APPENDICES

and

REFERENCES

APPENDIX A

Resolution of Intent

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MINUTES

Tuesday, May 24, 2011

East Bay Municipal Utility District
Board of Directors
375 Eleventh Street
Oakland, California

Regular Closed Session Meeting

President John A. Coleman called to order the Regular Closed Session Meeting of the Board of Directors at 11:03 a.m. in the Administration Center Board Room.

ROLL CALL

Directors Katy Foulkes, Andy Katz, Doug Linney, Lesa R. McIntosh, Frank Mellon, William B. Patterson, and President John A. Coleman were present at roll call.

Staff present included General Manager Alexander R. Coate, General Counsel Jylana Collins, Director of Water and Natural Resources Richard G. Sykes (Item 1a), Assistant General Counsel Craig Spencer (Item 1a), Attorney Karen Donovan (Item 1a), Attorney Derek McDonald (Item 1a), Assistant General Counsel Veronica Fauntleroy (Item 2), and Director of Wastewater David R. Williams (Item 2).

PUBLIC COMMENT

There was no public comment.

ANNOUNCEMENT OF CLOSED SESSION AGENDA

President Coleman announced the Closed Session agenda. The Board convened to Conference Room 8A/B for discussion.

Regular Business Meeting

President John A. Coleman called to order the Regular Business Meeting of the Board of Directors at 1:17 p.m. in the Administration Center Board Room.

ROLL CALL

Directors Katy Foulkes, Andy Katz, Doug Linney, Lesa R. McIntosh, Frank Mellon, William B. Patterson, and President John A. Coleman were present at roll call.

Staff present included General Manager Alexander R. Coate, General Counsel Jylana Collins, and Secretary of the District Lynelle M. Lewis.

BOARD OF DIRECTORS

President Coleman led the Pledge of Allegiance.

ANNOUNCEMENTS FROM CLOSED SESSION

The Board, in closed session this morning, by a unanimous vote of the Directors attending, decided not to file an appeal in the litigation entitled "Foothill Conservancy versus EBMUD," and to set aside the certification of Program EIR for the Water Supply Management Program 2040 and related project approvals, and to take further actions consistent with the court's ruling.

There were no other announcements required from closed session.

PRESENTATIONS

General Manager Alexander R. Coate announced the winners of the 2011 Employee Excellence Awards. He said that the following employees were nominated and selected by their fellow employees for their outstanding performance and achievements and each one has contributed to the District's success in a variety of important ways:

Cost Savings Achievement -- Colin Moy, Environmental Health and Safety Specialist II; **Creativity and Innovation** -- Bill Jeng, Associate Civil Engineer; **Customer Service** -- Bryan Dilts, Assistant Engineer; **Employee Leadership** -- Timothy McGowan, Associate Civil Engineer; **Environmental Excellence** -- Derek Lee, Senior Environmental Health and Safety Specialist; **Safety Excellence** -- Christian Dembiczak, Environmental Health and Safety Specialist II; **Management Achievement** -- Antonio Martinez, Construction Maintenance Superintendent; **Management Excellence** -- Roberto Cortez, Assistant Superintendent, Aqueduct; **Outstanding Performers** -- Benjamin Bray, Assistant Water Resources Specialist; David Beyer, Senior Civil Engineer; Edward Chang, Associate Civil Engineer; Linda Connolly, Senior Administrative Clerk; Michael Heaton, Wastewater Shift Supervisor; Joseph Kacyra, Assistant Engineer; Thomas Kruase, Electrical Technician; Martin Liu, Associate Civil Engineer; Robert Nishita, Gardener II; Danielle Roybal-Alviz, Senior Water Treatment Operator; Martin Sargent, Electrical Technician; James F. Smith, Superintendent of Water Treatment; **Team Achievement -- Upper San Leandro Raw Water Control Infrastructure Emergency Repair Team,** David J. Cherniss, Maintenance Machinist, Team Leader; Andrew A, Akelman, Manager of Purchasing; Sandra R. Beecher, Senior Environmental Health & Safety Specialist; Jeffrey L. Brissey, Crane Operator; Adam C. Erlach, Maintenance Machinist; Matthew T. Guihan, Associate Civil Engineer; Mark Lewis, Associate Corrosion Control Specialist; Sean C. Lyons, Maintenance Machinist; Richard L. Parks, Stores Supervisor; Craig N. Percival, Maintenance Machinist; Jimmie Rangel Assistant Construction & Maintenance Superintendent; David S. Salazar, Maintenance Machinist; Richard H. Wilson, Associate Mechanical Engineer; Elvester Woods, Pipeline Welder III; and Steven E. Wright, Maintenance Machinist; **Team Achievement -- Get The Lead Out!,** Randele Kanouse, Special Assistant IV, Team Leader; Marlaigne Dumaine, Special Assistant I; Joel Freid, Attorney III; Paul Gilbert-Synder, Associate Civil Engineer; Ronald Hunsinger, Manager of Water Quality; Eugene Lacatis, Maintenance Machinist; Jennifer McGregor, Associate Civil Engineer; Phillip Munoz Jr., Mechanical Supervisor; Rick Sakaji, Manager of Regulatory Planning; Richard Sykes, Director of Water and Natural Resources, and Steven Wright, Maintenance Machinist; **Teamwork -- Camanche Powerhouse PLF Upgrade Team,** David C. Oldham, Power & Treatment Plant Maintenance Supervisor - Team Leader; Roberto R. Davis, Electrical Technician; Douglas A. Hooper, Instrument Technician; Lorenzo Reyes, Hydroelectric Power Plant Operator II; **Teamwork -- Print Shop Team,** Joselito Jacob, Senior Printing Technician, Team Leader; Scott Pelkey, Printing Technician II; and Enrique Romero, Printing Technician II.

President Coleman presented the awards the winners. The Board thanked the winners for their hard work during this time of budget cuts and staff reductions and applauded them for their accomplishments. General Manager Coate invited the Board and staff to a reception to honor the winners immediately following the Board meeting.

PUBLIC COMMENT

There was no public comment.

CONSENT CALENDAR

- Item 8 was pulled from the Consent Calendar by Director Katz.

- Motion by Director McIntosh, seconded by Director Linney, to approve Items 1-7 and 9 on the Consent Calendar, carried (7-0) by voice vote.

1. **Motion No. 058-11** -- Approved the Regular Meeting Minutes of May 10, 2011.

2. The following documents were filed with the Board: 1) Memorandum dated May 24, 2011, to Board of Directors from Alexander R. Coate, General Manager, regarding the State Budget and Property Tax Update; 2) Presentation entitled "Board Meeting Presentation of Winners," dated May 24, 2011; 3) Presentation entitled "South East Bay Plain Groundwater Basin, Groundwater Management Plan," dated May 24, 2011; 4) Presentation entitled "Water Supply & Consumption, Water Supply Engineering," dated May 24, 2011; and 5) Memorandum dated May 24, 2011, to Board of Directors from Alexander R. Coate, General Manager, regarding Speaking Points Regarding WSMP 2040 Action.

3. **Motion No. 059-11** -- Awarded a contract to the lowest responsive/responsible bidder, Abhe & Svoboda, Inc., in the amount of $6,183,310 for construction of Recoat Mokelumne Aqueducts Phase 8 – Slough Crossings under Specification 2033.

4. **Motion No. 060-11** -- Authorized an agreement with the Civicorps (formerly East Bay Conservation Corps) in an amount not to exceed $429,000 to provide vegetation control and related duties at various District properties for a period of one year beginning July 1, 2011 through June 30, 2012.

5. **Motion No. 061-11** -- Authorized an agreement with Pacific States Marine Fisheries Commission in an amount not to exceed $250,000 annually for a marking/tagging and recovery program for Chinook salmon and steelhead trout at the Mokelumne River Fish Hatchery during the period July 1, 2011 to June 30, 2016.

6. **Motion No. 062-11** -- Authorized agreements with the following vendors to provide tree trimming and related services for an estimated total annual amount of $350,000 for the period July 1, 2011 through June 30, 2013, with three options to extend for additional one-year periods: Bartlett Tree Experts, Bob Fine Brush Grinding, Chandler Complete Tree Care, D & H Landscaping, Draft Horses for Hire, Evergreen Tree Service, Foothill Tree Service, Hamilton Tree Service, Labat's Tree Care, Larry's Tree Care Inc., Professional Tree Care Co., Reliable Tree Experts, RMT Landscape, and Yard Care Professionals. Authorized additional agreements with companies that meet District standards and offer pricing at or below the range described in the current proposed agreements to increase flexibility and ensure vendor availability pursuant to this recommendation.

7. **Motion No. 063-11** -- Authorized an amendment to the agreement with the Alameda County Public Works Agency (County) in an amount not to exceed $235,000 to perform additional work associated with the relocation of approximately 1,000 feet of 8-inch diameter pipeline as part of the County's Castro Valley Boulevard Street Improvement project.

8. **Motion No. 064-11** -- Authorized a Memorandum of Agreement between EBMUD and the Alameda County Flood Control and Water Conservation District - Zone 7, the Contra Costa Water District, the City and County of San Francisco Public Utilities Commission, and the Santa Clara Valley Water District to conduct further analysis of the Mallard Slough site for the Bay Area Regional Desalination Project at a cost to EBMUD of $200,000 in staff time.

– Item 8 was pulled from Consent Calendar by Director Katz.

- Motion by Director McIntosh, seconded by Director Patterson, to approve the recommended action, carried, (6-0-1) with Director Katz abstaining from the vote.

9. **Resolution No. 33817-11** -- Authorizing The Execution Of A Ten-Year License Agreement With The East Bay Regional Park District For The Continued Use Of District-Owned Watershed Property For An Access Road To Kennedy Grove Regional Park.

PUBLIC HEARING

10. **Conduct A Public Hearing To Receive Comments On Intent To Prepare A Groundwater Management Plan Covering The South East Bay Plain Basin.**

President Coleman opened the Public Hearing at 1:30 p.m.

Manager of Water Supply Improvements Michael Tognolini reported that EBMUD intends to prepare a Groundwater Management Plan (GMP) to manage and protect water quality and quantity in the South East Bay Plain Basin (SEBP) for potable uses. By preparing a GMP, he said EBMUD will take a leadership role in monitoring and managing the groundwater basin.

Mr. Tognolini highlighted the benefits of this effort, and he noted that the GMP will be of great value if and when EBMUD pursues the Bayside Phase 2 project. Preparation of the GMP is expected to take up to two years to complete, following Board adoption of a resolution of intent. Elements of the GMP will include basin delineation and characterization, establishment of basin objectives, description of monitoring activities, identification of management activities, and stakeholder participation. District staff will prepare the GMP, but depending on initial findings, some elements such as groundwater model development may require consultant support.

The Board asked no questions and President Coleman closed the Public Hearing at 1:41 p.m.

DETERMINATION AND DISCUSSION

11. **Adopt A Resolution Of Intent To Prepare A Groundwater Management Plan Covering The South East Bay Plain Basin.**

- Motion by Director Foulkes, seconded by Director Linney, to approve the recommended action, carried (7-0) by voice vote.

Resolution No. 33818-11 -- Declaring The Intent To Prepare A Groundwater Management Plan For The South East Bay Plain Groundwater Basin And Adopt A Statement Of Public Participation.

12. **Legislative Update.**

Special Assistant Marlaigne Dumaine reported that Governor Jerry Brown had released his "2011-12 May Revision to the Governor's Budget" (May Revise). The May Revise includes a combination of cuts and revenues to address an outstanding $10.8 billion deficit. She noted that the deficit figure was $6 billion lower than the earlier estimate due to higher than anticipated tax revenues. Additionally, she noted that the May Revise relies on the tax extensions which were proposed in the governor's earlier budget and would need to be approved by voters. It also continues to propose the elimination of redevelopment agencies and includes additional program cuts, such as additional health spending reductions.

Ms. Dumaine said the legislature will now consider the May Revise as they work to develop and pass a final state budget. The constitutional deadline for the legislature to act on the budget is June 15. With the passage of Proposition 25 in November 2010, the legislature may now pass the budget with a majority vote. The consequences for the failure to meet the June 15 deadline are the legislature's forfeiture of pay and travel and living reimbursements until a budget is passed and sent to the governor. Ms. Dumaine pointed out that despite the unanticipated $6 billion in tax revenues, the state budget situation remains dire and there is tremendous uncertainty regarding property tax revenues and whether the June 15 deadline will be met.

13. **General Manager's Report.**

Manager of Water Supply Eileen White presented an update on current water supply and recent consumption. She reported that precipitation and water content in the mountain snowpack have given us a good supply year. She also reported that although consumption had recently risen slightly, customers have changed their water use patterns since the last drought. Next, General Manager Coate presented the Board with speaking points regarding the current status of WSMP 2040. The Board asked no questions.

REPORTS AND DIRECTOR COMMENTS

13. **Committee Reports.**

- Filed with the Board were the EBMUD/EBRPD Liaison Committee Minutes of April 15, 2001 and the Planning Committee and the Legislative/Human Resources Committee Minutes of May 10, 2011.

14. **Director Comments.**

- Director Foulkes reported attending the following events: ACWA Spring Conference in Sacramento May 11–13; Piedmont City Council meeting on May 16; and the ACWA Region 5 meeting in Sacramento on May 22-23 that included a tour of the Sacramento River and Freeport Facility.
- Director Katz reported attending a meeting with the City of Emeryville Public Works officials on May 12 and the Alameda Labor Council Annual Gala on May 20.
- Director Linney had no comment.
- Director McIntosh had no comment.
- Director Mellon reported attending the following events: Alameda County Planning Commission in Castro Valley on May 2; Teamsters Assistance Program fundraiser on May 4; ACWA Spring Conference awards luncheon in Sacramento on May 12; Roswell Rodeo Parade in Castro Valley on May 14; and the ACWA Region 5 tour of the Freeport Facility on May 23. He announced that EBMUD received the Clair Hill award at the ACWA Spring Conference and he congratulated staff on this accomplishment.
- Director Patterson reported attending the ACWA Spring Conference in Sacramento on May 11–13.
- President Coleman reported attending the following events: ACWA Spring Conference in Sacramento May 11–13; Lafayette Rotary Club at Lafayette Reservoir on May 14; Lafayette Rotary Club Groundbreaking ceremony at Lafayette Reservoir on May 19; Contra Costa Council Board meeting in Richmond on May 20; and the ACWA Region 5 meeting in Sacramento on May 22. He noted his upcoming schedule includes attendance

at the following events: SIRS in Moraga on June 1; California State Chamber reception in Sacramento on June 1-2; United States Army Corps of Engineers change of command in Marin County on June 3; and the Upper Mokelumne River Water Authority conference call on June 10.

ADJOURNMENT

President Coleman adjourned the meeting at 2:00 p.m.

SUBMITTED BY:

Lynelle M. Lewis, Secretary of the District

APPROVED: June 14, 2011

John A. Coleman, President of the Board

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EBMUD

AGENDA NO. 11.
MEETING DATE May 24, 2011

TITLE **ADOPT RESOLUTION OF INTENT TO PREPARE A GROUNDWATER MANAGEMENT PLAN FOR THE SOUTH EAST BAY PLAIN BASIN**

☐ MOTION ________ ☒ RESOLUTION ________ ☐ ORDINANCE ________

RECOMMENDED ACTION

Adopt a resolution of intent to prepare a Groundwater Management Plan (GMP) covering the South East Bay Plain (SEBP) Basin.

SUMMARY

A GMP will support sustainability and protect water quality and water storage capabilities for the SEBP Basin, and thus be a benefit for existing users of the basin, including EBMUD. Additionally, a GMP will ensure that if EBMUD proceeds with expansion of the Bayside Well Project the local groundwater basin will be adequately and sustainably managed for all users. A presentation on the GMP was provided at the Planning Committee meeting on May 10, 2011. In accordance with California State Law, the District must hold a hearing and pass a resolution giving notice of the intention to develop a GMP.

DISCUSSION

In 1992, the California Legislature passed Assembly Bill (AB) 3030 which provided local public agencies increased management authority over their groundwater resources by developing groundwater management plans. In September 2002, Senate Bill 1938 expanded AB 3030 by requiring GMPs to include specific components in order to be eligible for grant funding for various types of groundwater related projects. A GMP provides the framework for coordinating groundwater management activities among stakeholders. In general, the documents are fashioned to identify basin management goals and objectives, along with guiding further efforts that will be undertaken to effectively monitor and manage the groundwater basin.

With the completion of Bayside Groundwater Project Bayside Phase 1 in March of 2010 and the potential future development of Bayside Phase 2, local groundwater resources are now a component of the District's future supplemental supply. The Bayside Project utilizes the SEBP Groundwater Basin (map attached). Preparation of a GMP is consistent with commitments made in the Phase 1 EIR's Mitigation, Monitoring and Reporting Program (MMRP). A GMP provides a mechanism for the District to monitor,

Funds Available: FY12	Budget Code: WSC/WNR/455/200569:01	
DEPARTMENT SUBMITTING Water & Natural Resources	DEPARTMENT MANAGER or DIRECTOR Richard G Sykes	APPROVED General Manager

Contact the Office of the District Secretary with questions about completing or submitting this form.

manage, and protect water quality and quantity in the SEBP Basin for potable uses. Preparation of the GMP is expected to take up to two years to complete, following Board adoption of a resolution of intent. By law, if the GMP is not completed in the 2-year period, it must be restarted. Elements of the GMP will include basin delineation and characterization, establishment of basin objectives, description of monitoring activities, identification of management activities, and stakeholder participation. District staff will prepare the GMP, but depending on initial findings, some elements such as groundwater model development may require consultant support.

A GMP for the SEBP will accomplish the following objectives:

- Provide statutory authority for District to manage the groundwater basin;
- Support basin sustainability;
- Maintain local control of groundwater;
- Support the rights and beneficial uses of groundwater for basin users;
- Foster collaboration and prevent legal disputes among stakeholders; and
- Increase opportunities for future grant funding.

The public notice of this hearing to adopt the Resolution of Intent was published in the Oakland Tribune May 7 and 14, 2011.

FISCAL IMPACT

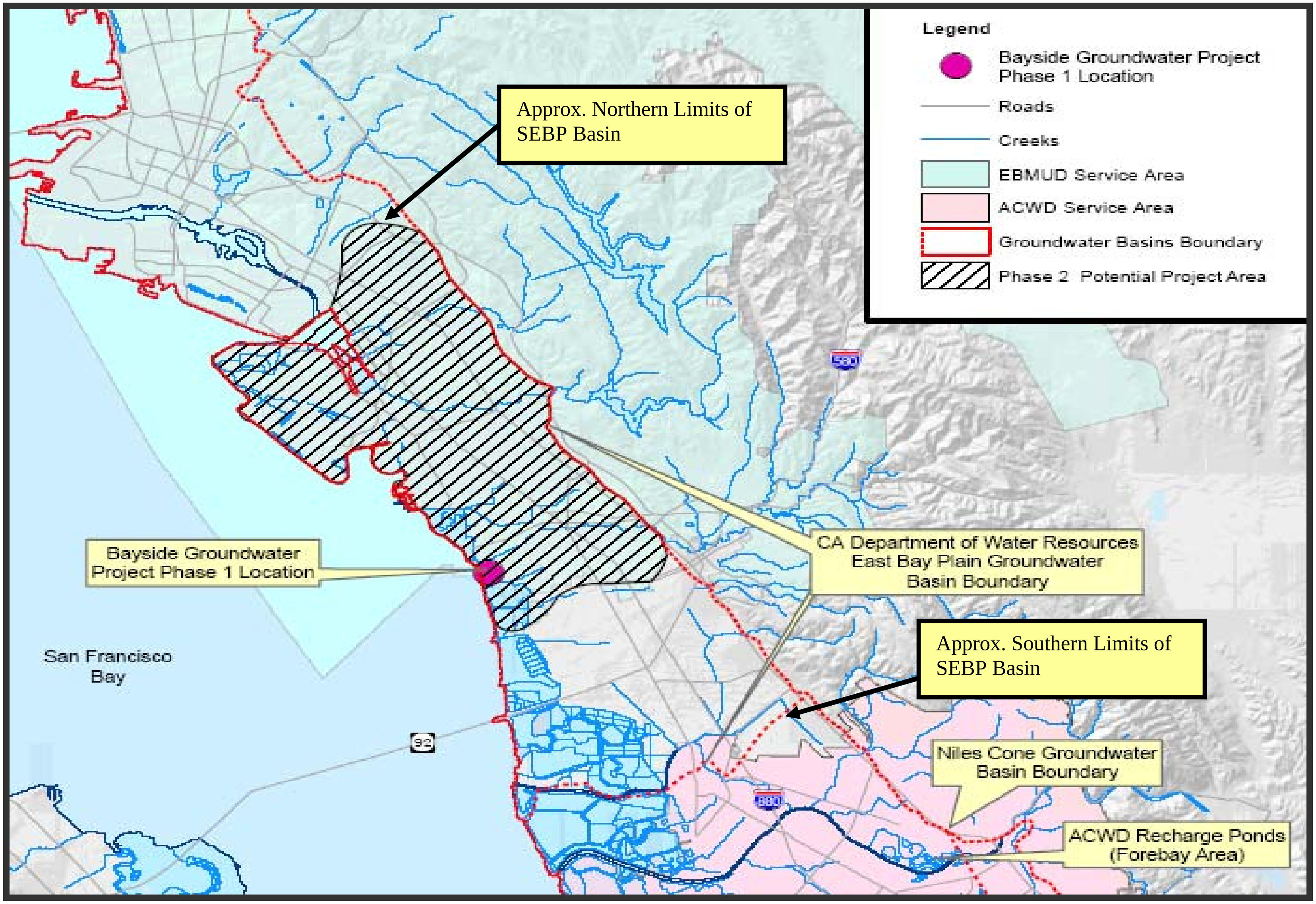
Funds for the GMP effort are included in the FY12 Capital Improvement Program

ALTERNATIVE

Do not adopt the resolution of intent. This alternative is not recommended because the SEBP Basin lacks local groundwater management protection to support its sustainability. Further, in the absence of local control under a GMP, the State of California may elect, in the future, to take on management authority in the basin. Since EBMUD is relying on the SEBP Basin for current and future supplemental water supply needs, it is in the District's interest to lead a groundwater management planning effort.

Attachments:

1. SEBP Basin Map
2. Board Resolution



Map: South East Bay Plain (SEBP) Groundwater Basin

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RESOLUTION NO. 33818-11

DECLARING THE INTENT TO PREPARE A GROUNDWATER MANAGEMENT PLAN FOR THE SOUTH EAST BAY PLAIN GROUNDWATER BASIN AND ADOPT A STATEMENT OF PUBLIC PARTICIPATION

Introduced by Director Foulkes ; Seconded by Director Linney

WHEREAS, the California Legislature enacted Assembly Bill 3030 and Senate Bill 1938, as set forth in Water Code Section 10750, et seq., to provide local public agencies the authority to implement groundwater management plans and be eligible for grant funds for groundwater related projects; and

WHEREAS, the State has emphasized local agency development of integrated regional solutions for water management and coordinating conjunctive management of surface and groundwater to improve regional supply, reliability and quality of water; and

WHEREAS, groundwater is a valuable natural resource in California and should be managed to ensure both its safe production and quality; and

WHEREAS, through the operation of the Bayside Groundwater Project Phase 1, the District will use water as stored in the South East Bay Plain Groundwater Basin (SEBP Basin) during times of drought; and

WHEREAS, the District has identified an expanded Bayside Groundwater Project as a potential future supplemental water supply; and

WHEREAS, there currently is no groundwater management plan in place to protect and sustain the SEBP Basin; and

WHEREAS, through the preparation of a groundwater management plan for the SEBP Basin, EBMUD along with other SEBP Basin stakeholders can collaborate on basin management objectives; and

WHEREAS, the District intends to prepare, adopt, and implement the SEBP Basin groundwater management plan in accordance with State law.

NOW, THEREFORE BE IT RESOLVED by the Board of Directors of the East Bay Municipal Utility District that:

1. The Board intends to prepare, adopt, and implement a groundwater management plan for the South East Bay Plain Groundwater Basin. The plan will include basin management objectives and management actions.

2. The District further intends to provide for and encourage public and stakeholder involvement in the preparation of the Groundwater Management Plan.

ADOPTED this 24th day of May, 2011 by the following vote:

AYES: Directors Foulkes, Katz, Linney, McIntosh, Mellon, Patterson and President Coleman.

NOES: None.

ABSTAIN: None.

ABSENT: None.

President

ATTEST:

Secretary

APPROVED AS TO FORM AND PROCEDURE:

General Counsel

APPENDIX B

San Lorenzo Creek Watershed Map and Stream Flow Summaries

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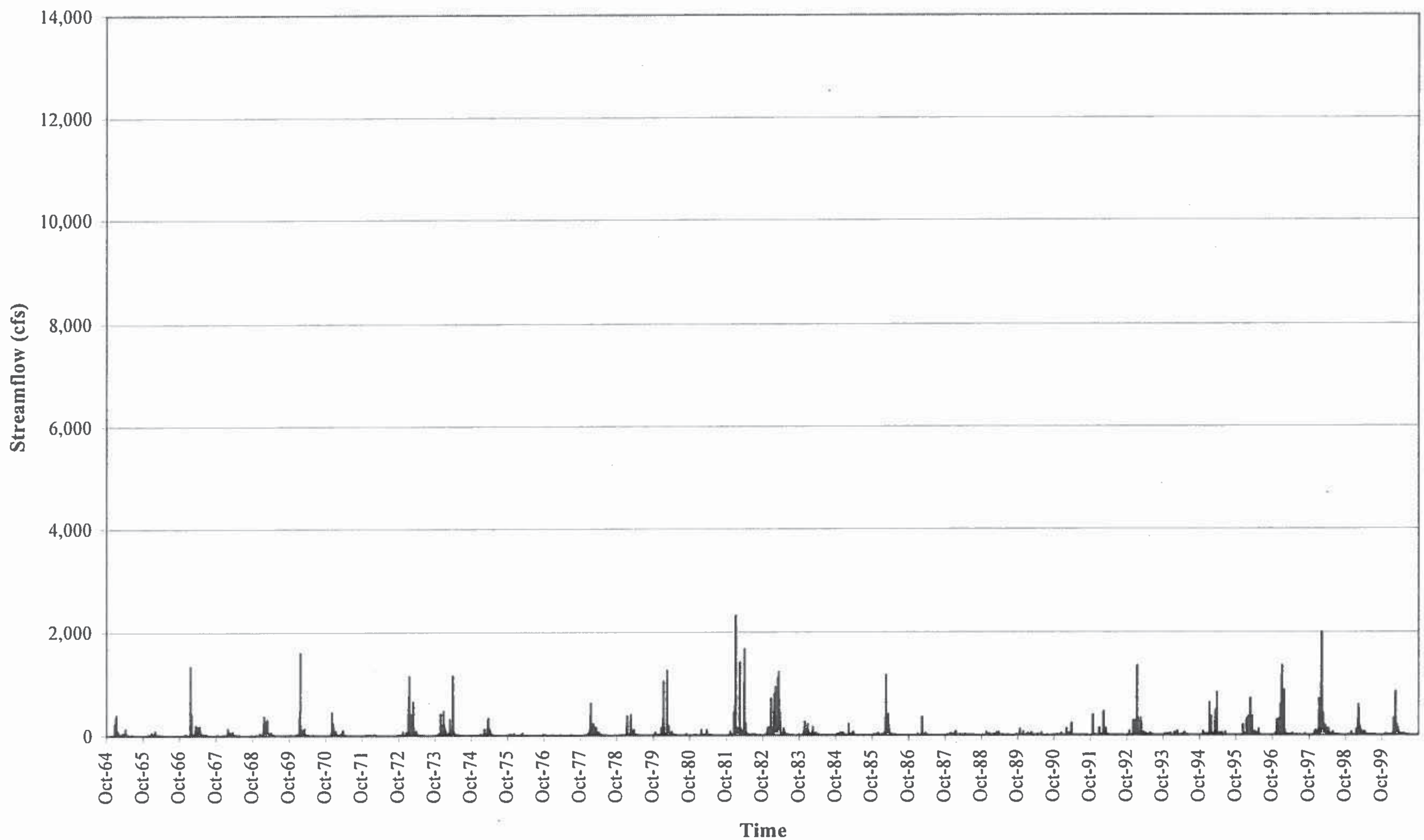
Western Alameda County Unincorporated Watersheds

A watershed is the land that water flows over or under on its way to a creek, lake or bay. Water travels down hills, across farm fields, suburban lawns, and city streets or it seeps into the soil and travels as ground water.



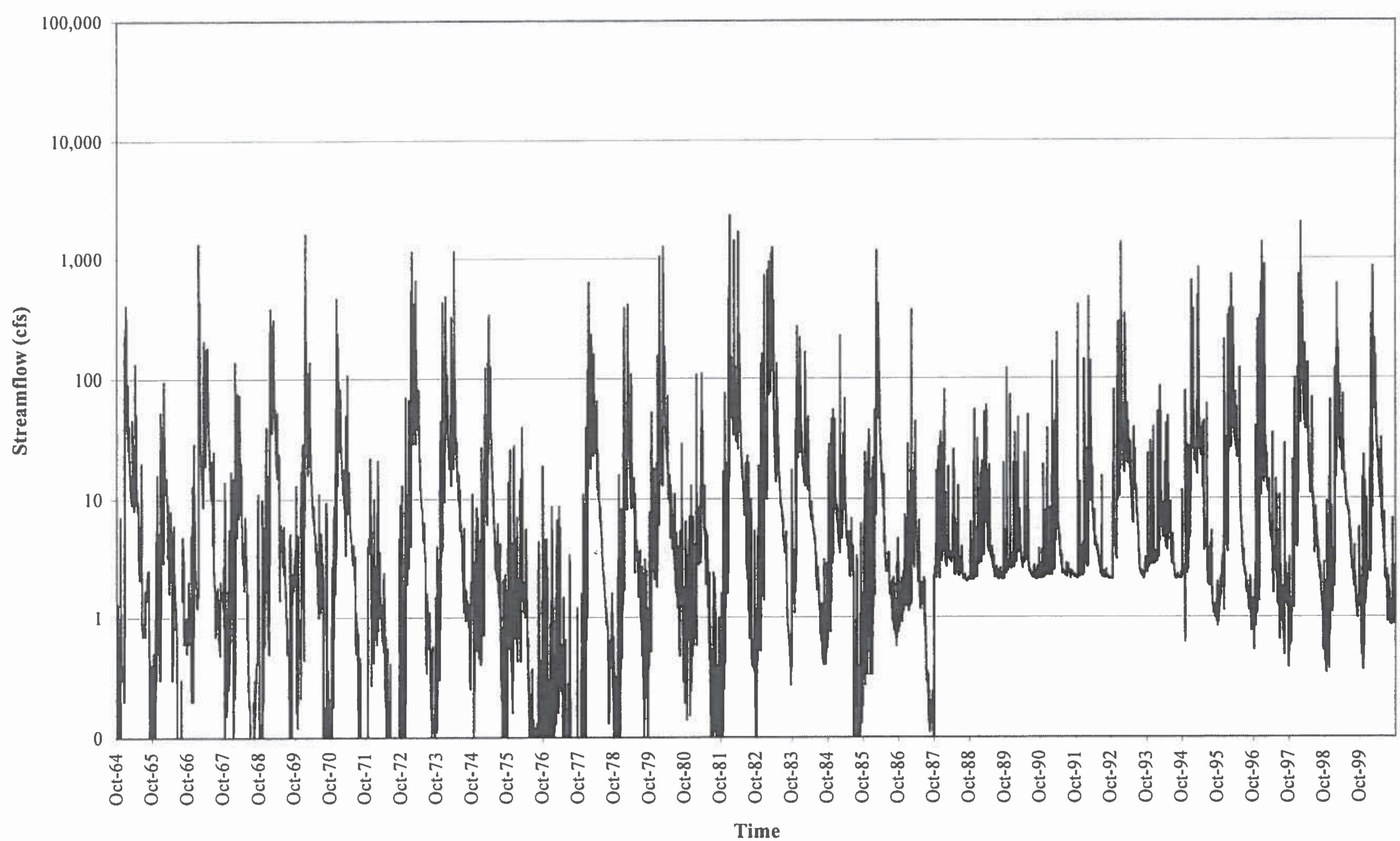
RIME

Niles Cone and South East Bay Plain Integrated Groundwater and Surface Water Model (NEBIGSM)

Daily Streamflow Hydrograph (normal scale) for San Lorenzo Creek at Hayward Gage (1965-2000)

December 2003

FIGURE 2.10c



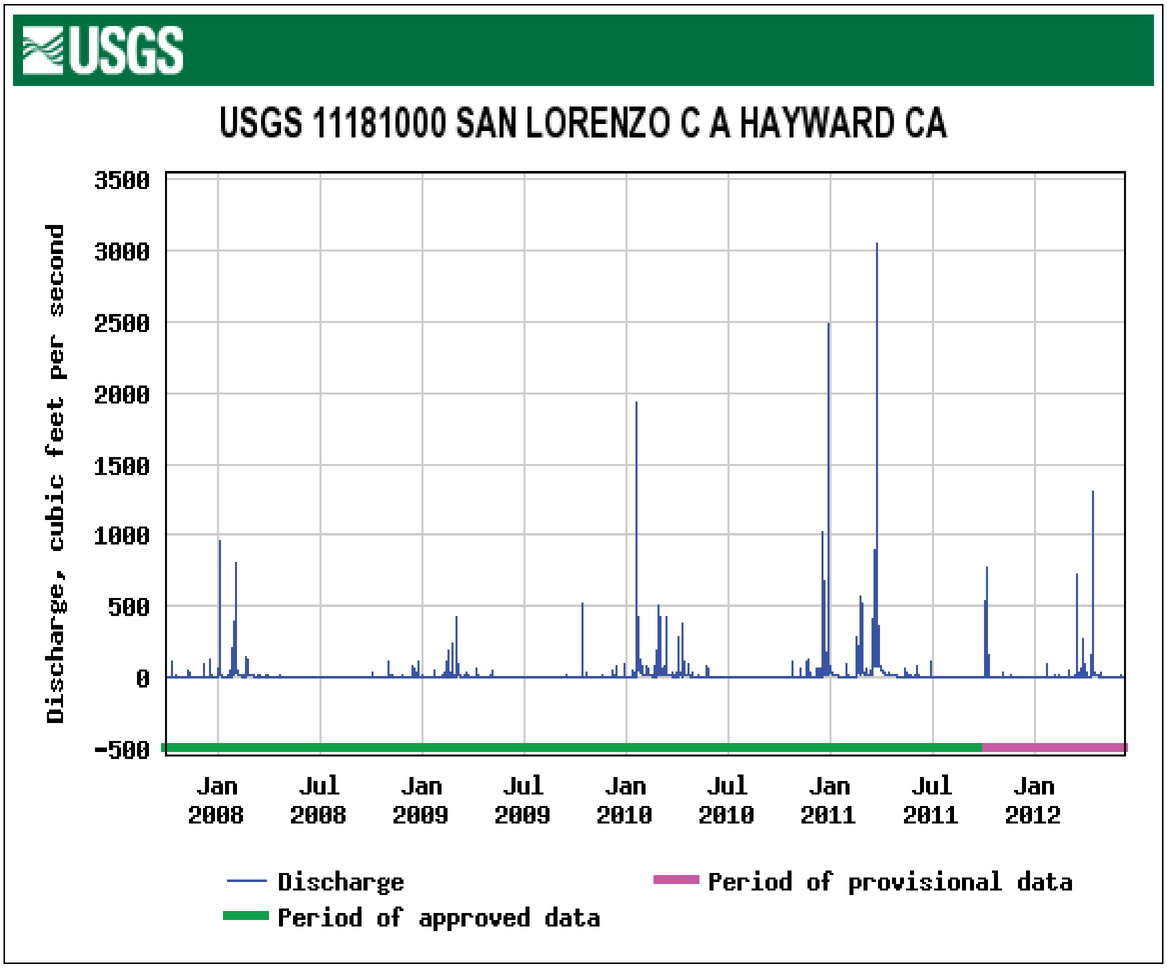
RIME

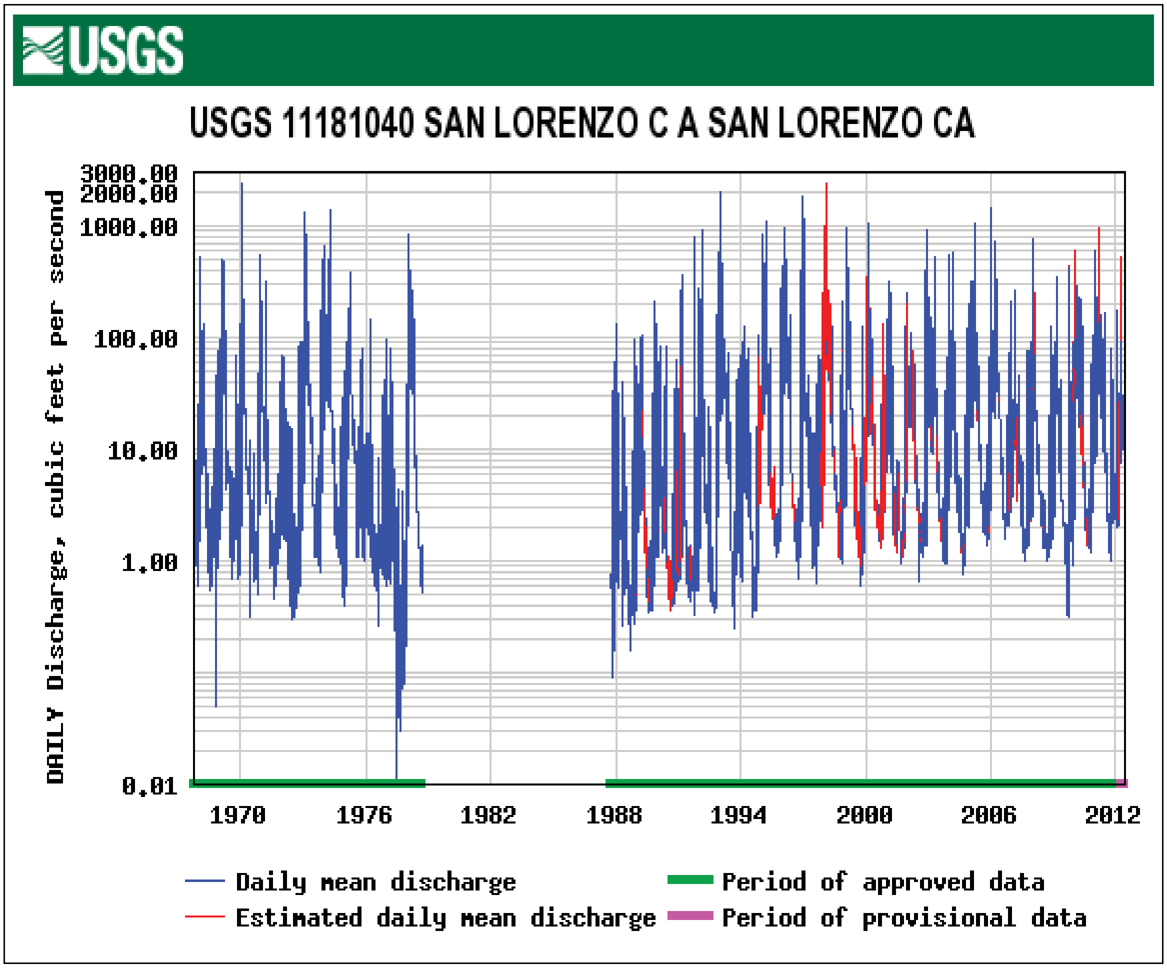
Niles Cone and South East Bay Plain Integrated Groundwater and Surface Water Model (NEBIGSM)

Daily Streamflow Hydrograph (logarithmic scale) for San Lorenzo Creek at Hayward Gage (1965-2000)

December 2003

FIGURE 2.10d


USGS
USGS 11181000 SAN LORENZO C A HAYWARD CA
Discharge, cubic feet per second
3500
3000
2500
2000
1500
1000
500
0
-500
Jan 2008
Jul 2008
Jan 2009
Jul 2009
Jan 2010
Jul 2010
Jan 2011
Jul 2011
Jan 2012
Discharge
Period of provisional data
Period of approved data


USGS
USGS 11181040 SAN LORENZO C A SAN LORENZO CA
DAILY Discharge, cubic feet per second
3000.00
2000.00
1000.00
100.00
10.00
1.00
0.01
1970
1976
1982
1988
1994
2000
2006
2012
Daily mean discharge
Estimated daily mean discharge
Period of approved data
Period of provisional data

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APPENDIX C

Flood Delineation Map Inserts

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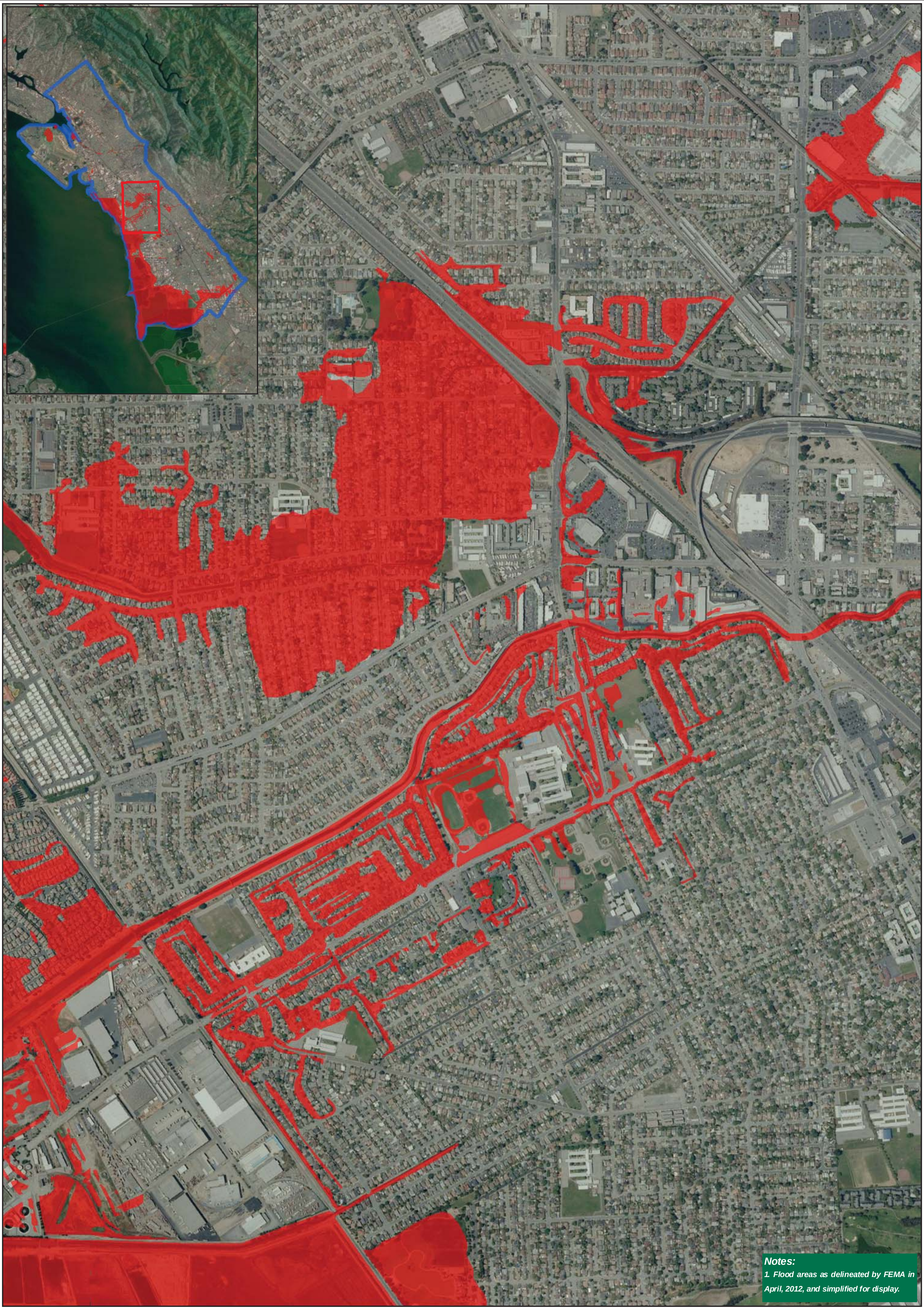

