

## **DWR staff review of R9 Ranch pumping and water levels**

Sam Perkins, KDA-DWR, March 26, 2019

To assist in the Chief Engineer's review of the public comment received related to the Hays R9 Ranch change applications, KDA-DWR staff assessed select data provided via the process, including the review and analysis of local groundwater level data and GMD 5 model output. Documentation of the requested work and results are summarized here.

### **Outline:**

- 1) Reported and projected groundwater pumping on the R9 Ranch (Figs. 1-2);
- 2) KGS Wizard water level measurement data including sites analyzed by KBE (6/21/2018)
- 3) Computed GMD 5 model historical and projected water level data
- 4) Comparison of computed GMD 5 model and measured water levels (Figs. 3-6);
- 5) Year-end computed GMD 5 model water levels averaged over R9 and subareas (Figs. 7-15);
- 6) Monthly computed GMD 5 model water levels at specified locations 1991-2041 (Figs. 16-23).

### **References**

### **Maps, Tables and Figures**

Map 1: R9 Ranch boundary and surrounding townships, KGS Wizard water level measurement sites, Hays observation and proposed PWS well sites, and PLSS section and groundwater model cell centers (nodes). Map identifies locations selected for plotting computed water level time series (Hays wells OW-XX and nodes A1-A8 and B1-B4 to south and west of R9 near areas designated "a" and "b" on map), and selected KGS Wizard sites in Keller-Bliesner's Table 1 and in Table 1 below. Four townships shown in Map 1 are 25S 19W ("NE"), 25S 20W ("NW"), 26S 19W ("SE") and 26S 20W ("SW"). For georeferencing, model grid projection is Kansas State Plane South NAD 1983 ft; sw corner grid origin (x0,y0) = (595870, 1568450) ft,  $\Delta X = \Delta Y = 2640$  ft, (nrow, ncol) = (180, 335).

Map 1a: close-up version of Map 1 to distinguish features within R9.

### **Tables**

- 1: Key to selected KGS Wizard sites in Keller-Bliesner Table 1 and in BMCD response to KBE.
- 2: Projected slopes and changes in computed water levels 1990-2041 for base and 4800 af cases.

### **Figures**

- 1a: Plot reported pumping and irrigated area for R9 Ranch.
- 1b: Plot reported pumping for R9 Ranch subareas within NE, SE and SW sectors by township.
- 2: Plot modeled R9 Ranch pumping for base, 4800-af and drought scenarios.
- 3: Plot measured and computed water levels for Wizard site 659 within the R9 Ranch.
- 4-6: Compare KGS Wizard measured water levels 1990-2018 with average over computed water levels at sites for townships in Map 1: NE, 25S 19W (4), SE, 26S 19W (5) and NW, 25S 20W (6).
- 7: Plot computed heads averaged over R9 for three future scenarios 1960-2041.
- 8-11: Plot computed heads averaged over R9 and R9 subareas within townships for each scenario:
  - 8: historical base case 1940-2007; 9: base case scenario 1960-2041; 10: 4800 af scenario 1960-2041;
  - 11: drought (OpsD) scenario 1960-2041.
- 12-15: Plot computed heads averaged over subareas a (SE) and b (SW) near R9 (see map).
  - 12: historical base case 1940-2007; 13: base case scenario 1960-2041; 14: 4800 af scenario 1960-2041; 15: drought (OpsD) scenario 1960-2041.

16-23: Plot computed heads 1991-2041 for base, 4800 af and drought scenarios at locations identified on Map 1.

16-19: Hays OW-11, OW-12, OW-2 and OW-30; 20-21: locs. A3 and A4; 22-23: locs. B1 and B2.

## **DWR staff review of R9 Ranch pumping and water levels**

### **1. Reported and projected groundwater pumping on the R9 Ranch (Figs. 1-2)**

Total reported groundwater pumping and irrigated area for R9 over years 1991-2017 are summarized in Figs. 1a and 1b, based on queries of the KDA-DWR Water Rights Information System (WRIS). Fig. 1a plots total reported pumping and irrigated area for R9. Fig. 1b plots the total pumping in R9 partitioned into three subareas corresponding to townships 25S 19W (northeast), 26S 19W (southeast) and 26S 20W (northwest). Modeled R9 total pumping for the three BMcD 51-year scenarios (base, 4800 af and drought) are plotted in Fig. 2, below and in Fig. 7 of the BMcD (2018) report.

### **2. KGS Wizard water level measurement data including sites analyzed by KBE (6/21/2018)**

KDA-DWR queried water level measurements within Groundwater Management District 5 (GMD 5) from the Kansas Geological Survey (KGS) Wizard database. The query returned water level measurements and site data for 681 sites for years 1990-2018. Water levels were summarized in Excel with a pivot table for the beginning of each calendar year based on a range of measurement dates from December of the previous year through March of the subsequent year, a range consistent with selection criteria used at KGS to track annual water level changes (personal communication with Brownie Wilson). Wizard measurement sites in or near the R9 Ranch are shown in Map 1, and are labeled by the query index numbers 1-681, each of which corresponds to a USGS-ID number. Those corresponding to sites analyzed in the Keller-Bliesner (KBE) report are identified in Map 1 as a highlighted selection (light blue dots).

Table 1 lists the KBE well set, with two at the bottom that BMcD noted were not in the KBE set. Column c (id.map) lists the Wizard query index numbers for these selected sites; column d (id.kbe) lists the identifying numbers 1-10 used in the KBE presentation; and column e lists figure numbers in this document that plot corresponding water level time series.

The Hays water level measurements for 2014-2018 have been described previously in reports from BMcD and are not reviewed here.

### **3. Computed GMD 5 model historical and projected water level data**

A postprocessor and variants were used to extract computed water level time series from model runs including both single-layer and original multilayer versions of the historical base case for 1940-2007 and future scenarios developed by BMcD. The multilayer historical base case was re-run with a modified output control file in order to write to file the model run's computed heads for the top layer at the end of each time step (three per stress period), consistent with the 1-layer model output for comparison. Computed heads from the BMcD scenarios were written at the end of each stress period.

Postprocessors wrote computed heads to text files in two forms: (a) computed heads at the end of each year (columns) for each model node (rows); and (b) computed heads (rows) at the end of each time step (historical model 1940-2007) or stress period (51-year scenarios 1991-2041) at 27 specified locations (columns), using a format based on the Modhyd package to specify hydrographs. Text files written by postprocessors were imported into Excel files for analysis and plotting. The first form (a), i.e. computed heads at the end of each year, are plotted in Figs. 3-15, either as computed heads for an individual cell in the case of Fig. 3 for comparison with measured water levels at a Wizard site, or as

averages over a selection of cells corresponding to Wizard sites (Figs. 4-15). The second form (b), i.e. computed heads at the end of every time step or stress period, are plotted in Figs. 16-23 for specified cells corresponding to Hays observation well locations and selected locations south of R9 (A1-A8) and west of R9 (B1-B4).

#### **4. Comparison of computed GMD 5 model and measured water levels (Figs. 3-6)**

Very few sites from the KGS Wizard database contain sufficient measurements to allow comparing computed and observed water level trends within or near R9. Figs. 3-6 plot water level time series for Wizard sites within three townships enclosing the R9 Ranch: 25S 19W (northeast, Figs. 3 and 4), 26S 19W (southeast, Fig. 5) and 25S 20W (northwest, Fig.6). A graph is not shown for the southwest township 26S 20W, which contains only one Wizard site, 202, several miles from R9 (see Map 1), and which was plotted by KBE as site #1 (see Table 1).

Fig. 3 plots water level time series for KGS Wizard sites 373, 502 and 659 in R9 and shown on Map 1. Year-end computed water levels for the cell containing site 659 agree well with available measurements 1992-2007. Fig. 3 suggests water levels are stable in the northeast part of R9 for the period 1991-2018.

Figs. 4-6 superimpose plots of measured water levels at Wizard sites and a spatial average taken over computed water levels at cells containing the measurement sites for three townships. In all of these, trends in the average computed water levels appear to agree with trends at the measured WL sites.

Fig. 4 plots measured water levels for all KGS Wizard sites in the northeast township 25S 19W, including those shown in Fig. 3 within R9, and also plots the average over computed year-end water levels for the cells corresponding to the measurement sites. Wizard sites outside R9 (15, 38 and 652) are all several miles from R9 in areas near active irrigation wells that likely explain downward water level trends unrelated to pumping within R9.

In the southeast township 26S 19W, Fig. 5 plots measured water levels with a roughly 16-ft decline at Wizard site 371 from 1990-2018, smaller declines at other sites, and agreement in trend of computed water levels averaged over the sites.

In the northwest township 25S 20W, Fig. 6 shows a roughly 7-ft water level decline for 1990-2018 at site 613, and roughly stable water levels at sites 618 and 69.

Computed water levels and trends in Figs. 3-6 show reasonably good agreement with available site data.

#### **5. Year-end computed GMD 5 model water levels averaged over R9 and subareas (Figs. 7-15)**

Figs. 7-15 characterize computed water level trends for R9, for R9 subareas within three townships, and for subareas a and b to the southeast and west of R9 (see map). Figs. 7-10 plot water level time series for R9 and subareas within townships, and Figs. 11-15 plot water levels for subareas a and b. Fig. 7 and 11 plot computed water levels based on historical model runs for 1940-2007, and the remaining figures 8-10 and 12-15 plot computed water levels for historical years 1960-1990 and for base case, 4800 af and drought scenarios by BMCD for years 1991-2041. Linear trends based on years 1990-2041

for the base case and 4800 af scenarios are summarized in Table 2, which lists rates of WL change (ft/yr) for R9 and subareas. Descriptions of Figs. 7-15 follow.

Fig. 7 plots computed water levels averaged over R9, an area represented by 38 model cells, for the historical base case years 1940-1990 and projections for the base, 4800 af, and drought cases. From the trend line for the base case over years 1960-2041, projected water levels show a decline of 0.142 ft/yr. The 4800 af scenario shows little difference from the base case, and the drought case shows an additional 5 ft of projected decline in 2029.

Fig. 8 compares plots of year-end computed water levels averaged over R9 with averages over northeast, southeast and southwest sectors within R9 for the historical simulation period 1940-2007. Water levels are stable into the 1970's, followed by declines through 2007. The decline rate is smallest in the southwest sector, followed by larger decline rates in the northeast and southeast sectors.

Figs. 9-11 are similar to Fig. 8, comparing year-end computed heads averaged over R9 and R9 sectors, but for historical years 1960-1990 and projections 1991-2041 for the base case (Fig. 9), 4800 af (Fig. 10) and drought (Fig. 11) scenarios.

Fig. 12-15 are analogous to Figs. 7-11, comparing computed year-end water levels averaged over eight model cells each for subareas a (south of R9 in 26S 19W) and b (west of R9 in 26S 20W). Fig. 12 plots the water levels for subareas a and b for the historical simulation period 1940-2007. Figs 13-15 plot the corresponding water levels for 1960-1990 years of historical simulation and projected years 1991-2041 for the base case (Fig. 13), 4800 af (Fig. 14) and drought (Fig. 15) scenarios.

