Holding Back the Ocean and Recharging Aquifers with Treated Wastewater

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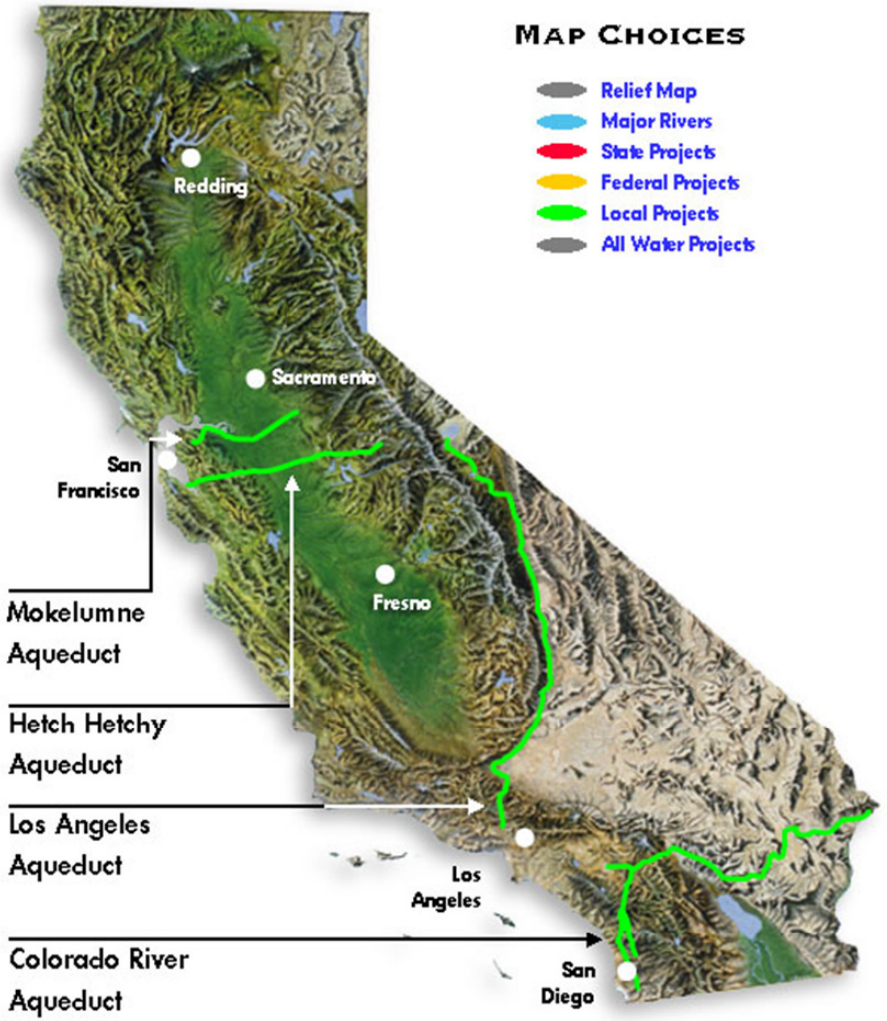
California State University, Fullerton

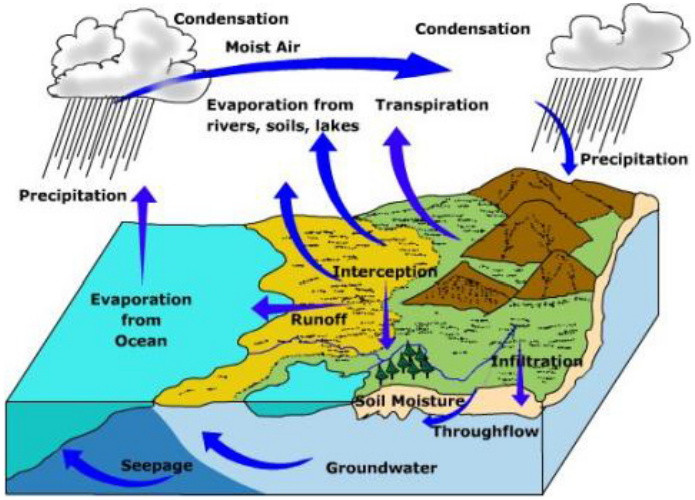
Department of Geological Sciences

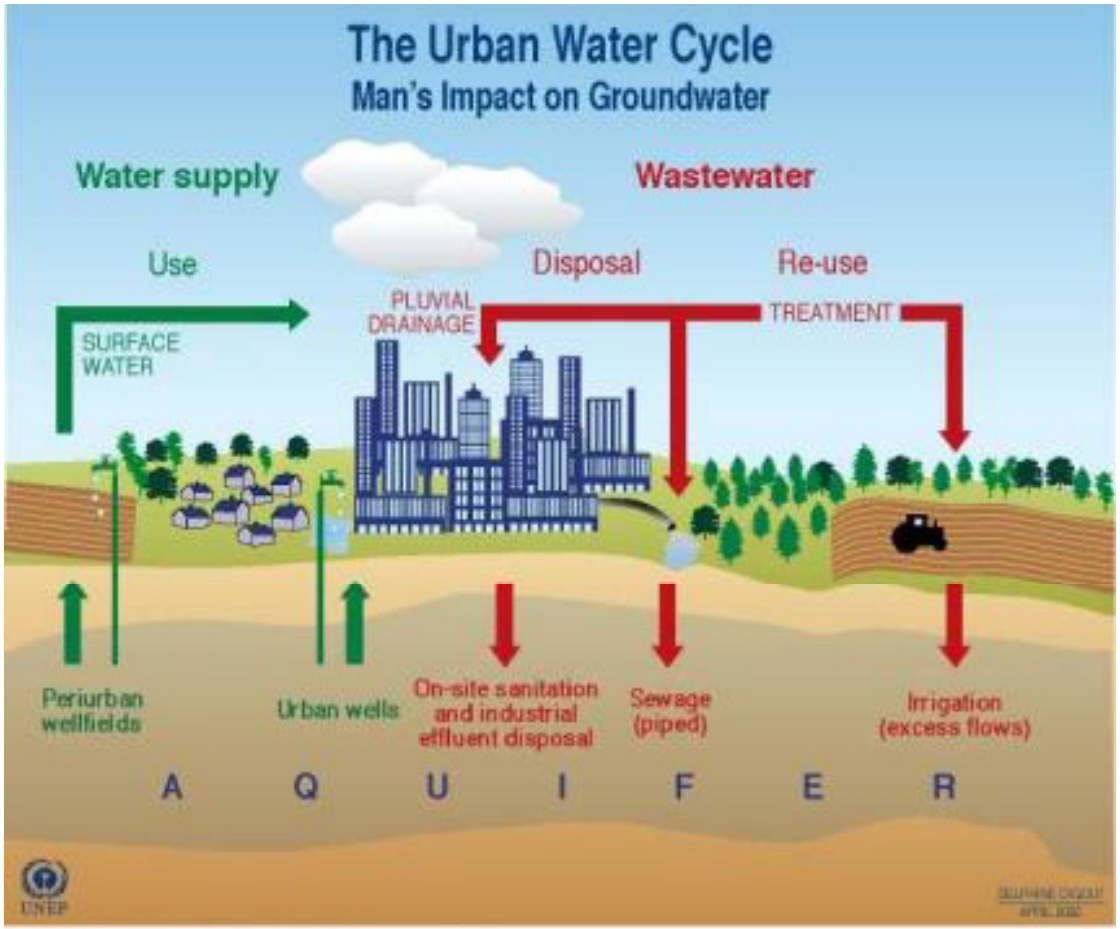
Sustainability

The urban water cycle: the new norm in the west. The west has experienced draught and population booms over the past few years. Orange County in its quest to become sustainable embarked on the idea of artificial recharge. The use of highly treated wastewater for injection along the shoreline to hold back the ocean and percolation upgradient to help provide drinking water to over 2 million people is now the norm. This has led Orange County's water resources to become virtually sustainable.



Hydrologic Cycle





Source: Brian Morris, British Geological Survey, 2001.

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Orange County, California

- History of Orange County
- Geology
- Hydrogeology
- Hydrology
- Injection/Percolation
- Conclusions

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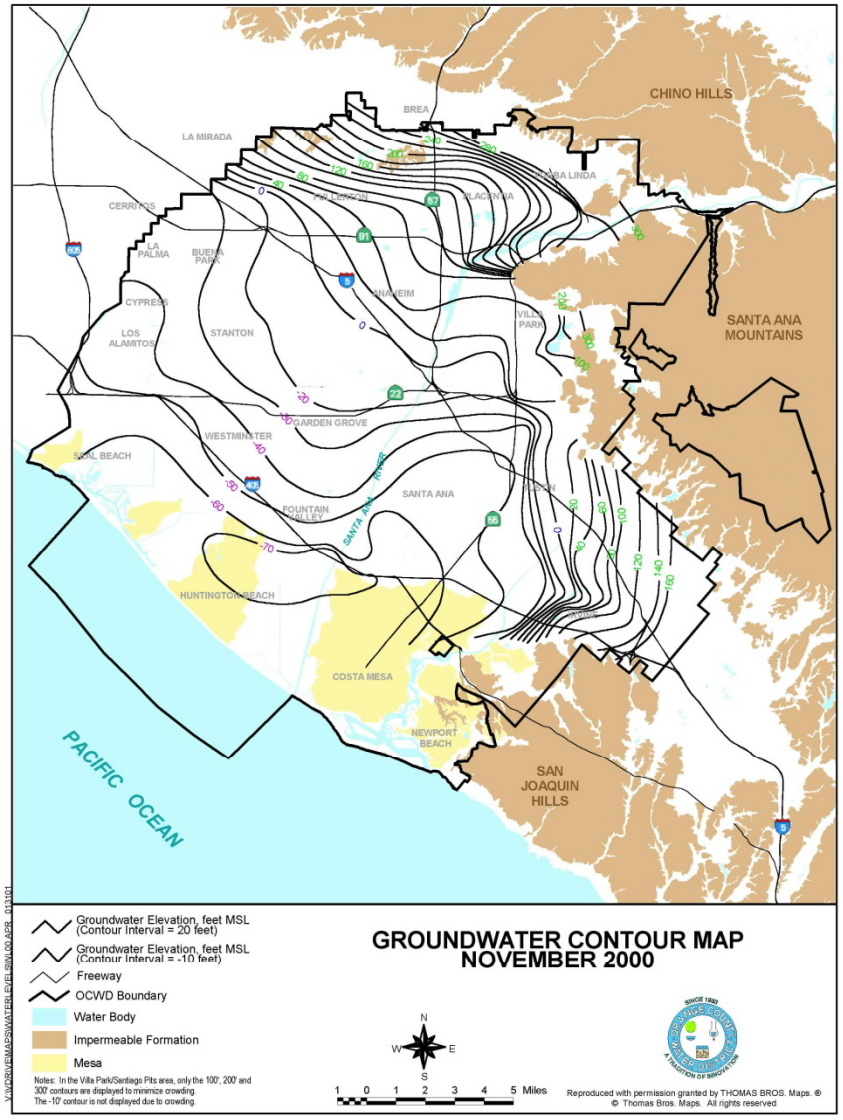
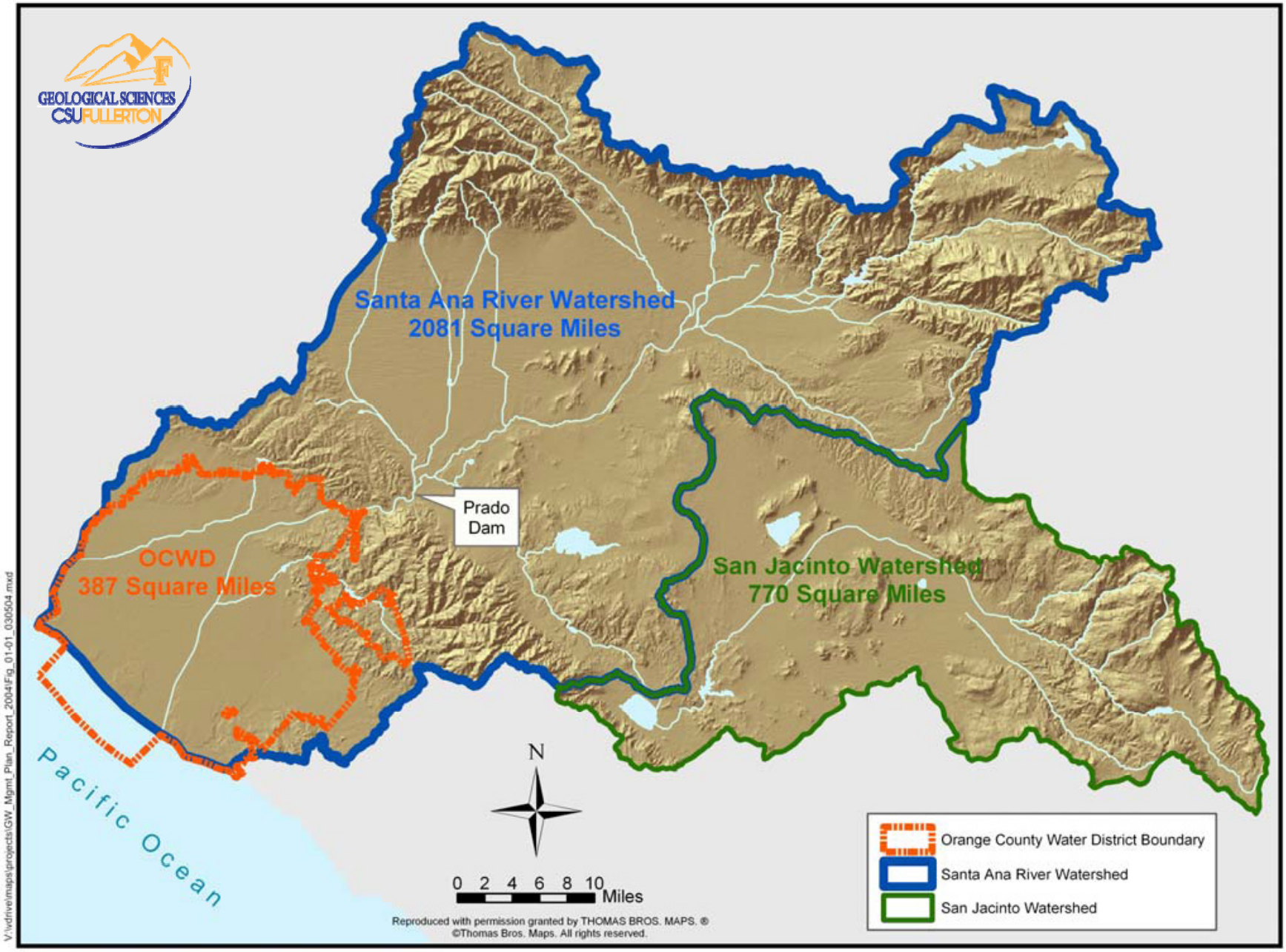
Orange County Water District

- 1933
- Management of basin
- 2+ million people
- Surface water and groundwater recharge



Over 100 Years Ago – Flowing Artesian Wells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Santa Ana River Watershed
2081 Square Miles
Prado
Dam
OCWD
387 Square Miles
San Jacinto Watershed
770 Square Miles
Pacific Ocean
N
0 2 4 6 8 10
Miles
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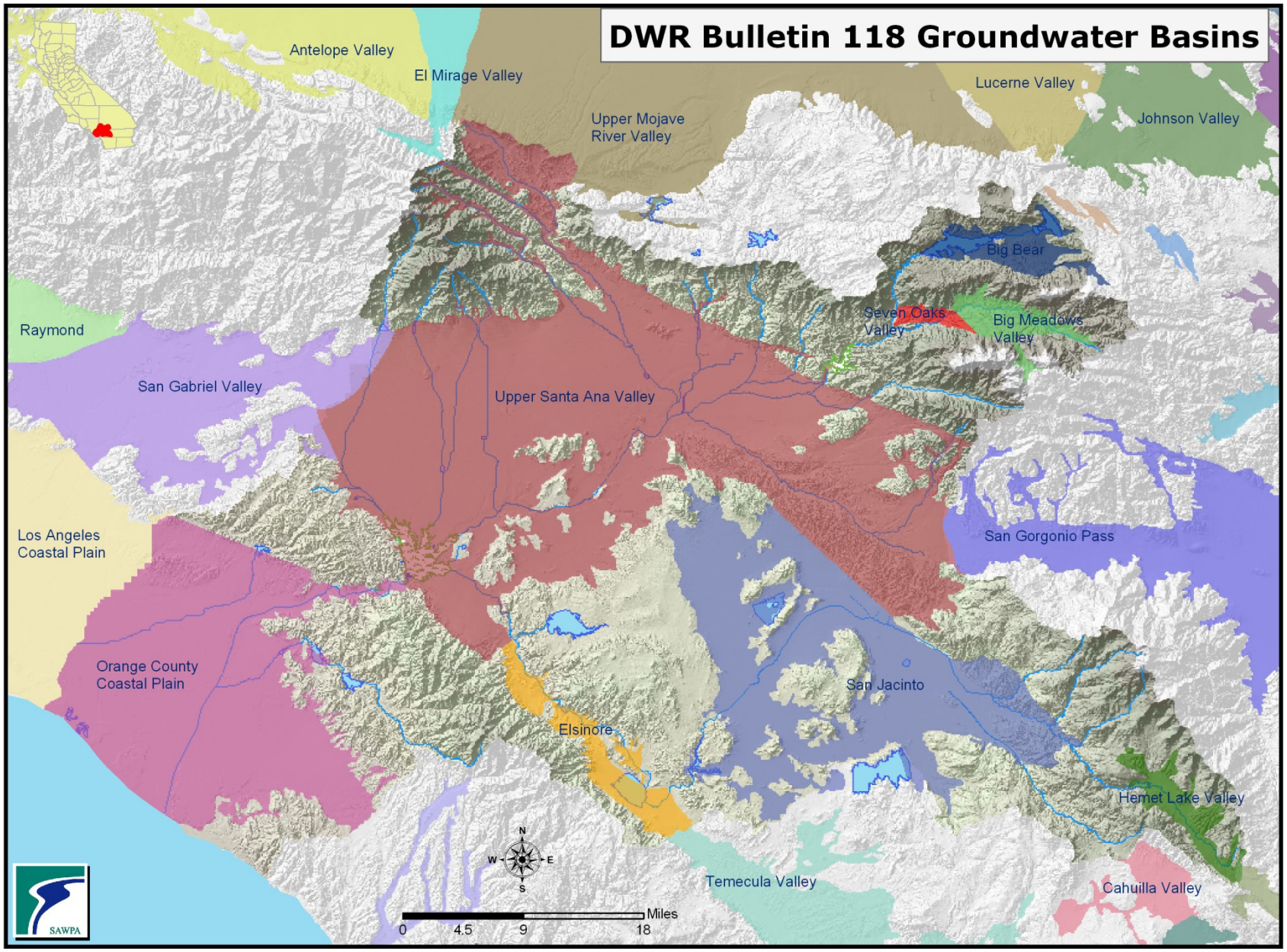
Orange County Water District Boundary
Santa Ana River Watershed
San Jacinto Watershed
V:\wdrive\maps\projects\GW_Mgmt_Plan_Report_2004\Fig_01-01_030504.mxd



