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Water Resources • Flood Control • Water Rights

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November 12, 2014

Richard Woodley
U.S. Bureau of Reclamation
2800 Cottage Way
Sacramento, CA 95821

Subject: Conaway Preservation Group 2014 Water Transfer Second Land Subsidence Report

Dear Mr. Woodley:

On behalf of Conaway Preservation Group (CPG), the purpose of this letter is to provide the enclosed Survey Control Project Report (Report) requested pursuant to Paragraph 16 of the Agreement Among the United States, CPG, and the Tehama-Colusa Canal Authority to Provide for Additional Water from the Central Valley Project for 2014, dated May 19, 2014 (Agreement). The Report details the results of a land subsidence monitoring survey conducted at the end of the 2014 irrigation season for CPG by Frame Surveying & Mapping in accordance with the approach identified in Exhibit E to the Agreement. The Report includes a comparison of the survey results with the initial land subsidence survey results transmitted to your office by letter dated August 28, 2014. A third land subsidence monitoring survey will be conducted prior to the start of the 2015 irrigation season; and following that survey, the results will be documented in a report to be provided in a future update pursuant to Exhibit E.

Please call if you have any questions or require additional information.

Sincerely,
MBK ENGINEERS

Darren Cordova

Enclosures
cc: Robert Thomas, Conaway Preservation Group
Regina Cherovsky, Conaway Preservation Group
Mike Hall, Conaway Preservation Group
Andrew Hitchings, Somach, Simmons & Dunn
Tim Durbin, Tim J. Durbin, Inc.
Jim Frame, Frame Surveying & Mapping
Jeff Sutton, Tehama-Colusa Canal Authority
Sheri Looper, U.S. Bureau of Reclamation
Stanley Parrott, U.S. Bureau of Reclamation
Trevor Joseph, Department of Water Resources
Chris Bonds, Department of Water Resources
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FRAME SURVEYING & MAPPING
609 A Street Davis, CA 95616
530.756.8584 jhframe@dcn.org

LICENSED LAND SURVEYOR JAMES H. FRAME III No. 5435 STATE OF CALIFORNIA

SURVEY CONTROL PROJECT REPORT

CONAWAY RANCH LAND SUBSIDENCE MONITORING
SEPTEMBER, 2014 MONITORING EVENT

PURPOSE

This report describes the results of the second monitoring event of the Conaway Ranch subsidence monitoring project. The initial (baseline) measurements were described in a June, 2014 report, which is a companion document to this report.

EXECUTIVE SUMMARY

Of the 10 monitoring stations within the immediate project area, measurable subsidence was detected at 6 of the stations. The measured subsidence ranged from 5 cm to 17 cm, with the largest value found at station SM10, which is located near the ranch headquarters and also near the DWR extensometer. Estimated measurement accuracy is 2 cm. See Appendix A for a graphical approximation of subsidence distribution.

MONITORING EVENT DESIGN

As with the June measurements, the September monitoring event consisted of 30-minute minimum GPS observation sessions at all monitored stations. OPUS Projects was used to establish current ellipsoid heights at 8 stations in and near the project area.

The only terrestrial measurement in the September event was a trig leveling check between SM10 and the nearby EX11, which was performed in response to the relatively large movement detected at SM10. It was determined that EX11 had subsided 0.016 m less than SM10. The June measurements to FERR and CONA were made to tie the project to the Yolo Subsidence Network, but aren't considered necessary to the ongoing monitoring effort.

DATA PROCESSING AND ADJUSTMENT

Substantially duplicating the process followed in June, GPS data files greater than 2 hours in length were processed in OPUS Projects, and the resulting adjustment again constrained stations LNC2, P267, P268 and SACR. The ellipsoid heights of the constraining stations showed very little change between the June and September events – 5 mm or less – validating the selection of these stations as stable vertical constraints.

TABLE E			
STATION POSITIONS - CCS83 US SURVEY FEET			
STATION	NORTHING	EASTING	ELEVATION
1031	2008599.383	6644606.877	33.236
CAST	1967456.543	6663504.495	17.005
COD1	1977287.674	6659463.132	21.206
COY1	1977246.445	6649648.950	27.478
CR27	1987259.421	6648517.853	29.651
EX11	1997336.718	6656626.527	24.513
P268	1934465.509	6662900.456	25.804
P271	2001341.660	6643182.771	42.554
RIVE	1997860.863	6683832.685	39.235
S16A	2008423.129	6663149.765	27.723
SM08	1987046.351	6662905.689	21.206
SM09	1988144.768	6673466.416	18.500
SM10	1997409.582	6656970.177	30.939
SM11	2006681.702	6655241.391	23.129
UCD1	1957204.975	6632828.912	102.613

HEIGHT COMPARISONS, SEPTEMBER 2014 – JUNE 2014

Table F below shows the difference in station height between the September and June 2014 monitoring events. A negative delta value indicates that a station has subsided.

These values constitute the data from which the subsidence contours shown in Appendix A were developed. Reiterating the cautionary note from Appendix A, these contours are based on interpolating between the very sparse data points available from the survey. While they are useful for showing in broad strokes the distribution of subsidence, they are not to be regarded as accurate except in the immediate vicinity of the individual monitoring stations.

TABLE C			
GEOGRAPHIC STATION POSITIONS			
STATION	LATITUDE	LONGITUDE	ELLIP HT (M)
1031	38-40-38.146911	121-42-34.079974	-20.568
CAST	38-33-50.779180	121-38-37.806580	-25.807
COD1	38-35-28.114860	121-39-28.223014	-24.459
COY1	38-35-28.054244	121-41-31.836450	-22.597
CR27	38-37-07.071749	121-41-45.661002	-21.847
EX11	38-38-46.406630	121-40-03.026719	-23.288
P268	38-28-24.681149	121-38-47.027881	-23.431
P271	38-39-26.447882	121-42-52.326075	-17.804
RIVE	38-38-50.462947	121-34-20.065279	-18.774
S16A	38-40-35.753116	121-38-40.255181	-22.202
SM08	38-37-04.450378	121-38-44.384113	-24.364
SM09	38-37-14.880094	121-36-31.260494	-25.163
SM10	38-38-47.114446	121-39-58.691662	-21.328
SM11	38-40-18.832764	121-40-20.061430	-23.630
UCD1	38-32-10.449924	121-45-04.379784	0.014

TABLE D			
STATION POSITIONS - CCS83 Meters			
STATION	NORTHING	EASTING	ELEVATION
1031	612222.316	2025280.227	10.131
CAST	599681.954	2031040.232	5.183
COD1	602678.488	2029808.422	6.464
COY1	602665.922	2026817.054	8.375
CR27	605717.883	2026472.295	9.038
EX11	608789.449	2028943.823	7.472
P268	589626.267	2030856.121	7.865
P271	610010.158	2024846.158	12.971
RIVE	608949.209	2037236.277	11.959
S16A	612168.594	2030932.110	8.450
SM08	605652.939	2030857.716	6.464
SM09	605987.737	2034076.632	5.639
SM10	608811.658	2029048.568	9.430
SM11	611637.806	2028521.633	7.050
UCD1	596557.269	2021690.296	31.277

accurate depiction of the distribution of that subsidence. If a more precise model of subsidence distribution is desired, the network of monitoring points will need to be densified. This can be accomplished by supplementing the rigorous static GPS network with infill measurements captured by means of more rapid – though slightly less accurate – GPS techniques.

TABLE F			
ORTHOMETRIC HEIGHT COMPARISONS			
SEPTEMBER 2014 - JUNE 2014 (METERS)			
STATION	**09/2014**	**06/2014**	**Δ ELEVATION**
1031	10.131	10.183	-0.053
CAST	5.183	5.170	0.013
COD1	6.464	6.475	-0.012
COY1	8.375	8.414	-0.039
CR27	9.038	9.125	-0.087
EX11	7.472	7.628	-0.156
P268	7.865	7.867	-0.002
P271	12.971	13.023	-0.053
RIVE	11.959	11.983	-0.024
S16A	8.450	8.445	0.004
SM08	6.464	6.471	-0.007
SM09	5.639	5.628	0.011
SM10	9.430	9.602	-0.172
SM11	7.050	7.121	-0.071
UCD1	31.276	31.295	-0.019

DWR EXTENSOMETER DATA, SEPTEMBER – JUNE 2014

Data from the Conaway Extensometer is available at

http://www.water.ca.gov/waterdatalibrary/docs/Hydstra/docs/09N03E08C004M/POR/GROUND_SURFACE_DISPLACEMENT_POINT_DATA.CSV

This data indicates that between June 10, 2014 and September 4, 2014 the ground surface was displaced downward 0.12 m (0.42 foot) at the extensometer site. This substantially corroborates the change in elevation shown in Table F above.

SUMMARY

The orthometric height values determined by this survey have an estimated accuracy of +/- 2 cm at the 95% confidence level. Although many of the 95% error estimates for heights shown in the Star*Net adjustment report (see Appendix D) are smaller by a magnitude, empirical evidence has demonstrated that GPS height transfer is not reliably accurate at that level.

