APPENDIX A

MATERIAL DAMAGE CRITERIA
N-AQUIFER WATER LEVELS

INTRODUCTION

This Appendix discusses the development of 'material damage' criteria as required by the "Stipulated Settlement Agreement of Appellants to Nizhoni Ani et.al. February, 2012 Request for Review", IV. Hydrology Claims: No. 2 which states:

> In the updated Kayenta Mine Complex CHIA, OSM shall identify and adopt, as material damage criteria for the Navajo Sandstone Aquifer ("N-Aquifer"), numeric water levels that will be physically measured for all wells screened in the confined area of the N-aquifer that are monitored by the U.S. Geological Survey(USGS).

OSMRE has defined 'material damage' as:

> Material damage to the hydrologic balance outside the permit area means any quantifiable adverse impact from surface coal mining and reclamation operations on the quality or quantity of surface water or groundwater that would preclude any existing or reasonably foreseeable use of surface water or groundwater outside the permit area.

Given the large size of the N-Aquifer system, its artesian head, depth, thickness and the amount of groundwater in storage, "precluding any existing or reasonably foreseeable use" of groundwater is an economic rather than physical concern. This is particularly true for the proposed future mine plan; historic mine pumping has declined from a high of about 4,500 ac-ft in 2005 to approximately 1,400 ac-ft in 2011 and will be further reduced in the future until ceasing completely in 2057. The question is not one of physical availability but of the cost to supply water from significant depth to users at the land surface.

AFFORDABILITY OF WATER

Many Navajo residents within the N-Aquifer study area reside in communities that receive water service through the Navajo Tribal Utility Authority (NTUA). Many Hopi have water service through village water systems. However, some members of both tribes in the study area have no water service, relying on hauled water for potable use. Transportation costs are typically many times higher than the commodity costs of the water itself.

Poverty rates among residents in the N-Aquifer study area are high; an estimated 38 percent of all households live in poverty, that is, with annual household income below the Federal poverty thresholds. Households in poverty have fewer economic resources and adjustment options to respond to increases in prices. Economic data from the Census Bureau suggests that while some Navajo and Hopi households in the study area have incomes above the poverty level, median household and per capita incomes are still below the corresponding values for off-reservation areas in Coconino and Navajo counties and across Arizona. Consequently, increases in commodity prices, such as water costs, may result in greater economic hardships for individuals living on the reservations within the N-Aquifer study area (Dutton 2016).

Given the above economic considerations, OSMRE has determined that "precluding any existing or reasonably foreseeable use" of N-Aquifer groundwater at the KMC is defined as increasing the cost of pumping water by more than one (1) dollar per month per connection (household) as a result of declining water levels in community production wells due to drawdown caused by water supply pumping at the Kayenta Mine Complex. Thus, the material damage numeric water levels in the confined area N-Aquifer community water supply wells monitored (for water levels) by the USGS are based on limiting the decline in water level to less than the cost of electric power to lift groundwater of $1/household/month for wells that supply potable water to communities.

Some of the USGS monitored wells are windmills and primarily supply water for livestock use. Water level change in these wells does not have an economic impact unless the water level falls below the ability of the windmill to lift water to the surface. This level is the depth of the windmill's drop pipe installed in the well. If the water level is drawn down below the bottom of the drop pipe, the drop pipe and cylinder have to be removed, lengthened and re-installed.

Review of the USGS monitored wells on Black Mesa, as of 2011, indicate that 14 wells meet the criterion of being 'screened in the confined N-aquifer' and 'monitored for water level by the USGS'. The USGS BM-series monitoring wells were excluded since the use at these locations are for observation; therefore, the preclusion of use is not applicable. These wells are given in Table 1, with key well data. Location of the wells is shown on Figure 1.

Table 1, USGS Monitored Wells Screened in Confined N-Aquifer

Well Name	Surface Elevation (ft msl)	2012 Water Level (ft msl)	2012 Depth to Water (ft bls)	Depth Top of N-Aquifer (ft bls)	Well Type [2]
Forest Lake NTUA1 (4T-523)	6,654	5,480	1,174	NR[1]	P
Keams Canyon PM2	5,809	5,311	498	900	P
Kitsiili NTUA2	6,780	5,444	1,336	2,205	P
Kykotsmovi PM1	5,657	5,445	212	880	Pa
Kykotsmovi PM3	5,618	5,367	251	840	P
Pinon PM6	6,397	5,480	917	1,870	Pa
Howell Mesa (3K-311)	5,855	5,411	444	615	W
Marsh Pass (8T-522)	6,040	5,912	128	480	W
Kayenta West (8T-541)	5,885	5,587	298	700	W
Rough Rock (10R-119)	5,775	5,518	257	310	W
Rough Rock (10T-258)	5,903	5,591	312	460	W
Rough Rock (10R-111)	5,757	5,558	199	210	W
Sweetwater Mesa (8K-443)	6,024	5,479	545	590	W
White Mesa Arch (1K-214)	5,771	5,551	220	250	W

1. NR – Not reported
2. P – Community Production Well
   Pa –Community Production Well Abandoned
   W – Windmill Livestock Well

MATERIAL DAMAGE NUMERIC WATER LEVELS

In order to set numerical water levels in the above wells to satisfy the material damage criteria, wells are divided into two categories: 1) community water supply wells, and 2) windmill equipped stockwatering wells.

Community Water Supply Wells

As described above, the material damage water level is set based on the depth to water below land surface (ft bls) that would result in increasing the household cost of water by no more than $1 per month. This depth to water, or lift, is computed as described below.

The cost of pumping groundwater is given by the following equation (Campbell 1973):

$$\boldsymbol{Cost/Hour} = \frac{(GPM)\ x\ (Lift)\ X\ (0.746)\ x\ (Elect\ Cost\ \$/KW-hr)}{(3960)\ x\ (Pump\ Eff)\ x\ (Motor\ Eff)}$$

Using typical Arizona well values for the following parameters:

- Pump efficiency (75 percent)
- Motor efficiency (90 percent)

The above equation with typical AZ values was solved for lift, (in ft); the equation in this form is:

$$\boldsymbol{Lift} = \frac{cost/hr}{\$\ KW - hr * GPM * 3.7411E - 04}$$

To calculate the lift it is necessary to estimate the usage, in gpm, per household. This was done by dividing the reported annual water system usage by the number of connections (households) served by the system. The systems with their annual withdrawal, number of households and use per household are given in Table 2.

Table 2, Confined N-Aquifer Water Systems Water Use

Water System	2011 Withdrawal (gpm)	Number of Households	2011 Use Per Day Per Household (GPD)[1]
Forest Lake	9.6	49	282
Keams Canyon	36.6	142	371
Kits'illi	13.1	74	254
Kykotsmovi	41.4	250	239
Pinon	208.5	1427	210

1. GPD – gallons per day

The estimated use per household numbers for these systems average 271 gallons per day, which is more than twice the 108 average for all NTUA systems (NTUA 2015). The reasons for this are uncertain; however, since lift is inversely proportional to use (pumping rate), these values suggest the analysis is conservative.

Current cost of electric power from NTUA is $0.07 KW-hr. To account for potential increases in power cost during the life of the mine the cost per kilowatt hour was increased by 30 percent to $0.091 KW-hr for this analysis. Since lift is inversely proportional to power cost, using a higher power cost results in a lower lift to meet the $1 dollar per month threshold, adding conservatism to the analysis.

Substituting the per household use (in gpm) into the lift equation and converting $/hour to $/month gives the additional lift to increase the cost of water by one dollar ($1) per household per month. Results of this calculation for the water system supply wells included in Table 1 are given in Table 3. It is not known, in detail, which wells supply which households. Therefore, for purposes of assigning material damage water levels to each identified USGS monitored community water supply well, the same numeric water level value is assigned to all wells within the area of the relevant water system.

Table 3, Lift and Material Damage Numeric Water Level

Well Name	Lift (ft)[1]	2012 Depth to Water (ft bls)	Material Damage Depth to Water (ft bls)	Material Damage Water Elevation (ft msl)
Forest Lake NTUA1 (4T-523)	274	1,174	1,448	5,206
Keams Canyon PM2	205	498	703	5,106
Kits'iili NTUA2	306	1,336	1,642	5,138
Kykotsmovi PM1	310	212	522	5,135
Kykotsmovi PM3	310	251	561	5,057
Pinon PM6	368	917	1,286	5,112

1. Lift resulting in a cost of $1/per month per household

Windmill Wells

As noted in Table 1, eight (8) of the USGS monitored confined N-Aquifer wells are windmills primarily used for livestock watering. For those monitored wells, a different basis for the numeric material damage water level is applied.

Once water levels in a windmill well fall below the bottom of the drop pipe, the windmill can no longer lift water to the surface; the drop pipe must be extended (deepened) for the windmill to continue to function. OSMRE has therefore set the material damage numeric water level equal to the depth of the windmill drop pipe. Unfortunately, the depth of the drop pipe was not available for two (2) of the windmill wells; Howell Mesa (3K-311) and White Mesa Arch (1K-214). For these windmills, the material damage water level was set at the top of the N-aquifer. On this basis, the material damage numeric water level for USGS monitored wells with windmills are given in Table 4.

