AQUA-Exhibit 32

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RE: Additional Comments and Recommendations on Draft Environmental Impact Report for Glenn Colusa Irrigation District's Groundwater Supplemental Supply Project, June 2015

This letter provides additional comments and recommendations for my July 29, 2015 letter (Custis, 2015) commenting on the June 2015 Draft Environmental Impact Report (DEIR) prepared by the Glenn Colusa Irrigation District (GCID). These additional comments are provided to clarify or correct information provided in my July 29th letter and focus on two issues: 1) the groundwater monitoring program of Butte County, and 2) the estimated duration of stream depletion required to recharge the pumped aquifers.

1. The DEIR stated on page 3-19 in Section 3.1.2 that there are no key wells within the simulated 5-foot-or-greater cone of depression in Butte County. This statement appears to be technically correct, but it gives an incorrect impression that there are no wells being monitored in Butte County's groundwater monitoring program that are relevant to evaluating the impacts from the GCID project. This also appears to be the justification for why the DEIR doesn't propose to utilize any of Butte County's groundwater monitoring data. There is however sufficient information to show that Butte County's groundwater monitoring program is relevant for monitoring GCID's project impacts and should therefore be incorporated into the mitigation monitoring measures WR-1 and WR-2.

   Exhibit 32A is a map taken from the Butte County's BMO Program's web site that shows the spring 2015 Alert Stages 1 and 2 for wells in the county (http://www.buttecounty.net/waterresourceconservation/GroundwaterLevels.aspx). Exhibit 32B is a composite map made of the Butte County Spring 2015 BMO map and DEIR Figure 3-8, which shows the drawdown in the deep aquifer for the November 15, 1992 simulation. Exhibit 32B shows that there are several wells adjacent to the 5-foot-plus drawdown that are in Alert Stage 1 or 2. Exhibit 32C is a composite map made of the Butte County Spring 2015 BMO map and DEIR Figure 3-6, which show the outermost drawdown area for the November 15, 1992 simulation. Exhibit 32C shows that there are a number of wells being monitored by Butte County that lie within the outermost impact area for the GCID project. Several of these wells are in Alert Stage 1 or 2. More information about the Butte County groundwater level monitoring program and BMOs can be found at web site http://www.buttecounty.net/waterresourceconservation/BasinManagementObjectives.aspx and Butte Count groundwater quality monitoring information at http://www.buttecounty.net/waterresourceconservation/GroundwaterQuality.aspx.

   Exhibit 32D is a map taken from Tehama County's AB-3030 Groundwater Management Plan that shows the key monitoring wells overlain by the GCID project's outermost drawdown area. There are several multilevel wells in southern Tehama County that are within or adjacent to the GCID project's impact area. These wells should be included in the GCID groundwater-monitoring program. Information on the characteristics of the aquifer in Tehama County, the key wells, hydrographs for key wells and groundwater trigger levels can be found at web sites: http://www.tehamacountypublicworks.ca.gov/Flood/wells.html, and http://www.tehamacountypublicworks.ca.gov/Flood/groundwater.html.

I recommend that the DEIR be amended to incorporate the Butte County groundwater level and quality monitoring program data into mitigation measures WR-1 and WR-2. In addition, groundwater level data from Butte and Tehama county wells should be evaluated for *long-term antecedent trends* as required for Glenn and Tehama county wells in mitigation measure WR-1.

2. In my July 29, 2015 comment no. 7f, I discussed the importance of the stream depletion factor (SDF) and the data presented in Table 3-6 of the DEIR. I stated that the information presented in Table 3-6 indicates that it may take decades for seepage from the surface water bodies listed in the table to recharge 95% of the groundwater pumped by the GCID project. I referenced technical documents by Jenkin's (1968), Miller and others (2007) and Wallace and others (1999), but didn't provide any additional explanation for my conclusion on the duration for recharge. This discussion provides additional information to clarify my comments on the importance of the SDF and additional discussion on how the SDF can be used to estimate the time needed to recover from a period of groundwater pumping when the source of recharge is seepage from adjacent surface water bodies.

   The use of the SDF in estimating the duration of recharge assumes that the seepage is naturally occurring, that the groundwater drawdown induces additional seepage or prevents groundwater discharge to the surface water body, and that there is no program for intentionally accelerating groundwater recharge such as spreading basins. Section 1.1.1.3 in the DEIR states that GCID currently has no program for intentional groundwater recharge, so the following discussion should apply to the GCID project. While the groundwater recharge that occurs from agricultural irrigation does contribute to groundwater storage, the GCID project is one where the source of agricultural irrigation is the underlying aquifer system and therefore the water applied for irrigation decreases rather than increases the volume of groundwater in storage, regardless of how much of the applied water infiltrates past the root zone. I other words, the GCID project's groundwater extraction adds additional losses in storage and stresses to the groundwater system that aren't compensated for by the pre-project baseline recharge from precipitation, agricultural irrigation and surface water seepage. The sources of recharge to backfill the loss in groundwater storage caused by the GCID project above the baseline infiltration and seepage are increases in stream depletion, increases in groundwater flow from adjacent groundwater basins in Butte and Tehama counties, and increases in the interception of groundwater that flows down gradient from the GCID well field to Colusa County. Unfortunately, the time needed to fully backfill the loss in groundwater storage caused by GCID project pumping and the duration of the resulting impacts will be decades as discussed below.

   Exhibit 33A is a Table that shows the maximum and average stream depletion rates given in Table 3-6 of the DEIR and the percentages relative to the maximum total pumping rate, 25,000 gallons-per-minute (gpm) or 55.7 cubic-feet-per-second (cfs), and relative to the sum of the maximum depletion rates. Exhibit 33A shows that at the maximum depletion rate the Main Canal has the greatest seepage rate, approximately 26% of the total pumping rate and approximately 37% of the sum of the maximum seepage. It should be noted that the maximum seepage rate for each listed stream doesn't occur at the same time in the simulation, with the timing of the maximums ranging from March 1986 to April 1993. It should be noted that the source of recharge from seepage in the Main Canal is from the underlying aquifer, thus this recharge is not additional waters to the groundwater basin. Instead the Main Canal recharge should be viewed as an inefficiency in the GCID project, one that looses the beneficial use of approximately 26% of the water pumped. It should also be noted that the maximum stream depletion rates listed in Exhibit 33A and Table 3-6 for the GCID wells are greater than the 12% maximum stream depletion assumed in the March 2015 USBR/SLDMWA Long-Term Water Transfers EIS/EIR for these GCID project wells and all other wells participating in the long-term groundwater substitution transfer program.

