SECTION II.B: SOIL WATER CONDITION

Introduction

The Water Agreement established procedures to determine which LADWP pumping wells can and cannot be operated based on soil water and vegetation measurements (On/Off status). As part of the monitoring effort for the Agreement, the ICWD regularly measures depth to groundwater (DTW) and soil water content at 25 monitoring sites in wellfields and eight sites in control areas. Three of the wellfield sites (TA1, TA2, TS6) are not used to determine the operational status of nearby pumping wells but are monitored to continue the data record. Each site is equipped with 1 to 6 soil water monitoring locations (i.e., 2-inch PVC access tubes). Soil water measurements are collected using a neutron gauge calibrated for each site (Dickey, 1990; Steinwand, 1996).

The purpose for monitoring soil water and the On/Off procedures is to manage pumping to protect plant communities that require periodic access to the water table for long-term survival. Generally, the sites with On-status have wet soil and shallow water tables, and sites in Off-status have dry soil and relatively deep water tables.

To assist the evaluation of LADWP pumping proposals, the Water Department examined the DTW and soil water data to determine whether groundwater is accessible to plants at the permanent monitoring sites at the beginning of the 2023 growing season.

How well plants can access groundwater depends on the vegetation type and water table depth. In similar soils, a shallower water table is necessary to supply groundwater to grasses than shrubs because of the shallower roots of the grasses.

For management, shrub-dominated sites are assigned a root zone of 4 m (13.1 feet); grass-dominated or mixed grass and shrub assemblages are assigned a root zone of 2 m (6.6 feet). These approximate values are not the actual rooting depth at a particular monitoring site, but they are useful to compare with the soil depth that received recharge from groundwater.

Soil water in the root zone can be supplied by infiltration from the surface (i.e., rain or irrigation) or from contact with the water table. It is usually possible to discriminate deeper soil affected by groundwater from soil near the surface affected by infiltration based on the depth and timing of the measured changes in soil water content.

Plant roots can utilize groundwater directly, and if the water table is within the root zone, it is reasonable to conclude that groundwater is available. A rising water table can progressively wet the root zone from below and provide water to plants. Plant roots can also tap groundwater that is drawn into the soil above the water table by capillarity where it is held in soil pores or adsorbed to soil particles.

Plant uptake during the summer depletes soil water, and when transpiration ceases in the fall, water from the moist soil above the water table will replenish the drier soil in the root zone via capillarity or through inactive plant roots even if the water table is stable or declining. This is a slow process and usually provides much less soil water recharge than a rising water table.

Results

Monitoring results for available soil water, vegetation water requirement, water table depth, and the On/Off status for all sites are presented in the figures that are periodically updated and available at Technical Group meetings and on the ICWD website (inyowater.org). At the beginning of the 2022-23 runoff year (April 1, 2022), 14 sites were in On-status: L1, L2, L3, BP1, BP3, BP4, TA4, TA5, TA6, TS2, TS3, TS4, SS3, and BG2 (the same On/Off Status as shown on Table 1). At the end of the runoff year (March 31, 2023), 19 sites were in On-status. The five sites that changed to On-status include: TA3, TS1, IO2, SS1 and SS4 (Table 3).

Table 1. June 2022 monitoring site status and July 1, 2022 soil/vegetation water balance calculations according to Green Book, Section III. These values of soil water required for well turn-on were derived using calculations based on percent cover that were routinely performed in the past. The values have not been updated to conform to the Green Book equations in section III.D.2, p. 57-59.

Site	June 2022 On/Off Status	July 2022 Vegetation Water Requirement	July 2022 Required Soil AWC For Turn-On	July 2022 Actual Soil AWC	July 2022 On/Off Status
LW 1	ON	2.7	NA	35.3	ON
LW 2	ON	1.6	NA	34.2	ON
LW 3	ON	3.9	NA	12.6	ON
BP 1	ON	7.8	NA	17.2	ON
BP 2	OFF	3.6	28.4	1.7	OFF (7/98)
BP 3	ON	4.7	NA	48.9	ON
BP 4	ON	2.9	NA	65.3	ON
TA 3	OFF	4.0	28.4	11.2	OFF (10/17)
TA 4	ON	3.6	NA	18.0	ON
TA 5	ON	1.9	NA	20.3	ON
TA 6	ON	4.9	NA	18.0	ON
TS 1	OFF	7.8	28.9	7.8	OFF (7/17)
TS 2	ON	2.5	NA	14.2	ON
TS 3	ON	2.7	NA	18.9	ON
TS 4	ON	9.5	NA	40.5	ON
IO 1	OFF	7.7	42.2	20.6	OFF (10/98)
IO 2	OFF	1.0	3.9	2.2	OFF (7/20)
SS 1	OFF	4.0	34.0	23.6	OFF (7/17)
SS 2	OFF	0.6	25.6	2.7	OFF (7/11)
SS 3	ON	4.0	NA	26.6	ON
SS 4	OFF	0.9	15.9	7.2	OFF (7/05)
BG 2	ON	1.1	NA	24.9	ON

