	1.00E-03	Aquitard	Layer 8; Lower Aquitard
HK_6006	Oakland and San Leandro Region	1.94E-03	1.00E-05	5.00E-03	Aquitard	Layer 8; Lower Aquitard
HK_6009	Hayward Region	5.00E-04	1.00E-05	1.00E-03	Aquitard	Layer 8; Lower Aquitard
HK_6010	Niles Cone Region	6.17E-04	1.00E-05	1.00E-03	Aquitard	Layer 8; Lower Aquitard
HK_6011	MF Berkeley Region	2.14E-04	1.00E-05	1.00E-03	Aquitard	Layer 8; Lower Aquitard
HK_6012	MF Oakland	7.04E-03	5.00E-04	5.00E-02	Aquitard	Layer 8; Lower Aquitard
HK_6013	MF San Leandro	5.00E-03	5.00E-04	5.00E-02	Aquitard	Layer 8; Lower Aquitard
HK_6014	MF Hayward	5.00E-04	5.00E-04	5.00E-02	Aquitard	Layer 8; Lower Aquitard
HK_7001	San Pablo Cone Region	2.50	0.1	10	Medium	Layers 9-11; Deep Aquifer Zone
HK_7003	Berkeley Region	27.8	2.5	250	Medium	Layers 9-11; Deep Aquifer Zone
HK_7006	Oakland and San Leandro Region	5 - 16	-	-	Medium	Layers 10-11; Deep Aquifer Zone
HK_7008	San Lorenzo Cone	29 - 110	-	-	Medium	Layers 10-11; Deep Aquifer Zone
HK_7009	Hayward Region	40 - 107	-	-	High	Layers 10-11; Deep Aquifer Zone
HK_7010	Niles Cone Region	12 - 65	-	-	High	Layers 10-11; Deep Aquifer Zone
HK_7011	MF Berkeley Region	1.50	0.02	20	Low	Layers 9-11; Deep Aquifer Zone
HK_7012	MF Oakland	0.30	0.05	5	Low	Layers 9-11; Deep Aquifer Zone
HK_7013	MF San Leandro	0.10	0.05	10	Low	Layers 9-11; Deep Aquifer Zone
HK_7014	MF Hayward	0.21	0.05	10	Low	Layers 9-11; Deep Aquifer Zone
HK_8001	San Pablo Cone Region	0.12	0.01	1	Low	Layer 12
HK_8003	Berkeley Region	0.26	0.01	1	Low	Layer 12
HK_8006	Oakland and San Leandro Region	0.13	0.01	1	Low	Layer 12
HK_8009	Hayward Region	0.01	0.01	1	Low	Layer 12
HK_8010	Niles Cone Region	12 - 65	-	-	High	Layer 12
HK_8011	MF Berkeley Region	0.06	0.01	1	Low	Layer 12
HK_8012	MF Oakland	0.20	0.01	1	Low	Layer 12
HK_8013	MF San Leandro	0.09	0.01	1	Low	Layer 12
HK_8014	MF Hayward	0.06	0.01	1	Low	Layer 12
HK_9006	Oakland and San Leandro Region	5 - 16	-	-	Medium	Layer 9; Deep Aquifer Zone
HK_9008	San Lorenzo Cone	9 - 35	-	-	High	Layer 9; Deep Aquifer Zone
HK_9009	Hayward Region	15 - 34	-	-	Medium	Layer 9; Deep Aquifer Zone
HK_9010	Niles Cone Region	16 - 86	-	-	High	Layer 9; Deep Aquifer Zone

Table A-3: Range of Parameters for Calibration Analysis (continued)

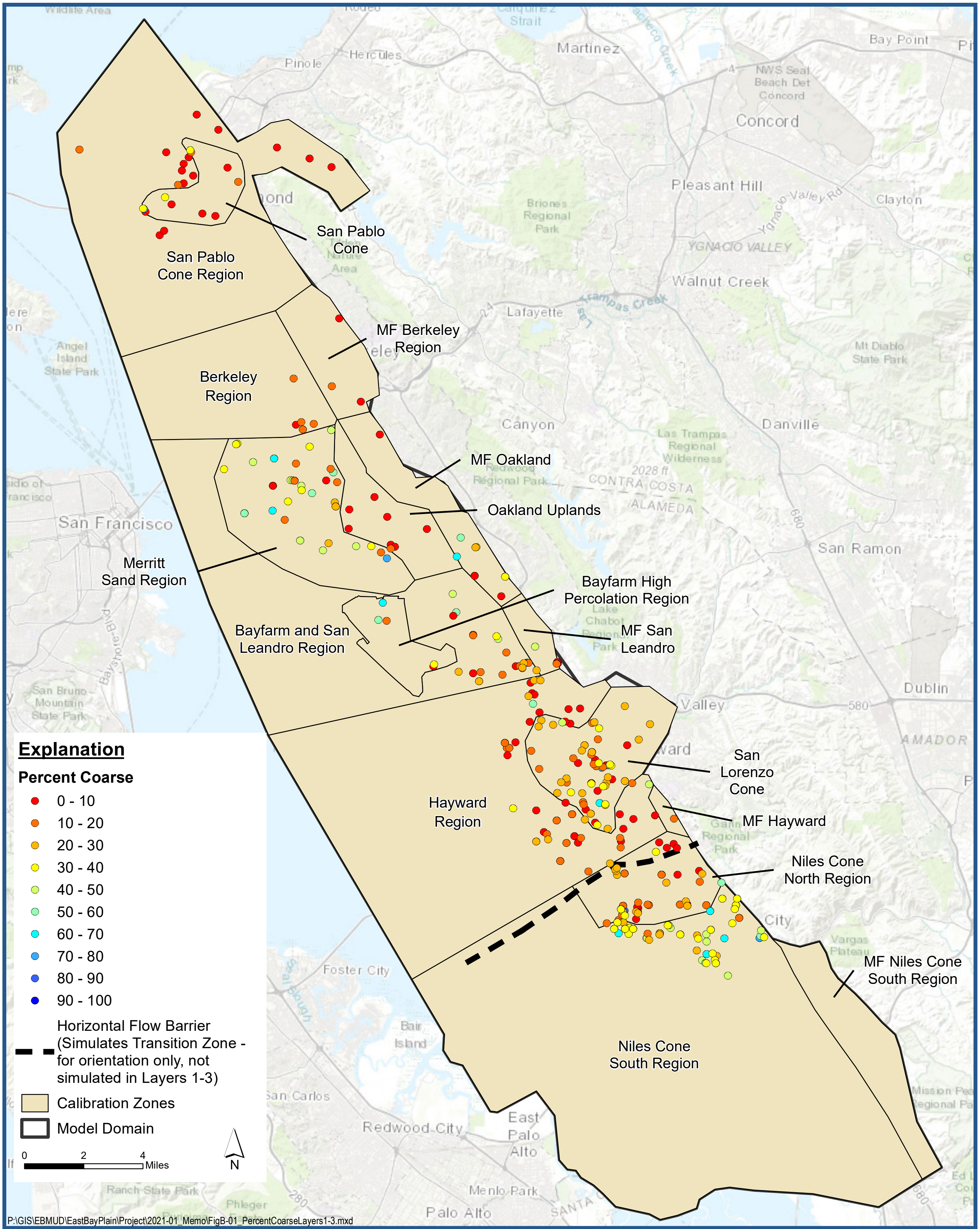
East Bay Plain Groundwater Model
Groundwater Sustainability Plan

Name	Area Description	Value	Range Minimum	Range Maximum	Qualitative Hydraulic Conductivity Category Based on Borehole Log Data	Layer/Aquifer Zone
Vertical Anisotropy Ratio (Horizontal Hydraulic Conductivity / Vertical Hydraulic Conductivity)						
VANI_1001	San Pablo Cone Region	5	5	100	-	Layers 1-3; Shallow Aquifer Zone
VANI_1002	San Pablo Cone	100	5	100	-	Layers 1-3; Shallow Aquifer Zone
VANI_1003	Berkeley Region	5	5	100	-	Layers 1-3; Shallow Aquifer Zone
VANI_1004	Merritt Sand Region	28	5	100	-	Layers 1-3; Shallow Aquifer Zone
VANI_1005	Oakland Uplands	17	5	100	-	Layers 1-3; Shallow Aquifer Zone
VANI_1007	San Leandro Region	18	5	100	-	Layers 1-3; Shallow Aquifer Zone
VANI_1008	San Lorenzo Cone	100	5	100	-	Layers 1-3; Shallow Aquifer Zone
VANI_1009	Hayward Region	5	5	100	-	Layers 1-3; Shallow Aquifer Zone
VANI_1010	Niles Cone Region	100	5	100	-	Layers 1-3; Shallow Aquifer Zone
VANI_1011	MF Berkeley Region	41	5	100	-	Layers 1-3; Shallow Aquifer Zone
VANI_1012	MF Oakland	5	5	100	-	Layers 1-3; Shallow Aquifer Zone
VANI_1013	MF San Leandro	78	5	100	-	Layers 1-3; Shallow Aquifer Zone
VANI_1014	MF Hayward	10	5	100	-	Layers 1-3; Shallow Aquifer Zone
VANI_1016	Bayfarm High Percolation Region	17	5	100	-	Layers 1-3; Shallow Aquifer Zone
VANI_4001	San Pablo Cone Region	21	1	100	-	Layer 4; Upper Aquitard
VANI_4003	Berkeley Region	30	1	100	-	Layer 4; Upper Aquitard
VANI_4006	Oakland and San Leandro Region	30	1	100	-	Layer 4; Upper Aquitard
VANI_4008	San Lorenzo Cone	100	1	100	-	Layer 4; Upper Aquitard
VANI_4009	Hayward Region	30	1	100	-	Layer 4; Upper Aquitard
VANI_4010	Niles Cone Region	3	1	100	-	Layer 4; Upper Aquitard
VANI_4011	MF Berkeley Region	3	1	100	-	Layer 4; Upper Aquitard
VANI_4012	MF Oakland	1	1	100	-	Layer 4; Upper Aquitard
VANI_4013	MF San Leandro	4	1	100	-	Layer 4; Upper Aquitard
VANI_4014	MF Hayward	22	1	100	-	Layer 4; Upper Aquitard
VANI_5001	San Pablo Cone Region	13	5	1000	-	Layers 5-7; Intermediate Aquifer Zone
VANI_5003	Berkeley Region	14	5	1000	-	Layers 5-7; Intermediate Aquifer Zone
VANI_5004	Merritt Sand Region	9	5	1000	-	Layers 5-7; Intermediate Aquifer Zone
VANI_5006	Oakland and San Leandro Region	11	5	1000	-	Layers 5-7; Intermediate Aquifer Zone
VANI_5008	San Lorenzo Cone	5	5	1000	-	Layers 5-7; Intermediate Aquifer Zone
VANI_5009	Hayward Region	5	5	1000	-	Layers 5-7; Intermediate Aquifer Zone
VANI_5010	Niles Cone Region	5	5	1000	-	Layers 5-7; Intermediate Aquifer Zone
VANI_5011	MF Berkeley Region	10	5	1000	-	Layers 5-7; Intermediate Aquifer Zone
VANI_5012	MF Oakland	5	5	1000	-	Layers 5-7; Intermediate Aquifer Zone
VANI_5013	MF San Leandro	11	5	1000	-	Layers 5-7; Intermediate Aquifer Zone
VANI_5014	MF Hayward	9	5	1000	-	Layers 5-7; Intermediate Aquifer Zone
VANI_5015	Castro Valley	11	5	1000	-	Layers 5-7; Intermediate Aquifer Zone
VANI_6001	San Pablo Cone Region	11	1	100	-	Layer 8; Lower Aquitard
VANI_6003	Berkeley Region	8	1	100	-	Layer 8; Lower Aquitard
VANI_6006	Oakland and San Leandro Region	16	1	100	-	Layer 8; Lower Aquitard
VANI_6009	Hayward Region	3	1	100	-	Layer 8; Lower Aquitard
VANI_6010	Niles Cone Region	3	1	100	-	Layer 8; Lower Aquitard
VANI_6011	MF Berkeley Region	16	5	100	-	Layer 8; Lower Aquitard
VANI_6012	MF Oakland	20	5	100	-	Layer 8; Lower Aquitard
VANI_6013	MF San Leandro	12	5	100	-	Layer 8; Lower Aquitard
VANI_6014	MF Hayward	10	5	100	-	Layer 8; Lower Aquitard
VANI_7001	San Pablo Cone Region	10	5	1000	-	Layers 10-11; Deep Aquifer Zone
VANI_7003	Berkeley Region	10	5	1000	-	Layers 10-11; Deep Aquifer Zone
VANI_7006	Oakland and San Leandro Region	10	5	1000	-	Layers 10-11; Deep Aquifer Zone
VANI_7008	San Lorenzo Cone	10	5	1000	-	Layers 10-11; Deep Aquifer Zone
VANI_7009	Hayward Region	10	5	1000	-	Layers 10-11; Deep Aquifer Zone
VANI_7010	Niles Cone Region	7	5	1000	-	Layers 10-11; Deep Aquifer Zone
VANI_7011	MF Berkeley Region	10	5	100	-	Layers 10-11; Deep Aquifer Zone
VANI_7012	MF Oakland	17	5	100	-	Layers 10-11; Deep Aquifer Zone
VANI_7013	MF San Leandro	19	5	100	-	Layers 10-11; Deep Aquifer Zone
VANI_7014	MF Hayward	10	5	100	-	Layers 10-11; Deep Aquifer Zone
VANI_8001	San Pablo Cone Region	13	5	100	-	Layer 12
VANI_8003	Berkeley Region	15	5	100	-	Layer 12
VANI_8006	Oakland and San Leandro Region	10	5	100	-	Layer 12
VANI_8009	Hayward Region	50	5	100	-	Layer 12
VANI_8010	Niles Cone Region	10	5	100	-	Layer 12
VANI_8011	MF Berkeley Region	12	5	100	-	Layer 12
VANI_8012	MF Oakland	13	5	100	-	Layer 12
VANI_8013	MF San Leandro	17	5	100	-	Layer 12
VANI_8014	MF Hayward	10	5	100	-	Layer 12
VANI_9006	Oakland and San Leandro Region	10	5	100	-	Layer 9; Deep Aquifer Zone
VANI_9008	San Lorenzo Cone	10	5	100	-	Layer 9; Deep Aquifer Zone
VANI_9009	Hayward Region	10	5	100	-	Layer 9; Deep Aquifer Zone
VANI_9010	Niles Cone Region	7	5	100	-	Layer 9; Deep Aquifer Zone
Storage Parameters						
Specific Storativity (feet^{-1})						
	Entire Model Domain	5.00E-06	1.00E-07	0.0001	-	Layers 1-3; Shallow Aquifer Zone
	Entire Model Domain	5.00E-06	1.00E-07	0.0001	-	Layer 4; Upper Aquitard
	East Bay Plain and Castro Valley	3.00E-04	1.00E-07	0.0001	-	Layers 5-7; Intermediate Aquifer Zone
	Niles Cone Region	5.00E-06	1.00E-07	0.0001	-	Layers 5-7; Intermediate Aquifer Zone
	Entire Model Domain	5.00E-06	1.00E-07	0.0001	-	Layer 8; Lower Aquitard
	Entire Model Domain	5.00E-07	1.00E-07	0.0001	-	Layer 9-11; Deep Aquifer Zone
	Entire Model Domain	5.00E-07	1.00E-07	0.0001	-	Layer 12
Specific Yield						
	Entire Model Domain	0.06	0.01	0.15	-	Layers 1-12
Other Parameters						
Recharge (multiplier)						
	Entire Model Domain (multiple polygons)	Table 3-2	0.55	1.5		Layer 1
General Head Boundary Conductance per Unit Area (day^{-1})						
	San Francisco Bay	0.095	0.001	0.1		Layer 1

The areas are illustrated in Appendix B

Appendix B.

Maps of Percent Coarse Material and Estimated Harmonic Means of Vertical Hydraulic Conductivity Based on Boring Log Data



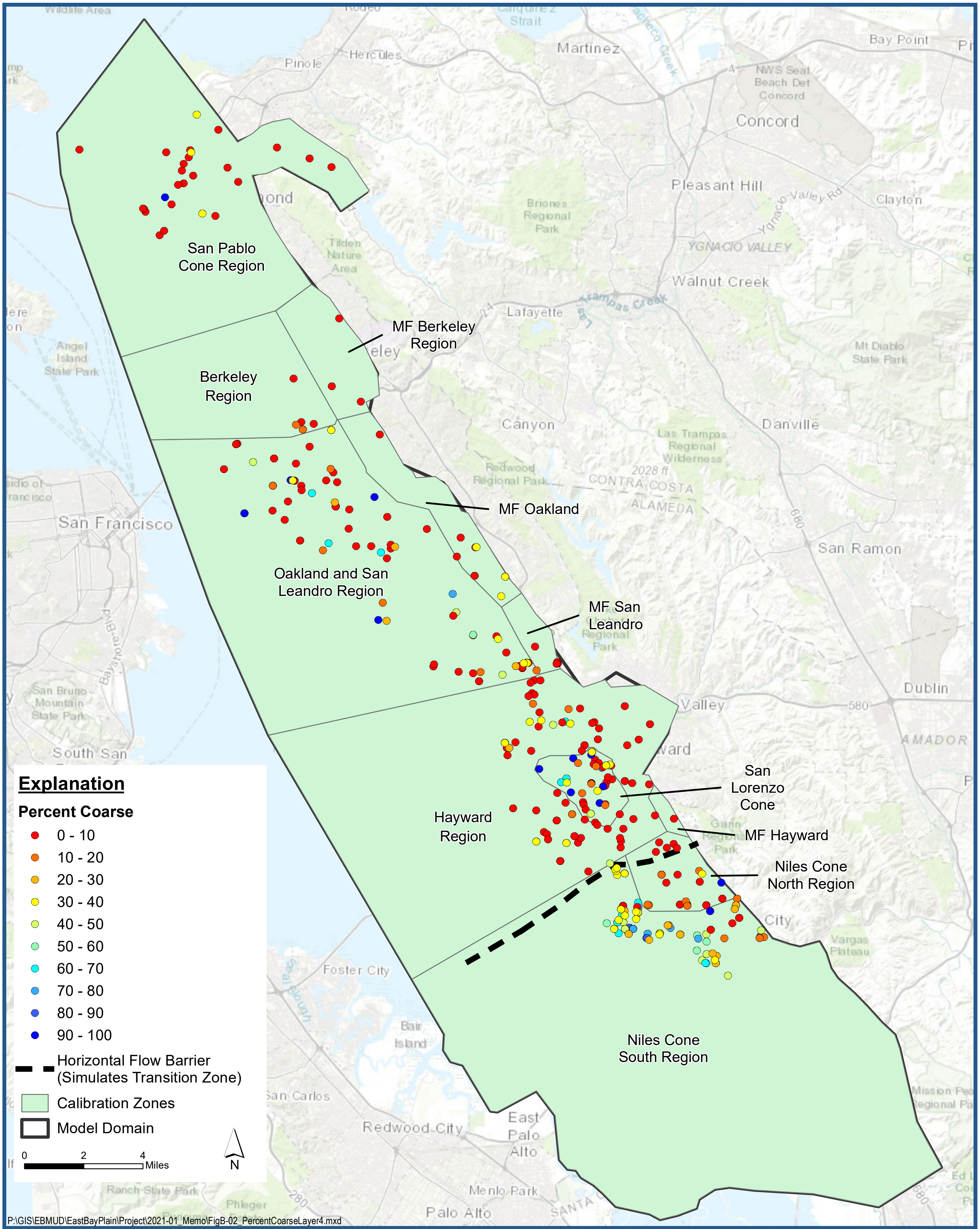
P:\GIS\EBMUD\EastBayPlain\Project\2021-01_Memo\FigB-01_PercentCoarseLayers1-3.mxd

LSCE TEAM

Percent Coarse
Inferred from Boring Logs, Model Layers 1-3

East Bay Plain Subbasin
Groundwater Sustainability Plan

Figure B-1



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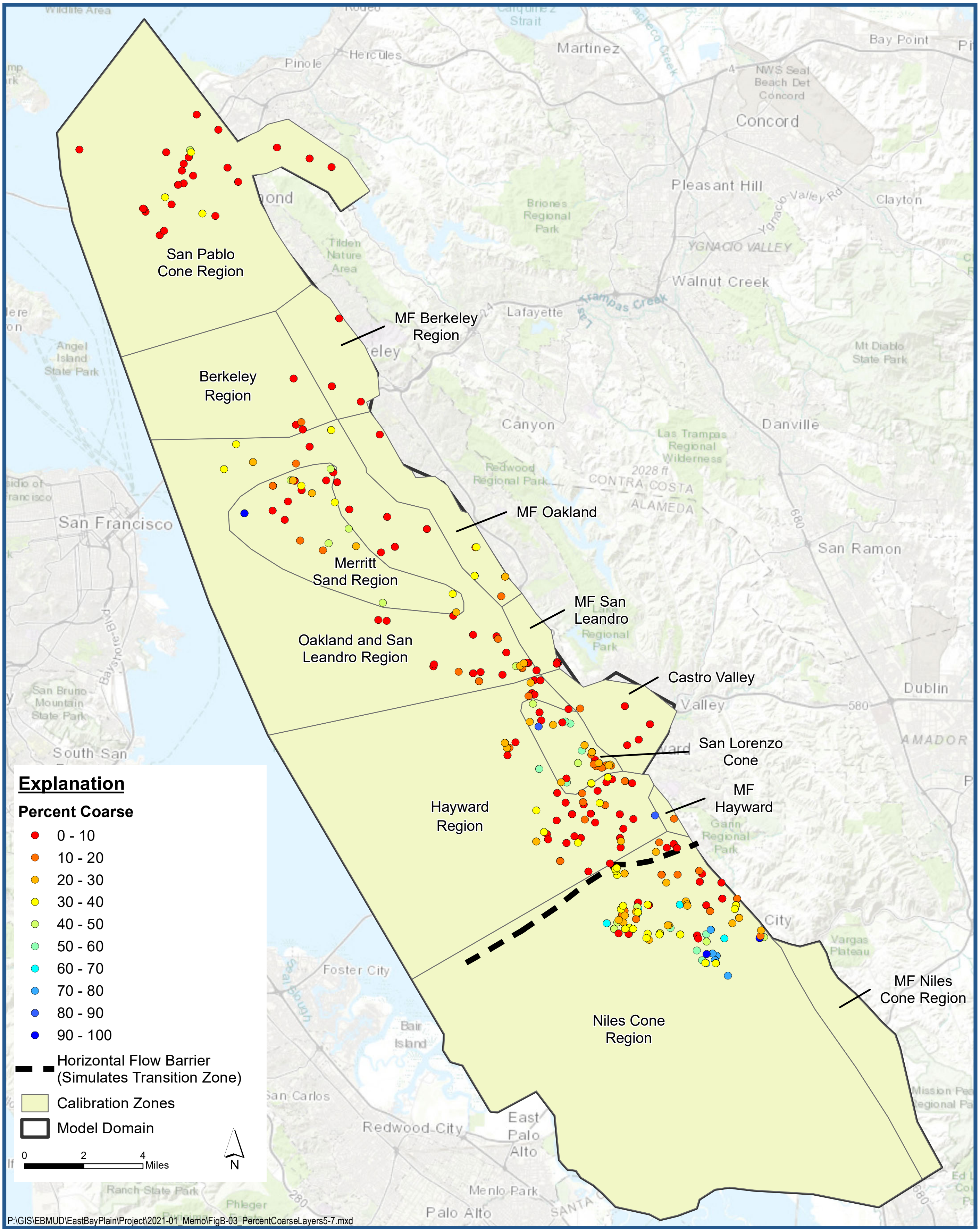
LSCE TEAM

Percent Coarse
Inferred from Boring Logs, Model Layer 4

East Bay Plain Subbasin
Groundwater Sustainability Plan

Figure B-2

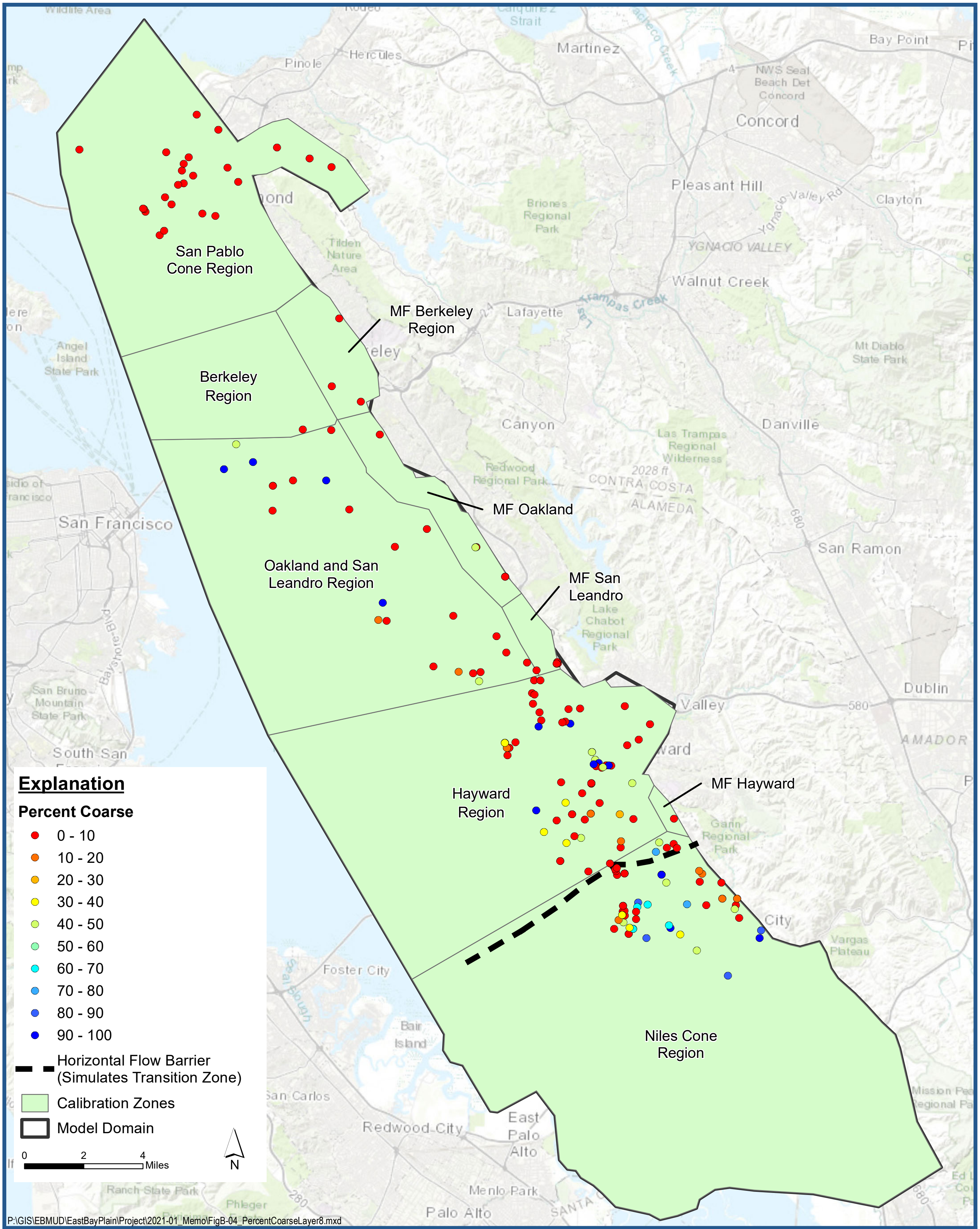


LSCE TEAM

Percent Coarse
Inferred from Boring Logs, Model Layers 5-7

East Bay Plain Subbasin
Groundwater Sustainability Plan

Figure B-3



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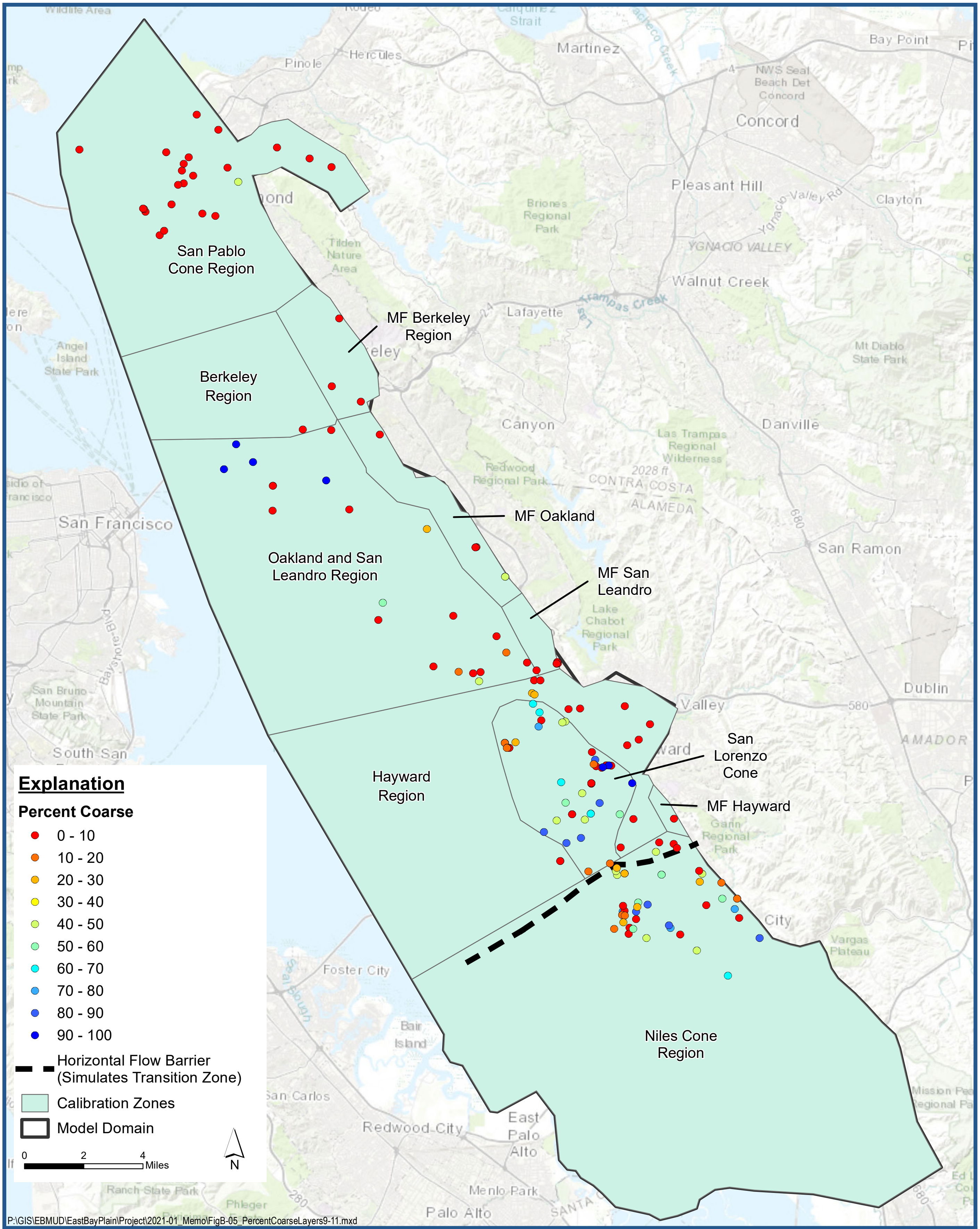
LSCE TEAM

Percent Coarse
Inferred from Boring Logs, Model Layer 8

East Bay Plain Subbasin
Groundwater Sustainability Plan

Figure B-4



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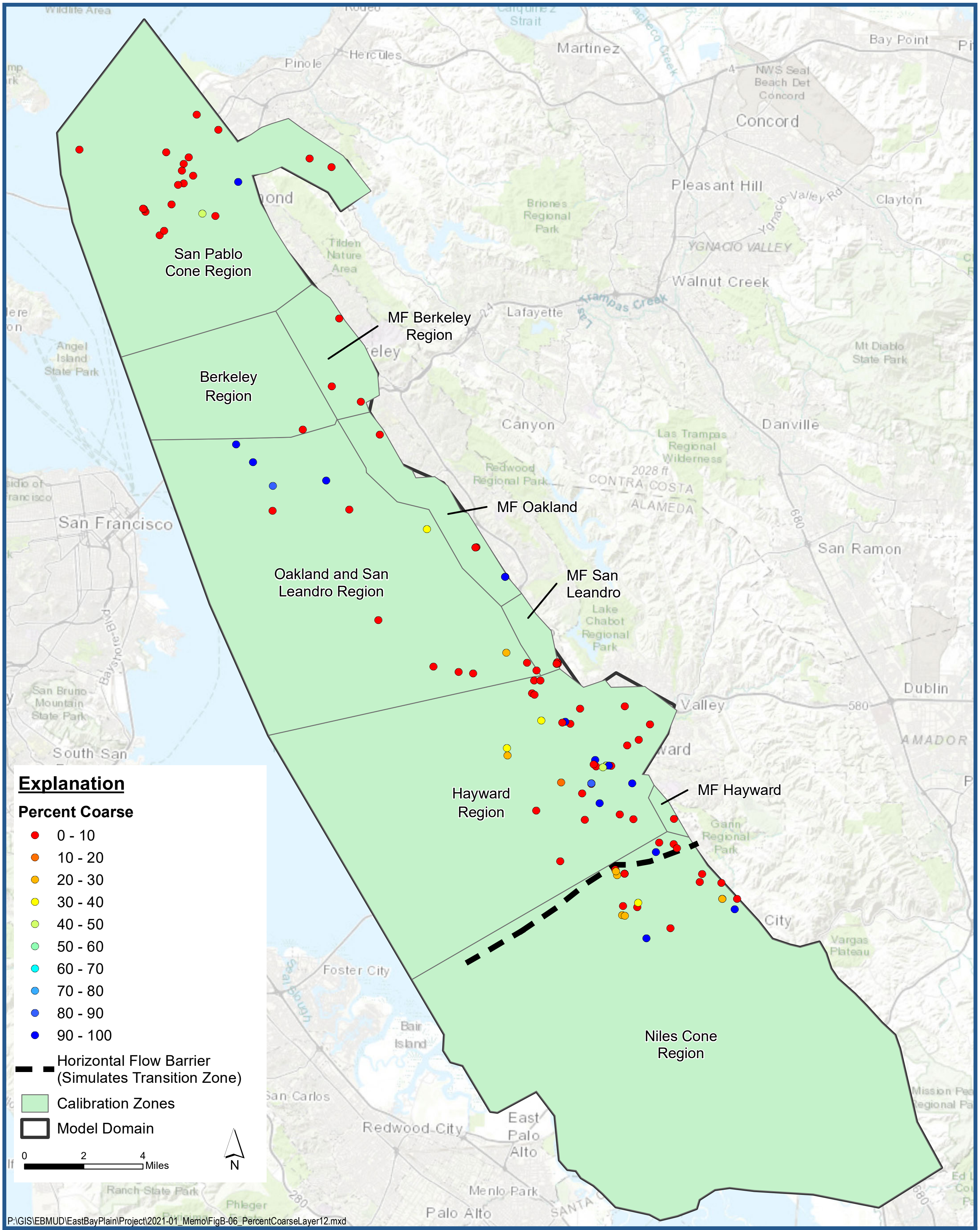
LSCE TEAM

Percent Coarse
Inferred from Boring Logs, Model Layers 9-11

East Bay Plain Subbasin
Groundwater Sustainability Plan

Figure B-5



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Percent Coarse
Inferred from Boring Logs, Model Layer 12

East Bay Plain Subbasin
Groundwater Sustainability Plan

Figure B-6

Maps with Harmonic Means of Estimated Vertical Hydraulic Conductivities Based on Evaluation of Boring Logs

The harmonic mean of a set of individual vertical hydraulic conductivity (Kv) values that span a layered stratigraphic sequence can provide an appropriate value for the overall average vertical Kv of the layered sequence (e.g. Freeze and Cherry, 1979), and is calculated as follows:

$$K_V = \frac{d}{\sum_{i=1}^{n} d_i / K_i}$$

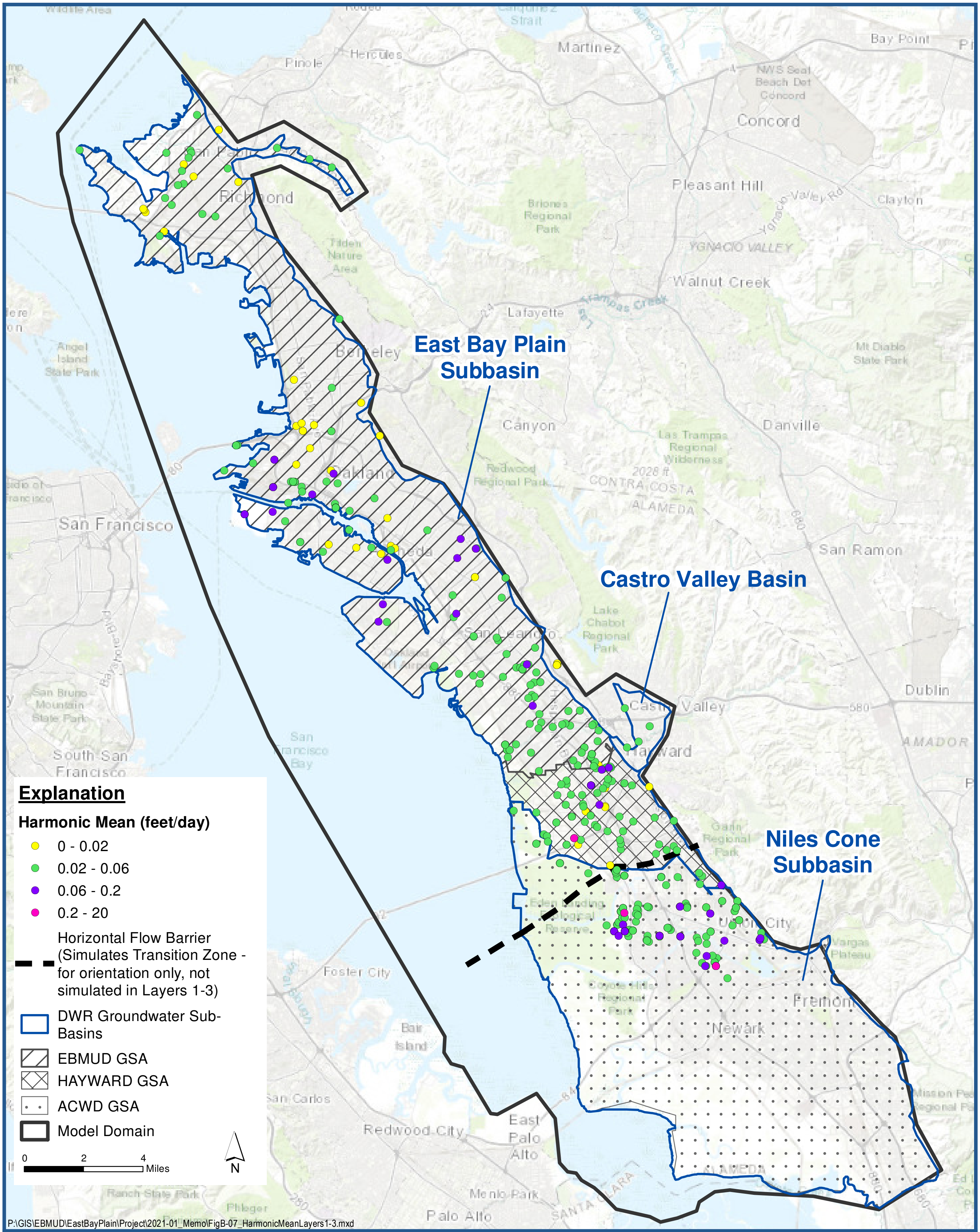
where,

Kv is the overall average vertical hydraulic conductivity or the sequence,

d is total thickness of the layered sequence,

di is thickness of each interval (generally 5 ft for each boring log in this case), and

Ki is the calculated **Kv** for each of the locations with data within the sequence (generally 5 ft intervals of boring logs in this case).