Table 4, Material Damage Numeric Water Level for Windmill Wells

Well Name	Top of N-Aquifer (ft bls)	Well Depth (ft bls)	2012 Depth to Water (ft bls)	Depth of Drop Pipe[1] (ft bls)	Material Damage Depth to Water (ft bls)	Material Damage Water Elevation (ft msl)
Howell Mesa (3K-311)	615	745	444	615(1)	615	5,240
Marsh Pass (8T-522)	480	933	128	189	189	5,851
Kayenta West (8T-541)	700	890	298	420	420	5,465
Rough Rock (10R-119	310	360	298	336	336	5,439
Rough Rock (10T-258)	460	670	257	336	336	5,567
Rough Rock (10R-111)	210	360	312	262	262	5,495
Sweetwater Mesa (8K-443)	590	720	199	588	588	5,436
White Mesa Arch (1K-214)	250	356	545	250(1)	250	5,521

(1) Drop pipe depth not available – Material Damage Water Elevation is Top of N-aquifer.

Numeric Water Levels are Conservative

The material damage numeric water levels given in Tables 3 and 4 are conservative since they do not differentiate between water level drawdown due to mine pumping and non-mine (community and windmill) pumping. The effects of all pumping are reflected in any change in water level. The threshold of economic impact ($1 dollar per month analysis) is protective of the most vulnerable population (those at or below the poverty level) and the cost of electric power is increased 30 percent, decreasing the material damage numeric depth to water value (shallower water level).

Differentiation of Change in Water Level Due to Pumping

As noted above, the material damage water levels do not differentiate between water level drawdown between PWCC mine-related pumping and that due to community, windmill and other pumping. Since OSMRE is responsible for regulating PWCC's activities and has no regulatory authority over community or other pumping, if a material damage level is reached in a given well, the pumping contributing to the drawdown must be assigned to PWCC and others. This will be accomplished by monitoring changes to pumping volumes by PWCC, the communities and any other withdrawals (including future industrial or other uses). Active windmills pump at generally consistent (and low) rates and can be excluded from the analysis. Changes in pumping rates can be input to

the PWCC Black Mesa Groundwater Flow Model to estimate the relative change in water level at the well under consideration due to each pumping source. The amount of drawdown due to PWCC can be computed and a determination made if the material damage numeric water level has been exceeded due to PWCC withdrawals.

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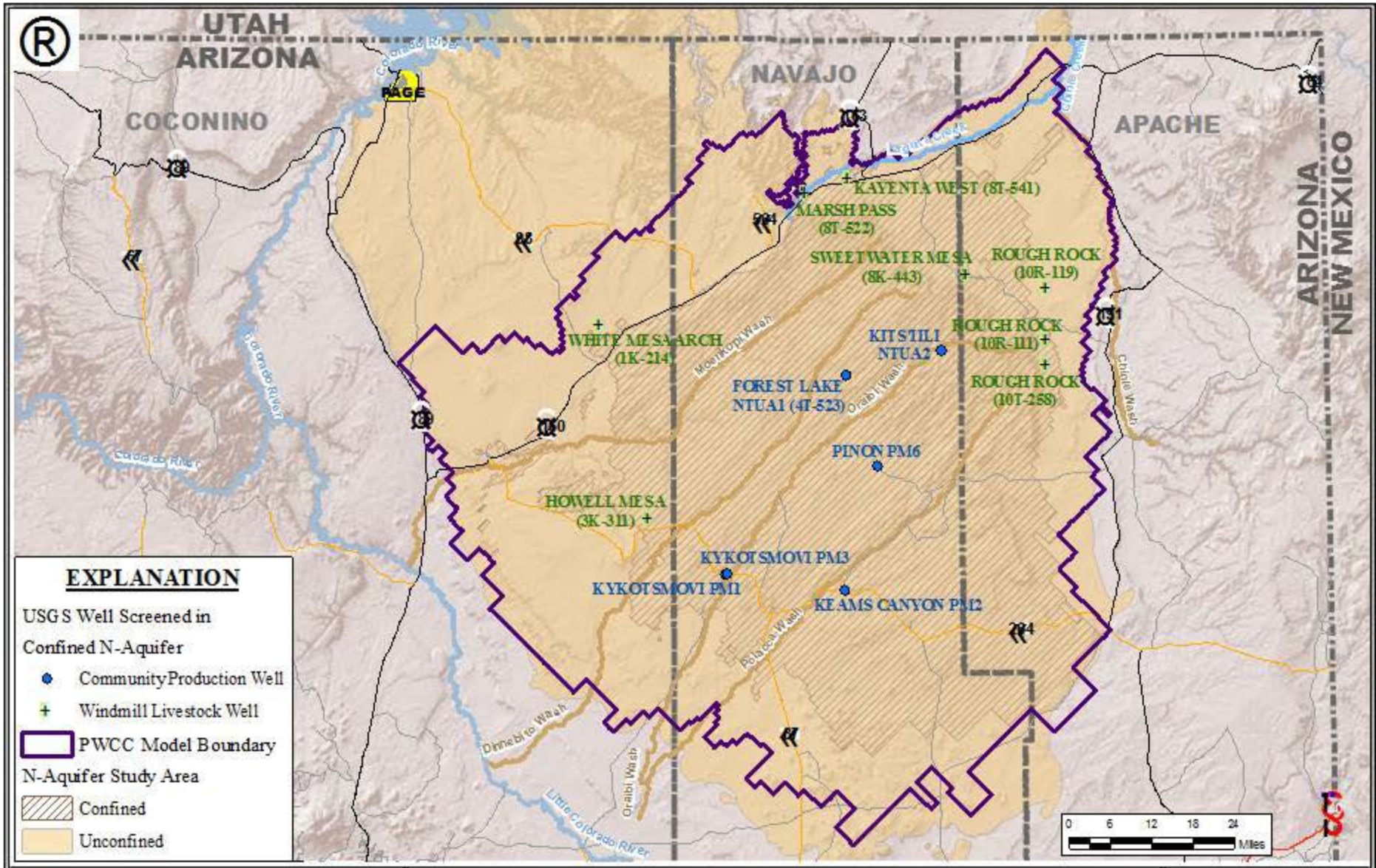


USGS MONITORED WELLS SCREENED IN CONFINED N-AQUIFER LOCATION MAP

Northeastern Arizona

Figure

LIFT (TDH) TO INCREASE WATER COST $1 PER MONTH PER HOUSEHOLD

$$Cost/Hour = \frac{(GPM)\ x\ (Lift)\ X\ (0.746)\ x\ (Elect\ Cost\ \$/KW-Hr)}{(3960)\ x\ (Pump\ Eff)\ x\ (Motor\ Eff)}$$

$$Lift = \frac{cost/hr}{\$\ KW-hr * GPM * 3.7411E-04}$$

Where:
$/kW/hr = 0.091
Pump Eff = 75%
Motor eff = 90%

Denominator = 2673
Numerator = 0.00746 GPM*TDH @ 0.01 KW/hr
0.06789 GPM*TDH @ 0.091 KW/hr
$/hr = 2.79087E-06 GPM*TDH @ 0.01 KW/hr
2.53969E-05 GPM*TDH @ 0.091 KW/hr
Lift= $/hr/2.79087-05*GPM @ 0.01 KW/hr
$/hr/2.55969E-05*GPM @ 0.091Kw-hr

Constant	$0.0 KW/hr
2.79E-06	1
5.58E-06	2
8.37E-06	3
1.12E-05	4
1.4E-05	5
1.67E-05	6
1.95E-05	7
2.23E-05	8
2.51E-05	9
2.54E-05	9.1
2.79E-05	10
3.07E-05	11
3.35E-05	12

Assume max increased cost of water per month = $1 per connection (household)

Forest Lakes	**afa**	**gpm**	**gpd**	
2011 Q =	15.5	9.6	13828	56 gpcd (5 PPH)
Connections =	49	0.1960	282	
$1/mo =	0.00136612	$/hr		
Lift =	**274**	0.091 KW/hr		

Kayenta	**afa**	**gpm**
2011 Q =	414	256
Connections	986	0.2601
$1/mo =	0.00136612	$/hr
Lift =	**207**	0.091 KW-hr

Pinon	**afa**	**gpm**
2011 Q =	337	209
Connections=	1427	0.1463
$1/mo =	0.00136612	$/hr
Lift =	**368**	0.091KW-hr

Kitsillie	**afa**	**gpm**
2011 Q =	21	13
Connections	74	0.1758
$1/mo =	0.00136612	$/hr
Lift =	**306**	0.091 KW-hr

