Colorado River Board of California

August 25, 2015

NOTICE OF REGULAR MEETING OF THE COLORADO RIVER BOARD

NOTICE IS HEREBY GIVEN pursuant to the call of the Chairperson, Dana B. Fisher, Jr., by the undersigned Executive Director of the Colorado River Board of California that a regular meeting of the Board Members is to be held as follows:

Date: Wednesday, September 9, 2015
Time: 10:00am
Place: Vineyard Room
Holiday Inn Ontario Airport
2155 Convention Center Way
Ontario, CA 91764
Tel: (909) 212-8000

The Colorado River Board of California welcomes any comments from members of the public pertaining to items included on this agenda and related topics. Oral comments can be provided at the beginning of each Board meeting; while written comments may be sent to Mr. Dana B. Fisher, Jr., Chairperson, Colorado River Board of California, 770 Fairmont Avenue, Suite 100, Glendale, California, 91203-1068.

An Executive Session may be held in accordance with provisions of Article 9 (commencing with Section 11120) of Chapter 1 of Part 1 of Division 3 of Title 2 of the Government Code and in accordance with Sections 12516 and 12519 of the Water Code to discuss matters concerning interstate claims to the use of Colorado River System waters in judicial proceedings, administrative proceedings, and/or negotiations with representatives from other states or the federal government.

Requests for additional information may be directed to: Ms. Tanya M. Trujillo, Executive Director, Colorado River Board of California, 770 Fairmont Avenue, Suite 100, Glendale, CA 91203-1068, or 818-500-1625. A copy of this Notice and Agenda may be found on the Colorado River Board's web page at www.crb.ca.gov.

A copy of the meeting agenda, showing the matters to be considered and transacted, is attached.

Tanya M. Trujillo
Executive Director

attachment: Agenda

Regular Meeting
COLORADO RIVER BOARD OF CALIFORNIA
Wednesday, September 9, 2015
10:00 a.m.

Vineyard Room
Holiday Inn Ontario Airport
2155 Convention Center Way
Ontario, CA 91764

At the discretion of the Board, all items appearing on this agenda, whether or not expressly listed for action, may be deliberated upon and may be subject to action by the Board. Items may not necessarily be taken up in the order shown.

1. Call to order

2. Opportunity for the Public to Address the Board as required by Government Code, Section 54954.3(a) (limited to 5 minutes)

3. Administration
   a. Consideration and Approval of the Minutes of the Meeting held August 12, 2015 **(Action)**

4. Colorado River Basin Water Reports
   a. Reports on current reservoir storage, reservoir releases, projected water use, and forecasted river flows
   b. State and Local Water Reports

5. Update regarding the California Drought

6. Staff Reports regarding the Colorado River Basin Programs
   a. Review status of the Basin States Drought Contingency Programs
   b. Review status of the Colorado River Basin Water Supply and Demand Study
   c. Review status of the implementation of Minute 319
   d. Review status of the Salinity Control Forum, Workgroup, and Advisory Council
   e. Review status of the Glen Canyon Dam Adaptive Management Work Group and Long-Term Experimental and Management Plan EIS
   f. Review Status of the Lower Colorado River Multi-Species Conservation Program

7. Announcements/Notices

8. Executive Session
   An Executive Session may be held by the Board pursuant to provisions of Article 9 (commencing with Section 11120) of Chapter 1 of Part 1 of Division 3 of Title 2 of the Government Code and Sections 12516 and 12519 of the Water Code to discuss matters concerning interstate claims to the use of Colorado River system waters in judicial proceedings, administrative proceedings, and/or negotiations with representatives from other states or the federal government.

9. Other Business

a. Next Board Meeting: Regular Meeting
October 14, 2015
10:00 a.m.
Vineyard Room
Holiday Inn Ontario Airport
2155 East Convention Center Way
Ontario, CA 91764-4452
Tel: (909) 212-8000, Fax: (909) 418-6703

Aug 31, 2015

LOWER COLORADO WATER SUPPLY REPORT

River Operations

Bureau of Reclamation

Questions: BCOOWaterops@usbr.gov

(702)293-8373

http://www.usbr.gov/lc/region/g4000/weekly.pdf

CURRENT STORAGE	PERCENT FULL	Content 1000 ac-ft (kaf)	Elev. (Feet above mean sea level)	7-Day Release (CFS)
LAKE POWELL	52%	12,646	3609.16	13,000
* LAKE MEAD	38%	9,866	1078.24	12,100
LAKE MOHAVE	93%	1,681	642.35	12,700
LAKE HAVASU	95%	587	448.36	8,800
TOTAL SYSTEM CONTENTS **	52%	30,879		
As of 08/30/2015				
SYSTEM CONTENT LAST YEAR	51%	30,226		

* Percent based on capacity of 26,120 kaf or elevation 1219.6 feet.

** TOTAL SYSTEM CONTENTS includes Upper & Lower Colorado River Reservoirs, less Lake Mead exclusive flood control space.

Salt/Verde System	50%	1,155		
Painted Rock Dam	0%	0	535.14	0
Alamo Dam	6%	55	1,089.37	25

Forecasted Water Use for Calendar Year 2015 (as of 08/31/2015) (values in kaf)

NEVADA	237	
SOUTHERN NEVADA WATER SYSTEM		208
OTHERS		29
CALIFORNIA	4,283	
METROPOLITAN WATER DISTRICT OF CALIFORNIA		905
IRRIGATION DISTRICTS		3,239
OTHERS		138
ARIZONA	2,583	
CENTRAL ARIZONA PROJECT		1,480
OTHERS		1,103
TOTAL LOWER BASIN USE		7,103
DELIVERY TO MEXICO - 2015 (Mexico Scheduled Delivery + Preliminary Yearly Excess[1])		1,523

OTHER SIGNIFICANT INFORMATION

UNREGULATED INFLOW INTO LAKE POWELL - AUGUST MID MONTH FORECAST DATED 08/18/2015

	MILLION ACRE-FEET	% of Normal
FORECASTED WATER YEAR 2015	10.335	95%
PRELIMINARY OBSERVED APRIL-JULY 2015	6.713	94%
JULY OBSERVED INFLOW	1.072	98%
AUGUST INFLOW FORECAST	0.400	80%

	Upper Colorado Basin	Salt/Verde Basin
WATER YEAR 2015 PRECIP TO DATE	92% (26.7")	91% (24.1")
CURRENT BASIN SNOWPACK[2]	NA% (NA)	NA% (NA)

[1] Delivery to Mexico forecasted yearly excess calculated using year-to-date observed and projected excess.

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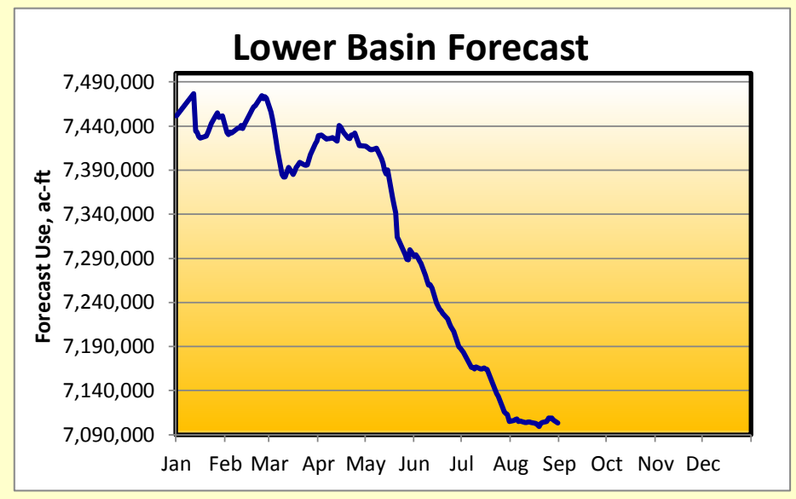
LOWER COLORADO REGION
CY 2015

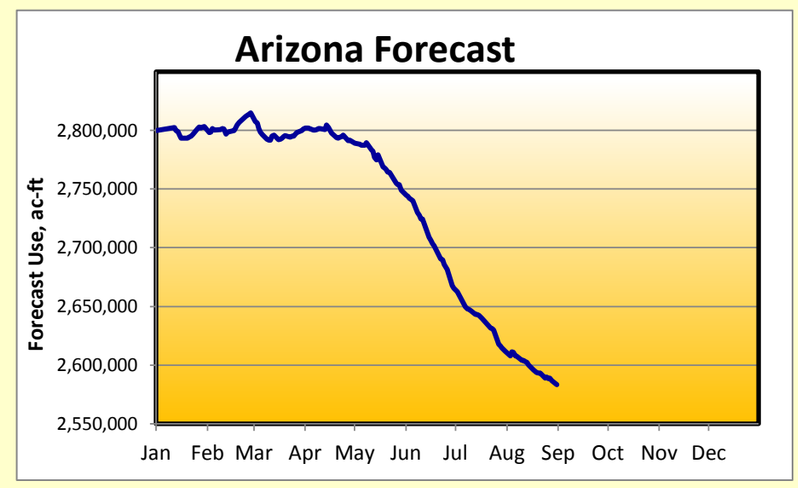
ARIZONA, CALIFORNIA, NEVADA, MEXICO
FORECAST OF END OF YEAR CONSUMPTIVE USE
FORECAST BASED ON USE TO DATE AND APPROVED ANNUAL WATER ORDERS [1]
(ACRE-FEET)

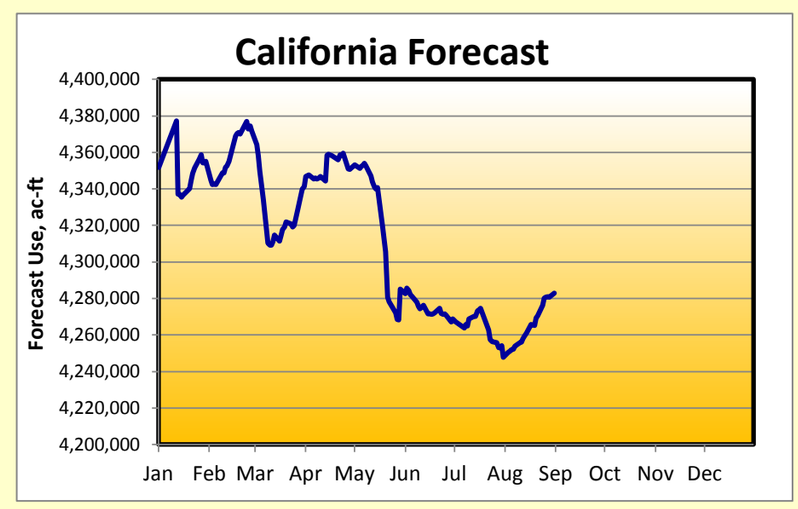
WATER USE SUMMARY	Use To Date CY2015	Forecast Use CY2015	Approved Use [2] CY2015	Excess to Approval CY2015
ARIZONA	1,789,684	2,583,392	2,792,835	-209,443
CALIFORNIA	3,194,061	4,282,788	4,351,727	-68,939
NEVADA	156,123	236,871	300,000	-63,129
STATES TOTAL [3]	5,139,868	7,103,051	7,444,562	-341,511
MEXICO IN SATISFACTION OF TREATY (Including downward delivery)	1,165,126	1,522,692	1,500,000	**22,692**
TO MEXICO AS SCHEDULED	1,152,515	1,500,000		
MEXICO IN EXCESS OF TREATY	12,611	22,692		
BYPASS PURSUANT TO MINUTE 242	95,423	145,462		
TOTAL LOWER BASIN & MEXICO	6,400,417	8,771,205		

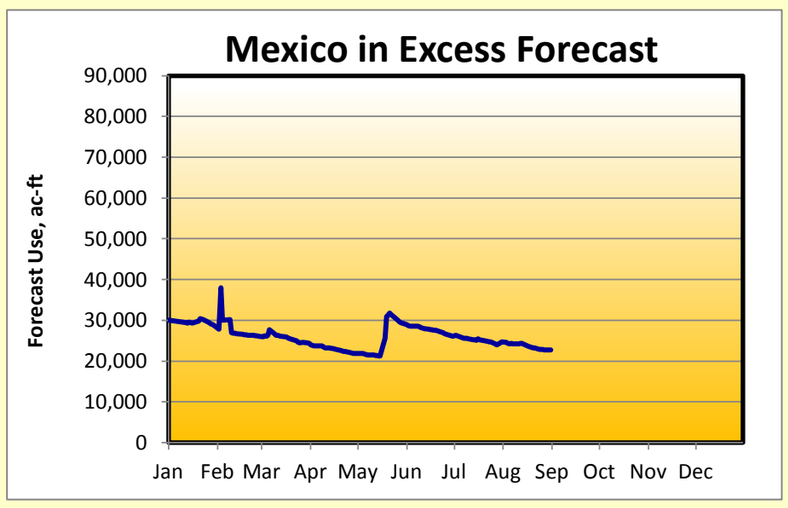
1/ Incorporates Jan-Jul USGS monthly data and 80 daily reporting stations which may be revised after provisional data reports are distributed by the USGS. Use to date estimated for users reporting monthly and annually.
2/ These values reflect adjusted apportionments. See Adjusted Apportionment calculation on each state page.
3/ Includes unmeasured returns based on estimated consumptive use/diversion ratios by user from studies provided by Arizona Department of Water Resources, Colorado River Board of California, and Reclamation.

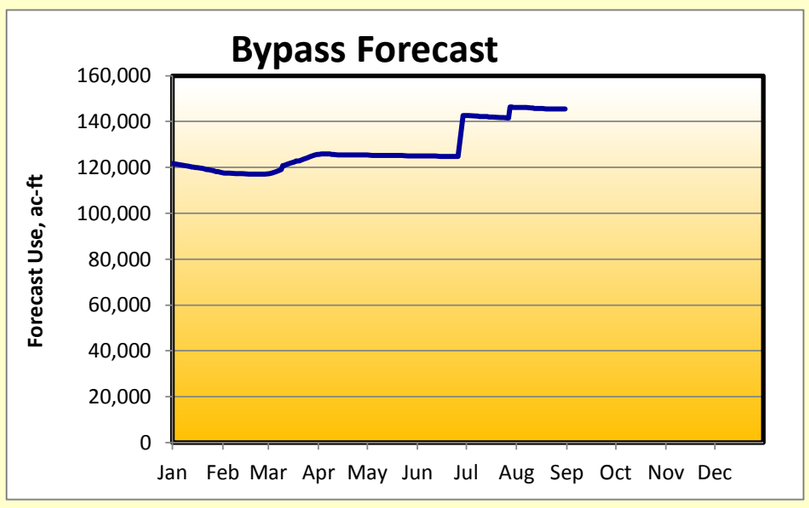
NOTE: Use to date values have been updated with July USGS Provisional data as well as monthly reported data. [8-31-2015]

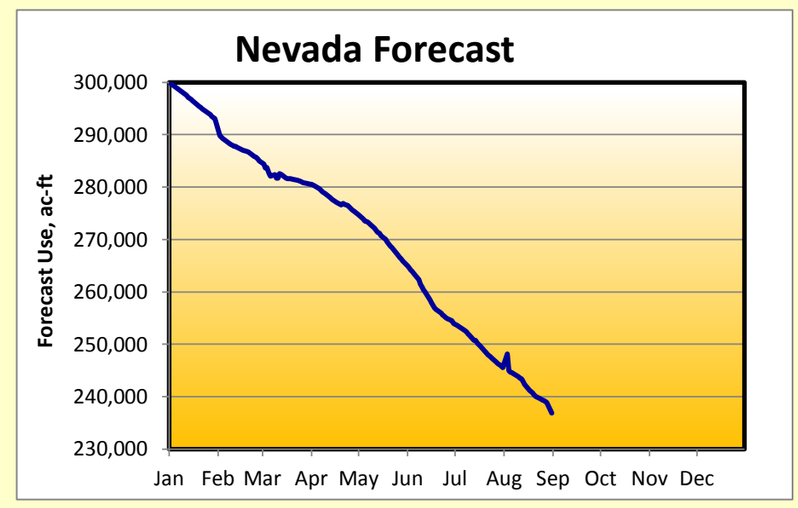


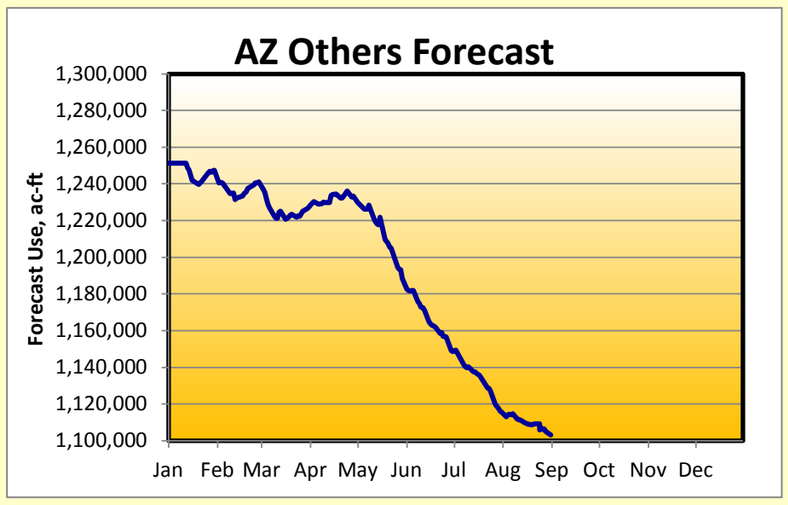


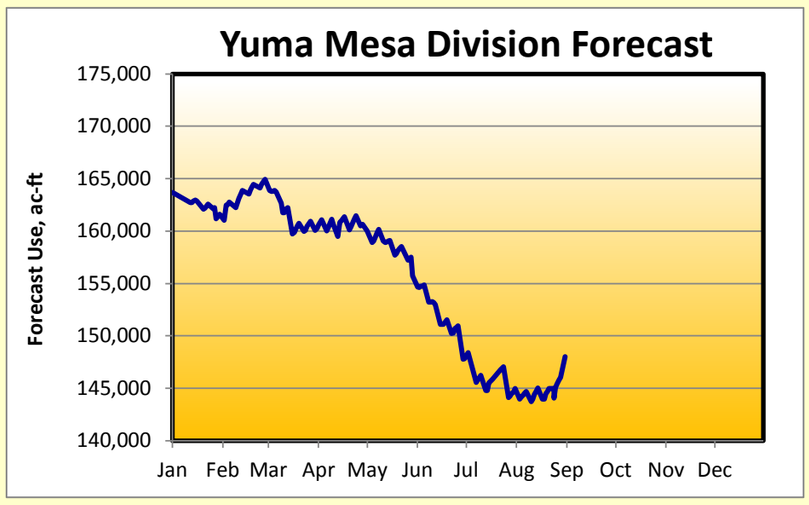


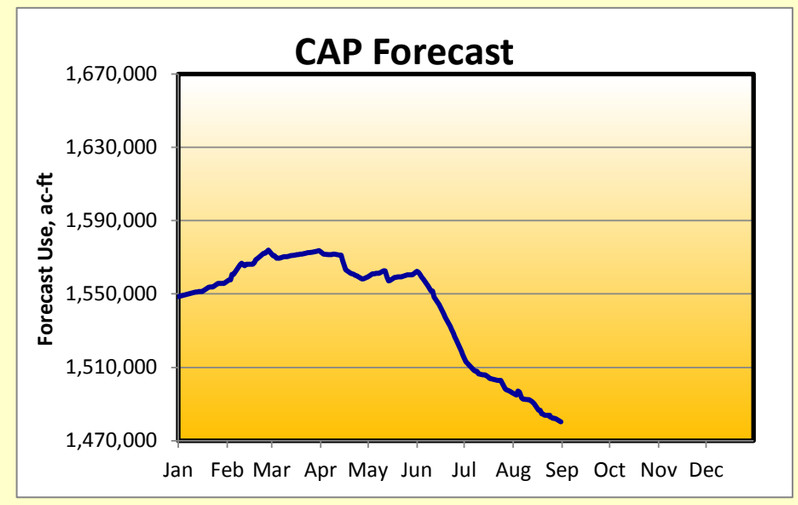


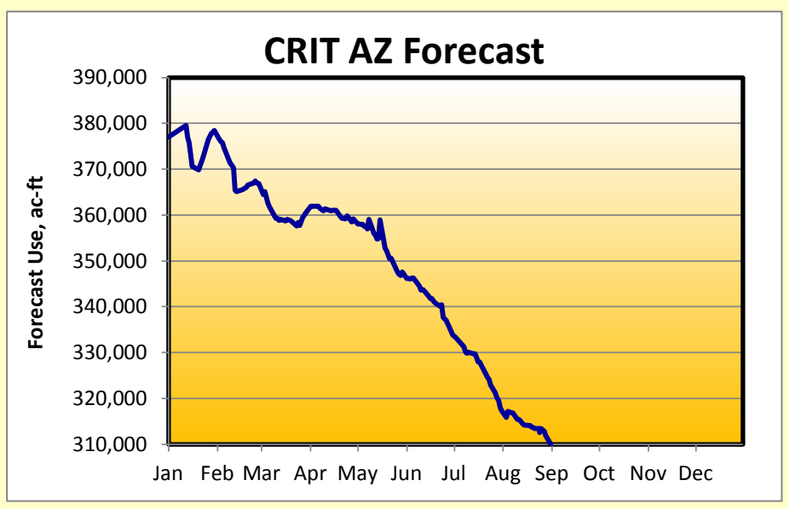


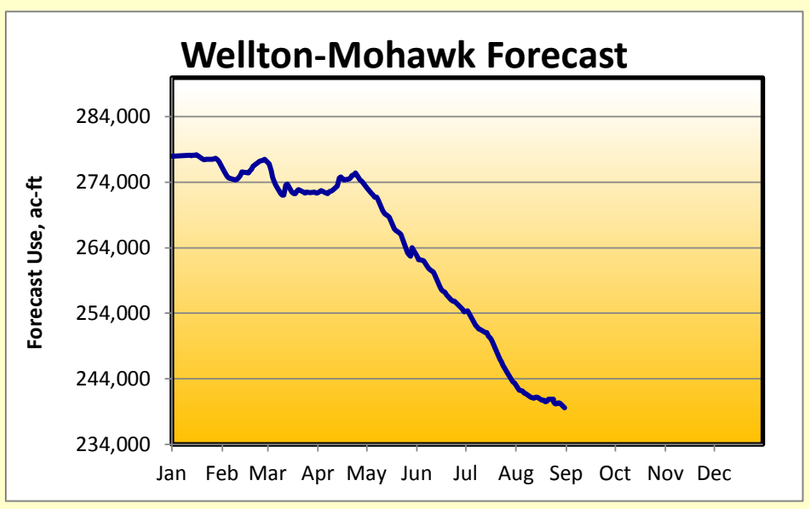


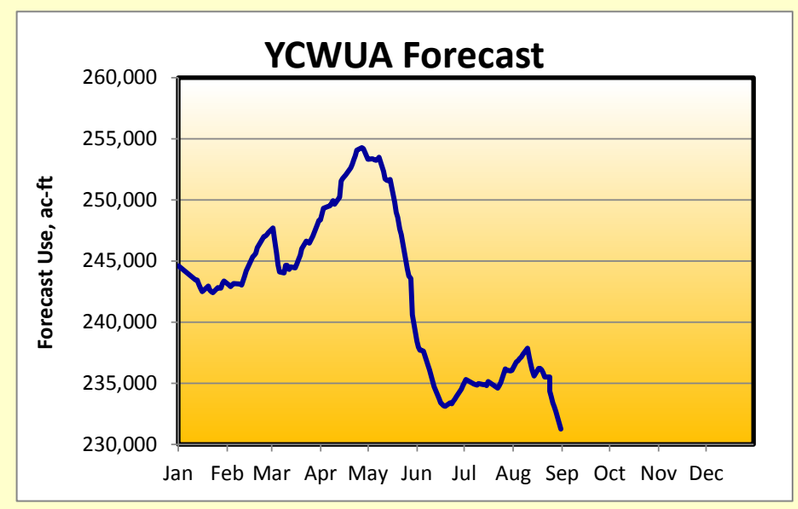












Graph notes: Jan 1 forecast use is scheduled use in accordance with the Annual Operating Plan's state entitlements, available unused entitlements, and over-run paybacks. A downward sloping line indicates use at a lower rate than scheduled, upward sloping is above schedule, and a flat line indicates a use rate equal to schedule. Lower priority users such as CAP, MWD, and Robt.B.Griffith may adjust use rates to meet state entitlements as higher priority use deviates from schedule. Abrupt changes in the forecast use line may be due to a diversion schedule change or monthly updating of provisional realtime diversions.

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LOWER COLORADO REGION
CY 2015

NOTE:
● Diversions and uses that are pending approval are noted in *red italics*.
● Water users with a consumptive use entitlement - **Excess to Estimated Use** column indicates overrun/underrun of entitlement. Dash in this column indicates water user has a diversion entitlement.
● Water user with a diversion entitlement - **Excess to Approved Diversion** column indicates overrun/underrun of entitlement. Dash in this column indicates water user has a consumptive use entitlement.

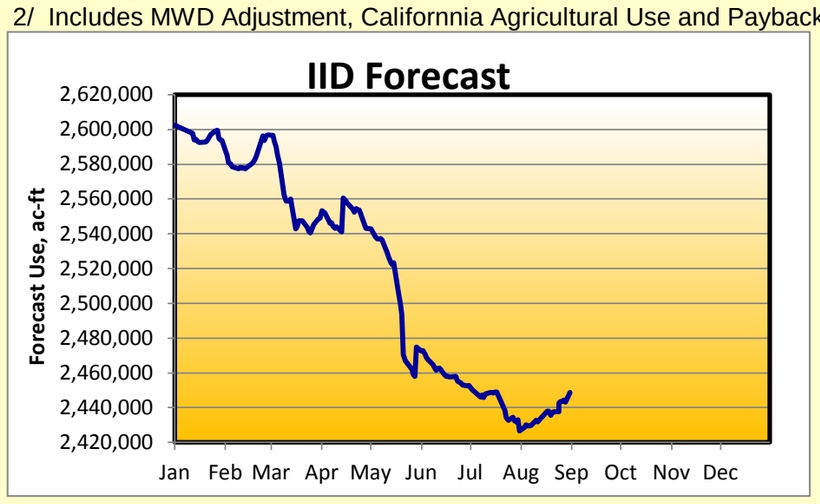
CALIFORNIA WATER USERS
FORECAST OF END OF YEAR CONSUMPTIVE USE
FORECAST BASED ON USE TO DATE AND APPROVED ANNUAL WATER ORDERS
California Schedules and Approvals
Historic Use Records (Water Accounting Reports)

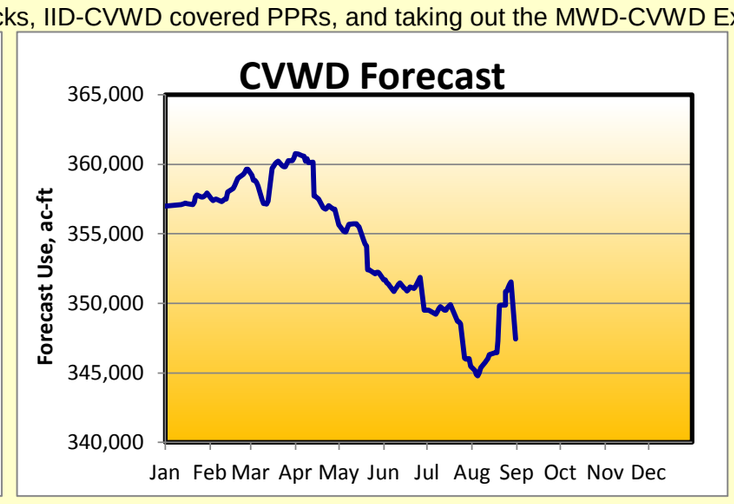
WATER USER	Use To Date CY2015	Forecast Use CY2015	Estimated Use CY2015	Excess to Estimated Use CY2015	Diversion To Date CY2015	Forecast Diversion CY2015	Approved Diversion CY2015	Excess to Approved Diversion CY2015
CALIFORNIA PUMPERS	1,256	1,680	1,680	---	2,278	3,047	3,047	0
FORT MOJAVE INDIAN RESERVATION, CA	6,361	8,004	8,996	---	11,825	14,877	16,720	-1,843
CITY OF NEEDLES (includes LCWSP use)	1,444	1,931	1,931	0	2,034	2,720	2,720	0
METROPOLITAN WATER DISTRICT	772,278	905,371	768,208	---	774,133	908,269	771,299	---
COLORADO RIVER INDIAN RESERVATION, CA	2,427	3,246	3,246	---	4,021	5,378	5,378	0
PALO VERDE IRRIGATION DISTRICT	314,592	392,487	431,782	---	628,518	869,034	946,750	-77,716
YUMA PROJECT RESERVATION DIVISION	34,244	46,160	48,586	---	65,618	96,102	104,200	-8,098
YUMA PROJECT RESERVATION DIVISION - INDIAN UNIT	---	---	---	---	31,945	46,487	50,200	-3,713
YUMA PROJECT RESERVATION DIVISION - BARD UNIT	---	---	---	---	33,673	49,615	54,000	-4,385
YUMA ISLAND PUMPERS	3,488	4,665	4,665	---	6,319	8,452	8,452	0
FORT YUMA INDIAN RESERVATION - RANCH 5	505	675	675	---	913	1,221	1,221	0
IMPERIAL IRRIGATION DISTRICT	1,761,136	2,448,652	2,602,481	-153,829	1,735,414	2,457,346	2,706,070	---
SALTON SEA SALINITY MANAGEMENT	60,422	121,636	121,636	0	62,946	126,826	126,826	---
COACHELLA VALLEY WATER DISTRICT	235,279	347,440	357,000	-9,560	244,297	362,094	371,671	---
OTHER LCWSP CONTRACTORS	502	671	671	---	797	1,066	1,066	0
CITY OF WINTERHAVEN	51	68	68	---	77	103	103	0
CHEMEHUEVI INDIAN RESERVATION	76	102	102	---	8,478	11,340	11,340	0
TOTAL CALIFORNIA	3,194,061	4,282,788			3,547,668	4,867,875	5,076,863	

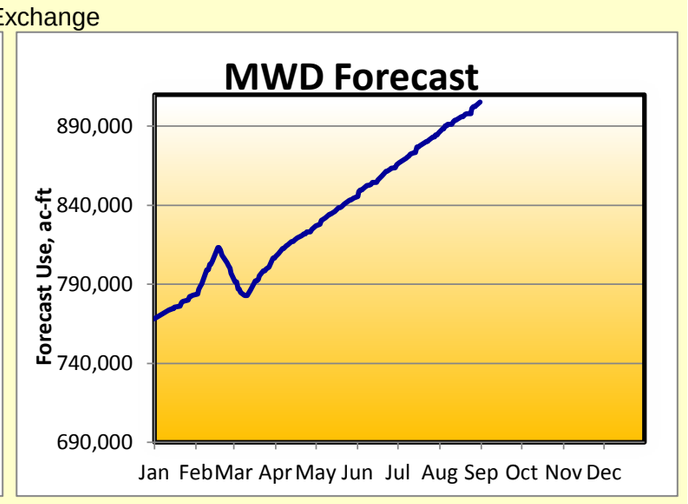
CALIFORNIA ADJUSTED APPORTIONMENT CALCULATION	
California Basic Apportionment	4,400,000
Conservation for Salton Sea Restoration - 2010 [1]	-23,273
Creation of Extraordinary Conservation ICS (IID)	-25,000
Creation of Extraordinary Conservation ICS (MWD)	
Total State Adjusted Apportionment	4,351,727
Excess to Total State Adjusted Apportionment	-68,939