LEGEND

FEMA 100-Year Flood Areas

N

0 500 1,000

Scale in Feet

East Bay Municipal
Utility District
South East Bay Plain
Basin Characterization Study

100-YR FLOOD AREAS: INSET 1

EBMUD

WEST YOST ASSOCIATES
Consulting Engineers

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LEGEND

FEMA 100-Year Flood Areas

N

0 500 1,000

Scale in Feet

East Bay Municipal
Utility District
South East Bay Plain
Basin Characterization Study

100-YR FLOOD AREAS: INSET 2

EBMUD

WEST YOST ASSOCIATES
Consulting Engineers

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LEGEND

FEMA 100-Year Flood Areas

N

0 500 1,000

Scale in Feet

East Bay Municipal Utility District
South East Bay Plain
Basin Characterization Study

100-YR FLOOD AREAS: INSET 3

EBMUD

WEST YOST ASSOCIATES
Consulting Engineers

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LEGEND

FEMA 100-Year Flood Areas

N

0 500 1,000

Scale in Feet

East Bay Municipal
Utility District
South East Bay Plain
Basin Characterization Study

100-YR FLOOD AREAS: INSET 4

EBMUD

WEST YOST ASSOCIATES
Consulting Engineers

LEGEND

FEMA 100-Year Flood Areas

N

0 500 1,000

Scale in Feet

East Bay Municipal Utility District
South East Bay Plain
Basin Characterization Study

100-YR FLOOD AREAS: INSET 5

EBMUD

WEST YOST ASSOCIATES
Consulting Engineers

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APPENDIX D

Updated Cross-Sections and Documentation of Methodology

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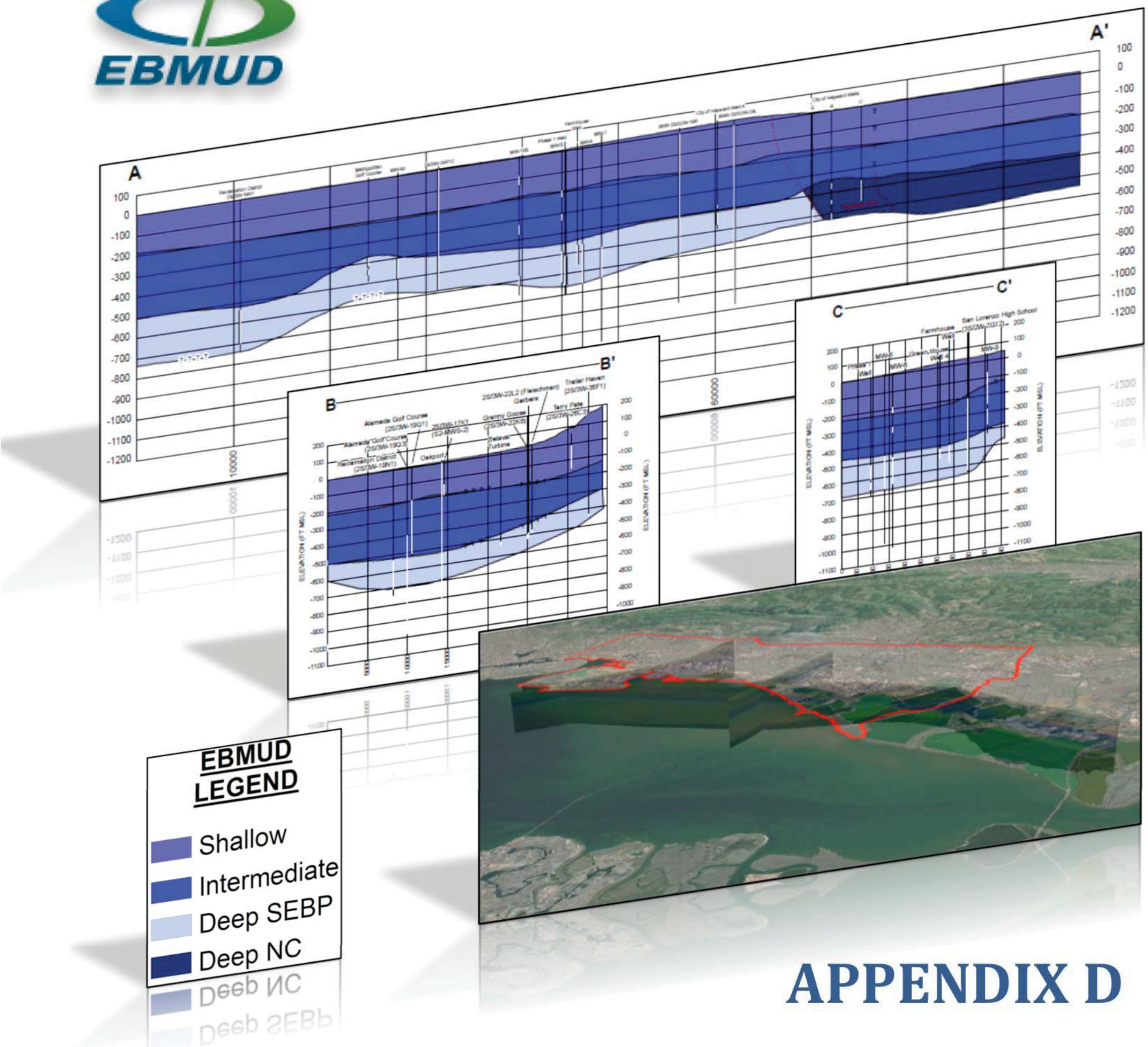
EBMUD



APPENDIX D

WEST YOST ARC HYDRO APROACH

TECHNICAL MEMO

WEST YOST
ASSOCIATES

TABLE OF CONTENTS

TABLE OF FIGURES

West Yost Associates is pleased to present this Technical Memorandum on the Application of Arc Hydro Groundwater (AHGW) for the Hydrogeological Study for the South East Bay Plain (SEBP) Groundwater Basin GMP Development Project (Figure 1). The focus of this technical memorandum is to document the GIS-based approach that is being used to improve the overall understanding of the hydrogeologic setting of the SEBP Basin by integrating empirical and analytical data into a GIS-framework.

The West Yost Arc Hydro Approach

The West Yost Arc Hydro Approach is a solution that will integrate the efficiency and organization of Arc Hydro Data Model, the functionality of the AHGW Toolkit and the sophistication of ArcGIS software for comprehensive data analysis and visualization.

AHGW is an ArcGIS-based set of tools used for managing groundwater data. The AHGW tools provide the bridge for integrating GIS capabilities with groundwater modeling needs inside an ArcGIS environment, which increases the efficiency of model development and post-processing. The AHGW tools help import, create, edit, manage, and archive groundwater data within a spatial database (geodatabase), based on the public domain Arc Hydro Groundwater data model.

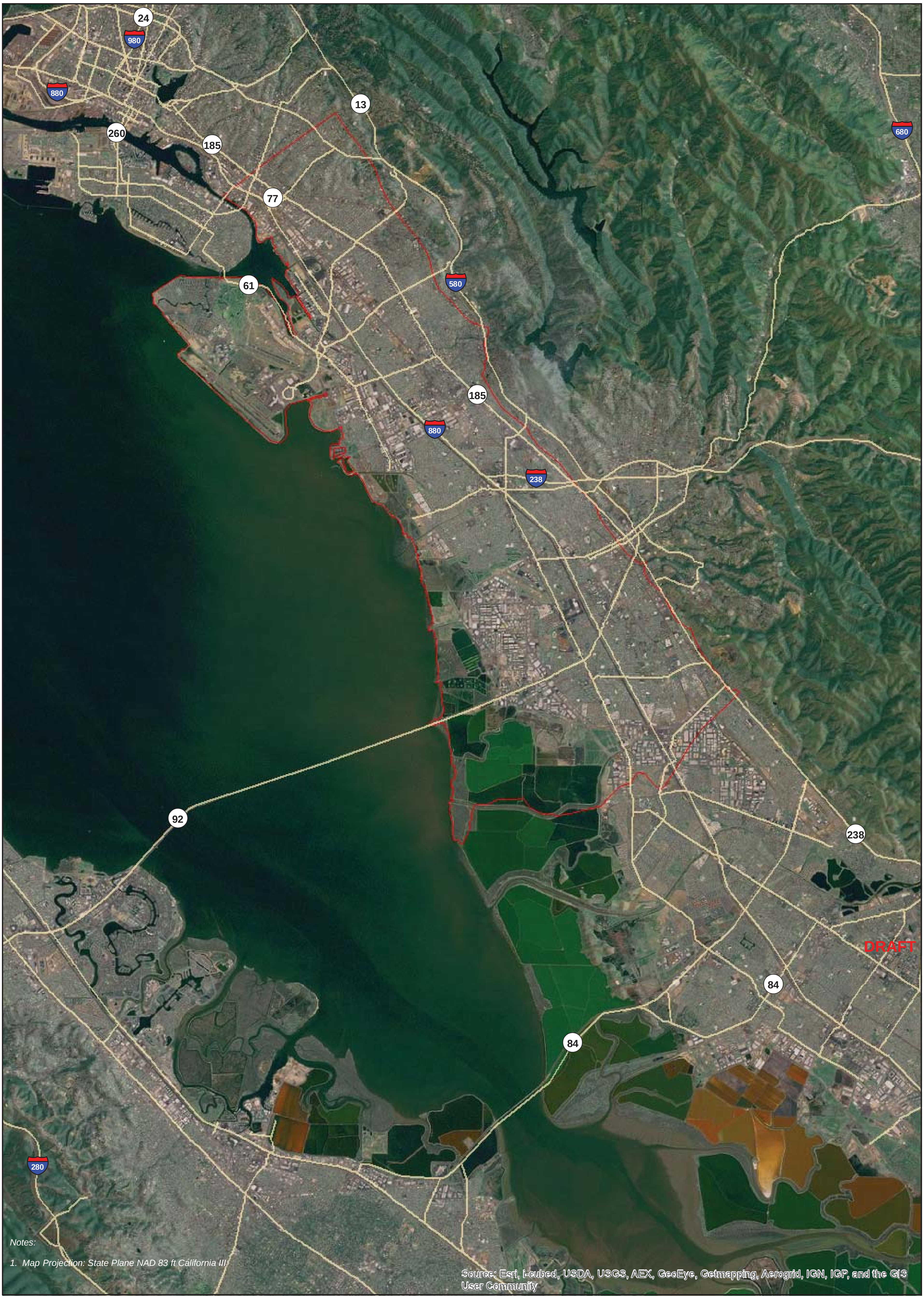
The Arc Hydro tools have three components:

> ***Groundwater Analyst:*** Groundwater Analyst provides a suite of tools that are used to import and map basic groundwater datasets such as wells and time series of water levels and water quality data into the geodatabase. We have utilized the geoprocessing tools in Groundwater Analyst to evaluate existing conditions (recharge, water quality, etc.).
>
> ***MODFLOW Analyst:*** MODFLOW Analyst contains tools that allow the user to create, edit, archive, and visualize MODFLOW models within ArcGIS. The tools in MODFLOW Analyst provide an option to import an existing model into a geodatabase and geo-reference the model so one can visualize and analyze the results in context with other GIS data, as well as create new models or edit existing models using GIS datasets.
>
> ***Subsurface Analyst:*** Subsurface Analyst provides a suite of tools to create, edit, and visualize three-dimensional hydrogeologic models within an ArcGIS environment, starting with classification and visualization of borehole logs, creation and editing of cross sections, and the generation of 3D volumes and fence diagrams. Subsurface Analyst continues to be a critical component in our solution for generating digitized lithologic data, updating lithology data with recent hydrogeological information, evaluating the existing groundwater flow models and finally updating surfaces for the selected modeling platform.

AHGW is a critical component of our analysis and is used throughout all phases of this project. The work associated with the hydrogeologic study is broken apart into two classes, completed in two tasks, broken down into subtasks.

DRAFT

EBMUD/GIS/MXDs/Memo/SiteVicinityAerial.mxd



N

0 5,000 10,000

Scale in Feet

1 inch = 10,000 feet

(when printed in 11 x 17)

LEGEND

SEBP Basin Boundary as per CA DWR Bulletin 118

EBMUD

FIGURE 1
East Bay Municipal Utility District
South East Bay Plain
Basin Characterization Study

SITE VICINITY MAP

WEST YOST ASSOCIATES

Figure 2 is an overview of our project workflow.

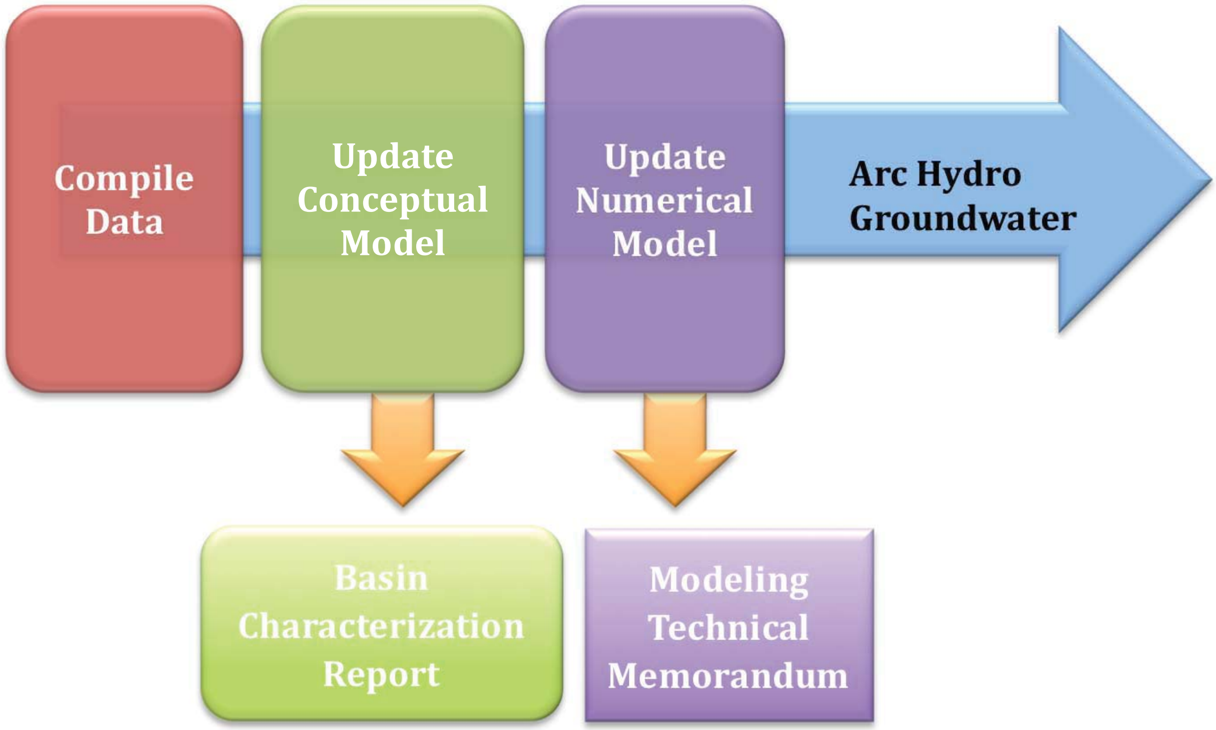


Figure 2. Project Workflow

The first task, Task A, includes the efforts associated with the hydrogeological study. Task A is divided in 5 subtasks: coordination, data compilation/data mining, comprehensive data analysis, basin characterization and report preparation.

During weekly coordination meetings, the AHGW geodatabase is presented to core team members from West Yost and EBMUD to see the progress of the work being completed and to gain consensus on updates and/or data gaps that were identified in the previous weeks. The geoprocessing tools provided the mechanism to view and analyze the data in our AHGW geodatabase more efficiently during the coordination meetings. This information is presented as web conferences during the weekly calls. The function of online collaboration is to closely integrate team members from EBMUD and West Yost during conceptual model development. This live interaction opens up a line of communication during the analysis phase that takes advantage of the interaction of all team members. Live demonstrations capture the flexibility and power of the EBMUD AHGW geodatabase as a tool to enhance our overall understanding of the hydrogeologic setting of the SEBP Basin.

In terms of data compilation/data mining, the AHGW geodatabase serves as the primary repository of information for the project and the primary tool used to compile and mine information. The data is formatted in the geodatabase consistent with the AHGW Data Model; facilitating the use of the AHGW toolset for advanced data analysis and visualization.

A subset of the information stored within the database includes lithological logs, water quality data, pumping test data, geological data, well locations, well construction data and geophysical data. This information is analyzed using geoprocessing tools and visualized in both two and three dimensions. Animations and video clips are also generated to provide enhanced visualization of complex data. The results of this work are presented in a Basin Characterization Report.

The second task, Task B, incorporates the efforts required to evaluate existing models in reference to the long-term needs of this project, identify current and future modeling needs for the agency, establish the model best suited to satisfy both short-term and long term goals, and then update the selected model with the most recent hydrogeological data that is available. Although separate tasks, much of the work associated with each task was used interchangeably throughout the project. The results of Task B are presented in a Modeling Technical Memorandum.

Arc Hydro Data Management

AHGW was selected as the platform for compiling and organizing the information that is being used to establish baseline conditions and develop the conceptual model for the SEBP Basin. Data was compiled into a spatial geodatabase using the AHGW file structure. Model surfaces are stored in raster catalogs and feature classes are separated into specific feature datasets, based on the type of data that is being stored. A subset of the information included in the geodatabase include well locations, subregional boundaries, land use data, soil type data, water chemistry data, etc. General base information is stored within a Base Data feature dataset. All subsurface geologic information used to develop fence diagrams, geovolumes, geosections or cross sections is stored within its own Subsurface feature dataset.

The AHGW toolkit facilitates the transition of three-dimensional geologic data into two-dimensional cross sections by utilizing pre-built automated tools that are part of Subsurface Analyst. These tools provide an option to generate grids, add or remove wells, and project surfaces from three-dimensions to two dimensions automatically or manually. These enhancements increase overall productivity and were integral in completing the tasks in a timely manner and within budget.

In addition to the enhancements offered by the suite of AHGW tools, because the tools are integrated into the ESRI ArcView environment and developed as part of the ESRI suite of available extensions, all of the functionality of ESRI's ArcMap software program can be utilized during the analysis as well. All of the geoprocessing tools used to manage data in the ESRI suite of ArcView extensions can also be used in conjunction with the AHGW toolkit.

Furthermore, after data analysis is complete, EBMUD has the option to view all of the two-dimensional and three-dimensional data using the standard ESRI Arc Map Interface and ArcScene, the 3-D Analyst extension for ArcMap.

The following narrative presents an overview of the application of AHGW for the cross section analysis.

Cross Section Analysis

The cross section analysis involves integrating various forms of data from numerous entities, including published lithologic transects, model surfaces, and hydrogeological and geophysical information, and comparing them together within one environment.

The selections of the cross section transect locations for the EBMUD model was an iterative process. Published cross sections from four different sources were reviewed and analyzed prior to the development of our final cross section transects that are being used to establish our conceptual interpretation of the SEBP subbasin (Error! Reference source not found.). The first two groups of cross sections were developed by consulting firms Luhdorff & Scalmanini ("L&S") (Luhdorff. & Scalmanini. 2003) and CH2M HILL (CH2M HILL. 2004). The third and fourth sets of cross sections reviewed include those prepared on behalf of the USGS by John Izbicki (Izbicki. 2003) and R.D. Catchings (Catchings. 2006) respectively.

In order to maximize on existing work that has been completed, EBMUD cross section transects were strategically designed to overlay existing work. This enhances our ability to visualize and analyze multiple sets of information within one common environment. The L&S Cross Sections 1-2, 2-3, 3-4, and 4-9 coincide with our primary north-south cross section location and is designated as our A-A' Transect. The east-west cross sections went through a series of iterations. The final location for B-B' coincides with the A-A' Cross Section transect provided in the Izbicki report. The final location for C-C' is midway between the Izbicki B-B' transect and the USGS cross section transects in their seismic refraction report.

Once the cross section transects have been defined, the remaining work from the cross section analysis is primarily done using the tools provided in Subsurface Analyst. We georeference each transect location and digitize the cross sections so EBMUD will have their information projected in real-world coordinates and in a well organized geodatabase. The benefit of projecting the published literature in real-world coordinates is that it provides a mechanism to overlay external data, enhancing our ability to review existing model input parameters with the most updated hydrogeological information.

Once the appropriate information has been brought into the geodatabase, a simple protocol was followed to perform each analysis. The following is a step-by-step overview of the methodology applied using the West Yost Arc Hydro Approach.

Cross Section Analysis Protocol

1. Create Geodatabase

To begin, a feature class must be created to represent the cross section transects that will be used for the analysis. It is also useful to define a model domain or boundary. The model boundary is often used to define the extents of data analysis.

2. Create and populate appropriate AHGW datasets and feature classes. Examples include well locations, borehole information, well construction tables, and raster catalogs.

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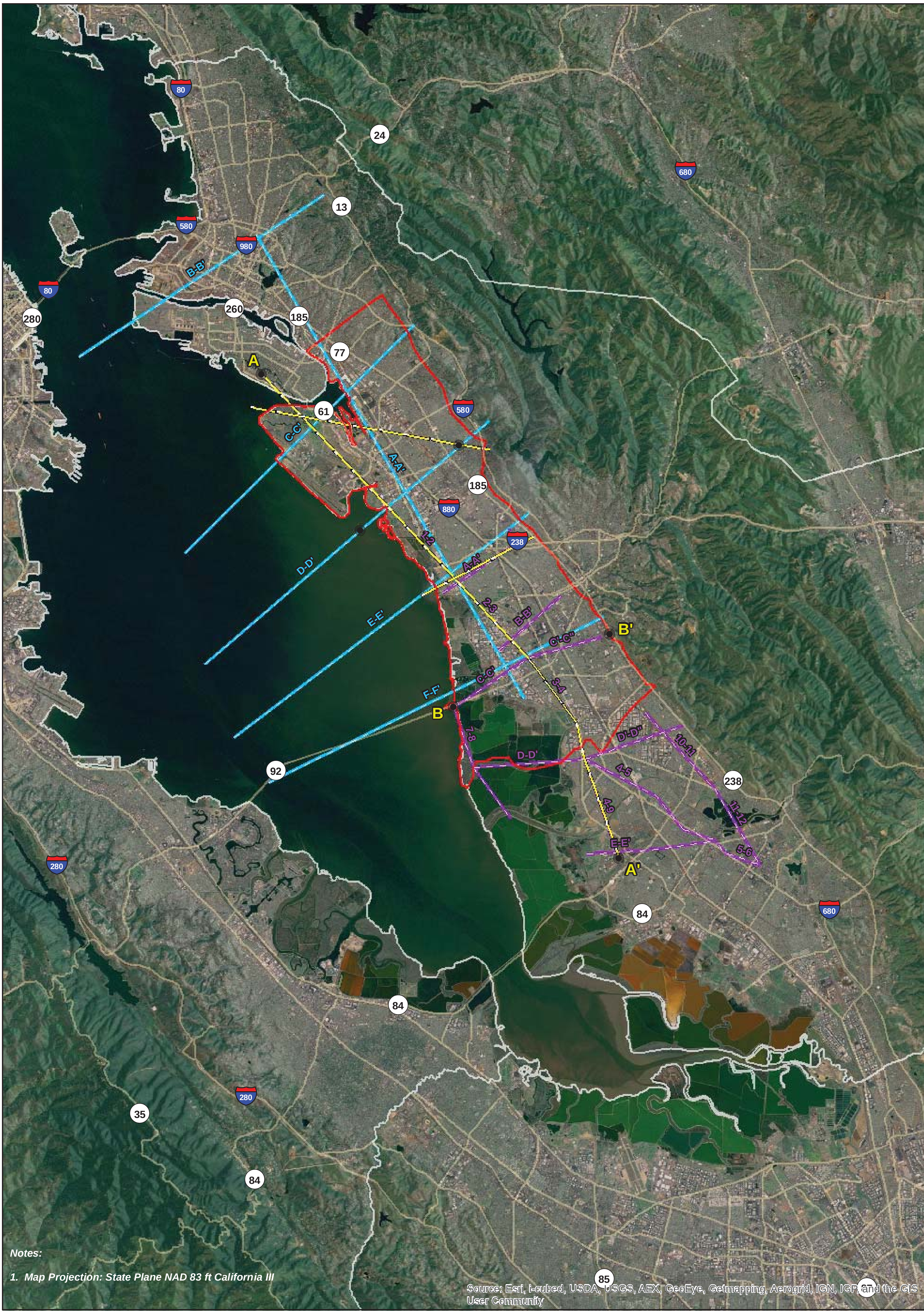
EBMUD/GIS/MXDs/MEMO/XS_transects.mxd



LEGEND

- SEBP Basin Boundary v020812 as per CA DWR Bulletin 118
- Luhdorff & Scalmanini Cross SectionTransects
- CH2MHILL Cross SectionTransects
- West Yost Cross Section Transects

N

0 7,500 15,000

Scale in Feet

1 inch = 15,000 feet

(when printed in 11 x 17)

EBMUD

FIGURE 3

East Bay Municipal Utility District
South East Bay Plain
Basin Characterization Study

CROSS SECTION TRANSECT LOCATIONS

WEST YOST ASSOCIATES

3. Recreate model surfaces and import into a raster catalog.

In order to be able to represent the existing groundwater flow models in AHGW, the model needs to be rebuilt in ArcGIS format. This is accomplished by recreating the model surfaces for both the existing MODFLOW and IGSM models as a set of raster files. Once the rasters are developed, they are brought into a raster catalog that is used for indexing data during the analysis.

Each raster is projected in ArcScene to verify the information was imported correctly. Figure 4 presents the raster files associated with the existing IGSM model and the presentation of the surfaces in ArcScene to confirm proper input.

Figure 4. IGSM Surface Rasters in ArcScene

4. Generate GeoVolumes

A GeoVolume is AHGW terminology that is used to represent solids in a geologic model. GeoVolumes are used to store and represent hydrogeologic units within a 3-D environment.. Figure 5 provides a representation of the IGSM GeoVolumes in ArcScene.

Figure 5. IGSM GeoVolumes in ArcScene

5. Generate GeoSections

A GeoSection is simply a "slice" in a GeoVolume that is defined by the Section Line. GeoSections were developed for both the IGSM and MODFLOW datasets and used to create fence diagrams and two-dimensional cross sections. Figure 6 provides a representation of the fence diagrams created from the IGSM and MODFLOW GeoVolumes. Each GeoSection can be displayed individually or grouped together.

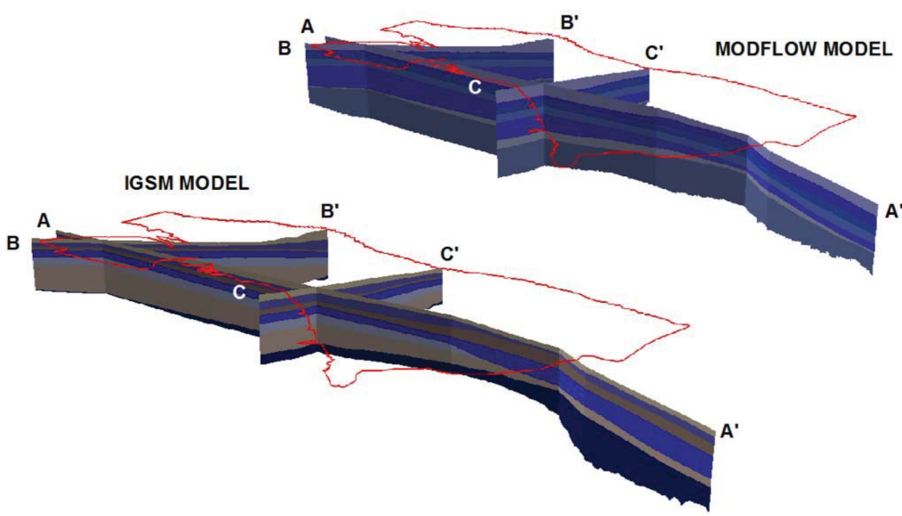


Figure 6. ISGM and MODFLOW GeoSections

6. Transform three-dimensional data (GeoSections) to two-dimensional data (Cross Section Panels)

Figure 7 represents the results of the transformation of IGSM GeoSection along A-A' to Cross Section Panels. Cross Section Panels are used to represent the hydrogeologic units in two-dimensions along each transect. Cross section grids are also defined in this step.

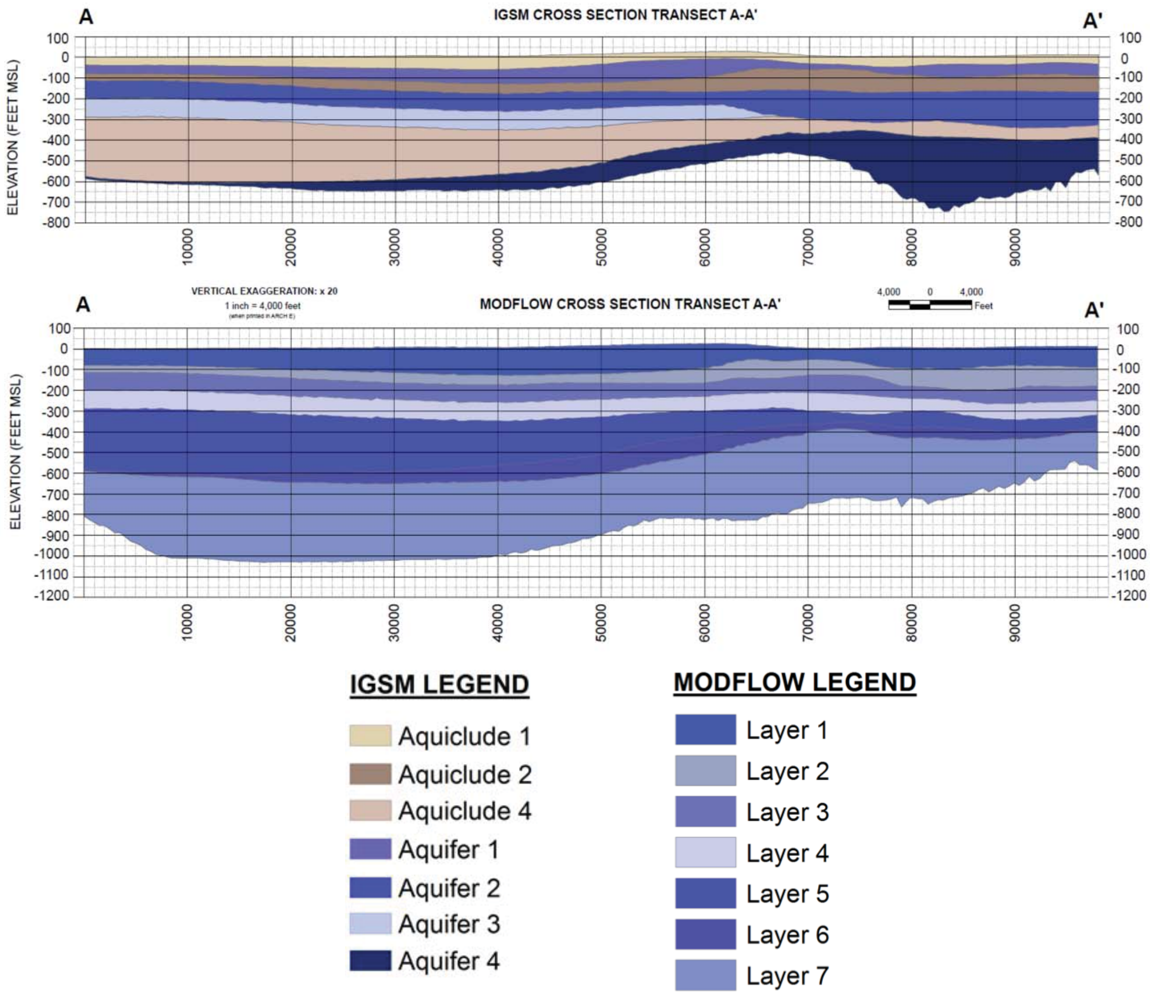


Figure 7. IGSM and MODFLOW Cross Section A-A'

Each cross section was presented individually (as shown above) and grouped together for final presentation (Figure 8).

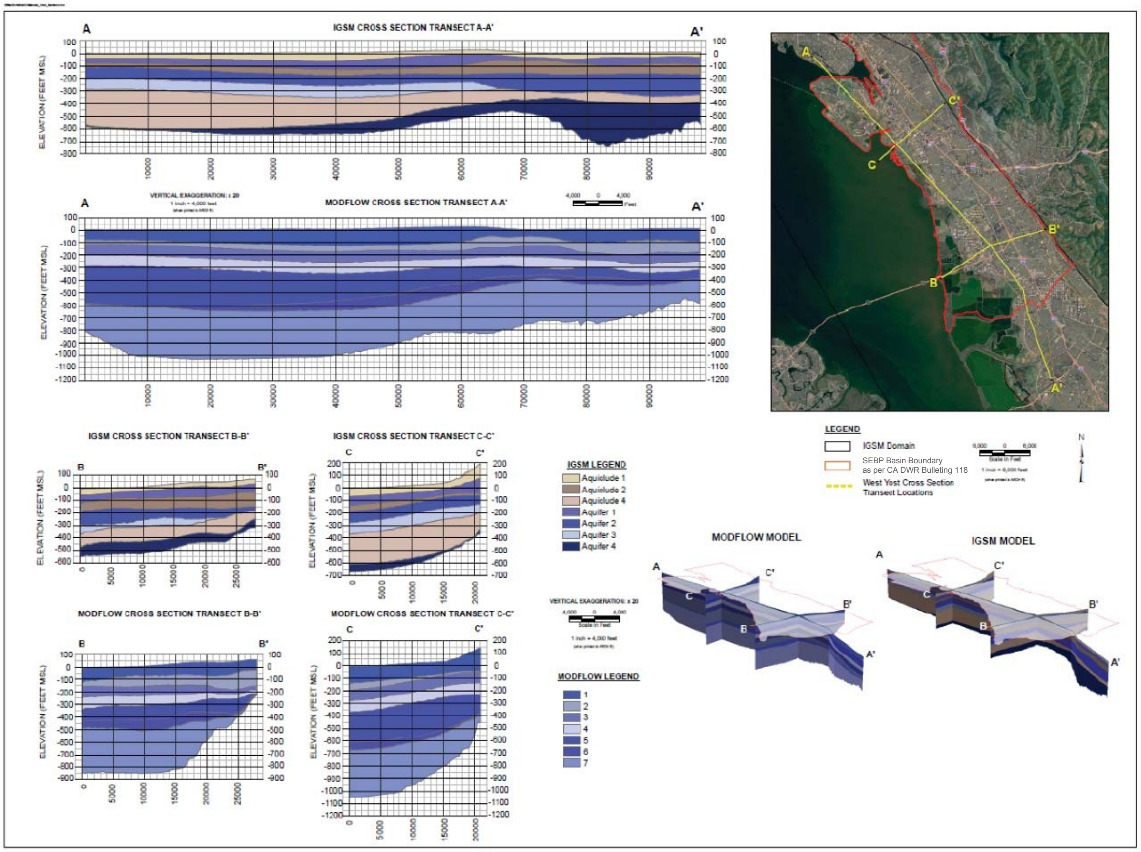


Figure 8. Presentation of AHGW Output

7. Populate geodatabase and feature classes

Once the base grid and model layers have been brought into Arc View, the information that will be used for the analysis needs to be projected within the same data frame. This includes well location and well construction details, geophysical information, and geology. A presentation of the key wells that were included in our two-dimensional cross sections is provided in Figure 9**.**

Upon completion of Step 7, a 10-step protocol was followed to complete the analysis along each transect. **Figure 10** through **Figure 21** present a section along A-A' to illustrate the 10-step process.