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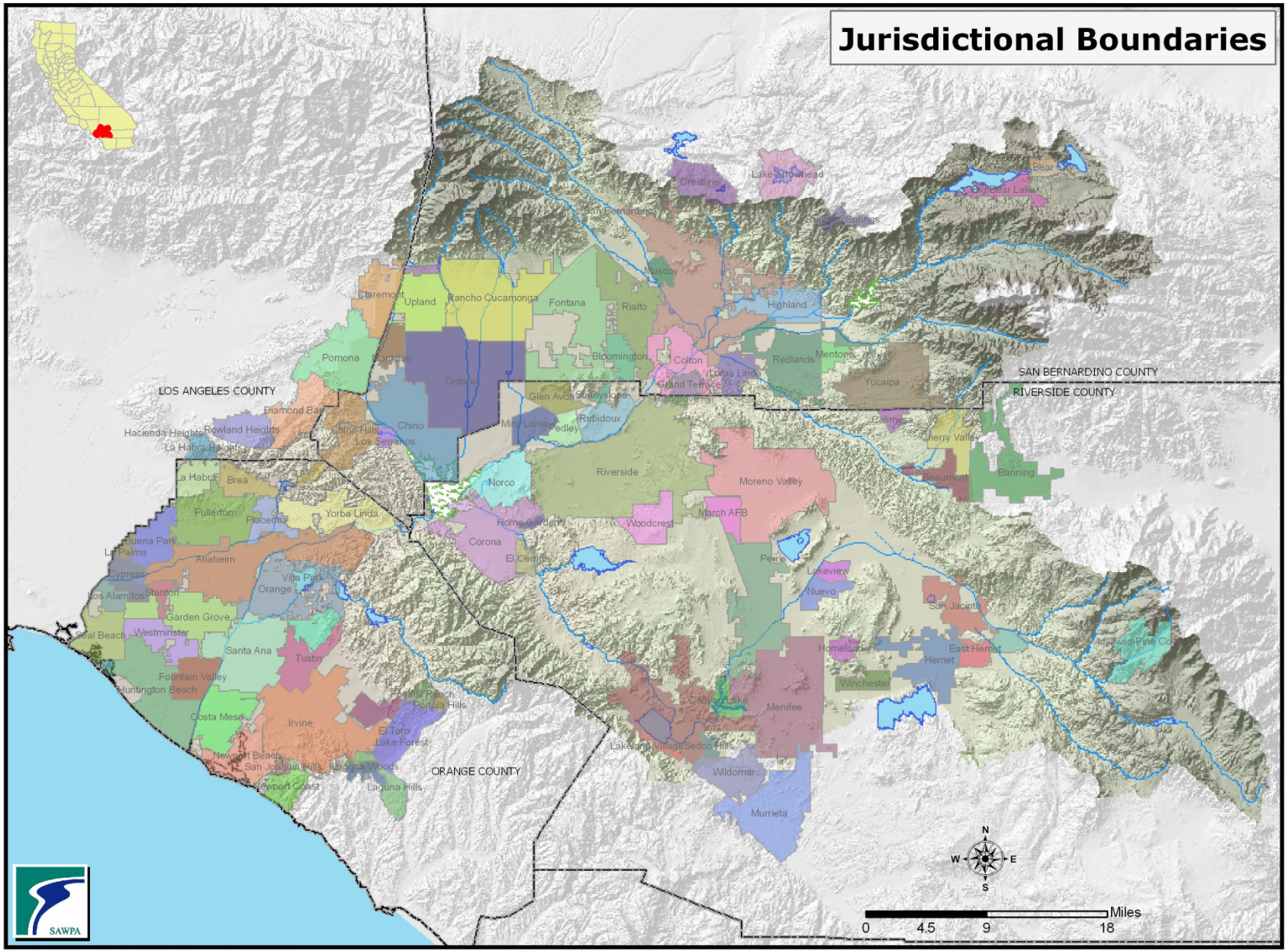

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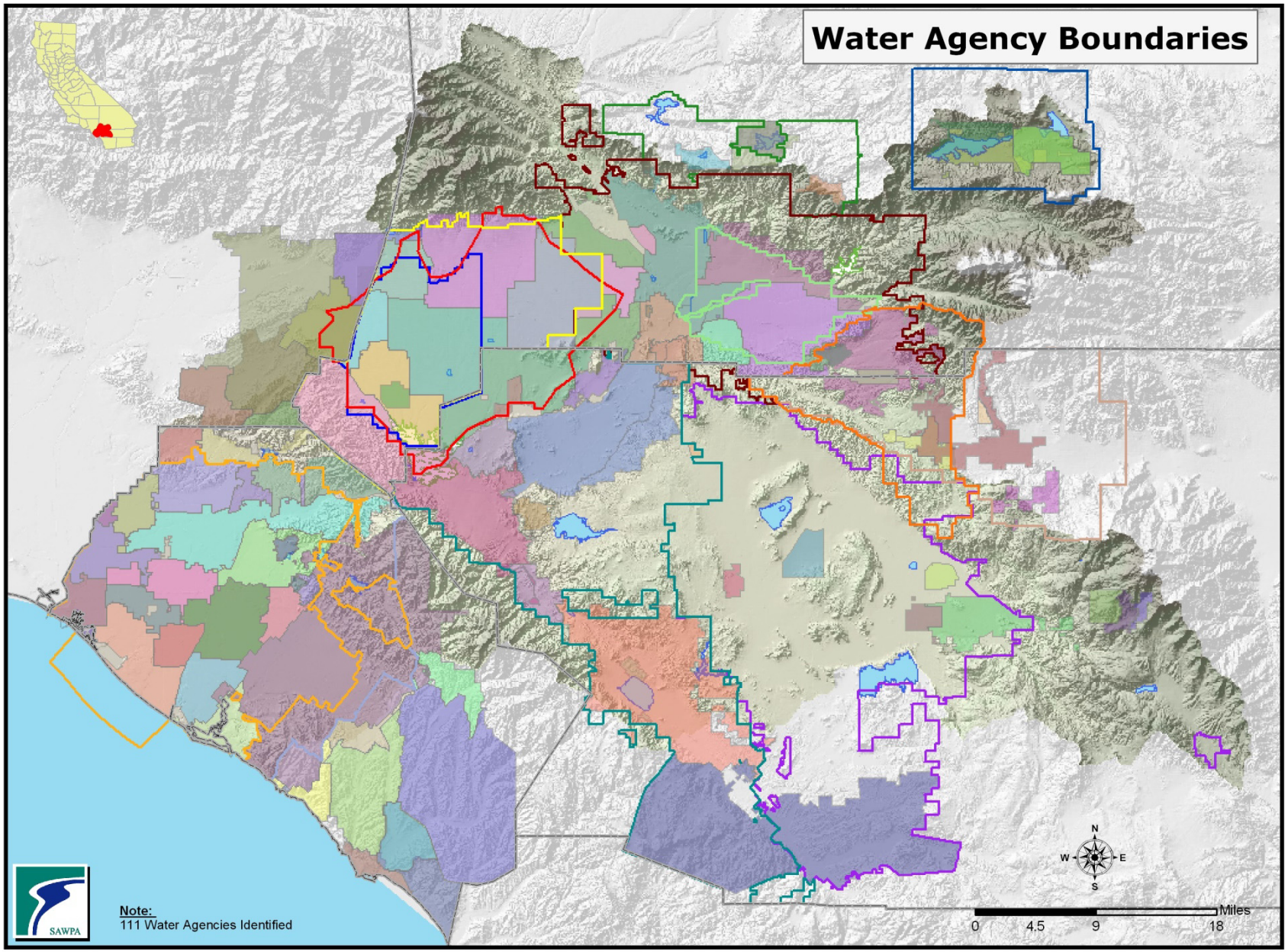

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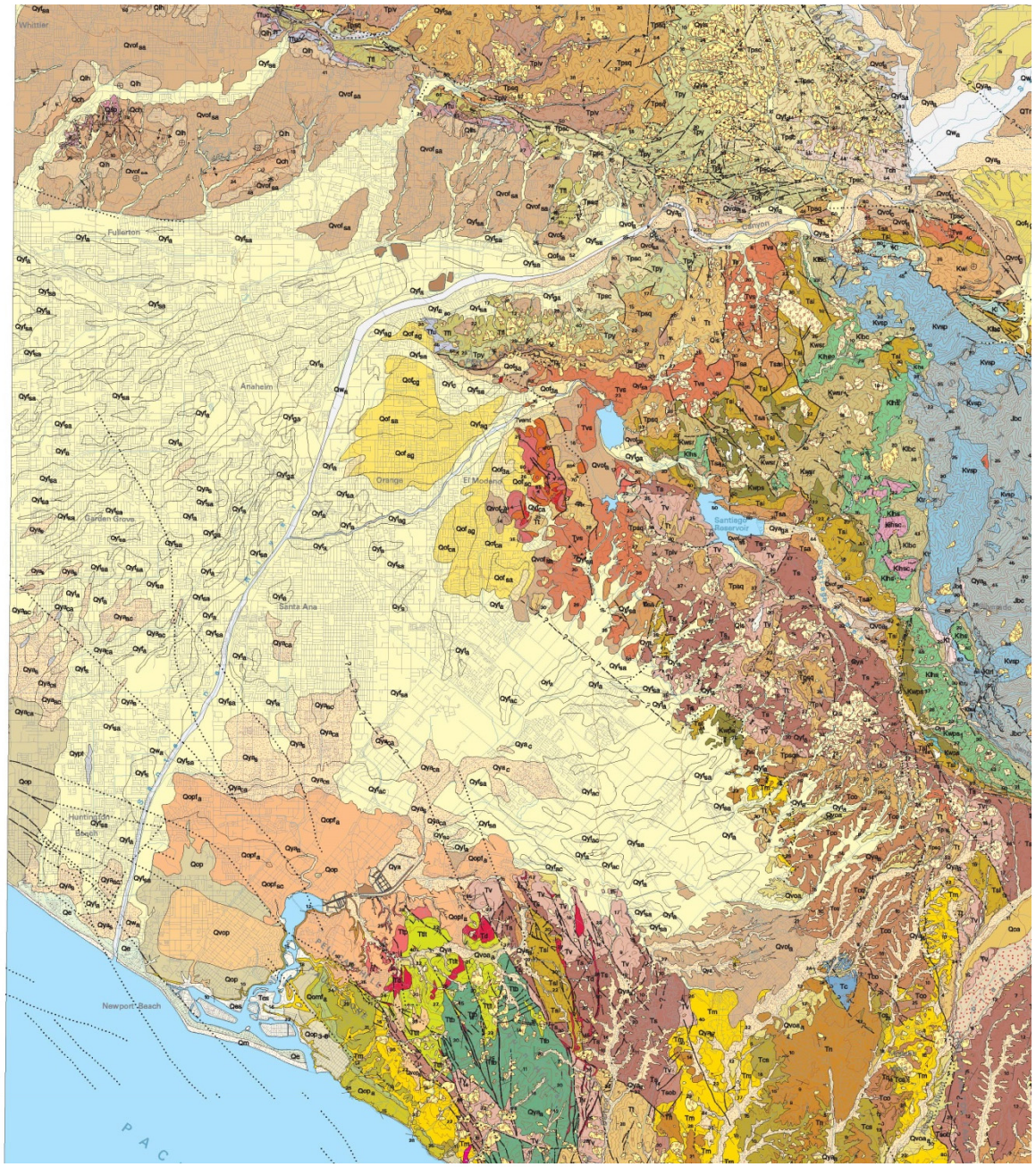
Geology



PRELIMINARY DIGITAL GEOLOGIC MAP OF THE SANTA ANA 30' X 60' QUADRANGLE, SOUTHERN CALIFORNIA

Version 2.0

Compiled by

D. M. Morton[1]

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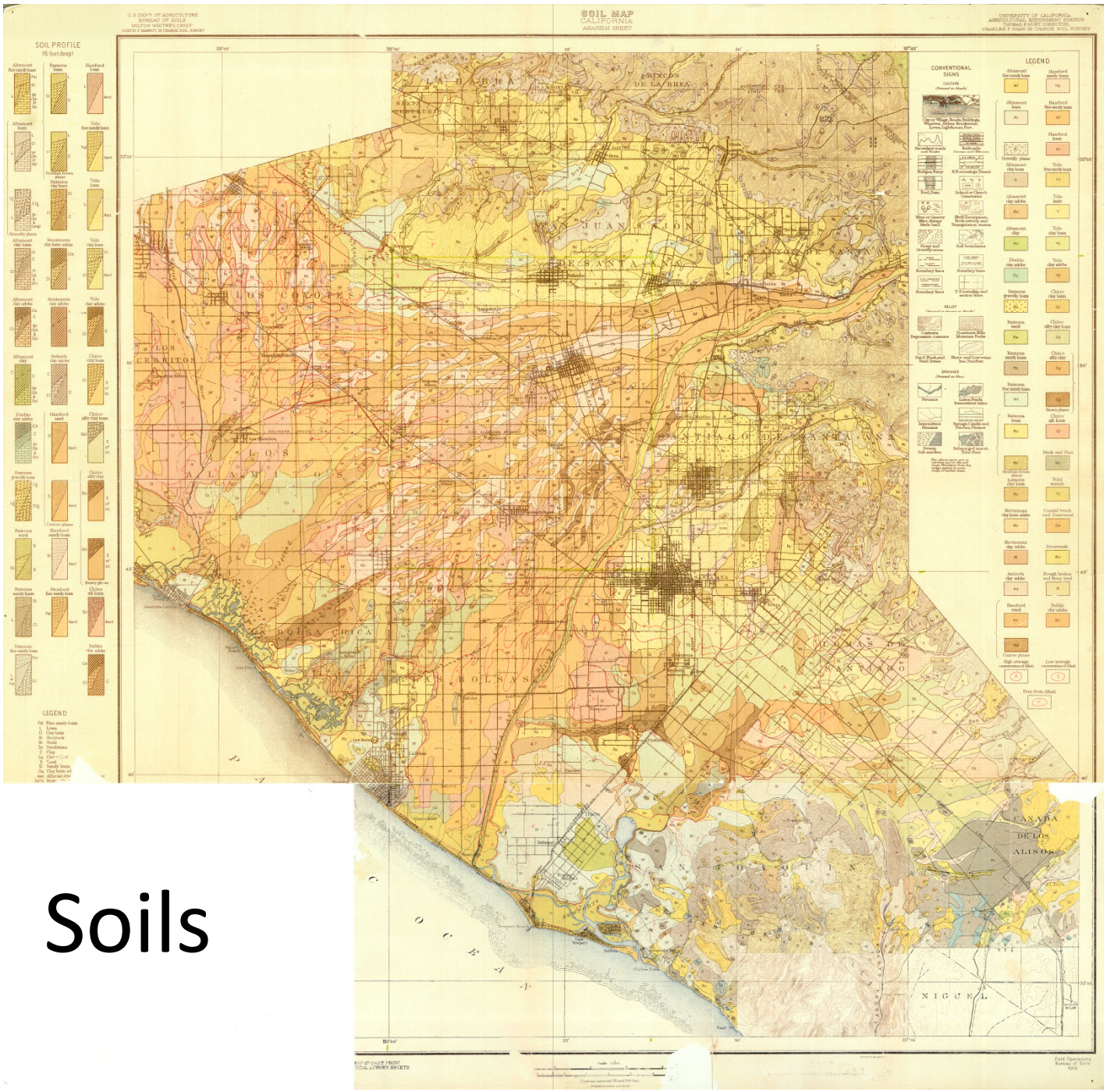

Soils

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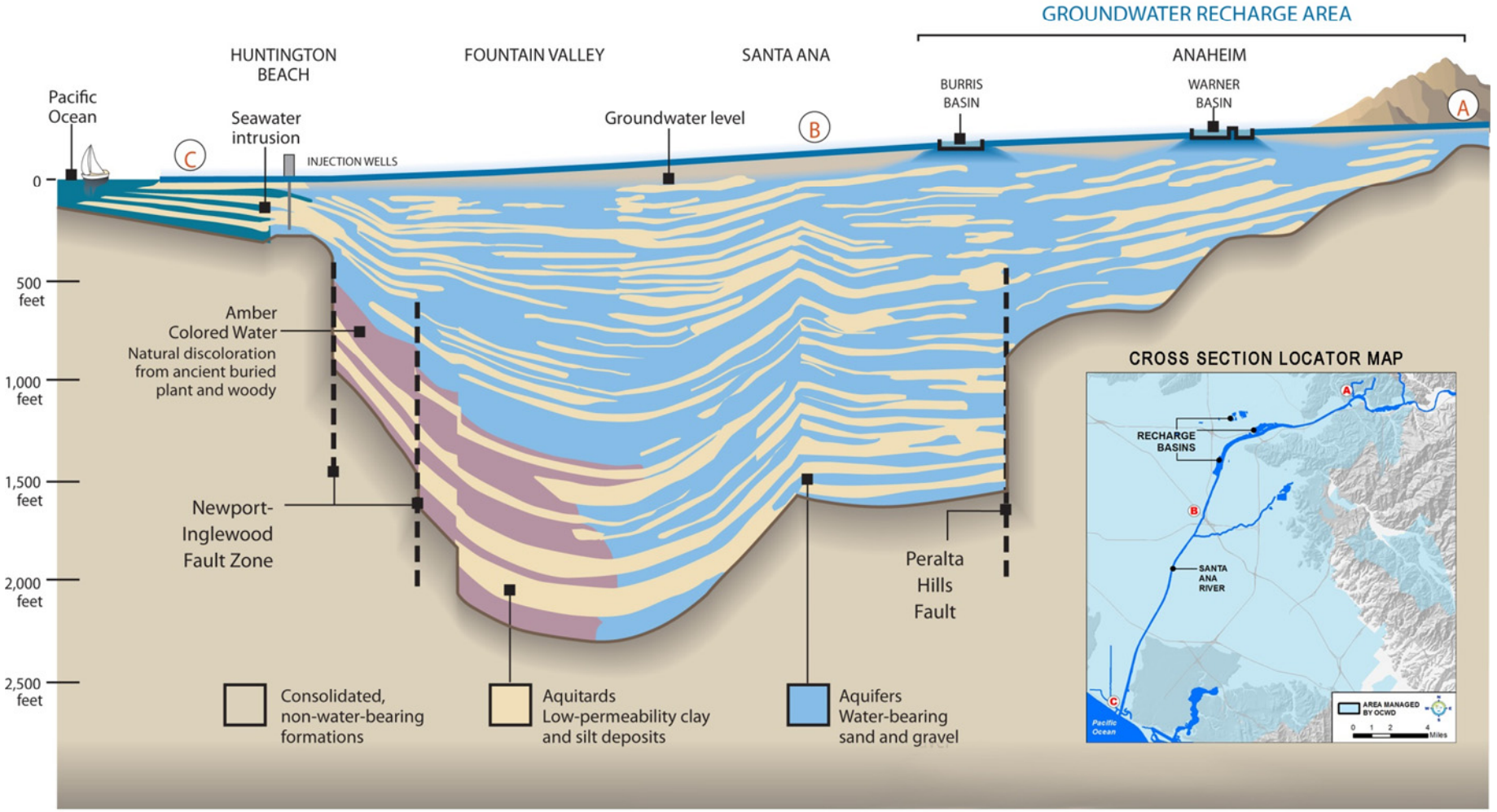
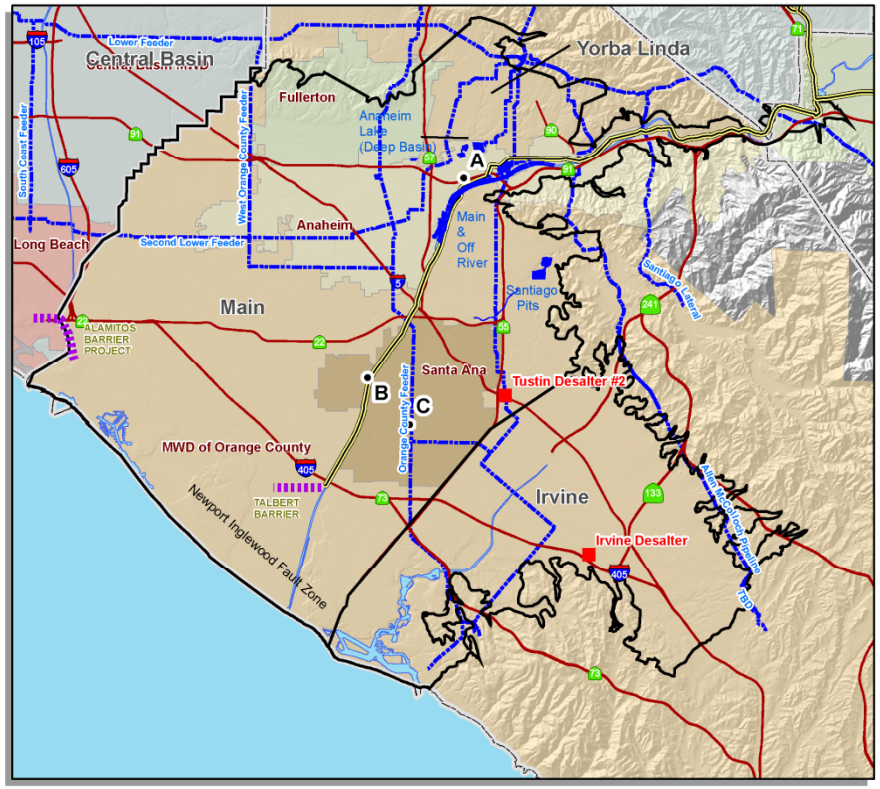
Hydrogeology

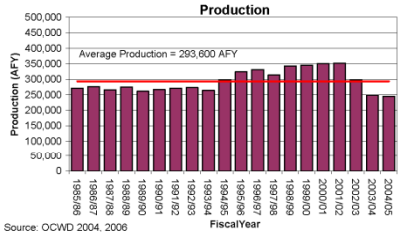
GEOLOGIC CROSS SECTION OF ORANGE COUNTY'S GROUNDWATER BASIN



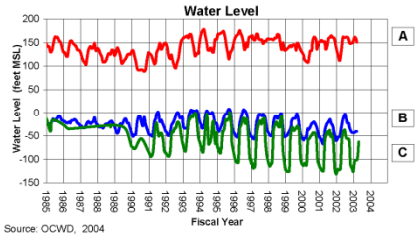


Orange County Basin

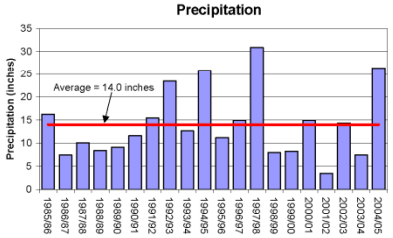
A • Key Well
Desalter
Recharge Basin
Seawater Barrier
County
Freeways
Water Body
MWD Pipeline
Santa Ana Regional Interceptor Line
Basin
MWD Member Agency Boundary (color varies)



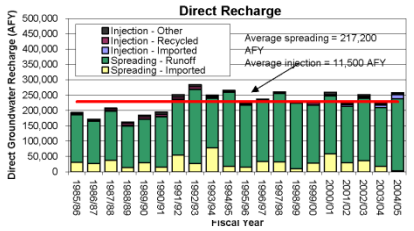
Source: OCWD 2004, 2006



Source: OCWD, 2004



Source: UC IPM, 2006



BASIN FACTS

Orange County Basin

Description
Location: Orange County
Watershed Surface Area: 350 square miles
Subbasins:
Main
Irvine
Yorba Linda
MWD Member Agencies:
Municipal Water District of Orange County
Management: Managed
Since 1933, OCWD has managed basin. OCWD manages production, water quality, spreading operations, and seawater intrusion barrier operations.