The results of this survey document land subsidence on the Conaway Ranch that occurred during the Summer 2014 season. However, the nature of the monitoring network does not permit

APPENDIX B - OPUS PROJECTS NETWORK ADJUSTMENT REPORT

NGS OPUS-PROJECTS NETWORK ADJUSTMENT REPORT
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All coordinate accuracies reported here are 1 times the formal uncertainties from the solution. For additional information: geodesy.noaa.gov/OPUS/Using_OPUS-Projects.html#accuracy

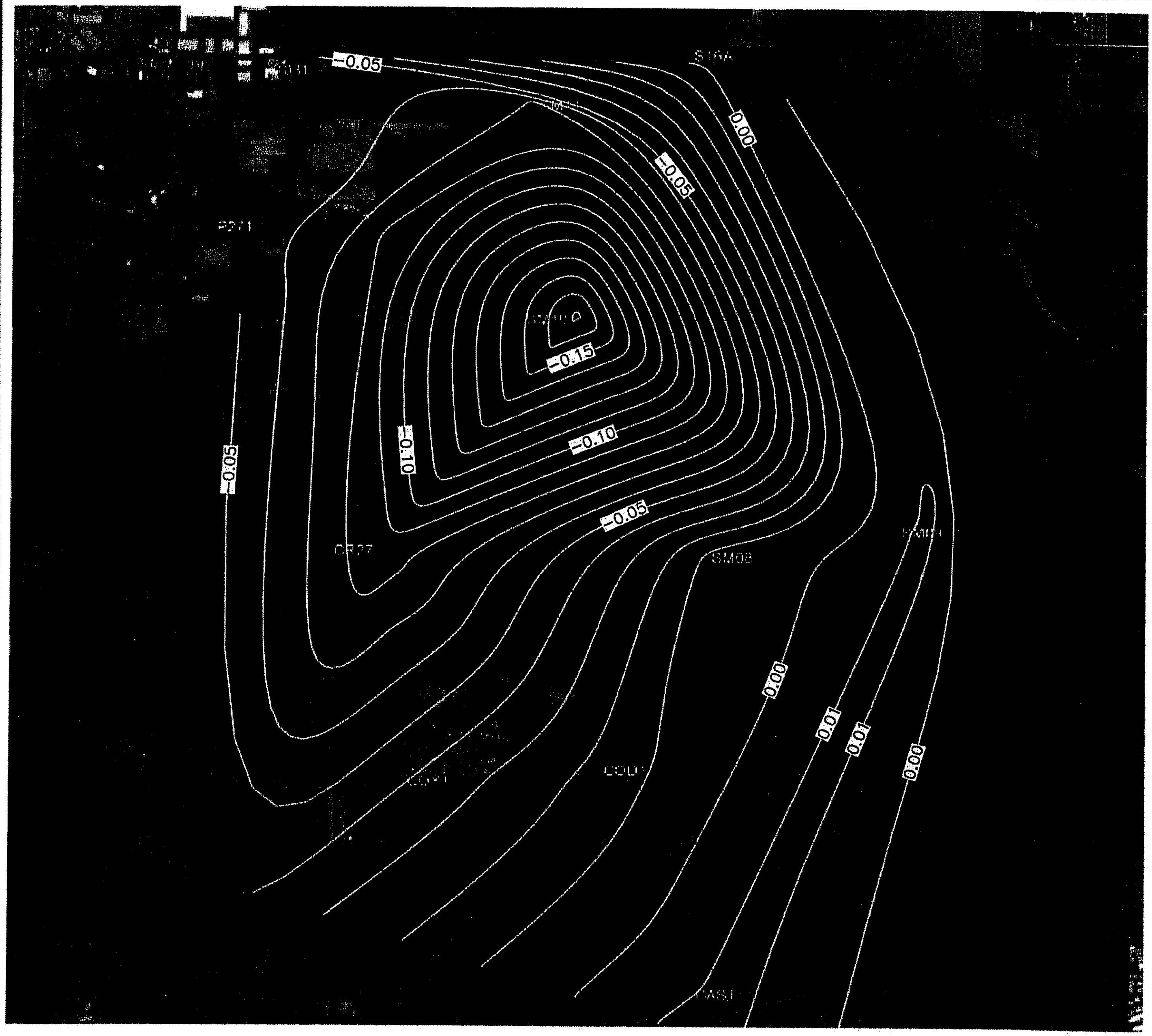
These positions were computed without any knowledge by the National Geodetic Survey regarding the equipment or field operating procedures used.

SUBMITTED BY:	jhframe
SOLUTION FILE NAME:	network-network-20140907-LNC2-P267-P2.sum
SOLUTION SOFTWARE:	GPSCOM(1210.24)
SOLUTION DATE:	2014-09-07T20:06:48 UTC
STANDARD ERROR OF UNIT WEIGHT:	0.500
TOTAL NUMBER OF OBSERVATIONS:	829229
TOTAL NUMBER OF MARKS:	16
NUMBER OF CONSTRAINED MARKS:	4

START TIME:	2014-09-03T00:00:00 GPS
STOP TIME:	2014-09-04T23:59:30 GPS
FREQUENCY:	L1-ONLY TO ION-FREE [BY BASELINE LENGTH]
OBSERVATION INTERVAL:	30 s
ELEVATION CUTOFF:	15 deg
TROPO INTERVAL:	1800 s [STEP-OFFSET PARAMETERIZATION]
DD CORRELATIONS:	ON

INCLUDED SOLUTION	RMS	SOFTWARE	RUN DATE
1) 2014-246 A	1.1 cm	GPSCOM(1210.24)	2014-09-07T19:41 UTC
2) 2014-246 B	1.3 cm	page5(1404.11)	2014-09-07T18:54 UTC
3) 2014-247 A	0.9 cm	GPSCOM(1210.24)	2014-09-07T19:30 UTC
4) 2014-247 B	0.9 cm	GPSCOM(1210.24)	2014-09-07T19:35 UTC

BASELINE	LENGTH	RMS	OBS	OMITTED	FIXED	IN SOLUTION(S)
1031-p271	2.254 km	0.4 cm	1566	0.4%	100.0%	1
coy1-cod1	2.992 km	0.5 cm	6924	2.5%	100.0%	2, 3, 4
sm08-cod1	3.154 km	0.6 cm	6951	4.4%	100.0%	2, 3, 4
sm10-sm08	3.640 km	0.6 cm	14526	3.6%	96.9%	1, 2, 3, 4
s16a-sm10	3.849 km	0.5 cm	3397	0.8%	100.0%	1, 4
p271-sm10	4.370 km	0.8 cm	17341	2.2%	100.0%	1, 2, 3, 4
sm08-coy1	5.025 km	0.6 cm	6216	1.4%	100.0%	3, 4
sm10-1031	5.083 km	0.6 cm	1565	0.5%	100.0%	1
s16a-1031	5.652 km	0.5 cm	957	2.6%	100.0%	1
s16a-p271	6.458 km	0.5 cm	1915	0.9%	100.0%	4
sm08-s16a	6.516 km	0.7 cm	3741	2.1%	100.0%	1, 4
coy1-sm10	6.539 km	0.6 cm	6300	0.5%	100.0%	3, 4
sm08-p271	7.425 km	0.9 cm	6409	2.5%	100.0%	1
coy1-p271	7.604 km	0.7 cm	6274	1.0%	100.0%	3, 4
ucd1-coy1	7.975 km	0.9 cm	6270	0.3%	100.0%	3, 4
ucd1-cod1	10.168 km	0.7 cm	2157	3.8%	100.0%	2
ucd1-p268	11.492 km	1.0 cm	57113	0.3%	100.0%	1, 3, 4
ucd1-sm08	12.915 km	1.0 cm	6361	2.5%	100.0%	1
p268-cod1	13.095 km	0.9 cm	7111	2.2%	100.0%	2, 3, 4
coy1-p268	13.651 km	0.9 cm	6310	0.3%	100.0%	3, 4
p271-ucd1	13.819 km	0.9 cm	56921	0.7%	98.8%	1, 3, 4



NOTES

1. SUBSIDENCE VALUES REPRESENT MOVEMENT DETECTED BETWEEN JUNE 10, 2014 AND SEPTEMBER 4, 2014.

2. CONTOUR LINES SHOWN WERE DERIVED FROM SPARSE DATA AND ARE INTENDED TO DEPICT APPROXIMATE SUBSIDENCE DISTRIBUTION ONLY EXCEPT IN THE IMMEDIATE VICINITY OF MONITORING STATIONS.

3. ABSOLUTE VALUES SMALLER THAN 0.02 METER ARE NOT CONSIDERED SIGNIFICANT DUE TO THE LIMITS OF THE MEASURSUREMENT TECHNOLOGY.