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EBMUD/GIS/MXDs/Memo/KeyLocs.mxd

FIGURE 9
East Bay Municipal Utility District
South East Bay Plain
Basin Characterization Study
KEY WELL LOCATIONS

EBMUD

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Cross Section Analysis 10-Step Process

Step 1. Add Key Wells into AHGW Data Frame

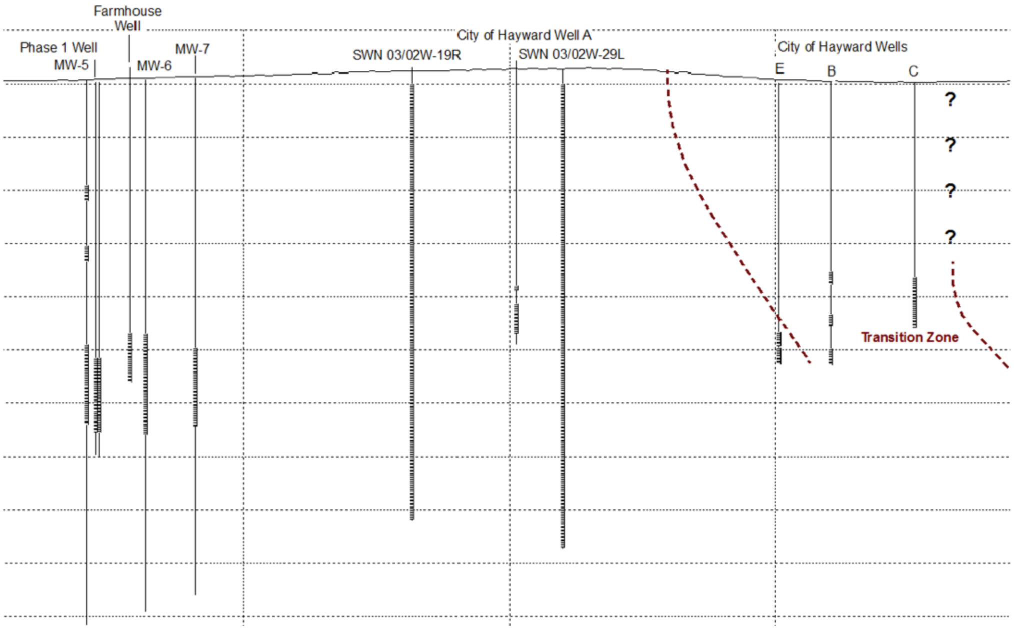


Figure 10. Key Wells Along a Section of A-A'

Step 2. Add IGSM model layers into AHGW Data Frame

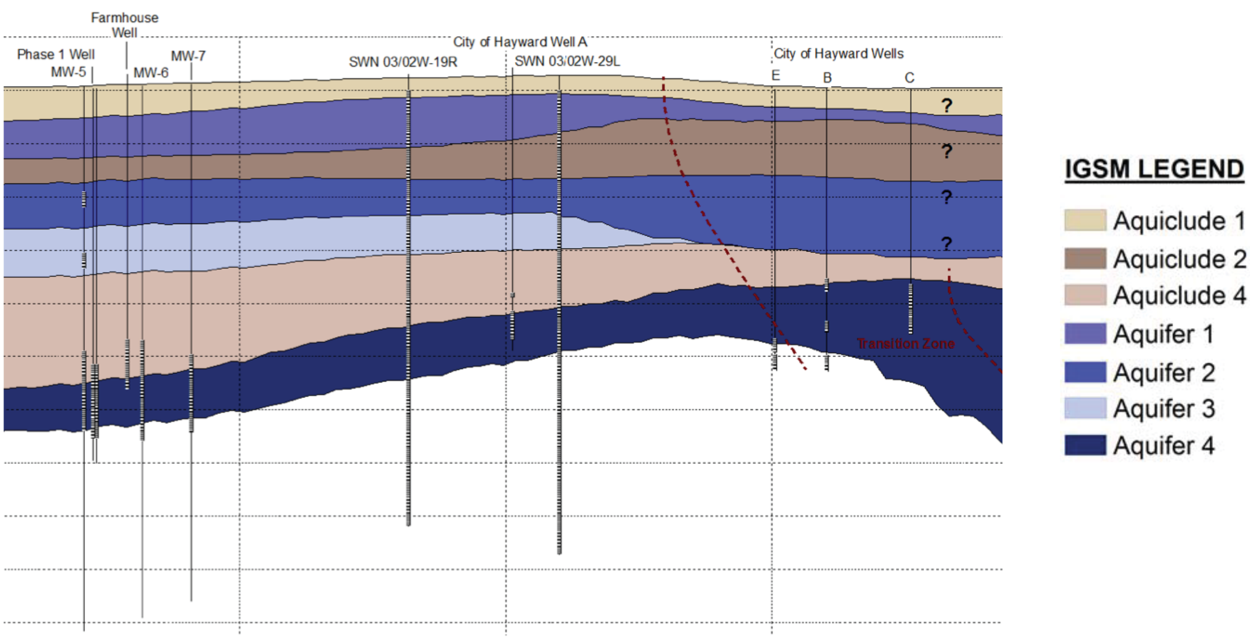


Figure 11. IGSM Model Layers Along a Section of A-A'

Step 3. Add MODFLOW model layers into AHGW Data Frame

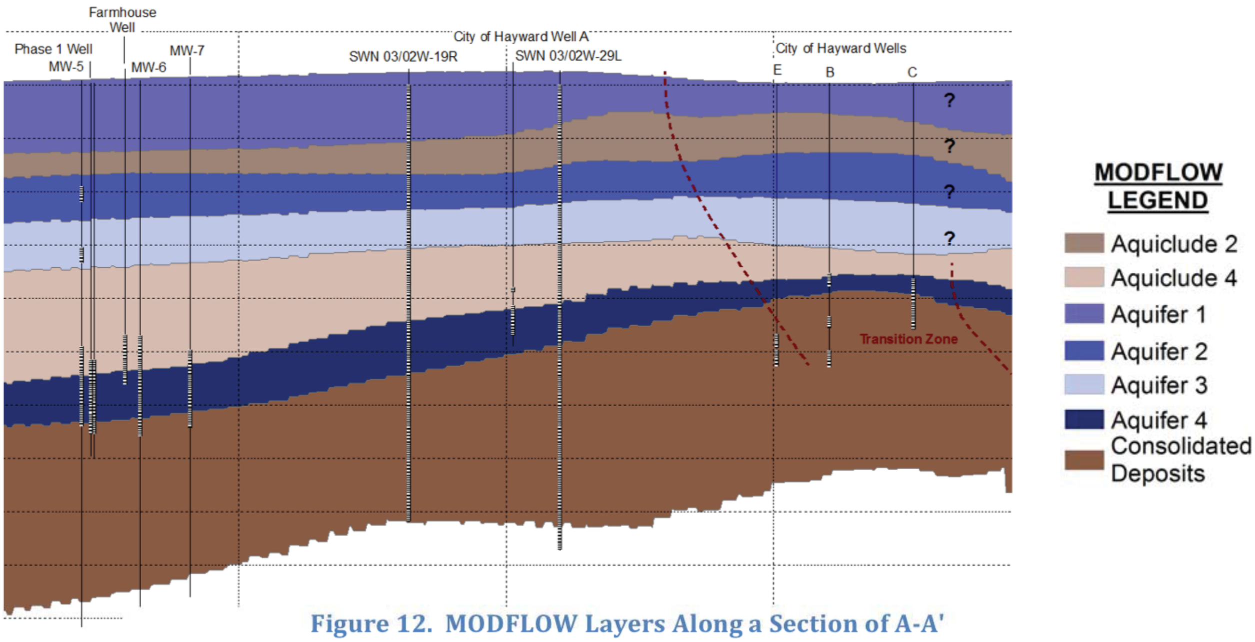


Figure 12. MODFLOW Layers Along a Section of A-A'

Step 4. Add Published Cross Sections

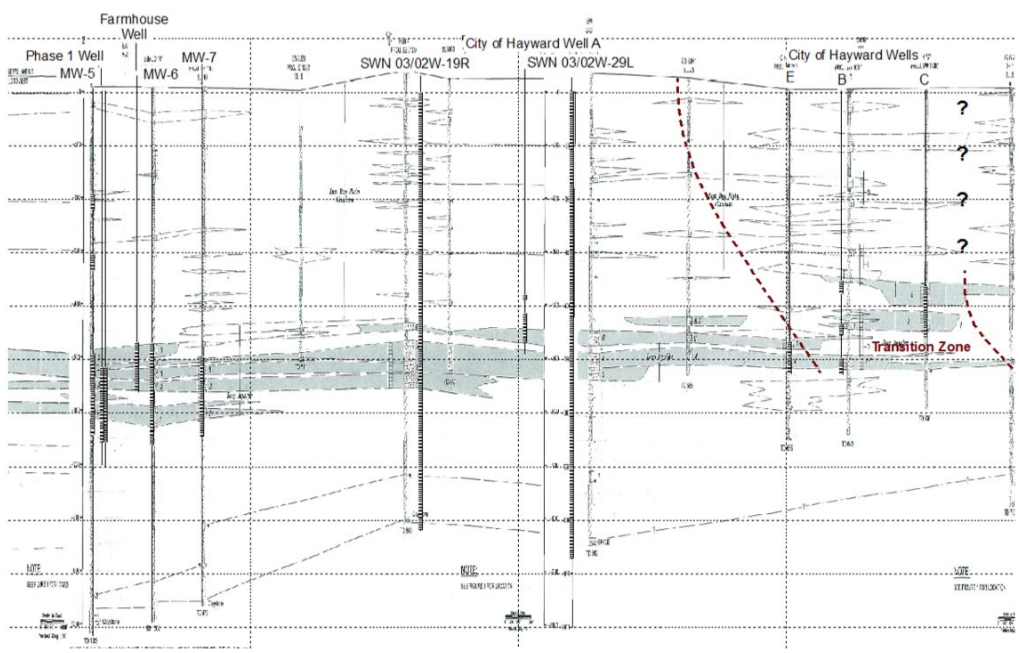


Figure 13. Published Cross Sections Along a Section of A-A'

Step 5. Compare Published Cross Sections with Existing Model Layering

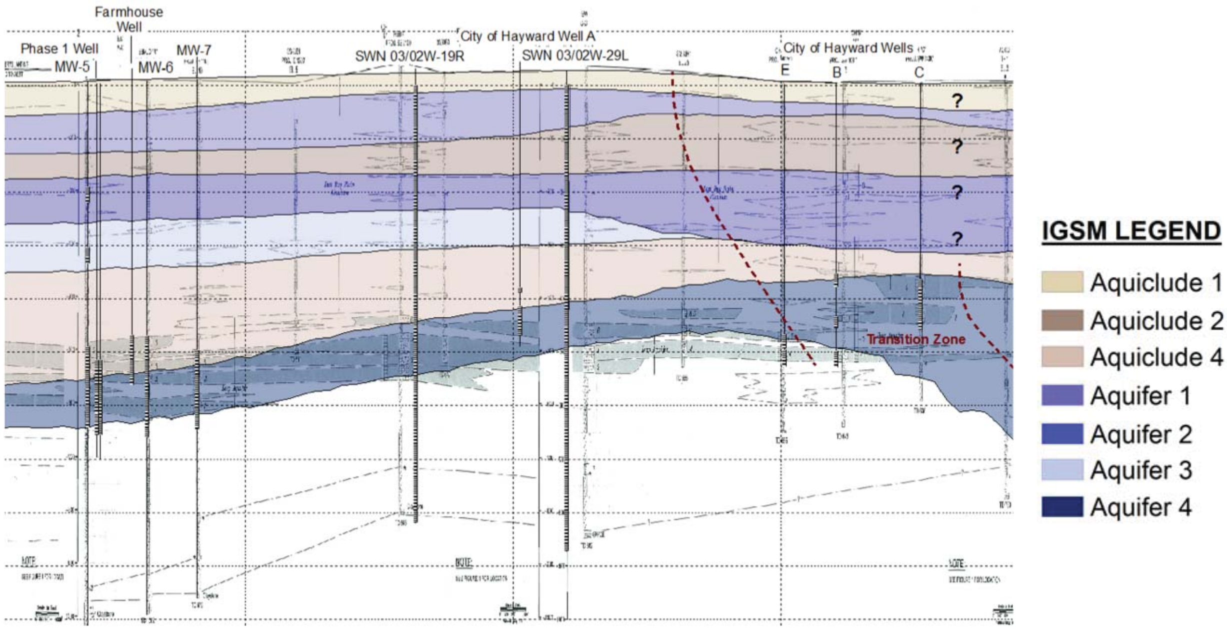


Figure 14. Comparison of IGSM Modeling Layering and L&S Cross Sections

Step 6. Compare Geophysical Data with Existing Model Layering

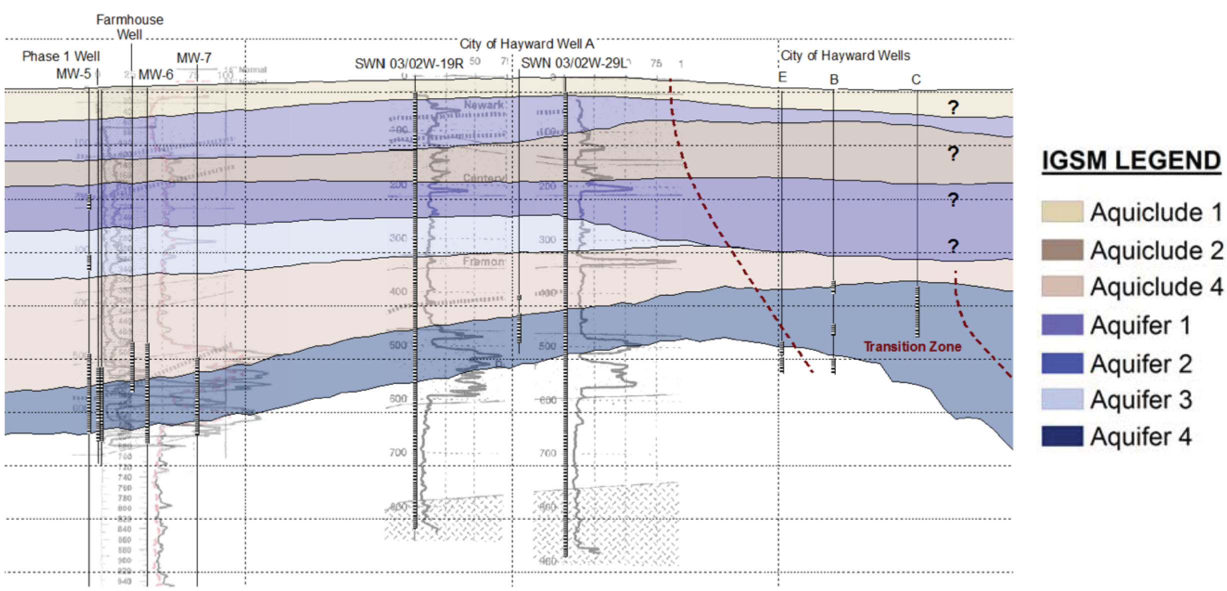


Figure 15. Comparison of Geophysical Data and IGSM Model Layering

Step 7. Review well screen information and pump test data

The process described in Step 1 through Step 6 provided the foundation for updating model layering. Areas along the entire transect were zoomed into to gain the highest resolution from each dataset and then adjustments were made to establish the EBMUD model layering.

For the transition zone, the interpretation that was presented in the L&S Cross Sections was extrapolated and brought into AHGW. Model layering in this area is critical. In addition to geophysical data and geology data, pump test data was used to interpret the new layering in this area.

Based on the results of the Luhdorff & Scalmanini pump test results, there are differences in the response from the City of Hayward Well E to the response of Well C, indicating that these wells are part of different systems (Figure 16).

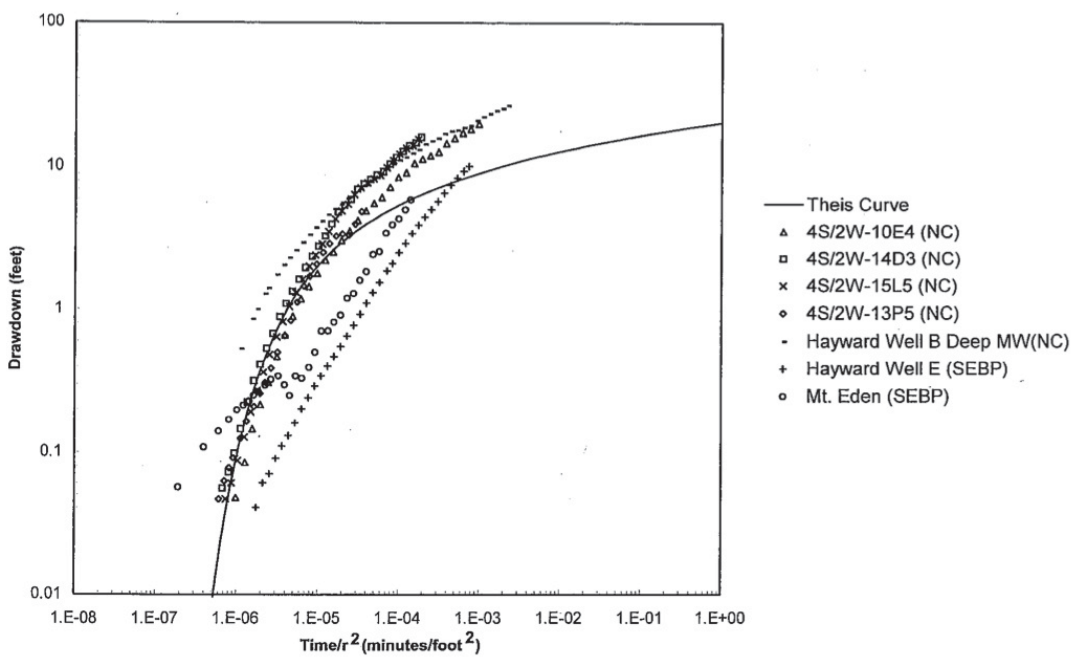


Figure 16. Luhdorff & Scalmanini Pump Test Analysis

Using the existing IGSM model layering and well screen intervals for presentation, the layering along A-A' within the transition zone was reviewed (Figure 17). Based on its review, the appropriate adjustments to layering were reflected in the EBMUD model interpretation (Figure 18).

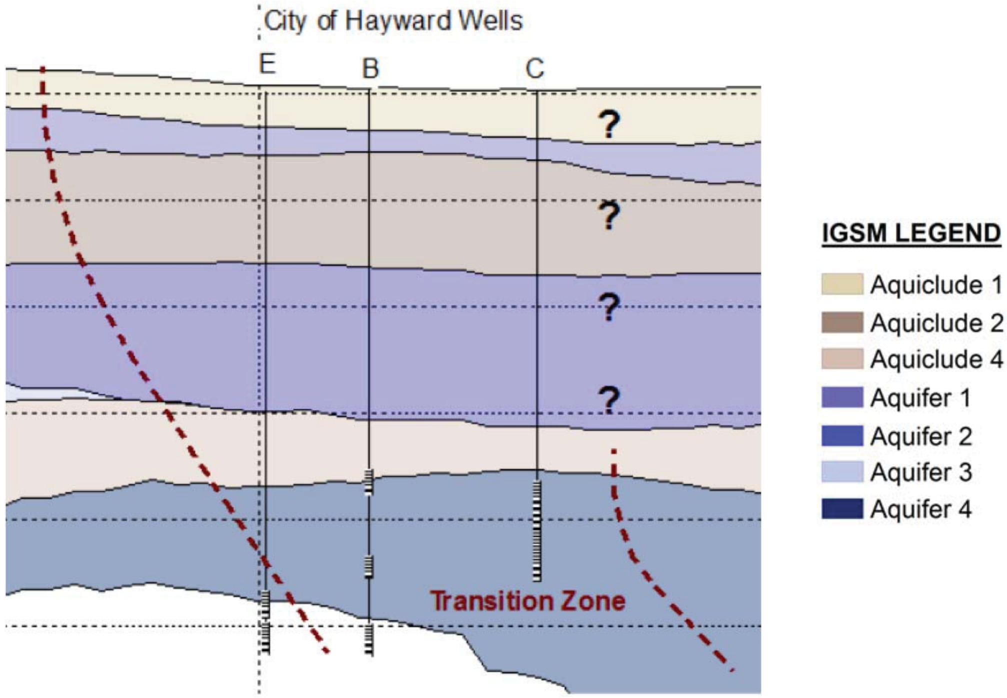


Figure 17. IGSM Model Layering in the Transition Zone along A-A'

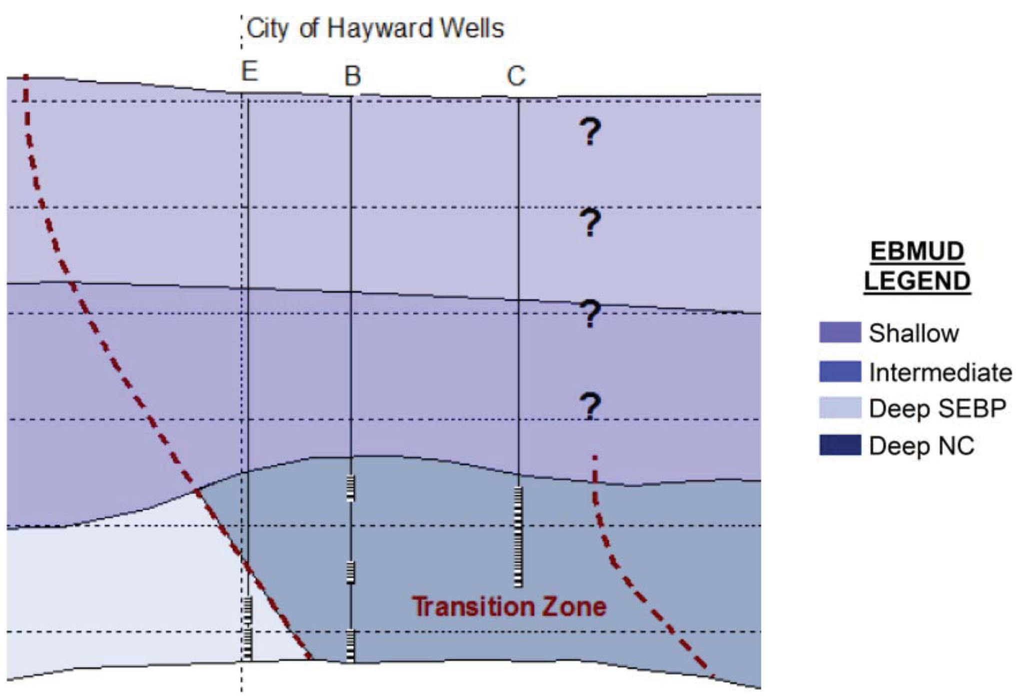


Figure 18: EBMUD Layering in the Transition Zone along A-A'

Step 8: Finalize model layering

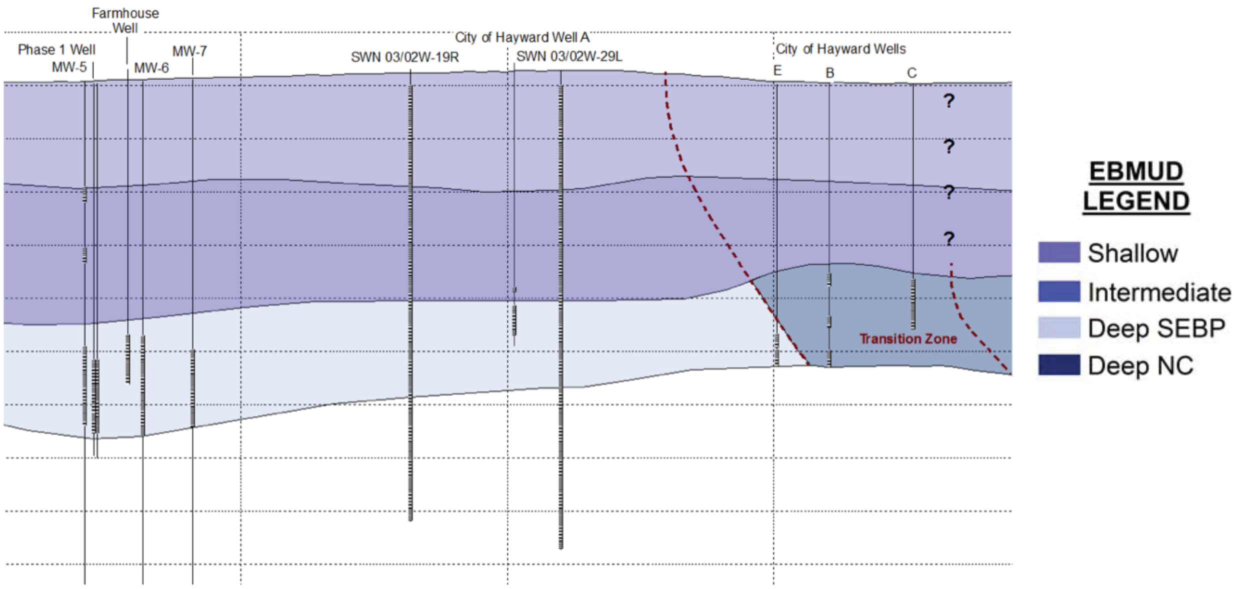


Figure 19: EBMUD Model Layering

Step 9: Check EBMUD Model Layering with Published Cross Sections

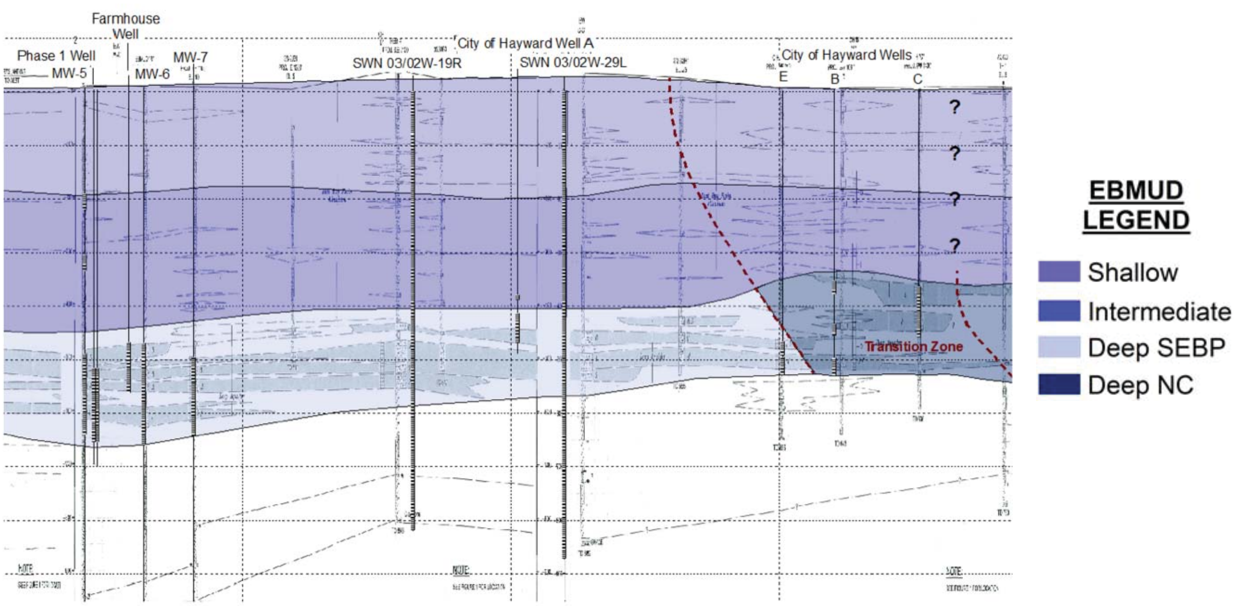


Figure 20: EBMUD Model Layering and Published Cross Sections

Step 10. Check EBMUD Model Layering with Geophysical Data

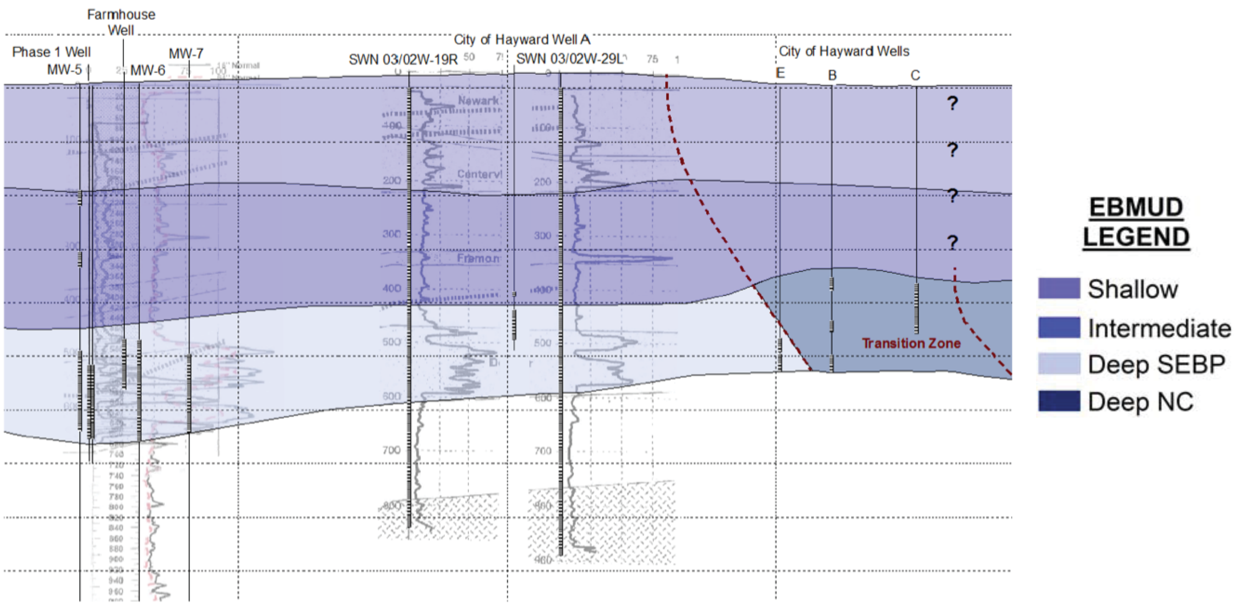


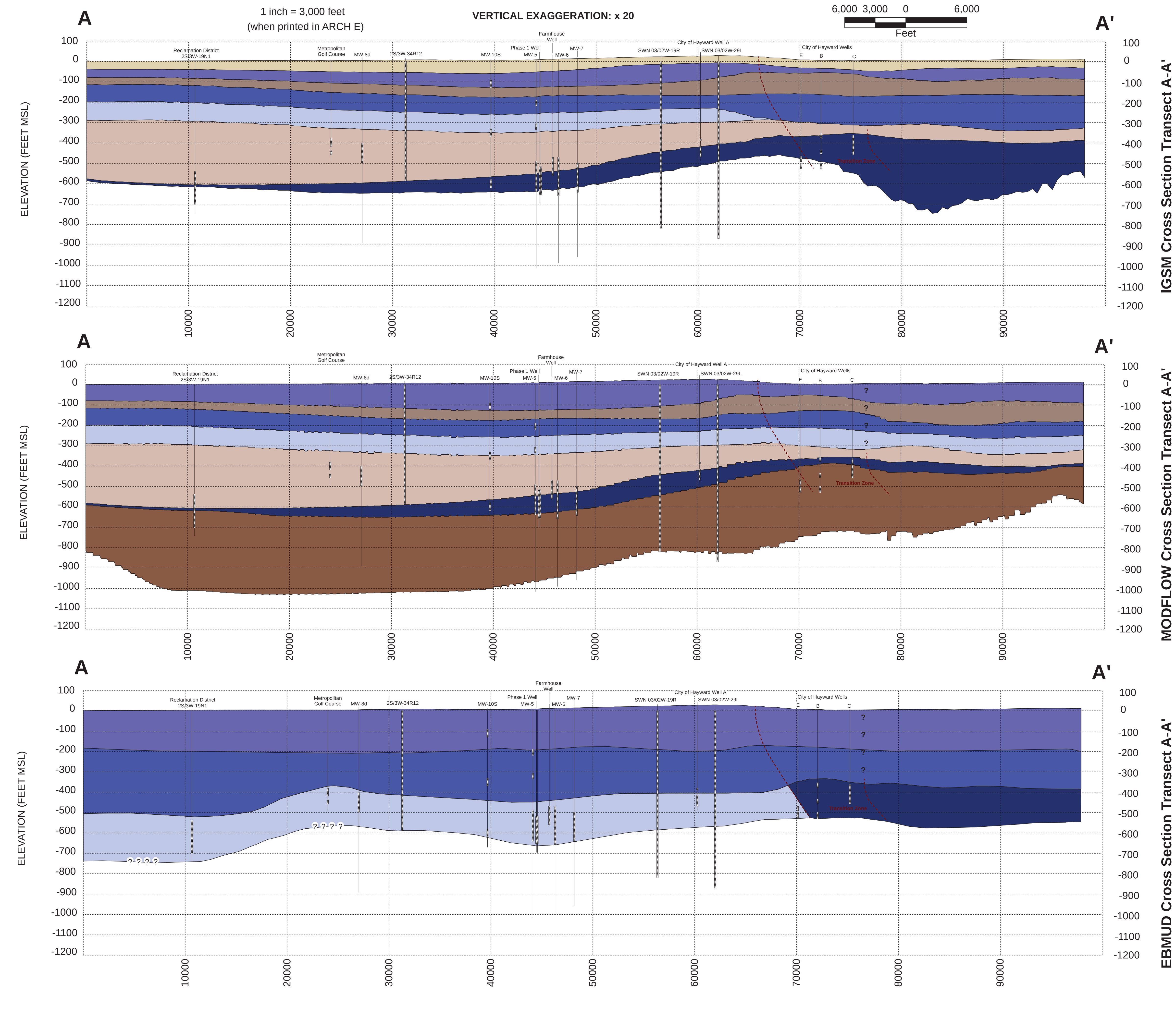
Figure 21: EBMUD Layering and Geophysical Data

Steps 1-10 present the protocol that was developed by West Yost to perform a sophisticated cross section analysis for improving the conceptual model for the SEBP Basin.

Figure 22 through **Figure 27** present an alternate representation of how model layering was reviewed and compared for this analysis. Having the ability to overlay the information into one data frame or view this information using separate data frames presented together on one layout is invaluable.

In summary, the West Yost Arc Hydro Approach provided the level of detail we needed to achieve our goals for this project.

This completes the work that was performed for the cross section analysis. The additional AHGW work relating to model updates will be presented in a separate technical memorandum.



West Yost Associates

East Bay Municipal Utility District
South East Bay Plain
Basin Characterization Study
MODEL CROSS SECTIONS A-A'

EBMUD

IGSM LEGEND

- Aquiclude 1
- Aquiclude 2
- Aquiclude 4
- Aquifer 1
- Aquifer 2
- Aquifer 3
- Aquifer 4

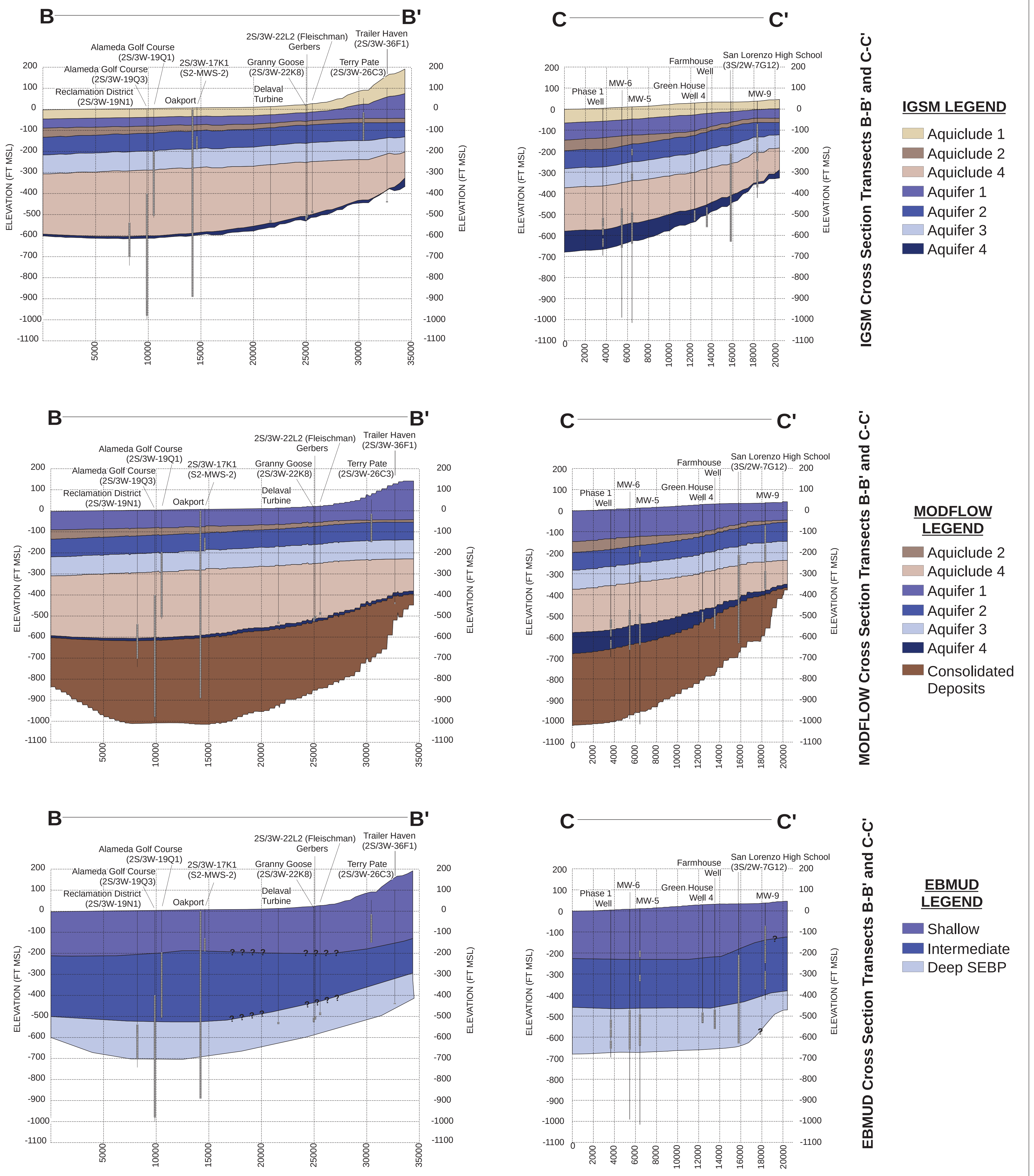
MODFLOW LEGEND

- Aquiclude 2
- Aquiclude 4
- Aquifer 1
- Aquifer 2
- Aquifer 3
- Aquifer 4
- Consolidated Deposits

EBMUD LEGEND

- Shallow
- Intermediate
- Deep SEBP
- Deep NC

DRAFT



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East Bay Municipal Utility District
South East Bay Plain
Basin Characterization Study

MODEL CROSS SECTIONS B-B' and C-C'

EBMUD

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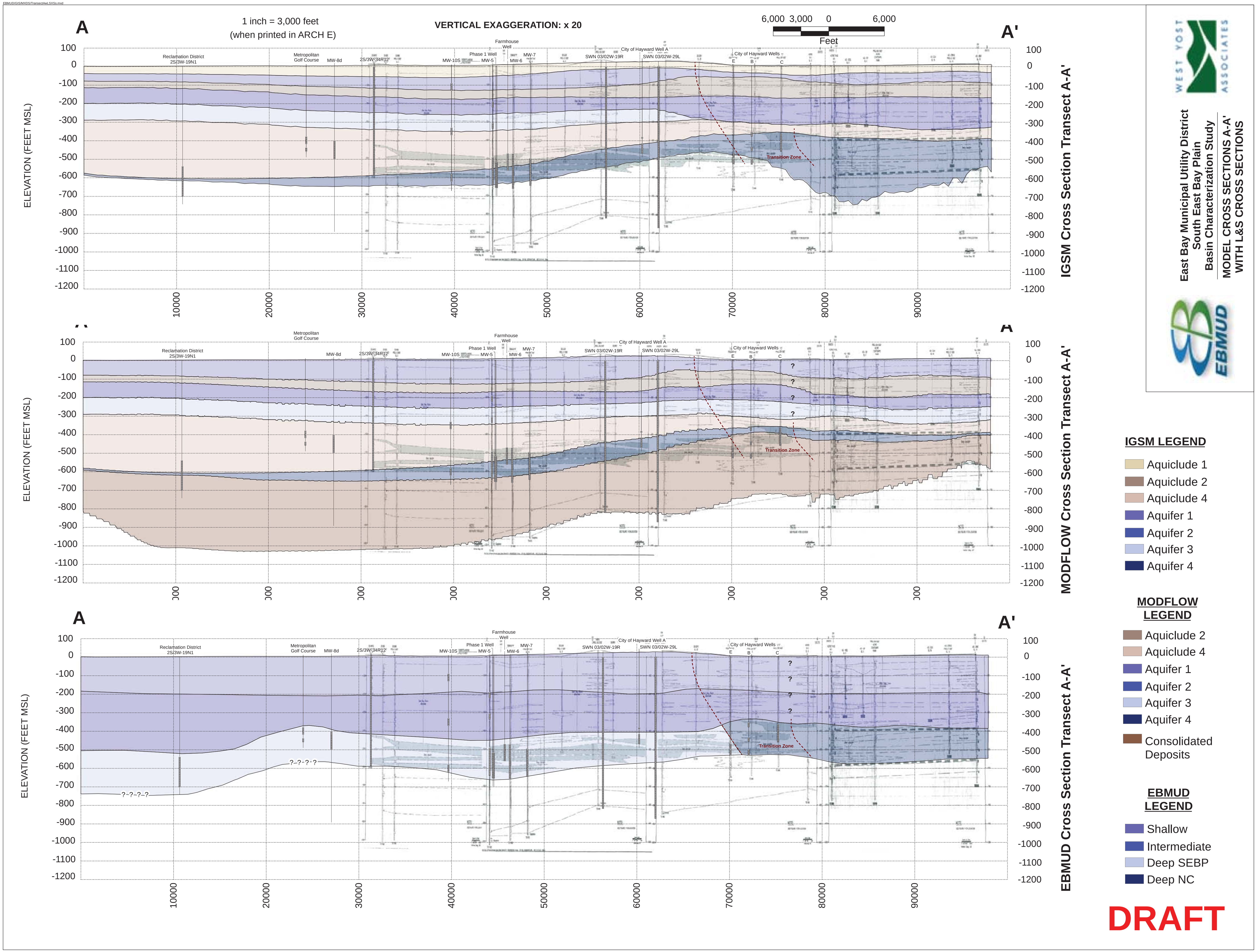
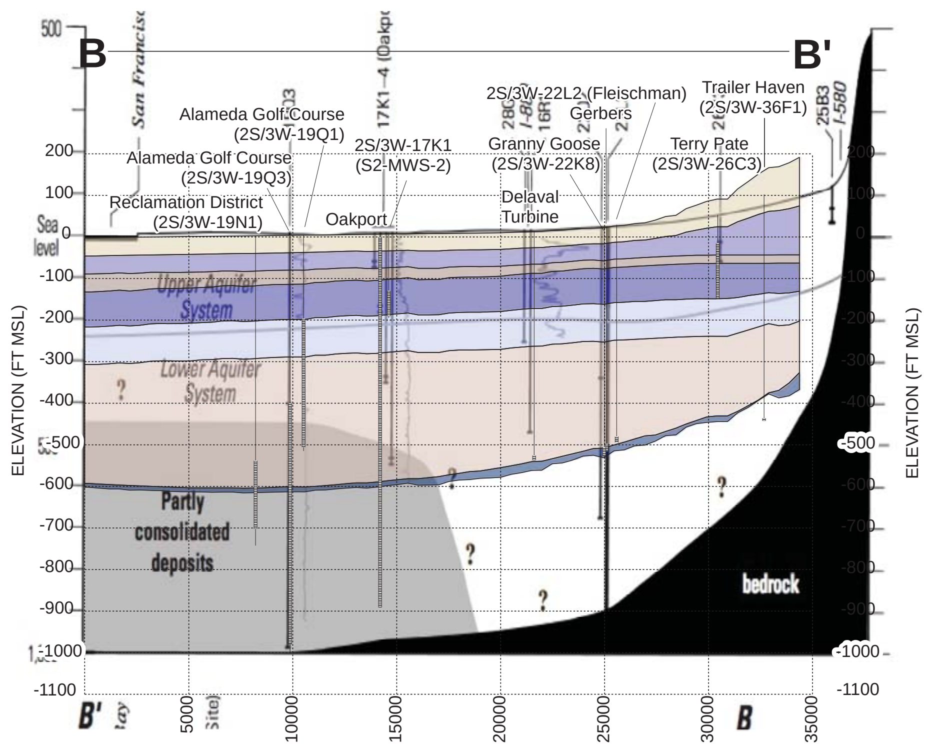
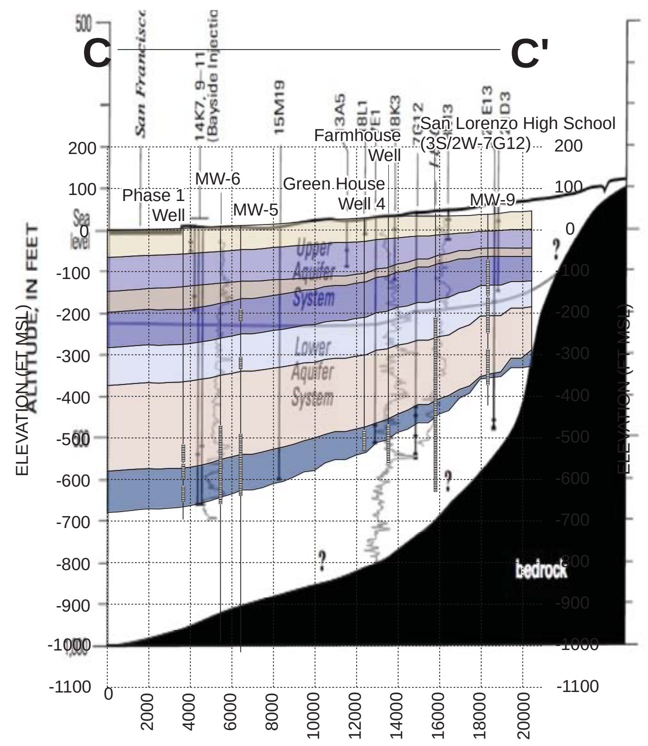
DRAFT


EBMUD\GIS\MXDS\TransectAwLSXSs.mxd
A
1 inch = 3,000 feet
(when printed in ARCH E)
VERTICAL EXAGGERATION: x 20
6,000 3,000 0 6,000
Feet
A'
ELEVATION (FEET MSL)
Reclamation District 2S/3W-19N1
Metropolitan Golf Course
MW-8d
2S/3W-34R12
MW-10S
Phase 1 Well
MW-5
Farmhouse Well
MW-7
MW-6
City of Hayward Well A
SWN 03/02W-19R
SWN 03/02W-29L
City of Hayward Wells
E
B
C
Transition Zone
IGSM Cross Section Transect A-A'
MODFLOW Cross Section Transect A-A'
EBMUD Cross Section Transect A-A'
?
?-?-?-?
100
0
-100
-200
-300
-400
-500
-600
-700
-800
-900
-1000
-1100
-1200
10000
20000
30000
40000
50000
60000
70000
80000
90000
WEST YOST ASSOCIATES
East Bay Municipal Utility District
South East Bay Plain
Basin Characterization Study
MODEL CROSS SECTIONS A-A'
WITH L&S CROSS SECTIONS
EBMUD
IGSM LEGEND
Aquiclude 1
Aquiclude 2
Aquiclude 4
Aquifer 1
Aquifer 2
Aquifer 3
Aquifer 4
MODFLOW LEGEND
Aquiclude 2
Aquiclude 4
Aquifer 1
Aquifer 2
Aquifer 3
Aquifer 4
Consolidated Deposits
EBMUD LEGEND
Shallow
Intermediate
Deep SEBP
Deep NC
DRAFT

