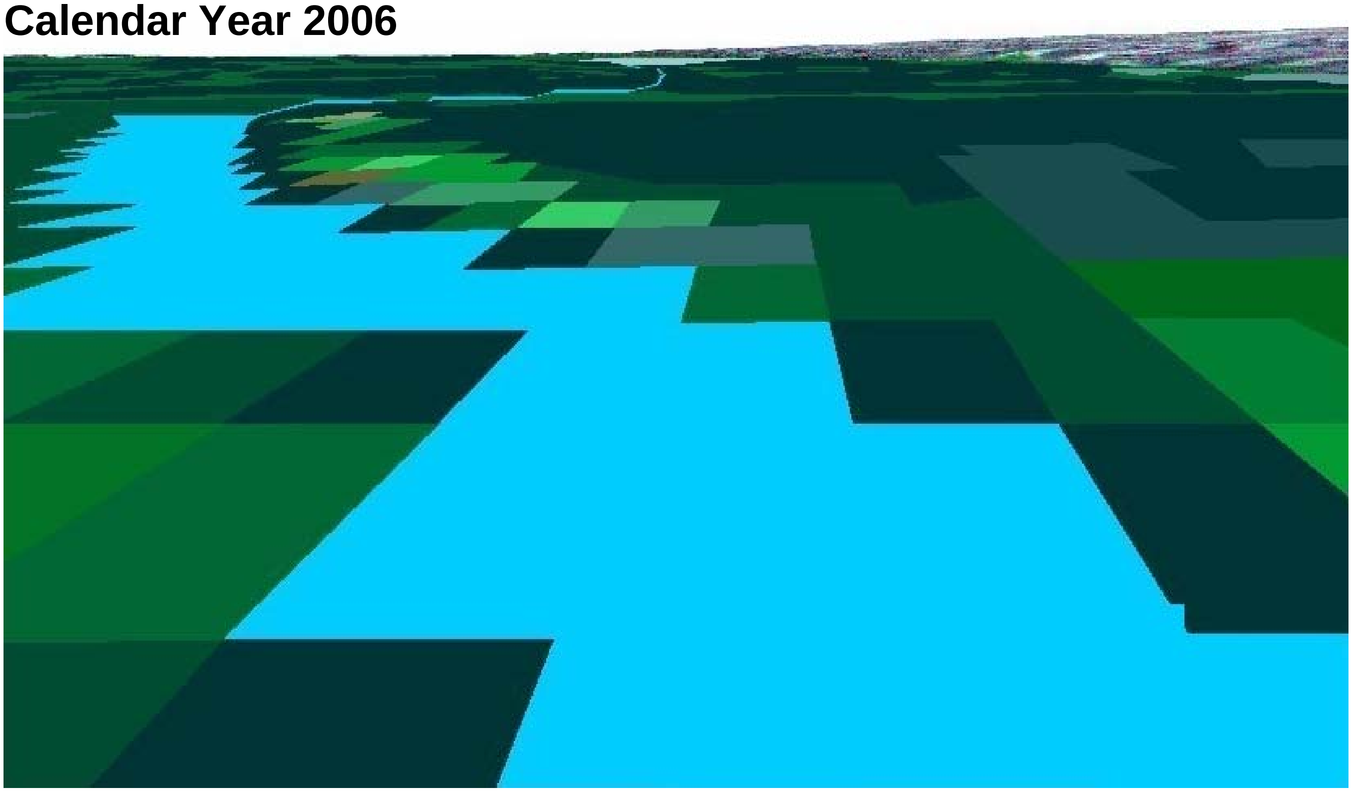
RECLAMATION
Managing Water in the West

Lower Colorado River Accounting System Evapotranspiration and Evaporation Calculations

Calendar Year 2006



U.S. Department of the Interior
Bureau of Reclamation

September 2007

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Calendar Year 2006

U.S. Department of the Interior
Bureau of Reclamation
Lower Colorado Regional Office
Boulder City, Nevada

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LCRAS Study Area
NEVADA
Las Vegas
Lake Mead
Hoover Dam
Boulder City
Colorado River
VICINITY MAP
NEVADA
UTAH
COLORADO
Colorado River Basin
CALIFORNIA
ARIZONA
NEW MEXICO
Los Angeles
San Diego
Phoenix
Tucson
Mexico
Lake Mohave
Davis Dam
Kingman
Needles
ARIZONA
Lake Havasu
Parker Dam
Bill Williams River
Alamo Lake
Alamo Dam
CALIFORNIA
Colorado River Aqueduct
Colorado River
Parker
CAP Canal
Blythe
Senator Wash Dam
Imperial Dam
Wellton-Mohawk Canal
All American Canal
Morelos Dam (Mex.)
Yuma
Gila Main Gravity Canal
MEXICO
N
S
E
W
0 10 20 40 60 80 Miles
Legend
Major Dams
Study Area
Agricultural Areas within Study Area

Table of Contents

List of Tables

List of Figures

Introduction

The lower Colorado River is the principal source of water for irrigation and domestic[1] use in Arizona, southern California, and southern Nevada. Reclamation must understand the disposition of water once it is released from Hoover Dam in order to effectively manage the lower Colorado River. The Lower Colorado River Accounting System (LCRAS) provides the following information for Reclamation to use as water management tools:

1. estimates of evapotranspiration (ET) from irrigated areas for monitoring of agricultural water use;
2. estimates of ET from riparian vegetation for environmental resources assessment and management; and
3. estimates of evaporation from the channel and reservoirs of the lower Colorado River, and evaporation from canals and lakes, lagoons, and other open-water areas along the river for river system resource assessment and management.

Reclamation uses these tools to monitor the current state of the river system, to assess potential impacts of changes to the river system, and as inputs to management decisions involving the administration of the laws, compacts, and U.S. Supreme Court decree which govern the diversion and use of Colorado River water.

Results

Table 1 shows the ET from agriculture[2] and riparian vegetation; and evaporation from the open water surfaces of lakes, ponds, lagoons, and other open water surfaces that are not part of the river channel or reservoirs of the lower Colorado River between Hoover Dam and Mexico for calendar year 2006. Table 1 includes areas irrigated with water diverted from the lower Colorado River which are not on the river itself, specifically the Wellton-Mohawk Irrigation and Drainage District on the Gila River in Arizona, and the Imperial Irrigation and the Coachella Valley Water districts in California. Detailed calculations and values used to develop the results presented in Table 1 can be found in, "Lower Colorado River Accounting System Appendix: Part 1, Evapotranspiration-Rate Calculations, and Part 2, Evapotranspiration Calculations" for calendar year 2006.

[1] Domestic use of Colorado River water includes for household, stock, municipal, mining, milling, industrial, and other like purposes. See U.S. Supreme Court in Consolidated Decree of the United States Supreme Court in *Arizona v. California*, 547 U.S. 150 (2006) in Article I.(I).

[2] ET includes evaporation from major delivery canals, see "Lower Colorado River Accounting System Appendix: Part 2, Evapotranspiration Calculations" for calendar year 2006.

Table 1 — Agricultural and Riparian Vegetation ET, and Evaporation by Water User, Lower Colorado River, Hoover Dam to Mexico

Units: Annual Acre-Feet

Diverter Name	Agricultural ET	Riparian Vegetation ET (Colorado River Floodplain)	Evaporation (Maintained Open Water)[3]	Evaporation (Not Maintained Open Water)[4]
Nevada (below Hoover Dam)				
Lake Mead National Recreation Area (Hoover Dam to Davis Dam)	0	192	0	0
Lake Mead National Recreation Area (Davis Dam to Parker Dam)	0	101	0	215
Fort Mohave Indian Reservation	2,176	6,191	0	46
State of Nevada	0	12,389	12	133
Nevada Totals	2,176	18,873	12	394
California				
Chemehuevi Indian Reservation	145	43	0	0
Fort Mohave Indian Reservation	14,937	5,079	0	0
Havasu National Wildlife Refuge	0	6,216	1,200	0
Moabi Park	0	234	0	0
Bernal Farm	0	1,241	0	0
Cibola National Wildlife Refuge	0	13,398	800	0
Clark Farm	0	134	0	0
Colorado River Indian Reservation	0	34,866	0	350
Imperial National Wildlife Refuge (Parker Dam to Imperial Dam)	0	23,506	4,250	940
Imperial National Wildlife Refuge (Imperial Dam to Mexico)	0	43	0	0
Imperial National Wildlife Refuge and Yuma Proving Ground	0	55	0	0
North Lyn-De Farm[5]	854	1	0	0
Palo Verde Irrigation District, CA.	320,830	8,691	3,563	580
Picacho State Recreation Area (Parker Dam to Imperial Dam)	0	5,215	0	470

[3] Maintained Open Water includes areas of open water which are fully or partially maintained by diversion from the Colorado River, such as man-made ponds, lakes, or lagoons. All open water areas within wildlife refuges are currently included in Maintained Open Water.

[4] Not Maintained Open Water includes areas of open water that are naturally part of the lower Colorado River, inclusive of lakes and reservoirs operated by Reclamation for the delivery of water.

[5]A portion of North Lyn-De farm is within Colorado River Indian Reservation diverter boundary.

Table 1 — Agricultural and Riparian Vegetation ET, and Evaporation by Water User, Lower Colorado River, Hoover Dam to Mexico

Units: Annual Acre-Feet

Diverter Name	Agricultural ET	Riparian Vegetation ET (Colorado River Floodplain)	Evaporation (Maintained Open Water)[3]	Evaporation (Not Maintained Open Water)[4]
Picacho State Recreation Area (Imperial Dam to Mexico)	0	1,180	0	11
South Lyn-De Farm	836	2	0	0
Imperial Irrigation District	1,889,373	0	6,916	0
Coachella Valley Water District	257,257	0	34,609	0
Fort Yuma Indian Reservation	2,653	13,221	0	198
Fort Yuma Indian Reservation, Indian Unit	15,859	882	104	0
Fort Yuma Indian Reservation, Bard Unit	21,897	920	149	0
Fort Yuma Indian Reservation and Picacho State Recreation Area	0	920	0	0
Fort Yuma Indian Reservation and Yuma Proving Ground	0	914	0	0
Yuma Proving Ground	0	8,855	0	0
State of California (Other uses, Davis Dam to Parker Dam)	0	17,889	0	409
State of California (Other uses, Parker Dam to Imperial Dam)	1,122	28,846	0	1,435
State of California (Other uses Imperial Dam to Mexico)	2,782	2,832	0	203
California Totals	2,528,545	175,183	51,591	4,596
Arizona				
Lake Mead National Recreation Area (Hoover Dam to Davis Dam)	0	1,219	0	15
Lake Mead National Recreation Area (Davis Dam to Parker Dam)	0	373	0	337
Fort Mojave Indian Reservation	42,189	47,381	0	158
Havasu National Wildlife Refuge	341	53,040	16,868	0
Havasu State Park (Windsor Beach)	0	3,623	0	0
Mohave Valley Irrigation and Drainage District	23,275	31,044	0	368
Arkelian Farms	1,143	2,590	0	0
Palo Verde Irrigation District, AZ.	664	587	0	230
Cibola Valley Irrigation and Drainage District	13,176	7,947	0	5
Cibola National Wildlife Refuge	8,185	34,376	2,020	0
Colorado River Indian Reservation	355,324	132,995	1,446	1,055
Ehrenberg Farm	3,853	0	0	0

Table 1 — Agricultural and Riparian Vegetation ET, and Evaporation by Water User, Lower Colorado River, Hoover Dam to Mexico

Units: Annual Acre-Feet

Diverter Name	Agricultural ET	Riparian Vegetation ET (Colorado River Floodplain)	Evaporation (Maintained Open Water)[3]	Evaporation (Not Maintained Open Water)[4]
Imperial National Wildlife Refuge (Parker Dam to Imperial Dam)	0	36,612	5,535	0
Imperial National Wildlife Refuge (Imperial Dam to Mexico)	56	6,553	2,038	32
Fort Yuma Indian Reservation and Homesteads	1,095	3,067	0	0
Fort Yuma Indian Reservation, Mittry Lake State Wildlife Area and Yuma Proving Ground	0	946	0	161
Hillander "C" Irrigation District	8,007	0	0	0
Mittry Lake State Wildlife Area	140	11,070	123	310
North Cocopah Indian Reservation	848	131	0	32
West Cocopah Indian Reservation	3,738	6,807	0	0
North Gila Valley Irrigation District	22,004	2,193	47	0
Sturges Gila Monster Ranch	6,468	882	92	16
Wellton-Mohawk Irrigation and Drainage District	194,209	7	633	0
Unit "B" Irrigation and Drainage District	6,866	0	105	0
University of Arizona Agricultural Station	234	0	0	0
Yuma Irrigation District	34,308	1,003	322	0
Yuma Mesa Irrigation and Drainage District	60,254	0	919	0
Yuma Proving Ground	0	692	0	0
Yuma County Water Users Association	136,282	11	1,644	5
State of Arizona (Other users, Davis Dam to Parker Dam)	0	4,003	133	36
State of Arizona (Other users, Parker Dam to Imperial Dam)	0	23,305	0	590
State of Arizona (Other users, Imperial Dam to Mexico)	10,111	13,277	91	128
State of Arizona – Limitrophe Section	2,817	3,995	0	0
State of Arizona – Down gradient of the Yuma Mesa Irrigation and Drainage District	19,477	0	0	0
Arizona Totals	955,064	429,729	32,016	3,478
Hoover Dam to Mexico Totals	3,485,785	623,785	83,619	8,468

Table 2 provides a Summary of ET and evaporation results along the lower Colorado River from Hoover Dam to Mexico and the Wellton-Mohawk Irrigation and Drainage District, the Imperial Irrigation District, and the Coachella Valley Water District (included in the Imperial Dam to Mexico reach).

