July 3, 2019

Tim Wilson, Acting State Engineer
Nevada Division of Water Resources
901 S. Stewart St., Suite 2002
Carson City, NV 89701

Mr. Wilson,

The Center for Biological Diversity is pleased to submit the attached technical memorandum from hydrologist Dr. Tom Myers, regarding the questions raised by Interim Order 1303.

As the Center has stated from the beginning of this process, our primary concern is ensuring long-term sustainable flows in the Muddy River Springs Area (MRSA) to ensure adequate habitat for the survival and recovery of the federally protected endangered Moapa dace. Protecting the dace is a legal obligation for the Division of Water Resources, in order to ensure compliance with the federal Endangered Species Act, and acting in compliance with NRS 533.370(2) to ensure that water right applications are not "detrimental to the public interest."

Dr. Myers' report contains three primary conclusions:

- The Division should not allow any pumping of the carbonate aquifer if the continued decrease in spring flow in the MRSA is to be avoided.
- The Kane Springs Valley should be managed as a part of the LWRFS.
- Some basin-fill pumping could occur without significantly affecting MRSA spring flow, with a preliminary estimate of 4,000 afa as a sustainable yield.

We appreciate this opportunity for engagement and look forward to further discussions on this issue.

Sincerely,

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Technical Memorandum

Groundwater Management and the Muddy River Springs, Report in Response to Nevada State Engineer Order 1303

June 1, 2019

Prepared for: Center for Biological Diversity

The Nevada State Engineer (NSE) is planning to establish a plan to conjunctively use groundwater and surface water in the Lower White River Flow System (LWRFS). The NSE has established the LWRFS as the valleys shown in Figure 1, except that only the northern portion of Black Mountains Area would be included. The basis for his planning is the Order 1169 aquifer test results and observations ongoing since the end of the test. The NSE in order 1303 requested that stakeholders provide reports with "further analysis of the historic and ongoing groundwater pumping data, the relationship of groundwater pumping within the LWRFS to spring discharge and flow of the fully decreed Muddy River, the extent of impact of climate conditions on groundwater levels and spring discharge, and the ultimate determination of the sustainable yield of the LWRFS" (NSE Order 1303, p 11). This report addresses the four points the NSE requests stakeholders to address, although in a different order:

1. The report summarizes the Order 1169 aquifer test, specifically regarding groundwater levels throughout the LWRFS and spring flows at Muddy River Springs, and extends the interpretations through the recovery period of 2013 through the present,
2. The report considers the reasons to consider Kane Springs Valley (KSV)as part of the LWRFS (the water level is just five feet higher than in Coyote Springs Valley (CSV), and pumping in KSV could reverse the gradient pulling water from CSV,
3. The report addresses the long-term quantity of water that could be pumped from the LWRFS without harming any Muddy River Springs. (Because of the flat gradient over the 1100 sq miles of the joint management area, there can be no location for pumping within the LWRFS that is safe meaning it would not affect Muddy River Springs),
4. Finally, the report also considers the relationship between alluvial and carbonate wells and how that could affect senior decreed rights to the Muddy River.

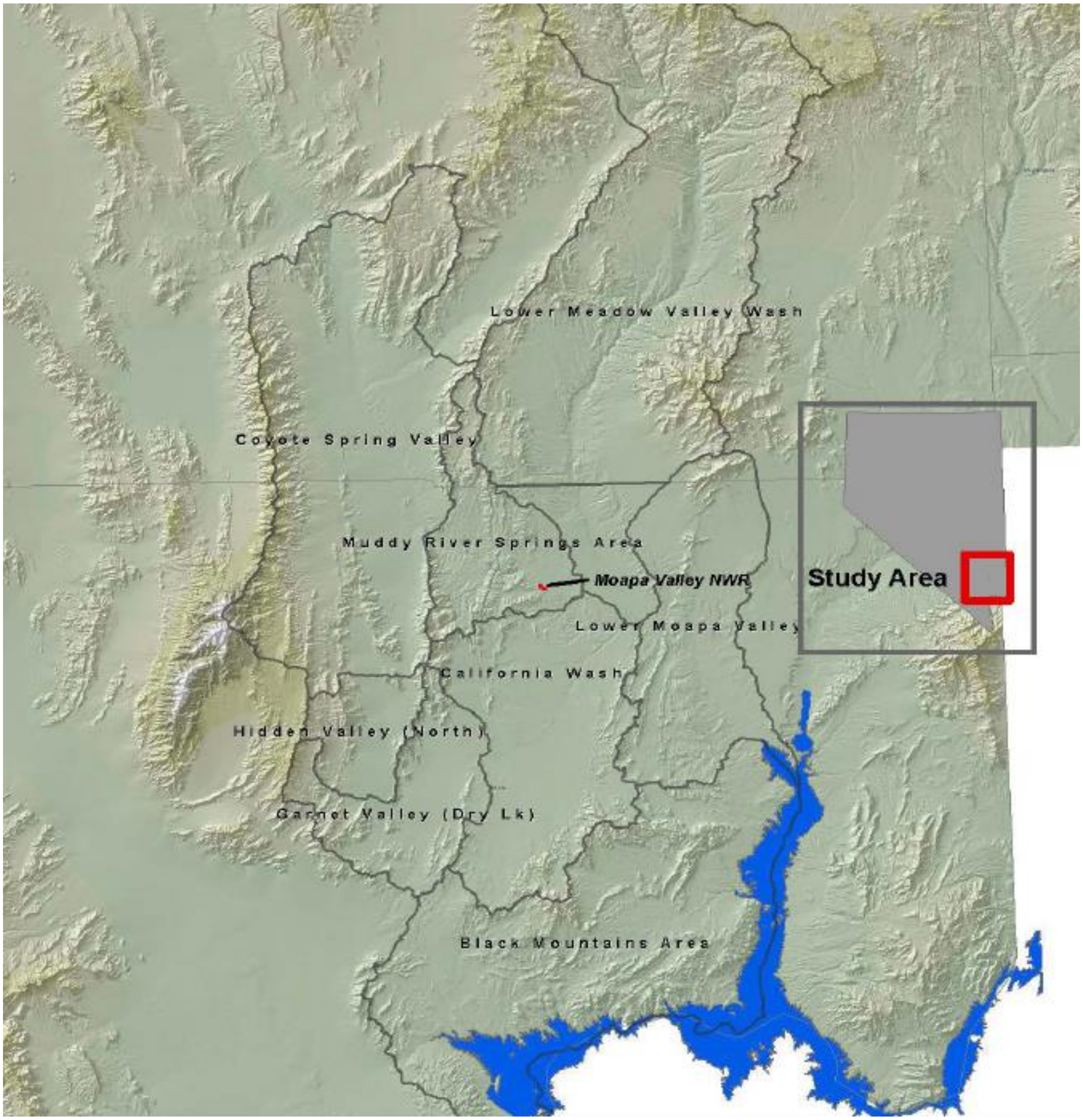

Figure 1: Study area showing the Lower White River Flow System. Kane Springs Valley is northeast of Coyote Spring Valley. Source: USDOI (2013).

Order 1169 Aquifer Test and the Period 2013 to 2019

NSE Ruling 6254 summarizes the finding of the 1169 aquifer test as reported on by various stakeholders including SNWA (2013), US DOI (2013), Myers (2013), and Johnson and Mifflin (2013). The 1169 aquifer test had been required by NSE Order 1169 to determine the effects of developing the carbonate aquifer in CSV. The order had required the participants to pump 8050 acre-feet per year (afa) from wells in CSV for two years. However, for the duration of the test, from November 15, 2010 to December 31, 2012, the total pumpage from the CSI wells and MX-5 well was 11,249 af, or only 5290 afa. During the test period, 79 monitoring and pumping wells (MWs and PWs) monitored water levels throughout the area (Figures 2 and 3). The CSV carbonate PWs lie on the east side of the valley near the boundary with Muddy River Springs Area (MRSA) and basin fill and carbonate MWs lie throughout the valley (Figures 2 and 3). MRSA wells concentrate along a trend along a wash running southeast through the middle of the valley (Figures 2, 3 and 4). The Arrow Canyon wells (Figure 3) are high-producing carbonate wells. The basin fill pumping wells on the southeast portion of MRSA are commonly called the Lewis Well field. The Muddy River Springs also lie in the far southeast portion of MRSA. The clastic rocks just east of the MRSA (Figure 4) may provide a structural boundary that partly controls flow and the location of the Muddy River springs (Johnson and Mifflin 2013).

Southern Nevada is generally very dry and average recharge over the LWRFS is very low (NSE Ruling 6254). But some years can be relatively very wet and the runoff that occurs during those years can cause recharge into washes and into outcrops of conductive rock. The twelve-month moving average of monthly precipitation ranges averages near half an inch but was close to zero in 2002 and approached 1.3 inches in 2005 (Figure 5). These monthly values correspond with an annual average of about 1 inch and 14 inches per year in those years, as reported by USDOI (2013). Several years in the 1990s have monthly average precipitation near an inch. During the aquifer test, the first year, 2011, appears to be slightly wetter than the average and 2012 became dry relative to most years.