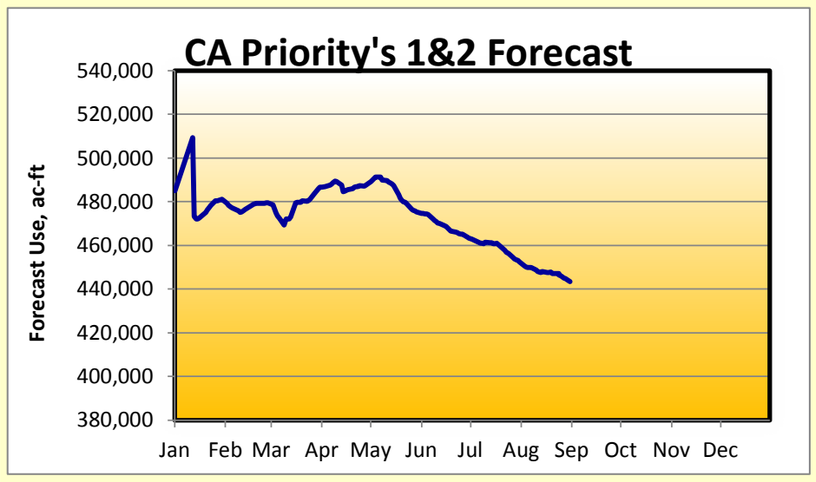
ISG ANNUAL TARGET COMPARISON CALCULATION	
Priorities 1, 2, 3b Use (PVID+YPRD+Island+PVID Mesa)	443,312
MWD Adjustment	-23,312
Total California Agricultural Use (PVID+YPRD+Island+IID+CVWD)	3,239,404
California Agricultural Paybacks	23,273
Misc. PPRs Covered by IID and CVWD	14,500
California ICS Creation (IID ICS)	25,000
Total Use for Target Comparison [2]	3,278,865
ISG Annual Target (Exhibit B)	3,448,000
Amount over/(under) ISG Annual Target	-169,135

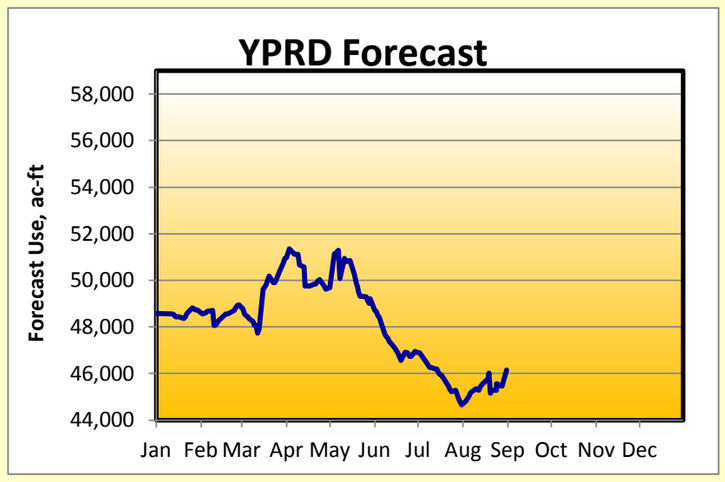
NOTES: Click on California Schedules and Approvals above for incoming diversion schedules and approvals.
1/ Pending approval by Imperial Irrigation District's Board of Directors.
2/ Includes MWD Adjustment, Californnia Agricultural Use and Paybacks, IID-CVWD covered PPRs, and taking out the MWD-CVWD Exchange

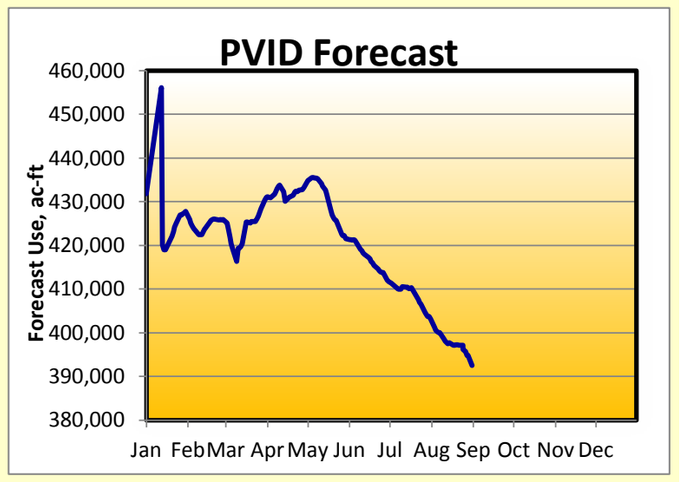












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LOWER COLORADO REGION
CY 2015

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ARIZONA WATER USERS
FORECAST OF END OF YEAR CONSUMPTIVE USE
FORECAST BASED ON USE TO DATE AND APPROVED ANNUAL WATER ORDERS
Arizona Schedules and Approvals
Historic Use Records (Water Accounting Reports)

WATER USER	Use To Date CY2015	Forecast Use CY2015	Estimated Use CY2015	Excess to Estimated Use CY2015	Diversion To Date CY2015	Forecast Diversion CY2015	Approved Diversion CY2015	Excess to Approved Diversion CY2015
ARIZONA PUMPERS	13,095	17,515	17,515	---	20,272	27,115	27,115	0
LAKE MEAD NRA, AZ - Diversions from Lake Mead	104	155	155	---	104	155	155	0
LAKE MEAD NRA, AZ - Diversions from Lake Mohave	130	189	189	---	130	189	189	0
DAVIS DAM PROJECT	1	2	2	---	56	75	75	0
BULLHEAD CITY	4,506	7,375	8,523	---	6,726	11,006	12,720	-1,714
MOHAVE WATER CONSERVATION	416	556	556	---	621	831	831	0
BROOKE WATER LLC	155	207	207	---	233	311	311	0
MOHAVE VALLEY IDD	12,181	19,179	22,260	---	22,556	35,515	41,220	-5,705
FORT MOJAVE INDIAN RESERVATION, AZ	30,439	38,713	42,390	---	56,369	71,691	78,500	-6,809
GOLDEN SHORES WATER CONSERVATION DISTRICT	236	316	316	---	354	473	473	0
HAVASU NATIONAL WILDLIFE REFUGE	3,747	4,420	3,563	---	26,660	34,550	41,820	-7,270
LAKE HAVASU CITY	4,968	7,850	8,928	---	8,016	12,664	14,400	-1,736
CENTRAL ARIZONA PROJECT	982,603	1,480,307		---	982,603	1,480,307		
TOWN OF PARKER	259	353	352	---	573	862	920	-58
COLORADO RIVER INDIAN RESERVATION, AZ	236,435	310,079	376,964	---	444,659	609,952	662,402	-52,450
EHRENBURG IMPROVEMENT ASSOCIATION	191	256	256	---	270	361	361	0
CIBOLA VALLEY IRRIGATION DISTRICT	12,673	16,951	16,951	---	17,724	23,707	23,707	0
CIBOLA NATIONAL WILDLIFE REFUGE	9,526	12,741	12,741	0	15,364	20,550	20,550	0
IMPERIAL NATIONAL WILDLIFE REFUGE	1,956	2,616	2,616	0	3,158	4,224	4,224	0
YUMA PROVING GROUND	369	518	550	---	369	518	550	-32
GILA MONSTER FARMS	2,509	3,569	5,244	---	4,399	6,432	9,156	-2,724
WELLTON-MOHAWK IDD	171,121	239,573	278,000	-38,427	256,851	375,175	424,350	
CITY OF YUMA	9,551	15,035	17,051	-2,016	16,226	25,354	27,318	-1,964
MARINE CORPS AIR STATION YUMA	966	1,450	1,500	---	966	1,450	1,500	-50
UNION PACIFIC RAILROAD	16	24	24	---	32	48	48	0
UNIVERSITY OF ARIZONA	449	680	764	---	449	680	764	-84
YUMA UNION HIGH SCHOOL DISTRICT	90	145	193	---	121	192	253	-61
DESERT LAWN MEMORIAL	68	91	91	---	96	129	129	0
NORTH GILA VALLEY IDD	9,081	11,082	10,099	---	30,710	42,984	41,000	**1,984**
YUMA IRRIGATION DISTRICT	28,002	39,053	42,581	---	49,877	71,077	75,900	-4,823
YUMA MESA IDD	73,036	97,872	111,022	---	129,090	182,017	204,904	-22,887
UNIT "B" IRRIGATION DISTRICT	14,383	18,662	17,330	---	20,466	28,063	28,050	**13**
FORT YUMA INDIAN RESERVATION	1,044	1,396	1,396	---	1,607	2,149	2,149	0
YUMA COUNTY WATER USERS' ASSOCIATION	164,228	231,236	244,599	---	246,370	365,144	388,000	-22,856
COCOPAH INDIAN RESERVATION	1,063	3,110	6,457	---	1,138	4,275	9,840	-5,565
RECLAMATION-YUMA AREA OFFICE	87	116	116	---	87	116	116	0
RETURN FROM SOUTH GILA WELLS								
TOTAL ARIZONA	1,789,684	2,583,392	2,792,855		2,365,302	3,440,341	3,685,354	
CAP	982,603	1,480,307				1,480,307		
ALL OTHERS	807,081	1,103,085	1,251,501			1,960,034	2,144,000	
YUMA MESA DIVISION, GILA PROJECT	110,119	148,007	350,000	-201,993		296,078		

ARIZONA ADJUSTED APPORTIONMENT CALCULATION	
Arizona Basic Apportionment	2,800,000
Payback of IOPP overruns - (Cocopah and Beattie)	-165
CAWCD/YMIDD Pilot Conservation Program [1]	-7000
Total State Adjusted Apportionment	2,792,835
Excess to Total State Adjusted Apportionment	-209,443
Estimated Allowable Use for CAP	1,692,923

1/ in 2013 CAWCD and YMIDD entered into a Pilot Fallowing Agreement. In 2015, it is estimated that 7,000 AF of water will be conserved by the program and that volume of water will remain in Lake Mead to benefit system storage.
NOTES: Click on Arizona Schedules and Approvals above for incoming diversion schedules and approvals.

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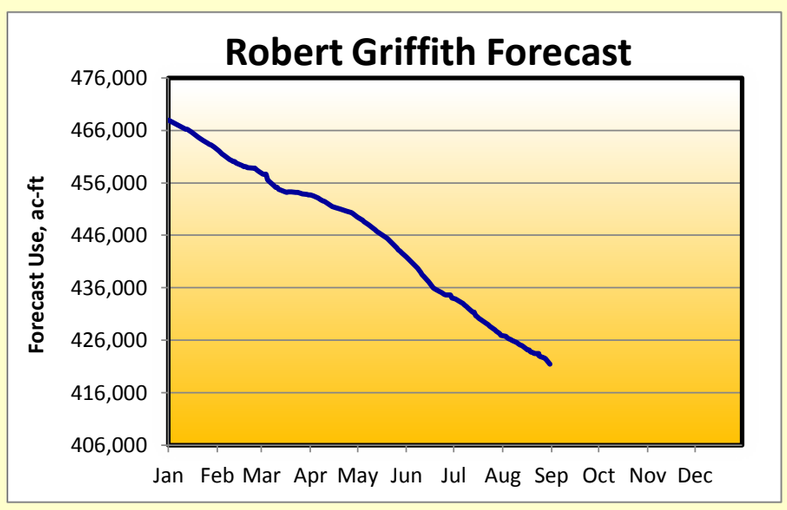
LOWER COLORADO REGION
CY 2015

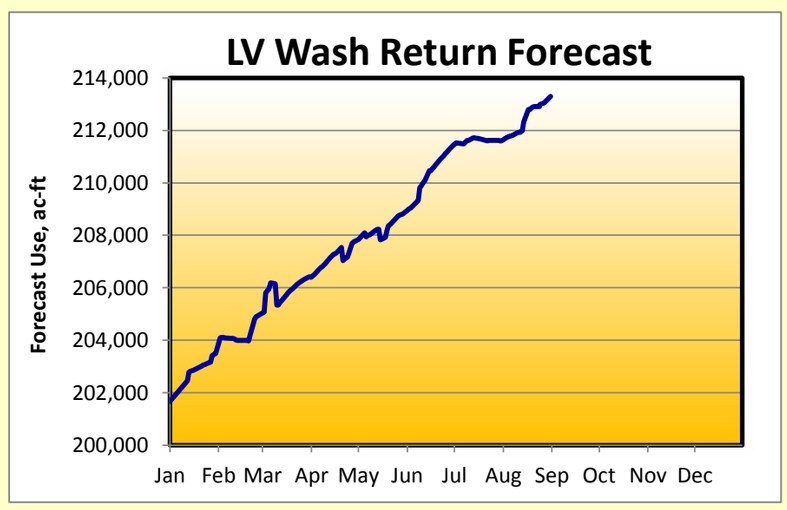
NOTE:
● Diversions and uses that are pending approval are noted in *red italics*.
● Water users with a consumptive use entitlement - **Excess to Estimated Use** column indicates overrun/underrun of entitlement. Dash in this column indicates water user has a diversion entitlement.
● Water user with a diversion entitlement - **Excess to Approved Diversion** column indicates overrun/underrun of entitlement. Dash in this column indicates water user has a consumptive use entitlement.

NEVADA WATER USERS
FORECAST OF END OF YEAR CONSUMPTIVE USE
FORECAST BASED ON USE TO DATE AND APPROVED ANNUAL WATER ORDERS
Nevada Schedules and Approvals
Historic Use Records (Water Accounting Reports)

WATER USER	Use To Date CY2015	Forecast Use CY2015	Estimated Use CY2015	Excess to Estimated Use CY2015	Diversion To Date CY2015	Forecast Diversion CY2015	Approved Diversion CY2015	Excess to Approved Diversion CY2015
ROBERT B. GRIFFITH WATER PROJECT (SNWS)	282,647	421,416	467,935	-46,519	282,651	421,420	467,935	-46,515
LAKE MEAD NRA, NV - Diversions from Lake Mead	277	406	422	---	277	406	422	-16
LAKE MEAD NRA, NV - Diversions from Lake Mohave	118	170	166	---	118	170	166	**4**
BASIC MANAGEMENT INC.	4,058	7,009	8,211	---	4,058	7,009	8,211	-1,202
CITY OF HENDERSON (BMI DELIVERY)	9,594	14,690	15,878	---	9,594	14,690	15,878	-1,188
NEVADA STATE DEPT. OF FISH & GAME	7	11	12	-1	333	457	363	---
PACIFIC COAST BUILDING PRODUCTS INC.	671	982	923	---	671	982	923	**59**
BOULDER CANYON PROJECT	130	174	174	---	226	302	302	0
BIG BEND WATER DISTRICT	1,268	2,799	4,061	---	3,217	6,294	10,000	-3,706
FORT MOJAVE INDIAN TRIBE	1,755	2,507	3,886	---	2,621	3,744	5,800	-2,056
LAS VEGAS WASH RETURN FLOWS	-144,402	-213,293	-201,668	---				
TOTAL NEVADA	156,123	236,871	300,000	-46,520	303,766	455,474	510,000	-54,620
SOUTHERN NEVADA WATER SYSTEM (SNWS)	138,245	208,123				421,420		
ALL OTHERS	17,878	28,748				34,054		
NEVADA USES ABOVE HOOVER	153,100	231,565				445,436		
NEVADA USES BELOW HOOVER	3,023	5,306				10,038		

Tributary Conservation & Imported Intentionally Created Surplus	
Total Requested Tributary Conservation Intentionally Created Surplus	29,500
Total Requested Imported Conservation Intentionally Created Surplus	9,000
5% System Cut for Creation of Intentionally Created Surplus	-1,925
Total Intentionally Created Surplus Left in Lake Mead	36,575
Pilot System Conservation Program	
Tributary Conservation - Left in Lake Mead [1]	7,500
NEVADA ADJUSTED APPORTIONMENT CALCULATION	
Nevada Basic Apportionment	300,000
Excess to Total State Adjusted Apportionment	-63,129



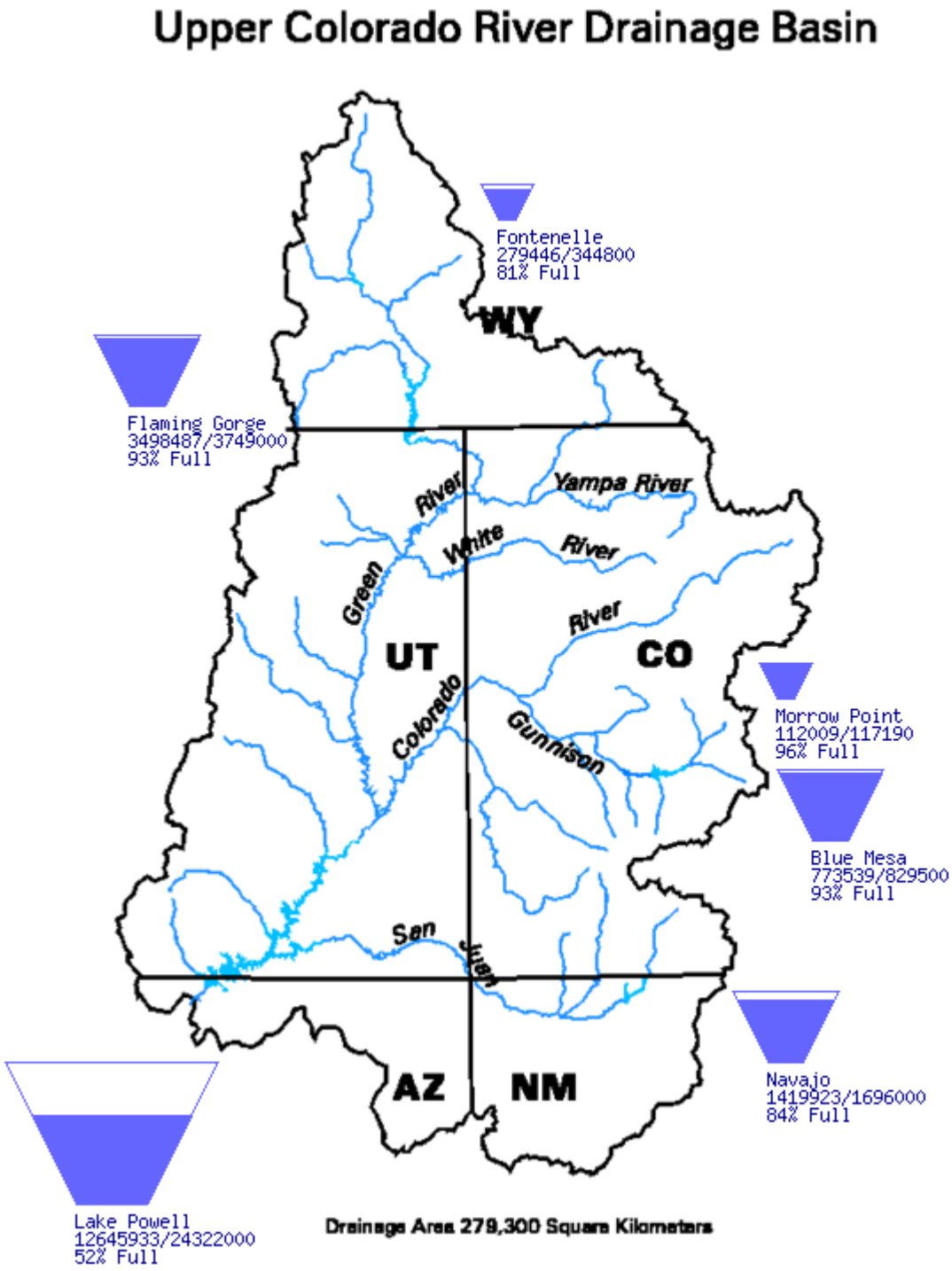


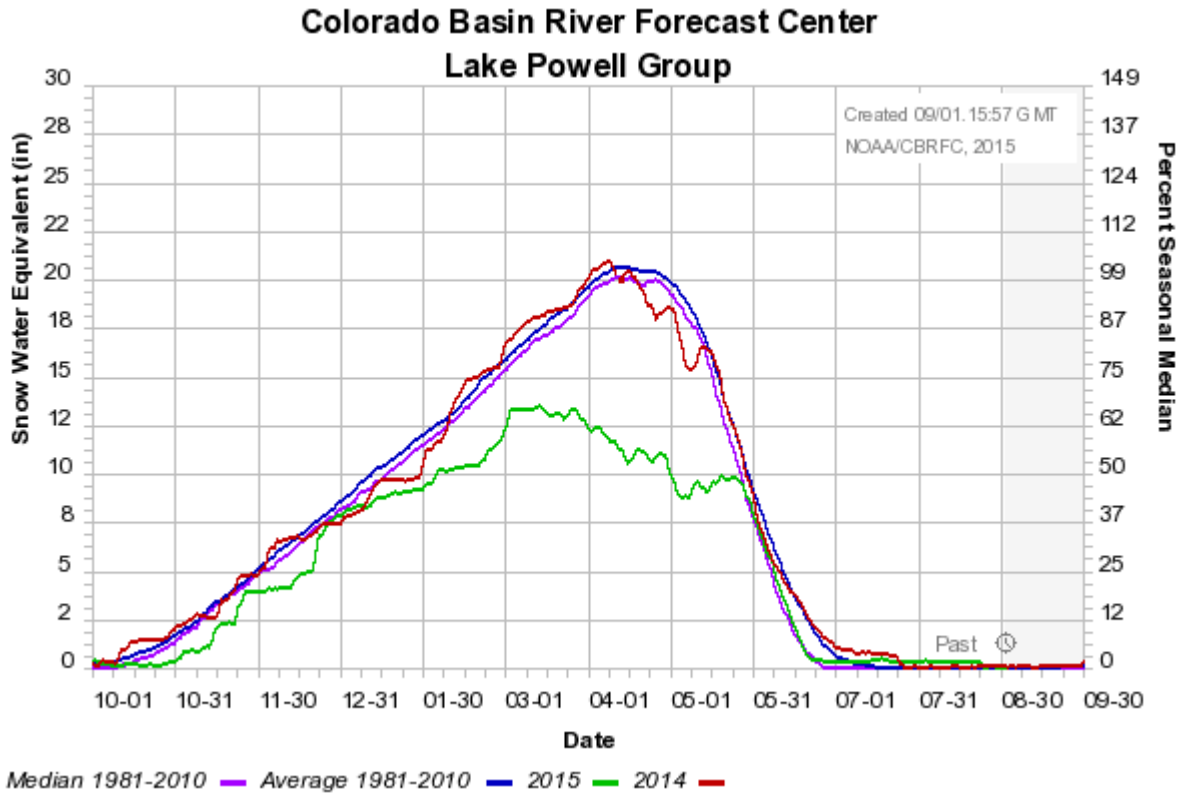
1/ On June 4, 2015, Reclamation and SNWA entered into a System Conservation Implementation Agreement in which SNWA agreed to conserve 7.500 AF of Colorado River water from its Tributary Conservation projects to create System Conservation Water.
NOTES: Click on Nevada Schedules and Approvals above for incoming diversion schedules and approvals.

Upper Colorado Region Water Resources Group

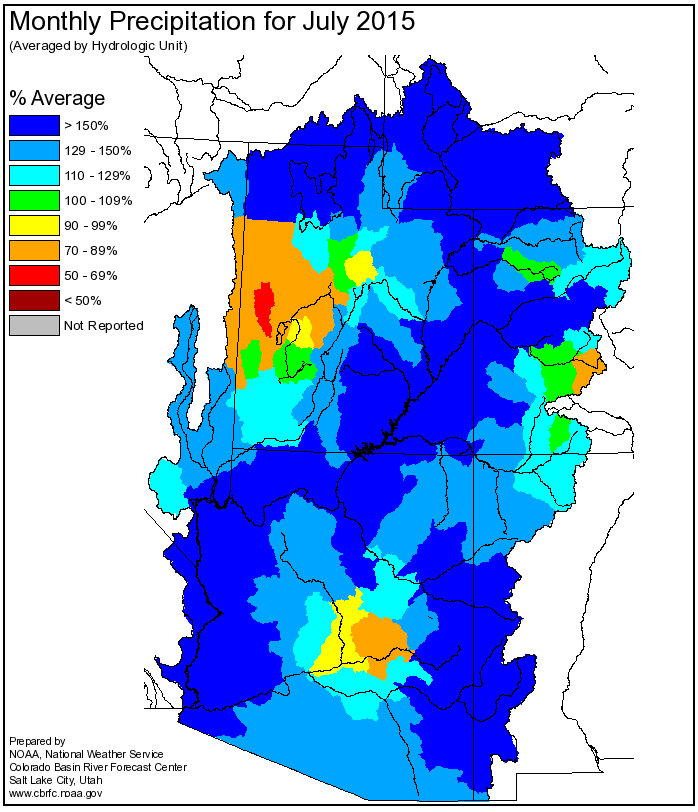
River Basin Tea-Cup Diagrams

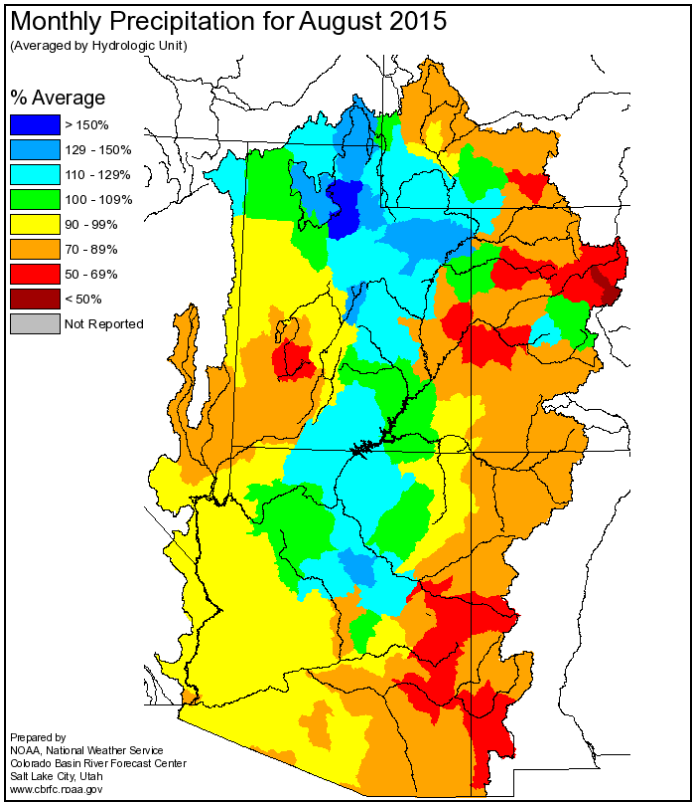
Data Current as of:
08/30/2015



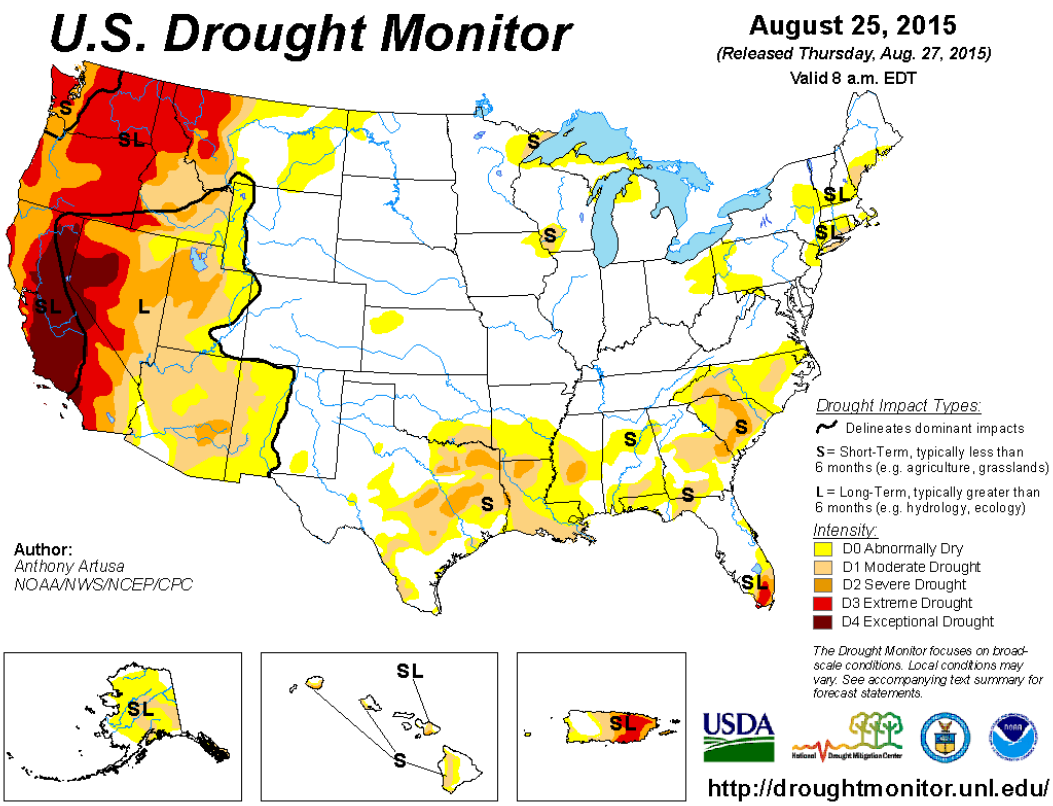

Colorado Basin River Forecast Center
Lake Powell Group
Created 09/01.15:57 G MT
NOAA/CBRFC, 2015
Past
Snow Water Equivalent (in)
Percent Seasonal Median
30
28
25
22
20
18
15
12
10
8
5
2
0
149
137
124
112
99
87
75
62
50
37
25
12
0
10-01
10-31
11-30
12-31
01-30
03-01
04-01
05-01
05-31
07-01
07-31
08-30
09-30
Date
Median 1981-2010
Average 1981-2010
2015
2014

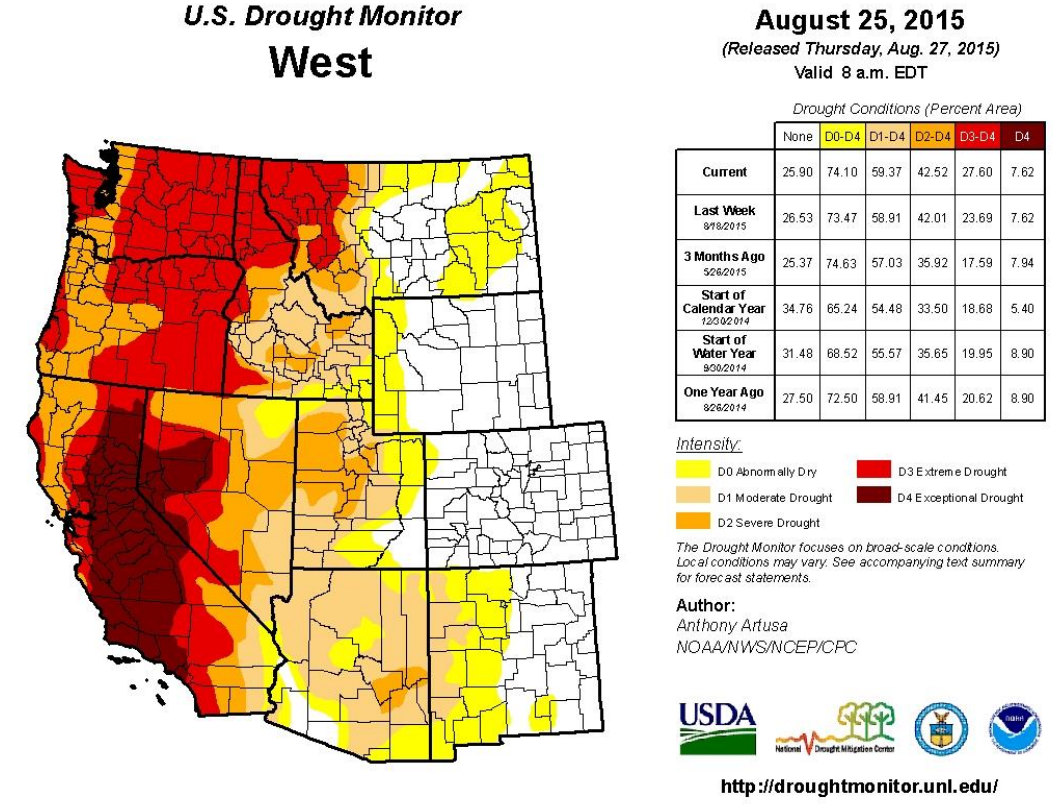
NOAA National Weather Service Monthly Precipitation Maps for July and August 2015





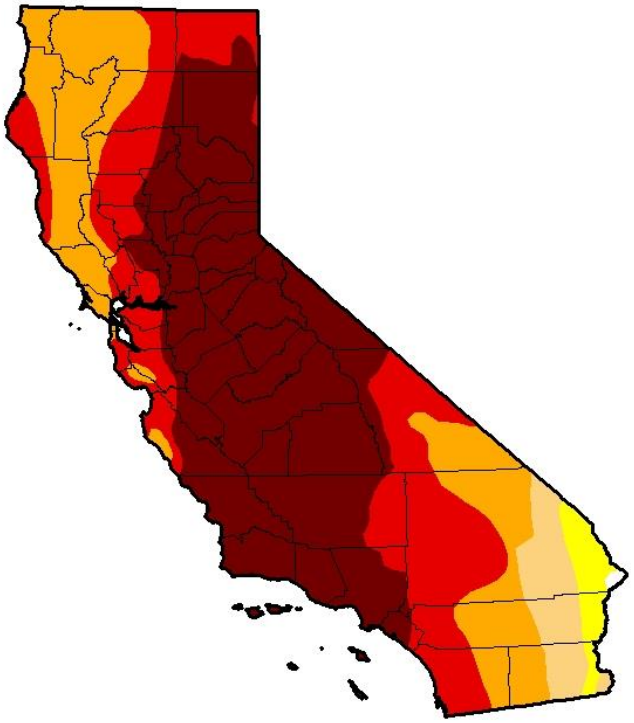
USDA United States Drought Monitor Map





U.S. Drought Monitor

California



August 25, 2015

(Released Thursday, Aug. 27, 2015)

Valid 8 a.m. EDT

Drought Conditions (Percent Area)

	None	D0-D4	D1-D4	D2-D4	D3-D4	D4
Current	0.14	99.86	97.35	92.36	71.08	46.00
Last Week 8/18/2015	0.14	99.86	97.35	92.36	71.08	46.00
3 Months Ago 5/26/2015	0.14	99.86	98.71	93.91	66.60	46.73
Start of Calendar Year 12/30/2014	0.00	100.00	98.12	94.34	77.94	32.21
Start of Water Year 9/30/2014	0.00	100.00	100.00	95.04	81.92	58.41
One Year Ago 8/26/2014	0.00	100.00	100.00	95.42	81.92	58.41

Intensity:

- D0 Abnormally Dry
- D1 Moderate Drought
- D2 Severe Drought
- D3 Extreme Drought
- D4 Exceptional Drought

The Drought Monitor focuses on broad-scale conditions. Local conditions may vary. See accompanying text summary for forecast statements.

