

## **Streamflow availability rating identifies high-magnitude flows for groundwater recharge in the Central Valley**

### **Technical Appendix**

#### **Web Tool**

The web tool provides a menu on the left side of the browser window where the user can choose between displaying the ‘Interactive Map’, the ‘STARR Map’, the ‘Data Explorer’ and ‘Resources’. The Interactive Map provides the decision support tool that displays the magnitude, timing, duration, inter-annual, and intra-annual frequency of high-magnitude flow for each of the 93 stream gauges within the Central Valley that were analyzed by Kocis and Dahlke (2017). The user can click on a station of interest in the map, which loads a bar graph for the selected station and displays the high-magnitude streamflow metric (e.g. magnitude), record length (e.g. full record or post-impairment record), and time period (e.g. January) (fig 3). The bar graph shows the average value for the selected metric and specified calculation periods considering only years with high-magnitude flow. When clicking on one of the 93 sites, the user is presented with a small pop-up window stating the site name, location, status (e.g. impaired or unimpaired) and metric value (e.g. high-magnitude streamflow volume) for the criteria selected. The user is also able to select a station of interest from a list of sites. In addition, the user can download data for one or more selected sites of interest using the ‘Data Explorer’ menu (fig 1). The STARR Map menu provides an interactive map displaying the STARR and OMR maps for different time periods (fig 2). The Resources menu provides a glossary of all terms and links to external resources (fig. 3).