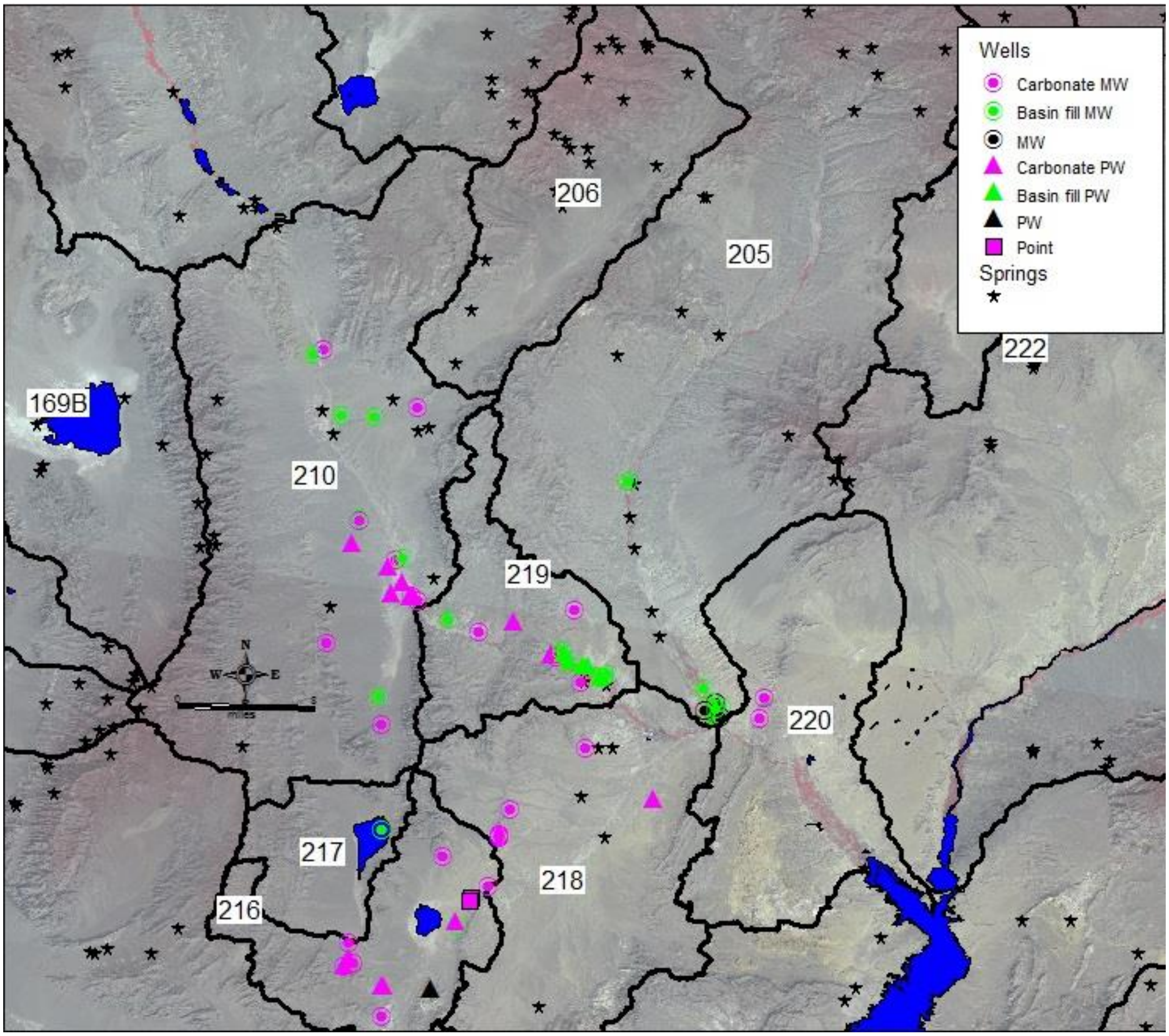

Figure 2: General layout and type of wells in the Coyote Spring Area. Basin 210 is Coyote Spring Valley, 219 is Muddy River Spring Area, 220 is Lower Moapa Valley, 218 is California Wash, 217 is Hidden Valley, 216 is Garnet Valley, 205 is Lower Meadow Valley Wash, and 206 is Kane Springs Valley. MW is monitoring well; PV is production well. See Figure 3 for the names for some of the wells. Source of well data: NVSE website.

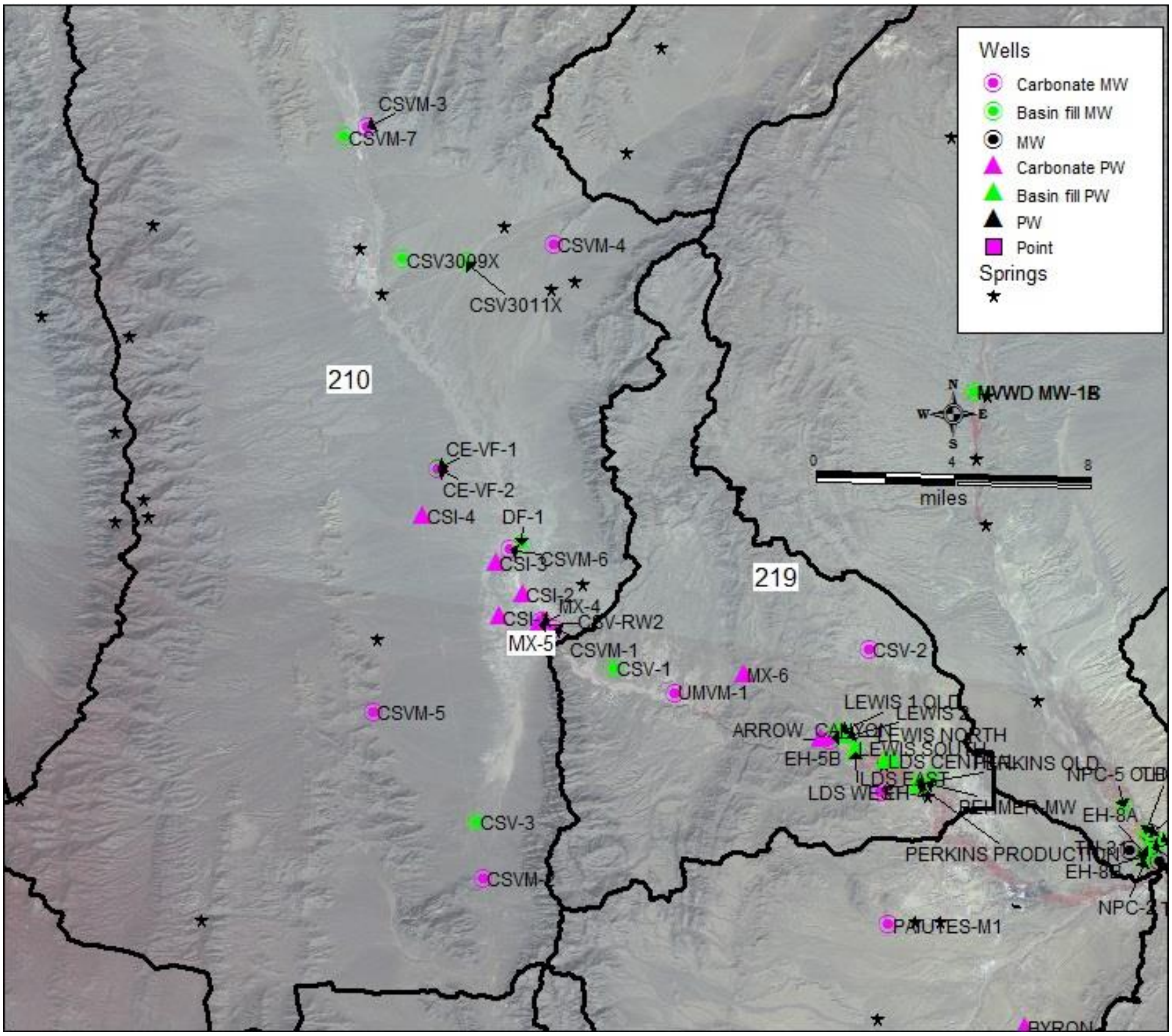

Figure 3: Detailed well layout and names for Coyote Spring Valley (210) and Muddy River Springs Area (219). Source of well data: NVSE website.

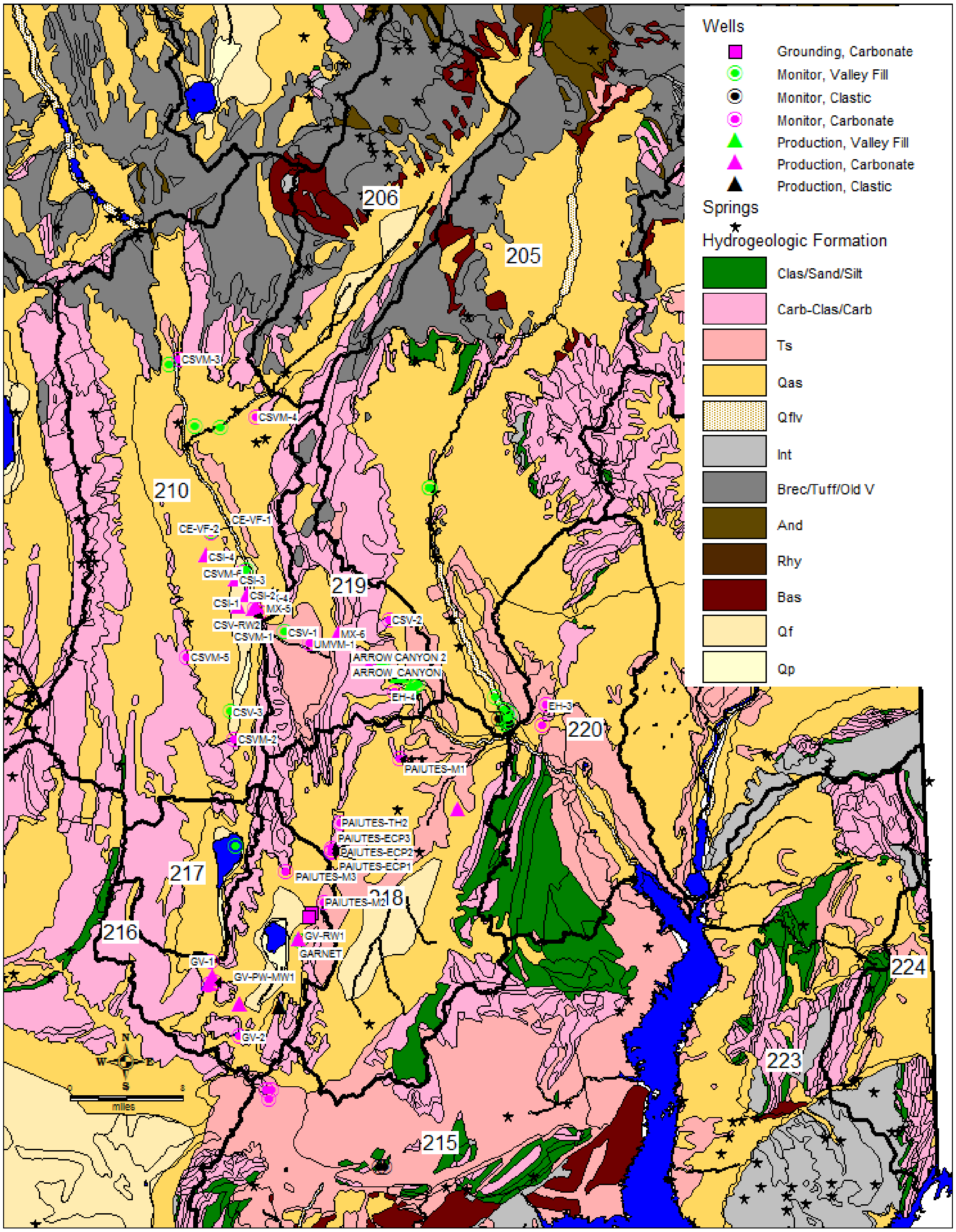

Figure 4: Lower White River Flow System wells and hydrogeology.

