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CHAPTER 18

PROBABLE HYDROLOGIC CONSEQUENCES

Introduction

This chapter contains a discussion of the probable hydrologic consequences of the life-of-mine mining plan upon the quality and quantity of surface and ground water for the proposed permit and adjacent areas. The significance of each impact or potential impact is determined. The determination of significance has been made considering the impact of any probable hydrologic consequence on: (1) the quality of the human environment; (2) any critical habitats or important plant species; or (3) any threatened and endangered wildlife species within the proposed life-of-mine permit and adjacent areas.

Ground Water

Interruption of Ground-Water Flow and Drawdown. A comparison of five year average Wepo water level contours and isopach maps which show pit bottom contour elevations for all areas to be mined, along with review of historic and recent records, indicates that portions of the J-1/N-6, N-2, N-7, N-10, N-11, J-16, J-19/20 and J-21 pits have already or will intercept the upper part of the Wepo aquifer for some period during the life of the mining areas. Flow in the portions of the Wepo aquifer truncated by overburden and coal removal will be intercepted since the ground-water gradient will rapidly orient itself in the direction of the sinks (pits). Review of Wepo water level contours developed from recent data (1995-2010) and actual field observations during mining indicates that pits in the J-7, J-21W, N-9, and N-14 mining areas will not appreciably intercept the Wepo aquifer.

Previously developed estimates of Wepo ground-water inflow to the above identified pits are presented in Tables 1 through 7, respectively. These estimates were prepared assuming that the total inflow would be derived from two principal sources: (1) the interception of pre-mining flow rates under a natural hydraulic gradient; and (2) the drainage of ground water from storage in the aquifers. It is assumed that the major portion of the Wepo ground-water inflow would be derived from lateral flow along bedding planes and fractures. Upward leakage from underlying aquifers was assumed to be negligible.

Two different techniques have been used to estimate the rates of groundwater inflow into the pits, depending on the technology available at the time the estimates were developed.

TABLE 1

Pit Inflows by Year for N-10

Pit Year	Total Length of Pit (Ft)	Constant Length in Water (L_W) (Ft)	Days in Water (t) (Day)	Constant Pit Adv./Day (Ft/Day)	Weighted T_F-Transmissivity (Gal/Day/Ft)	Weighted $T_{L,R}$ (Ft^2/Day)	I-Gradient (Ft/Ft)	Weighted Q_F (Gal/Yr)	Weighted Q_L (Gal/Yr)	Weighted Q_R (Gal/Yr)	Q_T (Gal/Yr)
2002*	8913	-	-	24.4	-	-	.018	-	-	-	-
2003*	8913	-	-	24.4	-	-	.018	-	-	-	-
2004*	8913	-	-	24.4	-	-	.018	-	-	-	-
2005	8913	1081	44	24.4	16.1	2.2	.018	20,833.0	12,541.0	832.0	34,206.0
2006	9566	2810	107	26.2	14.43	1.93	.018	123,834.2	34,176.8	271.0	158,282.0
2007	9566	2810	107	26.2	14.43	1.93	.018	243,574.7	67,223.8	533.1	311,331.6
2008	9566	2810	107	26.2	14.43	1.93	.018	331,589.0	91,514.8	725.8	423,829.6
2009	9566	2810	107	26.2	14.43	1.93	.018	324,425.1	89,537.6	710.1	414,672.8

*No mined area in water

Approach A was used for pits J-1/N-6, N-10, N-11, N-14, and J-16. This approach, described in more detail below, sums flow rates calculated from equations for steady flow under a hydraulic gradient, and transient, confined flow toward a linear drain (representing the sides of an approximately linear cut) and toward a well (representing the ends of the cut). The second approach (Approach B) was developed later, and applied to J-16, J-19/J-20, and J-21 in previous versions of this chapter, and to the N-11 extension (N11 Ext) in the current version. This approach can be used to calculate inflow under unconfined and/or confined conditions.

Approach A - Aquifer and pit characteristics and the definitions of terms used in pit inflow calculations may be found in Attachment 1. Pre-mining flow calculations are based on the following form of Darcy's law:

Q = TIL

Where:

Q = Quantity of water flowing through the aquifer at the proposed highwall locations in gal./day.

T = Transmissivity of the exposed aquifer in gal./day/ft.

I = Natural hydraulic gradient in ft./ft.

L = Length of aquifer exposed in the highwall normal to the natural hydraulic gradient in ft.

Aquifer testing at Wepo monitoring wells indicates that water in the Wepo aquifer is under some confining pressure. Some of the coal seams have very low hydraulic conductivities and act as aquitards. Water in the alluvium is believed to be in both unconfined and confined conditions depending on depth and location. Those units in the Wepo aquifer believed to transmit water are most of the coal seams and sandstone units below the prevailing water level. Alluvial ground water is assumed to flow from the entire saturated thickness of the alluvium.

In Approach A, the removal of ground water from aquifer storage was calculated using two equations; one to compute the radial component of inflow to the ends of a pit and the other to compute the linear component of inflow to the longitudinal sections of the pit. Radial inflow to each end of the pit was calculated using the following constant drawdown-variable discharge equation (Jacob and Lohman 1952 and Lohman 1972, pp. 23-24).

$$Q = 2\pi TG(\alpha)s$$

$$\alpha = \frac{Tt}{Sr_w^2}$$

Where:

Q = Radial discharge into one end of the pit in ft^3/day

T = Transmissivity of the exposed aquifer in ft^2/day

S = Storage coefficient

s = Drawdown in the aquifer at the pit face in ft.

r_w = Radius of the pit opening in ft.; equal to ½ the width of the initial box cut

$G(\alpha)$ = The G function of α (see Lohman, 1972, p. 23)

t = Time since discharge began in days

The linear portion of inflow from aquifer storage was calculated using the constant drawdown-variable discharge drain equation derived by Stallman (Lohman, 1972, pp. 41-43):

$$q = \frac{2s\sqrt{ST}}{\sqrt{\pi t}}$$

Where:

q = Discharge from an aquifer to both sides of a drain per unit length of drain in ft^2/day

S = Storage coefficient

s = Drawdown in water level at drain in ft.

T = Transmissivity of exposed aquifer in ft^2/day

t = Time since drain began discharging in days

With confined aquifer conditions, lowering of the water level occurs with the lowering of hydrostatic head. The release of water from aquifer storage under confined conditions is small per unit area, because it is only a function of the secondary effects of water expansion and aquifer compaction. After some length of exposure, the hydrostatic head may decline far enough that the aquifer becomes unconfined. Further declines in the water level would then be accompanied by significantly greater quantities of ground water discharge per unit area. It is assumed that during the life of the pits, ground water flow in the affected portions of the Wepo aquifer will remain under confined conditions or that the unconfined area would only extend a short distance from the pit.

The equation for radial inflow assumes that a constant concentric head surrounds each end of the pit. The actual situation representing radial flow to the ends of the pit can be described as an arc of a circle whose center coincides with the center of the pit. If overestimate the inflow rate. This approach is described in detail in Appendix 2. This method was used to predict inflow rates for J-16, J-19/J-20, and J-21 (Tables 5 through 7).

The following procedures were used and assumptions made in estimating inflow to the N11 Ext pit for calendar years 2005-2013. Plans for mining the N11 Ext pit that were originally developed in 2004 have been delayed beyond 2018. However, the mining sequence used to estimate inflows has not been revised and remains valid for the purposes of predicting impacts as described in the following discussion:

- Wepo wells in the area surrounding the N11 Ext pit were selected, and recent water level data were evaluated to determine whether water table elevations had changed significantly from those used in the calculation of the 1985 water-table map. The Wepo wells evaluated include: 38, 39, 40, 41, 42, 43, 44, 49, 52, 53, 54, 159, and 178. Data available through May of 2003 were used in this evaluation.

  Although there were obvious trends in the data for the majority of the 13 wells, the most recent data point was used in this evaluation, since this should be most representative of the water table at start of mining in N11 Ext. These data were compared to the 1985 water table map, and revisions made as necessary. As a result of these comparisons, Drawing No. 85611, 2003 Wepo Water Level Contour Map, has been constructed (see Volume 23, PAP).

- The May 2003 water-table map was then compared with the anticipated elevations for the bottom of the N11 Ext pit, and a 'difference' contour map was constructed that identified those areas where the 2003 water table was above the bottom of N11 Ext. The difference map indicates that the water table will be above base of pit along the majority of the eastern boundary, and in the northwestern section of N11 Ext (in the area between pits N11 and N6). The difference map was then overlaid on the projected cuts for Calendar Years (CY) 2005-2013, which indicated that only those cuts in the northwestern section of the pit will encounter water within this time period. Cuts to be completed in CY2005-2007 are all located within the southwestern section of N11 Ext, and will therefore encounter minimal water. In Calendar Years 2008-2013, cuts will be made both within the southwestern section of N11 Ext, and in the northwestern section where water inflow to the cuts is expected.

- The analytical code Mine1-2_3 was used to estimate the amount of flux entering the cuts in the northwestern section of N11 Ext for CY2008-2013. [Mine1-2_3 is a modification of Mine1-2 allowing pit geometry information to be input yearly, rather than using a single set of values for the entire mining period.] General parameters, and the selected values used as input to the code include:

- o The Wepo was simulated as confined, based on the lithology of the formation, and the low values of storage coefficient determined from aquifer tests.
- o The hydraulic conductivity was set to 0.03432 ft/day, which is the geometric mean of the 24 hydraulic conductivity values for Wepo wells listed in Table 32 (Chapter 15, Hydrologic Description, PAP). The arithmetic average conductivity value was not used, since this weighted the calculated value towards the fewer, significantly higher values of conductivity, and would have overestimated this parameter.
- o The regional hydraulic Gradient (0.014) was estimated from the May 2003 water-table map.
- o A conservative value for the storage coefficient ($1x10^{-4}$) was estimated from the larger of the two values presented in Table 32. Use of a lower value would result in lower values of inflow.

The remaining parameters are specific to the cuts within each calendar year, and include: saturated area; average width of cut; average saturated thickness, days open, and whether this was the first cut in the pit (inflow is assumed through both sides of the initial cut only).

There are two components that contribute to inflow into the cuts: flux controlled by the regional hydraulic gradient (termed $Q_{natural}$ in the code), and flux from water in storage (termed $Q_{drainage}$ in the code). The code assumes that the regional hydraulic gradient, and therefore the regional flux component, is perpendicular to the long axis of each cut. This assumption is generally valid for the southern two-thirds of the cuts located within the northwestern section of N11 Ext; however, the gradient is not perpendicular in the northern one-third of the cuts. In this area, groundwater discharge into the cuts will be less than if the gradient was perpendicular, and a correction factor must be applied to decrease the inflow appropriately (this is done outside of the code). Therefore, an approximate *dividing line* was identified between these two areas, separating Area A representing the northern one-third of the cuts, from Area B representing the southern two-thirds of the cuts, and the *area, saturated thickness,* and *days open* parameters were calculated separately for the sections of the cuts located within areas A and B. The correction used to calculate the regional component of inflow to the cuts in Area A is:

Corrected $Q_{natural} = Q_{natural}$*([width of cut]*sin(alpha) + [length of cut]*cos(alpha))

Alpha is the angle between a line perpendicular to the length of the cut, and the regional hydraulic gradient. The first component within the parentheses represents flux across the end of the cut, and the second component represents flux across the length of the cut. Maximum inflow to the cuts occurs when the regional hydraulic gradient is perpendicular to the length of the cut (angle alpha is 0 degrees in the above equation), and minimum inflow occurs when the gradient is parallel to the length of the cut (angle alpha is 90 degrees - this results in flux across the end of the cut only).

The regional hydraulic gradient is approximately parallel to the cuts in CY10-13, indicating that the regional flux component is minimal and is simulated as occurring across the end of the cuts only. The cut within CY08 does not extend north of the *dividing line*. For the cuts in CY09, an angle of 45 degrees was used to calculate the regional flux component.

Total lengths for all cuts within the northeastern section of N11 Ext for each calendar year were measured and summed in ArcView, and total areas were calculated. These were used to calculate average widths for each of the cuts as input to Mine1-2_3.

- Output from Mine1-2_3 includes values for $Q_{natural}$, $Q_{drainage}$, and Q_{total} for Areas A and B. For each of the cuts in Area A, a corrected $Q_{natural}$ value was calculated using the equation above, this value was added to $Q_{drainage}$, and a corrected Q_{total} determined. The corrected Q_{total} values were summed for each calendar year, and added to the corresponding Q_{total} values for that calendar year from Area B to derive a total flux per calendar year.

Results for N11 Ext are presented in Table 7a. [This nomenclature was adopted to avoid changes in table number throughout the remainder of this Chapter.] The predicted inflow varies from year to year because of changes in the length of the pits beneath the water table, and the estimated depth below the water table. In addition, drainage from two directions is assumed for the first year (2008), but from only one side in later years. The maximum estimated rate, which occurs in 2008, is approximately 10 gallons per minute (gpm); the lowest rate is predicted to be approximately 2.5 gpm, in 2010.

Table 7a. Estimated annual inflow for pit N11 Ext and length of time the base of the pit is below the pre-mining water table.

Year	Inflow (gallons)	Total No. of Days in Water
2008	1170710	84
2009	2105469	226
2010	485396	135
2011	607995	106
2012	1050225	264
2013	783849	241

For all pits including N11 Ext, the drawdown in the Wepo aquifer was estimated by using the predicted inflow rates and the analytical-element simulation program TWODAN (Fitts Geosolutions, 2000). This program solves the groundwater flow equations in two dimensions based on spatial and temporal superposition. Time-varying withdrawals can be simulated using wells. TWODAN solves a transient flow equation and can produce maps of drawdown. Although TWODAN can address cases where the aquifer is not continuous or infinite in extent, the limited drawdown that has been observed in Wepo wells in the vicinity of the pits indicated that it was not necessary to develop a more complex model incorporating the finite extent of the Wepo formation. The permeable units within the Wepo formation that have been mined or will be disturbed by mining are perched aquifers in some locations (e.g., J16 mining area near Wepo well 62R, J19 mining area near Wepo well 65), pinch out and/or are vertically displaced owing to some minor structure within the Peabody leasehold.

The estimated pit inflow rates change each year, because both the depth of the pit below the pre-mining water table and the length of time the pit is below the water table vary yearly. For each pit, the estimated inflow estimates were examined to determine if there was significant, systematic variation in the estimated inflow rate. If not, the average inflow rate was used in the model for each year that the pit was predicted to intercept the water table. If there was systematic variation, the time period was split into 2 or 3 periods of similar inflow, and the average inflow rate within each period was used. Thus, when a significant change in the estimated influx rate occurred, the change was incorporated in the model. When mining of a pit ceased, water production stopped, and inflow rate was set to zero. TWODAN simulates temporal changes in water budget by simulating discharge through wells. Two to five wells distributed around the perimeter and in the interior were used to represent each pit. The temporal changes in the location of the mining cuts within a pit are ignored.

The geometric mean of the hydraulic conductivities determined from aquifer tests of Wepo monitoring wells (Table 32, Chapter 15, Hydrologic Description, PAP), 0.03432 ft/d was used for the horizontal hydraulic conductivity of the Wepo, and the storage coefficient was set to 0.0001. The Wepo was assumed to be 200 feet thick uniformly through out the leasehold because of the limited depth of the pits, even though it is over 300 feet thick in the vicinity of these pits. This value was chosen to approximate the effect of partial penetration of the pits into the saturated Wepo, and to subtract the thickness of the Wepo above the water table. No recharge was assumed, which will cause drawdown to be over-predicted.

Figure 1 shows the locations of the 5-, 20-, 40-, and 60-foot drawdown contours, simulated using the TWODAN model, at the end of 2013. 2013 is the year when mining of N11 Ext below the water table and south of the beltline is scheduled for completion, and incorporates most of the mining currently underway or projected for the other pits such as J21. Thus, the drawdown contours shown on Figure 1 are cumulative of all past and proposed mining through 2013. A 5-foot drawdown cutoff was selected because natural water level fluctuations measured in the Wepo and alluvial monitoring wells on the PWCC leasehold are of that magnitude. Figure 1a shows the locations of the 5-, 20-, 40-, and 60-foot drawdown contours at the end of 2030. Both Figures 1 and 1a depict the locations of pre-existing shallow private wells and springs within and adjacent to the leasehold.

Because the approach used to estimate the pit inflow rates does not take into consideration the decline in water levels caused by inflow into the pit in previous years, it will tend to over-estimate the pit inflow rate in the later years. In addition, the predicted inflow rates have tended to be considerably higher than observed during mining. For example, Western Water & Land (2003) noted:

> The total [annual] inflows for pit J-1/N-6 were projected to range from approximately 50,000 gallons in 1972 to 3,182,179 gallons in 2003. As mining has progressed over the last several decades, it has generally been observed that pit inflows were overestimated, and in some cases no inflow has occurred at all. For example, initial mining of the southern portion of the N-6 Pit saw enough inflow to require pumping, but subsequent mining of this pit to the north has not resulted in any observed pit inflows.

In general, the drawdown estimates shown on Figure 1 are much larger and extend outward to distances much greater than has been observed in monitoring wells. No attempt was made to match these observations with the analytical model, as differences between the observed and estimated drawdown values would be expected. Most Wepo and many alluvial wells exhibit only a few feet of change during their period of record.

Table 8 presents a comparison of water-level changes predicted to occur because of dewatering of all the pits through 2013 with historical variability in currently active monitoring wells. Projected drawdowns, and water level ranges measured as background, during four historical periods of record (1988-1995, 1995-2000, and 2000-2004), and during the most recent seven-year period (2004-2010) are presented for both alluvial and Wepo monitoring wells. Table 8 also includes projected drawdown, historic completion and water level information, and an estimate of the percentage of available water height that may be lost due to pit inflows for two local wells (4K-389 and 8T-506) that were partially completed in the Wepo aquifer.

Table 8 shows current maximum water levels at nine of the twenty-five Wepo monitoring wells are greater than background or historic maximum water levels. At WEPO62R, current maximum water levels are 68.6 feet deeper than background maximum water levels for WEPO62. This deepening exceeds the theoretical maximum projected drawdown for WEPO62R by

Table 8

Projected Pit Inflow Drawdowns at Well Locations Versus Measured Water Level Ranges at Alluvial and Wepo Monitoring Wells and Static Water Levels at Local Wells

PWCC Well Id	Pit Inflow Analysis Maximum Projected Drawdown (feet)	Background Water Level Range		Historic Water Level Range 1988-1995		Historic Water Level Range 1995-2000		Historic Water Level Range 2000-2004		Current Water Level Range 2004-2010		Current Maximum Versus Background/ Historic Maximum (d)
		Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	
ALUV13R(a)	36.0	-	-	22.5	28.9	25.7	29.4	28.2	29.4	27.7	29.6	0.2 ft deeper
ALUV17	53.0	5.0	7.4	5.4	8.0	5.1	8.9	5.9	7.9	5.1	7.5	No change
ALUV19	32.0	5.6	9.4	6.2	9.6	7.0	14.9	14.7	Dry	9.7	Dry	> 7.5 ft deeper
ALUV23R	53.0	-	-	19.2	Dry	Dry	Dry	Dry	Dry	Dry	Dry	No change
ALUV27R	36.0	-	-	21.5	26.7	26.3	28.6	27.6	29.5	-	-	(b)
ALUV29	25.0	0.4	5.3	0.4	7.2	0.2	6.7	0.5	7.9	0.0	2.4	No change
ALUV31R(c)	39.0	7.3	15.8	6.2	17.9	18.1	26.0	23.2	24.2	9.5	23.8	8.0 ft deeper
ALUV69(b)	43.0	4.6	10.0	6.0	10.8	8.3	11.6	11.6	12.2	10.1	11.9	1.9 ft deeper
ALUV71(b)	28.0	14.6	16.6	15.6	16.9	15.7	16.6	16.4	16.8	15.4	17.5	0.9 ft deeper
ALUV72(b)	54.0	11.6	13.3	9.2	13.5	10.8	13.4	12.1	13.2	9.6	12.7	No change
ALUV77(c)	32.0	26.6	30.3	28.9	30.2	29.4	30.8	29.6	30.3	29.1	29.7	No change
ALUV80R	54.0	-	-	8.9	11.7	10.5	12.9	11.4	12.0	10.2	12.4	No change
ALUV83	40.0	0.9	3.3	1.0	3.4	0.8	3.5	-1.3	3.5	-3.4	2.1	No change
ALUV87	45.0	14.2	22.5	17.8	23.1	19.1	23.4	21.4	24.1	17.3	22.2	No change
ALUV89R	61.0	-	-	2.5	5.0	2.8	6.3	1.2	6.0	0.5	4.3	No change
ALUV93	23.0	25.2	29.1	25.9	29.8	26.0	32.8	33.4	37.4	38.0	39.6	10.5 ft deeper
ALUV95	20.0	3.0	4.9	3.1	5.3	3.7	5.6	5.4	7.5	7.3	8.7	3.8 ft deeper
ALUV98R	57.0	-	-	9.6	14.3	11.6	14.7	12.4	16.2	13.1	15.2	No change.
ALUV99R	46.0	-	-	9.8	13.8	11.9	16.0	13.2	18.4	12.4	Dry	5.2 ft deeper
ALUV101R	65.0	-	-	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	No change
ALUV104R	15.0	-	-	15.6	20.3	19.4	20.3	18.9	20.4	17.3	20.6	0.2 ft deeper
ALUV105R	19.0	-	-	8.1	Dry	9.5	10.2	9.7	Dry	6.9	Dry	No change
ALUV106R	22.0	-	-	4.6	Dry	6.7	8.2	7.8	Dry	5.1	Dry	No change
ALUV108R	33.0	-	-	7.1	11.0	8.8	11.6	11.2	13.6	12.3	14.9	1.3 ft deeper
ALUV165	65.0	-	-	20.3	28.7	27.2	30.2	29.2	31.9	31.4	33.0	1.1 ft deeper
ALUV168	34.0	-	-	- 0.4	1.4	0.6	1.9	1.3	2.6	2.4	2.8	0.2 ft deeper
ALUV169	36.0	-	-	7.2	9.0	7.2	9.2	7.9	9.7	7.5	9.6	No change
ALUV170	34.0	-	-	4.5	5.8	4.2	6.3	4.7	7.0	3.4	5.7	No change
ALUV172	19.0	-	-	13.1	14.1	14.5	18.7	17.8	21.4	10.0	19.0	No change
ALUV180	47.0	-	-	6.1	10.3	9.4	12.4	11.6	12.6	-	-	(b)
ALUV181(a)	32.0	-	-	11.8	16.8	15.0	20.1	19.7	20.6	14.7	18.6	No change
ALUV182	32.0	-	-	13.6	17.8	16.8	19.4	17.2	19.3	15.1	18.2	No change
ALUV193	46.0	-	-	10.9	12.4	9.8	13.0	10.6	12.6	12.7	14.7	1.7 ft deeper
ALUV197	32.0	-	-	10.2	13.2	11.8	19.9	19.7	24.9	14.3	22.8	No change
ALUV199	62.0	-	-	13.5	17.2	12.5	18.3	13.7	18.8	13.7	16.8	No change
ALUV200	53.0	-	-	4.1	5.9	3.8	6.4	4.4	5.8	3.0	5.4	No change
ALUV201	n/a	-	-	-	-	-	-	-	-	27.7	28.0	No change

Notes:
(a) Discontinued monitoring at these wells in 2002, but reinstated monitoring in 2005, due to opening of N9 mining area.
(b) Discontinued monitoring at these wells in 2002 (idled).
(c) Discontinued monitoring at these wells in 2002, but periodic measurement of water levels since then.
(d) Compared with background maximum (if available) or pre-2004 historic maximum.

Table 8 (cont.)

Projected Pit Inflow Drawdowns at Well Locations Versus Measured Water Level Ranges at Alluvial and Wepo Monitoring Wells and Static Water Levels at Local Wells

PWCC Well Id	Pit Inflow Analysis Maximum Projected Drawdown (feet)	Background Water Level Range		Historic Water Level Range 1988-1995		Historic Water Level Range 1995-2000		Historic Water Level Range 2000-2004		Current Water Level Range 2004-2010		Current Maximum Versus Background/ Historic Maximum (f)
		Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	
WEPO40	47.0	71.5	81.0	66.0	74.4	67.1	71.9	72.0	76.8	77.3	80.6	No change
WEPO41(a)	26.0	86.9	93.4	81.3	94.4	86.6	92.9	87.9	91.9	86.1	91.1	No change
WEPO42	54.0	-2.1	-1.5	-1.8	-1.3	-1.7	-1.0	-1.4	-1.0	-1.5	-1.2	0.3 ft deeper
WEPO43R(b)	43.0	138.6	150.6	138.9	144.4	135.3	138.1	138.3	142.2	130.4	142.1	No change
WEPO44	49.0	183.5	187.8	177.7	187.3	175.2	180.9	172.0	175.9	169.3	172.5	No change
WEPO45	37.0	83.4	88.2	80.0	86.4	80.8	82.8	82.7	83.1	82.2	83.2	No change
WEPO46	38.0	117.9	157.2	149.8	155.4	151.2	155.0	154.2	155.5	154.2	155.6	No change
WEPO47R(c)	15.0	-	-	-	-	31.4	32.6	30.7	32.4	27.7	30.6	No change
WEPO49	55.0	4.3	9.6	1.8	4.8	1.1	3.0	0.4	1.4	0.1	0.8	No change
WEPO51(a)	26.0	43.0	52.0	48.9	52.1	51.2	52.5	52.3	53.2	51.8	52.4	0.4 ft deeper
WEPO52(a)	35.0	16.3	24.3	18.0	23.8	17.8	19.0	17.9	18.0	17.9	31.0	6.7 ft deeper
WEPO53	65.0	36.7	55.4	46.4	54.7	54.8	66.0	66.9	73.2	70.5	71.5	16.1 ft deeper
WEPO54	60.0	47.4	55.7	49.5	51.4	50.3	51.8	50.8	52.1	50.4	51.5	No change
WEPO55	27.0	159.4	162.2	159.8	161.3	159.8	161.8	161.4	161.7	161.2	161.8	No change
WEPO56	35.0	30.9	40.4	32.8	38.4	35.0	37.6	36.6	38.0	38.1	39.7	No change
WEPO57	40.0	150.1	158.3	155.9	158.8	157.9	161.4	161.4	163.8	162.6	164.2	5.9 ft deeper
WEPO58	24.0	130.3	140.1	137.5	141.2	140.0	140.9	140.5	141.2	140.6	141.4	1.3 ft deeper
WEPO59	20.0	142.7	144.6	142.7	144.3	143.1	145.1	144.7	145.8	143.8	145.5	0.9 ft deeper
WEPO60	19.0	81.2	87.3	88.2	95.7	90.8	93.7	90.3	91.6	89.5	91.4	4.1 ft deeper
WEPO61	10.0	154.3	155.4	153.4	155.9	152.8	154.8	154.3	154.8	154.2	155.1	No change
WEPO62R(d)	63.0	114.1	139.7	133.1	197.7	213.1	227.7	207.9	212.1	205.8	208.3	68.6 ft deeper
WEPO65	50.0	71.9	164.5	113.8	128.7	125.0	143.5	143.6	146.6	141.7	145.9	No change
WEPO66	35.0	75.4	89.1	82.0	87.6	86.1	88.0	87.5	89.4	77.6	87.3	No change
WEPO67	25.0	129.5	204.5	182.4	187.7	181.4	184.0	175.9	181.2	183.2	185.8	No change
WEPO68 (e)	37.0	-	-	-	-	107.9	110.8	107.7	109.9	108.3	110.7	No change

Local Well Id	Pit Inflow Analysis Maximum Projected Drawdown (feet)	Total Well Depth (feet)	Static Water Level (feet)	Percent of Potential Water Height in Well Bore Lost to Pit Pumpage
4K-389	30.0	417	356	49.2
8T-506	49.0	552	34	9.5

Notes:

(a) Discontinued monitoring at these wells in 2002 (idled).

(b) Background and historic water levels through 2/97 are from WEPO43, corrected for ground surface elevation. WEPO43 was removed ahead of gravel-pit expansion in 1997 and WEPO43R was installed that same year.

(c) Background and historic water levels through 3/98 are from WEPO47, and from 4/98 to present are from WEPO47R; both uncorrected for ground surface elevation differences. WEPO47 was removed ahead of pond construction and WEPO47R was installed in 1998.

(d) Background and historic water levels through 3/98 (including 1995-2000 maximum) are from WEPO62, corrected for ground surface elevation. WEPO62 was removed in 1998 and WEPO62R was installed in 1997.

(e) WEPO68 was installed in 1997.

(f) Compared with background maximum (if available) or pre-2004 historic maximum.

5.6 feet. WEPO62 appears to have been open to one or more perched zones, which were gradually dewatered as the adjacent J-16 pit was mined. These perched zones are usually of limited aerial extent and can influence large well bore water level changes, which are not indicative of true aquifer water level changes. At WEPO53, current maximum water levels are 16.1 feet deeper than background and historic maximum water levels, yet are only 6.5 feet deeper than the theoretical projected maximum drawdown at 2013 for this well (65 feet). The 16.1 feet deepening at WEPO53 has likely been influenced by pit dewatering in both the N-6 and N-11 pits. The maximum current water levels that are deeper than historical values in the remaining four Wepo monitoring wells range from 0.3 feet to 6.7 feet, which are comparable to natural water fluctuations in the Wepo formation. Sixteen of the Wepo monitoring wells show no change in current maximum water levels compared with historic values. Wepo monitoring wells WEPO40, WEPO43R, and WEPO44, situated adjacent to the J1/N6 pit, show no change in current maximum water levels compared to their historical records. Out of a total of twenty-five Wepo monitoring wells, there are only two wells adjacent to wet pits that have exhibited drawdowns in excess of natural fluctuations (greater than seven feet), and that were most likely affected by dewatering of an adjacent pit. The remaining twenty-three wells have not shown appreciable drawdown impacts from pit dewatering even though many are within one-mile of the nearby pit, suggesting that the projected drawdowns depicted in both Figures 1 and 1a are extremely conservative.

Table 8 shows current maximum water levels at 4 of the 37 alluvial wells are deeper than 5 feet of their historical record. Three of the wells (ALUV19, ALUV31R, and ALUV93) are shallow monitoring wells constructed in the alluvium along the lower reaches of the major washes, several miles downstream of any of the wet pits. ALUV99R is located to the north of the J21 pit. These deeper water levels are a result of recent trends in lower precipitation and subsequent recharge from runoff and discharge from the Wepo formation. Many of the remaining 32 alluvial wells exhibit deeper current maximum water levels compared to their historical record, but they are generally comparable to or less than the several-feet natural fluctuation of water levels in the alluvium, and all have been influenced to some degree by recent trends in lower precipitation. Projected drawdowns at each alluvial monitoring well location using the TWODAN analytical method are generally an order of magnitude greater than the drawdowns measured to date.

Figure 1 shows drawdowns in the Wepo formation in the vicinity of the N11 Ext pit are projected to be 60 feet or greater by 2013. In addition, drawdowns beneath the adjacent portion of Coal Mine Wash are projected to range between 40 feet at ALUV83 and 54 feet at ALUV80R. The Wepo is believed to be the source of discharge into the wash downstream from where Coal Mine Wash passes beneath the overland conveyor. Peabody does not believe that there will be significant impacts on this discharge for several reasons. First, observations of pit discharge suggest that the technique overestimates the inflow rate, as noted above. Second, the mining of N6 has not caused a noticeable impact on the locations of discharge into Coal Mine Wash. Although the baseflow of Coal Mine Wash is not measured, a reduction in discharge caused by declining water levels beneath the wash would be also manifested by downstream movement of the location of the uppermost area of discharge. This has not been observed over many years of mining. Third, the water levels in WEPO40, a well close to both N6 and Coal Mine Wash, appear to be affected more by changes in local recharge than by dewatering.

Based on the theoretical pit inflow drawdown contours, local well 4K-389 is projected to have its water level deepened by 30 feet, or 49.2 percent of its total available water height of 61 feet. Local well 8T-506 is projected to have its water level deepened by 49 feet, or 9.5 percent of its available water height of 518 feet. Both wells were selected for comparison purpose due to their proximity to wet pits; however, local well 8T-506 was removed in advance of the mining operations in the N-6 mining area. From the historic and current water levels at Wepo and alluvial monitoring wells in the vicinity of the two local wells, it appears likely that the projected water level declines at the two local wells will be significantly less than that theoretically calculated. The drawdown that will eventually occur in the Wepo formation in the vicinity of local well 8T-506 and at local well 4K-389 from pit inflows will not be significant.

As mentioned previously, Figures 1 and 1a depict the locations of numerous pre-existing wells, springs, and ponds within and adjacent to the leasehold. Chapter 17, Protection of the Hydrologic Balance, provides a thorough discussion of the nature and status of the pre-existing water sources shown on Figures 1 and 1a. Many of the wells are inoperable, or are completed in different formations or multiple formations in addition to the Wepo. Many of the springs are undeveloped, have little to no measurable discharge, or emanate from a formation other than the Wepo. Chapter 17 provides a discussion of plans to provide replacement sources of water for those wells and springs that have been or will be removed by mining. All of the pre-existing wells and springs that are operable and have measureable output within the leasehold are monitored, and none of the recent measurements indicate a significant reduction in output as a result of pit dewatering.

In summary, water from the Wepo formation is expected to enter N11 Ext (and other) pits. Based on operational experience, the inflow rates have generally been lower than predicted by the techniques described here. Similarly, the simulated drawdowns caused by dewatering are no doubt much higher than will be encountered. Only two monitoring wells in the immediate vicinity of pits that have already been mined exhibit declines in water levels attributed to pit inflows, and drawdowns in other wells adjacent to previously mined pits are not evident. Inflow in the N11 Ext and other wet pits is likely to be less than indicated in Tables 1 through 7a. Drawdowns expected to occur in the Wepo formation as a result of pit dewatering should not extend as far nor be as high as depicted on Figures 1 and 1a, and will not be significant.

Removal of Local Wells and Springs. One existing local well (4T-404), completed in the Toreva aquifer, is located within the proposed life-of-mine mining plan area (J-19 mining area). In addition, two other local wells (4T-403 and 8T-506), both completed in the Toreva aquifer were removed in advance of the mining operations in the J-7 and N-6 mining areas, respectively. One local spring (Site #97) was removed in advance of mining at N-14. The impacts have been mitigated during mining by providing alternative water sources (N-aquifer public water standpipes). The three local wells will be replaced with ones of comparable quality and yield following the completion of mining and reclamation in the respective mining areas. The spring will be mitigated by retention of a permanent impoundment (see Chapter 19).

Containment of Pit Inflow Pumpage. It is sometimes necessary to pump ground water which seeps into pits to allow work to continue and to prevent slumping of spoil piles resulting from saturation near the bottom of the pit. Several sediment ponds and large dams (see Table 9) exist or will exist around the pits to contain all pit pumpage as well as storm water runoff and sediment from the disturbed areas up-watershed from the ponds.

Referring to Tables 1 through 7a, it can be seen that the maximum pit pumpage in any one year will be 19 to 37 acre-feet and will occur in the J-19/20 pit. Typical quantities of pit pumpage will be on the order of 2 or less acre-feet per year. The larger dams are designed to contain this additional volume of water with adequate freeboard. Reed Valley Dam has been designed to impound 475 acre-feet of water and J-7JR dam will hold an estimated 700 acre-feet of water. The capacity of smaller sediment ponds to contain storm runoff will be maintained by pumpage from the ponds. The current NPDES Permit (Chapter 16, Attachment 3) allows for pond dewatering or pond to pond pumpage.

Impact of Replaced Spoil Material on Ground-Water Flow and Recharge Capacity. Pits remain open only until the coal has been removed. Following the short-term impacts on the ground-water system associated with open pits, a longer term impact is experienced due to the placement of spoil material in the mined-out pits. A wide range in permeabilities for spoil material can occur depending on how it is placed.

Rahn (1976) reported that spoil material replaced using a dragline in one instance and a scraper in another, yielded hydraulic conductivities of 35.3 ft./day and 0.4 ft./day, respectively. Van Voast and Hedges (1975) concluded that greater porosities and hydraulic conductivities will result from volume changes (approximately one-fourth greater) between the spoil material in its original compacted, stratified state, and in its rearranged state following replacement, regardless of the method of replacement used.

Spoil material will be regraded by dozers and scrapers and final contouring will be accomplished with dozers. Based on the conclusions of the above studies, the spoil material should have higher porosities and permeabilities than it did in its original state. The topsoil surface will be disked as part of the reclamation activity; this procedure should further enhance the rainfall and overland flow infiltration rates.

that would account for these increases in TDS are Ca, Mg, Na, SO_4 and HCO_3.

On a related matter, Montana Department of State Lands personnel have noticed in their review of mine overburden data that materials with high salinity are generally quite shallow (less than 15 meters). Normal dragline operation would generally place some of the near surface overburden in the lower portions of the pit. This mining practice could cause the placement of some of the more saline materials in the resaturated zone and result in a greater degree of ground-water degradation. A review of overburden core data for portions of the pits that will intercept the Wepo aquifer (N-6, N-10, N-11, N-14, N99, J-16, J-19/20 and J-21) indicates that there are no significantly high conductivity zones in the overburden material. Therefore, significant salinity increases are not expected in resaturated graded spoil on the Black Mesa leasehold.

The second principal chemical reaction that occurs in spoil material and could affect ground-water quality is the oxidation and reduction of sulfides and organic sulfur. In the west, waters which contact spoil are rarely acidic. Acid zones will probably form in the spoil; however, sufficient carbonate materials and alkaline salts are available to neutralize acid production resulting from the oxidation of sulfides.

Cores from within or immediately adjacent to the wet portions of the pits have been analyzed to determine the acid potential of the overburden (see Appendix B). The overall acid-forming potential of core material involves a comparison of the acid potential and the neutralization potential expressed in terms of tons of $CaCO_3$ required per 1000 tons of material for neutralization (acid potential) and tons of $CaCO_3$ excess per 1000 tons of material (neutralization potential). Table 10 is a summary of: (1) the percent of the total core that is comprised of material with acid potential; (2) the mean weighted acid potential; and (3) the mean weighted neutralization potential. Cores from within or adjacent to wet pits, and new cores (2003) drilled in the J-21W, N-9, and N-11 Ext coal resource areas are also included. Only 1 core; Core #30356EO in the N-9 mining area had a higher mean weighted acid potential. All other cores indicate excess ($CaCO_3$) neutralization potential. The neutralization of the acid produced from the oxidation of sulfides and sulfates does have an adverse water quality related side effect. In the process of the carbonate minerals reacting to achieve neutralization, there is increased dissolution of alkaline salts and consequently elevated TDS levels.

Considerable controversy surrounds the potential activity of the different forms of sulfur and the significance of organic sulfur. In western mine settings as much as 70% of the total sulfur analyzed has been found to be organic sulfur. According to Dollhopf

TABLE 10

Summary of Acid and Neutralization Potential for Cores in Mining Areas Projected to Intercept the Wepo Aquifer

Overburden Core No.	% of Core With Negative Potential	Mean Weighted Acid Potential (Tons $CaCO_3$ Needed for Neutrality per 1000 Tons Material)	Mean Weighted Neutralization Potential (Tons $CaCO_3$ Excess per 1000 Tons Material)
N-6 Mining Area			
21104C	16.63	9.76	40.94
23163C	4.48	7.98	45.01
23164C	15.38	11.26	39.39
23165C	26.35	10.36	39.51
23166C	14.97	7.41	62.12
24093C	14.42	8.21	44.63
24094C	12.98	7.13	61.89
24095C	12.60	6.94	50.53
24096C	5.39	6.92	52.68
24097C	22.77	8.61	40.35
24098C	23.32	7.21	38.85
24099C	11.93	2.82	36.39
24400C	12.50	9.23	51.70
24401C	20.14	10.90	21.81
24402C	21.67	12.54	38.14
J-16 Mining Area			
23146C	44.57	24.37	32.29
23147C	33.14	17.81	28.66
23148C	41.22	30.79	39.28
23149C	1.42	4.59	24.60
23325C	37.64	13.89	28.80
23326C	32.34	11.06	40.85
23327C	45.26	23.06	39.89
23328C	34.72	24.12	39.41
26462C	12.28	2.65	27.30
J-19 Mining Area			
24406C	33.23	5.05	27.74
24407C	32.03	16.48	32.03
24408C	17.97	4.34	32.01
24418C	24.09	15.39	34.28
J-21 Mining Area			
24403C	12.02	7.44	79.73
24404C	11.98	4.97	73.07
24405C	12.36	8.49	54.99
J-21W Mining Area			
30365EO	13.04	7.71	48.83
N-9 Mining Area			
30355EO	29.64	16.10	51.16
30356EO	54.64	21.25	20.63
30357EO	34.30	18.57	41.57
30358EO	32.14	17.42	72.61
N-10 Mining Area			
21099C	46.63	20.02	21.97
21100C	40.09	23.89	28.40
21101C	38.21	20.86	24.10
30354EO	12.32	15.81	43.99
N-11 Mining Area			
26272C	29.61	18.73	42.57
26364C	25.91	18.50	49.32
26367C	20.76	14.00	69.67
26463C	37.84	17.98	58.24
N-14 Mining Area			
26269C	31.41	18.73	30.73
26271C	40.04	16.51	19.65

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TABLE 10 (Continued)

Summary of Acid and Neutralization Potential for Cores in Mining Areas Projected to Intercept the Wepo Aquifer

Overburden Core No.	% of Core With Negative Potential	Mean Weighted Acid Potential (Tons $CaCO_3$ Needed for Neutrality per 1000 Tons Material)	Mean Weighted Neutralization Potential (Tons $CaCO_3$ Excess per 1000 Tons Material)
N-11 Ext Mining Area			
30351EO	11.06	10.09	34.62
30352EO	32.00	14.47	28.76
30353EO	18.88	14.12	33.72
30368EO	28.11	15.11	33.91
30369EO	32.48	16.34	24.77
30370EO	17.19	15.12	33.15
30381EO	26.65	15.72	46.39

(1984), organic sulfur when oxidized produces approximately one-third less acid than the sulfide forms of sulfur in a low (< 4) pH environment. A comparison of total sulfur versus pyritic sulfur in cores taken on Black Mesa suggests that organic sulfur is approximately 20 percent of the total sulfur. In this comparison it was assumed that only the above two forms comprised the total amount of sulfur. Whether it is pyritic or organic sulfur, not all the forms of either will react to form acid. Considerable research remains to be done in this area.

