Black Mesa Case Study

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Consortium for Science, Policy, and Outcomes at Arizona State University

Theory on western water development

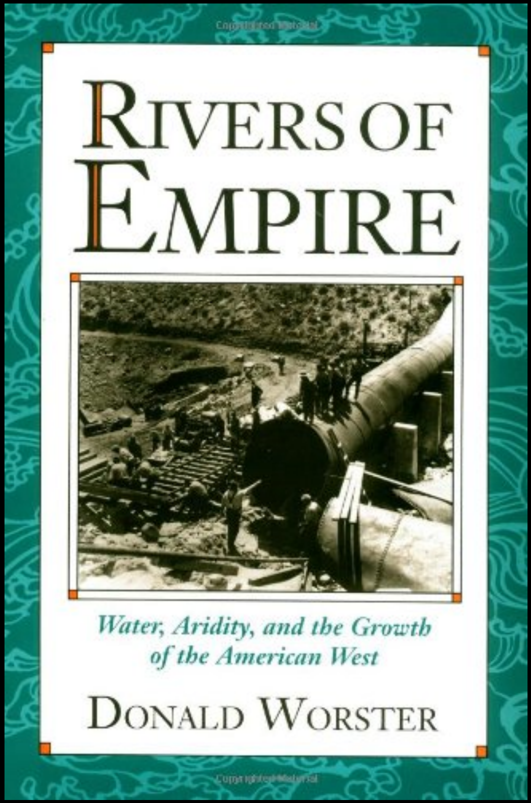
(Donald Worster 1985)

The development of the American West is best understood as:

"a modern hydraulic society… a social order based on the intensive, large-scale manipulation of water and its products in an arid setting."

The control of Western waters became:

"…an increasingly coercive, monolithic, and hierarchical system, ruled by a power elite based upon the ownership of capital and expertise"

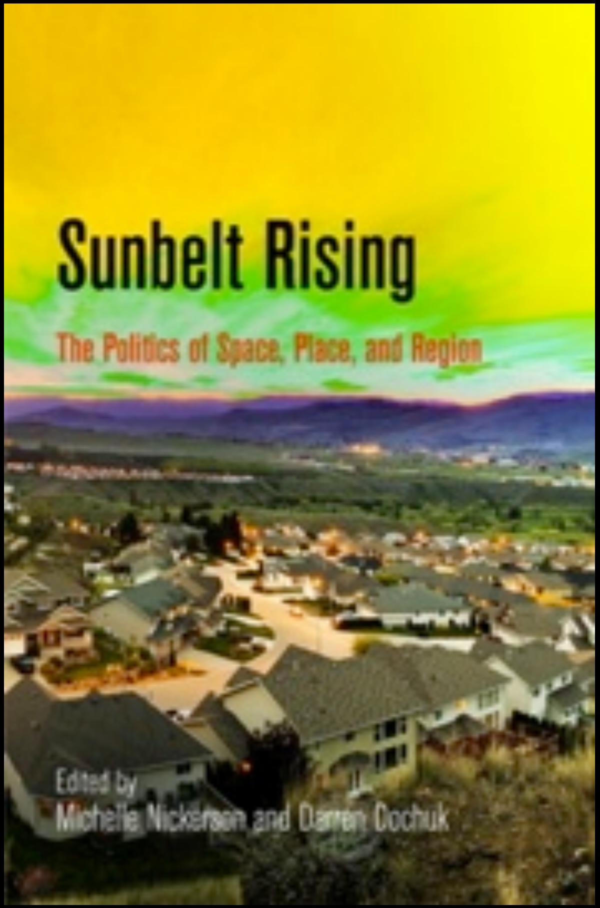


…on metropolitan Arizona's development
(Andrew Needham, in Nickerson & dochuk 2011)

Arizona development during the Post WWII:

"From the 1930s forward, Sunbelt strategies of growth produced new demand for water and energy resources located on federally controlled lands…

"…It was a fundamentally political project in which metropolitan representatives claimed authority over distant lands and resources… *Sunbelt cities became imperial entities.*"



Phoenix boosters' growth strategy…

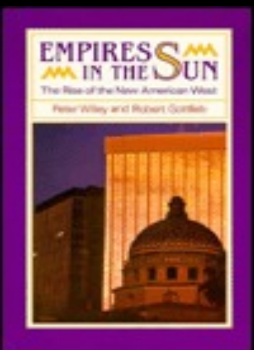
In 1900, the population of the Phoenix area was approx. 7,200

- Transform local policies to attract industry:
  - Lower taxes
  - lax environmental regulations
  - Prevent union organizing
  - Land grants / dev. bonds

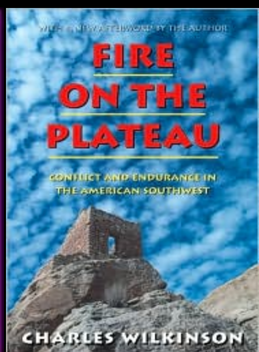
- Yet, boosters faced "city limits"…
  - Federal gov controlled energy and water resources on nearby tribal lands

- Their Goal: reorient federal natural resource and Indian policies toward local control
  - Support metro growth
  - "Land Freedom"
  - Termination plan for reservation lands

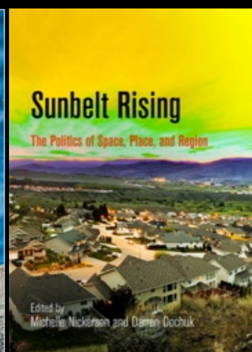
WEST Associate's "Grand Plan" and "The Big Buildup" on the Colorado Plateau



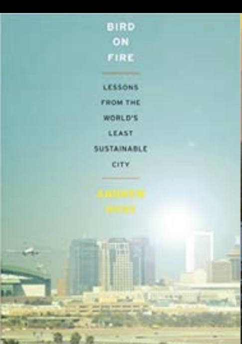
Wiley & Gottlieb 1982



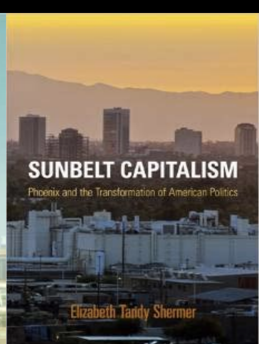
Wilkinson 1999



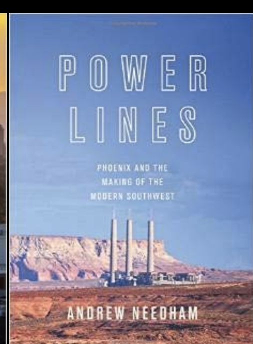
Nickerson & Dochuk 2011



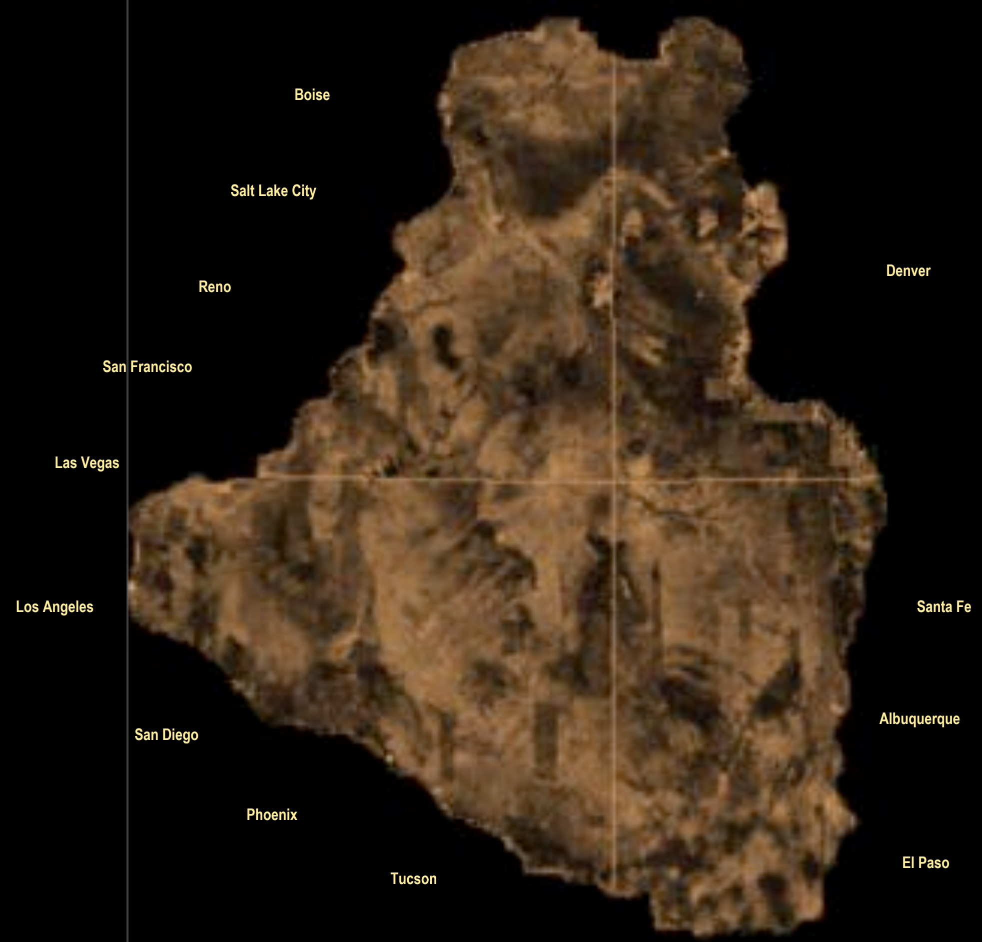
Ross 2013



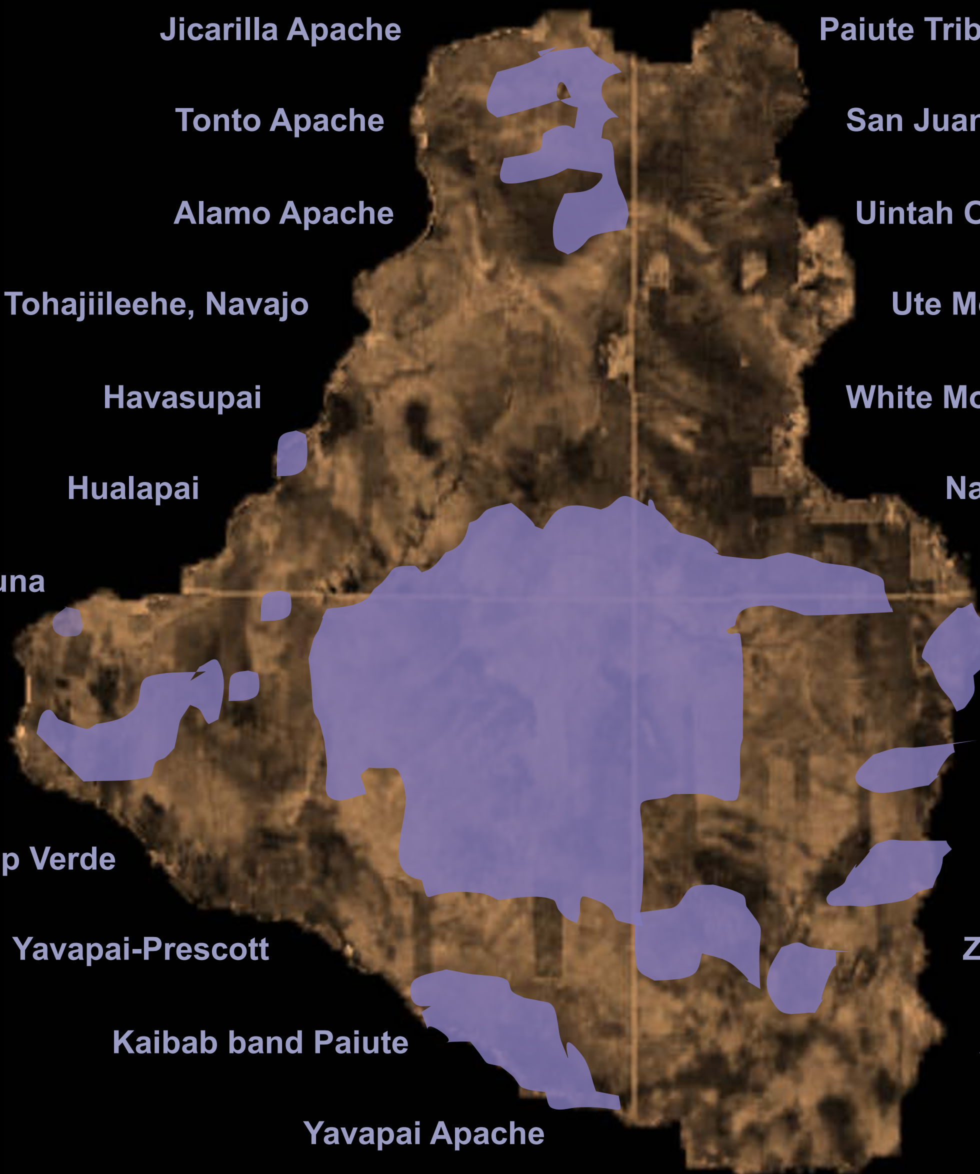
Tandy-Shermer 2013



Needham 2014

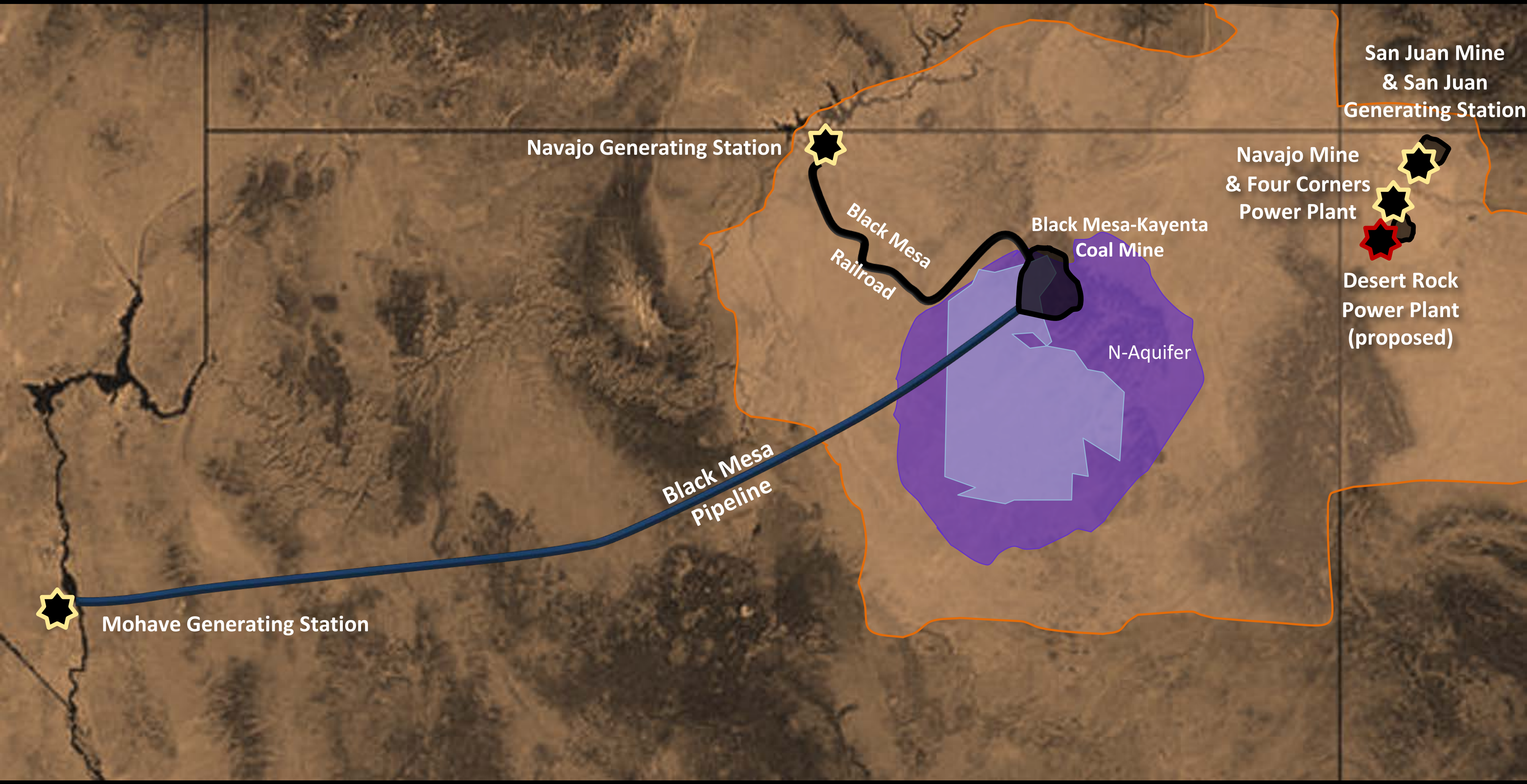


The Colorado Plateau



The Colorado Plateau

Black Mesa and the Four Corners Coal-Energy Infrastructure



The Navajo Generating Station

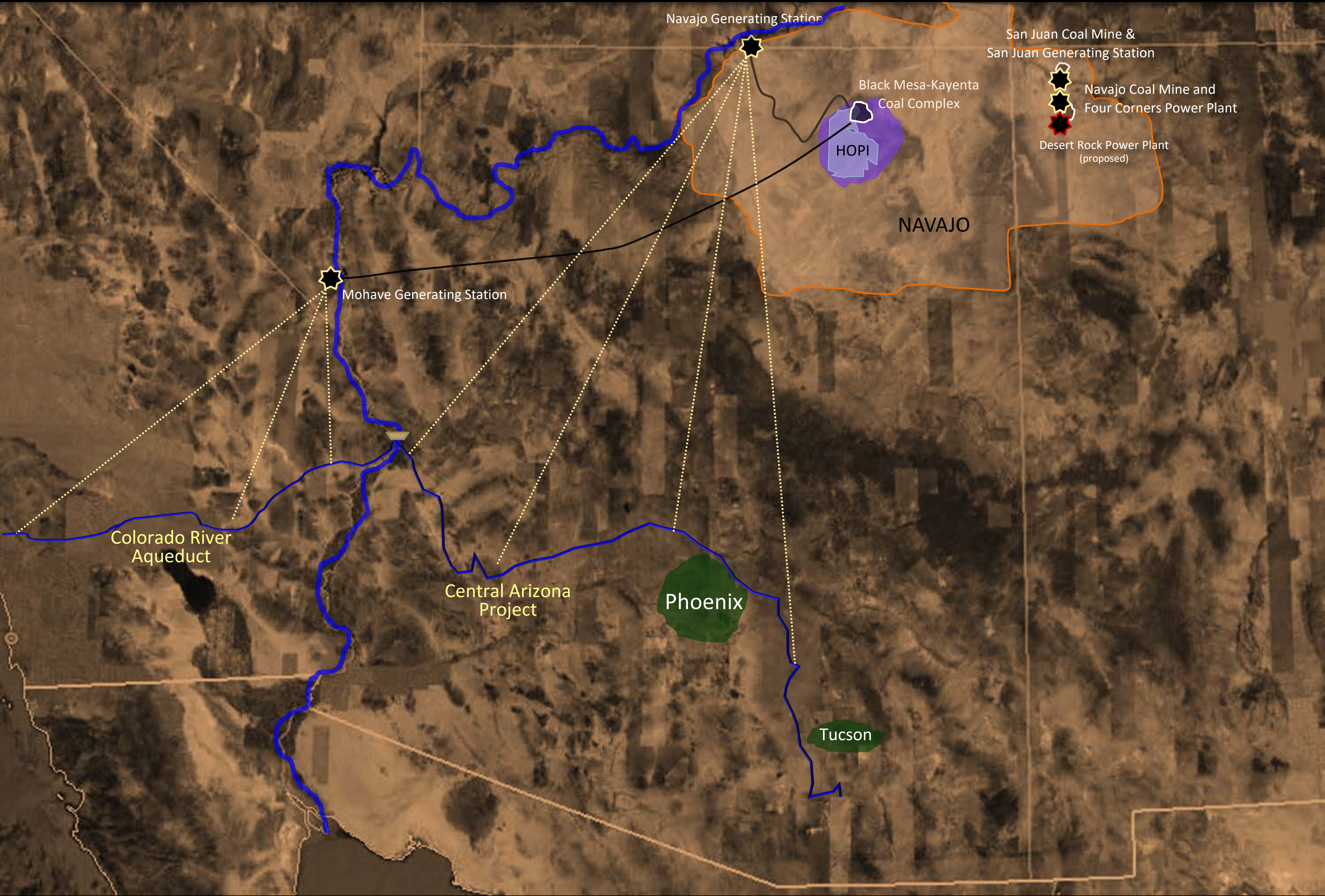
2,310 Megawatts: three 770,000 kilowatt units (1974, '75, '76)

23,000 tons of coal daily: 8,000,000 tons annually

"The Navajo Generating Station will be Arizona's largest electrical generating station. It will be the third power-generating station to be built under the *Western Energy Supply and Transmission* (WEST) *Associates* concept in which participating utilities cooperate in extensive regional planning of generating and transmission facilities and coordinate their investment in such facilities. Generating plants, much larger than any single utility would need, are constructed and operated by groups of utilities achieving economies that the participants could not otherwise experience. *This practice helps to keep consumers' power costs low and makes protection of the environment more feasible.*"

USBOR 1972: 31
emphasis added

Tribal Resources = Metro Water & Energy



Black Mesa Conflict

Hopi & Navajo Residents:

- Declining groundwater level
- Declining Groundwater quality
- Declining Discharge from springs
- Declining streamflow
- Biodiversity and cultural continuity

OSM, Peabody, and Tribal Governments:

- No mining-related impacts
- Adverse impacts caused by tribal groundwater pumping or drought

Case Study Approach

An evaluation of “expert” knowledge claims in EIS & CHIA

1) Postaudit of pre-development predictions (1966-1971)

2) Postaudit of EIS/CHIA predictions (1989-2006)

3) Postaudit of EIS/CHIA predictions (2006-present)

Impact Assessment

1966

- Feasibility Study

1971-1972

- Environmental Statement

1980-2006

- 1984 Probable Hydrologic Consequences (PHC)
- 1989 Cumulative Hydrologic Impact Assessment (CHIA)
- 1990 Environmental Impact Statement (EIS)

USGS Groundwater model (1989-2006)

2004-2009

- 2004 Probable Hydrologic Consequences
- 2006-08 Environmental Impact Statement
- 2008 Cumulative Hydrologic Impact Assessment

2010-2016

- 2010 Probable Hydrologic Consequences
- 2011 Environmental Assessment (EA)
- 2011 Cumulative Hydrologic Impact Assessment

Peabody Groundwater Model (1999)

2016-present

- 2016 Environmental Impact Assessment (EIS)
- 2016 Cumulative Hydrologic Impact Assessment (CHIA

Peabody Groundwater Model (2016)

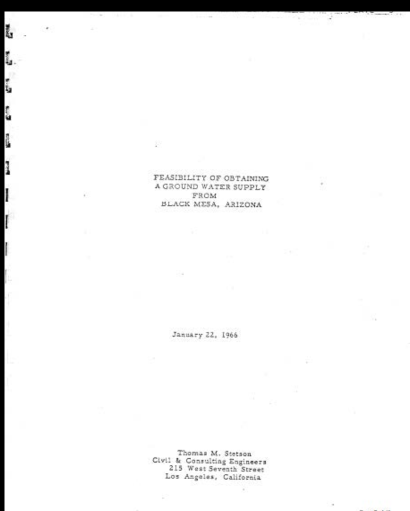
Pre-Development Predictions
(1966-1971)

Pre-Mining Predictions (I):

PEABODY'S ANNUAL GROUNDWATER WITHDRAWALS

Average annual withdrawals: 2,400 af/y

Maximum for any single year: 3,200 af/y

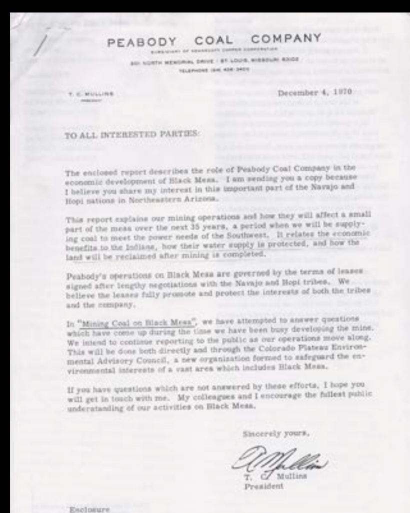

FEASIBILITY OF OBTAINING
A GROUND WATER SUPPLY
FROM
BLACK MESA, ARIZONA

January 22, 1966

Thomas M. Stetson
Civil & Consulting Engineers
215 West Seventh Street
Los Angeles, California

Page 7 of 48

Thomas Stetson (1966)
Peabody Hydrology Consultant


PEABODY COAL COMPANY

T. C. MULLINS

December 4, 1970

TO ALL INTERESTED PARTIES:

The enclosed report describes the role of Peabody Coal Company in the economic development of Black Mesa. I am sending you a copy because I believe you share my interest in this important part of the Navajo and Hopi nations in Northeastern Arizona.

This report explains our mining operations and how they will affect a small part of the mesa over the next 35 years, a period when we will be supplying coal to meet the power needs of the Southwest. It relates the economic benefits to the Indians, how their water supply is protected, and how the land will be reclaimed after mining is completed.

Peabody's operations on Black Mesa are governed by the terms of leases signed after lengthy negotiations with the Navajo and Hopi tribes. We believe the leases fully promote and protect the interests of both the tribes and the company.

In "Mining Coal on Black Mesa", we have attempted to answer questions which have come up during the time we have been busy developing the mine. We intend to continue reporting to the public as our operations move along. This will be done both directly and through the Colorado Plateau Environmental Advisory Council, a new organization formed to safeguard the environmental interests of a vast area which includes Black Mesa.

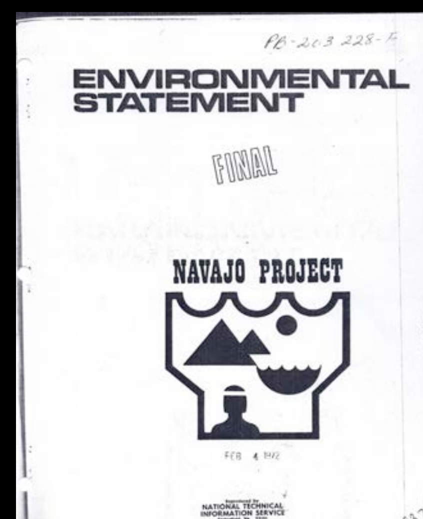
If you have questions which are not answered by these efforts, I hope you will get in touch with me. My colleagues and I encourage the fullest public understanding of our activities on Black Mesa.