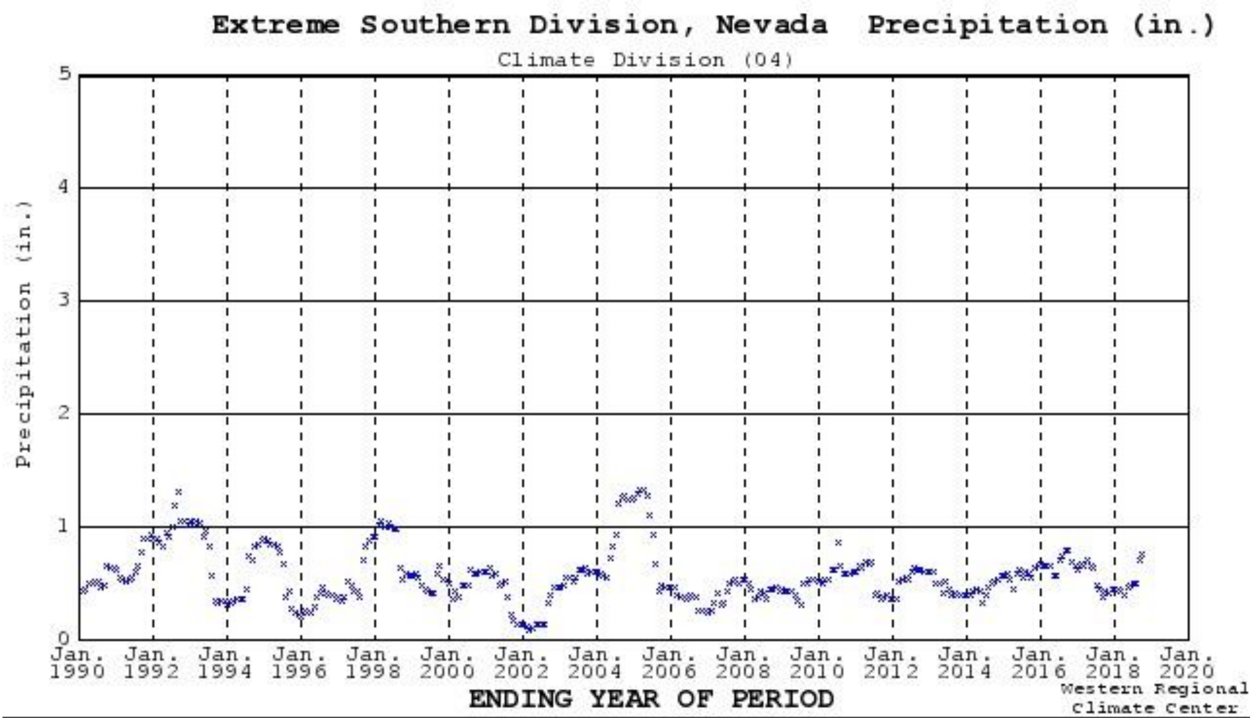

Figure 5: Twelve-month running average of precipitation for the southern zone of Nevada. Data from the Western Regional Climate Center, https://wrcc.dri.edu/spi/divplot2map.html

The NSE found that even the reduced pumping completed during the aquifer test satisfied its goals and that pumping in CSV caused impacts north in CSV "at least to Kane Springs Valley, south to Hidden Valley and Garnet Valley, and southeast to Muddy River Springs Area and California Wash" (NSE Order 6254, p 20-21). There was no monitoring for the test in Kane Springs Valley, so it is not possible to assess whether the impacts extended into that valley. USDOI (2013) concluded the impacts covered 1100 square miles. NSE summarized that groundwater level declines attributable to MX-5 pumping ranged from less than one foot in northern CSV to more than two feet in central CSV to more than a foot in central MRSA and California Wash (NSE Order 6254, p 21). The following paragraphs detail the water levels before, during, and after the aquifer test.

Carbonate MWs in central and southern CSV have varied in parallel since the early 2000s (Figure 6). The trend has been downward except for the increase during the wet period around 2005. All the carbonate MWs in central and southern CSV decreased more than two feet during the pump test period and all have recovered less than half the pump-test decrease by 2019 (Figure 6). The lack of recovery indicates the increased gradient, caused by the 2-foot drawdown, does not draw substantially more water from beyond the boundaries of the high-transmissivity area. Drawdown in northern CSV was much less (not shown). Basin fill well groundwater levels in the southern portion of CSV have also trended downward since the late

1990s, with an exception being during the wet period around 2005 (Figure 7). Well CSV3011M water levels increased from its installation in 2008 until the aquifer test. Well DF-1, a basin fill well in the middle of southern CSV, has water levels about 200 feet higher than other wells in the area.

Carbonate MWs in the MRSA also show a long-term downward trend commencing in the 1990s with an uptick in 2005 (Figure 8). USDOI (2013, p 11) identified several wet year responses in the groundwater levels, including in 1992, 1993, 2005, and to a lesser degree in 1998 and 2011. The small seasonal fluctuation may relate to pumping in the basin fill (Id.), which would reflect the connection between aquifers. The 1169 aquifer test accelerated the decline in the MWs in the MRSA with a decrease of as much as 2.5 feet. Recovery since the decline was as much as a foot in the first year, but levels have remained steady since.

Basin fill MWs in the Lewis Field portion of the MRSA have been steady since the 1990s except for a three-foot decline in the Lewis North MW (Figure 9). Lewis South and Lewis 1 Old have declined a couple feet since the 1990s, but with an almost ten-foot seasonal variation. Seasonal variation in Lewis North was much less. All wells in the Lewis Field portion of the MRSA exhibited a substantial drawdown of several feet during and for two years after the pump test (Figure 9).

Basin fill MWs near the springs have declined, other than the uptick in 2005, since the 1990s much more than the Lewis Field wells (Figure 10). The decline accelerated through the aquifer test period, although, in contrast to the carbonate wells, these basin fill wells have mostly recovered since the aquifer test. Seasonal variations are as much as ten feet. The downward trend probably reflects the trend in the carbonate wells, the source for most basin fill water. Recovery however could be due to decreased pumpage in the Lewis Field, as discussed below.

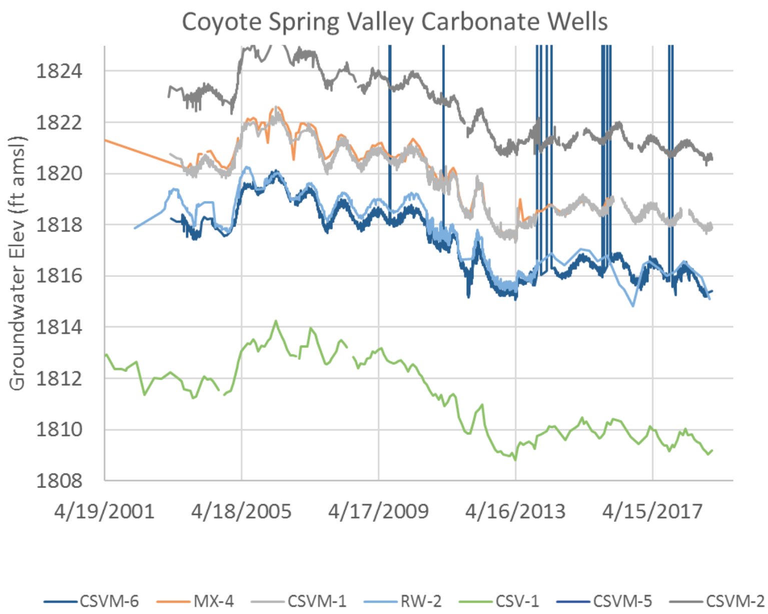

Figure 6: Hydrograph of carbonate monitoring wells in Coyote Spring Valley, through the Order 1169 pump test and to 2019. Source of data-NSE web page.

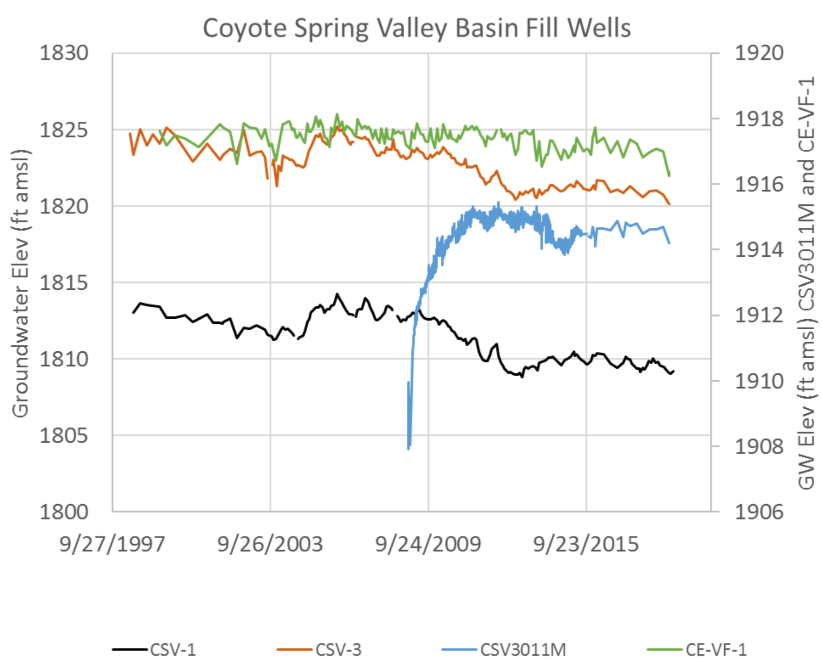

Figure 7: Hydrograph of basin fill monitoring wells in the south half of Coyote Spring Valley. Source of data - NSE web page.

