USGS
science for a changing world

Salinas Valley Watershed Model (SVWM) & Integrated Hydrologic Model (SVIHM)

Randall Hanson, Joe Hevesi, Scott Boyce, Wes Henson, Lorrie Flint, Alan Flint, Jon Traum
USGS California Water Science Center

Andre Ritchie, Amy Galanter, USGS New Mexico Water Science Center

Don Sweetkind & Emily Taylor USGS Geologic Division, Denver CO

USGS

One-Water Session
CWEMF Annual Meeting, Folsom, CA
Monday, March 20, 2017

MONTEREY COUNTY CALIFORNIA · 1850 ·

Salinas Valley Conjunctive-Use Water Management Issues

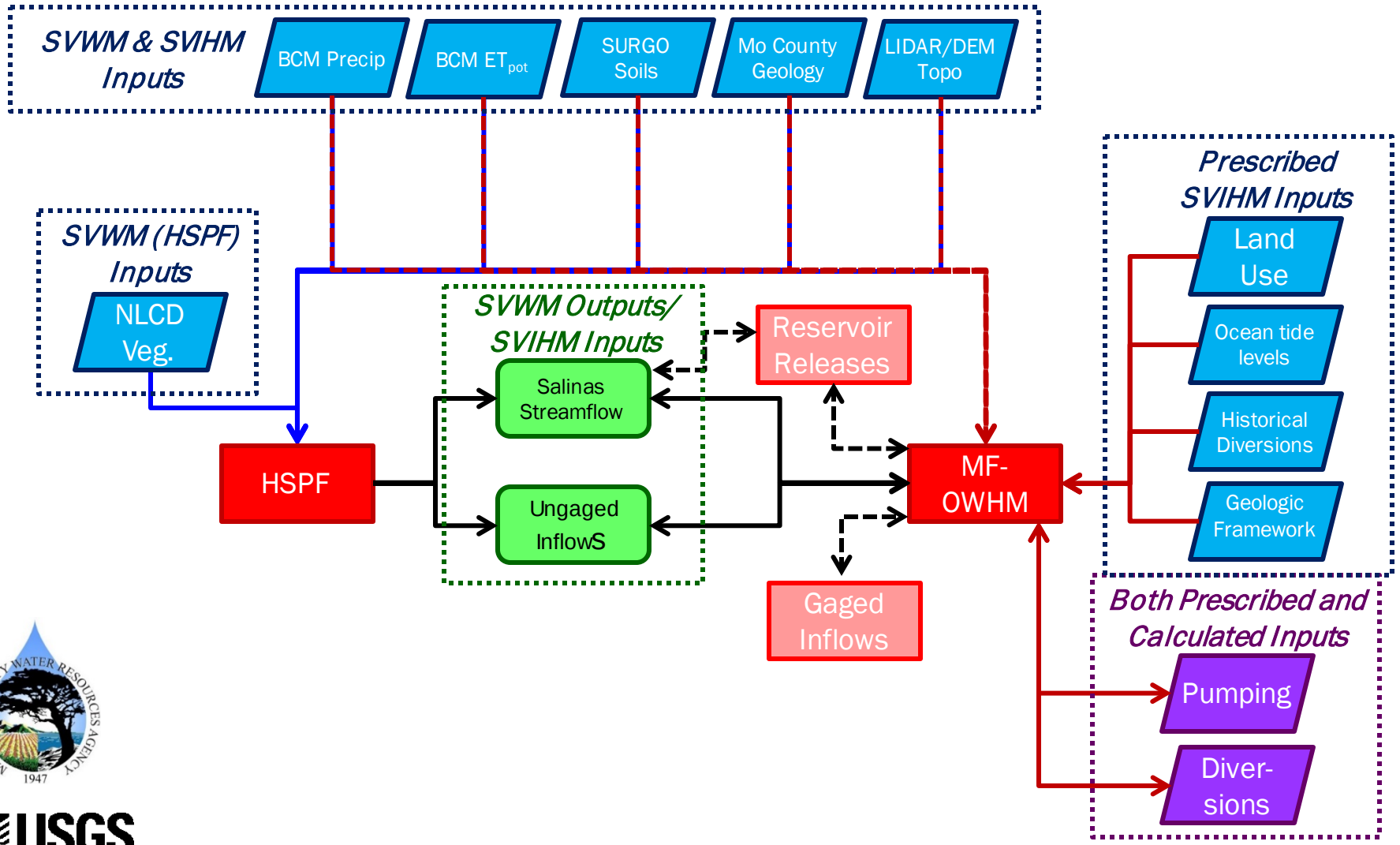
Agricultural/Urban Development ➔ more water-intensive crops, Urban growth, climate variability/change ➔ larger demands on sustainability of water resources from competing interests for flood-control, environmental, municipal, and agricultural needs

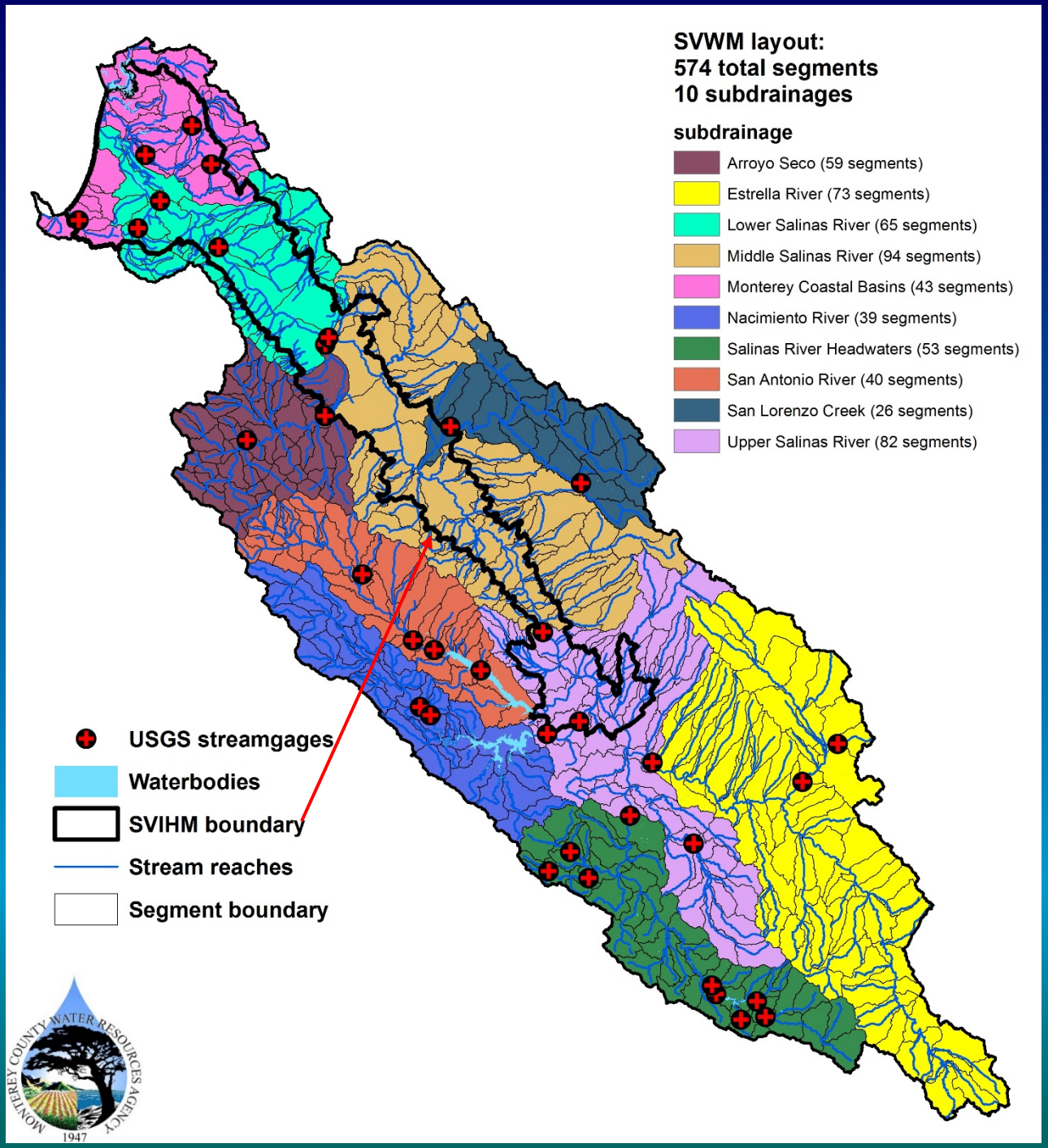
Increased Demand ➔ Increased crop rotation of high-value crops, salinity irrigation flushing demands, & environmental flows

Secondary Effects ➔
Reduced surface-water deliveries, streamflow depletion, seawater intrusion, saline-irrigation practices, and potential habitat degradation

Mitigation/Adaptation ➔
Reuse recycled water & dual-reservoir operation for flood control, water use, and enhanced dry-season releases Including the Inter-Lake Tunnel Project

Linkage Between Precip-Runoff (SVWM) and IHM (SVIHM) Models





SVWM model layout and segmentation

574 segments
Total area = 4,517 mi^2
Average area = 7.9 mi^2
Maximum area = 39.6 mi^2
Minimum area = 0.4 mi^2

574 pervious land units (PERLNDS)

50 impervious land units (IMPLNDS)

574 stream reaches (RCHRES)

10 sub-models (sub-drainages)

10 surface water outflows

MONTEREY COUNTY WATER RESOURCES AGENCY 1947

USGS science for a changing world

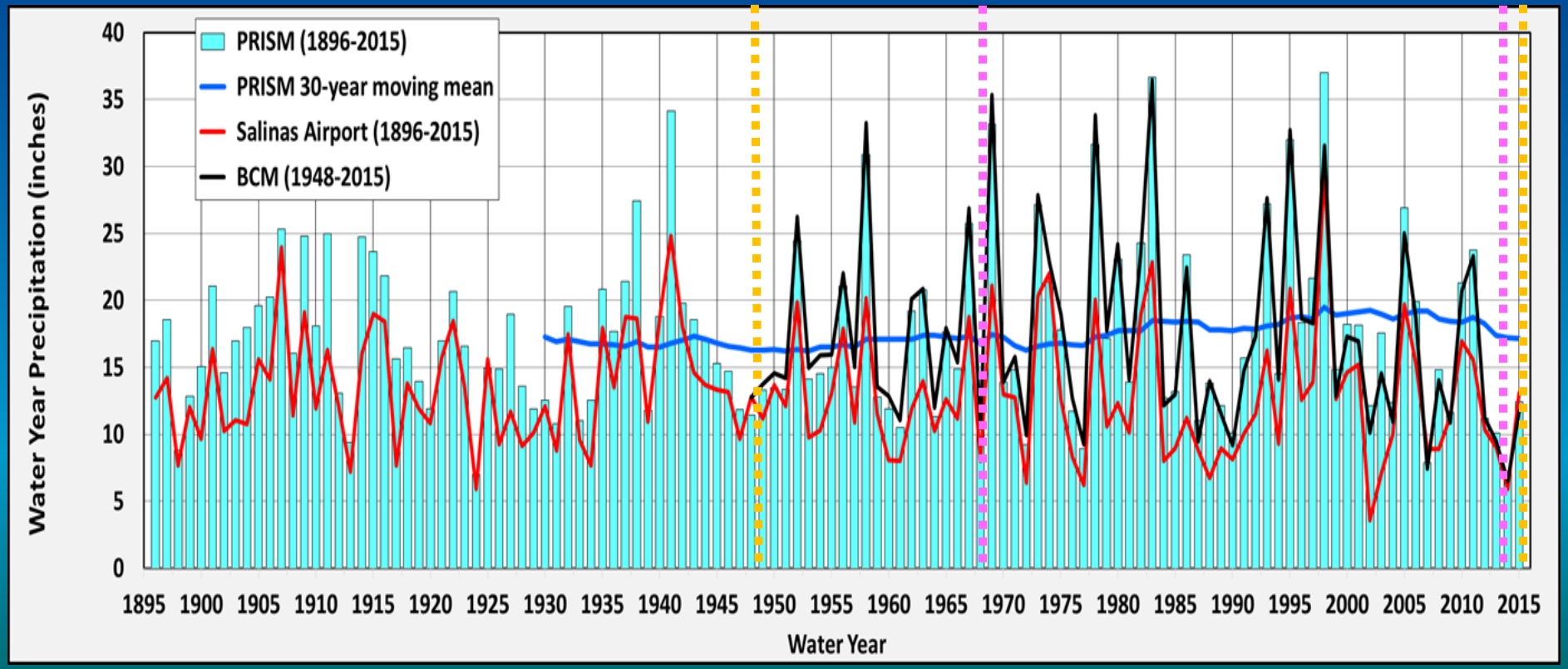
BCM - SVWM - SVIHM model integration: time steps and simulation periods

BCM daily simulation,
water years 1948 through 2015

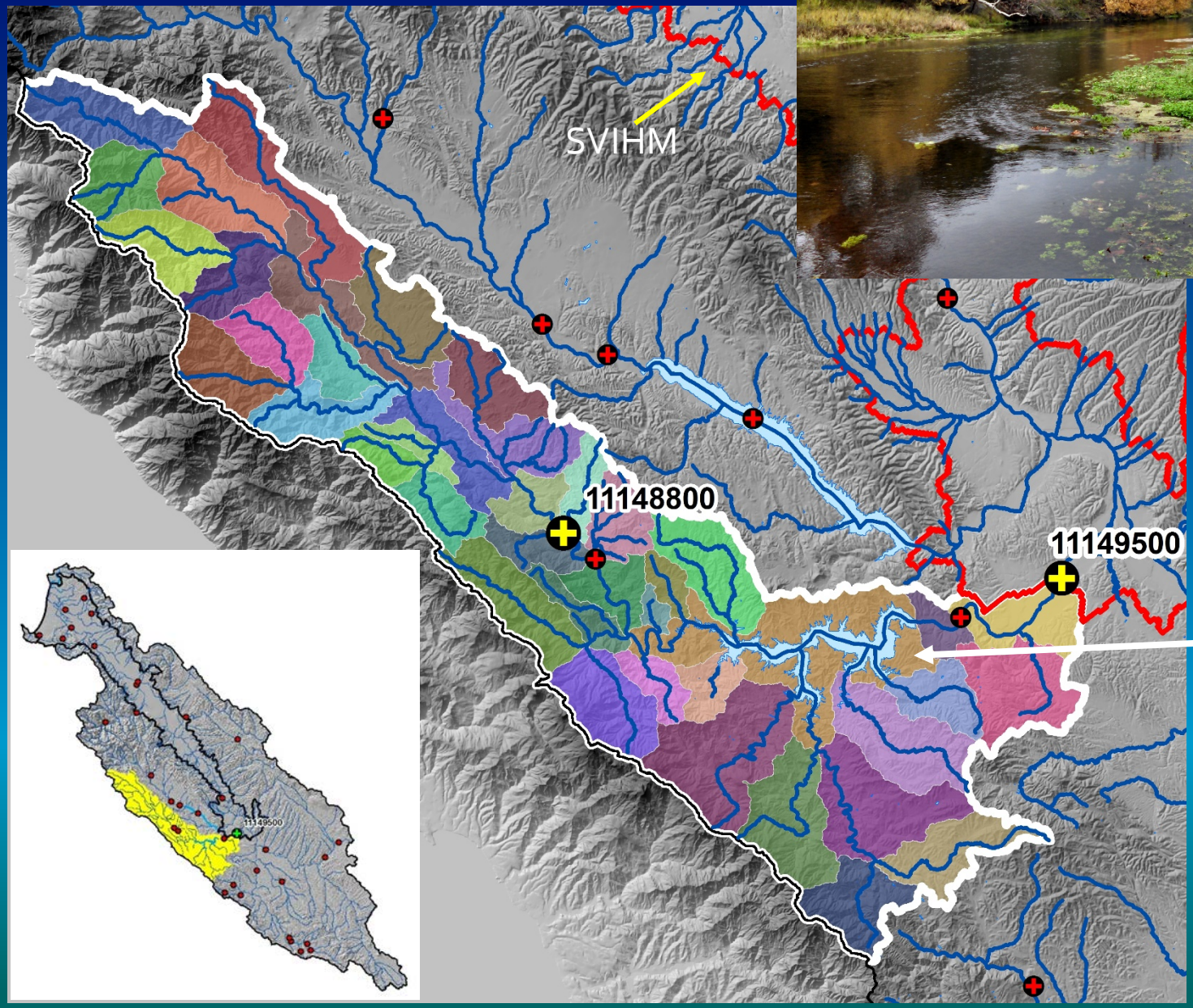
SVWM hourly simulation,
water years 1948 through 2015
(water year 1948 used only for model spin up)

