Evaluation of Restoration and Recharge Within Butte County Groundwater Basins

Recharge Constraints Analysis
Dual Systems

GEI CONSULTANTS
DAVIDS ENGINEERING
ERA ECONOMICS
LAND IQ

BUTTE WATER COMMISSION
JANUARY 3, 2018

Topics

- Task 2 – Preliminary GIS Assessment of Recharge Potential
  - Recharge Constraints Mapping
- Task 3 – Site Prioritization
  - Weighted Recharge Mapping
- Task 4 – Economic Evaluation of In-Lieu Groundwater Recharge
  - Dual System Analysis

Task 2 – Preliminary GIS Assessment and Mapping of Potential Groundwater Recharge Areas

- Data compilation
- Criteria development
- Alternatives definition
- Constraints mapping

Recharge Types

- Direct Recharge
  - Recharge Ponds
  - Field Flooding
  - Injection Wells
- Indirect Recharge
  - “In-Lieu” Recharge

Direct Recharge

Recharge Ponds

Considerations:

- Permeable soils
- Dedicated land area
- Recharges water table aquifer
  - Needs unsaturated area below
- Relatively low cost
- Operates year-round

Direct Recharge

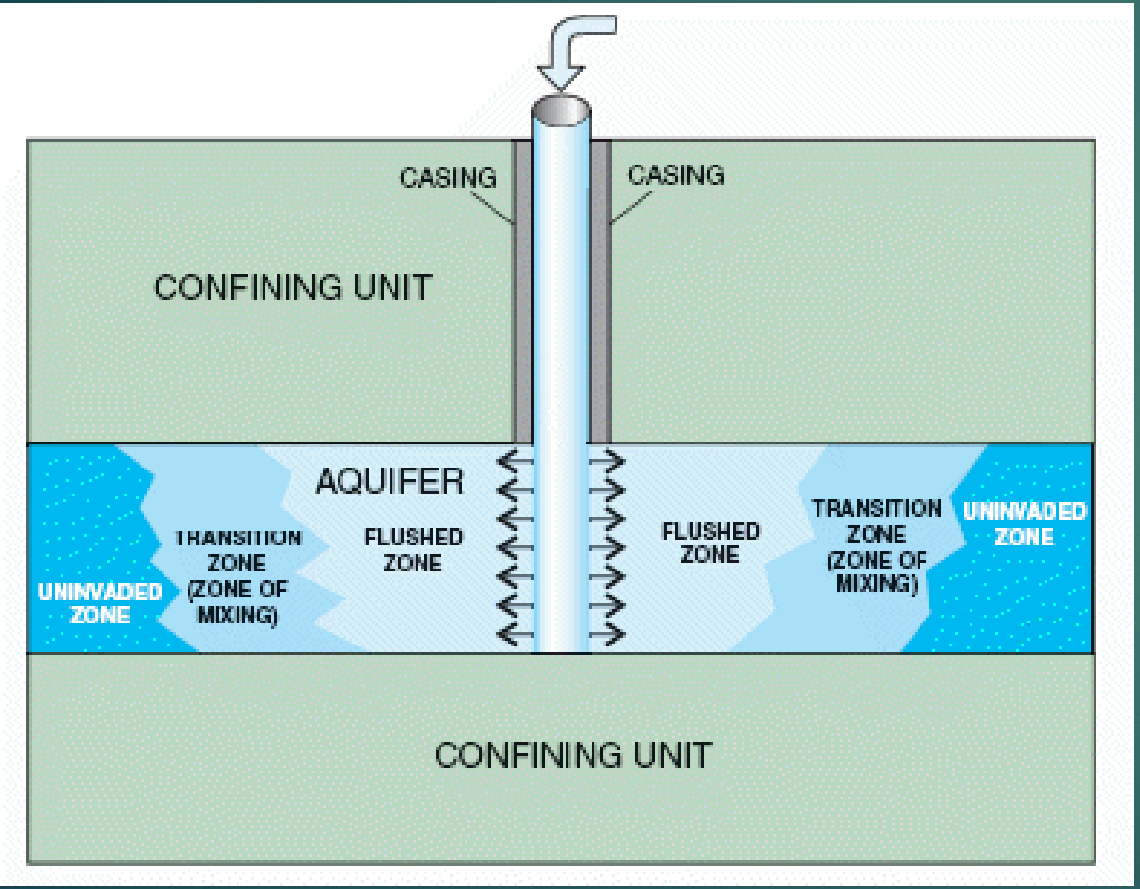
Field Flooding

Considerations:

- Permeable soils
- May require special preparation
- Recharges water table aquifer
  - Needs unsaturated area below
- Relatively low cost
- Seasonal use
  - Ability to use farm equipment

Direct Recharge

Injection Wells



Considerations:

- Low land requirements
- Needs high-quality water
- Can recharge confined aquifer
- Relatively high cost
- Year-round operation

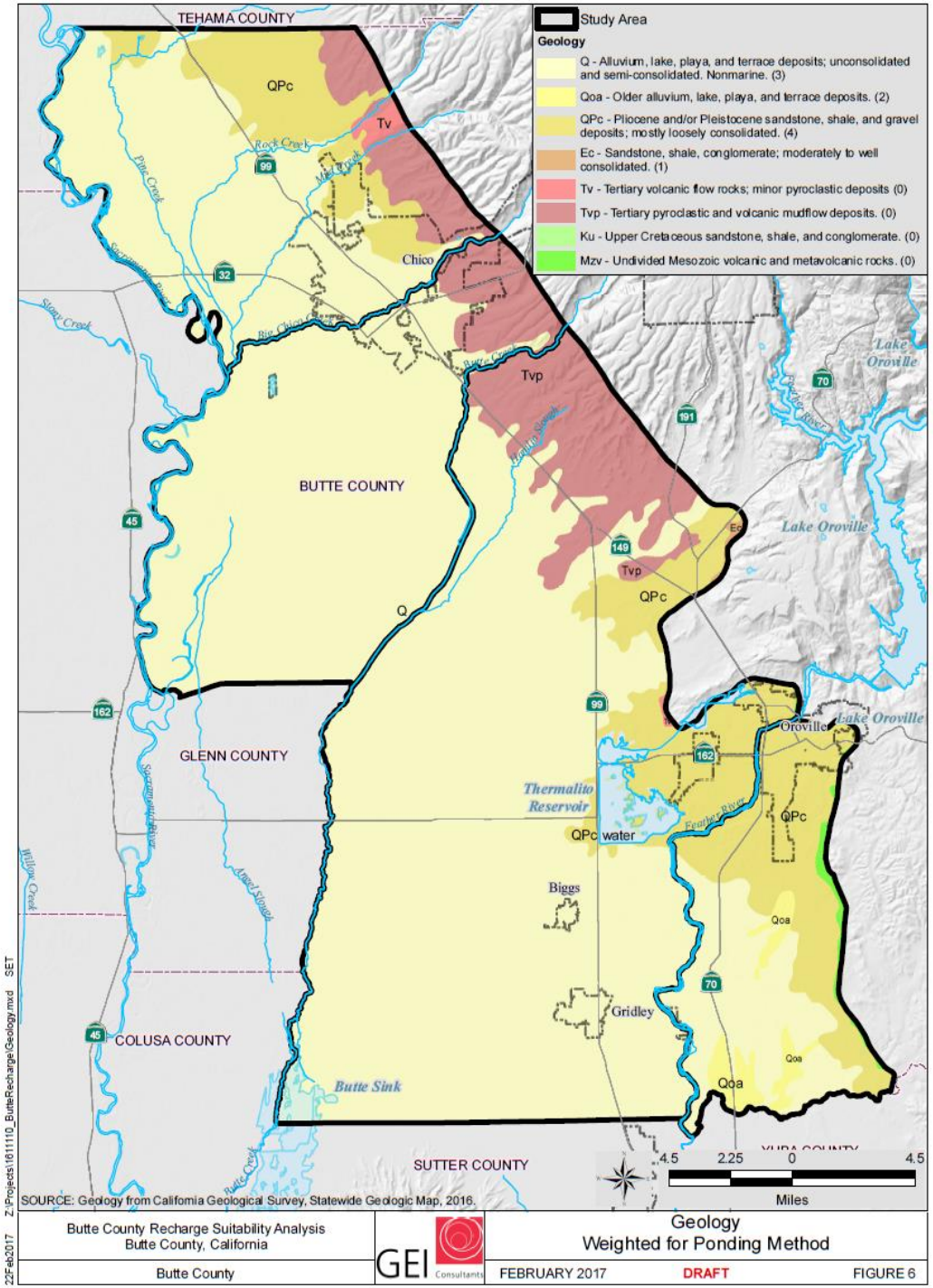
Indirect Recharge

In-Lieu Recharge

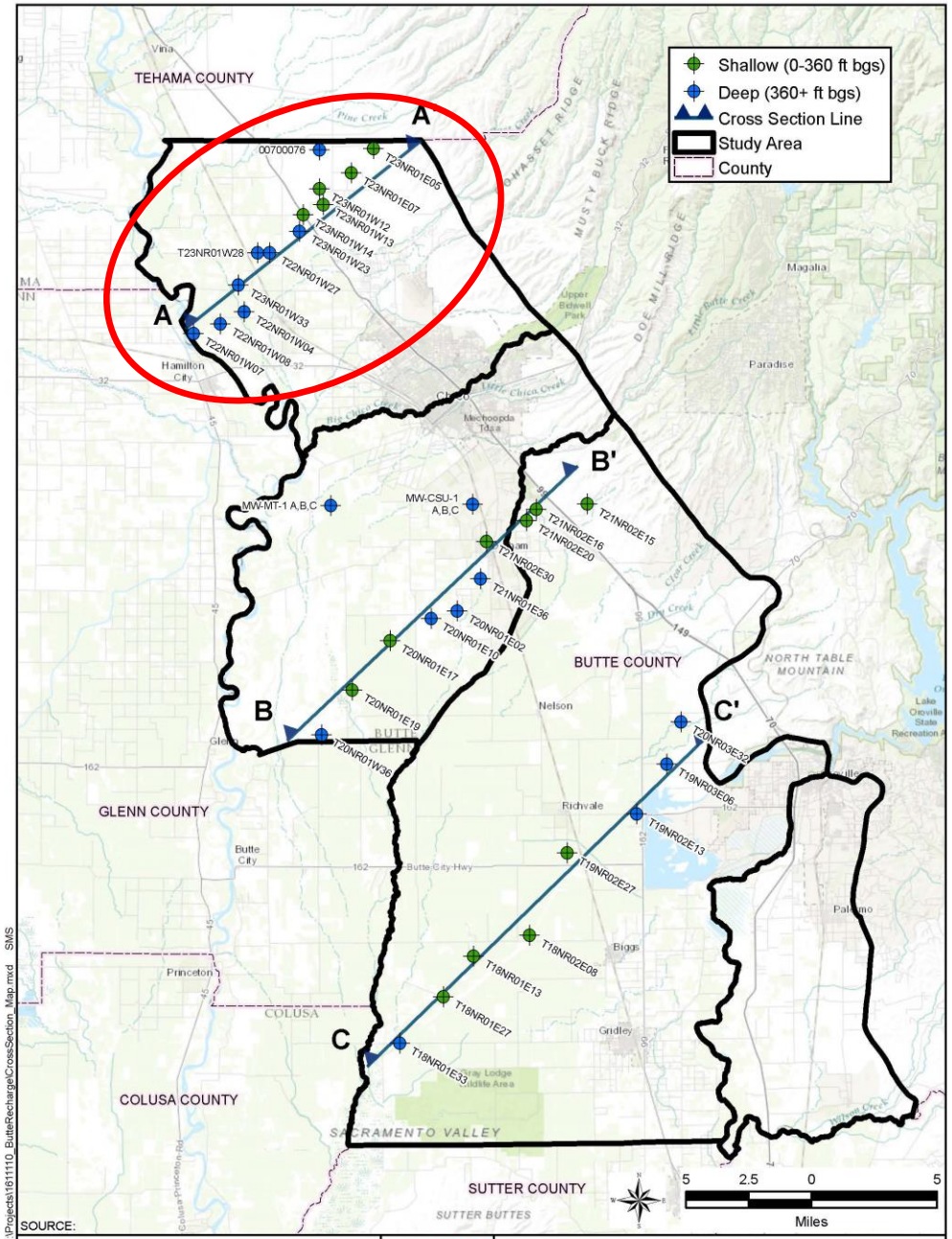
Considerations:

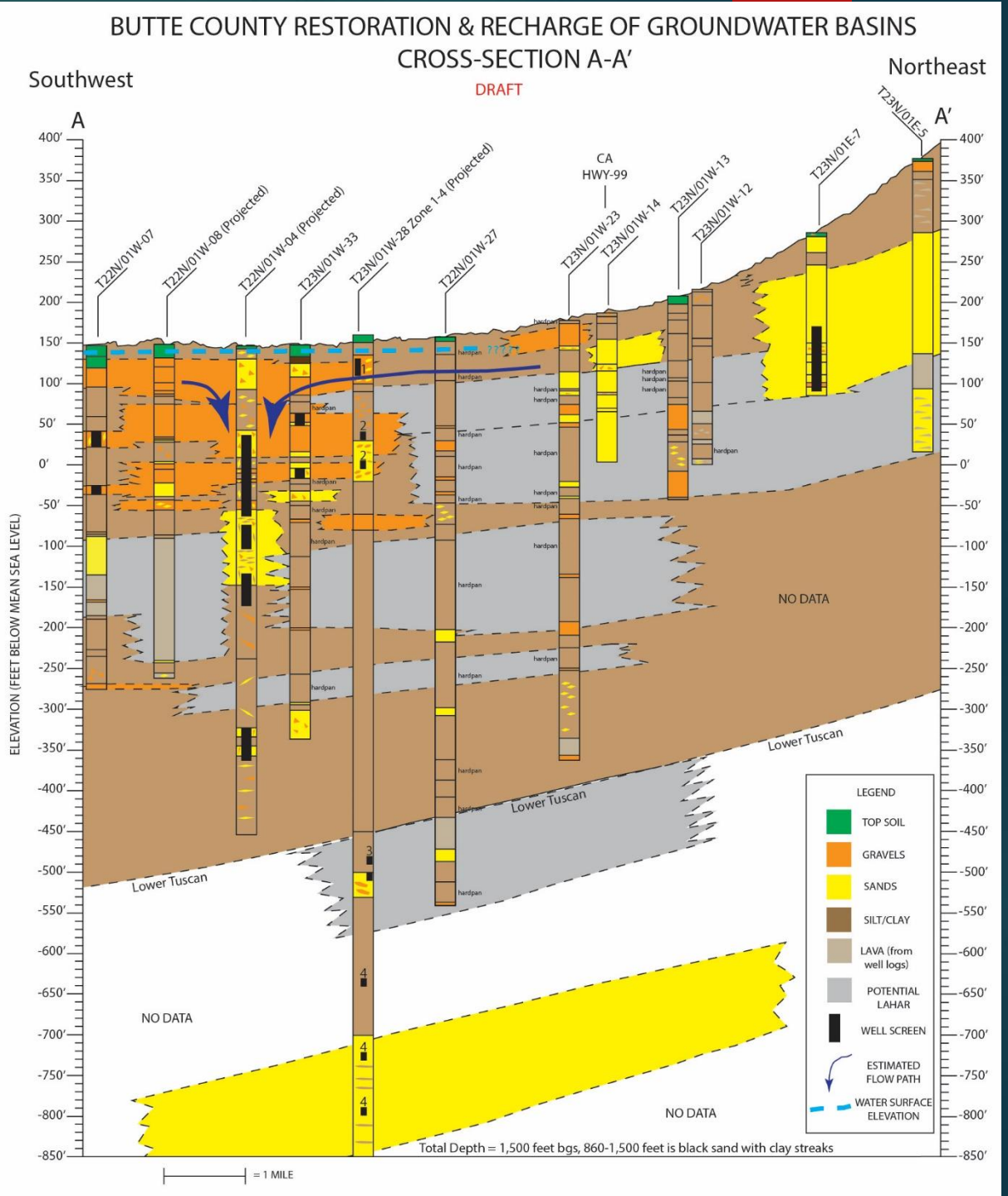
- Supply of surface water to areas using groundwater
- Can be both ag or urban
- Not restricted by soil type
- Recharges production aquifer
- Relatively low cost
- Seasonal use
- Conjunctive use of groundwater and surface water

