PUBLIC DRAFT

Yolo Subbasin Groundwater Agency

2022 Groundwater Sustainability Plan

APPENDIX A:

Yolo Subbasin Groundwater Agency Joint Powers Agreement

JOINT EXERCISE OF POWERS AGREEMENT
ESTABLISHING THE YOLO SUBBASIN GROUNDWATER AGENCY

THIS AGREEMENT is entered into and effective this 19th day of June, 2017 ("**Effective Date**"), pursuant to the Joint Exercise of Powers Act, Cal. Government Code §§ 6500 *et seq*. ("**JPA Act**") by and among the entities listed in Exhibit A attached hereto and incorporated herein (collectively "**Members**").

RECITALS

A. On August 29, 2014, the California Legislature passed comprehensive groundwater legislation contained in SB 1168, SB 1319 and AB 1739. Collectively, those bills, as subsequently amended, enacted the "Sustainable Groundwater Management Act" ("SGMA"). Governor Brown signed the legislation on September 16, 2014 and it became effective on January 1, 2015.

B. Each of the Members and Affiliated Parties overlies the Yolo Subbasin of the Sacramento Valley Groundwater Basin, California Department of Water Resources Basin No. 5-21.67 as its boundaries may be modified from time to time in accordance with Cal. Water Code Section 10722.2 ("Subbasin").

C. Each of the Members is authorized by SGMA to become, or participate in, a Groundwater Sustainability Agency under SGMA through a joint exercise of powers agreement.

D. The Members desire, through this Agreement, to form the Yolo Subbasin Groundwater Agency, a separate legal entity, for the purpose of acting as the Groundwater Sustainability Agency for the Subbasin. The boundaries of the Agency are depicted on the map attached hereto as Exhibit B and incorporated herein.

E. The mission of the Agency is to provide a dynamic, cost-effective, flexible and collegial organization to ensure compliance with SGMA within the Subbasin.

F. Subject to the reservation of authority in Article 8.5 of this Agreement, the Agency will serve a coordinating and administrative role regarding SGMA compliance within the Subbasin. Each of the Members and Affiliated Parties (or groups of Members and Affiliated Parties) will have initial responsibility for groundwater management within their respective Management Areas as delineated in the Groundwater Sustainability Plan ("GSP") adopted by the Agency.

THEREFORE, in consideration of the mutual promises, covenants and conditions herein set forth, the Members agree as follows:

ARTICLE 1: DEFINITIONS

1.1 **Definitions**. As used in this Agreement, unless the context requires otherwise, the meaning of the terms hereinafter set forth shall be as follows:

a. "**Affiliated Parties**" shall mean those entities that are legally precluded from becoming members of this Agreement but that, after entering into a memorandum of understanding with the Agency, will be granted a voting seat on the Board of Directors pursuant to the terms of this Agreement and the memorandum of understanding. The Affiliated Parties as of the Effective Date are listed in Exhibit C.

b. "**Agency"** shall mean the Yolo Subbasin Groundwater Agency established by this Agreement.

c. "**Agreement**" shall mean this Joint Exercise of Powers Agreement Establishing the Yolo Subbasin Groundwater Agency.

d. "**Board of Directors**" or "**Board**" shall mean the governing body formed to implement this Agreement as established herein.

e. "**DWR**" shall mean the California Department of Water Resources.

f. "**Effective Date**" shall be as set forth in the Preamble of this Agreement.

g. "**Groundwater Sustainability Agency**" or "**GSA**" shall mean an agency enabled by SGMA to regulate portion of the Subbasin cooperatively with all other Groundwater Sustainability Agencies in the Subbasin, in compliance with the terms and provisions of SGMA.

h. "**Groundwater Sustainability Plan**" or "**GSP**" shall have the definition set forth in SGMA.

i. "**GSA Boundary**" shall mean those lands depicted on the map shown in Exhibit B.

j. "**JPA Act**" shall mean the Joint Exercise of Powers Act, Cal. Government Code §§ 6500 et seq.

k. "**Management Area**" shall mean the areas delineated in the GSP for which Members and Affiliated Parties will have initial authority and responsibility for groundwater management in accordance with SGMA.

l. "**Member**" shall mean any of the signatories to this Agreement and "Members" shall mean all of the signatories to this Agreement, collectively. Each of the Members shall be authorized to become, or participate in, a Groundwater Sustainability Agency under SGMA.

m. "**SGMA**" shall mean the California Sustainable Groundwater Management Act of 2014 and all regulations adopted under the legislation (SB 1168, SB 1319 and AB 1739) that collectively comprise the Act, as that legislation and those regulations may be amended or supplemented from time to time.

n. "**Subbasin**" shall mean the Yolo Subbasin of the Sacramento Valley Groundwater Basin, California Department of Water Resources Basin No. 5-21.67 as its boundaries may be modified from time to time in accordance with Cal. Water Code Section 10722.2.

ARTICLE 2: ORGANIZING PRINCIPLES

2.1 The Members and Affiliated Parties intend to work together in mutual cooperation to develop and implement a GSP for the Subbasin in compliance with SGMA.

2.2 To the extent any Member determines, in the future, to become a GSA separate and apart from the Agency, the Agency will allow such Member to become a GSA and the Agency will work cooperatively with such Member to coordinate implementation of SGMA within the Subbasin.

2.3 The Members intend through this Agreement to obtain cost-effective consulting services for the development and implementation of a GSP, in particular for the development of water balances.

ARTICLE 3: FORMATION, PURPOSE AND POWERS

3.1 **Recitals:** The foregoing recitals are incorporated by reference.

3.2 **Certification.** Each Member certifies and declares that it is a legal entity that is authorized to be a party to a joint exercise of powers agreement and to contract with each other for the joint exercise of any common power under Article 1, Chapter 5, Division 7, Title 1, of the Government Code, commencing with section 6500 or other applicable law including but not limited to Cal. Water Code § 10720.3(c).

3.3 **Creation of the Agency.** Pursuant to the JPA Act, the Members hereby form and establish a public entity to be known as the "Yolo Subbasin Groundwater Agency," which shall be a public entity separate and apart from the Members.

3.4 **Designation.** Pursuant to Government Code § 6509, the Members hereby designate the County of Yolo for purposes of determining restrictions upon the manner of exercising the power of the Agency.

3.5 **Purposes of the Agency**. The purposes of the Agency are to:

a. Provide for the joint exercise of powers common to each of the Members and powers granted pursuant to SGMA (subject to the restrictions contained in this Agreement);

b. Cooperatively carry out the purposes of SGMA;

c. Become a GSA for purposes of management of the Subbasin in accordance with SGMA; and

d. Develop, adopt and implement a legally sufficient GSP for the Subbasin, subject to the limitations set forth in this Agreement.

3.6 **Powers of the Agency.** To the extent authorized through the Board of Directors, and subject to the limitations set forth in this Agreement, the Agency shall have and may exercise any and all powers commonly held by the Members in pursuit of the Agency's purposes, as described in Article 3.5, including but not limited to the power:

a. To exercise all powers granted to a GSA under SGMA;

b. To take any action for the benefit of the Members and Affiliated Parties necessary or proper to carry out the purposes of the Agency as provided in this Agreement and to exercise all other powers necessary and incidental to the exercise of the powers set forth herein;

c. To levy, impose and collect reasonable taxes, fees, charges, assessments and other levies to implement the GSP and/or SGMA;

d. To borrow funds and to apply for grants and loans for the funding of activities within the purposes of the Agency;

e. To adopt rules, regulations, policies, bylaws and procedures related to the purposes of the Agency;

f. To sue and be sued; and

g. To issue revenue bonds.

3.7 **Powers Reserved to Members.** Each of the Members reserves the right, in its sole and absolute discretion, to become a GSA and to exercise the powers conferred to a GSA within the Member's boundaries in accordance with Article 6.7 of this Agreement.

3.8 **Relationship of Members and Affiliated Parties to Each Other.** Each Member and each Affiliated Party shall be individually responsible for its own covenants, obligations and liabilities under this Agreement. No Member or Affiliated Party shall be deemed to be the agent of, or under the direction or control of, or otherwise have the right or power to bind, any other Member or Affiliated Party without the express written consent of the Member or Affiliated Party.

3.9 **Term.** This Agreement shall be effective as of the Effective Date and shall remain in effect until terminated in accordance with Article 6.5 of this Agreement.

3.10 **Boundaries of the Agency**. The geographic boundaries of the Agency and that portion of the Subbasin that will be managed by the Agency pursuant to SGMA are depicted in Exhibit B**.**

3.11 **Role of Members and Affiliated Parties.** Each Member and Affiliated Party agrees to undertake such additional proceedings or actions as may be necessary in order to carry out the terms and intent of this Agreement. The support of each Member and each Affiliated Party is required for the success of the Agency. This support will involve the following types of actions:

a. The Members and Affiliated Parties will provide support to the Board of Directors and any third party facilitating the development of the GSP by making available staff time, information and facilities within available resources.

b. Policy support shall be provided by the Members and Affiliated Parties to either approve, or respond quickly to, any recommendations made as to funding shares, operational decisions, fare structures, and other policy areas.

c. Each Member and Affiliated Party shall contribute its share of operational fund allocations, as established and approved by the Board of Directors in the Agency's annual budget.

d. Contributions of public funds and of personnel, services, equipment or property may be made to the Agency by any Member or Affiliated Party for any of the purposes of this Agreement, provided that no repayment will be made by the Agency for such contributions in the absence of a separate written contract between the Agency and the contributing Member or Affiliated Party.

e. To the extent that Members and Affiliated Parties make personnel available to the Agency as contemplated under the provisions of Section 3.11, the Members acknowledge and agree that at all times such personnel shall remain under the exclusive control of the Member or Affiliated Party supplying such personnel. The Agency shall not have any right to control the manner or means in which such personnel perform services. Rather, the Member or Affiliated Party supplying personnel shall have the sole and exclusive authority to do the following:

(i) Make decisions regarding the hiring, retention, discipline or termination of personnel. The Agency will have no discretion over these functions.

(ii) Determine the wages to be paid to personnel, including any pay increases. These amounts shall be determined in accordance with the Member or Affiliated Party's published publicly available pay schedule, if any, and shall be subject to changes thereto approved by its governing body.

(iii) Set the benefits of its personnel, including health and welfare benefits, retirement benefits and leave accruals in accordance with the Member or Affiliated Party's policies.

(iv) Evaluate the performance of its personnel through performance evaluations performed by a management level employee that reports directly to a representative of the Member or Affiliated Party or its governing body.

(v) Perform all other functions related to the service, compensation or benefits of any personnel assigned to perform services on behalf of the Agency.

3.12 **Employees**. The Members do not anticipate that the Agency will have any employees. However, the Agency may do any of the following:

a. Engage one or more Members or third parties to manage any or all of the business of the Agency on terms and conditions acceptable to the Board of Directors as specified in a separate written contract. To the extent that a manager is appointed, the manager shall at all times maintain exclusive control over any employees of the manager assigned to perform services under the manager's contract with the Agency, including, but not limited to, matters related to hiring, probationary periods, disciplinary action, termination, benefits, performance evaluations, salary determinations, promotions and demotions, and leave accruals.

b. The Board shall have the power to contract with competent registered civil engineers and other consultants to investigate and to carefully devise a plan or plans to carry out and fulfill the objects and purposes of SGMA, and complete a GSP.

3.13 **Participation of Affiliated Parties**. The Agency shall allow Affiliated Parties to participate in the governance of the Agency and on its Board of Directors in the same manner as Members, provided that each Affiliated Party agrees, through a memorandum of understanding ("MOU") with the Agency, to adhere to all applicable terms of this Agreement, including the payment of the Affiliated Party's assigned share of operational fund allocations, as established by the Board of Directors in the annual budget. The MOU may include provisions tailored to the unique circumstances or characteristics of the Affiliated Parties. The MOU shall also address, without limitation, the nature and extent of any obligations of the Agency to hold harmless, defend and indemnify Affiliated Parties. The designated representative of an Affiliated Party shall join the Board of Directors as soon as that Affiliated Party has entered into an MOU with the Agency. Affiliated Parties shall have the right to withdraw from participation in the governance of the Agency and on the Board of Directors, subject to the provisions of the MOU between the Agency and that Affiliated Party. Entities not listed in Exhibit C may request to be included as Affiliated Parties, and the Board of Directors shall decide whether to allow such entities to become Affiliated Parties in accordance with Article 6.1.

ARTICLE 4: GOVERNANCE

4.1 **Board of Directors**. The business of the Agency will be conducted by a Board of Directors that is hereby established and that shall be initially composed of one representative from each of the Members and one representative from each of the Affiliated Parties. Without amending this Agreement, the composition of the Board of Directors shall be altered from time to time to reflect the withdrawal or involuntary termination of any Member or Affiliated Party

and/or the admission of any new Member or Affiliated Party. Each Member and each Affiliated Party will appoint one member of the Agency Board of Directors. Each Member and each Affiliated Party may designate one alternate to serve in the absence of that Member's or Affiliated Party's appointed Director. All members of the Agency Board of Directors and all alternates will be required to file a Statement of Economic Interests (FPPC Form 700). Each Member and each Affiliated Party shall notify the Agency in writing of its designated representative on the Agency Board of Directors.

4.2 **Term of Directors.** Each member of the Agency Board of Directors will serve until replaced by the appointing Member or Affiliated Party.

4.3 **Officers.** The Board of Directors shall elect a chairperson, a vice chairperson, a secretary and a treasurer. The chairperson and vice-chairperson shall be directors of the Board and the secretary and treasurer may, but need not, be directors of the Board. The chairperson shall preside at all meetings of the Board and the vice-chairperson shall act as the chairperson in the absence of the chairperson elected by the Board. The treasurer shall meet the qualifications set out in Government Code section 6505.5 as a depositary of funds for the Agency.

4.4 **Powers and Limitations**. All the powers and authority of the Agency shall be exercised by the Board, subject, however, to the rights reserved by the Members and Affiliated Parties as set forth in this Agreement.

4.5 **Quorum.** A majority of the members of the Agency Board of Directors will constitute a quorum.

4.6 **Voting.** Except as to actions identified in Article 4.7, the Agency Board of Directors will conduct all business by majority vote of those directors present. Each member of the Board of Directors will have one (1) vote. Prior to voting, the Members and Affiliated Parties shall endeavor in good faith to reach consensus on the matters to be determined such that any subsequent vote shall be to confirm the consensus of the Members and Affiliated Parties. If any Member or Affiliated Party strongly objects to a consensus-based decision prior to a vote being cast, the Members and Affiliated Parties shall work in good faith to reasonably resolve such strong objection, and, if the same is not resolved collaboratively, then the matter will proceed to a vote for final resolution under this Article 4.6 or Article 4.7, below, as applicable.

4.7 **Supermajority Vote Requirement for Certain Actions.** The following actions will require a two-thirds (2/3) vote by the directors present:

a. Approval of the Agency's annual budget;

b. Decisions related to the levying, imposition or collection of taxes, fees, charges and other levies;

c. Decisions related to the expenditure of funds by the Agency beyond expenditures approved in the Agency's annual budget;

d. Adoption of rules, regulations, policies, bylaws and procedures related to the function of the Agency;

e. Decisions related to the establishment or adjustment of the Members' or Affiliated Parties' obligations for payment of the Agency's operating and administrative costs as provided in Article 5.1;

f. Approval of a GSP;

g. Involuntary termination of a Member or Affiliated Party pursuant to Article 6.3;

h. With respect to the addition of Affiliated Parties other than those listed in Exhibit D, approval of (i) a memorandum of understanding between the Agency and any such Affiliated Parties, (ii) the addition of such Affiliated Parties to this Agreement, and (iii) a voting seat for such Affiliated Parties on the Agency Board of Directors;

i. Amendment of this Agreement; provided, however, that the provisions of Article 6.7 (Rights of Member to Become GSA in Event of Withdrawal or Termination) may be amended only by unanimous vote of the Board of Directors;

j. Modification of the funding amounts specified in Exhibit D;

k. The addition of new Members to this Agreement; and

l. Termination of this Agreement.

4.8 **Meetings.** The Board shall provide for regular and special meetings in accordance with Chapter 9, Division 2, Title 5 of Government Code of the State of California (the "Ralph M Brown Act" commencing at section 54950), and any subsequent amendments of those provisions.

4.9 **By-Laws.** The Board may adopt by-laws to supplement this Agreement. In the event of conflict between this Agreement and the by-laws, the provisions of this Agreement shall govern.

4.10 **Administrator.** The Members hereby designate Yolo County Flood Control and Water Conservation District to serve as administrator of, and keeper of records for, the Agency.

ARTICLE 5: FINANCIAL PROVISIONS

5.1 **Contributions and Expenses:** Members and Affiliated Parties shall share in the general operating and administrative costs of operating the Agency in accordance with the funding amounts set forth in Exhibit D attached hereto and incorporated herein. Each Member and Affiliated Party will be assessed quarterly, beginning on July 1 of each year. Members and Affiliated Parties shall pay assessments within thirty (30) days of receiving assessment notice from the Treasurer. Each Member and each Affiliated Party will be solely responsible for raising funds for payment of the Member's or Affiliated Party's share of the Agency's general operating and administrative costs. The obligation of each Member and each Affiliated Party to make payments under the terms and provision of this Agreement is an individual and several obligation

and not a joint obligation with those of the other Members and Affiliated Parties. Contributions of grant funding, state, federal, or county funding may be provided as funding or a portion of funding on behalf of Members and Affiliated Parties.

5.2 **Liability for Debts.** The Members do not intend through this Agreement to be obligated either jointly or severally for the debts, liabilities or obligations of the Agency, except as may be specifically provided for in Government Code § 895.2 as amended or supplemented; provided, however, that if any Member is held liable for the acts and omissions of the Agency caused by negligent or wrongful acts or omissions occurring in the performance of this Agreement, such Member shall be entitled to contribution from the other Members so that after such contribution each Member bears its proportionate share of the liability in accordance with Article 5.1 and Exhibit D. This Article 5.2 shall not apply to acts or omissions of a Member in implementing the GSP adopted by the Agency within such Member's boundaries or a Management Area managed in whole or in part by such Member.

5.3 **Indemnification.** The Agency shall hold harmless, defend and indemnify the Members and their officers, employees and agents, and members of the Agency Board of Directors, from and against any and all liability, claims, actions, costs, damages or losses of any kind, including death or injury to any person and/or damage to property arising out of the activities of the Agency or its Board, officers, employees or agents under this Agreement. These indemnification obligations shall continue beyond the Term of this Agreement as to any acts or omissions occurring before or under this Agreement or any extension of this Agreement. The obligations of the Agency to hold harmless, defend and indemnify Affiliated Parties, if any, will be addressed in the separate MOUs between the Agency and Affiliated Parties.

5.4 **Repayment of Funds**. No refund or repayment of the initial commitment of funds specified in Article 5.2 will be made to a Member or Affiliated Party ceasing to be a Member or Affiliated Party, whether pursuant to removal by the Board of Directors or pursuant to a voluntary withdrawal. The refund or repayment of any other contribution shall be made in accordance with the terms and conditions upon which the contribution was made, the terms and conditions of this Agreement or other agreement of the Agency and withdrawing Member or Affiliated Party.

5.5 **Budget**. The Agency's fiscal year shall run from July 1 through June 30. Each fiscal year, the Board shall adopt a budget for the Agency for the ensuing fiscal year. Within ninety (90) days of the effective date of this Agreement, the Board shall adopt a budget. Thereafter, a budget shall be adopted no later than June 1 of the preceding fiscal year. A draft budget shall be prepared no later than March 1 of the preceding fiscal year.

5.6 **Alternate Funding Sources.** The Board may obtain State of California or federal grants.

5.7 **Depositary.** The Board shall designate a Treasurer of the Agency, who shall be the depositary and have custody of all money of the Agency, from whatever source, subject to the applicable provisions of any indenture or resolution providing for a trustee or other fiscal agent. All funds of the Agency shall be held in separate accounts in the name of the Agency and

not commingled with funds of any Member or Affiliated Party or any other person or entity. The Treasurer shall perform the duties specified in Government Code §§6505 and 6505.5.

5.8 **Accounting.** Full books and accounts shall be maintained for the Agency in accordance with practices established by, or consistent with, those utilized by the Controller of the State of California for like public entities. The books and records of the Agency shall be open to inspection by the Members and Affiliated Parties at all reasonable times, and by bondholders and lenders as and to the extent provided by resolution or indenture.

5.9 **Audit.** A qualified firm, serving in the capacity of auditor, shall audit the records and the accounts of the Agency annually in accordance with the provisions of section 6505 of the Law. Copies of such audit reports shall be filed with the State Controller and each Member and each Affiliated Party within six months of the end of the Fiscal Year under examination.

5.10 **Expenditures.** All expenditures within the designations and limitations of the applicable approved budget shall be made upon the approval of any officer so authorized by the Agency Board of Directors. The Treasurer shall draw checks or warrants or make payments by other means for claims or disbursements not within an applicable budget only upon the approval and written order of the Board. The Board shall requisition the payment of funds only upon approval of claims or disbursements and requisition for payment in accordance with policies and procedures adopted by the Board.

5.11 **Reconsideration of Voting Structure and Expense Allocation.** No later than the first Board meeting following the two-year anniversary of the Effective Date of this Agreement, the Board of Directors shall consider whether to recommend to the Members that the voting structure described in Article 4.6 and/or the expense allocation provisions described in Article 5.1 and Exhibit D should be modified in any respect. If the Board of Directors recommends modification of Article 4.6, Article 5.1, or Exhibit D, the governing body of each Member and each Affiliated Party shall consider the modifications recommended by the Board of Directors and, within 45 days following the Board recommendation, shall report back to the Board of Directors regarding the Member's or Affiliated Party's position regarding the recommended modifications.

ARTICLE 6: CHANGES TO MEMBERSHIP, WITHDRAWAL AND TERMINATION

6.1 **Changes to Members and Affiliated Parties.** The Agency Board of Directors may, in its sole and absolute discretion, approve the addition of new Members or Affiliated Parties to the Agency by supermajority vote. In the event of Board approval of a new Member the new Member shall execute this Agreement but amendment of this Agreement will not be required. In the event of Board approval of a new Affiliated Party the new Affiliated Party shall execute a memorandum of understanding in accordance with Article 3.13. The Board of Directors shall provide all Members and Affiliated Parties with 30 days' advance written notice prior to any Board action to add a new Member or Affiliated Party.

6.2 **Noncompliance**. In the event any Member or Affiliated Party (1) fails to comply with the terms of this Agreement, or (2) undertakes actions that conflict with or undermine the functioning of the Agency or the preparation or implementation of the GSP, such Member or

Affiliated Party shall be subject to the provisions for involuntary removal of a Member or Affiliated Party set forth in of Article 6.3 of this Agreement. Such actions of a Member or Affiliated Party shall be as determined by the Board of Directors and may include, for example, failure to pay its agreed upon contributions when due, refusal to participate in GSA activities or to provide required monitoring of sustainability indicators; refusal to enforce controls as required by the GSP; refusal to implement any necessary actions as outlined by the approved GSP minimum thresholds that are likely to lead to "undesirable results" under SGMA.

6.3 **Involuntary Termination**. If the Board of Directors determines that a Member or Affiliated Party is in noncompliance as provided in Article 6.2, the Board of Directors may terminate that Member's or Affiliated Party's participation in this Agency, provided that, prior to any such vote, all of the Members and Affiliated Parties shall meet and confer regarding all matters related to the proposed removal. In the event of the involuntary termination of a Member or Affiliated Party, the terminated Member or Affiliated Party shall remain fully responsible for its proportionate share of all financial obligations and liabilities incurred by the Agency prior to the effective date of termination as specified in Article 5.1 and Exhibit D, as existing as of the effective date of termination.

6.4 **Withdrawal of Members and Affiliated Parties.** Subject to the provisions of Article 6.7, a Member or Affiliated Party may, in its sole discretion, unilaterally withdraw from participation in the Agency, effective upon ninety (90) days' prior written notice to the Agency, provided that (a) the withdrawing Member or Affiliated Party will remain responsible for its proportionate share of any obligation or liability duly incurred by the Agency, as specified in Article 5.1 and Exhibit D, as existing as of the effective date of withdrawal. A withdrawing Member or Affiliated Party will not be responsible for any obligation or liability that the Member or Affiliated Party has voted against or has voiced its disapproval on at a Board meeting, providing the Member or Affiliated Party gives notice of its withdrawal from the Agency as soon thereafter as is practicable. In the event the withdrawing Member or Affiliated Party has any rights in any property or has incurred obligations to the Agency, the Member or Affiliated Party may not sell, lease or transfer such rights or be relieved of its obligations, except in accordance with a written agreement executed by it and the Agency. The Agency may not sell, lease, transfer or use any rights of a Member or Affiliated Party who has withdrawn without first obtaining the written consent of the withdrawing Member or Affiliated Party.

6.5 **Termination of Agreement**. This Agreement and the Agency may be terminated by a supermajority vote of the Board of Directors. However, in the event of termination, each of the Members and Affiliated Parties will remain responsible for its proportionate share of any obligation or liability duly incurred by the Agency, in accordance with Article 5.1 and Exhibit D, as existing as of the effective date of termination. Nothing in this Agreement will prevent the Members or Affiliated Parties from withdrawing as provided in this Agreement, or from entering into other joint exercise of power agreements.

6.6 **Disposition of Property Upon Termination**. Upon termination of this Agreement, the assets of the Agency shall be transferred to the Agency's successor, provided that a public entity will succeed the Agency, or in the event that there is no successor public entity, to the Members and Affiliated Parties in proportion to the contributions made by each Member or Affiliated Party. If the successor public entity will not assume all of the Agency's

assets, the Board shall distribute the Agency's assets between the successor entity and the Members and Affiliated Parties in proportion to the any obligation required by Articles 5.1 or 5.6.

6.7 **Rights of Members and Affiliated Parties to Become GSA in Event of Withdrawal or Termination.** Upon withdrawal or involuntary termination of a Member or Affiliated Party, or termination of this Agreement pursuant to Article 6.5, whether occurring before or after June 30, 2017, the withdrawing or terminated Member or Affiliated Party will retain all rights and powers to become or otherwise participate in a GSA for the lands within its boundaries. In such event, the Agency and its remaining Members and Affiliated Parties shall (i) not object to or interfere with the lands in the withdrawing or terminated Member's or Affiliated Party's boundaries being in a GSA, as designated by the withdrawing or terminated Member or Affiliated Party or otherwise; (ii) facilitate such transition to the extent reasonably necessary; and (iii) where the withdrawing Member or Affiliated Party has authority under SGMA to be or participate in a GSA, withdraw from managing that portion of the Subbasin within the boundaries of the withdrawing or terminated Member or Affiliated Party and so notify the California Department of Water Resources. In order to maintain compliance with SGMA in the event of the withdrawal or involuntary termination of a Member or Affiliated Party, where the withdrawing Member or Affiliated Party has authority under SGMA to be or participate in a GSA, the withdrawal or involuntary termination will not be effective until a GSA has been established in accordance with SGMA for those lands overlying the Subbasin affected by the withdrawal or involuntary termination.

6.8 **Use of Data**. Upon withdrawal, any Member or Affiliated Party shall be entitled to use any data or other information developed by the Agency during its time as a Member or Affiliated Party. Further, should a Member or Affiliated Party withdraw from the Agency after completion of the GSP, it shall be entitled to utilize the GSP for future implementation of SGMA within its boundaries.

ARTICLE 7: SPECIAL PROJECTS

7.1 **Special Project Agreements.** Fewer than all of the Members and Affiliated Parties may enter into a special project agreement to achieve any of the purposes or activities authorized by this Agreement, and to share in the expenses and costs of such special project, for example, to share in funding infrastructure improvements within the boundaries of only those Members and Affiliated Parties and their Management Areas. Special project agreements must be in writing and documentation and must be provided to each of the Members and Affiliated Parties.

7.2 **Expenses.** Members and Affiliated Parties that enter into special project agreements agree that any special project expenses incurred for each such special project are the costs of the special project participants, respectively, and not of any other Members or Affiliated Parties not participating in the special project, and the special project expenses shall be paid by the parties to the respective special project agreements.

7.3 **Indemnification of Other Members.** Members and Affiliated Parties participating in special project agreements if conducted by the Agency, shall hold other Members and Affiliated Parties who are not parties to the special project agreement free and harmless from and indemnify each of them against any and all costs, losses, damages, claims and liabilities arising from the special project agreement. The indemnification obligation of Members and Affiliated Parties participating in special project agreements shall be the same as specified in Article 5.2 for Members and Affiliated Parties in general, except that they shall be limited to liabilities incurred for the special project.

ARTICLE 8: ACTIONS BY THE AGENCY WITHIN MANAGEMENT AREAS AND INDIVIDUAL JURISDICTIONS

8.1 **Role of the Agency.** Subject to the reservation of authority set forth in Article 8.5, the Agency will serve a coordinating and administrative role in order to provide for sustainable groundwater management of the Subbasin in a manner that does not limit any Member's or Affiliated Party's rights or authority over its own water supply matters, including, but not limited to, a Member's or Affiliated Part's surface water supplies, groundwater supplies, facilities, operations, water management and financial affairs.

8.2 **Members' and Affiliated Parties' Responsibility within Management Areas and Individual Jurisdictions.** Subject to the reservation of authority in Article 8.5, each of the Members and Affiliated Parties (or groups of Members and Affiliated Parties) will have initial responsibility to implement SGMA and the GSP adopted by the Agency within their respective Management Areas, as delineated in the GSP.

8.3 **Water Budgets.** The GSP will provide for the preparation of water budgets by Members or Affiliated Parties or groups of Members and Affiliated Parties for their respective Management Areas. The GSP will specify the elements to be included in water budgets and the timing for completion.

8.4 **Sustainability.** In the event a water budget prepared in accordance with Article 8.3 shows that groundwater pumping within a Management Area exceeds such area's sustainable yield, as defined in Cal. Water Code § 10721(v) and (w), or an "undesirable result," as defined in Cal. Water Code § 10721(x), exists, the Member or Affiliated Party or group of Members and Affiliated Parties with groundwater management responsibility over such area shall develop and implement a plan to achieve sustainability or eliminate the undesirable result within that area. The GSP will specify the elements to be included in and time requirements for implementation of the plan.

8.5 **Reservation of Authority**. In the event of a failure by a Member or Affiliated Party or group of Members or Affiliated Parties to develop and implement a plan to achieve sustainability or eliminate an undesirable result within a Management Area as provided in Article 8.4, the Agency reserves and retains all requisite authority to (i) develop and implement a plan to achieve sustainability or eliminate an undesirable result, and (ii) allocate the cost of development and implementation of such plan to Members or Affiliated Parties within such

Management Area. The GSP will specify the procedures for development and implementation of a plan by the Agency under such circumstances.

ARTICLE 9: MISCELLANEOUS PROVISIONS

9.1 **Amendments**. This Agreement may be amended from time to time by a supermajority vote of the Board of Directors; provided, however, that the provisions of Article 6.7 (Rights of Member to Become GSA in Event of Withdrawal or Termination) may be amended only by unanimous vote of the Board of Directors.

9.2 **Binding on Successors**. The rights and duties of the Members and Affiliated Parties under this Agreement may not be assigned or delegated without the advance written consent of the Agency (as evidenced by a majority vote of the Board of Directors) and any attempt to assign or delegate such rights or duties in contravention of this Article 9.2 shall be null and void. Any approved assignment or delegation shall be consistent with the terms of any contracts, resolutions, indemnities and other obligations of the Agency then in effect.

9.3 **Notice**. Any notice or instrument required to be given or delivered under this Agreement may be made by: (a) depositing the same in any United States Post Office, postage prepaid, and shall be deemed to have been received at the expiration of 72 hours after its deposit in the United States Post Office; (b) transmission by facsimile copy to the addressee; (c) transmission by electronic mail; or (d) personal delivery to the addresses or facsimile numbers of the Members and Affiliated Parties set forth in Exhibit E to this Agreement.

9.4 **Counterparts**. This Agreement may be executed by the Members in separate counterparts, each of which when so executed and delivered shall be an original. All such counterparts shall together constitute but one and the same instrument.

9.5 **Choice of Law**. This Agreement shall be governed by the laws of the State of California.

9.6 **Severability**. If one or more clauses, sentences, paragraphs or provisions of this Agreement is held to be unlawful, invalid or unenforceable, it is hereby agreed by the Members that the remainder of the Agreement shall not be affected thereby. Such clauses, sentences, paragraphs or provisions shall be deemed reformed so as to be lawful, valid and enforced to the maximum extent possible.

9.7 **Headings**. The paragraph headings used in this Agreement are intended for convenience only and shall not be used in interpreting this Agreement or in determining any of the rights or obligations of the Members to this Agreement.

9.8 **Construction and Interpretation**. This Agreement has been arrived at through negotiation and each Member has had a full and fair opportunity to revise the terms of this Agreement. As a result, the normal rule of construction that any ambiguities are to be resolved

against the drafting Member shall not apply in the construction or interpretation of this Agreement.

9.9 **Entire Agreement.** This Agreement constitutes the entire agreement among the Members and supersedes all prior agreements and understandings, written or oral. This Agreement may only be amended by written instrument executed by all Members.

IN WITNESS WHEREOF, the Members have executed this Agreement on the day and year first above-written to form and establish the Yolo Subbasin Groundwater Agency.

City of Davis

By: _____
Robb Davis, Mayor

ATTEST:

By: _____
Zoe Mirabile, City Clerk

APPROVED AS TO FORM:

By: _____
Harriet Steiner, City Attorney

City of West Sacramento

By: _____
Christopher L. Cabaldon, Mayor

ATTEST:

By: Teresa Willock, Deputy
Kryss Rankin, City Clerk

APPROVED AS TO FORM:

By: _____
Jeffrey Mitchell, City Attorney

City of Winters

By: _____
Wade Cowan, Mayor

ATTEST:

By: _____
Nanci G. Mills, City Clerk

APPROVED AS TO FORM:

By: _____
Ethan Walsh, City Attorney

City of Woodland

By: _____
Angel Barajas, Mayor

ATTEST:

By: _____
Ana Gonzalez, City Clerk

APPROVED AS TO FORM:

By: _____
Kara Ueda, City Attorney

Dunnigan Water District

By: _____
Name: Blair Voelz
Its: President

Esparto Community Services District

By: _____
Name: Charlie Schaupp
Its: Chair

Madison Community Services District

By: _____
Name: Steve Gomez
Its: Chair

Reclamation District 108

By: _____
Name: Frederick "Fritz" Durst
Its: President

Dunnigan Water District

By: _____
Name: Blair Voelz
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Name: Steve Gomez
Its: Chair

Reclamation District 108

By: _____
Name: Frederick "Fritz" Durst
Its: President

Reclamation District 537

By: _____
Name: Kristen E. Pigman
Its: President

Reclamation District 827

By: _____
Name: Daniel F. Ramos
Its: President

Reclamation District 730

By: _____
Name: James Heidrick
Its: Trustee

Reclamation District 1600

By: _____
Name: Kent Lang
Its: President

Reclamation District 765

By: _____
Name:
Its:

Reclamation District 2035

By: _____
Name: Robert Thomas
Its: President

Reclamation District 785

By: _____
Name: Ross Peabody
Its: President

Yocha Dehe Wintun Nation

By: _____
Name: James Kinter
Its: Tribal Secretary

Reclamation District 787

By: _____
Name: Roger Cornwell
Its: President

Yolo County Flood Control and Water Conservation District

By: _____
Name: Erik Vink
Its: Chair

Reclamation District 537

By: _____
Name:
Its:

Reclamation District 730

By: James Heidrick
Name: James Heidrick
Its: Trustee

Reclamation District 765

By: _____
Name:
Its:

Reclamation District 785

By: _____
Name: Ross Peabody
Its: President

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Its: Tribal Secretary

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By: _____
Name: Erik Vink
Its: Chair

Reclamation District 537

By: _____
Name:
Its:

Reclamation District 730

By: _____
Name: James Heidrick
Its: Trustee

Reclamation District 765

By: _____
Name:
Its:

Reclamation District 785

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Name: Ross Peabody
Its: President

Reclamation District 787

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Name: Roger Cornwell
Its: President

Reclamation District 827

By: _____
Name:
Its:

Reclamation District 1600

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Name: Kent Lang
Its: President

Reclamation District 2035

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Name: Robert Thomas
Its: President

Yocha Dehe Wintun Nation

By: _____
Name: James Kinter
Its: Tribal Secretary

Yolo County Flood Control and Water Conservation District

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Name: Erik Vink
Its: Chair

Reclamation District 537

By: _____
Name:
Its:

Reclamation District 730

By: _____
Name: James Heidrick
Its: Trustee

Reclamation District 765

By: _____
Name: Doug Dickson
Its: President

Reclamation District 785

By: _____
Name: Ross Peabody
Its: President

Reclamation District 787

By: _____
Name: Roger Cornwell
Its: President

Reclamation District 827

By: _____
Name:
Its:

Reclamation District 1600

By: _____
Name: Kent Lang
Its: President

Reclamation District 2035

By: _____
Name: Robert Thomas
Its: President

Yocha Dehe Wintun Nation

By: _____
Name: James Kinter
Its: Tribal Secretary

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By: _____
Name: Erik Vink
Its: Chair

Reclamation District 537

By: _____
Name:
Its:

Reclamation District 730

By: _____
Name: James Heidrick
Its: Trustee

Reclamation District 765

By: _____
Name:
Its:

Reclamation District 785

By: _____
Name: Ross Peabody
Its: President

Reclamation District 787

By: _____
Name: Roger Cornwell
Its: President

Reclamation District 827

By: _____
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Its:

Reclamation District 1600

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Name: Kent Lang
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Reclamation District 2035

By: _____
Name: Robert Thomas
Its: President

Yocha Dehe Wintun Nation

By: _____
Name: James Kinter
Its: Tribal Secretary

Yolo County Flood Control and Water Conservation District

By: _____
Name: Erik Vink
Its: Chair

Reclamation District 537

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Name:
Its:

Reclamation District 730

By: _____
Name: James Heidrick
Its: Trustee

Reclamation District 765

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Name:
Its:

Reclamation District 785

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Reclamation District 787

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Name: Roger Cornwell
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Reclamation District 827

By: _____
Name:
Its:

Reclamation District 1600

By: _____
Name: Kent Lang
Its: President

Reclamation District 2035

By: _____
Name: Robert Thomas
Its: President

Yocha Dehe Wintun Nation

By: _____
Name: James Kinter
Its: Tribal Secretary

Yolo County Flood Control and Water Conservation District

By: _____
Name: Erik Vink
Its: Chair

Yolo County

By: _____
Duane Chamberlain, Chair
Board of Supervisors

APPROVED AS TO FORM:

By: _____
Philip J. Pogledich, County Counsel

ATTEST: Julie Dachtler, Deputy Clerk
Board of Supervisors

By: _____
Deputy (SEAL)

Exhibit A
List of Members

Member Agencies
City of Davis
City of West Sacramento
City of Winters
City of Woodland
Dunnigan Water District
Esparto Community Service District (CSD)
Madison CSD
Reclamation District (RD) 108
RD 537
RD 730
RD 765
RD 785
RD 787
RD 827
RD 1600
RD 2035
Yocha Dehe Wintun Nation
Yolo County
Yolo County Flood Control and Water Conservation District

Exhibit B

Map of Agency Boundaries

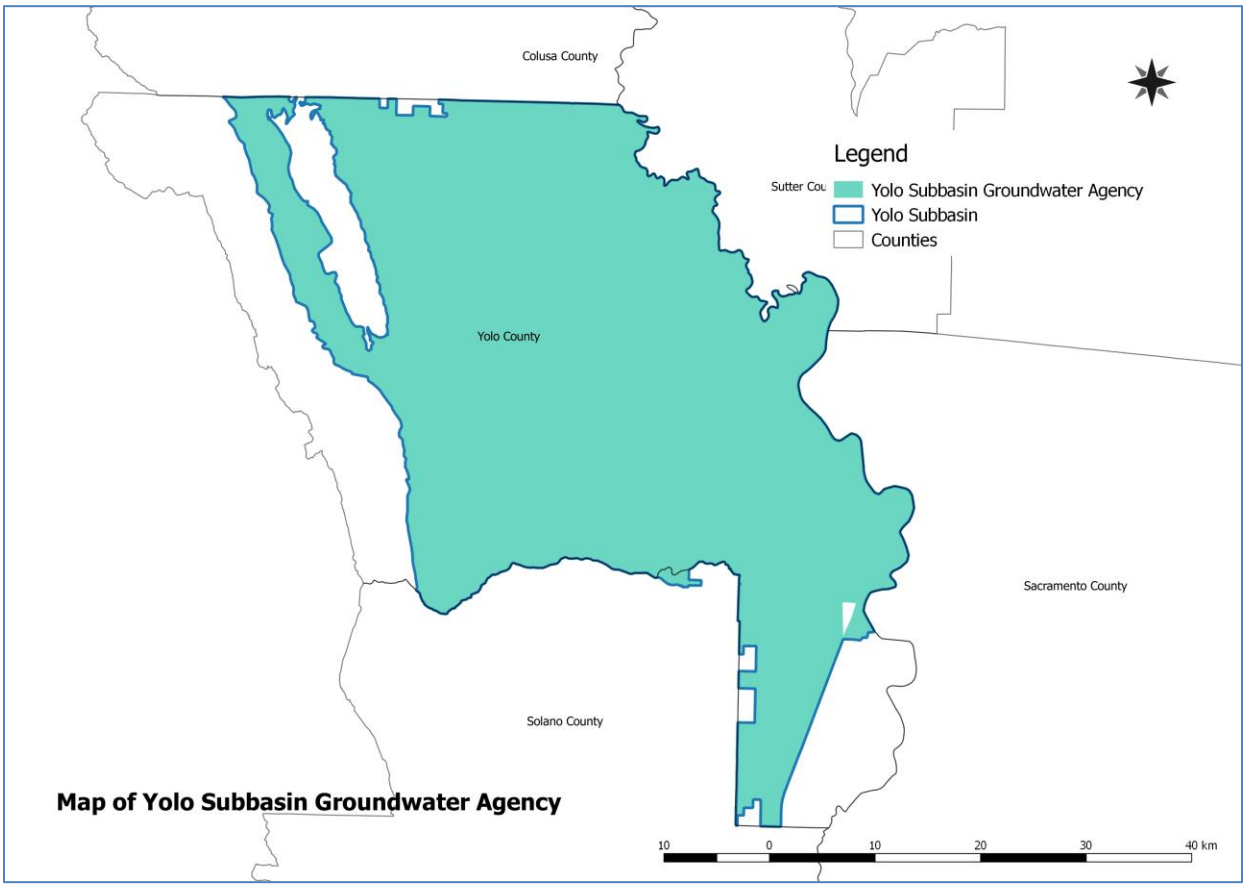

Exhibit C

List of Affiliated Parties

Affiliated Parties
California American Water Company -- Dunnigan
Colusa Drain Mutual Water Company
Environmental Party**
University of California, Davis
Private Pumper Representative as appointed by Yolo County Farm Bureau

**To be determined.

Exhibit D

Funding Amounts

It is proposed that administrative fees in the range of approximately $400,000 to $500,000 per year be collected for the first two years of the GSA. **After two years, the fee structure will be revisited and adjusted as appropriate.**

Key

Blue = JPA Parties and Existing WRA member

Orange = JPA Parties

Entity Contributions		
Municipal Agencies		**$**
City of Davis		$40,000
City of Woodland		$40,000
City of West Sacramento		$40,000
City of Winters		$20,000
Yocha Dehe Wintun Nation		$10,000
Esparto CSD		$5,000
Madison CSD		$5,000
		$160,000
Entity Contributions		
Rural Agencies ($0.50/acre) 0.5	**Acres**	**$**
Yolo County Flood Control & WCD	200,000	$100,000
Yolo County (White Areas)*	160,000	$40,000
Direct Contributions (White Areas)**	40,000	$20,000
Other Contributions from Rural Agencies***		$40,000
Dunnigan Water District	10,700	$5,350
RD 108	23,200	$11,600
RD 2035	18,000	$9,000
RD 537	5,200	$2,600
RD 730	4,498	$2,249
RD 765	1,400	$700
RD 785	3,200	$1,600
RD 787	9,400	$4,700
RD 827	1,225	$613
RD 1600	6,924	$3,462
	483,747	$241,874

**Yolo County is not $0.50/acre*

***Direct Contributions from private pumpers currently residing in "white areas"*

****RD 108, RD 787, RD 2035, and YCFCWCD ($10,000/each)*

Affiliated Parties with Board Voting Seats		
1	Base	**$**
University of California, Davis		$40,000
Colusa Drain Mutual Water Company		$10,000
California American Water Company - Dunnigan		$5,000
Yolo County Farm Bureau		$10,000
Environmental Party - TBD		
		$65,000

Sub Total:	$466,874

Exhibit E

Addresses for Notice

City of Davis
23 Russell Boulevard
Davis, CA 95616

Reclamation District 108
975 Wilson Bend Road
Grimes, CA 95950

Reclamation District 1600
429 First Street
Woodland, CA 95695

City of West Sacramento
1110 West Capitol Avenue
West Sacramento, CA 95691

Reclamation District 537
P.O. Box 822
West Sacramento, CA 95691

Reclamation District 2035
45332 County Road 25
Woodland, CA 95776

City of Winters
318 First Street
Winters, CA 95694

Reclamation District 730
429 First Street
Woodland, CA 95695

Yocha Dehe Wintun Nation
P.O. Box 18
Brooks, CA 95606

City of Woodland
300 First Street
Woodland, CA 95695

Reclamation District 765
1401 Halyard Drive Suite 140
West Sacramento, CA 95691

Yolo County
625 Court Street Room 206
Woodland, CA 95695

Dunnigan Water District
3817 First Street
Dunnigan, CA 95937

Reclamation District 785
429 First Street
Woodland, CA 95695

Yolo County Flood Control and Water Conservation District
34274 State Highway 16
Woodland, CA 95695

Esparto CSD
26490 Woodland Avenue
Esparto, CA 95627

Reclamation District 787
41758 County Road 112
Knights Landing, CA 95645

Madison CSD
2896 Main Street
Madison, CA 95653

Reclamation District 827
P.O. Box 781
West Sacramento, CA 95691

As allowed by Articles 6.1 and 9.4 of this YSGA Joint Powers Agreement, the following New Members were approved by the Board of Directors and formally added to the YSGA in 2019.

Reclamation District 999

By: Tom Slater
Name: Tom Slater
Its: President

Reclamation District 150

By: _____
Name: Warren Bogle
Its: President

Reclamation District 307

By: _____
Name: Pete Dwyer
Its: President

As allowed by Articles 6.1 and 9.4 of this YSGA Joint Powers Agreement, the following New Members were approved by the Board of Directors and formally added to the YSGA in 2019.

Reclamation District 999

By: _____
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By: _____
Name: Tom Slater
Its: President

Reclamation District 150

By: _____
Name: Warren Bogle
Its: President

Reclamation District 307

By: _____
Name: Peter G. Dwyer, Jr.
Its: President

PUBLIC DRAFT

Yolo Subbasin Groundwater Agency

2022 Groundwater Sustainability Plan

APPENDIX C:

Yolo Subbasin Water Budget Documentation

PUBLIC DRAFT

Yolo Subbasin Groundwater Agency

2022 Groundwater Sustainability Plan

APPENDIX C:

Yolo Subbasin Water Budget Documentation

Water Budgets Executive Summary

{Original work done by SEI; summary completed by Kristin Sicke}

Introduction

The Water Budget chapter describes the water budget of the Yolo Subbasin. Water budgets quantify all inflows and outflows of the area of interest with surrounding boundaries, and within the area of interest boundary at a spatial and temporal resolution that balances data and resource (human, financial, and time) availability with the overall goals of the water budget.

Historical, present, and future land surface and groundwater budgets were estimated at catchment, management area, and Subbasin scale. This Executive Summary is primarily a summary of the water budgets at the Subbasin-scale; please refer to the Water Budget and Model Documentation chapters for explanations of the Management Area-scale budgets.

Land surface water budgets quantify all the inflows and outflows to a specified area, from the bottom of the root zone, up to the land surface. Land surface inflows in the Yolo Subbasin are dominated by precipitation, surface water supply, and groundwater supply to meet multiple water demands (primarily agricultural and municipal water needs). Applied water re-use and recycled water are relatively minor inflows, quantitatively. Land surface outflows in the Yolo Subbasin are dominated by evapotranspiration (of precipitation and applied water), deep percolation (i.e., groundwater recharge), and surface runoff. Managed aquifer recharge is a quantitatively small land surface outflow for the Yolo Subbasin as a whole. The difference between these inflows and outflows represents the net change in land surface storage.

Groundwater budgets show all the inflows and outflows to the aquifer from the bottom of the root zone, down through all aquifer layers. Much of the Yolo Subbasin is underlain by an aquifer with three layers, as described in the Basin Setting chapter. Groundwater inflows in the Yolo Subbasin are dominated by deep percolation from the overlying land surface, followed by smaller contributions as recharge from the Yolo County Flood Control and Water Conservation District's unlined, earthen canal system. Groundwater outflows are largely comprised of pumping (for irrigation and municipal uses). Lateral flows (exchanges with neighboring subbasins) include groundwater exchanges with surface water bodies like rivers and creeks, and other smaller groundwater outflows from the Subbasin. The difference between groundwater inflows and outflows represents the net change in groundwater storage.

In the Yolo Subbasin, groundwater storage changes are positive in wet years and negative in dry years, with no significant trend (decline or increase) over the past 50 years.

Please see Section 1.3.7 Evaluating Water Budget Estimates to learn more about the uncertainty in the water budgets and YSGA model overall.

Model Overview

The Yolo Subbasin Groundwater Agency model (YSGA model) is a linked surface water-groundwater model developed using Water Evaluation and Planning (WEAP)[1] and MODFLOW[2]. The YSGA model includes not just the Yolo Subbasin boundary, but also portions of the Cache Creek watershed upstream of the Capay Valley (including Clear Lake and Indian Valley Reservoir). See the spatial domain of the YSGA model in the figure below.

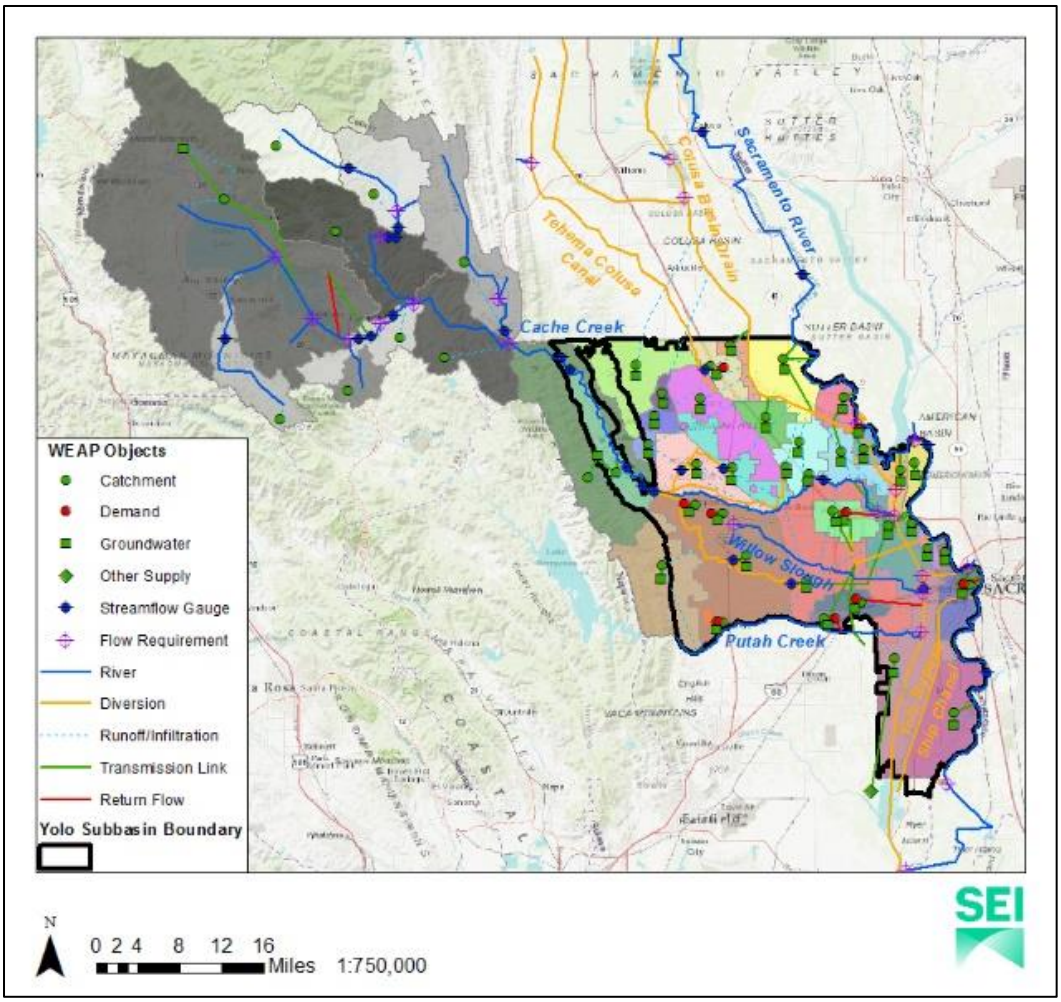
The YSGA model relies on a 48-year historical period, which covers a large spread of water year types: significant and contiguous drought and wet periods. The YSGA model runs at a monthly time period from Water Year 1971 to Water Year 2018. Water Year 2018 is treated as the current period within the model and documentation – climate and water rights data is updated to 2018; however, land use data was only available for 2016 (land use data from 2016 was kept constant until 2018).

Future projections in the YSGA model only capture climate change projections based on climate change model simulations centered around the mid-2030's and mid-2070's. Five future scenarios were incorporated where the demand is the same: urban demand is increased based on Urban Water Management Plan (UWMP) projections; the 2016/2018 irrigated crops are kept constant at 2016/2018 levels; and any change in irrigation demand is driven by the climate signal. **The five scenarios are as follows and the cumulative and average precipitation for the Yolo Subbasin is higher in all climate projections, compared to that in the 'Historical' scenario.**

1. 'Future_baseline' – urban demand increasing; irrigated crops constant; climate same as historical
2. 'Future_2030' – central tendency centered around 2030
3. 'Future_2070' – central tendency centered around 2030
4. 'Future_2070_DEW' – Dry-Extreme Weather
5. 'Future_2070_WMW' – Wetter-Moderate Warming

[1] WEAP is an integrated surface water-groundwater modeling tool, which integrates rainfall-runoff hydrology, reservoir operation, water demands from cities and crops, and allocations of water to those demands from surface water and groundwater supplies.

[2] MODFLOW is a finite-difference groundwater modeling tool develop by the USGS, which simulates the groundwater budget of the Yolo Subbasin's three-later aquifer and was built using the inputs, aquifer parameters, boundary conditions, and aquifer representation from a Yolo County Integrated Water Flow Model (IWFM).



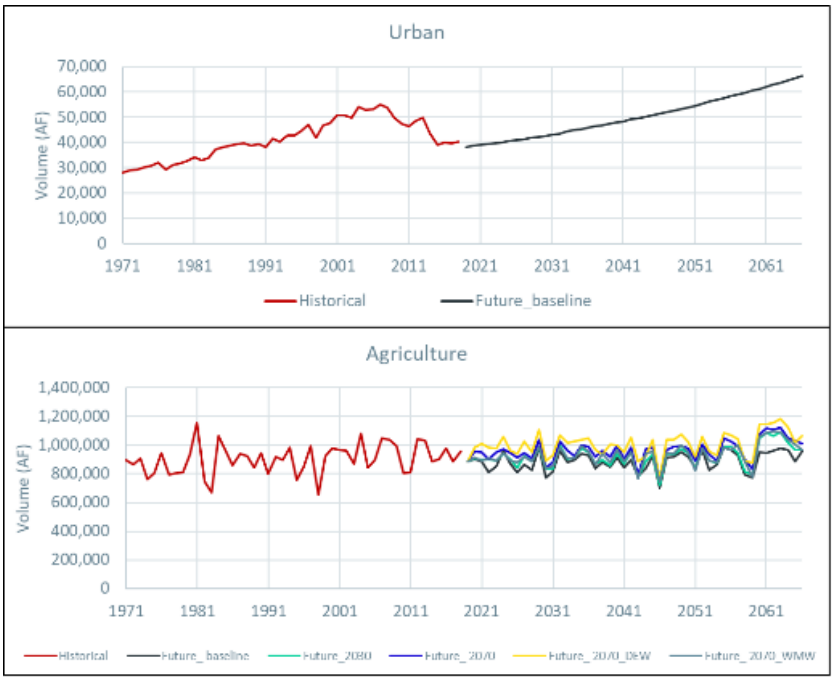
Land Use

Landcover in the Yolo Subbasin is dominated by agriculture and native vegetation. The table below shows the acreage and proportion of the main categories of Subbasin-wide land use for specific years where GIS data were available (1989, 1997, 2008, and 2016). An important feature of land use changes in the Yolo Subbasin is an increasing acreage of perennials, which have partly replaced field crops, and brought previously uncultivated area into production in some regions.

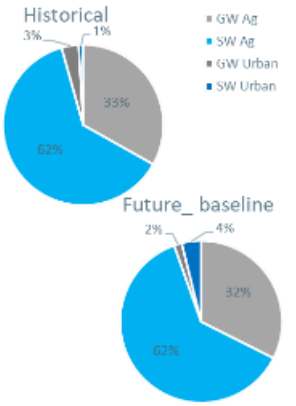
	Land Use (ac)				Land Use (Percent)			
	1989	1997	2008	2016	1989	1997	2008	2016
Entire Basin	**639,089**	**639,089**	**639,089**	**639,089**				
Deciduous	17,550	18,406	30,717	59,434	3	3	5	9
Field Crops	96,679	108,427	36,475	41,446	15	17	6	6
Grain	80,354	57,993	52,369	27,200	13	9	8	4
Managed Wetlands	0	483	459	0	0	0	0	0
Native Vegetation	288,058	284,997	319,938	330,463	45	45	50	52
Pasture	42,612	44,822	63,801	33,129	7	7	10	5
Rice	22,652	24,754	35,056	38,847	4	4	5	6
Subtropical	118	135	1,331	3,670	0	0	0	1
Truck Crops	56,953	55,160	46,968	46,930	9	9	7	7
Urban	26,347	29,153	33,220	33,270	4	5	5	5
Vine	2,543	9,536	13,384	19,329	0	1	2	3
Water	5,222	5,222	5,372	5,372	1	1	1	1

Water Demand and Supply

Total water demands for each scenario are presented in the figure below. Urban water demands (based on UWMPs) rise steadily but remain small relative to irrigation demand. Irrigation demand in the future scenarios stay within the range of historical simulations, but averages are successfully higher than the historical scenario. Since 'Future_baseline' and 'Historical' scenarios have the same climate, the impact of current, increased perennial crop acreage within the Yolo Subbasin is apparent (less inefficient, or more efficient, irrigation practices are altering evapotranspiration and deep percolation quantities). The supply sources for the 'Historical' and 'Future_baseline' scenarios shown in the pie chart illustrate the supply sources are expected to be about the same: the WDCWA's water supply accounts for the increase in urban surface water supply in the 'Future_baseline' scenario. Overall, the average annual water demand increases from 945 TAF to a maximum of 1,055 TAF from the 'Historical' to the 'Future_2070_DEW" (dry-extreme warming) scenario.



Average Annual Demand (Acre Feet)	
Urban	
Historical	41,102
Future(all scenarios are equal)	50,270
Agriculture	
Historical	904,090
Future_baseline	888,139
Future_2030	922,000
Future_2070	961,712
Future_2070_DEW	1,005,341
Future_2070_WMW	931,403



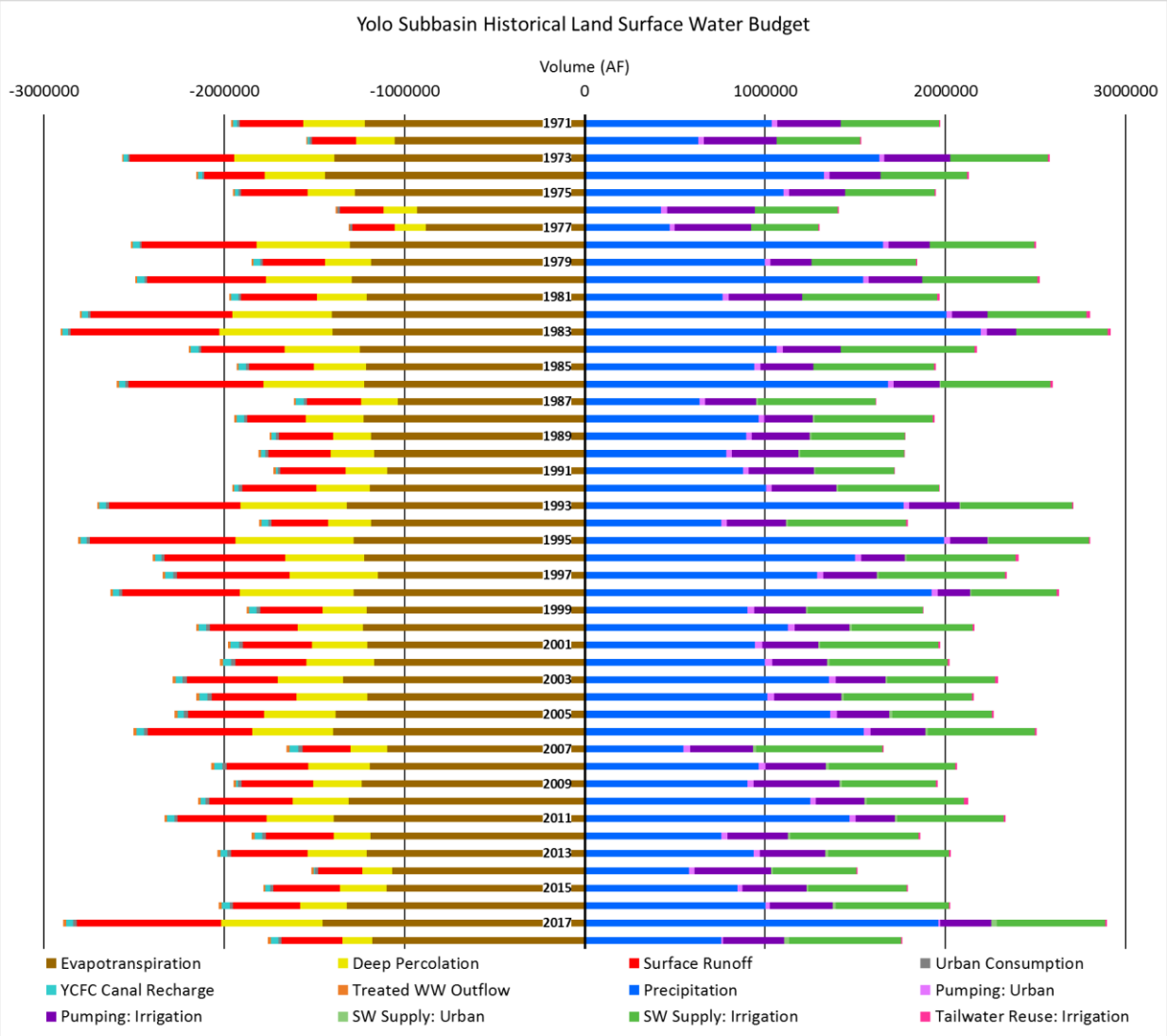
Catchments within Yolo County are shown as colored polygons, and catchments upstream of Capay Valley in the Cache Creek Watershed are shown in shades of grey. See the following figure for each catchment labeled by name.

Land Surface Water Budget

For the land surface water budget, outflows are dominated by evapotranspiration, surface runoff, and deep percolation. The key results for the *historical* average land surface water budget are discussed below:

- Precipitation accounts for 1.1.5 MAF, with total water supply accounting for the remaining 0.955 MAF of inflows
- Surface waters supply (0.6 MAF) makes up about 60% of the total water supply, with groundwater pumping making up the remaining 40%
- Agricultural irrigation demand accounts for more than 90% of the total water demand of 1 MAF
- Water supply sources to meet agricultural and urban demands are shown – note the urban demand was historically mt primarily by groundwater pumping
- Total outflows are very close to total inflows, indicating an overall mass balance of inflows and outflows
- Evapotranspiration is the largest of the outflows (at 1.2 MAF), approximately 8% higher than precipitation

See the butterfly chart below for a breakdown of the historical land surface water budget.



The key results for the *future* average land surface water budget are discussed below:

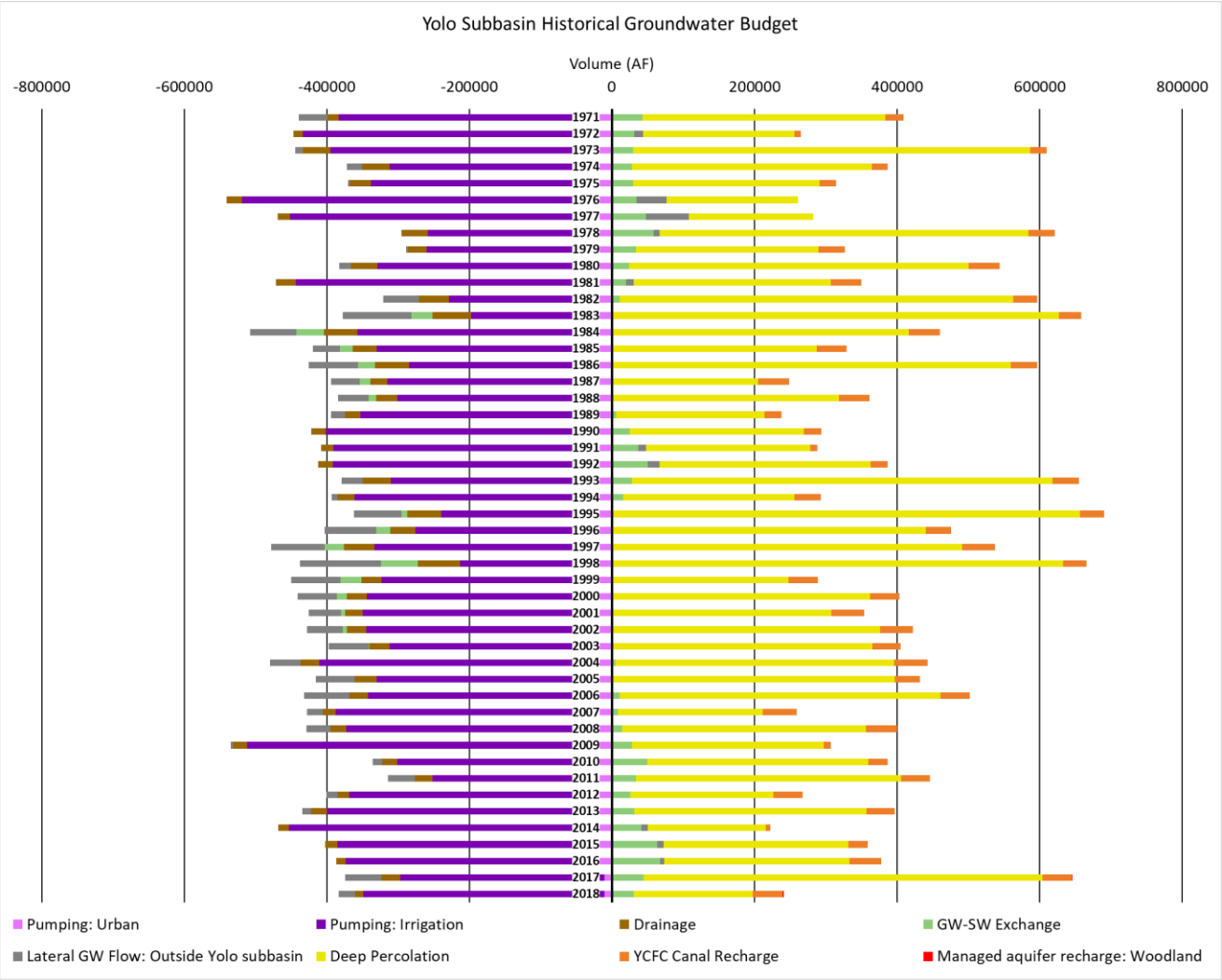
- Overall land surface mass balance is maintained (total inflows= outflows)
- The effect of increased perennial acreage results in more evapotranspiration and less deep percolation
- The effect of climate change results in more evapotranspiration and more deep percolation

Groundwater Budget

The key findings for the *historical* average groundwater budget are as follows:

- Inflows to the Yolo Subbasin are dominated by deep percolation
- Pumping (urban and irrigation) is the largest groundwater outflow
- Groundwater-surface exchange is on average positive
- The net lateral exchange with neighboring basins is negative; on average, lateral flow is leaving
- Some fluxes are 0 in some years (1976/77 and 2014 droughts led to no surface water deliveries)

The historical groundwater budget can be seen in the butterfly chart and table below.



The key findings for the *future* average groundwater budgets are as follows:

- Less deep percolation and more outflow than inflow is the result of increased perennial acreage and change in irrigation management
- The effect of climate change can be seen in the increase in deep percolation, falling storage in extreme dry scenario, balanced budgets in the central tendency scenarios, and increasing storage in the extreme wet scenario

The tables below include the average annual groundwater fluxes.

Historical Average Annual Groundwater Budget (TAF)												
	Outflows				Varying Flows				Inflows			
	Pumping: Urban	Pumping: Irrigation	Drainage	Total Outflows	GW-SW Exchange	Lateral GW Flow: Outside	Lateral GW Flow	Total Varying Flows	Deep Percolation	YCFC Canal Recharge	Managed aquifer	Total Inflows
Entire Basin												
Historical	-33	-313	-28	-374	15	-28	0.0	-13	353	33	0.04	386
Future_Baseline	-16	-304	-16	-336	25	-40	0.0	-15	308	37	1.37	346
Future_2030	-15	-322	-15	-352	23	-37	0.0	-15	321	39	1.43	361
Future_2070	-15	-343	-15	-373	22	-35	0.0	-13	340	40	1.31	381
Future_2070_DEW	-15	-385	-13	-413	46	-6	0.0	39	323	37	1.30	360
Future_2070_WMW	-14	-311	-24	-348	-29	-79	0.0	-108	424	43	1.40	468

Notes: In the historical scenario: GW-SW exchange is positive with Cache Creek (29 TAF), Putah Creek (13.9 TAF), Sacramento River (0.9 TAF) and negative with Yolo bypass (25.7 TAF), Knights Landing Ridge Cut (1.5 TAF) and Colusa Basin Drain (2 TAF). Other GW-SW exchanges are minor.

The table below provides another way to view the average annual groundwater fluxes by observing the delta, or difference, from the 'Historical' scenario.

Historical Average Annual Groundwater Budget (TAF)												
	Outflows				Varying Flows				Inflows			
	Pumping: Urban	Pumping: Irrigation	Drainage	Total Outflows	GW-SW Exchange	Lateral GW Flow: Outside Yolo	Lateral GW Flow	Total Varying Flows	Deep Percolation	YCFC Canal Recharge	Managed aquifer recharge:	Total Inflows
Entire Basin												
Historical	-33	-313	-28	-374	15	-28	0	-13	353	33	0.04	386
	Delta from Historical				Delta from Historical				Delta from Historical			
Future_Baseline	17	9	12	38	10	-12	0	-2	-45	4	1.33	-40
Future_2030	18	-9	13	22	8	-9	0	-2	-32	6	1.39	-25
Future_2070	18	-30	13	1	7	-7	0	0	-13	7	1.27	-5
Future_2070_DEW	18	-72	15	-39	31	22	0	52	-30	4	1.26	-26
Future_2070_WMW	19	2	4	26	-44	-51	0	-95	71	10	1.36	82

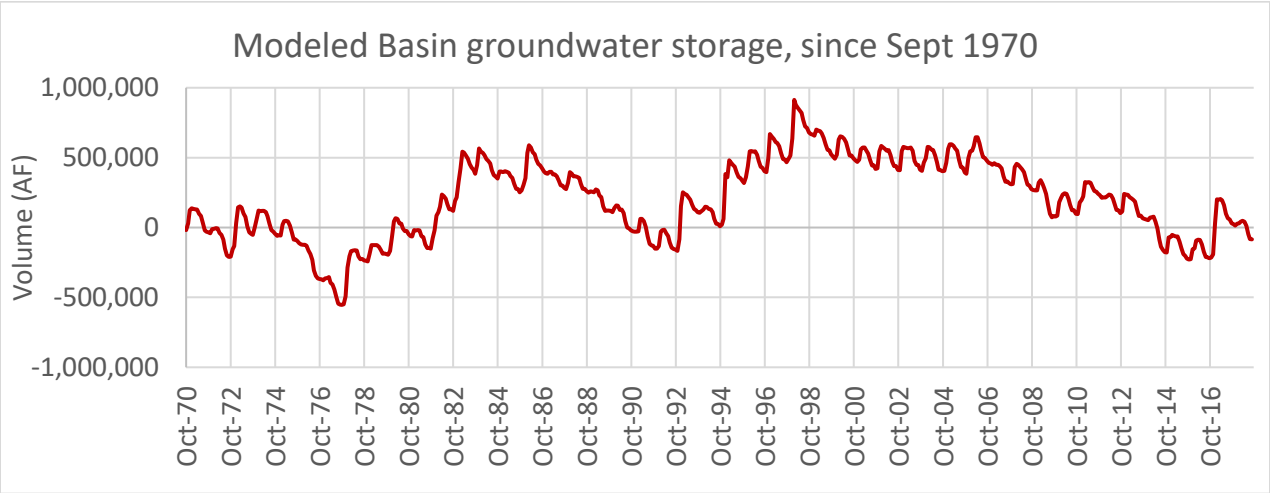
Groundwater Storage

Changes in groundwater storage over time are the aggregate (net) outcome of the individual inflows and outflows from the aquifer. Available groundwater storage in Yolo County (20 to 420 feet below ground surface), has been estimated at 14 million acre-ft (MAF) (Clendenen & Associates, 1976).

The MODFLOW portion of the YSGA model estimates Basin-wide groundwater storage capacity at 13.7 MAF.

Modeled basin groundwater storage is presented as cumulative change from initial storage in September 1970, as shown in the figure below. As you can see, groundwater is lost from storage in dry years and recharge occurs in wet years to allow Basin-wide recovery. Deep groundwater storage declines follow the deep droughts and storage recovery follows in the intervening wet periods. Over the past 50 years, there is no evidence of Basin-wide overdraft. Additionally, as previously mentioned, the dominant shift in land use in the Yolo Subbasin over this historical period has been from annual to perennial crops. **The groundwater storage trace implies that the climate signal has dominated over this historical period at the Basin-wide level.**

Groundwater extraction increases over the past decade were driven by the extended drought and acceleration of perennial acreage. Despite these factors, a wetter 2017 appears to have helped the Basin storage to almost recover to initial levels (at the end of the simulation in the historical period, modeled Basin groundwater storage is lower than the initial level by 86 TAF).

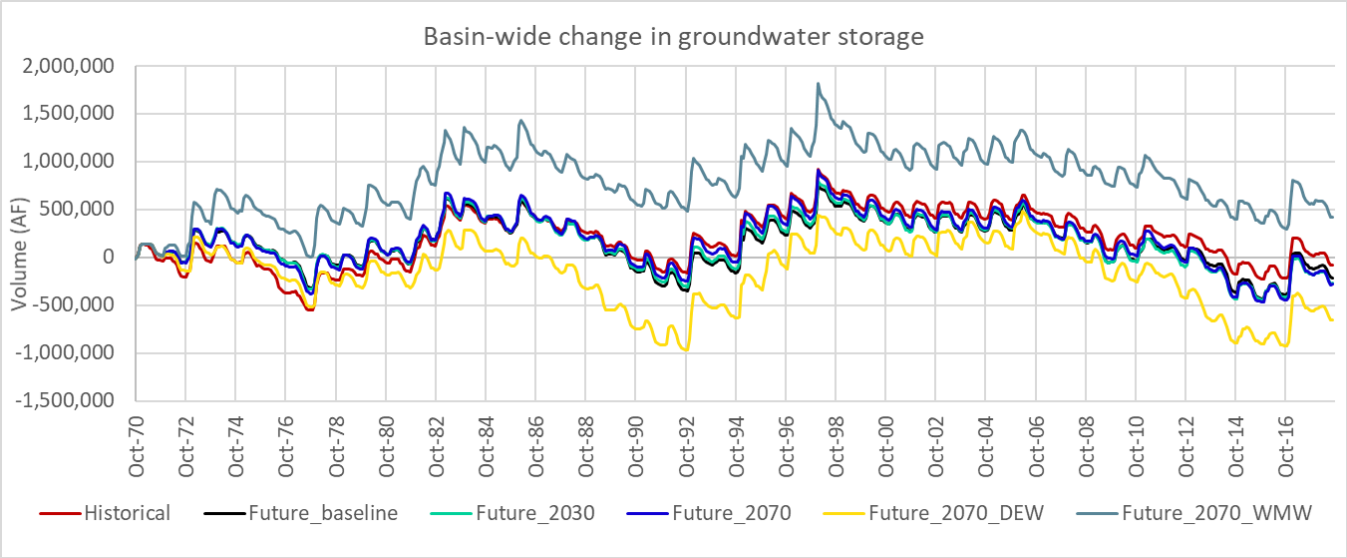


Decadal changes in storage are summarized below to further illustrate the fluctuation of groundwater storage in different wet and dry decades.

Decade	Change in Storage (AF)
WY 1971-1980	-24,806
WY 1981-1990	17,992
WY 1991-2000	521,671
WY 2001-2010	-390,769
WY 2011-2018	-208,710

The figure below illustrates the change in groundwater storage for each of the future scenarios relative to the 'Historical' scenario (red line). Groundwater storage patterns among scenarios follow the precipitation and temperature trends among scenarios, such as the following:

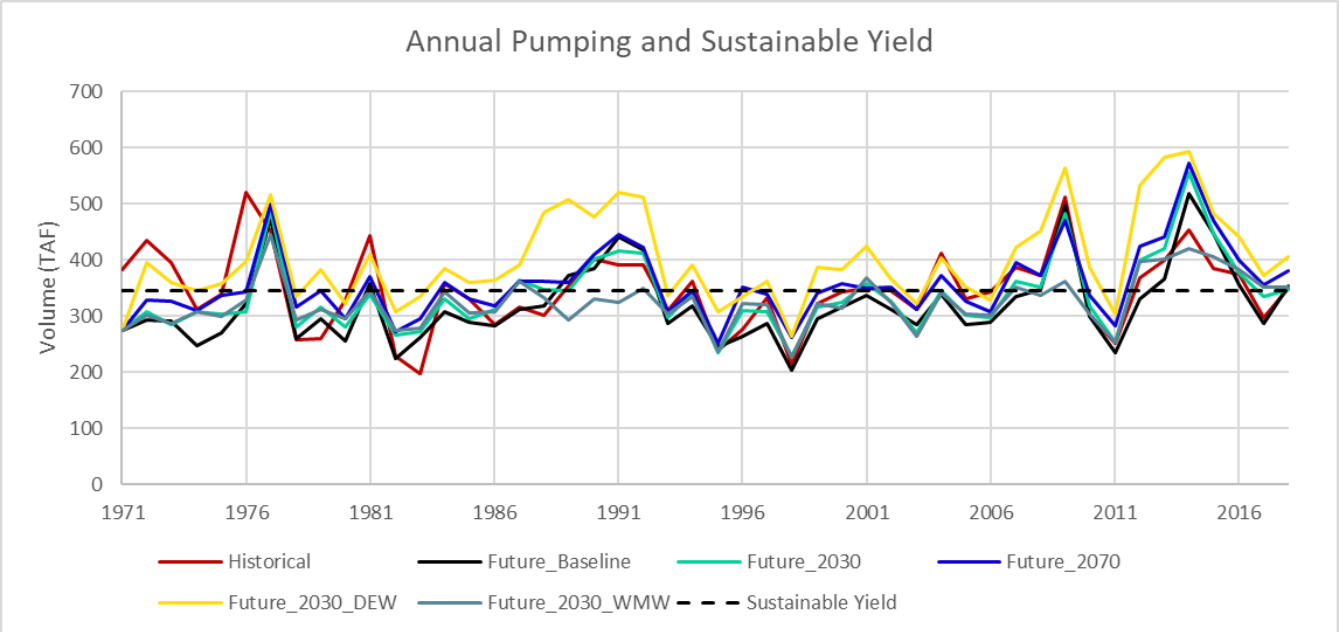
- The most groundwater declines occur in the driest, warmest scenario ('Future_70_DEW')
- Groundwater storage shows an overall increase in 'Future_70_WMW' scenario
- There is not much difference in groundwater storage between the central tendency scenarios ('Future_30' and 'Future_70') and the 'Future_baseline'.
- The 'Historical' and 'Future_baseline' have the same climate input and comparing them shows the sensitivity to current cropping patterns and irrigation management.



Sustainable Yield

Based on the information presented in the draft Water Budgets chapter, a Sustainable Yield of 346 TAF per year is being proposed for the Yolo Subbasin. (This number will be discussed by the TAC, Working Group, and Board of Directors before included in the final Yolo Subbasin GSP.)

The figure below shows the modeled pumping time series for the historical period with the future scenarios included along with the proposed sustainable yield (the horizonal reference line).



1. Water Budget

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1.1. Introduction

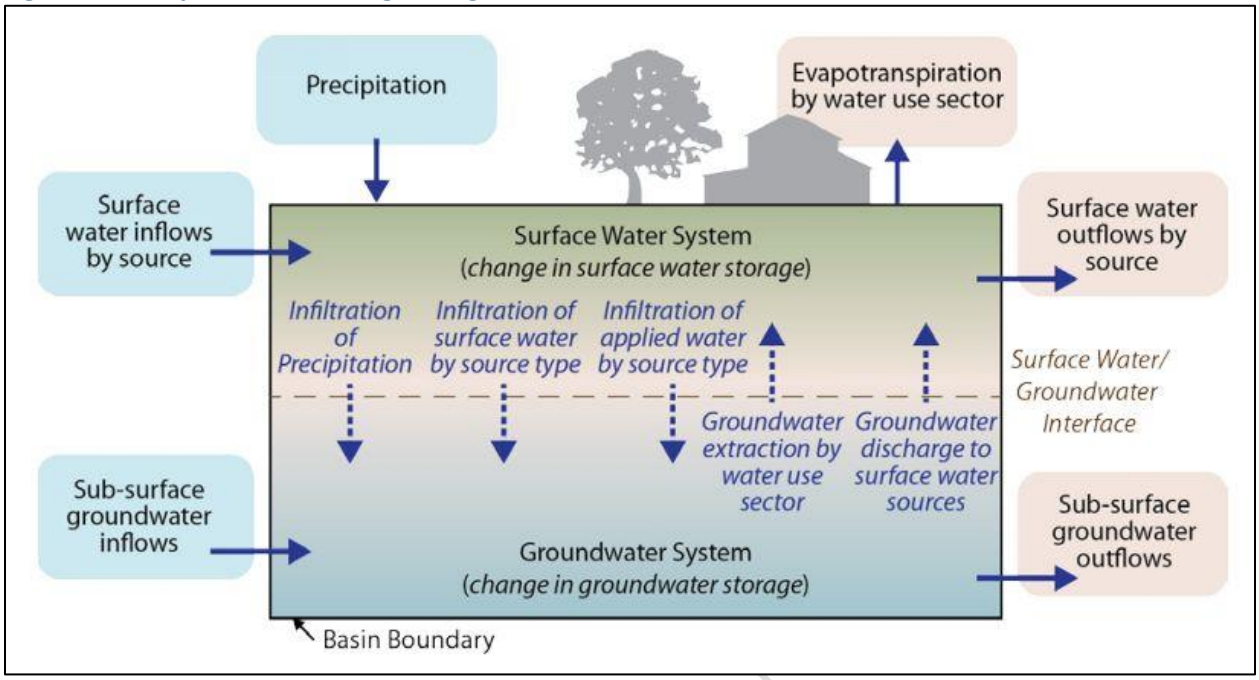
This chapter describes the water budget of the Yolo Subbasin (henceforth, "Basin" or "Yolo Subbasin"). Water budgets quantify all inflows and outflows of the area of interest (AOI) with surrounding boundaries, and within the AOI boundary at a spatial and temporal resolution that balances data and resource (human, financial, and time) availability with the overall goals of the water budget.

Figure 1 presents a simplified conceptual water budget schematic (California DWR, 2016), that includes typical inflows and outflows of the land surface and groundwater systems. Figure 1 can be thought of as a simplified slice of the land surface and underlying aquifer of the Basin. Land surface and groundwater budgets were calculated for the Yolo Subbasin.

Land surface water budgets quantify all the inflows and outflows to a specified area, from the bottom of the root zone, up to the land surface. As later sections show, land surface inflows in the Basin are dominated by precipitation, surface water supply, and groundwater supply to meet multiple water demands (primarily agricultural and municipal water needs). Applied water re-use and recycled water are relatively minor inflows, quantitatively. Land surface outflows in the Basin are dominated by evapotranspiration (of precipitation and applied water), deep percolation (i.e. groundwater recharge), and surface runoff. Managed aquifer recharge is a quantitatively small land surface outflow for the Basin as a whole. The difference between these inflows and outflows represents the net change in land surface storage.

Groundwater budgets show all the inflows and outflows to the aquifer from the bottom of the root zone, down through all aquifer layers. Much of the Basin is underlain by an aquifer with three layers, as described in the Basin Setting section. Groundwater inflows in the Basin are dominated by deep percolation from the overlying land surface, followed by smaller contributions as recharge from the unlined Yolo County Flood Control and Water Conservation District (YCFC) earthen canal system. Groundwater outflows are largely comprised of pumping (for irrigation and municipal uses). Lateral flows (exchanges with neighboring basins), and surface-groundwater (SW-GW) exchanges with surface water bodies like rivers and creeks are the other, smaller groundwater outflows from the Basin. The difference between groundwater inflows and outflows represents the net change in groundwater storage. ***In the Basin, groundwater storage changes are positive in wet years and negative in dry years, with no significant trend (decline or increase) over the past 50 years.***

Figure 1 Conceptual Water Budget Diagram



Historical, present and future land surface and groundwater budgets were estimated at catchment, management area, and basin scale (model disaggregation is described in Section 1.1.1). In this chapter we describe the land surface water budgets at county scale and groundwater budgets at basin scale, while explanations of the management area-scale groundwater budgets are provided in Appendix A.

Table 1 Useful Terms in this section

Term	Description
Basin	In this Chapter, Basin refers to the Yolo Subbasin
Land surface water budget	Mass balance describing the inflows and outflows of the surface water system, typically from the root zone up to the land surface
Groundwater budget	Mass balance of the groundwater system describing the inflows and outflows of the aquifer(s) underlying the basin.
Lateral flows	Groundwater flows, typically driven by hydraulic head differences. At the Basin scale, this refers to lateral flows to/from all adjacent basins. At the management area scale this refers to lateral flows to/from adjacent management areas and/or adjacent basins.

Term	Description
SW-GW exchange	Exchange between surface water bodies and groundwater aquifers. Includes seepage (from surface water to groundwater) and groundwater flow into surface water bodies
Boundary flows	Flows at the edges of boundaries of basins and models. When referring to models, boundary conditions are set as appropriately as possible given the state of knowledge.
Management Area	The Yolo Subbasin has 6 management areas (Figure 4).
Entity	Organizations with a water management role, authority, or mandate to manage water. In the Yolo Subbasin Groundwater Agency (YSGA) model, there are 19 entities explicitly represented made up of irrigation districts, cities, community services districts, and reclamation districts.
White Area	Parts of the County that do not formally fall within the service area or jurisdiction of an Entity.
Catchment	A catchment is an area in the YSGA model for which the land surface water budget is calculated. There are 47 catchments in the YSGA model domain, and 37 catchments in the County (See Table 3. Figure 2). Each catchment was drawn by considering topography, hydrogeology, and administrative/entity boundaries.
MODFLOW	Modular Three-Dimensional Finite-Difference Groundwater Flow Model
WEAP	Water Evaluation And Planning Model
IWFM	Integrated Water Flow Model
IGSM	Integrated Groundwater and Surface Water Model
YSGA Model	The coupled WEAP-MODFLOW model that has been developed for the YSGA and preparations of the Groundwater Sustainability Plan.

1.1.1. Model Overview

The Yolo Subbasin Groundwater Agency model (YSGA model) is a linked surface water-groundwater model developed using Water Evaluation And Planning (WEAP)[1] and MODFLOW[2]. WEAP (Yates et al., 2005a, 2005b) is an integrated surface water – groundwater modeling tool, which integrates rainfall-runoff hydrology, reservoir operation, water demands from cities and crops, and allocations of water to those demands from surface water and groundwater supplies. The WEAP model used in the YSGA model builds on several years of development of the Cache Creek system at the Yolo County scale (Mehta et al., 2018, 2011; Winter et al., 2017).

MODFLOW is a finite-difference groundwater modeling tool developed by the USGS (Harbaugh, 2005). In the YSGA model, MODFLOW simulates the groundwater budget of the Yolo Subbasin's three-layer aquifer. The MODFLOW model was built using the inputs, aquifer parameters, boundary conditions, and aquifer representation from a Yolo County IWFM model (Flores Arenas, 2016), which in turn was informed by an IGSM model of Yolo County (WRIME, 2006).

1.1.1.1.Temporal Scope

SGMA regulations point to three time periods regarding water budgets: a 10-year historical period, the 'current' year, and a projected period informed by a 50-year history. The current water year is defined in the GSP Regulations (§354.18(c)(1)) as the year with "the most recent population, land use, and hydrologic conditions". According to the GSP Regulations §354.18(c)(3)(A), "projected hydrology shall utilize 50 years of historical precipitation, evapotranspiration, and streamflow information as the baseline condition for estimating future hydrology". The Yolo Subbasin Water Budget model relies on a 48-year historical and future period, which is sufficient to project the 50-year period referenced by the Regulations.

1.1.1.1.1. Historical and Current Period

The YSGA model runs at a monthly time step. The historical to current period covers 48 years, from Water Year (WY) 1971 to WY 2018. Although GSP Regulations require a minimum 10-year period for historical water budgets, we leveraged and extended our earlier work that modeled a substantially longer period (WY 1971-WY 2005 (Mehta et al., 2013) and WY 1971-2008 (Mehta et al., 2018)).

These 48 years (WY 1971-WY 2018) cover a large spread of water year types, significant and contiguous drought periods (WY 1976-WY 1977, WY 1987-WY 1992, WY 2007-WY 2009, and WY 2012-WY 2016), and significant and contiguous wet periods of note (WY 1971-WY 1975, WY 1982-WY 1984, WY 1995-WY 2000, and WY 2005-WY 2006). The Water Year Index (Sacramento Valley) and the Water Year Types for the historical to current water year type are listed in Table 2. Water Year 2018 – the last year of the model simulation in the historical period – is treated as the current period. This is the most recent year

[1] See https://www.weap21.org/ for more information.

[2] See https://water.usgs.gov/ogw/modflow/ for more information.

for which almost all datasets are available. Climate and water rights data are updated to WY 2018 in the YSGA model. Land use data, however, is only available to 2016 (the LandIQ dataset provided by DWR in the SGMA Data Viewer[3]). Hence 2016 Land use data is used and kept constant through WY 2018.

Table 2 Sacramento River Water Year Index and Water Year Types

Water Year	Water Year Index	Water Year Type	Water Year	Water Year Index	Water Year Type
1971	10.37	W	1995	12.89	W
1972	7.29	BN	1996	10.26	W
1973	8.58	AN	1997	10.82	W
1974	12.99	W	1998	13.31	W
1975	9.35	W	1999	9.80	W
1976	5.29	C	2000	8.94	AN
1977	3.11	C	2001	5.76	D
1978	8.65	AN	2002	6.35	D
1979	6.67	BN	2003	8.21	AN
1980	9.04	AN	2004	7.51	BN
1981	6.21	D	2005	8.49	AN
1982	12.76	W	2006	13.2	W
1983	15.29	W	2007	6.19	D
1984	10.00	W	2008	5.16	C
1985	6.47	D	2009	5.78	D
1986	9.96	W	2010	7.08	BN
1987	5.86	D	2011	10.54	W
1988	4.65	C	2012	6.89	BN
1989	6.13	D	2013	5.83	D
1990	4.81	C	2014	4.07	C
1991	4.21	C	2015	4.00	C
1992	4.06	C	2016	6.71	BN
1993	8.54	AN	2017	14.14	W
1994	5.02	C	2018	7.14	BN

[3] See https://sgma.water.ca.gov/webgis/?appid=SGMADataViewer#waterbudget; Accessed 8.31.2018

1.1.1.1.2. Future period

Future projections use climate change projections provided by DWR on the SGMA Data Viewer[4], which are summarized here. Additional information is provided in later sections (Section 1.2) and in the Model Documentation Appendix. Climate projections in the YSGA model are based on climate change model simulations centered around the mid-2030's period and the mid-2070's period. In the YSGA model, each future projection uses the final state of the historical model simulation as the initial state of the future simulations. In other words, each climate projection in the model is investigating the outcome of that corresponding projection's climate occurring from WY 2019 on, for the next 48 years. For example, the future projection that uses the central tendency of the climate change models around the 2030's, investigates the outcome of that climate occurring from WY 2019 – WY 2067.

1.1.1.2.Spatial Scope

The spatial scope of the YSGA model is shown in Table 3.

Figure 2 and Table 3. An important feature to remember when reviewing the water budgets sections, is that the land surface water budget corresponds to the surface hydrology (Yolo County extent, overall), while the groundwater budget pertains to the alluvial aquifer of the Yolo Subbasin. Table 3.

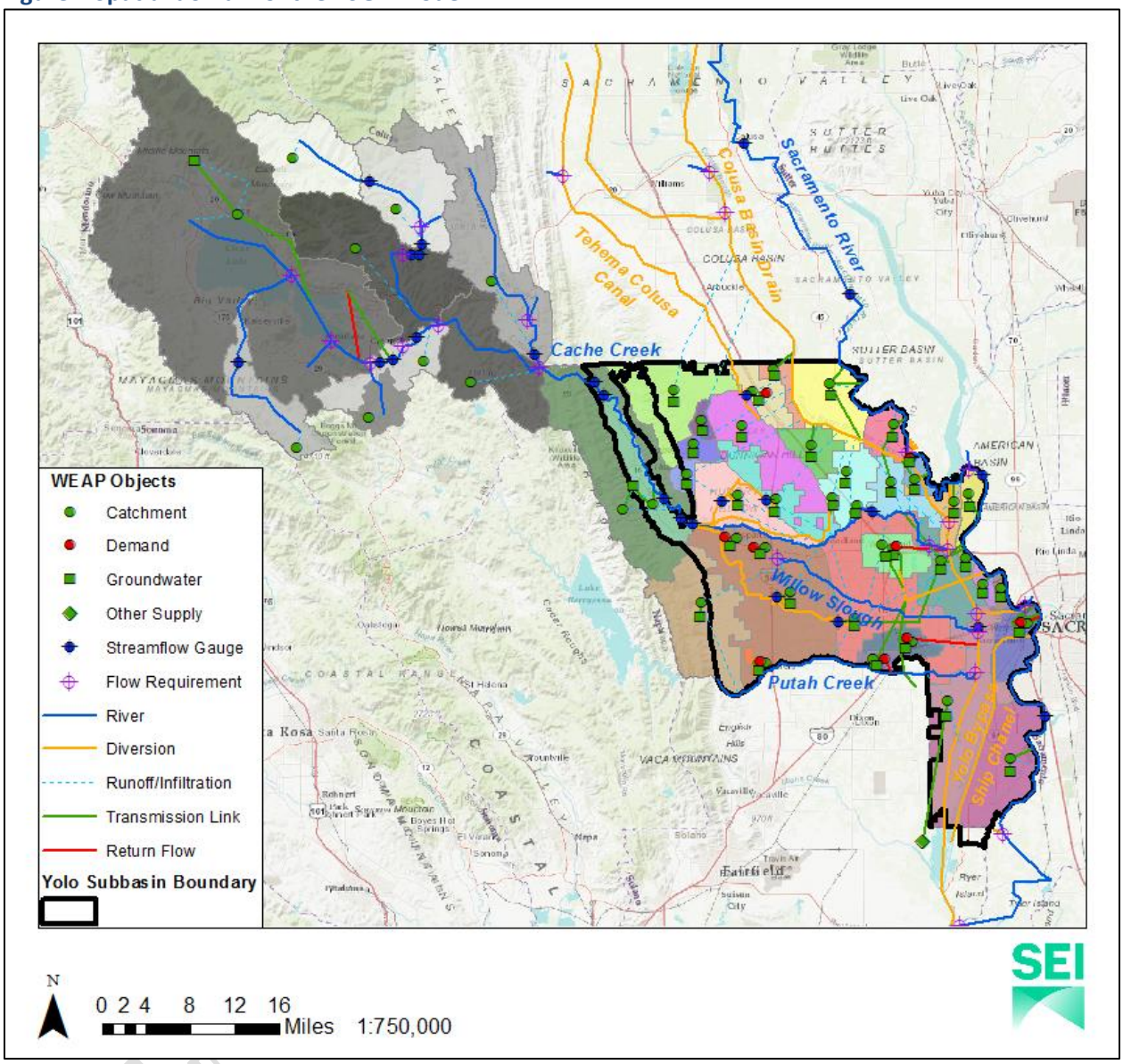
Figure 2 shows that the YSGA model explicitly includes not just the YSGA basin boundary, but also the portions of the Cache Creek watershed upstream of the Capay Valley (including Clear Lake and Indian Valley Reservoir). That is, the hydrology and operations of the entire Cache Creek watershed are simulated. Other important surface water inflows and boundaries are represented as input data, such as the flows of Tehama Colusa Canal and Colusa Basin Drain, and stream flows of the Sacramento River and Putah Creek. Surface water diversions and groundwater pumping were simulated at the scale of the catchments shown in Table 3.

[4] See https://sgma.water.ca.gov/webgis/?appid=SGMADataViewer#waterbudget Accessed 8.31.2020

Figure 2. These boundaries mostly represent water district, urban, or hydrogeologic boundaries. Regions outside of water districts and urban areas are considered “white areas” that fall under County jurisdiction for purposes of SGMA.

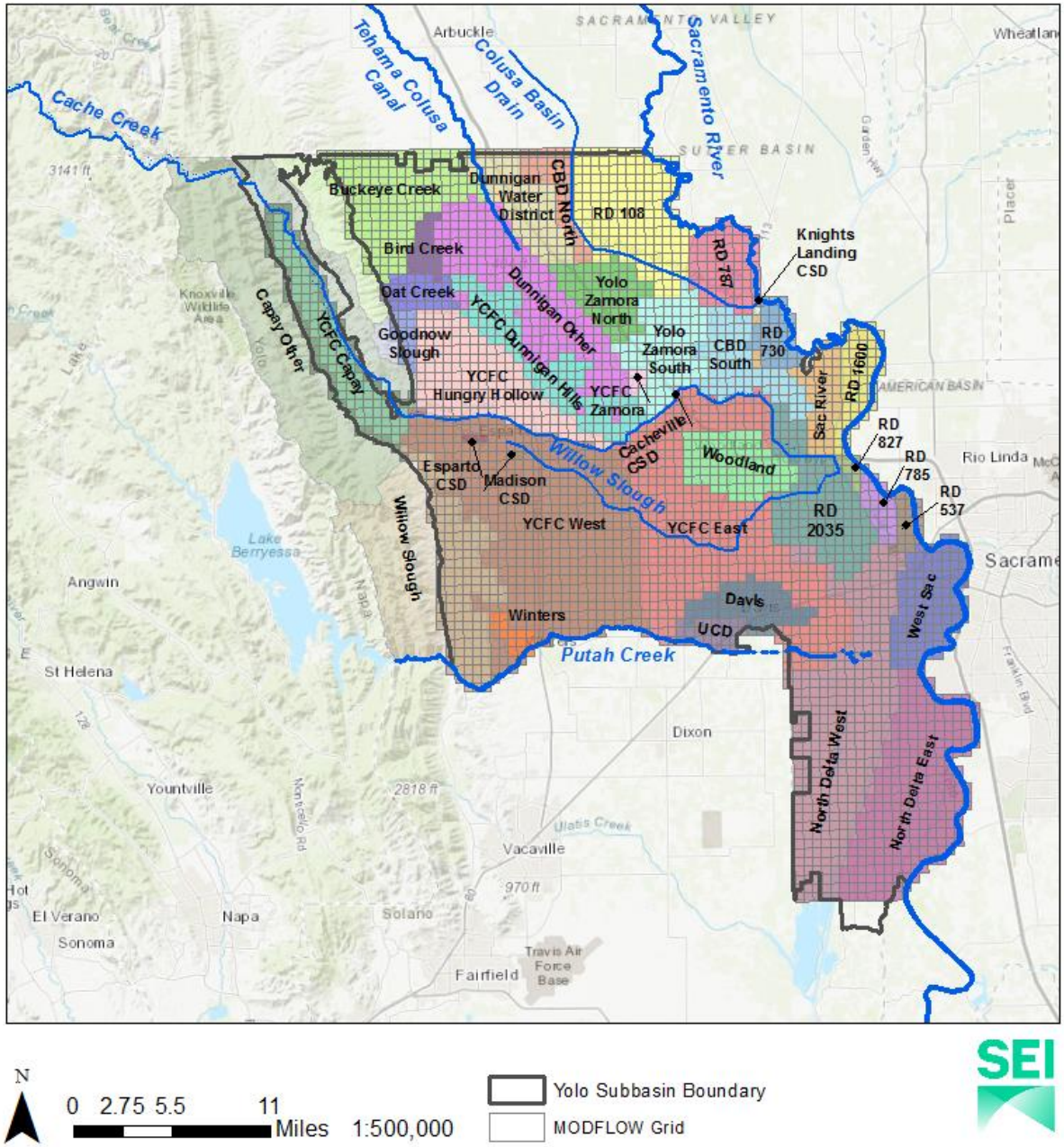
Figure 3 shows a closer view of the Yolo Subbasin disaggregation into catchments in the YSGA model, with the MODFLOW computational grid overlaid. The MODFLOW grid covers only those parts of the Yolo Subbasin boundary in which the groundwater aquifer exists, as represented in the IWFM model that it is derived from. For purposes of calculating water budgets, the individual catchments have been grouped into Management Areas, as shown in Figure 4 and Table 3.

Figure 2 Spatial domain of the YSGA model



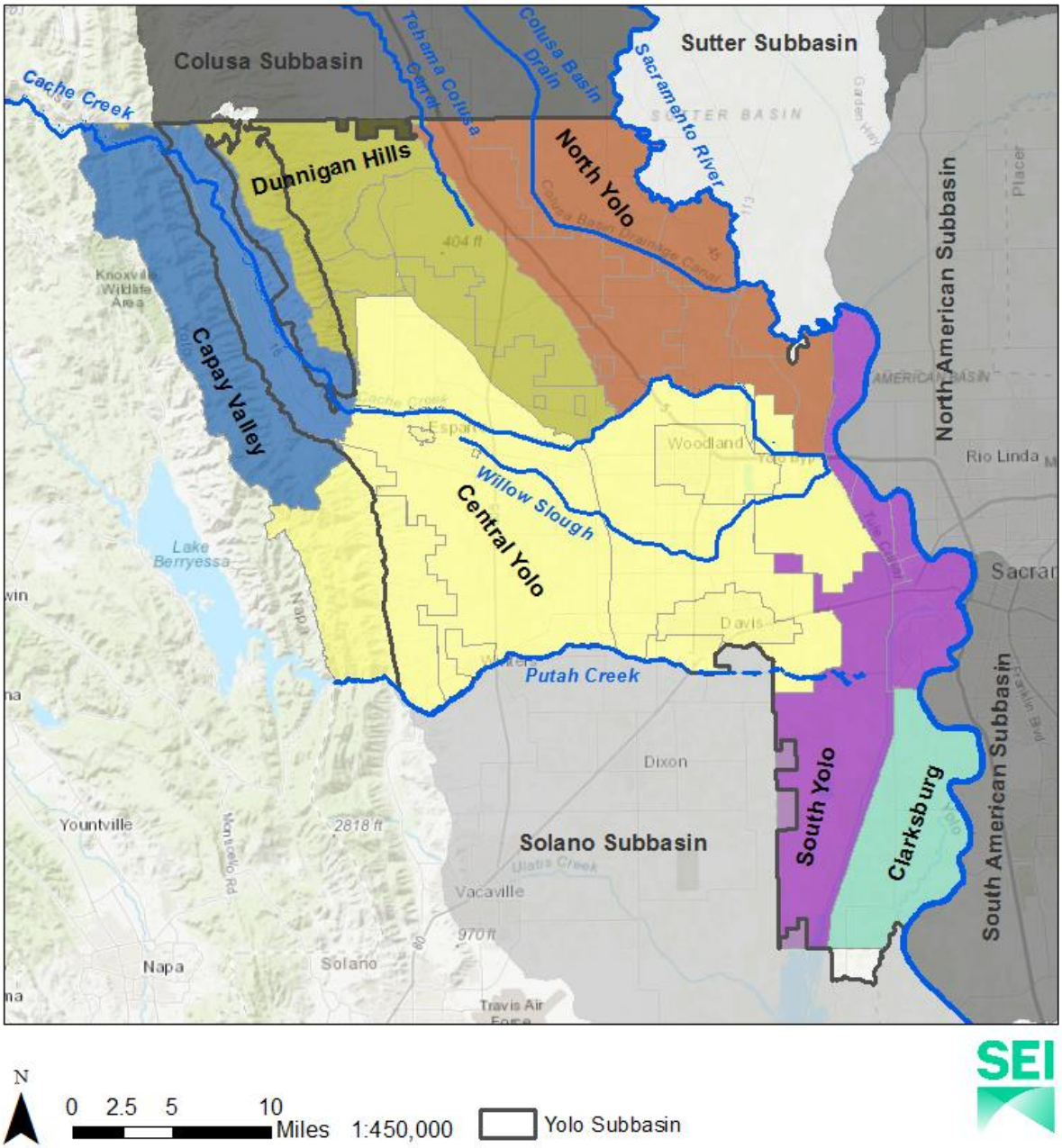
Catchments within Yolo County are shown as colored polygons, and catchments upstream of Capay Valley in the Cache Creek Watershed are shown in shades of grey. See the following figure for each catchment labeled by name.

Figure 3 Spatial domain of the MODFLOW groundwater model



Black boundary represents the official Basin boundary. The MODFLOW grid, which represents the modeled alluvial aquifer, is shown in grey. Colored polygons are the model catchments. Model catchments, for which the land surface water budgets are computed, extend beyond the alluvial aquifer, as is most obvious in western Yolo County (hills in Capay, west of Winters, and west of Buckeye Creek).

Figure 4 Subregion Boundaries, Management Areas and Neighboring Subbasins



The colored polygons show the model boundaries used to aggregate the land surface water budget into subregions for corresponding Management Areas. Entity boundaries are shown in light gray. The Yolo Subbasin is outlined in thick gray lines. Neighboring basins are shaded in grays. Major surface water bodies are labeled for reference. Official Management Area boundaries in this figure correspond to the intersection of the Yolo Basin boundary with the colored polygons.

The WEAP portion of the YSGA model, which covers the land surface system and hydrology, covers 1,197,657 acres This includes all of Yolo County (639,089 acres in the WEAP portion of the model) and the Cache Creek system in Lake County (558,568 acres).

The MODFLOW portion of the YSGA model covers 559,840 acres (Table 3). Due to the resolution and spatial extent of the MODFLOW model (as mentioned earlier, derived from the IWFM model), and the pre-existing WEAP model which covers the entire county, there are small differences between the official basin boundary (540,400 acres) and that in the YSGA model. Additionally, because catchment boundaries in the YSGA model are primarily determined by surface hydrology, there are small differences between the management area boundaries in the model and the official management area boundaries (shown in the Introduction and Basin Setting sections). Figure 5 below shows these differences, and Table 4 explains them. The total area of these differences is relatively small (19,440 acres, less than 3% of the Yolo Subbasin) and will not affect the model estimates substantively.

Table 3. Subdivisions of the YSGA model

Modeled Area Name	Entity Name/White Areas Included	Area (ac)
Entire Modeled Area		1,197,657
Yolo County		639,089
Capay Valley Management Area*		85,515
Capay Other	White Area, Small towns in Capay Valley	67,097
YCFC Capay	YCFC, Yocha Dehe Wintun Nation, White Area, Small towns in Capay Valley	18,418
Central Yolo Management Area		242,680
Davis catch	Davis	8,688
Esparto CSD catch	Esparto CSD	446
Madison CSD catch	Madison CSD	68
RD 2035	RD 2035	20,375
UCD catch	UCD	3,701
Willow Slough	White Area	44,339
Winters catch	Winters	2,053
Woodland catch	Woodland	12,701
YCFC East	YCFC	55,340
YCFC Hungry Hollow	YCFC	23,872
YCFC West	YCFC	71,097
Clarksburg Management Area*		36,500
North Delta East	RD 150, RD 307, RD 765, Most of RD 999, Town of Clarksburg	36,500
Dunnigan Hills Management Area*		92,345
Bird Creek	White Area	3,467
Buckeye Creek	White Area	34,409
Dunnigan Other	White Area	28,916
Goodnow Slough	White Area	4,083

Table 3. Subdivisions of the YSGA model

Modeled Area Name	Entity Name/White Areas Included	Area (ac)
Oat Creek	White Area	4,742
YCFC Dunnigan Hills	YCFC	16,728
North Yolo Management Area*		103,770
Cacheville CSD catch	Cacheville CSD	98
CBD North	White Area	5,119
CBD South	White Area	12,177
Dunnigan Water District	Dunnigan Water District, Cal Am Water Dunnigan, Town of Dunnigan	11,597
Knights Landing CSD catch	Knights Landing CSD	162
RD 108	RD 108	25,075
RD 730	RD 730	4,829
RD 787	RD 787	10,286
Sac River	White Area	7,833
YCFC Zamora	YCFC	669
Yolo Zamora North	Town of Zamora, White Area	10,581
Yolo Zamora South	White Area	15,344
South Yolo Management Area*		78,279
North Delta West	Parts of 2068, White Area	49,635
RD 1600	RD 1600	7,056
RD 537	RD 537	2,455
RD 785	RD 785	3,226
RD 827	RD 827	1,189
West Sac catch	West Sac, RD 900	14,718
Upper Cache Creek Watershed (in Lake County)		558,568
Bear Creek		66,247

Table 3. Subdivisions of the YSGA model

Modeled Area Name	Entity Name/White Areas Included	Area (ac)
Copsey Creek		20,384
Clear Lake		244,881
Kelsey Creek		26,165
Lower Indian Valley		66,445
Middle Indian Valley		36,751
Seigler Canyon		13,791
Upper Indian Valley		38,538
Upper Cache Creek		45,368
Yolo Subbasin (MODFLOW Model AREA)		559,840
Yolo Subbasin (Official)		540,400

- *Refers to boundaries as in Figure 4 Subregion Boundaries, Management Areas and Neighboring Subbasins*

Figure 5 Differences between model domain and YSGA/management area boundaries

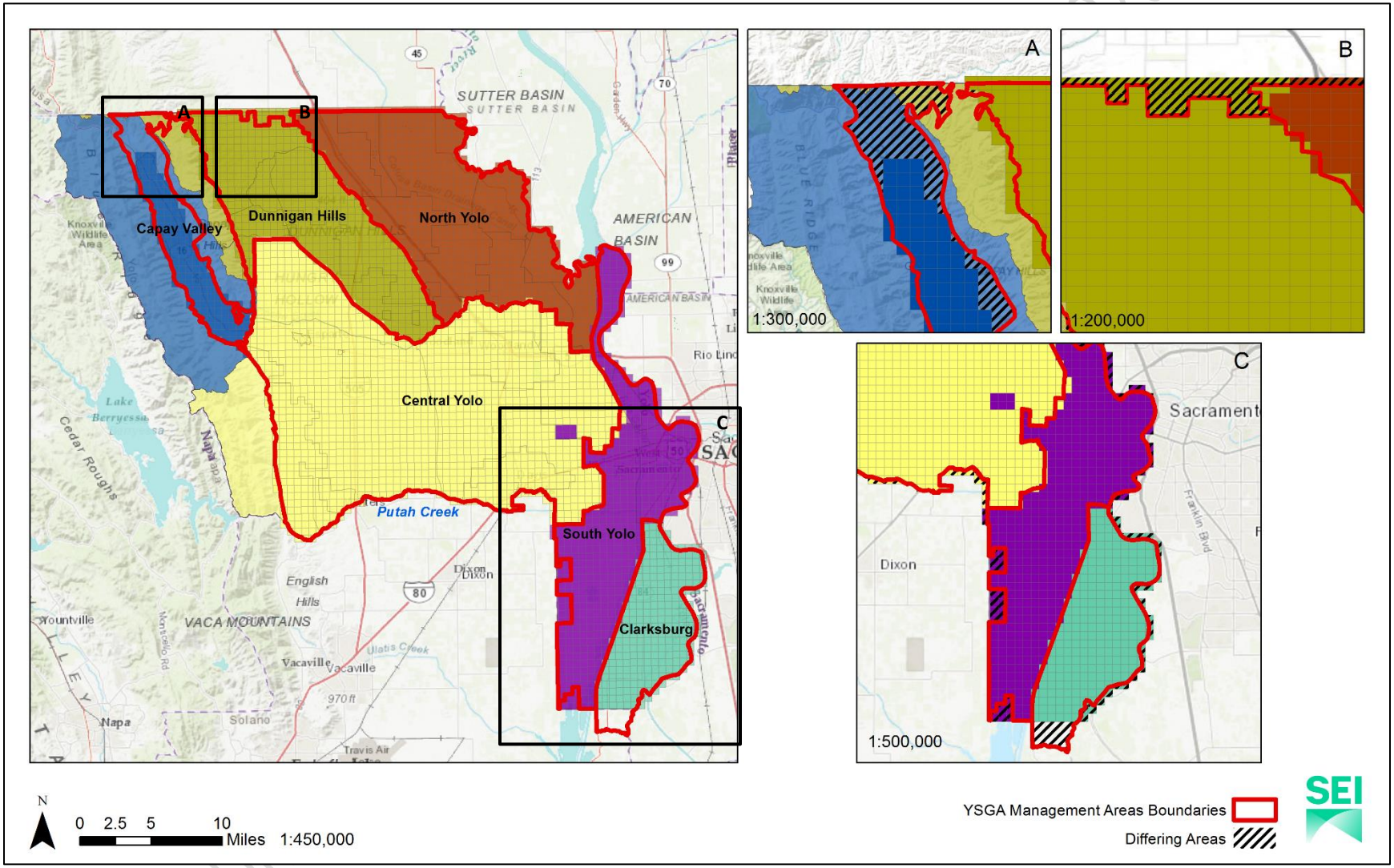


Table 4. Model domain difference from Yolo basin boundary

Region	Description	Status
A	Uppermost, hilly portion of Capay bordering Buckeye Creek headwaters	This portion is included in the model's land surface budget, but the MODFLOW grid and associated information shows that the alluvial aquifer does not extend into the hills; hence it is not included in the MODFLOW model or groundwater budgets (also see Figure 2). Runoff from this area does influence the groundwater, however, and is included in the model land surface water budget.
B	Northern boundary of basin and county	This part is not included in the Yolo Subbasin boundary, but is included in the model.
C	Southern tip of Clarksburg Management Area (RD 999 territory)	Not included in the model domain but was included in the YSGA boundary at a late stage of model development. It is in Solano County, and the model does not cover any portion of Solano County.
C	Small cut outs in South Yolo Management Area	Included in the model because it is in Yolo County but not included in the Yolo Subbasin, because these entities (RD 2068 and RD 2093are not part of YSGA.
C	Isolated plot to west	This portion is a 'white area' that does not fall into any entity, and was included into the South Yolo MA wáter budget.