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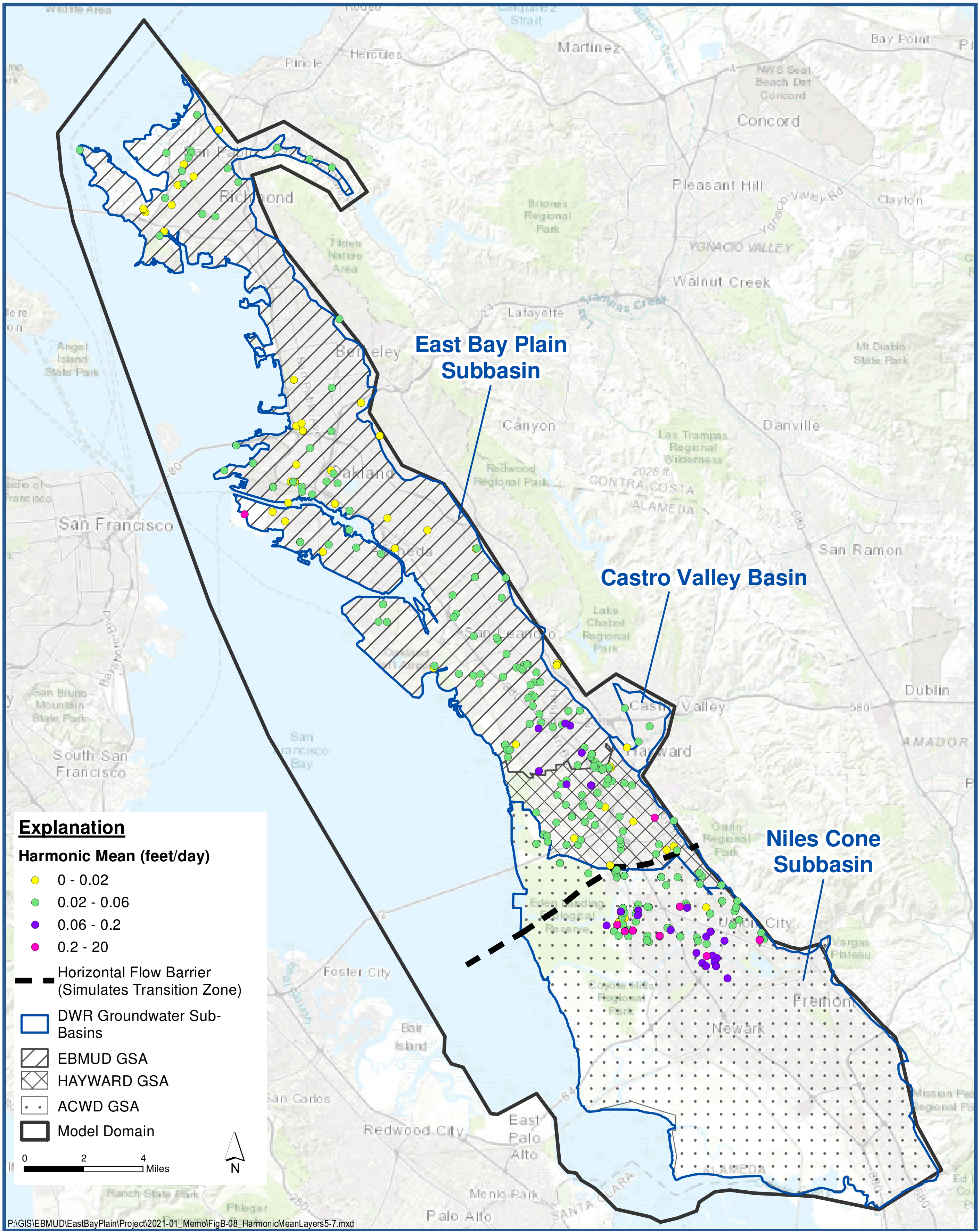
LSCE TEAM

Harmonic Mean of Vertical Hydraulic Conductivity Inferred from Boring Logs, Model Layers 1-3

East Bay Plain Subbasin
Groundwater Sustainability Plan

Figure B-7



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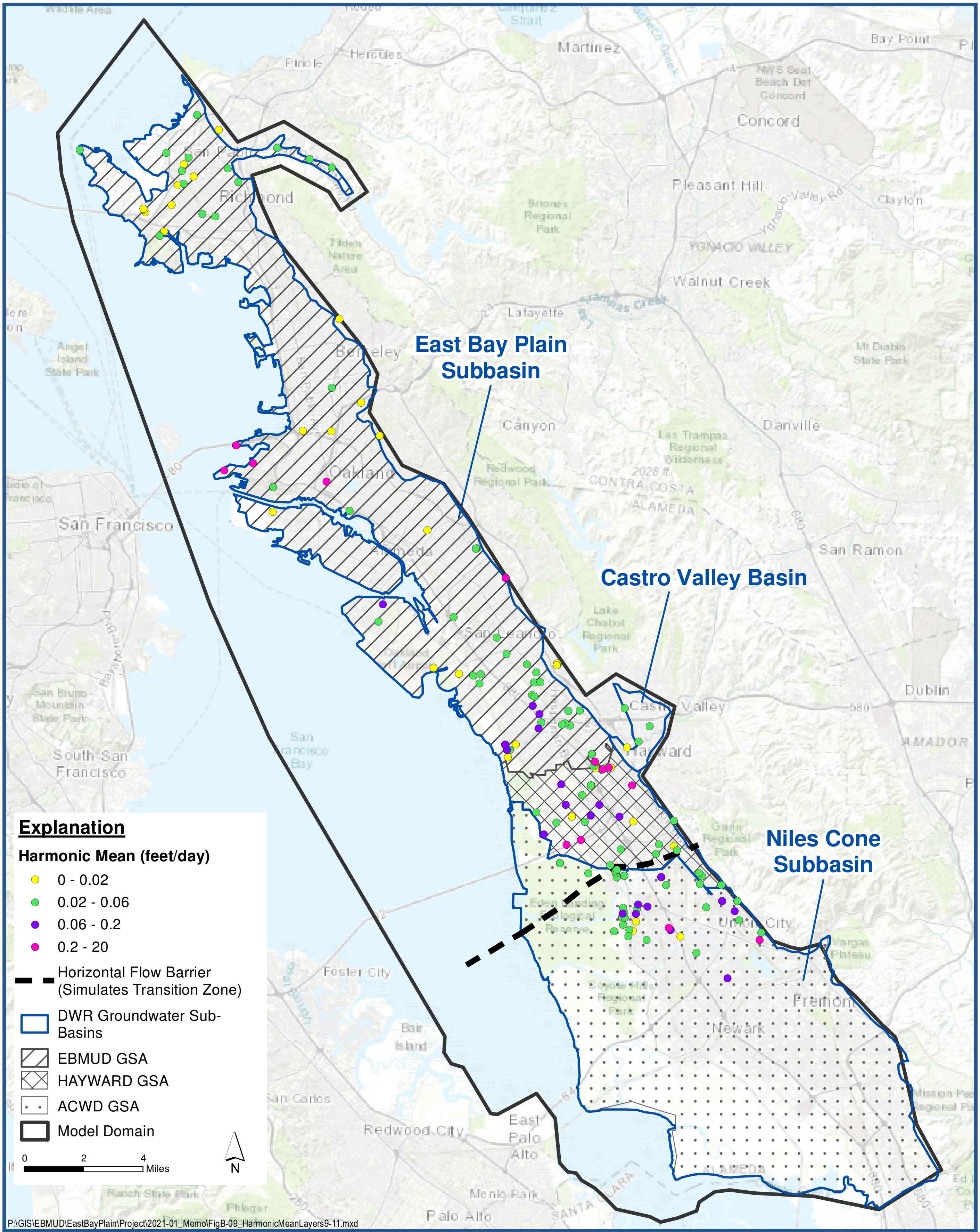
LSCE TEAM

Harmonic Mean of Vertical Hydraulic Conductivity Inferred from Boring Logs, Model Layers 5-7

East Bay Plain Subbasin
Groundwater Sustainability Plan

Figure B-8

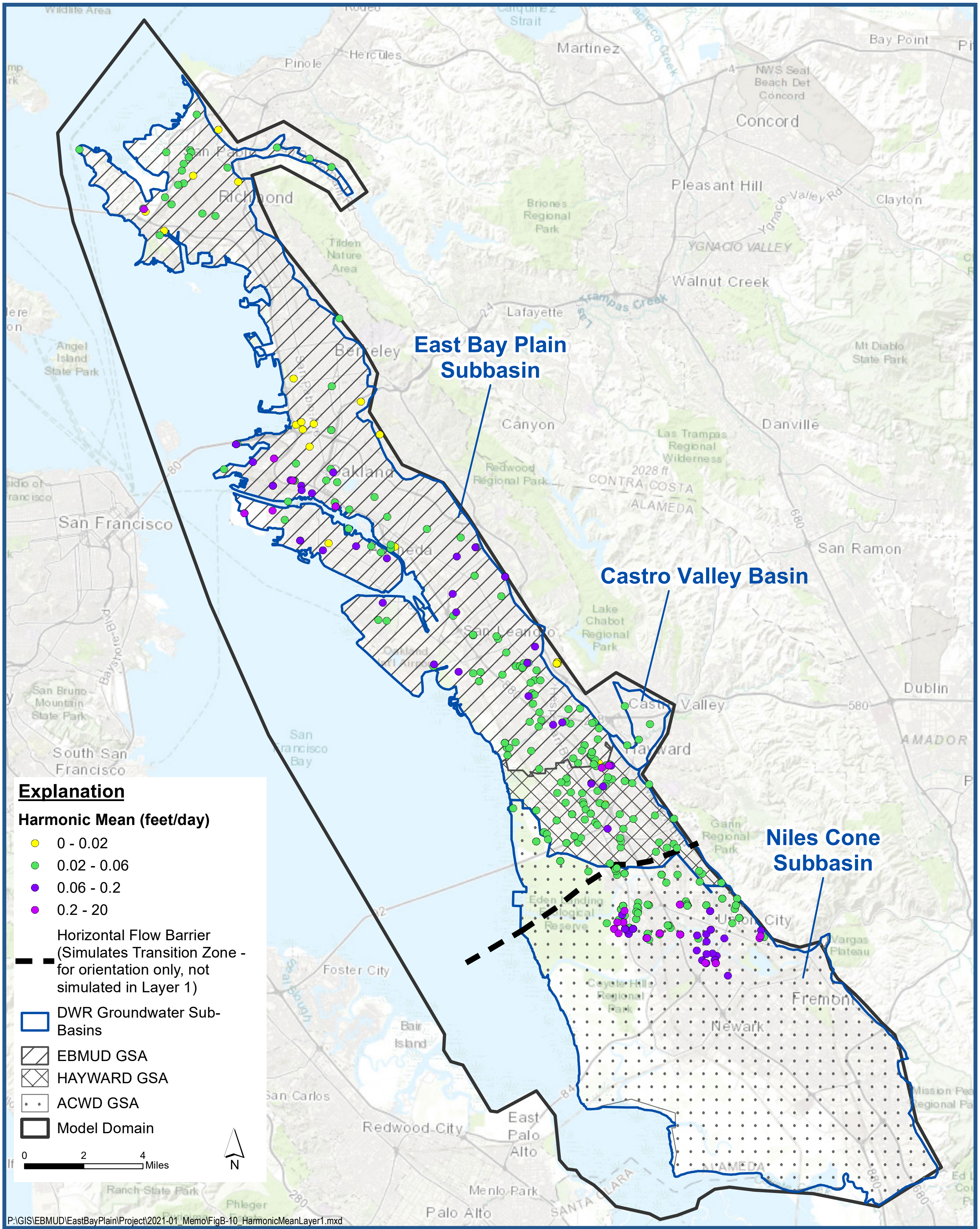


LSCE TEAM

Harmonic Mean of Vertical Hydraulic Conductivity Inferred from Boring Logs, Model Layers 9-11

East Bay Plain Subbasin
Groundwater Sustainability Plan

Figure B-9

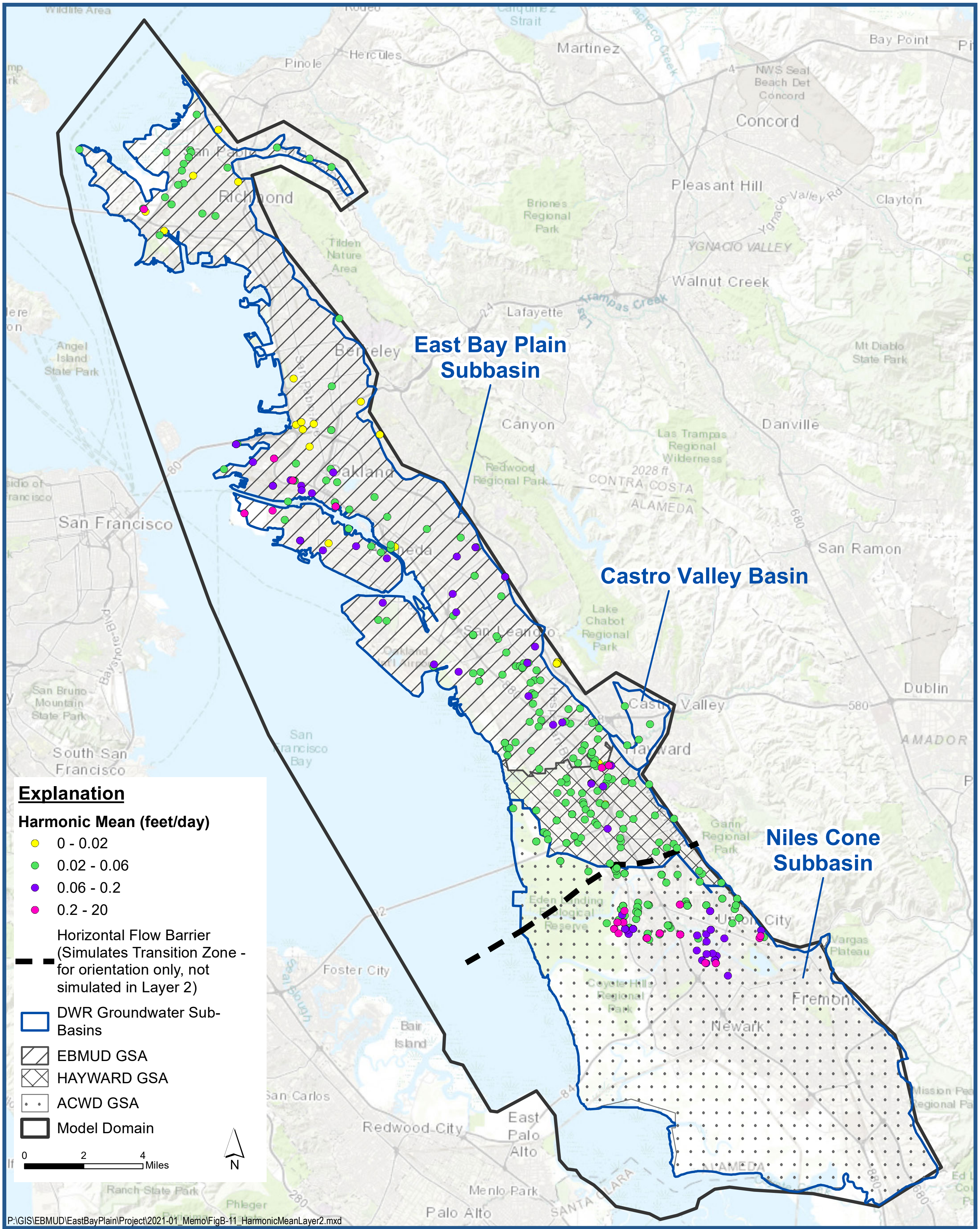


LSCE TEAM

Harmonic Mean of Vertical Hydraulic Conductivity Inferred from Boring Logs, Model Layer 1

East Bay Plain Subbasin
Groundwater Sustainability Plan

Figure B-10

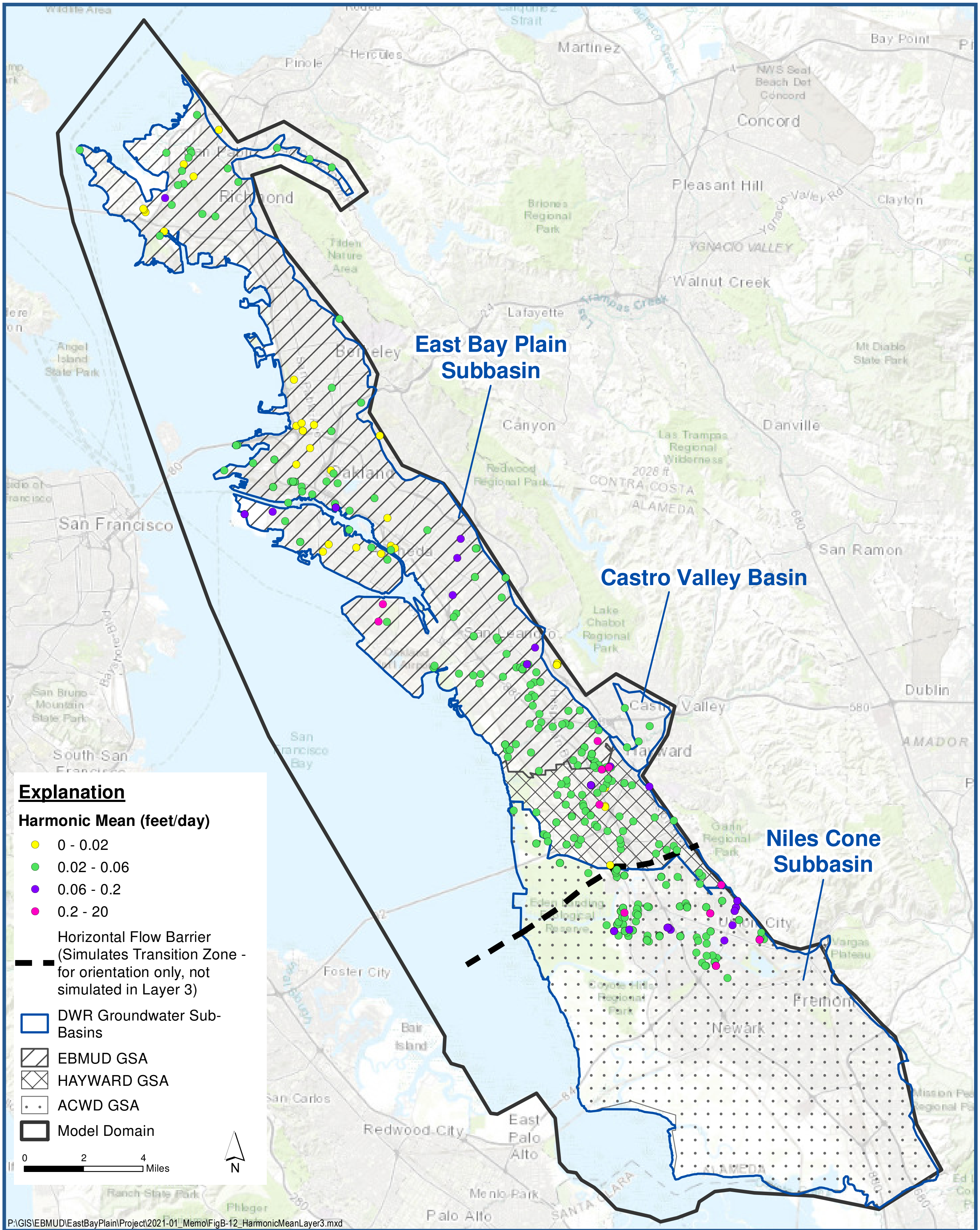


LSCE TEAM

Harmonic Mean of Vertical Hydraulic Conductivity Inferred from Boring Logs, Model Layer 2

East Bay Plain Subbasin
Groundwater Sustainability Plan

Figure B-11

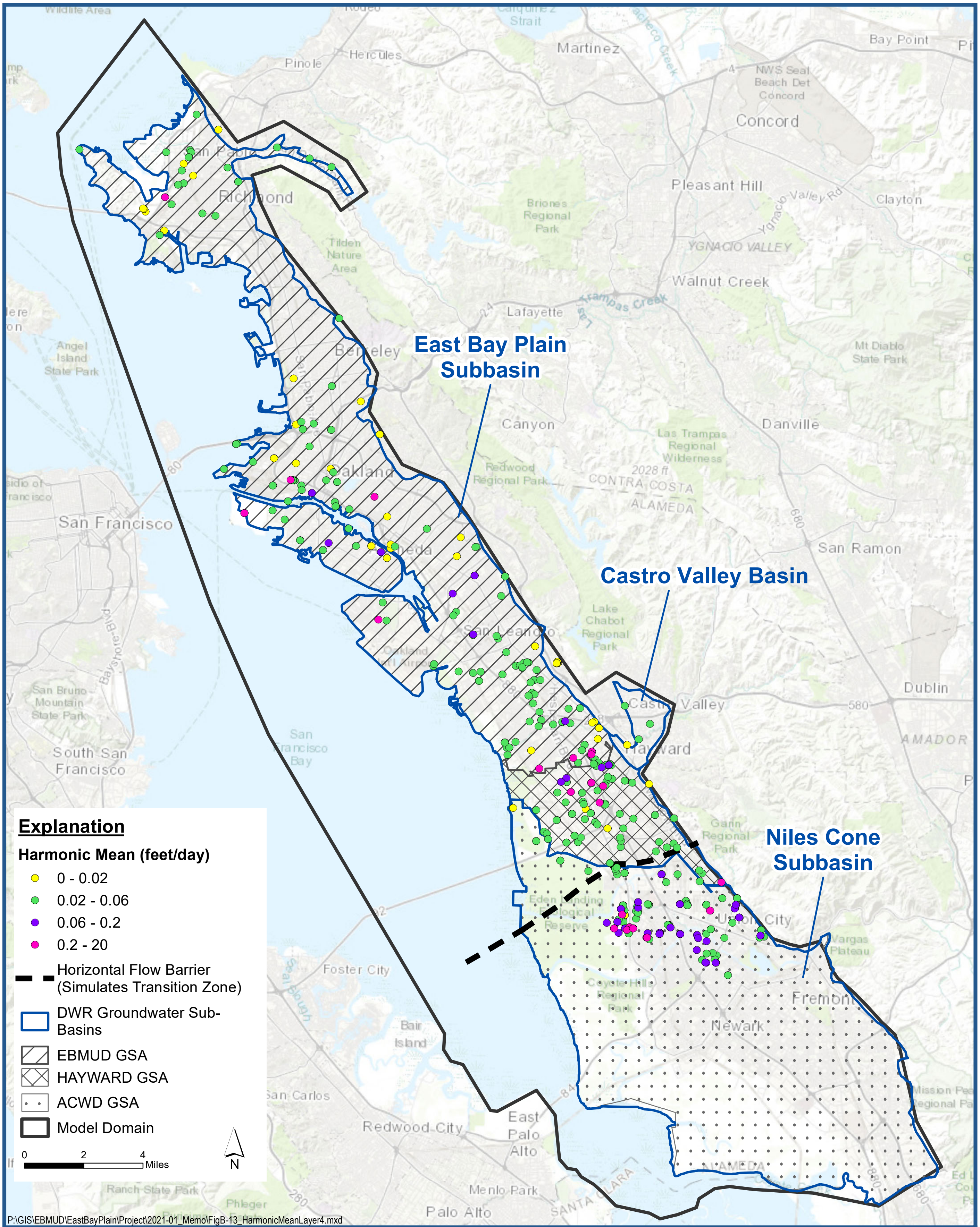


LSCE TEAM

Harmonic Mean of Vertical Hydraulic Conductivity Inferred from Boring Logs, Model Layer 3

Figure B-12

East Bay Plain Subbasin
Groundwater Sustainability Plan



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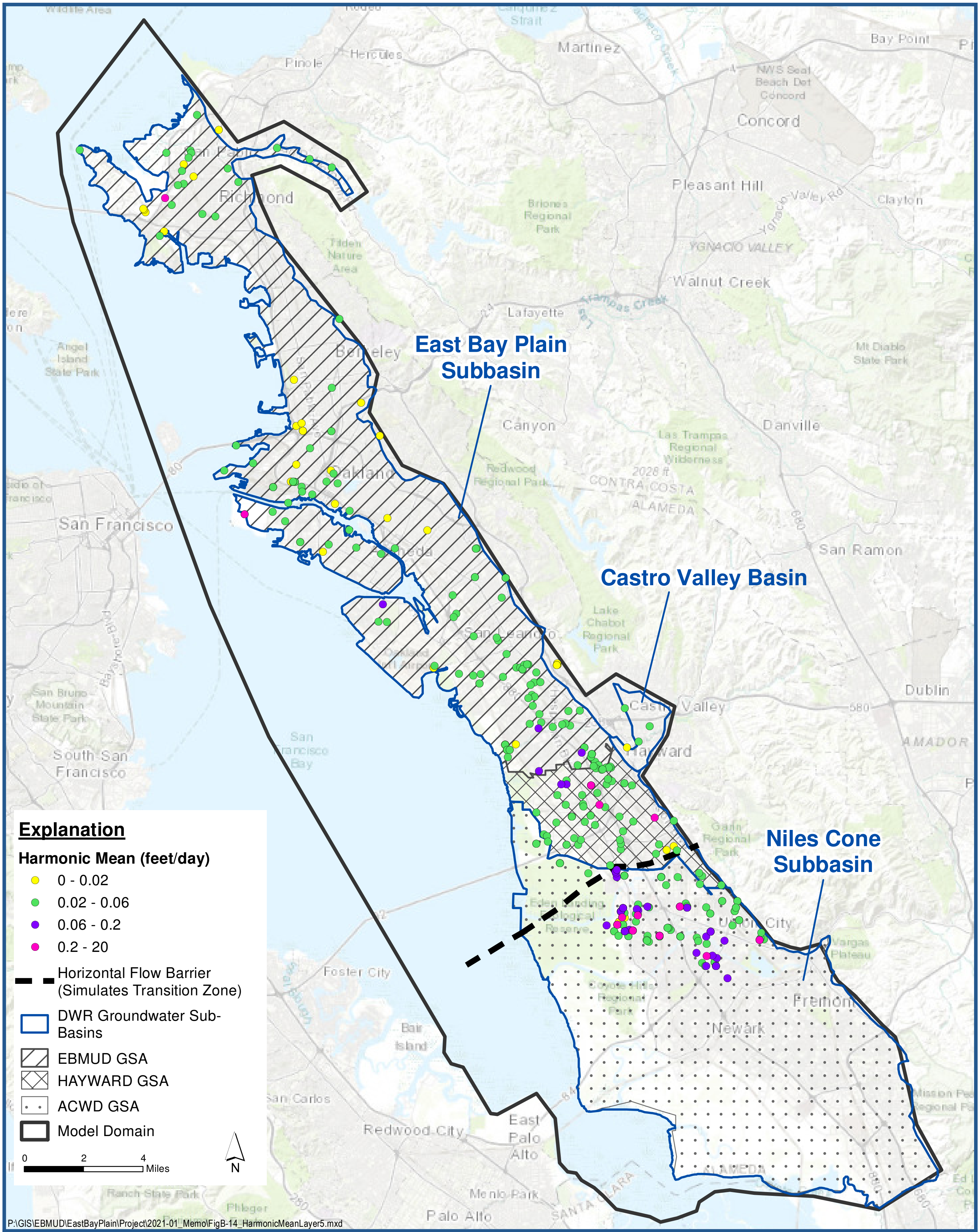
LSCE TEAM

Harmonic Mean of Vertical Hydraulic Conductivity Inferred from Boring Logs, Model Layer 4

East Bay Plain Subbasin
Groundwater Sustainability Plan

Figure B-13

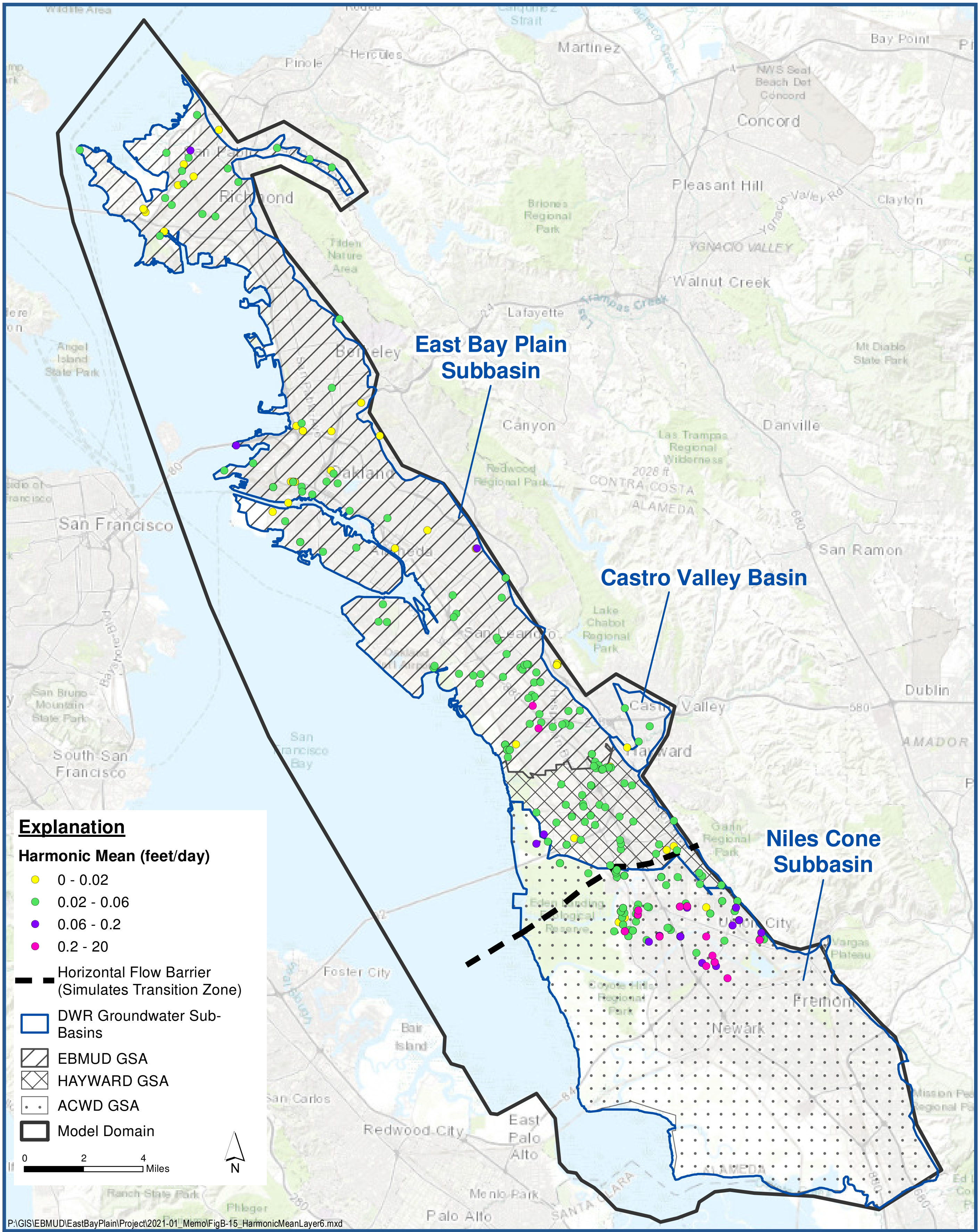


LSCE TEAM

Harmonic Mean of Vertical Hydraulic Conductivity Inferred from Boring Logs, Model Layer 5

East Bay Plain Subbasin
Groundwater Sustainability Plan

Figure B-14

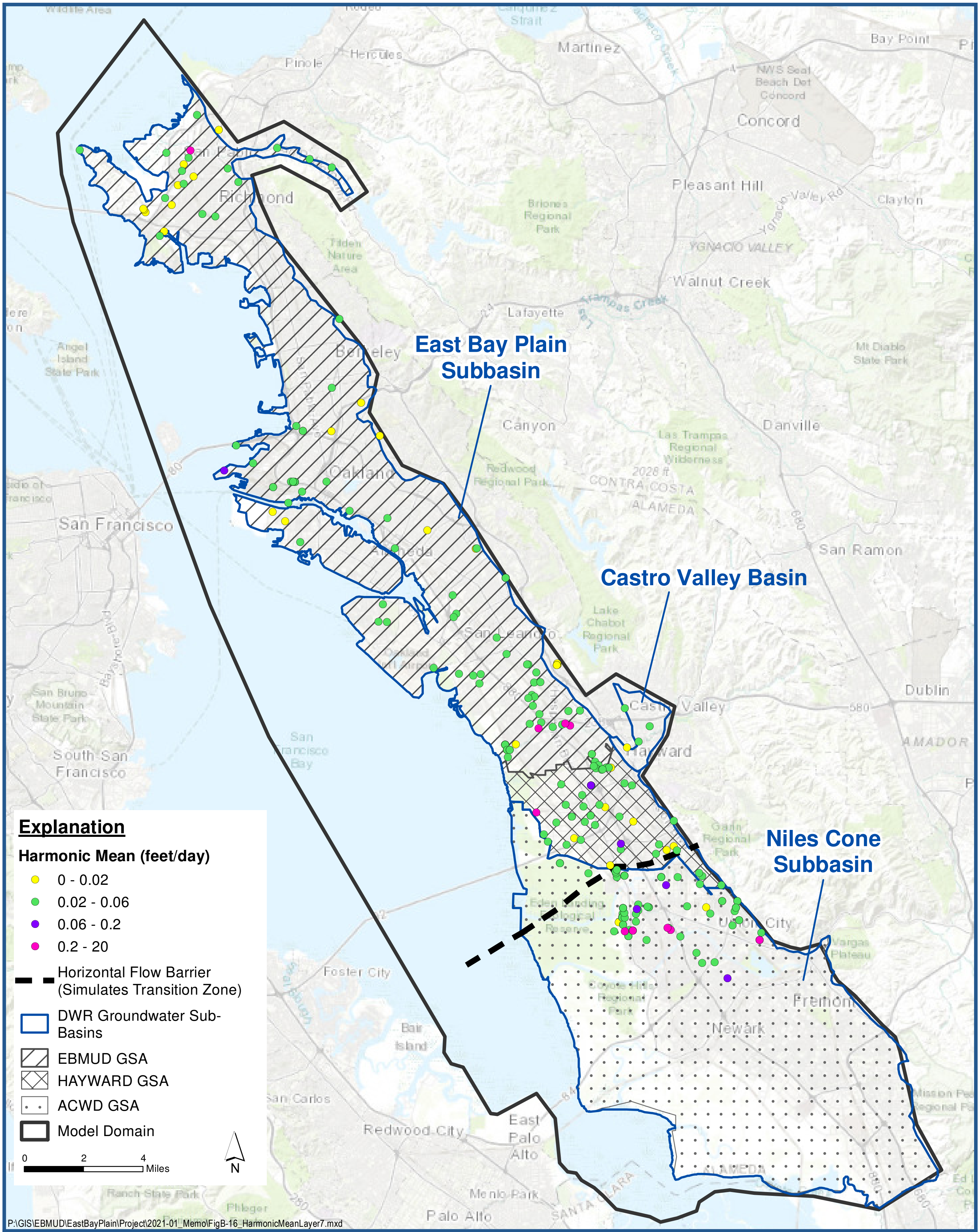


LSCE TEAM

Harmonic Mean of Vertical Hydraulic Conductivity Inferred from Boring Logs, Model Layer 6