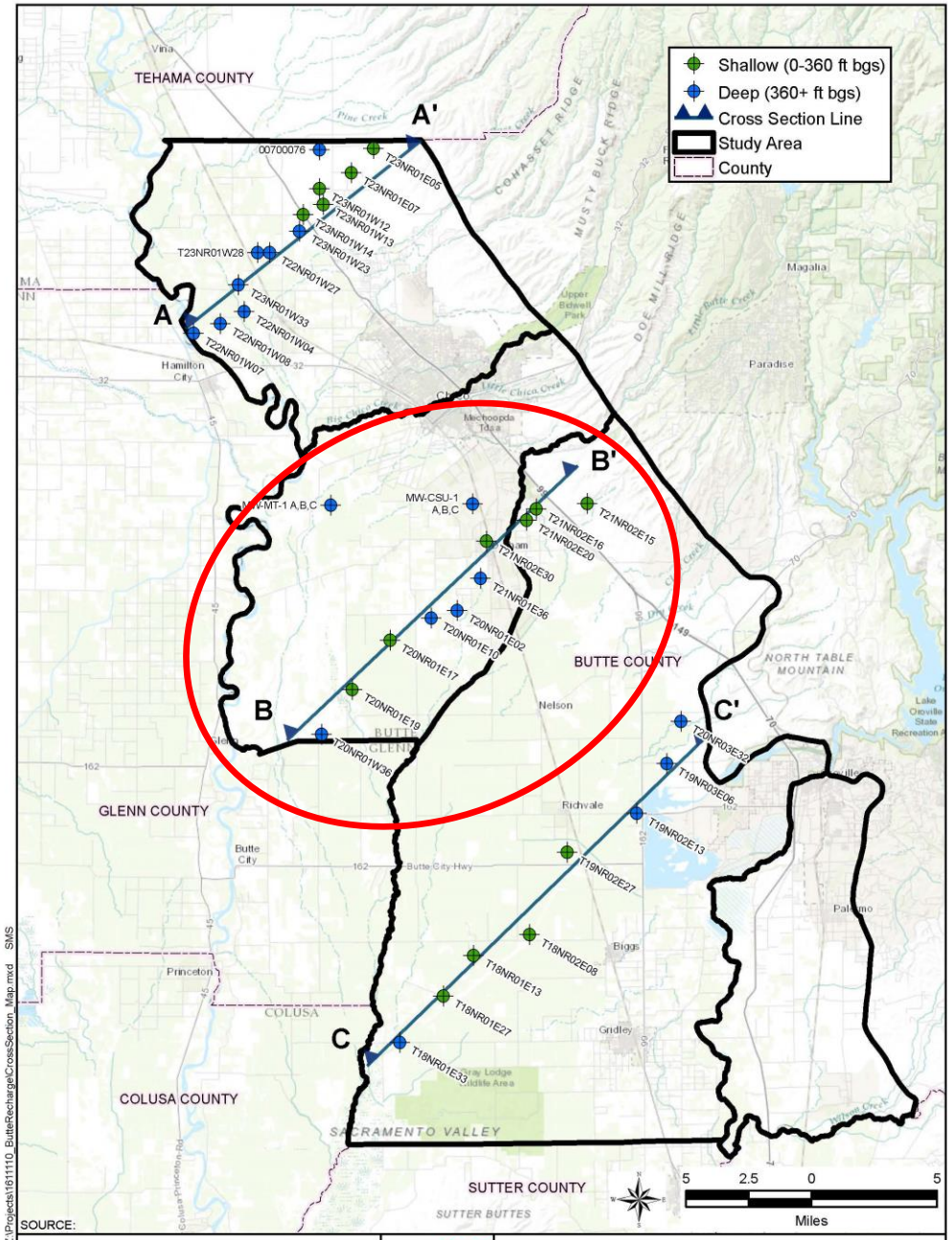
Geology

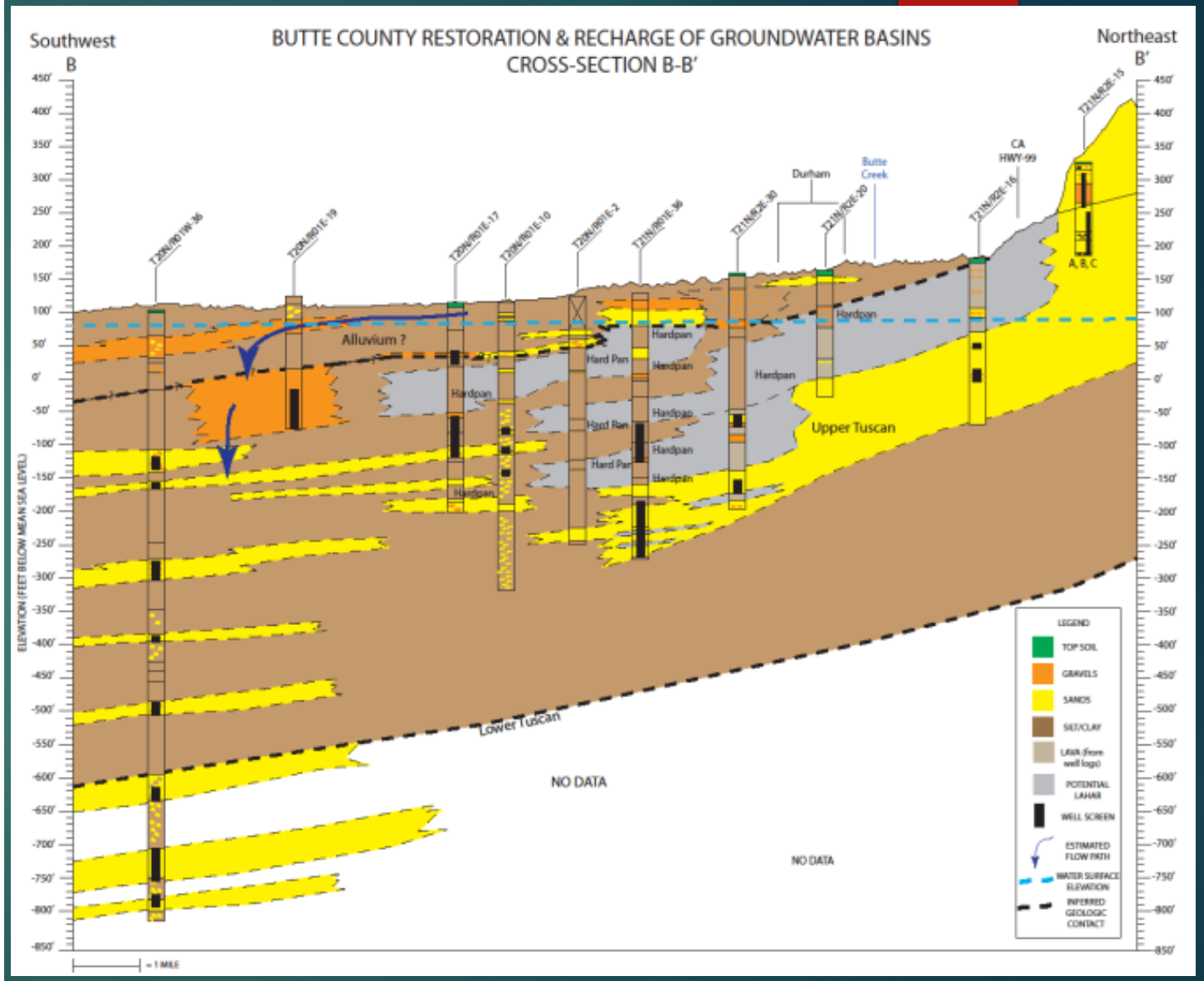


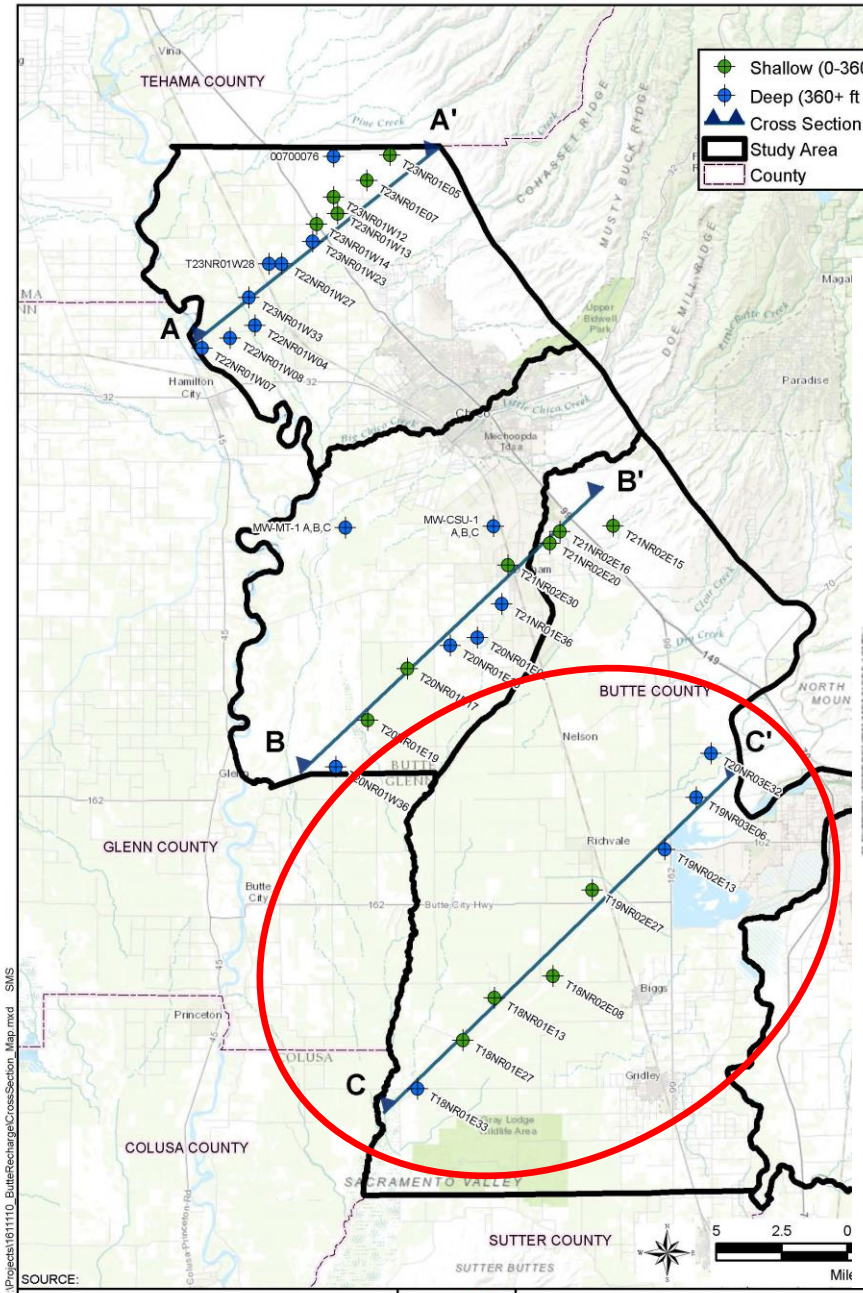
TEHAMA COUNTY
Study Area
Geology
Q - Alluvium, lake, playa, and terrace deposits; unconsolidated and semi-consolidated. Nonmarine. (3)
Qoa - Older alluvium, lake, playa, and terrace deposits. (2)
QPc - Pliocene and/or Pleistocene sandstone, shale, and gravel deposits; mostly loosely consolidated. (4)
Ec - Sandstone, shale, conglomerate; moderately to well consolidated. (1)
Tv - Tertiary volcanic flow rocks; minor pyroclastic deposits (0)
Tvp - Tertiary pyroclastic and volcanic mudflow deposits. (0)
Ku - Upper Cretaceous sandstone, shale, and conglomerate. (0)
Mzv - Undivided Mesozoic volcanic and metavolcanic rocks. (0)
QPc
Tv
Chico
Tvp
BUTTE COUNTY
Q
Ec
Lake Oroville
Oroville
GLENN COUNTY
Thermalito Reservoir
QPc water
Biggs
Gridley
Qoa
COLUSA COUNTY
Butte Sink
SUTTER COUNTY
4.5 2.25 0 4.5
Miles
SOURCE: Geology from California Geological Survey, Statewide Geologic Map, 2016.
Butte County Recharge Suitability Analysis
Butte County, California
Butte County
GEI Consultants
Geology
Weighted for Ponding Method
FEBRUARY 2017
DRAFT
FIGURE 6