BCM and SVWM simulation period: 10/1/1947 – 9/30/2015 (daily & hourly time step)

SVIHM simulation period: 10/1/1967 – 12/31/2014 (monthly stress period, biweekly time step)



Nacimiento Watershed calibration



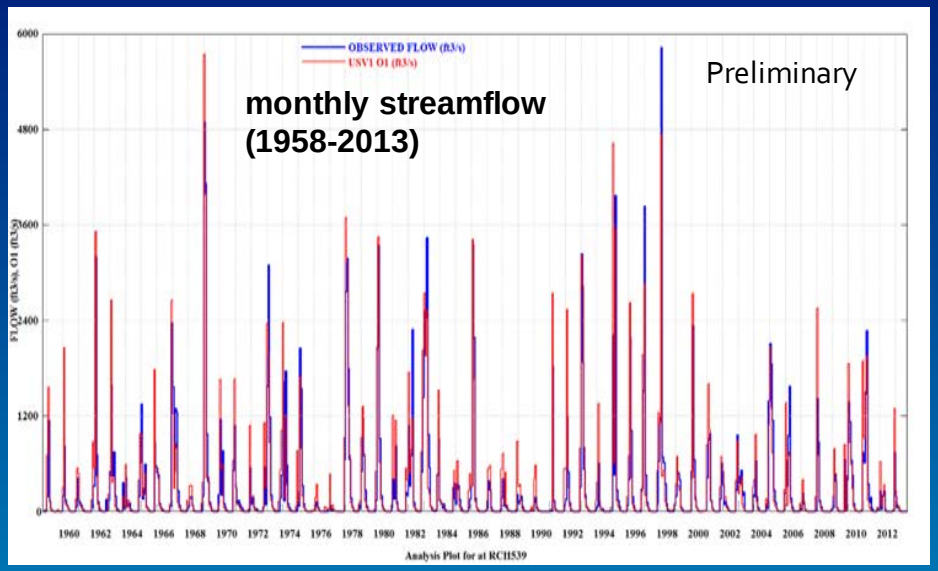
4 USGS streamgages (daily streamflow records)

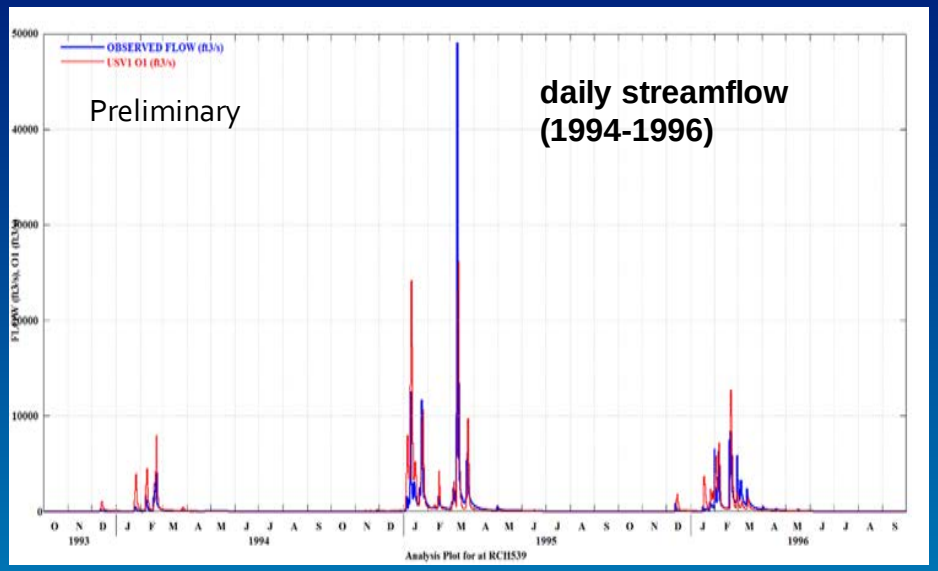
MCWRA records for Nacimiento Reservoir (estimated daily inflows)

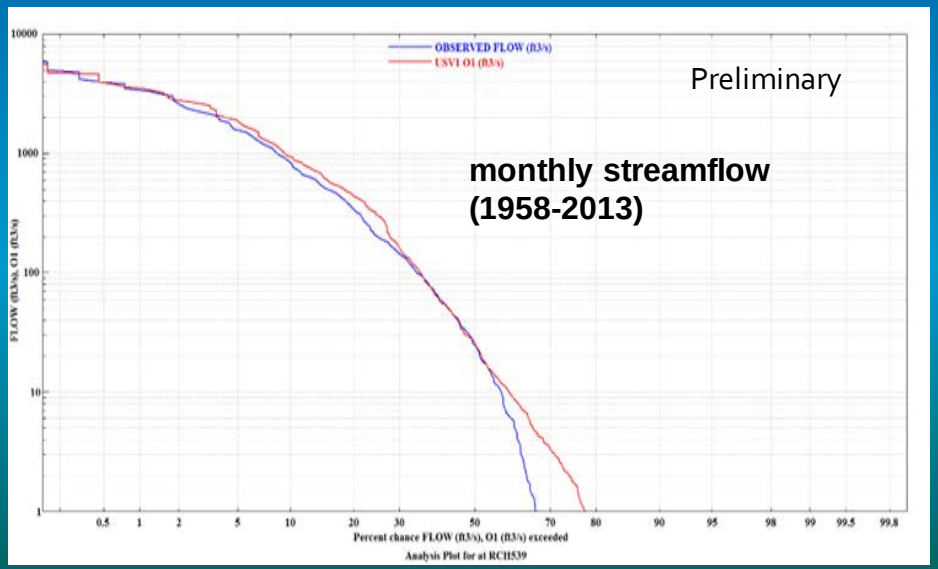
MONTEREY COUNTY WATER RESOURCES AGENCY 1947

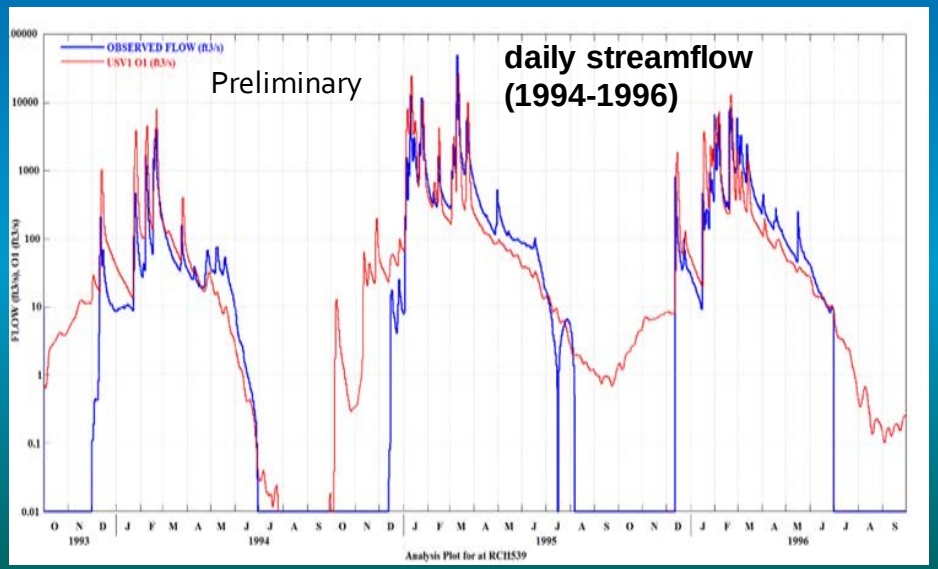
USGS science for a changing world

MCWRA estimated daily inflows to Nacimiento Reservoir (RCHRES 539)➔ Used for historical & projections



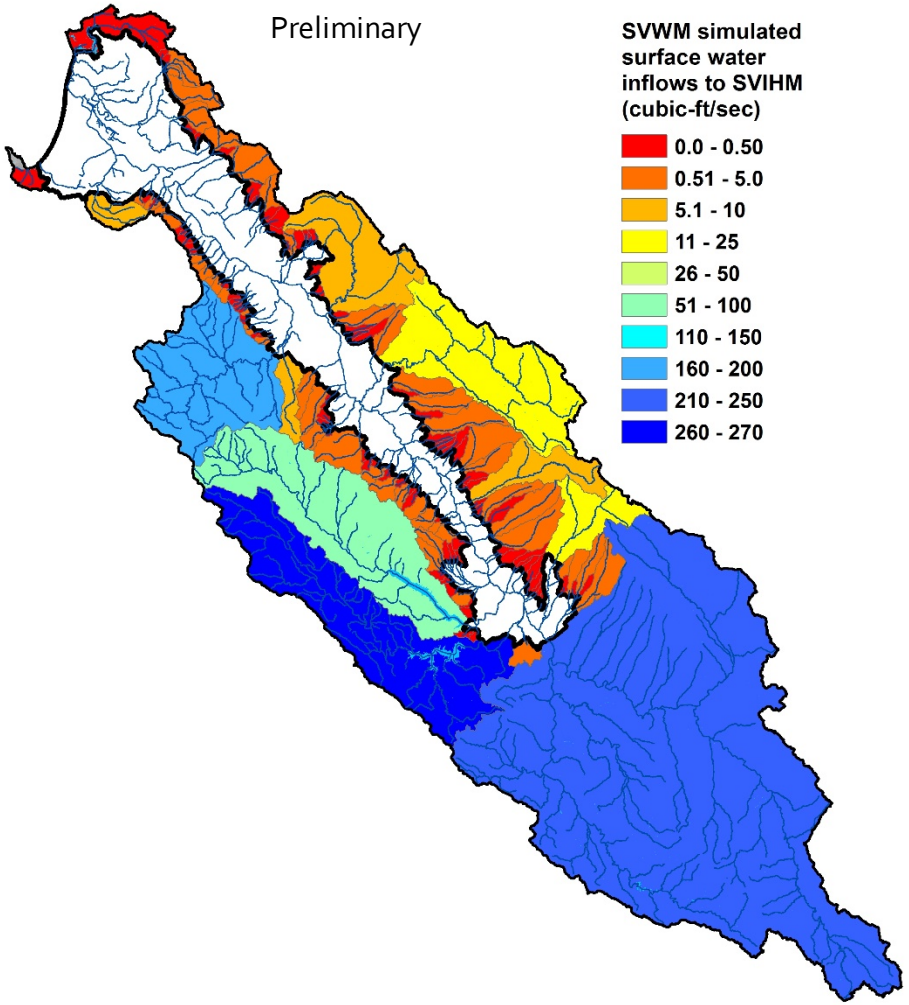




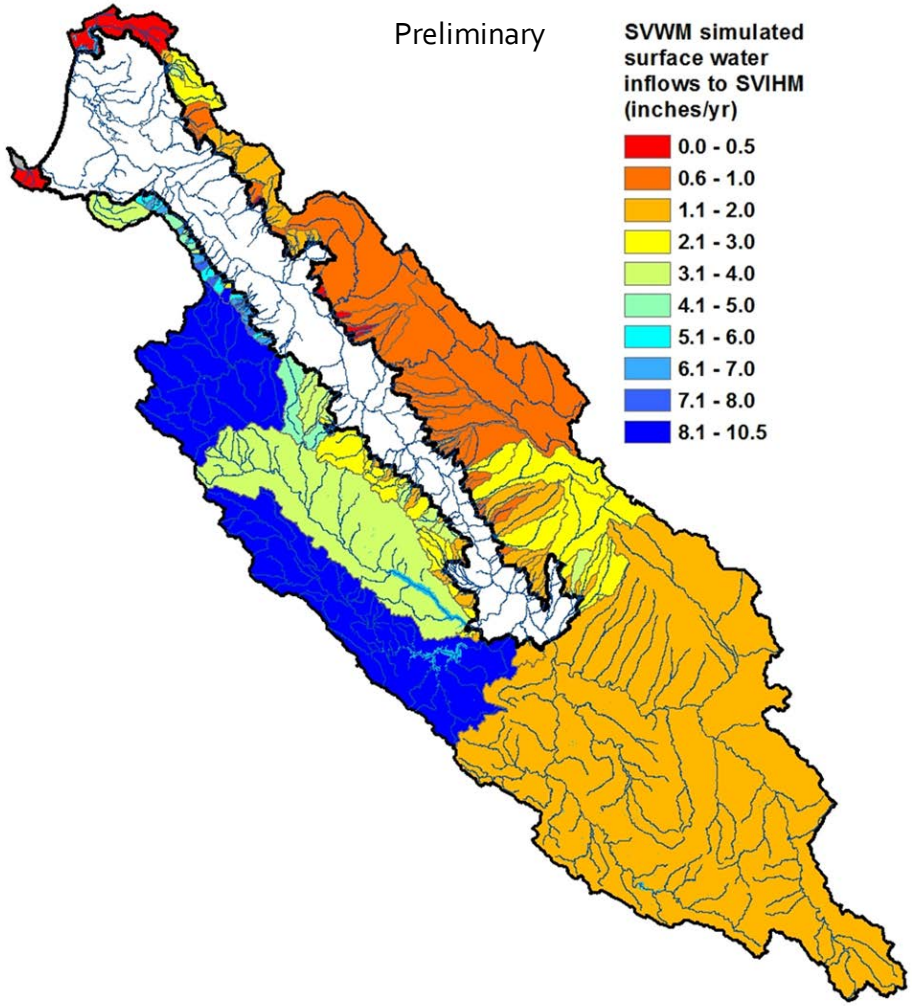


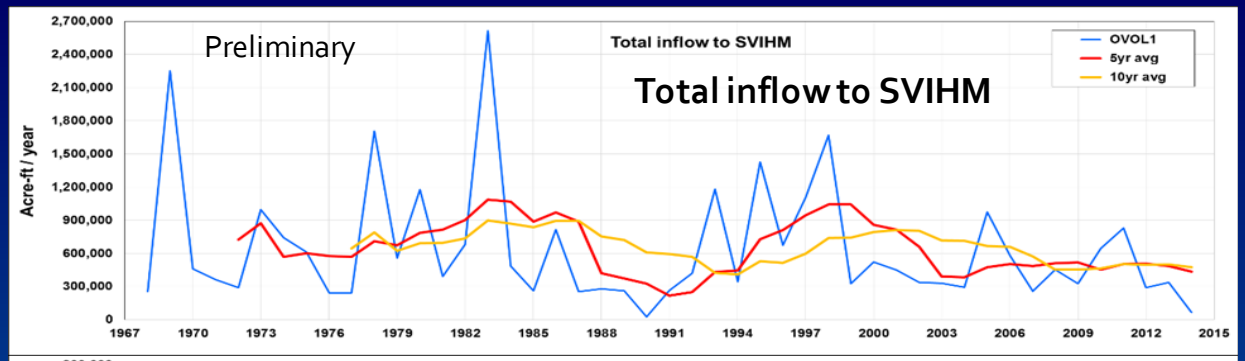
Preliminary SVWM simulation results: 1949-2015 average surface water inflows

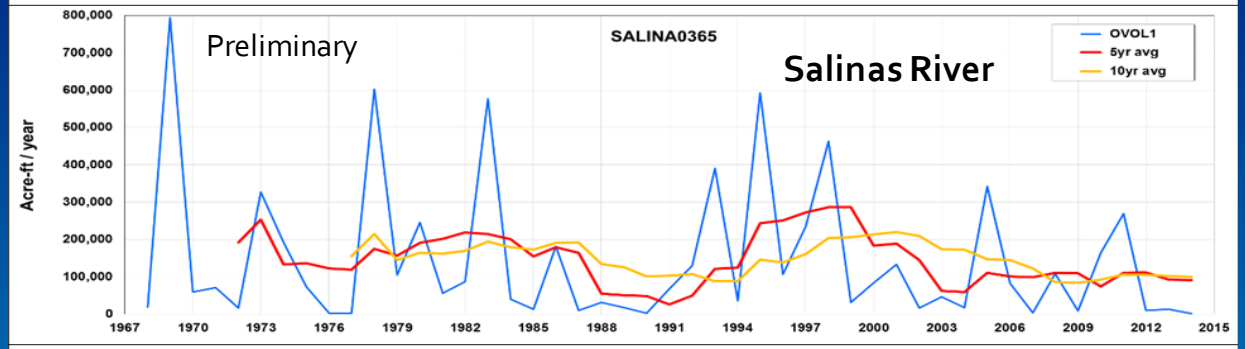
Average streamflow
Total inflow = 881 cfs
(638,000 acre-ft/yr)