Oxidation of sulfides primarily occurs above the water table in the zone of water level fluctuations or in zones of significant infiltration of precipitation. As was explained previously, significant recharge will not occur to the aquifer through the spoil material, so the potential of this as a mechanism for additional leachate movement and acid production on the leasehold is minimal. Also, the typical Wepo water level fluctuations range from 2 to 3 feet or less. This does not constitute a significant zone in which alternate weathering and leaching of ions could occur.

Below the water table, less oxygen may be available than in the overlying unsaturated vadose zone resulting in less sulfide oxidation-reduction increases in salinity or acidity of the water. Pionke and Rogowski (1979) state that water has an oxygen diffusion coefficient four magnitudes less than for sulfides in air. The opportunity exists during the mining process to minimize the oxidation of pyrites and the production of sulfates by burying localized pyritic zones in the postmining saturated zone. Sulfide reduction may be the dominant process occurring below the water table if substantial populations of sulfate reducing bacteria are present. No information exists regarding the possibility of the presence of these bacteria on the leasehold.

A final concern associated with the oxidation and reduction of sulfides and sulfates is the mobilization of trace metals in the ground-water system. Dollhopf et al. (1979, 1981) compared column leach extracts with spoil water quality. They found that the statistical means and ranges for the comparisons between column leachates and water from spoil wells often differed by as much as a factor of ten. Though they did state that column leachates were comparable to well water concentrations to a degree, they allowed that these correlations would have to be made at many mines with contrasting chemical conditions in order to verify the usefulness of this method for judging which overburden materials would be most suitable for aquifer reestablishment.

Evaluation of cores taken in the N-11, N-14, J-16, J-19/20 and J-21 mining areas for B, As, Se, Mo, Hg, Cu, Cd, Cr and Zn indicates that there are not high concentrations of any of these chemical constituents in the overburden material. During the oxidation and reduction stages of the sulfide zones in the saturated portions of the pits, trace metals will be alternately taken into solution as the pH drops and precipitated out as the acid is neutralized and additional alkali salts go into solution. Total recoverable metal analyses performed on Wepo and alluvial ground-water samples collected at below-mining monitors also support the core chemistry. Wepo and alluvial ground-water trace metal analyses presented in the annual "Hydrological Data Reports" and summarized in Table 11 indicate that both the dissolved and total recoverable concentrations of trace constituents at monitoring sites downgradient of wet pits are typically well below the livestock drinking water limits.

The above discussion has addressed the sources of potential ground-water quality degradation. In order to assess the significance of this potential degradation, the historic and potential use of the Wepo and alluvial ground water is considered. Table 12 is a summary of the principal constituents in both aquifers that render the water sources unsuitable for livestock drinking water. The monitoring sites chosen for Table 12 are either at or in the immediate vicinity (downgradient) of a pit that will intersect the Wepo and or alluvial aquifer. Recently promulgated Tribal water quality standards (NNEPA, 2008; Hopi, 2010) were principally used, as well as recommended standards for both TDS (NAS, 1974) and sulfate (Botz and Pederson, 1976). All chemical parameter values listed are for water quality sampling at each site from 1986 through 2010, and comparisons of standards for trace elements were limited to dissolved analyses.

The principal constituent rendering Wepo aquifer water unsuitable for use as livestock drinking water is pH (at four wells). The NO3, Se, TDS and sulfate standards were also exceeded at one site (WEPO46). Low pH levels appear to be isolated occurrences at two of the four wells, where only one or two low pH values appear in twenty or more measurements. Low pH values at these wells range from 6.2 to 6.5, which is only slightly below the livestock drinking water limit (lower limit is 6.5). A single high pH value (9.16) appears in 58 measurements taken at well 40 (higher limit is 9.0). Elevated NO3 levels can lead to methemoglobinemia and impaired liver function, whereas elevated Se can cause white muscle disease in livestock. Ingestion of sulfate levels greater than 3000 mg/l and TDS concentrations greater than 7000 mg/l in livestock drinking water tends to cause diarrhea, rundown ragged appearances, weakening, and death. Principal constituents in the alluvial aquifer that preclude livestock use are sulfate and TDS. Almost all occurrences of trace elements Cd, Pb and Se greater than the standards result from laboratory method detection limits greater than the standards. Alluvial well 199 consistently exhibits low pH values below the standard. Those portions of the Wepo aquifer potentially affected by pit interception do not appear to be significantly

Table 11.

Summary of Dissolved and Total Recoverable Trace Metal Concentrations in Portions of the Wepo and Alluvial Aquifers Below Mining (1986 – 2010)

Wepo Aquifer

Chemical Constituent	Range of Minimum Values (mg/l)	Range of Mean Values (mg/l)	Range of Maximum Values (mg/l)	Livestock Standards (mg/l)#
Arsenic (D)	<.0005-.003	.001-.004	<.0005-.004	0.2
Arsenic (TR)	.001-.003	.001-.004	<.001-.005	0.2
Boron (D)	.03-.79	.065-.88	.08-1.2	5.0
Cadmium (D)	<.003-.008	.003-.011	<.003-.02	0.05
Cadmium (TR)	<.003-.009	.005-.009	<.005-.009	0.05
Chromium (D)	<.01-.01	.01-.02	<.01-.01	1.0
Chromium (TR)	<.01-.01	.01-.01	<.01-.01	1.0
Copper (D)*	<.01-.01	.01-.03	<.01-.02	0.5
Copper (TR)	<.01-.02	.01-.037	<.01-.06	0.5
Lead (D)*	<.02-.02	.02-.02	<.02-.02	0.1
Lead (TR)	<.02-.08	.02-.08	<.02-.08	0.1
Mercury (D)*	<.0001-.0003	.0003 - .0003	<.0001-.0003	0.01
Mercury (TR)	<.0001-<.0001	-	<.0002-<.0002	0.01
Molybdenum (D)	<.001-.002	.001-.003	<.001-.003	N/A
Molybdenum (TR)	<.001-.002	.001-.003	.001-.005	N/A
Selenium (D)*	<.001-.011	.001-.09	<.001-.21	0.05
Selenium (TR)	<.001-.007	.001-.09	<.001-.21	0.05
Zinc (D)	<.01-.30	.01-.34	<.01-.40	25
Zinc (TR)	.01-.03	.02-.20	<.01-.53	25

Alluvial Aquifer

Chemical Constituent	Range of Minimum Values (mg/l)	Range of Mean Values (mg/l)	Range of Maximum Values (mg/l)	Livestock Standards (mg/l)#
Arsenic (D)	<.001-.013	.001-.013	<.0005-.015	0.2
Arsenic (TR)	<.001-.006	.001-.008	.001-.03	0.2
Boron (D)	<.02-.66	.088-.78	.07-.90	5.0
Cadmium (D)*	<.003-.02	.003-.02	<.01-.02	0.05
Cadmium (TR)	<.003-.02	.003-.02	<.01-.021	0.05
Chromium (D)*	<.01-.03	.01-.038	<.01-.07	1.0
Chromium (TR)	<.01-.03	.01-.11	<.01-.35	1.0
Copper (D)*	<.01-.04	.01-.055	<.01-<.1	0.5
Copper (TR)	<.01-.02	.01-.062	<.01-.22	0.5
Lead (D)*	<.02-.08	.02-.08	.02-.12	0.1
Lead (TR)	<.02-.04	.02-.14	<.02-.59	0.1
Mercury (D)*	<.0001-.0009	.0002-.002	<.0002-.003	0.01
Mercury (TR)*	<.0001-.0004	.0001-.0007	<.0001-.0013	0.01
Molybdenum (D)	<.001-.002	.001-.004	<.001-.01	N/A
Molybdenum (TR)	<.001-.002	.002-.008	<.001-.016	N/A
Selenium (D)	<.001-.017	.001-.014	<.002-.032	0.05
Selenium (TR)	<.001-.004	.001-.011	.002-.024	0.05
Zinc (D)*	<.01-.67	.02-.32	.02-.77	25
Zinc (TR)	<.01-.02	.02-.08	<.01-.47	25

* Range adjusted to exclude suspected outliers. Criteria used for identifying suspected outliers include measureable dissolved concentrations yet the pH is alkaline; dissolved concentrations higher than total recoverable concentrations; and one or two abnormally high dissolved values mixed with 40 below detection limit values.

Standards are taken from Navajo Nation Surface Water Quality Standards (NNEPA, 2008), and from Draft Hopi Water Quality Standards (Hopi, 2010 – mercury only).

Table 12 - Downgradient Wepo and Alluvial Well Chemistry vs. Livestock Drinking Water Standards

Analyte	Standard	No. Sites	Sites	Frequency	Exceedence Date Range	Exceedence Value Range	Exceedence Median
LIVESTOCK DRINKING WATER STANDARDS -- NNEPA (2008), HOPI (2010), BOTZ AND PEDERSON (1976)							
Aluminum, Dissolved	0.0000 - 5.0000	1	ALUV199	1/0/0/45	07/03/01-07/03/01	8.2000 - 8.2000	8.2000
Arsenic, Dissolved	0.0000 - 200.0000	0	none				
Boron, Dissolved	0.0000 - 5000.0000	0	none				
Cadmium, Dissolved	0.0000 - 50.0000	6	ALUV180	0/0/1/37	08/25/97-08/25/97(<)	200.0000 - 200.0000	200.0000
			ALUV181	0/0/1/42	08/25/97-08/25/97(<)	200.0000 - 200.0000	200.0000
			ALUV182	0/0/1/45	03/24/98-03/24/98(<)	60.0000 - 60.0000	60.0000
			ALUV19	0/0/1/62	01/27/98-01/27/98(<)	80.0000 - 80.0000	80.0000
			ALUV193	0/0/1/54	11/03/97-11/03/97(<)	400.0000 - 400.0000	400.0000
			ALUV197	0/0/2/54	11/03/97-01/27/98(<)	80.0000 - 400.0000	240.0000
Chromium, Dissolved	0.0000 - 1000.0000	0	none				
Copper, Dissolved	0.0000 - 500.0000	0	none				
Field Ph	6.5000 - 9.0000	5	ALUV199	22/0/0/45	05/31/94-05/07/10	5.8500 - 6.4800	6.3050
			WEPO40	1/0/0/58	10/25/95-10/25/95	9.1600 - 9.1600	9.1600
			WEPO42	2/0/0/59	02/16/94-03/09/95	6.3700 - 6.3700	6.3700
			WEPO46	5/0/0/50	03/11/93-06/03/09	6.2100 - 6.4900	6.2500
			WEPO49	2/0/0/55	06/29/92-03/09/95	6.2300 - 6.4700	6.3500
Lead, Dissolved	0.0000 - 100.0000	16	ALUV169	0/0/12/44	11/20/97-02/04/05(<)	200.0000 - 200.0000	200.0000
			ALUV170	0/1/31/55	04/21/97-08/23/10(B)	200.0000 - 200.0000	200.0000
					(<)	200.0000 - 200.0000	200.0000
			ALUV180	0/0/18/37	03/07/97-05/20/02(<)	200.0000 - 2000.0000	200.0000
			ALUV181	0/0/23/42	03/07/97-05/03/10(<)	200.0000 - 2000.0000	200.0000
			ALUV182	0/1/20/45	03/07/97-12/01/10(B)	300.0000 - 300.0000	300.0000
					(<)	200.0000 - 800.0000	200.0000
			ALUV19	0/0/16/61	02/04/97-02/25/09(<)	200.0000 - 200.0000	200.0000
			ALUV193	0/0/26/54	11/03/97-03/22/10(<)	200.0000 - 1000.0000	200.0000
			ALUV197	0/0/26/54	08/26/97-03/22/10(<)	200.0000 - 1000.0000	200.0000
			ALUV199	0/0/24/45	07/16/96-05/07/10(<)	200.0000 - 200.0000	200.0000
			ALUV27R	0/0/16/50	11/06/97-07/29/02(<)	200.0000 - 200.0000	200.0000
			ALUV80R	0/1/5/67	07/19/99-07/23/10(B)	200.0000 - 200.0000	200.0000
					(<)	200.0000 - 400.0000	200.0000
			ALUV83	0/0/34/70	07/16/96-08/13/10(<)	200.0000 - 200.0000	200.0000
			ALUV89R	0/0/24/67	03/02/98-10/11/10(<)	200.0000 - 200.0000	200.0000
			WEPO178	0/0/8/22	03/10/97-05/20/02(<)	200.0000 - 200.0000	200.0000
			WEPO46	0/0/4/29	09/18/97-05/19/06(<)	200.0000 - 200.0000	200.0000
			WEPO55	0/0/1/27	08/26/97-08/26/97(<)	200.0000 - 200.0000	200.0000
Mercury, Dissolved	0.0000 - 10.0000	0	none				
NO3_NO2 Nitrogen_N	0.0000 - 100.0000	2	ALUV200	1/0/0/55	03/25/08-03/25/08	323.0000 - 323.0000	323.0000
			WEPO46	2/0/0/25	09/18/97-11/06/97	202.0000 - 270.0000	236.0000
Nitrate Nitrogen_N	0.0000 - 100.0000	2	ALUV200	1/0/0/55	03/25/08-03/25/08	323.0000 - 323.0000	323.0000
			WEPO46	2/0/0/29	09/18/97-11/06/97	202.0000 - 269.0000	235.5000

Table 12 (cont.) - Downgradient Wepo and Alluvial Well Chemistry vs. Livestock Drinking Water Standards

Analyte	Standard	No. Sites	Sites	Frequency	Exceedence Date Range	Exceedence Value Range	Exceedence Median
Nitrite Nitrogen_N	0.0000 - 10.0000	0	none				
Selenium, Dissolved	0.0000 - 50.0000	2	ALUV200	2/0/0/55	03/25/08-04/16/08	56.0000 - 300.0000	178.0000
			WEPO46	13/0/0/29	06/24/86-06/03/09	51.0000 - 560.0000	160.0000
Solids, Dissolved	0.0000 - 6999.0000	7	ALUV170	13/0/0/55	03/18/93-04/17/01	7010.0000 - 9540.0000	7470.0000
			ALUV19	1/0/0/64	04/28/06-04/28/06	7120.0000 - 7120.0000	7120.0000
			ALUV197	26/0/0/54	08/28/98-09/14/10	7040.0000 - 7730.0000	7315.0000
			ALUV199	38/0/0/45	12/17/92-07/09/08	7050.0000 - 9692.0000	8400.0000
			ALUV200	1/0/0/55	03/25/08-03/25/08	13900.0000 - 13900.0000	13900.0000
			ALUV83	31/0/0/71	10/23/87-08/13/10	7002.0000 - 7670.0000	7210.0000
			WEPO46	2/0/0/59	09/18/97-11/06/97	7840.0000 - 8010.0000	7925.0000
Sulfate	0.0000 - 3000.0000	14	ALUV170	55/0/0/55	10/01/92-08/23/10	3300.0000 - 5800.0000	3960.0000
			ALUV180	18/0/0/37	08/09/94-08/17/01	3010.0000 - 3380.0000	3100.0000
			ALUV181	1/0/0/42	04/23/97-04/23/97	3140.0000 - 3140.0000	3140.0000
			ALUV182	4/0/0/45	09/05/95-04/28/97	3050.0000 - 3160.0000	3080.0000
			ALUV19	22/0/0/63	02/04/97-08/09/10	3040.0000 - 4200.0000	3355.0000
			ALUV193	30/0/0/54	09/21/93-08/09/10	3020.0000 - 4000.0000	3190.0000
			ALUV197	54/0/0/54	10/30/92-09/14/10	3441.0000 - 4640.0000	4110.0000
			ALUV199	45/0/0/45	12/17/92-05/07/10	4000.0000 - 6610.0000	5360.0000
			ALUV200	1/0/0/55	03/25/08-03/25/08	7900.0000 - 7900.0000	7900.0000
			ALUV27R	49/0/0/50	06/02/89-07/29/02	3293.0000 - 4110.0000	3676.0000
			ALUV83	70/0/0/71	07/17/86-08/13/10	3239.0000 - 5038.0000	4108.0000
			ALUV89R	4/0/0/67	01/13/00-04/15/05	3020.0000 - 3120.0000	3075.0000
			WEPO178	1/0/0/22	07/21/97-07/21/97	3170.0000 - 3170.0000	3170.0000
			WEPO46	7/0/0/29	10/17/88-06/03/09	3130.0000 - 4290.0000	3457.0000
Vanadium, Dissolved	0.0000 - 100.0000	2	WEPO40	0/0/1/37	04/23/86-04/23/86(<)	500.0000 - 500.0000	500.0000
			WEPO55	0/0/1/27	04/16/86-04/16/86(<)	500.0000 - 500.0000	500.0000
Zinc, Dissolved	0.0000 - 25.0000	4	ALUV19	0/0/1/61	01/12/00-01/12/00(<)	50.0000 - 50.0000	50.0000
			ALUV199	0/0/1/45	01/12/00-01/12/00(<)	50.0000 - 50.0000	50.0000
			ALUV83	0/0/1/70	01/14/00-01/14/00(<)	50.0000 - 50.0000	50.0000
			ALUV89R	0/0/1/67	01/13/00-01/13/00(<)	50.0000 - 50.0000	50.0000

Frequency = uncensored/between MDL&PQL/censored/no. samples, (B) = Between MDL&PQL range, (<) = Censored range affected as relatively few of the twelve Wepo wells exhibit unsuitable livestock water use potential. Also, those portions of the alluvial aquifer potentially affected by pit interception of the Wepo aquifer do not appear to be significantly affected because 4 of the 18 alluvial wells have typically had unsuitable livestock water use potential owing to TDS, and eight of the 18 wells have exhibited high levels of sulfate historically.

In summary, increases in concentrations of Ca, Mg, Na, SO_4 and HCO_3 and TDS will occur regardless of the nature of the spoil material placed in the saturated zone. The potential for acid formation and acid and trace metal migration is minimal, because of the overall buffering capacity of the overburden material. There will be some amount of additional TDS increases as a result of the neutralization of acid forming material placed in the saturated zones. Acid formation will occur primarily in response to oxidation of sulfides in advance of the wetting front during spoil resaturation. Reduction of sulfates will primarily occur following resaturation. Based on climatic conditions and the transmissivities of the material, resaturation and reestablishment of premining ground water flow gradients could take 10 years or more. The magnitude of the impact to either aquifer should be limited to the immediate pit areas, because gradients and transmissivities are very low.

The overall significance of this impact is minor. There are no present water users of the Wepo aquifer within the leasehold. In fact, only two wells (4K-389 and 4T-405) in the region are reported to be completed only in the Wepo aquifer (see Chapter 17). An inspection of the lithologic log for one of the wells suggests that it is actually completed in the upper member of the Toreva (155 feet of sandstone at the bottom of the well). No log could be found for the other well. Local wells are not completed in the Wepo aquifer for two reasons; (1) the yields are too low, and (2) the quality of the water may be unsuitable for domestic or livestock purposes

<u>Interception of Wepo Recharge to the Alluvial Aquifer by Pits</u>. Based on Drawing No. 85610, Wepo Water Level Contour Map, ground-water flow is from the Wepo aquifer to the alluvial aquifer system. Pit interception of portions of the Wepo aquifer in the N10, N11, N11 Ext, N6, J16, J19/20 and J21 pits can potentially cause local decline in the alluvial aquifer system. Distance drawdown projections for the combined pit pumpage (Figure 1 and Table 8) suggest portions of the alluvial aquifer system (Reed Valley, Red Peak Valley, Upper Moenkopi and Dinnebito alluvial aquifers) could potentially be affected to the extent that drawdowns exceed natural water level fluctuations.

It is difficult to predict the magnitude of the drawdowns as the alluvial aquifers have a large range of transmissivities and storage coefficients. Comparing this situation to the N-7/8 pit pumpage effects on the Yellow Water Canyon alluvial aquifer (Alluvial Well 74 and 75), it is estimated that drawdowns in the alluvial aquifer near the N-14, J-16 and J-19/20 pit areas could range from 8 to 20 feet during the period of maximum combined pit interception (1980 to 1983). Also, drawing on what was experienced at the N-7/8 pit, the alluvial aquifer drawdowns should be quite localized and limited in extent (less than one mile downgradient). These impacts should be partially offset by recharge to the aquifers from water impounded in Reed Valley, N-14D, N-14E, N-14F and J-16A dams. The significance of this impact is minimal because of the limited portions of the alluvial aquifer system affected and the absence of local use of the alluvial aquifer. As with the Wepo aquifer, the alluvial aquifer is low yielding throughout most of the leasehold and the quality is not suitable for domestic purposes and is marginal to unsuitable for livestock use. Therefore, water from the alluvium does not support the pre- or post-mining land use nor does it support any critical habitats or plant species (see Chapters 9 and 10).

Interception of Channel Runoff Recharge to Alluvial Aquifers by Dams and Sediment Ponds. Dams, sediment ponds and internal permanent impoundments will intercept the runoff from about 29 and 12 percent, respectively, of the Moenkopi and Dinnebito watersheds to the down drainage lease boundaries. These structures will remove some potential channel bottom transmission loss recharge to the alluvial aquifers downstream from the structures. Downstream aquifer recharge impacts associated with the dams should be offset by the impounded water recharge to the alluvial aquifer. The alluvial aquifer water level monitoring program indicates that the impact of the structures on alluvial water levels is insignificant. There is no evidence suggesting gradual water level declines in the alluvial aquifer system over time (see Chapter 15).

Truncation of Portions of the Alluvial Aquifers by Dams. Eight large dams have been constructed such that the embankments cut through the entire thickness of alluvium to bedrock. The embankments are designed and constructed to be impervious. These structures impact the alluvial aquifer system by disrupting the ground-water flow. A review of the five-year alluvial ground-water level hydrographs (Chapter 15) indicates that these impacts are of no significance probably owing to the following reasons. All dams, with the exception of J-7 Dam are on small tributaries, which only contribute minimal amounts of water to the alluvial ground-water system. Seepage occurs around J-7 Dam along sandstone bedding planes. The Wepo aquifer discharges to the alluvial aquifer all along the channel reaches. Any localized ground-water flow disruptions would be offset within short distances below the dams.

Effects of Altered Wepo Aquifer Water Quality on Alluvial Aquifer Water Quality. The effects of higher TDS water from resaturated spoil in the Wepo aquifer recharging the alluvial aquifer are expected to be minimal. The pits will require anywhere from several years to 100 years to resaturate and reestablish ground-water flow gradients because of limited precipitation recharge and very low Wepo ground-water flow rates. These same low transmissivities will continue to limit the Wepo feed and contaminant transport into the alluvial aquifer. In contrast, responses to snowmelt and rainfall runoff recharge are rapid and greater than Wepo feed during three seasons of the year. The potential for rapid dilution of elevated TDS inputs from the Wepo would be quite high during these significant recharge periods.

The significance will be minimal because, the alluvial aquifer water within the leasehold is unsuitable for domestic purposes and marginal to unsuitable for livestock drinking water. Water from the alluvial aquifer is not essential to support the postmining land use or critical habitats or plant species.

Mining Interruption of Spring Flow. To date, eleven natural and one artificial spring of any significance (more than just a damp spot along the side of a channel) have been identified and monitored within and immediately adjacent to the leasehold. Of these, one spring (NSPG97) at the northwest edge of N-14 has been removed by mining activities (N-14 channel realignment). Reference to the statistical water quality summary for springs in Chapter 15, Hydrologic Description, indicates that the water quality of the spring was unsuitable for livestock use. Those parameters and parameter concentrations above the livestock drinking water limits are presented in Table 13. Peabody has provided two alternate water supplies for this spring: (1) water impounded in the N14-D dam; and (2) two public water outlets on the leasehold. The alternate water supplied is greater in quantity and better in quality than the spring water. The water supplied at the public water outlets meets domestic drinking water requirements.

Impact of Peabody Wellfield Pumpage on Regional Water Levels and Stream and Spring Flows. Peabody operates a wellfield consisting of eight wells completed in the D aquifer and N aquifer (Navajo Sandstone, Kayenta Sandstone, and Wingate Sandstone) that provided water for the coal slurry pipeline serving the Mohave Generating Station through the end of 2005, and for other continuing operational uses. Pumpage was initiated in 1969 and has averaged about 4,000 acre-feet per year (1969-2005).

The pumping of water from the N aquifer by Peabody since 1969 has produced one of the longest term pumping tests ever. Water-level changes have been measured in wells at

TABLE 13

Chemical Parameters and Concentrations at Spring 97

Which Exceed Livestock Drinking Water Limits

Parameter	Mean Concentration (mg/l)	Recommended Livestock Limits[1] (mg/l)
Lead	0.167	0.1
Sulfate	4077	3000
Total Dissolved Solids	6846[2]	6999

(1) Limits are based on Navajo Nation (2008), Hopi Tribe (2010), National Academy of Science (1974), and Botz and Pederson (1976).

(2) One of four TDS values was greater than 6999 mg/l.

considerable distances and in several directions from the PWCC wellfield. The rates of pumping at the well field have been measured throughout the period of pumping. The result is a data set which, if properly evaluated, provides considerable information about the aquifer, and about the response of the aquifer to pumping. These measurements also provide information with which to estimate the effects of future water use. It is important to use appropriate tools to interpret this information. The analytical models, such as the Theis, Cooper-Jacob, Hantush, or other solutions of the flow equations, while appropriate for short-term tests, are commonly not suitable for longer tests because many of their simplifications affect long-term results. Material properties can vary over reasonably short distances, and boundaries can affect aquifer responses to pumping. Therefore, numerical models are better tools with which to properly interpret these long-term pumping tests, and to predict the effects of future pumping. In short, monitoring the effects of past water use provides information with which to predict future effects. This approach was first applied in the Black Mesa area in 1985 and 1987 by the USGS, through the development of a ground water flow model of the N aquifer beneath and surrounding the Black Mesa basin, and use of the calibrated model to predict the effects of future pumping. In 1998, consultants for Peabody started development and calibration of a more realistic, three-dimensional model of the aquifer and incorporating more recently collected information; this improved model is used to predict the effects of N aquifer water use by Peabody.

The following analysis of the effects of Peabody's pumping of the N Aquifer is based on data measured before and during the period of pumping through 1996, and on models based on these data. It considers the effect of pumping on drawdown at existing locations of groundwater use, groundwater discharge at springs and to streams, the structural integrity of the N aquifer, and water quality of the N aquifer that might be affected by increased leakance of water through the overlying Carmel.

Numerical Modeling. Several numerical models have been developed to estimate the impacts of pumping by Peabody and the tribal communities on the N Aquifer, beginning in 1983 (Eychaner, 1983). Most recently, Peabody has developed a model that includes the overlying D Aquifer (PWCC, 1999). The D Aquifer is also used as a water resource, but to a much lesser extent than the N Aquifer; model simulation results indicate that over the calibration period, approximately 3% of Peabody pumping is from the D. These models are the best tools available for determining the individual contribution of each pumping stress on the observed or measured effects (i.e., water levels and stream flows). The models are not of sufficient resolution to simulate flow at individual springs, but can be used to make intelligent observations of regional spring flow. Each model includes:

- Development of a basic description of the real system, including geologic controls on material properties (i.e., geometry of the rock layers, deformation of the rocks, etc.), areas and amounts of recharge and discharge, and distribution of water levels.
- Formulation of a mathematical description of the system to be modeled. This formulation is based on

  - o Darcy's Law - a mathematical expression that relates the rate of groundwater flow to observable differences in water levels.
  - o Mass balance - a mathematical expression of conservation of mass. For a groundwater-flow system, this means that flow into the system (recharge) must equal flow out of the system (pumping or discharge to streams or springs) plus the change in the amount of water held or released from storage as water levels change.
  - o Boundary conditions - mathematical statements of various conditions that exist on the boundaries of the modeled system. These require knowledge of the geometry of the rock formations and the processes and locations through which water enters and exits the system.
  - o Initial conditions - description of the water levels everywhere in the system at the beginning of the modeled time period.

- Development of a set of numerical values for all parameters appearing in the mathematical formulation. These include hydraulic conductivity, specific storage, and specific yield, all of which may be spatially variable.

- Application of a numerical algorithm that "solves" the mathematical formulation for different applied stresses. The algorithm calculates the spatial and temporal distribution of water levels and groundwater flow rates that satisfy the mathematical model for different pumping rates, recharge rates, etc.

Each model is put through a calibration process whereby model parameters are adjusted by either manual or automated methods until simulated results reasonably match measurements. This usually means matching historic water-level measurements at wells against model output. The model parameters adjusted towards calibration are typically flow and storage properties of the geologic material. They are adjusted within ranges reported in the scientific literature for the specific rock type. Boundary conditions such as recharge may also be adjusted if calibration can not be achieved with the independently derived estimates. The geometry of the flow system is typically held fixed during this process. Calibration can be performed for non-pumping (steady state) and pumping (transient) conditions whereby a single set of flow properties is derived to match water levels model-calibration process. In previous models, the model parameters represented a lumped average for the properties of several different formations. The calibration period was extended from 1956 through 1996 and the number of wells providing information on changes in water levels caused by pumping increased from nine to 47. This work was based on a database that included and went beyond the one compiled by SSPA (1993), in part, by adding information for the Carmel Formation and the D Aquifer, and including eleven additional years of pumping stresses, water-level measurements, and spring and streamflow measurements.

When the 3D model was developed, it was calibrated to both non-pumping (pre-1956) and pumping (1956 through 1996) conditions. Temporal changes in measured water levels were compared with changes in the simulated water levels. The calibration process relied more on data from wells BM-1, -2, -3, -4, -5 and -6 than from other wells, because (1) these wells were specifically chosen for monitoring the effects of pumping at the Peabody leasehold, (2) the higher quality and greater quantity of data from the BM-series, and (3) detailed information on pumping of community wells was not available. The calibrated model provides good agreement with the measured changes in water levels for the BM-series wells.

An automated calibration process that used both pre-pumping and pumping datasets was used. This facilitated the development of multiple calibrated models, each one calibrated to different estimates of recharge or other model parameters. In 1997, Lopes and Hoffmann (1997) used geochemical data to estimate the recharge rate near Shonto. Their estimated rate was approximately one-half that proposed by Brown and Eychaner for this area. Using a larger geochemical data set and a numerical transport model, Zhu and others (1998) and Zhu (2000) showed that the geochemical data are consistent with the higher, earlier estimates of recharge rates based on hydrologic data. Still, uncertainty in recharge rates remains. To address this uncertainty, the model was calibrated twice, first using a recharge value similar to Brown and Eychaner's and again, using a value similar to Lopes and Hoffmann's. In addition, two different approaches (full ET and low ET) to simulating discharge in non-wash settings were used, resulting in four calibrated models. These are termed FR/FET (full recharge and full ET), HR/FET (half recharge and full ET), FR/LET (full recharge and low ET), and HR/LET (half recharge, low ET). The use of different recharge estimates and different non-wash discharge approaches in the four calibrated models explicitly answers questions about the sensitivity of the models' predictions to uncertainty in these items.

These four models were used to estimate impacts of Peabody and tribal pumping on the D and N Aquifers. Unless otherwise indicated, the term "base-case model" refers to Peabody's FR/FET 3D model of the D and N aquifers using a recharge rate similar to that used by Eychaner (1983) and Brown and Eychaner (1988), and using MODFLOW's ET package to simulate discharge in the non-wash settings.

The 3D model was developed to improve the confidence in predictions of future effects of Peabody's pumping. The fact that the new model matched water-level information better than older models, while reassuring, does not necessarily mean that the predictions will be accurate. Earlier models produced reasonably good agreement with water-level change information available at the time of their calibration, but the agreement of measured and simulated water-level changes degraded with increasing time.

Calibration of the 3D model benefited from the collection of approximately eleven additional years of data since development of the earlier 2D models. These data provided additional indirect information about the groundwater system through a model-development process. Groundwater models are widely acknowledged to be "non-unique". Different models (boundary conditions, geometries, material properties, solution techniques) can produce equally good agreement with available information. However, they <u>may</u> yield different results when used to make predictions. Thus, an important aspect of using models to guide resource management decisions is to evaluate whether the model results agree with data not used to calibrate the model, such as newly collected water-level data. If the agreement is good, confidence in the model's predictive ability is increased. However, if the agreement is poor, the need for additional calibration work is indicated.

The accuracy of the 3D model to simulate water-level changes beyond the calibration period was tested using pumping and water level data through 2010, which includes the period beginning in January 2006 when Peabody pumping was considerably less than in previous periods. This checking of the model's predictive ability is called a model-validation test, or alternatively, a post audit, of the model. Water-level data from the BM-series wells and annual community pumping data were obtained from the U.S. Geological Survey through the end of 2010. Monthly pumpage data from each of the PWCC production wells were used in the simulations.

Simulations were performed using the four different models described in Peabody (1999). These four models, each individually calibrated, use a combination of two different recharge rates and two different upland (non-stream) discharge values simulated using different maximum ET rates. For the model validation tests, only the pumping rates for the period 1997 through 2010 were updated from the 1999 report; no other changes were made to the modeling data sets.

In the following temporal drawdown figures, the drawdown is calculated based on the time of the first available measurement in the indicated well. Errors in the first measurement would affect the calculation of the measured drawdown values. The effects of errors may be greatest at BM3, which displays considerable variation in water level because of local pumping.

Figures 4 through 9 provide comparisons of measured and simulated drawdown for the four models for the BM-series wells through 2010. At BM1, the agreements of the two models using the full recharge values are better than for the two models using half the full recharge values; the base case provides the best fit to the data. There is a measured long-term slow trend of declining water levels, with less than 1 foot of decline over more than 30 years. All four of the models simulated more drawdown for the calibration period than was observed. Thus, it is not a surprise that they continue to simulate more drawdown than has occurred.

At BM2, the simulated drawdowns for the four models approximate the same total drawdown as observed over the calibration period, although the simulated drawdowns occurred earlier than the measured values. The agreement between measured and simulated drawdown appears to have improved after about 1992, and all four models do a reasonably good job of approximating measured drawdown through the end of the calibration period. The base case and low upland discharge models provide the best fit to measured data. In recent years, measured drawdown has been occurring more rapidly than predicted drawdown. The simulations show a small response to the reduction in pumping by Peabody in 2006. The measured values show that the rate of drawdown has decreased but that water levels may have only recently started to rise.

Comparison of simulated and measured values is more difficult at BM3 because of the impacts of variable, local pumping and the resultant high variability of water levels in the well. The four models track the measured changes approximately equally well. The low upland discharge model provides better simulation results to an increase in drawdown between approximately 1977 and 1984 than the other three models. Although variability in