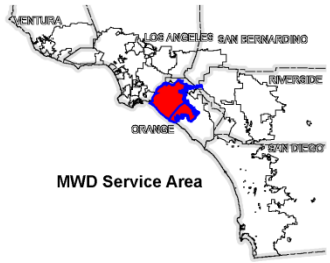
	Orange County
Natural Safe Yield	70,500 AFY
Basin Production Percentage (BPP) for 2005/06	64 percent
Total Storage	66 million AF
Unused Storage Space	Data not available
Portion of Unused Storage Space Available for Storage (2006)	135,000 AF (100,000 AF reserved wet-year storms)

Storage and Extraction Facilities

	Orange County
Production Wells	
Production Capacity	420,000 to 440,000 AFY
Average 1985/86-2004/05	293,645 AFY
Seawater Intrusion Barriers	
Injection Capacity	53,000 AFY
Average 1985/86-2004/05	11,495 AFY
Non-barrier Injection Wells	
Injection Capacity	None
Average 1985/06-2004/05	None
Spreading Basins	
Spreading Capacity	250,000 AFY
Average 1985/86-2004/05	217,225 AFY

Basin Management Considerations

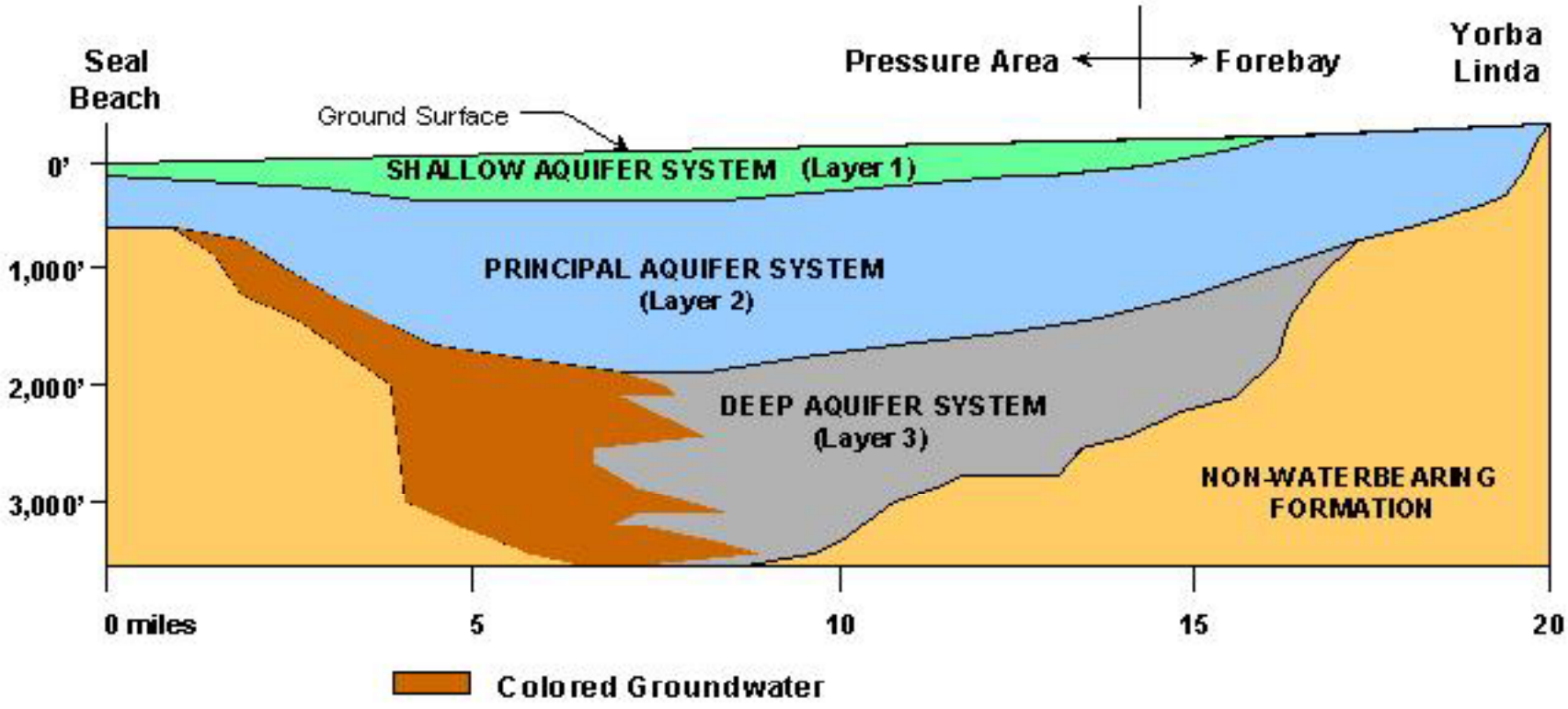
- Artificial recharge is a key management strategy for the Orange County Basin.
- Pumping in the basin is limited by the BPP, which is established annually by OCWD.
- The potential for seawater intrusion could limit the utilization of the basin unless additional seawater barrier facilities are constructed
- Water quality issues such as high TDS and nitrate in Irvine subbasin and colored water in the Lower aquifer system could limit ability to store and extract water from some portions of the aquifer.



MWD Service Area

Plate 10-1
Overview of Orange County Basin

CONCEPTUAL HYDROGEOLOGIC CROSS SECTION AND MODEL LAYERING



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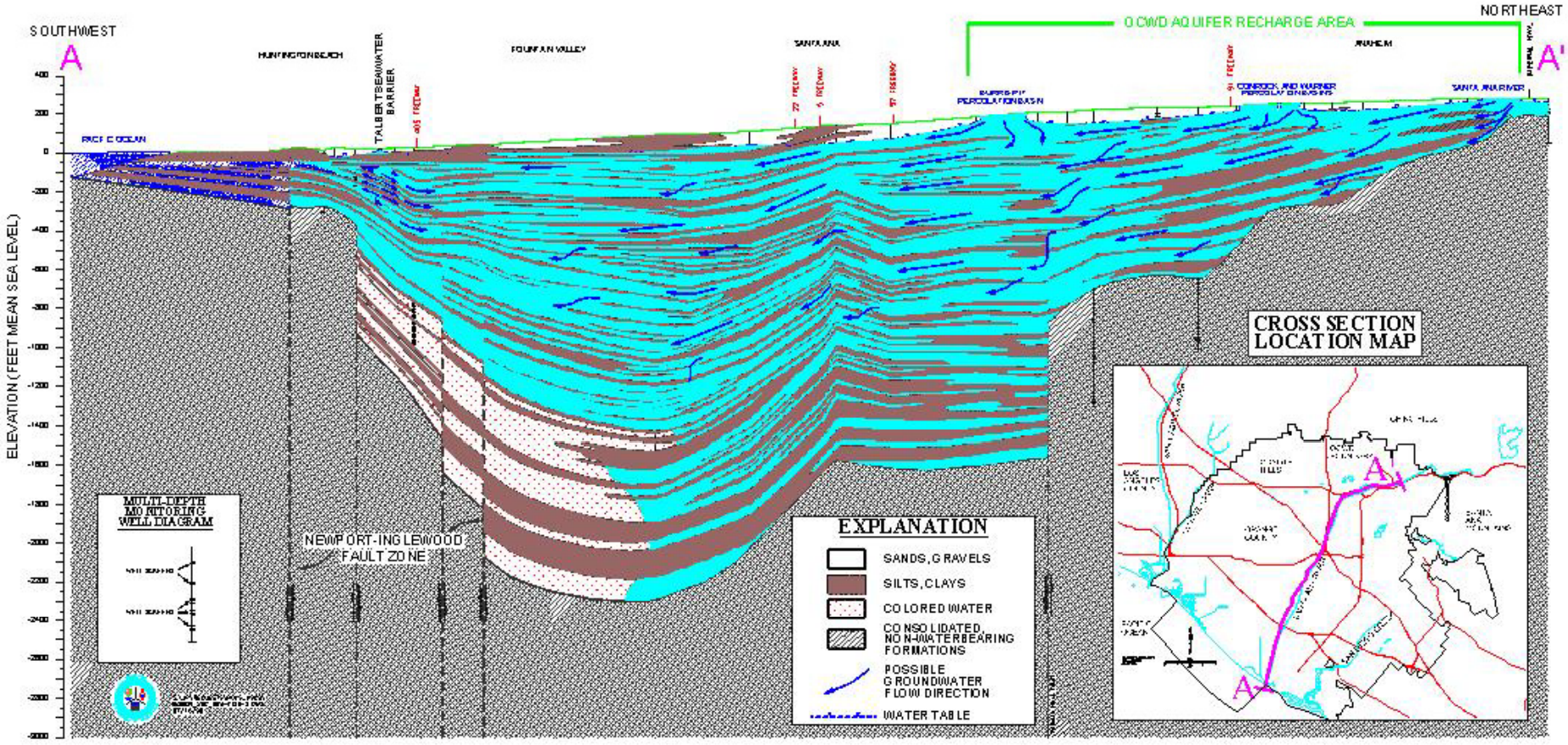
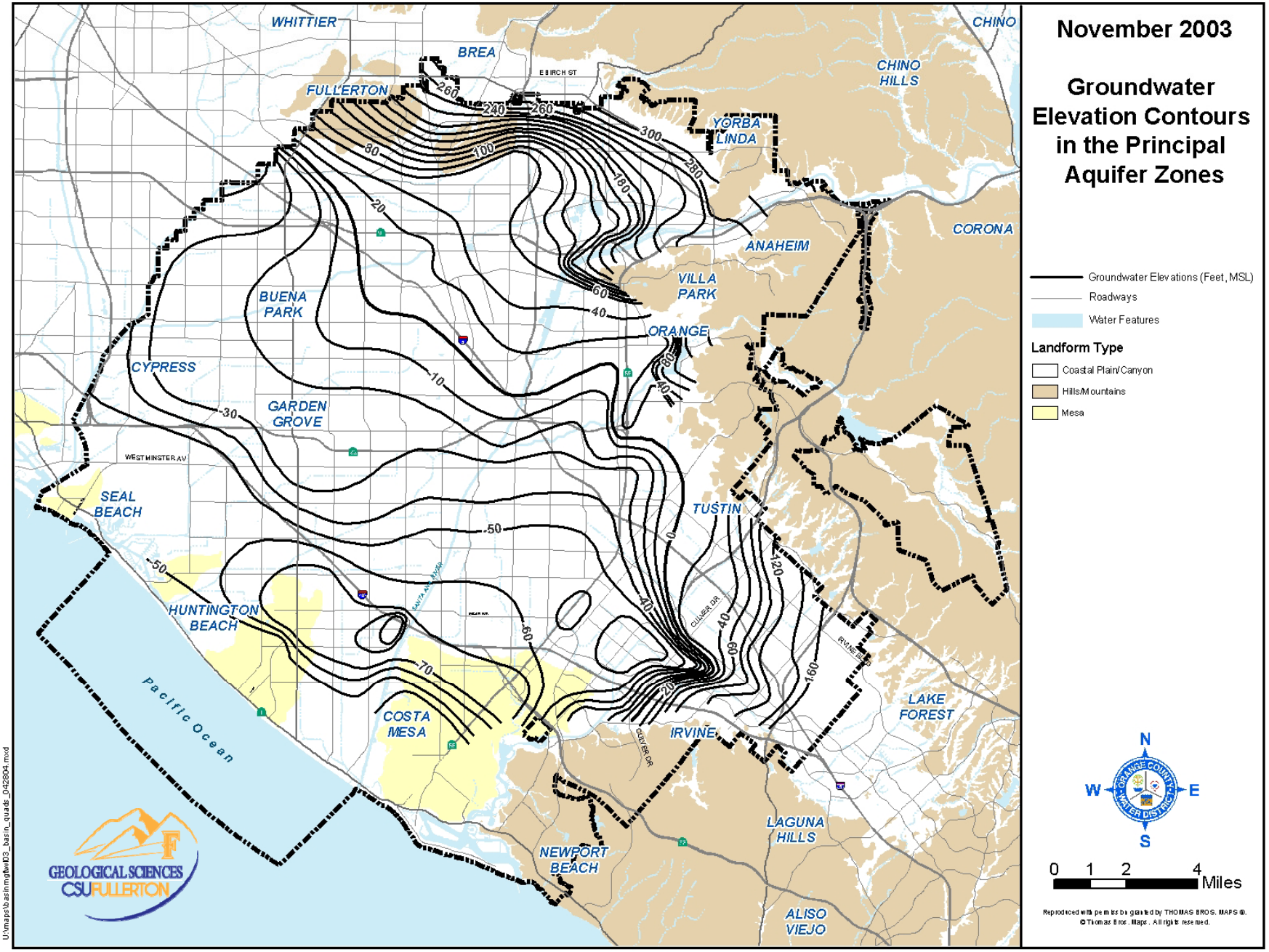
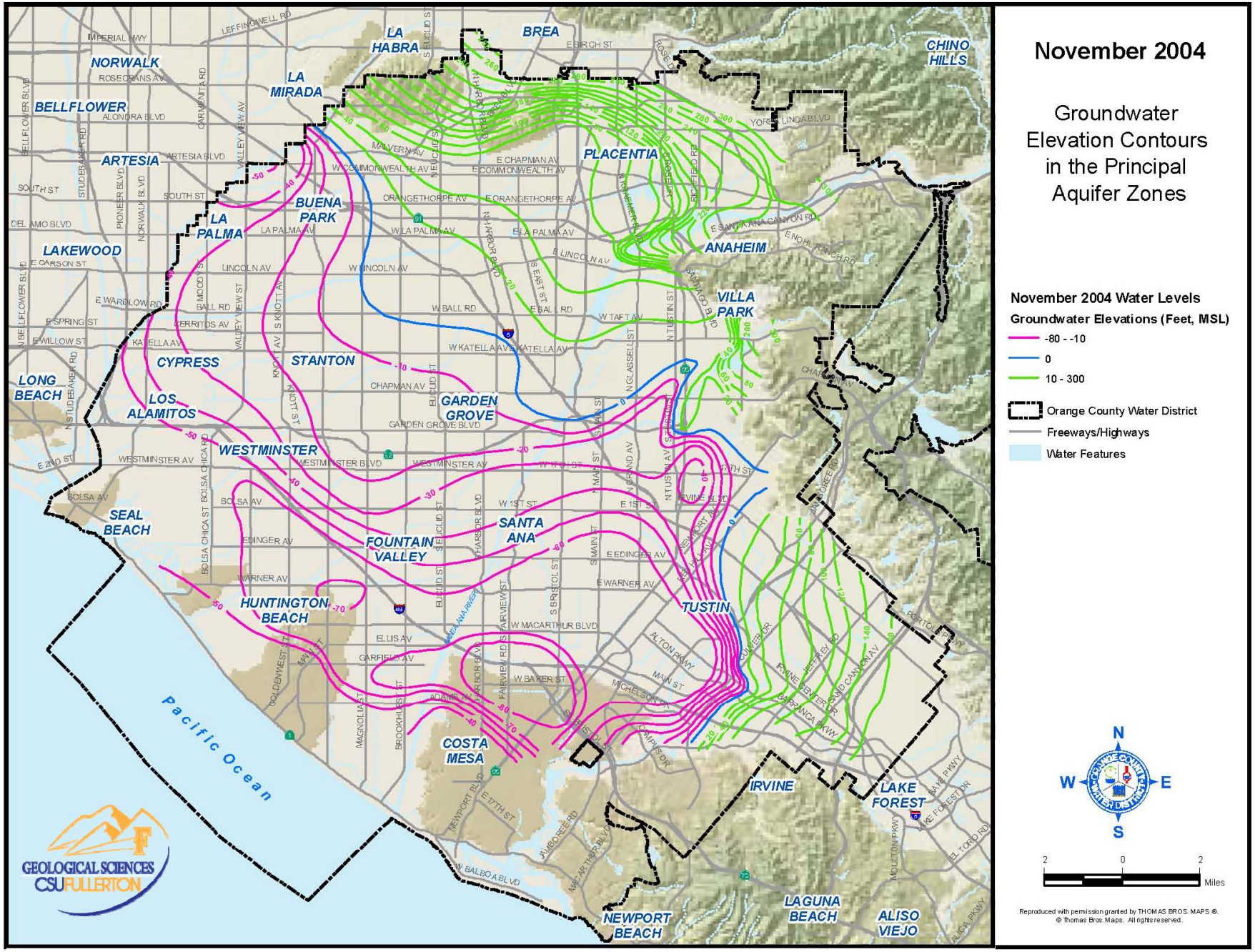