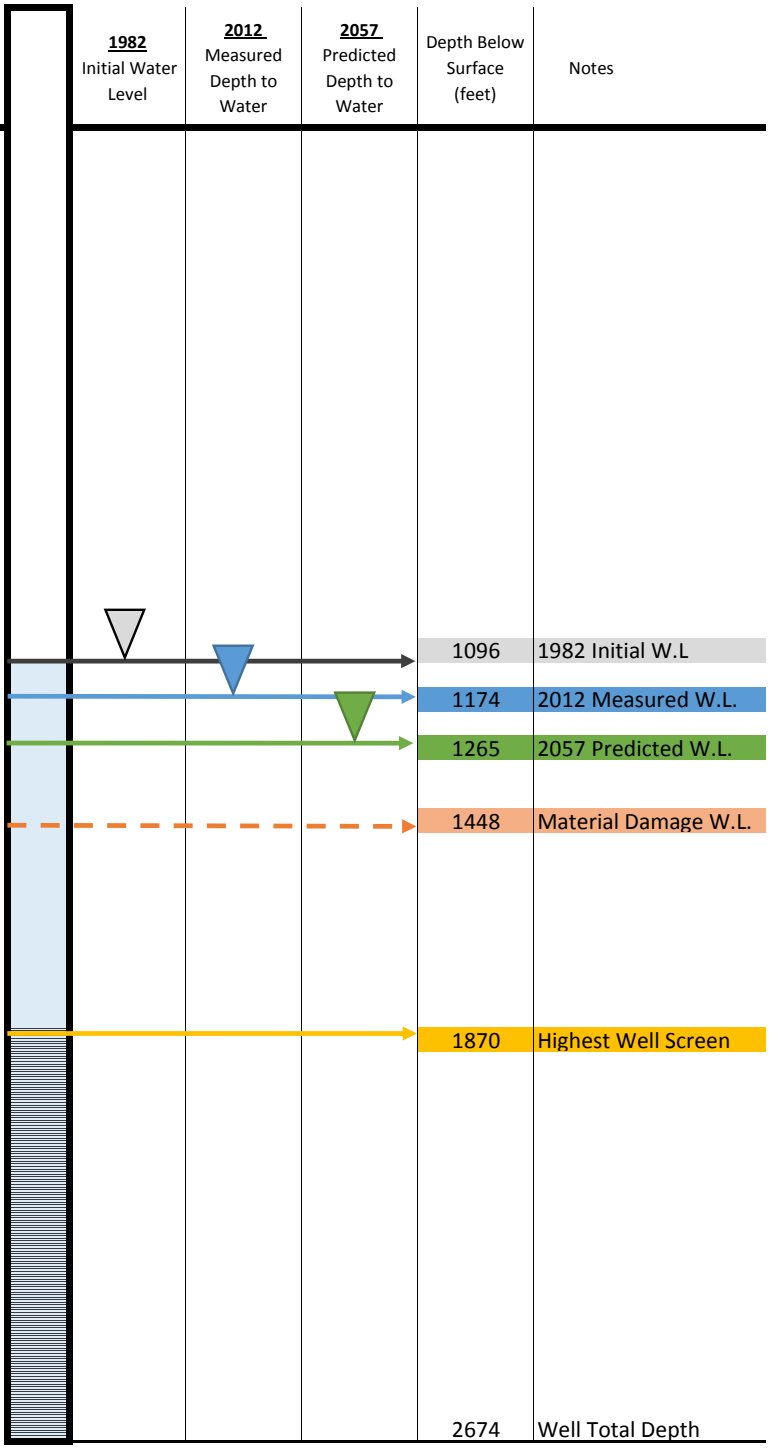
Rough Rock	**afa**	**gpm**
2011 Q =	19	12
Connections	127	0.0927
$1/mo =	0.00136612	$/hr
Lift =	**580**	0.091 KW-hr

Kykotsmovi	**afa**	**gpm**
2011 Q =	70	43
Connections	250	0.1735
$1/mo =	0.00136612	$/hr
Lift =	**310**	0.091 KW-hr

Keams Canyon	**afa**	**gpm**
2011 Q =	60	37
Connections	142	0.2618
$1/mo =	0.00136612	$/hr
Lift =	**205**	0.091 KW-hr

Hotevilla	**afa**	**gpm**
2011 Q =	24.5	15
Connections	144	0.1054
$1/mo =	0.00136612	$/hr
Lift =	**510**	0.091 KW-hr

Forest Lake Supply Well 4T-523



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Settlement Criteria Conditions:

(1) Wells monitored by USGS
(2) Wells in confined N-aquifer
(2a) 6 Supply Wells Measured for water level
(2b) 8 Windmills measured for water level
(3) Criterion are numeric water levels
(4) Water level is physically measured

Criteria Methodology:

Supply Wells
(1) *Consider Affordability of Water*
(1a) Considered most vulnerable population
(1b) Socioeconomic Analysis (Dutton 2016)
(1c) Considered 2010 Census Data
(1d) Affect $1.00/household/month

(2) *Consider power cost to lift water*
(2a) Current power rate $0.07 kW-hr
(2b) Assume 30% rate increase during LOM
(2b) Assumed power rate $0.091 kW-hr

(3) *Measured water level for 6 supply wells*
(3a) From pumping volume and power cost
(3b) Calculation Example: Forest Lake (4T-523)
(3c) Calculation Example: Pinon (PM6)

Windmills
(4) *Measured water level for 8 windmills*
(4a) Depth of drop pipe since no power need
(4b) If drop pipe unknown, use Top N-aquifer

Observation Wells
(5) *No criteria for USGS BM-series wells*
(5a) No use to preclude at observation well

Notes

(1) Life-of-Mine (LOM) Permit Application Period 2019 - 2057

(2) Projected Mine Operation Pumping: 2019-2044 (1200 af), 2044-2047 (500 af), 2047-2057 (100 af)

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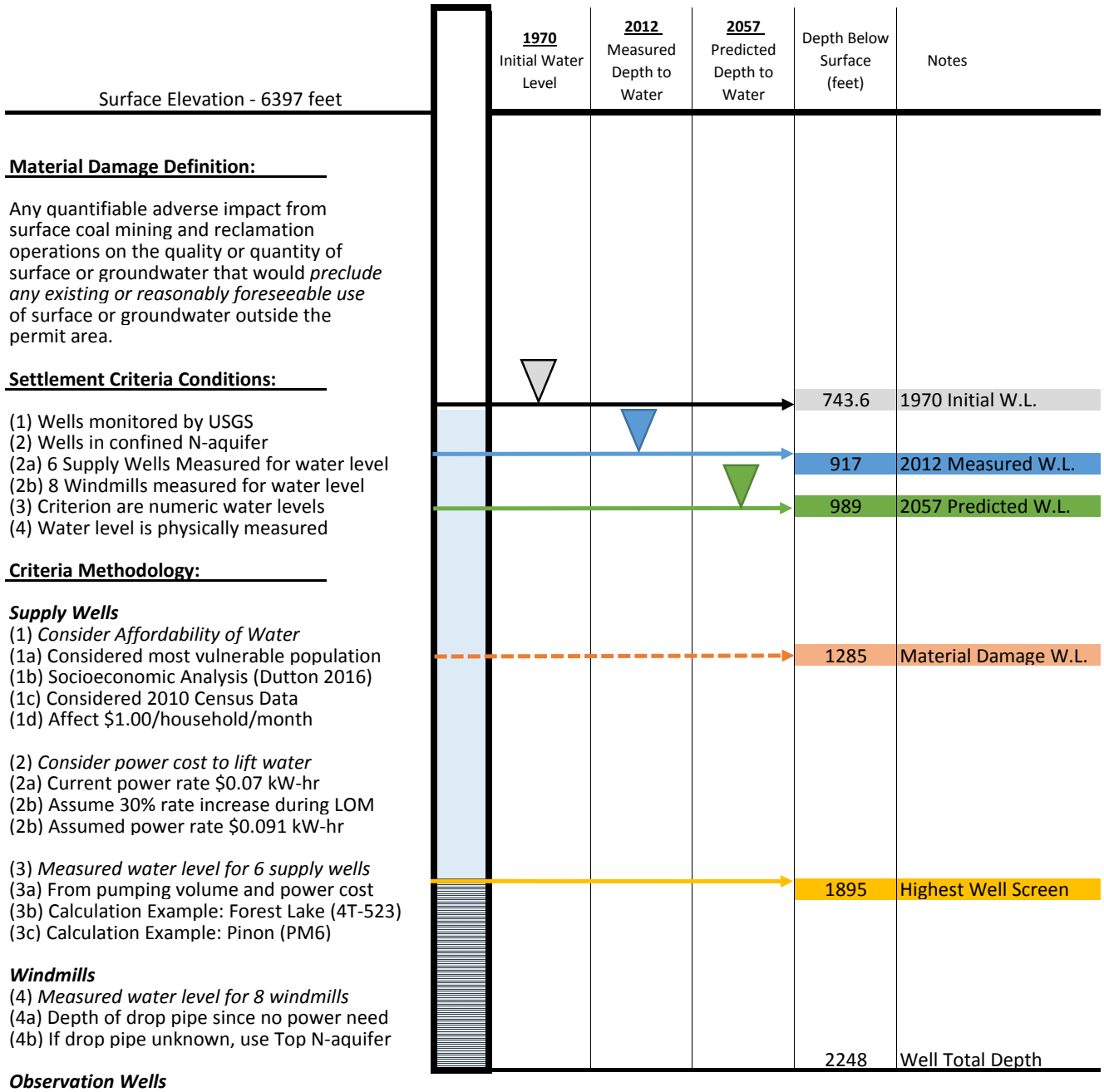
Pinon Supply Well PM6