Sincerely yours,

T. C. Mullins
President

Enclosure

T.C. Mullins (1970)
President, Peabody Coal Company


PB-203 228-F

ENVIRONMENTAL STATEMENT

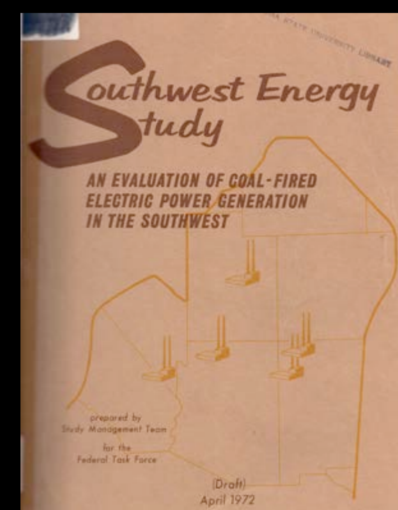
FINAL

NAVAJO PROJECT

FEB 4 1972

NATIONAL TECHNICAL INFORMATION SERVICE

U.S. Bureau of Recl. (1971-72)
Environmental Statement: Navajo Project


Southwest Energy Study

AN EVALUATION OF COAL-FIRED ELECTRIC POWER GENERATION IN THE SOUTHWEST

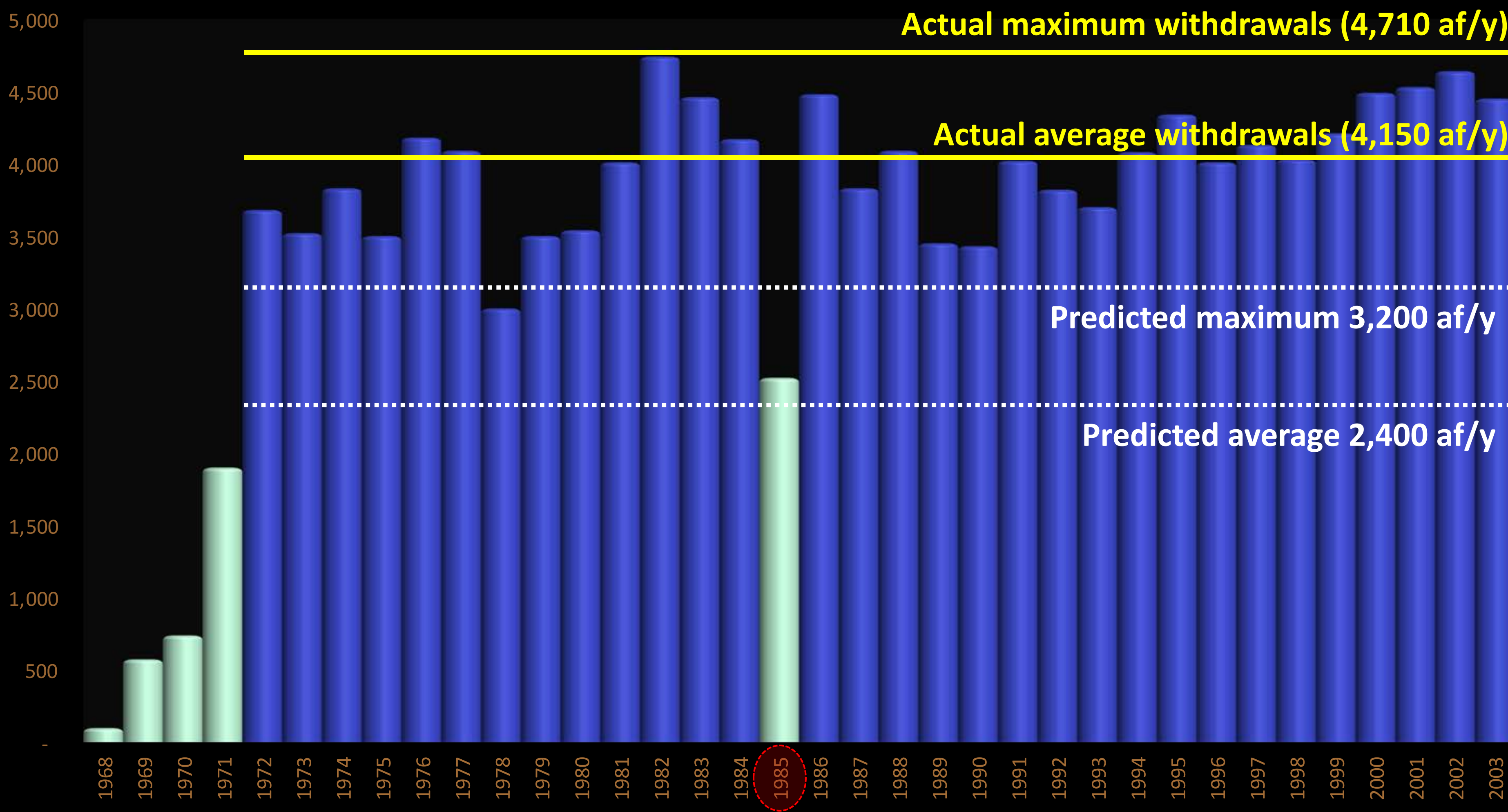
prepared by
Study Management Team
for the
Federal Task Force

(Draft)
April 1972

U.S. DOI (1971-72)
Southwest Energy Study

Predicted & Actual Withdrawals

1972-2003

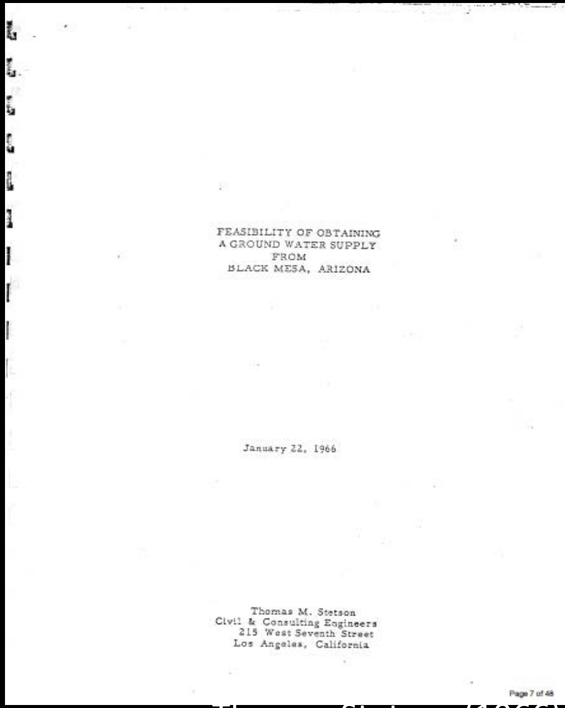


*Avg. withdrawals for years mining ops at full capacity: 1972-2003, not including 1985, when PWCC withdrawals ceased for 6 months due to maintenance issues at Mohave Generating Station

Prediction Data from Stetson (1966); Phelps (1971)
Mullins (1971); USBR (1972); SWETF (1972)
Actual Water Level Data from USGS
(Truini and Macy 2005)

Pre-development *framing* for sustainable groundwater development: based upon "Safe Yield Water Budget" logic

Natural Recharge:	235,000 acre-feet / year
PWCC withdrawals:	- 3,200 acre-feet / year
Total annual recharge:	+231,800 acre-feet / year


FEASIBILITY OF OBTAINING
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January 22, 1966

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Los Angeles, California

Page 7 of 48

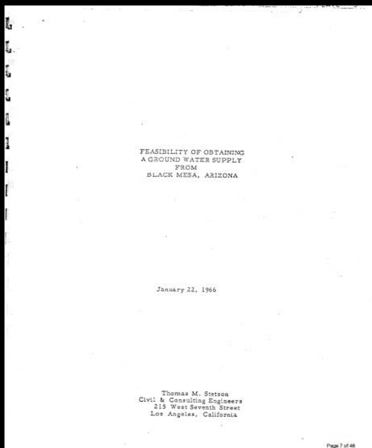
Thomas Stetson (1966)

"The impacts… are overestimated… at no time does the total withdrawal from the system exceed the recharge to the system"

Office of Surface Mining (1990 EIS: IV-24)

The "Water Budget Myth"

Pre-Development Assumptions (I):


FEASIBILITY OF OBTAINING
A GROUND WATER SUPPLY
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Los Angeles, California

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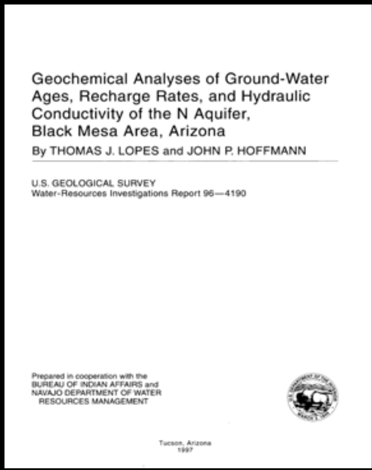
Stetson (1966):

Total annual recharge to the N-Aquifer

235,000 acre-feet per year

Thomas Stetson (1966)
Hydrology Consultant for Peabody
Feasibility of Obtaining a Groundwater Supply from Black Mesa, Arizona


Geochemical Analyses of Ground-Water Ages, Recharge Rates, and Hydraulic Conductivity of the N Aquifer, Black Mesa Area, Arizona

By THOMAS J. LOPES and JOHN P. HOFFMANN

U.S. GEOLOGICAL SURVEY
Water-Resources Investigations Report 96—4190

Prepared in cooperation with the
BUREAU OF INDIAN AFFAIRS and
NAVAJO DEPARTMENT OF WATER
RESOURCES MANAGEMENT

Tucson, Arizona
1997

USGS (1997):

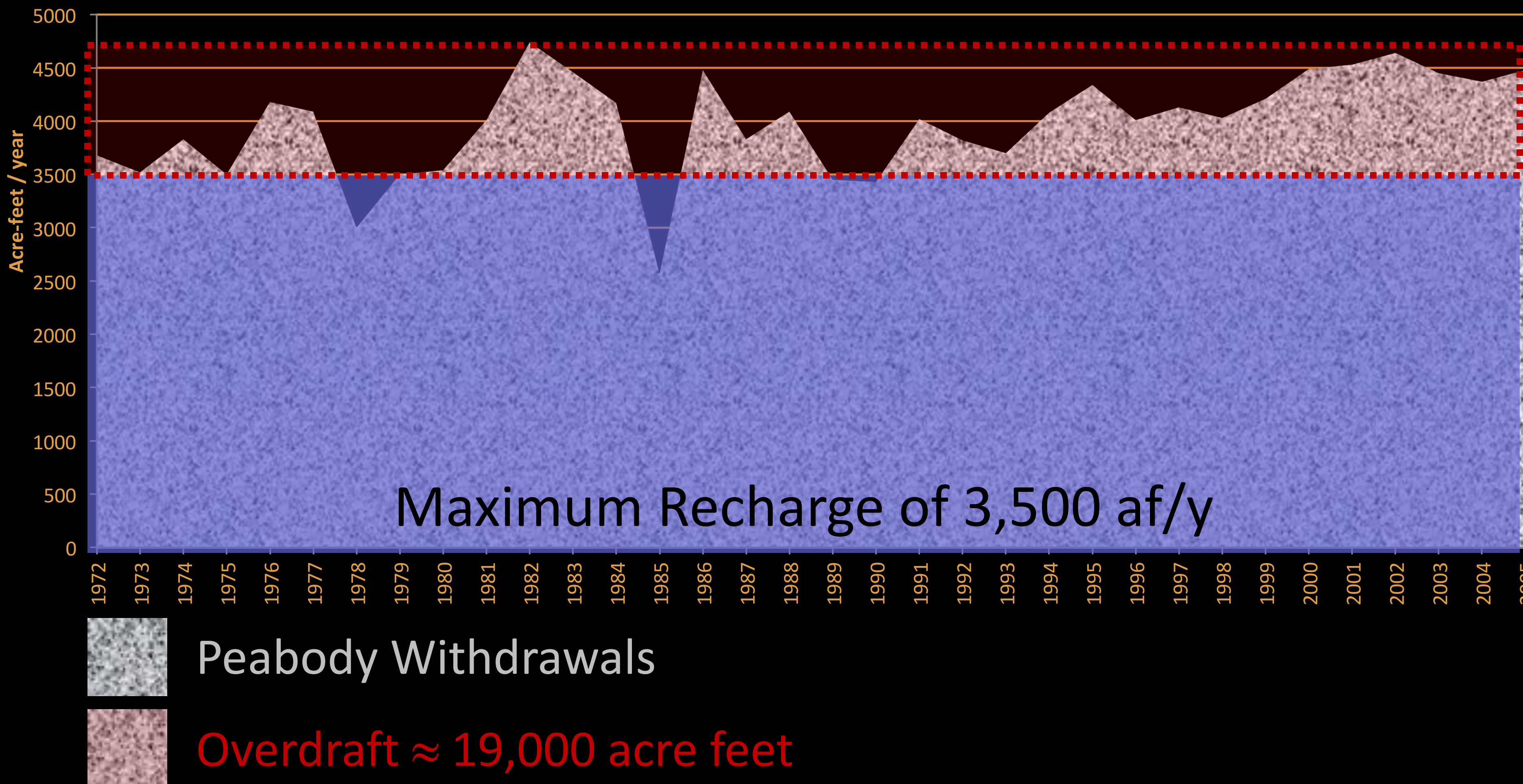
Total annual recharge to the N-Aquifer

2,500 – 3,500 acre-feet per year

(90% of N-Aquifer groundwater 10,000-35,000 years old)

Lopes and Hoffman (1997)

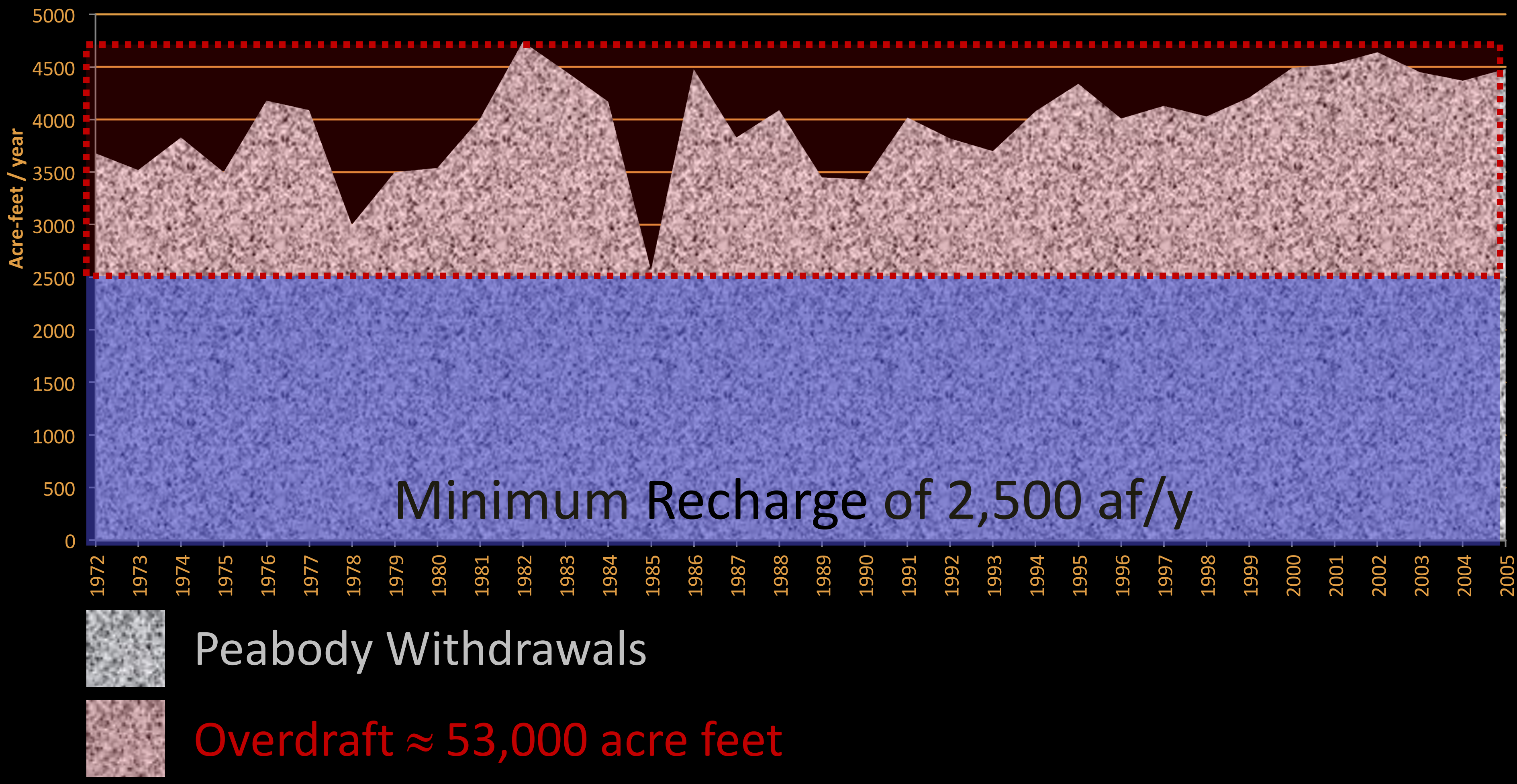
Peabody's actual withdrawals and the USGS recharge estimate



Higgins (2011, 2010)

* Recharge estimate by Lopes & Hoffman (1977)

Peabody's actual withdrawals and the USGS recharge estimate



Higgins (2011, 2010)

* Recharge estimate by Lopes & Hoffman (1977)

Black Mesa-Kayenta Mine Complex

(1989-Present)

1989 Cumulative Hydrologic Impact Statement (CHIA)
1990 Environmental Impact Statement (EIS)
2008 Environmental Impact Statement (EIS)
2008 Cumulative Hydrologic Impact Statement (CHIA)
2011 Environmental Assessment (EA)
2011 Cumulative Hydrologic Impact Statement (CHIA)

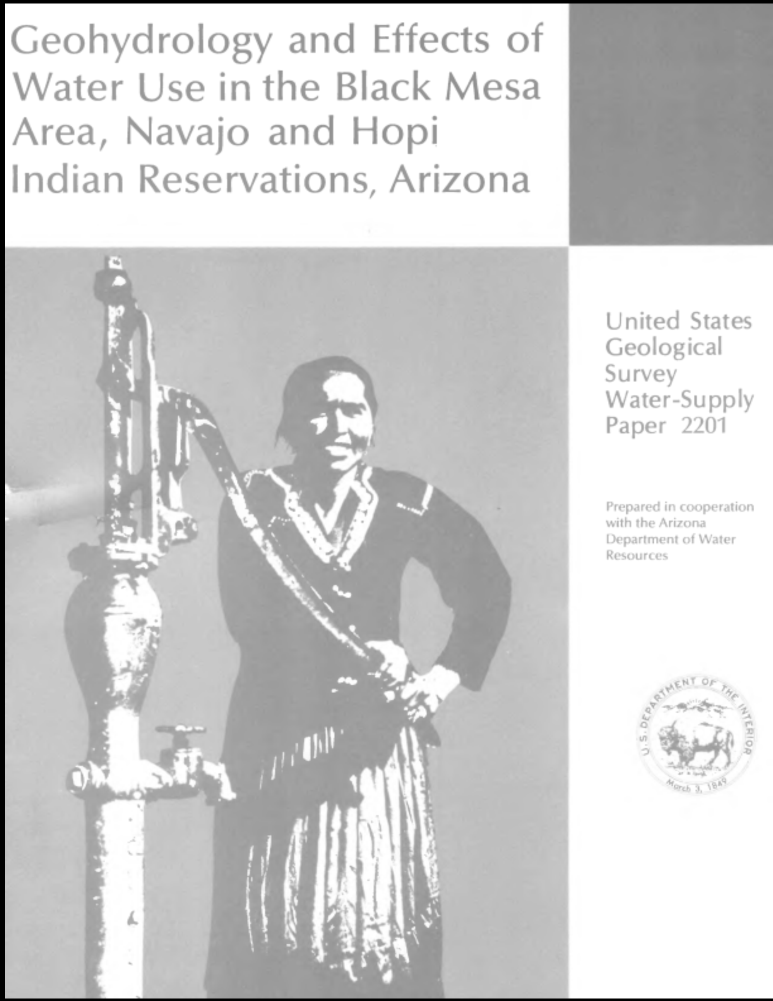
USGS Groundwater Model

(Eychaner 1983, 1981; Brown and Eychaner 1988)

- Wood 1971
- Eychaner 1981
- Eychaner 1983
- Brown and Eychaner 1988

"Although the 1988 model reasonably reproduced observed water-level changes in six observation wells, the solution is not unique. Equally close agreement to the observed heads was reached by the 1983 model… other [parameter value] combinations that are consistent with field observations could be selected that would simulate the N-aquifer equally well." (1988: 19)

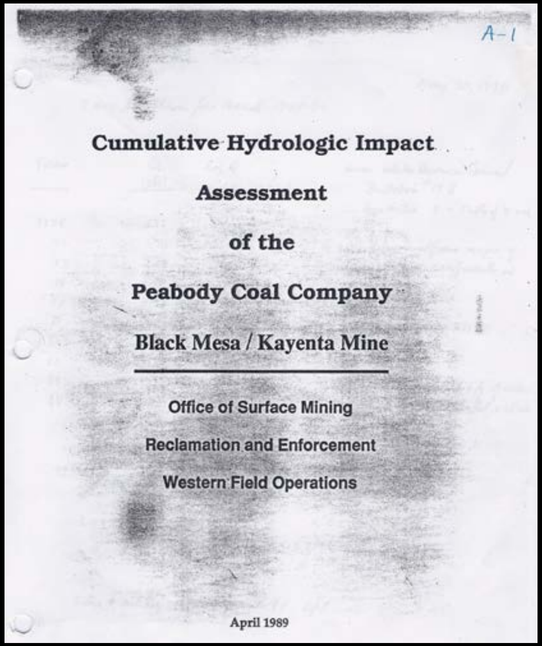
"[The USGS model] cannot adequately represent the local geology and simulate hydrologic processes in detail… projection results are better used to compare effects of different development plans rather than estimate actual future water levels and water budget components." (p. 25)



Eychaner (1983, 1981); Brown and Eychaner (1988)

OSM 1989:

Cumulative Hydrologic Impact Assessment
(CHIA)


A-1

Cumulative Hydrologic Impact
Assessment
of the
Peabody Coal Company
Black Mesa / Kayenta Mine

Office of Surface Mining
Reclamation and Enforcement
Western Field Operations

April 1989

"…a means of keeping the big picture of hydrologic impacts before the regulatory authority at all times, so that if the accumulated impacts reach potentially damaging magnitudes, they can be dealt with in a timely manner."

OSM (1985)

"Impacts associated with the proposed operation and all anticipated mining were identified but none of the projected impacts exceed material damage criteria. Therefore, OSMRE makes the finding that there will be no material damage to the hydrologic balance associated with the proposed operation and all anticipated mining."

OSM-CHIA (1989: 1)

1989 “Material Damage” Criteria

I. WATER QUANTITY

Potentiometric head must not fall below 100 ft above the top of the N-aquifer.

II. DISCHARGE FROM SPRINGS

Reductions in spring-discharge (caused by mining) must not exceed 10%

III. WATER QUALITY

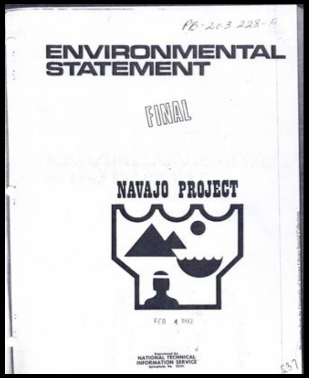
Leakage from the overlying D-aquifer (caused by mining) must not exceed 10%

IV. DISCHARGE TO STREAMS

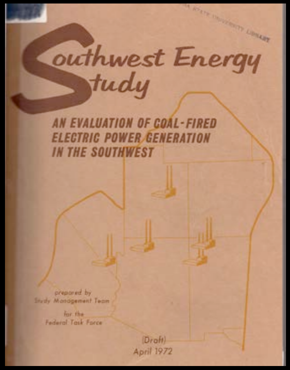
Any reduction of discharge to the alluvium (caused by mining) must stay below 10%.

U.S. Department of Interior on hydrogeology near Kayenta (1971)

“Hydrologists do not agree whether these domestic wells are in the same pressure zones as the Peabody wells, but a monitoring program has been devised to ascertain those facts. In the event the supply of the water to the Indian wells is affected, Peabody is under contractual obligation to provide the Indians with water in quality and quantity equal to that formerly available to them.”