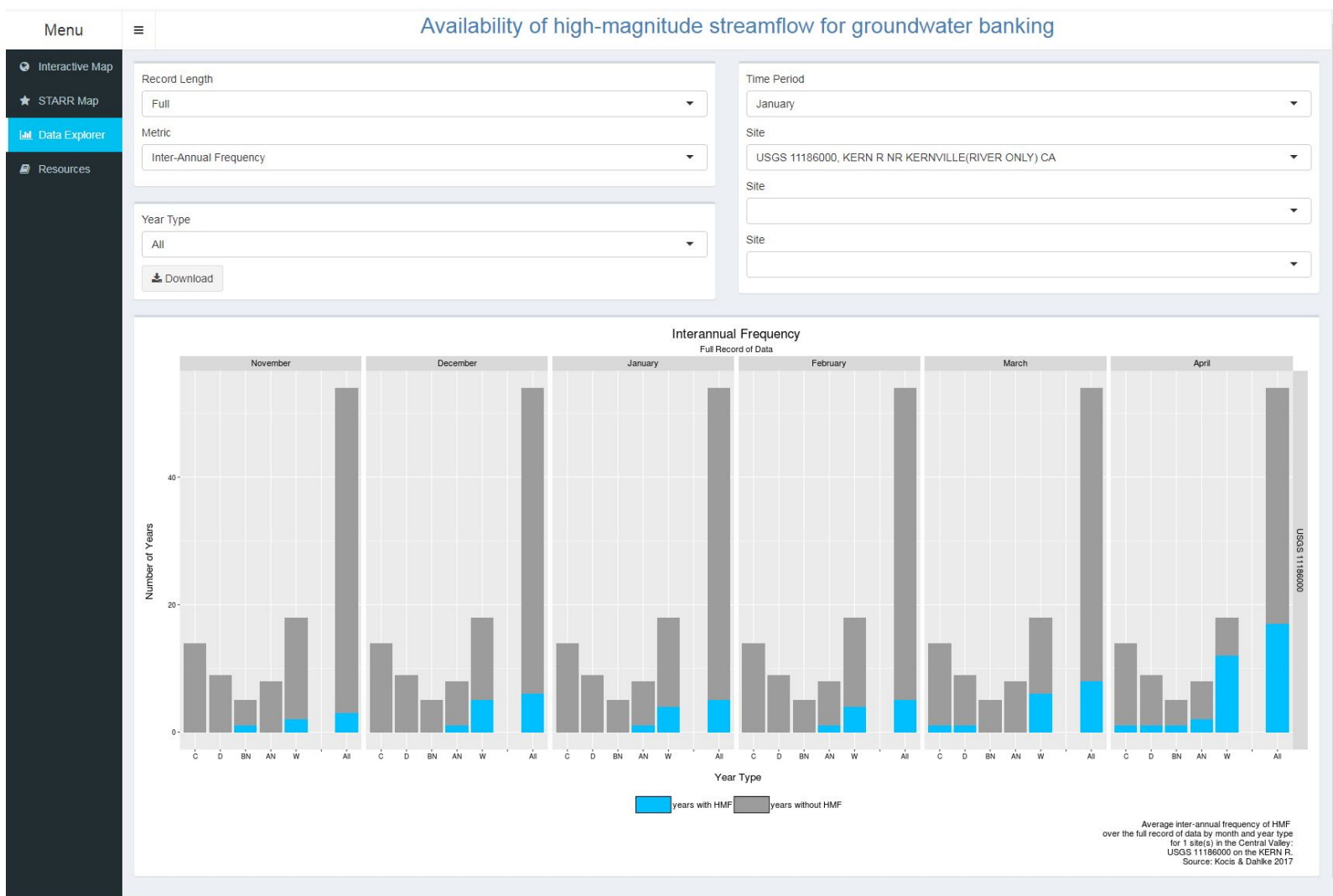


Fig. 1. Interactive, web-based tool providing data download for selected stream gauges, streamflow availability metrics and time periods.