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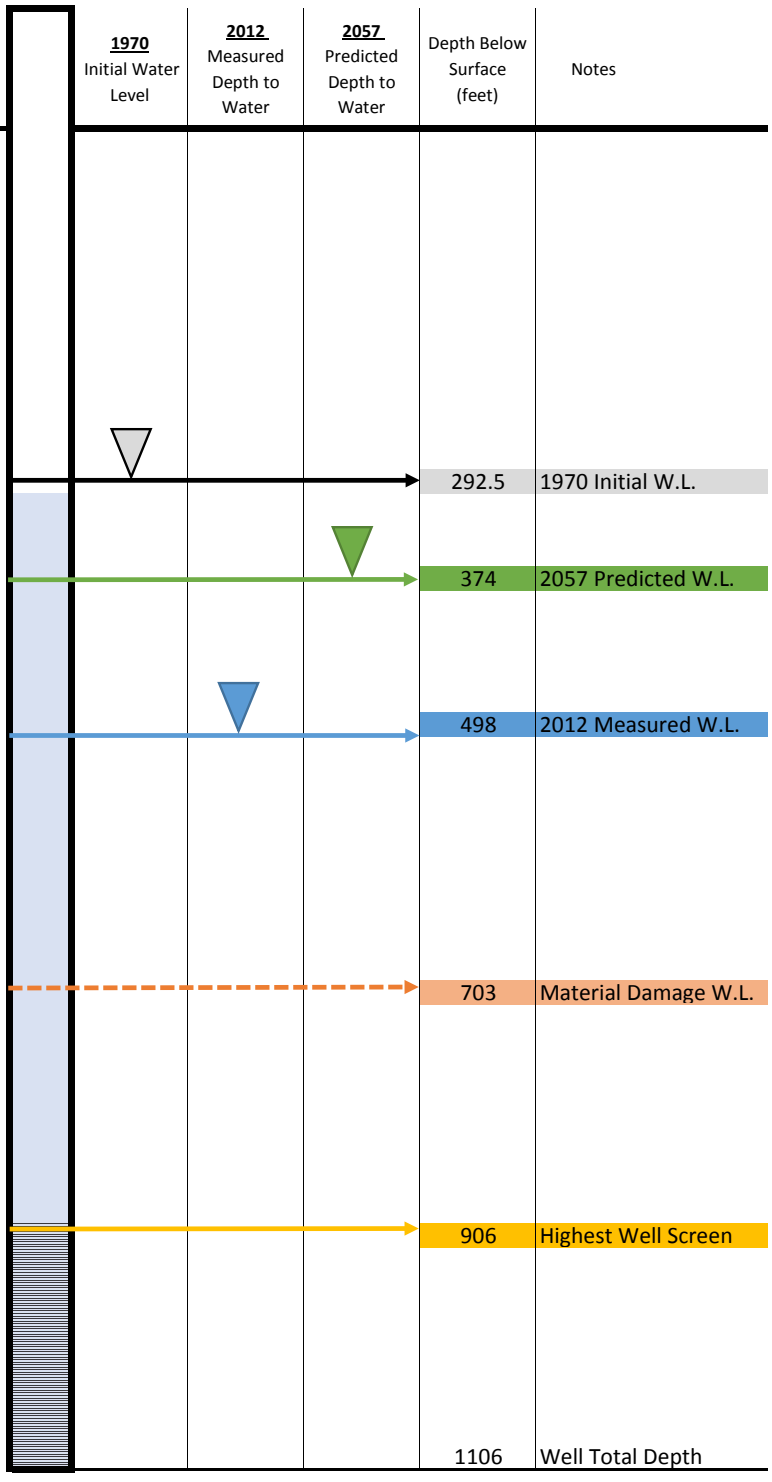
Keams Canyon Supply Well PM2



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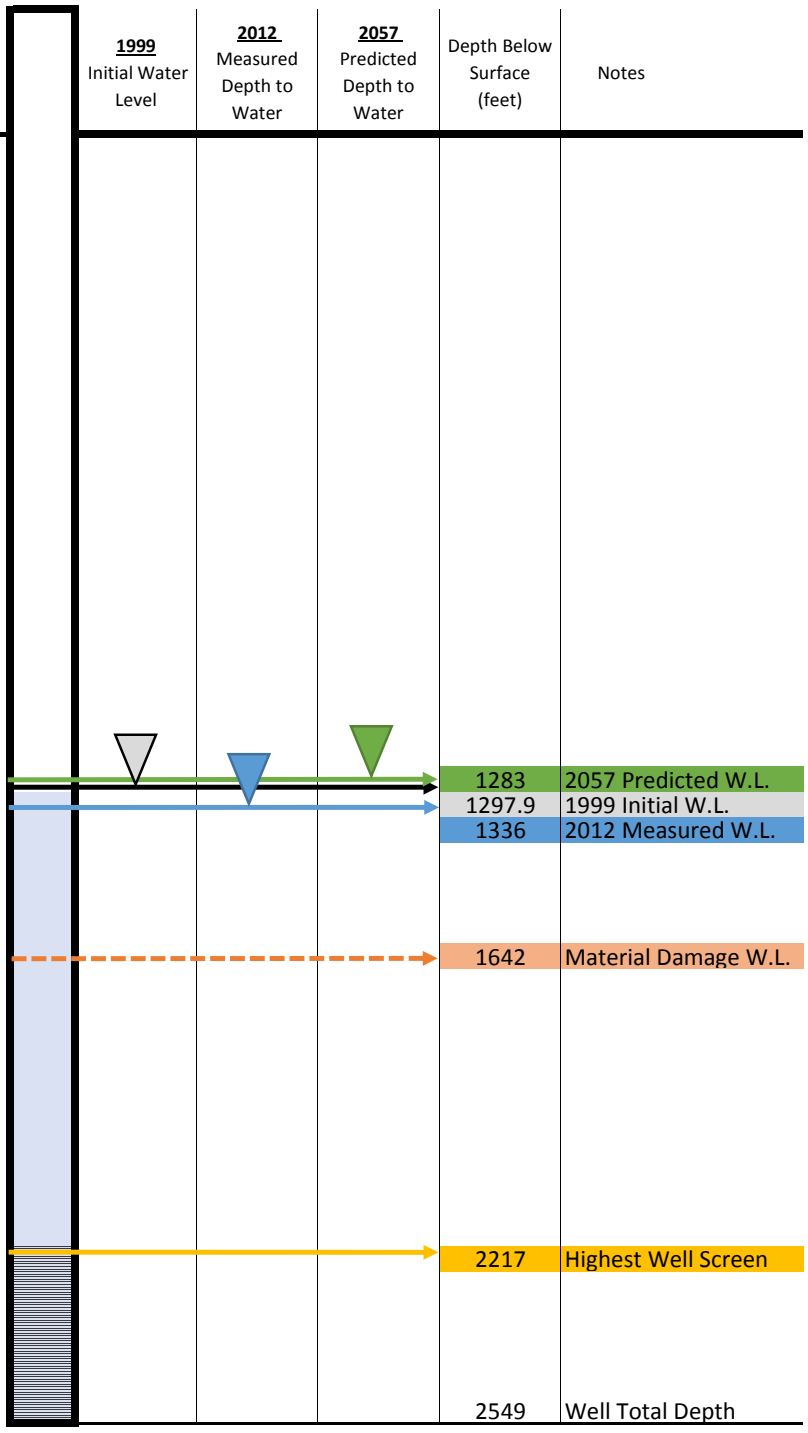
Kitsiili Supply Well NTUA2



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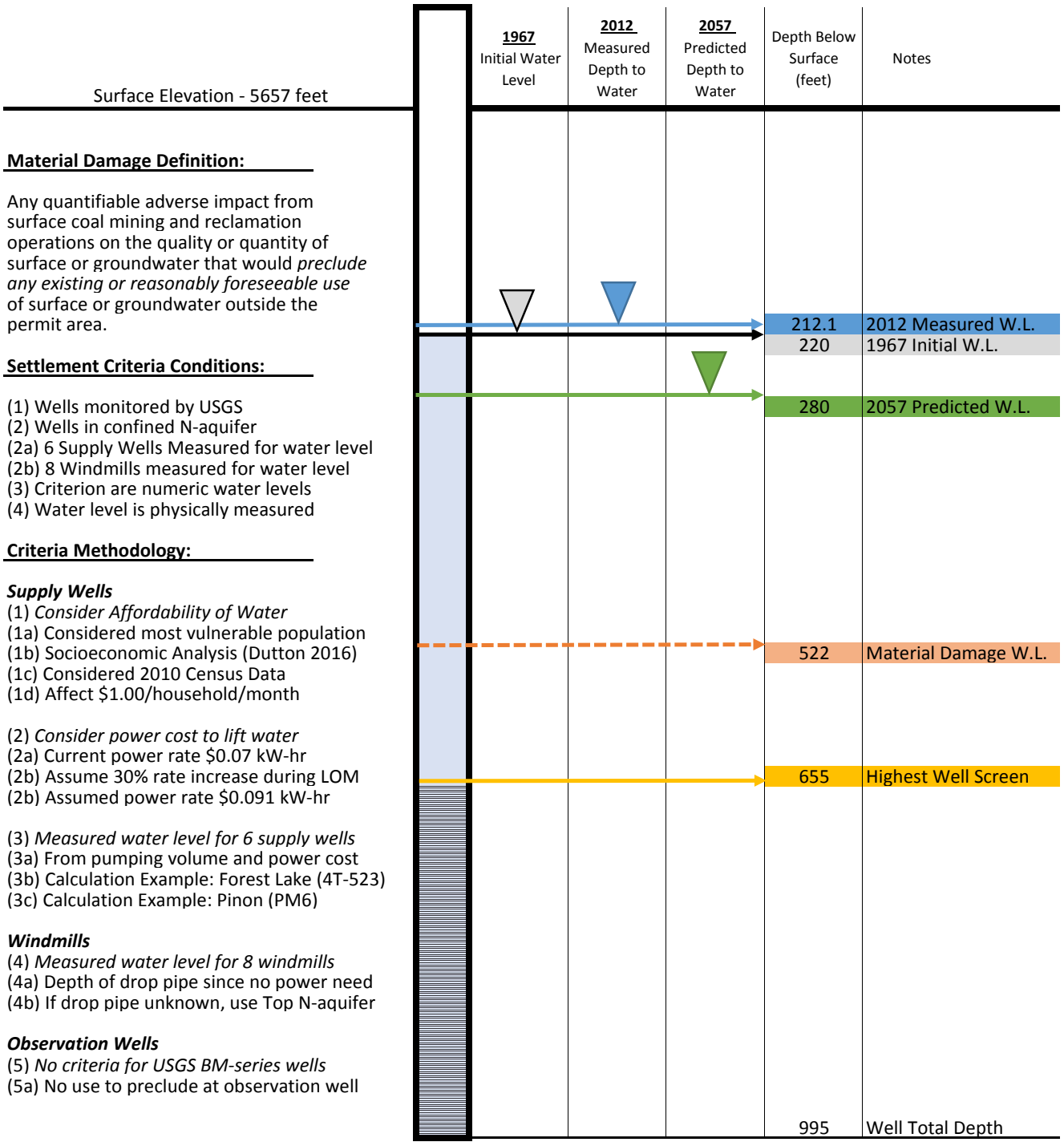
Kykotsmovi Supply Well PM1