Author:
Anthony Artusa
NOAA/NWS/NCEP/CPC

http://droughtmonitor.unl.edu/

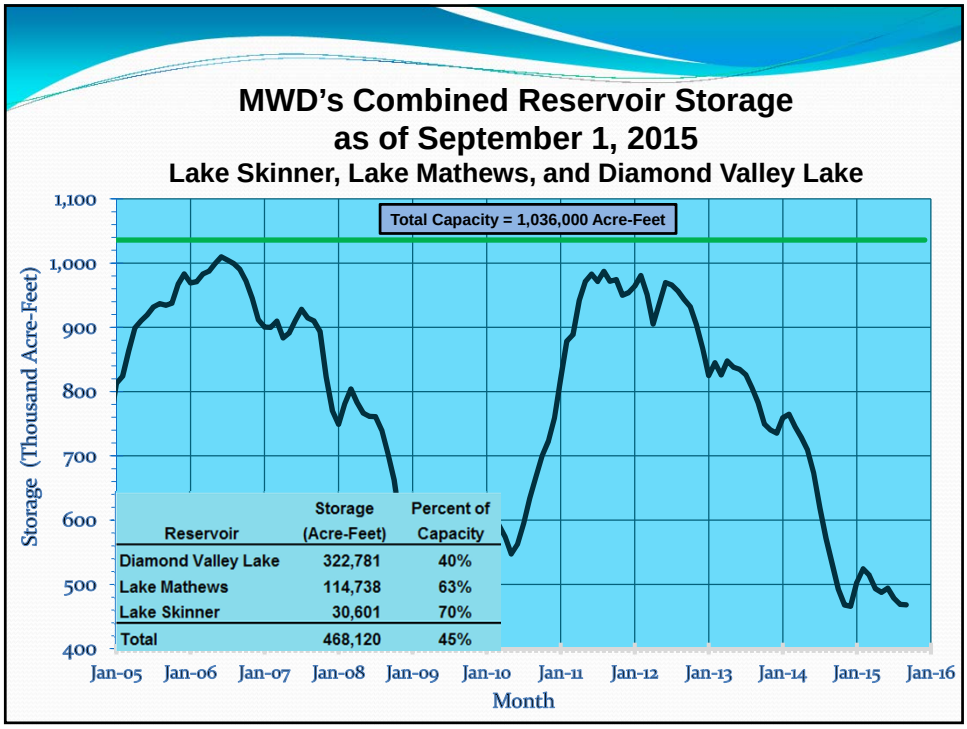
Percent of Traces with Event or System Condition

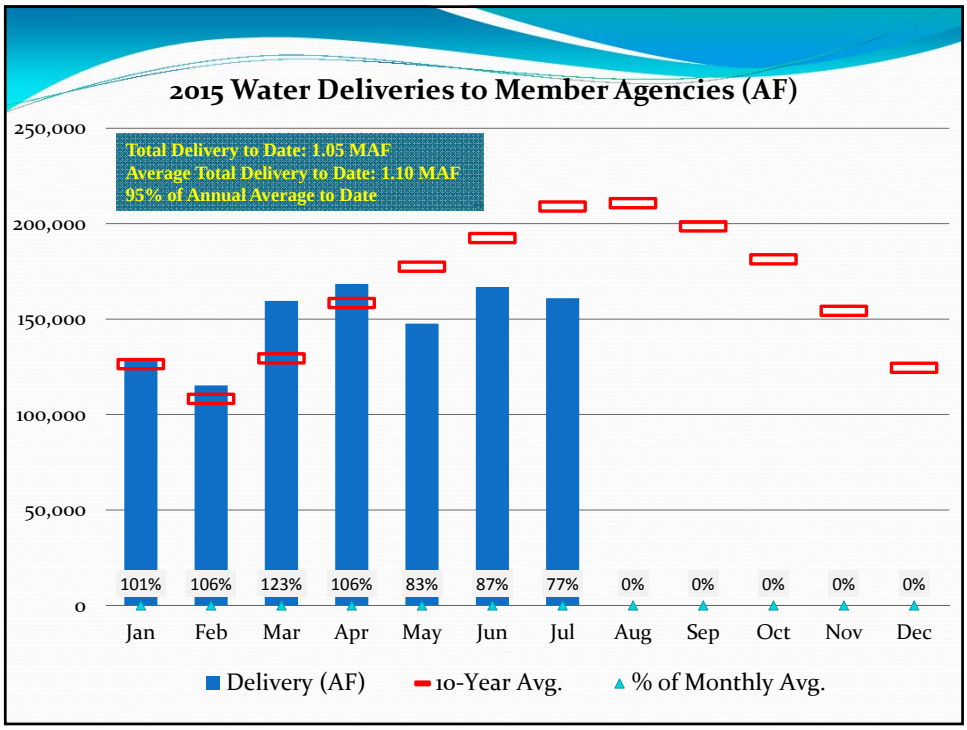
Results from August 2015 CRSS[1,2,3] (values in percent)

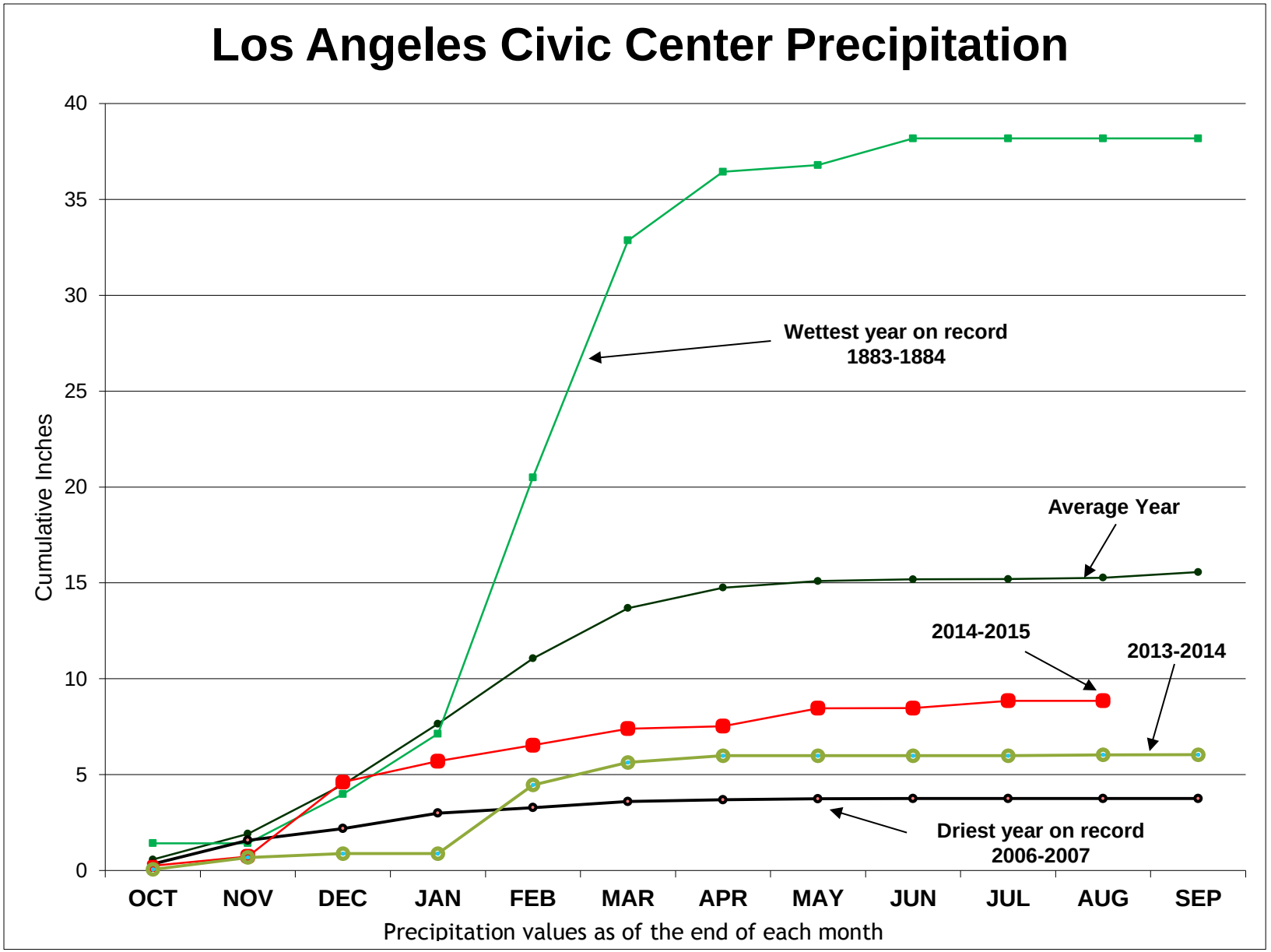
	Event or System Condition	2016	2017	2018	2019	2020
Upper Basin – Lake Powell	**Equalization Tier**	**8**	**24**	**23**	**27**	**29**
	Equalization – annual release > 8.23 maf	8	23	23	27	28
	Equalization – annual release = 8.23 maf	0	0	0	0	1
	Upper Elevation Balancing Tier	**92**	**52**	**55**	**54**	**47**
	Upper Elevation Balancing – annual release > 8.23 maf	82	39	43	42	36
	Upper Elevation Balancing – annual release = 8.23 maf	10	13	11	10	11
	Upper Elevation Balancing – annual release < 8.23 maf	0	0	1	2	0
	Mid-Elevation Release Tier	**0**	**24**	**19**	**10**	**17**
	Mid-Elevation Release – annual release = 8.23 maf	0	0	0	1	1
	Mid-Elevation Release – annual release = 7.48 maf	0	24	19	9	16
	Lower Elevation Balancing Tier	**0**	**0**	**3**	**9**	**7**
Lower Basin – Lake Mead	**Shortage Condition – any amount (Mead ≤ 1,075 ft)**	**0**	**18**	**52**	**65**	**59**
	Shortage – 1st level (Mead ≤ 1,075 and ≥ 1,050)	0	18	42	47	35
	Shortage – 2nd level (Mead < 1,050 and ≥ 1,025)	0	0	10	14	18
	Shortage – 3rd level (Mead < 1,025)	0	0	0	4	7
	Surplus Condition – any amount (Mead ≥ 1,145 ft)	**0**	**0**	**6**	**7**	**15**
	Surplus – Flood Control	0	0	0	2	2
	Normal or ICS Surplus Condition	**100**	**82**	**42**	**28**	**26**

[1] Reservoir initial conditions based on December 31, 2015 conditions using projections from the most probable August 2015 24-Month Study.
[2] Results are based on 107 hydrologic inflow sequences based on resampling of the observed natural flow record from 1906-2012.
[3] Percentages shown may not be representative of the full range of future possibilities that could occur with different modeling assumptions.

RECLAMATION


MWD's Combined Reservoir Storage
as of September 1, 2015
Lake Skinner, Lake Mathews, and Diamond Valley Lake
Total Capacity = 1,036,000 Acre-Feet
Storage (Thousand Acre-Feet)
1,100
1,000
900
800
700
600
500
400
Jan-05
Jan-06
Jan-07
Jan-08
Jan-09
Jan-10
Jan-11
Jan-12
Jan-13
Jan-14
Jan-15
Jan-16
Month
Reservoir | Storage (Acre-Feet) | Percent of Capacity
Diamond Valley Lake | 322,781 | 40%
Lake Mathews | 114,738 | 63%
Lake Skinner | 30,601 | 70%
Total | 468,120 | 45%


2015 Water Deliveries to Member Agencies (AF)
Total Delivery to Date: 1.05 MAF
Average Total Delivery to Date: 1.10 MAF
95% of Annual Average to Date
250,000
200,000
150,000
100,000
50,000
0
101%
106%
123%
106%
83%
87%
77%
0%
0%
0%
0%
0%
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Delivery (AF)
10-Year Avg.
% of Monthly Avg.

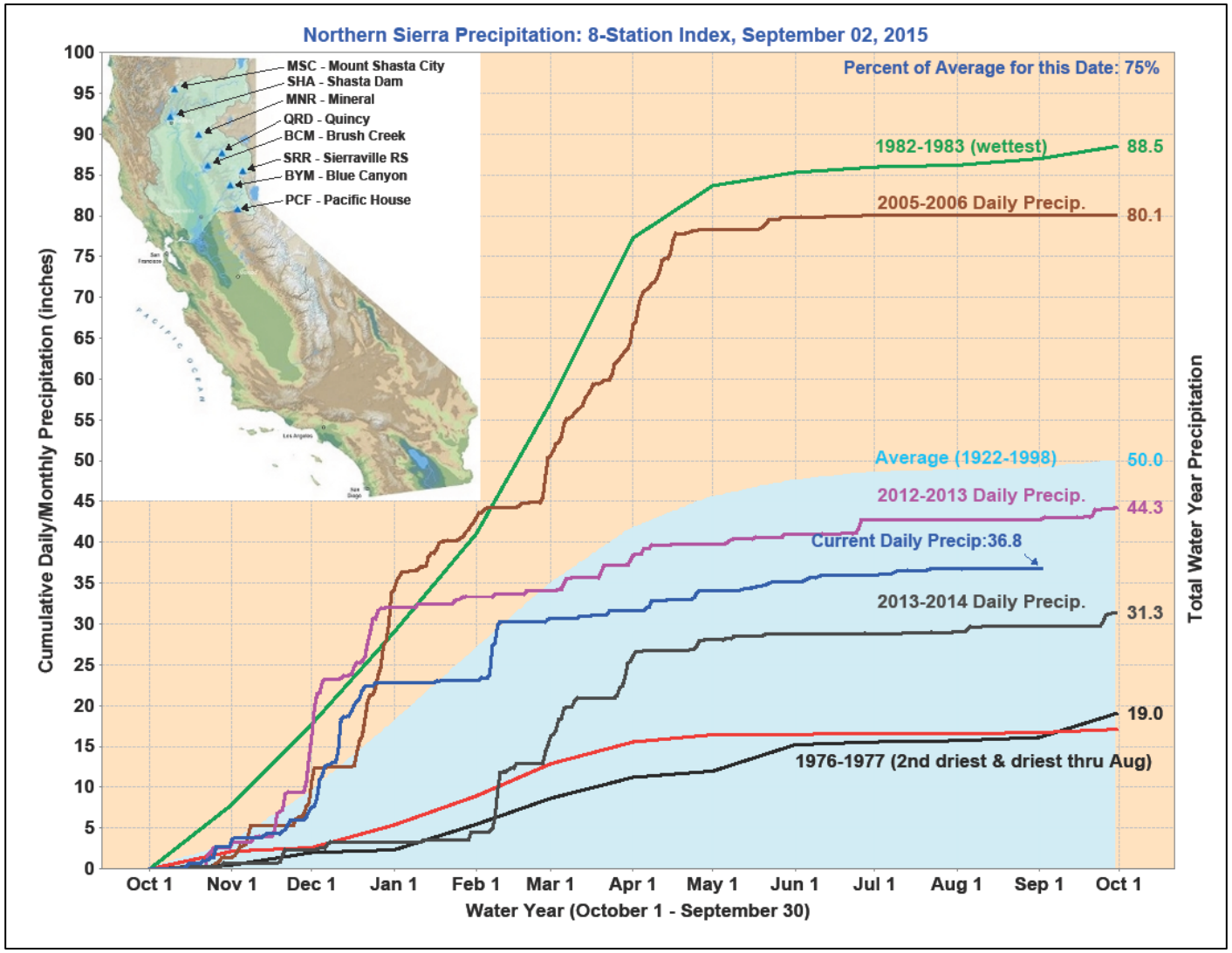

Los Angeles Civic Center Precipitation
Cumulative Inches
40
35
30
25
20
15
10
5
0
Wettest year on record
1883-1884
Average Year
2014-2015
2013-2014
Driest year on record
2006-2007
OCT
NOV
DEC
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
Precipitation values as of the end of each month

Precipitation at Six Major Stations in Southern California

From October 1, 2014 to August 31, 2015

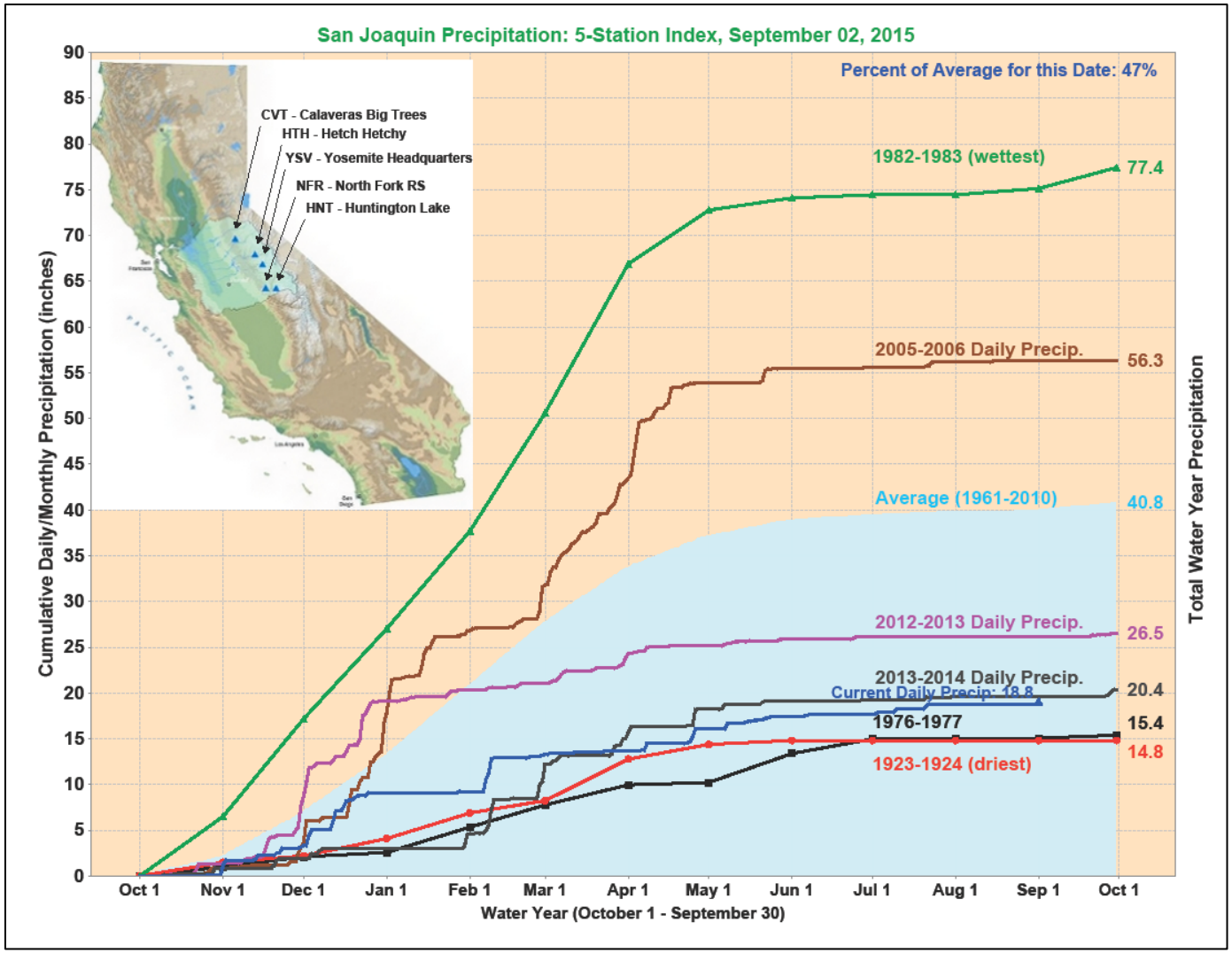
Station	Precipitation in inches		Average to Date	Percent of Average
	Aug	Oct 1 to Aug 31		
San Luis Obispo	0.00	8.82	22.18	40%
Santa Barbara	0.00	9.63	17.57	55%
Los Angeles	0.00	8.85	15.27	58%
San Diego	0.01	7.95	9.98	80%
Blythe	0.00	3.06	3.42	89%
Imperial	0.00	1.95	2.59	75%

Northern Sierra Precipitation-8 Station Index



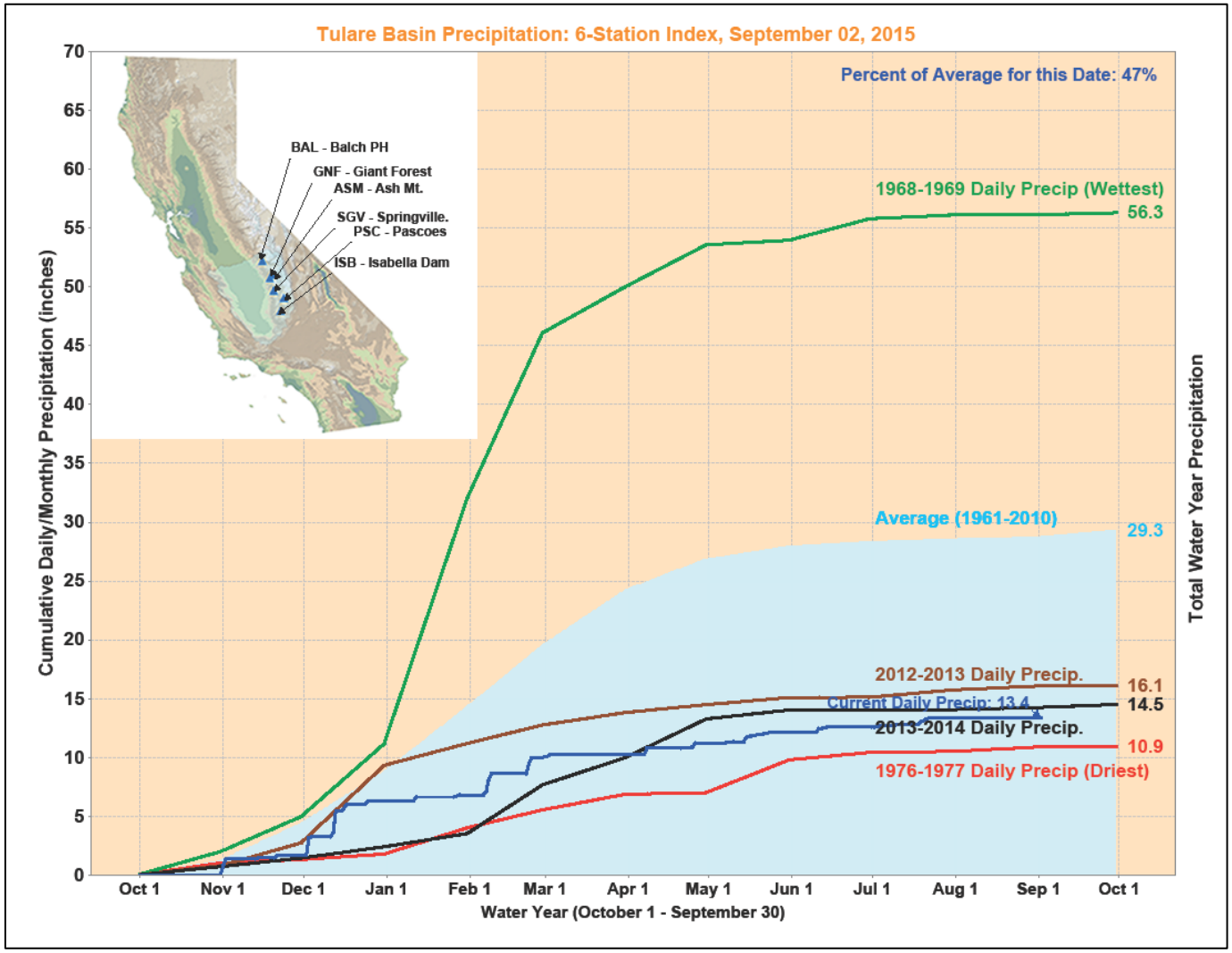
California Data Exchange Center
http://cdec.water.ca.gov/cgi-progs/products/PLOT_ESI.pdf

San Joaquin Precipitation-5 Station Index



California Data Exchange Center
http://cdec.water.ca.gov/cgi-progs/products/PLOT_FSI.pdf

Tulare Basin Precipitation-6 Station Index



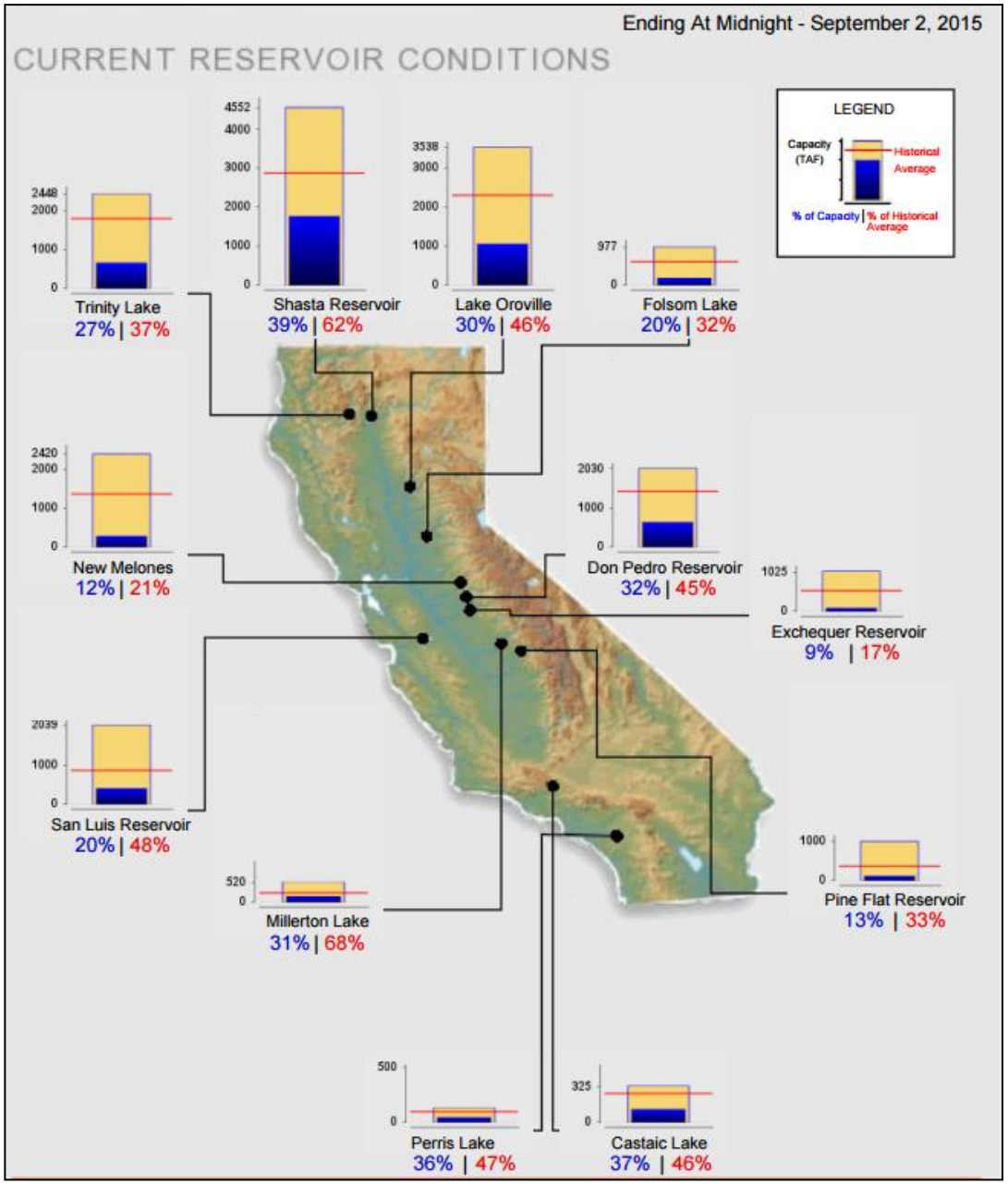
California Data Exchange Center
http://cdec.water.ca.gov/cgi-progs/products/PLOT_TSI.pdf

Comparison of SWP Water Storage

Reservoir	Capacity	2014 Storage (acre-feet) As of Sep 1	2014 Storage (acre-feet) % of Cap.	2015 Storage (acre-feet) As of Sep 1	2015 Storage (acre-feet) % of Cap.
Frenchman	55,475	20,404	37%	13,606	25%
Lake Davis	84,371	46,932	56%	39,483	47%
Antelope	22,564	18,043	80%	18,388	81%
Oroville	3,553,405	1,100,805	31%	1,070,070	30%
TOTAL North	3,715,815	1,186,184	32%	1,141,547	31%
Del Valle	39,914	39,907	100%	35,235	88%
San Luis (DWR)	1,062,180	157,200	15%	361,789	34%
Pyramid	169,901	167,025	98%	168,459	99%
Castaic	319,247	133,189	42%	120,561	38%
Silverwood	74,970	70,563	94%	70,506	94%
Perris	126,841	62,080	49%	46,698	37%
TOTAL South	1,793,053	629,964	35%	803,248	45%
TOTAL SWP	5,508,868	1,816,148	33%	1,944,795	35%

