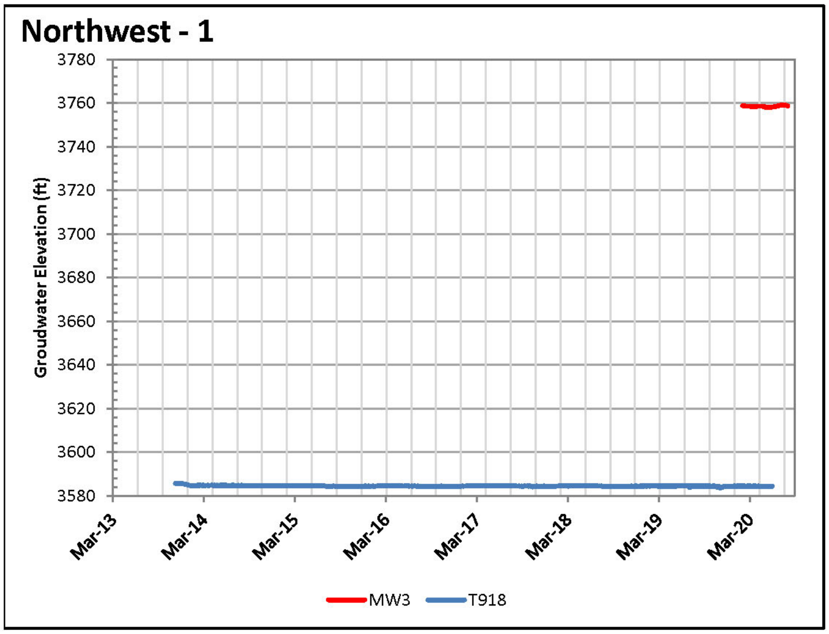
APPENDIX A

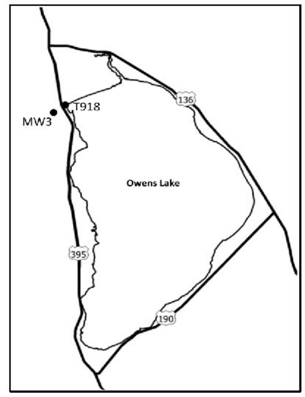
HYDROGRAPHS AND GROUNDWATER GRADIENTS (HORIZONTAL AND VERTICAL FOR KEY MONITORING WELLS

Appendix A: Horizontal Gradients

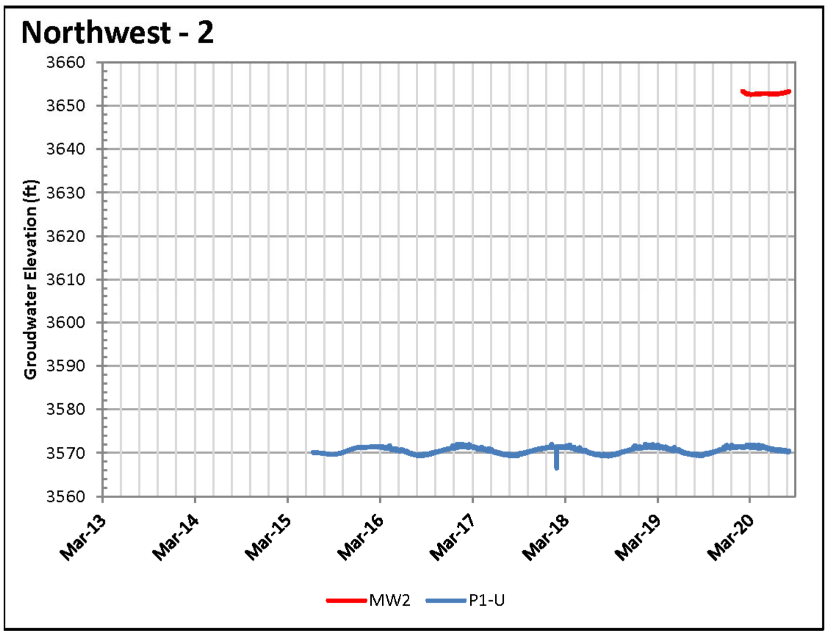
Owens Lake Groundwater Development Program