## **6. Monthly computed GMD 5 model water levels at specified locations 1991-2041 (Figs. 16-23)**

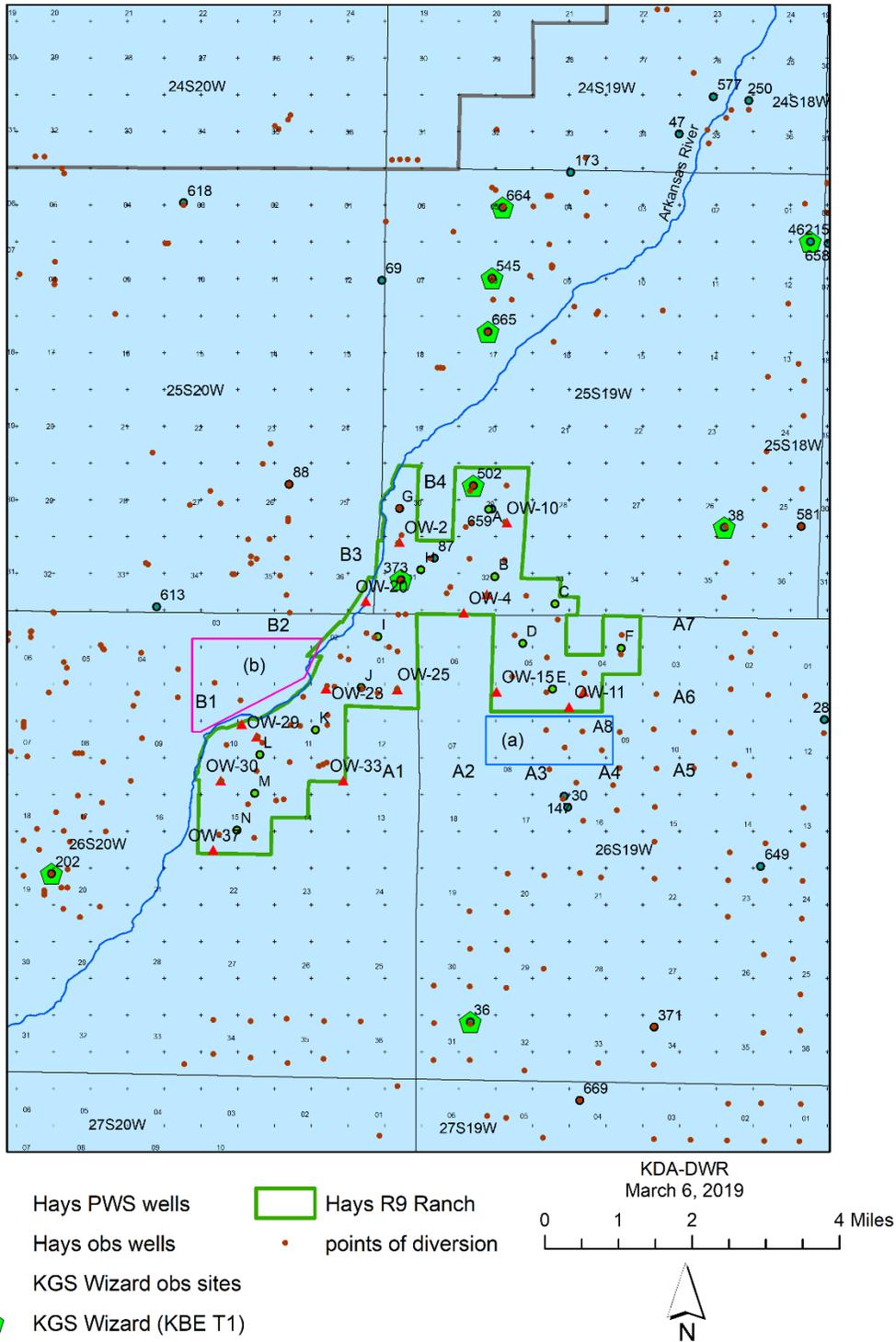
Figs. 16-23 are plots of computed heads at a specified model grid cell at the end of each stress period for years 1991-2041, comparing the base, 4800 af, and drought scenarios. The specified locations are for Hays observation wells (OW) and sites in or near subareas a and b, labeled A1-A8 and B1-B4 on Map 1. The plots include linear trends over years 1991-2041 for the base and 4800 af scenarios to assess differences in water levels between the two scenarios at specified locations. Figs. 16-18 correspond to Hays observation well locations 11, 12, 2 and 30. Figs. 19-23 correspond to locations near but to the south of R9 at A3 and A4, and to the west of R9 at B1 and B2. Most of these figures show small mean projected water level differences and nearly parallel trends between the 4800 af and base cases for the sites examined. For Hays Observation Well 12, Fig. 17 shows projected water levels for the 4800 af scenario to be nearly 1 ft below the base case scenario. For OW-13, Fig. 18 shows water levels for the 4800 af case to be nearly 2 ft below the base case scenario.

## **References**

KBE (6/21/2018): Keller, Andrew, Keller-Bliesner Engineering, 2018. Water Level Trends & Consumptive Use on the R9 Ranch. Hays-DWR public meeting June 21, Greensburg, KS.  
[https://agriculture.ks.gov/docs/default-source/dwr-water-appropriation-documents/hays-dwr-public-meeting-june-21--kb-for-waterpack-audiofinal.pdf?sfvrsn=14e086c1\\_0](https://agriculture.ks.gov/docs/default-source/dwr-water-appropriation-documents/hays-dwr-public-meeting-june-21--kb-for-waterpack-audiofinal.pdf?sfvrsn=14e086c1_0)

BMcD (8/21/2018: Burns & McDonnell Engineers, 2018. Review of Water Pack and Keller-Bliesner Engineering R9 Ranch Reports. [https://agriculture.ks.gov/docs/default-source/dwr-water-appropriation-documents/haysr9\\_bmcd\\_kbe\\_response\\_20180806.pdf?sfvrsn=f92587c1\\_0](https://agriculture.ks.gov/docs/default-source/dwr-water-appropriation-documents/haysr9_bmcd_kbe_response_20180806.pdf?sfvrsn=f92587c1_0)

Hays observation and proposed PWS wells on R9  
with Wizard sites and KBE Table 1 subset (pentagons)



Map 1. Hays observation wells, KGS Wizard sites and subset in Keller-Bliesner Table 1 (T. 1 below).



Table 1. A version of KBE Table 1 with correspondence to KGS Wizard sites in Map 1 (id.map, col. c), site identifiers 1-10 in KBE presentation (id.kbe, col. d) and hydrograph Figures 10-12, below. selected KGS Wizard sites in Map 1 appear in the KBE presentation. Sites listed in **bold** type are on the R9 Ranch. Wizard sites 373, 502 and 659 lie within the R9 Ranch are in the northeast township 25S 19W; Wizard site 659 is not in Keller Table 1. (\*) Wizard sites 613 and 618 are identified in Fig. 2 of BMcD Response as sites whose hydrographs are not shown in the KBE analysis.

a	b	c	d	e	f	g	h	i
USGS_ID	match	id.map	id.kbe	figure	quad	TSP	RNG	Section
374558099321601	165	202	1		SW	26S	20W	20BBC
374428099260501	152	36	3	11	SE	26S	19W	31AAC
374427099232901	151	371		11	SE	26S	19W	34BBD
374658099244302	176	147		11	SE	26S	19W	16BCB
374935099304801	218	613	*	12	NW	25S	20W	34CCC
<b>374954099270701</b>	<b>224</b>	<b>373</b>	<b>4</b>	<b>10</b>	<b>NE</b>	<b>25S</b>	<b>19W</b>	<b>31CAB</b>
<b>375106099261801</b>	<b>243</b>	<b>502</b>	<b>5</b>	<b>10</b>	<b>NE</b>	<b>25S</b>	<b>19W</b>	<b>29B</b>
375032099222001	232	38	6	10	NE	25S	19W	26DDB
375250099260101	269	665	7	10	NE	25S	19W	17BAD
375329099260101	274	545	8	10	NE	25S	19W	08BDD
375406099303401	288	618	*	12	NW	25S	20W	03BCD
375421099254401	293	664	9			25S	19W	05ACC
375357099211201	285	15	10	10	NE	25S	19W	01DDC
374434099343001	0	0				26S	21W	25CCC
374322099243401	124	669				27S	19W	04BCD
374225099275001	115	73	2			27S	20W	12BCD
Sites not in KBE set:								
<b>375055099255301</b>	<b>237</b>	<b>659</b>			<b>NE</b>	<b>25S</b>	<b>19W</b>	
375326099273801	272	69			NW	25S	20W	

Table 2. Rates of water level changes (ft/yr) and water level changes over years 1991-2041, based on computed water levels averaged over R9, R9 subareas by township and nearby subareas a and b identified on map.

area	township	no. cells	Rate of change (ft/yr)		51-yr change (ft)	
			base case	4800 af	base	4800 af
R9		38	-0.0972	-0.1016	-5.0	-5.2
R9.se	26S 19W	6	-0.1948	-0.2002	-9.9	-10.2
R9.ne	25S 19W	16	-0.1032	-0.1066	-5.3	-5.4
R9.sw	26S 20W	16	-0.0546	-0.0597	-2.8	-3.0
a	26S 19W	8	-0.2238	-0.2279	-11.4	-11.6
b	26S 20W	8	-0.0277	-0.0312	-1.4	-1.6

Fig. 1a. Reported pumping and irrigated area for R9 Ranch 1991-2017 (acre-ft/yr).

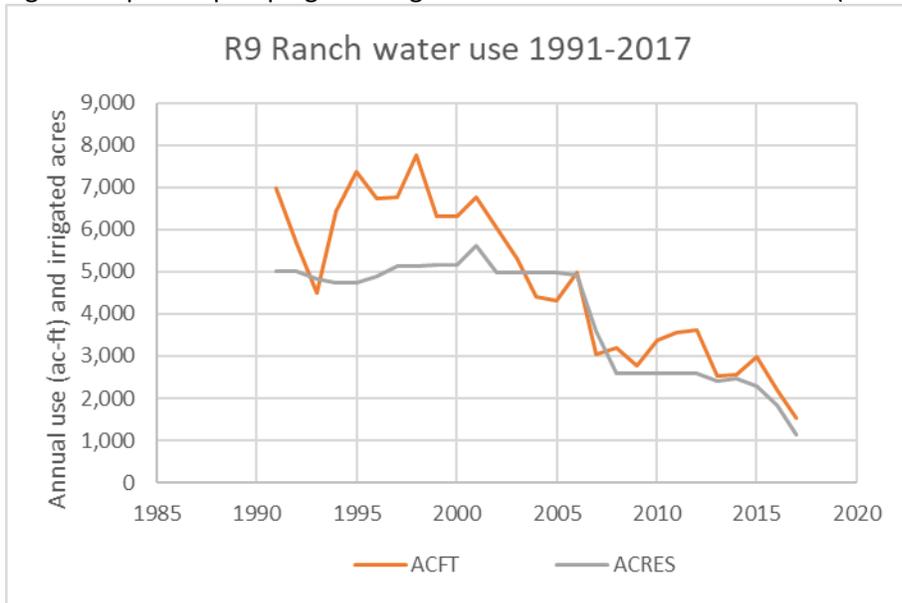


Fig. 1b. Reported pumping from R9 Ranch by township 1991-2017.

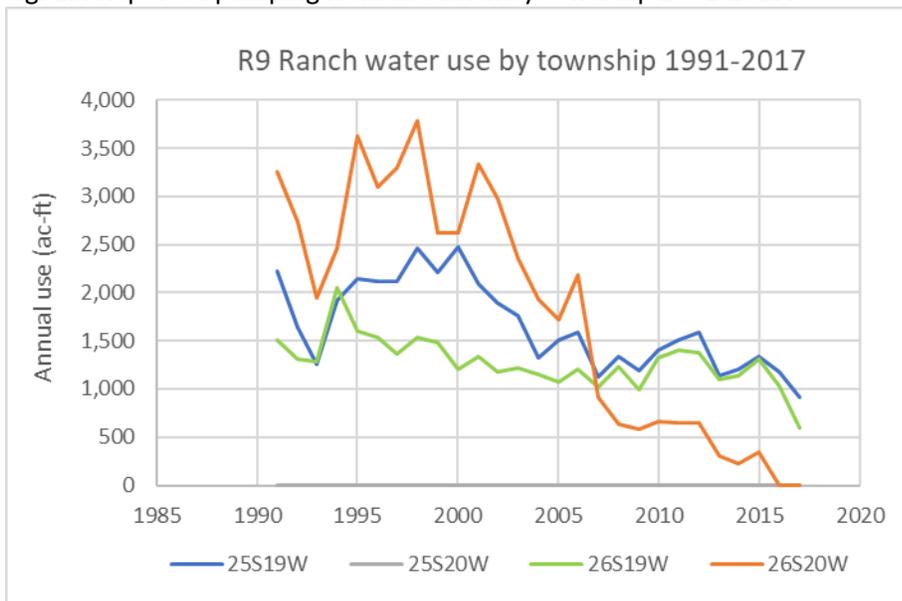


Fig. 2. Modeled pumping from R9 Ranch 1991-2041 for base, 4800-af and drought (OpsD) scenarios (acre-ft/yr).