State Water Project Projected Deliveries:
As of March 2, 2015, the Table-A allocations for 2015 is 20%

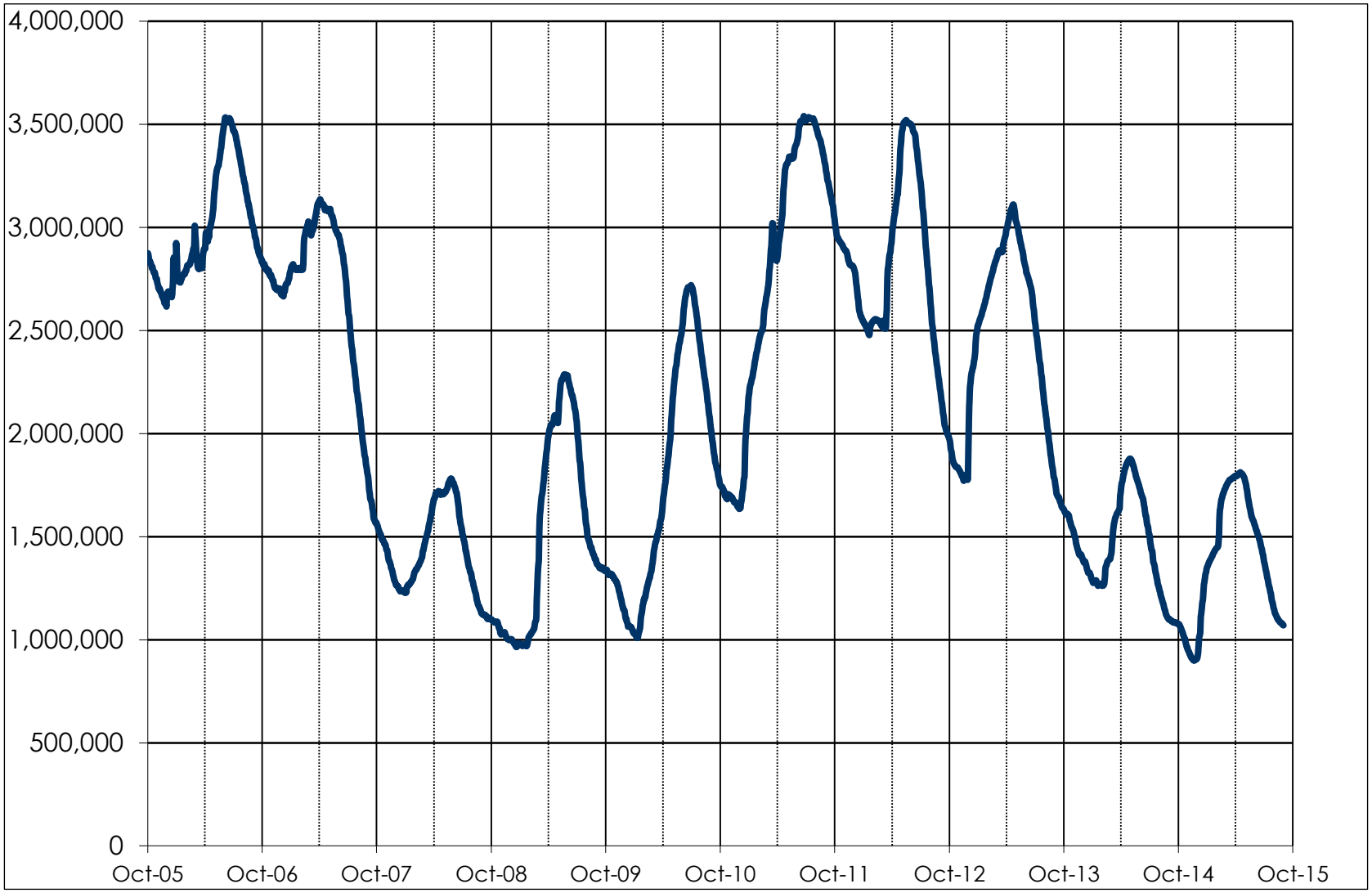
Current Reservoir Conditions



http://cdec.water.ca.gov/cdecapp/resapp/getResGraphsMain.action

Oroville Storage (acre-feet)

October 1, 2005 – August 31, 2015



Drought Update
Wednesday, September 2, 2015

KEY ACTION ITEMS FROM THIS WEEK

- **Californians Reduce Water Use by Over 31 Percent in July:** On August 27, the State Water Board announced that Californians surpassed June's conservation rate of 27 percent and reduced water use by 31.3 percent during July. This water use reduction exceeds Governor Brown's 25 percent conservation mandate for a second consecutive month since the emergency conservation mandate took effect on June 1. Cumulative statewide water savings since June 1 is 29.5 percent compared to the same months in 2013, saving 134 billion gallons of potable water.

  Saving water in the hot summer months is critical to meeting the State's overall 25 percent savings goal through February 2016, as the summer is when the greatest amount of water is traditionally used, particularly on outdoor landscapes. For more details, view the State Water Board's full press release here.

- **Reclamation to Release Additional Water from Trinity Reservoir to Supplement Flows in the Lower Klamath River:** On August 20, the Bureau of Reclamation (Reclamation) will release additional water from Trinity Reservoir for the lower Klamath River to help protect returning adult fall run Chinook salmon from a disease outbreak and mortality. For more details, please visit Reclamation's webpage here.

- **State Water Board Begins to Issue Informational Order to Four Russian River Tributaries:** On August 26, the State Water Board started issuing Informational Orders to the four Russian River tributaries to collect information on water diversion and use, and to inform potential future action. It is anticipated that all Informational Orders will be issued by September 8. For more details, please visit the State Water Board's Informational Order webpage here.

- **Change Petition Submitted to State Water Board Related to California WaterFix Implementation:** On August 27, the Department of Water Resources and the U.S. Bureau of Reclamation submitted a change petition to the State Water Board seeking approval to add three new points of diversion on the Sacramento River. This change petition would enable the proposed California WaterFix, which would greatly improve water conveyance through the Sacramento-San Joaquin Bay Delta. For more information, a fact sheet on the California WaterFix water right petition process is available here.

- **Drought, Conservation to Be Discussed at Upcoming Meeting of the State Board of Food and Agriculture:** On September 1, California State Board of Food and Agriculture (CDFA) will host a meeting to discuss drought impacts to the Russian River and the role of agriculture in conservation efforts. The meeting will be held from 10:00 a.m. to 2:00 p.m. at the California Department of Food and Agriculture main auditorium.

- **Joint Agency Workshop on California's Drought Response:** On August 28, the California Energy Commission led a joint agency workshop with the California Public Utilities Commission to discuss the impacts of the drought on California and its energy system, and to gather information on partner state agencies' efforts in reducing these impacts.

- **48th Annual Native American Day:** On September 25, the California State Tribal Liaison, in partnership with the California Tribal Chairmen's Association, will hold the 48th annual Native American Day on the West Steps of the State Capitol, focusing on the theme of water. This event is free to the public.

- **California's Water Conservation Education Program Campaign:** This past week, a video featuring the SF Giants AT&T Park Garden and its gardener was released. Additionally, Clear Channel Outdoor's donation of billboards went live in Sacramento and the Bay Area. The billboards will feature Save Our Water art with water conservation messages urging Californians to let their lawn fade to gold during the state's ongoing historic drought.

  For more tips and tools to help conserve water and keep trees healthy during the drought, please visit Save Our Water's website, which is available in both English and Spanish, or connect with the program on Facebook, Twitter or Instagram.

- **Governor's Drought Task Force:** The Task Force continues to take actions that conserve water and coordinate state response to the drought. During the most recent Task Force meeting on August 27, DWR updated that it continues to manage delta salinity, cold water supplies, and will begin advance planning for a dry 2016-2017 year. In addition, DWR is actively coordinating with U.S. Bureau of Reclamation and other agencies to begin the removal of the emergency salinity barrier starting September 1. The next regional Drought Task Force meeting is scheduled for September 2, near the Los Angeles area.

ONGOING DROUGHT SUPPORT

- **Emergency Food Aid, Utility and Employment Assistance:** The Department of Social Services (CDSS) Drought Food Assistance Program (DFAP) provides food assistance to affected communities that suffer high levels of unemployment from the drought. To date, over 847,875 boxes have been provided to community food banks in drought-impacted counties, with an average of approximately 13,250 food boxes per week since June 2014. Approximately 757,137 boxes of food have been picked up by 397,862 households.

  Food boxes distributions vary by county and occur 1-4 times per month. Nearly 70% of the food distributions have occurred in the Tulare Basin (Fresno, Kern, Kings and Tulare). There are 10,800 boxes scheduled for delivery for the week ending September 4 to Fresno, Kern, Riverside, and Tulare counties.

  The Department of Community Services and Development (CSD) allocated an additional $600,000, under the federally-funded Community Services Block Grant (CSBG), to continue the Drought Water Assistance Program (DWAP) which provides financial assistance to help low-income families pay their water bills. As of August 21, CSD has reported that a total of $378,294 has been issued to 1,916 households.

CSD is in the process of allocating $400,000, under CSBG, to continue the Migrant and Seasonal Farmworker (MSFW) drought assistance program, which provides assistance in employment training and placement services to individuals impacted by the drought. This program provides employment training and placement services to migrant and seasonal farmworkers suffering job loss or reduced employment due to the drought. To date, CSD has reported that a total of $10,843 has been issued to the Center for Employment Training, California Human Development, and Central Valley Opportunity Center with 14 participants enrolled.

In response to California's historic drought, CSD has received $7.5 million in General Fund to implement the Drought Emergency Assistance Program (DEAP) to provide emergency relief and support services to drought-impacted individuals and their families and households. As of August 21, CSD has reported that a total of $166,303 has been issued to 208 households.

- **Drought Response Funding:** The $687 million in state drought funding that was appropriated last March through emergency legislation, as well as $142 million provided in the 2014 Budget Act, continues to advance toward meeting critical needs. To date, $468 million has been committed, and nearly $625 million of the emergency funds appropriated in March came from sources dedicated to capital improvements to water systems. Since March, the Department of Water Resources has expedited grant approvals, getting $21 million immediately allocated to grantees that were pre-approved for certain projects.

  As planned in March, the next $200 million of expedited capital funding was awarded in October, and the remaining $250 million will be granted by fall 2015. The 2014 Budget Act appropriated an additional $53.8 million to CAL FIRE over its typical budget to enhance firefighter surge capacity and retain seasonal firefighters beyond the typical fire season.

  As a result of continuing drought conditions, emergency legislation was enacted in March 2015 that appropriated over $1 billion of additional funds for drought-related projects and activities. The Administration's May Revision proposal includes an additional $2.2 billion for programs that protect and expand local water supplies, improve water conservation, and provide immediate relief to impacted communities.

CURRENT DROUGHT CONDITIONS

- **Fire Activity**: Since the beginning of the year, firefighters from CAL FIRE have responded to over 4,743 wildfires across the state, burning 146,279 acres. Fire activity across California remains high with nearly 272 wildfires in just the past week.

- **CAL FIRE Suspends Outdoor Residential Burning**: California's increased fire activity this year, coupled with record-setting drought conditions, has caused CAL FIRE to suspend burn permits in all counties in the State Responsibility Area.

- **Dry Well Reports:** With California in its fourth year of a severe, hot drought, the Governor's Drought Task Force continues to monitor and identify communities and local water systems in danger of running out of water. Recently, a cross-agency team, led by DWR, developed a new system that improves and streamlines data collection and reporting for household water shortages for California water systems with fewer than 15 household connections.

As of August 26, approximately 2,257 wells statewide have been identified as critical or dry, which affects an estimated 11,285 residents. Cal OES has reported that 2,160 of the 2,257 dry wells are concentrated in the inland regions within the Central Valley. If you are experiencing a water supply shortage, please submit a report on DWR's website.

- **Vulnerable Water Systems:** The State Water Board continues to provide technical and funding assistance to several communities facing drinking water shortages, and is monitoring water systems across the state. Since January 2014, 92 out of the 126 projects approved to receive emergency funding for interim replacement drinking water have been executed. On May 19, the State Water Board adopted Guidelines for administering the latest emergency drought appropriations of $19 million announced this past March. To date, the State Water Board has received requests for $3.4 million of those funds.

- **Projected Reservoir Management:** Shasta Reservoir recorded 1,812,389 acre-feet (AF) on August 27 with a 10-day average reduction in storage of 6,313 AF/day. Releases are being held lower than normal to keep cold water in the reservoir for Winter Run Chinook Salmon later in the fall. Shasta Reservoir is projected to reach 1,460,000 AF by the end of September. This is higher than the 1976-77 record low storage of 700,000 AF.

  Oroville Reservoir recorded 1,080,474 AF on August 27 with a 10-day average reduction in storage of 1,311 AF/day. Releases are higher than normal to help make up for reduced flows out of Shasta. These higher flows are to keep salt water from coming too far into the Delta and to meet other joint federal-state obligations. Oroville Reservoir is projected to reach 900,000 AF by the end of September. This storage is about the same as the record low 1976-77 storage level.

  Folsom Reservoir recorded 201,600 AF on August 27 with a 10-day average reduction in storage of 2,545 AF/day. Releases are higher than normal to help make up for reduced flows out of Shasta. Folsom Reservoir is projected to reach 120,000 AF by the end of September. This is lower than the 1976-77 record low storage of 150,000 AF.

  Reservoir Levels as of August 30 remain low, including: Castaic Lake 37% of capacity (45% of year to date average); Don Pedro 32% of capacity (45% of average); Exchequer 9% of capacity (17% of average); Folsom Lake 20% of capacity (32% of average); Lake Oroville 30% of capacity (46% of average); Lake Perris 36% (47% of average); Millerton Lake 30% of capacity (65% of average); New Melones 12% of capacity (21% of average); Pine Flat 13% of capacity (33% of average); San Luis 20% of capacity (47% of average); Lake Shasta 39% of capacity (62% of average); and Trinity Lake 28% of capacity (38% of average). An update of water levels at other smaller reservoirs is also available.

- **Weather Outlook:** Warmer temperatures are expected for the Central Valley through Tuesday. Cooler temperatures and stronger onshore flow are expected to return by mid-week. Inland and Southern California areas will be expecting slightly below seasonal averages. Slow warming may return next weekend.

Local Government

- **Local Emergency Proclamations**: A total of 60 local Emergency Proclamations have been received to date from city, county, and tribal governments, as well as special districts:

    - **27 Counties:** Butte, El Dorado, Fresno, Glenn, Humboldt, Inyo, Kern, Kings, Lake, Madera, Mariposa, Merced, Modoc, Plumas, San Bernardino, San Joaquin, San Luis Obispo, Santa Barbara, Shasta, Siskiyou, Sonoma, Stanislaus, Sutter, Trinity, Tulare, Tuolumne and Yuba.

    - **12 Cities:** City of Live Oak (Sutter County), City of Lodi (San Joaquin County), City of Manteca (San Joaquin County), City of Montague (Siskiyou County), City of Porterville (Tulare County), City of Portola (Plumas County), City of Ripon (San Joaquin County), City of San Juan Bautista (San Benito County), City of Santa Barbara (Santa Barbara County), City of Rancho Cucamonga (San Bernardino County) and City of West Sacramento (Yolo County) and City of Willits (Mendocino County).

    - **9 Tribes:** Cortina Indian Rancheria (Colusa County), Hoopa Valley Tribe (Humboldt County), Karuk Tribe (Siskiyou/Humboldt Counties), Kashia Band of Pomo Indians of the Stewarts Point Rancheria (Sonoma County), Picayune Rancheria of Chukchansi Indians (Madera County) Sherwood Valley Pomo Indian Tribe (Mendocino County), Tule River Indian Tribe (Tulare County), Yocha Dehe Wintun Nation (Yolo County) and Yurok Tribe (Humboldt County).

    - **12 Special Districts:** Carpinteria Valley Water District (Santa Barbara County), Goleta Water District (Santa Barbara County), Groveland Community Services District (Tuolumne County), Lake Don Pedro Community Services District (Mariposa Stanislaus County), Mariposa Public Utility District (Mariposa County), Meiners Oaks Water District (Ventura County), Montecito Water District (Santa Barbara County), Mountain House Community Service District (San Joaquin County), Nevada Irrigation District (Nevada County), Placer County Water Agency (Placer County), Tuolumne Utilities District (Tuolumne County) and Twain Harte Community Services District (Tuolumne County).

- **Water Agency Conservation Efforts**: The Association of California Water Agencies (AWCA) has identified several hundred local water agencies that have implemented water conservation actions. These water agencies are responding to the drought by implementing conservation programs, which include voluntary calls for reduced water usage and mandatory restrictions where water shortages are worst.

  ACWA released a Drought Response Toolkit to assist water agencies as they take action to meet state-mandated water conservation target and communicate information about water use restrictions, enforcement and other issues with their customers, media and other audiences.

- **County Drought Taskforces:** A total of 33 counties have established drought task forces to coordinate local drought response. These counties include: Butte, Colusa, Glenn, Humboldt, Kern, Kings, Lake, Madera, Mendocino, Merced, Modoc, Monterey, Napa, Nevada, Orange, Placer, Plumas, Sacramento, San Francisco, San Joaquin, San Luis Obispo, San Mateo, Santa Barbara, Santa Clara, Siskiyou, Stanislaus, Solano, Sutter, Tehama, Trinity, Tulare, Tuolumne, and Yolo.

- **Tribal Taskforce:** A total of 7 tribes have established drought task forces to coordinate tribal drought response. These tribes include: Hoopa Valley Tribe (Humboldt County), Hopland Tribe (Mendocino County), Karuk Tribe (Siskiyou County), La Jolla Band of Luiseno Indians (San Diego County), Sherwood Valley Tribe (Mendocino County), Trinidad Tribe (Humboldt County), and Yurok Tribe (Humboldt and Del Norte County).

DROUGHT RELATED WEBSITES FOR MORE INFORMATION

Drought.CA.Gov: California's Drought Information Clearinghouse

State's Water Conservation Campaign, Save Our Water
Local Government, Drought Clearinghouse and Toolkit

California Department of Food and Agriculture, Drought Information
California Department of Water Resources, Current Water Conditions
California Data Exchange Center, Snow Pack/Water Levels
California State Water Resources Control Board, Water Rights, Drought Info and Actions
California Natural Resources Agency, Drought Info and Actions
State Water Resources Control Board, Drinking Water, SWRCB Drinking Water Program
California State Water Project, Information

U.S. Drought Monitor for Current Conditions throughout the Region
U.S. Drought Portal, National Integrated Drought Information System (NIDIS)
National Weather Service Climate Predictor Center
USDA Drought Designations by County CA County Designations
USDA Disaster and Drought Assistance Information USDA Programs
U.S. Small Business Administration Disaster Assistance Office: www.sba.gov/disaster

Subject: CBRFC 2015 Stakeholder Forum Reminder & Updated Agenda

The Agenda for the 2015 CBRFC Stakeholder Forum has been updated and can be found here.

The 2015 Stakeholder Forum will be held on October 20th 2015 in our office at 2242 West North Temple in Salt Lake beginning at 9 am MDT.

The theme of this year's Stakeholder Forum will focus on uncertainties in the forecast process. This includes uncertainties due to initial hydrologic model states, meteorological data inputs, river system depletions, and the incorporation of weather and climate into the water supply forecasts. We will also discuss the methodology, interpretation, and verification behind provided probabilistic forecasts.

If you would like to attend we invite you to register by contacting Valerie Offutt at Valerie.Offutt@noaa.gov or by calling 801-524-5130. There is no cost to attend other than lunch. Attendees will have the option of pre-ordering lunch from a local establishment.

There will be an option on the next day, October 21st for Stakeholders to stay and meet with CBRFC staff to discuss topics of their choice. Attendees should contact Greg.Smith@noaa.gov or Paul.Miller@noaa.gov if you have any specific topics you would like to discuss so we can set aside necessary time.

The 2015 Water Supply Verification Webinar will also take place on October 21st at 11 am MDT and last about 45 minutes.

For those who attend we are planning a demonstration of our forecast operations procedures, CBRFC web page interaction, and a tour of the Salt Lake Weather Forecast Office and discussion of RFC-WFO interactions.

For those who can't attend in person, we are planning to have a dial-in / gotomeeting option available. This information will be sent out at a later date.

For any further questions please contact Greg Smith at Greg.Smith@noaa.gov or Paul Miller at Paul.Miller@noaa.gov or call us at 801-524-5130.

The full announcement for the 2015 CBRFC Stakeholder Forum and can be found here.

Thank You,

Greg Smith & Paul Miller
Colorado Basin River Forecast Center / NWS / NOAA
Email: greg.smith@noaa.gov

CALIFORNIA DEPARTMENT OF WATER RESOURCES

NEWS FOR IMMEDIATE RELEASE

August 19, 2015

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NASA Report: Drought Causing Valley Land to Sink

SACRAMENTO, CA — As Californians continue pumping groundwater in response to the historic drought, the Department of Water Resources today released a new NASA report showing land in the San Joaquin Valley is sinking faster than ever before, nearly two inches per month in some locations.

"Because of increased pumping, groundwater levels are reaching record lows—up to 100 feet lower than previous records," said Department of Water Resources Director Mark Cowin. "As extensive groundwater pumping continues, the land is sinking more rapidly and this puts nearby infrastructure at greater risk of costly damage."

Sinking land, known as subsidence, has occurred for decades in California because of excessive groundwater pumping during drought conditions, but the new NASA data shows the sinking is happening faster, putting infrastructure on the surface at growing risk of damage. NASA obtained the subsidence data by comparing satellite images of the Earth's surface over time.

Land near Corcoran in the Tulare basin sank 13 inches in just eight months—about 1.6 inches per month. One area in the Sacramento Valley was sinking approximately half-an-inch per month, faster than previous measurements. NASA also found areas near the California Aqueduct sank up to 12.5 inches, with eight inches of that occurring in just four months of 2014.

The increased subsidence rates have the potential to damage local, state, and federal infrastructure, including aqueducts, bridges, roads, and flood control structures. Long-term subsidence has already destroyed thousands of public and private groundwater well casings in

the San Joaquin Valley. Over time, subsidence can permanently reduce the underground aquifer's water storage capacity.

The land sank so much at this location at the Delta-Mendota Canal, that now this bridge nearly touches the water.

In response to the new findings, and as part of an ongoing effort to respond to the effects of California's historic drought, the Governor's Drought Task Force has committed to working with affected communities to develop near-term and long-term recommendations to reduce the rate of sinking and address risks to infrastructure. This action builds on the historic Sustainable Groundwater Management Act, enacted by Governor Edmund G. Brown Jr. in September 2014, which requires local governments to form sustainable groundwater agencies that will regulate pumping and recharge to better manage groundwater supplies.

"Groundwater acts as a savings account to provide supplies during drought, but the NASA report shows the consequences of excessive withdrawals as we head into the fifth year of historic drought," Director Cowin said. "We will work together with counties, local water districts, and affected communities to identify ways to slow the rate of subsidence and protect vital infrastructure such as canals, pumping stations, bridges, and wells."

The Department of Water Resources is also launching a $10 million program to help counties with stressed groundwater basins to develop or strengthen local ordinances and conservation plans. This funding comes from the statewide Water Bond passed last year, and applications for funding will be posted in the coming days. This year's budget passed in July also enables

streamlined environmental review for any county ordinance that reduces groundwater pumping.

NASA will also continue its subsidence monitoring, using data from the European Space Agency's recently launched Sentinel-1 mission to cover a broader area and identify more vulnerable locations.

DWR also completed a recent land survey along the Aqueduct--which found 70-plus miles in Fresno, Kings, and Kern counties sank more than 1.25 feet in two years--and will now conduct a system-wide evaluation of subsidence along the California Aqueduct and the condition of State Water Project facilities. The evaluation will help the department develop a capital improvement program to repair damage from subsidence. Past evaluations found that segments of the Aqueduct from Los Banos to Lost Hills sank more than five feet since construction.

The report, Progress Report: Subsidence in the Central Valley, California, prepared for DWR by researchers at the National Aeronautics and Space Administration's (NASA's) Jet Propulsion Laboratory, is available here: http://www.water.ca.gov/waterconditions/index.cfm

California has been dealing with the effects of drought for four years. To learn about all the actions the state has taken to manage our water system and cope with the impacts of the drought, visit Drought.CA.Gov. Every Californian should take steps to conserve water. Find out how at SaveOurWater.com.

PUBLIC POLICY INSTITUTE OF CALIFORNIA

August 2015

PPIC WATER POLICY CENTER

What If California's Drought Continues?

Ellen Hanak | Jeffrey Mount | Caitrin Chappelle | Jay Lund | Josué Medellín-Azuara | Peter Moyle | Nathaniel Seavy

Research support from Emma Freeman, Jelena Jedzimirovic, Henry McCann, and Adam Soliman

Supported with funding from the California Water Foundation, an initiative of the Resources Legacy Fund

Summary

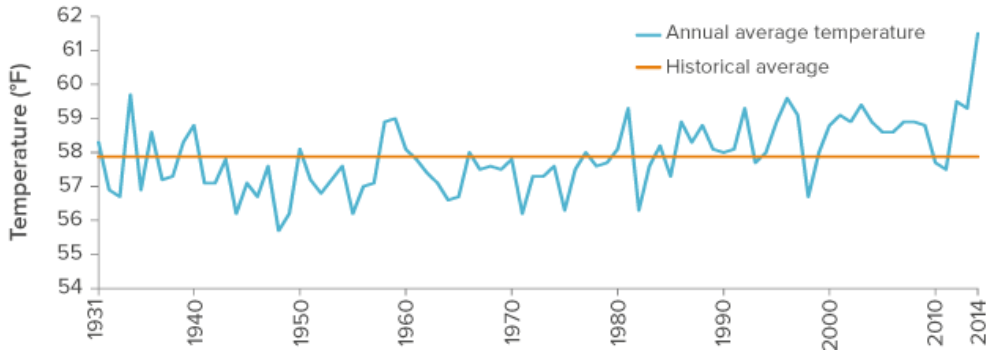
California is in the fourth year of a severe, hot drought—the kind that is increasingly likely as the climate warms. Although no sector has been untouched, impacts so far have varied greatly, reflecting different levels of drought preparedness. Urban areas are in the best shape, thanks to sustained investments in diversified water portfolios and conservation. Farmers are more vulnerable, but they are also adapting. The greatest vulnerabilities are in some low-income rural communities where wells are running dry and in California's wetlands, rivers, and forests, where the state's iconic biodiversity is under extreme threat. Two to three more years of drought will increase challenges in all areas and require continued—and likely increasingly difficult—adaptations. Emergency programs will need to be significantly expanded to get drinking water to rural residents and to prevent major losses of waterbirds and extinctions of numerous native fish species, including most salmon runs. California also needs to start a longer-term effort to build drought resilience in the most vulnerable areas.

Introduction

In 2015, California entered the fourth year of a severe drought. Although droughts are a regular feature of the state's climate, the current drought is unique in modern history. Taken together, the past four years have been the driest since record keeping began in the late 1800s.[1] This drought has also been exceptionally warm (Figure 1). Heat amplifies the effects of drought. It reduces snowpack, a major component of natural seasonal water storage. It decreases soil moisture, stressing natural vegetation and increasing irrigation demands. And it raises water temperatures, stressing fish and other species that live in rivers and lakes.

The combination of low flows and high temperatures make this a "drought of the future"—the type of drought California is increasingly likely to experience as the region's climate warms.[2]

Figure 1. California is experiencing record heat



SOURCE: National Oceanic and Atmospheric Administration.

NOTES: The figure shows annual average temperatures and the historical average for the period 1931 to 2014. For a breakdown by summer and winter months, see technical appendix, Figure A2.

Californians have been working hard to limit the drought's impacts on the state's economy, society, and environment. Since Governor Brown's January 2014 declaration of a statewide drought emergency, an Interagency Drought Task Force has met weekly to coordinate drought management.[3] The state and federal governments have funded emergency drought relief and water system investments intended to boost drought resiliency (Table 1). Local water agencies are collaborating to lessen regional water shortages. And farmers, nonfarm businesses, and residents across the state are stretching available supplies.

Table 1. Drought funding from state and federal sources (millions of dollars)

	State	Federal
Emergency community assistance	$200	$358
Impacted communities, workers (food, housing, training)	$102	$78
Safe drinking water systems	$90	$17
Technical guidance and planning	$8	$14
Feed subsidies for livestock producers*	$0	$250
Emergency ecosystem support	$66	$67
Emergency fire protection	$131	$4
Water system investments**	$2,609	$104
Total	**$3,006**	**$534**

SOURCES: Legislative Analyst's Office and White House fact sheets.

NOTES: The table includes funding from fiscal years 2013–14, 2014–15, and 2015–16. For details, see technical appendix tables A2 and A3.

*In 2015, more than $1 billion was announced to support livestock producers in all western states. We assume California's share will be equal to its 2014 allocation ($125 million).

**Most state water system investment support comes from voter-approved state bond funds. Many of these investments will take some time to implement.

These efforts have helped limit the economic impacts of the drought so far. But the experience is also revealing major gaps in California's preparedness to cope with the social and environmental impacts of extended, warm droughts. Too many decisions are being made on an emergency basis with the hope that the next winter will bring much-needed rain.

It would not be prudent to count on El Niño to end the drought.[4] To stand ready, the state needs to understand what impacts this drought has already had, what impacts to expect if it continues, and what steps may be warranted to prepare for this possibility.

This report provides insights into these questions. We focus on three areas of California's economy and society—cities, farms, and rural communities—and three acute ecosystem management challenges: waterbirds, fish, and forests. The analysis is informed by wide-ranging data sources and by conversations with officials, businesses, and stakeholders on the frontlines of drought management.[5] Table 2 summarizes the likely impacts and management challenges of continued drought, as described here. A technical appendix provides further details.

Table 2. Likely impacts and management challenges if the drought continues

Water availability	
Runoff and storage	Reduced runoff (between 25–40% of average) due to low rainfall and snowpack. Fall reservoir storage at 50% of historic average. Impacts vary regionally depending on precipitation patterns.
Deliveries and curtailments	Supply reduced for farms (8.5–9.0 million acre-feet/year) and cities (2.0–2.5 million acre-feet/year) compared to normal years. Central Valley Project and State Water Project allocations remain at 2015 levels. Surface water shortages require extensive curtailment of water rights, including many senior pre-1914 and riparian rights. Hydropower generation remains at half of recent average, increasing energy costs ($500 million/year or ~2%).
Groundwater	Central Valley continues heavy reliance on groundwater. Excess pumping of 6 million acre-feet/year (with $650+ million additional energy cost for pumping). Increase in dry wells; acceleration of widespread land subsidence and damage to infrastructure.
Water quality	Low flows and high air temperatures cause widespread decline in water quality in rivers and streams. Low reservoirs make managing Delta salinity increasingly difficult.
Cities and suburbs	
Large metropolitan areas have reasonably secure supplies, but require continued conservation efforts and some new supply investments. Isolated communities with a single water source face shortages and require alternative supplies. Some water- and snow-sensitive industries that rely heavily on water (e.g., boating, skiing) face financial hardships, but not enough to dampen statewide economic growth.	
Farms	
Net water shortfall of 2.5–3.0 million acre-feet/year results in roughly 550,000 acres fallowed annually; economy-wide economic losses of more than $2.8 billion, loss of more than 10,000 full-time, part-time, and seasonal farm jobs, and more than 21,000 jobs economy-wide.	
Rural communities	
Increasing number of rural water districts and homes that rely on shallow wells need emergency assistance as wells go dry. Fallowing of farmland exacerbates poor air quality in some parts of the Central Valley and increases economic hardship in farmworker communities.	
Ecosystems	
Native fishes	Record-low flows and high temperatures continue to degrade habitat for native fishes. As many as 18 native fishes face likelihood of near-term extinction, including delta smelt, most salmon runs, and several species of trout. Economic losses for commercial and recreational fisheries.
Waterbirds	Dramatic declines in fall and winter habitat for waterbirds of the Pacific Flyway from reduced water for wetlands and flooded farmland. Bird populations reduced by limited food supplies and disease from overcrowding.
Forests	Extreme wildfire hazard due to high temperatures, dry conditions, and increased tree mortality in California's forests. Severe wildfires (comparable to the 2013 Rim Fire) occur, impacting local communities, watersheds, wildlife, infrastructure, and air quality. Risks of permanent loss of conifer forest ecosystems in burned areas.