The times of the maximum depletion rates for the streams listed in Exhibit 33A and Table 3-6 appear to be related to the November 15, 1992 simulated pumping for the six-year severe drought period of 1987 to 1992. The exception is Walker Creek with a March 1986 date for the maximum depletion, which may be the result of the 1976 to 1977 period of drought simulated. The months of GCID well operation for the simulations began in February and end in November (page A-2 in DEIR Appendix A). Therefore it can be assumed that the 1987-1992 simulation began in February 1987. The time interval between the start of pumping for the 1987-1992 simulation period and the occurrence of a maximum stream depletion rate ranges from approximately 4 years and 4 months (4.33 years) to 9 years and 1 months (9.08 years) as shown in Exhibit 33A.

The importance of the time increment between the start of pumping and the maximum depletion rate is that it can be related to the time of the SDF and used to estimate the time needed to achieve recharge for 95% of the groundwater pumped. Because the SDF is dependent on the square of the distance between the pumping well and depleting surface water body, it should be expected that the impacts from each GCID well on an individual stream would vary, perhaps significantly. Unfortunately, the stream depletion rates given in Exhibit 33A and Table 3-6 are group rates for the ten GCID project wells and not for each individual well. Therefore the analysis given below is an estimate of the group-value of the SDF time for all ten GCID wells. If depletion information is provided separately for each well, an estimate of the SDF value for each well can be made using the same methodology.

Exhibit 33B is taken from Figure 2 in Miller and others (2007) and shows graphs of the ideal response curves for instantaneous stream depletion rate and cumulative stream depletion volume. The x-axis on this figure shows the logarithm of time from the start of pumping normalized by the time of the SDF. Thus, the value of 1 on the x-axis correlates to a duration of pumping equal to the SDF time. The lower curve relates the cumulative volume of stream depletion to the total volume pumped (*v/Qt*), while the upper curve relates the instantaneous rate of stream depletion to the total rate of pumping (*q/Q*). These ideal response curves can be used to estimate the time interval need to achieve the 95% recharge used by Wallace and others (1999) in the absence of actual simulated stream depletion response curves from each of the GCID project wells. Should simulated stream depletion response curves be provided for each GCID well, then the method given below of calculating the time for 95% recharge can be applied to the GCID project wells.

Exhibit 33B shows that when the duration of pumping equals the SDF (t/SDF = 1) the lower curve gives the cumulative stream depletion volume of 28% relative to the total pumped volume. The upper curve gives the instantaneous depletion rate of 48% relative to the total pumping rate. For the Sacramento River, Exhibit 33A gives the maximum stream depletion rate of approximately 22% based apparently on six continuous years of pumping 8-1/2 months per year at the maximum pumping rate of 25,000 gpm or 55.7 cfs, or 31.7% based on a 12-month time-weighted average total pumping rate of 17,705 gpm or 39.45 cfs. The

Sacramento River's maximum depletion rate occurs at approximately 5.75 years after the start of the pumping that simulated the 1987-1992 six-year drought, Exhibit 33A. The 22%-*q*/*Q*-value on the y-axis hits the upper curve, relative instantaneous pumping rate, at a *t*/*SDF*-value of approximately 0.32. For the time-weighted average 31.7%-*q*/*Q*-value, the *t*/*SDF*-value is approximately 0.5. Using these values, the range of the group-SDF time for GCID's wells depleting flows in the Sacramento River can be estimated at 11.5 to 18 years (SDF = *t*/0.32; SDF = 5.75 years /0.32 = 18 years). The SDF values for the other streams could be calculated in a similar manner.

Exhibit 33A shows that the cumulative average stream depletion rate is 10.55 cfs. The DEIR implies that this average stream depletion rate occurs over the entire 41 years of the simulation period (footnote c in Table 3-6) even though the pumping occurs only approximately 40% of the simulation time, 16 dry or critically dry years out of the 41 years simulated (Table A-1 in DEIR Appendix A). The DEIR's time-averaged stream depletion rate doesn't have much importance in assessing impacts because the pumping doesn't occur on a regular cycle and the instantaneous stream depletion rate that is most important to fish fluctuates with the pumping intervals. The average value however does provide an estimate of the volume of recharge that might occur over 41 years of pumping the GCID project wells 40% of the time. The total volume of pumped groundwater simulated for the DEIR was approximately 457,600 acre-feet resulting from 16 pumping seasons at 28,600 acre-feet per season (page A-3 of DEIR Appendix A). The SDF can also be calculated using the lower curve, the ideal cumulative stream depletion volume curve in Exhibit 33B.

If the total pumped volume were spread across the 41 years of simulation, a time-weighted average pumping rate would be approximately 15.35 cfs or 6,890 gpm. I'm assuming that the recharge to recover the loss in groundwater storage from the GCID groundwater pumping is derived only from stream depletion because the DEIR doesn't indicate that any additional water would be applied to accelerate aquifer recovery. The cumulative average stream depletion rate of 10.55 cfs for the 41 years of simulation is approximately 69% of the 41-year average pumping rate (10.55/15.35 = 0.685). Therefore, approximately one-third of the water pumped isn't recharged within the 41 years. The *v*/*Qt* value of 69% on the y-axis of Exhibit 33B intersects the lower cumulative depletion volume *v*/*Qt*-curve at a *t*/*SDF* value of 10. By making a calculation that is similar to the one done with the *q*/*Q*-curve shown above, an SDF value of 4.1 years is derived based on the cumulative volume of stream depletion over the 41-year simulation.