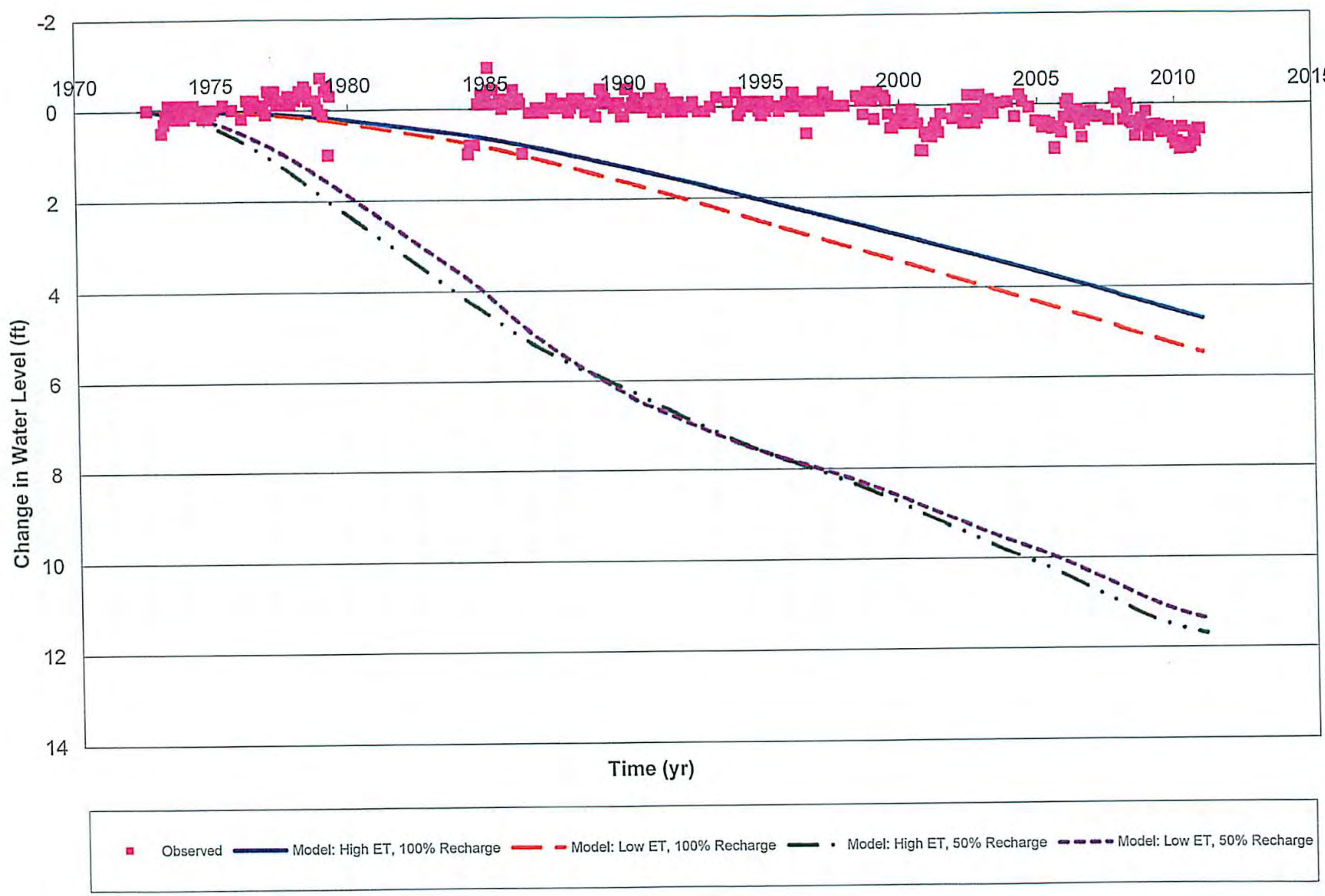

Figure 4. Simulated and Measured Drawdown at BM-1

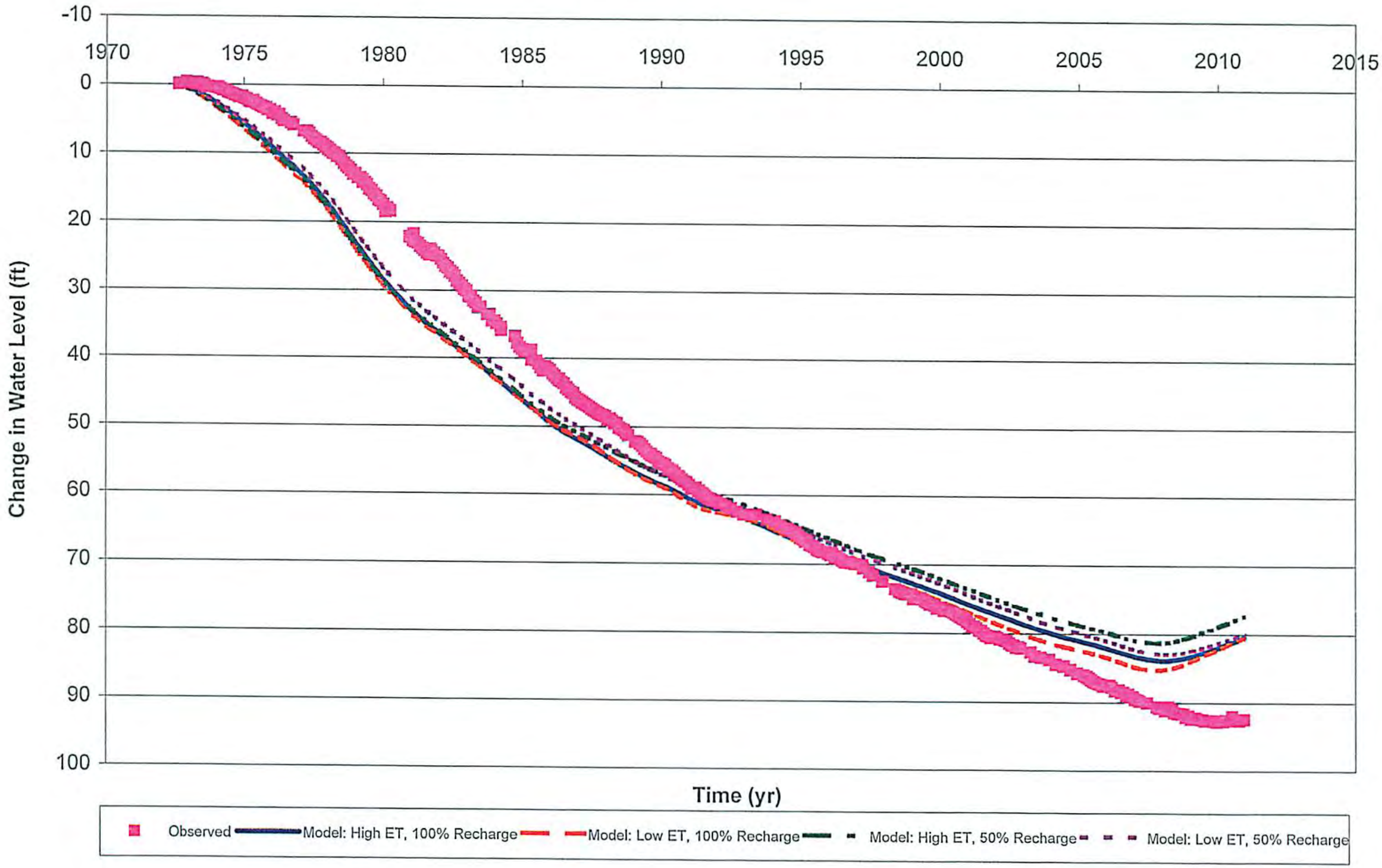

Figure 5. Simulated and Measured Drawdown at BM-2

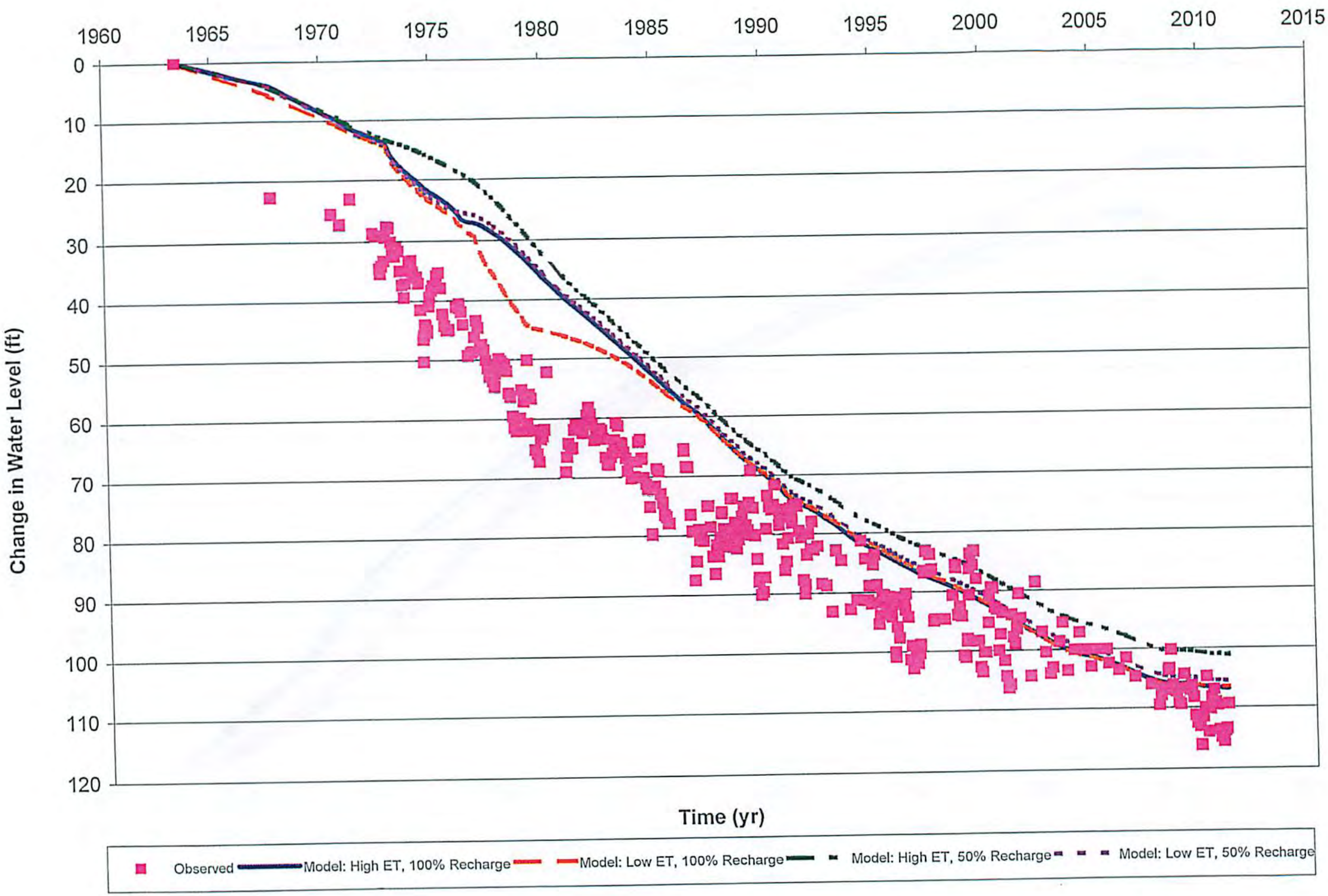

Figure 6. Simulated and Measured Drawdown at BM-3

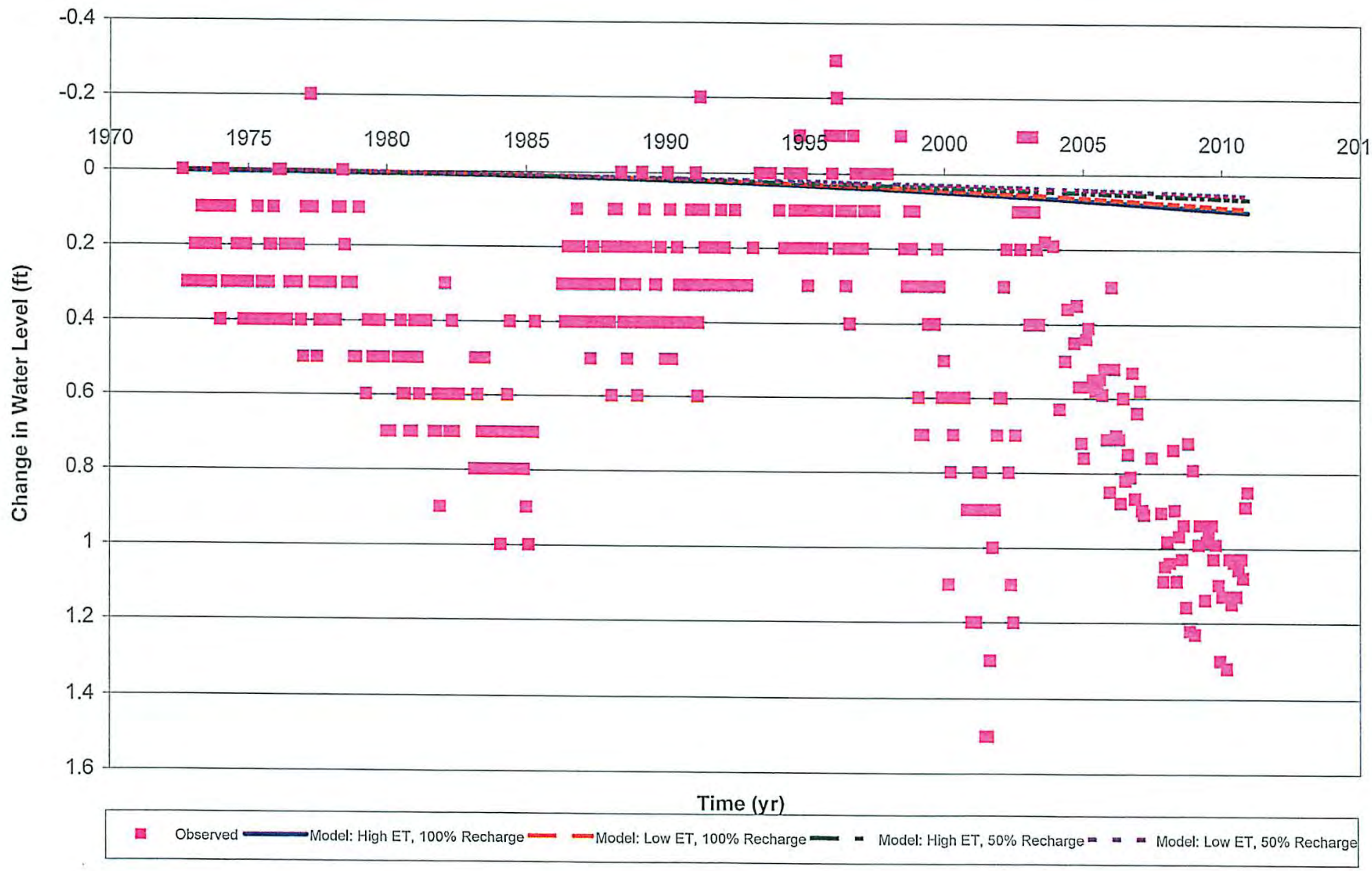

Figure 7. Simulated and Measured Drawdown at BM-4

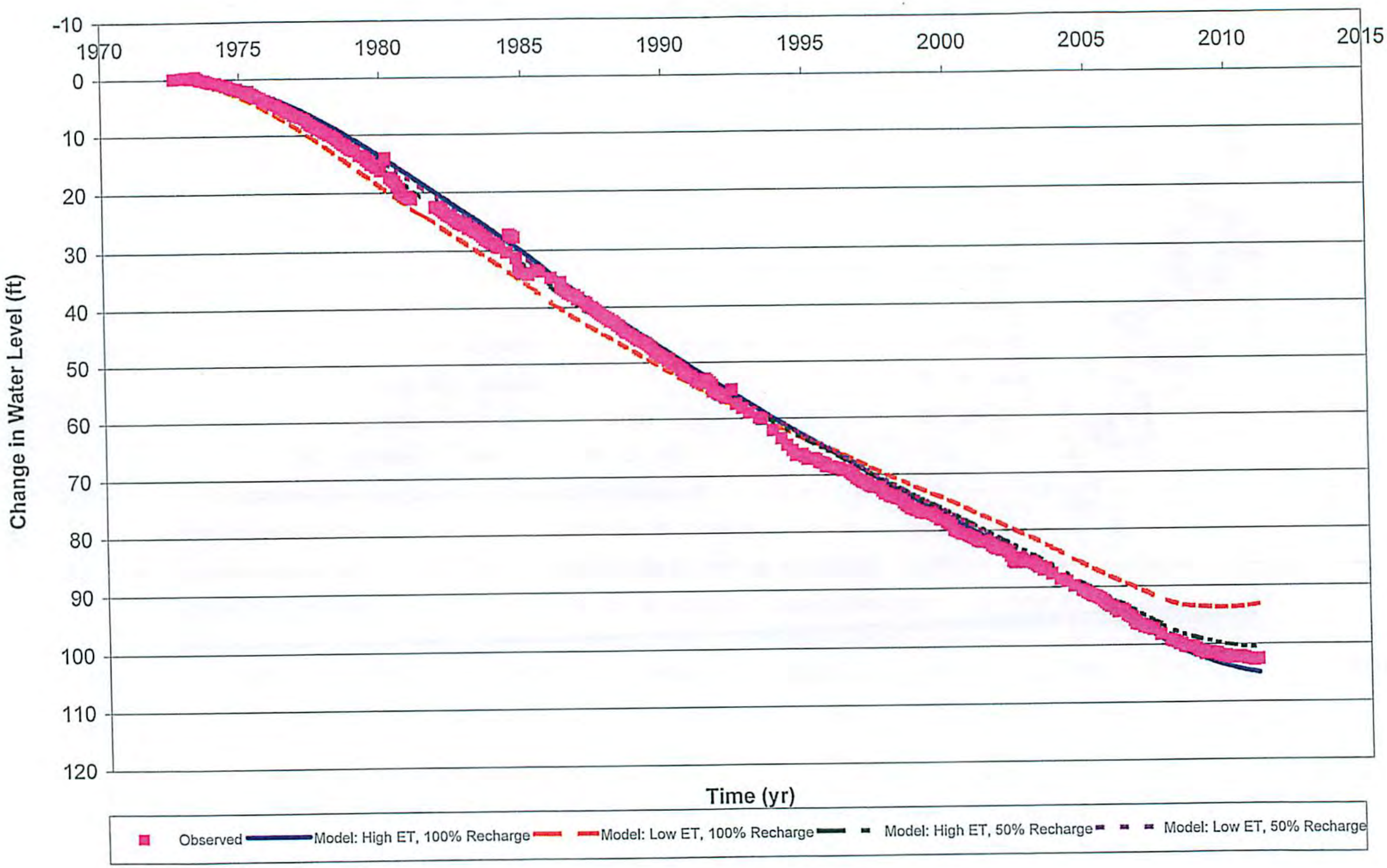

Figure 8. Simulated and Measured Drawdown at BM-5

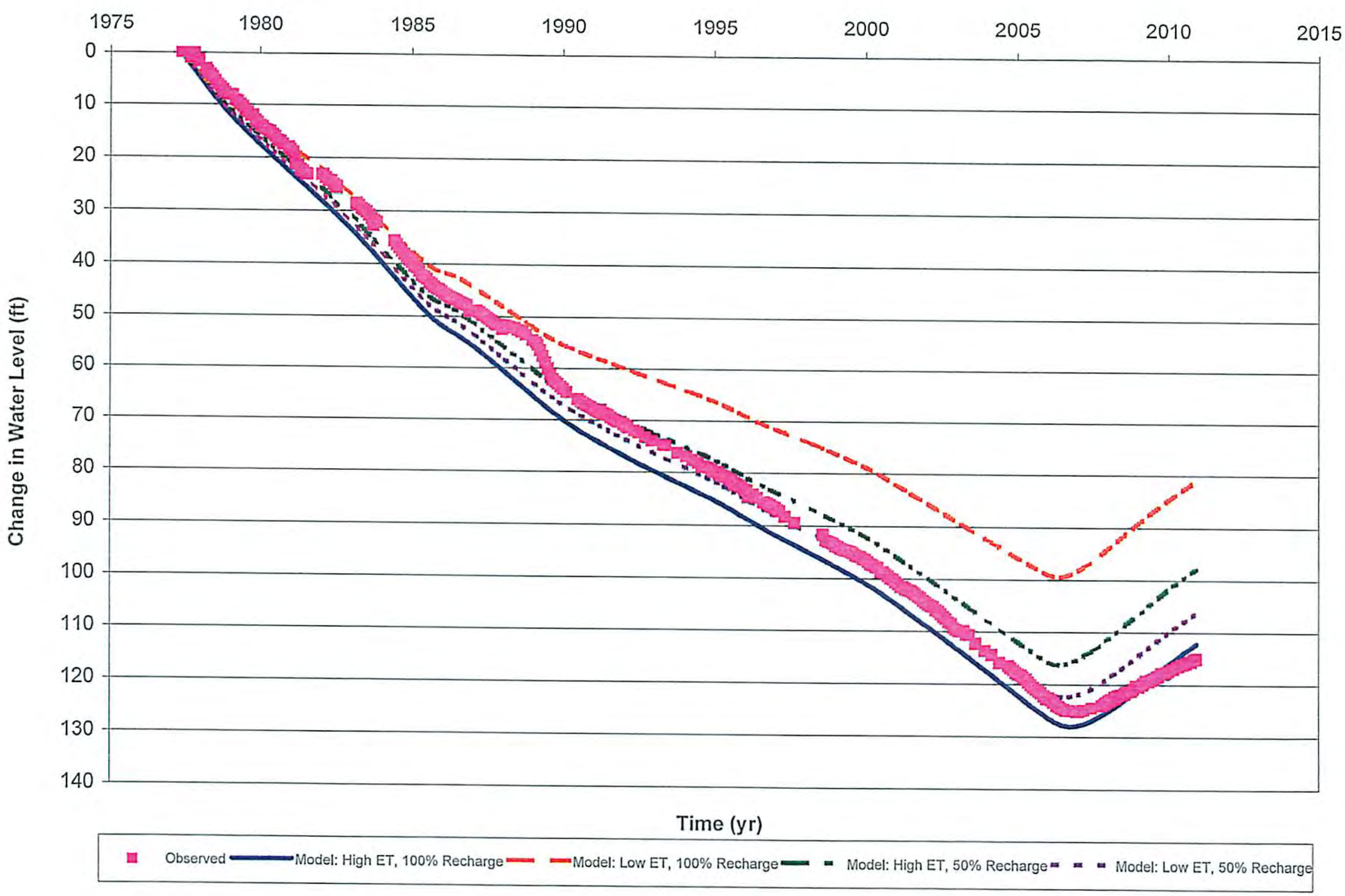

Figure 9. Simulated and Measured Drawdown at BM-6

the measured values makes comparison with the simulated values uncertain, the models simulate a slighter greater rate of drawdown than the measured from end of calibration through 2010. Effects of reduced pumpage by Peabody are not apparent in the data. The simulations show a decrease in the rate of drawdown but do not yet show recovery.

Little change has occurred in water-level measurements in BM4. A decline in water levels of approximately 1 ft occurred between 1998 and the beginning of 2003, but levels increased back to pre-1998 levels, and then began to decline again. As with BM1, the cause for the short-term decrease is not known. The models are beginning to simulate a small (<0.1 ft) amount of drawdown at this well.

The most recent 14 years of data (since the end of the calibration dataset) at BM5 are tracked very well by the four models, although the agreement of the full recharge/low ET model is not quite as good as the other three. The rate of drawdown at the well has decreased since PWCC pumping decreased at the end of 2005. The models are matching this change well, although the full recharge/low ET is showing the beginning of recovery.

At BM6, the full recharge/low ET model simulates about 20% less total drawdown than that measured over the calibration period, and less than the other three models. The rates of change calculated by the other three models agree quite well with the measured rate of change, although the base-case (full recharge/ET) and the half-recharge, low upland discharge models provide the best overall fit to the calibration data. The reduction in Peabody's pumping at the beginning of 2006 is apparent in the data and the simulation results, with the models having a slightly earlier and slightly faster recovery than the measurements. From the end of calibration through 2010, the base-case and half-recharge, low upland ET models continue to provide the best fits to measured drawdown. The agreement between measured drawdown and the predicted drawdowns calculated from these two models over this time period indicates that the two models should reliably predict drawdown for many years.

The four models match the observed water-level changes at the six BM monitoring wells quite well. The base-case model provides the best overall fit. The comparisons indicate that recalibration is not warranted at this time, and support the ability of the models to accurately predict the effects of pumping by Peabody within the groundwater basin. As with all models used to guide decisions, the models should be periodically evaluated as more data are collected, and updates made when appropriate. Near Kayenta, where pumping is more likely to affect stream flows, the models are conservative, in that they predict a faster rate of drawdown than is occurring.

The base-case model is used in the predictive simulations presented below. Previous testing of the four models used a pumping period similar to that evaluated in this PHC (Scenario A, PWCC, 1999), and indicated that all four models produce similar results. The predicted drawdowns are similar (because each model is calibrated to the same water-level and drawdown data), though not identical. Similarly, the predicted impacts on the discharge to streams are also quite similar. Obviously, for the half-recharge cases, the simulated discharge into the streams is less than for the full-recharge cases, and therefore the effects of pumping on stream discharge, expressed on a percentage basis, are slightly higher for the half-recharge cases. Because the effects of PWCC pumping on stream discharge are predicted to be low in Scenario A for all four cases, and because the pumping plan evaluated in the PHC envisions a decrease in pumping rates and a similar length of time of pumping, only the base-case model is evaluated below.

The effects of Peabody's withdrawals from the D and N aquifers have been simulated using conservative estimates of the annual pumping rate under the proposed mining scenario (Table 14). While PWCC has not and does not relinquish or restrict any right it has or may have to continue to utilize water from the N aquifer in accordance with the terms of its tribal lease agreements, the currently proposed mining plan does not include mining to supply coal to the power plant at Laughlin, NV, and therefore pumping at rates sufficient to provide water for the coal slurry pipeline is not considered in the computer simulations. Actual PWCC and community pumping data through 2010 were used.

Beginning in 2011 and continuing through 2041, the N-Aquifer wellfield is assumed to supply the needs of the Kayenta Mine (928 af/y). In addition, 247 af/y is pumped for maintenance of the Black Mesa wells not currently in operational use, and 61 af/y is pumped and provided to the public, for a total of 1,236 af/y. For the period from 2042 through 2044, the N-aquifer wellfield is assumed to supply 430 af/y for Kayenta Mine reclamation activities. The public supply pumping is assumed to increase to a rate of 75 af/y, for a total of 505 af/y. The Black Mesa wells continue to supply 247 af/y of the 505 af/y. For the remainder of the simulation (2045 through 2057), the combined pumping from wells in both mining areas is 444 af/y, including maintenance and public supply pumping.

Community pumping in the future is assumed to increase at a rate of 2.7% per year, as described in Chapter 6 of the 3D modeling report (PWCC, 1999), and shown in Attachment 3.

Table 14

Simulated Pumping Rates from the N Aquifer

Period	Simulated Pumping Rates
1956-2010	Actual
2011-2041	1236 af/y (928 Kayenta Mine, 247 well maintenance, 61 public supply)
2042-2044	505 af/y (430 Kayenta reclamation [247 well maintenance, 183 Kayenta mine], 75 public supply)
2045-2057	444 af/y (444 well maintenance, public water derived from the maintenance pumping)

Impacts of Drawdown at Community Pumping Centers. Pumping of water from the D and N aquifers causes lowering of water levels or confined pressures within the aquifer. Drawdown is necessary in order for water to be withdrawn from the aquifer by wells and occurs due to pumping at the Peabody well field, as well as at the communities. However, excessive drawdown may cause wells to become unusable (e.g., if the water level during pumping of the well is lowered to the pump intake, and the pump cannot be lowered). Drawdown also increases pumping costs. The USGS has been monitoring water levels in communities throughout the basin for several years, and has estimated the drawdown caused by pumping of water from the N aquifer.

Figure 10 shows the simulated drawdown through 2005 for the top part of the N aquifer, using the base-case 3D model, for both combined Peabody and Tribal pumping (Figure 10A) and for Peabody pumping only (Figure 10B). Drawdown resulting from Peabody's pumping is greatest beneath the leasehold, and is very small within the unconfined area. The transition from confined to unconfined conditions greatly limits drawdown because of the much greater storage coefficient under unconfined conditions. Drawdown caused by pumping at the communities is also apparent. Community drawdown is most obvious at Shonto and Tuba City, because drawdown due to Peabody pumping is essentially non-existent there. However, it also has occurred at other communities, for example, Polacca, Kykotsmovi, and Kayenta. This is evident when comparing the drawdowns presented in figures A and B. The model-estimated drawdown caused by pumping at the end of 2005 is presented in Table 15a. These wells were chosen because of their use by the USGS in the annual monitoring reports. The percentage of drawdown attributable to Peabody pumping was calculated from the base-case 3D modeling results, based on pumping simulations with and without Peabody pumping. Data on the depth of the N aquifer or uppermost open interval were obtained from USGS monitoring reports. The drawdown estimated from the combined community and Peabody pumping is added to the initial depth to water to estimate the pumping water level near the well. The pumping water level is compared with the depth of the N aquifer or the top of the well's open interval to determine the remaining column of water above the N aquifer or production interval. This thickness represents the additional drawdown available before the water level would be lowered to the top of the N aquifer or the top of the production interval in the well.

The greatest effects on water levels in 2005 are for Forest Lake, Chilchinbito, Rocky Ridge and Pinon, where the estimated drawdowns attributable to Peabody range from 68 to 198 feet. Elsewhere, the drawdown resulting from Peabody pumping is 35 feet or less. At all locations except Rough Rock, more than 439 feet of water remains above the top of the aquifer at of the end of 2005, based on simulations including both Peabody and community

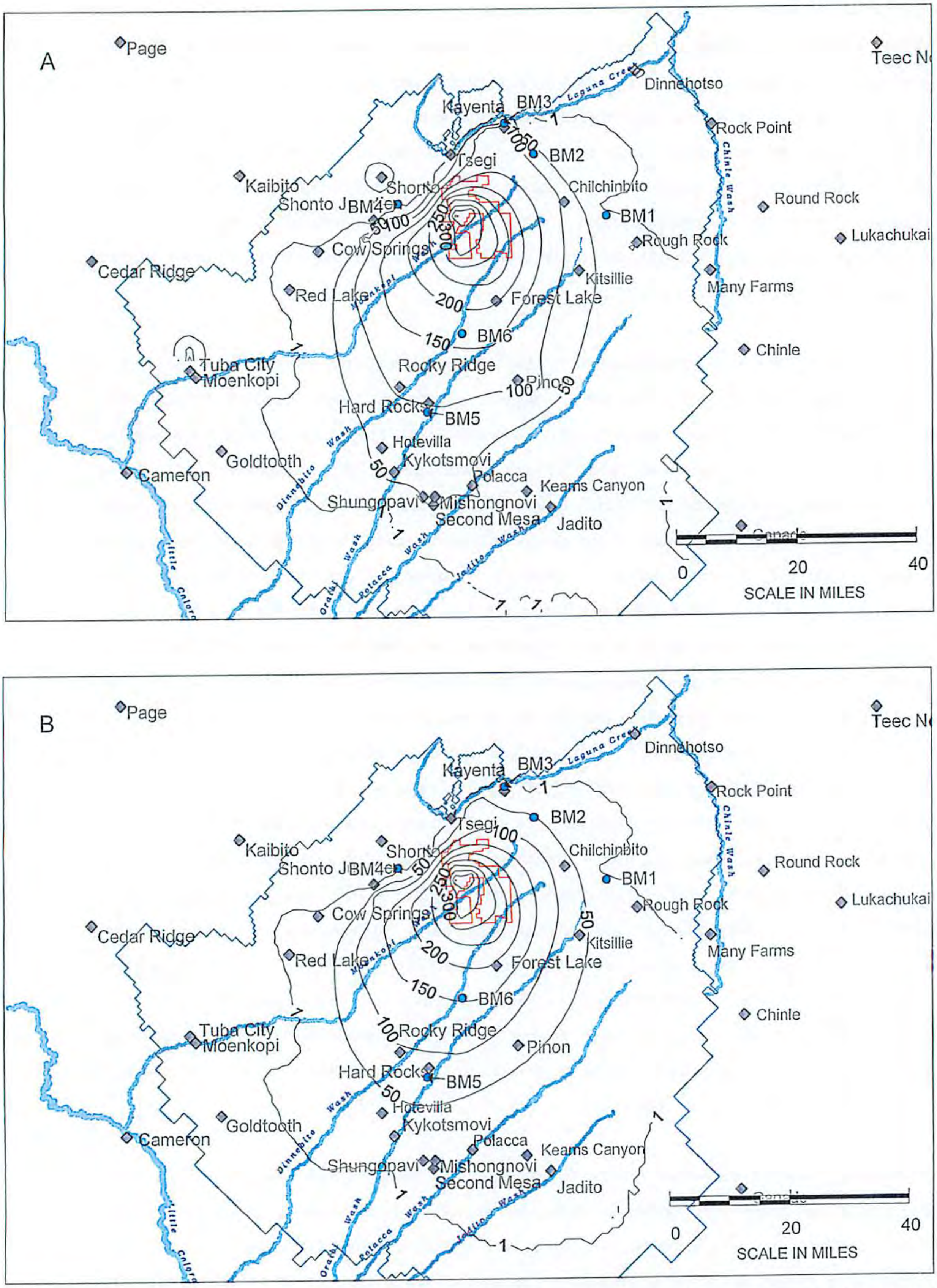

Figure 10. Simulated drawdown in the N Aquifer in 2005. A: Peabody and community pumping. B: Peabody pumping only. The contour interval is 50 feet, with a supplemental contour for 1 foot.

Table 15
Simulated Water Levels and Changes at Selected Community Wells Caused by Combined Pumping and by Peabody's Pumping

a. 2005

Community	Well	Initial DTW (ft)	Simulated Drawdown (ft)	PWCC Allocation (%)	PWCC Allocation (ft)	Depth to N or Top of Open Interval	Remaining Excess Water Column (ft)
Chilchinbeto	PM3	405.0	94	73%	68	1136	663
Forest Lake NTUA 1	4T-523	1096.0	217	92%	198	1870	576
Kayenta West	8T-541	227.0	125	27%	34	700	439
Keams Canyon	PM2	292.5	35	24%	8	900	599
Kykotsmovi	PM1	220.0	88	26%	23	880	637
Pinon	PM6	743.6	126	57%	72	1870	1054
Rocky Ridge	PM2	432.0	110	85%	93	1442	917
Rough Rock	10R-111	170.0	4	47%	2	210	38

b. 2005 and 2041

Community	Well	Water Level, 2005		Water Level, 2041		Changes		
		All but PWCC	All	All but PWCC	All	All but PWCC	All	PWCC
Chilchinbeto	PM3	1685.82	1665.01	1674.97	1667.33	-10.85	2.32	13.17
Forest Lake NTUA 1	4T-523	1727.96	1667.46	1717.88	1692.13	-10.08	24.67	34.76
Kayenta West	8T-541	1675.03	1664.23	1644.59	1638.26	-30.44	-25.97	4.48
Keams Canyon	PM2	1764.43	1761.85	1755.01	1752.11	-9.42	-9.73	-0.32
Kykotsmovi	PM1	1668.43	1661.40	1631.37	1623.98	-37.06	-37.42	-0.36
Pinon	PM6	1739.82	1717.84	1717.07	1702.38	-22.75	-15.46	7.29
Rocky Ridge	PM2	1709.91	1681.49	1699.76	1681.65	-10.15	0.16	10.31
Rough Rock	10R-111	1743.28	1742.76	1742.14	1741.56	-1.14	-1.21	-0.07

c. 2005 and 2057

Community	Well	Water Level, 2005		Water Level, 2057		Changes		
		All but PWCC	All	All but PWCC	All	All but PWCC	All	PWCC
Chilchinbeto	PM3	1685.82	1665.01	1665.95	1658.23	-19.87	-6.78	13.09
Forest Lake NTUA 1	4T-523	1727.96	1667.46	1710.48	1690.97	-17.47	23.51	40.99
Kayenta West	8T-541	1675.03	1664.23	1628.27	1623.59	-46.76	-40.64	6.12
Keams Canyon	PM2	1764.43	1761.85	1744.15	1741.74	-20.28	-20.11	0.17
Kykotsmovi	PM1	1668.43	1661.40	1603.45	1597.62	-64.98	-63.78	1.21
Pinon	PM6	1739.82	1717.84	1695.88	1684.08	-43.94	-33.77	10.17
Rocky Ridge	PM2	1709.91	1681.49	1692.02	1677.61	-17.89	-3.88	14.02
Rough Rock	10R-111	1743.28	1742.76	1741.28	1740.73	-1.99	-2.03	-0.03

All water level elevations and changes in ft pumping. Pumping of the well itself will cause additional drawdown. Information on this local drawdown is not available, and it is likely less than a few hundred feet. Thus these calculations indicate that the combined pumping will not cause sufficient drawdown to reduce the production of the aquifer by dewatering. For Rough Rock (well 10R-111), the water column above the top of the aquifer was only 40 feet thick before any pumping, and Peabody's pumping reduces it by approximately 2 feet. It is likely that the pump is already set below the top of the N aquifer, similar to wells in the unconfined area.

Figure 11 portrays the predicted drawdown in the N Aquifer at the end of 2041, due to combined Peabody and community pumping (Figure 11a), and Peabody pumping (Figure 11b). The drawdown beneath the leasehold has decreased, while that near the communities has typically increased. Figure 12 shows the change in simulated water drawdown between 2005 and 2041 for all pumping (Figure 12a) and Peabody pumping (Figure 12b). The recovery caused by the reduction in pumping is predicted to be greater than 250 feet beneath parts of the Peabody leasehold. Drawdown due to pumping near the communities will increase, and by more than 50 feet in some areas. For example, at Kykotsmovi, the drawdown is predicted to increase by greater than 50 feet between 2005 and 2041. Near Second Mesa, the increase is predicted to be similar.

Table 15b presents information on the predicted water levels at the end of 2005 and 2041, and the predicted change between these years. With reduction in the amount of water pumped at the leasehold, there will be reductions in the drawdown attributable to Peabody at the communities that are located closest to the leasehold (Chilchinbito, Forest Lake, Kayenta, Pinon, and Rocky Ridge), and increases in water levels at some communities as a result. Near the southern Hopi villages (for example, Keams Canyon and Kykotsmovi), Peabody's past pumping will result in small declines in levels compared to those in 2005. In all cases, the drawdown in community wells attributable to community pumping is predicted to increase between 2005 and 2041; water levels in Chilchinbito, Forest Lake, and perhaps Rocky Ridge are predicted to rise because of their close location to the leasehold and the greater relative impact of decreased Peabody pumping. Drawdown caused by pumping in the indicated community wells will be greater than simulated, and will further reduce the water column thickness in the wells where the local pumping is occurring. For nearly all of these wells, the remaining water column is hundreds of feet thick, indicating that the N aquifer will be able to continue to supply water at previous rates. The sole exception is possibly well 10R-111 near Rough Rock. As previously discussed, this well only had a water column of 40 feet above the top of the aquifer before pumping. Peabody's predicted reduction is approximately 0 feet, but local pumping from the well would be expected to have a greater impact. If the local drawdown due to pumping from 10R-111 is more than 38 feet, dewatering of the aquifer in the vicinity of

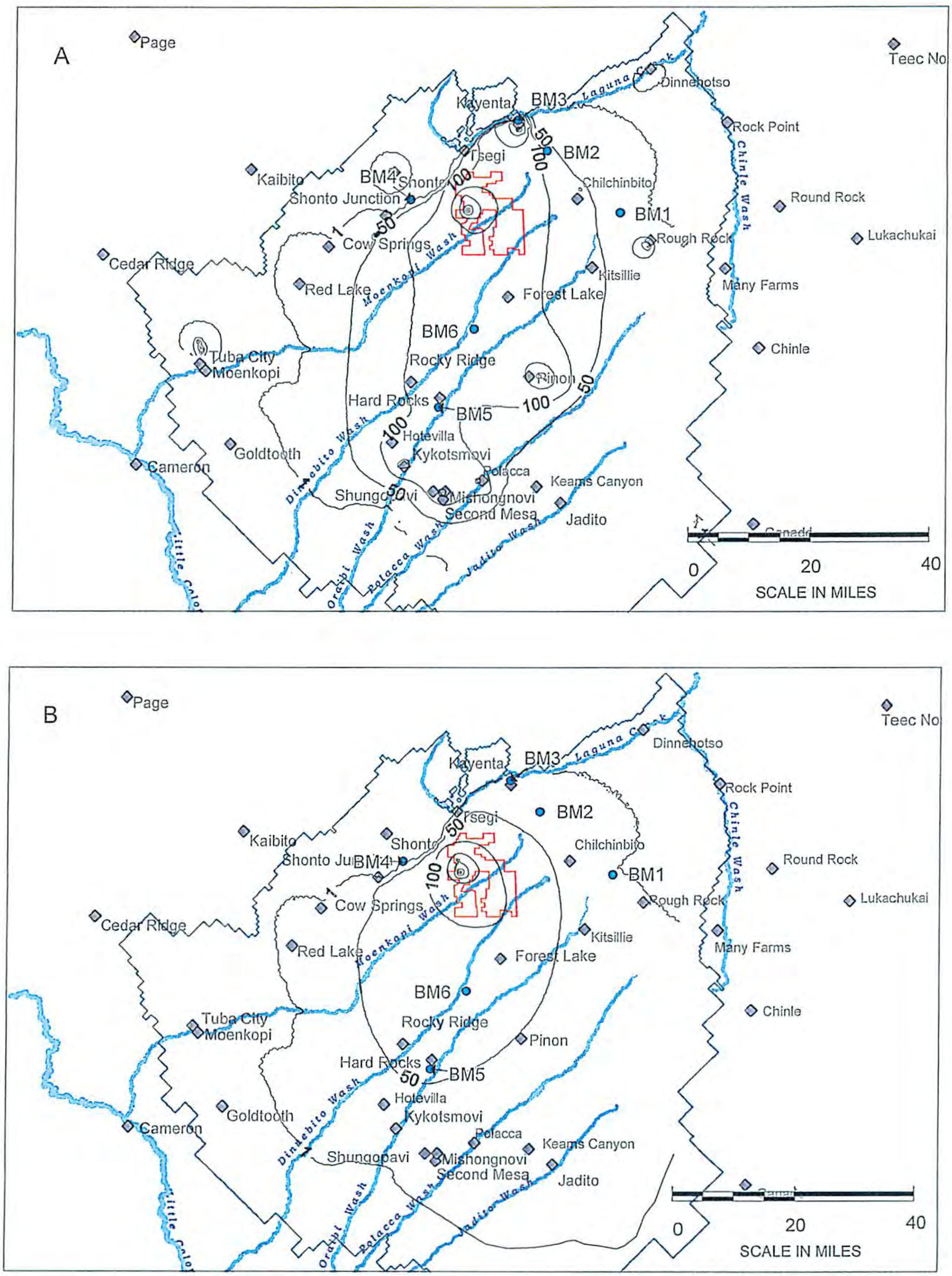

Figure 11. Simulated drawdown in the N Aquifer in 2041. A: Peabody and community pumping. B: Peabody pumping only. The contour interval is 50 feet, with a supplemental contour for 1 foot.

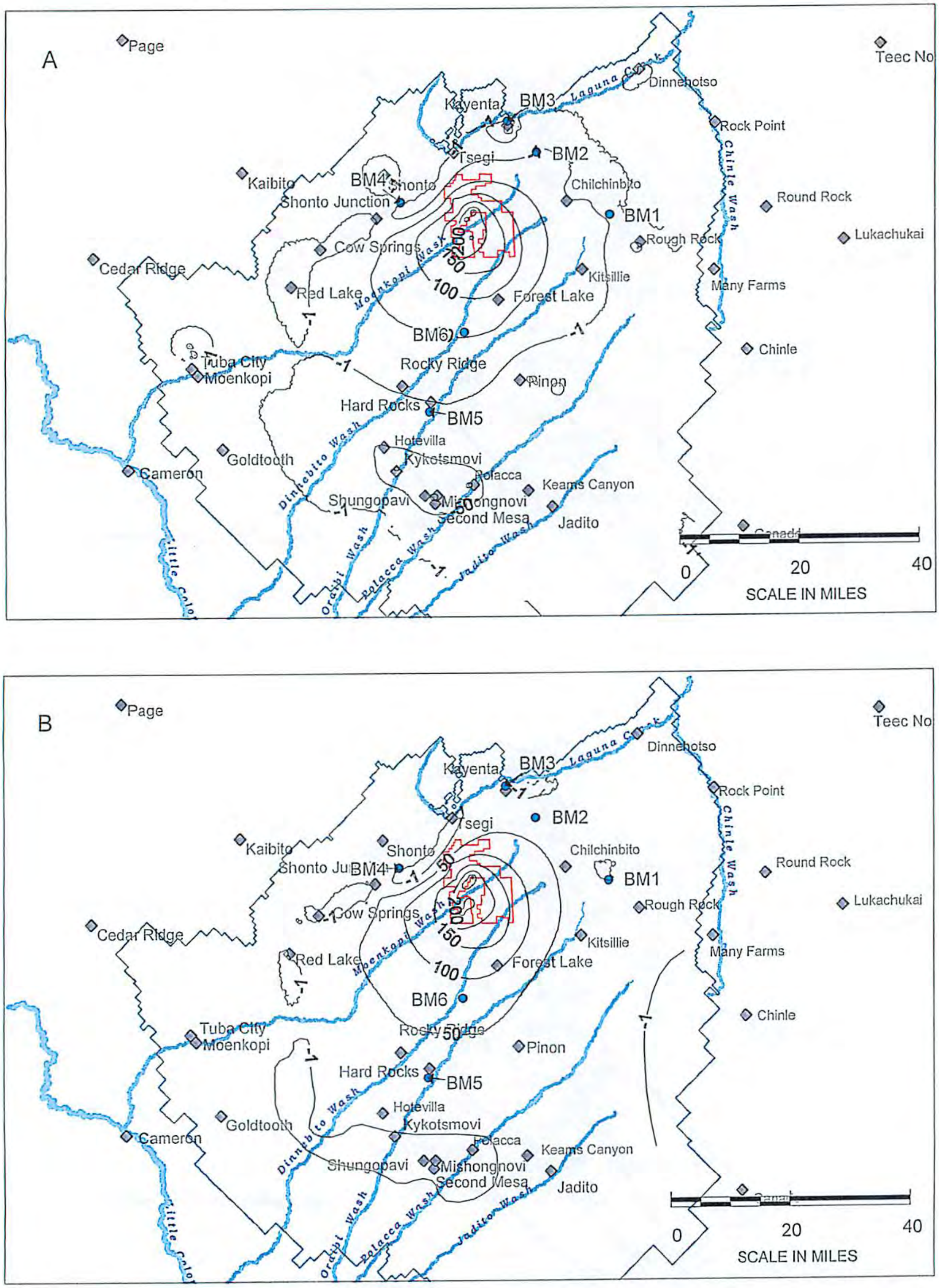

Figure 12. Simulated changes in water levels in the N Aquifer in 2041, relative to 2005. A: Peabody and community pumping. B: Peabody pumping only. The contour interval is 50 feet, with a supplemental contour for -1 foot. Positive values indicate recovery of water levels since 2005.

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the well may occur. Here, the N aquifer is approximately 600 ft thick, so that local dewatering, if it occurs, will have only a minor impact on aquifer productivity.

Under the proposed mining plan, pumping from the N aquifer beneath the leasehold would be reduced from 1,236 af/y in 2041 to 505 af/y in 2042, and to 444 af/y in 2045. Because these latter two rates are approximately the same, simulation results are presented only for 2057, after which Peabody pumping would cease. The simulated drawdowns at the end of 2057 are presented in Figure 13a (all pumping) and 13b (only Peabody pumping). Recovery continues beneath the leasehold, and the maximum drawdown beneath the leasehold resulting from Peabody's pumping is predicted to be approximately 100 ft. The increasing drawdown around the communities is more apparent in Figure 13a than in 11a. Simulated changes in water levels since 2005 are shown in Figure 14a (all pumping) and 14b (Peabody pumping). Beneath part of the leasehold, water levels are predicted to rise more than 300 feet as a result of the reduction in pumping beneath the leasehold. Near the communities, drawdown is predicted to increase.

Table 15c provides predicted water levels at communities for 2057. A notable change has occurred from the 2041 simulation results. At Keams Canyon and Kykotsmovi, the drawdown caused by Peabody's pumping is starting to decrease. The greater distance from the leasehold to these communities compared with Forest Lake, Rocky Ridge, and Pinon causes a delay in the response in water levels to changes at the leasehold. Thus, with the simulated reduction in pumping beginning in 2006, drawdown is predicted to continue to occur at the distant communities until after 2041, even though recovery begins sooner closer to the leasehold. By 2057, recovery from the effects of PWCC's pumping is occurring at all the communities evaluated.