FRAME SURVEYING & MAPPING
609 A STREET DAVIS, CA 95616
530.756.8584 (v&f) jhframe@dcn.org
1037-001

SUBSIDENCE CONTOURS
CONAWAY RANCH SUBSIDENCE MONITORING EVENT
SEPTEMBER, 2014 SCALE: 1"= 2000'
SUBSIDENCE VALUES SHOWN IN METERS

APPENDIX B - OPUS PROJECTS NETWORK ADJUSTMENT REPORT

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UNCONSTRAINED MARKS
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MARK:       1031 (1031     1)

REF FRAME:         NAD_83(2011) (2010.0000)              IGS08 (2014.6730)
X:               -2620586.835 m    0.002 m      -2620587.718 m    0.002 m
Y:               -4241524.000 m    0.002 m      -4241522.693 m    0.002 m
Z:                3964397.371 m    0.002 m       3964397.344 m    0.002 m
LAT:            38 40 38.14700     0.001 m     38 40 38.15946     0.001 m
E LON:         238 17 25.92000     0.001 m    238 17 25.86048     0.001 m
W LON:         121 42 34.08000     0.001 m    121 42 34.13952     0.001 m
EL HGT:               -20.585 m    0.002 m           -21.108 m    0.002 m
ORTHO HGT:             10.113 m    0.022 m  (H = h - N WHERE N = GEOID12A HGT)

                  UTM COORDINATES    STATE PLANE COORDINATES
                   UTM (Zone 10)        SPC (0402 CA 2)
NORTHING (Y)      4281753.255 m        612222.319 m
EASTING (X)        612257.527 m       2025280.226 m
CONVERGENCE        0.80658090 deg      0.18317207 deg
POINT SCALE        0.99975518          0.99993980
COMBINED FACTOR    0.99975841          0.99994303

US NATIONAL GRID DESIGNATOR: 10SFH1225781753 (NAD 83)

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MARK:       casr (casr a   1)

REF FRAME:         NAD_83(2011) (2010.0000)              IGS08 (2014.6726)
X:               -2705828.432 m    0.001 m      -2705829.321 m    0.001 m
Y:               -4207167.175 m    0.002 m      -4207165.810 m    0.002 m
Z:                3943880.560 m    0.002 m       3943880.595 m    0.002 m
LAT:            38 26 26.41470     0.001 m     38 26 26.42904     0.001 m
E LON:         237 15 10.83511     0.001 m    237 15 10.77384     0.001 m
W LON:         122 44 49.16489     0.001 m    122 44 49.22616     0.001 m
EL HGT:                11.968 m    0.002 m            11.467 m    0.002 m
ORTHO HGT:             43.427 m    0.022 m  (H = h - N WHERE N = GEOID12A HGT)

                  UTM COORDINATES    STATE PLANE COORDINATES
                   UTM (Zone 10)        SPC (0402 CA 2)
NORTHING (Y)      4254740.503 m        586187.630 m
EASTING (X)        522080.014 m       1934786.767 m
CONVERGENCE        0.15729779 deg     -0.47095370 deg
POINT SCALE        0.99960600          0.99997739
COMBINED FACTOR    0.99960412          0.99997551

US NATIONAL GRID DESIGNATOR: 10SEH2208054740 (NAD 83)
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p268-sm08	16.027 km	1.1 cm	17523	3.3%	100.0%	1, 3, 4
ucd1-p267	18.412 km	1.0 cm	56766	1.0%	100.0%	1, 3, 4
p268-p267	18.585 km	0.9 cm	76118	0.8%	100.0%	1, 2, 3, 4
sacr-lnc2	21.262 km	1.5 cm	35562	3.2%	100.0%	1, 2
s16a-sacr	25.379 km	1.2 cm	1974	3.9%	100.0%	1
sm08-sacr	25.707 km	1.6 cm	11738	3.9%	88.9%	1, 2
lnc2-s16a	31.759 km	0.9 cm	4209	0.8%	100.0%	1, 4
p268-sacr	32.469 km	1.4 cm	17971	2.2%	94.3%	1
lnc2-sm10	35.312 km	1.1 cm	6534	2.5%	100.0%	3
lnc2-sm08	36.090 km	1.1 cm	11122	3.3%	100.0%	3, 4
p271-lnc2	37.975 km	0.9 cm	37938	0.8%	96.3%	3, 4
p267-p261	42.752 km	0.9 cm	37922	1.0%	100.0%	3, 4
p268-lnc2	48.759 km	0.9 cm	38122	0.3%	100.0%	3, 4
p261-ucd1	58.923 km	1.0 cm	37904	0.4%	100.0%	3, 4
lnc2-cho5	70.520 km	1.0 cm	18787	1.3%	96.6%	1
p271-p261	71.169 km	0.9 cm	38068	0.5%	98.2%	3, 4
p267-casr	80.959 km	1.1 cm	18714	1.6%	98.4%	1
p267-s300	82.582 km	0.9 cm	18896	0.7%	98.1%	1
1031-cho5	83.947 km	0.8 cm	1542	1.8%	100.0%	1
cho5-s16a	83.951 km	1.0 cm	2304	0.7%	100.0%	1
casr-ucd1	87.522 km	1.2 cm	18719	1.0%	95.1%	1
s300-p268	89.915 km	0.9 cm	18999	0.3%	100.0%	1
p271-casr	93.160 km	1.2 cm	18686	1.8%	100.0%	1
casr-1031	94.167 km	1.3 cm	1551	0.3%	100.0%	1
sacr-s300	111.173 km	1.4 cm	17897	1.9%	98.4%	1
casr-s300	135.166 km	1.2 cm	18823	0.4%	92.7%	1
cho5-casr	144.661 km	1.3 cm	18515	2.5%	95.7%	1

APPENDIX B - OPUS PROJECTS NETWORK ADJUSTMENT REPORT

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MARK:      coy1 (coy1    1)

REF FRAME:          NAD_83(2011) (2010.0000)              IGS08 (2014.6757)
X:                 -2622442.280 m    0.001 m       -2622443.163 m    0.001 m
Y:                 -4247392.981 m    0.002 m       -4247391.673 m    0.002 m
Z:                  3956926.861 m    0.002 m        3956926.834 m    0.002 m
LAT:              38 35 28.05426     0.001 m      38 35 28.06670     0.001 m
E LON:           238 18 28.16354     0.001 m     238 18 28.10409     0.001 m
W LON:           121 41 31.83646     0.001 m     121 41 31.89591     0.001 m
EL HGT:                 -22.598 m    0.002 m            -23.122 m    0.002 m
ORTHO HGT:                8.375 m    0.022 m  (H = h - N WHERE N = GEOID12A HGT)

                    UTM COORDINATES     STATE PLANE COORDINATES
                     UTM (Zone 10)         SPC (0402 CA 2)
NORTHING (Y)        4272215.915 m         602665.922 m
EASTING (X)          613897.797 m        2026817.053 m
CONVERGENCE          0.81585354 deg       0.19407278 deg
POINT SCALE          0.99975975           0.99995154
COMBINED FACTOR      0.99976329           0.99995509

US NATIONAL GRID DESIGNATOR: 10SFH1389772215 (NAD 83)

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MARK:      p261 (p261 a   4)

REF FRAME:          NAD_83(2011) (2010.0000)              IGS08 (2014.6753)
X:                 -2677432.147 m    0.001 m       -2677433.022 m    0.001 m
Y:                 -4248807.523 m    0.002 m       -4248806.186 m    0.002 m
Z:                  3918882.060 m    0.002 m        3918882.053 m    0.002 m
LAT:              38 09 10.64359     0.001 m      38 09 10.65673     0.001 m
E LON:           237 46 56.91143     0.001 m     237 46 56.85175     0.001 m
W LON:           122 13 03.08857     0.001 m     122 13 03.14825     0.001 m
EL HGT:                 118.692 m    0.002 m            118.166 m    0.002 m
ORTHO HGT:              150.561 m    0.022 m  (H = h - N WHERE N = GEOID12A HGT)

                    UTM COORDINATES     STATE PLANE COORDINATES
                     UTM (Zone 10)         SPC (0402 CA 2)
NORTHING (Y)        4223075.294 m         554005.247 m
EASTING (X)          568556.824 m        1980933.176 m
CONVERGENCE          0.48340313 deg      -0.13714237 deg
POINT SCALE          0.99965788           1.00004578
COMBINED FACTOR      0.99963926           1.00002716

US NATIONAL GRID DESIGNATOR: 10SEH6855623075 (NAD 83)
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APPENDIX B – OPUS PROJECTS NETWORK ADJUSTMENT REPORT

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MARK:      cho5 (cho5 a  2)

REF FRAME:          NAD_83(2011) (2010.0000)               IGS08 (2014.6726)
X:                -2589569.372 m    0.001 m        -2589570.258 m    0.001 m
Y:                -4198613.275 m    0.002 m        -4198611.980 m    0.002 m
Z:                 4029540.481 m    0.002 m         4029540.456 m    0.002 m
LAT:             39 25 57.48598     0.001 m      39 25 57.49848      0.001 m
E LON:          238 20 06.18724     0.001 m     238 20 06.12729      0.001 m
W LON:          121 39 53.81276     0.001 m     121 39 53.87271      0.001 m
EL HGT:                 17.098 m    0.002 m              16.590 m    0.002 m
ORTHO HGT:              45.334 m    0.022 m  (H = h - N WHERE N = GEOID12A HGT)

                UTM COORDINATES    STATE PLANE COORDINATES
                 UTM (Zone 10)         SPC (0402 CA 2)
NORTHING (Y)     4365638.688 m         696087.317 m
EASTING (X)       614899.215 m        2028844.773 m
CONVERGENCE       0.84807839 deg       0.21123968 deg
POINT SCALE       0.99976254           0.99993307
COMBINED FACTOR   0.99975986           0.99993039

US NATIONAL GRID DESIGNATOR: 10SFJ1489965638 (NAD 83)

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MARK:      cod1 (cod1    1)

REF FRAME:          NAD_83(2011) (2010.0000)               IGS08 (2014.6751)
X:                -2619894.992 m    0.002 m        -2619895.875 m    0.002 m
Y:                -4248961.603 m    0.002 m        -4248960.295 m    0.002 m
Z:                 3956927.160 m    0.002 m         3956927.132 m    0.002 m
LAT:             38 35 28.11487     0.001 m      38 35 28.12732      0.001 m
E LON:          238 20 31.77700     0.001 m     238 20 31.71758      0.001 m
W LON:          121 39 28.22300     0.001 m     121 39 28.28242      0.001 m
EL HGT:                -24.460 m    0.002 m             -24.986 m    0.002 m
ORTHO HGT:               6.463 m    0.022 m  (H = h - N WHERE N = GEOID12A HGT)