The 69% recharge in 41 years is consistent with the findings of CH2MHill (2010) on the impacts from the 2009 groundwater-substitution pumping program where cumulative stream depletion was approximately 60% of the total volume pumped after 30 years (see my comments on page 12 of my July 29, 2015 letter). Therefore the estimated duration needed to achieve 95% recharge from the GCID project's pumping would exceed the DEIR's 41-year simulation period. The DEIR doesn't address how many years would be needed, but any calculation using the "average" stream depletion value would be too short because the depletion rate increases asymptotically, increasing at lesser amounts with time, similar to that shown in Figures 4, 5 and 6 in CH2MHill's 2009 groundwater substitution transfer impacts report.

Wallace and others (1999) have calculated the time needed to reach 95% recharge from pumping induced stream depletion at 127 times the SDF value for the ideal stream depletion response curve. Therefore, the estimated time needed to recharge 95% of the groundwater pumped by the GCID project wells if the Sacramento River were the only source of recharge would range from 1,461 to 2,286 years (18 yrs x 127 = 2,286 yrs). However, because there are at least six other streams being depleted by the GCIS project's pumping, the actual time for 95% recharge would be much shorter. If the Wallace and others method for calculating 95% recovery is applied to the 41-year cumulative stream depletion volume for all six rivers, the time need is approximately 521 years (4.1 yrs x 127 = 520.7 yrs).

Bredehoeft (2011) provides a discussion of how long-term cyclic groundwater pumping by GCID's project wells might affect long-term stream depletion, assuming it's the only source of recharge for the extraction, which is consistent with GCID's project. Bredehoeft's Figures 3 through 6 show how pumping individual wells at different distances or a collection of wells results in a gradual increase in the maximum stream depletion or recharge rate. All of the figures show that it takes decades for the cyclic pumping to reach a new "steady-state." Figure 3 shows that stream depletion fluctuates about a time-weighted average pumping rate. This graph might be interpreted as showing a "dynamic equilibrium" about a trending value. The long-term increase in stream depletion resulting from continued groundwater extraction, whether at a constant rate or at an increasing rate, should be expected for the GCID project wells. The 3,000 other pumping wells in Glenn County would have a similar progressive increase in stream depletion (recharge) with multiple years of extraction.

My July 29, 2015 comment no. 8 on page 14 identified nine of the wells with long-term groundwater measurements that show a steady overall downward trend in groundwater level since the mid-1990s (Exhibits 29-O-3A, -O-3B, -I-4, -I-6, -I-7, -I-11, -I-14, -I-17, -R-19). This gradual, long-term decline in groundwater levels may correlate with the gradual increase in stream depletion, which over decades provides the recharge needed to backfill the loss in aquifer storage caused by cyclic seasonal groundwater extractions. I discussed a similar pattern for the Sacramento Valley in my November 25, 2014 comments (Custis, 2014) on the Draft EIS/EIR for the USBR/SLDMWA Long-Term Water Transfers. I discussed in my 2014 comment no. 20 the results of the Department of Water Resource's C2VSim groundwater model of the Sacramento Valley as presented by the Northern California Water Association (2014) that show a relationship between the long-term changes in stream accretion (groundwater discharge to streams) with groundwater pumping in Sacramento Valley. In my 2014 comments, I provided in Exhibit 10.7 a graph compares the long-term changes in stream accretion with groundwater pumping. I've attached that 2014 exhibit as Exhibit 33C. Exhibit 33C shows that stream accretion between the 1940s and 1970s showed a fluctuation about a downward trend that is opposite a fluctuating long-term rise in groundwater pumping. Exhibit 33C also shows that, from the end of the 1980s to the end of the simulation in 2010, groundwater pumping continued to increase while the change in stream accretion generally trends downward, but with a reduced slope since the mid-1990s. Unfortunately, the C2VSim model used to develop the data plotted in Exhibit 33C ends in 2010 so the impacts of the recent drought aren't evaluated. The slowing of stream accretion that began in the mid-1990s would result in less recharge, which along with the continued increase in groundwater pumping likely contributes to the long-term decline in groundwater levels observed since the mid-1990s in the nine long-term monitoring wells I listed above.

I recommend that the DEIR be amended to address the issue of what duration is required to fully recharge the volume of groundwater taken from storage by the GCID project wells. This discussion should include providing stream depletion response curves for each GCID project well and any alternative well so the impacts from each well can be evaluated. I also recommend that the DEIR include a mitigation measure that uses the stream depletion response curves for each well to forecast the impacts on stream flow from each new pumping event.

This forecasting should give a cumulative impact from the new and past pumping events. The DEIR cumulative effects analysis should evaluate the impacts from the GCID project pumping along with the anticipated pumping from the 3,000 other wells in Glenn County and the adjacent wells in Butte, Colusa and Tehama counties.

References Cited

Bredehoeft, J., 2011, Hydrologic Trade-Offs in Conjunctive Use Management, Ground Water, vol. 49, no. 4, pgs 468-475.

CH2MHill, 2010, Technical Memorandum - Groundwater Substitution Transfer Impact Analysis, Sacramento Valley, To: Abdul Khan/California Department of Water Resources and Bob Niblack/California Department of Water Resources, From: Peter Lawson/CH2M HILL, Redding, California, March 29, 2010, Project No. 376301.08.01, pp. 21

Custis, K, November 25, 2014, Comments and Recommendations on U.S. Bureau of Reclamation and San Luis & Delta-Mendota Water Authority Draft Long-Term Water Transfer DRAFT EIS/EIR, dated September 2014, submitted as part of AquAlliance's December 1, 2014 comments on the Long Term North-to-South 2015-2024 Water Transfer Program Draft EIS/EIR, 48 pp.

Custis, K., July 29, 2015, Comments and Recommendations on Draft Environmental Impact Report for Glenn Colusa Irrigation District's Groundwater Supplemental Supply Project, June 2015, submitted as part of AquAlliance's July 30, 2015 comments on the GCID's 10-Well Draft EIR, SCH# 2014092076, 23 pp.