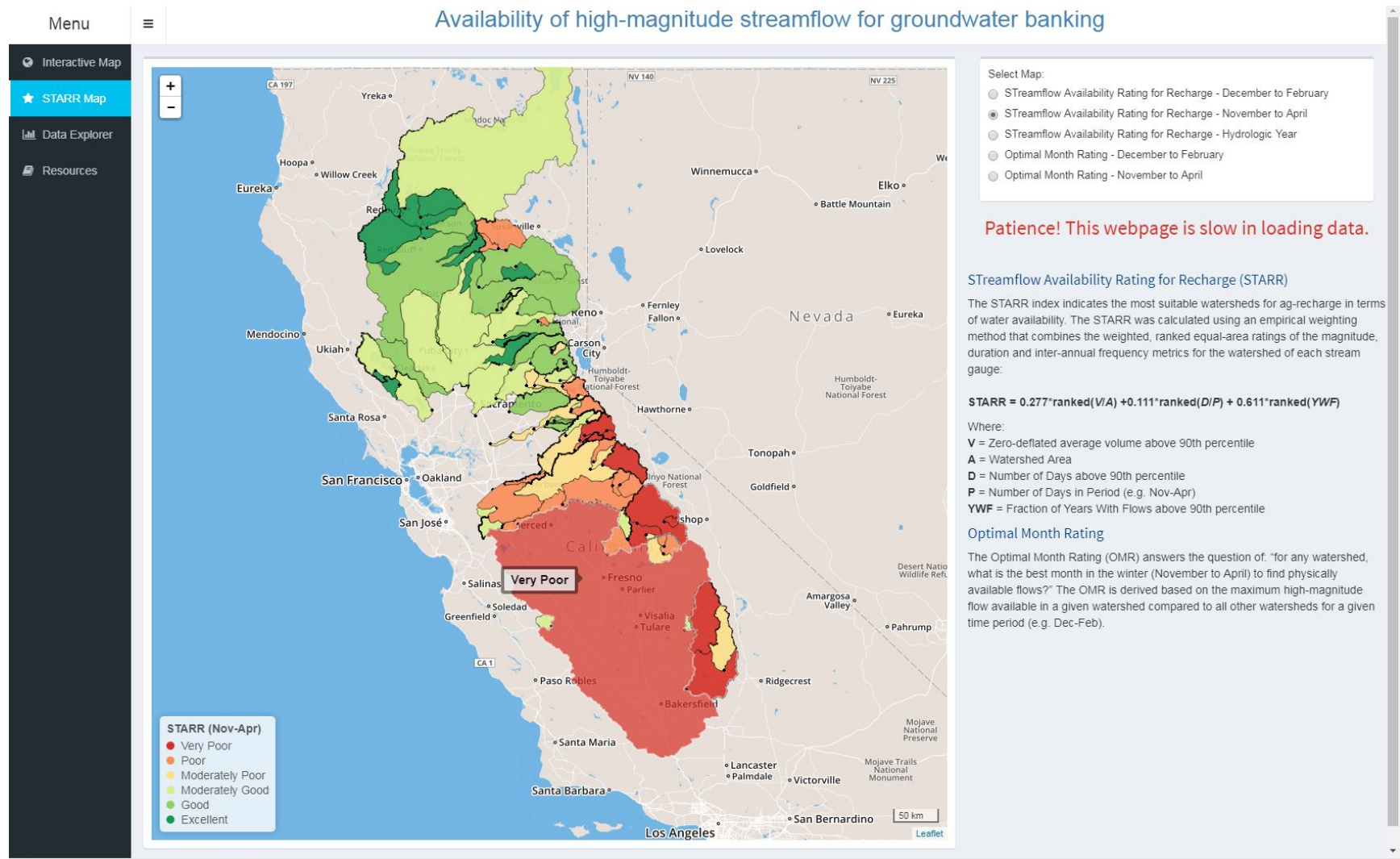


Fig. 2. Interactive, web-based map displaying the Streamflow Availability Rating for Recharge (STARR) and the Optimal Month Rating (OMR) for groundwater recharge.

**Menu** ☰ **Availability of high-magnitude streamflow for groundwater banking**

**Resources and Publications**  
For more information please see our publication in [Environmental Research Letters](#)!

**Data Sources:**

- Historic daily streamflow data was obtained from the United States Geological Survey's (USGS) Surface Water Data Library for the Nation.
- Unimpaired site data was obtained from the Hydro-Climatic Data Network (HCDN).

**Flow Metrics:**  
For each site, the 90th percentile was calculated for the full record of available data. For four metrics (magnitude, duration, timing, and intra-annual frequency), the average metric value was calculated only over years with flows above the 90th percentile and years with a zero value (no flow above the 90th percentile) were removed (zero-deflation).

**Magnitude**

- Magnitude is the total flow volume above the 90th percentile.

**Duration**

- Duration is the number of days with flow above the 90th percentile.

**Timing**

- Timing is the day of the hydrologic year (DOHY) of the center of mass (COM) of flows above the 90th percentile.

**Intra-annual Frequency**

- Intra-annual frequency is the count of 1-day peaks that occur over the 90th percentile. A 1-day peak event occurs on a day where the flow is higher than both the previous day and the next day.

**Inter-annual Frequency**

- Inter-annual frequency is the fraction of years with flow above the 90th percentile.

**Calculation Periods:**

**Full record period**

- Here metrics were calculated for the full record of available data.

**Post-impairment period**

- The post-impairment period is the record of data since the most recent impairment. For the post-impairment period the common year of all most recently constructed, significant dams within the watershed of each of the 93 gauges was determined using a GIS analysis. For the Sacramento River Basin and the San Joaquin Valley the post-impairment periods consisted of the years 1970–2014 and 1989–2014, respectively.

**Water Year Types:**  
The analysis of the high-magnitude flow metrics was conducted for several time periods and five different water year types (critical [C], dry [D], below normal [BN], above normal [AN] and wet [W]) defined in the San Joaquin Valley Index and Sacramento Valley Index ([Water Year Hydrologic Classification Indices](#)). Each metric was determined for the hydrologic year (October 1 to September 30 the following year), for November to April, December to February, and each month between November and April. These time period estimates were then split by year type, zero-deflated, and averaged inter-annually over both the entire period of record and from the most recent impairment year to the present. The timing metric was considered only over the hydrologic year.

Fig. 3. Resources webpage for the interactive, web-based tool providing a glossary of terms, information on data sources and links to scientific publications.

Table 1: USGS site numbers, station names, STARR and OMR ratings.

