APPENDIX IV
WELL DRILLING AND PUMPING COSTS

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Drilling Costs

The cost of drilling and finishing a well depends on a number of factors, including the yield of water that is required, the geologic media through which the drilling is made, the depth to the water table, the yield of the aquifer, and whether or not the borehole needs to be cased to provide long-term stability.

Estimates for drilling and completing five wells typical of those that are currently in use or might be envisioned in the area under consideration are given in WI96 and reproduced (with minor corrections) in Tables IV-1 through IV-5. Wells 1 and 2 are intended to show the costs that would be incurred in duplicating the two production wells (J13 and J12, respectively) that DOE currently maintains on Jackass Flats. Both are presumed to be drilled in the tuff aquifer and, like the two actual wells, the boreholes are fully cased and screened. (Note: The actual construction of Well J-13 was accomplished by using a telescoping diameter to overcome the caving difficulties that were encountered while drilling (WIT96).) Well 3 represents an agricultural well drilled in the alluvial aquifer, capable of providing sufficient water for a 1/4 section, center-pivot irrigation system. Well 4 represents a typical well for domestic use, sized to provide about 10 gallons of water per minute to satisfy the needs of one or two dwellings. Like Well 3, it is drilled into the alluvial deposits that comprise the alluvial aquifer. Both Wells 3 and 4 are fully cased and screened to provide stability. Finally, Well 5 is an uncased well drilled in welded and bedded tuff. At its design capacity of two gallons per minute, it would be sufficient to provide water to stock. Only the first 150 feet of Well 5 is cased.

On a $/foot basis, these five wells range from $97 to more than $500 to drill and finish, with an average cost of about $300/foot. An estimate derived from the costs cited by BCI Geonetics for the development of a deep well field in a remote desert environment indicates a cost of about $165/foot (BCI85). As few details are given in either reference for the rationale used in sizing the boreholes, the length of screens needed, or the bases of the unit costs used, these estimates should only be considered as very approximate values. Both references do include costs for extensive logging and testing of the wells.

Given the sparsity of supporting data in the two references, it is difficult to evaluate their reasonableness. In particular, the cost of $524/foot for Well 3, designed for irrigation use, is difficult to reconcile with the estimate of $40/foot quoted by a driller who has actual experience in providing well-drilling services in Amargosa Valley (DOY96). Likewise, the estimated cost of $97/foot for a domestic well is difficult to reconcile with costs of about $15/foot currently charged for drilling residential wells in a mountainous area of Colorado (GOL96).

However, some insight into the significance of drilling costs on the overall cost of water can be derived by estimating the costs of various wells (different uses and depths) from the data available and then calculating the capital cost per acre-foot. The well costs shown in Table IV-6 are for a private domestic well sized to provide sufficient water for about 10 persons (4 acre-feet/yr), a communal well sized to serve the domestic needs of about 300 persons (120 acre-feet/yr), and a large-scale agricultural well sized to provide irrigation for a 1/4 section (625 acre-feet/yr). Costs are computed for water depths of 100 feet, 300 feet, 600 feet, 900 feet, and 1,200 feet. In all instances, the wells are assumed to be 200 feet deeper than the water depth.

Unit drilling costs ($/foot) for the wells are based on $15/foot for a 4" diameter casing and scaled to the area of the casings using a 0.7 power function (e.g., an 8" casing has an area four times that of a 4" casing; thus the scaling factor is $4^{\wedge 0.7} = 2.64$ and cost = $40/ft.). Unit costs ($/foot) of drilling wells in the tuff aquifer were increased by 25 percent, to reflect the greater difficulty this media presents when compared to drilling in the alluvial aquifer. Pump costs are based on $8,000 for a five horsepower pump and scaling functions of 0.7 for pumps less than 20 horse-power, 0.6 for pumps between 20 and 100 horsepower, and 0.5 for pumps greater than 100 horsepower. The costs per acre-foot were computed by amortizing the costs shown over a 30 year period at seven percent interest and dividing by the yields of the wells in acre-feet per year.