Jenkins, C.T., 1968a, Computation of rate and volume of stream depletion by wells: U.S. Geological Survey Techniques of Water-Resources Investigations, book 4, chap. D1, pp. 17 (http://pubs.usgs.gov/twri/twri4d1/)

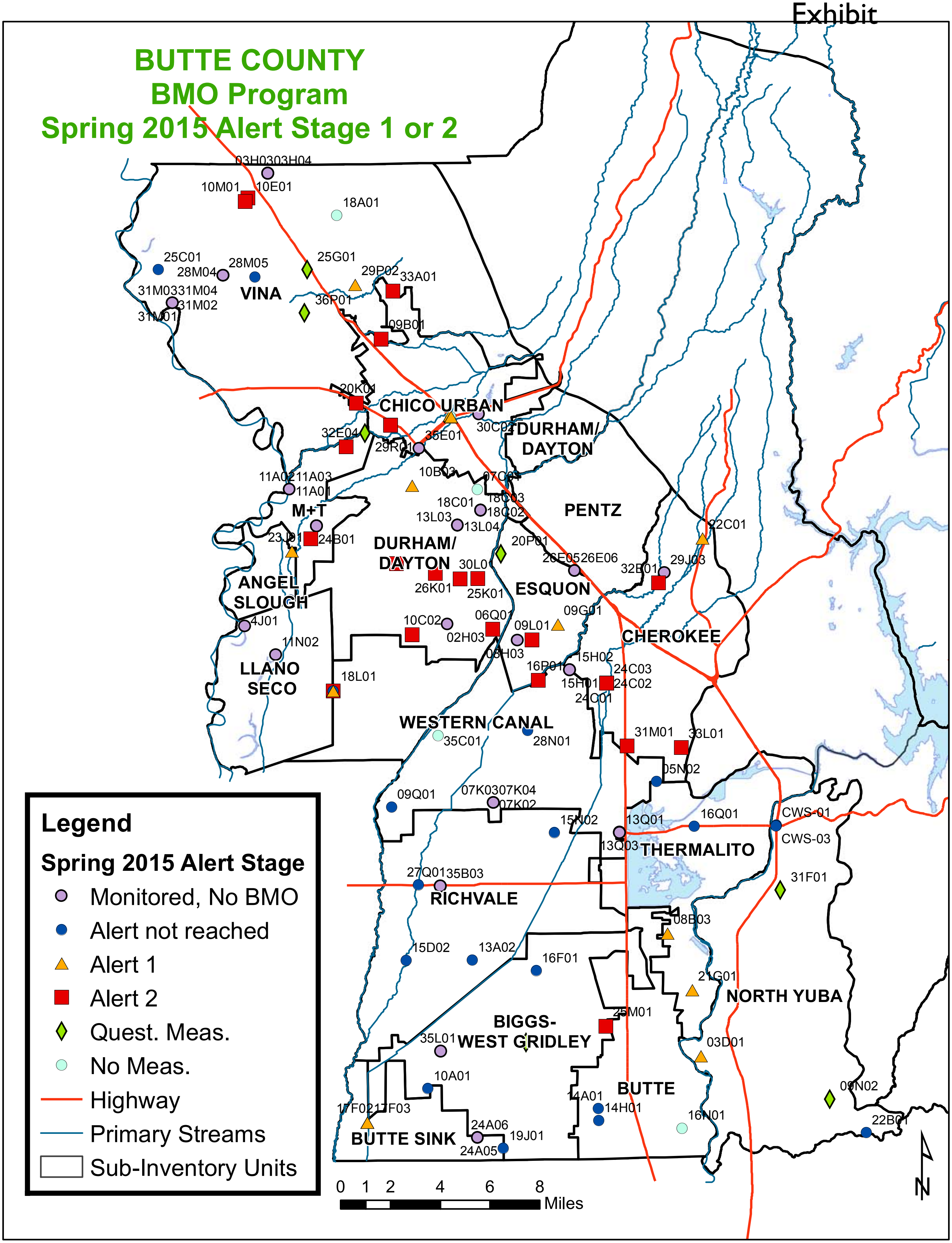
Miller, C.D., Durnford, D., Halstead, M.R., Altenhofen, J., and Flory, V., 2007, Stream depletion in alluvial valleys using the *SDF* semianalytical model, Ground Water, v. 45, no. 4, p. 506–514

Northern California Water Association, 2014, Sacramento Valley Groundwater Assessment, Active Management – Call to Action, Technical Supplement, prepared by Davids Engineering, Macaulay Water Resources, and West Yost Associates, June 2014, pp. 91 (http://www.norcalwater.org/res/docs/NCWA_supp-web.pdf)

Wallace, R.B., Yakup, D., and Annable, M.D., 1990, Stream depletion by cyclic pumping of wells, Water Resources Research, v. 26, no. 6, pgs. 1263–1270 (http://www.hydra.iwr.msu.edu/iwr/cv/proposals/publications/documents/1990/Stream%20Depletion%20by%20Cyclic%20Pumping%20of%20Wells%20Vol%2026%20No%206%20June%201990.pdf)