                UTM COORDINATES    STATE PLANE COORDINATES
                 UTM (Zone 10)         SPC (0402 CA 2)
NORTHING (Y)     4272260.928 m         602678.489 m
EASTING (X)       616888.293 m        2029808.422 m
CONVERGENCE       0.83727898 deg       0.21572122 deg
POINT SCALE       0.99976825           0.99995153
COMBINED FACTOR   0.99977209           0.99995537

US NATIONAL GRID DESIGNATOR: 10SFH1688872260 (NAD 83)
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APPENDIX B - OPUS PROJECTS NETWORK ADJUSTMENT REPORT

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MARK: s300 (s300 a 3)

REF FRAME:	NAD_83(2011) (2010.0000)		IGS08 (2014.6726)	
X:	-2645886.543 m	0.001 m	-2645887.420 m	0.001 m
Y:	-4307856.961 m	0.002 m	-4307855.641 m	0.002 m
Z:	3876512.196 m	0.002 m	3876512.164 m	0.002 m
LAT:	37 39 59.41374	0.001 m	37 39 59.42610	0.001 m
E LON:	238 26 30.28629	0.001 m	238 26 30.22763	0.001 m
W LON:	121 33 29.71371	0.001 m	121 33 29.77237	0.001 m
EL HGT:	496.304 m	0.002 m	495.757 m	0.002 m
ORTHO HGT:	528.063 m	0.022 m	(H = h - N WHERE N = GEOID12A HGT)	

	UTM COORDINATES UTM (Zone 10)	STATE PLANE COORDINATES SPC (0403 CA 3)
NORTHING (Y)	4169791.690 m	629987.304 m
EASTING (X)	627155.978 m	1906640.117 m
CONVERGENCE	0.88111774 deg	-0.64789689 deg
POINT SCALE	0.99979915	0.99993026
COMBINED FACTOR	0.99972129	0.99985239

US NATIONAL GRID DESIGNATOR: 10SFG2715569791 (NAD 83)

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MARK: sm08 (sm08 1)

REF FRAME:	NAD_83(2011) (2010.0000)		IGS08 (2014.6747)	
X:	-2618019.472 m	0.001 m	-2618020.355 m	0.001 m
Y:	-4247940.539 m	0.002 m	-4247939.231 m	0.002 m
Z:	3959248.615 m	0.002 m	3959248.587 m	0.002 m
LAT:	38 37 04.45037	0.001 m	38 37 04.46284	0.001 m
E LON:	238 21 15.61592	0.001 m	238 21 15.55649	0.001 m
W LON:	121 38 44.38408	0.001 m	121 38 44.44351	0.001 m
EL HGT:	-24.366 m	0.002 m	-24.892 m	0.002 m
ORTHO HGT:	6.462 m	0.022 m	(H = h - N WHERE N = GEOID12A HGT)	

	UTM COORDINATES UTM (Zone 10)	STATE PLANE COORDINATES SPC (0402 CA 2)
NORTHING (Y)	4275246.053 m	605652.939 m
EASTING (X)	617905.065 m	2030857.717 m
CONVERGENCE	0.84537168 deg	0.22339874 deg
POINT SCALE	0.99977119	0.99994765
COMBINED FACTOR	0.99977501	0.99995147

US NATIONAL GRID DESIGNATOR: 10SFH1790575246 (NAD 83)

APPENDIX B - OPUS PROJECTS NETWORK ADJUSTMENT REPORT

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MARK: p271 (p271 a 3)

REF FRAME:	NAD_83(2011) (2010.0000)		IGS08 (2014.6747)	
X:	-2621689.337 m	0.001 m	-2621690.215 m	0.001 m
Y:	-4242469.113 m	0.002 m	-4242467.793 m	0.002 m
Z:	3962672.872 m	0.002 m	3962672.829 m	0.002 m
LAT:	38 39 26.44791	0.001 m	38 39 26.46021	0.001 m
E LON:	238 17 07.67390	0.001 m	238 17 07.61429	0.001 m
W LON:	121 42 52.32610	0.001 m	121 42 52.38571	0.001 m
EL HGT:	-17.798 m	0.002 m	-18.342 m	0.002 m
ORTHO HGT:	12.977 m	0.022 m	(H = h - N WHERE N = GEOID12A HGT)	

	UTM COORDINATES UTM (Zone 10)	STATE PLANE COORDINATES SPC (0402 CA 2)
NORTHING (Y)	4279536.917 m	610010.159 m
EASTING (X)	611847.624 m	2024846.158 m
CONVERGENCE	0.80306366 deg	0.17997663 deg
POINT SCALE	0.99975405	0.99994232
COMBINED FACTOR	0.99975684	0.99994511

US NATIONAL GRID DESIGNATOR: 10SFH1184779536 (NAD 83)

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MARK: s16a (s16a 1)

REF FRAME:	NAD_83(2011) (2010.0000)		IGS08 (2014.6744)	
X:	-2615800.438 m	0.002 m	-2615801.321 m	0.002 m
Y:	-4244530.207 m	0.002 m	-4244528.900 m	0.002 m
Z:	3964338.733 m	0.002 m	3964338.706 m	0.002 m
LAT:	38 40 35.75313	0.001 m	38 40 35.76560	0.001 m
E LON:	238 21 19.74482	0.001 m	238 21 19.68534	0.001 m
W LON:	121 38 40.25518	0.001 m	121 38 40.31466	0.001 m
EL HGT:	-22.202 m	0.002 m	-22.726 m	0.002 m
ORTHO HGT:	8.450 m	0.022 m	(H = h - N WHERE N = GEOID12A HGT)	

	UTM COORDINATES UTM (Zone 10)	STATE PLANE COORDINATES SPC (0402 CA 2)
NORTHING (Y)	4281761.009 m	612168.595 m
EASTING (X)	617908.663 m	2030932.110 m
CONVERGENCE	0.84717221 deg	0.22412183 deg
POINT SCALE	0.99977120	0.99993988
COMBINED FACTOR	0.99977468	0.99994336

US NATIONAL GRID DESIGNATOR: 10SFH1790881761 (NAD 83)

APPENDIX B - OPUS PROJECTS NETWORK ADJUSTMENT REPORT

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CONSTRAINED MARKS
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MARK:       lnc2 (lnc2 a  2)
CONSTRAIN: 3-D NORMAL
ADJUST  X:   -0.007m (0.001m)   Y:   -0.008m (0.002m)   Z:     0.008m (0.002m)
ADJUST  N:   -0.000m (0.001m)   E:   -0.002m (0.001m)   H:     0.013m (0.001m)

REF FRAME:        NAD_83(2011) (2010.0000)                 IGS08 (2014.6744)
X:                -2587855.575 m    0.001 m       -2587856.456 m    0.001 m
Y:                -4247830.084 m    0.002 m       -4247828.780 m    0.002 m
Z:                 3979063.991 m    0.002 m        3979063.961 m    0.002 m
LAT:             38 50 47.41586     0.001 m      38 50 47.42845     0.001 m
E LON:          238 38 58.07306     0.001 m     238 38 58.01373     0.001 m
W LON:          121 21 01.92694     0.001 m     121 21 01.98627     0.001 m
EL HGT:                  6.394 m    0.001 m              5.865 m    0.001 m
ORTHO HGT:              36.400 m    0.022 m  (H = h - N WHERE N = GEOID12A HGT)

                UTM COORDINATES    STATE PLANE COORDINATES
                 UTM (Zone 10)        SPC (0402 CA 2)
NORTHING (Y)      4301035.814 m        631169.703 m
EASTING (X)        643142.392 m       2056377.344 m
CONVERGENCE        1.03477945 deg      0.40946695 deg
POINT SCALE        0.99985231          0.99992327
COMBINED FACTOR    0.99985131          0.99992227

US NATIONAL GRID DESIGNATOR: 10SFJ4314201035 (NAD 83)

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MARK:       p267 (p267 a  1)
CONSTRAIN: 3-D NORMAL
ADJUST  X:    0.015m (0.001m)   Y:    0.010m (0.002m)   Z:   -0.003m (0.002m)
ADJUST  N:    0.008m (0.001m)   E:    0.007m (0.001m)   H:   -0.015m (0.001m)

REF FRAME:        NAD_83(2011) (2010.0000)                 IGS08 (2014.6741)
X:                -2639830.530 m    0.001 m       -2639831.415 m    0.001 m
Y:                -4253760.634 m    0.002 m       -4253759.322 m    0.002 m
Z:                 3938614.254 m    0.002 m        3938614.228 m    0.002 m
LAT:             38 22 49.19452     0.001 m      38 22 49.20691     0.001 m
E LON:          238 10 36.40911     0.001 m     238 10 36.34962     0.001 m
W LON:          121 49 23.59089     0.001 m     121 49 23.65038     0.001 m
EL HGT:                -16.983 m    0.001 m            -17.508 m    0.001 m
ORTHO HGT:              14.863 m    0.022 m  (H = h - N WHERE N = GEOID12A HGT)

                UTM COORDINATES    STATE PLANE COORDINATES
                 UTM (Zone 10)        SPC (0402 CA 2)
NORTHING (Y)      4248670.398 m        579236.868 m
EASTING (X)        602783.963 m       2015446.347 m
CONVERGENCE        0.73070178 deg      0.11145439 deg
POINT SCALE        0.99973010          0.99998968
COMBINED FACTOR    0.99973276          0.99999234