Table IV-1. Well 1 - 3,385' Yielding 700 gpm w/ static head of 1,000 ft
Modeled on DOE Well J-13 (Adapted from WIT96)

Borehole Depth	3,450 ft
Well Depth	3,385 ft
Borehole Diameter	26 in
Casing Diameter	14 in
Screen Length	2,162 ft

Item	Quantity	Units	Unit Cost ($)	Total Cost ($)
Install 30" Conductor Casing	50	ft	175.00	8,750.00
Drill Pilot Hole	3,450	ft	45.00	155,250.00
E-log	1	ea	7,000.00	7,000.00
Ream Pilot Hole to 26"	3,450	ft	60.00	207,000.00
Caliper Log	1	ea	4,000.00	4,000.00
Install Blank Casing	1,223	ft	120.00	146,760.00
Install Screen	2,162	ft	160.00	345,920.00
Install Gravel Pack	2,515	ft	45.00	113,175.00
Gravel Tube	990	ft	6.00	5,940.00
Grout Seal	985	ft	55.00	54,175.00
Plumb & Alignment Test	1	ea	5,500.00	5,500.00
Surge/Airlift Development	24	hr	275.00	6,600.00
Pumping Development	24	hr	150.00	3,600.00
Step Test	10	hr	150.00	1,500.00
Constant Q Test	40	hr	150.00	6,000.00
Pump Cost	1	ea	20,000.00	20,000.00
Install Pump	1	ea	6,500.00	6,500.00
Electric & Wellhead Finish	1	ea	20,000.00	20,000.00
Total Cost				1,117,670.00
Cost per Foot				330.00

Table IV-2. Well 2 - 887' Yielding 800 gpm w/ static head of 800 ft
Modeled on DOE Well J-12 (Adapted from WIT96)

Borehole Depth	900 ft
Well Depth	887 ft
Borehole Diameter	22 in
Casing Diameter	12.75 in
Screen Length	75 ft

Item	Quantity	Units	Unit Cost ($)	Total Cost ($)
Install 22" Conductor Casing	50	ft	125.00	6,250.00
Drill Pilot Hole	900	ft	40.00	36,000.00
E-log	1	ea	4,000.00	4,000.00
Ream Pilot Hole to 22"	900	ft	50.00	45,000.00
Caliper Log	1	ea	2,000.00	2,000.00
Install Blank Casing	812	ft	55.00	44,660.00
Install Screen	75	ft	75.00	5,625.00
Install Gravel Pack	117	ft	25.00	2,925.00
Gravel Tube	125	ft	6.00	750.00
Grout Seal	783	ft	45.00	35,235.00
Plumb & Alignment Test	1	ea	2,500.00	2,500.00
Surge/Airlift Development	24	hr	275.00	6,600.00
Pumping Development	24	hr	150.00	3,600.00
Step Test	10	hr	150.00	1,500.00
Constant Q Test	40	hr	150.00	6,000.00
Pump Cost	1	ea	20,000.00	20,000.00
Install Pump	1	ea	6,500.00	6,500.00
Electric & Wellhead Finish	1	ea	20,000.00	20,000.00
Total Cost				249,145.00
Cost per Foot				280.00

Table IV-3. Well 3 - 320' Yielding ~2,400 gpm w/ static head of 150 ft
Modeled on typical 1/4 section irrigation well (Adapted from WIT96)

Borehole Depth	320 ft
Well Depth	320 ft
Borehole Diameter	28 in
Casing Diameter	16 in
Screen Length	150 ft

