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Project Memorandum

To:	**SWCA Environmental Consultants**	**Doc. No.:**	**N/A**
Attention:	**Chris Garrett, Donna Morey**	**cc:**	
From:	**Gabriele Walser**	**Date:**	**August 27, 2020**
Subject:	**Review of Desert Wellfield Subsidence Analysis**		
Project No.:	**1704007-06**		

1.0 INTRODUCTION

On behalf of the Secretary of Agriculture, the Tonto National Forest (TNF) and SWCA Environmental Consultants (SWCA) are preparing an Environmental Impact Statement (EIS) for the mining operations proposed by Resolution Copper Mining, LLC. (Resolution Copper). The proposed mining operations will require additional water beyond that produced by mine dewatering. The largest consumptive water use will be for the tailings storage facility. Thus, included in the proposed action is pumping of groundwater, including banked water credits. Pumping for the proposed Resolution Copper mine is proposed to occur at the Desert Wellfield, located in the east Salt River Valley; however, pumping in the Desert Wellfield may lead to land subsidence. Based on public comments received during the Draft EIS, SWCA and the TNF requested that BGC Engineering USA, Inc. (BGC) prepare this Technical Memorandum summarizing our review of available information about potential subsidence in the Desert Wellfield, including information presented by M&A (April 23, 2020). We also present estimates of the magnitude of possible subsidence, for the purpose of disclosing potential impacts in the Final EIS.

We first present some background information on subsidence in Arizona. This is followed by a summary of the potential volumes of water to be withdrawn by Resolution Copper at the Desert Wellfield and current and historic water levels at the Desert Wellfield. We then estimate potential subsidence from the proposed water withdrawal based on observed subsidence in the Hawk Rock Area, which is located northwest of the Desert Wellfield.

2.0 SUBSIDENCE IN ARIZONA

As summarized from Gelt (1992), the hydrogeological characteristics related to subsidence in Arizona can be described as follows. Broad alluvial basins surrounded by mountains characterize south-central Arizona. The mountains consist of igneous, metamorphic or sedimentary rocks. The basins are flat and wide and contain a great thickness of unconsolidated to moderately consolidated alluvium or loosely compacted alluvial sand and gravel. Large amounts of groundwater are stored in the alluvium. Groundwater occupies and moves through the pore spaces of the alluvial basin fill. If groundwater is pumped from the alluvium, water is taken from the pore spaces and the water surface drops. Without the water and the associated buoyant forces, the particles settle and become more tightly packed together. The more water is removed, the more the sediments compress until eventually the land surface subsides. This subsidence

occurs gradually and can be distributed over wide areas. Besides the amount of groundwater drawdown, the grainsize and prior density of the sediments also influence subsidence. In general, fine silt and clay sediments compact more than coarse-grained sand and gravel sediments.

Subsidence is most likely to occur in areas with clay layers and where drawdown exceeds 100 feet (Gelt, 1992) and is largely an irreversible process. That is, even if groundwater levels rise after subsidence has occurred, ground elevations will not return to prior levels.

Gelt (1992) documents that there are various locations within the Salt River Valley where subsidence is occurring. In the Queen Creek-Apache Junction area about 230 square miles had subsided more than three feet by 1977. Near Luke Air Force Base west of Phoenix and in the western part of the Salt River Valley 140 square miles had subsided more than three feet by 1977. At an area east of Mesa 5.2 feet of subsidence were measured. Subsidence has also been recorded in the Paradise Valley area in eastern Salt River Valley where the land surface subsided as much as five feet between 1965 and 1982 (Figure 1) (Gelt 1992). In Arizona, where multiple water users in a basin create additive drawdowns, subsidence is generally a basin-wide phenomenon, rarely attributable to a single water user.

Fissures may result from subsidence. Gelt (1992) states:

> "…Fissures result when subsidence is not uniform over an area because of differences in geology and rates of groundwater pumping.
>
> Bedrock is found close to the mountain ranges and, as a result, fissures commonly form along the margins of a subsiding basin. Here the alluvial soil pulls away from the mountains at the basin's edge because of uneven settling."

Fissures have been reported in numerous places including Queen Creek, Chandler and Scottsdale (AGS, December 2007).

3.0 WATER WITHDRAWAL

Resolution Copper plans to pump groundwater at the proposed Desert Wellfield, located in the east Salt River Valley within the Phoenix Active Management Area (AMA), approximately 3.5 miles southwest from the junction of Superstition Freeway (US-60) and AZ-79 along the MARRCO corridor. The MARRCO corridor is an approximately 28-mile long right-of-way, generally 200 ft wide, for the old Magma Arizona Railroad. Currently, several utilities are present within the MARRCO Corridor, including Arizona Water Company facilities and a water pipeline partially buried in the railbed. This 18-inch pipeline was installed by Resolution-Copper to deliver treated water from the existing water treatment plant at the Plant site to the New Magma Irrigation and Drainage District.

Maximum groundwater withdrawals would occur under Alternative 2 of the EIS (Tonto National Forest, August 9, 2019), with total groundwater withdrawals of 600,000 acre-feet (AF) and average pumping rates of approximately 8,862 gpm during the mining period (2028-2068). Water withdrawals during the mining period for all other alternatives, except Alternative 4, would be

slightly lower (7,469 to 8,233 gpm), while withdrawals for Alternative 4 would be significantly lower (2,656 gpm) (M&A, January 23, 2020).