SOURCE: See technical appendix Table A10 for details.

NOTES: Assumes two to three more years of 2014 conditions. Reductions in water availability are relative to a normal rainfall year.

Public discussions often frame drought policy in terms of trade-offs among different areas—for instance, cities versus farms, or farms versus fish. And to be sure, the drought is forcing difficult trade-offs. Drought preparedness cannot eliminate all costs and consequences of water scarcity, but it can help lessen vulnerabilities and enable society to handle trade-offs in a transparent and balanced way. Leadership from government, business, and civil society is needed to set priorities and navigate the trade-offs.

Water Availability in a Hot, Dry Time

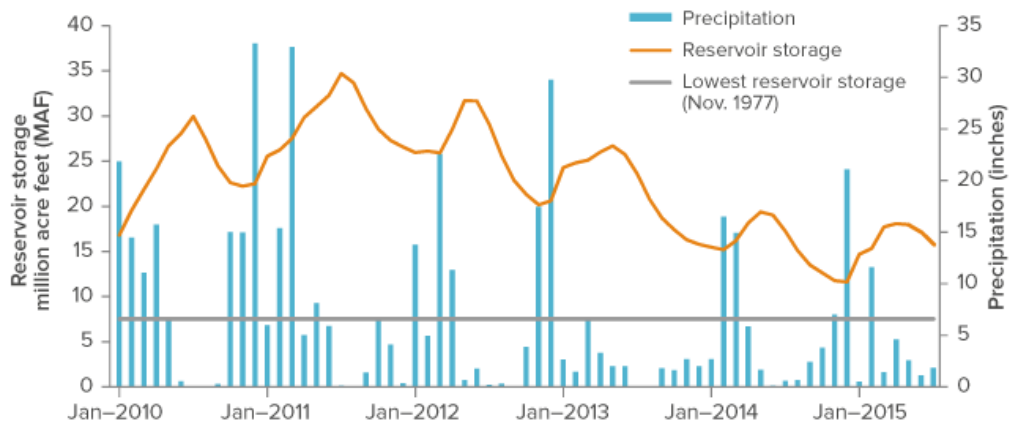
During droughts, California relies on water stored in surface reservoirs and especially groundwater basins to help offset shortfalls in precipitation. This drought is stressing both types of reserves and affecting the amount and quality of water for farms, cities, hydropower, and the environment.

IMPACTS AND ADAPTATIONS SO FAR

Surface Water

Thanks to an unusually wet 2011, the drought began with most surface reservoirs quite full. But these reserves are now significantly depleted (Figure 2). Since 2014, two of the state's largest water providers—the Central Valley Project (CVP) and the State Water Project (SWP)—have dramatically reduced water deliveries to agricultural and urban customers.[6] Deliveries from many local projects have also decreased.[7] Hydropower generation, which relies on releases from reservoirs, is at its lowest level since 1977 (technical appendix Figure A6).

Figure 2. Water stored in surface reservoirs is low



SOURCE: California Department of Water Resources.

NOTE: Precipitation is measured as the sum of the Northern Sierra 8-station and San Joaquin 5-station precipitation indices to account for most rainfall available for reservoir storage. Reservoir storage is the sum of monthly storage in 154 major reservoirs within the state (excluding storage in the Colorado River Basin).

Reduced flows and high temperatures have also affected both the quantity and quality of environmental flows. Water releases from large Sacramento Valley reservoirs help keep salty ocean water from intruding into the Sacramento–San Joaquin Delta, thereby maintaining water quality for agricultural and urban exports and supporting habitat for estuarine fishes such as delta and longfin smelt. These reservoirs are also the primary source of cold water needed by salmon and steelhead that spawn just downstream of the dams. Other water releases—including treated discharges from wastewater facilities—are also important for maintaining environmental flows. Since early 2014, water agencies across the state were granted emergency permits to change the volume, timing, or quality of required outflows 35 times (technical appendix Table A1). As described below, insufficient environmental flow releases at above-normal temperatures have put some fish species on the brink of extinction.

The drought has also exposed weaknesses in the state's technical capacity to forecast the effects of management decisions under extreme conditions of high temperatures and low flows. This has complicated the management of cold water in reservoirs, among other things.

And the drought is revealing strains in the state's surface water allocation system. In California's "first-in-time, first-in-right" system of surface water rights, those with more recent—or junior—rights generally have lower priority in times of shortage. In 2014, the State Water Resources Control Board, which administers water rights and quality standards, ordered curtailment of water diversions by many junior water-rights holders for the first time since 1977; these orders were extended to more senior rights holders in 2015, and the board has also begun issuing fines for non-compliance. Some senior rights holders are challenging the board's legal authority to curtail their diversions.[8] The process has revealed significant gaps in information needed to administer surface water rights in a timely and transparent manner.[9]

Groundwater

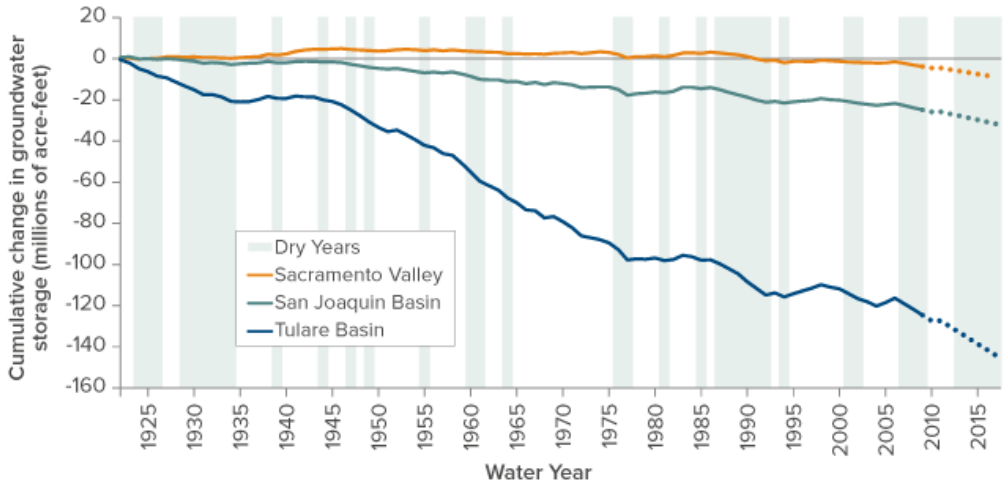
California's groundwater basins have considerably more dry-year storage capacity than its surface reservoirs, and many farms and cities are pumping additional groundwater to meet demands.[10] In a typical year, groundwater supplies about a third of total farm and urban water use. Since 2014, this share has exceeded 50 percent.[11]

Until recently, groundwater has been only loosely regulated by the state. Many urban areas now have well-developed groundwater programs that regulate and charge for pumping to keep groundwater basins from experiencing long-term declines. In contrast, groundwater oversight in most agricultural areas is still limited, and many basins have experienced overdraft—excess pumping that reduces long-term reserves and lowers the water table. Consequences include sinking lands, higher pumping costs, drying up of wells, and drying of some rivers and wetlands fed by groundwater.

Extra pumping during this drought has exacerbated these symptoms of chronic overdraft. Land levels in parts of the southern Central Valley have been falling by more than half a foot annually, causing damage to various types of infrastructure, including bridges, reservoirs, and major water arteries like the Delta Mendota Canal.[12] Falling water tables are raising pumping costs and drying up drinking water wells in some rural communities. In many places, the additional groundwater now being pumped is of poor quality, which lowers crop yields. Conditions are particularly acute in the Tulare Basin—the major agricultural region that includes Fresno, King, Tulare, and Kern Counties—where groundwater supplies have been declining for decades (Figure 3).

Widespread concern over the trajectory of many rural groundwater basins led to the enactment of the Sustainable Groundwater Management Act (SGMA) in September 2014. The act requires water users in the most stressed basins to develop sustainable groundwater management plans by 2020 and reach sustainability by 2040.[13]

Figure 3. Groundwater depletion is a growing challenge in the southern Central Valley



SOURCE: Historical data through 2009 from the California Department of Water Resources; author estimates after 2009.

NOTE: For changes after 2009, we assumed continued depletion of groundwater storage at the same rate as 2008–09, the third year of the last drought. The exception was 2011, a very wet year, for which we assumed that levels remained stable. Since surface water availability has been tighter during this drought, this method may underestimate recent depletions.

WHAT IF THE DROUGHT CONTINUES?

To consider the impacts of continued drought, we assume that the dry, hot conditions of the past two years will persist for at least another two to three years. One caveat is that worse conditions—and worse impacts—are possible. For instance, 1977 was drier than the driest years of the current drought (technical appendix Figure A1). Another caveat is that droughts often have considerable geographic variability. For example, 2015 saw record-low snowpack in the Sierra Nevada and near-record-low runoff in the Central Valley. Yet conditions in some North Coast communities improved dramatically thanks to isolated, intense winter and spring rains.

Continued drought will put additional stress on both surface and groundwater resources (technical appendix Table A10). Because the state's major Central Valley reservoirs have already drawn down most of the reserve built up by the 2011 rains, surface water deliveries from the CVP, SWP, and local projects will have to primarily rely on annual precipitation, as they did this past year. This means water deliveries will stay at least as low as currently—and possibly even fall lower—depending on decisions made regarding reservoir management for fish and wetlands and salinity in the Delta. Low flows and high temperatures will exacerbate declines in water quality in rivers and streams.

Groundwater will remain the primary drought reserve. But in some parts of the agricultural heartland, this will come at increasing costs, including more energy for pumping, more dry wells, reduced crop yields as water quality falls, and more damage to infrastructure from sinking lands.

Four Key Areas of Concern

The drought has left no part of California untouched, and continued drought will pose added—and in some cases acute—challenges. The severity of threats varies across management areas, reflecting both underlying vulnerabilities to water scarcity and the degree to which managers have prepared for and adapted to drought. Cities and their suburbs, where most Californians live and work, have been adapting fairly well. Farms—the economy's largest water user—have also been adapting, but they are inherently more vulnerable. Rural communities are home to the most vulnerable Californians, facing both job losses and drinking water shortages. California's ecosystems are in crisis. Fish and waterbirds that rely on freshwater in rivers, estuaries, and

wetlands are under extreme stress, and extinctions are likely. And trees in California's forests are dying at record rates, raising risks of devastating wildfires.

CITIES AND SUBURBS

If this drought has one bright spot, it is that California's cities and suburbs—home to 95 percent of California's population and an even higher share of economic activity—have become considerably more resilient since the 1987–92 drought, despite the addition of more than eight million residents since that time.[14]

Impacts and Adaptations So Far

Whatever impacts the drought may be having on the California economy, they have not been significant enough to derail a strong economic expansion fueled by other economic advantages in the state. Since 2011, California's real GDP and nonfarm employment have been growing at a faster pace than the national economy as a whole.

In part, the economy's drought resilience reflects the small share of farming in the state's economy (1–2%), and the fact that California now has relatively few nonfarm industries that are particularly water sensitive. But it also reflects the preparation urban water utilities have made to withstand droughts.

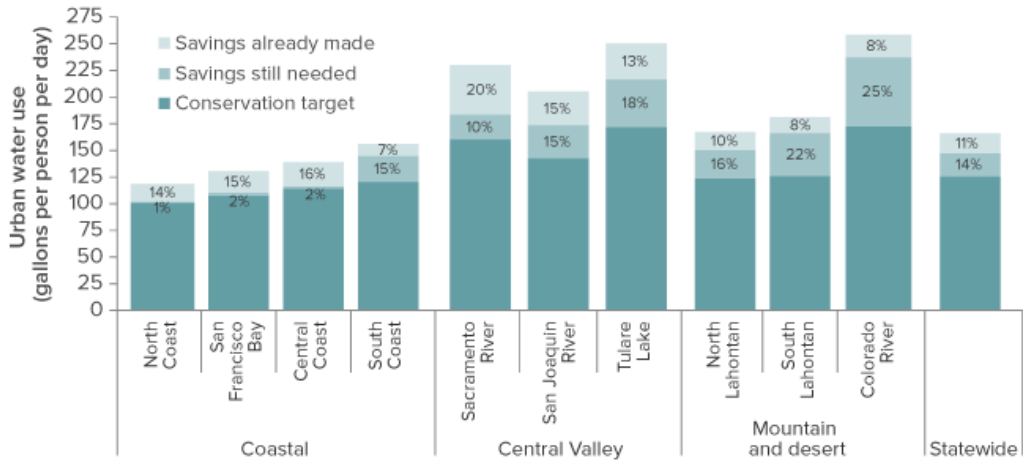
If this drought has one bright spot, it is that California's cities and suburbs have become considerably more resilient.

Since the early 1990s, water utilities have invested heavily in indoor conservation, surface and underground storage, new interconnections that enable supply sharing with neighboring agencies, use of recycled wastewater and stormwater, and water purchases through the state's water market.[15] This more-diversified portfolio enabled cities to enter this drought in good shape.

Improved regional cooperation is also helping cities cope. Water utilities are regularly sharing information and infrastructure and—where needed—supplies. As an example, Sacramento area agencies are collaborating to improve access to shared groundwater reserves as a back-up source for communities reliant on Folsom Reservoir, where water levels are low and falling.

Increased conservation is also a staple of the urban drought management toolkit. In May 2015, the State Water Board introduced a statewide urban conservation mandate, requiring 25 percent average savings compared to 2013. The mandate went further than many utilities would have gone on their own this year, given their local supply conditions. Statewide, utilities were nearly half way there (11%) by the time the mandate went into effect (Figure 4). In high-water-use regions the board set higher standards for water conservation. Attaining the target will require large reductions in outdoor water use, which often exceeds half of the urban total.[16] Although this will entail some initial costs and inconvenience, it need not diminish quality of life in California communities. The popularity of turf buyback programs—which give rebates to replace thirsty lawns with plants that use less water—suggests that Californians may be ready to permanently reduce urban outdoor water demand.[17]

Figure 4. Some communities are still well above state water conservation targets



SOURCE: Author estimates, using monthly urban water supply data from the State Water Resources Control Board. (See technical appendix Table A4 for details.)

NOTE: The figure shows per capita urban water use, including residential and commercial, institutional, and industrial customers. The "conservation target" is the targeted water use under the new state mandate, which went into effect in June 2015. "Savings already made" is the difference between water use in 2013 and the 12 months ending in May 2015. The North Lahontan region covers most of the northeastern Sierra; South Lahontan covers the eastern Sierra and high desert including Mono, Inyo, and parts of Kern, Los Angeles, and San Bernardino Counties; and the Colorado River region covers the southeastern portion of the state including Imperial and parts of Riverside, San Bernardino, and San Diego Counties.

If the Drought Continues

Can California's cities remain resilient? This question really has two parts: First, are water solutions available to avoid extreme scarcity? And second, will water management remain flexible enough to avoid large economic and social consequences?

Based on our conversations with water managers in major regions of the state,[18] the answer to the first question generally seems to be "yes." Many water utilities still have significant supplies in storage,[19] and their conservation programs are reducing near-term demands. Efforts are now underway to accelerate new investments in recycled wastewater, stormwater capture, groundwater clean-up, improved conveyance, and other measures.

Drought fixes to existing infrastructure are also in the mix. Examples include installing a lower water intake on Folsom Reservoir and pumping water upstream on the California Aqueduct and the Delta Mendota Canal to deliver water to locations north of Kern County groundwater banks and San Luis Reservoir.[20]

Lost hydropower production will have economic costs—on the order of $500 million in 2015—but recent increases in renewable energy sources have helped make up for shortfalls. And new efforts are reducing other water-related vulnerabilities of California's power grid—for instance, by making sure thermal power plants have adequate and diverse supplies for cooling, including recycled wastewater.[21]

For water utility managers, key issues appear to be cost (in particular, avoiding the most expensive solutions until necessary) and the pace of regulatory approvals for new projects. Recent legislation providing exemptions to the California Environmental Quality Act (CEQA) for recycled water project standards will help in this regard.[22] The state's emergency drought funding program (Table 1) has also aimed to speed up the disbursement of state bond funds to support new water projects.

Implementation of the conservation mandate sheds light on the second question: Will drought water management be flexible enough to avoid large costs? The mandate was adopted as an emergency measure, and its water savings will make it easier for many communities to weather a longer

drought. But it also raises some economic and social challenges. Because utilities lose money when water sales fall quickly, the mandate creates a fiscal crunch: net revenues are expected to fall by $500 to $600 million in 2015.[23] This will tap financial reserves when new investments to boost supplies may be needed. Sooner or later, utilities will need to adjust rates to make up the shortfall. Since a recent court ruling regarding Proposition 218 (a constitutional amendment that affects water pricing), utilities face new legal constraints in setting higher rates for higher levels of use.[24] And if they recoup their losses by raising fixed service fees rather than per-gallon charges, there are equity concerns because fixed fees hit lower-income households hardest.[25]

There can also be broader economic consequences if utilities indiscriminately apply conservation mandates to businesses. California is fortunate not to have many nonfarm businesses that require large volumes of water, and many businesses still have considerable room to conserve. But businesses that use water in their production processes—such as food and beverage processing—often have less flexibility than households to reduce water use without affecting competitiveness.[26] The new state mandate does not account for the fact that some communities have a much higher share of commercial and industrial water use than others.[27] Although larger utilities generally appear to be avoiding cutbacks that would cost jobs, utilities in some middle-sized, high-water-use communities have imposed across-the-board cuts on residents and businesses alike.

If the drought continues, both the state and water utilities should maintain some flexibility in applying conservation targets. Additional regulatory streamlining for urban supply projects may be warranted, as well as reform of the legal framework for rate setting. Urban areas—like farmers—would also benefit from improvements in the state's water market, which is not sufficiently transparent or flexible as a drought-management tool.[28] Over the longer term, the state should be encouraging utilities to continue to bolster supply investments as well as conservation efforts. Rigid conservation mandates can discourage such investments, because they can prevent communities from taking full advantage of the increased supplies.

FARMS

California's productive farm sector requires large volumes of water for irrigation, typically four times the annual use of cities.[29] This strong water dependency—along with the sector's sheer size—makes farming inherently vulnerable to droughts. Adaptation options are also more limited than for cities, which can generally afford higher-cost water supplies.

Impacts and Adaptations So Far

Like cities, California farmers have been adapting to water scarcity over the past few decades. They have made major investments in irrigation efficiency and shifted toward crops that generate higher revenues per unit of water used.[30] Some places (notably Kern County) have also invested in storing water in groundwater basins for use by local farmers and partner agencies in urban areas.[31]

Yet with the exception of new groundwater storage, these adaptations have generally not boosted drought resilience. In most places, irrigation efficiency has improved crop yields and quality, but not overall water availability.[32] That is because irrigation water in less efficient systems generally is not wasted; water not consumed by crops either returns to streams, where it is reused by others, or else percolates through soils to recharge aquifers.[33] Meanwhile, the long-term shift to high-revenue perennial nuts, fruits, and vines has made agricultural water demands more rigid, because these orchards must be watered every year to maintain farmers' investments.

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As a result, farmers have been hit hard by reduced surface water deliveries.[34] In 2014, Central Valley farms lost roughly a third of normal surface water supplies, or 6.5 million acre-feet (maf). In 2015, the deficit may rise to 8.7 maf. Economic losses from this cutback have been relatively modest so far because farmers in many places—including the southern Central Valley—have been able to pump additional groundwater: an extra 5 maf statewide in 2014 and as much as 6 maf in 2015.

Water trading has also helped keep the most profitable crops in production.[35] Strong commodity prices have also bolstered the farm economy during the drought, even encouraging new plantings of permanent crops such as almonds.

Statewide, farmers fallowed approximately 5 percent of cropland in 2014—mostly more flexible and lower-revenue field crops like rice—and that share is likely to increase slightly this year. The costs of fallowing and extra groundwater pumping—including the spillover effects on the rest of the economy—were on the order of $2.2 billion in 2014 and $2.7 billion in 2015. Direct costs for farmers were 3–4 percent of the roughly $47 billion in annual farm revenues.

Fallowing land also has both on- and off-farm effects on employment. Total farm employment has actually been increasing slightly despite the drought because the higher-revenue crops farmers are focusing on generally employ more people than the lower-revenue field crops that farmers are scaling back.[36] But with normal water supplies, California would have had an additional 7,500 full-, part-time, or seasonal farm jobs in 2014 and an additional 10,100 farm jobs this year. Taking into account spillover effects on the rest of the economy, there would have been an additional 17,000 jobs economy-wide in 2014 and 21,000 this year.

If the Drought Continues

A sharp fall in revenues or jobs statewide is unlikely. Instead, California should expect progressive increases in economic losses, particularly in the Central Valley, as yields on perennial crops decline from reduced watering and use of lower quality groundwater (Table 2 and technical appendix Table A5). Although groundwater pumping is becoming more costly, there are still abundant reserves in many places, and high commodity prices make this extra pumping affordable.

> Over the longer term, implementation of the 2014 Sustainable Groundwater Management Act (SGMA) will make California farming more resilient to future droughts.

Over the longer term, implementation of the 2014 Sustainable Groundwater Management Act (SGMA) will make California farming more resilient to future droughts. The concept, already used by many urban agencies, is to pump less—and recharge basins more—in wet and normal years. This makes groundwater more readily available (at lower cost) during droughts. And it lessens the threat of external costs in terms of local infrastructure damage from sinking lands and drying of shallower wells. Management actions under SGMA do not have to start until 2020, but banks are already changing their long-term farm lending practices with SGMA in mind—a sign that the market may help quicken the pace of implementation.[37]

In the near term, extra groundwater pumping is an important drought mitigation tool to reduce agricultural losses. But there is no system in place to mitigate the external costs of pumping. If the economic benefits from pumping outweigh these costs—as they well may—it could make sense to charge a mitigation fee to cover them rather than limit pumping during droughts.[38] If this proves too difficult, counties may wish to enact emergency ordinances that restrict new or deeper wells in areas of special concern.[39]

As with cities, farming would also benefit from improvements in the water market. Although trading has already helped somewhat, a more transparent, streamlined approval process could help move scarce water to the most economically productive farming areas, boosting both revenues and jobs.

RURAL COMMUNITIES

The drought is increasing hardship for California's small rural communities, which are already some of the state's most disadvantaged.

Impacts and Adaptations So Far

Farmland fallowing has cut jobs in some rural communities, and others have been hurt by declines in water-based recreational activities such as fishing and boating.[40] Drinking water supplies—already a problem in some areas because of contaminants such as nitrate—have been further

compromised by the drought.[41] Many rural households rely on shallow domestic wells or small, poorly funded community water supply systems. As of early July 2015, more than 2,000 dry domestic wells were reported, mostly in the Central Valley and Sierra, with more than half in Tulare County (technical appendix Table A7). Emergency water supply needs have also been identified for more than 100 small water community water systems around the state (technical appendix Table A6). Particulate air pollution from a combination of heat, dust, and fires has also increased in the San Joaquin Valley, likely exacerbating asthma and other health problems.[42]

State and federal governments recognized the vulnerability of rural communities early on and made emergency funding available for food and other support for impacted workers and for safe drinking water (Table 1).

Over the past two years, the state has significantly improved its emergency response for communities lacking drinking water. The multiple agencies involved have strengthened coordination to identify needs and deliver help.[43] Some community systems have gotten new wells and pipelines. In a few cases, people with dry domestic wells have been hooked up to local water systems. But in most cases, the solutions are stopgap: trucking in bottled water or delivering water to temporary holding tanks.[44] And in many places, the process for getting water to households in need is still too slow and difficult.

Farmland fallowing has cut jobs in some rural communities, and others have been hurt by declines in water-based recreational activities such as fishing and boating.

Only some counties (including Tulare) have a system for collecting information on dry wells, so it is likely that the scale of the problem is much larger than suggested by state data. State and federal funding rules are cumbersome, making it difficult to move quickly even on stopgap solutions. And the wait times to schedule well drillers to deepen or replace dry wells is very long—now typically 18 months.

If the Drought Continues

Community and domestic wells will run dry at an increasing pace, and emergency support programs will need to expand and improve. One priority is to make it easier for individuals to seek help if their wells run dry. Another is to strengthen the tracking system for addressing problems once they are identified. Longer-term solutions will also be needed to durably address both water supply and quality in these communities because many dry wells are unlikely to return to normal even after the rains return. The state has recently improved its institutional capacity to provide longer term assistance, and some new bond funds are available, but a long-term funding source is still needed to tackle this problem.[45]

ECOSYSTEMS

The most acute and severe impacts of this drought so far are on California's freshwater habitats and forested lands and on the biodiversity they support. These impacts stem, in part, from the severity of the drought and its combination of low flows and heat. More than a century of water and land practices have increased vulnerability by undermining the natural capacity of these ecosystems to handle occasional droughts.[46]

The environment doesn't have the same kinds of adaptation tools as other sectors—it generally can't pump more groundwater in dry times, for example.[47] But this troubling situation also reflects less investment in building drought resilience for the environment. California was unprepared for this environmental drought emergency and is now struggling to implement stopgap measures.

Here, we focus on three major management challenges of continued drought: risks to waterbirds of the Pacific Flyway from loss of wetlands, risks to native fishes from conditions in rivers and streams, and the growing potential for extreme wildfires.[48] Near-term water and land management changes can help address the urgent problems for waterbirds and fish, but this will require additional emergency funding.

WATERBIRDS

California is home to diverse populations of ducks, geese, shorebirds, and herons and is an essential stopping point on the Pacific Flyway. Wetlands in northeastern California and the Central Valley provide winter habitat for more than five million waterbirds.[49] Twentieth century land development drained most natural wetlands, so these birds now rely on a network of managed wetlands—intentionally flooded areas in federal and state refuges and on private lands.[50] They also make extensive use of flooded farmland, most notably rice farms that are flooded in the fall and winter to break down rice straw.[51]

Impacts and Adaptations So Far

The drought has dramatically reduced the amount of waterbird habitat. Water deliveries to refuges —already tight in normal times—were cut by 25 percent or more, and the sharp drop in rice acreage reduced the availability of flooded farmland.[52] In addition to reducing food supplies, reduced wetland habitat increases risk of disease because crowding can decrease water quality.

So far, management actions and lucky timing of late spring rains have helped stave off major declines in bird populations. Close coordination between wildlife refuges across California in the past year has also helped ensure that limited water is distributed to wetlands when it can provide the greatest habitat value for birds.

> California was unprepared for this environmental drought emergency and is now struggling to implement stopgap measures.

Another promising effort is paying farmers to make small adjustments in the timing and duration of flooding fields. For modest amounts of money, these “pop-up habitats” can be strategically located to make the most use of limited water availability. The Nature Conservancy’s BirdReturns is one such program, supported to date with philanthropic sources.[53] Federal funds support a similar program run by the Natural Resources Conservation Service.[54] These programs are prime examples of adaptively managing scarce resources to create a high return on investment.

If the Drought Continues

Risks of high bird mortality are increasing as the drought wears on. The Nature Conservancy estimates that refuges may face larger water cutbacks this coming winter, and that temporary wetlands in rice fields may be reduced by more than 85 percent.[55] Absent rains, food for ducks and geese will become critically scarce this coming fall precisely during the peak of bird migration.[56]

A continuation of current management efforts can help reduce ongoing drought impacts, but this will require dedication of both refuge water supplies and funds for purchasing farm water, which may become more costly as the drought wears on.

NATIVE FISHES

California is home to 129 species of freshwater fish, two-thirds of which are found only in the state. One hundred of these fishes are either already listed as threatened or endangered under federal and state Endangered Species Acts or in decline and on their way to being listed in the future.[57] Many are highly vulnerable to low flows and higher water temperatures, and this drought is taking a major toll.

Impacts and Adaptations So Far

Since 2013, rivers and streams throughout the state have been at record or near-record lows, with many waterways that would normally flow year-round becoming a series of disconnected pools or drying up (technical appendix Figure A4). Higher temperatures have increased stress on fishes, most notably salmon and trout, as well as some amphibians. Survey counts for estuarine fish such as delta smelt and longfin smelt are at or near record lows.

Emergency management actions have included drought-stressor monitoring and rescue operations by the Department of Fish and Wildlife (technical appendix Table A8). In several key salmon and steelhead streams, the State Water Board has ordered some water users to stop diversions or to reduce groundwater pumping that was depleting surface flows.[58] But, as noted above, the board

has also relaxed environmental flow standards on 35 occasions to accommodate urban and farm users (technical appendix Table A1).

While water managers have sought to manage the timing of flows in ways that benefit both fish and other water users, they have not always had that option. The drought has posed difficult trade-offs in managing scarce surface water, where goals of water supply, water quality, and fish flows often compete. This is best illustrated by ongoing efforts to preserve the 2015 cohort of winter-run Chinook salmon below Shasta Reservoir. Unplanned releases of warm water in 2014 caused a near-complete loss of wild-spawning winter-run eggs and fry.[59] Decisions made this year are likely to lead to a similar result, pushing this species very close or possibly to extinction. Restrictions on releases from Shasta Reservoir to try to correct these mistakes are affecting operations of Oroville and Folsom Reservoirs, reducing agricultural and urban supplies and making it difficult to meet salinity standards for water exports from the Delta.

If the Drought Continues

Eighteen native fish species appear to be at high risk of extinction in the wild, including most runs of salmon and steelhead and a diverse group of other fishes that reside in watersheds across the state.[60] Reasons include loss of rearing or spawning habitat due to reduced flows (an issue for all 18 species) and increased water temperatures (an issue for salmon, steelhead, and several other fish including delta smelt). The drought is also favoring conditions for invasive species that reduce the quality of habitat for some fish. For some salmon runs, an added stressor is the release of large numbers of hatchery-bred fishes, which can harm drought-stressed wild fish through competition, predation, or interbreeding that reduces the fitness of their offspring.

Beyond the fish rescue and monitoring efforts noted above, there is no comprehensive plan to address the potential for extinctions.

The drought has posed difficult trade-offs in managing scarce surface water, where goals of water supply, water quality, and fish flows often compete.

Near-term options for improving habitat in the wild are limited but could help in some cases. For instance, managing some smaller watersheds as refuges by restricting diversions and focusing restoration efforts could help some salmon runs. Better enforcement efforts may also help, especially where illegal diversions to marijuana farms and vineyards are depleting North Coast streams.[61]

And more generally, allowing a greater margin of safety on environmental flows for fish earlier in the season could improve chances of fish survival, though this would reduce availability of water for farms and cities. Creative approaches to acquire water and use it strategically, as in the BirdReturns case, could reduce conflict. Although the Department of Fish and Wildlife has tried to secure additional flows through voluntary agreements, the response has been limited. A sustained effort utilizing emergency funding to purchase water in selected watersheds may be needed to prevent extinctions.[62]

For many of these fish, it will also be prudent to develop a plan for protecting the species in captivity and rebuilding populations following the drought. This would mean expanding the state's program of conservation hatcheries—those specifically run to protect biodiversity. This would require rapid and substantial investments of resources because the state currently lacks the facilities, funding, and technical expertise to systematically pursue such an approach.[63] This approach would also be controversial because it would likely require shifting most current hatcheries away from producing fish for commercial and recreational fisheries, which are already taking a financial hit from fewer fish during this drought.[64]

FORESTS AND WILDFIRES

Conifer and hardwood forests cover roughly a quarter of California. These forests are naturally wildfire prone, and a century of suppressing fires has made them much denser, increasing the likelihood of large, devastating fires.[65]

Impacts and Adaptations So Far

Hotter temperatures, moisture deficits, and insect infestations are killing trees at a rapid pace. These conditions lead to severe wildfires, posing significant threats to public safety, power lines and other infrastructure, water supply, air quality, and wildlife. Since the start of this drought, California has experienced two of the three largest fires in recorded history (technical appendix Figure A9). When fires burn hot over large areas—as in the 2013 Rim Fire in and near Yosemite National Park—there is also a concern that conifer forest ecosystems may not recover.