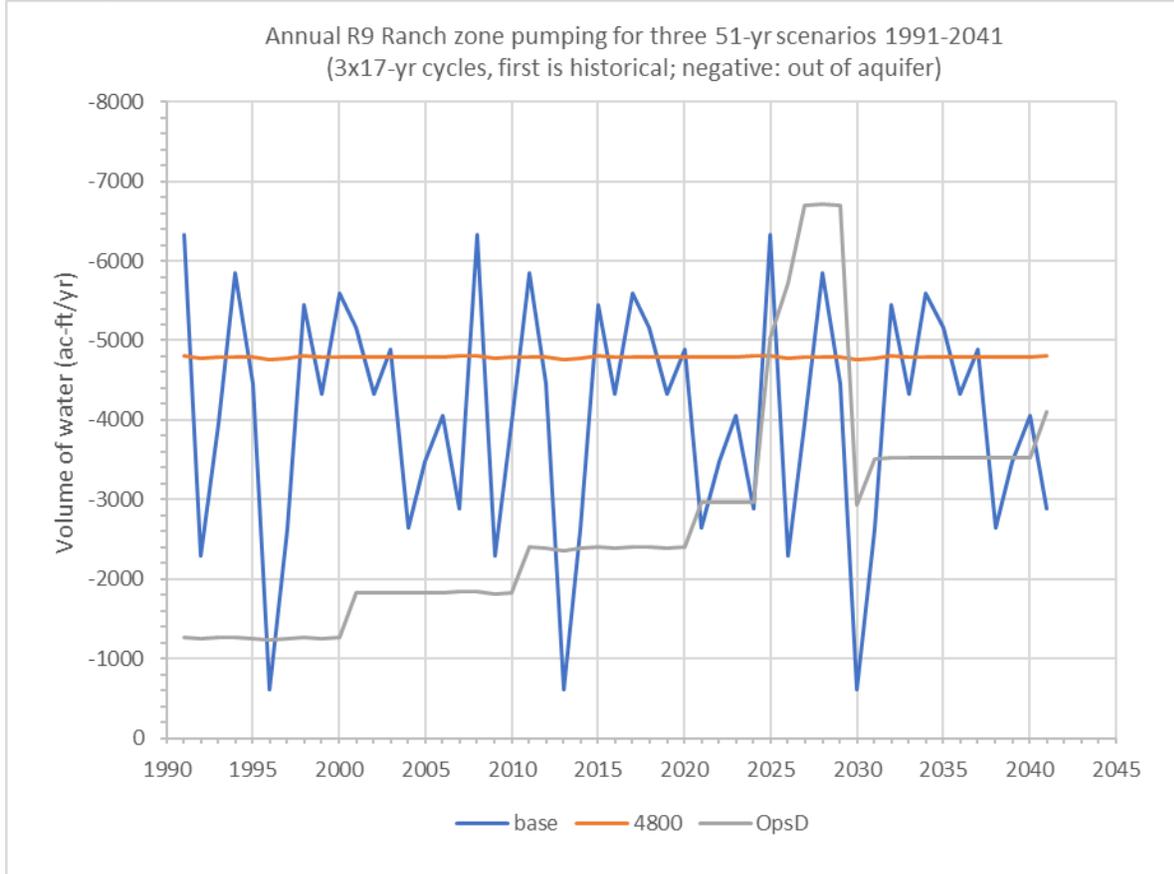


Fig. 3. Annual water levels at KGS Wizard sites within the R9 Ranch in the northeast township 25S19W, with computed heads from historical simulation at model cell containing site 659. Well sites with map id's 373 and 502 correspond to KBE site id's 4 and 5, respectively (see Map 1 and Table 1).

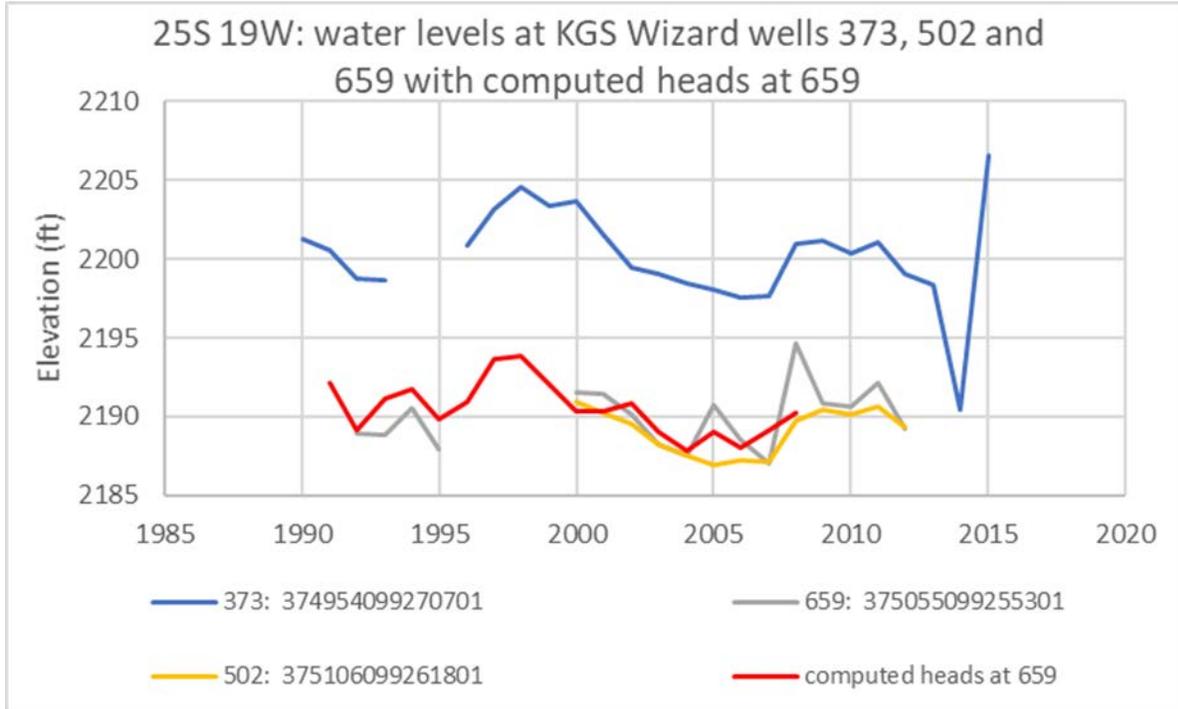


Fig. 4. Annual water levels at KGS Wizard sites in northeast township 25S19W. Well sites with map id's 373, 502, 38, 665, 545 and 15 correspond to KBE site id's 4, 5, 6, 7, 8 and 10, respectively (see also T. 1).

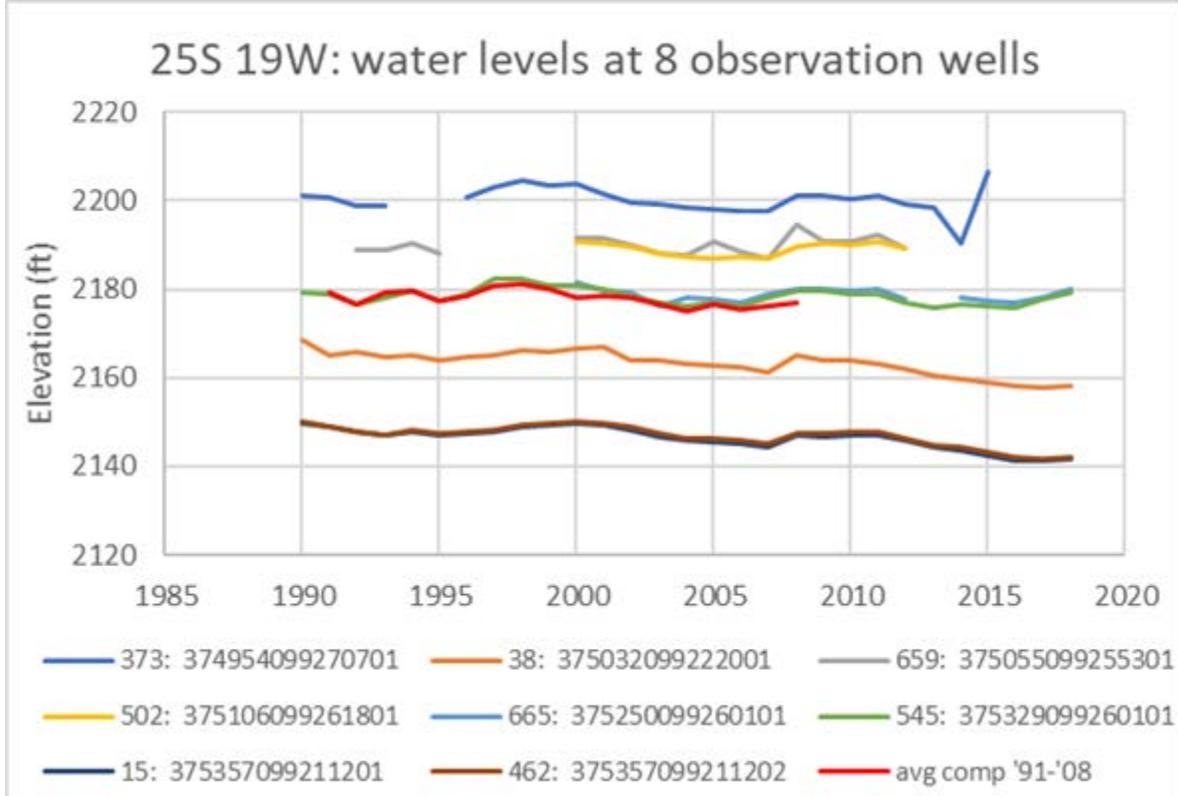


Fig. 5. Annual water levels at KGS Wizard sites in southeast township 26S19W. Well site map id 36 corresponds to KBE site id 3 (see also T. 1).

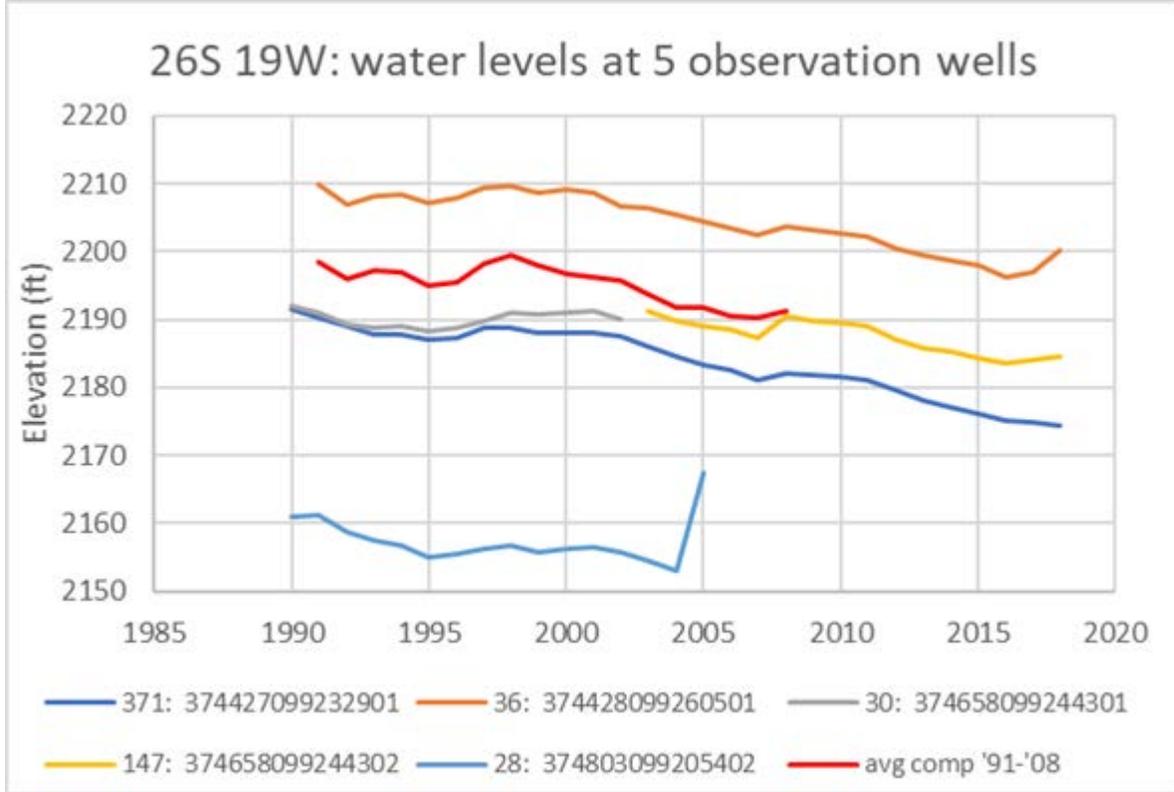


Fig. 6. Annual water levels at KGS Wizard sites in northwest township 25S20W. Well sites are not among KBE sites listed in Table 1.