Table 2. Monitoring site status and soil/vegetation water balance calculations for Oct. 1, 2022 according to Green Book, Section III. These values of soil water required for well turn-on were derived using calculations based on percent cover that were routinely performed in the past. The values have not been updated to conform with the Green book equations in section III.D.2, p. 57-59.

Site	July 1, 2022 On/Off Status	October 2022 Vegetation Water Requirement	October 2022 Required Soil AWC For Turn-On	October 2022 Actual Soil AWC	Soil AWC +40% Annual Precip.	October 1, 2022 On/Off Status
LW 1	ON	4.7	NA	30.3	36.6	ON
LW 2	ON	2.8	NA	31.9	38.2	ON
LW 3	ON	7.2	NA	7.9	14.2	ON
BP 1	ON	14.1	NA	15.2	21.5	ON
BP 2	OFF	6.7	28.4	1.2	NA	OFF (7/98)
BP 3	ON	8.3	NA	40.3	46.4	ON
BP 4	ON	5.1	NA	63.2	69.8	ON
TA 3	OFF	7.5	28.4	10.6	NA	OFF (10/17)
TA 4	ON	6.6	NA	15.4	21.2	ON
TA 5	ON	3.2	NA	20.7	27.3	ON
TA 6	ON	9.1	NA	14.4	20.2	ON
TS 1	OFF	14.5	28.9	7.6	NA	OFF (7/17)
TS 2	ON	4.5	NA	12.4	18.2	ON
TS 3	ON	5.0	NA	17.2	23.0	ON
TS 4	ON	17.4	NA	35.5	41.3	ON
IO 1	OFF	14.5	42.2	17.7	NA	OFF (10/98)
IO 2	OFF	1.9	3.9	3.4	NA	OFF (7/20)
SS 1	OFF	7.2	34.0	25.3	NA	OFF (7/17)
SS 2	OFF	1.0	25.6	3.3	NA	OFF (7/11)
SS 3	ON	7.5	NA	25.5	30.7	ON
SS 4	OFF	1.8	15.9	7.1	NA	OFF (7/05)
BG 2	ON	2.0	NA	24.8	30.1	ON

Table 3. Monitoring site status on April 1, 2023 according to Green Book, Section III. All values in cm. These values of soil water required for well turn-on were derived using calculations based on percent cover that were routinely performed in the past. The values have not been updated to conform with the Green book equations in section III.D.2, p. 57-59.