Item	Quantity	Units	Unit Cost ($)	Total Cost ($)
Install 30" Conductor Casing	50	ft	175.00	8,750.00
Drill Pilot Hole	320	ft	40.00	12,800.00
E-log	1	ea	3,000.00	3,000.00
Ream Pilot Hole to 28"	320	ft	50.00	16,000.00
Caliper Log	1	ea	2,000.00	2,000.00
Install Blank Casing	175	ft	65.00	11,375.00
Install Screen	150	ft	85.00	12,750.00
Install Gravel Pack	180	ft	35.00	6,300.00
Gravel Tube	145	ft	6.00	870.00
Grout Seal	140	ft	55.00	7,700.00
Plumb & Alignment Test	1	ea	2,500.00	2,500.00
Surge/Airlift Development	24	hr	275.00	6,600.00
Pumping Development	24	hr	150.00	3,600.00
Step Test	10	hr	150.00	1,500.00
Constant Q Test	40	hr	150.00	6,000.00
Pump Cost	1	ea	40,000.00	40,000.00
Install Pump	1	ea	6,000.00	6,000.00
Electric & Wellhead Finish	1	ea	20,000.00	20,000.00
Total Cost				167,745.00
Cost per Foot				524.00

Table IV-4. Well 4 - 600' Yielding 10 gpm w/ static head of 300 ft
Modeled on typical residential well (Adapted from WIT96)

Borehole Depth	600 ft
Well Depth	600 ft
Borehole Diameter	19 in
Casing Diameter	8 in
Screen Length	200 ft

Item	Quantity	Units	Unit Cost ($)	Total Cost ($)
Install 16" Conductor Casing	50	ft	100.00	5,000.00
Drill Pilot Hole	600	ft	35.00	21,000.00
E-log	1	ea	3,000.00	3,000.00
Ream Pilot Hole to 19"	600	ft	45.00	27,000.00
Caliper Log	1	ea	2,000.00	2,000.00
Install Blank Casing	400	ft	41.00	16,400.00
Install Screen	200	ft	60.00	12,000.00
Install Gravel Pack	260	ft	20.00	5,200.00
Gravel Tube	345	ft	6.00	2,070.00
Grout Seal	340	ft	40.00	13,600.00
Plumb & Alignment Test	1	ea	2,500.00	2,500.00
Surge/Airlift Development	24	hr	275.00	6,600.00
Pumping Development	24	hr	150.00	3,600.00
Step Test	10	hr	150.00	1,500.00
Constant Q Test	40	hr	150.00	6,000.00
Pump Cost	1	ea	8,000.00	8,000.00
Install Pump	1	ea	6,000.00	6,000.00
Electric & Wellhead Finish	1	ea	20,000.00	20,000.00
Total Cost				161,470.00
Cost per Foot				269.00

Table IV-5. Well 5 - 1,500' Yielding 2 gpm w/ static head of 1,000 ft
Modeled on simple stock water well (Adapted from WIT96)

Borehole Depth	1,500 ft
Well Depth	1,500 ft
Borehole Diameter	8 in
Casing Diameter	NA in
Screen Length	NA ft

Item	Quantity Units	Unit Cost($)	Total Cost($)
Install 16" Conductor Casing	50 ft	100.00	5,000.00
Drill Pilot Hole	1,500 ft	45.00	67,500.00
E-log	1 ea	5,000.00	5,000.00
Ream Pilot Hole	0 ft	NA	0.00
Caliper Log	1 ea	3,000.00	3,000.00
Install Blank Casing	150 ft	41.00	6,150.00
Install Screen	0 ft	NA	0.00
Install Gravel Pack	0 ft	NA	0.00
Gravel Tube	0 ft	NA	0.00
Grout Seal	0 ft	NA	0.00
Plumb & Alignment Test	0 ea	NA	0.00
Surge/Airlift Development	24 hr	275.00	6,600.00
Pumping Development	24 hr	150.00	3,600.00
Step Test	10 hr	150.00	1,500.00
Constant Q Test	40 hr	150.00	6,000.00
Pump Cost	1 ea	15,000.00	15,000.00
Install Pump	1 ea	6,000.00	6,000.00
Electric & Wellhead Finish	1 ea	20,000.00	20,000.00
Total Cost			145,350.00
Cost per Foot			97.00