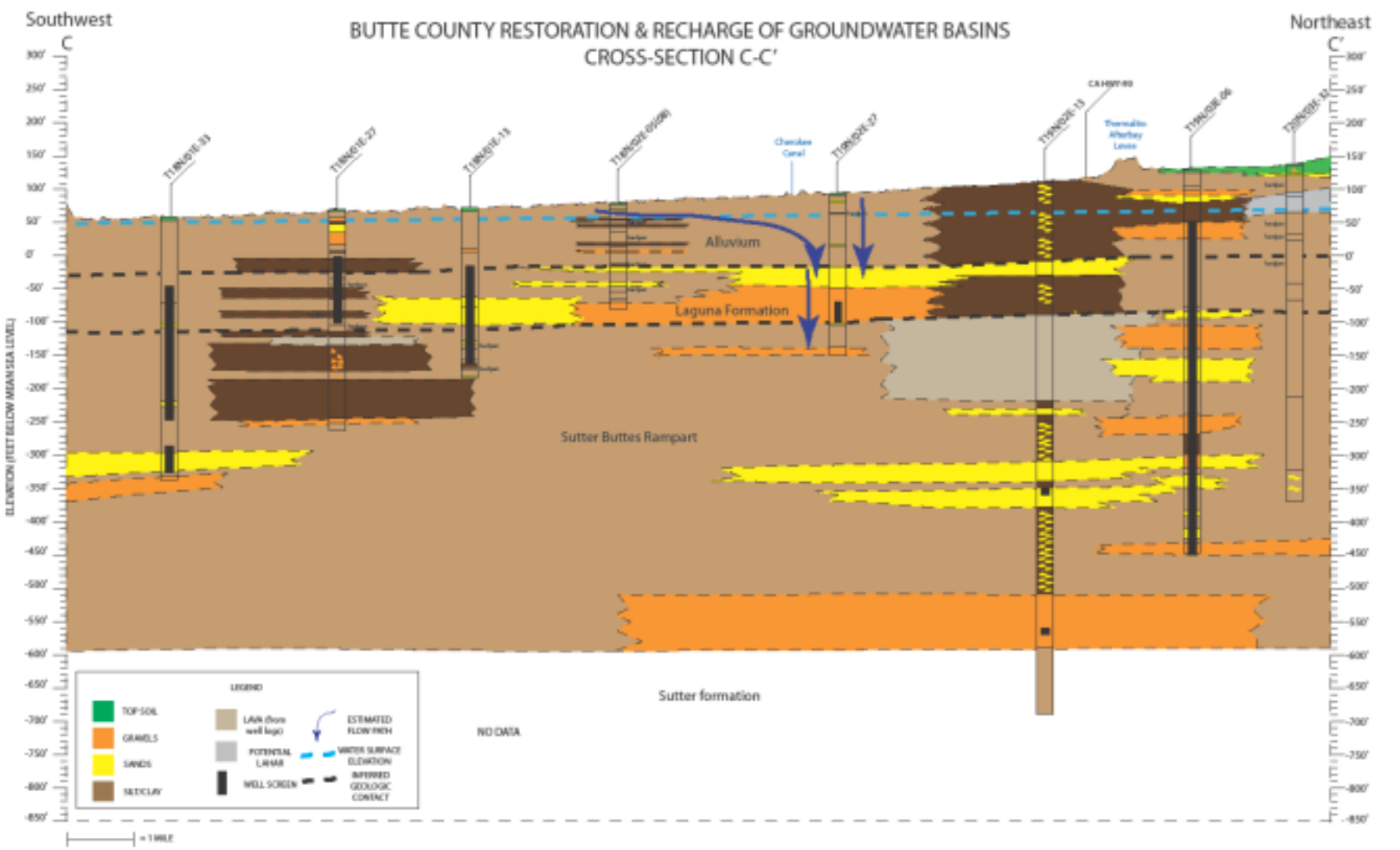

Shallow (0-360 ft bgs)
Deep (360+ ft bgs)
Cross Section Line
Study Area
County
TEHAMA COUNTY
BUTTE COUNTY
GLENN COUNTY
COLUSA COUNTY
SUTTER COUNTY
A
A'
B
B'
C
C'
00700076
T23NR01E05
T23NR01E07
T23NR01W12
T23NR01W13
T23NR01W14
T23NR01W23
T23NR01W28
T22NR01W27
T23NR01W33
T22NR01W04
T22NR01W08
T22NR01W07
MW-MT-1 A,B,C
MW-CSU-1 A,B,C
T21NR02E15
T21NR02E16
T21NR02E20
T21NR02E30
T21NR01E36
T20NR01E02
T20NR01E10
T20NR01E17
T20NR01E19
T20NR01W38
T20NR03E32
T19NR03E06
T19NR02E13
T19NR02E27
T18NR02E08
T18NR01E13
T18NR01E27
T18NR01E33
Vina
Magalia
Paradise
Chico
Nelson
Richvale
Biggs
Gridley
Butte City
Princeton
Hamilton City
NORTH TABLE MOUNTAIN
SACRAMENTO VALLEY
SUTTER BUTTES
5 2.5 0 5
Miles
SOURCE:
Butte County Recharge Suitability Analysis
Butte County, California
Butte County
GEI Consultants
Butte Cross Section Wells
JULY 2017
DRAFT
FIGURE ##
19Jul2017 Z:\Projects\1611110_ButteRechargeI\CrossSection_Map.mxd SMS


BUTTE COUNTY RESTORATION & RECHARGE OF GROUNDWATER BASINS
CROSS-SECTION A-A'
DRAFT
Southwest
Northeast
A
A'
ELEVATION (FEET BELOW MEAN SEA LEVEL)
T22N/01W-07
T22N/01W-08 (Projected)
T22N/01W-04 (Projected)
T23N/01W-33
T23N/01W-28 Zone 1-4 (Projected)
T22N/01W-27
CA HWY-99
T23N/01W-23
T23N/01W-14
T23N/01W-13
T23N/01W-12
T23N/01E-7
T23N/01E-5
hardpan
Lower Tuscan
NO DATA
LEGEND
TOP SOIL
GRAVELS
SANDS
SILT/CLAY
LAVA (from well logs)
POTENTIAL LAHAR
WELL SCREEN
ESTIMATED FLOW PATH
WATER SURFACE ELEVATION
Total Depth = 1,500 feet bgs, 860-1,500 feet is black sand with clay streaks
= 1 MILE


Shallow (0-360 ft bgs)
Deep (360+ ft bgs)
Cross Section Line
Study Area
County
TEHAMA COUNTY
GLENN COUNTY
COLUSA COUNTY
SUTTER COUNTY
BUTTE COUNTY
A
A'
B
B'
C
C'
Miles
SOURCE:
Butte County Recharge Suitability Analysis
Butte County, California
Butte County
GEI Consultants
Butte Cross Section Wells
JULY 2017
DRAFT
FIGURE ##


BUTTE COUNTY RESTORATION & RECHARGE OF GROUNDWATER BASINS
CROSS-SECTION B-B'
Southwest
B
Northeast
B'
ELEVATION (FEET BELOW MEAN SEA LEVEL)
Alluvium ?
Upper Tuscan
Lower Tuscan
NO DATA
NO DATA
Hardpan
Hard Pan
Durham
Butte Creek
CA HWY-99
LEGEND
TOP SOIL
GRAVELS
SANDS
SILT/CLAY
LAVA (from well logs)
POTENTIAL LAHAR
WELL SCREEN
ESTIMATED FLOW PATH
WATER SURFACE ELEVATION
INFERRED GEOLOGIC CONTACT

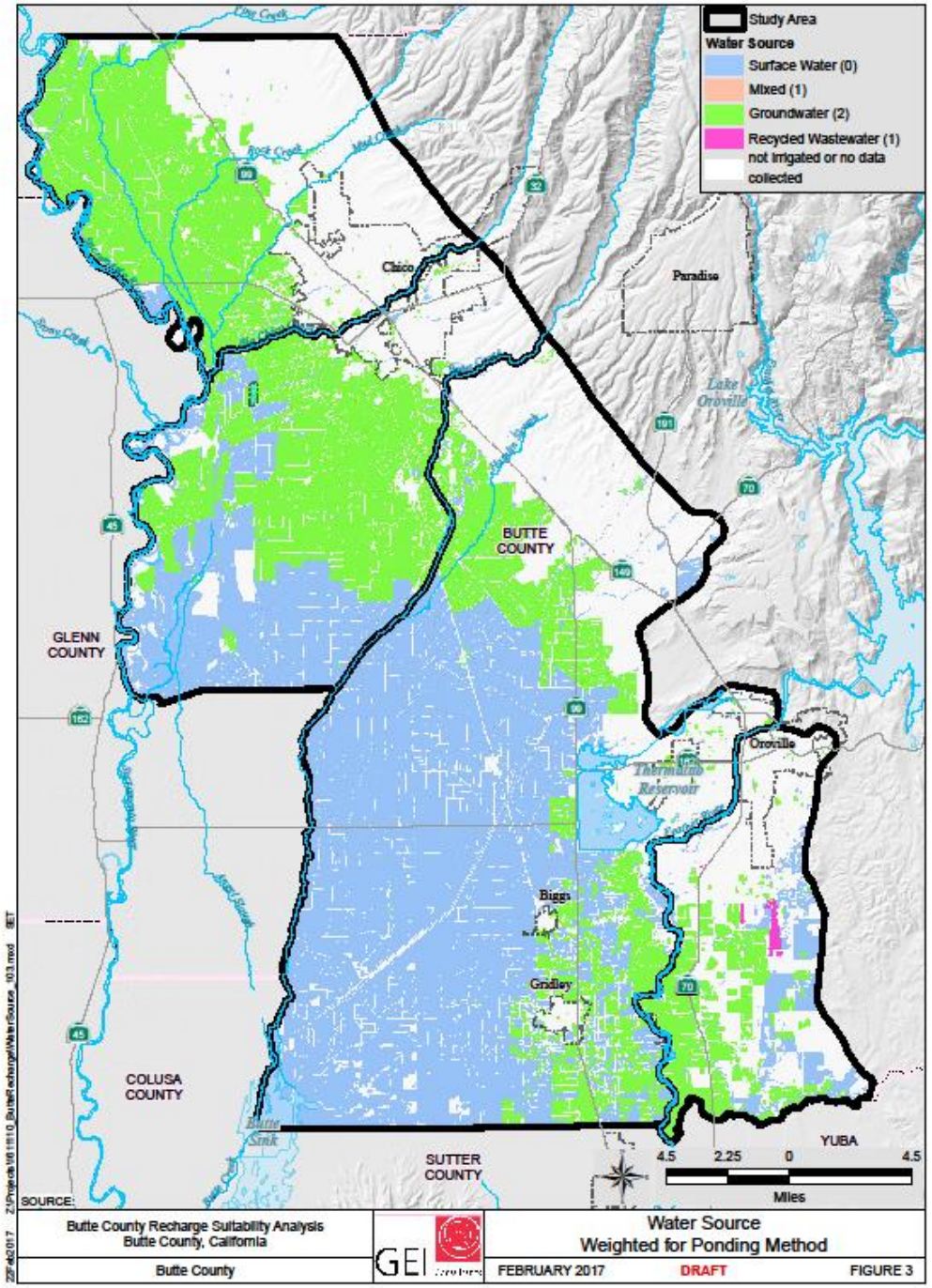




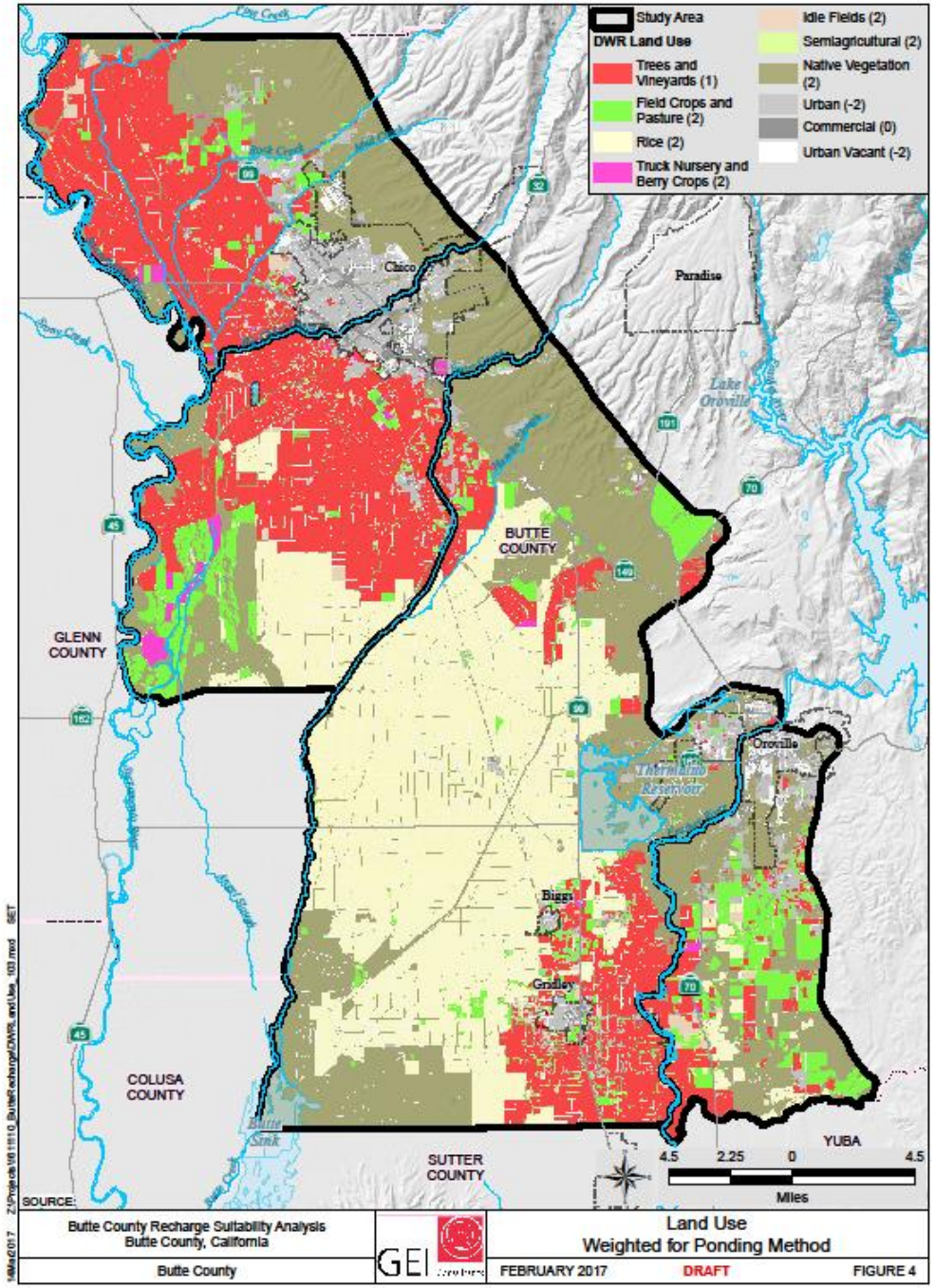
Butte County Recharge Suitability Analysis Butte County, California	GEI Consultants	Butte Cross Section Wells
Butte County	JULY 2017 DRAFT	FIGURE ##