AQUA-Exhibit 32

Exhibit



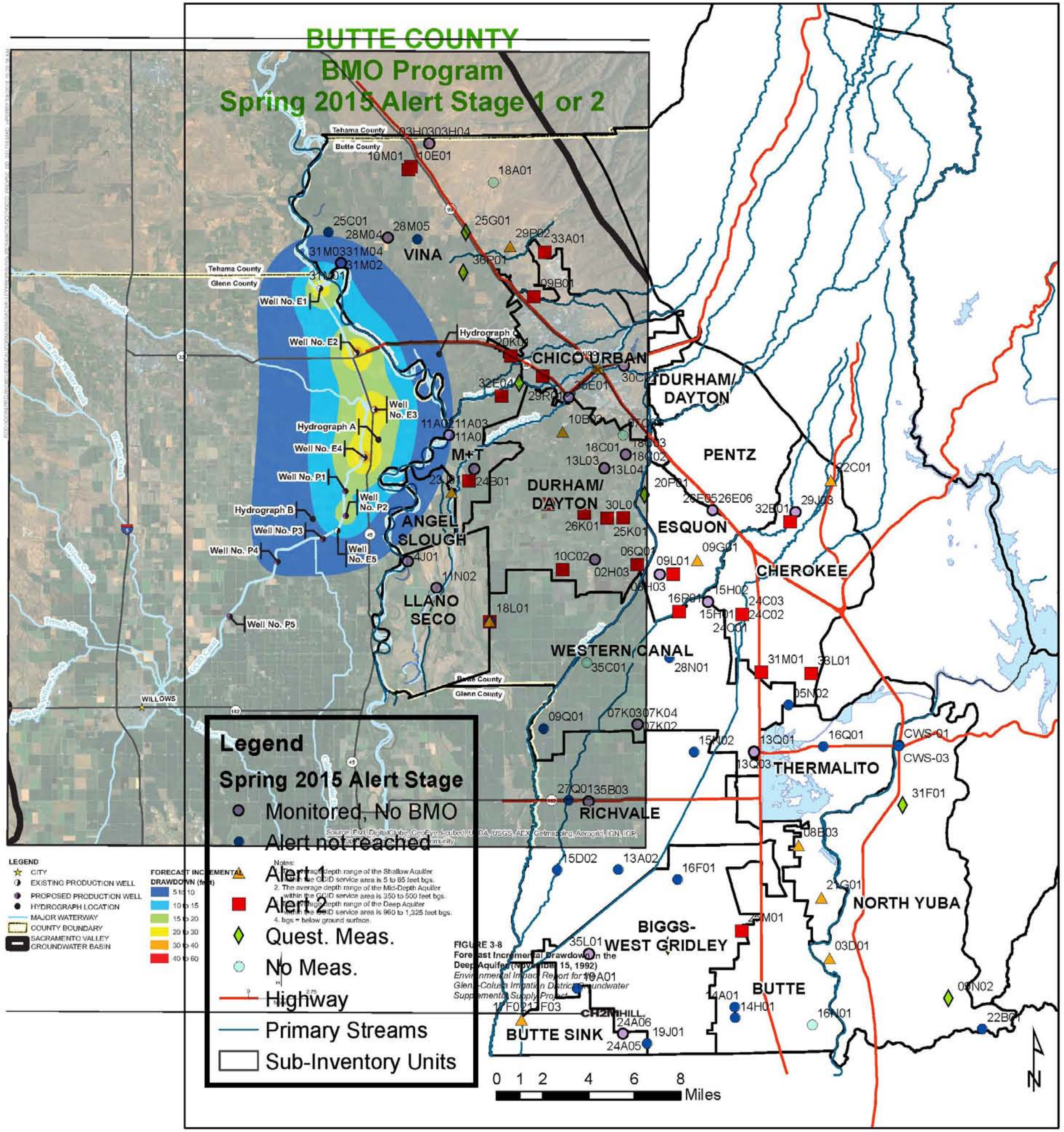
BUTTE COUNTY
BMO Program
Spring 2015 Alert Stage 1 or 2

Legend

Spring 2015 Alert Stage

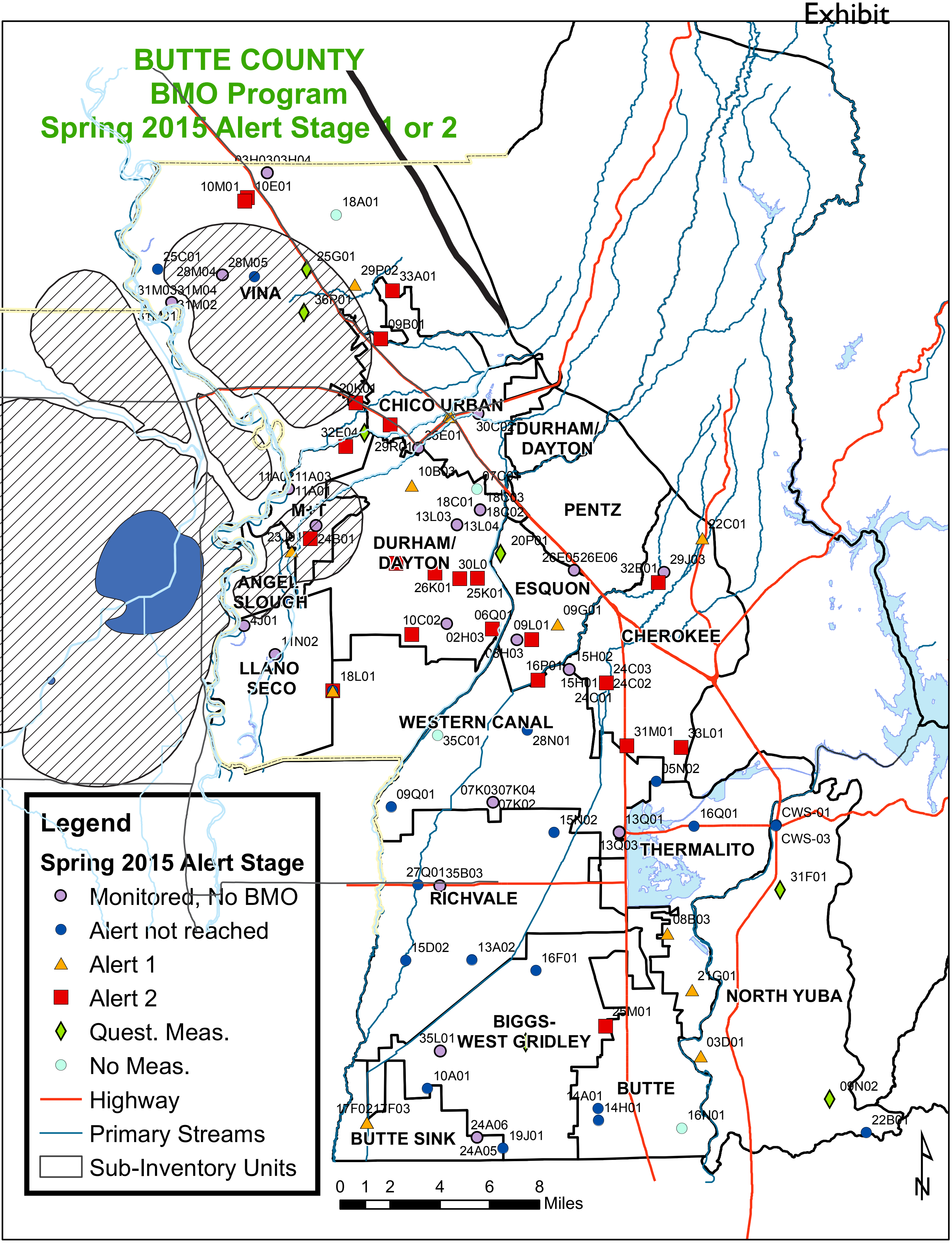
- ● Monitored, No BMO
- ● Alert not reached
- ▲ Alert 1
- 🟥 Alert 2
- ◆ Quest. Meas.
- ○ No Meas.
- — Highway
- — Primary Streams
- ☐ Sub-Inventory Units