1.1.2. Computational Aspects

This section summarizes the computational algorithms used in the YSGA model, with references to published literature for the detailed equations.

As mentioned in Section 1.1, the surface water budget (climate-driven hydrology and water allocation) is computed by WEAP's built-in routines, while the groundwater flow is computed by MODFLOW (Table 5).

Table 5 Computational aspects of model

YSGA Model regions	Algorithm	Reference to algorithm details	Computation time step	Reporting time step
Watersheds in Lake county	Soil Moisture Model	(Yates, 1996; Yates et al., 2005a, 2005b)	Monthly	Monthly
Catchments within Yolo basin	MABIA	(Jabloun and Sahli, 2012)	Daily	Monthly
Valley floor	MODFLOW	(Harbaugh, 2005)	Sub-daily	Monthly

WEAP has several built-in soil moisture budget algorithms to choose from. WEAP uses a Linear Program solver to allocate water from one or more sources to one or more demands, at every time step, based on a user-defined assignment of supply preferences and demand priorities. The allocation is constrained by operational rules such as reservoir release rules, canal capacities, and diversion restrictions based on water rights. This allocation routine is the same irrespective of which soil moisture budget is chosen.

1.1.2.1.Soil Moisture Method (SMM)

In the YSGA model, the upstream Clear Lake catchments' water budget (almost in Lake County) is computed by WEAP's Soil Moisture Method (SMM) algorithm, at a monthly time step. This part of the model domain is largely unchanged from earlier modeling efforts using WEAP (Mehta et al., 2018, 2013). The SMM equations are described in Yates et al. (2005b) and online[5]. The root zone soil moisture balance is expressed as a one-dimensional differential equation that is solved at each time step.

1.1.2.2.MABIA Method

The MABIA Method is a daily simulation of transpiration, evaporation, irrigation requirements and scheduling, crop growth, and yields. It was derived from the MABIA suite of software tools, developed at the Institut National Agronomique de Tunisie by Dr. Ali Sahli and Mohamed Jabloun. The algorithms and equations for the combined MABIA-WEAP calculation procedure are described in (Jabloun and Sahli, 2012). The MABIA Method uses the standard and well-known 'dual' crop coefficient method, as described in the classic FAO-56 article (Allen et al. 2005) whereby the K_c value is divided into a 'basal' crop coefficient, K_{cb}, and a separate component, K_e, representing evaporation from the soil surface. The basal crop coefficient represents actual ET conditions when the soil surface is dry but sufficient root zone moisture is present to support full transpiration.

1.1.2.3.MODFLOW, and WEAP-MODFLOW linkage

MODFLOW is a three-dimensional finite-difference groundwater modeling platform created by the U.S. Geological Survey (USGS). When properly linked, data and results flow back and forth between WEAP and MODFLOW for each WEAP calculation timestep. The versions of MODFLOW that can be linked to WEAP are MODFLOW 2000, MODFLOW 2005 and MODFLOW-NWT[6]. In MODFLOW, the groundwater flow equation is solved using the finite-difference approximation.

The MODFLOW model grid for the YSGA model is shown in Figure 3. Active cells correspond to those areas with an underlying aquifer layer below the land surface. All model parameters were imported, as a

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[5] See https://www.weap21.org/WebHelp/Two-bucket_Method.htm#:~:text=The%20Soil%20Moisture%20Method%20calculates,water%20above%20ground%20to%20decrease. Accessed 8.31.2020.

[6] See https://water.usgs.gov/ogw/modflow/modflow or http://water.usgs.gov/nrp/gwsoftware/modflow2000/modflow2000.html or http://en.wikipedia.org/wiki/MODFLOW

starting point, from the IWFM model (Flores Arenas, 2016). Some parameters were adjusted during the calibration process, which is detailed in the Model Documentation Appendix.

1.1.3. Data Sources

This section summarizes the data sources used in the YSGA model for the historical period, and the main assumptions for both historical and future scenarios.

Table 6 Data sources

Category	Variable	Historical		Future Projections	
		Sources	**Model use**	**Sources**	**Model use**
Climate	Precipitation	PRISM[1]	Input data	Historical, modified by Climate Change factors provided by DWR	Input data
	ETo	CIMIS[2]	Calibration	Historical, modified by Climate Change factors provided by DWR	Input data
	Minimum Temperature	PRISM[1]	Input data	NA	
	Maximum Temperature	PRISM[1]	Input data	NA	
	Wind speed	(Livneh et al., 2013); CIMIS[2]	Input data	NA	
	Humidity	PRISM[1]	Input data	NA	
Land Use	Agricultural land use	DWR Land Use Surveys3; Yolo County Annual Agriculture Commissioner Reports; DWR SGMA Portal (LandIQ dataset)	Input data	Agricultural landuse kept constant to Current Year	Input data
	Non-agricultural land uses	DWR Land Use Surveys[3];	Input data	Growth projections from urban master plans[6]	Input data
Irrigation	Schedule	Sacramento-San Joaquin basin Study[4] (Reclamation, 2015)	Input data	Same as historical	Input data
	Crop coefficients	Sacramento-San Joaquin basin Study[4] (Reclamation, 2015)	Input data; Calibration	Same as historical	Input data
	Irrigation efficiency	NA	Calibration	Same as historical	Input data
	Applied Water	DWR Applied Water Estimates[5], Groundwater management plans and personal communication[6]	Calibration	NA	Model output
	Water sources and supply	SWRCB eWRIMS water rights database[7],	Input Data	Same as historical	Input Data

Catego	Variable	Historical		Future Projections	
		Sources	Model use	Sources	Model use
		personal communication[6]			
Urban	Water demand, including population	Urban water plans and personal communication[6]; CA Department of Finance Population data[8]	Input data	Growth projections from urban master plans[6]	Input data
	Water sources and supply	Urban water plans and personal communication[6]; SWRCB eWRIMS water rights database[7]	Input data (water rights)	Urban water plans[6]	Input data (water rights)
Hydrology	Stream flows	USGS[9]; CDEC[10]	Calibration	NA	Model output
	Stream flows	USGS9; CDEC[10]	Input Data	Same as historical	Input data
	Initial groundwater conditions	WRID[11]; SGMA[12]; IWFM model (Flores Arenas, 2016)	Input data	Historical model end-of simulation set as future model run initial conditions	Input data
	Groundwater boundary conditions	IWFM model (Flores Arenas, 2016)	Input data, calibration	NA	Input data
	Groundwater elevations (time series)	WRID[11]; SGMA[12]; WDL [13];	Calibration, Model output	NA	Model output
	Reservoir operations (storage levels, outflows)	CDEC[10]; Conversations with and data supplied by YCFC[6]	Calibration, Model output	NA	Model output
	In-stream flow requirements	CDEC[10]; Conversations with and data supplied by YCFC[6]	Input data	Same as historical	Input data

1 http://www.prism.oregonstate.edu/explorer/ Accessed 5.19.2019

2 https://cimis.water.ca.gov/Default.aspx . Accessed 5.19.2019

3 https://gis.water.ca.gov/app/CADWRLandUseViewer/ Accessed 9.1.2020

4 https://www.usbr.gov/watersmart/bsp/docs/finalreport/sacramento-sj/Sacramento_SanJoaquin_TechnicalReport.pdf Accessed 9.1.2020

5 https://water.ca.gov/Programs/Water-Use-And-Efficiency/Land-And-Water-Use/Agricultural-Land-And-Water-Use-Estimates Accessed 2.1.2019.

6 A complete list of entity-specific data sources and personal communication is provided in the Model Documentation Appendix, and in spreadsheet format to the YSGA

7 https://www.waterboards.ca.gov/waterrights/water_issues/programs/ewrims/

8 http://www.dof.ca.gov/Forecasting/Demographics/Estimates/

9 https://waterdata.usgs.gov/nwis/sw

10 https://cdec.water.ca.gov/

11 Yolo County Water Resources Information Database (https://wrid.facilitiesmap.com/Login.aspx)

12 SGMA Data Viewer https://sgma.water.ca.gov/webgis/?appid=SGMADataViewer#gwlevels
13 California Water Data Library https://wdl.water.ca.gov/GroundWaterLevel.aspx

1.2. Future Scenarios

GSP regulations require the evaluation of future water budgets, i.e future scenarios. In this section the following is discussed:

(i) Projections of water demand
   a. Urban water demand projections were based on population and water use projections from urban water management plans.
   b. Irrigated landcover was kept constant at 2018 levels (which are based on 2016 datasets).

(ii) Climate change projections, in the form of perturbations (i.e. multipliers) applied to the historical climate.

1.2.1. Useful Terms in this section

Table 7. Useful Terms in this Section

Term	Description
Scenario	A plausible, often simplified representation about the future. A single scenario is a combination of projections in different dimensions (e.g. population, land use, and climate) about the future.
Projection	A plausible, often simplified description of one future condition (e.g. population)
Climate change	A change in the state of the climate that can be identified by changes in the mean and/or the variability of its properties (often by using statistical tests), and that persists for an extended period, typically decades or longer (California DWR, 2015)
Climate model	A numerical representation of the climate system based on the physical, chemical, and biological properties of its components, their interactions and feedback processes, and accounting for all or some of its known properties. (California DWR, 2015)
Climate projection	A projection of the response of the climate system to emission or concentration scenarios of greenhouse gases and aerosols, or radiative forcing scenarios, often based on simulations by climate models. (California DWR, 2015)
Intergovernmental Panel on Climate Change (IPCC)	Scientific panel overseen by the United Nations, which investigates the global impacts of climate change. (California DWR, 2015)

Table 7. Useful Terms in this Section

Term	Description
AR5	IPPC 5th Climate Change Assessment Report published in 2014. (California DWR, 2015)
GSA	Groundwater Sustainability Agency
GSP	Groundwater Sustainability Plan

1.2.2. Climate projections

The California Department of Water Resources (DWR) provides datasets, tools, and guidance regarding climate change datasets that can be used by GSA's to develop future projections for GSP's. DWR provides processed climate change datasets related to climatology, hydrology, and water operations. Climate projections are in the form of change factors for precipitation and reference evapotranspiration, provided in gridded format for the state. These were downloaded from the DWR SGMA Data Viewer[7].

These data were originally developed for the California Water Commission's Water Storage Investment Program (WSIP).

Data represent projections for two future climate periods: 2030 and 2070.

- There are 4 scenarios; one for 2030 representing the central tendency from several downscaled climate models; and three for 2070 (central tendency, dry-extreme warming, and wetter with moderate warming)
- The process involved a "climate period analysis". Historical inter-annual variability (1915-2011) is preserved while the magnitude of events is perturbed based on projected temperature and precipitation changes from general circulation models.

Additional details about the methods involved are provided in DWR's Guidance Document on Climate Change datasets (California DWR, 2018). Details on the processing of the data are provided in the Model Documentation Appendix.

1.2.3. Future scenarios

Five future scenarios were incorporated into the YSGA model based on different climate projections. In each of these scenarios, (a) the land-use is the same: increasing urban water demand based on urban water management plan projections, and agricultural land-use is kept constant at current year levels; (b)

[7] https://sgma.water.ca.gov/webgis/?appid=SGMADataViewer#waterbudget , Accessed 8/27/2019

water rights and supply conditions are kept the same as current year levels, and (c) Any change in irrigation demand is driven by the climate signal.

Table 8 Future scenarios

Scenario name	Summary
Future_Baseline	Urban demand increasing; irrigated crops constant at 2016/2018 ; climate same as historical
Future_2030	Climate representing the central tendency from many downscaled climate models, centered around 2030
Future_2070	Climate representing the central tendency from many downscaled climate models, centered around 2070
Future_2070_DEW	Climate representing dry-extreme warming from many downscaled climate models, centered around 2030
Future_2070_WMW	Climate representing wetter-moderate warming from many downscaled climate models, centered around 2030

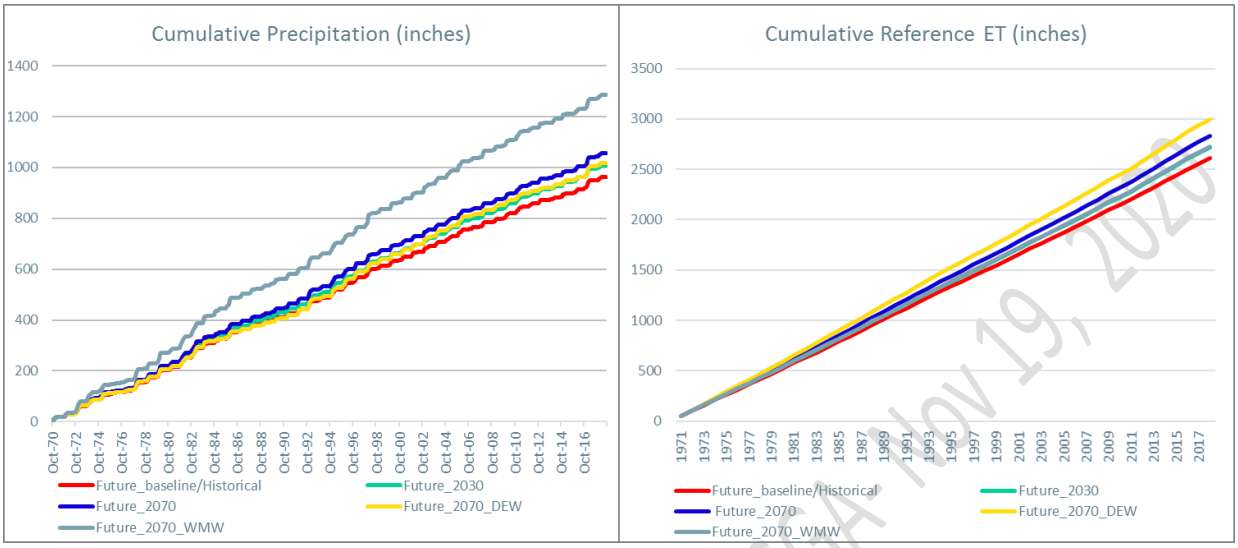
Table 9 below summarizes the differences in precipitation inputs over the City of Davis from these climate scenarios. Interestingly, the historical climate is dryer than any of the climate projections from the climate models. Within the 2070-centered projections, the wet-moderately warm projection is almost 20% wetter than the 2070 central tendency projection and the dry-extreme warming scenario is 3.5% drier.

Table 9. Total precipitation and reference ET over 48-year future simulations for the City of Davis

Scenario	Future_Baseline (same as Historical)	Future_ 2030	Future_ 2070	Future_ 2070_DEW	Future_ 2070_WMW
Total Precipitation (inches)	962	1009	1055	1018	1285
Total reference ET (inches)	2609	2718	2833	2997	2728

Figure 6 shows the time series of cumulative precipitation and cumulative reference ET for historical and future climate projections, for the City of Davis. Note that the date timeline is figurative; it represents the actual timeline only for the historical (corresponding to “Future_Baseline”) climate; otherwise it represents a representative future period of the same number of years, i.e. 48 years.

Figure 6 Cumulative precipitation and Reference ET for the City of Davis



1.3. Water Budgets

This section presents the land surface water budget, groundwater budget, and groundwater storage results for the historical (WY 1971 – WY 2018) and future scenarios. WY 2018 is considered as the "current year" in what follows, being the most recent year for which consistent datasets could be obtained or reasonably assumed (when not available).

Table 10. Useful terms in this section.

Term	Description
Deep percolation (DP)	Water that recharges the groundwater aquifer from all overlying catchments within the county. This includes water from precipitation and irrigation.
Drainage	In regions close to the Sacramento River where the water table can be close to the ground surface, surface channels provide a route for the discharge of groundwater into the surface water system. To mimic that process the MODFLOW DRN package was used to place a drainage boundary in Reclamation Districts 108, 1600, 730, 787, and North Delta East and North Delta West catchments.
Evapotranspiration (ET)	Evaporation from the land surface (soil and urban land cover) and transpiration from vegetation (agriculture and native vegetation) from all catchments within the county.
GW-SW Exchange	Exchange of groundwater to/from the Yolo basin and surface features (Cache Creek, the Colusa Basin Drain, Knights Landing Ridge Cut, Putah Creek, the Sacramento River, Ship Channel, Willow Slough, and the Yolo Bypass).
Lateral GW Flow: Outside Yolo subbasin	Groundwater flow between the Yolo Subbasin and the neighboring subbasins: Colusa, North American, Solano, South American, and Sutter subbasins.
Managed aquifer recharge: Woodland	Water recharged to the confined aquifer underlying the city of Woodland, through the Aquifer Storage and Recovery program.
Precipitation	Rain falling within the county.
Pumping: Irrigation	Groundwater supplied for agricultural irrigation in the county.
Pumping: Urban	Groundwater (from both the general aquifer and the Woodland confined aquifer) supplied to urban demands represented in the county
Surface Runoff (SRO)	Surface runoff from the land within the county to Cache Creek, the Colusa Basin Drain, Putah Creek, the Sacramento River, Willow Slough, and the Yolo Bypass,
SW supply: Irrigation	Water supplied for agricultural irrigation from the Colusa Basin Drain, Cache Creek via YCFC canals, the Delta, Putah Creek, Sacramento River and Tehama Colusa Canal, Willow Slough, and the Yolo Bypass.
SW supply: Urban	Water supplied from the Sacramento River (to West Sacramento and the Woodland Davis Clean Water Agency) and from Cache Creek (to the Yocha Dehe Wintun Nation Golf Course).
Tailwater re-use: Irrigation	Reuse of irrigation tailwater. Reclamation Districts and the North Delta East catchment can reuse 90% of tailwater for irrigation in the model, based on previous work describing reuse in RD108 (Davids Engineering, 2011).

Table 10. Useful terms in this section.

Term	Description
Treated WW Outflow	Return flows from the West Sacramento portion of the Sacramento wastewater treatment plant into the Sacramento River, from Davis and Woodland's wastewater treatment plants into the Yolo Bypass, and from Winters' wastewater treatment plant into Putah Creek.
Urban consumption	Water consumed within the urban demands represented in the county. Landscape irrigation is included within these demands.
YCFC canal recharge	Canal Recharge from the YCFC unlined canals.

1.3.1. Land Use

Landcover in the Yolo Subbasin is dominated by agriculture and native vegetation. Estimates of irrigated acreage have varied from 231,568 (in 2015, at the peak of a long-running drought) to 358,883 (in 1978) during the WY 1971-WY 2018 period (Source: DWR Land and Water Use Surveys

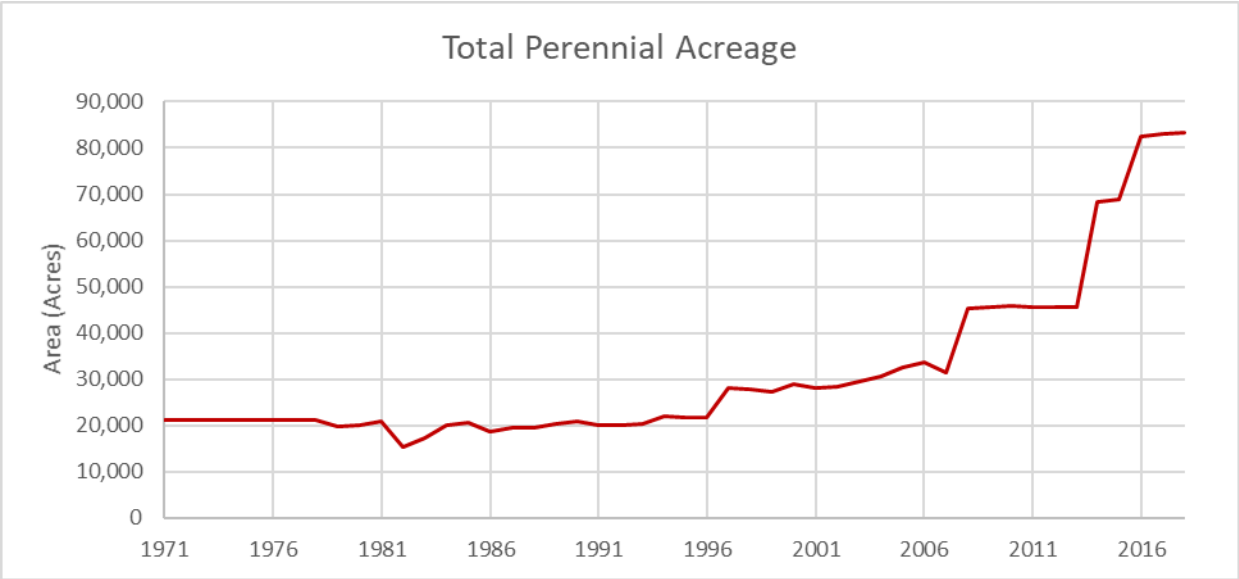
Figure 7 shows how perennial acreage has increased over the historical time period. Table 11 shows the acreage and proportion of the main categories of Basin-wide land use (as used in the YSGA model) for specific years where GIS data were available (1989, 1997, 2008, and 2016). Details on how a time series was constructed are in the Model Documentation Appendix. An important feature of land use change in the Yolo Subbasin is an increasing acreage of perennials, which have partly replaced field crops, and also brought previously uncultivated area into production in some regions.

Table 11 Land Use in the Yolo Subbasin

	Land Use (ac)				Land Use (Percent)			
	1989	1997	2008	2016	1989	1997	2008	2016
Entire Basin	**639,089**	**639,089**	**639,089**	**639,089**				
Deciduous	17,550	18,406	30,717	59,434	3	3	5	9
Field Crops	96,679	108,427	36,475	41,446	15	17	6	6
Grain	80,354	57,993	52,369	27,200	13	9	8	4
Managed Wetlands	0	483	459	0	0	0	0	0
Native Vegetation	288,058	284,997	319,938	330,463	45	45	50	52
Pasture	42,612	44,822	63,801	33,129	7	7	10	5
Rice	22,652	24,754	35,056	38,847	4	4	5	6
Subtropical	118	135	1,331	3,670	0	0	0	1
Truck Crops	56,953	55,160	46,968	46,930	9	9	7	7
Urban	26,347	29,153	33,220	33,270	4	5	5	5
Vine	2,543	9,536	13,384	19,329	0	1	2	3
Water	5,222	5,222	5,372	5,372	1	1	1	1

Source: DWR Land and Water Use Surveys

Figure 7 Total acreage of perennial crops



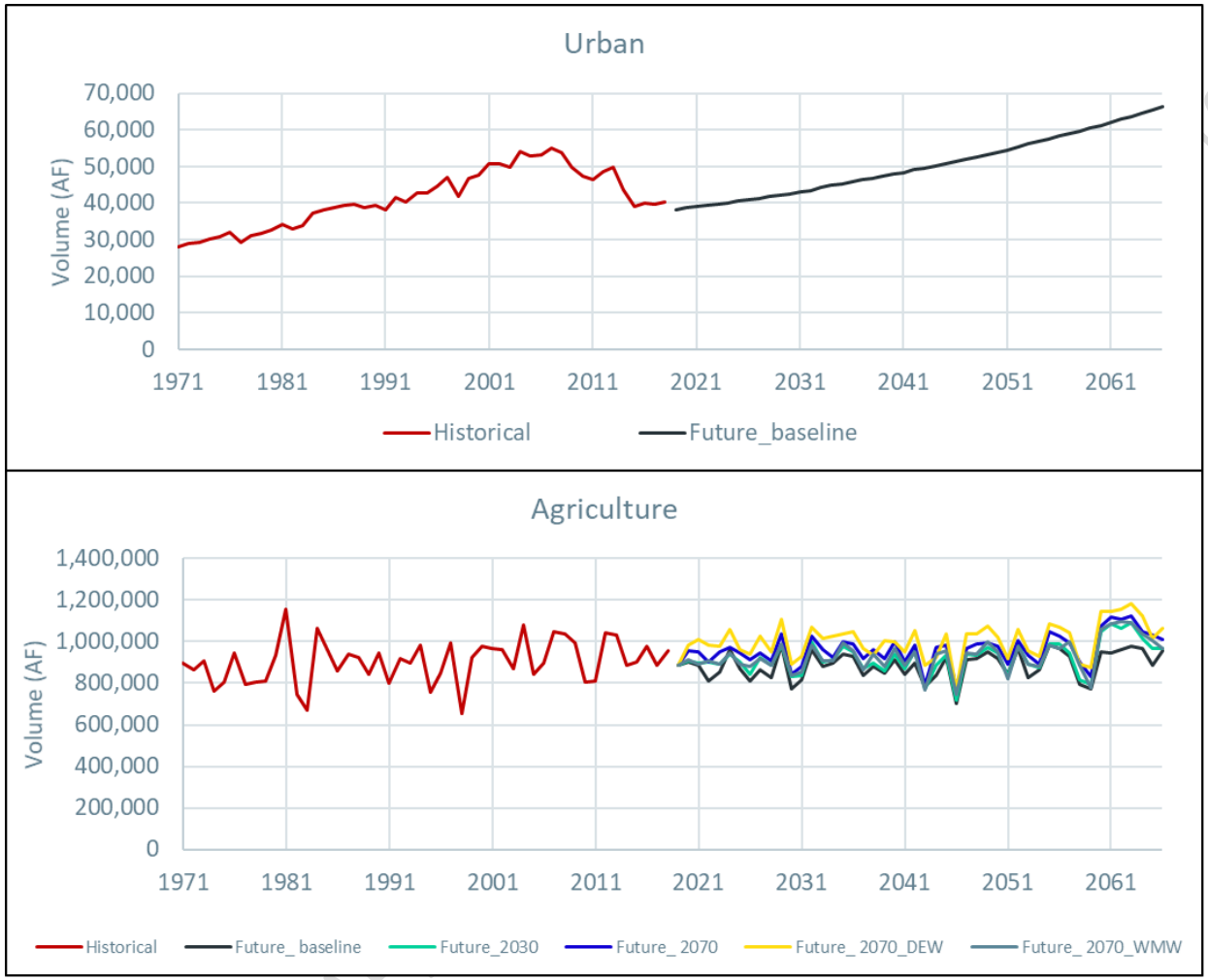
Source: DWR Land and Water Use Surveys; Yolo County Annual Crop Reports. Includes deciduous and subtropical orchards, and vineyards in Yolo County historically as represented in the model.

1.3.2. Water demand and supply

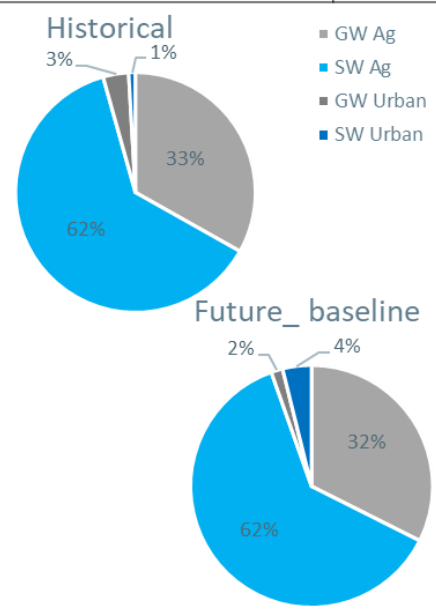
Before the Basin-wide water budgets are described in detail, this section summarizes the simulated total water demand and supply, for all scenarios. Total water demands for each scenario are presented below (Figure 8). Urban water demands, as informed by individual urban water management plans, rise steadily – but remain small relative to irrigation demand. Irrigation demand in the future scenarios, as shown in this figure, stay within the range of historical simulations, but their averages are successively higher than the Historical scenario in the following order: Future_baseline, Future_2030, Future_2070_WMW, Future_2070, and Future_2070_DEW.

The Future_baseline comparison against Historical is instructive: because the climate is the same between those two scenarios, it mainly shows the effect of current, increased perennial crop acreage in the Basin. The pie charts show that the supply sources are expected to be about the same, with surface water supply for irrigation on average at 66% of water supply, followed by groundwater for irrigation. The Woodland-Davis Clean Water Agency's water supply accounts for the increase in urban surface water supply in the Future_baseline scenario. Overall, the average annual water demand increases from 945 TAF in the historical scenario to a maximum of 1055 TAF in the extreme DEW scenario (Figure 8).

Figure 8 Water demands



Average Annual Demand (Acre Feet)	
Urban	
Historical	41,102
Future[1]	50,270
Agriculture	
Historical	904,090
Future_baseline	888,139
Future_2030	922,000
Future_2070	961,712
Future_2070_DEW	1,005,341
Future_2070_WMW	931,403



[1] Urban demand is the same in all future scenarios

1.3.3. Land Surface Water Budget

1.3.3.1.County-wide Historical and Current Year

The land surface water budget for the entire county is presented in this section, since all areas of Yolo County contribute to the overall water balance of the Yolo Subbasin (See Table 3.

Figure 2 and Figure 4).

Results are presented in summary form first, as annual averages (Table 12). Inflows are dominated by precipitation and water supply deliveries. Outflows are dominated by ET, surface runoff (SRO), and deep percolation.

The key results for the historical average land surface water budget are as follows:

- Precipitation accounts for 1.15 million acre-feet (MAF), with total water supply accounting for the remaining 0.955 MAF of inflows.
- Surface water supply (0.6 MAF) makes up about 60% of the total water supply, with groundwater pumping making up the remaining 40%.
- Agricultural irrigation demand accounts for more than 90% of the total water demand of 1 MAF.
- Water supply sources to meet agricultural and urban demands are shown. Note that urban demand was, historically, met primarily by groundwater pumping.
- Total outflows are very close to total inflows, indicating an overall mass balance of inflows and outflows (i.e. without any trends on average in change in soil moisture).
- ET is the largest of the outflows, at 1.2 MAF, approximately 8% higher than precipitation.

Table 12 aggregates many fluxes into larger categories; these are summarized in Table 10. For example, urban surface water supply aggregates (sums) the surface water supply to all the urban demands in the model. Similarly, Surface Runoff and Deep Percolation sum all the surface runoff that occurs from all the catchments in the YSGA model in the County.

Annual surface water budgets are presented in Table 12 and Table 13. Note that climate, land use, and water supply conditions have varied over the 48-year historical period. As shown in Table 2, there have been several significant droughts, and wet periods. Also, surface water supply has increased at different times and for different parts of the Basin. For example, Indian Valley Reservoir came online in 1975; the Tehama Colusa Canal provided surface water to Dunnigan Water District starting in the mid-1980's; and the Woodland Davis Clean Water Agency started supplying Sacramento River water to Woodland, Davis, and UC Davis in 2016, which were entirely reliant on groundwater before then.

Some of the changes over time are apparent in the Current Year budget. In Table 13 and Figure 9, the surface water budget for the Current Year, WY 2018, is shown. WY 2018 was a below normal Water Year, with precipitation at approximately 66% of the historical average precipitation from WY 1971 – WY 2018. As a result, all fluxes in the Current Year – except urban-related fluxes – are lower than their historical average counterparts. In the urban sector, current year demands are comparable to historical averages; the main difference is that the supply source has shifted from groundwater to surface water being the dominant supply – as a result of the Davis-Woodland Clean Water Project that now supplies Sacramento River water for Davis, Woodland, and UC Davis for most of the year. Canal recharge also shows different behavior, being larger in 2018 than on average – canal recharge in the YCFC system is very dependent on total reservoir storage in Clear Lake and Indian Valley Reservoir, timing of precipitation in the winter and spring, and releases made through the canal system. Moreover, the historical period includes early years before Indian Valley Reservoir was constructed, and a few drought years when no water was legally allowed (by the Solano Decree) to be released for irrigation – these factors lower the historical average compared to the Current Year canal recharge.

1.3.3.2.County-wide Future Scenarios

Table 12 also includes the annual average land surface budget for the future scenarios. As noted earlier, **the cumulative and average precipitation for the County and Basin, is higher in all the climate projections, compared to that in the historical scenario.** For example, annual average precipitation for the County in Future_2070_WMW (the wet extreme climate projection) is 1,530 TAF compared to 1,147 TAF in the historical scenario. The increased precipitation explains some of the main results, as noted below.

1. **Overall land surface mass balance is maintained:** In each scenario, the total inflows and outflows at Basin and MA scale are maintained.
2. **Effect of increased perennial acreage: More ET, less DP**
   The Future_Baseline scenario has the same historical climate, but different demand (current irrigation demand and projected urban demand) compared to the Historical scenario. This scenario is dominated by a land-use effect as mentioned earlier. As expected, the increased acreage in perennial crops in this scenario leads to an increase in ET of almost 50 TAF on an annual average basis, over Historical ET. Deep Percolation decreases by 43 TAF. This is because of a shift in crops from those with lower irrigation efficiency to higher efficiency over time, as has been reported (Orang et al., 2008). Area-weighted average irrigation efficiency in the MABIA module was 62% for 1971-2018 and 70% for the future scenarios.
3. **Effect of climate change: More ET, more DP**
   The climate change scenarios (Future_2030, Future_2070, Future_2070_DEW, Future_2070_WMW), when compared to Future_Baseline, show the sensitivity of the system (and the model) to climate; the cropping pattern and urban demand is the same in these five scenarios. Table 12 shows that in all four climate change scenarios, ET is higher compared to Future_Baseline. This is a direct effect of increased warming, since all four scenarios are warmer than the historical climate used in the Future_Baseline scenario. The greatest increase in ET, is in

the Dry and Extreme Warming scenario (Future_DEW), which has the most warming, followed by the Future_2070 scenario, which has the next highest warming. Meanwhile, Deep Percolation and runoff are affected more by precipitation differences: hence these fluxes are highest in the wettest scenario (Future_2070_WMW, which is the extreme wet with moderate warming scenario). Changes in the other budget components are small, although canal recharge and surface water supply for irrigation are slightly higher in the wetter scenarios.

1.3.3.3. Management Area budgets

Management Area budgets are presented in detail in Appendix A.

Table 12 County-wide average land surface water budgets

All values are in Thousand Acre Feet

Historical Average Annual Land Surface Water Budget (TAF)														
	Outflows							Inflows						
	Evapotranspiration	Deep Percolation	Surface Runoff	Urban Consumption	YCFC Canal Recharge	Treated WW Outflow	Total Outflows	Precipitation	Pumping: Urban	Pumping: Irrigation	SW Supply: Urban	SW Supply: Irrigation	Tailwater Reuse: Irrigation	Total Inflows
Entire Basin														
Historical	-1,227	-353	-459	-18	-33	-13	-2,102	1,147	33	313	9	591	10	2,102
Future_Baseline	-1,274	-308	-437	-23	-37	-16	-2,095	1,147	16	304	34	584	10	2,095
Future_2030	-1,314	-321	-471	-23	-39	-16	-2,184	1,201	15	322	35	600	11	2,184
Future_2070	-1,345	-340	-519	-23	-40	-16	-2,282	1,259	15	343	36	619	11	2,282
Future_2070_DEW	-1,346	-323	-549	-23	-37	-16	-2,293	1,229	15	385	35	620	9	2,293
Future_2070_WMW	-1,326	-424	-692	-23	-43	-16	-2,523	1,530	14	311	37	620	11	2,524

Figure 9 Land surface water budget for Yolo County

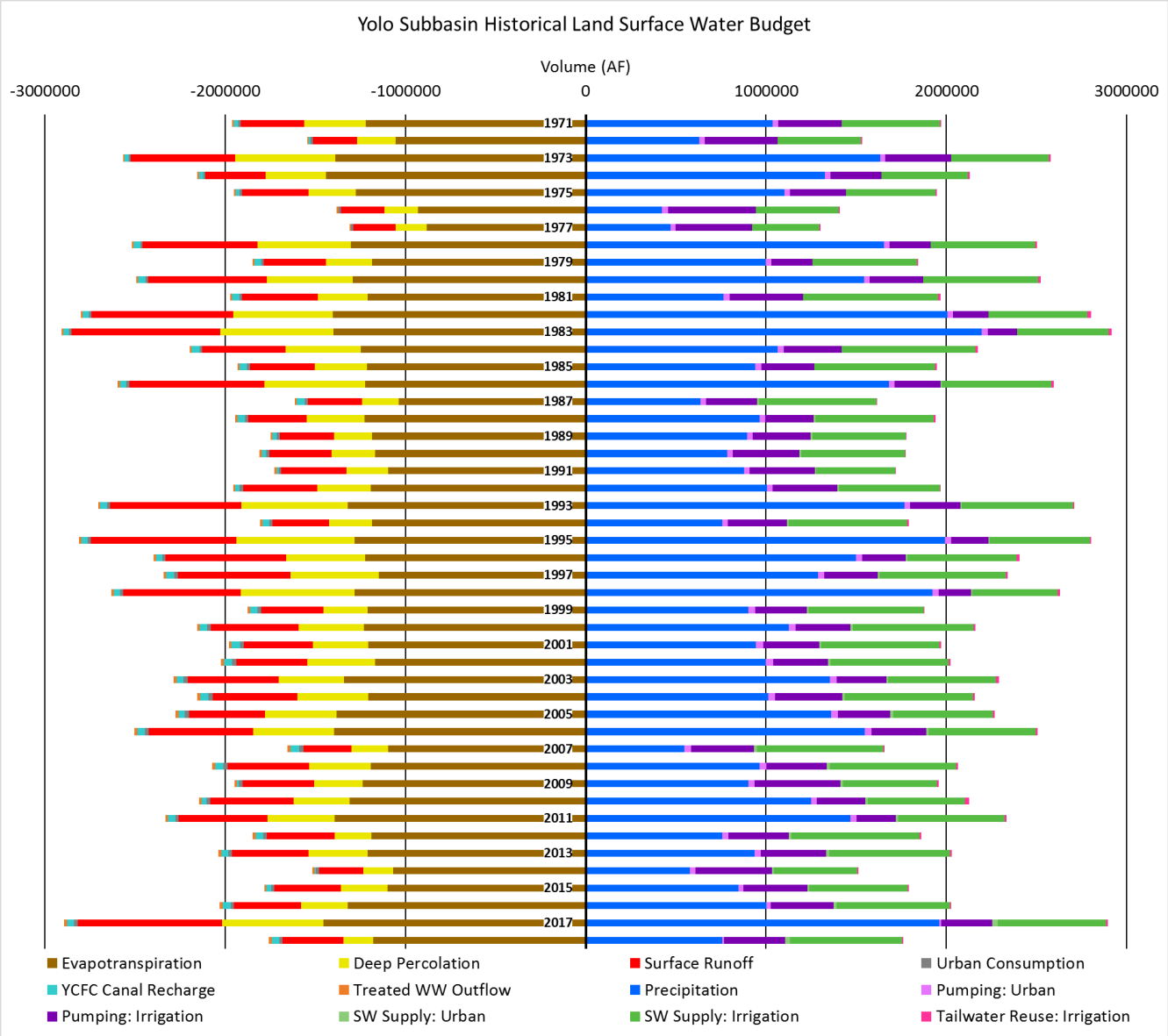


Table 13 Annual Land Surface Budget for the Yolo Subbasin

All values are in Thousand Acre-feet

Yolo Subbasin Historical Land Surface Budget (TAF)														
	Outflows							Inflows						
WY	Evapotranspiration	Deep Percolation	Surface Runoff	Urban Consumption	YCFC Canal Recharge	Treated WW Outflow	Total Outflows	Precipitation	Pumping: Urban	Pumping: Irrigation	SW Supply: Urban	SW Supply: Irrigation	Tailwater Reuse: Irrigation	Total Inflows
Average	-1,227	-353	-459	-18	-33	-13	-2,102	1,147	33	313	9	591	10	2,102
1971	-1,221	-340	-354	-12	-26	-9	-1,960	1,038	28	355	0	543	9	1,972
1972	-1,056	-212	-247	-12	-9	-9	-1,545	630	29	405	0	462	8	1,534
1973	-1,389	-557	-577	-12	-23	-9	-2,567	1,633	29	365	0	541	10	2,578
1974	-1,440	-336	-333	-13	-23	-9	-2,154	1,327	30	282	0	482	7	2,128
1975	-1,275	-262	-370	-13	-23	-9	-1,952	1,103	31	308	0	500	5	1,946
1976	-932	-184	-242	-13	0	-10	-1,381	423	32	487	0	460	8	1,410
1977	-881	-174	-235	-12	0	-9	-1,311	470	29	423	0	375	6	1,302
1978	-1,301	-518	-638	-13	-37	-9	-2,517	1,655	31	227	0	579	11	2,504
1979	-1,184	-256	-346	-13	-37	-10	-1,847	998	32	228	0	580	6	1,844
1980	-1,293	-477	-656	-14	-43	-10	-2,493	1,543	33	296	0	636	14	2,523
1981	-1,211	-276	-418	-14	-43	-10	-1,973	763	34	409	0	749	13	1,968
1982	-1,404	-552	-786	-14	-34	-10	-2,799	2,005	33	195	0	549	20	2,802
1983	-1,400	-627	-825	-14	-32	-10	-2,908	2,197	34	163	0	506	16	2,916
1984	-1,249	-416	-461	-16	-44	-11	-2,198	1,063	37	320	0	743	11	2,173
1985	-1,214	-288	-361	-16	-41	-11	-1,931	938	38	292	0	670	11	1,949
1986	-1,224	-560	-747	-16	-37	-11	-2,596	1,682	31	254	8	608	12	2,595
1987	-1,036	-205	-301	-17	-43	-12	-1,614	636	32	284	8	655	3	1,617
1988	-1,229	-319	-325	-17	-42	-12	-1,943	964	31	270	8	655	11	1,940
1989	-1,186	-208	-302	-16	-24	-11	-1,748	895	31	322	8	519	5	1,779
1990	-1,167	-245	-344	-17	-25	-12	-1,809	785	31	370	8	575	7	1,776
1991	-1,095	-230	-363	-16	-10	-11	-1,726	879	30	361	8	438	2	1,718
1992	-1,193	-296	-412	-18	-24	-12	-1,956	1,004	32	360	10	558	5	1,968
1993	-1,319	-590	-728	-17	-37	-12	-2,704	1,767	33	277	8	619	7	2,710
1994	-1,184	-240	-313	-18	-37	-13	-1,805	756	34	328	9	655	9	1,790
1995	-1,282	-657	-806	-18	-34	-12	-2,809	1,993	34	206	9	554	9	2,804
1996	-1,222	-440	-667	-19	-35	-13	-2,397	1,499	35	241	10	606	17	2,407
1997	-1,148	-491	-623	-20	-46	-14	-2,343	1,287	37	296	10	699	10	2,339
1998	-1,282	-633	-652	-18	-34	-12	-2,631	1,923	33	180	9	473	12	2,630
1999	-1,208	-248	-345	-20	-41	-14	-1,876	902	36	286	10	640	5	1,879
2000	-1,229	-362	-488	-21	-41	-14	-2,155	1,125	37	307	11	671	11	2,163
2001	-1,205	-308	-383	-22	-47	-15	-1,980	944	39	311	12	656	9	1,971
2002	-1,168	-376	-395	-22	-47	-15	-2,023	1,000	39	306	12	657	9	2,022
2003	-1,339	-365	-503	-22	-40	-15	-2,285	1,355	38	273	12	598	15	2,291
2004	-1,207	-391	-470	-24	-47	-16	-2,155	1,011	39	371	15	710	10	2,156
2005	-1,382	-396	-422	-23	-36	-16	-2,275	1,360	38	291	14	553	10	2,268
2006	-1,395	-450	-578	-23	-41	-16	-2,503	1,545	38	304	15	592	11	2,506
2007	-1,095	-203	-267	-24	-48	-17	-1,654	545	39	348	16	702	8	1,658
2008	-1,192	-343	-451	-24	-44	-17	-2,071	965	38	334	16	702	10	2,065
2009	-1,238	-269	-396	-22	-9	-15	-1,949	902	36	476	14	520	10	1,958
2010	-1,311	-310	-462	-21	-27	-15	-2,145	1,249	34	267	13	539	24	2,126
2011	-1,394	-372	-491	-20	-40	-14	-2,331	1,467	33	219	13	590	11	2,333
2012	-1,191	-201	-378	-21	-41	-15	-1,847	757	35	334	14	709	13	1,862
2013	-1,211	-326	-424	-22	-39	-16	-2,038	935	35	365	15	669	13	2,031
2014	-1,069	-165	-245	-19	-7	-14	-1,518	578	31	422	12	463	7	1,513
2015	-1,099	-259	-370	-16	-28	-12	-1,784	846	29	356	10	544	6	1,791
2016	-1,320	-260	-373	-17	-44	-17	-2,031	1,002	24	349	16	629	8	2,028
2017	-1,456	-560	-803	-18	-41	-16	-2,894	1,959	11	286	29	602	8	2,895
2018	-1,178	-167	-337	-18	-42	-16	-1,757	755	11	338	30	619	9	1,762

1.3.4. Groundwater Budget

This section describes the groundwater inflows to, and outflows from the Yolo Subbasin aquifer as simulated by the YSGA model for the historical period (WY 1971-WY 2018, with WY 2018 representing the Current Year), as well as for the future scenarios.

Table 14 Useful terms in this section[8]

Term	Description
Managed aquifer recharge: (MAR) Woodland	Refers to the recharge estimated by the model from the Woodland Managed Aquifer Recharge project. For the historical scenario, these volumes are simply set to observed volume made available to the team.
Lateral GW Flow	Refers to groundwater flow entering (+) or leaving (-) the Yolo Subbasin.

1.3.4.1.Basin-wide Historical and Current Year

Table 15 includes the average annual groundwater fluxes. Current Year 2018 groundwater fluxes are included in the Basin-wide time series budget, in Table 16. The key findings are:

- Inflows to the Yolo Subbasin are dominated by deep percolation, at 353 TAF averaged over the historical period (WY 1971 – WY 2018). Canal recharge from the YCFC canal system is about 10% of this, at 33 TAF per year.
- Pumping (urban and irrigation) is the largest groundwater outflow, estimated at an average of 346 TAF, with pumping for urban supply accounting for 9% of total pumping. Groundwater discharge in regions by the Sacramento River simulated as drains is less than 10% of total groundwater outflow on average (28 TAF per year).
- GW-SW exchange is on average positive at 14.8 TAF; considering Cache Creek, Putah Creek, Sacramento River, Willow Slough, and the Yolo Bypass, GW-SW exchange is a net positive to the groundwater balance. However, Table 16 and Figure 10 show that the direction and magnitude of GW-SW exchange varies with climate conditions. In successive wet years, the net direction of flow changes, i.e. groundwater tends to outflow to surface waters as the water table elevation increases.
- The net lateral exchange with neighboring basins is -28 TAF, that is, on average, the lateral flow is leaving the Yolo Subbasin. Approximately 12 TAF/yr on average leave the model domain flowing into Colusa County, however, much of that flow occurs from the portion of the model that is highly uncertain. Along the Sacramento River the annual average lateral exchange is 177 AF/yr out of the model domain. The lateral exchange with Solano County is an average of 15 TAF/yr out of the model domain with most of that occurring along the boundary defined by

[8] Terms described before are not repeated.

Putah Creek. These flow change with climate conditions in direction and magnitude. In particular, in drought years such as 1976-1977 and 1991-1992, the aggregate lateral flow is into the Basin as the water table elevation decreases.

- Some fluxes are zero in some years. For example, City of Woodland's Aquifer Storage Recovery recharge wells became operational starting in 2017; and canal flows were zero in the deep drought of 1976-1977 and recent drought of 2014, when no water was available from Clear Lake for YCFC deliveries.

The Current Year (WY 2018) Groundwater Budget (included in the annual water budget shown in Table 16) shows some distinct differences from the annual average, due to the same reasons as described for the Land Surface Water Budget. Namely, WY 2018 being a relatively dry year, deep percolation was lower while pumping was higher than the 48-year average, which resulted in outflows being higher than inflows. This is normally the case in dry years, as shown by the 48-year annual time series budget in Table 16 and Figure 10.

1.3.4.2.Basin-wide Groundwater Budget: Future Scenarios

Table 15 also includes the annual average groundwater budget for the future scenarios. The key messages are:

1. **Effect of increased perennial acreage and change in irrigation management: Less deep percolation, more outflow than inflow**
   The Future_Baseline scenario has the same historical climate but different demand (current year's irrigated acreage and projected urban demand) compared to the Historical scenario. This scenario is dominated by a land use effect caused by a shift to perennial crops and an increase in irrigation efficiency. As described in the earlier section on Land Surface Budgets, Deep Percolation decreases by 45 TAF, because of increased irrigation efficiency compared to the Historical scenario. Overall, the annual average deficit (outflows – inflows) increases slightly from 1 TAF in the historical period, to approximately 5 TAF. However, as the groundwater storage time series shows, the Basin continues to recover during wet periods (Section 1.3.5, Figure 14).
2. **Effect of climate change:**
   a. **More Deep Percolation**
      The climate change scenarios (Future_2030, Future_2070, Future_2070_DEW, Future_2070_WMW), when compared to Future_Baseline, show the sensitivity of the system (and the model) to climate changes only because the land use, irrigation management, and urban demand is the same in these five scenarios. Table 15 **shows that in all four climate change scenarios, Deep Percolation is higher compared to Future_Baseline.** This is a direct effect of wetter Future Scenarios (Table 9).
   b. **Falling storage in extreme dry scenario**
      When compared to the Future_Baseline scenario, the negative effect of climate change

on groundwater storage is clearly demonstrated in only one of the four climate change scenarios, the dry and extreme warming scenario (Future_2070_DEW), where the outflows, especially pumping, are substantially higher. Overall, the average annual outflows are approximately 14 TAF more than average annual inflows. Note that this is also the only scenario where the net direction of the 'varying flows' switches signs to become a net inflow and helps prevent even deeper deficits. Surface water streams contribute even more to the groundwater, and lateral outflows decrease in this scenario as water table elevations decrease.

c. **Balanced budgets in the central tendency scenarios**
In the central tendency climate scenarios (Future_2030 and Future_2070), the inflows and outflows are similar magnitudes. This is also seen in the groundwater storage time series presented later (Section 1.3.5) in Figure 14, which shows that groundwater storage recovers in wet periods, much like the historical scenario.

d. **Increasing storage in the extreme wet scenario**
The extreme wet scenario (Future_2070_WMW) leads to a surplus in the groundwater storage of 12 TAF on an annual average basis. This is despite the model estimating a net outflow of groundwater to surface water and a much higher lateral outflow to other basins. Deep percolation increases by more than 100 TAF over the Future_Baseline scenario. Again, the groundwater storage graph (Figure 14) shows this best.

Table 15 Basin-wide average groundwater budgets. *All values are in Thousand Acre Feet*

Historical Average Annual Groundwater Budget (TAF)												
	Outflows				Varying Flows				Inflows			
	Pumping: Urban	Pumping: Irrigation	Drainage	Total Outflows	GW-SW Exchange	Lateral GW Flow: Outside	Lateral GW Flow	Total Varying Flows	Deep Percolation	YCFC Canal Recharge	Managed aquifer	Total Inflows
Entire Basin												
Historical	-33	-313	-28	-374	15	-28	0.0	-13	353	33	0.04	386
Future_Baseline	-16	-304	-16	-336	25	-40	0.0	-15	308	37	1.37	346
Future_2030	-15	-322	-15	-352	23	-37	0.0	-15	321	39	1.43	361
Future_2070	-15	-343	-15	-373	22	-35	0.0	-13	340	40	1.31	381
Future_2070_DEW	-15	-385	-13	-413	46	-6	0.0	39	323	37	1.30	360
Future_2070_WMW	-14	-311	-24	-348	-29	-79	0.0	-108	424	43	1.40	468

Notes: In the historical scenario: GW-SW exchange is positive with Cache Cr (29 TAF), Putah Cr (13.9 TAF), Sacramento R (0.9 TAF) and negative with Yolo bypass (25.7 TAF), Knights Landing Ridge Cut (1.5 TAF) and Colusa Basin Drain (2 TAF). Other GW-SW exchanges are minor.

Figure 10 Groundwater budget for the Yolo Subbasin

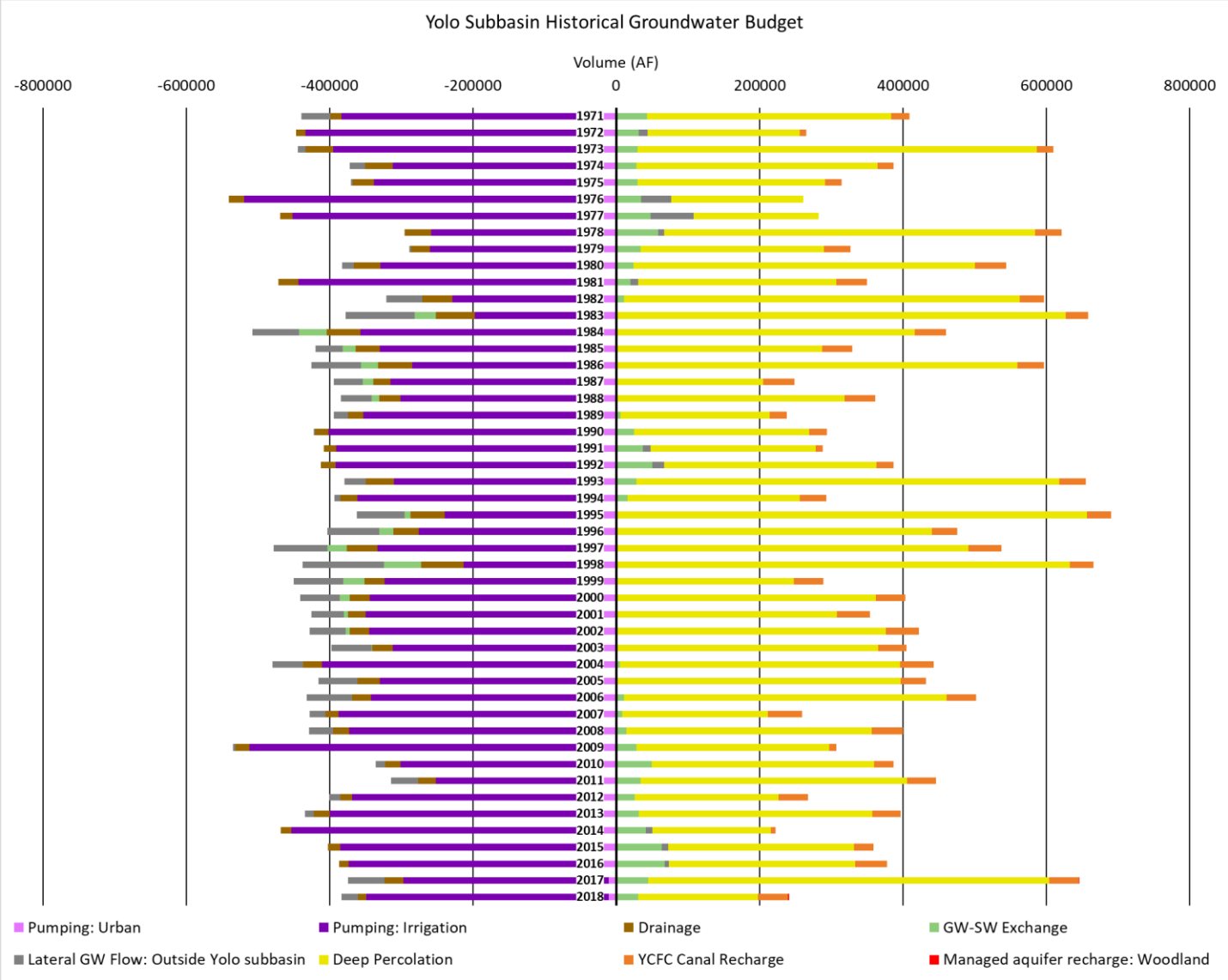


Table 16 Annual groundwater budget for the Yolo Subbasin. All values in Thousand Acre-feet.

Yolo Subbasin Historical Groundwater Budget (AF)											
	Outflows				Varying Flows			Inflows			
WY	Pumping: Urban	Pumping: Irrigation	Drainage	Total Outflows	GW-SW Exchange	Lateral GW Flow: Outside Yolo subbasin	Total Varying Flows	Deep Percolation	YCFC Canal Recharge	Managed aquifer recharge: Woodland	Total Inflows
Average	-33	-313	-28	-374	15	-28	-13	353	33	0	386
1971	-28	-355	-16	-399	43	-40	3	340	26	0	366
1972	-29	-405	-13	-447	32	12	44	212	9	0	222
1973	-29	-365	-39	-434	30	-10	19	557	23	0	580
1974	-30	-282	-38	-350	28	-22	7	336	23	0	359
1975	-31	-308	-30	-368	30	-2	28	262	23	0	285
1976	-32	-487	-21	-540	34	43	77	184	0	0	184
1977	-29	-423	-17	-469	48	60	108	174	0	0	174
1978	-31	-227	-36	-295	59	8	67	518	37	0	555
1979	-32	-228	-26	-286	34	-3	31	256	37	0	294
1980	-33	-296	-37	-366	24	-17	7	477	43	0	520
1981	-34	-409	-28	-471	20	11	31	276	43	0	319
1982	-33	-195	-42	-271	11	-50	-39	552	34	0	586
1983	-34	-163	-55	-252	-29	-96	-126	627	32	0	659
1984	-37	-320	-47	-404	-39	-65	-104	416	44	0	460
1985	-38	-292	-34	-363	-18	-38	-56	288	41	0	329
1986	-31	-254	-47	-332	-24	-69	-93	560	37	0	597
1987	-32	-284	-24	-339	-14	-40	-55	205	43	0	248
1988	-31	-270	-29	-330	-11	-43	-53	319	42	0	361
1989	-31	-322	-22	-375	6	-19	-13	208	24	0	232
1990	-31	-370	-19	-420	24	-1	23	245	25	0	270
1991	-30	-361	-17	-408	37	10	48	230	10	0	240
1992	-32	-360	-21	-412	51	16	67	296	24	0	321
1993	-33	-277	-40	-350	28	-29	-1	590	37	0	627
1994	-34	-328	-24	-385	16	-8	8	240	37	0	277
1995	-34	-206	-48	-287	-8	-67	-75	657	34	0	690
1996	-35	-241	-35	-310	-21	-72	-93	440	35	0	475
1997	-37	-296	-43	-376	-27	-75	-102	491	46	0	537
1998	-33	-180	-59	-272	-52	-114	-166	633	34	0	666
1999	-36	-286	-28	-351	-30	-69	-99	248	41	0	289
2000	-37	-307	-28	-372	-14	-55	-69	362	41	0	404
2001	-39	-311	-25	-374	-5	-45	-51	308	47	0	354
2002	-39	-306	-27	-372	-6	-50	-56	376	47	0	423
2003	-38	-273	-29	-341	-1	-56	-57	365	40	0	405
2004	-39	-371	-26	-437	5	-43	-38	391	47	0	438
2005	-38	-291	-31	-361	1	-55	-54	396	36	0	432
2006	-38	-304	-27	-369	11	-63	-52	450	41	0	491
2007	-39	-348	-18	-405	8	-22	-14	203	48	0	251
2008	-38	-334	-23	-395	14	-34	-20	343	44	0	387
2009	-36	-476	-19	-531	28	-3	24	269	9	0	279
2010	-34	-267	-22	-322	50	-13	37	310	27	0	337
2011	-33	-219	-24	-276	34	-38	-4	372	40	0	412
2012	-35	-334	-17	-385	26	-16	10	201	41	0	242
2013	-35	-365	-22	-422	31	-13	19	326	39	0	365
2014	-31	-422	-15	-468	41	9	51	165	7	0	172
2015	-29	-356	-18	-402	63	9	72	259	28	0	287
2016	-24	-349	-14	-387	68	6	73	260	44	0	304
2017	-11	-286	-27	-323	44	-51	-7	560	41	0	601
2018	-11	-338	-12	-360	31	-23	8	167	42	2	210

1.3.5. Groundwater Storage

Changes in groundwater storage over time are the aggregate (net) outcome of the individual inflows and outflows from the aquifer.

Available groundwater storage in Yolo County, in the depth interval of 20 to 420 feet, has been estimated at 14 million acre-ft (MAF) (Clendenen & Associates, 1976). The same report, which claims to be the first comprehensive Yolo County-wide groundwater investigation, estimates groundwater in storage in 1974 at 13 MAF, and estimated a decrease in storage of 0.5 MAF over the 30-year period from 1944-1974. The YSGA model (the MODFLOW part) estimates Basin-wide groundwater storage capacity at 13.7 MAF.

Modeled basin groundwater storage is presented as cumulative change from initial storage in September 1970, in Figure 11. The same is shown along with basin-averaged groundwater observations as standardized anomalies in Figure 12.

. The groundwater storage trace shows :

- Groundwater is lost from storage in dry years and recovers in wet years. Deep groundwater storage declines follow the deep droughts (WY 1976-WY 1977 ; WY 1987-WY 1992; WY 2007-2009; and WY 2012-WY 2016). Groundwater recovery follows in the intervening wet periods (WY 1971-WY 1975; WY 1982-1984; WY 1995-WY 2000; and WY 2005-WY 2006).

This feature of the Basin storage follows the pattern of groundwater-level observations basin-wide:

- So far, for the past nearly 50 years, there is no evidence of overdraft Basin-wide. Groundwater overdraft is defined by DWR[9], as a condition of pumping in excess of recharge, over a several-year period of average water supply conditions. In this GSP, we extend this definition, to (i) accommodate a longer time period of large hydroclimatic and water supply variability, and (ii) define overdraft as a continuously declining water table and modeled storage over this time period.
- At the end of the simulation in the historical period, modeled Basin groundwater storage is lower than the initial level by 86 TAF. To put this in context, this value is less than 6% of overall range in fluctuation (-553 TAF to +913TAF) modeled over the 48-year historical period (see Figure 11).
- Decadal changes in storage are summarized in Table 17, to further illustrate the fluctuation of groundwater storage in different wet and dry decades.

[9] **groundwater overdraft —** "The condition of a groundwater basin in which the amount of water withdrawn by pumping exceeds the amount of water that recharges the basin over a period of years during which water supply conditions approximate average conditions." DWR, https://water.ca.gov/Water-Basics/Glossary (Accessed 9/15/2020)

- As described elsewhere, the dominant shift in land use in the basin has been from annual to perennial crops over this historical period. The groundwater storage trace implies that the climate signal has dominated over this historical period – at the scale of the Basin.
- The past decade was marked by extended drought, as well as an acceleration of perennial acreage. These factors drive increased extraction of groundwater. Despite these circumstances, a wetter 2017 appears to have helped the Basin storage to almost recover to initial levels.

Figure 11 Basin groundwater storage change from Oct 1971 – Sept 2018 (WY 1971 – WY 2018)

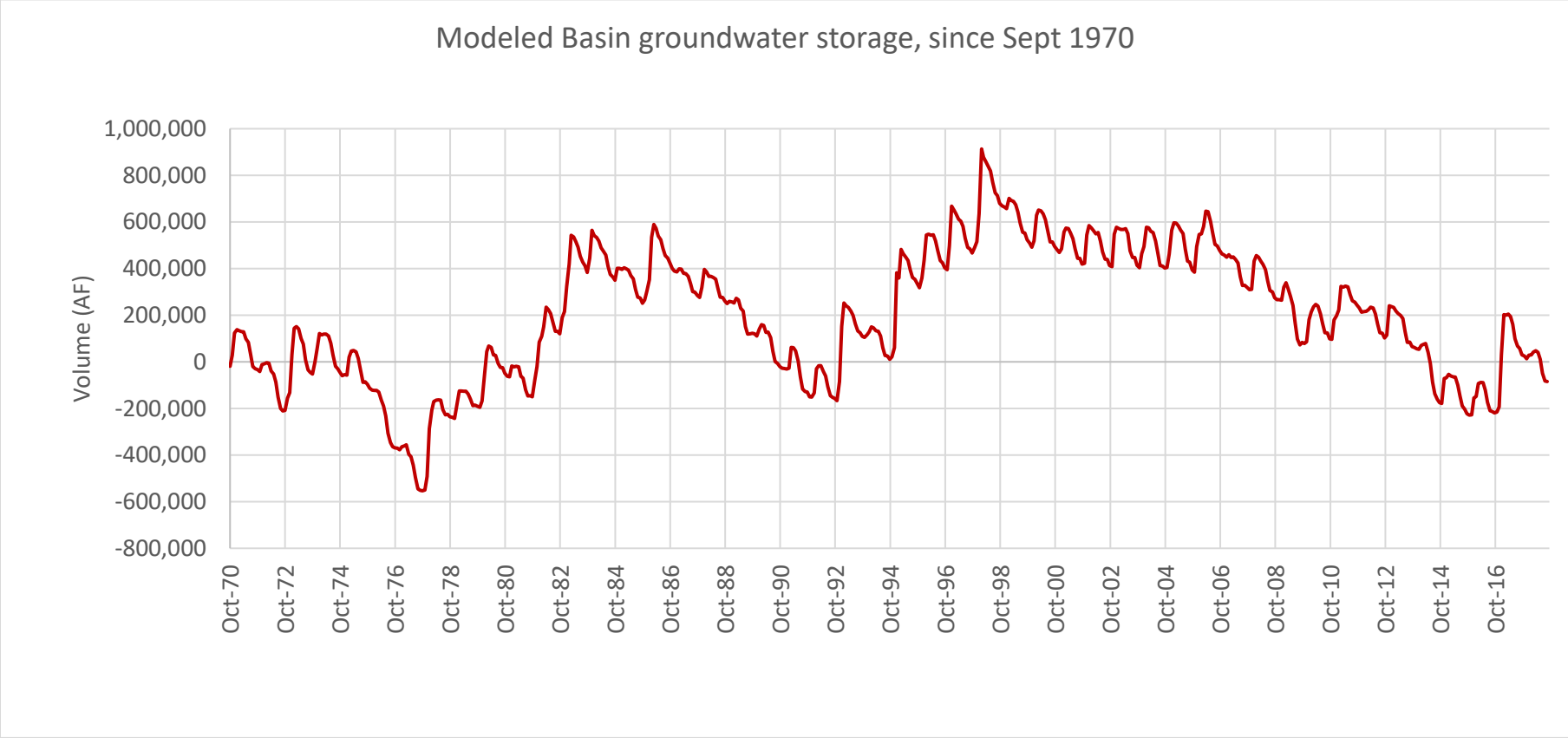
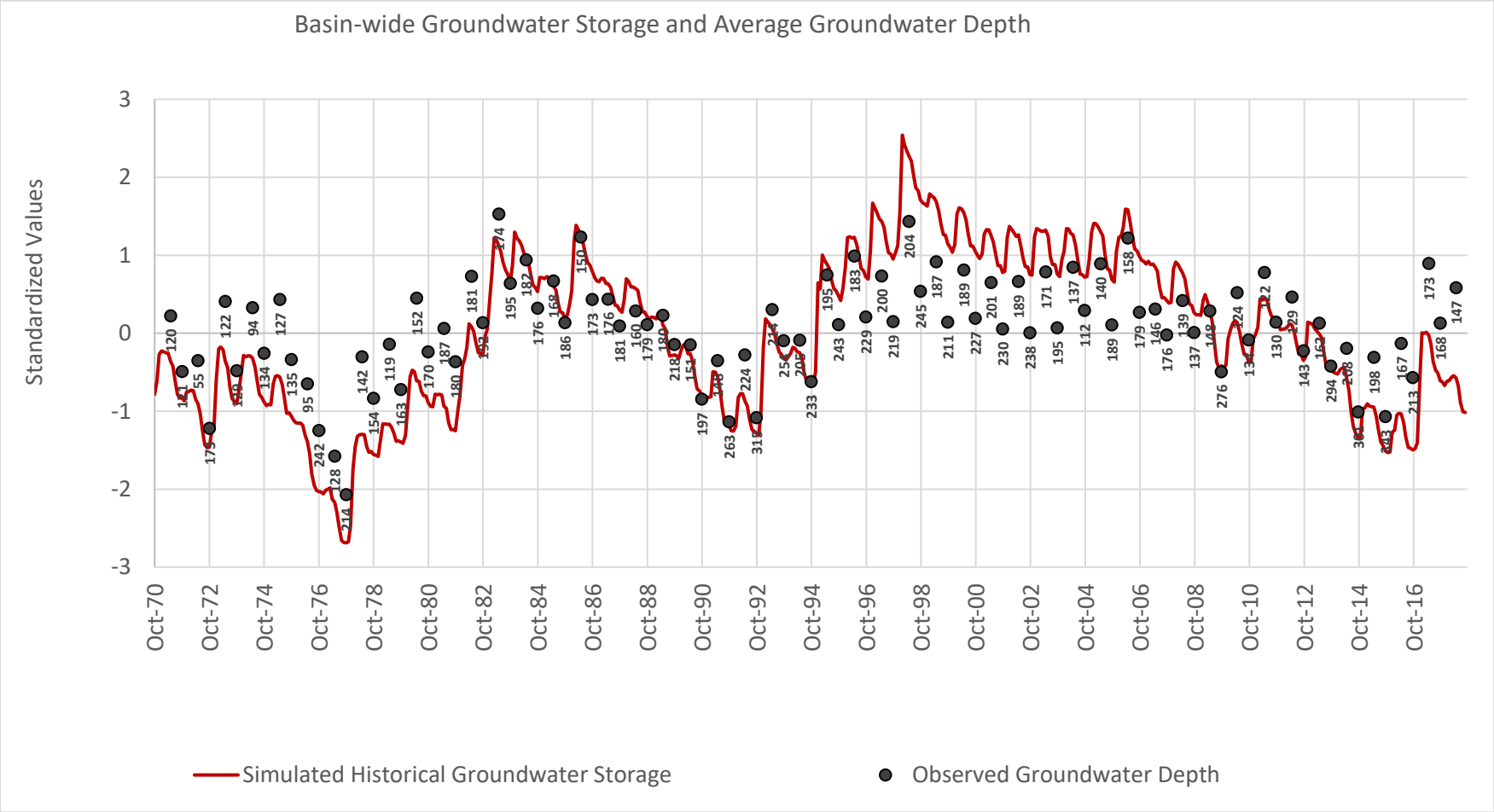


Figure 12 Standardized anomalies of groundwater storage and observed groundwater levels.



Note: data labels are the number of observations used to calculate the average.

Table 17 Decadal change in storage

Decade	Change in Storage (AF)
WY 1971-1980	-24,806
WY 1981-1990	17,992
WY 1991-2000	521,671
WY 2001-2010	-390,769
WY 2011-2018	-208,710

1.3.5.1. Management Areas: Groundwater Storage

In Section 1.3.5, the Basin-wide groundwater storage was discussed. In this section, modeled groundwater storage changes for Management Areas (MA) in the historical and current year period are discussed. Management Area maps and entities are in Figure 4. The WEAP portion of the YSGA model, which covers the land surface system and hydrology, covers 1,197,657 acres This includes all of Yolo County (639,089 acres in the WEAP portion of the model) and the Cache Creek system in Lake County (558,568 acres).

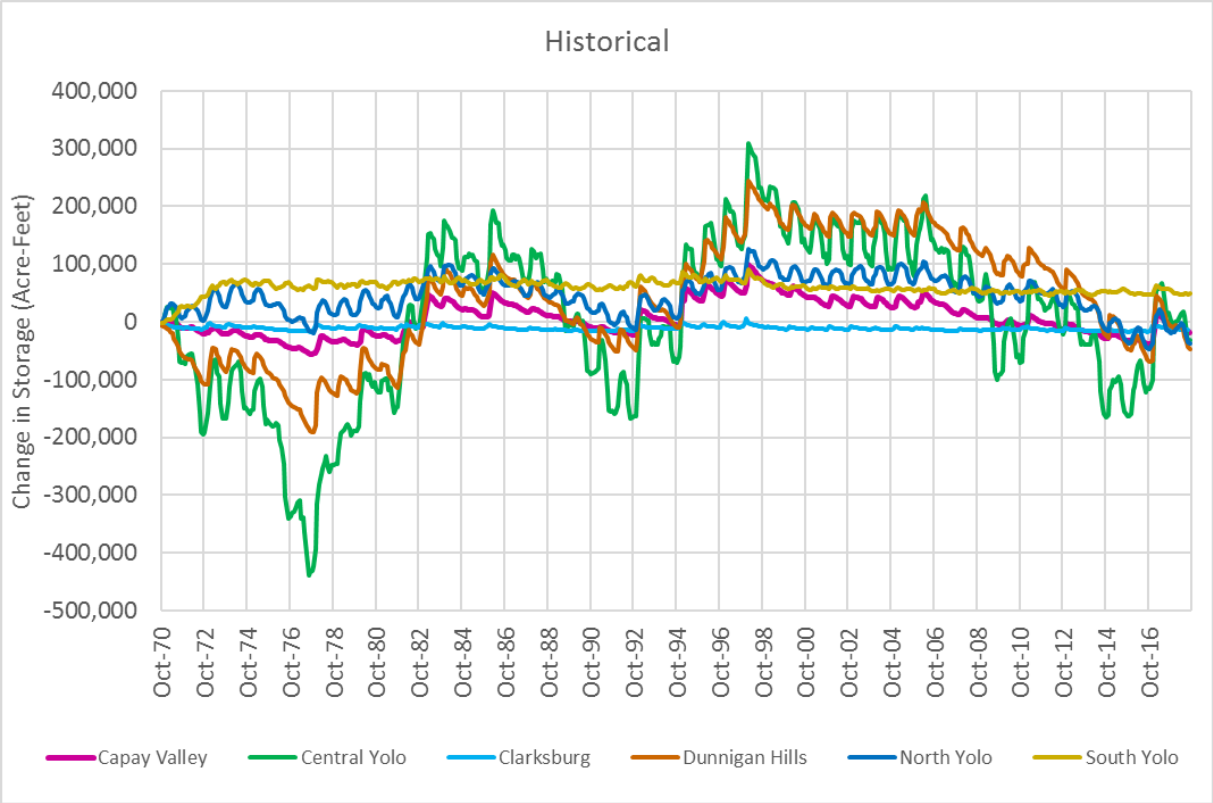
The MODFLOW portion of the YSGA model covers 559,840 acres (Table 3). Due to the resolution and spatial extent of the MODFLOW model (as mentioned earlier, derived from the IWFM model), and the pre-existing WEAP model which covers the entire county, there are small differences between the official basin boundary (540,400 acres) and that in the YSGA model. Additionally, because catchment boundaries in the YSGA model are primarily determined by surface hydrology, there are small differences between the management area boundaries in the model and the official management area boundaries (shown in the Introduction and Basin Setting sections). Figure 5 below shows these differences, and Table 4 explains them. The total area of these differences is relatively small (19,440 acres, less than 3% of the Yolo Subbasin) and will not affect the model estimates substantively.Groundwater storage in the historical scenario is presented first. Groundwater budgets and time series are presented in Appendix A.

Groundwater storage changes from the initial period (September 1970) are shown in Figure 13. Storage changes are shown on the same scale to visualize the relative volumes involved across Management Areas. For example, the MA's close to the Sacramento River, that also extract the least groundwater, show the least fluctuation in storage among all the MA's. This is followed by Capay Valley, and then by North Yolo and Dunnigan Hills MA's. The largest fluctuation is in the Central Yolo MA, which is the largest of the MA's in area, and is also an MA that uses a substantial amount of groundwater.

The description of the Basin-wide storage change applies to most of the MA's. Of note is the Dunnigan Hills MA, which may be showing a recent downward trend, due to increased perennial acreage in an area of the Basin that depends almost entirely on groundwater. This MA includes not just Dunnigan Hills, but also rangeland and new orchards in areas like Buckeye Creek, where no recent groundwater observations are available. **New monitoring in this MA is recommended to fill this data and knowledge gap.**

Note also that South Yolo MA shows an initial increase in storage in the first few years (the 1970's). The few groundwater observations from this MA appear to support this modeling result – although at the time of writing, the cause was unknown.

Figure 13 Groundwater Storage: Management Areas (WY 1971 – WY 2018)



1.3.6. Groundwater Storage: Future Scenarios

Figure 14 below shows the change in groundwater storage for each of the future scenarios, along with the groundwater storage change from the historical run (red line) for comparison.

Groundwater storage patterns among scenarios follow the precipitation and temperature trends among the scenarios, i.e.

- The most groundwater declines occur in the driest, warmest scenario – Future_70_DEW.
- Groundwater storage shows an overall increase compared to the historical simulation in the Future-70-WMW scenario.
- There is not much difference in groundwater storage between the central tendency scenarios (Future-30 and Future-70) and the Future-baseline.
- The historical and Future-baseline results provide useful insights. These simulations have the same climate input. Future-baseline shows the sensitivity to current cropping patterns and irrigation management, as described in the earlier section on groundwater budgets and fluxes.

Figure 14 Basin-wide groundwater storage for all scenarios

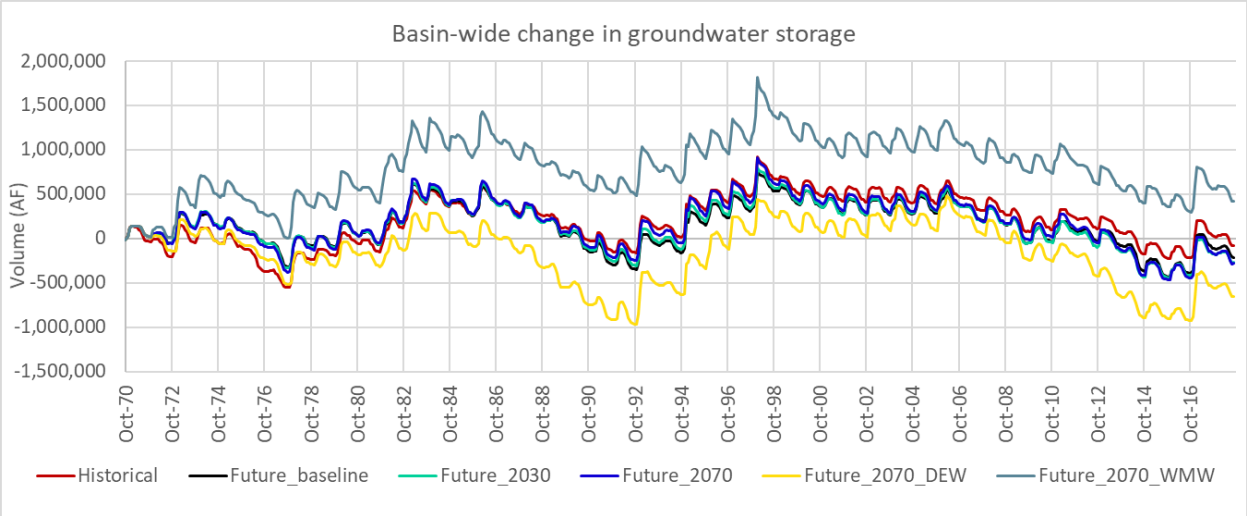


Table 18 Basin-wide storage change for all scenarios

Scenario	Pumping (TAF) Avg (Range)	Groundwater storage change compared to corresponding start (TAF)
Historical	346 (197 – 519)	-85
Future Baseline	320 (204 – 517)	-213
Future 2030	337 (228 – 555)	-273
Future 2070	357 (252 – 572)	-279
Future DEW	401 (263 – 594)	-650
Future WMW	325 (226 – 444)	+418

Management area groundwater storage for future scenarios are included in Appendix A.

1.3.7. Evaluating water budget estimates

1.3.7.1. Uncertainty

All models are simplified abstractions of reality, and therefore water budgets will always exhibit uncertainty (Loucks and van Beek, 2017). Uncertainty in model outputs arise from uncertain or missing input data, model parameter uncertainty, differing model structures, natural variability (in climate, hydrology, geology, land use), and measurement errors (California DWR, 2020). For example, large uncertainties are likely to exist in model estimates of groundwater levels in Buckeye Creek simply because of inadequate – or complete lack - of groundwater data. **These uncertainties directly affect model outputs.**

As described in more detail in Section 3.3 of the Model Documentation Appendix, the largest uncertainties in the Yolo Basin arise from:

Land use interpretation, and related irrigation management (variations in planting and harvest dates across space and time, for example) exhibit relatively large uncertainty. The Land use uncertainty affects all components of a water budget[10]. Details of crop acreage uncertainties rising from different data sources are in Section 2.1 of the Model Documentation Appendix.

Surface water supply in several areas of the Yolo Basin is not well known, as in some of the Reclamation Districts; and in the Willow Slough drainage, in the Clarksburg and Yolo bypass and Colusa Basin Drain region. Assumptions were made, which largely allowed surface water use to take precedence over groundwater pumping.

[10] This is true of all Basins

Groundwater levels and trends are uncertain in some areas like in north-west Yolo. Additionally, reference point elevations and screening depths from well logs are uncertain, and in many cases, missing. The latter made it challenging to ascertain which aquifer layer was being pumped; and the former directly impacted calibration statistics.

Geology and stratigraphy is uncertain in the Dunnigan Hills area (WRIME, 2006).

1.3.7.2. Discussion

For all the above reasons, any model, including the YSGA model, exhibits uncertainty. The same applies to other modeling efforts for Yolo County.

Additionally, different models are also not **strictly comparable** with each other because of differing spatial extents and resolution, time periods, boundary conditions, initial conditions, irrigation efficiencies, categorization of crops, assumptions involved in generating a time series of land use, calibration parameters and methods, and computational methods. In hydrology, **model equifinality – the fact that different parameters can give you equally good model calibration – remains a challenge.**

Keeping in mind the limitations of comparing different models, and of the major sources of uncertainty in the Yolo Basin, it may still be useful to compare certain important YSGA model outputs with a few studies.

Table 19 lists a summary of these differences for some modeling efforts in Yolo County, along with water budget estimates where available.

In general, from Table 19:

- Total demand from these different efforts appear to be within 10% of each other.
- YSGA model estimates of pumping is higher than the 1970's estimate (Clendenen & Associates, 1976), and lower than the IGSM model (WRIME, 2006).
- YSGA model estimates of percolation are lower than that of the IGSM model (WRIME, 2006)

In particular, when comparing the YSGA model and the IGSM model (WRIME, 2006) for the same time frame 1971-2000:

- Total Demand and Irrigated Area

For the years 1971-2000, the average annual total demand in the IGSM model was 987 TAF while in the YSGA model it was 945 TAF. Closer inspection reveals that the IGSM model has larger annual average irrigated acreage of 360,882 acres while the YSGA model has an average of 308,839 acres. While there are many uncertainties in the processing of land use data, as described Section 2.1 of the Model Documentation Appendix, areas of pasture in northern Yolo were decided through interaction with YCFC to be largely unirrigated rangeland. This change explains some of the differences in irrigated areas.

- Average water applied

Both IGSM (WRIME, 2006, pp. 4–7) and YSGA average about 2.6 ac-ft/ac of irrigation water applied.

- Groundwater Pumping

In the IGSM model there is an average of 493 TAF/yr of groundwater pumping for the 1971-2000 time period. During the same period the YSGA model has an average pumping of 335 TAF/yr. Closer inspection reveals that more surface water is available for irrigation in the YSGA model, which results in less groundwater pumping. In the YSGA model there is an average of 574 TAF/yr of surface water used for irrigation while in the IGSM model there was 496 TAF/yr. Some of the largest differences in groundwater pumping occur in East-Yolo South (YCFC East) and CBD-South.

- Deep Percolation

The annual average deep percolation for 1971-2000 in the IGSM model is 484 TAF, while in the YSGA model it is 373 TAF. Some of this difference is likely due to the difference in irrigated acreage, however, most of the difference is probably due to differences in the soil moisture calculation algorithms.

Table 19 Summary of water budget estimates from earlier literature

Source	Deep percolation (TAF)	Total Pumping (TAF)	Total demand (TAF)	Canal loss	Period	Spatial extent		Tools	
						Land surface budget	Groundwater budget	Land surface budget	Groundwater budget
YSGA Model **Aquifer area = 556,780 acres**	352	346	945	33	WY 1971-WY 2018	Yolo county, plus Cache Creek	Yolo Subbasin	WEAP MABIA Module	MODFLOW (finite difference)
Mehta et al, 2013	Not simulated at Basin scale	Not simulated at Basin scale	1035	NA	WY 1971-WY 2000	YCFC Boundary	YCFC Boundary	WEAP	WEAP's lumped model for groundwater
WRIME, 2006 **Aquifer Area = 566,044 acres**	484	493	987	22	WY 1971 - 2000	Yolo basin	Yolo Subbasin	IGSM	IGSM (finite element)
Borcalli and Associates, 2000	Not calculated	Not calculated	1035[11] 1976) 954 (1981) 1019 (1989)	NA	1976, 1981, 1989	Yolo County	NA	Spreadsheet estimates	NA
Clendenen & Associates, 1976	Not reported at Basin scale	305 (1963-1972)	835 (1970)	NA	1963-1972	Yolo County	Yolo Subbasin	Spreadsheet estimates	Partial

[11] *These estimates are for irrigation application only, based on DWR Landuse Surveys for the years listed in parenthesis (See Page 43 of the reference)*

1.3.7.3.Conclusion

An important observation from Table 19, is that the YSGA and IGSM models are consistent (in the 1971-2000 period) about pumping and deep percolation being fairly close to each other in magnitude.

For the YSGA model, the modeling team will investigate the water sources available to the CBD-South area, since it appears likely that area pumps more groundwater than is shown in the YSGA model currently. **These changes will be incorporated in the next draft of the Water Budget chapter.**

1.4. Sustainable Yield

SGMA describes 'Sustainable Yield' as the amount of groundwater that can be withdrawn annually without causing undesirable results. Section 354.18(b)(7) of the GSP Regulations requires that an estimate of the basin's sustainable yield be provided in the GSP. This sustainable yield estimate can be helpful for estimating the projects and programs needed to achieve sustainability. Note that SGMA does not incorporate sustainable yield estimates directly into sustainable management criteria. "Basinwide pumping within the sustainable yield estimate is neither a measure of, nor proof of, sustainability. Sustainability under SGMA is only demonstrated by avoiding undesirable results for the six sustainability indicators" (California DWR, 2017).

The results presented above show that the Yolo Subbasin has historically been sustainable (for the 48 years between WY 1971-WY 2018). Groundwater observations and the YSGA model results during this period show that while groundwater is lost from storage in drought years, it is replenished in wet years. As a result, groundwater storage and observed elevations have almost recovered by end of WY 2018 to initial storage and elevations. These results show that the Yolo Subbasin has not been overdrafted. The conjunctive use of surface water and groundwater – especially due to surface water available from Indian Valley Reservoir and to some extent the Tehama Colusa Canal; improved irrigation practices toward low-volume irrigation methods (Orang et al., 2008); and improved urban water conservation practices in the past decade have all contributed to this state. This appears to be a marked improvement from groundwater conditions in the decades before 1971, when the Basin was estimated to be in a state of overdraft (Clendenen & Associates, 1976).

From the literature available for Yolo County, the closest definition to 'sustainable yield' is an estimate for perennial yield provided in the Yolo County groundwater investigation from 1976 (Clendenen & Associates, 1976; Scott and Scalmanini, 1975). These investigators defined 'perennial yield' as "the amount of water which can be pumped annually from that basin, with no net change in storage over a selected period of time". This definition is materially the same as the SGMA definition mentioned earlier. **Perennial yield for Yolo county, for the period 1963-1972, was calculated at 304.5 TAF.**

With the above in mind, this GSP proposes that:

(i) The average annual pumping over WY 1971 – WY 2018 as the sustainable yield for the Yolo Subbasin: **346 Thousand Acre Feet (TAF) per year**. The estimated annual pumping varies widely over the historical period, from 197-519 TAF/year. Note that

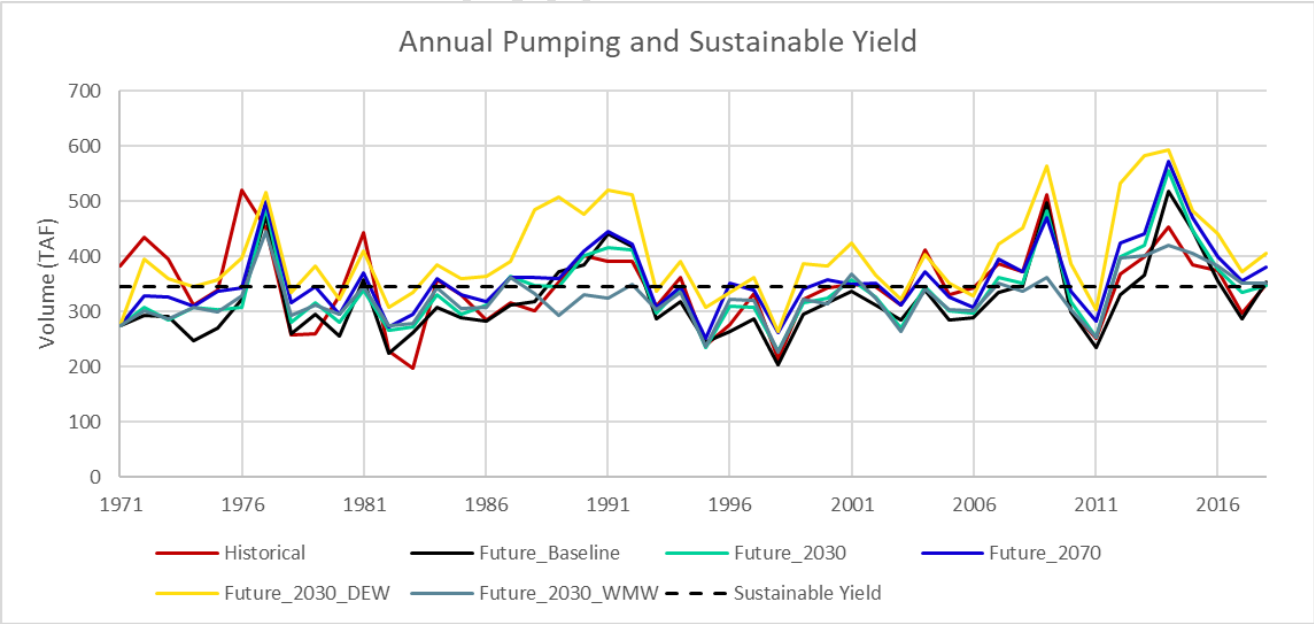
a. The proposed sustainable yield of 346 TAF is based on a longer period of time, more data, and from a period of additional surface water availability than was available back in the 1960's and early 1970's. Indeed, safe yield for Indian Valley reservoir is estimated at 50 TAF (Max Stevenson, pers. Comm 11/11/2020), which when added to the earlier perennial yield estimate from the 1970's, independently approximates the proposed 346 TAF value.

(ii) In the spirit of adaptive planning, the sustainable yield should be re-visited – and updated if needed – for each 5-year GSP update.

Based upon the analysis above, a sustainable yield of 346 TAF seems reasonable and justified.

For further comparison, Figure 15 below, shows the modeled pumping time series for the historical period, and for the future scenarios; the proposed Sustainable Yield of 346 TAF/year is shown as a horizontal reference line. Also, in Table 18, the average and range of annual pumping for each scenario is recorded. Figure 14 shows that Basin-wide groundwater storage, in all the investigated scenarios except for the DEW scenario, recovers to close to or above initial storage levels.

Figure 15 Annual pumping for all scenarios, compared to proposed sustainable yield



The data in Figure 15 is aggregated in a different way in Table 20 below, showing the number and percent of years, for each scenario, when the proposed Sustainable Yield is exceeded. In all except the Dry Extreme scenario, the frequency is close to or smaller than in the Historical scenario.

Table 20 Modeled pumping versus sustainable yield

Scenario	No. of years	%
Historical	25	52
Future_Baseline	14	29
Future_2030	17	35
Future_2070	26	54
Future_DEW	37	77
Future WMW	14	29

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Appendix A: Subregional and Management Area Water Budgets

1.5. Capay

1.5.1. Description

The Capay watershed drains an area of 85,515 acres in the YSGA model, from the north-western boundaries of Yolo County to Capay Dam on Cache Creek (Figure 4). It includes the hills (named as the Capay Other catchment (67,097 acres) in the model) which overlays hard-rock terrain, and the valley floor (named as the YCFC Capay catchment in the model, 18,418 acres), overlaying the alluvial aquifer. This valley floor catchment corresponds closely to the official Capay Valley Management Area boundary.

The valley floor of Capay is represented in the DWR's 2003 Groundwater Bulletin 118 as the "Capay Valley Groundwater Subbasin, 5-21.68" (California DWR, 2004). Primary, fresh-water bearing deposits within the Capay Valley sub-basin include recent stream channel deposits and the Tehama Formation. This is underlain by older, saline Cretaceous Marine rocks. Recent stream channel deposits consist of unconsolidated silt, fine- to medium-grained sand, gravel and occasionally cobbles deposited in and adjacent to Cache Creek and its tributaries (California DWR, 2004). Overall freshwater-bearing sediments in Capay Valley are reportedly more than 1000 feet thick (Harwood and Helley, 1987; WRIME, 2006). In the YSGA model, groundwater storage capacity in this area is estimated as 953 TAF for 20 to 420 ft of depth.

Groundwater flow typically follows the topographical line of the Valley running southeast (RMC Water and Environment, 2016). Groundwater levels have been stable in Capay Valley, usually varying from 10 to 40 feet below ground surface. Even in dry years the water table varies from 10 to 40 ft below surface (California DWR, 2004). Most domestic and irrigation wells are screened within the top 60 feet of the surface. Shallow wells are particularly common close to Cache Creek. Additional domestic and irrigation wells extend from 60 feet to 160 feet, but these are less common. Generally only larger wells operated by Yocha Dehe Wintun Nation are screened from 160 feet to 460 feet, and no wells are screened below 460 feet (RMC Water and Environment, 2016).

Land use in Capay MA is dominated by native vegetation, oak woodland landscapes that are prone to wildfires. In the Valley portion, orchards, field crops, and truck crops are cultivated (Table 21).

Table 21 Land Use for Capay MA

	Land Use (ac)				Land Use (Percent)			
	1989	1997	2008	2016	1989	1997	2008	2016
Capay Valley Management Area	**85,515**	**85,515**	**85,515**	**85,515**				
Deciduous	2,811	2,663	2,578	2,890	3	3	3	3
Field Crops	128	402	561	217	0	0	1	0
Grain	3,070	2,615	824	694	4	3	1	1
Managed Wetlands	0	0	0	0	0	0	0	0
Native Vegetation	77,478	78,028	79,021	79,187	91	91	92	93
Pasture	732	707	707	346	1	1	1	0
Rice	0	0	0	0	0	0	0	0
Subtropical	0	0	126	376	0	0	0	0
Truck Crops	735	422	508	596	1	0	1	1
Urban	58	176	635	635	0	0	1	1
Vine	3	2	55	74	0	0	0	0
Water	500	500	500	500	1	1	1	1

Source: DWR Land and Water Use Surveys

1.5.2. Data Sources and Assumption

In the YSGA model, Capay Valley floor (called YCFC Capay Catchment) irrigation demand is partly serviced by YCFC from Cache Creek. Demand not met by this surface water is met by groundwater pumping. The Capay Other catchment is largely composed of steep hills, dominated by natural oak and grassland vegetation. The region is dominated by native vegetation covering the hills. Deciduous orchards and grain crops dominate the irrigated land (Table 21). Several small towns, like Rumsey, Brooks, Guinda, and Capay, are assumed to pump groundwater through private wells. Information on water use for these, as well as the Cache Creek Casino and Yocha Dehe Wintun Nation, was available in the IGSM report from Capay (RMC Water and Environment, 2016). Non-agricultural water demand is small compared to agricultural demand in Capay Valley MA.

Data sources used to develop the representation of the Capay Valley MA are listed in the Model Documentation Section 3.4, Water Management Operation Inputs.

1.5.2.1.Assumptions for future scenarios.

- Urban water demands:
  - Population of all urban demands remains constant at 2004 levels, the last year for which data was available
- Agriculture water demands:
  - 2018 land use is held constant into the future
- Water supply:
  - Cache creek hydrology is modeled for each climate scenario.
  - The operating rules for releases from Clear Lake and Indian Valley Reservoir remain the same in the future simulations as in the last year in the historical simulation.

- Surface water available to the Yocha Dehe Golf Club and to agriculture in the YCFC Capay catchment are the same in the future simulations as in the last year of the historical simulation.
- There are no restrictions on groundwater pumping.

1.5.3. Water budgets

First, the table below describes what the inflows and outflows include for this region.

Table 22 Useful Terms in this section

Term	Description
Deep percolation	Water that recharges the groundwater aquifer from the overlying catchments within the management area (these are listed in Table 3). This includes water from rain events, inefficiency of irrigation and seepage from septic systems. It is assumed most urban demands (Yocha Dehe Wintun Nation Casino, Tribal Housing and rural water use from private pumping) return all water that is not consumed to septic systems and therefore, deep percolation.
Evapotranspiration (ET)	Evaporation from the land surface (soil and urban land cover) and transpiration from vegetation (agriculture and native vegetation) from all catchments within this management area (listed in Table 3).
GW-SW Exchange	Exchange between Cache Creek and the underlying aquifer.
Lateral GW Flow	Subsurface groundwater flow between the Capay Valley management area and the Central Yolo Management area.
Precipitation	Rain falling within the boundary.
Pumping: Irrigation	Water sourced from groundwater supplied to agricultural irrigation in the catchments within this area (these are listed in Table 3)
Pumping: Urban	Water sourced from groundwater supplied to all non-agricultural demands in Capay Valley: Yocha Dehe Wintun Nation Casino, Golf course, Tribal Housing and rural water use from private pumping
Surface Runoff (SRO)	Surface runoff from the land within this management area to Cache Creek, due to precipitation or irrigation runoff.
SW supply: Irrigation	Water sourced from Cache Creek supplied to agricultural irrigation in the catchments within this management area (these are listed in Table 3)

Term	Description
SW supply: Urban	Water sourced from Cache Creek supplied to the Yocha Dehe Wintun Nation Golf Course .
Urban consumption	Water consumed within the urban demand in this management area (not returned to a septic system): Yocha Dehe Wintun Nation Casino, Golf course, Tribal Housing and rural water use from private pumping. This includes water used for landscape irrigation within these demands.

Table 23 Average Annual Land Surface Water Budget for Capay Subregion

Historical Average Annual Land Surface Water Budget (TAF)											
	Outflows					Inflows					
	Evapotranspiration	Deep Percolation	Surface Runoff	Urban Consumption	Total Outflows	Precipitation	Pumping: Urban	Pumping: Irrigation	SW Supply: Urban	SW Supply: Irrigation	Total Inflows
Capay Valley											
Historical	-136	-24	-19	-0.2	-179	157	0.4	16	0.2	5	179
Future_Baseline	-136	-21	-18	-0.3	-176	157	0.5	14	0.2	4	176
Future_2030	-137	-23	-20	-0.3	-180	161	0.5	14	0.2	4	180
Future_2070	-139	-25	-26	-0.3	-191	170	0.5	15	0.2	5	191
Future_2070_DEW	-134	-24	-32	-0.3	-190	168	0.5	16	0.2	5	190
Future_2070_WMW	-138	-39	-47	-0.3	-224	205	0.5	14	0.2	4	224

Average annual land surface and groundwater budgets are presented in Table 23 and Table 24 respectively.

Key messages on the land surface water budget are similar to those provided for the County-wide results in Section "Land Surface Water Budget" in the main body of this report.

- Overall outflows and inflows are in balance for all scenarios.
- There is not much substantive change in the budget in the future scenarios, with the exception of the wet scenario (Future_WMW) in which both surface runoff and deep percolation increase due to the additional precipitation.

Table 24 Average Annual Groundwater Budget for Capay Valley MA

Historical Average Annual Groundwater Budget (TAF)								
	Outflows			Varying Flows			Inflows	
	Pumping: Urban	Pumping: Irrigation	Total Outflows	GW-SW Exchange	Lateral GW Flow	Total Varying Flows	Deep Percolation	Total Inflows
Capay Valley								
Historical	-0.4	-16	-16	-7	-1	-8	24	24
Future_Baseline	-0.5	-14	-14	-6	-1	-7	21	21
Future_2030	-0.5	-14	-15	-7	-1	-8	23	23
Future_2070	-0.5	-15	-15	-9	-1	-10	25	25
Future_2070_DEW	-0.5	-16	-16	-7	-1	-8	24	24
Future_2070_WMW	-0.5	-14	-15	-22	-1	-22	39	39

Figure 16 Capay Valley Groundwater Storage, all scenarios

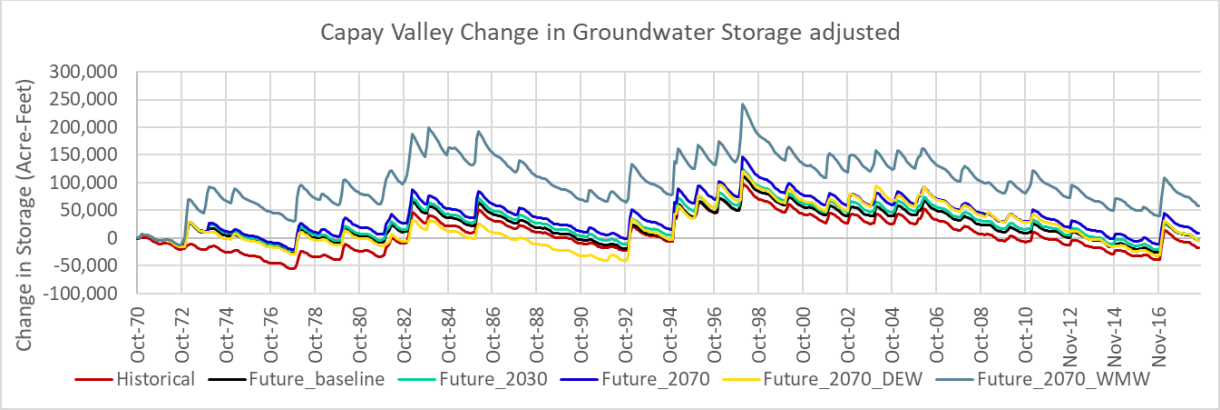


Table 24 and Figure 16 present the groundwater budget and storage change for all scenarios.

Key messages on the groundwater budget are:

- Historically, similar to the Basin-wide narrative, groundwater is depleted from storage in dry years, and recovers in wet years. The scale, or range, of these fluctuations is relatively small reflecting the stable groundwater levels that have been observed in the Capay Valley floor historically. At the end of the historical period of 48 years, groundwater storage is estimated to be 18 TAF below the start. The overall trace suggests that this MA has not been overdrafted in the past nearly five decades.

- Drought years like the 1976-1977 would not result in as severe a depletion as they did in the past, primarily because of increased surface water availability (e.g. Indian Valley Reservoir surface water).
- This MA has additional groundwater storage at the end of all future scenarios including in the extreme dry scenario (Future_DEW2070), reflecting the additional precipitation in these scenarios. This result is different from many of the other MA's and the basin-wide result. Partly, this is the result of the climate change factors being different not only for each climate projection, but also, (i) spatially among the MA's, and (ii) appear to have some trends over time. The Future_DW2070 scenario is wetter in the latter half of the simulation and shows some extremely wet months. Another reason is that the MA is dominated by native vegetation as the greatest proportion of land use, which tends to make the simulations more similar when compared to other MAs that are dominated by cropping.
- In the extreme wet scenario, GW-SW exchange increases to 22 TAF and groundwater storage increases to about 58 TAF above initial conditions, reflecting an elevated water table.

Overall, Capay Valley MA displays less vulnerability, both in the historical and future scenarios, when compared to the other MAs. The annual time series of the land surface and groundwater budgets are presented below in Figure 17 and Figure 18, respectively.

Figure 17 Capay Subregion Historical Land Surface Water Budget

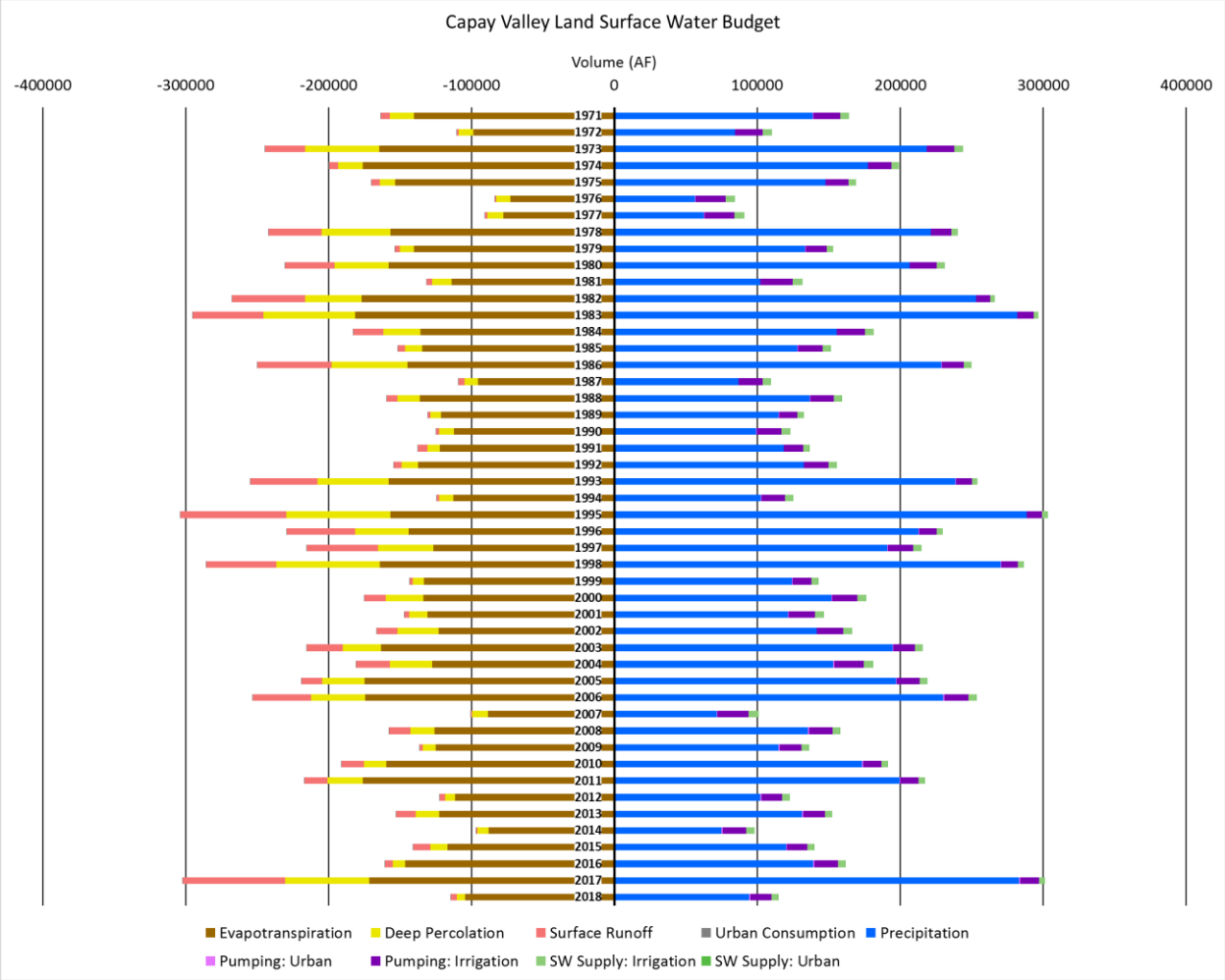
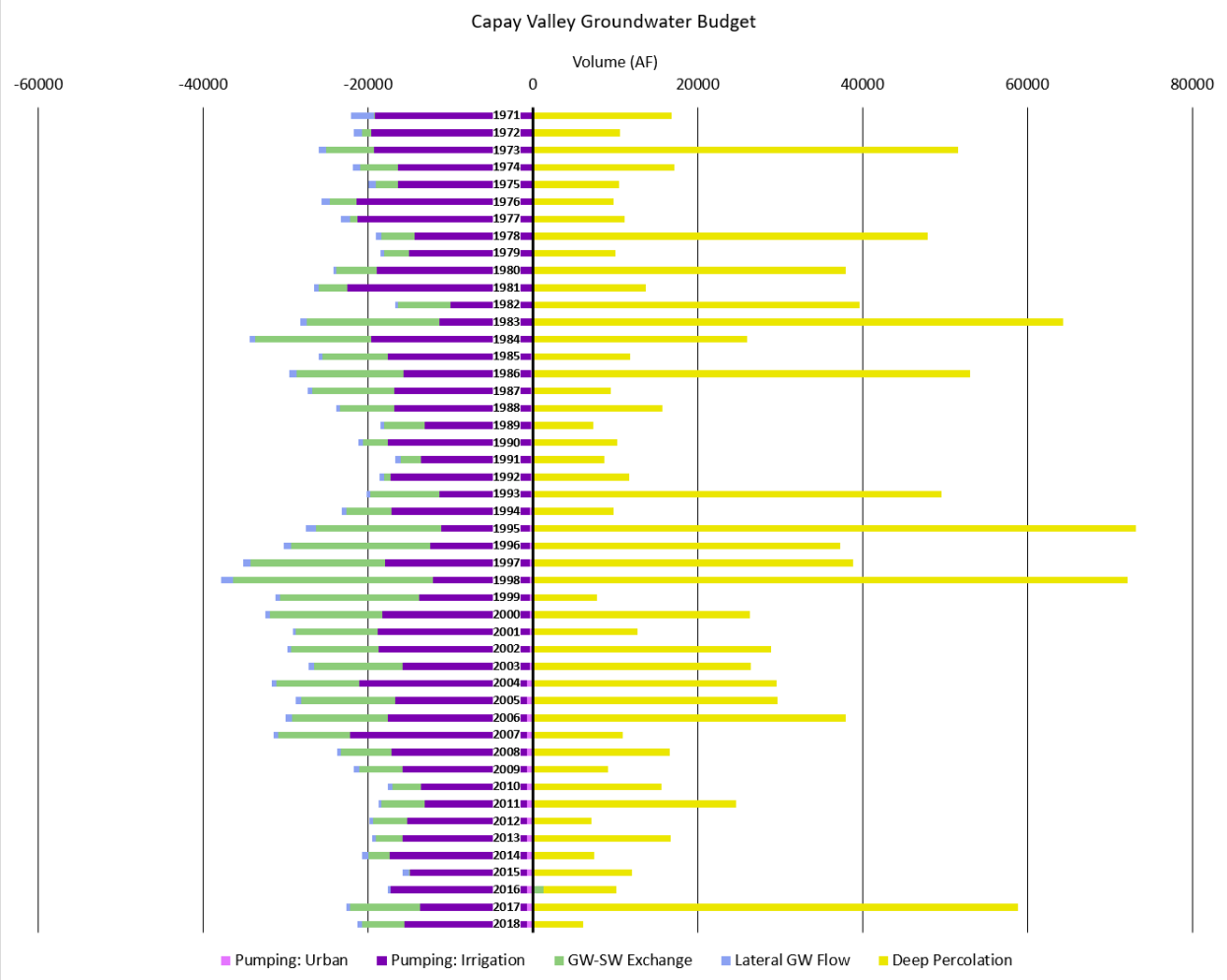


Figure 18 Capay Valley MA Historical Groundwater Budget



1.6. Central Yolo Subregion

1.6.1. Description

The Central Yolo Subregion covers 242,860 acres and extends from the Capay Diversion Dam in the west to the YCFC District boundary in the east. It extends into Hungry Hollow to the north of Cache Creek, south to Putah Creek, and to the western boundary of the Yolo Subbasin west of Winters. This MA includes the municipal demands of the cities of Davis, Winters, and Woodland, along with UC Davis, the towns of Esparto and Madison, and the irrigation demands of RD 2035 and YCFC customers. Willow slough runs through the middle of this MA, and the YCFC's earthen, unlined canal system contributes significantly to annual groundwater recharge.