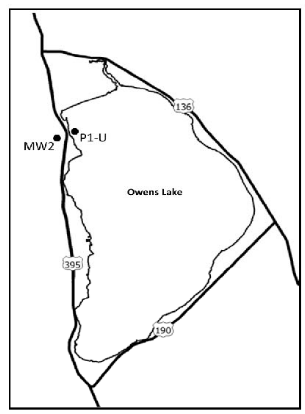
Horizontal Groundwater Gradient





*Horizontal Gradient**
174.3 feet

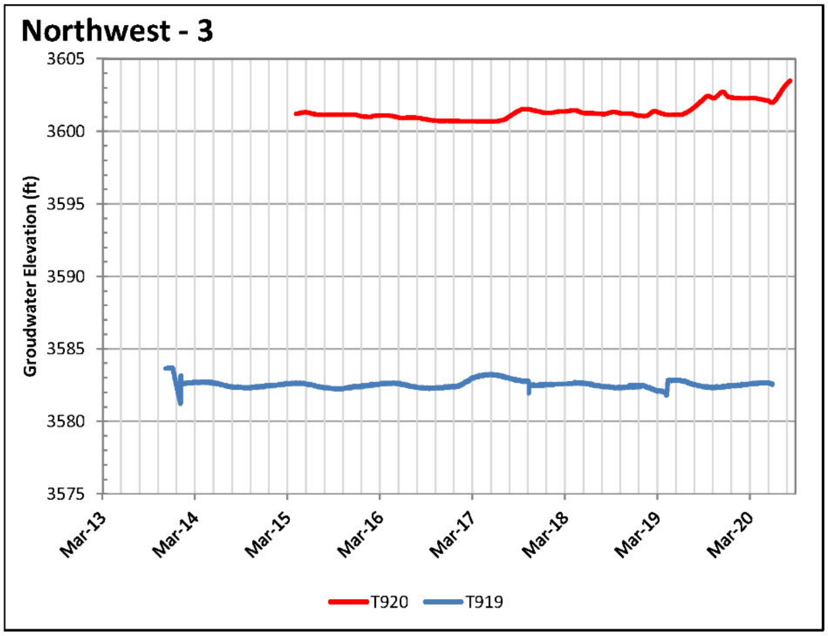


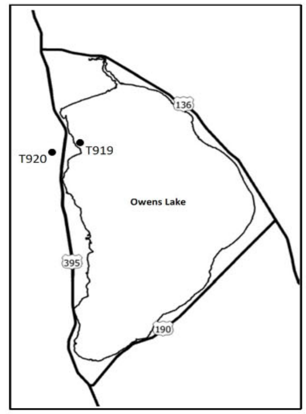


*Horizontal Gradient**
81.1 feet

Owens Lake Groundwater Development Program

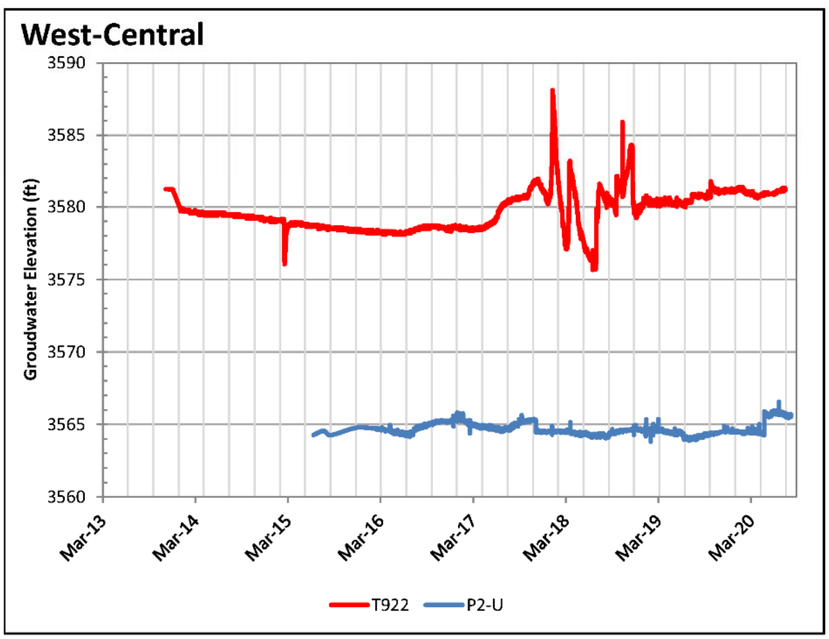
Horizontal Groundwater Gradient

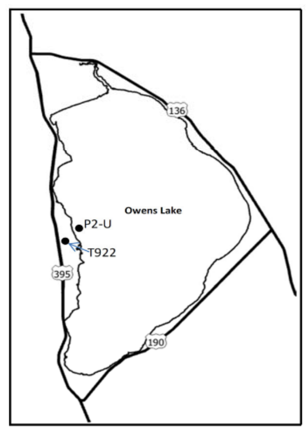




*Horizontal Gradient**

16.9 feet



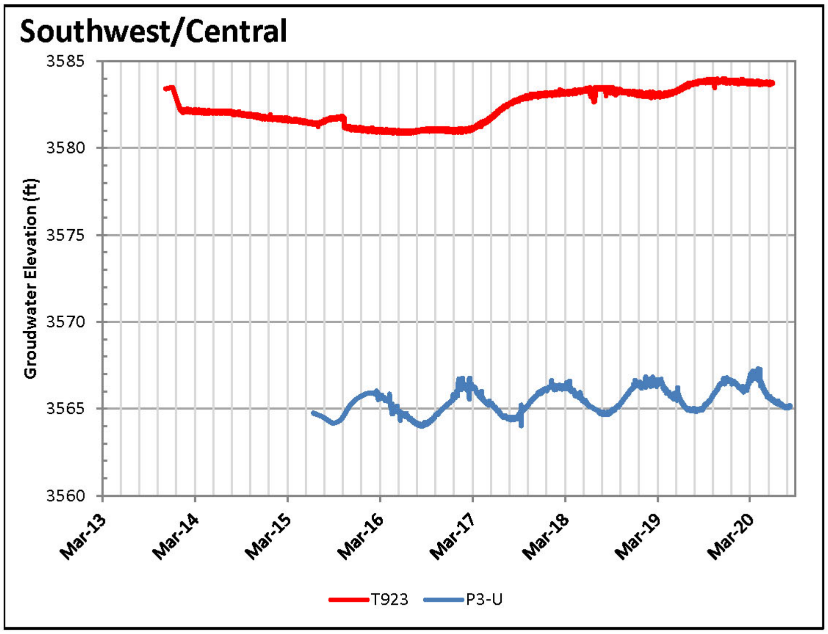


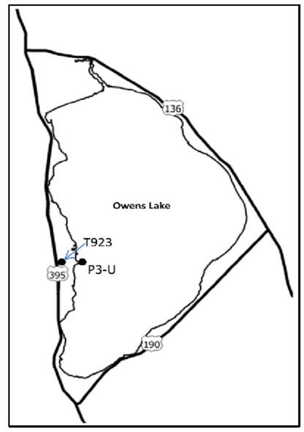
*Horizontal Gradient**

13.8 feet

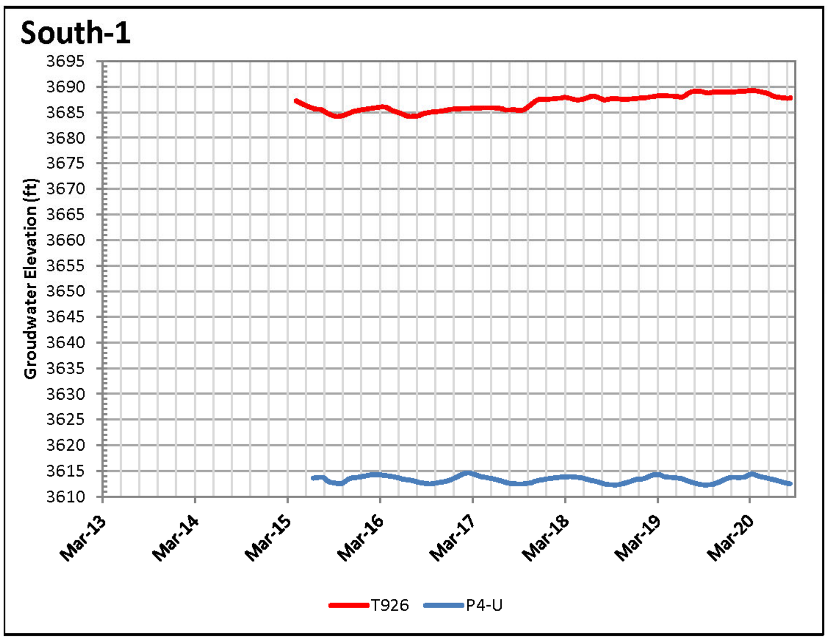
Owens Lake Groundwater Development Program

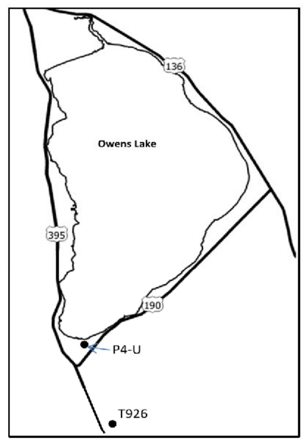
Horizontal Groundwater Gradient





*Horizontal Gradient**
17.9 feet

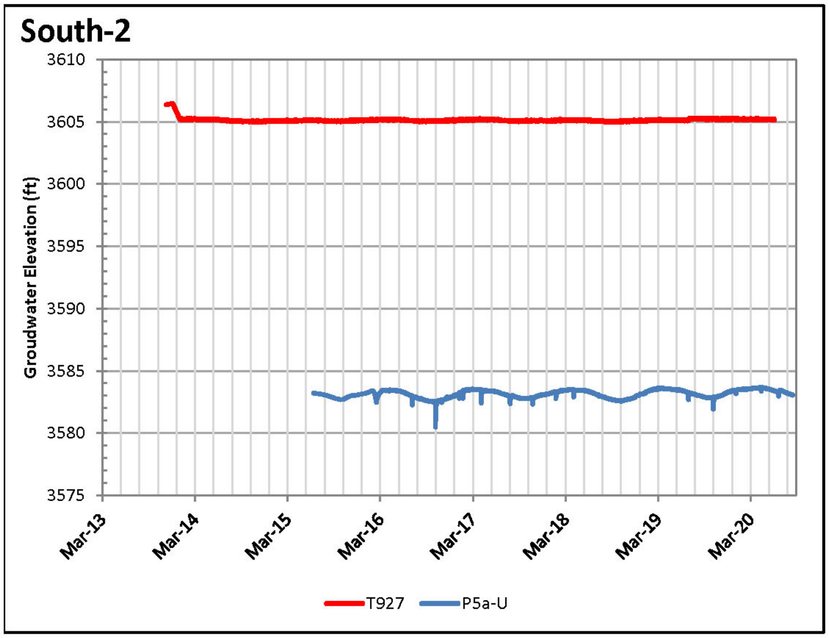


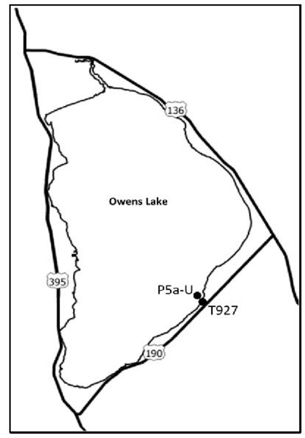


*Horizontal Gradient**
74.8 feet

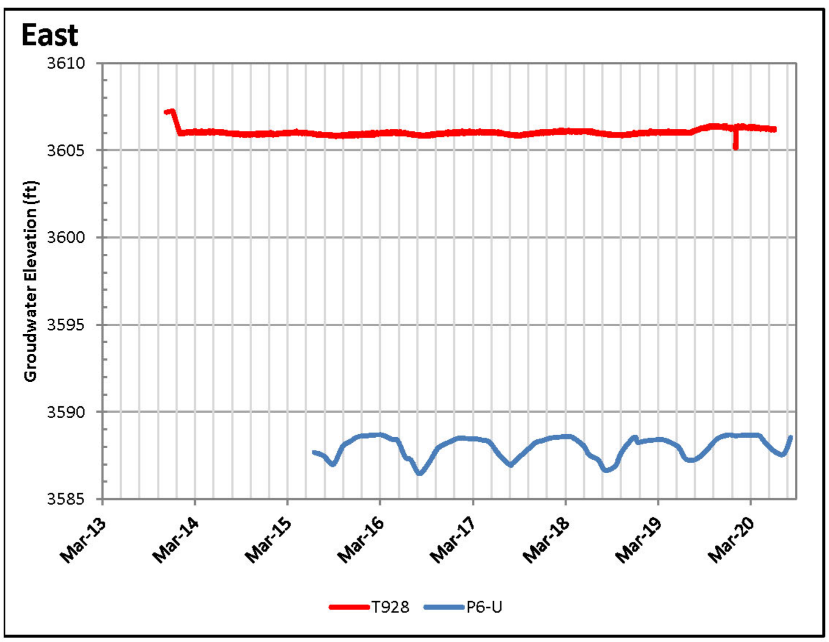
Owens Lake Groundwater Development Program