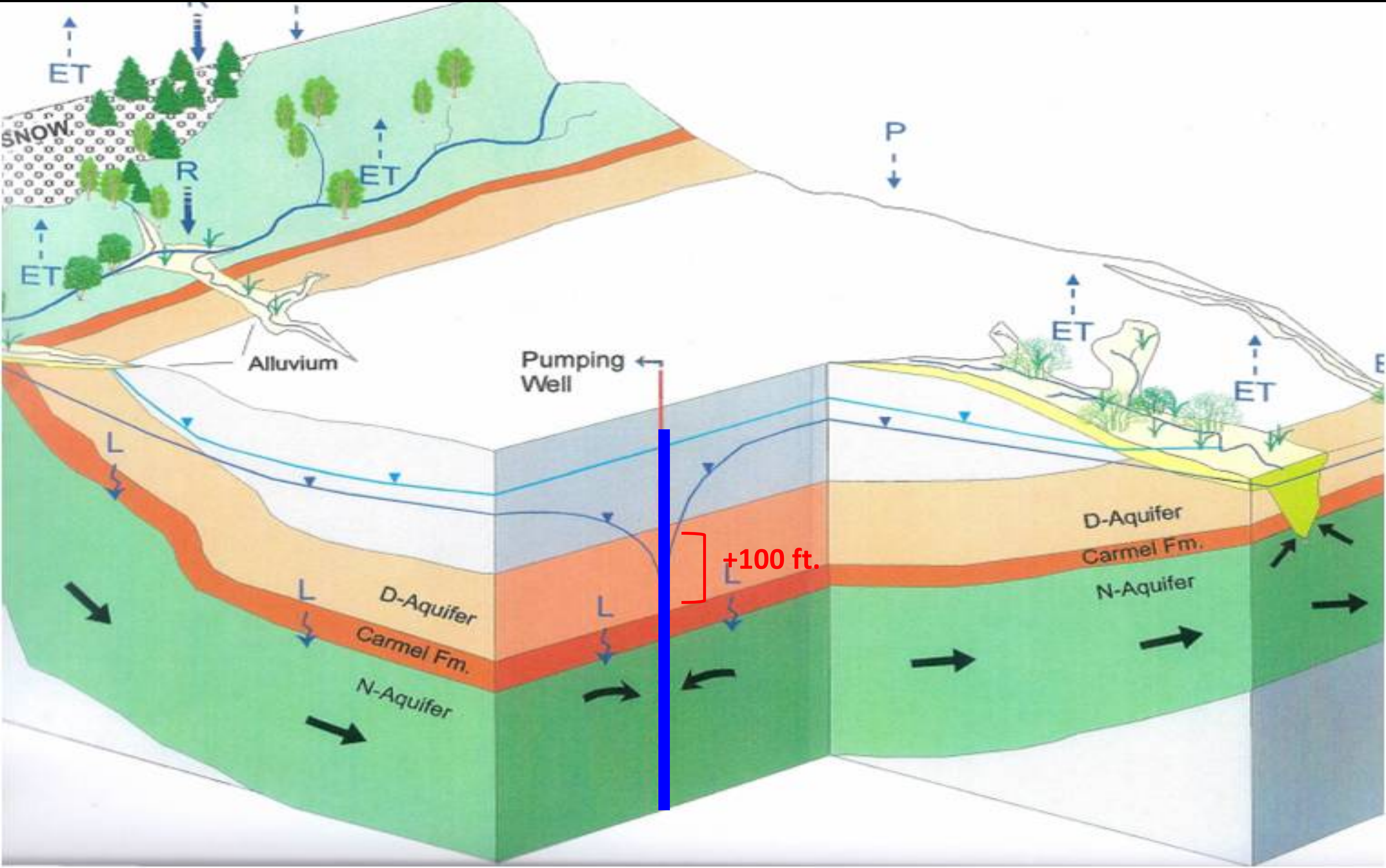
U.S. Bureau of Recl. (1971: 39)
Environmental Statement: Navajo Project



U.S. DOI (1971-72)
Southwest Energy Study

Criterion 1: Water Quantity

Maintain "head" of at least 100 ft. above the N-aquifer

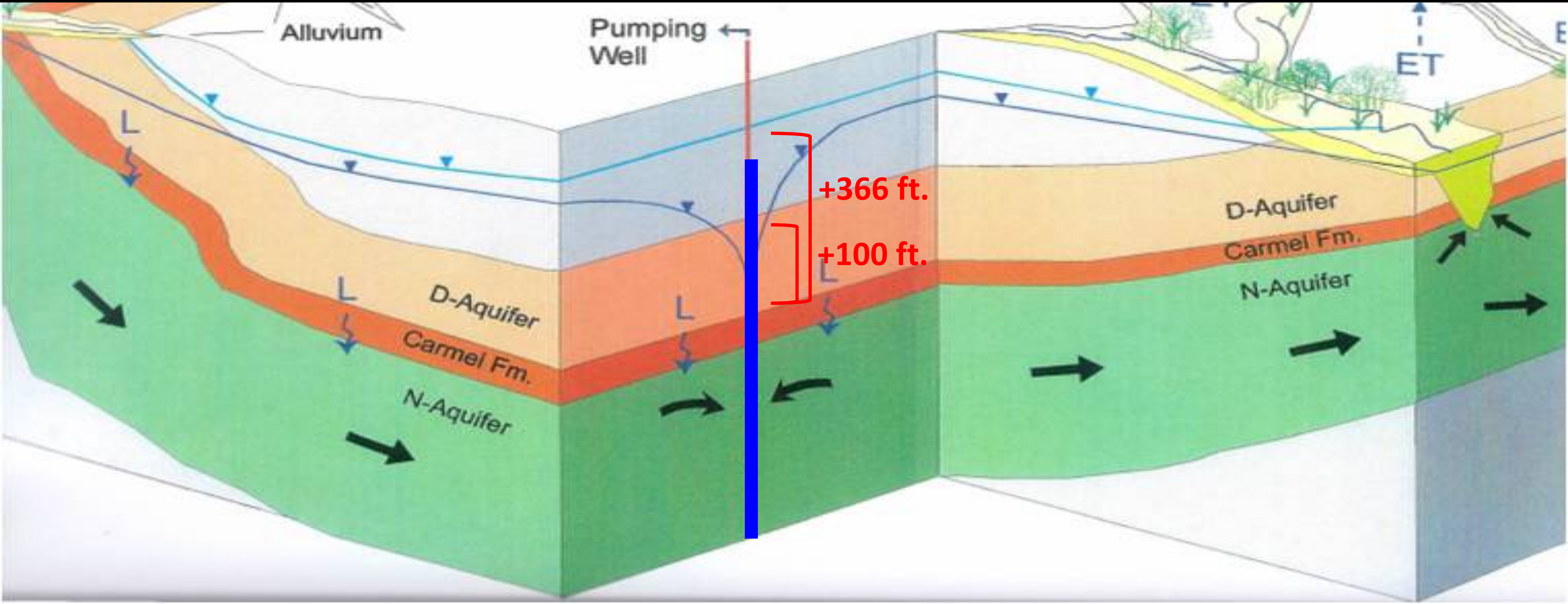


Criterion 1: Water Quantity

100 ft. above the N-aquifer

"It can be seen that at no time does the [water level] drop to this level anywhere within the affected area for any scenario. The closest [it] gets… is 366 feet at Keams Canyon in the year 2052."

OSM (1990 EIS)

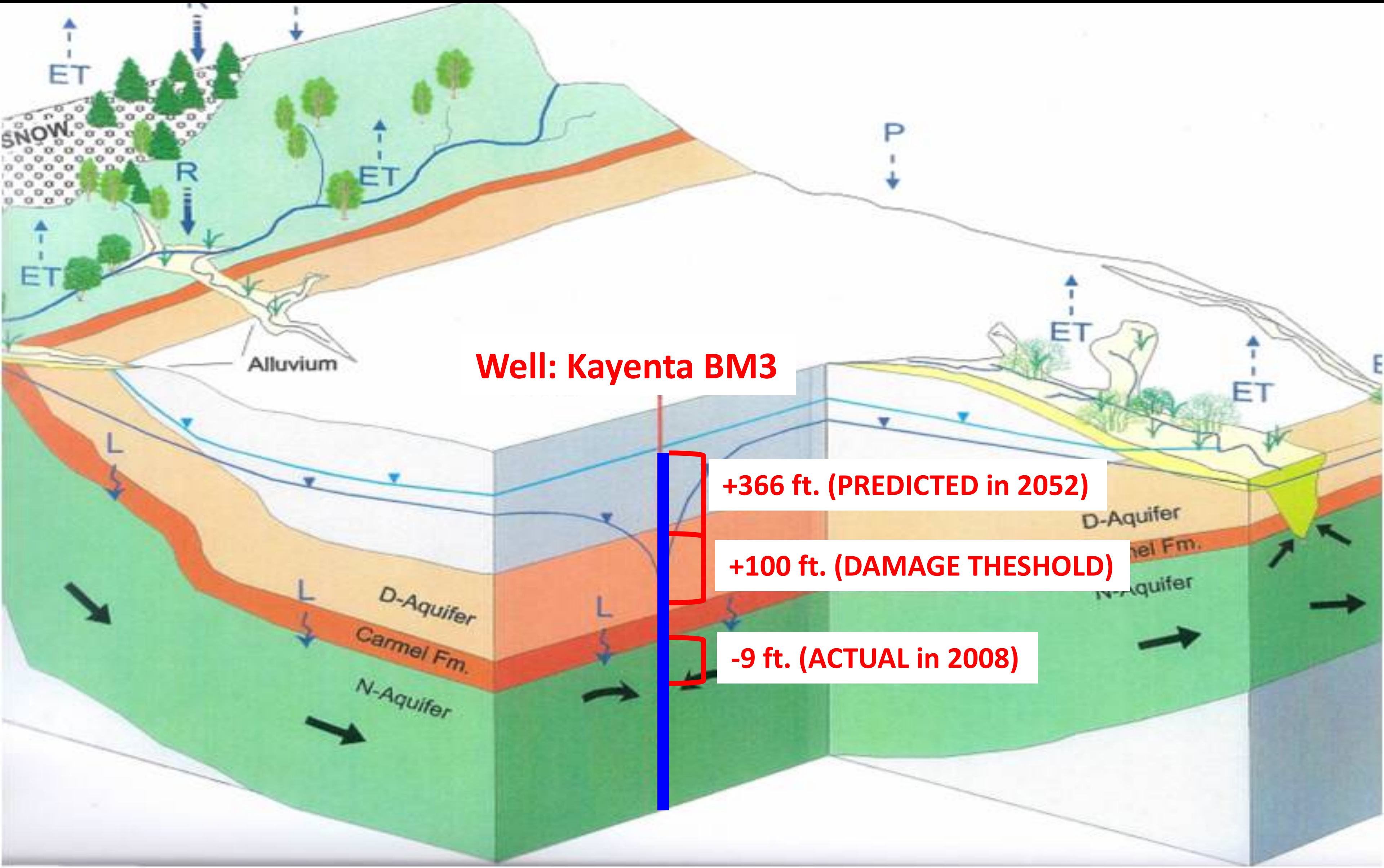


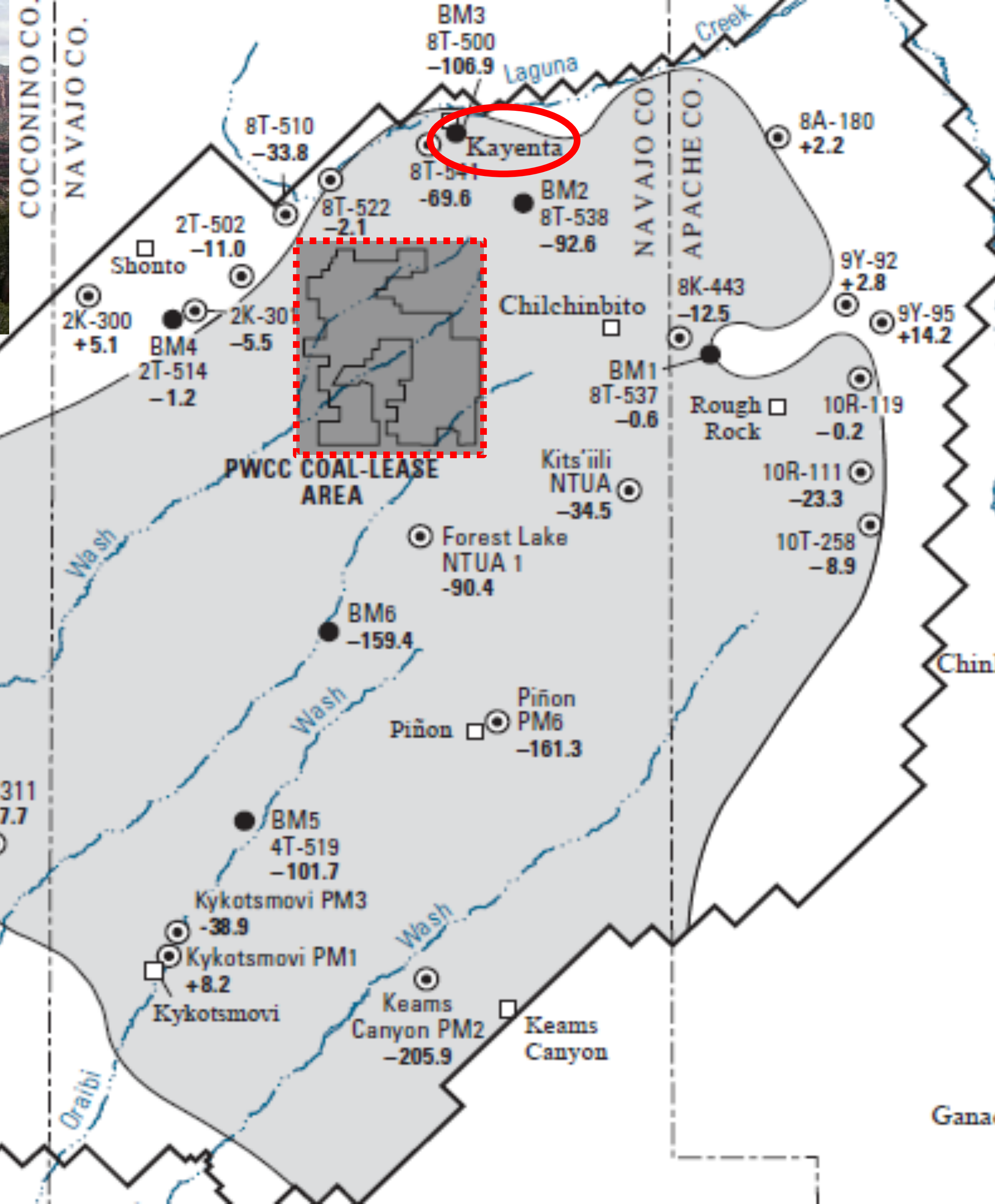
N-aquifer Water Levels in 2008

	WELL Common Name and Year Completed	A	B	C	D	E	F	G	H	
		PRE-STRESS (1965)					2008 MEASURED			
		Surface Elevation of well	water-level as ft below land surface	Altitude as feet above sea level	depth to top of aquifer from land surface	Potentiometric head of well in 1965	water-level as ft below land surface	Altitude as ft above sea level	Decline 1965-2008	Potentiometric head of well 2008
				(A+B)		(D+B)		(A+F)	(F+B)	(E+H)
1	BM2 (1972)	5656.0	-125.0	5531.0	452.0	327.0	-216.4	5439.6	-91.4	235.6
2	BM3 (1953)	5724.0	-55.0	5669.0	155.0	100.0	-161.6	5562.4	-106.6	-6.6
3	BM5 (1972)	5869.0	-324.0	5545.0	1520.0	1196.0	-424.3	5444.7	-100.3	1095.7
4	BM6 (1977)	6332.0	-697.0	5635.0	1950.0	1253.0	-858.7	5473.3	-161.7	1091.3
5	White Mesa Arch (1950)	5771.0	-188.0	5583.0	250.0	62.0	-219.6	5551.4	-31.6	30.4
6	Forest Lake NTUA 1 (1980)	6654.0	-1096.0	5558.0	-	-	-	5464.3	-93.7	-
7	Howell Mesa 3K-311 (1934)	5855.0	-463.0	5392.0	615.0	152.0	-449.6	5405.4	13.4	165.4
8	Howell Mesa 6H-55 (1944)	5635.0	-212.0	5423.0	310.0	98.0	-297.0	5338.0	-85.0	13.0
9	Sweetwater Mesa (1957)	6024.0	-529.4	5494.6	590.0	60.6	-542.3	5481.7	-12.9	47.7
10	Marsh Pass (1963)	6040.0	-125.5	5914.5	480.0	354.5	-127.7	5912.3	-2.2	352.3
11	Kayenta West (1976)	5885.0	-230.0	5655.0	700.0	470.0	-297.0	5588.0	-67.0	403.0
12	Rough Rock 10R-11 (1935)	5757.0	-170.0	5587.0	210.0	40.0	-193.5	5563.5	-23.5	16.5
13	Rough Rock 10R-119 (1953)	5775.0	-256.6	5518.4	310.0	53.4	-256.6	5518.4	0.0	53.4
14	Rough Rock 10T-258 (1960)	5903.0	-301.0	5602.0	460.0	159.0	-309.5	5593.5	-8.5	150.5
15	Keams Canyon PM2 (1970)	5809.0	-292.5	5516.5	900.0	607.5	-491.2	5317.8	-198.7	408.8
16	Kykotsmovi PM1 (1967)	5657.0	-220.0	5437.0	880.0	660.0	-211.7	5445.3	8.3	668.3
17	Kykotsmovi PM3 (1968)	5618.0	-210.0	5408.0	840.0	630.0	-243.6	5374.4	-33.6	596.4
18	Pinon PM6 (1970)	6397.0	-743.6	5653.4	1870.0	1126.4	-904.9	5492.1	-161.3	965.1

Criterion 1: N-Aquifer Water Quantity

100 ft. above the N-aquifer



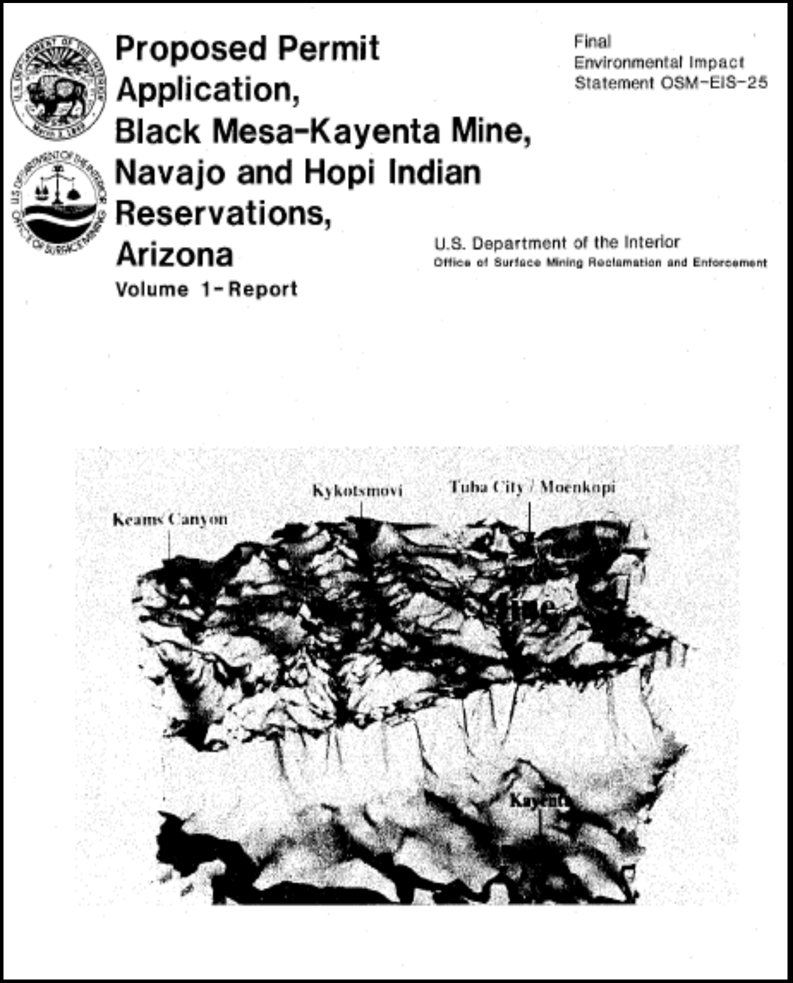

COCONINO CO.
NAVAJO CO.
NAVAJO CO.
APACHE CO.
Laguna
Creek
BM3
8T-500
–106.9
Kayenta
8T-510
–33.8
8T-541
-69.6
8T-522
–2.1
BM2
8T-538
–92.6
8A-180
+2.2
2T-502
–11.0
Shonto
Chilchinbito
8K-443
–12.5
9Y-92
+2.8
9Y-95
+14.2
2K-300
+5.1
BM4
2T-514
–1.2
2K-301
–5.5
BM1
8T-537
–0.6
Rough
Rock
10R-119
–0.2
1K-214
–31.9
PWCC COAL-LEASE
AREA
Kits'iili
NTUA
–34.5
10R-111
–23.3
Forest Lake
NTUA 1
-90.4
10T-258
–8.9
Wash
3T-546
-31.3
3T-508
-25.4
Tuba NTUA3
-27.7
Tuba City
Moenkopi
Rare Metals 2
+6.6
3T-333
–5.9
BM6
–159.4
Wash
Chinle
Piñon
Piñon
PM6
–161.3
3K-311
+17.7
3K-325
+4.8
BM5
4T-519
–101.7
3A-28
-2.0
Kykotsmovi PM3
-38.9
Kykotsmovi PM1
+8.2
Kykotsmovi
Wash
Keams
Canyon PM2
–205.9
Keams
Canyon
Little
Colorado
River
Wash
Oraibi
Ganad

OSM's 1990 EIS on Water Level at Kayenta

By 2052, the water level at Kayenta will fall 99 feet…

Kayenta causes 95 feet (96%)

Peabody causes 4 feet (4%)


Proposed Permit Application, Black Mesa-Kayenta Mine, Navajo and Hopi Indian Reservations, Arizona

Volume 1-Report

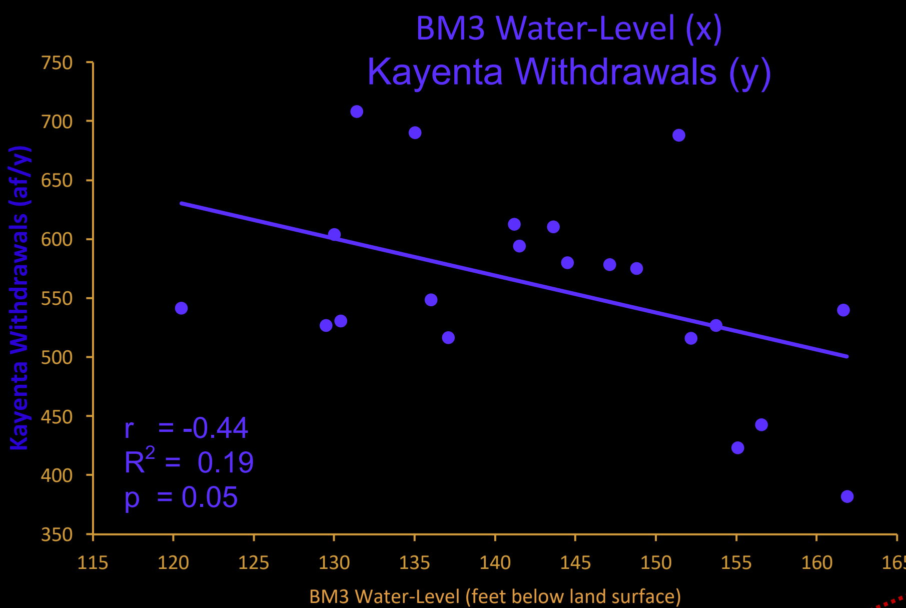
Final Environmental Impact Statement OSM-EIS-25

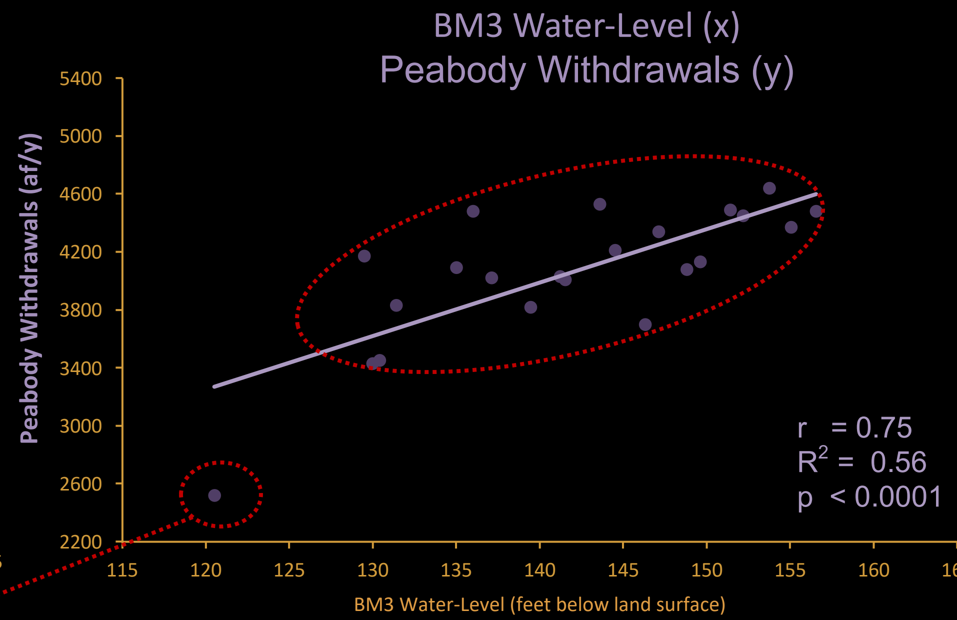
U.S. Department of the Interior
Office of Surface Mining Reclamation and Enforcement

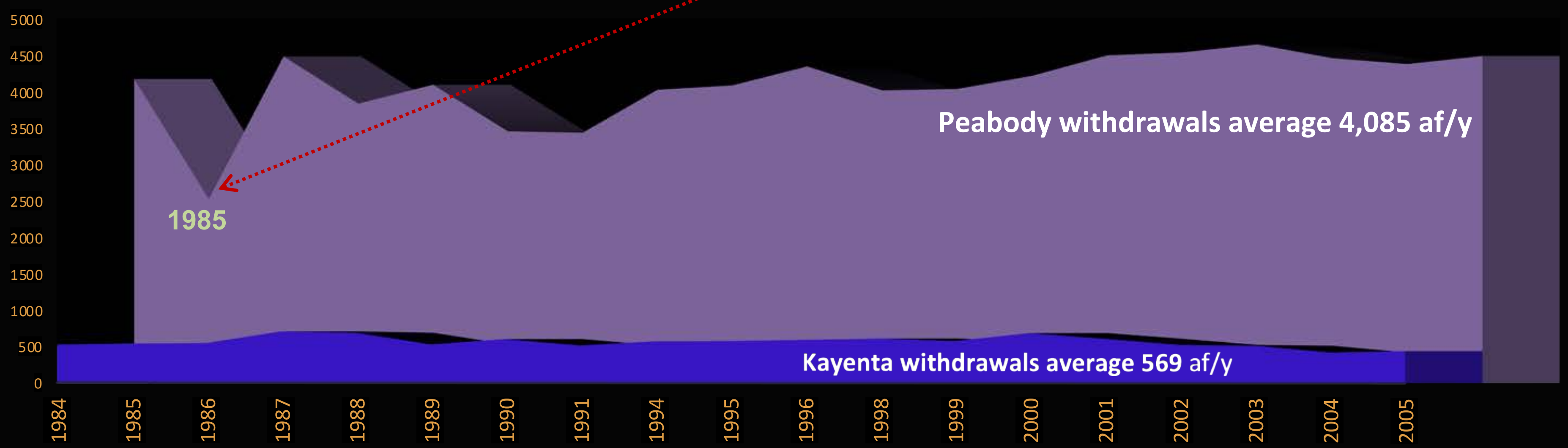
OSM-EIS 1990
Final Environmental Impact Statement

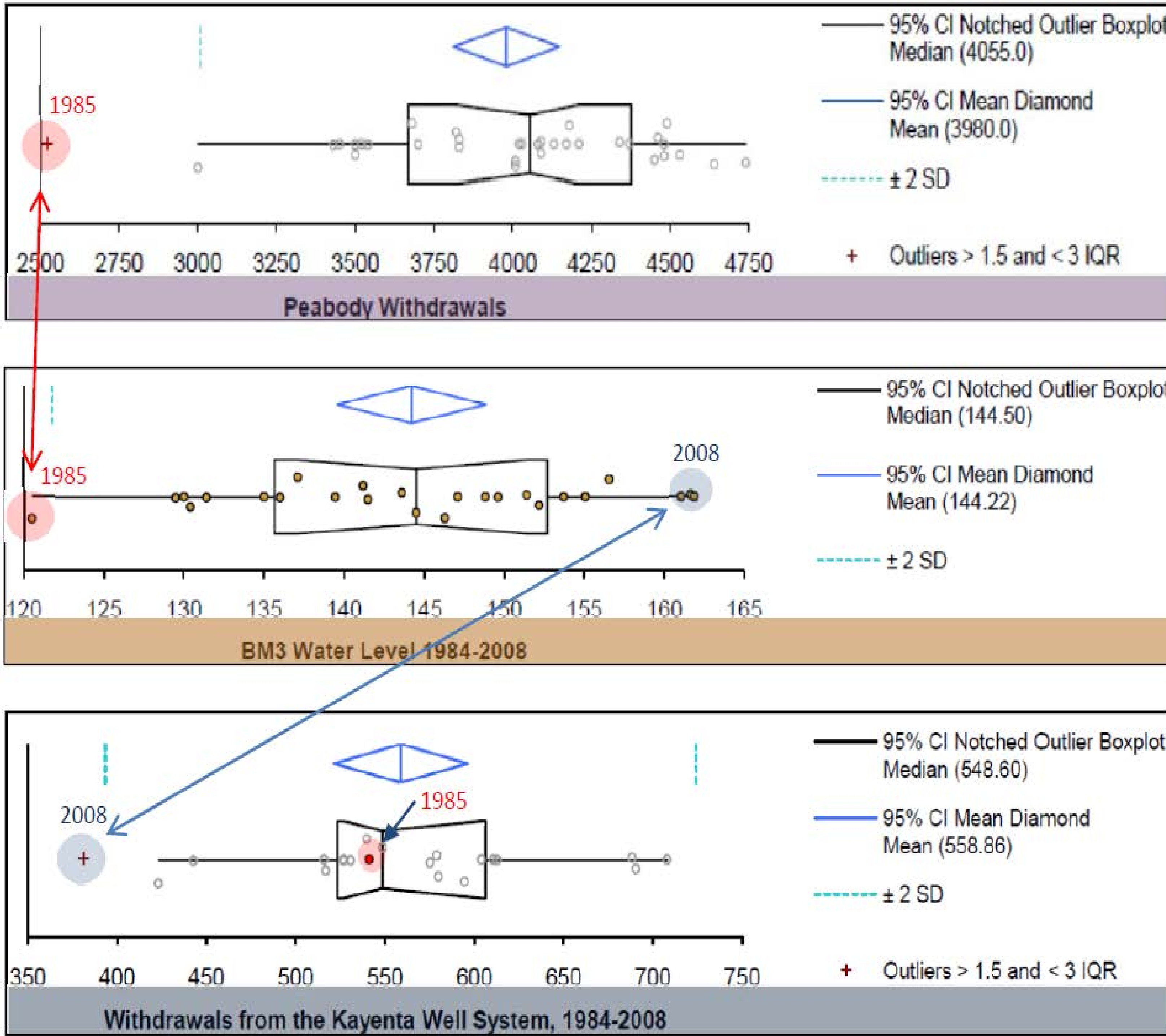
The source of Kayenta drawdown?