4.0 WATER LEVEL CHANGES NEAR THE DESERT WELLFIELD

Water levels in and around the Desert Wellfield declined from the earliest records around 1960 until about the mid-1990s (e.g., approximately 80 feet since 1975 for well No. 55-615235, and approximately 130 feet since 1963 for well No. 55-601703) (ADWR 2020b and M&A, April 23, 2020). Well locations around the Desert Wellfield are shown in Figure 2. Water levels for these wells are shown in Appendix A.

In the mid-1990s, due to changed water management practices, water levels started to recover. Furthermore, Resolution Copper has contributed water to Underground Storage Facilities (USF) in New Magma Irrigation and Drainage District since 2006. By December 2019, water levels had recovered approximately 60 feet in the northeast corner of the Desert Wellfield (No. 55-615235), approximately 85 feet near the southwest end of the Desert Wellfield (No. 55-202246), and 120 feet south of the Desert Wellfield in the New Magma Irrigation and Drainage District (No. 55-601703) (ADWR 2020b and M&A, April 23, 2020).

5.0 EXISTING SUBSIDENCE DATA

Historic subsidence was recorded along the railroad line running from Florence towards Phoenix between 1948 to 1993 and 1967 to 1993 (see Appendix B). Approximate subsidence ranged from 0.5 to 5 feet, with lesser amounts occurring closer to the proposed Desert Wellfield.

The Hawk Rock Area (ADWR 2020a) is northwest of the Desert Wellfield, starting approximately 6 miles from the Desert Wellfield and extending for approximately 20 miles toward Apache Junction and East Mesa (Figure 2). Subsidence in the Hawk Rock Area has been mapped since 1933 (ADWR 2020a). Measured subsidence for the central Hawk Rock Area is shown in Appendix B. Maximum measured subsidence in the central Hawk Rock Area was 1.37 feet between 1973 and 1980. Subsidence at adjacent locations ranged from 0.8 to 1.0 feet over the same time period (ADWR 2020a and Appendix B). From 1992 to 2000 subsidence in the Hawk Rock Area ranged up to 0.8 feet (ADWR 2020a and M&A, April 23, 2020). The corresponding subsidence rate in the Hawk Rock Area from 1992 to 2000 was up to 1.2 inches/year (ADWR 2020a and Appendix B). Fissures have also been recorded in the Hawk Rock area (ADWR 2020a and Appendix B).

6.0 POSSIBLE SUBSIDENCE FROM RESOLUTION GROUNDWATER PUMPING

When both subsidence and drawdown are known, subsidence can be correlated to drawdown, and this correlation can be used to approximately estimate future subsidence for expected drawdowns. However, no subsidence measurements are available for the proposed Desert Wellfield area.

In the Desert Wellfield, historic groundwater withdrawals and falling water levels through the mid-1990s (i.e., 80 to 130 feet, see Section 4.0) may have led to prior subsidence. This

(undocumented) subsidence would be largely irreversible but additional subsidence could occur if water levels fall below prior minimum water levels. For water supply pumping under Alternative 2 in the Resolution EIS (Tonto National Forest, August 9, 2019) the maximum simulated drawdown in the center of the Desert Wellfield was estimated to be approximately 210 feet. This estimate is based on M&A (January 23, 2020), and includes pumping from all users in the East Salt River Basin, however, pumping from other users does not show any impact at the location of the Desert Wellfield until after Resolution pumping ends. The expected drawdown of 210 feet is approximately 80 to 130 feet lower than the previous maximum reported drawdown (Section 4.0). Consequently, the range of 80 to 130-foot drawdown is appropriate for estimating future subsidence.

We use the Hawk Rock Area as an analogue for the Desert Wellfield by assuming the two areas have similar geology and hydraulic properties, and that an approximate linear relationship between drawdown and subsidence is appropriate. M&A (April 23, 2020) used subsidence in the Hawk Rock Area to show potential subsidence in alluvial deposits that may be similar to the Desert Wellfield.

For well GWSI ID 332308111345001 we estimate an average drawdown rate of 2.8 feet per year from 1992 to 2000 (Appendix A). With a drawdown rate of 2.8 feet per year and a subsidence rate in the neighborhood of this well of 0.8 to 1.2 inches per year from 1992 to 2000 (Appendix B), we estimate 0.3 to 0.4 inches of subsidence per foot of drawdown.

Assuming (1) the maximum drawdown beyond the historic drawdown in the Desert Wellfield will be approximately 80 to 130 feet over 20 years and (2) a subsidence rate similar to well GWSI ID 332308111345001 (i.e., 0.3 to 0.4 inches of subsidence per foot of drawdown), a calculated range of potential subsidence is 23 to 57 inches over 20 years.

Drawdown caused by the Desert Wellfield is predicted to be greatest near the wellfield, with potential drawdowns greater than historic drawdowns not extending farther than approximately two miles away from the Desert Wellfield (M&A, January 23, 2020). Therefore, appreciable subsidence from the Desert Wellfield pumping is unlikely to extend further.