Z:\Projects\1611110_ButteRechargeCrossSection_Map.mxd SMS
19Jul2017

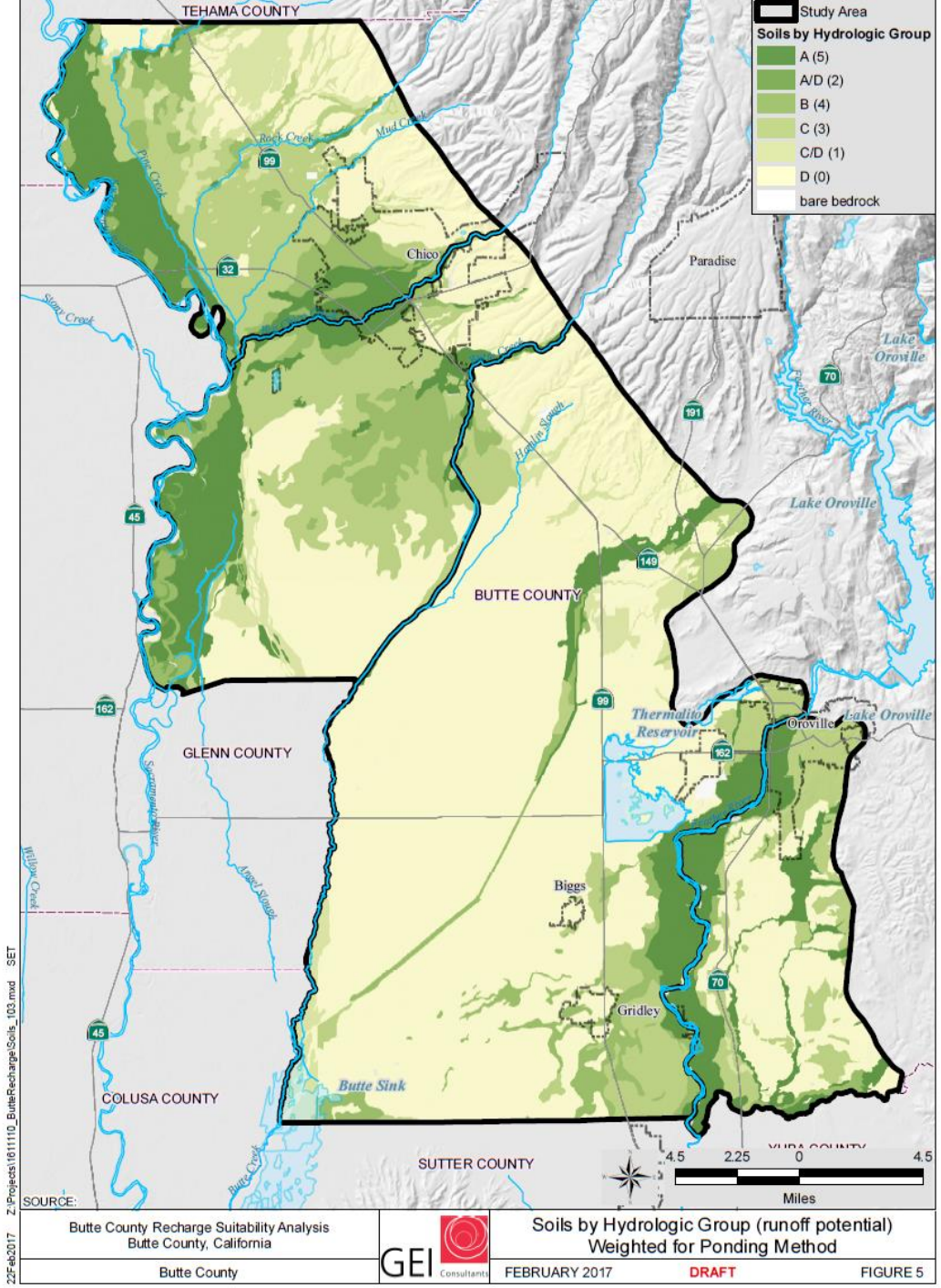
Water Source

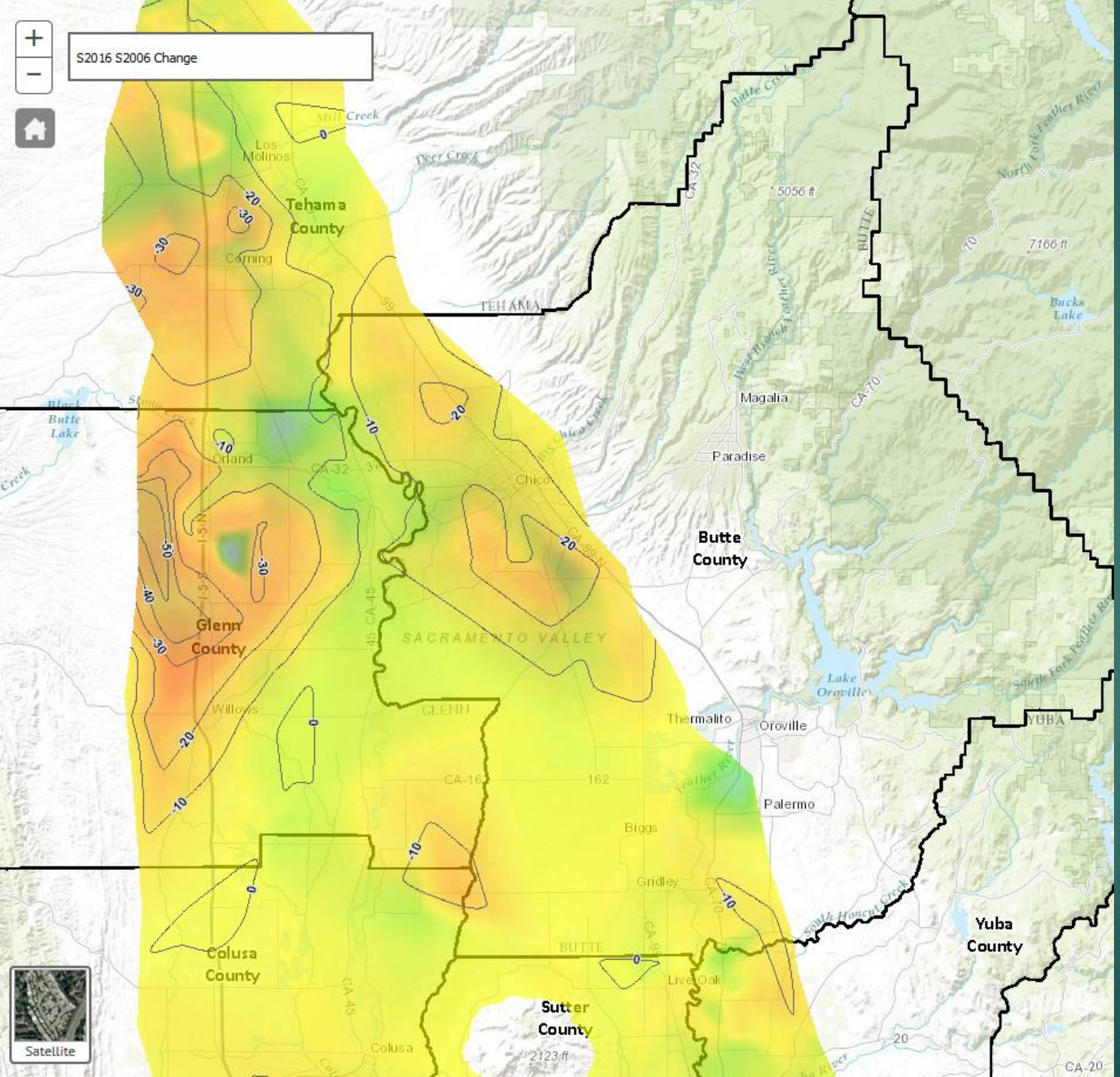


DWR Land Use


Study Area
DWR Land Use
Trees and Vineyards (1)
Field Crops and Pasture (2)
Rice (2)
Truck Nursery and Berry Crops (2)
Idle Fields (2)
Semiagricultural (2)
Native Vegetation (2)
Urban (-2)
Commercial (0)
Urban Vacant (-2)
Chico
Paradise
Lake Oroville
BUTTE COUNTY
GLENN COUNTY
Oroville
Thermalito Reservoir
Biggs
Gridley
COLUSA COUNTY
Butte Sink
SUTTER COUNTY
YUBA
4.5 2.25 0 4.5
Miles
SOURCE:
Butte County Recharge Suitability Analysis
Butte County, California
Butte County
GEI
Land Use
Weighted for Ponding Method
FEBRUARY 2017
DRAFT
FIGURE 4

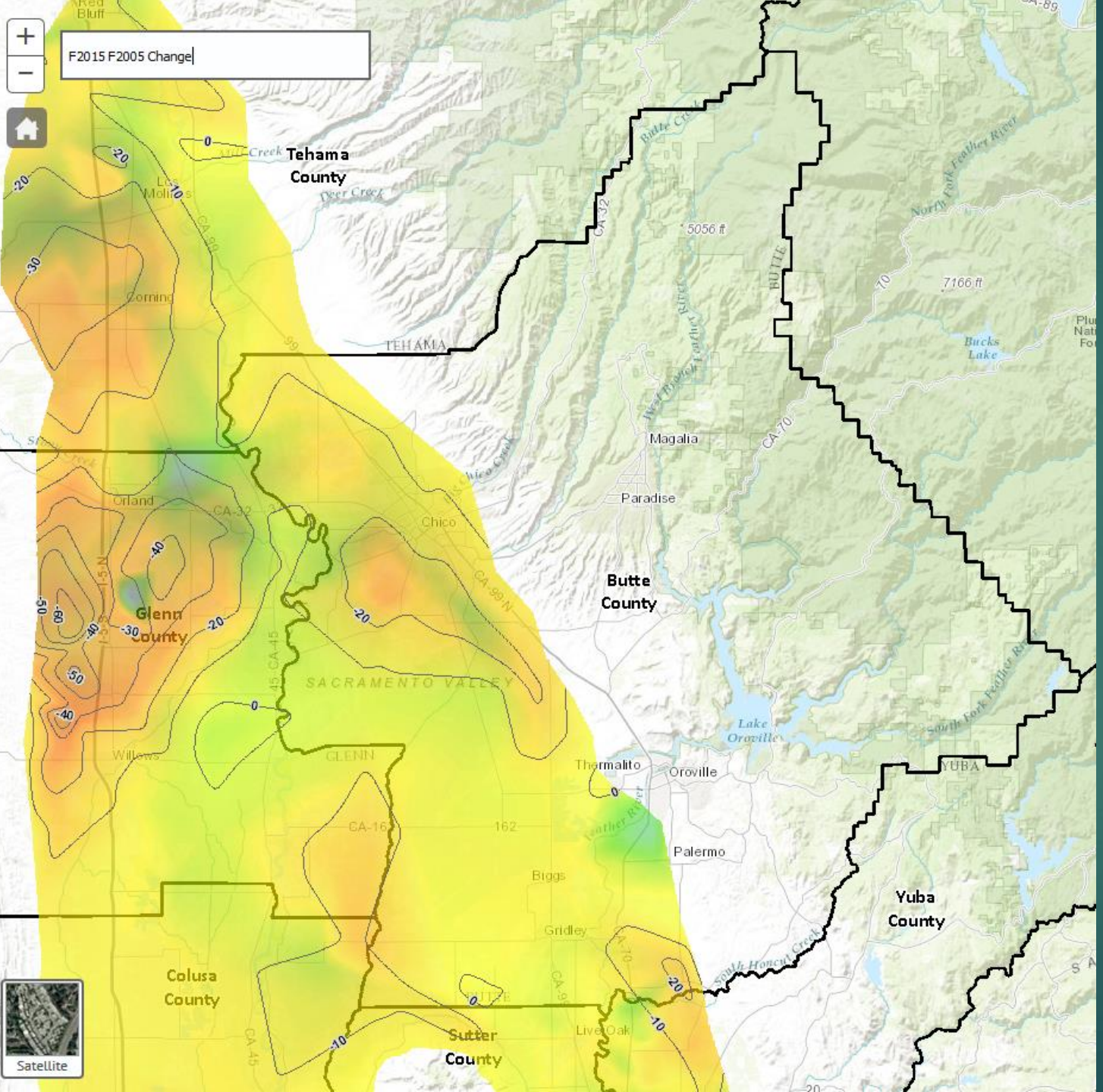
Hydrologic Soils Group





Spring 2006-16 Change

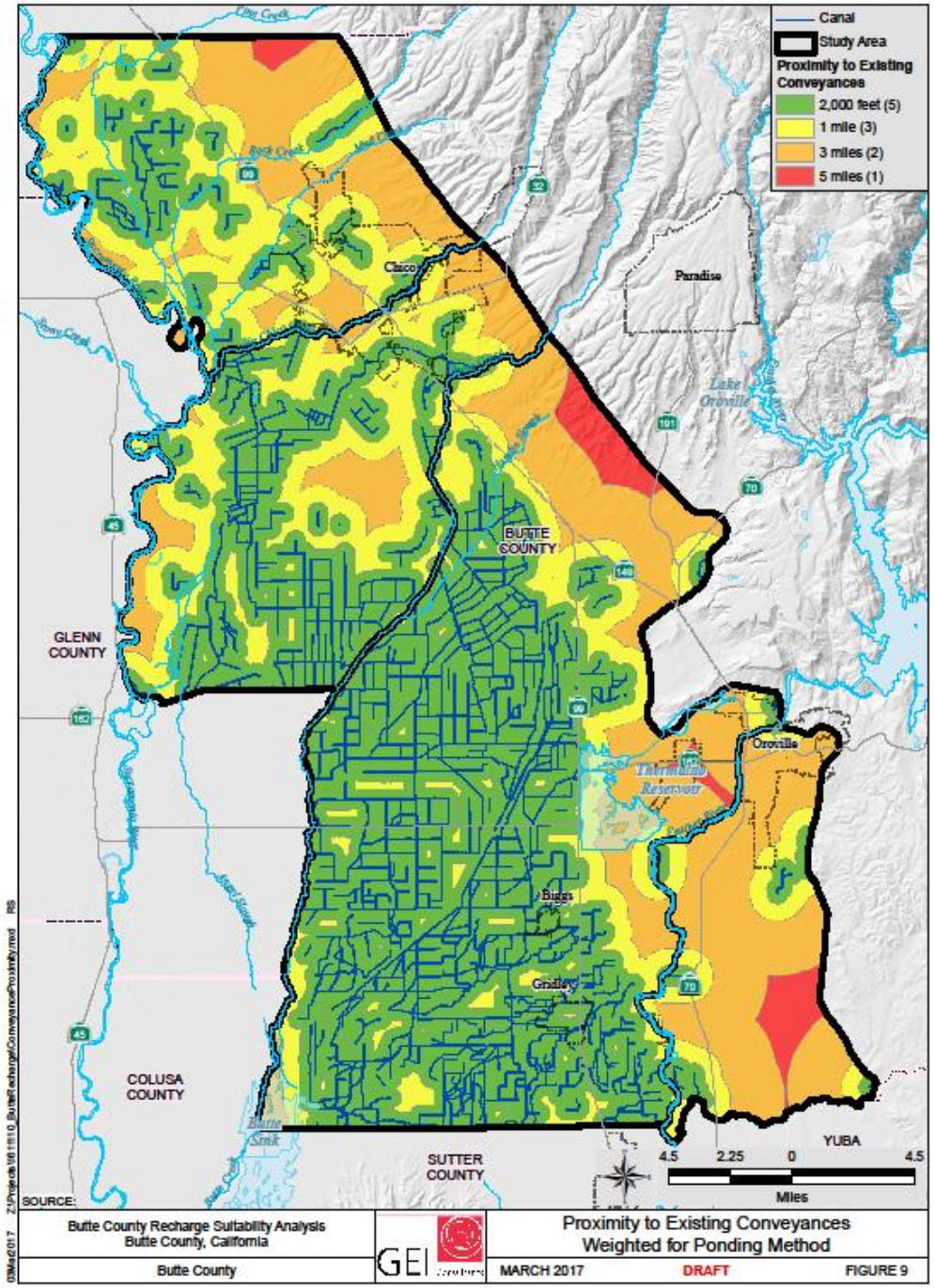
- Surrogate for subsidence potential
- Subsidence can occur from the initial dewatering of fine-grained soils
- If water levels are maintained above historical low levels, subsidence is not likely



Fall 2005-15 Change

- Surrogate for subsidence potential
- Subsidence can occur from the initial dewatering of fine-grained soils
- If water levels are maintained above historical low levels, subsidence is not likely