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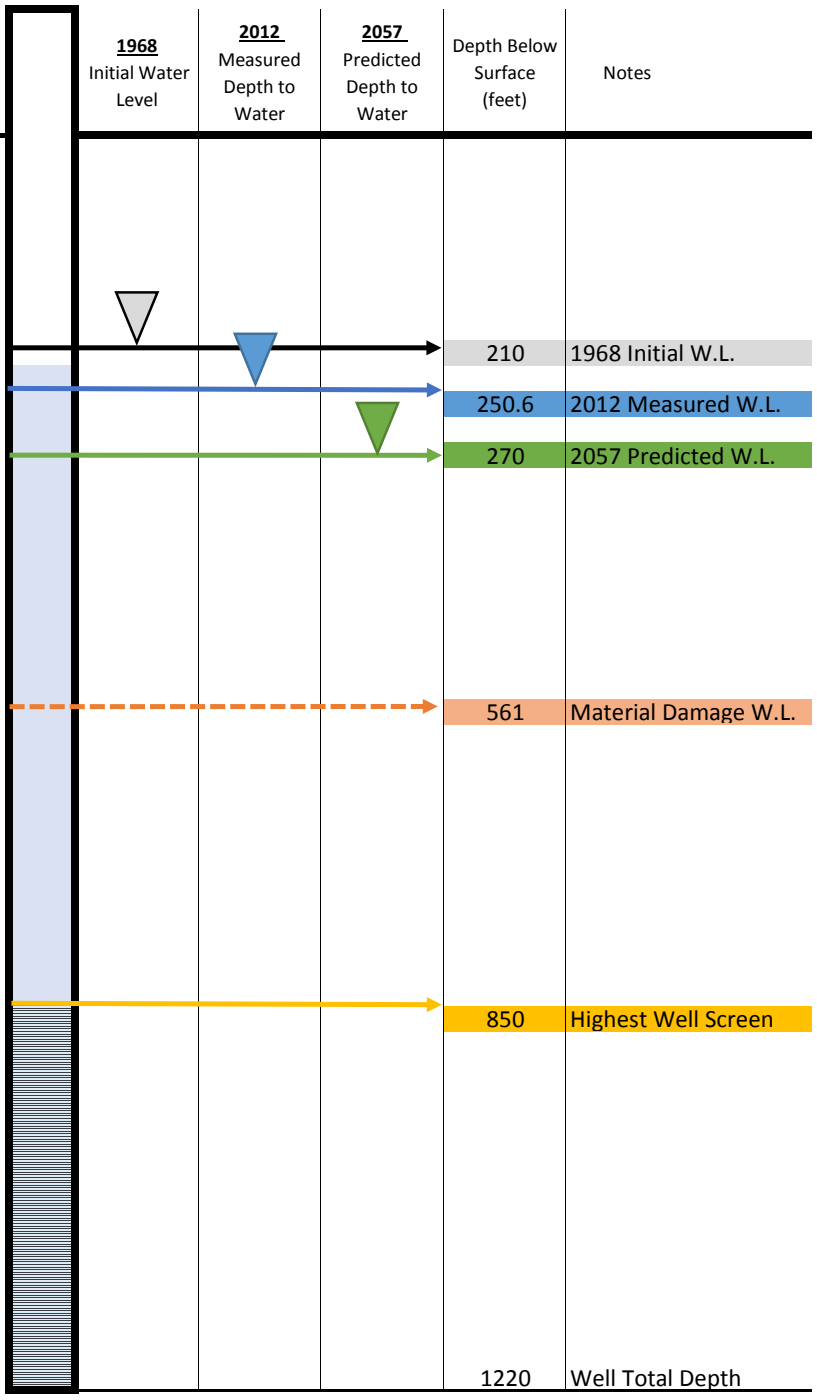
(5) References: (PWCC, 2016); (Macy, 2016); (SWGC, 2016); (Dutton, 2016)

Kykotsmovi Supply Well PM3



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(2b) 8 Windmills measured for water level
(3) Criterion are numeric water levels
(4) Water level is physically measured

Criteria Methodology:

Supply Wells
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(1a) Considered most vulnerable population
(1b) Socioeconomic Analysis (Dutton 2016)
(1c) Considered 2010 Census Data
(1d) Affect $1.00/household/month

(2) *Consider power cost to lift water*
(2a) Current power rate $0.07 kW-hr
(2b) Assume 30% rate increase during LOM
(2b) Assumed power rate $0.091 kW-hr

(3) *Measured water level for 6 supply wells*
(3a) From pumping volume and power cost
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(4) *Measured water level for 8 windmills*
(4a) Depth of drop pipe since no power need
(4b) If drop pipe unknown, use Top N-aquifer

Observation Wells
(5) *No criteria for USGS BM-series wells*
(5a) No use to preclude at observation well

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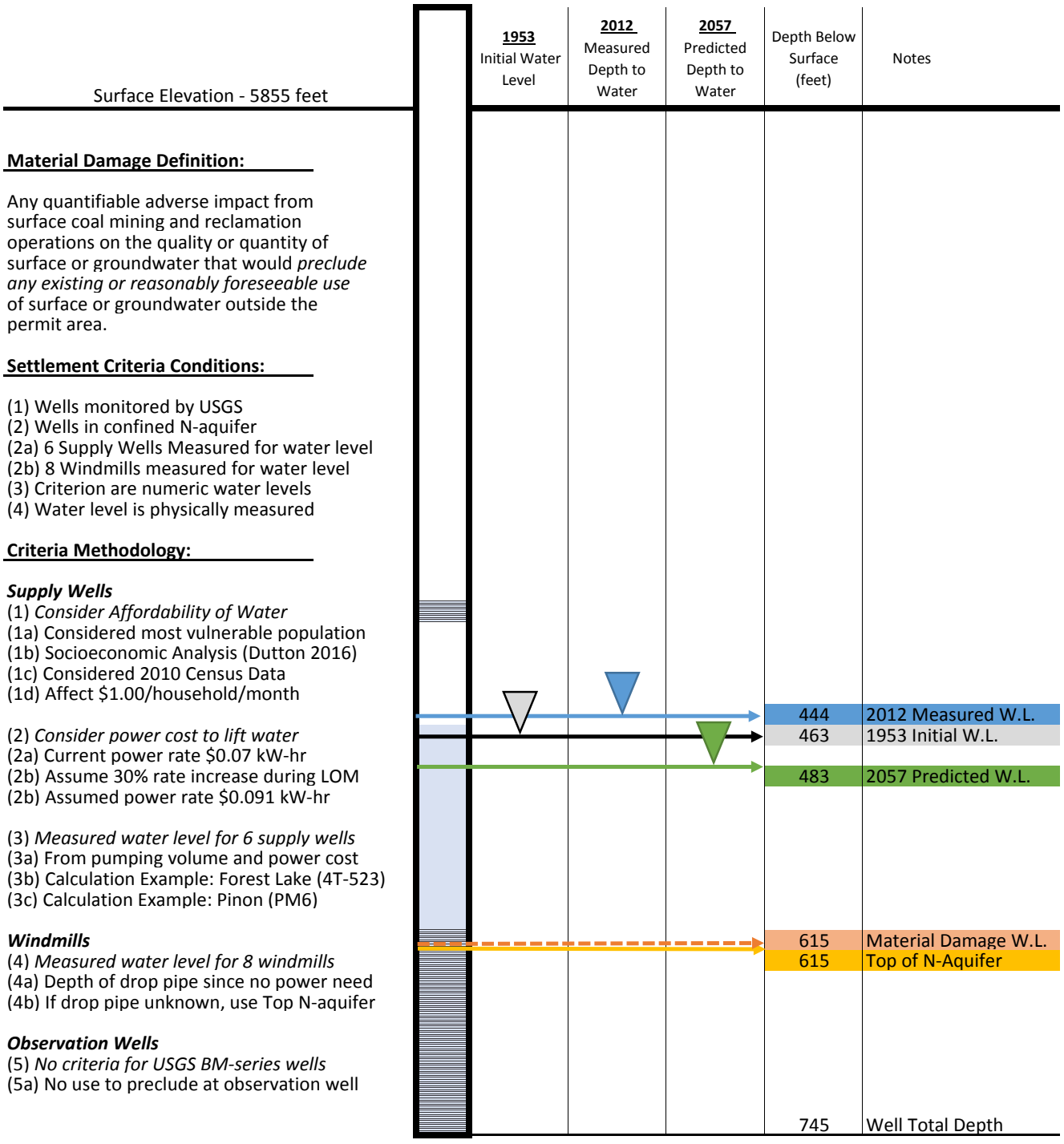
Howell Mesa Windmill (3K-311)