7.0 CONCLUSIONS

At the request of SWCA and the TNF, BGC estimated the magnitude of possible subsidence, for the purpose of disclosing potential impacts in the Final EIS. The Hawk Rock Area is considered an analogue for subsidence in the Desert Well Field (M&A, April 23, 2020). BGC estimated potential subsidence at the Desert Wellfield based on measured subsidence in one location at the Hawk Rock Area near well GWSI ID 332308111345001. However, subsidence is variable, and depends on the geology of an area and hydraulic and physical characteristics of the porous media. Subsidence is often a basin-wide phenomenon caused by additive drawdowns from multiple users and is rarely attributable to a single water user. This analysis is not designed to predict the exact amount of subsidence at the Desert Wellfield. Rather, this analysis indicates that subsidence at the Desert Wellfield caused by Resolution pumping could be on the order of several feet, but is likely less than ten feet even in the center of the Desert Wellfield. Subsidence is

expected to decrease as drawdown decreases with distance from the center of the wellfield. Because drawdown greater than historic groundwater drawdown is unlikely to occur more than approximately two miles from the Desert Wellfield, subsidence that could be attributed to pumping at the Desert Wellfield would be localized to the area of the Desert Wellfield. It is possible that earth fissures will be caused by this subsidence, however, this is somewhat unlikely given that the wellfield is distant from the valley perimeter where differential settlement that causes fissures is more likely.

8.0 CLOSURE

BGC Engineering Inc. (BGC) prepared this document for the account of SWCA Environmental Consultants (SWCA) and the Tonto National Forest as part of our scope of services under Subcontractor Master Services Agreement, dated September 13, 2016, and Work Authorization 10, dated April 7, 2020. The material in it reflects the judgment of BGC staff in light of the information available to BGC at the time of document preparation. Any use which a third party makes of this document or any reliance on decisions to be based on it is the responsibility of such third parties. BGC accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions based on this document.

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Yours sincerely,

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NE/MH/CAM/twc/mm

Attachments: Figures
Appendix A - Water Level Elevations For Selected Wells
Appendix B - Subsidence Measurements From ADWR

REFERENCES

ADWR (2020a). Arizona Department of Water Resources, Hydrology, Land Subsidence in Arizona. https://new.azwater.gov/hydrology/field-services/land-subsidence-arizona. Accessed June 5, 2020.

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Montgomery & Associates. (2020, January 23). Technical Memorandum, Desert Wellfield Pumping 100-Year Drawdown Analysis for ADWR Evaluation in Support of the Resolution Copper EIS, Project #: 605.7506.

Tonto National Forest, USDA Forest Service. (2019, August 9). Resolution Copper Project and Land Exchange Environmental Impact Statement, Tonto National Forest; Pinal County, AZ, Document Number: 2016-05781.