Table IV-6: Estimated Capital Costs of Wells - Yucca Mountain Area
Private Wells - Domestic Use
10 gpm/4 acre-feet per year (Adapted from WIT96)

100' Depth to Water		300' Depth to Water	
Alluvial Aquifer		Alluvial Aquifer	
4" Casing		8" Casing	
1.25 HP Pump		5 HP Pump	
Drilling Costs @ $15/foot=	$4,500	Drilling Costs @ $40/foot=	$20,000
Pump Cost	3,000	Pump Cost	8,000
Total Cost	7,500	Total Cost	28,000
Cost/acre-foot	$150	Cost/acre-foot	$565
600' Depth to Water		900' Depth to Water	
Tuff Aquifer		Tuff Aquifer	
8" Casing		8" Casing	
10 HP Pump		15 HP Pump	
Drilling Costs @ $50/foot=	$40,000	Drilling Costs @ $50/foot=	$55,000
Pump Cost	13,000	Pump Cost	17,000
Total Cost	53,000	Total Cost	72,000
Cost/acre-foot	$1,070	Cost/acre-foot	$1,450
1,200' Depth to Water			
Tuff Aquifer			
8" Casing			
20 HP Pump			
Drilling Costs @ $50/foot=	$70,000		
Pump Cost	21,000		
Total Cost	91,000		
Cost/acre-foot	$1,830		

CAUTION: Values shown in this table are deemed reliable only for the purposes of this report and only within the contexts used or implied by the calculational methodologies, assumptions, and data sources presented in the text.

Table IV-6. Estimated Capital Costs of Wells - Yucca Mountain Area - continued
Communal Wells
700 gpm/120 acre-feet per year (Adapted from WIT96)

100' Depth to Water		300' Depth to Water	
Alluvial Aquifer		Alluvial Aquifer	
14" Casing		14" Casing	
15 HP Pump		50 HP Pump	
Drilling Costs @ $85/foot=	$25,500	Drilling Costs @ $85/foot=	$42,500
Pump Cost	15,000	Pump Cost	24,000
Total Cost	40,500	Total Cost	66,500
Cost/acre-foot	$30	Cost/acre-foot	$45
600' Depth to Water		900' Depth to Water	
Tuff Aquifer		Tuff Aquifer	
14" Casing		14" Casing	
100 HP Pump		150 HP Pump	
Drilling Costs @ $105/foot=	$84,000	Drilling Costs @ $105/foot=	$115,500
Pump Cost	36,000	Pump Cost	46,000
Total Cost	120,000	Total Cost	161,500
Cost/acre-foot	$80	Cost/acre-foot	$110
1,200' Depth to Water			
Tuff Aquifer			
14" Casing			
200 HP Pump			
Drilling Costs @ $105/foot=	$147,000		
Pump Cost	55,000		
Total Cost	202,000		
Cost/acre-foot	$135		

CAUTION: Values shown in this table are deemed reliable only for the purposes of this report and only within the contexts used or implied by the calculational methodologies, assumptions, and data sources presented in the text.

Table IV-6. Estimated Capital Costs of Wells - Yucca Mountain Area - continued
Irrigation Wells
2,400 gpm/625 acre-feet per year (Adapted from WIT96)

100' Depth to Water		300' Depth to Water	
Alluvial Aquifer		Alluvial Aquifer	
16" Casing		16" Casing	
60 HP Pump		200 HP Pump	
Drilling Costs @ $100/foot=	$30,000	Drilling Costs @ $100/foot=	50,000
Pump Cost	40,000	Pump Cost	55,000
Total Cost	70,000	Total Cost	105,000
Cost/acre-foot	$9	Cost/acre-foot	$14
600' Depth to Water		900' Depth to Water	
Tuff Aquifer		Tuff Aquifer	
16" Casing		16" Casing	
400 HP Pump		600 HP Pump	
Drilling Costs @ $125/foot=	$100,000	Drilling Costs @ $125/foot=	$137,500
Pump Cost	78,000	Pump Cost	95,000
Total Cost	178,000	Total Cost	232,500
Cost/acre-foot	$23	Cost/acre-foot	$30
1,200' Depth to Water			
Tuff Aquifer			
16" Casing			
800 HP Pump			
Drilling Costs @ $125/foot=	$175,000		
Pump Cost	110,000		
Total Cost	285,000		
Cost/acre-foot	$37		