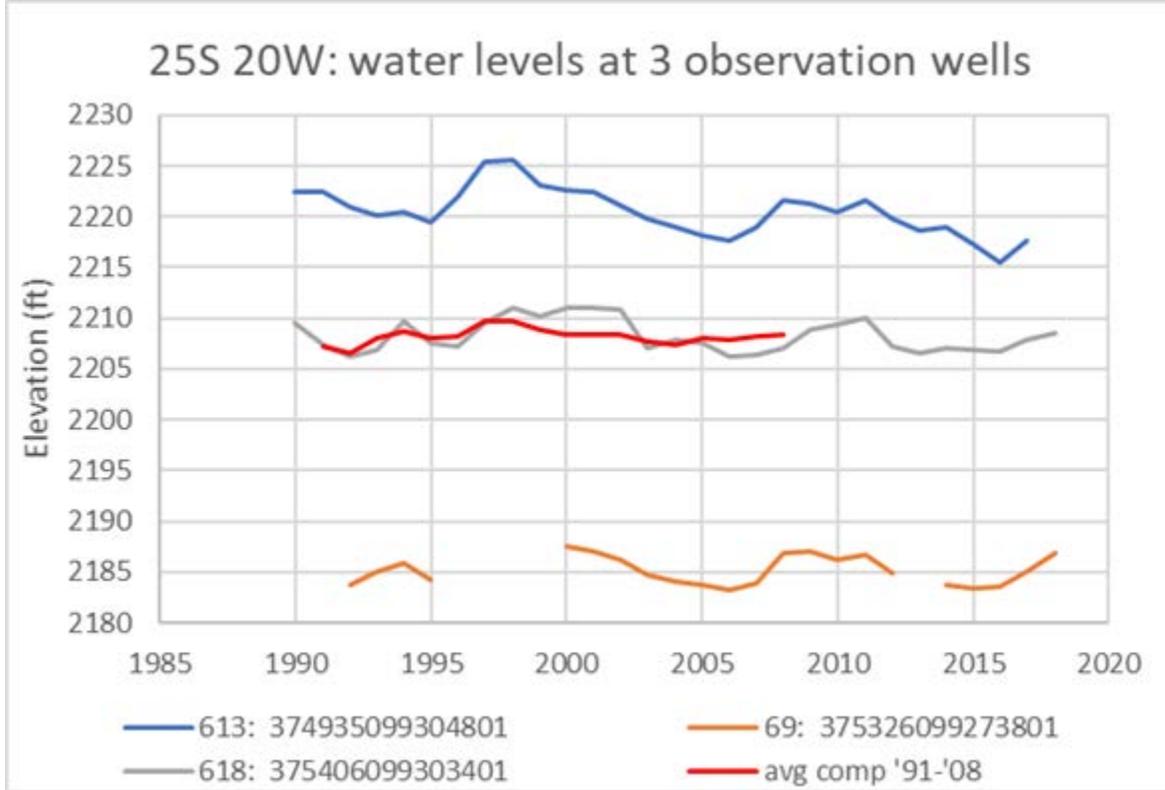


Fig. 7. Projected water levels spatially averaged over R9 Ranch for base case, 4800-af and drought scenarios.

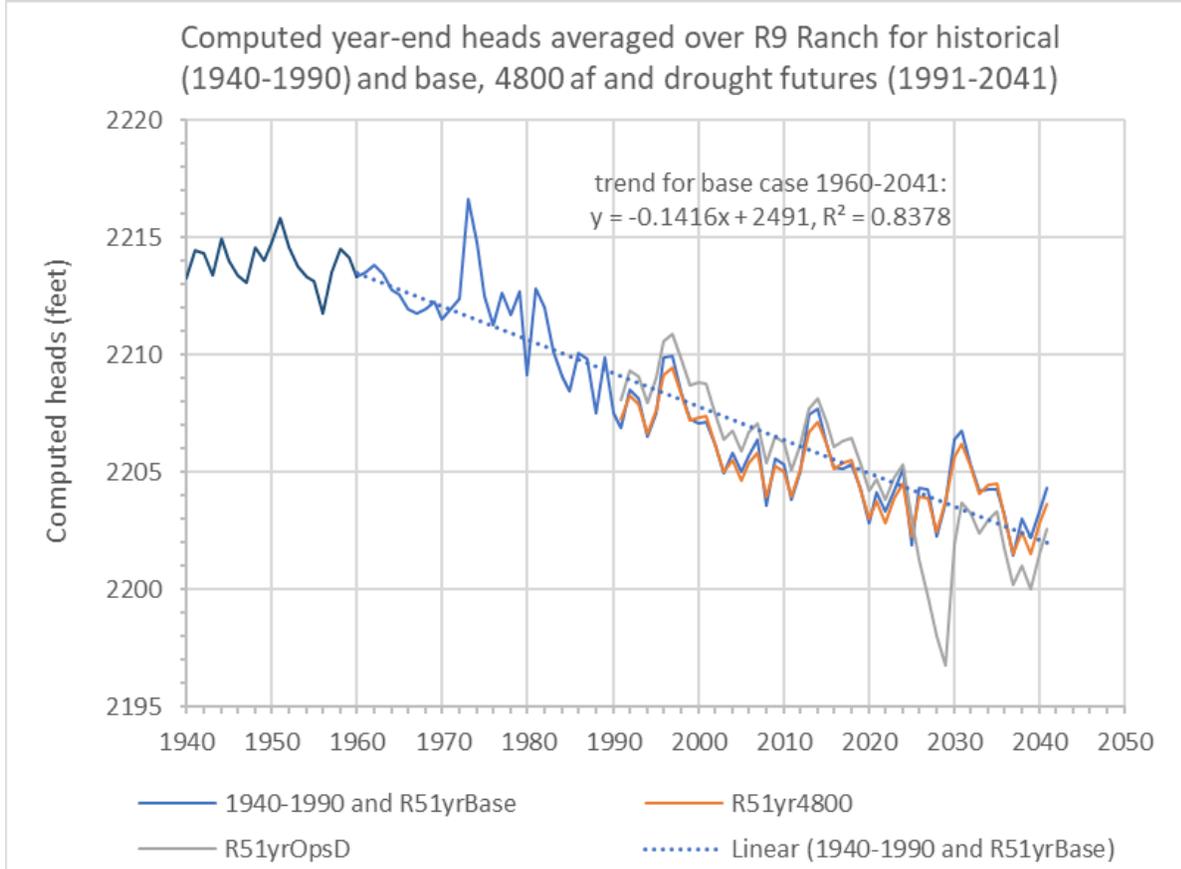


Fig. 8. Computed heads averaged over R9 and subareas by township for historical simulation 1940-2007.

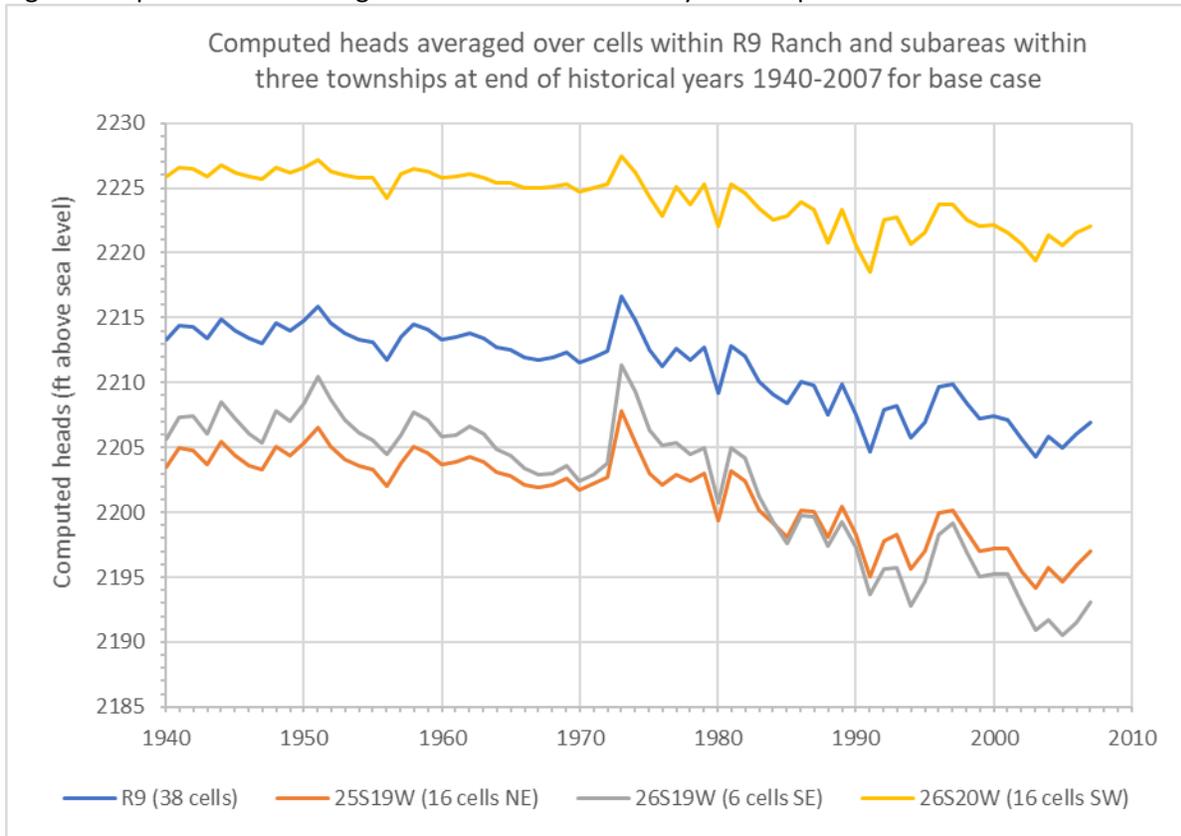


Fig. 9. Computed heads averaged over R9 and subareas by township for historical simulation years 1960-1990 and base case scenario 1991-2041.