Table 2 — Summary of ET and Evapotranspiration along the Lower Colorado River from Hoover Dam to Mexico Units: Annual Acre-Feet					
ET Category/Evaporation	Hoover Dam to Davis Dam	Davis Dam to Parker Dam	Parker Dam to Imperial Dam	Imperial Dam to Mexico	Hoover Dam to Mexico
Agricultural ET	0	83,063	705,987	2,696,735	3,485,785
Riparian Vegetation ET (Colorado River Floodplain)	1,411	187,606	354,312	80,456	623,785
Evaporation (Maintained Open Water)	0	18,213	17,614	47,792	83,619
Evaporation (Not Maintained Open Water)	15	1,702	5,655	1,097	8,469
Evaporation (Mainstream Open-Water)	139,744	102,331	47,713	5,443	295,231

Table 3 shows the ET from agriculture and riparian vegetation and evaporation from open water areas along the Bill Williams River from below Alamo Dam to Lake Havasu for calendar year 2006. Detailed calculations and values used to develop the results presented in Table 3 can be found in, "Lower Colorado River Accounting System Appendix: Part 1, Evapotranspiration-Rate Calculations, and Part 2, Evapotranspiration Calculations" for calendar year 2006.

Table 3 — Agricultural and Riparian Vegetation ET, and Evaporation by Water User, Bill Williams River, Alamo Dam to Lake Havasu Units: Annual acre-Feet			
Diverter Name	Agricultural ET	Riparian Vegetation ET (Bill Williams River Floodplain)	Evaporation
Bill Williams River, Alamo Dam to Bill Williams National Wildlife Refuge	2,205	4,003	0
Bill Williams National Wildlife Refuge	0	11,092	0

In addition to the evapotranspiration reported in tables 1 through 3, previous, 9,022 acre-feet of evapotranspiration was calculated from crops grown and 633 acre-feet of water evaporated from maintained ponds in Arizona adjacent to the boundary of the Wellton-Mohawk Irrigation and Drainage District on the Gila River. The origin of the water used to irrigate these crops and maintain these ponds is not reported. Detailed calculations and values used to develop this ET can be found in, "Lower Colorado River Accounting System Appendix: Part 1,

Key LCRAS ET Components

The key components of LCRAS ET and evaporation calculations are these:

1. identifying crop and riparian vegetation groups, and open-water areas;
2. calculating ET for crop groups and riparian vegetation groups; and
3. calculating evaporation from open-water areas (the channel and reservoirs of the lower Colorado River, evaporation from major delivery canals, ponds, and other open-water areas).

The following sections present a description of the key components of LCRAS ET calculations.

Identifying Crop Groups, Riparian Vegetation Groups, and Open-Water Areas

This section provides an overview of the image classification processes and Geographic Information Systems (GIS) technologies Reclamation used to identify and map crop and riparian vegetation groups, and open-water areas along the lower Colorado River below Hoover Dam, in the Wellton-Mohawk Irrigation and Drainage District on the Gila River, the Imperial Irrigation and Coachella Valley Water districts in California, and along the Bill Williams River below Alamo Dam in calendar year 2006.

Overview

Remote sensing is the process of acquiring information using indirect measurements. One example of remote sensing is the interpretation of features on the Earth's surface using imagery acquired by satellites orbiting the Earth. Image classification is the labeling of objects, features or areas based upon their appearance and using image processing programs with digital satellite imagery. Reclamation uses these techniques with GIS technologies, to determine the location and acreages of crop groups, riparian vegetation groups, and open-water areas along the lower Colorado River below Hoover Dam, in the Wellton-Mohawk Irrigation and Drainage District on the Gila River, the Imperial Irrigation and Coachella Valley Water districts in California, and along the Bill Williams River from below Alamo Dam to Lake Havasu on the Colorado River. This procedure is also referred to as 'mapping' in this report. The spatial extent (location and area of coverage) of the crop groups, riparian vegetation groups, and open-water areas are stored in digital spatial databases collectively referred to as a GIS database. Reclamation uses the data generated from these processes to accurately calculate ET from crops and riparian vegetation, and evaporation from open-water areas.

When remote sensing processes alone are insufficient to map crop and riparian vegetation groups, or open-water areas, data collected on the ground (ground reference surveys) are also used. For example, orchards are mapped from ground survey data due to the difficulty of correctly identifying those features using remote sensing processes alone. Once the data is entered into a GIS database, programs are used to calculate the number of acres of each crop group and riparian vegetation group for each diverter, as well as the open-water areas. Acreage calculations are completed for areas located within the flood plain along the mainstream of the lower Colorado River from Hoover Dam to Mexico; cropped areas upon the Palo Verde and Yuma Mesas, areas within and near the Wellton-Mohawk Irrigation and Drainage District, areas within Imperial Irrigation District, and areas within the Coachella Valley Water District; and areas along the Bill Williams River from Alamo Dam to Lake Havasu.

Once Reclamation maps the crop and riparian vegetation groups, and open-water areas (discussed in the following sections), Reclamation calculates the ET from crops and riparian vegetation for each diverter and evaporation from open-water areas. Currently, this analysis does not include estimates of ET or evaporation within the boundaries of domestic water users. Areas that are not located within a known diverter boundary are mapped and labeled with the name of the state they are located within for identification.

Collecting and Analyzing Remotely-Sensed Data

Satellite imagery is acquired from Thematic Mapper (TM) sensors mounted on the Landsat 5 and Landsat 7, and other satellite sensors when Landsat data is not sufficient. For its analysis, Reclamation selects satellite images that adequately cover the study area, are cloud-free, and capture the variation in crop planting practices during the year. Table 4 shows the dates, and path and row designations for which Reclamation purchased TM image data for analysis during calendar year 2006. Path and row designations refer to image locations based on the World Reference System[6].

[6] The World Reference System (WRS) catalogues Landsat 5 and 7 images by location (path and row) and date. The WRS for Landsat has 233 paths corresponding to the number of orbits required to cover the Earth every 16 days. The Landsat 5 and Landsat 7 satellite orbits are offset so any site on the Earth can be revisited every 8 days. Paths are numbered 001 to 233, east to west. The rows are numbered so that row 60 coincides with the equator on an orbit's descending node.

Table 4 — TM Image acquisition dates, path-row designations, and Platform/Sensor used in calendar year 2006		
Acquisition Date	Path, Row Designation	Platform/Sensor
January 29, 2006	Path 38, Row 36 & Row 37	Landsat 5
February 12, 2006	Path 40, Row 37	Landsat 5
February 21, 2006	Path 39, Row 37	Landsat 5
February 22, 2006	Path 38, Row 37	Landsat 7
April 26, 2006	Path 39, Row 36 & Row 37	Landsat 5
May 5, 2006	Path 38, Row 36 & Row 37	Landsat 5
May 29, 2006	N/A	ASTER
July 7, 2006	Path 39, Row 37	Landsat 5
July 8, 2006	Path 38, Row 36 & Row 37	Landsat 5
July 15, 2006	Path 39, Row 36	Landsat 5
November 20, 2006	Path 39, Row 36 & Row 37	Landsat 5
November 29, 2006	Path 38, Row 36 & Row 37	Landsat 5

Collecting Ground Reference Data

Correctly identifying and mapping crop and riparian vegetation groups using remotely-sensed data requires a thorough understanding of the spectral characteristics of vegetation types for representative (ground reference survey) sites throughout the study area. The term "spectral characteristics" refers to the amount of spectral reflectance from the Earth's surface recorded by the satellite sensors in different portions of the electromagnetic spectrum (ERDAS, 1999) for different vegetative types (i.e. crop types or riparian vegetation types). TM satellite image data contain digital values that represent the spectral reflectance values of these crop and riparian vegetation groups. Reclamation analyzes these digital values within ground reference survey sites to generate spectral statistics, or signatures (ERDAS, 1999) for specific crop and riparian vegetation groups.

Reclamation collects ground reference survey data for approximately 12% of the irrigated fields in the study area. Reclamation uses 60 to 65 percent of the ground reference survey data for image classification processing (to identify crop groups) and the remaining 35 to 40 percent to assess the accuracy of the image classifications. Reclamation selects ground reference survey sites in each major irrigated area involved in this analysis. To provide a statistically valid data set for image classification procedures, Reclamation selects irrigated fields randomly from a GIS database and adds additional fields to the random sample, where necessary, to ensure representation of all major crop groups. This sample is also stratified based upon an analysis of agricultural field size. The variability in planting and harvesting times for each crop group is a critical factor in selecting optimum image dates.

Reclamation purchases satellite images five times a year, and collects ground reference survey data four times a year to coincide with four of the image acquisition dates. Table 5 shows the crop groups sampled in calendar year 2006.

Table 5 — Crop groups sampled in calendar year 2006			
Alfalfa (Alfalfa, Alfalfa – Unwatered (dry and senescent)	**Melons –** Spring and Fall (Watermelon, Honeydew, Cantaloupe, Squash, Cucumbers)	**Tomatoes**	**Small Vegetables** (Carrots, Cilantro, Celery, Garlic, Dry Onions, Onions, Parsley, Radishes)
Cotton	**Grapes**	**Sudan** (includes Sunflower and Sesbania)	**Root Vegetables** (Table Beets, Parsnip, Turnip and Rutabaga)
Small Grain (Oats, Rye, Barley, Millet, Wheat)	**Bermuda/Rye Grass** (Bermuda, Bermuda Over seeded with Rye, Klein, Timothy)	**Legume/Solanum Vegetables** (Green, Dry and Garbanzo Beans; Peas, Peanuts, Fresh Peppers, Potatoes)	**Perennial Vegetables** (Artichoke, Asparagus)
Field Grain (Field Corn, Sorghum, Milo)	**Citrus** (Young, mature, Declining)	**Crucifers** (Broccoli, Cauliflower, Cabbage, Bok-Choy, Mustard, Kale, Okra)	**Sugar Beets** (Summer and Winter)
Lettuce - Spring and Fall (Head, Leaf [Red], Leaf [Green], Spinach, Other Lettuce)	**Idle** (Fields currently not in production, includes bare cultivated soil)	**Dates**	**Fallow**
Open Water (Fish Pond, Duck Pond, Off-Stream Lake or Reservoir)	**Jojoba Beans**	**Safflower**	**Moist Soil Unit**[7]
Seasonal Wetland[8]	**Nursery or Greenhouse** (Citrus Nursery, Native Nursery, Greenhouse, Other Nursery)	**Deciduous Orchards** (Pecans, Peaches, Almonds)	**Other**

Table 6 shows how Reclamation groups riparian vegetation types.

[7] An area gradually flooded in winter to develop migratory waterfowl forage and not irrigated in summer.

[8]An area flooded in winter but not irrigated in summer to maintain a wetland.

Table 6 — Riparian Vegetation Groups	
Group Name	Description
Marsh	40% cattail, bulrush, and phragmites
Barren	Less than 10% vegetation
Sc_low	11% to 60% salt cedar and less than 25% arrowweed
Sc_high	61% to100% salt cedar and less than 25% arrowweed
Sc/ms	11% to 60% salt cedar, 11% to 60% mesquite, and less than 25% arrowweed
Sc/aw	Less than 75% salt cedar and 25% or more arrowweed
Sc/ms/aw	15% to 45% salt cedar, 15% to 45% mesquite, and 20% to 40% arrowweed
Ms-low	11% to 60% screwbean and honey mesquite, and less than 25% arrowweed
Ms-high	61% to 100% screwbean and honey mesquite, and less than 25% arrowweed
Ms/aw	21% to 60% mesquite, 31% to 60% arrowweed, and less than 20% salt cedar
Aw	51% to 100% arrowweed and less than 10% any trees
Cw	61% to 100% cottonwood and willow
Low veg	Greater than 10% and less than 30% any riparian vegetation

Delineating Cropped Areas

Reclamation has developed a spatial relational database (GIS database, ESRI, 1995) that delineates the field borders in all irrigated areas involved in this analysis (field border database). Reclamation has linked all ground reference survey data collected for image classification to this field-border database. Reclamation originally created the GIS field-border database for the lower Colorado River by digitizing field boundaries using 10-meter Systemme Pour l'Observation de la Terre (SPOT) satellite image data as a reference. This imagery was acquired in June and August of 1992. Digitizing is the process of creating a graphical representation of a feature such as a road or agricultural field within a digital (computer) environment. Points representing the corners or center line of a feature are stored according to a real-world coordinate system and then are displayed or analyzed within the computer environment.

Since 1995, Reclamation has updated changes in field borders on the basis of ground reference survey data collected throughout the year. Reclamation also uses 5-meter Indian Remote Sensing (IRS) satellite images (1-C or 1-D sensors) and 2-meter USDA National Agricultural Imaging Program (NAIP) digital photography to both update and create new field border databases. For calendar year 2006, Reclamation made minor updates to existing field border databases using ground reference survey data and NAIP imagery. Reclamation will continue to use these two methods to update field borders.

Delineated cropped areas include all areas known by Reclamation to divert or pump water along the mainstream of the lower Colorado River from Davis Dam to Mexico, the Wellton-Mohawk Irrigation and Drainage District, the Imperial Irrigation District, the Coachella Valley Water District; and irrigated areas along the Bill Williams River from below Alamo Dam to Lake Havasu. Exhibits 2 through 8 and 11 through 14 show these areas. Exhibit 1 is a map index for those Exhibits of delineated cropped areas. Exhibit 9 is an example of digitized field borders, and Exhibit 10 is an index of diverter boundaries.

Using the analysis of remotely-sensed data, discussed previously, in conjunction with the GIS field border database, Reclamation identified the crop groups (Table 5) which were grown in each agricultural field throughout the calendar year. Post-classification accuracy assessment shows that, overall, the crop groups were mapped with an average accuracy of greater than 90 percent for each of the five image classification dates used in 2006.

Delineating Riparian Vegetation Areas

Reclamation updates riparian vegetation areas by comparing the current year Landsat TM summer satellite images to the previous year's images (change detection methods[9]). Reclamation field checks areas of spectral change to confirm that the change is actually due to change in land cover. Reclamation then remaps areas of land cover change and uses these maps to update the riparian vegetation database. Reclamation compared images from July 5, 2005, to images from July 8, 2006, to update riparian vegetation areas for calendar year 2006.