FIGURES

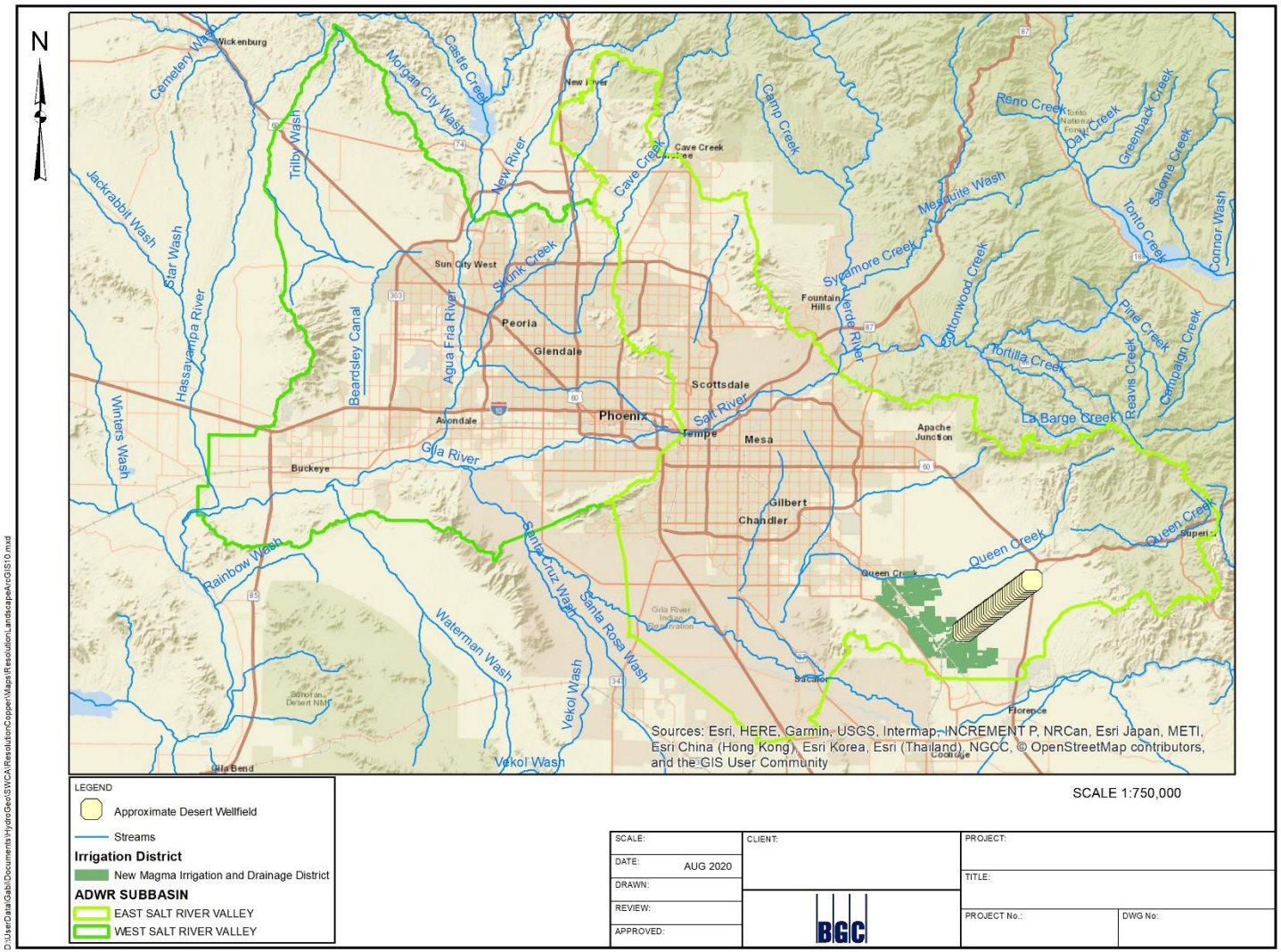


Figure 1. Salt River Valley.