The next set of figures (15-19) show the simulated drawdowns for layer 3, which represents the lower part of the D aquifer. The contour interval for these figures is 10 feet, with a supplemental contour of 1 foot. In 2005, there are two areas in which the model simulates drawdown in the D aquifer (Figure 15). Beneath the leasehold, a maximum drawdown of approximately 100 feet is simulated, as a result of several of the production wells being completed in both the D and N aquifers. The extent of the drawdown cone for the D is considerably less than for the N aquifer. The second area of simulated drawdown for the D aquifer is near Polacca. Between 2005 and 2041, D-aquifer water levels beneath the leasehold are predicted to recover up to 50 feet (Figures 16 and 17). Drawdown is projected to increase near Polacca. By 2057, drawdown in the D aquifer beneath the leasehold is predicted to generally be less than 20 ft (Figure 18), a recovery of approximately 121 feet since 2005 (Figure 19). Although there may be

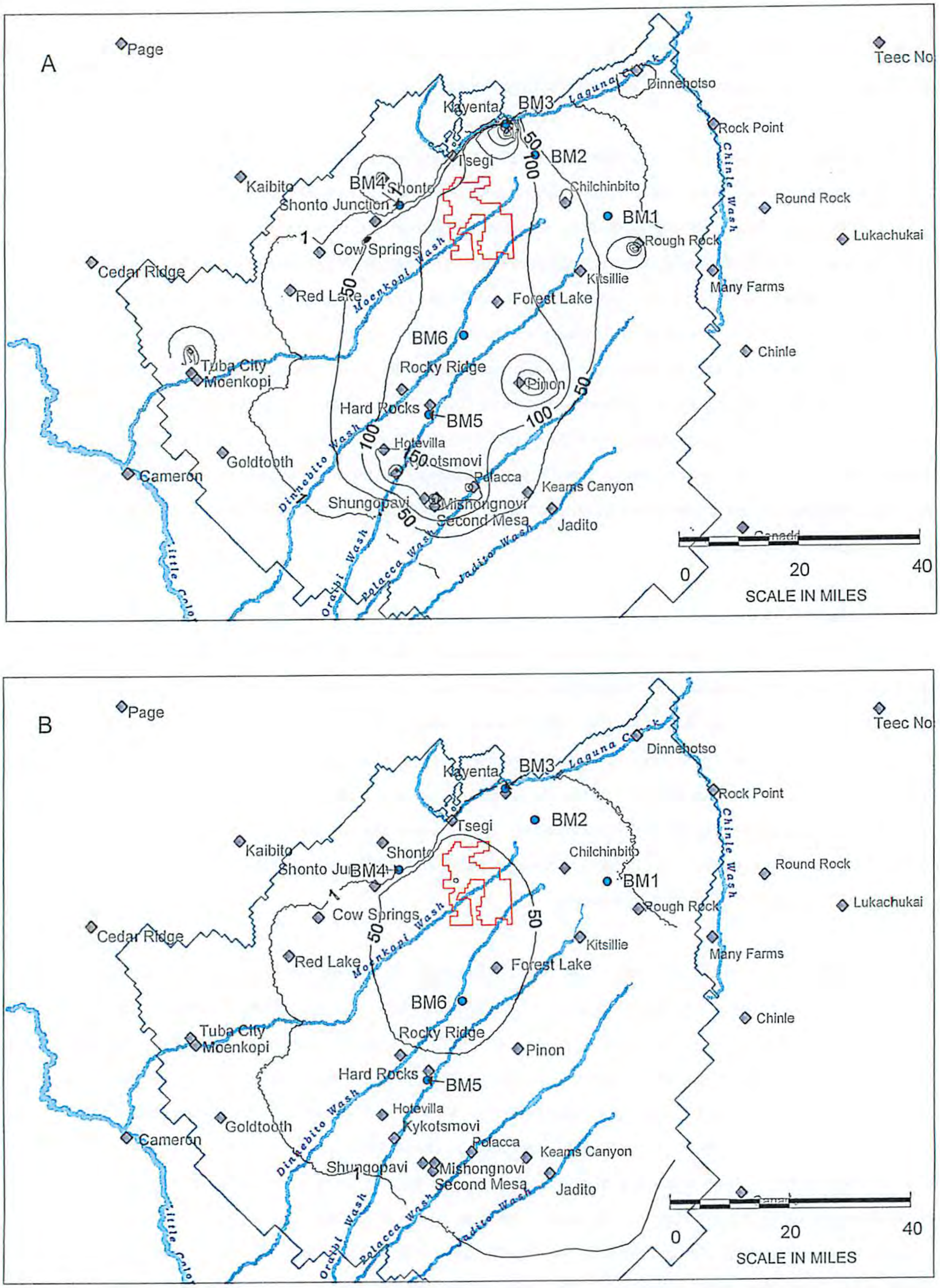


Figure 13. Simulated drawdown in the N Aquifer in 2057. A: Peabody and community pumping. B: Peabody pumping only. The contour interval is 50 feet, with a supplemental contour for 1 foot.

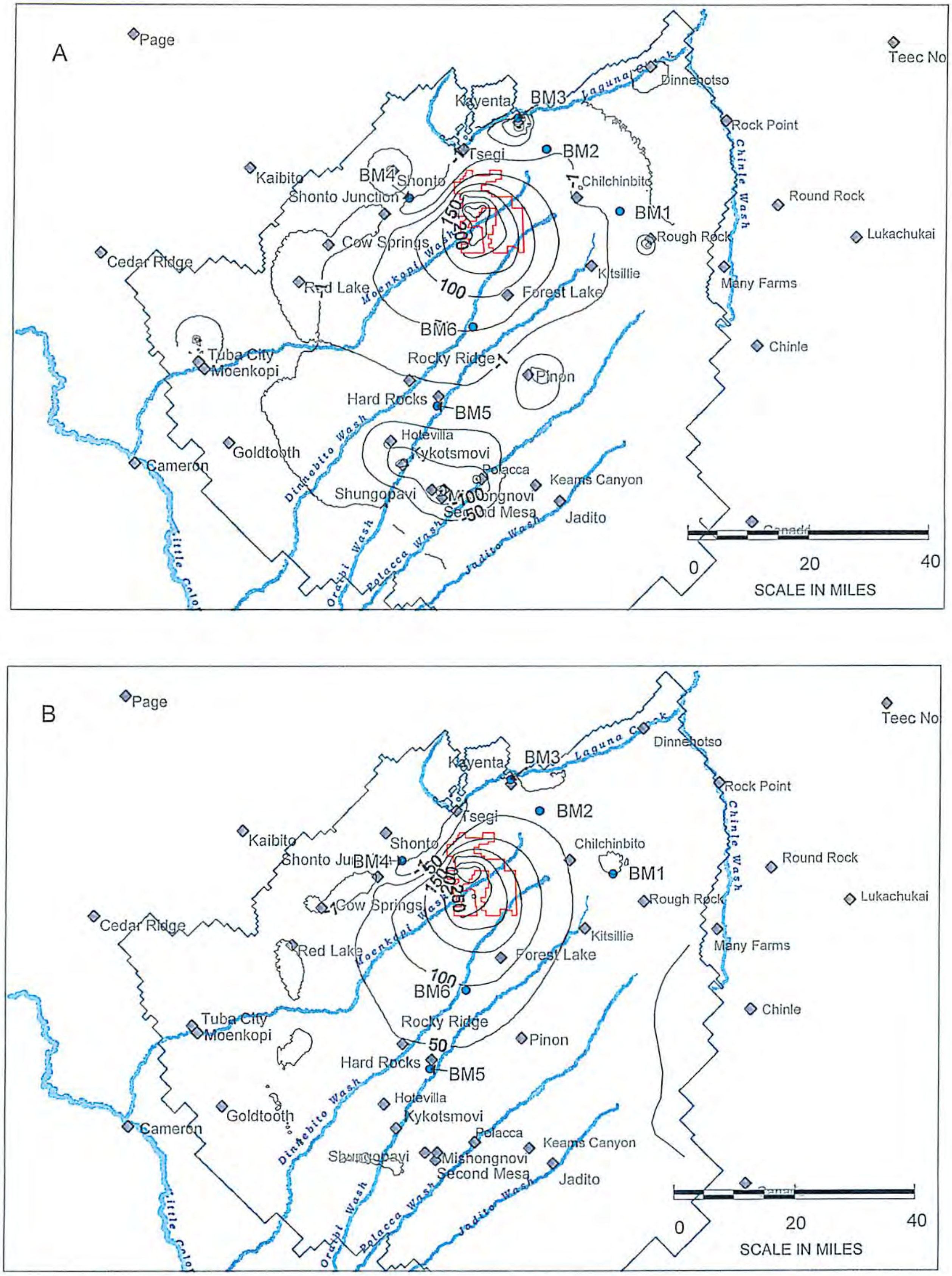
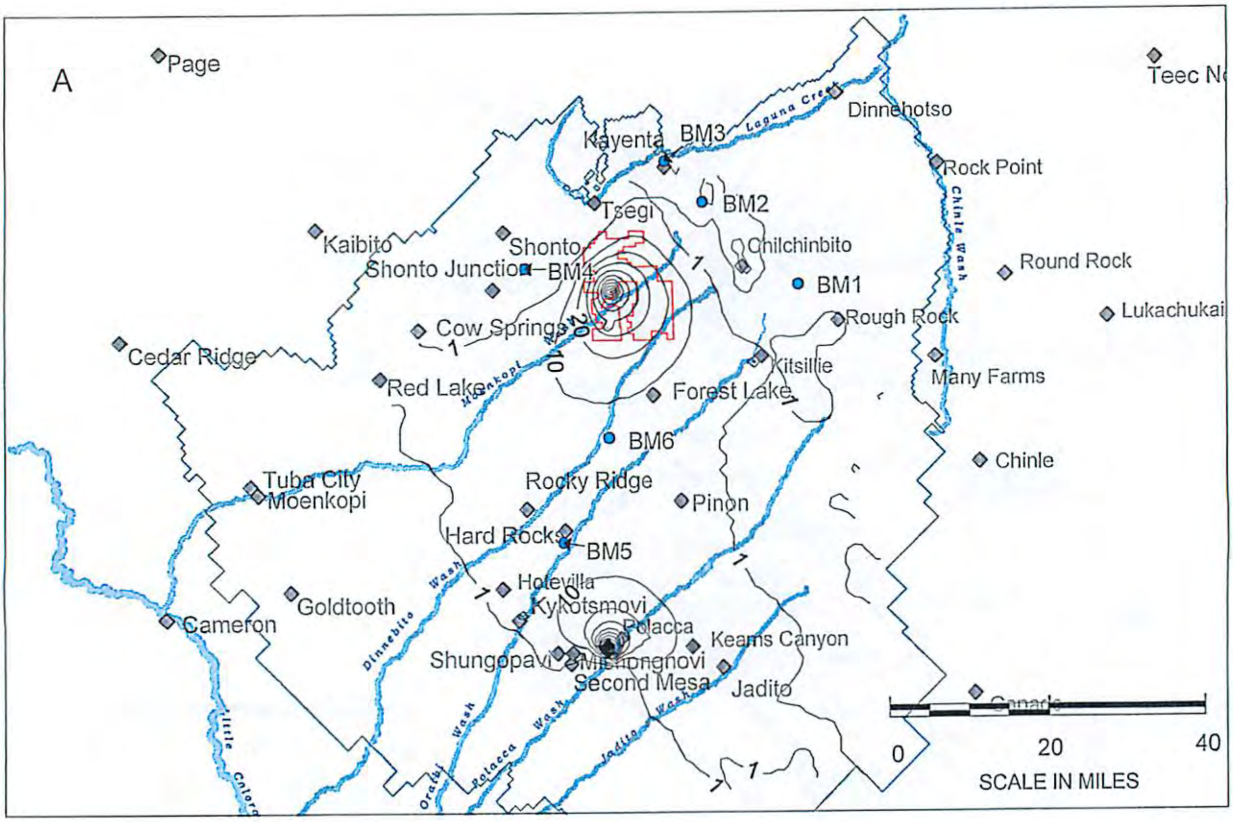


Figure 14. Simulated changes in water levels in the N Aquifer in 2057, relative to 2005. A: Peabody and community pumping. B: Peabody pumping only. The contour interval is 50 feet, with a supplemental contour for -1 foot. Positive values indicate recovery of water levels since 2005.



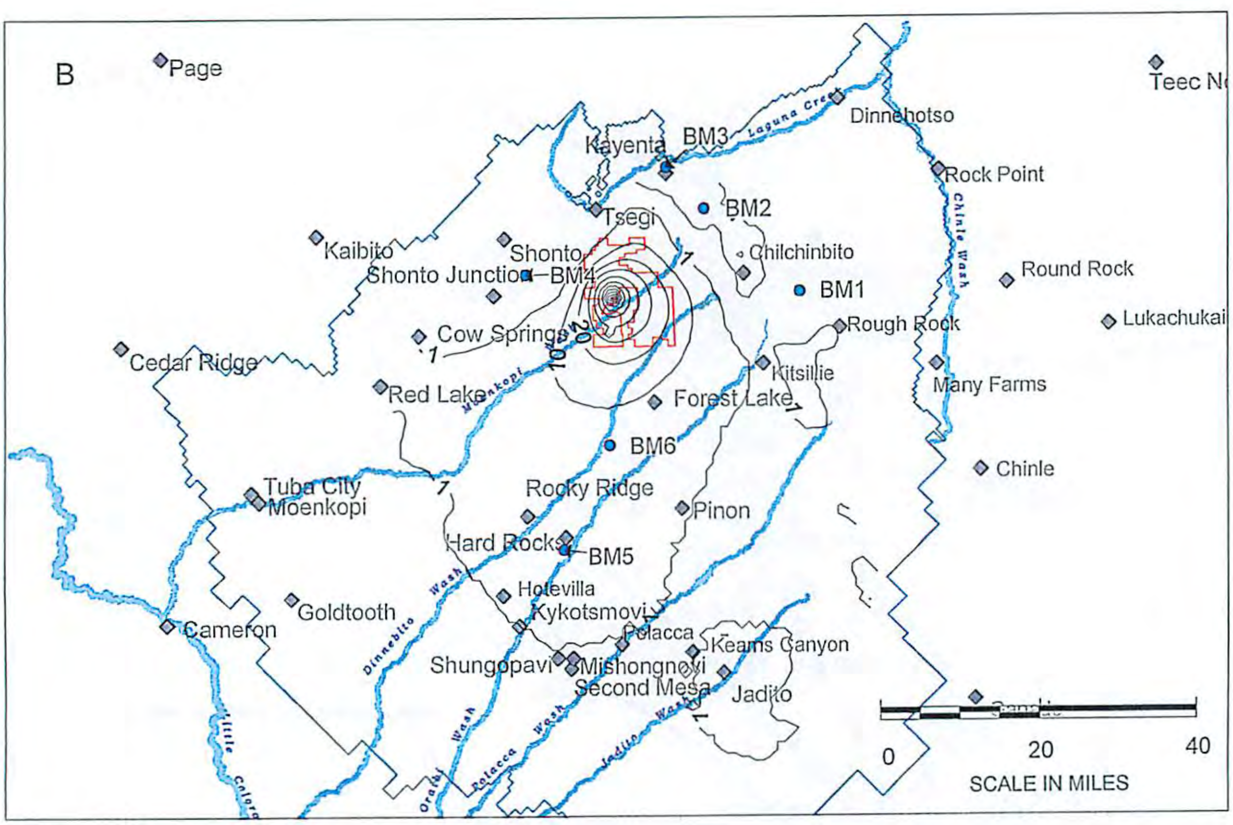


Figure 15. Simulated drawdown in the D Aquifer in 2005. A: Peabody and community pumping. B: Peabody pumping only. The contour interval is 10 feet, with a supplemental contour for 1 foot.

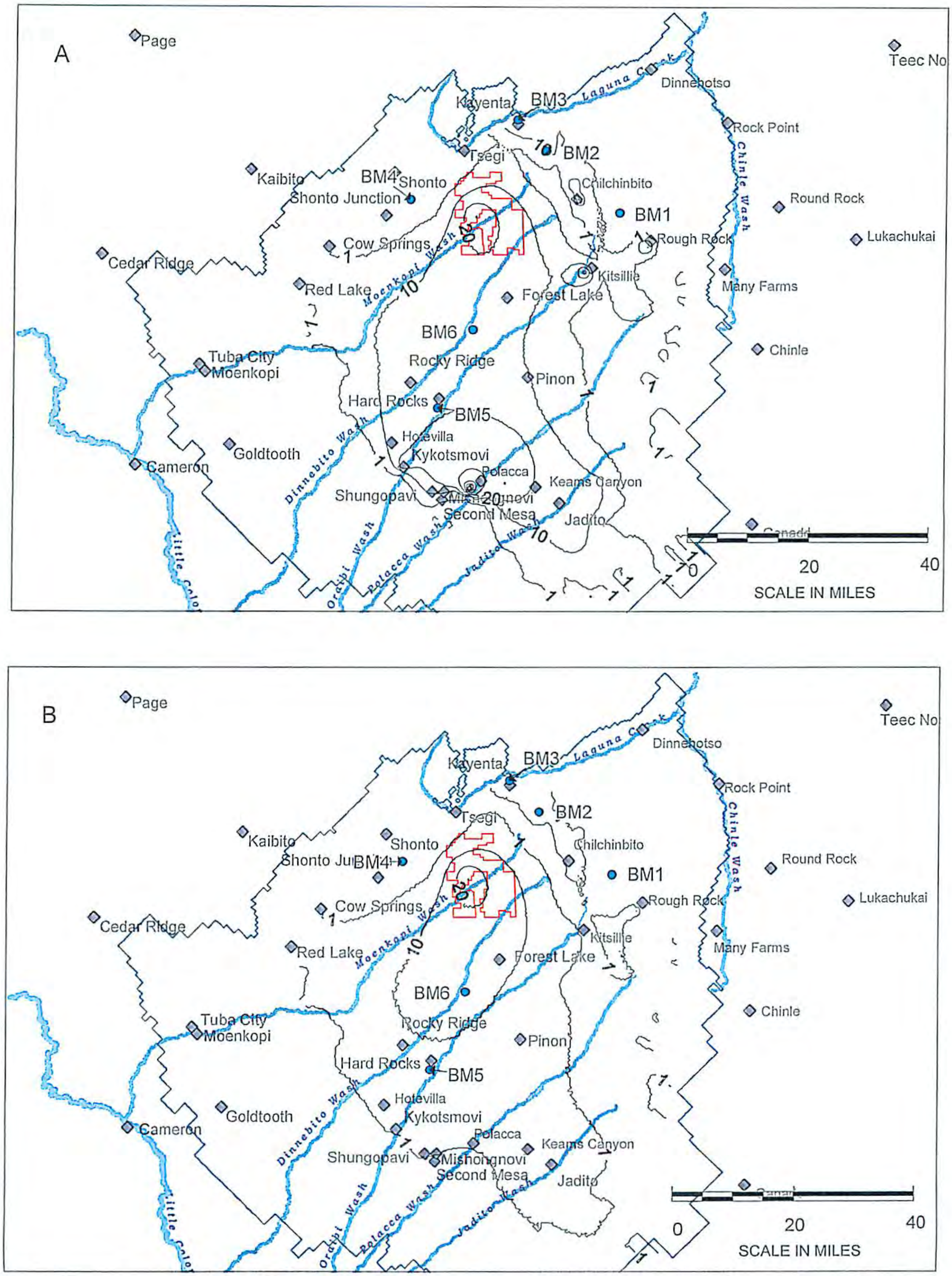
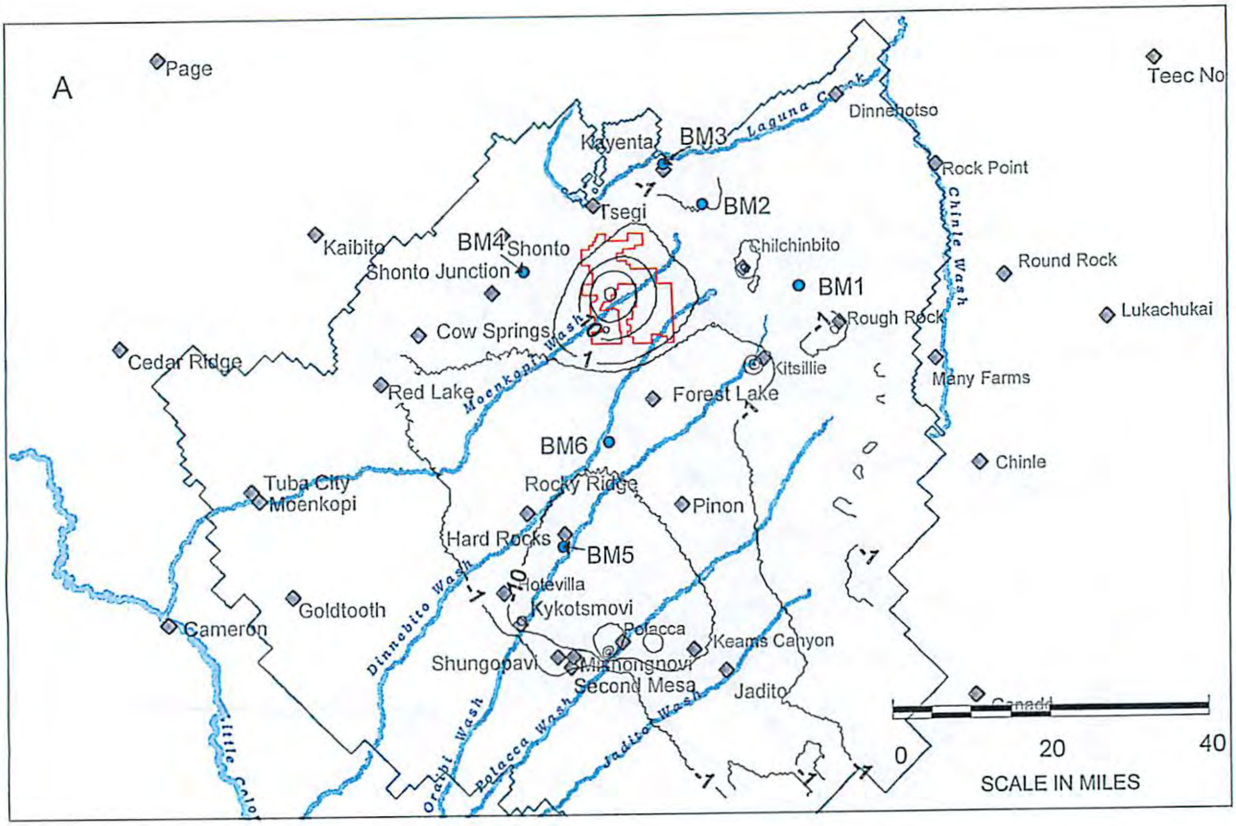


Figure 16. Simulated drawdown in the D Aquifer in 2041. A: Peabody and community pumping. B: Peabody pumping only. The contour interval is 50 feet, with supplemental contours for 1, 10, and 20 feet.



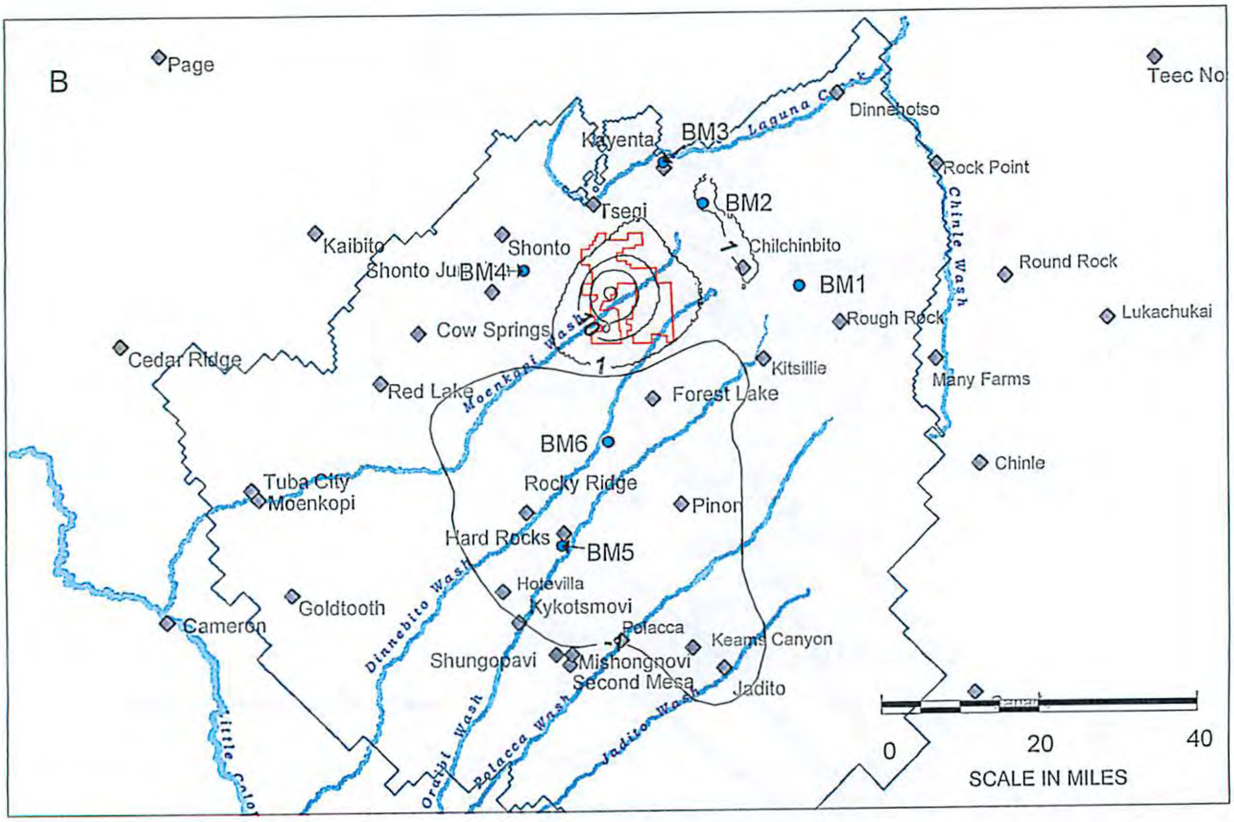


Figure 17. Simulated changes in water levels in the D Aquifer in 2041, relative to 2005. A: Peabody and community pumping. B: Peabody pumping only. The contour interval is 50 feet, with supplemental contours for -20, -10, -1, 1, 10, and 20 feet. Positive values indicate recovery of water levels since 2005.

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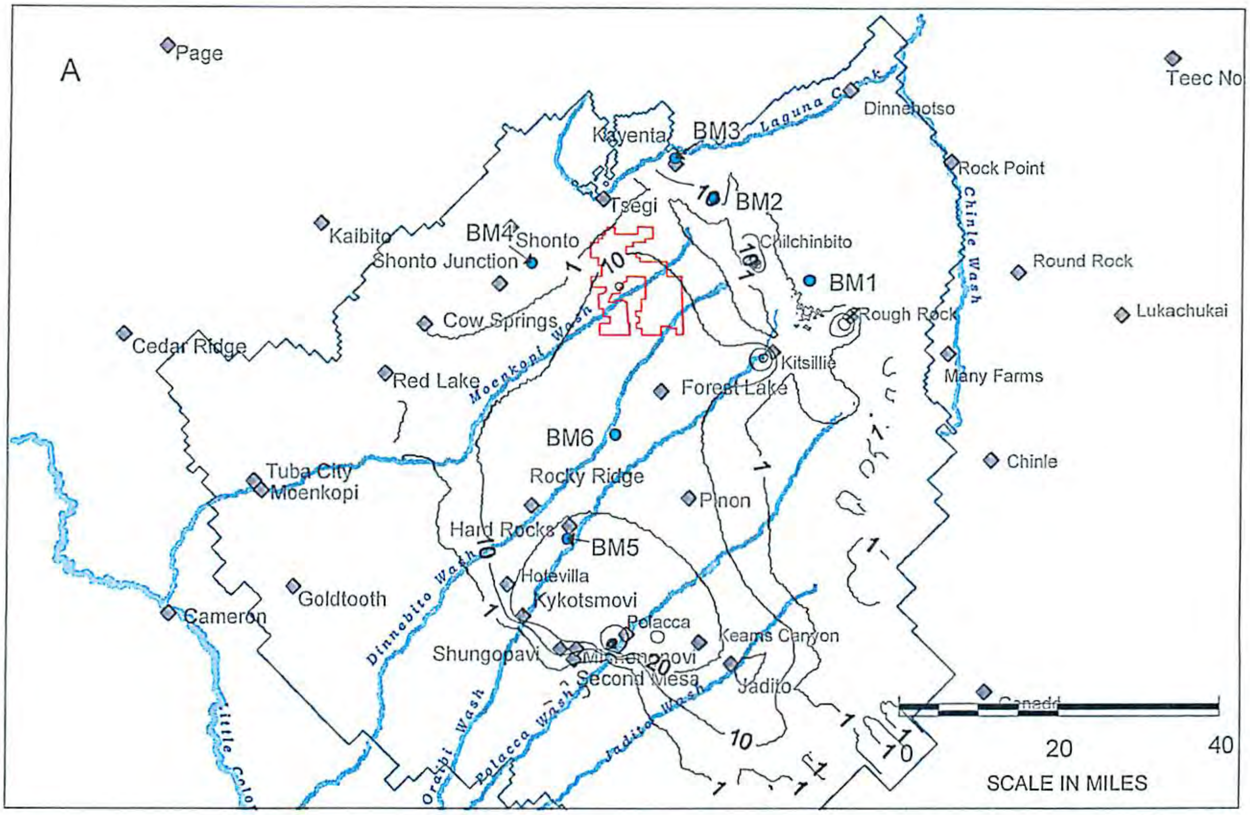

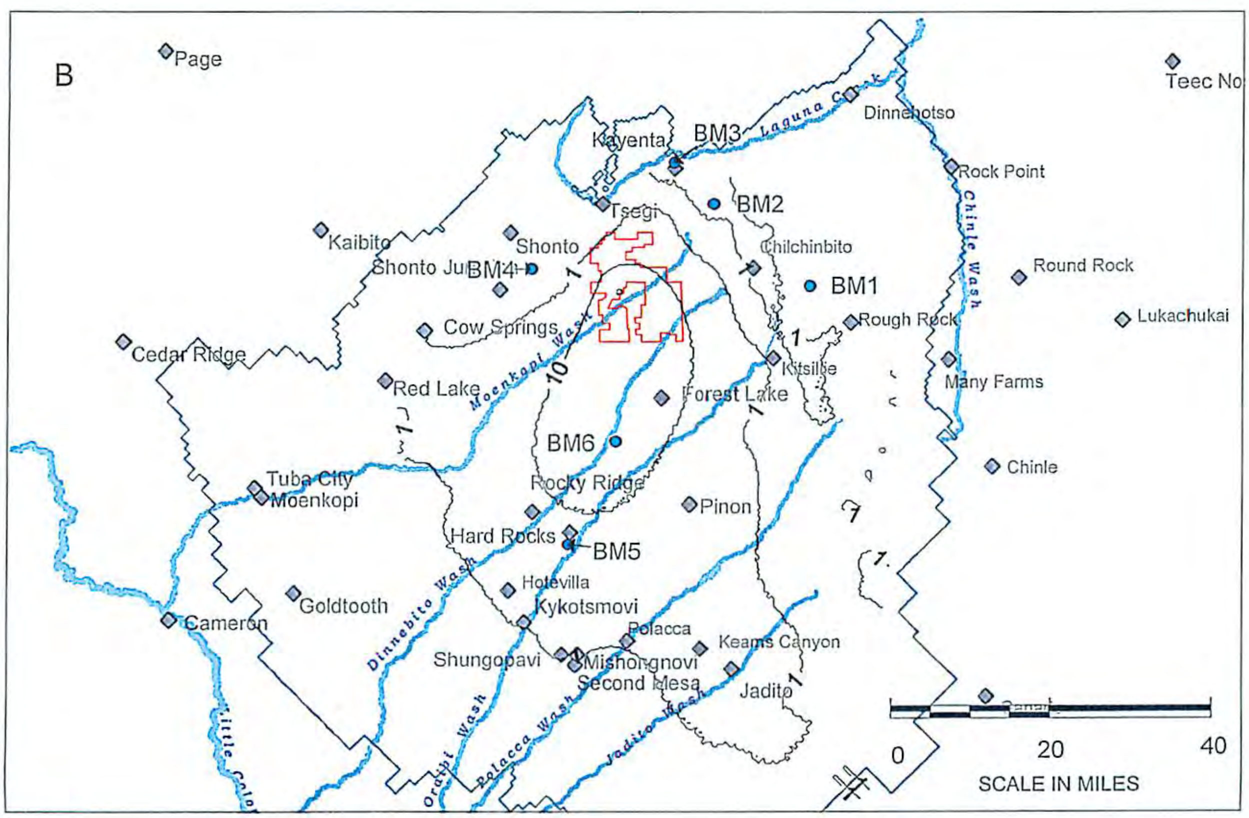

Figure 18. Simulated drawdown in the D Aquifer in 2057. A: Peabody and community pumping. B: Peabody pumping only. The contour interval is 50 feet, with supplemental contours for 1, 10, and 20 feet.

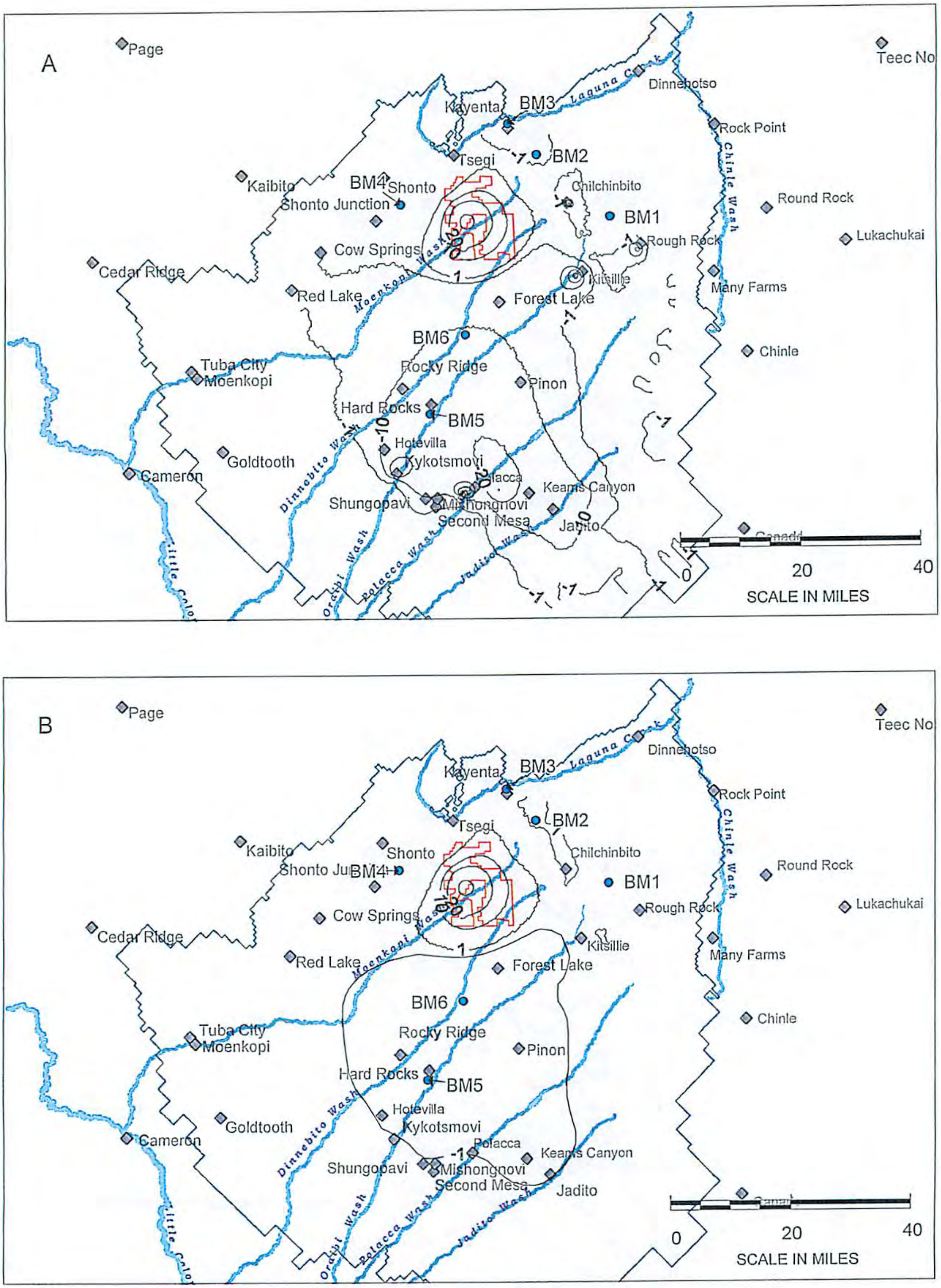

Figure 19. Simulated changes in water levels in the D Aquifer in 2057, relative to 2005. A: Peabody and community pumping. B: Peabody pumping only. The contour interval is 50 feet, with supplemental contours for -20, -10, -1, 1, 10, and 20 feet. Positive values indicate recovery of water levels since 2005.

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significant local drawdown around wells pumping from the D aquifer, the extent of drawdown throughout the region is limited.

Chapter 17, Protection of the Hydrologic Balance, presents information on local wells completed within or adjacent to the leasehold. Table 2 in Chapter 17 lists eight wells completed in the D Aquifer: 4T-516; 4K-387; 4K-407; 4T-399; 4T-402; 4T-503; 4T-504; and 4T-508. Figure 2 in Chapter 17 shows the locations of the eight wells. A comparison of the well locations with the drawdown contours shown on Figure 16b (2041) indicate wells 4T-516, 4K-407, 4T-399, and 4T-504 are outside of the 10-foot drawdown contour, and should not be measurably impacted by PWCC's withdrawals from the D Aquifer. Wells 4K-387, 4T-503, and 4T-508 are at or near the 10-foot drawdown contour. Information shown in Table 2 (Chapter 17) indicates the available water column in these wells ranges between about 340 to 550 feet. Drawdown in the range of ten feet due to PWCC's pumping from the wellfield should have only a minimal impact on these wells.

The database maintained by the USGS was queried (2/17/12) to find wells completed in the D aquifer to determine whether drawdown data in the D are available. All but two D aquifer wells had only a single depth-to-water measurement. Data for well 355924110485001, near Kykotsmovi, exhibit some variability (probably caused by local pumping or changes in local recharge rates) but no long-term trends. Only two measurements are available from well 363137110044701, located to the southeast of Kayenta. These measurements indicate a 2.5 foot increase in water levels between 1994 and 2001.

Well 4T-402 is the most proximate D aquifer well, situated in between the southern portions of the leasehold (Figure 2, Chapter 17). Drawdown contours in Figure 15 indicate approximately 40 feet of drawdown occurred at this well by 2005. Between 2005 and 2041, water levels are predicted to rise about 20 ft (Figure 17). Table 2 (Chapter 17) indicates there is about 380 feet of available water in the well. A review of available water level data from the USGS indicates no recent water levels are available from well 4T-402, where water is pumped periodically when the windmill is operational. PWCC has no information on water levels trends in well 4T-402; regardless, PWCC believes the potential impact on this well due to partial withdrawals from the D aquifer is minimal, has likely already occurred, and should lessen when water levels begin to recover due to reduced pumpage from the wellfield (Figures 16 and 18).

Impacts on stream baseflow and spring discharge rates. The effects of Peabody's pumping on stream baseflow and spring discharge rates are expected to be small. Two-dimensional simulations previously performed by the USGS (Eychaner, 1983; Brown and Eychaner, 1988) and by GeoTrans (1987) provided results consistent with this expectation.

Tables 16 through 18 summarize the predicted effects of pumping on discharge into streams. The tables present results from two simulations: the first simulation included both PWCC and non-PWCC pumping (columns labeled "All"), while the second simulation included community-only pumping (labeled "Non-PWCC"). The simulated annual discharge rates to streams from the two simulations were then used to calculate the change in the discharge rates for "All", "Non-PWCC", and "PWCC" pumping. The table columns labeled "% Reduction All" and "% Reduction PWCC" are the percentage reductions in the discharge rates to streams for all pumping, and for Peabody pumping, respectively. The results are presented for two different starting times, 1955 and 2005; the two starting points were selected to meet data requirements specified in both the CHIA and the EIS, respectively.

Table 16 presents the predicted effects of pumping on discharge into streams for the time period 1955 through 2005. The largest percentage reduction over this time period due to Peabody pumping is estimated to occur at Moenkopi Wash. The simulated pre-pumping (1955) discharge into Moenkopi Wash was 4305.1 acre-feet per year (af/y). At the end of 2005, the simulated discharge is predicted to be reduced by 21.8 af/y, of which 2.4 af/y is caused by non-PWCC pumping, and 19.4 af/y by PWCC pumping. The percentage reduction due to Peabody's pumping is estimated to be 0.45%. The percentage reductions caused by Peabody's pumping for all discharge areas are estimated to range from 0.0 to 0.45%.

The predicted effects of pumping on discharge rates to streams in 2041 are provided in Table 17a and 17b. The largest percentage change due to Peabody pumping occurs at Cow Springs (1.47% decrease in pre-pumping discharge rates from 1955 through 2041, of which 1.10% of the decrease occurs from 2005 through 2041); the magnitude in this predicted reduction in discharge is too small to be measurable. By the end of 2057, the decline at Cow Springs since 1955 was 1.84% (Table 18a), of which 1.47% occurred since 2005 (Table 18b). Measurable declines in stream discharge rates are predicted at Pasture Canyon due entirely to local, not Peabody, pumping.