The YSGA model (the MODFLOW portion) estimates the storage capacity of this area to be 5.4 million acre-feet between 20 and 420 feet of depth. Note that the spatial boundary of this MA is different from earlier efforts (Clendenen & Associates, 1976; WRIME, 2006), making any comparison to them challenging.

Cultivated land dominates this subregion with a diverse array of crops including orchard crops, field crops, grain, pasture, rice, truck crops, and some vineyards. Orchard acreage has been increasing (Table 25).

Table 25 Land Use for Central Yolo Subregion

	Land Use (ac)				Land Use (Percent)			
	1989	1997	2008	2016	1989	1997	2008	2016
Central Yolo Management Area	**242,680**	**242,680**	**242,680**	**242,680**				
Deciduous	8,210	8,574	13,867	30,533	3	4	6	13
Field Crops	34,817	44,405	17,795	17,901	14	18	7	7
Grain	46,679	32,201	26,922	14,461	19	13	11	6
Managed Wetlands	0	483	459	0	0	0	0	0
Native Vegetation	80,688	78,367	93,892	103,281	33	32	39	43
Pasture	18,164	23,513	32,714	14,677	7	10	13	6
Rice	9,794	11,077	13,052	17,100	4	5	5	7
Subtropical	118	86	494	655	0	0	0	0
Truck Crops	26,362	23,366	20,800	21,390	11	10	9	9
Urban	16,760	19,122	21,030	19,754	7	8	9	8
Vine	220	618	688	1,961	0	0	0	1
Water	867	867	967	967	0	0	0	0

Source: DWR Land and Water Use Surveys

1.6.2. Data Sources and Assumptions

Data sources used to develop the representation of the Central Yolo MA are listed in the Model Documentation Appendix, Section 2.1.5, Water Management Inputs.

1.6.2.1.Future scenarios Assumptions:

- Urban water demands:
  - For the City of Davis, the population grows from 70,000 (near 2019 level) at 0.7% (recent growth rate) and the water use rates are kept constant from the last historical levels, based on the 2015 Urban Water Management Plan.
  - For the City of Winters, the population grows at 1%. Recent population growth is closer to 2%, while in earlier years the population remained constant, so an average of 1% was used.
  - For the City of Woodland, population grows at 1.3%, based on the 2015 Urban Water Management Plan.
  - The population of Madison and Esparto CSDs were both kept constant from the last historical values.
  - UCD population grows at 1% while the aquaculture and landscape irrigation demands remain constant from the last historical values, based on the 2018 Long Range Development Plan.
  - Water demands for other small towns remain constant from the last historical values.
  - For all urban demands, per capita water use rates are kept constant from the last historical values.
- Agriculture water demands:
  - 2018 land use is held constant into the future.
- Water supply:
  - Since the climate and hydrology of the Cache Creek watershed is modeled, in future simulations flows in Cache Creek reflect the climate scenario.
  - Operating rules for releases at Clear Lake and Indian Valley Reservoir remain the same in the future simulations as the last year in the historical simulation.
  - YCFC operating rules remain the same in the future simulations as in the last year of the historical simulation.
  - Boundary conditions of all other streams entering the County remain the same as in the historical simulation.
  - There are no restrictions on groundwater pumping.
  - It is assumed the Woodland-Davis Clean Water Agency is able to use the entirety of both water rights (55 TAF in total) in the future scenarios, with limitations based on Shasta Critical Years, Project Water allocations and Term 91, when applicable.
  - Monthly distribution of the available water over the year is calculated from actual diversion data (2016-2018). The available water is divided among Woodland, Davis, and UC Davis as 60%, 34%, and 6%, based on the current operations of 18, 10.2, and 1.8 MGD, respectively.
  - The Woodland aquifer storage and recovery system in future scenarios has supply preferences set up in the following order: recycled water from the wastewater treatment plant (0.5 MGD) is first, then Aquifer Storage and Recovery (ASR) water, then the Woodland-Davis Clean Water Agency, and only after that is the confined aquifer (layer 2) used. Effectively, this represents Woodland's marked reduction in dependence

historically on the unconfined aquifer. Woodland's stated goal of ASR injection is 10,000 AF per year. However, for the future simulations, the YSGA model currently uses the 2018 amount of water reported to be injected (500 million gallons per year, or 1,534 AF), with a monthly distribution also determined from 2018 data. Of this injected water, 1,368 AF is pumped from the ASR for City use (based on 2018 data).

1.6.3. Water budgets

Table 26 Useful terms in this section

Term	Description
Deep percolation	Water that recharges the groundwater aquifer from the overlying catchments within the management area (these are listed in Table 3). This includes water from rain events, inefficiency of irrigation and seepage from septic systems (in the town of Capay and Monument Hills) and wastewater treatment ponds (these occur in Madison CSD, Esparto CSD, Winters and Davis)
Evapotranspiration (ET)	Evaporation from the land surface (soil and urban land cover) and transpiration from vegetation (agriculture and native vegetation) from all catchments within this management area (listed in Table 3) as well as evaporation from wastewater treatment ponds (these occur in Madison CSD, Esparto CSD, Winters and Davis)
GW-SW Exchange	Exchange between Cache Creek, Willow Slough, Putah Creek and the Yolo Bypass and the aquifer underlying the management area.
Lateral GW Flow	Subsurface groundwater flow between the Central Yolo management area and the neighboring management areas: Capay Valley, Dunnigan Hills, North Yolo and South Yolo.
Lateral GW Flow: Outside Yolo subbasin	Subsurface groundwater flow between the Central Yolo management area and the Solano subbasin.
Managed aquifer recharge: Woodland	Water recharged to the confined aquifer underlying the city of Woodland, through the Aquifer Storage and Recovery program.
Precipitation	Rain falling within the management area boundary.
Pumping: Irrigation	Water sourced from groundwater supplied to agricultural irrigation in the catchments within this management area (these are listed in Table 3)
Pumping: Urban	Water sourced from groundwater (both the general aquifer and the Woodland confined aquifer) supplied to the urban demands within this management area: City of Davis, City of Woodland, City of Winters, Esparto CSD, Madison CSD, UCD, and other small towns
Surface Runoff (SRO)	Surface runoff from the land within this management area to Cache Creek, Willow Slough, Putah Creek and the Yolo Bypass due to precipitation and irrigation runoff

Term	Description
SW supply: Irrigation	Water sourced from Cache Creek via YCFC canals, Putah Creek, Willow Slough, Sacramento River and the Yolo Bypass supplied to agricultural irrigation in the catchments within this management area (these are listed in Table 3).
SW supply: Urban	Water sourced from the Sacramento River supplied to the Woodland Davis Clean Water Agency.
Tailwater re-use: Irrigation	Reuse of irrigation tailwater. Reclamation Districts and the North Delta East catchment can reuse 90% of tailwater for irrigation in the model, based on previous work describing reuse in RD108 (Davids Engineering, 2011).
Treated WW Outflow	Return flows from wastewater treatment plants in the cities of Davis and Woodland to the Yolo Bypass and the city of Winters to Putah Creek.
Urban consumption	Water consumed within the urban demands in this management area (not returned to a septic system or wastewater treatment plant): City of Davis, City of Woodland, City of Winters, Esparto CSD, Madison CSD, UCD, Capay and Monument Hills. This includes water used for landscape irrigation within these demands.
YCFC canal recharge	Canal Recharge from the YCFC unlined canals.

Average annual land surface and groundwater budgets are presented in Table 27 and Table 28 respectively.

Key messages on the land surface water budget are similar to those provided for the Basin-wide results in Section "Land Surface Water Budget" in the main body of this report.

- Overall outflows and inflows are in balance for all scenarios.
- The Future_Baseline scenario differs from Historical due to the land use effect of increased perennial acreage. The main effects of this are:
    - An increase in ET.
    - Surface water supply is higher in Projected_Baseline than Historical, because of more surface water availability such as through Indian Valley reservoir, and the recent Woodland Davis Clean Water project.
    - Decrease in Deep Percolation and Surface Runoff, due to an overall increase in irrigation efficiency.
- The four climate scenarios show that:
    - Deep Percolation follows the pattern of precipitation, with the highest Deep Percolation in the wettest scenario (Future_2070_WMW) and the least in the driest scenario (Future_2070_DEW).
    - Similarly, Surface water supply for irrigation is largest in the wettest scenario (Future_2070_WMW) and lowest in the extreme dry scenario (Future_2070_DEW).

Table 27 Average Annual Land Surface Water Budget : Central Yolo Subregion

Historical Average Annual Land Surface Water Budget (TAF)														
	Outflows							Inflows						
	Evapotranspiration	Deep Percolation	Surface Runoff	Urban Consumption	YCFC Canal Recharge	Treated WW Outflow	Total Outflows	Precipitation	Pumping: Urban	Pumping: Irrigation	SW Supply: Urban	SW Supply: Irrigation	Tailwater Reuse: Irrigation	Total Inflows
Central Yolo														
Historical	-493	-169	-229	-12	-32	-8	-944	477	29	209	1	225	3	944
Future_Baseline	-514	-147	-215	-13	-36	-9	-933	477	14	187	17	235	3	933
Future_2030	-529	-151	-231	-13	-38	-9	-970	500	13	189	18	248	3	971
Future_2070	-541	-159	-255	-13	-39	-9	-1,016	526	13	200	19	255	3	1,016
Future_2070_DEW	-545	-153	-271	-13	-36	-9	-1,025	518	14	231	18	242	2	1,025
Future_2070_WMW	-532	-183	-334	-13	-41	-9	-1,112	635	12	177	20	265	3	1,112

Notes: Evapotranspiration is dominated by crop ET, evaporation from ponds is minor.

Table 28 Average annual groundwater budget for Central Yolo MA

Historical Average Annual Groundwater Budget (TAF)											
	Outflows			Varying Flows				Inflows			
	Pumping: Urban	Pumping: Irrigation	Total Outflows	GW-SW Exchange	Lateral GW Flow: Outside Yolo subbasin	Lateral GW Flow	Total Varying Flows	Deep Percolation	YCFC Canal Recharge	Managed aquifer recharge: Woodland	Total Inflows
Central Yolo											
Historical	-28.6	-209	-238	40	-17	12	35	169	32	0	202
Future_Baseline	-14.1	-187	-201	43	-27	-1	15	147	36	1	185
Future_2030	-13.1	-189	-202	41	-28	-2	11	151	38	1	191
Future_2070	-12.8	-200	-213	42	-28	0	13	159	39	1	199
Future_2070_DEW	-13.5	-231	-245	59	-9	2	52	153	36	1	189
Future_2070_WMW	-11.8	-177	-189	9	-51	8	-34	183	41	1	226

Notes: GW-SW Exchange is positive in Cache Creek (30 TAF), Putah Creek (15 TAF), and negative with the Yolo Bypass (4.5 TAF); Lateral GW flow is positive (incoming) from South Yolo (10 TAF), Dunnigan Hills (8.9 TAF) and Capay Valley (0.7 TAF); and negative (outflow) to North Yolo (7 TAF). Lateral flow outside the basin is towards Solano subbasin (17 TAF).

Figure 19 Groundwater storage in Central Yolo, all scenarios

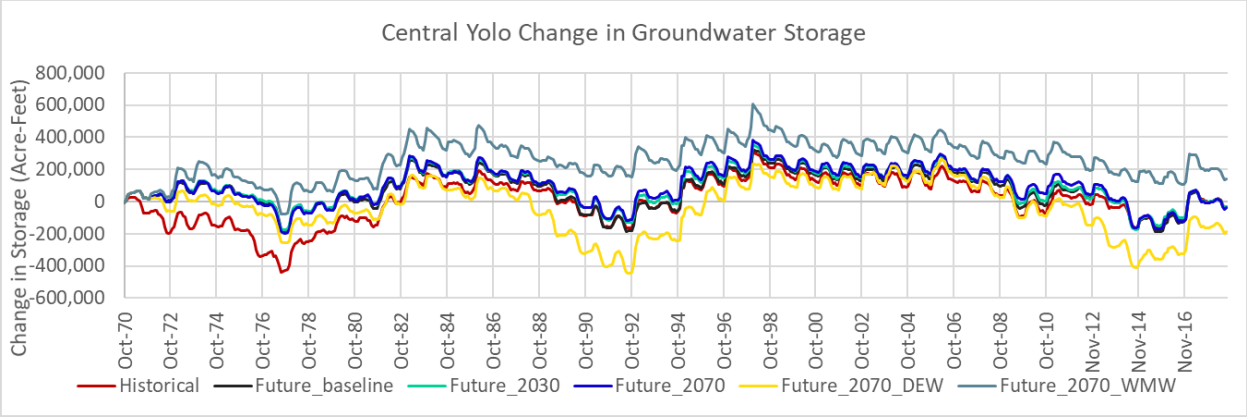


Table 28 and Figure 19 present the groundwater budget and storage change for all scenarios.

Key messages on the groundwater budget are:

- Historically, similar to the Basin-wide narrative, groundwater is depleted from storage in dry years, and recovers in wet years. At the end of the historical period of 48 years, groundwater storage is estimated to be 30 TAF below the start. The overall trace suggests that this MA has not been overdrafted in the past nearly five decades.
- Drought years like 1976-1977 would not result in as severe a depletion as they did in the past, primarily because of increased surface water availability (e.g. Indian Valley Reservoir surface water) and to some extent by overall increased irrigation efficiencies.
- Compared to the overall range of groundwater storage, there is not much difference between the Future_Baseline, and the Future_2030, Future_2070 scenarios.
- The greatest decrease in groundwater storage is in the extreme dry scenario (Future_DEW) when groundwater storage by the end of the 48-year simulation falls to almost 188 TAF below initial conditions.
- In contrast, in the extreme wet scenario, groundwater storage climbs to about 142 TAF above initial conditions.

Annual time series of the land surface and groundwater budgets for the Historical simulation are presented below in Figure 20 and Figure 21, respectively.

Figure 20 Annual Land Surface Water Budget for Central Yolo Subregion (WY 1971 – WY 2018)

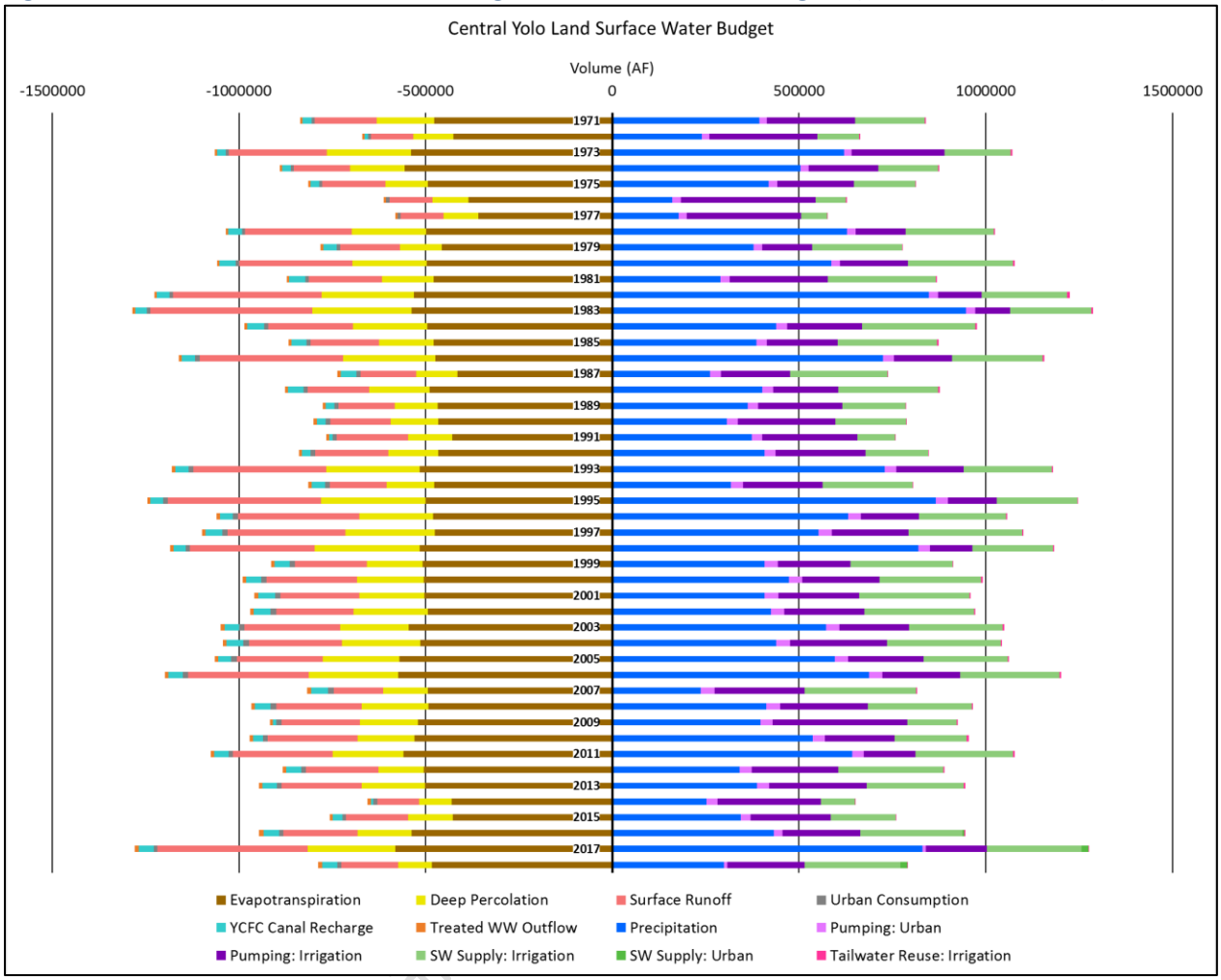
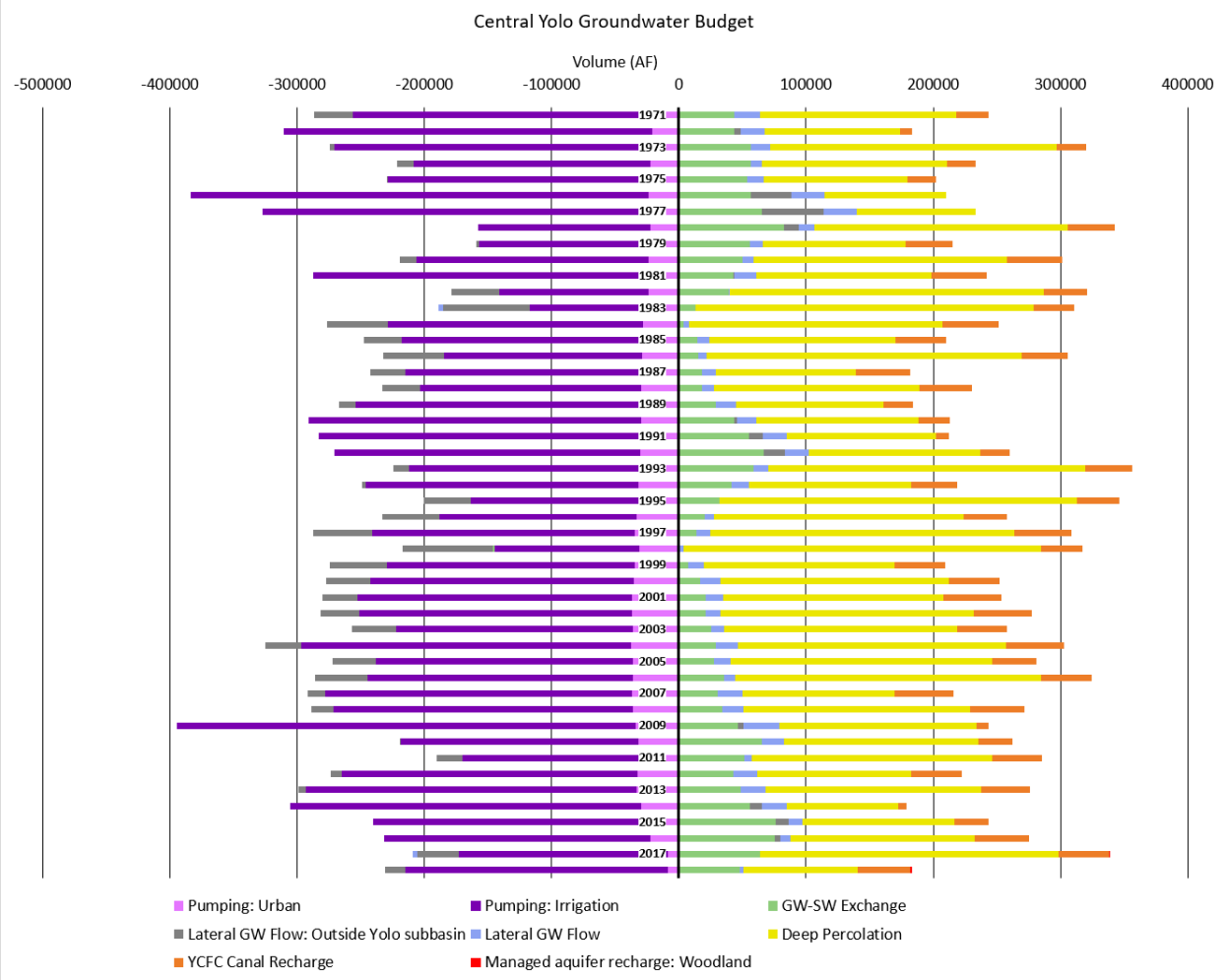


Figure 21 Annual Groundwater Budget for Central Yolo MA



1.7. Clarksburg Management Area[12]

1.7.1. Description

Clarksburg Management Area covers 36,500 acres in the southeast corner of Yolo County, between the shipping channel to the west and the Sacramento River to the east (See Figure 4). It is almost entirely agricultural and includes the areas of several reclamation districts, namely RD 150, RD 307, RD 765, and most of RD 999 (See The WEAP portion of the YSGA model, which covers the land surface system and hydrology, covers 1,197,657 acres This includes all of Yolo County (639,089 acres in the WEAP portion of the model) and the Cache Creek system in Lake County (558,568 acres).

The MODFLOW portion of the YSGA model covers 559,840 acres (Table 3). Due to the resolution and spatial extent of the MODFLOW model (as mentioned earlier, derived from the IWFM model), and the pre-existing WEAP model which covers the entire county, there are small differences between the official basin boundary (540,400 acres) and that in the YSGA model. Additionally, because catchment boundaries in the YSGA model are primarily determined by surface hydrology, there are small differences between the management area boundaries in the model and the official management area boundaries (shown in the Introduction and Basin Setting sections). Figure 5 below shows these differences, and Table 4 explains them. The total area of these differences is relatively small (19,440 acres, less than 3% of the Yolo Subbasin) and will not affect the model estimates substantively.). This MA is within the floodplain of the Sacramento River, with generally poorly drained lands. Field and truck crops dominate; although in the past two decades, vineyard acreage has increased.

The YSGA model (the MODFLOW portion) estimates the storage capacity of this area to be 678 TAF.

Cultivation in this MA is marked by significant and increasing acreage in vineyards. Field crops, winter grain, pasture, and some acreage in truck crops are also present (Table 29).

[12] Since the Clarksburg subregion boundary in the model is almost matches the official boundary, the description and budgets will refer simply to the Clarksburg MA.

Table 29 Land Use for Clarksburg MA

	Land Use (ac)				Land Use (Percent)			
	1989	1997	2008	2016	1989	1997	2008	2016
Clarksburg Management Area	**36,500**	**36,500**	**36,500**	**36,500**				
Deciduous	464	646	646	488	1	2	2	1
Field Crops	12,923	13,316	3,646	4,334	35	36	10	12
Grain	5,280	3,591	5,016	3,633	14	10	14	10
Managed Wetlands	0	0	0	0	0	0	0	0
Native Vegetation	5,370	2,725	5,390	7,299	15	7	15	20
Pasture	4,096	6,991	9,914	6,094	11	19	27	17
Rice	0	0	0	0	0	0	0	0
Subtropical	0	0	0	1	0	0	0	0
Truck Crops	5,467	2,586	1,707	1,895	15	7	5	5
Urban	285	285	560	560	1	1	2	2
Vine	1,702	5,447	8,708	11,284	5	15	24	31
Water	913	913	913	913	3	3	3	3

1.7.2. Data sources and Assumptions

Data sources for the historical scenario are described in the Model Documentation Appendix.

1.7.2.1.Future scenarios Assumptions

- Urban water demands:
  - Water demands for the town of Clarksburg are kept constant from the last historical values.
- Agriculture water demands:
  - 2018 land use is held constant into the future.
- Water supply:
  - Boundary conditions of the Sacramento River flow into the County remains the same as in the Historical scenario.
  - Surface water supply from the Sacramento River for irrigation is the same in the future simulations as in the last year of the historical simulation, unlimited.
  - There are no restrictions on groundwater pumping.

1.7.3. Water Budgets

Table 30 Useful Terms in this section

Term	Description
Deep percolation	Water that recharges the groundwater aquifer from the overlying catchments within the management area (these are listed in Table 3). This includes water from rain events, inefficiency of irrigation and seepage from septic systems. It is assumed the town of Clarksburg urban demand returns all water that is not consumed to septic systems, therefore, deep percolation.

Term	Description
Drainage	In regions close to the Sacramento River where the water table can be close to the ground surface, surface drains provide a route for the discharge of groundwater into the surface water system. To mimic that process the MODFLOW DRN package was used to place a drainage boundary in this management area in the model when the groundwater table reaches within 4 feet of the ground surface.
Evapotranspiration (ET)	Evaporation from the land surface (soil and urban land cover) and transpiration from vegetation (agriculture and native vegetation) from all catchments within this management area (listed in Table 3).
GW-SW Exchange	Exchange between the Sacramento River and Ship Channel and the aquifer underlying the management area.
Lateral GW Flow	Subsurface groundwater flow between the Clarksburg management area and the South Yolo management area.
Lateral GW Flow: Outside Yolo subbasin	Subsurface groundwater flow between the Clarksburg management area and the Solano and South American subbasins.
Precipitation	Rain falling within the management area boundary.
Pumping: Irrigation	Water sourced from groundwater supplied to agricultural irrigation in the catchments within this management area (these are listed in Table 3)
Pumping: Urban	Water sourced from groundwater supplied to the town of Clarksburg.
Surface Runoff (SRO)	Surface runoff from the land within this management area to the Sacramento River.
SW supply: Irrigation	Water sourced from the Sacramento River supplied to agricultural irrigation in the catchments within this management area (these are listed in Table 3).
Tailwater re-use: Irrigation	Reuse of irrigation tailwater. Reclamation Districts and the North Delta East catchment can reuse 90% of tailwater for irrigation in the model, based on previous work describing reuse in RD108 (Davids Engineering, 2011).
Urban consumption	Water consumed within the town of Clarksburg (not returned to a septic system). This includes water used for landscape irrigation within this demand.

The average annual land surface and groundwater budgets are presented for all scenarios in Table 31 and Table 32, respectively.

Key messages on the land surface water budget:

- Overall outflows and inflows are in balance for all scenarios.
- Future_Baseline vs Historical
    - The overall budget does not show much difference, except for somewhat reduced surface runoff and irrigation supply in the Future Baseline scenario. Both of these are related to the increase in perennial acreage in the form of vineyards, which replaced field and truck crops in this region.

- The four climate scenarios show that:
    - There is not that much variation between the Historical and Future_Baseline scenarios. Surface runoff and deep percolation do increase in the extreme scenario (Future_2070_WMW); and deep percolation is least in the extreme dry scenario (Future_DEW), as would be expected due to variation in precipitation.

Table 31 Average Annual Land Surface Water Budget for Clarksburg MA

Historical Average Annual Land Surface Water Budget (TAF)										
	Outflows					Inflows				
	Evapotranspiration	Deep Percolation	Surface Runoff	Urban Consumption	Total Outflows	Precipitation	Pumping: Urban	SW Supply: Irrigation	Tailwater Reuse: Irrigation	Total Inflows
Clarksburg										
Historical	-81	-11	-43	-0.3	-135	60	1	74	1	135
Future_Baseline	-81	-11	-35	-0.3	-127	60	1	66	1	127
Future_2030	-84	-11	-38	-0.3	-134	63	1	70	1	134
Future_2070	-87	-11	-42	-0.3	-140	65	1	73	1	140
Future_2070_DEW	-88	-9	-43	-0.3	-140	63	1	76	1	140
Future_2070_WMW	-85	-14	-53	-0.3	-152	81	1	70	0	152

Notes: Surface runoff drains to the Sacramento River; ET is dominated by Crop ET (86%) followed by native vegetation (11%).

The key messages from the groundwater budget (Table 32) and the groundwater storage graphs (Figure 22) are:

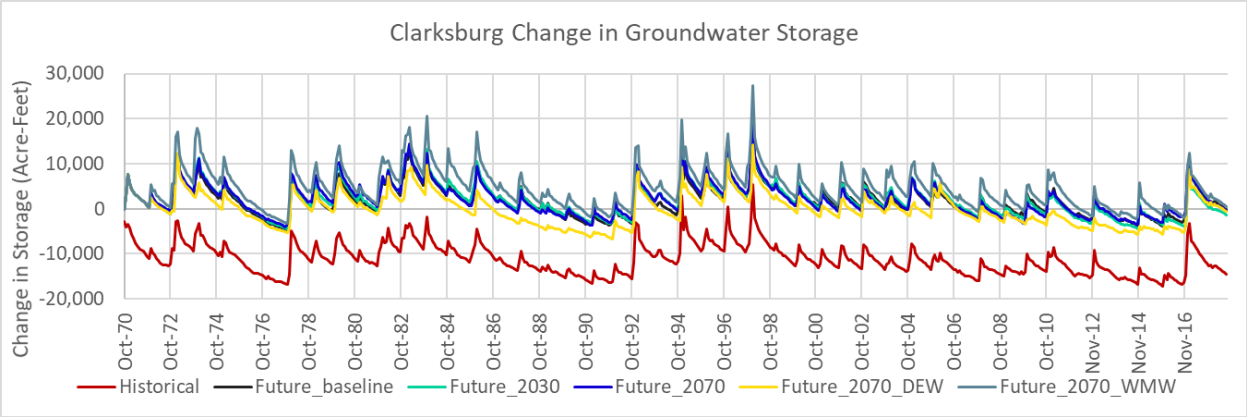
- There is not much that substantially differentiates the scenarios from each other.
- Although there are few groundwater observations publicly available from this MA, there is general knowledge that water levels are shallow (or groundwater elevations are high) in this MA, and indeed in much of the larger Sacramento River flood plain.
- Given the scarcity of data, uncertainties in groundwater model parameters exist.
- Taken altogether, there is no evidence of overdraft in Clarksburg Management Area.

Table 32 Average annual groundwater budget: Clarksburg MA

Historical Average Annual Groundwater Budget (TAF)									
	Outflows			Varying Flows				Inflows	
	Pumping: Urban	Drainage	Total Outflows	GW-SW Exchange	Lateral GW Flow: Outside Yolo subbasin	Lateral GW Flow	Total Varying Flows	Deep Percolation	Total Inflows
Clarksburg									
Historical	-0.6	-7	-8	-0.1	-10	6	-4	11	11
Future_Baseline	-0.6	-6	-6	0.0	-10	6	-4	11	11
Future_2030	-0.6	-6	-7	0.0	-10	6	-4	11	11
Future_2070	-0.6	-6	-7	0.0	-10	6	-4	11	11
Future_2070_DEW	-0.6	-5	-5	0.0	-9	5	-4	9	9
Future_2070_WMW	-0.6	-9	-9	-0.1	-11	6	-5	14	14

GW-SW exchange is near-zero because approximately the same amount that seeps in from the Sacramento River into this MA is drained/pumped out into the shipping channel; Lateral flow out of the Yolo Subbasin is to Solano Subbasin (-9.9TAF); and lateral inflow from is from South Yolo MA. Drainage represents the outflows from the catchment to the Sacramento River via the modeled drains.

Figure 22 Groundwater storage for Clarksburg MA, all scenarios



Notes: Each scenario's groundwater storage change time series is relative to its own origin/initial condition. For all the future scenarios, the initial conditions are defined in the model from the end of the historical scenario.

The annual time series, for the historical scenario, of land surface and groundwater budgets are provided in Figure 23 and Figure 24, respectively.

Figure 23 Annual Land Surface Water Budget: Clarksburg MA

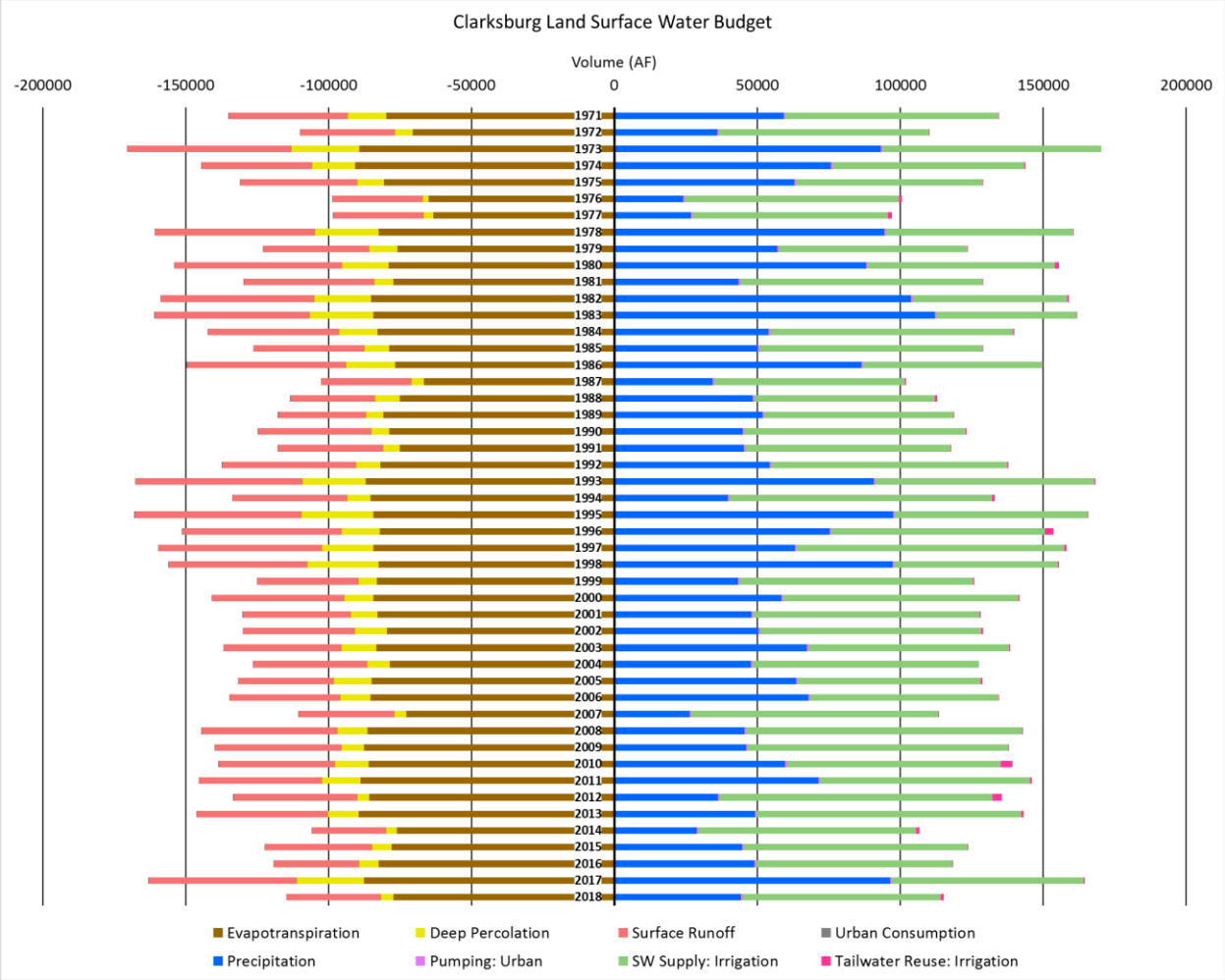
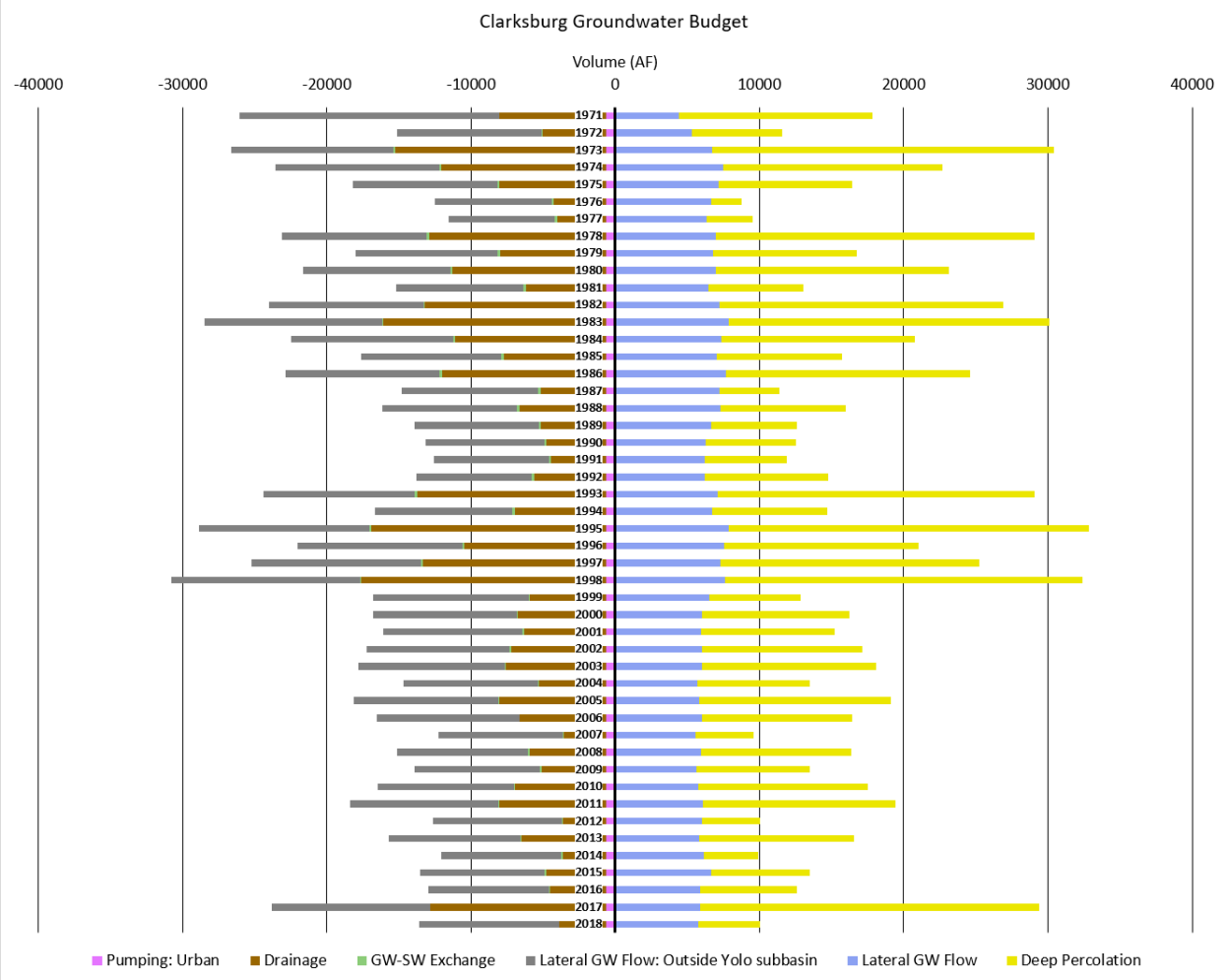


Figure 24 Historical Annual Groundwater Budget: Clarksburg MA



1.8. Dunnigan Hills Subregion

1.8.1. Description

The Dunnigan Hills Subregion of the model cover 92,345 acres in the northern and western portion of the Yolo Subbasin. Its western boundary includes rangeland in the upper reaches of Bird Creek, Buckeye Creek, and Oat Creek. The northern boundary is the shared boundary with Colusa Subbasin, in the south it skirts around Hungry Hollow, and to the east extends across Dunnigan Hills. That portion of the Region underlain by the alluvial aquifer, constitutes the Dunnigan Hills official MA boundary (Figure 4 and The WEAP portion of the YSGA model, which covers the land surface system and hydrology, covers 1,197,657 acres This includes all of Yolo County (639,089 acres in the WEAP portion of the model) and the Cache Creek system in Lake County (558,568 acres).

The MODFLOW portion of the YSGA model covers 559,840 acres (Table 3). Due to the resolution and spatial extent of the MODFLOW model (as mentioned earlier, derived from the IWFM model), and the pre-existing WEAP model which covers the entire county, there are small differences between the official basin boundary (540,400 acres) and that in the YSGA model. Additionally, because catchment boundaries in the YSGA model are primarily determined by surface hydrology, there are small differences between the management area boundaries in the model and the official management area boundaries (shown in the Introduction and Basin Setting sections). Figure 5 below shows these differences, and Table 4 explains them. The total area of these differences is relatively small (19,440 acres, less than 3% of the Yolo Subbasin) and will not affect the model estimates substantively.). Large areas of this region are not served by surface water. YCFC canals serve a small part, south of Dunnigan Hills (Figure 4 and The WEAP portion of the YSGA model, which covers the land surface system and hydrology, covers 1,197,657 acres This includes all of Yolo County (639,089 acres in the WEAP portion of the model) and the Cache Creek system in Lake County (558,568 acres).

The MODFLOW portion of the YSGA model covers 559,840 acres (Table 3). Due to the resolution and spatial extent of the MODFLOW model (as mentioned earlier, derived from the IWFM model), and the pre-existing WEAP model which covers the entire county, there are small differences between the official basin boundary (540,400 acres) and that in the YSGA model. Additionally, because catchment boundaries in the YSGA model are primarily determined by surface hydrology, there are small differences between the management area boundaries in the model and the official management area boundaries (shown in the Introduction and Basin Setting sections). Figure 5 below shows these differences, and Table 4 explains them. The total area of these differences is relatively small (19,440 acres, less than 3% of the Yolo Subbasin) and will not affect the model estimates substantively.).

This region has few monitoring wells. Especially in the northern rangelands in Buckeye and Bird Creeks, little groundwater development has happened, and little data is available. Similarly, there are no YSGA-monitoring wells in Dunnigan Hills proper; the few YSGA-monitoring wells are in the western foothills of Dunnigan Hills. However, groundwater development is active here, especially with rising acreage of orchards in the past decade. The Hills are a doubly plunging anticline; quaternary sediments have been

uplifted and folded along the anticline axis, and the underlying Tehama formation is exposed through the Hills (WRIME, 2006) .

Groundwater storage capacity in this area is estimated as 2,775 TAF in the YSGA model; however, much less is known about the stratigraphy in this region of the model domain (WRIME, 2006).

Native vegetation and unirrigated rangeland make up most of thisregions land use, mostly in the northern and north-western portions mentioned in the previous paragraphs. Of the cultivated acreage, orchards are significant, with acreage increasing over time (largely replacing annual field crops and also to some extent previously un-irrigated native vegetation) (Table 33).

Table 33 Land Use for Dunnigan Hills Region

	Land Use (ac)				Land Use (Percent)			
	1989	1997	2008	2016	1989	1997	2008	2016
Dunnigan Hills Management Area	**92,345**	**92,345**	**92,345**	**92,345**				
Deciduous	1,705	1,570	3,602	6,575	2	2	4	7
Field Crops	1,116	1,117	1,121	492	1	1	1	1
Grain	6,629	3,521	2,219	1,634	7	4	2	2
Managed Wetlands	0	0	0	0	0	0	0	0
Native Vegetation	80,365	80,622	79,372	74,636	87	87	86	81
Pasture	771	830	744	77	1	1	1	0
Rice	0	0	0	20	0	0	0	0
Subtropical	0	49	711	2,472	0	0	1	3
Truck Crops	538	897	325	323	1	1	0	0
Urban	546	546	578	578	1	1	1	1
Vine	550	3,068	3,548	5,414	1	3	4	6
Water	125	125	125	125	0	0	0	0

Source: DWR Land and Water Use Surveys

1.8.2. Data sources and assumptions

Data sources for the historical scenario are described in the Model Documentation Appendix.

1.8.2.1.Future scenarios Assumptions

- Urban water demands:
  - There are no urban demands represented in this MA.
- Agriculture water demands:
  - 2018 land use is held constant into the future.
- Water supply:
  - Since the climate and hydrology of the Cache Creek watershed is modeled, in future simulations, flows in Cache Creek reflect the climate scenario.
  - Clear Lake and Indian Valley Reservoir operating rules remain the same in the future simulations as in the Historical.
  - YCFC operating rules remain the same in the future simulations as in the last year of the historical simulation.

- Boundary conditions of all other surface water bodies flowing into the County remain the same as in the historical.
- All other surface water rights remain the same in the future simulations as in the last year of the Historical simulation.
- There are no restrictions on groundwater pumping.

1.8.3. Water budgets

Table 34 Useful terms in this section

Term	Description
Deep percolation	Water that recharges the groundwater aquifer from the overlying catchments within the management area (these are listed in Table 3). This includes water from rain events and inefficiency of irrigation.
Evapotranspiration (ET)	Evaporation from the land surface (soil and urban land cover) and transpiration from vegetation (agriculture and native vegetation) from all catchments within this management area (listed in Table 3).
GW-SW Exchange	Exchange between Cache Creek and the aquifer underlying the management area.
Lateral GW Flow	Subsurface groundwater flow between the Dunnigan Hills management area and the neighboring management areas: Central Yolo and North Yolo.
Lateral GW Flow: Outside Yolo subbasin	Subsurface groundwater flow between the Dunnigan Hills management area and the Colusa subbasin
Precipitation	Rain falling within the boundary.
Pumping: Irrigation	Water sourced from groundwater supplied to agricultural irrigation in the catchments within this management area (these are listed in Table XX)
Surface Runoff (SRO)	Surface runoff from the land within this management area to Cache Creek and the Colusa Basin Drain.
SW supply: Irrigation	Water sourced from the Cache Creek via YCFC canals supplied to agricultural irrigation in the catchments within this management area (these are listed in Table 3).
SW supply: Urban	Not applicable as no urban demands are represented in this management area in the model.
Tailwater re-use: Irrigation	Not applicable as tailwater is not available for reuse to any catchments in this management area.
YCFC canal recharge	Canal Recharge from the YCFC unlined canals.

The average annual land surface and groundwater budgets are presented for all scenarios in Table 35 and Table 36, respectively.

Key messages on the land surface water budget:

- Overall outflows and inflows are in balance for all scenarios.
- Future_Baseline vs Historical
  - Irrigation and ET increase substantively in the Future Baseline scenario as a result of increased perennial orchard acreage in the Dunnigan Hills portion of this MA. This pattern seems important to consider since there is hardly any groundwater usage in other parts of the MA.
- The four climate scenarios show that:
  - There is not much variation between them and the Projected_Baseline scenarios, except in the extreme wet (Future_2070_WMW) scenario in which Deep Percolation and Surface Runoff do substantially increase.

Table 35 Average Annual Land Surface Water Budget: Dunnigan Hills Subregion

Historical Average Annual Land Surface Water Budget (TAF)									
	Outflows					Inflows			
	Evapotranspiration	Deep Percolation	Surface Runoff	YCFC Canal Recharge	Total Outflows	Precipitation	Pumping: Irrigation	SW Supply: Irrigation	Total Inflows
Dunnigan Hills									
Historical	-114	-57	-7	-1	-179	154	18	7	179
Future_Baseline	-129	-58	-7	-1	-195	154	30	11	195
Future_2030	-133	-62	-7	-1	-204	161	31	12	204
Future_2070	-135	-69	-8	-1	-214	169	33	12	213
Future_2070_DEW	-132	-67	-9	-1	-209	163	35	11	209
Future_2070_WMW	-133	-102	-12	-1	-248	206	31	12	248

Notes: Surface runoff drains to Cache Creek (2.4 TAF AF) and the Colusa Basin Drain (4.8TAF); ET is dominated by native vegetation, however, crop ET grows from 17% to 34% of the total during the Historical simulation.

- The key messages from the groundwater budget (Table 36) and the groundwater storage graphs (Figure 25) are: Historically, similar to the Basin-wide narrative, groundwater is depleted from storage in dry years, and recovers in wet years. At the end of the historical period of 48 years, groundwater storage is estimated to be 48 TAF below the start. The overall trace suggests that this MA, as a whole, has not been overdrafted in the past nearly five decades, because it recovered in wet periods. However, within this MA:
  - The Dunnigan Hills portion of this MA shows some evidence of a gradual decline in water levels, based on the limited observations available here. More monitoring and possible projects may be required here.

- Also, there are no known groundwater observations in the northern and northwestern rangelands of Buckeye Creek and Bird Creek. Hence, the model uncertainty is high here. New monitoring is recommended in this portion.

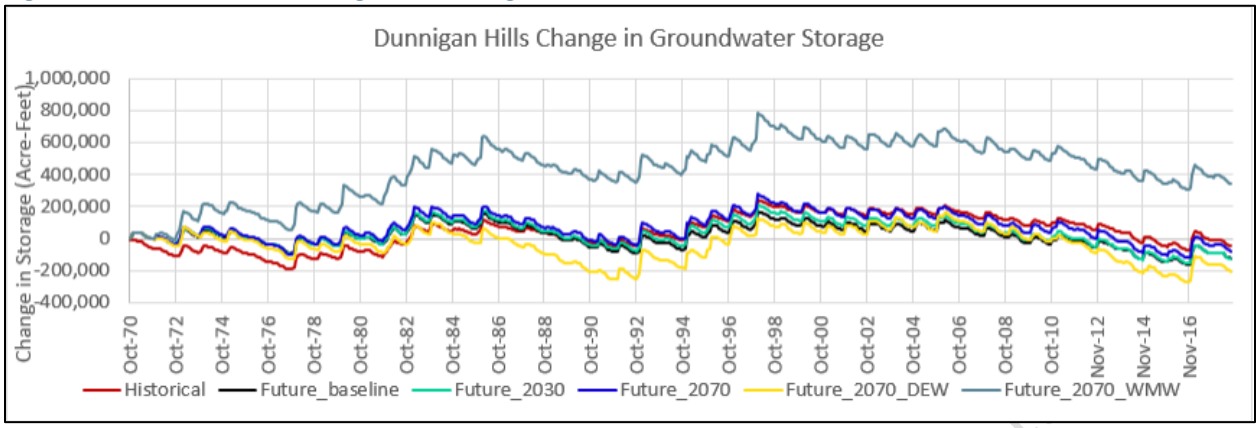
- Drought years like the 1976-1977 would not result in as severe a depletion as they did in the past, primarily because of increased surface water availability (e.g. Indian Valley Reservoir surface water) and to some extent by overall increased irrigation efficiencies.
- Compared to the overall range of groundwater storage, there is not much difference among the Future_Baseline, Future_2030, and Future_2070 scenarios.
- The greatest decrease in ground water storage is in the extreme dry scenario (Future_DEW) when groundwater storage by the end of the 48-year simulation falls to almost 204 TAF below initial conditions.
- In contrast, in the extreme wet scenario, groundwater storage climbs to about 342 TAF above initial conditions. This is the only scenario in which groundwater storage increases.

Table 36 Average Annual Groundwater Budgets: Dunnigan Hills MA

Historical Average Annual Groundwater Budget (TAF)									
	Outflows		Varying Flows				Inflows		
	Pumping: Irrigation	Total Outflows	GW-SW Exchange	Lateral GW Flow: Outside Yolo subbasin	Lateral GW Flow	Total Varying Flows	Deep Percolation	YCFC Canal Recharge	Total Inflows
Dunnigan Hills									
Historical	-18	-18	-0.1	-9	-31	-41	57	1	58
Future_Baseline	-30	-30	0.0	-8	-24	-31	58	1	59
Future_2030	-31	-31	0.0	-8	-27	-35	62	1	63
Future_2070	-33	-33	0.1	-9	-31	-39	69	1	70
Future_2070_DEW	-35	-35	0.2	-8	-30	-37	67	1	68
Future_2070_WMW	-31	-31	-0.4	-19	-46	-66	102	1	103

Notes: GW-SW exchange with Cache Creek is minimal (<100 AF) in this MA; Lateral groundwater flow to outside of the Yolo Subbasin is to Colusa Subbasin. Lateral groundwater outflow is to Central Yolo MA (9TAF) and North Yolo MA (22.5 TAF).

Figure 25 Groundwater storage for Dunnigan Hills MA



The annual time series, for the historical scenario, of land surface and groundwater budgets are provided in Figure 26Figure 23 and Figure 27Figure 24, respectively.

Figure 26 Annual Land Surface Water Budget: Dunnigan Hills

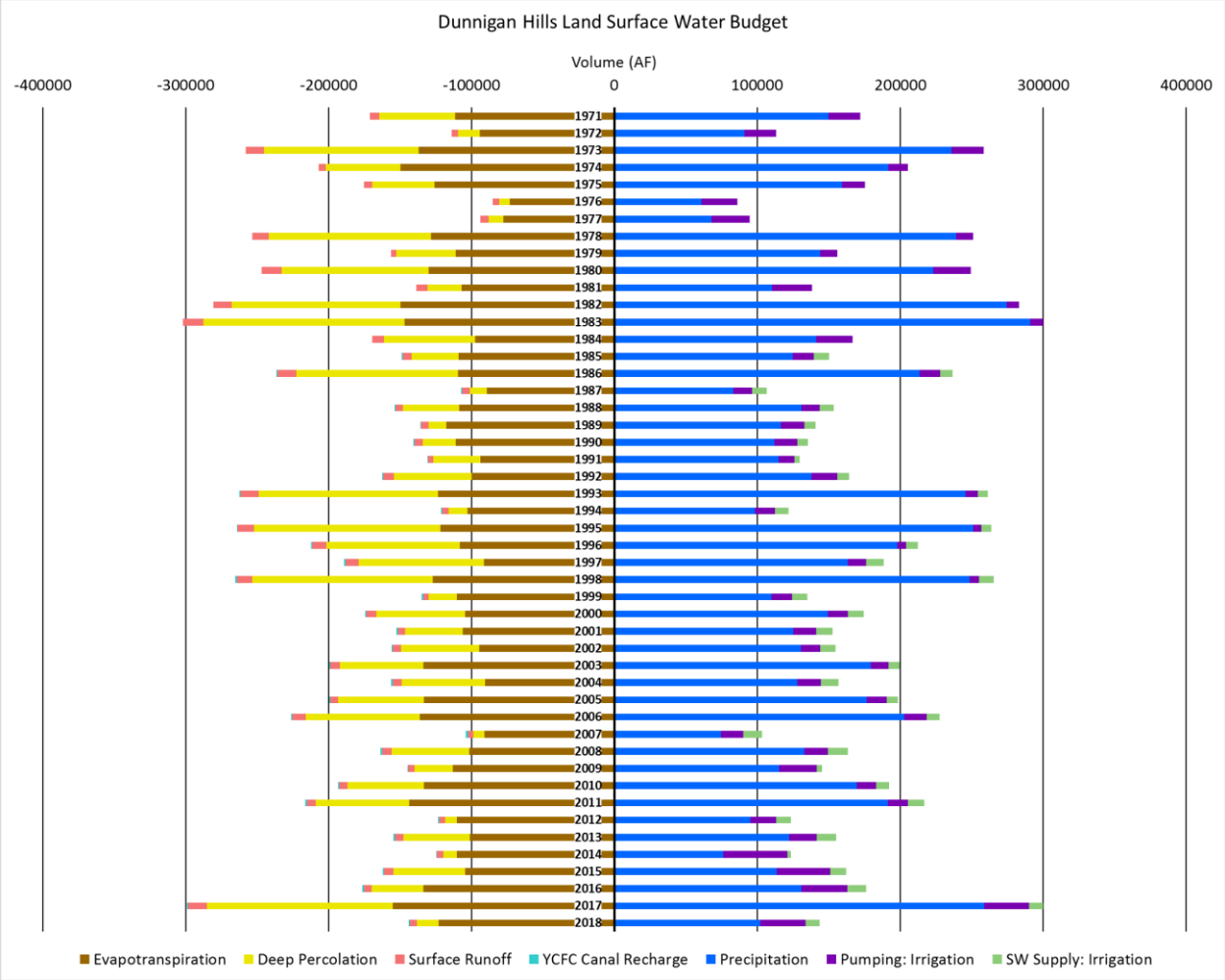
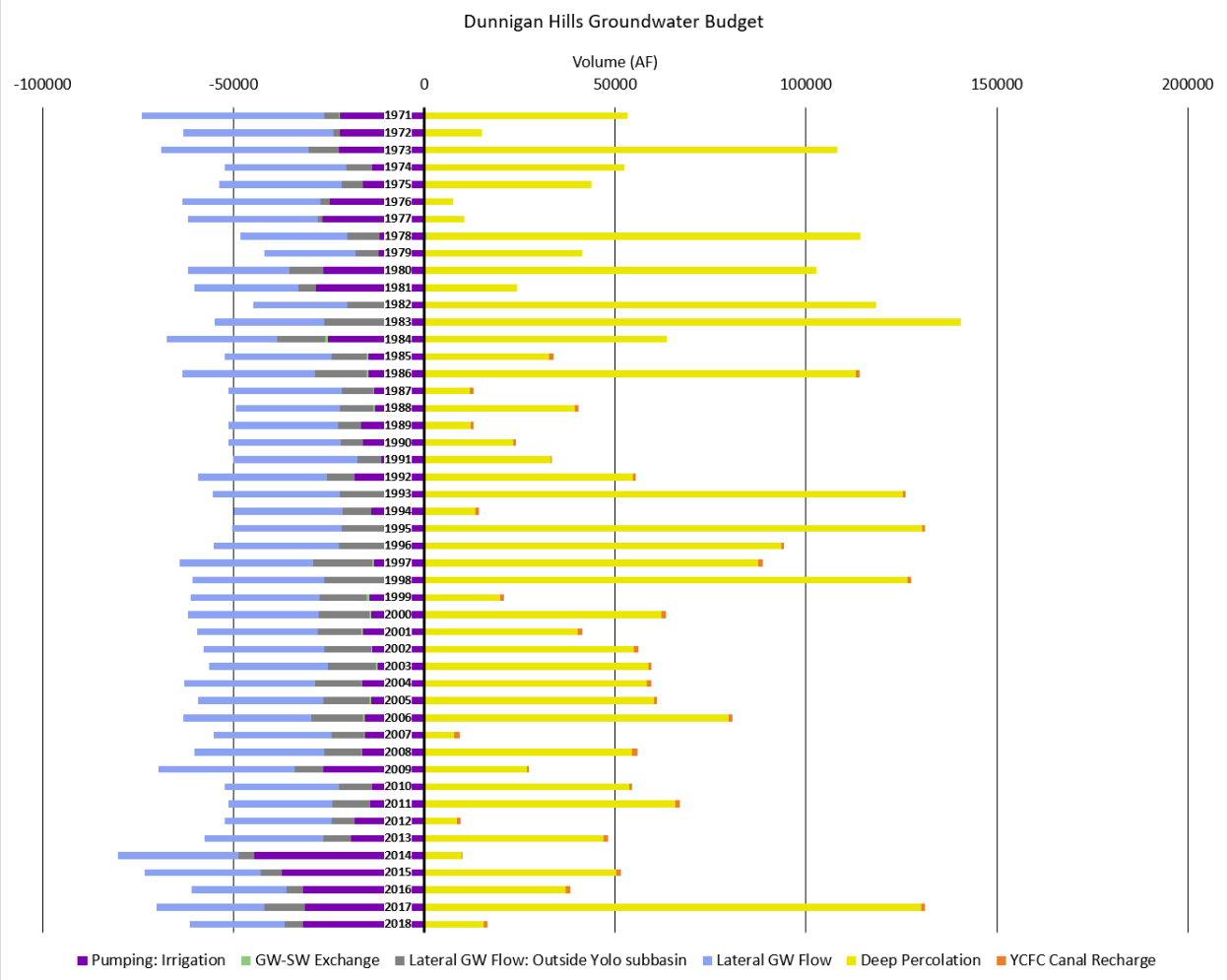


Figure 27 Annual Groundwater Budget: Dunnigan Hills MA



1.9. North Yolo Management Area[13]

1.9.1. Description

The North Yolo MA is 103,770 acres and borders the Colusa subbasin to the north, the Sacramento River to the east, the edge of Dunnigan Hills MA to the west and the Central Yolo MA boundary to the south (Figure 4). This MA includes several entities, including Dunnigan Water District, Cacheville and Knights Landing CSD's, RD 108, RD 730, and RD 787 (See The WEAP portion of the YSGA model, which covers the land surface system and hydrology, covers 1,197,657 acres This includes all of Yolo County (639,089 acres in the WEAP portion of the model) and the Cache Creek system in Lake County (558,568 acres).

The MODFLOW portion of the YSGA model covers 559,840 acres (Table 3). Due to the resolution and spatial extent of the MODFLOW model (as mentioned earlier, derived from the IWFM model), and the pre-existing WEAP model which covers the entire county, there are small differences between the official basin boundary (540,400 acres) and that in the YSGA model. Additionally, because catchment boundaries in the YSGA model are primarily determined by surface hydrology, there are small differences between the management area boundaries in the model and the official management area boundaries (shown in the Introduction and Basin Setting sections). Figure 5 below shows these differences, and Table 4 explains them. The total area of these differences is relatively small (19,440 acres, less than 3% of the Yolo Subbasin) and will not affect the model estimates substantively.). This MA also include several white areas, particularly along the Colusa Basin Drain (called "CBD North" and "CBD South" in the model) and in the Yolo-Zamora area (called "Yolo Zamora North" and "Yolo Zamora South" in the model (See The WEAP portion of the YSGA model, which covers the land surface system and hydrology, covers 1,197,657 acres This includes all of Yolo County (639,089 acres in the WEAP portion of the model) and the Cache Creek system in Lake County (558,568 acres).

The MODFLOW portion of the YSGA model covers 559,840 acres (Table 3). Due to the resolution and spatial extent of the MODFLOW model (as mentioned earlier, derived from the IWFM model), and the pre-existing WEAP model which covers the entire county, there are small differences between the official basin boundary (540,400 acres) and that in the YSGA model. Additionally, because catchment boundaries in the YSGA model are primarily determined by surface hydrology, there are small differences between the management area boundaries in the model and the official management area boundaries (shown in the Introduction and Basin Setting sections). Figure 5 below shows these differences, and Table 4 explains them. The total area of these differences is relatively small (19,440 acres, less than 3% of the Yolo Subbasin) and will not affect the model estimates substantively. and Figure 4).

Surface water is supplied to much of the area from the Sacramento River, Colusa Basin Drain, and Tehama Colusa Canal, with a small portion of land near Zamora being served by YCFC as well. Surface

[13] Since the subregion boundary in the model closely the official boundary, the description and budgets will refer simply to the MA.

water availability varies widely in this MA, with abundant Sacramento River water available to the Reclamation Districts and no surface water supplies currently available to Yolo Zamora North and South.

Groundwater storage capacity of this area in the YSGA model is estimated as 1,611 TAF. Agricultural land use is diverse, with substantial rice cultivation along with truck crops and field crops (Table 37). Deciduous orchard acreage has been increasing considerably (Table 37).

Table 37 Land Use for North Yolo MA

	Land Use (ac)				Land Use (Percent)			
	1989	1997	2008	2016	1989	1997	2008	2016
North Yolo Management Area	**103,770**	**103,770**	**103,770**	**103,770**				
Deciduous	2,124	2,265	7,597	15,622	2	2	7	15
Field Crops	23,254	27,016	10,336	14,500	22	26	10	14
Grain	14,647	13,045	11,700	5,799	14	13	11	6
Managed Wetlands	0	0	0	0	0	0	0	0
Native Vegetation	18,882	16,596	22,684	22,576	18	16	22	22
Pasture	9,970	4,564	8,565	5,686	10	4	8	5
Rice	12,711	13,452	18,550	18,295	12	13	18	18
Subtropical	0	0	0	106	0	0	0	0
Truck Crops	19,412	23,768	21,095	17,773	19	23	20	17
Urban	1,772	1,738	1,860	1,860	2	2	2	2
Vine	49	376	384	553	0	0	0	1
Water	950	950	1,000	1,000	1	1	1	1

Source: DWR Land and Water Use Surveys

1.9.2. Data sources and assumptions

Data sources for the historical scenario are in the Model Documentation Appendix.

1.9.2.1.Future scenarios Assumptions

In addition to the future scenario conditions and assumptions explained in section 1.2, we made assumptions specific to this MA regarding the growth of demands, and the operations and availability of water supply, which were applied across all future scenarios.

- Urban water demands:
  - Water demands for Cacheville CSD, Knights Landing CSD, the town of Zamora and domestic wells within the Dunnigan Water District area remain constant from the most current year.
- Agriculture water demands:
  - 2018 land use is held constant into the future.
- Water supply:
  - Boundary conditions of all surface water bodies flowing into the County remain the same as in the historical simulation.

- There are no restrictions on groundwater pumping.
- It is assumed that Dunnigan Water District has their full water right available in the future scenarios (19 TAF), in all years except where water rights are reduced based on water allocations.
- All other surface water rights remain the same in the future simulations as in the last year of the historical simulation with limitations based on Shasta Critical Years, Project Water allocations, and Term 91, where applicable.

1.9.3. Water Budgets

Table 38 Useful terms in this section

Term	Description
Deep percolation	Water that recharges the groundwater aquifer from the overlying catchments within the management area (these are listed in Table 3). This includes water from rain events, inefficiency of irrigation and seepage from septic systems (Cacheville CSD, the town of Zamora and domestic wells within the Dunnigan Water District area) and wastewater treatment ponds (these occur in Knights Landing CSD).
Drainage	In regions close to the Sacramento River where the water table can be close to the ground surface, surface drains provide a route for the discharge of groundwater into the surface water system. To mimic that process the MODFLOW DRN package was used to place a drainage boundary in reclamation districts 108, 730 and 787 in the model when the groundwater table reaches within 4 feet of the ground surface.
Evapotranspiration (ET)	Evaporation from the land surface (soil and urban land cover) and transpiration from vegetation (agriculture and native vegetation) from all catchments within this management area (listed in Table 3) as well as evaporation from wastewater treatment ponds (these occur in Knights Landing CSD)
GW-SW Exchange	Exchange between Cache Creek, the Colusa Basin Drain, Sacramento River, Yolo Bypass, Knights Landing Ridge Cut and the aquifer underlying the management area.
Lateral GW Flow	Subsurface groundwater flow between the North Yolo management area and the neighboring management areas: Central Yolo, Dunnigan Hills and South Yolo.
Lateral GW Flow: Outside Yolo subbasin	Subsurface groundwater flow between the North Yolo management area and the Colusa and Sutter subbasins.
Precipitation	Rain falling within the boundary.
Pumping: Irrigation	Water sourced from groundwater supplied to agricultural irrigation in the catchments within this management area (these are listed in Table 3)
Pumping: Urban	Water sourced from groundwater supplied to the urban demands within this management area: Cacheville CSD, Knights Landing CSD, the town of Zamora and domestic wells within the Dunnigan Water District area.
Surface Runoff (SRO)	Surface runoff from the land within this management area to Cache Creek, the Colusa Basin Drain, Sacramento River and Yolo Bypass.
SW supply: Irrigation	Water sourced from the Colusa Basin Drain, Cache Creek via YCFC canals, Sacramento River an Tehema Colusa Canal supplied to agricultural irrigation in the catchments within this management area (these are listed in Table 3).

Term	Description
Tailwater re-use: Irrigation	Reuse of irrigation tailwater. Reclamation Districts and the North Delta East catchment can reuse 90% of tailwater for irrigation in the model, based on previous work describing reuse in RD108 (Davids Engineering, 2011).
Urban consumption	Water consumed within the urban demands in this management area (not returned to a septic system or wastewater treatment plant): Cacheville CSD, Knights Landing CSD, the town of Zamora and domestic wells within the Dunnigan Water District area. This includes water used for landscape irrigation within these demands.

The average annual land surface and groundwater budgets are presented for all scenarios in Table 39 and Table 40, respectively.

Key messages on the land surface water budget inlude:

- Overall outflows and inflows are in balance for all scenarios.
- Future_Baseline vs Historical
  - Irrigation and ET increase as a result of increased perennial orchard and rice acreage.
- The four climate scenarios show that:
  - In the extreme dry scenario (Future_2070_DEW), irrigation demand increases substantially, and ET is also highest.
  - In the extreme wet scenario (Future_2070_WMW) Surface Runoff and Deep Percolation are substantially increased.

Table 39 Average Annual Land Surface Water Budget: North Yolo MA

Historical Average Annual Land Surface Water Budget (TAF)											
	Outflows					Inflows					
	Evapotranspiration	Deep Percolation	Surface Runoff	Urban Consumption	Total Outflows	Precipitation	Pumping: Urban	Pumping: Irrigation	SW Supply: Irrigation	Tailwater Reuse: Irrigation	Total Inflows
North Yolo											
Historical	-244	-46	-110	-0.3	-399	171	1	62	159	6	399
Future_Baseline	-270	-46	-116	-0.3	-433	171	1	73	181	7	433
Future_2030	-280	-48	-123	-0.3	-451	180	1	86	177	7	451
Future_2070	-289	-48	-132	-0.3	-470	188	1	94	180	7	470
Future_2070_DEW	-296	-45	-136	-0.3	-477	181	1	102	187	6	477
Future_2070_WMW	-283	-55	-165	-0.3	-504	231	1	87	177	8	504

Notes: SRO is to Sacramento River (28 TAF), Cache Creek (10 TAF), Colusa Basin Drain (66TAF), and Yolo Bypass (5.6TAF); SW supply is from the Sacramento River (111 TAF), Colusa Basin Drain (40 TAF), Tehama Colusa Canal (7.8 TAF), and YCFC (0.15T AF).

The key messages from the groundwater budget (Table 40) and the groundwater storage time series Figure 28) are:

- Historically, similar to the Basin-wide narrative, groundwater is depleted from storage in dry years, and recovers in wet years. At the end of the historical period of 48 years, groundwater storage is estimated to be 38 TAF below the start. The overall trace suggests that this MA, as a whole, has not been overdrafted in the past nearly five decades, because it recovered in wet periods. However, within this MA:
    - The Zamora portion of this MA shows some evidence of a gradual decline in water levels, based on the limited observations available here. More monitoring and possible projects may be required here.
- Increased Indian Valley Reservoir surface water is not as impactful here, at least not at the scale of the entire MA (since YCFC's canal system is not currently offering much coverage in the MA).
- The Future_2030, Future_2070 and the extreme dry scenario (Future_2070_DEW) are more impactful in this MA when compared to others, with groundwater storage showing signs of decline in these three respectively:
    - 111 TAF, 143 TAF, and 254 TAF below initial conditions
- Even in the extreme wet scenario, groundwater storage ends below initial conditions (5 TAF).

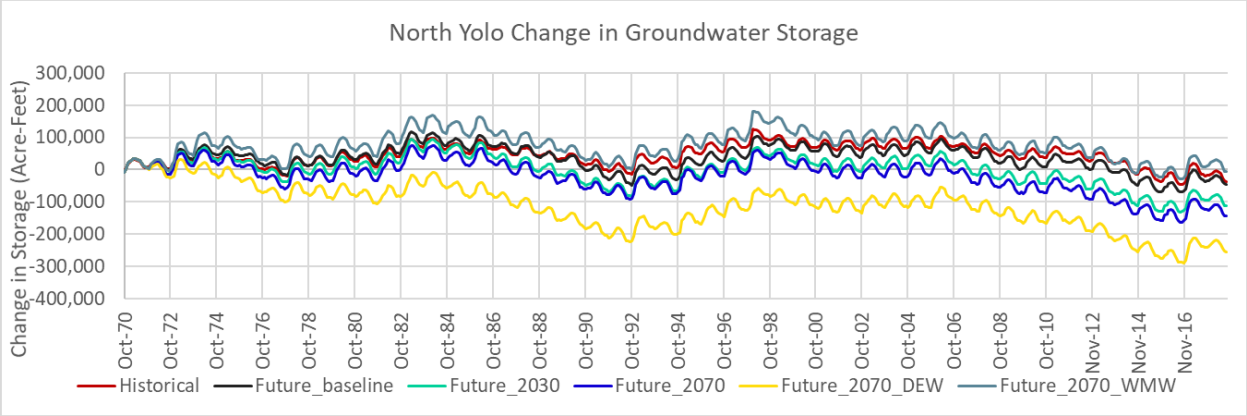
These results suggest that the North Yolo MA will need more attention; however only some parts of it, especially Zamora, may need management actions in the future.

Table 40 Average Annual Groundwater Budget: North Yolo MA

Historical Average Annual Groundwater Budget (TAF)										
	Outflows				Varying Flows				Inflows	
	Pumping: Urban	Pumping: Irrigation	Drainage	Total Outflows	GW-SW Exchange	Lateral GW Flow: Outside Yolo subbasin	Lateral GW Flow	Total Varying Flows	Deep Percolation	Total Inflows
North Yolo										
Historical	-0.7	-62	-8	-71	-1	-4	29	25	46	46
Future_Baseline	-0.7	-73	-3	-77	-1	-1	31	29	46	46
Future_2030	-0.7	-86	-2	-89	0	5	35	39	48	48
Future_2070	-0.7	-94	-2	-96	0	7	38	45	48	48
Future_2070_DEW	-0.7	-102	-1	-103	3	13	38	53	45	45
Future_2070_WMW	-0.7	-87	-6	-94	-3	0	42	39	55	55

Notes: GW-SW exchange is the net of inflow from Sacramento River (0.7 TAF), Cache Creek (6.5 TAF), and outflow to Knights Landing Ridge Cut (1.5TAF) and Yolo Bypass (6.7 TAF). Lateral GW Flow is the net of inflow from Dunnigan Hills (22.5 TAF), Central Yolo (7.1 TAF), and outflows to South Yolo (0.5 TAF) MA's. Lateral Flow out of the Yolo Subbasin is to the Colusa Subbasin.

Figure 28 Groundwater Storage for North Yolo MA



Annual time series of the budgets are provided in Figure 29 and Figure 30.

Figure 29 Annual Land Surface Water Budget for North Yolo MA

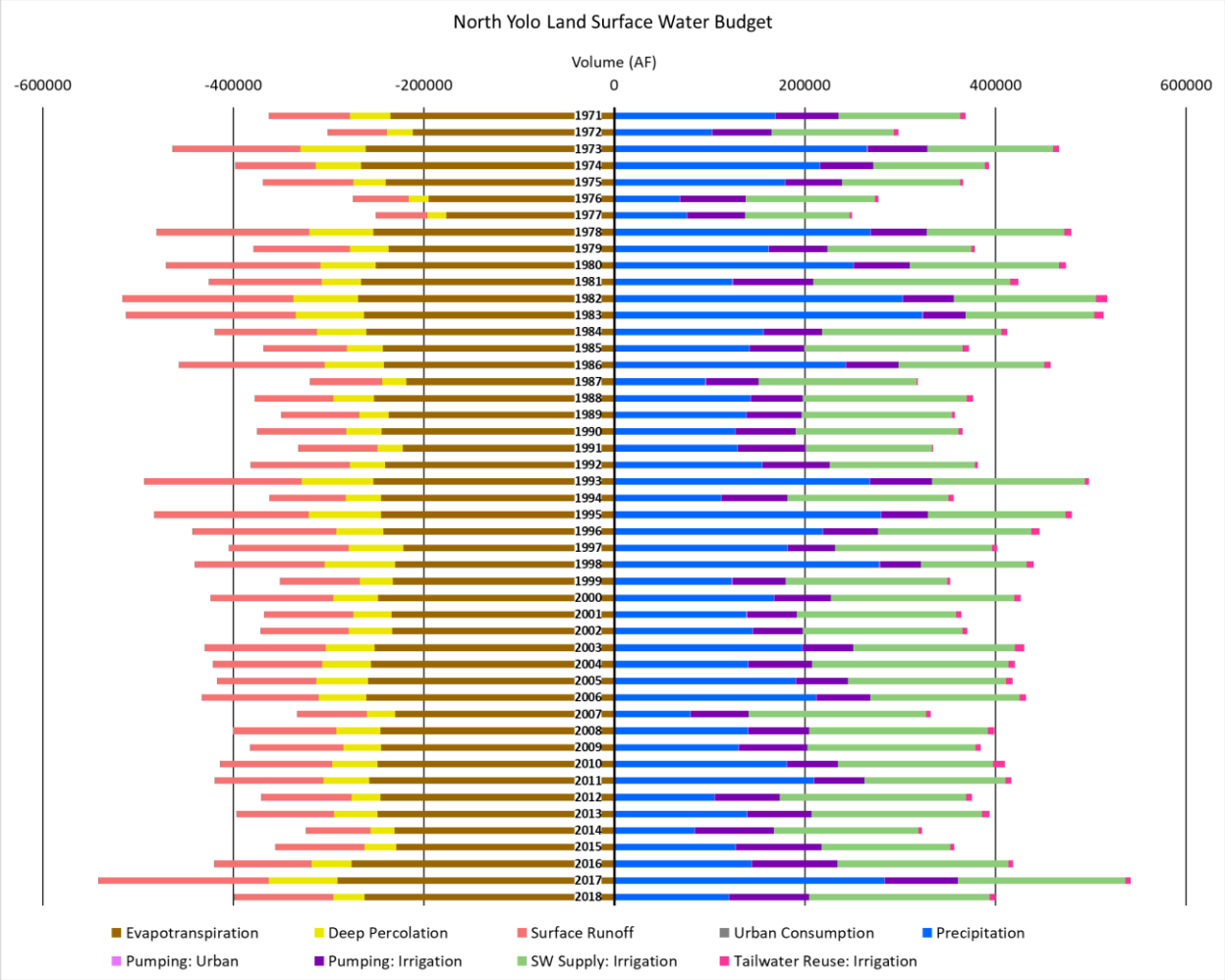
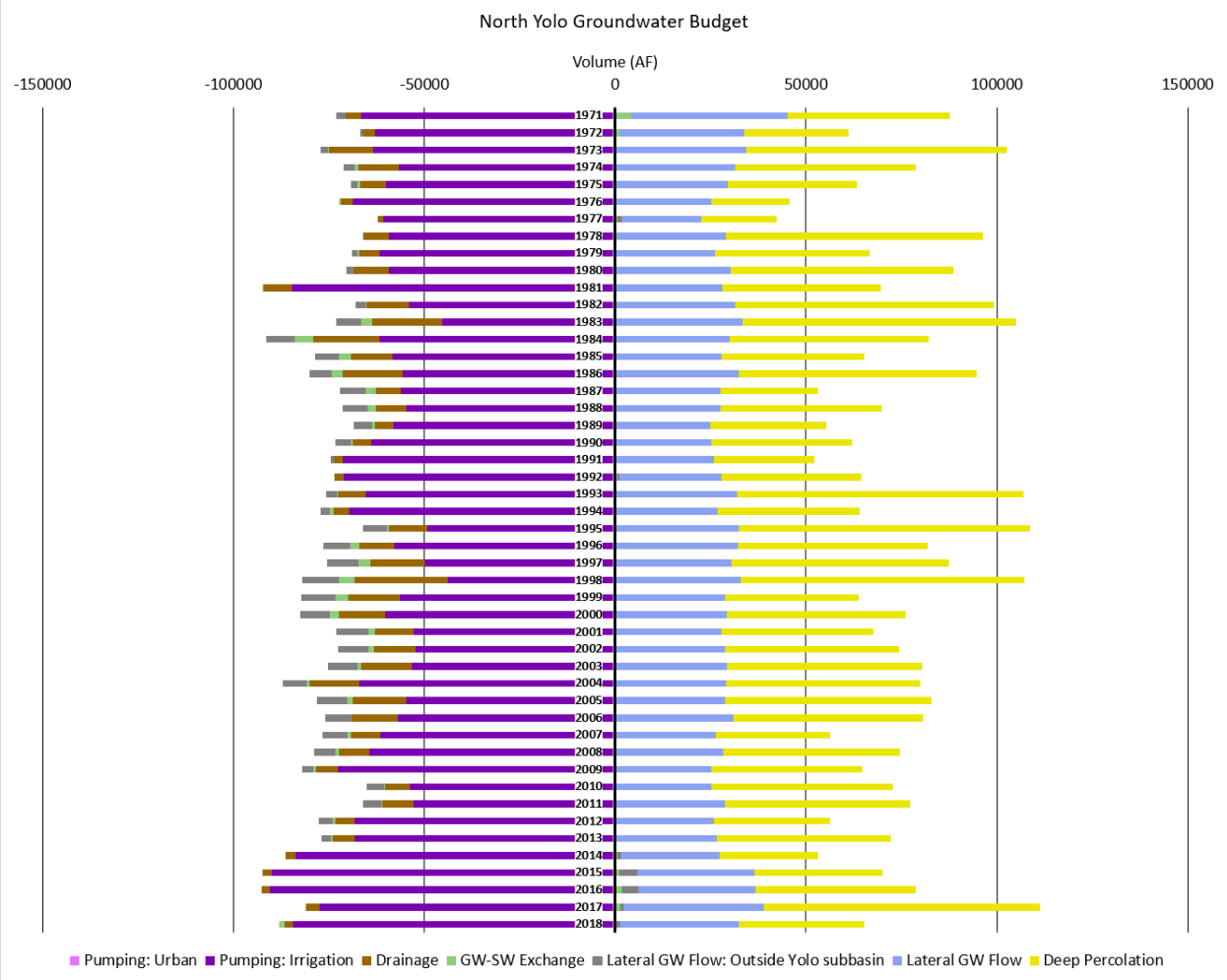


Figure 30 Annual Groundwater Budget for North Yolo MA



1.10. South Yolo Management Area[14]

1.10.1. Description

The South Yolo MA covers 49,635 acres and lies east of the Central Yolo MA and west of the Sacramento River and the shipping channel. It borders the North Yolo MA in the north (Figure 4). It includes the Yolo Bypass, City of West Sacramento, and Reclamation District 1600, and Reclamation Districts 537, 785, and 827 (which have since been consolidated into RD 537), and part of RD 2068 (See The WEAP portion of the YSGA model, which covers the land surface system and hydrology, covers 1,197,657 acres This includes all of Yolo County (639,089 acres in the WEAP portion of the model) and the Cache Creek system in Lake County (558,568 acres).

The MODFLOW portion of the YSGA model covers 559,840 acres (Table 3). Due to the resolution and spatial extent of the MODFLOW model (as mentioned earlier, derived from the IWFM model), and the pre-existing WEAP model which covers the entire county, there are small differences between the official basin boundary (540,400 acres) and that in the YSGA model. Additionally, because catchment boundaries in the YSGA model are primarily determined by surface hydrology, there are small differences between the management area boundaries in the model and the official management area boundaries (shown in the Introduction and Basin Setting sections). Figure 5 below shows these differences, and Table 4 explains them. The total area of these differences is relatively small (19,440 acres, less than 3% of the Yolo Subbasin) and will not affect the model estimates substantively.).

The groundwater storage capacity of this MA is estimated in the YSGA model as 2,100 TAF.

Native vegetation covers about half of this MA, predominantly in the Yolo Bypass. Agriculture is diverse in this MA, with rice, pasture, truck crops, field crops, and orchards present (Table 41).

[14] Since the subregion boundary in the model closely the official boundary, the description and budgets will refer simply to the MA.

Table 41 Land Use for South Yolo MA

	Land Use (ac)				Land Use (Percent)			
	1989	1997	2008	2016	1989	1997	2008	2016
South Yolo Management Area	**78,279**	**78,279**	**78,279**	**78,279**				
Deciduous	2,236	2,688	2,428	3,327	3	3	3	4
Field Crops	24,441	22,171	3,016	4,002	31	28	4	5
Grain	4,049	3,020	5,688	980	5	4	7	1
Managed Wetlands	0	0	0	0	0	0	0	0
Native Vegetation	25,275	28,659	39,579	43,484	32	37	51	56
Pasture	8,879	8,217	11,157	6,249	11	10	14	8
Rice	147	225	3,454	3,432	0	0	4	4
Subtropical	0	0	0	60	0	0	0	0
Truck Crops	4,439	4,121	2,533	4,952	6	5	3	6
Urban	6,926	7,286	8,557	9,883	9	9	11	13
Vine	19	25	0	43	0	0	0	0
Water	1,867	1,867	1,867	1,867	2	2	2	2

Source: DWR Land and Water Use Surveys

1.10.2. Data Sources and Assumptions

Data sources for the historical scenario are described in the Model Documentation Appendix.

1.10.2.1. Future scenarios Assumptions

- City of West Sacramento: For Future scenarios, using last available values for all parameters, except population, which starts at 2019 data value and grows at 2.72%, based on the 2015 UWMP's 20-year planning horizon (this is probably an overestimate if modeling for 50 years). Water use rates remain constant from 2018 values.
- Agriculture water demands:
  - 2018 land use is held constant into the future.
- Water supply:
  - Boundary conditions of all surface water bodies flowing into the County remain the same as in the historical simulation.
  - There are no restrictions on groundwater pumping.
  - All surface water rights remain the same in the future simulations as in the last year of the historical simulation, with limitations based on Shasta Critical Years, Project Water allocations, and Term 91, where applicable.

1.10.3. Water Budgets

Table 42 Useful terms in this section

Term	Description
Deep percolation	Water that recharges the groundwater aquifer from the overlying catchments within the management area (these are listed in Table 3). This includes water from rain events and inefficiency of irrigation.
Drainage	In regions close to the Sacramento River where the water table can be close to the ground surface, surface drains provide a route for the discharge of groundwater into the surface water system. To mimic that process the MODFLOW DRN package was used to place a drainage boundary in reclamation district 1600 and North Delta West catchment in the model when the groundwater table reaches within 4 feet of the ground surface.
Evapotranspiration (ET)	Evaporation from the land surface (soil and urban land cover) and transpiration from vegetation (agriculture and native vegetation) from all catchments within this management area (listed in Table 3).
GW-SW Exchange	Exchange between Putah Creek, the Sacramento River, Ship Channel, Willow Slough, Yolo Bypass and the aquifer underlying the management area.
Lateral GW Flow	Subsurface groundwater flow between the South Yolo management area and the neighboring management areas: Central Yolo, North Yolo and Clarksburg.
Lateral GW Flow: Outside Yolo subbasin	Subsurface groundwater flow between the North Yolo management area and the nighborin subbasins: Sutter, North American, South American and Solano subbasins.
Precipitation	Rain falling within the boundary.
Pumping: Irrigation	Water sourced from groundwater supplied to agricultural irrigation in the catchments within this management area (these are listed in Table 3)
Pumping: Urban	Water sourced from groundwater supplied to West Sacramento, in the past.
Surface Runoff (SRO)	Surface runoff from the land within this management area to Putah Creek, the Sacramento River, Willow Slough and the Yolo Bypass.
SW supply: Irrigation	Water sourced from the Sacramento River and the Delta supplied to agricultural irrigation in the catchments within this management area (these are listed in Table 3).
SW supply: Urban	Water sourced from the Sacramento River supplied to West Sacramento.
Tailwater re-use: Irrigation	Reuse of irrigation tailwater. Reclamation Districts and the North Delta East catchment can reuse 90% of tailwater for irrigation in the model, based on previous work describing reuse in RD108 (Davids Engineering, 2011).
Treated WW Outflow	Return flows from the West Sacramento portion of the Sacramento wastewater treatment plant into the Sacramento River.
Urban consumption	Water consumed within West Sacramento. This includes water used for landscape irrigation within these demands.

The average annual land surface and groundwater budgets are presented for all scenarios in Table 43 and Table 44, respectively.

Key messages on the land surface water budget:

- Overall outflows and inflows are in balance for all scenarios.
- Future_Baseline vs Historical:
  - Irrigation and ET are less in the Future_Baseline, largely because of the replacement of agriculture with urban land use and a shift from irrigated agriculture to native vegetation.
  - Urban pumping in this MA is mostly for City West Sacramento, which switched from groundwater to surface water in the 1980's.
- The four climate scenarios show that:
  - There is not much difference compared to the Future_Baseline, except in the extreme wet scenario (Future_2070_WMW), in which there is much more surface runoff and more deep percolation.

Table 43 Annual Average Land Surface Water Budget: South Yolo MA

Historical Average Annual Land Surface Water Budget (TAF)													
	Outflows						Inflows						
	Evapotranspiration	Deep Percolation	Surface Runoff	Urban Consumption	Treated WW Outflow	Total Outflows	Precipitation	Pumping: Urban	Pumping: Irrigation	SW Supply: Urban	SW Supply: Irrigation	Tailwater Reuse: Irrigation	Total Inflows
South Yolo													
Historical	-160	-45	-51	-5	-4	-266	128	2	8	8	120	0.2	266
Future_Baseline	-145	-25	-46	-9	-8	-232	128	0	1	17	87	0.2	232
Future_2030	-150	-26	-51	-9	-8	-244	135	0	1	17	91	0.3	244
Future_2070	-154	-27	-56	-9	-8	-253	140	0	1	17	95	0.3	253
Future_2070_DEW	-152	-26	-58	-9	-8	-252	135	0	1	17	99	0.3	252
Future_2070_WMW	-154	-30	-82	-9	-8	-283	173	0	1	17	91	0.2	283

Notes: SRO is to the Yolo Bypass (26.5 TAF), Willow Slough (0.3 TAF), Putah Creek (6.6 TAF), and Sacramento River (17.8 TAF). Surface water supply is from the Sacramento River.

The key messages from the groundwater budget (Table 44) and the groundwater storage time series Figure 31) are:

- Historically, there is very little variation in groundwater storage, except in the early years – the simulated increase in groundwater storage mimics an observed change in the observation wells, although the simulated change is more rapid than the observed. This MA has no signs of overdraft historically.

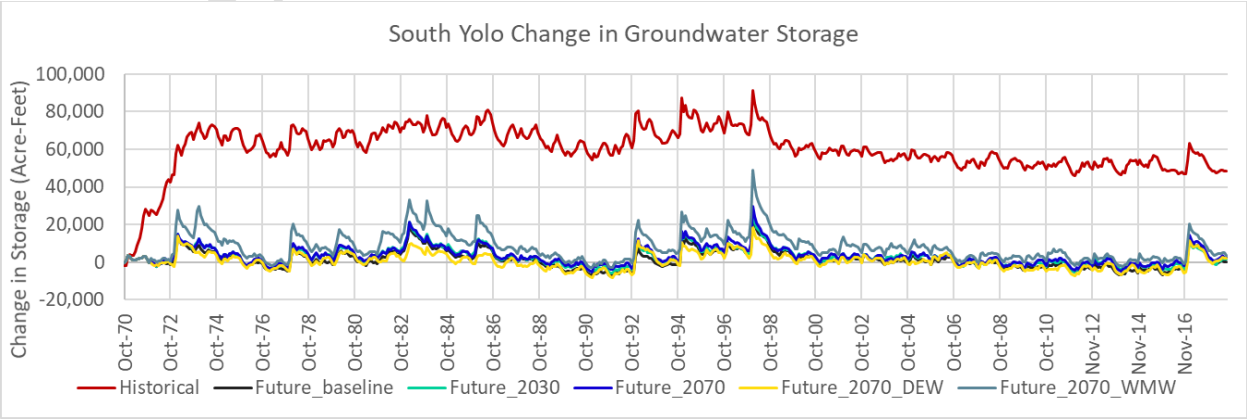
- Future_Baseline vs Historical:
    - The main difference is that urban supply for City of West Sacramento will continue to be entirely surface water.
- The four climate scenarios show little variation, except in the wet scenario (Future_2070_WMW), in which there is more deep percolation. These results suggest that South Yolo MA is not likely to face overdraft in the future scenarios investigated.

Table 44 Annual Average Groundwater Budget for South Yolo MA

Historical Average Annual Groundwater Budget (TAF)										
	Outflows				Varying Flows				Inflows	
	Pumping: Urban	Pumping: Irrigation	Drainage	Total Outflows	GW-SW Exchange	Lateral GW Flow: Outside Yolo subbasin	Lateral GW Flow	Total Varying Flows	Deep Percolation	Total Inflows
South Yolo										
Historical	-2	-8	-13	-23	-17	12	-16	-21	45	45
Future_Baseline	0	-1	-7	-8	-10	5	-12	-17	25	25
Future_2030	0	-1	-7	-8	-11	4	-11	-17	26	26
Future_2070	0	-1	-8	-9	-11	4	-11	-18	27	27
Future_2070_DEW	0	-1	-7	-8	-10	7	-14	-17	26	26
Future_2070_WMW	0	-1	-9	-11	-13	2	-9	-20	30	30

Notes: GW-SW exchange is into this MA from Sacramento River (0.2 TAF), and out of the MA to the Yolo Bypass (14.6 TAF), Deep Water Ship Channel (1.6 TAF), and Putah Creek (0.6 TAF). Lateral GW flow comes in from North Yolo (0.5 TAF), and flows out to Clarksburg (-6 TAF) and Central Yolo (-10 TAF) MA's. Net annual flow from neighboring basins is inward at 12 TAF. These flows are as follows: Solano (-0.5 TAF), South American (1.9 TAF), and North American (10.1 TAF) Subbasins.

Figure 31 Groundwater Storage for South Yolo MA



Annual time series of South Yolo MA's land surface and groundwater budgets are provided in Figure 32 and Figure 33.

Figure 32 Annual Land Surface Water Budgets: South Yolo MA

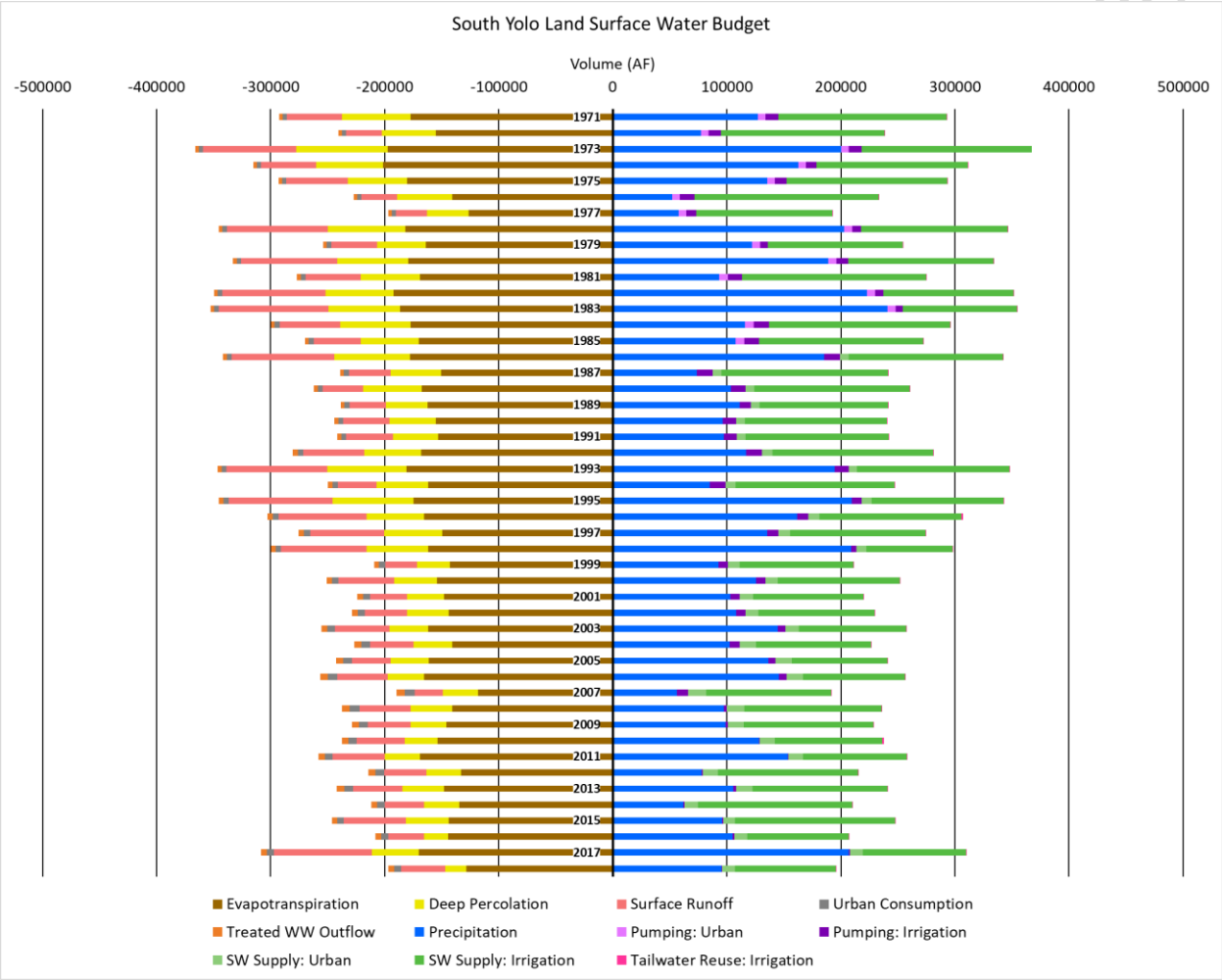
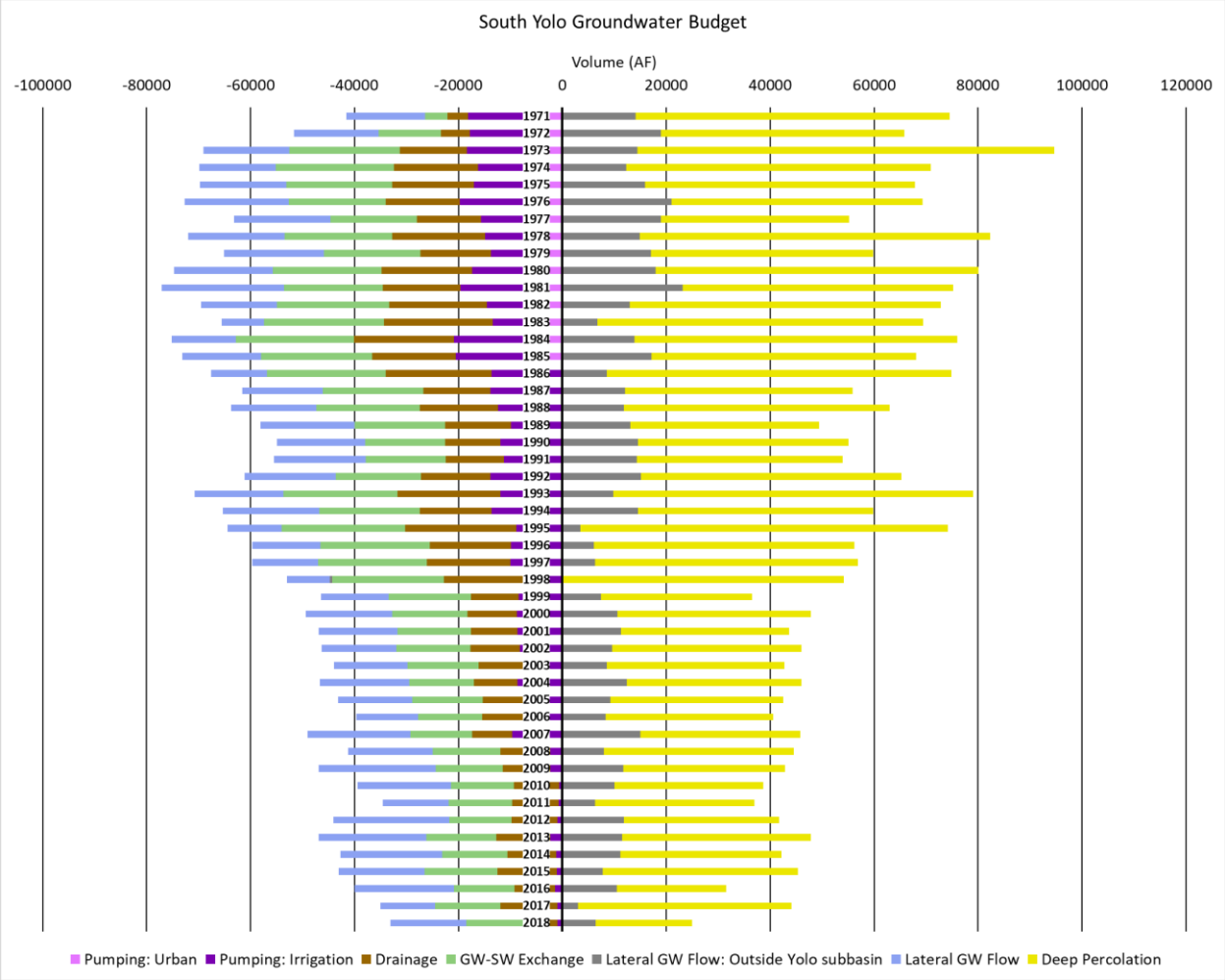


Figure 33 Annual Groundwater Budget: South Yolo MA



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Yolo Subbasin Groundwater Agency

2022 Groundwater Sustainability Plan

APPENDIX D:

Yolo SGA Model Documentation

Appendix

Yolo SGA Model Documentation

DRAFT

Draft Nov, 20, 2020

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1 Overview of the Yolo SGA Model

The Yolo Sustainable Groundwater Agency model (YSGA model) is a linked surface water-ground water model developed using Water Evaluation and Planning (WEAP)[1] and MODFLOW[2]. WEAP (Yates et al., 2005a, 2005b) is an integrated surface water – groundwater modeling tool, which integrates rainfall-runoff hydrology, reservoir operation, water demands from cities and crops, and allocations of water to those demands from surface and groundwater supplies. The WEAP model used in the YSGA model builds on several years of development of the Cache Creek system at the Yolo county scale (Mehta et al., 2018, 2011; Winter et al., 2017).

MODFLOW is a finite-difference groundwater modeling tool developed by the USGS (Harbaugh, 2005). In the YSGA model, MODFLOW simulates the groundwater budget of the Yolo basin's 3-layer aquifer. The MODFLOW model was built using the inputs, aquifer parameters, boundary conditions and aquifer representation from a Yolo county IWFM model (Flores Arenas, 2016) which in turn was informed by a IGSM model of Yolo County (WRIME, 2006).

1.1 Temporal Scope

SGMA regulations require that annual water budgets are based on three different periods: a ten-year historic period, the 'current' year, and a 50-year projected period. The current water year is defined in the GSP Emergency Regulations (§354.18(c)(1)) as the year with "the most recent population, land use, and hydrologic conditions".

1.1.1 Historical and Current Period

The YSGA model runs at a monthly time step. The historical to current period covers 48 years, from Water Year (WY) 1971 to WY 2018. Although GSP regulations require a minimum 10 year period for historical water budgets, we leveraged earlier work that modeled a substantially longer period (WY 1971-WY 2005 (Mehta et al., 2013), and WY 1971-2008 (Mehta et al., 2018). These 48 years cover a large spread of water year types, significant and contiguous drought periods (WY 1976-WY 1977, WY 1987-WY 1992, WY 2007-2009 and WY 2012-WY2016), and significant and contiguous wet periods of note (WY 1971-WY 1975, WY 1982-1984, WY 1995-WY 2000 and WY 2005-WY 2006). The Water Year Index (Sacramento Valley) and the Water Year Types for the historical to current water year type are listed in Table 1-1. Water Year 2018 – the last year of the model run in the historical period – is treated as the current period. This is the most recent year for which almost all datasets are available. Climate and water rights data are updated to WY 2018 in the YSGA model. Landuse data, however, is only available to 2016 (the LandIQ dataset provided by the SGMA data portal[3]). Hence 2016 Landuse data is used and kept constant through 2018.

[1] See https://www.weap21.org/ for more information.
[2] See https://water.usgs.gov/ogw/modflow/ for more information.
[3] See https://sgma.water.ca.gov/webgis/?appid=SGMADataViewer#waterbudget; Accessed 8.31.2018

Table 1-1. Sacramento River Water Year Index and Water Year Types, C = Critical, D = Dry, BN = Below Normal, AN = Above Normal, W = Wet.

Water Year	Water Year Index	Water Year Type	Water Year	Water Year Index	Water Year Type
1971	10.37	W	1995	12.89	W
1972	7.29	BN	1996	10.26	W
1973	8.58	AN	1997	10.82	W
1974	12.99	W	1998	13.31	W
1975	9.35	W	1999	9.8	W
1976	5.29	C	2000	8.94	AN
1977	3.11	C	2001	5.76	D
1978	8.65	AN	2002	6.35	D
1979	6.67	BN	2003	8.21	AN
1980	9.04	AN	2004	7.51	BN
1981	6.21	D	2005	8.49	AN
1982	12.76	W	2006	13.2	W
1983	15.29	W	2007	6.19	D
1984	10	W	2008	5.16	C
1985	6.47	D	2009	5.78	D
1986	9.96	W	2010	7.08	BN
1987	5.86	D	2011	10.54	W
1988	4.65	C	2012	6.89	BN
1989	6.13	D	2013	5.83	D
1990	4.81	C	2014	4.07	C
1991	4.21	C	2015	4	C
1992	4.06	C	2016	6.71	BN
1993	8.54	AN	2017	14.14	W
1994	5.02	C	2018	7.14	BN

1.1.2 Future period

Future projections use climate change projections provided by DWR on the SGMA data viewer[4] which is summarized here. Additional information is provided in later sections (Section 2.1.4). Climate projections in the YSGA model are based on climate change model runs centered around the mid-2030's period, and the mid- 2070's period. In the YSGA model, each future projection uses the final state of the historical model run as the initial state of the future run. In other words, each climate projection in the model is investigating the outcome of that corresponding projection's climate occurring from WY 2019 onwards, for the next 48 years. For example, the future projection that uses the central tendency of the climate change models around the 2030's, investigates the outcome of that climate occurring from WY 2019 – WY 2056.

[4] SEE https://sgma.water.ca.gov/webgis/?appid=SGMADataViewer#waterbudget Accessed 8.31.2020

1.2 Spatial Scope

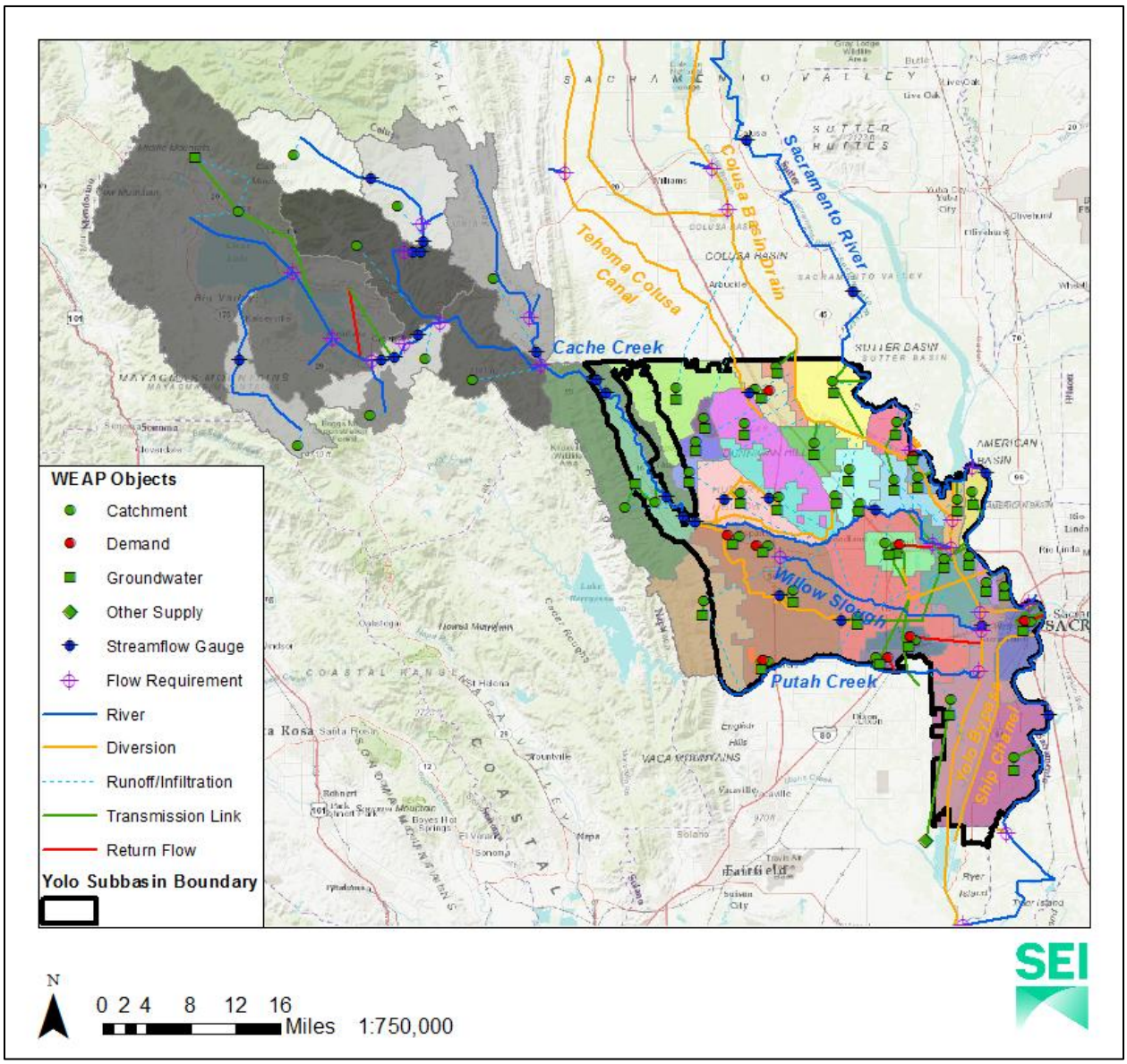
The spatial scope of the YSGA model is shown in Figure 1-1 and Figure 1-2. Figure 1-1 shows that the YSGA model's land surface water budget explicitly includes not just the YSGA basin boundary, but also the upstream Cache Creek watershed (including Clear Lake and Indian Valley reservoir). That is, the hydrology and operations of the Cache Creek watershed are simulated. Other important surface water inflows and boundaries are represented as input data, such as the Tehama Colusa Canal and Colusa Basin Drain, and stream flows (Sacramento River and Putah Creek).

Figure 1-2 shows a closer view of the Yolo basin disaggregation into catchments in the YSGA model, with the MODFLOW computational grid overlaid. Surface water diversions, recharge, and groundwater pumping were simulated at the scale of the catchments shown in Figure 1-2. These boundaries mostly represent water district, urban, or hydrogeologic boundaries. Regions outside of water districts and urban areas are considered "white areas" that fall under County jurisdiction for purposes of SGMA. The MODFLOW grid covers only those parts of the Yolo basin boundary in which the groundwater aquifer exists, as represented in the IWFM model that it is derived from. For purposes of calculating water budgets, the individual catchments have been grouped into Management Areas, as shown in Black boundary represents the official Basin boundary. The MODFLOW grid, which represents the modeled alluvial aquifer, is shown in grey. Colored polygons are the model catchments. Model catchments, for which the land surface water budgets are computed, extend beyond the alluvial aquifer, as is most obvious in western Yolo County (hills in Capay, west of Winters, and west of Buckeye Creek).

Figure 1-3 and **Error! Reference source not found.**.