Proximity to Conveyances



Landcover

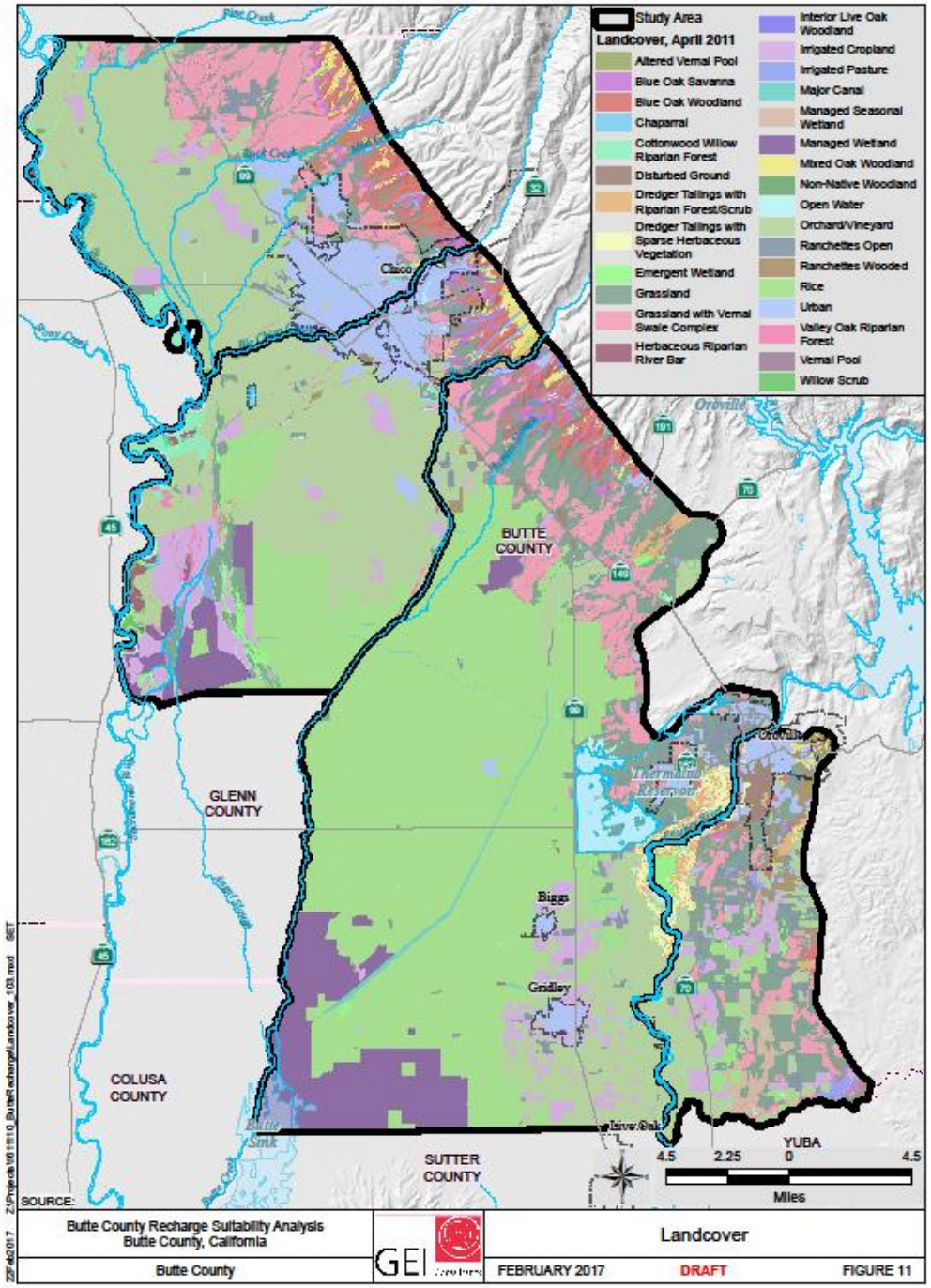

Study Area
Landcover, April 2011
Altered Vernal Pool
Blue Oak Savanna
Blue Oak Woodland
Chaparral
Cottonwood Willow Riparian Forest
Disturbed Ground
Dredger Tailings with Riparian Forest/Scrub
Dredger Tailings with Sparse Herbaceous Vegetation
Emergent Wetland
Grassland
Grassland with Vernal Swale Complex
Herbaceous Riparian River Bar
Interior Live Oak Woodland
Irrigated Cropland
Irrigated Pasture
Major Canal
Managed Seasonal Wetland
Managed Wetland
Mixed Oak Woodland
Non-Native Woodland
Open Water
Orchard/Vineyard
Ranchettes Open
Ranchettes Wooded
Rice
Urban
Valley Oak Riparian Forest
Vernal Pool
Willow Scrub
Chico
Oroville
BUTTE COUNTY
GLENN COUNTY
COLUSA COUNTY
SUTTER COUNTY
YUBA
Biggs
Gridley
Thermalito Reservoir
Butte Sink
4.5 2.25 0 4.5
Miles
SOURCE:
Butte County Recharge Suitability Analysis
Butte County, California
Butte County
GEI
Landcover
FEBRUARY 2017
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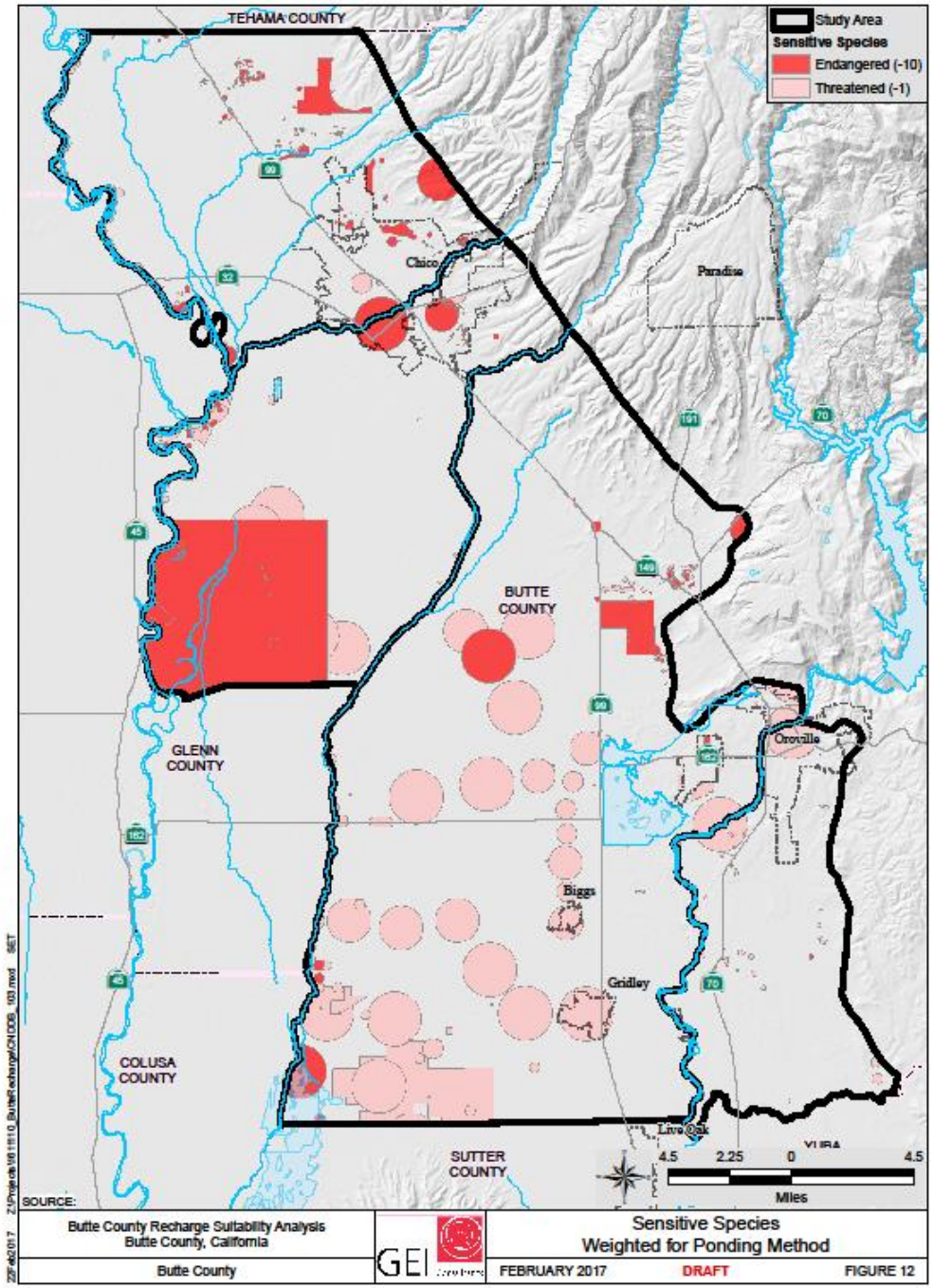
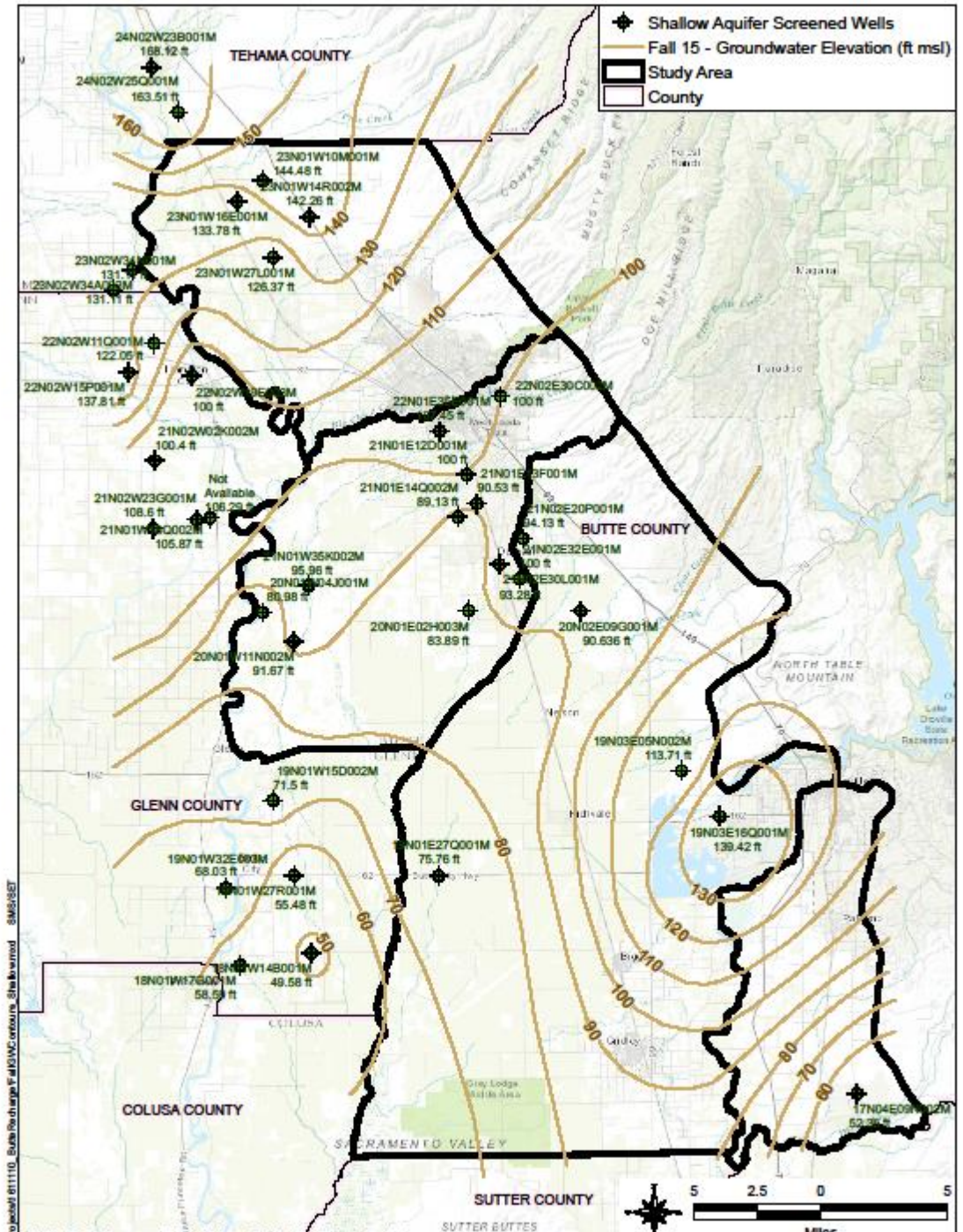
FIGURE 11