Site	October 2022 Actual Soil AWC	40% Annual Precipitation	Projected Soil AWC	October 2022 Vegetation Water Requirement	October 2022 Required Soil AWC For Turn-On	October 1, 2022 On/Off Status	April 2023 Soil AWC	April 2023 Required Soil AWC For Turn-On	April 2023 On/Off Status
LW 1	30.3	6.3	36.6	4.7	NA	ON	115.2	NA	ON
LW 2	31.9	6.3	38.2	2.8	NA	ON	46.3	NA	ON
LW 3	7.9	6.3	14.2	7.2	NA	ON	48.9	NA	ON
BP 1	15.2	6.3	21.5	14.1	NA	ON	38.4	NA	ON
BP 2	1.2	NA	NA	6.7	28.4	OFF (7/98)	21.8	28.4	OFF (7/98)
BP 3	40.3	6.1	46.4	8.3	NA	ON	66.2	NA	ON
BP 4	63.2	6.6	69.8	5.1	NA	ON	92.1	NA	ON
TA 3	10.6	NA	NA	7.5	28.4	OFF (10/17)	38.6	NA	On
TA 4	15.4	5.8	21.2	6.6	NA	ON	28.4	NA	ON
TA 5	20.7	6.6	27.3	3.2	NA	ON	39.3	NA	ON
TA 6	14.4	5.8	20.2	9.1	NA	ON	50.1	NA	ON
TS 1	7.6	NA	NA	14.5	28.9	OFF (7/17)	39.7	NA	ON
TS 2	12.4	5.8	18.2	4.5	NA	ON	37.1	NA	ON
TS 3	17.2	5.8	23.0	5.0	NA	ON	46.8	NA	ON
TS 4	35.5	5.8	41.3	17.4	NA	ON	72.9	NA	ON
IO 1	17.7	NA	NA	14.5	42.2	OFF (10/98)	41.8	42.2	OFF (10/98)
IO 2	3.4	NA	NA	1.9	3.9	OFF (7/20)	21.5	NA	ON
SS 1	25.3	NA	NA	7.2	34.0	OFF (7/17)	42.4	NA	ON
SS 2	3.3	NA	NA	1.0	25.6	OFF (7/11)	20.9	25.6	OFF (7/11)
SS 3	25.5	5.2	30.7	7.5	NA	ON	45.5	NA	ON
SS 4	7.1	NA	NA	1.8	15.9	OFF (7/05)	17.6	NA	ON
BG 2	24.8	5.3	30.1	2.0	NA	ON	33.9	NA	ON

Table 4. Comparison of DTW preceding the growing seasons (April) in 2022 and 2023. Depths are below ground surface. Positive values denote a rise in the water table.

Wellfield	April 1, 2022 DTW	April 1, 2023 DTW	DTW Change 2022-23	
Site	(m)	(m)	(m)	(ft)
Laws				
L1	4.43	1.94	2.49	8.18
L2	5.70	5.74	-0.04	-0.13
L3	4.98	2.10	2.88	9.46
Bishop Control				
BC1	3.00	1.95	1.05	3.45
BC2	4.41	3.83	0.58	1.89
BC3	1.89	0.92	0.97	3.19
Big Pine				
BP1	3.78	3.56	0.23	0.74
BP2	5.75	5.66	0.09	0.30
BP3	3.93	4.08	-0.15	-0.50
BP4	3.36	3.13	0.23	0.74
Taboose Aberdeen				
TA1	1.50	0.89	0.61	1.99
TA3	5.03	5.02	0.01	0.04
TA4	2.33	2.01	0.32	1.06
TA5	4.72	4.16	0.56	1.84
TA6	3.08	2.83	0.25	0.81
TAC	1.19	0.52	0.67	2.21
Thibaut Sawmill				
TS1	4.65	4.39	0.26	0.87
TS2	3.23	2.03	1.20	3.93
TS3	2.85	1.49	1.37	4.48
TS4	2.10	0.88	1.22	4.02
TS6	4.84	5.28	-0.44	-1.44
TSC	1.62	0.13	1.49	4.88
Independence Oak				
IO1	3.97	3.57	0.40	1.32
IO2	7.66	7.91	-0.25	-0.82
IC1	0.94	0.29	0.65	2.12
IC2	2.34	2.06	0.28	0.91
Symmes Shepherd				
SS1	4.50	4.62	-0.12	-0.40
SS2	6.70	7.01	-0.31	-1.01
SS3	3.55	3.62	-0.06	-0.20
SS4	6.12	6.27	-0.15	-0.49
Bairs George				
BG2	5.18	4.93	0.25	0.82
BGC	2.79	2.47	0.32	1.06

Hydrographs for the permanent monitoring sites are presented on the ICWD website (ICWD Annual Report - Vegetation Graphs), and the DTW measured near April 1 (i.e., the end of March) before the 2022 and 2023 growing seasons are presented in Table 4. At most sites, the shallowest DTW occurs near April 1. At sites BP1 and 3 in Big Pine, usually the water table rises during the summer and reaches a shallowest depth in the fall coinciding with the timing of diversions into the Big Pine canal for irrigation.

In 2022-23, the water table increased an average of 1.5 feet in wellfields and increased 2.5 feet in control areas. This was expected due to a below-average runoff year (59% of the 1971-2020 average) combined with less than average groundwater pumping and a very wet winter. See the Groundwater section of this report (Section II.a) for an assessment of water level changes using a larger set of monitoring wells.