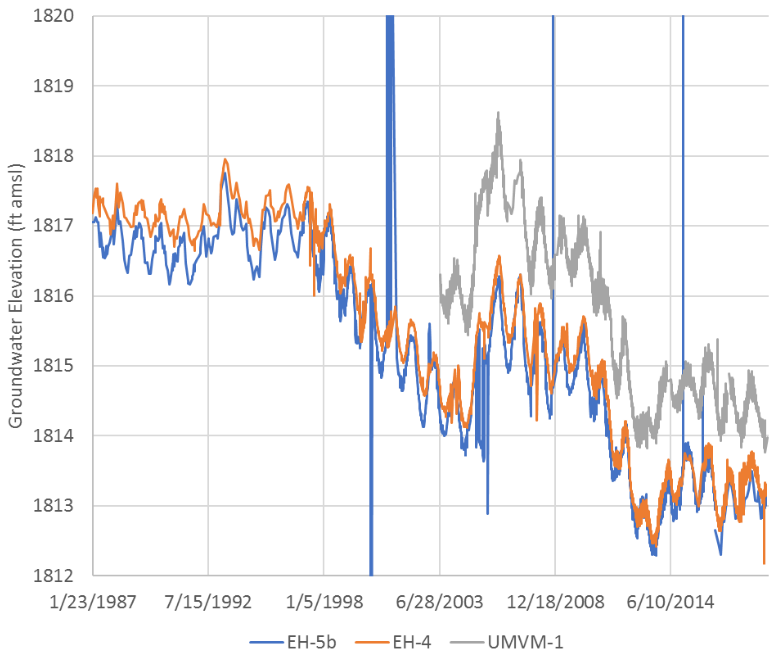

Figure 8: Muddy River Springs Area carbonate monitoring wells.

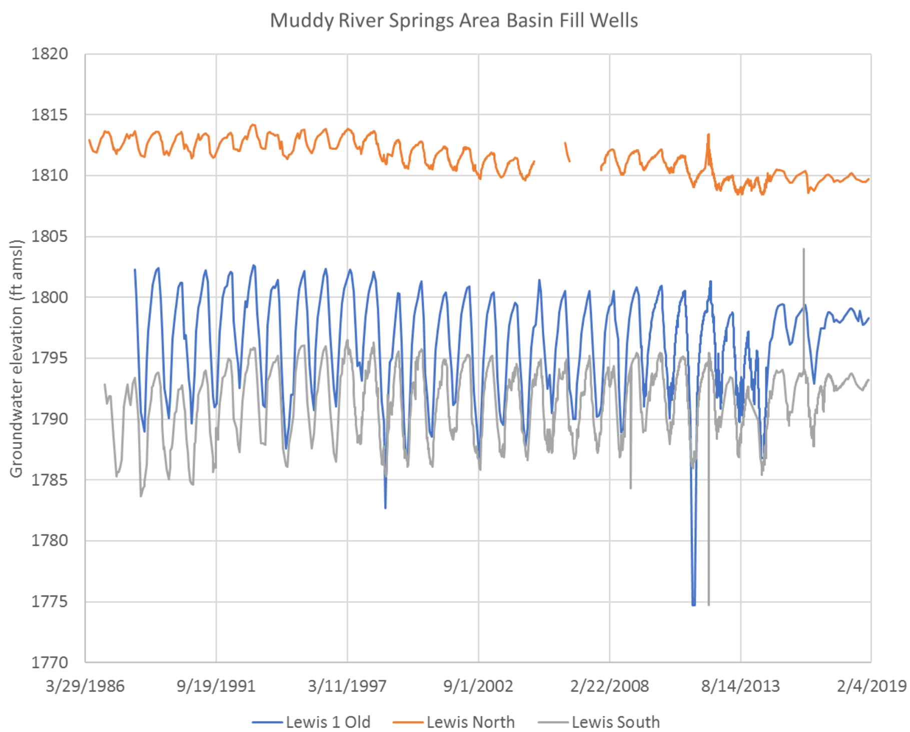

Figure 9: Hydrographs of basin fill wells in the Lewis Field portion of the Muddy River Springs Area. Perforations are from 28 to 68 feet bgs for Lewis North and are unknown for the other wells. Source of data - NSE web page.

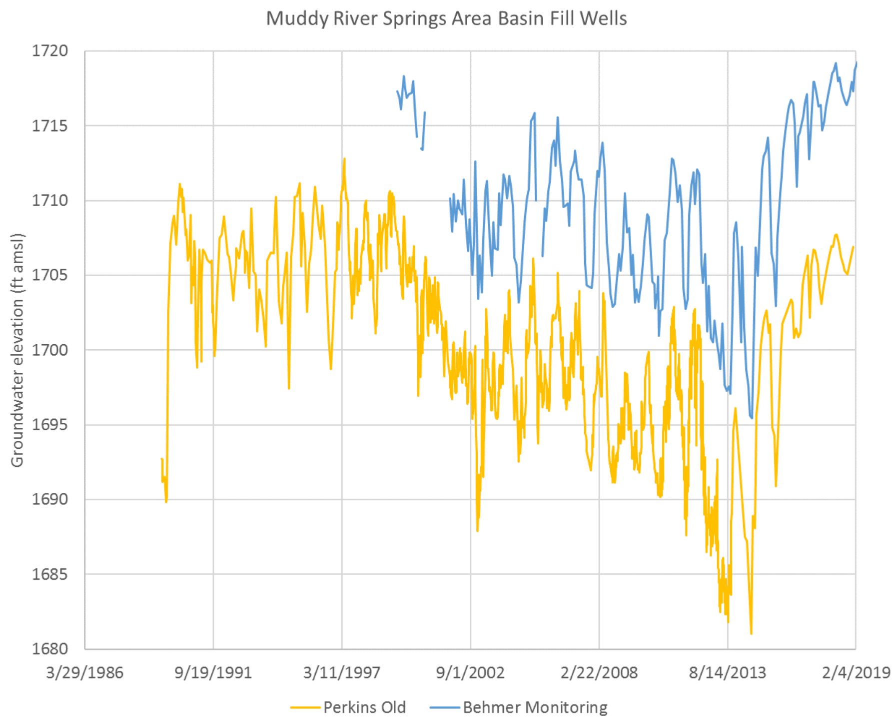

Figure 10: Hydrographs of basin fill wells in the Muddy River Springs portion of the Muddy River Springs Area. The Perkins Old well is screened from 20 to 60 ft bgs. Source of data -NSE web page.

The groundwater levels recorded at the end of the pump test throughout the CSV and MRSA show the very flat potentiometric surface from midway up CSV through the MRSA. The groundwater gradient through the area affected by the pump test is very flat because of the likely very high transmissivity from about the southern half of Coyote Spring Valley through the Muddy River Springs and further downstream to the Lower Moapa Valley (Figure 11). The groundwater elevation ranges from about 1815 ft above mean sea level (amsl) at CSVM-6 almost three miles northwest of MX-5 to about 1814 at UMVM-1 about 4 ½ miles southeast of MX-5. Interestingly, the groundwater elevation is 1817 at CSVM-1 which is very near MX-5, which itself is at 1813. In other words, there is a small rise in the potentiometric surface of the carbonate aquifer southeast of MX-5. The minor groundwater divide may be slightly southwest of the direct flow path, thereby partly bounding the divide. During pumping, water levels throughout this highly transmissive aquifer responded as if the aquifer water is a pond with water level changes transmitted quickly throughout.

Carbonate water levels in northern CSV are several tens to almost 400 feet higher than near the southeast portion of CSV, but the water levels did decline during the aquifer test (USDOI 2013). The groundwater level in MW CSVM-4, in CSV but near the southern end of Kane Springs Valley, is just six feet lower than well KMW-1 (206 S11 E64 06CACC1) further north in Kane Springs Valley. This suggests the high transmissivity carbonate rock extends into that valley.

Carbonate groundwater levels drop almost 250 feet between the MRSA and the southeast portion of the Lower Meadow Valley Wash valley. The carbonate groundwater levels in the MRSA are several tens of feet above the levels in the basin fill, which drives upward flow into the basin fill. Both observations support the idea of a flow impedance in the carbonate aquifer near the southeast boundary of MRSA which could be a major cause of the springs.

Basin fill water levels in Coyote Spring are substantially higher than the carbonate water levels. Most apparent is CE-VF-2 for which the water level is more than 50 feet lower in the carbonate (Figures 2 and 11). Basin fill well DF-1 groundwater levels exceed 2000 ft amsl while underlying carbonate wells have levels 200 feet lower. Because of the aridity of the area and because of the likely confining unit between the aquifers, it is unlikely the higher basin fill levels reflect substantial recharge to the carbonate. Rather it suggests a hydrologic disconnect. Groundwater levels in basin fill wells CSVM3009M and DF-1 have been trending upward, with no signal from the aquifer test; this also indicates there is no connection between carbonate and basin fill.

Downgradient in the Muddy River Springs Area, the carbonate water levels exceed those in the basin fill, which reflects the discharging springs in the area. In the Lower Meadow Valley Wash area, outside of the pump test study area, at wells MW-1 there is a substantial upward gradient from depth in a very thick basin fill aquifer.

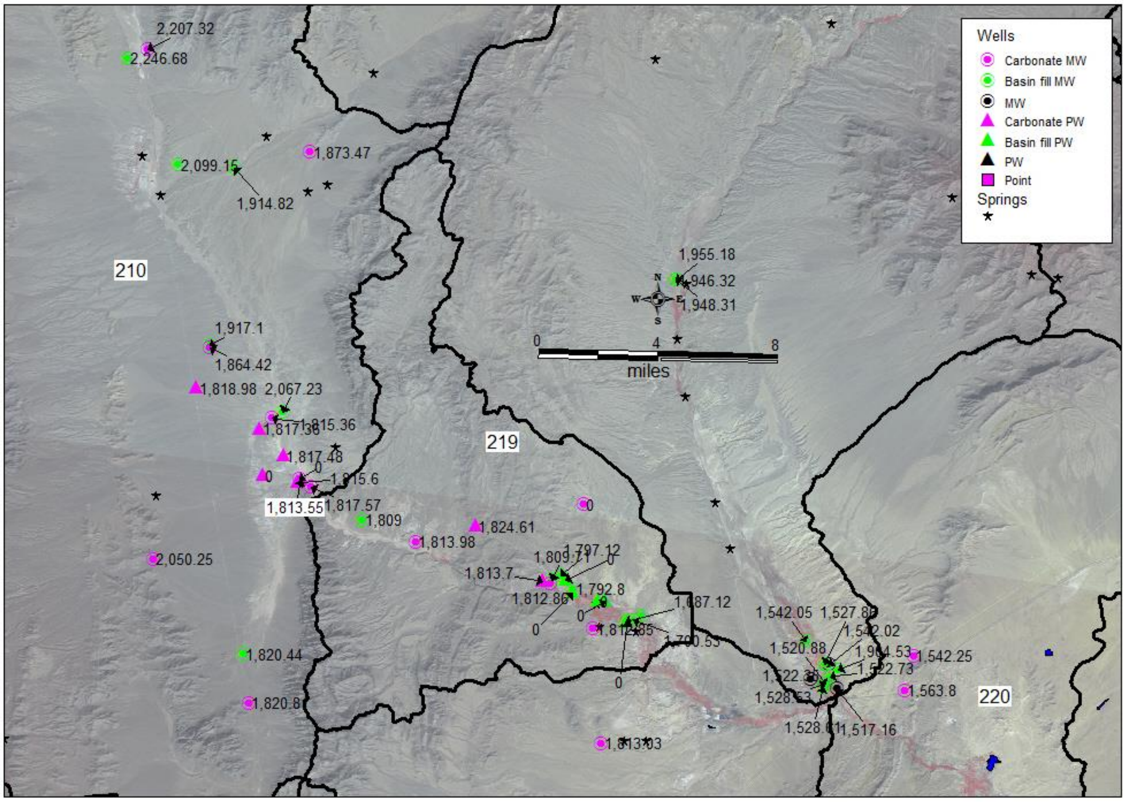

Figure 11: Groundwater level at various wells throughout the study area. See Figure * for the well names. The label 0 means either the data is not available or the well is a production well and the water level is very low.