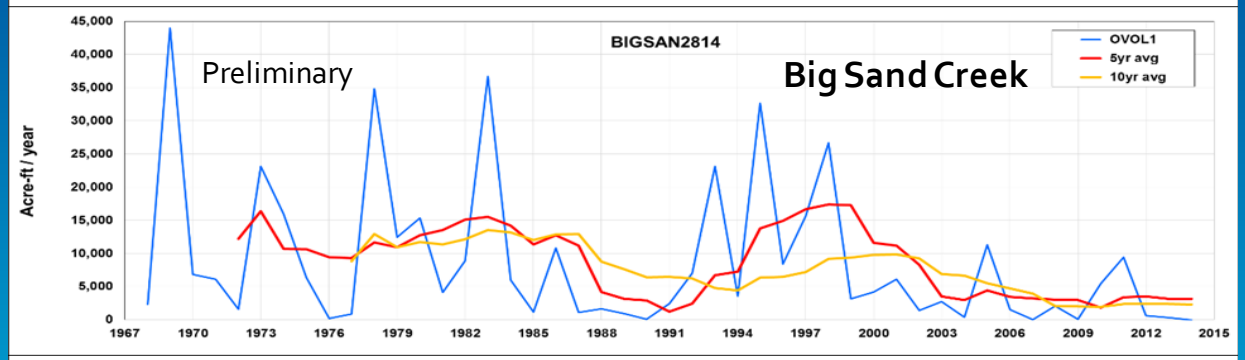


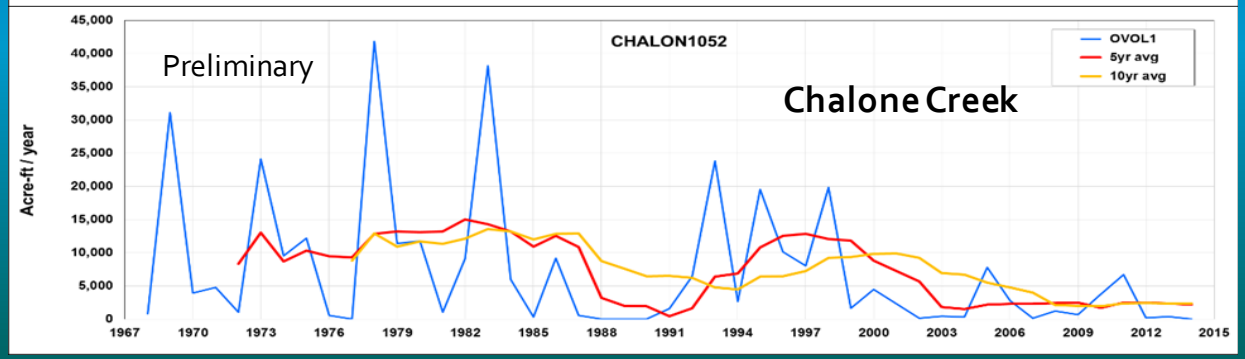
Average streamflow
Total inflow = 3.3 inches/year











Preliminary Results: 1968-2014 annual surface water inflows to SVIHM

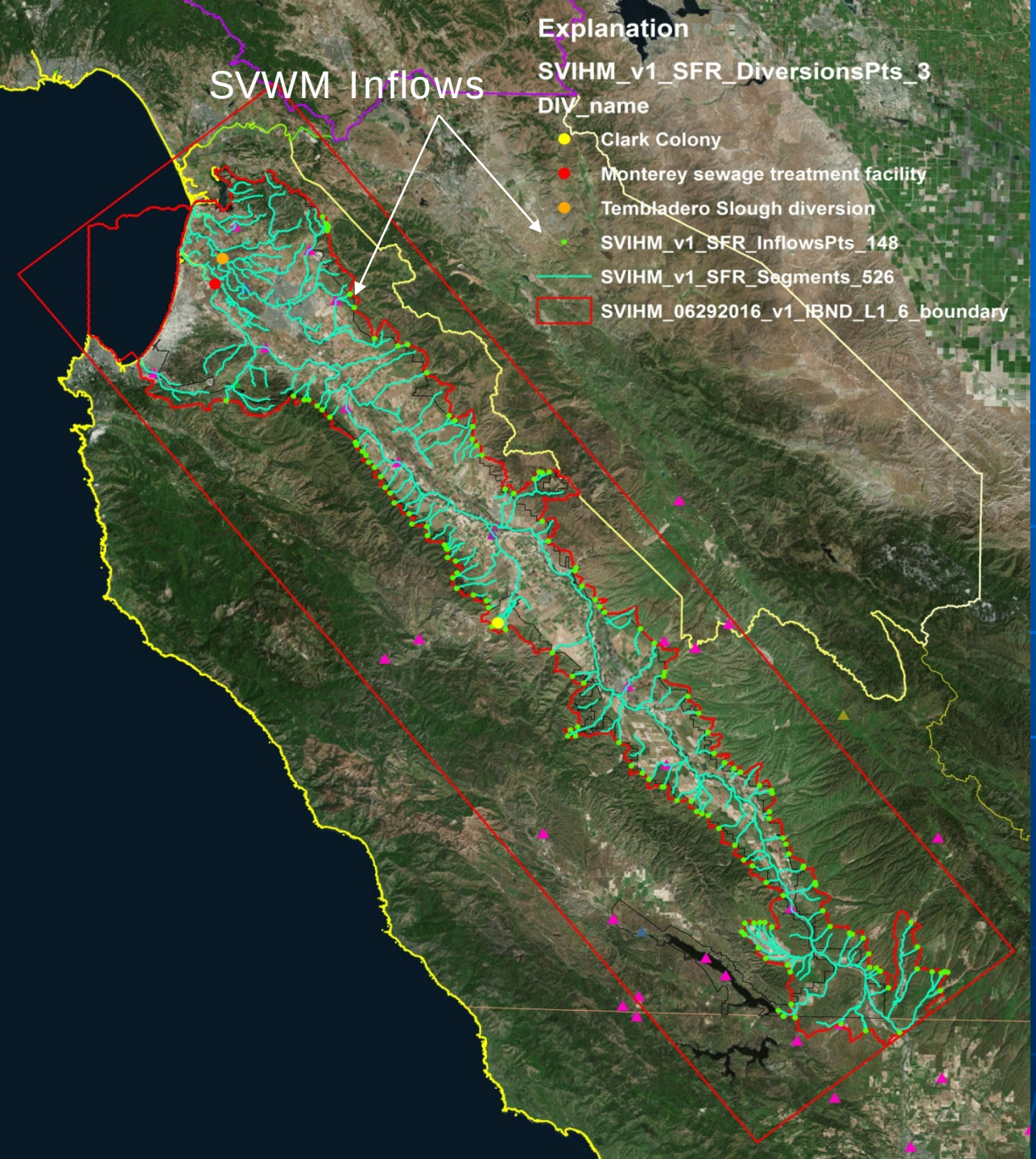
Total inflows to SVIHM:
Average = 641,000 acre-ft/yr
Max = 2,600,000 acre-ft
Min = 26,000 acre-ft

Salinas River:
Average = 146,000 acre-ft/yr
Max = 794,000 acre-ft
Min = 1,400 acre-ft

Big Sand Creek:
Average = 8,700 acre-ft/yr
Max = 44,000 acre-ft
Min = 0 acre-ft

Chalone Creek:
Average = 7,300 acre-ft/yr
Max = 42,000 acre-ft
Min = 0 acre-ft

USGS science for a changing world



SVIHM Streamflow Network

- 524 segments: river, tributary, canal, and drains
- 148 Inflow points → 3 gaged and 145 estimated
- 3 diversions → Arroyo Seco for Clark Colony, Salinas River for SRDF, & Tembladero Slough
- 3 Gaged Inflows →
  (a) "Nacimiento River 1" (USGS gage 11149500) below the Nacimiento reservoir,
  (b) "Arroyo Seco 1" (USGS gage 11152000) on Arroyo Secco, and
  (c) "San Lorenzo Creek 1" (USGS gage 11151300) on San Lorenzo Creek on the northern boundary of SVIHM

USGS science for a changing world

MONTEREY COUNTY WATER RESOURCES AGENCY 1947

Salinas Valley Integrated Hydrologic Model (SVIHM)

- *Hydrology ➔ SVIHM Conceptual Model (MF-OWHM Packages*

INFLOWS

- *Precipitation ➔ BCM*
- *Runoff from surrounding watersheds (MFR) ➔ SVWM*
- *Reservoir Releases (SFR)*
- *Groundwater Underflow (PasoRobles, Pajaro Valley)*
- *Seawater Intrusion (GHB ➔ SWI)*

OUTFLOWS

- *Runoff/Streamflow to Ocean (SFR)*
- *Evapotranspiration (Agriculture, Native, Urban) (BCM/FMP)*
- *MnI Pumpage (not recycled) (MNW2)*

INTERNAL FLOWS

- *Diversion of streamflow (SRDF & Clark Colony) (SFR/FMP)*
- *Wellbore flow between aquifers (MNW2)*
- *Recycled treated Urban wastewater (CSIP) (FMP ➔ NRD)*
- *Agricultural Drain flows (DRT ➔ FMP)*
- *Excess Irrigation Water (Artificial Recharge/Runoff) (FMP ➔ SFR)*
- *Flow Barriers as Faults (HFB)*

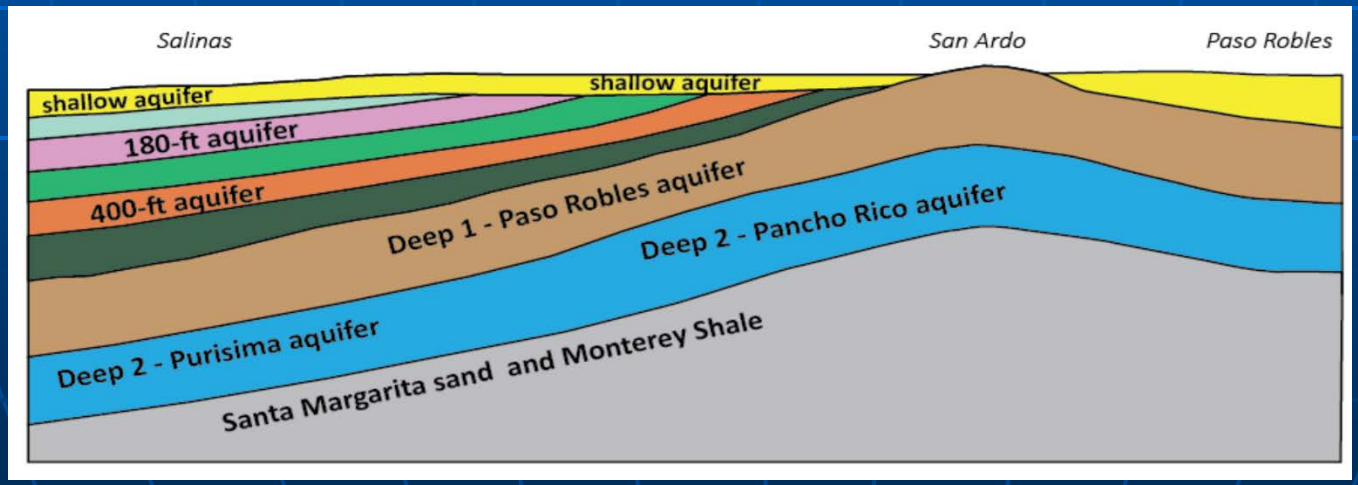
USGS science for a changing world

MONTEREY COUNTY WATER RESOURCES AGENCY 1947

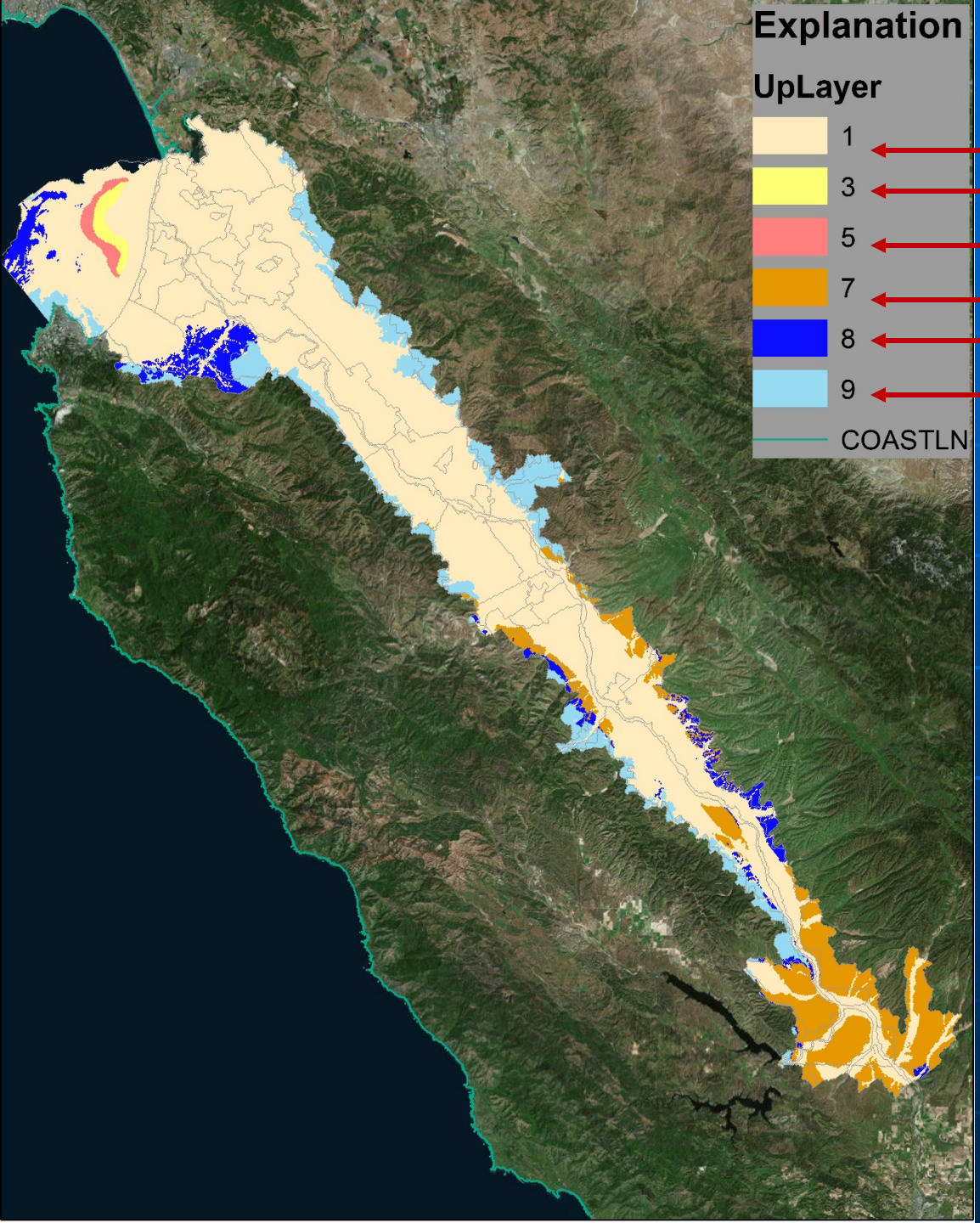
Salinas Valley Integrated Hydrologic Model (SVIHM)

Model Layering – 9 Layers

Layer 1 ➔ Salinas Shallow/Recent Aquifer
Layer 2 ➔ Salinas Valley Aquitard
Layer 3 ➔ 180-Ft Aquifer
Layer 4 ➔ Middle Aquitard
Layer 5 ➔ 400-Ft Aquifer
Layer 6 ➔ Deep Aquitard
Layer 7 ➔ Paso Robles Formation Aquifer
Layer 8 ➔ Purisima/Santa Margarita Aquifer
Layer 9 ➔ Composite Bedrock Aquifer



Example Cross Section of SVIHM Model Layers for SVIHM.