US NATIONAL GRID DESIGNATOR: 10SFH0278348670 (NAD 83)
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APPENDIX B - OPUS PROJECTS NETWORK ADJUSTMENT REPORT

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MARK: sm10 (sm10 1)

REF FRAME:	NAD_83(2011) (2010.0000)		IGS08 (2014.6754)	
X:	-2618513.325 m	0.001 m	-2618514.209 m	0.001 m
Y:	-4245316.972 m	0.002 m	-4245315.665 m	0.002 m
Z:	3961723.467 m	0.002 m	3961723.439 m	0.002 m
LAT:	38 38 47.11448	0.001 m	38 38 47.12692	0.001 m
E LON:	238 20 01.30834	0.001 m	238 20 01.24887	0.001 m
W LON:	121 39 58.69166	0.001 m	121 39 58.75113	0.001 m
EL HGT:	-21.329 m	0.002 m	-21.853 m	0.002 m
ORTHO HGT:	9.429 m	0.022 m	(H = h - N WHERE N = GEOID12A HGT)	

	UTM COORDINATES UTM (Zone 10)	STATE PLANE COORDINATES SPC (0402 CA 2)
NORTHING (Y)	4278384.382 m	608811.659 m
EASTING (X)	616062.043 m	2029048.568 m
CONVERGENCE	0.83300330 deg	0.21038524 deg
POINT SCALE	0.99976588	0.99994375
COMBINED FACTOR	0.99976923	0.99994710

US NATIONAL GRID DESIGNATOR: 10SFH1606278384 (NAD 83)

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MARK: ucd1 (ucd1 1)

REF FRAME:	NAD_83(2011) (2010.0000)		IGS08 (2014.6744)	
X:	-2628825.708 m	0.001 m	-2628826.591 m	0.001 m
Y:	-4247933.423 m	0.002 m	-4247932.114 m	0.002 m
Z:	3952176.600 m	0.002 m	3952176.573 m	0.002 m
LAT:	38 32 10.44989	0.001 m	38 32 10.46230	0.001 m
E LON:	238 14 55.62017	0.001 m	238 14 55.56071	0.001 m
W LON:	121 45 04.37983	0.001 m	121 45 04.43929	0.001 m
EL HGT:	0.014 m	0.001 m	-0.510 m	0.001 m
ORTHO HGT:	31.276 m	0.022 m	(H = h - N WHERE N = GEOID12A HGT)	

	UTM COORDINATES UTM (Zone 10)	STATE PLANE COORDINATES SPC (0402 CA 2)
NORTHING (Y)	4266053.262 m	596557.268 m
EASTING (X)	608838.628 m	2021690.295 m
CONVERGENCE	0.77808018 deg	0.15685004 deg
POINT SCALE	0.99974588	0.99996018
COMBINED FACTOR	0.99974588	0.99996018

US NATIONAL GRID DESIGNATOR: 10SFH0883866053 (NAD 83)

APPENDIX C - MINIMALLY-CONSTRAINED GPS ADJUSTMENT REPORT

Project Information		**Coordinate System**	
Name:	C:\Projects\1037-001 \1037-001-201409.vce	Name:	US State Plane 1983
Size:	902 KB	Datum:	NAD 1983 (Conus)
Modified:	9/7/2014 5:44:03 PM (UTC:-7)	Zone:	California Zone 2 0402
Time zone:	Pacific Standard Time	Geoid:	GEOID12A
Reference number:		Vertical datum:	
Description:			

Network Adjustment Report

Adjustment Settings

Set-Up Errors

GNSS

Error in Height of Antenna: 0.000 m

Centering Error: 0.000 m

Covariance Display

Horizontal:

Propagated Linear Error [E]: U.S.

Constant Term [C]: 0.000 m

Scale on Linear Error [S]: 1.960

Three-Dimensional

Propagated Linear Error [E]: U.S.

Constant Term [C]: 0.000 m

Scale on Linear Error [S]: 1.960

Adjustment Statistics

Number of Iterations for Successful Adjustment: 2

Network Reference Factor: 1.00

Chi Square Test (95%): Passed

APPENDIX B - OPUS PROJECTS NETWORK ADJUSTMENT REPORT

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MARK:       p268 (p268 a  1)
CONSTRAIN: 3-D NORMAL
ADJUST  X:   -0.004m (0.001m)   Y:     0.015m (0.002m)   Z:    -0.007m (0.002m)
ADJUST  N:    0.001m (0.001m)   E:    -0.011m (0.001m)   H:    -0.013m (0.001m)

REF FRAME:         NAD_83(2011) (2010.0000)                  IGS08 (2014.6742)
X:                -2623314.307 m    0.001 m        -2623315.190 m    0.001 m
Y:                -4256409.676 m    0.002 m        -4256408.366 m    0.002 m
Z:                 3946714.191 m    0.002 m         3946714.163 m    0.002 m
LAT:             38 28 24.68109     0.001 m       38 28 24.69352     0.001 m
E LON:          238 21 12.97215     0.001 m      238 21 12.91279     0.001 m
W LON:          121 38 47.02785     0.001 m      121 38 47.08721     0.001 m
EL HGT:                -23.431 m    0.001 m              -23.958 m    0.001 m
ORTHO HGT:               7.865 m    0.022 m  (H = h - N WHERE N = GEOID12A HGT)

                 UTM COORDINATES    STATE PLANE COORDINATES
                  UTM (Zone 10)        SPC (0402 CA 2)
NORTHING (Y)      4259223.306 m       589626.265 m
EASTING (X)        618077.039 m      2030856.122 m
CONVERGENCE        0.84224552 deg     0.22293573 deg
POINT SCALE        0.99977170         0.99997117
COMBINED FACTOR    0.99977538         0.99997485

US NATIONAL GRID DESIGNATOR: 10SFH1807759223 (NAD 83)

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MARK:       sacr (sacr a  1)
CONSTRAIN: 3-D NORMAL
ADJUST  X:    0.004m (0.001m)   Y:    -0.018m (0.002m)   Z:     0.009m (0.002m)
ADJUST  N:   -0.001m (0.001m)   E:     0.013m (0.001m)   H:     0.016m (0.002m)

REF FRAME:         NAD_83(2011) (2010.0000)                  IGS08 (2014.6727)
X:                -2595053.373 m    0.001 m        -2595054.254 m    0.001 m
Y:                -4259028.374 m    0.002 m        -4259027.067 m    0.002 m
Z:                 3962484.552 m    0.002 m         3962484.523 m    0.002 m
LAT:             38 39 17.97126     0.001 m       38 39 17.98386     0.001 m
E LON:          238 38 44.80724     0.001 m      238 38 44.74800     0.001 m
W LON:          121 21 15.19276     0.001 m      121 21 15.25200     0.001 m
EL HGT:                  7.491 m    0.002 m                6.960 m    0.002 m
ORTHO HGT:              37.958 m    0.022 m  (H = h - N WHERE N = GEOID12A HGT)

                 UTM COORDINATES    STATE PLANE COORDINATES
                  UTM (Zone 10)        SPC (0402 CA 2)
NORTHING (Y)      4279776.701 m       609909.476 m
EASTING (X)        643204.819 m      2056208.536 m
CONVERGENCE        1.02817703 deg     0.40714371 deg
POINT SCALE        0.99985254         0.99994262
COMBINED FACTOR    0.99985136         0.99994144

US NATIONAL GRID DESIGNATOR: 10SFH4320479776 (NAD 83)
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ID	(Meter)	(Meter)	(Meter)	(Meter)	(Meter)	(Meter)	
1031	2025278.783	0.002	612222.692	0.002	9.603	0.012	
CAST	2031038.789	0.002	599682.330	0.003	4.670	0.015	
COD1	2029806.978	0.002	602678.863	0.002	5.965	0.013	
COY1	2026815.610	0.002	602666.297	0.002	7.865	0.011	
CR27	2026470.851	0.002	605718.258	0.002	8.521	0.019	
P268	2030854.677	0.003	589626.646	0.002	7.335	0.011	
P271	2024844.715	?	610010.534	?	12.433	?	LLh
RIVE	2037234.834	0.004	608949.583	0.004	11.464	0.026	
S16A	2030930.667	0.002	612168.968	0.002	7.933	0.013	
SM08	2030856.272	0.002	605653.314	0.002	5.959	0.010	
SM09	2034075.188	0.003	605988.111	0.003	5.125	0.017	
SM10	2029047.124	0.002	608812.032	0.002	8.913	0.008	
SM11	2028520.190	0.002	611638.181	0.002	6.534	0.013	
UCD1	2021688.853	0.002	596557.647	0.001	30.744	0.008	

Adjusted Geodetic Coordinates

Point ID	Latitude	Longitude	Height (Meter)	Height Error (Meter)	Constraint
1031	N38°40'38.15923"	W121°42'34.13964"	-21.096	0.012	
CAST	N38°33'50.79156"	W121°38'37.86615"	-26.319	0.015	
COD1	N38°35'28.12719"	W121°39'28.28263"	-24.958	0.013	

Precision Confidence Level: 95%
Degrees of Freedom: 141

Post Processed Vector Statistics

Reference Factor: 1.00
Redundancy Number: 141.00
A Priori Scalar: 1.57

Control Coordinate Comparisons

Values shown are control coordinates minus adjusted coordinates.