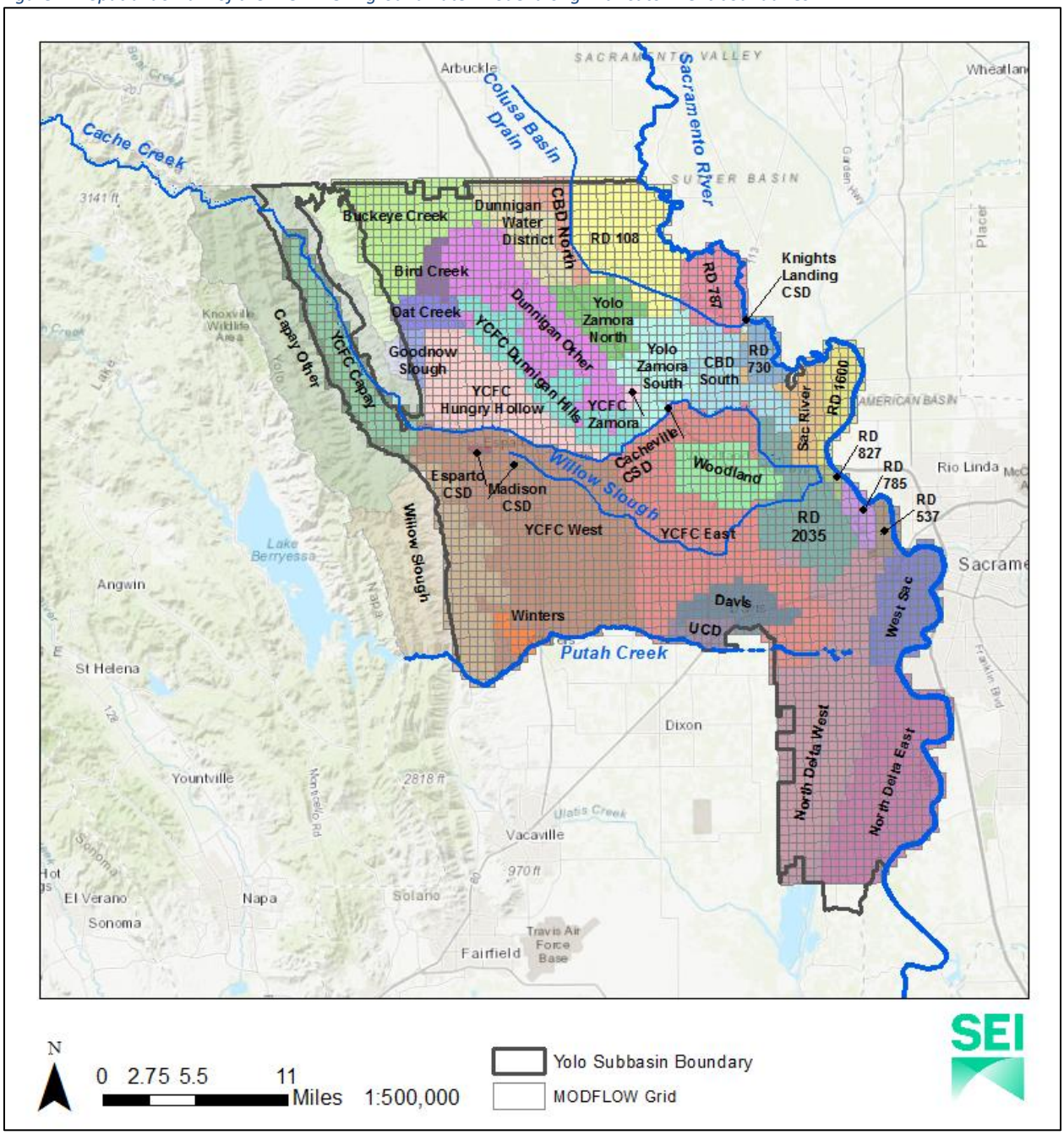
Data sources used to characterize the hydrology, agriculture, and urban water use are summarized in Section 1.4.

Figure 1-1. Spatial domain of the Land Surface Budget



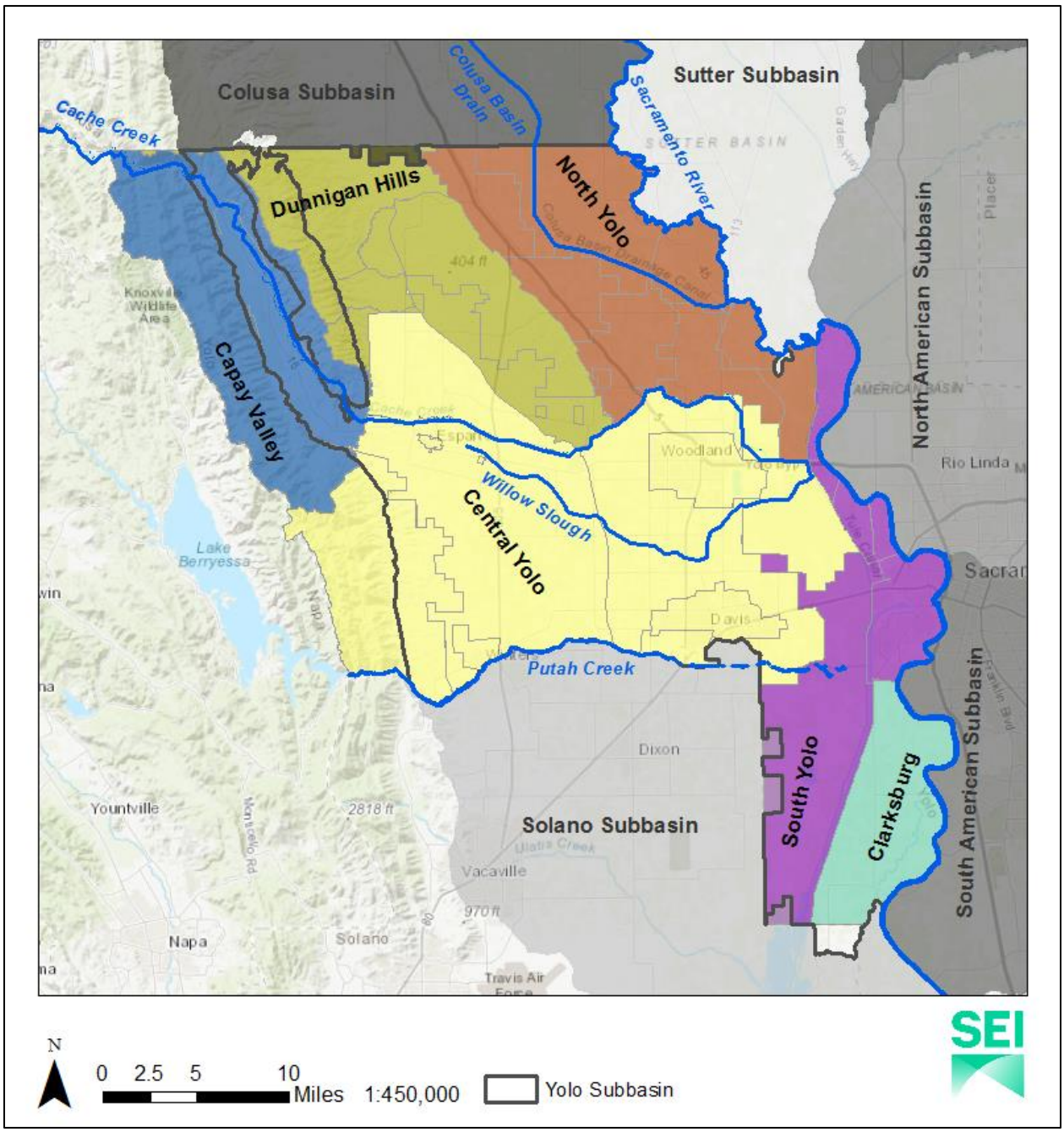
Catchments within Yolo County are shown as colored polygons, and catchments upstream of Capay Valley in the Cache Creek Watershed are shown in shades of grey. See the following figure for each catchment labeled by name. WEAP objects used to develop the WEAP schematic are also shown.

Figure 1-2 Spatial domain of the MODFLOW groundwater model along with catchment boundaries.



Black boundary represents the official Basin boundary. The MODFLOW grid, which represents the modeled alluvial aquifer, is shown in grey. Colored polygons are the model catchments. Model catchments, for which the land surface water budgets are computed, extend beyond the alluvial aquifer, as is most obvious in western Yolo County (hills in Capay, west of Winters, and west of Buckeye Creek).

Figure 1-3 Management Areas in the Yolo Basin and Neighboring Subbasins



The colored polygons show the model boundaries used to aggregate the land surface water budget for corresponding Management Areas. Entity boundaries are shown in light gray within the management areas. The Yolo Subbasin is outlined in thick gray lines. Neighboring basins are shaded in grays. Major surface water bodies are labeled for reference. Official Management Area boundaries in this figure correspond to the intersection of the Yolo Basin boundary with the colored polygons.

Table 2 Subdivisions of the YSGA model

Modeled Area name	Entity name/White Area name	Area (ac)
Entire Modeled Area	Yolo County and Cache Creek watershed in Lake County	1,197,657
Yolo County		639,089
Capay Valley Management Area		85,515
Capay Other	White Area, small towns	67,097
YCFC Capay	YCFC, Yocha Dehe Wintun Nation, Small towns	18,418
Central Yolo Management Area		242,680
Davis catch	Davis	8,688
Esparto CSD catch	Esparto CSD	446
Madison CSD catch	Madison CSD	68
RD 2035	RD 2035	20,375
UCD catch	UCD	3,701
Willow Slough	White Area	44,339
Winters catch	Winters	2,053
Woodland catch	Woodland	12,701
YCFC East	YCFC	55,340
YCFC Hungry Hollow	YCFC	23,872
YCFC West	YCFC	71,097
Clarksburg Management Area		36,500
North Delta East	RD 150, RD 307, RD 765, Most of RD 999	36,500
Dunnigan Hills Management Area		92,345
Bird Creek	White Area	3,467
Buckeye Creek	White Area	34,409
Dunnigan Other	Cal Am Water Dunnigan, White Area	28,916
Goodnow Slough	White Area	4,083
Oat Creek	White Area	4,742
YCFC Dunnigan Hills	YCFC	16,728
North Yolo Management Area		103,770
Cacheville CSD catch	Cacheville CSD	98
CBD North	White Area	5,119
CBD South	White Area	12,177
Dunnigan Water District	Dunnigan Water District	11,597
Knights Landing CSD catch	Knights Landing CSD	162
RD 108	RD 108	25,075
RD 730	RD 730	4,829
RD 787	RD 787	10,286
Sac River	White Area	7,833
YCFC Zamora	YCFC	669
Yolo Zamora North	White Area	10,581

Modeled Area name	Entity name/White Area name	Area (ac)
Yolo Zamora South	White Area	15,344
South Yolo Management Area		78,279
North Delta West	Parts of 2068, White Area	49,635
RD 1600	RD 1600	7,056
RD 537	RD 537	2,455
RD 785	RD 785	3,226
RD 827	RD 827	1,189
West Sac catch	West Sac, RD 900	14,718
Cache Creek Watershed		558,568
Bear Creek		66,247
Copsey Creek		20,384
Clear Lake		244,881
Kelsey Creek		26,165
Lower Indian Valley		66,445
Middle Indian Valley		36,751
Seigler Canyon		13,791
Upper Indian Valley		38,538
Upper Cache Creek		45,368
Yolo Subbasin		559,840
Yolo Subbasin (Official)		540,400

The WEAP portion of the YSGA model, which represents the land surface system and hydrology, covers 1,197,657 acres (**Error! Reference source not found.**). This includes all of Yolo County (639,089 acres in t he WEAP portion of the model) and the Cache Creek system in Lake County (558,568 acres).

The MODFLOW portion of the YSGA model covers 559,840 acres (**Error! Reference source not found.**). D ue to the resolution and spatial extent of the MODFLOW model (as mentioned earlier, derived from the IWFM model), and the pre-existing WEAP model which covers the entire county, there are small differences between the official Basin boundary (540,400 acres) and the YSGA's MODFLOW groundwater model boundary (Table 1-3). Figure 1-4 below shows these differences, and Table 1-3 explains them. The total area of these differences is very small (19,440 acres, less than 3% of the Yolo subbasin), and will not affect the model estimates significantly.

Figure 1-4 Differences between model domain and GSA/management area boundaries

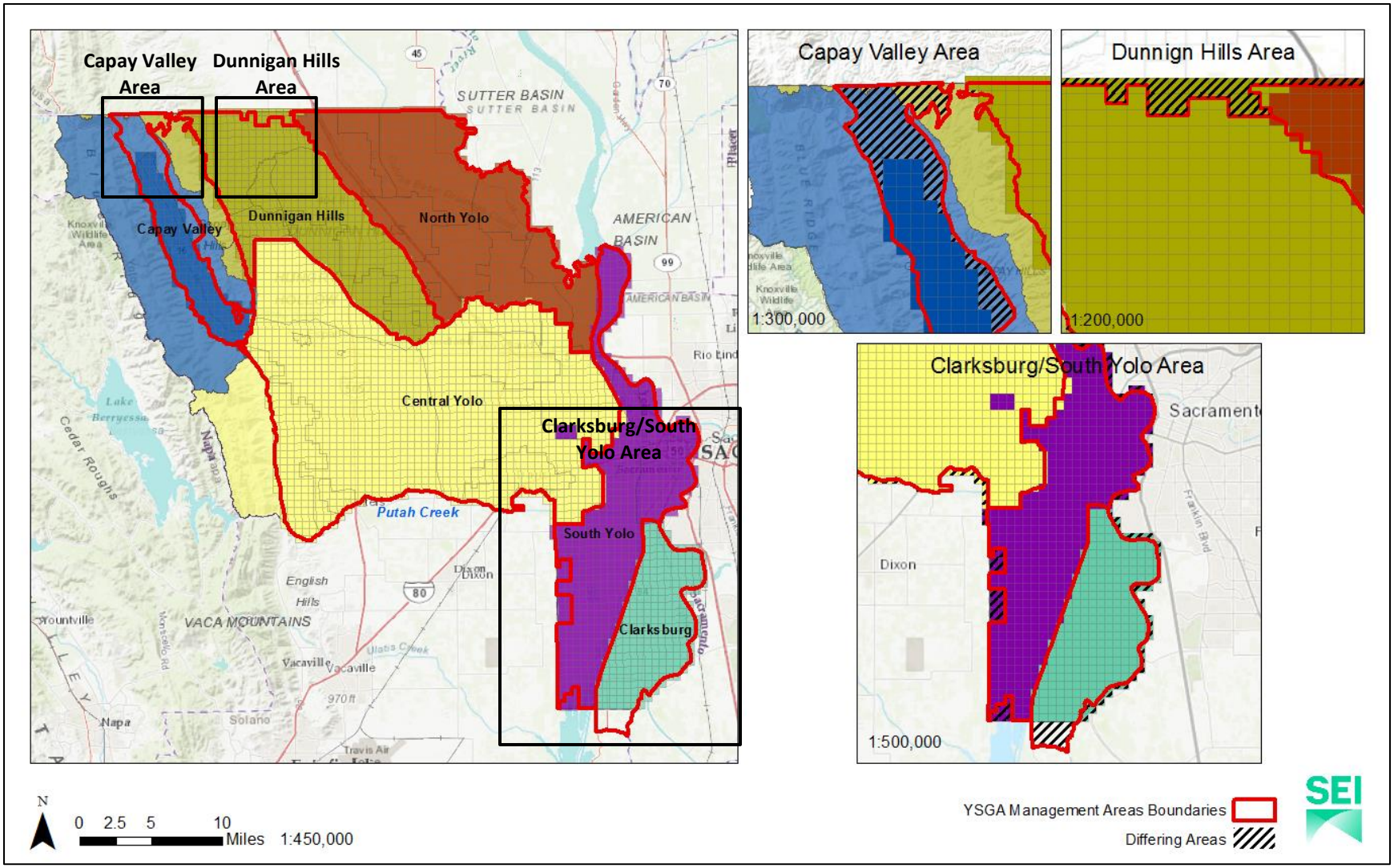


Table 1-3. Model domain difference from Yolo basin boundary

Region	Description	Status
Dunnigan Hills Area	Northern boundary of basin and county	This region is within the model domain because it is within Yolo County; but not included in the Yolo basin boundary.
Clarksburg/ South Yolo Area	Southern tip of Clarksburg Management Area	This region is included in the Yolo basin boundary, but it not included within the model because of data challenges related with the area being outside of the county.
Clarksburg/ South Yolo Area	Small cut outs in South Yolo Management Area	This region is included in the model because it is in Yolo County but not included in the Yolo subbasin.
Capay Valley Area	Uppermost, hilly portion of Capay bordering Buckeye creek headwaters	This portion is included in the model's land surface budget, but the MODFLOW grid and associated information shows that the alluvial aquifer does not extend into the hills; hence it is not included in the MODFLOW model however recharge from this region does enter the groundwater model (Also see Figure 2)

1.2.1 Upper Cache Creek Watershed Representation

The surface hydrology and reservoir operations of the entire Cache Creek watershed above the Yolo sub-basin is represented in the YSGA model because Indian Valley Reservoir and Clear Lake provide substantial surface water for irrigation in the Yolo sub-basin. Groundwater in this area upstream of the Yolo sub-basin in Lake County is not modeled with MODFLOW. Instead is represented using a lumped parameter model described below. The upper watershed is divided into 9 catchments (Figure 1-5). Catchment boundaries are an aggregated version of the HUC-12 watersheds layer. This aggregation was based on climate considerations, the locations of major infrastructure (reservoirs), in-stream flow requirements, and flow gauges. This portion of the model remains largely unchanged from the previously developed WEAP model, except for extending the input climate datasets (Mehta et al., 2013). Just as in the catchments that are within the Yolo sub-basin downstream, upstream climate and land-cover information is used to simulate rainfall-runoff, evapotranspiration and water demands. These catchments' water balance is calculated at a monthly time step using WEAP's soil moisture method (SMM). Runoff, interflow and baseflow from these catchments combine to simulate streamflow in Cache Creek, the North Fork of Cache Creek, Copsey Creek, Bear Creek and Kelsey Creek. The reason for the difference in algorithms between upstream and valley water balances is that the SMM model is better suited for simulating regions dominated by natural hydrology, while the MABIA module is better suited for simulation of irrigated agriculture. Details of these calculations are given in Section 1.3. Soil water parameters in these catchments were adjusted during calibration of streamflow using observations at three gauge locations from 1971 to 2000. Streamflow calibration is described in more detail in section **Error! Reference source not found.**.

Clear Lake and Indian Valley reservoirs and their operations are simulated based on the Gopcevic Decree (for flood releases) and Solano Decree (for irrigation releases), providing water for irrigation to the Yolo

County Flood Control and Water Conservation District (YCFC) catchments within the county. A detailed explanation of the representation of these reservoir operations is provided in 2.1.5.7.1, where the representation of YCFC is explained in detail.

Demands in the upper Cache Creek watershed are as represented in the Central Valley Planning Area model used in the Department of Water Resources Water Plan Updates.

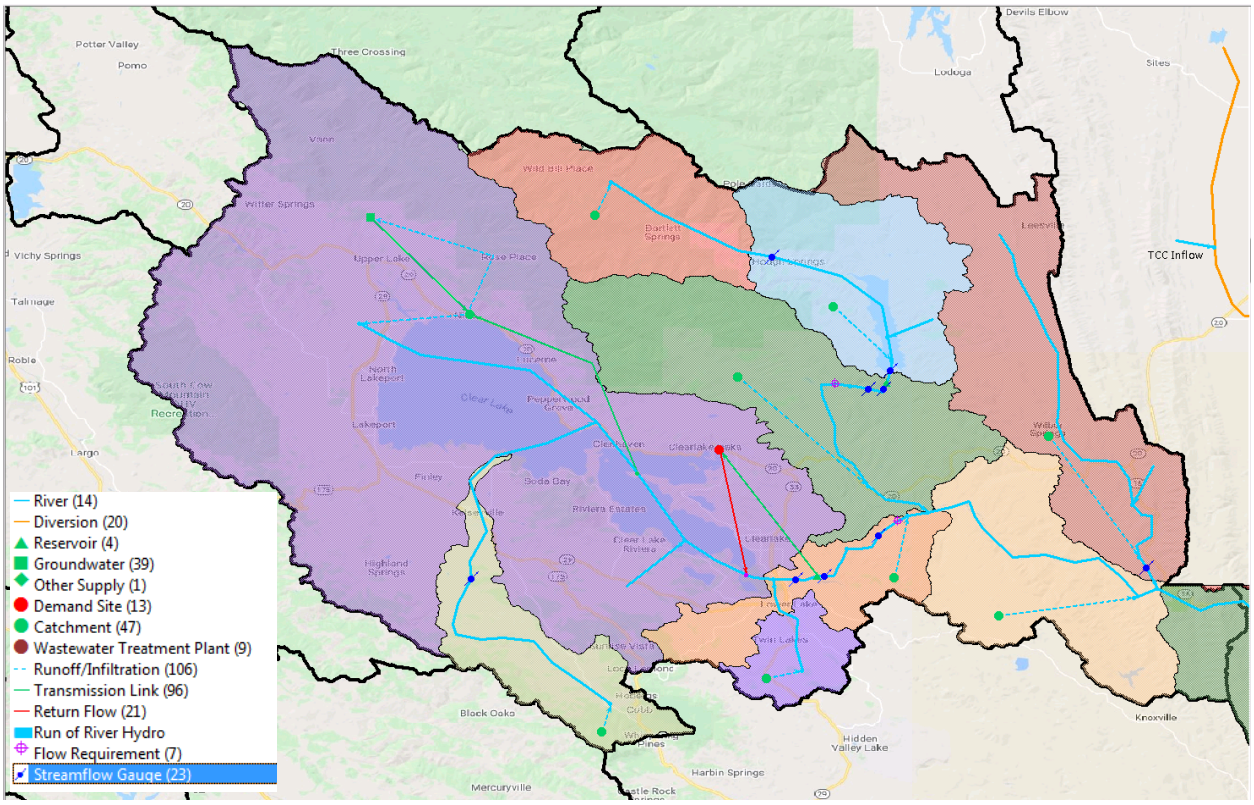


Figure 1-5. Representation of the Cache Creek watershed in the WEAP schematic view

1.2.2 Yolo County Representation

In Yolo County, the modeled area is divided into 38 catchments. These catchments represent the entities as well as parts of the landscape that are not covered by an entity's service area. **Error! R eference source not found.** Figure 1-2 shows the area that is represented by each catchment within WEAP, and its corresponding name. Catchment boundaries were developed using the water agency and urban boundaries, previously developed groundwater models' area boundaries and USGS Hydrologic Unit Code (HUC) 8[5] area boundaries. Some entity areas are divided into multiple catchments (e.g., YCFC), and some are fully contained in only one catchment.

The surface water balance of the 38 catchments within the county is calculated on a daily time step. This includes irrigation demand, evapotranspiration and runoff, using climate and land use data inputs to WEAP's MABIA method, as described in section 1.3.2. If irrigation occurs within the entity's boundary, the catchment is connected to at least one water source by a transmission link (green line) which delivers water from the source to the catchment. If irrigation water is available, the irrigation demand is

[5] See https://water.usgs.gov/GIS/huc.html for more information on the USGS hydrologic unit divisions of the U.S.

met up to the limit of available water, either from surface water or groundwater. Surface water is limited by water rights, canal constraints, and water availability. In most catchments, groundwater is not limited.

All catchments are connected to a groundwater node and surface water body by a runoff/infiltration link (blue dotted line) to allow for runoff and infiltration to flow from the catchment area to the receiving water bodies. Some catchments provide runoff to more than one surface water body because the catchment area overlies two watersheds (Table 1-4).

The County area of the model contains 37 groundwater objects (green squares) which represent the area of the underlying aquifer within the associated catchment. The boundaries of the groundwater objects in the model are the same as the boundaries of the catchments for all catchments except Capay Other and YCFC Capay, and catchments that do not entirely fall within the groundwater basin. Given the idiosyncrasies of how WEAP reports MODFLOW results, having the groundwater object boundaries follow the catchment boundaries simplifies groundwater budget reporting. In the Capay Valley, there is only one groundwater object which represents the aquifer underlying both catchments. The entirety of the County's sub basin is modeled within MODFLOW.

If an entity has water demands other than irrigation (for example, cities), the entity is also represented by a demand object (red dot, Figure 1-1), and often this is connected to a waste water treatment plant. The demand object is connected to at least one water supply to meet the corresponding demands. Entities that have access to both surface water and groundwater are set up such that they use surface water primarily, if it is available, and only use groundwater when there is not sufficient surface water to meet the demand.

Table 1-4. WEAP catchments and percentage of their area that runs off into the watersheds within Yolo County.

WEAP catchment Name	Water body	Percent of area's runoff contributing to water body	WEAP catchment Name	Water body	Percent of area's runoff contributing to water body
Bird Creek	Colusa Basin	100	RD 785	Bypass	100
Buckeye Creek	Colusa Basin	100	RD 787	Sac Riv	55
Cacheville CSD catch	Cache Creek	100	RD 787	Colusa Basin	45
Capay Other	Cache Creek	100	RD 827	Bypass	78
YCFC Capay	Cache Creek	100	RD 827	Willow Slough	22
CBD North	Colusa Basin	100	Sac River	Sac Riv	73
CBD South	Bypass	40	Sac River	Cache Creek	25
CBD South	Cache Creek	45	UCD catch	Putah Creek	100
CBD South	Colusa Basin	15	West Sac catch	Sac Riv	100
Davis catch	Bypass	100	Willow Slough	Putah Creek	48
Dunnigan Other	Colusa Basin	100	Willow Slough	Willow Slough	52
Dunnigan Water District	Colusa Basin	100	Winters catch	Putah Creek	100
Esparto CSD catch	Cache Creek	32	Woodland catch	Cache Creek	56
Esparto CSD catch	Willow Slough	68	Woodland catch	Willow Slough	44
Goodnow Slough	Cache Creek	85	YCFC Dunnigan Hills	Cache Creek	56
Goodnow Slough	Colusa Basin	15	YCFC Dunnigan Hills	Colusa Basin	44
Knights Landing catch	Sac Riv	100	YCFC East	Bypass	14
Madison CSD catch	Willow Slough	100	YCFC East	Cache Creek	21
North Delta East	Bypass	100	YCFC East	Putah Creek	16
North Delta West	Bypass	80	YCFC East	Willow Slough	49
North Delta West	Putah Creek	20	YCFC Hungry Hollow	Cache Creek	100
Oat Creek	Colusa Basin	100	YCFC West	Putah Creek	31
RD 108	Colusa Basin	74	YCFC West	Willow Slough	69
RD 108	Sac Riv	26	YCFC Zamora	Colusa Basin	100
RD 1600	Bypass	100	Yolo Zamora North	Colusa Basin	100
RD 2035	Bypass	37	Yolo Zamora South	Cache Creek	20
RD 2035	Cache Creek	22	Yolo Zamora South	Colusa Basin	80
RD 2035	Willow Slough	40			
RD 537	Bypass	100			
RD 730	Bypass	100			

1.3 Model Computation

This section summarizes the algorithms used for various modeling aspects in the YSGA model, with references to published literature for the detailed equations.

As mentioned in Section 1.1, the surface water budget (climate-driven hydrology and water allocation) is computed by WEAP's built-in routines, while the groundwater flow is computed by MODFLOW (Table 1-5).

Table 1-5 Computational aspects of model

YSGA Model regions	Algorithm within WEAP	Reference to algorithm details	Computation time step	Reporting time step
Watersheds in Lake county	Soil Moisture Model	(Yates, 1996; Yates et al., 2005a, 2005b)	Monthly	Monthly
Catchments within Yolo basin	MABIA	(Jabloun and Sahli, 2012)	Daily	Monthly
Valley floor	MODFLOW	(Harbaugh, 2005)	Sub-daily	Monthly

WEAP has several built-in soil moisture budget algorithms to choose from. WEAP uses a Linear Program solver to allocate water from one or more sources to one or more demands, at every time step, based on a user-defined assignment of supply preferences and demand priorities. The allocation is constrained by operations rules such as reservoir release rules, canal capacities, and diversion restrictions based on water rights. This allocation routine is the same irrespective of which soil moisture budget is chosen.

1.3.1 Soil Moisture Method (SMM)

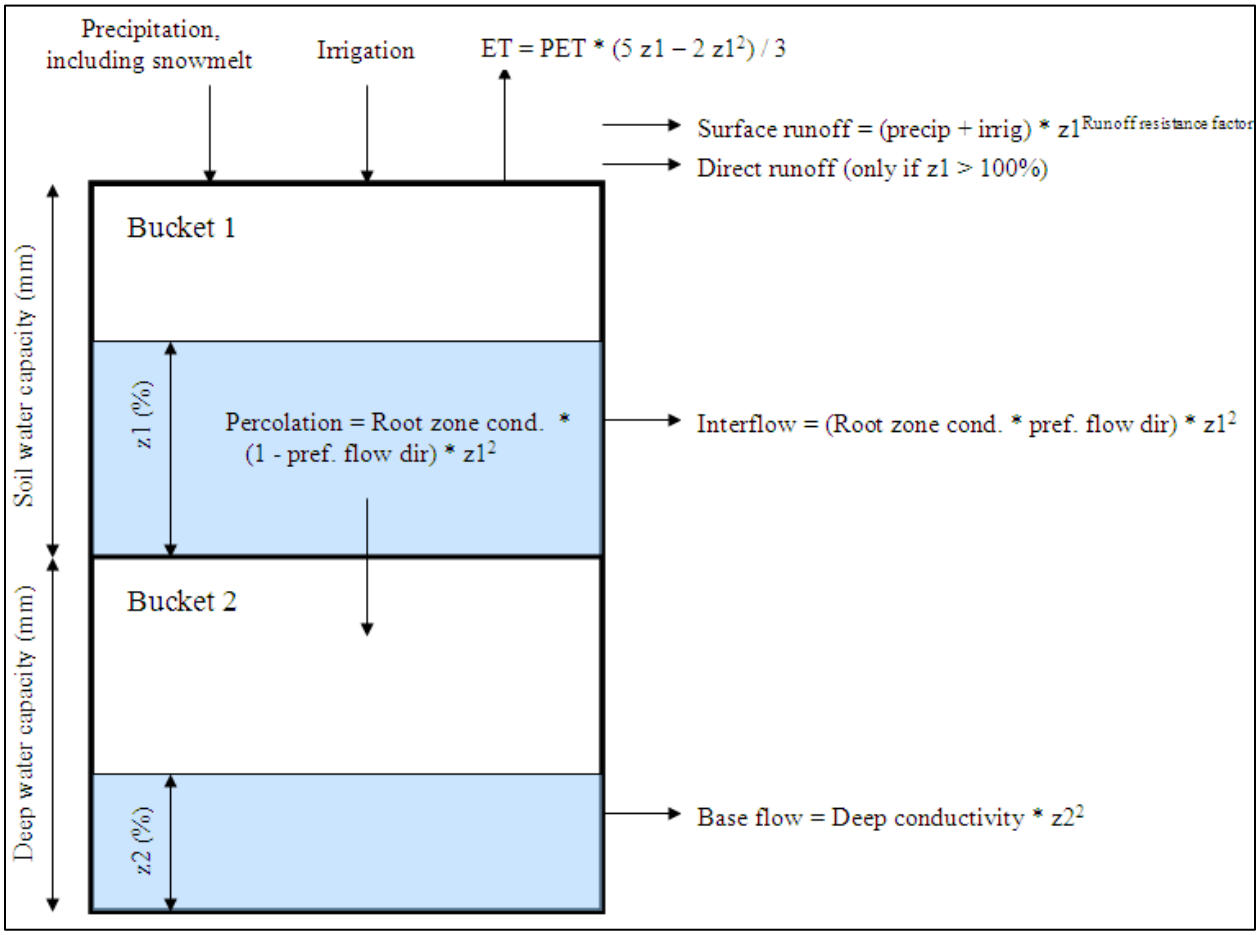
In the YSGA model, the upstream Clear Lake catchment's surface water budget, which is outside the MODFLOW model domain, is computed by WEAP's Soil Moisture Method (SMM) algorithm, at a monthly time step. The SMM equations are extensively described in Yates et al. (2005b) and online[6]. The root zone soil moisture balance is expressed as a one-dimensional differential equation which is solved at each time step (See Figure 1-6).

$$Rd_j \frac{dz_{1,j}}{dt} = P_e(t) - PET(t)k_{c,j}(t)\left(\frac{5z_{1,j} - 2z_{1,j}^2}{3}\right) - P_e(t)z_{1,j}^{RRF_j} - f_j k_{s,j} z_{1,j}^2 - (1 - f_j)k_{s,j} z_{1,j}^2 \qquad \text{Eq.1}$$

where $z_{1,j}$ ranges from 0.0 to 1.0 and is the relative storage given as a fraction of the total effective storage of bucket 1 (the root zone), Rd_j (mm) for land cover fraction, j. The effective precipitation, P_e, gets partitioned into the various outflows, ET (second term on right); Runoff (third term), interflow (fourth term) and deep percolation (5th term). In Eq 1., the calculation for the potential evapotranspiration, PET, is done using the Penman-Monteith equation modified for a standardized crop of grass, 0.12 m in height and with a surface resistance of 69 s/m. The $k_{c,j}$ is the crop/plant coefficient for each fractional land cover. The third term represents surface runoff, where RRF_j is the Runoff Resistance Factor of the land cover. Higher values of RRF_j lead to less surface runoff. The fourth and fifth terms are the interflow and deep percolation terms, respectively, where the parameter $k_{s,j}$ is an estimate of the root zone saturated conductivity (mm/time) and f_j is a partitioning coefficient related to soil, land cover type, and topography that fractionally partitions water both horizontally and vertically. In Figure 1-6, deep percolation feeds a second bucket which represents the aquifer. This bucket produces baseflow which is a function of a conductivity term and the relative storage in bucket 2.

[6] See https://www.weap21.org/WebHelp/Two-bucket_Method.htm#:~:text=The%20Soil%20Moisture%20Method%20calculates,water%20above%20ground%20to%20decrease. Accessed 8.31.2020.

Figure 1-6 Conceptual diagram of the Soil Moisture Method



1.3.2 MABIA Method

The MABIA Method is used in the YSGA model to simulate surface hydrology in the catchments overlying the MODFLOW groundwater model. MABIA is a daily simulation of transpiration, evaporation, irrigation requirements and scheduling, crop growth and yields. It was derived from the MABIA suite of software tools, developed at the Institut National Agronomique de Tunisie by Dr. Ali Sahli and Mohamed Jabloun. The algorithms and descriptions contained here are for the combined MABIA-WEAP calculation procedure. All the equations are described in (Jabloun and Sahli, 2012).

The MABIA Method uses the standard and well-known 'dual crop coefficient ' K_c method, as described in the classic FAO-56 article (Allen et al. 2005) whereby the K_c value is divided into a 'basal' crop coefficient, K_{cb}, and a separate component, K_e, representing evaporation from the bare soil surface. The basal crop coefficient represents actual ET conditions when the soil surface is dry but sufficient root zone moisture is present to support full transpiration.

In all catchments within the subbasin, irrigation demand and evapotranspiration from the land surface are calculated on a daily time step using the dual crop coefficient approach described in Food and

Agricultural Organization (FAO) Irrigation and Drainage Paper No. 56 (FAO 56)[7]. The method requires climate data inputs (described in section 2.1.2) to calculate a reference evapotranspiration using the Penman-Monteith Equation. Individual crops are assigned crop coefficients (described in section 2.1.3) that are used to scale the reference evapotranspiration to reflect crop planting dates, canopy development rates, and harvest dates. This approach is also used to simulate bare soil evaporation and water use by native vegetation.

MABIA estimates the soil moisture budget by estimating ET, surface runoff, infiltration, and deep percolation. It requires specification of soil parameters such as soil water capacity and soil depth. The Soil Conservation Service (SCS) curve number method is used in a modification to the MABIA method to calculate effective rainfall (NRCS, 1986; SCS, 1972). MABIA uses the reference evapotranspiration, crop specific parameters, and soil moisture status to calculate an irrigation demand for each crop type. In WEAP, these demands are met either by available surface and/or groundwater. Water availability is specific to the water rights and wells used by each entity, as described in section 2.1.5.1.

1.3.3 MODFLOW and WEAP-MODFLOW linkage

MODFLOW is a three-dimensional finite-difference groundwater modeling platform created by the U.S. Geological Survey (USGS). When linked, data and results flow back and forth between WEAP and MODFLOW for each WEAP calculation timestep. With this coupling between the models, it is possible to study how changes in management on the surface (recharge and pumping) affect the overall system (e.g., groundwater-stream interactions, drawdown, and lateral groundwater flows).

The versions of MODFLOW that can be linked to WEAP are MODFLOW 2000, MODFLOW 2005 and MODFLOW-NWT[8]. MODFLOW simulates steady and nonsteady flow in an irregularly shaped flow system in which aquifer layers can be confined, unconfined, or a combination of confined and unconfined. Flow from external stresses, such as flow to wells, areal recharge, evapotranspiration, flow to drains, and flow through riverbeds, can be simulated. Hydraulic conductivities or transmissivities for any layer may differ spatially and be anisotropic (restricted to having the principal directions aligned with the grid axes), and the storage coefficient may be heterogeneous. Specified head and specified flux boundaries can be simulated as can a head dependent flux across the model's outer boundary that allows water to be supplied to the boundary in the modeled area at a rate proportional to the head difference between a location outside the modeled area and the boundary cell.

The ground-water flow equation is solved using the finite-difference approximation. The flow region is subdivided into cells in which the medium properties are assumed to be uniform. In plan view, the cells are made from a grid of mutually perpendicular lines that may be variably spaced. Model layers can have varying thickness. A flow equation is written for each cell. Several solvers are provided for solving the resulting matrix problem; the user can choose the best solver for the particular problem. Flow-rate and cumulative-volume balances from each type of inflow and outflow are computed for each time step.

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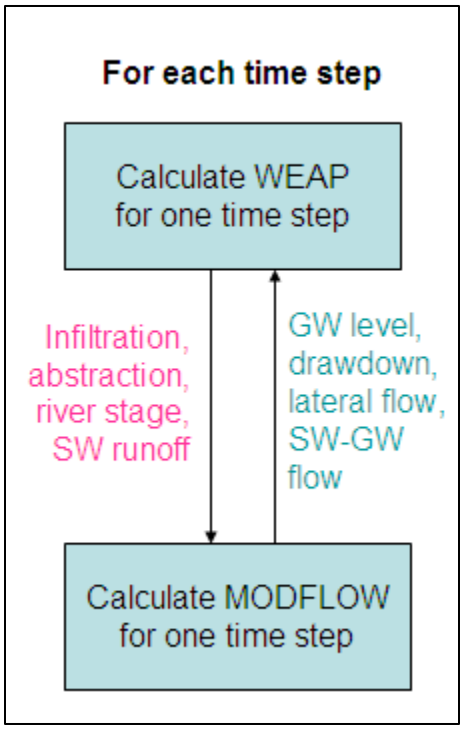
[7] http://www.fao.org/3/X0490E/X0490E00.htm

[8] See https://water.usgs.gov/ogw/modflow/modflow or http://water.usgs.gov/nrp/gwsoftware/modflow2000/modflow2000.html or http://en.wikipedia.org/wiki/MODFLOW

For more information about MODFLOW, see the USGS MODFLOW home page, Online Guide to MODFLOW, or the MODFLOW User Guide.

Figure 1-7 shows the linkage between MODFLOW and WEAP. At each WEAP time step, WEAP passes key fluxes it has computed (deep percolation, pumping demand, river stage) to MODFLOW, which then runs using a stress period the same length as the WEAP time step, and passes back to WEAP its calculation of the groundwater flux, stream seepage, drainage flows, and groundwater elevations.

Figure 1-7 WEAP-MODFLOW linkage



The MODFLOW model grid for the YSGA model is shown in Figure 1-2. Active cells correspond to those areas that have an underlying aquifer layer below the land surface. All model parameters were imported, as a starting point, from the IWFM model (Flores Arenas, 2016). Some parameters were adjusted during the calibration process, which is detailed in Section 3.2.

On the surface, the MABIA module of WEAP calculates evapotranspiration, irrigation demands, infiltration, and runoff at a daily timestep. The daily information is summed and passed as a monthly value for pumping and recharge to MODFLOW at the spatial scale of the catchment. Water availability from rivers, streamflows, flows in canals, and all other surface water related information is simulated at a monthly timestep using the water allocation routines in WEAP. Stream stage is passed to MODFLOW. MODFLOW calculates the groundwater balance, boundary flows, and resulting groundwater elevation and reports it back to WEAP on a monthly timestep.

1.4 Data Sources

This section summarizes the data sources used in the YSGA model for the historical period, and the main assumptions for both historical and future scenarios.

Table 1-6 Summary of data sources used in the YSGA model

Catego	Variable	Historical		Future Projections	
		Sources	**Model use**	**Sources**	**Model use**
Climate	Precipitation	PRISM[1]	Input data	Historical, modified by Climate Change factors provided by DWR	Input data
	ETo	CIMIS[2]	Calibration	Historical, modified by Climate Change factors provided by DWR	Input data
	Minimum Temperature	PRISM[1]	Input data	NA	
	Maximum Temperature	PRISM[1]	Input data	NA	
	Wind speed	(Livneh et al., 2013); CIMIS[2]	Input data	NA	
	Humidity	PRISM[1]	Input data	NA	
Land Use	Agricultural land use	DWR Land Use Surveys3; Yolo County Annual Agriculture Commissioner Reports; DWR SGMA Portal (LandIQ dataset)	Input data	Agricultural landuse kept constant to Current Year	Input data
	Non-agricultural land uses	DWR Land Use Surveys[3];	Input data	Growth projections from urban master plans[6]	Input data
Irrigatio	Schedule	Sacramento-San Joaquin basin Study[4] (Reclamation, 2015)	Input data	Same as historical	Input data

Catego	Variable	Historical		Future Projections	
		Sources	**Model use**	**Sources**	**Model use**
	Crop coefficients	Sacramento-San Joaquin basin Study[4] (Reclamation, 2015)	Input data; Calibration	Same as historical	Input data
	Irrigation efficiency	NA	Calibration	Same as historical	Input data
	Applied Water	DWR Applied Water Estimates[5], Groundwater management plans and personal communication[6]	Calibration	NA	Model output
	Water sources and supply	SWRCB eWRIMS water rights database[7], personal communication[6]	Input Data	Same as historical	Input Data
Urban	Water demand, including population	Urban water plans and personal communication[6]; CA Department of Finance Population data[8]	Input data	Growth projections from urban master plans[6]	Input data
	Water sources and supply	Urban water plans and personal communication[6]; SWRCB eWRIMS water rights database[7]	Input data (water rights)	Urban water plans[6]	Input data (water rights)
Hydrology	Stream flows	USGS[9]; CDEC[10]	Calibration	NA	Model output
	Stream flows	USGS9; CDEC[10]	Input Data	Same as historical	Input data
	Initial groundwater conditions	WRID[11]; SGMA[12]; IWFM model (Flores Arenas, 2016)	Input data	Historical model end-of simulation set as future model run initial conditions	Input data
			Input data,	NA	Input data

Catego	Variable	Historical		Future Projections	
		Sources	**Model use**	**Sources**	**Model use**
	Groundwater boundary conditions	IWFM model (Flores Arenas, 2016)	Calibration		
	Groundwater elevations (time series)	WRID[11]; SGMA[12]; WDL [13];	Calibration, Model output	NA	Model output
	Reservoir operations (storage levels, outflows)	CDEC[10]; Conversations with and data supplied by YCFC[6]	Calibration, Model output	NA	Model output
	In-stream flow requirements	CDEC[10]; Conversations with and data supplied by YCFC[6]	Input data	Same as historical	Input data

1 http://www.prism.oregonstate.edu/explorer/ Accessed 5.19.2019

2 https://cimis.water.ca.gov/Default.aspx . Accessed 5.19.2019

3 https://gis.water.ca.gov/app/CADWRLandUseViewer/ Accessed 9.1.2020

4 https://www.usbr.gov/watersmart/bsp/docs/finalreport/sacramento-sj/Sacramento_SanJoaquin_TechnicalReport.pdf Accessed 9.1.2020

5 https://water.ca.gov/Programs/Water-Use-And-Efficiency/Land-And-Water-Use/Agricultural-Land-And-Water-Use-Estimates Accessed 2.1.2019.

6 A complete list of entity-specific data sources and personal communication is provided in the Model Documentation Appendix, and in spreadsheet format to the YSGA

7 https://www.waterboards.ca.gov/waterrights/water_issues/programs/ewrims/

8 http://www.dof.ca.gov/Forecasting/Demographics/Estimates/

9 https://waterdata.usgs.gov/nwis/sw

10 https://cdec.water.ca.gov/

11 Yolo County Water Resources Information Database (https://wrid.facilitiesmap.com/Login.aspx)

12 SGMA Data Viewer https://sgma.water.ca.gov/webgis/?appid=SGMADataViewer#gwlevels

13 California Water Data Library https://wdl.water.ca.gov/GroundWaterLevel.aspx

2 Model Input Data

2.1 Surface Water Model Inputs

2.1.1 Land Use Data

Land use information for areas within Yolo County were gathered from several sources to create an annual time series of land use over the historical simulation period (WY 1971-WY 2018). In the Upper Cache Creek watersheds in Lake County it was assumed that recent land cover surveys represent conditions for the entire study period since much of the area is native vegetation.

2.1.1.1 Cache Creek Upper Watershed

In these catchments, land cover information is static and sourced from the National Landcover Data Set (NLCD)[9] for year 2001. The spatial data set was intersected with the catchment boundaries (Figure 1-5) to extract the area of each landcover type in each catchment. Table 2-1 shows the land use categories for these catchments and the corresponding descriptions from NLCD.

Table 2-1. Land Use categories for the Cache Creek Watershed catchments.

NLCD Code	*NLCD Name*	*WEAP Landuse Category*
11	Open Water	Water
21	Developed, Open Space	Developed, Open Space
22	Developed, Low Intensity	Developed, Low Intensity
23	Developed, Medium Intensity	Developed, Medium Intensity
24	Developed, High Intensity	Developed, High Intensity
31	Barren Land (Rock/Sand/Clay)	Barren
41	Deciduous Forest	Forest
42	Evergreen Forest	Forest
43	Mixed Forest	Forest
52	Shrub/Scrub	Forest
71	Grassland/Herbaceous	Grassland
81	Pasture/Hay	Pasture
82	Cultivated Crops	Cultivated
90	Woody Wetlands	Water

[9] https://www.mrlc.gov/data

95	Emergent Herbaceous Wetlands	Water

2.1.1.2 Yolo County Catchments

Within Yolo County, several data sources were used to assemble a time series of agricultural and non-agricultural land use for each catchment. Table 2-2 summarizes the different datasets used for different time periods. Figure 2-1 provides a visual narrative of data used for each catchment.

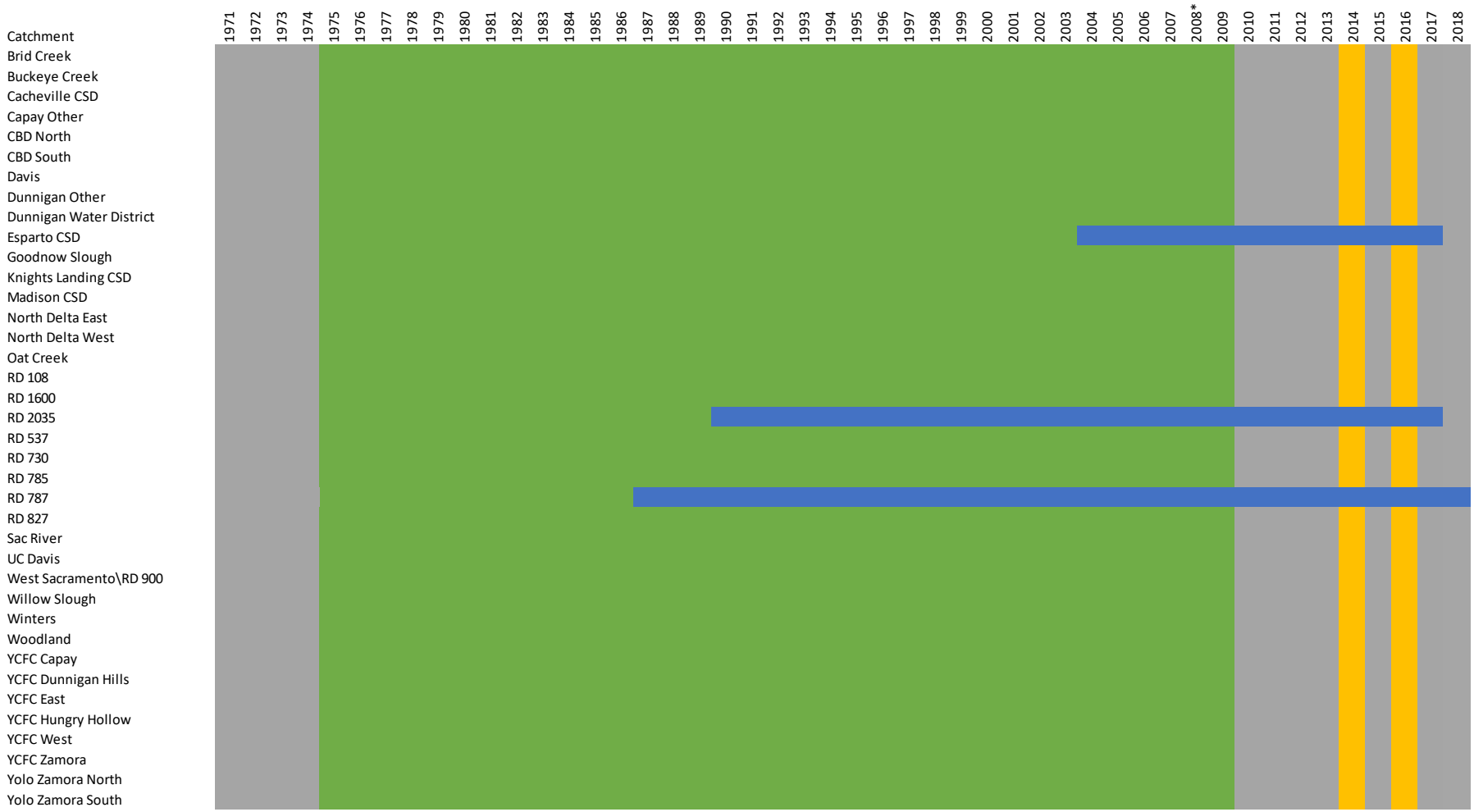
For the period 1975 – 2008, for most of the catchments, the area of each crop category in each catchment was calculated using a combination of (non-spatial) annual Agricultural Commissioner's reports[10] and (spatial) DWR Land Use surveys that were available from 1989, 1996, 2008, 2014 and 2016 (Table 2-2). The spatial distribution of each crop's total acreage (from the Crop Reports) was determined by the DWR Landuse Surveys - available for the years 1989, 1997, 2008, 2014, 2016. Between these years (and before 1981), the spatial distribution is assumed to be constant. Since the total annual irrigated acreage varies every year, the acreage of each crop in each catchment also varies every year. Some exception were:

- Some entities collect their own crop coverage data and these were used (Figure 2-1)
- In some cases, the interpolations led to fractional areas less than one acre which were not considered realistic. In those cases, professional judgement was used to make a decision based on a combination of satellite imagery investigations and meetings with Max Stevenson of YCFC.
- Of particular concern was determining irrigated pastures vs not irrigated (especially in Bear Creek, Oat Creek, and Buckeye Creek), and ensuring orchards were being introduced in the correct areas at the correct times, between the gaps in the spatial datasets. Mr. Stevenson, as Assistant General Manager with YCFC is well informed on the land use around the county.

For the 1971-1975 period, total acreage of crops from a 1976 study (Clendenen & Associates, 1976) was used, after finding unexplainable differences between the Agricultural Commissioner's Report and the acreages reported in this study.

After 2008, the Agricultural Commissioner's Crop Reports were not used for total acreage because of several discrepancies that were discussed in a meeting between the model development team and the Deputy Agricultural Commissioner in Woodland. Instead, the spatial datasets of DWR Land Use Surveys from 2014 and 2016 were used (Table 2-2).

[10] http://www.yolocounty.org/general-government/general-government-departments/agriculture-cooperative-extension/agriculture-and-weights-measures/crop-statistic



[1] Land use data were provided by the district but not sufficient to use

Land use data generated using DWR spatial data and Ag Comissioner Reports

Land use data generated using Land IQ dataset available on SGMA data portal

Land use data provided by the entity

Land use data held constant from the closest year with data

This does not take into account areas that were changed due to input from Max Stevenson, which should be added later.

*In years 2008 onward, modifications were made for new almond orchards: if almond area drastically increased, the new area was considered "young almonds" for the three years before being classified as "almond"

Figure 2-1. Graph showing the data sources used to develop timeseries of annual land use for each entity.

Table 2-2. Explanation of land use data sources for all catchments that did not supply their own data (all except Dunnigan Water District, RD 2035 and RD 787).

Year	Land use data source
1971-1974	Assumed same as 1975 data reported in (Clendenen & Associates, 1976)
1975-1989	Annual Yolo County Agricultural Commissioner's Crop Reports +1989 DWR Land Use Survey: spatial dataset
1990-1997	Annual Yolo County Agricultural Commissioner's Crop Reports + 1997 DWR Land Use Survey: spatial dataset
1998-2009	Annual Yolo County Agricultural Commissioner's Crop Reports + 2008 DWR Land Use Survey: spatial dataset
2010-2013	Held constant from 2009, except where young almonds switches to almonds after 3 years
2014	DWR Land Use Survey based on Land IQ dataset from DWR SGMA Data Viewer: spatial dataset
2015	Held constant from 2014 except where young almonds switches to almonds after 3 years
2016	DWR Land Use Survey based on Land IQ dataset from DWR SGMA Data Viewer: spatial dataset
2017	Same as 2016 except where young almonds switches to almonds after 3 years
2018	Same as 2017 except where young almonds switches to almonds after 3 years

2.1.1.3 Non-agricultural land use

Non-agricultural land use areas in the model within Yolo County are categorized into urban, water and native vegetation These were calculated from DWR Land Use Surveys[11] for years 1989, 1997 and 2008 (Table 2-3). This is a spatial dataset, which was intersected with each catchment to calculate the area of each land use category in each catchment. Prior to 1989 and after 2008 these values were held constant. In RD 2035, an additional non-agricultural land use category called managed wetlands was created. In these areas, the evapotranspiration is modeled the same as native vegetation, however, the area is flooded 12 inches deep between December and August each year(personal communication, Darren Cordova, MBK Engineering Add Date).

[11] https://water.ca.gov/Programs/Water-Use-And-Efficiency/Land-And-Water-Use

Table 2-3. Non agricultural land use classes included in the Yolo County catchments

WEAP Category	Description	DWR Definition	DWR Landuse Codes
Native Vegetation	The area remaining as the difference between the sum of all other agricultural and non-agricultural classes, and the total catchment area.	N\A	N\A
Urban	All Urban Classes in the DWR spatial datasets	Urban, Urban residential, Commercial, Industrial, Urban landscape, Vacant	U, UR, UC, UI, UL, UV
Water	Water surface	Water surface	NW

Evapotranspiration, rainfall, runoff, and soil moisture are calculated in these non-agricultural areas with the MABIA method the same way they are calculated in the agricultural land. These areas are not irrigated in the model.

2.1.2 Climate Data

The main source of historical climate data was the PRISM dataset (PRISM Climate Group, 2004) (http://www.prism.oregonstate.edu/explorer/ , downloaded on 5/19/2019). Temperature, precipitation and dew point temperature data are available as gridded monthly and daily datasets from 1982 onwards, at 4km resolution. Relative humidity was calculated from dewpoint temperature using Equation 3.1 and from vapor pressure deficit using Equation 3.2.

$$RH = \frac{e_a}{e_s} * 100 \tag{3.1}$$

where:

e_a (P_a) = vapor pressure at dew point temperature T(C) = $0.6108^{17.27T_{dew}/(T_{dew}+237.3)}$

e_s = saturation vapor pressure at ambient temperature T(C) =$0.6108^{17.27T/(T+237.3)}$

$$Rh = 100 - \left(100 * \frac{VPD}{SVP}\right) \tag{3.2}$$

where:

VPD = average vapor pressure deficit

SVP = saturation vapor pressure at ambient temperature T(C) =$0.6108^{17.27T/(T+237.3)}$

Data were averaged over the area of each catchment to develop a single time series of climate data per catchment. For the timeframe when PRISM data are not available (before 1982), or when a variable is not available in PRISM (wind speed), other datasets were use. These are summarized in Table 2-4**Error! Reference source not found.**.

Table 2-4. Climate Data Sources

Variable	Sources
Precipitation	PRISM (1982-2018) (Livneh et al., 2013) (Pre-1982)
ETo	CIMIS[12]
Minimum Temperature	PRISM(1982-2018) (Livneh et al., 2013) (Pre-1982)
Maximum Temperature	PRISM (1982-2018) (Livneh et al., 2013) (Pre-1982)
Wind speed	(Livneh et al., 2013); Upto 2011 CIMIS (2012-2018)
Dew point/vapor pressure	PRISM (1982-2018) (Livneh et al., 2013) (Pre-1982)

2.1.3 Crops

Eighteen irrigated crop categories are represented in the Yolo County catchments (Table 2-5). These categories are nearly identical to those in the DWR Agricultural Land and Water use estimates[13], facilitating calibration of modeled applied water and evapotranspiration to estimates provided by DWR.

[12] https://cimis.water.ca.gov/Default.aspx . Accessed 5.19.2019

[13] https://water.ca.gov/Programs/Water-Use-And-Efficiency/Land-And-Water-Use/Agricultural-Land-And-Water-Use-Estimates

DWR Category	DWR Crop Definition	DWR Landuse Codes[7]	WEAP category	MABIA crop
Grain	Wheat, barley, oats, miscellaneous grain and hay, and mixed grain and hay	G	Grain	Winter Wheat
Rice	Rice and wild rice	R	Rice	Rice[5]
Cotton	Cotton	F1	Cotton	Cotton
SgrBeet	Sugar beets	F5	Sugar beet	Sugar Beets
Corn	Corn (field and sweet)	F6	Corn	Corn
DryBean	Beans (dry)	F10	Dry Beans	Dry Beans
Safflwr	Safflower	F2	Safflower	Safflower
Oth Fld	Flax, hops, grain sorghum, sudan, castor beans, miscellaneous fields, sunflowers, hybrid sorghum/sudan, millet and sugar cane	F (all other)	Other field	Sunflower[3]
Alfalfa	Alfalfa and alfalfa mixtures	P1	Alfalfa	Alfalfa
Pasture	Clover, mixed pasture, native pastures, induced high water table native pasture, miscellaneous grasses, turf farms, bermuda grass, rye grass and klein grass	P (all other)	Pasture	Irrigated Pasture
Pro Tom	Tomatoes for processing	T15	Tomatoes	Tomatoes
Fr Tom	Tomatoes for market	T26		
Cucurb	Melons, squash and cucumbers	T9	Cucurbits	Squash[1]
On Gar	Onions and garlic	T10	Other truck	Asparagus[4]
Potato	Potatoes	T12		
Oth Trk	Artichokes, asparagus, beans (green), carrots, celery, lettuce, peas, spinach, flowers nursery and tree farms, bush berries, strawberries, peppers, broccoli, cabbage, cauliflower and brussel sprouts	T (all other)		
Al Pist	Almonds and pistachios	D12	Young Almonds [8]	Young Almonds
			Almonds	Almonds
Oth Dec	Apples, apricots, cherries, peaches, nectarines, pears, plums, prunes, figs, walnuts and miscellaneous deciduous	D (all other)	Other Deciduous	Walnuts[2]
Subtrop	Grapefruit, lemons, oranges, dates, avocados, olives, kiwis, jojoba, eucalyptus and miscellaneous subtropical fruit	C	Subtropical	Olives[6]
Vine	Table grapes, wine grapes and raisin grapes	V	Vine	Vines

[1] Based on Yolo County crop reports, melons, squash, and watermelons are grown in the area. Watermelons likely cover the largest area, but good cost and return data do not exist, which was required for economic modeling that will be conducted with this hydrologic model.

[2] Most common deciduous tree grown in Yolo County after almonds

[3] Most common field crop grown in Yolo County, after crops with their own categories

[4] Based on Yolo County crop reports, asparagus, broccoli, lettuce, cucumber, strawberries, are all grown in Yolo, but for purposes of economic modeling, cost studies on asparagus are most relevant for Yolo County.

[5] Rice flooding for decomposition is modeled in all rice areas in Yolo County in addition to typical flooding patterns

[6] Olives (for oil) are an important crop in the region and are becoming increasingly common

[7] Landuse codes are from the DWR Land Use Survey spatial datasets

[8] Starting in 2008, and new areas of almonds were categorized as "Young Almond" for the first three years they exist. After three years, these areas are reclassified as "Almond"

2.1.3.1 Crop Parameters

shows the crop categories from the DWR Agricultural Land and Water use estimates (column 1), the definition of the categories (column 2), the land use codes for each category from the DWR Land Use Surveys (column 3). Column 3 refers to the Class 1 and Subclass 1 codes from the DWR Land Use Surveys, which are two separate fields in the DWR Land Use Surveys.

Table 2-5. DWR crop names, and corresponding model assignations

DWR Category	DWR Crop Definition	DWR Landuse Codes[7]	WEAP category	MABIA crop
Grain	Wheat, barley, oats, miscellaneous grain and hay, and mixed grain and hay	G	Grain	Winter Wheat
Rice	Rice and wild rice	R	Rice	Rice[5]
Cotton	Cotton	F1	Cotton	Cotton
SgrBeet	Sugar beets	F5	Sugar beet	Sugar Beets
Corn	Corn (field and sweet)	F6	Corn	Corn
DryBean	Beans (dry)	F10	Dry Beans	Dry Beans
Safflwr	Safflower	F2	Safflower	Safflower
Oth Fld	Flax, hops, grain sorghum, sudan, castor beans, miscellaneous fields, sunflowers, hybrid sorghum/sudan, millet and sugar cane	F (all other)	Other field	Sunflower[3]
Alfalfa	Alfalfa and alfalfa mixtures	P1	Alfalfa	Alfalfa
Pasture	Clover, mixed pasture, native pastures, induced high water table native pasture, miscellaneous grasses, turf farms, bermuda grass, rye grass and klein grass	P (all other)	Pasture	Irrigated Pasture
Pro Tom	Tomatoes for processing	T15	Tomatoes	Tomatoes
Fr Tom	Tomatoes for market	T26		
Cucurb	Melons, squash and cucumbers	T9	Cucurbits	Squash[1]
On Gar	Onions and garlic	T10	Other truck	Asparagus[4]
Potato	Potatoes	T12		
Oth Trk	Artichokes, asparagus, beans (green), carrots, celery, lettuce, peas, spinach, flowers nursery and tree farms, bush berries, strawberries, peppers, broccoli, cabbage, cauliflower and brussel sprouts	T (all other)		
Al Pist	Almonds and pistachios	D12	Young Almonds [8]	Young Almonds
			Almonds	Almonds
Oth Dec	Apples, apricots, cherries, peaches, nectarines, pears, plums, prunes, figs, walnuts and miscellaneous deciduous	D (all other)	Other Deciduous	Walnuts[2]
Subtrop	Grapefruit, lemons, oranges, dates, avocados, olives, kiwis, jojoba, eucalyptus and miscellaneous subtropical fruit	C	Subtropical	Olives[6]
Vine	Table grapes, wine grapes and raisin grapes	V	Vine	Vines

[1] Based on Yolo County crop reports, melons, squash, and watermelons are grown in the area. Watermelons likely cover the largest area, but good cost and return data do not exist, which was required for economic modeling that will be conducted with this hydrologic model.

[2] Most common deciduous tree grown in Yolo County after almonds

[3] Most common field crop grown in Yolo County, after crops with their own categories

[4] Based on Yolo County crop reports, asparagus, broccoli, lettuce, cucumber, strawberries, are all grown in Yolo, but for purposes of economic modeling, cost studies on asparagus are most relevant for Yolo County.

[5] Rice flooding for decomposition is modeled in all rice areas in Yolo County in addition to typical flooding patterns

[6] Olives (for oil) are an important crop in the region and are becoming increasingly common

[7] Landuse codes are from the DWR Land Use Survey spatial datasets

[8]Starting in 2008, and new areas of almonds were categorized as "Young Almond" for the first three years they exist. After three years, these areas are reclassified as "Almond"

2.1.3.2 Crop Parameters

Within each catchment, each of the irrigated crops has several parameters that define the hydrological characteristics of the crop such as evapotranspiration rate, irrigation management, surface runoff, and deep percolation. These variables are listed in Table 2-6.

Each representative crop is included in the WEAP MABIA crop library which contains crop-specific information needed to calculate evapotranspiration and irrigation requirements for that crop. These parameters were adjusted during calibration as described in section 3.1.3**Error! Reference source not found.**. Other parameters, such as the depletion factor, maximum crop height, minimum and maximum rooting depth, and fraction wetted were based on FAO 56[14] and were not adjusted during calibration (Table 2-7). The percentage of the irrigation that does not recharge soil moisture and results in deep percolation was based on values found in the SacWAM model.

Table 2-6. Variables, their description, their set value within the model, and the source used to set their value, as included within all catchments using the MABIA method. Unless otherwise noted, values indicated are for all land use categories, agricultural and non agricultural.

[14] http://www.fao.org/3/X0490E/X0490E00.htm

Variable Type	Variable Name	Variable Description	Value setting	Notes
Land use	Area	Area of each land use/crop category, within each catchment	See section 2.1 for land use categories	See section 2.1.3
	Crops	Representative crop	See section 2.1 for representative crops and associated parameters	See section 2.1.3
	Surface Layer Thickness	Depth of surface layer subject to drying by evaporation	0.05 m	
	Total Soil Thickness	Depth of soil moisture simulation.	2 m for irrigated crops 0.5 m for native vegetation	
	Soil Water Capacity	Available water capacity – difference between field capacity and permanent wilting point.	Clay Loam (14.44%)	Common soil type in Yolo County
	Maximum Infiltration Rate	Amount of water than can infiltrate into soil over 24 hours	Unlimited	Default
	Maximum Percolation Rate	Amount of water that can percolate from soil to groundwater over 24 hours	Unlimited for all land use categories except rice, which is set to 0.635 mm/day	Rice is based on UC Cooperative Ext.
	Max Soil Retention	Used in calculating rainfall runoff with Curve Number	See section 1.3.2**Error! Reference source not found.**	
	Effective Precipitation	Percent of precipitation available for evapotranspiration	See section 1.3.2**Error! Reference source not found.**	
	Fraction Covered	Effective fraction of soil surface shaded by vegetation	Calculated as per FAO 56	Calculated
	Direct Recharge to Groundwater	Of the precipitation not available for evapotranspiration, the percent that goes directly to groundwater recharge	Zero everywhere except 100% for native vegetation in Buckeye, Oat, Bird, Willow Slough, Dunnigan Other	
Climate	Precipitation	Daily precipitation	See section 2.1.2	
	ETref	Daily evapotranspiration for a reference land class	Calculated by WEAP using the Penman-Monteith equation	
	Min Temperature	Minimum Daily Temperature	See section 2.1.2	
	Max Temperature	Maximum Daily Temperature	See section 2.1.2	
	Latitude	Latitude of catchment's center		
	Min Humidity	Minimum daily relative humidity	See section 2.1.2	
	Max Humidity	Maximum Daily Relative humidity	See section 2.1.2	
	Wind	Average daily windspeed	See section 2.1.2	
	Wind Speed measurement height	Height above ground of measurement of wind speed	2.0 m	
	Altitude	Altitude of catchment	50 m	
	Solar Radiation	Daily solar radiation	Calculated by WEAP using Hargreaves Formula	Calculated
	Krs	Adjustment coefficient for Hargreaves Formula	0.16	Default

Variable Type	Variable Name	Variable Description	Value setting	Notes
Irrigation[1]	Irrigation schedule	Irrigation method and schedule	For all crops except safflower and rice, each crop is fully irrigated from the plant date to harvest date. Safflower irrigation stops 16 days prior to harvest. See section 3.1.3 for details.	
	Fraction Wetted	Fraction of soil surface wetted by irrigation system	Crop specific, based on typical irrigation technology. See Table 2-6.	
	Irrigation Efficiency	Percent of supplied water available for evapotranspiration	See section 3.1.3.**Error! Reference source not found.**	Calibrated
	Pump Layer	MODFLOW layer from where irrigation water is pumped	Layer 2 for agricultural water uses	IWFM Model
	Loss to groundwater	Of the supplied water not available for transpiration, the percent that infiltrates to groundwater	Crop	SacWAM Model
	Loss to runoff	Of the supplied water not available for transpiration, the percent that runs off to surface water	100-Loss to groundwater	Calculated
	Irrigation use of runoff	Percent of catchment's runoff which can be used for irrigation internally within the catchment	Catchment specific, see .	
Flooding	Minimum Depth	Minimum required depth of flooding	0 for all land use categories except rice (see section 2.1.3) and managed wetlands (see section 0)	See section 2.1.3 and 0
	Maximum Depth	Maximum allowable depth of flooding	0 for all land use categories except rice (see section 2.1.3) and managed wetlands (see section 0)	See section 2.1.3 and 0
	Target Depth	If flooded depth is at or above minimum, will irrigate until this depth is reached	0 for all land use categories except rice (see section 2.1.3) and managed wetlands (see section 0)	See section 2.1.3 and 0
	Release Requirement	This amount of water will be released from flooded areas to be replaced with new supply	0 for all land use categories except rice (see section 2.1.3)	See section 2.1.3
	Initial Surface Depth	Initial value for surface depth at beginning of simulation	0 mm	Default
Priority	Irrigation Priority	Priority for irrigation demand. When there are shortages in water supply, demands with highest priority (lowest number value) receive water first	Catchment specific	

[1]These parameters only apply to agricultural land use categories. Non-agricultural land use categories are not irrigated. See section 2.1 for a discussion of land use categories.

Table 2-7. Crop specific parameters used in the MABIA module. Depletion Factor, Maximum Height, Root Depth, Fraction Wetted, and Loss to Groundwater. All values except Loss to Groundwater were based on FAO 56. Loss to Groundwater was based on the SacWAM model.

Crop	Depletion Factor	Maximum Height (m)	Min Root Depth (m)	Max Root Depth (m)	Fraction Wetted	Loss to Groundwater (%)
Alfalfa	0.55	0.7	1.5	1.5	1	94
Almonds	0.4	5	1.5	1.5	0.2	92
Young Almonds	0.4	2	0.75	0.75	0.2	92
Corn	0.55	1	0.15	1.35	0.5	94
Cotton	0.65	1.5	0.15	1.35	0.5	93
Cucurbits	0.5	0.3	0.5	0.5	0.5	93
Dry Beans	0.45	0.4	0.15	0.75	0.5	94
Grain	0.55	1	0.15	1.65	1	94
Other Deciduous	0.5	4	1.7	2.4	0.25	94
Other Field	0.45	2	0.8	1.5	0.5	93
Other Truck	0.45	0.8	1.2	1.8	0.75	94
Pasture	0.55	0.2	1.5	1.5	1	91
Rice	NA	NA	NA	NA	NA	94
Safflower	0.6	0.8	0.15	1.5	0.5	93
Subtropical	0.65	5	1.2	1.7	0.5	94
Sugar Beets	0.55	0.5	0.15	0.95	0.5	92
Tomatoes	0.4	0.6	0.15	1.1	0.5	91
Vines	0.45	2	1	1.5	0.2	92

2.1.3.3 Rice Parameters

Due to its unique cultivation method, rice has a different set of parameters than other crops. In the YSGA, the timing and magnitude of rice flooding was based on a rice management description written by Todd Hillaire of DWR. The flooding pattern begins with a pre-planting irrigation used to saturate the soil and pond water to a depth of 3 inches. This irrigation starts five days prior to planting day. Following planting, the water can drain. After plant emergence, water is ponded to a depth of 5 inches (125 mm) by May 26. This depth is maintained until July 1 at which point the depth is increased to a depth of 8 inches (200 mm) by July 31. This depth is maintained until the end of August at which point the field can drain until September 15.

During the winter months, the fields are flooded to promote rice-straw decomposition and to attract waterfowl. In the YSGA model, this flooding is assumed to start on October 15 and reach a *Target Depth* of 3 inches by January 1. Rainfall can collect in the fields up to a depth of 8 inches. Starting January 15, no more water is added to the fields. During the first two weeks of March, the fields are actively drained to a depth of zero inches.

The Target Depth and Minimum Depth parameters in the MABIA module was set using the time series described above. The maximum depth was specified using the time series described above with the exception at the end of the rice season this value was kept at 8 inches (200 mm) to allow the ponded water to dissipate due to evaporation and deep percolation.

In order to maintain favorable temperature and salinity levels, rice paddies have a continuous flow of water entering and leaving the paddy. In the MABIA module this is expressed as a depth of water per day. Based on the Hillaire description, this parameter was given a value of 2 mm/d to represent the continuous flow of water through the rice paddies.

2.1.4 Climate Change Projections

The California Department of Water Resources (DWR) provides datasets, tools and guidance regarding climate change datasets that can be used by GSA's to develop their GSP's. These datasets are related to climatology, hydrology and water operations. Climatological datasets are provided in the form of change factors for precipitation and reference evapotranspiration, as gridded data for the state. Projected stream flows are available as inflows for major Central Valley streams, and streamflow change factors for other watersheds. Most inflows and all operations data were simulated using the Calsim II model.

Data represent projections for two future climate periods: 2030, and 2070:

- There are 4 scenarios; one for 2030 representing the central tendency from several downscaled climate models; and three for 2070 (central tendency, dry-extreme warming, and wetter with moderate warming)
- The process involved a "climate period analysis". Historical inter-annual variability (1915-2011) is preserved while the magnitude of events is perturbed based on projected temperature and precipitation changes from general circulation models.

2.1.4.1 Processing Steps

The provided climate change datasets (eight in all, covering four scenarios and two change factors, for ETo and precipitation, in each scenario) had to be applied to the historical climate datasets in the YSGA model, for each catchment. The steps involved were:

- Downloading the grid and associated climate change datasets for the extent of the model using the SGMA Data Viewer Tool (accessed online Sept 15 2019) (https://sgma.water.ca.gov/webgis/?appid=SGMADataViewer#). There are 157 grid cells covering the rectangular region of the model boundary (See Figure 2-2).
- Using GIS geoprocessing tools, the spatially weighted average of each grid cell intersection with each model catchment boundary was computed, with intersection area composing the weights.
- This weighted average was applied to the historical climate series for that catchment, in every time step from 1971 to 2018 (the historical modeling period). For example,

Consider Pv and Ev are the precipitation and ET factors to be applied to the historical climate data for a catchment C at a particular time step.

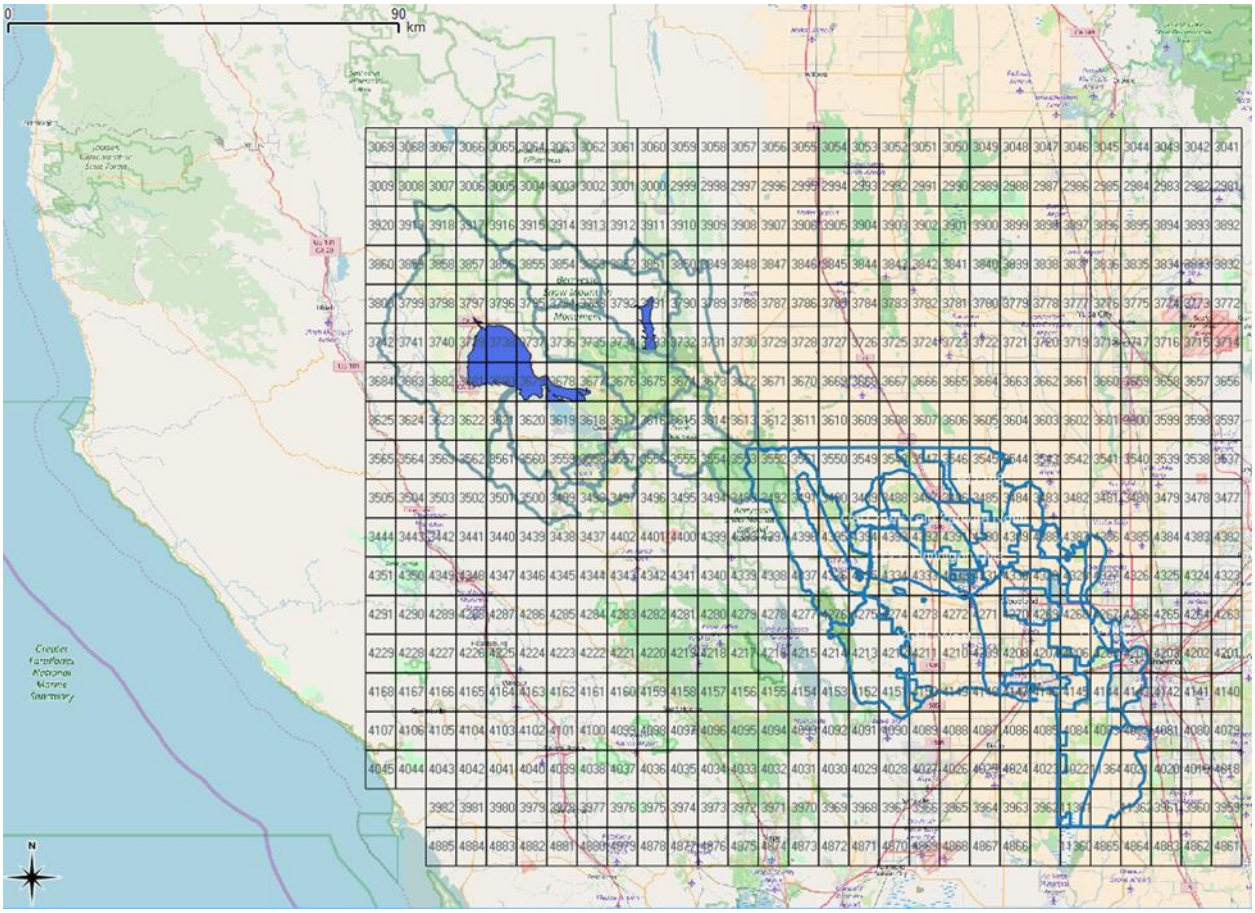
P(c) is a vector of precipitation change factors (available from 1915 to 2011) to be applied to relevant grids intersecting a catchment.

P(c) = avg(Av*Pv); where Av is the fractional area intersection between a climate grid v and the catchment c; and Pv is the Precipitation change factor vector for that grid.

Similarly, E(c), is a vector of ETo change factors (available from 1915 to 2011) to be applied to relevant grids intersecting a catchment.

E(c) = avg(Av*Ev); where Av is the fractional area intersection between a climate grid v and the catchment c; and Ev is the Precipitation change factor vector for that grid.

Figure 2-2. Climate change grids overlaid over YSGMA model boundary



However, the climate change factors are available only up to 2011. The following steps were taken to select change factors from water years that came closest to observations from 2011 to 2018:

- Water year types and flows were downloaded from CDEC (accessed 9/30/2019) http://cdec.water.ca.gov/reportapp/javareports?name=WSIHIST
- A historical water year type was assigned to the years 2012 – 2018, based on minimum absolute difference in Sacramento River Index WY flow sums from a given WY (between 1915-2011) and the missing years (2012-2018). Water Years were assigned to missing WY as shown Table 2-8.

Table 2-8 Water Years assigned to fill missing years

Actual WY	Change factor assigned from closest WY
2012	1979
2013	1979
2014	1994
2015	1988
2016	2005
2017	1983
2018	2009

Note: 2013 was closest, but cannot be used since the climate change factors only go upto 2011. Next closest WY was 1979.

2.1.5 Water Management Inputs

In this section, the rules and regulations that are used to manage surface water use within the basin are discussed.

2.1.5.1 Surface Water Rights

Many surface water rights registered with the State of California have restrictions. These can include any one or combination of the following:

1. **Instantaneous maximum diversion** (cfs), typically appropriative rights or riparian/Pre 1914 rights
2. **Monthly maximum diversions** (AF/month), typically USBR contracts
3. **Annual maximum diversions** (AF/water right year), typically USBR contracts or appropriative rights. These are limited to a certain amount available over a designated set of months, e.g. April-October or January-December. This time period will be referred to as the water right year.

For surface water rights that have one type of restriction, the restriction is implemented as a "maximum flow volume" in the YSGA model. For surface water rights that have more than one type of restriction (either instantaneous and annual, or monthly and annual), cumulative annual diversions are tracked and the water available at each time step is this amount subtracted from the total water right volume.

2.1.5.1.1 Woodland-Davis Clean Water Agency

The City of Woodland, City of Davis, and UC Davis established the Woodland-Davis CWA which recently acquired surface water rights for the Sacramento River. Given that the historical simulation runs through Water Year 2018, surface water is only available in the last two years of that simulation. Table 2-9 summarizes the water rights and their limitations.

Water licenses 5487a and 904a, which were transferred from the Conaway Preservation Group to the CWA, provide the cities with 10,000 AF of surface water from June to September each year, and monthly restrictions on diversions for these rights are designated by Settlement Contract 14-06-200-7422X-R-1. This right is subject to 25% reductions in Shasta Critical years.

The Woodland-Davis CWA also has permit 20281 which allocates 45,000 AF to the CWA each year (Jan 1-Dec 31), limited by a maximum diversion rate of 80.1 cfs on average each month. This right is subject to reductions due to Term 91, which ensures sufficient flows in the Delta, and therefore often restricts water rights during summer months.

Effectively, due to the capacity of the water treatment plant, the cities have 30 MGD available. This is allocated into 18 MGD, 10.2 MGD and 1.8 MGD for Woodland, Davis, and UCD, respectively when neither reduction due to a Shasta Critical year nor Term 91 are in effect. The diversion from the river is limited to the maximum instantaneous diversion rate of the two water rights, 80 cfs. Diversions to the three cities are limited by the MGD rate listed above. If Term 91 is in effect in a given month, no water can be diverted in the model. If it is a Shasta Critical Year, the total MGD mentioned above is reduced by 25%.

Table 2-9. Available water to the Woodland Davis CWA, divided between water rights.

Water licenses 5487a and 904a			**Permit 20281**	
Annual limitation	**Instantaneous limitation**	**Monthly limitation (per settlement contract 14-06-200-7422X-R-1)**	**Annual limitation (Jan 1-Dec 31)**	**Instantaneous limitation**
10,000 AF	80 cfs	Jun 2,500 AF Jul 3,500 AF Aug 500 AF Sep 3,500 AF	45,000 AF	80 cfs
10,000 AF/yr	57,917 AF/yr	10,000 AF/yr	45,000 AF/yr	4,760 AF/mo 57,917 AF/yr
Additional Restrictions: In a Shasta Critical year, base supply agreed to be diverted April-October is reduced by 25% each month			Additional Restrictions: Subject to reductions based on Term 91	

Sources of information

Settlement Contract 14-06-200-7422X-R-1 Draft, 4/4/2013
Water Permit 20281
Water License 904A
Water License 5487A
Davis Woodland CWA Water Rights Briefing Paper
Draft Environmental Assessment: Amendatory Contract between the United States and Conaway Preservation Group, LLC and Sacramento River Settlement Contract betweel the United Stated and the Woodland-Davis Clean Water Agency (July 2013)
Conversation with the City of Woodland, 6/8/17
Woodland Davis CWA Website, Accessed: Aug, 2017
Meeting with all participating entities: 5/31/18
ASR Well injection and recovery data and WDCWA deliveries data provided by City of Woodland and CivicSpark Fellows
Personal communication with Matt Cohen, City of Woodland, 10/10/2019

2.1.5.1.2 Water right restrictions

2.1.5.1.2.1 Central Valley Project Contracts

During the historical simulation period (WY 1971 - WY 2018) all settlement contracts were reduced during Shasta Critical Years by 25%.

During this same period, project allocations for agricultural and urban contractors north of the Delta were available from the Bureau of Reclamation for 1977-2018[15]. We adjusted allocations accordingly for the historical period of the model. If the allocation changed over time within the season, we took the latest allocation for that water year. For example, if the allocation started as 50% in March, but was 100% by April, we assumed April for the entire water year. Prior to 1977, we assumed 100% allocation for all contracts.

2.1.5.1.2.2 Term 91

For all water rights affected by Term 91, we developed assumptions based on data available for 2012-2018, based on water year type.[16] Per Table 2-10, when Term 91 is enacted, no surface water from the affected right is available in the model, until the month indicated under "Term 91 Lifted". Because this affects all rights granted since 1965, this is implemented during the entire historical period (1971-2018).

Table 2-10. Assumptions for Term 91, implemented in the WEAP model

Water Year Type	Term 91 Enacted	Term 91 Lifted
Critical	April	Nov
Dry	May	Sep
Below Normal	Jun	Oct
Above Normal	Jul	Sep
Wet	Not Enacted	Not Enacted

2.1.5.1.2.3 Water Rights not restricted by Term 91

Some water rights included in the YSGA model are not affected by Central Valley Project operations nor Term 91. Water available via these rights are limited according to their face value or diversion limitation, but not further limited, even in dry years, in the model. These are listed in Table 2-11, below.

Table 2-11. Areas within the model with unrestricted water rights

Catchment Name	**Water Source**
RD 108	Colusa Basin Drain
RD 787	Colusa Basin Drain
RD 2035	Willow Slough
UC Davis	Putah Creek

[15] Available from: https://www.usbr.gov/mp/cvo/vungvari/water_allocations_historical.pdf
[16] Based on information from https://www.waterboards.ca.gov/water_issues/programs/delta_watermaster/term91.html

2.1.5.1.2.4 Unrestricted Water Rights

It is likely that water right holders along the Sacramento River, Delta and Colusa Basin Drain are affected by some annual restrictions. However, due to lack of information about the type and face value of their rights and contracts, there are no restrictions – in the YSGA model - on the surface water available to the areas listed in Table 2-12 below.

Table 2-12. Areas within the model with unrestricted water rights

Catchment Name	Water Source
RD 537	Sacramento River
RD 730	Sacramento River
RD 827	Sacramento River
RD 1600	Sacramento River
CBD North	Colusa Basin Drain
CBD South	Colusa Basin Drain
North Delta East	Delta
North Delta West	Delta

Each individual water right represented in the model is described in the following section, where each entity's representation is explained in detail.

2.1.5.2 Cities/Towns/Urban Areas

2.1.5.2.1 City of Davis

Runoff simulated from the physical area representing the City of Davis ends up in the Yolo Bypass (See Table 1-4 for a summary of each catchment's assigned runoff destination). Agricultural areas within this area are irrigated with groundwater, pumped from layer 2 in the MODFLOW model. At this time, the water demand of golf courses is not explicitly incorporated in the model, nor are detention ponds.

Domestic demand is split into two categories of water use rates (residential and other) based on Drinc Portal data supplied by the City of Davis. This rate is multiplied by the population, sourced from the Department of Finance, to estimate total annual water demand for the city[17]. This annual demand gets distributed each month with a monthly variation that was developed based on the City of Davis Residential Use data supplied by Marie Graham.

Until June 2016, the city's domestic demand was met entirely by groundwater, also pumped from layer 2 in the MODFLOW groundwater model. In June 2016, Davis began supplying water from the Sacramento River via the Woodland-Davis CWA (see section 0 for more details). The eWRIMS Water rights database shows that Davis has a riparian right for Putah Creek. This is currently included in the model but never used, because this supply is not mentioned in the UWMPs, and City staff indicate that this right is not used.

[17] The information sourced from the Department of Finance differed slightly from population included in City of Davis Residential Use data provided by Marie Graham (2014-2017 data), however, in order to have a long contiguous record, the Department of Finance data was used.

The city's wastewater treatment plant is included in the YSGA model. Correspondence with the City of Davis indicated that the average inflow to the plant is 4.5 MGD, with an average effluent rate of 4 MGD. This was used to calculate monthly consumption before reaching the treatment plant (e.g. water used for irrigating lawns, which never reaches the sewer system). It is assumed all this consumption is largely evapotranspiration and therefore, it is higher in the summer than in the winter. Prior to 2016, the City of Davis Wastewater Treatment Facility was made up entirely of facultative ponds. After this, the city upgraded their system to an activated sludge plant that discharges into the Willow Slough bypass and then the Yolo bypass. In the historical model simulation prior to 2016, all water that reaches the treatment plant is consumed within treatment, with 80% evaporating from ponds and 20% infiltrating to groundwater. After 2016, 11% of inflows to the plant are lost during treatment, and the remaining flows out to the Yolo Bypass.

Sources of information

2015 Urban Water Management Plan
2006 City of Davis-UC Davis Groundwater Management Plan
2006 City of Davis Storm water Management Plan
Municipal Service Review and Sphere of Influence Study (2016): City of Davis, El Macro County Service Area, North Davis Meadows County Service Area, Willowbank County Service Area
Phase I Hydrogeologic Investigation Deep Aquifer Study (1999)
Various in person, phone and email conversations with Marie Graham and Stan Gryczko, City of Davis
City of Davis Residential Use data (Drinc Portal data) provided by Marie Graham 6/29/18
Monthly production data provided by Stan Gryczko 5/23/18
California Department of Finance (population data)
Meeting with cities 5/31/2018

2.1.5.2.2 City of West Sacramento/RD 900

The geographic area of RD 900 and West Sacramento are represented together by the West Sac catchment in the YSGA model. Prior to 2003, agricultural water demands are first met with water made available by RD 900's Settlement Contract 14-06-200-1779A-R-1, and then supplemented with groundwater pumped from layer 2 in the MODFLOW model if the surface water is not sufficient. After 2003, these demands are only met with groundwater. All groundwater for irrigation is assumed to be sourced from private wells. This is based on information provided by the City of West Sacramento, indicating that RD 900 no longer uses their surface water right. Surface runoff generated within the area of West Sacramento and RD 900 all flows into the Sacramento River (See Table 1-4 for each catchment's runoff destinations).

Domestic demand is split into two categories of water use rates (residential and other) based on Drinc Portal data supplied by Paulina Benner at the City of West Sacramento. This rate is multiplied by the population, sourced from the Department of Finance, to estimate the total annual water demand for the city. Annual demand is distributed for each month with a monthly variation based on supplied data.

Prior to 1986, all domestic demands are met with groundwater which is pumped from layer 2 in the MODFLOW model. It is possible that prior to 1986, before the city was incorporated, residents purchased surface water from the East Yolo Community Services District, however this is not confirmed

due to lack of records and therefore is not incorporated in the model. From 1986 onward, the water treatment plant was built and therefore surface water is available for domestic demands. These are met with water from the Sacramento River via three agreements : Water Permit 18150, USBR Contract 0-07-20-W0187 and water made available by the North Delta Water Agency (NDWA). In the model, the order of priorities for these sources are first, Permit water, then, CVP contract water, then water from the NDWA. The amount of water than can be delivered from the NDWA is unlimited, so groundwater is never pumped for domestic water use after 1986. In reality, the northern part of the city only receives permit and CVP water and the southern part receives NDWA water. Therefore, the northern part of the city could be at risk if there are shortages in surface water. However, this is not implemented into the model at this time.

Although West Sacramento previously had its own WWTP, and now sends its water to Sacramento's WWTP, only one plant is represented in the YSGA model which only receives water from West Sacramento.

Sources of information

Water Permit 18150
Contract 14-06-200-1779A-R-1
2010 Urban Water Management Plan
2015 urban Water Management Plan
Municipal Service Review/Sphere of Influence study, 2009
Various phone, email and in person conversations with Paulina Benner, City of West Sacramento
West Sac diversions spreadsheet provided by Paulina Benner 6/14/18
Residential consumption spreadsheet (Drinc Portal data) provided by Paulina Benner 7/3/18
Department of Finance (population data)
Meeting with cities 5/31/2018

2.1.5.2.3 City of Winters

Agricultural areas within the geographic boundary of the City of Winters is irrigated by groundwater pumped from layer 2 in the MODFLOW model. Any runoff generated within this catchment flows into Putah Creek (See Table 1-4 for each catchment's runoff destination).

The city's urban demand is also met entirely by groundwater pumped from layer 2. The per capita water use rate within this demand is divided into four categories based on Water Use Reports from the Drinc Portal (supplied by Carol Scianna): residential, commercial, industrial and landscape irrigation. This rate gets multiplied by the population, sourced from the Department of Finance, to estimate the total annual water demand[18]. Annual demand is distributed for each month with a monthly variation based on supplied data.

[18] Population data supplied by the City of Winters did not differ much from Department of Finance data, so Department of Finance data were used to maintain consistency of data source with other cities.

Wastewater from the urban demand is sent to the city's WWTP which has a capacity of 0.91 MGD according to the City of Winters Municipal Service Review and Sphere of Influence Study (2008). Because the ponds do not have an outflow, all water that reaches the plant either evaporates or contributes to groundwater. Although some treated wastewater has been sold to the nearby prune orchard for irrigation, and there is some spraying of effluent that occurs, these are likely small volumes that do not highly influence the overall water budget, so they are not represented in the model.

Sources of Information

Multiple Data Sets provided by Carol Scianna, City of Winters (historical monthly pumping 2006-2017, monthly water use in Drinc Portal Annual Reports 2013-2017, average WWTF influent flows 2008-2017, 2018-2006 Well Soundings data
City of Winters Municipal Service Review and Sphere of Influence Study (2008)
Winters Water Master Plan 2016
Winters Sewer Collection System Master Plan (2006)
Conversations with Carol Scianna, 4/26/2017, 5/24/2018, various email correspondences
Water License 6154
California Department of Finance (population data)
Meeting with cities 5/31/2018

2.1.5.2.4 City of Woodland

Agricultural areas withing the geographic boundary of the City of Woodland are irrigated with groundwater pumped from layer 2 in the MODFLOW model. Any runoff generated within the catchment flows into Willow Slough and Cache Creek, per fractions in Table 1-4.

Domestic demand is split into two categories of water use rates (residential and other). Due to lack of information, almost all the details of the domestic demand in Woodland are a replication of those from Davis. Water use rates from the city if Davis, were multiplied by the population of Woodland (sourced from the Department of Finance), to calculate the total annual water demand for the city. Annual demand is distributed for each month using City of Davis' monthly variation.

Before 2016, this demand is entirely met with groundwater, pumped from layer 2 of the MODFLOW model. Beginning in 2016, water from the Sacramento River via the Woodland Davis CWA becomes available to meet Woodland's domestic supply (See section 2.1.5.1.1). Woodlands confined Aquifer Storage and Recovery (ASR) project also became operational in 2016. Based on conversations and data provided by Matt Cohen, City of Woodland, from the middle of 2016, some of Woodland's allocation of CWA water is injected into the ASR wells, while the rest (the majority) is used for City delivery directly. This data is used directly from 2016 to 2018 in the YSGA model. Recycled water from the wastewater treatment plant (0.5 MGD), is also used as a water source in the YSGA model. Although Woodland purchases water from the spot market, no quantitative details were able to incorporate this in the YSGA model.

For future scenarios, supply preferences are set up in the following order: recycled water from the waste water treatment plant (0.5 MGD) is first, then Aquifer Storage and Recovery (ASR) water, then the

CWA and only after that is the unconfined aquifer (layer 2) used. Effectively, this represents Woodland's marked reduction in historical dependence on the unconfined aquifer. Woodland's stated goal of ASR injection 10,000 AF per year. However, for the future runs, the YSGA model currently uses the 2018 amount of water reported to be injected (500 million gallons per year, or 1,534 AF), with a monthly distribution also determined from 2018 data. Of this injected water, 1368 AF is pumped from the ASR for City use (again based on 2018 data).

Woodland's confined aquifer where ASR is implemented is not currently represented in MODFLOW, as it is beyond the scope of the YSGA model effort. It is represented as a simple groundwater object (a bucket model) instead. The ground water budget includes inflow and outflow volumes for this ASR, but its effects on regional or overlying unconfined layers, if any, cannot be modeled by the YSGA model. Extensive hydrogeologic and numerical modeling of Woodland's ASR, conducted as part of the feasibility and permitting process, are available from the City of Woodland.

Wastewater from the city is routed to the wastewater treatment plant which has a capacity of 14.7 MGD. A maximum of 0.5 MGD of treated water is available to the city as supply beginning in 2016 (per conversation with the City of Woodland, 6/8/17). The rest of the wastewater effluent is discharged into the Yolo Bypass. Due to lack of information, there are no treatment losses are included in the model.

Sources of information

City of Woodland Urban Water Management Plan 2015
City of Woodland Urban Water Management Plan 2010
Public Review Draft General Plan (2016)
City of Woodland Municipal Service Review/Sphere of Influence Update 2011
Conversations with the City of Woodland, 6/8/17, 10/10/18
ASR Well injection and recovery data provided by City of Woodland and CivicSpark Fellows
City of Davis Residential Use data (Drinc Portal data) provided by Marie Graham 6/29/18
City of Davis Monthly production data provided by Stan Gryczko 5/23/18
California Department of Finance (population data)
Meeting with cities 5/31/2018

2.1.5.2.5 University of California, Davis (UCD)

Agricultural water demand within the geographic boundary of UCD is irrigated preferentially with water from the Solano Project (4,000 AF per year from Putah Creek). If more water is needed, it is pumped from layer 2 in the MODFLOW model. Currently, the Russel Tract is not included in the UC Davis catchment but rather, it is included in the YCFC West catchment. This is due to limited information on the exact location and size of the farmed area. Similarly, the area of UC Davis outside of Yolo County is not currently included in the model due to lack of information on land use, water use and groundwater conditions there.

All runoff generated the UCD catchment is routed to Putah Creek. Detention ponds and the Arboretum are not currently represented in the model.

Urban demand is split into three categories, “Domestic”, “Aquaculture” and “Landscape irrigation”, with associated information taken directly from the UC Davis Water Supplies, Systems and Usage memorandum, dated 02/06/18 (hereafter, UC Davis Water Supply Memo). The domestic category has an annual activity level in units of weighted campus user, while the Landscape irrigation demand is in units of acres. Values are given in the UC Davis Water Supply Memo for years 2005-2008 and 2016-2017. Due to lack of information, it is assumed that the weighted campus user population was 60% of latest levels, in 1971 at the start of the simulation and grew linearly to 2005 and between 2008 and 2017. Landscape irrigation area is assumed to be constant from 1971 to 2005 at 2005 levels. Each are multiplied by water use rates to estimate total demand. Aquaculture demand is incorporated as a total demand, without an annual activity level or water use rate, and remains constant throughout the entire historical period at 2017 levels. Landscape irrigation demand fluctuates monthly based on the monthly variation calculated for the City of Davis. Consumption is calculated as 39% on average, based on 1.17 MGD average daily wastewater generation reported in the Long Range Development Plan EIR (2018).

Prior to 2016, all water is pumped from layer 2 in the MODFLOW model. Starting in water year 2016, 1.8 mgd of surface water from the Sacramento River is available to meet UCD urban demand. This source is preferentially used over groundwater. Additionally, starting in June 2016, 33 million gallons per year recycled water from the waste water treatment plant is available to meet the urban demand (per conversation with Camille Kirk, UCD). This is also preferentially used before groundwater, in the YSGA model.

All water not consumed is routed to the wastewater treatment plant. The plant has a capacity of 3.6 mgd (source: Long Range Development Plan EIR (2018), section 3.17). Outflows from the plant discharge into Putah Creek. No information was available on water lost in treatment.

Sources of Information

UC Davis Drought Response Action Plan (2014)
University of California, Davis Sewer System Management Plan (2009)
2018 Long Range Development Plan Environmental Impact Report, Sections 3.10, 3.13 and 3.17
2006 City of Davis-UC Davis Groundwater Management Plan
Phase I Hydrogeologic Investigation Deep Aquifer Study (1999)
Overview of The UC Davis Wastewater Collection And Treatment System Website: https://facilities.ucdavis.edu/utilities Accessed: 8/14/17
Memorandum: Infrastructure Information for LRDP Environmental Review Water Supplies, Systems and Usage, 2/6/2018
Conversations with Camille Kirk, UCD
Meeting with cities 5/31/2018

2.1.5.2.6 Rural Water Use

Rural water use includes demands for small towns or other non-agricultural demands in the County that do not receive water from a district or city supply. Their physical area is incorporated into the catchment where they are located (e.g. YCFC); their water demand estimations are documented below.

2.1.5.2.6.1 Capay Valley

Non-agricultural water demands in Capay Valley include those of the Cache Creek Casino, Yocha Dehe Golf Club (starting in 1985), Tribal Housing and rural water use from private pumping. These categories and total demands were developed based on a Capay Groundwater study (RMC Water and Environment, 2016) which provides demands for each category up to 2007 (in table 3.4 of the Capay Groundwater Study), after which point demands are held constant. Due to limited information, the total demand is included in the model, rather than a population and water use rate. The golf course portion of the demand only occurs from April to October and is met with 287 AF/year from Cache Creek. Additionally, 17% of water use is available for reuse, estimated from the Capay Groundwater Study. The rest of the demand is met with groundwater from layer 2. Due to lack of information, there is no monthly variation for the other demand categories. The consumption rate in both demand nodes is assumed as 40% (based on Madison CSD rates), due to lack of Capay-specific information. All water that is not consumed is routed to groundwater.

2.1.5.2.6.2 Small Towns

Non-agricultural demand for small towns are represented in aggregated manner within their respective catchments and Management Areas. Capay and Monument Hills, for example, are represented in aggregate in the YCFC West catchment of Central Yolo Management Area, in the YSGA model. Similarly, water demand for the town of Zamora is included in the North Yolo Management Area, and Clarksburg demand is included in the Clarksburg Management Area.

These demands are calculated as the area of the towns (estimated from the Yolo County GIS database, Yolo County Cities and Towns Open Data shapefile) multiplied by 2.0 af/ac, the water use rate used in the Capay Groundwater Study for estimating rural water use. The demands are met by groundwater pumped from layer 2. Consumption rate in all demand nodes is 40%, based on Madison CSD, due to lack of town-specific information. It is assumed septic systems are used therefore, all unconsumed water is returned to groundwater.

Domestic water use within the boundaries of Dunnigan Water District is represented in the Dunnigan urban demand and the wastewater treatment plant is represented. Currently, the demand node conceptually aggregates all 166 private wells that exist within this area, per the 2005 Hydrogeologic Characterization Report of Dunnigan Water District. Due to lack of information, the population of Dunnigan serviced by California American Water is not separate from the rest of the population of Dunnigan at this time. Similarly, due to lack of information, the waste water treatment plant is included in the model but is not active due to lack of information. The demand node has a consumption rate of 40%, based on Madison Community Service District and all remaining water is returned to groundwater.

Sources of Information

Technical Memorandum CCCR Event Center Projct TEIR Hydrological Model of Capay Valley April, 2010
Capay IGSM Update and Scenario Analysis: Final Report (RMC, 2016)
Madison Community Service District Final Facility Master Plan Report (2011)
Yolo County GIS database, "Yolo County Cities and Towns Open Data" shapefile

Email communication with Evan Jacobs, California American Water-Dunnigan
2005 Hydrogeologic Characterization Report, Dunnigan Water District (West Yost and Davids Engineering Inc, 2005)
2005 Groundwater Management Investigation, Dunnigan Water District (Dunnigan Water District and Davids Engineering Inc, 2005)

2.1.5.3 Community Service Districts (CSD)

2.1.5.3.1 Cacheville CSD

Cacheville CSD supplies the town of Yolo with water. There is no land within the District's boundaries that is categorized as agricultural. All runoff generated within the district's area flows into Cache Creek (See Table 1-4 for each catchments runoff destination).

The town of Yolo has a daily average water use rate of 118 gpm and a population of 452 (2030 Countywide General Plan, General Plan Amendment 2013-01). These values are included in the model to make up the domestic demand, and stay constant for the entire baseline scenario. Due to lack of additional information, there is no monthly variation in the model so demand does not vary with seasons. All water to meet this demand is pumped from layer 2 in the MODFLOW model. Groundater supply to the demand is limited by the sum of the capacity of the district's two wells (Cacheville CSD Municipal Service Review and Sphere of Influence Study, 2014). Because all water is treated by individual septic systems, there is no WWTP included for this entity. Consumption within the demand site is 40%, based on the Madison CSD consumption rate (see section on Madison CSD for details), and the remaining water is returned back to groundwater through septic systems.

Sources of information

Cacheville CSD Municipal Service Review and Sphere of Influence Study (2014)
2030 Countywide General Plan, General Plan Amendment 2013-01 Disadvantaged Unincorporated Communities Assessment
Madison Community Service District Final Facility Master Plan Report (2011)

2.1.5.3.2 Esparto CSD

Runoff generated within the district's area contributes to Cache Creek and Willow Slough (See Table 1-4 for each catchments runoff destination). Any area classified as agricultural within the district's area is irrigated with groundwater pumped from layer 2 in the MODFLOW model.

The average daily demand generated by the population of Esparto is 650 gpm and the population is 3108, per the Western Yolo Special Districts Municipal Service Review and Sphere of Influence Study (2014). These values stay constant in the model and make up the domestic demand for the district's service area. The demand is met with groundwater, also pumped from layer 2. This supply is limited by the summed capacity of Esparto CSD's wells (Well 1A, 5, 6, 5B and emergency well, combined capacity: 1432 gpm). Due to lack of information, there is no monthly variation in the model so demand does not vary with seasons. Consumption within the demand site is 40%, based on the Madison CSD consumption rate (see section on Madison CSD for details). The remaining water flows to the Esparto WWTP which is

made up of 10 facultative ponds. Consumption (evaporation) within the pond system is 45.5%, based on the calculated evaporation in the Madison system, and the remaining water recharges groundwater.

Sources of Information

Municipal Service Review and Sphere of Influence Study for the Western Yolo Special Districts (2015)
Town of Madison Flood Hazard Mitigation Study (1991)

2.1.5.3.3 Knights Landing CSD

Runoff generated within the district's area contributes to the Sacramento River (See Table 1-4 for each catchments runoff destination). Any area classified as agricultural within the district's area is irrigated with groundwater pumped from layer 2 in the MODFLOW model.

The domestic demand stays constant throughout the baseline run, based on a population of 902 people and 204 GPM daily average water demand (Knights Landing Municipal Service Review and Sphere of Influence Study, 2014). Domestic demands are met with groundwater from layer 2, with supply limited by the total capacity of Knights Landing CSD's three wells (Knights Landing Municipal Service Review and Sphere of Influence Study, 2014). Due to lack of information, there is no monthly variation in the model so demand does not vary with seasons. Consumption within the demand site is 40%, based on the Madison CSD consumption rate (see section on Madison CSD for details).

Wastewater from the urban demand is sent to the WWTP, which is made up of 10 facultative ponds with a capacity of 112,000 gpd (2030 Countywide General Plan, General Plan Amendment 2013-01). Due to lack of information, 45.5% of water that flows into the WWTP is "consumed" (evaporated), based on the Madison CSD WWTP. The remainder recharges groundwater.

Sources of information

Knights Landing CSD Municipal Service Review and Sphere of Influence Study (2014)
2030 Countywide General Plan, General Plan Amendment 2013-01 Disadvantaged Unincorporated Communities Assessment
Madison Community Service District Final Facility Master Plan Report (2011)

2.1.5.3.4 Madison CSD

Agricultural land within Madison CSD boundaries is irrigated with groundwater from layer 2 in the MODFLOW model. Domestic demand is also met with groundwater from layer 2.

The domestic demand is split into eight categories based on the Madison CSD Final Facility Master Plan Report (Master Plan), Appendix F, Table 1: low, medium and high density residential, general and local commercial, industrial, public/quasi-public and parks and recreation. Each of these categories has an annual activity level, in acres which stays constant for the entirehistorical period, except "Residential Low" whose activity level is defined as number of households. These are then multiplied by annual water use rates, also derived from the Master Plan, which also stay constant. The parks and recreation demand only exist between April and October, based on the Golf Course demand in Capay Valley (Technical Memorandum CCCR Event Center Project TEIR Hydrological Model of Capay Valley (April,

2010). Some pumping data were provided by Madison CSD, but because they are only for a few months, it was not enough information to use in the model at this time.

The urban demand has a pumping limit of 1050 gpd, which is the sum of the production rate of Park Wells 1, 2 and 3 (Master Plan, Appendix F, Table 1). The consumption rate within the demand node is 40%, which results in average daily flow to the WWTP of 0.15 MGD. Wastewater is sent to Madison's WWTP which has a capacity of 70,000 GPD. Almost half (45.5%) of the water is "consumed" during the treatment process in the model and is lost from the system. This represents evaporation from the ponds and is calculated based on values in the Madison Master Plan, Appendix G, Table 5. The remaining volume is recharges groundwater .

Sources of information

Madison Community Service District Final Facility Master Plan Report (2011)
Municipal Service Review and Sphere of Influence Study for the Western Yolo Special Districts (2015)
Town of Madison Flood Hazard Mitigation Study (1991)

2.1.5.4 Reclamation Districts 108, 787, 2035

2.1.5.4.1 RD 108

RD 108 agricultural lands are irrigated with water from the Sacramento River, Colusa Basin Drain, and groundwater. In the YSGA model, water availability from the Sacramento River is represented via 2 diversion links. One combines Water license 3065, 3066, 3067 and the riparian right, which are all limited to monthly allotments by Settlement Contract 14-06-200-876A-R-1. Within the model, water is available based on these monthly restrictions, but is not further restricted by the total 725 cfs max diversion rate for the combined rights. The second diversion link from the Sacramento River represents Permit 21274 by which RD 108 has access to 36,000 AF of Sacramento River water per year at a maximum of 240 cfs. In the YSGA model, water is also available from the Colusa Basin drain at 75 cfs from April 1 to October 1, representing Water License 7060.

Supply preferences in the YSGA model, are set such that irrigation demand is met first by surface water sources evenly across the different surface water rights, and then from groundwater, which is pumped from layer 2 in the MODFLOW model. However, there is likely too much water available to the catchment in the model because the entirety of the above-mentioned rights are available, however, only the area of the district within Yolo County is included in the model. For this reason, groundwater is rarely pumped in this district.

A portion of runoff generated within the catchment runs off to the Sacramento River and the Colusa Basin Drain (See Table 1-4 for each catchments runoff destination).

WEAP catchment Name	Water body	Percent of area's runoff contributing to water body	WEAP catchment Name	Water body	Percent of area's runoff contributing to water body
Bird Creek	Colusa Basin	100	RD 785	Bypass	100
Buckeye Creek	Colusa Basin	100	RD 787	Sac Riv	55
Cacheville CSD catch	Cache Creek	100	RD 787	Colusa Basin	45
Capay Other	Cache Creek	100	RD 827	Bypass	78
YCFC Capay	Cache Creek	100	RD 827	Willow Slough	22
CBD North	Colusa Basin	100	Sac River	Sac Riv	73
CBD South	Bypass	40	Sac River	Cache Creek	25
CBD South	Cache Creek	45	UCD catch	Putah Creek	100
CBD South	Colusa Basin	15	West Sac catch	Sac Riv	100
Davis catch	Bypass	100	Willow Slough	Putah Creek	48
Dunnigan Other	Colusa Basin	100	Willow Slough	Willow Slough	52
Dunnigan Water District	Colusa Basin	100	Winters catch	Putah Creek	100
Esparto CSD catch	Cache Creek	32	Woodland catch	Cache Creek	56
Esparto CSD catch	Willow Slough	68	Woodland catch	Willow Slough	44
Goodnow Slough	Cache Creek	85	YCFC Dunnigan Hills	Cache Creek	56
Goodnow Slough	Colusa Basin	15	YCFC Dunnigan Hills	Colusa Basin	44
Knights Landing catch	Sac Riv	100	YCFC East	Bypass	14
Madison CSD catch	Willow Slough	100	YCFC East	Cache Creek	21
North Delta East	Bypass	100	YCFC East	Putah Creek	16
North Delta West	Bypass	80	YCFC East	Willow Slough	49
North Delta West	Putah Creek	20	YCFC Hungry Hollow	Cache Creek	100
Oat Creek	Colusa Basin	100	YCFC West	Putah Creek	31
RD 108	Colusa Basin	74	YCFC West	Willow Slough	69
RD 108	Sac Riv	26	YCFC Zamora	Colusa Basin	100
RD 1600	Bypass	100	Yolo Zamora North	Colusa Basin	100
RD 2035	Bypass	37	Yolo Zamora South	Cache Creek	20
RD 2035	Cache Creek	22	Yolo Zamora South	Colusa Basin	80
RD 2035	Willow Slough	40			
RD 537	Bypass	100			
RD 730	Bypass	100			

Before contributing to these streams, 90% of runoff is available for reuse for irrigation, if there is a simulated demand for it. All groundwater recharge contributes to the groundwater node for RD 108.