Figure B-15

East Bay Plain Subbasin
Groundwater Sustainability Plan

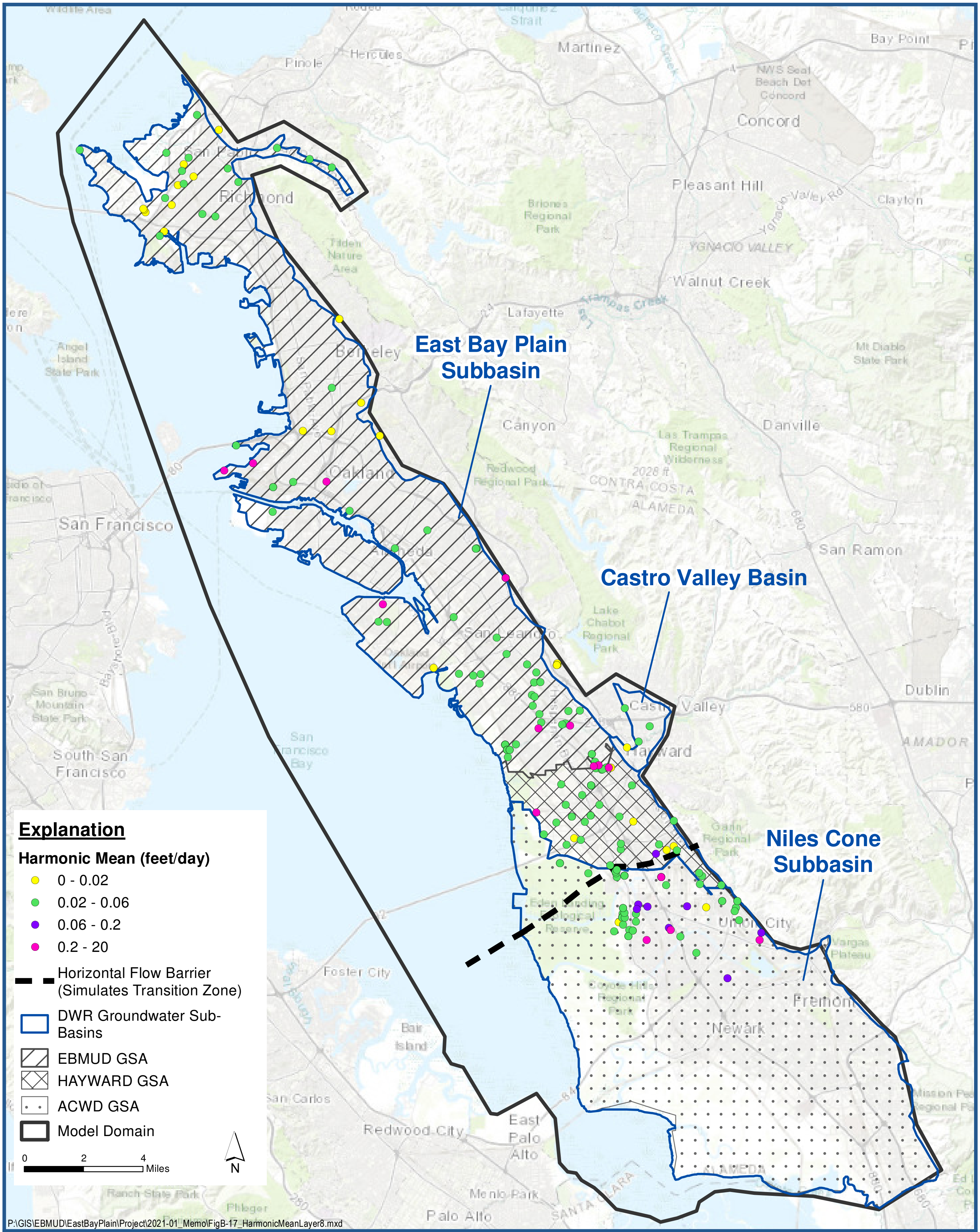


LSCE TEAM

Harmonic Mean of Vertical Hydraulic Conductivity Inferred from Boring Logs, Model Layer 7

East Bay Plain Subbasin
Groundwater Sustainability Plan

Figure B-16

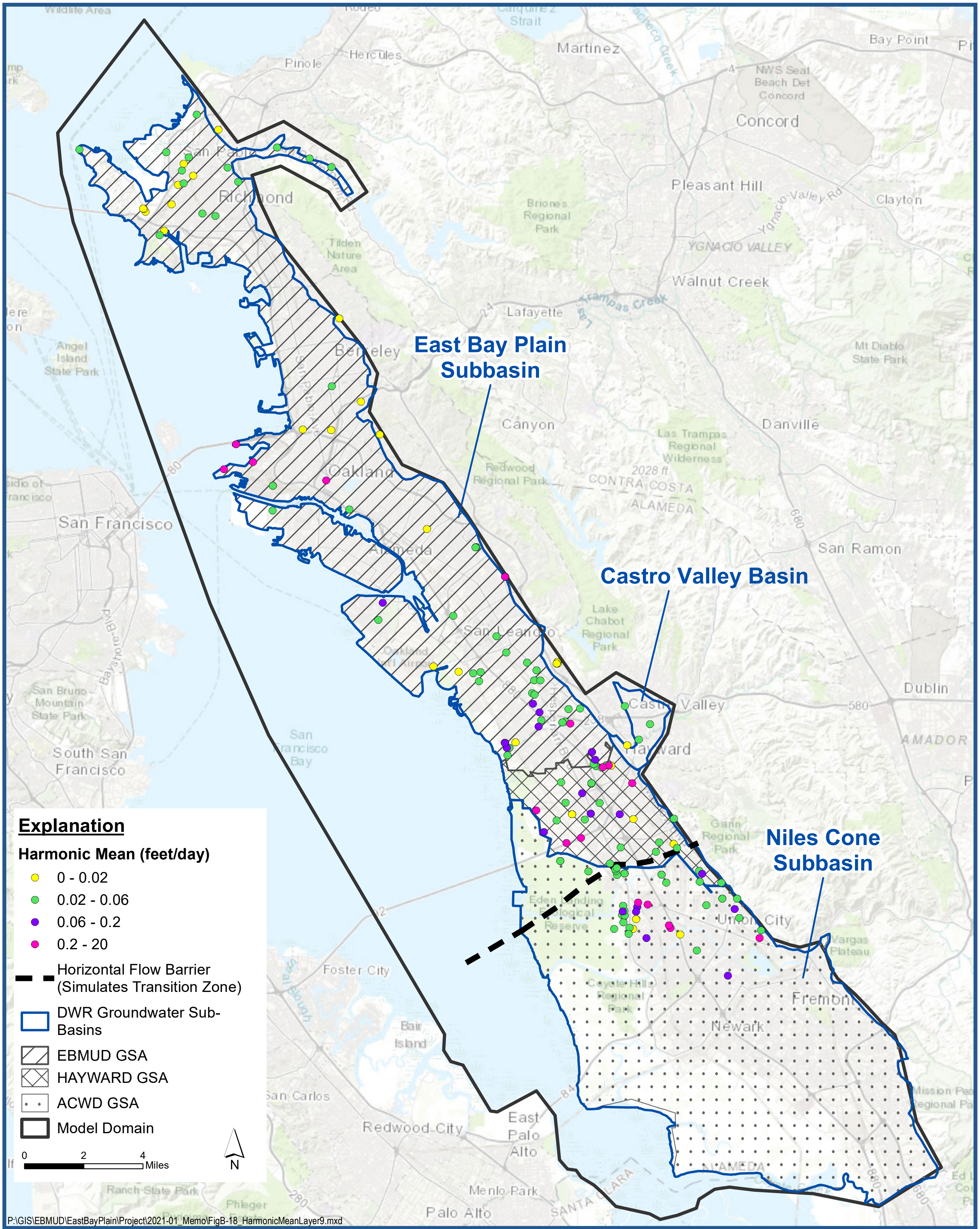


LSCE TEAM

Harmonic Mean of Vertical Hydraulic Conductivity Inferred from Boring Logs, Model Layer 8

East Bay Plain Subbasin
Groundwater Sustainability Plan

Figure B-17

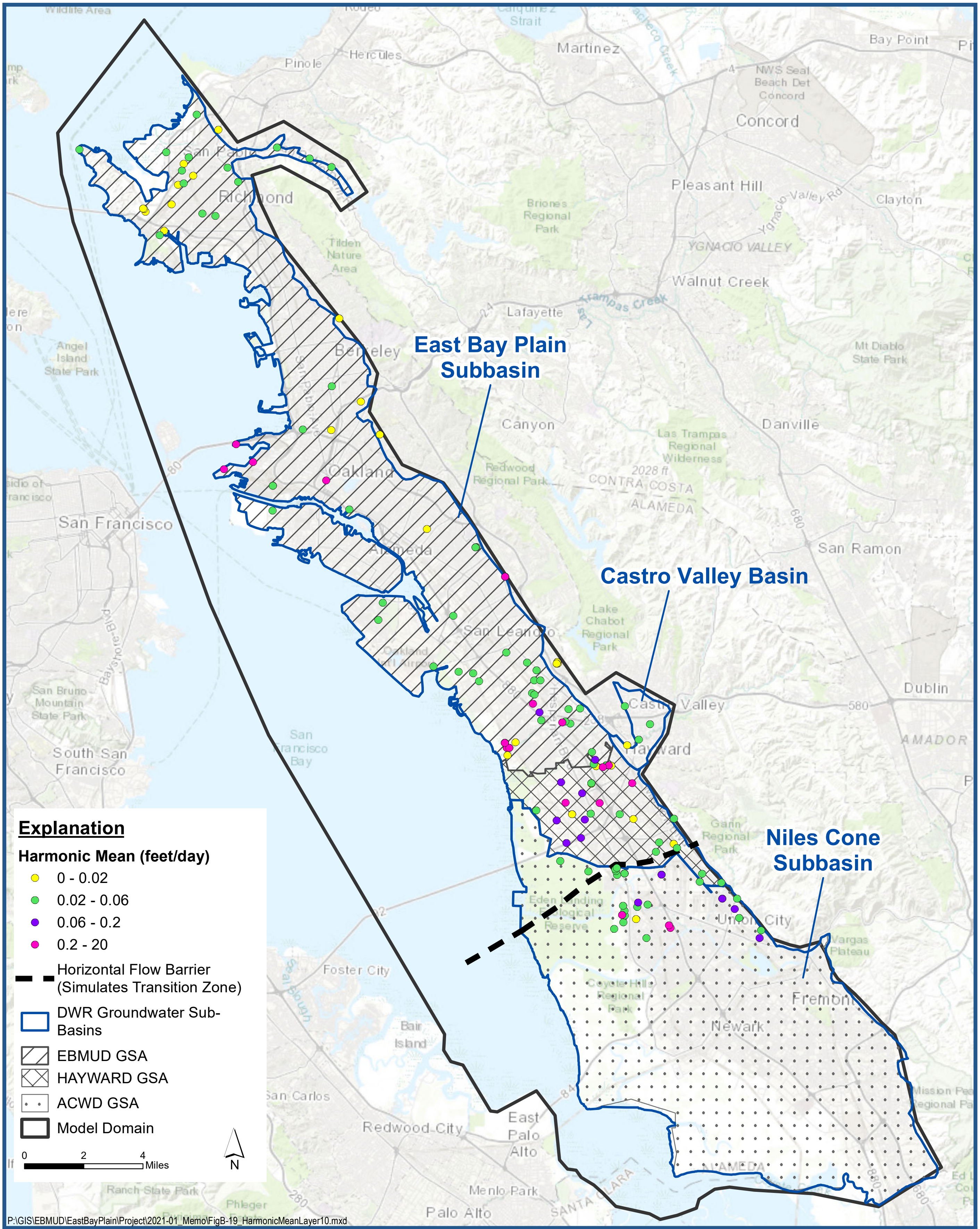


LSCE TEAM

Harmonic Mean of Vertical Hydraulic Conductivity Inferred from Boring Logs, Model Layer 9

East Bay Plain Subbasin
Groundwater Sustainability Plan

Figure B-18



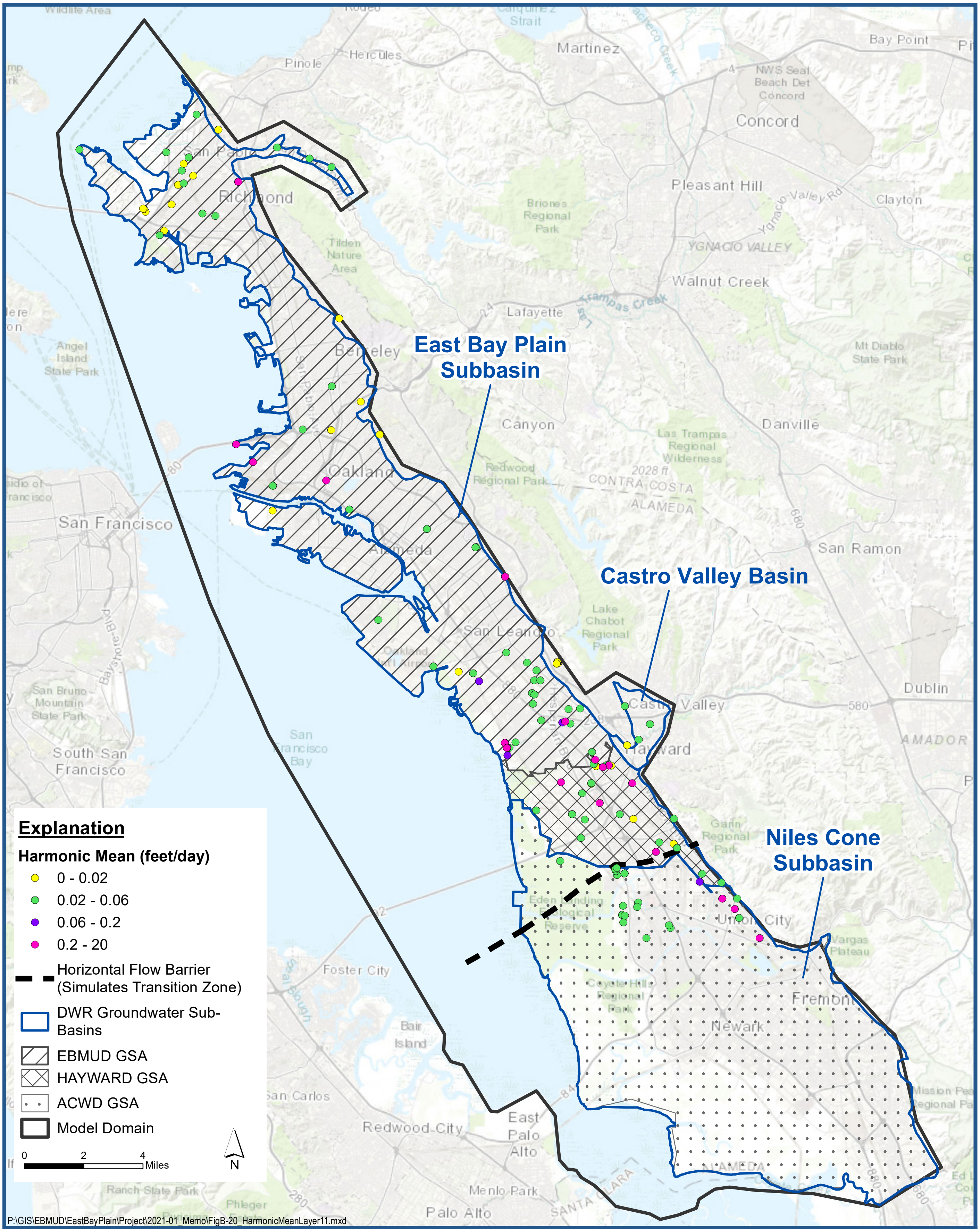
P:\GIS\EBMUD\EastBayPlain\Project\2021-01_Memo\FigB-19_HarmonicMeanLayer10.mxd

LSCE TEAM

Harmonic Mean of Vertical Hydraulic Conductivity Inferred from Boring Logs, Model Layer 10

East Bay Plain Subbasin
Groundwater Sustainability Plan

Figure B-19

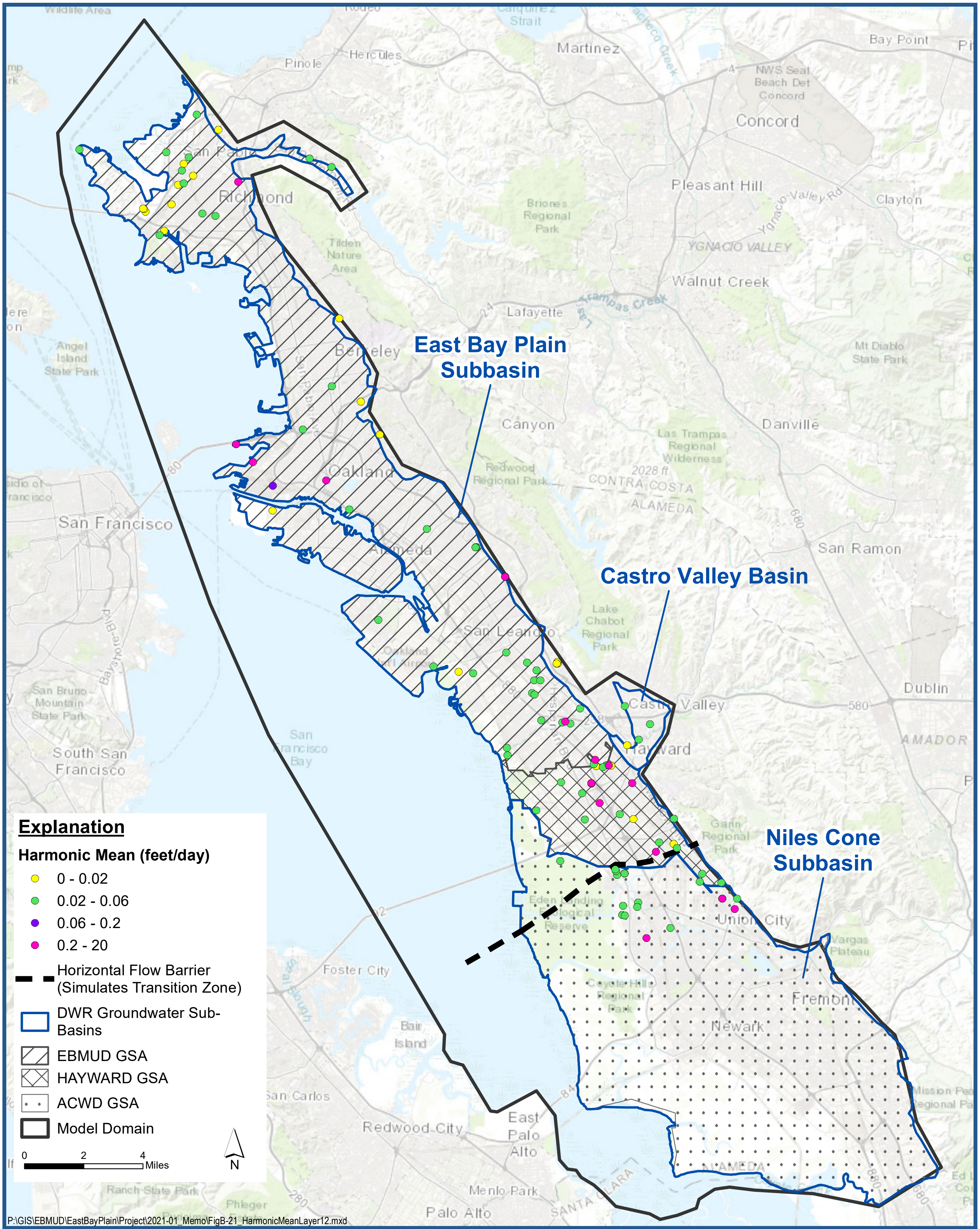


LSCE TEAM

Harmonic Mean of Vertical Hydraulic Conductivity Inferred from Boring Logs, Model Layer 11

East Bay Plain Subbasin
Groundwater Sustainability Plan

Figure 2-11



LSCE TEAM

Harmonic Mean of Vertical Hydraulic Conductivity Inferred from Boring Logs, Model Layer 12

East Bay Plain Subbasin
Groundwater Sustainability Plan

Figure B-21

APPENDIX 6. REFERENCES AND TECHNICAL STUDIES

6.F. Comments and Responses (Reg. Section 354.10)

Appendix 6.F Comments and Responses

Section	Table / Figure	Page #	Entity	Comment	Recommendation	Response
2.2.1		2-23	**ACWD**	a) The Draft GSP has modified the delineation of the Transition Zone between the East Bay Plain and the Niles Cone as originally delineated by Luhdorff & Scalmanini Consulting Engineers (LSCE) in 2003 which is now referred to as a Horizontal Flow Barrier (HFB) used in the groundwater model (2021 EBPGWM) supporting the Draft GSP. In regard to the HFB, the Draft GSP states "the western extent is uncertain; however, it is consistent with a concealed bedrock fault delineated by DWR (1967) parallel to the transition zone and extending into San Francisco Bay. In addition, the extent of the HFB was refined based on model calibration, and the final extent used in the 2021 EBPGWM provided the best overall calibration of simulations to the long-term aquifer pumping tests conducted at the City of Hayward Wells C and E (LSCE, 2003), and the EBMUD Bayside Well (Fugro, 2010)" (Section 3.3.1.5, page 14, of the Groundwater Model Documentation in Appendix 6). While such a fault could have hydrogeologic implications for the Santa Clara Basin, multiple factors suggest that further investigation of its presence is warranted. For example, this fault is unlikely in the broader structural geologic context. It is oriented approximately northeast-southwest, perpendicular all major faults in the region, and at odds with the orientation of the dominant structural forces since the Oligocene. Also, more recent reports do not appear to corroborate the existence of this fault. For instance, regional seismic refraction surveys by the USGS have shown that the substantial vertical offset interpreted from DWR's gravity survey is not present (Hazelwood, 1976). Later USGS aeromagnetic surveys also did not identify any comparable fault (Brabb and Hanna, 1981), while a USGS comprehensive review of the region's buried faults suggested that "…any continued dependence on the Department of Water Resources maps or their derivatives is now without foundation" including those of DWR, 1967 (Wentworth et al., 2010). ACWD has successfully implemented the transition zone in the NEBIM and modeled flows between the basins using the transition zone concept described by LSCE (2003) (and used the LSCE and Fugro 2010 pump test data). The NEBIM has been reasonably calibrated to the long-term trends in groundwater levels and short-term drawdowns experienced with the aquifer tests.		A few points of clarification may be helpful: 1) the term Horizontal Flow Barrier (HFB) is not equivalent to transition zone, rather the HFB is a MODFLOW package used to represent the impedance to groundwater flow that occurs within the transition zone; 2) the nature of the transition zone (e.g., the occurrence of a degree of impedance, its width, its geologic and hydraulic characteristics) are not dependent on the presence of the concealed fault - the GSP text just notes the coincidental occurrence of the DWR concealed fault through the transition zone and its alignment with the zone where impedance to groundwater flow occurs. The evidence to support the GSP characterization of the transition zone and impedance to groundwater flow includes the geologic (depositional environments, stratigraphy), hydraulic (long-term aquifer testing), and geochemical (isotope) studies described in detail in Appendix 2.A.b of the GSP (which are all independent lines of evidence that do not require presence of the DWR concealed fault). However, it should be noted that some further context is needed with regard to references cited in the comment. For example, the full quote from Wentworth et al. (2010) is, "Any continued dependence on the Department of Water Resources maps or their derivatives is now without foundation. Here, we focus on what we can say about the Silver Creek Fault using modern data and techniques." This report is not particularly relevant to EBP Subbasin, because it focused on a fault in a study area south of Coyote Hills in the Santa Clara Subbasin. Based on discussions and information presented during Interbasin Working Group meetings and ACWD's Updated Alternative GSP, the East Bay Plain (EBP) GSAs understand that the NEBIM does not include any impedance through the transition zone. Our interpretation is that this lack of impedance in the NEBIM appears to result in less successful calibration of NEBIM long-term aquifer test observation well data for pumping durations of two to eight weeks (especially relative to maximum drawdown simulation, which is most important from an impacts perspective); this has important implications to simulation of future projects. However, the EBP GSAs look forward to working closely with ACWD to further characterize the transition zone for the benefit of both the EBPGWM and the NEBIM.
2.2.1		2-23	**ACWD**	b) In addition, the Draft GSP states "a regional aquifer test is planned to further investigate the hydraulic connection between East Bay Plain and Niles Cone Subbasins in 2021. The results from this test will be incorporated in future GSP modeling efforts and refinement of the GSP. Analyses and application of these aquifer test data in groundwater modeling		EBMUD and Hayward appreciate the support from ACWD on the future aquifer pumping test proposed to further investigate the interconnection between the East Bay Plain and Niles Cone Subbasins. The EBP Subbasin GSAs look forward to the continued Interbasin Working Group coordination meetings with ACWD and the productive and collaborative discussions between the agencies.

Section	Table / Figure	Page #	Entity	Comment	Recommendation	Response
				will be instrumental in evaluating the degree of hydraulic connection between two Subbasins" (Section 7.2.3, page 104, of the Hydrogeologic Conceptual Model). ACWD appreciates and supports the future aquifer pump tests proposed in the Draft GSP and further investigation of the nature of the stratigraphy between the East Bay Plain and the Niles Cone as it may relate to the potential for inter-basin exchanges of groundwater. Additional pump tests and studies will provide more information about the interconnection between the respective Subbasins. In addition, it can identify possible data gaps and improve simulation of inter-basin flow. As in previous pump tests, ACWD looks forward to coordinating on such efforts. Our quarterly adjacent basin coordination meetings have been very informative and productive for our respective agencies and we fully support continuing these meetings in the future. These meetings provide a great venue to discuss respective groundwater basin management and project activities, as well as model specifics which lead to additional coordination and collaboration between our agencies.		
2.2.1		2-23	**ACWD**	c) The Draft GSP discusses the northwest area of the transition zone between the basins (Section 2.2.1.2 of the Draft GSP and ES-1 in the Groundwater Model Documentation in Appendix 6). The existing boundary is consistent with ACWD's pre-existing jurisdiction and legal authority and coincides with the geographic limits of the groundwater management authority long ago established to ACWD as a replenishment agency that was confirmed through DWR's Basin Boundary Modification to correct the graphical representation included in Bulletin 118 (2003). As previously stated, ACWD looks forward to continuing to coordinate with EBMUD and the City on evaluations of the hydraulic connections of the transition zone, including the northwest area.		DWR boundaries can be based on jurisdictional or hydrogeologic characteristics. The pre-2016 basin boundary was much more closely aligned with the hydrogeologic boundary between EBP and Niles Cone Subbasins defined by the transition zone. The 2016 basin boundary change resulted in an appendage of Niles Cone Subbasin occurring north of the transition zone and within the hydrogeologic portion of EBP Subbasin. It is important to note the distinction that the current basin boundary is jurisdictionally based rather than hydrogeologically based (the 2016 basin boundary charge application also noted it was a jurisdictional boundary change).
Section: 3.2-3.5			**ACWD**	The Draft GSP proposes to construct nested wells to monitor water levels near the Niles Cone. ACWD has advocated the more conventional approach of drilling separate single-cased wells since the validity of water level and quality data generated from nested wells may have issues due to artificial leakage between water-bearing zones. This is supported by concerns asserted by the Department of Water Resources (DWR) on page 37 of Bulletin 74- 90. Bulletin 74-90 states that; "A nested monitoring well can be difficult to construct because of multiple casings within the same borehole. Care is required during construction to ensure water-bearing zones for each casing string are hydraulically isolated from one another and the annular seals are effective." As a result, DWR Bulletin 74-90 requires that "casing spacers shall be used within the intervals	Therefore, if the nested wells will penetrate more than one aquifer, the construction of the nested wells should follow the DWR Bulletin 74-90 minimum requirements for sealing off strata and placement of annular seal material.	Comment noted. The EBP GSAs will be using stainless steel centralizers above and below each screen interval for every casing in the borehole and every 80 feet of blank casing, and each aquifer zone will be isolated with bentonite seals in accordance with DWR Bulletin 74-90 Section 9.

Appendix 6.F Comments and Responses

Section	Table / Figure	Page #	Entity	Comment	Recommendation	Response
				to be sealed to separate individual well casing strings from one another in a borehole of a nested monitoring well. The spacers shall be placed at intervals along the casing to ensure a minimum separation of 2 inches between individual casing strings" (page 44 of DWR Bulletin 74-90).		
	Figures: F-25, F-32 Table: C-2		**ACWD**	The Draft GSP has figures showing water quality data in the Niles Cone that do not appear to show actual conditions. For example, Figure F-25 in Appendix F shows "Average" Nitrate conditions for wells deeper than 50 feet but doesn't indicate if those are historical or current averages since enactment of SGMA. Also, Figure F-32 in Appendix F shows wells deeper than 50 feet where Nitrate data was collected after 2015 in the Niles Cone (the purple locations). It appears these results are from the GAMA mapping tool and may be from wells less than 50 feet based on ACWD's initial review. ACWD found that Table C-2 in Appendix C Summary of Groundwater Conditions includes nitrate concentrations for wells in the EBP, but it does not appear to identify the wells located in the Niles Cone used to create the various water quality maps in the Draft GSP.	ACWD requests that the Draft GSP Figures either clarify the time period for the various water quality results as a footnote in the figure or include Niles Cone data in a similar table as C-2 so ACWD can adequately review the information provided.	The data shown on Figure F-25 (and other similar figures) is all available historical data, and not just data since 2015. Figure F-32 is not just data collected after 2015, it is based on all historical data and shows the minimum values at each well (regardless of when that minimum occurred). The groundwater quality data come from all available data sources, not just GAMA (other sources include CASGEM, USGS, ACPWA, ACWD, EBMUD, Hayward, and various other reports). Wells with unknown depths are included in maps showing wells 50 feet and deeper. While it is possible some wells with unknown depths are shallower than 50 feet, the majority are likely deeper than 50 feet. Table C-2 was expanded to include Niles Cone wells shown on the maps in Appendix F, and a Supplement was added to GSP Appendix 2.A.b with the Niles Cone Subbasin groundwater quality data shown in Appendix F figures.
Section: 3.3.1.3		Page: 3-19	**ACWD**	The Draft GSP states: "If GSAs in the EBP Subbasin implement additional projects to increase net extraction, additional evaluation of potential impacts to neighboring subbasins will be conducted at that time." ACWD appreciates that this additional evaluation will be done and looks forward to coordinating with EBMUD and the City of Hayward on any future projects in the southern portion of the EBP. ACWD has plans to model the projects presented in the Draft GSP in the near future and looks forward to discussing ACWD's modeling results once complete during the quarterly coordination meetings.		EBMUD and Hayward look forward to the continued productive discussions and coordination with ACWD, including evaluation of any potential future projects in the East Bay Plain and Niles Cone Subbasins.
			ACWD	ACWD's comments are based on our initial review of the Draft GSP and we will continue to review this extensive document. Once again, ACWD would like to thank you for the opportunity to provide comments on the Draft GSP and we look forward to our agencies' ongoing coordination and cooperation in the quarterly adjacent basin coordination meetings and in our collaborative modeling efforts.		EBMUD and Hayward appreciate ACWD's comments. The EBP GSAs look forward to the continued interbasin coordination meetings with ACWD and discussing any additional questions and comments that ACWD may have on the EBP GSP.
Section: 2.2.2.6, 2.2.2.7	Table: 2-5	Page: 2-37	**CA Dept Fish & Wildlife**	GSPs must consider the interests of all beneficial uses and users of groundwater, including environmental users of groundwater. (Water Code § 10723.2). GSPs must also identify and consider potential effects on all beneficial uses and users of groundwater. (23 CCR §§ 354.10(a), 354.26(b)(3), 354.28(b)(4), 354.34(b)(2), and 354.34(f)(3)). The Draft GSP does not adequately identify all the environmental users in the Basin, their locations, the groundwater dependent habitat they depend on at certain life stages, and how the Draft GSP will meet their needs. GSPs must consider impacts to GDEs. (Water Code § 10727.4(l); see also 23 CCR § 354.16(g)). The	The Department recommends that clear language be included in the GSP detailing when and how additional GDEs will be identified and mapped. Furthermore, there should be a description of how this information will be used to update the GSP and inform the adaptive management process. The GSA should commit to identifying additional potential GDE units early on in the GSP implementation process. Furthermore, the GSP should commit to allocating monitoring and management resources (e.g., DWR Technical Support Services funding) to priority GDEs and interconnected	It should be noted that the GSP has identified GDEs and surface water depletion as having significant data gaps. Ongoing groundwater and GDE monitoring are planned to improve characterization of stream-aquifer interaction and potential GDEs, which will be necessary to assess effects of groundwater and surface water changes on plants and wildlife, as well as develop meaningful objectives. Appendix 2.A.b identifies the iGDE features (indicators of groundwater dependent ecosystems from a statewide database that require validation with local information) that need additional evaluation to determine if they should be classified as potential GDEs because, "… imagery and/or

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				Department is uncertain whether the Draft GSP accurately identifies all GDEs in the Basin or considers all the potential impacts to them due to groundwater pumping. Table 2-5 in the GSP lists Potential Groundwater Dependent Ecosystems and includes habitat classifications based on imagery analysis including Riparian Mixed Shrub/Hardwood, Riparian Mixed Hardwood, and Riparian Oak Woodland. However, the Draft GSP did not provide objectives that would be anticipated to support potential GDEs and does not include any discussion regarding aquatic fish and wildlife species that depend on surface water flow in the GSP area that could be impacted by groundwater pumping. This potentially includes critical species such as anadromous salmonids and the California red-legged frog (CRLF). The Draft GSP does not indicate where these species might be found in the basin and how these species could potentially be impacted by groundwater pumping. Future planned biological surveys seem to target plant species. While the GSP acknowledges the need to collect additional data on GDEs and ISWs and mentions some potential GDEs, the Draft GSP does not fully take into account or describe all special status or locally significant fish and wildlife species and habitats that potentially benefit from or are dependent on groundwater within the planning area. The plan does not identify all expected species, habitat, or ecosystem outcomes (both benefits and challenges) associated with each interim milestone or measurable objective being evaluated. GSPs must consider impacts to GDEs. (Water Code § 10727.4(l); see also 23 CCR § 354.16(g)). The Draft GSP does not provide sufficient detail when describing the methods that will be used for future planned studies for GDE identification, classification and mapping or information on the methods that will be used.	surface waters that have high habitat value or vulnerability, species dependency, and/or serve as 'indicator' GDEs or interconnected surface waters. Site selection for additional monitoring should represent the full spectrum of GDEs and interconnected surface waters in the basin. Representative monitoring stations should capture a range of GDE and interconnected surface water characteristics that will inform evaluation of groundwater management impacts over time. These characteristics include but are not limited to: geospatial and temporal habitat coverage; changes in groundwater interconnectivity status; habitat connectivity, heterogeneity, or density; habitat 'health' (e.g., application of biological indices, remote sensing/aerial imagery); and species/vegetation presence (e.g., biological surveys).	hydrologic data were not sufficient to determine if they could be defined as GDEs." (p. 65 of Appendix 2.A.b; Appendix I of Appendix 2.A.b). Fieldwork to facilitate the next step of potential GDE confirmation and evaluation of remaining iGDE features is planned to occur early in the GSP implementation process and additional detail on monitoring steps is included in the revised text for GSP Section 4.1.2.4. Installation of additional monitoring facilities (e.g., shallow monitoring wells, stream gauges) and studies are already incorporated in GSP implementation planning and budgeting to fill data gaps related to surface water depletion and GDEs. Biological surveys are also included in GSP implementation, planning, and budgeting. It is anticipated that a refined and more detailed analysis of surface water – groundwater interaction and GDEs will be provided in the first 5-Year Update Report. As discussed in the draft GSP (Section 4.1.2.1.4), ongoing GDE monitoring and evaluation are part of the implementation plan, consistent with the sustainability goal of the GSP. This further monitoring and evaluation would identify additional potential GDEs and recommend monitoring or site-specific review, as needed. Site selection for monitoring will aim to select representative GDEs from the range of habitats and conditions, in addition to prioritizing GDEs with high ecological value and susceptibility to changing groundwater conditions. Based on further review, available information indicates there are three watersheds in the EBP Subbasin that may support small runs of the federally threatened Central California Coast (CCC) steelhead. These watersheds include San Pablo Creek, Wildcat Creek, and San Leandro Creek. At present, only small, intermittent steelhead runs are found in these systems. Similarly, California red-legged frog has the potential to occur within a portion of the GSP area, although the only California Natural Diversity Database (CNDDB) occurrence record within the GSP area is located along the northeastern edge of the boundary immediately downstream of San Pablo Dam. Appendix 2.A.b, including supplemental text to these comment responses, provides a preliminary review and discussion of special-status species with occurrence records overlapping potential GDEs. The text of this document and special-status species table have been updated to include information relating to steelhead and California red-legged frog. While these species have been identified as possibly occurring within the potential GDEs identified in the GSP, an effect of groundwater depletion on these surface water dependent species would first require confirmation of interconnected surface water and groundwater for each GDE.
Section: **3.2.6,** **3.3.6,** **3.4.6**			**CA Dept Fish & Wildlife**	The GSA has established the following Minimum Threshold (MT) for the SMC for Depletion of ISWs sustainability criteria: "Two feet decline in Water Table Aquifer Zone groundwater levels beneath San Pablo or San Leandro Creek". Minimum Thresholds should ensure regional groundwater extractions do not lead to significant and adverse impacts on fish or wildlife resources by meeting plant and animal species temporal/spatial water needs	The Department recommends reconsidering this Minimum Threshold and Undesirable Result and revising the GSP to address and describe: - How Minimum Threshold prevents undesirable results	Surface water depletion and GDEs have been identified in the GSP as having significant data gaps. Consequently, several additional studies are planned to improve characterization of stream-aquifer interaction and potential GDEs. The GSAs plan to solicit input from CDFW and other interested Stakeholders during planning of these additional studies. While there are currently data gaps and insufficient data, specific details of potential