At most sites it was difficult to discriminate groundwater recharge from surface infiltration because of the wet winter in 2022-23 (Tables 5 and 6). Infiltration at some sites exceeded 1.2 meters resulting in substantial increases in soil water. At several of the monitoring locations, rain or melting snow preferentially flowed down the sides of the access tubes to soil depths well below typically wetted by infiltration, further complicating data interpretation. Winter precipitation on the valley floor was approximately 294% of average.

Table 5. Soil depth below ground surface replenished by groundwater in April 2023 at wellfield sites. Values are provided for each monitoring location within a site unless the identification of a specific depth was uncertain (UNK in table). Minimum DTW was measured in the associated test well from April 2022 to March 2023. If groundwater not recharging soil, greater than ">" sign used at maximum tube depth.

Site	Dominant plant species	Root Zone (m)	Minimum DTW (m)	Groundwater recharge depth (m)
L1	greasewood	4	1.9	UNK, UNK, UNK
L2	alk. sacaton, greasewood, saltbush	2	5.7	UNK, UNK, 3.1, 3.5, 3.3
L3	alk. sacaton, saltgrass	2	2.1	<0.9, 1.7, UNK, UNK, UNK, UNK
BP1	saltbush, greasewood	3	3.6	3.1, UNK, UNK, UNK, 2.7
BP2	saltbush, rabbitbrush	4	5.7	>5.3, >3.9, >3.9
BP3	greasewood, rabbitbrush	4	3.9	2.9, 2.9, 2.9
BP4	saltbush, greasewood	4	3.1	1.7, 2.1, 2.7
TA1	alk. sacaton, saltbush	2	0.9	UNK
TA2	alk. sacaton, saltbush, greasewood, rabbitbrush	2	0.9	0.9
TA3	saltbush, alk. sacaton, sagebrush	2	5.0	UNK, UNK, UNK
TA4	rabbitbrush, alk. sacaton	2	2.0	UNK, UNK, UNK
TA5	greasewood, alk. sacaton	2	4.2	UNK, UNK, UNK
TA6	saltbush, rabbitbrush	4	2.8	UNK, UNK, UNK
TS1	weeds, alk. sacaton	2	4.4	UNK, UNK, 3.5, UNK, 2.7
TS2	sagebrush, saltbush, alk. sacaton	2	2.0	UNK, 1.9, UNK
TS3	saltgrass, alk. sacaton	2	1.5	UNK, 1.3, <2.3, 1.9, UNK, UNK
TS4	greasewood, alk. sacaton, saltbush, saltgrass	2	0.9	<0.9, <0.9, <0.9, <0.9
TS6	alk. sacaton, saltbush, saltgrass	2	4.8	UNK
IO1	rabbitbrush, alk. sacaton, saltbush	2	3.6	1.5, 1.7, 3.1
IO2	saltbush	4	7.7	4.9, >3.9, >3.9
SS1	saltbush, greasewood	4	4.5	3.7, 2.5, 2.3

Site	Dominant plant species	Root Zone (m)	Minimum DTW (m)	Groundwater recharge depth (m)
SS2	saltbush	4	6.7	>5.5, >3.9, >3.9
SS3	saltbush	4	3.6	3.5, >3.3, 3.5
SS4	saltbush	4	6.1	>3.9,>3.7, >3.9
BG2	inkweed, saltbush	4	4.9	>3.7, >3.5, >3.7

Table 6. Soil depth below ground surface replenished by groundwater in April 2023 at control sites. Values are provided for each monitoring location within a site unless the identification of a specific depth was uncertain (UNK in table). Minimum DTW was measured in the associated test well from April 2022 to March 2023. If groundwater not recharging soil, greater than ">" sign used at maximum tube depth.