Some land use data were provided by RD 108 but are not currently incorporated into the model because they were only provided for a few years and were not enough to incorporate at this time. Land use is based on DWR spatial data and Yolo County Ag Commissioner Reports (see section 0 for more information).

Sources of Information

Water License 3065
Water License 3066
Water License 3067

Water License 7060
Water Permit 21274
Settlement Contract 14-06-200-876A-R-1
RD 108 Groundwater Management Plan (2008) (RD 108, 2008)
Conversation with Bill Vanderwaal, 3/8/17
Landuse data, maps and water balance data provided by Bill Vanderwaal, 3/8/17

2.1.5.4.2 RD 787

Runoff generated by RD 787 (River Garden Farms) flows into the Sacramento River and the Colusa Basin Drain (See Table 1-4 for each catchments runoff destination). Most of the land is owned by River Garden Farms, with a small portion owned by Faye Properties. Unlike most other catchments, the annual land use data for this catchment is based on information provided by the district for both River Garden Farms and Faye Properties, for years 1987-2015. Prior to 1987, land use from the methods described in Chapter 0 were used. The difference of the total area of the district (approximately 10,000 acres) and the area classified as a crop-covered by the information provided by the district (approximately 6,000-7,000 acres) is considered native vegetation and is not irrigated (approximately 3,000-4,000 acres).

River Garden Farms has water rights from the Sacramento River and the Colusa Basin Drain. All rights from the Sacramento River (License 1718, 3123) are represented by a single diversion link which is limited by monthly diversions per Settlement Contract 14-06-200-878A-R-1 plus 10.5 TAF per year. This additional water represents the water available to the Faye Property, which, according to Roger Cornwell of River Garden Farms, uses 9-12 TAF of surface water per year. All water diverted from the Sacramento River in the model is subject to reductions of 25% in Shasta Critical Years in the YSGA model. Water License 4636 for the Knights Landing Ridge Cut is represented by a diversion from the Colusa Basin Drain to the catchment, limited by the max diversion rate of 19 cfs From April 1 to Sept 15. The state's water rights database indicates that River Garden Farms has applied for a permit for water from Lateral 14A. This is not included in the model. Before runoff generated within this catchment contributes to the streams mentioned above, 90% of runoff is available for reuse for irrigation, if there is a demand for it.

In the model, the land is first irrigated with water from the Sacramento River, then from the Colusa Basin Drain, and if more water is still needed to meet the irrigation demand, water is pumped from layer 2 of the MODFLOW groundwater model.

Sources of information

Water License 1718
Water License 3123
Water License 4636
Settlement Contract 14-06-200-878A-R-1
RD 787 Groundwater Management Plan (Luhdorff and Scalmanini, Consulting Engineers, 2012)
Landuse and diversion data supplied by Darren Cordova, MBK Engineering
Email exchanges with Darren Cordova, MBK Engineering

2.1.5.4.3 RD 2035

This area is mainly made up of land owned by Conaway Ranch (approximately 15,500 acres) and the remaining area (6,000 acres) is owned by other landowners. Runoff from this area flows into Yolo Bypass, Cache Creek and Willow Slough (See Table 1-4 for each catchments runoff destination).

Unlike most other catchments, the annual land use data for this catchment is based on information provided by the district for the area of Conaway Ranch, for years 1990 to 2015[19]. Prior to 1990, land use is based on the method described in section 0.

Conaway Ranch has water rights for the Sacramento River, Willow Slough, Cache Creek and the Yolo Bypass. In the YSGA model, a diversion from the Sacramento River represents Licenses 5487b, 904b, and 905 which are restricted under Settlement Contract 14-06-200-7422A-R-1 and another diversion represents the riparian right. Water under all rights except the riparian right is available up to the monthly allocation as outlined in the Contract. The diversion from Willow Slough represents Water License 6320, which makes 9.4 cfs available between April and October. The diversion from the Yolo Bypass represents Permit 19372, which makes 10,000 AF per year available between April and September. Water from the Sacramento River under the CVP permit is the first priority, so water is first taken from the Sacramento River under this right to meet demands. If additional water is needed, it is taken under the Yolo Bypass permit, then Willow Slough, and finally pumped from layer 2 in the MODFLOW groundwater model.

Conaway Ranch's riparian rights, for the Sacramento River and Cache Creek are represented in the model, but due to limited information on how much water is actually used under these rights, no water is available under them in the model. RD 2035 has reported no diversions from Cache Creek since 2008, which supports this assumption. Before runoff from this catchment contributes to the streams mentioned above, 90% of runoff is available for reuse for irrigation, if there is a demand for it.

Sources of Information

Water License 904B
Water License 905
Watr License 5487B
Water License 6320
Water Permit 19372
Settlement Contract 14-06-200-7422a-r-1
RD 2035 Groundwater Management Plan (1995)
Municipal Service Review and Sphere of Influence Study Yolo County Public Water and Reclamation Districts (2005)
Diversion and crop data supplied by Darren Cordova, MBK Engineering 9/7/18

[19] By using this land use in the later years, while it makes the crop data for the fields in Conaway Ranch more accurate, it may reduce the total cropped area because the area of land not owned by Conaway Ranch is categorized as native vegetation.

Various personal and email correspondences with Darren Cordova, MBK Engineering and Mike Hall, Conaway Preservation Group

2.1.5.5 Reclamation Districts east of the ship channel

RDs 150, 307, 765 and 999 are currently represented in the model as one combined catchment representing the entire area between the Ship Channel and the Sacramento River. Land use data was assembled using the method described in section 0. Because these districts do not supply irrigation water, it is unknown exactly how much water is available to them. However, it is likely that individuals who own land within these areas have their own water rights and have no shortage of surface water and therefore, this catchment is connected to the Sacramento River with a diversion. This makes unrestricted surface water available from the Sacramento River, mimicking riparian rights. While this area can pump groundwater in the model, due to the unrestricted surface water supply, this never occurs in the historical simulation.

Reclamation District 765 is currently included within the catchment "North Delta West", which receives unlimited surface water for irrigation from a source in the model called "Delta". Based on interactions with this district, it is assumed there is no shortage of surface water supply to this area as they pump water out of the area year-round.

Before any runoff contributes to the streams however, 90% of runoff is available for reuse for irrigation, if there is enough demand for it.

Sources of Information

Previously developed IWFM model of Yolo County
Meeting with Reclamation Districts 8/13/2018
Municipal Service Review and Sphere of Influence Study Yolo County Public Water and Reclamation Districts (2005)

2.1.5.6 Other Reclamation Districts

RDs 537, 730, 785, 827, 1600 and the "white area" west of RD 1600, called "Sac River" catchment in the YSGA model, are each represented by one catchment. Land use data was assembled as described in section 0. Because these districts do not supply irrigation water, it is unknown exactly how much water is available to them. However, it is likely that individuals who own land within these areas have their own water rights and therefore, each catchment is connected to the Sacramento River with a diversion with unrestricted surface water available from the Sacramento River, mimicking riparian rights. While these areas can pump groundwater in the model, due to the unrestricted surface water supply, this never occurs in the historical scenario. RD 730 also has an unlimited supply of water available from the Colusa Basin Drain, based on information from the previous IWFM model developed in Yolo County. This source is preferred only if sufficient water is not available from the Sacramento River, which does not occur in the historical simulation.

Runoff generated from these catchments is routed to various water bodies, listed in Table 1-4 .

Sources of Information

Previously developed IWFM model of Yolo County

Meeting with Reclamation Districts 8/13/2018
Municipal Service Review and Sphere of Influence Study Yolo County Public Water and Reclamation Districts (2005)
Correspondence with Michele Clark, RD 1600

2.1.5.7 Other Districts

2.1.5.7.1 Yolo County Flood Control and Water Conservation District (YCFC)

YCFC's service area covers a large portion of Yolo County and the Yolo Groundwater Basin. YCFC's service area boundary is represented by six catchments in the YSGA model. YCFC Capay, YCFC East, YCFC West, YCFC Hungry Hollow, YCFC Dunnigan Hills and YCFC Zamora (Figure 1-2). Land use data were assembled as described in section 0. Runoff from these catchments flows into various surface water bodies, as shown in Table 1-4.

YCFC delivers water to its customers through two main canals, the Winters Canal and the West Adams Canal. All catchments can draw water from the canals except the catchment which represents YCFC's customers in the Capay Valley ("YCFC Capay"), which draw water directly from Cache Creek. All areas can also draw water from their respective groundwater sources, which they do only if there is not sufficient surface water to meet their demands.

The annual allocation of available surface water to the district is calculated based on the Solano Decree and allocation logic described below. The total allocation is then distributed over 12 months based on percentages developed from 2007 diversions at Capay dam, and then each month is divided among the five catchments (all excluding YCFC Capay) based on percentages developed from 2016 delivery data provided by Max Stevenson, YCFC. Because the Clover Canal which currently delivers water to YCFC Dunnigan Hills was not built until 1985, no water is delivered to that catchment until after 1985 (per conversation with Max Stevenson, YCFC).

2.1.5.7.1.1 Solano Decree

Clear Lake, located in Lake County northwest of Yolo County, is a source of surface water for YCFC who then sells it to growers within their service area. In 1914 the Cache Creek Dam was constructed to add additional storage and to control lake releases to Cache Creek. The YCFC has a prior appropriation right to water released from Clear Lake, which is controlled by the Solano Decree, a legally binding agreement between Lake and Yolo Counties (Superior Court of the State of California, 1995, 1978).

The Decree is used to determine the total amount of water available from Clear Lake for the entire irrigation season as a function of the lake level on April 1. If the level is greater than or equal to 7.56 feet Rumsey (a local datum) then the YCFC can divert 150 TAF of water from the Lake. If the lake level is less than 3.22 feet at Rumsey, then no water is available for release. For lake levels between those thresholds the volume available is prescribed through tables and charts. The YSG model explicitly integrates the working logic of the Solano decree, based on earlier published work by the modeling team (Mehta et al., 2013, 2018).

2.1.5.7.1.2 Indian Valley Reservoir

YCFC also has a prior appropriation right to water released from Indian Valley reservoir, which was built later, in 1975. Water released from Indian Valley Reservoir flows down the North Fork of Cache Creek

into Cache Creek where it is available to YCFC. All water in this reservoir is available to YCFC except 20 TAF, which is reserved for municipal water supply to a nearby town.

2.1.5.7.1.3 YCFCWCD Irrigation Allocation

The total water available to YCFC from both reservoirs in each water year is calculated in the YCFC model in April. Each year, the "allocation", a number between 0 and 1 which represents the fraction of a full allocation that is available each year is calculated based on Equation 2-1.

Equation 2-1

$$Allocation = \frac{CL_{allowable\ withdrawal} + IV_{Apr\ 1\ storage} - IV_{carryover} - IV_{Evap}}{Full\ Allocation}$$

Where:

$CL_{allowable\ withdrawal}$ *= the allowable withdrawal from Clear Lake calculated based on the Solano Decree (explained above)*

$IV_{Apr\ 1\ storage}$ *= the volume of water in Indian Valley on April 1st in the model*

$IV_{carryover}$*= 20 TAF, the volume of water in Indian Valley reserved for municipal use*

IV_{Evap} *= Volume of water that will evaporate in Indian Valley in the following year, therefore not available to withdrawal, calculated as 11.22% of Indian Valley's April 1 storage, based on 2000-2009 simulations of SacWAM[20].*

Full allocation = 235 TAF, the maximum volume YCFC has diverted from Cache Creek in one water year between 1976 and 2009. This occurred in 2007.

The allocation is then multiplied by the *target diversion*, which is the largest diversion in a water year that YCFC has recorded since water year 1976: 235 TAF, and the *monthly distribution* which distributes the annual water availability across the irrigation months, based on 2007 distributions at Capay. This then gives the total volume of water available to YCFC for the water year, set as the maximum diversion on the diversion from Cache Creek at Capay dam, which then gets distributed among the five catchments within YCFC.

2.1.5.7.1.4 YCFC Canal Losses

It is understood that the unlined canal system loses water to groundwater. Canal losses were set in the model based on earlier IGSM modeling (WRIME, 2006), and a canal recharge feasibility field study (YCFCWCD, 2012). The total water available from Capay dam, minus losses in canals, is distributed among each YCFC catchment based on delivery data from 2016 provided by Max Stevenson. Because the Clover Canal which currently delivers water to YCFC Dunnigan Hills was not built until 1985, no water is delivered to that catchment until after 1985. The fraction of total available flows from Capay dam available to each catchment is shown in Table 2-13.

[20] https://www.waterboards.ca.gov/waterrights/water_issues/programs/bay_delta/sacwam/

Table 2-13. Fraction of total available water that is allocated to each catchment serviced by YCFC, based on 2016 subsystem flows.

	Percent of Serviced area prior to 1985	Percent of Serviced area 1985 and later
YCFC West	0.693	0.639
YCFC East	0.161	0.148
YCFC Hungry Hollow	0.145	0.133
YCFC Zamora	0.001	0.001
YCFC Dunnigan Hills	0	0.078

Sources of Information

Previous WEAP model development, conducted in coordination with the District. See:
Mehta V, Young C, Bresney S, Spivak D, Winter J. 2018. How can we support the development of robust groundwater sustainability plans? Calif Agr 72(1):54-64. https://doi.org/10.3733/ca.2018a0005.
Various conversations and meetings with Tim O'Halloran, Kristin Sicke and Max Stevenson
Canal diversion and delivery data sets provided by Max Stevenson
Canal Recharge Feasibility Study 2012 (YCFCWCD, 2012)
IGSM Report (WRIME, 2006)

2.1.5.7.2 Dunnigan Water District (DWD)

Land use data for DWD up to 2004 was assembled as described in section 0. From 2004 to 2017, land use is based on crop information provided by DWD's Donita Hendrix. Runoff generated contributes to the Colusa Basin Drain (See Table 1-4). Before this runoff contributes to the stream however, 90% of runoff is available for reuse for irrigation, if there is enough simulated demand for it.

The District has rights to surface water from the Tehama Colusa Canal. In the YSGA model, the diversion from the Tehama Colusa Canal to the catchment represents DWD's CVP Contract 14-06-200-399A-IR5, which states 19,000 AF of water is available each year. Deliveries in the model begin in April 1983, as stated in the Groundwater Management Plan (Davids Engineering Inc, 2007). However, it seems Dunnigan Water District often uses less water than their total water right. Hence in the YSGA model for the historical simulation, recorded monthly diversions are made available to Dunnigan Water District, which is a different approach from the representation of all other surface water rights in the model. When the allocation is lower than the District's demand for water, the District purchases water from settlement contracts to meet its customers' needs. However, it is also stated in the District's Groundwater Management Plan (Davids Engineering Inc, 2007) that growers irrigate on average, 2 AF per acre, which is quite low compared to other regions in the county. This is confirmed by conversations with Donita Hendrix from the District who stated that growers under-irrigate and that not all land is cultivated each year. Because of the difficulty in understanding how much additional water the District actually needs, additional purchases are not implemented in the model at this time. If additional water is needed for irrigation in the model, water is pumped from groundwater.

Sources of Information

2007 Groundwater Management Plan (Dunnigan Water District and Davids Engineering Inc, 2005; Davids Engineering Inc, 2007)
2005 Hydrogeologic Characterization Report of Dunnigan Water District (Davids Engineering Inc, 2007)
CVP Project Contract 14-06-200-399A-IR5
Email, telephone and in person communication with Donita Hendrix, Dunnigan Water District
Land use and water delivery data provided by Donita Hendrix, Dunnigan Water District

2.1.5.8 Areas outside of any district: "White Areas"

White areas in the model are areas that do not fall within the jurisdiction of a Reclamation district, city or other water and land use management agency. These areas have their own catchments, and land use data were assembled as described in section 2.1.1. In the northwest part of Yolo County, white areas are in Buckeye Creek, Bird Creek, Oat Creek and Goodnow Slough (Figure 1-2), whose boundaries are based on USGS HUC8 boundaries. The area within the Capay Valley that is not part of the YCFC service area is predominantly the steep hills, represented in the YSGA model as "Capay Other" catchment (Figure 1-2). The area from the western border of YCFC to the western border of the county past City of Winters is represented by a catchment called Willow Slough (Figure 1-2). In the model, only groundwater is made available for any irrigation in these areas. Buckeye Creek, Bird Creek, Oat Creek and Goodnow Slough have little irrigated land in the historical period. Additionally, the groundwater system in this area is very poorly understood (WRIME, 2006). This poses many challenges for modeling groundwater flows in this area.

White areas in the northeast part of the county occur in five catchments: Dunnigan Other (the area in Dunnigan Hills that is not serviced by YCFC), CBD North, Yolo Zamora North, Yolo Zamora South, and CBD South (Figure 1-2). These boundaries are mainly based on previously develop models' boundaries.

Except for CBD North and CBD South, it is assumed that only groundwater is available for irrigation. In CBD North and South, an unlimited supply of surface water is assumed available from the Colusa Basin Drain. Sufficient information on the actual surface water diverted by growers in these regions is currently unknown.

The white area occurring west of the ship channel, is included in one catchment called "North Delta West" (Figure 1-2), whose boundaries are based on previous modeling efforts. The small area that borders the Sacramento River, North Delta East and West Sacramento is not technically a White Area but RD 765. However, at this time its area is included within the catchment with the rest of the area west of the ship channel.

The catchment called "Sac River", the only area along the river that is not serviced by a Reclamation district, is assumed to have unlimited surface water supply from the Sacramento River.

Sources of Information

2.2 Groundwater Model Inputs

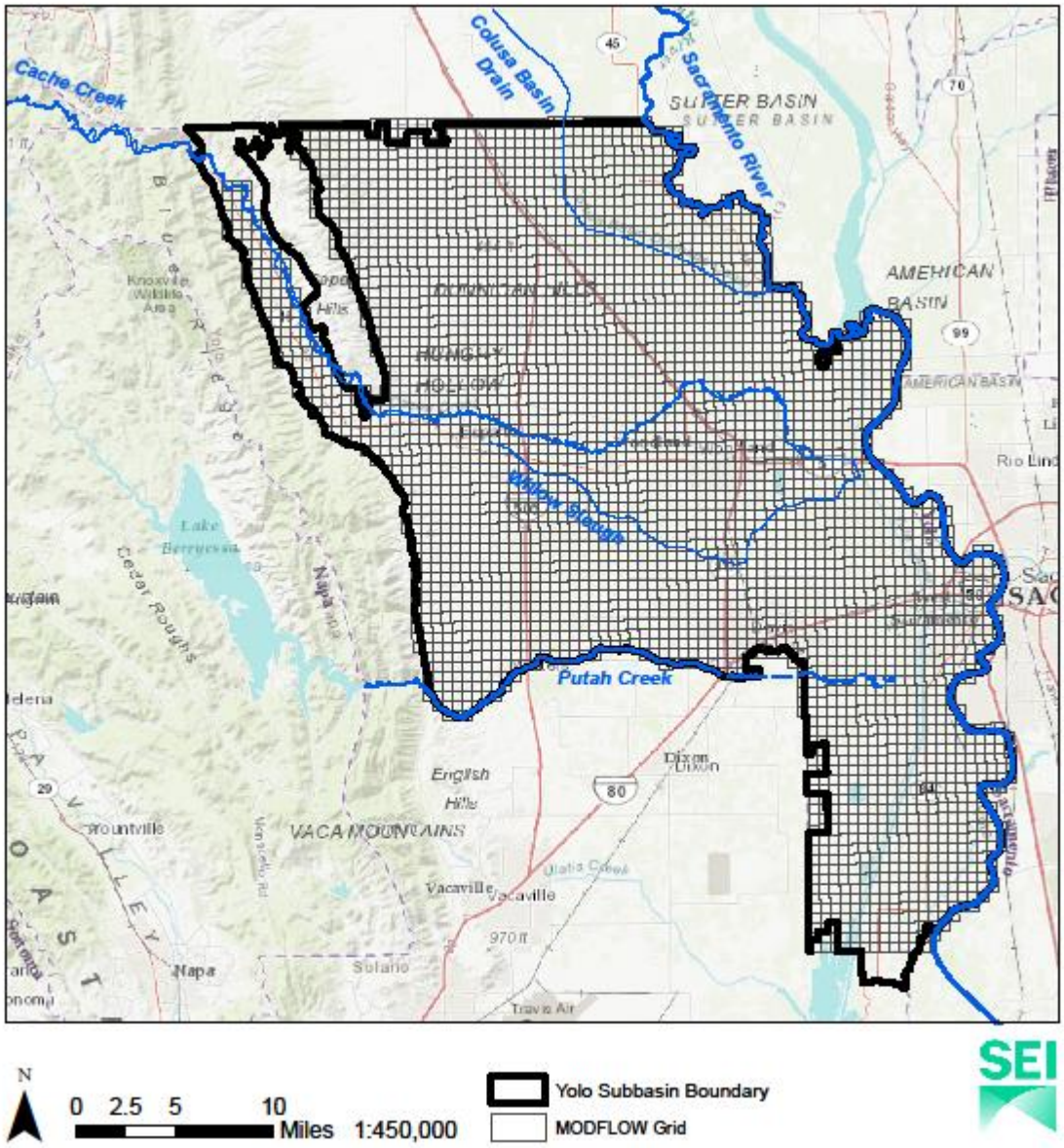
The MODFLOW model used in this effort was based on a model first developed by WRIME, Inc. using the IGSM software (WRIME, 2006) and further refined in the IWFM software by Carlos Arenas, Ph.D. student at U.C. Davis (Flores Arenas, 2016). For readers interested in a description of the hydrogeology of the Yolo County groundwater system and its representation in the original numerical model which served as the basis for this model, please see the WRIME (2006) report. Below, we provide a description of the MODFLOW model and the inputs that were extracted from the IWFM input files.

2.2.1 Model Domain

The MODFLOW model grid is made of uniform square cells that are ½ mile on a side. There are 85 rows from north to south and 80 columns from east to west. The size of the cells was chosen to provide resolution adequate to capture the shape of the important boundaries and features in the model domain. In the vertical dimension, the model consists of three layers representing the Quaternary Alluvium, the Upper Tehama Formation, and the Lower Tehama Formation. The ground surface elevation and geological unit contacts were extracted from the IWFM model input files. Elevations were interpolated for a point at the center of each MODFLOW grid cell using the nearby points on the IWFM mesh.

The boundary of the MODFLOW model domain follows the same boundaries as the IWFM model in most cases (Figure 2-3). The western edge corresponds with the contact between the Coast Range and the valley floor sediments and includes the Capay Valley floor. The northern border of the model coincides with the Yolo – Colusa County line. The eastern border of the model coincides with the Sacramento River. From the Sacramento River, moving west, the southern boundary coincides with boundary of Solano County. Near the city of Davis the model boundary follows Putah Creek upstream to where the creek emerges from the Coast Range close to the town of Winters. The southern boundary in this model differs from the IWFM model in that the boundary follows the county boundary (and Putah Creek) while the IWFM model has the boundary located south of the Creek. This change was made to simplify the specification of recharge and groundwater pumping boundaries using the existing WEAP model that has a boundary at the county border.

Figure 2-3. MODLFOW model domain and subbasin boundary.



2.2.2 Model Boundary Conditions

2.2.2.1 Pumping and Recharge Boundaries

The groundwater pumping and recharge boundaries are calculated on a monthly time step by the surface water hydrology and management routines in the WEAP software. The groundwater pumping boundary is applied to the same layers as specified in the IWFM model, mostly to layer 2. The WEAP software writes the input file for the MODFLOW WEL package for each month of the simulation. The recharge boundary is applied to layer 1 unless it does not exist in which case it is applied to layer 2. The WEAP software writes the input file for the MODFLOW RCH package for each month of the simulation.

2.2.2.2 Drain Boundary

In regions close to the Sacramento River where the water table can be close to the ground surface, surface channels provide a route for the discharge of groundwater into the surface water system. To mimic that process the MODFLOW DRN package was used to place a drainage boundary in reclamation Districts 108, 1600, 730, 787, and North Delta East and North Delta West. The drains were placed at an elevation 4 feet below the ground and given an estimated conductance of 4,500 ft^2/d.

2.2.2.3 Lateral boundaries

In general, the lateral boundaries in the MODFLOW model are either no-flow or general head boundaries, similar to the IWFM model. On the west side of the model the contact between the valley floor sediments and Coast Range (including the Capay Valley) is a no flow boundary. Along the northern edge of the model domain general head boundaries were imposed for all three layers. Along the eastern edge of the model, which follows the Sacramento River, general head boundaries were imposed in all three layers for the southern portion of the boundary starting due east of the city of Woodland and extending to the southernmost point on the model domain. The boundary north of the City of Woodland is no flow, remaining consistent with the IWFM model. General head boundaries were also applied in all three layers to the boundaries with Solano County. All general head boundary conditions were imposed using the MODFLOW GHB package.

2.2.2.4 Stream boundaries

Stream-aquifer interactions are simulated in the model using the MODFLOW RIV package. Remaining consistent with the IWFM model, these boundaries were applied for Cache Creek, Putah Creek, Willow Slough, Sacramento River, Knights Landing Ridge Cut, Colusa Basin Drain, Yolo Bypass, and the Ship Channel. Channel geometry information and streambed conductivity information were obtained from the IWFM input files.

2.2.3 Aquifer Hydraulic Parameters

In the MODFLOW model, the Block Centered Flow package version 6 (BCF6) was used to simulate groundwater flow. The aquifer hydraulic parameters required for this package were extracted from the IWFM input files. To obtain parameter values, a grid of points located at the MODFLOW cell centers was overlaid with the IWFM nodes and nearest neighbor assignments were made to each MODFLOW cell center. The values for horizontal hydraulic conductivity, specific yield, storage coefficient, and vertical hydraulic conductivity for each MODLFOW cell center were then extracted from the nearest neighboring IWFM node. VCONT values (vertical hydraulic conductivity divided by the thickness from a layer to the layer below) were calculated using the vertical hydraulic conductivities and layer thickness values using Equation 5-39 in the MODFLOW 2005 documentation (Harbaugh, 2005).

2.2.4 Initial heads

The MODFLOW model initial heads for October 1, 1970 were taken from the IWFM input files based on the nearest neighbor approach described above.

3 Model Calibration

The combined WEAP-MODFLOW model was calibrated in a series of steps. The initial steps were focused on the surface water processes including rainfall runoff, reservoir operations, crop ET, and irrigation management. With those portions of the model calibrated the groundwater pumping and recharge boundary conditions for the groundwater model were set and calibration of the ground water model was then completed. The observation data used in calibration are listed in Table 3-1.

Table 3-1 Calibration field and datasets

Type	Subtype	Location	Period of Data Downloaded	Data source
Catchment water balance	Streamflow	Kelsey Creek	Oct 1976-Sept 2008, monthly	USGS: https://waterdata.usgs.gov/ca/nwis/uv?11449500
Catchment water balance	Streamflow	Hough Springs	Oct 1976-Sept 2008, monthly	USGS: https://waterdata.usgs.gov/ca/nwis/uv?11451100
Catchment water balance	Streamflow	Cache Creek at Yolo	Oct 1974- Sept 2009, monthly	USGS: https://waterdata.usgs.gov/nwis/uv?site_no=11452500
Catchment water balance	Reference ET (ETo)	Davis CIMIS station	Aug 1982 to July 2017, monthly timestep	CIMIS: http://www.cimis.water.ca.gov/WSNReportCriteria.aspx Downloaded on 8/28/2017
Catchment water balance	Solar Radiation			
Catchment water balance	Actual ET	Actual ET for 19 crop categories	2005, monthly timestep	DWR's CUP model version 6.9: https://water.ca.gov/Programs/Water-Use-And-Efficiency/Land-And-Water-Use/Agricultural-Water-Use-Models Sacramento San Joaquin Basin Study: https://www.usbr.gov/watersmart/bsp/docs/finalreport/sacramento-sj/Sacramento_SanJoaquin_TechnicalReport.pdf
Catchment water balance	Applied Water	DWR water portfolio, at Detailed Analysis Unit (DAU) resolution	1998-2010, annual timestep	DWR Land and Water Use: http://www.water.ca.gov/landwateruse/anlwuest.cfm
Operations	YCFC deliveries sales and canal losses	Releases from Capay dam, and sales from Winters and West Adams canal	1975-2013, Monthly timestep	YCFC, personal communication, 2015
Operations	Reservoir Volume	Volume in Clear Lake and Indian Valley Reservoir	1974-2009, monthly timestep	YCFC, personal communication, 2015
Groundwater	Groundwater Levels	All wells in the database (in and near Yolo County)	Time series available for each well (varies by well)	WRID database (https://wrid.facilitiesmap.com/login.aspx) YCFC, personal communication, 1/30/2017
Groundwater	Groundwater Levels	All data for all wells within 5km of Yolo County's border	Time series available for each well (varies by well)	DWR Water Data Library http://www.water.ca.gov/waterdatalibrary/index.cfm downloaded 12/8/16

3.1 Surface Water Calibration

3.1.1 Rainfall Runoff

The initial step was to calibrate the catchments in the upper Cache Creek portion of the model that are upstream of the sub basin boundary but supply irrigation water to the sub basin. Streamflows in North Fork of Cache Creek at Hough Springs and Kelsey Springs, the tributaries to Indian Valley Reservoir and Clear Lake, respectively, which have USGS stream gauges, were calibrated in the model by adjusting soil parameters in the catchments which runoff into these creeks. Cache Creek downstream, at Yolo, was also calibrated by adjusting reservoir outflows, diversions (see the following sections on Operations) and soil parameters in the corresponding catchments. Goodness of fit statistics are shown in Table 3-2 and the observed and modeled streamflows for each creek are shown in Figure 3-1, Figure 3-2, and Figure 3-3.

Table 3-2. Calibration statistics for streamflows, compared to USGS gauges.

	Kelsey Creek	**North Fork Cache Creek at Hough Springs**	**Cache Creek at Yolo**
NSE	0.89	0.82	0.81
RMSE (AF)	2,592	5,609	40,247
PBias (%)	-5	-13	-13
Calibration period	Oct 1976-Sept 2008, monthly	Oct 1976-Sept 2008, monthly	Oct 1974- Sept 2009, monthly

Figure 3-1. Observed and modeled streamflow in Kelsey Creek.

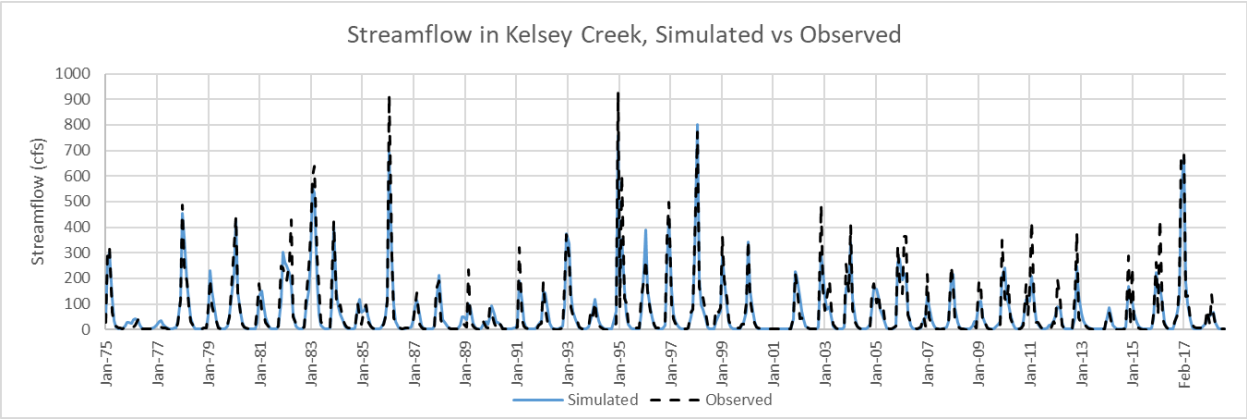


Figure 3-2 Observed and modeled streamflow in North Fork Cache Creek at Hough Springs.

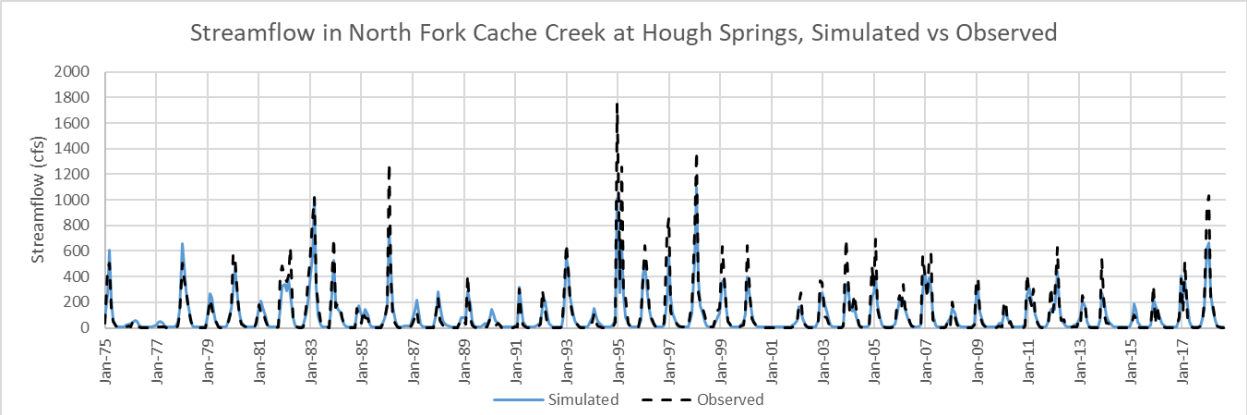
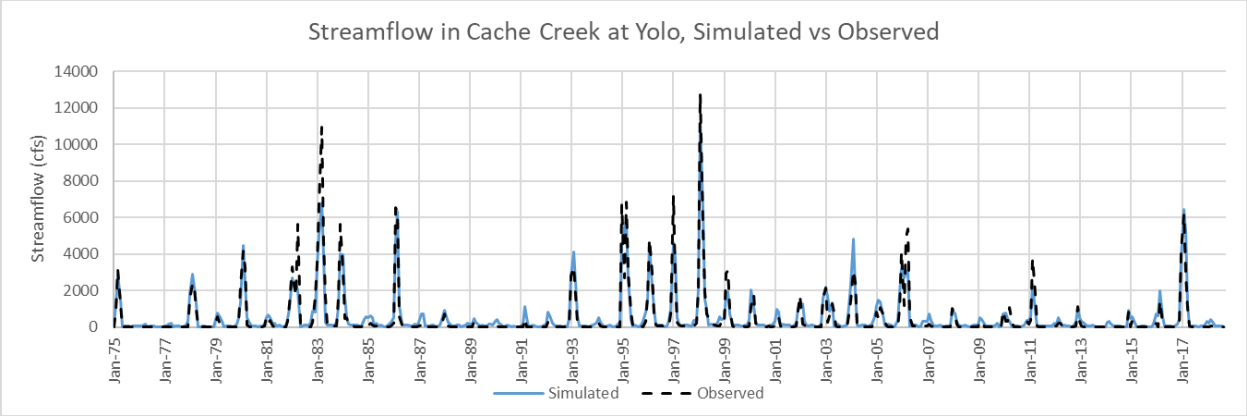


Figure 3-3. Observed and modeled streamflow in Cache Creek at Yolo.



3.1.2 Reservoir operations

The second stage of calibration was focused on Clear Lake and Indian Valley reservoirs. Reservoir volumes are determined by a combination of upstream hydrology, operating rules, and irrigation demands further downstream. Operating rules for Clear Lake are largely determined by the Solano Decree (Superior Court of the State of California, 1995, 1978) in the irrigation season and the Gopcevic decree in the winter. Indian Valley operating rules were obtained from YCFCWD. These rules have been integrated into the YSGA model, as described earlier in (Mehta et al., 2013). Later sections of this chapter describe the calibration of applied water and canal deliveries, which have a bearing on the calibration of these reservoir volumes.

Model performance for the two reservoirs are shown in Table 3-3. Modeled and observed volumes are shown in Figure 3-4 and Figure 3-5.

Table 3-3 Calibration statistics for the two reservoirs in the model

	Clear Lake	**Indian Valley**
NSE	0.91	0.89
RMSE (AF)	32,937	31,001
PBias (%)	-1.4	-2.4
Calibration period	Water Year 1974-2010 (monthly)	Oct 1975- May 2010 (monthly)

Figure 3-4. Clear Lake observed and modeled volumes.

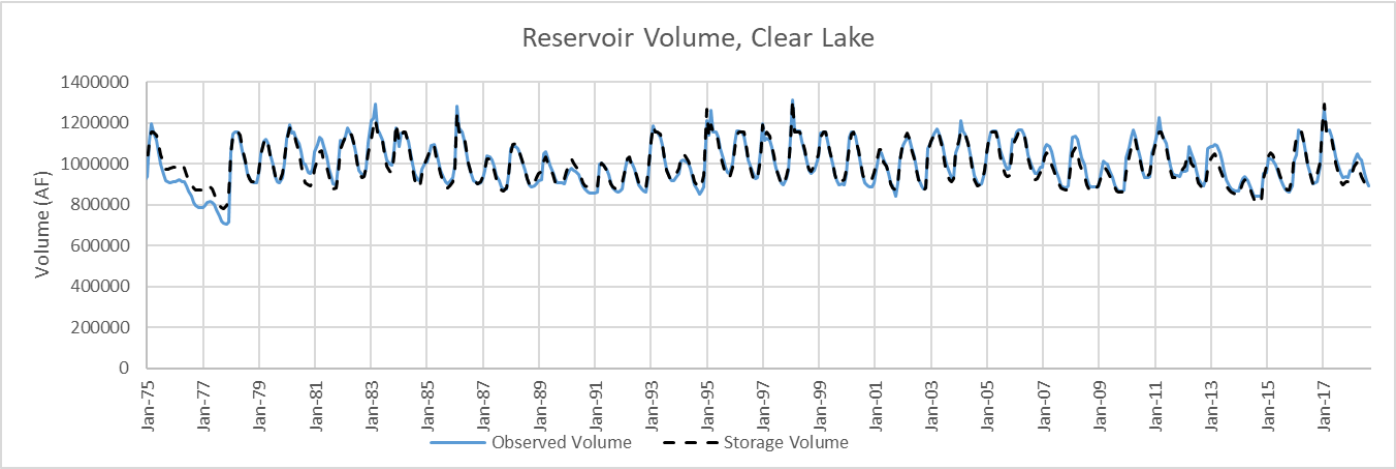
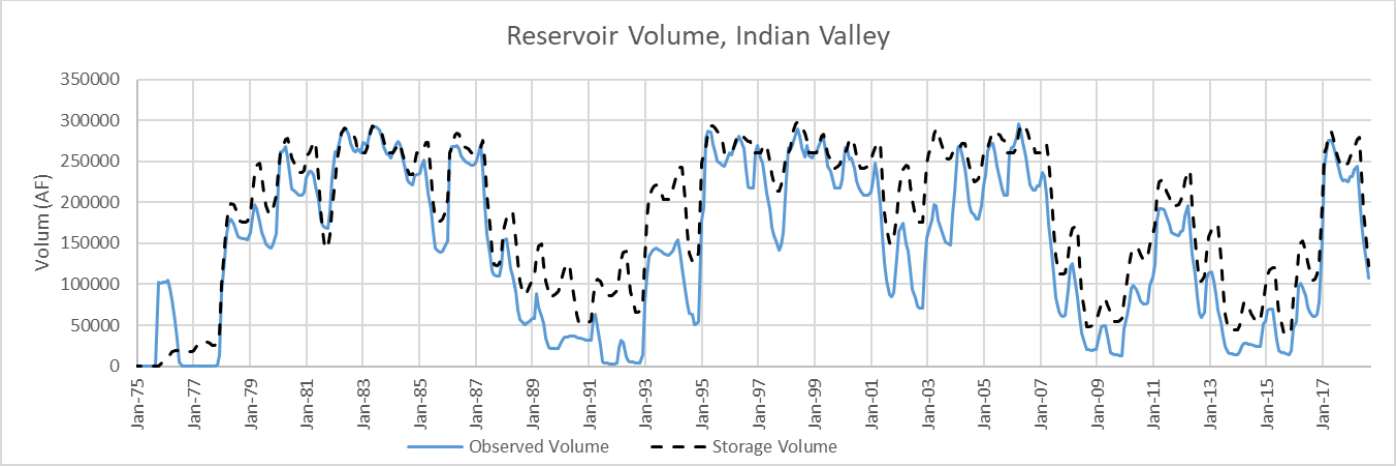


Figure 3-5. Indian Valley Reservoir observed and modeled volumes.



3.1.3 Crop evapotranspiration

Crop ET was simulated using the routines in the MABIA module of WEAP. These routines calculate crop ET using the dual crop coefficient approach described in FAO 56 (Allen et al., 2005). As a first step, the calculations of solar radiation and reference ET were validated by comparison with observations. Following that, basal crop coefficients were calibrated so that crop ET from the dual crop coefficient method in MABIA agreed with ET rates used in the Sacramento – San Joaquin Basin Study (Reclamation, 2015). The Basin Study ET rates were computed by Andy Draper of MWH in a technical memorandum using crop coefficients provided by DWR. The details of these calculations are not in the published reports on the Basin Study, they are provided as an appendix to this report.

3.1.3.1 Solar Radiation and Reference ET

Solar radiation and reference ET in the MABIA module are calculated using the Hargreaves method and the Penman Monteith equation. To verify the simulated values the calculated solar radiation and reference ET were compared against CIMIS data downloaded from the Davis CIMIS station. Average monthly modeled and CIMIS solar radiation values are shown in the following tables and figures (Solar radiation: Table 3-4 and Figure 3-6, Reference ET:

Table 3-5, Figure 3-7) for water year 1983-2015. The calculations show a reasonable match for solar radiation and reference ET.

Table 3-4. Monthly average solar radiation in watts per square meter (Averaged over WY 1983-2015).

Month	Modeled S (W/m2)	CIMIS S (W/m2)	Diff (Model-CIMIS), W/m2
Jan	91	80	11
Feb	128	124	4
Mar	181	183	-2
Apr	245	250	-5
May	295	294	1
Jun	325	328	-3
Jul	333	330	3
Aug	301	298	3
Sep	242	238	3
Oct	169	168	1
Nov	109	103	6
Dec	82	72	10

Figure 3-6. Monthly average solar radiation in watts per square meter. Averaged over WY 1983-2015.

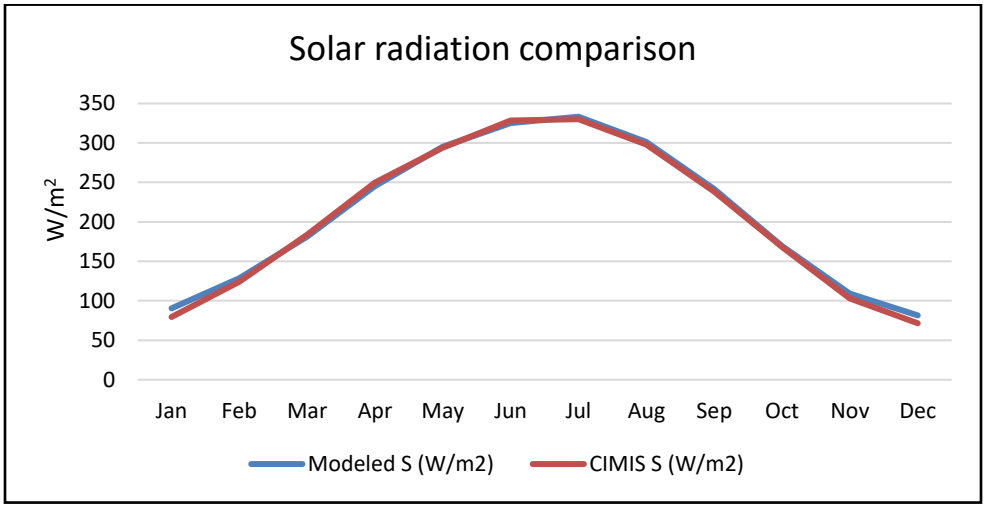
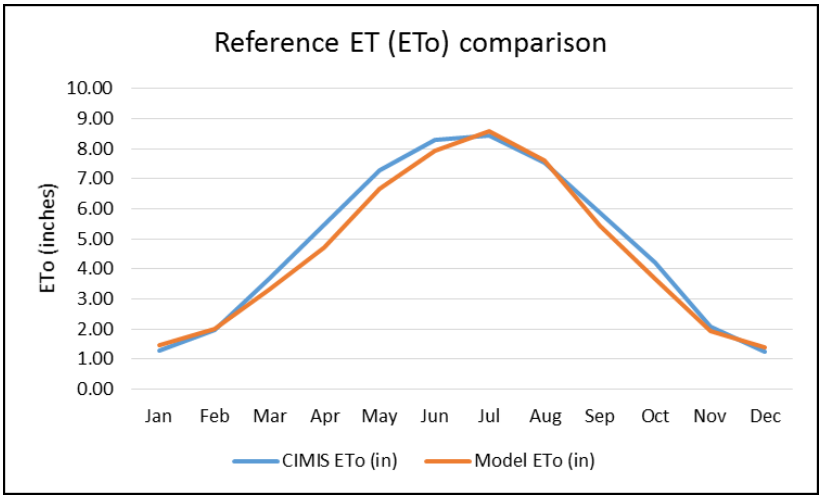


Table 3-5. Observed reference ET (ETo), modeled ETo and the difference between them. Averaged over WY 1983-2015.

Month	CIMIS ET_o (in)	Model ET_o (in)	Diff(Model ET_o-Obs ET_o)
Jan	1.27	1.48	0.20
Feb	1.96	2.01	0.05
Mar	3.69	3.30	-0.39
Apr	5.46	4.71	-0.75
May	7.27	6.68	-0.59
Jun	8.30	7.95	-0.35
Jul	8.45	8.60	0.15
Aug	7.53	7.60	0.06
Sep	5.86	5.46	-0.40
Oct	4.21	3.66	-0.55
Nov	2.08	1.95	-0.12
Dec	1.26	1.38	0.13
Total	57.34	54.77	-2.57

Figure 3-7. Average monthly ET_o, in inches (Averaged over WY 1983-2015).



3.1.3.2 Crop Coefficients

Basal crop coefficients were developed by adjusting the coefficients so that the crop ET from the YSGA model matched the monthly crop ET rates for the WY 2005 irrigation season as simulated using DWR's CUP model. ET rates for most crops came from the results of CUP model runs done for the Basin Study (Reclamation, 2015). Additional CUP model runs were done for crops not simulated in that study. Planting dates, harvest dates, and growth period lengths from the Basin Study were used for all crops (Table 3-6). The exceptions were the following cases:

1. Squash, the representative crop for Cucurbits. In this case, the planting date of April 1 from FAO 56 was used instead of Jan 15. Crop ET was simulated with CUP version 6.9.
2. Asparagus, the representative crop for Other Truck. Crop ET was simulated with CUP version 6.9.
3. Walnuts, representative crop for Other Deciduous. Crop ET was simulated with CUP version 6.9.
4. Sunflower, representative crop for Other Field. Crop ET was simulated with CUP version 6.9.
5. Olives, representative crop for Subtropical. Crop ET was simulated with CUP version 6.9.
6. The values for the Young Almonds category (almond trees up to three years old) were set based on a UCANR study on young almonds (Jarvis-Shean et al., 2018) as there was no representation of this category in the Basin Study.

In the YSGA model, the k_{cb} values in the MABIA module were adjusted so that crop ET from during the irrigation season was within a 3% difference of the CUP model value. For tomato and grain, it was necessary to adjust the length of the growth periods while maintaining overall season length. Even with the additional adjustments, grain ET could only be calibrated within a 4% difference from the Basin Study. This was likely due to differences in the input precipitation data sets. The YSGA model used gridded PRISM data that contain springtime rain that does not appear in the CIMIS record. For Safflower the irrigation schedule was adjusted to stop irrigation on July 15, even though harvest occurs on July 31, based on the literature which states that safflower is minimally irrigated, sometimes only once a season,

and irrigation could be stopped as early as May.[21] The comparison between the YSGA model and CUP model ET rates is shown in (Figure 3-8 and Table 3-7).

Following the effort described above, the basal crop coefficients were reduced by 5% to account for decreased crop vigor and bare spots (ITRC, 2003).

[21] Based on: https://coststudyfiles.ucdavis.edu/uploads/cs_public/63/a9/63a948b0-8cef-4843-b66c-ac27006f726f/safflowersv2011.pdf

CUP Model								YSGA model								Both models	
Crop name	Stage length (days)				Crop Coefficients			Crop Name	Stage length (days)				Crop Coefficients			Plant Date	Total Growing Season Days
	Init	Dev	Mid	Late	K_c ini	K_c mid	K_c end		Init	Dev	Mid	Late	K_{cb} ini	K_{cb} mid	K_{cb} end		
Alfalfa	91	91	91	91	1	1	1	Alfalfa	91	92	91	91	0.9	0.9	0.9	1-Jan	365
Almonds[1]	0	115	92	23	0.55	1.2	0.65	Almonds	0	115	91	23	0.4	0.95	0.65	1-Mar	229
Corn (grain)	31	38	46	38	0.2	1.05	0.6	Corn	31	38	46	38	0.12	0.85	0.52	1-May	153
Squash	18	28	27	18	0.5	0.95	0.75	Cucurbits	25	35	25	15	0.15	0.9	0.7	1-Apr[1]	100[2]
Dry Bean	26	17	55	10	0.15	0.9	0.15	Dry Bean	26	17	55	10	0.15	0.9	0.15	15-Jun	108
Wheat	53	74	64	21	0.3	1.05	0.15	Grain	53	79	39	41	0.05	0.7	0.05	1-Nov	212
Walnuts	0	115	57	57	0.55	1.2	0.6	Other Deciduous	0	115	57	57	0.5	1.1	0.55	1-Apr	229
Sunflower	27	33	47	27	0.2	1.05	0.4	Other Field	27	33	46	27	0.1	0.95	0.35	1-May	133
Asparagus	44	47	256	18	0.25	0.95	0.25	Other Truck	44	47	256	18	0.25	0.95	0.25	1-Jan	365
Pasture	91	91	91	91	0.95	0.95	0.95	Pasture	91	92	91	91	0.9	0.9	0.9	1-Jan	365
Rice	33	18	68	19	1.2	1.05	0.8	Rice	33	18	69	19	1.16	0.9	0.9	15-May	139
Safflower	21	34	43	24	0.2	1.05	0.25	Safflower	21	34	43	24	0.1	0.7	0.1	1-Apr	122
Sugarbeet	30	60	70	40	0.2	1.15	0.95	Sugarbeet	30	60	70	40	0.15	0.95	0.85	15-Mar	200
Olives	0	120	124	120	0.9	0.9	0.9	Subtropical	0	120	125	120	0.9	0.9	0.9	1-Jan	365
Tomato	38	38	46	31	0.2	1.2	0.6	Tomato	48	39	45	21	0.05	0.85	0.35	1-Apr	153
Wine grapes	0	54	108	54	0.45	0.8	0.35	Vine	0	54	107	54	0.05	0.5	0.25	1-Apr	215
NA								Young Almonds	0	115	57	57	0.2	0.5	0.3	1-Mar	229

[1] Mid-season crop coefficients for almonds and other tree crops may vary between 0.90 – 1.15 depending on whether a cover crop is present.

[2] Plant date is Jan 15 in the Basin Study

[3] Total number of days to maturity is 91 in the Basin Study

Table 3-6. Growth stage length and kc values from the Basin Study and the WEAP model, after calibration and modifications to reduce ET.

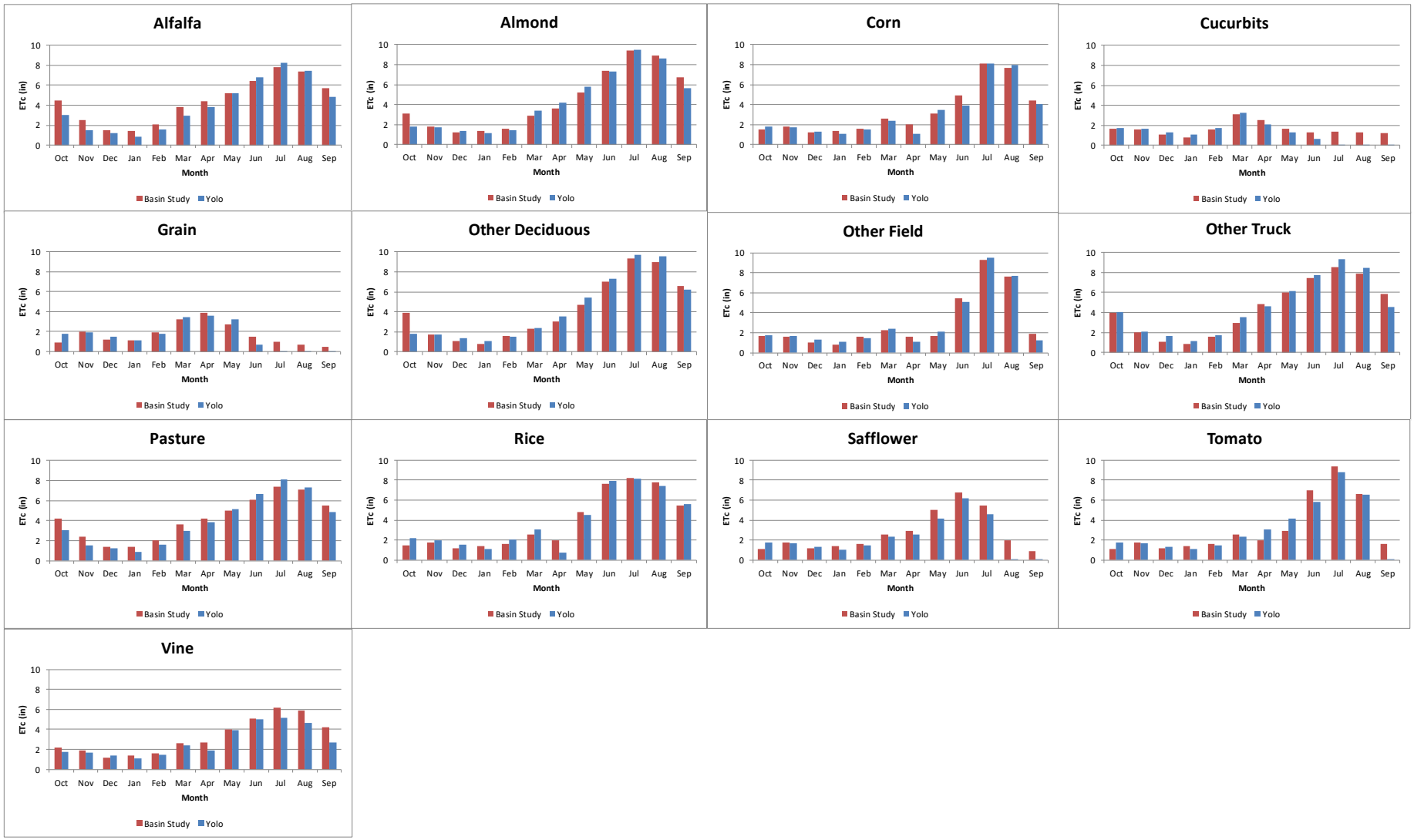


Figure 3-8. Comparison of monthly simulated crop ET rates from Basin Study (red) and YSGA models (blue).

Crop	Irrigation Season	Basin Study Actual ET (in)	WEAP Actual ET (in)	% Diff
Alfalfa	Ap-Sep	36.9	36.3	-1.5
Almond	March-Oct	47.2	46.1	-2.4
Corn	May-Sep	28.2	27.5	-2.6
Cucurbits	Jan-Apr	8.1	8.2	1.8
Grain	Nov-May	16.0	16.6	3.8
Other Deciduous	March-Oct	45.7	45.8	0.3
Other Field	May-Sep	26.0	25.7	-1.2
Other Truck	Ap-Sep	40.5	40.8	0.8
Pasture	Ap-Sep	35.3	35.9	1.7
Rice	May-Sep	33.9	33.6	-0.8
Safflower	Apr-Jul	20.2	17.5	-13.2
Tomato	April-Aug	27.9	28.4	1.8
Vine	April-Nov	32.2	26.8	-16.8

Table 3-7. WEAP and CUP ET comparison.

3.1.4 Irrigation water management

After setting the crop ET parameters, the applied water rates in the model were calibrated to DWR's applied water data[22] for the Detailed Analysis Unit titled "Lower Cache Creek." Average annual applied water was calculated for 1998-2010 for all crops that existed in those years. The irrigation efficiency parameter in the MABIA module was adjusted until the simulated applied water agreed with the DWR values within 3% (Table 3-8). The exceptions to this approach were for rice, cucurbits (squash) and other truck (asparagus). In MABIA the irrigation efficiency parameter is not used for flooded crops. Instead, to adjust applied water, the flow through parameter was adjusted to 2 mm/d. For cucurbits (squash), a value of 18 inches of applied water was indicated by the UC Davis Cooperative Extension[23], and 30 inches for other truck (asparagus).[24] For other truck, adjusting the irrigation efficiency was not enough to achieve the desired level of calibration, likely due to discrepancies in selected representative

[22] Data can be accessed here: https://water.ca.gov/Programs/Water-Use-And-Efficiency/Land-And-Water-Use/Agricultural-Land-And-Water-Use-Estimates

[23] 18 inches if based on information from the UC Davis Small Farm Program http://sfp.ucdavis.edu/crops/squash1/

[24] 30 inches is based on information from the UC Davis Vegetable Research and Information Center: https://anrcatalog.ucanr.edu/pdf/7234.pdf

crops between the DWR categories and the WEAP categories. Since this crop type is a relatively small area in Yolo County no further calibration was attempted.

Table 3-8. Comparison of average applied water from DWR DAU's and WEAP for each crop.

Crop	Irrigation Efficiency	WEAP	Lower Cache Creek DAU	Difference (%)
Alfalfa	54	5.15	5.29	-2.81
Almond	74	4.01	4.10	-2.25
Corn	58	2.91	2.99	-2.62
Cucurb	80	1.46	1.50[2]	-2.56
DryBean	69	1.88	1.91[3]	-1.60
Grain	28	1.16	1.16	-0.51
Oth Dec	72	4.22	4.12	2.43
Oth Fld	63	2.53	2.58	-1.79
Oth Trk	100	2.79	2.50[2]	10.47
Pasture	49	5.64	5.77	-2.35
Rice	83, 2[1]	5.38	5.52	-2.72
Safflwr	95	0.88	0.90	-1.66
SgrBeet	62	3.93	4.02[4]	-2.20
Subtrop	90	3.40	3.30[5]	2.94
Tomato	54	2.91	2.98	-2.47
Vine	96	1.55	1.59	-2.68
Young Almonds	95[6]			

[1] This value is the release requirement in flooding, in millimeters. This is the value that was adjusted in calibration for rice rather than irrigation efficiency, which is also indicated above.
[2] This value is from a UC Davis Cooperative Extension resource.
[3] This value is the average of 1998 only.
[4] This value is the average of 1998-2000 only.
[5] This value is the average of 2000 only.
[6] No observed information is available for Young Almonds, so efficiency was set and not later adjusted.

3.2 Groundwater Calibration

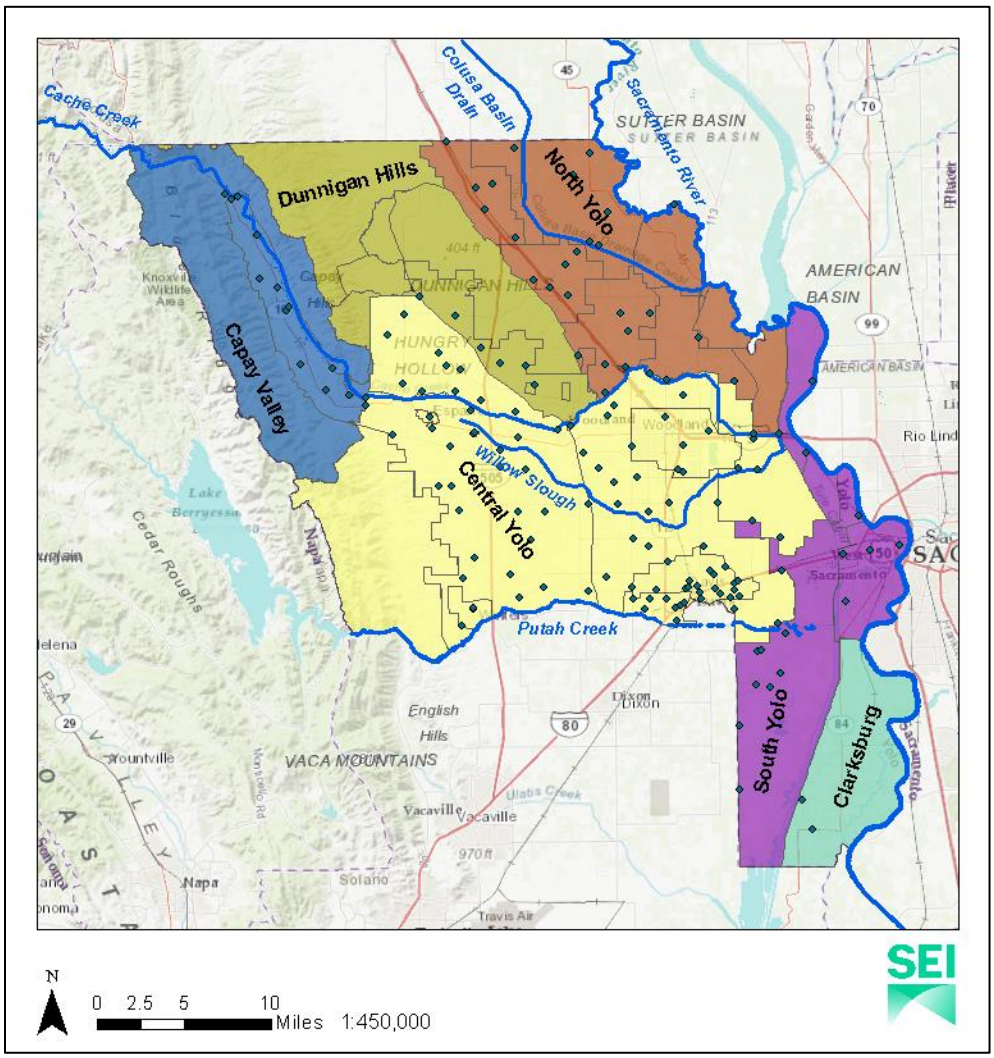
Calibration of the MODFLOW groundwater model was focused on comparisons of simulated values with observations of water levels in wells and reported stream seepage rates. In the discussion below, details about the calibration targets, calibration methods, and calibration results are provided.

3.2.1 Calibration Targets

3.2.1.1 Observation Wells

The modeling team worked with Yolo County Flood Control and Water Conservation District staff to identify 174 monitoring wells throughout the study area that have: a multi-decade record of observations during the study period of Water Years 1971 – 2018, a known well depth, and a known location and ground surface elevation. The wells are distributed throughout the County but do not provide uniform coverage of all regions (Figure 3-9). The Central Yolo, Capay Valley, and North Yolo management areas have the densest coverage of wells, largely due to the long running data collection efforts by the Yolo County Flood Control and Water Conservation district. The Clarksburg and South Yolo management areas have relatively few observation wells. The Dunnigan Hills management area has the largest area without any observation wells. This includes the Dunnigan Hillls, Buckeye Creek, Bird Creek, and Oat Creek sub-regions. Due to the lack of available observation data in some regions, the requirement that a well have multiple decades of observations was relaxed in some cases. The focus was on wells with multiple observations during the final two decades of the simulation period.

Figure 3-9. Location of observation wells used in groundwater model calibration.



3.2.1.2 Stream Seepage Estimations

Published estimations of stream seepage for water bodies in the Yolo County area were used to provide guidance in the calibration of stream bed conductivity.

A review of previous studies for Putah Creek reports a groundwater ridge in connection with the creek for most of the stream in the study area (Luhdorff and Scalmanini, Consulting Engineers, 2010). A study from 1961-1975 found an average annual stream seepage loss of 18,133 af/yr (Mullen and Nady, 1985). This is similar to the annual average value (1971-2000) from the IGSM groundwater model of 21,800 af/yr (WRIME, 2006).

In the same study for years 1961 – 1975 (Mullen and Nady, 1985) the portion of Cache Creek between Capay and Rumsey had an average gain of groundwater of 440 af/yr. The lower portion of the Creek from Capay to Yolo had an average loss of 25,400 af/yr. These values compare with 2,600 af/yr of gain and 37,900 af/yr of average loss for 1971-2000 from the IGSM model for the upper and lower reaches, respectively (WRIME, 2006).

Detailed analyses of other streams in the study area were not found. In general, an analysis of the C2VSim groundwater model suggests that all streams on the valley floor in the study area are losing streams during the period of 2000 - 2009 (The Nature Conservancy, 2014). This is in comparison to the IGSM study that indicates the Sacramento River and Yolo Bypass are gaining streams during 1971-2000.

3.2.2 Calibration of Groundwater Heads

The initial specification of aquifer hydraulic parameters, including horizontal and vertical hydraulic conductivity, specific yield, and storage coefficient, was done using the values in the IWFM model used in the dissertation by Carlos Arenas (Flores Arenas, 2016). Initial comparisons between simulated and observed heads at the wells discussed above showed relatively poor performance in comparison to that achieved by the IWFM model. To a degree, this was expected as the specification of pumping and recharge in the WEAP-MODFLOW model were calculated using a different algorithm than that in IWFM and they are not as highly resolved spatially. For that reason, the modeling team partnered with Carlos Arenas to work at improving model performance through a calibration process. The initial calibration was based on the assumption that the horizontal conductivities developed for the original IGSM model were the least uncertain. The other aquifer parameters, vertical conductivity and storage terms, were considered less certain and were adjusted to improve model performance.

During this stage of the calibration process the focus was on adjusting vertical conductivities to better match observed groundwater head elevations and adjusting storage terms to better match the seasonal fluctuations in groundwater heads. During this process it was found that a reduction in the fraction of irrigation inefficiency that results in deep percolation improved model performance for some regions. This was achieved by introducing a factor that scaled the parameters described in Section **Error! Reference source not found.**. This factor had a value of 1.0 in the Capay Valley sub-region, a value of 0.7 in the western portion of the Central Yolo management area and the entire Dunnigan Hills management area. A value of 0.3 was used in the North Yolo management area and the northern portion of the South Yolo management area. A value of 0.7 was used in the southern portion of the South Yolo management area and the Clarksburg management area.

During calibration it became apparent that in the region of Buckeye Creek, Bird Creek, Oat Creek, and Goodnow Slough simulated groundwater heads were falling and affecting the heads in Hungry Hollow area. A review of the original IGSM model showed a similar pattern of falling simulated heads in the Hungry Hollow wells which conflicts with the observations. This resulted in losses in groundwater storage that did not seem realistic, given that the well observations show a dynamic equilibrium similar to other wells. To remedy this, the native vegetation land cover parameters in Buckeye Creek, Bird Creek, Oat Creek, Dunnigan Other, and Goodnow Slough was adjusted to maximize deep percolation and produce little surface runoff. Horizontal hydraulic conductivity values were also adjusted by a factor of 0.5 in the Buckeye Creek, Bird Creek, Oat Creek, and Goodnow Slough sub-regions and by a factor of 0.1 for the Dunnigan Other sub-region. With this adjustment, the groundwater storage in this region fluctuated during the simulation but ended close to the initial storage at the end of 2018. Future efforts with this model should address the lack of information available in this region so that it can be better characterized.

Finally, comparisons of simulated and observed heads in the Dunnigan Water District and Yolo Zamora area showed simulated heads were too low. Additional research of this area, which has limited surface water availability suggests that irrigation efficiencies are relatively high in this region (Davids Engineering Inc, 2007). Irrigation efficiencies for this region were set to 85%, resulting in less groundwater pumping and higher simulated head values.

3.2.3 Calibration of Stream Seepage

Stream seepage was calibrated by adjusting the initial values of stream bed conductivity obtained from the IWFM model. Using the calibration targets discussed in Section 3.2.1.2, the stream bed conductivities of Cache Creek, Putah Creek and the Yolo Bypass were adjusted to provide a closer match between simulated and estimated values. Conflicting or limited information was available for other streams, such as the Sacramento River, therefore no additional calibration was conducted.

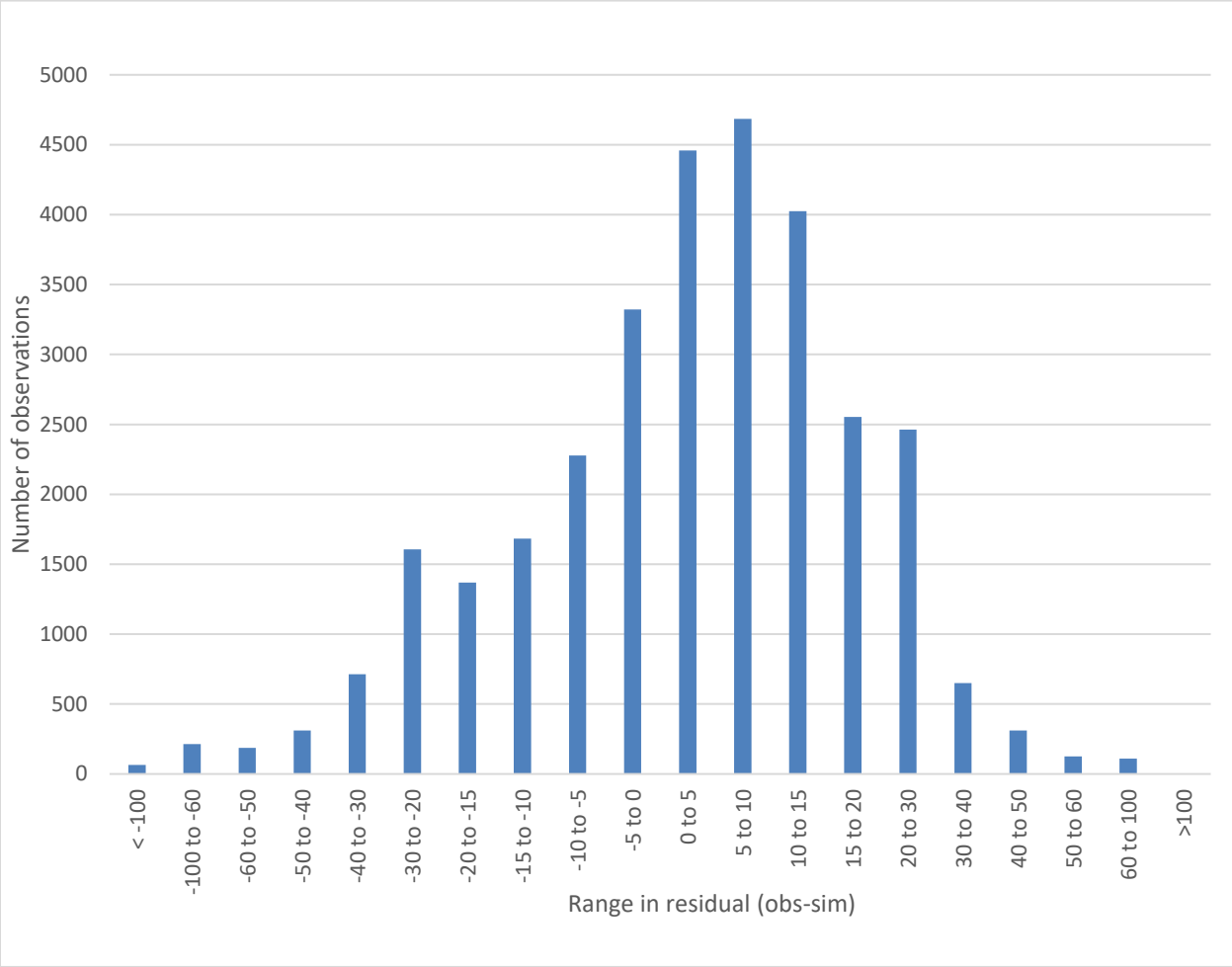
3.2.4 Calibration Results

Below is a discussion of the calibration results for the groundwater model. Both the groundwater heads and the stream seepage results are discussed

3.2.4.1 Groundwater Heads

Comparisons between observed and simulated groundwater heads at individual wells are provided for the 174 observation wells used in the calibration in the included groundwater graphing spreadsheet. A histogram of the residuals, calculated as observed minus simulated, is shown in Figure 3-10. The histogram shows that on average the model under predicts groundwater heads by 2.2 ft. 78% of the simulated values are within 20 feet of observed, 47% are within 10 ft, and 25% are within 5 ft of observed. As mentioned earlier, this fit is not as close as it was in the IGSM model (61% within 10 ft) nor the IWFM model (53% within 10 ft), however, this is not surprising as the recharge and pumping boundary conditions were applied uniformly at the catchment scale, compared with the finite element scale in the other models.

Figure 3-10. Histogram of residuals calculated as observed - simulated.

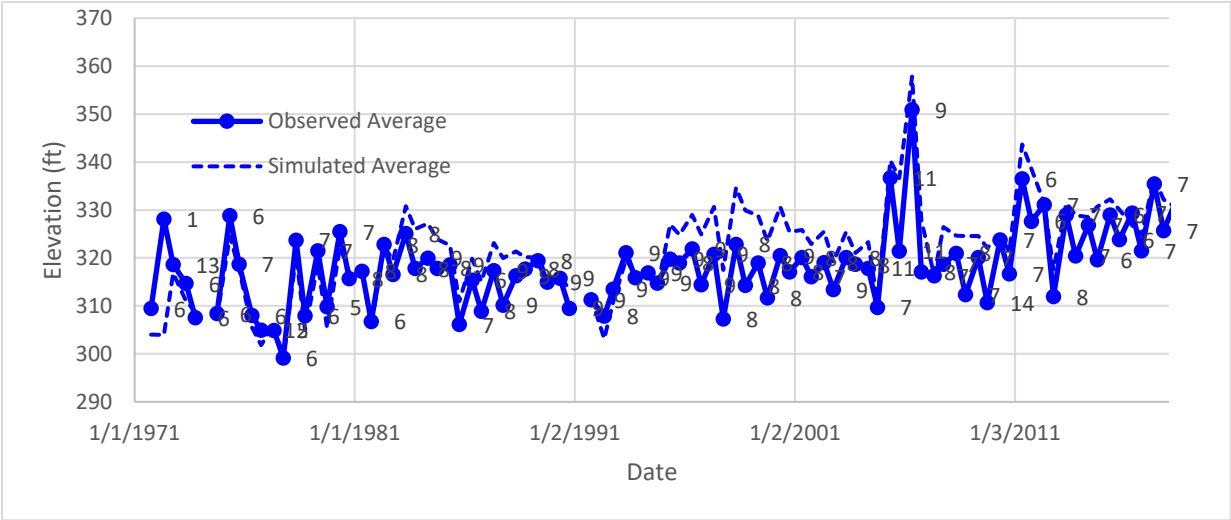


Due to the large number of wells, there will not be a discussion of each well. Instead, regions with similar behavior will be discussed and plots of observed and simulated heads averaged over multiple wells will be presented to demonstrate model behavior. It should not be expected that the plots, which average observations and simulated values from many wells, will provide a visually consistent reflection of water table behavior during the historical period. This is because observations wells, located at different elevations, go on- and off-line during the simulation period.

3.2.4.1.1 Capay Valley

Simulated heads in layer 1 of the Capay Valley provide a reasonable approximation of the observed heads with a general over prediction of water table elevation (Figure 3-11). The average bias for all observation wells is 8.5 ft. This means that the simulated values overpredicted head, on average.

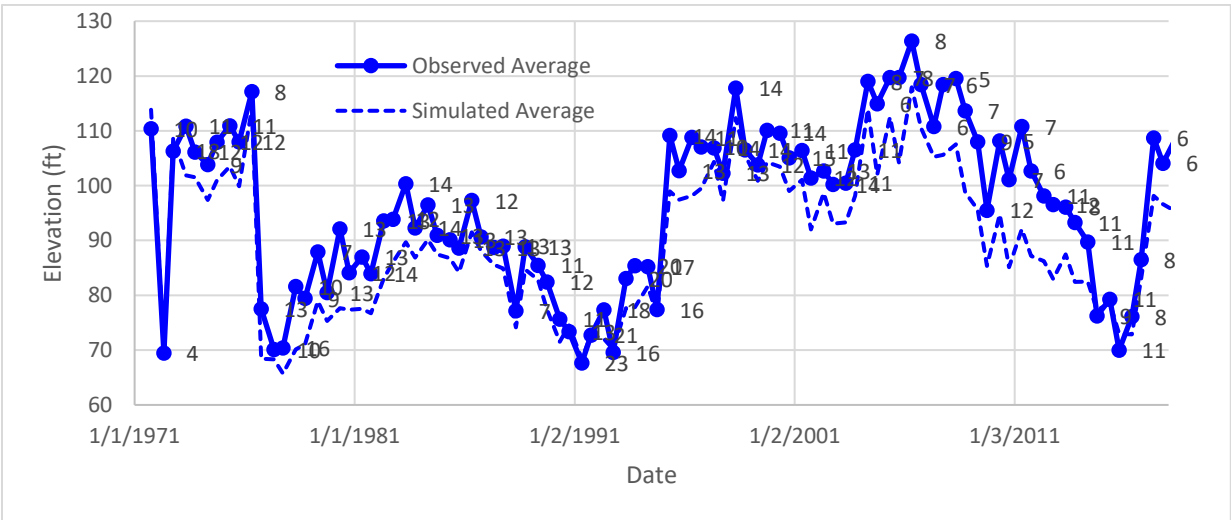
Figure 3-11. Average observed and simulated heads in layer 1 of Capay Valley. Numbers of observations are provided for each point.



3.2.4.1.2 Central Yolo

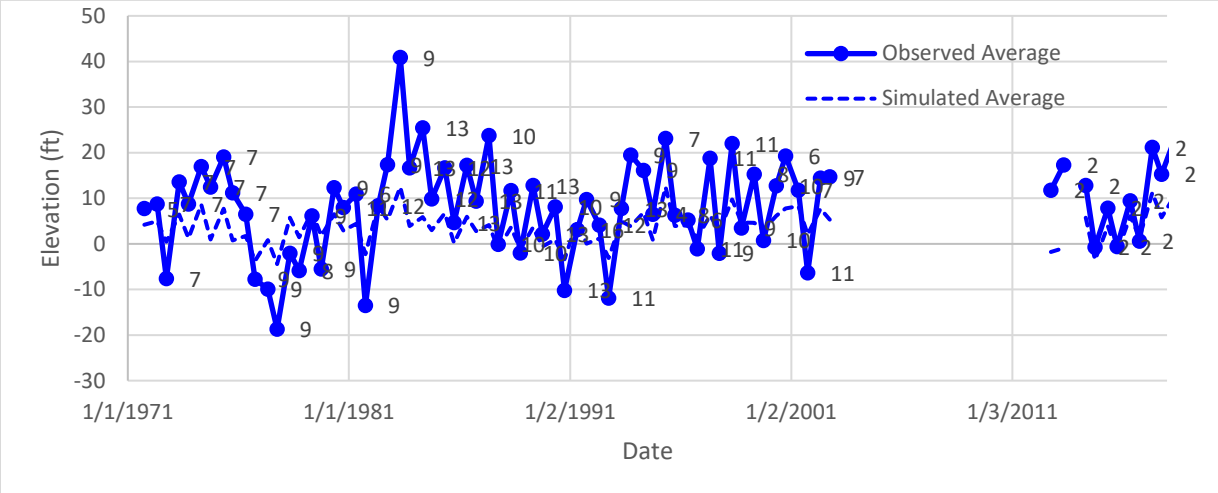
On the western side of the Central Yolo management area, the simulated heads in the YCFC West sub-region show a reasonable approximation by the model with a general underprediction of water table elevation (Figure 3-12). Average simulated values are within 10 ft of observed for most of the simulation and the average bias for all observation wells is -3.5 ft.

Figure 3-12. Average observed and simulated heads in layer 1 of the YCFC West sub-region. Number of observations are provided for each point.



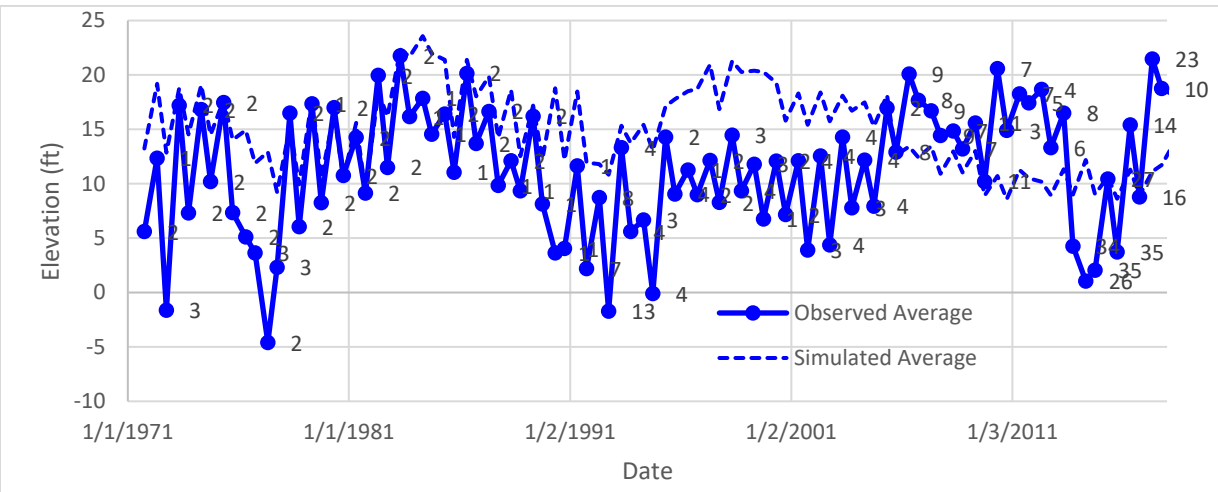
Further to the east the heads on the UC Davis campus show general agreement with the observations from layer 2 (Figure 3-13). The simulated values in this region do not track the variation in heads as well but do remain in the range of the observations. The average bias for these wells is 5.5 ft.

Figure 3-13. Average observed and simulated heads in layer 2 of the UC Davis sub-region. Number of observations are provided for each point.



At the far eastern edge of the management area the simulated heads for wells in layer 1 of RD 2035 are within range of the observations (Figure 3-14). The average bias for these wells is 3.7 ft.

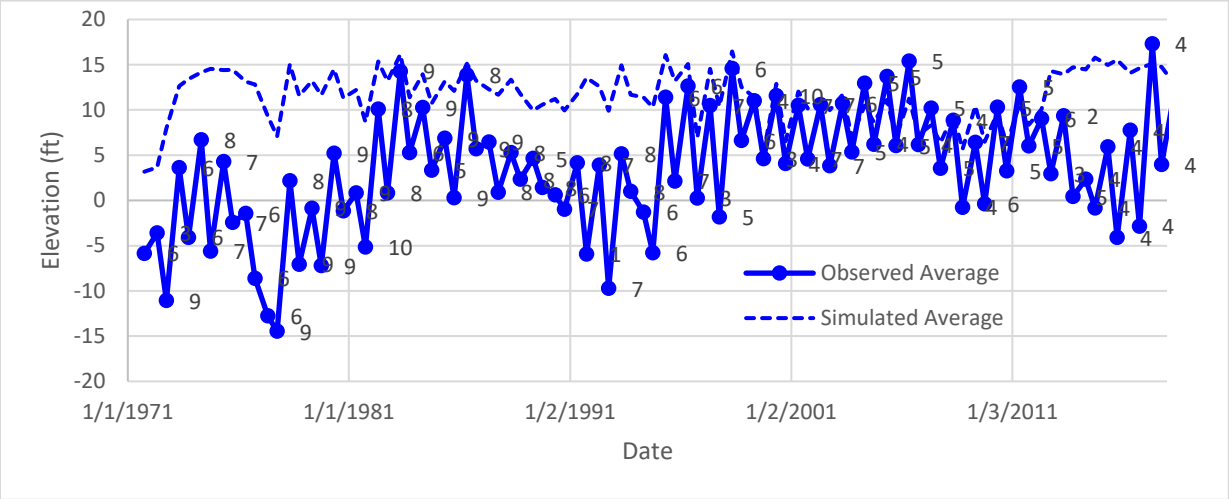
Figure 3-14. Average observed and simulated heads in layer 1 of the RD 2035 sub-region.



3.2.4.1.3 South Yolo

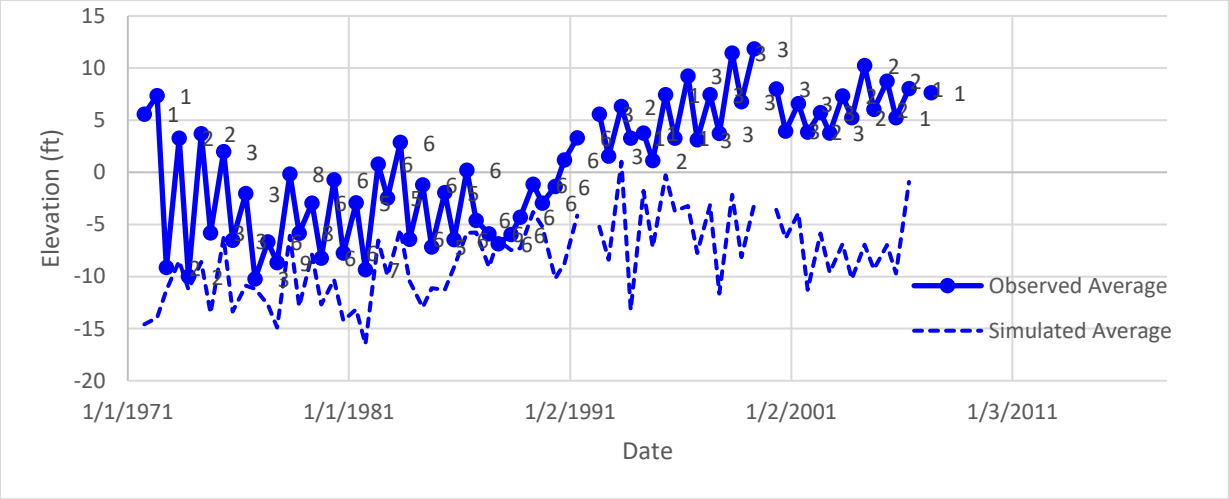
The largest sub-region in the South Yolo management area is North Delta West. This sub-region shows that on average the simulated heads in layer 1 are on average higher than the observations during the first half of the simulation and in the last decade (Figure 3-15). The average bias for these wells is 10.2 ft.

Figure 3-15. Average observed and simulated heads in layer 1 of North Delta East sub-region.



Most other sub-regions in the South Yolo management area do not have many observation wells. The West Sacramento sub-region has 3 wells that are in layer 2 (Figure 3-9). They show that the model generally underpredicts groundwater head but is within 5 to 10 ft much of the simulation (Figure 3-16). The average bias for these wells is -10.5 ft.

Figure 3-16. Average observed and simulated heads in layer 2 of the West Sacramento sub-region.



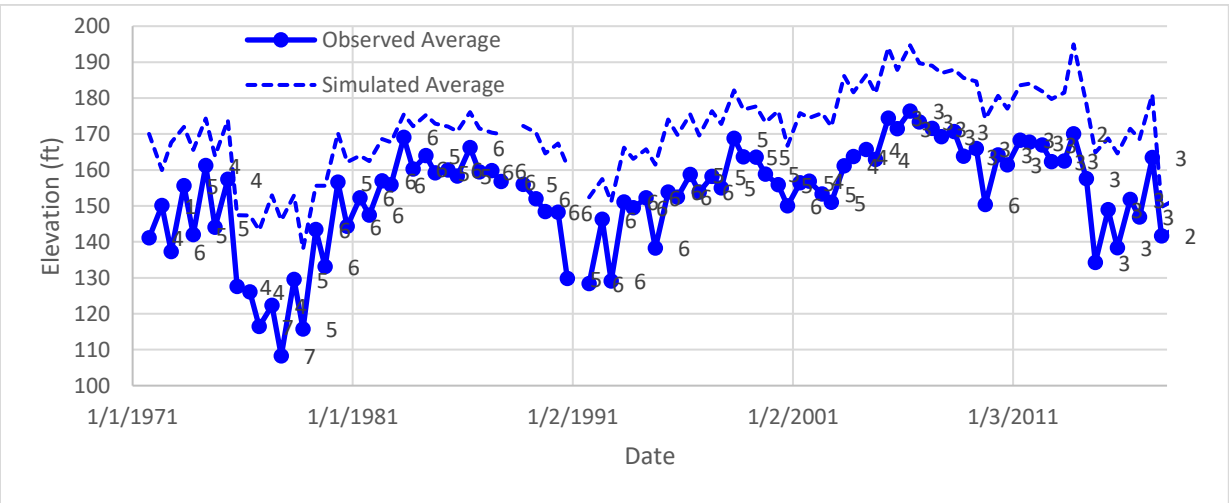
3.2.4.1.4 Clarksburg

The Clarksburg management area only has 2 observation wells in layer 1 with limited information. In much of the simulation period there is only one observation well available with observations that range over 3 to 4 feet seasonally. In general, the simulated values are within 1 or 2 feet of the observations.

3.2.4.1.5 Dunnigan Hills

The Dunnigan Hills management area is the most poorly defined region in the model. In addition to the uncertainty in hydrogeology of the region, there are few observation wells. This is probably due to the region having relatively little irrigated acreage historically. The observation wells that do exist are all located in the YCFC Hungry Hollow sub-region, an actively irrigated region. For these wells the model consistently overestimates water table elevation in layer 1 but does follow the inter-seasonal patterns (Figure 3-17). The average bias for these wells is 17.1 ft.

Figure 3-17. Average observed and simulated heads in layer 2 of the YCFC Hungry Hollow sub-region



3.2.4.1.6 North Yolo

The North Yolo management area is made up of 9 sub-regions. Many of the observation wells are located west and south of the Colusa Basin Drain. Simulated heads at wells located west and south of the Colusa Basin Drain show reasonable agreement with observations. In the Dunnigan Water District the simulated heads in layer 2 mimic the observed slow recovery of heads in the final years of the simulation (Figure 3-18). In the Yolo Zamora North sub-region the simulated heads of layer 2 are also in reasonable agreement with the observations (Figure 3-19). Average bias for the wells is 0.1 ft and 3.0 ft, respectively.

Figure 3-18. Average observed and simulated heads in layer 2 of Dunnigan Water District.

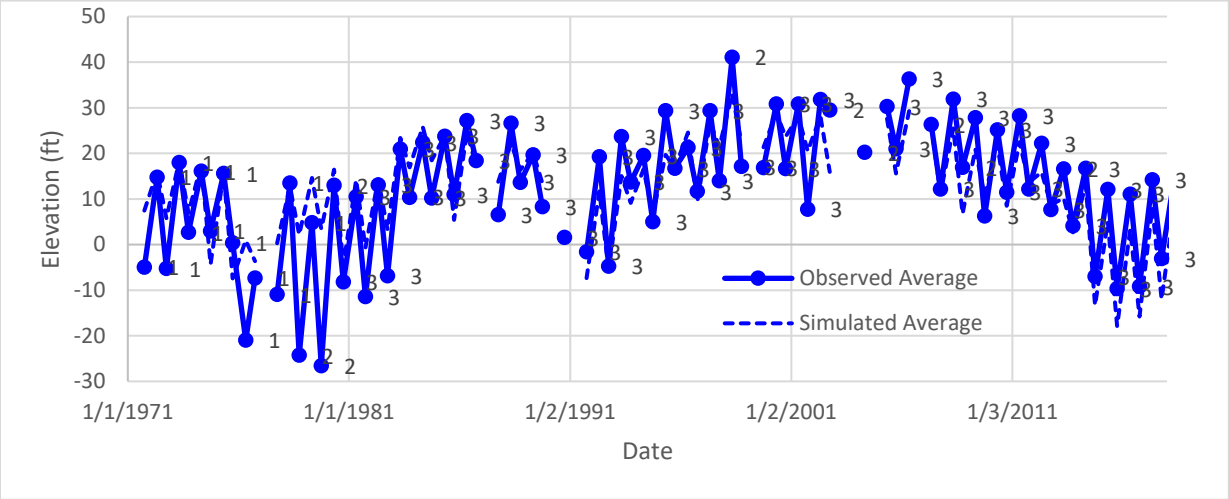
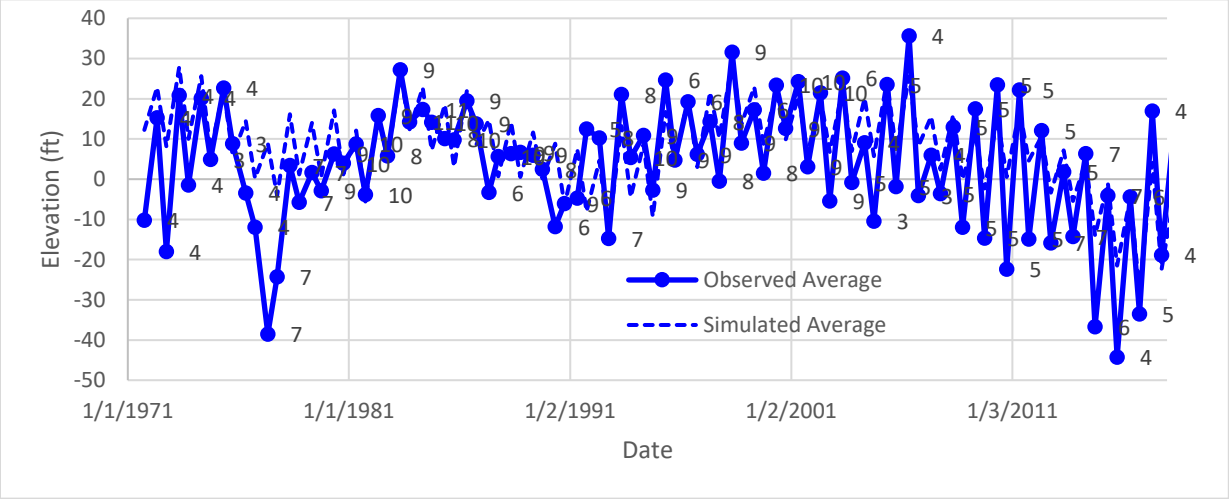
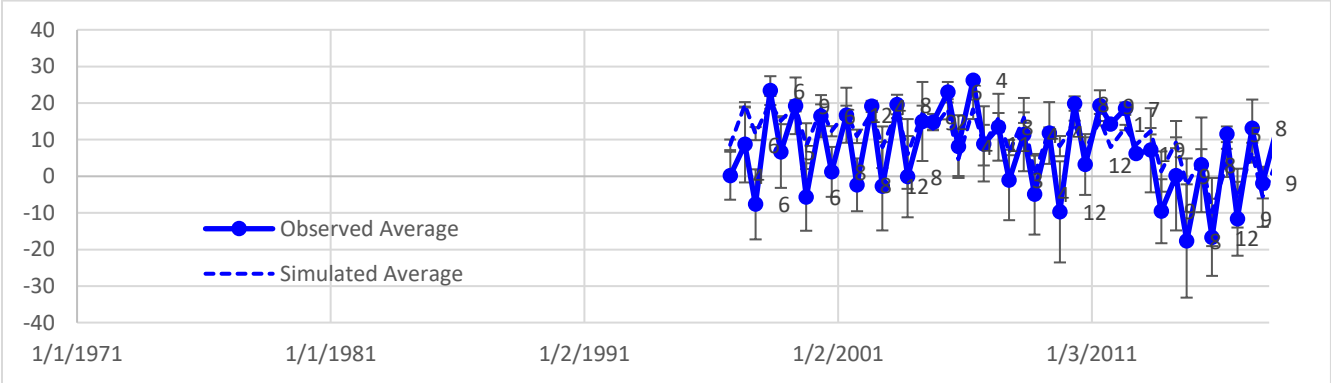


Figure 3-19. Average observed and simulated heads inlayer 2 of the Yolo Zamora North sub-region.



East of the Colusa Basin Drain the simulated values of head in RD 108 match reasonably well starting in the 2000s (Figure 3-20).

Figure 3-20. Average observed and simulated heads in layer 2 of RD 108.



3.2.4.2 Stream Seepage

The stream seepage calibration was conducted using the estimates of stream seepage found in the literature and the results published with the original IGSM model. Table 3-9 provides a comparison of simulated and estimated values.

Table 3-9. Simulated and estimated average annual stream seepage values (TAF). Positive values signify flow from aquifer to stream.

Stream Reach	Simulated Value (1971-2000)	IGSM (1971-2000)	Mullen and Nady (1961-1975)	TNC (2001-2009)
Upper Cache Creek	7.9	2.6	0.4	<0
Lower Cache Creek	-34.9	-37.9	-25.4	<0
Putah Creek	-13.9	-21.8	-18.1	<0
Willow Slough	0.0	-14.1	--	--
Colusa Basin Drain	0.0	1.3	--	--
Knights Landing Ridge Cut	1.6	4.9	--	--
Sacramento River	-1.0	15.3	--	<0
Yolo Bypass	33.0	41.7	--	<0

In agreement with the Mullen and Nady and IGSM estimates, the model has the upper Cache Creek between Capay and Rumsey gaining water from the aquifer. This is in disagreement with the TNC study, however, the resolution of that analysis may have averaged over the entire Cache Creek. The model simulates a losing stream for lower Cache Creek (from Capay to Yolo) in agreement with all three of the other estimations. Simulated stream seepage for Willow Sough and the Colusa Basin Drain were very small. This is in contrast to the 14.1 TAF average annual loss simulated in the IGSM model for Willow Slough. Since no corroborating information could be found for Willow Slough, the initial parameters were not adjusted. The Knights Landing Ridge Cut was simulated to be a gaining reach as it was in the IGSM model. The Sacramento River was simulated to have a stream loss of about 1 TAF per year, which agrees in direction with the TNC report. However, this is in contrast to the IGSM model which reports that the Sacramento River is gaining. Due to the conflicting estimates, the original

parameters were not adjusted. In the Yolo Bypass the model agrees with the IGSM model and has the reach gaining flow from the aquifer.

3.3 Uncertainty

All models are simplified abstractions of reality, and therefore water budgets will always exhibit uncertainty (Loucks and van Beek, 2017). Uncertainty in model outputs arise from uncertain or missing input data, model parameter uncertainty, natural variability (in climate, hydrology, geology, landuse), and measurement errors (California DWR, 2020). For example, large uncertainties are likely to exist in model estimates of SW-GW interaction and GDE's simply because of inadequate – or complete lack - of data.

For the Yolo Basin historical water budget:

Landuse and related irrigation management (variations in planting and harvest dates across space and time, for example) exhibit relatively large uncertainty. Section 2.1.1.2 describes some of the issues in generating a time series of cropping patterns for the Yolo Basin: different datasets with differing categorization; acreages not being the same; methods being different and so on. The Landuse uncertainty affects all components of a water budget[25].

Surface water supply in several areas of the Yolo Basin is not well known, as in some of the Reclamation Districts; and in the WIllow Slough drainage, and in the Clarksburg and Yolo bypass. Assumptions were made, which largely allowed surface water use to take precedence over groundwater pumping. See Section 2.1.5.

Groundwater levels and trends are uncertain in some areas like in north-west Yolo. Although groundwater observations are scarce in areas close to Sacramento R. as well, there is widespread knowledge that water levels are shallow there. Additionally, surface elevations and screening depths are uncertain, and in many cases, missing. The latter point made it challenging to ascertain which aquifer layer was being pumped.

Geology and stratigraphy is uncertain in the Dunnigan Hills area (WRIME, 2006).

Climate uncertainty, while it exists, is relatively less than the above uncertainties, because climate in the Yolo basin is not very spatially variable. Climate input from different sources of data (e.g. station data versus gridded PRISM data) can be used as a used as a measure of this uncertainty.

For the future scenarios' water budget, climate change and landuse change represent the main drivers in water budget uncertainty: these impacts are documented in the main text of the Water Budget Chapter.

3.3.1 Model sensitivity

Model sensitivity analysis explores the influence of selected uncertainties on model outputs of interest. Model sensitivity analysis can help test the robustness and stability of the model; impact of data

[25] This is true of all Basins

inaccuracies and uncertainties; and can help prioritize future monitoring by identifying those variables that most influence critical model outputs.

Model sensitivity is an extensive field of its own; comprehensive sensitivity analysis through approaches like GLUE for example are beyond the scope of this GSP. This section reports on a few sensitivity tests on data and parameters that were known to be influential: namely, landuse, climate change and vertical conductivity.

Metrics: TO BE DONE

Methods: TO BE DONE

Results: To BE DONE

4 References

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Appendix A Comparisons of simulated and observed groundwater heads.

Please see spreadsheet attachment.

Filename “04_Groundwater Graphing Tool_WaterBudgetDraft#2.xlsm” (emailed to Kristin Sicke on Nov 20, 2020.)