Delineating Open-Water Areas

Open water of the mainstream

An open-water GIS database contains the spatial boundaries of open-water surfaces such as reservoirs, rivers, and canals. Reclamation initially developed an open-water GIS database for calendar year 2000 and has updated this database annually by reviewing TM imagery acquired in July of each year. For calendar year 2006, Reclamation compared TM satellite images acquired on July 8, 2006 and NAIP imagery acquired for summer, 2004 and summer, 2006, to the calendar year 2005 open-water GIS database. This comparison identified significant changes in open-water acreage that may have occurred over the calendar year. Changes were identified as significant when greater than 90 m^2 while reviewing TM imagery, or greater than 30m^2 where NAIP imagery was available[10]. This analysis also identified open-water areas which were missed in previous years because of the lower resolution of TM imagery when compared to NAIP imagery.

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[9] See, Lower Colorado River Accounting System Demonstration of Technology Calendar Year 2001," Chapter 6, 6.23 - 6.26.

[10] NAIP imagery is available for farmed areas only in the LCRAS study area.

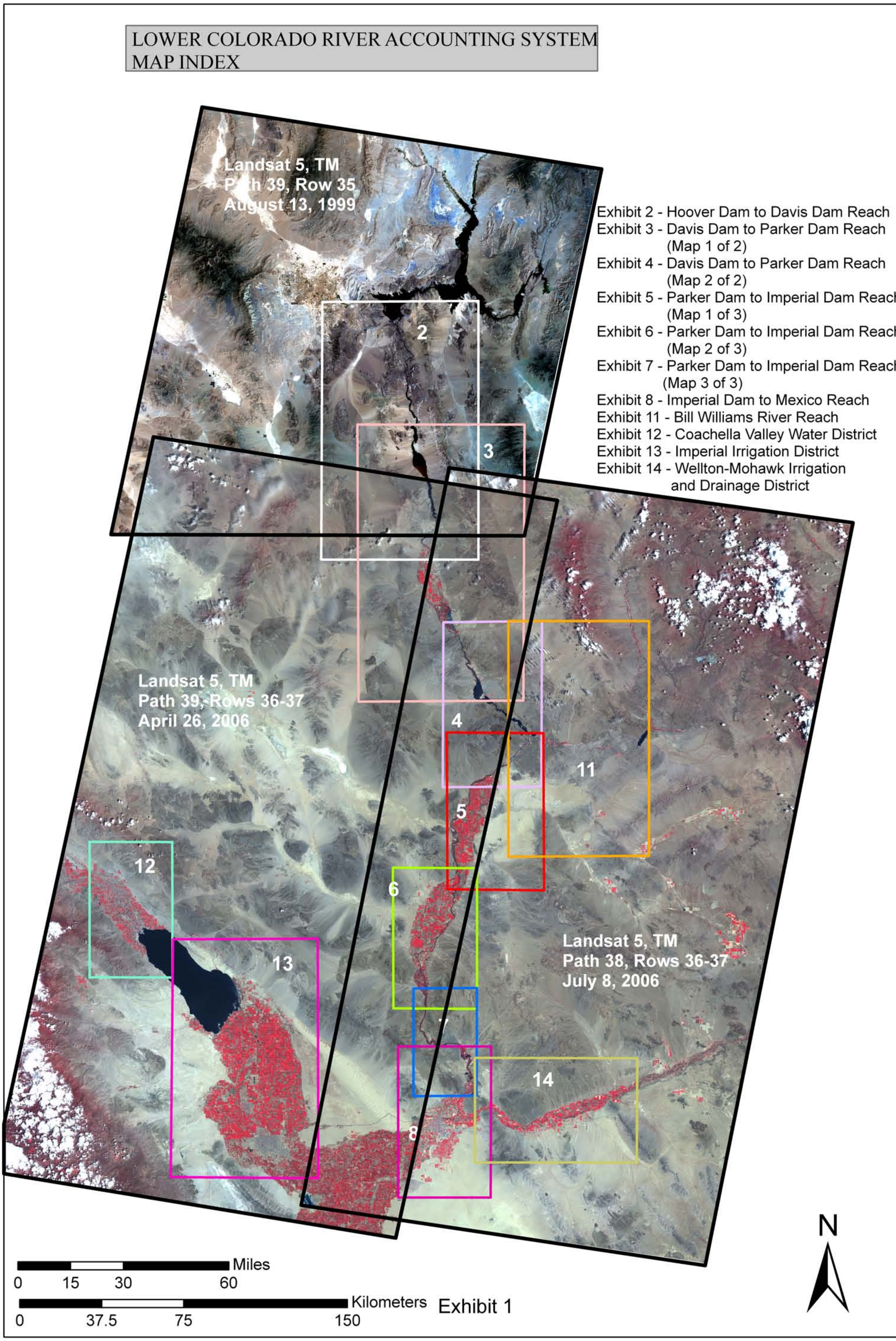

LOWER COLORADO RIVER ACCOUNTING SYSTEM
MAP INDEX
Landsat 5, TM
Path 39, Row 35
August 13, 1999
Exhibit 2 - Hoover Dam to Davis Dam Reach
Exhibit 3 - Davis Dam to Parker Dam Reach (Map 1 of 2)
Exhibit 4 - Davis Dam to Parker Dam Reach (Map 2 of 2)
Exhibit 5 - Parker Dam to Imperial Dam Reach (Map 1 of 3)
Exhibit 6 - Parker Dam to Imperial Dam Reach (Map 2 of 3)
Exhibit 7 - Parker Dam to Imperial Dam Reach (Map 3 of 3)
Exhibit 8 - Imperial Dam to Mexico Reach
Exhibit 11 - Bill Williams River Reach
Exhibit 12 - Coachella Valley Water District
Exhibit 13 - Imperial Irrigation District
Exhibit 14 - Wellton-Mohawk Irrigation and Drainage District
2
3
Landsat 5, TM
Path 39, Rows 36-37
April 26, 2006
4
11
5
12
6
13
Landsat 5, TM
Path 38, Rows 36-37
July 8, 2006
14
8
N
Miles
0 15 30 60
Kilometers
0 37.5 75 150

Exhibit 1

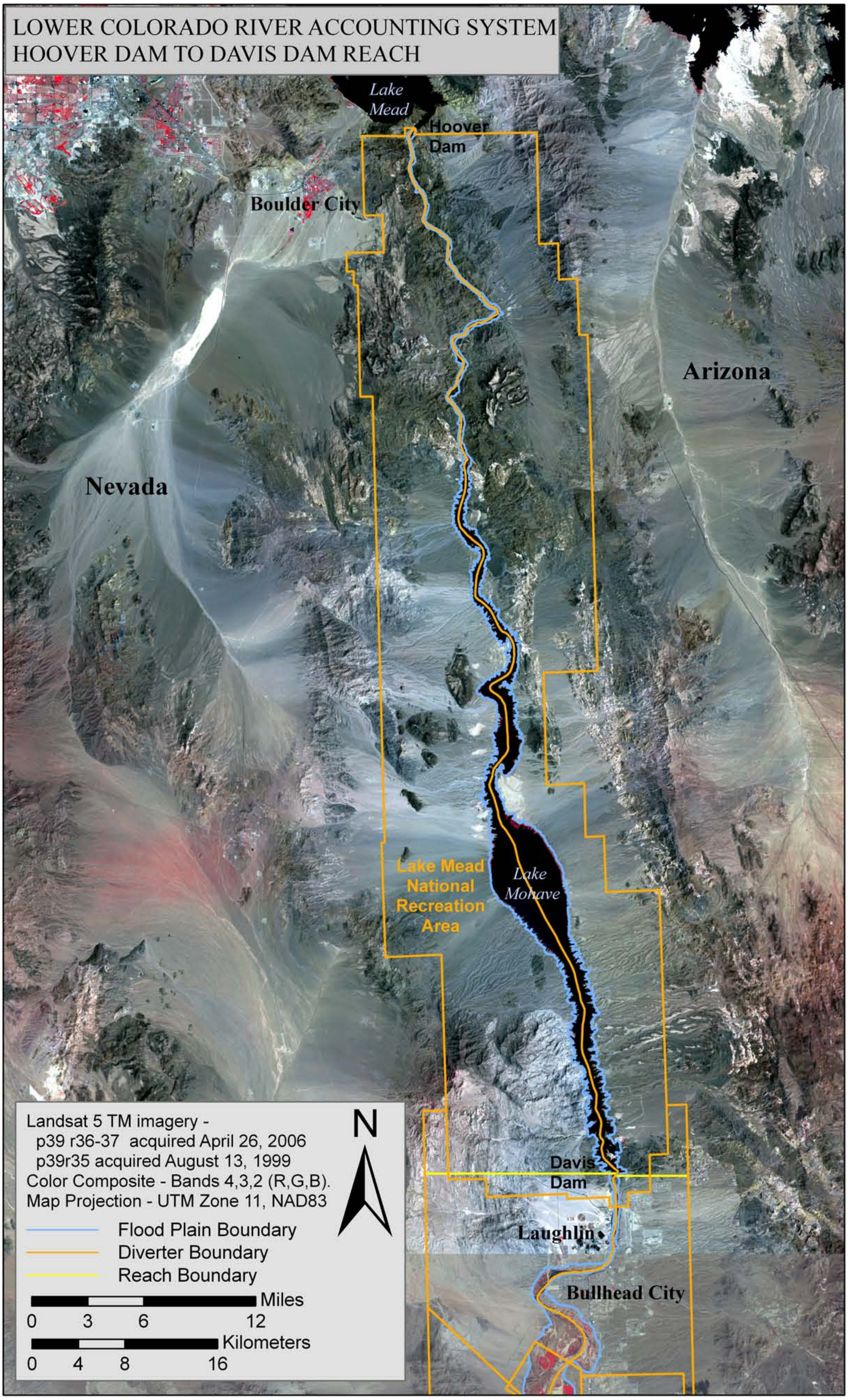
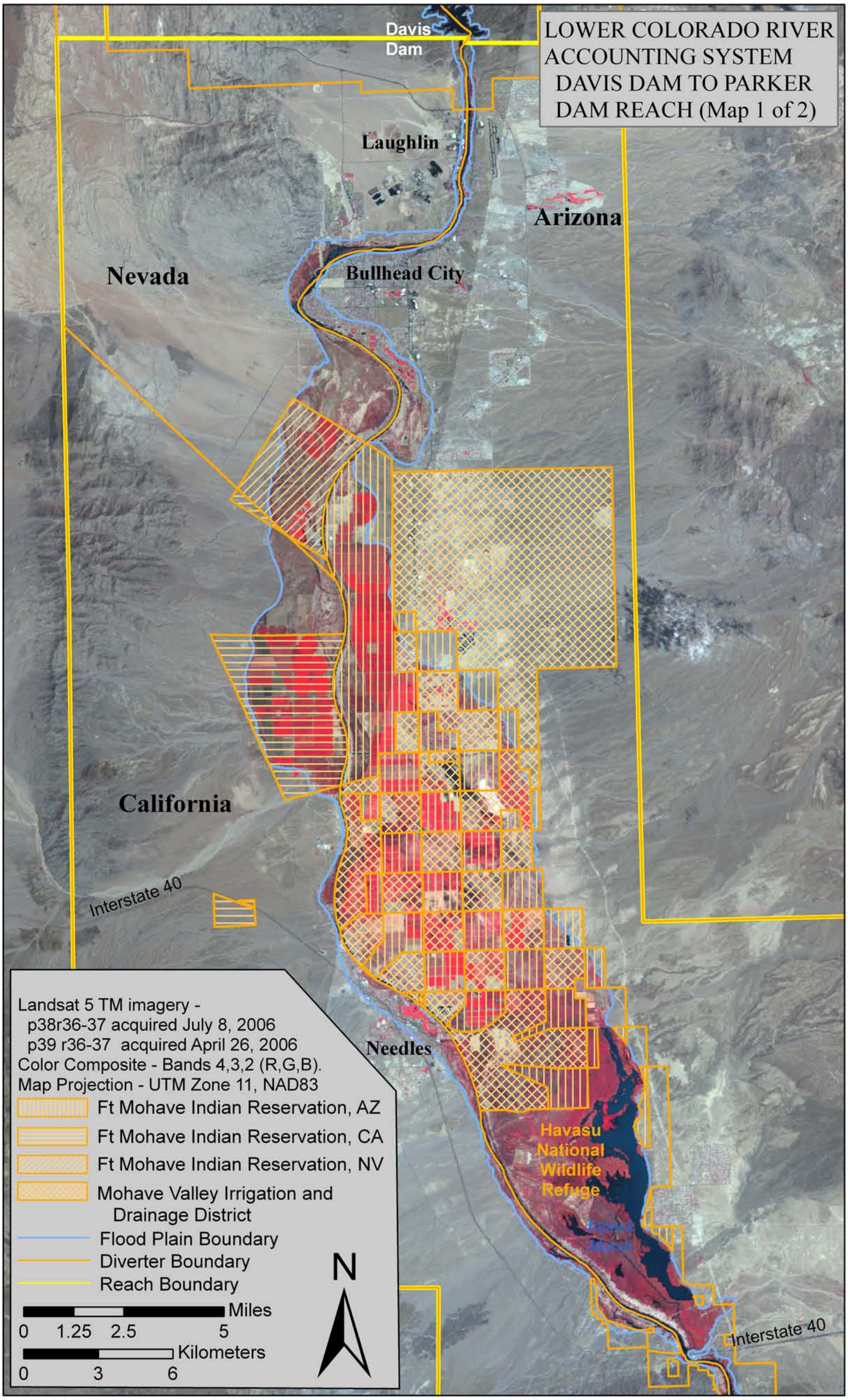

LOWER COLORADO RIVER ACCOUNTING SYSTEM
HOOVER DAM TO DAVIS DAM REACH
Lake Mead
Hoover Dam
Boulder City
Arizona
Nevada
Lake Mead National Recreation Area
Lake Mohave
Davis Dam
Laughlin
Bullhead City
Landsat 5 TM imagery -
p39 r36-37 acquired April 26, 2006
p39r35 acquired August 13, 1999
Color Composite - Bands 4,3,2 (R,G,B).
Map Projection - UTM Zone 11, NAD83
N
Flood Plain Boundary
Diverter Boundary
Reach Boundary
Miles
0 3 6 12
Kilometers
0 4 8 16