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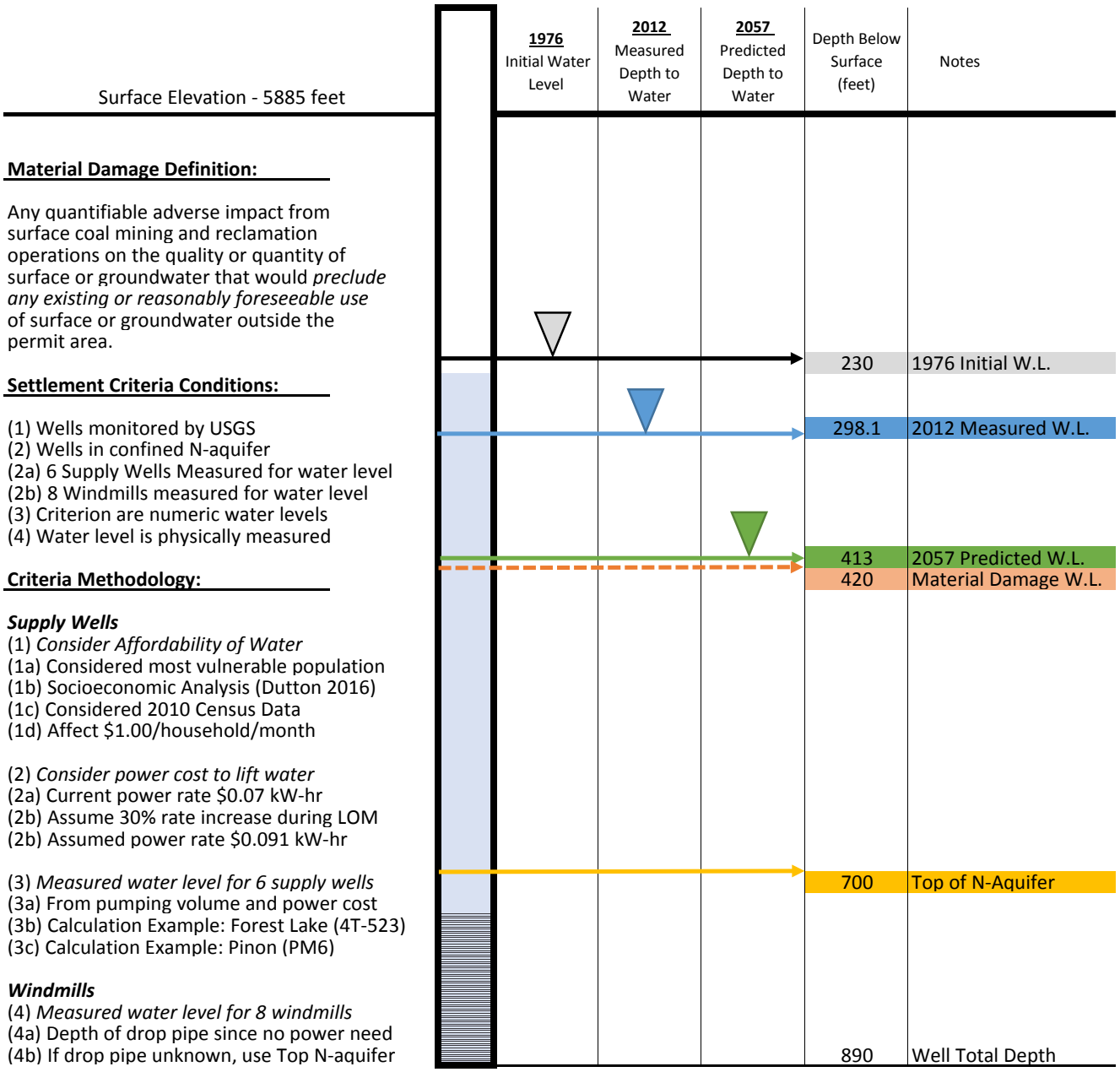
Kayenta West Windmill (8T-541)



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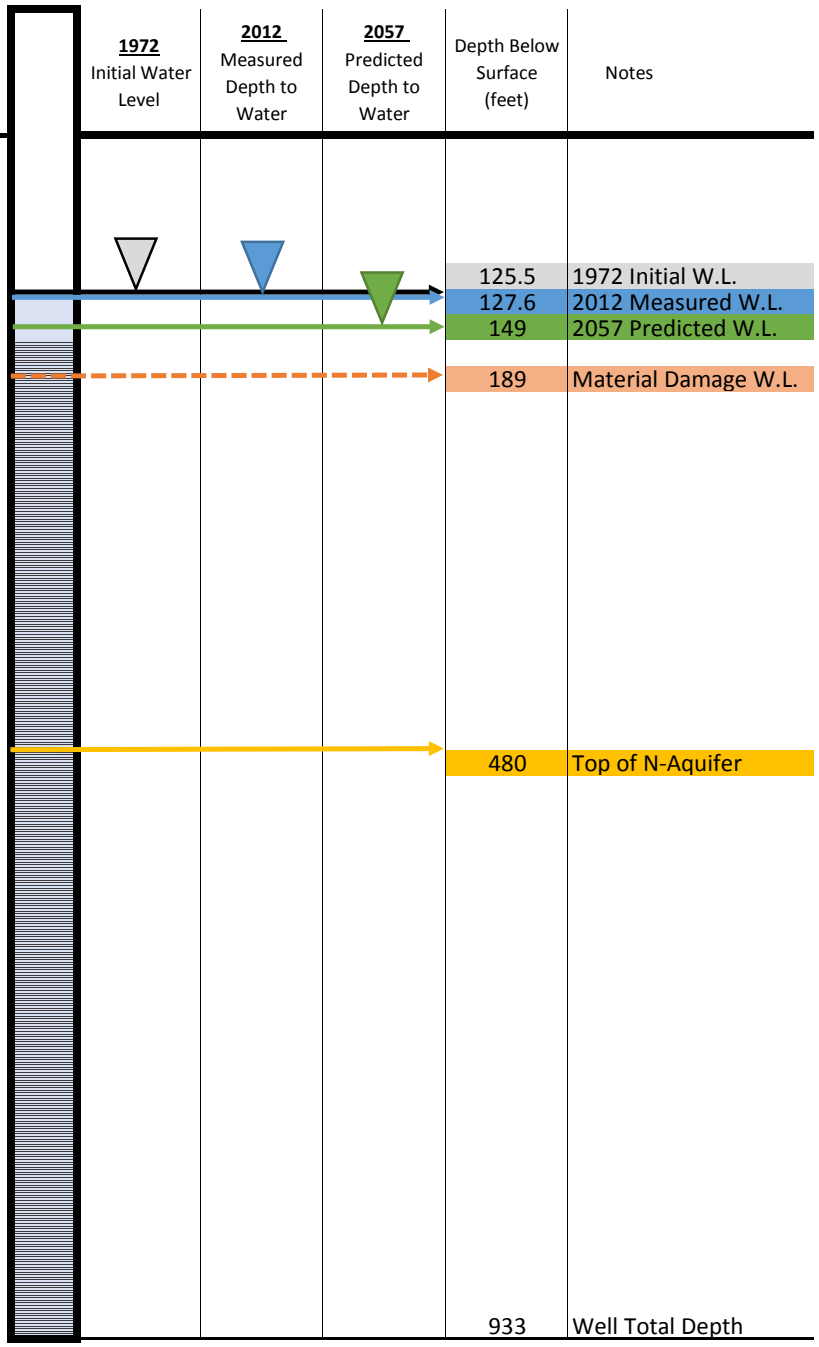
Marsh Pass Windmill (8T-522)