Site	Dominant plant species	Root Zone (m)	Minimum DTW (m)	Groundwater recharge depth (m)
BC1	rabbitbrush, saltbush, greasewood, alk. sacaton	4	1.9	UNK, 1.5, UNK
BC2	rabbitbrush, saltgrass	2	3.8	UNK, 2.3, UNK, 1.9
BC3	rabbitbrush, saltgrass, saltbush	2	0.9	<0.7, <0.7, <0.7
TAC	saltbush, rye grass, saltgrass, alk. sacaton	2	0.5	<0.3, <0.3, <0.3, <0.3
TSC	alk. sacaton, rabbitbrush, greasewood.	2	0.1	<0.3, <0.3, <0.3
IC1	saltbush, saltgrass, rabbitbrush	2	0.3	<0.5, <0.5, <0.5
IC2	rabbitbrush, alk. sacaton	2	2.1	UNK, UNK, UNK
BGC	saltbush, saltgrass	4	2.5	2.5, UNK, >3.3

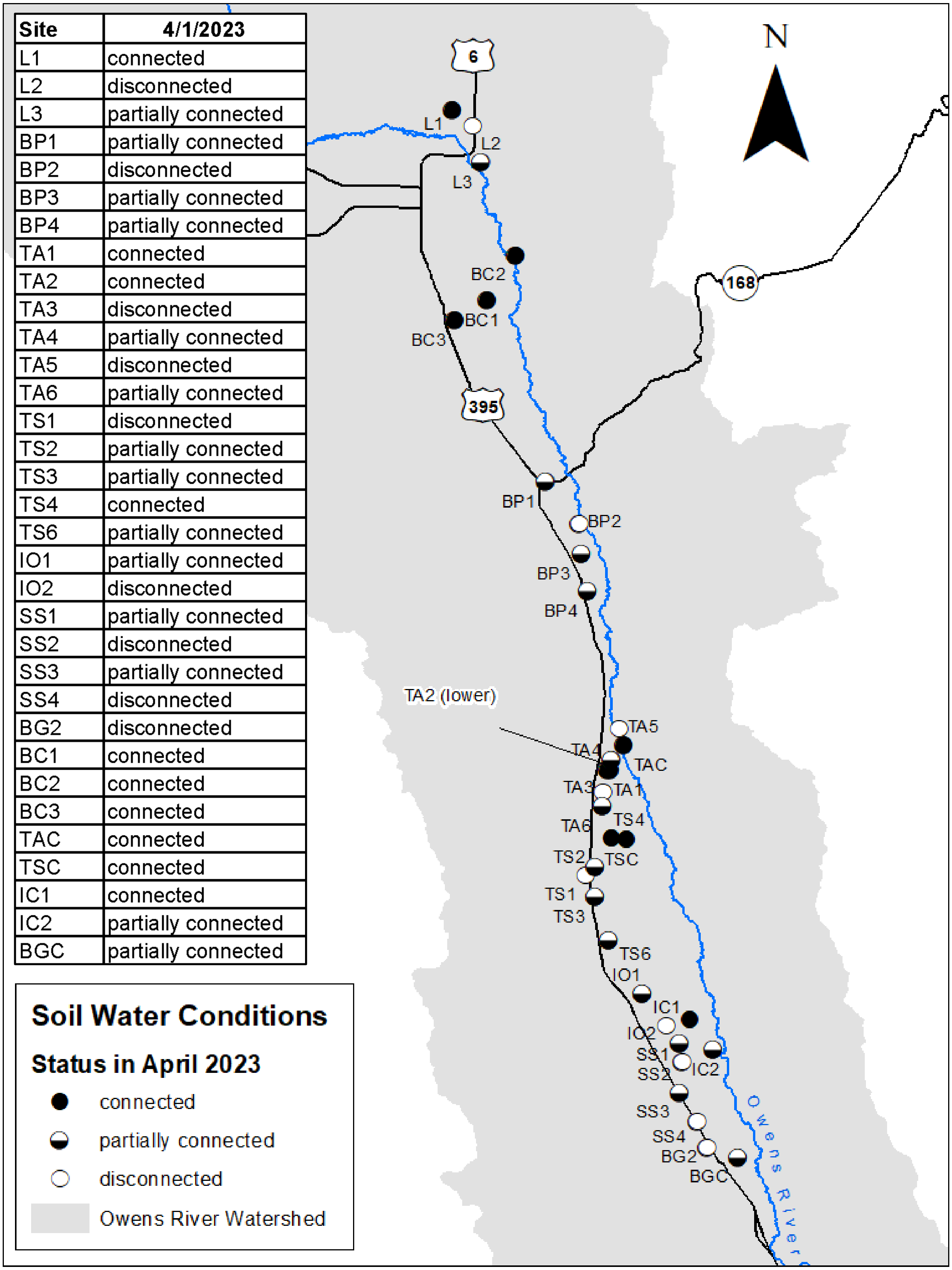
Most sites experienced some level of groundwater recharge into the root zone in 2022-23 and at greater amounts than the previous year. Soil moisture amounts, measured from April 1, 2022 to April 1, 2023, increased in all seven wellfields. Control area soil moisture also increased year-to-year.