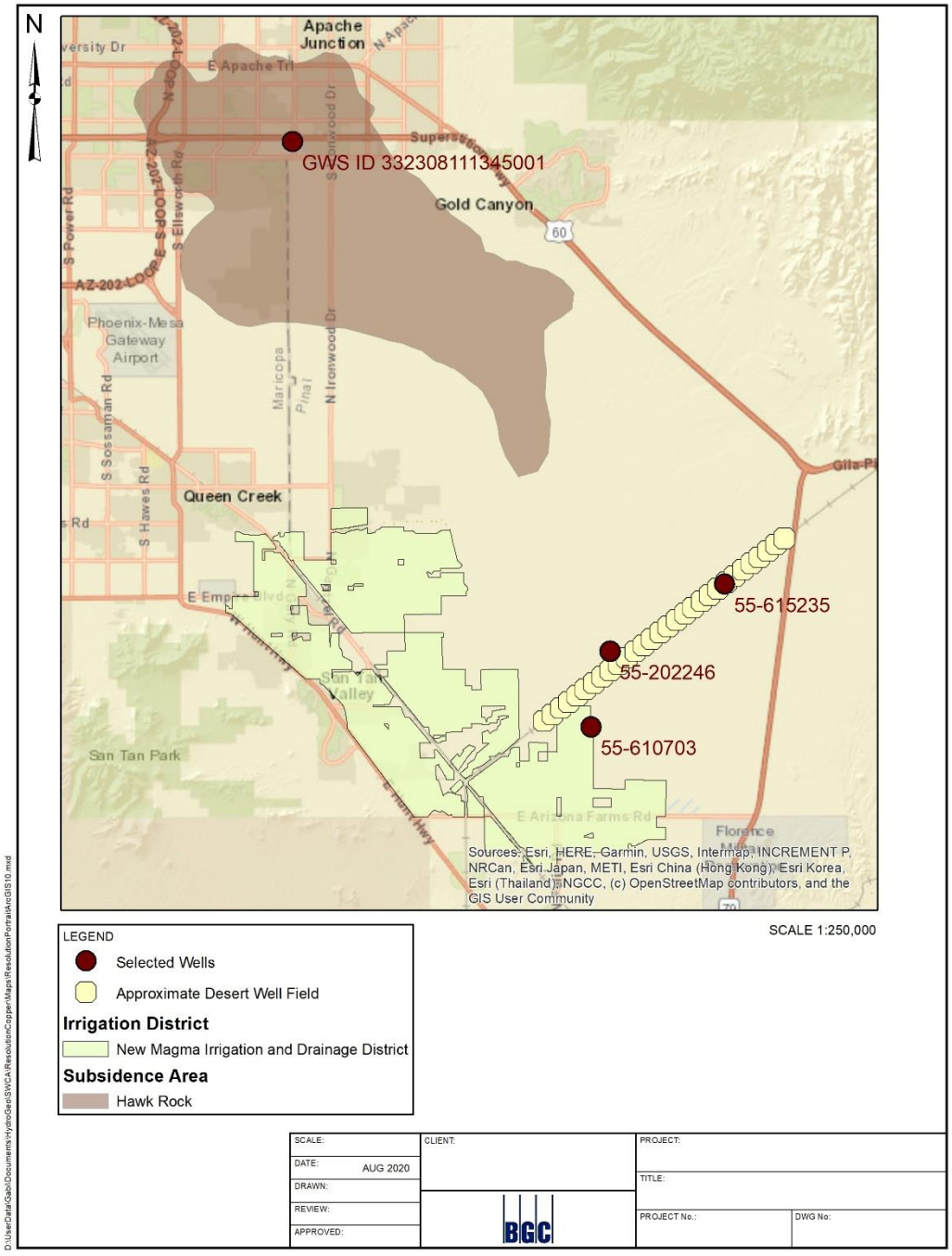
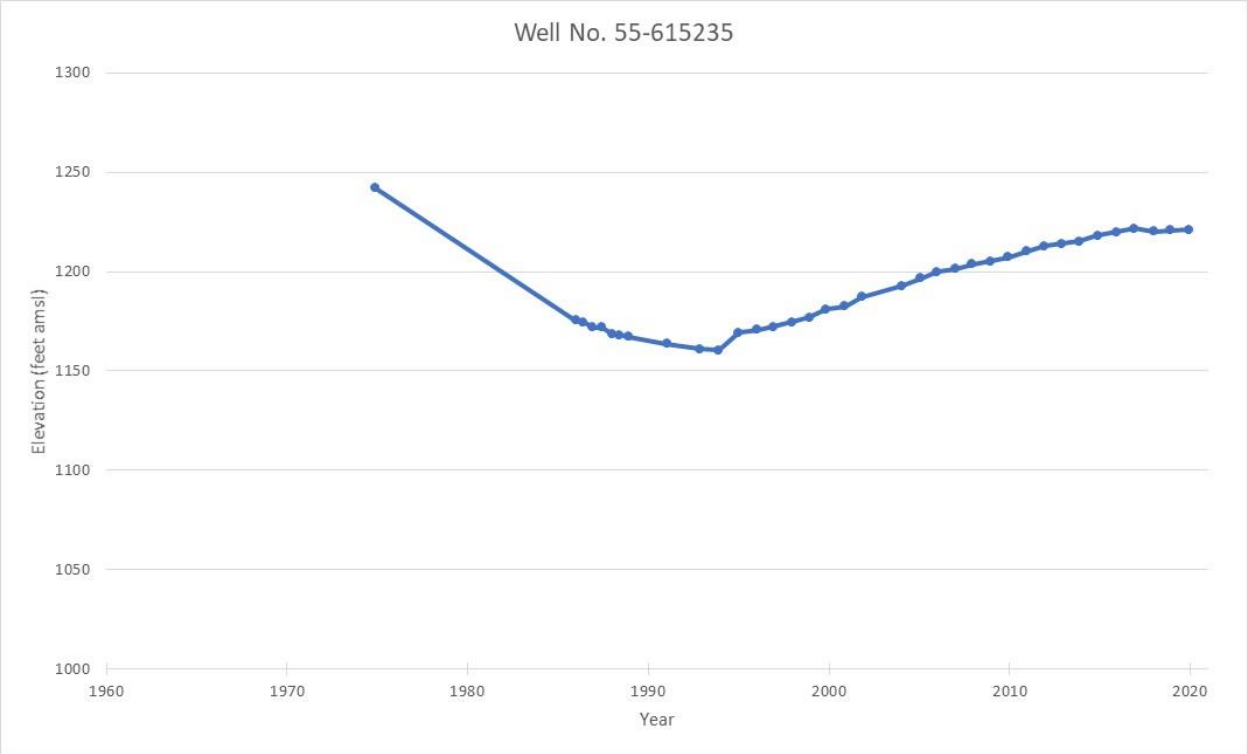
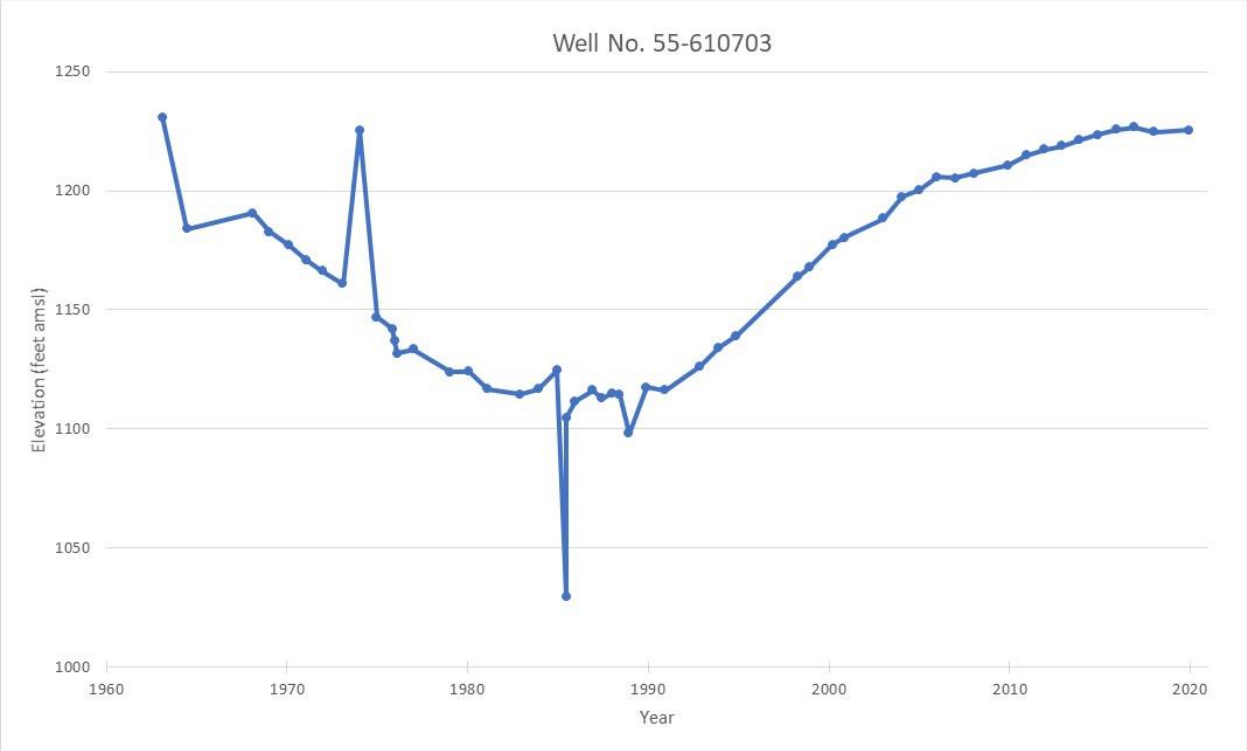