(well BM3)









95% CI Notched Outlier Boxplot
Median (4055.0)
95% CI Mean Diamond
Mean (3980.0)
± 2 SD
Outliers > 1.5 and < 3 IQR
1985
2500
2750
3000
3250
3500
3750
4000
4250
4500
4750
Peabody Withdrawals
95% CI Notched Outlier Boxplot
Median (144.50)
95% CI Mean Diamond
Mean (144.22)
± 2 SD
1985
2008
120
125
130
135
140
145
150
155
160
165
BM3 Water Level 1984-2008
95% CI Notched Outlier Boxplot
Median (548.60)
95% CI Mean Diamond
Mean (558.86)
± 2 SD
Outliers > 1.5 and < 3 IQR
2008
1985
350
400
450
500
550
600
650
700
750
Withdrawals from the Kayenta Well System, 1984-2008

OSM on Peabody's impact at Kayenta

1990: Kayenta pumping causes 96% of drawdown, Peabody 4% (EIS)

2008: Kayenta pumping causes "majority" of drawdown (EIS)

2011: Kayenta pumping causes 73% of drawdown (CHIA)

2011: The water level has not dropped below the top of the N-aquifer and it remains completely saturated (EIS)

2016: "Wells BM1 and BM2 are located in the confined area of the N aquifer and have experienced little water level change over the period of record… Well BM3 is located in the town of Kayenta and monitoring illustrates the variable influence of Kayenta wellfield pumping" (CHIA 2016) *BM3 is in the confined N-aquifer. Stabilization of drawdown and recovery in Kayenta wells illustrates the mine's impact (next slide).*

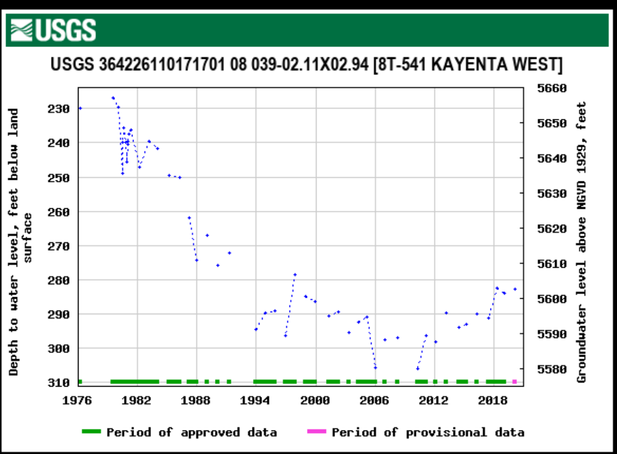
2020: Kayenta pumping causes 97% of drawdown, Peabody caused 3%

(OSM 2020 monitoring report)

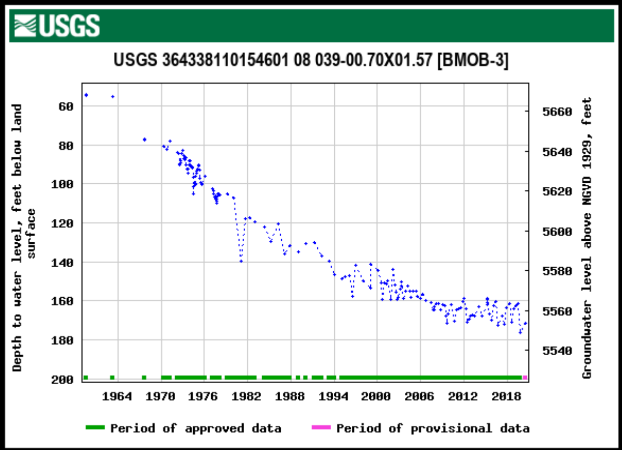
If *Municipal* pumping causes 97% of drawdown at Kayenta, why are the wells showing recovery?

(the distant wells show stabilization & recovery throughout the N-aquifer appear, generally, around 2012)

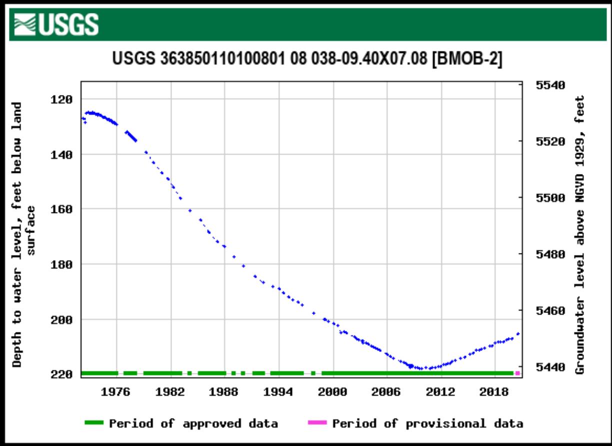
Kayenta West



Kayenta BM3



BM2 (SE of Kayenta)



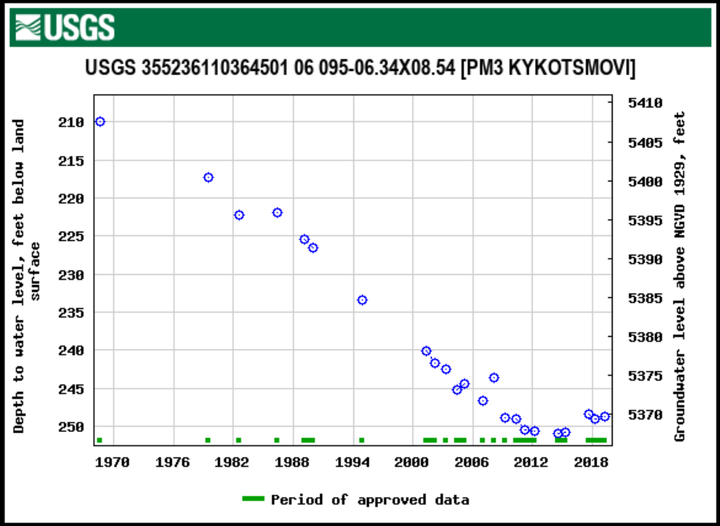
USGS 2020

Black Mesa Monitoring Program

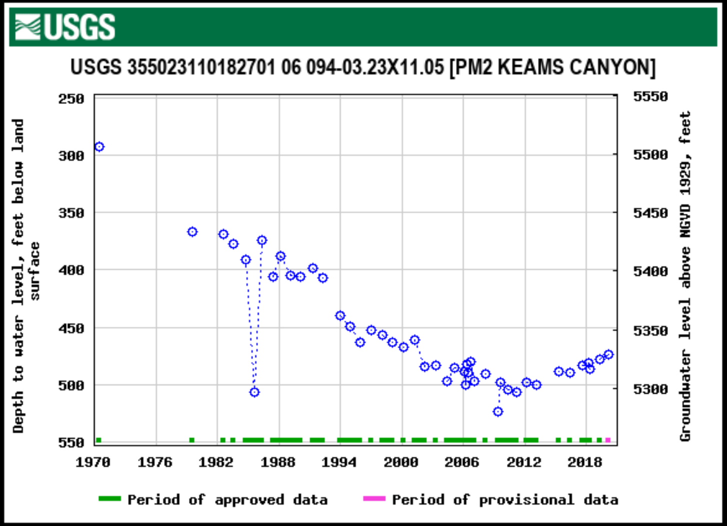
Peabody also maintains that drawdown by the Hopi Villages is caused primarily by municipal pumping, yet Kykotsmovi & Keams Canyon are also showing recovery

(also occurring around 2012)

Kykotsmovi PM3



Keams Canyon

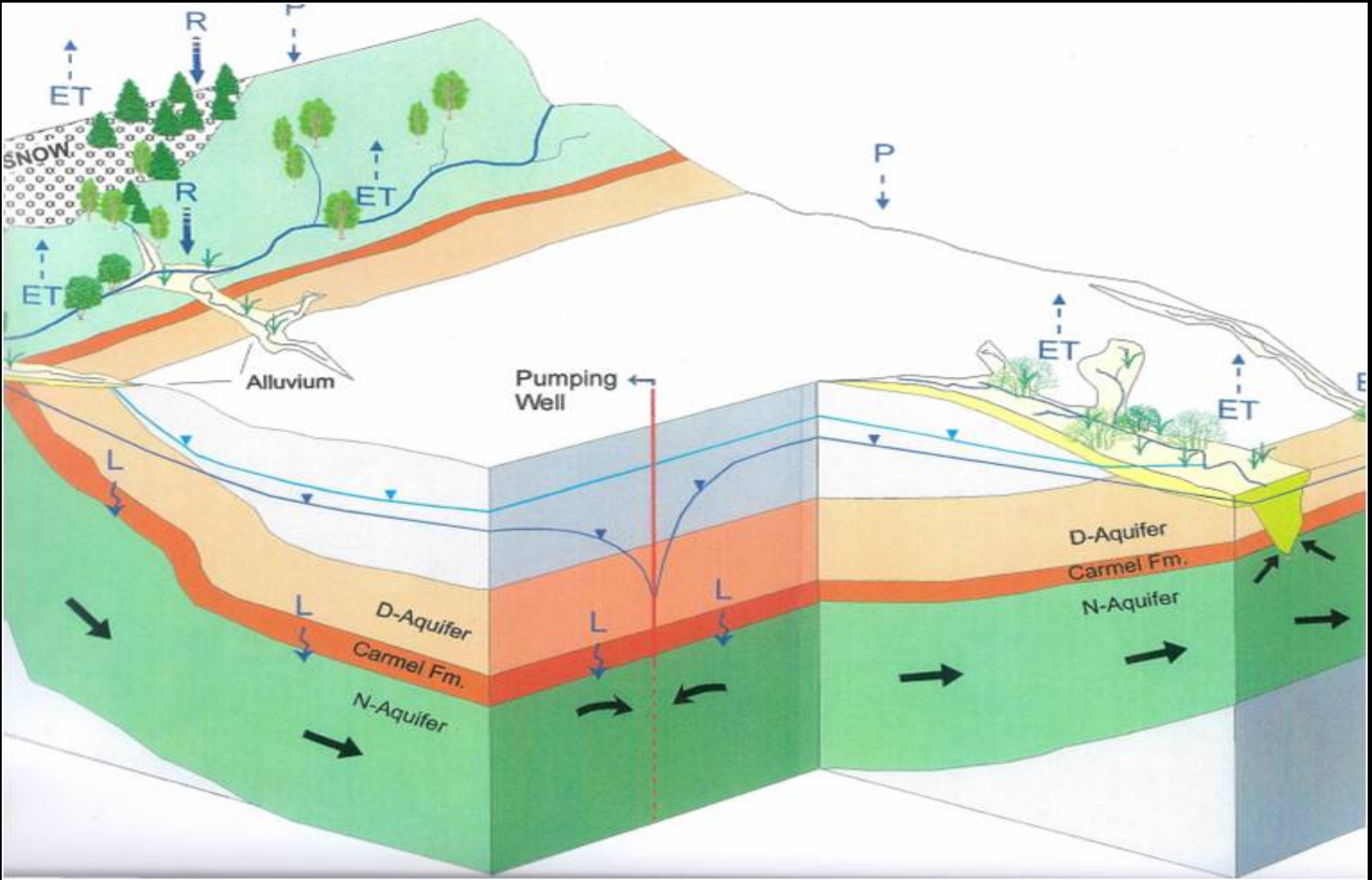


USGS 2020

Black Mesa Monitoring Program

Peabody has also been pumping groundwater from the D-aquifer

The Peabody model shows mine-related drawdown at locations more than 40 miles from the mine:
~ 10 feet, 20, feet, 40 feet, 60+ feet of water level decline attributable to mining ~



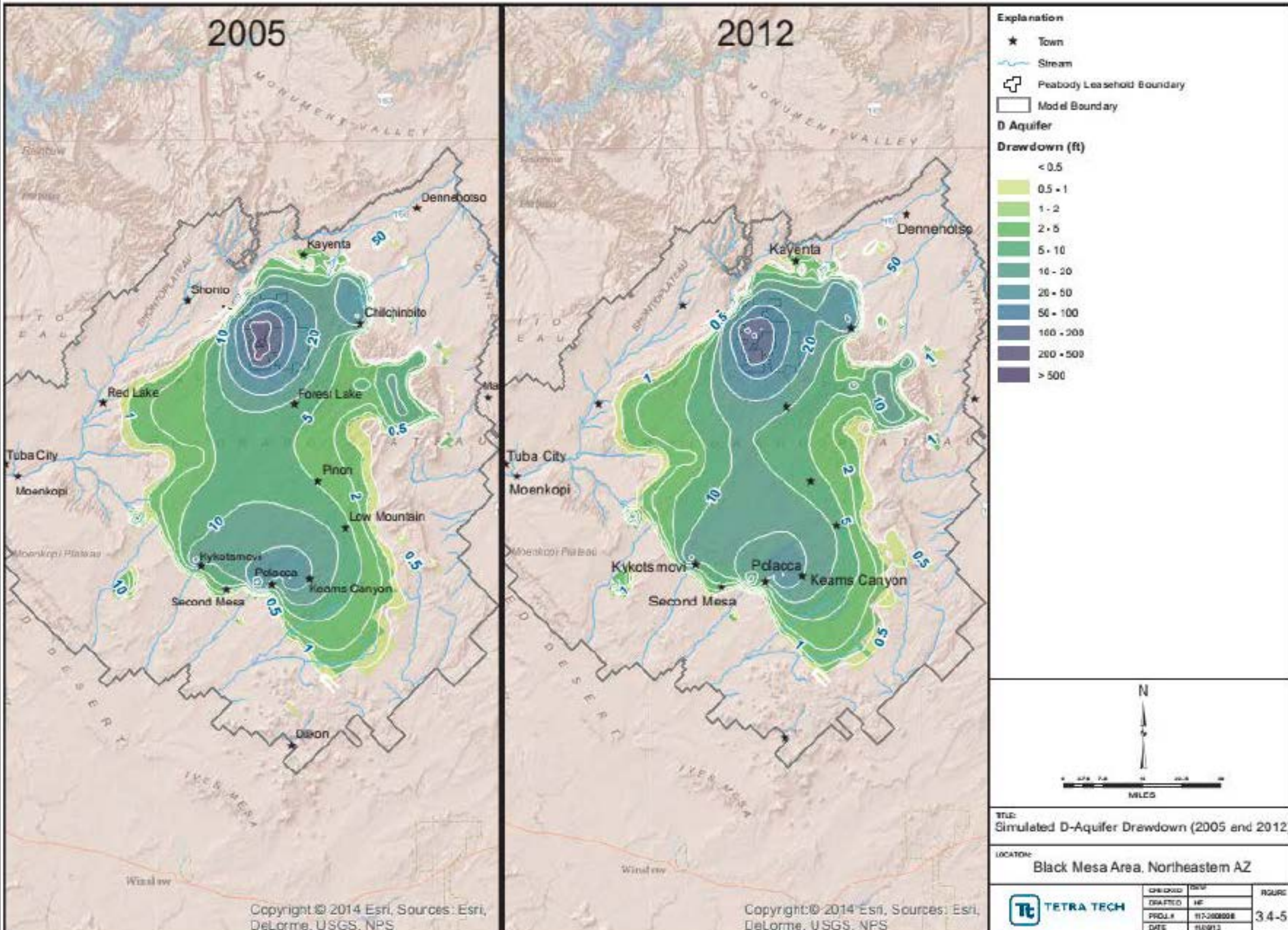


Figure 38: Groundwater Model Simulated D aquifer Drawdown in 2005 and 2012 (PWCC, v.11, ch.18, 2016).

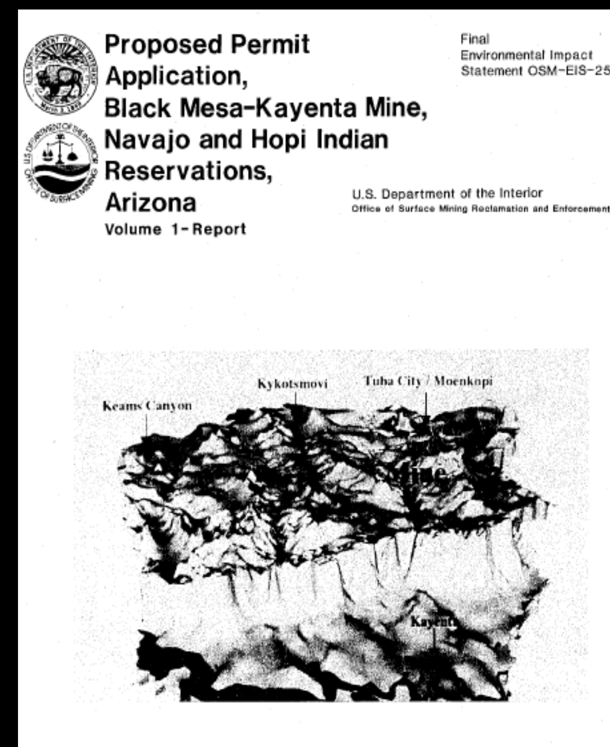
Springs

OSM's 1989 CHIA

Cumulative Hydrologic Impact Assessment

Spring decline near Tuba City / Moenkopi [1-2%] will be caused entirely by withdrawals from the Tuba City well system.

Village of Lower Moenkopi (Hopi)



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U.S. Department of the Interior

Office of Surface Mining Reclamation and Enforcement

OSM-EIS (1990)

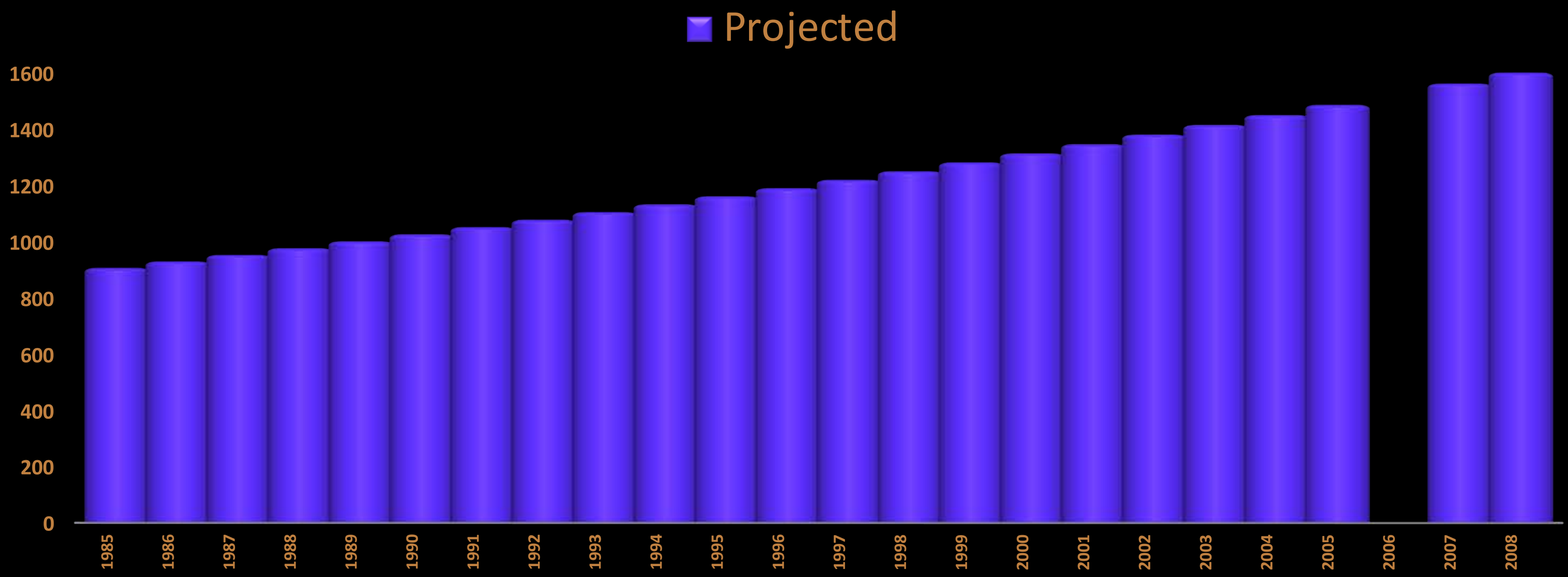
W.H. Carson (1994)
President, Peabody Western Coal Company

(Letter to the Editor of *The Los Angeles Times*, 30 April 1994)

Your editorial, "Saving the Hopi Culture" (April 14), requires clarification and correction... The facts are stated below.

...Peabody Western's use of water from the Navajo aquifer has no significant adverse impact on groundwater use on the Hopi Reservation. We are not aware of any "fact-based studies" which contradict these results... Changes in the flows from their springs may be the result of drought conditions in the region, and perhaps from increased pumpage from the Hopi community wells located near these springs... but Peabody Western's pumping from wells that are 2,500-3,000 feet deep does not affect these springs.