A profile of the carbonate groundwater levels through CSV and MRSA at the beginning and ending of the aquifer test demonstrates the flatness of the potentiometric surface in the high transmissivity zone through the area and how the response decreases to the north (Figure 12). For almost 20 miles, the carbonate water level is between 1820 and 1813 feet amsl. During the aquifer test, the level consistently dropped about 2 feet. The small rise at CSVM-1 may reflect a slightly higher groundwater ridge south in CSV, as seen at well CSVM-2 where the groundwater levels exceed 1820 feet amsl about five miles south of the profile line (Figure 11). This slight rise suggests there is no flow south from CSV but the groundwater levels in southern CSV did decline during the aquifer test.

Further north at CSVM-4, the groundwater level change was less than a foot. Groundwater levels at well CSVM-4 are also several tens of feet higher than further south. As noted, groundwater levels rise about six feet into Kane Springs. Even further north, carbonate groundwater levels are about 200 feet higher and there was little effect from the aquifer test. Transmissivity is probably lower in northern CSV as reflected by the steeper gradient. Inflow to CSV from Pahranagat or Delamar Valley flows through the lower transmissivity area to reach southern CSV and well MX-5.

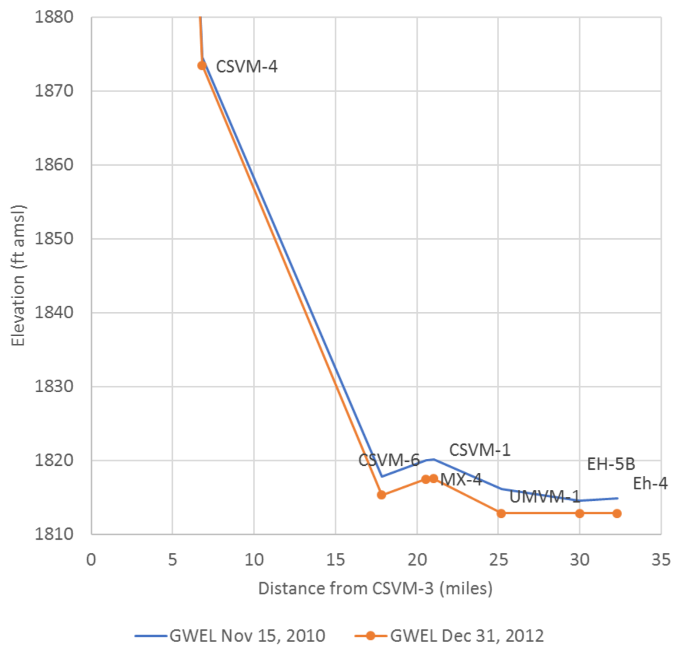

Figure 12: GW elevation from northern Coyote Spring Valley to well EH-4 at the beginning and end of the Order 1169 pump test.

The changes in groundwater levels in the carbonate aquifer manifests in the Muddy River Springs Area (Figure 13) spring flows. Pederson Springs and Warm Springs West provide most of the flow to one of the channels that is tributary to the Refuge Stream, which is then tributary to the Muddy River Channel (Figure 13). The Pederson Springs are the highest elevation springs on the site.

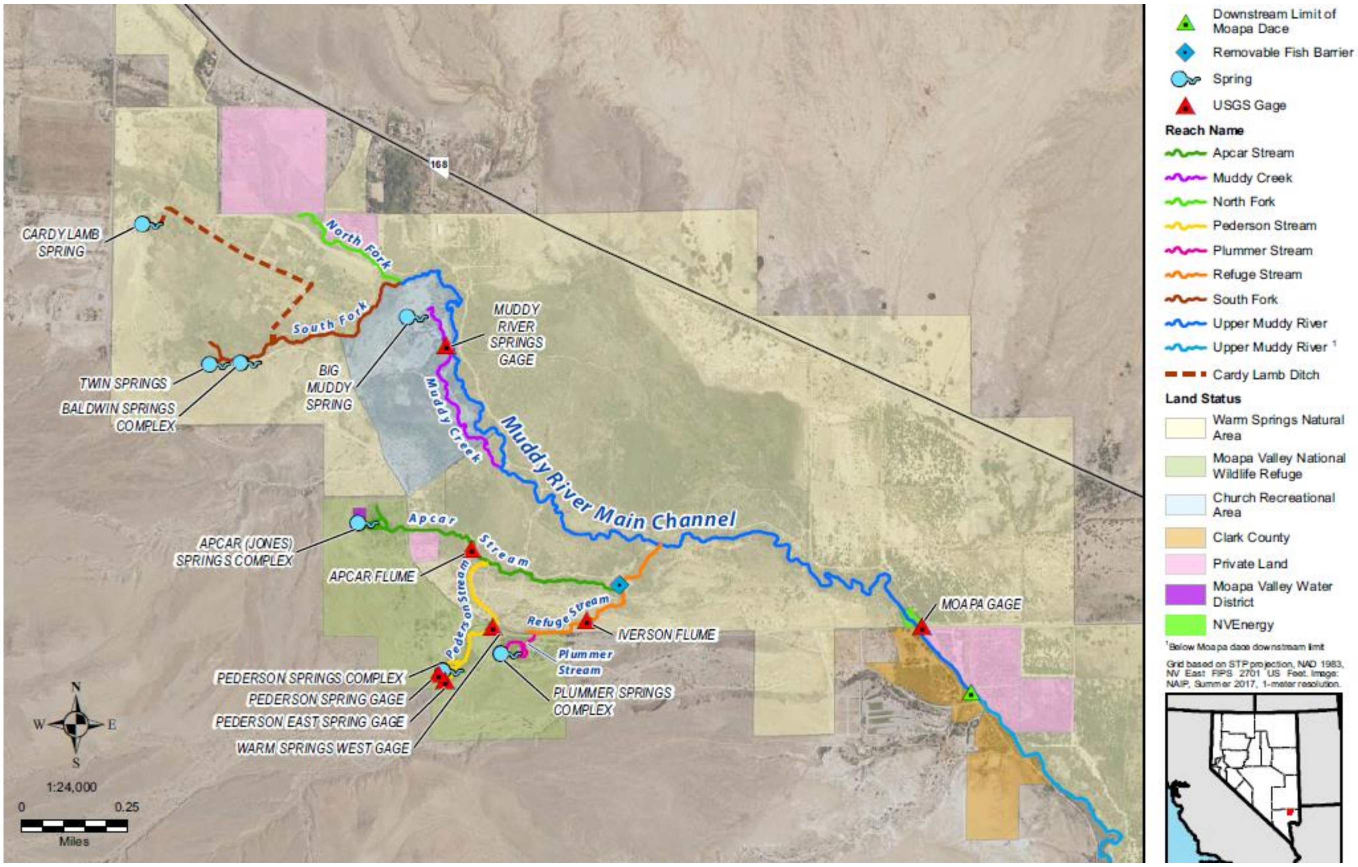

Figure 13: Muddy River Springs area. Source, SNWA (2018) Figure 2-1.

Discharge from the Warm Spring West decreased from about 4.0 cfs to as low as 3.4 cfs between the 1990s and mid-2000s, then after an uptick in flows in the wet period in 2005 (Figure 14) and during the Order 1169 pump test dropped to almost 3.2 cfs (Figure 14). It has recovered only to a little more than 3.4 cfs since 2012. At the Pederson springs, flow is about half of what it was in the mid-2000s, with much of the decrease occurring during the Order 1169 pump test (Figure 15). Flows recovered some after the test, but for about four years flows have been steadily low. At the Pederson Springs East gage, flows had fluctuated around 0.2 cfs prior to the pump test during which the flow decreased to about 0.14 cfs (Figure 15). The flow has not recovered at these springs.

USDOI (2013) determined that the flow rate at Pederson Springs had declined about 63% and at Pederson East Spring about 45% during the test. Flow at Warm Springs West (Figure 14) declined about 9% during the test. USDOI (2013) correlated spring flows to carbonate groundwater level drawdown and found that if the rate of drawdown observed during the aquifer test continued, Pederson Spring, the highest elevation spring in the MRSA, would have gone dry in 1.5 years. USDOI also estimated that Pederson East Spring would have gone dry in another 2.5 to 3 years if pumping continued. In other words, if the trend observed on Figure 15 had continued, the springs would be dry. Flow at Jones and Baldwin Springs (Figure 13) declined about 4%. Curiously, the flow at Muddy Springs increased by 19% per year, possibly due to decreased evapotranspiration (ET) resulting from a fire in July 2010.

USDOI also estimated that 80 to 90% of the groundwater pumped during the aquifer test was drawn from groundwater storage (USDOI 2013, p 4) which means that the groundwater system is far from being in equilibrium, which occurs when inflow (recharge and groundwater flow from adjoining basins) equals the outflow. Although several ecologically important springs had their flow reduced substantially during the aquifer test, those flow reductions represent only a small portion of the outflow from the LWRFS. Continued pumping at those rates would have continued to decrease spring flow as the pumping removed additional groundwater storage and decreased the groundwater level controlling discharge from the springs. Even after pumping ceases, groundwater discharge would continue to reduce as it is diverted to replenish the groundwater storage (make up drawdown).