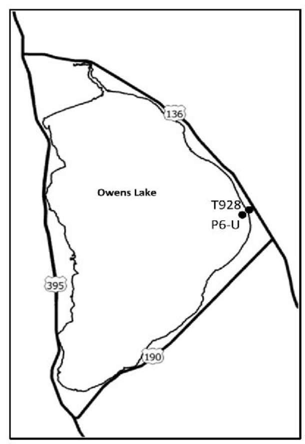
Horizontal Groundwater Gradient





*Horizontal Gradient**
20.3 feet

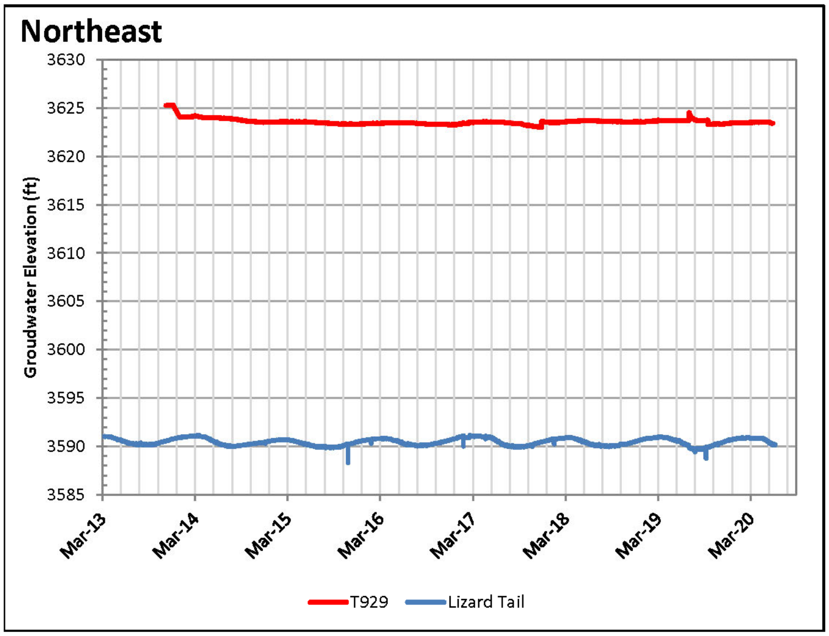


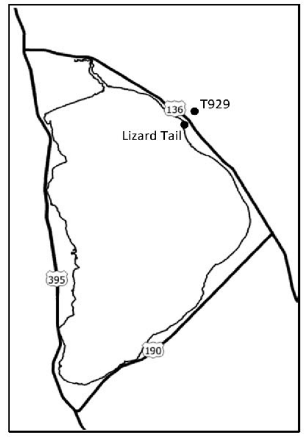


*Horizontal Gradient**
17.3 feet

Owens Lake Groundwater Development Program

Horizontal Groundwater Gradient





*Horizontal Gradient**

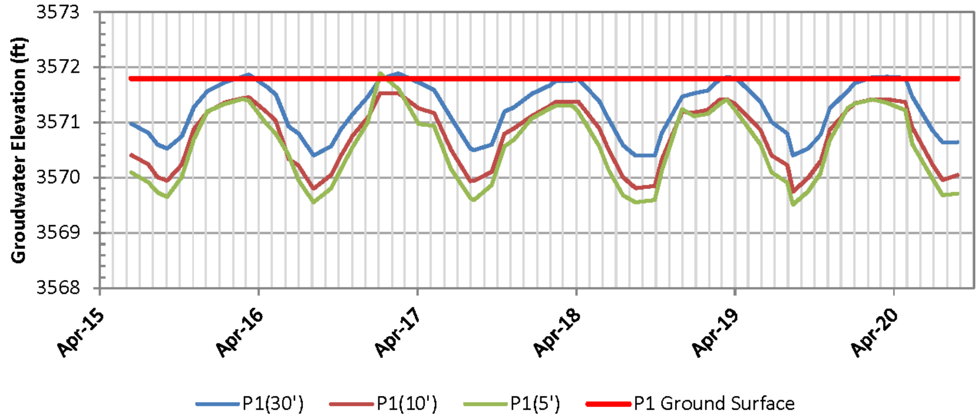
33.0 feet

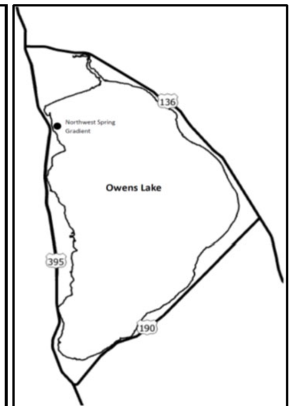
Appendix A: Vertical Gradients

Owens Lake Groundwater Development Program

Vertical Groundwater Gradient

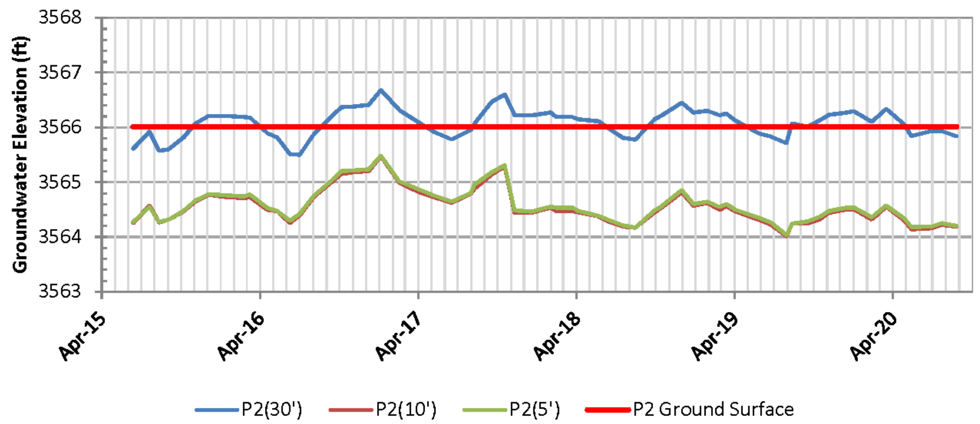
Northwest Spring





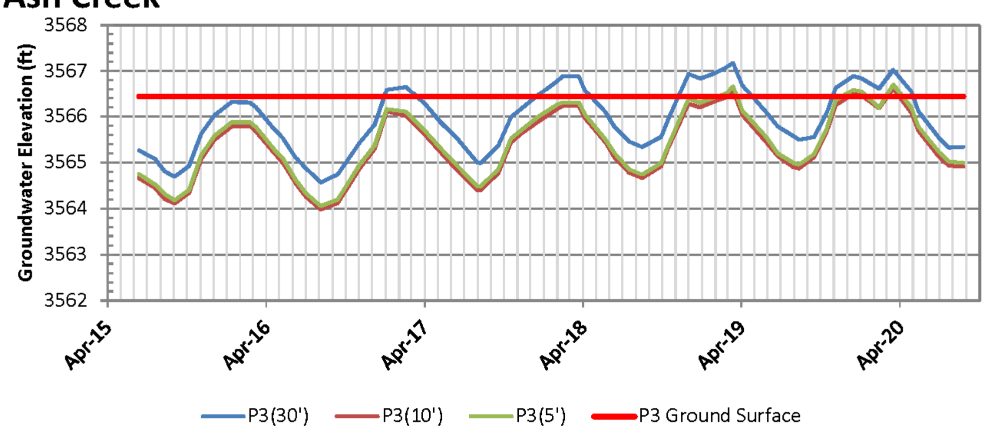
*Upward Gradient**
0.5 feet

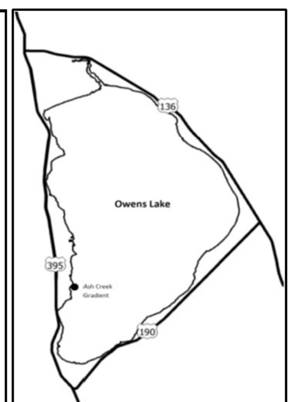
Cottonwood



*Upward Gradient**
1.1 feet

Ash Creek





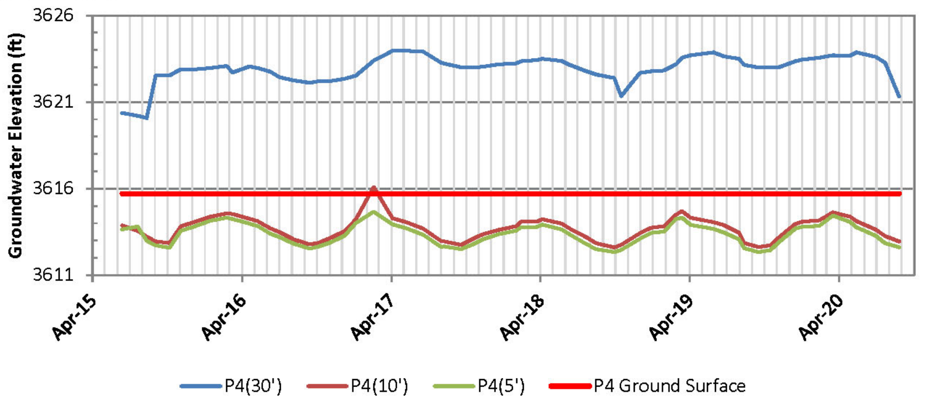
*Upward Gradient**
0.5 feet

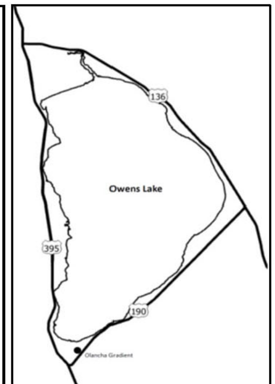
*Vertical Groundwater Gradient is the difference in groundwater level in the 30-foot deep monitoring well and 5-foot deep monitoring well at each site.