PUBLIC DRAFT

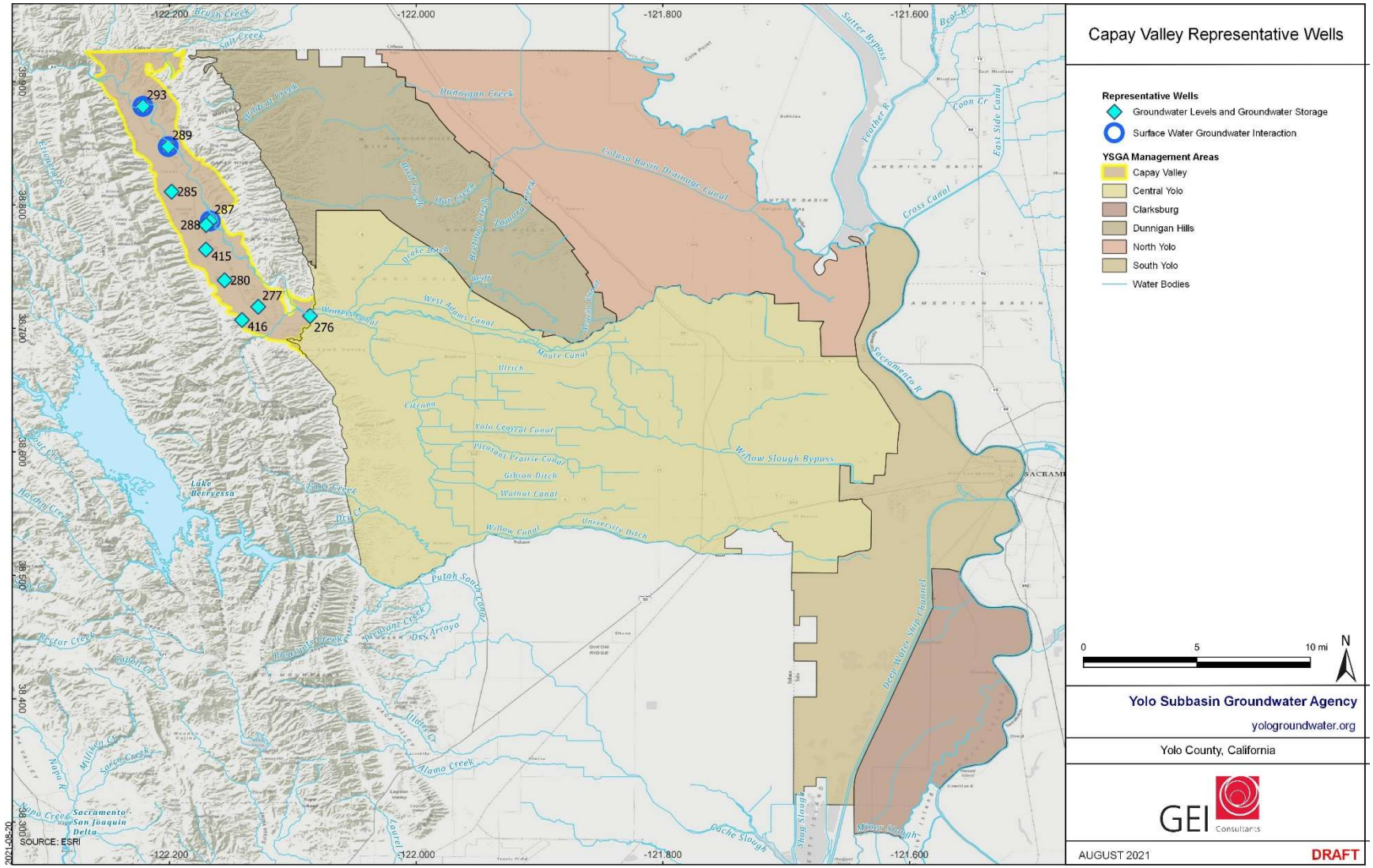
Yolo Subbasin Groundwater Agency

2022 Groundwater Sustainability Plan

APPENDIX E:

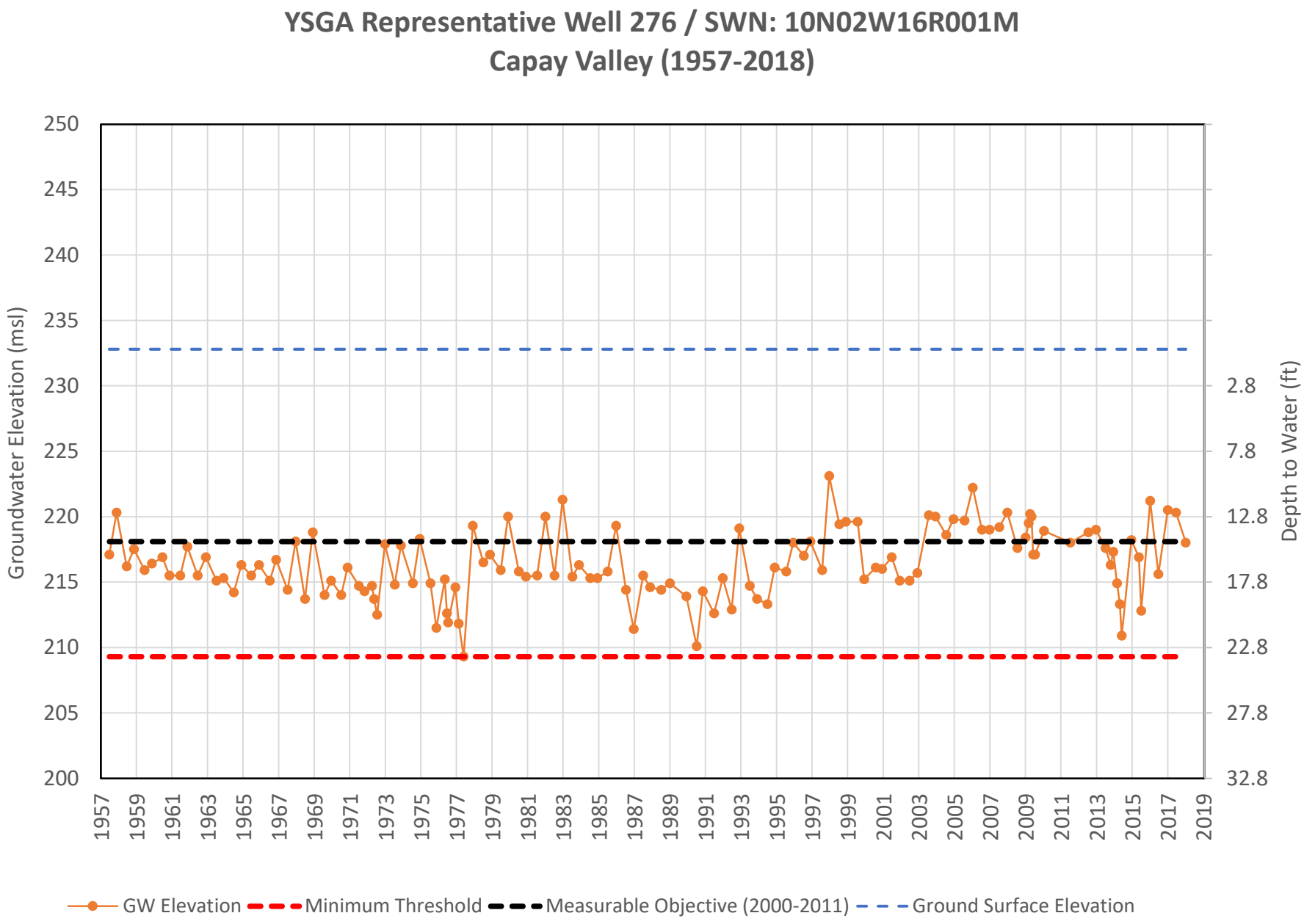
Yolo Subbasin Representative Well Hydrographs and Construction Information

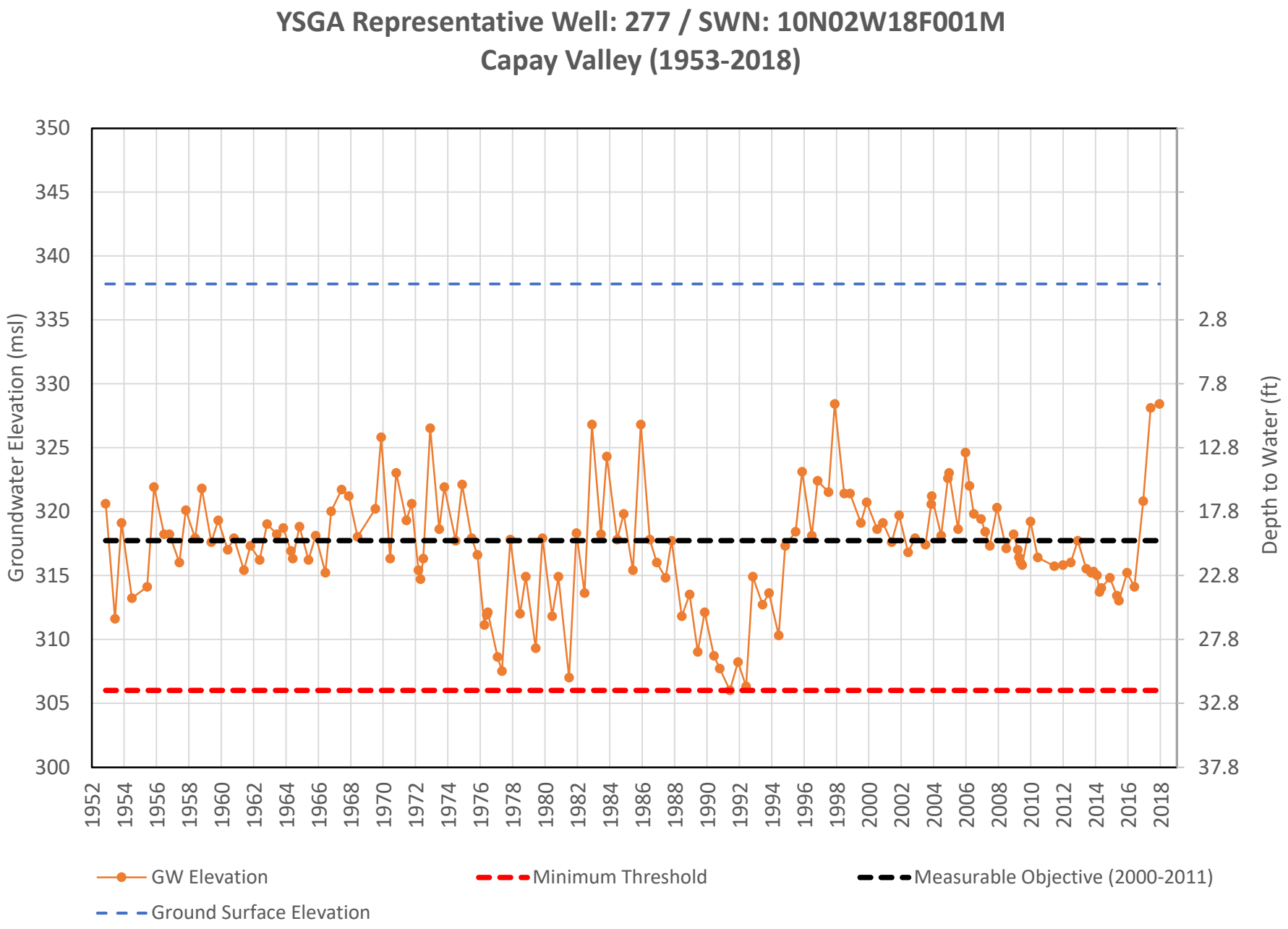
Capay Valley Management Area

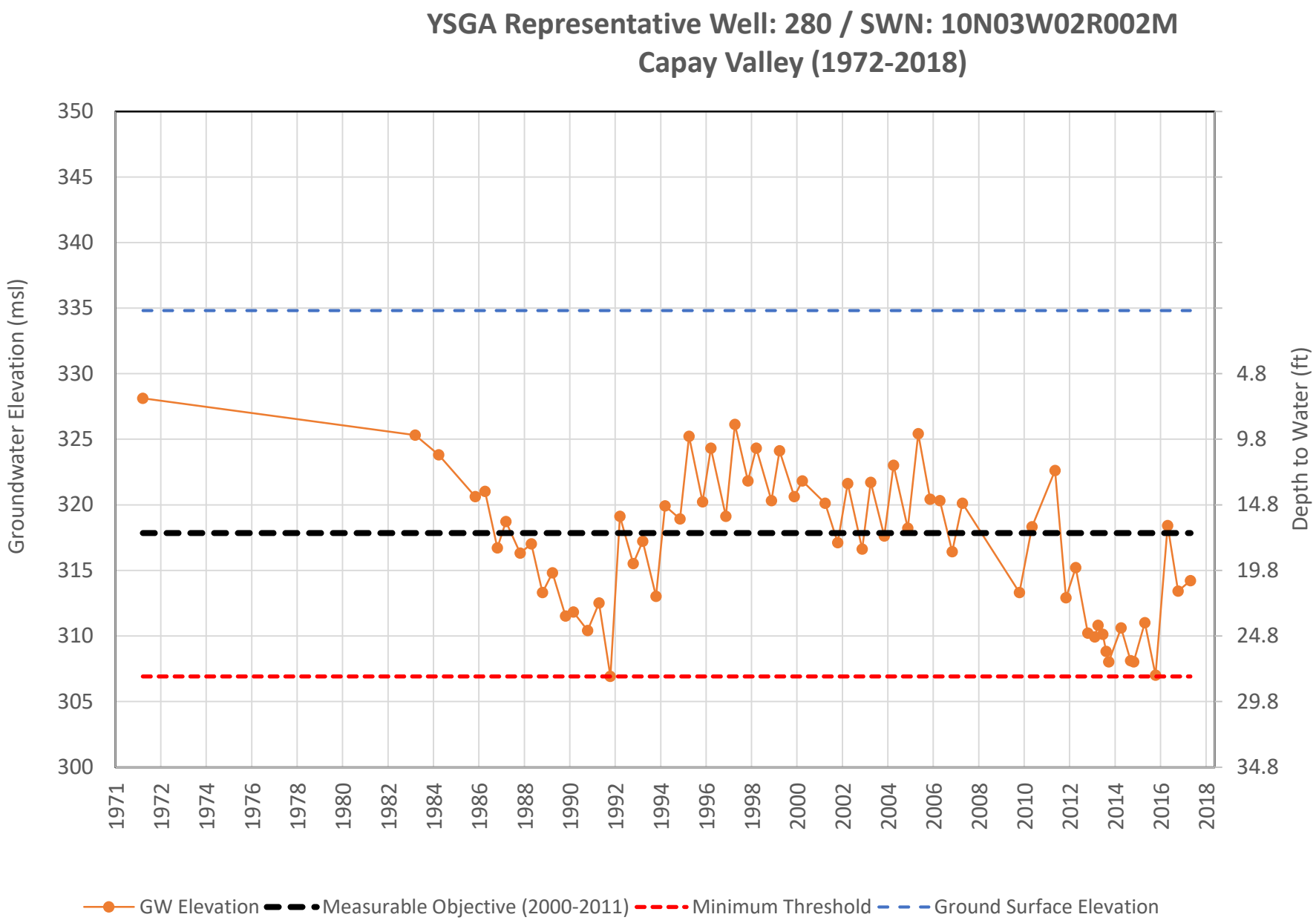


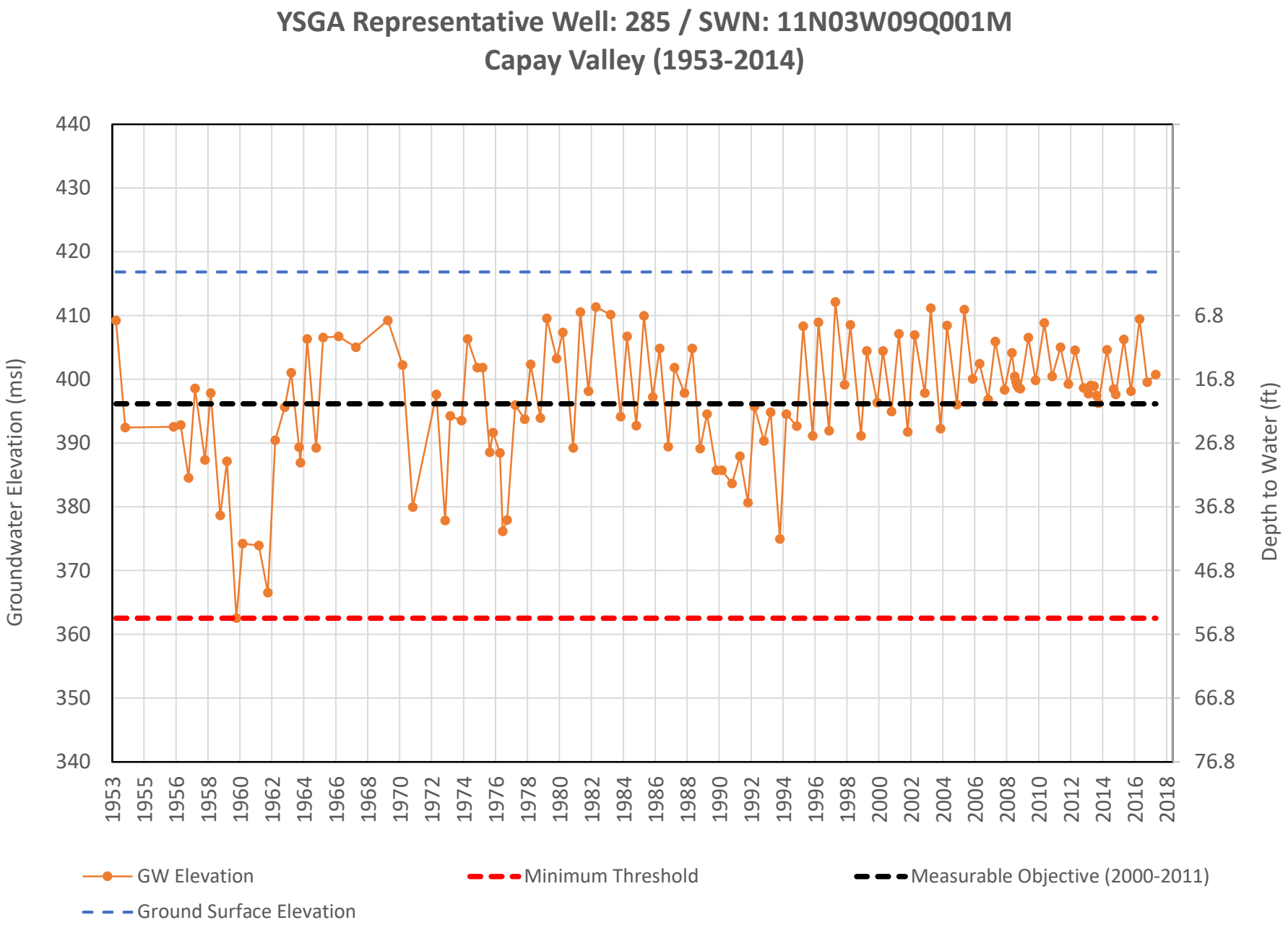
Capay Valley Management Area- Representative Monitoring Well Construction Information

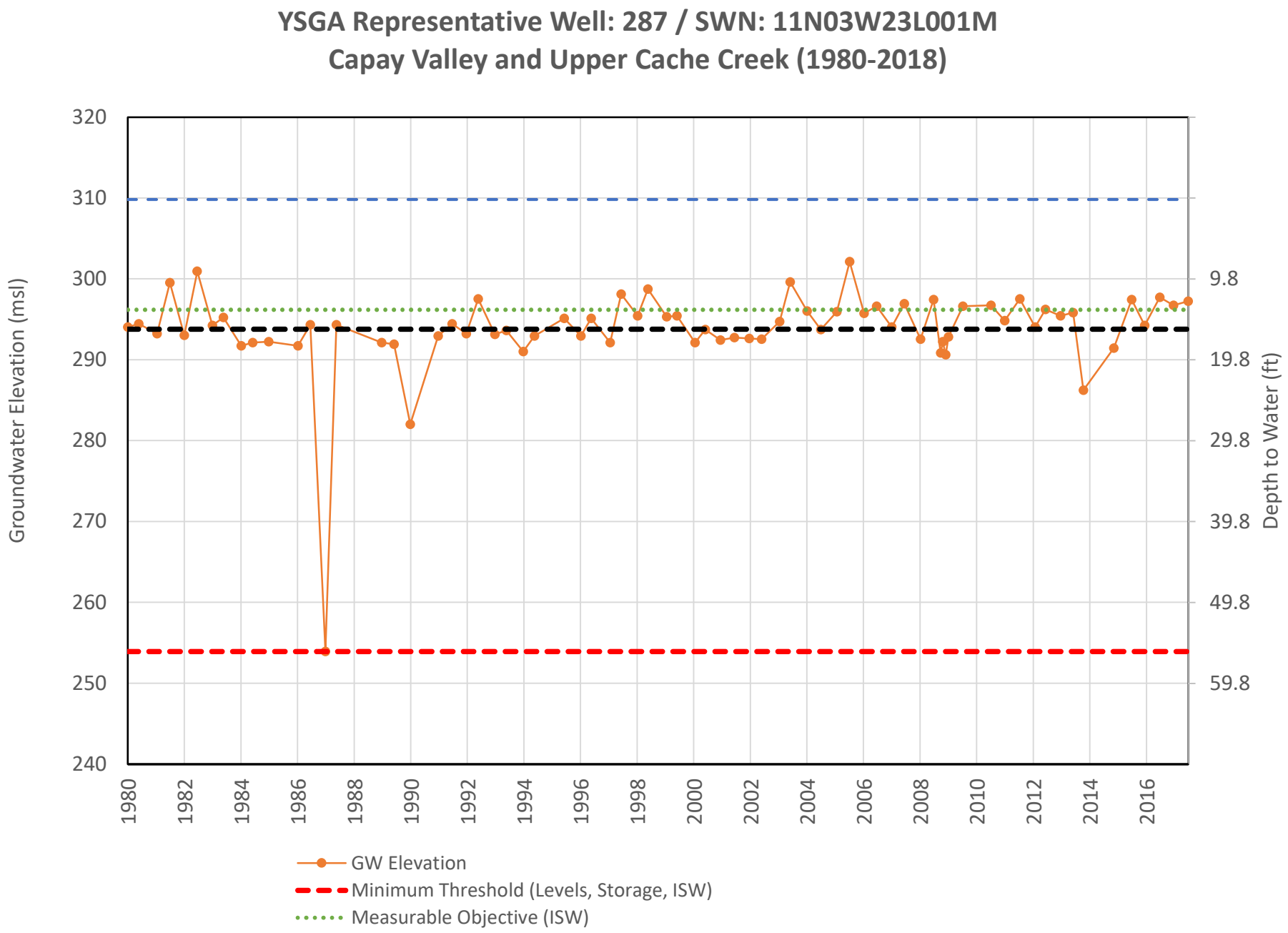
YSGA Well Number	State Well Number	Groundwater Elevations	Change in Storage	Depletion of ISW	Monitored by	Reference Point Elevation (feet)	Ground Surface Elevation (feet)	Well Use Type	Latitude	Longitude	Well Depth (ft bgs)	Well Completion Report Number	Top Perforation	Bottom Perforation
276	10N02W16R001M	X	X		YCFC	229.57	229.568	Domestic	38.7100196	-122.086044				
277	10N02W18F001M	X	X		YCFC	336.01	335.508	Domestic	38.717459	-122.128035				
280	10N03W02R002M	X	X		YCFC	338.14	337.52	Domestic	38.7389081	-122.155285	55			
285	11N03W09Q001M	X	X		YCFC	404.12	402.748	Irrigation	38.8107137	-122.198255	55		40	52
287	11N03W23L001M	X	X	X	YCFC	311.19	310.997	Irrigation	38.7870644	-122.166861	66			
288	11N03W23N001M	X	X		YCFC	320.13	319.976	Irrigation	38.7837588	-122.170247	136			
289	11N03W33F001M	X	X	X	YCFC	370.83	367.938	Domestic	38.8472892	-122.201005	75			
293	12N03W20D001M	X	X	X	YCFC	402.6	406.864	Irrigation	38.8798854	-122.22154	26			
415	11N03W35D003M	X	X		YCFC	309.25	307.923		38.7638099	-122.17044	162	57-1605	140	162
416	10N03W24B002M	X	X		YCFC	390.22	389.487		38.7067742	-122.141186	207	060182	60	180

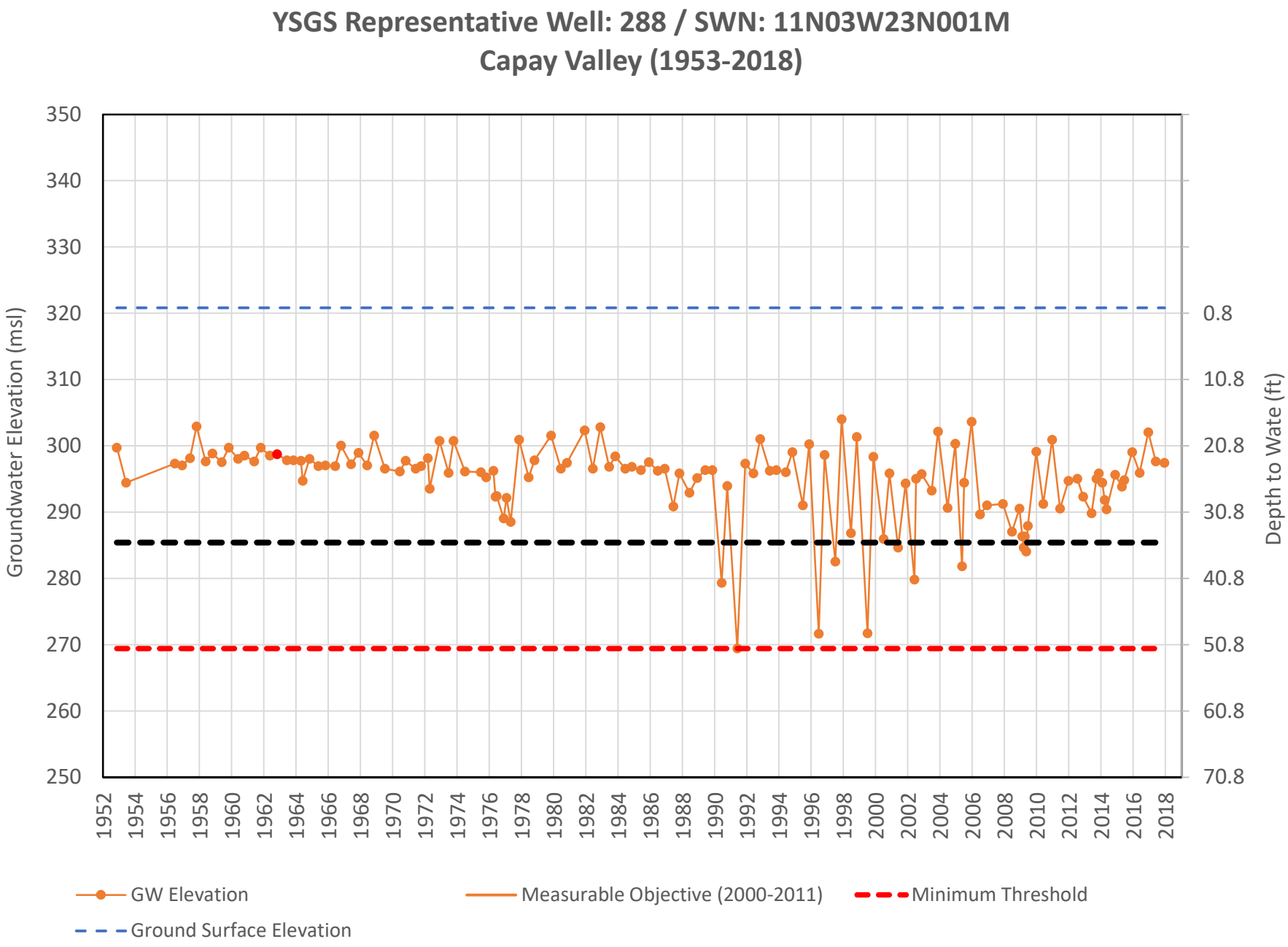

YSGA Representative Well 276 / SWN: 10N02W16R001M
Capay Valley (1957-2018)
Groundwater Elevation (msl)
Depth to Water (ft)
250
245
240
235
230
225
220
215
210
205
200
2.8
7.8
12.8
17.8
22.8
27.8
32.8
1957
1959
1961
1963
1965
1967
1969
1971
1973
1975
1977
1979
1981
1983
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003
2005
2007
2009
2011
2013
2015
2017
2019
GW Elevation
Minimum Threshold
Measurable Objective (2000-2011)
Ground Surface Elevation

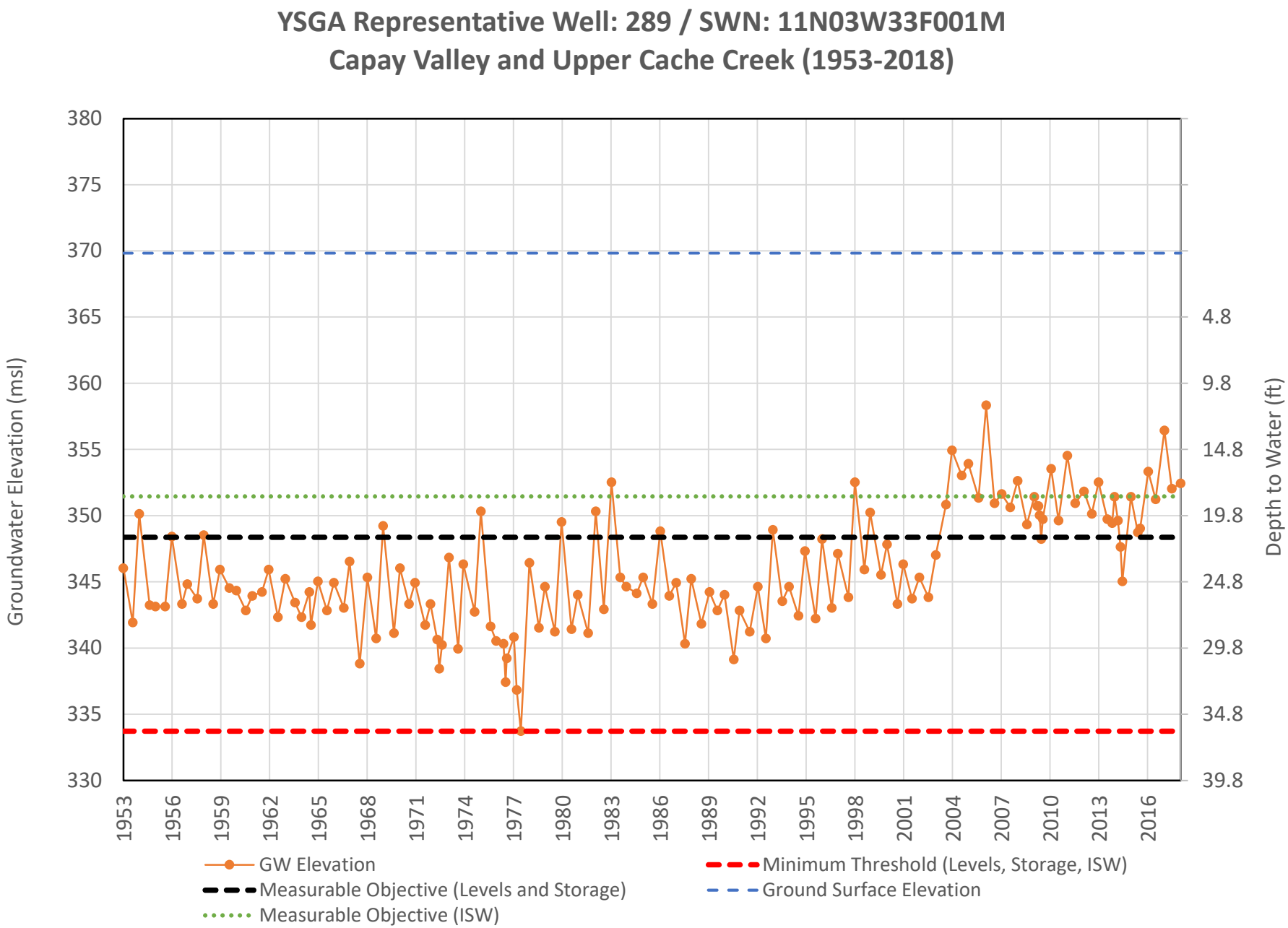

YSGA Representative Well: 277 / SWN: 10N02W18F001M
Capay Valley (1953-2018)
Groundwater Elevation (msl)
Depth to Water (ft)
350
345
340
335
330
325
320
315
310
305
300
2.8
7.8
12.8
17.8
22.8
27.8
32.8
37.8
1952
1954
1956
1958
1960
1962
1964
1966
1968
1970
1972
1974
1976
1978
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
2018
GW Elevation
Minimum Threshold
Measurable Objective (2000-2011)
Ground Surface Elevation

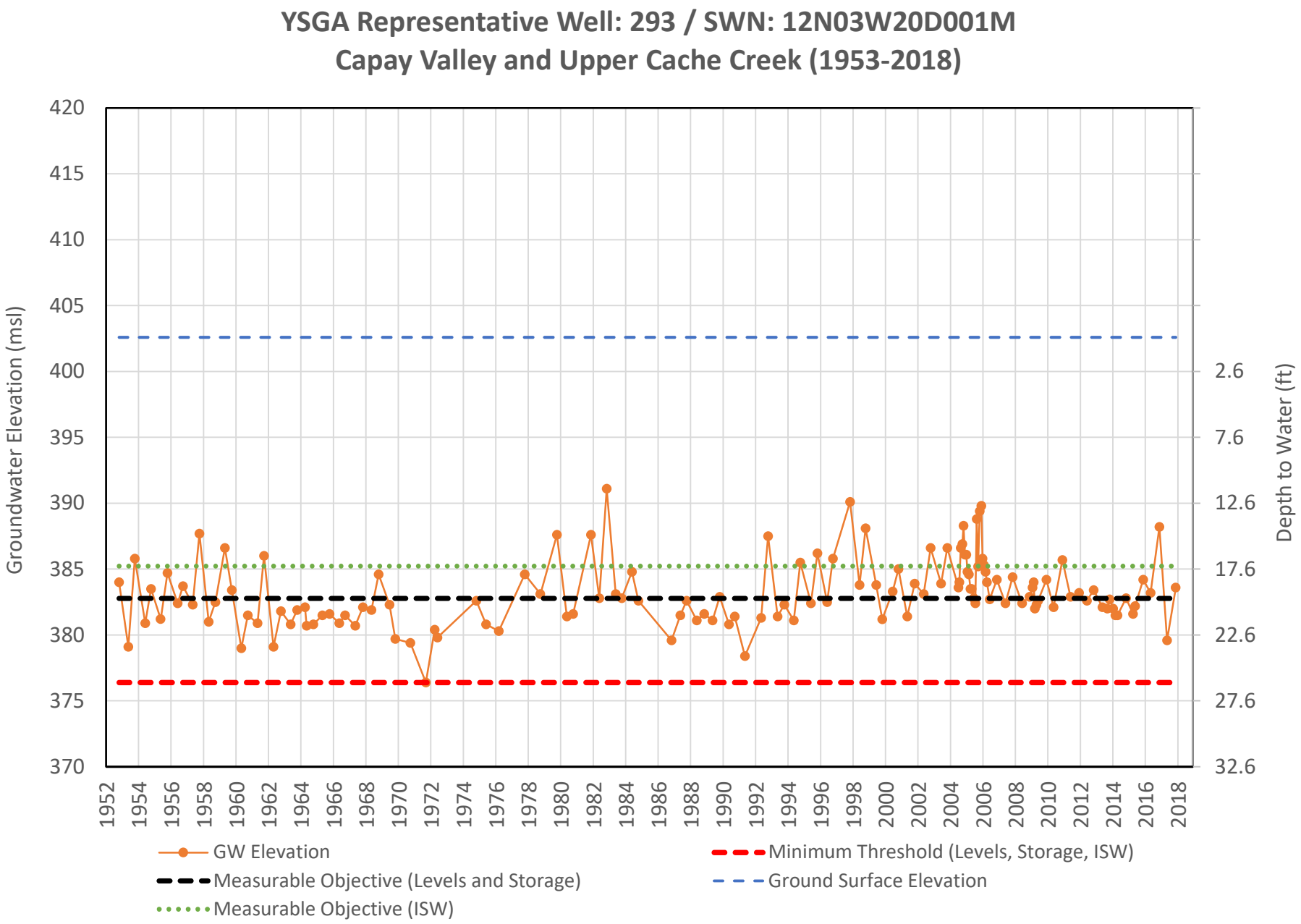

YSGA Representative Well: 280 / SWN: 10N03W02R002M
Capay Valley (1972-2018)
Groundwater Elevation (msl)
Depth to Water (ft)
350
345
340
335
330
325
320
315
310
305
300
4.8
9.8
14.8
19.8
24.8
29.8
34.8
1971
1972
1974
1976
1978
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
2018
GW Elevation
Measurable Objective (2000-2011)
Minimum Threshold
Ground Surface Elevation

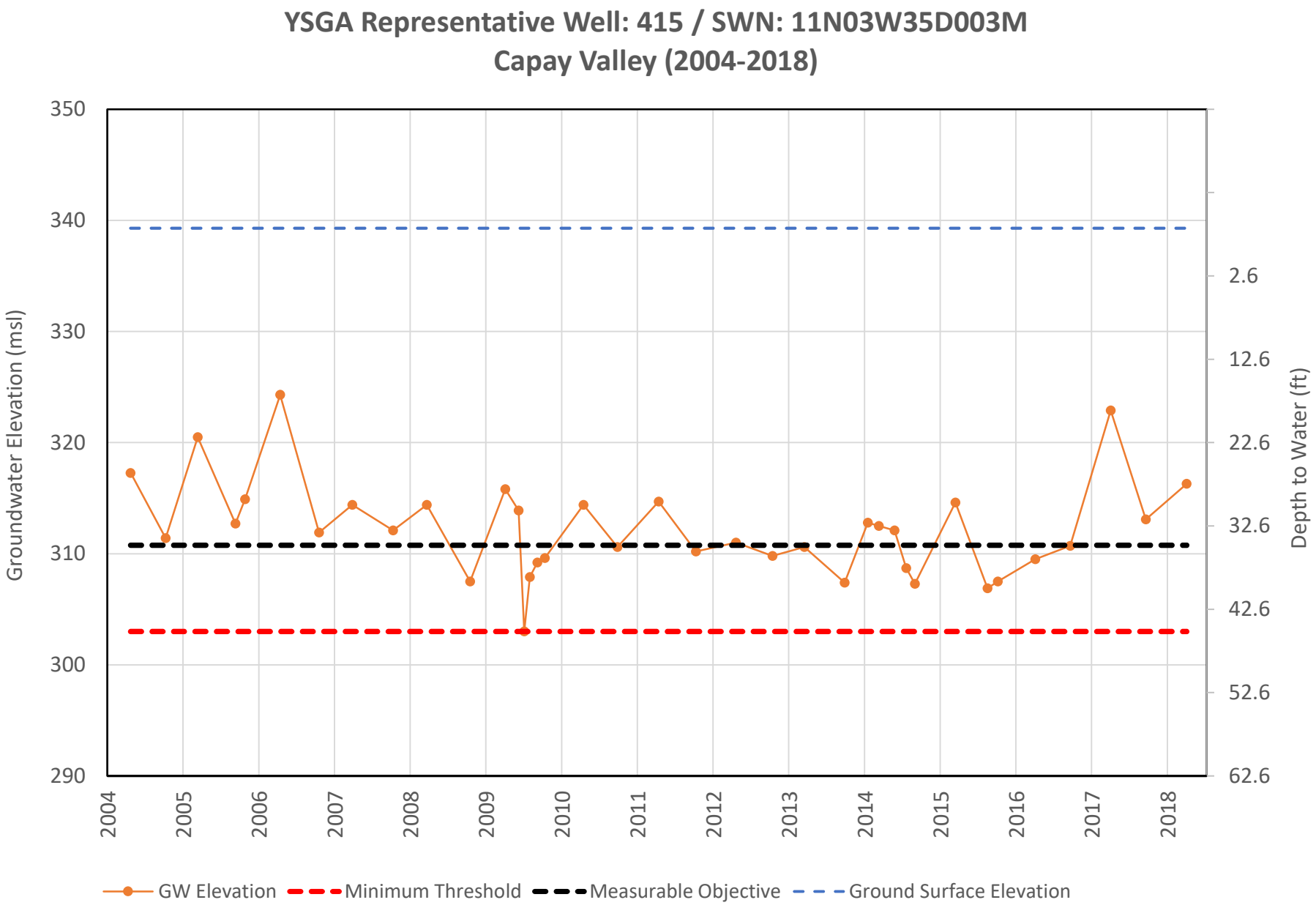

YSGA Representative Well: 285 / SWN: 11N03W09Q001M
Capay Valley (1953-2014)
Groundwater Elevation (msl)
Depth to Water (ft)
440
430
420
410
400
390
380
370
360
350
340
6.8
16.8
26.8
36.8
46.8
56.8
66.8
76.8
1953
1955
1956
1958
1960
1962
1964
1966
1968
1970
1972
1974
1976
1978
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
2018
GW Elevation
Minimum Threshold
Measurable Objective (2000-2011)
Ground Surface Elevation

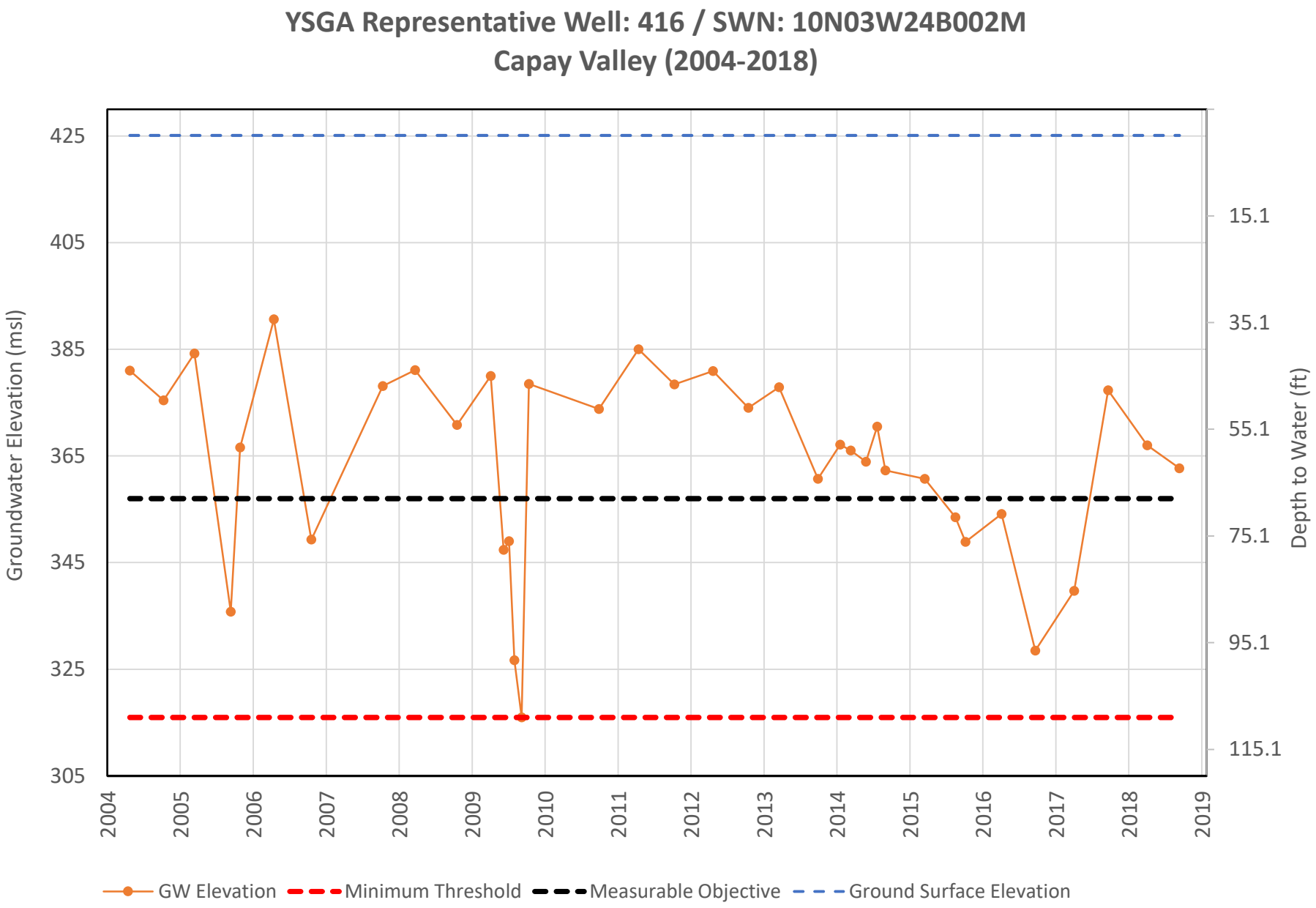

YSGA Representative Well: 287 / SWN: 11N03W23L001M
Capay Valley and Upper Cache Creek (1980-2018)
Groundwater Elevation (msl)
Depth to Water (ft)
320
310
300
290
280
270
260
250
240
9.8
19.8
29.8
39.8
49.8
59.8
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
GW Elevation
Minimum Threshold (Levels, Storage, ISW)
Measurable Objective (ISW)


YSGS Representative Well: 288 / SWN: 11N03W23N001M
Capay Valley (1953-2018)
Groundwater Elevation (msl)
Depth to Wate (ft)
350
340
330
320
310
300
290
280
270
260
250
0.8
10.8
20.8
30.8
40.8
50.8
60.8
70.8
1952
1954
1956
1958
1960
1962
1964
1966
1968
1970
1972
1974
1976
1978
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
2018
GW Elevation
Measurable Objective (2000-2011)
Minimum Threshold
Ground Surface Elevation


YSGA Representative Well: 289 / SWN: 11N03W33F001M
Capay Valley and Upper Cache Creek (1953-2018)
Groundwater Elevation (msl)
Depth to Water (ft)
380
375
370
365
360
355
350
345
340
335
330
4.8
9.8
14.8
19.8
24.8
29.8
34.8
39.8
1953
1956
1959
1962
1965
1968
1971
1974
1977
1980
1983
1986
1989
1992
1995
1998
2001
2004
2007
2010
2013
2016
GW Elevation
Minimum Threshold (Levels, Storage, ISW)
Measurable Objective (Levels and Storage)
Ground Surface Elevation
Measurable Objective (ISW)


YSGA Representative Well: 293 / SWN: 12N03W20D001M
Capay Valley and Upper Cache Creek (1953-2018)
Groundwater Elevation (msl)
Depth to Water (ft)
420
415
410
405
400
395
390
385
380
375
370
2.6
7.6
12.6
17.6
22.6
27.6
32.6
1952
1954
1956
1958
1960
1962
1964
1966
1968
1970
1972
1974
1976
1978
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
2018
GW Elevation
Minimum Threshold (Levels, Storage, ISW)
Measurable Objective (Levels and Storage)
Ground Surface Elevation
Measurable Objective (ISW)


YSGA Representative Well: 415 / SWN: 11N03W35D003M
Capay Valley (2004-2018)
Groundwater Elevation (msl)
350
340
330
320
310
300
290
Depth to Water (ft)
2.6
12.6
22.6
32.6
42.6
52.6
62.6
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
GW Elevation
Minimum Threshold
Measurable Objective
Ground Surface Elevation


YSGA Representative Well: 416 / SWN: 10N03W24B002M
Capay Valley (2004-2018)
Groundwater Elevation (msl)
425
405
385
365
345
325
305
Depth to Water (ft)
15.1
35.1
55.1
75.1
95.1
115.1
2004
2005
2006
2007
2008
2009
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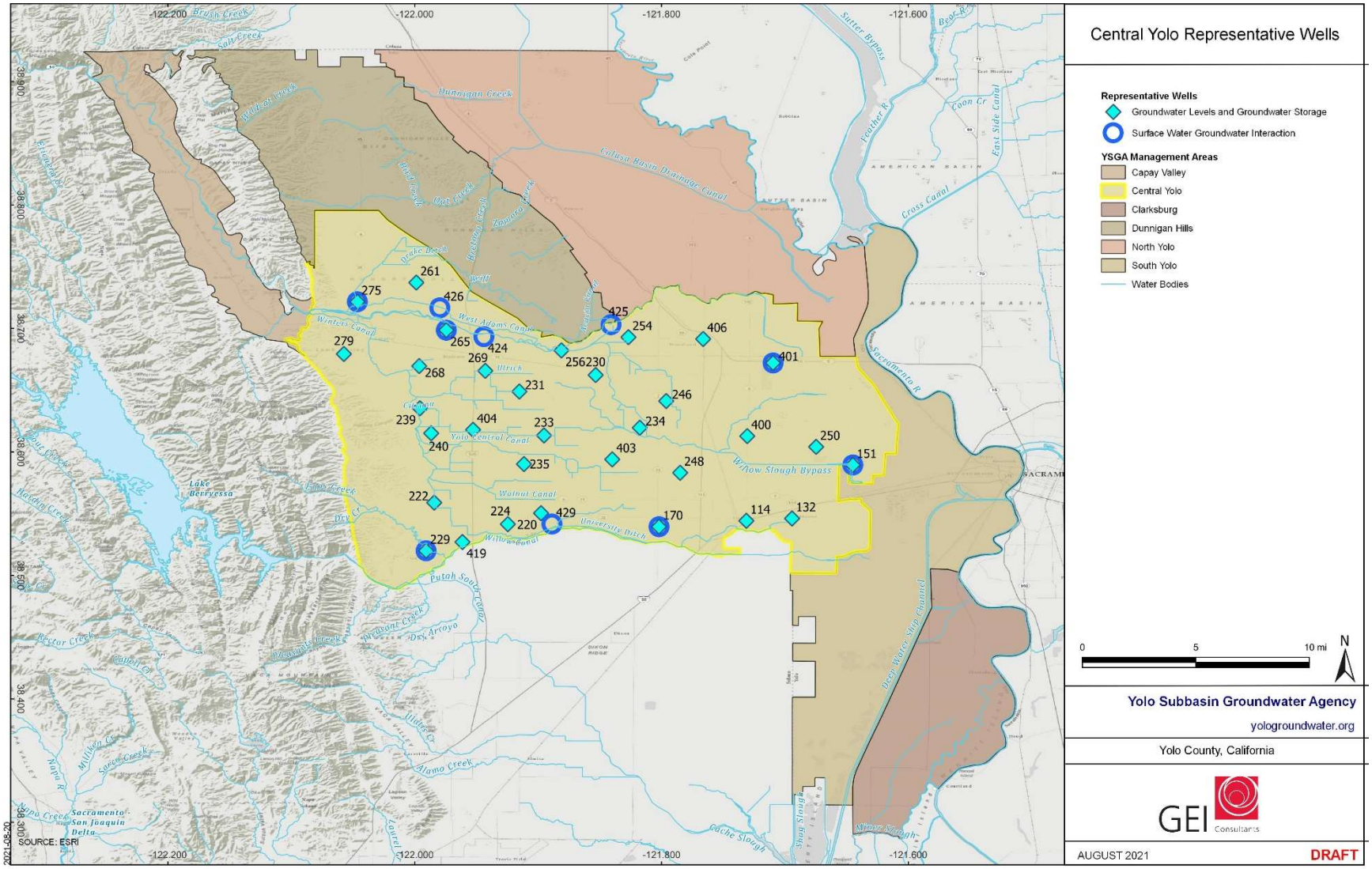
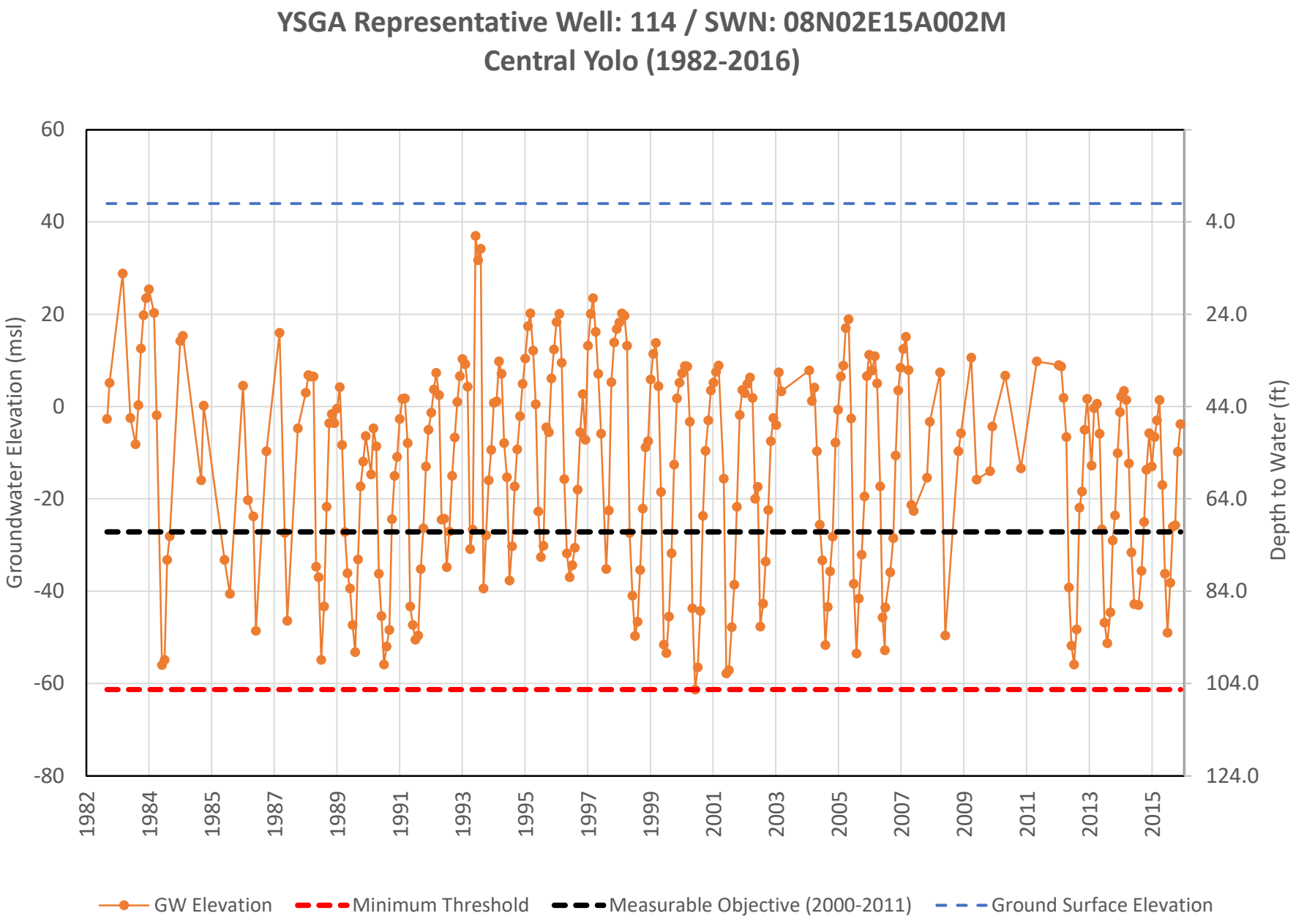
GW Elevation
Minimum Threshold
Measurable Objective
Ground Surface Elevation

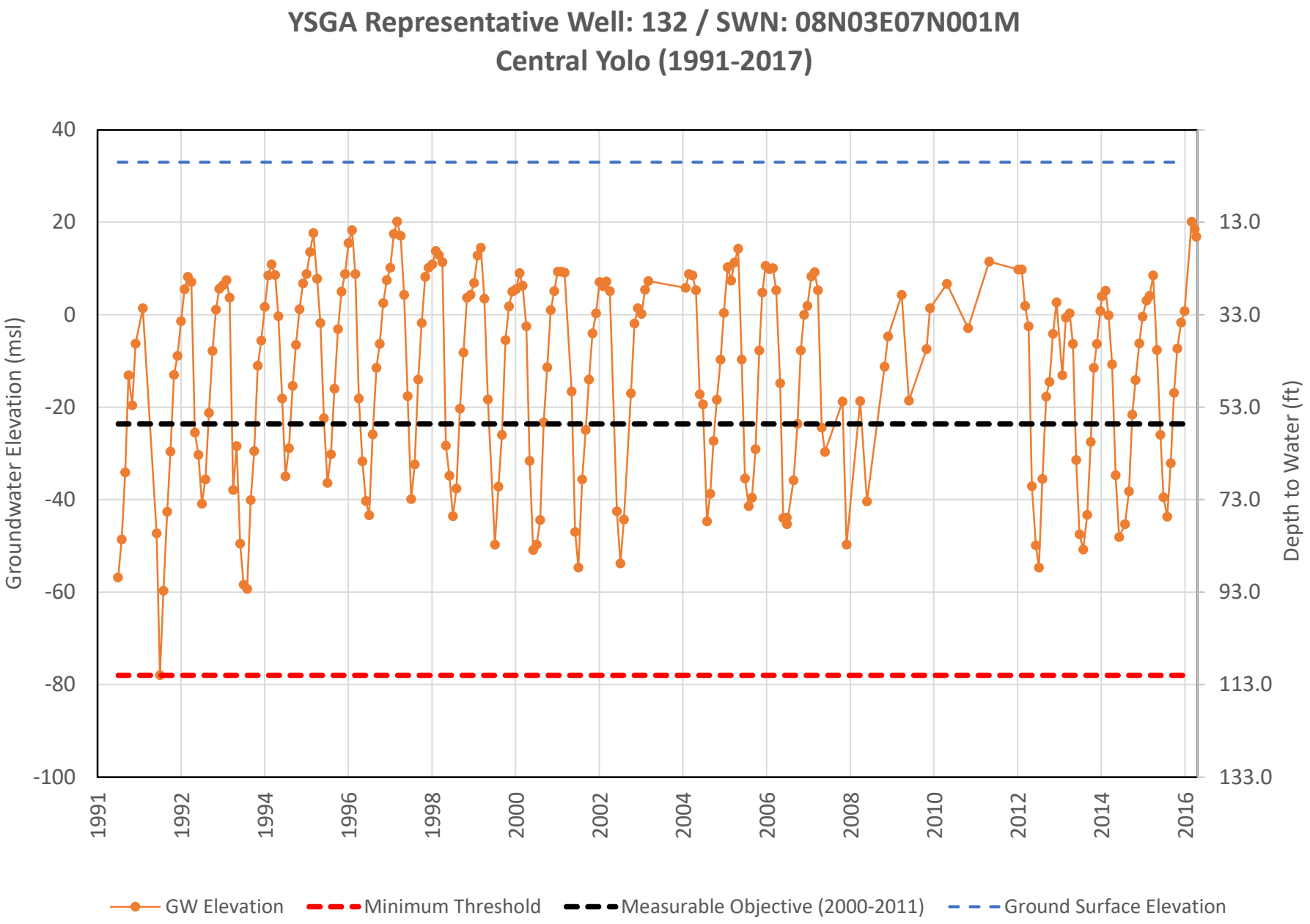
Central Yolo Management Area

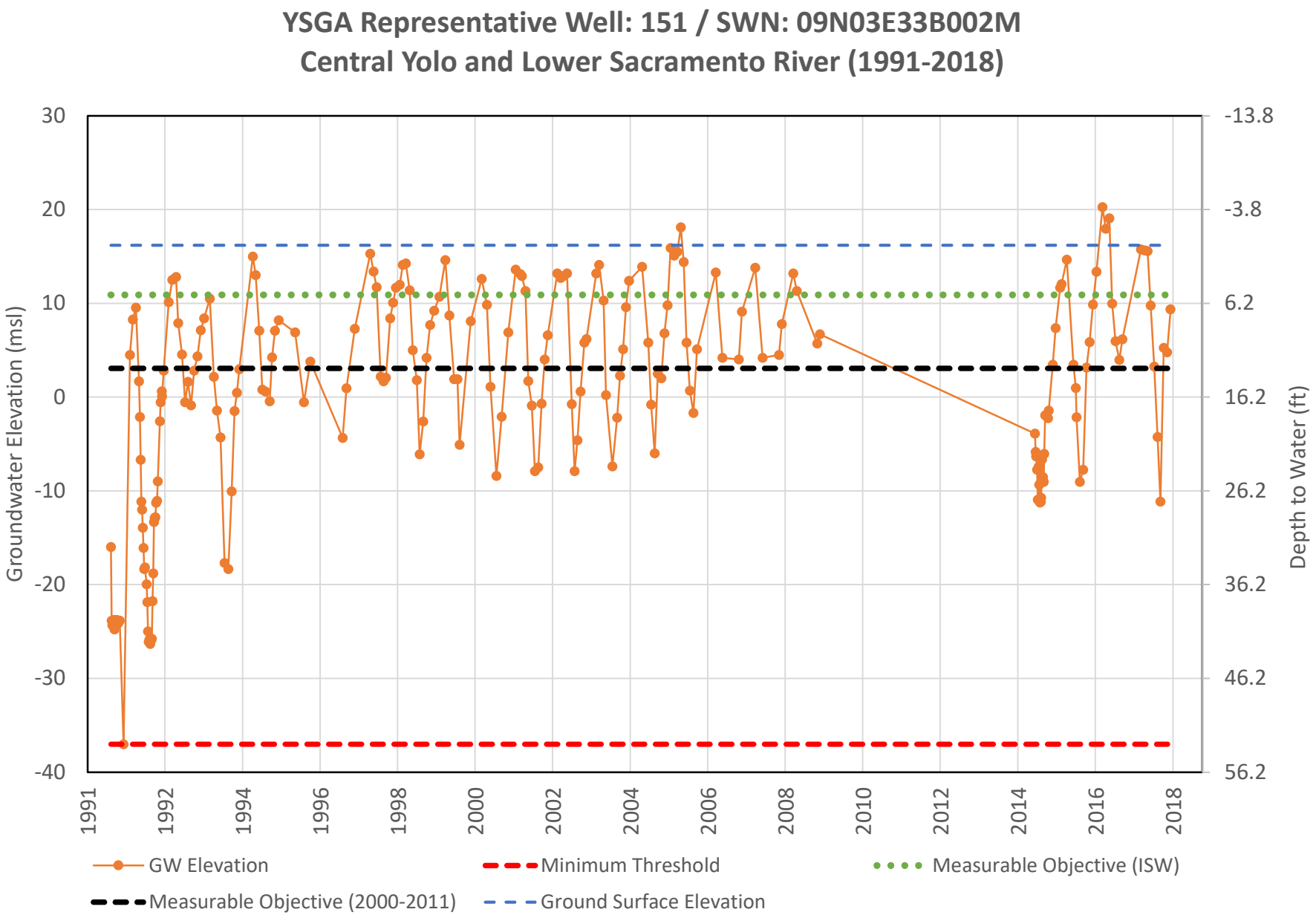


Central Yolo Management Area- Representative Monitoring Well Construction Information

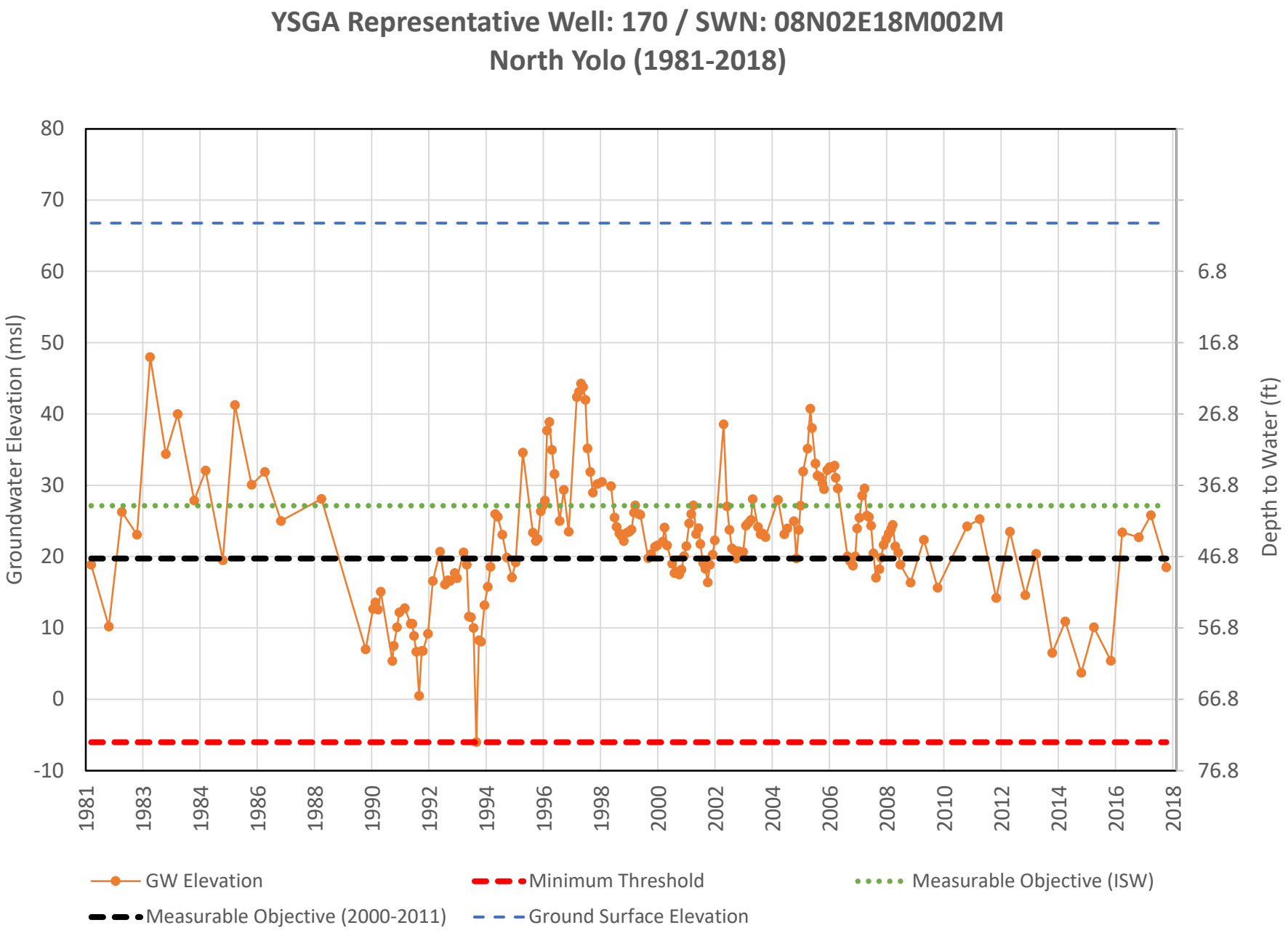
YSGA Well Number	State Well Number	Groundwater Elevations	Change in Storage	Depletion of ISW	Monitored by	Reference Point Elevation (feet)	Ground Surface Elevation (feet)	Well Use Type	Latitude	Longitude	Well Depth (ft bgs)	Well Completion Report Number	Top Perforation	Bottom Perforation
114	08N02E15A002M	X	X		City of Davis	46.4	43.28605	Public Supply	38.5441828	-121.731229	460	232130	208	447
132	08N03E07N001M	X	X		YSGA	36.3	33		38.5460704	-121.694196	471		237	455
151	09N03E33B002M	X	X	X	WDCWA	20.86	17.96	Monitoring	38.5894178	-121.644924	280	433668	150	260
170	08N02E18M002M	X	X	X	USBR	68.5	68.5	Irrigation	38.5393869	-121.80201	156			
220	08N01E07R001M	X	X		YCFC	107.54	107.203	Irrigation	38.5503372	-121.897634	143	10398	119	143
222	08N01W09C001M	X	X		YCFC	168.18	167.674	Irrigation	38.5589028	-121.984206	386	57-313		
224	08N01W13G003M	X	X		YCFC	117.66	117.489	Irrigation	38.5414744	-121.924539	127			
229	08N01W20R005M	X	X	X	YCFC	152.62	152.399	Domestic	38.5199068	-121.990789	300			
230	09N01E03C003M	X	X		YCFC	101.05	102.038	Irrigation	38.6622603	-121.853374	567	57-366	50	524
231	09N01E07D001M	X	X		YCFC	124.52	123.686	Irrigation	38.6488944	-121.915208	432	57-376	160	205
233	09N01E20E001M	X	X		YCFC	114.81	113.759	Irrigation	38.6133408	-121.89521	401			
234	09N01E24D001M	X	X		YCFC	69.33	69.179	Irrigation	38.6195492	-121.817586	300			
235	09N01E31D001M	X	X		YCFC	118.07	117.884	Irrigation	38.5901231	-121.911466	52			
239	09N01W08Q001M	X	X		YCFC	198.9	197.388	Irrigation	38.6352916	-121.995812	425	1027		
240	09N01W21E001M	X	X		DWR	175.21	174.947	Domestic	38.6150911	-121.986658	100	121591	89	99
246	09N02E07L001M	X	X		YCFC	70.78	69.732	Irrigation	38.6412045	-121.796173	425	57-1033	37	419
248	09N02E32M001M	X	X		YCFC	60.98	60.676	Irrigation	38.5830848	-121.784874	358	33046	132	358
250	09N03E19R002M	X	X		DWR/YCFC	24.25	23.705	Monitoring	38.6040776	-121.674667	295	433699	110	290
254	10N01E23Q002M	X	X		YCFC	91.81	91.119	Irrigation	38.6929297	-121.826814	216	57-297	100	216
256	10N01E29K001M	X	X		YCFC	112.76	112.474	Irrigation	38.6821856	-121.881097	336	57-672		
261	10N01W08B001M	X	X		YCFC	180.85	180.541	Other	38.7371555	-121.998711	133	1046		
265	10N01W21J001M	X	X	X	YCFC	161.3	161.324	Irrigation	38.698595	-121.974388	196		25	152
268	10N01W32E001M	X	X		YCFC	188.79	188.79	Irrigation	38.6695092	-121.996365	188			
269	10N01W35Q001M	X	X		YCFC	141.38	141.38	Irrigation	38.6656385	-121.942817	240		88	240
275	10N02W14A001M	X	X	X	YCFC	207.64	207.544	Irrigation	38.7216042	-122.046485	135	57-1253	76	128
279	10N02W26P001M	X	X		YCFC	354.35	352.597	Domestic	38.6793287	-122.05744	205	69905	174	204
406	10N02E29A001M	X	X		DWR	57.27	55.77	Residential	38.6914448	-121.766248	120	97952	39	79
400	09N02E22H002M	X	X		YCFC	38.99	38.114	Domestic	38.6127924	-121.730511	317			
401	10N02E36E001M	X	X	X	DWR	30.15	28.52	Monitoring	38.6720355	-121.70959	150	421810	90	150
403	09N01E26N001M	X	X		YCFC	80.15	78.882	Irrigation	38.593941	-121.839912	174	57-464	99	174
404	09N01W23D001M	X	X		YCFC	146.34	146.254	Irrigation	38.6179105	-121.952715	362	072976	219	362
424	10N01W23P001M			X	YCFC	145.34	145.192	Irrigation	38.6933589	-121.943941	80	1073	35	44
425	10N01E22H500M			X	Teichert	84.83	84.83		38.703084	-121.840927	60			
426	10N01W16G500M			X	Teichert	168.63	168.63		38.7167132	-121.97966	65			
429	08N01E17F001M			X	USBR	103.8	103.7	Domestic	38.5415585	-121.888788	200		20	200
419	08N01W22G500M	X	X		Winters		131.4635	Public Supply	38.526988	-121.961307	300	492121	170	300

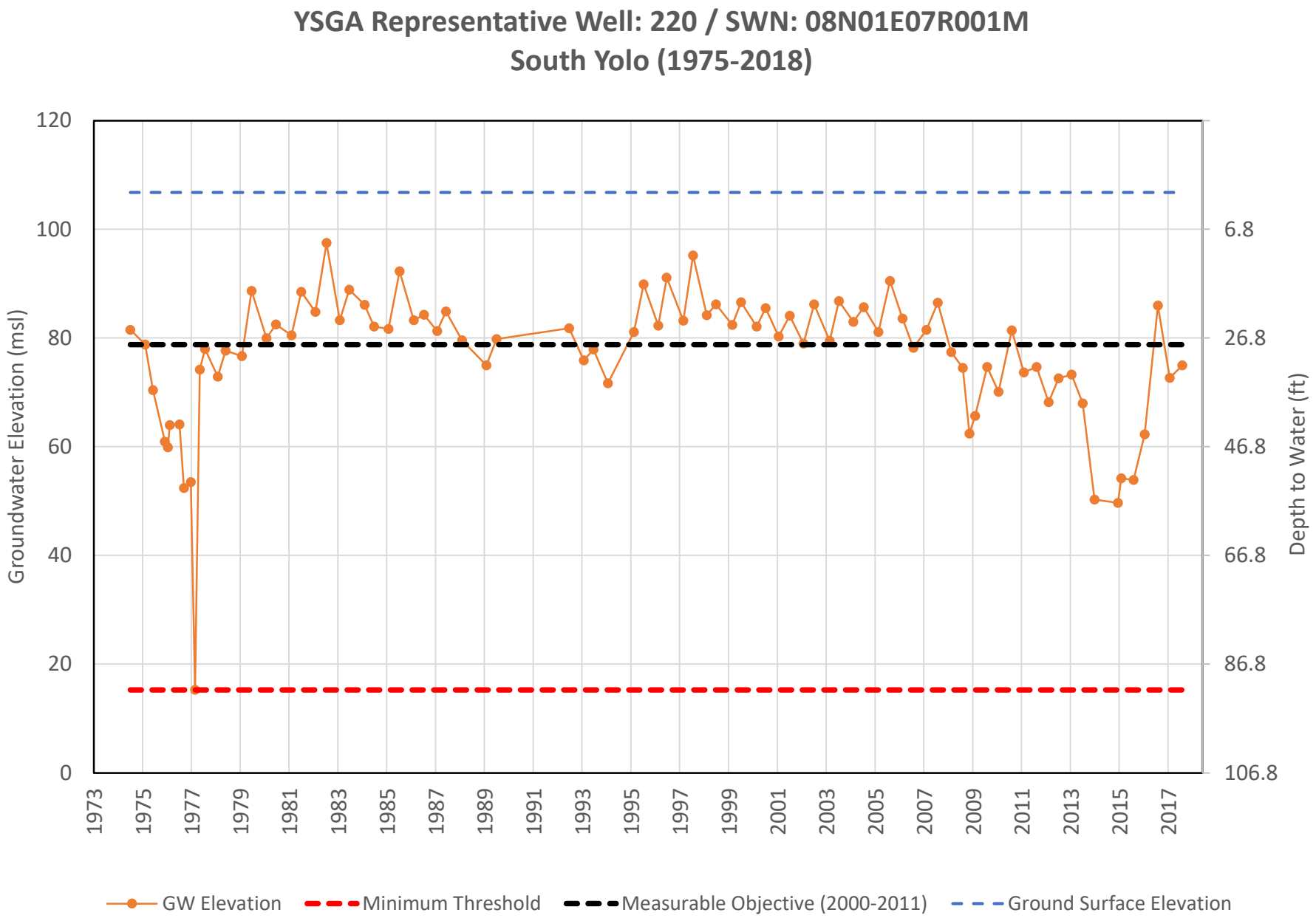

YSGA Representative Well: 114 / SWN: 08N02E15A002M
Central Yolo (1982-2016)
Groundwater Elevation (msl)
Depth to Water (ft)
60
40
20
0
-20
-40
-60
-80
4.0
24.0
44.0
64.0
84.0
104.0
124.0
1982
1984
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003
2005
2007
2009
2011
2013
2015
GW Elevation
Minimum Threshold
Measurable Objective (2000-2011)
Ground Surface Elevation

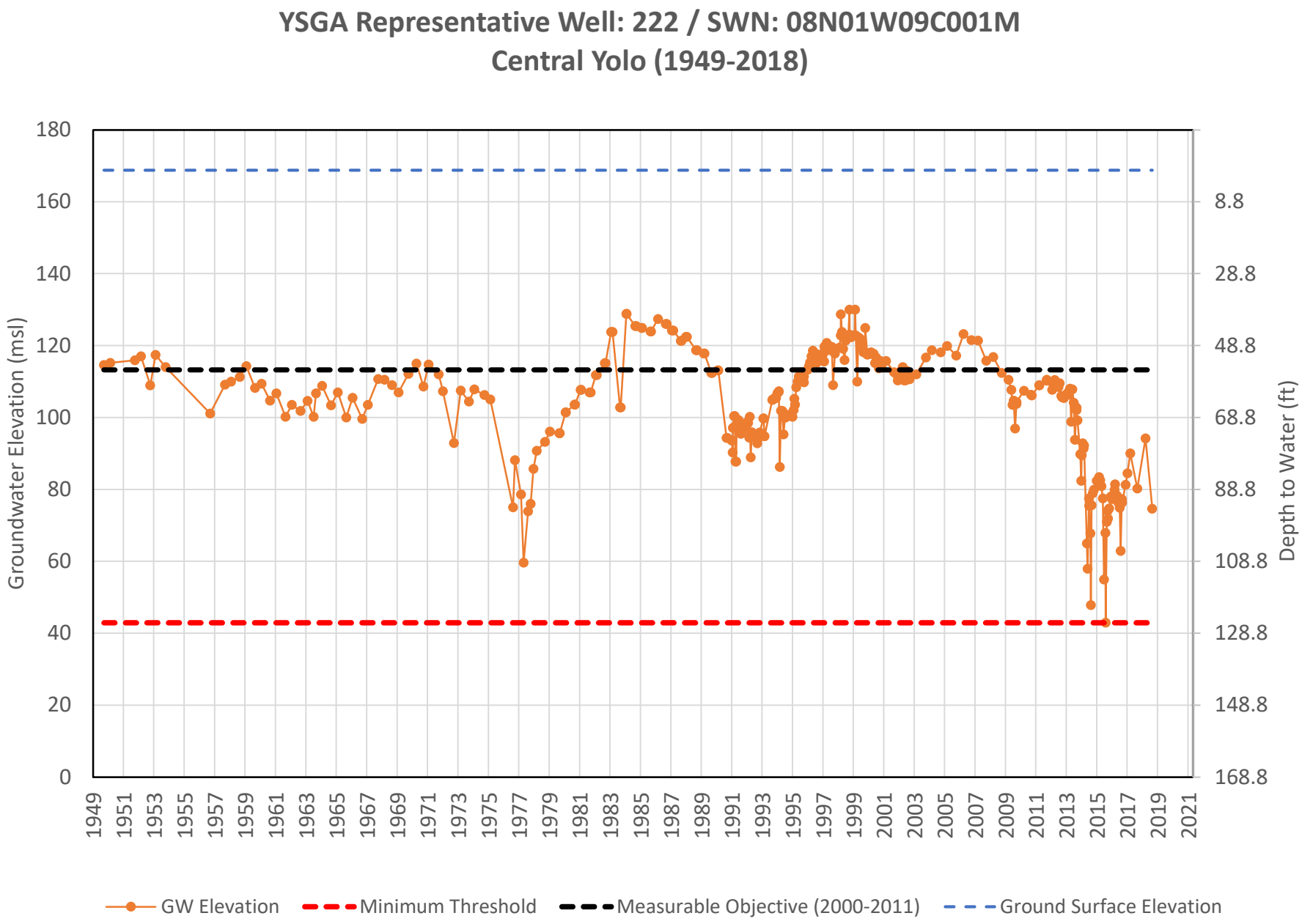

YSGA Representative Well: 132 / SWN: 08N03E07N001M
Central Yolo (1991-2017)
Groundwater Elevation (msl)
Depth to Water (ft)
40
20
0
-20
-40
-60
-80
-100
13.0
33.0
53.0
73.0
93.0
113.0
133.0
1991
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
GW Elevation
Minimum Threshold
Measurable Objective (2000-2011)
Ground Surface Elevation

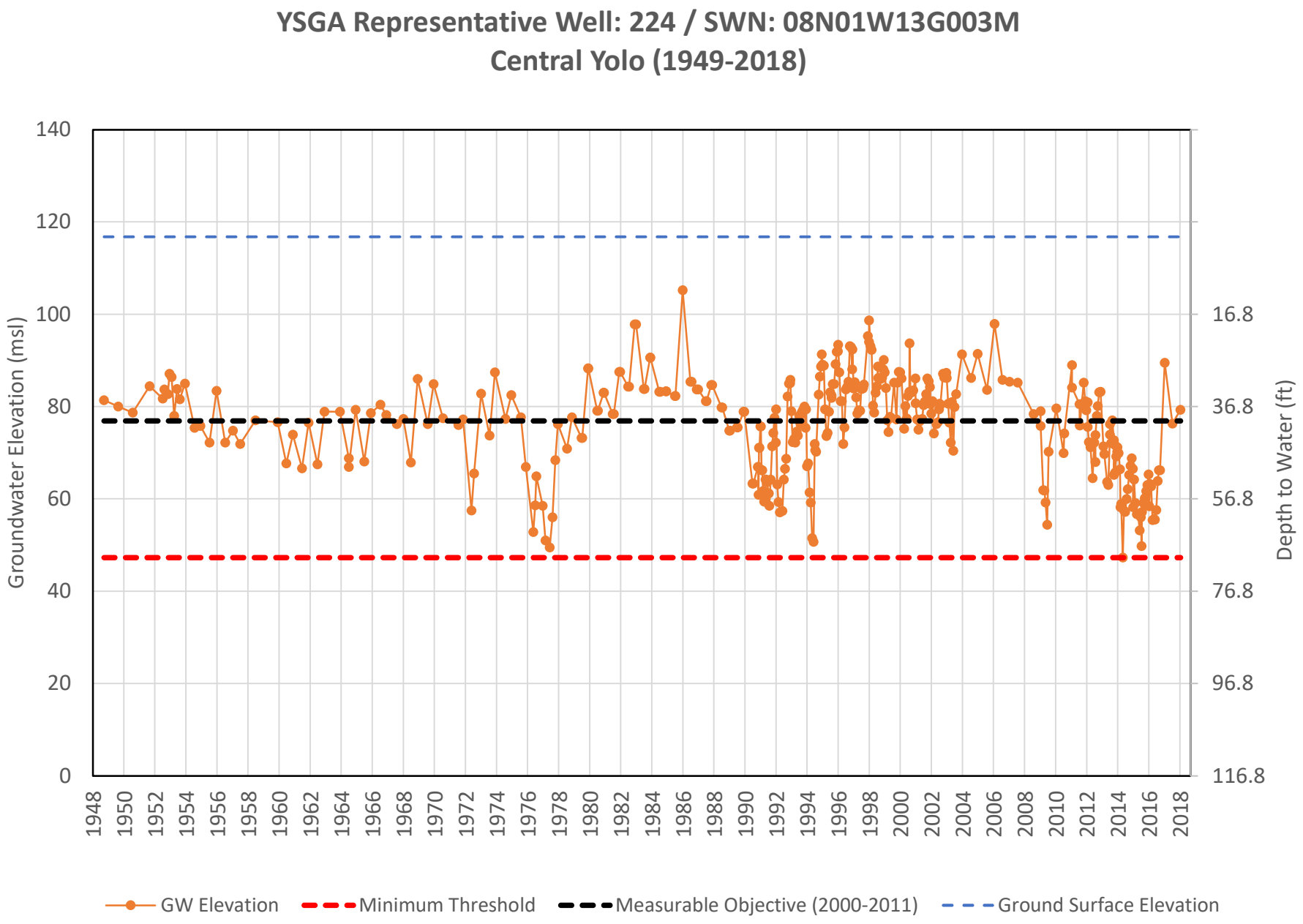


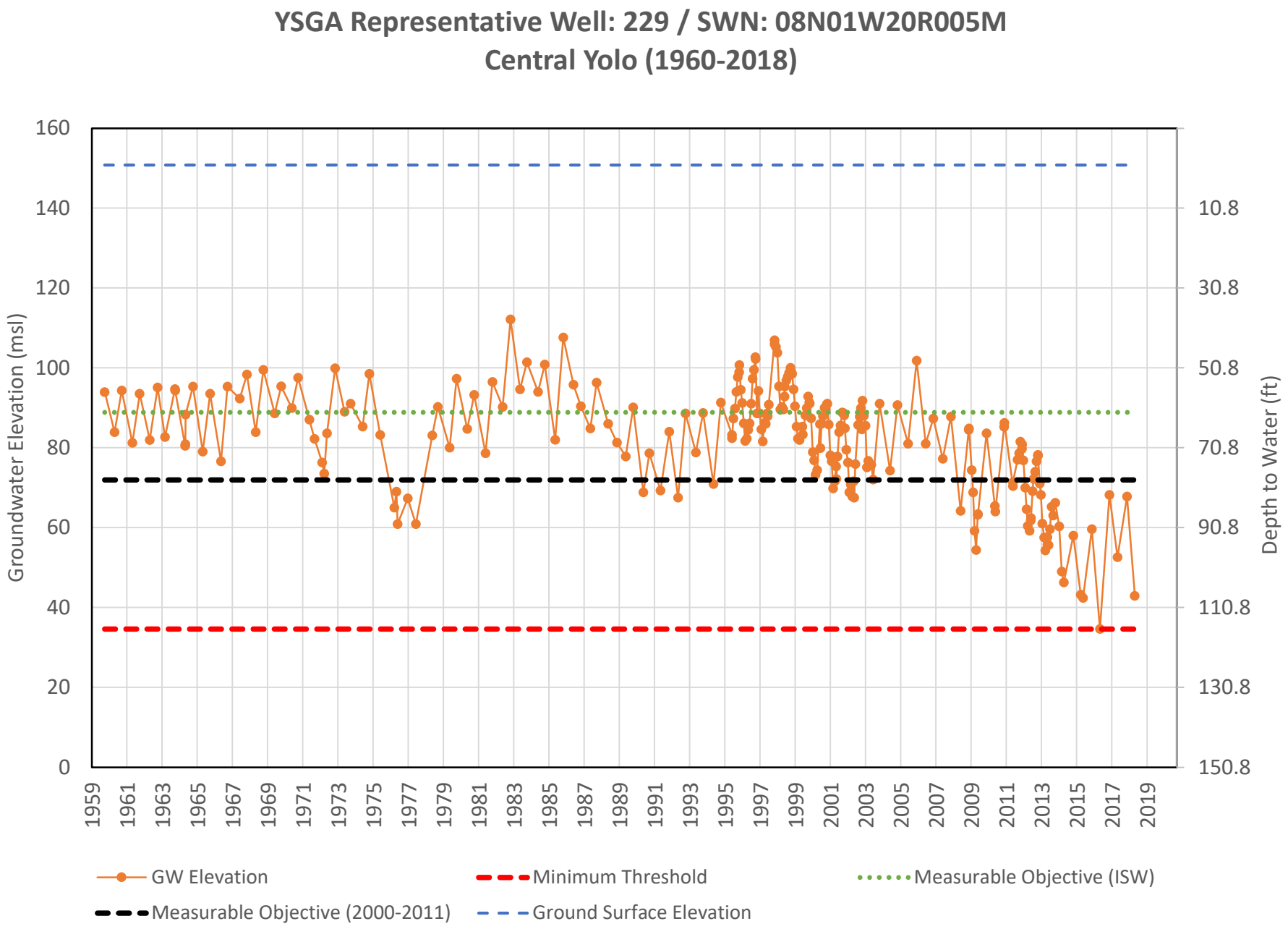
Note: April 20, 2006 GW elevation is reported above reported ground surface elevation.

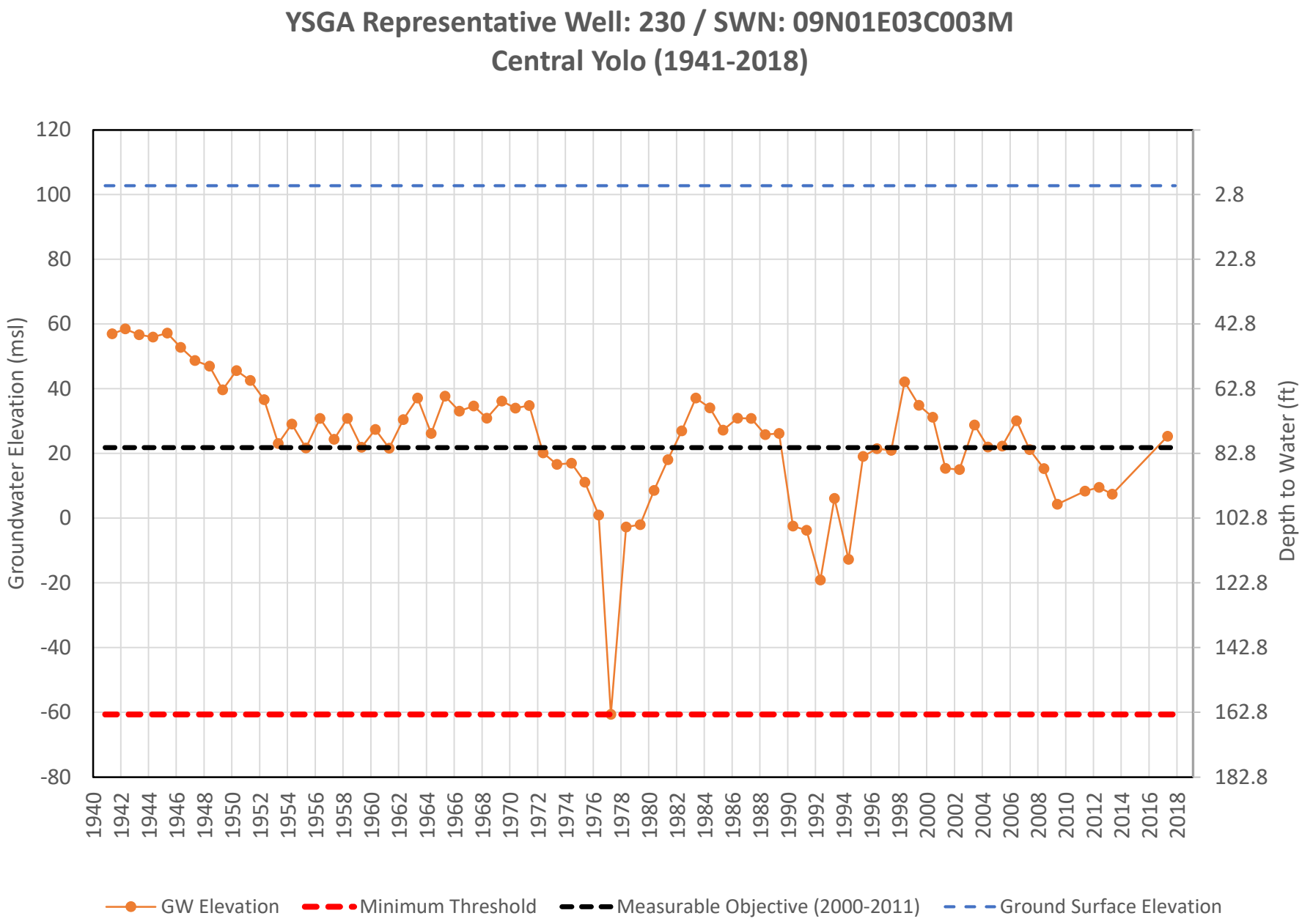

YSGA Representative Well: 170 / SWN: 08N02E18M002M
North Yolo (1981-2018)
Groundwater Elevation (msl)
Depth to Water (ft)
80
70
60
50
40
30
20
10
0
-10
6.8
16.8
26.8
36.8
46.8
56.8
66.8
76.8
1981
1983
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
2018
GW Elevation
Minimum Threshold
Measurable Objective (ISW)
Measurable Objective (2000-2011)
Ground Surface Elevation


YSGA Representative Well: 220 / SWN: 08N01E07R001M
South Yolo (1975-2018)
Groundwater Elevation (msl)
Depth to Water (ft)
120
100
80
60
40
20
0
6.8
26.8
46.8
66.8
86.8
106.8
1973
1975
1977
1979
1981
1983
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003
2005
2007
2009
2011
2013
2015
2017
GW Elevation
Minimum Threshold
Measurable Objective (2000-2011)
Ground Surface Elevation


YSGA Representative Well: 222 / SWN: 08N01W09C001M
Central Yolo (1949-2018)
Groundwater Elevation (msl)
Depth to Water (ft)
180
160
140
120
100
80
60
40
20
0
8.8
28.8
48.8
68.8
88.8
108.8
128.8
148.8
168.8
1949
1951
1953
1955
1957
1959
1961
1963
1965
1967
1969
1971
1973
1975
1977
1979
1981
1983
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003
2005
2007
2009
2011
2013
2015
2017
2019
2021
GW Elevation
Minimum Threshold
Measurable Objective (2000-2011)
Ground Surface Elevation


YSGA Representative Well: 224 / SWN: 08N01W13G003M
Central Yolo (1949-2018)
Groundwater Elevation (msl)
Depth to Water (ft)
140
120
100
80
60
40
20
0
16.8
36.8
56.8
76.8
96.8
116.8
1948
1950
1952
1954
1956
1958
1960
1962
1964
1966
1968
1970
1972
1974
1976
1978
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
2018
GW Elevation
Minimum Threshold
Measurable Objective (2000-2011)
Ground Surface Elevation


YSGA Representative Well: 229 / SWN: 08N01W20R005M
Central Yolo (1960-2018)
Groundwater Elevation (msl)
Depth to Water (ft)
160
140
120
100
80
60
40
20
0
10.8
30.8
50.8
70.8
90.8
110.8
130.8
150.8
1959
1961
1963
1965
1967
1969
1971
1973
1975
1977
1979
1981
1983
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003
2005
2007
2009
2011
2013
2015
2017
2019
GW Elevation
Minimum Threshold
Measurable Objective (ISW)
Measurable Objective (2000-2011)
Ground Surface Elevation


YSGA Representative Well: 230 / SWN: 09N01E03C003M
Central Yolo (1941-2018)
Groundwater Elevation (msl)
Depth to Water (ft)
120
100
80
60
40
20
0
-20
-40
-60
-80
2.8
22.8
42.8
62.8
82.8
102.8
122.8
142.8
162.8
182.8
1940
1942
1944
1946
1948
1950
1952
1954
1956
1958
1960
1962
1964
1966
1968
1970
1972
1974
1976
1978
1980
1982
1984
1986
1988
1990
1992
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1996
1998
2000
2002
2004
2006
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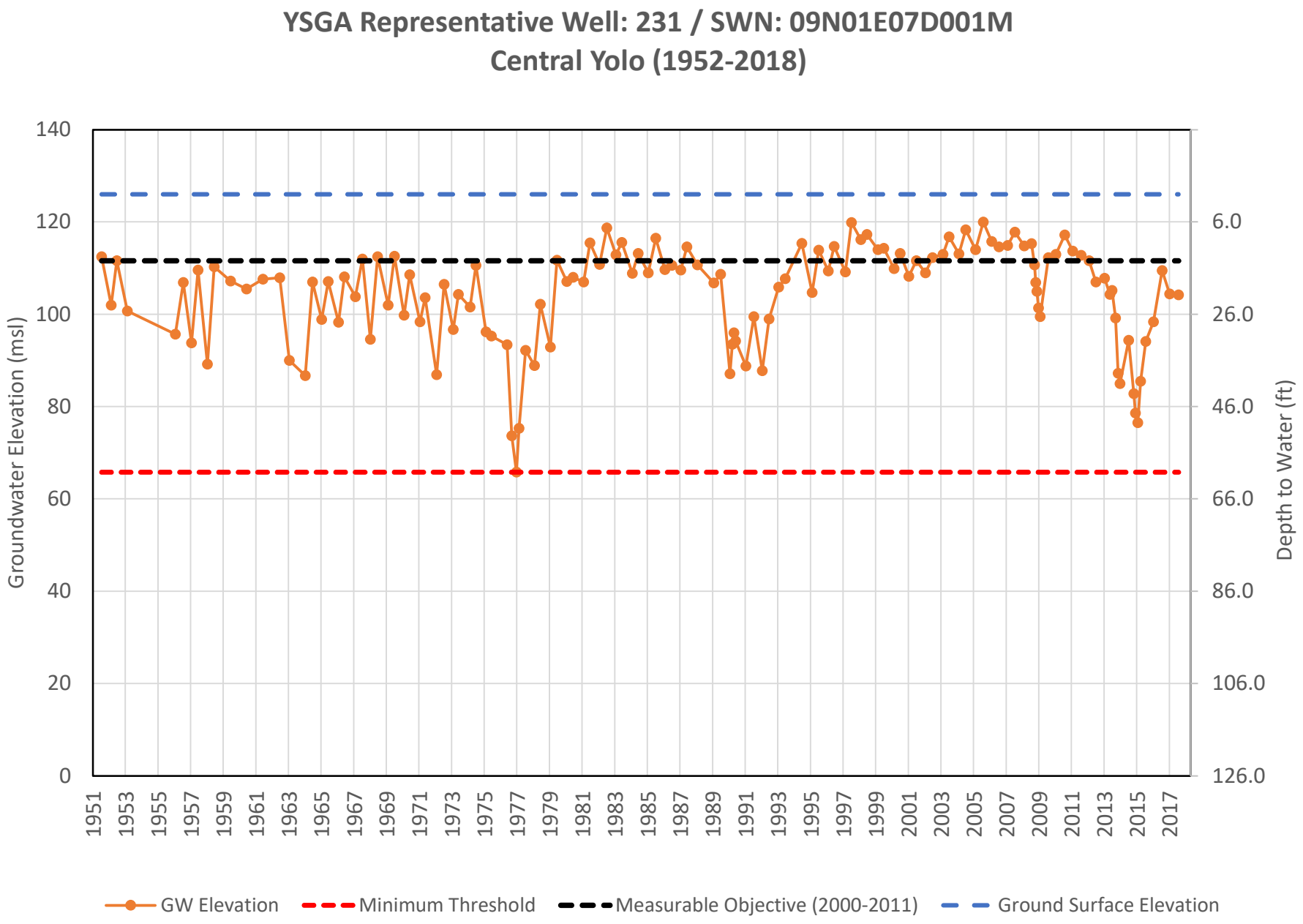
2014
2016
2018
GW Elevation
Minimum Threshold
Measurable Objective (2000-2011)
Ground Surface Elevation


YSGA Representative Well: 231 / SWN: 09N01E07D001M
Central Yolo (1952-2018)
Groundwater Elevation (msl)
Depth to Water (ft)
140
120
100
80
60
40
20
0
6.0
26.0
46.0
66.0
86.0
106.0
126.0
1951
1953
1955
1957
1959
1961
1963
1965
1967
1969
1971
1973
1975
1977
1979
1981
1983
1985
1987
1989
1991
1993
1995
1997
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2001
2003
2005
2007
2009
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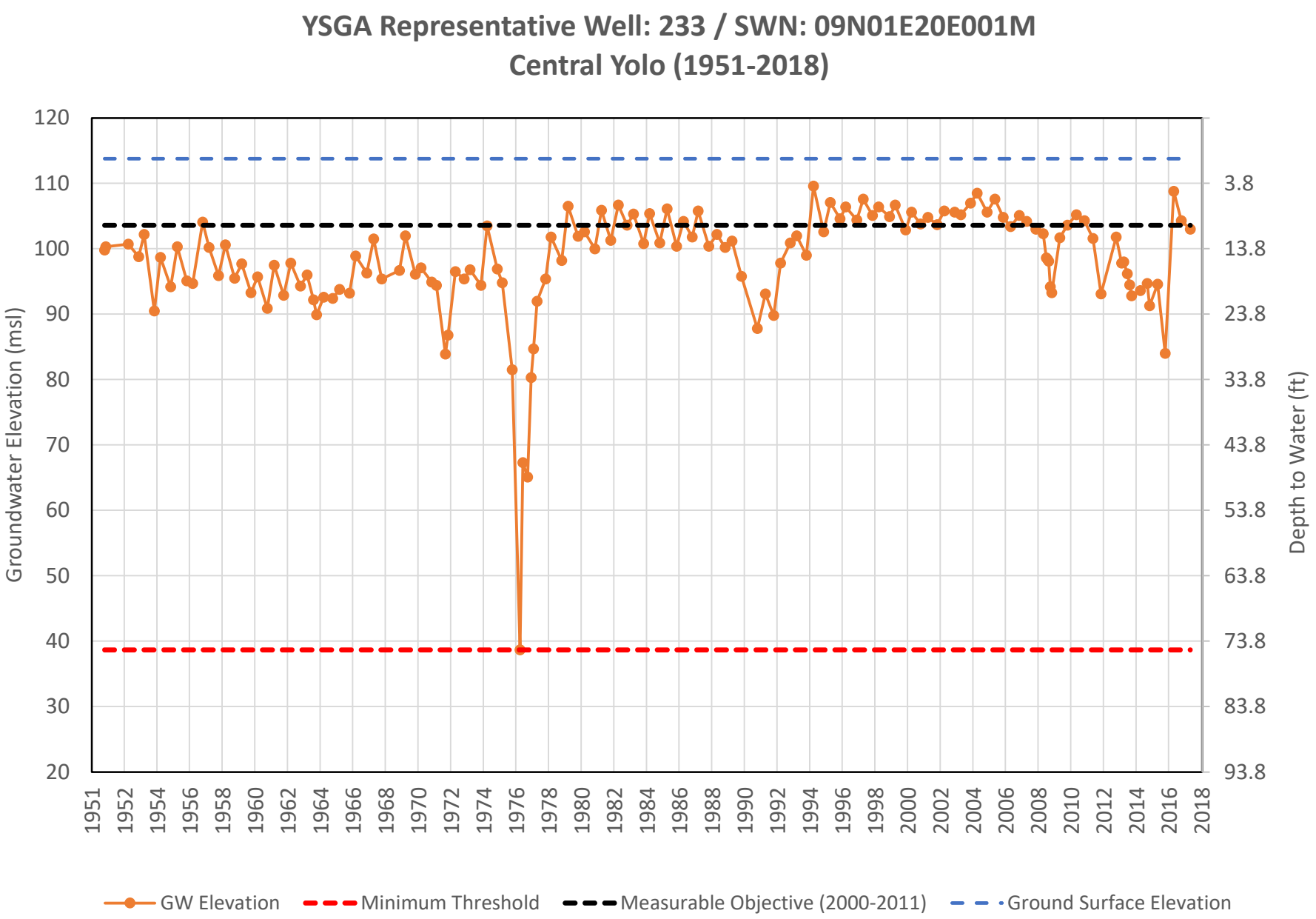
2013
2015
2017
GW Elevation
Minimum Threshold
Measurable Objective (2000-2011)
Ground Surface Elevation


YSGA Representative Well: 233 / SWN: 09N01E20E001M
Central Yolo (1951-2018)
Groundwater Elevation (msl)
Depth to Water (ft)
120
110
100
90
80
70
60
50
40
30
20
3.8
13.8
23.8
33.8
43.8
53.8
63.8
73.8
83.8
93.8
1951
1952
1954
1956
1958
1960
1962
1964
1966
1968
1970
1972
1974
1976
1978
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
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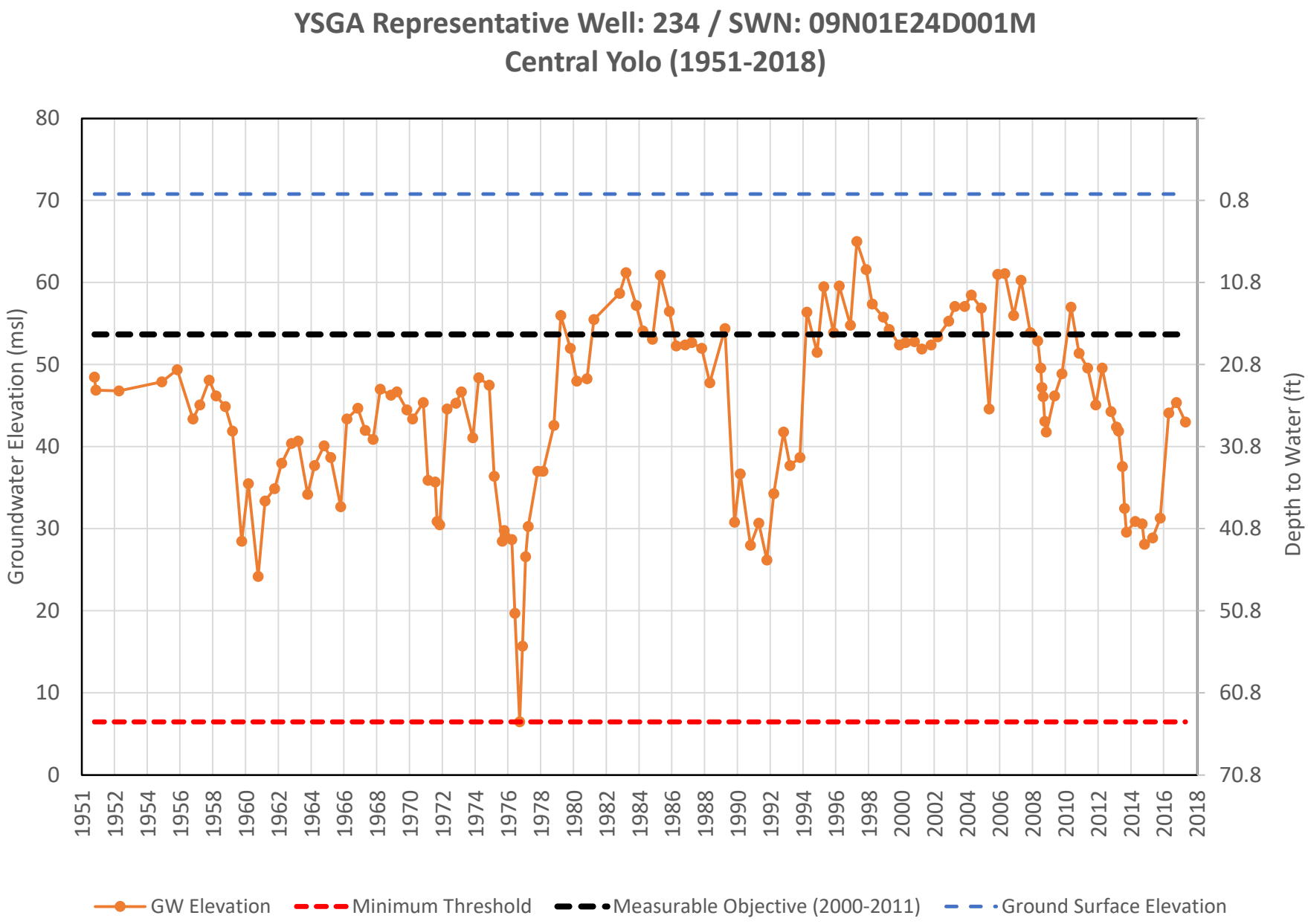
2012
2014
2016
2018
GW Elevation
Minimum Threshold
Measurable Objective (2000-2011)
Ground Surface Elevation


YSGA Representative Well: 234 / SWN: 09N01E24D001M
Central Yolo (1951-2018)
Groundwater Elevation (msl)
Depth to Water (ft)
80
70
60
50
40
30
20
10
0
0.8
10.8
20.8
30.8
40.8
50.8
60.8
70.8
1951
1952
1954
1956
1958
1960
1962
1964
1966
1968
1970
1972
1974
1976
1978
1980
1982
1984
1986
1988
1990
1992
1994
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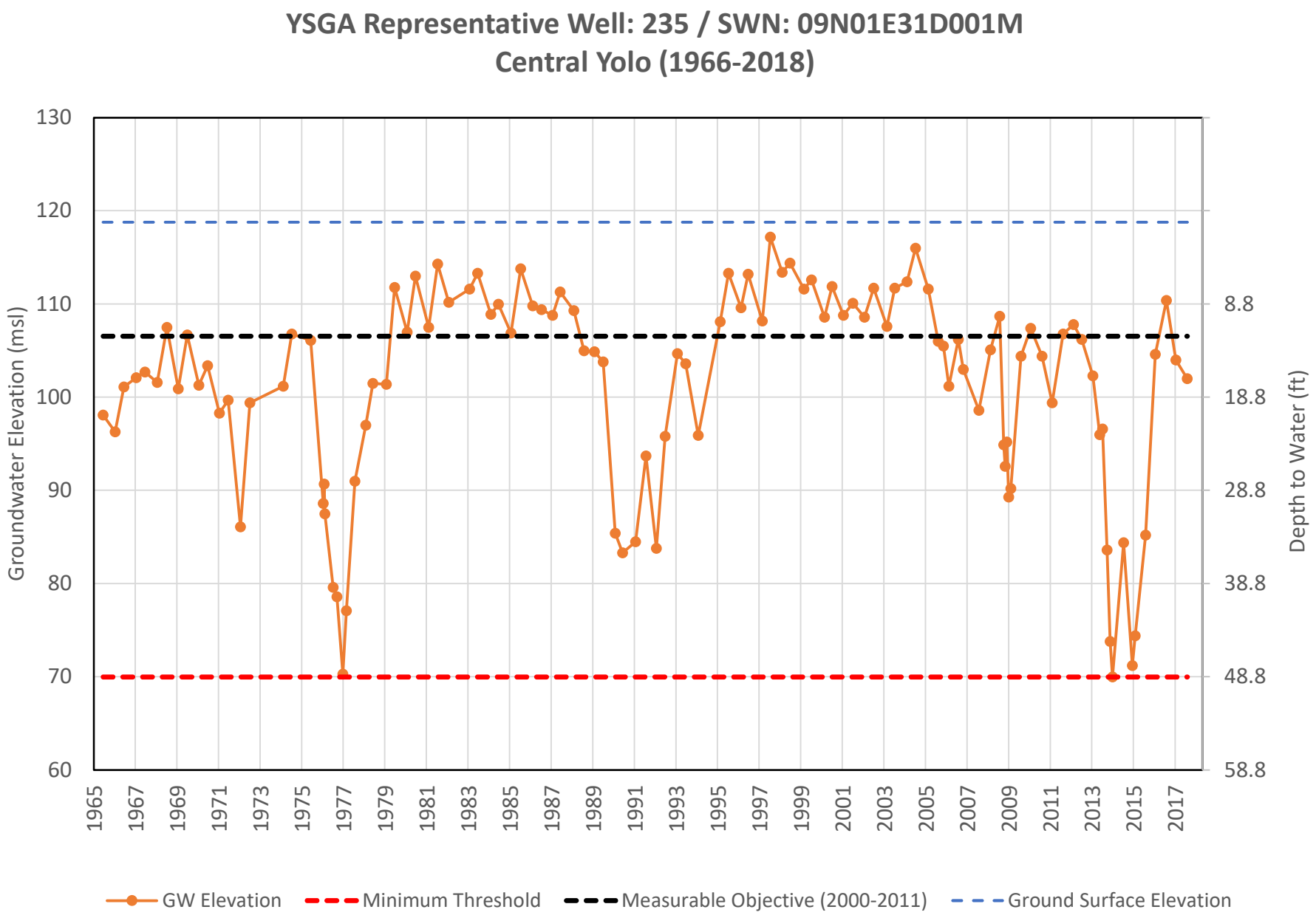
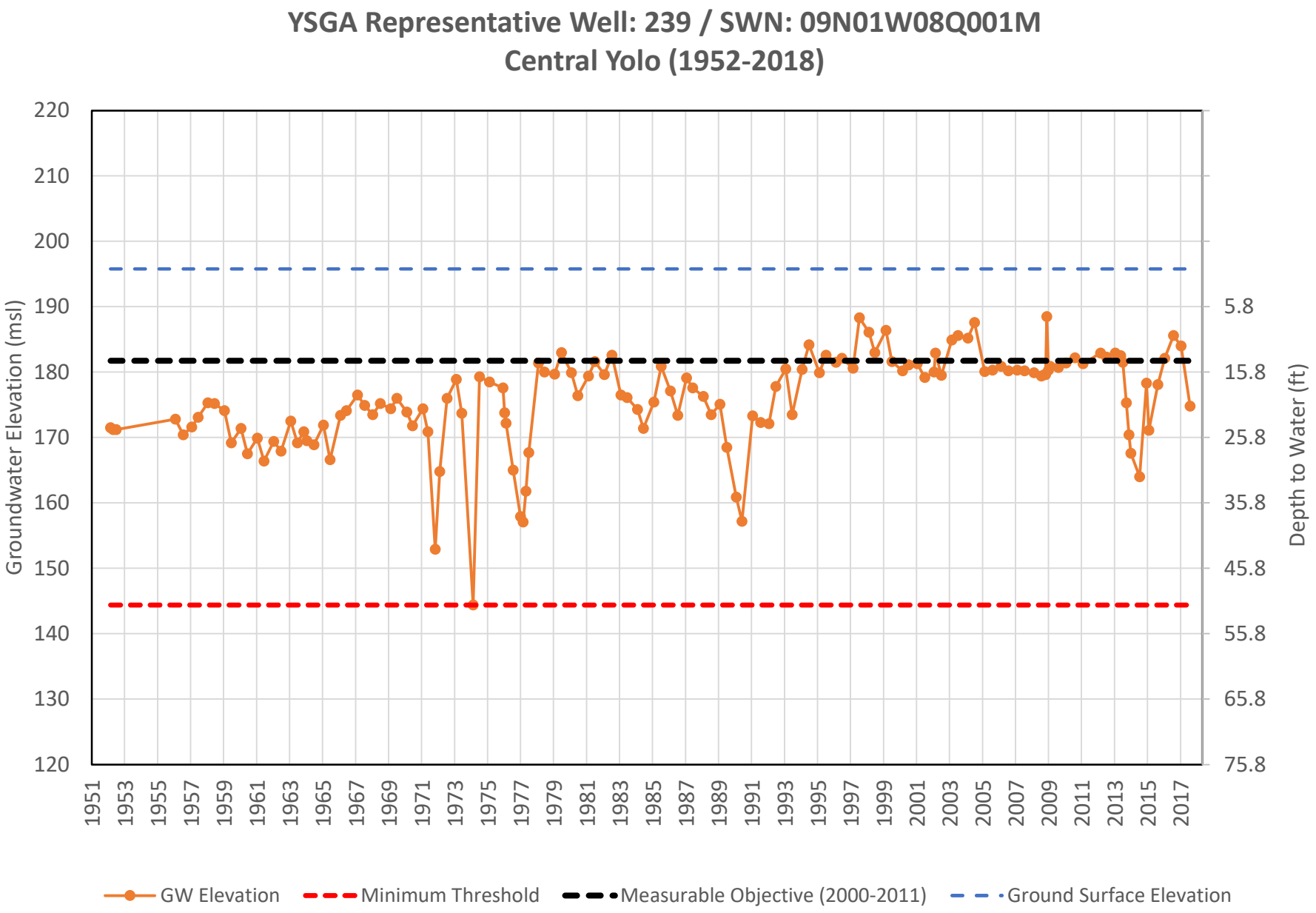
GW Elevation
Minimum Threshold
Measurable Objective (2000-2011)
Ground Surface Elevation


YSGA Representative Well: 235 / SWN: 09N01E31D001M
Central Yolo (1966-2018)
Groundwater Elevation (msl)
Depth to Water (ft)
130
120
110
100
90
80
70
60
8.8
18.8
28.8
38.8
48.8
58.8
1965
1967
1969
1971
1973
1975
1977
1979
1981
1983
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003
2005
2007
2009
2011
2013
2015
2017
GW Elevation
Minimum Threshold
Measurable Objective (2000-2011)
Ground Surface Elevation


YSGA Representative Well: 239 / SWN: 09N01W08Q001M
Central Yolo (1952-2018)
Groundwater Elevation (msl)
Depth to Water (ft)
220
210
200
190
180
170
160
150
140
130
120
5.8
15.8
25.8
35.8
45.8
55.8
65.8
75.8
1951
1953
1955
1957
1959
1961
1963
1965
1967
1969
1971
1973
1975
1977
1979
1981
1983
1985
1987
1989
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1993
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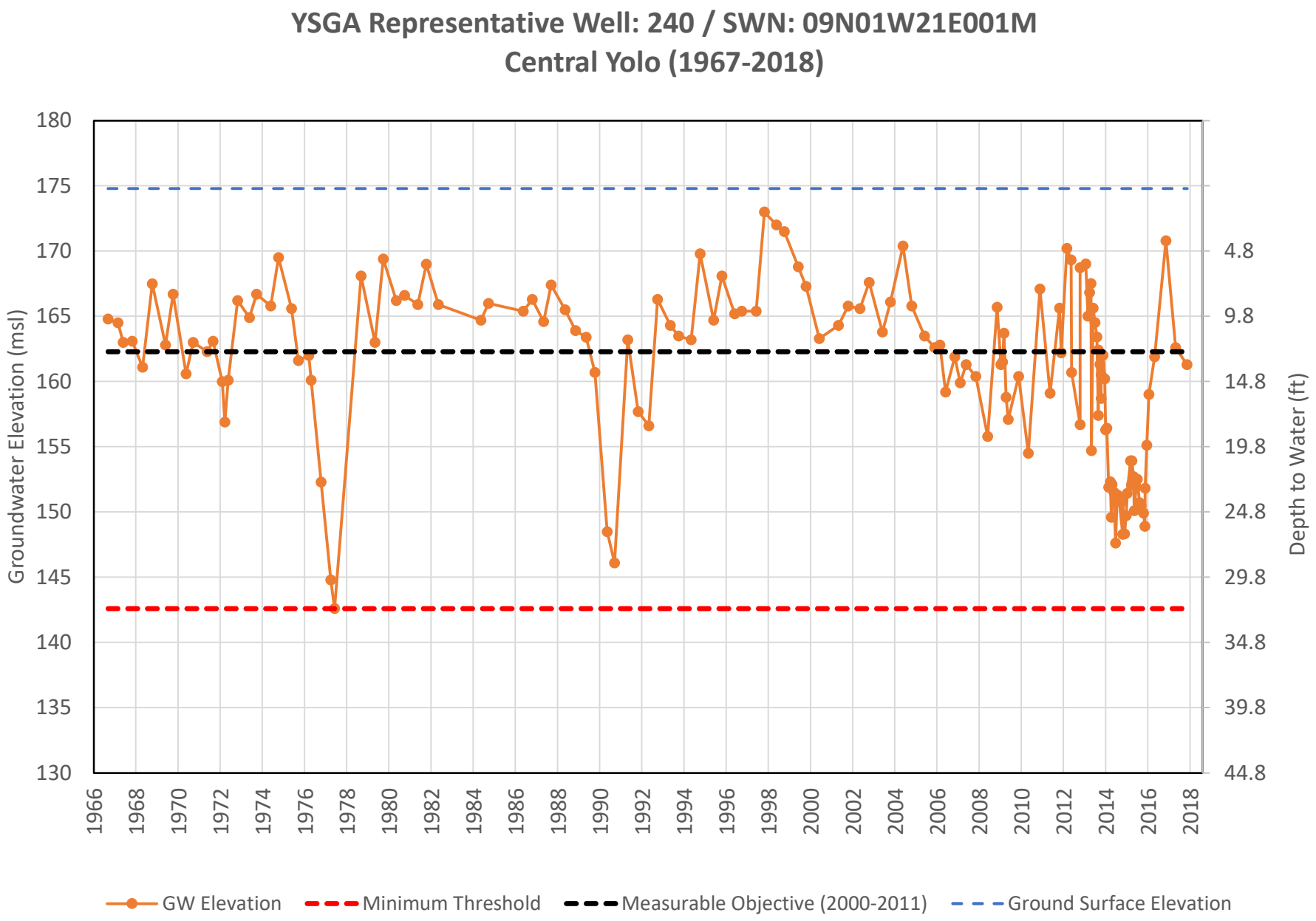
2015
2017
GW Elevation
Minimum Threshold
Measurable Objective (2000-2011)
Ground Surface Elevation


YSGA Representative Well: 240 / SWN: 09N01W21E001M
Central Yolo (1967-2018)
Groundwater Elevation (msl)
Depth to Water (ft)
180
175
170
165
160
155
150
145
140
135
130
4.8
9.8
14.8
19.8
24.8
29.8
34.8
39.8
44.8
1966
1968
1970
1972
1974
1976
1978
1980
1982
1984
1986
1988
1990
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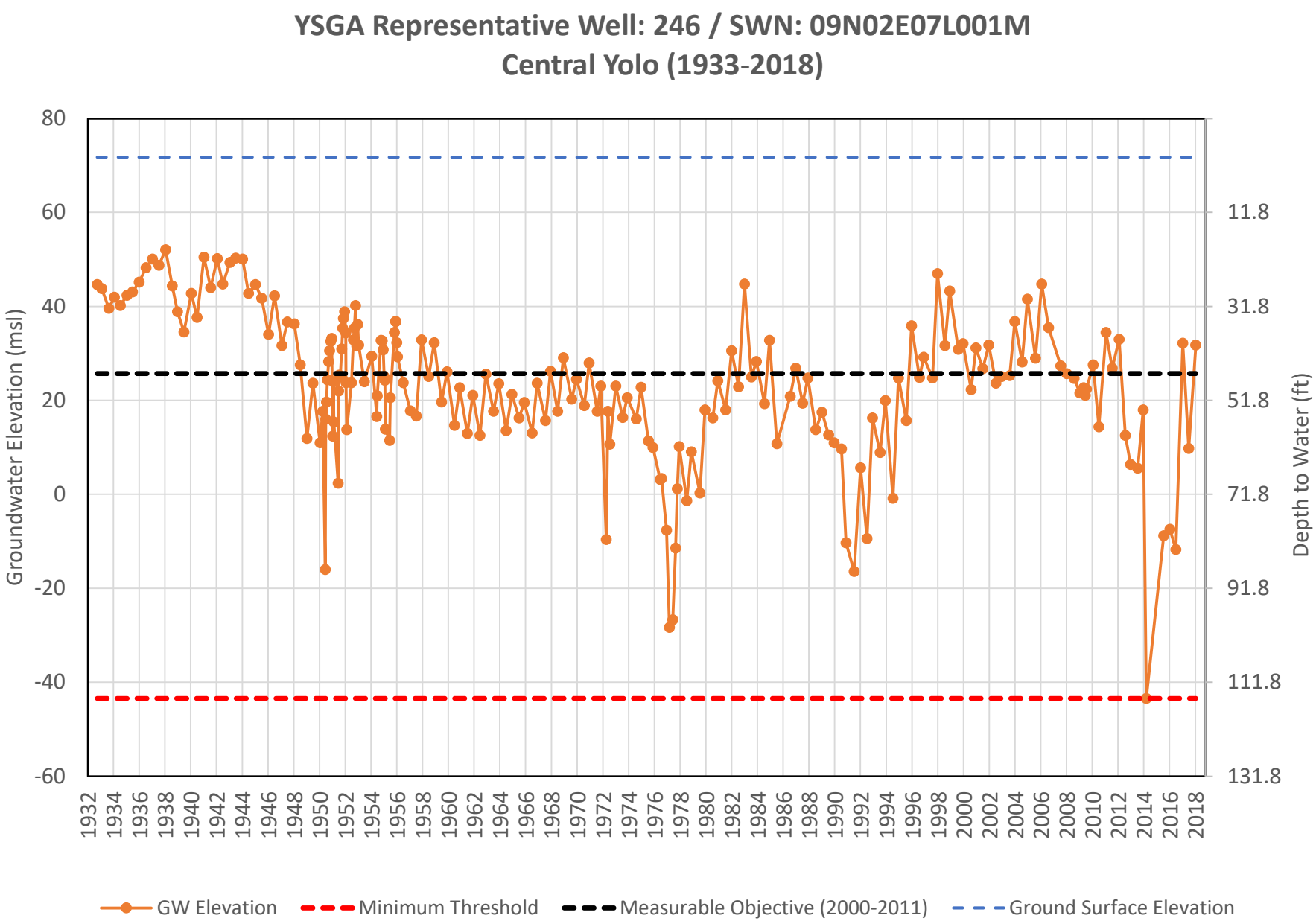
2016
2018
GW Elevation
Minimum Threshold
Measurable Objective (2000-2011)
Ground Surface Elevation