Exhibit 2



LOWER COLORADO RIVER ACCOUNTING SYSTEM DAVIS DAM TO PARKER DAM REACH (Map 1 of 2)
Davis Dam
Laughlin
Arizona
Nevada
Bullhead City
California
Interstate 40
Needles
Havasu National Wildlife Refuge
Interstate 40
Landsat 5 TM imagery -
p38r36-37 acquired July 8, 2006
p39 r36-37 acquired April 26, 2006
Color Composite - Bands 4,3,2 (R,G,B).
Map Projection - UTM Zone 11, NAD83
Ft Mohave Indian Reservation, AZ
Ft Mohave Indian Reservation, CA
Ft Mohave Indian Reservation, NV
Mohave Valley Irrigation and Drainage District
Flood Plain Boundary
Diverter Boundary
Reach Boundary
N
Miles
0 1.25 2.5 5
Kilometers
0 3 6

Exhibit 3

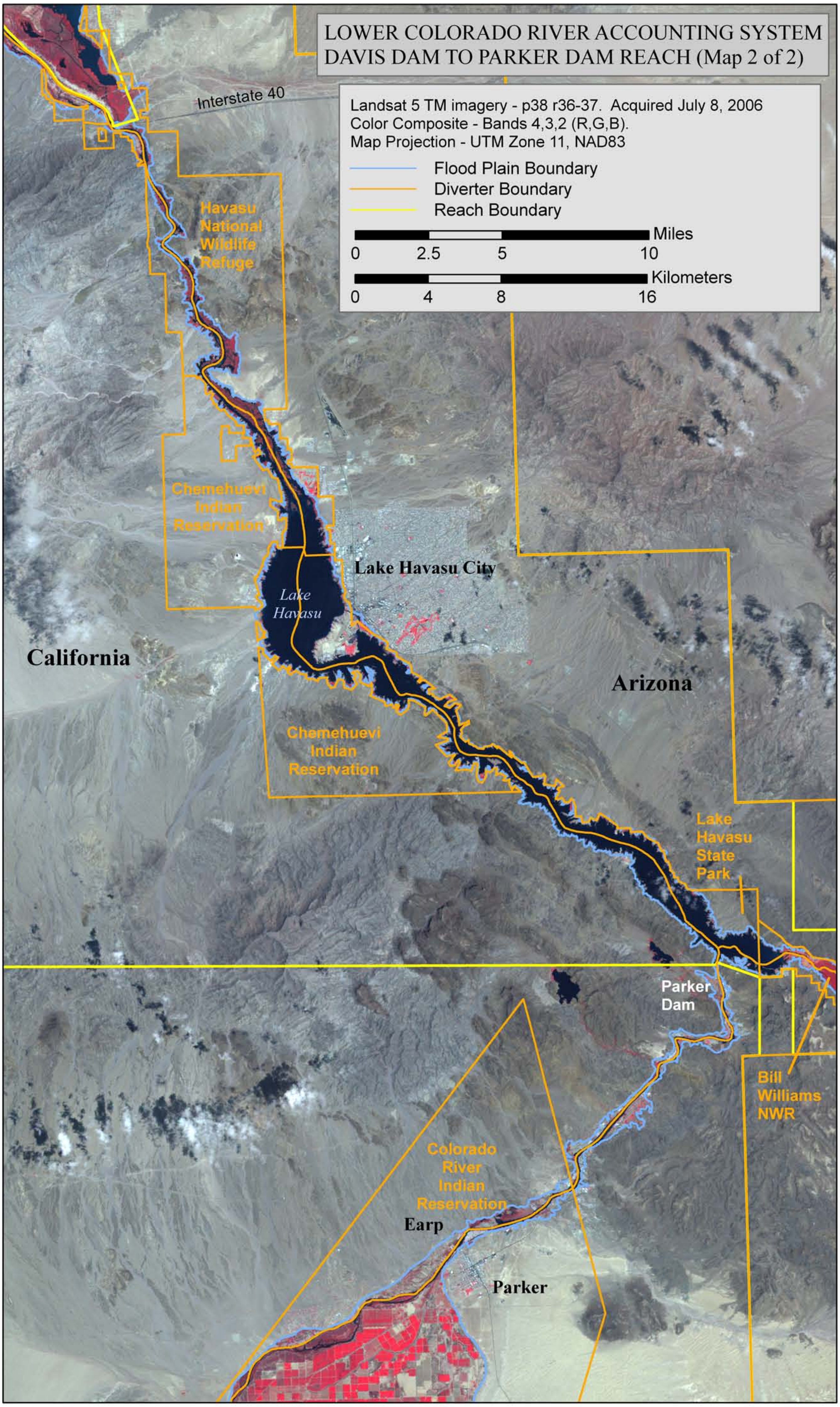
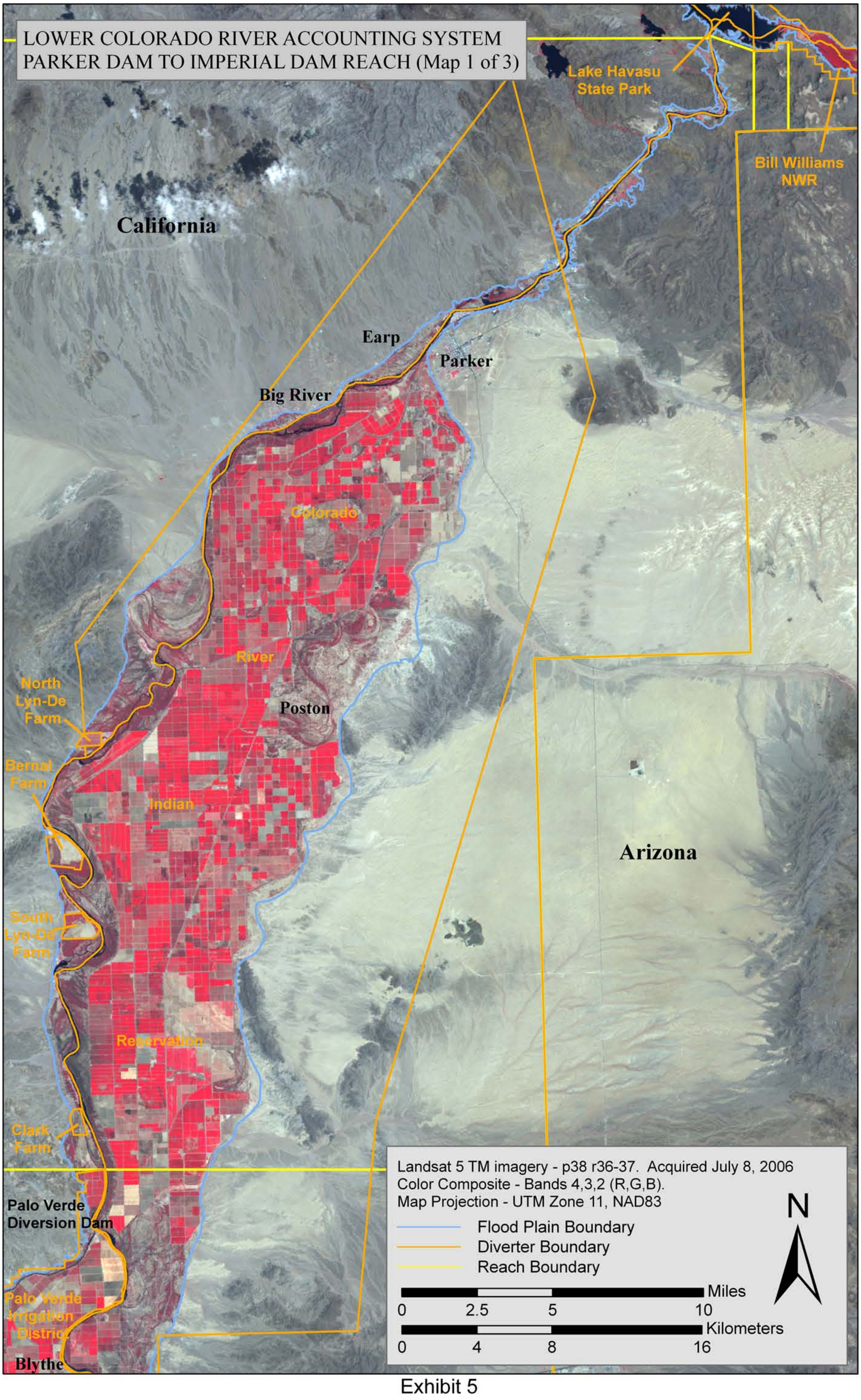

LOWER COLORADO RIVER ACCOUNTING SYSTEM
DAVIS DAM TO PARKER DAM REACH (Map 2 of 2)
Landsat 5 TM imagery - p38 r36-37. Acquired July 8, 2006
Color Composite - Bands 4,3,2 (R,G,B).
Map Projection - UTM Zone 11, NAD83
Flood Plain Boundary
Diverter Boundary
Reach Boundary
Miles
0 2.5 5 10
Kilometers
0 4 8 16
Interstate 40
Havasu National Wildlife Refuge
Chemehuevi Indian Reservation
Lake Havasu City
Lake Havasu
California
Arizona
Chemehuevi Indian Reservation
Lake Havasu State Park
Parker Dam
Bill Williams NWR
Colorado River Indian Reservation
Earp
Parker

Exhibit 4



LOWER COLORADO RIVER ACCOUNTING SYSTEM
PARKER DAM TO IMPERIAL DAM REACH (Map 1 of 3)
Lake Havasu
State Park
Bill Williams
NWR
California
Earp
Parker
Big River
Colorado
River
North
Lyn-De
Farm
Poston
Bernal
Farm
Indian
Arizona
South
Lyn-De
Farm
Reservation
Clark
Farm
Palo Verde
Diversion Dam
Palo Verde
Irrigation
District
Blythe
Landsat 5 TM imagery - p38 r36-37. Acquired July 8, 2006
Color Composite - Bands 4,3,2 (R,G,B).
Map Projection - UTM Zone 11, NAD83
Flood Plain Boundary
Diverter Boundary
Reach Boundary
N
Miles
0 2.5 5 10
Kilometers
0 4 8 16

Exhibit 5

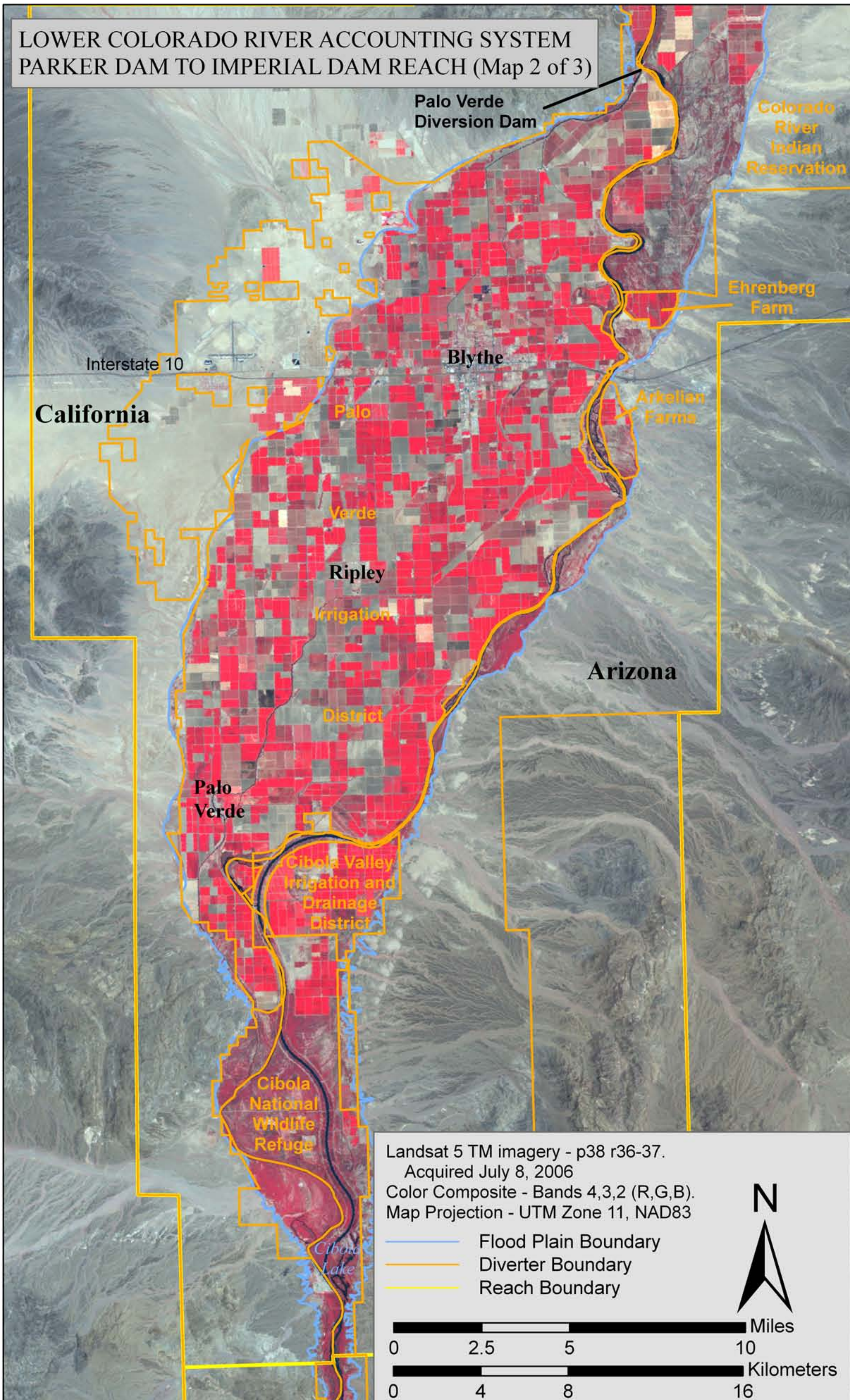
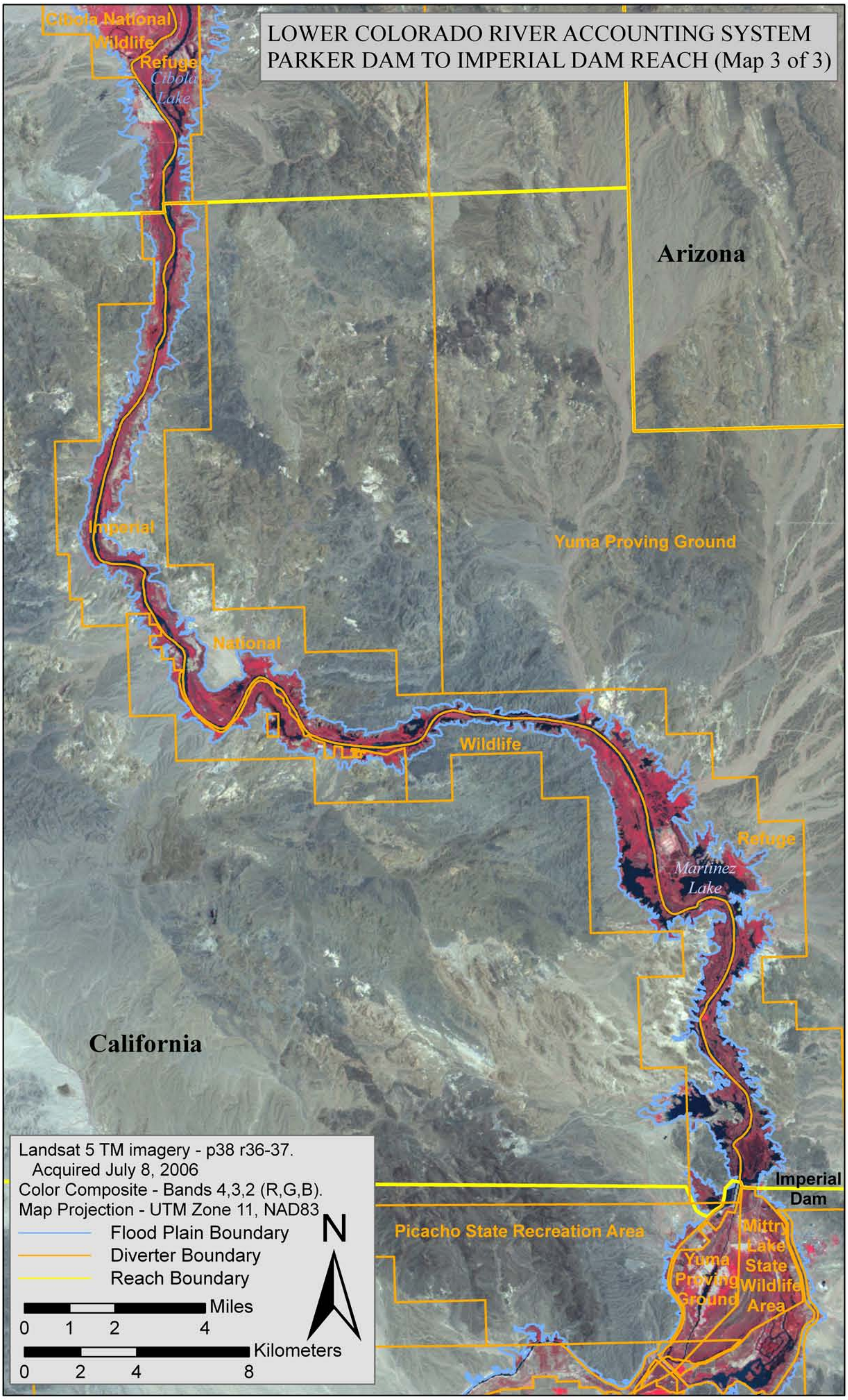