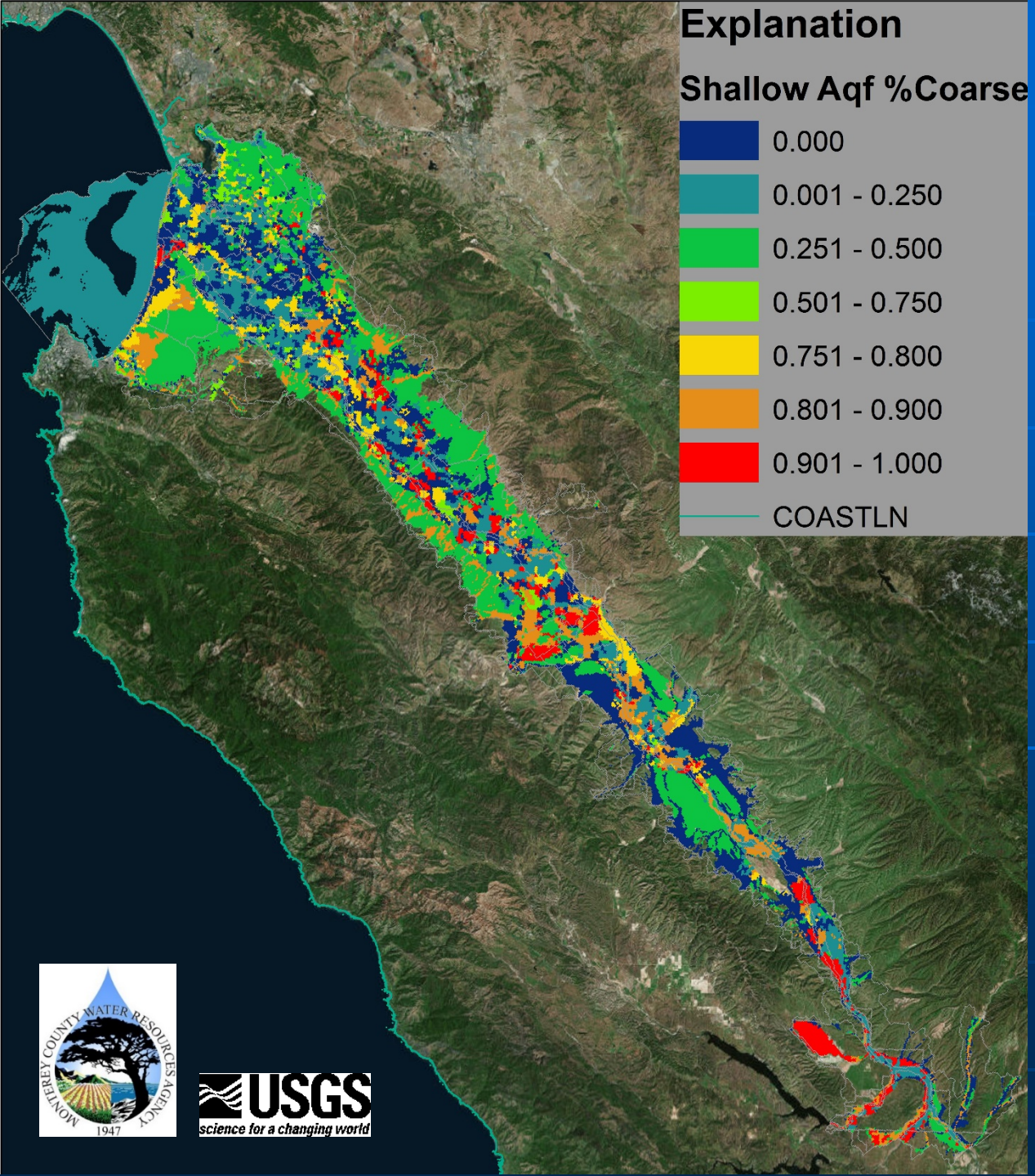


SVIHM - Uppermost Layers

- Alluvium
- 180-ft Aquifer
- 400-ft Aquifer
- Paso Robles
- Purisima Fm
- Bedrock Units

USGS science for a changing world

MONTEREY COUNTY WATER RESOURCES AGENCY 1947



MONTEREY COUNTY WATER RESOURCES AGENCY 1947

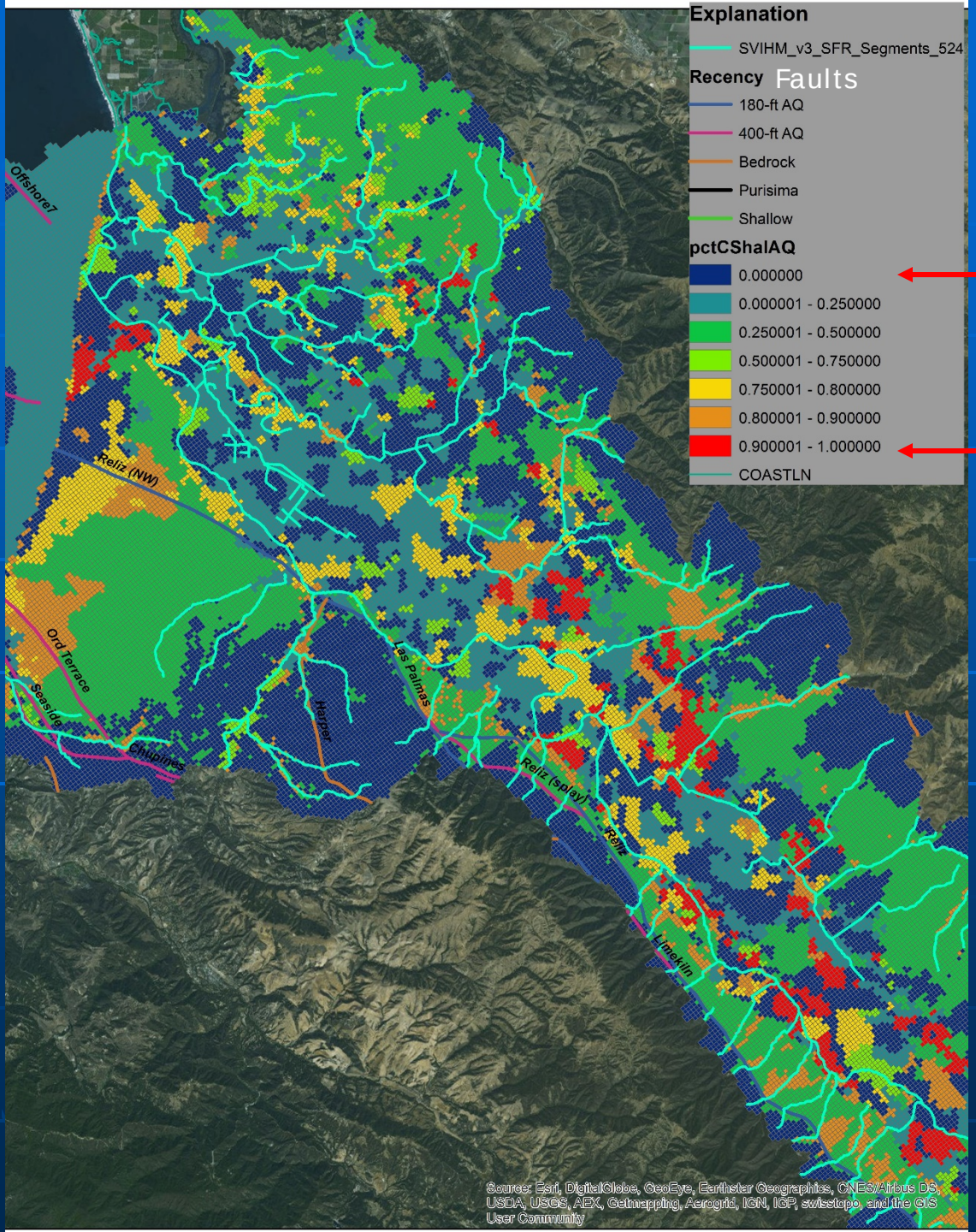
USGS science for a changing world

Hydraulic Properties for aquifers and confining layers distributed based on lithology-based texture distributions

Alluvial layers (Layers 1 - 7)

General lithology	Percent coarse (in %)	Lithologic description
Gravel	100	boulders, cobbles, fine gravel, gravel
Gravel and sand	90	coarse gravel/sand, coarse gravel/sand, gravel/sand
Coarse sand	80	coarse sand, sand, white sand, yellow sand
Fine sand	75	blue sand, fine sand, red sand, sandstone
Gravel and clay	50	gravel/clay, gravel/rocks/clay, gravel/rocks/cl, sand/gravel/clay, sand/gravel/clay, decomp granite decomposed granite, gravelly clay, gravelly clay
Sand and clay	25	quicksand, adobe, sand/clay, sandy blue clay sandy clay, sediment, sandy blue clay, top soil, topsoil
Clay	0	shale, blue clay, brown clay, clay, red clay, white clay yellow clay, granite, bedrock

Example of Alluvial Aquifer Texture Data



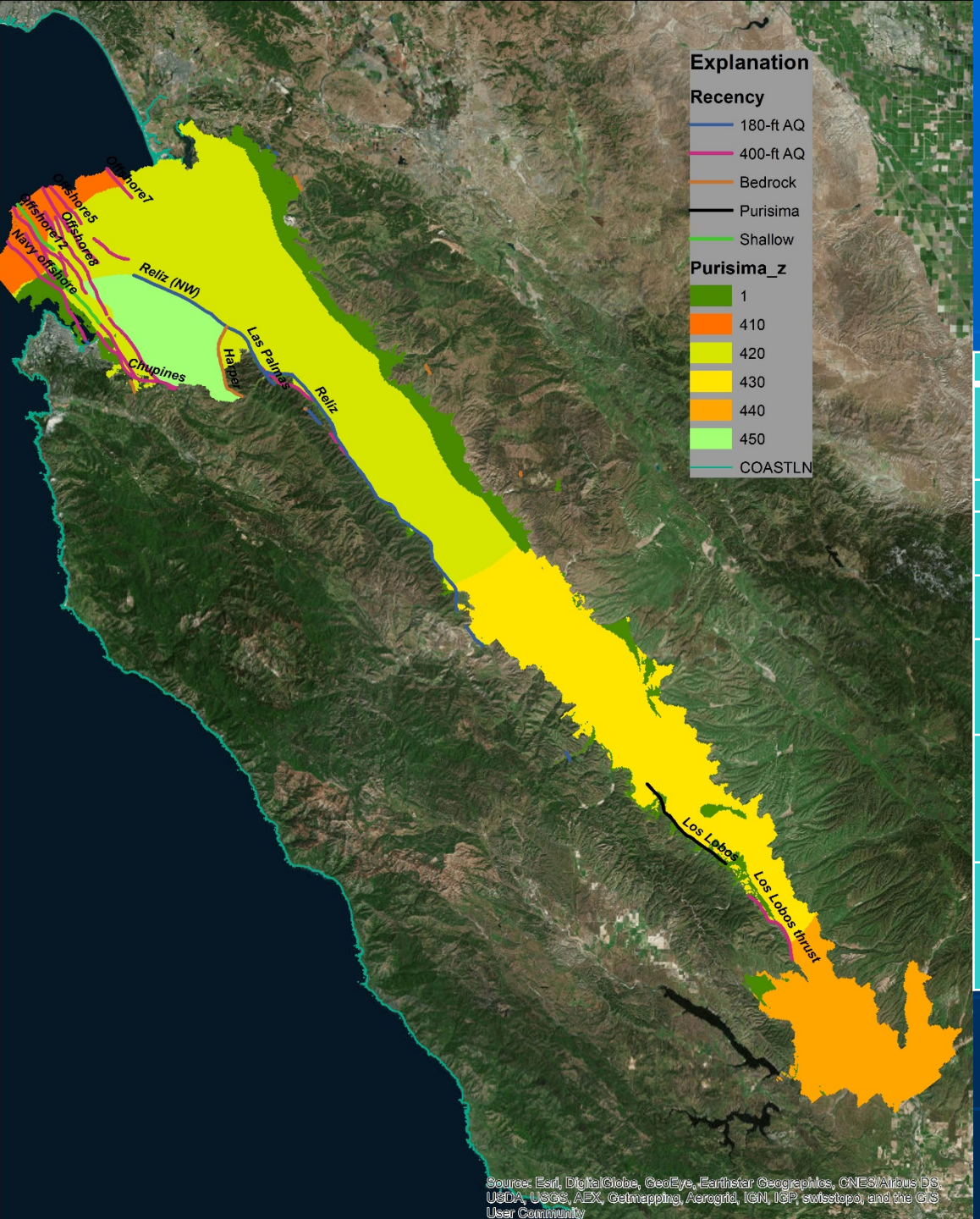
Fine-grained sediments

Coarse-grained sediments

USGS science for a changing world

MONTEREY COUNTY WATER RESOURCES AGENCY 1947

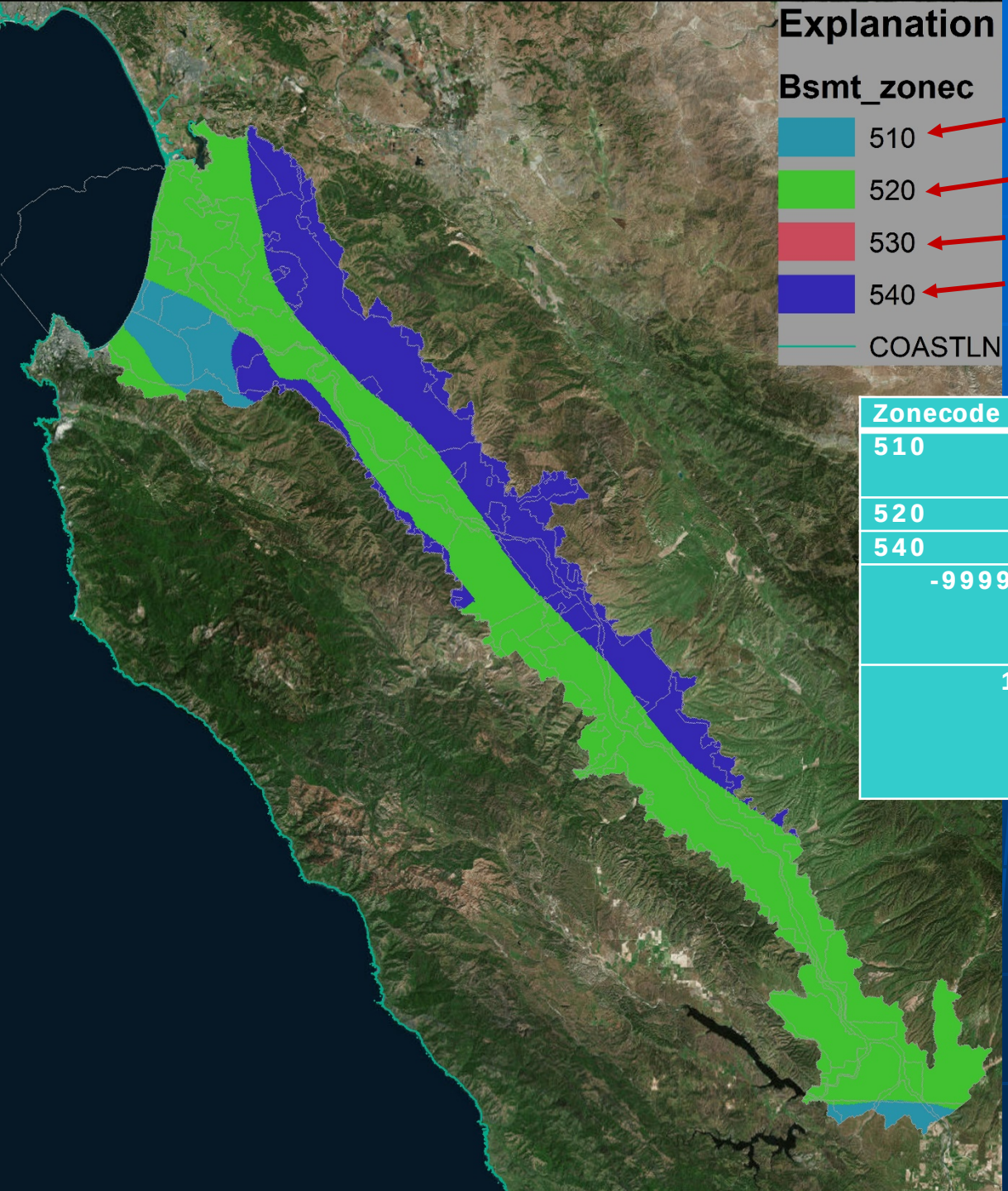
Pliocene Sedimentary Formations ➔ Purisima, Pancho Rico, & Santa Margarita Formations



Zonecode	Explanation
410	Purisima Fm mapped onshore in Pajaro area and offshore (by Johnson and others)
420	Purisima Fm in the subsurface
430	Pancho Rico Fm of central Salinas Valley
440	Pliocene marl sandstone mapped NE of Paso Robles
450	QT unit overlying Santa Margarita Fm in the El Toro area
-99999	Value assigned where HSU unit is absent with no overlying units present (thickness = 0)
1	Value assigned where HSU unit is absent but overlying units are present (thickness assigned as 1)

USGS science for a changing world

MONTEREY COUNTY WATER RESOURCES AGENCY 1947



Basement/Bedrock units

Santa Margarita Fm

Monterey Fm

Not Present

Crystalline rocks undivided

Zonecode	Explanation
510	Santa Margarita Fm (El Toro area and Paso Robles)
520	Monterey Formation, undivided
540	Crystalline rocks, undivided
-99999 → 0	Value assigned where HSU unit is absent with no overlying units present (thickness = 0)
1	Value assigned where HSU unit is absent but overlying units are present (thickness assigned as 1)