Owens Lake Groundwater Development Program

<u>Vertical Groundwater Gradient</u>

Olancha

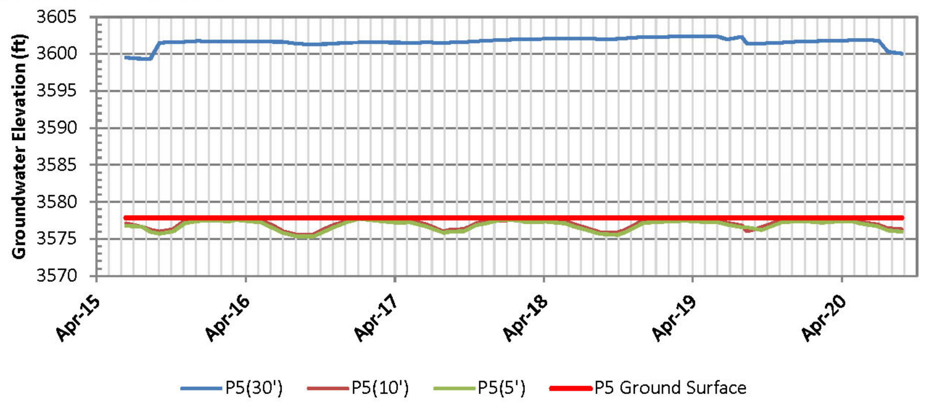


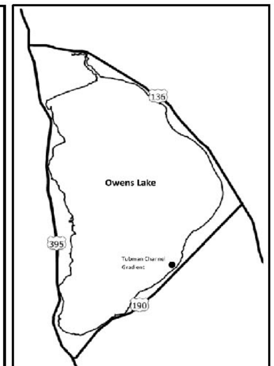


*Upward Gradient**

9.2 feet

Tubman Channel

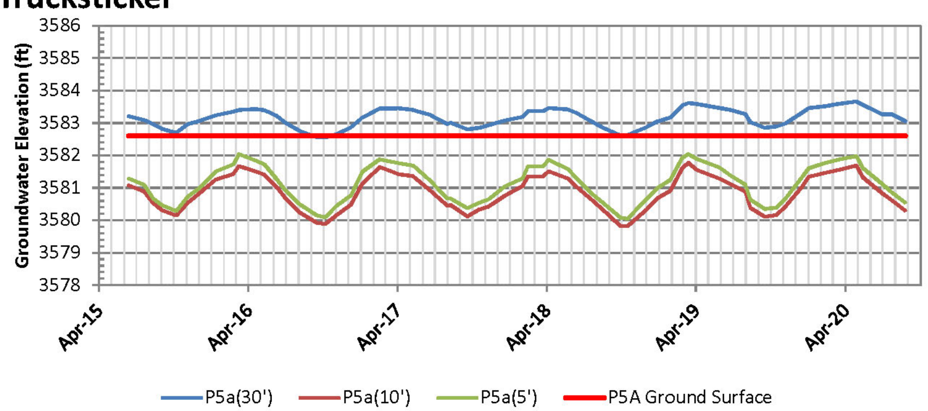




*Upward Gradient**

24.1 feet

Trucksticker



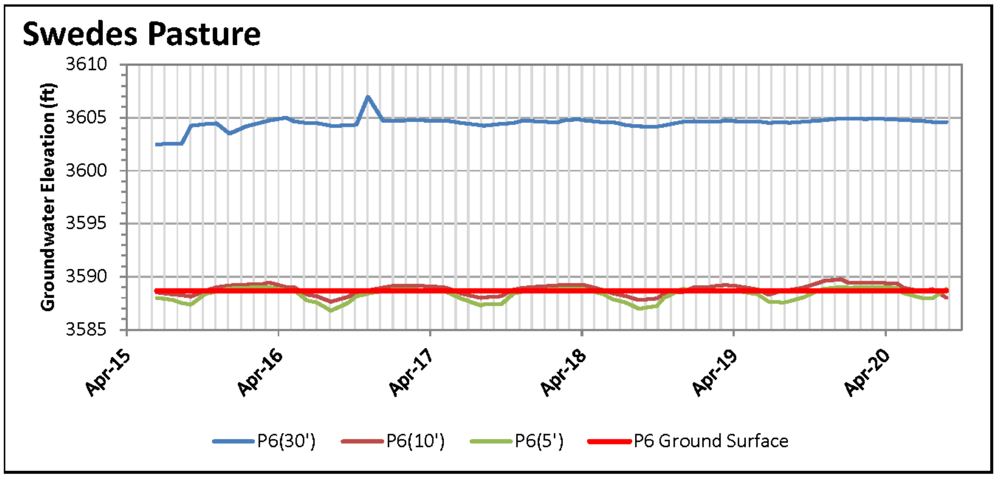
*Upward Gradient**

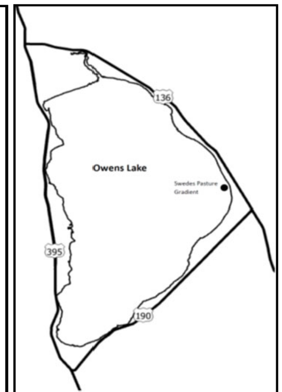
1.6 feet

*Vertical Groundwater Gradient is the difference in groundwater level in the 30-foot deep monitoring well and 5-foot deep monitoring well at each site.

Owens Lake Groundwater Development Program

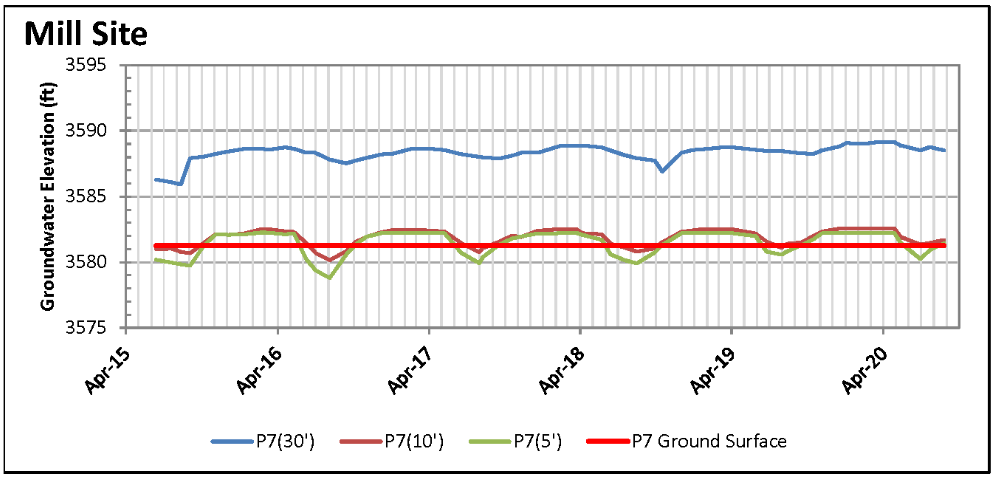
Vertical Groundwater Gradient

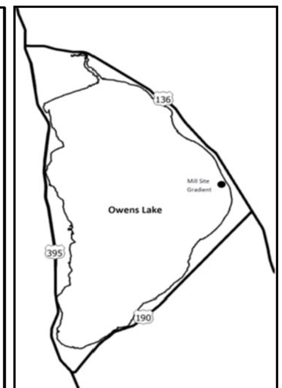




*Upward Gradient**

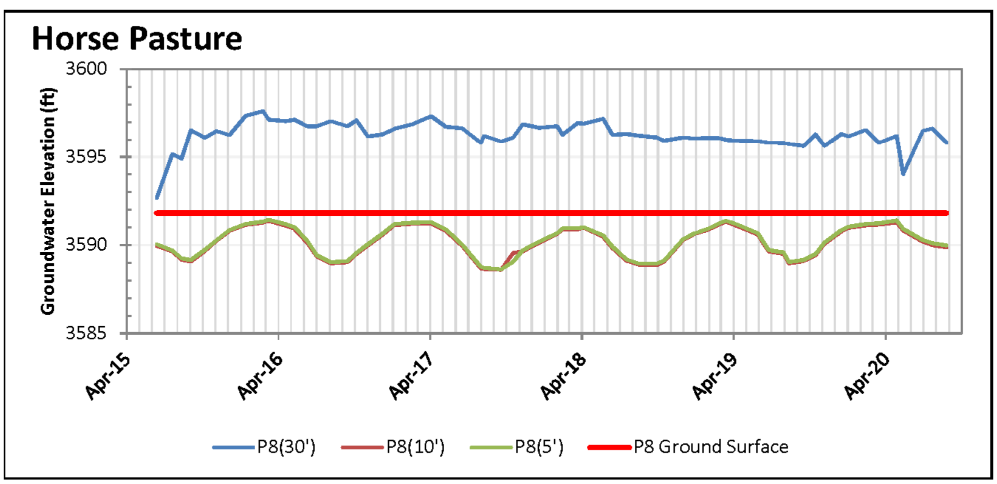
16.3 feet

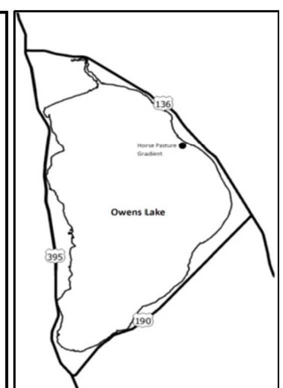




*Upward Gradient**

6.1 feet





*Upward Gradient**

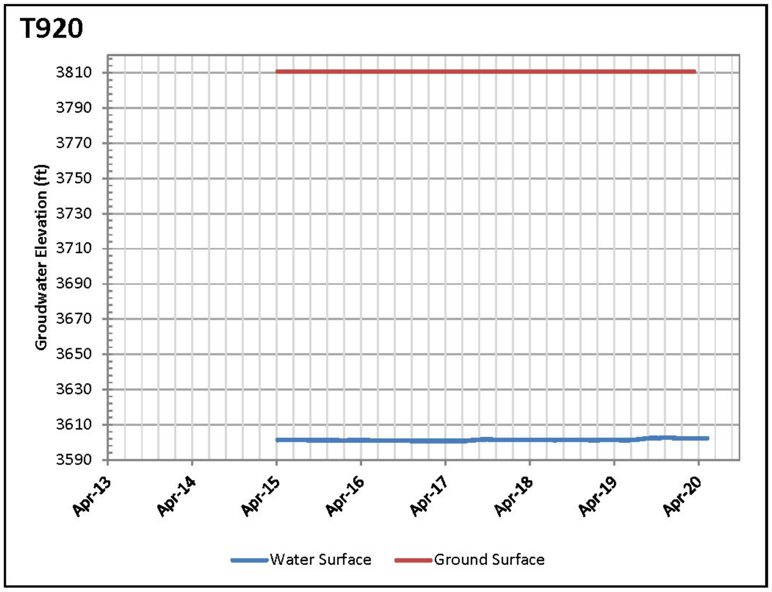
4.6 feet

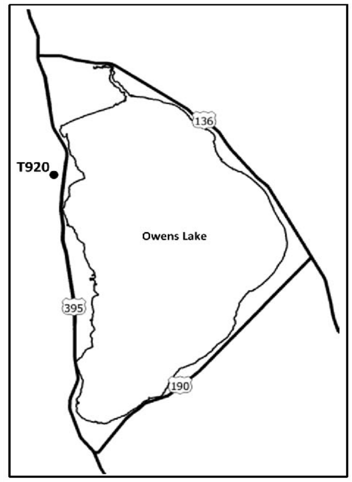
*Vertical Groundwater Gradient is the difference in groundwater level in the 30-foot deep monitoring well and 5-foot deep monitoring well at each site.

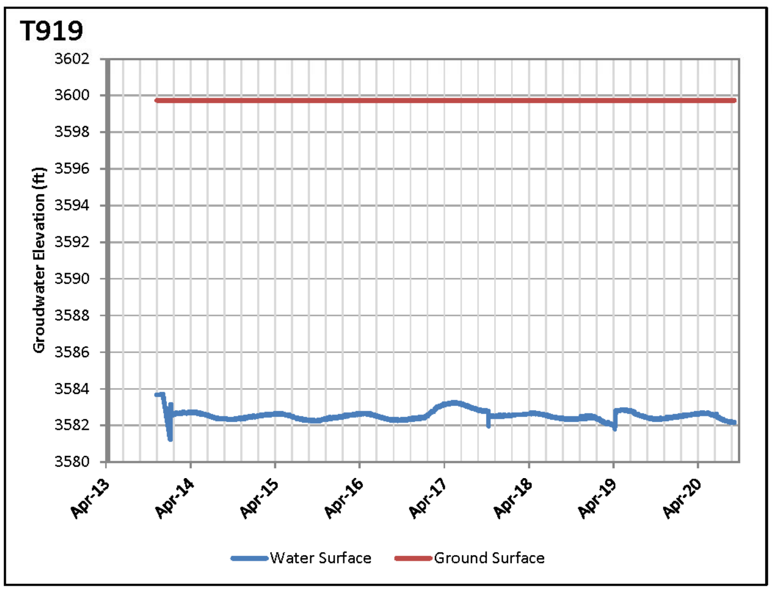
Appendix A: Trigger Wells

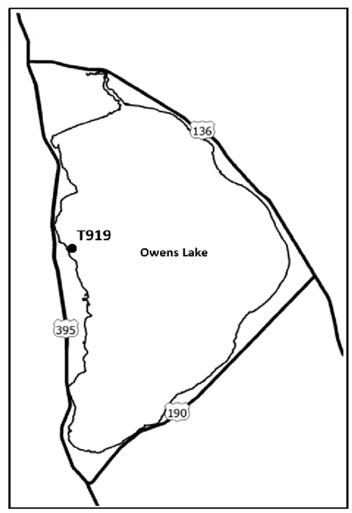
Owens Lake Groundwater Development Program