LOWER COLORADO RIVER ACCOUNTING SYSTEM
PARKER DAM TO IMPERIAL DAM REACH (Map 2 of 3)
Palo Verde
Diversion Dam
Colorado
River
Indian
Reservation
Ehrenberg
Farm
Interstate 10
Blythe
California
Palo
Verde
Irrigation
District
Arkelian
Farms
Ripley
Arizona
Palo
Verde
Cibola Valley
Irrigation and
Drainage
District
Cibola
National
Wildlife
Refuge
Cibola
Lake
Landsat 5 TM imagery - p38 r36-37.
Acquired July 8, 2006
Color Composite - Bands 4,3,2 (R,G,B).
Map Projection - UTM Zone 11, NAD83
Flood Plain Boundary
Diverter Boundary
Reach Boundary
N
Miles
0
2.5
5
10
Kilometers
0
4
8
16

Exhibit 6



LOWER COLORADO RIVER ACCOUNTING SYSTEM
PARKER DAM TO IMPERIAL DAM REACH (Map 3 of 3)
Cibola National
Wildlife
Refuge
Cibola
Lake
Arizona
Imperial
National
Wildlife
Refuge
Yuma Proving Ground
Martinez
Lake
California
Imperial
Dam
Picacho State Recreation Area
Yuma
Proving
Ground
Mittry
Lake
State
Wildlife
Area
Landsat 5 TM imagery - p38 r36-37.
Acquired July 8, 2006
Color Composite - Bands 4,3,2 (R,G,B).
Map Projection - UTM Zone 11, NAD83
Flood Plain Boundary
Diverter Boundary
Reach Boundary
N
Miles
0 1 2 4
Kilometers
0 2 4 8

Exhibit 7

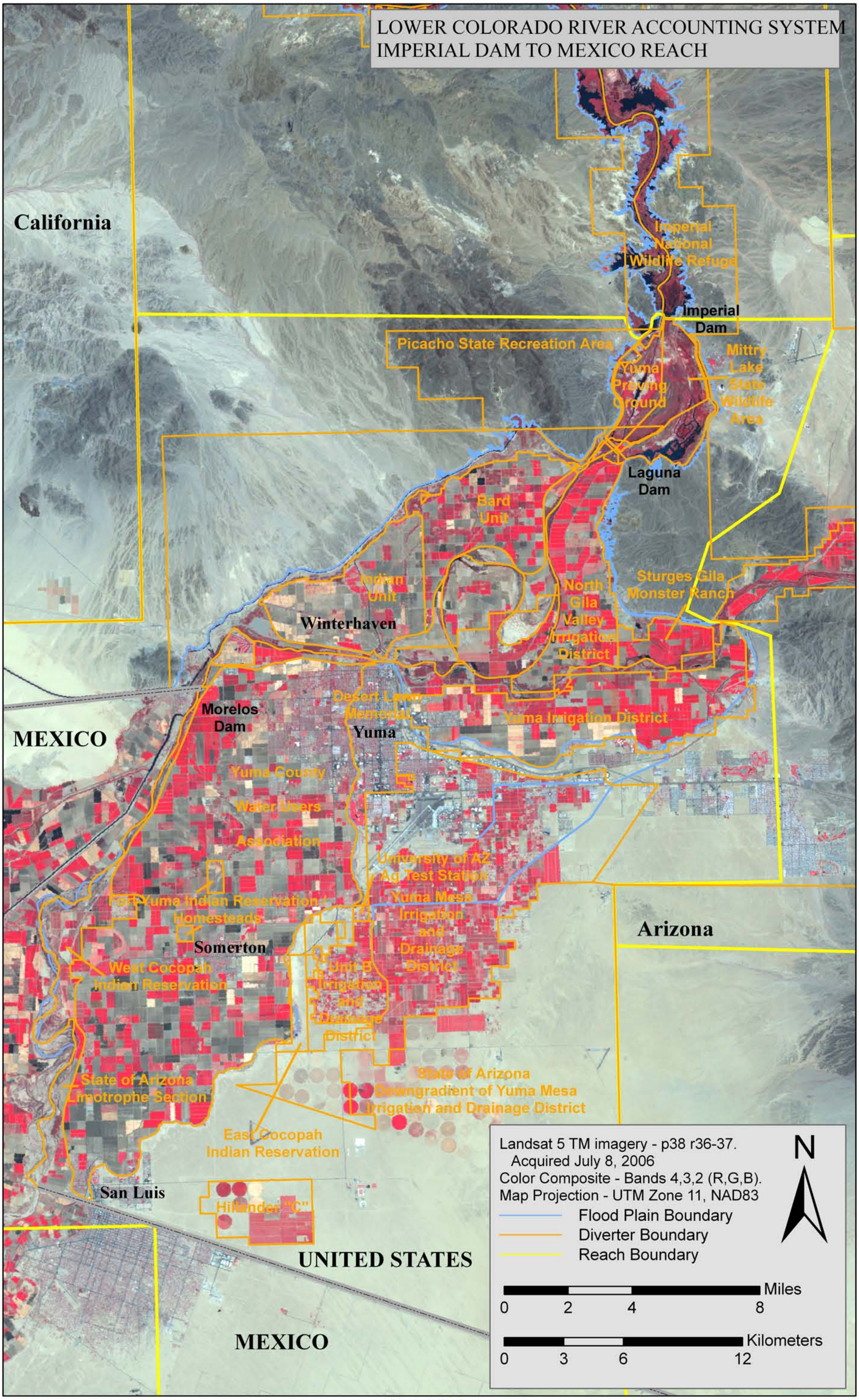

LOWER COLORADO RIVER ACCOUNTING SYSTEM
IMPERIAL DAM TO MEXICO REACH
California
Imperial National Wildlife Refuge
Imperial Dam
Picacho State Recreation Area
Yuma Proving Ground
Mittry Lake State Wildlife Area
Laguna Dam
Bard Unit
Indian Unit
North Gila Valley Irrigation District
Sturges Gila Monster Ranch
Winterhaven
Morelos Dam
Desert Lawn Memorial
Yuma
Yuma Irrigation District
MEXICO
Yuma County Water Users Association
University of AZ Ag Test Station
Yuma Mesa Irrigation and Drainage District
Fort Yuma Indian Reservation / Homesteads
Somerton
Arizona
West Cocopah Indian Reservation
Unit B Irrigation and Drainage District
State of Arizona Limotrophe Section
State of Arizona Downgradient of Yuma Mesa Irrigation and Drainage District
East Cocopah Indian Reservation
San Luis
Hillander "C"
UNITED STATES
MEXICO
Landsat 5 TM imagery - p38 r36-37.
Acquired July 8, 2006
Color Composite - Bands 4,3,2 (R,G,B).
Map Projection - UTM Zone 11, NAD83
Flood Plain Boundary
Diverter Boundary
Reach Boundary
N
Miles
0 2 4 8
Kilometers
0 3 6 12

Exhibit 8

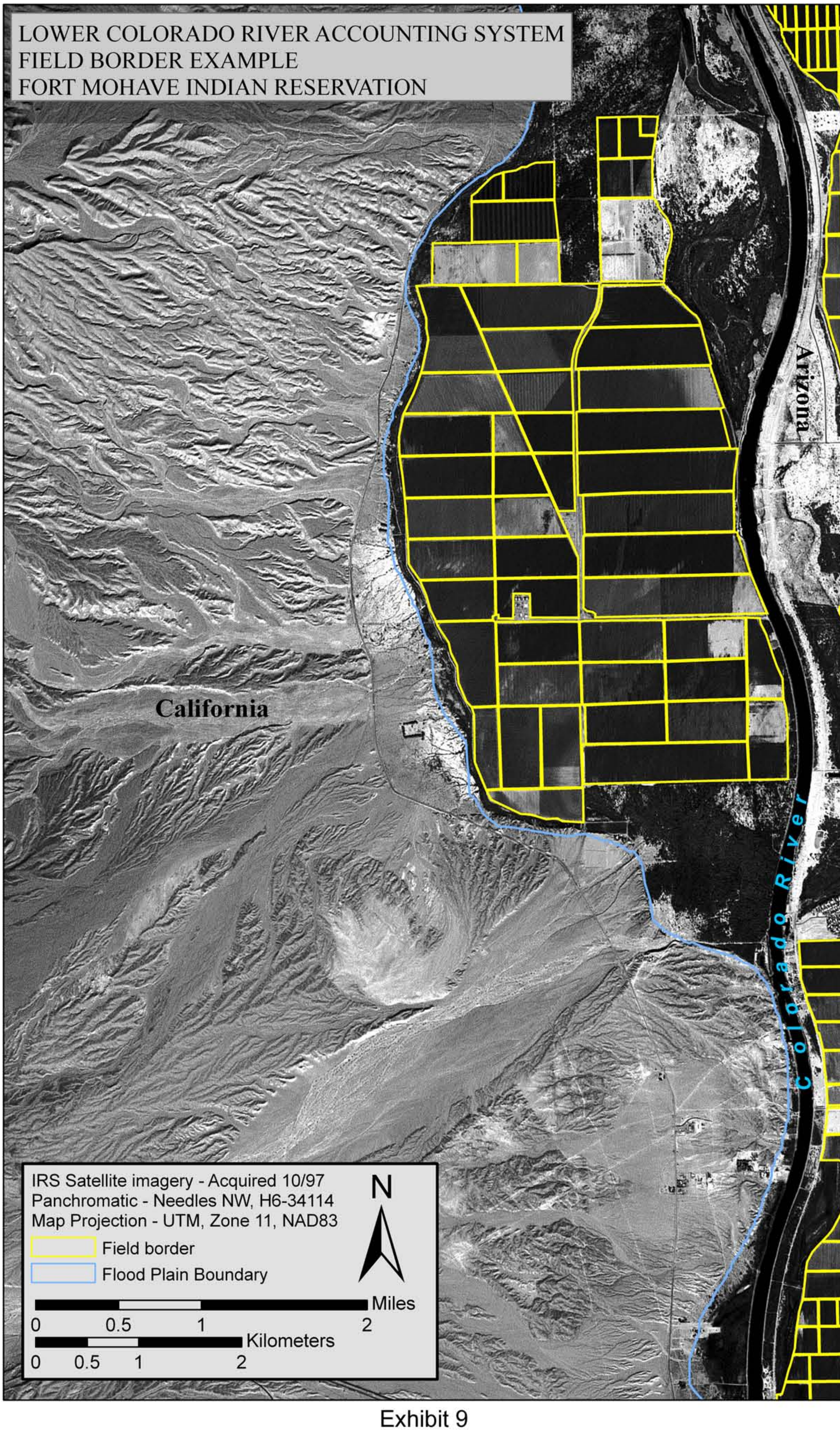

LOWER COLORADO RIVER ACCOUNTING SYSTEM
FIELD BORDER EXAMPLE
FORT MOHAVE INDIAN RESERVATION
Arizona
California
Colorado River
IRS Satellite imagery - Acquired 10/97
Panchromatic - Needles NW, H6-34114
Map Projection - UTM, Zone 11, NAD83
Field border
Flood Plain Boundary
N
Miles
0
0.5
1
2
Kilometers
0
0.5
1
2