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				including water availability especially for Threatened and Endangered species and Species of Special Concern. They should be designed to account for climatic/water year type variability. Where specific data are lacking, MTs should be conservative with respect to preserving fish and wildlife beneficial users of groundwater from undesirable results. Furthermore, the GSP states an undesirable result for this SMC would be "50% or more RMS wells below MT for two consecutive non-drought year spring measurements". It is unclear how the metric for this undesirable result relates to ecological impacts. The GSP should identify monitoring metrics for GDEs that will enable the GSA to characterize GDE vulnerability to groundwater depletion and associated undesirable results, and to undertake management intervention accordingly.	- The effect the Minimum Threshold will have on environmental beneficial uses and users of groundwater, and what impact it will have on fish and wildlife How the Minimum Threshold accounts for climatic/water year type variability	ecological impacts and monitoring metrics will be discussed with CDFW and other Stakeholders when these additional studies are completed. In the absence of these additional surveys and data, the interim MTs were based on a conservative evaluation of model results and available information on plant rooting depths. The planned surveys that will be developed with CDFW and other interested Stakeholder input will be used to re-evaluate the MTs, and if necessary, modify them.
Section: 3.5.4.8		Page: 3-77	**CA Dept Fish & Wildlife**	The GSP acknowledges that more data are needed to better understand groundwater recharge and discharge mechanisms in the Subbasin, including surface water-groundwater interactions and the amount and location of groundwater extractions. The GSA should consider including RMPs for Interconnected Surface Waters in locations in the GSP area that support anadromous salmonid species. For example, Wildcat Creek might be a location the GSA should consider for additional monitoring. A Department 'Stream Habitat Assessment Report' found that "Wildcat Creek should be managed as an anadromous, natural production stream" (CDFW, 2013).	- The Department recommends the GSA make a commitment in the GSP to expand the RMP Network to include areas where potential GDEs exist that may be impacted due to surface water depletions resulting from groundwater pumping.	CDFW is correct to note that Wildcat Creek likely supports a small number of steelhead in the lowermost reaches of the creek, including where GDEs were identified. However, passage barriers within the lower watershed, including flood control channels and a culvert at San Pablo Ave limits the presence of steelhead to all but the lowermost reaches of the creek. Additionally, these reaches are unlikely to support the prolonged residence of fish given the absence of suitable spawning and rearing habitat. The GSP was revised to clearly indicate that Wildcat Creek will be a location under consideration for siting of shallow monitoring wells and synoptic stream surveys. Additional studies related to GDEs and aquatic species will be conducted during GSP implementation to help inform future monitoring. As discussed in the response to the City of San Pablo comment below, GDE monitoring will be prioritized according to the TNC guidance, which considers a GDE's ecological value and how susceptible the GDE is to changing groundwater conditions. GDEs supporting steelhead would be considered high ecological value.
Section: 4.1.2			**CA Dept Fish & Wildlife**	Management actions should include specifics on how and on what timeline adverse impacts will be reversed, if observed. The GSP should specify adaptive management strategies to account for 'lag' impacts wherein groundwater responses to changes in management regimes are delayed due to aquifer characteristics. Projects and management actions should seek to maximize multiple-benefit solutions, including habitat improvements.	Department encourages the GSA to consider implementing recharge projects that facilitate floodplain inundation. These projects offer multiple benefits including downstream flood attenuation, groundwater recharge, and ecosystem restoration. Managed floodplain inundation can recharge floodplain aquifers, which in turn slowly release stored water back to the stream during summer months. These projects also reconnect the stream channel with floodplain habitat, which can benefit juvenile salmonids by creating off-channel habitat characterized by slow water velocities, ample cover in the form of submerged vegetation, and high food availability. Additionally, these types of multi-benefit projects likely have more diverse grant funding opportunities that can lower their cost as compared to traditional off-channel recharge projects.	While floodplain inundation may be appropriate in other subbasins, it is not appropriate or feasible in an urban setting such as occurs in the EBP Subbasin. In addition, it should be noted that the EBP Subbasin is currently sustainable and has been sustainable since at least the 1970s, with groundwater pumping being only a small fraction of the estimated sustainable yield. Shallow Aquifer Zone groundwater levels are already quite high, and no projects or management actions are needed to make the basin sustainable.

Appendix 6.F Comments and Responses

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Exec Summary		Page: 23	**City of San Pablo**	Where it states a future project under consideration is the use of groundwater to supplement flows into San Leandro Creek, it may be good to clarify that there is a current agreement to release water from the dam.		Clarification has been added in the Executive Summary and in Chapter 4. Since the late 1990's, EBMUD has released water from Chabot Dam to San Leandro Creek to approximate the historic leakage flows from Lake Chabot to the creek prior to the repairs to the Chabot Dam outlet works. Note that the releases are being done voluntarily by EBMUD and not through an agreement.
Exec Summary		Page: 25	**City of San Pablo**	Since the sustainability goals are already met per Section 3.1.2 (page 4), future monitoring and management actions should consider minimizing the cost impacts on ratepayers.		The GSAs agree that the proper balance needs to be established for an appropriate level of monitoring and management actions that meets the requirements of SGMA within the context of GSP implementation for a basin that has been sustainable since the 1970s.
Section: 2.1.1		Page: 1	**City of San Pablo**	It may help to clarify at the beginning of the paragraph that GSP regulations require that federal lands (including tribal lands) be identified in the report.		The following sentence was added to GSP Chapter 2: "GSP regulations require that federal (including tribal) and state lands within the EBP Subbasin be identified."
Section: 3.5.2.8		Page: 68	**City of San Pablo**	Please explain what kind of biological monitoring is required for the identified Groundwater Dependent Ecosystems. This section states it is baseline to be repeated every 5 years. Section 4.1.2.1.4 mentions specific species and rooting depth. Since there are 127 acres of land to be monitored, it can get quite costly. If allowed by the SGMA, costs should be factored into the decision on the extent of the biological monitoring, as sometimes a simpler monitoring plan can provide the necessary information.		The GSAs agree that the proper balance needs to be established for an appropriate level of biological monitoring for potential GDEs that meets the requirements of SGMA within the context of GSP implementation for a basin that has been sustainable since the 1970s. Additional studies to further identify and evaluate the ecological value and risk to groundwater impacts of GDEs would guide future monitoring efforts. To prioritize biological monitoring actions, priority shall be given to the GDEs identified as having the highest risk to adverse impacts caused by groundwater conditions and those with the highest ecological value (e.g., such as those supporting special-status species) (see TNC 2018, Step 4.2). Ecological monitoring for these GDEs is expected to include the map verification (changes to GDE boundaries, e.g., vegetation changes, will be assessed every 5 years using aerial imagery), and field monitoring where selected locations will be revisited every 5 years to assess ecological conditions (e.g., dominant plant species, percent cover of native and nonnative species, soil surface saturation condition, presence of surface flow, wildlife habitat value, and overall ecological value).
			City of San Leandro	The high uncertainty in the current climate modeling for increased precipitation and evapotranspiration may warrant a more conservative approach for the groundwater recharge and streamflow levels than were modeled and discussed in the Draft Plan. Additionally, there may be unanticipated interactions between increased sea level rise, increased precipitation, and groundwater recharge. The City requests that an indicator be added around localized flooding and subsequent monitoring actions.		As described in GSP Appendix 6.D, climate modeling predictions call for increased precipitation and streamflow, which would lead to increased groundwater recharge in the future. The GSP is conservative in not including increased groundwater recharge, which would have resulted in a greater sustainable yield estimate and reduced impacts on streams and GDEs for the same amount of groundwater pumping. While localized flooding related to increased rainfall and streamflow may be a concern, localized flooding is not an issue (in and of itself) meant to be addressed under SGMA.
			City of San Leandro	The City of San Leandro also has general equity concerns about the potential distribution of water and their source quality. This should be included and discussed in the Final Plan as well as in future updates to the Plan.		All the residents within the Subbasin have access to the high-quality drinking water provided by EBMUD or the City of Hayward. Water served by the GSAs consistently meets or surpasses all State and Federal requirements regardless of the source. The GSAs are not aware of any

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						residents that exclusively or primarily use groundwater as a source of drinking water supply. The primary source of EBMUD water is the Mokelumne River delivered via 90-mile aqueduct system to the East Bay. EBMUD also employs varying water supplies to serve different portions of service area. Local runoff is stored in several East Bay reservoirs for treatment and delivery to customers and to assure supplies are available in an emergency. Any additional water sources must meet EBMUD's strict standards for high water quality. When new sources of water are added to EBMUD's system, like supplemental water supplies from the Central Valley Project (CVP) during drought, EBMUD's rigorous treatment process ensures that the drinking water for all customers meets our high water quality standards. EBMUD does not currently include groundwater in its drinking water blend, but is actively investigating groundwater options (Demonstration, Recharge, Extraction and Aquifer Management and Bayside) to help diversify its water supply portfolio. Any groundwater sources added to EBMUD's water supply portfolio will undergo the same rigorous treatment processes. EBMUD also provides a Customer Assistance Program (CAP), the most generous in the state, to ensure all customers are able to afford their water service. The City of Hayward receives all the water it supplies to its customers from the San Francisco Public Utilities Commission through their Regional Water System. This water comes from protected and carefully managed sources including snowmelt in the Sierra Nevada and rainfall collected in local reservoirs. The water is rigorously tested daily to ensure a high-quality level. The City of Hayward also provides a reduced rate for low-income customers.
Exec Summary		Page: 8	**City of San Leandro**	Under 'Description of the Plan Area' it states "The Subbasin does not contain federal or state lands…" However, there are portions of the marshlands that are under long-term lease from the State Lands Commission.		Additional research was conducted on both federal and state lands. A new map was developed for inclusion in Chapter 2 of the GSP. While no state marshlands were identified within the EBP Subbasin, such lands were identified immediately south of and adjacent to EBP Subbasin (within the area that was part of the EBP Subbasin prior to the 2016 Basin Boundary Modification). The ACWD Alternative (to a GSP) may include discussion of these State marsh lands. There were some additional federal lands identified within the EBP Subbasin, primarily related to military facilities.
Exec Summary		Page: 13	**City of San Leandro**	Under 'Future Scenario' it states "The recharge of the basin will slightly outpace discharge from the basin, resulting in a net benefit increase in basin storage." When California has experienced multi-year drought events (as long as 8 consecutive years), what is the basis for this statement?		This statement is based on long-term hydrology and not short-term climatic cycles. Droughts have been and always will be a part of California's climatic cycles, as will wet years.
Section: 1	Figure: 1-1		**City of San Leandro**	*In Chapter 1, Figure 1-1:* Please provide the complete link for the source of identified DACs and SDACs. In looking online at the 'US Census-cities' as noted in the graphic's legend, information appeared to not be the same as represented in the graphic (San Leandro as shown in the graphic is underrepresented). Why wasn't OEHHA or California Climate Investments Priority Populations 3.0 by Census Tract data used?		SDAC and DAC information from the government of California (DWR) was used because this is used as the basis for Proposition 1 funding received for development of the EBP GSP. The link for the data is: DAC Mapping Tool (ca.gov) With Regard to Figure 1-1, San Leandro City limits extend north and south of the dot on the map and include some DAC and SDAC areas.

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Section: 2.1.2.3		Page: 2-9	**City of San Leandro**	*Chapter 2, Section 2.1.2.3, Land Subsidence Monitoring, top of Page 9:* It states that Appendix 2.A.b presents additional information on extensometer monitoring. Appendix 2 is comprised of 3,511 pages.	A more specific citation, including a page number would be helpful.	A reference to Section 3.2.3 of Appendix 2.A.a and Section 5.5 of Appendix 2.A.b were added in the GSP text.
Section: 2.1.4.3		Page: 2-13	**City of San Leandro**	*Chapter 2, Section 2.1.4.3, Page 13:* It states "…numerous types of facilities and land uses can be potential sources of chemical constituents…".	Specific examples should be included so readers have a more complete understanding	The following text was added to the GSP, "(e.g., gas stations, landfills, wastewater treatment plants)"
Section 2.1.4.9		Page: 2-15	**City of San Leandro**	*Chapter 2, Section 2.1.4.9, Page 15:* Is there no more recent data than 2010 regarding total water demand?		This text citing 2010 water demand is referenced as being derived from the EBMUD Water Conservation Master Plan prepared in 2011. It is just providing an example comparing water demands in 2010 to water demands in the 1970s. More recent water demand data is cited and used in other places in the GSP, such as Appendix 2.A.b for calculation of recharge from leaking pipes and in Section 2.1.2.1 of the GSP.
Section 2.1.4.9		Page: 2-15	**City of San Leandro**	*Chapter 2, Section 2.1.4.9, Page 15:* What is the status for implementation of the conservation measures noted approximately mid-page?		EBMUD has made substantial progress in implementing the conservation measures from its 2011 Water Conservation Plan which are listed in Chapter 2, Section 2.1.4.9. In addition, EBMUD is currently finalizing the 2021 update to that plan. Highlights of the implementation status for each conservation measure are summarized below. More details can be found in the EBMUD's 2020 Urban Water Management Plan: https://www.ebmud.com/water/uwmp. Water Management Services • Developed a new customer facing web portal that allows customers to view and analyze data on their water consumption and receive targeted information on ways to save. • Expanded its Water Report program. • Sends leak alerts to customers via email, text, and print. Education and Outreach • Social media is used to inform customers about issues like droughts and to market programs and tools. • Created a drought theater program for school assemblies. • Developing a series of new workbooks for K-12 education, including material and activities related to water conservation. Conservation Incentives • Primary focus of the rebate program shifted from indoor to outdoor water savings, to transform landscapes to reduce irrigation water use. • Launched a new rebate program for flowmeters in 2019 that allows customers to monitor their water use in near real-time. Regulations and Legislation • Met its 20% water use reduction target by 2020 as required by the SBx7-7 legislation. • Maintains and enforces its own water use regulations, including water use efficiency requirements for new service.

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						Supply Side Conservation • Reducing losses within its distribution system through pipeline leak detection and repair, corrosion control, pressure management, meter testing, and pipeline replacement. • In October 2017, established an internal Water Loss Committee and a procedure for preparing the audit each year. • In 2020, started preparing its first Water Loss Control Plan. Research and Development • Finalizing two pilot studies evaluating the water and energy savings associated with Advanced Metering Infrastructure and web-interface technology. The City of Hayward is among the lowest per-capita water users statewide and compared to other agencies that purchase water from San Francisco Public Utilities Commission, partially because Hayward has long been committed to implementing effective water conservation measures. Some key five-year statistics to illustrate the breadth of Hayward's water conservation efforts are summarized below. The City's 2020 Urban Water Management Plan includes a full discussion of Hayward's water conservation measures and programs and can be found at: https://www.hayward-ca.gov/documnets/urban-water-management-plan. Water Management Services • Implemented an Advanced Metering Infrastructure (AMI) system to automatically transmit water consumption for billing purposes. • Developed a web portal allowing customers to view and analyze data on their water consumption and receive leak alerts. Education and Outreach • Informed customers through social media and its website about drought and water reduction efforts, water conservation measures and programs. • Provided WaterWise in-class curriculum to over 2,500 fifth grade students. • Administered School Assembly Program tailored to specific grade levels attended by over 30,000 students. • Hosted 15 Water Efficient Landscape Classes attended by 750 people. Conservation Incentives and Assistance • Provided more than 930 rebates for high efficiency clothes washers and toilets, lawn replacements and rain barrels. • Developed Large Landscape Water Budgets for 330 irrigation accounts. • Provided about 4,400 water efficient shower heads and faucet aerators, and 20 water efficient commercial pre-rinse spray valves. • Performed 1,000 residential customer water efficiency surveys.

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						- Regulations and Legislation - Achieved its water use reduction target by 2020 as required by SBx7-7 legislation. - Administered Water Waste Prohibition Ordinance, Bay-Friendly Water Efficient Landscape Ordinance, and the Civic Bay-Friendly Landscaping Ordinance. Supply Side Conservation - Tracked and managed a distribution system leak detection survey and repair program uncovering 75 leaks and breaks. Research and Development - May implement a Commercial and Industrial Water Use Survey program.
Section 2.2.1.2		Page: 23	**City of San Leandro**	*Chapter 2, Section 2.2.1.2, Page 23:* What is the basis for the sentence "It is likely that the Deep Aquifer Zone extends a significant distance to the west beneath San Francisco Bay…"?		The Deep Aquifer Zone sediments were deposited under very different conditions than exist today with respect to climate, presence/absence of San Francisco Bay, and regional geology (see Appendix 2.A.b, Sections 4 and 7). These sediments are indicated to have been deposited well out into and beneath the present location of San Francisco Bay. In addition, aquifer testing for the EBMUD Phase 1 Well (located near San Francisco Bay margin) indicated no boundary condition is present near the well (i.e., the Deep Aquifer does not pinch out near the well), which implies the Deep Aquifer extends a significant distance out beneath the Bay.
Section 2.2.1.4		Page: 25	**City of San Leandro**	*Chapter 2, Section 2.2.1.4, Page 25:* Appendix 2.A.b was again noted (as reference for a long-term regional test of groundwater elevations). A more specific reference, including a page number would be helpful, especially as this appendix has over 3,500 pages. With San Leandro primarily underlain by the intermediate and deep aquifers, and based on the Figures listed in Appendix 2.A.b, it appears that the long-term testing dates back to 1953 for the intermediate aquifer and 1965 for the deep aquifer. However, as evidenced by the Figures 5 series, the comparison of groundwater elevations in the corresponding Spring and Fall (and looking at just either the Intermediate Aquifer or Deep Aquifer) don't always show that the same locations were tested (for example, the measured elevation 'dot' shown near the western end of San Leandro Creek on the Intermediate Aquifer Contour Maps starting in 1953, is absent in the Fall 2002 Map). How can historic data be reliably used to hypothesize on potential future conditions if it's not an 'apples-to-apples' comparison?		The local and regional aquifer testing is described in Section 7 of Appendix 2.A.b. The wells available to be monitored over time (years and decades) for water levels often change for many reasons (wells are abandoned or destroyed, well owners decide to stop participating in the monitoring program, new wells are drilled and then monitored, monitoring agencies stop their monitoring programs). However, many groundwater level hydrographs are presented in Appendix 2.A.b that show changes in water levels over time at the same well. The groundwater model is calibrated to the historical groundwater level data, which allows for a level of confidence in predictions of future groundwater levels from the model.
Section 2.2.2.5		Page: 36	**City of San Leandro**	*Chapter 2, Section 2.2.2.5, Page 36:* Regarding this section's discussion of land subsidence, I would agree that further evaluation and on-going management of the potential for land subsidence should occur. In looking at the historic groundwater levels, it's important to note that when the data started to be recorded back in 1953, the portions of the City covered by		The historical water balance analysis presented in the GSP covers the time period from 1990 to 2015, during which time urban development and paved areas were fairly consistent. Groundwater levels prior to 1990 are presented for completeness and do not impact or relate to the historical water balance period the GSP is based on (i.e., 1990 to 2015). As discussed in the GSP (e.g., Section 2.1.3.1), future paved areas (and groundwater

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				hardscape was much less than what exists today, and C3 requirements for development did not exist. A logical conclusion would be that the region's ability to recharge groundwaters has been reduced as development has expanded, and this factors in to future projections (not just how much is pumped in/out of the aquifers).		recharge) will likely be similar to 2015 given minimal vacant land and the trend towards increasing use of green infrastructure.
Section 2.2.3.6		Page: 46	**City of San Leandro**	*Chapter 2, Section 2.2.3.6, Page 46:* Did Muir's study look at subsidence?		Muir's study on recharge (Muir, 1994) mentions subsidence as a potential source of water (i.e., compaction squeezing water out of clay layers), but states subsidence was not occurring in the time period for which his study was conducted (1990s).
Section 2.2.3.6		Page: 47	**City of San Leandro**	*Chapter 2, Section 2.2.3.6, Page 47:* In mentioning sewer pipe outflow, was there any consideration of the court order that EBMUD is under and/or sewer lateral ordinances that many jurisdictions have enacted? The assumption being that the contribution of sewer pipe outflow should be decreasing over time.		The water balance in the GSP should be considered a starting point. The components of the water balance will be reevaluated in the future (e.g., 5-Year Update Reports), and new information will be considered in refining the components of the water balance (including sewer pipe leakage).
Section 3.2.4		Page: 9, 25	**City of San Leandro**	*Chapter 3, Section 3.2.4, Pages 9 and 25:* Why is regional-scale damage to public infrastructure the only metric for determining significance of subsidence? There are hundreds (if not 1,000+) of San Leandro homes in proximity to the EBMUD Bayside Phase 1 Facility that would be impacted should subsidence occur in the future.		Land subsidence that may occur from groundwater pumping is regional in nature and is a result of compaction of deep clay layers. It typically does not cause problems for houses because it occurs over spatial scales much larger than the size of a house. Such regional land subsidence should be distinguished from differential settlement. Homes may be impacted by shallow soil differential settlement, but that is not related to regional subsidence caused by groundwater pumping.
Section 3.3.6.1		Page: 35	**City of San Leandro**	*Chapter 3, Section 3.3.6.1, Page 35:* The statement "…the change in connectivity along San Leandro Creek has no significant effect onstream-aquifer interaction because the channel is lined" is partially incorrect. A majority of San Leandro Creek is not lined (only the portion west of approximately Alvarado St. is lined).		This is a typo; this statement should be referring to San Lorenzo Creek and has been corrected in the GSP text.
Section 3.5.1.4		Page: 58	**City of San Leandro**	Chapter 3, Section 3.5.1.4, Page 58: The second bullet "Review periodic subsidence surveys that may be conducted by others" seems to imply that if no other agency/entity has a study performed, then there would be nothing to review. Given the ongoing cycle of drought years (some historically extending to 6 consecutive years), EBMUD should be required to have subsidence reports completed whenever groundwater levels in the Subbasin come within a certain percentage of the minimum threshold for subsidence.		It should be noted that subsidence would not occur due to drought alone, and likely has the potential to occur only if groundwater pumping increases substantially to the point of approaching/exceeding the MTs. This is because groundwater elevations at and below the MTs have already occurred for an extended period of time in the past (1950s and early 1960s), and most subsidence associated with those levels would have occurred at that time (assuming there was any subsidence at that time). New subsidence likely would only occur if those historical groundwater elevations (i.e., the MTs in the GSP) were to be exceeded. Since there were no reports of subsidence at the time of these historically low groundwater elevations, it is not necessarily the case that subsidence would occur even if the MTs were exceeded; thus, the MTs are considered to be conservative. If the MTs were to be approached to the extent that it appears they may be exceeded, steps would be taken to further evaluate subsidence that may include additional subsidence surveys.
	Figures 1-1, 2-2		**NC, CWA, LGC, UCS, Audubon**	The identification of Disadvantaged Communities (DACs) and drinking water users is incomplete. The GSP provides information on DACs, including identification by name and location on a map (Figure 1-1). However, the GSP fails to clearly	Provide the population of each identified DAC. Include a map showing domestic well locations and average well depth across the subbasin.	It is important to note that EBP Subbasin GSAs are not aware of any residents who are solely or primarily dependent on groundwater for a drinking water supply. Effectively, all residents have access to high quality drinking water supplies from either EBMUD or Hayward, including DACs.

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				state the population of each DAC. The GSP provides a density map of domestic wells in the subbasin (Figure 2-2). However, the plan fails to provide depth of these wells (such as minimum well depth, average well depth, or depth range) within the subbasin. These missing elements are required for the GSAs to fully understand the specific interests and water demands of these beneficial users, and to support the consideration of beneficial users in the development of sustainable management criteria and selection of projects and management actions.		Thus, all residents have access to drinking water of similar quality. Domestic wells referenced in the GSP are used as a supplemental source for irrigation. Additional information on domestic well depths is provided in GSP Appendix 3.A.
Section 2.2.2.6			**NC, CWA, LGC, UCS, Audubon**	The identification of Interconnected Surface Waters (ISW) is insufficient, due to lack of supporting information provided for the ISW analysis. Section 2.2.2.6 of the GSP describes surface water and groundwater Interaction. This section concludes with the following statement (p. 2-36): *"In general, depths to groundwater in the Upper Shallow Aquifer Zone are less than 20 ft bgs in most of the EBP Subbasin, although there are some areas with groundwater levels between 20 ft and 30 ft bgs or more. Overall, depth to groundwater generally decreases from northeast (near the East Bay Hills) to southwest (San Francisco Bay) across the Subbasin, albeit with significant local variations. Thus, it can be expected that the potential for surface water/groundwater connection increases from east to west. In addition, where a surface water/groundwater connection is present, it can be expected that losing conditions are more likely in the eastern portion of the Subbasin and gaining conditions have more potential to occur in the western portion of the Subbasin. It should also be noted that portions of creek lengths are lined within the EBP Subbasin; particularly, for San Lorenzo Creek where a majority of the creek bed is lined until about one mile inland from the Bay Margin."* Appendix H of Appendix 2.A.b provides a review of prior surface water - groundwater interaction studies. It concludes with the following statement: *"Taken together, the studies document flashy stream behavior, with a major component of streamflow generation from groundwater, even during runoff events."* The two sections of the GSP described herein imply that most or all of the subbasin's surface water reaches are interconnected. However, no figure of stream reaches in the subbasin is provided that presents the conclusions of the ISW analysis. Section 2.2.2.6 of the GSP (Surface Water/Groundwater Interaction) refers to Figure 2-37 (Map of Depth to Water Table – Spring 2015). These are the only data discussed when referring to depth to water. Using seasonal groundwater elevation data over multiple water year types is an essential component of identifying ISWs. The use of data from one point in time does not reflect the temporal (seasonal and interannual) variability inherent in California's climate.	Provide a map showing all the stream reaches in the subbasin, with reaches clearly labeled as interconnected (gaining/losing) or disconnected. Consider any segments with data gaps as potential ISWs and clearly mark them as such on maps provided in the GSP. Provide depth-to-groundwater contour maps using the best practices presented in Attachment D. Specifically, ensure that the first step is contouring groundwater elevations, and then subtracting this layer from land surface elevations from a digital elevation model (DEM) to estimate depth to groundwater contours across the landscape. This will provide accurate contours of depth-to-groundwater along streams and other land surface depressions where GDEs are commonly found. Use seasonal data over multiple water year types to capture the variability in environmental conditions inherent in California's climate, when mapping ISWs. We recommend the 10-year pre-SGMA baseline period of 2005 to 2015.	Stream-Aquifer interconnection (i.e., Interconnected Surface Waters or ISW) has been identified as a significant data gap in the GSP, and there are currently insufficient data available to develop maps of interconnected stream reaches. Several data collection efforts are identified in the GSP and planned to be conducted in the initial five years of the GSP Implementation Period including: synoptic stream surveys, installation of additional stream gage stations, installation of shallow monitoring wells along streams and in GDE areas, and an additional isotope study. There is also an isotope study currently underway for San Pablo and San Leandro Creeks. The 5-year Update Report will include evaluation of all the additional data to be collected and address the information being requested in this comment.

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	Figures 5-61, 5-62		**NC, CWA, LGC, UCS, Audubon**	The identification of Groundwater Dependent Ecosystems (GDEs) is insufficient. The GSP took initial steps to identify and map GDEs using the Natural Communities Commonly Associated with Groundwater dataset (NC dataset), referred to as the iGDE dataset in the GSP. However, we found that some mapped features in the NC dataset were improperly disregarded. NC dataset polygons were incorrectly removed in areas adjacent to irrigated fields or due to the presence of surface water supplies. However, this removal criteria is flawed since GDEs can rely on multiple water sources – including shallow groundwater receiving inputs from irrigation return flow from nearby irrigated fields – simultaneously and at different temporal/spatial scales. NC dataset polygons adjacent to irrigated land or surface water supplies can still potentially be reliant on shallow groundwater aquifers, and therefore should not be removed solely based on their proximity to irrigated fields or surface water supplies. The GSP states that depth to groundwater from fall 2014 and spring 2015 (Figures 5-61 and 5-62) were used to assess the GDE polygons' connection to groundwater. The GSP states (p. 66 of Appendix 2.A.b): *"No GDEs were excluded based on depth to groundwater. Depth to groundwater, based on Fall 2014 data, was 30 ft or less across the East Bay Subbasin (although data are lacking for most areas along the eastern margin of EBP Subbasin where depth to water may be greatest)."* While we recognize that no NC dataset polygons were removed based on depth to groundwater, we recommend using groundwater data from multiple seasons and water year types to determine the range of depth to groundwater around NC dataset polygons and to more completely describe groundwater conditions within the subbasin's GDEs. The GSP states (p. 65 of Appendix 2.A.b): *"After review of aerial imagery, a total of 38 acres of potential GDEs were excluded from the original iGDE database, 537 acres were flagged as needing additional data (e.g., field assessments), and 154 were verified as potential GDEs."* The GSP continues (p. 70 of Appendix 2.A.b): *"Field investigations for the 537 acres of features flagged as needing additional data are recommended in the future (after submittal of the GSP) to better assess vegetation communities and hydrologic inputs."* We recommend	Use depth-to-groundwater data from multiple seasons and water year types (e.g., wet, dry, average, drought) to determine the range of depth to groundwater around NC dataset polygons. We recommend that a baseline period (10 years from 2005 to 2015) be established to characterize groundwater conditions over multiple water year types. Refer to Attachment D of this letter for best practices for using local groundwater data to verify whether polygons in the NC Dataset are supported by groundwater in an aquifer. Provide depth-to-groundwater contour maps, noting the best practices presented in Attachment D. Specifically, ensure that the first step is contouring groundwater elevations, and then subtracting this layer from land surface elevations from a DEM to estimate depth-to-groundwater contours across the landscape. If insufficient data are available to describe groundwater conditions within or near polygons from the NC dataset, include those polygons as "Potential GDEs" in the GSP until data gaps are reconciled in the monitoring network.	No NC dataset polygons were removed in areas adjacent to irrigated fields or due to the presence of surface water supplies. Furthermore, no NC dataset polygons were removed based on depth to groundwater. Sufficient mapping of groundwater was conducted in the GSP for the initial analysis of potential GDEs. Mapping of groundwater elevations and depth to groundwater will be further evaluated during GSP implementation as more monitoring wells are installed and more data are collected. The GSP identified lands as "Potential GDEs" when sufficient data were available to conclude it is likely to be a GDE (although final field confirmation and characterization are still needed; hence they are referred to as "Potential GDEs"). The 537 acres listed as requiring additional field investigation did not have sufficient data available to conclude they were likely to be "Potential GDEs"; therefore, they remain to be further evaluated for inclusion as "Potential GDEs". The 537 acres will be further evaluated as part of the initial baseline field investigation.