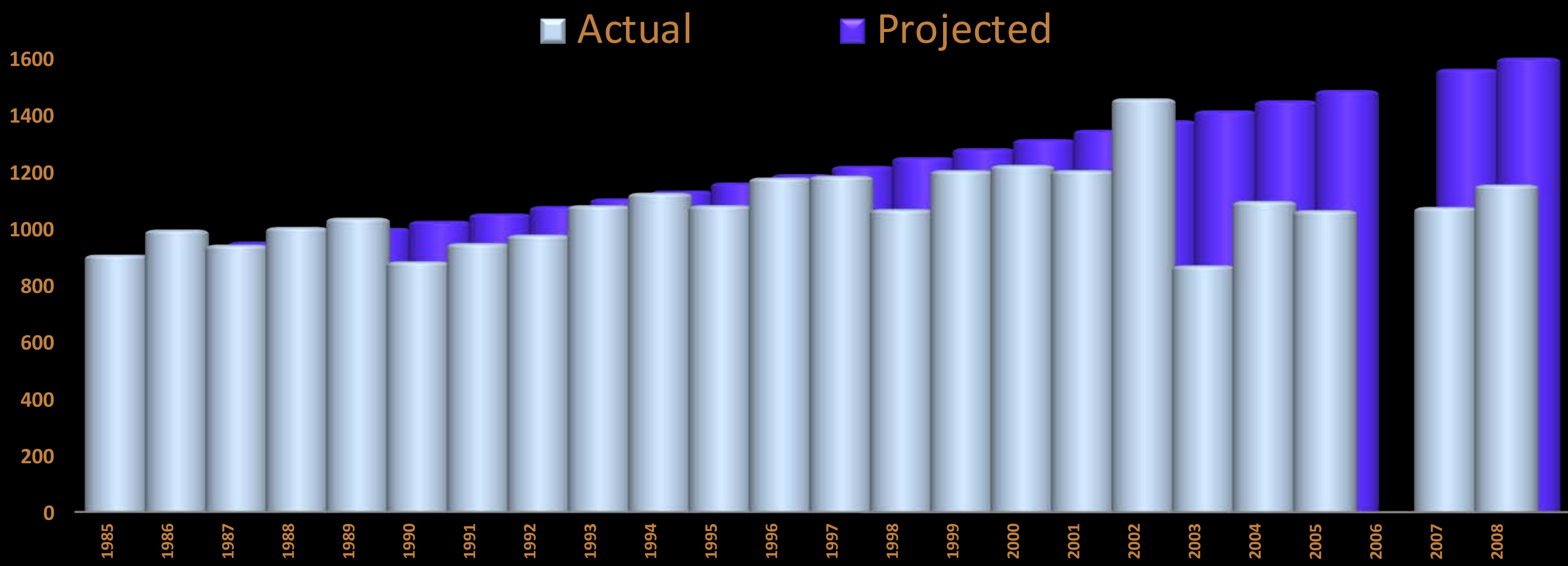
Withdrawal Projections for Tuba City (1985-2008)



Projected: 27,787 acre-feet

Tuba City Withdrawals were Overestimated by 11%

(*Thus, Tuba City's impact on nearby springs should also have been over-estimated*)



Projected: 27,787 acre-feet

Actual: 24,730 acre-feet

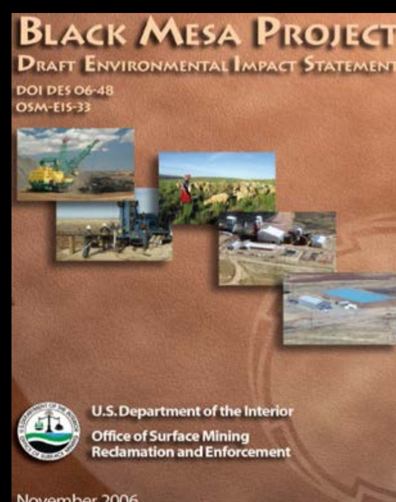
Difference: 3,056 acre-feet (*total withdrawals 1985-2008*)

Annual: 138 acre-feet / year (*11%*)

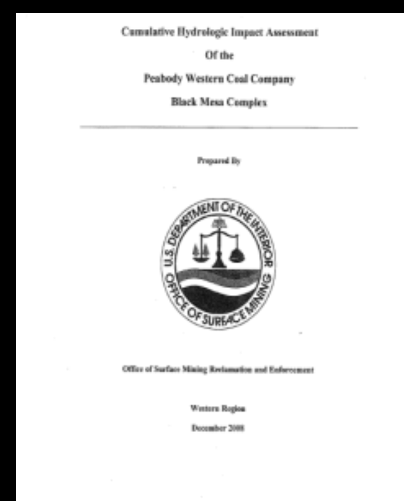
OSM's 2008-2011 CHIA & EA

"The USGS concludes that "*for the consistent periods of record for all four springs, the discharges have fluctuated but long term trends are not apparent*" (USGS 1985-2005)".

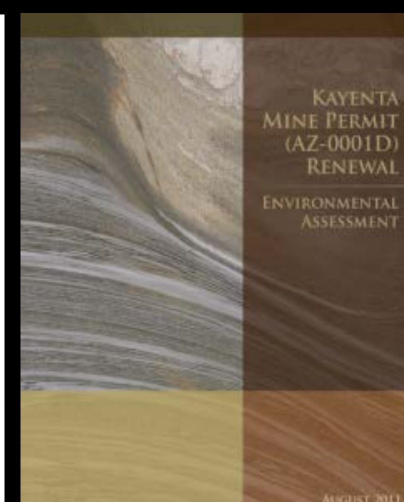
OSM EA 2011: B-26



2006/2008 EIS



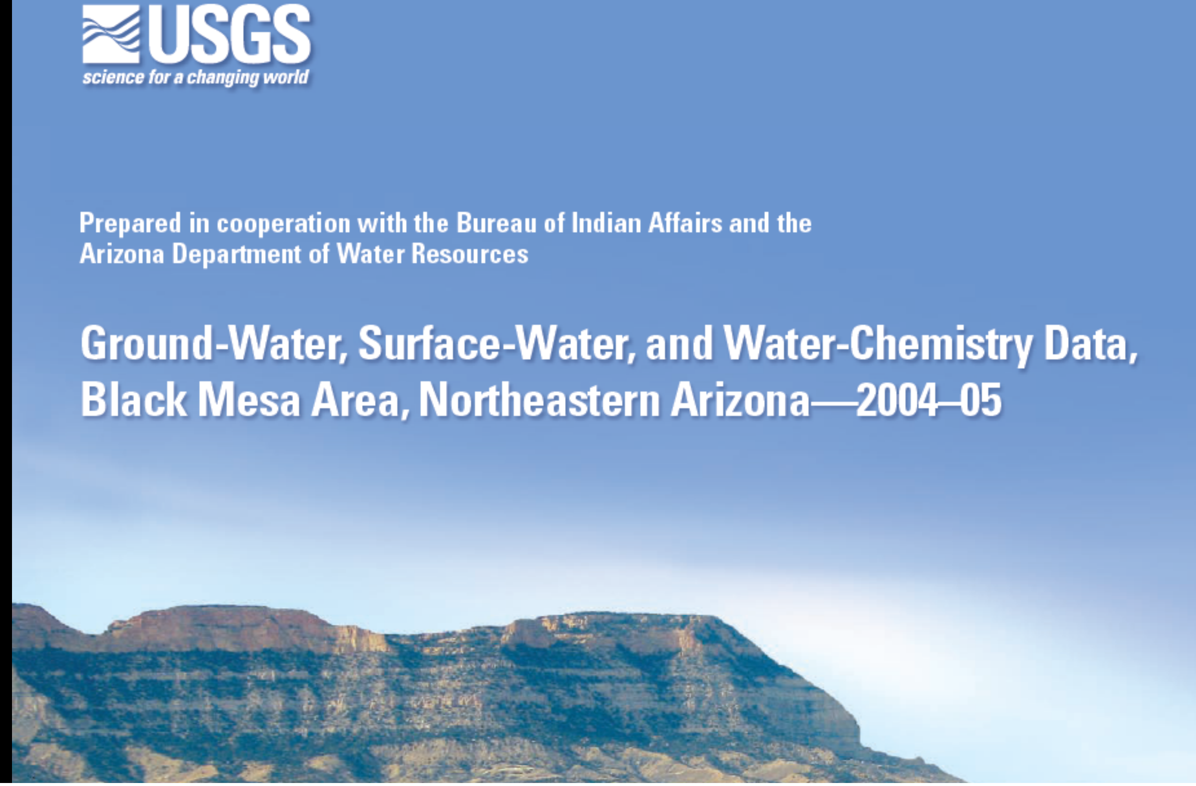
2008 CHIA

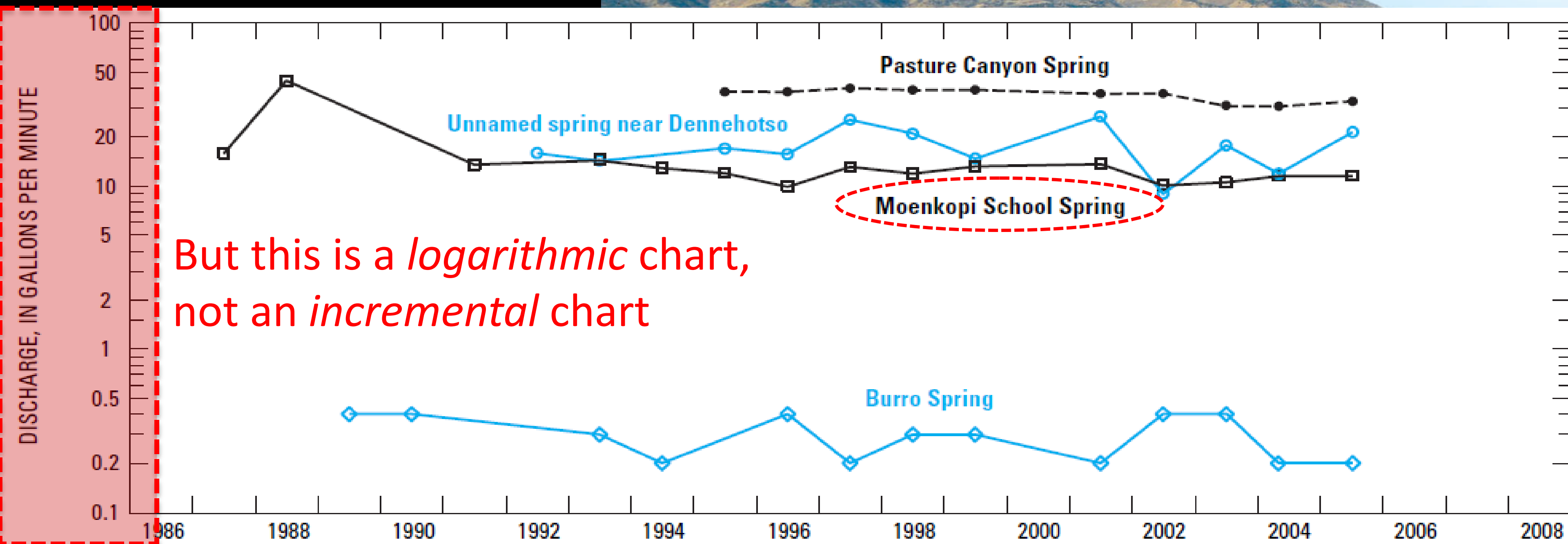


2008 EA

2005 USGS Monitoring Report

(Truini & Macy 2006)

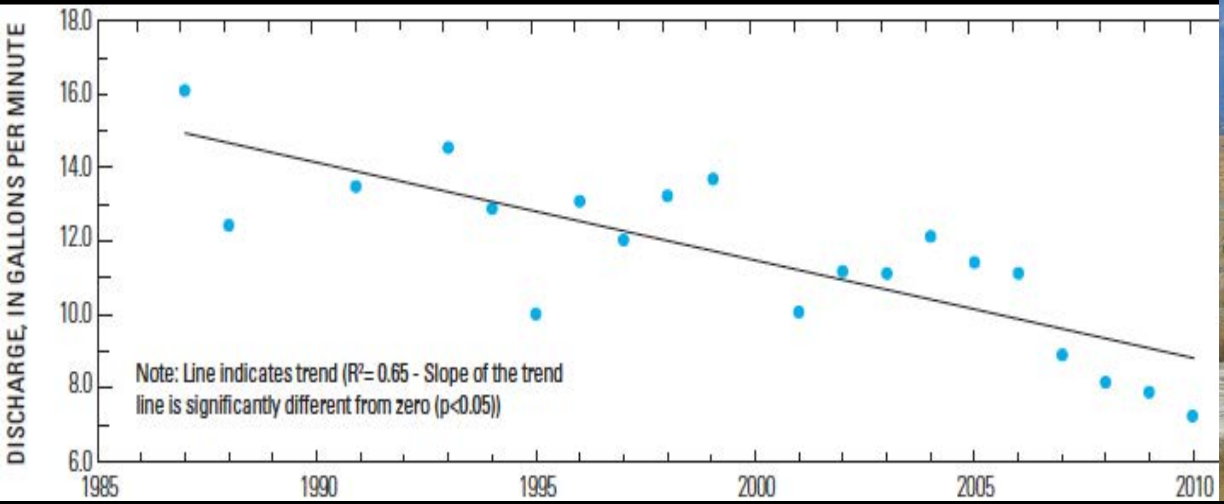


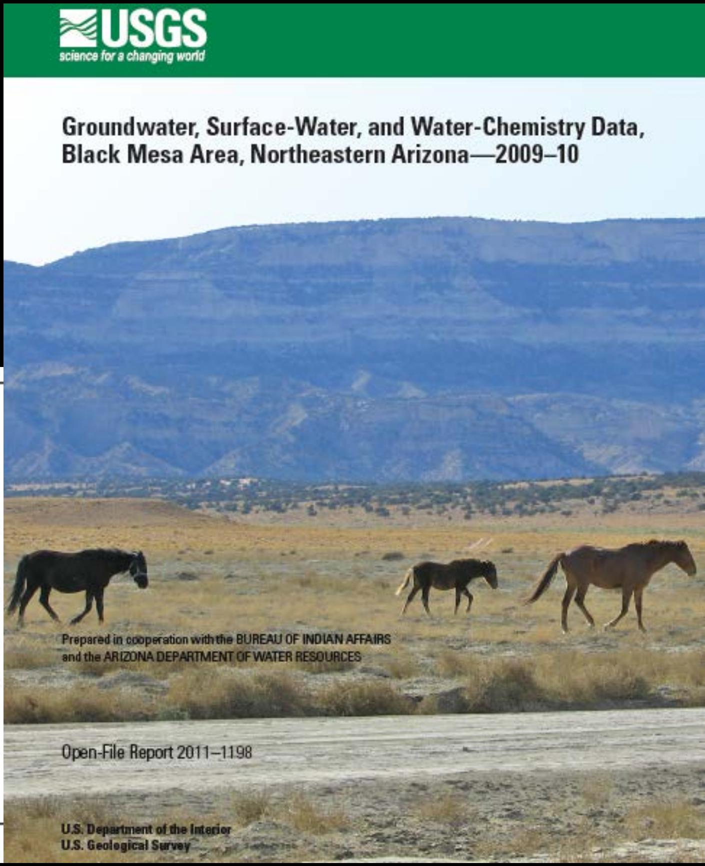


Since 2005, all USGS monitoring reports have used *incremental* charts:

"…for the period of record, discharge measurements have a significant decreasing trend."

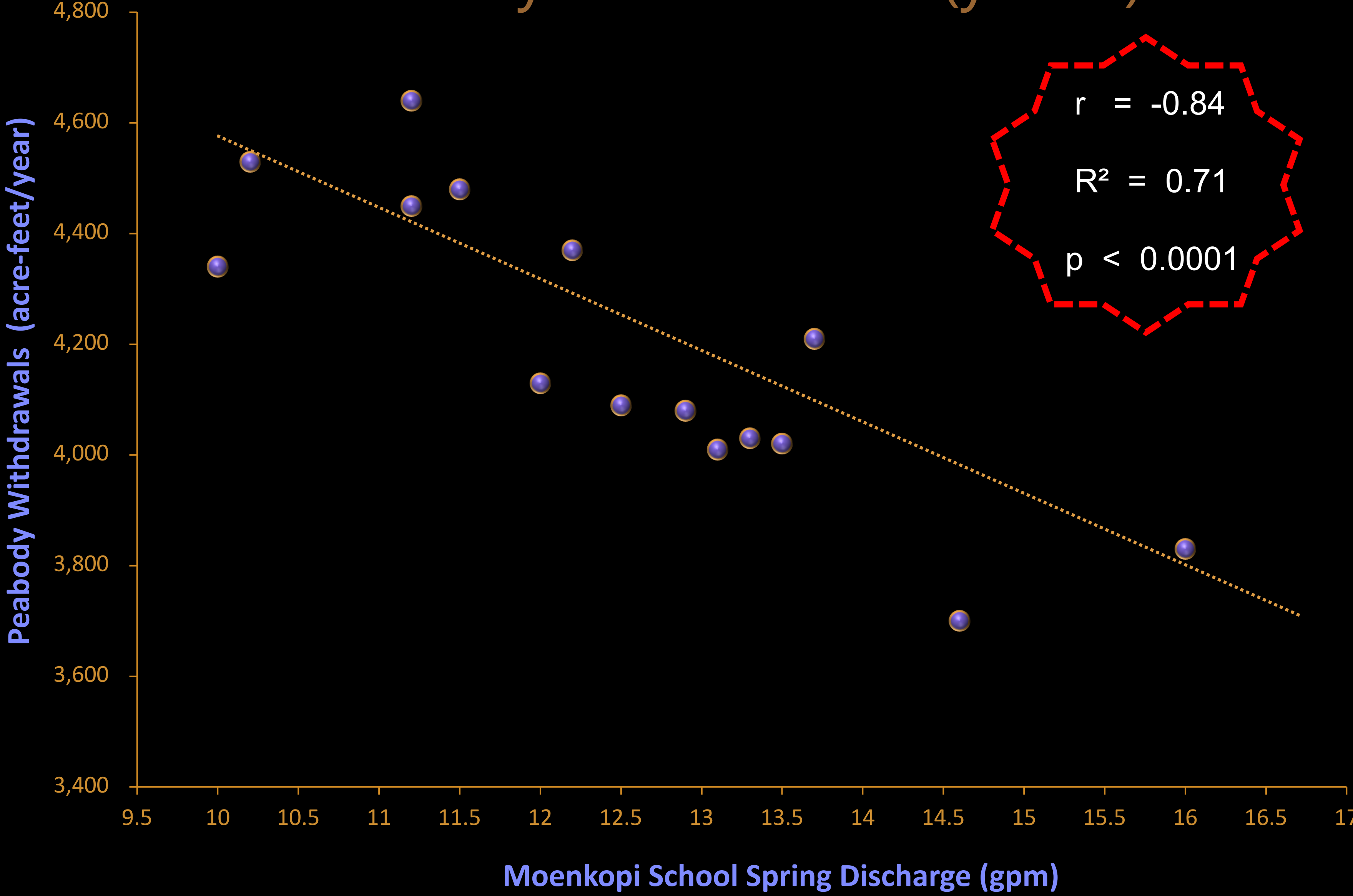
Macy and Brown 2011

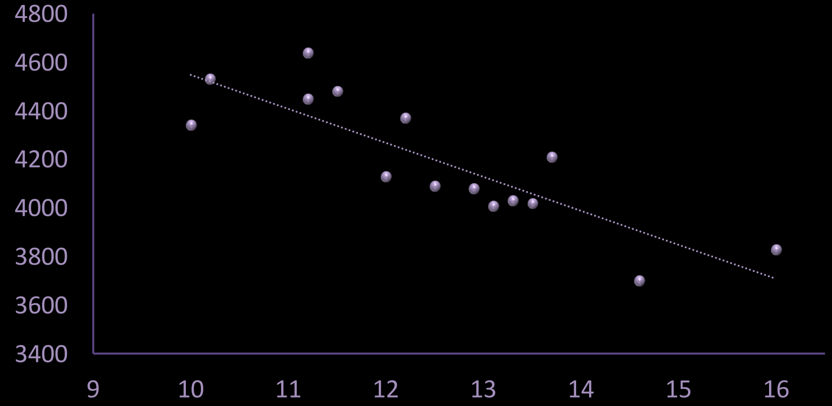




USGS 2007, 2008, 2009, 2010, 2011

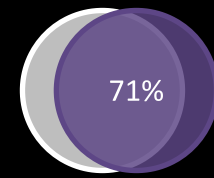
Moenkopi School Spring Discharge (x-axis)
Peabody Withdrawals (y-axis)



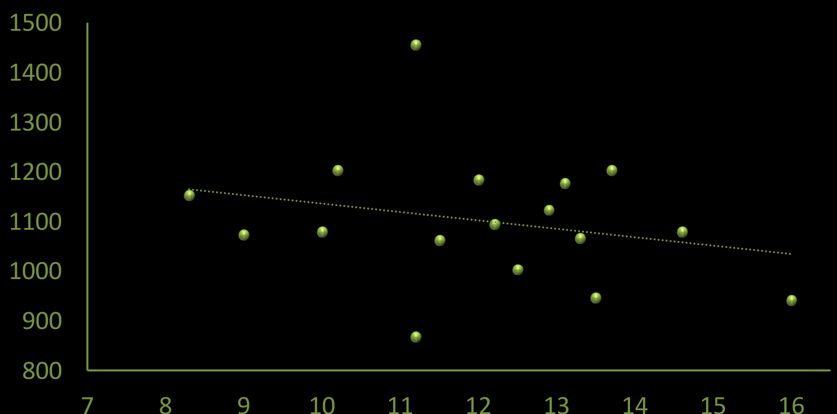


Correlation with PWCC Withdrawals

r = -0.84
R^2 = 0.71
p < 0.0001

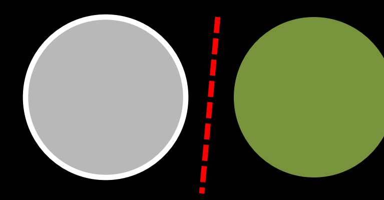


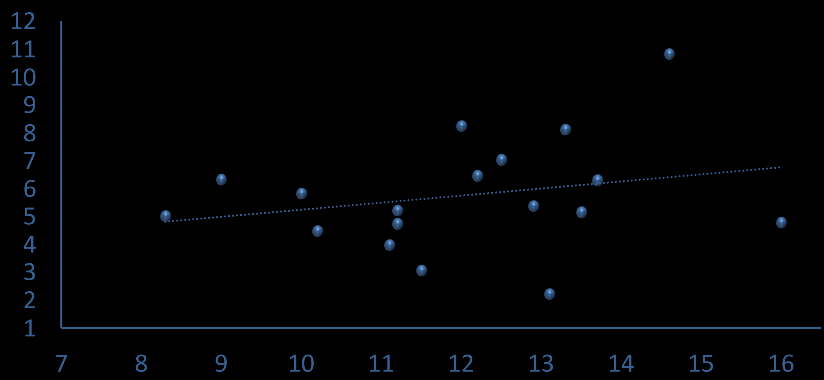
Correlation with Tuba City's withdrawals or local precipitation?



Tuba City Withdrawals

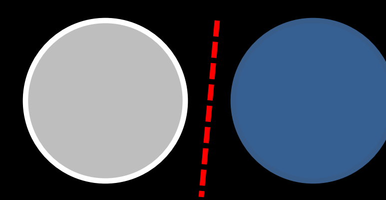
r = -0.30
R^2 = 0.09
p = 0.28



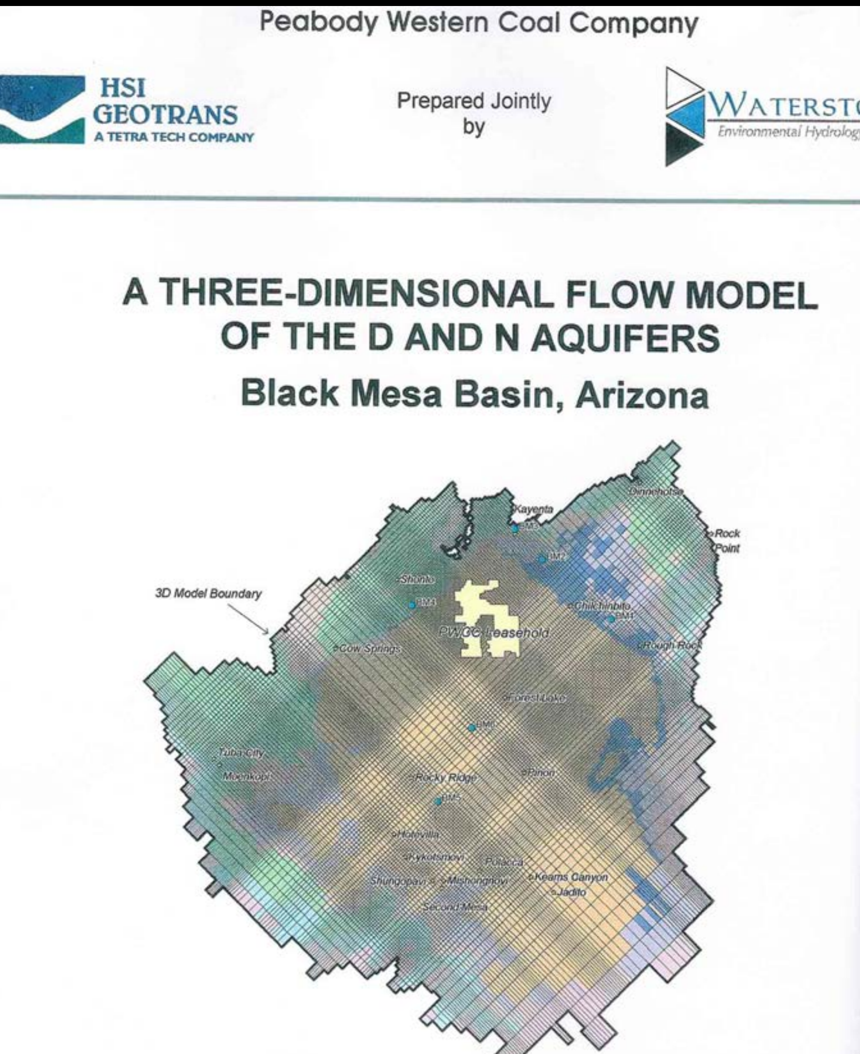


Tuba City Precipitation

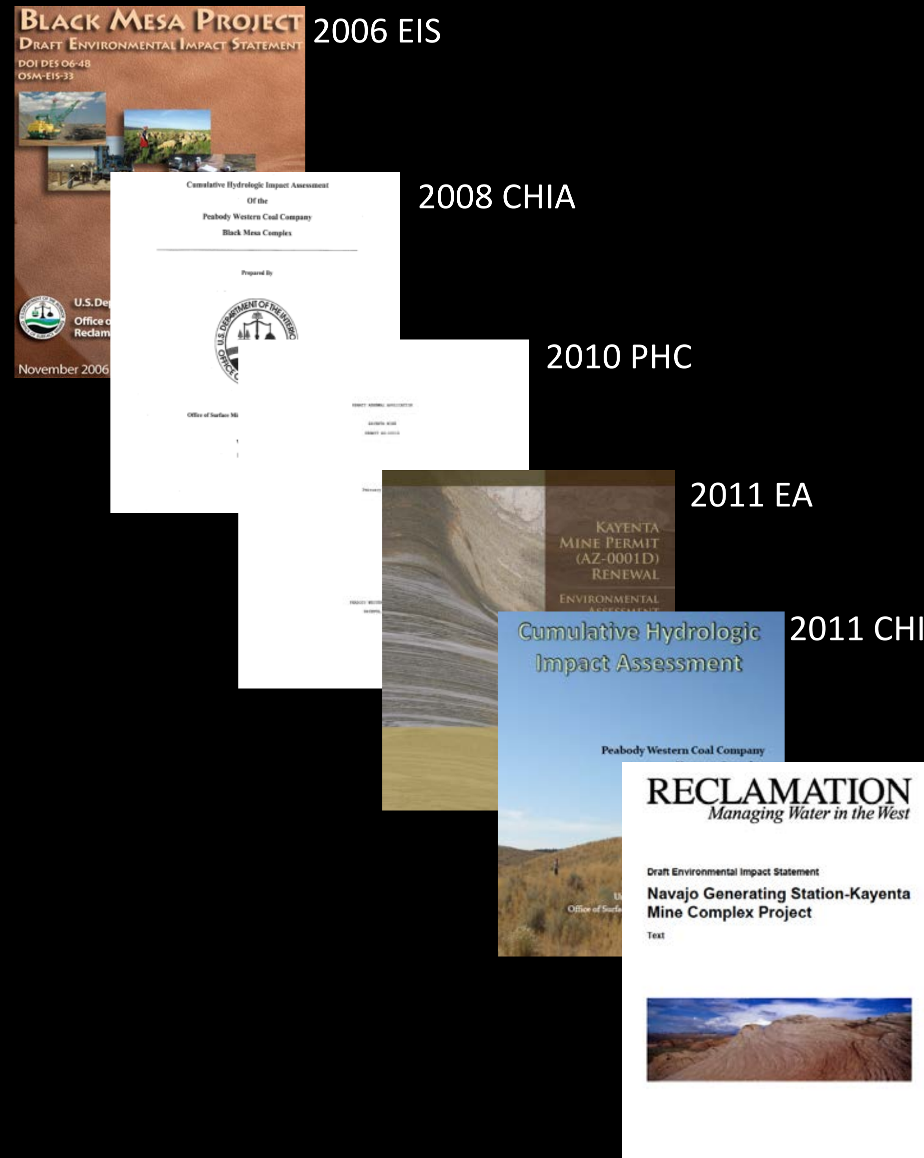
r = 0.34
R^2 = 0.11
p = 0.17



The Peabody Groundwater Model



HSIGeoTrans & WEHE (1999)
GeoTrans (2005)