YSGA Representative Well: 246 / SWN: 09N02E07L001M
Central Yolo (1933-2018)
Groundwater Elevation (msl)
Depth to Water (ft)
80
60
40
20
0
-20
-40
-60
11.8
31.8
51.8
71.8
91.8
111.8
131.8
1932
1934
1936
1938
1940
1942
1944
1946
1948
1950
1952
1954
1956
1958
1960
1962
1964
1966
1968
1970
1972
1974
1976
1978
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
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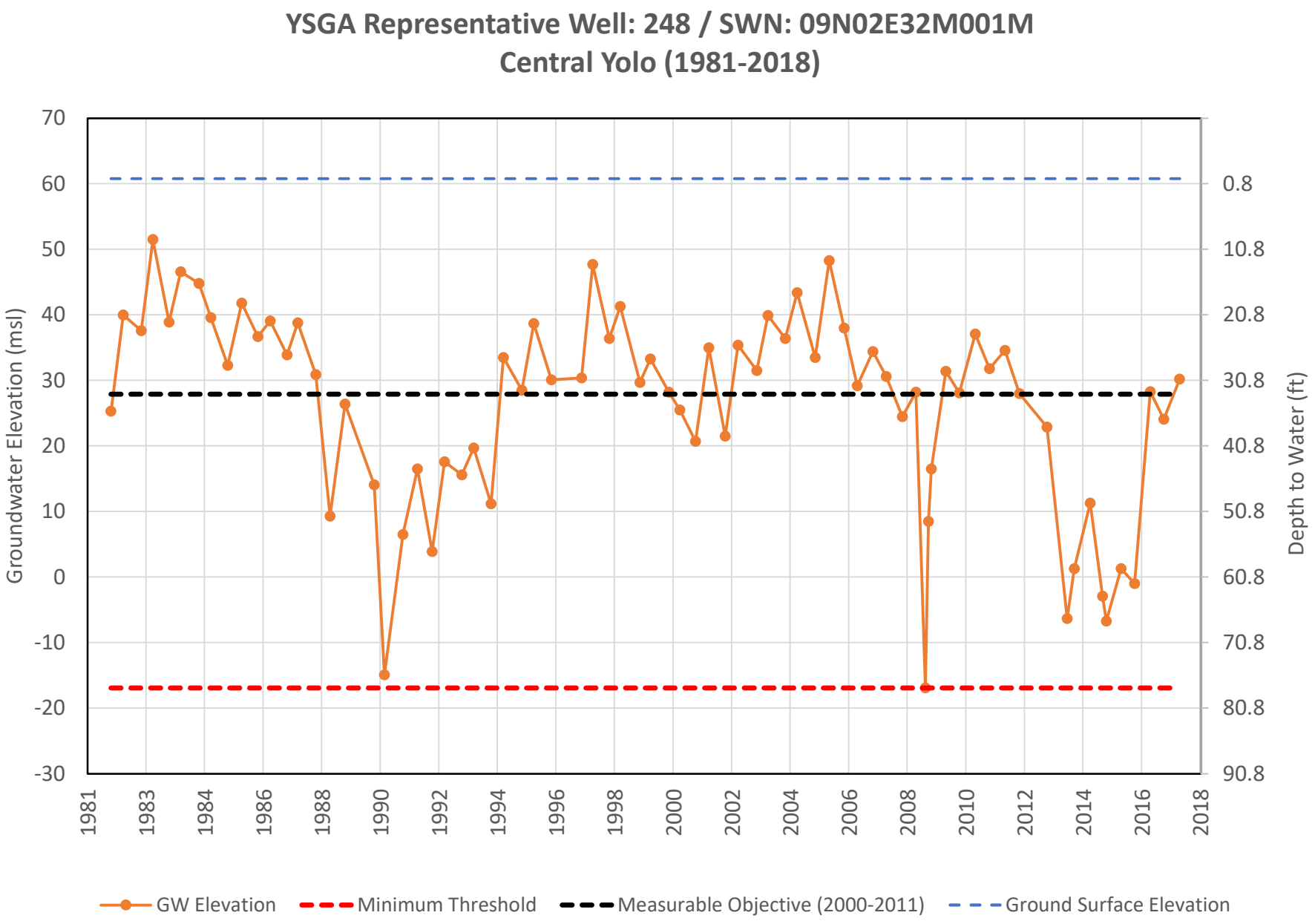
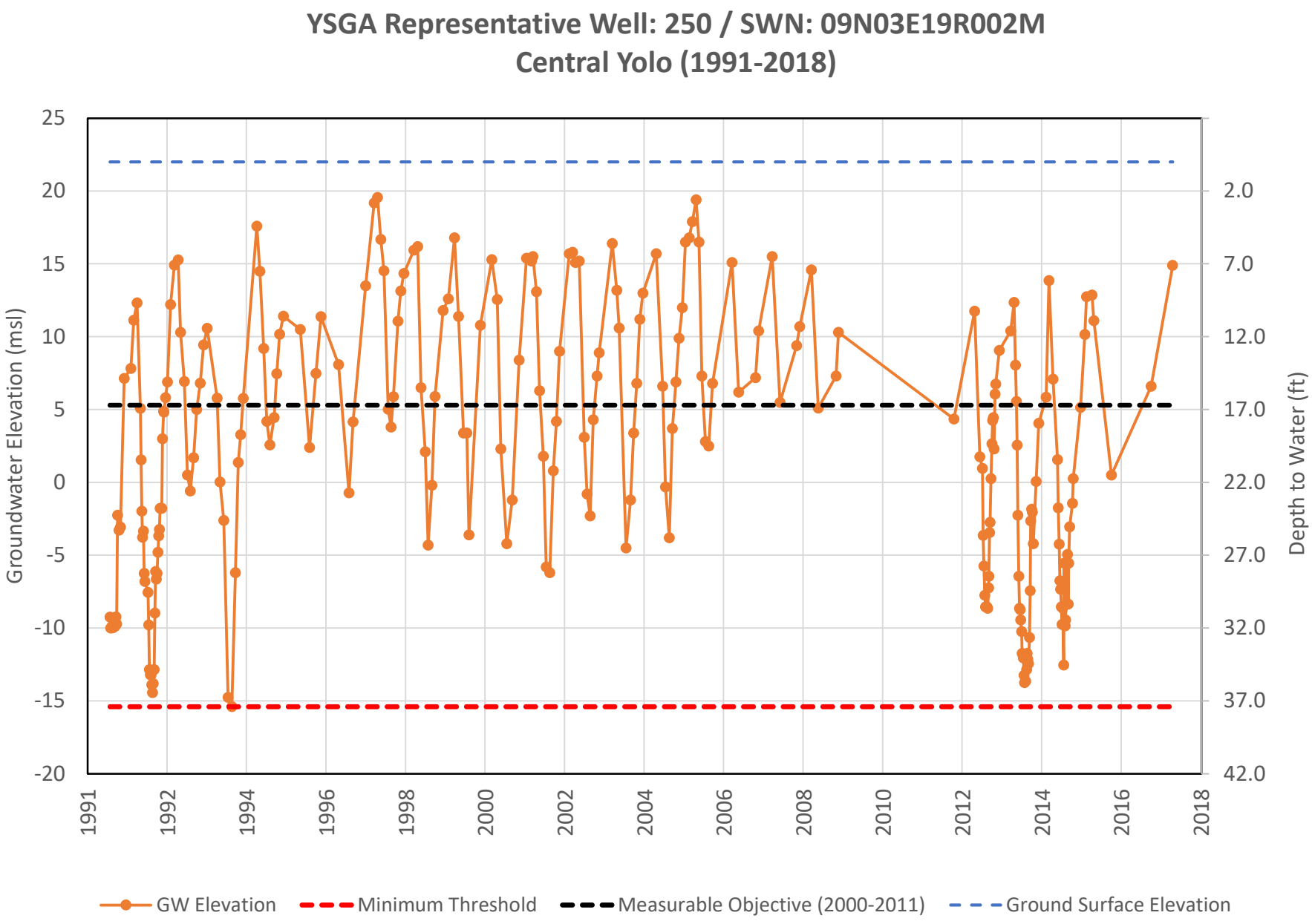
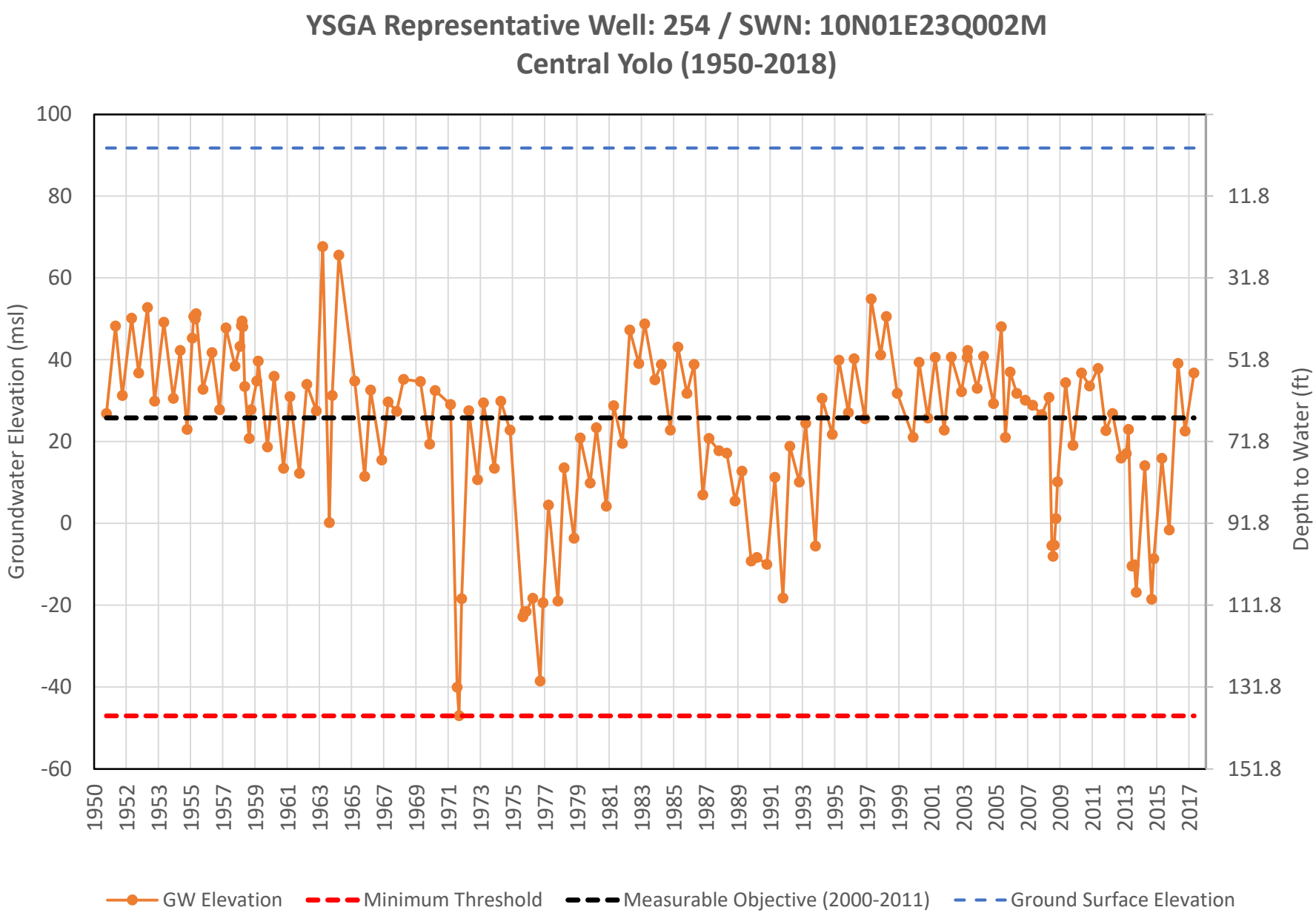
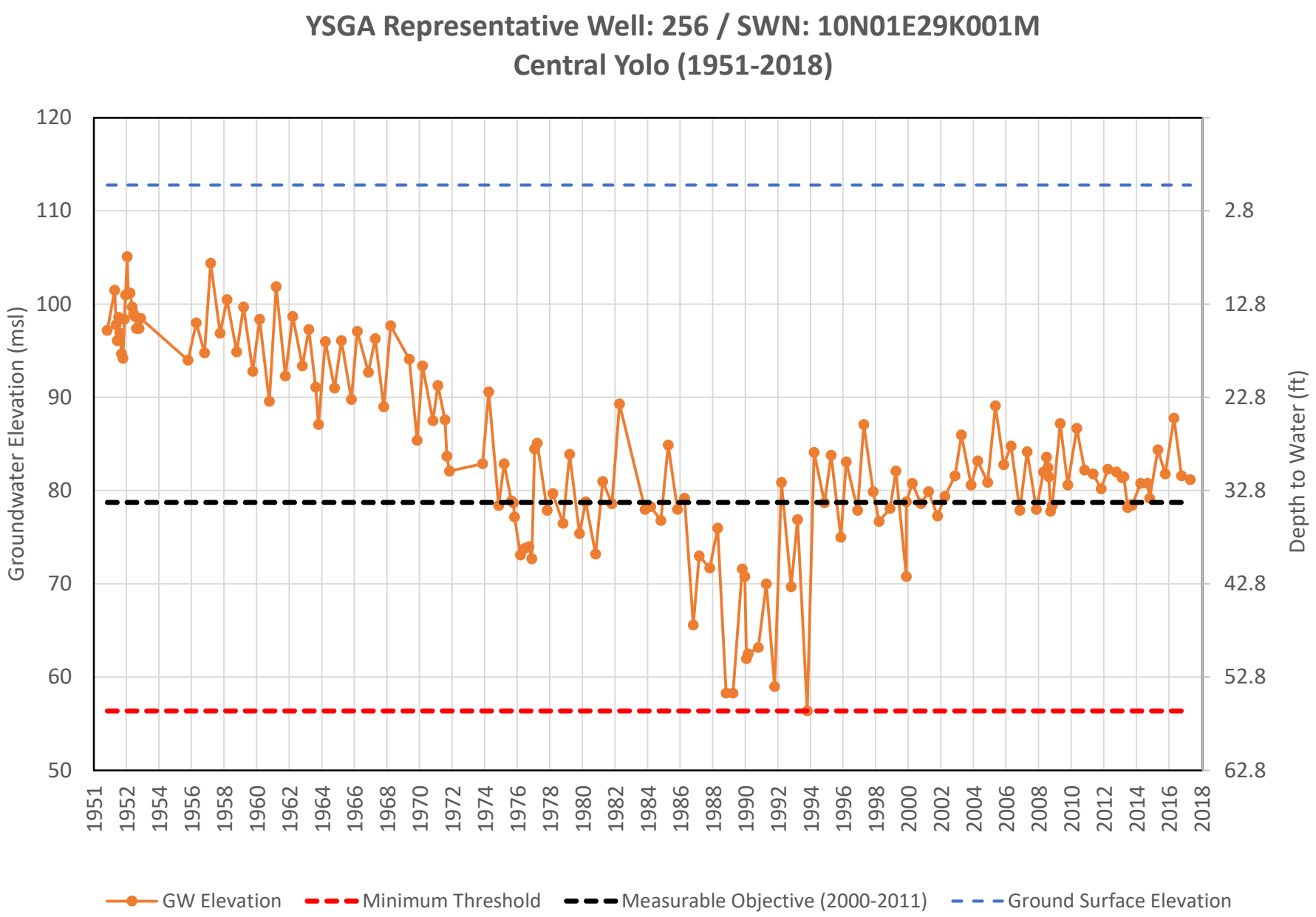
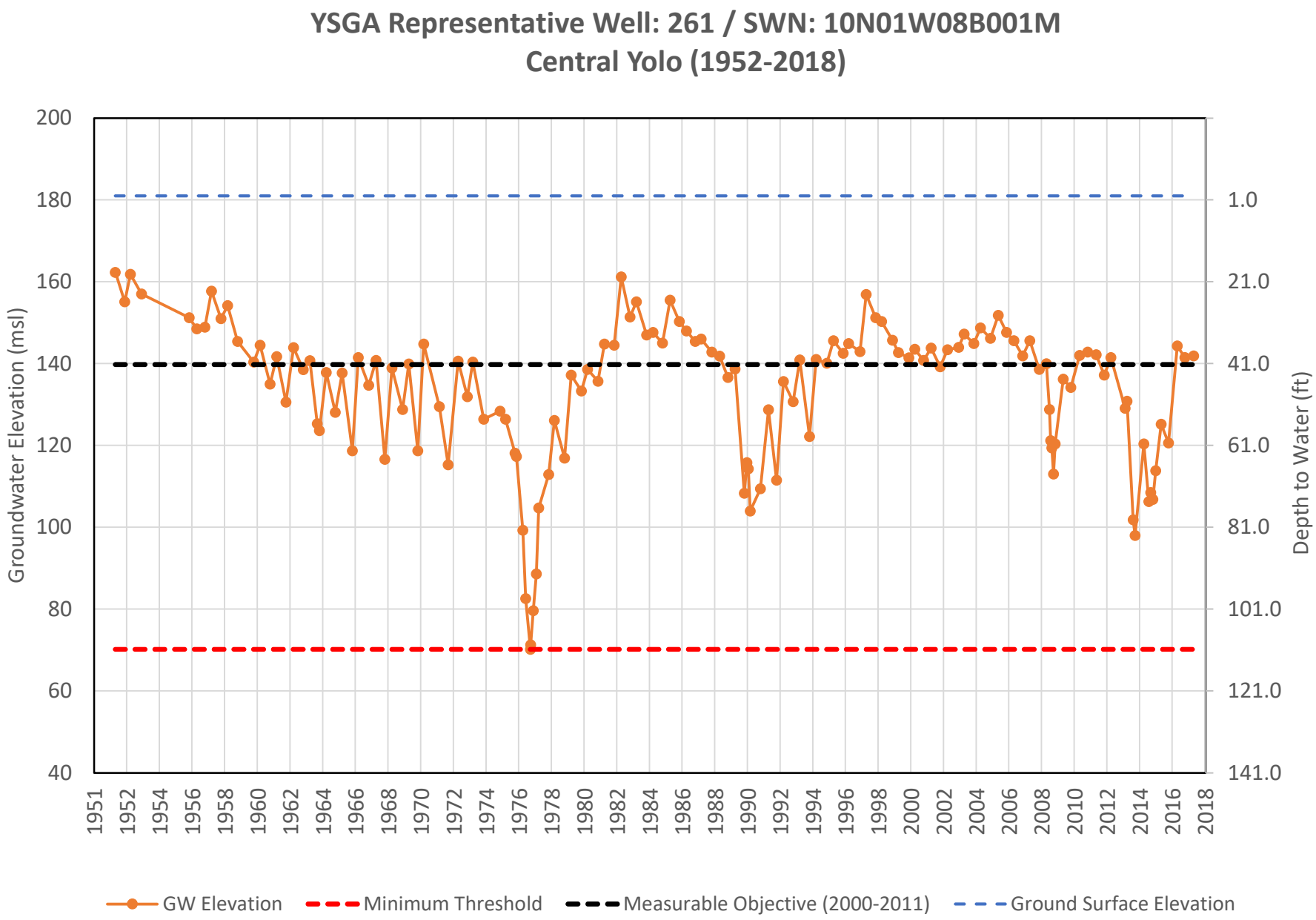
2004
2006
2008
2010
2012
2014
2016
2018
GW Elevation
Minimum Threshold
Measurable Objective (2000-2011)
Ground Surface Elevation

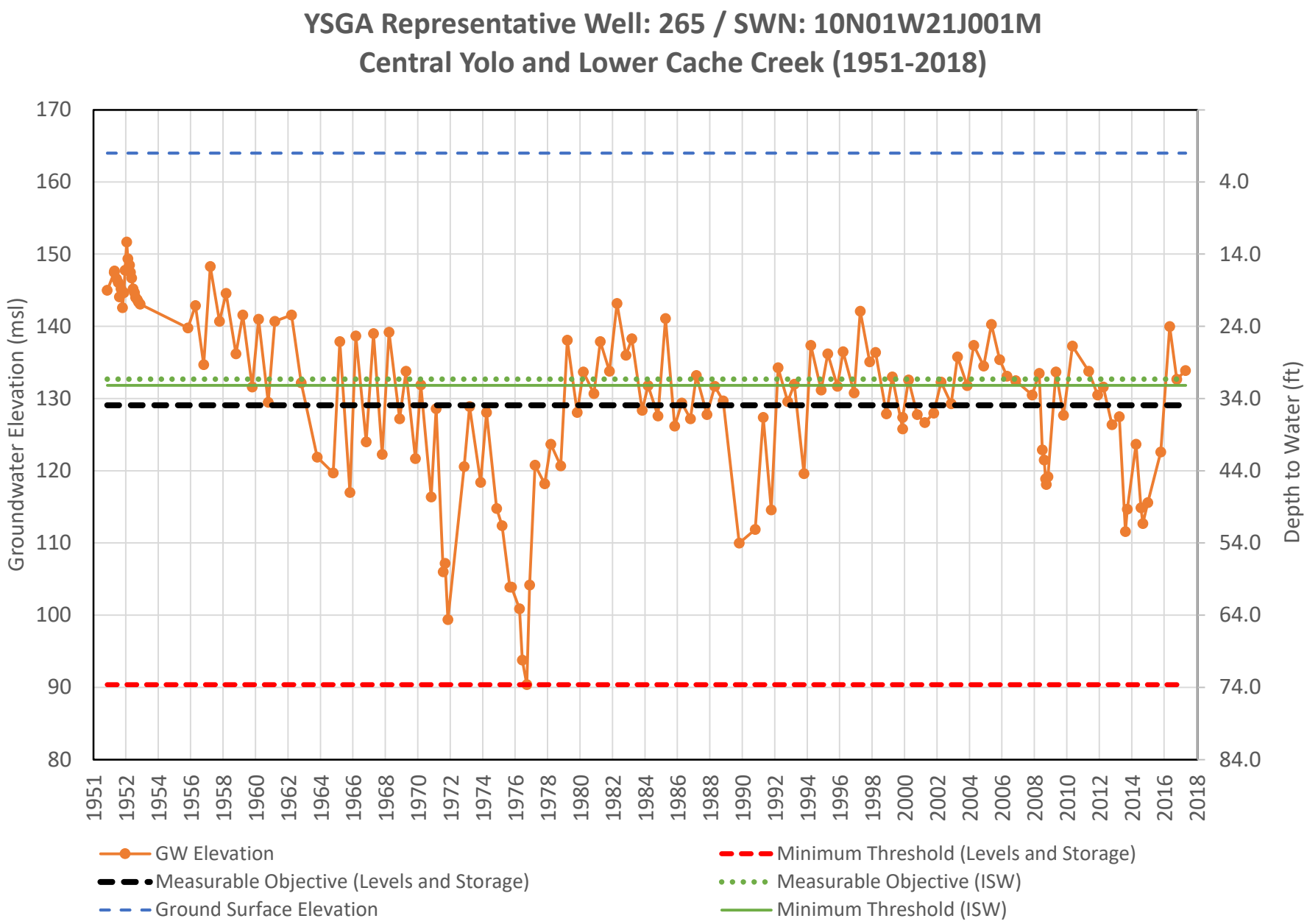

YSGA Representative Well: 248 / SWN: 09N02E32M001M
Central Yolo (1981-2018)
Groundwater Elevation (msl)
Depth to Water (ft)
70
60
50
40
30
20
10
0
-10
-20
-30
0.8
10.8
20.8
30.8
40.8
50.8
60.8
70.8
80.8
90.8
1981
1983
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
2018
GW Elevation
Minimum Threshold
Measurable Objective (2000-2011)
Ground Surface Elevation

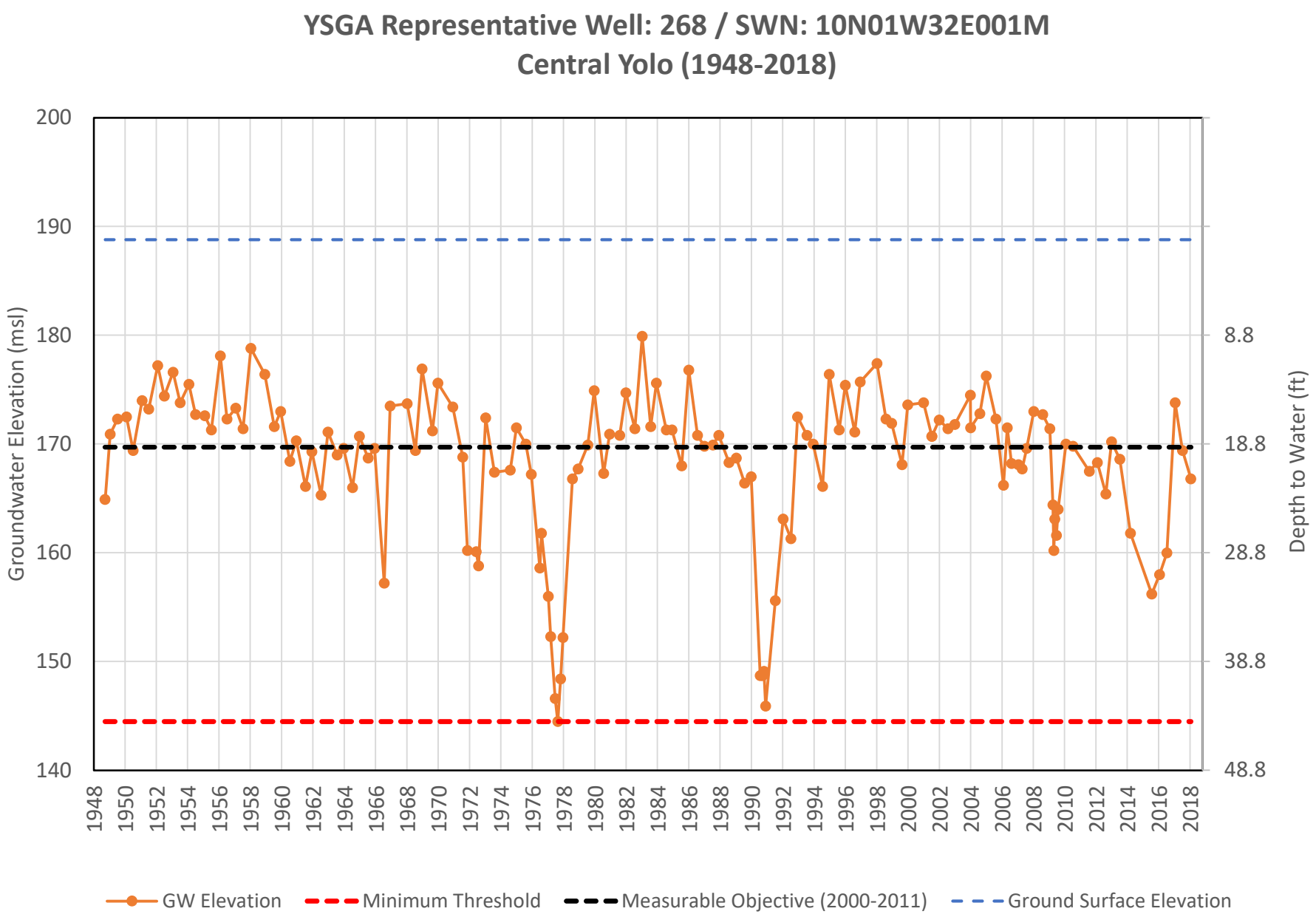

YSGA Representative Well: 250 / SWN: 09N03E19R002M
Central Yolo (1991-2018)
Groundwater Elevation (msl)
Depth to Water (ft)
25
20
15
10
5
0
-5
-10
-15
-20
2.0
7.0
12.0
17.0
22.0
27.0
32.0
37.0
42.0
1991
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
2018
GW Elevation
Minimum Threshold
Measurable Objective (2000-2011)
Ground Surface Elevation

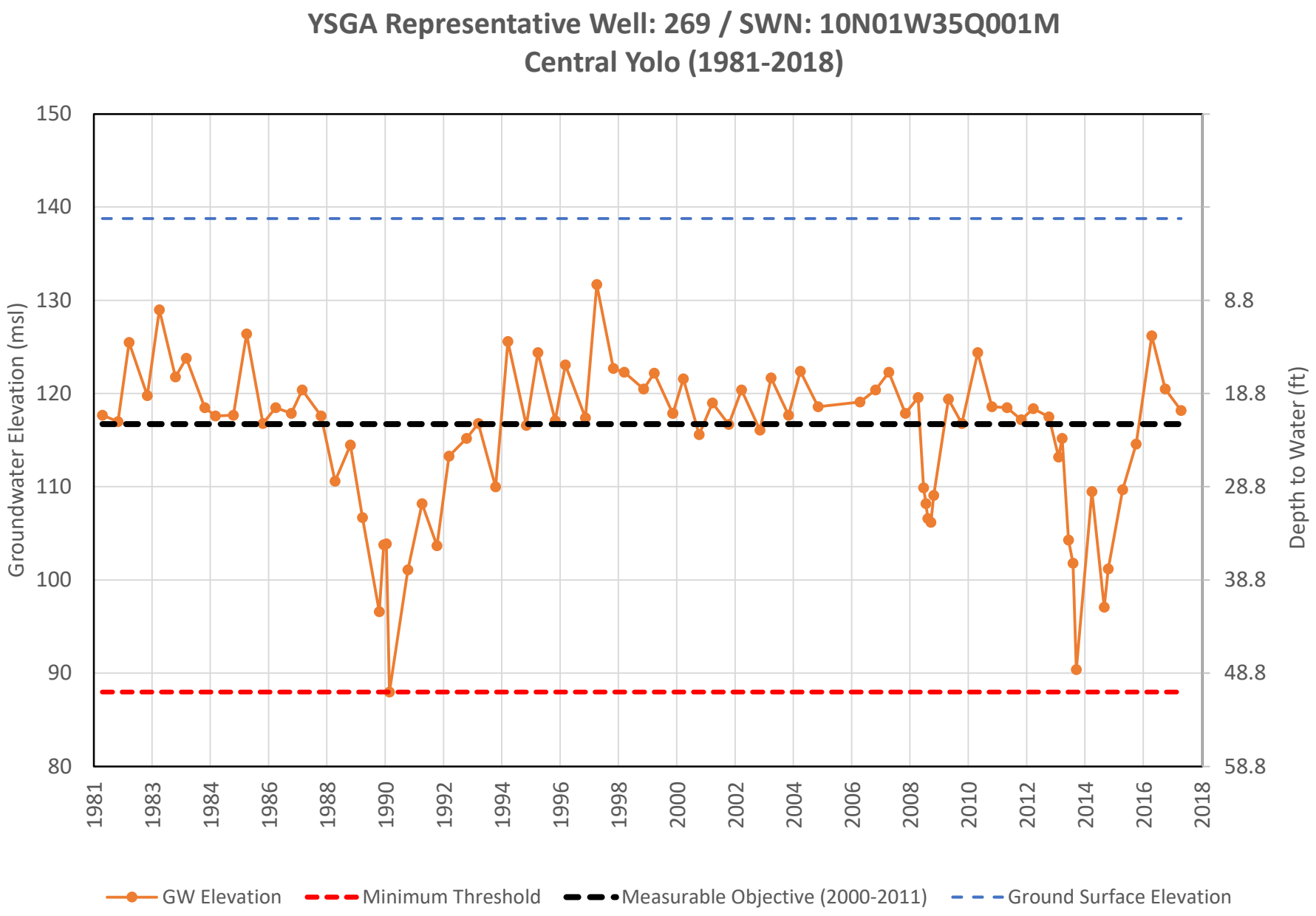

YSGA Representative Well: 254 / SWN: 10N01E23Q002M
Central Yolo (1950-2018)
Groundwater Elevation (msl)
Depth to Water (ft)
100
80
60
40
20
0
-20
-40
-60
11.8
31.8
51.8
71.8
91.8
111.8
131.8
151.8
1950
1952
1953
1955
1957
1959
1961
1963
1965
1967
1969
1971
1973
1975
1977
1979
1981
1983
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003
2005
2007
2009
2011
2013
2015
2017
GW Elevation
Minimum Threshold
Measurable Objective (2000-2011)
Ground Surface Elevation

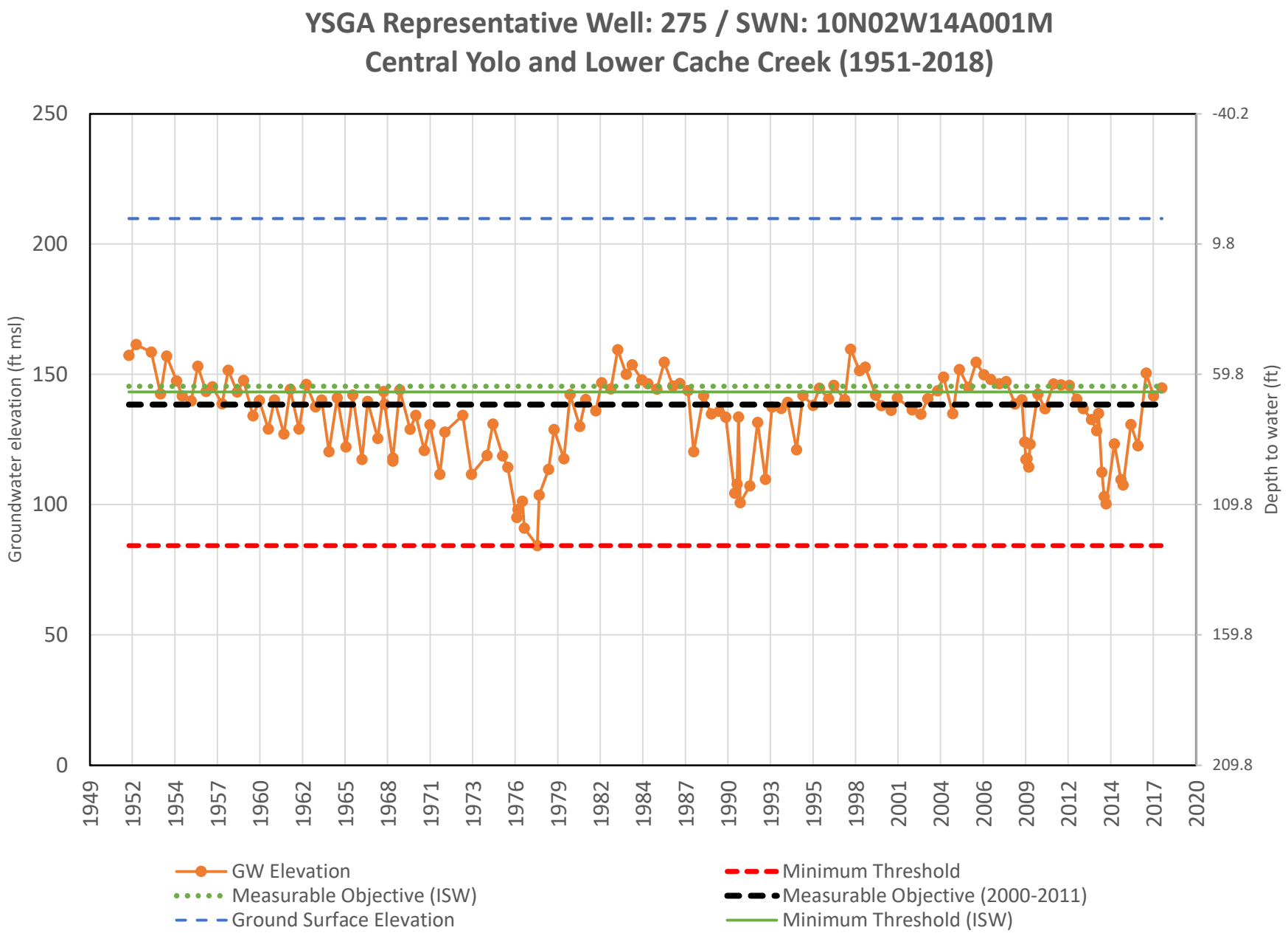

YSGA Representative Well: 256 / SWN: 10N01E29K001M
Central Yolo (1951-2018)
Groundwater Elevation (msl)
Depth to Water (ft)
120
110
100
90
80
70
60
50
2.8
12.8
22.8
32.8
42.8
52.8
62.8
1951
1952
1954
1956
1958
1960
1962
1964
1966
1968
1970
1972
1974
1976
1978
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
2018
GW Elevation
Minimum Threshold
Measurable Objective (2000-2011)
Ground Surface Elevation

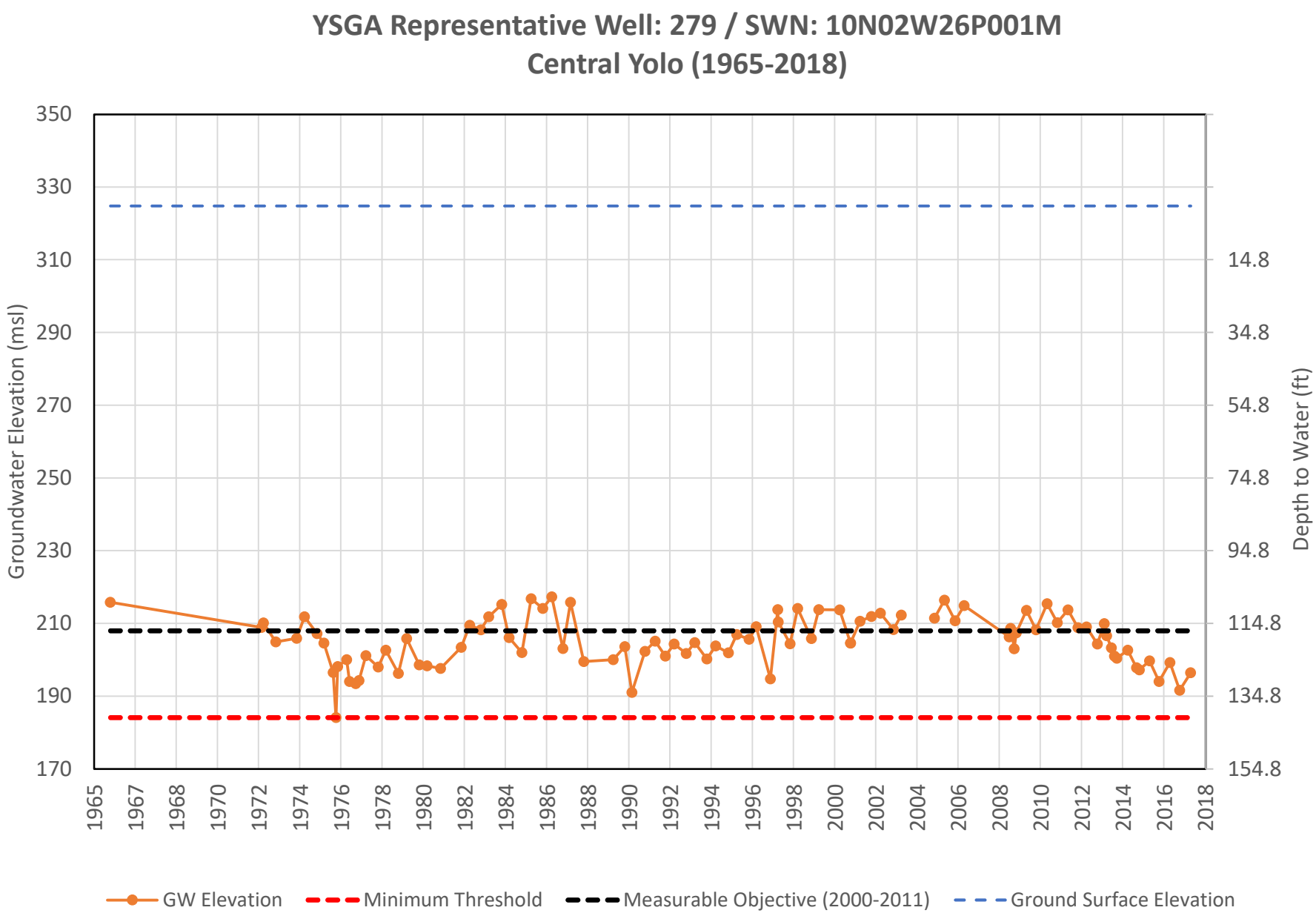

YSGA Representative Well: 261 / SWN: 10N01W08B001M
Central Yolo (1952-2018)
Groundwater Elevation (msl)
Depth to Water (ft)
200
180
160
140
120
100
80
60
40
1.0
21.0
41.0
61.0
81.0
101.0
121.0
141.0
1951
1952
1954
1956
1958
1960
1962
1964
1966
1968
1970
1972
1974
1976
1978
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
2018
GW Elevation
Minimum Threshold
Measurable Objective (2000-2011)
Ground Surface Elevation

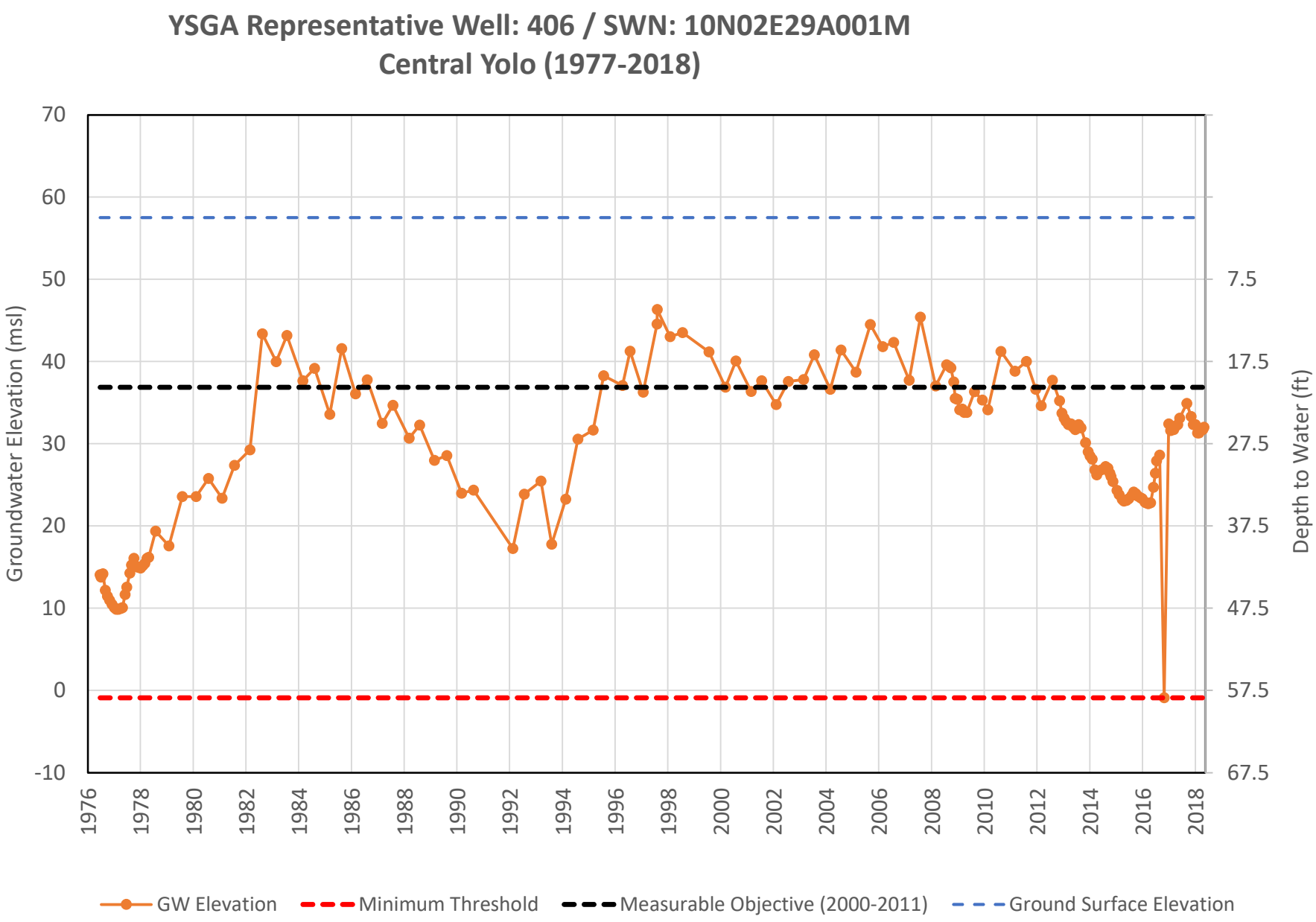

YSGA Representative Well: 265 / SWN: 10N01W21J001M
Central Yolo and Lower Cache Creek (1951-2018)
Groundwater Elevation (msl)
Depth to Water (ft)
170
160
150
140
130
120
110
100
90
80
4.0
14.0
24.0
34.0
44.0
54.0
64.0
74.0
84.0
1951
1952
1954
1956
1958
1960
1962
1964
1966
1968
1970
1972
1974
1976
1978
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
2018
GW Elevation
Minimum Threshold (Levels and Storage)
Measurable Objective (Levels and Storage)
Measurable Objective (ISW)
Ground Surface Elevation
Minimum Threshold (ISW)

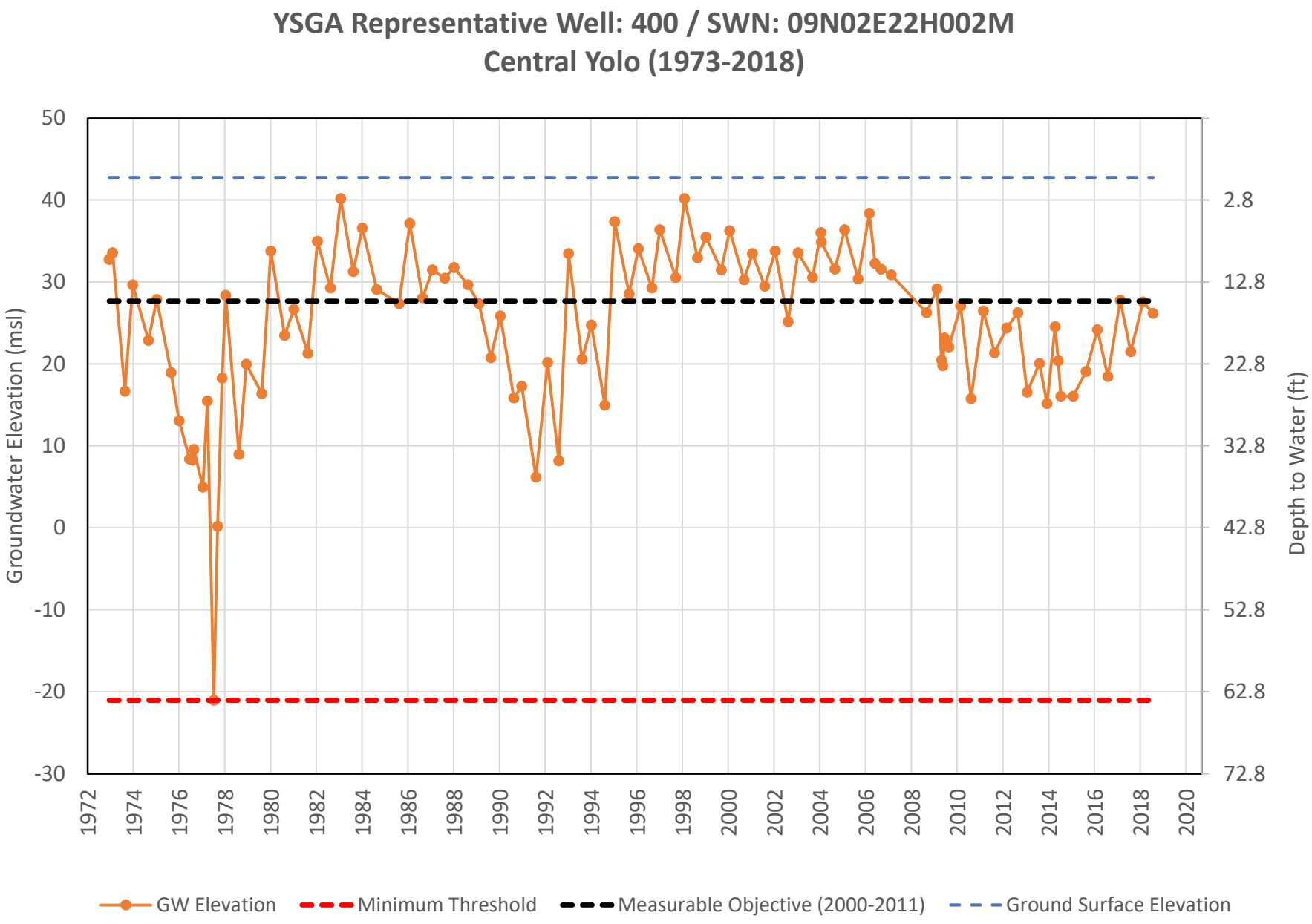

YSGA Representative Well: 268 / SWN: 10N01W32E001M
Central Yolo (1948-2018)
Groundwater Elevation (msl)
Depth to Water (ft)
200
190
180
170
160
150
140
8.8
18.8
28.8
38.8
48.8
1948
1950
1952
1954
1956
1958
1960
1962
1964
1966
1968
1970
1972
1974
1976
1978
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
2018
GW Elevation
Minimum Threshold
Measurable Objective (2000-2011)
Ground Surface Elevation

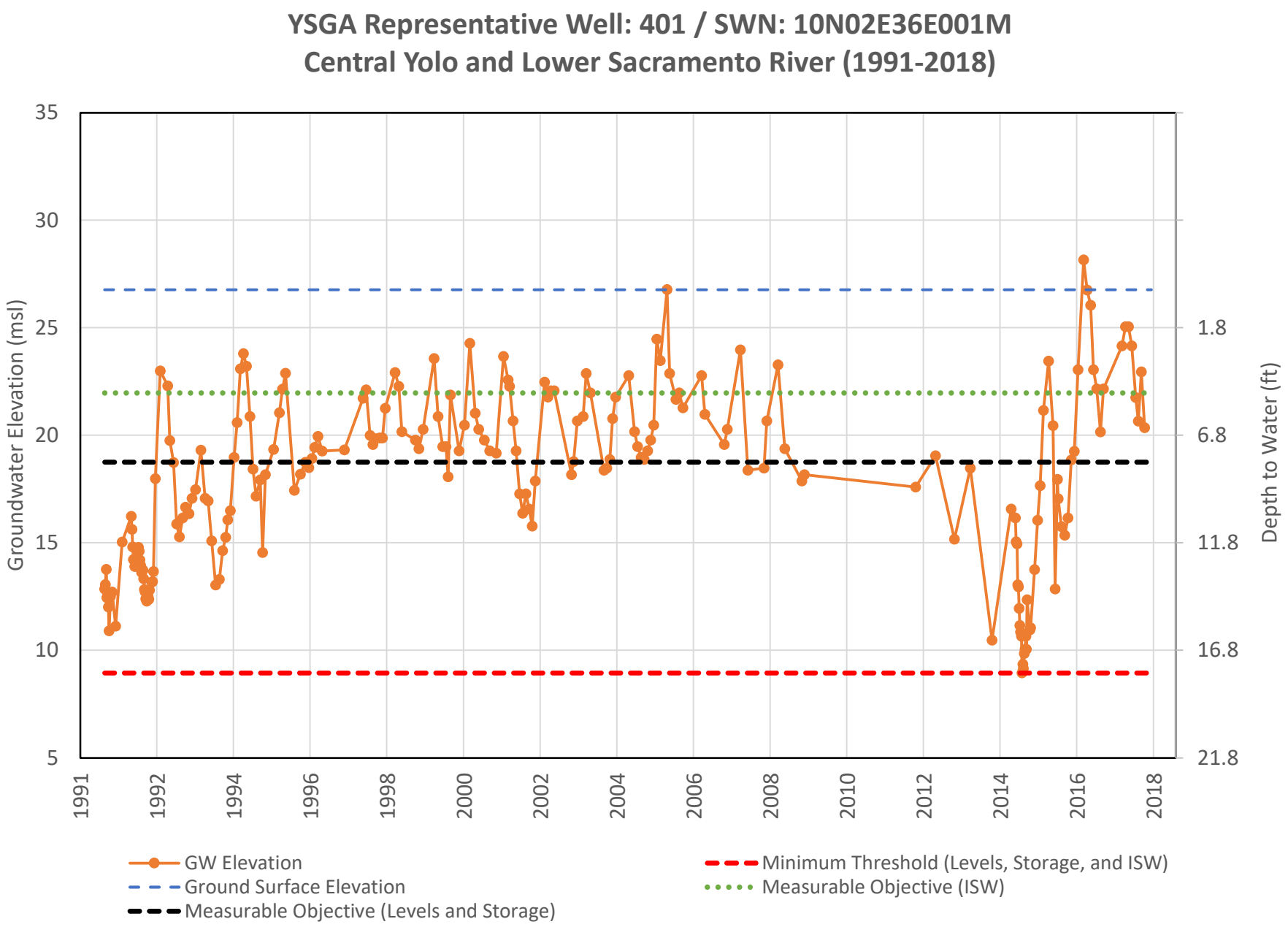

YSGA Representative Well: 269 / SWN: 10N01W35Q001M
Central Yolo (1981-2018)
Groundwater Elevation (msl)
Depth to Water (ft)
150
140
130
120
110
100
90
80
8.8
18.8
28.8
38.8
48.8
58.8
1981
1983
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
2018
GW Elevation
Minimum Threshold
Measurable Objective (2000-2011)
Ground Surface Elevation

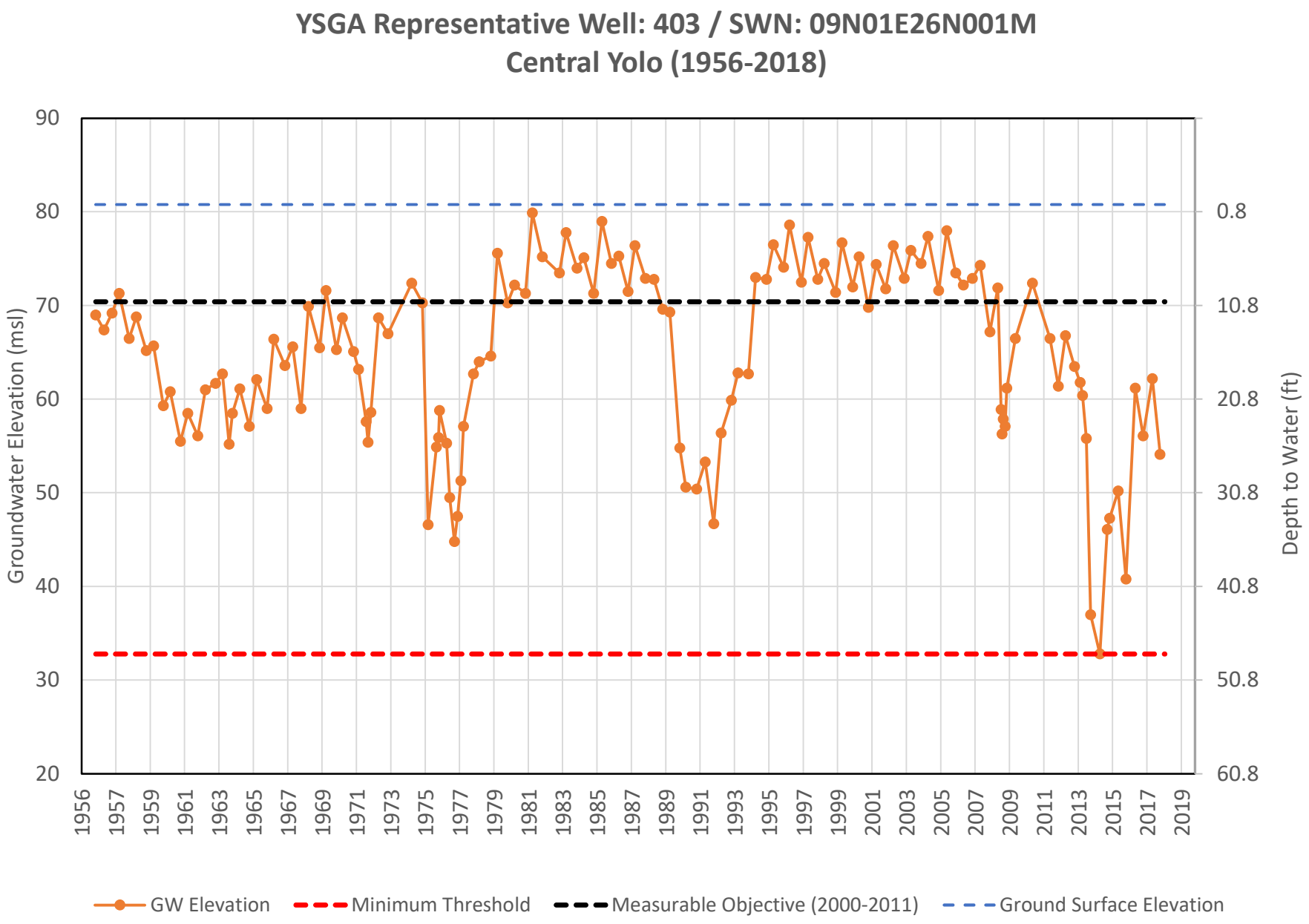

YSGA Representative Well: 275 / SWN: 10N02W14A001M
Central Yolo and Lower Cache Creek (1951-2018)
Groundwater elevation (ft msl)
Depth to water (ft)
250
200
150
100
50
0
-40.2
9.8
59.8
109.8
159.8
209.8
1949
1952
1954
1957
1960
1962
1965
1968
1971
1973
1976
1979
1982
1984
1987
1990
1993
1995
1998
2001
2004
2006
2009
2012
2014
2017
2020
GW Elevation
Measurable Objective (ISW)
Ground Surface Elevation
Minimum Threshold
Measurable Objective (2000-2011)
Minimum Threshold (ISW)

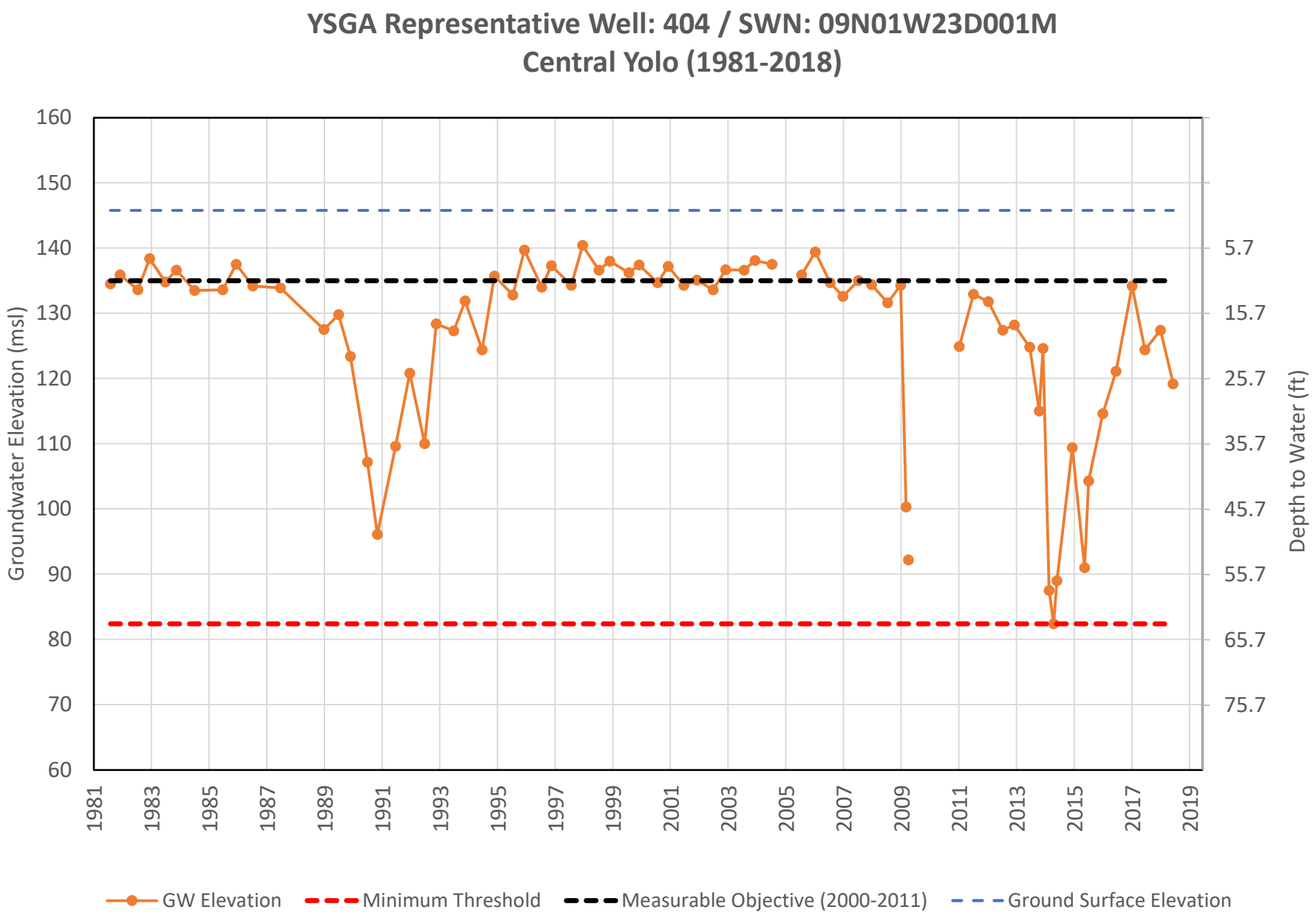

YSGA Representative Well: 279 / SWN: 10N02W26P001M
Central Yolo (1965-2018)
Groundwater Elevation (msl)
Depth to Water (ft)
350
330
310
290
270
250
230
210
190
170
14.8
34.8
54.8
74.8
94.8
114.8
134.8
154.8
1965
1967
1968
1970
1972
1974
1976
1978
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
2018
GW Elevation
Minimum Threshold
Measurable Objective (2000-2011)
Ground Surface Elevation

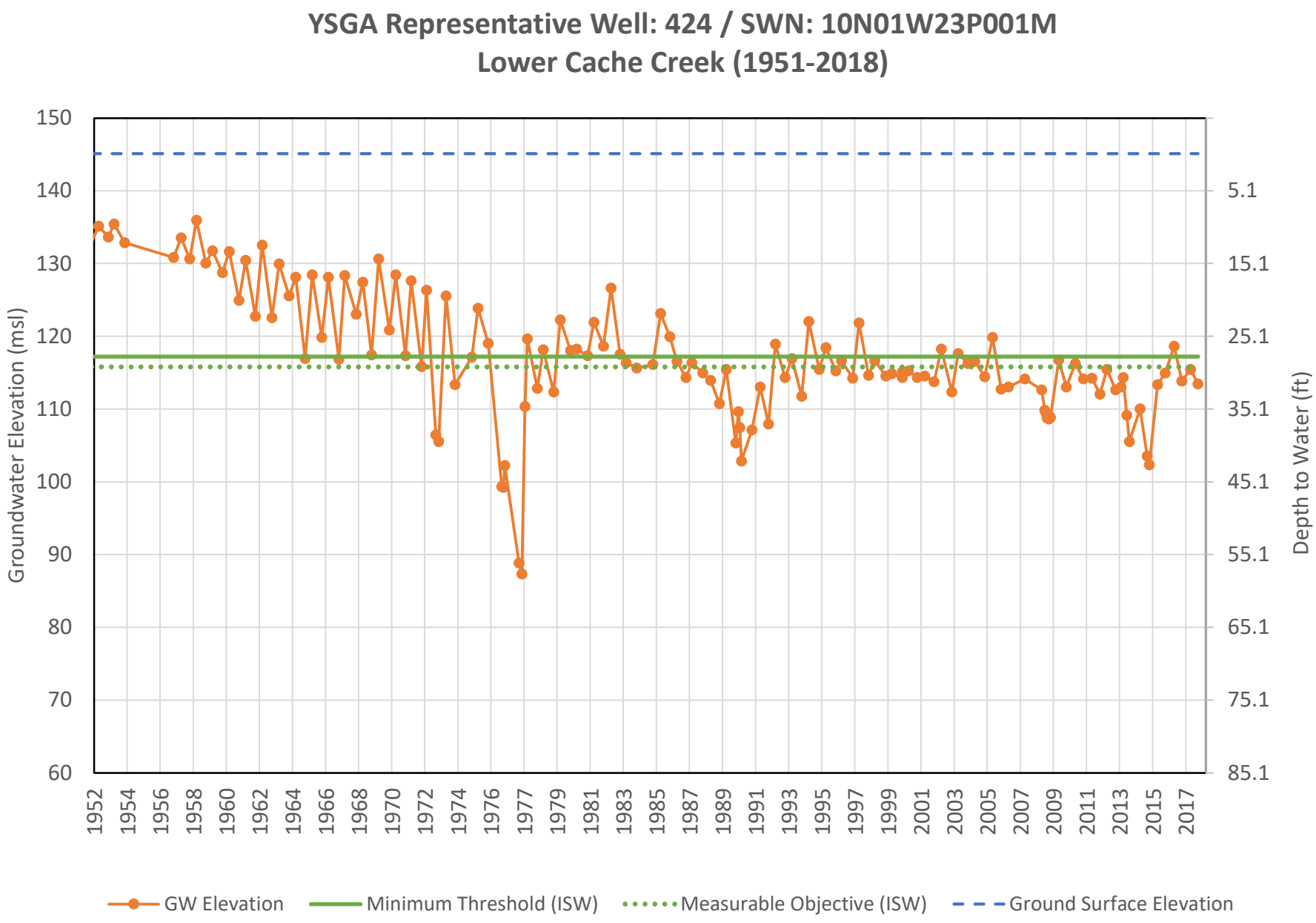

YSGA Representative Well: 406 / SWN: 10N02E29A001M
Central Yolo (1977-2018)
Groundwater Elevation (msl)
Depth to Water (ft)
70
60
50
40
30
20
10
0
-10
7.5
17.5
27.5
37.5
47.5
57.5
67.5
1976
1978
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
2018
GW Elevation
Minimum Threshold
Measurable Objective (2000-2011)
Ground Surface Elevation

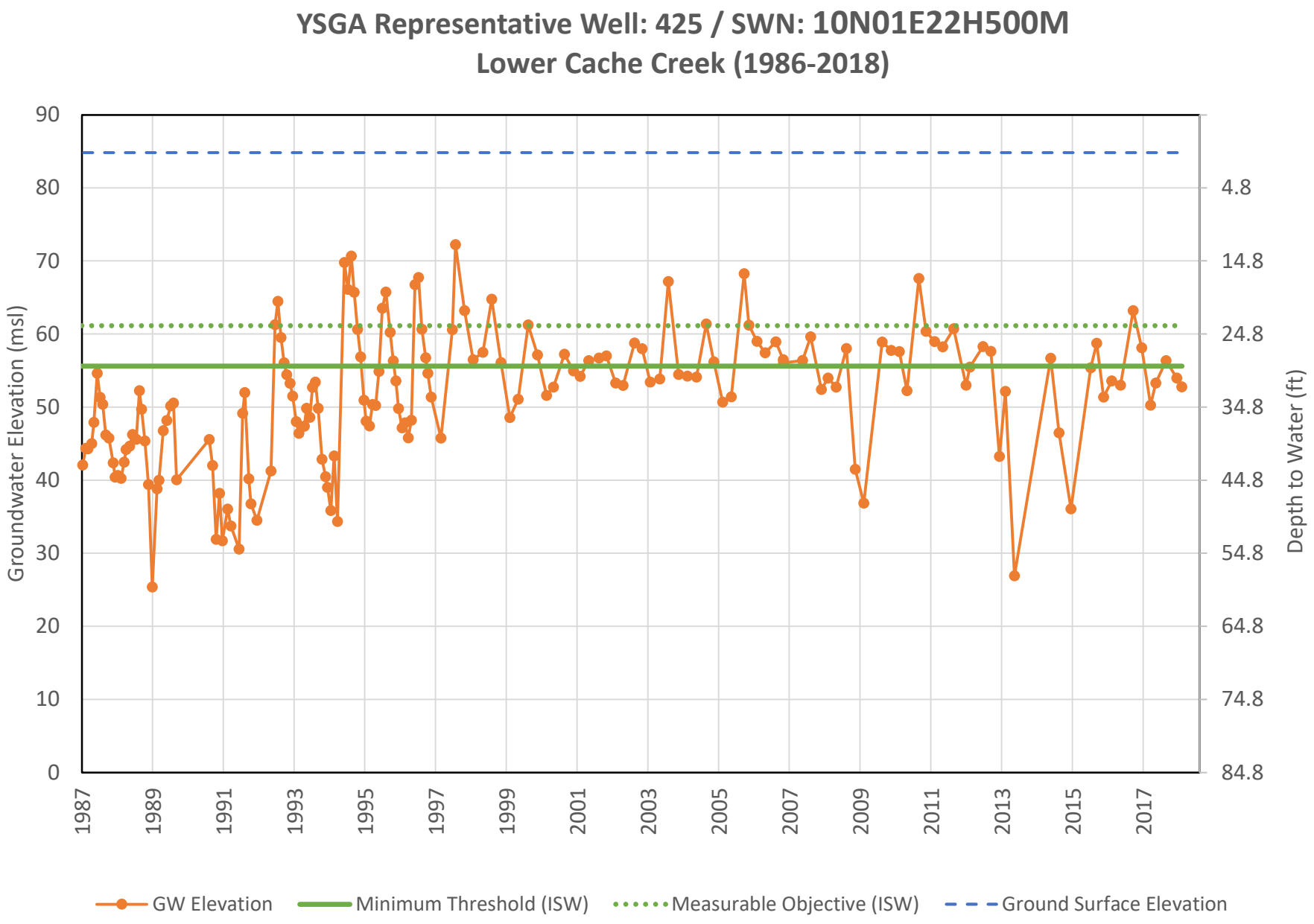

YSGA Representative Well: 400 / SWN: 09N02E22H002M
Central Yolo (1973-2018)
Groundwater Elevation (msl)
Depth to Water (ft)
50
40
30
20
10
0
-10
-20
-30
2.8
12.8
22.8
32.8
42.8
52.8
62.8
72.8
1972
1974
1976
1978
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
2018
2020
GW Elevation
Minimum Threshold
Measurable Objective (2000-2011)
Ground Surface Elevation

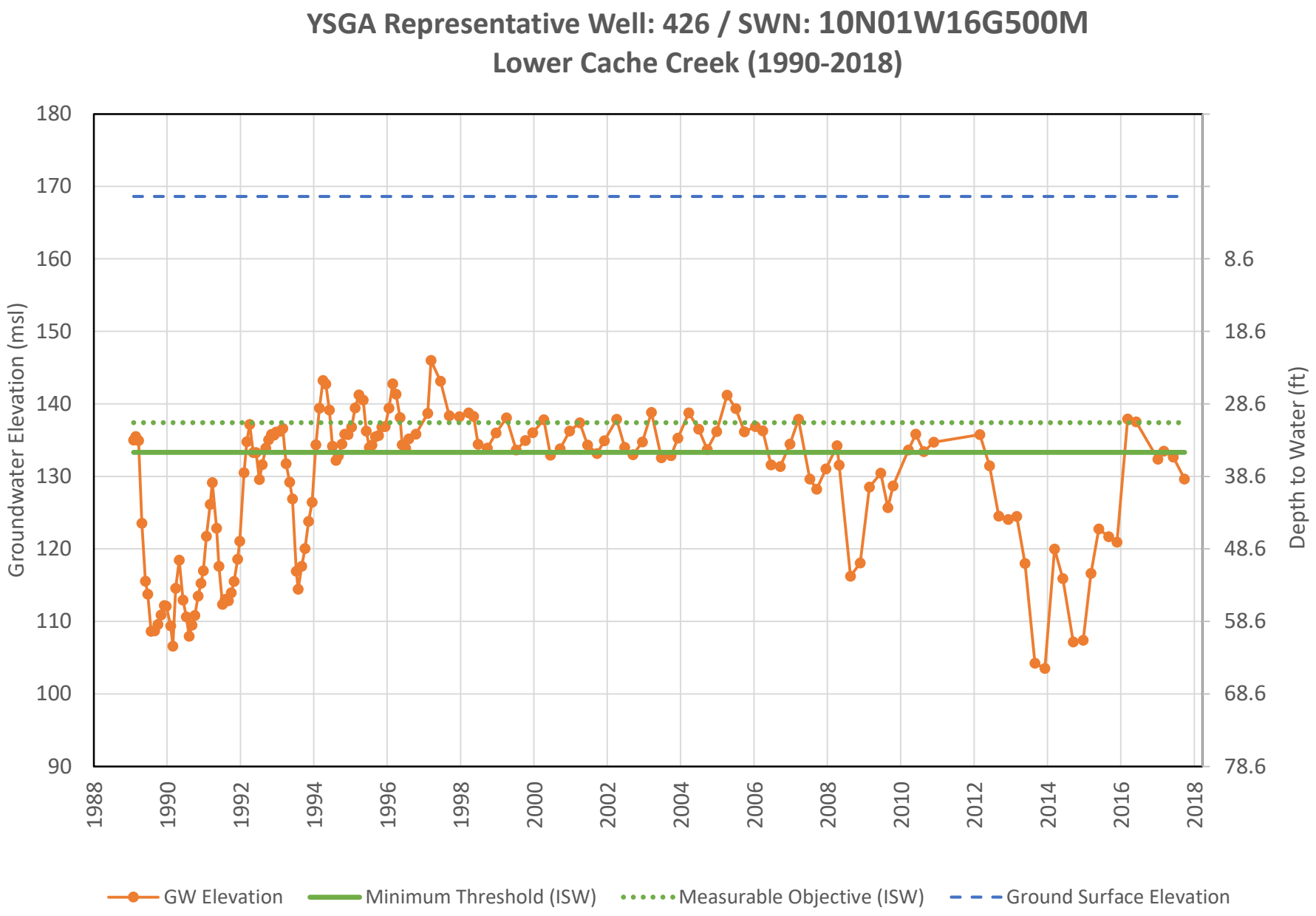

YSGA Representative Well: 401 / SWN: 10N02E36E001M
Central Yolo and Lower Sacramento River (1991-2018)
Groundwater Elevation (msl)
Depth to Water (ft)
35
30
25
20
15
10
5
1.8
6.8
11.8
16.8
21.8
1991
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
2018
GW Elevation
Ground Surface Elevation
Measurable Objective (Levels and Storage)
Minimum Threshold (Levels, Storage, and ISW)
Measurable Objective (ISW)

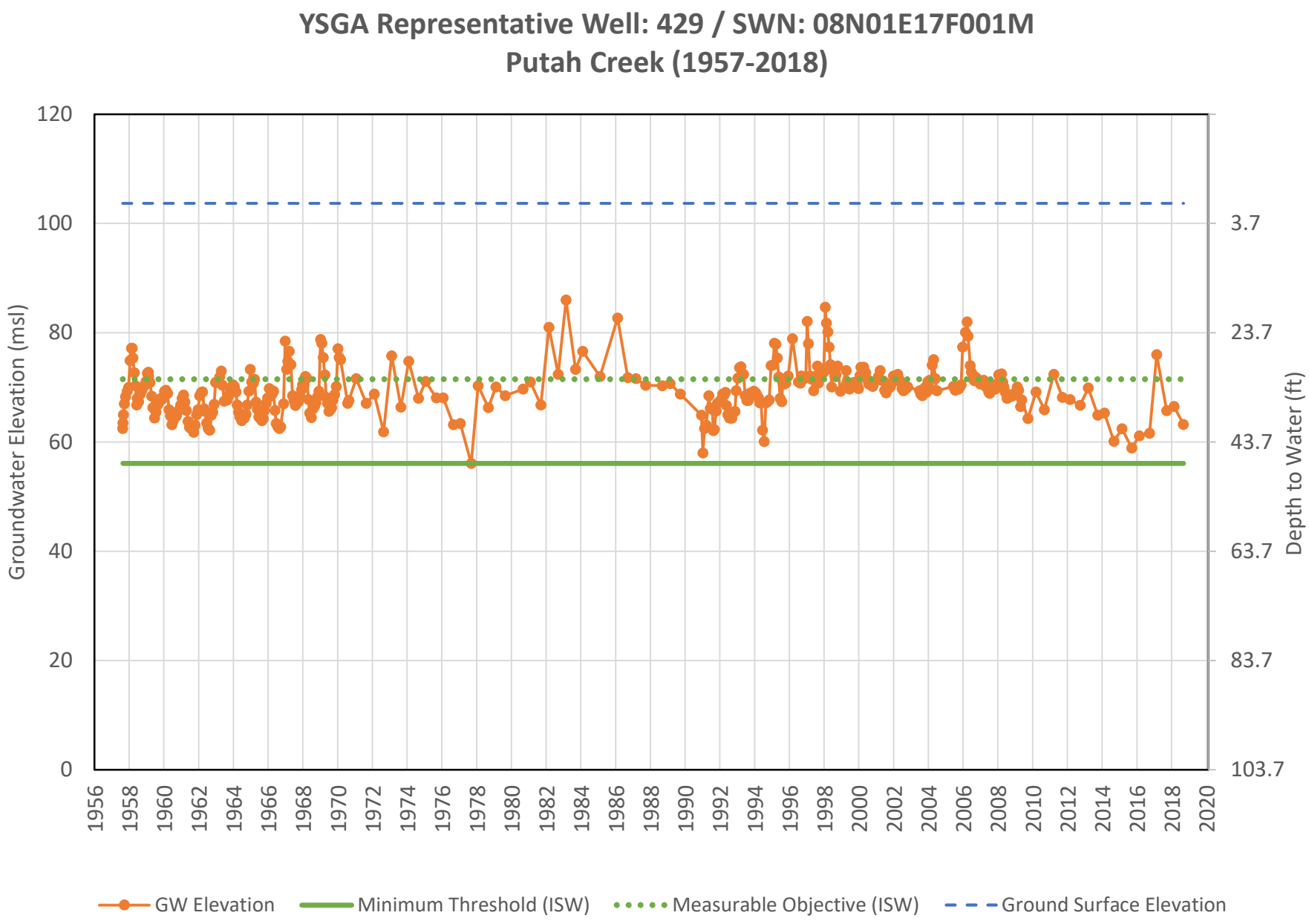

YSGA Representative Well: 403 / SWN: 09N01E26N001M
Central Yolo (1956-2018)
Groundwater Elevation (msl)
Depth to Water (ft)
90
80
70
60
50
40
30
20
0.8
10.8
20.8
30.8
40.8
50.8
60.8
1956
1957
1959
1961
1963
1965
1967
1969
1971
1973
1975
1977
1979
1981
1983
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003
2005
2007
2009
2011
2013
2015
2017
2019
GW Elevation
Minimum Threshold
Measurable Objective (2000-2011)
Ground Surface Elevation

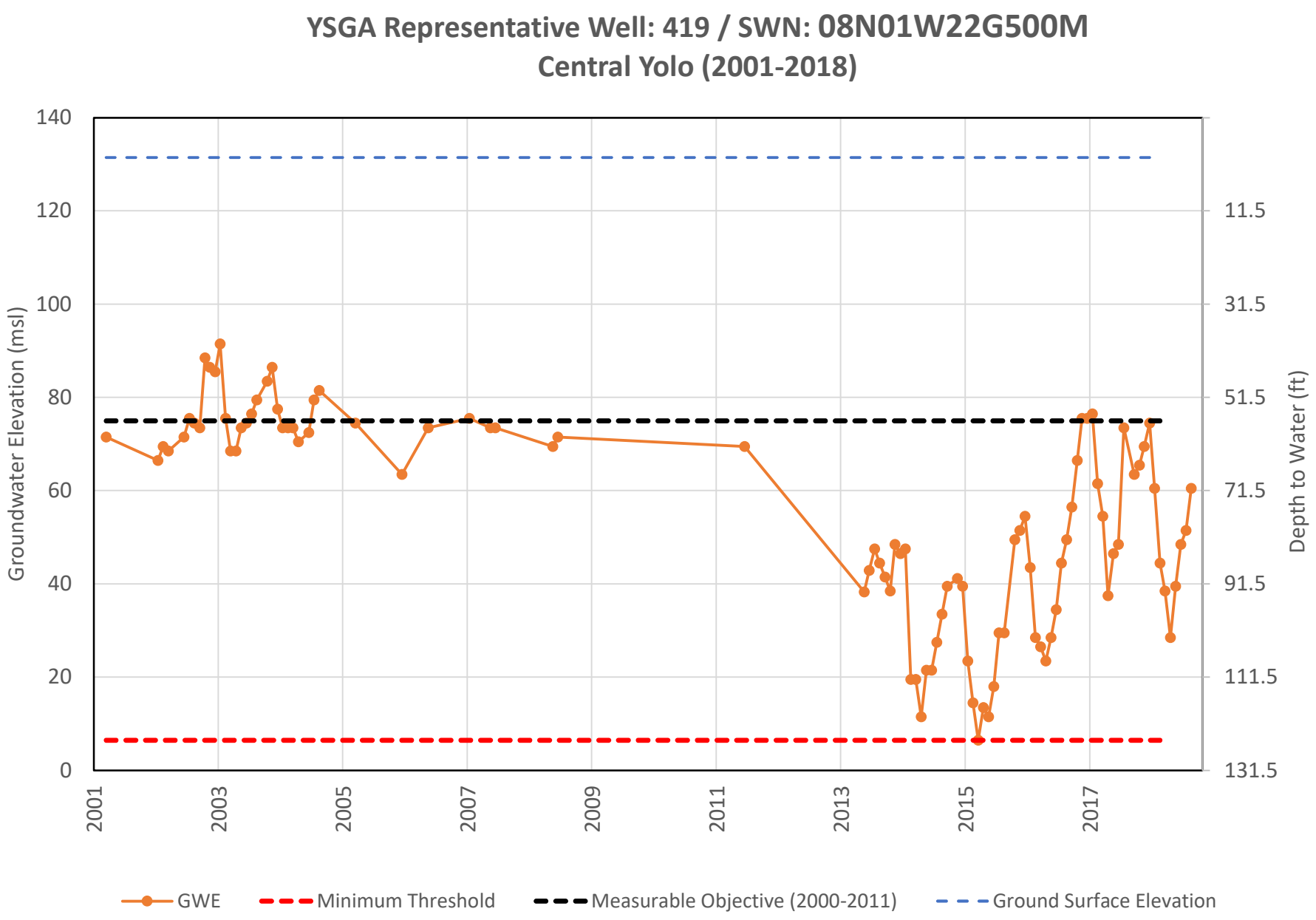

YSGA Representative Well: 404 / SWN: 09N01W23D001M
Central Yolo (1981-2018)
Groundwater Elevation (msl)
Depth to Water (ft)
160
150
140
130
120
110
100
90
80
70
60
5.7
15.7
25.7
35.7
45.7
55.7
65.7
75.7
1981
1983
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003
2005
2007
2009
2011
2013
2015
2017
2019
GW Elevation
Minimum Threshold
Measurable Objective (2000-2011)
Ground Surface Elevation


YSGA Representative Well: 424 / SWN: 10N01W23P001M
Lower Cache Creek (1951-2018)
Groundwater Elevation (msl)
Depth to Water (ft)
150
140
130
120
110
100
90
80
70
60
5.1
15.1
25.1
35.1
45.1
55.1
65.1
75.1
85.1
1952
1954
1956
1958
1960
1962
1964
1966
1968
1970
1972
1974
1976
1977
1979
1981
1983
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003
2005
2007
2009
2011
2013
2015
2017
GW Elevation
Minimum Threshold (ISW)
Measurable Objective (ISW)
Ground Surface Elevation

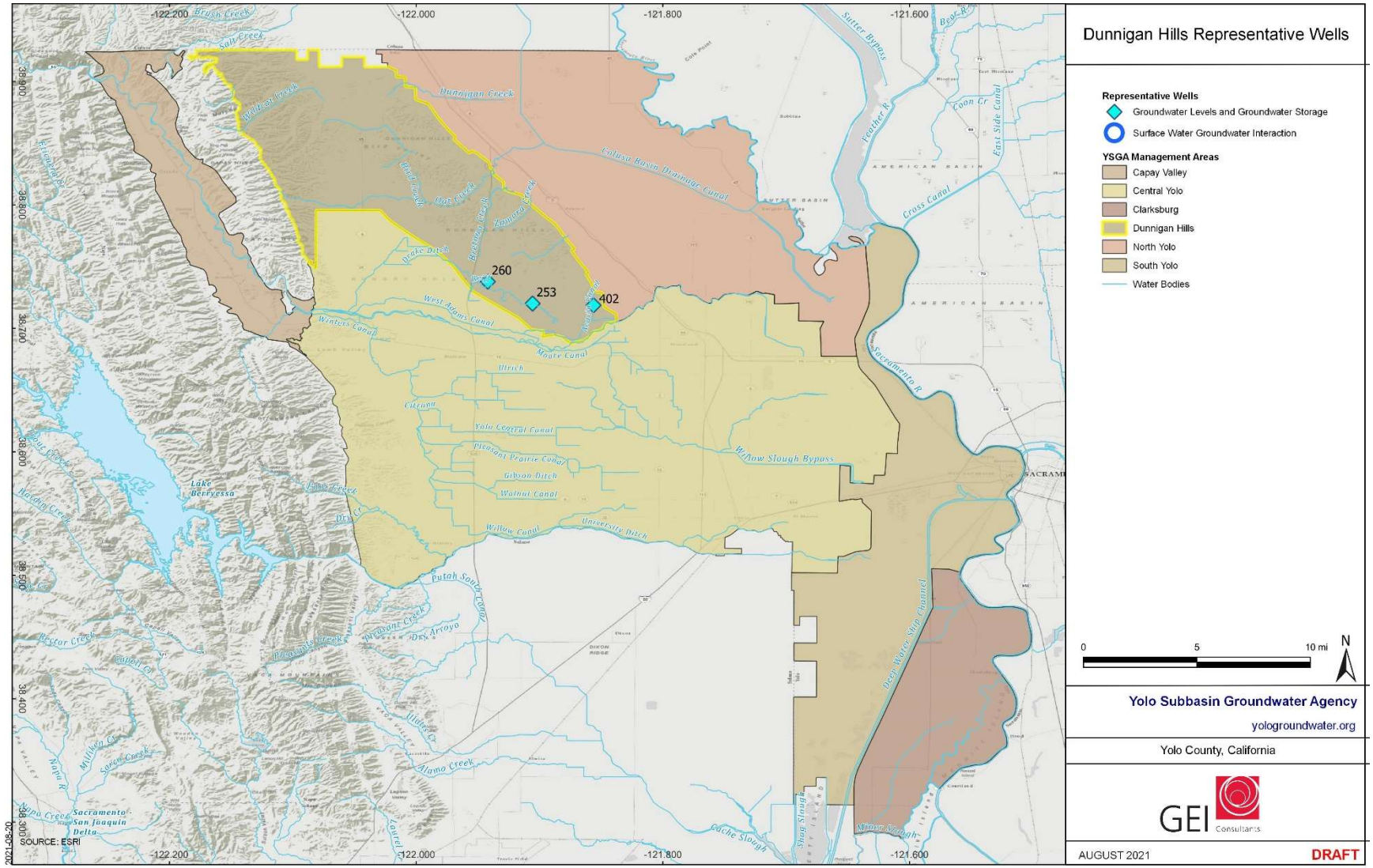

YSGA Representative Well: 425 / SWN: 10N01E22H500M
Lower Cache Creek (1986-2018)
Groundwater Elevation (msl)
Depth to Water (ft)
90
80
70
60
50
40
30
20
10
0
4.8
14.8
24.8
34.8
44.8
54.8
64.8
74.8
84.8
1987
1989
1991
1993
1995
1997
1999
2001
2003
2005
2007
2009
2011
2013
2015
2017
GW Elevation
Minimum Threshold (ISW)
Measurable Objective (ISW)
Ground Surface Elevation


YSGA Representative Well: 426 / SWN: 10N01W16G500M
Lower Cache Creek (1990-2018)
Groundwater Elevation (msl)
Depth to Water (ft)
180
170
160
150
140
130
120
110
100
90
8.6
18.6
28.6
38.6
48.6
58.6
68.6
78.6
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
2018
GW Elevation
Minimum Threshold (ISW)
Measurable Objective (ISW)
Ground Surface Elevation


YSGA Representative Well: 429 / SWN: 08N01E17F001M
Putah Creek (1957-2018)
Groundwater Elevation (msl)
Depth to Water (ft)
120
100
80
60
40
20
0
3.7
23.7
43.7
63.7
83.7
103.7
1956
1958
1960
1962
1964
1966
1968
1970
1972
1974
1976
1978
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
2018
2020
GW Elevation
Minimum Threshold (ISW)
Measurable Objective (ISW)
Ground Surface Elevation

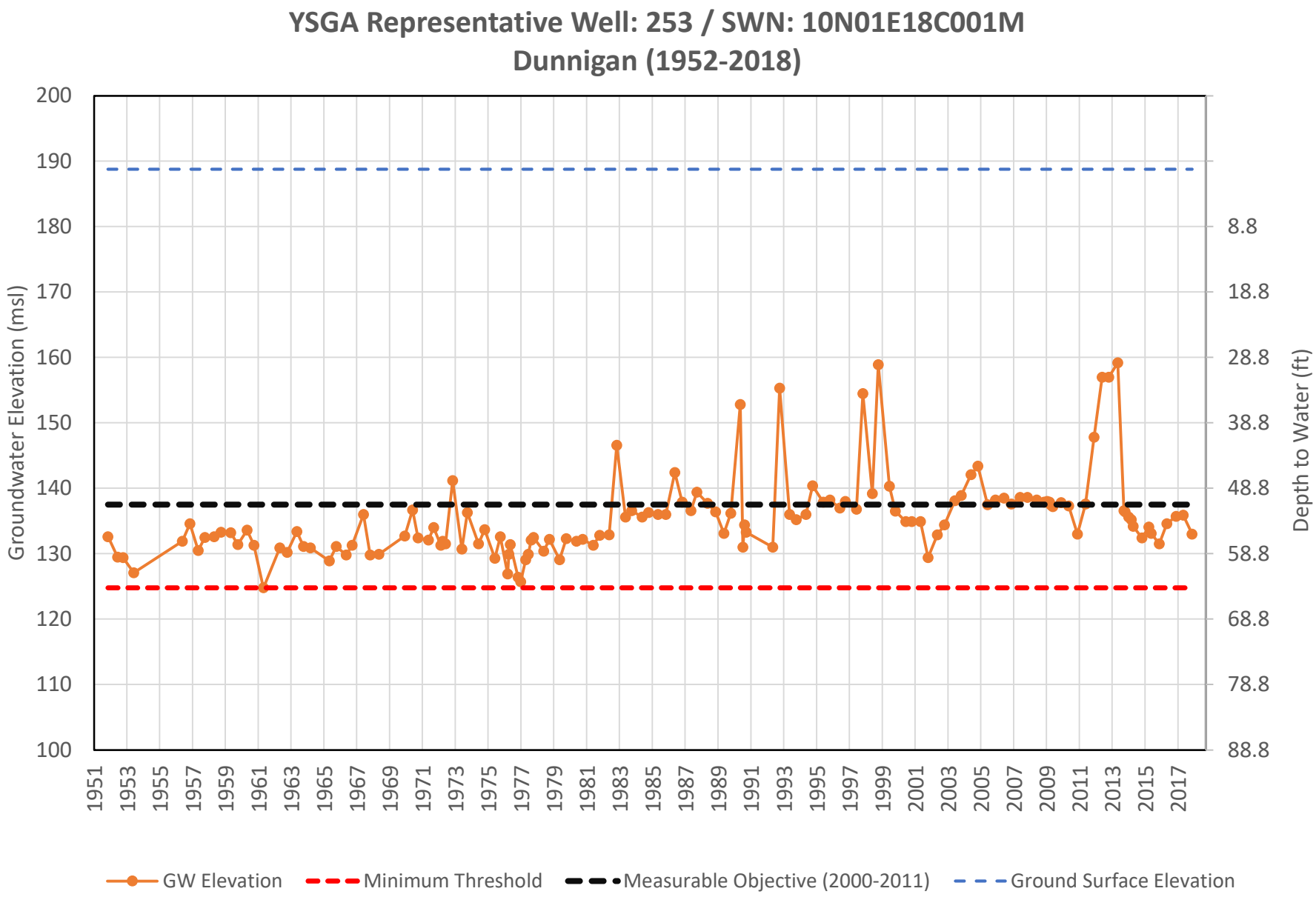

YSGA Representative Well: 419 / SWN: 08N01W22G500M
Central Yolo (2001-2018)
Groundwater Elevation (msl)
Depth to Water (ft)
140
120
100
80
60
40
20
0
11.5
31.5
51.5
71.5
91.5
111.5
131.5
2001
2003
2005
2007
2009
2011
2013
2015
2017
GWE
Minimum Threshold
Measurable Objective (2000-2011)
Ground Surface Elevation

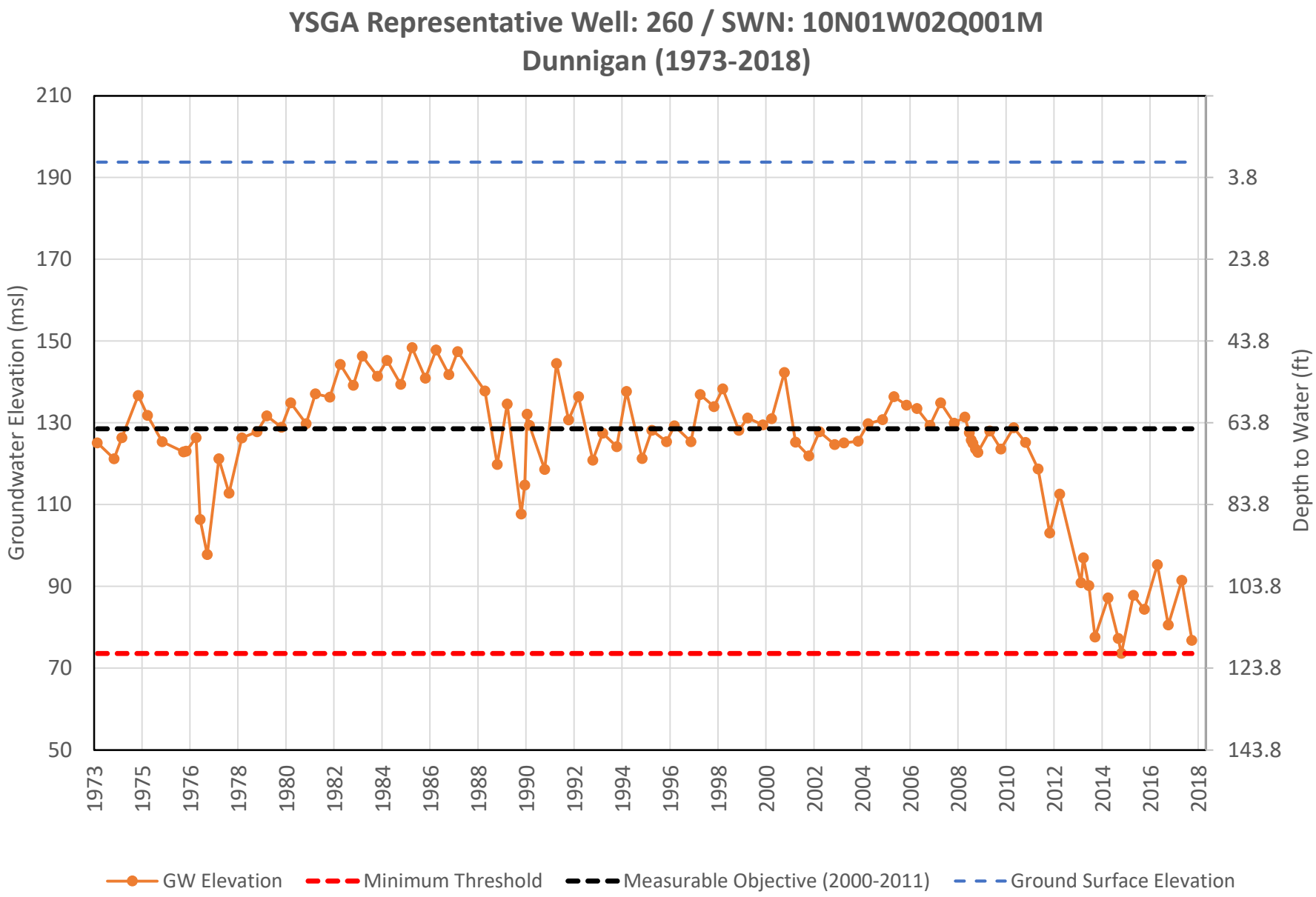
Dunnigan Hills Management Area

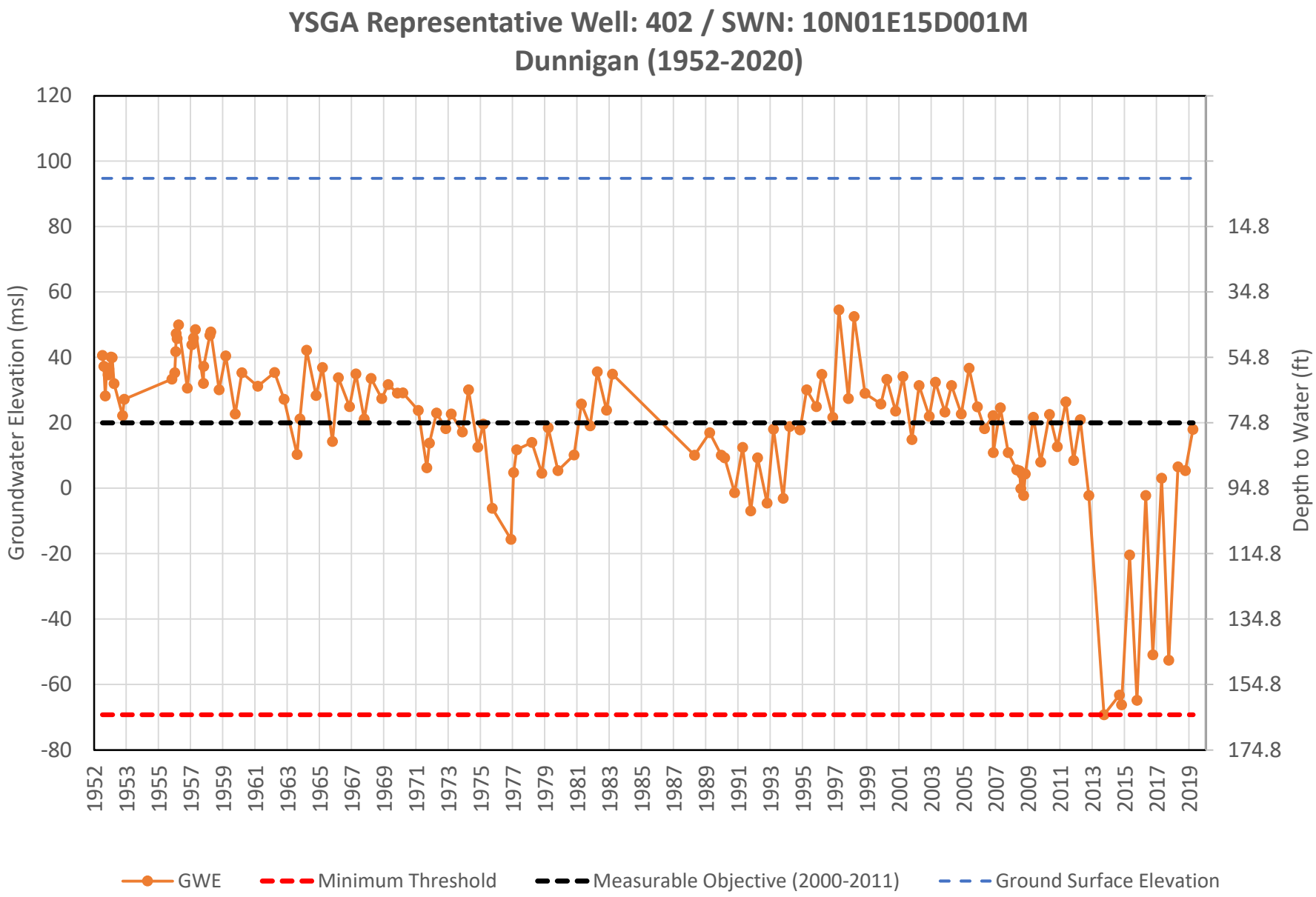


Dunnigan Hills Management Area- Representative Monitoring Well Construction Information

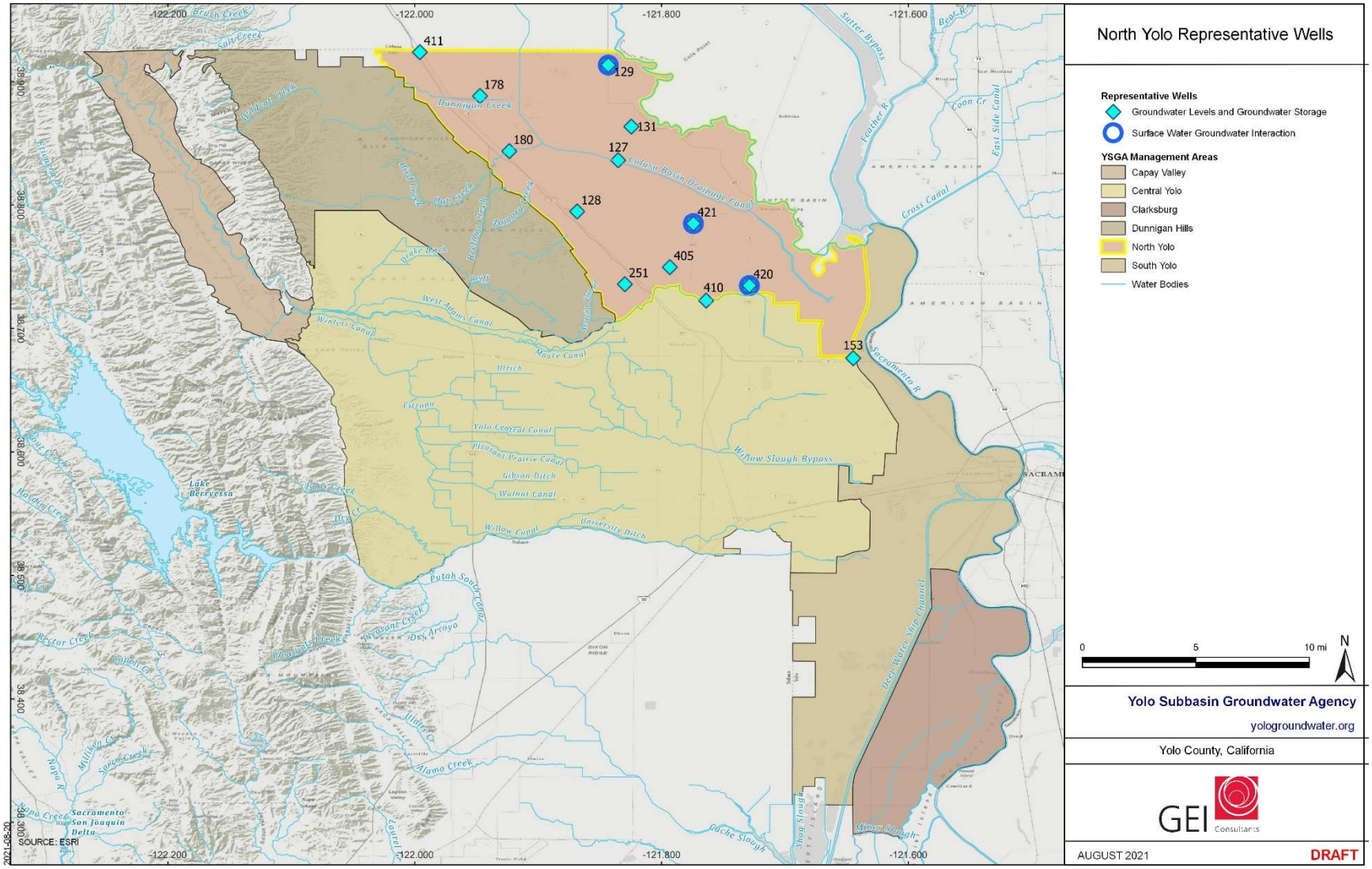
YSGA Well Number	State Well Number	Groundwater Elevations	Change in Storage	Depletion of ISW	Monitored by	Reference Point Elevation (feet)	Ground Surface Elevation (feet)	Well Use Type	Latitude	Longitude	Well Depth (ft bgs)	Well Completion Report Number	Top Perforation	Bottom Perforation
253	10N01E18C001M	X	X		YCFC	194.44	194.378	Stockwatering	38.7200927	-121.905594	110	57-291		
260	10N01W02Q001M	X	X		YCFC	194.78	194.33	Domestic	38.7378446	-121.941865	350		250	270
402	10N01E15D001M	X	X		YCFC	94.45	94.327	Irrigation	38.7186859	-121.856202	518	57-288	70	518


YSGA Representative Well: 253 / SWN: 10N01E18C001M
Dunnigan (1952-2018)
Groundwater Elevation (msl)
Depth to Water (ft)
200
190
180
170
160
150
140
130
120
110
100
8.8
18.8
28.8
38.8
48.8
58.8
68.8
78.8
88.8
1951
1953
1955
1957
1959
1961
1963
1965
1967
1969
1971
1973
1975
1977
1979
1981
1983
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003
2005
2007
2009
2011
2013
2015
2017
GW Elevation
Minimum Threshold
Measurable Objective (2000-2011)
Ground Surface Elevation


YSGA Representative Well: 260 / SWN: 10N01W02Q001M
Dunnigan (1973-2018)
Groundwater Elevation (msl)
Depth to Water (ft)
210
190
170
150
130
110
90
70
50
3.8
23.8
43.8
63.8
83.8
103.8
123.8
143.8
1973
1975
1976
1978
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
2018
GW Elevation
Minimum Threshold
Measurable Objective (2000-2011)
Ground Surface Elevation

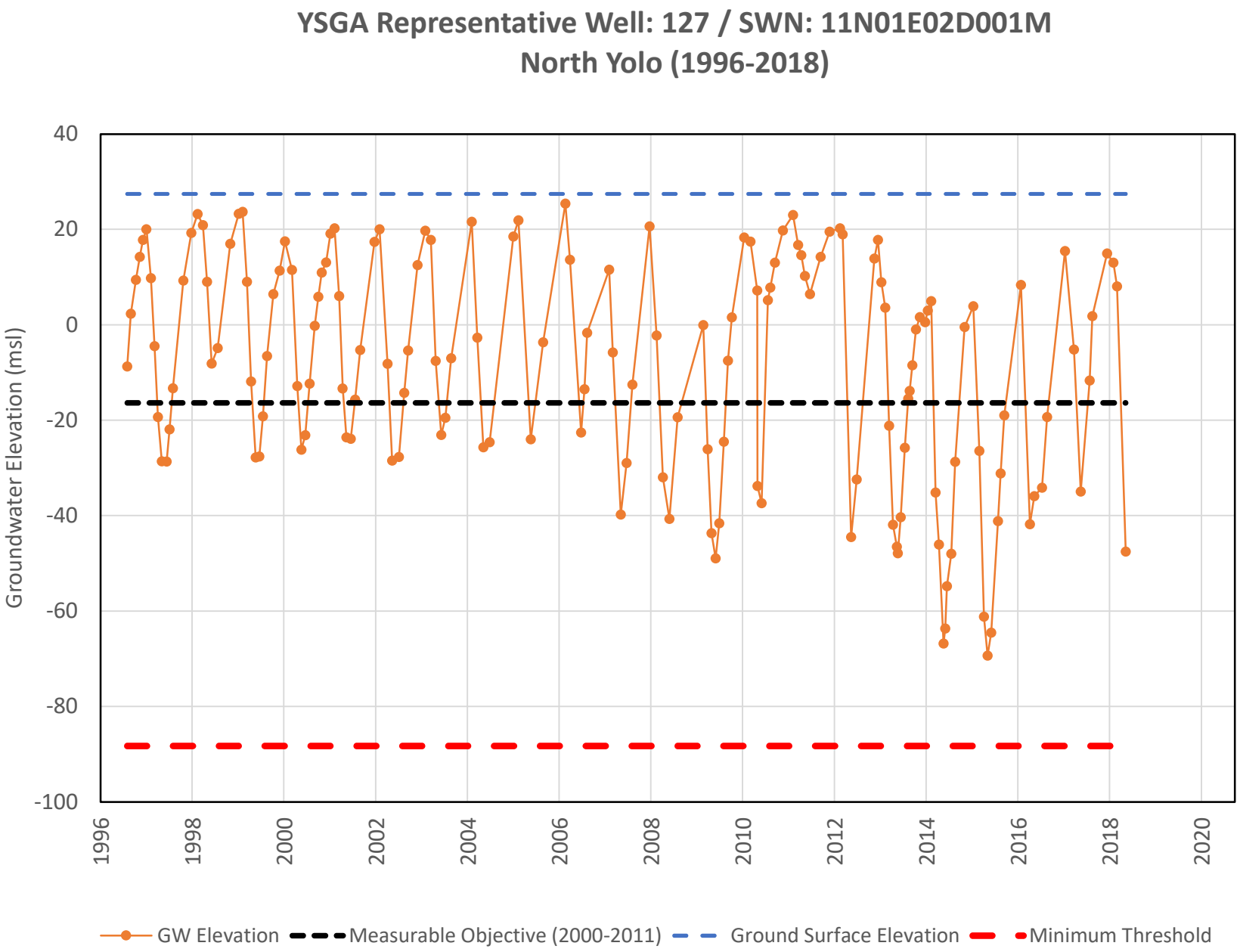

YSGA Representative Well: 402 / SWN: 10N01E15D001M
Dunnigan (1952-2020)
Groundwater Elevation (msl)
Depth to Water (ft)
120
100
80
60
40
20
0
-20
-40
-60
-80
14.8
34.8
54.8
74.8
94.8
114.8
134.8
154.8
174.8
1952
1953
1955
1957
1959
1961
1963
1965
1967
1969
1971
1973
1975
1977
1979
1981
1983
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003
2005
2007
2009
2011
2013
2015
2017
2019
GWE
Minimum Threshold
Measurable Objective (2000-2011)
Ground Surface Elevation