The discharge before the aquifer test was spring discharge and existing pumpage. As pumpage increased, the spring discharge would decrease until the sum equals the inflow. Because of the extremely flat gradient through the carbonate system, the pump test has essentially reset steady state conditions. A major recharge event may eventually allow some temporary recovery, as was seen in 2005, but the ongoing pumping would resume the drawdown trend.

The limited recovery in carbonate groundwater levels and springs indicates there is a steady state inflow to the system. Inflow from upstream would not increase due to drawdown in CSV because the controlling gradient is quite high due to the drop from Delamar and Pahranagat Valley into CSV. Between Hoyt Spring in Pahranagat Valley and MW CSVM-3, a distance of 11.47 miles, the water level drops from 3195 to 2207 ft amsl for a gradient of 0.0163. This assumes the water level in Hoyt Springs is that of the carbonate aquifer. Between Delamar Valley and Coyote Spring Valley, the gradient would be the difference in water level between well 182 S07 E64 19ACDB1 at about 3480 ft amsl and CSVM-3 over 20 miles, or be 0.012. Between groundwater levels in Kane Springs Valley at well 206 S11 E64 06CACC1 at 1878 ft amsl and CSVM-4 at 1873 ft amsl over about 6 miles, the gradient is about 0.00016. The flat gradient through the Coyote Spring Valley apparently extends into Kane Springs Valley, so it is possible that some flow could be induced from Kane Springs Valley by pumping in CSV.

The drawdown in the MRSA alluvial wells suggests that lowering the water levels in the carbonate is decreasing the inflow from below into the alluvium. Spring flow has decreased but it is doubtful this has been sufficient to decrease secondary recharge.

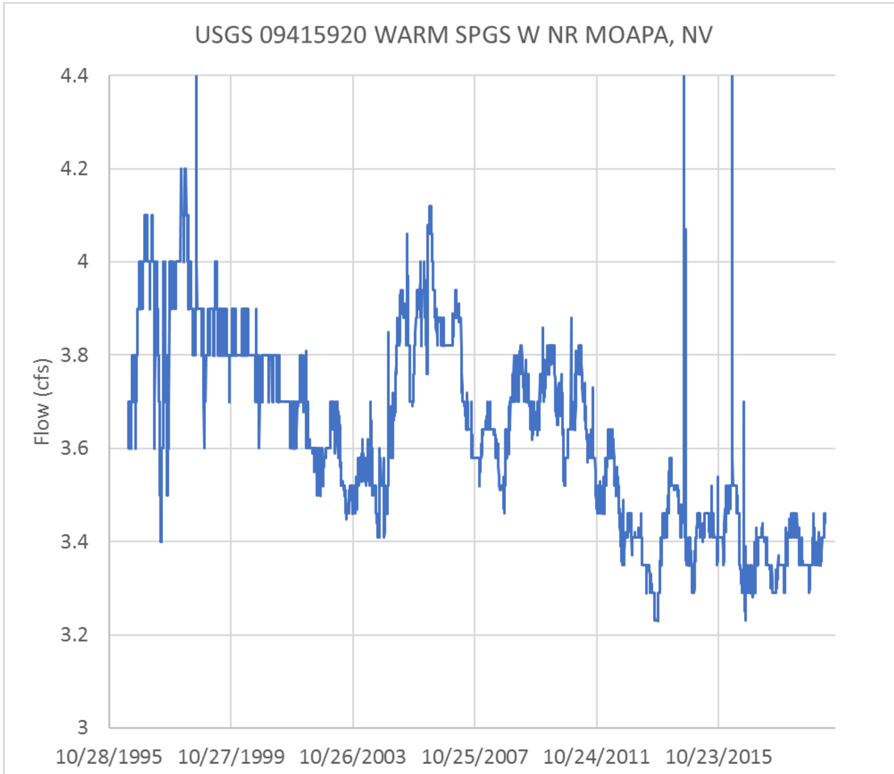

Figure 14: Daily flow at Warm Springs W near Moapa.

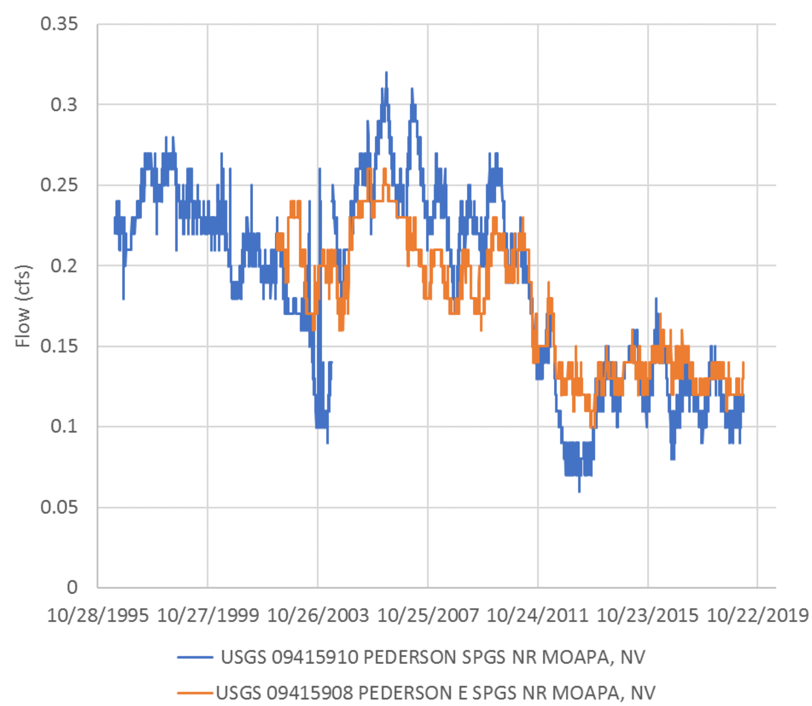

Figure 15: Daily flow at the Pederson gages

Boundary of the Lower White River Flow System

NSE Order 1303 requests the reports filed in response to the order address the "geographic boundary of the hydrologically connected groundwater and surface water systems comprising the Lower White River Flow System" (NSE Order 1303, p 13). The NSE has already outlined reasons for including CSV, MRSA, Garnet Valley, Hidden Valley, a portion of the Black Mountains Area, and the Lower Moapa Valley. The analysis herein and the analyses of USDOI (2013), SNWA (2013), Myers (2013), and NSE Order 5462 found a large high transmissivity area within the carbonate aquifer of these areas and basin fill aquifers within CSV, MRSA and Lower Moapa Valley that should be managed as one basin.

Information presented herein suggests that Kane Springs Valley should be added to the LWRFS. Because water levels in that basin are just a few feet higher than in adjoining portions of CSV, the gradient between them is very low. Pumping in Kane Springs Valley that decreases that gradient would decrease flow into CSV in a time frame likely measured in less than a few years. I base the time frame estimate on the rapid response observed in the aquifer in CSV and the assumption that a carbonate aquifer extending into Kane Springs Valley would also have a high transmissivity. Because of the very low perennial yield in Kane Springs Valley and lack of inflow to the valley from upgradient valleys, pumpage in Kane Springs Valley could reverse the gradient and draw water from CSV. Considering how fast MX-5 pumping manifest through the carbonate aquifer, a decreased flow into or reversed flow from the high transmissivity portion of the CSV carbonate aquifer would also spread through the system and lower the groundwater levels. It would have a significant effect on water rights through the LWRFS. Lowering the water table in CSV could increase the gradient between CSV and Kane Springs and draw a small amount of groundwater into the CSV. Because groundwater at the source in Kane Springs is limited, inducing flow from Kane Springs Valley is not a sustainable means of increasing the available water in LWRFS. Kane Springs should be managed as part of LWRFS.

Groundwater levels in northern CSV were several hundred feet higher than in southern CSV and there was no apparent effect of the drawdown reaching MW CSVM-3. Transmissivity in northern CSV is likely lower than further south. There is no evidence of an impedance caused by a fault structure isolating north CSV because a fault would prevent groundwater from flowing south through CSV. The pump test did not propagate to that point during the test but there is no evidence suggesting it would not do so if the pumping continued. Developing groundwater in this area would intercept groundwater flowing into southern CSV and have the same effect as diverting from Kane Springs Valley; it would decrease flow to the springs and downgradient water rights.

The ultimate source of groundwater for the LWRFS is upgradient in Pahranagat and Delamar Valley. Recharge in each of these valleys could combine with interbasin flow from upstream to provide the inflow to CSV. Groundwater developed upstream, especially in Delamar, Dry Lake or Cave Valleys, would ultimately decrease flow to CSV. The only question is timing. Once depletions upstream reach CSV, they will manifest as a loss of flow to the LWRFS. The inflow of approximately 47,900 afa will begin decrease[1]. As shown by the Order 1169 aquifer test, this reduced flow will propagate through the system and manifest as reduced carbonate water levels and spring flows. The Judge Esty order[2] properly requires that the NSE not grant any water rights above CSV in order to protect water rights and spring flows in the LWRFS in perpetuity.

The White River Flow System above CSV does not have to be added to LWFRS boundary in order to manage it properly. Developing groundwater in the LWRFS will not propagate impacts north of CSV.

Long-term Quantity of Water that Could be Pumped from LWRFS

One limit on pumping water in the LWRFS are the impacts caused by that pumping on spring flow necessary to support the Moapa Dace and water rights to flow from the springs and in the Muddy River. The recovery plan for the Moapa Dace requires that existing instream flow and historical habitat be protected in three of five channels supported by springs in order to reclassify the dace. The five channels are Apcar, Baldwin, Cardy Lamb, Muddy Spring, and Refuge (Figure 13) (USFWS 1996, p 33, 34). According to the recovery plan, all five must be protected for delisting. USFWS does not specify a required flow rate for each channel, but a Memorandum of Agreement (MOA) signed by Southern Nevada Water Authority, Coyote Springs Investment, Moapa Valley Water District, and the Moapa Valley Paiute Tribe, established trigger ranges for flows at Warm Springs West. Figure 16, sourced from the NSE

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[1] The DEIS groundwater model (SNWA 2009) simulated that all flow went from Delamar Valley to Pahranagat Valley and then to CSV (as shown in a data file accompanying the original reference: folder/file deis groundwater model/simulation files/3_Detailed_Results/Interbasin-Flow-Tables/IBF_rev2_1b_NoAction.xls). The estimated flow was 41,900 afa. The value did not vary due to project development. There was also 1900 afa flow from Kane Springs Valley to CSV. NSE Ruling 6167 concluded that inflow from Tikaboo South Valley to CSV is 4100 afa. This brings the total inflow to 47,900 afa. In his presentation on LWRFS of July 24, 2018, the NSE estimated inflow equaled 47,502 afa. He also estimated CSV LWRFS recharge at approximately 3000 afa, so the total supply is 50,500 afa, which the NSE stated was "50,000 afa or less" (NSE July 24, 2018 LWRFS Presentation, p 41).