FIGURE 3-2. GEOLOGIC CROSS SECTION THROUGH ORANGE COUNTY GROUNDWATER BASIN ALONG SANTA ANA RIVER




November 2004
Groundwater Elevation Contours in the Principal Aquifer Zones
November 2004 Water Levels
Groundwater Elevations (Feet, MSL)
-80 - -10
0
10 - 300
Orange County Water District
Freeways/Highways
Water Features
N
W
E
S
2
0
2
Miles
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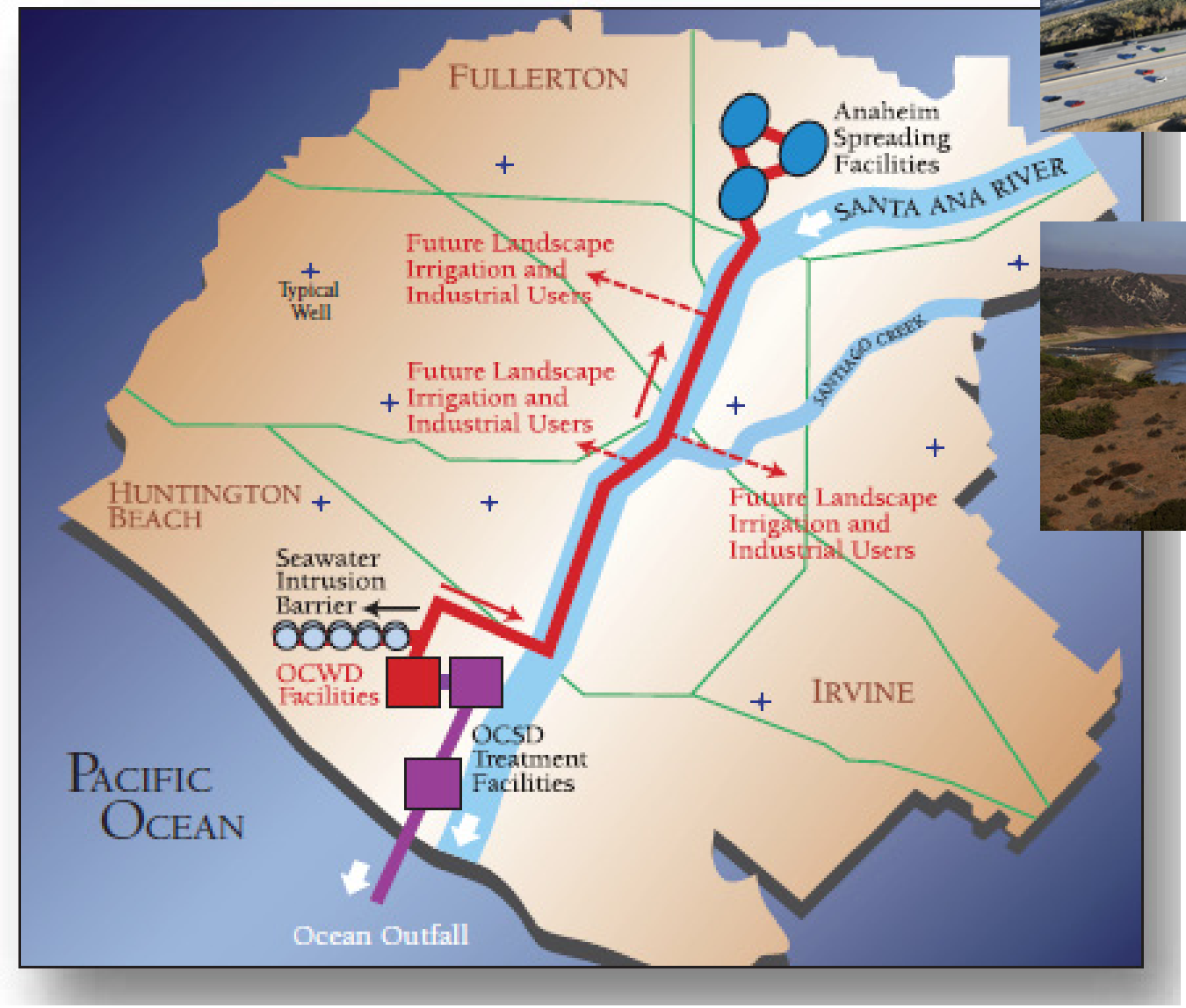
Pacific Ocean
NORWALK
BELLFLOWER
ARTESIA
LAKEWOOD
LONG BEACH
SEAL BEACH
LOS ALAMITOS
CYPRESS
LA MIRADA
LA HABRA
BUENA PARK
LA PALMA
STANTON
WESTMINSTER
GARDEN GROVE
HUNTINGTON BEACH
FOUNTAIN VALLEY
SANTA ANA
COSTA MESA
NEWPORT BEACH
BREA
PLACENTIA
ANAHEIM
VILLA PARK
TUSTIN
IRVINE
LAKE FOREST
LAGUNA BEACH
ALISO VIEJO
CHINO HILLS

Hydrology



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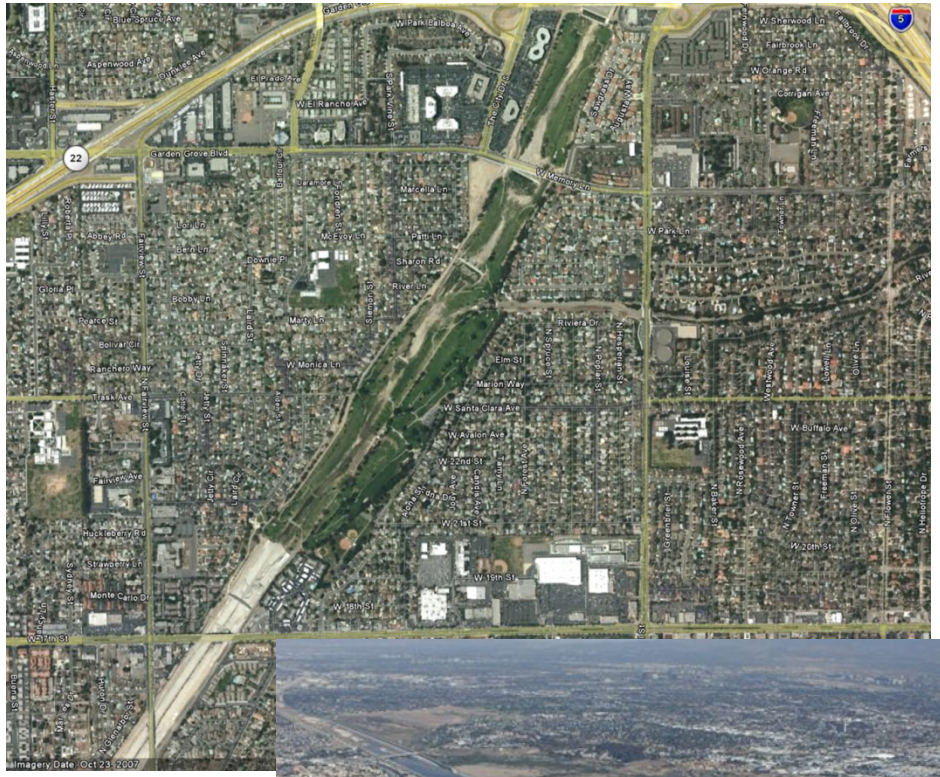
Santa Ana River




Prodo Dam
83
71
91
River Rd
Corydon St
Railroad St
N Smith Ave
Auto Center Dr
Chino Valley Fwy
Palisades Dr
W 6th St
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Image County of San Bernardino
© 2010 Google
Imagery Dates: Feb 1, 2009 - Nov 16, 2009
33°54'20.31" N 117°37'41.54" W elev 490 ft
Eye alt 22577 ft
Google

Water Treatment

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Ellis Ave
Crane Cir
Waxwing Cir
Thrush Ave
Parakeet Cir
Egret Ave
Teal Cir
Owl Cir
Ward St
Garfield Ave
Kentucky
Indiana Ave
New York Ave
New Jersey St
Vermont Ave
Gisler Ave
©2009 Google
© 2010 Google
Imagery Date: Oct 23, 2007
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Eye alt 3216 ft

Reverse Osmosis

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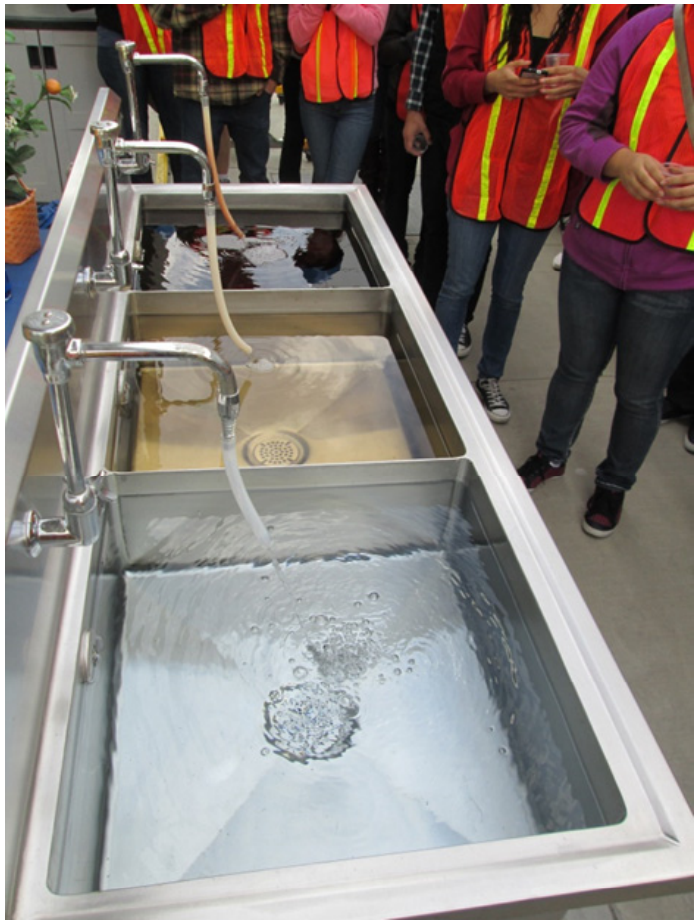
Drinkable at end of plant



UV and Oxidation

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Injection and Percolation

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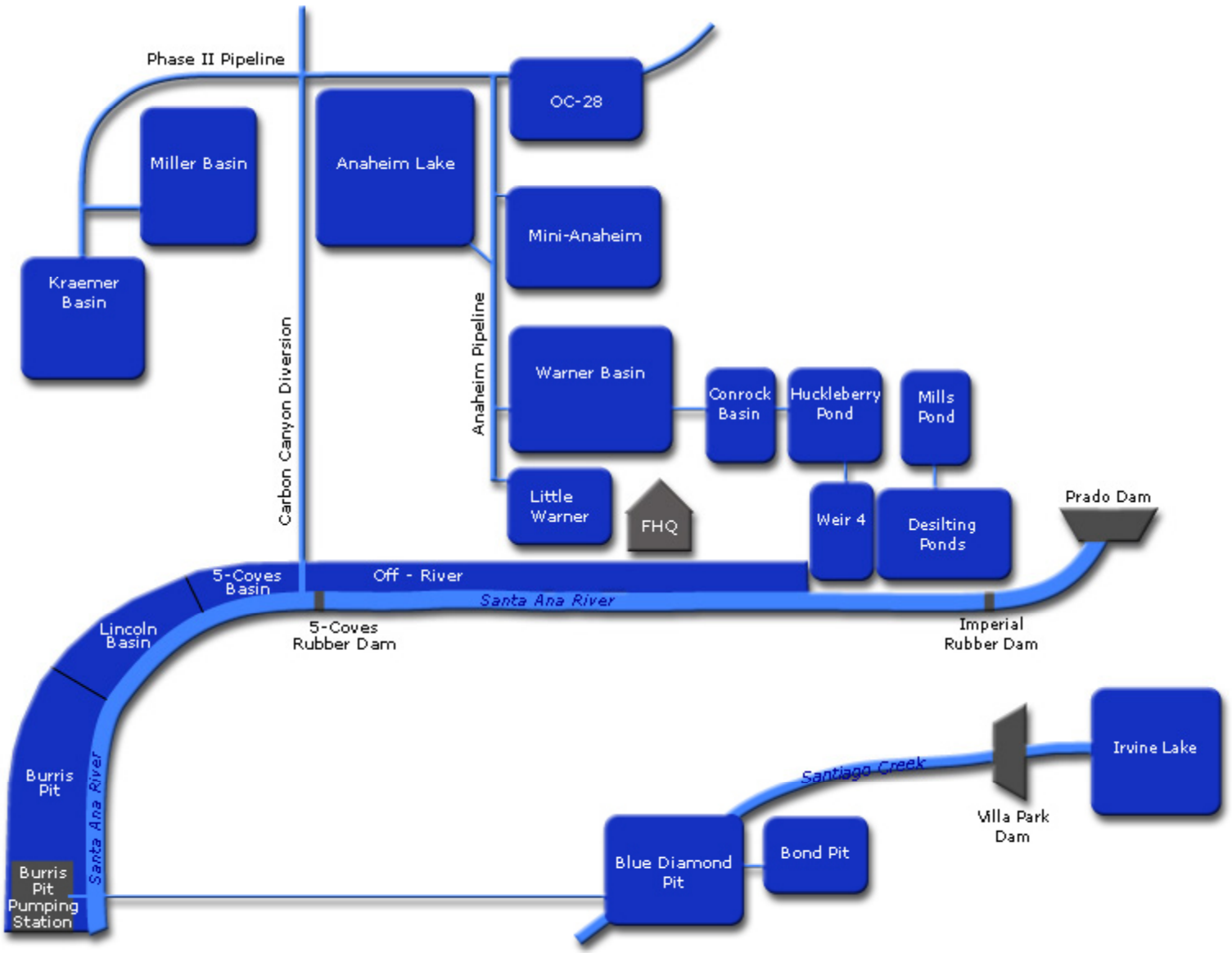

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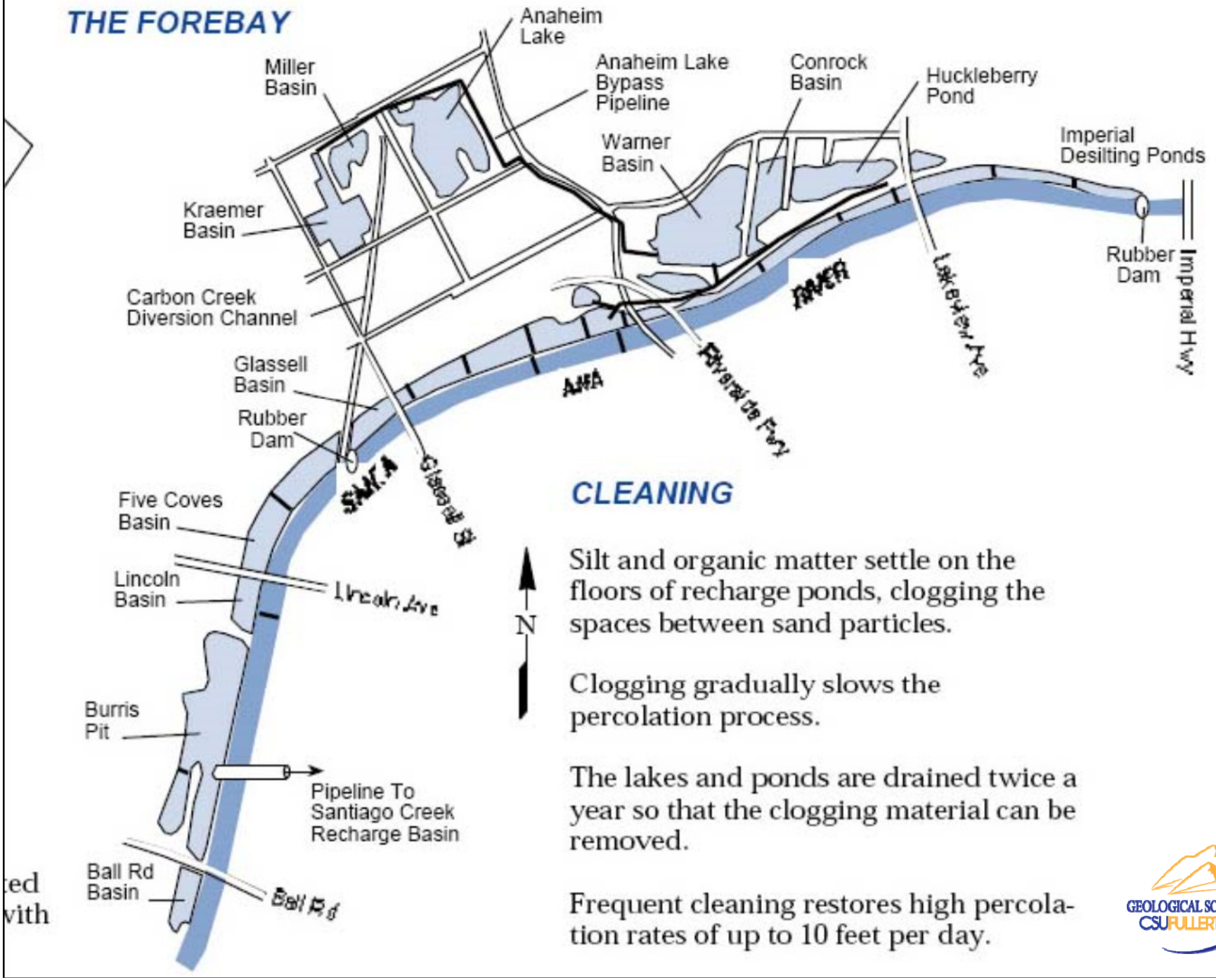
THE FOREBAY



CLEANING

Silt and organic matter settle on the floors of recharge ponds, clogging the spaces between sand particles.

Clogging gradually slows the percolation process.

The lakes and ponds are drained twice a year so that the clogging material can be removed.

Frequent cleaning restores high percolation rates of up to 10 feet per day.

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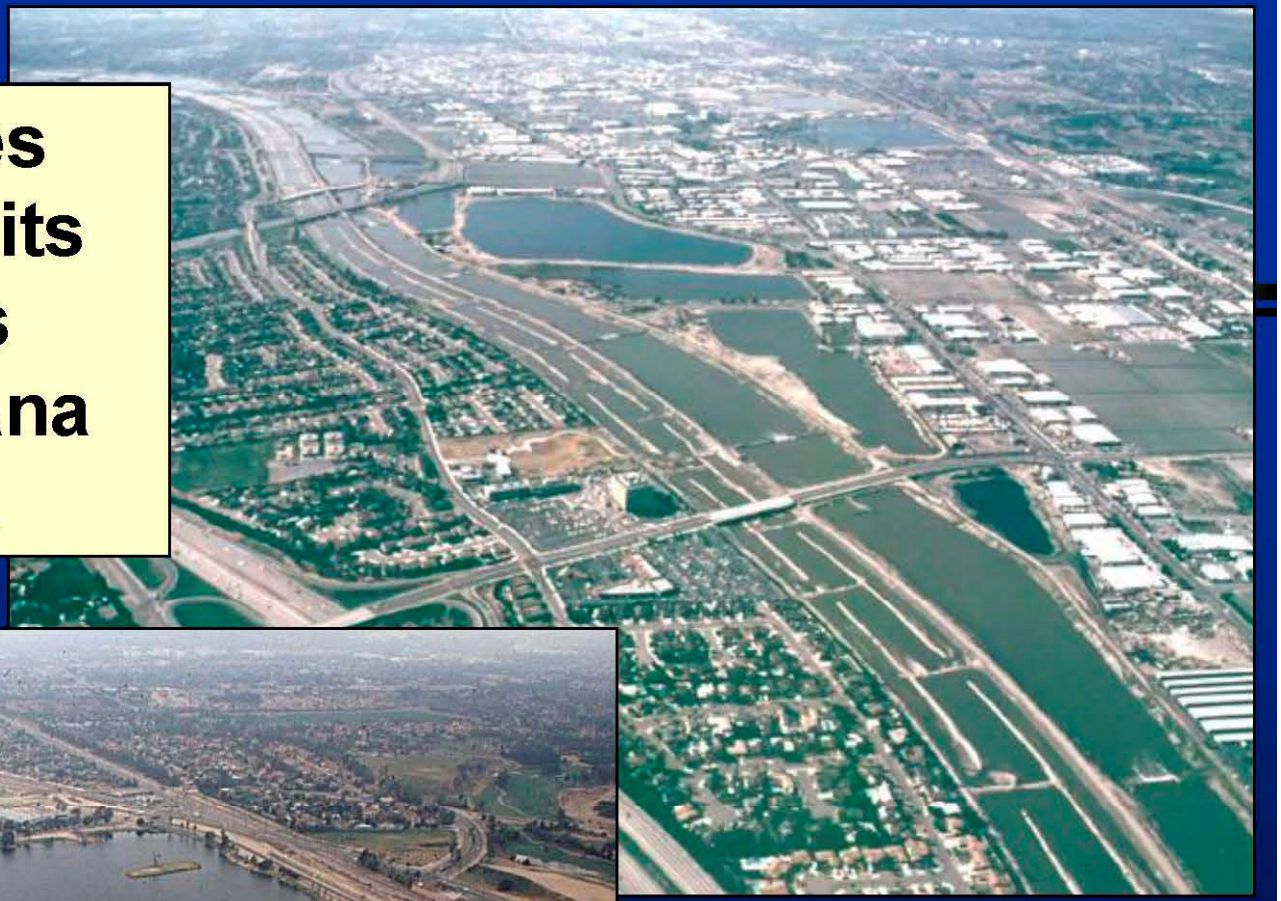
OCWD replenishes the aquifer using its recharge facilities along the Santa Ana River in Anaheim.