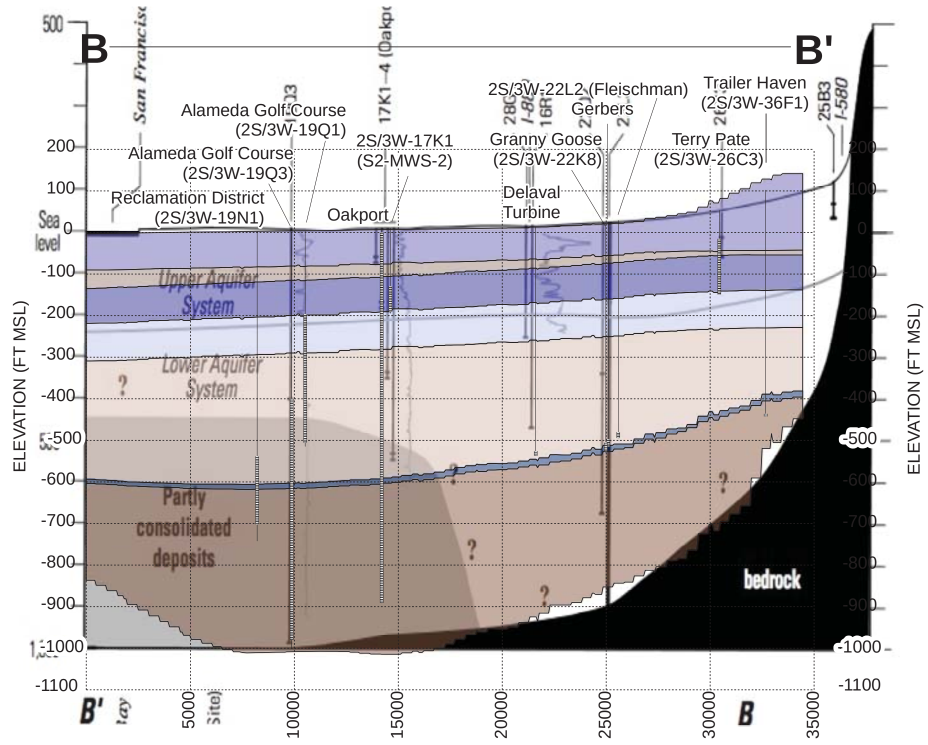


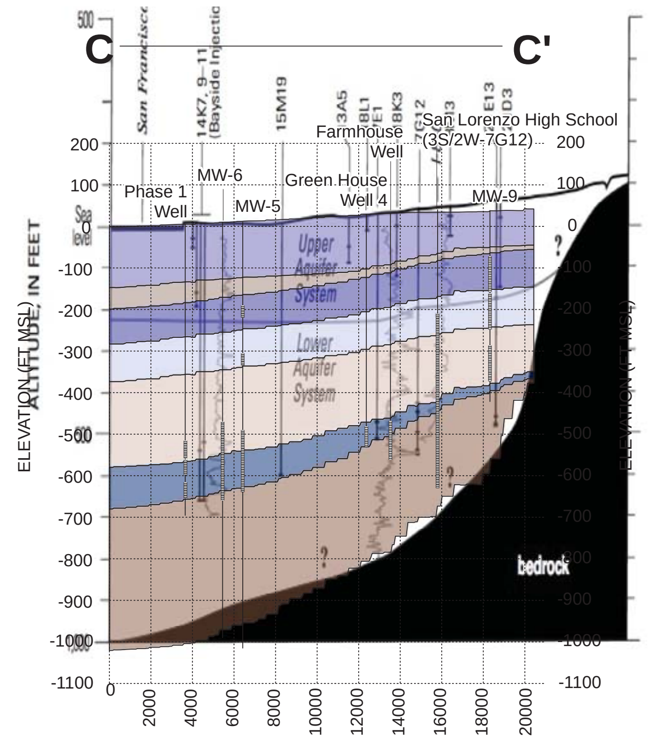


IGSM Cross Section Transects B-B' and C-C'

IGSM LEGEND

- Aquiclude 1
- Aquiclude 2
- Aquiclude 4
- Aquifer 1
- Aquifer 2
- Aquifer 3
- Aquifer 4

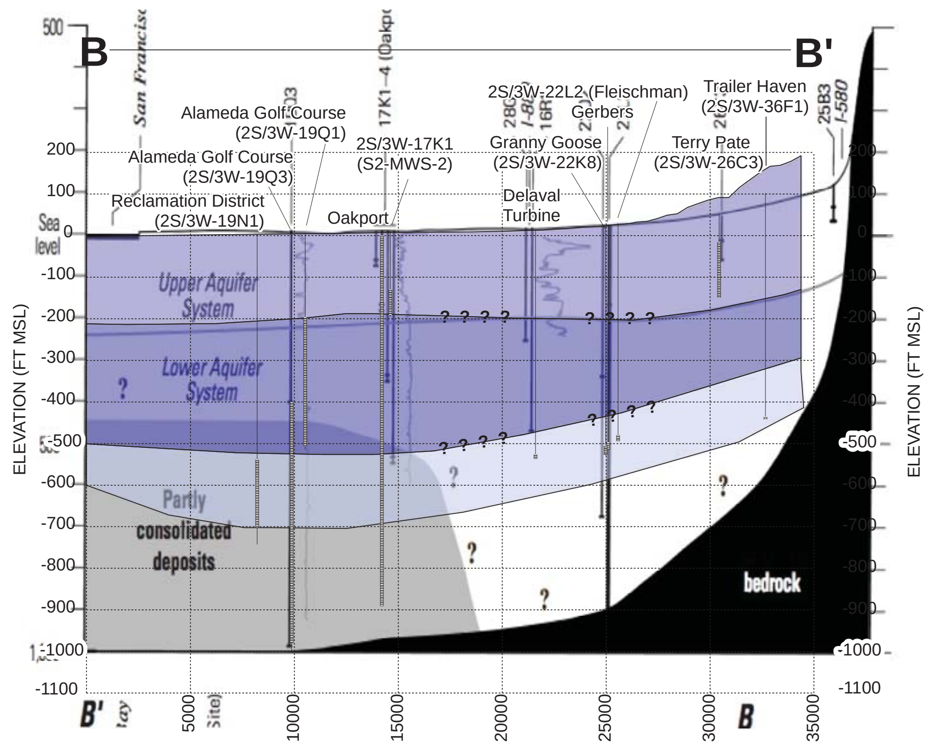


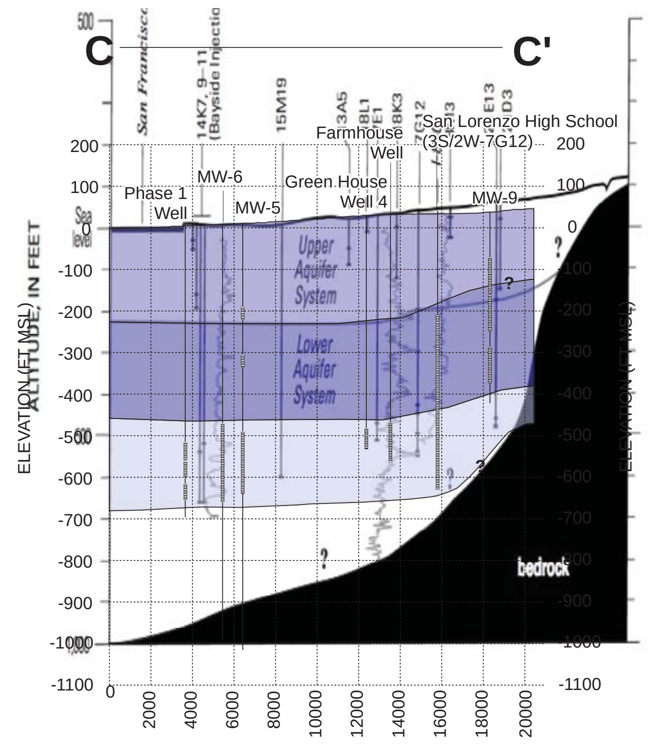


MODFLOW Cross Section Transects B-B' and C-C'

MODFLOW LEGEND

- Aquiclude 2
- Aquiclude 4
- Aquifer 1
- Aquifer 2
- Aquifer 3
- Aquifer 4
- Consolidated Deposits





EBMUD Cross Section Transects B-B' and C-C'

EBMUD LEGEND

- Shallow
- Intermediate
- Deep SEBP

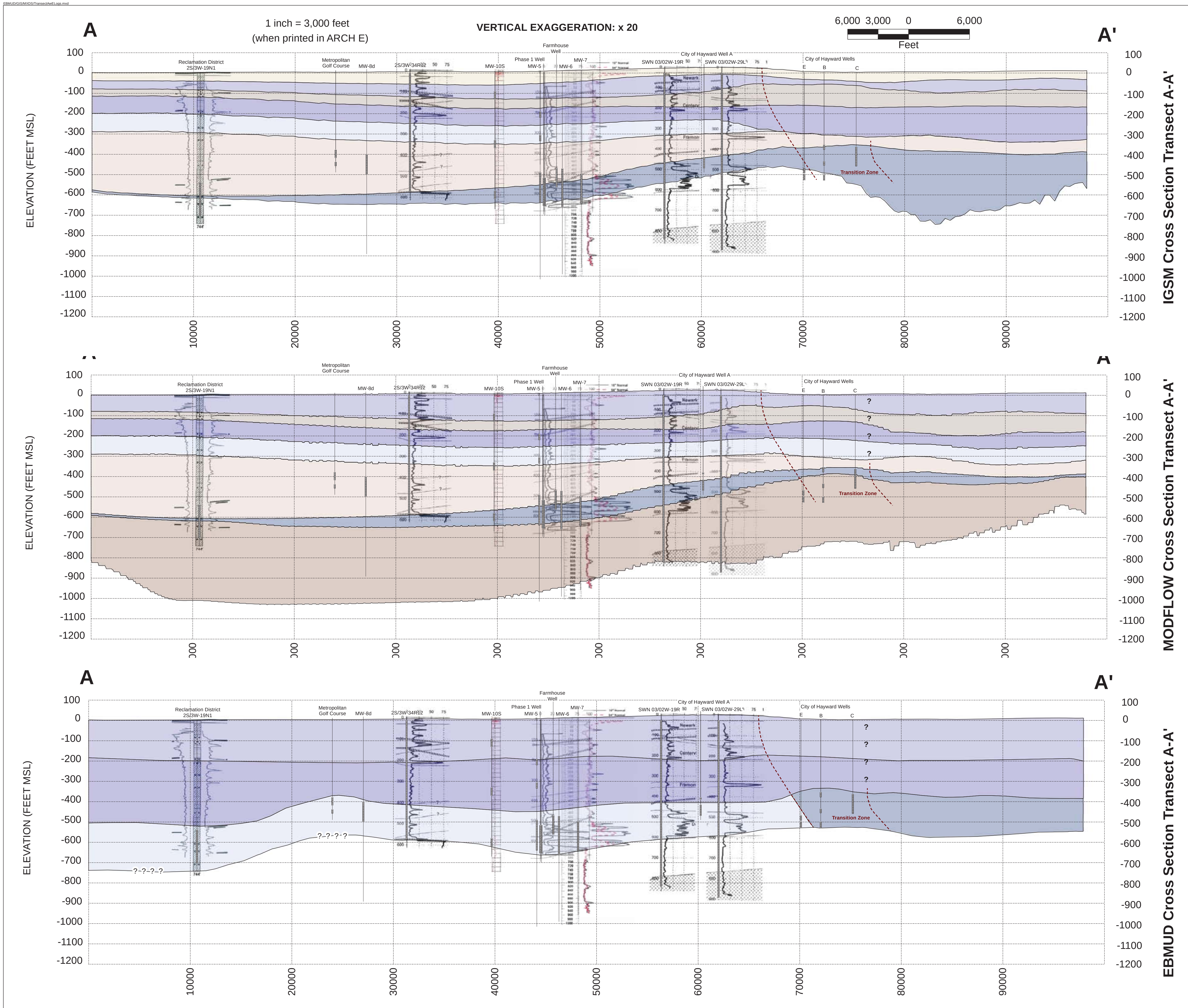
DRAFT

East Bay Municipal Utility District
South East Bay Plain
Basin Characterization Study

MODEL CROSS SECTIONS B-B' and C-C'
WITH IZBICKI CROSS SECTION OVERLAYS

WEST YOST ASSOCIATES

DRAFT



East Bay Municipal Utility District
South East Bay Plain
Basin Characterization Study

MODEL CROSS SECTIONS A-A'
WITH GEOPHYSICAL DATA

WEST YOST ASSOCIATES

EBMUD

IGSM LEGEND

- Aquiclude 1
- Aquiclude 2
- Aquiclude 4
- Aquifer 1
- Aquifer 2
- Aquifer 3
- Aquifer 4

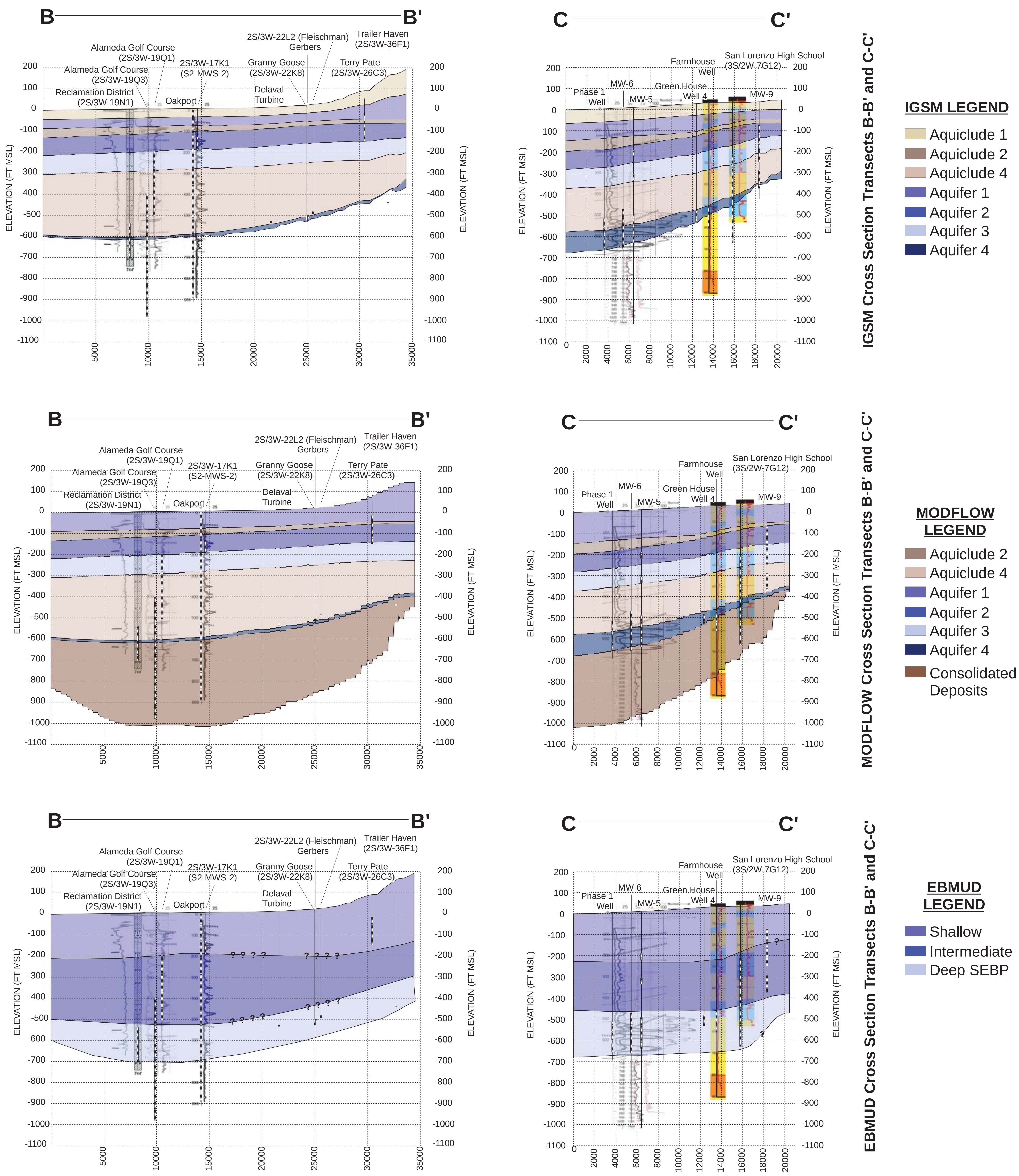
MODFLOW LEGEND

- Aquiclude 2
- Aquiclude 4
- Aquifer 1
- Aquifer 2
- Aquifer 3
- Aquifer 4
- Consolidated Deposits

EBMUD LEGEND

- Shallow
- Intermediate
- Deep SEBP
- Deep NC

DRAFT



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East Bay Municipal Utility District
South East Bay Plain
Basin Characterization Study

MODEL CROSS SECTIONS B-B' and C-C' WITH GEOPHYSICAL DATA

DRAFT

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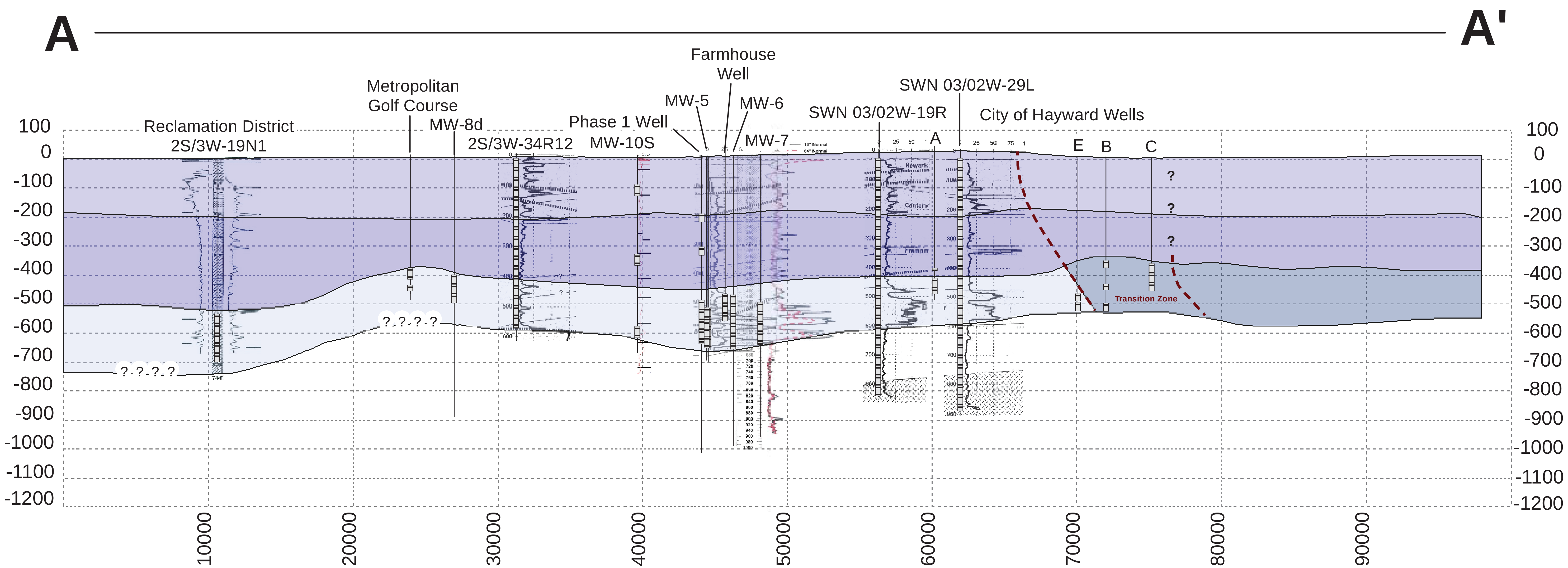


LEGEND

- Shallow
- Intermediate
- Deep SEBP
- Deep NC

DRAFT

7,500 3,750 0 7,500

Feet

1 inch = 7,000 feet

Vertical Exaggeration: 20

EBMUD

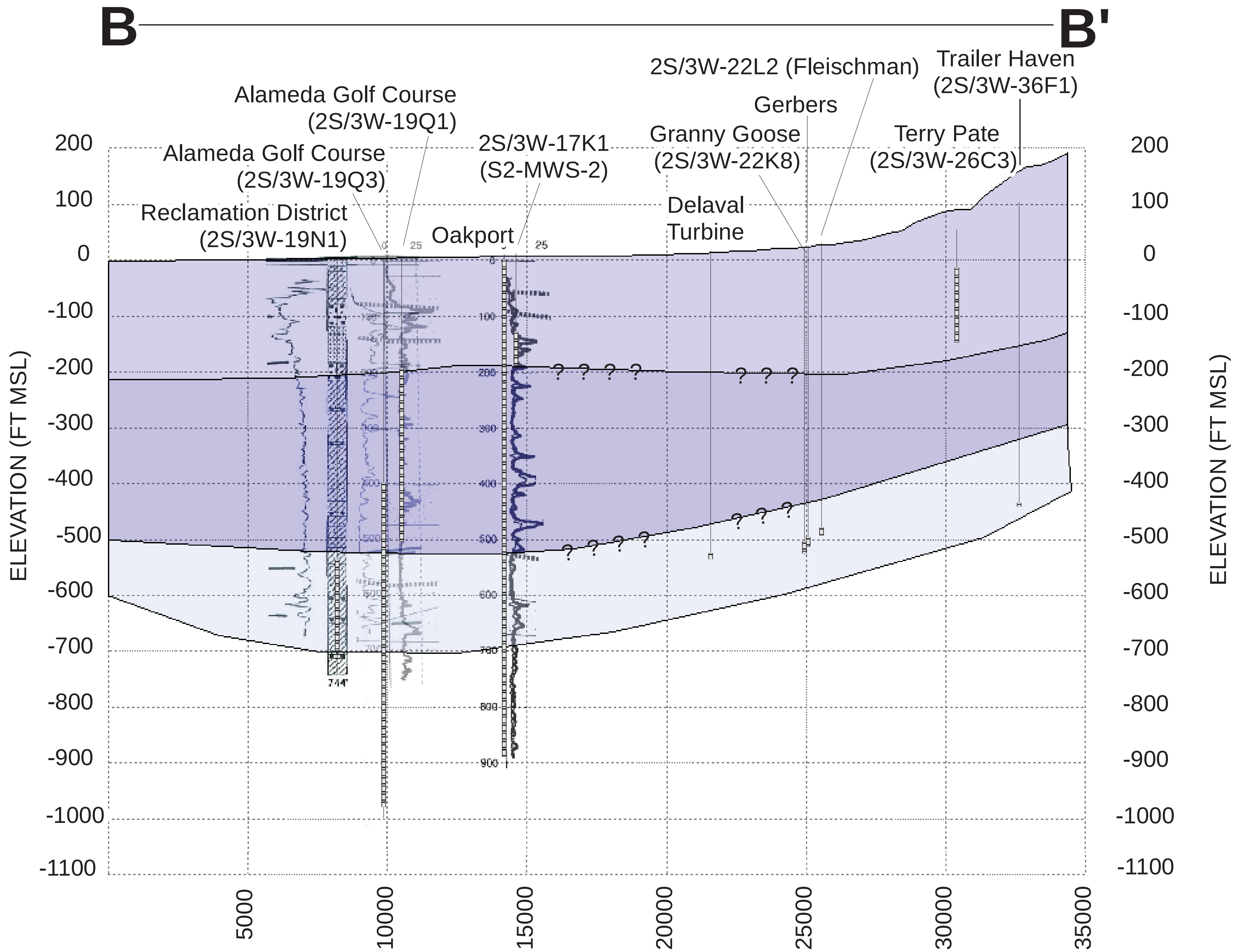
FIGURE D-1

East Bay Municipal Utility District
South East Bay Plain
Basin Characterization Study

MODEL CROSS SECTION A-A'
WITH GEOPHYSICAL DATA

WEST YOST ASSOCIATES

EBMUD/GIS/MXDs/XS_Bmemo.mxd



LEGEND

Shallow

Intermediate

Deep SEBP

DRAFT

4,500 2,250 0 4,500

Feet

1 inch = 4,500 feet

Vertical Exaggeration: 20

EBMUD

FIGURE D-2

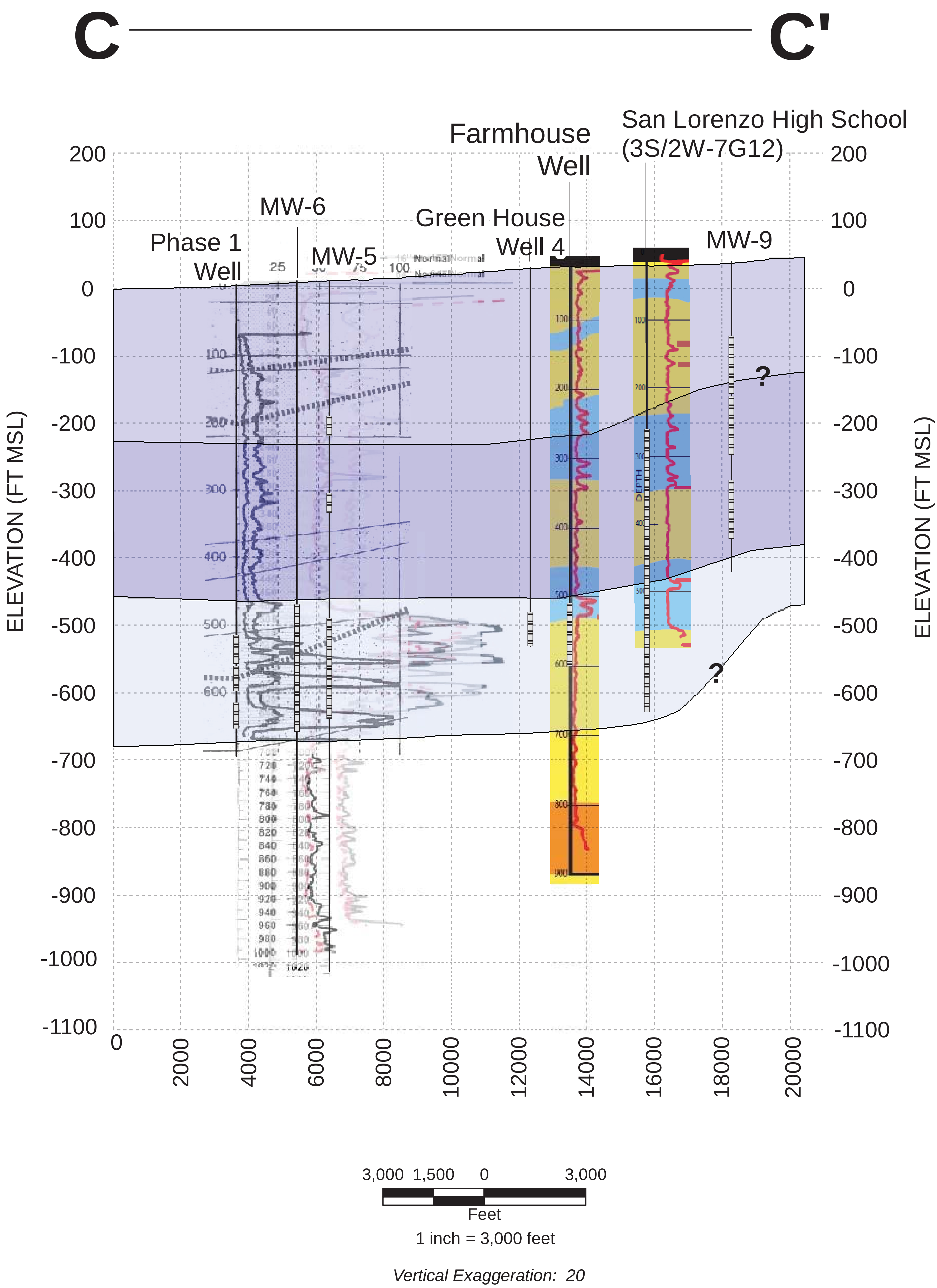
East Bay Municipal Utility District
South East Bay Plain
Basin Characterization Study

MODEL CROSS SECTION B-B'
WITH GEOPHYSICAL DATA

WEST YOST ASSOCIATES

DRAFT

EBMUD/GIS/MXDs/XS_Cmemo.mxd



LEGEND

- Shallow
- Intermediate
- Deep SEBP

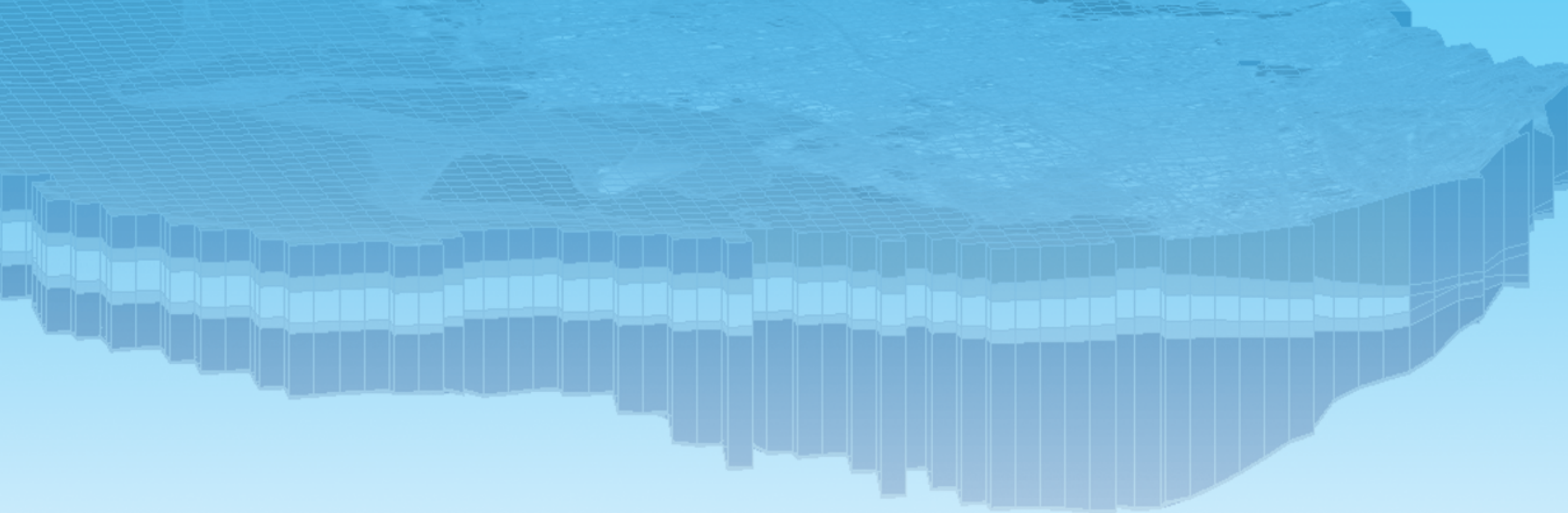
EBMUD

FIGURE D-3

East Bay Municipal Utility District
South East Bay Plain
Basin Characterization Study

MODEL CROSS SECTION C-C'
WITH GEOPHYSICAL DATA

WEST YOST ASSOCIATES



EBMUD

WEST YOST ASSOCIATES

APPENDIX E

Water Quality Tables

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Summary of Total Dissolved Solids Data - South East Bay Plain Basin

Sample Location	Well Depth (ft BLS)	Sample Date	Analyte	Results (mg/L)	Qualifier
002S003W22Q002M	-9999	7-Dec-99	Dissolved solids	487	
< 200 ft BLS					
003S003W14K011M	60	7-Dec-98	Dissolved solids	84000	
002S003W17K002M	85	8-Dec-98	Dissolved solids	30300	
003S003W13A005M	90	9-Dec-98	Dissolved solids	482	
003S002W08E003M	120	17-Dec-08	Dissolved solids	577	V
003S003W11F003M	120	16-Dec-08	Dissolved solids	396	V
004S001W21F001M	120	2-Aug-78	Dissolved solids	570	
004S001W17M008M	125	22-Mar-02	Dissolved solids	409	
004S002W13P004M	145	27-Mar-02	Dissolved solids	581	E
004S001W20R002M	150	30-May-79	Dissolved solids	513	
003S002W18K003M	155	24-Aug-99	Dissolved solids	551	
004S001W28D009M	175	30-May-79	Dissolved solids	506	
			Median TDS	**551**	
200 - 500 ft BLS					
003S003W14K010M	200	7-Dec-98	Dissolved solids	647	
004S001W21P006M	200	27-Jul-77	Dissolved solids	445	
002S003W17K001M	205	8-Dec-98	Dissolved solids	5880	
003S002W08E002M	210	17-Dec-08	Dissolved solids	433	V
003S003W13D009M	210	15-Dec-08	Dissolved solids	469	E
004S002W12K010M	240	5-Nov-02	Dissolved solids	553	E
002S003W28G001M	250	25-Aug-99	Dissolved solids	2570	
004S001W17M007M	260	19-Mar-02	Dissolved solids	522	
004S002W13P007M	280	27-Mar-02	Dissolved solids	667	E
003S003W13D008M	325	15-Dec-08	Dissolved solids	459	E
003S002W08E001M	335	17-Dec-08	Dissolved solids	477	V
002S004W03E001M	353	26-Aug-99	Dissolved solids	525	
002S003W17K003M	360	23-Mar-99	Dissolved solids	1010	
003S003W11F002M	360	16-Dec-08	Dissolved solids	464	V
004S002W13P006M	360	26-Mar-02	Dissolved solids	709	E
004S002W13P005M	420	26-Mar-02	Dissolved solids	750	E
004S002W10E004M	440	4-Nov-02	Dissolved solids	474	E
004S002W14D003M	450	16-Apr-03	Dissolved solids	364	
004S002W03L001M	452	27-Mar-02	Dissolved solids	338	E
004S001W17M006M	460	19-Mar-02	Dissolved solids	541	E
004S002W04R001M	466	29-Oct-02	Dissolved solids	513	
004S002W15L005M	470	29-Oct-02	Dissolved solids	861	E
004S002W02H001M	472	20-Mar-02	Dissolved solids	398	E
002S003W34F001M	490	6-Jul-00	Dissolved solids	404	
002S003W16R001M	495	11-Dec-98	Dissolved solids	913	
			Median TDS	**522**	

Summary of Chloride Data - South East Bay Plain Basin

Sample Location	Well Depth, ft BLS	Sample Date	Analyte	Results, mg/L
002S003W22Q002M	-	7-Dec-99	Chloride	152
003S003W14K014M	-	7-Sep-06	Chloride	370
< 200 ft BLS				
003S003W14K011M	60	7-Dec-98	Chloride	41,900
002S003W17K002M	85	8-Dec-98	Chloride	17,500
003S002W08M003M	85	24-Mar-99	Chloride	46
002S003W25B003M	88	10-Dec-98	Chloride	34
003S003W13A005M	90	9-Dec-98	Chloride	58
002S003W26C003M	100	25-Mar-99	Chloride	26
003S002W19R004M	112	16-Nov-98	Chloride	61
003S002W08E003M	120	17-Dec-08	Chloride	52
003S003W11F003M	120	16-Dec-08	Chloride	43
004S001W21F001M	120	13-Jun-79	Chloride	130
004S001W17M008M	125	22-Mar-02	Chloride	74
004S002W13P004M	145	27-Mar-02	Chloride	121
004S001W20R002M	150	27-Jun-79	Chloride	130
003S002W18K003M	155	24-Aug-99	Chloride	61
004S001W28D009M	175	27-Jun-79	Chloride	140
003S003W14K010M	200	7-Dec-98	Chloride	136
004S001W21P006M	200	2-Aug-78	Chloride	170
			Median	**74**
200 to 500 ft BLS				
002S003W17K001M	205	8-Dec-98	Chloride	3,630
003S002W08E002M	210	17-Dec-08	Chloride	47
003S003W13D009M	210	15-Dec-08	Chloride	56
003S002W21D003M	220	31-Mar-99	Chloride	18
004S002W12K010M	240	5-Nov-02	Chloride	78
002S003W28G001M	250	25-Aug-99	Chloride	1,470
004S001W17M007M	260	19-Mar-02	Chloride	83
004S002W13P007M	280	27-Mar-02	Chloride	151
003S002W18L001M	300	31-Mar-99	Chloride	65
003S003W13D008M	325	15-Dec-08	Chloride	63
003S002W08E001M	335	17-Dec-08	Chloride	53
002S004W03E001M	353	26-Aug-99	Chloride	150
002S003W17K003M	360	23-Mar-99	Chloride	384
003S003W11F002M	360	16-Dec-08	Chloride	53
004S002W13P006M	360	26-Mar-02	Chloride	233

Summary of Chloride Data - South East Bay Plain Basin, cont'd

Sample Location	Well Depth, ft BLS	Sample Date	Analyte	Results, mg/L
004S002W13P005M	420	26-Mar-02	Chloride	315
004S002W10E004M	440	4-Nov-02	Chloride	118
004S002W14D003M	450	16-Apr-03	Chloride	46
004S002W03L001M	452	27-Mar-02	Chloride	49
004S001W17M006M	460	19-Mar-02	Chloride	131
004S002W04R001M	466	29-Oct-02	Chloride	133
004S002W15L005M	470	29-Oct-02	Chloride	346
004S002W02H001M	472	20-Mar-02	Chloride	62
002S003W34F001M	490	6-Jul-00	Chloride	40
002S003W16R001M	495	11-Dec-98	Chloride	422
			Median	**83**
> 500 ft BLS				
004S002W12K008M	510	5-Nov-02	Chloride	39
004S002W12C001M	512	20-Mar-02	Chloride	103
004S002W04F006M	534	9-Dec-98	Chloride	37
004S002W04E001M	535	30-Oct-02	Chloride	122
003S002W07E001M	540	10-Feb-00	Chloride	104
004S002W14D004M	540	6-Nov-02	Chloride	136
003S002W21E013M	550	25-Aug-99	Chloride	60
004S002W04F003M	550	21-Mar-02	Chloride	66
002S003W22K008M	551	12-Aug-98	Chloride	100
002S003W17K004M	555	23-Mar-99	Chloride	188
003S002W07G012M	595	15-Nov-99	Chloride	60
003S002W20L020M	600	29-Oct-02	Chloride	46
003S002W29L006M	600	30-Oct-02	Chloride	99
003S003W15M019M	600	25-Aug-99	Chloride	71
003S003W11F001M	610	16-Dec-08	Chloride	123
003S003W14K007M	660	7-Dec-98	Chloride	61
003S003W14K009M	660	13-Nov-97	Chloride	57
002S003W22L003M	945	11-Dec-98	Chloride	227
002S003W19Q003M	1000	8-Dec-99	Chloride	639
			Median	**99**

Summary of Nitrate Data - South East Bay Plain Basin

Sample Location	Well Depth (ft BLS)	Sample Date	Analyte	Results (mg/L)	Qualifier
002S003W22Q002M	-9999	7-Dec-99	Nitrate	0.54	
003S003W14K014M	-9999	7-Sep-06	Nitrate	1	E
< 200 ft BLS					
003S003W14K011M	60	7-Dec-98	Nitrate	0.05	ND
002S003W17K002M	85	8-Dec-98	Nitrate	0.05	ND
003S003W13A005M	90	9-Dec-98	Nitrate	0.05	ND
004S001W17M008M	125	22-Mar-02	Nitrate	0.195	
004S002W13P004M	145	27-Mar-02	Nitrate	2.38	
003S002W18K003M	155	24-Aug-99	Nitrate	10.4	
			Median	**0.1225**	
200 -500 ft BLS					
003S003W14K010M	200	7-Dec-98	Nitrate	0.05	ND
004S001W21P006M	200	12-May-76	Nitrate	2.4	
002S003W17K001M	205	8-Dec-98	Nitrate	1.36	
004S002W12K010M	240	5-Nov-02	Nitrate	8.07	
002S003W28G001M	250	25-Aug-99	Nitrate	0.176	
004S001W17M007M	260	19-Mar-02	Nitrate	1.63	
004S002W13P007M	280	27-Mar-02	Nitrate	9.5	
002S004W03E001M	353	26-Aug-99	Nitrate	0.04	ND
002S003W17K003M	360	23-Mar-99	Nitrate	10.1	
004S002W13P006M	360	26-Mar-02	Nitrate	3.75	
004S002W13P005M	420	26-Mar-02	Nitrate	2.52	E
004S002W10E004M	440	4-Nov-02	Nitrate	0.109	
004S002W14D003M	450	16-Apr-03	Nitrate	0.096	
004S002W03L001M	452	27-Mar-02	Nitrate	0.909	
004S001W17M006M	460	19-Mar-02	Nitrate	3.52	
004S002W04R001M	466	29-Oct-02	Nitrate	2.08	E
004S002W15L005M	470	29-Oct-02	Nitrate	0.06	ND
004S002W02H001M	472	20-Mar-02	Nitrate	0.656	E
002S003W34F001M	490	6-Jul-00	Nitrate	0.05	ND
			Median	**1.36**	
> 500 ft BLS					
004S002W12K008M	510	5-Nov-02	Nitrate	0.351	E
004S002W12C001M	512	20-Mar-02	Nitrate	1.37	
004S002W04E001M	535	30-Oct-02	Nitrate	0.06	ND
003S002W07E001M	540	10-Feb-00	Nitrate	0.05	ND
004S002W14D004M	540	6-Nov-02	Nitrate	0.06	ND
003S002W21E013M	550	25-Aug-99	Nitrate	2.56	
004S002W04F003M	550	21-Mar-02	Nitrate	0.313	

Summary of Nitrate Data - South East Bay Plain Basin, cont'd

Sample Location	Well Depth (ft BLS)	Sample Date	Analyte	Results (mg/L)	Qualifier
002S003W17K004M	555	23-Mar-99	Nitrate	0.05	ND
003S002W07G012M	595	15-Nov-99	Nitrate	0.225	
003S002W20L020M	600	29-Oct-02	Nitrate	0.06	ND
003S002W29L006M	600	30-Oct-02	Nitrate	0.109	
003S003W15M019M	600	25-Aug-99	Nitrate	0.05	ND
003S003W14K007M	660	7-Dec-98	Nitrate	0.012	
003S003W14K009M	660	13-Nov-97	Nitrate	0.05	ND
002S003W19Q003M	1000	8-Dec-99	Nitrate	0.02	ND
			Median	**0.06**	

Summary of Median Concentrations of TDS, Chloride and Nitrate by Depth – South East Bay Plain Basin

Depth	Total Dissolved Solids	Chloride	Nitrate
<200	551	74	0.12
200-500	522	83	1.36
>500	479	99	0.06

APPENDIX F

Monitoring Guidelines

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Department of Water Resources

Groundwater Elevation Monitoring

Guidelines

December 2010

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Introduction to the CASGEM Program

On November 4, 2009 the state legislature amended the Water Code with SB 6, which mandates a statewide, locally-managed groundwater elevation monitoring program to track seasonal and long-term trends in groundwater elevations in California's groundwater basins. To achieve that goal the amendment requires collaboration between local Monitoring Entities and the Department of Water Resources (DWR) to collect groundwater elevation data. In accordance with the amendment, DWR developed the California Statewide Groundwater Elevation Monitoring (CASGEM) program.