Trigger Wells



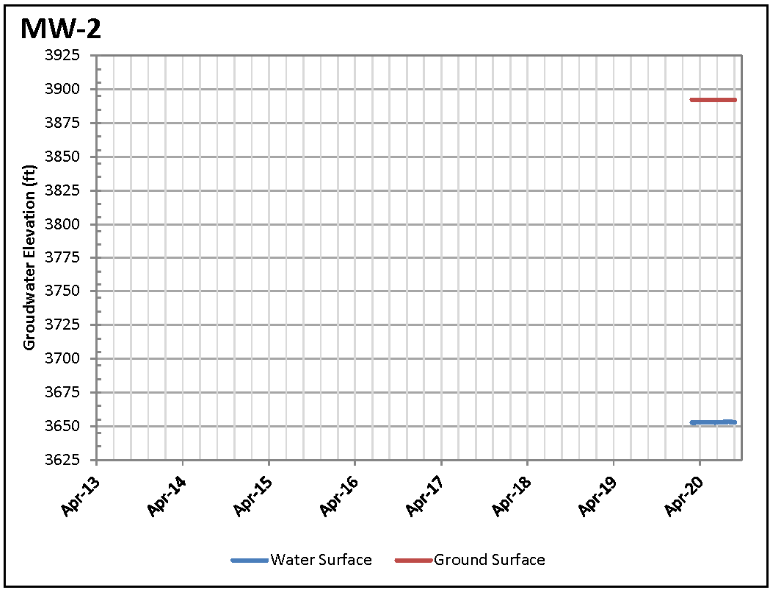


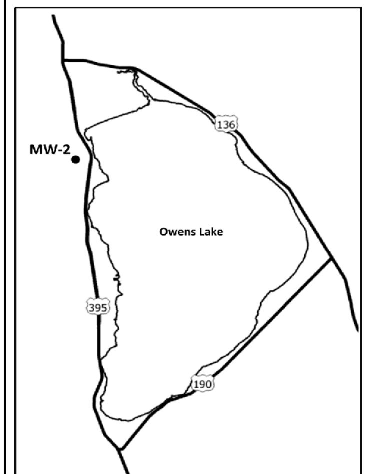


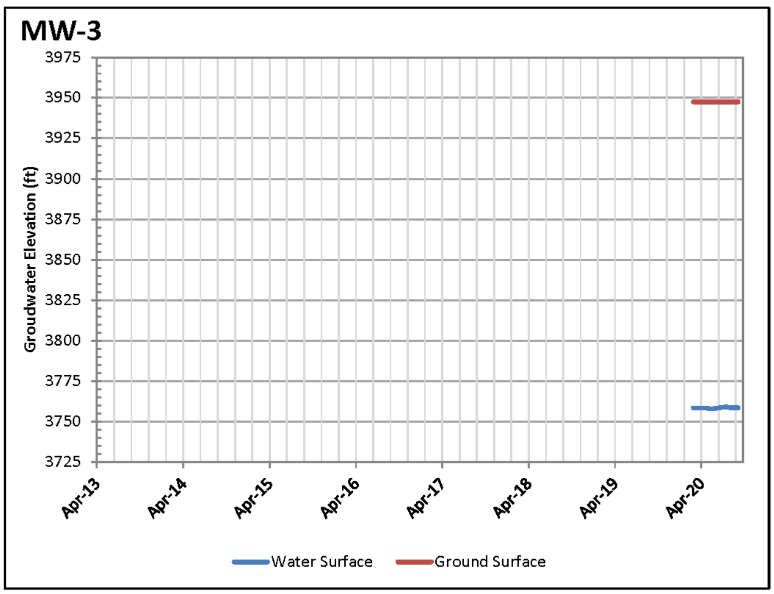


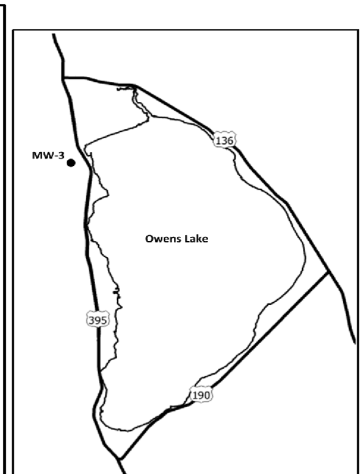
Owens Lake Groundwater Development Program

Trigger Wells



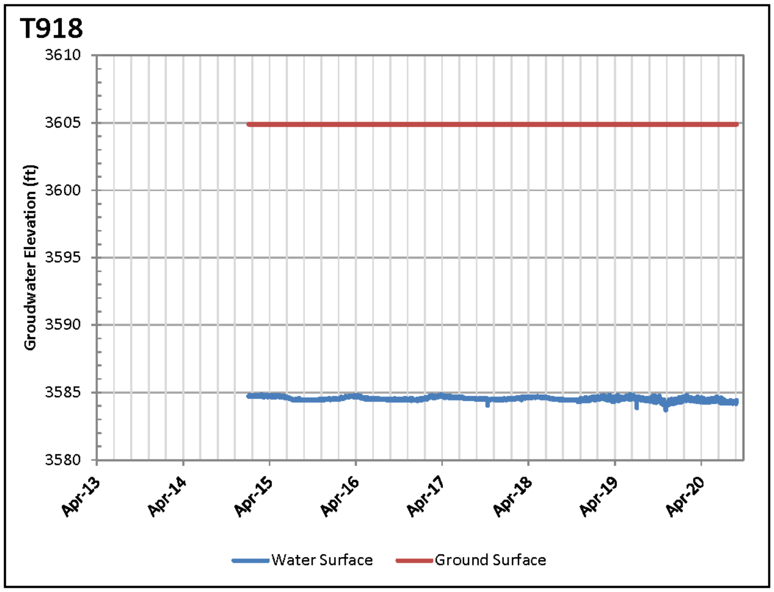


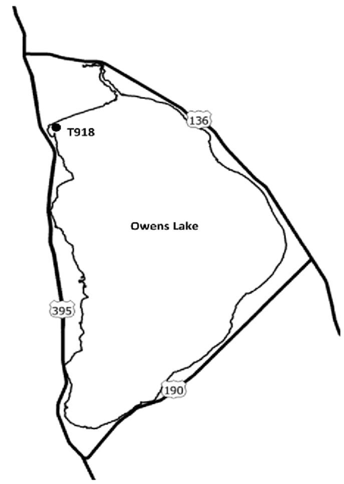


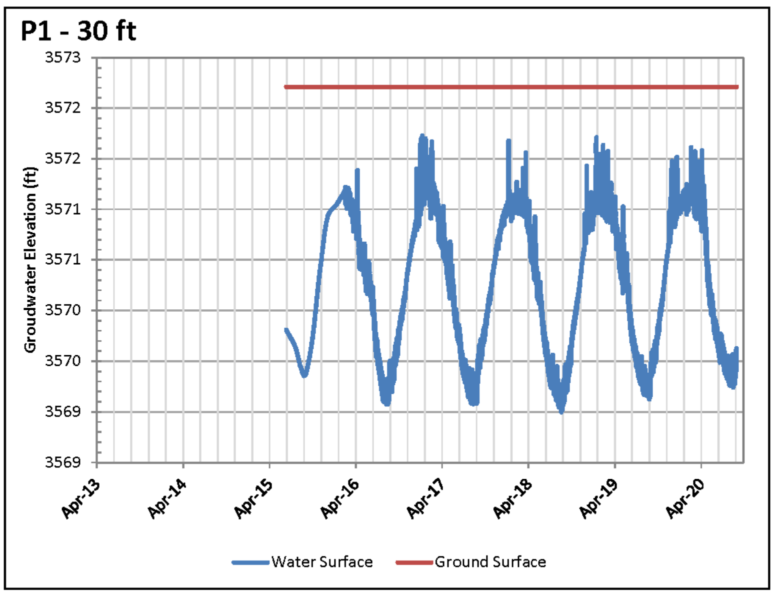


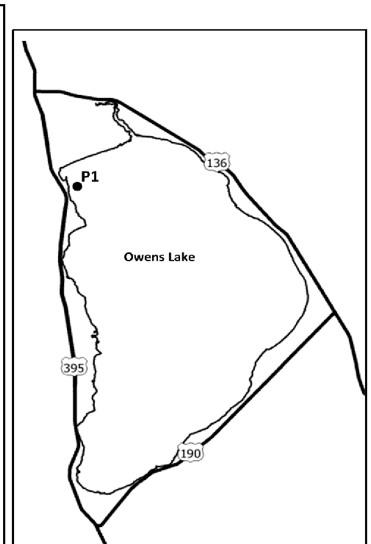
Owens Lake Groundwater Development Program