[2] White Pine County and Consolidate Cases, Et al, v Jason King, P.E., Nevada State Engineer, State of Nevada Division of Water Resources. In the Seventh Judicial District Court of the State of Nevada in and for the County of White Pine. Case No. CV1204049. The ruling required the NSE to recalculate "appropriations from Cave Valley, Dry Lake and Delamar Valley to avoid over appropriation or conflicts with downgradient, existing water rights". (NSE Ruling 6446, p 109)

July 24, 2018 presentation regarding the LWRFS, describes the trigger ranges and pumping limitations for the MOA. Warm Springs West is on the Pederson Stream which is not listed as one of the channels for protection in the recovery plan but does contribute to the Apcar Channel (Figure 13). Warm Springs West flows almost dropped to 3.2 cfs during the aquifer test (Figure 14).

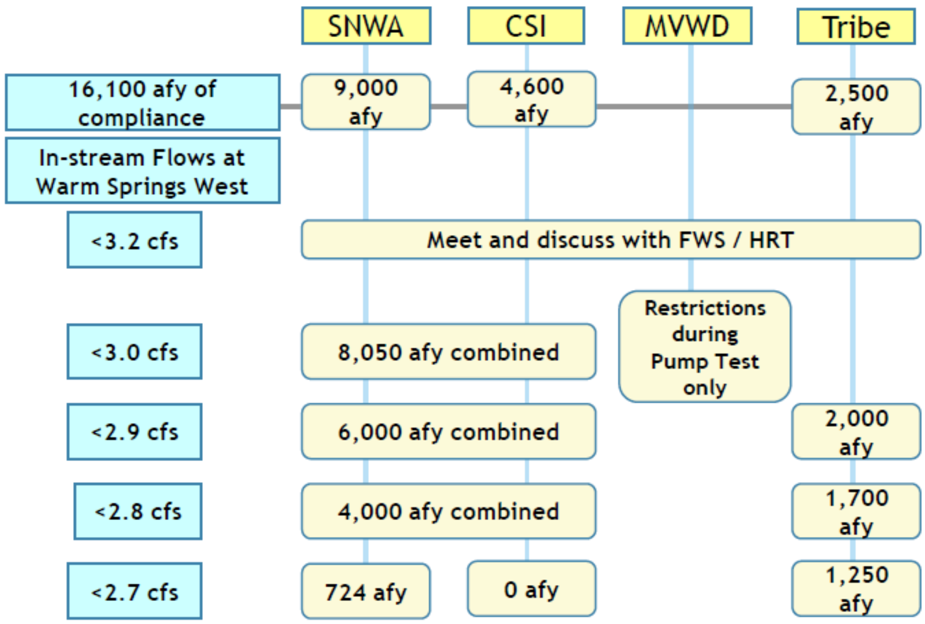

Figure 16: Description of trigger flows and pumping limits for those trigger flow for the Memorandum of Agreement described in the text.

The 1920 Muddy River Decree has total rights of 37,000 afa, as noted by NSE Order 1169. There are other stream and spring rights listed in the hydrographic abstract that could be in addition to Muddy River Decree rights.

The best way to determine the effect of pumping on the LWRFS is to consider the water balance of the system that feeds the Muddy River Springs. Ignoring local recharge which is probably to basin fill, the inflow through CSV is about 50,500 afa. The Muddy River Springs represent most of the outflow from the area, although estimating that ouflow is complicated by the irrigation in the area and ET from the basin fill. The gaging station Muddy River near Moapa (#9416000) is downstream of and therefore includes flow for all area springs (Figure 13) but the gaging station description notes irrigation diversions above the gage. Based on the gage, discharge from the LWRFS had been estimated to be about 36,000 afa from springs that supply the MRSA (Eakin 1964, p 24). However, none of the recorded flows since 1943 have been that high (Figure 17). From about 1943 to 1960, the recorded flow was just less than 34,000 afa. After 1960, the flow rate decreased to less than 24,000 afa. After the wet year in 2005, it began to increase again to over 30,000 afa in 2012.

Trends at the Muddy River gage are likely due to surface and groundwater development upstream from the gage, including diversion of up to 9.2 cfs to the Reid-Gardner electrical generating station which began in 1968 (USFWS 1996). Decreasing spring flow likely began in the 1990s with carbonate pumping. The increase just after 2005 may be due to the high precipitation year and after 2010 could be due to the decreased ET after a fire in 2010 (Figure 17). Flows have been relatively constant at about 30,500 afa since 2014. Notwithstanding the portions of the decree satisfied by diversions upstream of the gage, flow at the gage has not been meeting the requirements of the Muddy River Decree because the flow has been less than 37,000 afa (Figure 17).

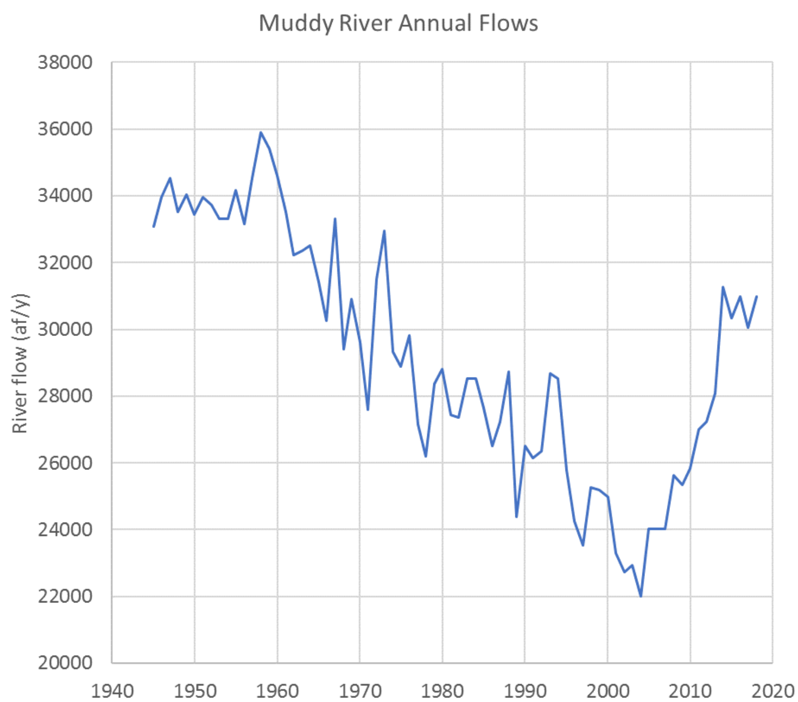

Figure 17: Annual flows (cfs) at the Muddy River near Moapa, NV gage (09416000)

Pumpage since 2000 has been from variable sources. Monthly pumpage varied from 500 to 1600 af/mnth between 2000 and 2010, with the 12-month average ranging from 800 to a little more than 1000 af/mnth (Figure 18), which converts to annual pumping from about 9600 to 12,000 afa. Total carbonate pumping increased from about 400 to 600 af/mnth, or 4800 to 7200 afa between 2000 and 2010, so there was a decrease in alluvial pumping in MRSA (Figure 18). There was a substantial jump in pumping between 2010 and 2012 due to the 1169 aquifer test. After the test and especially since 2014, total pumping has decreased to just over 8000 afa with carbonate pumping being most of it. Alluvial pumping has dropped to close to zero since 2015 (Figure 19).

Carbonate pumping in CSV first began in 2005, so flow in the carbonate system upstream from the springs has only been pumped for 14 years. MRSA carbonate pumping has been steady or slightly decreasing with ranges from 100 to 400 af/mnth (Figure 19). Production is primarily from the Arrow Canyon wells. During the aquifer test, CSV carbonate pumping dominated the pumping from the carbonate aquifer. Since the aquifer test, CSV carbonate pumping has been about half that in MRSA.

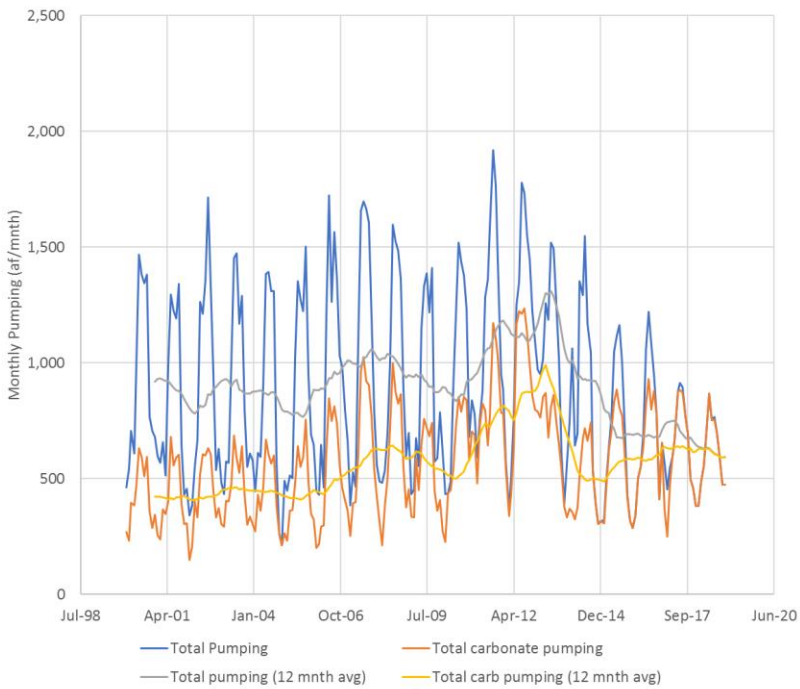

Figure 18: Total pumping and total carbonate pumping, by month and by 12-month moving average, for the study area. Data from NSE Web page.