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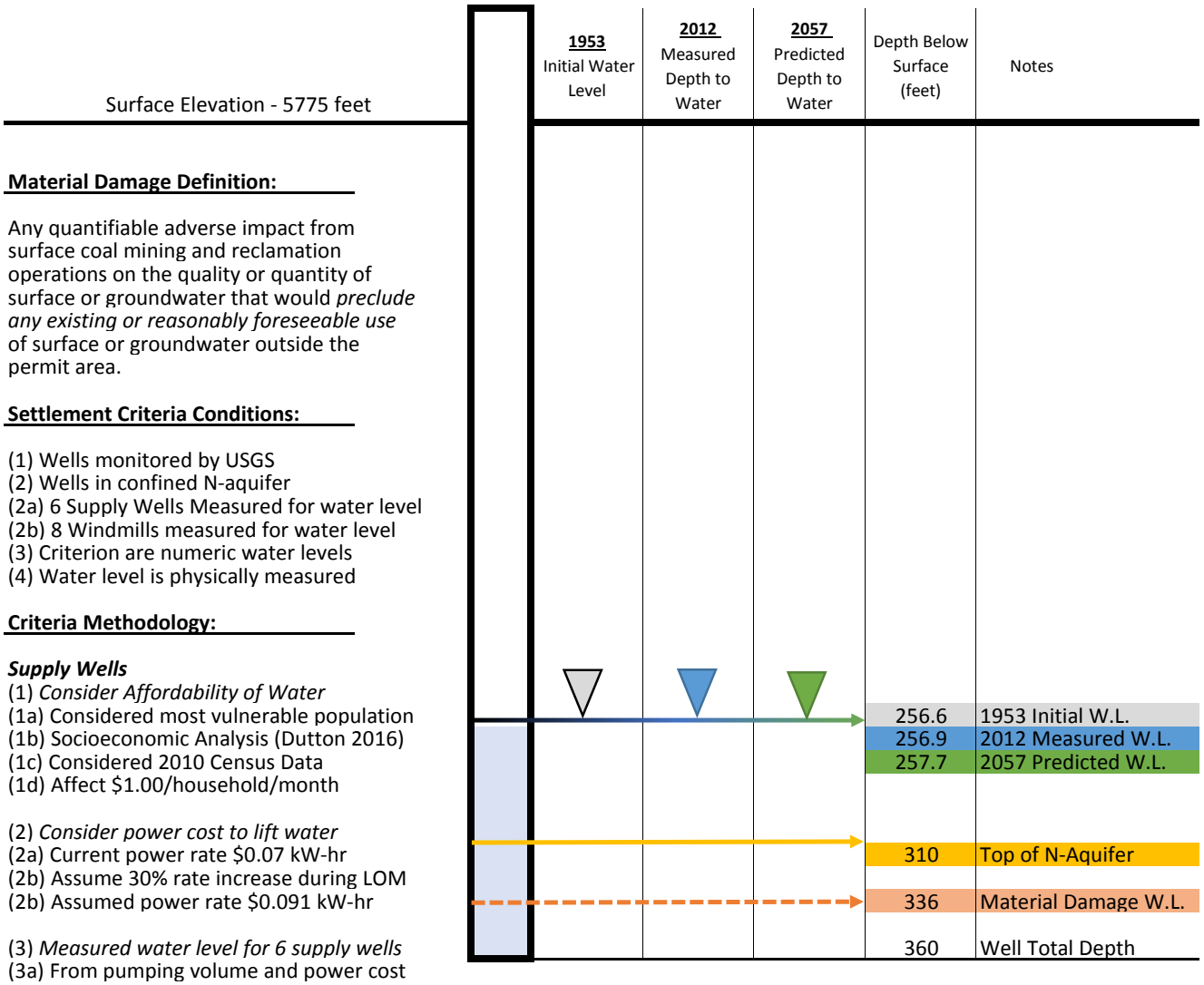
Rough Rock Windmill (10R-119)



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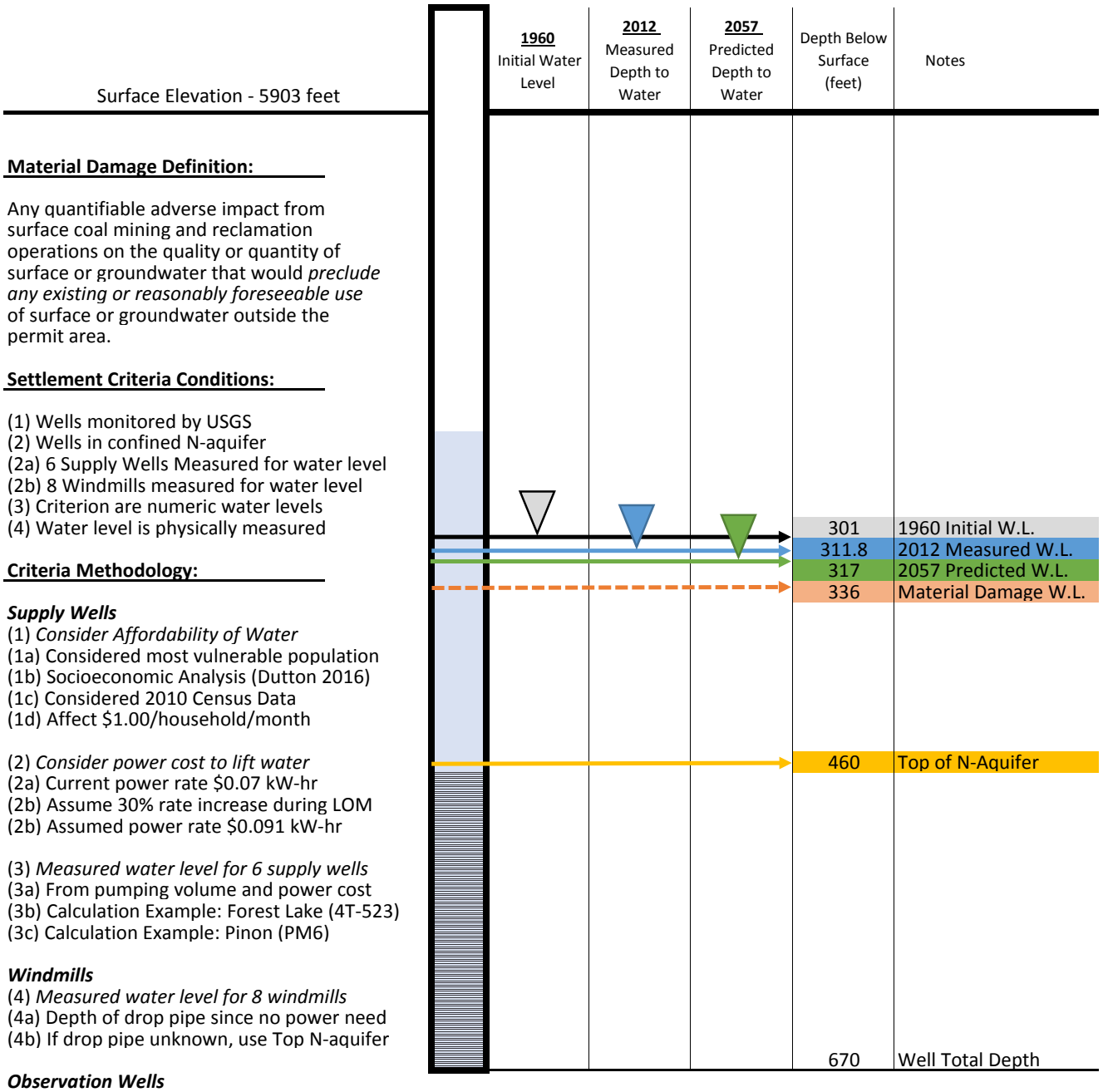
Rough Rock Windmill (10T-258)



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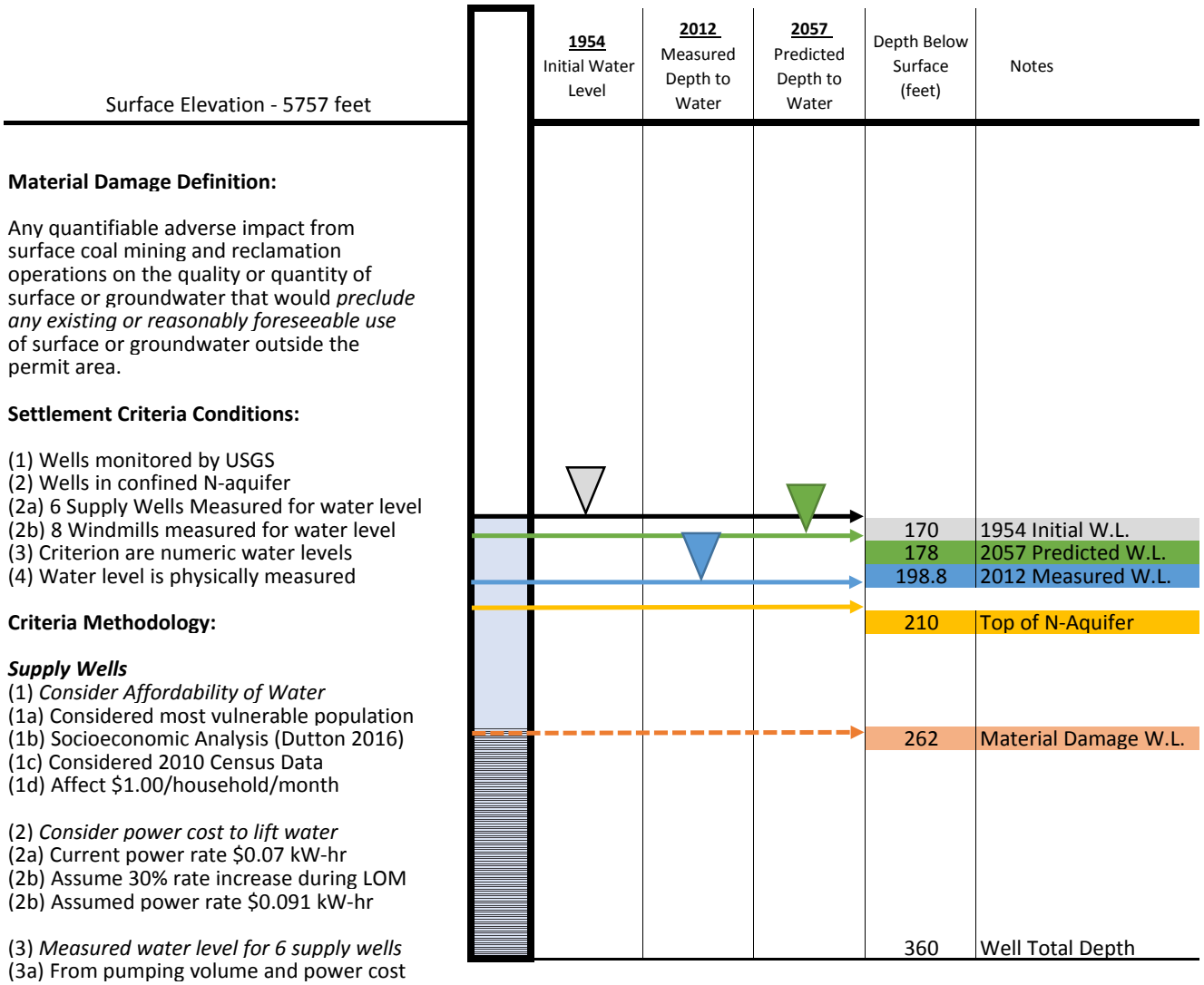
Rough Rock Windmill (10R-111)