If no local entities volunteer to monitor groundwater elevations in a basin or part of a basin, DWR may be required to develop a monitoring program for that part. If DWR takes over monitoring of a basin, certain entities in the basin may not be eligible for water grants or loans administered by the state.

DWR will report findings of the CASGEM program to the Governor and the Legislature by January 1, 2012 and thereafter in years ending in 5 or 0.

Purpose of Guidelines for DWR Monitoring

The following Guidelines were developed to assist DWR by establishing criteria for the selection and measurement of monitoring wells in the event that DWR is required to perform the groundwater monitoring functions in lieu of a local monitoring agency pursuant to Water Code Section 10933.5(a).

The primary objective of the CASGEM monitoring program is to define the seasonal and long-term trends in groundwater elevations in California's groundwater basins. The scale for this evaluation should be the static, regional groundwater table or potentiometric surface. A secondary objective is to provide sufficient data to draw representative contour maps of the elevations. These maps could be used to estimate changes in groundwater storage and to evaluate potential areas of overdraft and subsidence.

Although it is not an objective of the CASGEM program, it would be valuable to include monitoring wells near localized features that impact more dynamic groundwater elevations. These features would include wells near aquifer storage and recovery projects, near high volume pumping wells, and near rivers.

NETWORK DESIGN CONCEPTS

SELECTION OF MONITORING WELLS FOR MONITORING PLANS

The number of groundwater wells that need to be monitored in a basin to adequately represent static water levels (and corresponding elevations) depends on several factors, some of which include: the known hydrogeology of the basin, the slope of the groundwater table or potentiometric surface, the existence of high volume production wells and the frequency of their use, and the availability of easily-accessible monitoring wells. Dedicated groundwater monitoring wells with known construction information are preferred over production wells to determine static water levels, and monitoring wells near rivers or aquifer storage and recovery projects should be avoided due to the potential for rapidly fluctuating water levels and engineered groundwater systems. The selection of wells should be aquifer-specific and wells which are screened across more than one aquifer should not be candidates for selection.

Heath (1976) suggested a density of groundwater monitoring wells ranging from 2 wells per 1,000 square miles (mi^2) for a large area in which only major features are to be mapped, to 100 wells per 1,000 mi^2 for a complex area to be mapped in considerable detail. The objective of the Heath (1976) design was to evaluate the status of groundwater storage and the areal extent of aquifers.

Sophocleous (1983) proposed a redesign of a water-level monitoring program for the state of Kansas based on efficiency, economics, statistical analysis, comparison of water-level hydrographs, and consistency across the state. The Sophocleous study recommended a “square well network” with a density of 1 observation well per 16 mi^2.

The Texas Water Development Board proposed varying well network densities for counties according to the amount of groundwater pumpage. These densities range from 0.7 wells per 100 mi^2 for counties with 1,000-2,500 acre-feet per year (AF/yr) of pumpage to 4 wells per 100 mi^2 for counties with over 100,000 AF/yr of pumpage (Hopkins, 1994). These densities were converted to pumpage per 100 mi^2 area by dividing by the size of an average county in Texas of about 1,000 mi^2 (Table 2)

Most designs of water-level monitoring programs rely on a probabilistic approach. Alley (1993) discussed four probabilistic designs: (1) simple random sampling throughout an aquifer; (2) stratified random sampling within different strata of an aquifer; (3) systematic grid sampling (e.g., at the midpoint of each section within an aquifer); and (4) random sampling within blocks (e.g., randomly selected wells within each section of an aquifer). The Sophocleous (1983) program used the third approach, systematic grid sampling. The guidelines on well density from the programs mentioned above are summarized in Table 2.

Based on the few referenced studies with specific recommendations, the consensus appears to fall between 2 and 10 groundwater monitoring wells per 100 mi^2. The exceptions to this density range include the lower end of the Heath (1976) range and the low-use counties in Texas.

There will always be a tradeoff between the improved spatial (and temporal) representation of water levels in an aquifer and the expense of monitoring. A higher-resolution contour map would be warranted in an area with a greater reliance upon groundwater in order to anticipate potential problems, such as supply and groundwater contamination concerns, while a lower-resolution contour map might be sufficient in an area with few people or a low reliance upon groundwater. Ideally, areas with relatively steep groundwater gradients or areas of high recharge or discharge would have a greater density of monitoring wells.

The illustrations in Figure 1 show a local groundwater elevation contour map developed with different numbers of wells. The examples cover the same area and use the same dataset, with wells randomly deleted by grid area from the full dataset to create a less dense network of wells. The resulting range of plotting density is 2 to 20 groundwater monitoring wells per 100 mi^2. The contours in Figure 1 show how the accuracy and resolution of the contour map increases with the density of wells used for plotting. To avoid presenting misleading contour maps, only wells with the best possible elevation accuracies should be used. These accuracies are a combination of the accuracies in the water-level measurement and the reference point (RP) measurement. Unless the RP elevation has been surveyed, it will be the limiting factor on elevation accuracy.

Program and(or) Reference	Density of monitoring wells (wells per 100 mi^2)
Heath (1976)	0.2 – 10
Sophocleous (1983)	6.3
Hopkins (1994) (a) Basins with >10,000 AF/yr groundwater pumping per 100 mi^2 area	4.0
(b) Basins with 1,000-10,000 AF/yr groundwater pumping per 100 mi^2 area	2.0
(c) Basins with 250-1,000 AF/yr groundwater pumping per 100 mi^2 area	1.0
(d) Basins with 100--250 AF/yr groundwater pumping per 100 mi^2 area	0.7

Table 1. Recommended density of monitoring wells for groundwater-level monitoring programs.

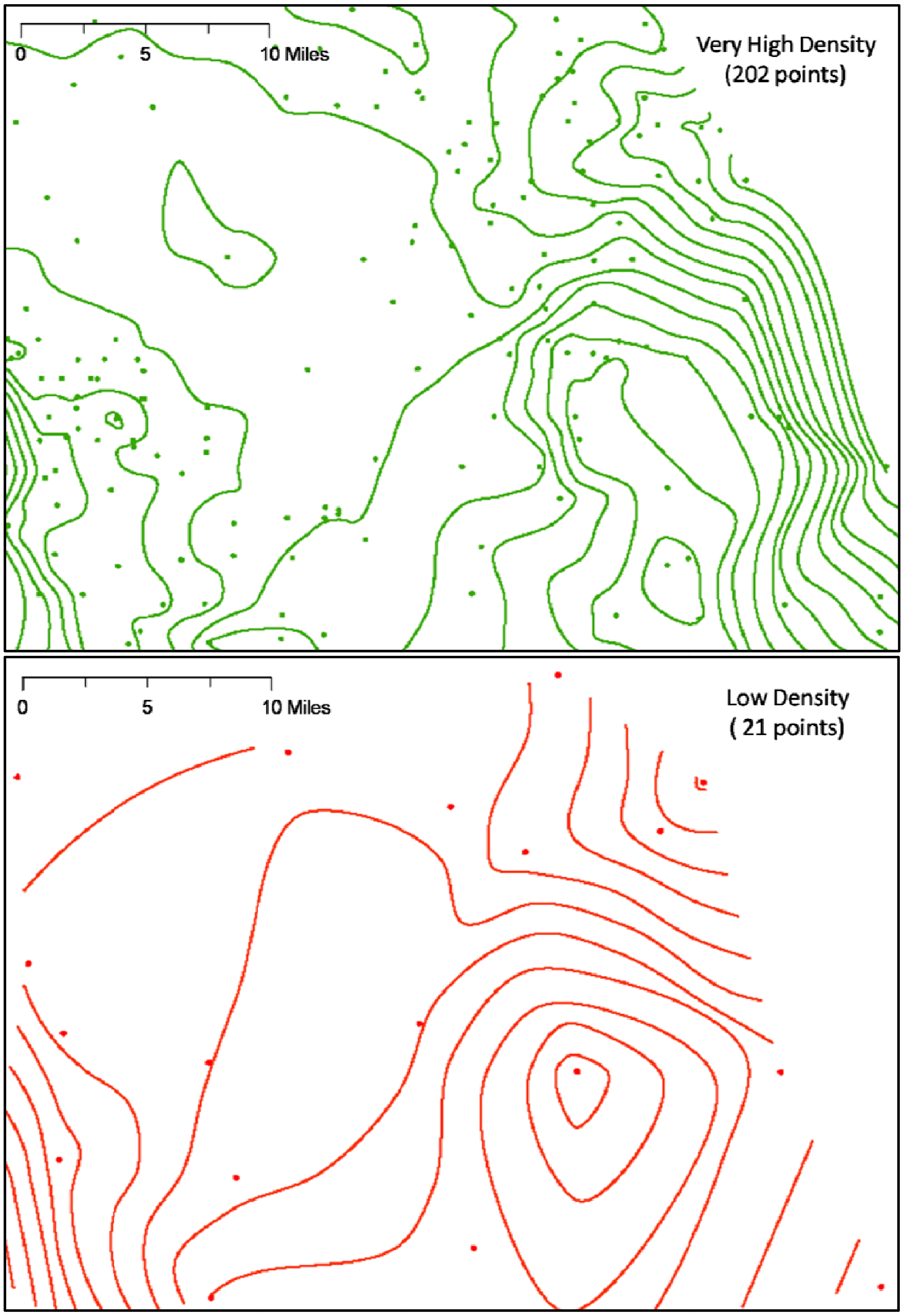

Figure 1. Contour maps – Contours of a very high-density well network (about 20 wells per 100 mi^2) compared to a low-density well network (about 2 wells per 100 mi^2).

Frequency of Water-Level Measurements

To determine and define seasonal and long-term trends in groundwater levels a consistent measurement frequency must be established. At minimum, semi-annual monitoring of the designated wells in each basin or subbasin should be conducted to coincide with the high and low water-level times of year for each basin. However, quarterly- or monthly-monitoring of wells provides a better understanding of groundwater fluctuations. The DWR office responsible for monitoring a particular basin should use independent judgment to determine when the high and low water-level times occur in a groundwater basin, and to provide a justification for measurement rationale. The semi-annual frequency is a compromise between more frequent measurements (continuous, daily, monthly, or quarterly) and less frequent measurements (annual). A good discussion of water level measurement frequency and other issues related to the design of water-level monitoring programs can be found in the USGS Circular 1217 (Taylor and Alley, 2001).

An example of the effect of different measurement frequencies on the water-level hydrographs in a Northern California well is shown in Figure 2. The data shows that higher-frequency monitoring (e.g., daily or monthly) best captures the seasonal fluctuations in the groundwater levels, quarterly monitoring identifies some of the elevation change, but semi-annual measurements often miss the true seasonal highs and lows.

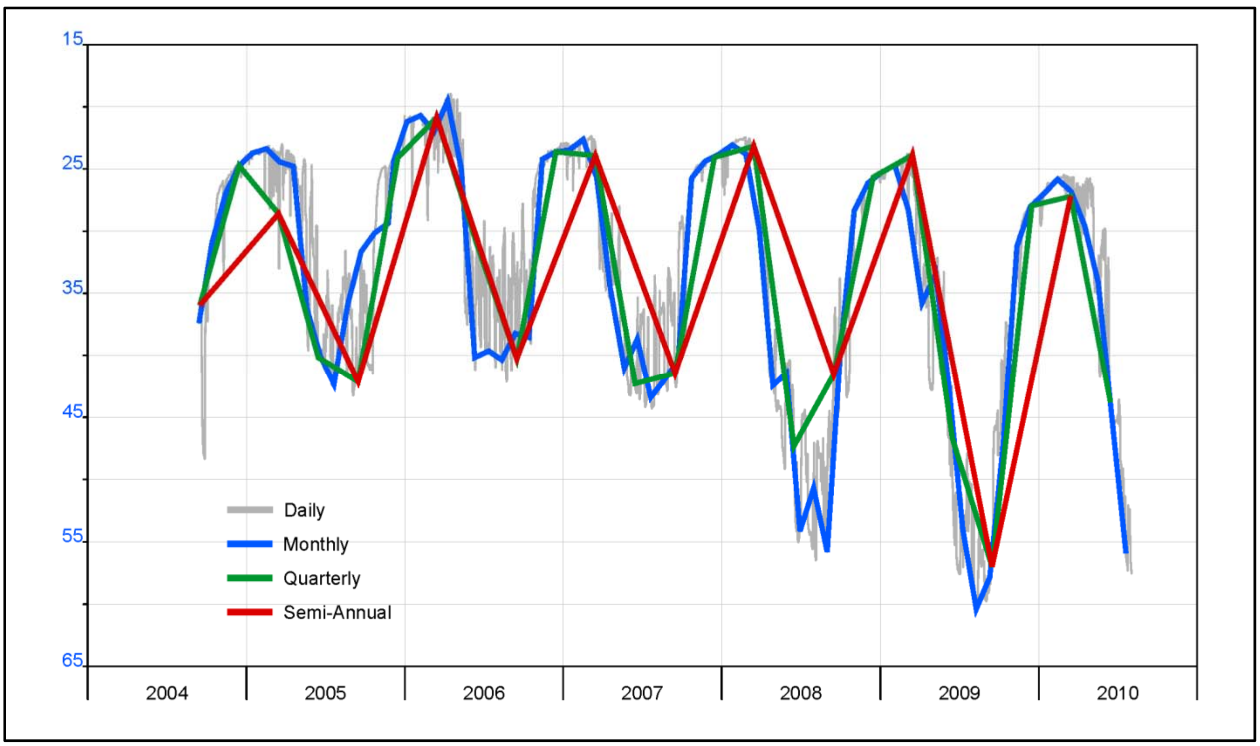

Figure 2. Groundwater Hydrographs – Groundwater elevation changes in a monitoring well over time comparing various measurement frequencies.

The Subcommittee on Ground Water of the Advisory Committee on Water Information generally recommends more frequent measurements than are being required by the CASGEM program; quarterly to annually for aquifers with very few groundwater withdrawals, monthly to quarterly for aquifers with moderate groundwater withdrawals, and daily to monthly for aquifers with many groundwater withdrawals (Table 2). The general effect of environmental factors on the recommended measurement frequency is illustrated in Figure 3.

Measurement Type	Aquifer Type	Nearby Long-Term Aquifer Withdrawals		
		Very Few Withdrawals	***Moderate Withdrawals***	***Many Withdrawals***
Baseline Measurements	**All aquifer types**	Once per month	Once per day	Once per hour
Surveillance Measurements	**All aquifer types:** "low" hydraulic conductivity (<200 ft/d), "low" recharge (<5 in/yr)	Once per year	Once per quarter	Once per month
	All aquifer types: "high" hydraulic conductivity (>200 ft/d), "high" recharge (>5 in/yr)	Once per quarter	Once per month	Once per day
Data made available to NGWMN	All aquifer types, throughout range of hydraulic conductivity	As stored in local database, but at least annually	As stored in local database, but at least annually	As stored in local database, but at least annually

Table 2. Information on recommended minimum water-level measurement frequency from the Subcommittee on Ground Water of the Advisory Committee on Water Information (2009) (abbreviations: ft/d, feet per day; in/yr, inches per year; NGWMN, National Ground Water Monitoring Network). NOTE: These are not recommendations of the CASGEM program.

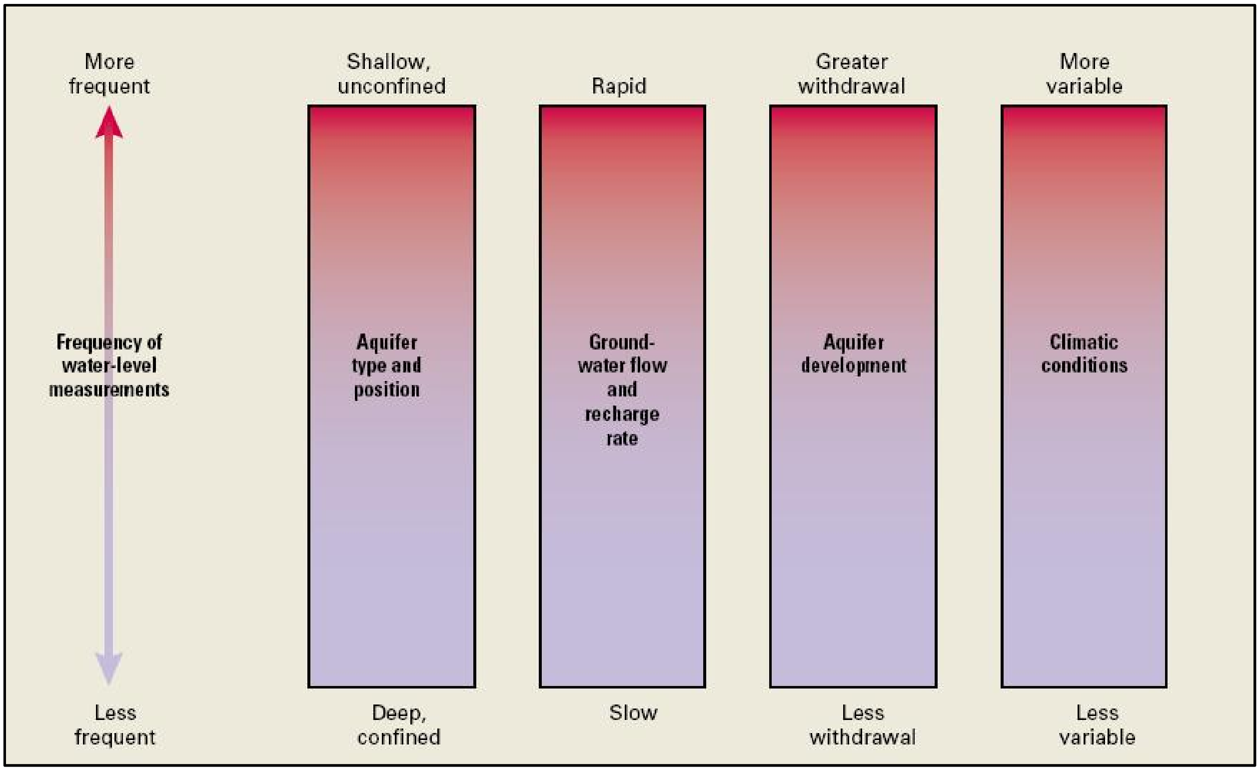

Figure 3. Common environmental factors that influence the choice of frequency of water-level measurements (from Taylor and Alley, 2001).

FIELD GUIDELINES FOR CASGEM WATER-LEVEL MEASUREMENTS

INTRODUCTION

This document presents guidelines for measuring groundwater levels in wells for the CASGEM program to ensure consistency between DWR offices. Following these guidelines will help ensure that groundwater level measurements are accurate and consistent in both unconfined and confined aquifers. Although a well network comprised entirely of dedicated monitoring wells (hereafter referred to as monitoring wells) is preferred, by necessity active production wells used for irrigation or domestic purposes and abandoned production wells that were used for domestic, irrigation, and public supply purposes will also need to be included. **The portions of these guidelines that apply to only production wells will be shown in bold throughout.** DWR does not currently plan to include public supply wells in the CASGEM well networks due to security concerns of the California Department of Public Health.

The main reference used for these guidelines is the United States Geological Survey (USGS) National Field Manual (NFM) (U.S. Geological Survey, 2006). The final report of the Subcommittee on Groundwater (SOGW) of the Advisory Committee on Water Information was also used as a main reference, although in general it relied on the USGS guidelines (Subcommittee on Ground Water of the Advisory Committee on Water Information, 2009). The water-level measurement portion of the USGS guidelines were written for monitoring wells and not for production wells (Taylor and Alley, 2001; U.S. Geological Survey, 2006). Thus, although the USGS guidelines have been adopted with only minor modifications for the monitoring well guidelines of the CASGEM program, additional modifications have been incorporated in the guidelines for production wells. **The most significant changes made to the USGS guidelines for production wells are: (1) reducing the required precision for consecutive depth to water measurements, (2) checking for obstructions in the well, and (3) not attaching weights to the steel tape so as not to hang up on obstructions.**

The guidelines presented in this document are for the use of steel tape, electric sounding tape, sonic water-level meters, or pressure transducers. Although the semi-annual measurements required by the CASGEM program can be satisfied with the use of a steel or electric sounding tape or sonic meter, a pressure transducer with a data logger provides a much better picture of what is happening with water levels over time. The use of the air-line or flowing-well methods should not be needed in most basins. However, if they are, guidelines for these methods are available in sections A4-B-4 (pages B17-B20) and A4-B-5 (pages B21-B24), respectively of the NFM (U.S. Geological Survey, 2006).

Establishing the Reference Point

Water-level measurements from a given well must be referenced to the same datum (the reference point, or RP) to ensure data comparability (see Figure 4). For monitoring wells, the RP should be marked on the top of the well casing. For production wells, the RP will most likely be the top of the access tube or hole to the well casing. The RP must be as permanent as possible and be clearly visible and easily located. It can be marked with a permanent marker, paint, imprinting a mark with a chisel or punch, or by cutting a slot in the top of the casing. In any case, the location of the RP should be clearly described on DWR Form 429 (see Table 3). A photograph of the RP, with clear labeling, should be included in the well folder. In some cases, it may be valuable to establish multiple RPs for a well, depending on the consistent accessibility of the primary RP. In this case, each RP should be clearly described on DWR Form 429 and labeled in the field. The RP should be established with the following coordinate system: horizontal location (decimal latitude and longitude referenced to the North American Datum of 1983; NAD83) and vertical elevation (referenced to the North American Vertical Datum of 1988; NAVD88, in feet).

The land-surface datum (LSD) is established by the person making the initial water-level measurement at the well. The LSD is chosen to represent the average elevation of the ground around the well. Because LSD around a well may change over time, the distance between the RP and LSD should be checked every 3 to 5 years. If appropriate, a concrete well pad or well vault may be chosen as the LSD, since they will be more permanent than the surrounding ground surface.

The elevation of the RP can be determined in several ways: (1) surveying to a benchmark, (2) using a USGS 7.5’ quadrangle map, (3) using a digital elevation model (DEM), or (4) using a global positioning system (GPS). While surveying is the most accurate (± 0.1 ft), it is also the most expensive. Depending on the distance to the nearest benchmark, the cost can be prohibitive. The latitude and longitude of the well can be established accurately using a handheld GPS. From this information, the LSD can be located on a USGS quadrangle and the elevation estimated. However, the accuracy is only about ± one half of the contour interval. Thus, for a contour interval of 5 feet, the accuracy of the elevation estimate would be about ± 2.5 feet. The contour interval of high quality DEMs is currently about 30 feet. Therefore, the accuracy of using

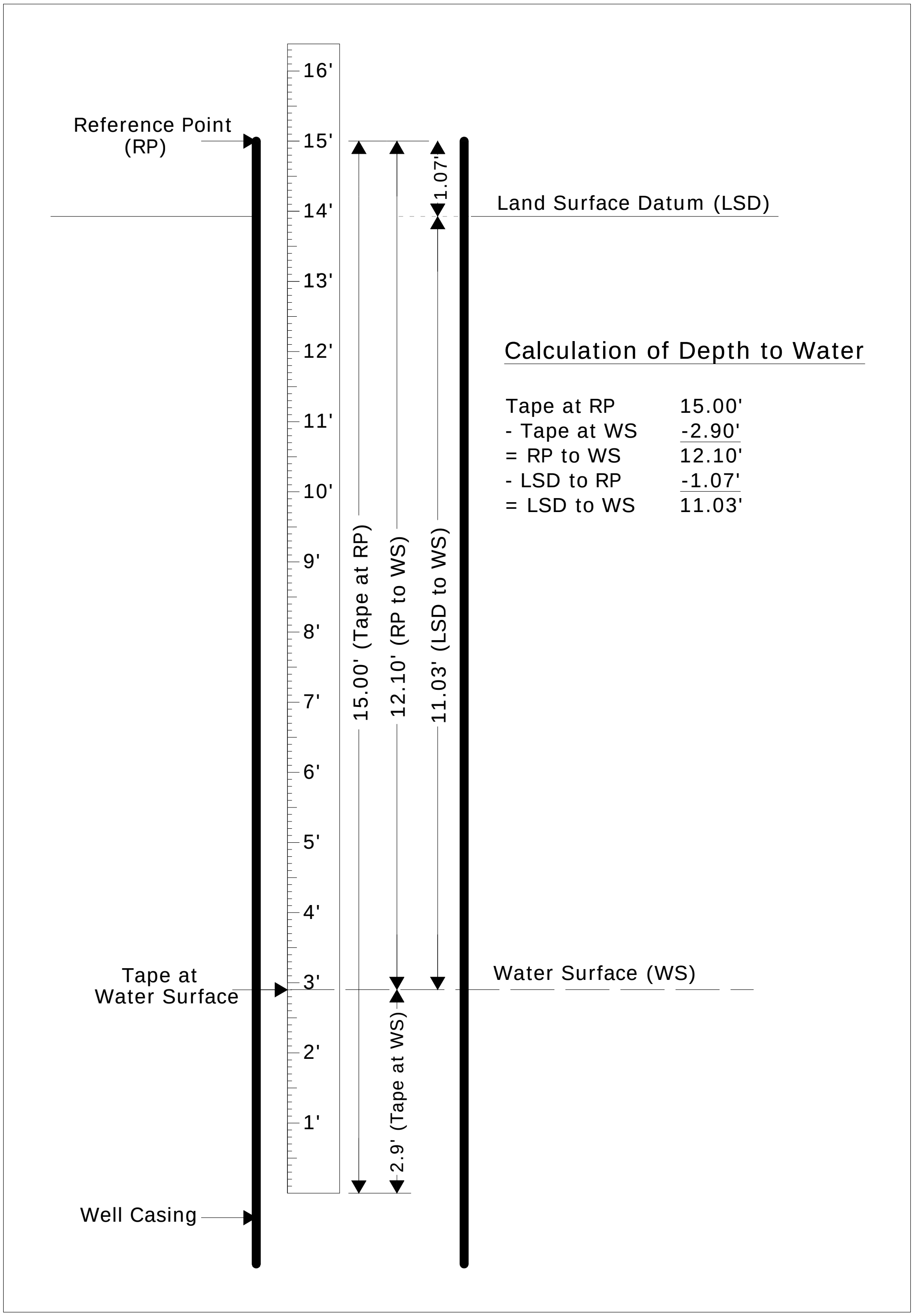

Figure 4. Groundwater-level measurements using a graduated steel tape (modified from U.S. Geological Survey, 2006).

State of California | DEPARTMENT OF WATER RESOURCES | California Natural Resources Agency

WELL DATA

State No. ______________________

District ______________________

OWNER	STATE NO.
ADDRESS	OTHER NO.
TENANT	
ADDRESS	

TYPE OF WELL	☐ SPECIAL STUDIES	☐ MONTHLY	☐ SEMI ANNUAL	☐ WATER QUALITY

LOCATION: COUNTY	BASIN	NO.
U.S.G.S. QUAD.		QUAD NO.

1/4	1/4 SECTION	TWP.	RGE.	MD ☐ SB BASE & MERIDIAN H ☐

COORDINATES X:	Y:	SOURCE:

DESCRIPTION

REFERENCE POINT DESCRIPTION

WHICH IS	FT.	ABOVE ☐ BELOW ☐	LAND SURFACE.	GROUND ELEVATION	FT.
REFERENCE POINT ELEVATION	FT.	DETERMINED FROM			
WELL: USE	CONDITION	DEPTH	FT.		
CASING, SIZE	IN.,	PERFORATIONS			

MEASUREMENTS BY:	☐ DWR	☐ USGS	☐ USBR	☐ COUNTY	☐ IRR. DIST.	☐ WATER DIST.	☐ CONS. DIST.

CHIEF AQUIFER: NAME	DEPTH TO TOP AQ.	DEPTH TO BOT. AQ.
TYPE OF MATERIAL	PERM. RATING	THICKNESS
GRAVEL PACKED? ☐ YES ☐ NO	DEPTH TO TOP GR.	DEPTH TO BOT GR.
SUPP. AQUIFER	DEPTH TO TOP AQ.	DEPTH TO BOT. AQ.
DRILLER	DATE DRILLED:	LOG NUMBER:

EQUIPMENT: PUMP, TYPE		MAKE	
SERIAL NO.	SIZE OF DISCHARGE PIPE IN.	WATER ANALYSIS: MIN. (1)	SAN. (2) H.M. (3)
POWER, KIND	MAKE	WATER LEVELS AVAILABLE: YES (1)	NO
H.P.	MOTOR SERIAL NO	PERIOD OF RECORD: BEGIN	END
ELEC. METER NO.	TRANSFORMER NO.	COLLECTING AGENCY:	
YIELD	G.P.M. PUMPING LEVEL FT.	PROD. REC. (1) PUMP TEST (2)	YIELD (3)

SKETCH (N)	REMARKS
	RECORDED BY:
	DATE:

DWR 429 (Rev. 1/09)

Table 3. General well data form (DWR Form 429).

DEMs to determine the elevation of the LSD is about ± 15 feet. While a handheld GPS unit is not very accurate for determining elevation, more expensive units with the Wide Area Augmentation System can be more accurate. However, GPS readings are subject to environmental conditions, such as weather conditions, overhead vegetative cover, topography, interfering structures, and location. Thus, the most common method of determining the elevation will probably be the use of USGS quadrangles. The method used needs to be identified on DWR Form 429 (Table 3). The important matter is that all measurements at a well use the same RP, as the elevation of that point can be more accurately established at a later date. The equipment and supplies needed for establishing the RP are shown in Table 4.

If possible, establish a clearly displayed reference mark (RM) in a location near the well; for example, a lag bolt set into a nearby telephone pole or set in concrete in the ground. The RM is an arbitrary datum established by permanent marks and is used to check the RP or to re-establish an RP should the original RP be destroyed or need to be changed. Clearly locate the RP and RM on a site sketch that goes into the well folder (see Table 3). Include the distance and bearing between the RP and the RM and the height of the lag bolt above the ground surface. Photograph the site, including the RP and RM locations; draw an arrow to the RP and RM on the photograph(s) using an indelible marker, and place the photos in the well file.

Table 4. Equipment and Supply List

Equipment and supplies needed for (a) all measurements, (b) establishing permanent RP, (c) steel tape method, (d) electric sounding tape method, (e) sonic water-level meter, and (f) automated measurements with pressure transducer.
(a) All measurements
GPS instrument, digital camera, watch, calculator, and maps
General well data form (DWR Form 429; see Table 3)
Pens, ballpoint with non-erasable blue or black ink, for writing on field forms and equipment log books
Well file with previous measurements
Measuring tape, graduated in feet, tenths, and hundredths of feet
Two wrenches with adjustable jaws and other tools for removing well cap
Key(s) for opening locks and clean rags
(b) Establishing a permanent reference point
Steel tape, graduated in feet, tenths, and hundredths of feet
Calibration and maintenance log book for steel tape
Paint (bright color), permanent marker, chisel, punch, and(or) casing-notching tool

Table 4. Equipment and Supply List (continued)

(c) Steel tape method
DWR field form 1213 (see Table 5)
Steel tape, graduated in feet, tenths, and hundredths of feet
Calibration and maintenance log book for steel tape
Weight (stainless steel, iron, or other noncontaminating material – do not use lead)
Strong ring and wire, for attaching weight to end of tape. Wire should be strong enough to hold weight securely, but not as strong as the tape, so that if the weight becomes lodged in the well the tape can still be pulled free.
Carpenters' chalk (blue) or sidewalk chalk
Disinfectant wipes, and deionized or tap water for cleaning tape.
(d) Electric sounding tape method
DWR field form 1213 (see Table 5)
Steel tape, graduated in feet, tenths, and hundredths of feet
An electric tape, double-wired and graduated in feet, tenths, and hundredths of feet, accurate to 0.01 ft. Electric sounding tapes commonly are mounted on a hand-cranked and powered supply reel that contains space for the batteries and some device ("indicator") for signaling when the circuit is closed.
Electric-tape calibration and maintenance log book; manufacturer's instructions.
Disinfectant wipes, and deionized or tap water for cleaning tape.
Replacement batteries, charged.
(e) Sonic water-level meter method
DWR field form 1213 (see Table 5)
Temperature probe with readout and cable
Sonic water-level meter with factory cover plate
Custom sized cover plates for larger well diameters
Replacement batteries
(f) Automated measurements with pressure transducer
Transducer field form (see Figures 1 and 2 in Drost, 2005: http://pubs.usgs.gov/of/2005/1126/pdf/ofr20051126.pdf)
Transducer, data logger, cables, suspension system, and power supply.
Data readout device (i.e., laptop computer loaded with correct software) and data storage modules.
Spare desiccant, and replacement batteries.
Well cover or recorder shelter with key.
Steel tape (with blue carpenters' chalk or sidewalk chalk) or electric sounding tape, both graduated in hundredths of feet.
Tools, including high-impedance (digital) multimeter, connectors, crimping tool, and contact-burnishing tool or artist's eraser.

GUIDELINES FOR MEASURING WATER LEVELS

Monitoring wells typically have a cap on the wellhead. After the cap is removed, the open top of the well is easily accessible for sampling water levels and water quality. If the well is to be sampled for water quality in addition to water level, the water-level measurement should be made before the well is purged. Before discussing the detailed measurement steps for different methods, some guidance is provided on the common issues of well caps, recovery time after pumping, and cascading water in a well.

Well caps are commonly used in monitoring wells to prevent the introduction of foreign materials to the well casing. There are two general types of well caps, vented and unvented. Vented well caps allow air movement between the atmosphere and the well casing. Unvented well caps provide an airtight seal between the atmosphere and the well casing.

In most cases it is preferred to use vented well caps because the movement of air between the atmosphere and the well casing is necessary for normal water level fluctuation in the well. If the cap is not vented the fluctuation of groundwater levels in the well will cause increased or decreased air pressure in the column of air trapped above the water in the casing. The trapped air can prevent free movement of the water in the casing and potentially impact the water level that is measured. Vented caps will allow both air and liquids into the casing so they should not be used for wells where flooding with surface water is anticipated or contamination is likely from surface sources near the well.

Unvented well caps seal the top of the well casing and prevent both air and liquid from getting into the well. They are necessary in areas where it is anticipated that the well will be flooded from surface water sources or where contamination is likely if the casing is not sealed. Because the air above the water in the casing is trapped in the casing and cannot equalize with the atmospheric pressure, normal water level fluctuation may be impeded. When measuring a well with an unvented cap it is necessary to remove the cap and wait for the water level to stabilize. The wait time will vary with many different factors, but if several sequential water-level measurements yield the same value it can be assumed the water level has stabilized.

Unlike monitoring wells, production wells have obstructions in the well unless it is an abandoned production well and the pump has been removed. In addition, the wellhead is not always easily accessible for monitoring water levels. Since pumping from the production wells will create a non-static water level, the water-level measurement should ideally not be made until the water level has returned to static level. However, this recovery time will vary from site to site. Some wells will recover from pumping level to static level within a few hours, while many wells will take much longer to recover. Some wells will recover from pumping level to static level within a few hours, while many wells will take much longer to recover. Thus, as a general recommendation, measurements should not be collected until 24 hours after pumping has ceased, however, site specific

conditions may require deviating from this. The time since pumping should be noted on the field form.

Water may enter a well above the water level, drip or cascade down the inside of the well, and lead to false water level measurements. Sometimes cascading water can be heard dripping or flowing down the well and other times it is discovered when water levels are abnormally shallow and/or difficult to determine. Both steel tapes and electric sounding tapes can give false readings. A steel tape may be wet from the point where water is entering the well making it hard to see the water mark where the tape intersects the water level in the well. An electric sounding tape signal may start and then stop as it is lowered down the well. If this happens, you can lightly shake the tape. The signal often becomes intermittent when water is running down the tape, but remains constant in standing water. On most electric sounding tapes, the sensitivity can be turned down to minimize false readings. It should be noted when a water level measurement is taken from a well with cascading water.

(1) Steel Tape Method

The graduated steel-tape (wetted-tape) procedure is considered to be the most accurate method for measuring water levels in nonflowing wells. A graduated steel tape is commonly marked to 0.01 foot. When measuring deep water levels (>500 ft), thermal expansion and stretch of the steel tape starts to become significant (Garber and Koopman, 1968). The method is most accurate for water levels less than 200 feet below land surface. The equipment and supplies needed for this method are shown in Table 4.

The following issues should be considered with this method:

- It may be difficult or impossible to get reliable results if water is dripping into the well or condensing on the well casing.
- If the well casing is angled, instead of vertical, the depth to water should be corrected, if possible. This correction should be recorded in the field folder.
- **Check that the tape is not hung up on obstructions.**

Before making a measurement:

1. Maintain the tape in good working condition by periodically checking the tape for rust, breaks, kinks, and possible stretch. Record all calibration and maintenance data associated with the steel tape in a calibration and maintenance log book.

2. If the steel tape is new, be sure that the black sheen on the tape has been dulled so that the tape will retain the chalk.

3. Prepare the field forms (DWR Form 1213; see Table 5). Place any previous measured water-level data for the well into the field folder.

4. Check that the RP is clearly marked on the well and accurately described in the well file or field folder. If a new RP needs to be established, follow the procedures above.

5. In the field, wipe off the lower 5 to 10 feet of the tape with a disinfectant wipe, rinse with de-ionized or tap water, and dry the tape.

6. If possible, attach a weight to the tape that is constructed of stainless steel or other noncontaminating material to protect groundwater quality in the event that the weight is lost in the well. **Do not attach a weight for production wells.**

Making a measurement:

1. If the water level was measured previously at the well, use the previous measurement(s) to estimate the length of tape that should be lowered into the well. Preferably, use measurements that were obtained during the same season of the year.

2. Chalk the lower few feet of the tape by pulling the tape across a piece of blue carpenter's chalk or sidewalk chalk (the wetted chalk mark identifies that part of the tape that was submerged).

3. Slowly lower the weight (for monitoring wells only) and tape into the well to avoid splashing when the bottom end of the tape reaches the water. Develop a feel for the weight of the tape as it is being lowered into the well. A change in this weight will indicate that either the tape is sticking to the side of the casing or has reached the water surface. Continue to lower the end of the tape into the well until the next graduation (a whole foot mark) is at the RP and record this number on DWR Form 1213 (Table 5) next to "Tape at RP" as illustrated on Figure 4.

4. Rapidly bring the tape to the surface before the wetted chalk mark dries and becomes difficult to read. Record the number to the nearest 0.01 foot in the column labeled as "Tape at WS."

5. If an oil layer is present, read the tape at the top of the oil mark to the nearest 0.01 foot and use this value for the "Tape at WS" instead of the wetted chalk mark. Mark an "8" in the QM column of DWR Form 1213 (see Table 5) to indicate a questionable measurement due to oil in the well casing. There are methods to correct for oil, such as the use of a relatively inexpensive water-finding paste. The paste is applied to the lower end of the steel tape and the top of the oil shows as a wet line and the top of the water shows as a distinct color change. Since oil density is about three-quarters that of water, the water level can be estimated by adding three-quarters of the thickness of the oil layer to the oil-water interface elevation (U.S. Geological Survey, 2006).

6. Subtract the “Tape at WS” number from the “Tape at RP” number and record the difference (to the nearest 0.01 ft) as “RP to WS”. This reading is the depth to water below the RP.

7. Wipe and dry off the tape and re-chalk based on the first measurement.

8. Make a second measurement by repeating steps 3 through 5, recording the time of the second measurement on the line below the first measurement (Table 5). The second measurement should be made using a different “Tape at RP” than that used for the first measurement. If the second measurement does not agree with the original within 0.02 of a foot **(0.2 of a foot for production wells)**, make a third measurement, recording this measurement and time on the row below the second measurement with a new time. If more than two readings are taken, record the average of all reasonable readings.

After making a measurement:

1. Clean the exposed portion of the tape using a disinfectant wipe, rinse with de-ionized or tap water, and dry the tape. Do not store a steel tape while dirty or wet.

GROUNDWATER LEVEL DATA FORM
MANUAL MEASUREMENTS

WELL ID NUMBER	WELL NAME	STATE WELL NUMBER	COUNTY	B-118 BASIN OR SUBBASIN	MEASURING AGENCY	LAND SURFACE DATUM (LSD) ELEV.	RP TO LAND SURFACE DATUM (LSD), IN FT	REFERENCE POINT (RP) ELEV.

NO MEASUREMENT (NM)
0. Measurement discontinued
1. Pumping
2. Pump house locked
3. Tape hung up
4. Can't get tape in casing
5. Unable to locate well
6. Well has been destroyed
7. Special
8. Casing leaky or wet
9. Temporarily inaccessible

QUESTIONABLE MEASUREMENT (QM)
0. Caved or deepened
1. Pumping
2. Nearby pump operating
3. Casing leaky or wet
4. Pumped recently
5. Air or pressure gauge measurement
6. Other
7. Recharge operation at or nearby well
8. Oil in casing

MEASUREMENT METHOD (MM)
0. Steel tape
1. Electric sounding tape
2. Other

DATE	TIME	N M	Q M	MM	TAPE at RP	TAPE at WS	RP to WS	LSD to WS	OBS	COMMENTS

[For explanation of terms, see figure 1.]

DWR Form 1213 (modified 6/28/2010) (data for Water Data Library)

Table 5. Groundwater level data form for manual measurements (DWR Form 1213).

(2) Electric Sounding Tape Method

The electric sounding tape procedure for measuring depth to the water surface is especially useful in wells with dripping water or condensation, although there are still precautions needed as noted in the beginning of this section. Other benefits of this method include:

- Easier and quicker than steel tapes, especially with consecutive measurements in deeper wells.
- Better than steel tapes for making measurements in the rain.
- Less chance for cross-contamination of well water than with steel tapes, as there is less tape submerged.

The accuracy of electric sounding tape measurements depends on the type of tape used and whether or not the tape has been stretched out of calibration after use. Tapes that are marked the entire length with feet, tenths, and hundredths of a foot should be read to 0.01 ft. Electric sounding tapes are harder to keep calibrated than are steel tapes. As with steel tapes, electric sounding tapes are most accurate for water levels less than 200 ft below land surface, and thermal expansion and stretch start to become significant factors when measuring deep water levels (>500 ft) (see Garber and Koopman, 1968). Equipment and supplies needed for this method are shown in Table 4.

The following issues should be considered with this method:

- If the well casing is angled, instead of vertical, the depth to water will have to be corrected, if possible. This correction should be recorded in the field folder.
- **Check that the electric sounding tape is not hung up on an obstruction in the well.**
- The electric sounding tape should be calibrated annually against a steel tape in the field (using monitoring wells only) as follows: Compare water-level measurements made with the electric sounding tape to those made with a steel tape in several wells that span the range of depths to water encountered in the field. The measurements should agree to within ± 0.02 ft. If this accuracy is not met, a correction factor should be applied. All calibration and maintenance data should be recorded in a calibration and maintenance log book for the electric sounding tape.
- **Oil on the surface of the water may interfere with obtaining consistent readings and could damage the electrode probe. If oil is present, switch to a steel tape for the water-level measurement.**
- If using a repaired/spliced tape: see section A4-B-3(b) (page B16) of the NFM (U.S. Geological Survey, 2006).