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				that the 537 acres flagged as needing additional data are also included as potential GDEs until the data gaps are filled.		
Section 2.2.3			**NC, CWA, LGC, UCS, Audubon**	Native vegetation and managed wetlands are water use sectors that are required to be included into the water budget. The integration of native vegetation into the water budget is insufficient. The water budget did not explicitly include the current, historical, and projected demands of native vegetation. The omission of explicit water demands for native vegetation is problematic because key environmental uses of groundwater are not being accounted for as water supply decisions are made using this budget, nor will they likely be considered in project and management actions. Managed wetlands are not mentioned in the GSP, so it is not known whether or not they are present in the subbasin.	Quantify and present all water use sector demands in the historical, current, and projected water budgets with individual line items for each water use sector, including native vegetation. State whether or not there are managed wetlands in the subbasin. If there are, ensure that their groundwater demands are included as separate line items in the historical, current, and projected water budgets.	Native vegetation is expected to be a very small component of the water budget (due to their small areas of native riparian vegetation) and is currently included as part of the term that includes groundwater discharge to streams and sewer outflow (this is the residual term for the water budget). There is currently insufficient information to determine the portion of this component of the water balance that should be attributed to native vegetation. However, it is expected to be quantified as part of the 5-Year Update Report by evaluating total areas of riparian vegetation within Subbasin boundaries and evaluating their consumptive use (ET) demands.
Section: Appendix 2.B.a			**NC, CWA, LGC, UCS, Audubon**	Stakeholder engagement during GSP development is insufficient. SGMA's requirement for public notice and engagement of stakeholders is not fully met by the description in the Stakeholder Communication and Engagement Plan (Appendix 2.B.a). We note the following deficiencies with the overall stakeholder engagement process: The opportunities for public involvement and engagement are described in very general terms for listed stakeholders. They include attendance at GSA board and general stakeholder meetings, updates to the SGMA webpage, and access to GSA staff via email/telephone. There is no described outreach during the GSP development process that is specifically directed at DACs, domestic well owners, or environmental stakeholders. Aside from the continuation of engagement strategies used during the GSP development process, the Stakeholder Communication and Engagement Plan does not include a detailed plan for continual opportunities for engagement through the *implementation* phase of the GSP that is specifically directed to DACs, domestic well owners, and environmental stakeholders.	In the Stakeholder Communication and Engagement Plan, describe active and targeted outreach to engage DAC members, domestic well owners, and environmental stakeholders throughout the GSP development and implementation phases. Refer to Attachment B for specific recommendations on how to actively engage stakeholders during all phases of the GSP process. Utilize DWR's tribal engagement guidance to comprehensively address all tribes and tribal interests in the subbasin within the GSP.	The GSAs are looking to expand outreach to DACs and have identified additional groups that will be contacted about their interest in being included during GSP implementation. With the release of the 2020 census data, the GSAs will have more information to target outreach. The GSAs are not aware of any DACs or domestic well owners that exclusively or primarily use groundwater as a source of drinking water supply. All the DACs within the Subbasin have access to the high-quality drinking water provided by EBMUD or the City of Hayward. Domestic wells owners generally use groundwater only for irrigation. Information on domestic well owners in the Subbasin is sparse, and the GSAs are working towards compiling more information on well owners and plan to contact them about their interest in being included in the Stakeholders list as they become available. Environmental stakeholders have been included in the GSP development process and have been invited to attend all the General Stakeholder meetings. The GSAs also did additional outreach to key environmental stakeholders during the development of the GSP, including asking if they wanted to have more detailed, individual discussions with the GSAs. Tribal interests in the Subbasin are listed in Section 2.1.1. Only one tribe within the EBP Subbasin had been identified during development of the GSP: the Lytton Band of Pomo Native Americans. They do not use groundwater but are included in all the Stakeholder communications and meeting invitations. Similar to the GSP development process, the GSAs will continue to engage with Stakeholders during GSP implementation. The Communications and Engagement Plan will be updated to include the engagement plan during implementation.
		Page: 3-15	**NC, CWA, LGC, UCS, Audubon**	For chronic lowering of groundwater levels, the minimum threshold for shallow aquifer zone groundwater levels is set at 50 feet below the ground surface. To explain the rationale, the	Describe direct and indirect impacts on DACs and drinking water users when describing undesirable	The GSAs are not aware of any DACs or domestic well owners that exclusively or primarily use groundwater as a source of drinking water

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				GSP states (p. 3-15): *"California well standards require a minimum 50-foot well seal for community water system and municipal water supply wells. Domestic and industrial wells have a 20-foot minimum well seal requirement. With respect to development of drinking water supply wells in the urban EBP Subbasin (including domestic wells that may serve as drinking water supply wells), it is reasonable to assume that drinking water supply wells of any type would have a well seal that is at least 50-feet or greater in depth (preferably at least 100 feet deep) to protect the well from potential contaminants originating at ground surface (e.g., fuel hydrocarbons, solvents, nitrate) that are known to impact the upper 100 feet of sediments in the EBP Subbasin. Thus, a conservative assumption is that drinking water supply wells are a minimum of 60 feet deep to allow for a 50-foot well seal and some intake area; it is very likely that drinking water supply wells would need to be considerably deeper than 60 feet to obtain groundwater of suitable quality and to have some protection against the most likely potential contaminants. Based on the assessment of the DWR WCR database described above, the methodology for establishing MT for the shallow (water table) zone chronic lowering of groundwater levels is based in part on an assumed minimum well depth for drinking water supply wells of 60 feet."* The GSP states that depth to water is generally less than 20 feet in the shallow aquifer zone. Furthermore, as stated in the quoted text above, domestic and industrial wells have a 20-foot minimum well seal requirement. Therefore, minimum thresholds at 50 feet below the ground surface may not protect shallow domestic wells in the subbasin. The GSP does not sufficiently describe whether minimum thresholds will avoid significant and unreasonable loss of drinking water to domestic well users that are not protected by the minimum threshold, and whether the undesirable results are consistent with the Human Right to Water policy. In addition, the GSP does not sufficiently describe or analyze direct or indirect impacts on DACs or drinking water users when defining undesirable results, nor does it describe how the groundwater levels minimum thresholds are consistent with Human Right to Water policy and will avoid significant and unreasonable impacts on beneficial users.	results and defining minimum thresholds for chronic lowering of groundwater levels. Consider and evaluate the impacts of selected minimum thresholds and measurable objectives on DACs and drinking water users within the subbasin. Further describe the impact of passing the minimum threshold for these users. For example, provide the number of domestic wells that would be de-watered at the minimum threshold.	supply. All the DACs within the Subbasin have access to the high-quality drinking water provided by EBMUD or the City of Hayward. Domestic wells in the EBP Subbasin provide for supplemental irrigation water; these residents also have the option of using water from EBMUD or Hayward for their irrigation supply.
				The minimum thresholds for degraded water quality for each of the four identified key water quality constituents (nitrate, arsenic, chloride, TDS) are based on the greater of MCLs or the baseline concentration plus 20%. According to the state's anti-degradation policy, high water quality should be protected and is only allowed to worsen if a finding is made that it is in the best interest of the people of the State of California. No analysis has been done and no such finding has been made.	Describe direct and indirect impacts on DACs and drinking water users when defining undesirable results for degraded water quality. For specific guidance on how to consider these users, refer to "Guide to Protecting Water Quality Under the Sustainable Groundwater Management Act."	The basis for selection of the four key constituents is provided in Appendix 2.A.b of the GSP. The 20% allowance for an increase over baseline concentrations is intended to account for the variability in lab reported concentrations that can occur due to natural (e.g., groundwater system) fluctuations and laboratory (e.g., chemical analysis) procedures. The basis for this is described in detail in the GSP and 20% is a relatively conservative allowance considering how much a given sample result can vary. Regardless of the 20% allowance, all DACs in the EBP Subbasin receive drinking water

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				Furthermore, exceedances of the MCL constitute a violation of the state's water quality law and are not permitted. Additionally, Section 2.2.2.3 of the GSP (Groundwater Quality) discusses other contaminants associated with cleanup sites that are distributed throughout the urban EBP subbasin. SMC should be established for all COCs in the subbasin impacted or exacerbated by groundwater use and/or management, in addition to coordinating with water quality regulatory programs. The GSP only includes a very general discussion of impacts on drinking water users when defining undesirable results and evaluating the impacts of proposed minimum thresholds. The GSP does not, however, mention or discuss direct and indirect impacts on DACs or drinking water users when defining undesirable results for degraded water quality, nor does it evaluate the cumulative or indirect impacts of proposed minimum thresholds on DACs or drinking water users.	Evaluate the cumulative or indirect impacts of proposed minimum thresholds for degraded water quality on DACs and drinking water users. Set minimum thresholds and measurable objectives for all water quality constituents within the subbasin that are impacted or exacerbated by groundwater use and/or management. Set minimum thresholds that do not allow water quality to degrade to levels at or above the MCL trigger level.	from surface water sources via EBMUD and Hayward, and pumping from domestic wells in the EBP Subbasin is for irrigation rather than drinking water. Therefore, there are no direct or indirect drinking water impacts on DACs because their drinking water supply comes from the high-quality water served by the GSAs, the same as for non-DAC areas. During the very short-term use of emergency wells in Hayward GSA and use of Bayside Phase 1 Well in extended drought, groundwater would be a very small component of supply for all customers (i.e., both DAC and non-DAC areas). The GSAs ensure that the drinking water continues to meet or exceed State and Federal drinking water standards when additional sources of water are added.
		Pages: 3-7, 10, 15	**NC, CWA, LGC, UCS, Audubon**	For chronic lowering of groundwater levels, the GSP recognizes the potential impact of groundwater level minimum thresholds on GDEs. The minimum thresholds are established as follows (p. 3-7): *"In these areas [Shallow Aquifer Zone at RMS wells located adjacent to GDEs], the initial interim MT for Shallow Aquifer Zone groundwater levels is set to 7.5 feet below existing/baseline conditions, and this will be updated (and potentially revised) pending additional hydrogeologic/ biologic data collection and studies."* The GSP states (3-15): *"GDEs directly dependent on groundwater levels would not necessarily be protected by an MT that is protective of drinking water supply wells. Therefore, areas of the EBP Subbasin coinciding with known GDEs will have adjustments to the groundwater level MT established to protect drinking water supply wells. Additional work is needed in the early stages of GSP implementation to conduct further evaluation of potential GDEs, rooting depths of various species, and how declines in groundwater levels may impact various potential GDE vegetative species."* The GSP continues (p. 3-19): *"If a 6-year drought and projected water level declines to MT levels were to occur, potential effects on GDEs could include short-term adverse impacts such as water stress and possibly longer-term impacts such as reduced growth and recruitment."* Therefore, while the GSP recognizes that there could be impacts on GDEs, no further details on these impacts are provided, such as which habitat types could be affected, or the anticipated physiological responses based on minimum threshold groundwater levels.	When defining undesirable results for chronic lowering of groundwater levels, provide specifics on what biological responses (e.g., extent of habitat, growth, recruitment rates) would best characterize a significant and unreasonable impact to GDEs. Undesirable results to environmental users occur when significant and unreasonable effects on beneficial users are caused by one of the sustainability indicators (i.e., chronic lowering of groundwater levels, degraded water quality, or depletion of interconnected surface water). Thus, potential impacts on environmental beneficial uses and users need to be considered when defining undesirable results in the subbasin. Defining undesirable results is the crucial first step before the minimum thresholds can be determined. When defining undesirable results for depletion of interconnected surface water, include a description of potential impacts on instream habitats within ISWs when minimum thresholds in the subbasin are reached. The GSP should confirm that minimum thresholds for ISWs avoid adverse impacts on environmental beneficial users of interconnected surface waters as these environmental users could be left unprotected by the GSP. These recommendations apply especially to environmental beneficial users that are already protected under pre-existing state or federal law. When establishing SMC for the subbasin, consider that the SGMA statute [Water Code§10727.4(l)] specifically	Appendix 2.A.b of the GSP provides a preliminary assessment of special-status species with occurrence records overlapping potential GDEs. The text of this document has been updated to provide additional discussion on potential impacts to wildlife and plant species. More detailed biological field investigations are planned to better characterize specific species present, extent of habitats, and establish baseline ecological health conditions (see GSP Section 4.1.2.1.4). The GSAs will seek CDFW input on the location, methods, and type of field investigations. This improved understanding of GDE conditions will then allow development of a better assessment of how lowered groundwater levels may affect the ecosystems that are present. This updated assessment will be provided in the 5-Year Update Report.

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				For depletion of interconnected surface water, groundwater elevations are used as proxy for establishing SMC. The GSP states (3-10): *"The MT for non-drought shallow groundwater levels (as a proxy) is set at two feet below current baseline water levels in the Water Table Aquifer Zone beneath the major creeks. This is considered an interim MT, and the MT will be refined with collection of additional data to improve the understanding of stream-aquifer connectivity and potential for streamflow depletion related to groundwater pumping."* The GSP notes that the proposed minimum thresholds require use of shallow wells along major creeks, which are planned to be installed for use as representative monitoring sites (RMSs). The interim MT are based on model estimated groundwater levels. While the GSP clearly recognizes the data gap for depletion of interconnected surface water SMC, we would like to see further discussion of how the interim SMC will affect beneficial users, and more specifically GDEs, or the impact of these minimum thresholds on GDEs in the subbasin. The GSP makes no attempt to evaluate how the proposed minimum thresholds and measurable objectives avoid significant and unreasonable effects on surface water beneficial users in the subbasin (see Attachment C for a list of environmental users in the subbasin), such as increased mortality and inability to perform key life processes (e.g., reproduction, migration).	calls out that GSPs shall include "impacts on groundwater dependent ecosystems"	
Section 2.2.3			**NC, CWA, LGC, UCS, Audubon**	The SGMA statute identifies climate change as a significant threat to groundwater resources and one that must be examined and incorporated in the GSPs. The GSP Regulations require integration of climate change into the projected water budget to ensure that projects and management actions sufficiently account for the range of potential climate futures. The effects of climate change will intensify the impacts of water stress on GDEs, making available shallow groundwater resources especially critical to their survival. Condon *et al*. (2020) shows that GDEs are more likely to succumb to water stress and rely more on groundwater during times of drought. When shallow groundwater is unavailable, riparian forests can die off and key life processes (e.g., migration and spawning) for aquatic organisms, such as steelhead, can be impeded. The integration of climate change into the projected water budget is insufficient. The GSP incorporates climate change into the projected water budget using DWR change factors. However, the plan does not clearly specify which change factors were used (e.g., 2030 or 2070). Furthermore, the plan does not make clear whether multiple climate scenarios (e.g., the 2070 extremely wet and extremely dry climate scenarios) were considered in the projected water budget. The GSP should indicate which DWR change factors were used for the projected water budget and also clearly and transparently incorporate the	Clarify if extremely wet and dry scenarios are incorporated into all elements of the projected water budget to form the basis for development of sustainable management criteria and projects and management actions. If there are data available, expand your integration of climate change into surface water flow inputs, including imported water, for the projected water budget. Estimate sustainable yield based on the projected water budget with climate change incorporated. Incorporate climate change scenarios into projects and management actions.	Appendix 6.D provides characterization and assessment of climate change factors for both 2030 and 2070. This assessment demonstrated that the net result of these climate change factors would be more streamflow and more groundwater recharge. However, the future scenarios were conservative and assumed these increases in streamflow and groundwater recharge would not occur, instead utilizing historical conditions that were drier than would otherwise be simulated utilizing the DWR climate change factors. The GSP is just a starting point, and future updates to the GSP (especially 5-Year Update Reports) will incorporate actual climate conditions that occur in the future as well as evaluate new information developed for predictions of future climate change. It should be noted that changes in the imported surface water budget do not directly impact groundwater modeling results or other analyses in the GSP. Imported surface water budget changes would only impact the analyses in the GSP if they change the use of groundwater in the Subbasin. For example, potential future reductions in imported surface water may be compensated by increased water conservation with no changes to how much groundwater is pumped from EBP Subbasin. Climate change was incorporated into the calculation of sustainable yield in a conservative fashion by assuming no future increases in groundwater recharge due to climate change. If climate change factors developed by DWR were incorporated into the sustainable yield analysis, the estimated sustainable yield would be greater than 12,500 AFY.

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				extremely wet and dry scenarios provided by DWR into projected water budgets or select more appropriate extreme scenarios for the subbasin. While these extreme scenarios may have a lower likelihood of occurring, their consequences could be significant and their inclusion can help identify important vulnerabilities in the subbasin's approach to groundwater management. The GSP incorporates climate change into key inputs (e.g., precipitation, evapotranspiration, and sea level rise) of the projected water budget. However, imported water should also be adjusted for climate change and incorporated into the surface water flow inputs of the projected water budget. Furthermore, the GSP does not provide a sustainable yield based on the projected water budget with climate change incorporated. If the water budgets are incomplete, including the omission of projected climate change effects on imported water inputs, and sustainable yield is not calculated based on climate change projections, then there is increased uncertainty in virtually every subsequent calculation used to plan for projects, derive measurable objectives, and set minimum thresholds. Plans that do not adequately include climate change projections may underestimate future impacts on vulnerable beneficial users of groundwater such as ecosystems, DACs, and domestic well owners.		
	Figure: 3-11		**NC, CWA, LGC, UCS, Audubon**	The consideration of beneficial users when establishing monitoring networks is insufficient, due to lack of specific plans to increase the Representative Monitoring Sites (RMSs) in the monitoring network that represent water quality conditions and shallow groundwater elevations around DACs and domestic wells in the subbasin. Figure 3-11 (Groundwater Quality RMS Wells) shows insufficient representation of DACs and drinking water users for water quality monitoring. Figure 3-15 (Shallow Aquifer Groundwater Level RMS Wells) shows insufficient representation of DACs and drinking water users for shallow groundwater elevation monitoring. Refer to Attachment E for maps of these monitoring sites in relation to key beneficial users of groundwater. These beneficial users may remain unprotected by the GSP without adequate monitoring and identification of data gaps in the shallow aquifer. The Plan therefore fails to meet SGMA's requirements for the monitoring network.	Provide maps that overlay current and proposed monitoring well locations with the locations of DACs, domestic wells, GDEs, and ISWs to clearly identify monitored areas. Increase the number of RMSs in the shallow aquifer across the subbasin as needed to adequately monitor all groundwater condition indicators across the subbasin and at appropriate depths for *all* beneficial users. Prioritize proximity to DACs, domestic wells, GDEs, and ISWs when identifying new RMSs. Ensure groundwater elevation and water quality RMSs are monitoring groundwater conditions spatially and at the correct depth for *all* beneficial users - especially DACs, domestic wells, and GDEs.	A sufficient degree of monitoring is provided in relation to DACs and domestic wells (see GSP Section 3.5.1.1); especially when considering that DACs are not dependent on groundwater and domestic wells are only used to supplement irrigation water supplies. Residents of DACs and domestic well owners have access to high quality water supplies served by EBMUD and Hayward.
Section 4.1.1			**NC, CWA, LGC, UCS, Audubon**	The consideration of beneficial users when developing projects and management actions is insufficient due to the failure to completely identify benefits or impacts of identified projects and management actions, including water quality impacts, to key beneficial users of groundwater such as GDEs, aquatic habitats, surface water users, DACs, and drinking water users.	For DACs and domestic well owners, include a drinking water well impact mitigation program to proactively monitor and protect drinking water wells through GSP implementation. Refer to Attachment B for specific recommendations on how to implement a drinking water well mitigation program.	The potential impacts of proposed projects and management actions were sufficiently evaluated using the groundwater model and other available data (see Appendix 6.E, Section 6.3). Potential impacts (i.e., drawdown) to shallow groundwater levels were quantified and found to be negligible. Therefore, beneficial users will be protected. Monitoring will be conducted

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				Therefore, potential project and management actions may not protect these beneficial users. Groundwater sustainability under SGMA is defined not just by sustainable yield, but by the avoidance of undesirable results for *all* beneficial users. While Section 4.1.1 documents EBMUD's potable water injection facility, it fails to describe the project's explicit benefits or impacts to beneficial users, such as DACs. The plan also fails to include a domestic well mitigation program to avoid significant and unreasonable loss of drinking water.	For DACs and domestic well owners, include a discussion of whether potential impacts to water quality from projects and management actions could occur and how the GSAs plan to mitigate such impacts. Recharge ponds, reservoirs, and facilities for managed stormwater recharge can be designed as multiple-benefit projects to include elements that act functionally as wetlands and provide a benefit for wildlife and aquatic species. For guidance on how to integrate multi-benefit recharge projects into your GSP, refer to the "Multi-Benefit Recharge Project Methodology Guidance Document. Develop management actions that incorporate climate and water delivery uncertainties to address future water demand and prevent future undesirable results.	to further confirm that no significant and unreasonable impacts to key beneficial users occur. As already stated in other responses, DACs and domestic wells owners are not dependent on groundwater for drinking water. Domestic wells only provide supplemental irrigation water. Residents of DACs and domestic well owners have access to high quality water supplies from EBMUD and Hayward. EBMUD's Bayside Phase 1 Well is intended to only be used during extended droughts for which groundwater would be a small component of supply for both DAC and non-DAC areas. The GSAs ensure that the drinking water continues to meet or exceed State and Federal water quality standards when additional sources of water are added.

Comment Letters

East Bay Plain Subbasin Groundwater Sustainability Plan
Public Draft Comment Form

INSTRUCTIONS

1. Please use the table below to enter your comments. Use only the Microsoft Word or PDF document titled "East Bay Plain Subbasin GSP Comments".

2. Once you have completed all your comments, please save the file with your last name or organization at the end in parentheses. For example:
    - *East Bay Plain Subbasin GSP Comments (Smith)*

3. Email the completed form to Amy Underwood at amy@ebmud.com

4. Comments are due by **November 1, 2021.**

East Bay Plain Subbasin Groundwater Sustainability Plan
Public Draft Comment Form

Comments are due by November 1, 2021

Commenter Name: Karineh Samkian **Commenter Affiliation (if applicable):** City of San Pablo

Contact Information (Optional): (mailing address, phone number, and/or email):

1000 Gateway Ave, San Pablo, CA 94806, 510-215-3064/karinehs@sanpabloca.gov

Section/ Subsection Number	Page Number	Figure/ Table Number (if applicable)	Comment
Executive Summary	23		Where it states a future project under consideration is the use of groundwater to supplement flows into San Leandro Creek, it may be good to clarify that there is a current agreement to release water from the dam.
Executive Summary	25		Since the sustainability goals are already met per Section 3.1.2 (page 4), future monitoring and management actions should consider minimizing the cost impacts on ratepayers.
2.1.1	1		It may help to clarify at the beginning of the paragraph that GSP regulations require that federal lands (including tribal lands) be identified in the report.
3.5.2.8	68		Please explain what kind of biological monitoring is required for the identified Groundwater Dependent Ecosystems. This section states it is baseline to be repeated every 5 years. Section 4.1.2.1.4 mentions specific species and rooting depth. Since there are 127 acres of land to be monitored, it can get quite costly. If allowed by the SGMA, costs should be factored into the decision on the extent of the biological monitoring, as sometimes a simpler monitoring plan can provide the necessary information.

From:	Underwood, Amy
To:	Su, Grace
Subject:	FW: City of San Leandro Comments on the Draft East Bay Plain Subbasin Groundwater Sustainability Plan
Date:	Monday, November 1, 2021 11:09:11 AM
Attachments:	image002.jpg

Amy Underwood
EBMUD
Water Supply Improvements
amy@ebmud.com

From: Pollart, Debbie <DPollart@sanleandro.org>
Sent: Monday, November 1, 2021 11:00 AM
To: Underwood, Amy <amy.underwood@ebmud.com>
Subject: City of San Leandro Comments on the Draft East Bay Plain Subbasin Groundwater Sustainability Plan

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Hello Ms. Underwood – Below are the City of San Leandro's comments on the Draft East Bay Plain Groundwater Sustainability Plan. We appreciate the opportunity to provide comment on this document and look forward to reviewing the Final Plan.

General Comments

The high uncertainty in the current climate modeling for increased precipitation and evapotranspiration may warrant a more conservative approach for the groundwater recharge and streamflow levels than were modeled and discussed in the Draft Plan. Additionally, there may be unanticipated interactions between increased sea level rise, increased precipitation, and groundwater recharge. The City requests that an indicator be added around localized flooding and subsequent monitoring actions.

The City of San Leandro also has general equity concerns about the potential distribution of water and their source quality. This should be included and discussed in the Final Plan as well as in future updates to the Plan.

Specific Comments

-

- *In Executive Summary, Page 8, Chapter 2:* Under 'Description of the Plan Area' it states "The Subbasin does not contain federal or state lands…"

However, there are portions of the marshlands that are under long-term lease from the State Lands Commission.

- *In Executive Summary, Page 13:* Under 'Future Scenario' it states "The recharge of the basin will slightly outpace discharge from the basin, resulting in a net benefit increase in basin storage." When California has experienced multi-year drought events (as long as 8 consecutive years), what is the basis for this statement?
- *In Chapter 1, Figure 1-1:* Please provide the complete link for the source of identified DACs and SDACs. In looking online at the 'US Census-cities' as noted in the graphic's legend, information appeared to not be the same as represented in the graphic (San Leandro as shown in the graphic is underrepresented). Why wasn't OEHHA or California Climate Investments Priority Populations 3.0 by Census Tract data used?
- *Chapter 2, Section 2.1.2.3, Land Subsidence Monitoring, top of Page 9:* It states that Appendix 2.A.b presents additional information on extensometer monitoring. Appendix 2 is comprised of 3,511 pages. A more specific citation, including a page number would be helpful.
- *Chapter 2, Section 2.1.4.3, Page 13:* It states "…numerous types of facilities and land uses can be potential sources of chemical constituents…". Specific examples should be included so readers have a more complete understanding.
- *Chapter 2, Section 2.1.4.9, Page 15:* Is there no more recent data than 2010 regarding total water demand?
- *Chapter 2, Section 2.1.4.9, Page 15:* What is the status for implementation of the conservation measures noted approximately mid-page?
- *Chapter 2, Section 2.2.1.2, Page 23:* What is the basis for the sentence "It is likely that the Deep Aquifer Zone extends a significant distance to the west beneath San Francisco Bay…"?
- *Chapter 2, Section 2.2.1.4, Page 25:* Appendix 2.A.b was again noted (as reference for a long-term regional test of groundwater elevations). A more specific reference, including a page number would be helpful, especially as this appendix has over 3,500 pages. With San Leandro primarily underlain by the intermediate and deep aquifers, and based on the Figures listed in Appendix 2.A.b, it appears that the long-term testing dates back to 1953 for the intermediate aquifer and 1965 for the deep aquifer. However, as evidenced by the Figures 5 series, the comparison of groundwater elevations in the corresponding Spring and Fall (and looking at just either the Intermediate Aquifer or Deep Aquifer) don't always show that the same locations were tested (for example, the measured elevation 'dot' shown near the western end of San Leandro Creek on the Intermediate Aquifer Contour Maps starting in 1953, is absent in the Fall 2002 Map). How can historic data be reliably used to hypothesize on potential future conditions if it's not an 'apples-to-apples'

comparison?

- *Chapter 2, Section 2.2.2.5, Page 36:* Regarding this section's discussion of land subsidence, I would agree that further evaluation and on-going management of the potential for land subsidence should occur. In looking at the historic groundwater levels, it's important to note that when the data started to be recorded back in 1953, the portions of the City covered by hardscape was much less than what exists today, and C3 requirements for development did not exist. A logical conclusion would be that the region's ability to recharge groundwaters has been reduced as development has expanded, and this factors in to future projections (not just how much is pumped in/out of the aquifers).
- *Chapter 2, Section 2.2.3.6, Page 46:* Did Muir's study look at subsidence?
- *Chapter 2, Section 2.2.3.6, Page 47:* In mentioning sewer pipe outflow, was there any consideration of the court order that EBMUD is under and/or sewer lateral ordinances that many jurisdictions have enacted? The assumption being that the contribution of sewer pipe outflow should be decreasing over time.
- *Chapter 3, Section 3.2.4, Pages 9 and 25:* Why is regional-scale damage to public infrastructure the only metric for determining significance of subsidence? There are hundreds (if not 1,000+) of San Leandro homes in proximity to the EBMUD Bayside Phase 1 Facility that would be impacted should subsidence occur in the future.
- *Chapter 3, Section 3.3.6.1, Page 35:* The statement "…the change in connectivity along San Leandro Creek has no significant effect on stream-aquifer interaction because the channel is lined" is partially incorrect. A majority of San Leandro Creek is <u>not</u> lined (only the portion west of approximately Alvarado St. is lined).
- *Chapter 3, Section 3.5.1.4, Page 58:* The second bullet "Review periodic subsidence surveys that may be conducted by others" seems to imply that if no other agency/entity has a study performed, then there would be nothing to review. Given the ongoing cycle of drought years (some historically extending to 6 consecutive years), EBMUD should be required to have subsidence reports completed whenever groundwater levels in the Subbasin come within a certain percentage of the minimum threshold for subsidence.

<u>Typos</u>

- Chapter 2, Page 14, Section 2.1.4.9, third line: "…EBMUD prepare**d**…"
- Chapter 2, Page 28, 'Spring' is both capitalized (Spring 2002) and lowercase (spring 2018)
- Chapter 2, Page 44, line 11: "However, there is significant uncertainty ~~**is**~~ associated with…"

Chapter 4, Page 13, Section 4.1.3.2: "This potential future project would use ~~of~~ groundwater in lieu…"

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ALAMEDA COUNTY WATER DISTRICT

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October 29, 2021

Ms. Kelly McAdoo, City Manager
City of Hayward
777 B Street
Hayward, CA 94541

Mr. Clifford C. Chan
East Bay Municipal Utility District
375 11th Street
Oakland, CA 94607

Dear Ms. McAdoo and Mr. Chan:

Subject: Draft Groundwater Sustainability Plan for the East Bay Plain Subbasin 2-09.04

The Alameda County Water District (ACWD) wishes to thank you for the opportunity to comment on the Draft Groundwater Sustainability Plan (GSP) for the East Bay Plain Subbasin, and for the ongoing coordination between our agencies on our respective Sustainable Groundwater Management Act (SGMA) efforts. ACWD is the Groundwater Sustainability Agency and an exclusive agency created by statute and identified in the SGMA to manage groundwater for the adjacent Niles Cone Subbasin 2-09.01 (Niles Cone). For over 100 years, ACWD has managed the groundwater of the Niles Cone to protect and improve water supplies for all groundwater users and the environment. ACWD has reviewed the Draft GSP and offers the following comments for your consideration:

1. <u>Transition Zone</u>

   a) The Draft GSP has modified the delineation of the Transition Zone between the East Bay Plain and the Niles Cone as originally delineated by Luhdorff & Scalmanini Consulting Engineers (LSCE) in 2003 which is now referred to as a Horizontal Flow Barrier (HFB) used in the groundwater model (2021 EBPGWM) supporting the Draft GSP. In regard to the HFB, the Draft GSP states “the western extent is uncertain; however, it is consistent with a concealed bedrock fault delineated by DWR (1967) parallel to the transition zone and extending into San Francisco Bay. In addition, the extent of the HFB was refined based on model calibration, and the final extent used in the 2021 EBPGWM provided the best overall calibration of simulations to the long-term aquifer pumping tests conducted at the City of Hayward Wells C and E (LSCE, 2003), and the EBMUD Bayside Well (Fugro, 2010)" (Section 3.3.1.5, page 14, of the Groundwater Model Documentation in Appendix 6).

While such a fault could have hydrogeologic implications for the Santa Clara Basin, multiple factors suggest that further investigation of its presence is warranted. For example, this fault is unlikely in the broader structural geologic context. It is oriented approximately northeast-southwest, perpendicular all major faults in the region, and at odds with the orientation of the dominant structural forces since the Oligocene. Also, more recent reports do not appear to corroborate the existence of this fault. For instance, regional seismic refraction surveys by the USGS have shown that the substantial vertical offset interpreted from DWR's gravity survey is not present (Hazelwood, 1976). Later USGS aeromagnetic surveys also did not identify any comparable fault (Brabb and Hanna, 1981), while a USGS comprehensive review of the region's buried faults suggested that "…any continued dependence on the Department of Water Resources maps or their derivatives is now without foundation" including those of DWR, 1967 (Wentworth et al., 2010).

ACWD has successfully implemented the transition zone in the NEBIM and modeled flows between the basins using the transition zone concept described by LSCE (2003) (and used the LSCE and Fugro 2010 pump test data). The NEBIM has been reasonably calibrated to the long-term trends in groundwater levels and short-term drawdowns experienced with the aquifer tests.

b) In addition, the Draft GSP states "a regional aquifer test is planned to further investigate the hydraulic connection between East Bay Plain and Niles Cone Subbasins in 2021. The results from this test will be incorporated in future GSP modeling efforts and refinement of the GSP. Analyses and application of these aquifer test data in groundwater modeling will be instrumental in evaluating the degree of hydraulic connection between two Subbasins" (Section 7.2.3, page 104, of the Hydrogeologic Conceptual Model).

ACWD appreciates and supports the future aquifer pump tests proposed in the Draft GSP and further investigation of the nature of the stratigraphy between the East Bay Plain and the Niles Cone as it may relate to the potential for inter-basin exchanges of groundwater. Additional pump tests and studies will provide more information about the interconnection between the respective Subbasins. In addition, it can identify possible data gaps and improve simulation of inter-basin flow. As in previous pump tests, ACWD looks forward to coordinating on such efforts.

Our quarterly adjacent basin coordination meetings have been very informative and productive for our respective agencies and we fully support continuing these meetings in the future. These meetings provide a great venue to discuss respective groundwater basin management and project activities, as well as model specifics which lead to additional coordination and collaboration between our agencies.

c) The Draft GSP discusses the northwest area of the transition zone between the basins (Section 2.2.1.2 of the Draft GSP and ES-1 in the Groundwater Model Documentation in Appendix 6). The existing boundary is consistent with ACWD's pre-existing jurisdiction and legal authority and coincides with the geographic limits of the groundwater management authority long ago established to ACWD as a replenishment agency that was confirmed through DWR's Basin Boundary Modification to correct the graphical representation included in Bulletin 118 (2003). As previously stated, ACWD looks forward to continuing to coordinate with EBMUD and the City on evaluations of the hydraulic connections of the transition zone, including the northwest area.

2. Proposed Nested Wells

The Draft GSP proposes to construct nested wells to monitor water levels near the Niles Cone. ACWD has advocated the more conventional approach of drilling separate single-cased wells since the validity of water level and quality data generated from nested wells may have issues due to artificial leakage between water-bearing zones. This is supported by concerns asserted by the Department of Water Resources (DWR) on page 37 of Bulletin 74-90. Bulletin 74-90 states that; "A nested monitoring well can be difficult to construct because of multiple casings within the same borehole. Care is required during construction to ensure water-bearing zones for each casing string are hydraulically isolated from one another and the annular seals are effective." As a result, DWR Bulletin 74-90 requires that "casing spacers shall be used within the intervals to be sealed to separate individual well casing strings from one another in a borehole of a nested monitoring well. The spacers shall be placed at intervals along the casing to ensure a minimum separation of 2 inches between individual casing strings" (page 44 of DWR Bulletin 74-90). Therefore, if the nested wells will penetrate more than one aquifer, the construction of the nested wells should follow the DWR Bulletin 74-90 minimum requirements for sealing off strata and placement of annular seal material.

3. Water Quality

The Draft GSP has figures showing water quality data in the Niles Cone that do not appear to show actual conditions. For example, Figure F-25 in Appendix F shows "Average" Nitrate conditions for wells deeper than 50 feet but doesn't indicate if those are historical or current averages since enactment of SGMA. Also, Figure F-32 in Appendix F shows wells deeper than 50 feet where Nitrate data was collected after 2015 in the Niles Cone (the purple locations). It appears these results are from the GAMA mapping tool and may be from wells less than 50 feet based on ACWD's initial review.

ACWD found that Table C-2 in Appendix C Summary of Groundwater Conditions includes nitrate concentrations for wells in the EBP, but it does not appear to identify the wells located in the Niles Cone used to create the various water quality maps in the Draft GSP. ACWD requests that the Draft GSP Figures either clarify the time period for the various water quality results as a footnote in the figure or include Niles Cone data in a similar table as C-2 so ACWD can adequately review the information provided.

4. Future Projects

The Draft GSP states: "If GSAs in the EBP Subbasin implement additional projects to increase net extraction, additional evaluation of potential impacts to neighboring subbasins will be conducted at that time." ACWD appreciates that this additional evaluation will be done and looks forward to coordinating with EBMUD and the City of Hayward on any future projects in the southern portion of the EBP. ACWD has plans to model the projects presented in the Draft GSP in the near future and looks forward to discussing ACWD's modeling results once complete during the quarterly coordination meetings.

5. Coordination and Contact Information

ACWD's comments are based on our initial review of the Draft GSP and we will continue to review this extensive document. Once again, ACWD would like to thank you for the opportunity to provide comments on the Draft GSP and we look forward to our agencies' ongoing coordination and cooperation in the quarterly adjacent basin coordination meetings and in our collaborative modeling efforts.

Please call Michelle Myers, Groundwater Resources Manager at (510) 668-4454 if you or your team would like more information regarding ACWD's activities related to the Sustainable Groundwater Management Act.

Sincerely,

Ed Stevenson
General Manager

mam/tf
cc: Alex Ameri, City of Hayward
Cheryl Munoz, City of Hayward
Linda Ko, City of Hayward
Michael Tognolini, EBMUD
Linda Hu, EBMUD
Bradley Ledesma, EBMUD
Grace Su, EBMUD
Amy Underwood, EBMUD
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State of California – Natural Resources Agency
DEPARTMENT OF FISH AND WILDLIFE
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GAVIN NEWSOM, Governor
CHARLTON H. BONHAM, Director

October 29, 2021

Amy Underwood
East Bay Municipal Utility District Groundwater Sustainability Agency
amy@ebmud.com

Subject: CALIFORNIA DEPARTMENT OF FISH AND WILDLIFE COMMENTS ON THE EAST BAY PLAIN SUBBASIN GROUNDWATER BASIN DRAFT GROUNDWATER SUSTAINABILITY PLAN

Dear Linda Ko:

The California Department of Fish and Wildlife (Department) appreciates the opportunity to provide comments on the East Bay Plain Groundwater Sustainability Agency (GSA) Draft East Bay Plain Subbasin Groundwater Sustainability Plan (GSP) prepared pursuant to the Sustainable Groundwater Management Act (SGMA). The Basin is designated as ‘Medium’ priority under SGMA and must be managed under a GSP by January 31, 2022.

The Department is writing to support ecosystem preservation and enhancement in compliance with SGMA and its implementing regulations based on Department expertise and best available information and science. As trustee agency for the State’s fish and wildlife resources, the Department has jurisdiction over the conservation, protection, and management of fish, wildlife, native plants, and the habitat necessary for biologically sustainable populations of such species (Fish & G. Code §§ 711.7 and 1802).

Development and implementation of GSPs under SGMA represents a new era of California groundwater management. The Department has an interest in the sustainable management of groundwater, as many sensitive ecosystems, species, and public trust resources depend on groundwater and interconnected surface waters (ISWs), including ecosystems on Department-owned and managed lands within SGMA-regulated basins.

SGMA and its implementing regulations afford ecosystems and species specific statutory and regulatory consideration, including the following as pertinent to GSPs:

- GSPs must **consider impacts to groundwater dependent ecosystems** (GDEs) (Water Code § 10727.4(l); see also 23 CCR § 354.16(g));
- GSPs must consider the interests of all beneficial uses and users of groundwater, including environmental users of groundwater (Water Code § 10723.2) and GSPs must **identify and consider potential effects on all**

beneficial uses and users of groundwater (23 CCR §§ 354.10(a), 354.26(b)(3), 354.28(b)(4), 354.34(b)(2), and 354.34(f)(3));

- GSPs must **establish sustainable management criteria that avoid undesirable results** within 20 years of the applicable statutory deadline, including **depletions of interconnected surface water that have significant and unreasonable adverse impacts on beneficial uses of the surface water** (23 CCR § 354.22 *et seq*. and Water Code §§ 10721(x)(6) and 10727.2(b)) and describe monitoring networks that can identify adverse impacts to beneficial uses of interconnected surface waters (23 CCR § 354.34(c)(6)(D)); and

- GSPs must **account for groundwater extraction for all water use sectors,** including managed wetlands, managed recharge, and native vegetation (23 CCR §§ 351(al) and 354.18(b)(3)).

Furthermore, the Public Trust Doctrine imposes a related but distinct obligation to consider how groundwater management affects public trust resources, including navigable surface waters and fisheries. Groundwater hydrologically connected to surface waters is also subject to the Public Trust Doctrine to the extent that groundwater extractions or diversions affect or may affect public trust uses. (*Environmental Law Foundation v. State Water Resources Control Board* (2018), 26 Cal. App. 5th 844; *National Audubon Society v. Superior Court* (1983), 33 Cal. 3d 419). The GSA has “an affirmative duty to take the public trust into account in the planning and allocation of water resources, and to protect public trust uses whenever feasible.” (*National Audubon Society*, *supra*, 33 Cal. 3d at 446). Accordingly, groundwater plans should consider potential impacts to and appropriate protections for ISWs and their tributaries, and ISWs that support fisheries, including the level of groundwater contribution to those waters.