2006 EIS

2008 CHIA

2010 PHC

2011 EA

2011 CHIA

2016 CHIA

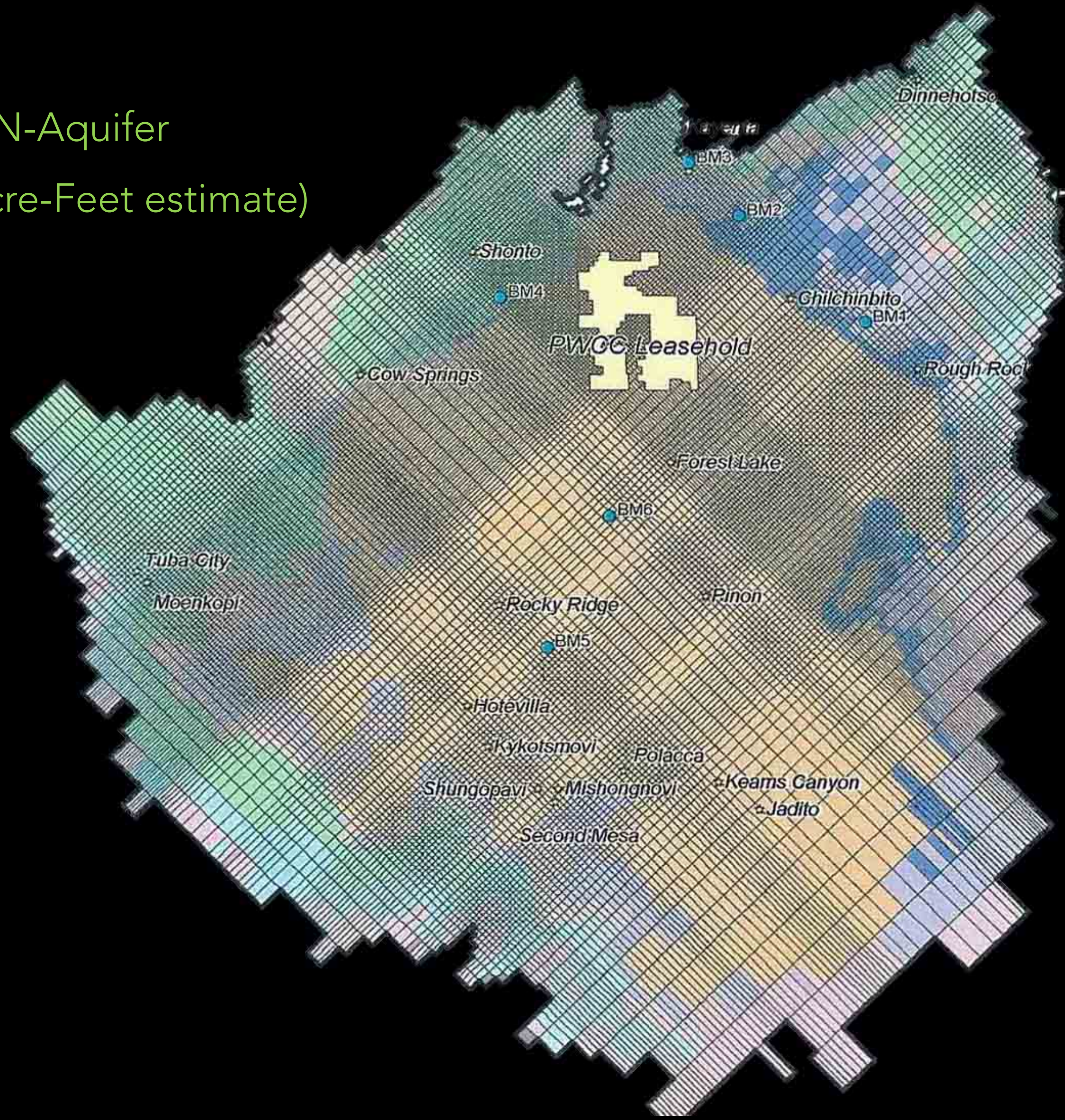
Review of Peabody's 3-Dimensional, $3 Million Groundwater Model

1) Integrated the D-Aquifer into the N-Aquifer (to come up with its 400 Million Acre-Feet estimate)

2) Could not be calibrated without creating 4 *fictional* geological formations that do no exist in the actual N-aquifer

3) Parameter values taken from 5 models that are not associated with the N-aquifer

4) Principal parameter values from the (now defunct) USGS model



Review of Peabody's 3-Dimensional, $3 Million Groundwater Model

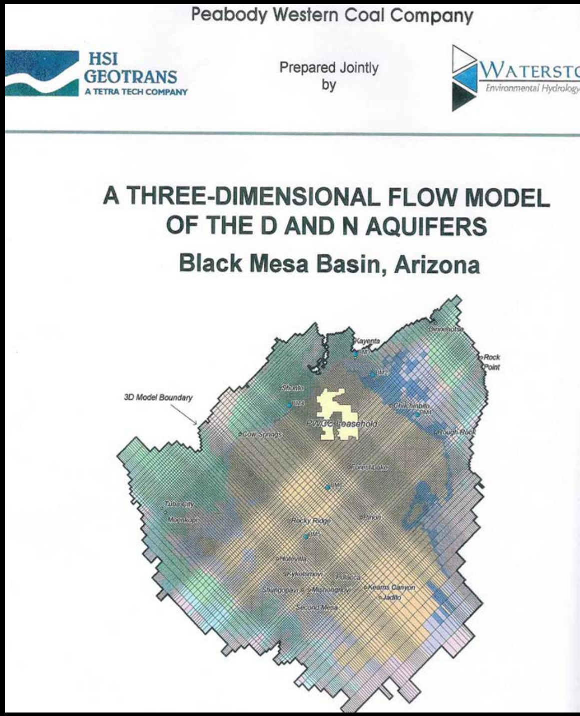
5) The model's recharge estimation method did not work (p. 5-65)
   a) 18,000 acre-feet (using an alternative method)
   b) or 42,355 – 51,629 acre-feet per year (p. 4-35)
   c) or 70,904 – 88-630 acre-feet per year (p. 1-13)
   d) or 35,452 – 70-904 acre-feet per year (p. 8-6)

   (Thus, Peabody's recharge estimate ranges from ≈ 18,000 – 90,000 af/y)

6) The D-aquifer is not monitored… (p. 1-11)

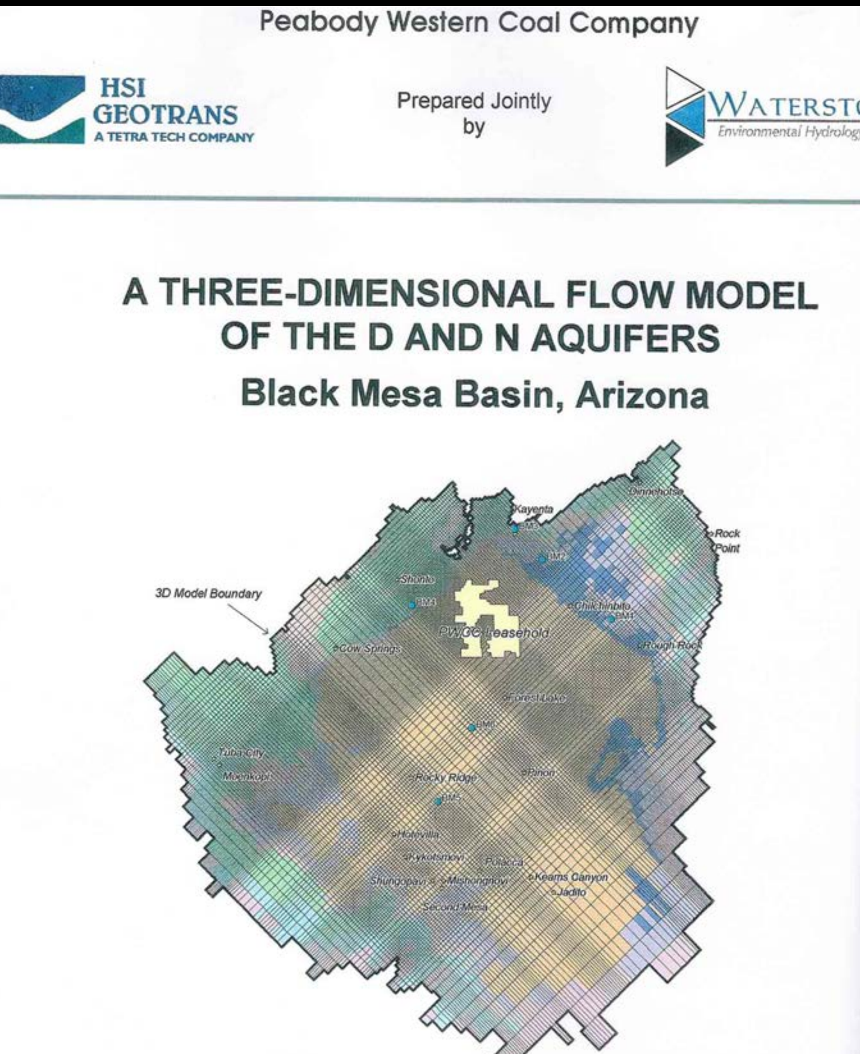
7) Yet leakage from the D- to the N- is 4,034 af/y (p. 5-51)

8) A discharge estimate was not attempted (p. 5-24) because
   a) Spring discharge is not well known (p. 4-42)
   b) Stream discharge is not well known (p. 4-43)
   c) Evapotranspiration is not well known (p. 5-24)
   d) These measurements are difficult, expensive, and unfeasible to obtain (p. 5-63)

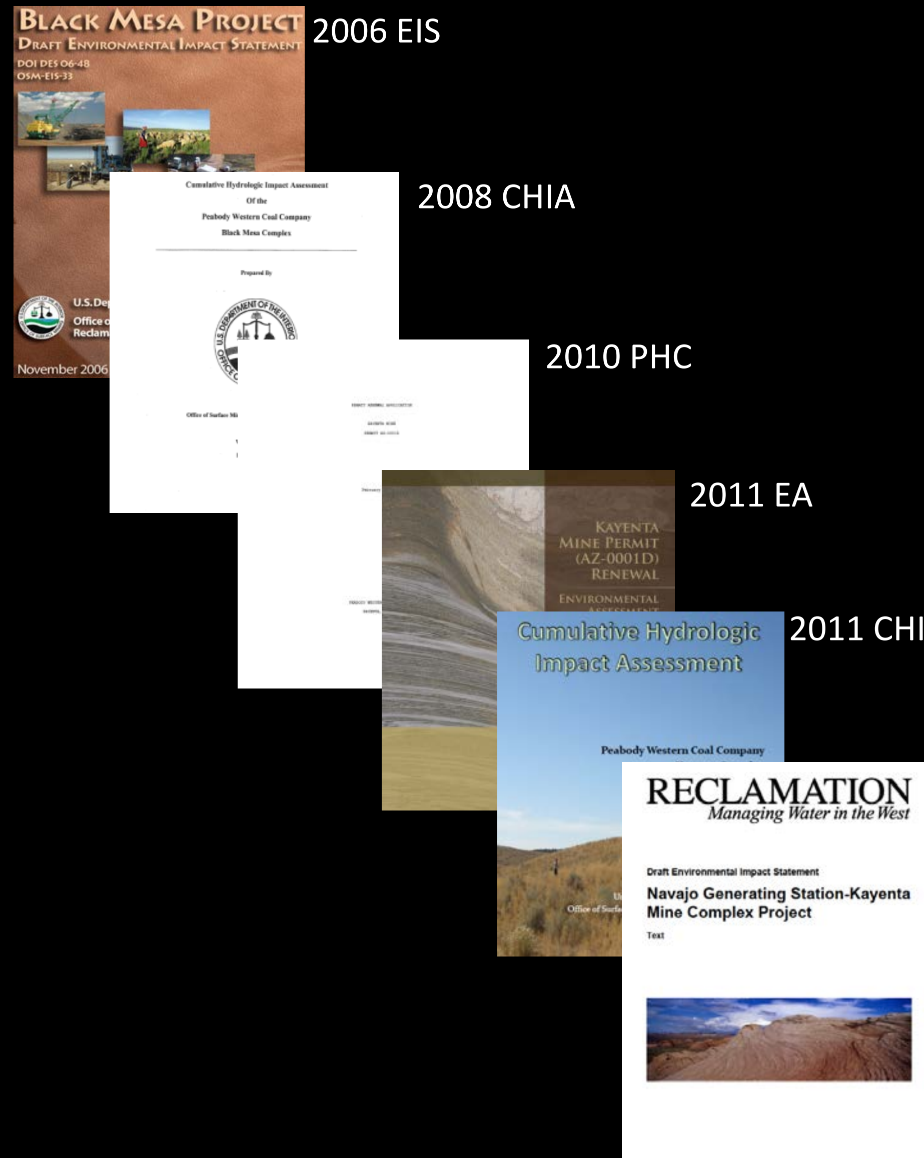


HSIGeoTrans & WEHE (1999)

The Peabody Model and Recent EISs/CHIAs



HSIGeoTrans & WEHE (1999)
GeoTrans (2005)



2006 EIS

2008 CHIA

2010 PHC

2011 EA

2011 CHIA

2016 CHIA

OSM has had four different sets of *Material Damage Criteria* since 1989

CRITERION	1989	*1989 criterion status:*
Water Quantity	Head at +100 ft above N-aquifer	crossed
Water Quality	Decline > 10% caused by mine	never evaluated using CHIA method
Spring Discharge	decline > 10% caused by mine	crossed
Stream Discharge	decline > 10% caused by mine	never evaluated using CHIA method

OSM has had four different sets of *Material Damage Criteria* since 1989

CRITERION	1989	*1989 criterion status:*	2008
Water Quantity	Head at +100 ft above N-aquifer	crossed	-
Water Quality	Decline > 10% caused by mine	never evaluated using CHIA method	Mine area ONLY
Spring Discharge	decline > 10% caused by mine	crossed	Burro Spring ONLY
Stream Discharge	decline > 10% caused by mine	never evaluated using CHIA method	> 10% reduction for ten years

**Peabody's groundwater model will be used to determine if any of these impacts were caused by Peabody*

OSM has had four different sets of *Material Damage Criteria* since 1989

CRITERION	1989	1989 criterion status:	2008	2011
Water Quantity	Head at +100 ft above N-aquifer	crossed	-	26-50% increase in tribal pumping cost
Water Quality	Decline > 10% caused by mine	never evaluated using CHIA method	Mine area ONLY	Mine area ONLY
Spring Discharge	decline > 10% caused by mine	crossed	Burro Spring ONLY	-
Stream Discharge	decline > 10% caused by mine	never evaluated using CHIA method	> 10% reduction for ten years	Moenkopi Wash ONLY
			**Peabody's groundwater model will be used to determine if any of these impacts were caused by Peabody*	**Peabody's groundwater model will be used to determine if any of these impacts were caused by Peabody*

OSM has had four different sets of *Material Damage Criteria* since 1989

CRITERION	1989	*1989 criterion status:*	2008	2011
Water Quantity	Head at +100 ft above N-aquifer	crossed	-	26-50% increase in tribal pumping cost
Water Quality	Decline > 10% caused by mine	never evaluated using CHIA method	Mine area ONLY	Mine area ONLY
Spring Discharge	decline > 10% caused by mine	crossed	Burro Spring ONLY	-
Stream Discharge	decline > 10% caused by mine	never evaluated using CHIA method	> 10% reduction for ten years	Moenkopi Wash ONLY
			**Peabody's groundwater model will be used to determine if any of these impacts were caused by Peabody*	**Peabody's groundwater model will be used to determine if any of these impacts were caused by Peabody*

2016

(1) A decline in baseflow discharge from the N-aquifer to Moenkopi Wash of greater than 30%.

**Peabody's groundwater model will be used to determine if decline is caused by Peabody's Groundwater pumping.*

(2) "Limiting the decline of water level in municipal wells to less than the cost of electric power to lift groundwater of $1 / household / month for wells that supply potable water to communities"

**to be calculated by OSM*

Summary Notes

- Municipal-caused drawdown: consistently overestimated
- Industrial-caused drawdown: consistently underestimated
- Some empirical evidence: community drawdown & spring discharge – PWCC pumping
- No empirical evidence these impacts are related to municipal (tribal) pumping
- New MD criteria are evaluated via computer model, *not* actual monitoring data
  - The model was developed and is maintained by the company being regulated
- The only data that support OSM's conclusions are from the Peabody model simulations
- When EIS or CHIA predictions are debunked, material damage criteria are eliminated or changed in such a way that the prior thresholds can no longer be enforced.
- OSM has framed this conflict as being about different communities having different perspectives and understanding about very technical hydro-geological data.

Rather, this case study demonstrates how deterministic modeling and impact assessments are "elaborate rituals" in which political decisions are disguised as scientific facts.

Peabody's response:

"The issues raised by activists long opposed to mining are heavy on rhetoric and light on facts," reads a statement released by the company in response to Higgins' research. "The Navajo Aquifer is healthy and robust, and mining has not harmed any regional water supplies."

Cindy Yurth quoting
Peabody Spokesperson Beth Sutton,
in the *Navajo Times,* 28 July 2011

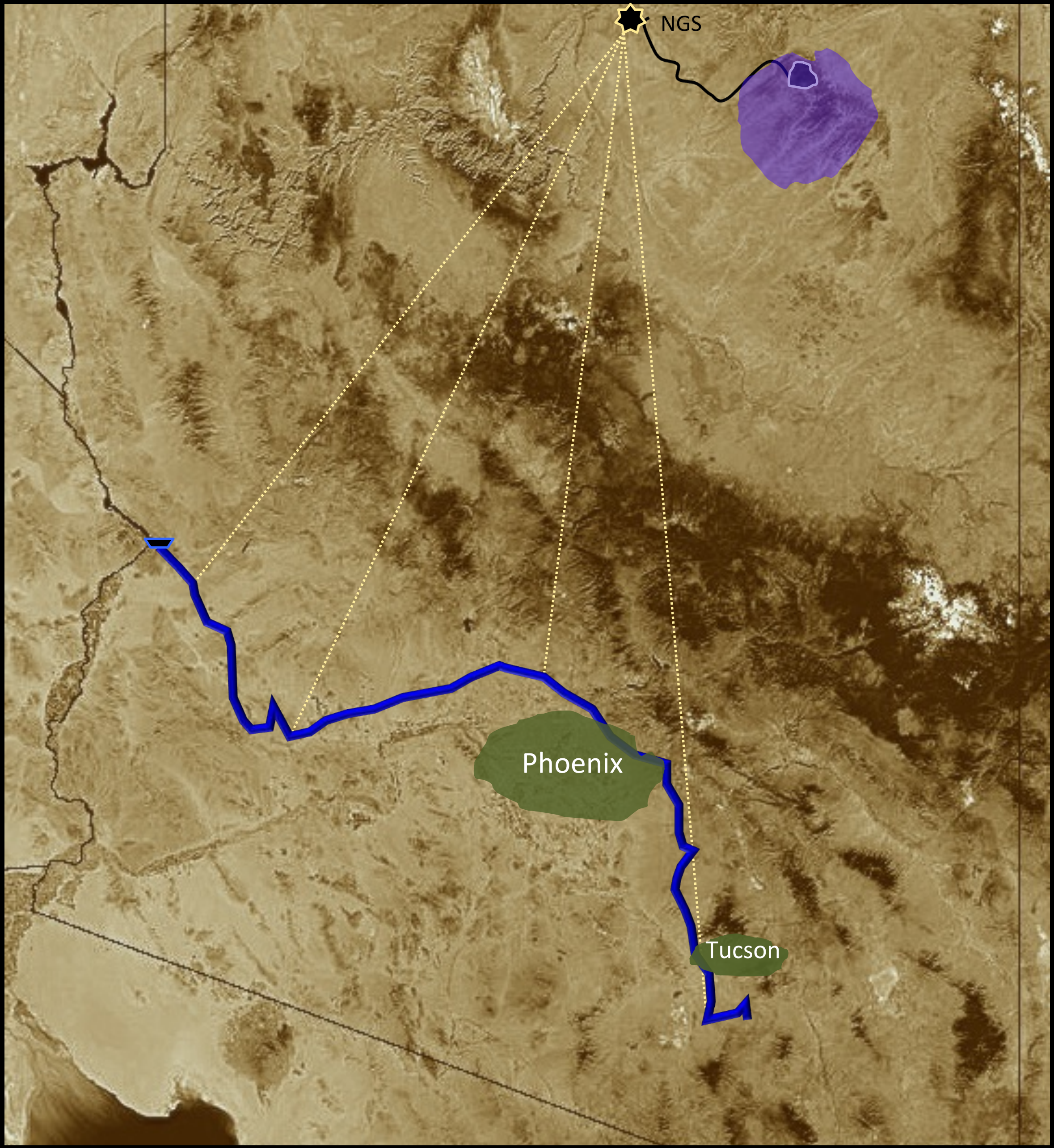
OSM's response:

"OSM has reviewed the report you provided and would like to offer the following clarifications. The documentation referenced for comment is several decades old, is based on predictions with limited data compared to the currently available data sets, and therefore is not appropriate for use given the availability of the current documentation."

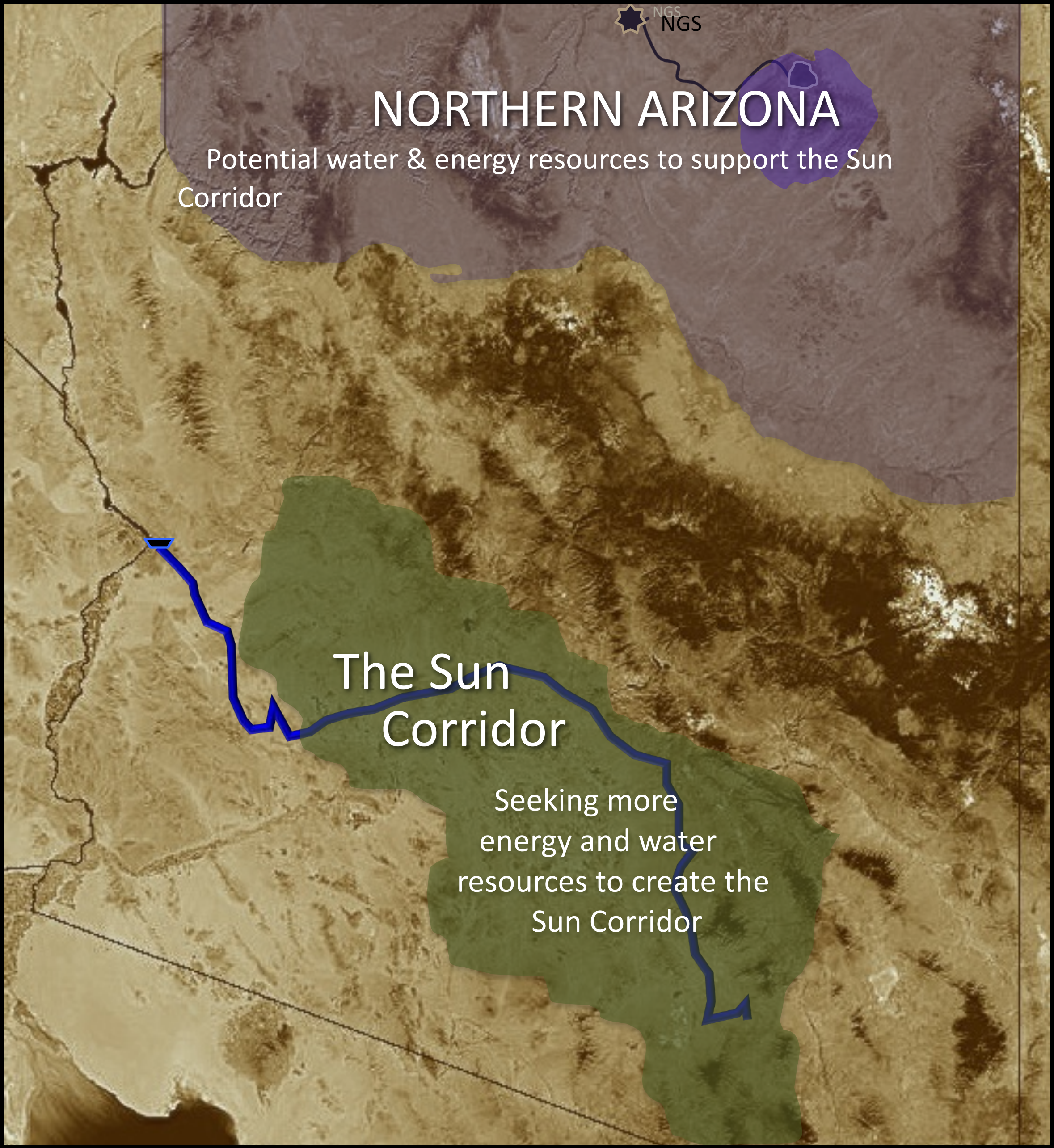
Allen Klein (2011)
Director, Office of Surface Mining (Western Region)
on behalf of Joseph Pizarchik, Director, US Office of Surface Mining

21st Century: the "Sun Corridor"