Before making a measurement:

1. Inspect the electric sounding tape and electrode probe before using it in the field. Check the tape for wear, kinks, frayed electrical connections and possible stretch; the

cable jacket tends to be subject to wear and tear. Test that the battery and replacement batteries are fully charged.

2. Check the distance from the electrode probe’s sensor to the nearest foot marker on the tape, to ensure that this distance puts the sensor at the zero foot point for the tape. If it does not, a correction must be applied to all depth-to-water measurements. Record this in an equipment log book and on the field form.

3. Prepare the field forms (DWR Form 1213; see Table 5) and place any previous measured water-level data for the well into the field folder.

4. After reaching the field site, check that the RP is clearly marked on the well and is accurately described in the well file or field folder. If a new RP needs to be established, follow the procedures above.

5. Check the circuitry of the electric sounding tape before lowering the electrode probe into the well. To determine proper functioning of the tape mechanism, dip the electrode probe into tap water and observe whether the indicator needle, light, and/or beeper (collectively termed the “indicator” in this document) indicate a closed circuit. For an electric sounding tape with multiple indicators (sound and light, for instance), confirm that the indicators operate simultaneously. If they do not operate simultaneously, determine which is the most accurate and use that one.

6. Wipe off the electrode probe and the lower 5 to 10 feet of the tape with a disinfectant wipe, rinse with de-ionized or tap water, and dry.

Making a measurement:

1. If the water level was measured previously at the well, use the previous measurement(s) to estimate the length of tape that should be lowered into the well. Preferably, use measurements that were obtained during the same season of the year.

2. Lower the electrode probe slowly into the well until the indicator shows that the circuit is closed and contact with the water surface is made. Avoid letting the tape rub across the top of the well casing. Place the tip or nail of the index finger on the insulated wire at the RP and read the depth to water to the nearest 0.01 foot. Record this value in the column labeled “Tape at RP”, with the appropriate measurement method code and the date and time of the measurement (see Table 5).

3. Lift the electrode probe slowly up a few feet and make a second measurement by repeating step 2 and record the second measurement with the time in the row below the first measurement in Table 5. Make all readings using the same deflection point on the indicator scale, light intensity, or sound so that water levels will be consistent between measurements. If the second measurement does not agree with the first measurement within 0.02 of a foot **(0.2 of a foot for production wells)**, make a third measurement,

recording this measurement with the time in the row below the second measurement. If more than two readings are taken, record the average of all reasonable readings.

After making a measurement:

1. Wipe down the electrode probe and the section of the tape that was submerged in the well water, using a disinfectant wipe and rinse thoroughly with de-ionized or tap water. Dry the tape and probe and rewind the tape onto the tape reel. Do not rewind or otherwise store a dirty or wet tape.

(3) Sonic Water-Level Meter Method

This meter uses sound waves to measure water levels. It requires an access port that is 5/8 – inch or greater in diameter and measurement of the average air temperature in the well casing. The meter can be used to quickly measure water levels in both monitoring wells and production wells. Also, since this method does not involve contact of a probe with the water, there is no concern over cross contamination between wells. However, the method is not as accurate as the other methods, with a typical accuracy of 0.2 ft for water levels less than 100 ft or 0.2% for water levels greater than 100 ft. Equipment and supplies needed for this method are shown in Table 4.

The following issues should be considered with this method:

- The accuracy of the meter decreases with well diameter and should not be used with well diameters greater than 10 inches.
- An accurate air temperature inside the well casing is necessary so that the variation of sound velocity with air temperature can be accounted for.
- **Obstructions in the well casing can cause erroneous readings, especially if the obstruction is close to half the well diameter or more.**

Before making a measurement:

1. Check the condition of the meter, especially the batteries. Take extra batteries to the field.

2. Take a temperature probe with a readout and 50-ft cable.

3. If open wellheads with diameter greater than the factory cover plate and less than 10 inches will be monitored, fabricate appropriately-sized cover plates using plastic or sheet metal.

4. Prepare the field forms (DWR Form 1213; see Table 5). Place any previous measured water-level data for the well into the field folder.

5. Check that the RP is clearly marked on the well and accurately described in the well file or field folder. If a new RP needs to be established, follow the procedures above.

Making a measurement:

1. If the water level was measured previously at the well, lower the temperature probe to about half that distance in the well casing. Preferably, use measurements that were obtained during the same season of the year.

2. Record this temperature in the comments column of DWR form 1213 (see Table 5). Use this temperature reading to adjust the temperature toggle switch on the sonic meter.

3. Select the appropriate depth range on the sonic meter.

4. For a covered wellhead, insert the meter duct into the access port and push the power-on switch. Record the depth from the readout.

5. For an open wellhead, slip the provided cover plate onto the wellhead to provide a seal. If the cover plate is not large enough, use a fabricated cover plate for diameters up to 10 inches. Record the depth from the readout.

After making a measurement:

1. Make sure the temperature probe and the sonic meter are turned off and put away in their cases.

(4) Pressure Transducer Method

Automated water-level measurements can be made with a pressure transducer attached to a data logger. Care should be taken to choose a pressure transducer that accurately measures the expected range of groundwater levels in a well. Pressure-transducer accuracy decreases linearly with increases in the depth range (also known as pressure rating). A pressure transducer with a depth range of 0 to 10 ft (0 to 4.3 psi) has an accuracy of 0.01 ft while a pressure transducer with a depth range of 0 to 100 ft (0 to 43 psi) has an accuracy of 0.1 ft. But if the measurement range exceeds the depth range of a pressure transducer, it can be damaged. So it is important to have a good idea of the expected range of groundwater levels in a well, and then refer to the manufacturer's specification when selecting a pressure transducer for that well.

Some of the advantages of automated monitoring include:

- No correction is required for angled wells, as pressure transducers only measure vertical water levels.
- A data logger can be left unattended for prolonged periods until data can be downloaded in the field.
- Downloaded data can be imported directly into a spreadsheet or database.

Some of the disadvantages of automated monitoring include:

- It may be necessary to correct the data for instrument drift, hysteresis, temperature effects, and offsets. Most pressure transducers have temperature compensation built-in.
- Pressure transducers operate only in a limited depth range. The unit must be installed in a well in which the water level will not fluctuate outside the operable depth range for the specific pressure transducer selected. Wells with widely fluctuating water levels may be monitored with reduced resolution or may require frequent resetting of the depth of the pressure transducer.
- With some data loggers, previous water-level measurements may be lost if the power fails.

There are two types of pressure transducers available for measuring groundwater levels; non-vented (absolute) and vented (gauged). A non-vented pressure transducer measures absolute pressure, is relative to zero pressure, and responds to atmospheric pressure plus pressure head in a well (see Figure 5). A vented pressure transducer measures gauge pressure, is relative to atmospheric pressure, and only responds to pressure head in a well.

Non-vented pressure transducer data require post processing. Barometric pressure data must be collected at the same time as the absolute pressure data at the well, and subtracted from each absolute pressure data record before the data can be used to calculate groundwater levels. Thus, if a non-vented pressure transducer is used, a barometric pressure transducer will also be needed near the well. This subject is usually covered in more detail by the manufacturer of the pressure transducer. In an area with little topographic relief, a barometer at one site should be sufficient for use by other sites within a certain radius (9 miles reported by Schlumberger http://www.swstechnology.com/ groundwater-monitoring/groundwater-dataloggers/baro-diver and 100 miles reported by Global Water http://www.globalw.com/support/barocomp.html). In an area of significant topographic relief, it would be advisable to have a barometer at each site.

Vented pressure transducers can be programmed so no post processing of the data is necessary. The vent is usually a small tube in the communication cable that runs from the back of the pressure transducer to the top of the well. This vent enables the pressure transducer to cancel the effect of atmospheric pressure and record groundwater level as the distance from the RP to the WS (see Figure 5). However, if the vent is exposed to excessive moisture or submerged in water it can cause failure and damage to the pressure transducer.

The existing well conditions should be considered when deciding which type of pressure transducer to use. Non-vented pressure transducers should be used when the top of a well or its enclosure may at any time be submerged in water. This can happen when artesian conditions have been observed or are likely, the well is completed at or below the LSD, or the well or its enclosure are susceptible to periods of high water. Otherwise, it is advisable to use a vented pressure transducer.

The following guidelines are USGS guidelines from Drost (2005) and Freeman and others (2004) for the use of pressure transducers. These USGS guidelines have not been incorporated as yet in the NFM. The equipment and supplies needed for automated measurements of water level using a pressure transducer are shown in Table 4.

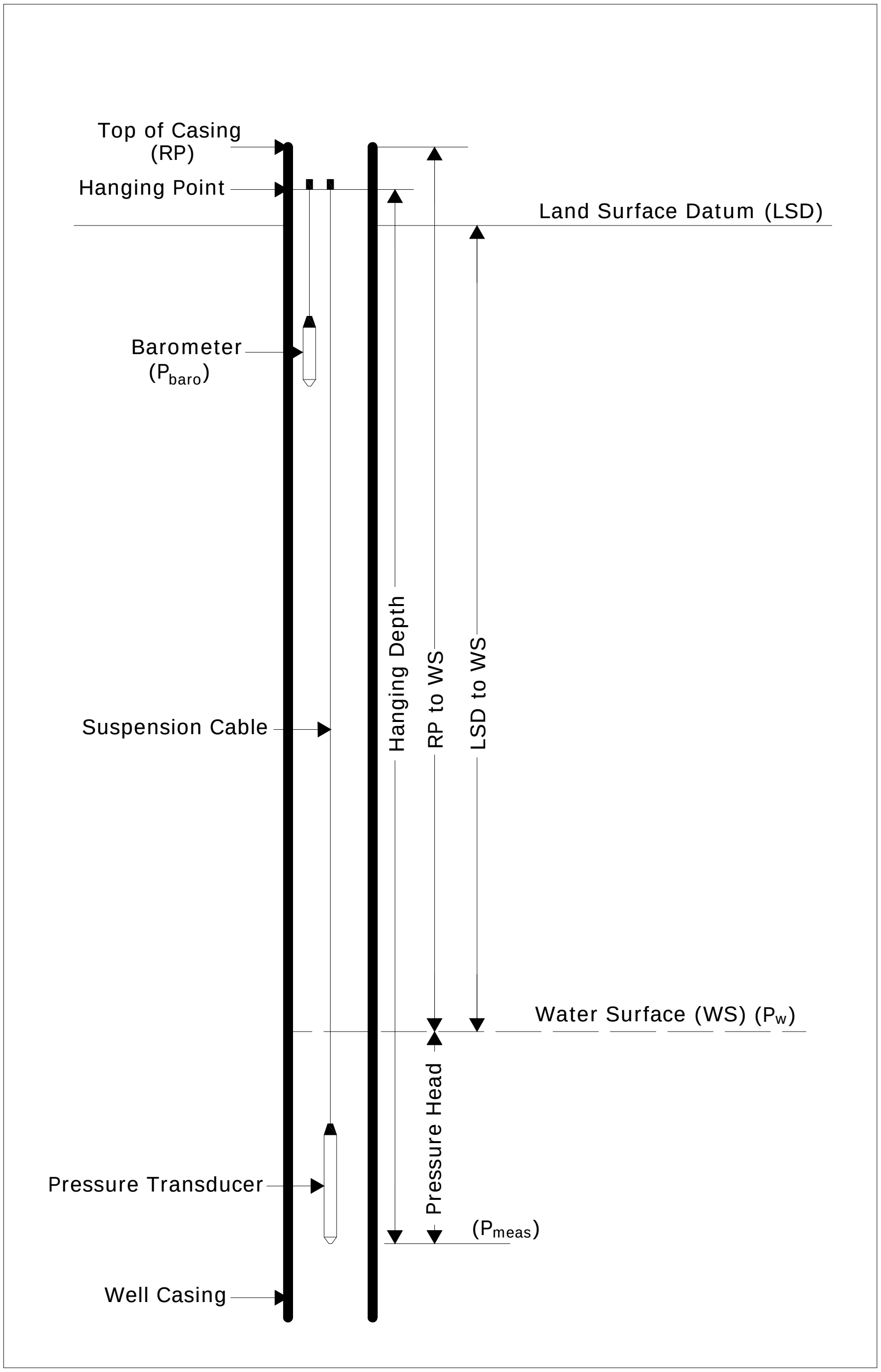

Figure 5. Groundwater-level measurements using a pressure transducer (vented or non-vented) (modified from Drost, 2005).

Before making a measurement:

1. Keep the pressure transducer packaged in its original shipping container until it is installed.

2. Fill out the DWR field form (Table 6), including the type, serial number, and range of measurement device; and what units are being measured (ft, psi).

3. Take a reading from the pressure transducer before placing into the well. For a vented pressure transducer the reading should be zero. For a non-vented pressure transducer the reading should be a positive number equivalent to atmospheric pressure. Configure the units (ft, psi) on a barometric pressure transducer the same as the non-vented pressure transducer. A reading from the barometric pressure transducer should be the same as the non-vented pressure transducer reading.

4. Lower the pressure transducer into the well slowly. Conduct a field calibration of the pressure transducer by raising and lowering it over the anticipated range of water-level fluctuations. Take two readings at each of five intervals, once during the raising and once during the lowering of the pressure transducer. Record the data on the DWR field form (see Table 6). If using a non-vented pressure transducer, take a reading from the barometric pressure transducer at the same time as the other readings.

5. Lower the pressure transducer to the desired depth below the water level (caution: do not exceed the depth range of the pressure transducer).

6. Fasten the cable or suspension system to the well head using tie wraps or a weatherproof strain-relief system. If the vent tube is incorporated in the cable, make sure not to pinch the cable too tightly or the vent tube may be obstructed.

7. Make a permanent mark on the cable at the hanging point, so future slippage, if any, can be determined.

8. Measure the static water level in the well with a steel tape or electric sounding tape. Repeat if measurements are not consistent within 0.02 ft **(0.2 ft for production wells)**.

9. Record the well and RP configuration, with a sketch. Include the RP height above the LSD, the hanging point, and the hanging depth (see Figure 5).

GROUNDWATER LEVEL DATA FORM
VENTED OR NON-VENTED PRESSURE TRANSDUCER WITH DATALOGGER

Station Information						Transducer Information						
Well ID Number	Well Name	State Well Number	County	Bulletin 118 GW Basin or Subbasin	Measuring Agency	Type of Pressure Transducer -- (A) Gauged (vented) or (B) Absolute (non-vented)?	Manufac-turer	Model	Serial Number	PSI Rating	Cable Length	Barometer Serial Number

Datum Measurements (in feet) [Date of Measurements:]

Reference Point (RP) Elevation (MSL) [from DWR Form 429]	RP to Land Surface Datum (LSD)	(1) RP to Hanging Point	(2) Hanging Depth	(3) RP to Pressure Transducer

Manual Readings									Datalogger Readings						Datalogger Servicing		
Date	Time	Obser-ver	NM	QM	MM	(4) Tape at RP	(5) Tape at WS	(6) RP to WS	(7) Transducer pressure (psi)	(8) Barometric pressure (psi)	(9) WS pressure (psi)	(10) WS above transducer (ft)	(11) RP to WS (ft)	Test Name	Download-ed data? (Y/N)	Batt. life left / new batteries? (%; Y/N)	Comments

These cells only need to be filled out for non-vented transducers (which will have a barometer at the well in addition to the transducer)

Notes about calculated entries in form (referenced by number in cell): (3) = (1) + (2); (6) = (4) - (5) for steel tape; (6) = (4) for electric sounding tape; (9) = (7) - (8) for non-vented transducer; (9) = (7) for vented transducer; (10) = 2.3067 * (9); (11) = (3) - (10) [for explanation of terms, see figure 2]

NM (No Measurement) Codes: 0--Measurement discontinued 1--Pumping 2--Pump house locked 3--Tape hung up 4--Can't get tape in casing 5--Unable to locate well 6--Well has been destroyed 7--Special 8--Casing leaky or wet 9--Temporarily inaccessible

QM (Questionable Measurement) Codes: 0--Caved or deepened 1--Pumping 2--Nearby pump operating 3--Casing leaky or wet 4--Pumped recently 5--Air or pressure gauge measurement 6--Other 7--Recharge operation at or nearby well 8--Oil in casing

MM (Measurement Method) Codes: 0--Steel tape 1--Electric sounding tape 2--Other

DWR Form xxxx (data for Hydstra)

Table 6. Groundwater level data form for vented or non-vented pressure transducer with data logger.

10. Connect the data logger, power supply, and ancillary equipment. Configure the data logger to ensure the channel, scan intervals, units, etc., selected are correct. Activate the data logger. Most data loggers will require a negative slope in order to invert water levels for ground-water applications (i.e., distance from the RP to the WS). If using a non-vented pressure transducer the data logger will not require a negative slope, but atmospheric pressure data will need to be collected by a barometric pressure transducer.

Making a measurement:

1. Retrieve water-level data (to 0.01 ft) using instrument or data logger software. If using a non-vented pressure transducer, retrieve barometric pressure data.

2. Measure the water level with a steel tape or electric sounding tape (to 0.01 ft) and compare the reading with the value recorded by the pressure transducer and data logger. Record the reading and time in the file folder. If using a non-vented pressure transducer, subtract the barometric pressure value from the transducer pressure value to obtain the water level pressure value. The water level pressure can then be multiplied by 2.3067 to convert from psi of pressure to feet of water (Freeman and others, 2004). Report the calculated water level to the nearest 0.01 ft.

3. If the tape and pressure transducer readings differ by more than **(the greater of 0.2 ft or)** two times the accuracy of the specific pressure transducer, raise the pressure transducer out of the water and take a reading to determine if the cable has slipped, or whether the difference is due to drift. The accuracy of a pressure transducer is typically defined as 0.001 times the full scale of the pressure transducer (e.g., a 0 to 100 ft pressure transducer has a full scale of 100 ft). The accuracy of a specific pressure transducer should be specified by the manufacturer's specifications.

4. If drift is significant, recalibrate the pressure transducer as described using a steel tape. If using a non-vented pressure transducer, keep the pressure transducer out of the water and calibrate to the barometric pressure transducer value. If field calibration is not successful, retrieve the transducer and send back to the manufacturer for re-calibration.

5. Use the multimeter (see Table 4) to check the charge on the battery, and the charging current supply to the battery. Check connections to the data logger, and tighten as necessary. Burnish contacts if corrosion is occurring.

6. Replace the desiccant, battery (if necessary), and data module. Verify the data logger channel and scan intervals, document any changes to the data logger program and activate the data logger.

7. If possible, wait until data logger has logged a value, and then check for reasonableness of data.

Glossary of Terms

The following terms are used in this document. Although many are commonly used in the groundwater- and data-management fields, they are defined here to avoid confusion.

Aquifer – A geologic formation from which useable quantities of groundwater can be extracted. A confined aquifer is bounded above and below by a confining bed of distinctly less permeable material. The water level in a well installed in a confined aquifer stands above the top of the confined aquifer and can be higher or lower than the water table that may be present in the material above it. In some cases, the water level can rise above the ground surface, yielding a flowing well. An unconfined aquifer is one with no confining beds between the saturated zone and the ground surface. The water level in a well installed in an unconfined aquifer stands at the same level as the groundwater outside of the well and represents the water table. An alternative and equivalent definition for an unconfined aquifer is an aquifer in which the groundwater surface is at atmospheric pressure.

Atmospheric or barometric pressure – The force per unit area exerted against a surface by the weight of the air above that surface at any given point in the Earth's atmosphere. At sea level, the atmospheric pressure is 14.7 psi. As elevation increases, atmospheric pressure decreases as there are fewer air molecules above the ground surface. The atmospheric pressure is measured by a barometer. This pressure reading is called the barometric pressure. Weather conditions can increase or decrease barometric pressure.

Blue carpenter's chalk – A primarily calcium carbonate chalk with some silica. It is primarily used to make chalk-lines for long lasting bright marks. Some other formulations of chalk (e.g., sidewalk chalk) substitute different ingredients such as rice starch for silica.

Data logger – A microprocessor-based data acquisition system designed specifically to acquire, process, and store data. Data usually are downloaded from onsite data loggers for entry into office data systems. The storage device within a data logger is called the data module. A desiccant, such as, silica gel, calcium sulfate, or calcium chloride, is used to absorb and keep moisture away from the data module.

Dedicated monitoring well – A well designed for the sole purpose of long-term monitoring.

Domestic well – A water well used to supply water for the domestic needs of an individual residence or systems of four or fewer service connections.

DWR Bulletin 118 – DWR publication on the status of California's groundwater. Prior to this 2003 update, the latest Bulletin 118 was published in 1980. This publication defines the 515 basins to be monitored in the SB 6 monitoring program. The report reference is: California Department of Water Resources, 2003, California's groundwater: Bulletin 118, 246 p., available online at: http://www.water.ca.gov/pubs/groundwater/bulletin_118/california's_groundwater__bulletin_118_-_update_2003_/bulletin118_entire.pdf

Electric sounding tape – This term is used in this document to mean both the electric tape and the electrode probe attached to the end of the tape. This water-level measuring device is also known by many other names, including a sounder, an electric tape, an E tape, an electric sounder, an electric well sounder, a depth sounder, etc.

Electrode probe – This is the electronic sensor in the electronic sounder attached to the end of the electric tape. It senses water based on the electrical conductivity and triggers an alert.

GPS – This stands for global positioning system. These devices come in many sizes and costs. The handheld devices are capable of very accurate locations in the xy plane (latitude longitude). However, only very expensive and large GPS units are currently capable of accurate readings for the altitude (z direction).

Groundwater – Water occurring beneath the ground surface in the zone of saturation.

Groundwater basin – An alluvial aquifer or a stacked series of alluvial aquifers with reasonably well-defined boundaries in a lateral direction and having a definable bottom.

Groundwater elevation – The elevation (generally referenced to mean sea level as the datum) to which water in a tightly cased well screened at a given location will rise. Other terms that may be used include groundwater level, hydraulic head, piezometric head, and potentiometric head.

Groundwater surface – The highest elevation at which groundwater physically occurs in a given location in an aquifer (i.e., top of aquifer formation in a confined aquifer and the groundwater level or water table in an unconfined aquifer). Also referred to as a water surface in this document.

Groundwater subbasin – A subdivision of a groundwater basin created by dividing the basin using geologic and hydrologic conditions or institutional boundaries.

Hysteresis – The maximum difference in output, at any measured value within the specified range, when the value is approached first with an increasing and then a decreasing measured property. Hysteresis is expressed in percent of the full-scale output.

Instrument Drift – A change in instrument output over a period of time that is not a function of the measured property. Drift is normally specified as a change in zero (zero drift) over time and a change in sensitivity (sensitivity drift) over time.

Irrigation well – A well used to irrigate farmland. The water from the well is not intended for domestic purposes.

Metadata – “data about data”; it is the data describing context, content and structure of records and their management through time.

NFM – This stands for National Field Manual. This is a living, online, document of the USGS. It is the protocol document for USGS methods of surface water, groundwater, and water quality field activities. The portion of the NFM that related to the field methods of collecting groundwater levels is in the following reference: U.S. Geological Survey, 2006, Collection of water samples (ver. 2.0): U.S. Geological Survey Techniques of Water-Resources Investigations, book 9, chap. A4, September, accessed 12/30/09 at: http://pubs.water.usgs.gov/twri9A4/

Nonflowing well – A well in which the water level is below the land surface.

Pressure head – The height of a column of groundwater above a point that is supported by pressure at that point.

Pressure transducer – A type of measurement device that converts pressure-induced mechanical changes into an electrical signal.

Production well – A well with a pump installed that is used to bring groundwater to the land surface. This is a general term that can be applied to a domestic well, irrigation well, or public-supply well.

Public-supply well – A well that pumps groundwater from a relatively extensive saturated area and is used as part of a public water system, supplying water for human consumption to at least 3,300 people.

SOGW – This stands for Subcommittee on Groundwater. This is a subcommittee of the Advisory Committee on Water Information, which is developing a national framework for groundwater in the United States. The reference for the SOGW work is: Subcommittee on Ground Water of the Advisory Committee on Water Information, 2009, A national framework for ground-water monitoring in the United States: final version approved by the Advisory Committee on Water Information, June 2009, 78 p., accessed 1/11/10 at: http://acwi.gov/sogw/pubs/tr/index.html

Static water level – Groundwater level in a well during non-pumping conditions.

Vent tube – A tube in the cable which connects to the pressure transducer, allowing atmospheric pressure to be in contact with one side of the strain gauge in the pressure sensor. It cancels out the barometric effects in the readings.

Well casing – The metal or plastic pipe separating the well from the surrounding geologic material.

Wellhead – The top of the well containing the casing hanger and the point at which the motor is attached for a vertical line shaft turbine pump or where the seal is secured for a submersible pump.

Well purging – Pumping out standing groundwater from a monitoring well. This is done prior to water quality sampling of wells, but **not** before taking a water-level measurement.

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APPENDIX G

Water Quality Sampling Plan

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South East Bay Plain Basin Groundwater Quality Sampling Plan

LIMS PROD	METHODREF	Analyte
*300 IC ANIONS (1-3)		
+FLD DATA	None	
		CHLORINE RESIDUAL: TOTAL
		PH
+REPORT		
+SAMP KIT		
+TRANSMITTAL	Per Subcontract Laboratory Report	
552	EPA 552.2	
		BROMOCHLOROACETIC ACID
		BROMODICHLOROACETIC ACID
		CHLORODIBROMOACETIC ACID
		DALAPON
		DIBROMOACETIC ACID
		DICHLOROACETIC ACID
		HAA(5)
		HAA(9)
		MONOBROMOACETIC ACID
		MONOCHLOROACETIC ACID
		TRIBROMOACETIC ACID
		TRICHLOROACETIC ACID
8260-THMS	EPA 8260B	
		BROMODICHLOROMETHANE
		BROMOFORM
		CHLOROFORM
		DIBROMOCHLOROMETHANE
ALKALINITY: CO3	SM(20)4500-CO2 D	ALKALINITY: CARBONATE
ALKALINITY: HCO3	SM(20)4500-CO2 D	ALKALINITY: BICARBONATE
ALKALINITY: OH	SM(20)4500-CO2 D	ALKALINITY: HYDROXIDE
ALKALINITY: TOTAL	SM2320 B-1997	ALKALINITY: TOTAL AS CACO3
AMMONIA: TITR	SM4500-NH3 B,C-1997	AMMONIA AS N
CHLORIDE: IC	EPA 300.1	CHLORIDE
HARDNESS: TOTAL	SM2340 C-1997	HARDNESS: TOTAL AS CACO3
NITRATE: IC	EPA 300.1	NITRATE AS N
SULFATE: IC	EPA 300.1	SULFATE
TDS: GRAVIMETRIC	SM2540 C-1997	TOTAL DISSOLVED SOLIDS
*ICP EPA 200.7		
CA EPA 200.7	EPA 200.7	CALCIUM
FE EPA 200.7	EPA 200.7	IRON
K EPA 200.7	EPA 200.7	POTASSIUM
MG EPA 200.7	EPA 200.7	MAGNESIUM
MN EPA 200.7	EPA 200.7	MANGANESE
NA EPA 200.7	EPA 200.7	SODIUM
8260-THMS	EPA 8260B	field blank
524	EPA 524.2	
		Benzene
		Carbon Tetrachloride
		1,2-Dichlorobenzene
		1,4-Dichlorobenzene
		1,1-Dichloroethane

LIMS PROD	METHODREF	Analyte
		1,2-Dichloroethane
		1,1-Dichloroethylene
		cis-1,2-Dichloroethylene
		trans-1,2-Dichloroethylene
		Dichloromethane
		1,2-Dichloropropane
		1,3-Dichloropropene
		Ethylbenzene
		Methyl-tert-butyl ether
		Monochlorobenzene
		Styrene
		1,1,2,2-Tetrachloroethane
		Tetrachloroethylene
		Toluene
		1,2,4-Trichlorobenzene
		1,1,1-Trichloroethane
		1,1,2-Trichloroethane
		Trichloroethylene
		Trichlorofluoromethane
		1,1,2-Trichloro-1,2,2-Trifluoroethane
		Vinyl Chloride

APPENDIX H

Well Standards

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ORDINANCE NO. 73-68

AN ORDINANCE TO REGULATE THE CONSTRUCTION, REPAIR, RECONSTRUCTION, DESTRUCTION OR ABANDONMENT OF WELLS WITHIN THE BOUNDARIES OF THE COUNTY OF ALAMEDA.

The Board of Supervisors of the County of Alameda do ordain as follows:

SECTION I

Article 14 is hereby added to Chapter 6, Title 3, of the Alameda County Ordinance Code to read as follows:

CHAPTER 6
ARTICLE 14

CONSTRUCTION, REPAIR, RECONSTRUCTION, DESTRUCTION OR ABANDONMENT OF WELLS.

Section 3-160.0. Purpose: It is the purpose of this ordinance to provide for the construction, repair, reconstruction, and destruction of wells, including cathodic protection wells and exploratory holes, to the end that the groundwater found wholly or partially with the County of Alameda will not be polluted or contaminated and the water obtained from water wells will be suitable for the beneficial uses intended and will not jeopardize the health, safety or welfare of the people of the County of Alameda, and for the destruction of abandoned wells or well s found to be public nuisances, including cathodic protection wells and exploratory holes, to the end that such well s will not cause pollution or contamination or groundwater or otherwise jeopardize the health, safety, or welfare of the people of the County of Alameda.

Section 3-160.1 . Definitions: Definitions of terms for the construction, repair, reconstruction, destruction, or abandonment of wells shall be as set forth in Chapter II and in Appendix I, of the Department of Water Resources Bulletin No. 74, "Water Well Standards: State of California," as modified and with additions herein.

(1) "County" shall mean the County of Alameda.

(2) "Board" shall mean the Board of Supervisors of the County of Alameda.

(3) "Advisory Board" shall mean a Well Standards Advisory Board, consisting of three (3) qualified persons, which may be appointed by the Board of Supervisors for two (2) year terms, ending 12:00 noon on the first Monday after January 1 of each odd numbered year. The matter of qualification lies solely within the discretion of the Board of Supervisors. In the event a Well Standards Advisory Board is not created, the Board of Supervisors shall assume the duties of said Advisory Board.

(4) "Director of Public Works" shall mean the Director of Pub1ic Works of the County of Alameda and the Alameda County Flood Control and Water Conservation District.

(5) "Person" shall mean any person, firm, corporation, municipality, district, or public agency.

(6) "Well" shall mean any artificial excavation constructed by any method for the purpose extracting water from, or injecting water into, the underground. This definition shall not include: (a) oil and gas wells, or geothermal wells constructed under the jurisdiction of the Department of Conservation, except those wells converted to use as water wells; or (b) wells used for the purpose of (1) dewatering excavation during construction, or (2) stabilizing hillsides or earth embankments .

(7) "Cathodic Protection Well" shall mean any artificial excavation constructed by any method for the purpose of installing equipment or facilities for the protection electrically of metallic equipment in contact with the ground, commonly referred to as cathodic protection.

(8) "Construction, Reconstruction" shall mean to dig, drive, bore, drill, or deepen a well, or to reperforate, remove, replace, or extend a well casing.

(9) "Destruction" shall mean the proper filling, sealing, or otherwise rendering unusable a well that is no longer useful or has become hazardous to public health or safety, so as to assure that the groundwater is protected and to eliminate a potential physical hazard.

(10) "Repair" shall mean the deepening or enlargement of a well or the perforation or replacement of a casing or sealing-off of aquifers, or other work to improve or maintain the integrity of the well and its water-producing capacity.

(11) "Exploratory Hole" shall mean any artificial excavation constructed by any method for the purpose of determining subsurface geological or hydrological conditions.

(12) "Public Nuisance" shall mean any well which threatens to impair the quality groundwater or otherwise jeopardize the health or safety of the public.

Section 3-160.2. Jurisdiction: This ordinance shall have effect in the unincorporated area of the County of Alameda and in those incorporated areas which have by ordinance or resolution adopted the provisions of this ordinance by reference thereto and have designated the Alameda County Public Works Department, through the Alameda County Flood Control and Water Conservation District, as the administering agency.

Section 3-160.3. Prohibitions: No person, firm , corporation, or special district formed under the laws of this State shall, within the area subject to the provisions of this ordinance, construct, repair, reconstruct, destroy, alter, or abandon any well unless a written permit has been obtained therefor from the Director of Public Works of the County of Alameda as provided in this ordinance; provided, however, that any incorporated area may elect to adopt this ordinance by reference by resolution of the city council city ordinance, which resolution or ordinance shall designate the Alameda County Department of Public Works as administering agency.

Section 6-160.4. Permit Procedure:

(1) Application: Written permits required by this Ordinance shall be issued by the Director of Public Works, subject to conditions set forth in this Ordinance, required by law or established by the Director of Public Works. The Director of Public Works shall prescribe and provide a regular form of application for the use of any applicant for a permit required by this Ordinance. The application form shall contain space for the name and address, together with such detail as in the judgement of the Director of Public Works is necessary to establish the identity of the applicant and the location, description of work to be done, and purpose of the proposed work, or other pertinent information. In addition, drawings and/or specifications of the proposed work shall be submitted in an approved form for review by the Director of Public Works; the Director may also require submission of a statement as to the environmental impact of any proposed work to be performed under this ordinance, in accordance with the provisions of the California Environmental Quality Act of 1970.

(2) Fees and Costs: The schedule of fees and costs will be those recommended by the Director of Public Works and established and adopted by the Board from time to time by resolution. Before a permit is issued, the applicant shall deposit with the County cash or a certified or cashier's check, in a sufficient sum to cover the fee for issuance of the permit, charges for field investigation, and the fee for necessary inspection or other work, all in accordance with schedules established and adopted by the Board. Public utilities or other governmental agencies may, at the option of the Director of Public Works, make payment for the above charges as billed by the County instead of by advance deposit as required above. If, upon completion of any work under a permit, there remains any excess of deposit or of fees or charges, the Director of Public Works shall certify the same to the auditor for refund to the permittee or refund the same from any trust fund established under his jurisdiction for such purposes.

(3) Waiver of Fees and Costs: Neither the County of Alameda, its departments, nor its contractors shall be required to make applications for permits as provided for hereunder, providing an agreed procedure for the mutual clearance of plans and prosecution of the proposed work has been reached between the County department heads responsible for such work and the Director of Public Works. All other public agencies must apply for permits but no permit fee shall be charged to them, and investigation and inspection costs for such permits may be waived by the Director of Public Works unless in his opinion they would constitute an undue burden upon the County. All privately owned public utilities making permit applications may have the fees and costs therefor waived upon a finding by the Director of Public Works that the County will incur no costs or expense beyond that which would normally be incurred under the procedure indicated above for other public agencies.

(4) Term and Completion of Work: The permittee shall begin the work authorized by a permit issued pursuant to this Ordinance within ninety (90) days from the date of issuance unless a different period is stated in the permit. If the work is not begun within ninety (90) days or within the time stated in the permit, then the permit shall become void. The permittee shall notify County three (3) working days in advance of beginning his permitted work of the date of said beginning of work. A permit shall be valid for a term of one year from the date of issuance unless a different term is specified in the permit, unless sooner terminated by discontinuance of the work for which the permit was issued, or revocation by the Board upon a showing of good cause therefor. The permittee shall complete the work authorized by a permit issued pursuant to this Ordinance within the time specified in the permit. A time extension to complete the work under the permit may be granted if, in the judgement of the Director of Public Works, a time extension is warranted.

(5) Guarantee of Performance: Prior to the issuance of a permit, the applicant shall post with the Director of Public Works a cash deposit or bond guaranteeing compliance with the terms of this Ordinance and the applicable permit, such bond to be in an amount deemed necessary by the Director of Public Works to remedy improper or uncompleted work, but not in excess of the total estimated cost of the work. Such deposit or bond may be waived by the Director of Public Works where other assurances of compliance are deemed adequate by him.

(6) Compliance with Other Regulations: The issuance of any permit pursuant to this ordinance shall not in any manner relieve the permittee from compliance with applicable Federal, State, County, Municipal, and local regulations regarding well work and public health requirements, and from the necessity of obtaining any permits or consents required thereof, nor impose upon the County any obligation with respect to said permits or consents.

(7) Liability: Permittee shall be responsible for all liability imposed by law for personal injury or property damage proximately caused by work permitted and done by permittee under the permit, or proximately caused by failure on permittee’s part to perform his obligation under said permit. If any claim of such liability is made against the County, or Alameda County Flood Control and Water Conservation

District, and its agents, officers, or employees, permittee shall defend, indemnify, and hold them and each of them, harmless from such claim.

(8) Review and Appeal: Any person aggrieved in any manner under the procedures established under this ordinance may request in writing that the matter be reviewed by the Advisory Board or may appeal directly to the Board of Supervisors. If request for review is made, the Director of Public Works shall schedule the matter for review by said Advisory Board and give reasonable notice of the time and place thereof to the applicant. Recommendations by said Advisory Board shall not be binding and may be appealed to the Board of Supervisors. Such appeals must be submitted in writing and filed with the Board of Supervisors within ten (10) days after said Advisory Board recommendations have been sent to or served upon the applicant. The Board of Supervisors shall hold a hearing of said appeal and shall give reasonable notice of the time and place thereof to the applicant. The decision of the Board of Supervisors shall be binding upon all parties. In the event of the Advisory Board is not created under this Ordinance, requests for review of grievances shall be submitted in writing and filed directly with the Board of Supervisors. The Board of Supervisors shall hold a hearing of review of such grievances and shall give reasonable notice of the time and place thereof to the applicant. The decision of the Board of Supervisors shall be binding upon all parties.

Section 3-160.5. Standards: Standards for the construction, repair, reconstruction, destruction, or abandonment of wells shall be as set forth in Chapter II of the Department of Water Resources Bulletin No. 74, "Water Well Standards: State of California ," and Appendixes E, F, and G a part thereof, together with the supplemental standards of Department of Water Resources Bulletin No . 74-2, "Water Well Standards: Alameda County," and Department of Water Resources Bulletin No. 74-1. "Cathodic Protection Wells Standards: State of California," with the following modifications:

(1) No well intended to produce fresh groundwater shall be perforated opposite aquifers producing saline water. It is recognized that in some instances production may be desired from areas and/or depths which contain poor or marginal quality water in all aquifers penetrated. It is not the intent of these standards to preclude such situations so long as the integrity of the fresh water supplies is maintained. Final judgement on well construction that would cause intermingling of waters of different qualities shall be at the discretion of the County.

(2) In wells open to fresh water aquifers, penetrated aquifers producing saline water shall be sealed off as specified in Section 13, Chapter II, Bulletin No. 74, and in Chapter IV, Bulletin 74-2.

(3) Perched saline water shall be excluded from wells by a deep annular seal as specified in Section 9, Chapter II, Bulletin No. 74, and in Chapter IV, Bulletin74-2.

(4) As a guideline, saline water is considered as water which contains more than 250 ppm chloride ion. During well construction, the permittee shall provide some provision for the determination of groundwater quality characteristics of the major aquifers penetrated so that a judgement can be made as to whether or not intermingling will take place. Such determination can consist of evaluation of data regarding adjacent wells, evaluation of samples of formation materials encountered. Final judgement as to the probability of intermingling and the need for evaluation of conditions shall be at the discretion of the County.

(5) Backfilling work on exploratory holes, as defined herein, shall be subject to requirements equivalent to those in the destruction of abandoned wells.

(6) All water wells shall be maintained in such a manner that water quality samples can be readily collected. The County shall be empowered to collect water quality samples and to perform tests on any well at any reasonable time.

(7) All work in the construction, repair, reconstruction, and destruction of wells shall be performed by contractors licensed in accordance with the provisions of the Contractors License Law (Chapter 9, Division 3, of the Business and Professions Code) unless exempted by that act.

(8) In no case will an outer casing or conductor casing be an acceptable substitute for a seal.

Section 3-160.6. Enforcement:

(1) Notice: In the event a well subject to this Ordinance is found to be a public nuisance or constructed, repaired, reconstructed, or destroyed contrary to the terms of this Ordinance or a permit issued for such well pursuant to this Ordinance, the Director of Public Works may send written notice to the owner of the land as shown on the most recent equalized assessment roll or the permittee, at his address listed on the permit, which notice shall state the manner in which the well is in violation, what corrective measures must be taken, the time within which such correction must be made, and that if the land owner or permittee fails to make corrections within the period provided, the corrections may be made by the County and the land owner or permittee sha11 be 1iab1e for the costs thereof.

(2) Abatement by the County: If the corrections listed in the notice given pursuant to (1) above are not made as required in said notice, the Director of Public Works with the approval of the Board of Supervisors, and after a reasonable opportunity for the person notified to be heard by said Board, may abate the condition and the cost thereof shall be a charge against the person notified.

(3) Emergency Abatement: If the Director of Public Works finds that the condition or operation of a well subject to this Ordinance is, by its operation or maintenance, causing significant irreparable damage to the groundwater and that it is impracticable to notify the owner or permittee, he may abate the condition without giving notice as required in (1) above, and the cost thereof shall be a charge against the owner of the land as shown on the last equalized assessment roll.

(4) Penalty: Any person who does any work for which a permit is required by this Ordinance and who fails to obtain a permit shall be guilty of a misdemeanor punishable by fine not exceeding FIVE HUNDRED DOLLARS ($500.00) or by imprisonment not exceeding six (6) months, or by both such fine and imprisonment, and such person shall be deemed guilty of a separate offense for each and every day a portion thereof during which any such violation is committed, continued, or permitted, and shall be subject to the same punishment as for the original offense.

Section 3-160.7. Conflicts: All ordinances of the County in conflict herewith are hereby repealed to the extent of such conflict.

Section 3-1 60.8. Severability: If any section, sub-section, paragraph, sub-paragraph, sentence, clause, or phrase of this Ordinance is for any reason held to be invalid or unconstitutional, such invalidity or unconstitutionality shall not affect the validity or constitutionality of the remaining portions of this Ordinance; and the Board declares that this Ordinance and each section, sub-section, paragraph, sub-paragraph, sentence, clause , and phrase thereof would have been adopted irrespective of the fact that one or more of such section, sub- section, paragraph, sub-paragraph, sentence, clause, or phrase be declared invalid or unconstitutional.

SECTION II

This Ordinance shall take effect and be in force thirty (30) days from and after the date of its passage and before the expiration of fifteen (15) days after its passage it shall be published once with the names of the members voting for and against the same in The Inter-City Express, a newspaper published in the County of Alameda.

Adopted by the Board of Supervisors of the County of Alameda on this 17th day of July, 1973, by the following called vote:
AYES: Supervisors Cooper, Hannon, Murphy, and Chairman Bort - 4.
NOES: Supervisors None.
EXCUSED: Supervisor Bates - 1.