Site No	USGS gauge name	STARR HY	STARR Nov-Apr	STARR Dec-FEB	OMR Nov-Apr	OMR Dec-Feb	Common River Name
11186000	KERN R NR KERNVILLE(RIVER ONLY) CA	Poor	Very Poor	Very Poor	April	January	Kern River near Kernville, CA
11189500	SF KERN R NR ONYX CA	Poor	Moderately Poor	Very Poor	April	February	South Fork Kern River
11192500	KERN R NR DEMOCRAT SPRINGS(RIVER ONLY) CA	Very Poor	Very Poor	Very Poor	April	February	Kern River
11192501	KERN R NR DEMOCRAT SPRINGS CA (TOTAL FLOW) CA	Moderately Poor	Moderately Good	Moderately Good	April	January	North Fork of Middle Fork Tule River near Springville
11202001	NF OF MF TULE R NR SPRINGVILLE (TOTAL FLOW) CA	Moderately Poor	Moderately Good	Moderately Good	April	January	North Fork of Middle Fork Tule River
11214600	HELMS C BL COURTRIGHT DAM CA	Moderately Good	Poor	Poor	April	January	Helms Creek
11215000	NF KINGS R NR CLIFF CAMP CA	Moderately Poor	Moderately Poor	Moderately Poor	April	January	North Fork Kings River near Cliff Camp, CA
11218400	NF KINGS R BL DINKEY C NR BALCH CAMP CA	Moderately Poor	Moderately Poor	Moderately Poor	April	January	North Fork Kings River
11224500	LOS GATOS C AB NUNEZ CYN NR COALINGA CA	Moderately Good	Moderately Good	Moderately Good	March	February	Los Gatos Creek
11230500	BEAR C NR LAKE THOMAS A EDISON CA	Moderately Good	Very Poor	Very Poor	January	January	Bear Creek
11234760	SAN JOAQUIN R AB SHAKEFLAT C NR BIG CREEK CA	Poor	Very Poor	Very Poor	April	January	Upper San Joaquin River
11237500	PITMAN C BL TAMARACK C CA	Good	Moderately Poor	Very Poor	April	December	Pitman Creek
11242000	SAN JOAQUIN R AB WILLOW C NR AUBERRY CA	Poor	Very Poor	Very Poor	April	January	San Joaquin River at Willow Creek
11246500	WILLOW C A MOUTH NR AUBERRY CA	Moderately Poor	Moderately Good	Moderately Good	February	February	Willow Creek
11251000	SAN JOAQUIN R BL FRIANT CA	Poor	Poor	Poor	April	February	San Joaquin River below Friant Dam
11261500	SAN JOAQUIN R A FREMONT FORD BRIDGE CA	Very Poor	Very Poor	Moderately Poor	March	January	San Joaquin Valley floor
11264500	MERCED R A HAPPY ISLES BRIDGE NR YOSEMITE CA	Good	Poor	Very Poor	April	December	Merced River at Happy Isles Bridge
11266500	MERCED R A POHONO BRIDGE NR YOSEMITE CA	Good	Poor	Very Poor	April	December	Merced River at Pohono Bridge
11270900	MERCED R BL MERCED FALLS DAM NR SNELL CA	Poor	Poor	Poor	April	February	Merced River below Merced Falls Dam
11274000	SAN JOAQUIN R NR NEWMAN CA	Very Poor	Poor	Poor	February	February	San Joaquin River near Newman, CA
11274500	ORESTIMBA C NR NEWMAN CA	Poor	Moderately Good	Moderately Good	March	February	Orestimba Creek
11274630	DEL PUERTO C NR PATTERSON CA	Moderately Poor	Moderately Good	Good	March	February	Del Puerto Creek
11276500	TUOLUMNE R NR HETCH HETCHY CA	Moderately Good	Very Poor	Very Poor	April	January	Tuolumne River near Hetch Hetchy
11277300	CHERRY C BL VALLEY DAM NR HETCH HETCHY CA	Poor	Poor	Poor	December	December	Cherry Creek
11278300	CHERRY C NR EARLY INTAKE CA	Moderately Poor	Moderately Poor	Poor	April	December	Cherry Creek near Early Intake, CA
11290000	TUOLUMNE R A MODESTO CA	Poor	Moderately Poor	Moderately Poor	March	February	Tuolumne River at Modesto, CA
11292000	MF STANISLAUS R AT KENNEDY MDWS NR DARDANELLE CA	Moderately Poor	Very Poor	Poor	April	January	Middle Fork Stanislaus River at Hells Half Acre Bridge