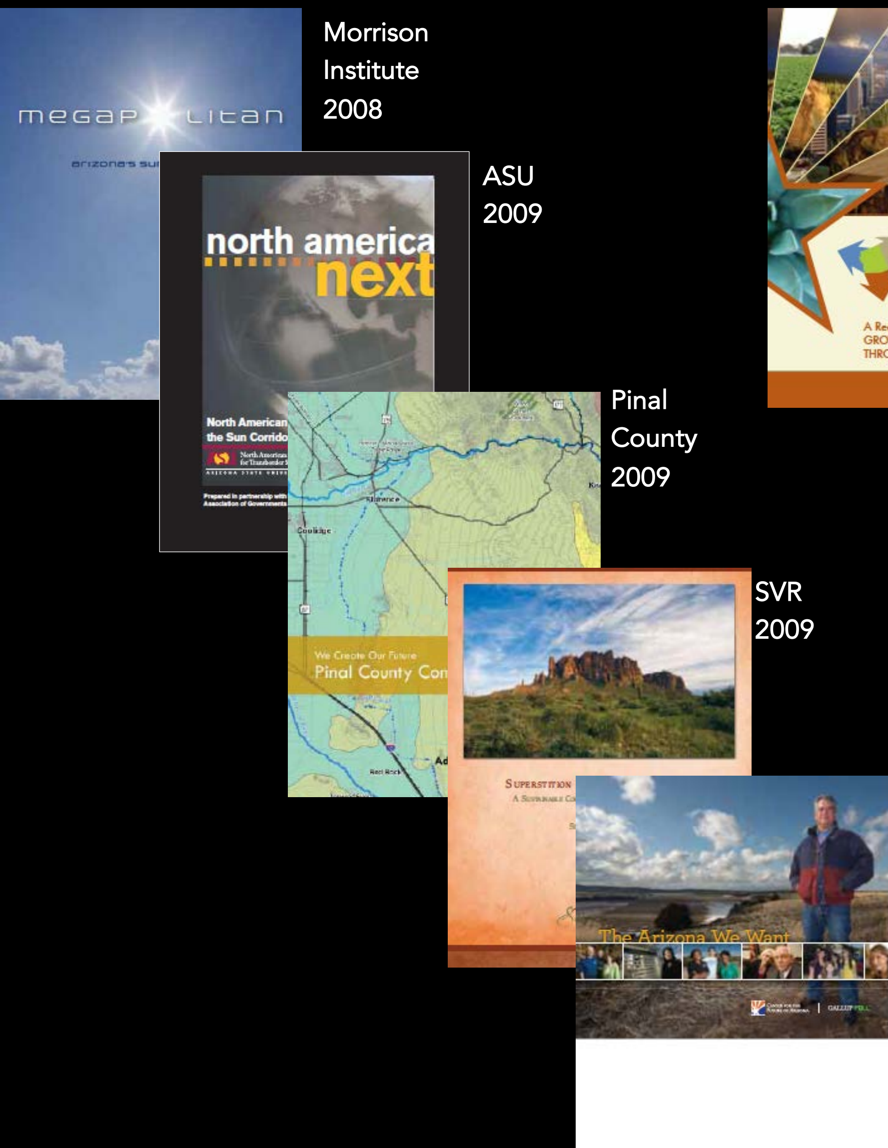
The 20th Century: Building "The Valley of the Sun"



The 21st Century: Building "The Sun Corridor"



21st Century: the "Sun Corridor"



Morrison Institute 2008

ASU 2009

Pinal County 2009

SVR 2009

CFA 2010

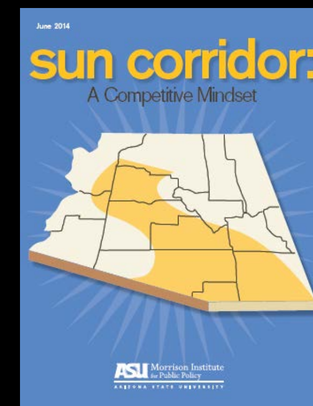
Urban Land Institute 2010

Robert Lang 2011

Brookings Institute 2011

Morrison Institute 2011

AECOM 2011

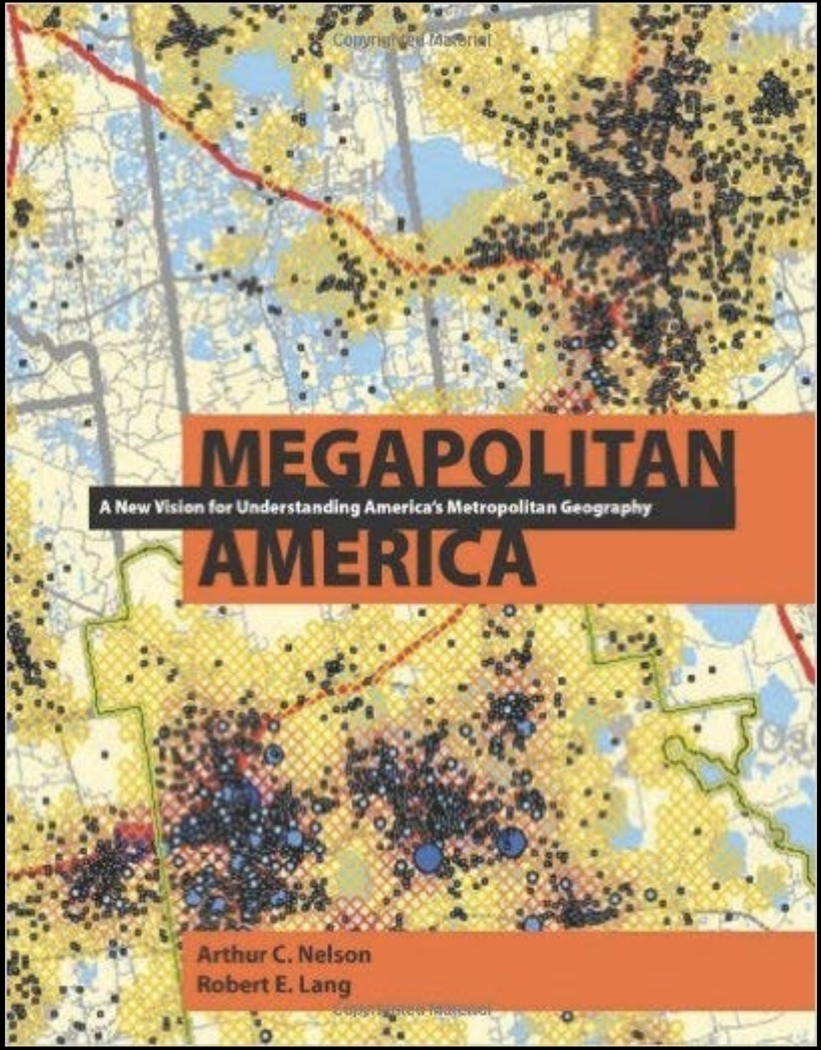


Morrison Institute 2014

21st Century: the "Sun Corridor"

I. MEGAREGIONS & MEGAPOLITANS

- "Megapolitan" concept: a new paradigm for thinking about regions and urban systems… A framework for national planning to 2050
- Plan for American (2004) & American 2050
  - University of Pennsylvania
  - Regional Planning Association
  - Lincoln Institute of Land Policy
- Trajectory & Prediction:
  - Accounting for 60% of US population
  - Living in 10% of its land area

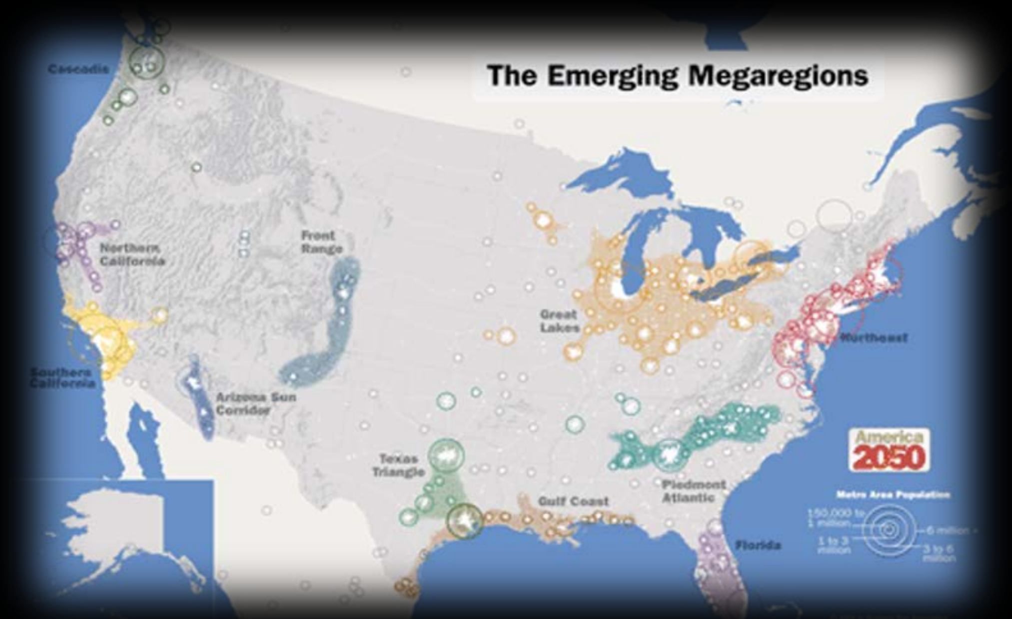


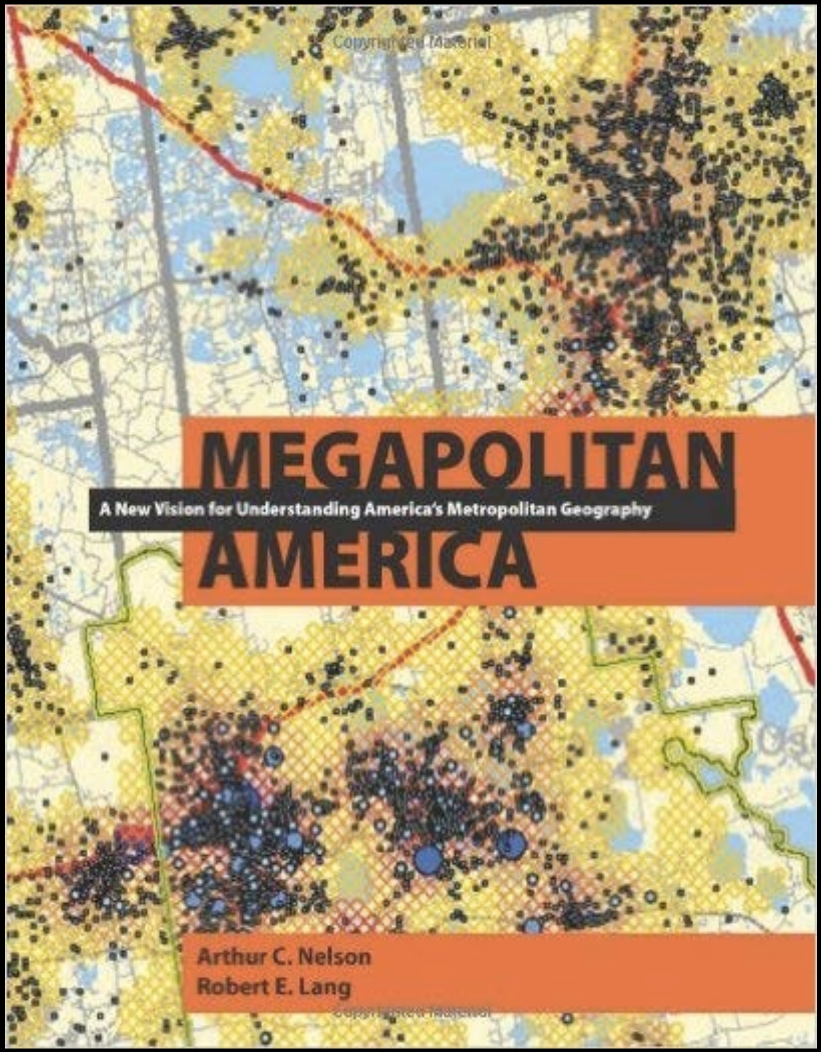
Nelson & Lang 2011

21st Century: the "Sun Corridor"

II. MEGAREGIONS & MEGAPOLITANS

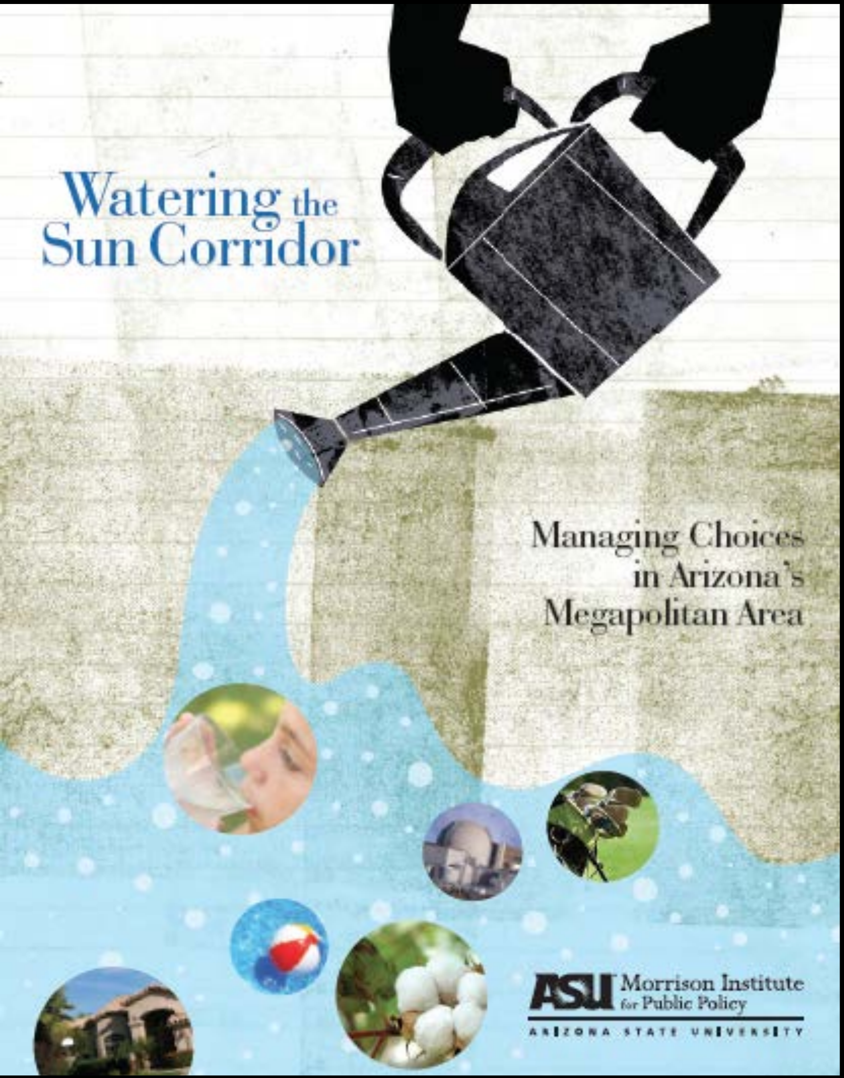
- Census criterion for category of "Megapolitan"
  - Economic interdependence
  - Two or more metro areas w/ overlapping commuting
  - "employment interchange measure" of 15%
- 11 Megaregions & 20 megapolitans





Nelson & Lang 2011

21st Century: the "Sun Corridor"



ASU's Morrison Institute for public policy (2011)

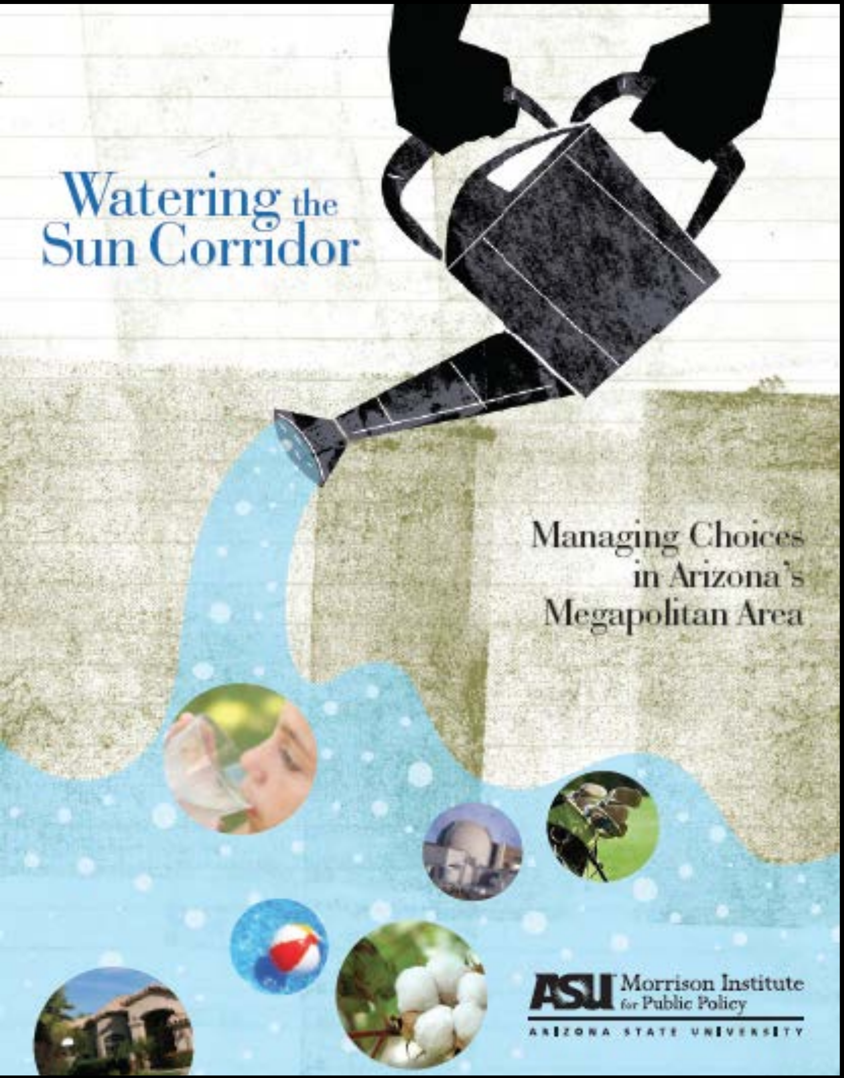
I. PHEONIX–TUCSON–PRESCOTT MEGAPOLITAN AREA

- "Watering the Sun Corridor" (MIPP/ASU 2011)

  "contribute… a more open and informed conversation about the relationship of water and future growth"

- Two critical issues for the Sun Corridor:
  1. Water resources
  2. Tradeoff between population growth & quality of life

21st Century: the "Sun Corridor"

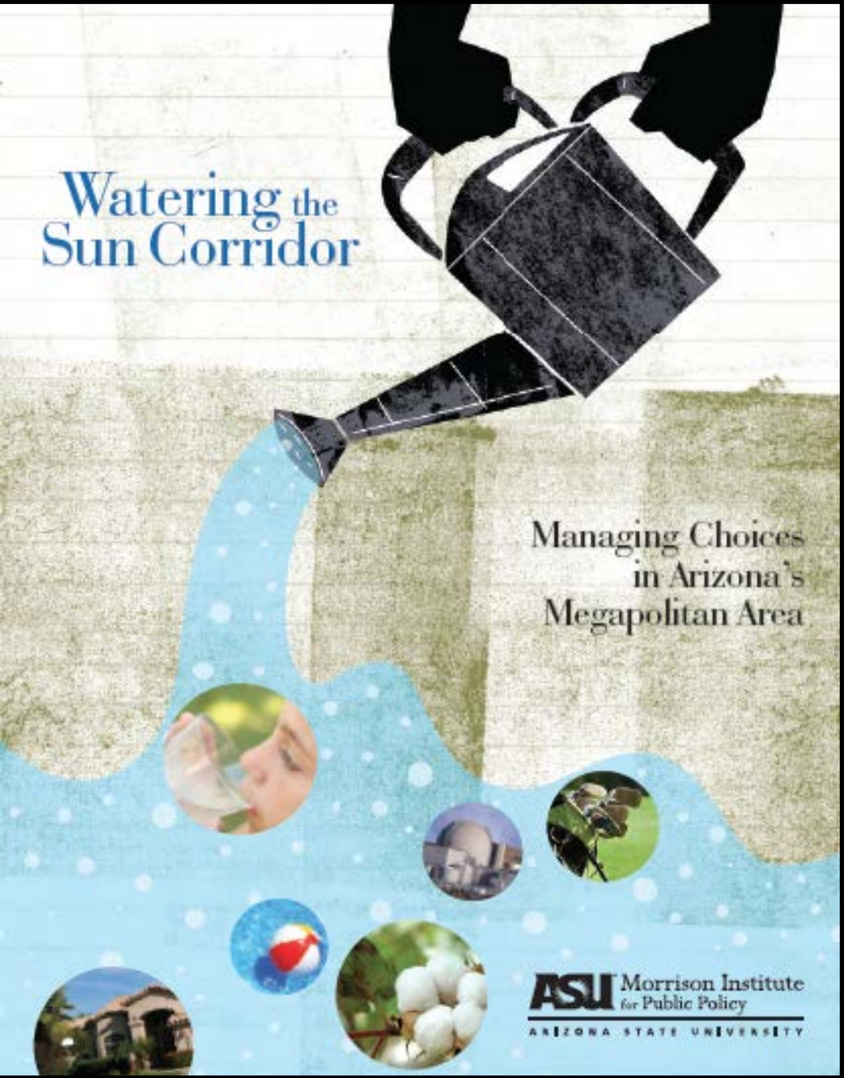


ASU's Morrison Institute for public policy (2011)

II. PHEONIX–TUCSON–PRESCOTT MEGAPOLITAN AREA

- 2.4 million acre feet: support 9.5 million residents
- Renewable water supplies to the Sun Corridor provide, on average, 2.5–3 million acre feet
- "The Sun Corridor's plumbing systems include"
  - Reservoirs in Arizona (SRP)
  - Reservoirs on the Colorado River (CAP)
  - Groundwater banking (GMA)
  - These supply 4-5 years of AZ's water needs
- Arizona's population projections:
  - 8 million by 2030
  - 9 million by 2040
  - 10 million by 2050

21st Century: the “Sun Corridor”

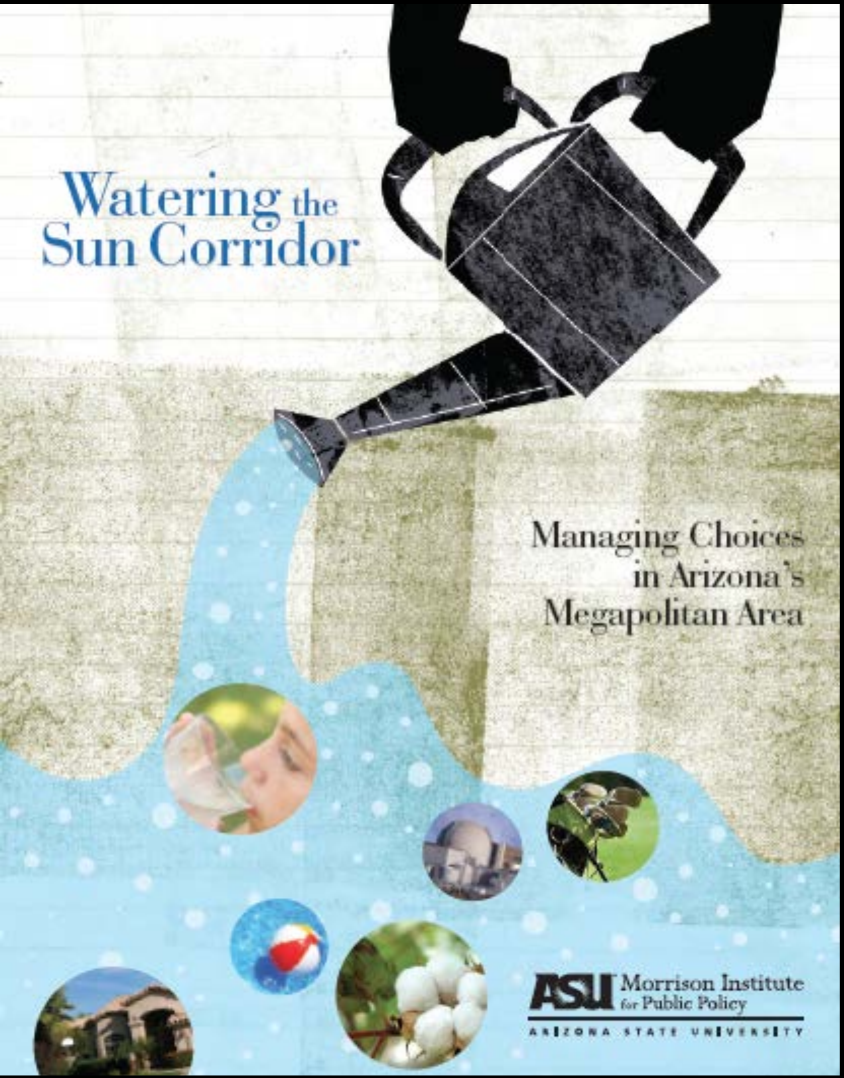


ASU’s Morrison Institute for public policy (2011)

III. PHEONIX–TUCSON–PRESCOTT MEGAPOLITAN AREA

“We bring water from farther away, and there have been some reports that criticize us because we bring water from so far away, namely the Colorado River which is water from the Rockies, *but the truth is that probably makes us more sustainable*, because it means that we have a fairly large surface water supply, which is a renewable resource, as opposed to groundwater, and we have water that comes from central Arizona through SRP… and those are different climatic zones though they’re related…” (PBS Arizona Horizon, August 31 2011)

21st Century: the "Sun Corridor"

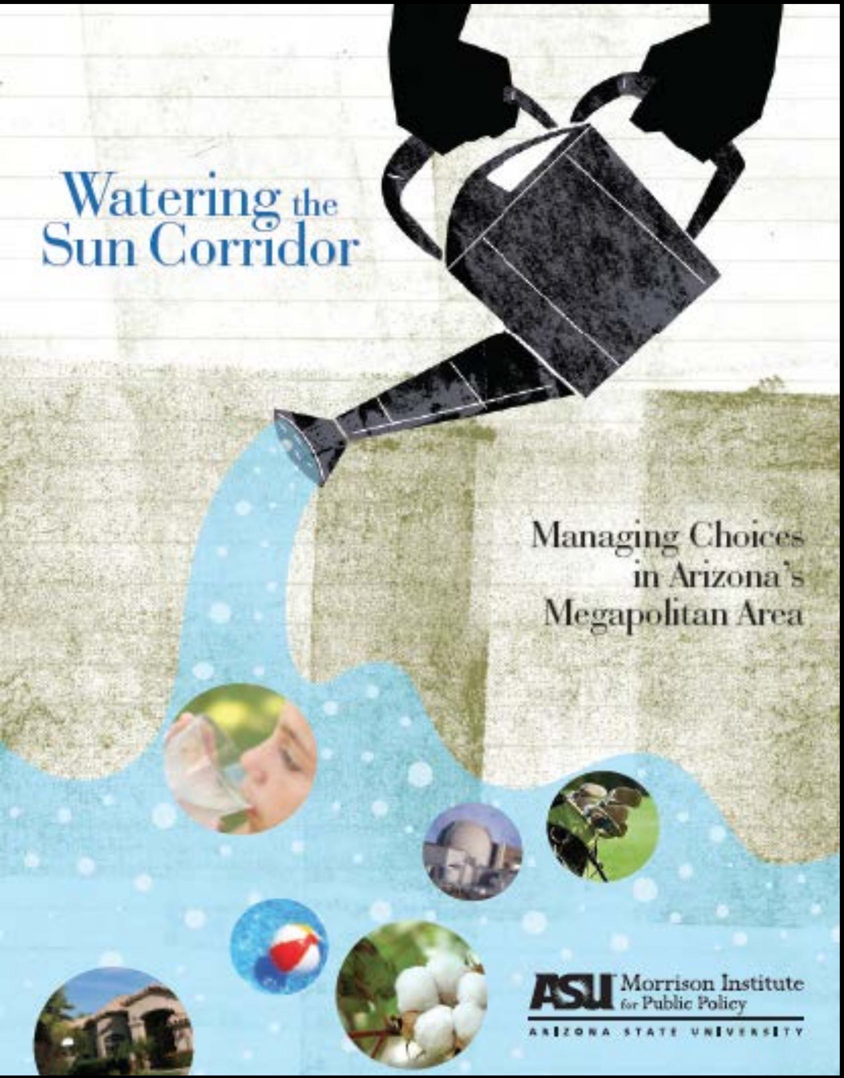


ASU's Morrison Institute for public policy (2011)

IV. PHEONIX–TUCSON–PRESCOTT MEGAPOLITAN AREA

"…Arizona is different than a lot of the country because we know we have a highly variable water supply… we've built a system to take care of that sort of normal fluctuation that is much more flexible than most urban areas of the United States… the dilemma for us is the amplitude of the variability that we've been dealing with is going to get greater so we have to increase our capacity because of climate change and other things, but we just don't know how much."