Sensitive Species

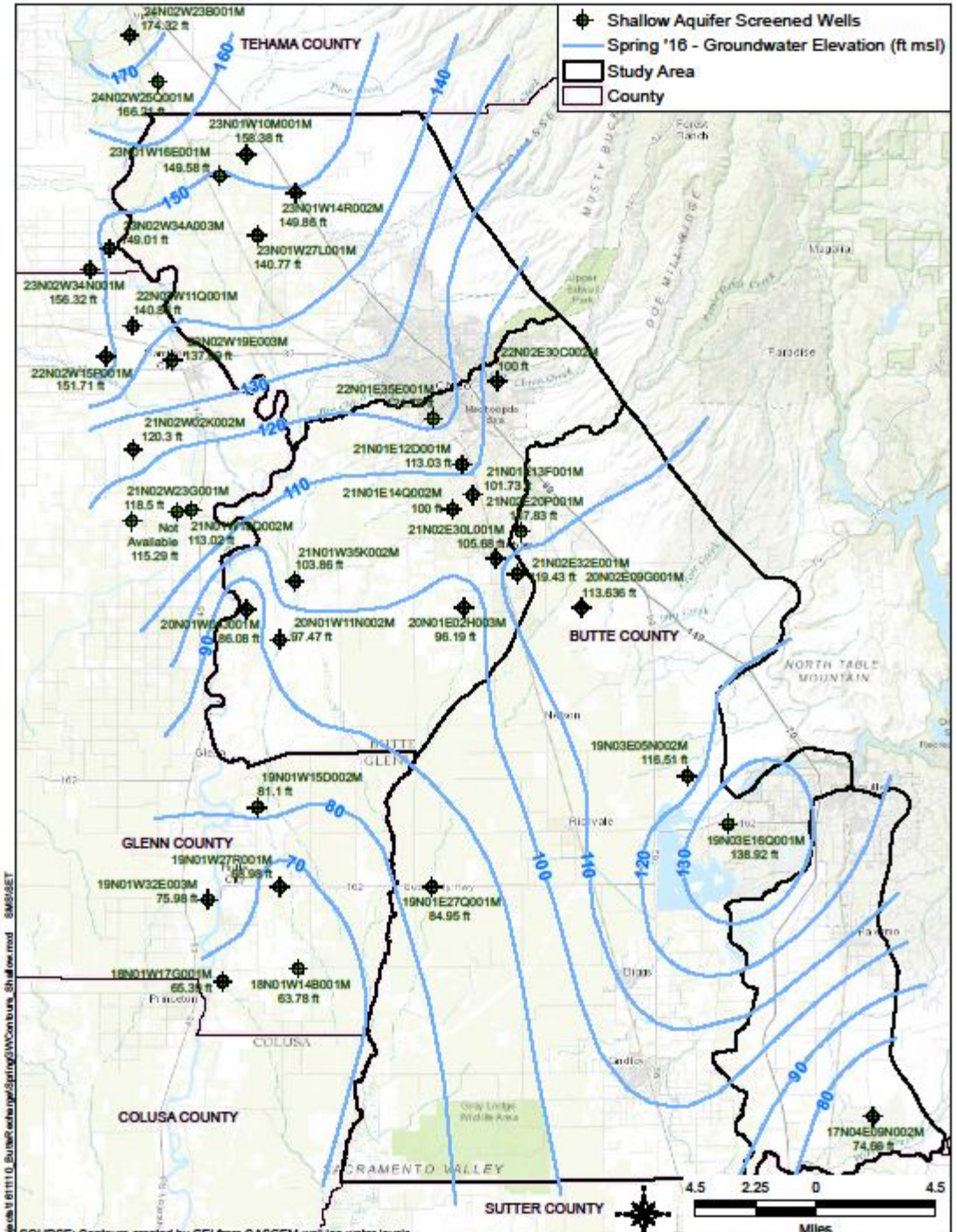


Groundwater Elevation Contours

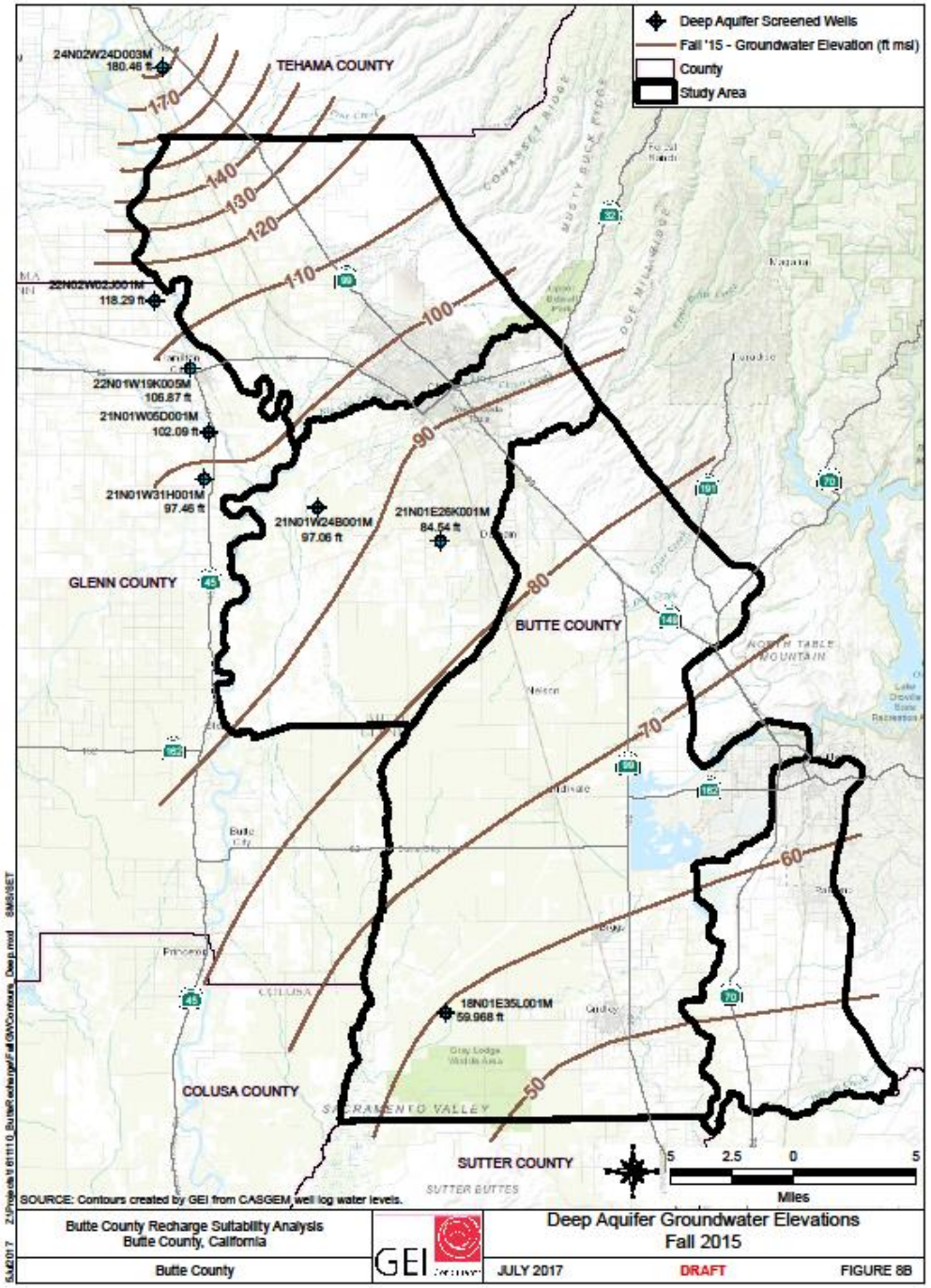
- DWR CASGEM data
- Selected wells with a consistent measurement history, high quality well logs, and publicly available locations
- Sorted by into two depth categories
  - Well screens shallower than 350 feet (shallow wells, including domestic wells)
  - Well screens deeper than 350 feet (deep wells in lower semi-confined aquifer)
- General groundwater flow direction
  - Westerly in the area near Chico
  - Southwesterly in the southern area



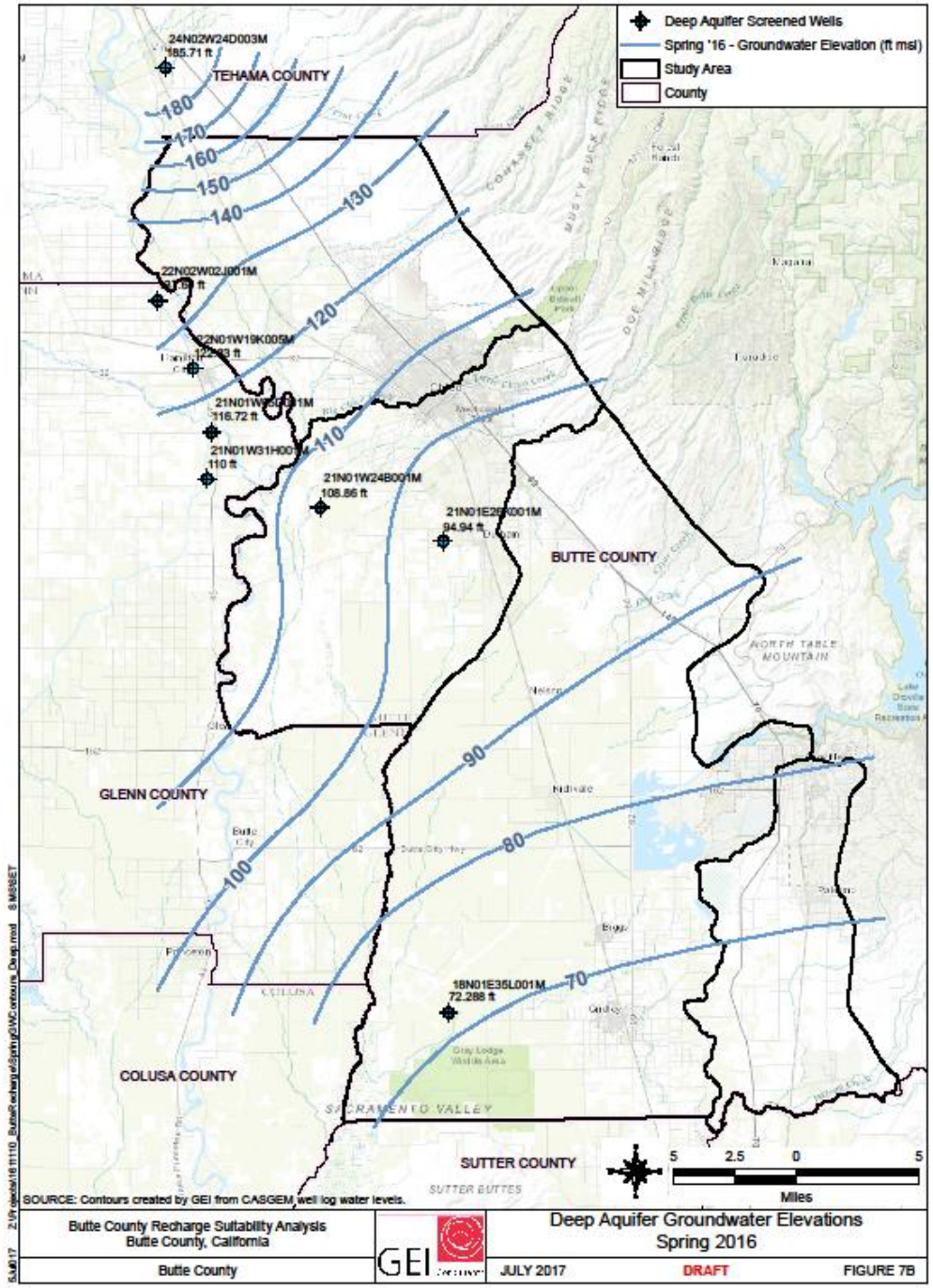
Shallow Aquifer GW Elevation Fall 2015



Shallow Aquifer GW Elevation Spring 2015



Deep Aquifer GW Elevation Fall 2015



Deep Aquifer GW Elevation Fall 2015

Task 3 – Site Prioritization Mapping

- Alternatives definition
- Weighted criteria mapping

Preliminary Constraints Maps

- Recharge Ponds
- Field Flooding
- Injection Wells
- In-Lieu

Recharge Criteria

Spreading Basins/ Field Flooding*

Unconfined aquifer system

Relatively large area (10+ acres)

Permeable soils with no impermeable layers in near-surface

Significant unsaturated depth below surface

Hydraulic connection with production aquifers

Ability to perform routine maintenance (e.g. scraping of pond sediments)

Unsaturated permeable margin areas beyond pond boundaries

Source supply compatible with native groundwater. No TDS constraint.

Proximity to conveyances

Injection/ASR

Confined or semi-confined aquifer system

Low land requirements (<1 acre)

Transmissive target aquifer

"Head room" in aquifer, i.e. pressure surface significantly below ground surface

Number of wells within pressurized management zone

High quality (drinking water or better) source required

In-lieu

No aquifer constraint

Land presently irrigated with groundwater

Ability to serve water during irrigation season / proximity to conveyances

Water table below root zone

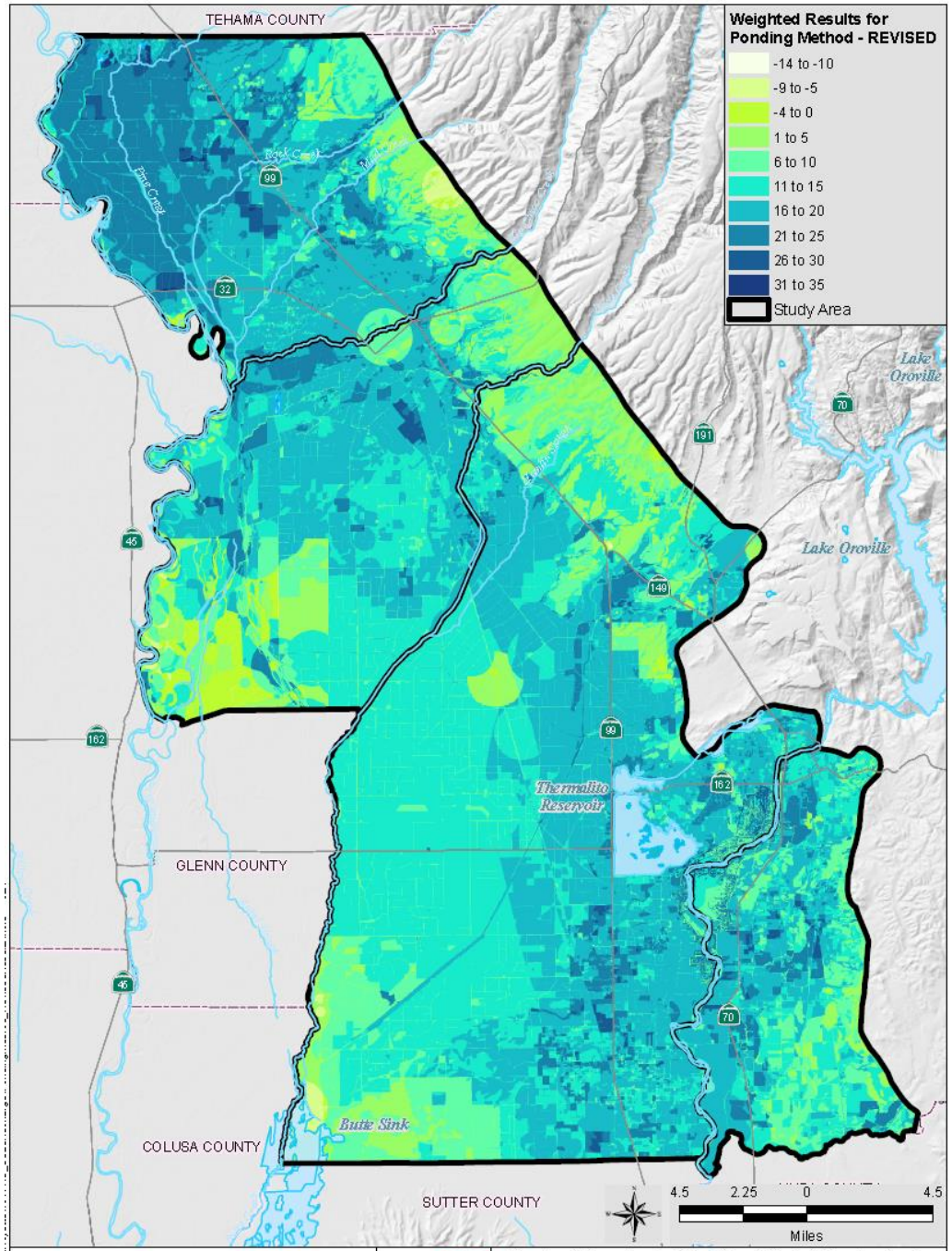
Good quality supply suitable for agronomic application. Possible treatment for drip irrigation uses.