11292700	MF STANISLAUS R A HELLS HALF ACRE BRIDGE CA	Moderately Poor	Very Poor	Poor	April	January	Middle Fork Stanislaus River
11292900	MF STANISLAUS R BL BEARDSLEY DAM CA	Moderately Poor	Very Poor	Poor	April	January	Middle Fork Stanislaus River below Beardsley Dam
11294000	HIGHLAND C BL SPICER MEADOWS RES CA	Moderately Good	Moderately Poor	Moderately Poor	March	February	Highland Creek
11294500	NF STANISLAUS R NR AVERY CA	Moderately Good	Moderately Good	Moderately Poor	April	February	North Fork Stanislaus River
11296500	SF STANISLAUS R A STRAWBERRY CA	Good	Very Poor	Very Poor	April	December	South Fork Stanislaus River
11298000	SF STANISLAUS R NR LONG BARN CA	Good	Poor	Poor	April	January	South Fork Stanislaus River near Long Barn, CA
11302000	STANISLAUS R BL GOODWIN DAM NR KNIGHTS FERRY CA	Poor	Moderately Poor	Moderately Good	March	February	Stanislaus River below Godwin Dam
11303000	STANISLAUS R A RIPON CA	Poor	Poor	Moderately Poor	April	January	Stanislaus River at Ripon, CA
11303500	SAN JOAQUIN R NR VERNALIS CA	Very Poor	Poor	Poor	March	February	San Joaquin River near Vernalis, CA
11314500	NF MOKELUMNE R BL SALT SPRINGS DAM CA	Moderately Good	Poor	Very Poor	April	December	North Fork Mokelumne River
11315000	COLE C NR SALT SPRINGS DAM CA	Excellent	Moderately Good	Moderately Poor	April	December	Cole Creek
11316800	FOREST C NR WILSEYVILLE CA	Moderately Poor	Good	Moderately Good	March	February	Forest Creek
11317000	MF MOKELUMNE R A WEST POINT CA	Moderately Poor	Good	Moderately Good	March	February	Middle Fork Mokelumne River
11318500	SF MOKELUMNE R NR WEST POINT CA	Moderately Poor	Good	Good	March	February	South Fork Mokelumne River
11319500	MOKELUMNE R NR MOKELUMNE HILL CA	Moderately Poor	Moderately Poor	Moderately Good	April	February	Mokelumne River near Mokelumne Hill, CA
11323500	MOKELUMNE R BL CAMANCHE DAM CA	Poor	Moderately Poor	Moderately Poor	April	January	Mokelumne River below Camanche Dam
11325500	MOKELUMNE R A WOODBRIDGE CA	Poor	Moderately Poor	Moderately Poor	April	January	Mokelumne River at Woodbridge, CA
11335000	COSUMNES R A MICHIGAN BAR CA	Moderately Good	Good	Good	February	February	Cosumnes River
11370500	SACRAMENTO R A KESWICK CA	Poor	Moderately Good	Moderately Good	February	February	Upper Sacramento River
11372000	CLEAR C NR IGO CA	Good	Excellent	Excellent	February	February	Clear Creek
11374000	COW C NR MILLVILLE CA	Good	Excellent	Excellent	January	January	Little Cow Creek
11376000	COTTONWOOD C NR COTTONWOOD CA	Moderately Good	Good	Good	February	February	Cottonwood Creek
11376550	BATTLE C BL COLEMAN FISH HATCHERY NR COTTONWOOD CA	Moderately Good	Good	Good	February	February	Battle Creek
11377100	SACRAMENTO R AB BEND BRIDGE NR RED BLUFF CA	Good	Excellent	Excellent	February	February	Sacramento River at Bend Bridge
11379500	ELDER C NR PASKENTA CA	Good	Excellent	Excellent	January	January	Elder Creek
11381500	MILL C NR LOS MOLINOS CA	Good	Excellent	Excellent	February	February	Mill Creek
11383500	DEER C NR VINA CA	Good	Excellent	Excellent	February	February	Deer Creek
11389500	SACRAMENTO R A COLUSA CA	Moderately Good	Good	Good	February	February	Sacramento River at Colusa, CA
11390000	BUTTE C NR CHICO CA	Good	Excellent	Excellent	February	February	Butte Creek
11390500	SACRAMENTO R BL WILKINS SLOUGH NR GRIMES CA	Moderately Good	Moderately Good	Good	February	February	Sacramento River at Wilkins Slough