Point ID	ΔEasting (Meter)	ΔNorthing (Meter)	ΔElevation (Meter)	ΔHeight (Meter)
1031	0.003	0.007	?	-0.012
COD1	0.005	0.004	?	-0.028
COY1	0.003	0.004	?	-0.014
S16A	0.004	0.006	?	-0.007
SM08	0.006	0.004	?	-0.023
SM10	0.004	0.006	?	-0.008
UCD1	0.000	0.000	?	0.008

Control Point Constraints

Point ID	Type	East σ (Meter)	North σ (Meter)	Height σ (Meter)	Elevation σ (Meter)
P271	Global	Fixed	Fixed	Fixed	
Fixed = 0.000001(Meter)					

Adjusted Grid Coordinates

Point	Easting	Easting Error	Northing	Northing Error	Elevation	Elevation Error	Constraint

Error Ellipse Components

Point ID	Semi-major axis (Meter)	Semi-minor axis (Meter)	Azimuth
1031	0.003	0.002	2°
CAST	0.003	0.003	25°
COD1	0.003	0.003	46°
COY1	0.003	0.002	54°
CR27	0.003	0.003	50°
P268	0.004	0.002	85°
RIVE	0.006	0.004	50°
S16A	0.003	0.003	9°
SM08	0.003	0.002	49°
SM09	0.004	0.003	40°
SM10	0.002	0.002	29°
SM11	0.003	0.002	180°
UCD1	0.002	0.002	84°

Adjusted GPS Observations

Observation ID		Observation	A-posteriori Error	Residual	Standardized Residual
P271 --> SM10 (PV45)	**Az.**	106°05'53"	0.078 sec	-0.053 sec	-0.374
	ΔHt.	-3.503 m	0.008 m	-0.036 m	-4.824
	Ellip Dist.	4370.220 m	0.002 m	0.002 m	1.044
SM10 --> SM08 (PV22)	**Az.**	150°24'31"	0.099 sec	0.127 sec	1.269
	ΔHt.	-3.024 m	0.009 m	-0.034 m	-4.145
	Ellip Dist.	3640.323 m	0.002 m	0.001 m	0.248
SM08 --> COY1 (PV11)	**Az.**	233°45'00"	0.068 sec	-0.037 sec	-0.480
	ΔHt.	1.761 m	0.011 m	-0.032 m	-2.774
	Ellip Dist.	5025.113 m	0.002 m	0.003 m	1.025
SM10 --> SM08 (PV74)	**Az.**	150°24'31"	0.099 sec	-0.109 sec	-0.907
	ΔHt.	-3.024 m	0.009 m	0.015 m	2.002

COY1	N38°35'28.06656"	W121°41'31.89604"	-23.108	0.011	
CR27	N38°37'07.08407"	W121°41'45.72062"	-22.363	0.019	
P268	N38°28'24.69364"	W121°38'47.08739"	-23.961	0.011	
P271	N38°39'26.46021"	W121°42'52.38571"	-18.342	?	LLh
RIVE	N38°38'50.47531"	W121°34'20.12486"	-19.269	0.026	
S16A	N38°40'35.76543"	W121°38'40.31483"	-22.719	0.013	
SM08	N38°37'04.46272"	W121°38'44.44375"	-24.869	0.010	
SM09	N38°37'14.89242"	W121°36'31.32010"	-25.676	0.017	
SM10	N38°38'47.12675"	W121°39'58.75130"	-21.845	0.008	
SM11	N38°40'18.84508"	W121°40'20.12109"	-24.146	0.013	
UCD1	N38°32'10.46230"	W121°45'04.43930"	-0.518	0.008	

Adjusted ECEF Coordinates

Point ID	X (Meter)	X Error (Meter)	Y (Meter)	Y Error (Meter)	Z (Meter)	Z Error (Meter)	3D Error (Meter)	Constraint
1031	-2620587.728	0.005	-4241522.703	0.008	3964397.346	0.008	0.013	
CAST	-2619838.599	0.007	-4251192.973	0.010	3954579.934	0.009	0.015	
COD1	-2619895.892	0.006	-4248960.313	0.009	3956927.146	0.009	0.014	
COY1	-2622443.173	0.005	-4247391.683	0.008	3956926.840	0.007	0.011	
CR27	-2621727.204	0.008	-4245595.486	0.013	3959313.317	0.012	0.019	
P268	-2623315.192	0.005	-4256408.360	0.008	3946714.164	0.007	0.012	
P271	-2621690.215	?	-4242467.792	?	3962672.829	?	?	LLh
RIVE	-2611508.416	0.011	-4249555.556	0.018	3961805.692	0.017	0.027	
S16A	-2615801.329	0.006	-4244528.905	0.009	3964338.705	0.009	0.014	
SM08	-2618020.370	0.005	-4247939.245	0.007	3959248.599	0.007	0.011	
SM09	-2615172.663	0.007	-4249456.549	0.011	3959499.368	0.011	0.017	
SM10	-2618514.217	0.004	-4245315.671	0.006	3961723.440	0.005	0.009	
SM11	-2618025.447	0.006	-4243539.221	0.008	3963930.476	0.008	0.013	
UCD1	-2628826.589	0.004	-4247932.109	0.005	3952176.568	0.005	0.008	

	ΔHt.	-3.024 m	0.009 m	-0.014 m	-1.617
	Ellip Dist.	3640.323 m	0.002 m	-0.002 m	-1.329
COY1 --> CR27 (PV59)	Az.	353°44'57"	0.164 sec	0.004 sec	0.029
	ΔHt.	0.744 m	0.018 m	0.012 m	0.620
	Ellip Dist.	3071.527 m	0.002 m	0.003 m	1.598
P271 --> 1031 (PV55)	Az.	11°16'53"	0.158 sec	-0.053 sec	-0.584
	ΔHt.	-2.754 m	0.012 m	0.016 m	1.588
	Ellip Dist.	2254.475 m	0.002 m	-0.001 m	-0.381
UCD1 --> P268 (PV123)	Az.	127°15'11"	0.033 sec	-0.004 sec	-0.207
	ΔHt.	-23.443 m	0.009 m	0.008 m	1.587
	Ellip Dist.	11491.744 m	0.002 m	0.000 m	0.300
S16A --> RIVE (PV61)	Az.	117°16'36"	0.122 sec	0.156 sec	1.374
	ΔHt.	3.451 m	0.025 m	-0.025 m	-1.137
	Ellip Dist.	7079.040 m	0.003 m	-0.006 m	-1.578
P271 --> SM11 (PV44)	Az.	66°17'40"	0.111 sec	-0.016 sec	-0.112
	ΔHt.	-5.804 m	0.013 m	0.031 m	1.566
	Ellip Dist.	4019.980 m	0.002 m	-0.002 m	-0.650
UCD1 --> CAST (PV41)	Az.	71°40'41"	0.050 sec	-0.016 sec	-0.298
	ΔHt.	-25.801 m	0.015 m	0.004 m	0.209
	Ellip Dist.	9858.657 m	0.002 m	0.005 m	1.543
SM08 --> CAST (PV13)	Az.	178°28'21"	0.075 sec	-0.006 sec	-0.057
	ΔHt.	-1.450 m	0.014 m	-0.026 m	-1.526
	Ellip Dist.	5974.062 m	0.002 m	0.003 m	0.939
COY1 --> CR27 (PV4)	Az.	353°44'57"	0.164 sec	-0.143 sec	-0.655
	ΔHt.	0.744 m	0.018 m	-0.029 m	-1.482
	Ellip Dist.	3071.527 m	0.002 m	0.001 m	0.443
SM08 --> CR27 (PV10)	Az.	271°04'18"	0.110 sec	-0.249 sec	-1.445
	ΔHt.	2.506 m	0.018 m	-0.007 m	-0.153
	Ellip Dist.	4386.131 m	0.002 m	0.001 m	0.225
UCD1 --> COY1 (PV39)	Az.	40°09'45"	0.051 sec	0.008 sec	0.151
	ΔHt.	-22.590 m	0.012 m	-0.002 m	-0.147
	Ellip Dist.	7975.266 m	0.002 m	0.005 m	1.418

	Ellip Dist.	3640.323 m	0.002 m	0.003 m	2.619
P271 --> SM10 (PV46)	**Az.**	106°05'53"	0.078 sec	-0.039 sec	-0.401
	ΔHt.	-3.503 m	0.008 m	-0.022 m	-2.389
	Ellip Dist.	4370.220 m	0.002 m	0.000 m	0.025
P271 --> SM10 (PV87)	**Az.**	106°05'53"	0.078 sec	0.052 sec	0.774
	ΔHt.	-3.503 m	0.008 m	0.018 m	2.326
	Ellip Dist.	4370.220 m	0.002 m	0.001 m	0.429
SM10 --> S16A (PV19)	**Az.**	29°30'24"	0.104 sec	-0.019 sec	-0.200
	ΔHt.	-0.874 m	0.012 m	-0.022 m	-2.170
	Ellip Dist.	3849.477 m	0.002 m	0.001 m	0.548
UCD1 --> CAST (PV107)	**Az.**	71°40'41"	0.050 sec	-0.075 sec	-0.914
	ΔHt.	-25.801 m	0.015 m	0.033 m	1.287
	Ellip Dist.	9858.657 m	0.002 m	-0.006 m	-2.101
COY1 --> CAST (PV3)	**Az.**	125°26'17"	0.096 sec	-0.018 sec	-0.152
	ΔHt.	-3.211 m	0.014 m	-0.022 m	-1.334
	Ellip Dist.	5171.245 m	0.002 m	0.006 m	2.021
UCD1 --> P271 (PV97)	**Az.**	13°21'33"	0.029 sec	-0.007 sec	-0.349
	ΔHt.	-17.824 m	0.008 m	-0.009 m	-1.988
	Ellip Dist.	13818.769 m	0.001 m	0.000 m	-0.446
S16A --> 1031 (PV62)	**Az.**	270°46'07"	0.098 sec	-0.004 sec	-0.032
	ΔHt.	1.624 m	0.015 m	-0.033 m	-1.938
	Ellip Dist.	5652.479 m	0.002 m	-0.002 m	-0.696
P271 --> COY1 (PV93)	**Az.**	165°09'29"	0.059 sec	0.032 sec	0.378
	ΔHt.	-4.766 m	0.011 m	0.028 m	1.795
	Ellip Dist.	7604.498 m	0.002 m	0.000 m	-0.158
UCD1 --> COY1 (PV105)	**Az.**	40°09'45"	0.051 sec	-0.013 sec	-0.201
	ΔHt.	-22.590 m	0.012 m	0.027 m	1.735
	Ellip Dist.	7975.266 m	0.002 m	0.001 m	0.335
P268 --> CAST (PV120)	**Az.**	1°16'19"	0.057 sec	0.003 sec	0.054
	ΔHt.	-2.358 m	0.016 m	0.045 m	1.701
	Ellip Dist.	10057.739 m	0.003 m	-0.003 m	-0.666
SM10 --> SM08 (PV18)	**Az.**	150°24'31"	0.099 sec	-0.085 sec	-0.981