USGS science for a changing world

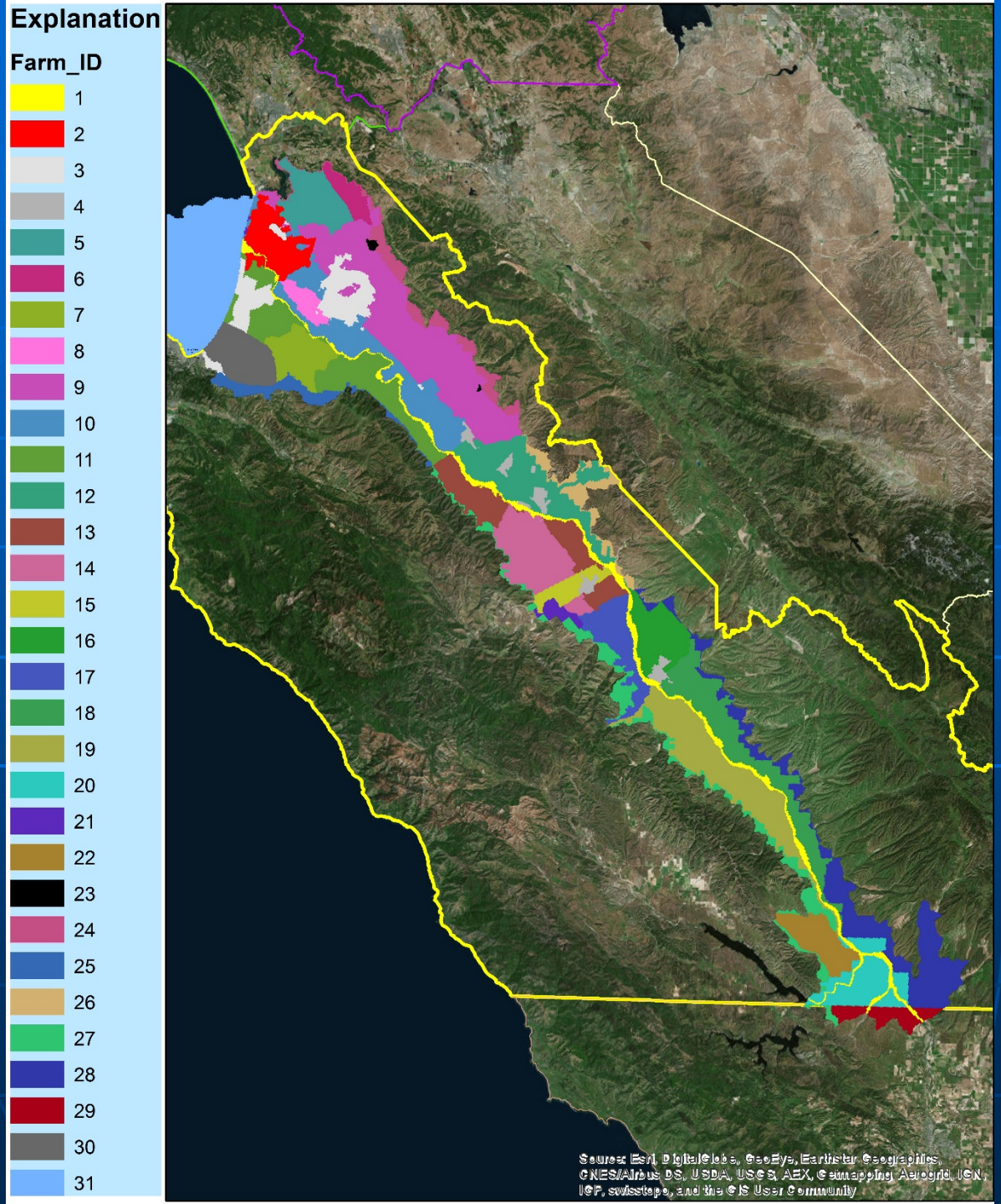
MONTEREY COUNTY WATER RESOURCES AGENCY 1947

30 SVIHM Water-Balance Accounting Units

(1) Riparian Corridor (Monterey and SLO Counties) ➔ *Preserved Fish and Plant Habitat Salinas River*
(2) CSIP Area ➔ *Recycled Water Irrigation Region*
(3) Coastal Urban areas (Salinas, Castroville, Marina, parts of Monterey, Del Rey Oaks) ➔ *Urban Demand*
(4) Inland Urban areas (Chualar, Gonzales, Soledad, Greenfield, King City, & San Ardo) ➔ *Urban Demand*
(5) *Agriculture* ➔ Highlands South
(6) *Agriculture* ➔ Granite Ridge
(7) *Suburban* ➔ Corral De Tierra inside of Zone 2C
(8) *Agriculture* ➔ Blanco Drain Area (Not in CSIP)
(9) *Agriculture* ➔ Remainder of Zone2C – East Side
(10) *Agriculture* ➔ Remainder of Zone2C – Pressure NE of Salinas River
(11) *Agriculture* ➔ Remainder of Zone2C – Pressure SW of Salinas River
(12) *Agriculture* ➔ Remainder of Zone 2C – Forebay NE side of Salinas River
(13) *Agriculture* ➔ Remainder of Zone 2C – Forebay SW side of Salinas River
(14) *Agriculture* ➔ Remainder of Zone 2C – Arroyo Secco
(15) *Agriculture/SW Delivery* ➔ Clark Colony 1905 (non-urban)
(16) *Agriculture* ➔ Zone 2C -- Upper Valley NE subregion East of Salinas R & Northeast of King City
(17) *Agriculture* ➔ Zone 2C -- Upper Valley NW subregion West of Salinas R & West of King City
(18) *Agriculture* ➔ Zone 2C -- Upper Valley SE subregion East of Salinas R & East of King City
(19) *Agriculture* ➔ Zone 2C -- Upper Valley SW subregion West of Salinas R & West of King City
(20) *Agriculture* ➔ Zone 2C – Below Dam
(21) *Native* ➔ Westside Regions Active outside Zone 2C boundary in Monterey County for Inland Region (some reported pumpage) Southwest of Arroyo Seco and Clark Colony
(22) *New Agriculture* ➔ Hames Valley – Monterey County
(23) NE Quarries ➔ *Mining*
(24) *Native* ➔ Boundary of Model outside of Zone 2C on the Northeast side of the remainder of the East Side, Granite Ridge, and Highlands South subregions
(25) *Native* ➔ Southwest side Region Active outside of Coastal Pressure subegion Zone 2C boundary in Monterey County
(26) *Native* ➔ Boundary of Model outside of Zone 2C on the Northeast side of the remainder of the Forebay subregion
(27) *Native* ➔ Boundary of Model outside of Zone 2C on the Southwest side of the Upper Valley, Arroyo Seco, and Forebay regions, Hames Valley, and SLO active Regions
(28) *Native* ➔ Eastside Regions Active East and outside of Below Dam and Upper Valley subregions of Zone2C boundary in Monterey County
(29) *Native* ➔ Remainder of Paso Robles Basin in active model grid in SLO County (SLO Model Active Grid Extent)
(30) Seaside Adjudicated Basin (landward only) ➔ *Urban Demand/Native-area recharge*
(31) Offshore (gw analysis only) ➔ *Source of Seawater Intrusion*

GEMS – Monthly Reported Pumpage Observations

USGS science for a changing world



30 SVIHM Water-Balance Accounting Units

- Seaside Basin Included
- Coastal and Inland Urban areas grouped
- Zone 2C regions subdivided
- Additional regions added outside of Zone 2C
- Offshore region completed based on Geologic Framework Model

USGS science for a changing world

MONTEREY COUNTY WATER RESOURCES AGENCY 1947

Initial Crop/Land-Use Categories & Climate Zones Developed

- Selected Individual Crops
- Selected Crops Groupings
- Coastal and Inland Groups
- Early-year/SVIGSM Groups

USGS science for a changing world

Crop_ID	Crop/Land-Use Group	Sub-Group Components
1	Spring Mix (Baby Crops)-Inland 30 Day	Baby lettuce, baby kale, baby mustard
10	Spring Mix (Baby Crops)-Coastal 30 Day	Baby lettuce, baby kale, baby mustard
1	Truck & vegetables row crops-Inland 60 Day	Lettuce, Romaine, Pepper Spice, Endive Escarol, Cilantro, Peppers, Mustard, Parsley
2	Truck & vegetables row crops-Coastal 60 Day	Lettuce, Pepper Spice, Endive Escarol, Cilantro, Peppers, Mustard, Parsley
5	Truck & vegetables row crops-Inland 90 Day	Brocoli, Califlower, Kale, Peas, Asparagus, Cabbage, Cole Crops-Coastal, Leek, Swiss Chard
6	Truck & vegetables row crops-Coastal 90 Day	Brocoli, Califlower, Kale, Peas, Asparagus, Cabbage, Cole Crops-Inland, Leek, Swiss Chard
11	Carrots	
12	Onions, Garlic, Corn	
13	Brussel Sprouts	
14	Potato, Sugarbeets	
15	Celery,Green Beans, Squash, Cucumbers, Tomatoes -Inland	
16	Celery,Green Beans, Squash, Cucumbers, Tomatoes, Melons -- Coastal	
30	Irrigated Row and Field Crops	Used for earlier Land-Use periods, less detailed maps
18	Field crops	Wheat
22	Pasture	Alfalfa, Turf/Sod
3	Strawberries-Inland	
4	Strawberries-Coastal	
7	Artichokes (annual)	
23	Grain and hay crops	Oats
17	Cane/Bush Berries	Blackberries and raspberries
19	Deciduous fruits and nuts	Apple, Walnuts, Stone Fruit-Peach
20	Citrus and subtropical	Lemon, Orange, Avocado, Pomegranite, Olive, Kiwi
21	Vineyards	Wine & Table Grapes
28	Nurseries	Nursery, Outdoor Flowers, OF-Bulb, GP-Bulb, Mushrooms
29	Cropland and pasture	Rangeland
31	Non-irrigated	Used for earlier Land-Use periods, less detailed maps
32	Semiagricultural	Uncultivated Non-AG, Beehive, (livestock feedlots, diaries, poultry farms)
33	Idle/fallow	
34	Ag_Trees	Cristmas Trees, TMBRLND
41	Grolf Course Turf/Parks	
24	Urban	Turf, Landscape
40	Quarries	Sand and Aggregate mining
27	Water	
35	Riparian	Crop/Land-Use Group Color Codes
36	Upland Grasslands/Shrub Lands	Individual
37	Woodlands	FOREST (Grouped)
38	Beach-Dunes	Native Vegetation/Undeveloped Land
39	Barren/Burned	

4 general Groups of Land Use

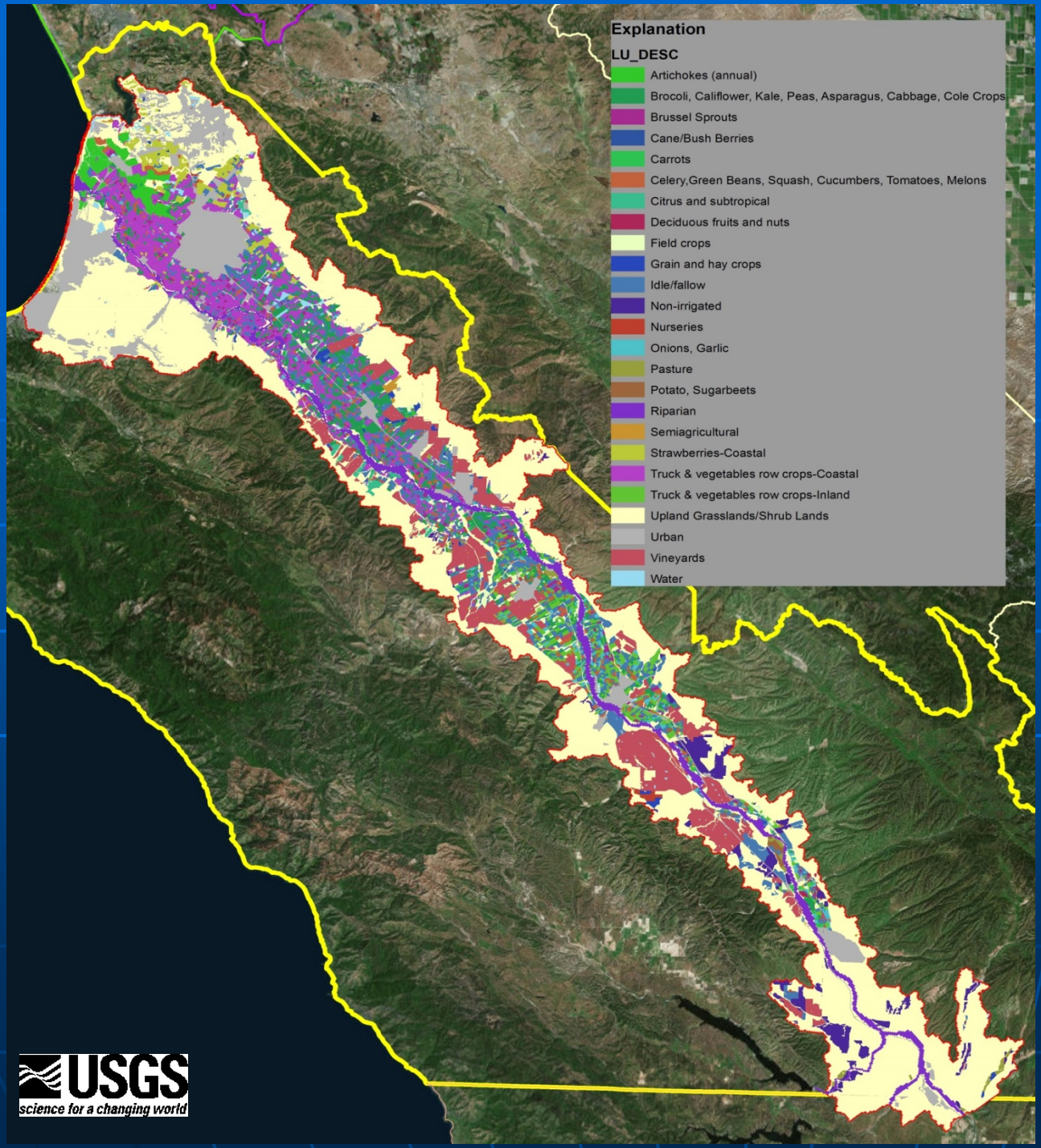
(1) Rotational Crops/Land Use changing every 30 -90 days

(2) Annual/Seasonal Crops/Land Use

(3) Multi-year Crops/Land Use

(4) "permanent" Native-Urban Crops/Land Use

MONTEREY COUNTY WATER RESOURCES AGENCY 1947



2000-2001 Land Use

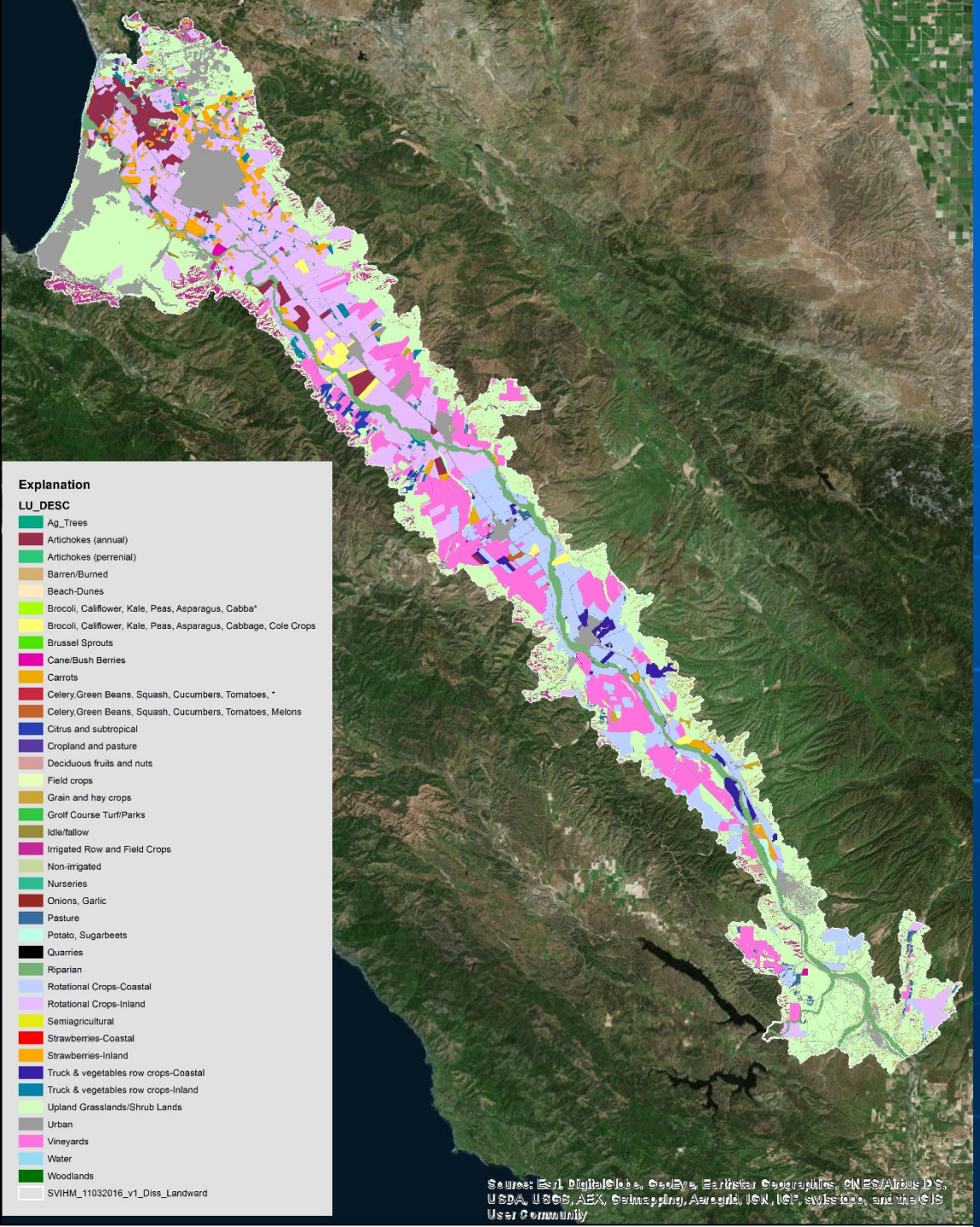
- NLCD 2001,
- Urban from SVIHM WBS Cells,
- DWR 2000