In the context of SGMA statutes and regulations, and Public Trust Doctrine considerations, groundwater planning should carefully consider and protect environmental beneficial uses and users of groundwater, including fish and wildlife and their habitats, GDEs, and ISWs.

The Department recognizes and appreciates the effort of the GSA to characterize subbasin groundwater conditions based on the data available. However, the Department believes the GSP could improve its consideration of environmental users of groundwater, interconnected surface waters, and establish more protective management criteria. Accordingly, the Department recommends that the East Bay Plain GSA address the following comments below before submitting the GSP to the Department of Water Resources (DWR).

COMMENTS AND RECOMMENDATIONS

The Department comments are as follows:

Consideration of Groundwater Dependent Ecosystems and Interconnected Surface Waters

GSPs must consider the interests of all beneficial uses and users of groundwater, including environmental users of groundwater. (Water Code § 10723.2). GSPs must also identify and consider potential effects on all beneficial uses and users of groundwater. (23 CCR §§ 354.10(a), 354.26(b)(3), 354.28(b)(4), 354.34(b)(2), and 354.34(f)(3)). The Draft GSP does not adequately identify all the environmental users in the Basin, their locations, the groundwater dependent habitat they depend on at certain life stages, and how the Draft GSP will meet their needs. GSPs must consider impacts to GDEs. (Water Code § 10727.4(l); see also 23 CCR § 354.16(g)). The Department is uncertain whether the Draft GSP accurately identifies all GDEs in the Basin or considers all the potential impacts to them due to groundwater pumping.

Table 2-5 in the GSP lists Potential Groundwater Dependent Ecosystems and includes habitat classifications based on imagery analysis including Riparian Mixed Shrub/Hardwood, Riparian Mixed Hardwood, and Riparian Oak Woodland. However, the Draft GSP did not provide objectives that would be anticipated to support potential GDEs and does not include any discussion regarding aquatic fish and wildlife species that depend on surface water flow in the GSP area that could be impacted by groundwater pumping. This potentially includes critical species such as anadromous salmonids and the California red-legged frog (CRLF). The Draft GSP does not indicate where these species might be found in the basin and how these species could potentially be impacted by groundwater pumping. Future planned biological surveys seem to target plant species.

While the GSP acknowledges the need to collect additional data on GDEs and ISWs and mentions some potential GDEs, the Draft GSP does not fully take into account or describe all special status or locally significant fish and wildlife species and habitats that potentially benefit from or are dependent on groundwater within the planning area. The plan does not identify all expected species, habitat, or ecosystem outcomes (both benefits and challenges) associated with each interim milestone or measurable objective being evaluated. GSPs must consider impacts to GDEs. (Water Code § 10727.4(l); see also 23 CCR § 354.16(g)). The Draft GSP does not provide sufficient detail when describing the methods that will be used for future planned studies for GDE identification, classification and mapping or information on the methods that will be used.

Recommendation: The Department recommends that clear language be included in the GSP detailing when and how additional GDEs will be identified and mapped. Furthermore, there should be a description of how this information will be used to update the GSP and inform the adaptive management process. The GSA should commit to identifying additional potential GDE units early on in the GSP implementation process. Furthermore, the GSP should commit to allocating monitoring and management resources (e.g., DWR Technical Support Services funding) to priority GDEs and interconnected surface waters that have high habitat value or vulnerability, species dependency, and/or serve as 'indicator' GDEs or interconnected surface waters.

Site selection for additional monitoring should represent the full spectrum of GDEs and interconnected surface waters in the basin. Representative monitoring stations should capture a range of GDE and interconnected surface water characteristics that will inform evaluation of groundwater management impacts over time. These characteristics include but are not limited to: geospatial and temporal habitat coverage; changes in groundwater interconnectivity status; habitat connectivity, heterogeneity, or density; habitat 'health' (e.g., application of biological indices, remote sensing/aerial imagery); and species/vegetation presence (e.g., biological surveys).

Sustainable Management Criteria (SMC) for Depletion of Interconnected Surface Waters (ISWs)

Comment: The GSA has established the following Minimum Threshold (MT) for the SMC for Depletion of ISWs sustainability criteria: "Two feet decline in Water Table Aquifer Zone groundwater levels beneath San Pablo or San Leandro Creek". Minimum Thresholds should ensure regional groundwater extractions do not lead to significant and adverse impacts on fish or wildlife resources by meeting plant and animal species temporal/spatial water needs including water availability especially for Threatened and Endangered species and Species of Special Concern. They should be designed to account for climatic/water year type variability. Where specific data are lacking, MTs should be conservative with respect to preserving fish and wildlife beneficial users of groundwater from undesirable results. Furthermore, the GSP states an undesirable result for this SMC would be "50% or more RMS wells below MT for two consecutive non-drought year spring measurements". It is unclear how the metric for this undesirable result relates to ecological impacts. The GSP should identify monitoring metrics for GDEs that will enable the GSA to characterize GDE vulnerability to groundwater depletion and associated undesirable results, and to undertake management intervention accordingly.

Recommendation: The Department recommends reconsidering this Minimum Threshold and Undesirable Result and revising the GSP to address and describe:

- How Minimum Threshold prevents undesirable results
- The effect the Minimum Threshold will have on environmental beneficial uses and users of groundwater, and what impact it will have on fish and wildlife
- How the Minimum Threshold accounts for climatic/water year type variability

Planned Monitoring to Address Data Gaps

Comment: The GSP acknowledges that more data are needed to better understand groundwater recharge and discharge mechanisms in the Subbasin, including surface water-groundwater interactions and the amount and location of groundwater extractions.

The GSA should consider including RMPs for Interconnected Surface Waters in locations in the GSP area that support anadromous salmonid species. For example, Wildcat Creek might be a location the GSA should consider for additional monitoring. A Department 'Stream Habitat Assessment Report' found that "Wildcat Creek should be managed as an anadromous, natural production stream" (CDFW, 2013).

Recommendation: The Department recommends the GSA make a commitment in the GSP to expand the RMP Network to include areas where potential GDEs exist that may be impacted due to surface water depletions resulting from groundwater pumping.

Implementation/Management Actions

Comment: Management actions should include specifics on how and on what timeline adverse impacts will be reversed, if observed. The GSP should specify adaptive management strategies to account for 'lag' impacts wherein groundwater responses to changes in management regimes are delayed due to aquifer characteristics. Projects and management actions should seek to maximize multiple-benefit solutions, including habitat improvements.

Recommendation: The Department encourages the GSA to consider implementing recharge projects that facilitate floodplain inundation. These projects offer multiple benefits including downstream flood attenuation, groundwater recharge, and ecosystem restoration. Managed floodplain inundation can recharge floodplain aquifers, which in turn slowly release stored water back to the stream during summer months. These projects also reconnect the stream channel with floodplain habitat, which can benefit juvenile salmonids by creating off-channel habitat characterized by slow water velocities, ample cover in the form of submerged vegetation, and high food availability. Additionally, these types of multi-benefit projects likely have more diverse grant funding opportunities that can lower their cost as compared to traditional off-channel recharge projects.

In conclusion, the Department believes the GSP could improve compliance with several aspects of SGMA statutes and regulations by expanding upon its consideration of environmental users of groundwater; refining the Sustainable Management Criteria; improving its assessment of what constitutes an undesirable result for environmental users; and providing better characterization, measurement, and monitoring of interconnected surface water depletions.

If have any questions related to the Department's comments and/or recommendations on the East Bay Plain Groundwater Subbasin Draft GSP please contact Jessie Maxfield, Water Rights Coordinator, at Jessica.maxfield@wildlife.ca.gov.

Sincerely,

DocuSigned by:
Stephanie Fong
CF047D7F8D234E1...

Stephanie Fong
Acting Regional Manager
Bay Delta Region

ec: California Department of Fish and Wildlife

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REFERENCES

CDFW. 2013. California Department of Fish and Wildlife Contra Costa County San Pablo Bay Watershed Stream Habitat Assessment Reports: Wildcat Creek (Surveyed in 2010, Report Completed in 2013)

The Nature Conservancy
Audubon | CALIFORNIA
Local Government Commission
Leaders for Livable Communities
Union of Concerned Scientists
Science for a healthy planet and safer world
CLEAN WATER ACTION | CLEAN WATER FUND

November 1, 2021

East Bay Municipal Utility District
375 11th Street
Oakland, CA 94607

Submitted via email: amy@ebmud.com

Re: Public Comment Letter for East Bay Plain Subbasin Draft GSP

Dear Amy Underwood,

On behalf of the above-listed organizations, we appreciate the opportunity to comment on the Draft Groundwater Sustainability Plan (GSP) for the East Bay Plain Subbasin being prepared under the Sustainable Groundwater Management Act (SGMA). Our organizations are deeply engaged in and committed to the successful implementation of SGMA because we understand that groundwater is critical for the resilience of California's water portfolio, particularly in light of changing climate. Under the requirements of SGMA, Groundwater Sustainability Agencies (GSAs) must consider the interests of all beneficial uses and users of groundwater, such as domestic well owners, environmental users, surface water users, federal government, California Native American tribes and disadvantaged communities (Water Code 10723.2).

As stakeholder representatives for beneficial users of groundwater, our GSP review focuses on how well disadvantaged communities, drinking water users, tribes, climate change, and the environment were addressed in the GSP. While we appreciate that some basins have consulted us directly via focus groups, workshops, and working groups, we are providing public comment letters to all GSAs as a means to engage in the development of 2022 GSPs across the state. Recognizing that GSPs are complicated and resource intensive to develop, the intention of this letter is to provide constructive stakeholder feedback that can improve the GSP prior to submission to the State.

Based on our review, we have significant concerns regarding the treatment of key beneficial users in the Draft GSP and consider the GSP to be **insufficient** under SGMA. We highlight the following findings:

1. Beneficial uses and users **are not sufficiently** considered in GSP development.
    a. Human Right to Water considerations **are not sufficiently** incorporated.
    b. Public trust resources **are not sufficiently** considered.
    c. Impacts of Minimum Thresholds, Measurable Objectives and Undesirable Results on beneficial uses and users **are not sufficiently** analyzed.
2. Climate change **is not sufficiently** considered.

3. Data gaps **are not sufficiently** identified and the GSP **needs additional plans** to eliminate them.
4. Projects and Management Actions **do not sufficiently consider** potential impacts or benefits to beneficial uses and users.

Our specific comments related to the deficiencies of the East Bay Plain Subbasin Draft GSP along with recommendations on how to reconcile them, are provided in detail in **Attachment A.**

Please refer to the enclosed list of attachments for additional technical recommendations:

Attachment A	GSP Specific Comments
Attachment B	SGMA Tools to address DAC, drinking water, and environmental beneficial uses and users
Attachment C	Freshwater species located in the basin
Attachment D	The Nature Conservancy's "Identifying GDEs under SGMA: Best Practices for using the NC Dataset"
Attachment E	Maps of representative monitoring sites in relation to key beneficial users

Thank you for fully considering our comments as you finalize your GSP.

Best Regards,

Ngodoo Atume
Water Policy Analyst
Clean Water Action/Clean Water Fund

J. Pablo Ortiz-Partida, Ph.D.
Western States Climate and Water Scientist
Union of Concerned Scientists

Samantha Arthur
Working Lands Program Director
Audubon California

Danielle V. Dolan

Danielle V. Dolan
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Local Government Commission

E.J. Remson
Senior Project Director, California Water Program
The Nature Conservancy

Melissa M. Rohde

Melissa M. Rohde
Groundwater Scientist
The Nature Conservancy

Attachment A

Specific Comments on the East Bay Plain Subbasin Draft Groundwater Sustainability Plan

1. Consideration of Beneficial Uses and Users in GSP development

Consideration of beneficial uses and users in GSP development is contingent upon adequate identification and engagement of the appropriate stakeholders. The (A) identification, (B) engagement, and (C) consideration of disadvantaged communities, drinking water users, tribes,[1] groundwater dependent ecosystems, streams, wetlands, and freshwater species are essential for ensuring the GSP integrates existing state policies on the Human Right to Water and the Public Trust Doctrine.

A. Identification of Key Beneficial Uses and Users

Disadvantaged Communities and Drinking Water Users

The identification of Disadvantaged Communities (DACs) and drinking water users is **incomplete**. The GSP provides information on DACs, including identification by name and location on a map (Figure 1-1). However, the GSP fails to clearly state the population of each DAC.

The GSP provides a density map of domestic wells in the subbasin (Figure 2-2). However, the plan fails to provide depth of these wells (such as minimum well depth, average well depth, or depth range) within the subbasin.

These missing elements are required for the GSAs to fully understand the specific interests and water demands of these beneficial users, and to support the consideration of beneficial users in the development of sustainable management criteria and selection of projects and management actions.

RECOMMENDATIONS

- Provide the population of each identified DAC.
- Include a map showing domestic well locations and average well depth across the subbasin.

Interconnected Surface Waters

The identification of Interconnected Surface Waters (ISW) is **insufficient**, due to lack of supporting information provided for the ISW analysis.

Section 2.2.2.6 of the GSP describes surface water and groundwater Interaction. This section concludes with the following statement (p. 2-36): *"In general, depths to groundwater in the Upper Shallow Aquifer Zone are less than 20 ft bgs in most of the EBP Subbasin, although there are*

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[1] Our letter provides a review of the identification and consideration of federally recognized tribes (Data source: SGMA Data viewer) within the GSP from non-tribal members and NGOs. Based on the likely incomplete information available to our organizations for this review, we recommend that the GSA utilize the California Department of Water Resources' "Engagement with Tribal Governments" Guidance Document (https://water.ca.gov/Programs/Groundwater-Management/SGMA-Groundwater-Management/Best-Management-Practices-and-Guidance-Documents) to comprehensively address these important beneficial users in their GSP.

some areas with groundwater levels between 20 ft and 30 ft bgs or more. Overall, depth to groundwater generally decreases from northeast (near the East Bay Hills) to southwest (San Francisco Bay) across the Subbasin, albeit with significant local variations. Thus, it can be expected that the potential for surface water/groundwater connection increases from east to west. In addition, where a surface water/groundwater connection is present, it can be expected that losing conditions are more likely in the eastern portion of the Subbasin and gaining conditions have more potential to occur in the western portion of the Subbasin. It should also be noted that portions of creek lengths are lined within the EBP Subbasin; particularly, for San Lorenzo Creek where a majority of the creek bed is lined until about one mile inland from the Bay Margin."

Appendix H of Appendix 2.A.b provides a review of prior surface water - groundwater interaction studies. It concludes with the following statement: *"Taken together, the studies document flashy stream behavior, with a major component of streamflow generation from groundwater, even during runoff events."* The two sections of the GSP described herein imply that most or all of the subbasin's surface water reaches are interconnected. However, no figure of stream reaches in the subbasin is provided that presents the conclusions of the ISW analysis.

Section 2.2.2.6 of the GSP (Surface Water/Groundwater Interaction) refers to Figure 2-37 (Map of Depth to Water Table – Spring 2015). These are the only data discussed when referring to depth to water. Using seasonal groundwater elevation data over multiple water year types is an essential component of identifying ISWs. The use of data from one point in time does not reflect the temporal (seasonal and interannual) variability inherent in California's climate.

RECOMMENDATIONS

- Provide a map showing all the stream reaches in the subbasin, with reaches clearly labeled as interconnected (gaining/losing) or disconnected. Consider any segments with data gaps as potential ISWs and clearly mark them as such on maps provided in the GSP.

- Provide depth-to-groundwater contour maps using the best practices presented in Attachment D. Specifically, ensure that the first step is contouring groundwater elevations, and then subtracting this layer from land surface elevations from a digital elevation model (DEM) to estimate depth to groundwater contours across the landscape. This will provide accurate contours of depth-to-groundwater along streams and other land surface depressions where GDEs are commonly found.

- Use seasonal data over multiple water year types to capture the variability in environmental conditions inherent in California's climate, when mapping ISWs. We recommend the 10-year pre-SGMA baseline period of 2005 to 2015.

Groundwater Dependent Ecosystems

The identification of Groundwater Dependent Ecosystems (GDEs) is **insufficient**. The GSP took initial steps to identify and map GDEs using the Natural Communities Commonly Associated with Groundwater dataset (NC dataset), referred to as the iGDE dataset in the GSP. However, we found that some mapped features in the NC dataset were improperly disregarded. NC dataset polygons were incorrectly removed in areas adjacent to irrigated fields or due to the presence of surface water supplies. However, this removal criteria is flawed since GDEs can rely on multiple water sources – including shallow groundwater receiving inputs from irrigation return flow from nearby irrigated fields – simultaneously and at different temporal/spatial scales. NC dataset polygons adjacent to irrigated land or surface water supplies can still potentially be reliant on shallow groundwater aquifers, and therefore should not be removed solely based on their proximity to irrigated fields or surface water supplies.

The GSP states that depth to groundwater from fall 2014 and spring 2015 (Figures 5-61 and 5-62) were used to assess the GDE polygons' connection to groundwater. The GSP states (p. 66 of Appendix 2.A.b): *"No GDEs were excluded based on depth to groundwater. Depth to groundwater, based on Fall 2014 data, was 30 ft or less across the East Bay Subbasin (although data are lacking for most areas along the eastern margin of EBP Subbasin where depth to water may be greatest)."* While we recognize that no NC dataset polygons were removed based on depth to groundwater, we recommend using groundwater data from multiple seasons and water year types to determine the range of depth to groundwater around NC dataset polygons and to more completely describe groundwater conditions within the subbasin's GDEs.

The GSP states (p. 65 of Appendix 2.A.b): *"After review of aerial imagery, a total of 38 acres of potential GDEs were excluded from the original iGDE database, 537 acres were flagged as needing additional data (e.g., field assessments), and 154 were verified as potential GDEs."* The GSP continues (p. 70 of Appendix 2.A.b): *"Field investigations for the 537 acres of features flagged as needing additional data are recommended in the future (after submittal of the GSP) to better assess vegetation communities and hydrologic inputs."* We recommend that the 537 acres flagged as needing additional data are also included as potential GDEs until the data gaps are filled.

RECOMMENDATIONS

- Use depth-to-groundwater data from multiple seasons and water year types (e.g., wet, dry, average, drought) to determine the range of depth to groundwater around NC dataset polygons. We recommend that a baseline period (10 years from 2005 to 2015) be established to characterize groundwater conditions over multiple water year types. Refer to Attachment D of this letter for best practices for using local groundwater data to verify whether polygons in the NC Dataset are supported by groundwater in an aquifer.

- Provide depth-to-groundwater contour maps, noting the best practices presented in Attachment D. Specifically, ensure that the first step is contouring groundwater elevations, and then subtracting this layer from land surface elevations from a DEM to estimate depth-to-groundwater contours across the landscape.

- If insufficient data are available to describe groundwater conditions within or near polygons from the NC dataset, include those polygons as "Potential GDEs" in the GSP until data gaps are reconciled in the monitoring network.

Native Vegetation and Managed Wetlands

Native vegetation and managed wetlands are water use sectors that are required to be included into the water budget.[2,3] The integration of native vegetation into the water budget is **insufficient**. The water budget did not explicitly include the current, historical, and projected demands of native vegetation. The omission of explicit water demands for native vegetation is problematic because key environmental uses of groundwater are not being accounted for as water supply decisions are made using this budget, nor will they likely be considered in project and management actions. Managed wetlands are not mentioned in the GSP, so it is not known whether or not they are present in the subbasin.

RECOMMENDATIONS

- Quantify and present all water use sector demands in the historical, current, and projected water budgets with individual line items for each water use sector, including native vegetation.
- State whether or not there are managed wetlands in the subbasin. If there are, ensure that their groundwater demands are included as separate line items in the historical, current, and projected water budgets.

B. Engaging Stakeholders

Stakeholder Engagement during GSP development

Stakeholder engagement during GSP development is **insufficient**. SGMA's requirement for public notice and engagement of stakeholders is not fully met by the description in the Stakeholder Communication and Engagement Plan (Appendix 2.B.a).[4] We note the following deficiencies with the overall stakeholder engagement process:

- The opportunities for public involvement and engagement are described in very general terms for listed stakeholders. They include attendance at GSA board and general stakeholder meetings, updates to the SGMA webpage, and access to GSA staff via email/telephone. There is no described outreach during the GSP development process that is specifically directed at DACs, domestic well owners, or environmental stakeholders.
- Aside from the continuation of engagement strategies used during the GSP development process, the Stakeholder Communication and Engagement Plan does not include a detailed plan for continual opportunities for engagement through the *implementation* phase of the GSP that is specifically directed to DACs, domestic well owners, and environmental stakeholders.

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[2] "'Water use sector' refers to categories of water demand based on the general land uses to which the water is applied, including urban, industrial, agricultural, managed wetlands, managed recharge, and native vegetation." [23 CCR §351(al)]

[3] "The water budget shall quantify the following, either through direct measurements or estimates based on data: (3) Outflows from the groundwater system by water use sector, including evapotranspiration, groundwater extraction, groundwater discharge to surface water sources, and subsurface groundwater outflow." [23 CCR §354.18]

[4] "A communication section of the Plan shall include a requirement that the GSP identify how it encourages the active involvement of diverse social, cultural, and economic elements of the population within the basin." [23 CCR §354.10(d)(3)]

RECOMMENDATIONS

- In the Stakeholder Communication and Engagement Plan, describe active and targeted outreach to engage DAC members, domestic well owners, and environmental stakeholders throughout the GSP development and implementation phases. Refer to Attachment B for specific recommendations on how to actively engage stakeholders during all phases of the GSP process.
- Utilize DWR's tribal engagement guidance to comprehensively address all tribes and tribal interests in the subbasin within the GSP.[5]

C. Considering Beneficial Uses and Users When Establishing Sustainable Management Criteria and Analyzing Impacts on Beneficial Uses and Users

The consideration of beneficial uses and users when establishing sustainable management criteria (SMC) is **insufficient**. The consideration of potential impacts on all beneficial users of groundwater in the basin are required when defining undesirable results and establishing minimum thresholds.[6,7,8]

Disadvantaged Communities and Drinking Water Users

For chronic lowering of groundwater levels, the minimum threshold for shallow aquifer zone groundwater levels is set at 50 feet below the ground surface. To explain the rationale, the GSP states (p. 3-15): *"California well standards require a minimum 50-foot well seal for community water system and municipal water supply wells. Domestic and industrial wells have a 20-foot minimum well seal requirement. With respect to development of drinking water supply wells in the urban EBP Subbasin (including domestic wells that may serve as drinking water supply wells), it is reasonable to assume that drinking water supply wells of any type would have a well seal that is at least 50-feet or greater in depth (preferably at least 100 feet deep) to protect the well from potential contaminants originating at ground surface (e.g., fuel hydrocarbons, solvents, nitrate) that are known to impact the upper 100 feet of sediments in the EBP Subbasin. Thus, a conservative assumption is that drinking water supply wells are a minimum of 60 feet deep to allow for a 50-foot well seal and some intake area; it is very likely that drinking water supply wells would need to be considerably deeper than 60 feet to obtain groundwater of suitable quality and to have some protection against the most likely potential contaminants. Based on the assessment of the DWR WCR database described above, the methodology for establishing MT for the shallow (water table) zone chronic lowering of groundwater levels is based in part on an assumed minimum well depth for drinking water supply wells of 60 feet."*

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[5] Engagement with Tribal Governments Guidance Document. Available at: https://water.ca.gov/-/media/DWR-Website/Web-Pages/Programs/Groundwater-Management/Sustainable-Groundwater-Management/Best-Management-Practices-and-Guidance-Documents/Files/Guidance-Doc-for-SGM-Engagement-with-Tribal-Govt_ay_19.pdf

[6] "The description of undesirable results shall include [...] potential effects on the beneficial uses and users of groundwater, on land uses and property interests, and other potential effects that may occur or are occurring from undesirable results." [23 CCR §354.26(b)(3)]

[7] "The description of minimum thresholds shall include [...] how minimum thresholds may affect the interests of beneficial uses and users of groundwater or land uses and property interests." [23 CCR §354.28(b)(4)]

[8] "The description of minimum thresholds shall include [...] how state, federal, or local standards relate to the relevant sustainability indicator. If the minimum threshold differs from other regulatory standards, the agency shall explain the nature of and the basis for the difference." [23 CCR §354.28(b)(5)]

The GSP states that depth to water is generally less than 20 feet in the shallow aquifer zone. Furthermore, as stated in the quoted text above, domestic and industrial wells have a 20-foot minimum well seal requirement. Therefore, minimum thresholds at 50 feet below the ground surface may not protect shallow domestic wells in the subbasin. The GSP does not sufficiently describe whether minimum thresholds will avoid significant and unreasonable loss of drinking water to domestic well users that are not protected by the minimum threshold, and whether the undesirable results are consistent with the Human Right to Water policy.[9] In addition, the GSP does not sufficiently describe or analyze direct or indirect impacts on DACs or drinking water users when defining undesirable results, nor does it describe how the groundwater levels minimum thresholds are consistent with Human Right to Water policy and will avoid significant and unreasonable impacts on beneficial users.

The minimum thresholds for degraded water quality for each of the four identified key water quality constituents (nitrate, arsenic, chloride, TDS) are based on the greater of MCLs or the baseline concentration plus 20%. According to the state's anti- degradation policy,[10] high water quality should be protected and is only allowed to worsen if a finding is made that it is in the best interest of the people of the State of California. No analysis has been done and no such finding has been made. Furthermore, exceedances of the MCL constitute a violation of the state's water quality law and are not permitted. Additionally, Section 2.2.2.3 of the GSP (Groundwater Quality) discusses other contaminants associated with cleanup sites that are distributed throughout the urban EBP subbasin. SMC should be established for all COCs in the subbasin impacted or exacerbated by groundwater use and/or management, in addition to coordinating with water quality regulatory programs.

The GSP only includes a very general discussion of impacts on drinking water users when defining undesirable results and evaluating the impacts of proposed minimum thresholds. The GSP does not, however, mention or discuss direct and indirect impacts on DACs or drinking water users when defining undesirable results for degraded water quality, nor does it evaluate the cumulative or indirect impacts of proposed minimum thresholds on DACs or drinking water users.

RECOMMENDATIONS

Chronic Lowering of Groundwater Levels

- Describe direct and indirect impacts on DACs and drinking water users when describing undesirable results and defining minimum thresholds for chronic lowering of groundwater levels.

- Consider and evaluate the impacts of selected minimum thresholds and measurable objectives on DACs and drinking water users within the subbasin. Further describe the impact of passing the minimum threshold for these users. For example, provide the number of domestic wells that would be de-watered at the minimum threshold.

Degraded Water Quality

- Describe direct and indirect impacts on DACs and drinking water users when defining undesirable results for degraded water quality.[11] For specific guidance on how to

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[9] California Water Code §106.3. Available at: https://leginfo.legislature.ca.gov/faces/codes_displaySection.xhtml?lawCode=WAT&sectionNum=106.3

[10] Anti-degradation Policy https://www.waterboards.ca.gov/board_decisions/adopted_orders/resolutions/1968/rs68_016.pdf

[11] "Degraded Water Quality [...] collect sufficient spatial and temporal data from each applicable principal aquifer to determine groundwater quality trends for water quality indicators, as determined by the Agency, to address known water quality issues." [23 CCR §354.34(c)(4)]

consider these users, refer to “Guide to Protecting Water Quality Under the Sustainable Groundwater Management Act.”[12]

- Evaluate the cumulative or indirect impacts of proposed minimum thresholds for degraded water quality on DACs and drinking water users.
- Set minimum thresholds and measurable objectives for all water quality constituents within the subbasin that are impacted or exacerbated by groundwater use and/or management.
- Set minimum thresholds that do not allow water quality to degrade to levels at or above the MCL trigger level.

Groundwater Dependent Ecosystems and Interconnected Surface Waters

For chronic lowering of groundwater levels, the GSP recognizes the potential impact of groundwater level minimum thresholds on GDEs. The minimum thresholds are established as follows (p. 3-7): *“In these areas* [Shallow Aquifer Zone at RMS wells located adjacent to GDEs]*, the initial interim MT for Shallow Aquifer Zone groundwater levels is set to 7.5 feet below existing/baseline conditions, and this will be updated (and potentially revised) pending additional hydrogeologic/ biologic data collection and studies.”*

The GSP states (3-15): *“GDEs directly dependent on groundwater levels would not necessarily be protected by an MT that is protective of drinking water supply wells. Therefore, areas of the EBP Subbasin coinciding with known GDEs will have adjustments to the groundwater level MT established to protect drinking water supply wells. Additional work is needed in the early stages of GSP implementation to conduct further evaluation of potential GDEs, rooting depths of various species, and how declines in groundwater levels may impact various potential GDE vegetative species.”* The GSP continues (p. 3-19): *“If a 6-year drought and projected water level declines to MT levels were to occur, potential effects on GDEs could include short-term adverse impacts such as water stress and possibly longer-term impacts such as reduced growth and recruitment.”* Therefore, while the GSP recognizes that there could be impacts on GDEs, no further details on these impacts are provided, such as which habitat types could be affected, or the anticipated physiological responses based on minimum threshold groundwater levels.

For depletion of interconnected surface water, groundwater elevations are used as proxy for establishing SMC. The GSP states (3-10): *“The MT for non-drought shallow groundwater levels (as a proxy) is set at two feet below current baseline water levels in the Water Table Aquifer Zone beneath the major creeks. This is considered an interim MT, and the MT will be refined with collection of additional data to improve the understanding of stream-aquifer connectivity and potential for streamflow depletion related to groundwater pumping.”* The GSP notes that the proposed minimum thresholds require use of shallow wells along major creeks, which are planned to be installed for use as representative monitoring sites (RMSs). The interim MT are based on model estimated groundwater levels. While the GSP clearly recognizes the data gap for depletion of interconnected surface water SMC, we would like to see further discussion of how the interim SMC will affect beneficial users, and more specifically GDEs, or the impact of these minimum thresholds on GDEs in the subbasin. The GSP makes no attempt to evaluate how the proposed minimum thresholds and measurable objectives avoid significant and unreasonable effects on surface water beneficial users in the subbasin (see Attachment C for a list of

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[12] Guide to Protecting Water Quality under the Sustainable Groundwater Management Act https://d3n8a8pro7vhmx.cloudfront.net/communitywatercenter/pages/293/attachments/original/1559328858/Guide_to_Protecting_Drinking_Water_Quality_Under_the_Sustainable_Groundwater_Management_Act.pdf?1559328858.

environmental users in the subbasin), such as increased mortality and inability to perform key life processes (e.g., reproduction, migration).

RECOMMENDATIONS

- When defining undesirable results for chronic lowering of groundwater levels, provide specifics on what biological responses (e.g., extent of habitat, growth, recruitment rates) would best characterize a significant and unreasonable impact to GDEs. Undesirable results to environmental users occur when 'significant and unreasonable' effects on beneficial users are caused by one of the sustainability indicators (i.e., chronic lowering of groundwater levels, degraded water quality, or depletion of interconnected surface water). Thus, potential impacts on environmental beneficial uses and users need to be considered when defining undesirable results in the subbasin.[13] Defining undesirable results is the crucial first step before the minimum thresholds can be determined.[14]

- When defining undesirable results for depletion of interconnected surface water, include a description of potential impacts on instream habitats within ISWs when minimum thresholds in the subbasin are reached.[15] The GSP should confirm that minimum thresholds for ISWs avoid adverse impacts on environmental beneficial users of interconnected surface waters as these environmental users could be left unprotected by the GSP. These recommendations apply especially to environmental beneficial users that are already protected under pre-existing state or federal law.[6,16]

- When establishing SMC for the subbasin, consider that the SGMA statute [Water Code §10727.4(l)] specifically calls out that GSPs shall include "impacts on groundwater dependent ecosystems".

2. Climate Change

The SGMA statute identifies climate change as a significant threat to groundwater resources and one that must be examined and incorporated in the GSPs. The GSP Regulations require integration of climate change into the projected water budget to ensure that projects and management actions sufficiently account for the range of potential climate futures.[17] The effects of climate change will intensify the impacts of water stress on GDEs, making available shallow groundwater resources especially critical to their

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[13] "The description of undesirable results shall include [...] potential effects on the beneficial uses and users of groundwater, on land uses and property interests, and other potential effects that may occur or are occurring from undesirable results". [23 CCR §354.26(b)(3)]

[14] The description of minimum thresholds shall include [...] how minimum thresholds may affect the interests of beneficial uses and users of groundwater or land uses and property interests." [23 CCR §354.28(b)(4)]

[15] "The minimum threshold for depletions of interconnected surface water shall be the rate or volume of surface water depletions caused by groundwater use that has adverse impacts on beneficial uses of the surface water and may lead to undesirable results." [23 CCR §354.28(c)(6)]

[16] Rohde MM, Seapy B, Rogers R, Castañeda X, editors. 2019. Critical Species LookBook: A compendium of California's threatened and endangered species for sustainable groundwater management. The Nature Conservancy, San Francisco, California. Available at: https://groundwaterresourcehub.org/public/uploads/pdfs/Critical_Species_LookBook_91819.pdf

[17] "Each Plan shall rely on the best available information and best available science to quantify the water budget for the basin in order to provide an understanding of historical and projected hydrology, water demand, water supply, land use, population, climate change, sea level rise, groundwater and surface water interaction, and subsurface groundwater flow." [23 CCR §354.18(e)]

survival. Condon *et al*. (2020) shows that GDEs are more likely to succumb to water stress and rely more on groundwater during times of drought.[18] When shallow groundwater is unavailable, riparian forests can die off and key life processes (e.g., migration and spawning) for aquatic organisms, such as steelhead, can be impeded.

The integration of climate change into the projected water budget is **insufficient**. The GSP incorporates climate change into the projected water budget using DWR change factors. However, the plan does not clearly specify which change factors were used (e.g., 2030 or 2070). Furthermore, the plan does not make clear whether multiple climate scenarios (e.g., the 2070 extremely wet and extremely dry climate scenarios) were considered in the projected water budget. The GSP should indicate which DWR change factors were used for the projected water budget and also clearly and transparently incorporate the extremely wet and dry scenarios provided by DWR into projected water budgets or select more appropriate extreme scenarios for the subbasin. While these extreme scenarios may have a lower likelihood of occurring, their consequences could be significant and their inclusion can help identify important vulnerabilities in the subbasin's approach to groundwater management.

The GSP incorporates climate change into key inputs (e.g., precipitation, evapotranspiration, and sea level rise) of the projected water budget. However, imported water should also be adjusted for climate change and incorporated into the surface water flow inputs of the projected water budget. Furthermore, the GSP does not provide a sustainable yield based on the projected water budget with climate change incorporated. If the water budgets are incomplete, including the omission of projected climate change effects on imported water inputs, and sustainable yield is not calculated based on climate change projections, then there is increased uncertainty in virtually every subsequent calculation used to plan for projects, derive measurable objectives, and set minimum thresholds. Plans that do not adequately include climate change projections may underestimate future impacts on vulnerable beneficial users of groundwater such as ecosystems, DACs, and domestic well owners.

RECOMMENDATIONS

- Clarify if extremely wet and dry scenarios are incorporated into all elements of the projected water budget to form the basis for development of sustainable management criteria and projects and management actions.
- If there are data available, expand your integration of climate change into surface water flow inputs, including imported water, for the projected water budget.
- Estimate sustainable yield based on the projected water budget with climate change incorporated.
- Incorporate climate change scenarios into projects and management actions.

3. Data Gaps

The consideration of beneficial users when establishing monitoring networks is **insufficient**, due to lack of specific plans to increase the Representative Monitoring Sites (RMSs) in the monitoring network that represent water quality conditions and shallow groundwater elevations around DACs and domestic wells in the subbasin.

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[18] Condon et al. 2020. Evapotranspiration depletes groundwater under warming over the contiguous United States. Nature Communications. Available at: https://www.nature.com/articles/s41467-020-14688-0

Figure 3-11 (Groundwater Quality RMS Wells) shows insufficient representation of DACs and drinking water users for water quality monitoring. Figure 3-15 (Shallow Aquifer Groundwater Level RMS Wells) shows insufficient representation of DACs and drinking water users for shallow groundwater elevation monitoring. Refer to Attachment E for maps of these monitoring sites in relation to key beneficial users of groundwater. These beneficial users may remain unprotected by the GSP without adequate monitoring and identification of data gaps in the shallow aquifer. The Plan therefore fails to meet SGMA's requirements for the monitoring network.[19]

RECOMMENDATIONS

- Provide maps that overlay current and proposed monitoring well locations with the locations of DACs, domestic wells, GDEs, and ISWs to clearly identify monitored areas.
- Increase the number of RMSs in the shallow aquifer across the subbasin as needed to adequately monitor all groundwater condition indicators across the subbasin and at appropriate depths for *all* beneficial users. Prioritize proximity to DACs, domestic wells, GDEs, and ISWs when identifying new RMSs.
- Ensure groundwater elevation and water quality RMSs are monitoring groundwater conditions spatially and at the correct depth for *all* beneficial users - especially DACs, domestic wells, and GDEs.