Exhibit 9

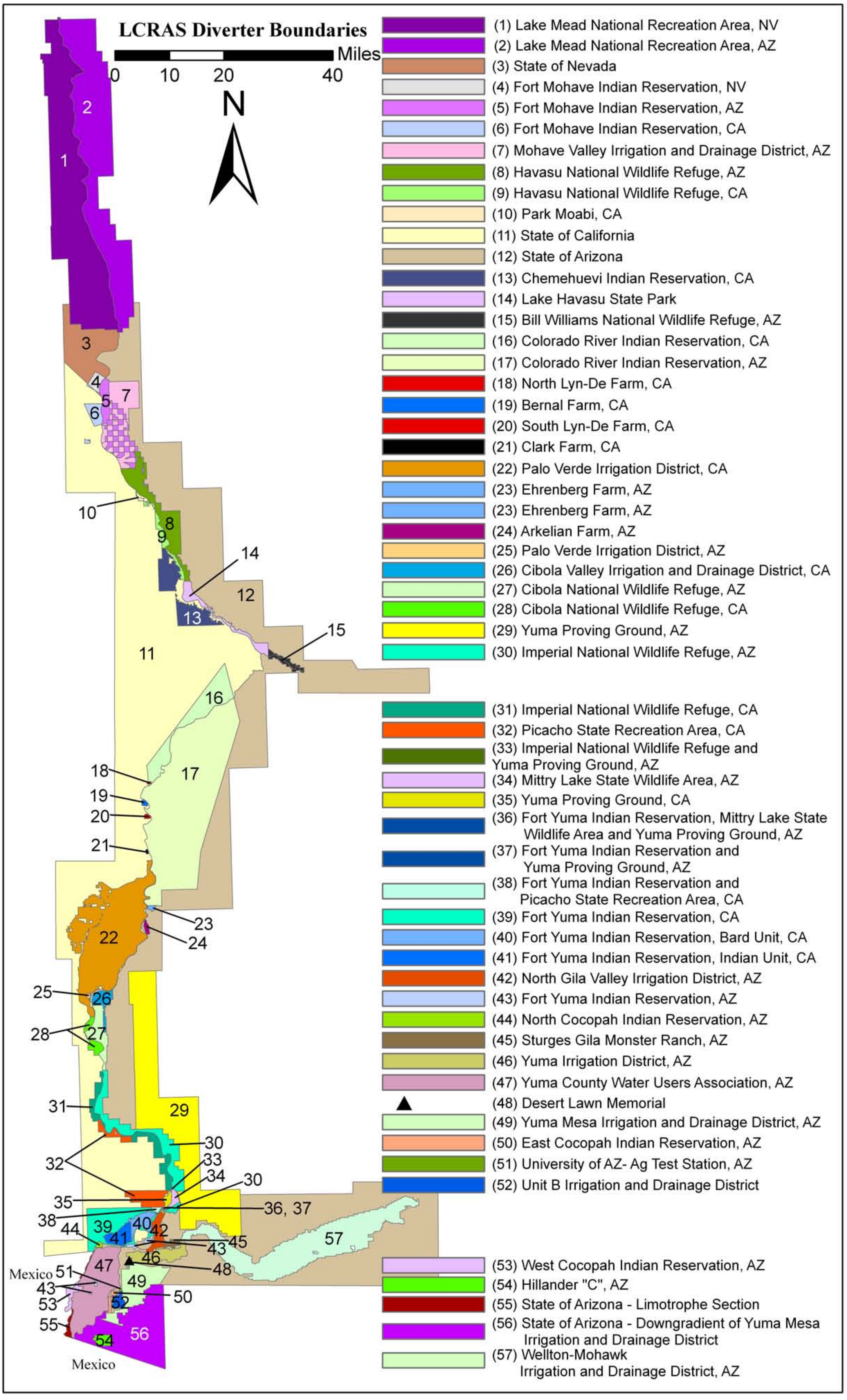

LCRAS Diverter Boundaries
Miles
0 10 20 40
N
(1) Lake Mead National Recreation Area, NV
(2) Lake Mead National Recreation Area, AZ
(3) State of Nevada
(4) Fort Mohave Indian Reservation, NV
(5) Fort Mohave Indian Reservation, AZ
(6) Fort Mohave Indian Reservation, CA
(7) Mohave Valley Irrigation and Drainage District, AZ
(8) Havasu National Wildlife Refuge, AZ
(9) Havasu National Wildlife Refuge, CA
(10) Park Moabi, CA
(11) State of California
(12) State of Arizona
(13) Chemehuevi Indian Reservation, CA
(14) Lake Havasu State Park
(15) Bill Williams National Wildlife Refuge, AZ
(16) Colorado River Indian Reservation, CA
(17) Colorado River Indian Reservation, AZ
(18) North Lyn-De Farm, CA
(19) Bernal Farm, CA
(20) South Lyn-De Farm, CA
(21) Clark Farm, CA
(22) Palo Verde Irrigation District, CA
(23) Ehrenberg Farm, AZ
(23) Ehrenberg Farm, AZ
(24) Arkelian Farm, AZ
(25) Palo Verde Irrigation District, AZ
(26) Cibola Valley Irrigation and Drainage District, CA
(27) Cibola National Wildlife Refuge, AZ
(28) Cibola National Wildlife Refuge, CA
(29) Yuma Proving Ground, AZ
(30) Imperial National Wildlife Refuge, AZ
(31) Imperial National Wildlife Refuge, CA
(32) Picacho State Recreation Area, CA
(33) Imperial National Wildlife Refuge and Yuma Proving Ground, AZ
(34) Mittry Lake State Wildlife Area, AZ
(35) Yuma Proving Ground, CA
(36) Fort Yuma Indian Reservation, Mittry Lake State Wildlife Area and Yuma Proving Ground, AZ
(37) Fort Yuma Indian Reservation and Yuma Proving Ground, AZ
(38) Fort Yuma Indian Reservation and Picacho State Recreation Area, CA
(39) Fort Yuma Indian Reservation, CA
(40) Fort Yuma Indian Reservation, Bard Unit, CA
(41) Fort Yuma Indian Reservation, Indian Unit, CA
(42) North Gila Valley Irrigation District, AZ
(43) Fort Yuma Indian Reservation, AZ
(44) North Cocopah Indian Reservation, AZ
(45) Sturges Gila Monster Ranch, AZ
(46) Yuma Irrigation District, AZ
(47) Yuma County Water Users Association, AZ
(48) Desert Lawn Memorial
(49) Yuma Mesa Irrigation and Drainage District, AZ
(50) East Cocopah Indian Reservation, AZ
(51) University of AZ- Ag Test Station, AZ
(52) Unit B Irrigation and Drainage District
(53) West Cocopah Indian Reservation, AZ
(54) Hillander "C", AZ
(55) State of Arizona - Limotrophe Section
(56) State of Arizona - Downgradient of Yuma Mesa Irrigation and Drainage District
(57) Wellton-Mohawk Irrigation and Drainage District, AZ
Mexico
Mexico

Exhibit 10

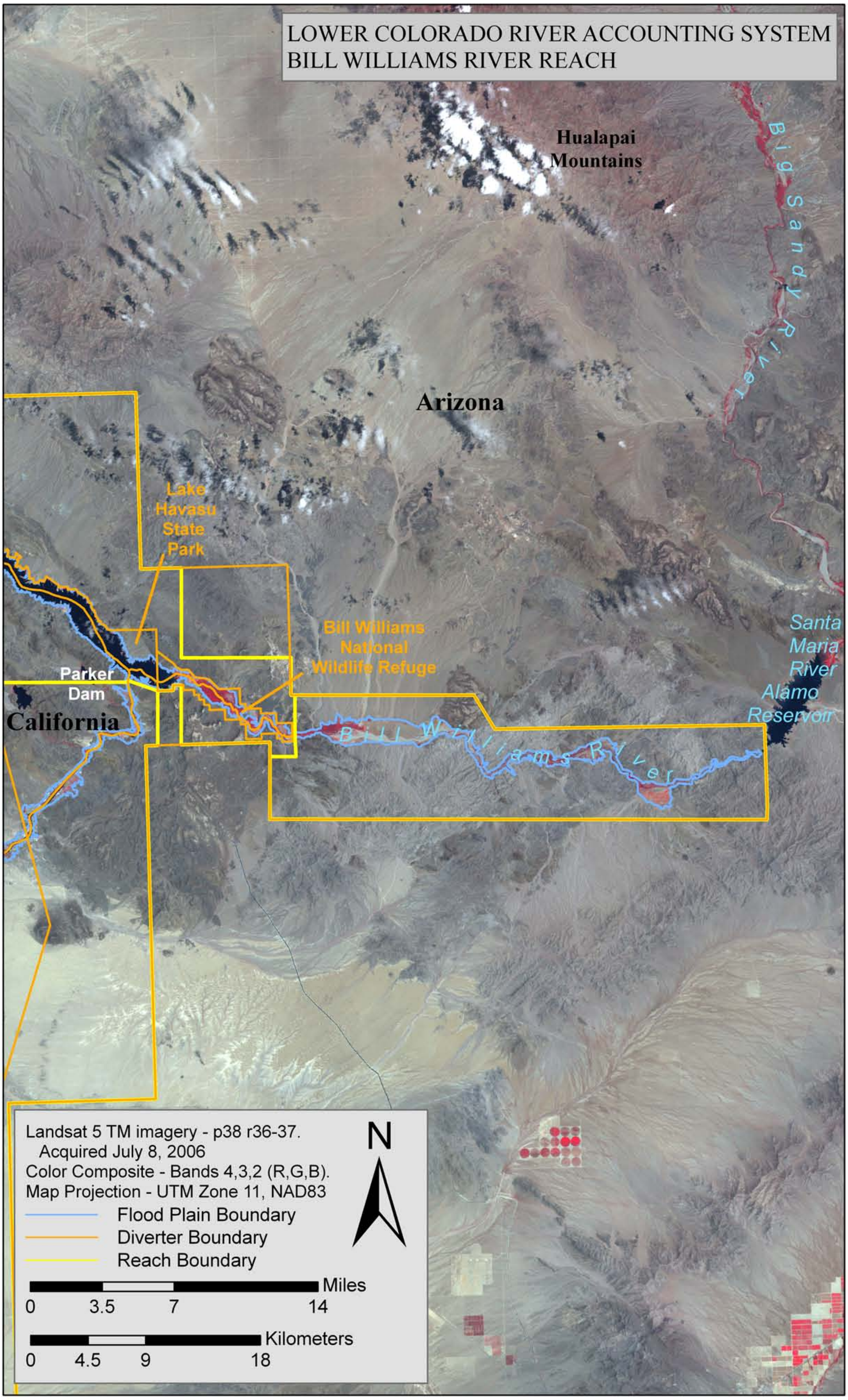

LOWER COLORADO RIVER ACCOUNTING SYSTEM
BILL WILLIAMS RIVER REACH
Hualapai Mountains
Big Sandy River
Arizona
Lake Havasu State Park
Bill Williams National Wildlife Refuge
Santa Maria River
Alamo Reservoir
Parker Dam
California
Bill Williams River
Landsat 5 TM imagery - p38 r36-37.
Acquired July 8, 2006
Color Composite - Bands 4,3,2 (R,G,B).
Map Projection - UTM Zone 11, NAD83
Flood Plain Boundary
Diverter Boundary
Reach Boundary
N
Miles
0 3.5 7 14
Kilometers
0 4.5 9 18