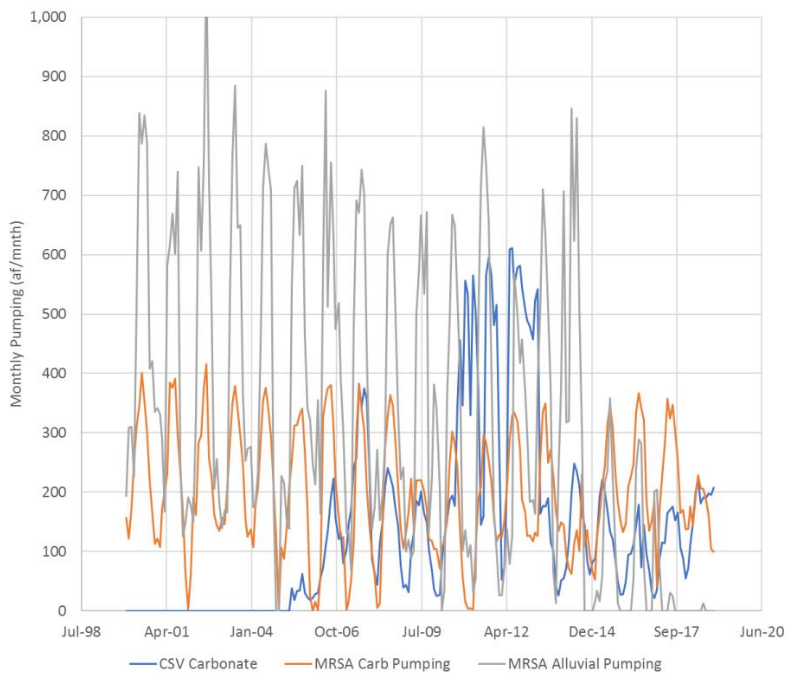

Figure 19: Carbonate pumping for Coyote Spring Valley and the Muddy River Springs Area. Source of data: NSE web page.

Prior to the pump test, the trend for water levels in most carbonate monitoring wells had been for them to decrease except during brief wet periods. This may be seen by plotting the carbonate groundwater levels with carbonate pumping, as done by the USDOI (Figure 20). Groundwater levels began to decrease as carbonate pumping commenced. Carbonate spring flow also began to decrease with pumping in the mid-1990s, also except during very wet years. The trend has been for the flows to decrease. At Warm Springs West, flow had been near 4.0 cfs in the 1990s and now is near 3.4 cfs, having recovered about 0.1 cfs since the aquifer test (Figure 14). Smaller, higher altitude springs are flowing at a little more than half of their 1990s flow.

Carbonate pumping as it occurred in the 1990s caused spring flow and groundwater levels to decline; total pumping was less than 10,000 afa and carbonate pumping was less than 5000 afa. Excepting those downstream of the springs, the basin fill wells were not experiencing a water level decline even with the alluvial pumping of near 5000 afa.

It is therefore apparent that any carbonate pumping removes water from the springs. Prior to the pump test, the small amount of carbonate pumping was causing a small but measurable decrease in spring flow. The decrease would occasionally be partially countered by extremely wet years, such as in 2005. As noted above, the majority of carbonate pumping was removed from storage, so the flow decreases would continue into the future as the storage recovers.

The conclusion therefore is that the NSE should not allow any carbonate pumping in the LWRFS to prevent further decreases and to allow recovery in the flow to Muddy River Area Springs. Pumping carbonate water intercepts spring flow and upward flowing groundwater recharge to the basin fill. With carbonate pumping, it is only a matter of time before the spring flow on which the Moapa dace depends decreases significantly or is completely lost. The next section addresses the potential for basin fill pumpage.

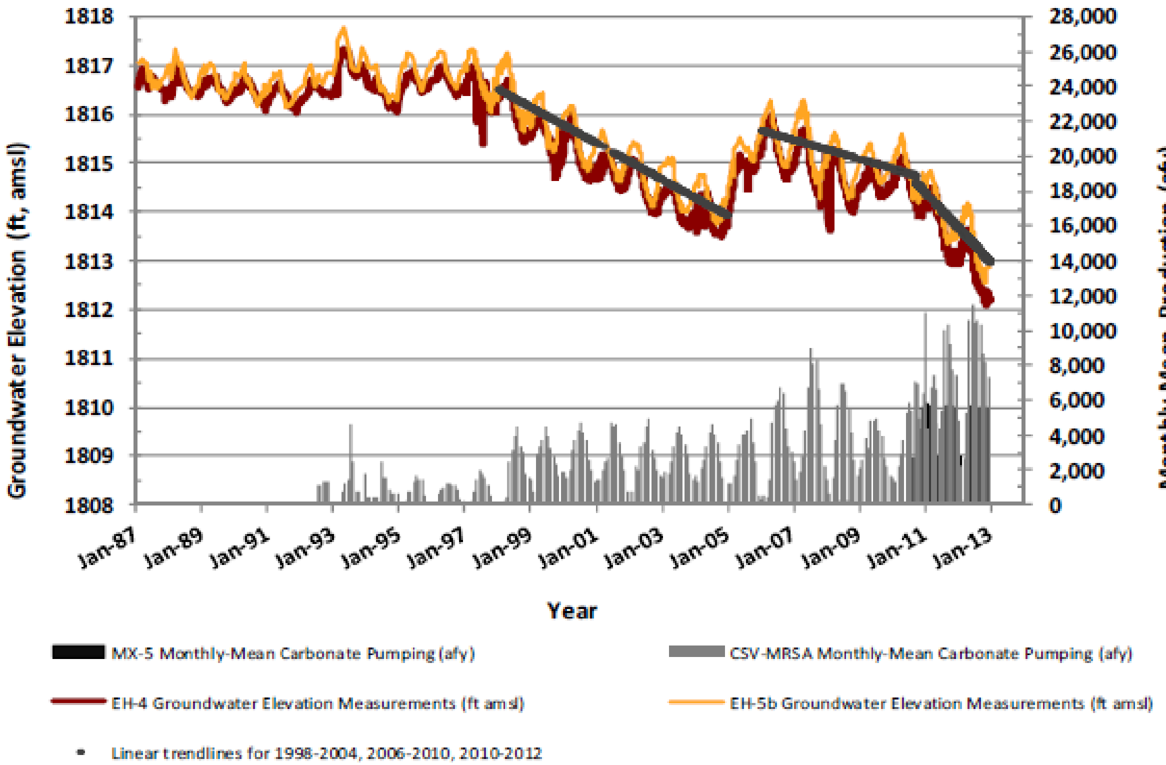

Figure 20: Trends in carbonate water levels at MWs EH-4 and EH-5b with carbonate pumping in Coyote Spring Valley and Muddy River Springs Area. Source: USDOI (2013) Figure 1.2.

Relation between Carbonate and Basin Fill Wells and the Potential for Conjunctive Use

The pumping and water level relations discussed in the previous section suggest that some water can be pumped if sourced from the basin fill aquifer. Except in the far southeast portion of MRSA, basin fill groundwater levels did not decline due to carbonate pumping. This is probably because carbonate water discharging into the basin fill supports the basin fill aquifer. Secondary recharge, probably including both direct spring flow and irrigation recharge, supports the basin fill water levels. Some basin fill pumping could be acceptable in MRSA because alluvial groundwater is partly secondary recharge from the springs. As secondary recharge, the water has already been used in the spring channels most important for the dace. The existing levels of pumping in MRSA basin fill, about 4000 afa, is probably acceptable.

Although there is no basin fill pumping in CSV, it is possible that some basin fill pumping there could be sustainable. The evidence for this is that basin fill water is likely disconnected from the carbonate and not responsible for substantial recharge. That basin fill water levels increased during the aquifer test exemplifies that. Prior to allowing basin fill pumping, it is essential to determine where the basin fill groundwater discharges. If ultimately it supports carbonate groundwater, it should not be pumped.

NSE Order 1303 requests reports address "effects of movement of water rights between alluvial wells and carbonate wells on deliveries of senior decreed rights to the Muddy River" (NSE Order 1303, p 14). This suggests that reports consider the change in the point of diversion from one to the other aquifer. As noted previously, carbonate pumping would eventually dry the Muddy River Springs, but carbonate groundwater flow also supports basin fill water through direct discharge from the carbonate to the basin fill and secondary recharge of springflow into the basin fill. The long-term decline of flow in the Muddy River indicates there is a limit to the amount of even basin fill groundwater that can be pumped without affecting Muddy River flows.

Conclusion

The Order 1169 pump test made apparent that there is a broad highly transmissive carbonate aquifer underlying CSV, MRSA, Garnet Valley, Hidden Valley and California Wash. The aquifer is interconnected so much among basins that it is necessary to manage groundwater through all basins as if they were part of a whole basin. The primary conclusion of this analysis is that the NSE not allow any pumping of the carbonate aquifer if the continued decrease in spring flow in MRSA is to be avoided. This conclusion results from the direct correlation of carbonate pumping and carbonate water level and spring discharge decline. Because the spring flow is directly responsible for Muddy River flows, preventing any additional carbonate pumpage is also necessary for protecting downstream water rights.

Another conclusion is that Kane Springs Valley should be managed as part of LWRFS. This conclusion results from the flat carbonate water level extending into that valley and the likelihood that water pumped from Kane springs Valley would quickly contribute to the depletion of the carbonate aquifer in CSV and MRSA.

A third conclusion is that some basin fill pumping could occur without significantly affecting the spring flow. A preliminary estimate is the pumping that occurred prior to significant carbonate pumping, or about 4000 afa. It is probably not possible to increase that pumpage by transferring carbonate rights to basin fill wells because of the observed long-term decline in Muddy River flows.

References

Johnson C, Mifflin M (2013) Summary of Order 1169 Testing Impacts, per Order 1169A. Mifflin and Associates, Inc.

Myers T (2013) Technical Memorandum, Comments on Carbonate Order 1169 Pump Test Data and the Groundwater Flow System in Coyote Springs and Muddy River Springs Valley, Nevada. Prepared for Great Basin Water Network.

SNWA (Southern Nevada Water Authority) (2018) Assessment of Environmental Conditions Related to Moapa Dace in the Lower White River Flow System. Las Vegas, Nevada, 55 p.

SNWA (Southern Nevada Water Authority) (2013) Nevada State Engineer Order 1169 and 1169A Study Report. Las Vegas, Nevada, Doc. No, WMP-ED_0001, x p.

US DOI (US Fish and Wildlife Service, Bureau of Land Management, National Park Service) (2013) Test Impacts and Availability of Water Pursuant to applications Pending Under Order 1169.

USFWS (US Fish and Wildlife Service, Region 1) (1996) Recovery Plan for the Rare Aquatic Species of the Muddy River Ecosystem, First Revision. Portland OR