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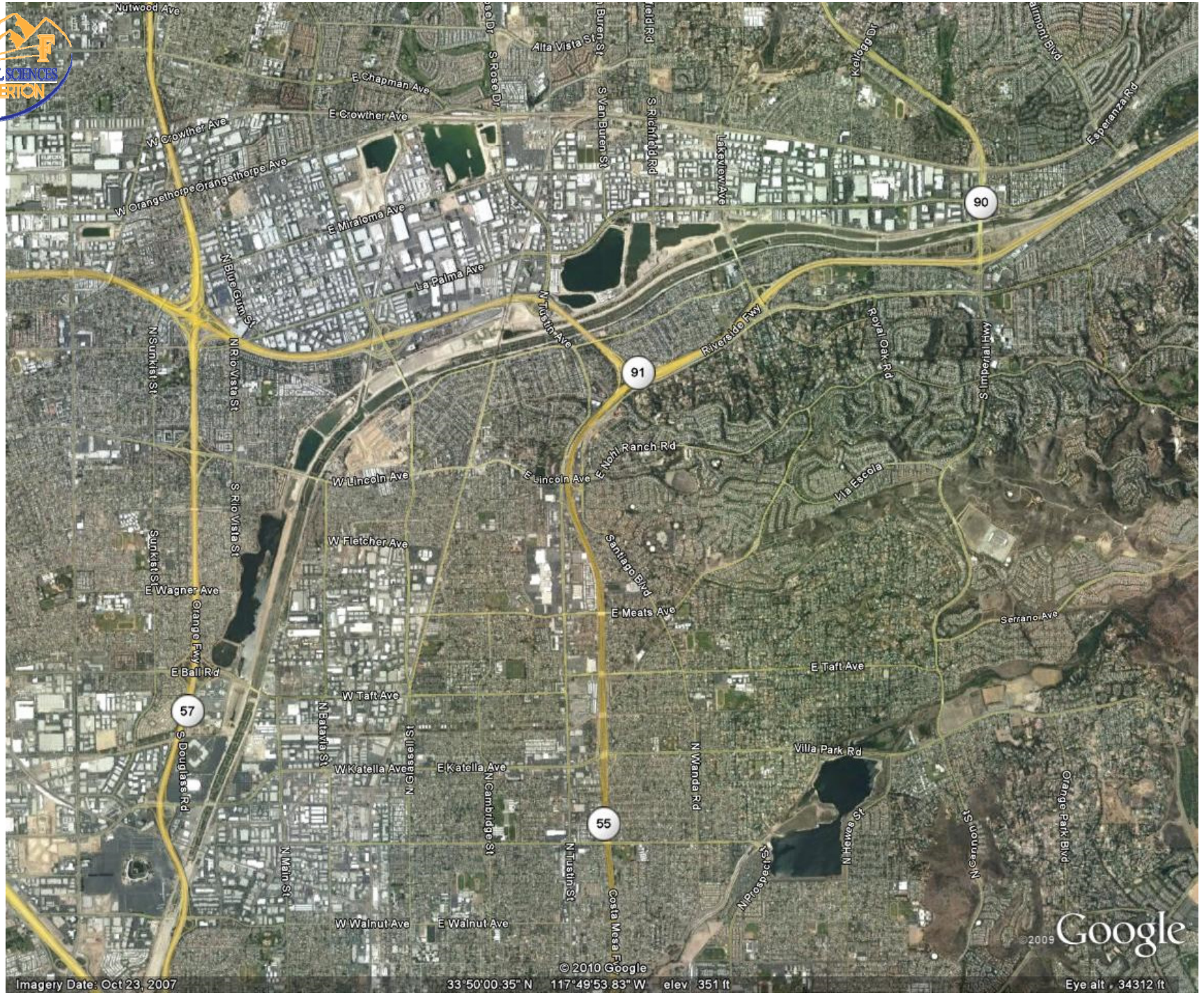
Rubber Dams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Nutwood Ave
E Chapman Ave
E Crowther Ave
W Crowther Ave
W Orangethorpe Ave
E Miraloma Ave
La Palma Ave
N Blue Gum St
N Sunkist St
N Rio Vista St
S Rose Dr
Alta Vista St
S Van Buren St
S Richfield Rd
Lakeview Ave
Kellogg Dr
Belmont Blvd
Esperanza Rd
90
91
N Tustin Ave
Riverside Fwy
Royal Oak Rd
S Imperial Hwy
E Nohl Ranch Rd
Via Escola
W Lincoln Ave
E Lincoln Ave
S Rio Vista St
Sunkist St
W Fletcher Ave
E Wagner Ave
Orange Fwy
Santiago Blvd
E Meats Ave
Serrano Ave
E Taft Ave
E Ball Rd
W Taft Ave
57
S Douglass Rd
N Batavia St
N Glassell St
W Katella Ave
E Katella Ave
N Cambridge St
N Wanda Rd
Villa Park Rd
55
N Hewes St
N Tustin St
N Prospect St
N Orange St
Orange Park Blvd
N Main St
W Walnut Ave
E Walnut Ave
Costa Mesa Fwy
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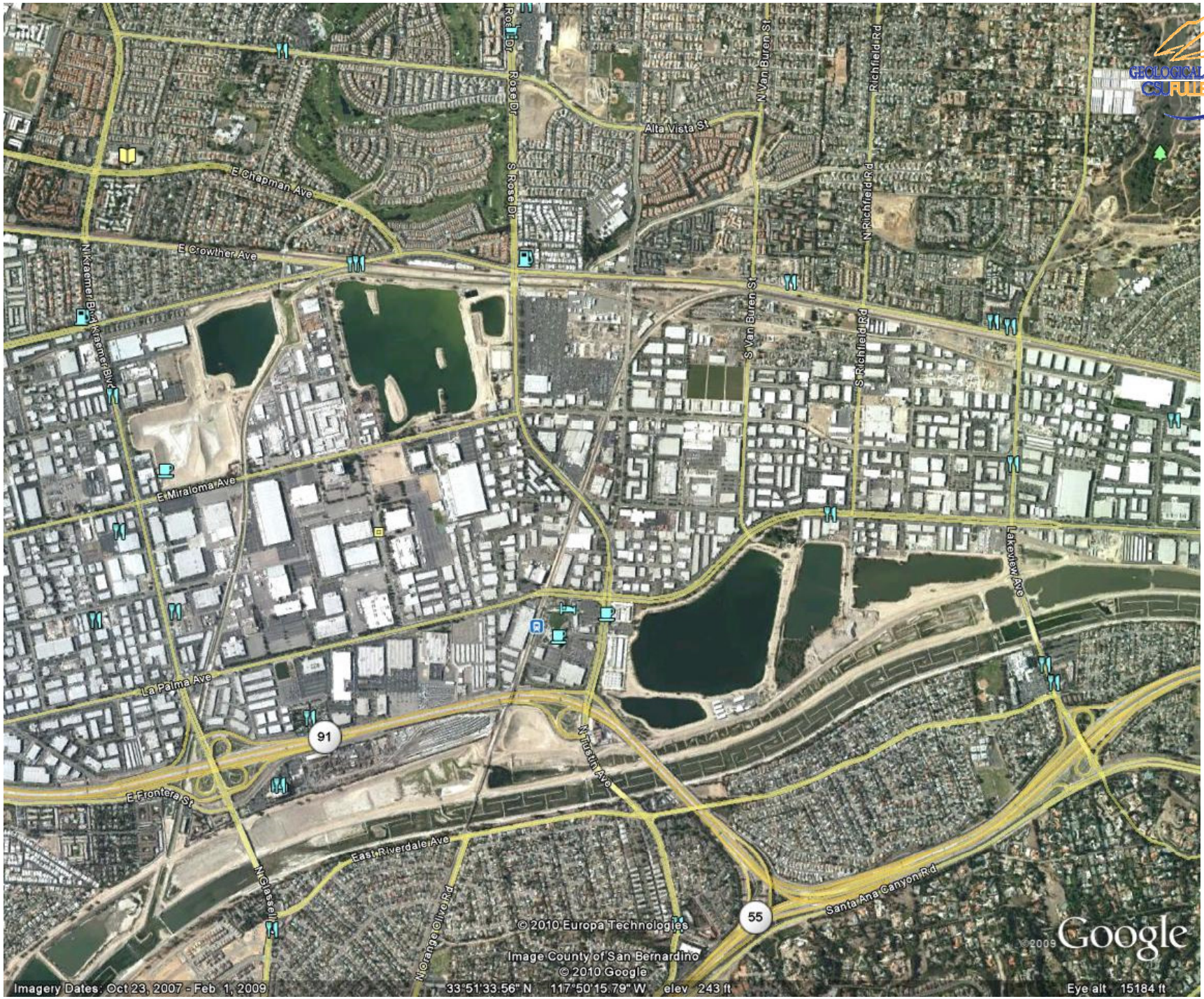
Eye alt 34312 ft


Rose Dr
S Rose Dr
Alta Vista St
N Van Buren St
Richfield Rd
N Richfield Rd
E Chapman Ave
E Crowther Ave
N Kraemer Blvd
S Van Buren St
S Richfield Rd
E Miraloma Ave
Lakeview Ave
La Palma Ave
91
N Tustin Ave
E Frontera St
East Riverdale Ave
N Gilbert
N Orange Olive Rd
55
Santa Ana Canyon Rd
© 2010 Europa Technologies
Image County of San Bernardino
© 2010 Google
Imagery Dates: Oct 23, 2007 - Feb 1, 2009
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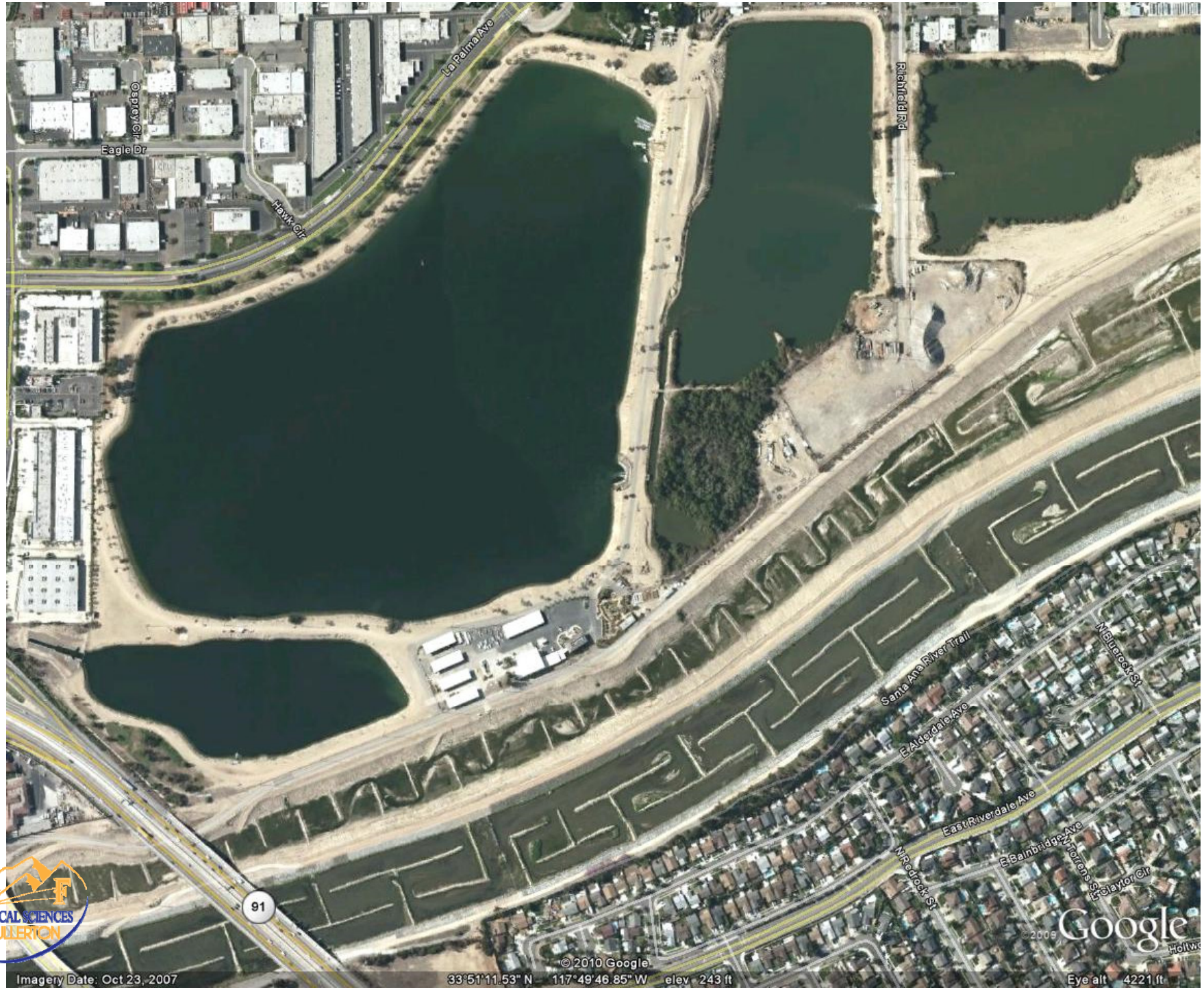
Google



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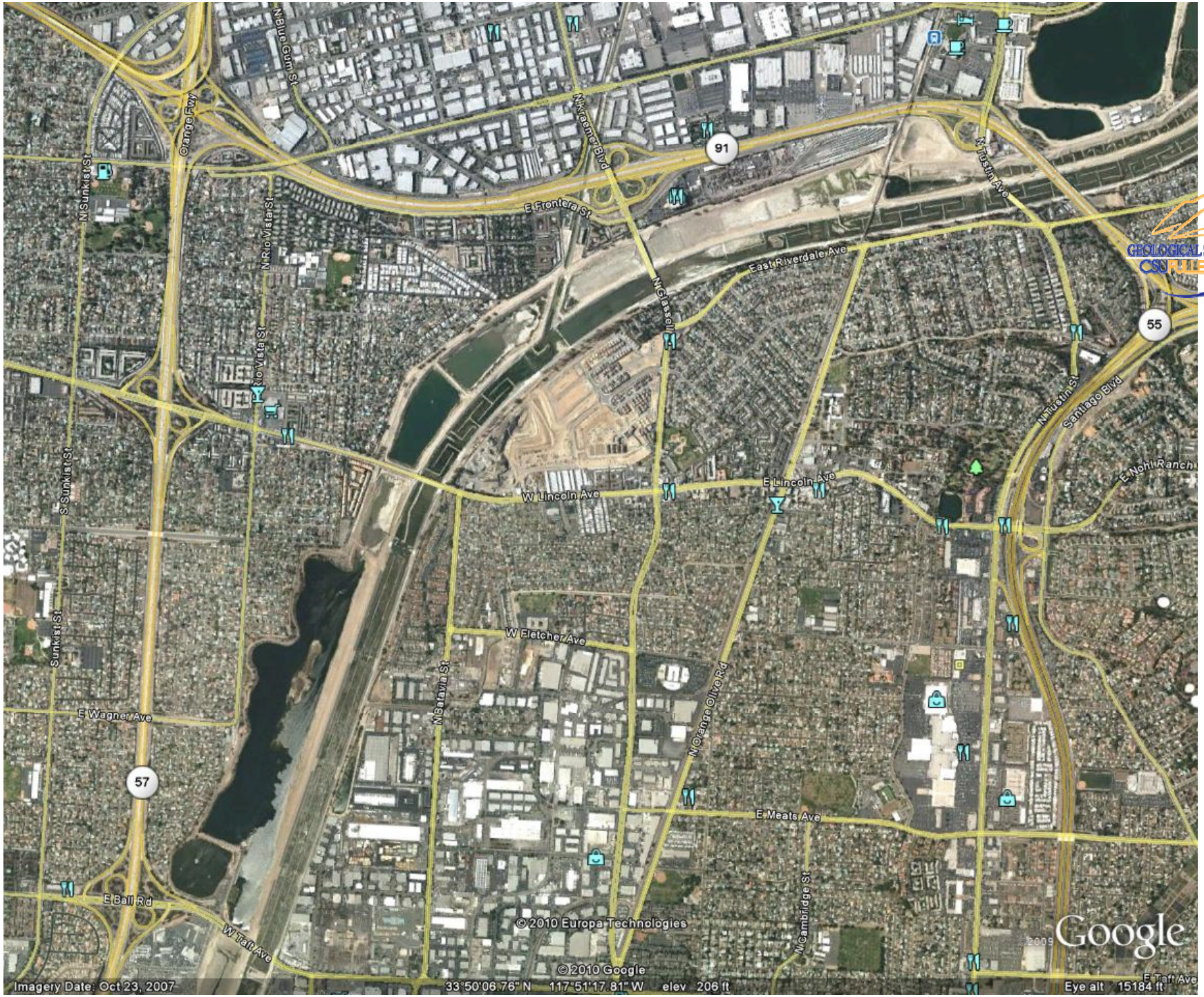
N Blue Gum St
Orange Fwy
N Kraemer Blvd
91
N Tustin Ave
N Sunkist St
E Frontera St
N Rio Vista St
East Riverdale Ave
N Glassell St
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N Tustin St
Santiago Blvd
E Nohl Ranch
W Lincoln Ave
E Lincoln Ave
S Sunkist St
Sunkist St
W Fletcher Ave
N Batavia St
N Orange Olive Rd
E Wagner Ave
57
E Meats Ave
E Ball Rd
W Taft Ave
N Cambridge St
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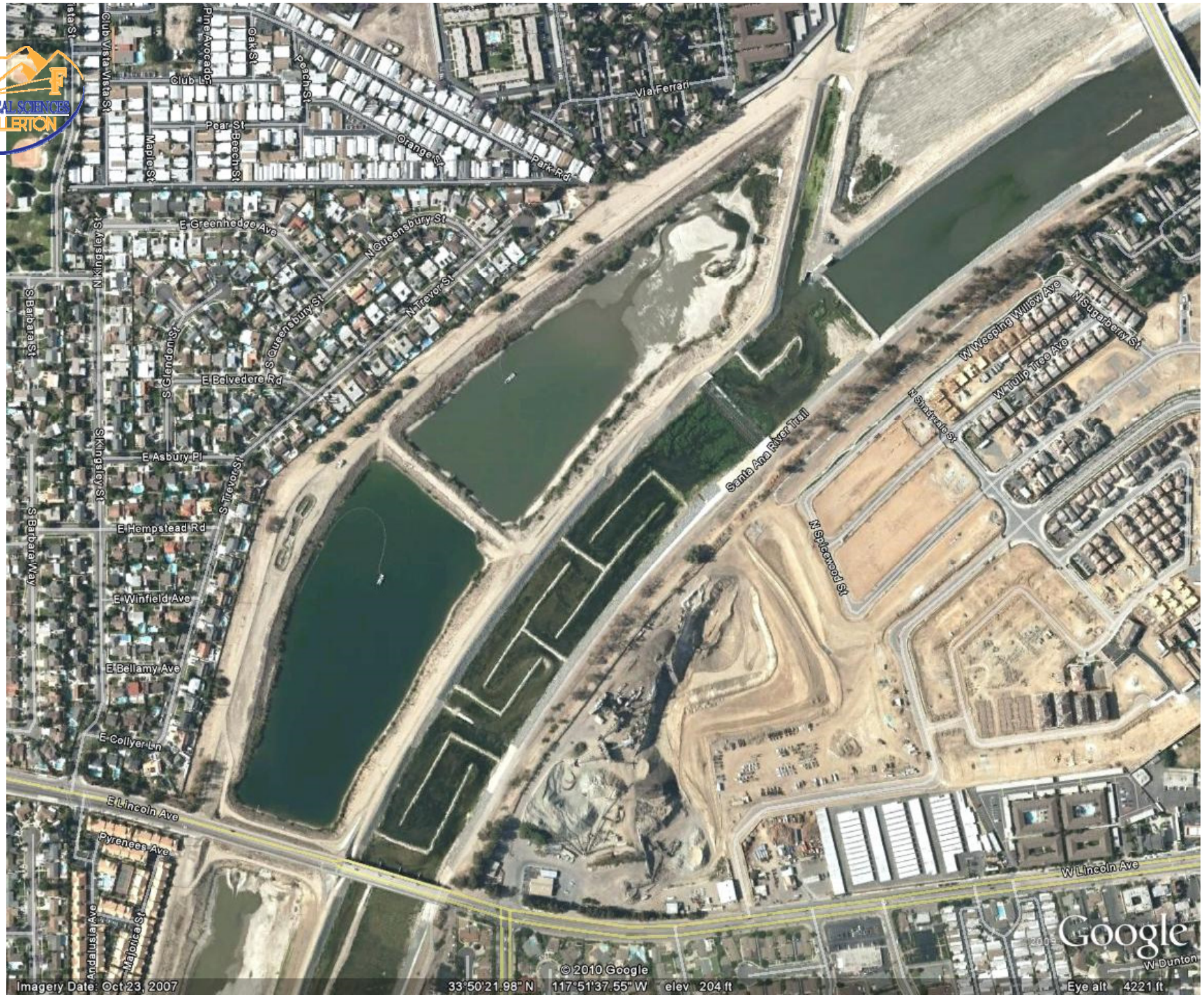
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Club Vista Vista St
Pine Avocado
Oak St
Peach St
Club Dr
Via Ferrari
Pear St
Beech St
Maple St
Orange St
Park Rd
E Greenhedge Ave
N Queensbury St
N Kingsley St
S Barbara St
S Queensbury St
N Trevor St
S Glendon St
E Belvedere Rd
W Weeping Willow Ave
N Sugarberry St
W Tulip Tree Ave
N Sandtrail St
E Asbury Pl
S Kingsley St
S Trevor St
Santa Ana River Trail
E Hempstead Rd
S Barbara Way
N Spicewood St
E Winfield Ave
E Bellamy Ave
E Collyer Ln
E Lincoln Ave
Pyrenees Ave
W Lincoln Ave
Andalusia Ave
Majorca St
W Dunton
Google
Imagery Date: Oct 23, 2007
© 2010 Google
33°50'21.98" N 117°51'37.55" W elev 204 ft
Eye alt 4221 ft