Exhibit 11

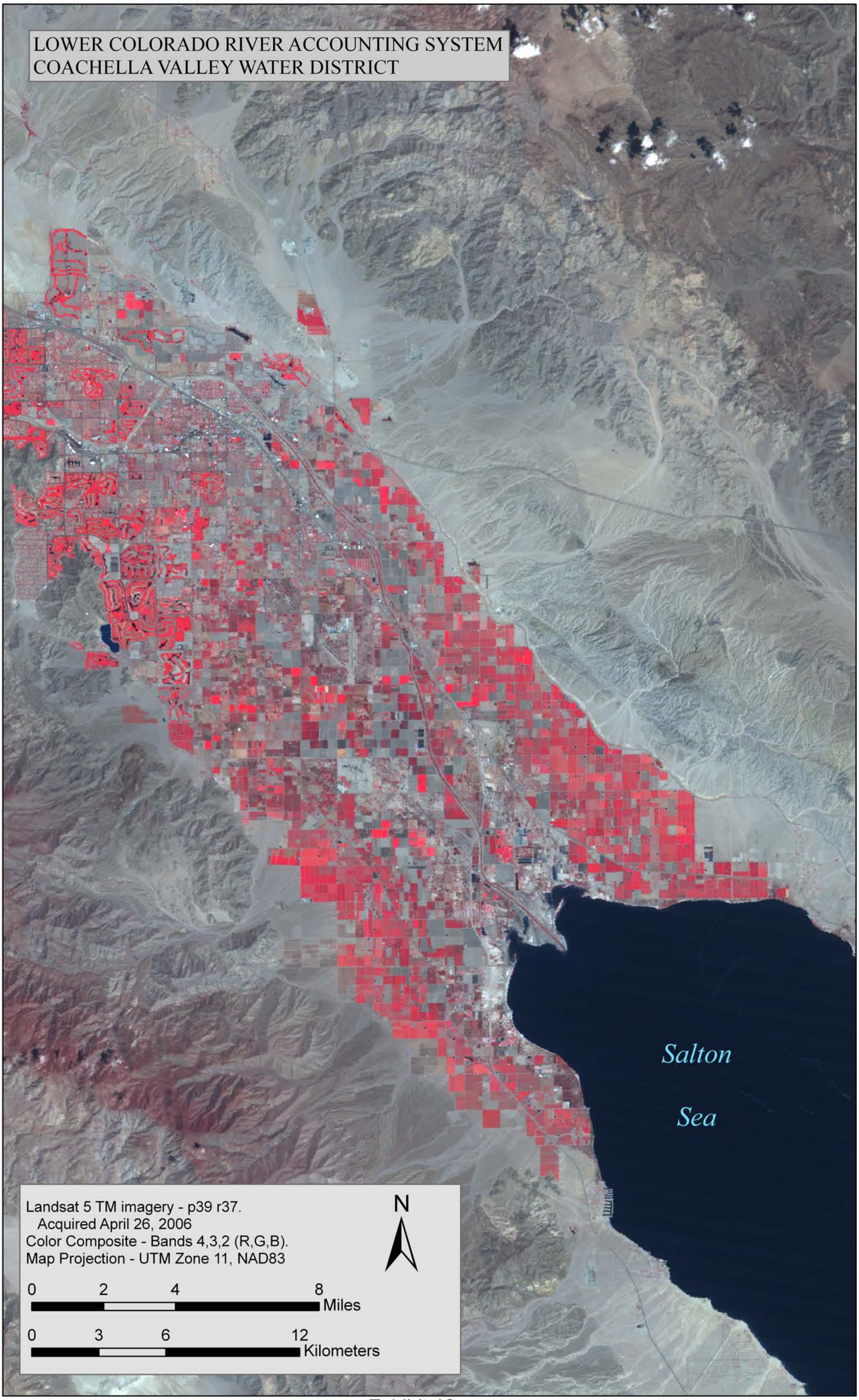

LOWER COLORADO RIVER ACCOUNTING SYSTEM
COACHELLA VALLEY WATER DISTRICT
Salton
Sea
Landsat 5 TM imagery - p39 r37.
Acquired April 26, 2006
Color Composite - Bands 4,3,2 (R,G,B).
Map Projection - UTM Zone 11, NAD83
N
0 2 4 8 Miles
0 3 6 12 Kilometers

Exhibit 12

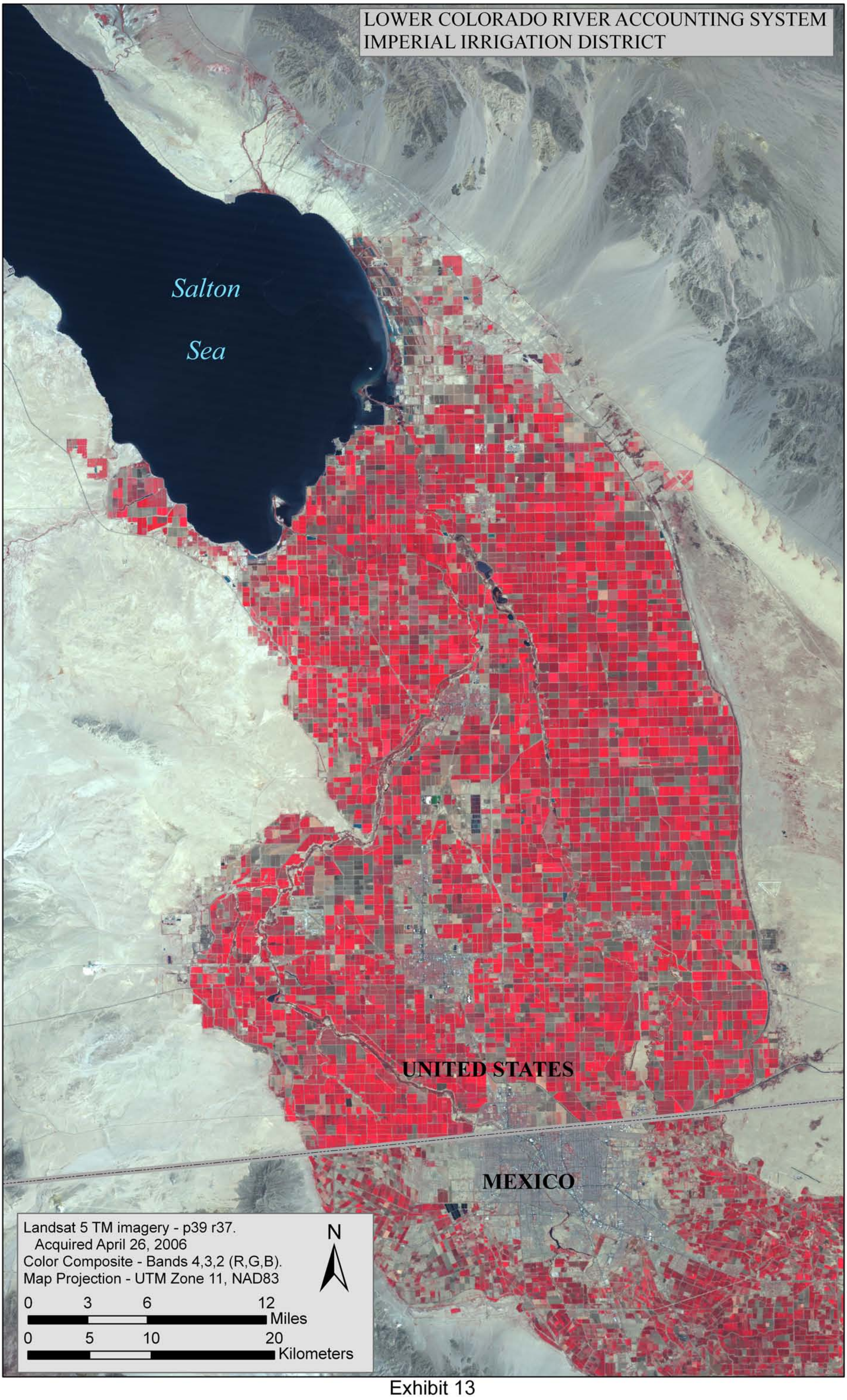

LOWER COLORADO RIVER ACCOUNTING SYSTEM
IMPERIAL IRRIGATION DISTRICT
Salton
Sea
UNITED STATES
MEXICO
Landsat 5 TM imagery - p39 r37.
Acquired April 26, 2006
Color Composite - Bands 4,3,2 (R,G,B).
Map Projection - UTM Zone 11, NAD83
N
0 3 6 12
Miles
0 5 10 20
Kilometers

Exhibit 13

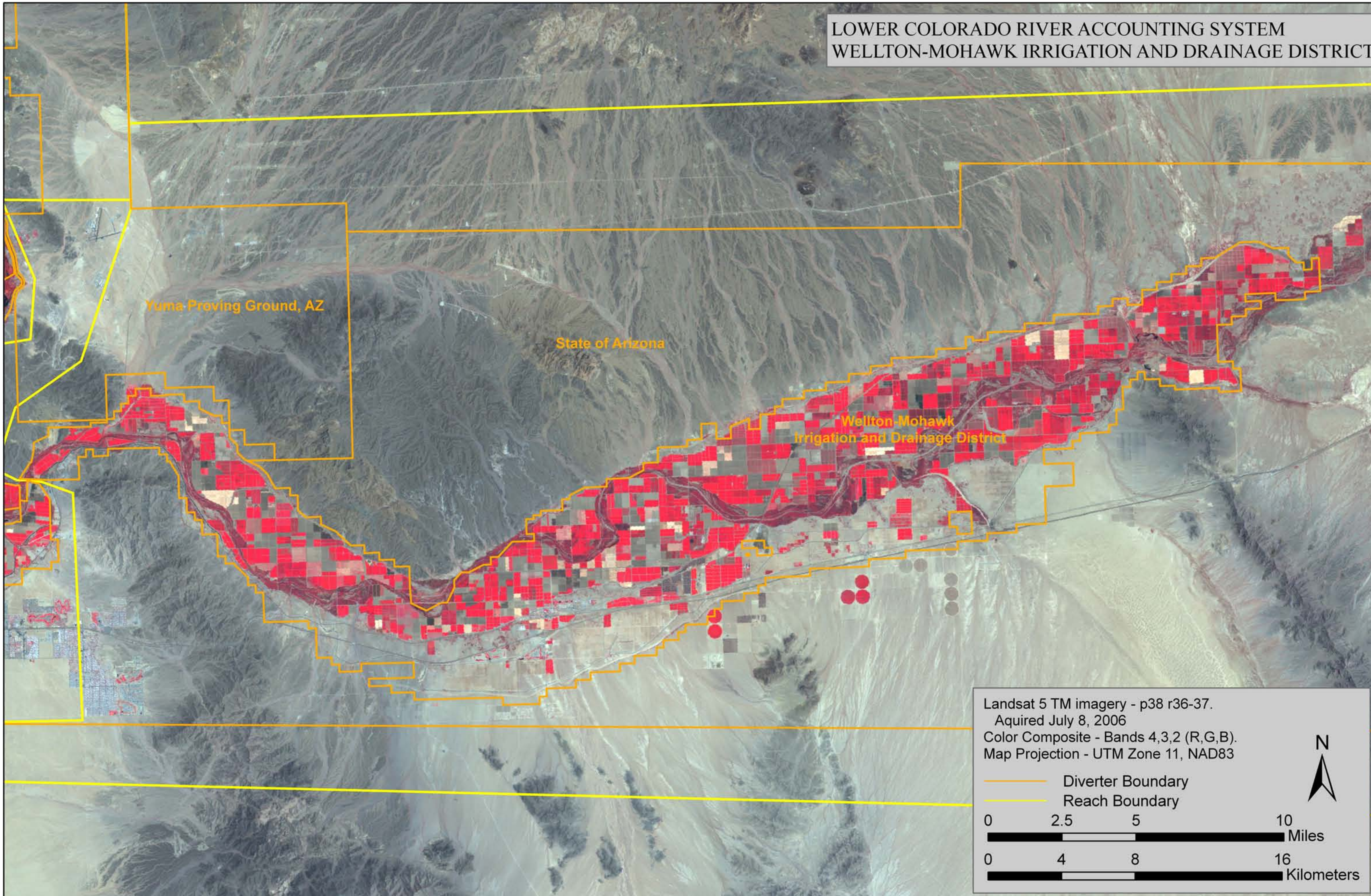

LOWER COLORADO RIVER ACCOUNTING SYSTEM
WELLTON-MOHAWK IRRIGATION AND DRAINAGE DISTRICT
Yuma Proving Ground, AZ
State of Arizona
Wellton-Mohawk
Irrigation and Drainage District
Landsat 5 TM imagery - p38 r36-37.
Aquired July 8, 2006
Color Composite - Bands 4,3,2 (R,G,B).
Map Projection - UTM Zone 11, NAD83
Diverter Boundary
Reach Boundary
N
0 2.5 5 10 Miles
0 4 8 16 Kilometers

Exhibit 14

Reclamation also utilized a backwater GIS database (BIO-WEST, 2006) to identify open-water areas previously unidentified. Updates to the open-water database were only made if open-water could be verified on corresponding TM or NAIP imagery.

Reclamation has begun to refine evaporation calculations to distinguish between evaporation from the open water of the river channel and reservoirs, evaporation from man-made areas of open water which are partially or completely maintained by diverting water from the river, and evaporation from man-made and/or natural areas of open water adjacent to the river channel which are not maintained by diverting water from the river. Man-made and/or natural areas adjacent to the river channel which have not yet been determined to be maintained or not maintained with diversions from the Colorado River are included in the not maintained category of open-water areas until field investigations, conversations with owners/operators, or other methods of acquiring information can take place.

Open water in major delivery canals

LCRAS calculates evaporation from major canals that serve districts and Indian reservations. Reclamation initially identified bank-to-bank canal area (in acres) by digitizing canal banks using 5 meter IRS panchromatic satellite imagery as a reference for calendar year 2000. This information was added to the open-water GIS database. From this, Reclamation calculated the acreage of open water within each canal.

Calculating ET for Crop Groups and Riparian Vegetation Groups

Reclamation calculates ET from crop and riparian vegetation groups found along the lower Colorado River flood plain, on the Palo Verde and Yuma Mesas, within and near the Wellton-Mohawk Irrigation and Drainage District, within the Imperial Irrigation District, within the Coachella Valley Water District, and the flood plain of the Bill Williams River from Alamo Dam to Lake Havasu.

ET calculations require the following items:

1. Reference ET;
2. ET coefficients for each crop and riparian vegetation group;
3. Number of acres covered by each crop and riparian vegetation group; and
4. Effective precipitation (used to calculate crop ET only).

The following sections describe how Reclamation calculates the four items mentioned above.

Calculating Reference ET

The first step in calculating ET is securing or calculating a reference-ET value for the area of interest. Reference ET represents a fundamental measure of the rate of water use by vegetation (in linear units, such as inches) to which the rate of water use of all types of vegetation (as well as the rate of evaporation from a water body) can be related. Along the lower Colorado River, Reclamation uses reference-ET values calculated with the standardized equation derived from the American Society of Civil Engineers (ASCE) Penman Monteith equation (standardized equation) and climatological data provided by the California Irrigation Management Information System (CIMIS) and Arizona Meteorological Network (AZMET) stations located in irrigated areas along the Colorado River from Davis Dam to Mexico. The standardized equation is currently recognized by the ET community of scientists as the most accurate representation of a fundamental measure of water use by vegetation available.

The AZMET and CIMIS networks report reference-ET values directly; however, Reclamation has noticed a disparity in the reference-ET values reported by each network for the lower Colorado River. Upon investigation, Reclamation discovered that the AZMET and CIMIS networks do not use exactly the same equation to calculate reference ET. Calculating reference ET using the standardized equation and the climatological data provided by the AZMET and CIMIS networks eliminates this disparity in reference ET values reported by the networks along the lower Colorado River. The use of the standardized equation leaves only site conditions, equipment calibration, and micro-climatic differences as sources of site-to-site variations in reference-ET values. Reclamation currently uses the reference ET values provided by the CIMIS network for the Imperial and Coachella valleys, and reference ET values from the AZMET network for the Wellton-Mohawk area.