In contrast with the regionally significant discharge areas, the models did not specifically evaluate the effect of pumping on individual springs in non-wash settings (1) because of the difficulty of accurately simulating these impacts considering the topographic relief and constraints on grid spacing, and (2) because of the limited drawdown in unconfined areas caused by distant pumping. The locations of many of the

Table 16

Effects of Pumping on Simulated Discharge to Streams, through 2005

a. 1955 through 2005

	1955		2005		Change due to Pumping			% Reduction	
Pumping	All	Non-PWCC	All	Non-PWCC	All	Non-PWCC	PWCC	All	PWCC
Chinle Wash	498.9	498.9	498.8	498.8	0.1	0.1	0.0	0.01	0.00
Laguna Creek	2,535.4	2,535.4	2,434.5	2,443.2	100.9	92.2	8.7	3.98	0.34
Pasture Canyon	426.8	426.8	389.4	389.4	37.4	37.4	0.0	8.75	0.000
Moenkopi Wash	4,305.1	4,305.1	4,283.3	4,302.7	21.8	2.4	19.4	0.51	0.45
Dinebito Wash	515.6	515.6	515.0	515.3	0.6	0.3	0.3	0.12	0.06
Oraibi Wash	458.1	458.1	455.5	455.9	2.6	2.2	0.4	0.57	0.10
Polacca Wash	440.5	440.5	431.1	432.1	9.4	8.4	1.0	2.13	0.22
Jaidito Wash	2,027.4	2,027.4	2,015.1	2,018.2	12.3	9.2	3.1	0.61	0.15
Cow Springs	2,178.0	2,178.0	2,169.1	2,177.3	8.9	0.7	8.2	0.41	0.37

All discharge rates in af/y

Table 17

Effects of Pumping on Simulated Discharge to Streams, through 2041

a. 1955 through 2041

Pumping	1955		2041		Change due to Pumping			% Reduction	
	All	Non-PWCC	All	Non-PWCC	All	Non-PWCC	PWCC	All	PWCC
Chinle Wash	498.9	498.9	498.7	498.7	0.2	0.2	0.0	0.04	0.00
Laguna Creek	2,535.4	2,535.4	2,322.8	2,334.6	212.6	200.8	11.8	8.39	0.47
Pasture Canyon	426.8	426.8	286.3	286.3	140.5	140.5	0.0	32.93	0.000
Moenkopi Wash	4,305.1	4,305.1	4,272.1	4,295.9	33.0	9.2	23.8	0.77	0.55
Dinebito Wash	515.6	515.6	513.4	514.5	2.2	1.1	1.0	0.42	0.20
Oraibi Wash	458.1	458.1	449.4	451.0	8.7	7.1	1.6	1.91	0.36
Polacca Wash	440.5	440.5	416.9	418.2	23.6	22.3	1.3	5.36	0.30
Jaidito Wash	2,027.4	2,027.4	1,983.7	1,994.9	43.7	32.5	11.2	2.16	0.55
Cow Springs	2,178.0	2,178.0	2,140.1	2,172.1	37.9	5.9	32.0	1.74	1.47

b. 2005 through 2041

Pumping	2005		2041		Change due to Pumping			% Reduction	
	All	Non-PWCC	All	Non-PWCC	All	Non-PWCC	PWCC	All	PWCC
Chinle Wash	498.8	498.8	498.7	498.7	0.2	0.2	0.0	0.03	0.00
Laguna Creek	2,434.5	2,443.2	2,322.8	2,334.6	111.7	108.6	3.1	4.59	0.13
Pasture Canyon	389.4	389.4	286.3	286.3	103.2	103.2	0.0	26.49	0.000
Moenkopi Wash	4,283.3	4,302.7	4,272.1	4,295.9	11.2	6.8	4.4	0.26	0.10
Dinebito Wash	515.0	515.3	513.4	514.5	1.6	0.9	0.7	0.30	0.14
Oraibi Wash	455.5	455.9	449.4	451.0	6.1	4.9	1.2	1.34	0.26
Polacca Wash	431.1	432.1	416.9	418.2	14.2	13.9	0.3	3.29	0.08
Jaidito Wash	2,015.1	2,018.2	1,983.7	1,994.9	31.4	23.3	8.1	1.56	0.40
Cow Springs	2,169.1	2,177.3	2,140.1	2,172.1	29.1	5.2	23.8	1.34	1.10

All discharge rates in af/y

Table 18

Effects of Pumping on Simulated Discharge to Streams, through 2057

a. 1955 through 2057

Pumping	1955		2057		Change due to Pumping			% Reduction	
	All	Non-PWCC	All	Non-PWCC	All	Non-PWCC	PWCC	All	PWCC
Chinle Wash	498.9	498.9	498.5	498.5	0.4	0.4	0.0	0.08	0.00
Laguna Creek	2,535.4	2,535.4	2,241.5	2,255.0	293.9	280.4	13.5	11.59	0.53
Pasture Canyon	426.8	426.8	263.9	263.9	162.9	162.9	0.0	38.18	0.000
Moenkopi Wash	4,305.1	4,305.1	4,267.4	4,290.7	37.7	14.4	23.3	0.88	0.54
Dinebito Wash	515.6	515.6	512.6	513.8	3.0	1.8	1.2	0.59	0.23
Oraibi Wash	458.1	458.1	445.4	447.2	12.7	10.9	1.8	2.77	0.40
Polacca Wash	440.5	440.5	411.1	412.4	29.4	28.1	1.3	6.68	0.29
Jaidito Wash	2,027.4	2,027.4	1,964.7	1,976.9	62.7	50.5	12.1	3.09	0.60
Cow Springs	2,178.0	2,178.0	2,126.7	2,166.8	51.3	11.2	40.1	2.36	1.84

b. 2005 through 2057

Pumping	2005		2057		Change due to Pumping			% Reduction	
	All	Non-PWCC	All	Non-PWCC	All	Non-PWCC	PWCC	All	PWCC
Chinle Wash	498.8	498.8	498.5	498.5	0.3	0.3	0.0	0.07	0.00
Laguna Creek	2,434.5	2,443.2	2,241.5	2,255.0	192.9	188.2	4.8	7.93	0.20
Pasture Canyon	389.4	389.4	263.9	263.9	125.6	125.6	0.0	32.25	0.000
Moenkopi Wash	4,283.3	4,302.7	4,267.4	4,290.7	15.9	12.0	3.9	0.37	0.09
Dinebito Wash	515.0	515.3	512.6	513.8	2.4	1.6	0.9	0.47	0.17
Oraibi Wash	455.5	455.9	445.4	447.2	10.1	8.7	1.4	2.21	0.31
Polacca Wash	431.1	432.1	411.1	412.4	20.0	19.7	0.3	4.65	0.08
Jaidito Wash	2,015.1	2,018.2	1,964.7	1,976.9	50.3	41.3	9.0	2.50	0.45
Cow Springs	2,169.1	2,177.3	2,126.7	2,166.8	42.5	10.5	32.0	1.96	1.47

All discharge rates in af/y

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smaller springs are determined by the geometric relationships between beds of different hydraulic properties, and by locations of fracture zones. Many of the smaller springs discharge from formations, such as those in the D aquifer, that contain low hydraulic conductivity beds. These lower conductivity beds, which are responsible for the occurrence of the springs, will tend to isolate the springs from the effects of pumping in the N aquifer.

Further, the discharge rates of these springs are likely to be more sensitive to changes in local recharge than to drawdown caused by distant pumping. These springs are typically located near recharge areas, and temporal changes in their discharge rates caused by short-term changes in local recharge rates would be expected. Observations of springs discharging from the Wepo formation on the leasehold confirm the temporal variability of these smaller springs. Tree-ring studies performed throughout the southwestern U.S. document the variability of precipitation on the scale of decades (see, for example, Stahle and others, 2000). Even if good spring flow data were available, the variability in precipitation rates would make calibration to the spring discharge data difficult. Because of the character of these springs and of the groundwater system, the effects of Peabody's pumping are expected to be negligible. Measurement of pumping effects on these springs will be difficult because of the expected small magnitude of these effects, seasonal changes of precipitation and evapotranspiration rates, and longer term changes in local precipitation rates.

In summary, groundwater models are the best tools available for evaluating the contributions of different pumping stresses on water levels and stream flows. Models of the N Aquifer flow system have been developed by both the USGS and by Peabody since the 1980's, with each successive effort improving on the previous. As additional data have been collected and improved computational tools made available, the models have incorporated more knowledge of the groundwater system.

The models have varied in detail; however, they were each based on the data available at the time of the model's development and incorporate the major components of the N Aquifer flow system. Further, each model has been subjected to a calibration process whereby the ability of the model to simulate historical measurements is demonstrated. Peabody's 3D model has been used to evaluate the effects of uncertainty in the recharge rate. Importantly, the models are consistent with respect to their predictions of the impacts from pumping on the N Aquifer flow system. They predict that water levels in the confined part of the N aquifer will be reduced by pumping but that the water levels will

Wells in the Peabody wellfield have been routinely sampled since approximately 1981; results have been provided to OSM in annual monitoring reports. Until the mid 1980's, laboratory problems produced data of uncertain quality. These problems have since been resolved, and the analytical results over the last fifteen years show only occasional "noise" and no clear temporal trends.

Four of the wells (NAV 4, NAV 5, NAV 7, and NAV 8) in the wellfield are completed in both the N and D aquifers. Based on the chemical data, the contribution to the wells' pumpage from the D aquifer is small. Table 19 presents average concentrations of major ions for D aquifer well 4T-402 and the Peabody production wells. The percentage of water derived from the D aquifer is also presented, based on the mixing equation for chloride:

$$X\,Cl_{Daq} + (1-X)\,Cl_{Naq} = Cl_{sample}$$

where X is the proportion of water from the D aquifer, Cl_{Daq}, Cl_{Naq}, and Cl_{sample} are the chloride concentrations in the D aquifer, N aquifer, and the water sample, respectively. Even in the wells that are partially completed in the D aquifer, the chloride-based values are less than 2% contribution from the D aquifer, even after more than 30 years of pumping. The chloride data indicate that the percent of D aquifer-derived water is approximately 0.2% or less. The lack of a significant trend of increasing concentrations suggests that these concentrations are largely determined by pre-pumping N aquifer chemistry. The sulfate values suggest a greater contribution from the D aquifer, but may be affected by gypsum particles deposited with the quartz and other mineral grains.

Beginning in 2006, pumping from Peabody's wellfield was significantly reduced due to the shutdown of Mohave Generating Station and the cessation of coal shipments via the coal slurry pipeline. As a result, pumping of wells 3, 4, 5, 7, and 9 has been significantly reduced, limited to incidental withdrawals of groundwater for mine related uses and for collecting water quality samples in accordance with procedures summarized in Chapter 16, Hydrologic Monitoring Program. Reductions in pumping at individual wells partially completed in the D-Aquifer (wells 4, 5, and 7) may slightly alter water quality within the bore hole and in the N-Aquifer for some distance adjacent to each well bore. However, a review of water quality data collected in these wells and reported in the 2010 Annual Hydrologic Data Report (PWCC, 2011) indicate no significant impacts have occurred through 2010. No trends in chloride concentration have been detected in any of the N aquifer wells through 2010, and the ranges of TDS, sulfate, and dissolved sodium measured in wells 4, 5, and 7 during 2010 are comparable to the historical ranges for these parameters from 1986 through 2005 when pumping was significantly higher. Through 2010, the water use potential for all N aquifer wells is unchanged over previous years and remains suitable for domestic drinking water uses.

The program ZONEBDGT (Harbaugh, 1990) was used to calculate flow within the N aquifer across a specified block that encompassed the Peabody wellfield, using fluxes calculated from a predictive run using the base-case 3D model and the pumping schedule described in Table 14. The ZONEBDGT results indicate that the leakage rate from the D to the N aquifer within this block increased by a factor of 1.8 between the pre-pumping period and 2005 (this factor will decrease in later years as N Aquifer pumping is reduced). They also indicate that lateral flow into the block from the N aquifer would increase by a factor of about 20. Thus, the chemistry of the water pumped from the wellfield would primarily be determined from chemistry of the water in the N aquifer in areas surrounding the wellfield. The small component of D aquifer water in the N aquifer water (Table 19), even if assumed to be entirely representative of pre-pumping conditions in the N aquifer, indicates that the effect of pumping on the water quality is insignificant. This results because of (1) the limited leakage rate under non-pumping conditions (evidenced by the present water chemistry), (2) the limited increase in leakage rate (factor of 1.8), and (3) the flow dynamics produced by pumping water primarily from the N aquifer.

Based on ZONEBDGT calculations and mixing equations, the change in sulfate concentrations in several different areas within the N aquifer basin was calculated. The results are shown in Table 20, respectively, and reflect the cumulative effect of pumping by PWCC between 1956 and 2057. Because of the small amount of leakage through the Carmel under natural conditions (indicated by the low TDS levels in the N aquifer even after leakage from the D aquifer for thousands of years), the increase in leakage due to pumping is predicted to cause very minor changes in the chemistry of the N Aquifer water. Where natural leakage is believed to be higher (in the eastern part of the basin) based on water chemistry data, approximately 100 years of pumping is predicted to cause an increase in sulfate concentrations of about 0.6%. In all other areas, the increase is predicted to be less than 0.3 percent.

Surface Water

Effects of Dams, Sediment Ponds and Permanent Internal Impoundments on Runoff and Channel Characteristics. Nine major dams (MSHA) have been constructed on principal tributaries confluent to Moenkopi Wash during the life of the mining operation. Portions of the drainages above as well as below the dams will be affected. The reach immediately above a dam will gradually aggrade headward as more and more water is impounded until a pool level is reached that is in equilibrium with water gains and losses. Channel reaches below the dams will become incised by smaller active meandering channels whose widths are a function of drastically reduced runoff potential, channel gradients and sediment load particle size ranges. Vegetation will begin encroaching on the edges of the new active channels as there will be insufficient runoff to remove it.

The effects of sediment ponds and permanent internal impoundments on runoff and channel characteristics will be minimal on an individual basis, but comparable to the effects of dams when considered in total. It is estimated that more than 320 sediment ponds and several permanent internal impoundments have been or will be constructed during the life of the mining operation. The internal impoundments are typically small, excepting PIIs like N2-RA, N7-D and the one impoundment proposed for the J-19 coal resource area, and most have been built on pre-law lands. Channel effects will be similar to those described for dams. Since most of the sediment ponds are on very small side tributaries, there will not be any up-drainage impacts of any significance. Because of the number of ponds and their wide range of locations, the downstream effects (active channel narrowing and vegetative encroachment) will be manifested over longer channel distances.

Table 20

Maximum predicted sulfate concentrations (mg/L) resulting from PWCC pumping, 1956-2057

Subarea	Initial Concentration (mg/L)		Final Concentration (mg/L)	Change
	D Aquifer	Navajo sandstone	Navajo sandstone	
Northeast	250	70	70.064	0.0913%
East	850	100	100.623	0.6230%
Hopi Buttes	360	50	50.143	0.2866%
Forest Lake	1000	100	100.059	0.0595%
Kitsillie	75	30	30.002	0.0071%
Pinon	200	5	5.006	0.1274%
Rocky Ridge	250	10	10.013	0.1286%
Preston Mesa	400	10	10.000	0.0006%
Leasehold	400	30	30.019	0.0628%
Pinon to Kitsillie	1000	20	20.037	0.1873%
Surrounding leasehold	100	45	45.002	0.0040%
Red Lake to Tuba City	400	50	50.013	0.0270%
Hotevilla to Kabito	200	35	35.007	0.0189%
Pinon to Rocky Ridge	210	140	140.003	0.0024%

In addition to the permanent internal impoundments, 31 sediment control structures (see Chapter 6, Table 9) are proposed for consideration as permanent impoundments that will remain as permanent features of the postmining landscape. The total drainage area that these 31 permanent impoundments will encompass amounts to only 0.5 percent and 2.2 percent of the entire Dinnebito and Moenkopi watersheds, respectively (down to each confluence with the Little Colorado River).

The impacts of the sediment ponds and dams will be of little significance as there are no local users of water for flood irrigation (see Alluvial Valley Floor section of Chapter 17). Following removal of the dams and sediment ponds, there will be certain short-term impacts to the channel reaches immediately below these structures. Sediment loads will temporarily increase as the active channel widens in response to the increased runoff potential. The increased channel bank vegetation should provide some stability during this active channel readjustment period. The potential for flood flows overtopping the channels will be negligible as the typical channel banks are 15 to 20 plus feet high above the active channel. The frequency of the larger runoff events will dictate how fast the channels reestablish themselves in quasi-equilibrium with the environmental conditions.

<u>Effects of Dams, Sediment Ponds and Permanent Internal Impoundments on Downstream Users</u>. As of December 2010, the total Dinnebito and Moenkopi watershed areas to the leasehold boundary draining to PWCC dams, ponds and impoundments are 4.56 and 65.76 square miles, respectively. There are numerous large tributaries to both washes between the leasehold and the Little Colorado River. Comparing the above impounded drainage areas to the total drainage areas for both washes (812.8 square miles for Dinnebito Wash and 2,605.3 square miles for Moenkopi Wash) suggests that this loss of runoff is of little significance at the points where the runoff water has any potential for being used for flood irrigation. As of December 2010, the impounded drainage areas on the leasehold amounted to only 0.6 percent and 2.5 percent of the total Dinnebito and Moenkopi watersheds, respectively.

Busby (1966) developed estimates of average annual runoff in the counterminous United States, including Northeastern Arizona. Based on these average annual estimates, runoff was calculated for the total watershed areas of both Dinnebito and Moenkopi washes to their respective confluences with the Little Colorado River. Average annual runoff for each basin was determined by summing the calculated runoff for partial areas defined as the watershed area lying between each pair of average annual runoff isopleths that transect the basin. The average annual runoff isopleths shown for the Black Mesa region on the Hydrologic Investigation Atlas HA-212 were used. Therefore, the lower portions of each basin were assigned an average annual runoff value of 0.1 inches, and the upper portions of each basin, including those portions in which PWCC's leasehold are situated, were assigned much higher average annual runoff numbers (1.25 to 1.75 inches). Based on Busby's empirical estimates, the average annual runoff for the entire Dinnebito basin was calculated to be 17,242 acre-feet, and 57,022 acre-feet of average annual runoff for the entire Moenkopi basin was determined.

Table 21 presents combined annual runoff measured from 1987 through 2008 at continuous flow monitoring sites SW155, SW25, and SW26, as well as annual runoff measured for the same period at the USGS Streamflow-gaging station (09401260) located on Moenkopi Wash at Moenkopi, Arizona. The runoff values are presented as acre-feet and inches of runoff. The inches of runoff for the PWCC sites were calculated by dividing the total runoff in acre-feet by the combined drainage area (in acres) above all three monitoring sites that was not controlled by PWCC dams, ponds and impoundments for each year shown (e.g., 188.65 square miles in 2000) and multiplied by 12. Similarly, the inches of runoff for the USGS Moenkopi gage was calculated by first subtracting baseflow contributions from ground water discharge from each year's total measured runoff, then dividing the adjusted total runoff (acre-feet) by the total drainage area (in acres) above the gage that was not controlled by PWCC impoundments (e.g., 1564.38 square miles in 2000). The inches of runoff presented for both locations represent runoff generated from precipitation events.

For the twenty-two year period presented in Table 21, the upper sites (SW155, SW25, and SW26) averaged 0.15 inches of runoff, and the USGS gage at Moenkopi averaged 0.07 inches of runoff. The average annual runoff in inches determined from the 22-year record at the USGS gage at Moenkopi (0.07 inches) was used to estimate the average annual runoff (in acre feet) for the entire watersheds of both the Dinnebito and Moenkopi basins, and are presented on Table 22. Comparing Table 22 values with the average annual runoff estimated for both basins using Busby's estimates (17,242 acre-feet for Dinnebito; 57,022 acre-feet for Moenkopi), it is obvious that Busby's empirical estimates of average annual runoff for the Black Mesa region are extremely high and unrealistic compared to average annual runoff calculations that are based on local stream flow measurements.

Table 22 also presents drainage areas and average annual runoff estimates for the watershed areas draining PWCC dams, ponds and impoundments (impounded areas) within both Dinnebito and Moenkopi washes as of December 2010 and for December 2018, the last month of Year 5 of the five-year mining plan for 2014 through 2018. Impounded areas are based on summing designed drainage areas for the existing impoundments (December 2010) and those proposed to be constructed from 2011 through 2018(see Drawing 85406, Volume 22).

Table 21

Measured Annual Runoff at PWCC's Continuous Flow Monitoring Sites and at the USGS Streamflow-Gaging Station 09401260, Moenkopi Wash at Moenkopi, Arizona

	PWCC Sites[1] Total		USGS Station 09401260[2]		
Calendar Year	Total Runoff (acre-ft)	Runoff[3] (in.)	Total Runoff (acre-ft)	Adjusted Total Runoff[4] (acre-ft)	Runoff[5] (in.)
1987	3,307.2	0.32	10,030	9,230	0.11
1988	3,387.7	0.32	8,970	7,990	0.10
1989	1,475.4	0.14	3,270	2,480	0.03
1990	1,899.0	0.19	7,610	6,680	0.08
1991	276.2	0.03	1,750	1,000	0.01
1992	1,864.2	0.18	3,820	3,110	0.04
1993	414.4	0.04	8,000	7,050	0.08
1994	124.1	0.01	1,370	410	0.005
1995	1,092.7	0.11	2,720	1,790	0.02
1996	374.9	0.04	1,610	730	0.01
1997	2,860.7	0.28	8,520	7,620	0.09
1998	548.8	0.05	1,650	610	0.01
1999	1,618.1	0.16	13,810	12,870	0.15
2000	210.9	0.02	3,430	2,370	0.03
2001	800.1	0.08	14,739	13,974	0.17
2002	920.4	0.09	9,026	8,215	0.10
2003	2,647.2	0.26	12,448	11,590	0.14
2004	909.8	0.09	7,327	6,433	0.08
2005	896.6	0.09	6,409	5,569	0.07
2006	4,105.8	0.41	13,650	12,812	0.15
2007	1,976.2	0.20	9,972	9,126	0.11
2008	1,036.7	0.10	4,135	3,384	0.04
	Avg.	0.15		Avg.	0.07

1 - Combined Measured Annual Runoff from Sites SW155, SW25, and SW26 (PWCC Annual Hydrology Reports, 1987 - 2008)

2 - USGS records (NWISWeb, 2003 and 2010)

3 - Based on the combined drainage area for all three sites (253.27 square miles) less total PWCC-impounded area during each calendar year

4 - Runoff numbers adjusted to remove groundwater baseflow component and reflect only snowmelt and rainfall runoff

5 - Based on the total drainage area for USGS Station 09401260 (1629 square miles) less total PWCC-impounded area during each calendar year

Table 22

Drainage Areas and Estimates of Annual Runoff

	Moenkopi Wash Basin		Dinnebito Wash Basin	
	Total Area (mi^2)	Runoff (ac-ft)	Total Area (mi^2)	Runoff (ac-ft)
Totals without PWCC Ponds	2,605.3	9,726.5[1]	812.8	3,034.5[1]
PWCC Dams, Ponds, and PII's - December 2010	65.76	526.2[2]	4.56	36.5[2]
PWCC Dams, Ponds, and PII's - December 2018[3]	63.96	511.7[2]	5.47	43.7[2]
Post-mining Permanent Impoundments[4]	57.50	460.0[2]	3.71	29.7[2]

1 - Based on 22-year average annual runoff measured at USGS Station 09401260.

2 - Based on 22-year average annual runoff measured at PWCC gages SW155, SW25, and SW26.

3 - Year 5 of the 5-year mine plan (2014 to 2018).

4 - See Table 9, Chapter 6, Facilities.

Table 22 shows the December 2010 impounded area is 0.6 percent and 2.5 percent respectively of the total drainage areas for the Dinnebito and Moenkopi basins. In December 2018, the total impounded area increases slightly to 0.7 percent of the total Dinnebito drainage area and decreases to 2.45 percent of the total Moenkopi drainage area. Between December 2010 and December 2018, 3 new temporary sediment ponds are proposed for construction in the Dinnebito basin, and 14 new temporary sediment ponds are proposed for construction in the Moenkopi basin. Impounded areas shown on Table 22 also take into account reclamation of ponds J7-CD, J7-E and J7-F in 2011 and additional temporary sediment ponds scheduled for reclamation from 2012 through 2018.

The 22-year average measured runoff at the three PWCC sites (Table 21) was used to estimate average annual runoff for the December 2010 and December 2018 impounded areas. The estimates of average annual runoff for the December 2010 impounded area are 1.2 and 5.4 percent respectively of the average annual runoff calculated for the entire Dinnebito and Moenkopi basins. Table 22 shows average annual runoff for December 2018 will increase slightly to 1.4 percent of the average annual runoff calculated for the entire Dinnebito basin, and will decrease for the entire Moenkopi basin. Additional impounding area for the life of mining will include construction of three proposed permanent impoundments in the J19, J21, and N10 reclaimed landscapes (see Chapter 6, Facilities). Additional temporary sediment structures may be constructed after 2018 to provide treatment of disturbed area runoff from future mining areas (e.g., J21W); however, the dates for construction and reclamation of these facilities are unknown at this time.

Table 22 also presents the total impounded area of permanent impoundments proposed to remain in the post-mining landscape in both the Dinnebito and Moenkopi basins (see Chapter 6, Facilities, and Chapter 14, Land Use). Following final reclamation of all mining areas, the drainage area associated with PWCC's proposed permanent impoundments will comprise 0.5 percent of the total Dinnebito drainage area and 2.2 percent of the total Moenkopi drainage area. Using the annual average runoff of 0.15 inches determined from 22 years of stream flow measurements collected at the three PWCC gages, the permanent impoundments may impound about 1.0 and 4.7 percent of the average annual runoff at the lower ends of the Dinnebito and Moenkopi basins, respectively.

Based on percentages of impounded drainage areas presented in Table 22 for the December 2010, December 2018, and permanent impoundments with the total basin areas of Dinnebito and Moenkopi washes, loss of runoff in each basin is of little significance at downstream points where runoff water has any potential for being used. An alluvial farm plot and phreatophyte survey performed by Intermountain Soils, Inc. in June, 1985 documented that there is no evidence that flood irrigation was ever practiced in the past or that it is presently being practiced along the major washes and tributaries within the leasehold. All agricultural plots inspected were located on high terraces and were planted with shallow rooting cultivars, which are solely reliant on rainfall infiltration. Inspection of regional reservation land use maps indicates that flood irrigation is not practiced below the leasehold along lower Dinnebito and Moenkopi Washes other than some 70 miles below the leasehold at the town of Moenkopi. PWCC is not aware of any other diversions immediately downstream of, or further downstream for approximately 70 miles in either Dinnebito or Moenkopi Washes. Runoff from precipitation events in both washes typically occurs as flash floods, with rapidly rising water levels, high velocities, and very high concentrations of suspended solids. The channel beds and banks of both channels are subject to significant changes in width and depth as a result of runoff events, often changing appreciably during each event, which can create significant problems regarding the construction and maintenance of water diversion structures.

Comparisons of average annual runoff estimates indicate the impounded areas through December 2018 have the potential to, on average, reduce average annual runoff in the Dinnebito basin by about 1.4 percent, and in the Moenkopi basin by approximately 5.3 percent. Total runoff in the basins is greatly affected by depression storage, channel transmission losses and evapotranspiration. Channel transmission losses along the sand-bed channel bottoms within the leasehold have been estimated to be quite high, potentially resulting in more than a 50 percent reduction of flow volumes during runoff events that occur along the major channels within the leasehold (see Chapter 15, Hydrologic Description).

Review of historical daily records from both the three upper PWCC sites (PWCC Annual Hydrology Reports, 1997 through 2002, see Preface to Chapter 15, Hydrologic Description) and the USGS Moenkopi gage (NWISWeb, 2002) indicate significant loss of runoff from the upper basin area can occur. From August 7 through August 8, 1987, 1,328.7 acre-feet of runoff was measured at the three PWCC gages. One large event was measured at SW155 on August 8, featuring a peak discharge of 10,100 cfs and a total runoff volume of 638.7 acre-feet. Total runoff volume measured at the USGS gage from August 8 through 9, 1987 was 668.7 acre-feet, suggesting almost 50 percent of the total runoff (1,328.7 acre-feet) from the three upper sites was lost downstream if these were the sole source of runoff recorded at Moenkopi. On August 16, 1989, summer thunderstorms generated moderate-sized flash floods at all three gages at about 1600 hours, resulting in a total runoff volume of 524.8 acre-feet. No runoff had occurred at any of the three sites for at least 6 days prior. Runoff at the USGS Moenkopi gage was only 1.3 acre-feet on the same day, and only

117 acre-feet was measured on August 17, 1998. The record comparison indicates about 77 percent of the 524.8 acre-feet of runoff generated from this portion of the basin was lost. On July 27, 1998, a flash flood passed by SW25 at a peak flow of 1,650 cfs resulting in a total runoff volume of 206.7 acre-feet. This one event was more than 37 percent of the total runoff measured at the three PWCC gages in 1998. The USGS gage measured only 14 acre-feet of runoff from July 27 through 29, 1998, indicating a loss of more than 93 percent of the 206.7 acre-feet. It is likely the 14 acre-feet measured at the USGS gage was comprised of return flow from bank storage from the upstream, 70-mile channel reach, and that the entire volume of the 200-plus acre-feet runoff event from the upper basin was lost in the channel. It should be pointed out that these comparisons assume no additional inflows to Moenkopi Wash below the leasehold occurred. This is an unlikely assumption considering that the entire basin above the USGS gage is large, and summer thunderstorms in the region often move great distances while maintaining high rainfall amounts and intensities, even though the areal extent of individual storm cells may be relatively small.

Table 21 indicates actual runoff is highly variable from year to year in both the upper and lower portions of the Moenkopi basin. Runoff variability is closely related to the highly variable climatic differences typical in this semi-arid environment, and the limited areal extent and varying intensities of the storms that do occur. From 1987 through 2008, measured annual runoff at the three PWCC gages has ranged from 124.1 acre-feet in 1994 to a high of 4,105.8 acre-feet in 2006. For the same 22-year period, measured runoff at the USGS Moenkopi gage was also lowest in 1994, but the highest annual runoff was 13,974 acre-feet in 2001. Total measured runoff at the three PWCC gages in 1988 was greatly influenced by one extremely large runoff event measured at SW25 on August 26, 1988. The peak discharge was estimated at 25,000 cfs for a total runoff volume of 1,836 acre-feet. This one event accounted for more than 50 percent of the total runoff measured at the three PWCC gages in 1988. The total runoff measured at the three PWCC gages from August 25 through August 27, 1988 was 2,624.5 acre-feet, about 69 percent of the annual total measured in 1988. For the same period, the USGS gage measured 2,945.5 acre-feet, indicating that this extreme event fell on other portions of the Moenkopi basin and contributed additional runoff to the gage some 70 miles downstream.

By contrast, the total runoff measured at the USGS Moenkopi gage in 1988 was only the seventh highest of the twenty-two years presented for this gage (see Table 21). Combined total measured runoff at the three PWCC gages as a percentage of the USGS Moenkopi gage ranged widely from 5.7 percent in 2001 to 90.0 percent in 1998, illustrating the considerable variability in runoff within the basin. In fact, total measured runoff from the upper part of the basin (PWCC gages) in 2001 was only 5.7 percent of the highest annual measured runoff at the USGS Moenkopi gage (13,974 acre-feet).

Review of the measured daily records at both the three PWCC gages and USGS Moenkopi gage and the annual measured runoff shown in Table 21 suggests that 1) considerable amounts of runoff generated in the upper basin can be lost before reaching downstream locations, ranging from 50 percent of runoff events in excess of 1,000 acre-feet upwards to 100 percent for smaller events (200 acre-feet); 2) areal and temporal variability of runoff within both Dinnebito and Moenkopi basins is high; 3) channel transmission losses can significantly reduce annual runoff contributed from the upper portions of both basins; and 4) the impact of PWCC impounded areas in the upper part of both the Dinnebito and Moenkopi basins is minimal.

Peabody has monitored annual water levels and volumes in the MSHA size dams since construction, beginning with J7-DAM in August 1978. Estimates of water volumes in all ponds based on quarterly and monthly inspections were compiled for the years 1989, 1990, and 1996 through 2010. Table 23a is a compilation of the results of the above-referenced monitoring and water volume estimates. The values listed in each column are the volumes of water in acre-feet measured or estimated in the ponds and MSHA dams for each year or period presented.

Table 23a shows a 722 acre-foot increase in the amount of water impounded from 1996 to 1997, a 465 acre-foot increase from 1998 to 1999, and a 566 acre-foot increase from 2002 to 2003. Assuming the increases shown for these three periods represent only surface water runoff, dividing the amounts by the total impounded area present during each period yields values of annual runoff in inches of 0.22 for 1997, 0.13 for 1999, and 0.17 for 2003. The values compare reasonably well with the inches of runoff measured at the three PWCC gages in 1997 (0.28) and 1999 (0.16) as shown on Table 21. The annual runoff measured at the PWCC gages in 1999 was only 12.6 percent of the annual runoff measured some 70 miles downstream at the USGS Moenkopi gage. The estimate of runoff based on the increase in the amount of water impounded for 2003 (0.17 inches) is lower than the 0.26 inches of runoff measured at the three PWCC gages in 2003 (PWCC, 2004), but likely resulted from the variability of storm events that occurred during 2003 in the upper portion of the Moenkopi basin. Considering the variability in measured annual runoff from year to year at the upper portion of the Moenkopi basin at PWCC's leasehold compared to measurements made further downstream at the USGS gage at Moenkopi, impounded runoff in

TABLE 23a

Summary of Maximum Impounded Surface Runoff in

MSHA Dams and Sediment Ponds by Year

(Acre-feet)

Year	J2-A	J-7	J7-JR	J16-A	J16-L	N14-D	N14-E	N14-F	N14-G	N14-H	All Other Ponds[1]	Total
8/78-8/79		137										
8/79-8/80		117										
8/80-8/81		37										
8/81-8/82		182		**		8	**	0.5	5		60	256
8/82-8/83		180		**		80	**	2	6		60	328
8/83-8/84		425		13	220	153	**	4	40		60	915
8/84-8/85		305		4	***	150	**	4	26		60	549
8/85-8/86	*	335		10	65	153	**	4	13	2	60	642
1989-1990	42	300		50	69	107	0.1	6	35	38	305	952
1996	24	100		3	36	29	2	1	2	29	88	314
1997	47	338		48	101	90	**	3	33	47	329	1036
1998	36	140		8	44	53	**	0.4	15	39	295	630
1999	23	293		63	235	123	1	6	43	73	235	1095
2000	17	184		15	137	70	**	3	33	59	158	676
2001	14	157	*	44	104	34	**	2	19	30	233	637
2002	30	96	4	34	115	24	**	1	21	21	172	518
2003	36	85	72	92	222	162	13	17	63	68	255	1084
2004	63	162	166	93	207	159	4	16	61	68	205	1205
2005	32	221	198	29	136	90	2	6	43	57	247	1061
2006	5	252	178	43	103	72	1	6	20	30	326	1036
2007	21	369	164	47	160	120	4	7	24	27	427	1370
2008[2]	131	424	156	103	286	146	2	26	65	48	395	1782
2009[3]	38	342	146	59	29	74	1	16	37	30	173	945
2010[4]	24	232	119	168	254	52	9	27	64	32	291	1272

* Pond under construction ** Negligible amount of water impounded *** Pond drained for repair

1 Assumed 60 acre-feet impounded each year between 8/81 and 8/86

2 Ponds J2-A and J16-L were dewatered 78 acre-feet and 242 acre-feet, respectively, during 2008

3 Pond J-7 was dewatered 9 acre-feet during 2009

4 Pond J16-A was dewatered 34 acre-feet during 2010

TABLE 23c

Channel Bed Infiltration Loss for Each Hour of Flow Over the Channel Bed Area Between the Leasehold and the Town of Moenkopi

Channel Bottom Area for Each Lineal Foot in Acres	Infiltration Rate in feet/hour	Acre Feet of Flow Loss for Each Mile of Flow with an 18.4 Hour Duration
.0018	.083	14.5

The above analysis was performed using very conservative numbers. Average channel bottom widths from the leasehold to the town of Moenkopi are considerably larger than 80 feet and would account for larger infiltration losses per mile than were used. Channel bed infiltration rates are considerably higher than the 1 inch per hour rate that was used. This rate is probably more indicative of saturated flow infiltration rates. The flow duration would increase as the flow hydrograph peak lowers and the flow rate slows in the downstream direction. The 18.4 hours is the shortest time span during which flow losses over each square foot of the channel would occur. Finally the total flow volume used (644 acre feet) is extreme and is an accumulation of runoff from many storms. Individual storm volume totals lost due to the impoundments would be considerably smaller and totally lost as channel bed infiltration in shorter distances from the leasehold. Considering watershed areas, estimates of annual runoff, comparisons of daily stream flow measurements and measured annual runoff, and runoff volumes impounded, the sediment ponds and dams on the leasehold do not have any measurable impact on surface water use at the town of Moenkopi.

Effects of Dams, Sediment Ponds and Permanent Internal Impoundments on Stream-Water Quality. The effects of pond and dam discharges on stream-water quality will be negligible, because all sediment ponds and dams are designed to contain the 10-year, 24-hour runoff volumes plus sediment. Pond and dam discharges resulting from storm runoff have and should continue to be infrequent. In the event of their occurrence, PWCC will make all efforts to comply with the effluent limits and monitoring requirements of the NPDES permit (No. NN0022179, Attachment 3, Chapter 16, Hydrologic Monitoring Program). The disposal of sediment removed from sediment ponds is conducted in a manner that protects stream water quality and is described in the section entitled "Design Methodology" of Chapter 6, Facilities.

The NPDES Permit allows pond dewatering as a means of providing sufficient detention time and storage to help ensure discharge effluent limits are met and there are no significant water quality impacts to the streams. Pond to pond pumping is also periodically employed. Seepage from dam embankments or around the sides of embankments is also presently being monitored in accordance with the NPDES Permit to ensure that pond seepage poses no significant threat to the receiving stream water quality.

Runoff discharges from the permanent internal impoundments are extremely unlikely. Should they occur, impacts to the stream-water quality will be negligible. Table 24 shows average concentrations for select chemical constituents measured in permanent internal impoundments from 1986 through 2010. Almost all the impoundments selected contain surface water runoff and have no appreciable ground-water contribution from resaturated spoil, with the exception of Pond N2-RA. Table 25 shows average concentrations for the same chemical constituents measured in stream flows generated by rainfall runoff at stream monitoring sites for the same period. Excepting pond N2-RA, water quality documented in the permanent internal impoundments is similar to slightly lower in range and magnitude compared to stream flows.

Annual Hydrology Reports (AHR's) present comparisons of recent and historical pond and stream water quality data with existing numeric limits for livestock drinking water and other uses. Sources of the livestock drinking water limits used in the AHR's include the Navajo EPA (2008) and Hopi Tribe (2010). In the March 5, 2001 Hydrologic Monitoring Program Permit Revision package, PWCC attached the document entitled "Justification of Monitor and Monitoring Frequency Reductions at the Black Mesa and Kayenta Mines, Arizona" (PWCC, 2001). The document presents a thorough evaluation of summary statistics, water types, trend analyses, and comparisons of historical stream water quality with livestock and other use limits. Based on the livestock limit comparisons presented in the document that used total recoverable metal analyses, all stream flow generated by storm runoff is not suitable for livestock drinking water. The document also mentions, if only dissolved analyses are used for comparison purposes, most of the stream water quality is suitable for livestock drinking.

The Navajo Nation's surface water quality standards (NNEPA, 2008) establish livestock drinking water limits using both dissolved (B, Co, Cu & V) and total (As, Cd, Cr, Pb, Se & Zn) metal analyses. Using these standards, and those promulgated by the Hopi Tribe (Hopi, 2010), and recommended standards for TDS (NAS, 1974) and sulfate (Botz and Pedersen, 1976), comparisons were made between permanent internal impoundment and stream flow water quality collected from 1986 through 2010. Table 26 lists the

TABLE 24

Mean Concentrations of Selected Chemical Parameters Measured In

Permanent Internal Impoundments on Reclaimed Areas

(1986-2010)

Monitoring Site

Parameter	116	124	118*	N1-RA	122*	123*	112*	113*	119*	N7-D	N2-RA	N2-RB	N2-RC	N8-RA
pH	8.2	7.8	8.6	9.5	8.0	7.5	7.8	7.9	7.9	8.1	8.7	8.1	8.6	8.0
TDS	459	205	144	440	143	177	281	603	165	939	8530	566	227	133
Alk	84	100	105	142	96	102	109	205	116	74	242	113	97	56
SO_4	225	68	16	197	15	21	98	252	25	595	5862	297	79	34
Ca	63	44	24	35	25	26	24	46	29	155	324	108	44	26
Mg	25	13	11	24	9	9	12	21	12	56	387	34	12	4
Na	29	4	5	70	4	7	44	117	9	41	1736	12	6	2
Cl	10	3	5	7	5	6	4	8	2	20	43	7	4	4

*Pre-law area ponds

TABLE 25

Mean Concentrations of Selected Chemical Parameters

Measured at Stream Station Sites

During Rainfall Runoff Events

(1986 - 2010)

Stream Monitoring Site

	Dinnebito Wash		Reed Valley Wash	Yellow Water Wash				Coal Mine Wash		R.P. Valley Wash[1]		Moenkopi Wash	
Parameter	34	78	37*	50	15	157	16	18**	25	14	155	35	26
pH	8.0	8.0	8.0	8.0	8.0	8.1	8.1	8.0	8.1	8.2	8.3	8.1	8.1
TDS	1130	1462	1485	755	686	229	471	1335	1534	271	348	292	958
Alk	98	87	121	86	85	112	80	123	129	95	99	68	101
SO_4	699	919	694	437	398	112	242	809	932	106	148	118	543
Ca	168	191	162	125	127	48	87	165	168	46	48	52	131
Mg	64	95	105	44	34	8	19	80	93	12	13	11	55
Na	65	96	100	19	16	4	13	104	140	15	35	5	71
Cl	16	22	213	17	10	3	8	27	22	10	11	4	41

Notes:

1 Red Peak Valley Wash

* Excludes chemical data for two samples that were influenced by magnesium chloride spills, upgradient of this monitoring site.

** Includes chemical data from sub-sites FLUM18 and CG18.

comparison results for the permanent internal impoundments, and Table 27 shows the comparison results for the stream monitoring sites. Table 26 shows that, excepting the high pH values measured in PIIs N1-RA and N2-RA, the high TDS and sulfate values at pond N2-RA, and only single excursions of these same standards at four other ponds historically, the permanent impoundment water quality is suitable for use as livestock drinking water. Table 27 also indicates most of the stream flow generated by rainfall runoff meets the pH, NO3_NO2, TDS and sulfate standards. Historical analyses for the dissolved forms of trace elements indicate rainfall runoff meets livestock drinking water standards expressed as dissolved. Occurrences of high values for trace elements expressed as total or total recoverable are attributed to high sediment loads typically featured in rainfall runoff. The high pH values documented in Pond N1-RA would likely be reduced by contact with soil and channel bed materials if a discharge occurs. An unlikely discharge from either Pond N1-RA or N2-RA would be diluted when mixing with the larger volumes of stream flow runoff. Due to the similarity in water quality between permanent internal impoundments and stream flows, discharges from permanent internal impoundments would not significantly affect stream-water quality, and would not change the potential stream water use.

<u>Effects of Stream Channel Diversions on Channel Characteristics and Runoff Water Quality</u>. Six channel diversions affecting approximately 6.0 miles of channel in tributaries to Moenkopi Wash have or will be constructed during the life of the mining operations. The effects of channel diversions on channel characteristics and stability will be minor for the following reasons. All diversion channels will be at least as wide as the existing channel, which should eliminate the potential for flow constrictions and excessive lateral erosion. All diversion channel slopes will approximate original channel slopes so that comparable flow velocity ranges will be maintained. Energy dissipators will be constructed at the entrance and exit points of each diversion to provide an additional control on flow velocities and erosion potential at these points. The only anticipated channel effects from the diversions would be the channel's natural tendency to reestablish meanders. This will cause some minor erosion on alternating sides of the diversion where the meandering thalweg intersects side slopes. The stability of the channel diversions will be no less than the stability of the natural channels.