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Santa Ana River Trail
Google
2009
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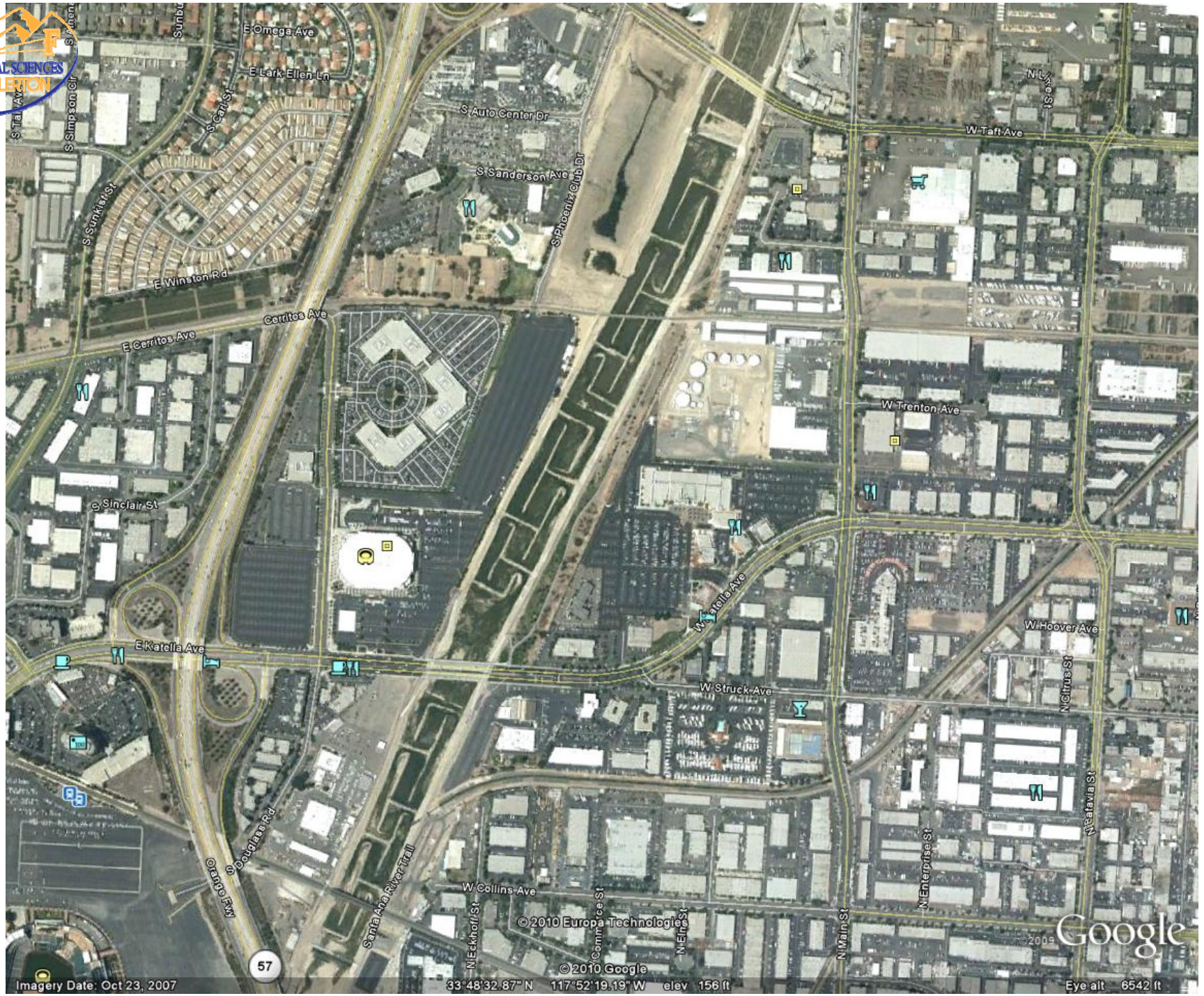
Eye alt 892 ft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E Omega Ave
E Lark Ellen Ln
S Auto Center Dr
S Sanderson Ave
S Phoenix Club Dr
W Taft Ave
N Lake St
S Sunkist St
E Winston Rd
Cerritos Ave
E Cerritos Ave
W Trenton Ave
E Sinclair St
W Katella Ave
E Katella Ave
W Hoover Ave
W Struck Ave
N Citrus St
S Douglass Rd
Orange Fwy
Santa Ana River Trail
W Collins Ave
N Eckhoff St
Commerce St
N Elm St
N Main St
N Enterprise St
N Batavia St
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© 2010 Europa Technologies
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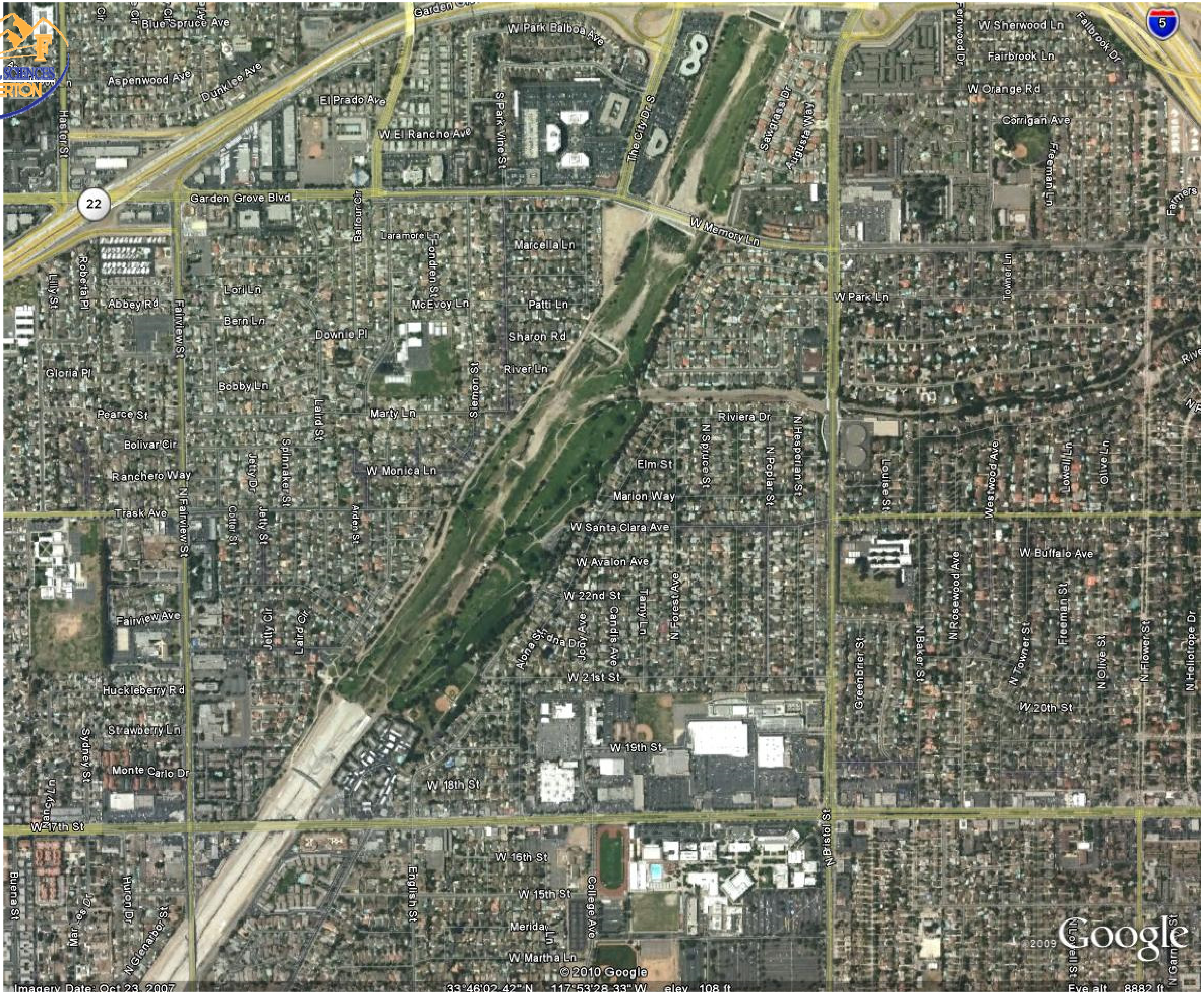
GEOLOGICAL SCIENCES
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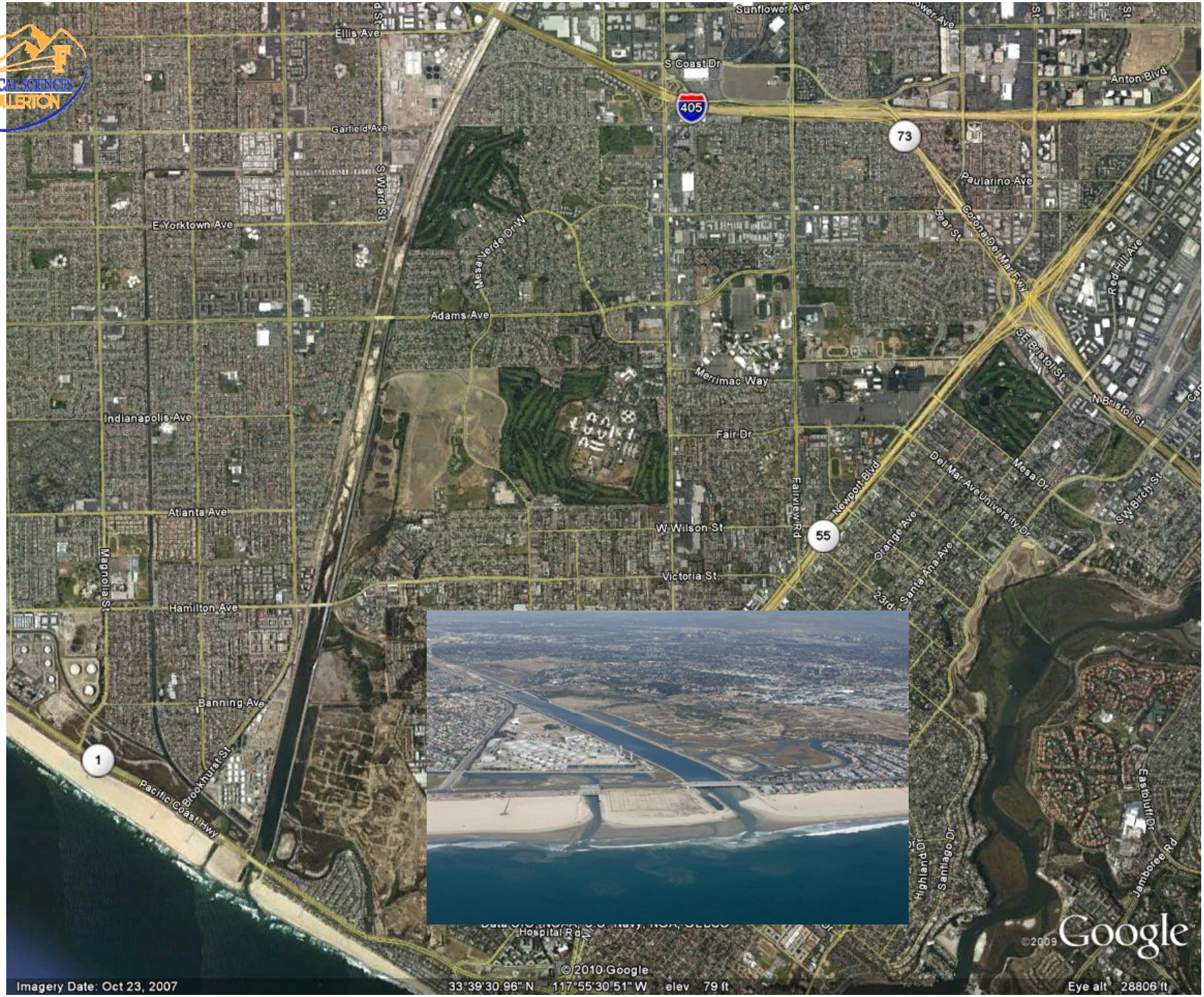
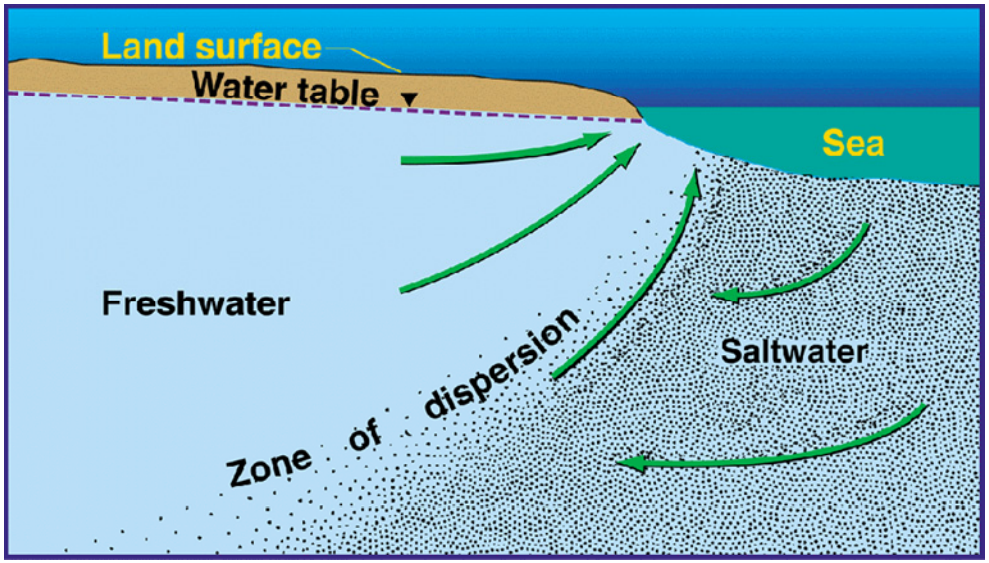
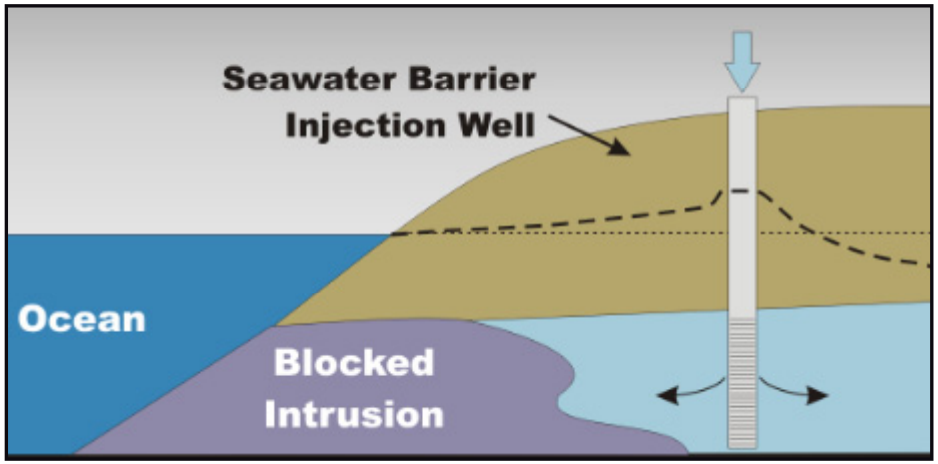
5
22
Blue Spruce Ave
Aspenwood Ave
Dunklee Ave
El Prado Ave
W El Rancho Ave
W Park Balboa Ave
S Park Vine St
The City Dr S
Sawgrass Dr
Augusta Way
W Sherwood Ln
Fairbrook Dr
Fairbrook Ln
W Orange Rd
Corrigan Ave
Freeman Ln
Farmers
Haster St
Garden Grove Blvd
Balfour Cir
Laramore Ln
Fondren St
Marcella Ln
W Memory Ln
Robertа Pl
Lily St
Abbey Rd
Lori Ln
Bern Ln
McEvoy Ln
Patti Ln
Towner Ln
W Park Ln
Fairview St
Downie Pl
Sharon Rd
Gloria Pl
Bobby Ln
River Ln
Siemon St
Pearce St
Laird St
Marty Ln
Riviera Dr
N Spruce St
N Hesperian St
Bolivar Cir
Spinnaker St
Jetty Dr
Ranchero Way
W Monica Ln
Elm St
N Poplar St
Louise St
Westwood Ave
Lowell Ln
Olive Ln
Marion Way
Trask Ave
N Fairview St
Colter St
Jetty St
Arden St
W Santa Clara Ave
W Buffalo Ave
W Avalon Ave
W 22nd St
Tamy Ln
N Forest Ave
N Rosewood Ave
Fairview Ave
Jetty Cir
Laird Cir
Alona St
Edna Dr
Jody Ave
Candis Ave
Greenbrier St
N Baker St
N Towner St
Freeman St
N Olive St
N Flower St
N Heliotrope Dr
W 21st St
Huckleberry Rd
W 20th St
Strawberry Ln
Sydney St
W 19th St
Monte Carlo Dr
W 18th St
W 17th St
N Bristol St
W 16th St
W 15th St
English St
College Ave
Buena St
Huron Dr
N Glenarbor St
Merida Ln
W Martha Ln
N Lowell St
© 2010 Google
Google
Imagery Date: Oct 23, 2007
33°46'02.42" N 117°53'28.33" W elev 108 ft
Eye alt 8882 ft