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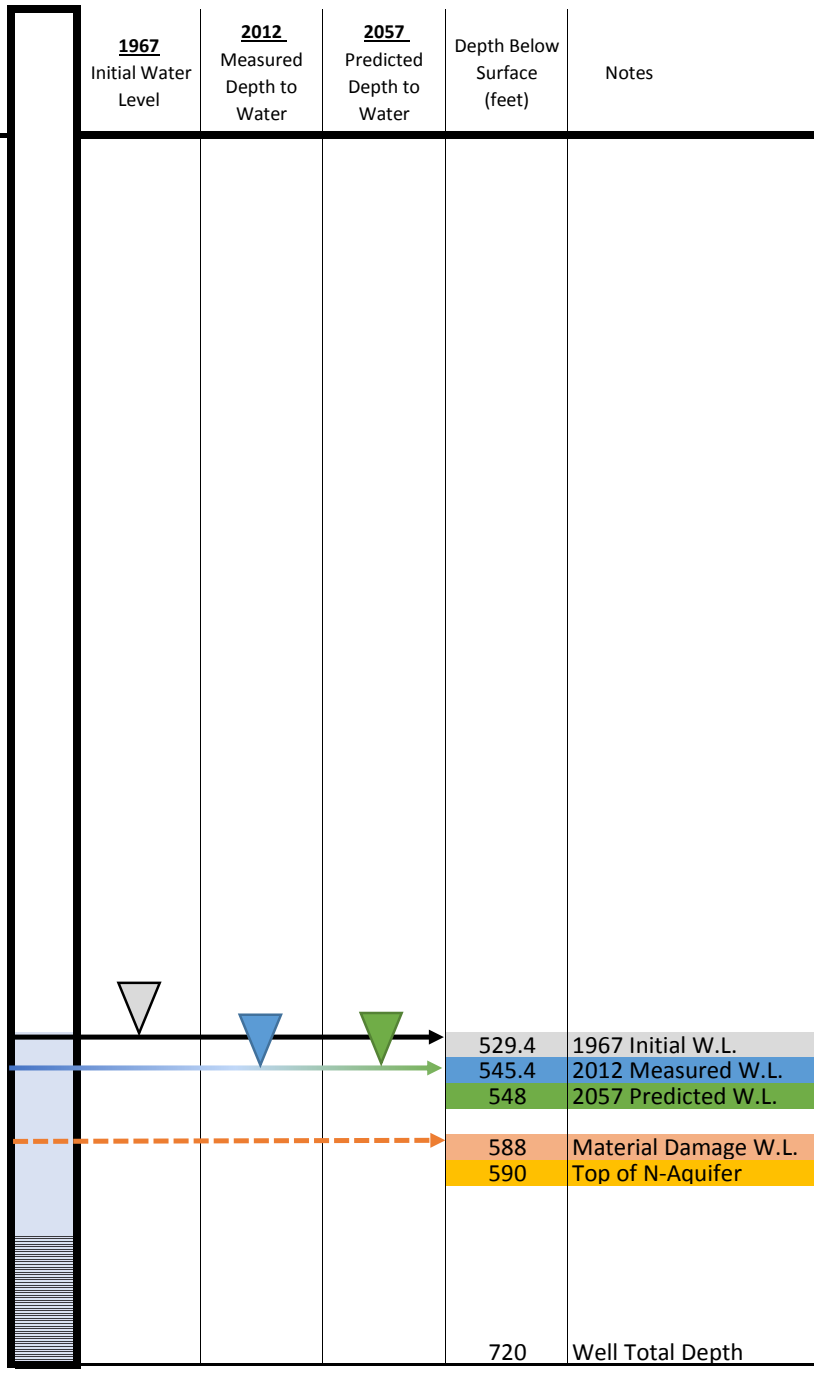
Sweetwater Mesa Windmill (8K-443)



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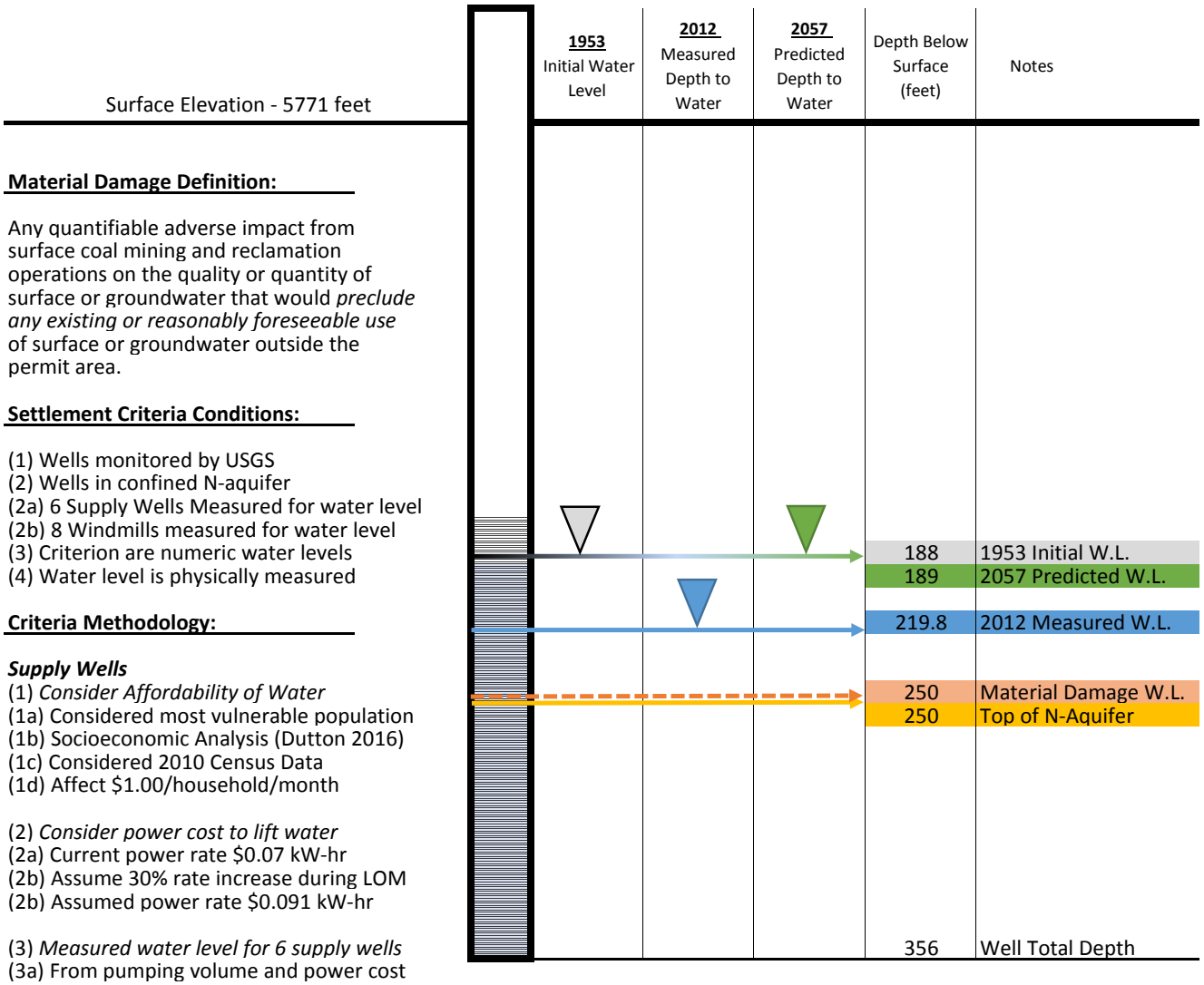
White Mesa Arch Windmill (1K-214)



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