The diversion channel construction activity and the natural meandering tendency of the active channel thalweg will expose fresh alluvial surfaces to weathering and erosion. This will result in additional amounts of sediment and dissolved chemicals being contributed to the streamflows. Several years of monitoring downstream from the Coal Mine Wash and Yazzie Wash channel changes indicates that natural background levels of

Table 26

Exceedances of Livestock Drinking Water Limits at Permanent Internal Impoundments (1986 - 2010)

Analyte	Standard	No. Sites	Sites	Frequency	Exceedence Date Range	Exceedence Value Range	Exceedence Median
LIVESTOCK WATERING STANDARDS -- NNEPA (2008), Hopi (2010), NAS (1974), Botz and Pederson (1976)							
Aluminum, Dissolved	0.0000 - 5.0000	0	none				
Boron, Dissolved	0.0000 - 5000.0000	0	none				
Copper, Dissolved	0.0000 - 500.0000	0	none				
Field Ph	6.5000 - 9.0000	5	N1-RA-P	11/0/0/13	01/28/92-09/18/00	9.1200 - 10.6100	9.4600
			N2-RA-P	5/0/0/28	01/13/06-07/21/10	9.1500 - 9.7200	9.3500
			N2-RB-P	1/0/0/4	01/28/99-01/28/99	9.1000 - 9.1000	9.1000
			PII116-P	1/0/0/2	07/28/98-07/28/98	9.0200 - 9.0200	9.0200
			PII118-P	1/0/0/5	05/27/93-05/27/93	9.4200 - 9.4200	9.4200
NO3_NO2 Nitrogen_N	0.0000 - 132.0000	0	none				
Solids, Dissolved	0.0000 - 6999.0000	1	N2-RA-P	19/0/0/33	03/05/86-04/10/00	7832.0000 - 18100.0000	12708.0000
Sulfate	0.0000 - 3000.0000	2	N2-RA-P	22/0/0/33	03/05/86-07/07/05	3690.0000 - 12965.0000	8080.0000
			N7-D-P	1/0/0/10	12/09/92-12/09/92	3482.0000 - 3482.0000	3482.0000
Total Recoverable As	0.0000 - 200.0000	0	none				
Total Recoverable Cd	0.0000 - 50.0000	0	none				
Total Recoverable Cr	0.0000 - 1000.0000	0	none				
Total Recoverable Cu	0.0000 - 500.0000	0	none				
Total Recoverable Hg	0.0000 - 10.0000	0	none				
Total Recoverable Pb	0.0000 - 100.0000	2	N2-RA-P	1/0/4/26	09/20/90-07/07/05	200.0000 - 200.0000	200.0000
					(<)	200.0000 - 400.0000	300.0000
			N2-RC-P	0/0/1/5	07/21/99-07/21/99(<)	200.0000 - 200.0000	200.0000
Total Recoverable Se	0.0000 - 50.0000	0	none				
Total Recoverable V	0.0000 - 100.0000	0	none				
Total Recoverable Zn	0.0000 - 25.0000	0	none				
Vanadium, Dissolved	0.0000 - 100.0000	1	N2-RA-P	0/0/1/22	03/05/86-03/05/86(<)	500.0000 - 500.0000	500.0000

Frequency = uncensored/between MDL&PQL/censored/no. samples, (B) = Between MDL&PQL range, (<) = Censored range

Table 27

Exceedences of Livestock Drinking Water Limits at Stream Monitoring Sites During Rainfall Runoff Events (1986-2010)

Analyte	Standard	No. Sites	Sites	Frequency	Exceedence Date Range	Exceedence Value Range	Exceedence Median
LIVESTOCK DRINKING WATER STANDARDS -- NNEPA (2008), HOPI (2010), NAS (1974), BOTZ AND PEDERSON (1976)							
Aluminum, Dissolved	0.0000 - 5.0000	0	none				
Arsenic, Dissolved	0.0000 - 200.0000	0	none				
Boron, Dissolved	0.0000 - 5000.0000	0	none				
Cadmium, Dissolved	0.0000 - 50.0000	0	none				
Chromium, Dissolved	0.0000 - 1000.0000	0	none				
Copper, Dissolved	0.0000 - 500.0000	0	none				
Field Ph	6.5000 - 9.0000	0	none				
Lead, Dissolved	0.0000 - 100.0000	0	none				
Mercury, Dissolved	0.0000 - 10.0000	0	none				
NO3_NO2 Nitrogen_N	0.0000 - 132.0000	0	none				
Selenium, Dissolved	0.0000 - 50.0000	1	CG37	0/0/1/10	05/07/92-05/07/92(<)	200.0000 - 200.0000	200.0000
Solids, Dissolved	0.0000 - 6999.0000	2	CG37	2/0/0/21	05/07/92-11/01/95	7600.0000 - 10170.0000	8885.0000
			SW25	1/0/0/41	07/21/98-07/21/98	7750.0000 - 7750.0000	7750.0000
Sulfate	0.0000 - 3000.0000	3	CG37	1/0/0/21	05/07/92-05/07/92	6660.0000 - 6660.0000	6660.0000
			FLUM18	1/0/0/10	07/24/91-07/24/91	3132.0000 - 3132.0000	3132.0000
			SW25	3/0/0/41	07/10/92-04/15/05	3460.0000 - 4880.0000	4116.0000
Total Recoverable Al	0.0000 - 5.0000	14	CG14	14/0/0/14	08/06/91-10/23/00	33.6000 - 1090.0000	273.5000
			CG157	10/0/0/10	07/23/91-08/22/00	14.0000 - 976.0000	273.0000
			CG18	9/0/0/9	07/23/97-07/10/01	70.4000 - 1950.0000	519.0000
			CG34	32/0/0/32	07/28/89-07/29/10	7.9100 - 2490.0000	400.5000
			CG37	17/0/0/17	07/28/89-10/23/00	15.1000 - 1440.0000	262.0000
			CG78	18/0/0/19	07/28/89-08/05/05	8.9100 - 1360.0000	223.5000
			FLUM15	12/0/0/12	07/05/90-05/19/01	15.4000 - 1480.0000	484.0000
			FLUM18	6/0/0/6	07/24/91-08/25/96	38.4000 - 507.0000	198.0000
			SW155	24/0/0/24	07/29/91-07/29/10	11.5000 - 2190.0000	359.5000
			SW16	14/0/0/15	09/05/90-07/10/01	99.4000 - 1270.0000	353.0000
			SW25	31/0/0/33	07/31/89-07/30/10	8.1300 - 1650.0000	241.0000
			SW26	31/0/0/34	07/24/91-07/29/10	12.4000 - 1650.0000	258.0000
			SW35	10/0/0/10	07/28/89-07/09/01	40.6000 - 586.0000	147.0000
			SW50	11/0/0/11	08/06/91-08/22/00	157.0000 - 1660.0000	421.0000
Total Recoverable As	0.0000 - 200.0000	11	CG157	1/0/0/10	07/23/91-07/23/91	400.0000 - 400.0000	400.0000
			CG34	6/0/0/32	07/17/90-07/29/10	210.0000 - 1550.0000	290.0000
			CG37	4/0/0/17	07/28/89-08/10/00	220.0000 - 310.0000	285.0000
			CG78	2/0/0/19	07/28/89-08/03/00	300.0000 - 540.0000	420.0000

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Table 27 (cont.)

Exceedences of Livestock Drinking Water Limits at Stream Monitoring Sites During Rainfall Runoff Events (1986-2010)

Analyte	Standard		No. Sites	Sites	Frequency	Exceedence Date Range		Exceedence Value Range		Exceedence Median
				FLUM15	1/0/0/12	07/23/91-07/23/91		500.0000 -	500.0000	500.0000
				FLUM18	1/0/0/6	07/24/91-07/24/91		800.0000 -	800.0000	800.0000
				SW155	2/0/0/24	07/29/91-07/29/10		220.0000 -	460.0000	340.0000
				SW16	3/0/0/15	09/05/90-07/24/91		350.0000 -	800.0000	400.0000
				SW25	3/0/0/33	07/31/89-07/30/10		280.0000 -	790.0000	470.0000
				SW26	3/0/0/34	07/24/91-07/29/10		230.0000 -	1200.0000	370.0000
				SW50	2/0/0/11	08/06/91-08/05/92		250.0000 -	300.0000	275.0000
Total Recoverable Cd	0.0000 -	50.0000	14	CG14	1/1/0/14	08/09/93-08/04/97		200.0000 -	200.0000	200.0000
							(B)	130.0000 -	130.0000	130.0000
				CG157	1/0/0/10	08/04/97-08/04/97		250.0000 -	250.0000	250.0000
				CG18	1/1/0/9	10/07/97-07/09/01		78.0000 -	78.0000	78.0000
							(B)	60.0000 -	60.0000	60.0000
				CG34	3/2/2/32	07/28/89-07/29/10		53.0000 -	440.0000	220.0000
							(B)	80.0000 -	90.0000	85.0000
							(<)	60.0000 -	200.0000	130.0000
				CG37	1/2/0/17	07/28/89-10/07/97		129.0000 -	129.0000	129.0000
							(B)	60.0000 -	100.0000	80.0000
				CG78	4/1/0/19	07/28/89-10/23/00		61.0000 -	120.0000	108.5000
							(B)	150.0000 -	150.0000	150.0000
				FLUM15	1/0/1/12	10/03/97-07/12/99		120.0000 -	120.0000	120.0000
							(<)	60.0000 -	60.0000	60.0000
				FLUM18	0/0/1/6	08/11/94-08/11/94	(<)	500.0000 -	500.0000	500.0000
				SW155	0/3/2/24	08/28/96-07/29/10	(B)	60.0000 -	130.0000	60.0000
							(<)	100.0000 -	100.0000	100.0000
				SW16	1/1/0/15	08/24/96-07/10/01		80.0000 -	80.0000	80.0000
							(B)	80.0000 -	80.0000	80.0000
				SW25	2/1/2/33	07/31/89-07/30/10		76.0000 -	250.0000	163.0000
							(B)	90.0000 -	90.0000	90.0000
							(<)	100.0000 -	100.0000	100.0000
				SW26	1/0/3/34	07/24/91-07/30/07		90.0000 -	90.0000	90.0000
							(<)	60.0000 -	100.0000	100.0000
				SW35	1/0/0/10	07/28/89-07/28/89		190.0000 -	190.0000	190.0000
				SW50	0/0/2/11	08/25/96-06/17/99	(<)	60.0000 -	60.0000	60.0000
Total Recoverable Cr	0.0000 -	1000.0000	10	CG14	1/0/0/14	08/06/91-08/06/91		1200.0000 -	1200.0000	1200.0000
				CG18	0/1/0/9	06/17/99-06/17/99	(B)	2200.0000 -	2200.0000	2200.0000
				CG34	9/0/0/32	07/28/89-07/29/10		1070.0000 -	3200.0000	1530.0000
				CG78	3/0/0/19	07/08/98-08/05/05		1160.0000 -	1300.0000	1300.0000
				FLUM15	2/0/0/12	07/23/91-06/17/99		1100.0000 -	1500.0000	1300.0000
				SW155	3/0/0/24	07/30/06-07/29/10		1220.0000 -	2680.0000	2300.0000
				SW16	1/0/0/15	07/21/98-07/21/98		1270.0000 -	1270.0000	1270.0000
				SW25	4/0/0/33	07/13/95-07/30/10		1050.0000 -	1900.0000	1645.0000
				SW26	2/0/0/34	07/24/91-07/23/97		1200.0000 -	1900.0000	1550.0000
				SW50	3/0/0/11	08/06/91-06/17/99		1100.0000 -	1700.0000	1500.0000

Table 27 (cont.)

Exceedences of Livestock Drinking Water Limits at Stream Monitoring Sites During Rainfall Runoff Events (1986-2010)

Analyte	Standard		No. Sites	Sites	Frequency	Exceedence Date Range		Exceedence Value Range		Exceedence Median
Total Recoverable Cu	0.0000 -	500.0000	14	CG14	7/0/0/14	08/06/91-07/14/99		520.0000 -	2200.0000	810.0000
				CG157	4/0/0/10	07/23/91-08/22/00		900.0000 -	1270.0000	1075.0000
				CG18	6/1/0/9	07/23/97-07/09/01		530.0000 -	1120.0000	770.0000
							(B)	2500.0000 -	2500.0000	2500.0000
				CG34	17/0/0/32	07/28/89-07/29/10		540.0000 -	4140.0000	1200.0000
				CG37	6/0/0/17	07/28/89-07/13/99		610.0000 -	1600.0000	985.0000
				CG78	7/0/0/19	07/28/89-08/05/05		600.0000 -	2400.0000	1620.0000
				FLUM15	6/0/0/12	07/23/91-07/12/99		640.0000 -	2100.0000	1255.0000
				FLUM18	1/0/0/6	07/24/91-07/24/91		900.0000 -	900.0000	900.0000
				SW155	13/0/0/24	07/29/91-07/29/10		560.0000 -	2600.0000	1000.0000
				SW16	7/0/0/15	09/05/90-07/10/01		650.0000 -	2010.0000	1000.0000
				SW25	12/1/0/33	07/31/89-07/30/10		560.0000 -	2920.0000	1215.0000
							(B)	900.0000 -	900.0000	900.0000
				SW26	12/0/0/34	07/24/91-09/04/09		560.0000 -	2800.0000	725.0000
				SW35	2/0/0/10	07/28/89-07/09/99		800.0000 -	900.0000	850.0000
				SW50	6/0/0/11	08/06/91-08/22/00		570.0000 -	3500.0000	1205.0000
Total Recoverable Hg	0.0000 -	10.0000	3	CG34	1/0/0/21	07/08/98-07/08/98		13.0000 -	13.0000	13.0000
				SW26	1/0/0/21	07/24/91-07/24/91		12.0000 -	12.0000	12.0000
				SW50	1/0/0/11	08/06/91-08/06/91		20.0000 -	20.0000	20.0000
Total Recoverable Pb	0.0000 -	100.0000	14	CG14	5/3/4/14	08/06/91-10/23/00		380.0000 -	1700.0000	700.0000
							(B)	230.0000 -	700.0000	400.0000
							(<)	200.0000 -	400.0000	300.0000
				CG157	4/2/1/10	07/23/91-08/22/00		190.0000 -	970.0000	745.0000
							(B)	900.0000 -	1000.0000	950.0000
							(<)	200.0000 -	200.0000	200.0000
				CG18	2/5/1/9	07/23/97-07/09/01		380.0000 -	650.0000	515.0000
							(B)	300.0000 -	3000.0000	700.0000
							(<)	400.0000 -	400.0000	400.0000
				CG34	12/9/2/32	07/28/89-07/29/10		130.0000 -	3600.0000	1490.0000
							(B)	140.0000 -	800.0000	500.0000
							(<)	200.0000 -	200.0000	200.0000
				CG37	9/4/1/17	07/28/89-10/23/00		130.0000 -	1400.0000	700.0000
							(B)	120.0000 -	500.0000	340.0000
							(<)	200.0000 -	200.0000	200.0000
				CG78	8/4/2/19	07/28/89-08/05/05		130.0000 -	2000.0000	580.0000
							(B)	200.0000 -	1500.0000	350.0000
							(<)	200.0000 -	400.0000	300.0000
				FLUM15	4/6/1/12	07/05/90-05/19/01		510.0000 -	1800.0000	895.0000
							(B)	140.0000 -	1900.0000	450.0000
							(<)	200.0000 -	200.0000	200.0000
				FLUM18	4/1/1/6	07/24/91-08/25/96		210.0000 -	700.0000	360.0000
							(B)	200.0000 -	200.0000	200.0000
							(<)	200.0000 -	200.0000	200.0000

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Table 27 (cont.)

Exceedences of Livestock Drinking Water Limits at Stream Monitoring Sites During Rainfall Runoff Events (1986-2010)

Analyte	Standard	No. Sites	Sites	Frequency	Exceedence Date Range		Exceedence Value Range	Exceedence Median
			SW155	7/12/2/24	07/29/91-07/29/10		300.0000 - 2900.0000	690.0000
						(B)	140.0000 - 2000.0000	450.0000
						(<)	400.0000 - 800.0000	600.0000
			SW16	8/5/2/15	07/28/89-07/10/01		300.0000 - 1500.0000	1000.0000
						(B)	110.0000 - 600.0000	200.0000
						(<)	200.0000 - 200.0000	200.0000
			SW25	11/9/5/33	07/31/89-07/30/10		120.0000 - 2500.0000	700.0000
						(B)	170.0000 - 1900.0000	500.0000
						(<)	200.0000 - 1000.0000	200.0000
			SW26	11/13/4/34	07/24/91-07/29/10		140.0000 - 3000.0000	580.0000
						(B)	110.0000 - 900.0000	300.0000
						(<)	200.0000 - 800.0000	600.0000
			SW35	2/4/2/10	07/28/89-07/09/01		200.0000 - 400.0000	300.0000
						(B)	190.0000 - 700.0000	300.0000
						(<)	200.0000 - 200.0000	200.0000
			SW50	5/5/1/11	08/06/91-08/22/00		230.0000 - 3100.0000	450.0000
						(B)	300.0000 - 1600.0000	600.0000
						(<)	400.0000 - 400.0000	400.0000
Total Recoverable Se	0.0000 - 50.0000	1	CG34	2/0/0/32	07/08/98-08/05/05		60.0000 - 75.0000	67.5000
Total Recoverable V	0.0000 - 100.0000	14	CG14	13/0/0/14	08/06/91-10/23/00		130.0000 - 2400.0000	640.0000
			CG157	9/0/0/10	07/23/91-08/22/00		142.0000 - 2030.0000	810.0000
			CG18	9/0/0/9	07/23/97-07/10/01		143.0000 - 3800.0000	940.0000
			CG34	27/0/0/32	07/28/89-07/29/10		116.0000 - 4780.0000	1060.0000
			CG37	15/0/0/17	07/28/89-10/23/00		190.0000 - 2820.0000	760.0000
			CG78	15/0/0/19	07/28/89-08/05/05		120.0000 - 2650.0000	650.0000
			FLUM15	11/0/0/12	07/05/90-05/19/01		160.0000 - 2820.0000	990.0000
			FLUM18	5/0/0/6	07/24/91-08/25/96		400.0000 - 1500.0000	400.0000
			SW155	21/0/0/24	07/29/91-07/29/10		264.0000 - 4500.0000	860.0000
			SW16	14/0/0/15	09/05/90-07/10/01		200.0000 - 2700.0000	850.0000
			SW25	27/0/0/33	07/31/89-07/30/10		106.0000 - 3560.0000	670.0000
			SW26	27/0/0/34	07/24/91-07/29/10		109.0000 - 3180.0000	600.0000
			SW35	8/1/0/10	07/28/89-07/09/01		110.0000 - 1200.0000	380.0000
						(B)	290.0000 - 290.0000	290.0000
			SW50	11/0/0/11	08/06/91-08/22/00		340.0000 - 3100.0000	740.0000
Total Recoverable Zn	0.0000 - 25.0000	0	none					
Vanadium, Dissolved	0.0000 - 100.0000	0	none					
Zinc, Dissolved	0.0000 - 25.0000	0	none					

Frequency = uncensored/between MDL&PQL/censored/no. samples, (B) = Between MDL&PQL range, (<) = Censored range

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sediment are so high that these minor additions are negligible (Chapter 15). Dissolved chemical loads have been historically quite variable. Stream water chemistry appears to be significantly affected by the portion of the watershed the flow originates in and the magnitude of the sediment load being transported by the flow. The cation exchange capacity of the sediment is high, and this does affect the flow chemistry. It is concluded that the water chemistry effects of channel diversions are minimal as they cannot be distinguished from natural fluctuations.

Effects of Culverts at Road Crossings on Stream Runoff and Water Quality. The effects of culverts on stream runoff and water quality will be minimal for the following reasons. All culverts or combinations of culverts are designed to pass the 10-year 6-hour flow with at least 1 foot of freeboard. If culvert exit velocities exceed six feet per second, riprapped energy dissipators will be employed to reduce the velocities. If exit velocities are between four to six feet per second, culverts will be inspected periodically for evidence of accelerated erosion immediately below their outfalls. If accelerated erosion is occurring, riprapped energy dissipators will be constructed at these points. Finally, these structures involve such minor areas of disturbance that chemical and sediment changes in the flows will be undetectable.

Removal of Pre-existing Surface Water Structures. One pre-existing surface water structure (DM-1) will be removed as a result of constructing the Reed Valley Wash channel diversion. One pre-existing structure (DM-7) was disturbed as a result of upgrading the original embankment for sediment control (K-P pond). The K-P pond has since been reclaimed because it became a redundant pond as a result of the completion of Wild Ram Valley Dam (J2-A pond) downstream. One pre-existing structure (DM-9) was impacted by construction of the main J-1/N-6 haul road. A portion of the pre-existing watershed was truncated as a result of the haul road alignment. The pre-existing watershed will not be restored because the haul road will most probably be retained as part of the postmining land use plan.

The probable hydrologic consequences of mining and related activities on 22 actual or suspected pre-existing surface water structures will be nill or inconsequential. This conclusion is reached for one or more of the following reasons: 1) minimal or no direct or indirect physical disturbance will occur at several of the pond sites or in impounding watersheds during the life-of-mine activities; 2) several sites do not actually exist; 3) several structures are non-functional due to structural failure; and 4) several structures are not applicable to this permitting action.

Interim impacts caused by the loss of the three structures previously discussed have been or will be mitigated by providing alternate water sources (N-aquifer public water standpipes and existing and proposed sediment control structures). The three structures will be replaced with one of vastly superior structural design following the completion of mining and reclamation in the affected areas.

The loss of structure DM-7 will be mitigated by the retention of the J2-A pond as a permanent impoundment. The loss of DM-9 will be mitigated by the retention of several pre-law internally draining ponds in reclaimed portions of the J-1/N-6 or J-3 coal resource areas, or the retention of Ponds J3-D or J3-E as permanent impoundments. The loss of structure DM-1 will be mitigated by the retention of the J16-L sediment control structure (Reed Valley Dam) as a permanent impoundment. All the proposed permanent impoundments currently meet, or will be upgraded to meet the permanent performance standards (see Chapter 6 for design information). All proposed permanent impoundments and pre-law internally draining ponds have been demonstrated to have superior persistence capabilities (see Chapters 6 and 15 and Appendix E to Permit AZ-0001E and the 1/17/94 cover letter response, including Appendices 1 and 2, to technical Deficiency Number 3 to Chapter 16, Permit AZ-0001D). Monitoring of water quality will provide sufficient information to demonstrate the suitability of these sources to support the intended post-mining land uses.

<u>Effects of Runoff From Reclaimed Areas on the Quantity and Quality of Streamflow</u>. Considering the natural physiographic region in which Peabody is reclaiming lands disturbed by mining, and criteria imposed by regulatory authorities for evaluating reclamation efforts with regard to bond release, probable hydrologic consequences of runoff from post-law reclaimed areas is addressed in the following sections. Bond release criteria include the successful establishment of vegetative cover, topsoil stabilization, and the effects of runoff from reclaimed areas on the quantity and quality of waters in the receiving streams. Runoff from reclaimed areas will flow into receiving streams following the removal of sediment structures at the time of bond release.

Reclamation efforts undertaken by Peabody in post-law coal resource areas on the leasehold occur in a physiographic region typified by a mild mean annual temperature (48F) and a low mean annual precipitation (10 inches). Mean annual precipitation is based on nonheated recording rain gauges. Including the contributions from snow, the mean effective precipitation on the leasehold is about twelve inches. Typical basin morphologies in the region include highly eroded landscapes of moderate to high relief, with entrenched sandbed channels and headward-cutting arroyos.

In this arid climate, intense summer thunderstorms produce flash-flooding in ephemeral channels resulting in high concentrations of sediment loads (10^5 mg/l). The highly erodible natural soils provide a significant contribution to the sediment yields produced in this climate. The limited vegetative cover in this region due to climatic and grazing conditions contributes to the flashy response of ephemeral channels from intense storms. Figure 21a shows a relationship among effective annual precipitation (EAP), climate and annual sediment yield (Langbein and Schumm 1958). Considering this diagram, EAP and climate on Black Mesa correlate to the highest annual sediment yields. Figure 21b shows the same relationship as Figure 21a, including the effect of mean annual temperature (MAT) (Schumm 1977). MAT on Black Mesa, in combination with EAP and climate, correlate to extreme annual sediment yields. Estimates of annual sediment yields (tons/mi^2) on the leasehold, incorporating site-specific parameters into the USLE, range between 4,666 tons/mi^2 and 14,477 tons/mi^2. These estimates were made taking into account the factors that affect erosion in the region, including the typical sparse cover and highly erodable soils (see Annual Sediment Yield Estimates, Chapter 15).

Reclaimed areas created by Peabody on Black Mesa will have topography characterized by long slopes no greater than 3:1 (h:v). Topsoil material used to cover regraded spoil material will be spread to a minimum depth of twelve inches. Spoil material will be compacted to some degree during regrading, as it contains higher clay contents than topsoil material. The only suitable topsoil materials available are highly erosive due to their overall fine-sandy texture and lack of organic material, and are typical of those forming regionally under arid conditions. The "K" value assigned to topsoil material used for reclaimed areas by Intermountain Soils, Inc. personnel is .43 (Chapter 8), which confirms the high erosion potential of the topsoil.

Topsoiled reclaimed areas will feature vegetation established sufficiently to support the stabilization of topsoil material and the postmining land use of livestock grazing.

Vegetative ground cover in the reclaimed areas will be similar to the native vegetation. For a discussion of vegetative ground cover and success standards for cover see Chapters 23 and 26, Permit AZ-0001E.

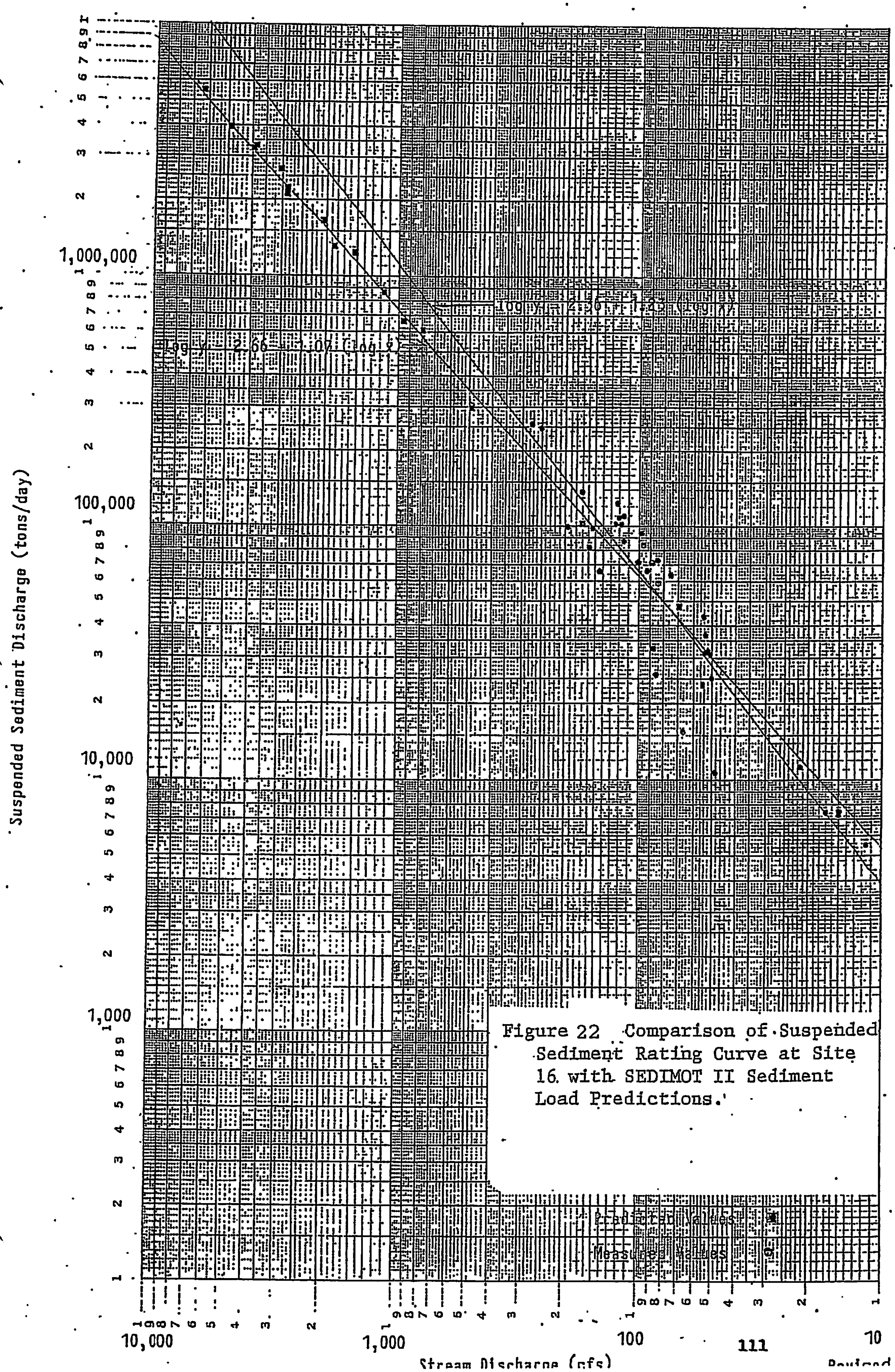

Figure 22 Comparison of Suspended Sediment Rating Curve at Site 16 with SEDIMOT II Sediment Load Predictions.

areas become less pronounced. Model predictions for the entire Coal Mine Wash watershed at Site 18 show a reduction in sediment yield (5 percent) and a 1 percent increase in peak sediment concentration for postmining conditions. The order of magnitude for both predicted parameters is 10^5, which diminishes the significance of the difference in these parameters between premining and postmining conditions.

As flow in receiving streams proceeds downstream, lateral inflow from undisturbed watersheds will contribute to sediment loads in the main channels. These additional contributions will tend to mask the localized decreases in sediment loads resulting from watersheds comprised mainly of reclaimed areas. Finally, sediment yield contributions from channel beds and sides may be as high as 40 percent, which will offset the predicted reductions in sediment loads from reclaimed areas. Channel contributions to sediment loads are predicted to completely mask the localized effects of reclaimed area contributions in the downstream direction.

Water Quality. Receiving stream-water quality has been monitored since 1981 at stream station sites on the leasehold (see Stream Water Quality Section, Chapter 15). Permanent internal impoundments (PII) established in both pre-law and post-law reclaimed areas on Peabody's leasehold have also been sampled for water quality. Previously introduced tables 24 and 25 are summaries of sample means for selected major chemical parameters. Table 24 presents mean parameter values measured in PII's from 1986 through 2010 that were constructed in both pre-law and post-law areas, and Table 25 presents mean parameter values measured at stream station sites for the same period.

Generally, PII's created in pre-law areas have water quality similar to post-law areas. Runoff flowing into PII's in pre-law areas occurs on regraded spoil material. Although post-law areas were topsoiled, comparisons using mean parameter values from post-law and pre-law PII's indicate no significant differences in the quality of water flowing over spoil material versus topsoil material.

Mean chemical parameter values from PII's are similar to but slightly lower in range and magnitude compared with stream flows, with the exception of PII's N1-RA and N2-RA. Mean pH measured in PII's range between 7.5 and 8.6 (except PII N1-RA), while stream pH values range similarly between 8.0 and 8.3. Excepting PII N2-RA, which receives a significant amount of high-TDS water from resaturated spoil in addition to runoff from reclaimed to 135 feet which includes a fifteen foot apron on each side of the channel. The main channels and aprons will not be topsoiled to prevent topsoil loss. Application of the seed mixes will be used to revegetate and further stabilize the non-topsoiled areas.

The establishment of the drainage network outlined above will increase the overall time of concentration of flows and reduce peak flows from the reclaimed area basins. Flow velocities will be controlled, as surface manipulations, including those performed in downdrains and the main channels, provide roughness and resistance to scour. Thus, drainage development in reclaimed areas will be planned and controlled, thereby minimizing the number and size of rills. Landform stability and vegetative development supportive of the post-mining land use can be achieved, because the reclaimed area drainage development will have been controlled and reasonably stabilized rather than in a state of quasi-equilibrium between storms of large return periods as in the natural drainage system.

Summary

This chapter has presented a discussion of probable hydrologic consequences of the proposed life-of-mine mining plan. Table 28 summarizes the discussion by listing the probable hydrologic consequences and the results of the analysis of each. As can be seen, all the probable impacts have been determined to have either no impact or no short or long term significant impacts.

TABLE 28

Summary of Probable Hydrologic Consequences of the Life-of-Mine Mining Plan for the Kayenta Complex

Probable Hydrologic Consequences	Analysis Results	Significance
Ground Water		
1. Interruptions of ground-water flow and drawdown in the Wepo aquifer	Theoretical percent reductions in water levels range from 10 to 49 percent in 2 wells partially completed in Wepo Formation	No short or long term significant impacts
2. Removal or elimination of local wells and springs	Three local wells completed in the Toreva aquifer and one spring will be removed by mining. Alternate water supply is being provided until the wells and spring are replaced	Impact during the life of the pit. Following reclamation, Peabody will replace the wells and spring. No short or long term significant impacts
3. Containment and discharge of pit inflow pumpage	Pumpage can be treated with settling basins so that discharge meets applicable standards	No short or long term significant impacts

TABLE 28 (Cont.)

Summary of Probable Hydrologic Consequences of the Life-of-Mine Mining Plan for the Kayenta Complex

Probable Hydrologic Consequences	Analysis Results	Significance
Ground Water		
4. Impact of replaced spoil material on ground-water flow and recharge	Resaturation will take from a few to as many as 100 years. Water levels will recover to near premining levels. Water is not currently used to support land use activities due to quality and yield. Alternate water supply is available.	No short or long term significant impacts
5. Impact of replaced spoil on ground-water quality	Increased levels of Ca, Mg, Na, SO_4, HCO_3, and TDS in the resaturated portion of Wepo aquifer within mining areas only. Potential for acid formation and trace element migration is minimal. Water not currently used to support land use activities due to quality and yield. Alternative water supply available. Water use category will remain unchanged.	No short or long term significant impacts

TABLE 28 (Cont.)

Summary of Probable Hydrologic Consequences of the Life-of-Mine Mining Plan for the Kayenta Complex

Probable Hydrologic Consequences	Analysis Results	Significance
Ground Water		
6. Interruptions of Wepo recharge to the alluvial aquifer	0-20 foot localized (time and space) declines in portions of the alluvial aquifer near N-14, J-16 and J-19/20. No local use of alluvial aquifer on leasehold and water does not support critical habitat or species. Impact is transient.	No short or long term significant impact
7. Truncation of alluvial aquifers by dams	No observed impact on existing alluvial water levels since dams are mainly in small tributaries and Wepo discharges to alluvium.	No short or long term significant impact
8. Recharge of alluvial aquifer from resaturated spoil in Wepo formation	Low transmissivity in Wepo so this source has less impact than other sources of recharge (rainfall and snowmelt).	No short or long term significant impact

TABLE 28 (Cont.)

Summary of Probable Hydrologic Consequences of the Life-of-Mine Mining Plan for the Kayenta Complex

Probable Hydrologic Consequences	Analysis Results	Significance
Ground Water		
8. (Cont.)	No local use of alluvial aquifer on leasehold and water does not support critical habitats or plant species. Impact is transient.	
9. Interruptions of spring flows (Wepo or alluvial)	No Wepo or alluvial springs expected to be impacted by remaining mining operations. One spring at N-14 removed by mining has been mitigated by alternative water sources.	No short or long term significant impacts
10. Peabody wellfield pumpage reducing regional water levels and stream and spring flows	PWCC wellfield pumping will lower confined water levels basin-wide. The majority of drawdown has already occurred. Predicted drawdowns at surrounding communities are not large enough to affect aquifer productivity. At Rough Rock, where pre-pumping head was about 40 feet, PWCC-caused drawdown predicted to be only 2 feet. Water levels near the leasehold will begin to recover following the reduction or	No short or long term significant impact

TABLE 28 (Cont.)

Summary of Probable Hydrologic Consequences of the Life-of-Mine Mining Plan for the Kayenta Complex

Probable Hydrologic Consequences	Analysis Results	Significance
Ground Water		
10. (Cont.)	cessation of mining. No risk of structural damage to the aquifer. Maximum predicted reduction in baseflow of regional streams (all PWCC pumping) as of 2057 is 0.54 percent or less, except at Cow Springs, where a reduction of up to 1.84 percent is predicted. This assumes a low recharge rate, and is still insignificant.	
11. Impact of induced leakage from D-aquifer to N-aquifer	No evidence suggesting impacts to N-aquifer due to leakage from D-aquifer.	No short or long term significant impact
Surface Water		
1. Impact of dams, ponds or impoundments on runoff and channel characteristics	Minor headward aggradation above embankments in stream. Minor incising of streams below dams.	No short or long term significant impact

TABLE 28 (Cont.)

Summary of Probable Hydrologic Consequences of the Life-of-Mine Mining Plan for the Kayenta Complex

Probable Hydrologic Consequences	Analysis Results	Significance
1. (Cont.)	Vegetation encroachment on new channels. Most ponds and dams temporary structures. Small percentage of drainage impounded and structure to be dewatered. Following removal sediment loads will temporarily increase. Channels will reestablish.	
2. Impact of dams, ponds or impoundments on downstream water users	No flood irrigation practice on or downstream of leasehold for several miles. Only 0.7 percent and 2.45 percent of total Dinnebito and Moenkopi watersheds to be dammed through 2018. Record review does not indicate significant impacts have or will occur downstream.	No short or long term significant impacts
3. Impact of dams, ponds or impoundments on stream water quality	Infrequent discharges will meet applicable NPDES effluent limits. Discharge from permanent internal impoundments unlikely.	No short or long term significant impacts

TABLE 28 (Cont.)

Summary of Probable Hydrologic Consequences of the Life-of-Mine Mining Plan for the Kayenta Complex

Probable Hydrologic Consequences	Analysis Results	Significance
Surface Water		
4. Impact of stream channel diversion on channel characteristics and water quality	Diversion as wide as actual channels. Slopes approximate natural slopes. Energy dissipation when needed. Construction and reclamation will temporarily increase sediment loads. Downstream monitoring shows no effect.	No short or long term significant impacts
5. Effects of culverts at road crossings on stream runoff and water quality	Proper engineering design and use of energy dissipators minimize erosion and allow adequate discharge.	No short or long term significant impacts
6. Removal of pre-existing surface water structures	Three pre-existing surface water structures will be removed by mining. Alternate water supply is being provided until the structures are replaced by permanent impoundments	No short or long term significant impacts
7. Runoff from reclaimed areas to streams	Reshaping of regraded spoils, revegetation and soil reconstruction activities result in localized decreases in peak discharge, runoff volumes, peak sediment concentrations, sediment yield and chemical	No short or long term significant impacts

TABLE 28 (Cont.)