J. P. BORT,
Chairman of the Board of Supervisors
of the County of Alameda,
State of California.

ATTEST:
JACK K. POOL
Clerk of the Board of Supervisors of
the County of Alameda,
State of California.
734834 -- 7-27-lf

Foreward

The Alameda County Public Works Agency, Water Resources Section has the responsibility and authority to issue drilling permits and to enforce the County Well Ordinance. This jurisdiction covers the western Alameda County areas and the Cities of Oakland, Alameda, Piedmont, Emeryville, Albany, San Leandro, San Lorenzo, Castro Valley and Hayward. The purpose of the drilling permits are to ensure that any new well or the destruction of wells, including geotechnical investigation and the environmental sampling within the above jurisdiction and within Alameda County will not cause pollution or contamination of groundwater or otherwise jeopardize the health safety or welfare of the people of Alameda County.

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1 Introduction

1.1 Background

Alameda County ("District") has the responsibility of ensuring that the groundwater within the area of the Cities will not be degraded, polluted or contaminated by improper construction, use, operation, maintenance, repair, reconstruction, improvement, inactivation, decommissioning, or destruction of wells, exploratory holes, other excavations, and appurtenances.

The District is the local enforcement agency for wells, exploratory holes, other excavations, and appurtenances in the Cities of Oakland, Alameda, Piedmont, Emeryville, Albany, San Leandro, San Lorenzo, Castro Valley and Hayward, under the statutory authority granted to the District Well Ordinance 73-68. Therefore, it is the District's responsibility to administer the ordinance and to develop the technical standards set forth herein.

The Standards are derived from water well industry procedures and processes deemed most effective at meeting local groundwater protection needs and are based on the standards developed by the State of California Department of Water Resources (DWR). These Standards establish the minimum requirements for work on any well, exploratory hole, other excavation, or appurtenances as defined herein.

1.2 Permits

All work regulated by Alameda County Ordinance No. 73-68, requires a permit. Application for a permit may be obtained from the District's Water Resources Section, at 399 Elmhurst Street, Hayward, CA 94544 or online from the District's website at www.acgov.org/pwa/wells.

2 Definitions

Section 3-160.1. Definitions: Definitions of terms for the construction, repair, reconstruction, destruction, or abandonment of wells shall be as set forth in Chapter II and in Appendix I, of the Department of Water Resources Bulletin No. 74, "Water Well Standards: State of California," as modified and with additions herein.

(1) "County" shall mean the County of Alameda.

(2) "Board" shall mean the Board of Supervisors of the County of Alameda.

(3) "Advisory Board" shall mean a Well Standards Advisory Board, consisting of three (3) qualified persons, which may be appointed by the Board of Supervisors for two (2) year terms, ending 12:00 noon on the first Monday after January 1 of each odd numbered year. The matter of qualification lies solely within the discretion of the Board of Supervisors. In the event a Well Standards Advisory Board is not created, the Board of Supervisors shall assume the duties of said Advisory Board.

(4) "Director of Public Works" shall mean the Director of Pub1ic Works of the County of Alameda and the Alameda County Flood Control and Water Conservation District.

(5) "Person" shall mean any person, firm, corporation, municipality, district, or public agency.

(6) "Well" shall mean any artificial excavation constructed by any method for the purpose extracting water from, or injecting water into, the underground. This definition shall not include: (a) oil and gas wells, or geothermal wells constructed under the jurisdiction of the Department of Conservation, except those wells converted to use as water wells; or (b) wells used for the purpose of (1) dewatering excavation during construction, or (2) stabilizing hillsides or earth embankments .

(7) "Cathodic Protection Well" shall mean any artificial excavation constructed by any method for the purpose of installing equipment or facilities for the protection electrically of metallic equipment in contact with the ground, commonly referred to as cathodic protection.

(8) "Construction, Reconstruction" shall mean to dig, drive, bore, drill, or deepen a well, or to reperforate, remove, replace, or extend a well casing.

(9) "Destruction" shall mean the proper filling, sealing, or otherwise rendering unusable a well that is no longer useful or has become hazardous to public health or safety, so as to assure that the groundwater is protected and to eliminate a potential physical hazard.

(10)"Repair" shall mean the deepening or enlargement of a well or the perforation or replacement of a casing or sealing-off of aquifers, or other work to improve or maintain the integrity of the well and its water-producing capacity.

(11)"Exploratory Hole" shall mean any artificial excavation constructed by any method for the purpose of determining subsurface geological or hydrological conditions.

(12)"Public Nuisance" shall mean any well which threatens to impair the quality groundwater or otherwise jeopardize the health or safety of the public.

Section 3-160.2. Jurisdiction: This ordinance shall have effect in the unincorporated area of the County of Alameda and in those incorporated areas which have by ordinance or resolution adopted the provisions of this ordinance by reference thereto and have designated the Alameda County Public Works Department, through the Alameda County Flood Control and Water Conservation District, as the administering agency.

Section 3-160.3. Prohibitions: No person, firm , corporation, or special district formed under the laws of this State shall, within the area subject to the provisions of this ordinance, construct, repair, reconstruct, destroy, alter, or abandon any well unless a written permit has been obtained therefor from the Director of Public Works of the County of Alameda as provided in this ordinance; provided, however, that any incorporated area may elect to adopt this ordinance by reference by resolution of the city council city ordinance, which resolution or ordinance shall designate the Alameda County Department of Public Works as administering agency.

"Abandoned" shall mean any well, exploratory hole, or other excavation as defined in the Alameda County Ordinance No. 73-68

"Applicant" or "Permittee" shall mean the legal owner(s) of the property or person authorized by the owner on which a well, exploratory hole, or other excavation is to be constructed, repaired, inactivated or destroyed.

"Appurtenances" shall mean any part or feature of a well or other excavation necessary for its operation (*e.g.*, column pipe, well pump or motor, or wellhead).

"Aquifer" shall mean a geologic formation from which groundwater may be extracted.

"Aquitard" shall mean a geologic formation with very low permeability.

"Construction" shall mean digging, driving, drilling, excavating, jetting, pushing, boring, casing, perforating, screening, gravel packing, deepening and/or sealing by any method of a new well, exploratory hole, or other excavation.

"Contamination" shall mean an impairment of the quality of waters of the state by waste to a degree which creates a hazard to the public health through poisoning or through the spread of disease and includes any equivalent effect resulting from the disposal of waste, whether or not waters of the state are affected.

"Destruction" or "Destroy" shall mean the proper sealing of wells, exploratory holes, and other excavations to ensure that the groundwater supply is protected and preserved for future use and to eliminate potential physical hazards.

"District" shall mean the Alameda County Flood Control and Water Conservation District and the Alameda County Public Works Agency. .

"Exploratory Hole" shall mean any temporary excavation that is open for less than 24 hours and constructed by any method, for the purpose of determining subsurface geological or hydrogeological information. An exploratory hole that is opened for less than 24 hours and used to inject fluids or other substances to enhance remediation at cleanup sites is also included within this definition. Exploratory holes are also known as exploratory boreholes, boreholes, or borings.

"Groundwater" shall mean the water beneath the natural surface of the ground, whether or not flowing through known and definite channels.

"Inactivation" or "Decommissioning" shall mean taking any well or other excavation temporarily out of service, and maintaining the well or other excavation in compliance with the provisions of Alameda County Ordinance No. 73-68 while it is temporarily out of service.

"Mud Pit" shall mean any excavated pit or enclosed structure that is used to confine drilling fluids so that the drilling fluids may be cycled, mixed, or temporarily stored.

"Other Excavations" shall mean an excavation or structure, other than a well or an exploratory hole, constructed by any method that intersects an aquifer, or that may impact the integrity of any aquitard located directly above an aquifer. The following structures are also deemed to be other excavations:

1. "Cathodic Protection Well" shall mean any artificial excavation constructed by any method for the sole purpose of installing equipment or facilities for the protection of metallic equipment in contact with the ground.

2. "Cleanup Site Excavation" shall mean an excavation associated with cleanup site activity under the oversight of a regulatory agency.

3. "Elevator Shaft" shall mean any cased structure constructed to contain the mechanism for an elevator system that intersects an aquifer, or that may impact the integrity of any aquitard located directly above an aquifer.

4. "Inclinometer" shall mean any artificial excavation constructed by any method for the purpose of monitoring ground movement.

5. "Shaft," "Tunnel," or "Directional Borehole" shall mean any passage or opening that intersects an aquifer, or that may impact the integrity of any aquitard located directly above an aquifer.

6. "Support Piers," "Piles," or "Caissons" shall mean any cased or uncased pier, pile, or caisson that intersects an aquifer, or that may impact the integrity of any aquitard located directly above an aquifer.

7. "Vibrating Wire Piezometer" shall mean a device used to monitor pore water pressures or the effects of ground improvement systems.

8. "Wick Drains" shall mean an artificial drainage system used to remove water from soil and accelerate the consolidation of compressible soil.

"Pollution" shall mean an alteration of the quality of the waters of the state by waste to a degree which unreasonably affects the beneficial uses of water or facilities which serve these beneficial uses. Pollution may include contamination as defined herein.

"Repair," "Reconstruction" or "Improvement" shall mean digging, driving, drilling, excavating, jetting, pushing, boring, casing, perforating, sleeving, removal of well casing, reperforating, screening, gravel packing, deepening and/or sealing by any method of an existing well or other excavation.

"Use" or "Operation" shall mean to put into service or utilize a well or other excavation for its intended purpose.

"Well" shall mean any artificial excavation constructed by any method for the purpose of monitoring groundwater levels, extracting, injecting, or circulating water, or extracting, injecting, or circulating other fluid or gas solely for the purpose of soil or groundwater remediation beneath the natural surface of the ground. In addition, for purposes of these Standards, the following structures are also defined as wells:

1. "Agricultural Well" shall mean any well used to supply water only for irrigation of an agricultural crop.

2. "Community Domestic Well" shall mean any water well used to supply water for domestic purposes to a public water system as defined by the State of California, Department of Water Resources, Bulletin 74-81, Water Well Standards: State of California. Such wells are also referred to as "Municipal Wells," "City Wells," "Public Water Supply Wells" or "Small Water System Wells."

3. "Dewatering Well" shall mean any cased hole used for the purpose of permanent dewatering or temporarily removing groundwater during construction or stabilizing hillsides or earth embankments.

4. "Domestic Well" shall mean any water well used to supply domestic water to one residential or commercial property.

5. "Extraction Well" shall mean any artificial excavation constructed by any method for the purpose of removing groundwater for cleanup of contamination.

6. "Geothermal Heat Exchange Well" shall mean any artificial excavation constructed by any method for the purpose of using the heat exchange capacity of the earth for heating and cooling. Geothermal heat exchange wells are also known as ground source heat pump wells.

7. "Horizontal Well" shall mean a well drilled horizontally or at an angle different from vertical.

8. "Industrial Well" shall mean any water well used to supply a specific industry.

9. "Injection Well" shall mean any artificial excavation constructed by any method for one of the following purposes:

    a. Introducing water, treated water, or reclaimed water into the underground as a means of replenishing the groundwater basin.

    b. Introducing gas, nutrients, fluids, or other compounds as a means of enhancing remediation of chemical constituents at clean-up sites or establishing hydraulic control.

10. "Monitoring Well" shall mean any artificial excavation constructed by any method for the purpose of monitoring fluctuations in groundwater levels, quality of groundwater, or

the concentrations of contaminants in groundwater.

11. "Nested Wells" shall mean two or more casing strings within the same borehole.

12. "Vapor Well" shall mean any artificial excavation constructed by any method for the purpose of monitoring or extraction of vapors from the predominantly unsaturated zone above the water table.

13. "Water Well" shall mean any well constructed for the purpose of water supply. This includes community and domestic wells, and agricultural or industrial water wells, and injection water wells.

14. "Well Pump" shall mean any device or method which enables the extraction of water from a well.

3 Standards

3.1 General

These Standards apply to all wells, exploratory holes, other excavations, and appurtenances regulated under The Districts Ordinance No. 73-68 (Appendix B), adopted on July 17, 1973 , pursuant commencing with Section 31142.20 of the California Water Code) (Appendix A). These Standards are derived from applicable sections or portions of sections of water well industry procedures and processes deemed most effective at meeting local groundwater protection needs.

Unless otherwise indicated in these Standards, the minimum standards are provided in DWR's Bulletin No. 74-2, "Water Well Standards: Alameda County" (June, 1964); Bulletin No. 74-81, "Water Well Standards: State of California" (December, 1981), together with the supplemental standards of DWR Bulletin No. 74-90, "California Well Standards; Water Wells, Monitoring Wells, and Cathodic Protection Wells" (June, 1991), and subsequent revisions and/or supplements.

Contractors shall call USA (Underground Service Alert) toll free at 811 or 1-800-227-2600 at least two working days (48 hours) before any subsurface work begins.

3.2 Water Well Construction

The following standards establish the minimum requirements for the construction of:

- water wells
- agricultural wells
- community domestic wells
- domestic wells
- horizontal wells
- industrial wells
- injection wells

Unless otherwise indicated in these Standards, the minimum standards are provided in DWR's Bulletin No. 74-2, "Water Well Standards: Alameda County" (June, 1964); Bulletin No. 74-81, "Water Well Standards: State of California" (December, 1981), together with the supplemental standards of DWR Bulletin No. 74-90, "California Well Standards; Water Wells, Monitoring Wells, and Cathodic Protection Wells" (June, 1991), and subsequent revisions and/or supplements.

Specifications for water well construction are discussed in Part II of the Water Well Standards in DWR Bulletins 74-81 and 74-90 and in Chapter IV of DWR Bulletin 74-2. A typical water well construction is shown on Figure No. 1 in Appendix D.

Well Completion Report forms and instructions may be obtained by visiting DWR's website at *http://www.water.ca.gov/groundwater/well_info_and_other/well_completion_reports.cfm*.

3.2.1 Well Location with Respect to Contaminants and Pollutants

Specifications for well location with respect to contaminants and pollutants are discussed in Part II, Section 8 of the Water Well Standards in DWR Bulletins 74-81 and 74-90.

Wells shall be located an adequate horizontal distance from known or potential sources of contamination and pollution. Such sources include, but are not limited to: sanitary sewers; septic tanks and leach fields; sewage and industrial waste ponds; barnyard and stable areas; solid waste disposal sites; above and below ground storage tanks and pipelines for storage and conveyance of petroleum products or other chemicals; and, storage and preparation areas for pesticides, fertilizers, and other chemicals. In addition, consideration must also be given to ensure adequate separation from sites or areas with known or suspected soil or groundwater pollution or contamination.

The following horizontal separation distances are generally considered minimum distances; local conditions may require greater separation distances to ensure groundwater quality protection.

Potential Pollution or Contamination Source	Minimum Horizontal Distance Between Well and Known or Potential Source
Any sewer line (sanitary; main or lateral)	50 feet
Watertight septic tank or subsurface sewage leaching field	100 feet
Cesspool or seepage pit	150 feet
Animal or fowl enclosure	100 feet
Above and below ground storage tanks and associated pipelines.	100 feet
Leaking Underground Fuel Tank Cleanup Sites and Spills, Leaks, Investigation, and Cleanup Sites	150 feet
Bioswales, Graywater or Porous Pavement Areas	100 feet

3.2.2 <u>Sealing the Upper Annular Space</u>

Specifications for sealing the upper annular space are discussed in Part II, Section 9 of the Water Well Standards in DWR Bulletins 74-81 and 74-90.

Drilling may be accomplished through a variety of methods. For the construction of all water wells, a drilling method should be chosen that is large enough to provide at least a two-inch annular space between the outside of the well casing and the borehole wall. The annular space between the borehole wall and casing must be effectively sealed to prevent it from being a preferential pathway for either the movement of pollutants, contaminants from surface spills and leaks, or from poor-quality water flow between aquifers. The annular seal can also serve to protect the structural integrity of the well casing and to protect the casing from chemical attack and corrosion. In no case will an outer casing or conductor casing be an acceptable substitute for an annular seal.

3.2.2.1 Minimum Depth of Seal

The depth of the required annular seal for a water well will depend on the geologic setting and will be determined by the District on a case by case basis. During well construction, the permittee shall provide some method for the determination of groundwater quality characteristics of the major aquifers penetrated so that a judgment can be made as to whether or not inter-aquifer groundwater flow (also known as intermingling) will be allowed. Such determination can consist of evaluation of data from adjacent wells, evaluation of samples of formation materials encountered, or by running a geophysical log. Final judgment on water well construction that would be required to prevent intermingling of waters of different qualities shall be at the discretion of the District. At a minimum, an annular seal of fifty (50) feet is required for all new water wells.

3.2.2.2 Wells that Penetrate Zones Containing Poor-quality Water, Pollutants, or Contaminants

Geologic units known to contain poor-quality water, pollutants, or contaminants require precautions (*i.e.,* conductor casing) to isolate zones containing poor-quality water, pollutants, or contaminants during drilling and well construction operations. The precaution is necessary so that poor-quality water, pollutants, or contaminants do not move through the borehole during drilling and well construction operations, thereby significantly degrading groundwater quality in other units before sealing material can be installed. The District may consider substitutions to a conductor casing on a case-by-case basis, provided the proposed substitution is acceptable to the District and is equal to or exceeds these Standards in performance and level of protection. Additional information regarding conductor casings is located in Section 3.2.6.1.

3.2.2.3 Sealing Materials and Placement

(1) <u>Water</u>
The water used to prepare sealing mixtures must be of drinking water quality.

(2) <u>Grout</u>
The sealing material shall be a neat cement grout composed of one sack of Portland Type I/II Cement (94 lbs.) or Portland Type II/V to five gallons of clean water or a sand-cement slurry with a minimum of eleven (11) sacks of Portland Cement per cubic yard of sand-cement slurry. The sand-cement slurry must be mixed at a batch plant; mixing of

sand-cement slurries onsite will not be allowed. Cement-based sealing materials shall be mixed thoroughly to provide uniformity and ensure that no lumps exist.

(3) Minimum Set and Curing Time
The minimum time required for sealing materials containing Portland Cement to set and begin curing before construction operations on a well can be resumed is seventy-two (72) hours.

(4) Bentonite
A bentonite spacer or transition seal can be used, but is considered part of the gravel pack. Bentonite clay products must be specifically prepared for such use, and the preparation and placement of bentonite clay products shall follow the manufacturer’s specifications. Bentonite is allowed as an additive to cement-based sealing mixes, at a ratio of up to 5% percent by weight of cement used. Bentonite shall not be used as a sealing material.

(5) Radial Thickness of Seal
A minimum of two (2) inches of sealing material shall be maintained between the casing and the borehole wall, within the interval to be sealed. In addition, two (2) inches of sealing material shall be maintained between each casing, such as permanent conductor casing, well casing (including the diameter of joint areas), gravel fill pipes, etc.

(6) Centralizers
Well centralizers are to be attached to the well column every twenty-five (25) feet for water wells so that the well casing can be properly centered in the borehole. Centralizers shall be metal or plastic and must be positioned to allow the proper placement of sealing material around the casing within the interval to be sealed. Any metallic component of a centralizer used with metallic casing shall consist of the same material as the casing. Metallic centralizer components shall meet the same metallurgic specifications and standards as the metallic casing to reduce the potential for galvanic corrosion of the casing.

(7) Placement
The sealing material shall be placed in one continuous operation until the specified interval or borehole is filled.

(8) Free-fall Grouting
Sealing materials may be installed by “free-fall” from the surface if the interval to be sealed has less than five (5) feet of water present and the total depth is less than thirty (30) feet deep.

(9) Tremie Grouting
If five (5) feet or more of standing water is present or if there is more than a thirty (30) foot length to be sealed, the sealing material shall be placed by means of a tremie pipe (maximum diameter of 3 inches) lowered to within three (3) feet of the underlying layer of material or bottom of the well. The sealing material shall be placed in one continuous operation until the specified interval or borehole is filled. If a tremie pipe is used, the end

of the tremie pipe shall remain in place in the sealing material until placement is complete.

3.2.3 **<u>Surface Construction Features</u>**

Specifications for surface construction features are discussed in Part II, Section 10 of the Water Well Standards in DWR Bulletins 74-81 and 74-90.

3.2.4 **<u>Disinfection and Other Sanitary Requirements</u>**

Specifications for disinfection and other sanitary requirements are discussed in Part II, Section 11 of the Water Well Standards in DWR Bulletins 74-81 and 74-90.

Prior to the commencement of drilling each hole, the drilling equipment, such as drill stem and augers, shall be cleaned to avoid the introduction of off-site contamination or cross contamination between well installation activities.

3.2.4.1 Disinfection

All wells producing water for domestic use (i.e., drinking or food processing) shall be disinfected following construction, repair, or when work is done on the pump, before the well is placed in service.

3.2.4.2 Gravel

Gravel used in gravel-packed wells shall come from clean sources and should be thoroughly washed before being placed in the well. Gravel purchased from a supplier should be washed at the pit or plant prior to delivery to the well site.

During the placement of the gravel in the annular space, disinfectants (usually sodium hypochlorite in tablet or granular form) shall be added to the gravel at a uniform rate (two tablets per cubic foot or one pound of the granular form per cubic yard).

3.2.5 **<u>Casing</u>**

Specifications for casing are discussed in Part II, Section 12 of the Water Well Standards in DWR Bulletins 74-81 and 74-90.

All casing materials used in well construction shall be new. All PVC casings shall be joined by flush threaded or locking bell joints; no glue, tape, or cements shall be used unless approved by the District. Casing shall be equipped with centering guides or “centralizers” to ensure the even radial thickness of the annular seal (see Section 3.2.2.3). The bottom of all well casings shall be plugged or capped to prevent sediment or rock from entering the well.

3.2.6 **<u>Sealing-off Strata</u>**

Specifications for sealing-off strata are discussed in Part II, Section 13 of the Water Well Standards in DWR Bulletins 74-81 and 74-90.

3.2.6.1 Conductor Casing

Geologic units known to contain poor-quality water, pollutants, or contaminants require precautions (*i.e.*, conductor casing) to isolate zones containing poor-quality water, pollutants, or contaminants during drilling and well construction operations. The precaution is necessary so that poor-quality water, pollutants, or contaminants do not move through the borehole during drilling and well construction operations, thereby significantly degrading groundwater quality in other units before sealing material can be installed. The District may consider substitutions to a conductor casing on a case-by-case basis, provided the proposed substitution is acceptable to the District and is equal to or exceeds these Standards in performance and level of protection.

If a permanent conductor casing is to be installed to facilitate the construction of a well, steel casing must be used. In no case shall PVC casing be used as conductor casing. The conductor casing must be installed in an oversized hole at least four (4) inches greater in diameter than the outside diameter of the permanent conductor casing. The conductor casing must be driven or pushed a minimum of two to three feet into an aquitard above the aquifer where the well will be installed.

The annular space between the borehole wall and conductor casing must be effectively sealed to prevent it from being a preferential pathway for either the movement of pollutants or contaminants from surface spills and leaks or from poor-quality water interaquifer flow.

3.2.6.2 Multiple Screens

Multiple screens may not be installed in more than one aquifer, if one or more of the aquifers contains water that, if allowed to mix in sufficient quantity, will result in a significant deterioration of the quality of water in the other aquifer(s) or the quality of water produced. The strata producing such poor-quality water shall be effectively sealed off to prevent entrance of the water into the well or its migration to other aquifer(s). In order to seal off questionable water quality, the depth of the annular seal of the well shall extend through the zone of poor-quality water and into the immediate overlying aquitard above the water-bearing zone in which the well is perforated or screened.

3.2.6.3 Filter Material

The gravel or filter pack shall not extend into any confining layers that overlie or underlie the targeted aquifer, unless otherwise approved by the District.

3.2.7 <u>Well Development</u>

Specifications for well development are discussed in Part II, Section 14 of the Water Well Standards in DWR Bulletins 74-81 and 74-90.

If mechanical development procedures are to be used, the well seal must be allowed to bond to the casing for 72 hours prior to development.

3.2.8 <u>Water Quality and Quantity for Individual Water Wells</u>

Specifications for water quality sampling are discussed in Part II, Section 15 of the Water Well Standards in DWR Bulletins 74-81 and 74-90.

The Alameda County Department of Environmental Health is the regulatory agency that oversees the quality and quantity requirements of the water for individual water wells and other sources such as springs. For questions regarding water quality and quantity requirements, please contact the Alameda County Department of Environmental Health at (510) 567-6700 or visit their web site at *http://www.acgov.org/aceh/septic/well_test.htm*.

3.2.9 Rehabilitation, Repair, and Deepening of Wells

Specifications for rehabilitation, repair, and deepening of wells are discussed in Part II, Section 18 of the Water Well Standards in DWR Bulletins 74-81 and 74-90.

3.2.10 Drilling Fluids and Cuttings

Drilling fluids and cuttings shall be properly managed and disposed of in accordance with applicable local, regional, and state requirements. Discharge of drilling wastes into the sanitary sewer or storm drain is prohibited.

Mud pits created to confine drilling fluids shall be properly maintained during the well drilling operation. It shall be the permittee's responsibility to ensure that the mud pit is properly evacuated and backfilled upon completion of the job.

3.2.11 Temporary Cover

Specifications for temporarily covering wells are discussed in Part II, Section 19 of the Water Well Standards in DWR Bulletins 74-81 and 74-90.

During any periods when no work is being performed on the well, such as overnight, the well and surrounding excavation shall be covered and secured. The cover shall be sufficiently strong and anchored to prevent the introduction of foreign material into the well and to protect the public from a potentially hazardous situation.

3.3 Water Well Destruction

The following standards establish the minimum requirements for the destruction of:

- water wells
- agricultural wells
- community domestic wells
- domestic wells
- horizontal wells
- industrial wells
- injection wells

Unless otherwise indicated in these Standards, the recommended minimum standards are provided in DWR's Bulletin No. 74-2, "Water Well Standards: Alameda County" (June, 1964); Bulletin No. 74-81, "Water Well Standards: State of California" (December, 1981), together with the supplemental standards of DWR Bulletin No. 74-90, "California Well Standards; Water Wells, Monitoring Wells, and Cathodic Protection Wells" (June, 1991), and subsequent revisions and/or supplements.

Specifications for well destruction are discussed in Part III of the Water Well Standards in DWR Bulletins 74-81 and 74-90 and under Chapter IV of DWR Bulletin 74-2.

If pollutants or contaminants are discovered during the well destruction process, it shall be the responsibility of the permittee to notify the proper agencies and to properly contain and dispose of contaminated materials.

3.3.1 Steel Cased Wells

Before the well is destroyed, the motor, pump column and bowl assembly, etc., must be removed so that the well can be investigated to determine its condition, details of construction, and whether there are obstructions that will interfere with the process of sealing. This may include the use of a downhole camera for visual inspection of the well.

Steel cased wells must be redrilled or cleaned out to their original depth. The well shall be cleaned so that all undesirable materials and obstructions such as debris, oil from oil-lubricated pumps, or pollutants and contaminants that could interfere with well destruction are removed for disposal.

In order to destroy steel cased water wells, the casing must be ripped or perforated near the surface to prevent surface water intrusion and in aquitards between aquifers to prevent interconnection of the aquifers. Perforated zones are required for water well destructions in order to insure that sealing material fills any voids in the annular space and to prevent inter-aquifer flow, either through the well or outside of the casing. The well casing shall be ripped or perforated with a minimum 3/8-inch Mills Knife perforator. An alternate process to rip or perforate the casing may also be approved if it equals or exceeds this standard in performance and level of protection. In destroying gravel-packed wells, the sealing material will be placed within the casing and forced out under pressure into the gravel envelope through the perforated intervals. A typical steel cased water well destruction is shown on Figure No. 2 in Appendix D.

Sealing materials shall consist of the following:

(1) Water
The water used to prepare sealing mixtures must be of drinking water quality.

(2) Grout
The sealing material shall be a neat cement grout composed of one sack of Portland Type I/II Cement (94 lbs.) or Portland Type II/V to five gallons of clean water or a sand-cement slurry with a minimum of eleven (11) sacks of Portland Cement per cubic yard of sand-cement slurry. The sand-cement slurry must be mixed at a batch plant; mixing of sand-cement slurries onsite will not be allowed. Cement-based sealing materials shall be mixed thoroughly to provide uniformity and ensure that no lumps exist.

(3) Bentonite
Bentonite is allowed as an additive to cement-based sealing mixes, at a ratio of up to 5% percent by weight of cement used. Bentonite shall not be used as a sealing material.

The sealing material shall be placed in one of the following methods in one continuous operation until the specified interval or borehole is filled:

(1) Free-fall Grouting
Sealing materials may be installed by "free-fall" from the surface if the interval to be sealed has less than five (5) feet of water present and the total depth is less than thirty (30) feet deep.

(2) <u>Tremie Grouting</u>

If five (5) feet or more of standing water is present or if there is more than a thirty (30) foot length to be sealed, the sealing material shall be placed by means of a tremie pipe (maximum diameter of 3 inches) lowered to within three (3) feet of the underlying layer of material or bottom of the well. The sealing material shall be placed in one continuous operation until the specified interval or borehole is filled. If a tremie pipe is used, the end of the tremie pipe shall remain in place in the sealing material until placement is complete.

After the well is properly sealed, a hole shall be excavated around the well casing to a depth of five (5) feet below ground surface and the well casing removed to the bottom of the excavation. Any well that is destroyed within a road right-of-way must be excavated to a depth of ten (10) feet below ground surface. The sealing material used for the upper portion of the well shall be allowed to spill over into the excavation to form a cap. After the well has been properly filled, including sufficient time for sealing material in the excavation to set, the excavation shall be backfilled to finished grade with compacted material, to conform to native conditions.

3.3.2 Non-Steel Cased Wells

Before the well is destroyed, the motor, pump column and bowl assembly, etc., must be removed so that the well can be investigated to determine its condition, details of construction, and whether there are obstructions that will interfere with the process of sealing. This may include the use of a downhole camera for visual inspection of the well.

All PVC and other non-steel cased wells shall be destroyed by drilling and removing all well construction materials such as casing, screen, cement seal, gravel or sandpack, etc. to the full depth and diameter of the original boring; the hole shall then be backfilled with approved sealing materials. Sealing material and placement must conform to Section 3.3.1 of these Standards.

3.4 Monitoring Well Construction

The following Standards establish the minimum requirements for the construction of:

- monitoring wells for sampling
- monitoring wells for water levels
- extraction wells
- horizontal wells
- injection wells
- nested wells
- piezometers
- vapor monitoring wells
- vapor extraction wells
- vadose monitoring wells

Unless otherwise indicated in these Standards, the recommended minimum standards are provided in the DWR Bulletin No. 74-2, “Water Well Standards: Alameda County” (June, 1964); Bulletin No. 74-81, “Water Well Standards: State of California” (December, 1981), together with the supplemental standards of DWR Bulletin No. 74-90, “California Well Standards; Water Wells, Monitoring Wells, and Cathodic Protection Wells” (June, 1991), and subsequent revisions and/or supplements.

Specifications for monitoring well constructions are discussed in Part II of the Monitoring Well Standards in DWR Bulletin 74-90. A typical monitoring well construction is shown on Figure No. 3 in Appendix D.

3.4.1 Well Location with Respect to Contaminants and Pollutants

Specifications for monitoring well location with respect to contaminants and pollutants are discussed in Part II, Section 8 of the Monitoring Well Standards in DWR Bulletin 74-90.

Monitoring wells installed for the purpose of investigation or monitoring of cleanup sites are not subject to the minimum horizontal distance requirements. All other monitoring wells are subject to the same minimum horizontal distance requirements as water wells (Section 3.2.1).

3.4.2 Sealing the Upper Annular Space

Specifications for sealing the upper annular space are discussed in Part II, Section 9 of the Monitoring Well Standards in DWR Bulletin 74-90.

Drilling may be accomplished through a variety of methods. For the construction of all monitoring wells, a drilling method should be chosen that is large enough to provide at least a two-inch annular space between the outside of the well casing and the borehole wall. The annular space between the borehole wall and casing must be effectively sealed to prevent it from being a preferential pathway for either the movement of pollutants, contaminants from surface spills and leaks, or from poor-quality water flow between aquifers. The annular seal can also serve to protect the structural integrity of the well casing and to protect the casing from chemical attack and corrosion. In no case will an outer casing or conductor casing be an acceptable substitute for an annular seal.

3.4.2.1 Minimum Depth of Seal

The depth of the required annular seal for monitoring wells will depend on the geologic setting and will be determined by the District on a case by case basis. During well construction, the permittee shall provide some method for the determination of groundwater quality characteristics of the major aquifers penetrated so that a judgment can be made as to whether or not inter-aquifer groundwater flow (also known as intermingling) will be allowed. Such determination can consist of evaluation of data from adjacent wells, evaluation of samples of formation materials encountered, or by running a geophysical log. Final judgment on monitoring well construction that would be required to prevent intermingling of waters of different qualities shall be at the discretion of the District.

The minimum seal requirement for monitoring wells installed in the shallow water-bearing zone is 5 feet below ground surface. Exceptions to the minimum seal depth may be approved by the District on a case by case basis for wells located in areas where shallow groundwater conditions are known to exist.

3.4.2.2 Wells that Penetrate Zones Containing Poor-quality Water, Pollutants, or Contaminants

Geologic units known to contain poor-quality water, pollutants, or contaminants require precautions (*i.e.*, conductor casing) to isolate zones containing poor-quality water, pollutants, or contaminants during drilling and well construction operations. The precaution is necessary so that poor-quality water, pollutants, or contaminants do not move through the borehole during drilling and well construction operations, thereby significantly degrading groundwater quality in other units before sealing material can be installed. The District may consider substitutions to a conductor casing on a case-by-case basis, provided the proposed substitution is acceptable to the District and is equal to or exceeds these Standards in performance and level of protection. Additional information regarding conductor casings is located in Section 3.4.7.1.

3.4.2.3 Sealing Materials and Placement

(1) Water
The water used to prepare sealing mixtures must be of drinking water quality.

(2) Grout
The sealing material shall be a neat cement grout composed of one sack of Portland Type I/II Cement (94 lbs.) or Portland Type II/V to five gallons of clean water or a sand-cement slurry with a minimum of eleven (11) sacks of Portland Cement per cubic yard of sand-cement slurry. The sand-cement slurry must be mixed at a batch plant; mixing of sand-cement slurries onsite will not be allowed. Cement-based sealing materials shall be mixed thoroughly to provide uniformity and ensure that no lumps exist.

(3) Minimum Set and Curing Time
The minimum time required for sealing materials containing Portland Cement to set and begin curing before construction operations on a well can be resumed is seventy-two (72) hours.

(4) Bentonite
A bentonite spacer or transition seal can be used, but is considered part of the gravel pack. Bentonite clay products must be specifically prepared for such use, and the preparation and placement of bentonite clay products shall follow the manufacturer’s specifications. Bentonite is allowed as an additive to cement-based sealing mixes, at a ratio of up to 5% percent by weight of cement used. Bentonite shall not be used as a sealing material.

(5) Radial Thickness of Seal
A minimum of two (2) inches of sealing material shall be maintained between all casings and the borehole wall, within the interval to be sealed. In addition, two (2) inches of sealing material shall be maintained between each casing, such as between a permanent conductor casing and the well casing.

(6) Centralizers
Well centralizers are to be attached to the well column every 15 feet in monitoring wells so that the well casing can be properly centered in the borehole. Centralizers shall be metal, plastic, or other non-degradable material and must be positioned to allow the proper placement of sealing material around the casing within the interval to be sealed. Centralizers are not required when constructing through the center of a hollow-stem auger. Any metallic component of a centralizer used with metallic casing shall consist of the same material as the casing. Metallic centralizer components shall meet the same

metallurgic specifications and standards as the metallic casing to reduce the potential for galvanic corrosion of the casing.

(7) Placement
The sealing material shall be placed in one continuous operation until the specified interval or borehole is filled.

(8) Free-fall Grouting
Sealing materials may be installed by "free-fall" from the surface if the interval to be sealed has less than five (5) feet of water present and the total depth is less than thirty (30) feet deep.

(9) Tremie Grouting
If five (5) feet or more of standing water is present or if there is more than a thirty (30) foot length to be sealed, the sealing material shall be placed by means of a tremie pipe (maximum diameter of 3 inches) lowered to within three (3) feet of the underlying layer of material or bottom of the well. The sealing material shall be placed in one continuous operation until the specified interval or borehole is filled. If a tremie pipe is used, the end of the tremie pipe shall remain in place in the sealing material until placement is complete.

3.4.3 Surface Construction Features

Specifications for surface construction features are discussed in Part II, Section 10 of the Monitoring Well Standards in DWR Bulletin 74-90.

The surface construction features should protect the well from unauthorized access, as well as, physical damage and the entrance of surface water, pollutants, and contaminants. Examples of surface construction features include, but is not limited to, a locking cover, water tight casing cap, concrete base or pad, traffic rated well boxes or vaults, and bollards. A typical flush mounted traffic rated well box and a typical protective riser and bollard are shown on Figures No. 4 and 5 in Appendix D, respectively.

3.4.4 Special Precautions for Areas of Known Contamination

Appropriate safety measures should be applied in the possible presence of hazardous materials. Prior to the commencement of drilling each hole, the drilling equipment, such as drill stem and augers, shall be cleaned to avoid the introduction of off-site contamination or cross contamination between well installation activities.

3.4.5 Filter Packs

Specifications for filter packs are discussed in Part II, Section 11 of the Monitoring Well Standards in DWR Bulletin 74-90.

The filter pack shall not extend into any confining layers that overlie or underlie the water bearing zone to be monitored, unless otherwise approved by the District.

3.4.6 <u>Casing</u>

Specifications for casing are discussed in Part II, Section 12 of the Monitoring Well Standards in DWR Bulletin 74-90.

All casing materials used in well construction shall be new. All PVC cased wells shall have a minimum diameter of two (2) inches. All PVC casings shall be joined by flush threaded joints; no glue, tape, or cements shall be used. Casing shall be equipped with centering guides or "centralizers" to ensure the even radial thickness of the annular seal. Centralizers may not be required when constructing through the center of a hollow-stem auger.

For wells screened in the shallow water-bearing zone, the placement of the uppermost slot or perforation should reflect anticipated fluctuations in the water table. No well screens shall be allowed to connect two relatively permeable lenses which appear to be separated by a relatively impermeable zone without the approval of the District. The bottom of all monitoring well casings shall be plugged or capped to prevent sediment or rock from entering the well.

3.4.7 <u>Sealing-off Strata</u>

3.4.7.1 Conductor Casing

If a permanent conductor casing is to be installed to facilitate the construction of a well, steel casing must be used. In no case shall PVC casing be used as conductor casing. The conductor casing must be installed in an oversized hole, at least four (4) inches greater in diameter than the outside diameter of the permanent conductor casing. The conductor casing must be driven or pushed a minimum of two to three feet into an aquitard above the aquifer where the well will be installed. A typical monitoring well construction with a conductor casing is shown on Figure No. 6 in Appendix D.

The annular space between the borehole wall and conductor casing must be effectively sealed to prevent it from being a preferential pathway for either the movement of pollutants or contaminants from surface spills and leaks or from poor-quality water interaquifer flow.

3.4.7.2 Multiple Screens

Multiple screens may not be installed in more than one aquifer, if one or more of the aquifers contains water that, if allowed to mix in sufficient quantity, will result in a significant deterioration of the quality of water in the other aquifer(s) or the quality of water produced. The strata producing such poor-quality water shall be effectively sealed off to prevent entrance of the water into the well or its migration to other aquifer(s). In order to seal off questionable water quality, the depth of the annular seal of the well shall extend through the zone of poor-quality water and into the immediate overlying aquitard above the water-bearing zone in which the well is perforated or screened.

3.4.8 <u>Well Development</u>

Specifications for well development are discussed in Part II, Section 13 of the Monitoring Well Standards in DWR Bulletin 74-90.

All new groundwater monitoring wells shall be initially developed to clean the well and to stabilize the sand, gravel, and aquifer materials around the slots/perforations. Well development may be accomplished by bailing, mechanical or air lift pumping, surging or swabbing. If mechanical development procedures are to be used, the well seal must be allowed to bond to the casing for 72 hours prior to development. Since development can volatilize contaminants present, the well must be allowed to settle for at least 72 hours between development and the first purging/sampling event.

3.4.9 Rehabilitation and Repair of Monitoring Wells

Specifications for rehabilitation and repair are discussed in Part II, Section 14 of the Monitoring Well Standards in DWR Bulletin 74-90.

3.4.10 Drilling Fluids and Cuttings

Drilling fluids and cuttings shall be properly managed and disposed of in accordance with applicable local, regional, and state requirements. Discharge of drilling wastes into the sanitary sewer or storm drain is prohibited.

Mud pits created to confine drilling fluids shall be properly maintained during the well drilling operation. It shall be the permittee's responsibility to see that the mud pit is properly evacuated and backfilled upon completion of the job.

3.4.11 Temporary Cover

Specifications for temporary covers are discussed in Part II, Section 15 of the Monitoring Well Standards in DWR Bulletin 74-90.

During any periods when no work is being performed on the well, such as overnight, the well and surrounding excavation shall be covered and secured. The cover shall be sufficiently strong and anchored to prevent the introduction of foreign material into the well and to protect the public from a potentially hazardous situation.

3.4.12 Injection Wells

Monitoring wells used to inject gas, water, or fluids to enhance remediation at cleanup sites are permitted on a case by case basis. These wells have been identified by the EPA as Class V Injection Wells. For more information regarding EPA reporting requirements please visit the EPA Region 9 website at *http://www.epa.gov/region09/water/groundwater/uic-classv.html* or email Elizabeth Janes at *janes.elizabeth@epa.gov*.

3.5 Monitoring Well Destruction

The following standards establish the minimum requirements for the destruction of:

- monitoring wells for sampling
- monitoring wells for water levels
- extraction wells
- horizontal wells
- injection wells
- nested wells
- piezometers
- vapor monitoring wells
- vapor extraction wells
- vadose monitoring wells

Unless otherwise indicated in these Standards, the recommended minimum standards are provided in DWR Bulletin No. 74-2, “Water Well Standards: Alameda County” (June, 1964); Bulletin No. 74-81, “Water Well Standards: State of California” (December, 1981), together with the supplemental standards of DWR Bulletin No. 74-90, “California Well Standards; Water Wells, Monitoring Wells, and Cathodic Protection Wells” (June, 1991), and subsequent revisions and/or supplements.

Specifications for monitoring well destructions are discussed in Part III of the Monitoring Well Standards in DWR Bulletin 74-90. A typical monitoring well destruction by hollow stem auger is shown on Figure No. 7 in Appendix D.

If pollutants or contaminants are discovered during the well destruction process, it shall be the responsibility of the permittee to notify the proper agencies and to properly contain and dispose of contaminated materials.

3.5.1 Steel Cased Wells

Before the well is destroyed, all appurtenances must be removed so that the well can be investigated to determine its condition and details of its construction. The well shall be sounded to determine if there are obstructions that will interfere with the process of sealing. This may include the use of a downhole camera for visual inspection of the well.

Steel cased monitoring wells are subject to the same destruction requirements as water wells. If the steel well will be destroyed by overdrilling, then it shall be destroyed by drilling and removing all well construction materials such as casing, screen, cement seal, gravel or sandpack, etc. to the full depth and diameter of the original boring; the hole shall then be backfilled with approved sealing materials.