USGS science for a changing world

MONTEREY COUNTY WATER RESOURCES AGENCY 1947

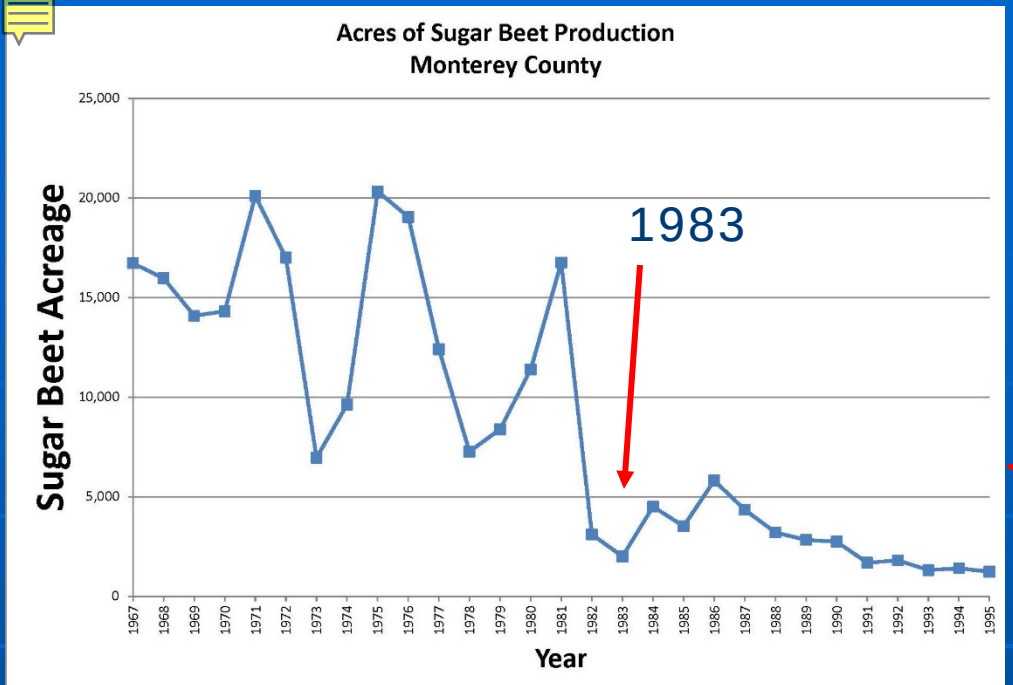
2012 Ranch Map Land Use

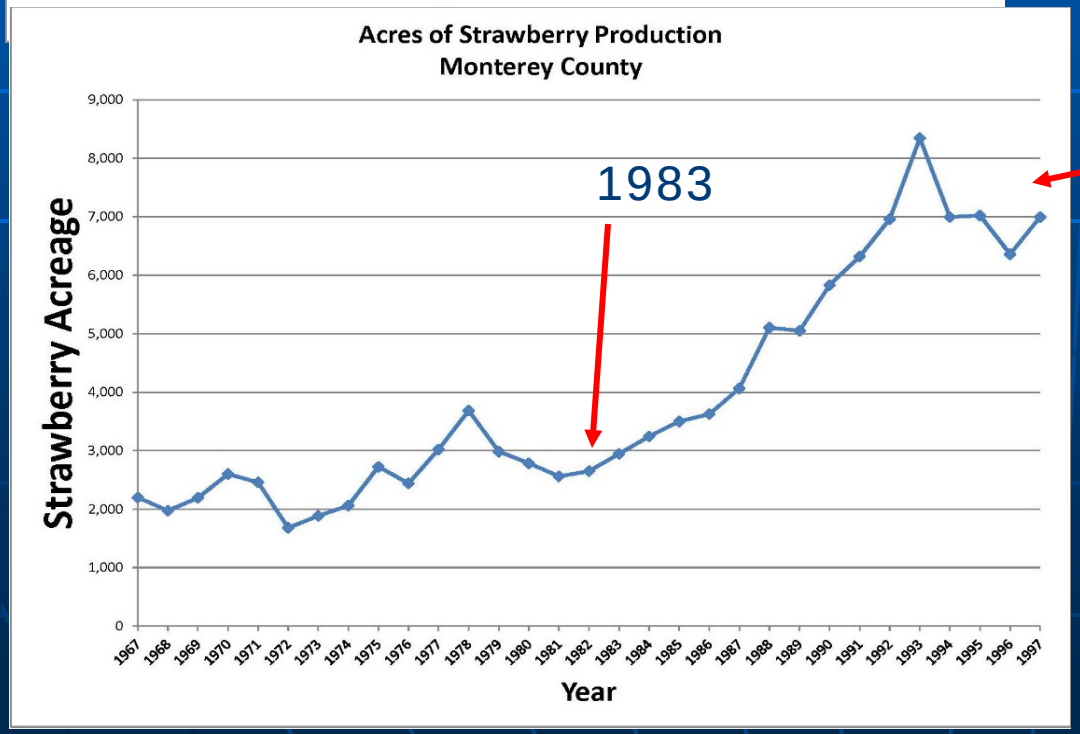
- NLCD 2011,
- Urban from SVIHM WBS Cells,
- DWR 2000/2002



USGS science for a changing world

MONTEREY COUNTY WATER RESOURCES AGENCY 1947





Example Crop trends in Monterey County through time

Sugar Beets (1967-1995)

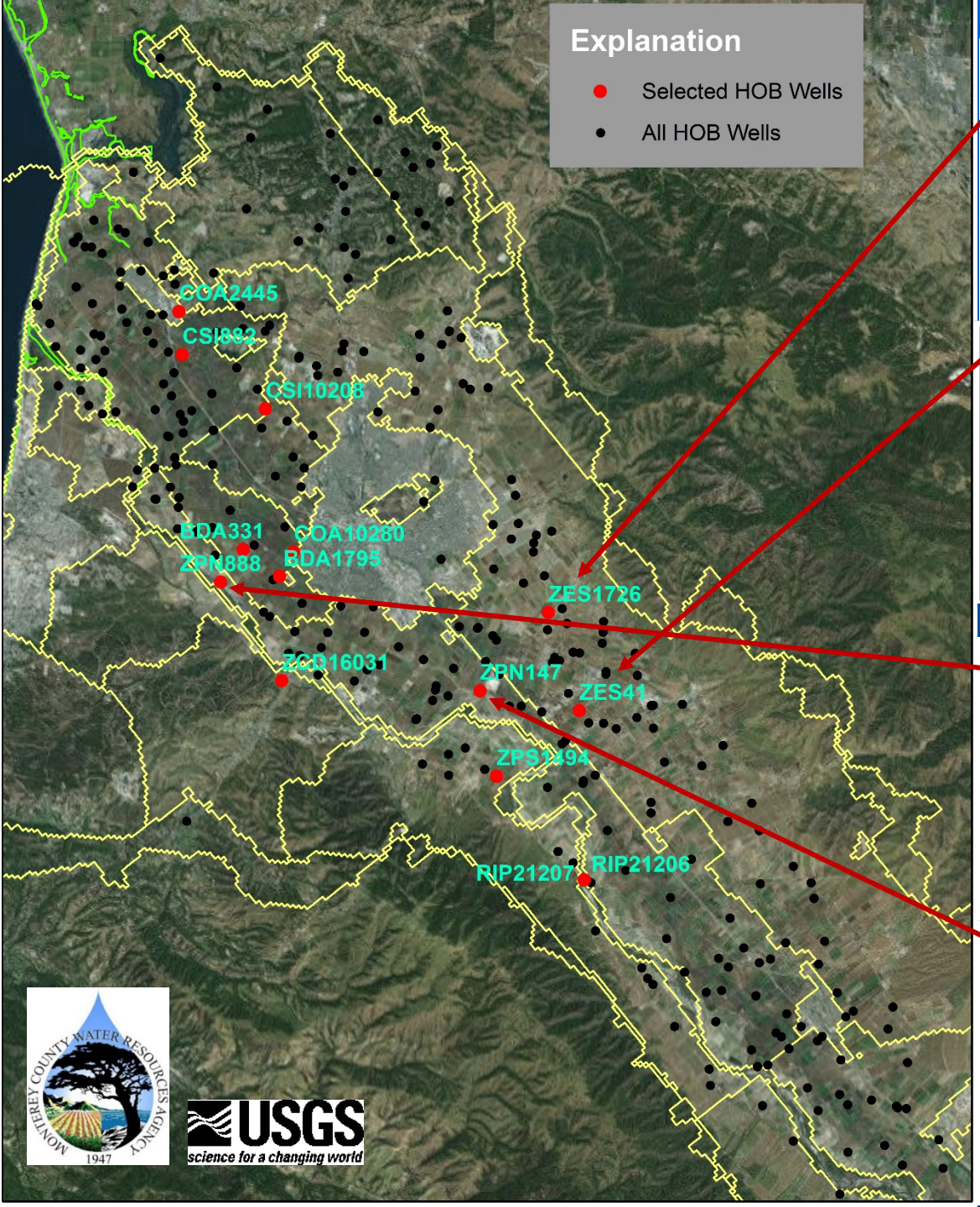
&

Strawberries (1967 – 1997)

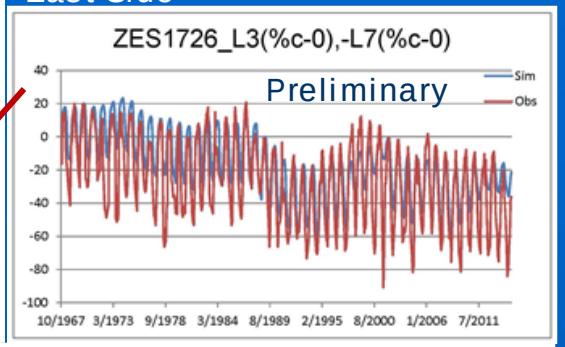
Break Point

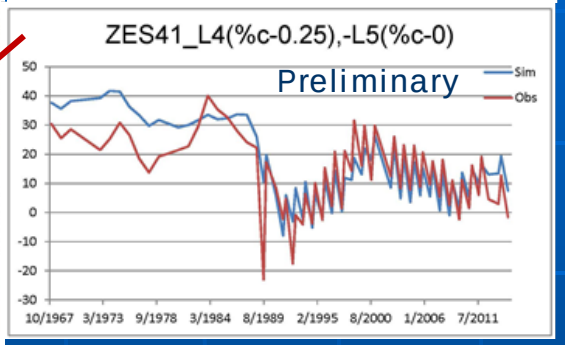
➔1983 (El Nino)?