21st Century: the "Sun Corridor"



ASU's Morrison Institute for public policy (2011)

V. PHEONIX–TUCSON–PRESCOTT MEGAPOLITAN AREA

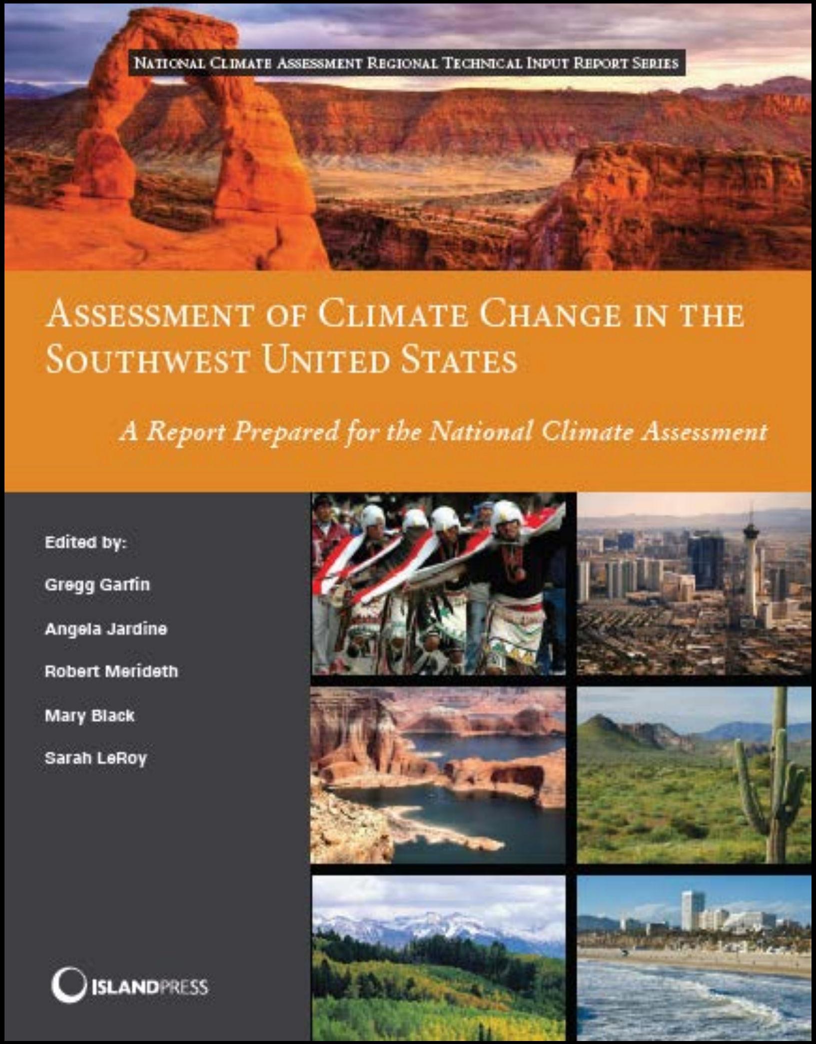
- The Sun Corridor won't run out of water
- > 9 but < 10 million residents is sustainable
- Arizona better prepared than anywhere else for increasing variability due to climate change

"Water, among other things, has been what Arizona does really well."

The 21st Century and Climate Change in the Southwest

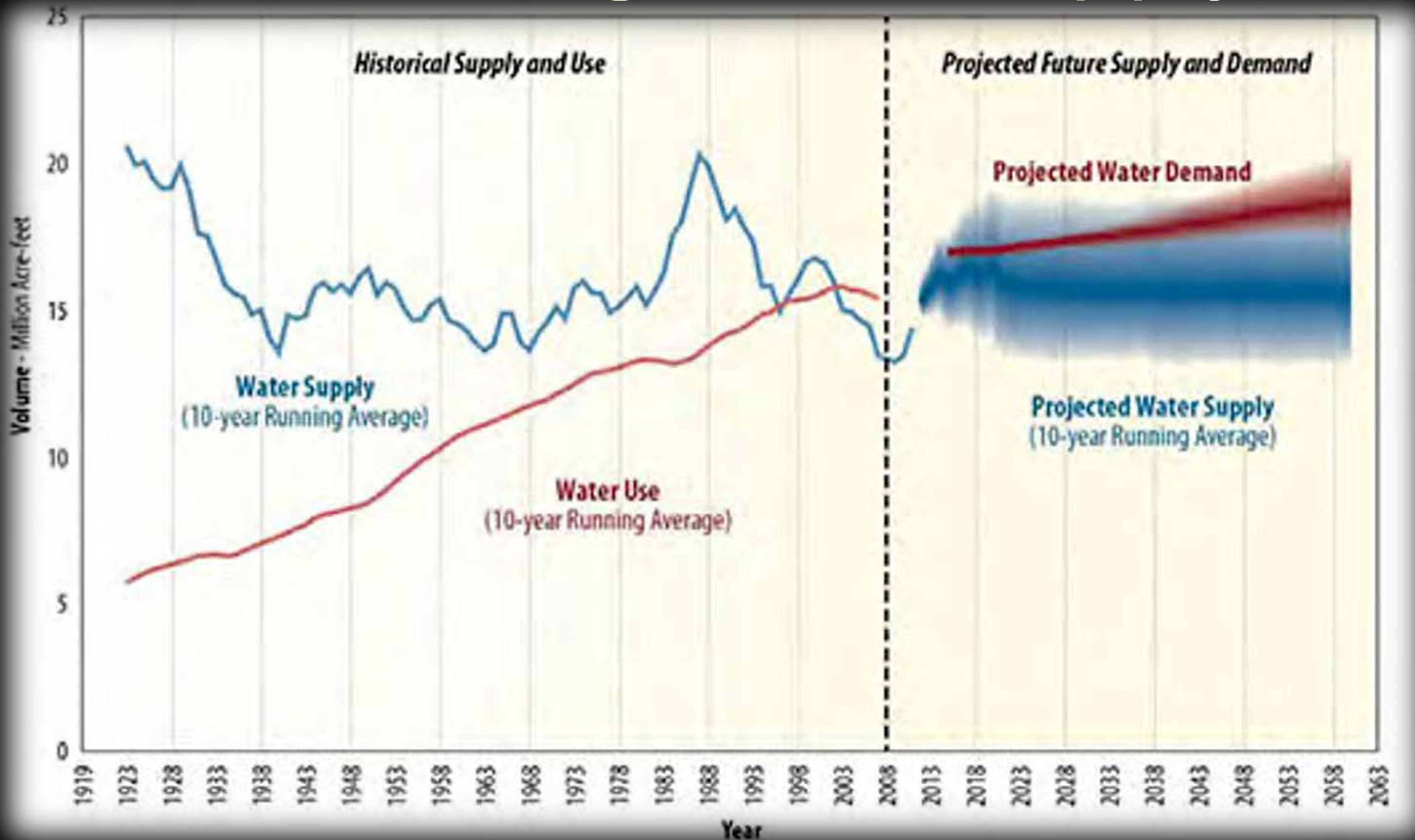
"The Southwest can be considered to be one of the most "climate-challenged" regions of North America."

- Increasing Temperatures
- Increasing Drought (duration/intensity)
- Decreasing Precipitation
- Decreasing flow in Colorado River
- Increasing severity of wet periods & floods
- Increasing forest fires
- Increasing demand on resources
- Past will no longer provide a guide to future

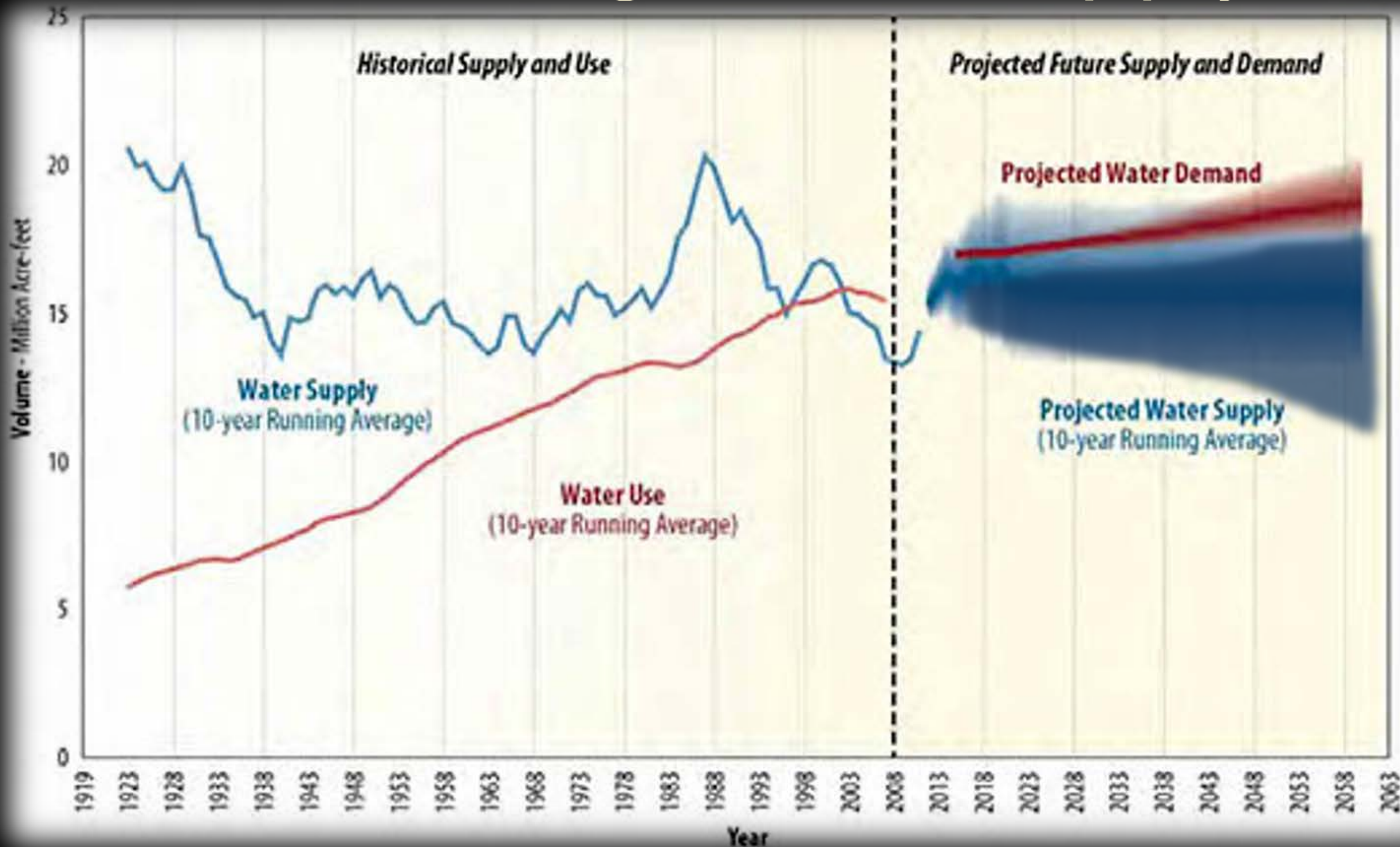


Garfin et al. (2013)

Increasing Population & Decreasing Water Supply



Increasing Population & Decreasing Water Supply



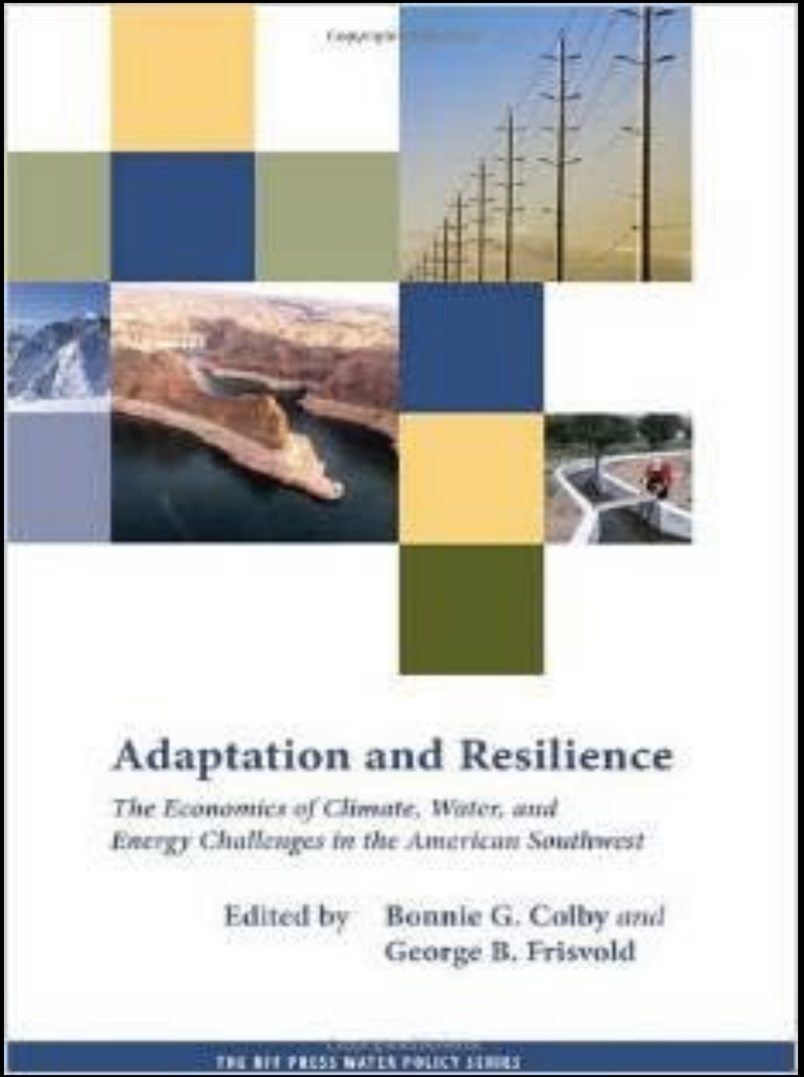
Adaptation and Resilience: The Economics of Climate, Water, and Energy Challenges in the American Southwest

"Regional response to climate variability and change can be usefully viewed from a resilience framework (Nelson et al. 2007)."

Colby and Frisvold 2011: 253

"To summarize, the chapters in this book suggest that the Southwest as a whole is relatively resilient to climate change…"

Colby and Frisvold 2011: 259



Colby & Frisvold (2011)

Arizona's "Adaptive Capacity"

~ Will we have enough water to supply the Sun Corridor? ~

- Increase supply
  - Desalination
  - Reuse
  - Interstate water trade
  - Import from rural areas
- Reduce demand
  - M&I conservation
  - Agricultural Conservation
  - Efficiencies (energy development, etc)
- Modify operations
  - Water transfers
  - Operational efficiencies
- Government program incentives
- Conservation
  - Water banking

The Goal:

Ensure the supply for the increasing demand

Arizona's Water Future:

Sustainable, Resilient, or Maladaptive?

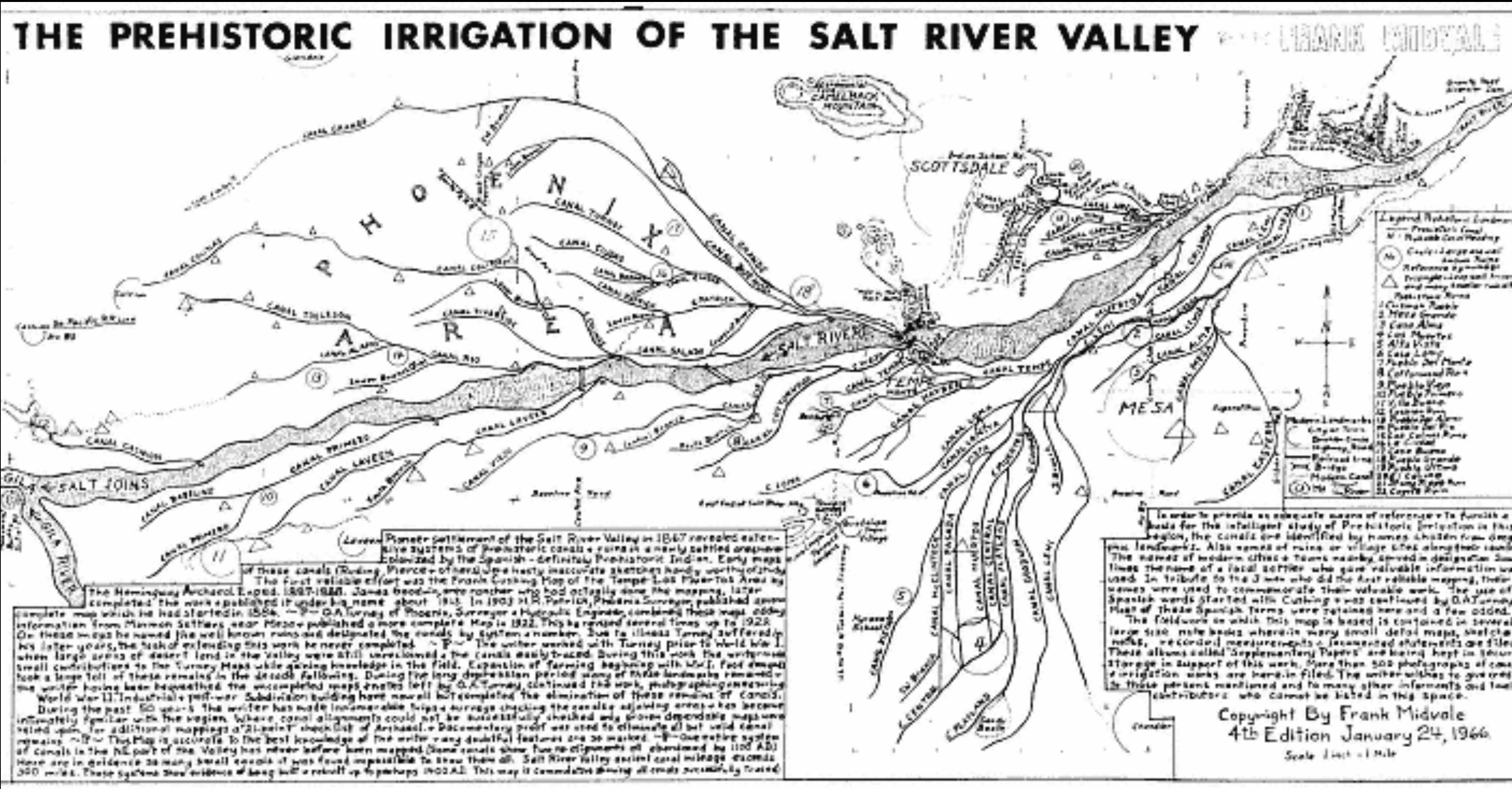
We can know that a system is sustainable only *after the fact*…

"What usually passes as a definition of sustainability are usually predictions of the set of conditions that will lead to a sustainable system… [but] we know if a system actually is sustainable only after we have had enough time to observe whether the prediction holds."

Robert Costanza (1996)

Designing Sustainable Ecological Economic Systems

in Engineering within Ecological Constraints



"When we talk about sustainability, we are talking about decision-making. Nothing just happens… What could be learned from the Hohokam was that the future of Phoenix would not be strictly determined by its limited resources but rather by whether its residents could cooperate and wisely interact with each other in order to stave off the most dire outcomes."

~Andrew Ross (2011)

Conceptual Model of Arizona's Sustainability Problem:

In Arizona, there are two conversations occurring simultaneously about sustainability… but they're occurring separately. Southern Arizona is concerned about meeting the water and energy needs of the future *Sun Corridor*, and northern Arizona is concerned about the development of its water and energy resources that supply the South's demand.

Underlying these concerns, however, is both regions' desire for robust economic growth: civic leaders envision doubling the population of the metropolitan South, while civic leaders in the North continue to believe that supplying the South's demands will provide their pathway to development.

Solutions to the South's urban planning problem and the North's resource development problem are assumed to be achievable through continued enhancements of the technological and economic configurations that structure and order the state. There is, however, no substantive discussion about departing from the *oasis culture* that underlies the Phoenix growth machine: Arizona asks only if it will be able to meet the demands of the *Sun Corridor* and it seeks only to increase the number "innovative" interventions that it will take to get there. It is from this perspective, by possessing a broad array of techno-economic mechanisms with which to manipulate and control Arizona's water and energy systems (i.e., social-ecological systems), that civic leaders, politicians, and resource managers have deemed Arizona's water-energy future as *Resilient* and *Sustainable*.

Bringing all of this together…

- The "Valley of the Sun": artificially cheap prices for water & energy
  - over-estimated & over-allocated water supply
  - law/policy promoting maximum use & preventing conservation
- The "Sun Corridor": Increasing demand during decreasing supply

We are already in the recursive loop of endless problem solving: *responding to unexpected changes caused by our efforts to stabilize the natural variability of water in the Southwest…*

✓ Future controls will also generate unexpected change

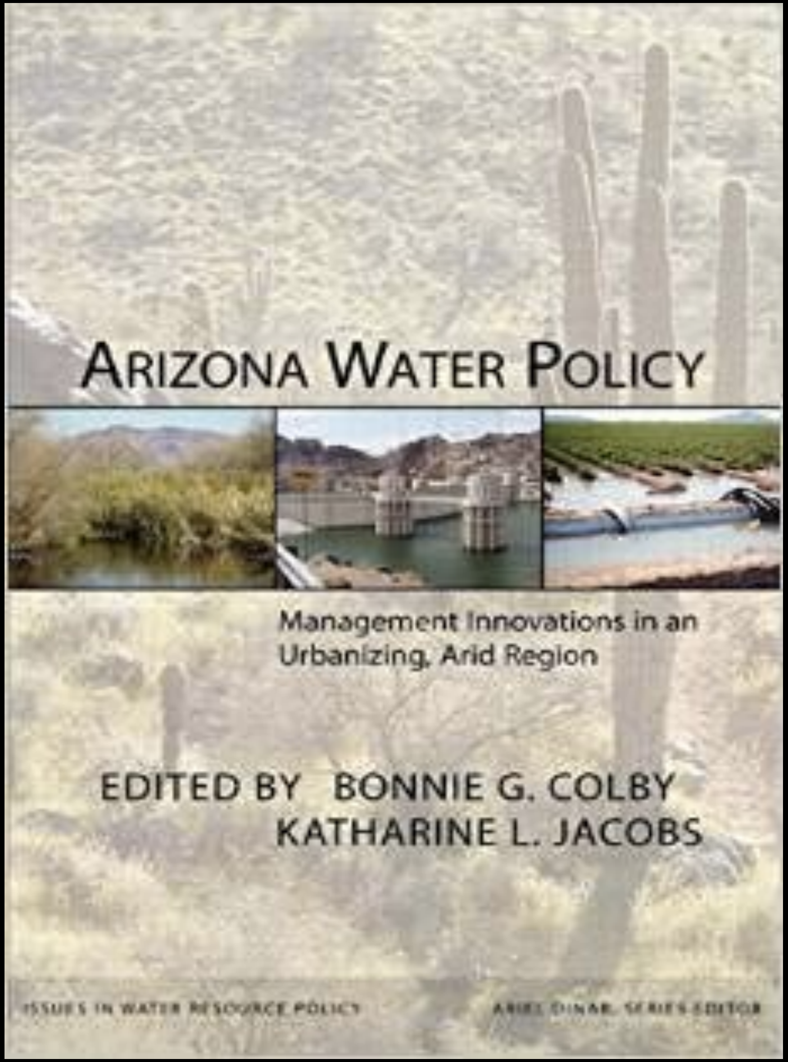
✓ Tightening the ratchet effect on already scarce resources

✓ Increasing vulnerability to disturbance, diminishing resilience

✓ This is the definition of *Maladaptive Resilience*

"For at least the past century, water has provided Arizona's clearest consensus: we need more, we will use all we can get, we will stretch it as far as we can, and we will fight anyone who tries to take it away."

August & Gammage (2007)
in Colby & Jacobs (2007)



Colby & Jacobs (2007)