Sealing materials shall consist of the following:

(1) Water
The water used to prepare sealing mixtures must be of drinking water quality.

(2) Grout
The sealing material shall be a neat cement grout composed of one sack of Portland Type I/II Cement (94 lbs.) or Portland Type II/V to five gallons of clean water or a sand-cement slurry with a minimum of eleven (11) sacks of Portland Cement per cubic yard of sand-cement slurry. The sand-cement slurry must be mixed at a batch plant; mixing of sand-cement slurries onsite will not be allowed. Cement-based sealing materials shall be mixed thoroughly to provide uniformity and ensure that no lumps exist.

(3) Bentonite
Bentonite is allowed as an additive to cement-based sealing mixes, at a ratio of up to 5% percent by weight of cement used. Bentonite shall not be used as a sealing material.

The sealing material shall be placed in one of the following methods in one continuous operation until the specified interval or borehole is filled:

(1) Free-fall Grouting

Sealing materials may be installed by "free-fall" from the surface if the interval to be sealed has less than five (5) feet of water present and the total depth is less than thirty (30) feet deep.

(2) Tremie Grouting
If five (5) feet or more of standing water is present or if there is more than a thirty (30) foot length to be sealed, the sealing material shall be placed by means of a tremie pipe (maximum diameter of 3 inches) lowered to within three (3) feet of the underlying layer of material or bottom of the well. The sealing material shall be placed in one continuous operation until the specified interval or borehole is filled. If a tremie pipe is used, the end of the tremie pipe shall remain in place in the sealing material until placement is complete.

3.5.2 Non-Steel Cased Wells

Before the well is destroyed, all appurtenances must be removed so that the well can be investigated to determine its condition and details of its construction. The well shall be sounded to determine if there are obstructions that will interfere with the process of sealing. This may include the use of a downhole camera for visual inspection of the well.

All PVC and other non-steel cased wells shall be destroyed by drilling and removing all well construction materials such as casing, screen, cement seal, gravel or sandpack, etc. to the full depth and diameter of the original boring; the hole shall then be backfilled with approved sealing materials. Sealing material and placement must conform to Section 3.5.1 of these Standards.

3.6 Geothermal Heat Exchange Well Construction

In April 1999, DWR issued draft well standards for geothermal heat exchange wells; however, DWR has not adopted the draft document as formal standards. Therefore, the following are the minimum requirements for geothermal heat exchange wells.

3.6.1 Well Location with Respect to Contaminants and Pollutants

Since geothermal heat exchange wells can act as vertical or horizontal conduits for contamination, geothermal heat exchange wells are subject to the same minimum horizontal distance requirements as water wells (Section 3.2.1).

3.6.2 Construction and Sealing the Upper Annular Space

The depth, diameter, and sealing material required for the annular seal for geothermal heat exchange wells will depend on the geologic setting and will be determined by the District on a case by case basis. During the permit approval process, the permittee shall provide some method for the determination of groundwater quality characteristics of the major aquifers penetrated so that a judgment can be made as to whether or not intermingling will be allowed. Such determination can consist of evaluation of data from adjacent wells, evaluation of samples of formation materials encountered, or by running a geophysical log. Final judgment on the seal requirements that would be required to prevent intermingling of waters of different qualities shall be at the discretion of the District.

3.6.3 Allowed Fluid Systems

In order to protect the groundwater basin, potable water is the only approved fluid for use in geothermal heat exchange systems.

3.7 Geothermal Heat Exchange Well Destruction

All geothermal heat exchange wells that are no longer needed or have been classified as abandoned must be properly destroyed in order to protect the groundwater basin and to eliminate potential physical hazards.

Destruction specifications for geothermal heat exchange wells will be determined on a case by case basis and will depend on the location, geologic setting, and how the well was constructed. At a minimum, the casing and appurtenances must be removed and backfilled with approved sealing material to a depth specified by the District.

3.8 Dewatering Well Construction

3.8.1 Permanent Dewatering Wells

Permanent dewatering wells are subject to the same construction standards as water wells (Section 3.2).

3.8.2 Temporary Dewatering Wells

Drilling may be accomplished through a variety of methods. The filter pack shall not extend into any confining layers that overlie or underlie the unit to be dewatered, unless otherwise approved by the District. A water tight cover shall be installed to prevent it from being a preferential pathway for the movement of pollutants, contaminants from surface spills and leaks.

Dewatering wells located within or adjacent to areas where known contaminated sites exist may impact the remediation and cleanup of those sites. Therefore, it shall be the permittee’s responsibility to notify the appropriate local oversight agency as well as to ensure the proper disposal of the groundwater in accordance with Federal, State, and local regulations.

3.9 Dewatering Well Destruction

3.9.1 Permanent Dewatering Wells

Permanent dewatering wells are subject to the same destruction standards as water wells (Section 3.3).

3.9.2 Temporary Dewatering Wells

Destruction specifications for temporary dewatering wells will be determined on a case by case basis and will depend on the location, geologic setting, and how the well was constructed. At a minimum, the casing and appurtenances must be removed and the borehole backfilled with approved sealing material to a depth specified by the District. Sealing material and placement must conform to Section 3.3.1 of these Standards.

3.10 Exploratory Holes

Unless otherwise indicated in these Standards, the recommended minimum standards are provided in DWR Bulletin No. 74-90, "California Well Standards; Water Wells, Monitoring Wells, and Cathodic Protection Wells" (June, 1991), and subsequent revisions and/or supplements.

All exploratory holes must be properly destroyed by backfilling the exploratory hole with approved sealing materials.

Sealing materials shall consist of the following:

(1) Water
The water used to prepare sealing mixtures must be of drinking water quality.

(2) Grout
The sealing material shall be a neat cement grout composed of one sack of Portland Type I/II Cement (94 lbs.) or Portland Type II/V to five gallons of clean water or a sand-cement slurry with a minimum of eleven (11) sacks of Portland Cement per cubic yard of sand-cement slurry. The sand-cement slurry must be mixed at a batch plant; mixing of sand-cement slurries onsite will not be allowed. Cement-based sealing materials shall be mixed thoroughly to provide uniformity and ensure that no lumps exist.

(3) Bentonite
Bentonite is allowed as an additive to cement-based sealing mixes, at a ratio of up to 5% percent by weight of cement used. Bentonite shall not be used as a sealing material.

The sealing material shall be placed in one of the following methods in one continuous operation until the specified interval or borehole is filled:

(1) Free-fall Grouting
Sealing materials may be installed by "free-fall" from the surface if the interval to be sealed has less than five (5) feet of water present and the total depth is less than thirty (30) feet deep.

(2) Tremie Grouting
If five (5) feet or more of standing water is present or if there is more than a thirty (30) foot length to be sealed, the sealing material shall be placed by means of a tremie pipe (maximum diameter of 3 inches) lowered to within three (3) feet of the underlying layer of material or bottom of the well. If a tremie pipe is used, the end of the tremie pipe shall remain in place in the sealing material until placement is complete.

3.10.1 **Special Provisions**

3.10.1.1 Temporary Soil Vapor Sampling

All temporary soil vapor probes and construction materials must be destroyed by overdrilling to the full depth and diameter of the original borehole the same day they are installed.

3.10.1.2 Percolation Tests

All percolation tests must be completed the same day they are installed. All construction materials must be removed by over drilling to the full depth and diameter of the original borehole.

3.10.1.3 Injection Boreholes

Exploratory boreholes used to inject gas or fluids to enhance remediation at cleanup sites are permitted on a case by case basis. These boreholes have been identified by the EPA as Class V Injection Wells. For more information regarding EPA reporting requirements please visit the EPA Region 9 website at *http://www.epa.gov/region09/water/groundwater/uic-classv.html* or email Elizabeth Janes at *janes.elizabeth@epa.gov*.

3.10.1.4 Direct Push or Cone Penetrometer Boreholes

The sealing material for direct push and cone penetrometer test holes with a diameter less than 3 inches shall be a neat cement grout composed of one sack of Portland Type I/II Cement (94 lbs.) or Portland Type II/V to six gallons of clean water.

3.11 Other Excavations

3.11.1 **Cathodic Protection Well Construction**

Unless otherwise indicated in these Standards, the recommended minimum standards are provided in DWR Bulletin No. 74-90, "California Well Standards; Water Wells, Monitoring Wells, and Cathodic Protection Wells" (June, 1991), and subsequent revisions and/or supplements.

Specifications for cathodic protection well constructions are discussed in Part II of the Cathodic Protection Well Standards in DWR Bulletin 74-90. A typical cathodic protection well construction is shown on Figure No. 8 in Appendix D.

3.11.1.1 Well Location with Respect to Contaminants and Pollutants

Specifications for cathodic protection well location with respect to contaminants and pollutants are discussed in Part II, Section 6 of the Cathodic Protection Well Standards in DWR Bulletin 74-90.

Cathodic protection wells are subject to the same minimum horizontal distance requirements as water wells (Section 3.2.1).

3.11.1.2 Sealing the Upper Annular Space

Specifications for sealing the upper annular space are discussed in Part II, Section 7 of the Cathodic Protection Well Standards in DWR Bulletin 74-90.

Drilling may be accomplished through a variety of methods. For the construction of all cathodic protection wells, a drilling method should be chosen that is large enough to provide at least a two-inch annular space between the outside of the well casing and the borehole wall. The annular space between the borehole wall and casing must be effectively sealed to prevent it from being a preferential pathway for either the movement of pollutants, contaminants from surface spills and leaks, or from poor-quality water flow between aquifers. The annular seal can also serve to protect the structural integrity of the well casing and to protect the casing from chemical attack and corrosion. In no case will an outer casing or conductor casing be an acceptable substitute for an annular seal.

3.11.1.2.1 Minimum Depth of Seal

The depth, diameter, and sealing material required for the annular seal for cathodic protection wells will depend on the geologic setting and the requirements of the metallic equipment to be protected and will be approved by the District on a case by case basis. During the permit approval process, the permittee shall provide some method for the determination of groundwater quality characteristics of the major aquifers penetrated so that a judgment can be made as to whether or not intermingling will be allowed. Such determination can consist of evaluation of data from adjacent wells, evaluation of samples of formation materials encountered, or by running a geophysical log. Final judgment on the seal requirements that would be required to prevent intermingling of waters of different qualities shall be at the discretion of the District.

3.11.1.2.2 Sealing Materials and Placement

(1) Water
The water used to prepare sealing mixtures must be of drinking water quality.

(2) Grout
The sealing material shall be a neat cement grout composed of one sack of Portland Type I/II Cement (94 lbs.) or Portland Type II/V to five gallons of clean water or a sand-cement slurry with a minimum of eleven (11) sacks of Portland Cement per cubic yard of sand-cement slurry. The sand-cement slurry must be mixed at a batch plant; mixing of sand-cement slurries onsite will not be allowed. Cement based sealing materials shall be mixed thoroughly to provide uniformity and ensure that no lumps exist.

(3) Minimum Set and Curing Time
The minimum time required for sealing materials containing Portland Cement to set and begin curing before construction operations on a well can be resumed is seventy-two (72) hours.

(4) Bentonite
A bentonite spacer or transition seal can be used, but is considered part of the gravel pack. Bentonite clay products must be specifically prepared for such use, and the preparation and placement of bentonite clay products shall follow the manufacturer’s specifications. Bentonite is allowed as an additive to cement-based sealing mixes, at a ratio of up to 5% percent by weight of cement used. Bentonite shall not be used as a sealing material.

(5) Radial Thickness of Seal
A minimum of two (2) inches of sealing material shall be maintained between all casings and the borehole wall, within the interval to be sealed. In addition, two (2) inches of sealing material shall be maintained between each casing, such as between a permanent conductor casing and the well casing.

(6) Centralizers
Well centralizers are to be attached to the well column every 25 feet in cathodic protection wells so that the well casing can be properly centered in the borehole. Centralizers shall be metal, plastic, or other non-degradable material and must be positioned to allow the proper placement of sealing material around the casing within the interval to be sealed. Centralizers are not required when constructing through the center of a hollow-stem auger. Any metallic component of a centralizer used with metallic casing shall consist of the same material as the casing. Metallic centralizer components shall meet the same metallurgic specifications and standards as the metallic casing to reduce the potential for galvanic corrosion of the casing.

(7) Placement
The sealing material shall be placed in one continuous operation until the specified interval or borehole is filled.

(8) Free-fall Grouting
Sealing materials may be installed by “free-fall” from the surface if the interval to be sealed has less than five (5) feet of water present and the total depth is less than thirty (30) feet deep.

(9) Tremie Grouting
If five (5) feet or more of standing water is present or if there is more than a thirty (30) foot length to be sealed, the sealing material shall be placed by means of a tremie pipe (maximum diameter of 3 inches) lowered to within three (3) feet of the underlying layer of material or bottom of the well. The sealing material shall be placed in one continuous operation until the specified interval or borehole is filled. If a tremie pipe is used, the end of the tremie pipe shall remain in place in the sealing material until placement is complete.

3.11.1.3 Surface Construction Features

Specifications for surface construction features are discussed in Part II, Section 8 of the Cathodic Protection Well Standards in DWR Bulletin 74-90.

The surface construction features should protect the well from unauthorized access, as well as, physical damage and the entrance of surface water, pollutants, and contaminants. Examples of surface construction features include, but are not limited to, a locking cover, casing cap, concrete base or pad, traffic rated well boxes or vaults, and bollards.

3.11.1.4 Casing

Specifications for casing are discussed in Part II, Section 9 of the Cathodic Protection Well Standards in DWR Bulletin 74-90.

All casing materials used in well construction shall be new. All PVC cased wells shall have a minimum diameter of two (2) inches. All PVC casings shall be joined by flush threaded joints; no glue, tape, or cements shall be used. Casing shall be equipped with centering guides or "centralizers" to ensure the even radial thickness of the annular seal. Centralizers may not be required when constructing through the center of a hollow-stem auger.

The bottom of all cathodic protection well casings shall be plugged or capped to prevent sediment or rock from entering the well.

3.11.1.5 Sealing-Off Strata

Specifications for sealing-off strata are discussed in Part II, Section 10 of the Cathodic Protection Well Standards in DWR Bulletin 74-90.

The annular space between the borehole wall and casing must be effectively sealed to prevent it from being a preferential pathway for either the movement of pollutants or contaminants from surface spills and leaks or from poor-quality water interaquifer flow.

Anodes shall not be installed in more than one aquifer, if one or more of the aquifers contains water that, if allowed to mix in sufficient quantity, will result in a significant deterioration of the quality of water in the other aquifer(s) or the quality of water produced. The strata producing such poor-quality water shall be effectively sealed off to prevent entrance of the water into the well or its migration to other aquifer(s). In order to seal off questionable water quality, the depth of the annular seal of the well shall extend through the zone of poor-quality water and into the immediate overlying aquitard above the water-bearing zone in which the anodes are placed.

3.11.1.6 Repair of Cathodic Protection Wells

Specifications for repair are discussed in Part II, Section 11 of the Cathodic Protection Well Standards in DWR Bulletin 74-90.

3.11.1.7 Temporary Cover

Specifications for temporary covers are discussed in Part II, Section 12 of the Cathodic Protection Well Standards in DWR Bulletin 74-90.

During any periods when no work is being performed on the well, such as overnight, the well and surrounding excavation shall be covered and secured. The cover shall be sufficiently strong and anchored to prevent the introduction of foreign material into the well and to protect the public from a potentially hazardous situation.

3.11.2 Cathodic Protection Well Destruction

Destruction specifications for cathodic protection wells will be determined on a case by case basis and will depend on the location, geologic setting, and how the well was constructed. At a minimum, the casing, cables, and other construction materials and appurtenances must be removed and the borehole backfilled with approved sealing material to a depth specified by the District.

Sealing materials shall consist of the following:

(1) Water
The water used to prepare sealing mixtures must be of drinking water quality.

(2) Grout
The sealing material shall be a neat cement grout composed of one sack of Portland Type I/II Cement (94 lbs.) or Portland Type II/V to five gallons of clean water or a sand-cement slurry with a minimum of eleven (11) sacks of Portland Cement per cubic yard of sand-cement slurry. The sand-cement slurry must be mixed at a batch plant; mixing of sand-cement slurries onsite will not be allowed. Cement-based sealing materials shall be mixed thoroughly to provide uniformity and ensure that no lumps exist.

(3) Bentonite
Bentonite is allowed as an additive to cement-based sealing mixes, at a ratio of up to 5% percent by weight of cement used. Bentonite shall not be used as a sealing material.

The sealing material shall be placed in one of the following methods in one continuous operation until the specified interval or borehole is filled:

(1) Free-fall Grouting
Sealing materials may be installed by "free-fall" from the surface if the interval to be sealed has less than five (5) feet of water present and the total depth is less than thirty (30) feet deep.

(2) Tremie Grouting
If five (5) feet or more of standing water is present or if there is more than a thirty (30) foot length to be sealed, the sealing material shall be placed by means of a tremie pipe (maximum diameter of 3 inches) lowered to within three (3) feet of the underlying layer of material or bottom of the well. If a tremie pipe is used, the end of the tremie pipe shall remain in place in the sealing material until placement is complete.

3.11.3 Cleanup Site Excavations

Cleanup site excavations are associated with cleanup site activity under the oversight of either the Alameda County Department of Environmental Health (sites within the City of Newark), the District, the City of Fremont Fire Department, the City of Union City Fire Department, the California Department of Toxic Substances Control, or the California Regional Water Quality Control Board – San Francisco Bay Region. Cleanup site excavations that are not properly backfilled can act as a vertical conduit and may create preferential pathways that allow runoff to rapidly infiltrate the subsurface and bypass soils which have the capacity to remove pollutants and protect the groundwater supply. For this reason, cleanup site excavations are included in these Standards.

Cleanup site excavations must be backfilled in a manner that will prevent the creation of: 1) a preferential pathway that could allow runoff to rapidly infiltrate the subsurface, or 2) an interconnection of aquifers or water-bearing zones. This can be done by using a minimum of five feet of materials identified in Section 3.11.2 or by using clean, compacted, low permeability material near the top of the excavation so that groundwater is protected from surface contaminants or pollutants.

This requirement does not supersede any local, state or federal regulations, but is intended to supplement any other regulations.

3.11.4 Elevator Shafts

Elevator shafts are constructed similar to wells. A borehole is drilled and a casing is installed in the borehole. If the annular space between the borehole wall and the casing is not properly sealed, it can act as a vertical conduit and may create preferential pathways that allow runoff to rapidly infiltrate the subsurface and bypass soils which have the capacity to remove pollutants and protect the groundwater supply. For this reason, elevator shafts are included in these Standards.

The elevator shaft must be installed in an oversized hole, at least four (4) inches greater in diameter than the outside surface of the casing. The annular space between the borehole wall and casing must be effectively sealed to prevent it from being a preferential pathway for either the movement of pollutants or contaminants from surface spills and leaks or from poor-quality water interaquifer flow.

Sealing Materials and Placement:

(1) Water
The water used to prepare sealing mixtures must be of drinking water quality.

(2) Grout
The sealing material shall be a neat cement grout composed of one sack of Portland Type I/II Cement (94 lbs.) or Portland Type II/V to five gallons of clean water or a sand-cement slurry with a minimum of eleven (11) sacks of Portland Cement per cubic yard of sand-cement slurry. The sand-cement slurry must be mixed at a batch plant; mixing of sand-cement slurries onsite will not be allowed. Cement based sealing materials shall be mixed thoroughly to provide uniformity and ensure that no lumps exist.

(3) Minimum Set and Curing Time
The minimum time required for sealing materials containing Portland Cement to set and begin curing before construction operations on an elevator shaft can be resumed is seventy-two (72) hours.

(4) Bentonite
Bentonite is allowed as an additive to cement-based sealing mixes, at a ratio of up to 5% percent by weight of cement used. Bentonite shall not be used as a sealing material.

(5) Radial Thickness of Seal
A minimum of two (2) inches of sealing material shall be maintained between all casings and the borehole wall, within the interval to be sealed.

(6) Centralizers

Well centralizers are to be attached to the shaft column every 25 feet in elevator shafts so that the casing can be properly centered in the borehole. Centralizers shall be metal, plastic, or other non-degradable material and must be positioned to allow the proper placement of sealing material around the casing within the interval to be sealed. Centralizers are not required when constructing through the center of a hollow-stem auger. Any metallic component of a centralizer used with metallic casing shall consist of the same material as the casing. Metallic centralizer components shall meet the same metallurgic specifications and standards as the metallic casing to reduce the potential for galvanic corrosion of the casing.

(7) Placement
The sealing material shall be placed in one continuous operation until the specified interval or borehole is filled.

(8) Free-fall Grouting
Sealing materials may be installed by "free-fall" from the surface if the interval to be sealed has less than five (5) feet of water present and the total depth is less than thirty (30) feet deep.

(9) Tremie Grouting
If five (5) feet or more of standing water is present or if there is more than a thirty (30) foot length to be sealed, the sealing material shall be placed by means of a tremie pipe (maximum diameter of 3 inches) lowered to within three (3) feet of the underlying layer of material or bottom of the well. The sealing material shall be placed in one continuous operation until the specified interval or borehole is filled. If a tremie pipe is used, the end of the tremie pipe shall remain in place in the sealing material until placement is complete.

The bottom of all elevator shafts shall be plugged or capped to prevent sediment or rock from entering the casing as well to prevent the escape of hydraulic fluids. For steel cased elevator shafts, the bottom may be sealed by welding a plate to the bottom of the casing or by installing a cement plug of adequate thickness. PVC casings must be installed with a PVC cap.

Elevator shaft destructions are subject to the same standards as water wells (Section 3.3).

3.11.5 Inclinometers

Inclinometers are subject to the same standards as monitoring wells (Sections 3.4 and 3.5).

3.11.6 Shafts, Tunnels, or Directional Boreholes

Shafts, tunnels, and directional boreholes are constructed similar to wells and exploratory holes, but at a much larger scale. An opening or passage is created by excavation or by drilling a borehole, and then a structure or casing is installed in the opening. If the annular space between the excavation or borehole wall and the structure/casing is not properly sealed, it can act as a vertical conduit and may create preferential pathways that allow runoff to rapidly infiltrate the subsurface and bypass soils which have the capacity to remove pollutants and protect the groundwater supply. For this reason, shafts, tunnels, and directional boreholes are included in these Standards.

The depth, diameter, and sealing material required for the annular seal for shafts, tunnels, and directional boreholes will depend on the geologic setting and will be determined by the District on a case by case basis. During the permit approval process, the permittee shall provide some method for the determination of groundwater quality characteristics of the major aquifers penetrated so that a judgment can be made as to whether or not intermingling will be allowed. Such determination can consist of evaluation of data from adjacent wells, evaluation of samples of formation materials encountered, or by running a geophysical log. Final judgment on the seal requirements that would be required to prevent intermingling of waters of different qualities shall be at the discretion of the District.

Shafts, tunnels, or directional boreholes must be constructed in a manner that will prevent the creation of: 1) a preferential pathway that could allow runoff to rapidly infiltrate the subsurface, or 2) an interconnection of aquifers or water-bearing zones. Destruction specifications for shafts, tunnels, or directional boreholes will be determined on a case by case basis and will depend on the location, geologic setting, and how the shaft, tunnel, or directional borehole was constructed.

3.11.7 Vibrating Wire Piezometers

Vibrating wire piezometers are often installed similar to wells. A borehole is drilled and a casing is installed with the vibrating wire equipment attached to the casing. Vibrating wire piezometers installed with either PVC or Steel casing are subject to the same standards as monitoring wells (Sections 3.4 and 3.5).

Vibrating wire piezometers installed without casing are subject to the same standards as exploratory holes (Section 3.10).

3.12 Appurtenances

All appurtenances connected to wells and other excavations shall be installed, repaired or maintained in such a manner that all openings are sealed from surface waters or the entrance of undesirable fluids or foreign matter, and to prevent accidental entry or unauthorized access.

Appurtenances may include, but is not limited to: 1) well pumps and motors; 2) openings designated to provide access to the wells for measuring water levels, sampling, chlorinating, or adding gravel; and 3) any pipes, cables, or equipment that is installed in the well or other excavation.

If a pump has been temporarily removed for repair or replacement, the well shall be adequately covered and secured to prevent injury to people and animals and to prevent the entrance of foreign material, surface water, pollutants, or contaminants into the well during the pump repair period.

ACPWA Ordinace 73-68

GEOTHERMAL HEAT EXCHANGE WELLS

WELL STANDARDS

DRAFT

April 1999

STANDARDS

SPECIAL NOTE: The first three pages of this draft are to be included in the Introduction of the new California Well Standards, Bulletin 74-99. Bulletin 74-99 will be one document including standards for water wells, monitoring wells, cathodic protection wells, and geothermal heat exchange wells.

Exemption Due to Unusual Conditions -- If the enforcing agency finds that compliance with any of the requirements prescribed herein is impractical for a particular location because of unusual conditions or that compliance would result in an unsatisfactory well, or that there is a best available technology (BAT) or state-of-the-art technology not enumerated in these standards that would provide suitable protection, the enforcing agency may waive compliance and prescribe alternative requirements that would afford the same level of protection provided by these standards.

Geothermal Heat Exchange Well Locations -- Geothermal heat exchange wells that are sealed their entire length may be installed closer to contaminant or pollutant sources or structures than the distances specified for water wells in DWR Bulletin 74-90 and subsequent revisions. Iron markers, trace tapes, or wire shall be installed at each well to facilitate locating the buried wells.

Exclusions -- The geothermal heat exchange well standards prescribed in Bulletin 74-99 do not apply to shallow construction systems as defined in Bulletin 74-99. The enforcing agency may prescribe additional regulations when the fluid is circulated in a loop in a shallow system. To prevent groundwater contamination, the enforcing agency shall prescribe additional regulations for the destruction of shallow geothermal heat exchange systems.

Driller Qualifications -- In accordance with the provisions of Section 13750.5 of the California Water Code:

"Section 13750.5. Person responsible for construction, alteration, destruction, or abandonment; license necessary

"No person shall undertake to dig, bore, or drill a water well, cathodic protection well, groundwater monitoring well, or geothermal heat exchange well, to deepen or reperforate such a well, or to abandon or destroy such a well, unless the person responsible for that construction, alteration, destruction, or abandonment possesses a C-57 Water Well Contractor's License."

Reports -- Reports concerning a water well, cathodic protection well, groundwater monitoring well, or geothermal heat exchange well shall be prepared in accordance with the provisions of California Water Code Section 13751. The description of the site prepared under 13751. (b)(2)(A) shall be sufficiently exact to permit location of each geothermal heat exchange well.

"Section 13751. Report of completion

"(a) Every person who digs, bores, or drills a water well, cathodic protection well, groundwater monitoring well, or geothermal heat exchange well, abandons or destroys such a well, or deepens or reperforates such a well, shall file with the department a report of completion of that well within 60 days from the date its construction, alteration, abandonment, or destruction is completed.

"(b) The report shall be made on forms furnished by the department and shall contain information as follows:

"(1) In the case of a water well, cathodic protection well, or groundwater monitoring well, the report shall contain information as required by the department, including, but not limited to all of the following information:

"(A) A description of the well site sufficiently exact to permit location and identification of the well.

"(B) A detailed log of the well.

"(C) A description of type of construction.

"(D) The details of perforation.

"(E) The methods used for sealing off surface or contaminated waters.

"(F) The methods used for preventing contaminated waters of one aquifer from mixing with the waters of another aquifer.

"(G) The signature of the well driller.

"(2) In the case of a geothermal heat exchange well, the report shall contain all of the following information:

"(A) A description of the site that is sufficiently exact to permit the location and identification of the site and the number of geothermal heat exchange wells drilled on the same lot.

"(B) A description of borehole diameter and depth and the type of geothermal heat exchange system installed.

"(C) The methods and materials used to seal off surface or contaminated waters.

"(D) The methods used for preventing contaminated water in one aquifer from mixing with the water in another aquifer.

"(E) The signature of the well driller."

Reports submitted on water wells, monitoring wells, or cathodic protection wells are subject to California Water Code Section 13752. Reports submitted on geothermal heat exchange wells are open for public inspection.

"Section 13752. Inspection of reports

"Reports made in accordance with paragraph (1) of subdivision (b) of Section 13751 shall not be made available for inspection by the public, but shall be made available to governmental agencies for use in making studies. However, any report shall be made available to any person who obtains a written authorization from the owner of the well."

Geothermal Heat Exchange Well Standards

PART I. General

Section 1. Definitions

A. Geothermal heat exchange well. Any uncased artificial excavation by any method for the purpose of using the heat exchange capacity of the earth for heating and cooling and in which the ambient ground temperature is 86° Fahrenheit (30° Celsius) or less and which uses a closed loop fluid system to prevent the discharge or escape of its fluid into the surrounding aquifers or geologic formations. Geothermal heat exchange wells are also known as ground source heat pump wells. Such wells or boreholes are not intended to produce water or steam.

B. Types of systems. Geothermal heat exchange systems may use a number of different combinations of circulating fluids, construction methods, and heat sources. These are commonly classified as follows:

1. Circulating fluid systems. This refers to the type of piping system used to circulate heat exchange fluids.

   a. Closed loop system. This type of system features continuous piping systems which prevent the circulating fluid from coming in contact with the aquifers or geologic formations. The fluid is repeatedly recirculated. The fluid is commonly water, but may be some other approved fluid.

   b. Open loop system. An open loop system results when the circulating fluid is discharged from the piping systems after the heat exchange. The most common open loop system consists of groundwater being pumped from a well and then injected back into the aquifer through the same well or through a second well. Open loop systems, if approved by the Regional Water Quality Control Board or by the enforcing agency, shall conform to Water Well Standards prescribed in DWR Bulletin 74-90 and subsequent revisions.

2. Construction method systems. This refers to the type of construction and the depth to which the excavation(s) penetrate the

ground. Based upon their normal orientation with the surface, a shallow construction system is sometimes called a "horizontal system," while a well construction system is often described as a "vertical system" or a "vertical borehole system."

a. Shallow construction system. This type of system is defined as any heat exchange system having an excavation whose bottom does not exceed a depth of 20 feet from ground surface. The standards prescribed in Parts II & III do not apply to shallow construction systems as defined above. The enforcing agency may prescribe additional regulations for a shallow construction system.

b. Well construction system. This type of system is defined as any heat exchange system in which the bottom of the excavation exceeds 20 feet from ground surface.

3. Heat exchange systems. This refers to the heating or cooling source for a geothermal heat exchange system.

a. Ground source heat exchange system. This system results from the placement of the closed loop circulating pipes directly into the ground, and backfilling the excavation around the circulating pipes with grout or other impervious material. Ground source heat exchange systems shall be constructed as either vertical borehole or shallow systems. Such systems shall be approved by the enforcing agency prior to construction.

b. Groundwater source heat exchange system.

(1). Closed loop. A geothermal heat exchange system using a standing column of groundwater within a water well as the heat source. The fluid is circulated through a closed loop submerged in the groundwater. The standing groundwater in the well is the heat exchange medium. The water well shall conform to water well standards prescribed in DWR Bulletin 74-90 and subsequent revisions.

(2). Open loop. These systems shall be approved by the enforcing agency and the Regional Water Quality Control Board prior to construction. The water well shall conform to water well standards prescribed in

DWR Bulletin 74-90 and subsequent revisions. Open loop groundwater geothermal heat exchange systems should only be considered in aquifers where high quality groundwater is plentiful and in which water wells can provide adequate water flow.

(a). Standing column well system. A geothermal heat exchange system using a standing column of groundwater within a water well as the heat source. Groundwater is extracted from the bottom of the well and pumped directly to the heat exchanger. After circulating through the heat exchanger, the water is pumped back into the top of the column. There shall be sufficient groundwater present to maintain the standing column of water.

(b). Open loop 2-well system. Groundwater is extracted from one well and pumped through the heating/cooling system and back into the ground through a second well, the recharge well.

C. Enforcing Agency. An agency designated by duly authorized local, regional or State government to administer and enforce laws or ordinances pertaining to the protection of water quality, construction, alteration, maintenance or destruction of geothermal heat exchange wells.

Section 2. Application to type of well

A. These standards shall apply to all geothermal heat exchange wells using a closed loop circulating fluid ground source heat exchange system.

In all geothermal heat exchange wells that use a groundwater source heat exchange system with either an open or a closed loop, well construction and destruction shall conform to the water well standards prescribed in DWR Bulletin 74-90 and subsequent revisions.

Section 3. Best Available Technology (BAT)

1. These standards provide a minimum level of protection for groundwater resources of California. New materials and techniques that are developed in the future that are approved and adopted by industry groups, including, but not limited to, International Ground Source Heat Pump Association, National Ground Water Association, or California Groundwater Association, and that provide equal or greater protection for California=s groundwater quality shall be encouraged and allowed. Such new materials and techniques must equal or exceed the standards in this publication in performance and level of protection.

PART II. Geothermal Heat Exchange Well Construction

Section 4. Borehole diameter of geothermal heat exchange wells

A. Diameter of borehole. The smaller the diameter of the borehole, the greater the thermal exchange efficiency. It may be necessary to drill a variable borehole diameter to allow proper construction to the design depth. The system designer shall consider the impact of borehole diameter on heat transfer as well as the diameter of the loop piping and the need to install a properly sized tremie pipe for successful grouting of the borehole.

The borehole diameter of a geothermal heat exchange well shall be sufficient to allow placement of a 1 1/4 inch tremie pipe, in addition to the loop pipes, to emplace material in the borehole that surrounds the loop pipes. It may be necessary to use a larger diameter tremie pipe in deeper holes to ensure proper placement of the sealing material and filler material.

Such material includes the sealing material and any thermal conductive material that is placed in the borehole in lieu of sealing material to enhance heat exchange. Both sealing material and thermal conductive material shall fill the hole and surround all loop pipes. The diameter of the tremie pipe shall be adequate to ensure proper placement of the sealing material, any thermal conductive material, and filler material. Gravity installation or free fall of sealing material or fill materials without use of a tremie pipe is not permitted. A grout pump shall be required for placing sealing material through a tremie pipe. Any clean fill placed between seals shall be chlorinated.

Section 5. Sealing geothermal heat exchange wells

A. Depth of seal. The sealing of a geothermal heat exchange well shall be completed immediately after the well is drilled to avoid cave-in of the uncased borehole. Full-length sealing material placed by tremie pipe is required to prevent surface contamination or to prevent contaminated water from one aquifer from mixing with waters of another aquifer. The enforcing agency may waive the requirement for full-length sealing in vertical borehole systems provided the agency prescribes alternative sealing methods that meet the minimum standards of this Section and Section 7.

B. Sealing materials. The following sealing materials are approved for use in geothermal heat exchange wells:

1. Bentonite slurry. The seal shall consist of high solids sodium bentonite slurry made from bentonite grout or an 8 mesh granulated bentonite polymer slurry meeting NSF Standard 61 (National Sanitation Foundation) with a minimum of twenty percent (20%) by weight solids (9.4 pounds per gallon grout weight) mixed according to the manufacturer's specification.

   Drilling mud or cuttings shall not be used as sealing materials. Water used in preparing bentonite slurry shall meet the standards in Section 9.D.1. of the Water Well Standards. Bentonite slurry shall be emplaced using a tremie pipe from the bottom of the geothermal heat exchange well to the top of the borehole, excluding the excavation for the header assembly. The tremie pipe may be left in place provided it is completely filled with the high solids bentonite slurry.

   It is recommended that high solids sodium bentonite slurry be used in all geothermal heat exchange wells.

2. Other grout. Other types of grout may be used if approved by Bulletin 74-90 and subsequent revisions or is considered a BAT and has been approved by industry organizations in accordance with Section 3, above.

1. Cement is not permitted as a sealing material because of the expansion of the polyethylene loop pipe caused by the heat of hydration of the cement, and subsequent contraction of the pipe after cooling. Such expansion and contraction does not provide an effective seal.

C. Placement of sealing material. Before placing the sealing material, all loose cuttings or other obstructions shall be removed from the borehole. Sealing material shall be placed in a continuous operation from the bottom of the geothermal heat exchange well to the top of the borehole, excluding the excavation for the header assembly. The sealing material shall be emplaced by pressure pumping through a 1 1/4 inch or larger tremie pipe. The pump shall be such that it can adequately complete the pumping to the total depth of the borehole. The discharge end of the tremie pipe shall be continuously submerged in the sealing material until the zone to be sealed or filled is completed. The sealing material shall fill the hole and surround all heat exchange loop pipes.

If the heat exchange loop pipe can not be emplaced to the total depth of the borehole, the contractor shall ensure that the borehole is sealed from the top of the borehole to the total depth. The tremie pipe may be left in place provided it is completely filled with the high solids bentonite slurry. Gravity installation or free fall of sealing materials without use of a tremie pipe is not permitted.

Section 6. Construction materials

A. Casing. Temporary casing may be used to install geothermal heat exchange wells. Such casing shall be removed upon completion of the well. If a permanent casing must be used, the casing material and installation methods and sealing shall comply with the applicable provisions for casing materials, installation and sealing as specified for water wells in DWR Bulletin 74-90 and subsequent revisions.

B. Heat exchange loop materials.

1. Type of material. In a geothermal heat exchange well, the material used to make up the heat exchange loop must meet industry standards for this application as specified by the International Ground Source Heat Pump Association (IGSHPA). PVC (polyvinyl chloride) pipe shall not be used as loop materials in geothermal heat exchange wells. Generally, closed loop materials are composed of high density polyethylene pipe. Other materials that conform to IGSHPA standards may be used in geothermal heat exchange wells.

2. Connections. All heat exchange loop pipe connections to be placed in the borehole shall be thermally fused according to manufacturer's instructions and shall not leak after assembly. Only fused fittings or non-metallic mechanical stab fittings that meet ASTM D-2513, Section 6.10.1, Category 1, may be used in the header assembly and manifold.

3. Installation. Heat exchange loop materials shall be installed and sealed immediately upon completion of drilling of each geothermal heat exchange well borehole.

4. Metal pipe and fittings. If metal pipe or fittings are to be installed underground, cathodic protection shall be provided. Such a cathodic protection system shall be maintained in operating condition.

C. Loop fluids. Fluids circulated in the loop as the heat exchange medium in geothermal heat exchange wells shall have low toxicity as defined below, and shall be biodegradable. Such fluids are typically water, or water plus a freeze protection additive. Pure water should be used whenever possible. Any water used in the fluid shall be from a potable source.

Commonly used and acceptable freeze protection additives include propylene glycol and ethanol.

The loop fluid, including the water and any additives, shall have an LD_{50} for humans of greater than 25,000 mg/kg of body weight. LD_{50} is the dose that will be lethal to 50% of the population who ingest the fluid in 1 hour.

Undiluted freeze protection additives shall have an LD_{50} for humans of greater than 5,000 mg/kg of body weight. If the LD_{50} for humans is known for a specific additive, that LD_{50} shall be used when calculating the toxicity of the loop fluid. In the absence of human toxicity data, the estimated LD_{50} shall be based on the toxicity data of the most sensitive species, using uncertainty factors as appropriate and in accordance with standard practices in toxicology.

D. Final testing. If pressure testing with water or air to 150 percent above the manufacturer's heat pump operating specifications for a period of 30 minutes shows that any geothermal heat exchange loop leaks, the leaking loop shall be repaired or replaced. If the loop can not be repaired, the loop shall be replaced. If the loop can not be repaired or replaced, the loop and the borehole shall be destroyed in accordance with Part III.

Section 7. Minimum requirements for non-fully sealed geothermal heat exchange systems

A. Hydrogeology and groundwater quality. Construction of non-fully sealed geothermal heat exchange wells shall require knowledge about the site hydrogeology and groundwater quality sufficient to ensure that construction of non-fully sealed wells does not degrade groundwater quality. If such knowledge about the site is not available, only fully sealed geothermal heat exchange wells shall be permitted.

Where groundwater quality meets drinking water standards, no additional action is necessary. Where groundwater quality does not meet drinking water standards as determined by site exploration, the strata containing that poor quality water shall be sealed in accordance with paragraph D below.

B. Borehole size requirements. See Section 4, above.

C. Minimum depth of seals. If the borehole is not sealed throughout its entire length, the minimum depth of surface annular seal shall be the same as specified for domestic water wells in DWR Bulletin 74-90 and subsequent revisions.

D. Sealing between aquifers. If full-length sealing is not done and the geothermal heat exchange well penetrates more than one aquifer and one or more of the aquifers contains water that, if allowed to mix in sufficient quantity, may result in a significant deterioration of the quality of the water in the other aquifer(s), the strata producing such poor-quality water shall be sealed off to prevent mixing of this water with other aquifers. The seal shall extend no less than ten feet (10') above and ten feet (10') below the strata to be sealed off, even if the strata to be sealed is less than 10 feet in thickness. If the stratum to be sealed is at the bottom of the well, the seal need extend only in the upward direction. The sealing material shall fill the borehole and any surrounding void spaces in the interval to be sealed. The seal shall be placed by 1 1/4 inch tremie pipe and adequate pump from bottom to top of the interval to be sealed. Gravity installation or free fall of sealing materials without use of a tremie pipe is not permitted.

E. Fill material. Any fill materials used in non-fully sealed wells shall meet the standards of Bulletin 74-90 and subsequent revisions and shall have appropriate thermal characteristics for the intended heat exchange purpose. Such fill material shall be emplaced by means of a tremie pipe. Gravity installation or free fall of fill materials without use of a tremie pipe is not permitted. Any clean fill placed between seals shall be chlorinated.

F. Placement of fill. Fill material shall be emplaced by use of a 1 1/4 inch tremie pipe. The tremie pipe shall be lowered to the bottom of the zone being filled, and raised slowly as the material is introduced. All fill shall be emplaced in one continuous operation upward from the bottom of the borehole. When using the tremie pipe method to install fill material, the bottom of the tremie shall be maintained as close as possible to, but not inside of, the emplaced fill.

Gravity installation or free fall of fill materials without use of a tremie pipe is not permitted.

G. Sealing materials. Sealing materials shall meet the standards prescribed in Section 5. B.

PART III. Destruction of Geothermal Heat Exchange Wells

Section 8. Destroying a closed loop ground source heat exchange system

A. To destroy a geothermal heat exchange well using a closed loop, ground source heat exchange system, the following procedures shall be completed:

1. Fluid removal. All fluid in the heat exchange loop shall be displaced and disposed of properly.

2. Near surface excavation. A hole shall be excavated at least five feet below the surface around the borehole. The loop pipe in this excavation shall be removed.

3. Sealing the loop in the borehole. The remaining loop shall be completely filled with a high solids bentonite slurry as specified in Section 5.B.(1). The slurry shall be allowed to spill into the excavation to provide a cap at least one foot (1') thick above the loop pipe. The remainder of the excavation shall be filled with compacted earth or pavement.

Section 9. Destroying an open loop or closed loop, groundwater source heat exchange system

A. Destruction of an open loop or closed loop groundwater source heat exchange system shall be completed in conformance with the destruction standards for water wells in DWR Bulletin 74-90 and subsequent revisions.

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