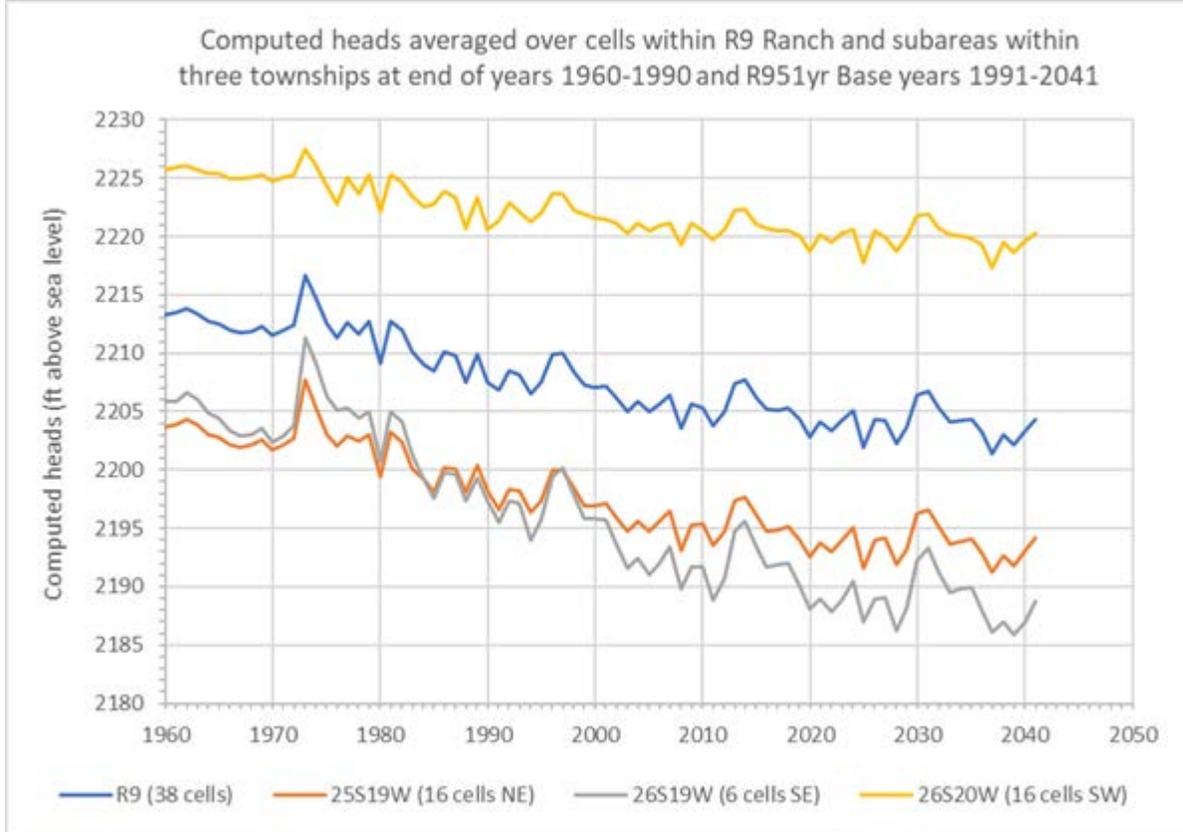


Fig. 10. Computed heads averaged over R9 Ranch and subareas by township for historical simulation years 1960-1990 and 4800-af scenario 1991-2041.

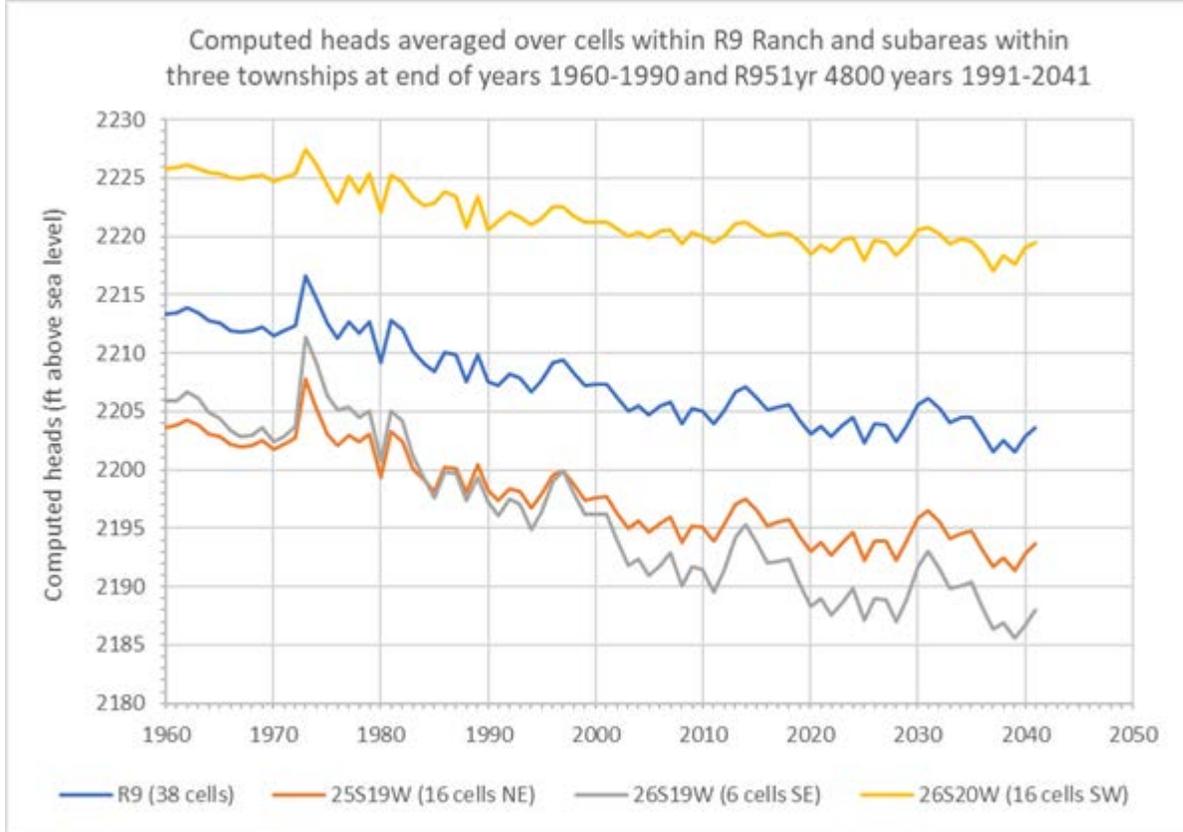


Fig. 11. Computed heads averaged over R9 Ranch and subareas by township for historical simulation years 1960-1990 and drought case scenario 1991-2041.

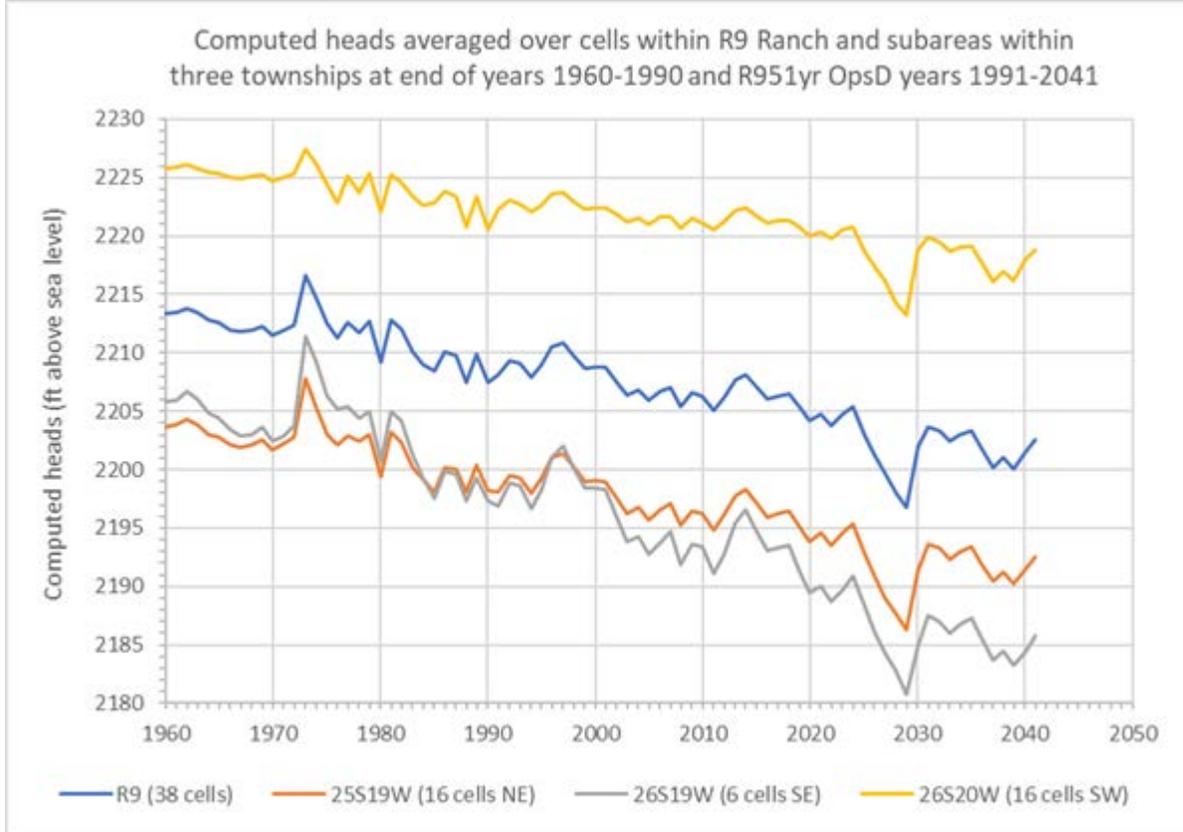


Fig. 12. Computed heads averaged over cell groups a (SE) and b (NW) for historical years 1940-2007.

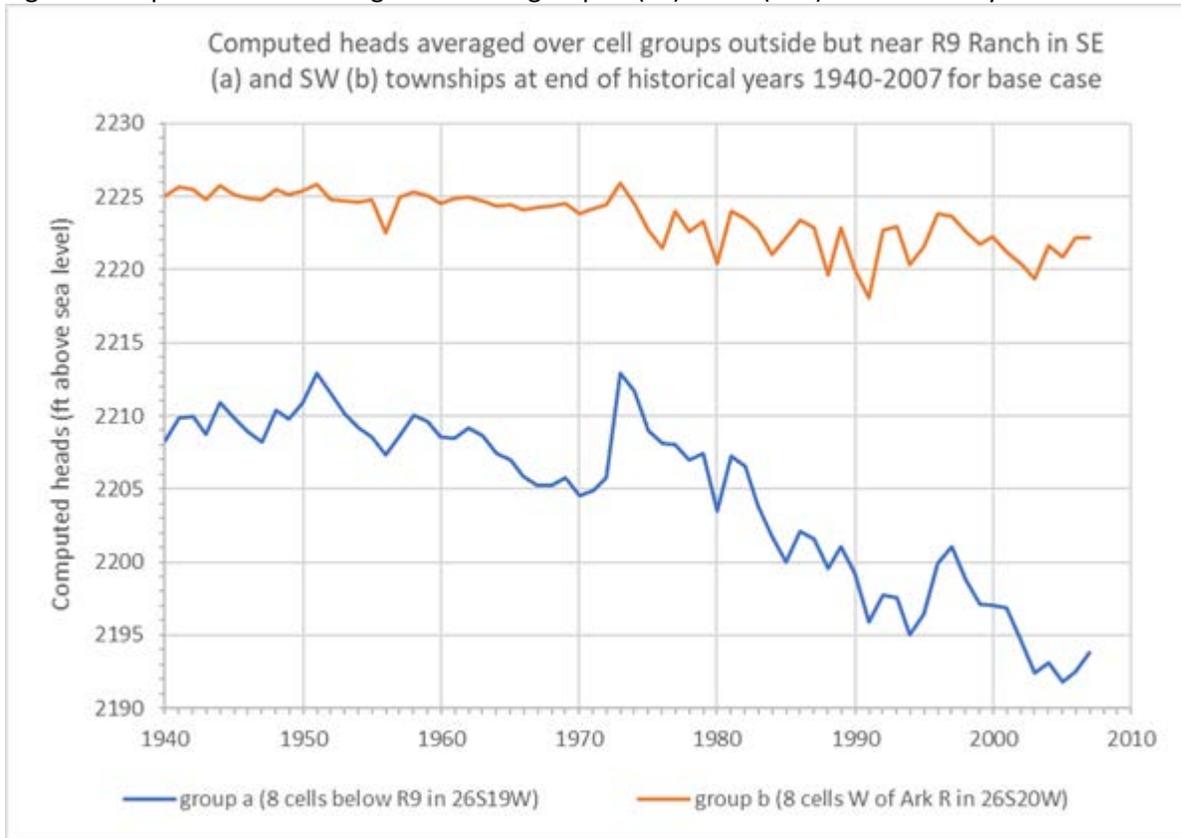


Fig. 13. Computed heads averaged over cell groups a (SE) and b (NW) for historical simulation years 1960-1990 and base case scenario 1991-2041.