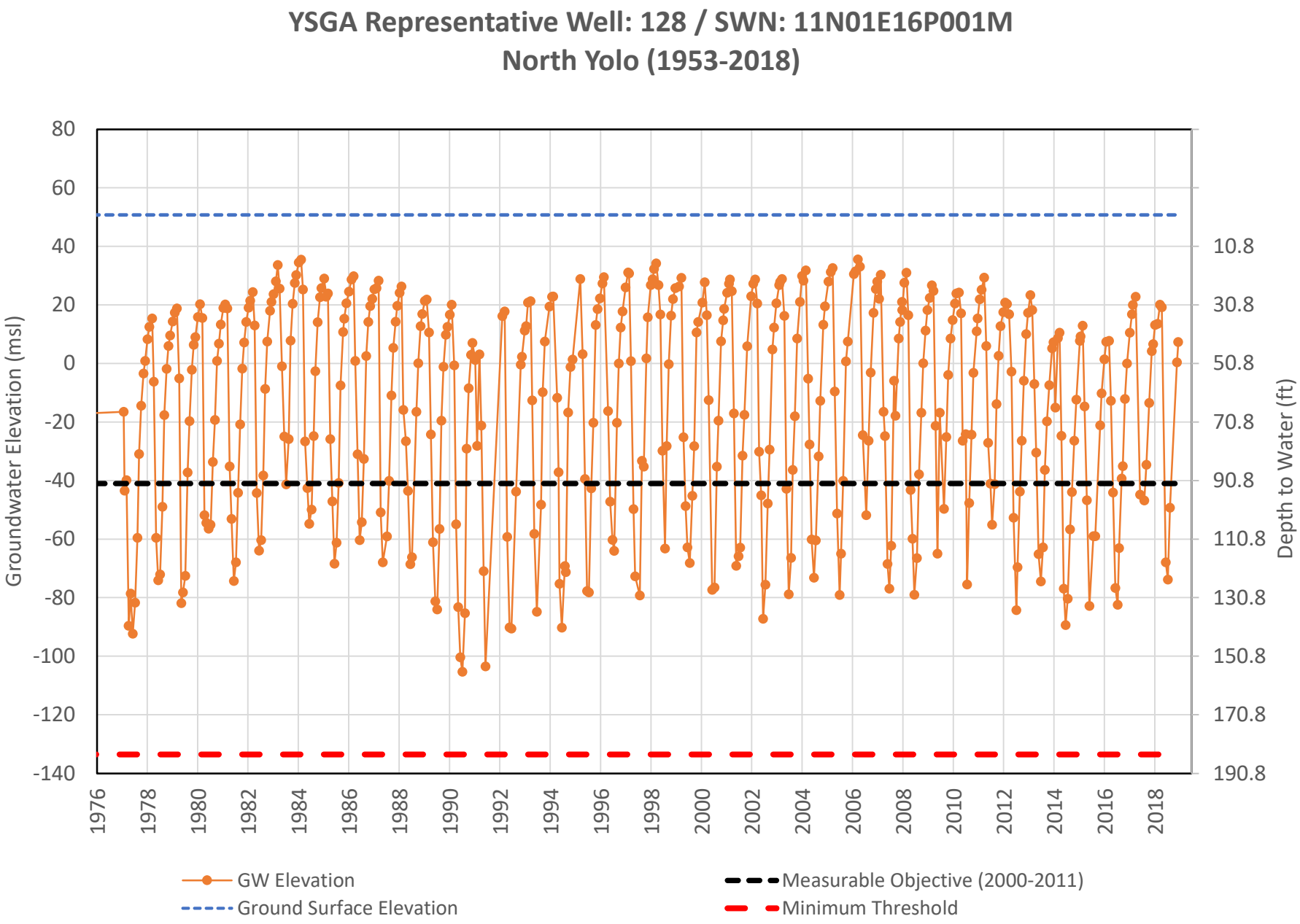
North Yolo Management Area

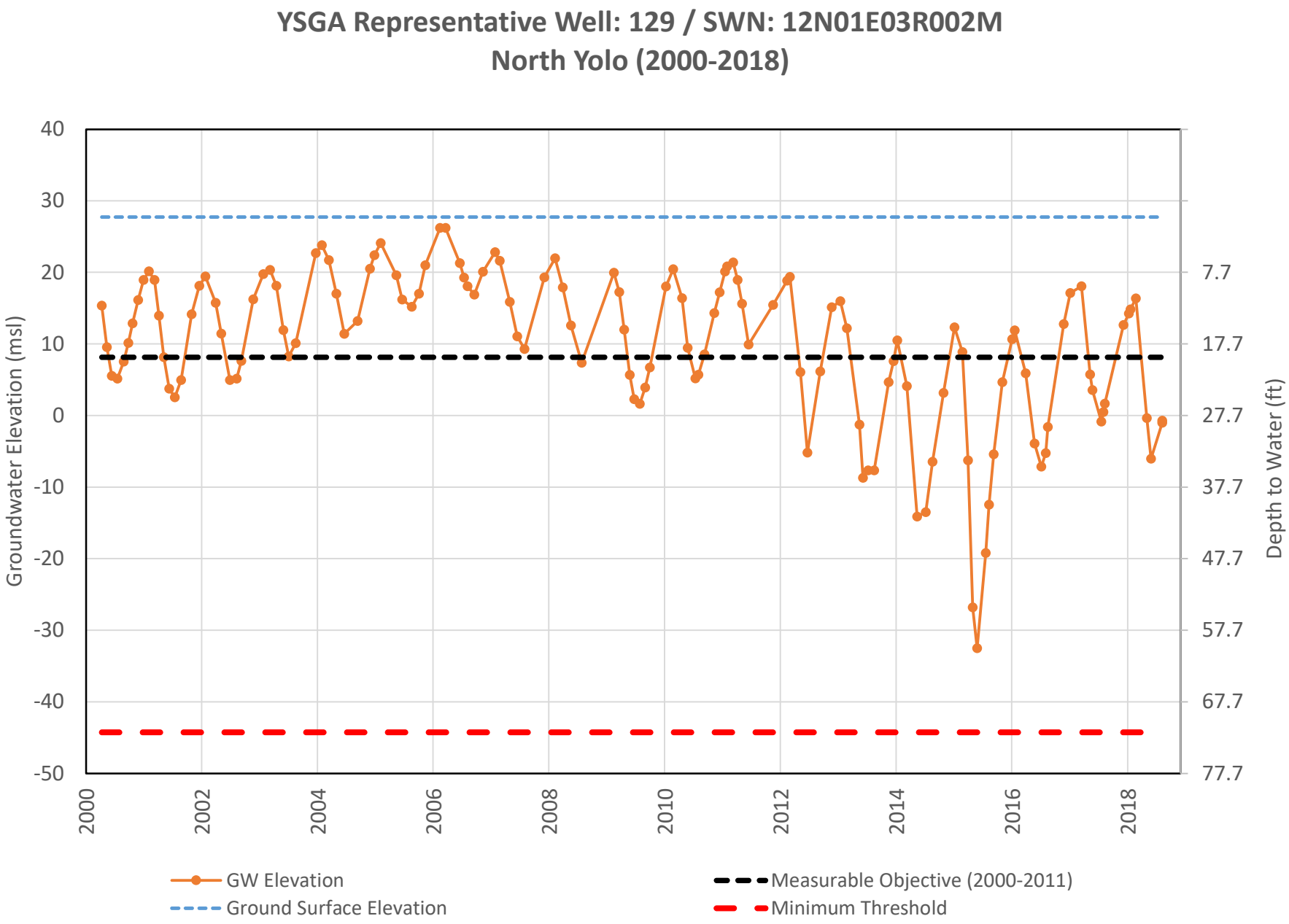


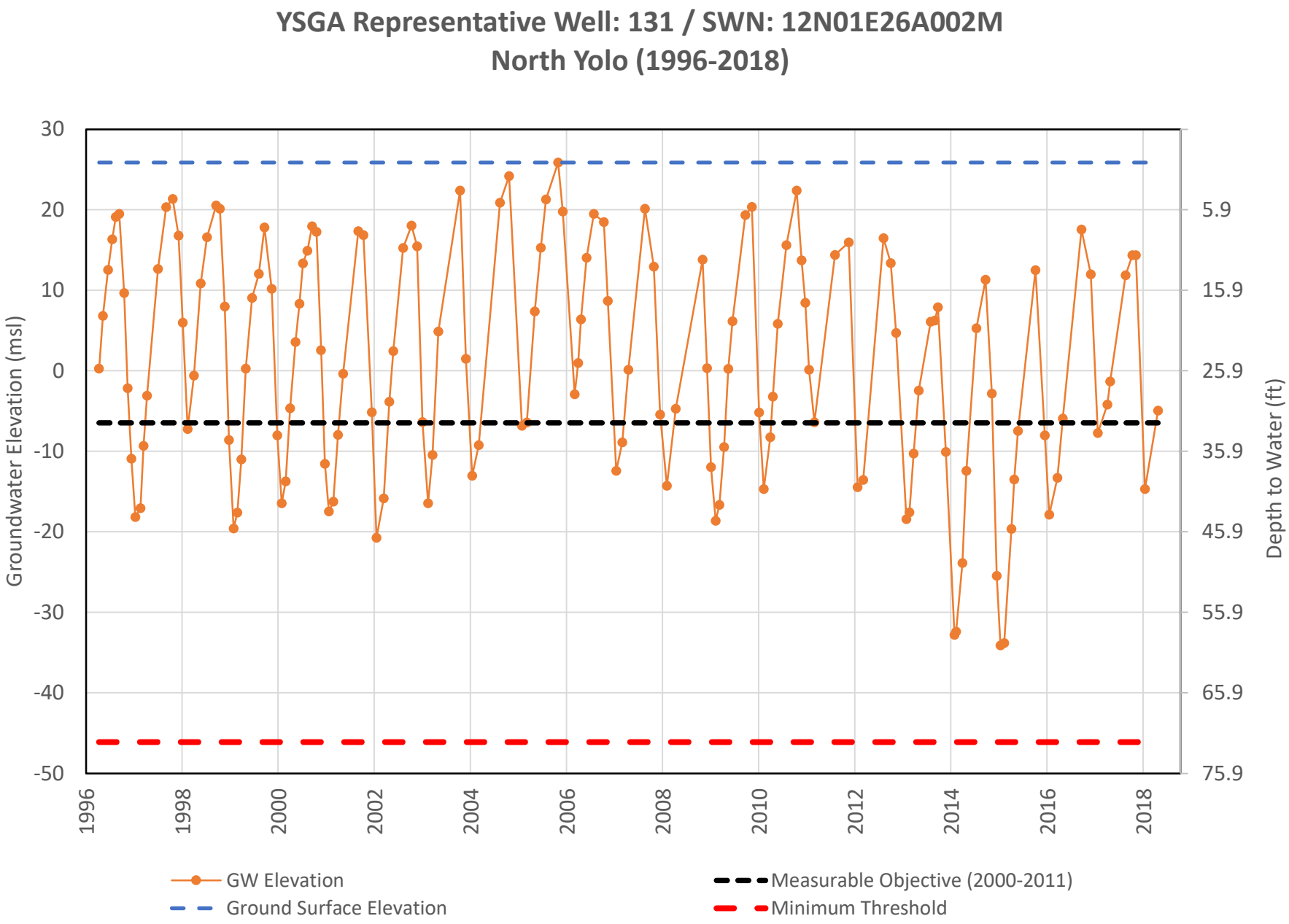
North Yolo Management Area- Representative Monitoring Well Construction Information

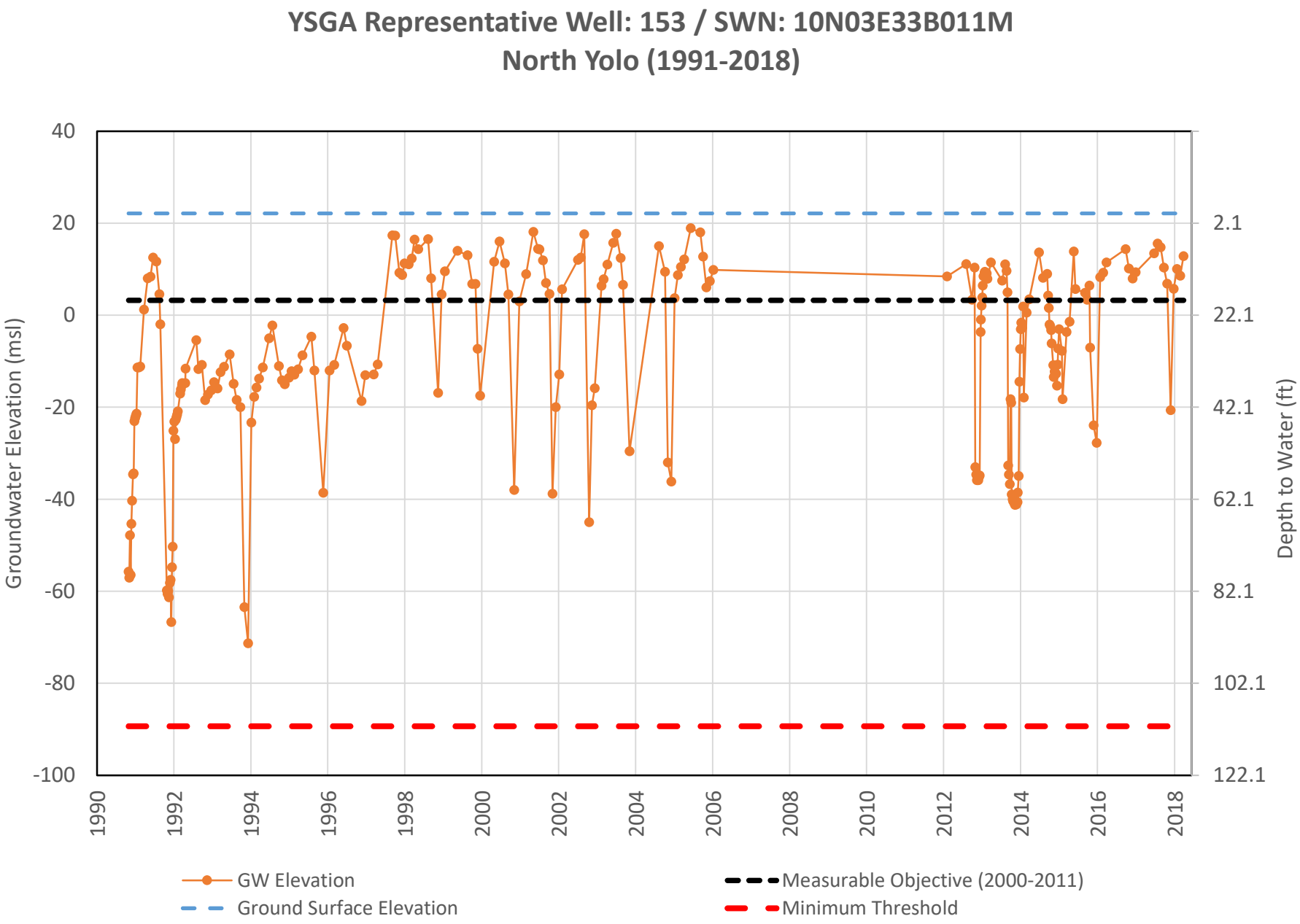
YSGA Well Number	State Well Number	Groundwater Elevations	Change in Storage	Depletion of ISW	Monitored by	Reference Point Elevation (feet)	Ground Surface Elevation (feet)	Well Use Type	Latitude	Longitude	Well Depth (ft bgs)	Well Completion Report Number	Top Perforation	Bottom Perforation
127	11N01E02D001M	X	X		DWR	28.21	27.45	Observation	38.8362336	-121.835173	690		603	683
128	11N01E16P001M	X	X		DWR	55.5	52.5	Domestic	38.7947207	-121.868378	172	68808	156	172
129	12N01E03R002M	X	X		DWR	32.3	30.62	Monitoring	38.913331	-121.843129	580		560	570
131	12N01E26A002M	X	X		DWR	25.87	25.06	Monitoring	38.8634752	-121.824459	490		400	480
153	10N03E33B011M	X	X		DWR	24.76	23.88	Monitoring	38.6758964	-121.644628	285	483648	140	280
178	12N01W14M001M	X	X		USBR	47.48	45.98	Irrigation	38.8882367	-121.947098	594		428	594
180	12N01W36K002M	X	X		DWR	40.49	39.49	Irrigation	38.8436036	-121.923328	633	110682	301	633
251	10N01E02Q002M	X	X		YCFC	77.26	76.76	Irrigation	38.735858	-121.829684	235	57-211		
405	10N02E06B001M	X	X		YCFC	60.68	61.162	Irrigation	38.7496214	-121.793259	300			
411	12N01W05B001M	X	X		DWR	143.9	140.4		38.9237557	-121.995829	150			
410	10N02E09N001M	X	X		YCFC	61.36	61.356	Irrigation	38.7225225	-121.763798	490	808		
420	10N02E03R002M	X		X	YCFC	38.28	37.99	Irrigation	38.7347294	-121.728774	83.5			
427	12N01E03R003M			X	DWR	38.28	30.62	monitoring	38.913331	-121.843129	350		330	340
421	11N02E20K004M	X		X	DWR	53.47	52.47		38.7849213	-121.774172	232	66696	220	232

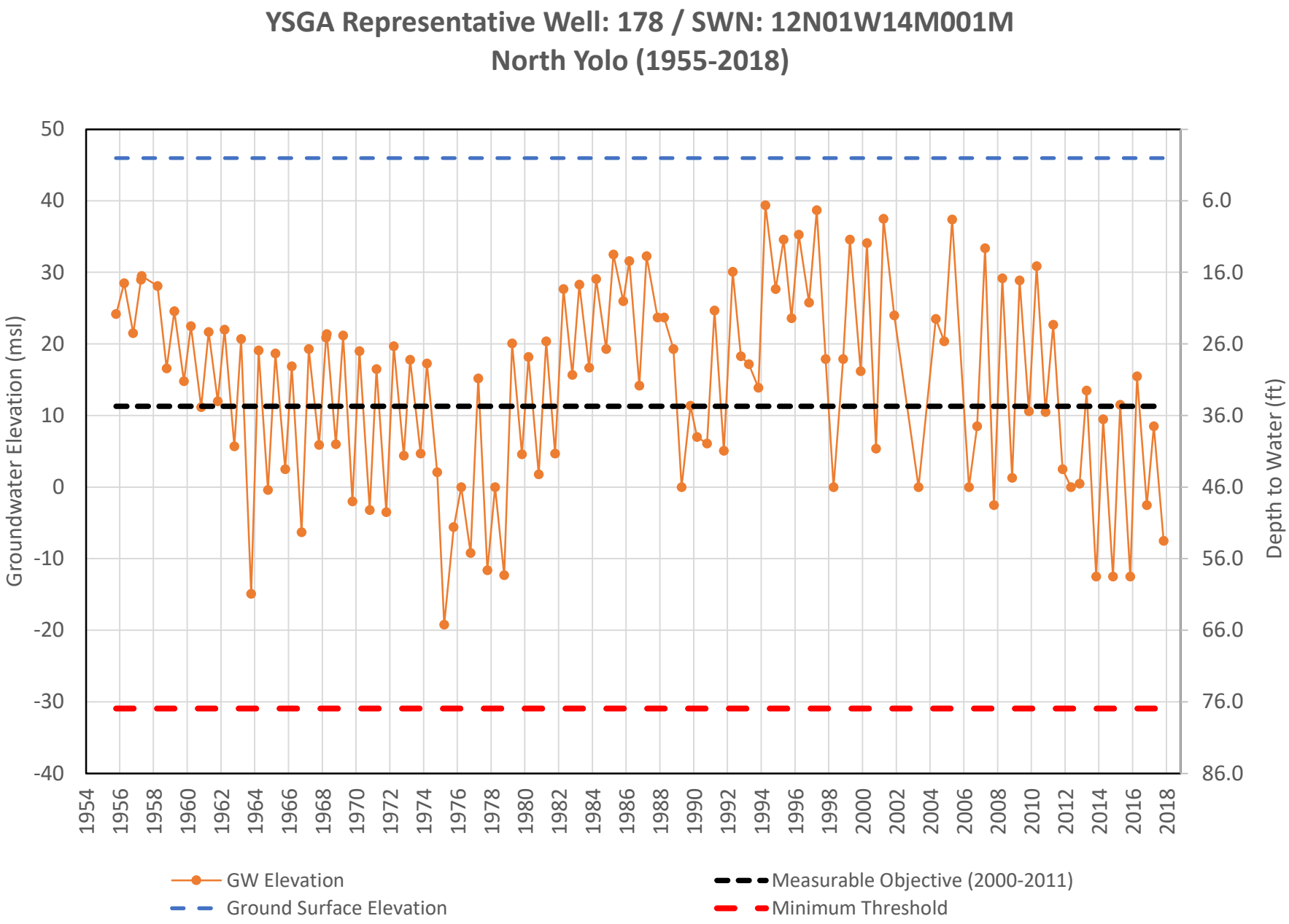

YSGA Representative Well: 127 / SWN: 11N01E02D001M
North Yolo (1996-2018)
Groundwater Elevation (msl)
40
20
0
-20
-40
-60
-80
-100
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
2018
2020
GW Elevation
Measurable Objective (2000-2011)
Ground Surface Elevation
Minimum Threshold

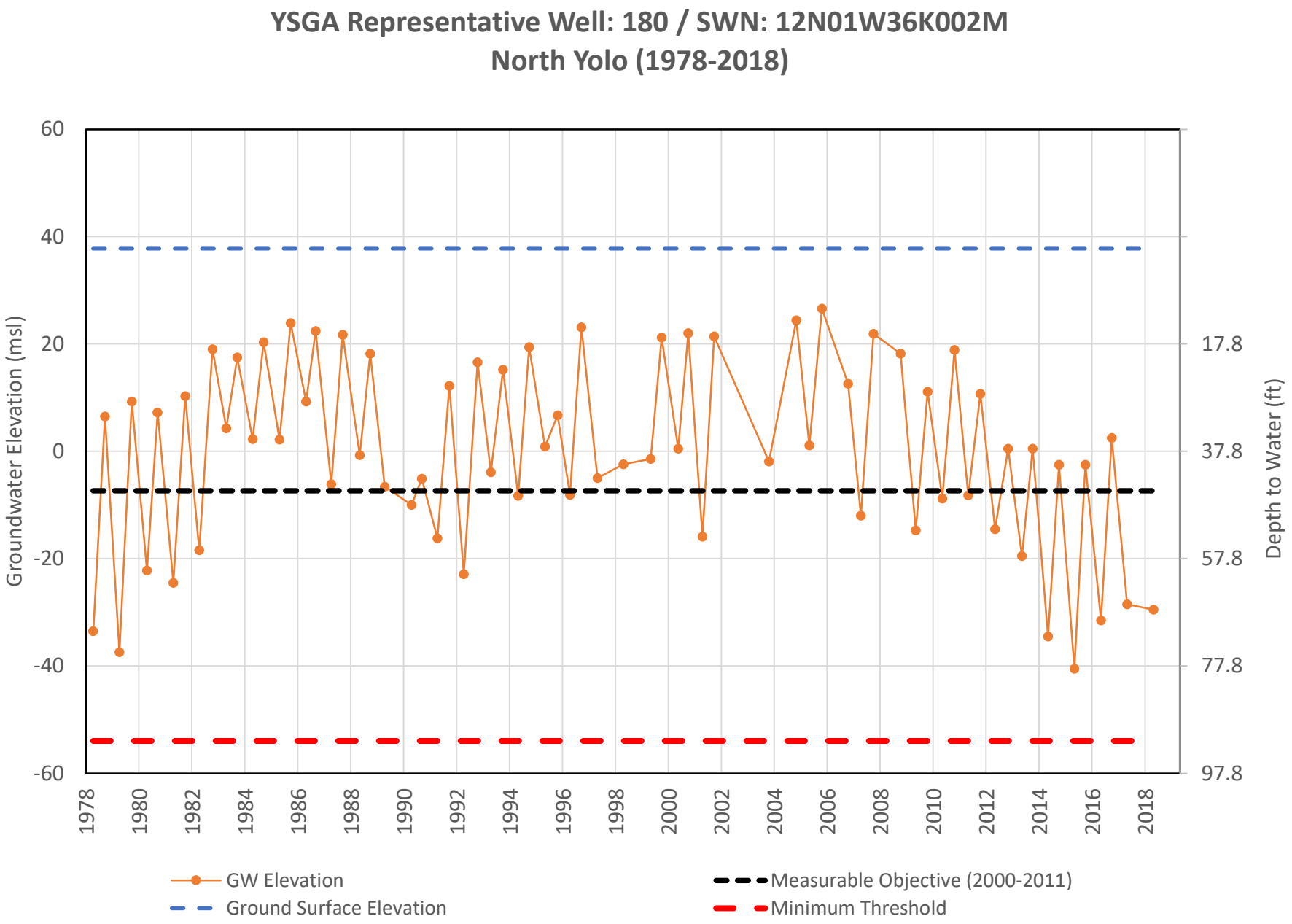

YSGA Representative Well: 128 / SWN: 11N01E16P001M
North Yolo (1953-2018)
Groundwater Elevation (msl)
Depth to Water (ft)
80
60
40
20
0
-20
-40
-60
-80
-100
-120
-140
10.8
30.8
50.8
70.8
90.8
110.8
130.8
150.8
170.8
190.8
1976
1978
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
2018
GW Elevation
Ground Surface Elevation
Measurable Objective (2000-2011)
Minimum Threshold

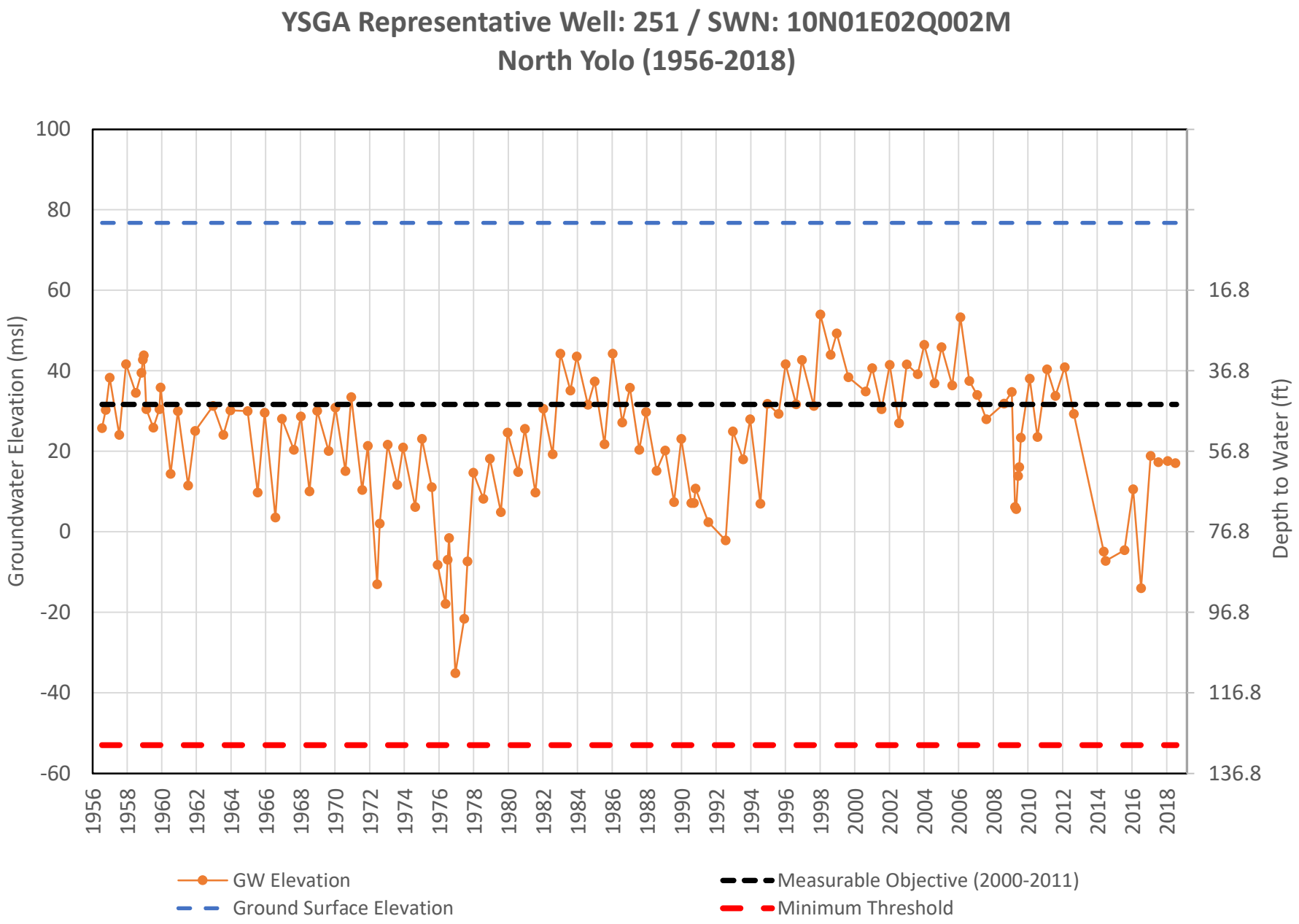

YSGA Representative Well: 129 / SWN: 12N01E03R002M
North Yolo (2000-2018)
Groundwater Elevation (msl)
Depth to Water (ft)
40
30
20
10
0
-10
-20
-30
-40
-50
7.7
17.7
27.7
37.7
47.7
57.7
67.7
77.7
2000
2002
2004
2006
2008
2010
2012
2014
2016
2018
GW Elevation
Ground Surface Elevation
Measurable Objective (2000-2011)
Minimum Threshold

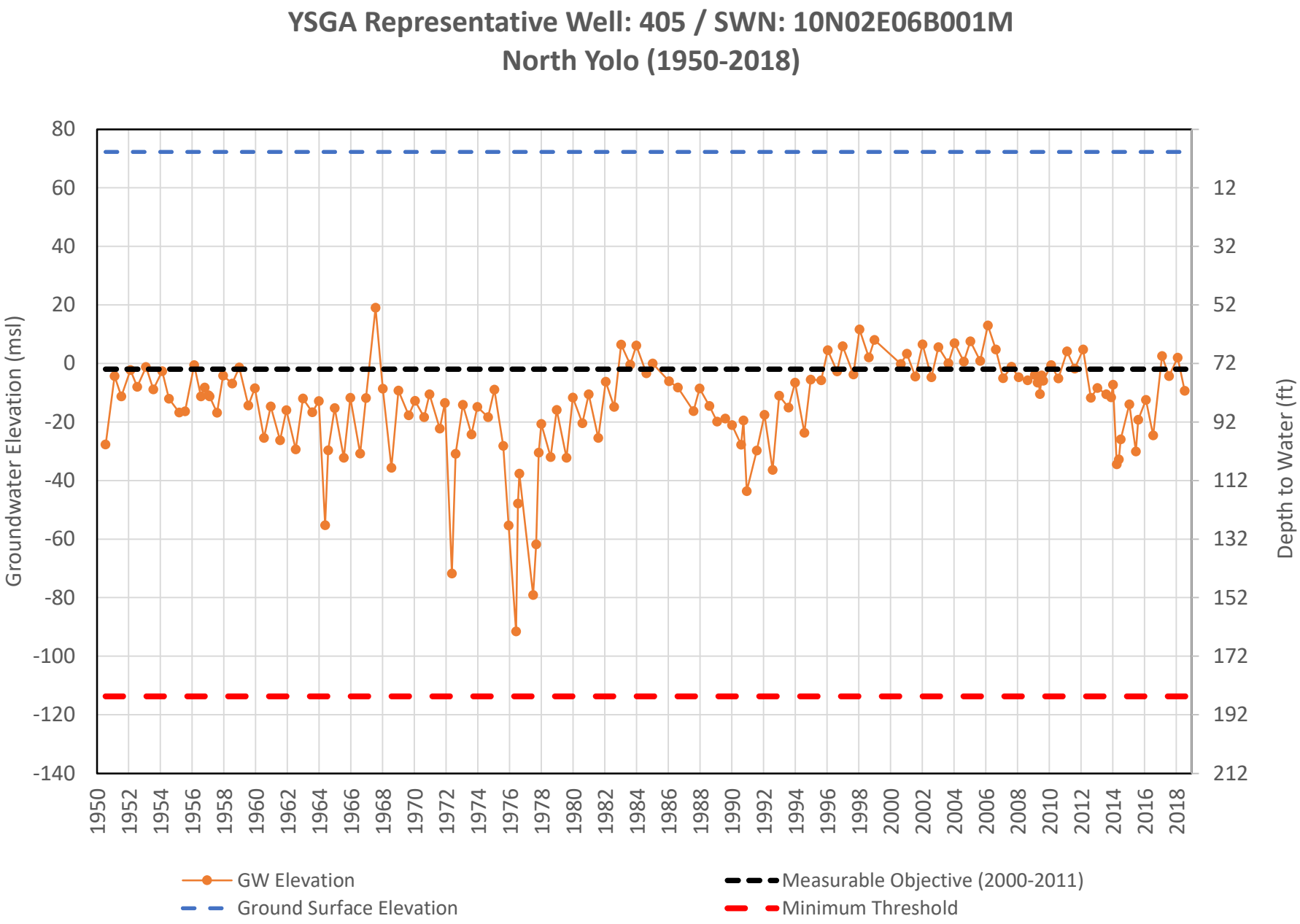

YSGA Representative Well: 131 / SWN: 12N01E26A002M
North Yolo (1996-2018)
Groundwater Elevation (msl)
Depth to Water (ft)
30
20
10
0
-10
-20
-30
-40
-50
5.9
15.9
25.9
35.9
45.9
55.9
65.9
75.9
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
2018
GW Elevation
Ground Surface Elevation
Measurable Objective (2000-2011)
Minimum Threshold

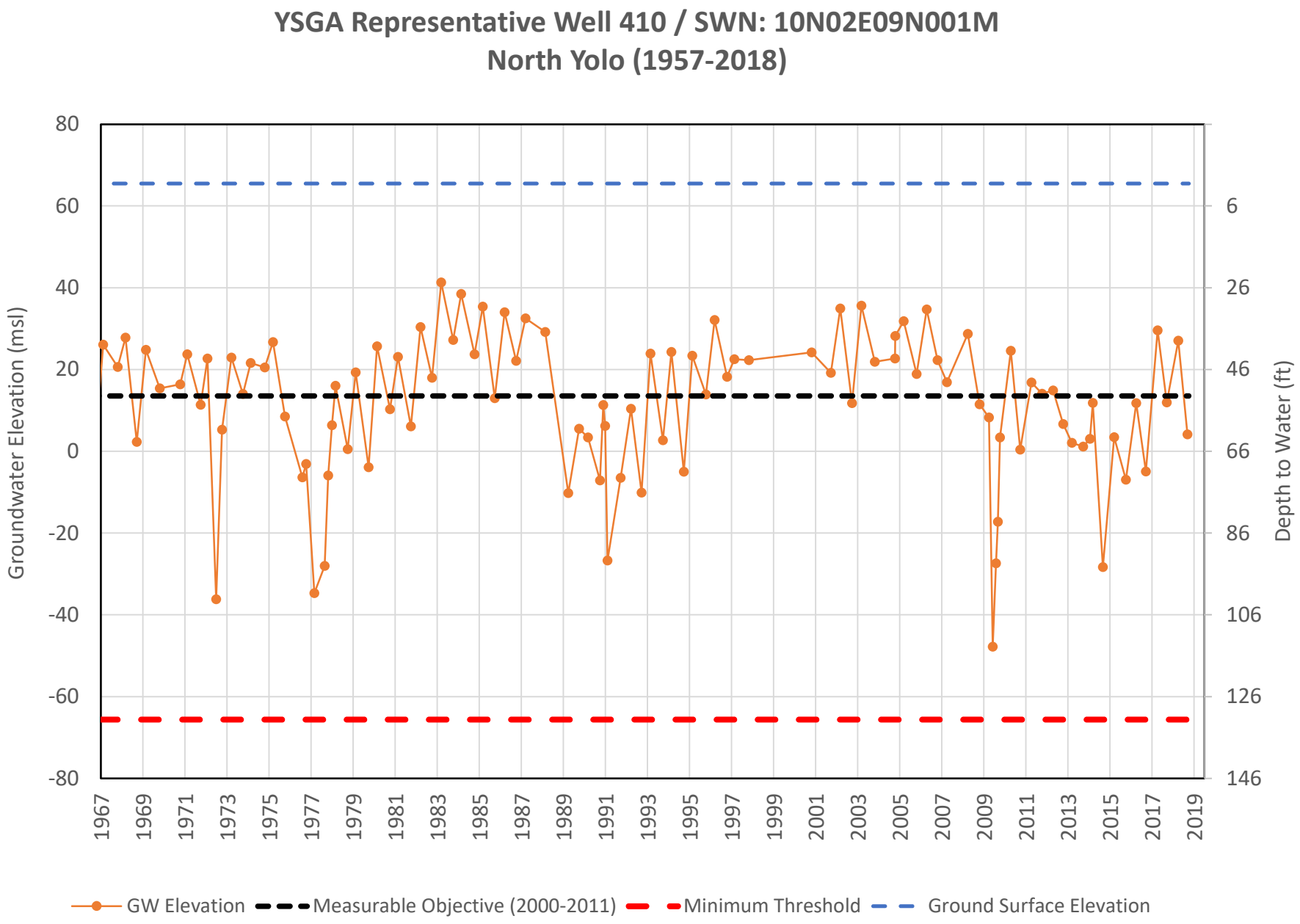

YSGA Representative Well: 153 / SWN: 10N03E33B011M
North Yolo (1991-2018)
Groundwater Elevation (msl)
Depth to Water (ft)
40
20
0
-20
-40
-60
-80
-100
2.1
22.1
42.1
62.1
82.1
102.1
122.1
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
2018
GW Elevation
Ground Surface Elevation
Measurable Objective (2000-2011)
Minimum Threshold

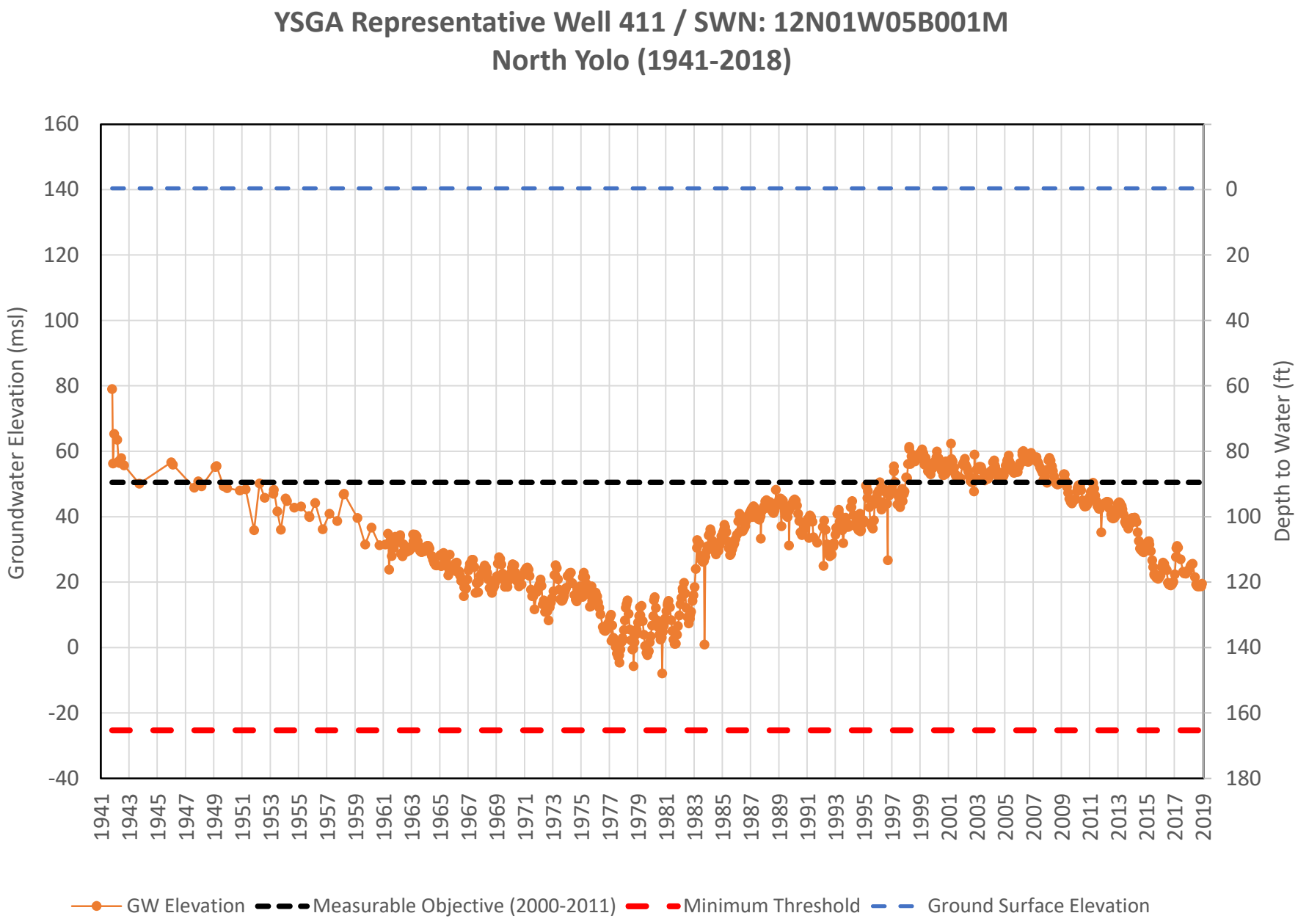

YSGA Representative Well: 178 / SWN: 12N01W14M001M
North Yolo (1955-2018)
Groundwater Elevation (msl)
Depth to Water (ft)
50
40
30
20
10
0
-10
-20
-30
-40
6.0
16.0
26.0
36.0
46.0
56.0
66.0
76.0
86.0
1954
1956
1958
1960
1962
1964
1966
1968
1970
1972
1974
1976
1978
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
2018
GW Elevation
Ground Surface Elevation
Measurable Objective (2000-2011)
Minimum Threshold

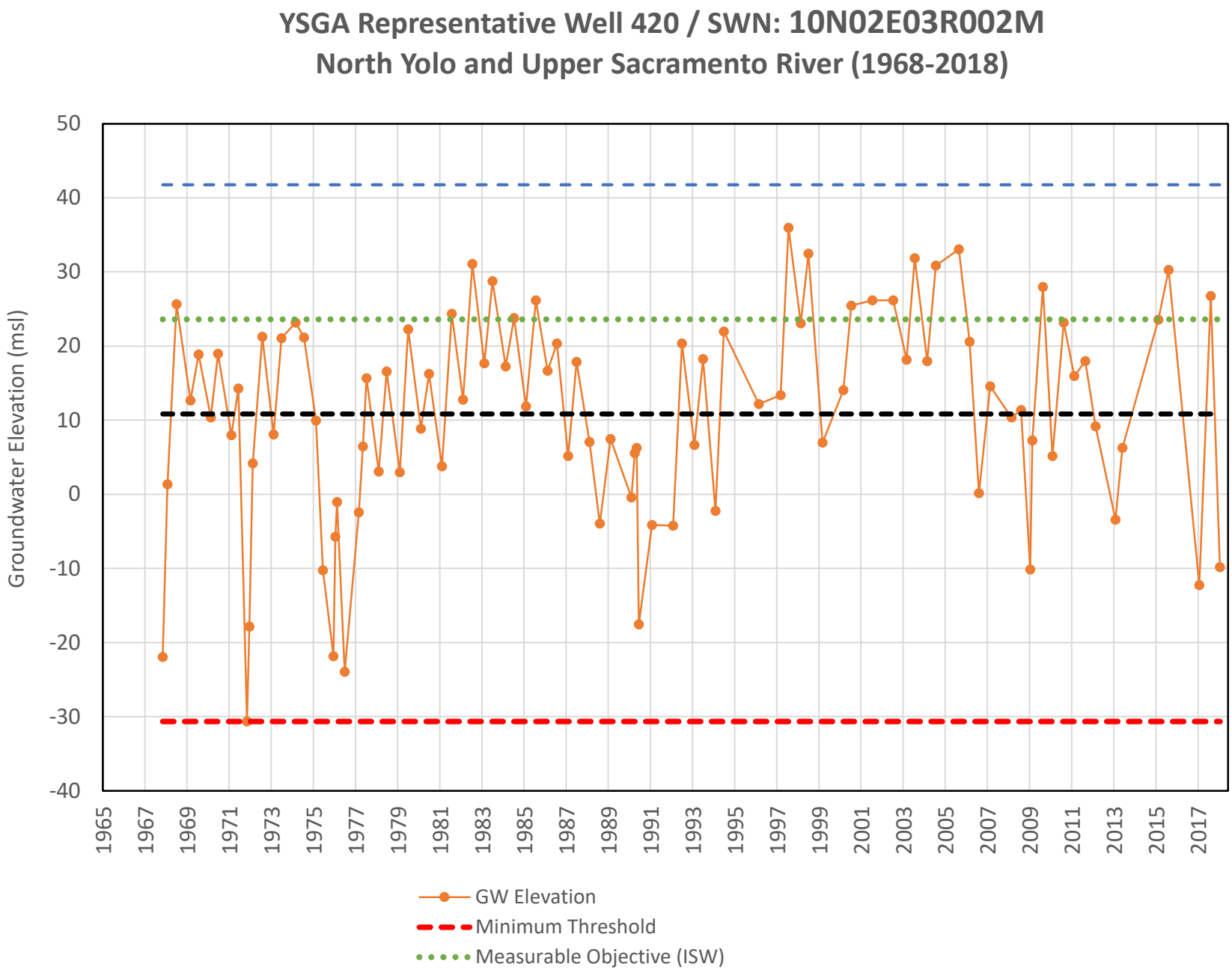

YSGA Representative Well: 180 / SWN: 12N01W36K002M
North Yolo (1978-2018)
Groundwater Elevation (msl)
Depth to Water (ft)
60
40
20
0
-20
-40
-60
17.8
37.8
57.8
77.8
97.8
1978
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
2018
GW Elevation
Ground Surface Elevation
Measurable Objective (2000-2011)
Minimum Threshold

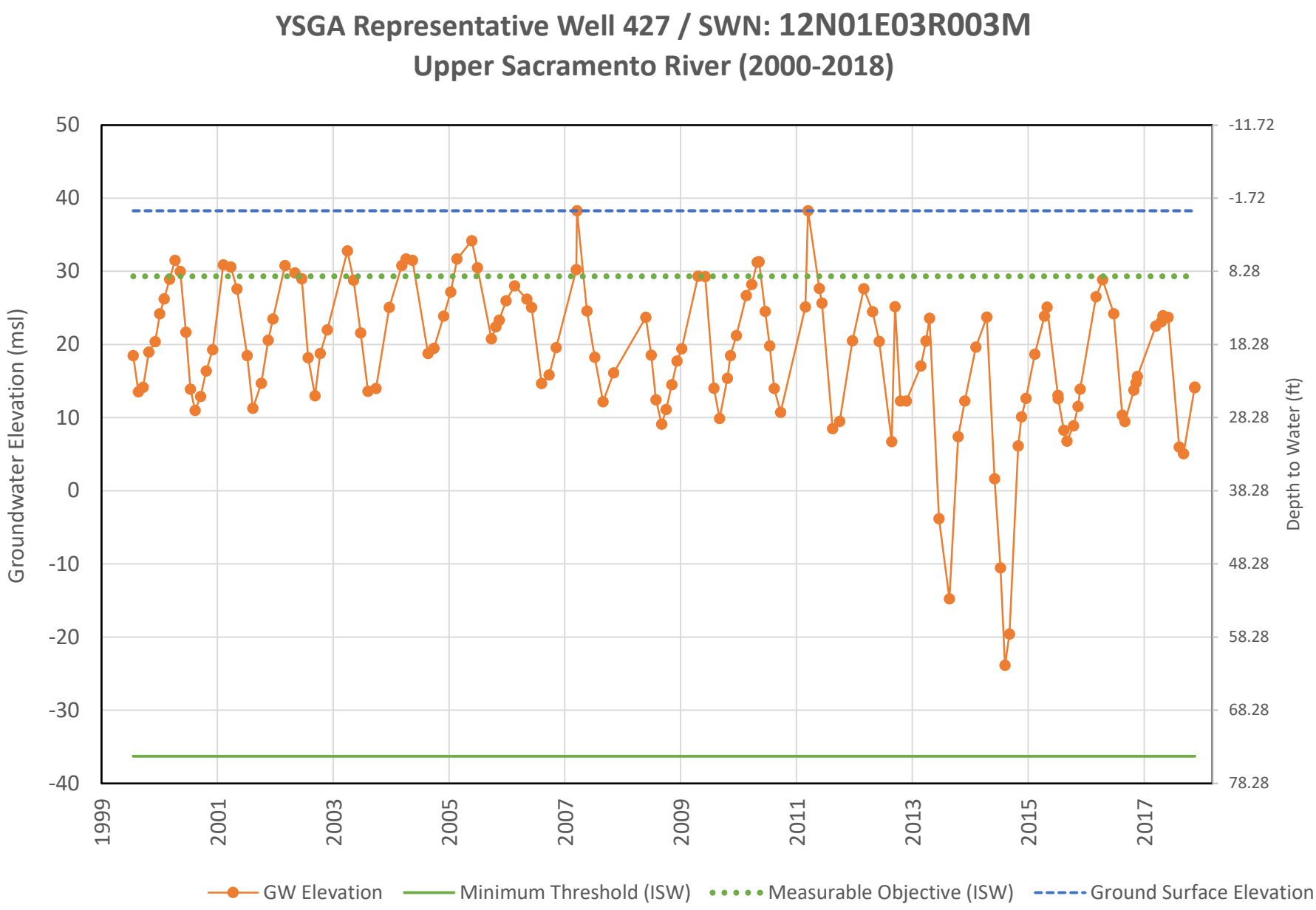

YSGA Representative Well: 251 / SWN: 10N01E02Q002M
North Yolo (1956-2018)
Groundwater Elevation (msl)
Depth to Water (ft)
100
80
60
40
20
0
-20
-40
-60
16.8
36.8
56.8
76.8
96.8
116.8
136.8
1956
1958
1960
1962
1964
1966
1968
1970
1972
1974
1976
1978
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
2018
GW Elevation
Ground Surface Elevation
Measurable Objective (2000-2011)
Minimum Threshold

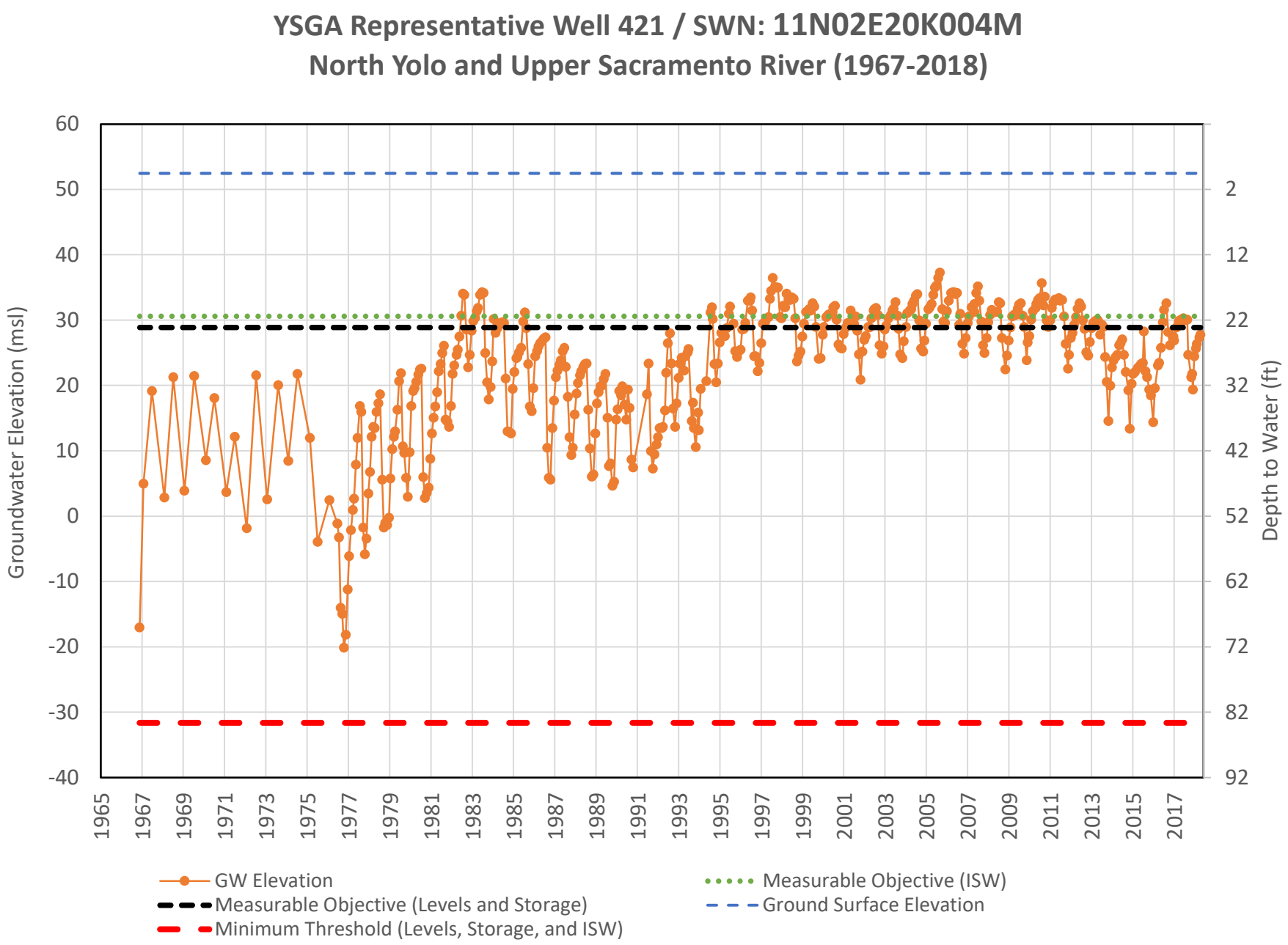

YSGA Representative Well: 405 / SWN: 10N02E06B001M
North Yolo (1950-2018)
Groundwater Elevation (msl)
Depth to Water (ft)
80
60
40
20
0
-20
-40
-60
-80
-100
-120
-140
12
32
52
72
92
112
132
152
172
192
212
1950
1952
1954
1956
1958
1960
1962
1964
1966
1968
1970
1972
1974
1976
1978
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
2018
GW Elevation
Ground Surface Elevation
Measurable Objective (2000-2011)
Minimum Threshold


YSGA Representative Well 410 / SWN: 10N02E09N001M
North Yolo (1957-2018)
Groundwater Elevation (msl)
Depth to Water (ft)
80
60
40
20
0
-20
-40
-60
-80
6
26
46
66
86
106
126
146
1967
1969
1971
1973
1975
1977
1979
1981
1983
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003
2005
2007
2009
2011
2013
2015
2017
2019
GW Elevation
Measurable Objective (2000-2011)
Minimum Threshold
Ground Surface Elevation

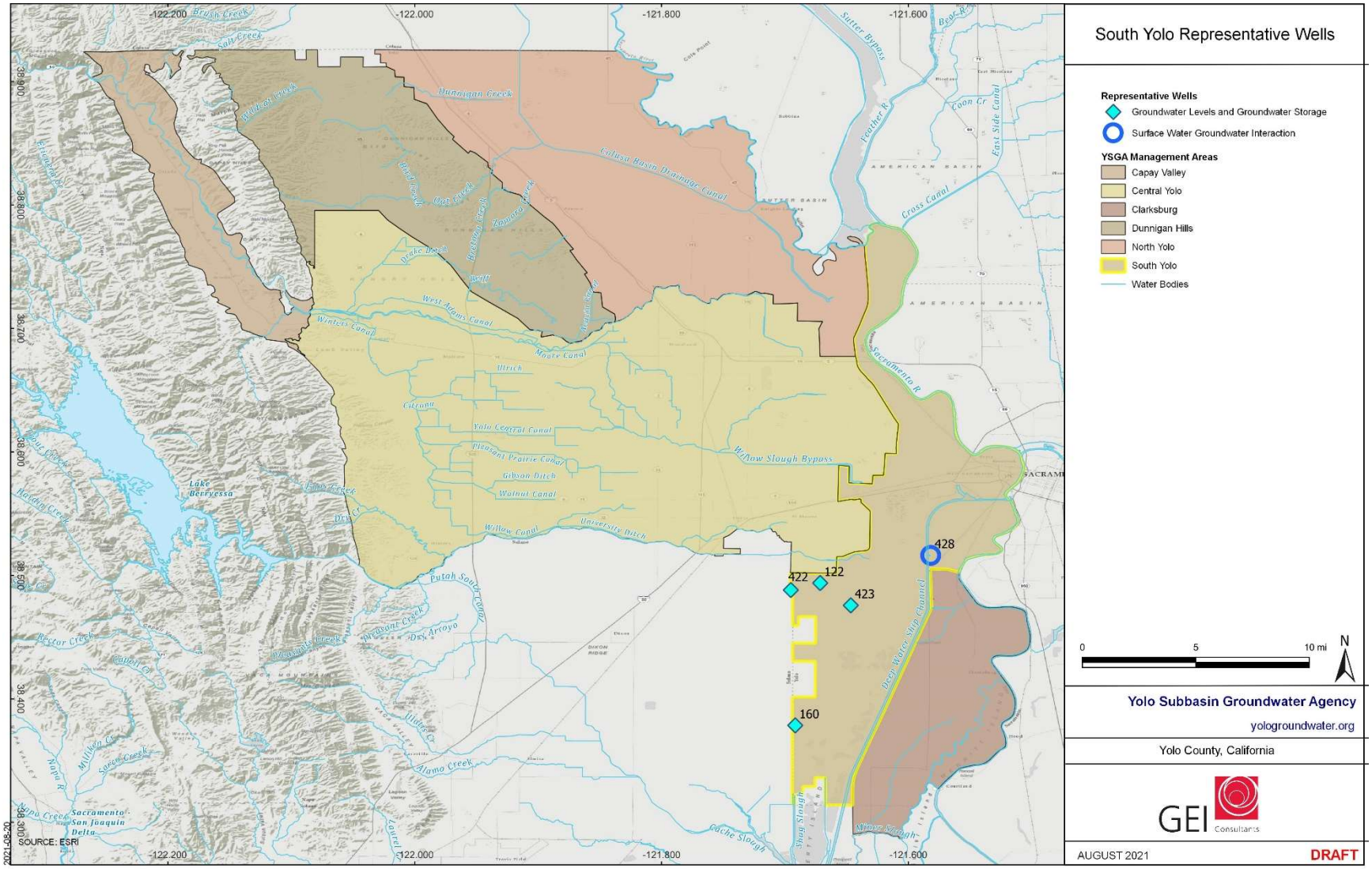

YSGA Representative Well 411 / SWN: 12N01W05B001M
North Yolo (1941-2018)
Groundwater Elevation (msl)
Depth to Water (ft)
160
140
120
100
80
60
40
20
0
-20
-40
0
20
40
60
80
100
120
140
160
180
1941
1943
1945
1947
1949
1951
1953
1955
1957
1959
1961
1963
1965
1967
1969
1971
1973
1975
1977
1979
1981
1983
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003
2005
2007
2009
2011
2013
2015
2017
2019
GW Elevation
Measurable Objective (2000-2011)
Minimum Threshold
Ground Surface Elevation


YSGA Representative Well 420 / SWN: 10N02E03R002M
North Yolo and Upper Sacramento River (1968-2018)
Groundwater Elevation (msl)
50
40
30
20
10
0
-10
-20
-30
-40
1965
1967
1969
1971
1973
1975
1977
1979
1981
1983
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003
2005
2007
2009
2011
2013
2015
2017
GW Elevation
Minimum Threshold
Measurable Objective (ISW)


YSGA Representative Well 427 / SWN: 12N01E03R003M
Upper Sacramento River (2000-2018)
Groundwater Elevation (msl)
Depth to Water (ft)
50
40
30
20
10
0
-10
-20
-30
-40
-11.72
-1.72
8.28
18.28
28.28
38.28
48.28
58.28
68.28
78.28
1999
2001
2003
2005
2007
2009
2011
2013
2015
2017
GW Elevation
Minimum Threshold (ISW)
Measurable Objective (ISW)
Ground Surface Elevation

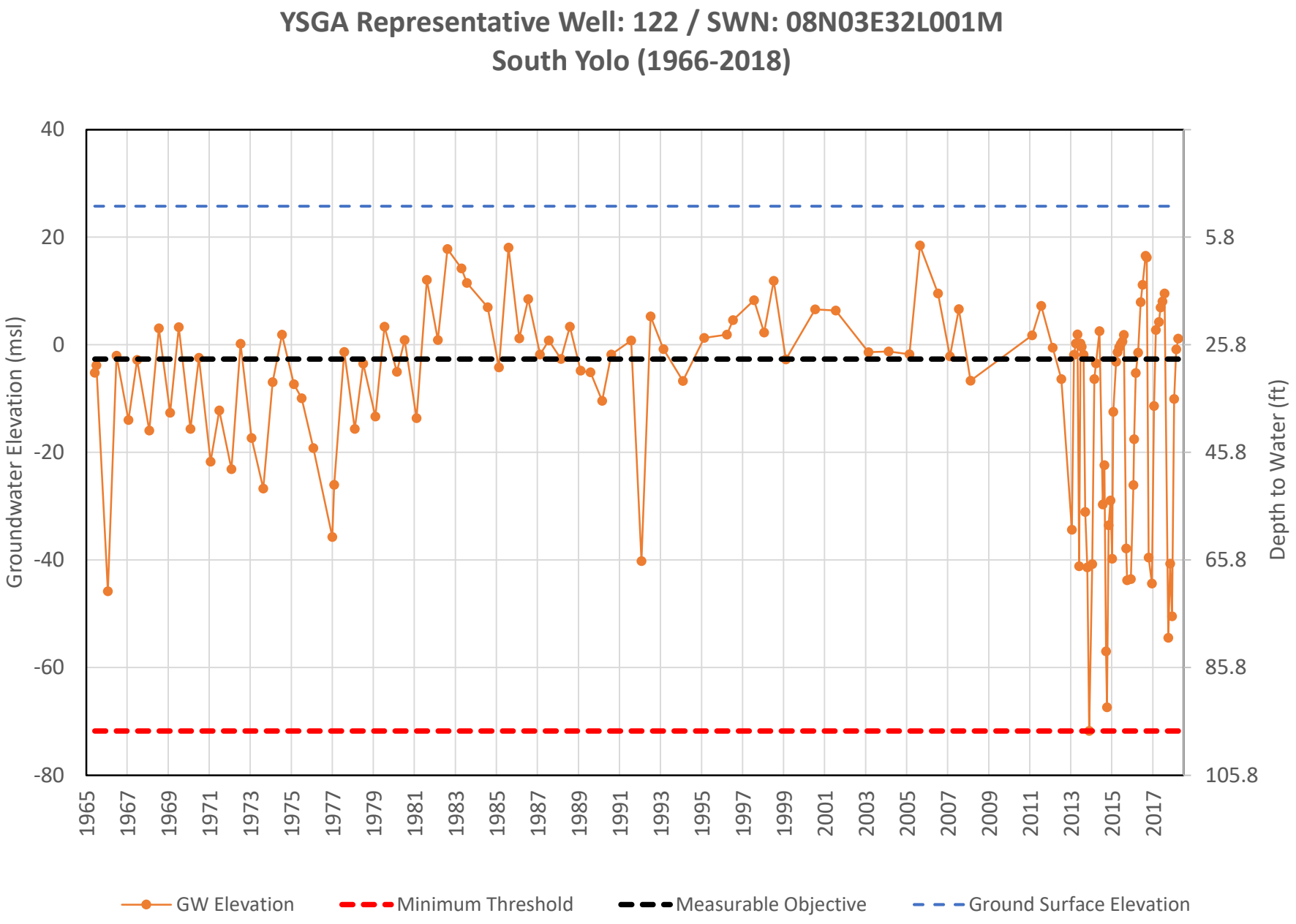

YSGA Representative Well 421 / SWN: 11N02E20K004M
North Yolo and Upper Sacramento River (1967-2018)
Groundwater Elevation (msl)
Depth to Water (ft)
60
50
40
30
20
10
0
-10
-20
-30
-40
2
12
22
32
42
52
62
72
82
92
1965
1967
1969
1971
1973
1975
1977
1979
1981
1983
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003
2005
2007
2009
2011
2013
2015
2017
GW Elevation
Measurable Objective (ISW)
Measurable Objective (Levels and Storage)
Ground Surface Elevation
Minimum Threshold (Levels, Storage, and ISW)

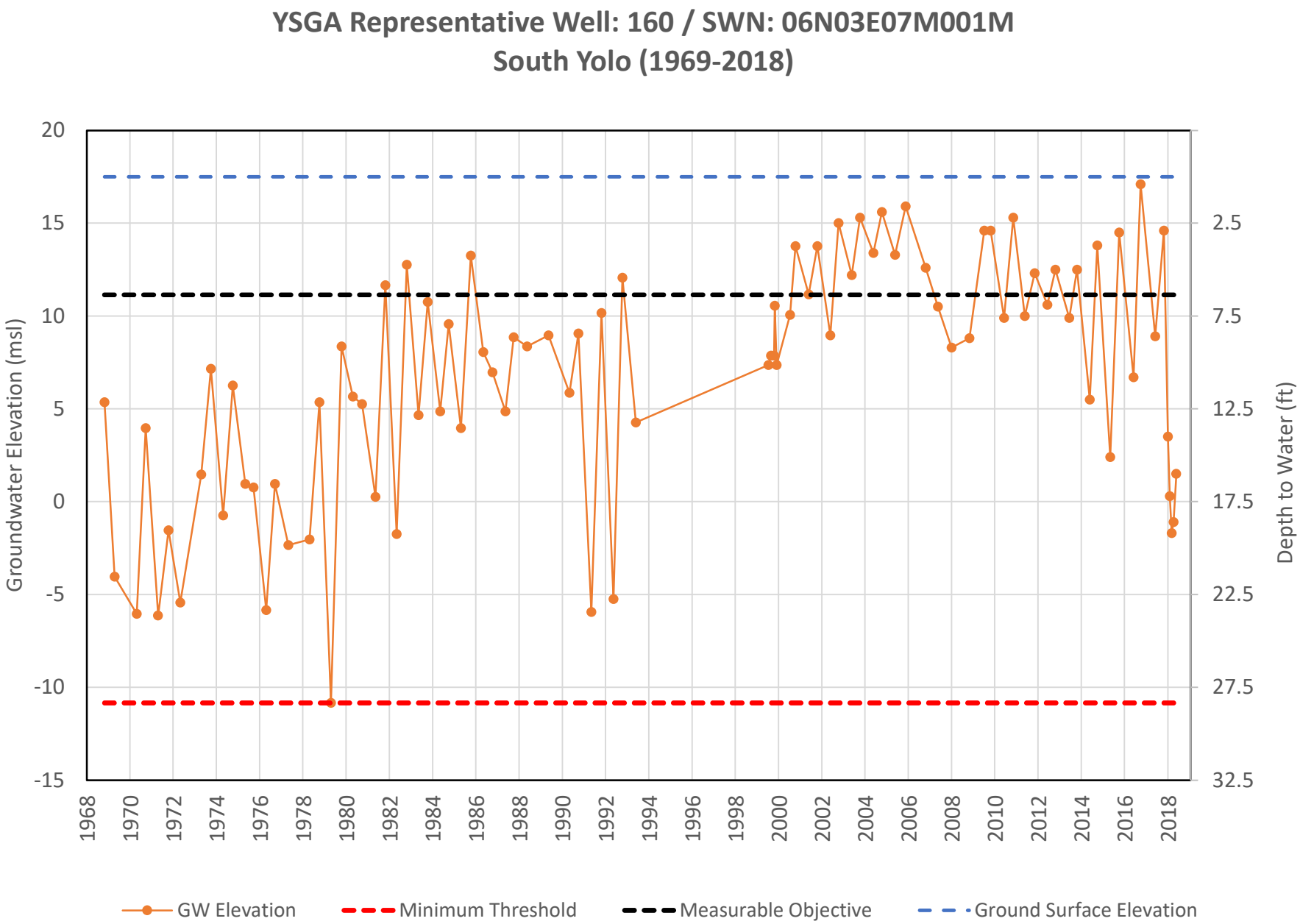
South Yolo Management Area

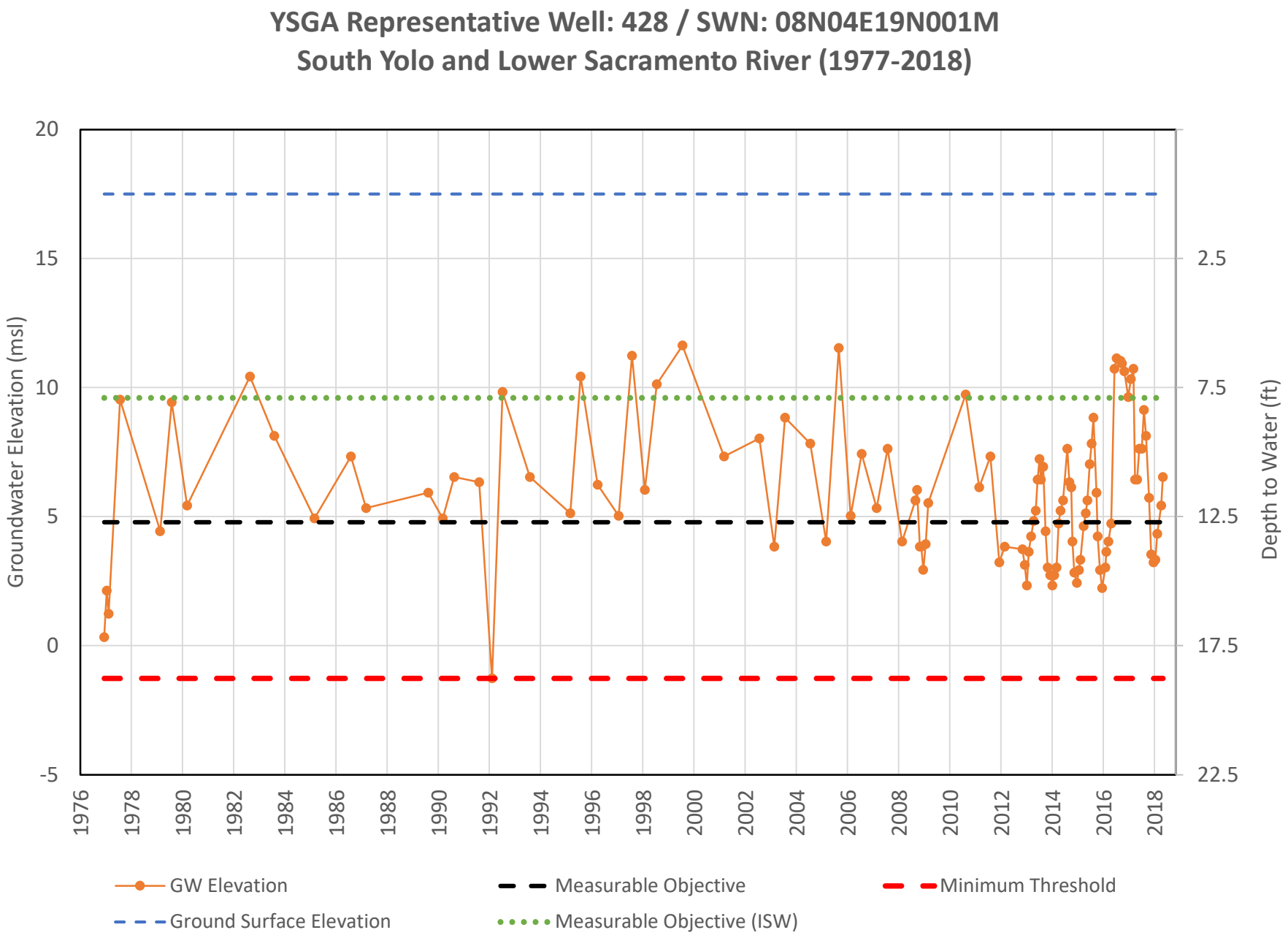


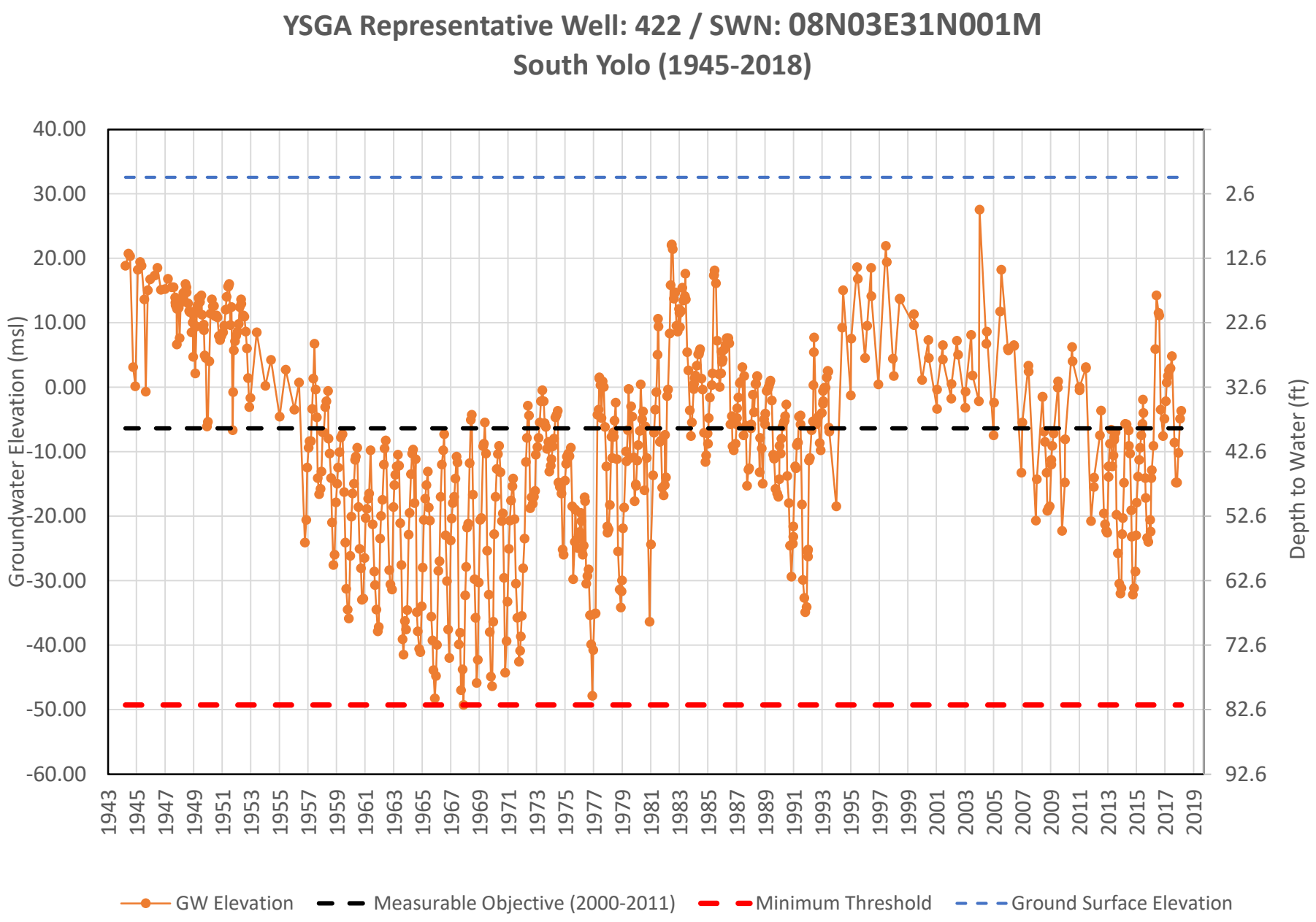
South Yolo Management Area- Representative Monitoring Well Construction Information

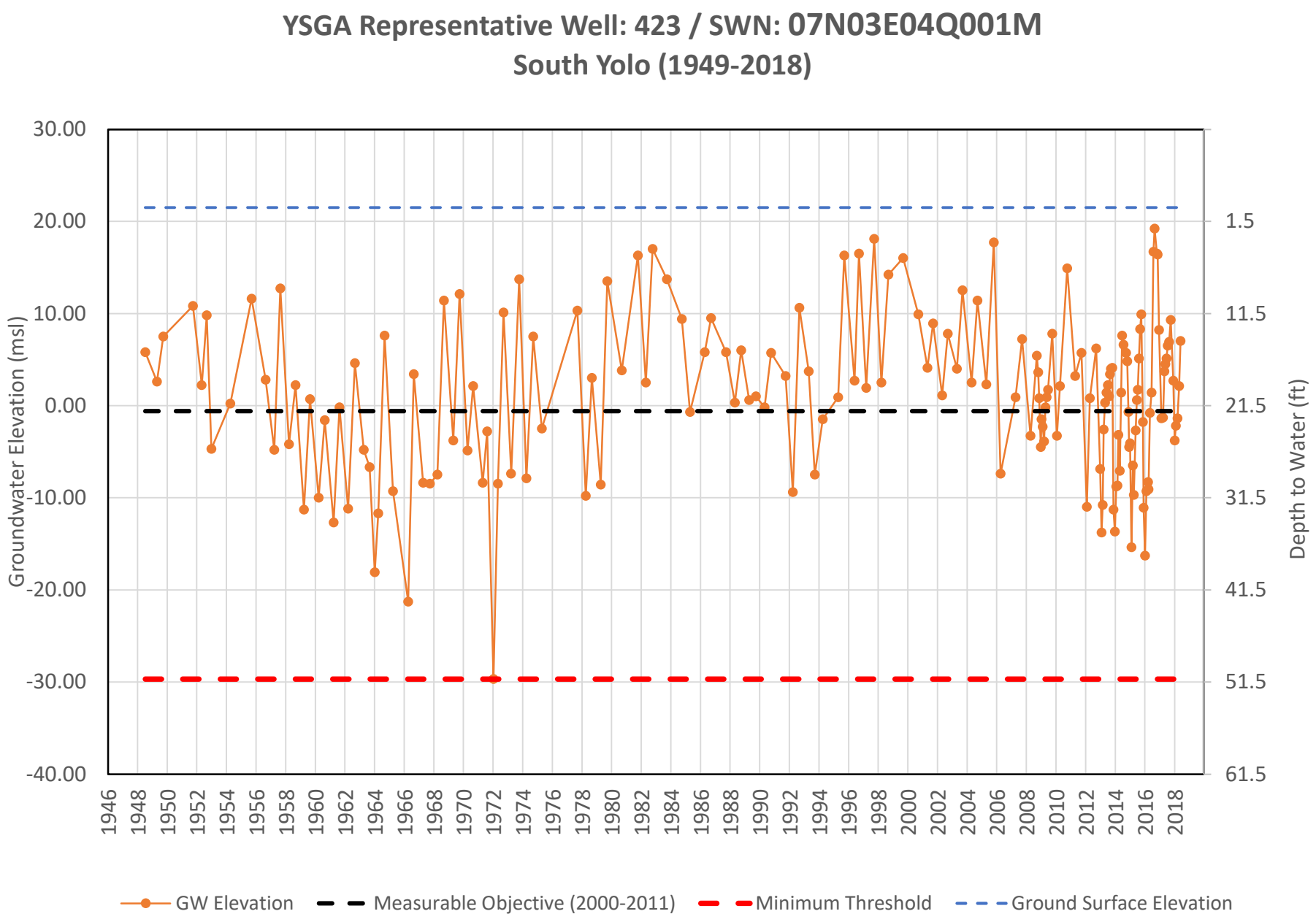
YSGA Well Number	State Well Number	Groundwater Elevations	Change in Storage	Depletion of ISW	Monitored by	Reference Point Elevation (feet)	Ground Surface Elevation (feet)	Well Use Type	Latitude	Longitude	Well Depth (ft bgs)	Well Completion Report Number	Top Perforation	Bottom Perforation
122	08N03E32L001M	X	X		DWR	28.53	27.53	Irrigation	38.4937847	-121.671393	420	106444	164	420
160	06N03E07M001M	X	X		DWR - discontin	18.86	15.76	Irrigation	38.3784824	-121.691605	91			
428	08N04E19N001M			X	DWR	18.03	17.53	Domestic	38.5162002	-121.581825	260	8625		
422	08N03E31N001M	X			YSGA	33.53	32.53	Other	38.4881	-121.6952	89			
423	07N03E04Q001M	X			YSGA/DWR	24.52	21.52	Irrigation	38.4757	-121.6466	88			


YSGA Representative Well: 122 / SWN: 08N03E32L001M
South Yolo (1966-2018)
Groundwater Elevation (msl)
Depth to Water (ft)
40
20
0
-20
-40
-60
-80
5.8
25.8
45.8
65.8
85.8
105.8
1965
1967
1969
1971
1973
1975
1977
1979
1981
1983
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003
2005
2007
2009
2011
2013
2015
2017
GW Elevation
Minimum Threshold
Measurable Objective
Ground Surface Elevation


YSGA Representative Well: 160 / SWN: 06N03E07M001M
South Yolo (1969-2018)
Groundwater Elevation (msl)
Depth to Water (ft)
20
15
10
5
0
-5
-10
-15
2.5
7.5
12.5
17.5
22.5
27.5
32.5
1968
1970
1972
1974
1976
1978
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
2018
GW Elevation
Minimum Threshold
Measurable Objective
Ground Surface Elevation


YSGA Representative Well: 428 / SWN: 08N04E19N001M
South Yolo and Lower Sacramento River (1977-2018)
Groundwater Elevation (msl)
Depth to Water (ft)
20
15
10
5
0
-5
2.5
7.5
12.5
17.5
22.5
1976
1978
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
2018
GW Elevation
Measurable Objective
Minimum Threshold
Ground Surface Elevation
Measurable Objective (ISW)


YSGA Representative Well: 422 / SWN: 08N03E31N001M
South Yolo (1945-2018)
Groundwater Elevation (msl)
Depth to Water (ft)
40.00
30.00
20.00
10.00
0.00
-10.00
-20.00
-30.00
-40.00
-50.00
-60.00
2.6
12.6
22.6
32.6
42.6
52.6
62.6
72.6
82.6
92.6
1943
1945
1947
1949
1951
1953
1955
1957
1959
1961
1963
1965
1967
1969
1971
1973
1975
1977
1979
1981
1983
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003
2005
2007
2009
2011
2013
2015
2017
2019
GW Elevation
Measurable Objective (2000-2011)
Minimum Threshold
Ground Surface Elevation


YSGA Representative Well: 423 / SWN: 07N03E04Q001M
South Yolo (1949-2018)
Groundwater Elevation (msl)
Depth to Water (ft)
30.00
20.00
10.00
0.00
-10.00
-20.00
-30.00
-40.00
1.5
11.5
21.5
31.5
41.5
51.5
61.5
1946
1948
1950
1952
1954
1956
1958
1960
1962
1964
1966
1968
1970
1972
1974
1976
1978
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
2018
GW Elevation
Measurable Objective (2000-2011)
Minimum Threshold
Ground Surface Elevation

PUBLIC DRAFT

Yolo Subbasin Groundwater Agency

2022 Groundwater Sustainability Plan

APPENDIX F:

Table of Projects and Management Actions

Project/MA Number	MA Name	Cirumstance for Implementation	Public Noticing Process	Permitting and Regulatory Process Requirements	Implementing YSGA Member Agency	Status	Timetable / Circumstances for Initiation	Timetable for Completion	Timetable for Accural of Expected Benefits	Expected Benefits				Source(s) of Water, if Applicable	Legal Authority Required	Disadvantaged Community?	Management Area	Estimated Costs		
										Primary		Secondary								
										Water Supply Augmentation	Water Demand Reduction	Water Quality Improvement	Water Management Flexibility / Efficiency					One-time Costs	Ongoing Costs (per year)	Potential Funding Source(s)
MA 1	Continued and Improved Groundwater Monitoring Program	Ongoing	YSGA Board Meetings & Website	N/A	YSGA, Member Agencies	Ongoing	Ongoing	Continuous	2022	N/A	N/A			N/A	N/A	Yes	Yolo Subbasin	TBD	TBD	TBD
MA 2	Continue coordination efforts with other management and monitoring entities	Ongoing	YSGA Board Meetings & Website	N/A	YSGA, Member Agencies	Ongoing	Ongoing	Continuous	2022	N/A	N/A			N/A	N/A	Yes	Yolo Subbasin	TBD	TBD	TBD
MA 3	Subsidence Monitoring Program	Ongoing	YSGA Board Meetings & Website	N/A	YSGA, Member Agencies	Ongoing	Ongoing	Continuous	Ongoing	N/A	N/A			N/A	N/A	Yes	Yolo Subbasin	TBD	TBD	TBD
MA 4	Preparedness through Increased Groundwater Recharge and Managed Aquifer Recharge Projects	Ongoing	YSGA Board Meetings & Website	Project Specific	YSGA, Member Agencies	Ongoing	Ongoing	Continuous	Ongoing	TBD	N/A		•	Project Dependent	Project Dependent	Yes	Yolo Subbasin	TBD	TBD	TBD
MA 5	Conjunctive Water Use Program	Ongoing	YSGA Board Meetings & Website	Project Specific	YSGA, Member Agencies	Ongoing	Ongoing	Continuous	Ongoing	N/A	TBD		•	Project Dependent	N/A	Yes	Yolo Subbasin	TBD	TBD	TBD
MA 6	Increased outreach and information sharing of groundwater resources and knowledge within the Yolo Subbasin.	Upon adoption of Yolo GSP	YSGA Board Meeting & Website	N/A	YSGA, Member Agencies	Ongoing	2022-2027	Continuous	Continuous	N/A	N/A		•	N/A	N/A	Yes	Yolo Subbasin	TBD	TBD	TBD
MA 7	Domestic Well Impact Mitigation Program	Upon adoption of Yolo GSP	YSGA Board Meeting & Website	Project Specific	YSGA, Member Agencies	Not yet started	2022-2027	2027	Drought period following project implementation	N/A	N/A			N/A	N/A	Yes	Yolo Subbasin	TBD	TBD	TBD
MA 8	Surface Water Monitoring Program	Ongoing	YSGA Board Meetings & Website	N/A	YSGA, Member Agencies	Ongoing	Ongoing	Continuous	Continuous	N/A	N/A			N/A	N/A	No	Yolo Subbasin	TBD	TBD	TBD
MA 9	Management Consideration of Grey Areas in the Yolo Subbasin	Upon adoption of Yolo GSP	YSGA Board Meeting & Website	N/A	YSGA	Not yet started	Upon adoption of the Yolo GSP	Continuous	Continuous	N/A	N/A			N/A	N/A	Yes	Yolo Subbasin	TBD	TBD	TBD
MA 10	Coordination Efforts with Land Use Planning Entities	Upon adoption of Yolo GSP	YSGA Board Meetings & Website	N/A	YSGA, Member Agencies	Not yet started	Upon adoption of the Yolo GSP	Continuous	Continuous	N/A	N/A			N/A	N/A	Yes	Yolo Subbasin	TBD	TBD	TBD
MA 11	Continued Investigation of subsurface geology and aquifer properties in the Yolo Subbasin	Upon adoption of Yolo GSP	YSGA Board Meetins & Website	N/A	YSGA	Not yet started	Upon adoption of the Yolo GSP	Continuous	Continuous	N/A	N/A			N/A	N/A	Yes	Yolo Subbasin	TBD	TBD	TBD
MA 12	Coordinated Response to Minimum Threshold Exceedances	Upon adoption of Yolo GSP	YSGA Board Meeting & Website	Site and Project Dependent	YSGA, Yolo County, Member Agencies	Not yet started	Upon adoption of the Yolo GSP	Continuous	Continuous	N/A	N/A			N/A	N/A	Yes	Yolo Subbasin	TBD	TBD	TBD
P 1	Identification of Locations Vulnerable to Damage from Subsidence - Catalog of Infrastructure Damage Reports	Upon completion of feasibility analysis.	YSGA Board Meetings & Website	N/A	YSGA, Member Agencies	Not yet started	2022	2027	Immediately following project completion	N/A	N/A			N/A	N/A	Yes	Yolo Subbasin	TBD	TBD	TBD
P 2	Groundwater Model Enhancement Program/YSGA Model Improvements	Upon adoption of Yolo GSP	YSGA Board Meetings & Website	N/A	YSGA, Member Agencies	Ongoing	Ongoing	Continuous	Immediately following project completion	N/A	N/A			N/A	N/A	Yes	Yolo Subbasin	TBD	TBD	TBD
P 3	Water Resources Information Database Project	Upon adoption of Yolo GSP	YSGA Board Meetings & Website	N/A	YSGA, Member Agencies	Ongoing	Ongoing	Continuous	Continuous	N/A	N/A			N/A	N/A	Yes	Yolo Subbasin	TBD	TBD	TBD
P 4	Topographic Mapping (LiDAR Project)	Upon adoption of Yolo GSP	YSGA Board Meetings & Website	N/A	YSGA	Not yet started	Upon adoption of the Yolo GSP	TBD	Immediately following project completion	N/A	N/A			N/A	N/A	Yes	Yolo Subbasin	TBD	TBD	YSGA/Yolo County

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										Primary		Secondary								
										Water Supply Augmentation	Water Demand Reduction	Water Quality Improvement	Water Management Flexibility / Efficiency					One-time Costs	Ongoing Costs (per year)	Potential Funding Source(s)
P 5	Additional monitoring wells along ephemeral streams, interconnected surface water bodies, and near GDEs.	Upon completion of feasibility and permitting requirements	YSGA Board Meeting & Website	Project Specific	YSGA, Member Agencies	Not yet started	2022-2027	Continuous	Immediately following project completion	N/A	N/A			N/A	N/A	No	Yolo Subbasin	TBD	TBD	TBD
P 6	Vegetative and aquatic surveys in related to groundwater dependent ecosystems	Upon completion of feasibility and permitting requirements	YSGA Board Meeting & Website	Project Specific	YSGA, Member Agencies	Not yet started	2022-2027	Continuous	Immediately following project completion	N/A	N/A			N/A	N/A	No	Yolo Subbasin	TBD	TBD	TBD
P 7	AEM Flights to improve subsurface geology data	Upon completion of feasibility analysis.	YSGA Board Meeting & Website	N/A	YSGA	Not yet started	TBD	TBD	Immediately following project completion	N/A	N/A			N/A	N/A	Yes	Yolo Subbasin	TBD	TBD	TBD
P 8	Abandoned Well Incentive Program	Upon completion of feasibility and permitting requirements	YSGA Board Meeting & Website	Project Specific	YSGA	Ongoing	Ongoing	Continuous	Continuous	N/A	N/A	●		N/A	N/A	Yes	Yolo Subbasin	TBD	TBD	TBD
P 9	Modernization Project: Integrated Precision Water Management	Ongoing	YSGA Board Meeting & Website	Project Specific	YCFCWCD	Ongoing	Ongoing	Continuous	Upon project completion	N/A	N/A		●	N/A	N/A	No	Yolo Subbasin	TBD	TBD	YCFCWCD
P 10	Exchanges between CVP or SWP system and Cache Creek System	Upon completion of feasibility and permitting requirements	YSGA Board Meeting & Website	Project Specific	YSGA	Not yet started	TBD	Continuous	Continuous	TBD	N/A		●	Sites Reservoir, CVP, and SWP	TBD	Yes	Yolo Subbasin	TBD	TBD	TBD
P 11	Flood Monitoring Network Project	Ongoing	YSGA Board Meeting & Website	N/A	YCFCWCD	Ongoing	Ongoing	Ongoing	Upon project completion	N/A	N/A			N/A	N/A	Yes	Yolo Subbasin	TBD	TBD	TBD
P 12	Yolo County Drains and Sloughs - Governance and Maintenance Study	Ongoing	YSGA Board Meeting & Website	N/A	Yolo County	Ongoing	Ongoing	Ongoing	Upon project completion	N/A	N/A			N/A	N/A	Yes	Yolo Subbasin	$150,000	TBD	TBD
P 13	Zamora area winter recharge from Cache Creek via China Slough	Upon completion of feasibility and permitting requirements	YSGA Board Meetings & Website	TBD	YCFCWCD	Not yet started	Dependent on feasibility analysis	TBD	Wet year following project completion	2,000 AF/year	N/A			Cache Creek	TBD	Yes	North Yolo	$1,172,160	TBD	ARP, DWR, SWRCB, YCFCWCD
P 14	Dunnigan Hills Winter Runoff Capture for Recharge	Upon completion of feasibility and permitting requirements	YSGA Board Meetings & Website	TBD	YCFCWCD	Not yet started	Dependent on feasibility analysis	TBD	Wet year following project completion	TBD	N/A			Dunnigan Hills runoff	TBD	Yes	North Yolo	TBD	TBD	TBD
P 15	Winter Diversions from Tehama-Colusa Canal	Upon completion of feasibility and permitting requirements	YSGA Board Meetings & Website	TBD	YCFCWCD	Not yet started	Dependent on feasibility analysis	TBD	Wet year following project completion	TBD	N/A			Tehama Colusa Canal	TBD	Yes	North Yolo	TBD	TBD	TBD
P 16	Bird Creek surface water storage	Upon completion of feasibility and permitting requirements	YSGA Board Meetings & Website	TBD	DWD/RD 108/YSGA	Not yet started	Dependent on feasibility analysis	TBD	After completion of project	160TAF Total Storage	N/A			Bird Creek, Dunnigan Hills watershed	TBD	Yes	North Yolo	TBD	TBD	TBD
P 17	Bird Creek, Oat Creek, Buckeye Creek , 2047 Canal groundwater recharge infrastructure improvements	Upon completion of feasibility and permitting requirements	YSGA Board Meetings & Website	TBD	DWD/RD 108/YSGA	Not yet started	Dependent on feasibility analysis	TBD	Wet year following project completion	TBD	N/A			Bird Creek, Oat Creek, Buckeye Creek	TBD	Yes	North Yolo	TBD	TBD	TBD
P 18	Hardwood Subdivision Recharge	Upon completion of feasibility and permitting requirements	YSGA Board Meetings & Website	TBD	DWD/RD 108/YSGA	Not yet started	Dependent on feasibility analysis	TBD	After completion of project	TBD	N/A			Local runoff	TBD	Yes	North Yolo	TBD	TBD	DOT, DWR, NRCS
P 19	Schaad Ranch/Buckeye Creek Recharge	Upon completion of feasibility and permitting requirements	YSGA Board Meetings & Website	TBD	DWD/RD 108/YSGA	Not yet started	Dependent on feasibility analysis	TBD	After completion of project	TBD	N/A			Buckeye Creek/	TBD	Yes	North Yolo	TBD	TBD	TBD

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										Primary		Secondary								
										Water Supply Augmentation	Water Demand Reduction	Water Quality Improvement	Water Management Flexibility / Efficiency					One-time Costs	Ongoing Costs (per year)	Potential Funding Source(s)
P 20	Trickle flow to ephemeral streams	Upon completion of feasibility and permitting requirements	YSGA Board Meetings & Website	TBD	RD 108	Not yet started	Upon completion of feasibility analysis	TBD	Wet year following project completion	TBD	N/A	•	•	Tehama Colusa Canal	TBD	Yes	North Yolo	~$8,000	$16 - $100 per Acre-foot	RD 108
P 21	Extension of Tehama Colusa Canal	Upon completion of feasibility and permitting requirements	YSGA Board Meetings & Website	TBD	YSGA, DWD, RD 108	Not yet started	Upon completion of feasibility and permitting requirements	TBD	Wet year following project completion	TBD	N/A		•	Tehama Colusa Canal	TBD	Yes	North Yolo	TBD	TBD	TBD
P 22	Conjunctive Use/groundwater recharge/surface water delivery extension to the area around Zamora (Placeholder for WGIM)	Upon completion of feasibility and permitting requirements	YSGA Board Meetings & Website	TBD	YSGA, DWD	Not yet started	Upon completion of feasibility and permitting requirements	TBD	Wet year following project completion	TBD	N/A		•	2047, 215, Sites Reservoir, excess winter flows	TBD	Yes	North Yolo	TBD	TBD	TBD
P 23	Additional Extensometers in North Yolo MA	Upon completion of feasibility and permitting requirements	YSGA Board Meetings & Website	TBD	DWD/RD 108/YSGA	Not yet started	Upon identification of funding sources.	TBD	After completion of project	N/A	N/A			N/A	TBD	Yes	North Yolo	~$1,000,000 per Extensometer	$20-40k per year	TBD
P 24	Add real time static level monitoring equipment to Washington Street well in Yolo	Ongoing	YSGA Board Meetings & Website	Completed	YCFCWCD/Cacheville CSD	Not yet started	Upon GSP Adoption	2023	2023	N/A	N/A			N/A	TBD	Yes	North Yolo	~ $3,500	$500	Yolo County, CSA
P 25	Add real time static level monitoring equipment to Ridgecut well in Knights Landing	Ongoing	YSGA Board Meetings & Website	Completed	YCFCWCD/KLCSD	Not yet started	Upon GSP Adoption	2023	2023	N/A	N/A			N/A	TBD	Yes	North Yolo	~ $3,500	$500	Yolo County, KLCSA
P 26	Sites West Sac. Valley Water Filtration System	Upon completion of feasibility and permitting requirements	YSGA Board Meetings & Website	TBD	YSGA	Not yet started	Upon completion of feasibility analysis	2030	2030	25,000 AF	N/A			Sites Reservoir	TBD	Yes	TBD	$400,000,000	TBD	Federal Infrastructure Funding
P 27	Springhorn Sutter Buttes and Willows Fault Arsenic and Saltwater Study	Upon completion of feasibility and permitting requirements	YSGA Board Meetings & Website	N/A	YSGA	Not yet started	Upon GSP Adoption	TBD	Immediately after completion	N/A	N/A	•		N/A	TBD	Yes	TBD	$1,000,000	TBD	DWR
P 28	Forbes Ranch Regulating Pond	Upon completion of feasibility and permitting requirements	YSGA Board Meetings and Website	TBD	YCFCWCD	Not yet started	TBD	TBD	Irrigation season after project completion	TBD	N/A			Cache Creek/stormwater	TBD	No	Central Yolo	$700,000	$50,000	YCFCWCD
P 29	West Adams Canal Renovation and China Slough Rehabilitation.	Upon completion of feasibility and permitting requirements	YSGA Board Meetings and Website	TBD	YCFCWCD	Not yet started	TBD	TBD	Wet year following project completion	TBD	10,000 AF average annual reduction in GW demand		•	Cache Creek via District Canals	TBD	No	Central Yolo	$15,671,929	Unknown	YCFCWCD
P 30	Diaz in-line reservoir	Upon completion of feasibility and permitting requirements	YSGA Board Meetings and Website	TBD	YCFCWCD	Not yet started	TBD	TBD	Irrigation season after project completion	TBD	N/A		•	Clover Canal	TBD	No	Central Yolo	TBD	TBD	TBD
P 31	Magnolia Canal Loss Reduction and Extension Project	Upon completion of feasibility and permitting requirements	YSGA Board Meetings and Website	TBD	YCFCWCD/Teichert	Undergoing pre-feasibility analysis	TBD	TBD	Irrigation season after project completion	200 - 800 AF	N/A		•	Magnolia Canal	TBD	No	Central Yolo	1.95 - 2.35 MM	TBD	Teichert
P 32	Demand Delivery on Yolo Central and Pleasant Prairie Canals	Upon completion of feasibility and permitting requirements	YSGA Board Meetings and Website	TBD	YCFCWCD	Undergoing pre-feasibility analysis	TBD	TBD	Irrigation season after project completion	TBD	N/A		•	Yolo Central and Pleasant Prarie	TBD	No	Central Yolo	TBD	TBD	TBD
P 33	North of Winters multi-use, stormwater, and water storage pond, 'Winters North Area Stormwater Pond'	Upon completion of feasibility and permitting requirements	YSGA Board Meetings and Website	TBD	YCFCWCD/City of Winters	Not yet started	TBD	TBD	Wet year following project completion	TBD	TBD	•	•	Cache Creek, Winters Canal	TBD	No	Central Yolo	TBD	TBD	TBD

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										Primary		Secondary								
										Water Supply Augmentation	Water Demand Reduction	Water Quality Improvement	Water Management Flexibility / Efficiency					One-time Costs	Ongoing Costs (per year)	Potential Funding Source(s)
P 34	West Winters Aquifer Storage and Recovery well field	Upon completion of feasibility and permitting requirements	YSGA Board Meetings and Website	TBD	City of Winters	Not yet started	TBD	TBD	TBD	TBD	TBD		●	Putah Creek	TBD	No	Central Yolo	TBD	TBD	TBD
P 35	Development of Surface Water Source for the City of Winters	Upon completion of feasibility and permitting requirements	YSGA Board Meetings and Website	TBD	City of Winters	Not yet started	TBD	TBD	TBD	TBD	TBD	●	●	Putah Creek	TBD	No	Central Yolo	TBD	TBD	TBD
P 36	City of Davis - Aquifer Storage and Recovery (ASR)	Ongoing	YSGA Board Meetings and Website	TBD	City of Davis	Pilot testing underway	Ongoing	Ongoing	Ongoing	TBD	N/A		●	Sac River	TBD	Yes	Central Yolo	TBD	TBD	TBD
P 37	Upstream Flow Management to Prevent Madison Flooding and to Facilitate GW Recharge	Upon completion of feasibility and permitting requirements	YSGA Board Meetings and Website	TBD	YCFCWCD/Madison CSD	Not yet started	TBD	TBD	Wet year following project completion	TBD	N/A	●		Lamb Valley, Cottonwood, S. Fork Willow Slough	TBD	No	Central Yolo	TBD	TBD	TBD
P 38	Madison Farmer Field Stormwater Capture and Groundwater Recharge	Upon completion of feasibility and permitting requirements	YSGA Board Meetings and Website	TBD	Madison CSD	Undergoing pre-feasibility analysis	TBD	TBD	Wet year following project completion	TBD	N/A			Runoff	TBD	No	Central Yolo	$100,000 - $400,000	TBD	TBD
P 39	City of Davis -Site Survey for Hardscape Conversion to Pervious Pavement	Upon completion of feasibility and permitting requirements	YSGA Board Meetings and Website	TBD	Davis	Not yet started	TBD	TBD	Immediately after completion	TBD	N/A			Precipitation	TBD	Yes	Central Yolo	$40,000	$0	City of Davis
P 40	City of Davis - West Area Pond Redesign	Upon completion of feasibility and permitting requirements	YSGA Board Meetings and Website	TBD	Davis	Not yet started	TBD	TBD	Immediately after completion	TBD	N/A			Precipitation	TBD	Yes	Central Yolo	$100,000	TBD	City of Davis
P 41	Sac River Water to Davis/Woodland	Ongoing	YSGA Board Meetings and Website	TBD	City of Davis, City of Woodland	Implemented	Effects being studied	Ongoing	Ongoing	40,000 AF/year	N/A			Sac River	TBD	Yes	Central Yolo	Funding Secured	Funding Secured	Funding secured
P 42	City of Woodland - Well 31 ASR Project	Ongoing	YSGA Board Meetings and Website	Completed	City of Woodland	Pre-design	Ongoing	2027	Ongoing	2,000 gpm during injection	N/A			Treated surface water	TBD	Yes	Central Yolo	$6,250,000	TBD	City of Woodland
P 43	City of DavisLeak Detection Survey	Ongoing	YSGA Board Meetings and Website	TBD	City of Davis	Options Being Explored	Ongoing	Ongoing	Ongoing	N/A	N/A	●		N/A	N/A	Yes	Central Yolo	$150,000	TBD	TBD
P 44	Woodland Recycled Water Utility Expansion Project (Phase II)	Ongoing	YSGA Board Meetings and Website, City of Woodland Website	TBD	City of Woodland	Ongoing	Ongoing	TBD	Immediately after completion	110 acre-feet/year	N/A			WPCF effluent	TBD	Yes	Central Yolo	$2,500,000	TBD	TBD
P 45	Woodland Recycled Water Utility Expansion Project (Phase III)	Ongoing	City of Woodland Website	TBD	City of Woodland	Ongoing	Ongoing	TBD	Immediately after completion	70 acre-feet/year	N/A			WPCF effluent	TBD	Yes	Central Yolo	$925,000	TBD	TBD
P 46	City of Davis -Recycled Water Pump Station	Ongoing	City of Davis Website	TBD	City of Davis	Construction planned for Fall 2021 or early 2022	2022	2022	2023 - future	TBD	TBD		●	City of Davis Wastewater Treatment Plant	TBD	Yes	Central Yolo	$1,800,000	TBD	TBD
P 47	YCFCWCD Winter Recharge	Upon completion of feasibility and permitting requirements	YCFCWCD Board Meetings and Website	TBD	YCFCWCD	Ongoing	Ongoing	Ongoing	Wet year following project completion	0-30,000 AF/year	N/A		●	Cache Creek System	TBD	Yes	Central Yolo	$3,000,000	TBD	YCFCWCD

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										Primary		Secondary								
										Water Supply Augmentation	Water Demand Reduction	Water Quality Improvement	Water Management Flexibility / Efficiency					One-time Costs	Ongoing Costs (per year)	Potential Funding Source(s)
P 48	City of Winters Recycled Water Utilization	Ongoing	City of Winters	Completed	City of Winters	Ongoing	Ongoing	Ongoing	Currently Accruing	250 AF/year	N/A			City of Winters WWTF	N/A	No	Central Yolo	Funding Secured	Funding Secured	Funding secured
P 49	Citrona Ditch Pressurization Project	Upon completion of feasibility and permitting requirements	YSGA Board Meetings and Website	TBD	YCFCWCD	Not yet started	TBD	TBD	Irrigation season after project completion	TBD	N/A		●	Citrona Ditch	TBD	No	Central Yolo	TBD	TBD	TBD
P 50	RD 2035 - Groundwater Studies	Upon adoption of Yolo GSP	YSGA Board Meetings and Website	TBD	RD 2035	Ongoing	Ongoing	Ongoing	Immediately after completion	N/A	N/A			N/A	N/A	No	Central Yolo	TBD	TBD	TBD
P 51	RD 2035 - Floodway Corridor Project	Upon adoption of Yolo GSP	YSGA Board Meetings and Website	TBD	RD 2035	Not yet started	Upon adoption of Yolo GSP	TBD	Immediately after completion	N/A	N/A			N/A	N/A	No	Central Yolo	TBD	TBD	TBD
P 52	RD 2035 - Conjunctive Use Study	Upon adoption of Yolo GSP	YSGA Board Meetings and Website	TBD	RD 2035	Not yet started	Upon adoption of Yolo GSP	TBD	Immediately after completion	N/A	N/A			N/A	N/A	No	Central Yolo	TBD	TBD	TBD
P 53	Water Hexavalent Chromium (Cr6) Compliance Project	Ongoing	YSGA Board Meetings and Website	TBD	City of Winters	Ongoing	Ongoing	Ongoing	Ongoing	N/A	N/A	●		Groundwater, Putah Creek	TBD	No	Central Yolo	$6 - 8,000,000	TBD	TBD
P 54	UC Davis Arboretum Waterway Wetland Restoration and Enhancement	Ongoing	YSGA Board Meetings and Website	TBD	UC Davis	Ongoing	Ongoing	Ongoing	Ongoing	N/A	N/A	●		Stormwater Discharge	TBD	Yes	Central Yolo	$4,000,000	TBD	TBD
P 55	City of Woodland - North Regional Pond and Pump Station	Ongoing	YSGA Board Meetings and Website	TBD	Woodland	Completed	Completed	2022	Wet season after completion	N/A	N/A			South Canal and Gibson Channel	TBD	Yes	Central Yolo	$8,000,000	$100,000	Funding secured
P 56	Improved hydrologic flows, increased runoff retention, and improved watershed health in the Capay Valley	Upon adoption of Yolo GSP	YSGA Board Meeting & Website	TBD	Capay Valley Vision	Not yet started	Upon adoption of GSP	End 2022	2022-2040	Up to 50% increase in precip retention	N/A		●	Cache Creek/Precipitation	TBD	No	Capay Valley	$25,000 - $50,000, $50,000/mile on tributaries	TBD	NRCS EQIP funds, CalFire
P 57	Enhanced water infiltration via grazing management and crop production practices in the Capay Valley	Upon adoption of Yolo GSP	YSGA Board Meeting & Website	TBD	Capay Valley Regeneration	Not yet started	2022	2026-2040	2027-2040	20,000 gallons/acre	TBD		●	Precipitation	TBD	No	Capay Valley	TBD	TBD	CA Healthy Soils funding
P 58	Oak woodland, riparian, and chaparral restoration in the Capay Valley	Upon adoption of Yolo GSP	YSGA Board Meeting & Website	TBD	Capay Valley Vision with Cache Creek Conservancy	Not yet started	2022	2027-2040	2028-2040	TBD	N/A	●		N/A	TBD	No	Capay Valley	TBD	TBD	TBD
P 59	Establish an equipment and knowledge hub in the Capay Valley	Upon adoption of Yolo GSP	YSGA Board Meeting & Website	N/A	Capay Valley Regeneration	Not yet started	Upon adoption of GSP	Ongoing	Ongoing	TBD	N/A	●	●	N/A	N/A	No	Capay Valley	TBD	TBD	TBD
P 60	Rumsey and Guinda Ditch Winter Recharge	Upon completion of feasibility and permitting requirements	YSGA Board Meeting & Website	TBD	YCFCWCD	Not yet started	Dependent on feasibility analysis	TBD	Wet year following project completion	2,000 AF/year	N/A			Cache Creek	TBD	No	Capay Valley	TBD	TBD	YCFCWCD
P 61	Guinda Ditch summer irrigation and pipelines from Cache Creek to other side of HWY 16	Upon completion of feasibility and permitting requirements	YSGA Board Meeting & Website	TBD	YCFCWCD	Not yet started	Dependent on feasibility analysis	TBD	Wet year following project completion	2,000 AF/year	N/A			Cache Creek	TBD	No	Capay Valley	TBD	TBD	YCFCWCD
P 62	Yocha Dehe Wintun Nation - expansion of Surface Water Diversion	Upon completion of feasibility and permitting requirements	YSGA Board Meetings and Website	TBD	Yocha Dehe Wintun Nation, YCFCWCD	Undergoing pre-feasibility analysis	TBD	TBD	Irrigation season after project completion	TBD	TBD		●	Cache Creek	TBD	No	Capay Valley	TBD	TBD	TBD
P 63	Improve Subsidence data collection and analysis in the Capay Valley management area	Upon completion of feasibility and permitting requirements	YSGA Board Meeting & Website	TBD	YSGA	Not yet started	Upon adoption of GSP	Ongoing	Ongoing	N/A	N/A			N/A	N/A	No	Capay Valley	TBD	TBD	TBD
P 64	Incorporation of Capay IGSM into the YSGA Model	Upon completion of feasibility, securement of funds, and cost-benefit analysis.	YSGA Board Meeting & Website	N/A	YSGA	Not yet started	2022-2027	2027	2027-Future	N/A	N/A			N/A	N/A	No	Capay Valley	TBD	TBD	TBD

Project/MA Number	MA Name	Cirumstance for Implementation	Public Noticing Process	Permitting and Regulatory Process Requirements	Implementing YSGA Member Agency	Status	Timetable / Circumstances for Initiation	Timetable for Completion	Timetable for Accural of Expected Benefits	Expected Benefits				Source(s) of Water, if Applicable	Legal Authority Required	Disadvantaged Community?	Management Area	Estimated Costs		
										Primary		Secondary								
										Water Supply Augmentation	Water Demand Reduction	Water Quality Improvement	Water Management Flexibility / Efficiency					One-time Costs	Ongoing Costs (per year)	Potential Funding Source(s)
P 65	Yolo Bypass Conservation Projects	Upon completion of feasibility and permitting requirements	Yolo GSA Board Meetings & Website	TBD	Yolo County	Ongoing	Ongoing	Ongoing	Ongoing	TBD	TBD			N/A	TBD	No	South Yolo	TBD	TBD	TBD
P 66	Revisions to the YSGA Model for Urban Groundwater usage in the South Yolo MA	Upon completion of feasibility and permitting requirements	Yolo GSA Board Meetings & Website	TBD	YSGA	Not Yet Started	2022	2022-2027	After project completion	N/A	N/A			N/A	N/A	No	South Yolo	TBD	TBD	TBD
P 67	Methylmercury Impacts analyses for the Yolo Bypass	Upon completion of feasibility and permitting requirements	Yolo GSA Board Meetings & Website	TBD	Yolo County	Undergoing pre-feasibility analysis	Dependent on feasibility analysis	Ongoing	After Completion of Analyses	N/A	N/A	•		N/A	N/A	No	South Yolo	$100,000	TBD	Yolo County
P 68	West Sacramento Aquifer Storage and Recovery	Upon completion of feasibility and permitting requirements	Yolo GSA Board Meetings & Website; City Council process	CEQA	City of West Sacramento	Undergoing pre-feasibility analysis	2021	2024	2024	500-1000 AFY	N/A	•	•	City of West Sacramento CVP Contract	West Sac and USBR	Yes	South Yolo	TBD	TBD	West Sac, State, and USBR
P 69	West Sacramento and City of Sacramento Intertie	Upon completion of feasibility and permitting requirements	Yolo GSA Board Meetings & Website; City Council process	CEQA	City of West Sacramento	Undergoing pre-feasibility analysis	2021	2024	2024	500-5000 AFY	N/A		•	City of Sacramento Water Assets	West Sac, City of Sac, USBR	Yes	South Yolo	TBD	TBD	West Sac, State, and USBR
P 70	Dry well groundwater recharge on California Olive Ranch	Upon completion of feasibility and permitting requirements	Yolo GSA Board Meetings & Website	TBD	Water and Land Solutions LLC/California Olive Ranch	Not yet started	TBD	TBD	Wet year following project completion	TBD	N/A			TBD	N/A	Yes	Dunnigan Hills	TBD	TBD	TBD
P 71	Projects to improve understanding of surface water/groundwater interaction around Oat Creek and Buckeye Creek/others in Dunnigan/North Yolo areas.	Upon completion of feasibility and permitting requirements	Yolo GSA Board Meetings & Website	TBD	YSGA	Not yet started	Upon adoption of GSP	TBD	Continuous	N/A	N/A			N/A	N/A	Yes	Dunnigan Hills	TBD	TBD	TBD
P 72	Additional groundwater monitoring wells in the Dunnigan Hills MA	Upon completion of feasibility and permitting requirements	Yolo GSA Board Meetings & Website	TBD	YSGA	Not yet started	Upon adoption of GSP	TBD	Continuous	N/A	N/A			N/A	N/A	Yes	Dunnigan Hills	TBD	TBD	TBD
P 73	O'Halloran off-stream reservoir site	Upon completion of feasibility and permitting requirements	Yolo GSA Board Meetings & Website	TBD	YCFCWCD	Not yet started	Upon adoption of GSP	TBD	Wet year following project completion	N/A	N/A			Cache Creek System	TBD	Yes	Dunnigan Hills	TBD	TBD	TBD
P 74	Additional groundwater monitoring wells in the Clarksburg MA	Upon adoption of Yolo GSP	Yolo GSA Board Meetings & Website	TBD	YSGA	Not yet started	2022	Continuous	Ongoing	N/A	N/A			N/A	N/A	No	Clarksburg	TBD	TBD	TBD
P 75	Reclamation District 999 - Elk Slough Groundwater Quality Improvement and Flood Protection Project	Upon completion of feasibility and permitting requirements	Yolo GSA Board Meetings & Website	TBD	RD 999	Undergoing pre-feasibility analysis	Upon adoption of GSP	TBD	Following project completion	N/A	N/A	•		Elk Slough	TBD	No	Clarksburg	TBD	TBD	TBD