CALFIRE's strategy for this drought, in partnership with federal and local authorities, is to reduce the potential for large, destructive fires by suppressing fires as quickly as possible.

If the Drought Continues

California faces significant risk of more devastating fires like the Rim Fire over the next two to three years.

Given the scale of wildfire risk, CALFIRE's fire suppression strategy is the only real near-term option. But this strategy could become harder as the drought wears on and forest conditions degrade. Management options to reduce severe fire risk will be of limited value in the short term, given the problem's vast scale. Fuel reduction efforts that can reduce fire intensity—including thinning and reintroduction of more frequent, low-intensity fires—require sustained efforts over large areas for decades. Although some efforts are underway on private lands, fuel reduction efforts on federal land—roughly half the forested lands in California—have proven difficult for a variety of reasons, including permitting.[66]

Building Drought Resilience

The ongoing drought has served as a stress test for California's water management systems, and continuing drought will test them further. Managers and businesses are employing an array of tools and strategies. Many of these have helped California reduce drought impacts. Others will need refinement and further investment.

Current drought actions fall into three general categories: those that are working well and may need minor improvements; those that are still works in progress, requiring support and refinement; and those that require substantial policy reforms or investments.

WHAT'S WORKING

- **Diversified water portfolios:** Historic investments in diversifying water supply sources and managing demand have yielded great benefits. Further investments could be aided by streamlined permitting, as with recent CEQA exemptions for recycled wastewater standards.
- **Regional infrastructure:** Coordinated infrastructure development among multiple agencies has built regional diversity in water supplies and reduced vulnerability.
- **Coordinated emergency response:** Unprecedented coordination among state, federal, and local agencies has improved emergency response and reduced the economic costs of the drought.

WORKS IN PROGRESS

- **Mandatory conservation:** Although highly successful at reducing urban use, statewide conservation mandates can have unintended economic and social consequences if they are not implemented with some flexibility. They can reduce local financial capacity and appetite for new supply investments, and they can cost jobs if they are not considerate of business water use. They can also convey an overly negative impression about urban water conditions in the state—potentially dampening future business investments.
- **Water pricing:** Many urban utilities have encouraged conservation with tiered water pricing, but they now face significant uncertainty about the legality of these rates. Low-income households are vulnerable if utilities make up for lost water revenues with higher fixed monthly fees. Legal reforms to Proposition 218 may be needed to support both efficient and equitable pricing.[67]

- **Rural community supplies:** Some domestic and small community water supplies will always be vulnerable during droughts, and emergency response has improved. But the mechanisms to report dry wells should be strengthened and response times shortened for getting water to affected residents. Continued progress is also needed to provide long-term safe water solutions to rural communities.

- **Groundwater management:** Groundwater is a vital drought reserve, and extra pumping has reduced the economic costs of the drought. The new Sustainable Groundwater Management Act will boost the long-term drought resilience of California's farming sector and reduce negative impacts of unsustainable pumping. State and federal support for key technology and tools—such as groundwater models and well metering—can enable locals to move faster in implementing the law.[68] Addressing acute short-term impacts of pumping, such as infrastructure harm from sinking lands, may require charging new pumping fees or limiting new wells in some areas.

- **Water trading:** Water trading has helped reduce the economic costs of the drought so far, and it will be vital if the drought continues. But the market is not sufficiently transparent or flexible. Processes for approving trades are complex and often opaque. Little information is publicly available about trading rules, volumes, or prices.[69]

- **Waterbird management:** The risks to waterbird populations can be reduced by coordinating the management of water on refuge wetlands and flooded farm fields. State and federal investment in creative approaches, such as programs that pay farmers to flood fields, can yield great benefits with limited water and funds.

DIFFICULT WORK AHEAD

- **Improving the curtailment process:** In principle, California's seniority-based water-rights system is designed to handle droughts. But making it work well will require better information on water availability and use, clearer state authority, and more effective enforcement.

- **Modernizing water information:** To facilitate all facets of water management—including trading, curtailments, and environmental flows—the state will need to make major investments in the collection, analysis, and reporting of water information.[70] This includes updating models to consider the extreme temperature and flow conditions of modern droughts.

- **Managing wildfires:** The stopgap measure of suppressing fires during drought may work in the short-term, but a long-term strategy of improved forestry and fire management—with strong federal participation—is needed.

- **Managing surface water trade-offs:** The state and federal governments have not gone through the difficult exercise of defining and prioritizing objectives among competing uses of scarce supplies, especially when managing reservoirs. The difficulties of managing Shasta Reservoir to protect wild salmon highlight the need to do better forecasting and build in a margin of safety for environmental flows.

- **Avoiding extinctions of native fish:** Continued drought will likely lead to multiple extinctions of native fish species in the wild, and California lacks a plan to address this. More cautious strategies to save reservoir water for environmental flows may help, and purchasing water to boost flows could reduce conflicts. It may also be prudent to make immediate investments in conservation hatcheries.

- **Building environmental resilience:** Beyond stopgap measures, California also needs to invest in improving the capacity of our native biodiversity to weather droughts and a changing climate. This requires a plan and the funding to put it into action.[71]

Conclusion

Since statehood, California has developed water supply infrastructure and supporting laws to manage water scarcity during droughts. Yet the intensity and duration of the ongoing drought is stress-testing the state's management systems. In many respects, this drought is California's dry run for a drier, warmer future.

Californians at all levels have shown a commitment to reducing the economic, social, and environmental harm from the drought with many successes. Yet if the drought continues for another two to three years, the challenges will grow. Addressing the most pressing threats will require stopgap measures—for instance, delivering drinking water supplies to rural residents with dry wells, setting up conservation hatcheries to prevent fish extinctions, and making spot decisions about tough trade-offs. But the state also needs to leverage the lessons of the past four years to build longer-term drought resilience. That way, we will be more prepared for future droughts and have less need for stopgap, emergency solutions.

NOTES

1. See technical appendix Figure A1 and related discussion.
2. J. Mount and D. Cayan. "A Dry Run for a Dry Future" (PPIC blog, May 27, 2015).
3. A list of state drought actions.
4. Some long-range models indicate that a strong El Niño may improve rainfall in California next winter, but the reliability of these forecasts is low and the relationship between El Niño and precipitation in Northern California is weak. See D. Cayan and J. Mount, "Don't Count on El Nino to End the Drought," (PPIC blog, July 9, 2015).
5. We spoke with close to 50 individuals, representing 11 state and federal agencies, urban water agencies in five regions, agricultural water supply, food processing, and lending activities, and nonprofits working on rural water supply and environmental management.
6. CVP settlement and exchange contractors, a group of agricultural districts that usually get 100 percent of their contractual amounts, received 75 percent in 2014, and may receive just 55 percent in 2015. CVP urban customers south of the Delta, including Santa Clara Valley Water District, were cut from the usual 75 percent to 25 percent. Some CVP agricultural contractors have received 0 percent of their contracts since 2014 (down from a 2008–13 average of 64% for those located north of the Delta and 39% for those located south of the Delta). SWP Feather River Settlement Agreement holders, agricultural districts that usually get 100 percent of their contracts, got only 50 percent in 2015. Regular SWP urban and agricultural contractors, who received an average of 50 percent from 2008–13, got just 5 percent in 2014 and 20 percent in 2015.
7. For instance, the Los Angeles Aqueduct, which conveys water to LA from Mono Lake and Inyo County, is projected to deliver just 32,000 acre-feet this year: the lowest since its construction (mostly from pumped groundwater rather than snowmelt runoff). Deliveries since 2008 have averaged 150,000 acre-feet/year.
8. See for instance D. Kasler and R. Sabalow, "Water Rights Ruling a Setback for California Drought," *Sacramento Bee*, July 10, 2015.
9. See for instance F. Nirappil, "California Drought: Regulators Say First Water Diversion Prosecution Aided by Detailed Records," Contra Costa Times, July 23, 2015. For a discussion of information needs, see J. Mount et al., *Policy Priorities for Managing Drought* (PPIC, 2015).
10. California's groundwater basins hold at least three times as much usable water as state surface reservoirs, and a large share of surface reservoir storage is for seasonal uses, not carryover storage for dry years. See J. Lund et al., *California's Water: Storing Water* (PPIC, 2015).
11. For groundwater use from 1998 to 2010, see C. Chappelle et al., *Reforming California's Groundwater Management* (PPIC, 2015). Recent estimates of more than 50 percent are based on work by R. Howitt et al., described in technical appendix Table A5.
12. For a general overview, see California Department of Water Resources, *Summary of Recent, Historical, and Estimated Potential for Future Land Subsidence in California*, 2014. During the drought of the late 2000s, the US Geological Survey found land sinking, or subsidence, rates ranging from 1 to 21 inches over a three-year period. These rates are likely to be accelerating with the pumping now occurring. (M. Sneed et al., *Land Subsidence along the Delta–Mendota Canal in the Northern Part of the San Joaquin Valley, California, 2003–2010*: US Geological Survey Scientific Investigations Report 2013-5142.) For a discussion of impacts to Sack Dam, where continued subsidence will cost local farmers $10 million to move water, see "California farmers dig deeper for water, sipping their neighbors dry," *New York Times*, June 5, 2015. Subsidence-related damage to a bridge over a canal in Fresno County will cost $2.5 million to repair. See "Groundwater pumping causing Central Valley bridges to sink," KSFN, July 21, 2015.
13. Basins identified as critically overdrafted need to meet this timeline. Other priority basins have an additional two years to adopt and start implementing their plans. The law gives local agencies the authority to implement the plans, including the ability to measure use and charge fees for pumping. The State Water Board can intervene if it deems local efforts inadequate.
14. The urban population share is from the 2010 US Census. For a discussion of the economic statistics in this section, including the urban economy's share of economic activity and recent GDP and employment trends, see the technical appendix discussion of nonfarm economic impacts.

15. For instance, the Metropolitan Water District of Southern California has increased storage more than 13-fold since the early 1990s (Metropolitan Water District of Southern California, Regional Progress Report. Implementing the Diversified Resource Portfolio. February 2014, p. 3). See our map of per capita water use trends. For a discussion of water trading trends, see technical appendix Figure A5.
16. E. Hanak et al., *California's Water: Water for Cities* (PPIC, 2015).
17. The largest program is run by the Metropolitan Water District of Southern California. Following the success of a $100 million rebate program, Met's board approved an additional $350 million in rebates—enough to replace roughly 4,000 acres of turf. The program was fully subscribed within the first month. M. Stevens and M. Moran, "Southland Water District Ends Popular Lawn-Removal Rebate Program," *Los Angeles Times*, July 10, 2015.
18. We spoke with officials from urban water agencies about conditions in their regions in the Sacramento area, North Coast, San Francisco Bay Area, Fresno area, and Southern California.
19. For many Central Valley cities, this includes substantial groundwater reserves. San Francisco's Hetch Hetchy reservoir, which serves many Bay Area communities, began this summer at 95 percent capacity. Metropolitan Water District of Southern California's reserves were substantially diminished last year, but they began the summer with nearly 1.2 million acre-feet in dry year storage, including surface reservoirs on the Colorado River system and groundwater basins (Metropolitan Water District of Southern California. Report: Water Surplus and Drought Management: Attachment 1 2015 WSDM Storage Detail. April 14, 2015). Met member agencies also have significant underground reserves.
20. The Santa Clara Valley Water District has shelved its plan to ship supplies north from storage in Kern County for the time being. (P. Rogers, "California Drought: Plans to Make State Water Project Flow Backward Shelved for This Year," *Mercury News*, May 4, 2015). But in June 2015, the City of Tracy and some agricultural districts began pumping water north from the San Luis Reservoir through the Delta Mendota Canal (G. Warren, "Emergency Drought Project Reverses Flow in Delta-Mendota Canal," KXTV Sacramento, June 30, 2015.)
21. See the discussion of electricity in the technical appendix. California's dependence on hydropower has significantly declined over time, from more than 30 percent of electricity use in the 1960s to an average of just 12 percent since 2000. The supply of other renewables (solar, wind) has tripled in recent years. Thermal power plants have been reducing water use and transitioning to recycled water since the early 2000s, and recent efforts have focused on reducing vulnerability for plants dependent on unreliable surface water sources.
22. H. McCann and C. Chappelle, "Drought Bills: Small Changes, High Impact" (PPIC blog, June 30, 2015).
23. See the discussion of urban water utilities in the technical appendix. The fiscal challenge for utilities arises because the majority (typically 70-80%) of their costs are fixed, while a similar proportion of their bill is variable, tied to the volume of water sold. The estimate of net revenue losses is from S. Moss et al., *Executive Order B-29-15 State of Emergency Due to Severe Drought Conditions Economic Impact Analysis* (M. Cubed, 2015); it excludes the losses from voluntary conservation already achieved before the mandate went into effect.
24. The case involves tiered water rates in the City of San Juan Capistrano. See the discussion of urban water utilities in the technical appendix.
25. E. Hanak, "The High Cost of Drought for Low Income Californians" (PPIC blog, June 18, 2015).
26. This is especially true for businesses that have already made significant investments in reusing processing water, for instance. For a review of potential impacts of the drought on water-sensitive activities, see the discussion of nonfarm economic impacts in the technical appendix.
27. The conservation tiers for each community were set based on per capita residential use, but the target it is being applied to total urban water use.
28. See the discussion of water markets in the technical appendix, including Figure A5 on market trends.
29. See J. Mount et al., *Water Use in California* (PPIC, 2014) and E. Hanak et al., *California's Water: Water for Farms* (PPIC, 2015).
30. For shifts in crop types, see Figure 3.7 in E. Hanak et al., *Managing California's Water* (PPIC, 2011). For irrigation efficiency trends, see G. Tindula et al., "Survey of Irrigation Methods in California in 2010," *Journal of Irrigation Drainage Engineering*, 2013, Vol. 139(3): 233-238.
31. See E. Hanak and E. Stryjewski, *California's Water Market, By the Numbers: Update 2012* (PPIC, 2012).
32. See J. Lund et al., "Taking Agricultural Conservation Seriously," (Californiawaterblog.com, March 15, 2011).
33. For cities and suburbs, conservation usually results in system-wide savings. Because so many Californians live in coastal areas, saving water indoors reduces outflows of treated wastewater to the ocean. And across the state, saving water outdoors by replacing turf with lower-water landscapes saves water, without reducing economic activity.
34. Data on farm impacts are from analyses done by the UC Davis Center for Watershed Sciences for the California Department of Food and Agriculture. See technical appendix Table A5 and related discussion.
35. See the discussion of water marketing in the technical appendix, including Figure A5 on market trends.
36. J. Medellín-Azuara et al., "California Drought Killing Farm Jobs Even as They Grow" (Californiawaterblog.com, June 8, 2015).
37. For long-term loans, banks are requiring farms to have multiple water sources—not just groundwater. This should limit the expansion of new orchards onto non-irrigated ranchland.
38. Little information is available on the costs of subsidence in agricultural areas. Examples of local infrastructure damage described above (see note 12) suggest these costs may not always be very high—e.g., $2.5 million for a bridge repair, $10 million for conveyance changes from a local reservoir—in part because these areas are not as built up as cities.
39. Such ordinances should be temporary, in anticipation of the adoption of sustainable pumping rules under SGMA. Because the rights to use groundwater in California are not based on seniority, but rather on ownership of land overlying the basin, it does not necessarily make sense for local agencies implementing SGMA to give priority to those with existing wells. Instead, they may wish to apportion pumping rights based on acreage, irrespective of the volumes current being pumped. Either way, a cap and trade system, which facilitates the trading of pumping rights within the basin, can help lessen the overall costs of implementation.

40. For fishing and water-based recreation, see the discussion of nonfarm economic impacts in the technical appendix.
41. For a discussion of drinking water quality issues in rural communities, see E. Hanak et al., *Paying for Water in California* (PPIC, 2014) and T. Harter et al., *Addressing Nitrate in California's Drinking Water with a Focus on Tulare Lake Basin and Salinas Valley Groundwater.* Report for the State Water Resources Control Board Report to the Legislature. (Center for Watershed Sciences, University of California, Davis, 2012).
42. See discussion of drought-related public health issues in the technical appendix.
43. For the state, this includes the State Water Board, the Department of Water Resources, the Department of Housing and Community Development, the Office of Emergency Services, and the Governor's Office of Planning and Research. County officials are also involved, as well as local non-profits and in some cases nearby water districts.
44. There are legal constraints to providing state funding to directly invest in private property improvements.
45. Recent reforms include the creation of a special office within the State Water Board to support funding for disadvantaged communities and legislation that authorizes the board to require consolidation of small systems. Proposition 1, the new water bond, also contains more than $500 million for small rural water and wastewater systems. State and federal funds are typically restricted to covering capital costs, whereas some systems will also need support for operations. See E. Hanak et al., *California's Water: Paying for Water* (PPIC, 2015). The new law that makes well logs public (Senate Bill 83, June 2015) should also help, because it makes it possible to project likely areas where wells will go dry with falling groundwater levels. This information will be useful for well owners and for focusing emergency state support.
46. See chapter 5 of E. Hanak et al., *Managing California's Water: From Conflict to Reconciliation* (PPIC, 2011).
47. One exception is wetlands, where groundwater can replace lost surface flows.
48. Other species are also vulnerable, including many terrestrial animals and plants. For most species, including some of the populations discussed in the text, the state lacks sufficient monitoring information to either gauge drought impacts or guide management.
49. See Central Valley Joint Venture, accessed July 9, 2015.
50. Managed wetlands account for a relatively small share of water use in California: typically 1.5 million acre-feet, or less than 2 percent of the total (J. Mount et al., *Water Use in California*, PPIC, 2014).
51. N. Seavy et al., "Farms That Help Wildlife," (PPIC blog, April 21, 2015) and J. Mount et al., *California's Water: Water for the Environment* (PPIC, 2015).
52. Rice acreage fell from an average of 567,000 acres in 2010–13 to just 434,000 acres in 2014 (-24%), and acreage in 2015 is projected at 385,000 (-32%) (US Department of Agriculture, National Agricultural Statistics Service, California Acreage Reports, accessed July 28, 2015). Tight water conditions are also reducing the acreage that gets flooded post-harvest.
53. The Nature Conservancy California, "Precision Conservation," accessed July 9, 2015.
54. The program is called the Critical Waterbird Habitat Fund Pool. Whereas the BirdReturns program uses an auction to determine payments, the NRCS program makes fixed payments.
55. Personal communication, Jay Ziegler, The Nature Conservancy, July 8, 2015.
56. Unpublished modeling work, Ducks Unlimited. This modeling was specific to ducks and geese, but the shortfall in habitat could impact shorebirds as well.
57. P.B. Moyle et al., "Rapid decline of California's native inland fishes: a status assessment." *Biological Conservation*, 2014, Vol. 144(10): 2414–2423; P.B. Moyle et al., "Climate change vulnerability of native and alien freshwater fishes of California: a systematic assessment approach," *PLoS One* 2013; and P.B. Moyle et al., *Fish Species of Special Concern in California*. Sacramento: California Department of Fish and Wildlife, 2015.
58. This includes periodic curtailment of diversions on Antelope Creek and Deer Creek since 2014 to support spring-run Chinook salmon, and recent orders to stop groundwater use on landscapes on several creeks in the Russian River watershed to support coho salmon and steelhead.
59. J. Mount, "Better Reservoir Management Would Take the Heat Off Salmon" (PPIC blog, June 23, 2015).
60. See technical appendix TableA9 and related discussion for a list of the species, the methodology used for this assessment, and a discussion of potential management actions.
61. C. Chappelle and L. Pottinger, "California's Streams Going to Pot from Marijuana Boom" (PPIC blog, July 23, 2015).
62. The development of native fish-oriented flow regimes below many dams would also be beneficial. See T. Grantham et al., "Systematic screening of dams for environmental flow assessment and implementation," *Bioscience*, 2014, Vol. 64: 1006–1018.
63. Some species are already kept in captivity with the goal of preventing extinction (such as delta smelt, Central Coast coho salmon, McCloud River redband trout, and Central Valley winter-run Chinook salmon). The use of conservation hatcheries will be more difficult for fish that do not already have captive populations or populations that live outside of their native range. See technical appendix Table A9 and related discussion.
64. For some fishery sector statistics, see technical appendix Figure A8 and related discussion.
65. P.J. McIntyre et al., "Twentieth-century Shifts in Forest Structure in California: Denser Forests, Smaller Trees, and Increased Dominance of Oaks," *Proceedings of the National Academy of Sciences*, 2015, Vol. 112(5): 1458–1463.
66. The federal government owns 55 percent of forests and woodlands in California (California Department of Forestry and Fire Protection: Forest and Rangelands 2010 Assessment). On permitting challenges on federal lands, see M. North et al., "Constraints on Mechanized Treatment Significantly Limit Mechanical Fuels Reduction Extent in the Sierra Nevada," *Journal of Forestry*, 2014, Vol. 113(1): 40–48.
67. See E. Hanak et al., *Paying for Water in California* (PPIC, 2014).
68. The Center for Irrigation Technology at Fresno State University estimates that only about a third of wells are now metered; such metering can be useful for efficient on-farm water use as well as groundwater basin management. See the interview with David Zoldoske in L. Pottinger, "The Challenges of Getting More Crop per Drop," (PPIC blog, July 28, 2015).

69. See the discussion on water markets in the technical appendix.
70. Some promising recent changes in this direction include new reporting and measurement requirements for surface water diversions. See H. McCann and C. Chappelle, "Drought Bills: Small Changes, High Impact" (PPIC blog, June 30, 2015).
71. One promising approach to environmental drought planning comes from Australia. See J. Mount et al., *Policy Priorities for Managing Drought* (PPIC, 2015).

ACKNOWLEDGMENTS

We wish to thank the many individuals who provided information and insights on drought management through interviews conducted in late June and July 2015. We also thank the following individuals for very helpful reviews of a draft version of this report: Richard Howitt, Eric McGhee, David Mitchell, Patrick Murphy, Tim Quinn, Lester Snow, and Kathy Viatella. Lori Pottinger, Mary Severance, and Lynette Ubois provided expert editorial guidance and support. Any remaining errors are entirely the responsibility of the authors.

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Josué Medellín-Azuara is a research scientist at the Center for Watershed Sciences at the University of California, Davis who focuses on water resources economics. His professional experience includes project and environmental management positions for industry and consulting for nongovernmental organizations such as the Natural Heritage Institute, the Stockholm Environment Institute, El Colegio de México, The Nature Conservancy, and the World Bank. He has directed modeling and research projects on water supply, remote sensing of water use, salinity and nitrate problems, and adaptation to climate change in California. He holds a master's degree in agricultural and resource economics and a PhD in ecology from UC Davis.

Peter Moyle is Distinguished Professor in the Department of Wildlife Fish and Conservation Biology and associate director of the Center for Watershed Sciences at the University of California, Davis. He has been researching the ecology California's freshwater and estuarine fishes since 1969. He has coauthored numerous papers on the ecology, status, and trends of California's diverse and endemic fishes, including salmon and trout. His present research focuses on climate change, effects of drought on fishes, and strategies for ecological reconciliation. He is lead author of *Suisun Marsh: Ecological History and Possible Futures* (2014, UC Press), which reflects his 40 years of study of fish and water issues in the San Francisco Estuary. He has also studied fish and water issues in Botswana, Sri Lanka, and Spain.

Nathaniel Seavy is research director of the Pacific Coast and Central Valley Group at Point Blue Conservation Science Organization. His research is focused on the ecology and conservation of riparian ecosystems, understanding bird migration and preparing for the ecological effects of climate change, and applying science to conservation decision making and public policy. He has traveled all across North America, Central America, and Africa conducting various research projects and has published more than 45 peer-reviewed scientific papers and book chapters in journals such as *Ecological Applications*, *Journal of Wildlife Management*, *Biological Conservation*, *Conservation Biology*, and *PLoS ONE*. He holds a PhD in zoology from the University of Florida.

OTHER PUBLICATIONS

Reforming California's Groundwater Management
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Glen Canyon Dam Adaptive Management Program
Adaptive Management Work Group Meeting, August 26-27, 2015

DoubleTree by Hilton, 2100 South Priest Drive, Tempe, AZ 85282, 480-967-1441

Wednesday, August 26, 2015
Webinar Information:
https://ucbor-events.webex.com/ucbor-events/onstage/g.php?MTID=ea8cc75105f323e19735a6274e6b25f74

Phone: 877-913-4721 Participant Passcode: 3330168

D R A F T A G E N D A

START TIME [1] (Duration)	Wednesday, August 26, 2015 Topic, Presenter, and Purpose[2]	Materials/ Tabs
9:30 a.m. (:30)	**Welcome and Administrative** – Jennifer Gimbel, Secretary's Designee *Information, discussion, and possible action* • Introductions and Determination of Quorum (13 members) • Approval of May 28, 2015, Meeting Minutes • Action Item Tracking Report • Progress on Nominations and Reappointments • Scott VanderKooi new Grand Canyon Monitoring and Research Center (GCMRC) Chief • Introduction of new Science Advisor • Adaptive Management Work Group (AMWG) Charter Renewal • Commemorating Jason Thiriot	Agenda Draft Minutes/ Action Items
10:00 a.m. (:30)	**FY 2016 Budget and Work Plan** – Glen Knowles, Bureau of Reclamation; Scott VanderKooi, Grand Canyon Monitoring and Research Center; and Shane Capron, Technical Work Group Vice-Chair and Budget Ad Hoc Group Chair *Information, discussion, and action* • Presentation (15 minutes) • Q&A, discussion, and action (15 minutes) **Motion Recommended by the TWG**: AMWG recommends to the Secretary of the Interior for her approval the Final FY 2015-17 Triennial Budget and Work Plan from the Bureau of Reclamation and the Grand Canyon Monitoring and Research Center as recommended by AMWG August 28, 2014 for implementation in FY 2016, with a FY 2015 corrected CPI of 1.7%, and corrections to the GCMRC overhead rates.	Budget
10:30 a.m. (:45)	**Basin Hydrology and 2016 Hydrograph** – Katrina Grantz, Bureau of Reclamation; Robert Snow, Department of the Interior; Vineetha Kartha, Technical Work Group Chair *Information, discussion, and action* • Presentation (30 minutes) • Q&A, discussion (15 minutes) **Motion Recommended by the TWG**: Please see AIF.	Hydrology and Hydrograph

START TIME [1] (Duration)	Wednesday, August 26, 2015 Topic, Presenter, and Purpose[2]	Materials/ Tabs
11:15 a.m. (:30)	**Lees Ferry Recreational Trout Fishery Management Recommendations** – John Jordan, International Federation of Fly Fishers/Trout Unlimited; John Hamill, Theodore Roosevelt Conservation Partnership *Information and discussion* • Presentation (15 minutes) • Q&A, discussion (15 minutes)	Stakeholder Perspective
11:45 a.m. (1:00)	**LUNCH**	
12:45 p.m. (3:15)	**Non-Market Values for Alternative Operation of Glen Canyon Dam Panel** – Lucas Bair**,** Grand Canyon Monitoring and Research Center; Michael Hanemann, Arizona State University; Holly Doremus, UC Berkeley Law; John Duffield, University of Montana; Hank Jenkins-Smith, University of Oklahoma *Information and discussion* • Presentation (2 hours 15 minutes) • Break at approximately 2:00 pm (15 minutes) • Questions, responses, discussion (45 minutes)	Socio-economic panel
4:00 p.m. (:45)	**Stakeholder's Perspective and HFE Effect on Beaches – the View from Camp** – Sam Jansen, Grand Canyon River Guides (GCRG); and Paul "Zeke" Lauck, GCRG Adopt-A-Beach Coordinator *Information and discussion* • Stakeholder Perspective (15 minutes) • HFE Impact on Camping Beaches (15 minutes) • Q&A, discussion (15 minutes)	Stakeholder Perspective
4:45 p.m. (:15)	**Public Comment**	
5:00 p.m.	**ADJOURN FOR THE DAY**	

[1] Every effort will be made to adhere to the schedule and agenda, but on occasion, for unforeseen reasons, some modifications may occur.

[2] Action may be by consensus or a vote; and either may be a recommendation to the Secretary of the Interior or feedback to presenter(s) or to subordinate groups.

Glen Canyon Dam Adaptive Management Program
Adaptive Management Work Group Meeting, August 26-27, 2015
DoubleTree by Hilton, 2100 South Priest Drive, Tempe, AZ 85282, 480-967-1441

Thursday, August 27, 2015
Webinar Information:
https://ucbor-events.webex.com/ucbor-events/onstage/g.php?MTID=eb0e5737636fcca798a5654597d6b3650
Phone: 877-913-4721 Participant Passcode: 3330168

D R A F T A G E N D A

START TIME [1] (Duration)	Thursday, August 27, 2015 Topic, Presenter, and Purpose [2]	Materials/ Tabs
8:00 a.m. (:15)	**Welcome and Administrative** – Jennifer Gimbel, Secretary's Designee ● Introductions and Determination of Quorum (13 members)	
8:15 a.m. (:30)	**Havasu Creek Translocation Update** – Martha Hahn, National Park Service, Grand Canyon National Park *Information and discussion* ● Presentation (15 minutes) ● Q&A, discussion (15 minutes)	Science Updates
8:45 a.m. (1:00)	**Basin Fund and Revenue Overview** – Lynn Jeka, Western Area Power Administration *Information and discussion* ● Presentation (45 minutes) ● Questions, responses, and discussion (15 minutes)	Power Updates
9:45 a.m. (:15)	**BREAK**	
10:00 a.m. (1:00)	**Lake Mead Issues and Lower Basin Shortage Preparedness** – Jayne Harkins, Colorado River Commission of Nevada; Tanya Trujillo, Colorado River Board of California; Tom Buschatzke, Arizona Department of Water Resources *Information and discussion* ● Presentation (40 minutes) ● Questions, responses, and discussion (20 minutes)	Lower Basin Report
11:00 a.m. (:45)	**Tribal Liaison Report** – Sarah Rinkevich, Federal Tribal Liaison for the Glen Canyon Dam Adaptive Management Program; Loretta Jackson-Kelly, Hualapai Tribe *Information and discussion* ● Presentation (30 minutes) ● Q&A, discussion (15 minutes)	Tribal Liaison Report
11:45 a.m. (1:00)	**LUNCH**	

START TIME [1] (Duration)	Thursday, August 27, 2015 Topic, Presenter, and Purpose [2]	Materials/ Tabs
12:45 p.m. (1:00)	**GCMRC Science Updates** – Scott VanderKooi and Paul Grams, Grand Canyon Monitoring and Research Center *Information and discussion* ● Presentation (45 minutes) ● Questions, responses, and discussion (15 minutes)	GCMRC Updates
1:45 p.m. (1:00)	**Long-Term Experimental and Management Plan EIS** – Glen Knowles, Reclamation; Rob Billerbeck, National Park Service; Kirk LaGory, Argonne National Laboratory *Information, discussion, and feedback* ● Status update on process and schedule (30 minutes) ● Q&A and discussion (30 minutes)	LTEMP EIS
2:45 p.m. (:05)	**Public Comment**	
2:50 p.m. (:10)	**WRAP-UP and ADJOURN** – Jennifer Gimbel, Secretary's Designee ● Please fill out the meeting evaluation sheet at your place.	
3:00 p.m.	**ADJOURN**	

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[2] Action may be by consensus or a vote; and either may be a recommendation to the Secretary of the Interior or feedback to presenter(s) or to subordinate groups.