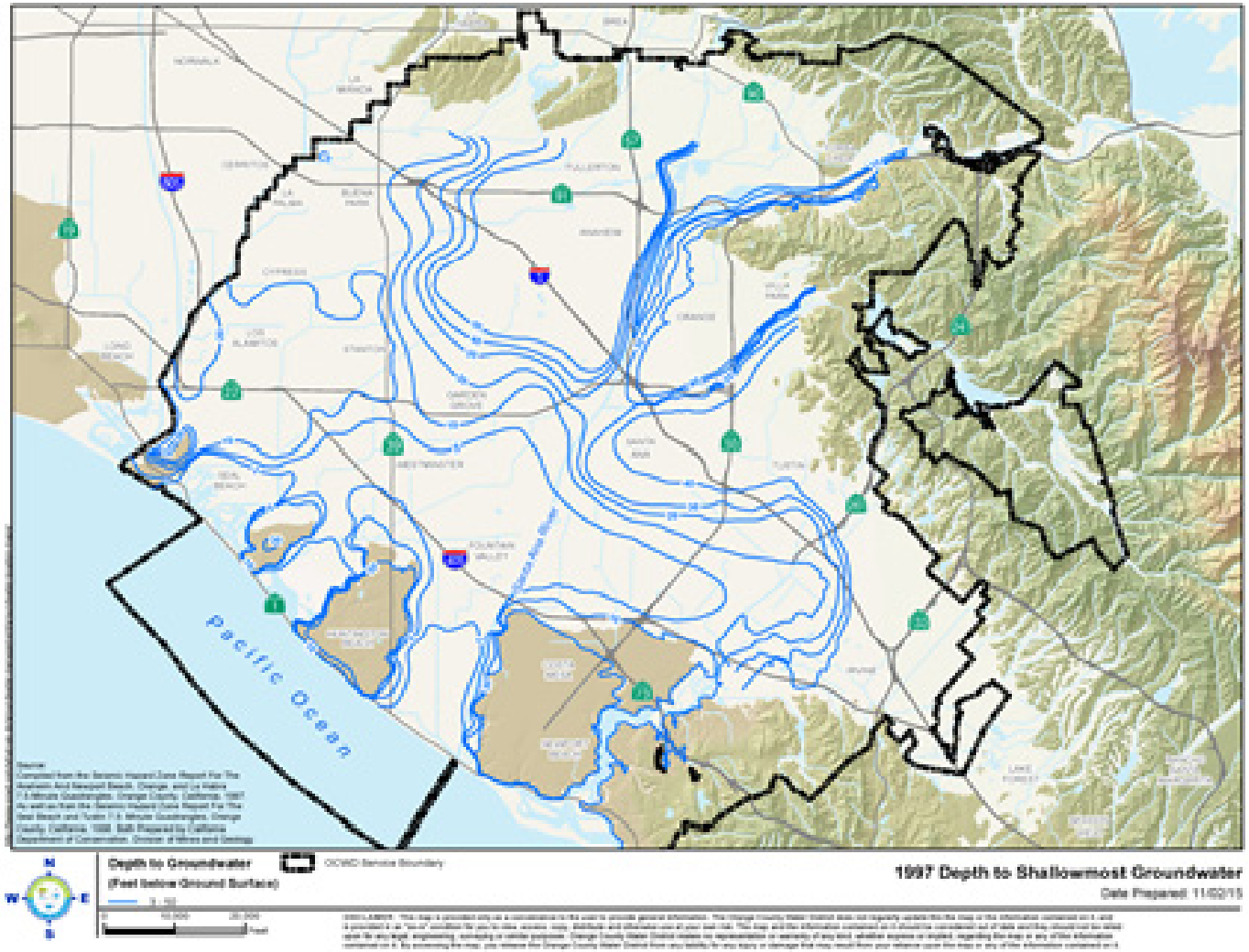

GEOLOGICAL SCIENCES
CSUFULLERTON
Sunflower Ave
Ellis Ave
S Coast Dr
Anton Blvd
405
73
Garfield Ave
S Harbor Blvd
Paularino Ave
E Yorktown Ave
Mesa Verde Dr W
Bear St
Corona Del Mar Fwy
Red Hill Ave
Adams Ave
SE Bristol St
Merrimac Way
N Bristol St
Indianapolis Ave
Fair Dr
Del Mar Ave
University Dr
Mesa Dr
SW Birch St
Newport Blvd
Fairview Rd
Atlanta Ave
W Wilson St
55
Orange Ave
Magnolia St
Victoria St
Hamilton Ave
23rd St
Santa Ana Ave
Banning Ave
1
Brookhurst St
Pacific Coast Hwy
Eastcliff Dr
Highland Dr
Santiago Dr
Jamboree Rd
Hospital Rd
©2009 Google
©2010 Google
Imagery Date: Oct 23, 2007
33°39'30.96" N 117°55'30.51" W elev 79 ft
Eye alt 28806 ft

Sea Water Barrier





Sea Water Barrier



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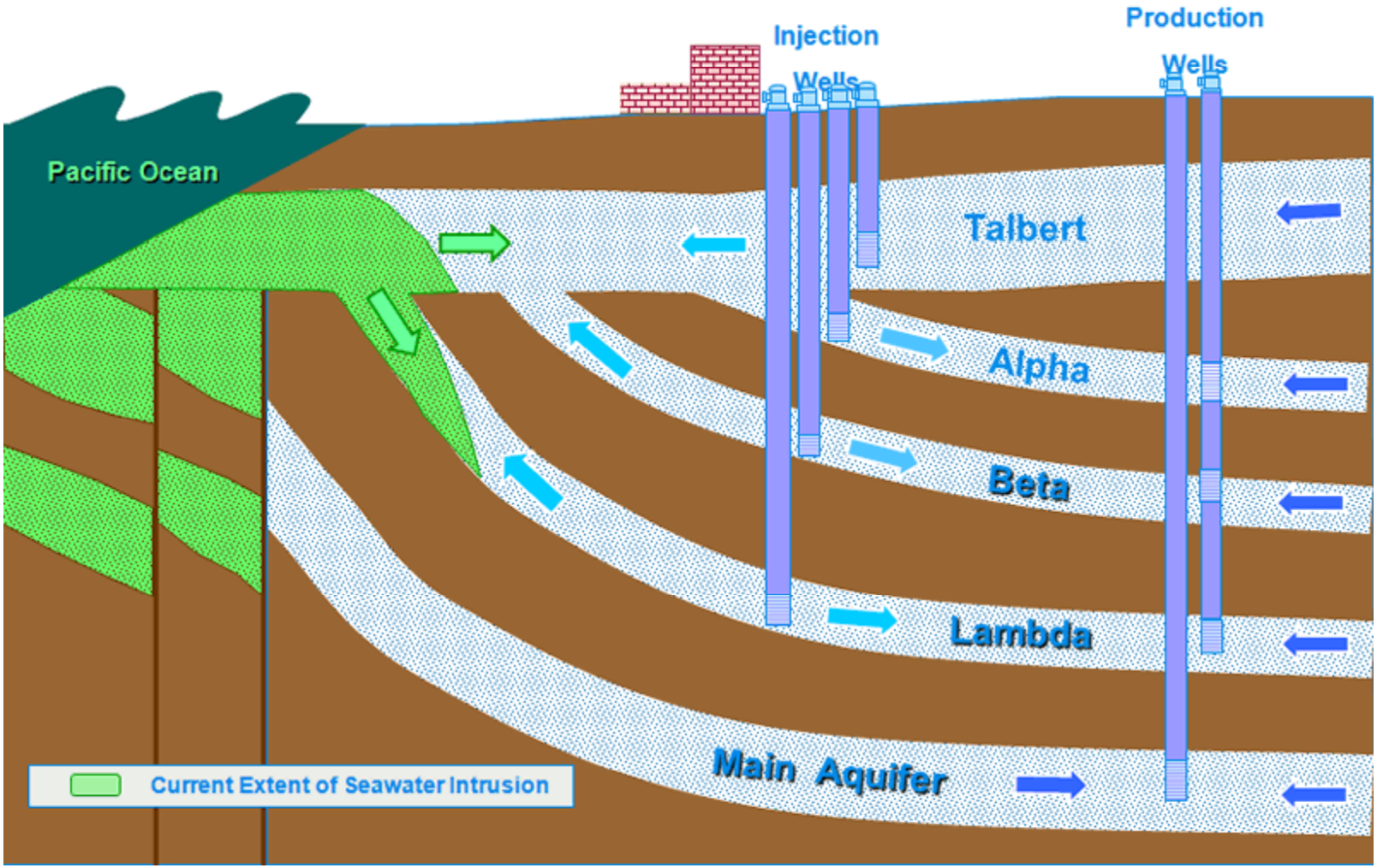
Talbert Seawater Intrusion Barrier



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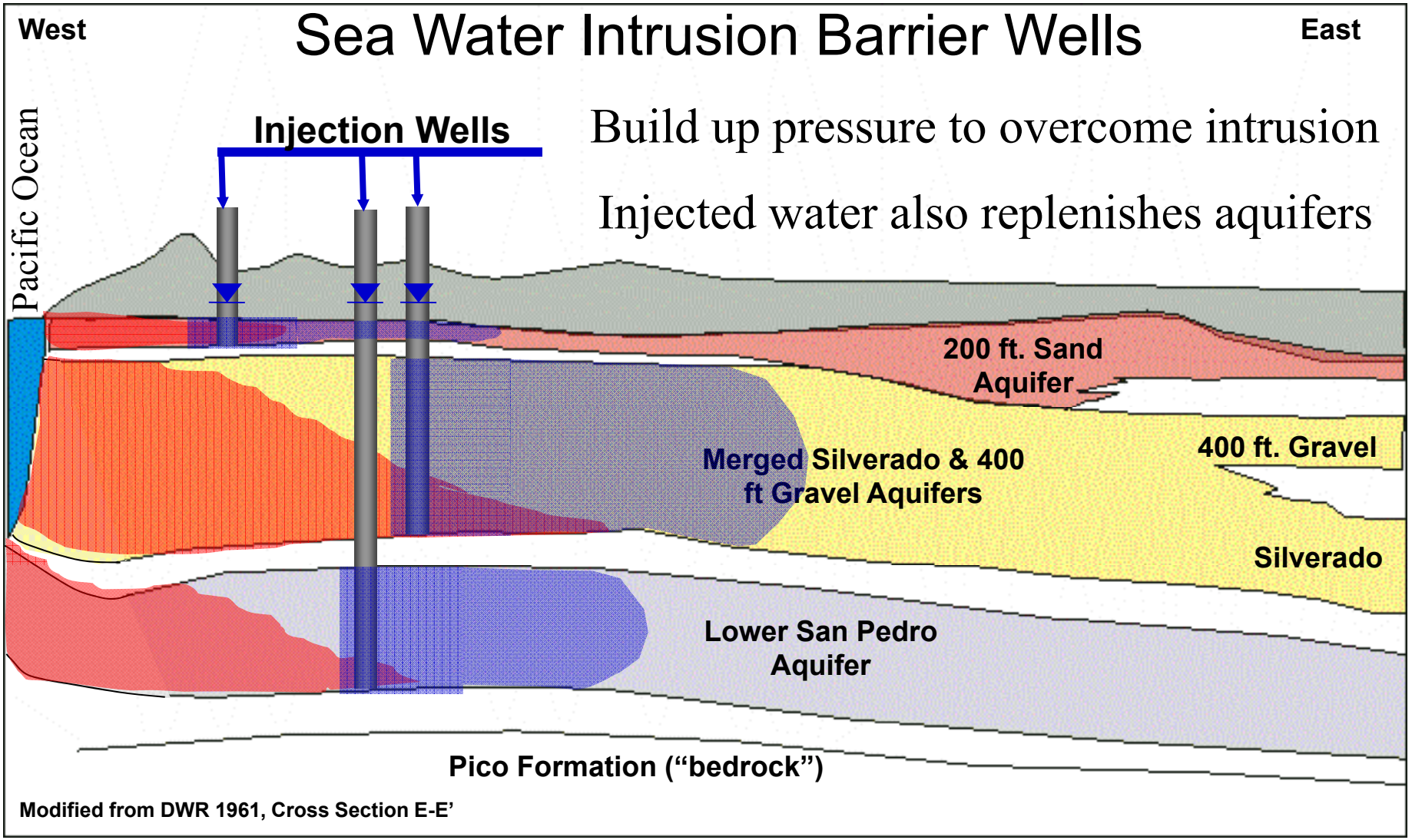
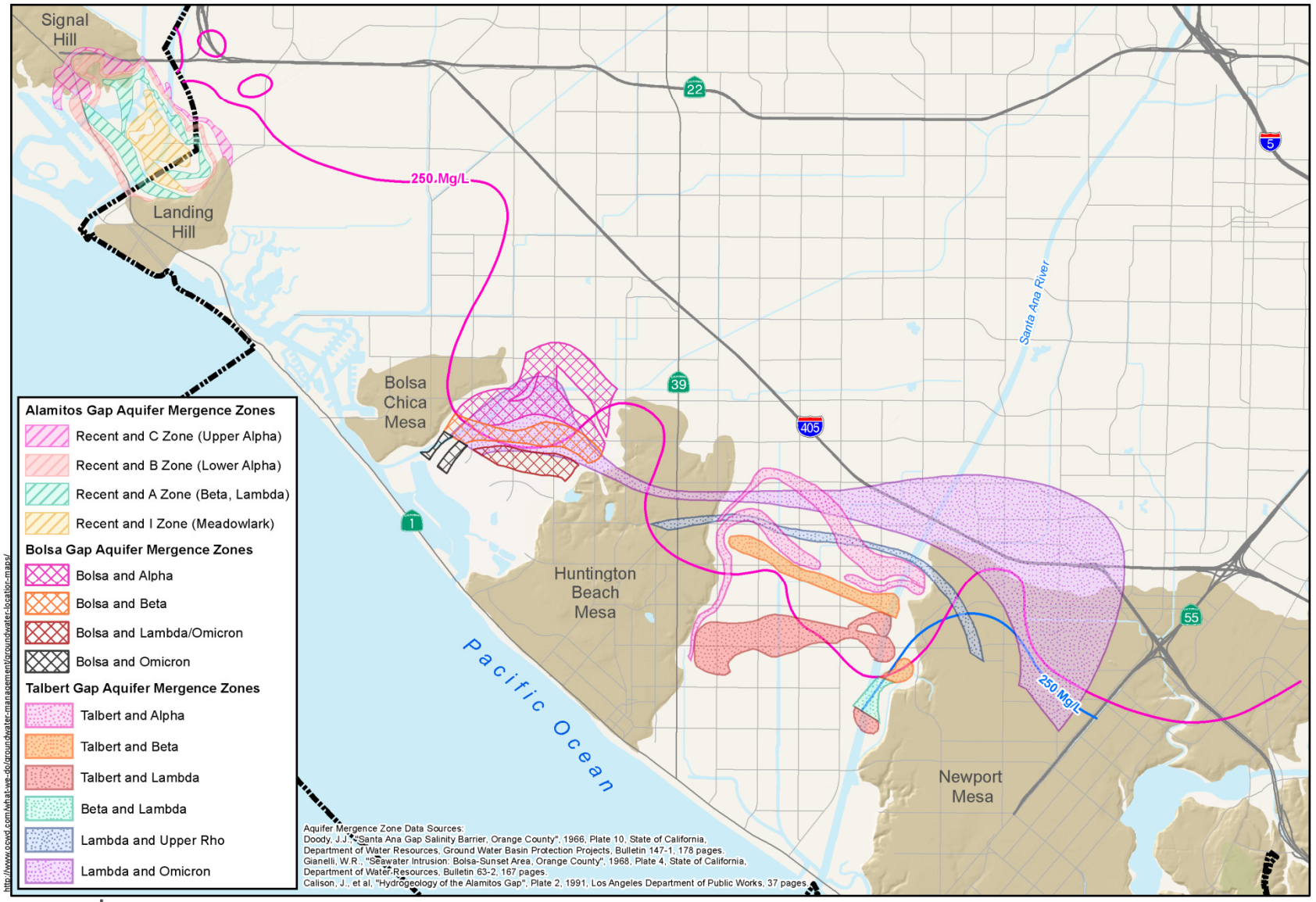
~30,000 MGD into Barriers





N
W
E
S

Coastal Area Chloride Concentrations (Fall 2014)

Main Aquifer Chloride Concentration (Fall 2014)

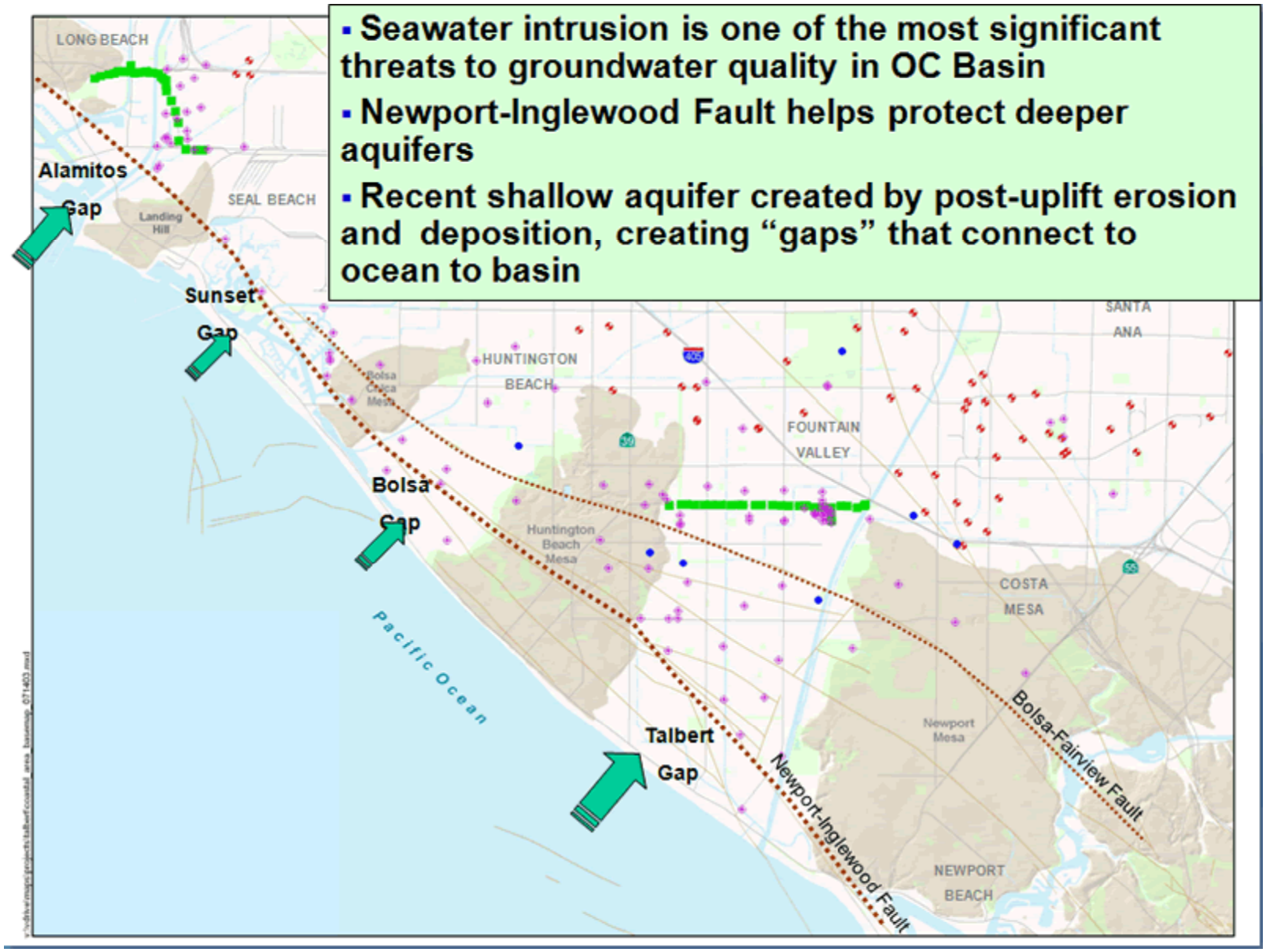
OCWD Service Boundary

0 4,000 8,000 Feet

Coastal Aquifer Mergence Zones and Chloride Concentration

Date Prepared: 11/02/15

GEOLOGICAL SCIENCES CSUFULLERTON



- Seawater intrusion is one of the most significant threats to groundwater quality in OC Basin
- Newport-Inglewood Fault helps protect deeper aquifers
- Recent shallow aquifer created by post-uplift erosion and deposition, creating "gaps" that connect to ocean to basin