Figure 2. Location of Desert Wellfield, selected wells and Hawk Rock Area.

APPENDIX A:
WATER LEVEL ELEVATIONS FOR SELECTED WELLS

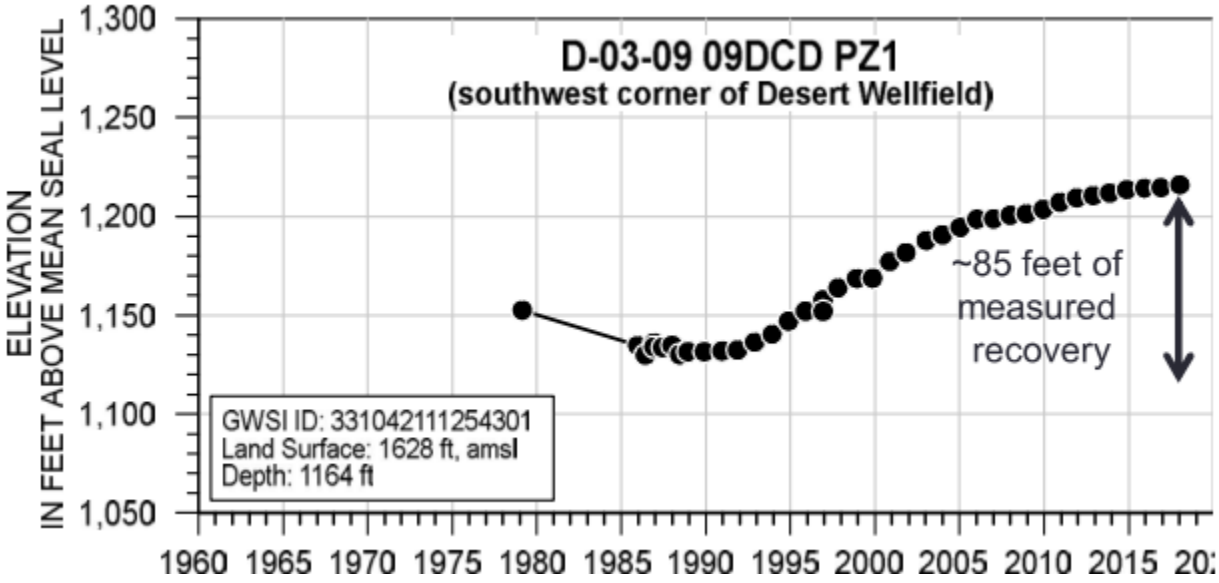