	Ellip Dist.	2468.373 m	0.002 m	0.000 m	0.174
COY1 --> COD1 (PV57)	**Az.**	89°57'13"	0.136 sec	-0.029 sec	-0.253
	ΔHt.	-1.851 m	0.011 m	-0.009 m	-0.962
	Ellip Dist.	2991.539 m	0.002 m	0.001 m	0.394
SM08 --> SM09 (PV15)	**Az.**	84°17'08"	0.189 sec	0.019 sec	0.142
	ΔHt.	-0.807 m	0.014 m	0.022 m	0.961
	Ellip Dist.	3236.451 m	0.003 m	0.000 m	0.156
1031 --> SM11 (PV85)	**Az.**	100°24'19"	0.152 sec	0.045 sec	0.286
	ΔHt.	-3.051 m	0.014 m	-0.011 m	-0.920
	Ellip Dist.	3293.883 m	0.002 m	0.000 m	0.104
SM08 --> COD1 (PV12)	**Az.**	199°39'17"	0.117 sec	0.077 sec	0.919
	ΔHt.	-0.089 m	0.012 m	0.002 m	0.224
	Ellip Dist.	3154.264 m	0.002 m	0.001 m	0.775
COD1 --> CAST (PV1)	**Az.**	157°52'09"	0.142 sec	-0.073 sec	-0.541
	ΔHt.	-1.361 m	0.014 m	0.008 m	0.454
	Ellip Dist.	3239.991 m	0.002 m	0.002 m	0.901
SM10 --> SM11 (PV27)	**Az.**	349°38'56"	0.129 sec	0.026 sec	0.216
	ΔHt.	-2.301 m	0.012 m	0.014 m	0.889
	Ellip Dist.	2875.019 m	0.002 m	-0.002 m	-0.731
SM08 --> CR27 (PV65)	**Az.**	271°04'18"	0.110 sec	0.001 sec	0.006
	ΔHt.	2.506 m	0.018 m	-0.017 m	-0.872
	Ellip Dist.	4386.131 m	0.002 m	-0.002 m	-0.873
SM08 --> CAST (PV68)	**Az.**	178°28'21"	0.075 sec	0.018 sec	0.212
	ΔHt.	-1.450 m	0.014 m	0.002 m	0.075
	Ellip Dist.	5974.062 m	0.002 m	-0.003 m	-0.834
1031 --> SM11 (PV30)	**Az.**	100°24'19"	0.152 sec	-0.014 sec	-0.092
	ΔHt.	-3.051 m	0.014 m	0.014 m	0.826
	Ellip Dist.	3293.883 m	0.002 m	0.000 m	-0.263
S16A --> RIVE (PV6)	**Az.**	117°16'36"	0.122 sec	-0.019 sec	-0.158
	ΔHt.	3.451 m	0.025 m	0.023 m	0.787
	Ellip Dist.	7079.040 m	0.003 m	-0.002 m	-0.817
S16A --> 1031 (PV7)	**Az.**	270°46'07"	0.098 sec	-0.008 sec	-0.061

SM09 --> RIVE (PV17)	**Az.**	47°06'04"	0.132 sec	0.046 sec	0.457
	ΔHt.	6.408 m	0.024 m	-0.007 m	-0.274
	Ellip Dist.	4330.789 m	0.004 m	0.004 m	1.389
COD1 --> CAST (PV56)	**Az.**	157°52'09"	0.142 sec	0.002 sec	0.018
	ΔHt.	-1.361 m	0.014 m	-0.017 m	-1.304
	Ellip Dist.	3239.991 m	0.002 m	-0.001 m	-0.553
COY1 --> COD1 (PV2)	**Az.**	89°57'13"	0.136 sec	-0.045 sec	-0.383
	ΔHt.	-1.851 m	0.011 m	0.013 m	1.281
	Ellip Dist.	2991.539 m	0.002 m	0.001 m	0.775
SM08 --> COD1 (PV67)	**Az.**	199°39'17"	0.117 sec	-0.079 sec	-0.702
	ΔHt.	-0.089 m	0.012 m	-0.011 m	-1.172
	Ellip Dist.	3154.264 m	0.002 m	-0.001 m	-0.642
SM10 --> SM11 (PV82)	**Az.**	349°38'56"	0.129 sec	0.036 sec	0.260
	ΔHt.	-2.301 m	0.012 m	-0.014 m	-1.135
	Ellip Dist.	2875.019 m	0.002 m	0.000 m	-0.059
S16A --> SM09 (PV16)	**Az.**	153°15'34"	0.098 sec	0.001 sec	0.010
	ΔHt.	-2.957 m	0.018 m	-0.024 m	-1.129
	Ellip Dist.	6935.160 m	0.003 m	-0.001 m	-0.472
UCD1 --> P268 (PV109)	**Az.**	127°15'11"	0.033 sec	0.002 sec	0.091
	ΔHt.	-23.443 m	0.009 m	-0.005 m	-1.077
	Ellip Dist.	11491.744 m	0.002 m	0.000 m	0.244
SM10 --> S16A (PV75)	**Az.**	29°30'24"	0.104 sec	-0.012 sec	-0.115
	ΔHt.	-0.874 m	0.012 m	0.002 m	0.171
	Ellip Dist.	3849.477 m	0.002 m	0.003 m	1.030
SM10 --> CR27 (PV77)	**Az.**	219°59'43"	0.117 sec	-0.013 sec	-0.119
	ΔHt.	-0.518 m	0.019 m	0.022 m	0.977
	Ellip Dist.	4026.212 m	0.003 m	-0.001 m	-0.399
COY1 --> CAST (PV58)	**Az.**	125°26'17"	0.096 sec	0.010 sec	0.080
	ΔHt.	-3.211 m	0.014 m	0.011 m	0.474
	Ellip Dist.	5171.245 m	0.002 m	-0.003 m	-0.970
S16A --> SM11 (PV84)	**Az.**	257°48'20"	0.191 sec	0.025 sec	0.146
	ΔHt.	-1.427 m	0.013 m	-0.011 m	-0.963

P271 --> COY1 (PV52)	**Az.**	165°09'29"	0.059 sec	-0.031 sec	-0.376
	ΔHt.	-4.766 m	0.011 m	0.001 m	0.099
	Ellip Dist.	7604.498 m	0.002 m	0.000 m	0.028
P271 --> CR27 (PV92)	**Az.**	159°25'51"	0.110 sec	0.016 sec	0.175
	ΔHt.	-4.021 m	0.019 m	0.002 m	0.131
	Ellip Dist.	4590.237 m	0.002 m	0.001 m	0.260
SM10 --> SM09 (PV73)	**Az.**	119°31'50"	0.120 sec	0.007 sec	0.034
	ΔHt.	-3.831 m	0.016 m	0.002 m	0.043
	Ellip Dist.	5767.112 m	0.003 m	0.001 m	0.095

Covariance Terms

From Point	To Point		Components	A-posteriori Error	Horiz. Precision (Ratio)	3D Precision (Ratio)
1031	P271	**Az.**	191°17'05"	0.157 sec	1 : 1057493	1 : 1057519
		ΔHt.	2.754 m	0.012 m		
		ΔElev.	2.830 m	0.012 m		
		Ellip Dist.	2254.475 m	0.002 m		
1031	S16A	**Az.**	90°43'41"	0.098 sec	1 : 2552733	1 : 2552187
		ΔHt.	-1.624 m	0.015 m		
		ΔElev.	-1.670 m	0.015 m		
		Ellip Dist.	5652.479 m	0.002 m		
1031	SM11	**Az.**	100°24'19"	0.153 sec	1 : 1653677	1 : 1651496
		ΔHt.	-3.051 m	0.014 m		
		ΔElev.	-3.069 m	0.014 m		
		Ellip Dist.	3293.883 m	0.002 m		
CAST	COD1	**Az.**	337°52'41"	0.142 sec	1 : 1340853	1 : 1339734
		ΔHt.	1.361 m	0.014 m		
		ΔElev.	1.294 m	0.014 m		
		Ellip Dist.	3239.991 m	0.002 m		
CAST	COY1	**Az.**	305°28'06"	0.096 sec	1 : 2395191	1 : 2392920
		ΔHt.	3.211 m	0.014 m		