Exhibit


BUTTE COUNTY
BMO Program
Spring 2015 Alert Stage 1 or 2
Legend
Spring 2015 Alert Stage
Monitored, No BMO
Alert not reached
Alert 1
Alert 2
Quest. Meas.
No Meas.
Highway
Primary Streams
Sub-Inventory Units
VINA
CHICO URBAN
DURHAM/ DAYTON
PENTZ
M+T
DURHAM/ DAYTON
ESQUON
ANGEL SLOUGH
CHEROKEE
LLANO SECO
WESTERN CANAL
THERMALITO
RICHVALE
NORTH YUBA
BIGGS-WEST GRIDLEY
BUTTE
BUTTE SINK
Tehama County
Butte County
Glenn County
WILLOWS
Well No. E1
Well No. E2
Well No. E3
Well No. E4
Well No. E5
Well No. P1
Well No. P2
Well No. P3
Well No. P4
Well No. P5
Hydrograph A
Hydrograph B
LEGEND
CITY
EXISTING PRODUCTION WELL
PROPOSED PRODUCTION WELL
HYDROGRAPH LOCATION
MAJOR WATERWAY
COUNTY BOUNDARY
SACRAMENTO VALLEY GROUNDWATER BASIN
FORECAST INCREMENTAL DRAWDOWN (feet)
5 to 10
10 to 15
15 to 20
20 to 30
30 to 40
40 to 60
FIGURE 3-8
Forecast Incremental Drawdown in the Deep Aquifer (November 15, 1992)
Environmental Impact Report for the Glenn-Colusa Irrigation District Groundwater Supplemental Supply Project
CH2MHILL
0 1 2 4 6 8
Miles
N

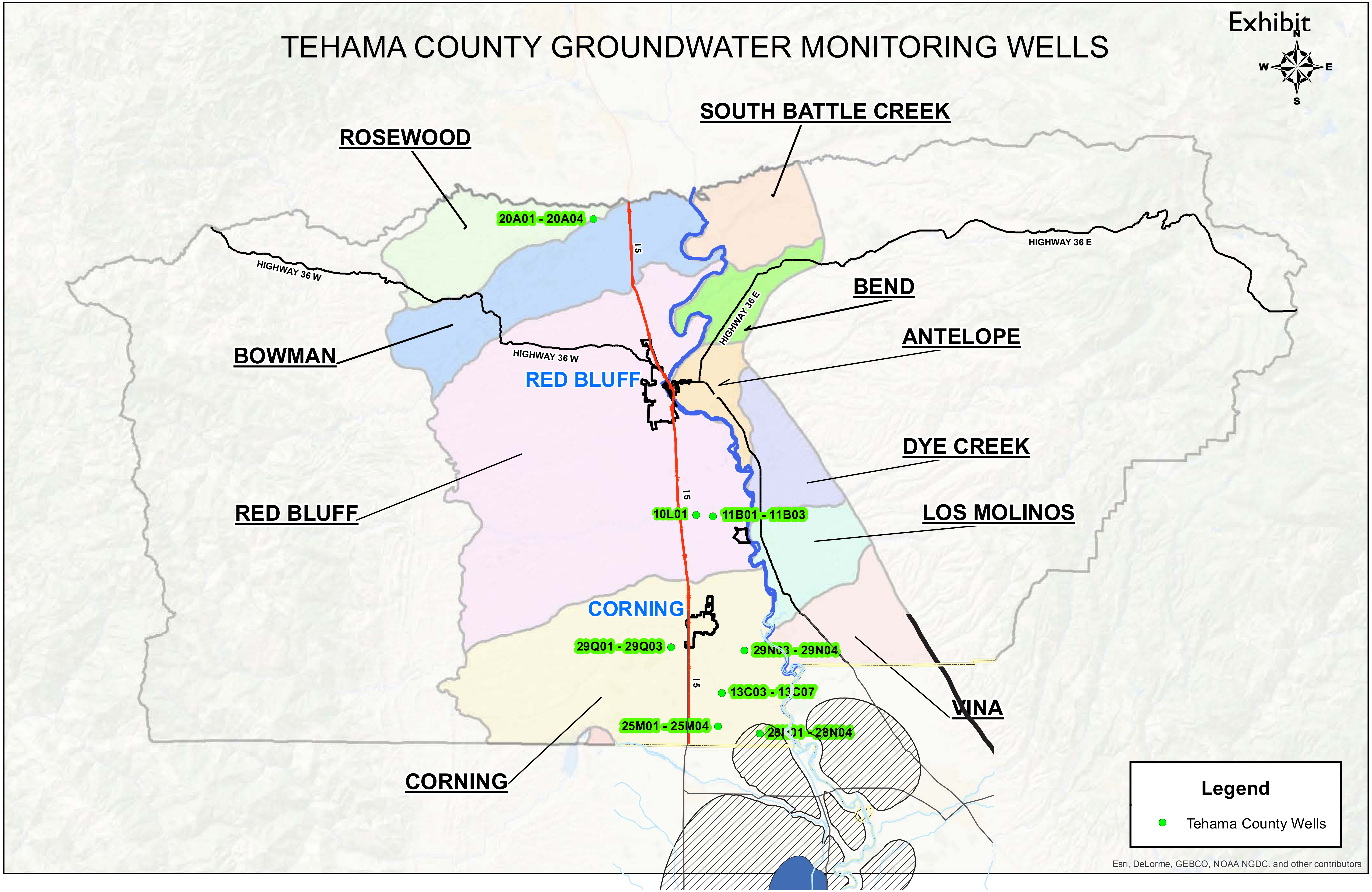
AQUA-Exhibit 32

Exhibit



Exhibit

TEHAMA COUNTY GROUNDWATER MONITORING WELLS



Esri, DeLorme, GEBCO, NOAA NGDC, and other contributors

AQUA-Exhibit 32

Exhibit 33A

Glenn-Colusa Irrigation District DEIR Table 3-6
Calculation of Stream Depletion as Percentage of Total Pumping Rate