***Uncropped during spreading or crops tolerant of flooding**

Criteria Used for Recharge Constraints Maps

Consideration		GIS Layer Source	Recharge Type			
			Pond	Field Flooding	Injection	In-lieu
Land Use (Possible Score)						
	Agricultural Water Supply	DWR Land Use 2015	(0 for Surface, 1 for Mixed Use, 2 for Groundwater)	(0 for Surface, 1 for Mixed Use, 2 for Groundwater)	0	(-5 for Surface, 0 for Mixed Use, 5 for Groundwater)
	Use Type	DWR Land Use 2015	(-2 for Urban, 0 for Commercial or unknown, 1 for Citrus, Deciduous, Vineyards, 2 for Truck, Field, Grain and Hay, Rice, Pasture, Idle and Native)	(-2 for Urban, 0 for Commercial, unknown, Citrus, Deciduous, 1 for Vineyards,Truck, 2 for Field, Grain and Hay, 3 for Rice and Pasture, 4 for Idle and Native)	0	(0 for Urban, Commercial, Idle, Native, unknown, 2 for Citrus, Deciduous, Vineyards, Truck, Field, Grain and Hay, Rice, and Pasture)
	Crop ET	combine DWR Land Use 2015 and Water Use Spreadsheet (2000-2015) from Davids Eng	0	0	0	(0 for Unknown or Idle, 2 for 20 to 30 in/yr, 4 for 30 to 40, 6 for 40 to 50)
Percolation Rate (Possible Score)						
	SAGBI Mod Soil data (assumes that all soils with restrictive layers have been removed by deep tillage)	rat_grp (Excellent, Good, Moderately Good, Moderately Poor, Poor, Very Poor)	Excellent=5 Good =4 Moderately Good=3 Moderately Poor=2 Poor=1 Very Poor = 0	Excellent=5 Good =4 Moderately Good=3 Moderately Poor=2 Poor=1 Very Poor = 0	0	0
	Bedrock Geology	CGS 2015 Statewide Geologic Map	4 for QPc, 3 for Q, 2 for Qoa, 1 for Ec	4 for QPc, 3 for Q, 2 for Qoa, 1 for Ec	4 for QPc, 3 for Q, 2 for Qoa, 1 for Ec	0
	Depth to groundwater	GEI	Shallow Aquifer GW Elevations 1 point per 20' contour (1-6) for Spring 2016 and Fall 2015	Shallow Aquifer GW Elevations 1 point per 20' contour (1-6) for Spring 2016 and Fall 2015	Deep Aquifer GW Elevations 1 point per 20' contour (1-6) for Spring 2016 and Fall 2015	0
Location (Possible Score)						
	Proximity to Existing Conveyance	need to modify Hydrology layer provided by County	(5 for 2000 feet from conveyance, 3 for 1 mile, 2 for 1 to 3 miles, 1 for 3 to 5 miles, 0 >5 miles)	(5 for 2000 feet from conveyance, 3 for 1 mile, 2 for 1 to 3 miles, 1 for 3 to 5 miles, 0 >5 miles)	(5 for 2000 feet from conveyance, 3 for 1 mile, 2 for 1 to 3 miles, 1 for 3 to 5 miles, 0 >5 miles)	(5 for 2000 feet from conveyance, 3 for 1 mile, 2 for 1 to 3 miles, 1 for 3 to 5 miles, 0 >5 miles)
	Minimum parcel size	County	(0 for < 5 ac, 1 for 5 to 10 ac, 2 for 10 to 30 ac, 3 for 30 to 80 ac, 4 > 80ac)	(0 for < 20 ac, 1 for 20 to 40 ac, 2 for 40 to 80 ac, 3 for 80 to 120 ac, 4 >120ac)	(-5 for < 0.25 ac)	(0 for < 40 ac, 1 for 40 to 80 ac, 2 for 80 to 160 ac, 3 for 160 to 320 ac, 4 >320ac)
Environmental Constraints (Possible Sco						
	Wetlands or Sensitive Area	Land Cover from GP2030 data	Vernal Pool, Wetland, Woodlands, Chaparral, Riparian = -10 woodland, vineyard, rice = -5 Grassland = -3 Urban, Developed = 1 Irrigated Crops/Pasture = 3 Disturbed = 5	Vernal Pool, Wetland, etc. = -10 Woodlands, Chaparral = -5, -3 Urban, Developed = 1 Riparian, Cropland, Disturbed = 5	Vernal Pool, Wetland = -5 Woodland, Chaparral = 3 Riparian, Urban, Developed, Cropland, Disturbed = 5	0
	Endangered Species	California Natural Diversity Database (CNDDB)	(-10 for Endangered, -1 for Threatened and Rare, 0 for No Status)	(-10 for Endangered, -1 for Threatened and Rare, 0 for No Status)	(-2 for Endangered, -1 for Threatened and Rare, 0 for No Status)	(-2 for Endangered, -1 for Threatened and Rare, 0 for No Status)
Possible Range of Values			**(-14 to 48)**	**(-14 to 48)**	**(-7 to 35)**	**(-7 to 22)**

Recharge Ponds



Butte County Recharge Suitability Analysis
Butte County, California

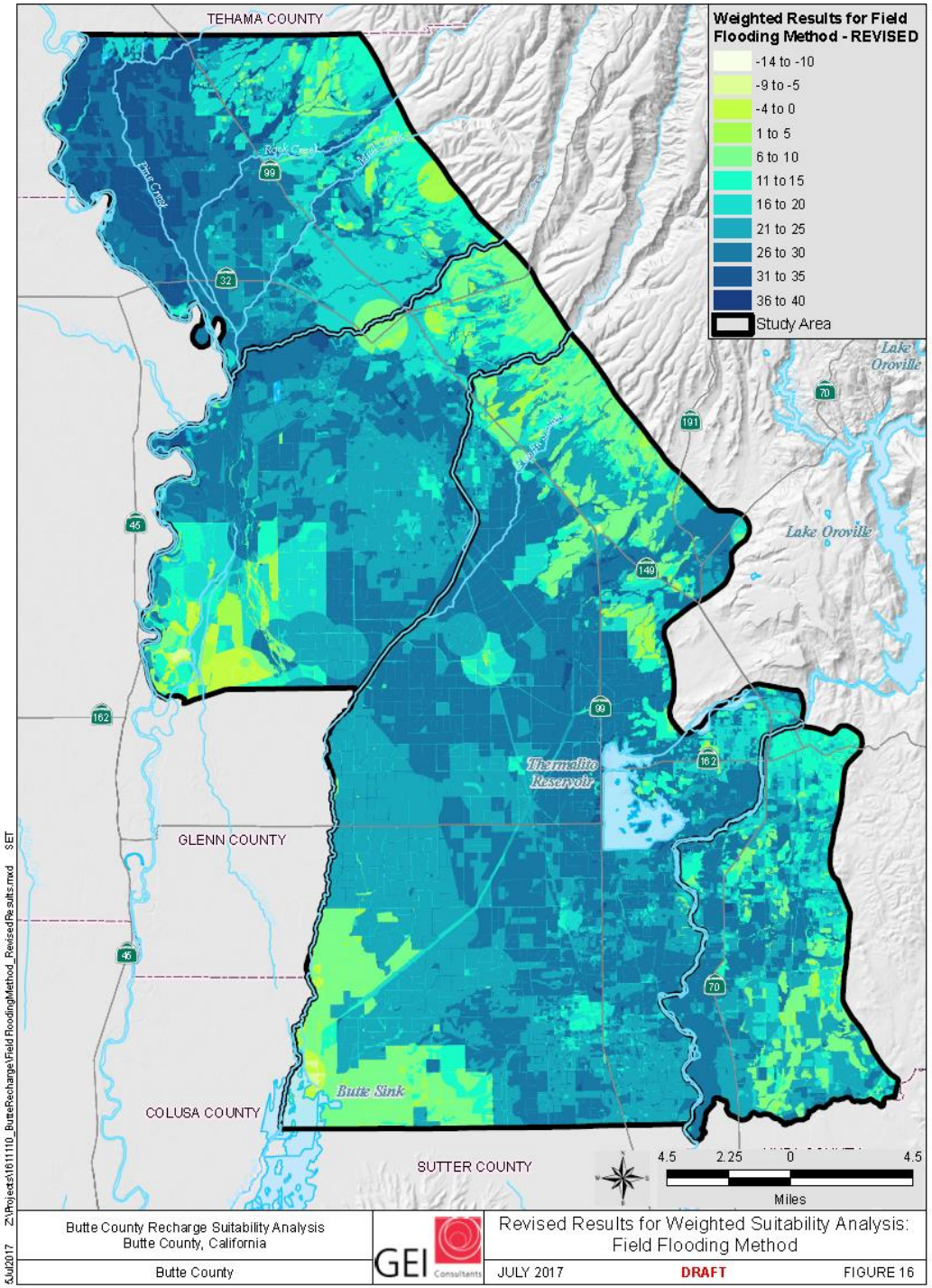
Butte County

GEI Consultants

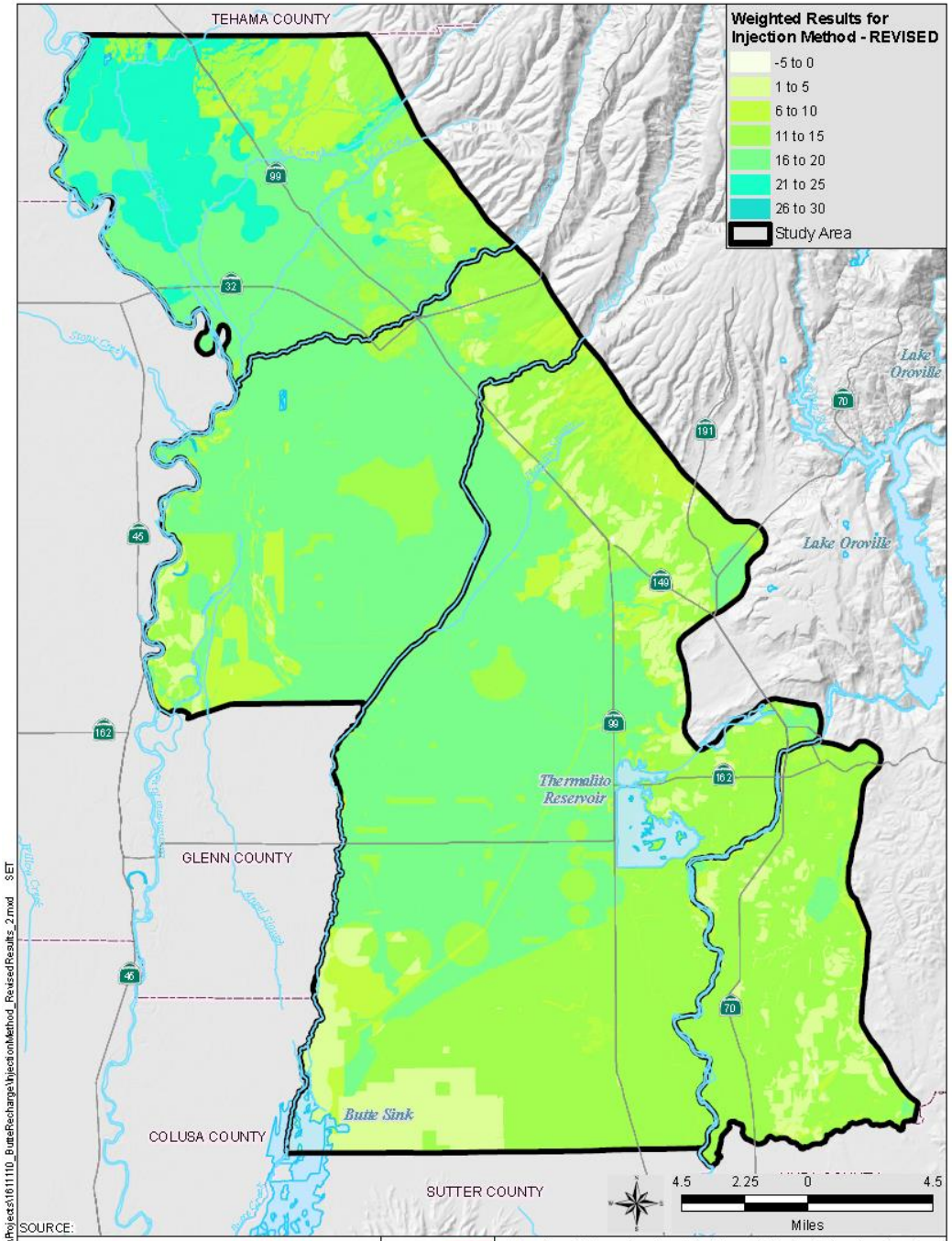
Revised Results for Weighted Suitability Analysis: Ponding Method

JULY 2017 DRAFT FIGURE 15

Field Flooding



Injection



SOURCE:

Butte County Recharge Suitability Analysis
Butte County, California

Butte County

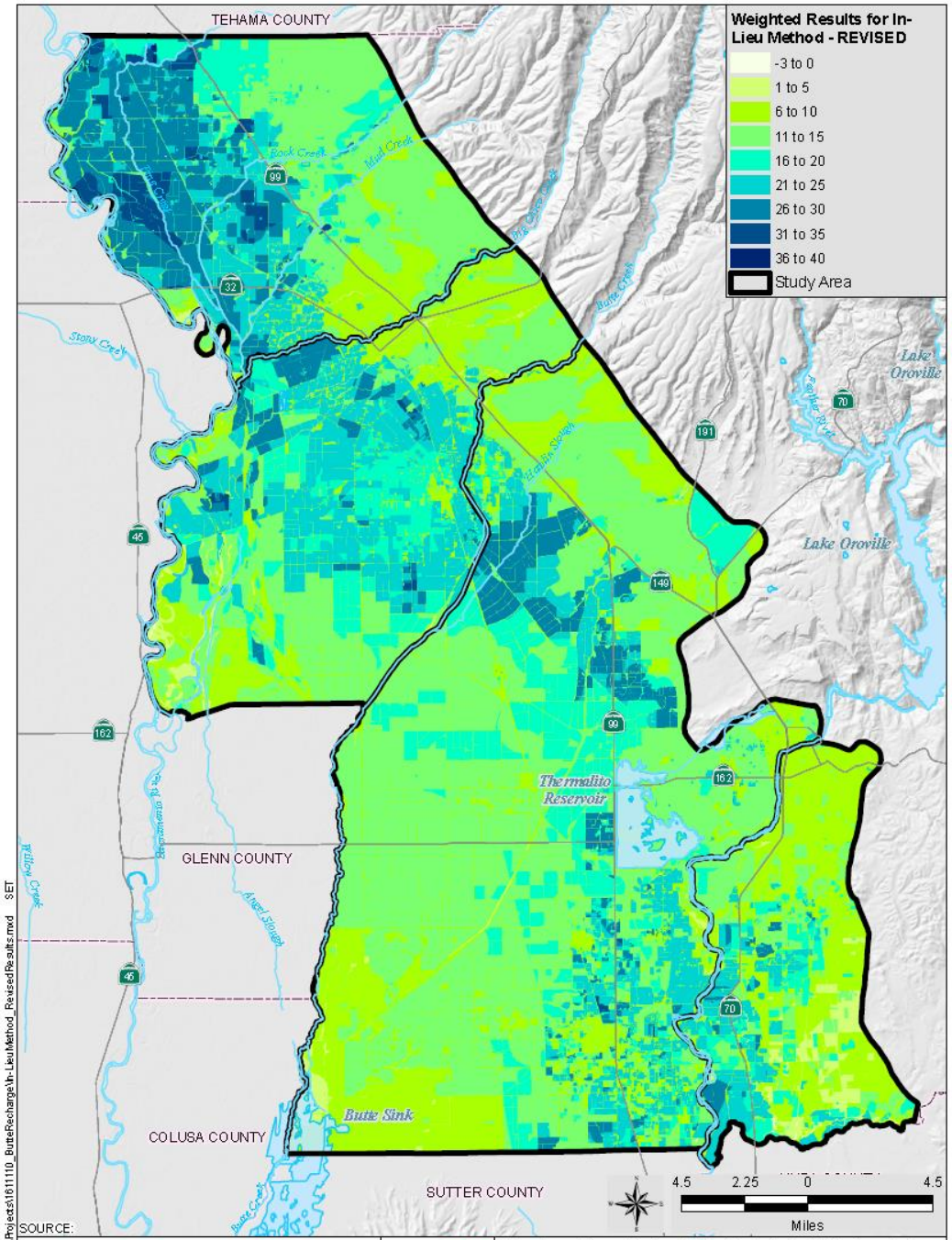
GEI Consultants

Revised Results for Weighted Suitability Analysis: Injection Method

JULY 2017 DRAFT FIGURE 17

5Jul2017 Z:\Projects\1611110_ButteRecharge\InjectionMethod_RevisedResults_2.mxd SET

In-Lieu Recharge



SOURCE:

Butte County Recharge Suitability Analysis Butte County, California	GEI Consultants	Revised Results for Weighted Suitability Analysis: In-Lieu Method
Butte County		JULY 2017 DRAFT FIGURE 18

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Discussion

GEI Consultants

DAVIDS ENGINEERING, INC

ERA Economics
Environment • Resources • Agriculture

LAND IQ

Task 4 – Economic Evaluation of In-Lieu Groundwater Recharge

- Dual System Analysis

Evaluation of Restoration and Recharge Within Butte County Groundwater Basins

Dual Systems

GEI CONSULTANTS
DAVIDS ENGINEERING
ERA ECONOMICS
LAND IQ

SEPTEMBER 25, 2017

Evaluation of Dual Source Irrigation Systems

- Dual Source Irrigation Systems:

On-farm irrigation systems capable of using groundwater or surface water

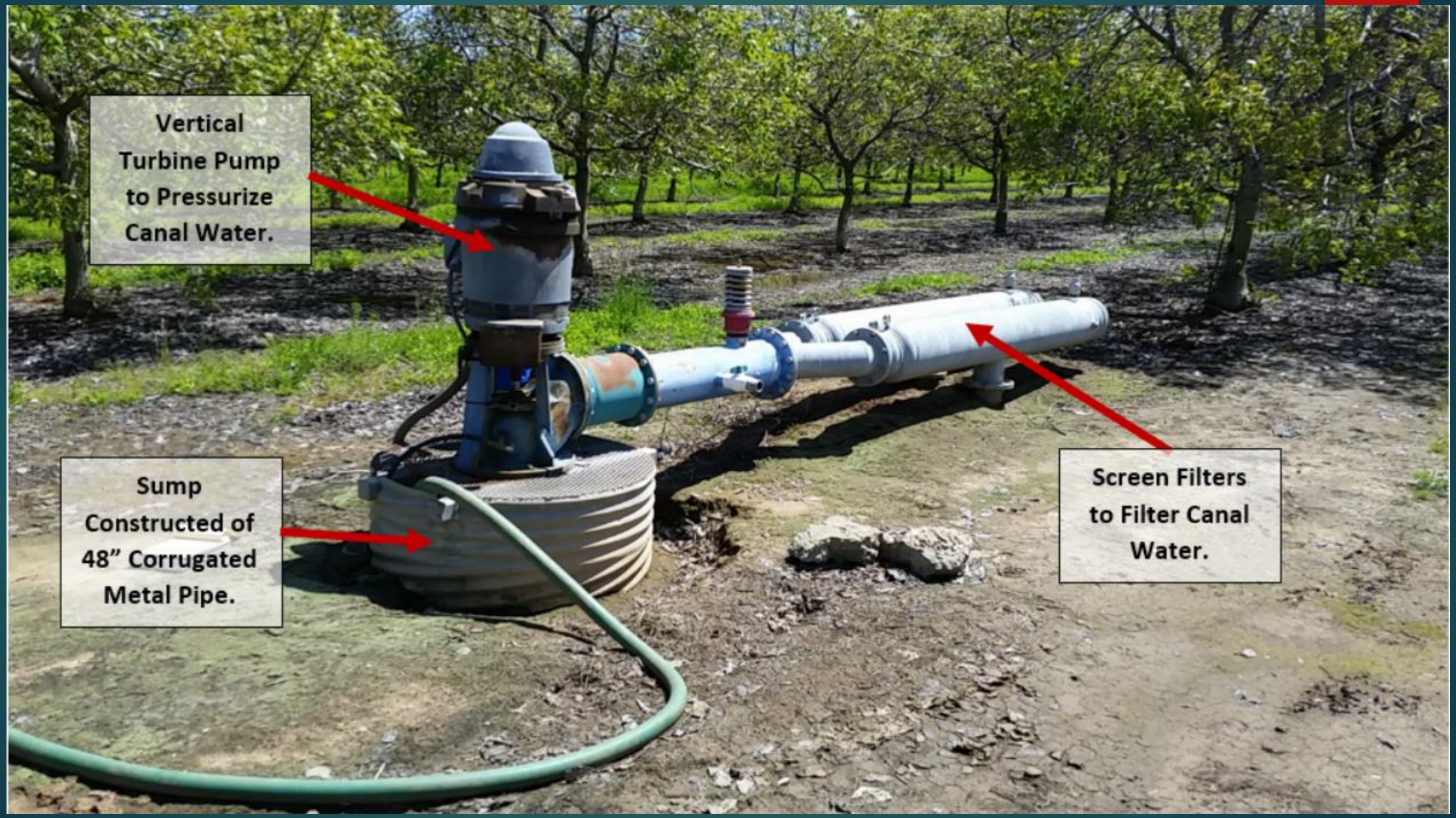
Evaluation Tasks

- Characterize Dual Source Systems
- Develop Cost Estimates for Dual Systems
- Evaluate Agronomic Factors Related to Dual Systems
- Assess Regional Benefits

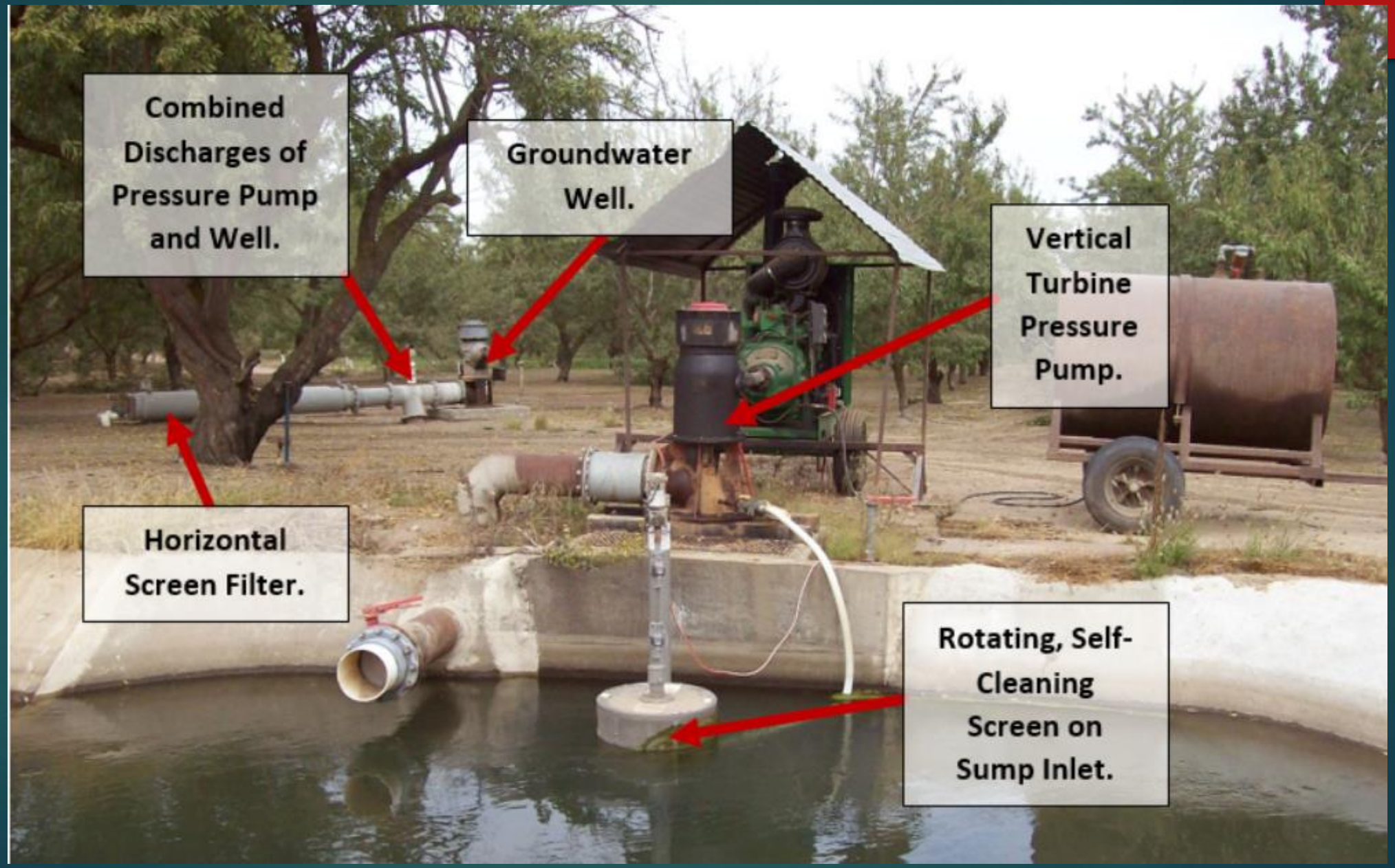
Dual System Components

- Turnout and Pre-Screening
- Conveyance to Booster Pump & Filter
- Booster Pump & Filter
- Conveyance to System Tie-In

Dual System Example (Butte County)



Dual System Example (Glenn County)



Dual System Example (Stanislaus County)

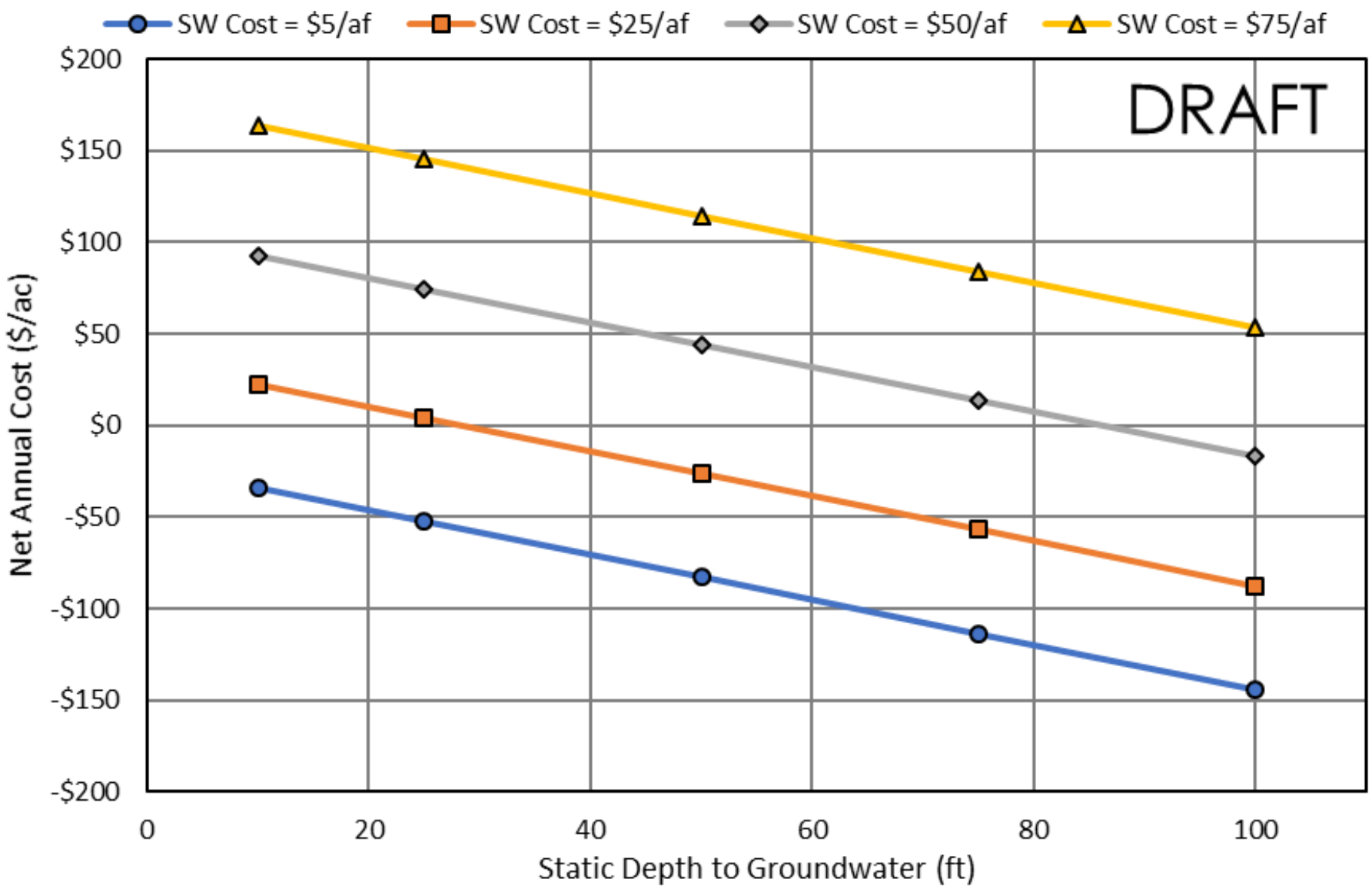
Dual System Example (Yuba County)

Dual System Costs

- Data Sources
  - Butte County Resource Conservation District, NRCS Payment Schedules, Davids Engineering Internal Database
- Cost Estimation Tool
  - 16 Selectable Parameters
  - Initial and Amortized Capital Costs
  - Annual Maintenance and Operations
  - Marginal Dual System Costs
  - Ability to Evaluate Multiple Scenarios and Marginal Cost Sensitivity to Input Parameters

Cost Estimation Tool Results: Variable Pumping Depth and SW Purchase Cost

- 100-Acre Example Walnut Orchard
- Net Annual Cost
- Static Depth to GW from 10 to 100 feet
- SW Purchase cost from $5/af to $75/af



Factors Affecting Decision Whether to Use Surface Water

- What factors influence the decision to use groundwater when surface water is available?
- Potential Factors
  - Cost
  - Flexibility
  - Water Quality
  - Disease Risk
  - Others

Economic Analysis of Dual Systems

- Benefits to growers of dual systems will increase under SGMA
  - Under SGMA dual systems provide benefits to individual fields **and** other irrigators in the basin
- Field benefits of additional surface water use will include:
  - Lower pumping costs
- Regional benefits of additional surface water use to remaining groundwater users will include:
  - Avoided Pumping Costs
  - Stabilization Value to Avoid Fallowing

County-Wide Cost Analysis

- Capital and Maintenance Costs
  - On-Farm and Conveyance
  - Stranded Capital in Existing Groundwater Systems
- Operating Costs
  - Difference Between Groundwater Only and Dual System

Key Assumptions

- Reconnaissance-Level Costs
  - Assumes optimum selection of fields/Not based on specific projects
  - Does not explicitly factor agronomic considerations
  - Assumes surface water purchase cost similar to past, in-County transfers
- **Preliminary** Estimates of Overdraft by Subbasin
  - Vina: ~5,000 acre-feet +/- 50%
  - West Butte: ~5,000 acre-feet +/- 50%
  - East Butte: ~5,000 acre-feet +/- 50%
  - Wyandotte Creek: ~1,000 acre-feet +/- 50%

Preliminary Benefits and Costs

- Avoided Pumping Costs: ~$3,210,000 +/- 50%
- Risk Reduction to Avoid Fallowing: ~245,000 +/- 50%
- Total Benefits: ~$3,455,000 +/- 50%

- Net Implementation Costs: ~$330,000 (low)

- Conclusion: Appears to satisfy economic feasibility criteria, but refinement of assumptions and more detailed analysis needed.

Discussion

GEI Consultants

DAVIDS ENGINEERING, INC

ERA Economics
Environment • Resources • Agriculture

LAND IQ

Identified Potential Water Sources

- Oro-Chico Canal
- Pipeline from Oroville to Chico
- Construction of recharge basins over Lower Tuscan Aquifer recharge area
- Diversion of water from Sacramento River
- Improvements to Cherokee Canal

Findings from Detailed Screening

Alternatives	Screening Findings
1. Pipeline Along Oro-Chico Conduit 2. Pipeline Along Sac Northern RR ROW	• Alt 1 Rough/difficult terrain • Alt 2 Shorter alignment, but requiring easements • Capital cost $71 – $108M
3. Sacramento River Diversion from Existing M&T Facilities 4. Sacramento River Diversion using Radial Collector Wells	• Diversions could be reduced to meet Shasta temperature control restrictions • Lower treatment costs for radial collector well option • Ongoing maintenance with M&T diversion • Capital cost $20 – $32M
5. Partnership with Paradise Irrigation District	• Water rights above Lake Oroville would limit available supply timing • Capital cost $100M