Data Source: ADWR 2020b



Data Source: ADWR 2020b

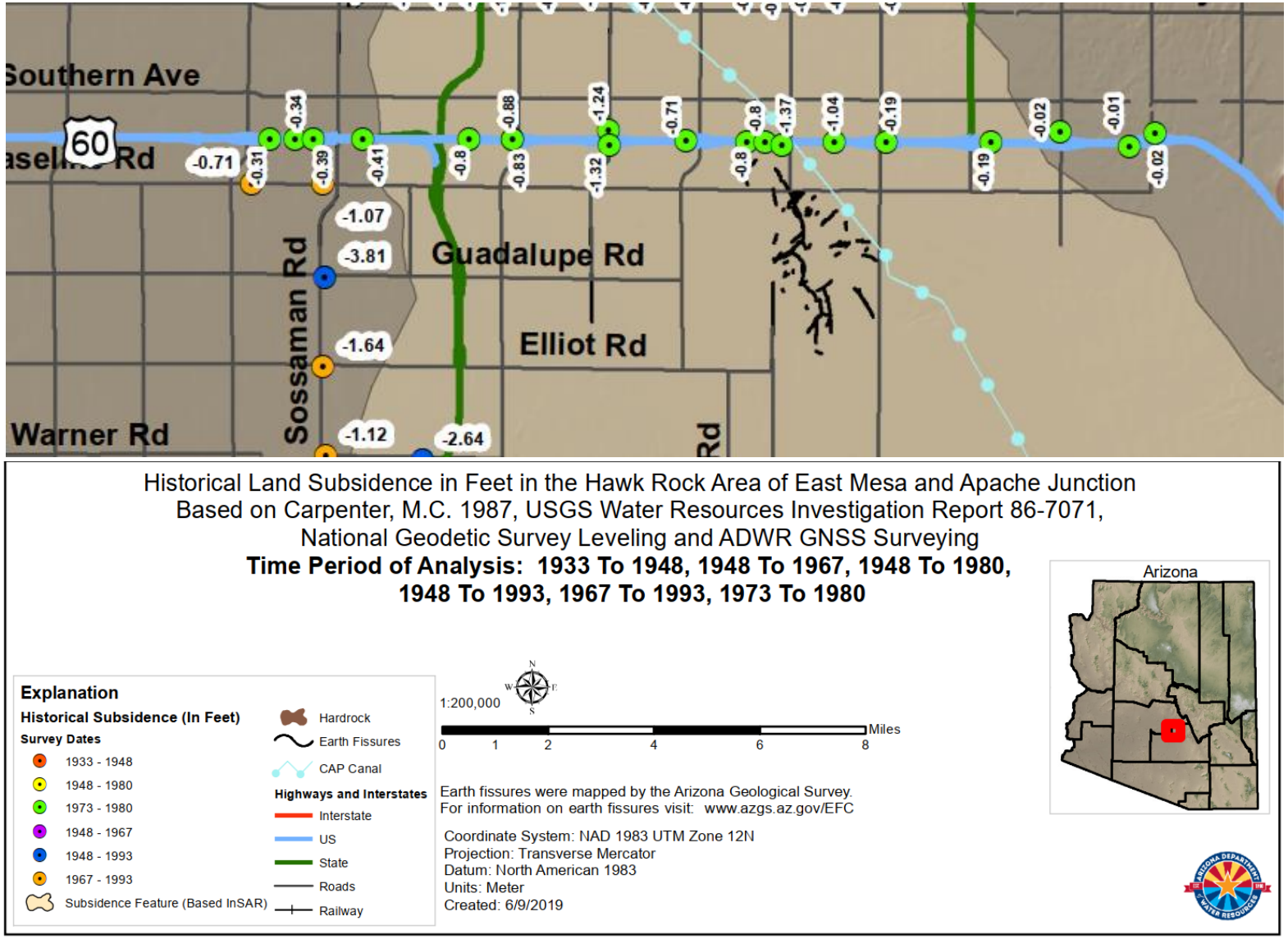
Well No. 55-202246



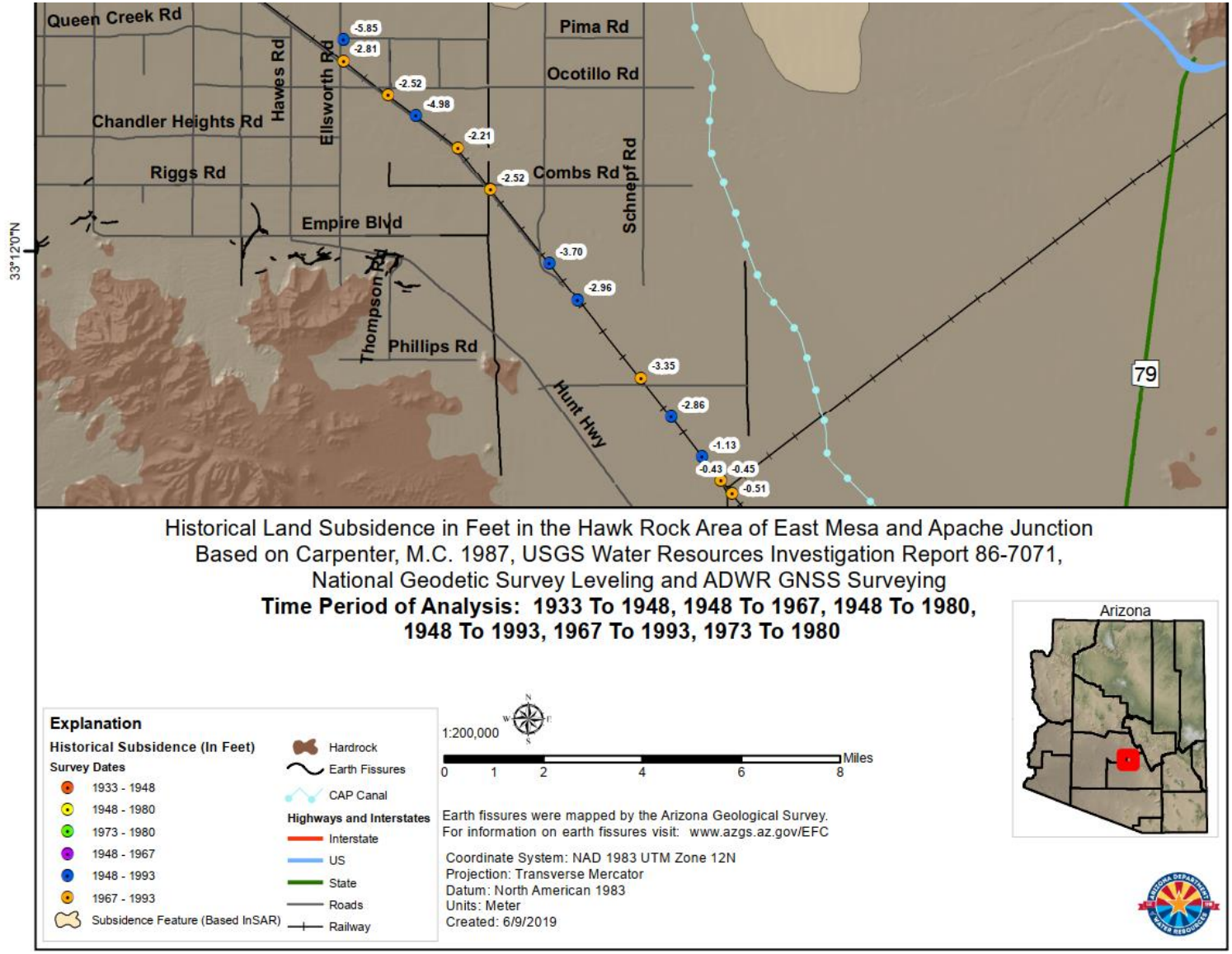
Source: M&A (April 23, 2020)