Where possible, the monitoring sites were grouped into simple categories to summarize the connection between soil water in the root zone and the water table as of April 2023. Brief descriptions of the three categories and the results are given below:

1. **Connected:** Water table fluctuations resulted in soil water recharge in the top half of the root zone at most monitoring locations within a site. Four wellfield and six control sites were placed in this category.
2. **Partially connected:** Water table fluctuations resulted in soil water recharge in the bottom half of the root zone at most monitoring locations within a site. Twelve wellfield and two control sites were placed in this category.
3. **Disconnected:** No recharge from groundwater occurred in the root zone. Nine wellfield sites and no control sites were in this category.

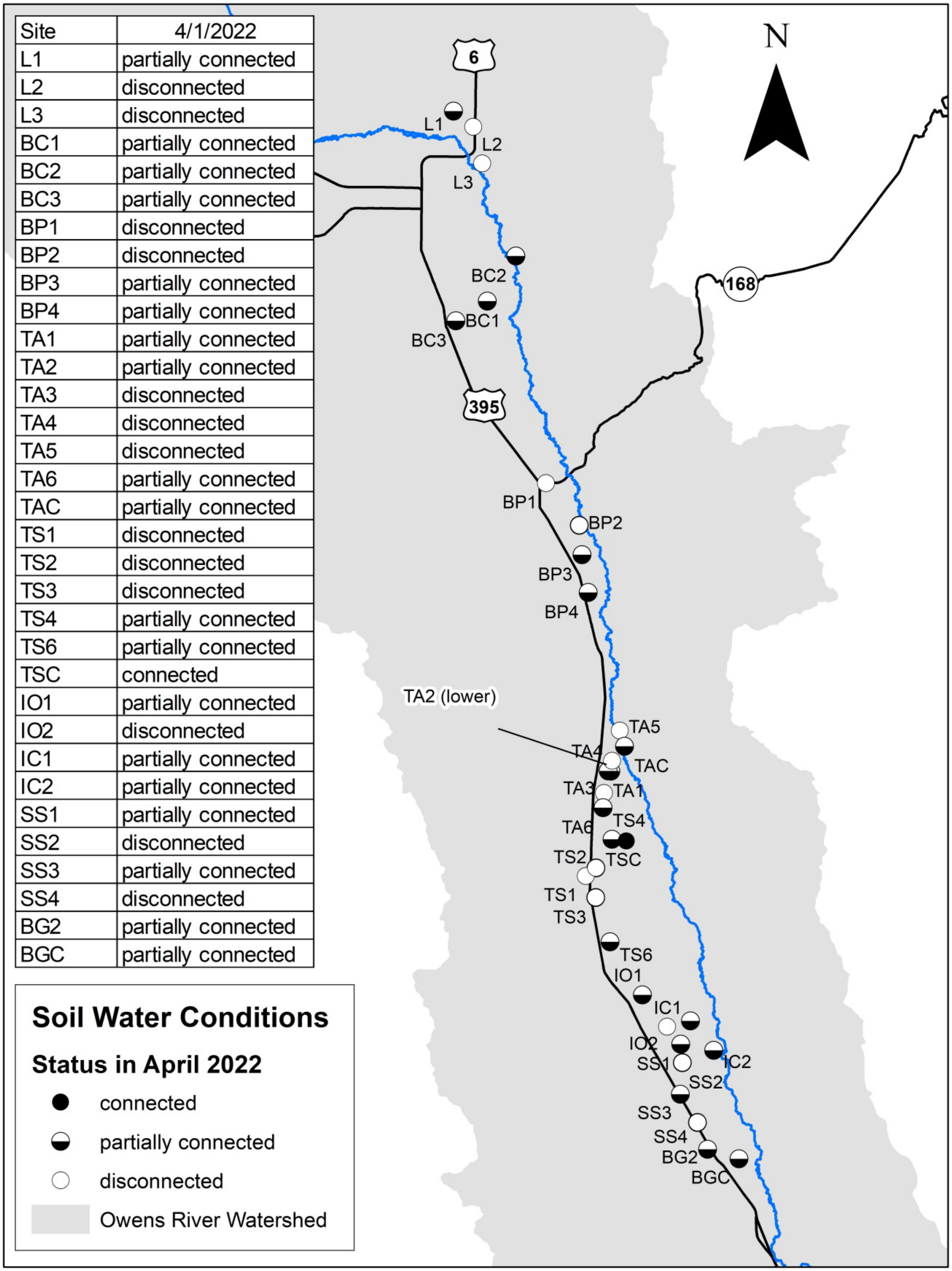
At some monitoring locations, BP2 and SS1 and SS3 for example, soil water content exhibited increasing amounts at certain depths well above the water table while lower depths showed little or no change. Water can be transported during winter from wetter, deeper soil layers through plant roots to recharge dry soil at shallower depths (Horton and Hart, 1998; Jackson et al., 2000), but without additional information, assigning that cause is speculative. The increase in water content was small and barely detectable. Regardless of the exact mechanism causing the increase in soil water, the monitoring and On/Off management was able to measure and account for that source of water.