Interannual changes and trends not captured well in Current set of Land Use maps

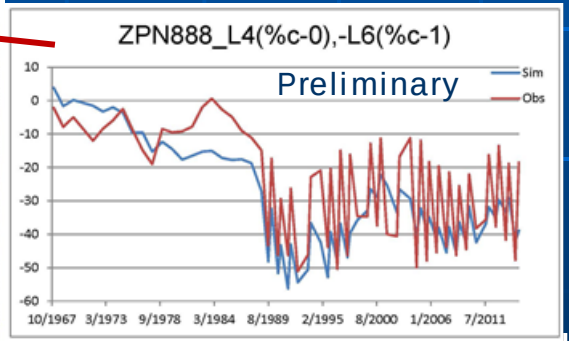


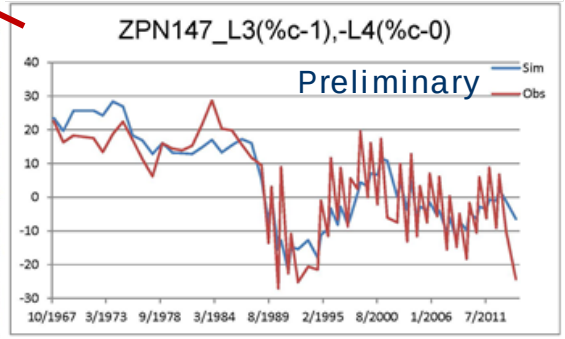
East Side





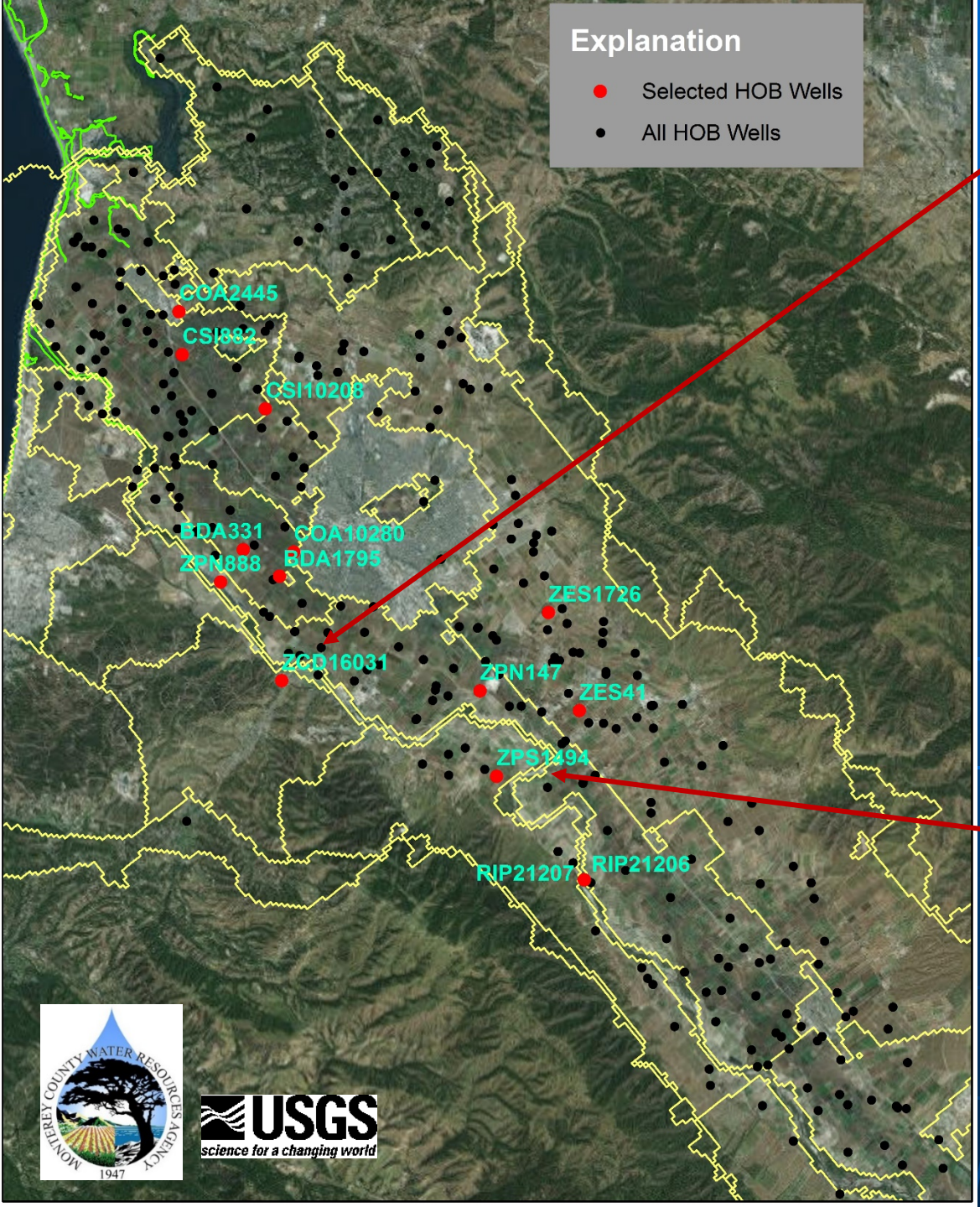
Pressure NE



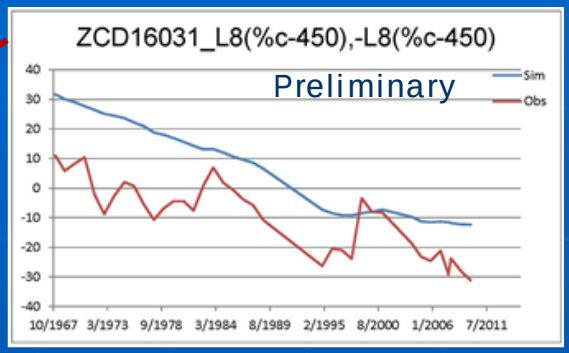


MONTEREY COUNTY WATER RESOURCES AGENCY 1947

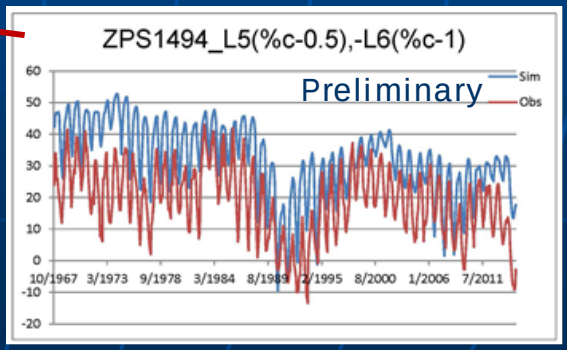
USGS science for a changing world

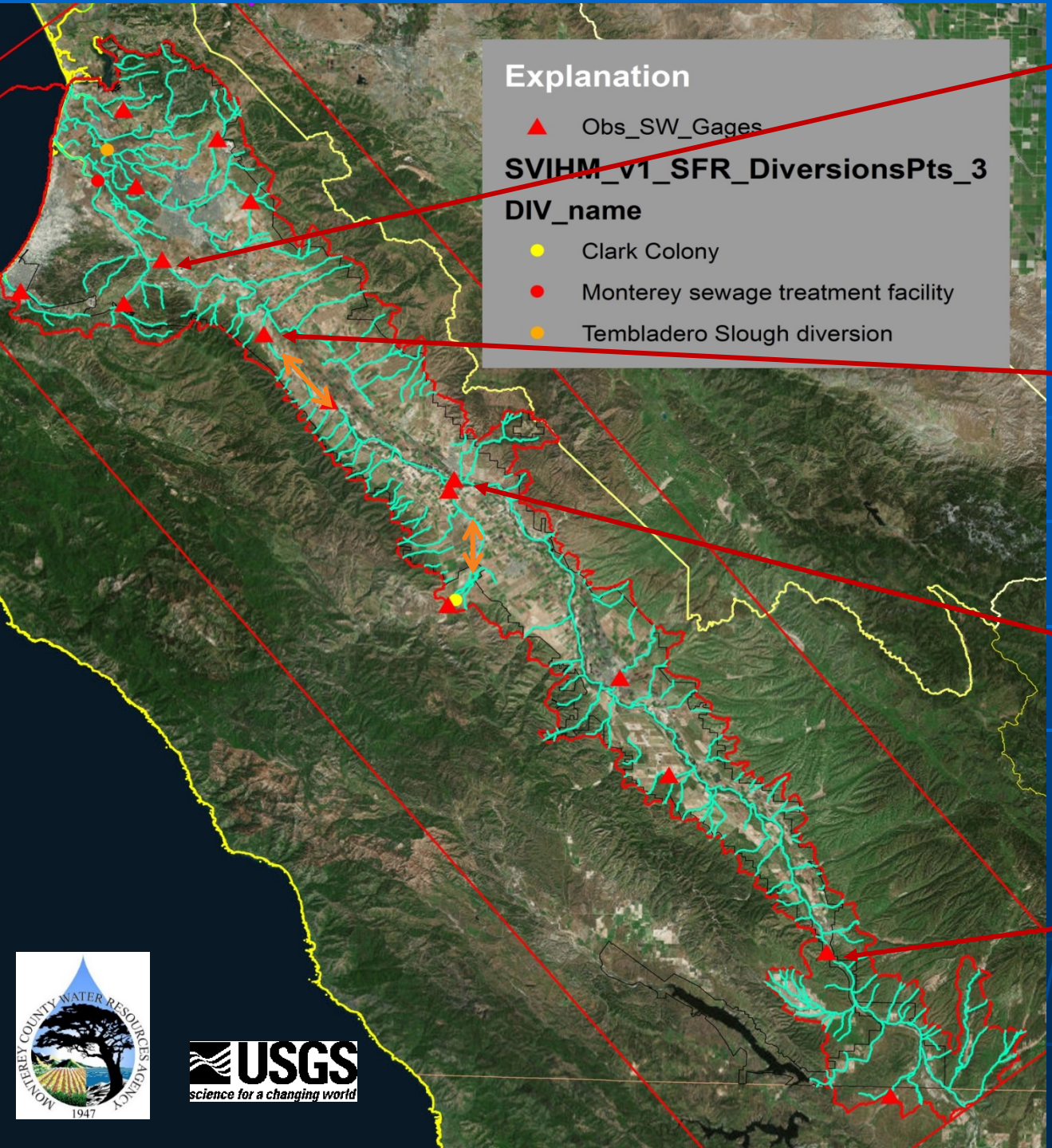


Corral De Tierra

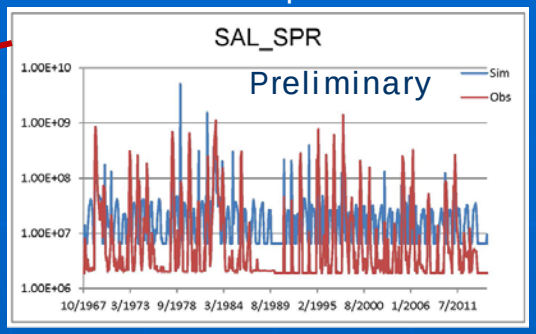


Pressure SW

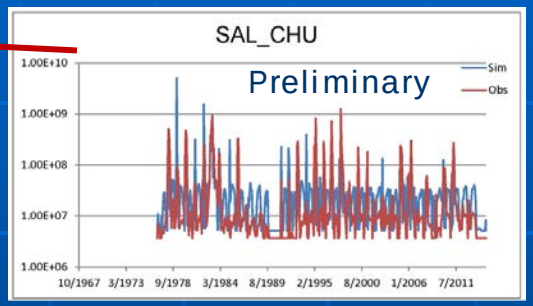




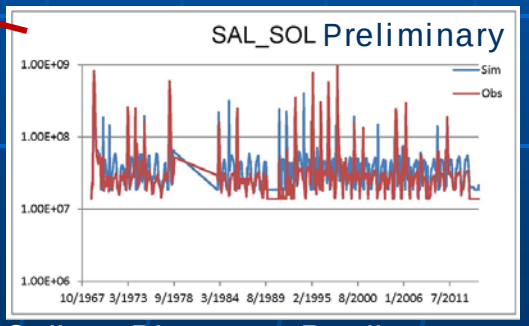
Salinas River at Spreckles



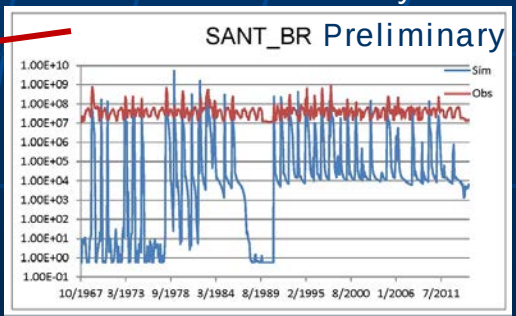
Salinas River at Chular



Salinas River at Soledad

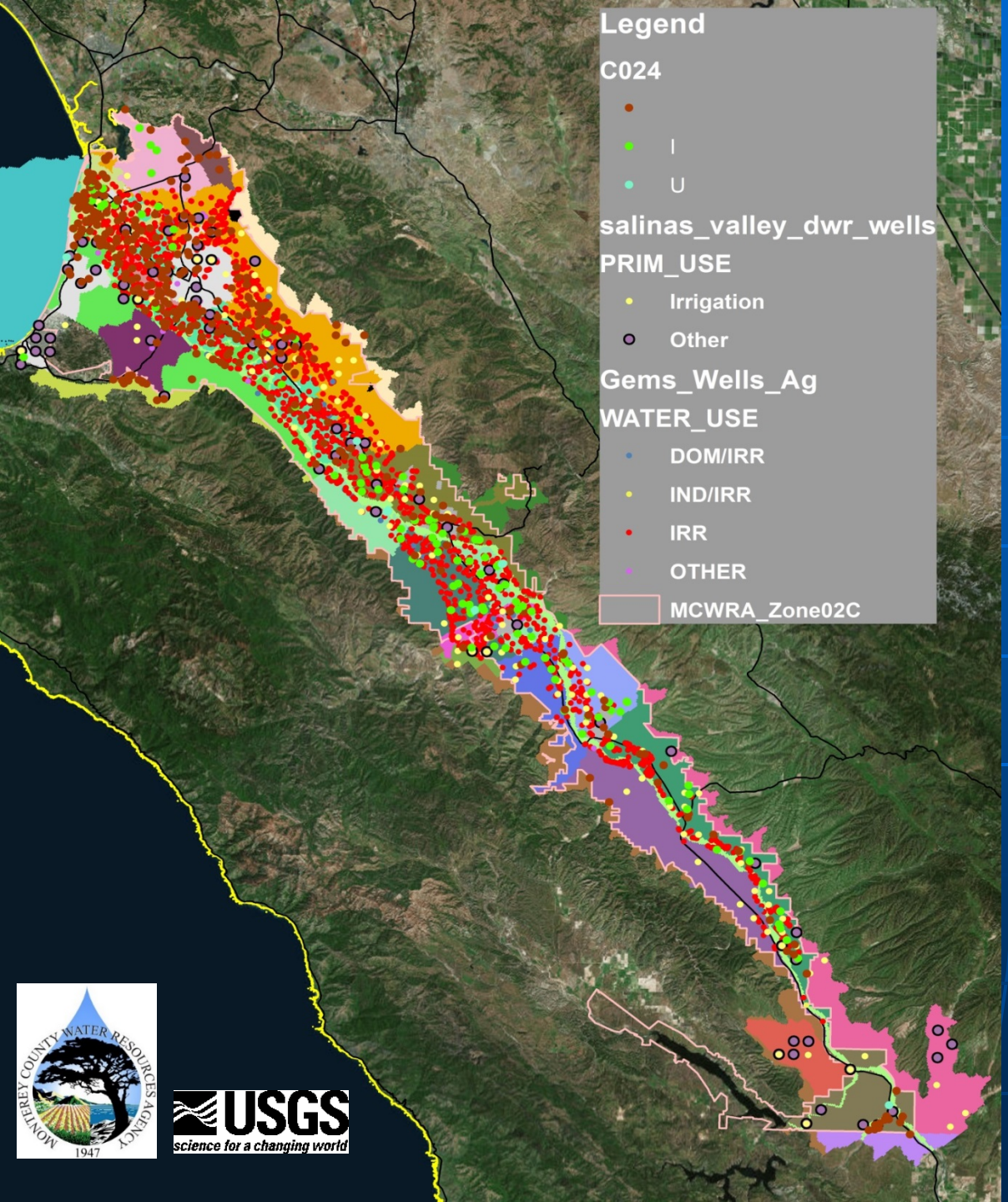


Salinas River near Bradley



MONTEREY COUNTY WATER RESOURCES AGENCY 1947

USGS science for a changing world



Agricultural Wells for FMP

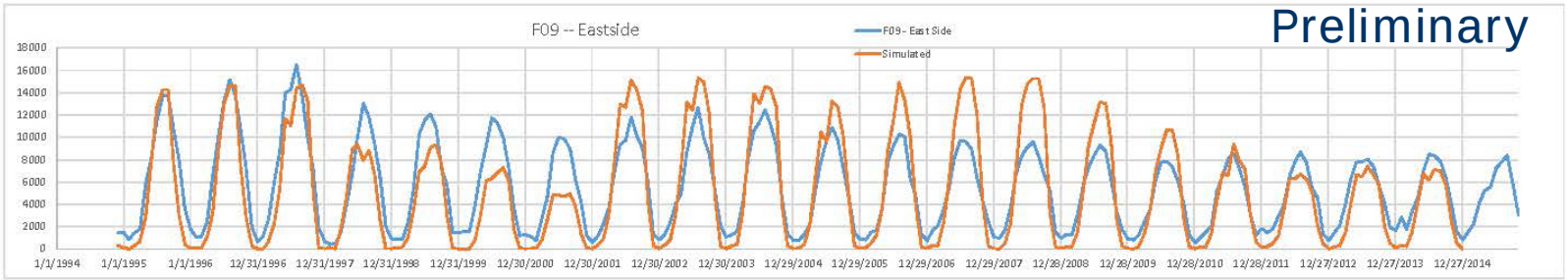
GEMS ➔ 2,005 wells
USGS-NWIS ➔ 193 wells
DWR ➔ 200 wells

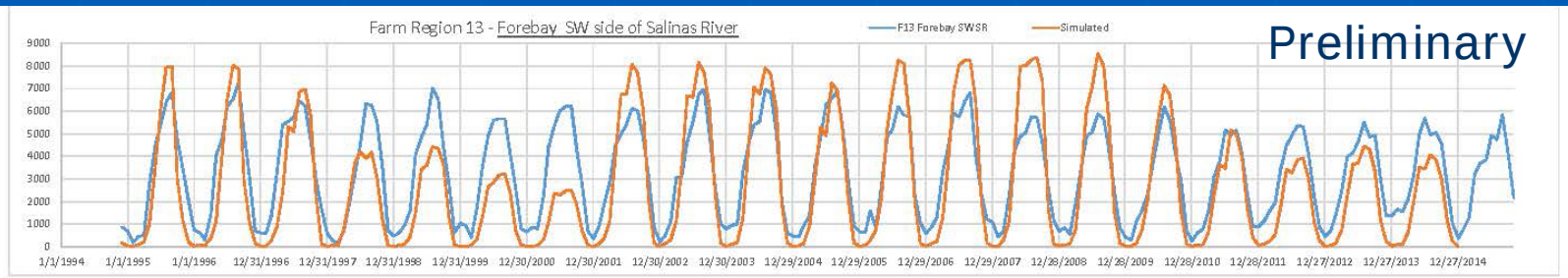
- The additional wells from USGS and DWR will be used to either supplement pre-1994 wells and to supplement regions outside of Zone 2C in the Granite Hills, Highlands South, Hames Valley, Other regions outside of Zone 2C, & SLO county portion
- Distribution of Ag Well pumpage is proportional to pumping capacities