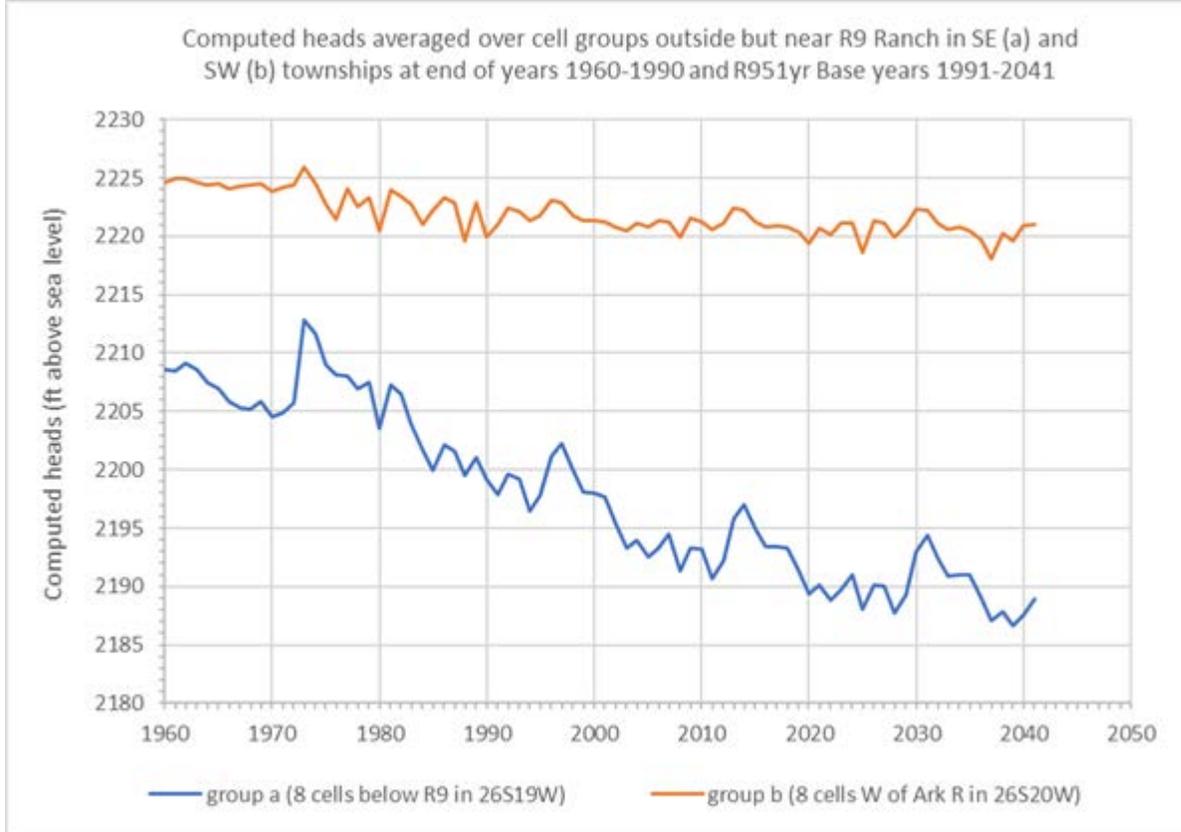


Fig. 14. Computed heads averaged over cell groups a (SE) and b (NW) for historical simulation years 1960-1990 and 4800-af scenario 1991-2041.

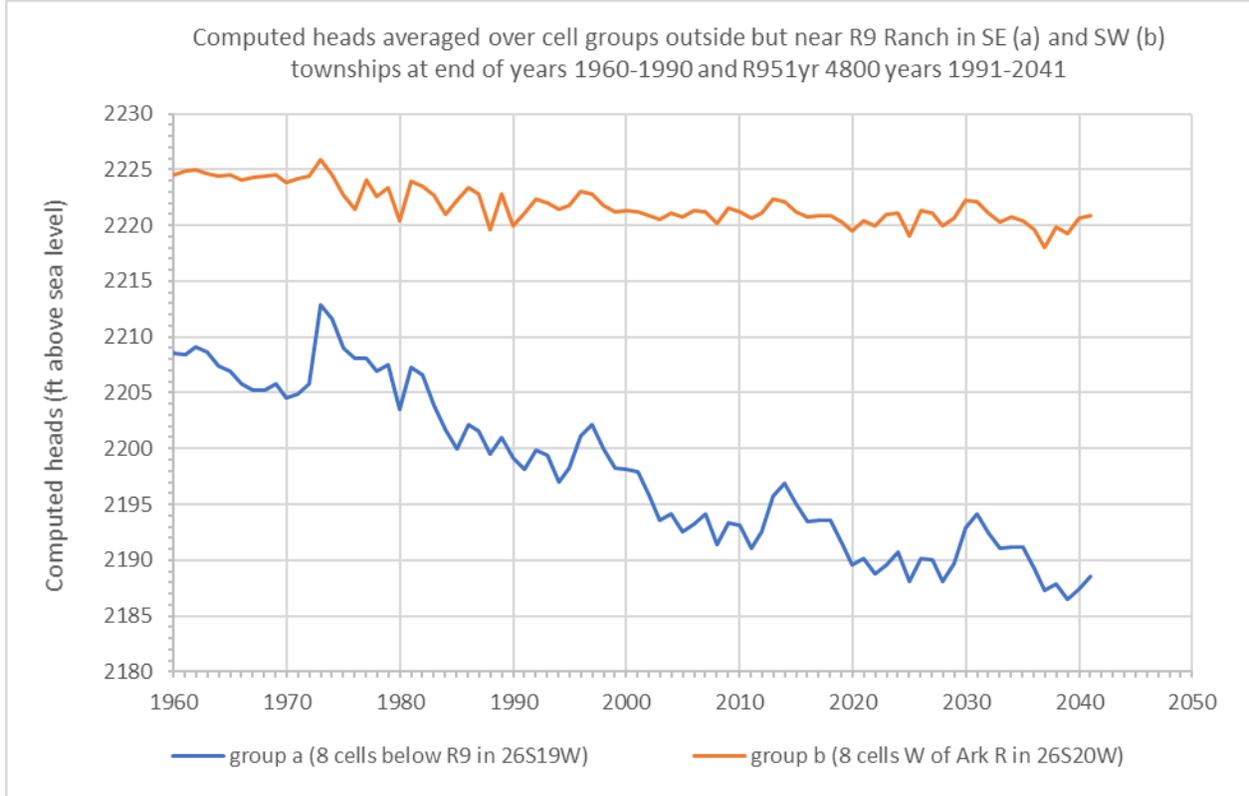


Fig. 15. Computed heads averaged over cell groups a (SE) and b (NW) for historical years 1960-1990 and drought (OpsD) scenario years 1991-2041.

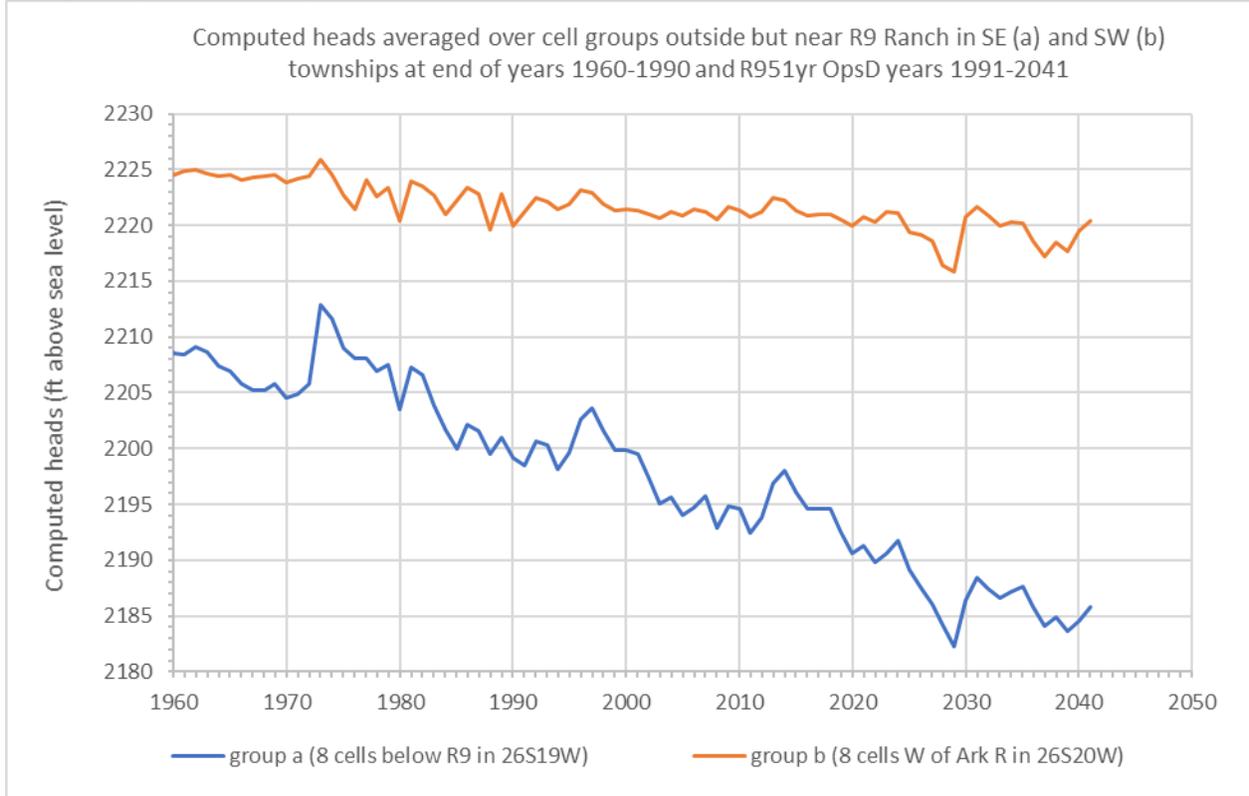


Fig. 16. Computed heads at Hays well OW-11 in southeast township 26S 19W for base, 4800-af and drought scenarios 1991-2041, with linear trend lines for base and 4800-af scenarios.