Trigger Wells



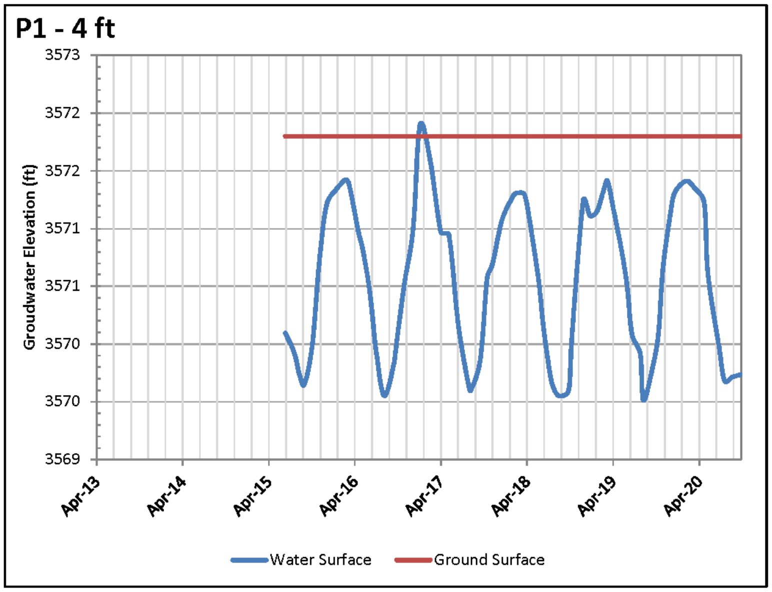


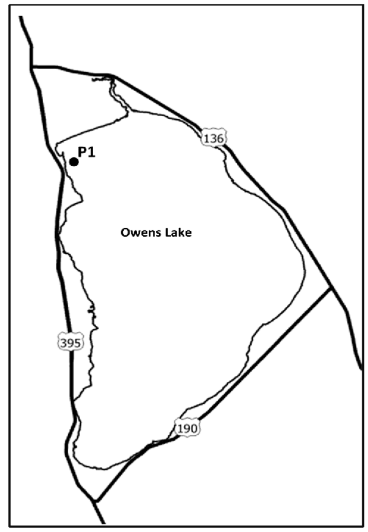


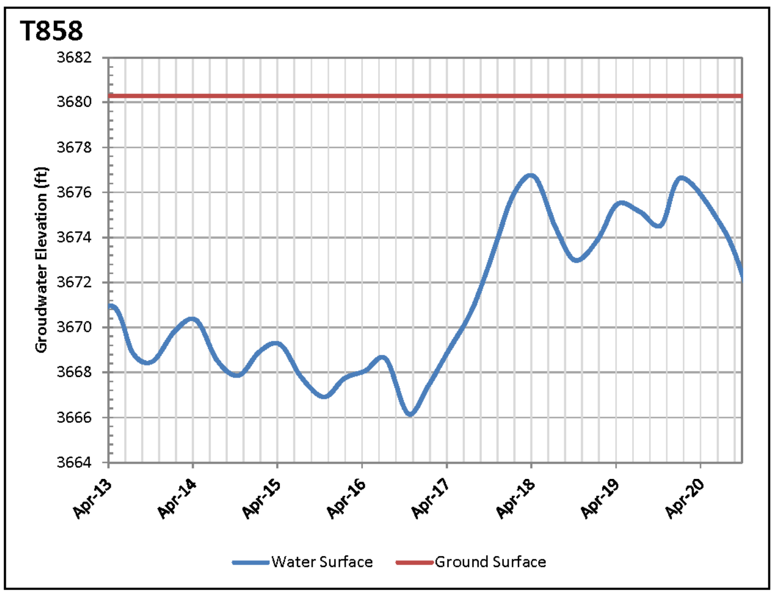


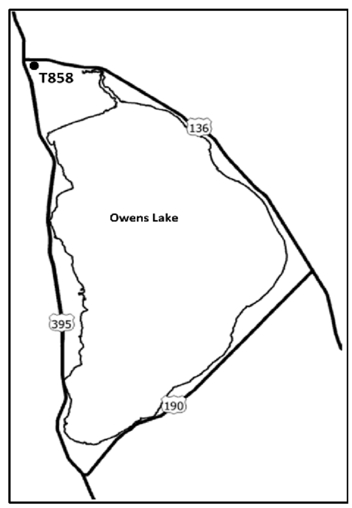
Owens Lake Groundwater Development Program

Trigger Wells



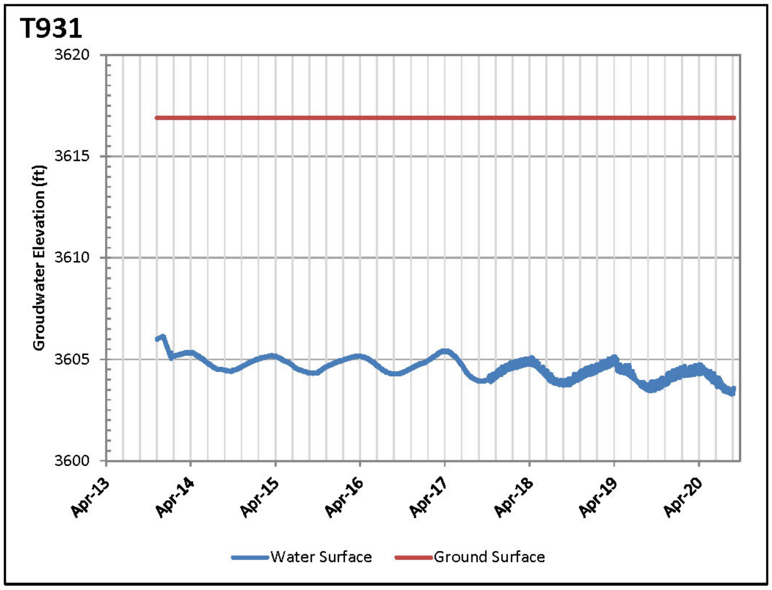


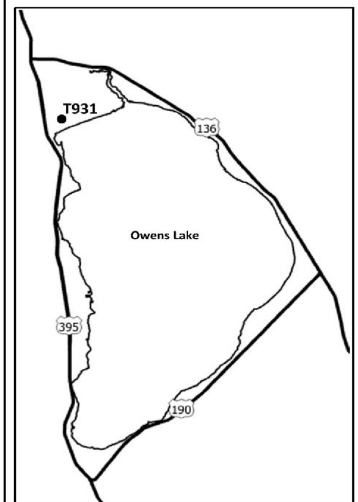


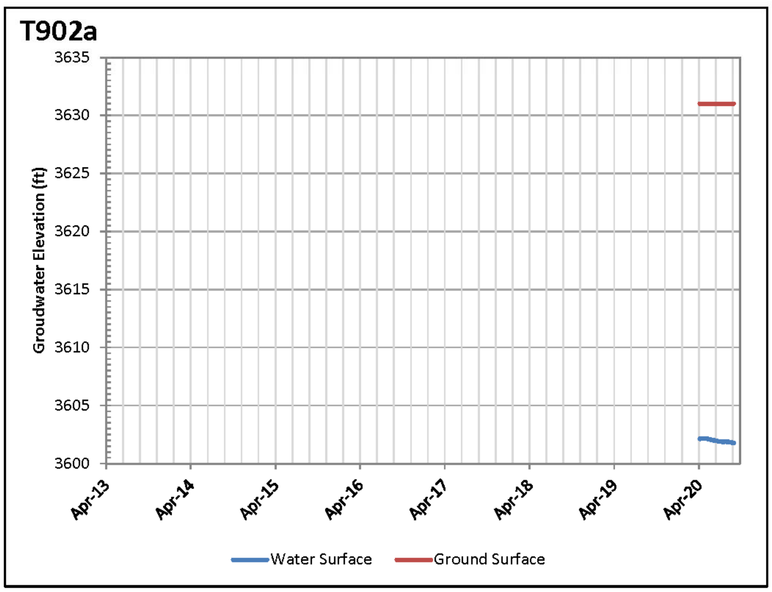


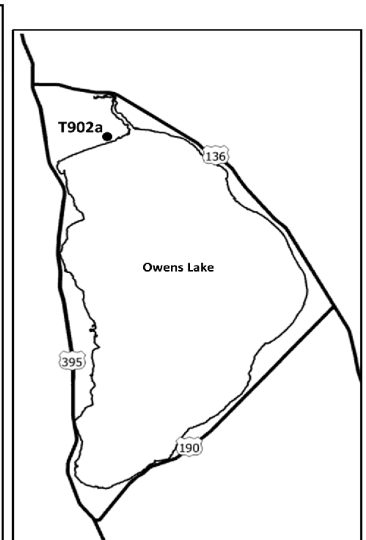
Owens Lake Groundwater Development Program

Trigger Wells



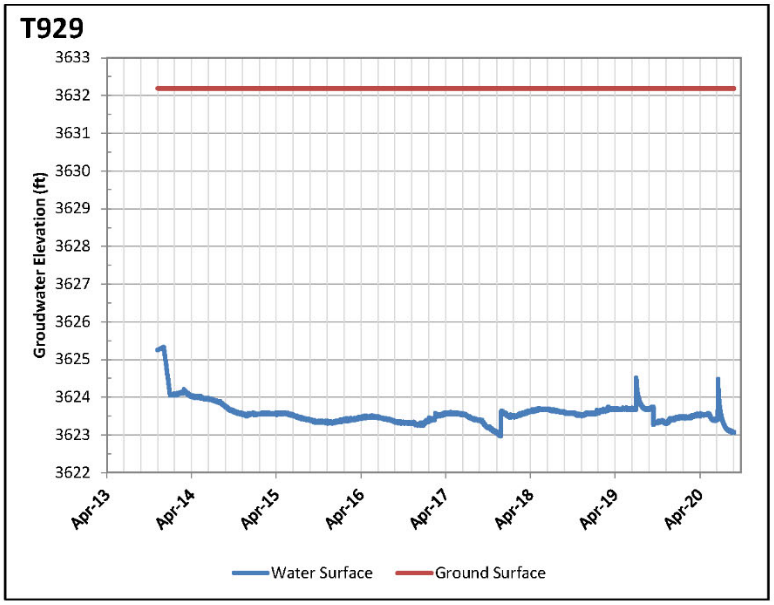


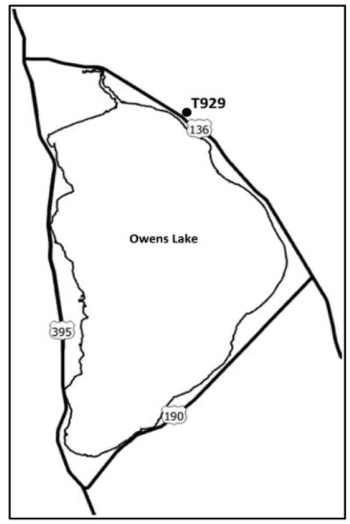


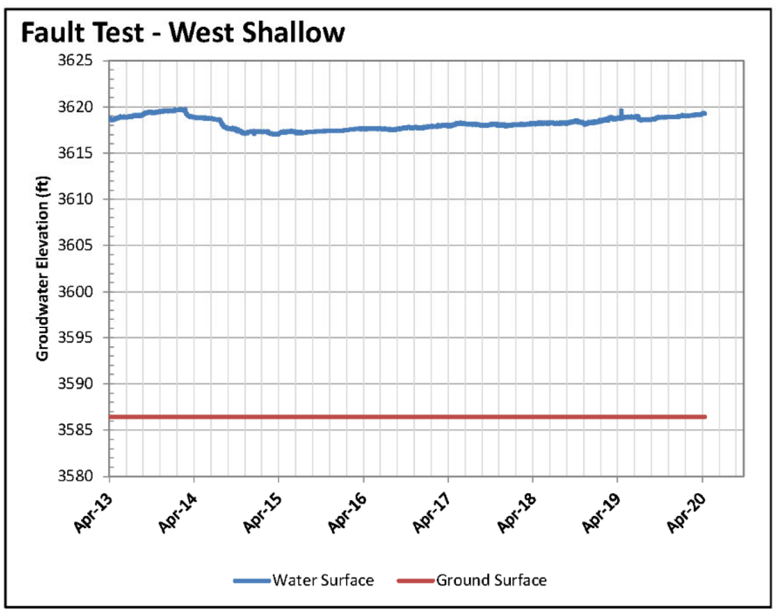


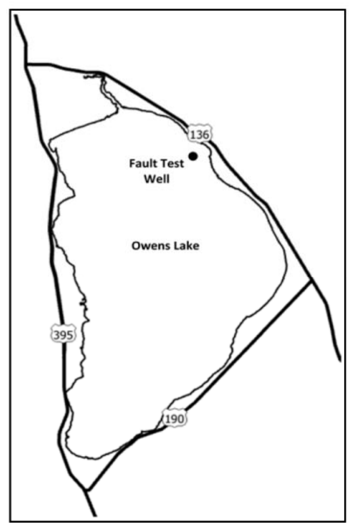
Owens Lake Groundwater Development Program