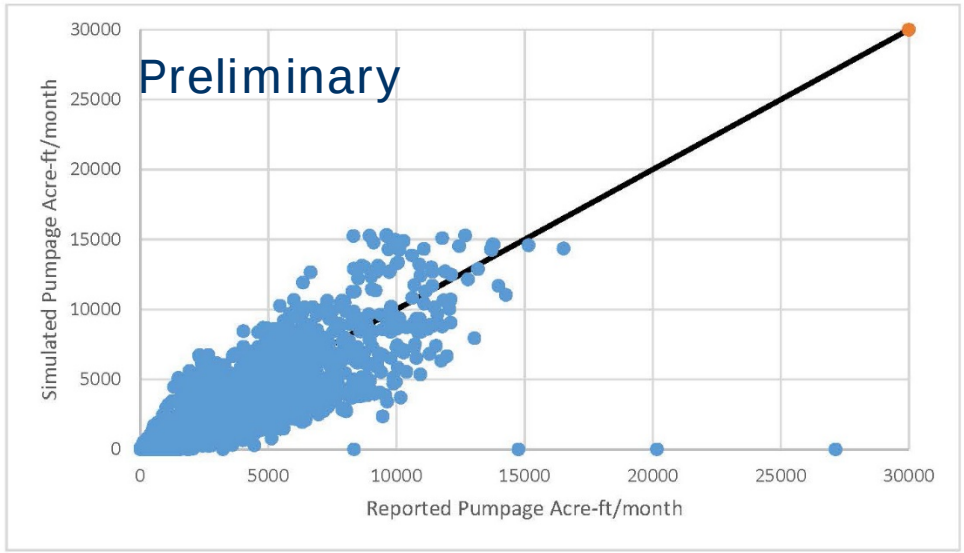
TOTAL MNW2 Wells ➔
2,295 Wells

- FMP Wells ➔ 2,004
- MnI Wells ➔ 291

Agricultural Groundwater Pumpage Comparisons (Preliminary)



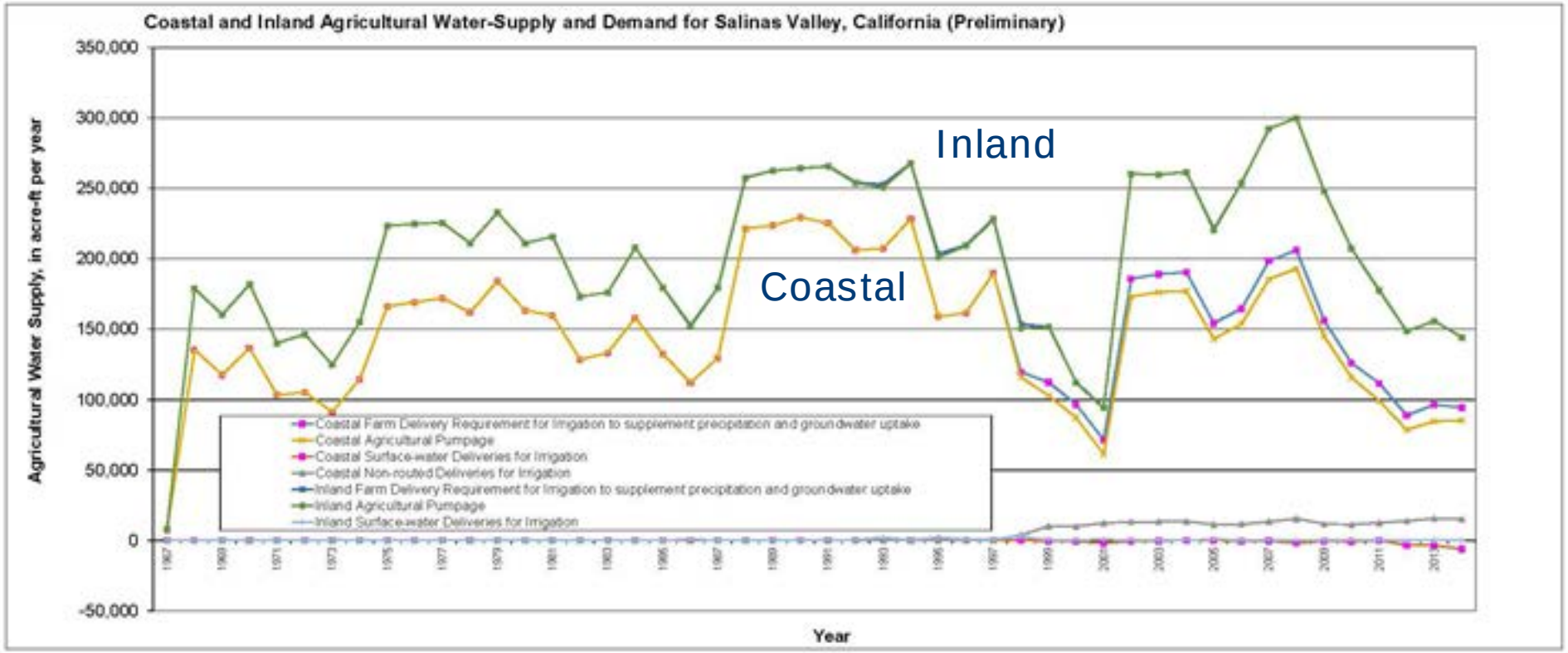




Pumpage (Acre-Ft/month):
Mean Error 523 Ac-ft/month, RMSE 1,516 Ac-Ft/month, 0.36% of Average total Agricultural Reported Pumpage, and 89% within 1,000 AC-ft/month

Summary Preliminary Water Budgets

Total Farm Delivery Requirement for Coastal and Inland Regions of Salinas Valley, CA



USGS science for a changing world

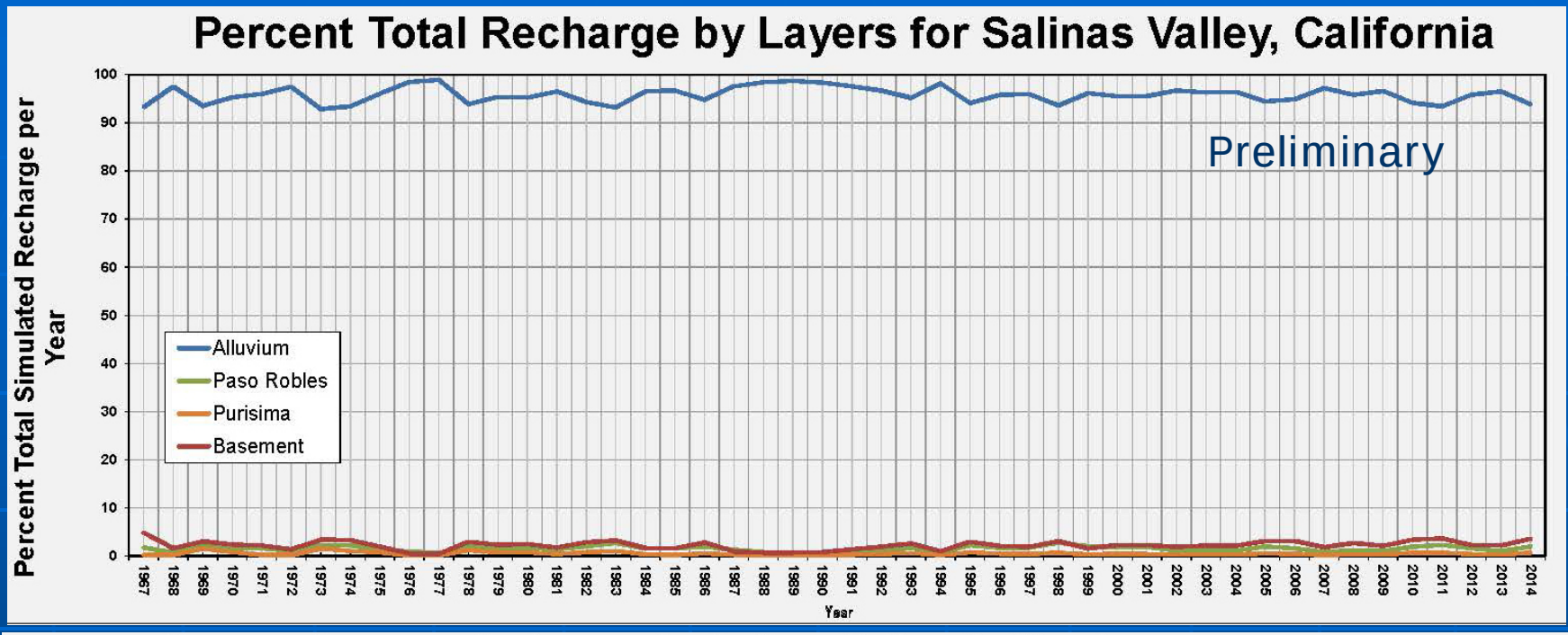
MONTEREY COUNTY WATER RESOURCES AGENCY 1947

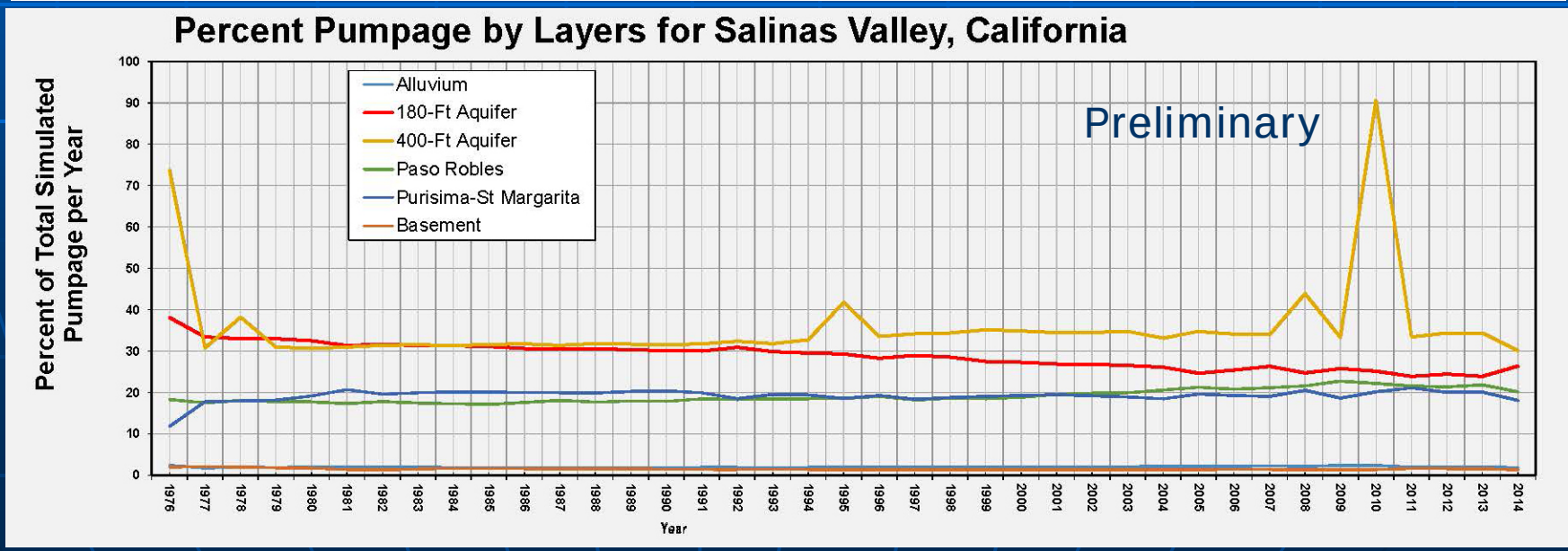
Distribution of Pumpage and Recharge by Aquifer Layer

Most Recharge Recent Alluvium aquifer

Typical Mismatch

Most Pumpage 180 & 400-ft aquifers





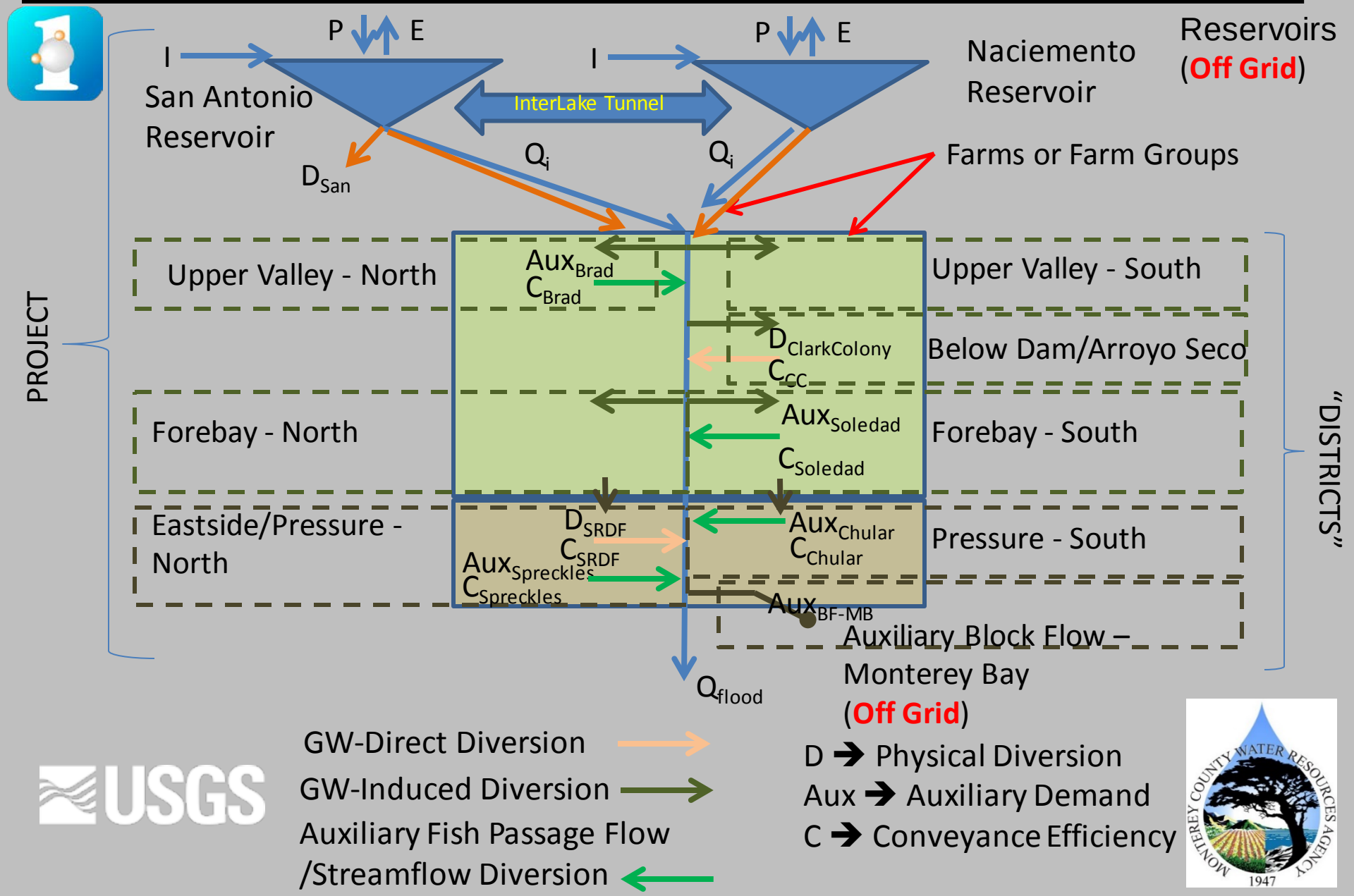
SVIHM Model Development & Uses

- Complete Model Calibration & Analysis 1967-2014
- Add additional Features (SWI & SWO)
- Updates for 2015 - 2017
- Assessment of Baseline Conditions
- Application to Inter-Lake Tunnel Operations
- Application to Build-Out Assessment 2045
- Application to USBR/USGS Water Smart Project for Salinas Valley/Carmel River Valley ➔ Assessment of Supply & Demand – Historical/Future + Adaptation/Mitigation
- SGMA(?)

MONTEREY COUNTY WATER RESOURCES AGENCY 1947

USGS science for a changing world

SCHEMATIC for Salinas Valley Project Surface-Water Operations (SWO)



Dynamic Linkage to San Antonio & Nacemiento Reservoirs

Reservoir Connection New Structure➔Grid-Mapped Identifiers

<u>Current FMP3</u>: Water Accounting Supply-and-Demand Units)

- Farm

<u>MF-OWHM:FMP4+Surface-Water Ops SWO</u>: (Simulates/Analyzes Multi-Level Accounting)

- Project → Irrigated lands with common SW supply
- District → Irrigated lands with common SW allocation
- Unit → Irrigated lands with common point(s) of diversion, charge, and credit (NOTE: Unit = Service Area)
- Farm → Irrigated lands with common set of SW and GW deliveries
- Auxiliary/OffGrid→ Additional flow requirements (Fish passage flows, treaties, external deliveries, etc.)

Supports <u>demand driven</u> & <u>prescribed</u> releases for supply-and-demand linkage for "agricultural" water-supply and environmental flows dependent on <u>Demand, Supply, & Conveyance</u>!!!

USGS science for a changing world

U.S. DEPARTMENT OF THE INTERIOR BUREAU OF RECLAMATION

MONTEREY COUNTY WATER RESOURCES AGENCY 1947

CONJUNCTIVE-USE ANALYSIS in the Salinas Valley and across Monterey Bay with One Water (MF-OWHM)

Thanks for your attention….Questions or Comments??

ONE WATER

USGS
science for a changing world