4. Addressing Beneficial Users in Projects and Management Actions

The consideration of beneficial users when developing projects and management actions is **insufficient** due to the failure to completely identify benefits or impacts of identified projects and management actions, including water quality impacts, to key beneficial users of groundwater such as GDEs, aquatic habitats, surface water users, DACs, and drinking water users. Therefore, potential project and management actions may not protect these beneficial users. Groundwater sustainability under SGMA is defined not just by sustainable yield, but by the avoidance of undesirable results for *all* beneficial users.

While Section 4.1.1 documents EBMUD's potable water injection facility, it fails to describe the project's explicit benefits or impacts to beneficial users, such as DACs. The plan also fails to include a domestic well mitigation program to avoid significant and unreasonable loss of drinking water.

RECOMMENDATIONS

- For DACs and domestic well owners, include a drinking water well impact mitigation program to proactively monitor and protect drinking water wells through GSP implementation. Refer to Attachment B for specific recommendations on how to implement a drinking water well mitigation program.

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[19] "The monitoring network objectives shall be implemented to accomplish the following: [...] (2) Monitor impacts to the beneficial uses or users of groundwater." [23 CCR §354.34(b)(2)]

- For DACs and domestic well owners, include a discussion of whether potential impacts to water quality from projects and management actions could occur and how the GSAs plan to mitigate such impacts.

- Recharge ponds, reservoirs, and facilities for managed stormwater recharge can be designed as multiple-benefit projects to include elements that act functionally as wetlands and provide a benefit for wildlife and aquatic species. For guidance on how to integrate multi-benefit recharge projects into your GSP, refer to the "Multi-Benefit Recharge Project Methodology Guidance Document."[20]

- Develop management actions that incorporate climate and water delivery uncertainties to address future water demand and prevent future undesirable results.

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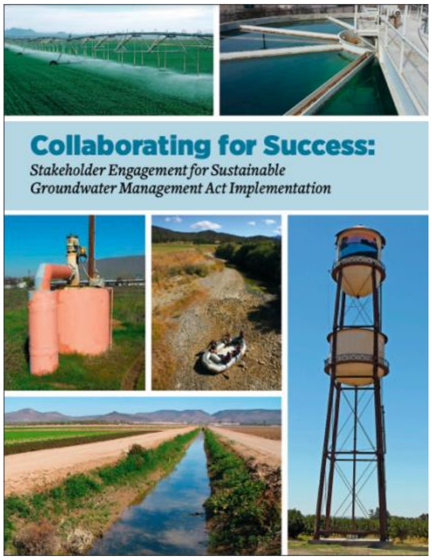
[20] The Nature Conservancy. 2021. Multi-Benefit Recharge Project Methodology for Inclusion in Groundwater Sustainability Plans. Sacramento. Available at: https://groundwaterresourcehub.org/sgma-tools/multi-benefit-recharge-project-methodology-guidance/

Attachment B

SGMA Tools to address DAC, drinking water, and environmental beneficial uses and users

Stakeholder Engagement and Outreach



Collaborating for Success:

Stakeholder Engagement for Sustainable Groundwater Management Act Implementation

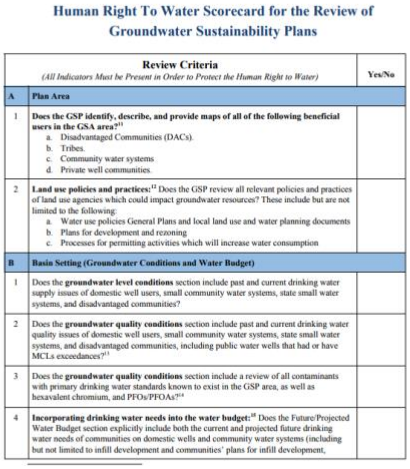
Clean Water Action, Community Water Center and Union of Concerned Scientists developed a guidance document called Collaborating for success: Stakeholder engagement for Sustainable Groundwater Management Act Implementation. It provides details on how to conduct targeted and broad outreach and engagement during Groundwater Sustainability Plan (GSP) development and implementation. Conducting a targeted outreach involves:

- Developing a robust Stakeholder Communication and Engagement plan that includes outreach at frequented locations (schools, farmers markets, religious settings, events) across the plan area to increase the involvement and participation of disadvantaged communities, drinking water users and the environmental stakeholders.

- Providing translation services during meetings and technical assistance to enable easy participation for non-English speaking stakeholders.

- GSP should adequately describe the process for requesting input from beneficial users and provide details on how input is incorporated into the GSP.

The Human Right to Water

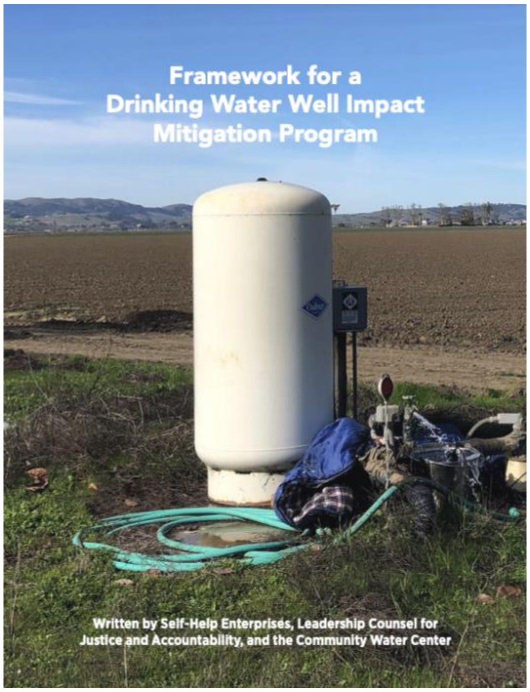


Human Right To Water Scorecard for the Review of Groundwater Sustainability Plans

	Review Criteria *(All Indicators Must be Present in Order to Protect the Human Right to Water)*	**Yes/No**
A	**Plan Area**	
1	**Does the GSP identify, describe, and provide maps of all of the following beneficial users in the GSA area?**[11] a. Disadvantaged Communities (DACs). b. Tribes. c. Community water systems d. Private well communities.	
2	**Land use policies and practices:**[12] Does the GSP review all relevant policies and practices of land use agencies which could impact groundwater resources? These include but are not limited to the following: a. Water use policies General Plans and local land use and water planning documents b. Plans for development and rezoning c. Processes for permitting activities which will increase water consumption	
B	**Basin Setting (Groundwater Conditions and Water Budget)**	
1	Does the **groundwater level conditions** section include past and current drinking water supply issues of domestic well users, small community water systems, state small water systems, and disadvantaged communities?	
2	Does the **groundwater quality conditions** section include past and current drinking water quality issues of domestic well users, small community water systems, state small water systems, and disadvantaged communities, including public water wells that had or have MCLs exceedances?[13]	
3	Does the **groundwater quality conditions** section include a review of all contaminants with primary drinking water standards known to exist in the GSP area, as well as hexavalent chromium, and PFOs/PFOAs?[14]	
4	**Incorporating drinking water needs into the water budget:**[15] Does the Future/Projected Water Budget section explicitly include both the current and projected future drinking water needs of communities on domestic wells and community water systems (including but not limited to infill development and communities' plans for infill development,	

The Human Right to Water Scorecard was developed by Community Water Center, Leadership Counsel for Justice and Accountability and Self Help Enterprises to aid Groundwater Sustainability Agencies (GSAs) in prioritizing drinking water needs in SGMA. The scorecard identifies elements that must exist in GSPs to adequately protect the Human Right to Drinking water.

Drinking Water Well Impact Mitigation Framework

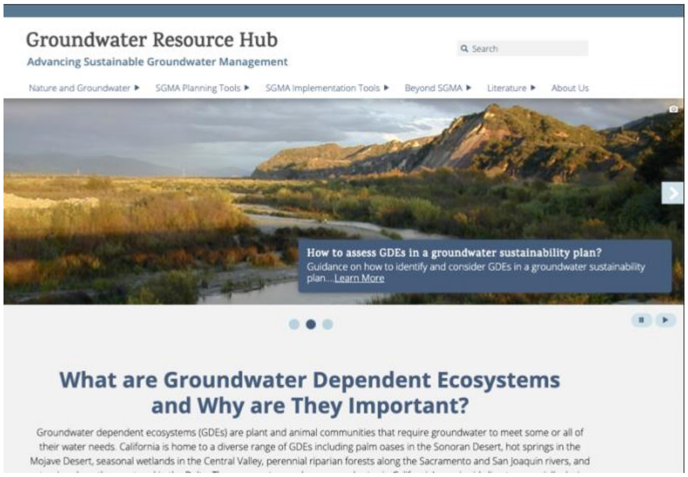


Framework for a Drinking Water Well Impact Mitigation Program

Written by Self-Help Enterprises, Leadership Counsel for Justice and Accountability, and the Community Water Center

The Drinking Water Well Impact Mitigation Framework was developed by Community Water Center, Leadership Counsel for Justice and Accountability and Self Help Enterprises to aid GSAs in the development and implementation of their GSPs. The framework provides a clear roadmap for how a GSA can best structure its data gathering, monitoring network and management actions to proactively monitor and protect drinking water wells and mitigate impacts should they occur.

Groundwater Resource Hub



How to assess GDEs in a groundwater sustainability plan?
Guidance on how to identify and consider GDEs in a groundwater sustainability plan....Learn More

What are Groundwater Dependent Ecosystems and Why are They Important?

Groundwater dependent ecosystems (GDEs) are plant and animal communities that require groundwater to meet some or all of their water needs. California is home to a diverse range of GDEs including palm oases in the Sonoran Desert, hot springs in the Mojave Desert, seasonal wetlands in the Central Valley, perennial riparian forests along the Sacramento and San Joaquin rivers, and

The Nature Conservancy has developed a suite of tools based on best available science to help GSAs, consultants, and stakeholders efficiently incorporate nature into GSPs. These tools and resources are available online at GroundwaterResourceHub.org. The Nature Conservancy's tools and resources are intended to reduce costs, shorten timelines, and increase benefits for both people and nature.

Rooting Depth Database

The Plant Rooting Depth Database provides information that can help assess whether groundwater-dependent vegetation are accessing groundwater. Actual rooting depths will depend on the plant species and site-specific conditions, such as soil type and availability of other water sources. Site-specific knowledge of depth to groundwater combined with rooting depths will help provide an understanding of the potential groundwater levels are needed to sustain GDEs.

How to use the database

The maximum rooting depth information in the Plant Rooting Depth Database is useful when verifying whether vegetation in the Natural Communities Commonly Associated with Groundwater (NC Dataset) are connected to groundwater. A 30 ft depth-to-groundwater threshold, which is based on averaged global rooting depth data for phreatophytes[1], is relevant for most plants identified in the NC Dataset since most plants have a max rooting depth of less than 30 feet. However, it is important to note that deeper thresholds are necessary for other plants that have reported maximum root depths that exceed the averaged 30 feet threshold, such as valley oak (*Quercus lobata*), Euphrates poplar (*Populus euphratica*), salt cedar (*Tamarix spp.*), and shadescale (*Atriplex confertifolia*). The Nature Conservancy advises that the reported max rooting depth for these deeper-rooted plants be used. For example, a depth-to groundwater threshold of 80 feet should be used instead of the 30 ft threshold, when verifying whether valley oak polygons from the NC Dataset are connected to groundwater. It is important to re-emphasize that actual rooting depth data are limited and will depend on the plant species and site-specific conditions such as soil and aquifer types, and availability to other water sources.

The Plant Rooting Depth Database is an Excel workbook composed of four worksheets:

1. California phreatophyte rooting depth data (included in the NC Dataset)
2. Global phreatophyte rooting depth data
3. Metadata
4. References

How the database was compiled

The Plant Rooting Depth Database is a compilation of rooting depth information for the groundwater-dependent plant species identified in the NC Dataset. Rooting depth data were compiled from published scientific literature and expert opinion through a crowdsourcing campaign. As more information becomes available, the database of rooting depths will be updated. Please Contact Us if you have additional rooting depth data for California phreatophytes.

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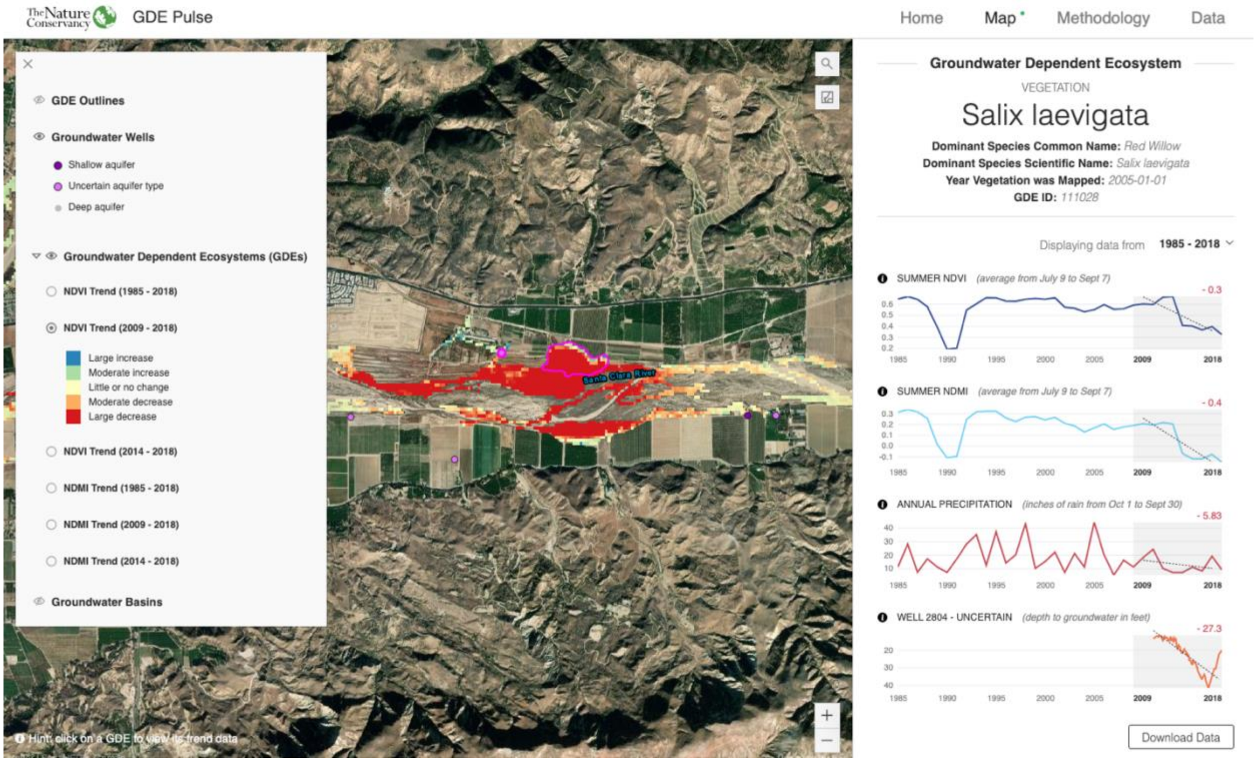
[1] Canadell, J., Jackson, R.B., Ehleringer, J.B. et al. 1996. Maximum rooting depth of vegetation types at the global scale. Oecologia 108, 583–595. https://doi.org/10.1007/BF00329030

GDE Pulse



Groundwater Dependent Ecosystem

VEGETATION

Salix laevigata

Dominant Species Common Name: *Red Willow*
Dominant Species Scientific Name: *Salix laevigata*
Year Vegetation was Mapped: *2005-01-01*
GDE ID: *111028*

Displaying data from **1985 - 2018**

GDE Pulse is a free online tool that allows Groundwater Sustainability Agencies to assess changes in groundwater dependent ecosystem (GDE) health using satellite, rainfall, and groundwater data. Remote sensing data from satellites has been used to monitor the health of vegetation all over the planet. GDE pulse has compiled 35 years of satellite imagery from NASA's Landsat mission for every polygon in the Natural Communities Commonly Associated with Groundwater Dataset. The following datasets are available for downloading:

Normalized Difference Vegetation Index (NDVI) is a satellite-derived index that represents the greenness of vegetation. Healthy green vegetation tends to have a higher NDVI, while dead leaves have a lower NDVI. We calculated the average NDVI during the driest part of the year (July - Sept) to estimate vegetation health when the plants are most likely dependent on groundwater.

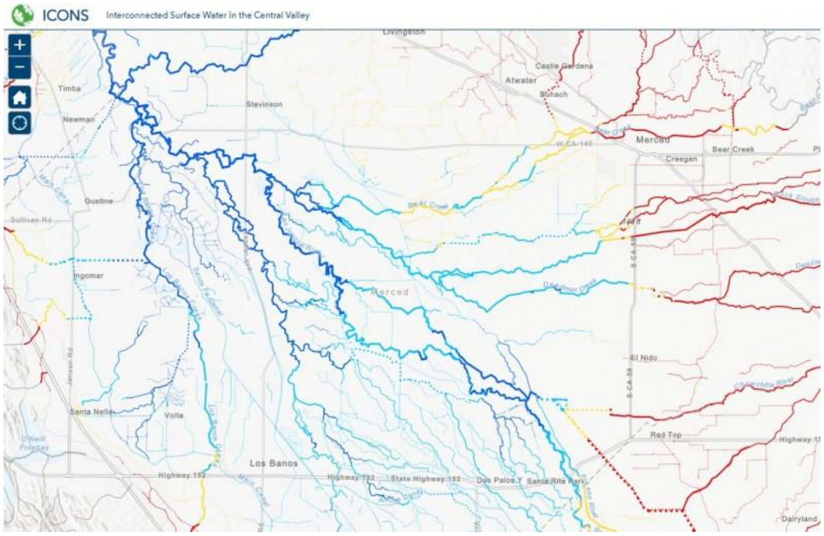
Normalized Difference Moisture Index (NDMI) is a satellite-derived index that represents water content in vegetation. NDMI is derived from the Near-Infrared (NIR) and Short-Wave Infrared (SWIR) channels. Vegetation with adequate access to water tends to have higher NDMI, while vegetation that is water stressed tends to have lower NDMI. We calculated the average NDVI during the driest part of the year (July–September) to estimate vegetation health when the plants are most likely dependent on groundwater.

Annual Precipitation is the total precipitation for the water year (October 1st – September 30th) from the PRISM dataset. The amount of local precipitation can affect vegetation with more precipitation generally leading to higher NDVI and NDMI.

Depth to Groundwater measurements provide an indication of the groundwater levels and changes over time for the surrounding area. We used groundwater well measurements from nearby (<1km) wells to estimate the depth to groundwater below the GDE based on the average elevation of the GDE (using a digital elevation model) minus the measured groundwater surface elevation.

ICONOS Mapper

Interconnected Surface Water in the Central Valley



[ICONS](#) maps the likely presence of interconnected surface water (ISW) in the Central Valley using depth to groundwater data. Using data from 2011-2018, the ISW dataset represents the likely connection between surface water and groundwater for rivers and streams in California's Central Valley. It includes information on the mean, maximum, and minimum depth to groundwater for each stream segment over the years with available data, as well as the likely presence of ISW based on the minimum depth to groundwater. The Nature Conservancy developed this database, with guidance and input from expert academics, consultants, and state agencies.

We developed this dataset using groundwater elevation data available online from the California Department of Water Resources (DWR). DWR only provides this data for the Central Valley. For GSAs outside of the valley, who have groundwater well measurements, we recommend following our methods to determine likely ISW in your region. The Nature Conservancy's ISW dataset should be used as a first step in reviewing ISW and should be supplemented with local or more recent groundwater depth data.

Attachment C

Freshwater Species Located in the Santa Clara Valley - East Bay Plain Subbasin

To assist in identifying the beneficial users of surface water necessary to assess the undesirable result "depletion of interconnected surface waters", Attachment C provides a list of freshwater species located in the Santa Clara Valley - East Bay Plain Subbasin. To produce the freshwater species list, we used ArcGIS to select features within the California Freshwater Species Database version 2.0.9 within the basin boundary. This database contains information on ~4,000 vertebrates, macroinvertebrates and vascular plants that depend on fresh water for at least one stage of their life cycle. The methods used to compile the California Freshwater Species Database can be found in Howard et al. 2015[1]. The spatial database contains locality observations and/or distribution information from ~400 data sources. The database is housed in the California Department of Fish and Wildlife's BIOS[2] as well as on The Nature Conservancy's science website[3].

Scientific Name	Common Name	Legal Protected Status		
		Federal	State	Other
BIRDS				
Geothlypis trichas sinuosa	Saltmarsh Common Yellowthroat	Bird of Conservation Concern	Special Concern	BSSC - Third priority
Laterallus jamaicensis coturniculus	California Black Rail	Bird of Conservation Concern	Threatened	
Actitis macularius	Spotted Sandpiper			
Aechmophorus clarkii	Clark's Grebe			
Aechmophorus occidentalis	Western Grebe			
Agelaius tricolor	Tricolored Blackbird	Bird of Conservation Concern	Special Concern	BSSC - First priority
Aix sponsa	Wood Duck			
Anas acuta	Northern Pintail			
Anas americana	American Wigeon			
Anas clypeata	Northern Shoveler			
Anas crecca	Green-winged Teal			
Anas cyanoptera	Cinnamon Teal			
Anas discors	Blue-winged Teal			
Anas platyrhynchos	Mallard			
Anas strepera	Gadwall			
Anser albifrons	Greater White-fronted Goose			
Ardea alba	Great Egret			

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[1] Howard, J.K. et al. 2015. Patterns of Freshwater Species Richness, Endemism, and Vulnerability in California. PLoSONE, 11(7). Available at: https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0130710

[2] California Department of Fish and Wildlife BIOS: https://www.wildlife.ca.gov/data/BIOS

[3] Science for Conservation: https://www.scienceforconservation.org/products/california-freshwater-species-database

Ardea herodias	Great Blue Heron			
Aythya affinis	Lesser Scaup			
Aythya americana	Redhead		Special Concern	BSSC - Third priority
Aythya collaris	Ring-necked Duck			
Aythya marila	Greater Scaup			
Aythya valisineria	Canvasback		Special	
Botaurus lentiginosus	American Bittern			
Bucephala albeola	Bufflehead			
Bucephala clangula	Common Goldeneye			
Butorides virescens	Green Heron			
Calidris alpina	Dunlin			
Calidris mauri	Western Sandpiper			
Calidris minutilla	Least Sandpiper			
Chen caerulescens	Snow Goose			
Chen rossii	Ross's Goose			
Chlidonias niger	Black Tern		Special Concern	BSSC - Second priority
Chroicocephalus philadelphia	Bonaparte's Gull			
Cistothorus palustris palustris	Marsh Wren			
Coturnicops noveboracensis	Yellow Rail	Bird of Conservation Concern	Special Concern	BSSC - Second priority
Cygnus columbianus	Tundra Swan			
Cypseloides niger	Black Swift	Bird of Conservation Concern	Special Concern	BSSC - Third priority
Egretta thula	Snowy Egret			
Empidonax traillii	Willow Flycatcher	Bird of Conservation Concern	Endangered	
Fulica americana	American Coot			
Gallinago delicata	Wilson's Snipe			
Geothlypis trichas trichas	Common Yellowthroat			
Grus canadensis canadensis	Lesser Sandhill Crane		Special Concern	BSSC - Third priority
Haliaeetus leucocephalus	Bald Eagle	Bird of Conservation Concern	Endangered	
Himantopus mexicanus	Black-necked Stilt			
Histrionicus histrionicus	Harlequin Duck		Special Concern	BSSC - Second priority
Icteria virens	Yellow-breasted Chat		Special Concern	BSSC - Third priority
Limnodromus scolopaceus	Long-billed Dowitcher			
Lophodytes cucullatus	Hooded Merganser			
Megaceryle alcyon	Belted Kingfisher			

Mergus merganser	Common Merganser			
Mergus serrator	Red-breasted Merganser			
Numenius americanus	Long-billed Curlew			
Numenius phaeopus	Whimbrel			
Nycticorax nycticorax	Black-crowned Night-Heron			
Oxyura jamaicensis	Ruddy Duck			
Pandion haliaetus	Osprey		Watch list	
Pelecanus erythrorhynchos	American White Pelican		Special Concern	BSSC - First priority
Phalacrocorax auritus	Double-crested Cormorant			
Phalaropus tricolor	Wilson's Phalarope			
Pipilo aberti	Abert's Towhee			
Piranga rubra	Summer Tanager		Special Concern	BSSC - First priority
Plegadis chihi	White-faced Ibis		Watch list	
Pluvialis squatarola	Black-bellied Plover			
Podiceps nigricollis	Eared Grebe			
Podilymbus podiceps	Pied-billed Grebe			
Porzana carolina	Sora			
Rallus limicola	Virginia Rail			
Recurvirostra americana	American Avocet			
Riparia riparia	Bank Swallow		Threatened	
Rynchops niger	Black Skimmer			
Setophaga petechia	Yellow Warbler			BSSC - Second priority
Tachycineta bicolor	Tree Swallow			
Tringa melanoleuca	Greater Yellowlegs			
Tringa semipalmata	Willet			
Tringa solitaria	Solitary Sandpiper			
Xanthocephalus xanthocephalus	Yellow-headed Blackbird		Special Concern	BSSC - Third priority
CRUSTACEANS				
Americorophium spp.	Americorophium spp.			
Crangonyx spp.	Crangonyx spp.			
Cyprididae fam.	Cyprididae fam.			
Cyzicus californicus	California Clam Shrimp			
Gammarus spp.	Gammarus spp.			
Hyalella spp.	Hyalella spp.			
Pacifastacus spp.	Pacifastacus spp.			
Palaemon macrodactylus				Not on any status lists
Ramellogammarus spp.	Ramellogammarus spp.			
FISH				
Acipenser medirostris ssp. 1	Southern green sturgeon	Threatened	Special Concern	Endangered - Moyle 2013

Oncorhynchus tshawytscha - CV winter	Central Valley winter Chinook salmon	Endangered	Endangered	Vulnerable - Moyle 2013
Spirinchus thaleichthys	Longfin smelt	Candidate	Threatened	Vulnerable - Moyle 2013
Oncorhynchus mykiss - CCC winter	Central California coast winter steelhead	Threatened	Special	Vulnerable - Moyle 2013
HERPS				
Actinemys marmorata marmorata	Western Pond Turtle		Special Concern	ARSSC
Ambystoma californiense californiense	California Tiger Salamander	Threatened	Threatened	ARSSC
Anaxyrus boreas boreas	Boreal Toad			
Rana draytonii	California Red-legged Frog	Threatened	Special Concern	ARSSC
Taricha granulosa	Rough-skinned Newt			
Taricha torosa	Coast Range Newt		Special Concern	ARSSC
Thamnophis sirtalis sirtalis	Common Gartersnake			
Anaxyrus boreas halophilus	California Toad			ARSSC
Pseudacris regilla	Northern Pacific Chorus Frog			
Pseudacris sierra	Sierran Treefrog			
Thamnophis atratus atratus	Santa Cruz Gartersnake			Not on any status lists
Thamnophis elegans elegans	Mountain Gartersnake			Not on any status lists
Thamnophis elegans terrestris	Coast Gartersnake			Not on any status lists
Thamnophis ordinoides	Northwestern Gartersnake			ARSSC
INSECTS & OTHER INVERTS				
Abedus indentatus				Not on any status lists
Ablabesmyia spp.	Ablabesmyia spp.			
Aeshna walkeri	Walker's Darner			
Agabus disintegratus				Not on any status lists
Agabus spp.	Agabus spp.			
Alotanypus spp.	Alotanypus spp.			
Anax junius	Common Green Darner			
Apedilum spp.	Apedilum spp.			
Argia spp.	Argia spp.			
Argia vivida	Vivid Dancer			
Baetidae fam.	Baetidae fam.			
Baetis spp.	Baetis spp.			
Baetis tricaudatus	A Mayfly			
Brillia spp.	Brillia spp.			

Chironomidae fam.	Chironomidae fam.			
Chironomus spp.	Chironomus spp.			
Coenagrionidae fam.	Coenagrionidae fam.			
Conchapelopia spp.	Conchapelopia spp.			
Corisella spp.	Corisella spp.			
Corixidae fam.	Corixidae fam.			
Cricotopus spp.	Cricotopus spp.			
Cryptochironomus spp.	Cryptochironomus spp.			
Dicosmoecus pallicornis	A Caddisfly			
Dicrotendipes adnilus				Not on any status lists
Dicrotendipes spp.	Dicrotendipes spp.			
Dytiscidae fam.	Dytiscidae fam.			
Enallagma civile	Familiar Bluet			
Enochrus carinatus				Not on any status lists
Enochrus hamiltoni				Not on any status lists
Ephydridae fam.	Ephydridae fam.			
Eubrianax edwardsii				Not on any status lists
Gyrinus plicifer				Not on any status lists
Hydropsyche oslari	A Caddisfly			
Hydroptila ajax	A Caddisfly			
Hydroptila spp.	Hydroptila spp.			
Hydroptilidae fam.	Hydroptilidae fam.			
Ischnura cervula	Pacific Forktail			
Ischnura gemina	San Francisco Forktail		Special	IUCN - Vulnerable
Ischnura perparva	Western Forktail			
Lepidostoma spp.	Lepidostoma spp.			
Lestes stultus	Black Spreadwing			
Lestidae fam.	Lestidae fam.			
Libellula pulchella	Twelve-spotted Skimmer			
Malenka spp.	Malenka spp.			
Metriocnemus spp.	Metriocnemus spp.			
Micropsectra spp.	Micropsectra spp.			
Mystacides alafimbriatus	A Caddisfly			
Narpus spp.	Narpus spp.			
Neophylax rickeri	A Caddisfly			
Nereis spp.	Nereis spp.			
Optioservus spp.	Optioservus spp.			
Orthocladius appersoni				Not on any status lists
Orthocladius spp.	Orthocladius spp.			
Oxyethira spp.	Oxyethira spp.			

Paltothemis lineatipes	Red Rock Skimmer			
Pantala flavescens	Wandering Glider			
Pantala hymenaea	Spot-winged Glider			
Paraleptophlebia spp.	Paraleptophlebia spp.			
Parametriocnemus spp.	Parametriocnemus spp.			
Paratanytarsus spp.	Paratanytarsus spp.			
Paratendipes spp.	Paratendipes spp.			
Pentaneura inconspicua				Not on any status lists
Pentaneura spp.	Pentaneura spp.			
Phaenopsectra dyari				Not on any status lists
Phaenopsectra spp.	Phaenopsectra spp.			
Polypedilum spp.	Polypedilum spp.			
Procladius spp.	Procladius spp.			
Psectrotanypus spp.	Psectrotanypus spp.			
Psychodidae fam.	Psychodidae fam.			
Rheotanytarsus spp.	Rheotanytarsus spp.			
Rhionaeschna multicolor	Blue-eyed Darner			
Rhyacophila spp.	Rhyacophila spp.			
Sialis spp.	Sialis spp.			
Sigara spp.	Sigara spp.			
Simulium spp.	Simulium spp.			
Sperchon spp.	Sperchon spp.			
Sperchon stellata				Not on any status lists
Sperchontidae fam.	Sperchontidae fam.			
Sympetrum corruptum	Variegated Meadowhawk			
Sympetrum illotum	Cardinal Meadowhawk			
Sympetrum pallipes	Striped Meadowhawk			
Tanypus spp.	Tanypus spp.			
Tanytarsus spp.	Tanytarsus spp.			
Trichocorixa spp.	Trichocorixa spp.			
Zavrelimyia spp.	Zavrelimyia spp.			
MAMMALS				
Ondatra zibethicus	Common Muskrat			Not on any status lists
MOLLUSKS				
Pomatiopsis californica	Pacific Walker		Special	E
Anodonta californiensis	California Floater		Special	
Assiminea californica				Not on any status lists
Ferrissia fragilis	Fragile Ancylid			CS
Ferrissia spp.	Ferrissia spp.			

Gonidea angulata	Western Ridged Mussel		Special	
Gyraulus circumstriatus	Disc Gyro			CS
Gyraulus spp.	Gyraulus spp.			
Helisoma spp.	Helisoma spp.			
Hydrobiidae fam.	Hydrobiidae fam.			
Lymnaea spp.	Lymnaea spp.			
Margaritifera falcata	Western Pearlshell		Special	
Menetus opercularis	Button Sprite			CS
Menetus spp.	Menetus spp.			
Physa spp.	Physa spp.			
Physella propinqua	Rocky Mountain Physa			CS
Pisidium casertanum				Not on any status lists
Pisidium spp.	Pisidium spp.			
Planorbidae fam.	Planorbidae fam.			
Pyrgulopsis stearnsiana	Yaqui Springsnail			T
Sphaeriidae fam.	Sphaeriidae fam.			
Sphaerium spp.	Sphaerium spp.			
Stagnicola elodes	Marsh Pondsnail			CS
PLANTS				
Alisma triviale	Northern Water-plantain			
Alnus rubra	Red Alder			
Arundo donax	NA			
Azolla filiculoides	NA			
Bolboschoenus maritimus paludosus	NA			Not on any status lists
Carex densa	Dense Sedge			
Carex nebrascensis	Nebraska Sedge			
Carex nudata	Torrent Sedge			
Carex obnupta	Slough Sedge			
Carex senta	Western Rough Sedge			
Castilleja miniata miniata	Greater Red Indian-paintbrush			
Chloropyron maritimum palustre			Special	CRPR - 1B.2
Cicendia quadrangularis	Oregon Microcala			
Cotula coronopifolia	NA			
Darmera peltata	Umbrella Plant			
Eleocharis macrostachya	Creeping Spikerush			
Elodea canadensis	Broad Waterweed			
Eryngium aristulatum aristulatum	California Eryngo			
Euthamia occidentalis	Western Fragrant Goldenrod			

Glyceria leptostachya	Slim-head Mannagrass			
Helenium puberulum	Rosilla			
Isolepis cernua	Low Bulrush			
Jaumea carnosa	Fleshy Jaumea			
Juncus effusus effusus	NA			
Juncus lescurii				Not on any status lists
Juncus phaeocephalus paniculatus	Brownhead Rush			
Juncus phaeocephalus phaeocephalus	Brown-head Rush			
Juncus xiphioides	Iris-leaf Rush			
Lasthenia conjugens	Contra Costa Goldfields	Endangered	Special	CRPR - 1B.1
Lepidium oxycarpum	Sharp-pod Pepper-grass			
Limnanthes douglasii douglasii	Douglas' Meadowfoam			
Limonium californicum	California Sea-lavender			
Limosella acaulis	Southern Mudwort			
Ludwigia peploides peploides	NA			Not on any status lists
Mimulus guttatus	Common Large Monkeyflower			
Navarretia leucocephala leucocephala	White-flower Navarretia			
Oenanthe sarmentosa	Water-parsley			
Panicum dichotomiflorum	NA			
Paspalum distichum	Joint Paspalum			
Perideridia kelloggii	Kellogg's Yampah			
Persicaria lapathifolia				Not on any status lists
Persicaria punctata	NA			Not on any status lists
Phacelia distans	NA			
Phragmites australis australis	Common Reed			
Phyla nodiflora	Common Frog-fruit			
Plagiobothrys chorisianus	NA		Special	CRPR - 1B.2
Plagiobothrys glaber	Hairless Allocarya		Special	CRPR - 1A
Plantago elongata elongata	Slender Plantain			
Platanus racemosa	California Sycamore			

Pleuropogon californicus californicus				Not on any status lists
Pogogyne douglasii	NA			
Polygonum marinense	Marin Knotweed		Special	CRPR - 3.1
Populus trichocarpa	NA			Not on any status lists
Psilocarphus tenellus	NA			
Ranunculus repens	NA			
Rumex californicus				Not on any status lists
Rumex conglomeratus	NA			
Rumex crassus				Not on any status lists
Rumex occidentalis				Not on any status lists
Rumex salicifolius salicifolius	Willow Dock			
Ruppia maritima	Ditch-grass			
Salix exigua exigua	Narrowleaf Willow			
Salix laevigata	Polished Willow			
Salix lasiandra lasiandra				Not on any status lists
Salix lasiolepis lasiolepis	Arroyo Willow			
Scirpus microcarpus	Small-fruit Bulrush			
Sequoia sempervirens				
Sidalcea neomexicana	Rocky Mountain Checker-mallow		Special	CRPR - 2B.2
Sinapis alba	NA			
Spartina densiflora	NA			
Spartina foliosa	California Cordgrass			
Spiranthes romanzoffiana	Hooded Ladies'-tresses			
Spirodela polyrhiza	NA			
Stachys ajugoides	Bugle Hedge-nettle			
Suaeda californica	California Sea-blite	Endangered	Special	CRPR - 1B.1
Symphyotrichum frondosum	Alkali Aster			
Symphyotrichum lentum	Suisun Marsh Aster		Special	CRPR - 1B.2
Triglochin maritima	Common Bog Arrow-grass			
Triglochin striata	Three-ribbed Arrow-grass			
Veronica americana	American Speedwell			
Zannichellia palustris	Horned Pondweed			

Attachment D

The Nature Conservancy

July 2019

IDENTIFYING GDEs UNDER SGMA

Best Practices for using the NC Dataset

The Sustainable Groundwater Management Act (SGMA) requires that groundwater dependent ecosystems (GDEs) be identified in Groundwater Sustainability Plans (GSPs). As a starting point, the Department of Water Resources (DWR) is providing the Natural Communities Commonly Associated with Groundwater Dataset (NC Dataset) online[1] to help Groundwater Sustainability Agencies (GSAs), consultants, and stakeholders identify GDEs within individual groundwater basins. To apply information from the NC Dataset to local areas, GSAs should combine it with the best available science on local hydrology, geology, and groundwater levels to verify whether polygons in the NC dataset are likely supported by groundwater in an aquifer (Figure 1)[2]. This document highlights six best practices for using local groundwater data to confirm whether mapped features in the NC dataset are supported by groundwater.