25,000 gallons per minute maximum pumping rate
55.7 cubic feet per second maximum pumping rate

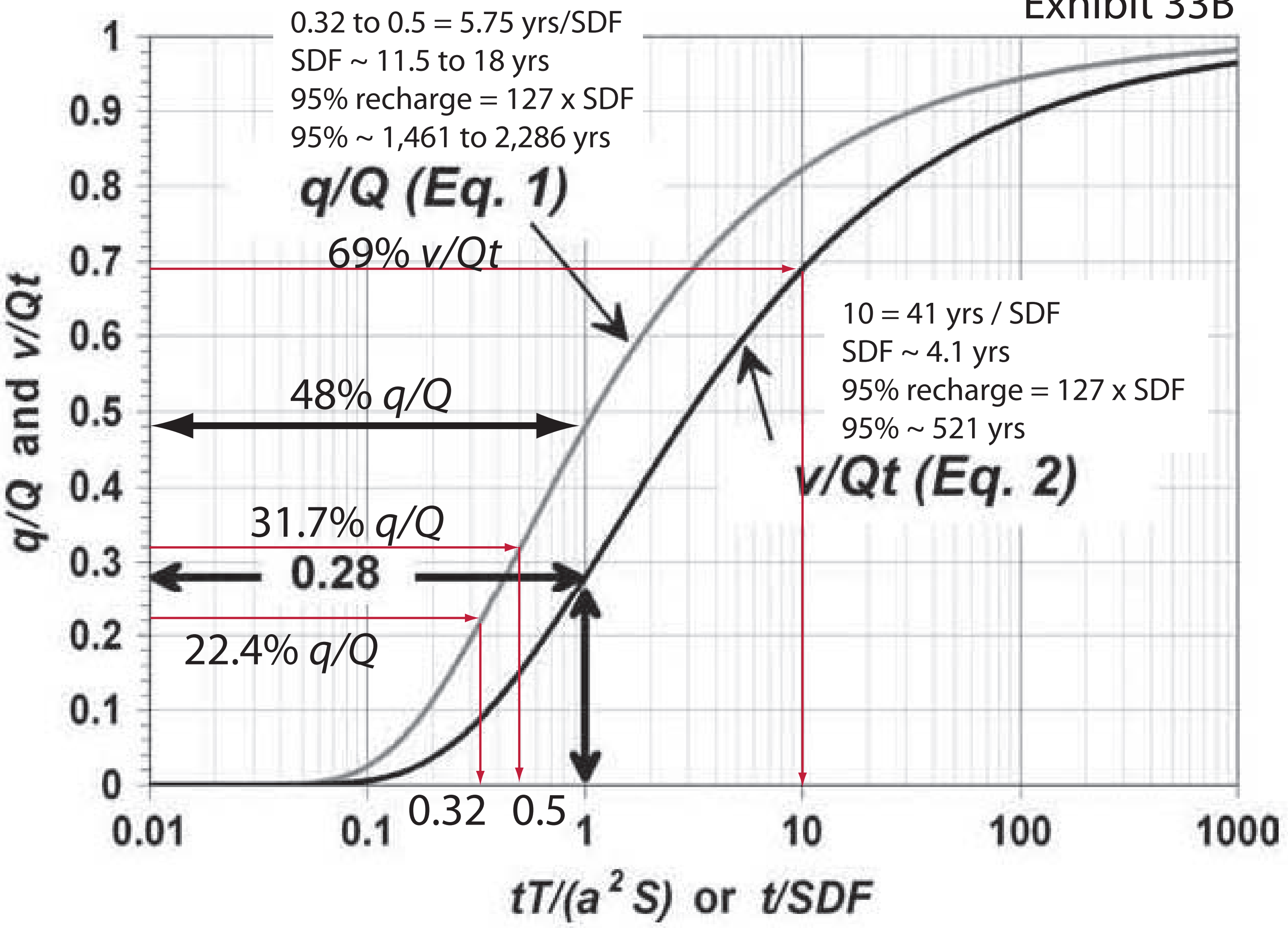
Stream	Maximum, cfs	Maximum % of 25K gpm[a]	Month/Year of Maximum	Time to Maximum, Years[b]	41 Year Average, cfs	41-Yr Average, % of Total Vol. Pumped[c]
Main Canal	14.4	25.9%(36.5%)	Jun-91	4.33	3.5	22.7%
Sac River	12.5	22.4%(31.7%)	Nov-92	5.75	4.2	27.3%
Stony Crk	11.6	20.8%(29.4%)	Oct-92	5.67	1.8	11.7%
Little Chico Crk	3	5.4%(7.6%)	Jan-93	5.92	0.5	3.2%
Big Chico Crk	1	1.8%(2.5%)	Apr-93	6.17	0.3	1.9%
Colusa Drain	0.9	1.6%(2.3%)	Mar-96	9.08	0.23	1.5%
Walker Crk	0.2	0.4%(0.5%)	Mar-86	n.a.	0.02	0.1%
			41-Yr Average Stream Depletion, cfs		10.55	
			41-Yr Average of Total Pumped, cfs		15.35	
				% of Total Volume Pumped over 41 Years		68.5%

a) Value in parenthesis is based on an annual time-weighted average of 25,000 gpm for 12 months = 17,705 gpm = 39.45 cfs

b) Time to maximum calculated for 6 years of sequential pumping starting from February 1987

c) Percentage is based on a 41-year time-weighted average pumping rate for 16 years at 28,600 acre-feet/year