11395030	SF FEATHER R BL LITTLE GRASS VALLEY DAM CA	Good	Moderately Good	Moderately Good	April	January	South Fork Feather River below Little Grass Valley
11395200	SF FEATHER R BL DIV DAM NR STRAWBERRY VALLEY CA	Good	Good	Good	January	January	South Fork Feather River below Strawberry Valley
11396000	LOST C NR CLIPPER MILLS CA	Moderately Good	Good	Moderately Good	April	February	Lost Creek
11396200	SF FEATHER R BL FORBESTOWN DAM CA	Moderately Poor	Good	Good	March	February	South Fork Feather River below Forbestown Dam
11399500	NF FEATHER R NR PRATTVILLE CA	Poor	Poor	Poor	April	December	North Fork Feather River
11400500	BUTT C BL ALMANOR-BUTT C TU NR PRATTVILLE CA	Poor	Poor	Moderately Poor	April	December	Butte Creek near Prattville
11402000	SPANISH C AB BLACKHAWK C AT KEDDIE CA	Moderately Good	Excellent	Good	February	February	Spanish Creek
11404500	NF FEATHER R A PULGA CA	Moderately Poor	Good	Moderately Good	April	February	North Fork Feather River at Pulga, CA
11407000	FEATHER R A OROVILLE CA	Poor	Good	Moderately Good	March	February	Feather River at Oroville, CA
11413000	N YUBA R BL GOODYEARS BAR CA	Good	Good	Good	April	February	North Yuba River
11416500	CANYON C BL BOWMAN LK CA	Moderately Poor	Poor	Moderately Poor	April	January	Canyon Creek
11417500	S YUBA R A JONES BAR NR GRASS VALLEY CA	Good	Good	Good	February	February	South Yuba River
11418500	DEER C NR SMARTSVILLE CA	Good	Excellent	Excellent	February	February	Deer Creek near Smartsville, CA
11421000	YUBA R NR MARYSVILLE CA	Moderately Good	Moderately Good	Good	February	February	Yuba River
11424000	BEAR R NR WHEATLAND CA	Moderately Good	Excellent	Excellent	March	February	Bear River
11425500	SACRAMENTO R A VERONA CA	Poor	Moderately Good	Moderately Good	February	February	Sacramento River at Verona, CA
11427000	NF AMERICAN R A NORTH FORK DAM CA	Good	Good	Good	March	February	North Fork American River
11427500	MF AMERICAN R A FRENCH MEADOWS CA	Moderately Poor	Moderately Poor	Moderately Poor	April	February	Middle Fork American River at French Meadows, CA
11427700	DUNCAN CYN C NR FRENCH MEADOWS CA	Good	Good	Good	April	December	Duncan Canyon Creek
11429500	GERLE C BL LOON LK NR MEEKS BAY CA	Moderately Good	Good	Good	March	December	Gerle Creek
11430000	SF RUBICON R BL GERLE C NR GEORGETOWN CA	Good	Good	Good	January	January	South Fork Rubicon River
11433300	MF AMERICAN R NR FORESTHILL CA	Moderately Good	Poor	Poor	April	January	Middle Fork American River near Foresthill, CA
11436000	SILVER LK OUTLET NR KIRKWOOD CA	Good	Moderately Poor	Poor	April	December	Silver Lake outlet
11439500	SF AMERICAN R NR KYBURZ(RIVER ONLY) CA	Moderately Good	Poor	Poor	April	January	Upper South Fork American River
11439501	SF AMERICAN R NR KYBURZ TOTAL FLOW CA	Moderately Poor	Moderately Poor	Moderately Poor	April	February	South Fork American River
11441500	SF SILVER C NR ICE HOUSE CA	Moderately Good	Moderately Poor	Poor	April	January	South Fork Silver Creek
11441900	SILVER C BL CAMINO DIV DAM CA	Moderately Poor	Moderately Good	Moderately Good	January	January	Silver Creek
11443500	SF AMERICAN R NR CAMINO CA	Moderately Poor	Moderately Poor	Moderately Poor	April	February	South Fork American River near Camino, CA
11444500	SF AMERICAN R NR PLACERVILLE CA	Poor	Moderately Poor	Moderately Good	April	January	South Fork American River near Placerville, CA
11446500	AMERICAN R A FAIR OAKS CA	Moderately Poor	Moderately Good	Moderately Good	February	February	American River

11447650	SACRAMENTO R A FREEPORT CA	Poor	Moderately Good	Moderately Good	February	February	Sacramento River at Freeport, CA
11449500	KELSEY C NR KELSEYVILLE CA	Excellent	Excellent	Excellent	February	February	Kelsey Creek
11451000	CACHE C NR LOWER LAKE CA	Moderately Poor	Moderately Good	Good	March	February	Upper Cache Creek
11452500	CACHE C A YOLO CA	Moderately Poor	Good	Good	February	February	Cache Creek
11453500	PUTAH C NR GUENOC CA	Excellent	Excellent	Excellent	January	January	Putah Creek near Guenoc, CA
11454000	PUTAH C NR WINTERS CA	Moderately Good	Moderately Good	Moderately Good	February	February	Putah Creek