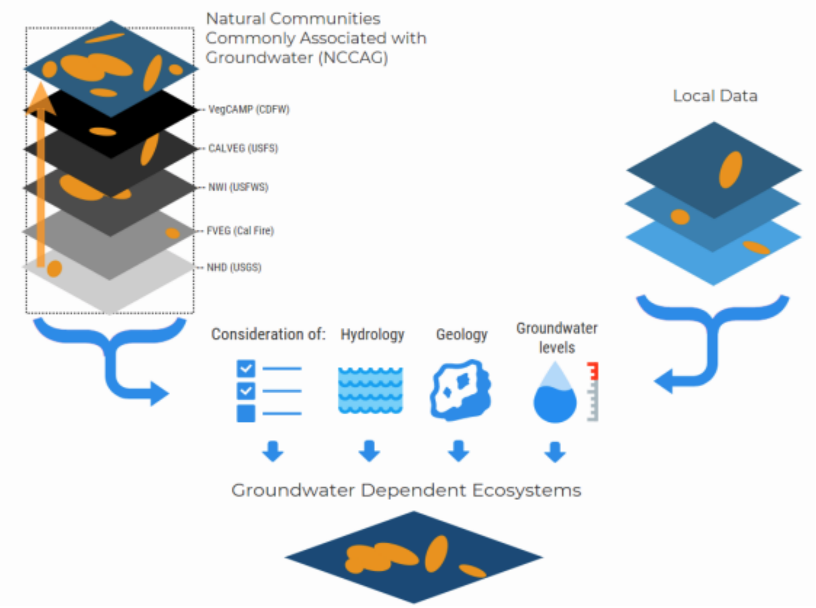

Figure 1. Considerations for GDE identification.
Source: DWR[2]

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[1] NC Dataset Online Viewer: https://gis.water.ca.gov/app/NCDatasetViewer/

[2] California Department of Water Resources (DWR). 2018. Summary of the "Natural Communities Commonly Associated with Groundwater" Dataset and Online Web Viewer. Available at: https://water.ca.gov/-/media/DWR-Website/Web-Pages/Programs/Groundwater-Management/Data-and-Tools/Files/Statewide-Reports/Natural-Communities-Dataset-Summary-Document.pdf

The NC Dataset identifies vegetation and wetland features that are good indicators of a GDE. The dataset is comprised of 48 publicly available state and federal datasets that map vegetation, wetlands, springs, and seeps commonly associated with groundwater in California[3]. It was developed through a collaboration between DWR, the Department of Fish and Wildlife, and The Nature Conservancy (TNC). TNC has also provided detailed guidance on identifying GDEs from the NC dataset[4] on the Groundwater Resource Hub[5], a website dedicated to GDEs.

BEST PRACTICE #1. Establishing a Connection to Groundwater

Groundwater basins can be comprised of one continuous aquifer (Figure 2a) or multiple aquifers stacked on top of each other (Figure 2b). In unconfined aquifers (Figure 2a), using the depth-to-groundwater and the rooting depth of the vegetation is a reasonable method to infer groundwater dependence for GDEs. If groundwater is well below the rooting (and capillary) zone of the plants and any wetland features, the ecosystem is considered disconnected and groundwater management is not likely to affect the ecosystem (Figure 2d). However, it is important to consider local conditions (e.g., soil type, groundwater flow gradients, and aquifer parameters) and to review groundwater depth data from multiple seasons and water year types (wet and dry) because intermittent periods of high groundwater levels can replenish perched clay lenses that serve as the water source for GDEs (Figure 2c). Maintaining these natural groundwater fluctuations are important to sustaining GDE health.

Basins with a stacked series of aquifers (Figure 2b) may have varying levels of pumping across aquifers in the basin, depending on the production capacity or water quality associated with each aquifer. If pumping is concentrated in deeper aquifers, SGMA still requires GSAs to sustainably manage groundwater resources in shallow aquifers, such as perched aquifers, that support springs, surface water, domestic wells, and GDEs (Figure 2). This is because vertical groundwater gradients across aquifers may result in pumping from deeper aquifers to cause adverse impacts onto beneficial users reliant on shallow aquifers or interconnected surface water. The goal of SGMA is to sustainably manage groundwater resources for current and future social, economic, and environmental benefits. While groundwater pumping may not be currently occurring in a shallower aquifer, use of this water may become more appealing and economically viable in future years as pumping restrictions are placed on the deeper production aquifers in the basin to meet the sustainable yield and criteria. Thus, identifying GDEs in the basin should done irrespective to the amount of current pumping occurring in a particular aquifer, so that future impacts on GDEs due to new production can be avoided. A good rule of thumb to follow is: *if groundwater can be pumped from a well - it's an aquifer*.

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[3] For more details on the mapping methods, refer to: Klausmeyer, K., J. Howard, T. Keeler-Wolf, K. Davis-Fadtke, R. Hull, A. Lyons. 2018. Mapping Indicators of Groundwater Dependent Ecosystems in California: Methods Report. San Francisco, California. Available at: https://groundwaterresourcehub.org/public/uploads/pdfs/iGDE_data_paper_20180423.pdf

[4] "Groundwater Dependent Ecosystems under the Sustainable Groundwater Management Act: Guidance for Preparing Groundwater Sustainability Plans" is available at: https://groundwaterresourcehub.org/gde-tools/gsp-guidance-document/

[5] The Groundwater Resource Hub: www.GroundwaterResourceHub.org

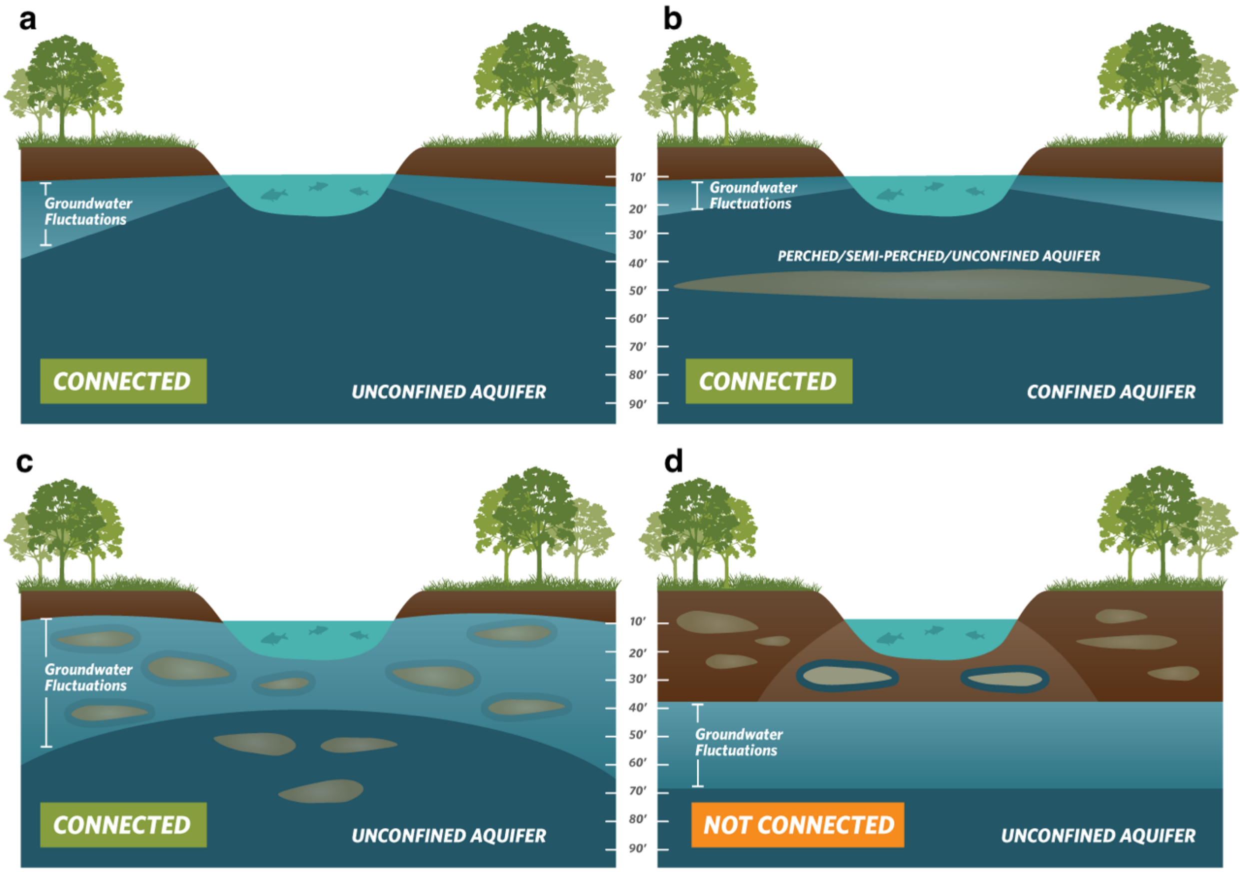

Figure 2. Confirming whether an ecosystem is connected to groundwater. Top: (a) Under the ecosystem is an unconfined aquifer with depth-to-groundwater fluctuating seasonally and interannually within 30 feet from land surface. **(b)** Depth-to-groundwater in the shallow aquifer is connected to overlying ecosystem. Pumping predominately occurs in the confined aquifer, but pumping is possible in the shallow aquifer. **Bottom: (c)** Depth-to-groundwater fluctuations are seasonally and interannually large, however, clay layers in the near surface prolong the ecosystem's connection to groundwater. **(d)** Groundwater is disconnected from surface water, and any water in the vadose (unsaturated) zone is due to direct recharge from precipitation and indirect recharge under the surface water feature. These areas are not connected to groundwater and typically support species that do not require access to groundwater to survive.

BEST PRACTICE #2. Characterize Seasonal and Interannual Groundwater Conditions

SGMA requires GSAs to describe current and historical groundwater conditions when identifying GDEs [23 CCR §354.16(g)]. Relying solely on the SGMA benchmark date (January 1, 2015) or any other single point in time to characterize groundwater conditions (e.g., depth-to-groundwater) is inadequate because managing groundwater conditions with data from one time point fails to capture the seasonal and interannual variability typical of California's climate. DWR's Best Management Practices document on water budgets[6] recommends using 10 years of water supply and water budget information to describe how historical conditions have impacted the operation of the basin within sustainable yield, implying that a baseline[7] could be determined based on data between 2005 and 2015. Using this or a similar time period, depending on data availability, is recommended for determining the depth-to-groundwater.

GDEs depend on groundwater levels being close enough to the land surface to interconnect with surface water systems or plant rooting networks. The most practical approach[8] for a GSA to assess whether polygons in the NC dataset are connected to groundwater is to rely on groundwater elevation data. As detailed in TNC's GDE guidance document[4], one of the key factors to consider when mapping GDEs is to contour depth-to-groundwater in the aquifer that is supporting the ecosystem (see Best Practice #5).

Groundwater levels fluctuate over time and space due to California's Mediterranean climate (dry summers and wet winters), climate change (flood and drought years), and subsurface heterogeneity in the subsurface (Figure 3). Many of California's GDEs have adapted to dealing with intermittent periods of water stress, however if these groundwater conditions are prolonged, adverse impacts to GDEs can result. While depth-to-groundwater levels within 30 feet[4] of the land surface are generally accepted as being a proxy for confirming that polygons in the NC dataset are supported by groundwater, it is highly advised that fluctuations in the groundwater regime be characterized to understand the seasonal and interannual groundwater variability in GDEs. Utilizing groundwater data from one point in time can misrepresent groundwater levels required by GDEs, and inadvertently result in adverse impacts to the GDEs. Time series data on groundwater elevations and depths are available on the SGMA Data Viewer[9]. However, if insufficient data are available to describe groundwater conditions within or near polygons from the NC dataset, include those polygons in the GSP until data gaps are reconciled in the monitoring network (see Best Practice #6).

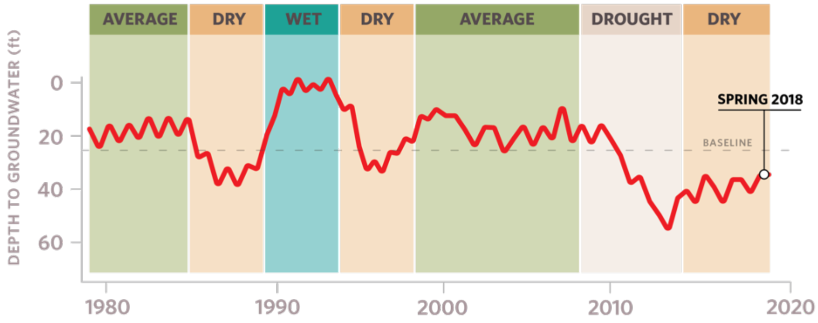

Figure 3. Example seasonality and interannual variability in depth-to-groundwater over time. Selecting one point in time, such as Spring 2018, to characterize groundwater conditions in GDEs fails to capture what groundwater conditions are necessary to maintain the ecosystem status into the future so adverse impacts are avoided.

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[6] DWR. 2016. Water Budget Best Management Practice. Available at: https://water.ca.gov/LegacyFiles/groundwater/sgm/pdfs/BMP_Water_Budget_Final_2016-12-23.pdf

[7] Baseline is defined under the GSP regulations as "historic information used to project future conditions for hydrology, water demand, and availability of surface water and to evaluate potential sustainable management practices of a basin." [23 CCR §351(e)]

[8] Groundwater reliance can also be confirmed via stable isotope analysis and geophysical surveys. For more information see The GDE Assessment Toolbox (Appendix IV, GDE Guidance Document for GSPs[4]).

[9] SGMA Data Viewer: https://sgma.water.ca.gov/webgis/?appid=SGMADataViewer

BEST PRACTICE #3. Ecosystems Often Rely on Both Groundwater and Surface Water

GDEs are plants and animals that rely on groundwater for all or some of its water needs, and thus can be supported by multiple water sources. The presence of non-groundwater sources (e.g., surface water, soil moisture in the vadose zone, applied water, treated wastewater effluent, urban stormwater, irrigated return flow) within and around a GDE does not preclude the possibility that it is supported by groundwater, too. SGMA defines GDEs as "ecological communities and species that depend on groundwater emerging from aquifers or on groundwater occurring near the ground surface" [23 CCR §351(m)]. Hence, depth-to-groundwater data should be used to identify whether NC polygons are supported by groundwater and should be considered GDEs. In addition, SGMA requires that significant and undesirable adverse impacts to beneficial users of surface water be avoided. Beneficial users of surface water include environmental users such as plants or animals[10], which therefore must be considered when developing minimum thresholds for depletions of interconnected surface water.

GSAs are only responsible for impacts to GDEs resulting from groundwater conditions in the basin, so if adverse impacts to GDEs result from the diversion of applied water, treated wastewater, or irrigation return flow away from the GDE, then those impacts will be evaluated by other permitting requirements (e.g., CEQA) and may not be the responsibility of the GSA. However, if adverse impacts occur to the GDE due to changing groundwater conditions resulting from pumping or groundwater management activities, then the GSA would be responsible (Figure 4).

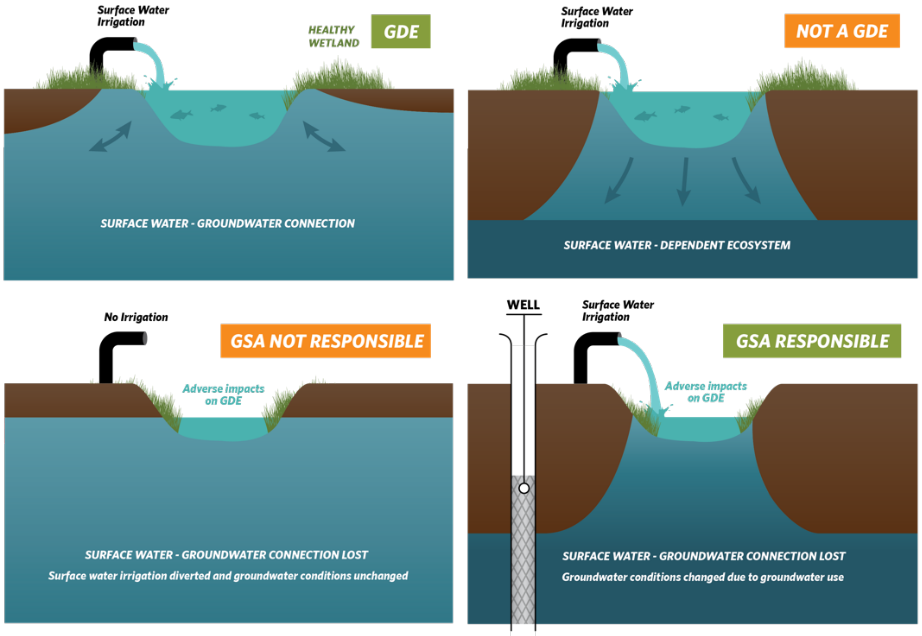

Figure 4. Ecosystems often depend on multiple sources of water. Top: (Left) Surface water and groundwater are interconnected, meaning that the GDE is supported by both groundwater and surface water. **(Right)** Ecosystems that are only reliant on non-groundwater sources are not groundwater-dependent. **Bottom: (Left)** An ecosystem that was once dependent on an interconnected surface water, but loses access to groundwater solely due to surface water diversions may not be the GSA's responsibility. **(Right)** Groundwater dependent ecosystems once dependent on an interconnected surface water system, but loses that access due to groundwater pumping is the GSA's responsibility.

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[10] For a list of environmental beneficial users of surface water by basin, visit: https://groundwaterresourcehub.org/gde-tools/environmental-surface-water-beneficiaries/

BEST PRACTICE #4. Select Representative Groundwater Wells

Identifying GDEs in a basin requires that groundwater conditions are characterized to confirm whether polygons in the NC dataset are supported by the underlying aquifer. To do this, proximate groundwater wells should be identified to characterize groundwater conditions (Figure 5). When selecting representative wells, it is particularly important to consider the subsurface heterogeneity around NC polygons, especially near surface water features where groundwater and surface water interactions occur around heterogeneous stratigraphic units or aquitards formed by fluvial deposits. The following selection criteria can help ensure groundwater levels are representative of conditions within the GDE area:

- Choose wells that are within 5 kilometers (3.1 miles) of each NC Dataset polygons because they are more likely to reflect the local conditions relevant to the ecosystem. If there are no wells within 5km of the center of a NC dataset polygon, then there is insufficient information to remove the polygon based on groundwater depth. Instead, it should be retained as a potential GDE until there are sufficient data to determine whether or not the NC Dataset polygon is supported by groundwater.

- Choose wells that are screened within the surficial unconfined aquifer and capable of measuring the true water table.

- Avoid relying on wells that have insufficient information on the screened well depth interval for excluding GDEs because they could be providing data on the wrong aquifer. This type of well data should not be used to remove any NC polygons.

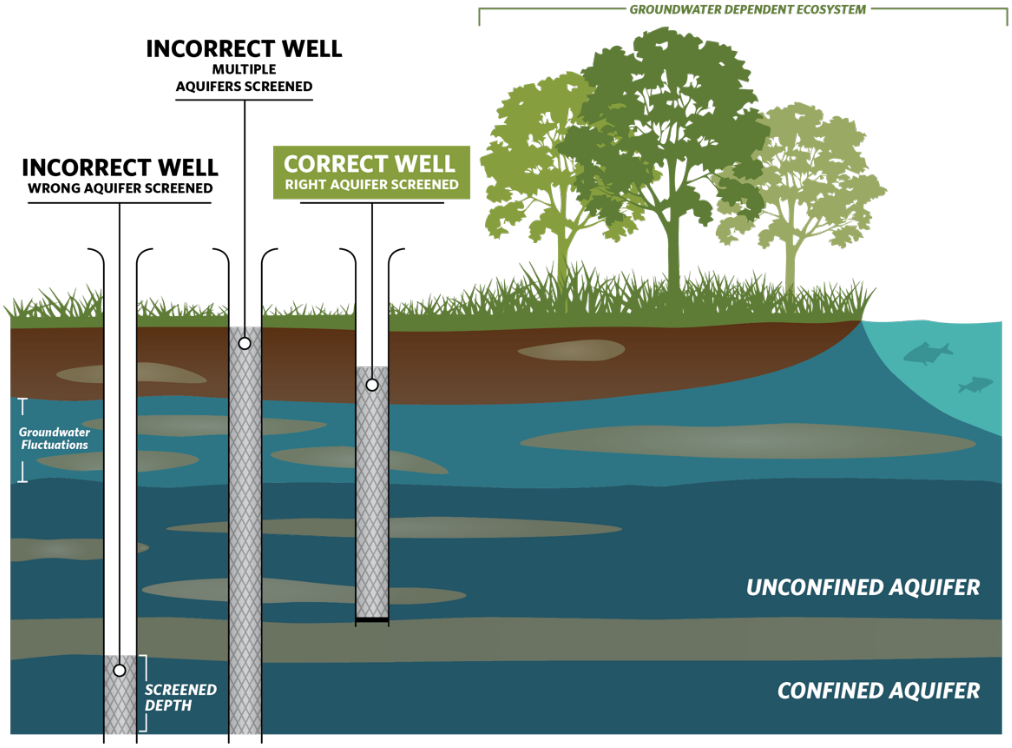

Figure 5. Selecting representative wells to characterize groundwater conditions near GDEs.

BEST PRACTICE #5. Contouring Groundwater Elevations

The common practice to contour depth-to-groundwater over a large area by interpolating measurements at monitoring wells is unsuitable for assessing whether an ecosystem is supported by groundwater. This practice causes errors when the land surface contains features like stream and wetland depressions because it assumes the land surface is constant across the landscape and depth-to-groundwater is constant below these low-lying areas (Figure 6a). A more accurate approach is to interpolate **groundwater elevations** at monitoring wells to get groundwater elevation contours across the landscape. This layer can then be subtracted from land surface elevations from a Digital Elevation Model (DEM)[11] to estimate depth-to-groundwater contours across the landscape (Figure b; Figure 7). This will provide a much more accurate contours of depth-to-groundwater along streams and other land surface depressions where GDEs are commonly found.

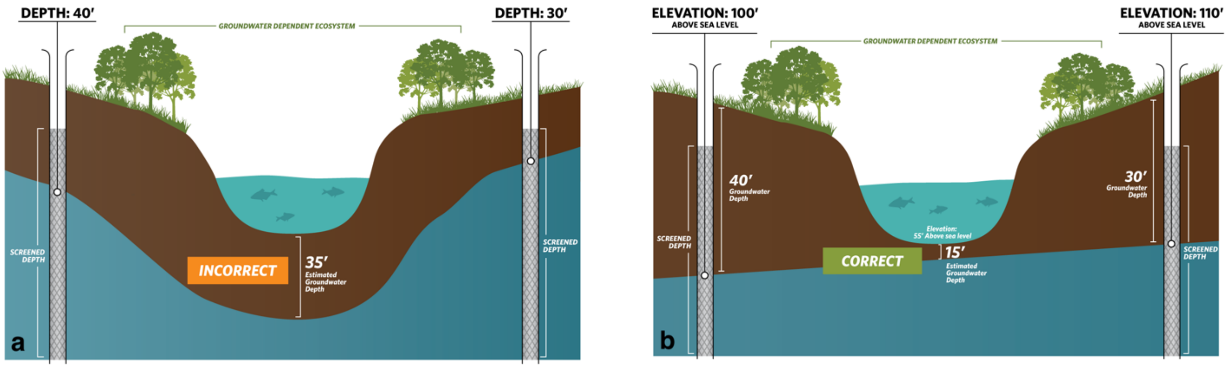

Figure 6. Contouring depth-to-groundwater around surface water features and GDEs. (a) Groundwater level interpolation using depth-to-groundwater data from monitoring wells. **(b)** Groundwater level interpolation using groundwater elevation data from monitoring wells and DEM data.

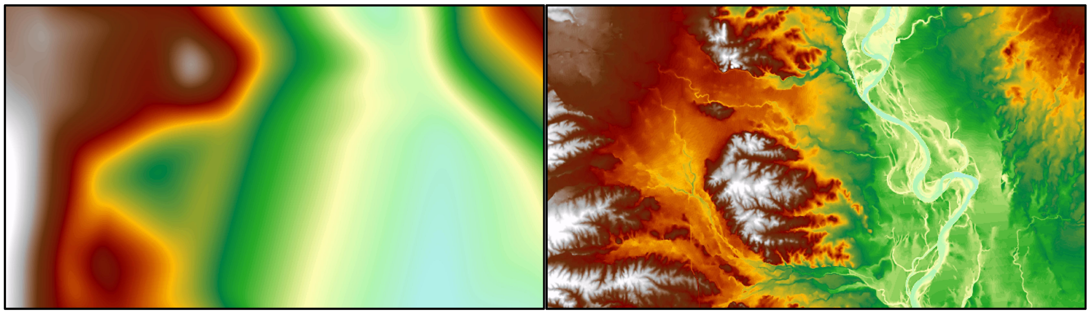

Figure 7. Depth-to-groundwater contours in Northern California. (Left) Contours were interpolated using depth-to-groundwater measurements determined at each well. **(Right)** Contours were determined by interpolating groundwater elevation measurements at each well and superimposing ground surface elevation from DEM spatial data to generate depth-to-groundwater contours. The image on the right shows a more accurate depth-to-groundwater estimate because it takes the local topography and elevation changes into account.

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[11] USGS Digital Elevation Model data products are described at: https://www.usgs.gov/core-science-systems/ngp/3dep/about-3dep-products-services and can be downloaded at: https://iewer.nationalmap.gov/basic/

BEST PRACTICE #6. Best Available Science

Adaptive management is embedded within SGMA and provides a process to work toward sustainability over time by beginning with the best available information to make initial decisions, monitoring the results of those decisions, and using the data collected through monitoring programs to revise decisions in the future. In many situations, the hydrologic connection of NC dataset polygons will not initially be clearly understood if site-specific groundwater monitoring data are not available. If sufficient data are not available in time for the 2020/2022 plan, **The Nature Conservancy strongly advises that questionable polygons from the NC dataset be included in the GSP until data gaps are reconciled in the monitoring network.** Erring on the side of caution will help minimize inadvertent impacts to GDEs as a result of groundwater use and management actions during SGMA implementation.

KEY DEFINITIONS

Groundwater basin is an aquifer or stacked series of aquifers with reasonably well-defined boundaries in a lateral direction, based on features that significantly impede groundwater flow, and a definable bottom. *23 CCR §341(g)(1)*

Groundwater dependent ecosystem (GDE) are ecological communities or species that depend on groundwater emerging from aquifers or on groundwater occurring near the ground surface. *23 CCR §351(m)*

Interconnected surface water (ISW) surface water that is hydraulically connected at any point by a continuous saturated zone to the underlying aquifer and the overlying surface water is not completely depleted. *23 CCR §351(o)*

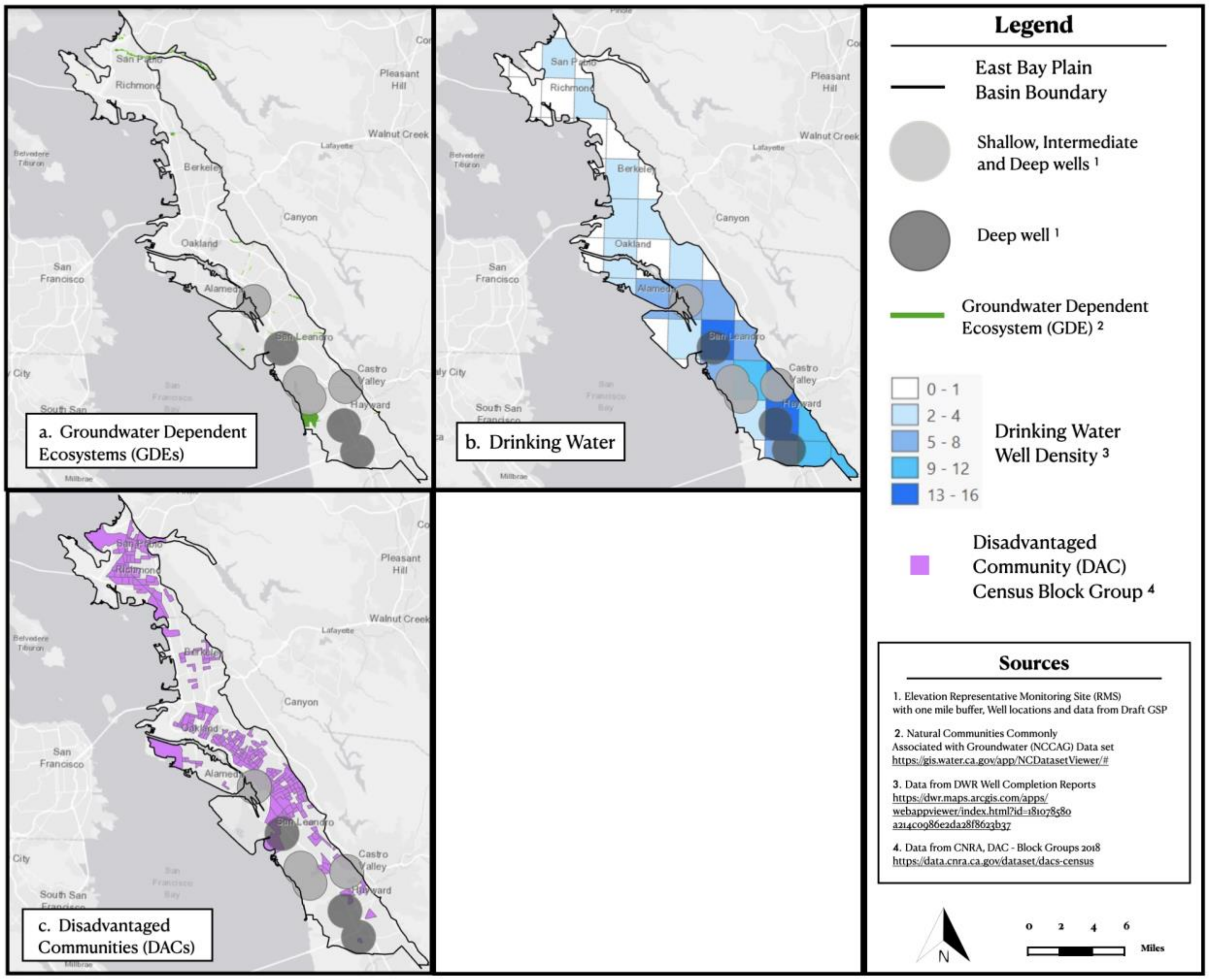
Principal aquifers are aquifers or aquifer systems that store, transmit, and yield significant or economic quantities of groundwater to wells, springs, or surface water systems. *23 CCR §351(aa)*

ABOUT US

The Nature Conservancy is a science-based nonprofit organization whose mission is *to conserve the lands and waters on which all life depends*. To support successful SGMA implementation that meets the future needs of people, the economy, and the environment, TNC has developed tools and resources (www.groundwaterresourcehub.org) intended to reduce costs, shorten timelines, and increase benefits for both people and nature.

Attachment E

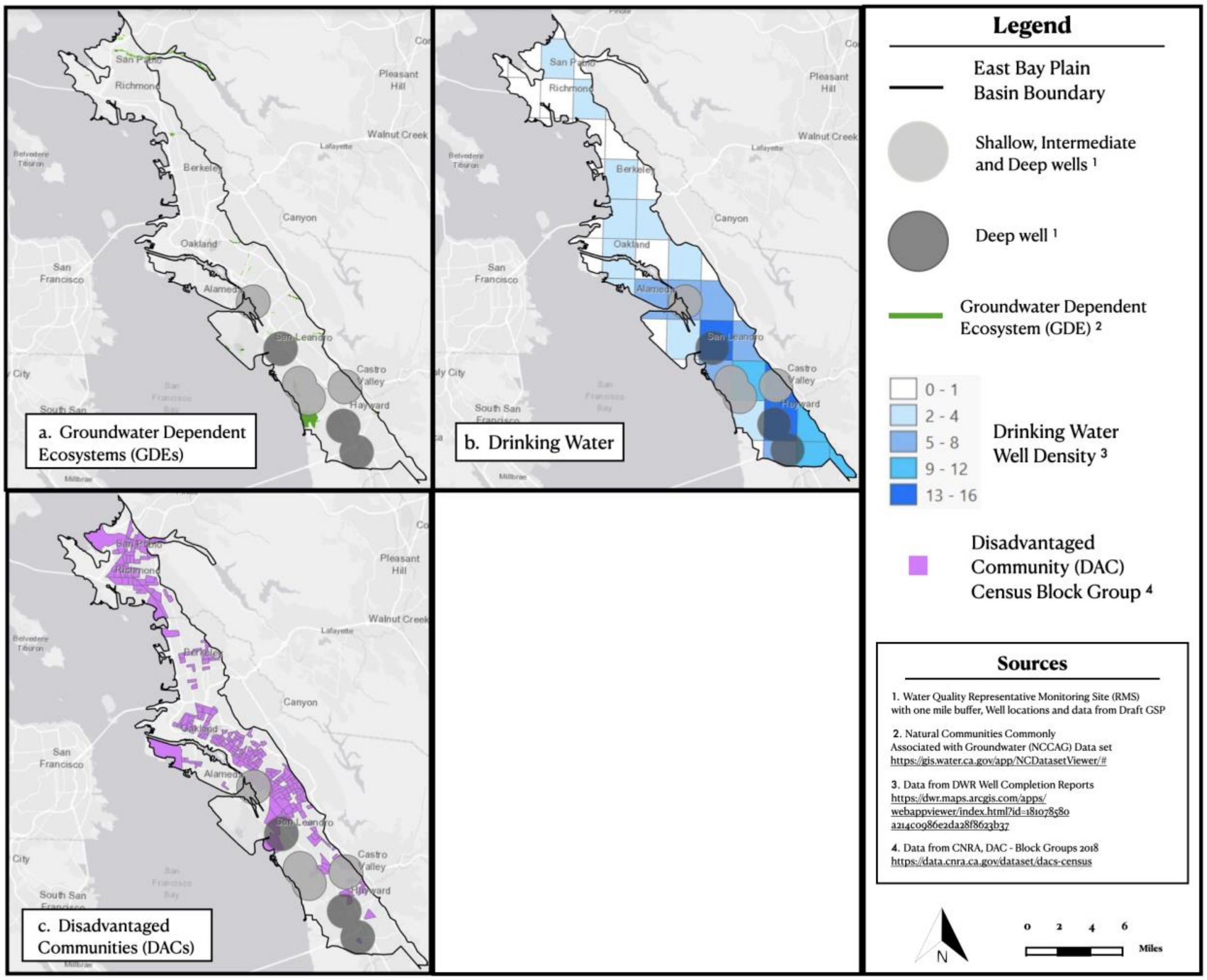
Maps of representative monitoring sites in relation to key beneficial users



Sources

1. Elevation Representative Monitoring Site (RMS) with one mile buffer, Well locations and data from Draft GSP
2. Natural Communities Commonly Associated with Groundwater (NCCAG) Data set https://gis.water.ca.gov/app/NCDatasetViewer/#
3. Data from DWR Well Completion Reports https://dwr.maps.arcgis.com/apps/webappviewer/index.html?id=181078580a214c0986e2da28f8623b37
4. Data from CNRA, DAC - Block Groups 2018 https://data.cnra.ca.gov/dataset/dacs-census

Figure 1. Groundwater elevation representative monitoring sites in relation to key beneficial users: a) Groundwater Dependent Ecosystems (GDEs), b) Drinking Water users, c) Disadvantaged Communities (DACs), and d) Tribes.



a. Groundwater Dependent Ecosystems (GDEs)

b. Drinking Water

c. Disadvantaged Communities (DACs)

Sources

1. Water Quality Representative Monitoring Site (RMS) with one mile buffer, Well locations and data from Draft GSP

2. Natural Communities Commonly Associated with Groundwater (NCCAG) Data set https://gis.water.ca.gov/app/NCDatasetViewer/#

3. Data from DWR Well Completion Reports https://dwr.maps.arcgis.com/apps/webappviewer/index.html?id=181078580a214c0986e2da28f8623b37

4. Data from CNRA, DAC - Block Groups 2018 https://data.cnra.ca.gov/dataset/dacs-census

Figure 2. Groundwater quality representative monitoring sites in relation to key beneficial users: a) Groundwater Dependent Ecosystems (GDEs), b) Drinking Water users, c) Disadvantaged Communities (DACs), and d) Tribes.