Source: M&A (April 23, 2020)

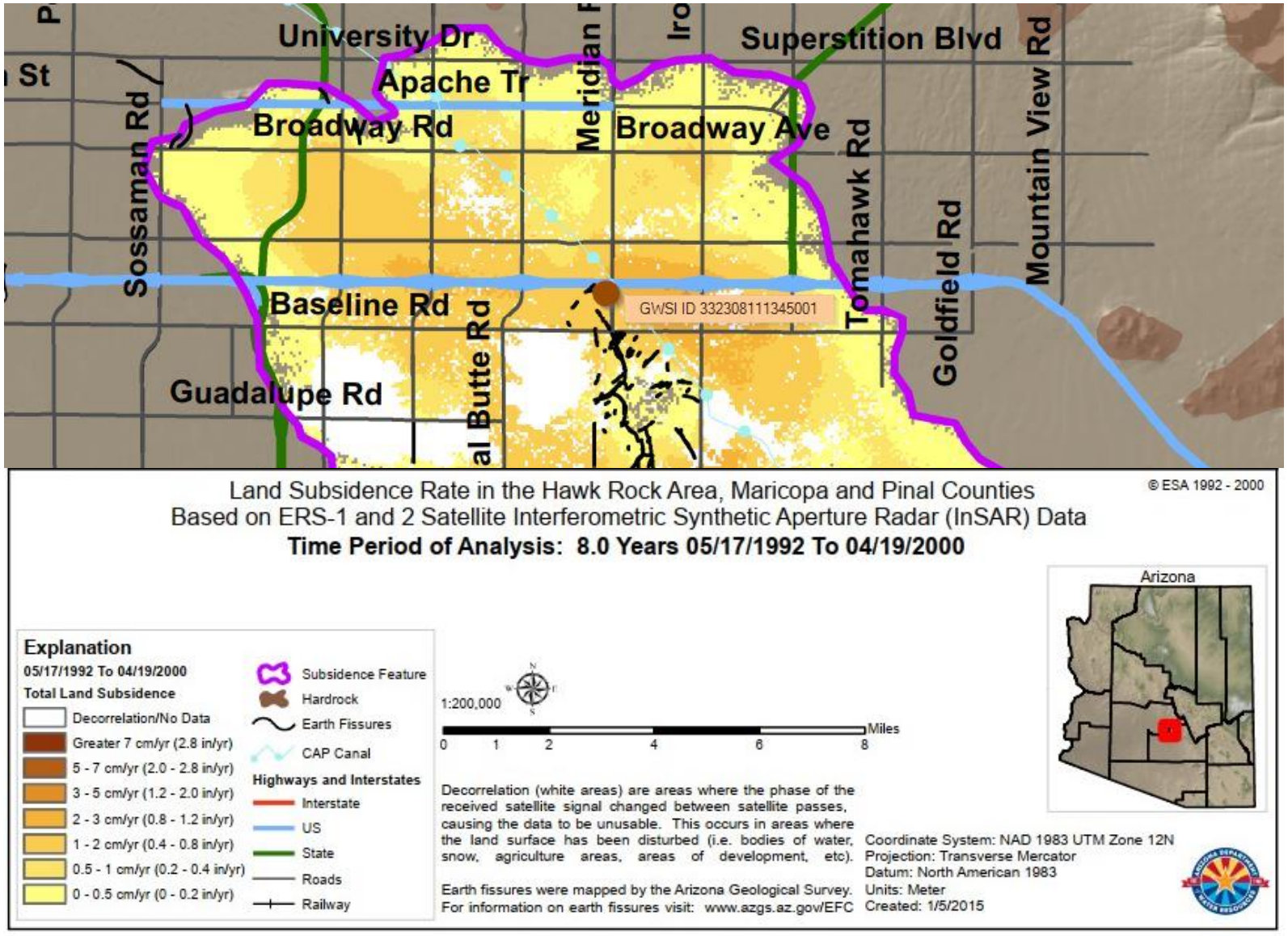
APPENDIX B:
SUBSIDENCE MEASUREMENTS FROM ADWR



Historical land subsidence in feet in the Central Hawk Rock Area. Figure snippet from ADWR (2020a).



Historical land subsidence in feet in the Hawk Rock Area along the railroad line. Figure snippet from ADWR (2020a).



Land subsidence rate in the Central Hawk Rock Area. Figure snippet from ADWR (2020a).