Reclamation develops area-specific reference-ET values for the Mohave Valley, the Parker/ Palo Verde Valleys, the Imperial/Coachella valleys, the Wellton-Mohawk area (when more than one station is available), and the Yuma Area by averaging reference-ET values from sites within these areas. Figure 1 shows the reference-ET and precipitation values used to develop the ET-rate estimates used by this report to calculate ET from crop and riparian vegetation groups.

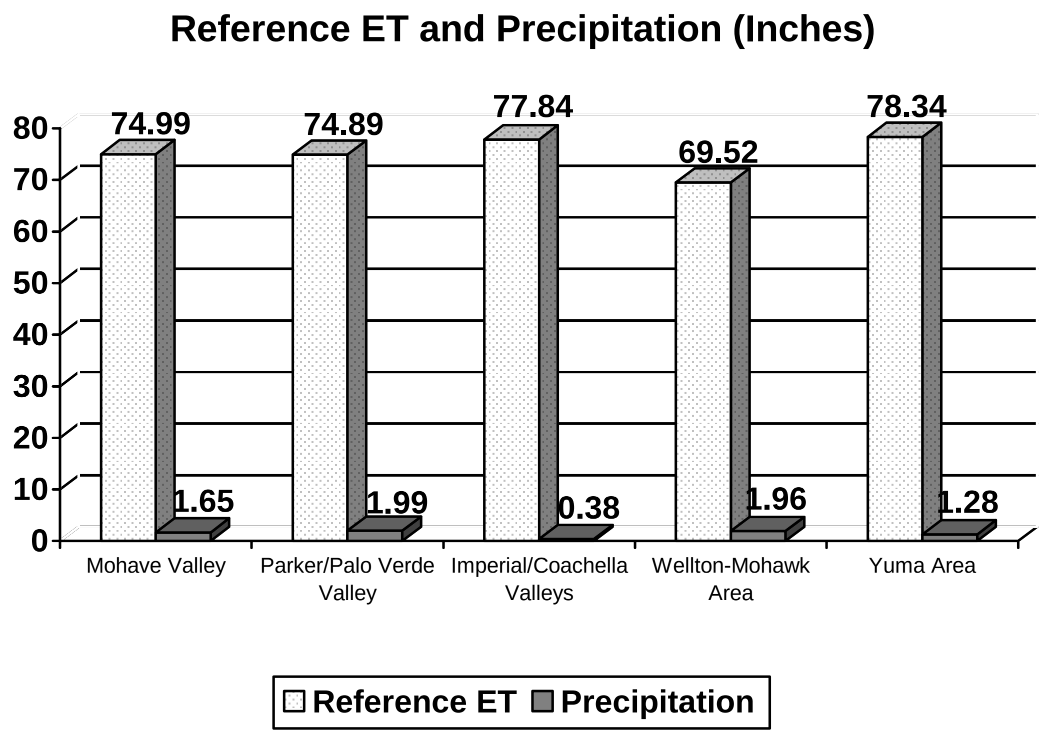


Figure 1 — Reference ET and Precipitation

Refining ET Coefficients for Crop and Riparian Vegetation Groups

ET coefficients are the values that relate reference ET to the ET rate of specific crop and riparian vegetation groups (as well as the evaporation rate from a water body). Jensen (1998) presents the rationale used to develop the original crop and riparian vegetation groups and ET coefficients for each group along the lower Colorado River and the Bill Williams River used by the LCRAS program. Jensen (2002) presents the adjustments made to the crop and riparian vegetation groups and the ET and evaporation coefficients used in this report. The ET coefficients developed for the Yuma area are used to calculate crop ET for the Wellton-Mohawk Irrigation and Drainage District.

The evapotranspiration-rate (ET-rate) coefficients used for crops grown by the Imperial irrigation district (IID) and the Coachella Valley Water District (CVWD) are derived from coefficients reported in, “Assessment of 1987-1996 Water Use by the Imperial Irrigation District using Water Balance and Cropping Data Special Report June 1977” by Marvin E. Jensen and Ivan A Walter (Jensen, 1997). These ET-rate coefficients were compared with crop ET-rate coefficients developed by J.M. Lord for the CVWD (provided by M.E. Jensen), and found to be similar, therefore the same ET-rate coefficients are used for the IID and CVWD. For a more in-depth description of the ET coefficients used for IID and CVWD, see Lower Colorado River Accounting System Evapotranspiration and Evaporation Calculations for calendar year 2004.

Calculating the Number of Acres of Each Crop and Riparian Vegetation Group

The number of acres of each crop and riparian vegetation group are required to calculate ET. Reclamation calculated the number of acres of each crop and riparian vegetation group by applying the analysis previously described in "Identifying Crop Groups, Riparian Vegetation Groups, and Open Water."

Calculating Effective Precipitation

Effective precipitation is a correction to the ET rate of crop groups, required to remove the impact of precipitation so the ET calculated is that of Colorado River water. Reclamation calculates effective precipitation as the product of recorded precipitation and an effective-precipitation coefficient. Precipitation gauges at CIMIS and AZMET stations and those operated by the National Weather Service (NWS) along the lower Colorado River record precipitation. Reclamation developed a single daily precipitation value for the Mohave Valley, the Parker/Palo Verde valleys, the Wellton-Mohawk area, the Imperial and Coachella valleys, and the Yuma area by averaging precipitation measured at the AZMET, CIMIS, and NWS stations in each area. Jensen (1993) contains the documentation for the effective precipitation coefficients used in this report. Reclamation uses the following equation to calculate effective precipitation:

Effective Precipitation = Daily Precipitation H Monthly Effective Precipitation Coefficient

The amount of precipitation the lower Colorado River Valley received in calendar year 2004 ranged from zero, measured by several stations, to 3.54 inches, measured by the Blythe Airport NWS station. The correction to the ET rate for precipitation is very small, as can be discerned from an examination of Figure 1, previous, which shows annual reference ET and annual precipitation.

Calculating Crop ET

To calculate ET from crops in the study area, Reclamation must calculate an ET rate for each crop group. To calculate an ET rate (inches) for each crop group, Reclamation multiplies the average daily reference-ET values (inches) by each group's unique daily ET coefficient (dimensionless). Reclamation considers the effect of rainfall on crop water use by subtracting effective precipitation (inches) from the ET rate for each crop group to yield a net ET rate (inches). Reclamation sums the daily ET rates for each crop group to produce a monthly ET rate (inches) for each crop group.

In parallel with the calculations of ET rate, Reclamation must determine the number of acres covered by each crop group within each diverter boundary. Reclamation determines this acreage by using GIS technologies, remote sensing, and field survey data described previously.

With the ET rates for, and number of acres covered by, each crop group described previously, Reclamation calculates the ET (in acre-feet) of each crop group grown within each diverter boundary, by multiplying the ET rate for each crop group by the area covered by each crop group (acres) within each diverter boundary, and divides by 12 (inches/foot). These calculations are performed monthly and the results summed to produce annual agricultural ET values within each diverter boundary. Table 5, previous, lists the crop groups used for this report.

The following example illustrates an ET calculation for cotton:

$$\text{ET cotton} = n\,[(ET_0 \text{ H } \text{K cotton}) - \text{Effective PPT}]\ \text{AC cotton })\ 12$$

Where:

ET cotton	=	Monthly or annual ET by cotton for the diverter in question (acre-feet)
n	=	Summation for n time (monthly)
ET_0	=	Daily reference ET (inches)
K cotton	=	Daily ET coefficient specific to cotton (dimensionless)
AC cotton	=	Acreage of cotton for the diverter in question (acres)
Effective PPT	=	Effective precipitation (inches)

Calculating ET from Riparian Vegetation

Reclamation calculates ET from riparian vegetation for this report the same way it calculates agricultural ET, except that Reclamation makes no correction to the ET rates of riparian vegetation for effective precipitation. The sum of the ET from all riparian vegetation groups within a diverter boundary yields the riparian vegetation ET for an individual diverter.

Reclamation analyzed remotely-sensed data and aerial photography to develop the original acreage values for each riparian vegetation group used to calculate ET from riparian vegetation for 1995. Beginning with calendar year 1996, and continuing through calendar year 2006, Reclamation has updated riparian vegetation acreage values using change detection methods (described previously) and by field verifying major changes (usually due to fire or development). Table 6 (previous) lists the riparian vegetation groups used in this report.

Calculating Evaporation

Calculating evaporation from the mainstream

Reclamation calculates mainstream evaporation from Lakes Mohave and Havasu, and the open water of the Colorado River and adjacent backwaters (such as Topock Marsh and Mittry Lake) from Hoover Dam to Mexico. Reclamation calculates open-water evaporation as follows:

1. Sum the average daily reference ET (inches) for a month;
2. Multiply the monthly sum of daily reference ET by a monthly evaporation coefficient (dimensionless);
3. From the product in 2, subtract the precipitation recorded at precipitation gages nearest the area of open water for each month of the year (inches);
4. Divide the result in (3) by 12 inches per foot to yield units of feet;
5. Multiply the result in (4) by the open-water area in acres to yield the monthly open-water evaporation in acre-feet;
6. Perform the calculations previously described in (1) through (5) for all months of the year; and
7. Sum the monthly evaporation for all months of the year to yield an annual evaporation in acre-feet.

Reclamation verified the open-water area for this report by analyzing data received from BIO-WEST, 2006, satellite images acquired on July 8, 2006, and NAIP imagery acquired in summer, 2004 and summer, 2006.

Calculating evaporation from major delivery canals serving irrigation districts and Indian reservations

Reclamation calculates evaporation from major delivery canals using the same technique used to calculate evaporation from the mainstream, except that the open-water area is that of the major delivery canals. Reclamation categorized major delivery canals into two groups: those that provide water to a single irrigation district or Indian reservation (single user canals) and those that provide water to two or more irrigation districts or Indian reservations (shared canals). The Colorado River Indian Reservation Main Canal is an example of a single user canal, and the All American Canal is an example of a shared canal.

Reclamation calculates the proportionate use of a shared canal using a process described by the following paragraphs:

1. Calculate a single diversion point distance from the canal headworks for each irrigation district or Indian reservation by calculating the average distance of each district's or Indian reservation's points of diversion from the canal headworks and weighing these distances by the diversion amount through each point (these values have units of miles).
2. Multiply the value from (1) for each irrigation district or Indian reservation by the total diversion of each irrigation district or Indian reservation (these values have units of acre-foot miles).
3. Divide the acre-foot-mile values for each irrigation district and Indian reservation by the sum of acre-foot-mile values for all irrigation districts and Indian reservations that receive water from the canal. The proportionate use of the canal can be expressed as fractions or percentages.

Once Reclamation assigns the portion of the open-water area of the shared canal to each irrigation district or Indian reservation, each district's or Indian reservation's assignment of the evaporation is calculated as the proportion of open-water area of the shared canal assigned to each district or Indian reservation multiplied by the monthly evaporation coefficients previously described for evaporation from the mainstream.

LCRAS Improvements for Calendar Year 2006

Reclamation reviews each application of LCRAS and incorporates "lessons learned" into subsequent reports. Reclamation also modifies each application of LCRAS in response to information provided by water users and as modified processes become available after analysis of long-term questions and issues.

The following paragraphs describe improvements to crop and riparian vegetation identification and ET calculations made since the issuance of the 2005 LCRAS evapotranspiration report, and potential improvements under active consideration during the past year.

Improving ET Estimates for Riparian Vegetation

Reclamation completed a cooperative study initiated in fiscal year 2001 with the Nevada Water Science Center of the US Geological Survey to improve estimates of ET from riparian vegetation. The study's objective, to refine ET estimates for the most common riparian vegetation communities found along the lower Colorado River using parameters measured by three micro-meteorological stations placed above riparian vegetation stands in Topock Marsh, is documented in , "Evapotranspiration by Phreatophytes Along the Lower Colorado River at

Havasu National Wildlife Refuge, Arizona," Scientific Investigations Report 2006-5043. This report includes,

1. Estimates of ET from riparian vegetation,

2. A comparing these estimates with estimates of ET from riparian vegetation calculated using ET coefficients and reference ET currently used by LCRAS, and

3. A description of adjustments for the riparian vegetation ET coefficients used by the LCRAS program.

Reclamation expects the results of this study to be introduced in future LCRAS reports.

Adjusting Diverter Boundaries

Reclamation consults with irrigation districts, Indian reservations, and other diverters within defined service areas to resolve discrepancies between Reclamation's understanding of diverter boundaries and diverter's understandings of their boundaries. Reclamation uses this information and other information that may become available to update diverter boundaries used by LCRAS. Such information sharing and gathering is an ongoing process. Reclamation also adjusts diverter boundaries where fields are split by a diverter boundary. The field split by the diverter boundary is placed into the boundary of the diverter from which the field receives water. For calendar year 2006, minor adjustments to diverter boundaries were made.

Determining Accuracies of ET Estimates based on Remote Sensing and GIS Procedures

Reclamation continues a study with an independent statistician to quantify the effects of remote-sensing-based crop classification error on accuracies of ET estimates. See, Stehman, S.V. and Milliken, J.A., 2007. "Estimating the effect of crop classification error on evapotranspiration derived from remote sensing in the lower Colorado River basin, USA", Remote Sensing of Environment 106 (2007) 217 – 227, Elsevier Inc., for results of these ongoing studies.

Refinement of Open Water Areas

Reclamation has begun to refine the open water data base to distinguish between the open water of the river channel and reservoirs, man-made areas of open water which are partially or completely maintained by diverting water from the river, and man-made and/or natural areas of open water adjacent to the river channel which are not maintained by diverting water from the river. Reclamation anticipated that this refinement will be a continuous process as areas of open water are identified and investigated to determine if they are man made and if these areas are supported by diversions from the Colorado River.

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