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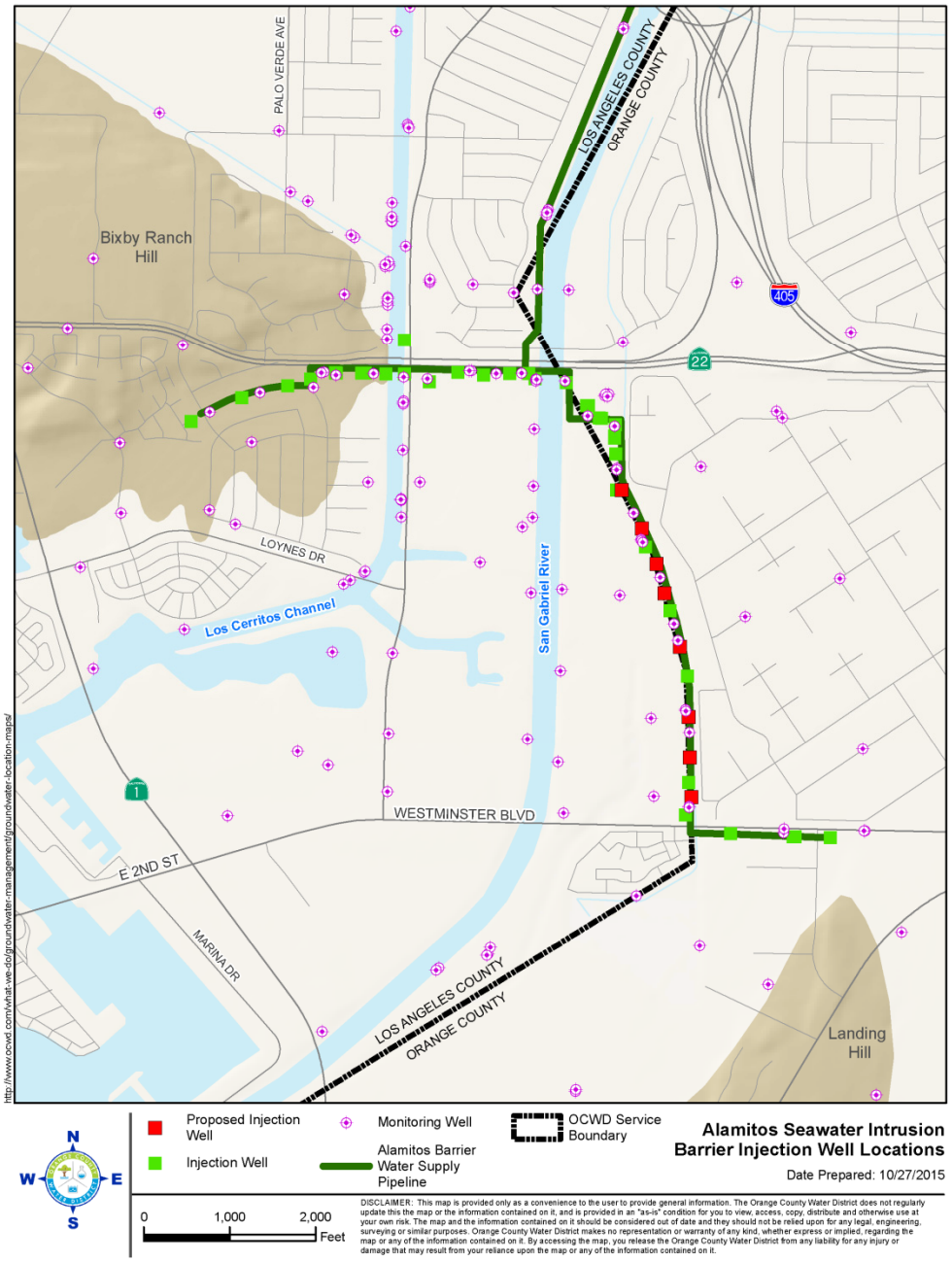
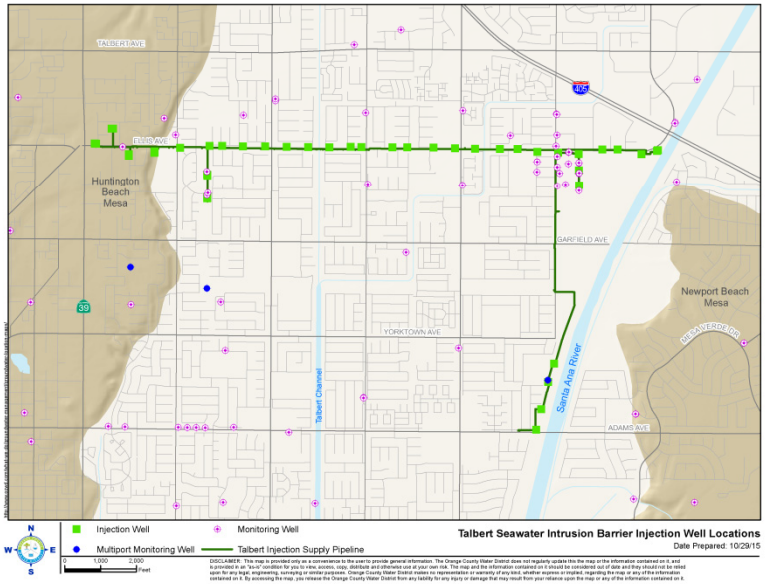
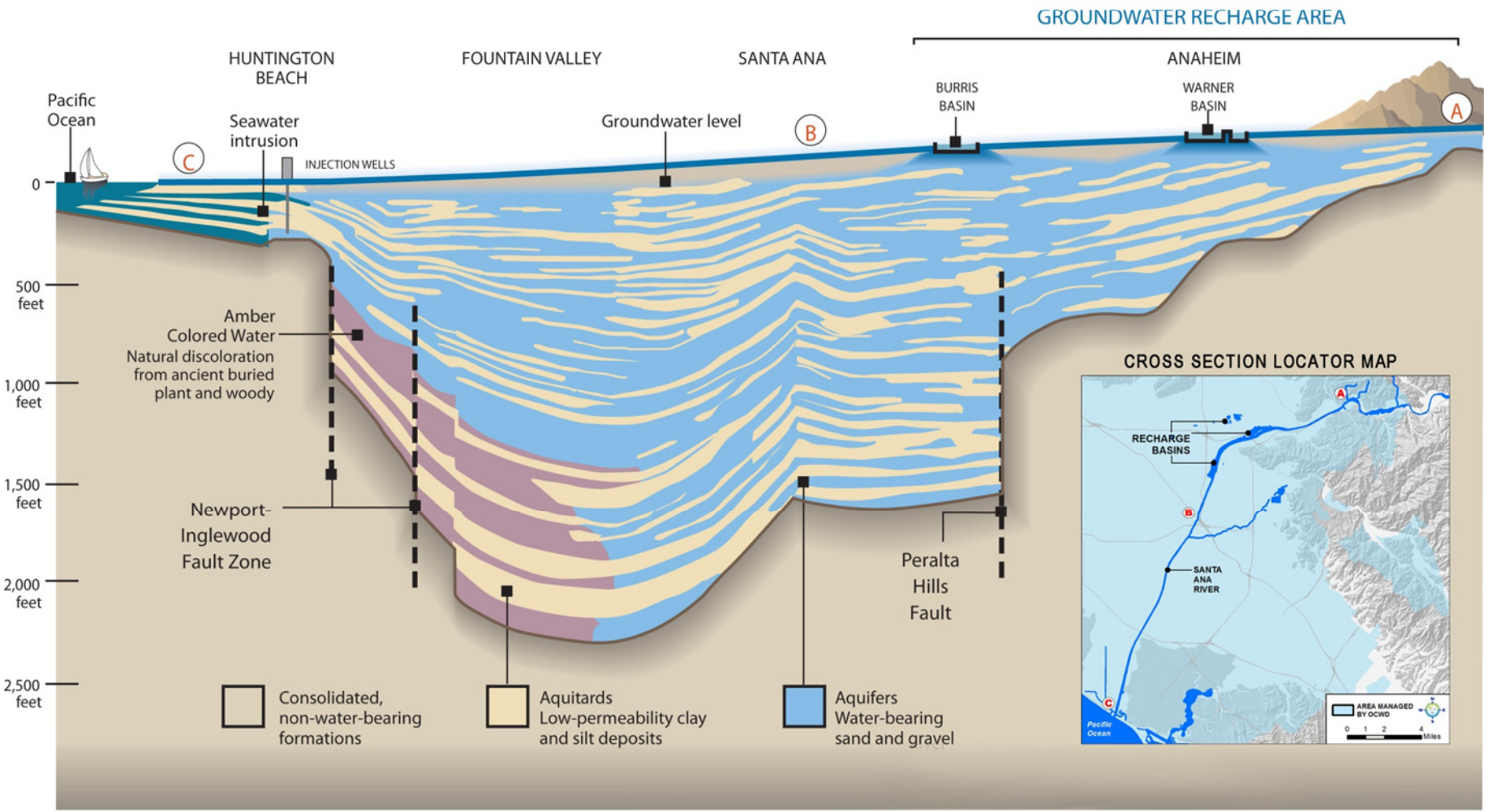
Alamitos Barrier



Talbert Barrier



Barrier Wells + Recharge Basins

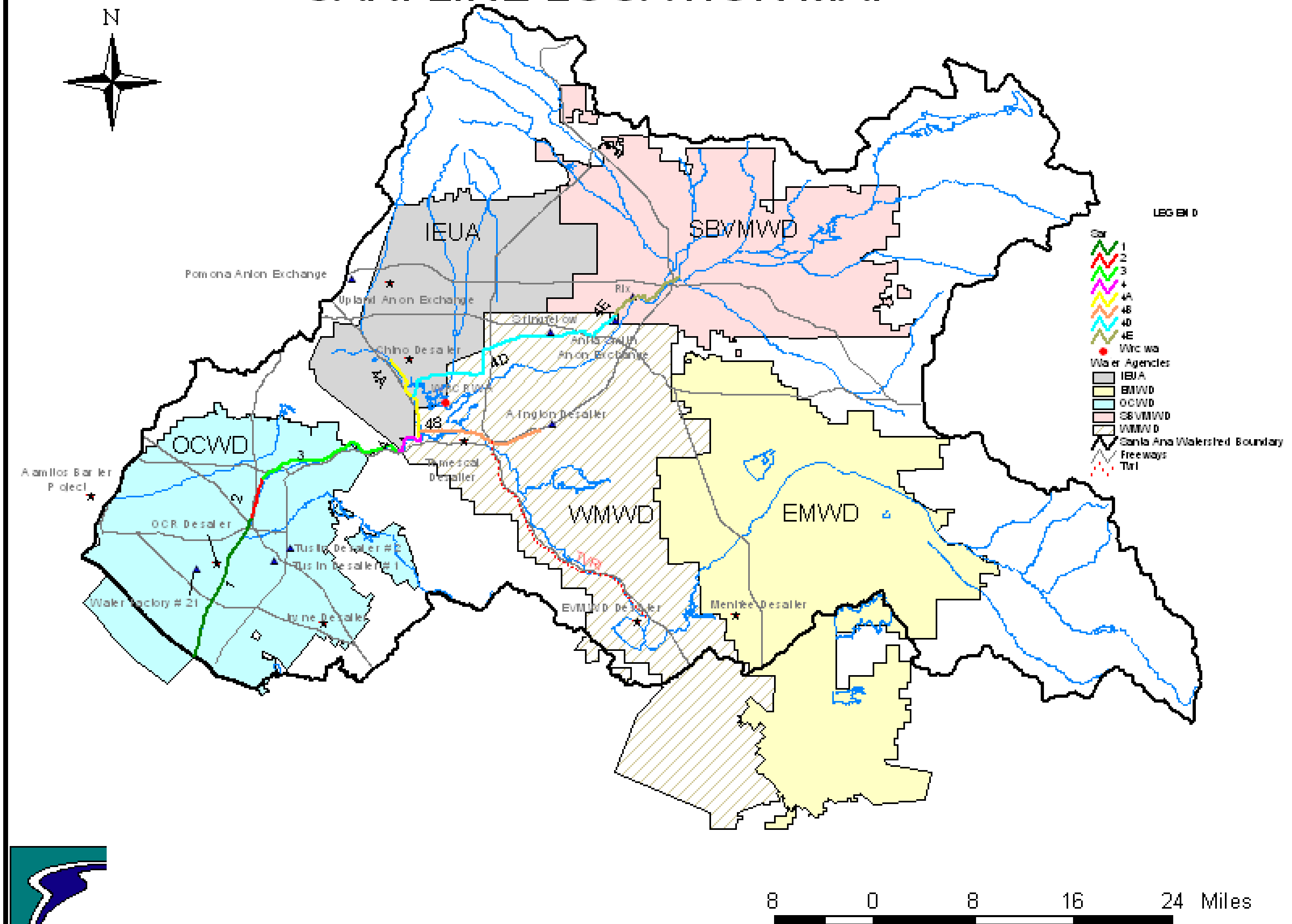


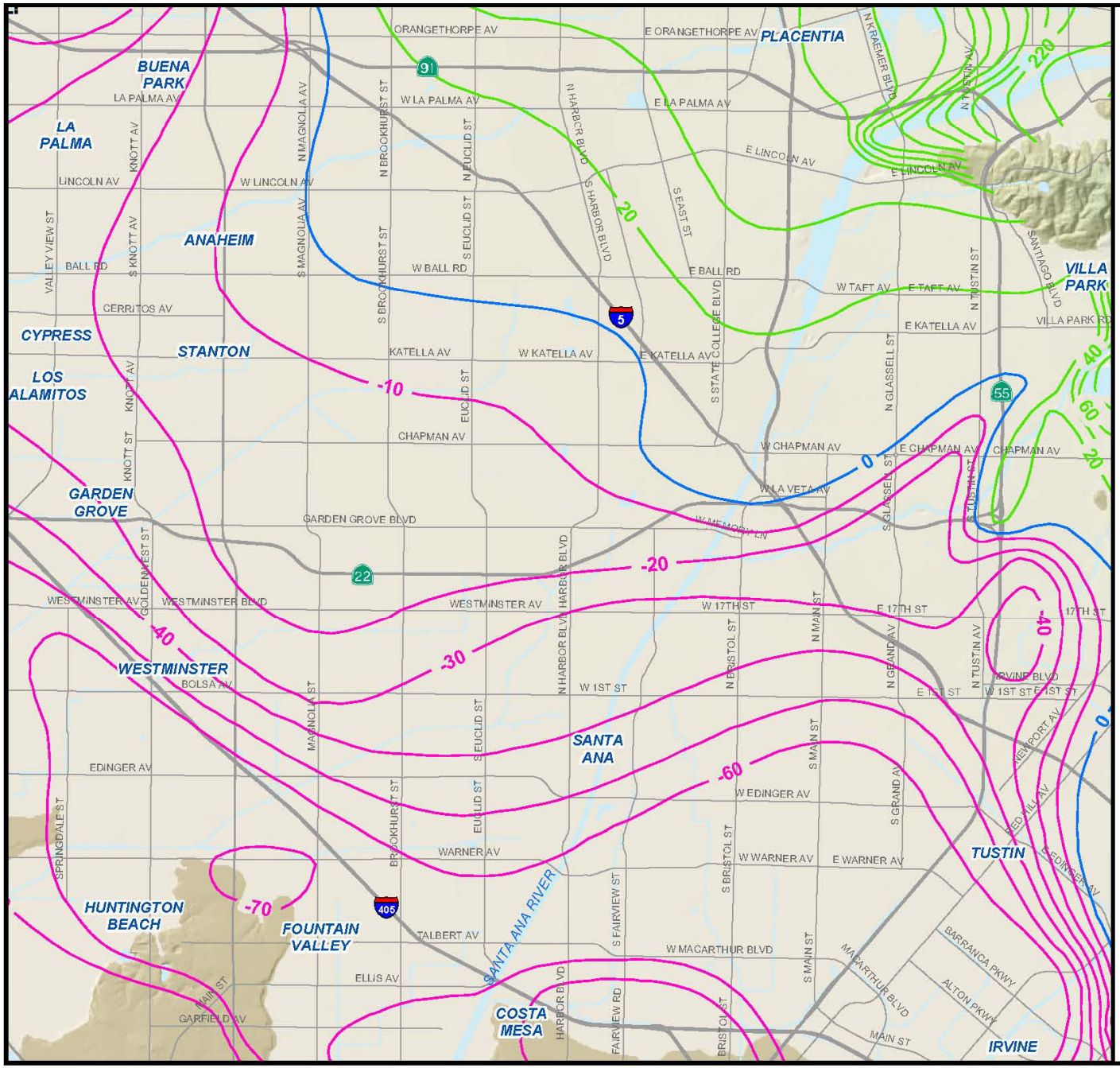
Questions


E Chapman Ave
Jamboree Rd
Canyon View Ave
241
Eastern Transportation Corridor
E Santiago Canyon Rd
Image County of San Bernardino
Image © 2010 DigitalGlobe
© 2010 Google
Imagery Dates: Dec 31, 2005 - Feb 1, 2009
33°47'27.75" N 117°44'12.85" W elev 796 ft
Eye alt 23013 ft
Google


Santiago Blvd
E Shoshone Ave
Sherwood Cir
Huntington Cir
Athens Ave
Prado Woods Dr
Sharon Ln
Old Lam
Via Corta
Lemon St
Sterling Ave
Camden Cir
Sycamore Cir
Briley Way
Ludwig St
Knuth Cir
Workman Cir
Old Ranch Cir
Sycamore St
Abbott Ln
Jerome St
Durfee Cir
Hallsworth Cir
Evergreen Cir
Cannon St
Villa Park Rd
E Santiago Canyon Rd
E Valencia Dr
E San Juan
Beardsley Cir
Fredrick Dr
Potter Cir
Miller Cir
Center Dr
Wulff Dr
Lincoln St
E Lincoln Cir
Hastings Dr
N Christine St
N Richard St
N Linda Vista St
E Elsinore Ave
N Cannon St
N Avila Pl
Adams Ranch Rd
Adams Cir
E Jackson Ave
Montana Cir
E Monroe Ave
N Granada Dr
N Encanto St
Cerritos Dr
E Locust Ave
Locust Ave
Vida Dr
E Jacaranda Ave
Fernando Cir
E Juniper Ave
Collins Ave
Wonderview Dr
E Muir Dr
Glen Albyn Ln
N Sonora Cir
N Antonio Cir
N Cheyenne St
E Stetson Ln
N Big Sky Ln
N Hewes St
E Swallow Ave
E Equestrian Ln
N Morgan St
N Mallard St
Homestead Cir
N Prospect St
E Balmoral Dr
N Pageant Dr
N Red Robin St
N Rancho Santiago Blvd
E Blue Jay Ave
N Swan
E Lomita Ave
E Bond Ave
E Charter Oak Dr
N Oxford Ct
N James St
N La Nae Cir
N Rick St
E El Salvador Ave
© 2010 Europa Technologies
© 2010 Google
©2009 Google
Imagery Date: Oct 23, 2007
33°48'23.18" N 117°48'24.36" W elev 333 ft
Eye alt 7397 ft

SARI LINE LOCATION MAP




ORANGETHORPE AV
E ORANGETHORPE AV
PLACENTIA
BUENA PARK
LA PALMA AV
W LA PALMA AV
E LA PALMA AV
LA PALMA
LINCOLN AV
W LINCOLN AV
E LINCOLN AV
ANAHEIM
BALL RD
W BALL RD
E BALL RD
VILLA PARK
CERRITOS AV
W TAFT AV
E TAFT AV
CYPRESS
STANTON
KATELLA AV
W KATELLA AV
E KATELLA AV
LOS ALAMITOS
CHAPMAN AV
W CHAPMAN AV
E CHAPMAN AV
GARDEN GROVE
GARDEN GROVE BLVD
W LA VETA AV
WESTMINSTER AV
WESTMINSTER BLVD
W 17TH ST
E 17TH ST
WESTMINSTER
BOLSA AV
W 1ST ST
E 1ST ST
IRVINE BLVD
SANTA ANA
EDINGER AV
W EDINGER AV
WARNER AV
W WARNER AV
E WARNER AV
TUSTIN
HUNTINGTON BEACH
FOUNTAIN VALLEY
TALBERT AV
W MACARTHUR BLVD
SANTA ANA RIVER
ELLIS AV
COSTA MESA
MAIN ST
IRVINE
-10
-20
-30
-40
-60
-70
0
20
40
60
220
November 2004
Groundwater Elevation Contours in the Principal Aquifer Zones
Central Quadrant of OCWD
November 2004 Water Levels
Groundwater Elevations (Feet, MSL)
-80 - -10
0
10 - 300
Orange County Water District
Freeways/Highways
Water Features
N
W
E
S
1
0
1
Miles
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Water Use

- Irrigation
  - Percent of open space
  - Over irrigation
    - 200-300%
- Wastewater
  - 490 gpd per household
- Serra Retreat
  - Large irrigated areas


11 15'00