At the beginning of the 2023 growing season (April), the water table had supplied or was capable of supplying water to the root zone at 16 of the 25 wellfield monitoring sites (Figure 1). The trend from 2022-23 was soil sites becoming “more” connected to the water table (Figure 2, previous year’s April status). Nine wellfield sites are now disconnected from the water table and have low soil moisture levels; four of these sites are categorized as alkali sacaton vegetation. The eight control sites had groundwater supplied to their respective root zones.



Site	4/1/2023
L1	connected
L2	disconnected
L3	partially connected
BP1	partially connected
BP2	disconnected
BP3	partially connected
BP4	partially connected
TA1	connected
TA2	connected
TA3	disconnected
TA4	partially connected
TA5	disconnected
TA6	partially connected
TS1	disconnected
TS2	partially connected
TS3	partially connected
TS4	connected
TS6	partially connected
IO1	partially connected
IO2	disconnected
SS1	partially connected
SS2	disconnected
SS3	partially connected
SS4	disconnected
BG2	disconnected
BC1	connected
BC2	connected
BC3	connected
TAC	connected
TSC	connected
IC1	connected
IC2	partially connected
BGC	partially connected

Figure 1. Owens Valley permanent monitoring sites and groundwater recharge classes as of April 2023. It is difficult to distinguish TA1 and TA2 on this map because of their proximity to one another. TA1 and TA2 are connected.



Site	4/1/2022
L1	partially connected
L2	disconnected
L3	disconnected
BC1	partially connected
BC2	partially connected
BC3	partially connected
BP1	disconnected
BP2	disconnected
BP3	partially connected
BP4	partially connected
TA1	partially connected
TA2	partially connected
TA3	disconnected
TA4	disconnected
TA5	disconnected
TA6	partially connected
TAC	partially connected
TS1	disconnected
TS2	disconnected
TS3	disconnected
TS4	partially connected
TS6	partially connected
TSC	connected
IO1	partially connected
IO2	disconnected
IC1	partially connected
IC2	partially connected
SS1	partially connected
SS2	disconnected
SS3	partially connected
SS4	disconnected
BG2	partially connected
BGC	partially connected

Figure 2. For comparison purposes, Figure 2 contains the Soil Water Conditions "connection" status as of the previous year (April 2022). It is difficult to distinguish TA1 and TA2 on this map because of their proximity to one another. TA1 and TA2 were partly connected.

References

Dickey, G.L. 1990. Field calibration of neutron gauges: SCS method. p. 192-201. In S.R. Harris (ed.) Irrigation and drainage. Proc. 1990 National Conference. Durango, Co., July 11-13, 1990. Am. Soc. Civil Eng., New York, NY.

Horton, J.L. and S.C. Hart. 1998. Hydraulic lift: a potentially important ecosystem process. Tree 13:232-235.

Jackson, R.B., J.S. Sperry, and T.E. Dawson. 2000. Root water uptake and transport: using physiological processes in global predictions. Trends Plant Sci. 5:482-488.

Steinwand, A.L, 1996. Protocol for Owens Valley neutron probe soil water monitoring program. Report to the Inyo/Los Angeles Technical Group, August 6, 1996.