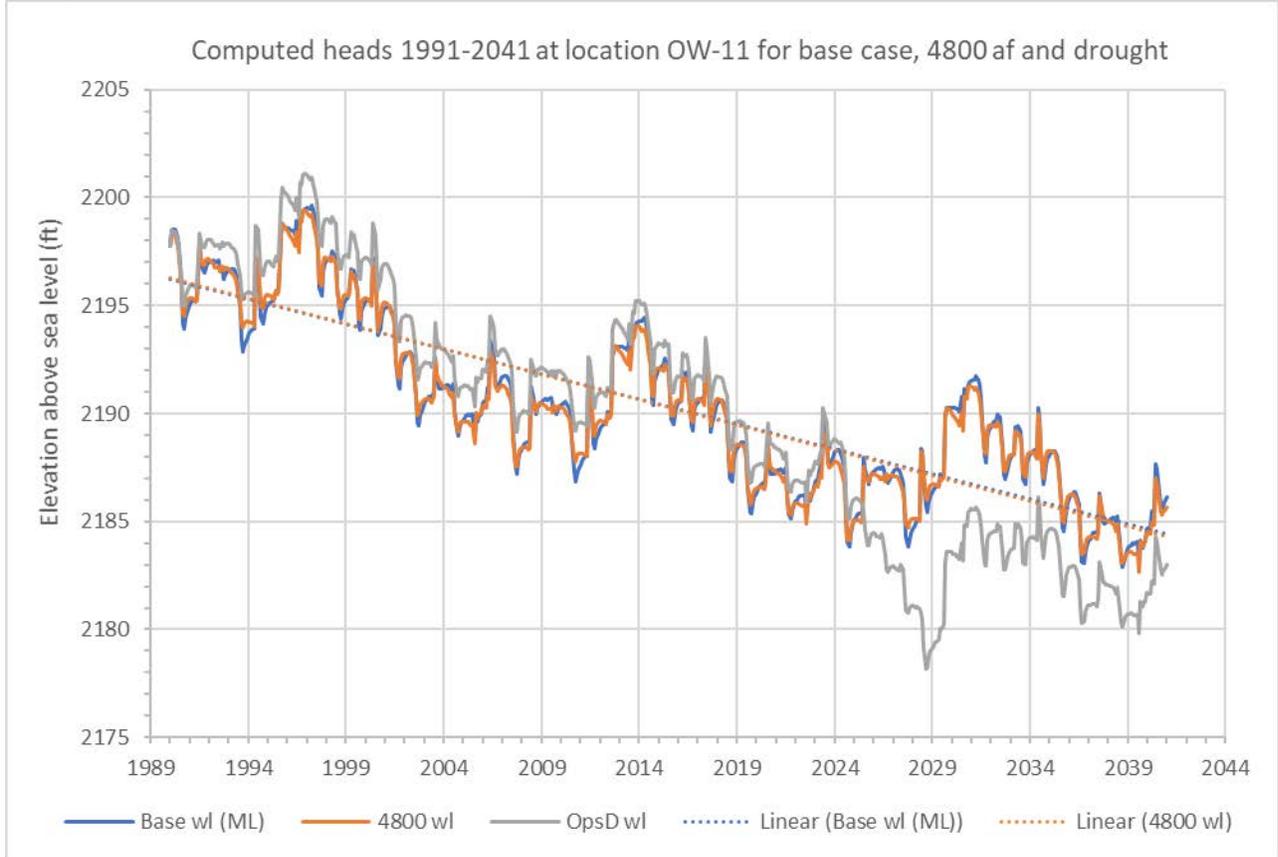


Fig. 17. Computed heads at Hays well OW-12 in northeast township 25S 19W for base, 4800-af and drought scenarios 1991-2041, with linear trend lines for base and 4800-af scenarios.

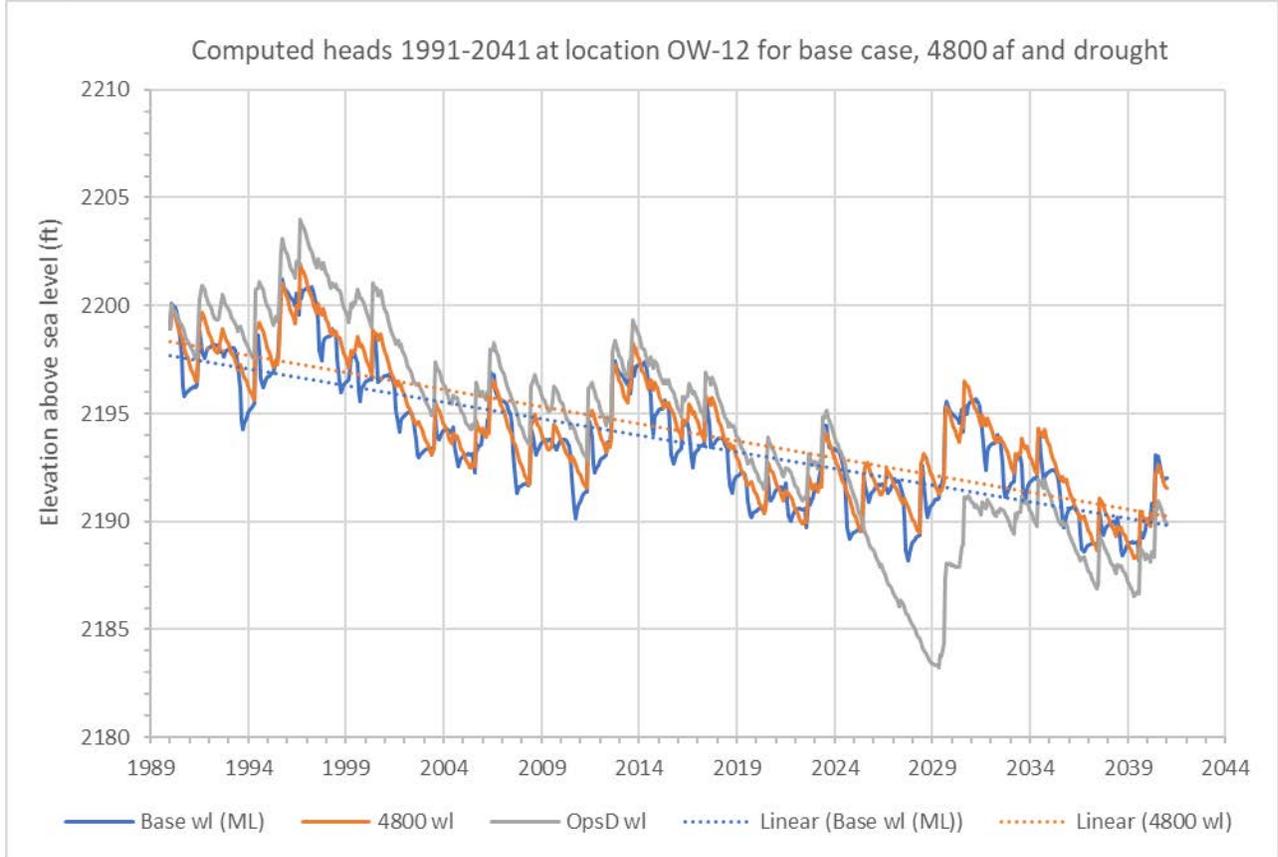


Fig. 18. Computed heads at Hays well OW-2 in northeast township 25S 19W for base, 4800-af and drought scenarios 1991-2041, with linear trend lines for base and 4800-af scenarios.

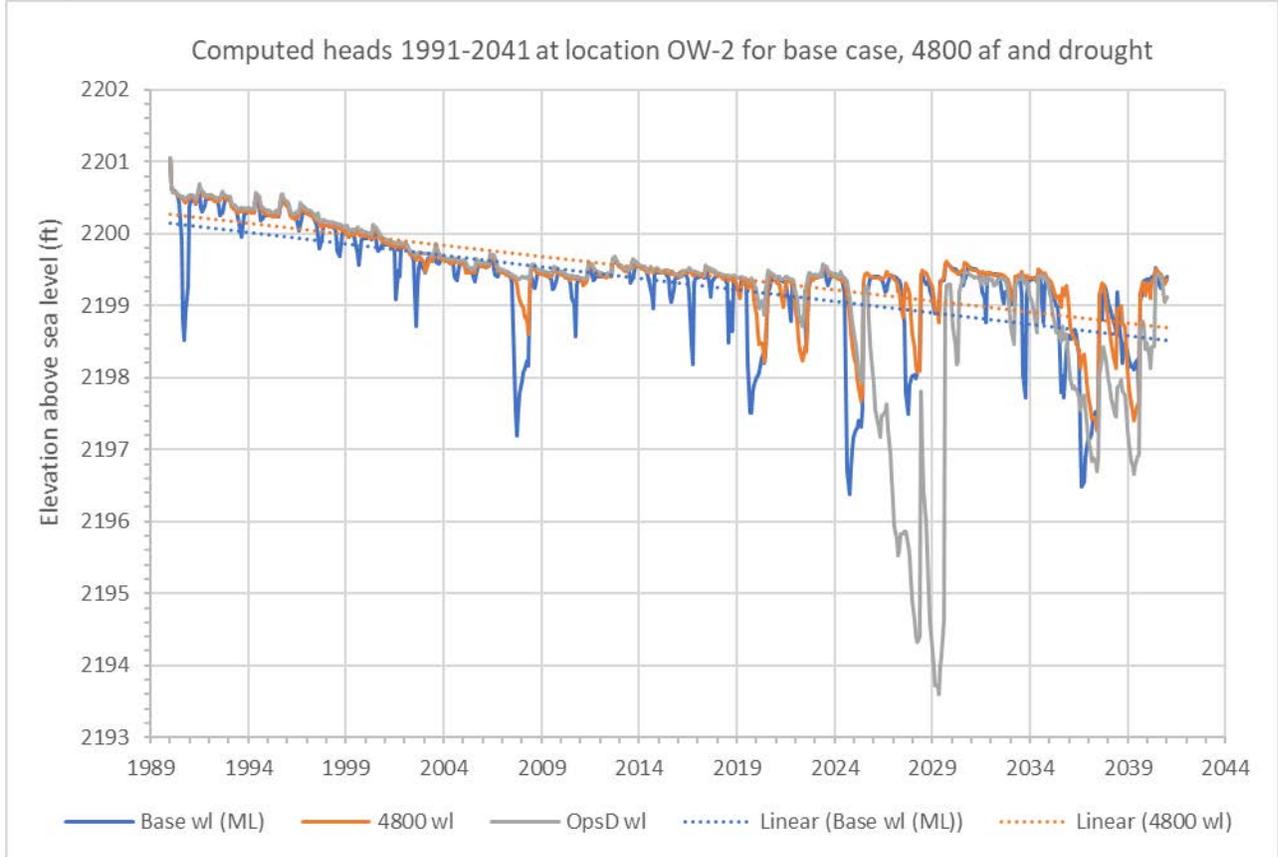


Fig. 19. Computed heads at Hays well OW-30 in southwest township 26S 20W for base, 4800-af and drought scenarios 1991-2041, with linear trend lines for base and 4800-af scenarios.

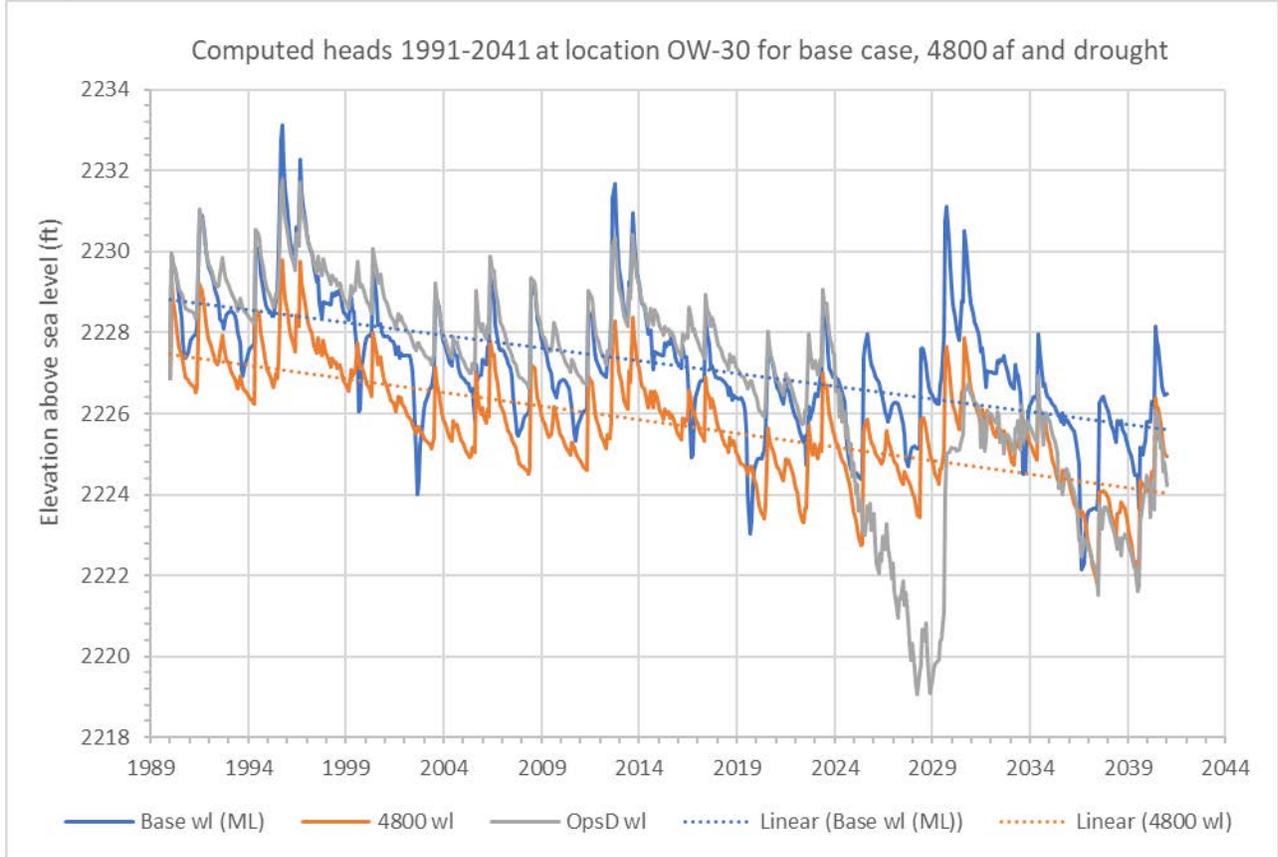


Fig. 20. Computed heads at location A3 south of R9 in 26S 19W for base, 4800-af and drought scenarios 1991-2041, with linear trend lines for base and 4800-af scenarios.