Summary of Probable Hydrologic Consequences of the Life-of-Mine Mining Plan for the Kayenta Complex

Probable Hydrologic Consequences	Analysis Results	Significance
Surface Water 7. (Cont.)	constituents. However, effects will be minor compared to total flow and quality of receiving streams. Original premining conditions will likely be approximated with time following reclamation. Total disturbed area small in comparison to total watersheds.	No short or long term significant impacts
8. Impact of the Reclamation Plan on the Stability of Reclaimed Areas	Development of contour terraces, downdrains and main channels in reclaimed areas with engineering design to insure a controlled drainage development. Sediment yields and flow rates and volumes from reclaimed areas should be lower. Some maintenance may be required, particularly in pre-plan reclaimed areas.	No short or long term significant impacts

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Attachment 3

Annual PWCC Portion of Drawdown at Community Wells Located in the Confined Portion of the N Aquifer under the 1236 af/yr Pumping Scenario (Table 14)

																																				PWCC Portion of Drawdown (ft)					
Community Name	Well ID	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Bacavi	only well	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.3	0.5	0.9	1.3	1.8	2.5	3.2	4.0	4.9	5.9	6.9	7.9	9.0	10.1	11.3	12.5	13.6	14.8	16.0	17.1	18.3	19.4	20.4	21.5	22.6	23.6	24.6	25.6	26.5	27.5	28.5	29.5
Chilchinbito	1	0.0	0.1	0.2	0.5	1.2	2.6	5.0	8.0	11.5	15.2	19.0	22.8	26.1	29.2	32.0	34.7	37.5	40.2	42.7	44.8	46.6	48.3	49.8	51.1	52.3	53.4	54.6	55.7	56.9	58.2	59.4	60.6	61.7	63.0	64.2	65.5	66.9	68.2	69.5	70.2
Chilchinbito	2	0.0	0.0	0.1	0.3	0.8	1.8	3.4	5.7	8.3	11.1	13.9	16.8	19.5	21.9	24.0	26.1	28.2	30.3	32.2	33.8	35.2	36.5	37.7	38.7	39.6	40.4	41.3	42.2	43.2	44.1	45.0	46.0	46.8	47.8	48.7	49.7	50.7	51.7	52.7	53.3
Chilchinbito	PM2	0.0	0.0	0.0	0.0	0.1	0.2	0.4	0.6	0.9	1.2	1.6	1.9	2.2	2.5	2.8	3.1	3.3	3.6	3.8	4.0	4.2	4.4	4.5	4.7	4.8	4.9	5.0	5.2	5.2	5.4	5.5	5.6	5.8	5.9	6.0	6.1	6.3	6.4	6.6	6.7
Chilchinbito	PM3	0.0	0.1	0.2	0.5	1.2	2.6	5.0	8.0	11.5	15.2	19.0	22.8	26.1	29.2	32.0	34.7	37.5	40.2	42.7	44.8	46.6	48.3	49.8	51.1	52.3	53.4	54.6	55.7	56.9	58.2	59.4	60.6	61.7	63.0	64.2	65.5	66.9	68.2	69.5	70.2
Forest Lake	4T-523	0.4	1.3	2.7	6.2	15.0	28.2	41.7	53.8	65.2	76.1	83.9	89.4	94.8	100.5	107.4	115.7	123.6	128.0	130.0	135.5	141.1	145.5	147.8	149.6	151.3	153.0	155.3	158.8	161.8	164.2	167.0	170.1	174.7	179.6	184.4	189.3	194.2	198.5	194.7	184.5
Hard Rock	2	0.0	0.1	0.2	0.4	1.0	2.4	4.7	7.8	11.5	15.6	19.8	24.1	28.2	32.1	36.0	39.9	44.0	48.1	52.0	55.5	59.1	62.6	65.9	69.0	71.9	74.5	77.0	79.3	81.7	84.1	86.3	88.5	90.7	93.0	95.4	98.0	100.6	103.3	105.8	107.6
Hopi Civic Center	only well	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.4	0.6	0.9	1.3	1.9	2.5	3.1	3.9	4.7	5.5	6.5	7.4	8.4	9.4	10.5	11.5	12.6	13.7	14.8	15.8	16.9	17.9	18.9	19.8	20.8	21.8	22.7	23.6	24.5	25.4	26.3
Hopi Cultural Center	only well	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.2	0.4	0.6	0.9	1.3	1.7	2.2	2.8	3.5	4.2	4.9	5.7	6.6	7.4	8.3	9.3	10.2	11.2	12.1	13.0	13.9	14.9	15.7	16.6	17.5	18.4	19.2	20.0	20.9	21.7	22.5
Hopi High School	No. 1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.2	0.3	0.4	0.6	0.8	1.0	1.2	1.5	1.8	2.1	2.4	2.7	3.1	3.4	3.8	4.2	4.6	4.9	5.3	5.6	6.0	6.4	6.7	7.0	7.3	7.7	8.0	8.3	8.6
Hopi High School	No. 2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.2	0.3	0.4	0.6	0.8	1.0	1.2	1.5	1.8	2.1	2.4	2.7	3.1	3.4	3.8	4.1	4.5	4.9	5.2	5.5	5.9	6.2	6.6	6.9	7.2	7.5	7.8	8.1	8.4
Hopi High School	No. 3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.2	0.3	0.4	0.6	0.8	1.0	1.3	1.5	1.9	2.2	2.5	2.9	3.2	3.6	4.0	4.4	4.8	5.2	5.6	6.0	6.4	6.9	7.2	7.6	8.0	8.4	8.7	9.1	9.5
Hotevilla	PM1	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.3	0.6	0.9	1.4	2.0	2.7	3.5	4.3	5.2	6.3	7.3	8.4	9.5	10.7	11.9	13.1	14.3	15.6	16.8	18.0	19.1	20.3	21.4	22.5	23.6	24.6	25.6	26.6	27.6	28.6	29.6	30.6
Hotevilla	PM2	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.2	0.4	0.7	1.1	1.6	2.2	2.9	3.6	4.4	5.2	6.2	7.2	8.2	9.3	10.3	11.4	12.5	13.6	14.7	15.8	16.9	18.0	19.0	20.0	21.0	22.0	22.9	23.9	24.8	25.8	26.7	27.6
Kayenta	1	0.0	0.1	0.2	0.4	0.9	1.9	3.2	4.8	6.2	7.5	9.1	10.6	11.9	13.1	14.3	15.6	17.0	18.3	19.4	17.5	17.9	19.7	17.7	21.4	22.9	23.2	20.9	24.0	22.6	22.6	23.3	23.8	23.8	24.6	25.1	25.4	25.7	25.9	26.0	26.0
Kayenta	2	0.0	0.0	0.0	0.1	0.3	0.4	0.8	1.2	1.6	2.0	2.5	3.0	3.6	4.1	4.7	5.3	6.0	6.6	7.3	7.4	7.8	8.5	7.5	9.4	8.7	8.7	9.9	9.4	9.8	10.1	9.4	9.2	9.5	9.3	9.3	9.4	10.3	11.4	12.2	12.9
Kayenta	3	0.0	0.0	0.1	0.3	0.7	1.3	2.3	3.4	4.3	5.2	6.3	7.4	8.5	9.4	10.4	11.5	12.6	13.6	14.6	13.9	14.3	15.5	14.4	16.8	17.6	17.8	17.3	18.6	18.3	18.4	18.9	19.3	19.5	20.1	20.5	20.9	21.3	21.7	22.0	22.2
Kayenta	4	0.0	0.1	0.2	0.4	1.0	2.0	3.5	5.1	6.6	8.1	9.7	11.3	12.7	14.0	15.2	16.6	18.0	19.4	20.5	17.8	18.2	20.4	17.8	22.4	24.1	24.3	21.0	25.1	23.1	22.9	23.7	24.3	23.9	25.0	25.4	25.7	25.8	25.9	26.0	25.9
Kayenta	5	0.0	0.1	0.2	0.5	1.0	2.2	3.7	5.4	7.1	8.6	10.3	12.0	13.5	14.8	16.1	17.6	19.2	20.6	21.7	20.3	20.6	22.3	20.8	23.9	25.5	26.1	24.2	27.1	26.1	26.1	26.8	27.5	27.6	28.4	29.0	29.4	29.7	30.0	30.3	30.2
Kayenta	6	0.0	0.1	0.2	0.5	1.2	2.5	4.3	6.3	8.3	10.2	12.1	14.1	15.8	17.3	18.7	20.2	21.9	23.4	24.7	13.3	14.7	21.2	12.3	26.0	29.5	28.8	15.4	30.1	20.9	19.9	22.0	23.5	23.9	24.6	25.3	25.7	25.9	25.9	25.9	25.8
Kayenta	7	0.0	0.0	0.1	0.1	0.3	0.7	1.1	1.6	0.5	0.9	1.2	1.6	2.1	2.5	3.0	3.4	3.9	4.4	5.0	5.3	5.6	6.0	6.3	6.7	7.1	7.3	7.5	7.6	7.6	7.6	7.7	7.8	7.9	8.2	8.5	8.8	9.1	9.4	9.7	10.0
Kayenta	PM2	0.0	0.0	0.0	0.0	0.1	0.2	0.3	0.5	0.8	1.1	1.4	1.8	2.3	2.8	3.3	3.9	4.5	5.2	5.8	6.5	7.0	7.5	8.0	8.5	9.1	9.5	10.0	10.5	10.9	11.3	11.7	12.1	12.4	12.7	13.1	13.4	13.7	14.1	14.6	15.0
Kayenta	PM3	0.0	0.0	0.0	0.0	0.1	0.2	0.3	0.5	0.8	1.1	1.4	1.8	2.3	2.8	3.3	3.9	4.5	5.2	5.8	6.5	7.0	7.5	8.0	8.5	9.1	9.5	10.0	10.5	10.9	11.3	11.7	12.1	12.4	12.7	13.1	13.4	13.7	14.1	14.6	15.0
Keams Canyon	No. 2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.2	0.3	0.5	0.6	0.9	1.1	1.3	1.6	2.0	2.3	2.6	3.0	3.4	3.7	4.1	4.5	4.9	5.3	5.7	6.0	6.4	6.8	7.1	7.5	7.8	8.1	8.5	8.8	9.1
Keams Canyon	No. 3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.2	0.3	0.5	0.6	0.9	1.1	1.3	1.6	2.0	2.3	2.6	3.0	3.4	3.7	4.1	4.5	4.9	5.3	5.7	6.0	6.4	6.8	7.1	7.5	7.8	8.1	8.5	8.8	9.1
Kitsillie	1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.2	0.3	0.3	0.3	0.4	0.4	0.5	0.5	0.5	0.6	0.6	0.6	0.7	0.7	0.8	0.8	0.8
Kitsillie	2	0.0	0.0	0.1	0.2	0.5	1.1	2.3	4.1	6.5	9.2	12.3	15.5	18.6	21.7	24.6	27.4	30.2	33.0	35.8	38.3	40.7	43.0	45.1	47.2	49.0	50.7	52.2	53.6	55.1	56.4	57.8	59.2	60.5	61.9	63.3	64.8	66.3	67.9	69.5	70.8
Kykotsmovi	PM1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.3	0.6	0.9	1.2	1.8	2.3	3.0	3.7	4.5	5.3	6.2	7.2	8.1	9.2	10.2	11.2	12.3	13.3	14.4	15.5	16.5	17.5	18.5	19.5	20.4	21.4	22.3	23.3	24.2	25.1	26.0
Kykotsmovi	PM2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.3	0.4	0.7	1.0	1.4	1.9	2.5	3.1	3.7	4.5	5.2	6.0	6.9	7.7	8.6	9.5	10.5	11.4	12.3	13.2	14.0	14.9	15.8	16.6	17.4	18.2	19.1	19.8	20.6	21.4	22.2
Kykotsmovi	PM3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.3	0.6	0.9	1.2	1.7	2.3	3.0	3.6	4.4	5.2	6.1	7.0	7.9	8.9	9.9	10.9	11.9	12.9	13.9	14.9	15.8	16.8	17.7	18.7	19.6	20.4	21.3	22.2	23.1	23.9	24.8
Low Mountain	PM2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.2	0.3	0.5	0.7	1.0	1.2	1.5	1.8	2.2	2.5	2.9	3.2	3.6	4.0	4.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Mishongnovi	only well	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.2	0.4	0.6	0.8	1.1	1.4	1.8	2.3	2.7	3.2	3.8	4.4	5.0	5.6	6.3	7.0	7.7	8.4	9.0	9.7	10.4	11.1	11.7	12.4	13.0	13.6	14.3	14.9	15.5
Pinon	1	0.0	0.0	0.0	0.1	0.2	0.4	0.9	1.7	2.9	4.5	6.3	8.4	10.7	13.1	15.5	17.9	20.4	22.9	25.5	28.0	30.5	32.9	35.3	37.6	39.9	42.0	44.0	45.9	47.7	49.4	51.1	52.8	54.4	55.9	57.5	59.1	60.7	62.4	64.1	65.7
Pinon	2	0.0	0.0	0.0	0.0	0.1	0.2	0.6	1.1	2.0	3.1	4.6	6.3	8.1	10.1	12.1	14.2	16.3	18.5	20.7	22.9	25.1	27.2	29.3	31.4	33.4	35.3	37.1	38.8	40.4	42.0	43.5	45.0	46.4	47.8	49.1	50.6	52.0	53.4	54.9	56.4
Pinon	3	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.5	0.9	1.5	2.3	0.0	4.4	5.7	7.0	8.4	9.8	11.3	12.7	14.2	15.7	17.2	18.7	20.1	21.6	22.9	24.2	25.5	26.7	27.9	28.9	30.0	31.0	32.1	33.0	34.0	35.0	36.0	37.0	38.0
Pinon	PM6	0.0	0.0	0.0	0.1	0.3	0.6	1.4	2.6	4.2	6.3	8.7	11.3	14.1	16.9	19.6	22.4	25.3	28.2	31.2	34.0	36.8	39.5	42.2	44.8	47.3	49.6	51.7	53.8	55.7	57.6	59.5	61.3	63.0	64.8	66.5	68.3	70.2	72.1	74.0	75.9
Polacca	PM4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.2	0.3	0.5	0.8	1.1	1.4	1.9	2.4	2.9	3.4	4.0	4.7	5.3	6.0	6.7	7.4	8.1	8.9	9.6	10.3	11.0	11.7	12.4	13.1	13.8	14.4	15.1	15.7	16.3	16.9
Polacca	PM5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.2	0.2	0.2	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.4	0.4	0.4	0.4
Polacca	PM6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.2	0.2	0.2	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.4	0.4	0.4	0.4
Rocky Ridge	PM2	0.0	0.0	0.1	0.3	0.7	1.7	3.4	5.8	8.8	12.2	15.8	19.6	23.3	26.8	30.3	33.9	37.5	41.2	44.8	48.2	51.5	54.8	57.9	60.9	63.6	66.2	68.6	70.9	73.2	75.4	77.5	79.6	81.7	83.8	86.1	88.4	90.8	93.2	95.6	97.5
Rocky Ridge	PM3	0.0	0.0	0.1	0.3	0.7	1.7	3.4	5.8	8.8	12.2	15.8	19.6	23.3	26.8	30.3	33.9	37.5	41.2	44.8	48.2	51.5	54.8	57.9	60.9	63.6	66.2	68.6	70.9	73.2	75.4	77.5	79.6	81.7	83.8	86.1	88.4	90.8	93.2	95.6	97.5
Rough Rock	1	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.3	0.5	0.8	1.1	1.5	2.0	2.5	3.1	3.5	4.0	4.5	5.0	5.5	6.0	6.4	6.8	7.2	7.6	7.9	8.2	8.5	8.8	9.1	9.3	9.6	0.1	10.1	10.3	10.6	10.8	11.1	11.4	11.6
Rough Rock	PM3	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.4	0.7	1.0	1.4	1.8	2.3	2.8	0.0	3.7	4.2	4.7	5.1	5.5	5.9	6.3	6.7	7.1	7.4	7.7	8.0	8.2	8.5	8.8	9.0	9.2	9.4	9.7	9.9	10.2	10.4	10.7	10.9
Rough Rock	PM5	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.4	0.6	0.9	1.2	1.6	2.1	2.5	3.0	3.4	3.8	4.2	4.6	5.0	5.4	5.8	6.1	6.5	6.8	7.1	7.3	7.5	7.8	8.0	8.2	8.5	8.7	8.9	9.1	9.4	9.6	9.8	10.0
Rough Rock	PM6	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.3	0.5	0.7	1.0	1.3	1.6	2.0	2.3	2.7	3.0	3.3	3.7	4.0	4.3	4.6	4.9	5.2	5.4	5.6	5.8	6.0	6.2	6.4	6.6	6.8	7.0	7.2	7.3	7.5	7.7	7.9	8.1
Rough Rock	PM7	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.4	0.7	1.0	1.4	1.8	2.3	2.8	0.0	3.7	4.2	4.7	5.1	5.5	5.9	6.3	6.7	7.1	7.4	7.7	8.0	8.2	8.5	8.8	9.0	9.2	9.4	9.7	9.9	10.2	10.4	10.7	10.9
Second Mesa	No. 1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.2	0.4	0.6	0.8	1.0	1.3	1.7	2.0	2.5	2.9	3.4	3.9	4.4	4.9	5.5	6.1	6.6	7.2	7.8	8.4	8.9	9.5	10.0	10.6	11.1	11.7	12.2	12.7
Second Mesa	PM2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.2	0.3	0.5	0.7	1.0	1.3	1.7	2.1	2.5	3.0	3.5	4.1	4.7	5.3	5.9	6.5	7.2	7.8	8.5	9.1	9.8	10.4	11.0	11.6	12.3	12.9	13.5	14.1	14.7
Shipaulovi	No. 2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.2	0.3	0.5	0.7	1.0	1.3	1.7	2.1	2.5	3.0	3.5	4.1	4.7	5.3	5.9	6.5	7.2	7.8	8.5	9.1	9.8	10.4	11.0	11.6	12.3	12.9	13.5	14.1	14.7
Shungopovi	only well	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.2	0.3	0.4	0.6	0.8	1.1	1.4	1.7	2.1	2.5	2.9	3.3	3.8	4.3	4.8	5.2	5.7	6.3	6.8	7.3	7.7	8.2	8.7	9.2	9.6	10.1	10.5	11.0	11.4

Annual PWCC Portion of Drawdown at Community Wells Located in the Confined Portion of the N Aquifer under the 1236 af/yr Pumping Scenario (Table 14)

Community Name	Well ID	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047
Bacavi	only well	30.4	31.4	32.2	33.0	33.7	34.3	34.8	35.2	35.4	35.6	35.7	35.7	35.6	35.5	35.3	35.1	34.8	34.5	34.2	33.9	33.5	33.1	32.7	32.3	31.8	31.3	30.8	30.3	29.8	29.2	28.6	28.1	27.7	27.3	26.9	26.5	26.1	25.8	25.4	25.1
Chilchinbito	1	70.0	68.9	67.1	64.9	62.6	60.2	58.0	55.9	53.9	52.1	50.5	49.0	47.7	46.5	45.4	44.5	43.6	42.7	42.0	41.2	40.3	39.2	38.0	36.6	35.2	33.8	32.4	31.1	29.9	28.7	27.7	26.7	34.0	33.8	33.6	33.3	33.0	32.5	31.9	31.2
Chilchinbito	2	53.3	52.6	51.3	49.7	47.9	46.2	44.4	42.8	41.3	39.9	38.7	37.6	36.5	35.6	34.8	34.1	33.4	32.8	32.2	31.6	31.0	30.2	29.3	28.2	27.2	26.1	25.0	24.0	23.1	22.2	21.4	20.7	26.3	26.1	26.0	25.8	25.5	25.2	24.7	24.2
Chilchinbito	PM2	6.7	6.7	6.5	6.4	6.2	6.0	5.8	5.6	5.5	5.3	5.2	5.1	5.0	4.9	4.8	4.7	4.6	4.6	4.5	4.5	4.4	4.3	4.2	4.1	4.0	3.9	3.8	3.6	3.5	3.4	3.4	3.3	3.9	3.9	3.9	3.9	3.9	3.8	3.8	3.7
Chilchinbito	PM3	70.0	68.9	67.1	64.9	62.6	60.2	58.0	55.9	53.9	52.1	50.5	49.0	47.7	46.5	45.4	44.5	43.6	42.7	42.0	41.2	40.3	39.2	38.0	36.6	35.2	33.8	32.4	31.1	29.9	28.7	27.7	26.7	34.0	33.8	33.6	33.3	33.0	32.5	31.9	31.2
Forest Lake	4T-523	174.1	165.1	157.4	150.8	145.0	140.0	135.6	131.6	128.0	124.8	121.8	119.2	116.7	114.4	112.3	110.4	108.6	107.0	105.0	102.2	99.2	95.5	91.3	87.3	83.7	80.4	77.5	74.7	72.2	69.9	67.7	65.5	85.1	84.5	84.0	83.1	81.6	79.7	77.8	76.0
Hard Rock	2	108.2	107.9	106.9	105.5	103.8	102.0	100.1	98.2	96.3	94.4	92.6	90.8	89.1	87.5	85.9	84.4	82.9	81.6	80.2	78.9	77.5	76.1	74.5	72.8	71.0	69.2	67.3	65.5	63.6	61.9	60.2	58.5	63.8	63.1	62.4	61.8	61.2	60.4	59.6	58.8
Hopi Civic Center	only well	27.2	28.1	29.0	29.8	30.5	31.1	31.7	32.1	32.4	32.7	32.8	32.9	33.0	32.9	32.8	32.7	32.5	32.3	32.0	31.7	31.4	31.1	30.7	30.3	30.0	29.5	29.1	28.6	28.1	27.6	27.1	26.6	26.1	25.8	25.4	25.1	24.8	24.4	24.1	23.8
Hopi Cultural Center	only well	23.3	24.1	24.9	25.7	26.3	27.0	27.5	28.0	28.4	28.7	29.0	29.1	29.2	29.3	29.2	29.2	29.1	28.9	28.7	28.5	28.2	28.0	27.7	27.3	27.0	26.6	26.2	25.8	25.4	24.9	24.5	24.0	23.5	23.2	22.9	22.6	22.3	22.0	21.7	21.5
Hopi High School	No. 1	8.9	9.3	9.5	9.8	10.1	10.4	10.6	10.8	11.0	11.1	11.2	11.3	11.4	11.4	11.4	11.3	11.3	11.2	11.2	11.1	11.0	10.9	10.8	10.7	10.6	10.4	10.3	10.2	10.0	9.9	9.7	9.5	9.3	9.2	9.1	9.0	8.9	8.7	8.6	8.6
Hopi High School	No. 2	8.7	9.0	9.3	9.6	9.9	10.1	10.3	10.5	10.7	10.8	10.9	11.0	11.0	11.0	11.0	11.0	11.0	10.9	10.8	10.7	10.6	10.5	10.4	10.3	10.2	10.1	10.0	9.8	9.7	9.5	9.4	9.3	9.0	8.9	8.8	8.7	8.6	8.5	8.4	8.3
Hopi High School	No. 3	9.8	10.2	10.6	10.9	11.3	11.6	11.9	12.1	12.3	12.5	12.7	12.8	12.9	13.0	13.1	13.1	13.1	13.1	13.0	13.0	13.0	12.9	12.8	12.8	12.7	12.6	12.5	12.4	12.2	12.1	12.0	11.9	9.0	8.9	8.8	8.7	8.6	8.5	8.4	8.3
Hotevilla	PM1	31.6	32.6	33.5	34.3	35.0	35.6	36.0	36.4	36.6	36.8	36.8	36.8	36.7	36.5	36.4	36.1	35.8	35.5	35.1	34.8	34.4	34.0	33.5	33.1	32.6	32.1	31.6	31.1	30.5	30.0	29.4	28.7	28.4	28.0	27.6	27.2	26.8	26.4	26.0	25.7
Hotevilla	PM2	28.5	29.4	30.3	31.1	31.8	32.3	32.8	33.2	33.5	33.7	33.8	33.9	33.8	33.7	33.6	33.4	33.2	32.9	32.6	32.3	32.0	31.6	31.2	30.8	30.4	30.0	29.5	29.0	28.5	28.0	27.5	26.9	26.5	26.1	25.8	25.4	25.0	24.7	24.4	24.0
Kayenta	1	25.8	25.3	24.7	23.9	23.2	23.0	22.9	22.9	22.7	21.6	20.8	20.2	19.7	18.8	17.1	16.1	15.7	15.6	15.5	15.8	16.3	16.5	16.5	16.5	16.5	16.6	16.7	15.7	13.1	11.3	9.7	11.3	12.9	13.8	14.5	15.0	15.3	15.5	15.8	15.9
Kayenta	2	13.4	13.8	14.1	14.4	14.6	14.9	15.1	15.3	15.6	15.9	16.1	16.2	16.4	16.5	16.3	16.1	15.9	15.7	15.5	15.3	15.0	14.7	14.4	14.1	13.9	13.7	13.6	13.6	13.5	13.5	13.4	13.2	13.7	13.4	13.2	13.0	12.8	12.7	12.5	12.5
Kayenta	3	22.2	22.0	21.8	21.4	21.0	21.4	21.4	21.5	21.6	21.0	20.4	20.0	19.7	18.7	17.5	16.8	16.4	16.3	16.2	15.8	15.6	15.3	15.0	14.7	14.7	15.0	15.2	15.2	14.8	14.0	13.3	12.7	13.6	13.4	13.6	13.5	13.5	13.5	13.5	13.4
Kayenta	4	25.6	25.1	24.3	23.5	22.7	22.3	22.2	22.2	21.9	20.6	19.5	18.9	18.3	17.6	15.0	13.4	12.7	12.6	12.4	13.5	15.0	15.8	16.3	16.5	16.7	16.7	16.8	16.9	16.4	15.7	15.0	14.6	15.1	15.2	15.3	15.5	15.6	15.8	16.0	16.1
Kayenta	5	29.9	29.3	28.6	27.8	27.0	26.8	26.6	26.5	26.2	25.4	24.5	23.9	23.4	22.4	21.0	20.2	19.8	19.7	19.5	19.4	19.4	19.2	18.9	18.7	18.5	18.4	18.5	18.2	17.4	16.6	15.8	15.5	17.4	17.5	17.6	17.6	17.5	17.6	17.6	17.2
Kayenta	6	25.7	25.3	24.9	24.2	23.5	22.7	22.3	22.1	21.9	21.8	21.5	21.1	20.7	20.2	19.7	19.3	19.0	18.8	18.6	18.5	18.4	18.3	18.3	18.2	18.1	18.1	18.0	18.0	18.0	18.1	18.0	18.0	18.0	18.0	18.0	18.0	18.0	18.0	17.9	17.9
Kayenta	7	10.3	10.5	10.7	10.8	10.9	10.9	11.0	11.0	11.1	11.2	11.3	11.3	11.4	11.4	11.3	11.2	11.0	10.8	10.7	10.6	10.6	10.5	10.5	10.5	10.6	10.6	10.6	10.7	10.8	10.8	10.9	11.0	11.3	11.3	11.4	11.5	11.5	11.6	11.6	11.7
Kayenta	PM2	15.5	15.8	16.2	16.6	16.9	17.3	17.7	18.1	18.7	19.2	19.7	20.0	20.3	20.5	20.3	20.0	19.7	19.4	19.1	18.8	18.3	17.8	17.3	16.7	16.2	15.8	15.7	15.6	15.6	15.6	15.6	15.6	16.2	16.2	16.1	16.1	16.0	15.9	15.7	15.7
Kayenta	PM3	15.5	15.8	16.2	16.6	16.9	17.3	17.7	18.1	18.7	19.2	19.7	20.0	20.3	20.5	20.3	20.0	19.7	19.4	19.1	18.8	18.3	17.8	17.3	16.7	16.2	15.8	15.7	15.6	15.6	15.6	15.6	15.6	16.2	16.2	16.1	16.1	16.0	15.9	15.7	15.7
Keams Canyon	No. 2	9.4	9.8	10.1	10.4	10.7	10.9	11.2	11.4	11.5	11.6	11.7	11.8	11.8	11.8	11.8	11.8	11.7	11.6	11.6	11.5	11.4	11.3	11.2	11.1	10.9	10.8	10.7	10.5	10.4	10.2	10.0	9.9	9.6	9.5	9.4	9.3	9.2	9.1	9.0	8.9
Keams Canyon	No. 3	9.4	9.8	10.1	10.4	10.7	10.9	11.2	11.4	11.5	11.6	11.7	11.8	11.8	11.8	11.8	11.8	11.7	11.6	11.6	11.5	11.4	11.3	11.2	11.1	10.9	10.8	10.7	10.5	10.4	10.2	10.0	9.9	9.6	9.5	9.4	9.3	9.2	9.1	9.0	8.9
Kitsillie	1	0.9	0.9	0.9	1.0	1.0	1.0	1.0	1.1	1.1	1.1	1.1	1.2	1.2	1.2	1.2	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4
Kitsillie	2	71.7	71.8	71.4	70.5	69.2	67.7	66.0	64.3	62.6	60.9	59.3	57.8	56.3	54.9	53.6	52.4	51.2	50.2	49.2	48.2	47.3	46.3	45.2	44.1	42.8	41.5	40.2	38.9	37.6	36.4	35.1	34.0	37.9	37.5	37.2	36.8	36.5	36.1	35.7	35.2
Kykotsmovi	PM1	27.0	27.9	28.7	29.6	30.3	31.0	31.6	32.1	32.4	32.7	33.0	33.1	33.2	33.2	33.1	33.1	32.9	32.7	32.5	32.3	32.0	31.7	31.4	31.0	30.6	30.2	29.8	29.4	28.9	28.4	28.0	27.5	24.6	24.3	23.9	23.6	23.3	22.9	22.6	22.3
Kykotsmovi	PM2	0.2	23.8	24.5	25.2	25.8	26.4	26.9	27.3	27.6	27.9	28.1	28.1	28.2	28.2	28.1	28.0	27.9	27.7	27.5	27.2	27.0	26.7	26.4	26.0	25.7	25.4	25.0	24.6	24.2	23.8	23.3	22.9	22.5	22.1	21.8	21.5	21.2	20.9	20.6	20.4
Kykotsmovi	PM3	25.6	26.5	27.3	28.0	28.7	29.3	29.8	30.2	30.5	30.8	30.9	31.0	31.0	31.0	30.9	30.8	30.6	30.4	30.1	29.9	29.6	29.2	28.9	28.5	28.2	27.8	27.4	26.9	26.5	26.0	25.5	25.0	24.6	24.3	23.9	23.6	23.3	22.9	22.6	22.3
Low Mountain	PM2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9.5	9.4	9.3	9.2	9.1	9.0	8.9	8.8
Mishongnovi	only well	16.1	16.7	17.3	17.9	18.5	19.0	19.5	19.9	20.3	20.7	20.9	21.2	21.4	21.5	21.6	21.6	21.6	21.5	21.4	21.3	21.1	20.9	20.7	20.4	20.1	19.8	19.5	19.2	18.8	18.5	18.2	17.9	17.4	17.2	16.9	16.7	16.5	16.3	16.1	15.9
Pinon	1	67.2	68.3	69.0	69.3	69.2	68.9	68.3	67.6	66.8	65.8	64.8	63.7	62.7	61.6	60.5	59.5	58.4	57.4	56.4	55.5	54.6	53.6	52.7	51.7	50.6	49.5	48.4	47.3	46.1	44.9	43.8	0.4	43.9	43.4	42.9	42.4	41.9	41.5	41.0	40.5
Pinon	2	57.7	58.8	59.6	60.0	60.2	60.1	59.8	59.3	58.7	57.9	57.1	56.3	55.4	54.5	53.5	52.6	51.7	50.9	50.0	49.1	48.3	47.5	46.7	45.9	45.0	44.1	43.1	42.1	41.1	40.1	39.1	38.1	38.9	38.4	38.0	37.5	37.1	36.7	36.3	35.9
Pinon	3	39.0	39.9	40.6	41.2	41.5	41.7	41.6	41.5	41.2	40.8	40.3	39.8	39.2	38.6	38.1	37.5	36.8	36.3	35.7	35.1	34.5	34.0	33.4	32.8	32.3	31.7	31.0	30.4	29.7	29.0	28.3	27.7	27.9	27.5	27.2	26.9	26.6	26.3	26.0	25.7
Pinon	PM6	77.3	78.2	78.7	78.7	78.3	77.7	76.8	75.8	74.7	73.5	72.3	71.0	69.7	68.5	67.3	66.0	64.9	63.7	62.6	61.6	60.5	59.4	58.3	57.2	56.0	54.7	53.4	52.1	50.8	49.4	48.1	46.8	48.8	48.2	47.6	47.1	46.6	46.1	45.6	45.0
Polacca	PM4	17.6	18.2	18.8	19.4	19.9	20.4	20.9	21.3	21.6	21.9	22.1	22.2	22.3	22.4	22.4	22.3	22.3	22.1	22.0	21.9	21.7	21.5	21.3	21.0	20.8	20.5	20.2	19.9	19.6	19.3	19.0	18.6	18.2	17.9	17.7	17.4	17.2	17.0	16.8	16.6
Polacca	PM5	0.5	0.5	0.5	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.4	0.4	0.4	0.4	0.4	0.1	0.2	0.0	0.1	0.2
Polacca	PM6	0.5	0.5	0.5	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.4	0.4	0.4	0.4	0.4	0.1	0.2	0.0	0.1	0.2
Rocky Ridge	PM2	98.5	98.7	98.3	97.4	96.2	94.8	93.2	91.7	90.0	88.4	86.8	85.2	83.7	82.2	80.8	79.4	78.1	76.8	75.6	74.3	73.1	71.8	70.4	0.7	67.3	65.6	64.0	62.3	60.7	59.0	57.4	55.9	60.1	59.4	58.8	58.2	57.5	56.9	56.1	55.4
Rocky Ridge	PM3	98.5	98.7	98.3	97.4	96.2	94.8	93.2	91.7	90.0	88.4	86.8	85.2	83.7	82.2	80.8	79.4	78.1	76.8	75.6	74.3	73.1	71.8	70.4	0.7	67.3	65.6	64.0	62.3	60.7	59.0	57.4	55.9	60.1	59.4	58.8	58.2	57.5	56.9	56.1	55.4
Rough Rock	1	11.8	12.1	12.2	12.3	12.2	12.1	11.9	11.7	11.5	11.3	11.0	10.7	10.5	10.2	10.0	9.8	9.5	9.4	9.2	9.0	8.9	8.7	8.5	8.4	8.2	8.0	7.8	7.6	7.4	7.2	7.0	6.8	7.2	7.1	7.1	7.0	6.9	6.9	6.8	6.8
Rough Rock	PM3	11.2	11.4	11.5	11.5	11.5	11.4	11.3	11.1	10.9	10.6	10.4	10.2	9.9	9.7	9.5	9.3	9.1	8.9	8.7	8.6	8.4	8.3	8.1	7.9	7.8	7.6	7.4	7.3	7.1	6.9	6.7	6.5	6.8	6.8	6.7	6.6	6.6	6.5	6.5	6.4
Rough Rock	PM5	10.3	10.4	10.6	10.7	10.6	10.6	10.4	10.3	10.1	9.9	9.6	9.4	9.2	9.0	8.8	8.6	8.4	8.3	8.1	8.0	7.8	7.7	7.5	7.4	7.3	7.1	7.0	6.8	6.6	6.4	6.2	6.1	6.4	6.3	6.3	6.2	6.2	6.1	6.1	6.0
Rough Rock	PM6	8.2	8.4	8.5	8.6	8.6	8.5	8.4	8.3	8.2	8.0	7.8	7.6	7.5	7.3	7.2	7.0	6.9	6.7	6.6	6.5	6.4	6.3	6.2	6.0	5.9	5.8	5.7	5.5	5.4	5.2	5.1	5.0	5.2	5.2	5.1	5.1	5.0	5.0	5.0	4.9
Rough Rock	PM7	11.2	11.4	11.5	11.5	11.5	11.4	11.3	11.1	10.9	10.6	10.4	10.2	9.9	9.7	9.5	9.3	9.1	8.9	8.7	8.6	8.4	8.3	8.1	7.9	7.8	7.6	7.4	7.3	7.1	6.9	6.7	6.5	6.8	6.8	6.7	6.6	6.6	6.5	6.5	6.4
Second Mesa	No. 1	13.3	13.7	14.3	14.8	15.3	15.7	16.2	16.6	16.9	17.3	17.5	17.7	17.9	18.1	18.2	18.2	18.2	18.2	18.2	18.1	17.9	17.7	17.5	17.2	16.9	16.6	16.3	16.0	15.7	15.4	15.1	14.9	14.5	14.3	14.1	14.0	13.8	13.6	13.5	13.4
Second Mesa	PM2	15.3	15.8	0.2	17.0	17.5	18.0	18.5	18.9	19.3	19.6	19.9	20.1	20.3	20.4	20.5	20.6	20.6	20.5	20.5	20.3	20.2	20.0	19.7	19.5	19.2	18.9	18.6	18.2	17.9	17.6	17.3	17.0	16.5	16.3	16.1	15.9	15.7	15.5	15.4	15.2
Shipaulovi	No. 2	15.3	15.8	0.2	17.0	17.5	18.0	18.5	18.9	19.3	19.6	19.9	20.1	20.3	20.4	20.5	20.6	20.6	20.5	20.5	20.3	20.2	20.0	19.7	19.5	19.2	18.9	18.6	18.2	17.9	17.6	17.3	17.0	16.5	16.3	16.1	15.9	15.7	15.5	15.4	15.2
Shungopovi	only well	11.8	12.2	12.7	13.1	13.5	13.8	14.2	14.5	14.8	15.0	15.2	15.3	15.4	15.5	15.5	15.5	15.5	15.4	15.3	15.2	15.1	15.0	14.8	14.7	14.5	14.3	14.1	13.9	13.7	13.5	13.3	13.1	12.7	12.6	12.4	12.2	12.1	11.9	11.8	11.6

Annual PWCC Portion of Drawdown at Community Wells Located in the Confined Portion of the N Aquifer under the 1236 af/yr Pumping Scenario (Table 14)

Community Name	Well ID	2048	2049	2050	2051	2052	2053	2054	2055	2056	2057	Comments
Bacavi	only well	24.7	24.4	24.0	23.6	23.3	22.9	22.5	22.1	21.7	21.3	
Chilchinbito	1	30.4	29.7	29.0	28.4	27.8	27.2	26.7	26.2	25.7	25.3	
Chilchinbito	2	23.6	23.0	22.5	22.0	21.5	21.1	20.7	20.3	20.0	19.7	
Chilchinbito	PM2	3.7	3.6	3.6	3.5	3.5	3.4	3.4	3.4	3.3	3.3	pumped from D Aquifer (Entrada Formation)
Chilchinbito	PM3	30.4	29.7	29.0	28.4	27.8	27.2	26.7	26.2	25.7	25.3	
Forest Lake	4T-523	74.3	72.8	71.4	70.1	68.9	67.8	66.8	65.8	64.9	64.0	
Hard Rock	2	57.8	56.9	56.0	55.1	54.2	53.3	52.4	51.6	50.8	50.1	
Hopi Civic Center	only well	23.5	23.2	22.9	22.6	22.3	21.9	21.6	21.3	20.9	20.6	
Hopi Cultural Center	only well	21.2	20.9	20.7	20.4	20.1	19.9	19.6	19.3	19.0	18.7	
Hopi High School	No. 1	8.5	8.4	8.3	8.2	8.1	8.0	7.9	7.8	7.7	7.6	
Hopi High School	No. 2	8.2	8.1	8.0	7.9	7.9	7.8	7.7	7.6	7.5	7.4	
Hopi High School	No. 3	8.2	8.1	8.0	8.0	7.9	7.8	7.7	7.6	7.5	7.4	pumped from D and N Aquifers
Hotevilla	PM1	25.3	24.9	24.6	24.2	23.8	23.4	23.0	22.6	22.2	21.8	
Hotevilla	PM2	23.7	23.4	23.0	22.7	22.3	22.0	21.6	21.2	20.9	20.5	
Kayenta	1	15.8	15.6	15.3	15.0	14.6	13.6	12.5	11.6	11.4	11.5	
Kayenta	2	12.3	12.1	11.9	11.8	11.8	11.8	11.8	11.7	11.7	11.7	
Kayenta	3	12.8	12.3	12.3	9.2	6.7	6.8	8.4	9.4	10.0	10.3	
Kayenta	4	16.1	15.9	15.7	15.5	15.4	15.2	14.9	14.5	14.1	13.9	
Kayenta	5	16.4	15.7	15.3	15.0	13.6	9.4	6.5	8.5	9.7	10.4	
Kayenta	6	17.9	17.8	17.7	17.6	17.4	17.3	17.1	16.9	16.7	16.6	
Kayenta	7	11.7	11.8	11.9	12.0	12.0	12.1	12.2	12.3	12.3	12.4	
Kayenta	PM2	15.6	15.6	15.6	15.7	15.7	15.9	16.0	16.2	16.5	16.8	
Kayenta	PM3	15.6	15.6	15.6	15.7	15.7	15.9	16.0	16.2	16.5	16.8	
Keams Canyon	No. 2	8.8	8.7	8.6	8.5	8.4	8.3	8.2	8.1	8.0	7.9	
Keams Canyon	No. 3	8.8	8.7	8.6	8.5	8.4	8.3	8.2	8.1	8.0	7.9	
Kitsillie	1	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	pumped from D Aquifer (Entrada Formation)
Kitsillie	2	34.6	34.1	33.5	32.8	32.2	31.7	31.1	30.5	30.0	29.5	came online after 1999 PWCC 3-D report
Kykotsmovi	PM1	22.0	21.7	21.4	21.1	20.8	20.5	20.1	19.8	19.5	19.1	pumped from D and N Aquifers
Kykotsmovi	PM2	20.1	19.8	19.5	19.2	18.9	18.6	18.3	17.9	17.6	17.3	
Kykotsmovi	PM3	22.0	21.7	21.4	21.1	20.8	20.5	20.1	19.8	19.5	19.1	
Low Mountain	PM2	8.7	8.6	8.5	8.4	8.3	8.2	8.1	8.1	8.0	7.9	Well taken out of service (USGS OFR 03-503, Table 3)
Mishongnovi	only well	15.8	15.6	15.4	15.2	15.1	14.9	14.7	14.5	14.3	14.1	
Pinon	1	40.0	39.5	38.9	38.4	37.8	37.2	36.7	36.1	35.6	35.0	
Pinon	2	35.4	35.0	34.5	34.0	33.5	33.1	32.6	32.1	31.6	31.1	
Pinon	3	25.4	25.1	24.8	24.5	24.1	23.8	23.5	23.1	22.8	22.5	
Pinon	PM6	44.4	43.8	43.2	42.5	41.9	41.2	40.6	40.0	39.3	38.7	Well taken out of service (USGS OFR 03-503, Table 3)
Polacca	PM4	16.4	16.2	16.0	15.8	15.6	15.4	15.2	15.0	14.8	14.7	not metered, estimated on per capita basis by USGS (USGS OFR 03-503)
Polacca	PM5	0.2	0.3	0.3	0.3	0.4	0.4	0.4	0.4	0.4	0.5	pumped from D Aquifer (Entrada Formation)
Polacca	PM6	0.2	0.3	0.3	0.3	0.4	0.4	0.4	0.4	0.4	0.5	pumped from D Aquifer (Entrada Formation)
Rocky Ridge	PM2	54.5	53.7	52.8	52.0	51.1	50.3	49.5	48.7	48.0	47.2	
Rocky Ridge	PM3	54.5	53.7	52.8	52.0	51.1	50.3	49.5	48.7	48.0	47.2	
Rough Rock	1	6.7	6.6	6.5	6.4	6.3	6.2	6.1	6.0	5.9	5.9	
Rough Rock	PM3	6.4	6.3	6.2	6.1	6.0	5.9	5.8	5.8	5.7	5.6	
Rough Rock	PM5	5.9	5.9	5.8	5.7	5.6	5.6	5.5	5.4	5.3	5.2	
Rough Rock	PM6	4.9	4.8	4.8	4.7	4.6	4.6	4.5	4.4	4.4	4.3	
Rough Rock	PM7	6.4	6.3	6.2	6.1	6.0	5.9	5.8	5.8	5.7	5.6	
Second Mesa	No. 1	13.2	13.1	12.9	12.8	12.7	12.5	12.4	12.2	12.1	11.9	
Second Mesa	PM2	15.0	14.8	14.7	14.5	14.3	14.2	14.0	13.8	13.7	13.5	
Shipaulovi	No. 2	15.0	14.8	14.7	14.5	14.3	14.2	14.0	13.8	13.7	13.5	
Shungopovi	only well	11.5	11.4	11.2	11.1	11.0	10.9	10.7	10.6	10.5	10.4	

Annual Pumping Volumes from Community Wells Located in the Confined Portion of the N Aquifer under the 1236 af/yr Pumping Scenario (Table 14)