CAUTION: Values shown in this table are deemed reliable only for the purposes of this report and only within the contexts used or implied by the calculational methodologies, assumptions, and data sources presented in the text.

Pumping Costs

Pumping costs for water can be computed based on the following equation:

$$C_{AF} = (K \cdot L \cdot P_{Kwh})/E$$

where:

C_{AF} = cost per acre-foot ($)
K = number of kilowatt hours needed to lift one acre-foot of water one foot at 100 percent pump efficiency
L = lift of water (feet)
E = overall pumping efficiency
P_{Kwh} = price per kilowatt hour of electricity ($)

Based on the density of water of one gram per cubic centimeter (g/cm^3), K can be calculated to be about 1.024. The lift of water, which is specific for any given well, is simply the depth to the water from the land elevation at the head of the well. Overall pumping efficiency depends on both the efficiency of the pump and frictional losses that depend on the diameter of the well casing and the lift of the well. Current pumps range from 65 to 80 percent efficient. The following calculation assumes an overall efficiency of 70 percent. The cost of electricity in the Amargosa Valley is currently about $0.05 per kilowatt hour, which is significantly lower than the national average. Using these values, the cost of a one foot lift of an acre-foot of water is $0.073. In Table IV-7, this is rounded to $0.075/foot of lift.

Using a marginal value of $800 per acre-foot for domestic use water and a marginal value of $40 per acre-foot for irrigation use water as guides, the capital costs of private wells for domestic use become prohibitive at depths between 300 and 600 feet. For communal domestic use and irrigation use, the capital costs do not become prohibitive even at depths of 1,200 feet. However, the capital costs do not include pumping costs or any of the costs for distribution facilities that would be needed for a community water supply or an irrigation system.

Pumping costs are not likely to be sufficient to affect the observations made on the economic feasibility of wells for private or communal domestic use. Indeed, the wells at Lathrop Wells and on Jackass Flats demonstrate that private and communal water systems have already been deemed economically justified in those locations. This conclusion is consistent with the finding

made by the Center for Nuclear Waste Regulatory Analyses in their study of the use of ground water in arid and semi-arid parts of the United States (WIT96). They state "[t]he well water data suggest that water use practice in the immediate vicinity of YM [Yucca Mountain] may have included a small cluster of homes supplied by one or more small-diameter, low discharge, high-lift wells or a community or suburb supplied by wells similar in construction to J-13 had the land not been withdrawn by the Federal government."

However, because of the very large volumes of water needed for irrigating field crops, particularly in the climate of Amargosa Valley, pumping costs are very significant for such agricultural applications. Combining the pumping cost estimates in Table IV-7 with the capital cost estimates in Table IV-6, the marginal value of water for irrigation is exceeded at depths to water greater than 300 feet. In fact, since these estimates do not consider the distribution costs for the irrigation system or any maintenance costs over the 30-year amortization period, it is not surprising to see that commercial agricultural activities in Amargosa Valley have been restricted thus far to areas where the depth to water is generally less than about 200 feet.

Table IV-7. Calculated Pumping Costs for Various Lifts

100' Lift = $ 7.50/acre-foot
300' Lift = $22.50/acre-foot
600' Lift = $45.00/acre-foot
900' Lift = $67.50/acre-foot
1,200' Lift = $90.00/acre-foot

REFERENCES FOR APPENDIX IV

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