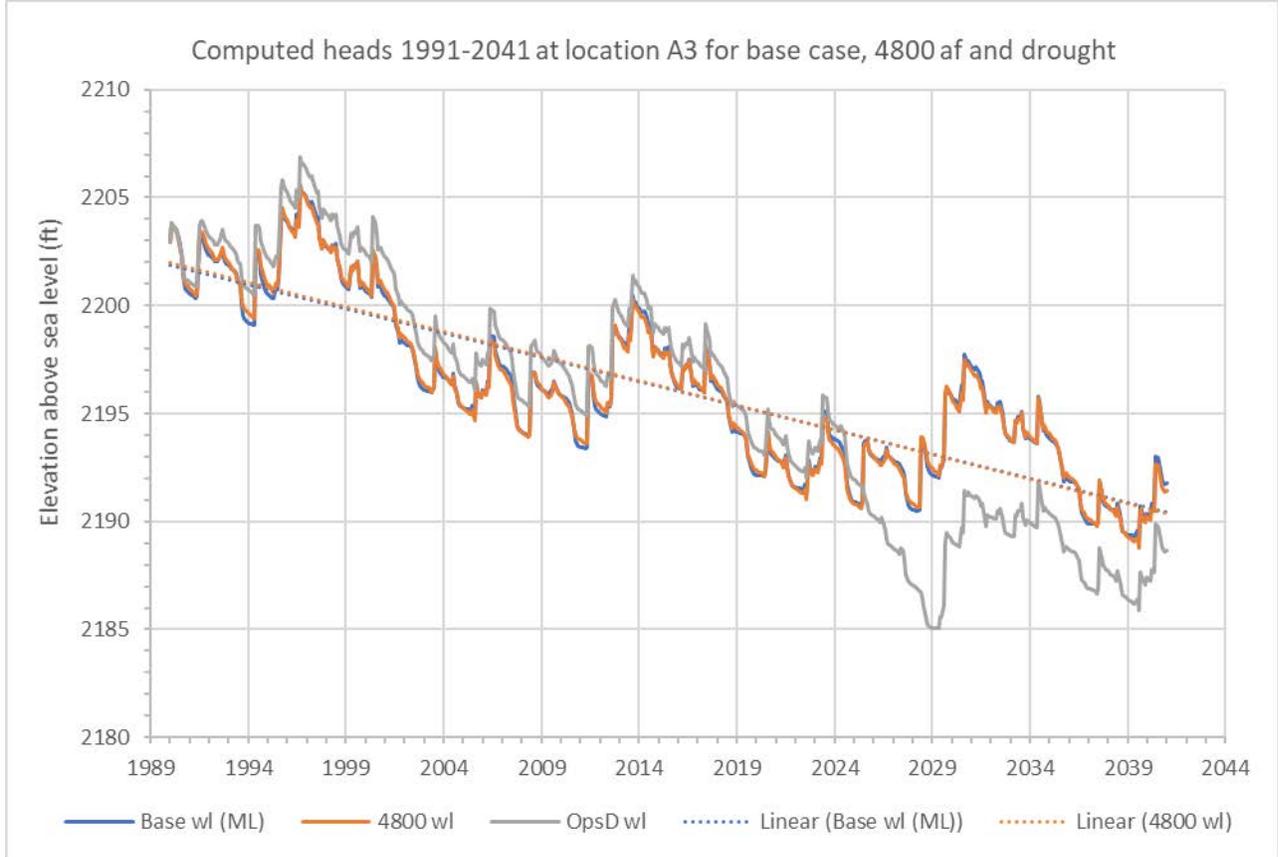


Fig. 21. Computed heads at location A4 south of R9 in 26S 19W for base, 4800-af and drought scenarios 1991-2041, with linear trend lines for base and 4800-af scenarios.

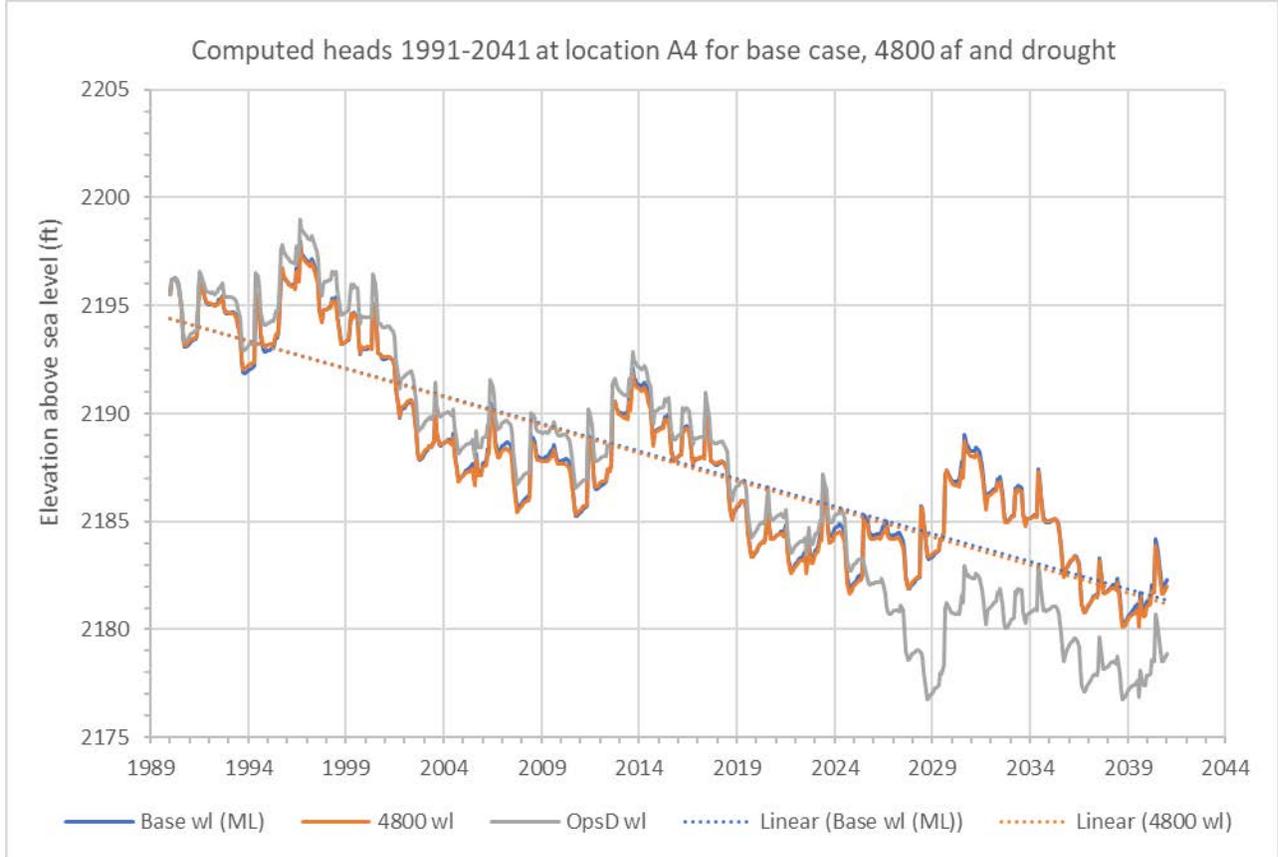


Fig. 22. Computed heads at location B1 west of R9 in southwest township 26S 20W for base, 4800-af and drought scenarios 1991-2041, with linear trend lines for base and 4800-af scenarios.

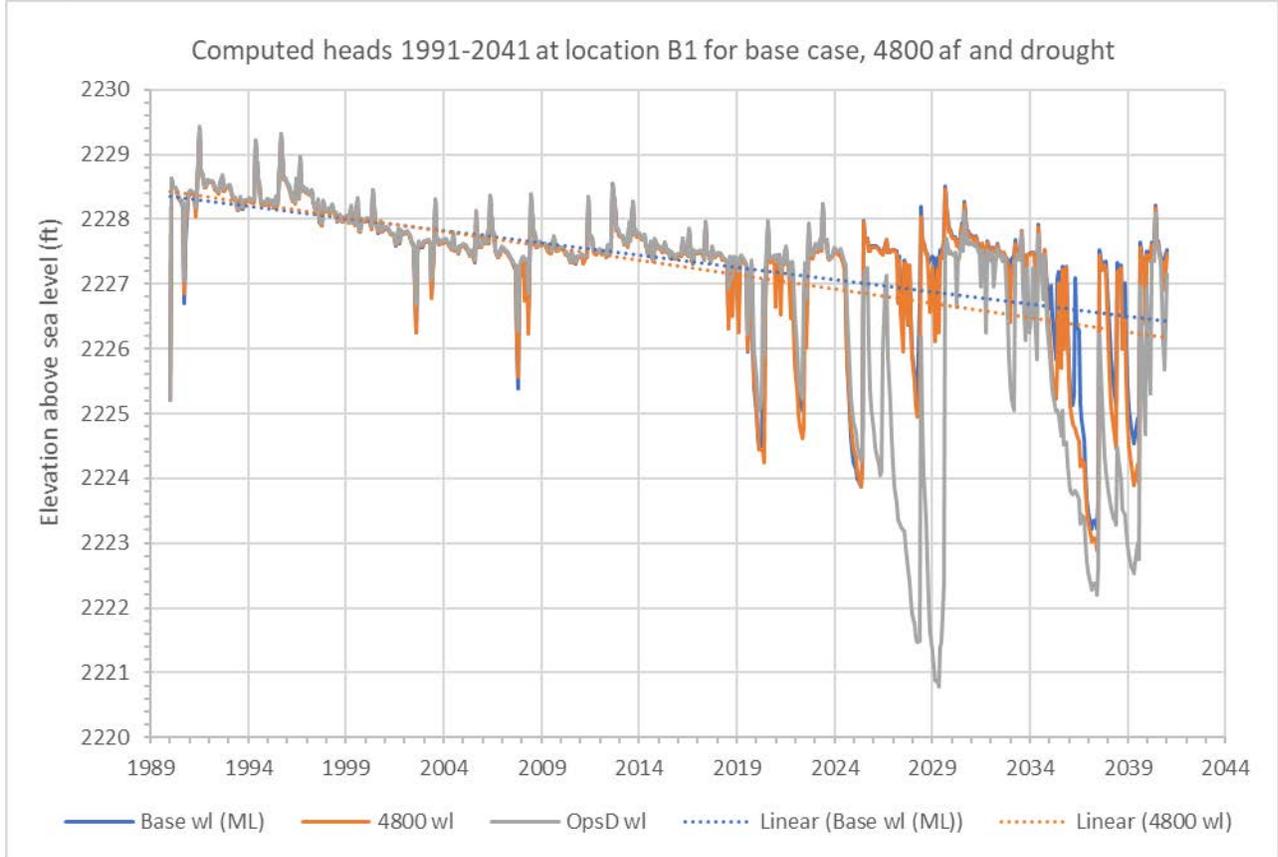


Fig. 23. Computed heads at location B2 west of R9 in southwest township 26S 20W for base, 4800-af and drought scenarios 1991-2041, with linear trend lines for base and 4800-af scenarios.