		Volume Pumped (af/yr)																																							
Community Name	Well ID	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Bacavi	only well	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.34	23.18	18.11	21.41	19.19	22.00	21.50	4.44	4.56	4.68	4.80	4.92	5.05	5.18
Chilchinbito	1	0.00	0.00	0.00	0.00	0.00	10.01	2.12	10.01	1.92	20.02	18.01	18.01	12.01	10.67	10.34	10.34	13.76	15.94	15.94	14.49	14.49	16.66	18.16	16.16	13.55	13.91	6.76	4.06	5.79	16.11	25.35	34.61	25.49	15.47	15.86	16.27	16.69	17.13	17.58	18.04
Chilchinbito	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	12.01	10.67	10.34	10.34	13.76	15.94	15.21	15.21	15.21	15.94	17.58	17.69	21.56	23.69	32.89	34.80	34.77	14.01	13.80	13.59	12.20	26.19	26.87	27.56	28.28	29.01	29.77	30.55
Chilchinbito	PM2	0.00	0.00	0.00	0.00	0.00	0.00	21.01	20.01	20.61	0.00	0.00	0.00	0.00	0.00	0.00	0.00	13.21	17.61	4.90	5.60	7.90	7.60	7.00	0.00	0.00	0.00	0.00	0.00	0.00	3.27	3.35	3.43	3.52	3.61	3.71	3.80	3.90	4.00	4.11	4.21
Chilchinbito	PM3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	41.29	7.24	5.07	5.79	5.79	7.24	7.24	7.24	7.97	6.52	7.24	5.07	4.34	3.79	4.00	6.81	7.79	5.56	5.70	5.85	6.00	6.16	6.32	6.48
Forest Lake	4T-523	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.57	1.01	1.44	1.87	2.30	5.70	9.21	10.11	15.81	11.31	12.80	11.41	9.61	11.28	10.60	9.92	9.72	8.41	9.65	10.90	12.79	12.59	12.92	13.25	13.60	13.95	14.31	14.69
Hard Rock	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.55	0.71	0.00	0.00	10.87	17.71	11.99	6.31	22.21	1.69	1.74	1.78	1.82	1.87	1.92	1.97
Hopi Civic Center	only well	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.45	2.45	2.45	2.45	2.45	2.45	2.45	2.45	2.45	2.45	2.45	2.45	2.45	2.17	2.17	0.72	1.45	1.45	2.90	1.81	1.60	2.01	2.49	3.18	3.26	3.34	3.43	3.52	3.61	3.70
Hopi Cultural Center	only well	0.00	0.50	0.59	0.89	1.24	1.63	2.07	2.52	2.96	3.41	3.85	4.29	4.74	5.18	5.63	6.07	6.51	6.96	7.43	7.91	8.38	8.88	11.20	8.69	8.69	10.14	10.14	8.69	8.69	9.89	9.80	7.79	10.69	9.98	10.24	10.51	10.78	11.06	11.35	11.65
Hopi High School	No. 1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	11.59	0.00	9.42	7.24	8.69	15.21	7.24	9.42	10.86	14.49	8.69	8.69	8.69	7.61	10.10	4.20	2.61	3.58	3.67	3.77	3.86	3.96	4.07	4.18
Hopi High School	No. 2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.43	0.00	3.62	6.52	0.00	0.72	4.34	5.79	7.24	8.69	4.34	0.72	6.52	6.19	7.40	12.79	17.91	5.45	5.59	5.74	5.88	6.04	6.19	6.36
Hopi High School	No. 3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.43	0.00	2.90	4.34	9.42	6.52	2.17	0.00	3.62	8.69	5.07	8.69	2.90	5.51	1.81	5.51	17.71	11.39	11.68	11.99	12.30	12.62	12.95	13.29
Hotevilla	PM1	7.23	7.59	7.95	8.31	8.67	9.03	9.40	9.76	10.12	10.48	10.84	11.20	11.56	11.93	12.29	12.65	13.04	13.37	1.45	12.31	14.49	21.73	21.01	23.18	28.25	31.88	19.56	13.04	12.31	8.20	5.89	4.71	4.80	9.32	9.56	9.81	10.06	10.32	10.59	10.87
Hotevilla	PM2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.25	4.88	6.51	8.13	9.76	11.38	13.04	14.64	15.21	12.31	7.24	7.97	3.62	0.00	0.00	0.00	0.00	0.00	0.00	19.05	19.53	20.02	20.54	21.07	21.61	22.17	22.74	23.34	23.95	24.57
Kayenta	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	74.03	64.37	70.00	63.57	57.98	62.77	64.37	64.46	66.65	58.68	88.38	86.93	73.89	59.68	65.53	86.96	69.26	43.73	69.85	68.82	38.70	57.56	76.39	81.81	73.26	75.15	77.08	79.08	81.14	83.26	85.44
Kayenta	2	31.89	36.27	42.49	49.01	42.99	74.59	75.24	70.29	75.89	74.03	64.37	70.00	63.57	57.98	62.77	64.37	64.46	66.65	58.68	89.11	86.93	74.62	58.18	29.58	62.69	68.77	17.21	58.24	45.64	67.81	65.73	63.69	55.79	60.99	62.56	64.18	65.84	67.56	69.32	71.14
Kayenta	3	31.89	36.27	42.49	49.01	42.99	74.59	75.24	70.29	75.89	74.03	64.37	70.00	63.57	57.98	62.77	64.37	64.46	66.65	58.68	89.11	86.21	73.89	68.04	61.68	83.85	66.69	70.32	50.99	77.52	77.99	71.51	64.99	66.30	74.98	76.91	78.90	80.95	83.05	85.22	87.45
Kayenta	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	74.03	64.37	70.00	63.57	57.98	62.77	64.37	64.46	66.65	58.68	89.11	86.93	73.89	86.06	45.07	49.90	31.83	45.57	91.05	113.74	139.79	132.51	125.19	107.01	91.01	93.36	95.77	98.25	100.81	103.43	106.14
Kayenta	5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	64.37	70.00	63.57	57.98	62.77	64.37	64.46	66.65	59.40	88.38	86.93	73.89	229.65	90.87	115.28	230.84	156.00	161.49	89.83	36.51	69.50	102.51	152.20	132.71	136.13	139.65	143.27	146.99	150.83	154.78
Kayenta	6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	64.37	70.00	63.57	57.98	62.77	64.37	64.46	67.37	58.68	89.11	86.21	73.89	95.58	68.90	41.74	27.39	99.59	24.99	65.92	100.59	85.96	71.30	95.79	71.20	73.03	74.91	76.86	78.86	80.91	83.03
Kayenta	7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	64.37	70.00	63.57	57.98	62.77	64.37	64.46	66.65	58.68	89.11	86.93	73.89	82.55	79.80	70.01	58.83	47.48	48.52	52.88	80.60	40.30	0.00	53.09	72.97	74.85	76.79	78.78	80.83	82.94	85.11
Kayenta	PM2	31.89	36.27	42.49	49.01	42.99	74.59	75.24	70.29	75.89	74.03	64.37	70.00	63.57	57.98	62.77	64.37	81.86	125.33	99.97	68.82	63.03	64.47	55.06	50.71	45.64	32.60	36.22	37.67	39.12	33.10	31.71	35.21	34.61	50.91	52.22	53.57	54.96	56.39	57.86	59.38
Kayenta	PM3	31.89	36.27	42.49	49.01	42.99	74.59	75.24	70.29	75.89	74.03	64.37	70.00	63.57	57.98	62.77	64.37	81.86	30.42	11.59	12.31	21.01	23.18	21.73	25.36	35.50	34.77	41.29	36.22	41.29	37.31	41.10	40.51	41.69	41.99	43.07	44.18	45.33	46.51	47.72	48.97
Keams Canyon	No. 2	0.00	0.00	3.92	4.76	5.60	6.44	7.28	8.12	8.96	9.80	10.64	11.48	12.32	13.16	14.00	14.84	11.23	38.39	37.67	49.26	39.12	47.09	32.60	62.30	36.22	34.05	39.12	41.29	21.01	26.09	40.30	29.49	39.59	21.60	22.15	22.73	23.32	23.92	24.55	25.19
Keams Canyon	No. 3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.92	5.39	6.86	8.33	9.80	11.27	11.27	11.27	11.23	12.31	26.80	26.08	26.08	37.67	31.15	28.25	12.31	10.86	17.38	10.14	10.14	23.01	39.71	47.49	54.10	12.09	12.40	12.72	13.05	13.39	13.74	14.10
Kitsillie	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.30	6.60	8.60	7.30	7.20	7.40	10.41	7.50	5.73	5.80	5.47	4.67	6.52	8.29	5.80	3.29	0.80	7.38	7.57	7.76	7.96	8.17	8.38	8.60
Kitsillie	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.60	11.10	8.20	19.60	13.28	12.69	12.89	13.10	13.31	13.53
Kykotsmovi	PM1	2.88	3.32	3.75	4.18	4.61	5.05	5.48	5.91	6.35	6.78	7.21	7.64	8.08	8.51	8.94	9.37	10.14	14.49	37.67	41.29	43.47	26.08	23.18	29.70	14.49	0.00	0.00	0.00	0.00	28.75	29.47	30.23	31.00	31.79	32.61	33.45	34.32	35.21	36.13	37.08
Kykotsmovi	PM2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	8.88	11.84	14.81	17.77	20.73	23.69	26.65	29.61	25.36	18.84	16.66	18.11	29.70	42.74	31.88	28.98	28.25	26.80	26.08	40.57	25.49	23.69	22.39	19.39	36.19	37.13	38.08	39.07	40.09	41.13	42.21
Kykotsmovi	PM3	2.45	2.91	3.37	3.83	4.29	4.75	5.21	5.67	6.13	6.59	7.05	7.51	7.97	8.43	8.89	9.35	9.81	15.94	0.00	0.00	0.00	0.00	2.90	0.72	31.15	37.67	39.12	42.02	42.02	39.59	37.90	48.21	48.00	25.97	26.64	27.32	28.03	28.76	29.51	30.29
Low Mountain	PM2	0.00	0.00	0.00	0.00	2.90	3.63	4.35	5.08	5.80	6.53	7.25	7.98	8.71	9.43	10.16	10.88	11.61	0.00	0.00	0.00	6.52	9.42	7.97	8.69	5.79	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mishongnovi	only well	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.17	1.20	1.30	1.70	2.80	3.10	3.62	3.62	4.34	4.34	5.79	5.79	5.80	6.10	6.99	6.01	7.21	7.40	7.59	7.78	7.99	8.20	8.41
Pinon	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	22.46	11.59	8.69	12.31	17.38	23.90	54.58	20.63	49.19	37.38	33.23	50.23	62.30	60.79	70.71	80.60	76.19	58.39	59.90	61.44	63.04	64.68	66.37	68.10
Pinon	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	23.18	11.59	8.69	12.31	17.38	24.63	15.09	50.87	36.95	54.33	71.28	69.17	94.90	76.90	81.81	86.70	90.19	48.96	50.22	51.52	52.85	54.23	55.64	57.10
Pinon	3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	22.46	10.86	7.97	13.04	16.66	23.90	8.57	49.33	45.85	46.08	57.20	50.74	84.04	124.60	115.24	105.89	122.59	18.34	18.82	19.30	19.80	20.32	20.85	21.39
Pinon	PM6	0.00	0.00	4.25	5.16	6.08	6.99	7.90	8.81	9.72	10.63	11.55	12.46	13.37	14.28	15.19	16.10	17.01	35.32	37.32	31.22	31.15	37.72	35.52	30.42	33.00	34.05	34.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Polacca	PM4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	29.61	29.61	34.77	37.67	34.05	31.15	29.70	29.70	29.70	33.32	41.29	39.84	39.84	41.69	42.75	43.84	44.96	46.12	47.30	48.53	49.78	51.08	52.41	53.78
Polacca	PM5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	29.61	29.61	0.00	0.00	48.54	84.03	26.08	26.08	26.08	26.08	26.08	97.80	76.79	67.30	72.40	80.01	92.21	90.92	93.26	95.67	98.15	100.70	103.33	106.03
Polacca	PM6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	29.61	29.61	0.00	0.00	27.53	0.00	3.62	3.62	3.62	3.62	3.62	3.62	10.86	2.61	2.31	3.29	2.31	8.21	8.42	8.64	8.87	9.10	9.33	9.58
Rocky Ridge	PM2	4.29	4.65	5.00	5.36	5.72	6.08	6.43	6.79	7.15	7.51	7.86	8.22	8.58	8.94	9.29	9.65	10.01	28.13	5.79	6.52	0.00	1.45	5.79	3.62	3.62	2.90	0.72	1.45	10.14	0.21	0.21	0.30	0.00	9.33	9.57	9.81	10.07	10.33	10.60	10.88
Rocky Ridge	PM3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.50	3.44	4.38	5.32	6.25	7.19	8.13	9.07	10.14	28.13	6.52	7.97	11.59	10.14	8.69	9.42	8.69	11.59	13.76	12.31	10.14	11.10	9.80	10.99	13.71	13.82	14.17	14.54	14.92	15.31	15.71	16.12
Rough Rock	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	9.11	12.51	9.61	11.20	12.61	12.41	12.01	16.66	16.66	17.38	18.11	13.76	10.14	15.99	14.15	12.29	12.86	13.16	13.46	13.77	14.10	14.44	14.78	15.14
Rough Rock	PM3	4.79	5.32	5.91	6.56	7.30	8.10	9.01	9.37	8.97	7.04	7.81	7.81	7.81	8.60	9.81	10.61	12.31	5.07	2.17	5.07	2.90	2.90	0.72	0.72	0.00	0.00	0.00	2.17	4.34	2.90	3.91	7.20	6.40	4.41	4.52	4.62	4.73	4.84	4.96	5.08
Rough Rock	PM5	4.79	5.32	5.91	6.56	7.30	8.10	9.01	9.37	8.97	7.04	7.81	7.81	7.81	8.60	9.81	10.61	13.04	12.31	12.31	7.97	0.00	11.59	13.04	21.73	23.18	15.94	1.45	12.31	12.31	10.95	11.19	11.44	11.69	11.96	12.23	12.52	12.81	13.12	13.43	13.76
Rough Rock	PM6	4.79	5.32	5.91	6.56	7.30	8.10	9.01	9.37	8.97	7.04	7.81	7.81	7.81	8.60	9.81	10.61	12.31	15.94	18.84	18.84	23.90	25.36	22.46	28.98	22.46	36.94	20.28	18.11	17.38	12.11	11.49	8.79	11.61	19.63	20.08	20.55	21.03	21.54	22.05	22.59
Rough Rock	PM7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.07	5.79	2.17	2.90	5.79	4.34	5.79	5.79	5.07	5.07	0.72	5.79	2.99	4.71	5.39	5.80	3.55	3.63	3.72	3.81	3.90	3.99	4.09
Second Mesa	No. 1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.80	0.59	0.89	0.80	0.24	0.25	0.25	0.26	0.27	0.27	0.28
Second Mesa	PM2	1.09	1.29	1.50	1.70	1.90	2.11	2.31	2.52	2.72	2.92	3.13	3.33	3.54	3.74	3.94	4.15	4.35	16.66	10.14	10.14	8.69	7.97	8.69	18.11	5.79	5.79	8.69	7.24	0.00	0.21	2.10	5.60	5.60	4.61	4.73	4.85	4.97	5.10	5.24	5.37
Shipaulovi	No. 2	0.00	0.00	1.00	1.21	1.43	1.64	1.86	2.07	2.29	2.50	2.72	2.93	3.14	3.36	3.57	3.79	2.10	7.97	18.11	18.51	17.81	18.51	22.71	25.36	27.53	28.25	27.53	27.53	40.57	36.60	31.80	23.90	23.60	45.67	46.84	48.05	49.30	50.58	51.90	53.26
Shungopovi	only well	0.00	0.00	0.00	0.00	0.00	3.00	3.82	4.64	5.46	6.28	7.09	7.91	8.73	9.55	10.37	11.19	12.01	11.11	12.31	13.11	14.91	19.31	18.91	18.84	18.11	18.84	21.01	19.56	22.46	22.71	25.11	28.01	21.20	25.19	25.84	26.51	27.19	27.90	28.63	29.38

Annual Pumping Volumes from Community Wells Located in the Confined Portion of the N Aquifer under the 1236 af/yr Pumping Scenario (Table 14)

		Volume Pumped (af/yr)																			
Community Name	Well ID	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027
Bacavi	only well	5.32	5.46	5.61	5.75	5.91	6.06	6.23	6.39	6.57	6.75	6.93	7.11	7.30	7.50	7.70	7.91	8.13	8.35	8.57	8.80
Chilchinbito	1	18.51	19.00	19.50	20.02	20.55	21.10	21.67	22.25	22.85	23.47	24.10	24.75	25.42	26.11	26.81	27.54	28.28	29.04	29.83	30.63
Chilchinbito	2	31.35	32.18	33.03	33.91	34.81	35.74	36.70	37.69	38.71	39.75	40.82	41.93	43.06	44.22	45.42	46.64	47.90	49.19	50.52	51.89
Chilchinbito	PM2	4.32	4.44	4.56	4.68	4.80	4.93	5.06	5.20	5.34	5.48	5.63	5.78	5.94	6.10	6.27	6.43	6.61	6.79	6.97	7.16
Chilchinbito	PM3	6.65	6.83	7.01	7.20	7.39	7.59	7.79	8.00	8.22	8.44	8.66	8.90	9.14	9.39	9.64	9.90	10.17	10.44	10.72	11.02
Forest Lake	4T-523	15.07	15.47	15.88	16.30	16.74	17.19	17.64	18.12	18.61	19.11	19.63	20.16	20.70	21.26	21.84	22.43	23.03	23.65	24.29	24.95
Hard Rock	2	2.02	2.08	2.13	2.19	2.25	2.31	2.37	2.43	2.50	2.57	2.64	2.71	2.78	2.85	2.93	3.01	3.09	3.18	3.26	3.35
Hopi Civic Center	only well	3.80	3.90	4.01	4.11	4.22	4.33	4.45	4.57	4.69	4.82	4.95	5.08	5.22	5.36	5.51	5.66	5.81	5.97	6.13	6.29
Hopi Cultural Center	only well	11.95	12.26	12.59	12.92	13.27	13.62	13.99	14.37	14.75	15.15	15.56	15.98	16.41	16.86	17.31	17.78	18.26	18.75	19.26	19.78
Hopi High School	No. 1	4.28	4.40	4.52	4.63	4.76	4.89	5.02	5.15	5.29	5.43	5.58	5.73	5.88	6.04	6.21	6.38	6.55	6.72	6.91	7.09
Hopi High School	No. 2	6.52	6.70	6.87	7.06	7.25	7.44	7.64	7.84	8.05	8.27	8.50	8.73	8.96	9.20	9.45	9.71	9.97	10.24	10.51	10.80
Hopi High School	No. 3	13.64	13.99	14.36	14.75	15.14	15.54	15.96	16.39	16.83	17.29	17.75	18.23	18.73	19.23	19.75	20.28	20.83	21.39	21.97	22.56
Hotevilla	PM1	11.15	11.45	11.75	12.06	12.39	12.72	13.06	13.41	13.77	14.14	14.53	14.92	15.32	15.73	16.16	16.60	17.04	17.50	17.98	18.46
Hotevilla	PM2	25.22	25.88	26.57	27.27	28.00	28.75	29.52	30.32	31.13	31.97	32.83	33.72	34.63	35.57	36.53	37.52	38.53	39.57	40.64	41.74
Kayenta	1	87.69	90.00	92.38	94.83	97.36	99.96	102.64	105.40	108.25	111.17	114.17	117.26	120.42	123.67	127.01	130.44	133.96	137.58	141.29	145.11
Kayenta	2	73.00	74.93	76.91	78.96	81.06	83.23	85.46	87.76	90.13	92.56	95.06	97.63	100.26	102.97	105.75	108.60	111.54	114.55	117.64	120.82
Kayenta	3	89.75	92.11	94.55	97.06	99.65	102.31	105.06	107.88	110.80	113.79	116.86	120.02	123.26	126.58	130.00	133.51	137.12	140.82	144.62	148.53
Kayenta	4	108.93	111.81	114.76	117.81	120.95	124.18	127.51	130.95	134.48	138.11	141.84	145.67	149.60	153.64	157.79	162.05	166.43	170.92	175.54	180.28
Kayenta	5	158.85	163.04	167.35	171.79	176.37	181.08	185.94	190.95	196.10	201.39	206.83	212.42	218.15	224.04	230.09	236.31	242.68	249.24	255.97	262.88
Kayenta	6	85.22	87.46	89.78	92.16	94.61	97.14	99.75	102.43	105.20	108.04	110.96	113.95	117.03	120.19	123.43	126.77	130.19	133.71	137.31	141.02
Kayenta	7	87.34	89.65	92.02	94.47	96.98	99.57	102.24	105.00	107.83	110.74	113.73	116.80	119.96	123.20	126.52	129.94	133.45	137.05	140.75	144.55
Kayenta	PM2	60.94	62.55	64.20	65.90	67.66	69.47	71.33	73.25	75.23	77.26	79.35	81.49	83.69	85.95	88.27	90.65	93.10	95.61	98.20	100.85
Kayenta	PM3	50.26	51.58	52.95	54.35	55.80	57.29	58.83	60.41	62.04	63.72	65.44	67.21	69.02	70.88	72.80	74.76	76.78	78.86	80.98	83.17
Keams Canyon	No. 2	25.85	26.53	27.24	27.96	28.70	29.47	30.26	31.08	31.91	32.78	33.66	34.57	35.50	36.46	37.45	38.46	39.50	40.56	41.66	42.78
Keams Canyon	No. 3	14.47	14.85	15.25	15.65	16.07	16.50	16.94	17.40	17.87	18.35	18.84	19.35	19.87	20.41	20.96	21.53	22.11	22.71	23.32	23.95
Kitsillie	1	8.83	9.06	9.30	9.55	9.80	10.06	10.33	10.61	10.90	11.19	11.49	11.80	12.12	12.45	12.79	13.13	13.49	13.85	14.22	14.61
Kitsillie	2	13.76	13.99	14.23	14.48	14.73	14.99	15.26	15.54	15.83	16.12	16.42	16.73	17.05	17.38	17.71	18.06	18.42	18.78	19.15	19.54
Kykotsmovi	PM1	38.05	39.06	40.09	41.16	42.25	43.38	44.54	45.74	46.98	48.25	49.55	50.89	52.26	53.67	55.12	56.61	58.14	59.71	61.32	62.98
Kykotsmovi	PM2	43.32	44.46	45.64	46.85	48.10	49.38	50.71	52.07	53.48	54.92	56.41	57.93	59.49	61.10	62.75	64.44	66.19	67.97	69.81	71.69
Kykotsmovi	PM3	31.08	31.90	32.75	33.62	34.51	35.43	36.39	37.36	38.37	39.41	40.47	41.56	42.69	43.84	45.02	46.24	47.49	48.77	50.09	51.44
Low Mountain	PM2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mishongnovi	only well	8.63	8.86	9.09	9.33	9.58	9.84	10.10	10.38	10.65	10.94	11.24	11.54	11.85	12.17	12.50	12.84	13.19	13.54	13.91	14.28
Pinon	1	69.89	71.74	73.63	75.59	77.60	79.68	81.82	84.02	86.28	88.61	91.01	93.47	95.99	98.58	101.24	103.98	106.78	109.66	112.63	115.67
Pinon	2	58.60	60.14	61.74	63.38	65.07	66.80	68.60	70.44	72.34	74.30	76.30	78.36	80.48	82.65	84.88	87.18	89.53	91.95	94.43	96.98
Pinon	3	21.96	22.54	23.13	23.74	24.38	25.03	25.70	26.39	27.11	27.84	28.59	29.36	30.16	30.97	31.80	32.66	33.55	34.45	35.38	36.34
Pinon	PM6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Polacca	PM4	55.20	56.65	58.15	59.70	61.29	62.92	64.61	66.35	68.14	69.98	71.87	73.81	75.81	77.85	79.95	82.11	84.33	86.61	88.95	91.35
Polacca	PM5	108.82	111.69	114.64	117.69	120.82	124.05	127.38	130.81	134.34	137.97	141.69	145.52	149.45	153.48	157.62	161.88	166.25	170.74	175.35	180.08
Polacca	PM6	9.83	10.09	10.35	10.63	10.91	11.21	11.51	11.82	12.13	12.46	12.80	13.14	13.50	13.86	14.24	14.62	15.02	15.42	15.84	16.27
Rocky Ridge	PM2	11.16	11.46	11.76	12.07	12.39	12.73	13.07	13.42	13.78	14.15	14.54	14.93	15.33	15.75	16.17	16.61	17.06	17.52	17.99	18.47
Rocky Ridge	PM3	16.54	16.98	17.43	17.89	18.37	18.86	19.36	19.88	20.42	20.97	21.54	22.12	22.72	23.33	23.96	24.61	25.27	25.95	26.66	27.37
Rough Rock	1	15.52	15.91	16.31	16.73	17.16	17.61	18.07	18.55	19.06	19.57	20.10	20.64	21.20	21.77	22.36	22.96	23.58	24.22	24.87	25.54
Rough Rock	PM3	5.21	5.34	5.47	5.61	5.76	5.91	6.06	6.23	6.40	6.57	6.75	6.93	7.12	7.31	7.50	7.71	7.91	8.13	8.35	8.57
Rough Rock	PM5	14.10	14.46	14.82	15.20	15.59	16.00	16.42	16.86	17.32	17.79	18.27	18.76	19.27	19.79	20.32	20.87	21.43	22.01	22.60	23.22
Rough Rock	PM6	23.15	23.73	24.33	24.95	25.60	26.27	26.96	27.68	28.43	29.20	29.99	30.79	31.63	32.48	33.36	34.26	35.18	36.13	37.11	38.11
Rough Rock	PM7	4.19	4.30	4.40	4.52	4.63	4.76	4.88	5.01	5.15	5.29	5.43	5.58	5.73	5.88	6.04	6.20	6.37	6.54	6.72	6.90
Second Mesa	No. 1	0.29	0.30	0.30	0.31	0.32	0.33	0.34	0.35	0.36	0.36	0.38	0.38	0.40	0.41	0.42	0.43	0.44	0.45	0.46	0.48
Second Mesa	PM2	5.52	5.66	5.81	5.96	6.12	6.29	6.46	6.63	6.81	6.99	7.18	7.38	7.57	7.78	7.99	8.21	8.43	8.66	8.89	9.13
Shipaulovi	No. 2	54.66	56.10	57.59	59.11	60.69	62.31	63.98	65.70	67.48	69.30	71.17	73.09	75.07	77.09	79.18	81.31	83.51	85.76	88.08	90.46
Shungopovi	only well	30.15	30.95	31.77	32.61	33.48	34.37	35.29	36.24	37.22	38.23	39.26	40.32	41.41	42.53	43.68	44.85	46.06	47.31	48.58	49.90

Community Name	Well ID	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047
Bacavi	only well	9.04	9.29	9.54	9.80	10.06	10.33	10.61	10.90	11.19	11.49	11.80	12.12	12.45	12.79	13.13	13.48	13.85	14.22	14.61	15.00
Chilchinbito	1	31.46	32.31	33.18	34.08	35.00	35.94	36.92	37.91	38.93	39.99	41.06	42.17	43.31	44.48	45.68	46.91	48.18	49.48	50.82	52.19
Chilchinbito	2	53.29	54.73	56.20	57.72	59.28	60.88	62.53	64.21	65.95	67.73	69.55	71.43	73.36	75.34	77.38	79.47	81.61	83.81	86.08	88.40
Chilchinbito	PM2	7.35	7.55	7.75	7.96	8.18	8.40	8.63	8.86	9.10	9.34	9.60	9.85	10.12	10.39	10.67	10.96	11.26	11.56	11.87	12.19
Chilchinbito	PM3	11.31	11.62	11.93	12.25	12.58	12.92	13.27	13.63	14.00	14.38	14.76	15.16	15.57	15.99	16.42	16.87	17.32	17.79	18.27	18.76
Forest Lake	4T-523	25.62	26.31	27.03	27.75	28.50	29.27	30.06	30.87	31.71	32.57	33.44	34.35	35.27	36.23	37.20	38.21	39.24	40.30	41.39	42.50
Hard Rock	2	3.44	3.53	3.63	3.73	3.83	3.93	4.04	4.15	4.26	4.37	4.49	4.61	4.74	4.86	5.00	5.13	5.27	5.41	5.56	5.71
Hopi Civic Center	only well	6.46	6.64	6.82	7.00	7.19	7.38	7.58	7.79	8.00	8.21	8.44	8.66	8.90	9.14	9.38	9.64	9.90	10.17	10.44	10.72
Hopi Cultural Center	only well	20.31	20.86	21.42	22.00	22.60	23.21	23.83	24.48	25.14	25.82	26.51	27.23	27.96	28.72	29.49	30.29	31.11	31.95	32.81	33.70
Hopi High School	No. 1	7.28	7.48	7.68	7.89	8.10	8.32	8.55	8.78	9.01	9.26	9.51	9.76	10.03	10.30	10.57	10.86	11.15	11.46	11.76	12.08
Hopi High School	No. 2	11.09	11.39	11.70	12.01	12.34	12.67	13.01	13.36	13.72	14.09	14.48	14.87	15.27	15.68	16.10	16.54	16.98	17.44	17.91	18.40
Hopi High School	No. 3	23.17	23.80	24.44	25.10	25.78	26.47	27.19	27.93	28.68	29.45	30.25	31.06	31.91	32.77	33.65	34.56	35.49	36.45	37.43	38.45
Hotevilla	PM1	18.96	19.47	20.00	20.54	21.09	21.66	22.25	22.85	23.47	24.10	24.75	25.42	26.10	26.81	27.53	28.27	29.04	29.82	30.63	31.46
Hotevilla	PM2	42.86	44.02	45.21	46.43	47.68	48.97	50.29	51.65	53.04	54.47	55.95	57.46	59.01	60.60	62.23	63.92	65.64	67.41	69.23	71.10
Kayenta	1	149.03	153.05	157.18	161.43	165.79	170.26	174.86	179.58	184.43	189.41	194.53	199.78	205.17	210.71	216.40	222.24	228.24	234.40	240.73	247.23
Kayenta	2	124.08	127.43	130.87	134.40	138.03	141.76	145.59	149.52	153.56	157.70	161.96	166.33	170.82	175.44	180.17	185.03	190.03	195.16	200.43	205.84
Kayenta	3	152.53	156.65	160.88	165.23	169.69	174.27	178.98	183.81	188.77	193.87	199.10	204.48	210.00	215.67	221.49	227.47	233.61	239.92	246.40	253.05
Kayenta	4	185.14	190.14	195.28	200.55	205.96	211.52	217.24	223.10	229.12	235.31	241.66	248.19	254.89	261.77	268.84	276.10	283.55	291.21	299.07	307.15
Kayenta	5	269.98	277.27	284.75	292.44	300.33	308.44	316.77	325.33	334.11	343.13	352.40	361.91	371.68	381.72	392.02	402.61	413.48	424.64	436.10	447.88
Kayenta	6	144.83	148.74	152.76	156.88	161.12	165.47	169.93	174.52	179.23	184.08	189.04	194.15	199.39	204.78	210.30	215.98	221.81	227.80	233.95	240.27
Kayenta	7	148.45	152.46	156.58	160.80	165.15	169.60	174.19	178.89	183.72	188.68	193.77	199.01	204.38	209.90	215.56	221.38	227.36	233.50	239.80	246.28
Kayenta	PM2	103.57	106.37	109.24	112.19	115.22	118.33	121.52	124.80	128.17	131.64	135.19	138.84	142.59	146.44	150.39	154.45	158.62	162.90	167.30	171.82
Kayenta	PM3	85.42	87.72	90.09	92.52	95.02	97.59	100.22	102.93	105.71	108.56	111.49	114.50	117.59	120.77	124.03	127.38	130.82	134.35	137.98	141.70
Keams Canyon	No. 2	43.94	45.12	46.34	47.60	48.88	50.20	51.55	52.95	54.38	55.85	57.35	58.90	60.49	62.13	63.80	65.52	67.29	69.11	70.98	72.89
Keams Canyon	No. 3	24.60	25.26	25.94	26.64	27.36	28.10	28.86	29.64	30.44	31.26	32.11	32.97	33.87	34.78	35.72	36.68	37.67	38.69	39.73	40.81
Kitsillie	1	15.00	15.41	15.82	16.25	16.69	17.14	17.60	18.08	18.57	19.07	19.58	20.11	20.66	21.21	21.78	22.37	22.98	23.60	24.23	24.89
Kitsillie	2	19.93	20.34	20.75	21.18	21.62	22.07	22.53	23.01	23.50	24.00	24.51	25.04	25.72	26.41	27.12	27.86	28.61	29.38	30.17	30.99
Kykotsmovi	PM1	64.67	66.42	68.22	70.06	71.95	73.89	75.89	77.93	80.04	82.20	84.42	86.70	89.04	91.45	93.91	96.45	99.05	101.73	104.47	107.30
Kykotsmovi	PM2	73.63	75.62	77.66	79.75	81.91	84.12	86.39	88.72	91.12	93.58	96.10	98.70	101.37	104.10	106.91	109.80	112.76	115.81	118.93	122.14
Kykotsmovi	PM3	52.83	54.26	55.72	57.22	58.77	60.35	61.99	63.66	65.38	67.14	68.96	70.82	72.73	74.69	76.71	78.78	80.90	83.09	85.33	87.64
Low Mountain	PM2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mishongnovi	only well	14.67	15.07	15.47	15.89	16.32	16.76	17.21	17.68	18.15	18.65	19.15	19.66	20.20	20.74	21.30	21.88	22.47	23.07	23.70	24.34
Pinon	1	118.79	122.00	125.29	128.67	132.15	135.72	139.38	143.15	147.01	150.98	155.05	159.24	163.54	167.96	172.49	177.15	181.93	186.84	191.89	197.07
Pinon	2	99.60	102.29	105.05	107.89	110.80	113.79	116.86	120.02	123.26	126.59	130.00	133.51	137.12	140.82	144.62	148.53	152.54	156.66	160.88	165.23
Pinon	3	37.32	38.32	39.36	40.42	41.51	42.64	43.79	44.97	46.18	47.43	48.71	50.03	51.38	52.76	54.19	55.65	57.15	58.69	60.28	61.91
Pinon	PM6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Polacca	PM4	93.81	96.35	98.95	101.62	104.36	107.18	110.08	113.05	116.10	119.23	122.45	125.76	129.15	132.64	136.22	139.90	143.68	147.56	151.54	155.63
Polacca	PM5	184.95	189.94	195.07	200.34	205.74	211.30	217.01	222.87	228.88	235.06	241.41	247.93	254.62	261.50	268.56	275.81	283.26	290.90	298.76	306.82
Polacca	PM6	16.71	17.16	17.62	18.10	18.59	19.09	19.60	20.13	20.68	21.24	21.81	22.40	23.00	23.62	24.26	24.91	25.59	26.28	26.99	27.72
Rocky Ridge	PM2	18.97	19.49	20.01	20.55	21.11	21.68	22.26	22.87	23.48	24.11	24.77	25.44	26.12	26.83	27.55	28.29	29.06	29.84	30.65	31.48
Rocky Ridge	PM3	28.12	28.87	29.65	30.45	31.27	32.12	32.99	33.88	34.79	35.73	36.70	37.69	38.71	39.75	40.82	41.93	43.06	44.22	45.41	46.64
Rough Rock	1	26.23	26.94	27.67	28.42	29.19	29.97	30.78	31.61	32.47	33.34	34.24	35.17	36.12	37.10	38.10	39.12	40.18	41.26	42.38	43.52
Rough Rock	PM3	8.81	9.04	9.29	9.54	9.80	10.06	10.33	10.61	10.90	11.19	11.49	11.80	12.12	12.45	12.78	13.13	13.48	13.85	14.22	14.60
Rough Rock	PM5	23.84	24.49	25.15	25.83	26.52	27.24	27.98	28.73	29.51	30.30	31.12	31.96	32.83	33.71	34.62	35.56	36.52	37.50	38.51	39.55
Rough Rock	PM6	39.14	40.20	41.28	42.40	43.54	44.72	45.93	47.17	48.44	49.75	51.09	52.47	53.89	55.34	56.83	58.37	59.95	61.56	63.23	64.93
Rough Rock	PM7	7.09	7.28	7.47	7.67	7.88	8.10	8.31	8.54	8.77	9.01	9.25	9.50	9.76	10.02	10.29	10.57	10.85	11.15	11.45	11.76
Second Mesa	No. 1	0.49	0.50	0.52	0.53	0.54	0.56	0.57	0.59	0.61	0.62	0.64	0.66	0.68	0.69	0.71	0.73	0.75	0.77	0.79	0.81
Second Mesa	PM2	9.37	9.63	9.89	10.15	10.43	10.71	11.00	11.30	11.60	11.92	12.24	12.57	12.91	13.25	13.61	13.98	14.36	14.74	15.14	15.55
Shipaulovi	No. 2	92.90	95.41	97.98	100.63	103.35	106.14	109.00	111.94	114.97	118.07	121.26	124.53	127.90	131.35	134.89	138.53	142.27	146.12	150.06	154.12
Shungopovi	only well	51.24	52.63	54.05	55.51	57.01	58.55	60.13	61.75	63.42	65.13	66.89	68.70	70.55	72.45	74.41	76.42	78.48	80.60	82.78	85.01

Annual Pumping Volumes from Community Wells Located in the Confined Portion of the N Aquifer under the 1236 af/yr Pumping Scenario (Table 14)

Community Name	Well ID	2048	2049	2050	2051	2052	2053	2054	2055	2056	2057	Comments
Bacavi	only well	15.41	15.82	16.25	16.69	17.14	17.60	18.08	18.57	19.07	19.58	
Chilchinbito	1	53.60	55.05	56.53	58.06	59.63	61.24	62.89	64.59	66.33	68.12	
Chilchinbito	2	90.79	93.24	95.76	98.34	101.00	103.72	106.53	109.40	112.36	115.39	
Chilchinbito	PM2	12.52	12.86	13.21	13.56	13.93	14.31	14.69	15.09	15.50	15.92	pumped from D Aquifer (Entrada Formation)
Chilchinbito	PM3	19.27	19.79	20.32	20.87	21.44	22.02	22.61	23.22	23.85	24.49	
Forest Lake	4T-523	43.65	44.83	46.04	47.28	48.56	49.87	51.22	52.60	54.02	55.48	
Hard Rock	2	5.86	6.02	6.18	6.35	6.52	6.69	6.88	7.06	7.25	7.45	
Hopi Civic Center	only well	11.01	11.31	11.61	11.93	12.25	12.58	12.92	13.27	13.63	13.99	
Hopi Cultural Center	only well	34.61	35.54	36.50	37.48	38.50	39.54	40.60	41.70	42.83	43.98	
Hopi High School	No. 1	12.41	12.74	13.09	13.44	13.80	14.18	14.56	14.95	15.36	15.77	
Hopi High School	No. 2	18.89	19.41	19.93	20.47	21.02	21.59	22.17	22.77	23.38	24.02	
Hopi High School	No. 3	39.48	40.55	41.64	42.77	43.92	45.11	46.33	47.58	48.86	50.18	pumped from D and N Aquifers
Hotevilla	PM1	32.30	33.18	34.07	34.99	35.94	36.91	37.90	38.93	39.98	41.06	
Hotevilla	PM2	73.02	74.99	77.02	79.10	81.24	83.43	85.68	87.99	90.37	92.81	
Kayenta	1	253.91	260.76	267.80	275.04	282.46	290.09	297.92	305.96	314.22	322.71	
Kayenta	2	211.40	217.11	222.97	228.99	235.17	241.52	248.05	254.74	261.62	268.68	
Kayenta	3	259.88	266.90	274.11	281.51	289.11	296.91	304.93	313.16	321.62	330.30	
Kayenta	4	315.44	323.96	332.70	341.69	350.91	360.39	370.12	380.11	390.37	400.91	
Kayenta	5	459.97	472.39	485.15	498.24	511.70	525.51	539.70	554.28	569.24	584.61	
Kayenta	6	246.76	253.42	260.26	267.29	274.51	281.92	289.53	297.35	305.37	313.62	
Kayenta	7	252.93	259.76	266.77	273.97	281.37	288.97	296.77	304.78	313.01	321.46	
Kayenta	PM2	176.46	181.22	186.12	191.14	196.30	201.60	207.04	212.63	218.38	224.27	
Kayenta	PM3	145.53	149.46	153.49	157.64	161.89	166.27	170.76	175.37	180.10	184.96	
Keams Canyon	No. 2	74.86	76.88	78.96	81.09	83.28	85.53	87.84	90.21	92.64	95.15	
Keams Canyon	No. 3	41.91	43.04	44.20	45.40	46.62	47.88	49.17	50.50	51.87	53.27	
Kitsillie	1	25.56	26.25	26.96	27.69	28.43	29.20	29.99	30.80	31.63	32.49	pumped from D Aquifer (Entrada Formation)
Kitsillie	2	31.83	32.68	33.57	34.47	35.40	36.36	37.34	38.35	39.39	40.45	came online after 1999 PWCC 3-D report
Kykotsmovi	PM1	110.19	113.17	116.22	119.36	122.58	125.89	129.29	132.78	136.37	140.05	pumped from D and N Aquifers
Kykotsmovi	PM2	125.44	128.83	132.31	135.88	139.55	143.32	147.19	151.16	155.24	159.43	
Kykotsmovi	PM3	90.00	92.43	94.93	97.49	100.12	102.83	105.61	108.46	111.39	114.39	
Low Mountain	PM2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	Well taken out of service in 1993? (USGS OFR 03-503, Table 3)
Mishongnovi	only well	24.99	25.67	26.36	27.07	27.80	28.55	29.33	30.12	30.93	31.77	
Pinon	1	202.39	207.86	213.47	219.23	225.15	231.23	237.47	243.89	250.47	257.23	
Pinon	2	169.69	174.27	178.98	183.81	188.77	193.87	199.10	204.48	210.00	215.67	
Pinon	3	63.58	65.29	67.06	68.87	70.73	72.64	74.60	76.61	78.68	80.81	
Pinon	PM6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	Well taken out of service in 1995? (USGS OFR 03-503, Table 3)
Polacca	PM4	159.83	164.15	168.58	173.13	177.81	182.61	187.54	192.60	197.80	203.14	not metered, estimated on per capita basis by USGS (USGS OFR 03-503)
Polacca	PM5	315.11	323.61	332.35	341.33	350.54	360.01	369.73	379.71	389.96	400.49	pumped from D Aquifer (Entrada Formation)
Polacca	PM6	28.46	29.23	30.02	30.83	31.67	32.52	33.40	34.30	35.23	36.18	pumped from D Aquifer (Entrada Formation)
Rocky Ridge	PM2	32.33	33.20	34.09	35.01	35.96	36.93	37.93	38.95	40.00	41.08	
Rocky Ridge	PM3	47.90	49.19	50.52	51.89	53.29	54.73	56.20	57.72	59.28	60.88	
Rough Rock	1	44.70	45.91	47.15	48.42	49.73	51.07	52.45	53.86	55.32	56.81	
Rough Rock	PM3	15.00	15.40	15.82	16.25	16.69	17.14	17.60	18.07	18.56	19.06	
Rough Rock	PM5	40.62	41.72	42.84	44.00	45.19	46.41	47.66	48.95	50.27	51.63	
Rough Rock	PM6	66.69	68.49	70.34	72.23	74.19	76.19	78.25	80.36	82.53	84.76	
Rough Rock	PM7	12.07	12.40	12.73	13.08	13.43	13.79	14.17	14.55	14.94	15.34	
Second Mesa	No. 1	0.83	0.86	0.88	0.90	0.93	0.95	0.98	1.00	1.03	1.06	
Second Mesa	PM2	15.97	16.40	16.84	17.30	17.77	18.25	18.74	19.24	19.76	20.30	
Shipaulovi	No. 2	158.28	162.55	166.94	171.45	176.07	180.83	185.71	190.73	195.88	201.16	
Shungopovi	only well	87.31	89.66	92.09	94.57	97.12	99.75	102.44	105.21	108.05	110.96	