Glen Canyon Dam Adaptive Management Work Group
Agenda Item Information
August 26-27, 2015

Agenda Item

Lake Mead Issues and Lower Basin Shortage Preparedness

Action Requested

Information item only; we will answer questions but no action is requested.

Presenter(s)

Jayne Harkins, Colorado River Commission of Nevada
Thomas Buschatzke, Arizona Department of Water Resources
Tanya Trujillo, Colorado River Board of California

Previous Action Taken

N/A

Relevant Science

N/A

Background Information

Colorado River water is apportioned, regulated and managed among the seven basin states (Arizona, California, Colorado, Nevada, New Mexico, Utah and Wyoming) and the Republic of Mexico through compacts, treaty, federal laws, court decisions, decrees, contracts, regulatory guidelines and other documents, collectively known as the "Law of the River".

To prepare for possible shortages in the Lower Basin and to guide Colorado River operations during low reservoir conditions, water delivery operations are described and contemplated in the 2007 Colorado River Interim Guidelines for Lower Basin Shortages and Coordinated Operations for Lake Powell and Lake Mead (2007 Interim Guidelines). Each year, the Secretary of the Interior determines the projected plan of operations of the storage reservoirs in the Colorado River Basin and determines when normal, surplus, or shortage conditions occur in the Lower Colorado River Basin. According to the 2007 Interim Guidelines, a shortage condition is determined when insufficient mainstream water is available to satisfy 7.5 million acre-feet (maf) of annual consumptive use in the Lower Division states. A key factor for determining annual operations is the amount of storage (as measured by water elevation) in Lake Mead.

Releases and diversions are made from Lake Mead to meet water deliveries in Arizona, California, Nevada, and Mexico, while Lake Powell is operated to deliver water from the Upper Basin to the Lower Basin. As part of the 2007 Interim Guidelines, water levels in these two reservoirs are coordinated to allow better management of the Colorado River supply. The 2007 Interim Guidelines outlines a method for releasing water from Lake Powell to Lake Mead that takes into consideration

the elevations of both reservoirs – modifying annual delivery volumes according to reservoir elevations.

Three factors that significantly affect the water levels in lakes Powell and Mead are:

1. The hydrology of the Colorado River, such as the amount of precipitation that falls within the basin and the resulting runoff that flows into the river and reaches the reservoirs,
2. Colorado River water use, such as the amount of water needed for agricultural and urban purposes in both the Upper and Lower Basins, and
3. Colorado River reservoir operations.

To date, the Secretary has never determined a shortage condition in the Lower Basin pursuant to the 2007 Interim Guidelines. However, the Colorado River Basin is now likely experiencing the lowest 16-year period in the observed historical record dating back over 100 years. Further, the Basin runoff during this period is comparable with the lowest 16-year period in the paleo record that dates back over 1200 years. In addition, given the basic apportionments in the Lower Basin, the allotment to Mexico, and evaporation losses, Lake Mead annual outflow is about 1.2 maf more than the annual inflow. The result is an imbalance that causes Lake Mead to drop by 12 feet or more every year when there is a "normal" release of 8.23 maf from Lake Powell. Lake Mead elevation has fallen approximately 126 feet from 2000 to the end of 2014, bringing it closer to elevations critical to a shortage determination. If a shortage is determined in the near future, quantified reductions in deliveries to Arizona, Nevada, and Mexico (pursuant to Minute 319 in effect through December 2017) would be implemented as shown below:

Lake Mead Jan 1, Elevation*	**Shortage Tier**	**Arizona Reduction**	**Nevada Reduction**	**Mexico Reduction**
1075'	1	320,000 AF	13,000 AF	50,000 AF
1050'	2	400,000 AF	17,000 AF	70,000 AF
1025'	3	480,000 AF	20,000 AF	125,000 AF
	** Projected Jan 1 Elevation from August 24-Month Study*			

Nevada – *Perspective provided by Colorado River Commission of Nevada*

Lake Mead is currently at 37% of capacity and lake elevation is projected to decrease this summer to levels not observed since Lake Mead was filled. Reclamation modeling predicts continued decreases in lake elevations and a near equal probability of a Lower Basin shortage in 2017. If a Tier 1 shortage is determined, Nevada would suffer a 4% reduction in Colorado River deliveries. Nevada's consumptive use, however, is currently about 75,000 acre-feet less than its full allocation due in part to the significant investment in water conservation programs by the Southern Nevada Water Authority.

Southern Nevada relies on Colorado River water for about 90% of its water supply. The Southern Nevada Water Authority is responsible for pumping and treating Colorado River water from Lake Mead for delivery to the Cities of Boulder City, Henderson, North Las Vegas, and the Las Vegas Valley Water District (the Las Vegas Valley Water District serves the City of Las Vegas and portions

of unincorporated Clark County in the metropolitan area). Currently, there are two intakes and two pumping stations in Lake Mead at depths of 1,050 and 1,000 feet above mean sea level. If lake surface elevations continue to decline, there are risks of losing the ability to access and pump water. Design and construction of a new intake and pumping station are under way and when completed they will have the ability to pump water at a depth of 860 feet. The new intake will be completed in the fall of 2015 and the new pumping station will not be completed for another 5 years at a cost estimated around $1.4 billion dollars for the entire project. The new lower intake will connect to the current pumping station to allow for pumping from the new intake. The cold, clear water at lower depths provides for better quality water and reduces water treatment costs. Once the intake is complete, southern Nevada will have access to better quality water and once the new pumping station is complete Nevada will have improved access if drought conditions continue.

Lower water levels in Lake Mead have reduced the amount of potential energy generated at Hoover Dam. When lake elevations are high, more energy is produced from the weight (or head) of the water pushing through the turbines. Decreased power production often causes customers to purchase power on the open market at higher costs. At lower elevations, turbines run less efficiently and can cause operational issues. Reclamation believes that power can be generated to an elevation of 950 feet with less efficiency, but there is some uncertainty of operations at these low elevations. Hoover Dam, Parker Dam, and Davis Dam derived power also fund the Colorado River Basin Salinity Control Program. Reduced power production reduces the available funding for this program.

The physical and chemical properties of water released from Glen Canyon Dam can influence Lake Mead. Temperature and salinity between the river and lake can dictate the depth at which the water inserts itself into the lake. Water inserted at the top layer can reinforce stratification and lead to less oxygenated conditions. Increased sediment delivery that reaches the water intakes can impact water treatment costs.

Arizona – *Perspective provided by Arizona Department of Water Resources*

The Colorado River supplies approximately 40% of Arizona's water needs. The remaining needs are met through use of other surface water supplies such as the Salt and Gila River systems, reuse of treated wastewater, water recharged in groundwater aquifers and groundwater supplies. If a shortage is declared on the Colorado River, Arizona bears the brunt of the reductions, with the Central Arizona Project (CAP) taking most of the reductions. Operational agreements and policies have been in place for many years establishing priorities for the different water use sectors of Arizona's Colorado River water.

Who in AZ will be impacted by tier 1 shortage?
Based on established priorities and the existing policies, tier 1 shortages to Colorado River water in the next few years will primarily impact agricultural users that receive CAP water. In addition, supplies available to the Arizona Water Banking Authority and the Central Arizona Groundwater Replenishment District would also be eliminated. Arizona cities will not see a reduction in their Colorado River supplies at the higher tiers of shortages.

Is Arizona prepared for shortage?
Because Arizona has recognized its lower priority on the Colorado River, Arizona has been proactively building resilience and implementing innovative water management strategies to secure and manage its other water supplies. Arizona has set a precedent with rigorous water conservation and sustainability laws that protect Arizona water users. Arizona's Groundwater Management Act is the most far-reaching groundwater management regulatory framework in the United States. Arizona leads the nation in the implementation of efficient water reuse programs to use treated wastewater for beneficial uses including agriculture, municipal uses, groundwater recharge, power generation, industrial uses, and turf irrigation uses. Arizona's engagement in collaborative long-term planning and comprehensive strategies has allowed water providers and private entities to store water supplies underground to reduce their vulnerability to shortage. Collectively, Arizona has stored over 8 million acre-feet (more than 2.5 trillion gallons) of water. Over 3.2 million acre-feet of this stored water has been recharged by the Arizona Water Banking Authority to provide back-up supplies for municipal, industrial and Native American Colorado River water users in times of a shortage.

What is being done?
The Arizona Department of Water Resources, along with other stakeholders such as the CAP, are committed to continuing work with the other Colorado River Basin States, Mexico and federal partners to implement proactive measures that will reduce the near-term risks of drought as well as address the long-term imbalances between supply and demands on the Colorado River system. Addressing the challenges facing the Colorado River System will require solutions that incorporate creativity, cooperation, and shared sacrifice.

California – *Perspective provided by Colorado River Board of California*

California and the other Basin States have been working since at least the 1990's to prepare for potential water supply shortages in the Lower Basin. Shortages to allocations, although hopefully avoided, are a fundamental element of western water law's basic priority system that has been embedded within the allocations and operations of the Colorado River Basin system. For example, in addition to addressing coordinated operations between Lake Powell and Lake Mead, the 1968 Colorado River Basin Project Act recognized existing allocations of water among the States and identified a process for allocation of shortages among Arizona, California, and Nevada. The 1968 Act provides that the Secretary should allocate water first by satisfying the present and perfected water rights that existed prior to 1929 in all three States, then to the remaining normal apportionment rights within California, then to other uses in Arizona and Nevada, and finally to the uses to be developed through the Central Arizona Project, which was newly authorized for construction through the 1968 Act. Adopted forty years later, the 2007 Interim Guidelines describe the specific delivery amounts for each of the Lower Basin states under defined Shortage Conditions when Lake Mead's elevations are projected to meet certain specified trigger levels. To date, neither the shortage provisions in the 1968 Act or the 2007 Interim Guidelines have been applied, but current low elevation levels at Lake Mead have led to continued efforts to try to improve system efficiencies, increase conservation and look for innovative ways to manage and expand existing water supplies.

In addition to the Colorado River Basin's current historic drought, California has been experiencing its own unprecedented, multi-year drought, with record-low snowpack in the northern California Sierra-Nevada Mountains, exacerbated by record-high temperatures. As a result of well below-

average precipitation, the water supply for urban and agricultural contractors from the California State Water Project and federal Central Valley Project has been severely diminished over the past three years. In response to the unprecedented drought conditions, California's Governor Brown issued an Executive Order on April 1, 2015, requiring each municipal water supplier in the State to reduce its water use in order to achieve a 25% average statewide reduction. Over 500,000 acres of irrigated land has been fallowed within California during each of the past three years due to lack of water. During these exceptionally dry years, the Colorado River provides a very important component of the water supply for over 19 million people in southern California in addition to providing water to irrigate over 800,000 acres of farmland.

For over two decades, California's Colorado River water users have spent billions of dollars to implement programs to conserve and efficiently utilize Colorado River water, which has resulted in a reduction in overall use by California of approximately 800,000 acre-feet of water per year since 2003, and has allowed California to stay within the normal allocation of 4.4 million acre-feet of Colorado River water allocated to California under the 1928 Boulder Canyon Project Act. To date, over 3 million acre-feet of water have been conserved and transferred from agricultural to municipal users per the 2003 Quantification Settlement Agreement (QSA) and other long-term, innovative agreements such as the fallowing agreement between the Palo Verde Irrigation District and Metropolitan. Over the past two years, the Metropolitan Water District (MWD) has invested over $500 million on turf removal, appliance rebates and other conservation programs, in addition to amounts spent on conservation programs by the State of California and other local agencies. In November 2014, California voters approved a $7.4 billion bond initiative that will enable construction of additional water storage and conservation projects and other programs over the next several years. On the Colorado River, California entities have participated with other States to fund ongoing programs to generate additional water for the Colorado River System, improve system reliability and create additional water for storage in Lake Mead. Flexibility and innovative programs on the Colorado River System have helped California manage its diverse water supplies during the current drought.

As water levels drop in Lake Mead, California entities (representing 56% of the contracted power allocation from Hoover Dam) are affected along with contractors in Arizona and Nevada by decreased power production capacity at Hoover Dam and decreased benefits from programs such as the Colorado River Basin Salinity Control Program. During Shortage Conditions under the 2007 Interim Guidelines, Colorado River contractors in California, Arizona and Nevada are subject to reduced water delivery flexibilities in connection with programs such as the Inadvertent Overrun Payback Policy.

There are strong incentives for California to continue its efforts to coordinate with Arizona and Nevada, the other Basin States, federal agencies, and our partners in Mexico through the efforts to implement Minute 319 and potential successor agreements, on efforts to bolster the strength of the Colorado River System, prevent Lower Bain shortages, improve water use efficiencies and increase the amount of water stored in Lake Mead.

THE SECRETARY OF THE INTERIOR
WASHINGTON

AUG 17 2015

The Honorable Lisa Murkowski
Chairwoman, Committee on Energy
and Natural Resources
United States Senate
Washington, DC 20510

Dear Chairwoman Murkowski:

The enclosed Report on the operation of Glen Canyon Dam by the Department of the Interior (Interior) is submitted pursuant to section 1804 of the Grand Canyon Protection Act of 1992, which provides:

> Each year after the date of the adoption of criteria and operating plans pursuant to paragraph (1), the Secretary shall transmit to the Congress and to the Governors of the Colorado River Basin States a report, separate from and in addition to the report specified in section 602(b) of the Colorado River Basin Project Act of 1968 on the preceding year and the projected year operations undertaken pursuant to this Act.

This Report provides an update from the last report submitted by Interior on August 29, 2014. This Report covers activities from 2014 through 2015.

Interior continues to closely monitor conditions in the Colorado River Basin and looks forward to continuing to work with Congress, the seven Colorado River Basin States, and other interested stakeholders regarding the management of this vital component of the Colorado River system.

If you have any questions concerning this Report, please contact Mr. Brent Rhees, Regional Director for the Bureau of Reclamation's Upper Colorado Region, at (801) 524-3600.

Sincerely,

Sally Jewell

Enclosure

Identical Letters Sent To:

Honorable Maria Cantwell
Ranking Member, Committee on Energy
and Natural Resources
United States Senate
Washington, DC 20510

Honorable Rob Bishop
Chairman, Committee on Natural Resources
House of Representatives
Washington, DC 20515

Honorable Raul Grijalva
Ranking Member, Committee on
Natural Resources
House of Representatives
Washington, DC 20515

Honorable Matt Mead
Governor of Wyoming
Cheyenne, Wyoming 82002

Honorable Gary Herbert
Governor of Utah
Salt Lake City, Utah 84114

Honorable Brian Sandoval
Governor of Nevada
Carson City, Nevada 89701

Honorable Susana Martinez
Governor of New Mexico
Santa Fe, New Mexico 87501

Honorable Jerry Brown
Governor of California
Sacramento, California 95814

Honorable John Hickenlooper
Governor of Colorado
Denver, Colorado 80203

Honorable Doug Ducey
Governor of Arizona
Phoenix, Arizona 85007

cc: Mr. Ali Zaidi, Associate Director for Natural Resources, Energy & Science
Office of Management and Budget
Executive Office Building
639 17th Street, NW
Washington, DC 20006

RECLAMATION
Managing Water in the West

Report to Congress
Operations of Glen Canyon Dam
Pursuant to the Grand Canyon Protection Act of 1992

2014-2015

U.S. Department of the Interior
Bureau of Reclamation

August 2015

EXECUTIVE SUMMARY

This report by the Department of the Interior (Interior) is submitted pursuant to section 1804 of the Grand Canyon Protection Act (GCPA) of 1992, which provides

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This report provides an update from the last report, **submitted on August 29, 2014**, by Interior for 2013-2014, and covers activities for 2014 and 2015.

INTRODUCTION

Glen Canyon Dam was authorized for construction by the Colorado River Storage Project Act of 1956. 43 U.S.C. § 620. The dam was completed in 1963 and is operated by the Bureau of Reclamation (Reclamation). In 1992, Congress enacted the GCPA, which requires the Secretary of the Interior (Secretary) to operate Glen Canyon Dam

> in accordance with the additional criteria and operating plans specified in section 1804 and exercise other authorities under existing law in such a manner as to protect, mitigate adverse impacts to, and improve the values for which Grand Canyon National Park and Glen Canyon National Recreation Area were established, including, but not limited to natural and cultural resources and visitor use.

Congress also directed that such operations be undertaken

> in a manner fully consistent with and subject to the Colorado River Compact, the Upper Colorado River Basin Compact, the Water Treaty of 1944 with Mexico, the decree of the Supreme Court in Arizona vs. California, and the provisions of the Colorado River Storage Project Act of 1956 and the Colorado River Basin Project Act of 1968 that govern allocation, appropriation, development, and exportation of the waters of the Colorado River Basin.

In 1997, the Secretary established the Glen Canyon Dam Adaptive Management Program (GCDAMP) to carry out the requirements of the GCPA. As part of the GCDAMP, the Secretary also established the Adaptive Management Work Group (AMWG), a 25-member federal advisory committee that operates pursuant to the provisions of the Federal Advisory Committee Act, 5 U.S.C. § App. 2. The Secretary's designee, currently Principal Deputy Assistant Secretary for Water and Science Jennifer Gimbel, serves as the Chair of the AMWG.

STATUS REPORT

Five agencies within Interior have responsibilities under the GCPA and undertake operations pursuant to the GCPA; the: (1) Bureau of Indian Affairs (BIA); (2) Reclamation; (3) National Park Service (NPS); (4) United States Fish and Wildlife Service (FWS); and (5) United States Geological Survey (USGS). Collectively these five agencies fund five American Indian Tribes (Hopi, Hualapai, Pueblo of Zuni, Kaibab Paiute, and the Navajo Nation) to participate in the GCDAMP and two Tribal Liaison positions within Interior that assist in coordination between Interior and the tribes. The Western Area Power Administration (Western) also has statutory responsibilities pursuant to the Department of Energy Organization Act, Flood Control Act, Reclamation Project Act, Colorado River Storage Project Act, and the GCPA. The role of each responsible Interior agency under the GCPA is briefly addressed below.

Bureau of Indian Affairs

The BIA's mission, among other objectives, includes enhancing quality of life, promoting economic opportunity, and protecting and improving trust assets of Indian Tribes and individual American Indians. This is accomplished within the framework of a government-to-government relationship in which the spirit of Indian self-determination is paramount. As part of the AMWG, the BIA works hand-in-hand with interested tribes and other participating agencies to ensure that this fragile, unique, and traditionally important landscape is preserved and protected.

Bureau of Reclamation

Reclamation operates Glen Canyon Dam in accordance with and subject to interstate compacts, an international treaty, federal laws, court decisions and decrees, contracts, and regulatory guidelines collectively known as the "Law of the River", additional criteria and operating plans specified in section 1804 of the GCPA, and approved experimental plans. Reclamation also provides support to the Secretary's designee in administering the GCDAMP, including coordinating logistics for the AMWG and the Technical Work Group (TWG).

National Park Service

The NPS manages units of the national park system and administers resource-related programs under the authority of various federal statutes, regulations, and executive orders, and in accordance with written policies set forth by the Secretary and the Director of the NPS, including the NPS Management Policies 2006 and the NPS Director's Orders. The NPS manages Grand Canyon National Park and Glen Canyon National Recreation Area under the NPS Organic Act, 16 U.S.C. §§ 1 and 2-4, as amended; other acts of Congress applicable generally to units of the national park system; and the legislation specifically establishing those park units. 16 U.S.C. §§ 221-228j and 16 U.S.C. §§ 460dd through 460dd-9 (2006). The NPS Organic Act directs the NPS to "promote and regulate the use of . . . national parks . . . in such manner and by such means as will leave them unimpaired for the enjoyment of future generations." The NPS helps the Secretary achieve the goals outlined in the GCPA through its resource-management and resource-monitoring activities.

U.S. Fish and Wildlife Service

The FWS provides Endangered Species Act (ESA) conservation and associated consultation and recovery leadership with various stakeholders primarily to benefit four listed species: the

humpback chub (*Gila cypha*), razorback sucker (*Xyrauchen texanus*), southwestern willow flycatcher (*Empidonax trailii extimus*), and Kanab ambersnail (*Oxyloma haydeni kanabensi*).

U.S. Geological Survey

The Grand Canyon Monitoring and Research Center (GCMRC) of the USGS was created to fulfill the mandate in the GCPA for the establishment and implementation of a long-term monitoring and research program for natural, cultural, and recreation resources of Grand Canyon National Park and Glen Canyon National Recreation Area. GCMRC provides independent, policy-neutral scientific information to the GCDAMP on (a) the effects of the operation of Glen Canyon Dam and other related factors on resources of the Colorado River ecosystem using an ecosystem approach, and (b) the flow and non-flow measures to mitigate adverse effects. The GCMRC's activities are focused on (a) monitoring the status and trends in natural, cultural, and recreational resources that are affected by dam operations, and (b) working with land and resource management agencies in an adaptive management framework to carry out and evaluate the effectiveness of alternative dam operations and other resource conservation actions described in this report.

2014 OPERATIONS

Bureau of Indian Affairs

In 2014, the BIA continued to consult with stakeholder tribes on formulating funding requests for various projects related to the GCDAMP. The BIA additionally participated in consultation meetings with the tribes regarding the Tribal Consultation Plan, attended a Section 7 consultation "working lunch" with stakeholder tribes and the FWS, conducted pre-meetings with tribal representatives prior to the AMWG meetings, and participated in meetings regarding cultural and natural resources issues and concerns. Principal among tribal concerns for 2014 remains the importance of Traditional Cultural Values and their inclusion in the Long-Term Experimental and Management Plan (LTEMP) Environmental Impact Statement (EIS) process. All parties involved continue to work to find a way to quantify such values such that they can be adequately analyzed in the LTEMP EIS. The BIA is also a cooperating agency on the LTEMP EIS. The BIA was also involved with the High-Flow Experimental Protocol for Glen Canyon Dam and coordination with the tribes, particularly as it relates to monitoring impacts on cultural resources. The BIA continued to provide its portion of funding to tribes for their participation in the GCDAMP. Other activities included continued coordination of efforts for tribal participation in the GCDAMP and working with the Interior Tribal Liaisons to maximize tribal consultation and involvement.

Bureau of Reclamation

Water Operations

As in 2010 through 2013, a water year (WY) 2014 hydrograph was jointly developed by the Interior AMWG agencies and Western. The recommended hydrograph was consistent with the Law of the River (including the GCPA) and was designed to enhance protection of downstream

resources. This approach to operations is consistent with the Interim Guidelines, operating criteria, and 2007 Record of Decision (ROD), and falls within the parameters of the modified low fluctuating flow (MLFF) alternative adopted in the 1996 ROD. The recommended hydrograph received consensus support from members of the AMWG and was approved by the Secretary on December 9, 2013.

Releases from Lake Powell in WY 2014 continued to reflect consideration of the uses and purposes identified in the authorizing legislation for Glen Canyon Dam and were consistent with the 1996 ROD; the 2012 Environmental Assessment/Finding of No Significant Impact (EA/FONSI) for Development and Implementation of a Protocol for High-Flow Experimental Releases from Glen Canyon Dam, Arizona, 2011-2020; and the 2014 hydrograph. The monthly release volumes for WY 2014 are displayed in Table 1. The end of water year 2014 elevation for Lake Powell was 3,606 feet.

Table 1. Lake Powell Monthly Release Volumes
Water Year 2014

Month	Monthly Release Volumes (maf*)
October 2013	0.481
November 2013	0.696
December 2013	0.600
January 2014	0.800
February 2014	0.599
March 2014	0.504
April 2014	0.502
May 2014	0.493
June 2014	0.598
July 2014	0.800
August 2014	0.801
September 2014	0.604
Total Releases	7.480

*maf = million acre-feet

The third experimental release under the High-Flow Experimental Protocol was successfully conducted during November 2014. Reclamation released the maximum available capacity (38,000 cubic feet per second [cfs]) during the experiment, which began on November 10 and ended on November 15, 2014. Preliminary findings suggest that the first three high-flow experimental releases have been very successful in transporting sediment accumulated near the confluence of the Colorado and Paria rivers to beaches and sandbars where sediment replenishment was needed. Reports from the Grand Canyon white water rafting community have been extremely positive on the improvement of beaches in Grand Canyon over this 3-year period. Fisheries researchers have also indicated that these releases have temporarily rebuilt important backwater habitats where sandbars are adequately enhanced throughout Grand Canyon.

In 2014, Reclamation continued to fund and support Grand Canyon National Park with several projects including humpback chub translocations in Havasu and Shinumo creeks, non-native fish removal in Bright Angel Creek, fish surveys in the mainstem Colorado River, a staff position for the permitting office, cultural monitoring, and support staff to complete National Environmental Policy Act (NEPA) compliance for the Glen and Grand Canyon Comprehensive Fisheries Management Plan.

LTEMP EIS

In 2014, Reclamation and the NPS continued developing the LTEMP EIS using the Department of Energy's Argonne National Laboratory as the third-party contractor, funded by Reclamation.

The LTEMP EIS Team held a second structured decision analysis workshop with the cooperating agencies and AMWG members March 31-April 1, 2014, where the results of the modeling and related analysis of the draft alternatives was presented. In April 2014, the stakeholders were given a swing weighting exercise to help provide input on the LTEMP alternatives. The following entities participated in the exercise: FWS, Arizona Department of Water Resources, Arizona Game and Fish Department, International Fly Fishing Federation, National Parks Conservation Association, Hopi Tribe, Hualapai Tribe, Navajo Nation (water), Salt River Project, Utah Associated Municipal Power Systems, and Colorado River Energy Distributors Association. The LTEMP EIS Team is continuing to work on analysis of alternatives based on alternatives and analysis methods discussed at the structured decision analysis workshops. A review of the most recent results and extended hydropower analysis was provided at the February 26, 2015, AMWG meeting. The goal of Reclamation and the NPS is to release a public draft EIS in late fall of 2015.

Conservation Measures for Humpback Chub and Razorback Sucker

From fiscal years 2009 through 2015, Reclamation has funded NPS to remove non-native rainbow trout and translocate humpback chub into Shinumo Creek, Havasu Creek, and if non-native removal is successful, Bright Angel Creek in order to fulfill conservation measures from two biological opinions on the operations of Glen Canyon Dam. These actions will provide additional refuge populations that minimize the effects of predation and competition from non-native fish, may establish new spawning populations, and also contribute to the mainstem populations of humpback chub.

Approximately 300 tagged humpback chub were introduced per year from 2009 to 2013 in Shinumo Creek. Passive integrated transponder (PIT) tag antennae indicate that high emigration rates occur shortly after a translocation. However, fish leaving the creek appear to contribute to the mainstem aggregations. Some have remained in the creek for 3½ years, have growth rates similar to or higher than those seen in the Little Colorado River, and have attained the minimum size and age required for reproduction. No spawning in Shinumo Creek has been detected. Trout have been removed as part of every monitoring trip and the structure of the trout population has shifted from moderate numbers of larger fish to greater numbers of small and young-of-the-year fish. In May 2014, a lightning-caused fire burned 6,100 acres in the drainage and was followed by monsoon flood events in July and August. These events greatly altered

habitat conditions for fish and destroyed the PIT tag antennae. Biologists hiked into the drainage in September and observed severe flood disturbance in the translocation reach, below Shinumo falls, and the only fish that could be located were speckled dace. As a result, no translocations occurred in 2014.

As of June 5, 2014, a total of 1,350 PIT-tagged humpback chub had been translocated to Havasu Creek. Prior to the first translocations in 2012, baseline fish surveys were conducted. These surveys turned up a surprising 13 wild humpback chub considered to be resident fish and fortunately, very few non-natives were present in the system. Surveys have relocated many of the tagged fish each year including multiple male humpback chub in spawning condition and ripe females, as well as immature untagged humpback chub, and very small untagged juveniles, all indicating that natural reproduction is occurring in Havasu Creek.

Translocations of humpback chub cannot currently be accomplished in Bright Angel Creek due to the large numbers of brown and rainbow trout that inhabit the creek. Consequently, trout removal efforts were increased beginning in 2012 that include a fish weir to trap spawning brown trout near the confluence and electrofishing trips in Bright Angel Creek from Roaring Springs to the mouth of the creek. Reduction efforts to date have yielded 12,456 and 10,545 brown trout and 1,735 and 1,400 rainbow trout in 2012-2013 and 2013-2014, respectively. In addition, from November through December 2013, the NPS (in cooperation with the GCMRC) initiated the Bright Angel Creek inflow reduction project as a pilot study within a defined 5.5-mile section of river at the confluence of Bright Angel Creek with the mainstem of the Colorado. Researchers removed 1,370 rainbow trout and 336 brown trout during the pilot study.

Monitoring has shown that abundance of adult chub in the mainstem has increased or remained stable at all aggregations since sampling began in the 1990s. Humpback chub translocated to Shinumo Creek and to Havasu Creek from 2009-2014 have contributed to the mainstem aggregations that are located at the tributary mouths. Two chub translocated to Shinumo were re-located almost 40 miles upstream at the mouth of the Little Colorado River where they were spawned. Preliminary data analysis from 2014 mainstem aggregation sampling indicate that humpback chub translocated into Shinumo and Havasu tributaries are approximately 70 percent and 35 percent of the total aggregation, respectively. In addition, a large number of adult humpback chub recently located at River Mile (RM) 35 suggests the possibility of a new aggregation or expansion of the 30-mile aggregation. Other areas not associated with known aggregations were sampled in 2013 and 2014, and results indicate that chub are more widely distributed in the mainstem than had been detected previously.

Grand Canyon National Park employs a permitting specialist and staff who review all proposals for projects to be completed in the park. Reclamation funds these positions to offset the park's administrative burden from the GCDAMP activities. In 2014, Grand Canyon National Park's Research Office issued 26 river trip permits, which fulfilled obligations under the GCDAMP. Although the GCMRC has been working to consolidate research trips, this was an increase 2 applications, up from the 24 filed in 2013. The GCMRC was issued 10 research and collection permits and 16 river launch permits, totaling 4,326 river user days. In addition to science trips, the GCMRC permits included logistics for 5 tribal monitoring trips and sponsors 2 trips each year for Grand Canyon Youth. Due to the sensitivity of the Little Colorado River area to tribes

and others, efforts have been made to reduce, combine, and eliminate river trips and helicopter flights into the area wherever possible.

Reclamation continued financial and staff support of a monitoring project for razorback sucker aimed at better understanding the use and life history needs of the species in Lake Mead and western Grand Canyon. While researchers have known that razorback sucker occupy and are able to reproduce and recruit in Lake Mead since the 1990s, this project has found that the species also uses the Colorado River in western Grand Canyon as far upstream as Lava Falls. Other findings include the presence of juvenile fish in the Lake Mead inflow area indicating recruitment, larval fish at Lava Falls indicating spawning and possible recruitment in the river reach, and long-distance movement of adult razorback suckers throughout Lake Mead and western Grand Canyon. Because the capture of larval fishes helps to identify where spawning takes place, the duration of spawning activities, habitat use, and availability and fish community dynamics, Reclamation funded additional research for larval fish surveys in the lower reaches of Grand Canyon.

In 2013, two razorbacks were captured downstream of Diamond Creek (RM 225), more than 50 miles upstream from Pearce Ferry. In an attempt to track movements and possibly locate spawning aggregations, in March 2014, nine sonic-tagged adult razorback suckers were released downstream of Lava Falls (RM 180). During the subsequent April monitoring trip, biologists located several of the newly released sonic-tagged fish as well as previously tagged fish that had migrated upstream from Lake Mead. They also located larval razorback suckers at 9 of 47 locations, all upstream from Lake Mead, with the furthest upstream location being Lava Falls (RM 179.2). The detection of these larvae fish indicates that razorback suckers may be naturally reproducing in an area where the species has not been seen in more than 20 years.