Exhibit 33B



0.32 to 0.5 = 5.75 yrs/SDF
SDF ~ 11.5 to 18 yrs
95% recharge = 127 x SDF
95% ~ 1,461 to 2,286 yrs

10 = 41 yrs / SDF
SDF ~ 4.1 yrs
95% recharge = 127 x SDF
95% ~ 521 yrs

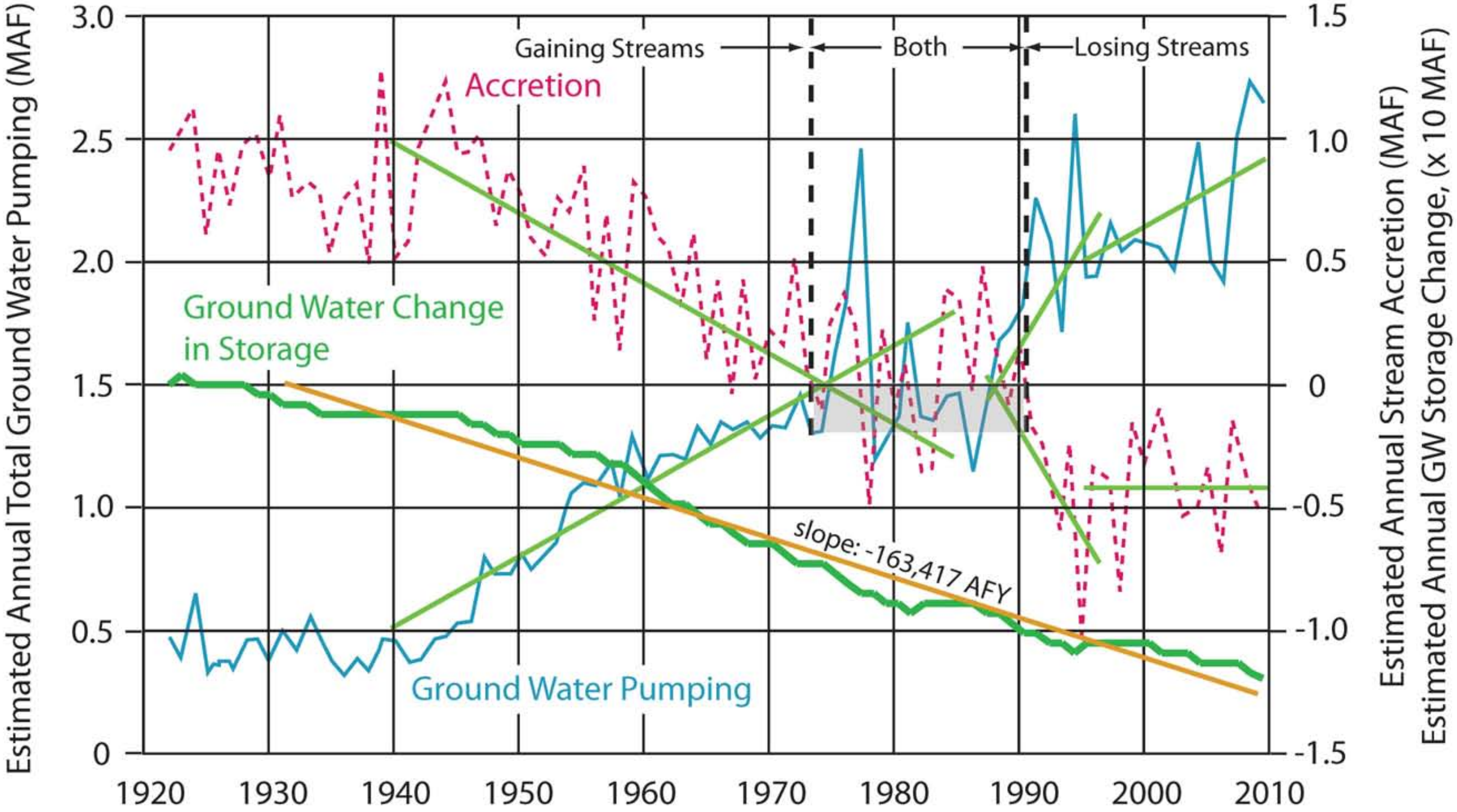
Figure 2. Ideal response curves for stream depletion rate and volume.

(from Miller and others, 2007)

AQUA-Exhibit 32

Exhibit

Comparison of Ground Water Pumping and Accretion
Sacramento Valley
1920's to 2009



Changes in Accretion, Ground Water Pumping and Ground Water Storage

1. 1920's: ~+953 TAFY accretion with ~+451 TAFY gw pumping = ~ 1,400 TAFY loss in gw storage
2. Late 1960's to Early 1970's: first zero accretion occurs with ~1,300 to ~1,500 TAFY gw pumping
3. 1920' to 2009: ~ +953 TAFY accretion to ~ - 445 TAFY accretion = ~ 1,400 TAFY difference
4. Slope of Accretion 1940 to mid-1970's ~ -27,000 AFY; late 1980's to mid-1990's ~ - 85,000 AFY; ratio ~ 3X
5. 1940 to mid-1970s' and late 1980's to mid 1990's slopes of ground water pumping increases are mirror images of slopes of accretion losses
6. Mid -1990's to 2010 groundwater pumping slope is similar to 1940 to mid-1970's, but accretion slope is flat.
7. Ground water change in storage ~ 12 to 14 MAF 1922 to 2009 (Figure 35, C2VSim User's Manual v. 3.02-CG, v. R374, June 2013, and Table 10 C2VSim Final Report 3.02-CG, v. R374, June 2013)

* From AquAlliance - Custis Nov. 25, 2014 comment no. 20 and Exhibit 10.7 on Sept. 2014 USBR/SLDMWA Long-Term Water Transfers