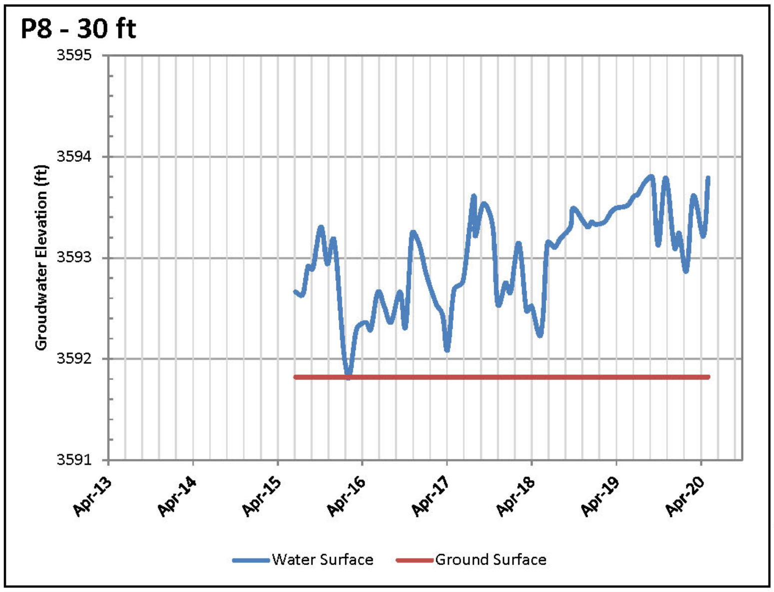
Trigger Wells

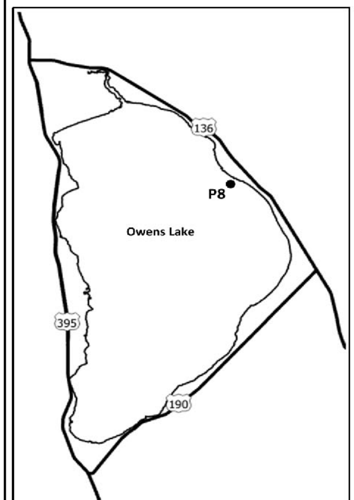


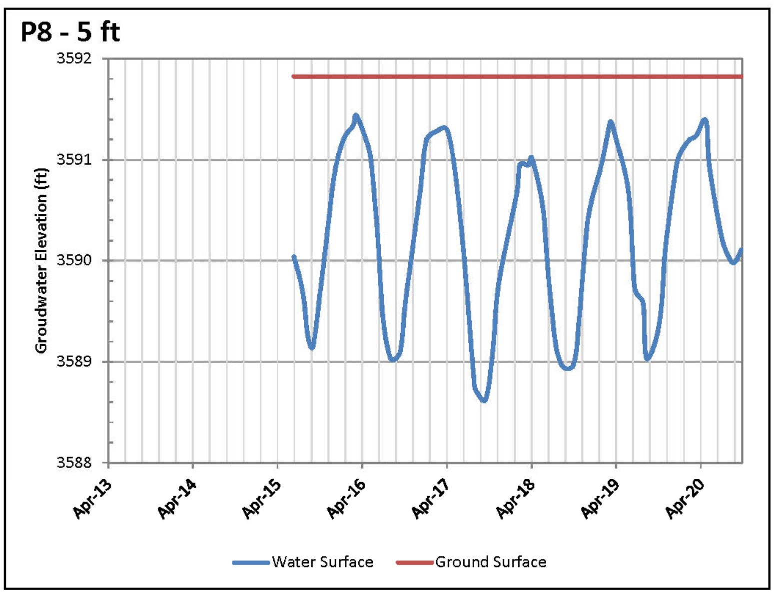


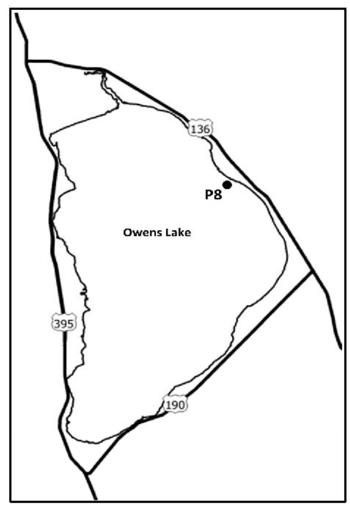





P8 - 30 ft
Groudwater Elevation (ft)
3595
3594
3593
3592
3591
Apr-13
Apr-14
Apr-15
Apr-16
Apr-17
Apr-18
Apr-19
Apr-20
Water Surface
Ground Surface


136
P8
Owens Lake
395
190


P8 - 5 ft
Groudwater Elevation (ft)
3592
3591
3590
3589
3588
Apr-13
Apr-14
Apr-15
Apr-16
Apr-17
Apr-18
Apr-19
Apr-20
Water Surface
Ground Surface


136
P8
Owens Lake
395
190

APPENDIX B

Groundwater Access and Use by *Sarcobatus* from Published Papers and Two Monitoring Wells at Owens Lake

Note:

The following table is designed to be printed on a 11X17 inch pape

Reference	Study Area	Period	Groundwater Depth	Avg. ETa (cm)	Avg Precip (cm)	Avg. ETa-Precip (cm)	Daily Water Table Oscillations	Groundwater Change Over Period	Groundwater Seasonal Change	Relationship to Plant Cover/Health/Stress	Rootzone	Conclusions
Robinson 1970	Tank expts near Winnemucca, NV	1963-1967					Observed and used to calculate GW seasonal change		*Sarcobatus* transpires 0.18-0.24 m / yr of GW			Seasonal GW use up to 24 cm
Nichols 1994	Six Great Basin sites in Nevada with 95% *Sarcobatus* vegetation (plus 1 site with sagebrush/rabbitbrush); 1192-1845 m elev	1989-1992	1.7-6.4 m; one site had GW depth of 5.8 m but perched saturated zone at 2.7 m					End of season GW depth was measured and ranged from 1.7-6.4 m	With GW at 1.8 to 12.2 m depth and equivalent plant density of 0.25 estimated GW use for 100 d period from late June-early Sept was 30.8 to 2.4 cm, respectively.	Greater cover increased GW use	Rooting depths constrained by GW but up to a maximum of 18 m	Seasonal GW use during summer depends on depth to GW and plant density. Up to 30.8 cm use reported for 100 day period with GW at 1.8 m depth.
Devitt et al. 2011	Snake Valley, Spring Valley, White River Valley, NV; 1564-1762 m elev range; 13-62% total cover (12-100 % *Sarcobatus*; other species included rabbitbrush, sagebrush, shadscale, saltgrass); Note that one irrigated pasture (SV2b) is not included in this summary	2005-2007	12.2 -24.4 m wells; screened 3 m at first encountered GW	14.9 (growing season)	2.1 (growing season)	10.7 (does not include vadose zone stored water from non-growing season precip)	3 cm daily in some growing season months and sites	4.64-9.31 average depth across sites for 2006-2007 period; net change not reported)	Decline during growing season from late May-early September averaged 6 cm/mo. At Snake Valley sites 18 cm decline was found from late June-early Sept (2.25 mo; Fig 4)	"ET rates in 2007 were highly correlated with the percentage cover of greasewood (R^2 = 0.96), regardless of the depth to groundwater." Comparing a high precip (2005) versus low precip (2007) year at the Spring Valley site showed similar end of season stress levels of ~-4.4 MPa in August but much lower stress in the wet year in May (Fig 5). Differences in GW depth among sites did not show up as large differences in stress levels	Despite variation in GW depth from 4.6-9.3 m across sites all had ET in late summer related to *Sarcobatus* cover. This, plus observations of daily oscillations and *Sarcobatus* stress levels, suggests that this species was effective at rooting to capillary fringe at all sites, up to 9.3 m or more (see Devitt and Bird 2016 for data to 10.75 m).	Midday leaf water potential declined seasonally showing "that whatever groundwater extraction was occurring, it was not adequate to offset stress during the later periods of summer." ET was highly correlated to *Sarcobatus* cover, regardless of depth to GW. Seasonal variation of up to 30 cm possible during growing season GW decline (6 cm/mo x 5 mo) or 18 cm in 2.25 mo.
Devitt and Bird, 2016	Snake Valley NV; 1564 m elev; 13% cover (100% *Sarcobatus*)	2007-2013	12.2 m well; screen 6.2-12.2 m	22.34 (annual total; eddy co-variance)	14.57 (annual)	7.77; greater GW extraction in low precip years (range of seasonal ET provided by GW ranged from 12-55%)	Observed Sept 2007 (7 days) and Oct-Nov 2013 (32 days); range 1-5 cm/day; daily oscillations ceased with leaf senescence in early Nov 2013; observation of oscillations depended on texture i.e. sandier aquifer with higher specific yield prevented observation of oscillations for 2225 days between 2007 and 2013. Oscillations re-appeared when GW surface crossed a textural boundary into less sandy aquifer with lower specific yield.	9.2-10.7 m depth (1.5 m decline based on Fig. 1, but 1.3 m based on text statements); decline due to GW pumping for alfalfa irrigation 2.36 km away; Precip actually increased during this period	Average decline was 22.2 cm/yr over 6.2 yr period	"Observations of plant cover/health indicated no negative changes during the late summer periods of 2007–2012" despite a 1.3 m decline in GW	"Rootzone for greasewood at our site extended to at least a depth of 10·75m. All of our findings, including the groundwater oscillations, deep unsaturated zone extraction and shifts in soil water in storage based on precipitation support a very flexible and dynamic utilization of multiple water sources by greasewood."	"Our results indicate that a decline in the groundwater level of 130 cm over 6.2 years did not exceed the ability of greasewood root systems to adjust and that a depth of 10·7 m did not represent a physiological maximum for rooting depth at our site"
Wagner et al. 2018	Spring Valley, NV; 1756 m elev; total cover 45% of which 19% was *Sarcobatus* and 71% sagebrush	mid-June-mid-Oct; year not given	5.5-6.0 m below surface from mid-June to mid-Oct	22.63 (April-Sept)	8.92 (April-Sept)	13.71 (April-Sept)		0.5 m decline from mid-June to mid-Oct partly due to GW pumping for alfalfa irrigation but also due to GW use by plants	0.5 m decline from mid-June to mid-Oct partly due to GW pumping for alfalfa irrigation but also due to GW use by plants	Isotope analyses of precip, vadose zone water, groundwater, and shrub stem water showed that *Sarcobatus* shifted from 30 % GW use in July to 2 % in Sept suggesting at this site that it was not acting as a phreatophyte in late summer; Conversely, *Sarcobatus* shifted from using deep, vadose zone water (90-180 cm depth) at 38% in July to 97% in Sept. This saline soil moisture could be used by *Sarcobatus* because of its salt tolerance but was not extracted by the less salt-tolerant sagebrush and rabbitbrush. Leaves of *Sarcobatus* had midday water potentials as low as ~ -5 MPa by July and remained at this level through end of September.	To 6 m for *Sarcobatus*; other shrubs more restricted to vadose zone above high salinity layer at 140-180 cm depth	*Sarcobatus* decreased GW use in late summer and increased uptake from a saline, vadose zone layer at intermediate depth (90-180 cm). "Greasewood demonstrated plasticity in accessing different water sources" over time.
Elmore et al. 2003	Owens Valley	1984-1998	171 monitoring wells		13			variable from none to more than -7 m		For shrub communities the relationship in Fig 7b shows a possible loss of 25.5 % cover with a 7 m decline in GW level from 1986-1992 during an extended precipitation drought period	Variable among communities and locations.	Based on Fig 7b, a decline of 1.1 m in GW level from 1986-1992 would be needed to produce a detectible change in live cover (given the error reported of +/- 3.8 %). Smaller changes in GW level (over multiple years) are unlikely to cause any detectible change in cover of GW dependent shrub communities.
Steinwand et al. 2006	Owens Valley; sites used for this summary are shrub dominated sites, especially desert shrub sink (DSS communities dominated by *Sarcobatus* and rabbitbrush or saltbush dominated communities)	2000-2003	Access tubes installed in spring and nearby piezometers for determination of fluctuations	Growing season (26 Mar-15 Oct) ET for DSS sites were 108 and 205 mm for 2002 and 2003 (wetter preceding winter), respectively	10-15	For shrub dominated sites GW supply to growing season ET was 21-33% or 11-51 mm; For 4 shrub dominated communities growing season GW use per unit spring maximum LAI ranged from 40-140 mm	Yes, but not reported for DSS communities	3.9-4.1 m for scrub sites with connection to GW; Similar spring GW depth at the beginning of each year	Seasonal decline from spring to fall; in low cover scrub communities up to 20 cm seasonal change was observed	Fig. 7 shows GW use (annual ET - precip) increasing from 50 - 840 mm as cover increased from 10 -70% and decreasing from 840 - 50 mm as depth to water increased from 0 - 5 m.	GW use per unit spring maximum LAI varied 10 fold from ~40 to 400 mm as GW depth varied from > 5 to 1.3 m across sites, respectively (Fig 6)	Growing season daily fluctuations could be an indicator of GW use (but see Devitt and Bird 2016 who suggest this is influenced by aquifer texture and specific yield). Estimates of annual ET minus precipitation (i.e. GW use), as shown "in Fig. 7 could substitute for poorly defined or arbitrary functions in models for regions dominated by these plant communities.
Trent et al. 1997	Eagle Valley, NV. 1234 m elev	1991-1992	Eight 3-m- deep, perforated access tubes were monitored monthly		11.5 cm (1991 =14.6 cm and 1992 = 9.6 cm)		Not determined (monthly observations only)	1991 May -Oct GW declined from 1.7-2.5 m; By 1992 Jun GW was > 3 m	0.8 m decline during first season;	*Allenrolfea* and *Sarcobatus* maintain similar leaf xylem potentials from a low-precipitation year with a water table depth remaining above 3 m to a dry year when the water table drops below 3 m.	Most roots in 30-60 cm deep soils but some to 150 cm. GW EC ranged from 18-25 dS/m, well within tolerance of both shrub species.	"Years of high soil moisture result in low water- use efficiencies [for both shrub species]. In contrast to this, plants have the ability to reduce leaf conductance and increase water-use efficiencies in low-precipitation years. This allows the plants to maintain predawn and afternoon water potentials, which vary little from high- to low-precipitation years in these saline environments."
Toft 1995	Mono Lake, CA; 1966 m elev.; *Chrysothamnus nauseosus* ssp. *consimilis* was monitored in an area co-dominated with *Sarcobatus*; *Sarcobatus* not censused because of difficulty in determining genetic individuals.	1983-1992	Clover test hole 2 (LADWP well 55) and the Dreiss test hole 5A and Mono Lake elevation		16.0 cm		Not determined (monthly or less frequent observations only)	1983-1985 declined ~ 1 m; 1986-1992 during major drought period GW declined another 1.4-1.7 m (Fig 3 D & E)		1983-1985 with GW decline of 1 m resulted in no mortality and no decrease in canopy size; 1986-1992 with further GW decline some mortality and reduced growth began in 1987 but reached maximum only after several years of GW decline (Fig 3 A & B). Smaller shrubs and shrubs growing higher on dunes (farther from GW level) had greater risk of reduced growth or mortality.	Rooting depth up to 6 m, estimated.	"Thus, the larger the shrub, the less the risk it had of dying during the study. To a lesser degree, the higher the elevation (i.e., the farther from ground water) the greater the risk of dying, although this effect was much weaker than that of size and only marginally significant." "The years of drought (1987-1990) were characterized by higher mortality of individuals in this population and by no known replacement of those individuals." Growth reduction and mortality was not initiated until more than 1 m of GW drawdown over multiple years.

Reference	Study Area	Period	Groundwater Depth	Avg. ETa (cm)	Avg Precip (cm)	Avg. ETa-Precip (cm)	Daily Water Table Oscillations	Groundwater Change Over Period	Groundwater Seasonal Change	Relationship to Plant Cover/Health/Stress	Rootzone	Conclusions
Toft and Frazier 2003	Mono Lake, CA; 1966 m elev.; *Chrysothamnus nauseosus* ssp. *consimilis* was monitored in an area co-dominated with *Sarcobatus* ; *Sarcobatus* not censused because of difficulty in determining genetic individuals.	1983-2001	Clover test hole 2 (LADWP well 55) and perforated access tubes at lagoon and dune sites.		16.0 cm		Not determined (monthly or less frequent observations only)	1984 3.7 m depth at beginning of drought period. Minimum was 5.8 m depth in 1992 with recovery to 4.1 m in 1998.		Mortality and growth decline occurred through the drought period, especially for smaller plants (see Toft 1995). Larger plants (>70 cm diameter), however, were essentially 'immortal' with no detectable mortality and they flowered every year of the 17 year study that included a major, multi-year drought. The canopy size of these plants did decline slightly during the drought but recovered as GW levels rose after the drought. (Fig 2)	Rooting depth up to 6 m, estimated.	"The minimum size of shrub able to access deep soil moisture reliably was apparently ~25–30 cm of canopy diameter (Fig. 4), which was also the threshold size of flowering." Shrubs larger than 70 cm diameter were able to tolerate the 2.1 m variation in GW depth observed during this 17 yr study. These long established, large adult shrubs adjusted to a 2.1 m decline in GW level during multi-year drought with small declines in canopy size and recovered to initial sizes afterward. They showed no mortality and flowered every year. This range of variability in GW level (up to 2.1 m) can be tolerated by these phreatophytic dune species with no impact on the plant community resource.
T931 hydrograph	Owens Lake, CA, near VDA01; 3617 ft (1102.4 m) elev; dense, high cover shrub vegetation of *Sarcobatus* and several other species in vicinity of the well.	Nov 2013-Apr 2019	62 ft deep well with perforation from 27-57 ft.				Yes, in 2019 when monitored hourly; late April 2019 showed daily oscillations of up to 0.14 ft.	Average GW depth for the period was 12.09 ft below ground surface. Depth increased from 13.93 ft in Dec 2013 to the maximum depth of 16.17 ft near the end of the drought period in Sept 2017 with recovery to a minimum of 11.76 ft in early April 2019.	Seasonal decline from March to September was 0.91, 0.84, 0.81, 1.38 ft for 2014, 2015, 2016, 2017, respectively. In 2017 the mimimum spring depth was later, in May, making the seasonal decline 1.80 ft from May to September.			Daily fluctuations of up to 0.14 ft observed. Seasonal decline of 0.81-1.80 ft observed during the growing season.
Keeler Landfill Monitoring Piezometer	Owens Lake, CA, near VDA08; 3606 ft (1099.1 m) elev; dense, high cover shrub vegetation of *Suaeda* and *Sarcobatus* in vicinity of the well.	Mar 1999-Nov 2017	25 ft deep well with perforation from 20-25 ft.				Not determined (spring and fall observations only)	Average GW depth for the period was 8.14 ft below ground surface. Lowest levels were 9.76 ft in Dec 2000 and 9.37 ft in September 2017. Shallowest depth was 6.98 ft in May 2005.	Seasonal decline was observed from spring (generally Mar-May) until fall (Sept-Nov) in all 18 years, although the dates of monitoring were not completely consistent. Average growing seasonal decline was 1.15 ft (35.1 cm). Minimum decline was 0.11 ft (in 2008 and the highest declines were seen in 2003 (2.10 ft) and 2017 (1.81 ft).			Seasonal decline of 0.11-2.10 ft observed during the growing season (18 of 18 years of record).