Tribal Activities

Reclamation continued to fund five American Indian Tribes (Hopi, Hualapai, Pueblo of Zuni, Kaibab Paiute, and the Navajo Nation) to participate and provide their perspectives to the GCDAMP. They identify and monitor traditional cultural properties and provide annual reports detailing their activities, findings, and monitoring data.

Several government-to-government consultations with interested tribes were conducted throughout the year, and additional staff level meetings and conference calls with interested tribes were also held.

In addition to the high-flow experimental release and consultations for the LTEMP EIS, Reclamation continues to conduct government-to-government consultations with American Indian Tribes as part of the GCDAMP on operations of Glen Canyon Dam and activities of the GCDAMP in services of its responsibilities, including those under Section 106 of the National Historic Preservation Act, Executive Order 13175, Secretarial Order 3206, and the November 5, 2009, Presidential Memorandum on Tribal Consultation.

Reclamation continued implementation of two memoranda of agreement (MOA) to mitigate for adverse effects under Section 106 of the National Historic Preservation Act for the High-Flow

Experimental Protocol and non-native fish management described above. The consultation process leading to execution of these two MOAs included consensus determination of eligibility of the Grand Canyon as a traditional cultural property for several tribes, at their request. Reclamation also continued its efforts with the signatories to develop a new Programmatic Agreement (PA) for operation of Glen Canyon Dam pursuant to the GCPA that is consistent with the LTEMP, and anticipates completing the new PA in conjunction with the LTEMP ROD.

National Park Service

Three units of the NPS (Glen Canyon National Recreation Area, Grand Canyon National Park, and Lake Mead National Recreation Area) provided essential logistical support for implementation of the November 2014 high-flow experiment (HFE). The park units established individual response systems to manage and coordinate activities related to the HFE. Safety was the primary concern, with visitor information and outreach being the primary tool used to communicate the changes in flow release volumes from Glen Canyon Dam. Before and during the HFE, the Glen Canyon National Recreation Area successfully worked with the three concessionaires on Lake Powell to minimize impacts to their marina operations.

LTEMP EIS

In 2014, the NPS and Reclamation continued developing the LTEMP EIS using the Department of Energy's Argonne National Laboratory as the third-party contractor, funded by Reclamation. The NPS's Intermountain Regional Office, Washington Office, Grand Canyon, Glen Canyon, and Lake Mead all participated in various LTEMP activities including writing, reviewing, and editing sections of draft documents. The NPS also participated in numerous meetings between Interior representatives and tribal and state representatives.

Archaeological/Cultural Resources

Grand Canyon National Park: Field work in 2014 consisted of condition assessments at 122 river corridor archaeological sites as part of ongoing Colorado River Management Plan implementation. The NPS participated on two tribal monitoring river trips visiting ethnographic resources to determine condition and threats from a tribal perspective. The NPS accompanied a cultural resources assessment river trip with GCMRC and USGS scientists documenting geomorphic setting, impacts, and the potential for HFE-derived sediment to be transported into site boundaries.

The NPS worked with the Pueblo of Zuni to stabilize one site impacted by trailing and potential for inadvertent damage to rock writings from visitors. Zuni Cultural Resource Advisors documented tribal values and assisted in determining appropriate stabilization techniques. The Tribe and the NPS will continue to monitor the success of stabilization at this location.

Glen Canyon National Recreation Area: In 2014, the NPS Submerged Resources Center assisted with documentation and development of monitoring protocols to evaluate potential effects to the Spencer Steamboat. Additional field observations were conducted prior to, during, and following the November HFE to assess changes in resource condition at specific locations. The

NPS also continued to support the GCMRC's monitoring of dam-related topographic changes at select cultural sites.

Tribal Consultation

In 2014, the NPS continued to participate in consultation meetings with the various tribes who are directly involved in the GCDAMP and other Colorado River related programs. The NPS's Grand Canyon National Park and Glen Canyon National Recreation Area continued discussions with tribes and incorporated tribal perspectives into implementation of the NPS's Comprehensive Fisheries Management Plan. Tribal advisors were consulted on specific monitoring and mitigation protocols relative to Grand Canyon National Park's Colorado River Management Plan implementation. The NPS participated in on-river monitoring with the Pueblo of Zuni and continue to work closely with tribal staff on monitoring and mitigation protocols and implementation.

The NPS worked with Reclamation to consult with interested tribes involved in the LTEMP. Consultation is government-to-government and includes all tribes who are interested in the planning effort regardless of their role as a cooperating agency for the EIS.

Humpback Chub Translocation and Fisheries Management

In 2014, the Grand Canyon National Park continued implementation of the Comprehensive Fisheries Management Plan for native fish within the Grand Canyon National Park and sport fish in the Lees Ferry area of the Glen Canyon National Recreation Area. These efforts included an evaluation of the status and habitat use of newly rediscovered endangered razorback sucker, translocations and monitoring of endangered humpback chub to Havasu and Shinumo creeks, and the removal of non-native fishes threatening endangered and native fish in Shinumo and Bright Angel creeks and the Bright Angel Creek inflow area of the Colorado River. A large flash flood and debris flow was recorded in Shinumo Creek during the summer monsoon season. Impacts to native fish were immediately identified and initial assessments suggested little or no survival.

Wildlife Surveys and Monitoring

Grand Canyon National Park: In 2014, Grand Canyon National Park activities included assisting researchers with a desert bighorn sheep study to inform connectivity models, determine genetic diversity of herds, and gain insights on desert bighorn sheep ecology. Park biologists continued monitoring condors and Mexican spotted owls.

Glen Canyon National Recreation Area: In 2014, Glen Canyon National Recreation Area staff and partners worked on great blue heron, waterfowl, and raptor surveys along the 16-mile reach below the dam. The great blue heron colony has expanded to >40 nests. Work continued on monitoring aquatic/riparian invertebrates and terrestrial vertebrate populations creating open water habitat at Leopard Frog Marsh for potential reintroduction of extirpated northern leopard frogs. The first frog breeding pool was created. In early 2015, a native adult tiger salamander was discovered in this pond and is the first record of this species along the river corridor.

Vegetation Management/Exotic Species Removal

Grand Canyon National Park: In 2014, the NPS continued to implement exotic plant species removal at priority sites, expand plant collection and propagation efforts in preparation for future watershed restoration projects, and provide hands-on stewardship opportunities. The NPS also maintained native plant species at Granite Camp as part of a pilot riparian restoration project. Specific accomplishments along the river corridor in Grand Canyon National Park were:

- Continued the Adopt-a-Camp program by working with individuals, Grand Canyon Youth, and commercial companies to remove priority exotic plant species from the camps and attraction sites.
- Continued the first riparian restoration project in the river corridor at Granite Camp (RM 94) through site maintenance and outreach to project partners.
- Continued propagation of riparian plant species for supplemental planting at Granite Camp or other future riparian restoration projects.
- Removed the following exotic plant species:

    - ✓ Camelthorn - 1,535 (from camps and attraction sites)
    - ✓ Pampas grass - 1 (from along the river corridor)
    - ✓ Ravenna grass - 1 (from along the river corridor)
    - ✓ Russian olive - 1 (from along the river corridor)
    - ✓ Sahara mustard - 692 (from along the river corridor and at Lees Ferry)
    - ✓ Silverleaf nightshade - 1,082 (from camps and along the river corridor)
    - ✓ Tamarisk - 1,025 (from Granite Camp and attraction sites)

Glen Canyon National Recreation Area: In 2014, the NPS, partners, and volunteers implemented invasive plant management efforts, native plant restoration activities, and vegetation monitoring efforts along the Colorado and Paria rivers below Glen Canyon Dam. Specific accomplishments in Glen Canyon National Recreation Area were:

- Grand Canyon Wildlands Council staff and Vanderbilt University Alternative Spring Break students improved fencing around planted cottonwoods and willows to protect from beaver herbivory at the Lees Ferry 10-acre restoration site.
- Grand Canyon Wildlands Council (under cooperative agreement with the NPS) continued monitoring native plant restoration success at Hidden Slough.
- Grand Canyon Wildlands Council, Prescott College students, and the NPS began re-establishing open water habitat at Leopard Frog Marsh and Hidden Slough for potential reintroduction of extirpated northern leopard frogs.
- Continued native seed collection and plant propagation efforts for restoration activities at Hidden Slough, Leopard Frog Marsh, and Paria River Bridge.
- Controlled, mapped, and/or monitored the following invasive non-native species infestations:

    - ✓ Russian olive - 5 treated between the Glen Canyon Dam and Glen Canyon/Grand Canyon boundary and 16 treated between the Glen Canyon/Bureau of Land Management boundary and Paria River/Colorado River confluence.

- ✓ Tamarisk - Continued monitoring of tamarisk leaf beetle impacts at Hidden Slough, Leopard Frog Marsh, and Lees Ferry.
- ✓ Ravenna grass - 4 treated between the Glen Canyon Dam and Glen Canyon/Grand Canyon boundary.

Research Review and Permitting

The Grand Canyon's Research Office continues to have one of the largest research and collection permitting programs within the NPS. There are more than 120 researchers that are listed as either principal or co-principal investigators presiding over current studies. In 2014, the Grand Canyon's Research Office received 26 river trip applications to fulfill obligations under the GCDAMP. The GCMRC was issued 10 research and collection permits and 16 stand-alone river permits, totaling 4,326 user days. Five tribal research permits with corresponding river trips were permitted for the Hopi, Hualapai, Navajo, Paiute, and Zuni tribes, totaling 861 user days. Overall, 5,187 user days were spent on the river conducting GCDAMP-related research.

For each GCMRC and tribal permit, an interdisciplinary team of technical experts reviewed and provided comments on the research proposal or logistics and assistance was given to the principal investigator in completing the minimum requirement analysis and related compliance documents.

Additionally in 2014, Grand Canyon Science and Resource Management staff participated in GCDAMP-related meetings and river trips; attended and participated in GCMRC's annual reporting meeting; and attended Glen Canyon Dam Technical Work Group meetings, knowledge assessment workshops, and other meetings with the GCMRC and TWG. These discussions are integral to future collaborations and allow for shared input and an increase in NPS involvement in the GCDAMP.

Outside of the GCDAMP, the research office continued to review proposals, coordinate efforts, and provide permitting guidance as needed for all GCPA projects in 2014. An additional 39 research permits were issued to independent or university researchers and logistical planning was provided to various disciplines including vegetation baseline monitoring, geomorphology, terrestrial remote sensing, and soundscape monitoring.

The Glen Canyon National Recreation Area continued administration of 10 research permits associated with the GCDAMP between Glen Canyon Dam and the Paria River. The NPS anticipates continuation of research and permitting activities in 2015 at similar levels as 2014. For each of the research projects in support of the GCPA, evaluation of need for NEPA compliance and completion of minimum requirement analysis will be completed. Updating of annual investigator reports will be done for each research permit and coordination with Reclamation will continue.

Resource Monitoring and Mitigation

In 2014, the Grand Canyon National Park continued the integrated campsite monitoring and mitigation program. The trip conducted in February included photographic documentation of

campsites, and campsite rehabilitation projects in areas above the 25,000 cfs flow line and pre-dam high water areas. The Grand Canyon National Park is continuing to evaluate and refine their monitoring and mitigation protocols to ensure applicability to changing field conditions and management needs. A revised draft monitoring plan was completed in September 2014 and monitoring is scheduled for April 2015.

The Glen Canyon National Recreation Area continued multi-faceted efforts to prevent aquatic invasive species transport to and from Lake Powell and Lees Ferry. Aquatic invasive species present extreme potential impacts to a wide range of GCPA associated resources.

The Glen Canyon National Recreation Area also employed the use of cameras at several localities to monitor terrace erosion and changes related to dam operations and HFEs. This work will continue in 2015.

Greater Grand Canyon Landscape Assessment

In 2014 the NPS, in collaboration with Northern Arizona University and numerous other partners (including federal and state agencies, tribes, universities, non-profit organizations, and special interest groups), continued working on the Greater Grand Canyon Landscape Assessment to assess the condition and trends of natural and cultural resources throughout Grand Canyon National Park and contiguous watersheds. During 2014, the efforts of the previous year's technical work groups, comprised of subject matter experts and interested stakeholders, helped to provide expertise and guidance for assessing the identified focal resources. Data for many of the focal resources have been synthesized and used to develop spatial layers that will be used in subsequent analyses. During June 2014, the second interdisciplinary stakeholder workshop was convened to garner feedback on draft products and provide an opportunity for input into the prioritization process. The remainder of 2014 involved finalizing condition assessments for the focal resources and drafting a NPS Natural Resource Condition Assessment report, which will serve as a baseline for current resource conditions and help guide future park planning and decision making.

U.S. Fish and Wildlife Service

The FWS has been participating in the LTEMP as a cooperating agency and has been active in the development of alternatives and modeling for biological resources through attendance at webinars and providing comments to the joint lead agencies.

The FWS continued to provide technical assistance to support the NPS's Comprehensive Fisheries Management Plan, which guides NPS activities for native and non-native fish in Grand Canyon National Park and Glen Canyon National Recreation Area. The FWS will continue to participate in the AMWG, TWG, and various ad hoc groups and other related assignments. The FWS is also engaged with Grand Canyon National Park in the development of resource conditions for the Greater Grand Canyon Landscape Assessment process.

In 2014, the FWS conducted four monitoring trips on the Little Colorado River to generate population estimates for humpback chub and to monitor trends of other native fishes. Since

2006, the Little Colorado River population of humpback chub in Grand Canyon has significantly increased in size and continues to remain stable at elevated levels. The FWS conducted one trip on the Little Colorado River to monitor the success of upstream translocations of humpback chub within the Little Colorado River. These translocation efforts have been successful, with humpback chub experiencing high growth rates, high survival, and retention (range expansion) in this upper portion of the river. In 2014, the FWS continued this translocation effort, moving an additional 305 humpback chub upstream of Chute Falls.

The FWS has continued to work collaboratively with the GCMRC and the Grand Canyon National Park in the collection and transport of young humpback chub for translocation into Havasu Creek. A total of 660 humpback chub were collected in 2014, transported to the Southwest Native Aquatic Resources and Recovery Center in Dexter, New Mexico, and will be held there until they are large enough to be marked with a small tag and translocated in 2015.

The FWS has taken the lead, and continues to work collaboratively with the GCMRC and the NPS, to develop and refine a monitoring program to effectively sample mainstem aggregations of humpback chub in the Colorado River in Grand Canyon. In 2014, the FWS and the GCMRC conducted two sampling trips to estimate the population size of humpback chub in these aggregations. It is encouraging that the effect of translocating humpback chub into Shinumo and Havasu creeks has resulted in a measurable augmentation of these two mainstem aggregations.

U.S. Geological Survey

U.S. Geological Survey/Grand Canyon Monitoring and Research Center

In 2014, the GCMRC continued to serve in its role as the primary science provider to the GCDAMP. The GCMRC's primary activities during 2014 were: (1) conducting an annual reporting meeting that summarized findings from the previous year's research and monitoring activities and summarized knowledge-to-date concerning the Colorado River ecosystem, (2) developing a 3-year Budget and Work Plan encompassing fiscal years 2015-2017, (3) maintaining a stream flow and sediment transport measurement and internet-based real-time reporting program that was the foundation for planning a November HFE, (4) analysis of those data so as to inform dam and river management activities in the months immediately before the HFE, (5) collection and reporting of data describing resource condition immediately following the HFE, and (6) collection and reporting of native and non-native fish population data in support of management decisions regarding non-native fish control. Additionally, the GCMRC conducted numerous field and laboratory studies and provided logistics support for river trips and other field activities as outlined in the fiscal year 2013/2014 Budget and Work Plan, and provided scientific support for development of the LTEMP EIS.

Knowledge Synthesis

In January 2014, the GCMRC conducted a meeting with GCDAMP stakeholders during which results from research and monitoring in key resource areas in Glen and Grand canyons from the previous year were presented. The foci of the January meeting were biology, ecology, hydrology, sediment transport, geomorphology, cultural resources, and recreation resources.

Results from research and monitoring conducted by scientists from the GCMRC and cooperating agencies were presented. All materials presented at the workshops were made available in electronic postings at the GCMRC and Reclamation websites.

Development of a 3-Year Budget and Work Plan for Fiscal Years 2015-2017

In close cooperation with the GCDAMP stakeholders, the GCMRC developed a 3-year Budget and Work Plan for fiscal years 2015-2017. Similar to the 2013/2014 Budget and Work Plan, the new plan was organized into a relatively small number of focused projects. Key topics of study include hydrology, sediment transport, geomorphology, fisheries, aquatic ecology, riparian vegetation, cultural resources, and socioeconomics.

Implementation of Stream Flow and Sediment Measurement Program in Support of the High-Flow Experimental Protocol

The period July 1 to November 30, 2014, marked the third "sediment accumulation period" as defined under the High-Flow Experimental Protocol that was adopted by the Secretary in 2012. This HFE Protocol necessitates the estimation in real time of fine sediment delivery from the Paria River and fine sediment retention in Marble Canyon in the months immediately prior to the HFE. The GCMRC worked in collaboration with the Arizona and Utah Water Science Centers to measure suspended sediment transport and to process field samples in the GCMRC sediment lab. Telemetered data from remotely deployed instruments were shared in real time on the GCMRC website while data from physical samples were shared with Reclamation on a monthly basis in an unmatched effort to provide sediment data in a real-time format for HFE planning purposes. The GCMRC staff estimated that between 900,000 and 1,300,000 metric tons of fine sediment was delivered from the Paria River to the Colorado River during the period between July 1 and November 9, 2014. The HFE began on November 10 and ended on November 15, 2014.

Analyses of Sediment Transport Data to Inform HFE Planning and Design

The GCMRC scientists evaluated sediment transport and sediment mass balance data and made recommendations to Reclamation concerning the design of the HFE hydrograph so as to provide the most effective benefit-to-resource condition and scientific learning, consistent with the protocol defined in the 2012 published environmental assessment. Following consideration by Reclamation and vetting with various stakeholders, this hydrograph was the one implemented in the November HFE.

Implementation of a Plan to Evaluate HFE Effects

The GCMRC utilized a network of field time-lapse cameras to evaluate the effects of the HFE on sandbars throughout the Colorado River ecosystem. Scientists were sent into the field in December 2014 and January 2015 to collect photographic data and recover gaging station data. Preliminary results indicate that there was favorable bar building in Marble and Grand canyons caused by the fall 2014 high-flow experiment. The most recent topographic surveys of long-term monitoring sites from fall 2013 indicate sandbars increased in size during the first 2-years of implementation of the HFE Protocol. The first presentation concerning the effects of the HFE

was made to the Upper Colorado River Commission at its Las Vegas meeting in mid-December 2014 with additional data presented at the January 2015 annual reporting meeting described above. Additional information about the effects of the HFE were presented at a GCDAMP meeting and HFE workshop in late February 2015. In addition, rainbow trout populations and the aquatic food base in Glen Canyon were sampled before and after the HFE to evaluate any effects on the aquatic ecosystem of the event. Results and analysis to date indicate that HFEs do not trigger downstream movement of rainbow trout and suggest that the aquatic foodbase only responds weakly to fall HFEs as shown by slight increases in abundance of some aquatic insects and an invasive snail species and slight decreases in abundance of other non-insect invertebrates (tubificid worms and amphipods) within weeks to months of these events.

Fisheries Information in Support of Non-Native Fish Control EA

The GCMRC conducted monitoring of native and non-native fish populations in support of Reclamation's non-native fish control environmental assessment and its associated biological opinion for endangered humpback chub. This biological opinion identifies several triggers which if met require management actions to be taken to reduce non-native fish populations in an effort to protect humpback chub. Information provided by the GCMRC for specific triggers includes the abundance of non-native rainbow trout and brown trout in the Colorado River near the Little Colorado River confluence. The GCMRC and its cooperators also generated estimates of the abundance of several life stages of humpback chub in the Little Colorado River itself and near its confluence in the Colorado River, as well as survival rates of juvenile humpback chub in this latter area. Although the trigger level for rainbow trout abundance was exceeded in 2014, no other trigger levels, including those for humpback chub, were reached so no non-native fish control actions were required or implemented. As of April 2015, it appears that, due to declining rainbow trout abundance system wide, the trigger for rainbow trout abundance has no longer been exceeded based on surveys in January and April of 2015.

Other Science Activities and Findings

In the course of its regular and mandated science monitoring and research activities, the GCMRC and its cooperators provided stakeholders and the GCDAMP with other information including (1) critical data concerning the status and trends of endangered humpback chub populations in the Colorado River downstream of Glen Canyon Dam as well as key tributaries; (2) status and trends of rainbow trout in Glen Canyon, Marble Canyon, and near the Little Colorado River confluence; (3) distribution and relative abundance of potentially harmful non-native fish species between Glen Canyon Dam and Lake Mead reservoir; (4) status and trends of the aquatic foodbase in the Colorado River ecosystem; and (5) status of archaeological and other cultural sites and monitoring the transport of HFE derived sand by wind into these sites.

The GCMRC was permitted for and provided logistics support for 26 mainstem river trips in 2014, two more trips than in 2013. Trips in 2014 included 16 GCDAMP approved research and monitoring trips led by GCMRC or cooperating agency scientists that launched from Lees Ferry; 1 HFE monitoring trip that launched from Lees Ferry; 1 fisheries monitoring trip that launched from Diamond Creek; 1 project to replace the Diamond Creek cableway, which included daily launches from Diamond Creek; and 5 tribal-led monitoring trips. Logistics support, including

helicopter support, was also provided for GCDAMP funded projects in the Little Colorado River conducted by the FWS, Arizona Game and Fish Department, and GCRMC. Five Little Colorado River trips were conducted in 2014 (two fewer than 2013) with each trip requiring two flight days, one to take crews into field camps along the river and one to retrieve them. One additional flight day (one less than in 2013) was required to accommodate crew exchanges for the Arizona Game and Fish Department.

Many GCMRC scientists also provided support to the ongoing LTEMP EIS process. Support included model development, data analysis, participation on subject matter expert panels, document review, peer review coordination, and other activities to help ensure a sound scientific foundation for the development of the EIS.

2015 OPERATIONS

Bureau of Indian Affairs

In 2015, the BIA will continue to take an active role in supporting stakeholder tribes related to the GCDAMP. The BIA will participate in meetings concerning the Tribal Consultation Plan, pre-meetings with tribal representatives prior to AMWG meetings, and continue to participate in various ad hoc groups regarding tribal, cultural, and natural resource issues and concerns. The BIA is also a cooperating agency on the LTEMP EIS and will be actively involved in that process. The BIA will also continue to be involved with any future HFE releases from Glen Canyon Dam. The BIA will coordinate with, and if necessary meet with, Interior's Tribal Liaisons to facilitate stakeholder tribe participation in various aspects of the GCDAMP.

Bureau of Reclamation

Water Operations

As in 2010 through 2014, a WY 2015 hydrograph was jointly developed by the Interior AMWG agencies and Western. The recommended hydrograph is consistent with the Law of the River (including the GCPA) and is designed to enhance the protection of downstream resources. This approach to operations is consistent with the Interim Guidelines, operating criteria, and 2007 ROD, and falls within the parameters of the MLFF alternative adopted in the 1996 ROD. The recommended hydrograph received broad support from members of the AMWG and was approved by the Secretary on September 29, 2014.

Releases from Lake Powell in WY 2015 reflect consideration of the uses and purposes identified in the authorizing legislation for Glen Canyon Dam and were consistent with the 1996 ROD; the 2012 EA/FONSI for Development and Implementation of a Protocol for High-Flow Experimental Releases from Glen Canyon Dam, Arizona, 2011-2020; and the 2015 hydrograph. As of August 13, 2015, the observed and projected monthly release volumes for WY 2015 are displayed in Table 2. The end of water year 2015 elevation for Lake Powell is projected to be 3,608 feet.

Table 2. Lake Powell Monthly Release Volumes
Water Year 2015

Month	Monthly Release Volumes (maf*)
October 2014	0.598
November 2014	0.777
December 2014	0.864
January 2015	0.862
February 2015	0.589
March 2015	0.649
April 2015	0.600
May 2015	0.699
June 2015	0.800
July 2015	1.048
August 2015**	0.800
September 2015**	0.713
Total Releases**	9.000

* maf = million acre-feet
** = projected release

Reclamation will continue planning for high-flow experimental releases from Glen Canyon Dam in November 2015 in accordance with the High-Flow Experimental Protocol and Reclamation's May 12, 2012, FONSI.

LTEMP EIS

In 2015, Reclamation and the NPS will continue development of the LTEMP EIS leading to publication of a draft document for public release in late fall of 2015.

Conservation Measures for Humpback Chub and Tribal Activities

Many of the activities described above will continue in 2015, but may be modified depending on the completion of the LTEMP EIS and the biological opinion that will follow. Reclamation will continue to provide funding to the GCMRC and the NPS for cultural, aquatic, and sediment research and for the participation of five American Indian Tribes in the GCDAMP (as described above for 2014). Reclamation will continue efforts to develop a new Programmatic Agreement for operation of Glen Canyon Dam pursuant to the GCPA and consistent with the LTEMP.

National Park Service

LTEMP EIS

In 2015, the NPS and Reclamation plan to continue development of the LTEMP EIS using the Department of Energy's Argonne National Laboratory as the third-party contractor, funded by

Reclamation. The NPS's Intermountain Regional Office, Washington Office, Grand Canyon, Glen Canyon, and Lake Mead all participated in various LTEMP activities. The NPS will participate with Reclamation and Interior in the public meetings and review and comment on the draft EIS, anticipated to be released in the late fall of 2015.

Archaeological/Cultural Resources

Grand Canyon National Park: In 2015, work will include participating in tribal monitoring field sessions along the river. One field session devoted specifically to testing monitoring protocols for visitor use will also document visitor impacts to a selection of archaeological sites.

The NPS and tribal consultants continue working collaboratively on an interpretive brochure for the Unkar Delta sites. One river trip will include the NPS and tribes to review the work to date on site.

Glen Canyon National Recreation Area: In 2015, work will include progress in the development and evaluation of monitoring protocols for terrestrial resources to evaluate potential effects resulting from dam operations. Staff will continue opportunistic monitoring around planned high-flow experiments.

Tribal Consultation

In 2015, the NPS anticipates continued participation in consultation meetings with the various tribes who are directly involved in the GCDAMP and other Colorado River related programs. The Grand Canyon National Park and the Glen Canyon National Recreation Area will continue discussions with tribes to incorporate tribal perspectives into implementation of the NPS's Comprehensive Fisheries Management Plan. Tribal advisors will continue to be consulted on specific monitoring and mitigation protocols relative to the Colorado River Management Plan implementation. The Grand Canyon National Park anticipates working with the Pueblo of Zuni and external partners on projects to better protect important resources along the Colorado River. Specific efforts will be made with the Pueblo of Zuni relative to creating a "buffer" zone near the confluence of Bright Angel Creek and Ribbon Falls Creek. This zone will incorporate specific removal techniques including use of nets and elimination of electrofishing in that area. Additional crew training will occur with representatives from Zuni to discuss specific concerns. Park staff anticipates working with representatives from traditionally associated tribes to gather information on the Salt Mines located along the river downstream of the Little Colorado River confluence.

The NPS will continue to work with Reclamation to consult with interested tribes involved in the LTEMP. Consultation is government-to-government and includes all tribes who are interested in the planning effort regardless of their role as a cooperating agency for the EIS.

Humpback Chub Translocation and Fisheries Management

In Grand Canyon, implementation of the Comprehensive Fisheries Management Plan will continue into 2015. These efforts will include an evaluation of the status and habitat use of

newly rediscovered endangered razorback sucker, translocations and monitoring of endangered humpback chub to Havasu and Shinumo creeks, and the removal of non-native fishes threatening endangered and native fish in Shinumo and Bright Angel creeks and the Bright Angel Creek inflow area of the Colorado River. Collaboration with Reclamation, FWS, GCMRC and others will continue on all fisheries projects leading to well integrated projects.

Wildlife Surveys and Monitoring

Grand Canyon National Park: In 2015, the Grand Canyon National Park will continue work on bighorn sheep including distribution and potential disease pathogen identification. Biologists will continue to monitor condors and Mexican spotted owls. Additionally, ground truthing the northern leopard frog habitat model will be completed.

Glen Canyon National Recreation Area: In 2015, the Glen Canyon National Recreation Area plans to continue programs related to desert bighorn sheep, aquatic/riparian invertebrates and terrestrial vertebrate populations, and northern leopard frog and ambersnail habitat enhancements.

Vegetation Management/Exotic Species Removal

In FY 2015, the NPS will attempt to continue the Adopt-a-Camp program through work with commercial guides. Nursery staff will continue to propagate riparian plant species for future restoration projects along the river corridor. Funding for the restoration of two more riparian restoration sites was pushed to 2016, but vegetation program staff will work with wildlife staff and compliance staff to continue strategic planning efforts for that project.

In 2015, the NPS, partners, and volunteers will continue invasive plant management, native plant restoration, and vegetation monitoring activities along the Colorado and Paria rivers below Glen Canyon Dam.

Research Review and Permitting

The NPS anticipates continuation of research and permitting activities in 2015 at similar levels as 2014. For each of the research projects in support of the GCPA, peer review of the proposals, evaluation of need for NEPA compliance, and completion of minimum requirement analysis will be completed. Updating of annual investigator reports will be done for each research permit and coordination with Reclamation will continue.

Resource Monitoring and Mitigation

The Grand Canyon National Park will continue integrated campsite monitoring in 2015 based on the revised campsite monitoring protocols. The NPS will continue to conduct campsite use surveys. One trip for Lower Gorge campsites is planned to mitigate vegetation encroachment on campsites below Separation Canyon.

Greater Grand Canyon Landscape Assessment

In 2015, an interdisciplinary team of NPS experts, agency partners, scientists, and other groups and individuals will continue to conduct the Greater Grand Canyon Landscape Assessment in an effort to identify resource conditions and trends and prioritize conservation needs to facilitate ecosystem-based stewardship. Final reports are due in late 2015. The NPS will continue to work on a pilot riparian rehabilitation project at Granite Camp, including the removal of non-native tamarisk and revegetation with native plants.

U.S. Fish and Wildlife Service

In 2015, the FWS will conduct four monitoring trips on the Little Colorado River to generate population estimates for humpback chub and other native fishes, and to also monitor the success of upstream translocations. The FWS will continue to work cooperatively with the NPS and Havasupai Tribe on monitoring Havasu Creek and completing additional translocations of humpback chub in the summer of 2015. Fish will be collected for translocations from the Little Colorado River and held at the Southwest Native Aquatic Resources and Recovery Center until they are large enough to be marked with a small tag. The FWS will continue to take the lead on developing a monitoring protocol for effectively sampling the mainstem aggregations of humpback chub and will conduct 1 sampling trip in 2015.

U.S. Geological Survey

The major focus of the GCMRC's activities in 2015 is to continue to serve in its role as the primary science provider to the GCDAMP by conducting the field and laboratory studies described in the fiscal years 2015-2017 Budget and Work Plan. Additionally, the GCMRC plans to continue providing real-time scientific data needed to implement the High-Flow Experimental Protocol. Specifically, the GCMRC will maintain its internet-based real-time reporting of stream flow and sediment storage and transport in Marble and Grand canyons as well as continue providing estimates of the mass of fine sediment supplied to the Colorado River by the Paria and Little Colorado rivers and the mass of fine sediment stored in various parts of Marble and Grand canyons. The GCMRC will continue monitoring and reporting on resource conditions following HFEs and working with Reclamation in refining HFE planning protocols. Native and non-native fish population data will continue to be collected and reported on in support of management decisions regarding non-native fish control. The GCMRC will also provide science support in planning and developing the LTEMP EIS.