	ΔHt.	1.624 m	0.015 m	-0.003 m	-0.119
	Ellip Dist.	5652.479 m	0.002 m	-0.002 m	-0.694
SM08 --> SM09 (PV70)	Az.	84°17'08"	0.189 sec	0.077 sec	0.364
	ΔHt.	-0.807 m	0.014 m	-0.001 m	-0.228
	Ellip Dist.	3236.451 m	0.003 m	0.002 m	0.693
P271 --> CR27 (PV51)	Az.	159°25'51"	0.110 sec	-0.014 sec	-0.067
	ΔHt.	-4.021 m	0.019 m	0.031 m	0.690
	Ellip Dist.	4590.237 m	0.002 m	0.001 m	0.213
P271 --> SM11 (PV86)	Az.	66°17'40"	0.111 sec	0.032 sec	0.211
	ΔHt.	-5.804 m	0.013 m	0.002 m	0.171
	Ellip Dist.	4019.980 m	0.002 m	-0.002 m	-0.657
UCD1 --> P271 (PV43)	Az.	13°21'33"	0.029 sec	0.004 sec	0.211
	ΔHt.	-17.824 m	0.008 m	0.003 m	0.608
	Ellip Dist.	13818.769 m	0.001 m	0.000 m	-0.437
SM08 --> COY1 (PV66)	Az.	233°45'00"	0.068 sec	-0.037 sec	-0.435
	ΔHt.	1.761 m	0.011 m	-0.006 m	-0.410
	Ellip Dist.	5025.113 m	0.002 m	-0.002 m	-0.583
SM09 --> RIVE (PV72)	Az.	47°06'04"	0.132 sec	0.047 sec	0.561
	ΔHt.	6.408 m	0.024 m	-0.005 m	-0.373
	Ellip Dist.	4330.789 m	0.004 m	-0.002 m	-0.560
S16A --> SM11 (PV29)	Az.	257°48'20"	0.191 sec	-0.032 sec	-0.195
	ΔHt.	-1.427 m	0.013 m	0.007 m	0.493
	Ellip Dist.	2468.373 m	0.002 m	-0.001 m	-0.382
P268 --> CAST (PV134)	Az.	1°16'19"	0.057 sec	0.030 sec	0.472
	ΔHt.	-2.358 m	0.016 m	-0.004 m	-0.218
	Ellip Dist.	10057.739 m	0.003 m	-0.001 m	-0.245
P271 --> 1031 (PV96)	Az.	11°16'53"	0.158 sec	-0.024 sec	-0.182
	ΔHt.	-2.754 m	0.012 m	-0.003 m	-0.349
	Ellip Dist.	2254.475 m	0.002 m	-0.001 m	-0.446
S16A --> SM09 (PV71)	Az.	153°15'34"	0.098 sec	0.091 sec	0.391
	ΔHt.	-2.957 m	0.018 m	-0.006 m	-0.122
	Ellip Dist.	6935.160 m	0.003 m	0.001 m	0.189

COY1	UCD1	**Az.**	220°11'58"	0.051 sec	1 : 3412861	1 : 3411619
		ΔHt.	22.590 m	0.012 m		
		ΔElev.	22.879 m	0.012 m		
		Ellip Dist.	7975.266 m	0.002 m		
CR27	P271	**Az.**	339°26'32"	0.110 sec	1 : 2014188	1 : 2015173
		ΔHt.	4.021 m	0.019 m		
		ΔElev.	3.912 m	0.019 m		
		Ellip Dist.	4590.237 m	0.002 m		
CR27	SM08	**Az.**	91°02'25"	0.110 sec	1 : 1837654	1 : 1839212
		ΔHt.	-2.506 m	0.018 m		
		ΔElev.	-2.562 m	0.018 m		
		Ellip Dist.	4386.131 m	0.002 m		
CR27	SM10	**Az.**	39°58'37"	0.117 sec	1 : 1578617	1 : 1578491
		ΔHt.	0.518 m	0.019 m		
		ΔElev.	0.392 m	0.019 m		
		Ellip Dist.	4026.212 m	0.003 m		
RIVE	S16A	**Az.**	297°19'18"	0.122 sec	1 : 2116031	1 : 2118405
		ΔHt.	-3.451 m	0.025 m		
		ΔElev.	-3.532 m	0.025 m		
		Ellip Dist.	7079.040 m	0.003 m		
RIVE	SM09	**Az.**	227°07'26"	0.132 sec	1 : 1055317	1 : 1054019
		ΔHt.	-6.408 m	0.024 m		
		ΔElev.	-6.339 m	0.024 m		
		Ellip Dist.	4330.789 m	0.004 m		
S16A	SM09	**Az.**	153°15'34"	0.098 sec	1 : 2574971	1 : 2573056
		ΔHt.	-2.957 m	0.018 m		
		ΔElev.	-2.807 m	0.018 m		
		Ellip Dist.	6935.160 m	0.003 m		
S16A	SM10	**Az.**	209°31'13"	0.103 sec	1 : 1726658	1 : 1727353
		ΔHt.	0.874 m	0.012 m		
		ΔElev.	0.980 m	0.012 m		
		Ellip Dist.	3849.477 m	0.002 m		
S16A	SM11	**Az.**	257°48'20"	0.191 sec	1 : 1312698	1 : 1313696
		ΔHt.	-1.427 m	0.013 m		

		ΔElev.	3.195 m	0.014 m		
		Ellip Dist.	5171.245 m	0.002 m		
CAST	P268	Az.	181°16'24"	0.057 sec	1 : 3773990	1 : 3772785
		ΔHt.	2.358 m	0.016 m		
		ΔElev.	2.665 m	0.016 m		
		Ellip Dist.	10057.739 m	0.003 m		
CAST	SM08	Az.	358°28'25"	0.075 sec	1 : 2408874	1 : 2408166
		ΔHt.	1.450 m	0.014 m		
		ΔElev.	1.289 m	0.014 m		
		Ellip Dist.	5974.062 m	0.002 m		
CAST	UCD1	Az.	251°44'42"	0.050 sec	1 : 4123090	1 : 4118443
		ΔHt.	25.801 m	0.015 m		
		ΔElev.	26.074 m	0.015 m		
		Ellip Dist.	9858.657 m	0.002 m		
COD1	COY1	Az.	269°58'30"	0.136 sec	1 : 1527228	1 : 1528903
		ΔHt.	1.851 m	0.011 m		
		ΔElev.	1.901 m	0.011 m		
		Ellip Dist.	2991.539 m	0.002 m		
COD1	SM08	Az.	19°38'49"	0.116 sec	1 : 1461741	1 : 1460875
		ΔHt.	0.089 m	0.012 m		
		ΔElev.	-0.006 m	0.012 m		
		Ellip Dist.	3154.264 m	0.002 m		
COY1	CR27	Az.	353°44'57"	0.163 sec	1 : 1317734	1 : 1317312
		ΔHt.	0.744 m	0.018 m		
		ΔElev.	0.656 m	0.018 m		
		Ellip Dist.	3071.527 m	0.002 m		
COY1	P271	Az.	345°10'19"	0.059 sec	1 : 4083332	1 : 4081238
		ΔHt.	4.766 m	0.011 m		
		ΔElev.	4.568 m	0.011 m		
		Ellip Dist.	7604.498 m	0.002 m		
COY1	SM08	Az.	53°43'15"	0.068 sec	1 : 2385709	1 : 2386218
		ΔHt.	-1.761 m	0.011 m		
		ΔElev.	-1.906 m	0.011 m		
		Ellip Dist.	5025.113 m	0.002 m		

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		ΔElev.	-1.399 m	0.013 m		
		Ellip Dist.	2468.373 m	0.002 m		
SM08	SM09	**Az.**	84°17'08"	0.189 sec	1 : 1086141	1 : 1087567
		ΔHt.	-0.807 m	0.014 m		
		ΔElev.	-0.834 m	0.014 m		
		Ellip Dist.	3236.451 m	0.003 m		
SM08	SM10	**Az.**	330°25'17"	0.099 sec	1 : 2290748	1 : 2290777
		ΔHt.	3.024 m	0.009 m		
		ΔElev.	2.954 m	0.009 m		
		Ellip Dist.	3640.323 m	0.002 m		
SM09	SM10	**Az.**	299°33'59"	0.120 sec	1 : 2173531	1 : 2175731
		ΔHt.	3.831 m	0.016 m		
		ΔElev.	3.787 m	0.016 m		
		Ellip Dist.	5767.112 m	0.003 m		
SM10	P271	**Az.**	286°07'41"	0.078 sec	1 : 2798098	1 : 2798632
		ΔHt.	3.503 m	0.008 m		
		ΔElev.	3.520 m	0.008 m		
		Ellip Dist.	4370.220 m	0.002 m		
SM10	SM11	**Az.**	349°38'56"	0.129 sec	1 : 1335421	1 : 1335663
		ΔHt.	-2.301 m	0.012 m		
		ΔElev.	-2.379 m	0.012 m		
		Ellip Dist.	2875.019 m	0.002 m		
SM11	P271	**Az.**	246°19'15"	0.111 sec	1 : 2111126	1 : 2110872
		ΔHt.	5.804 m	0.013 m		
		ΔElev.	5.899 m	0.013 m		
		Ellip Dist.	4019.980 m	0.002 m		
UCD1	P268	**Az.**	127°15'11"	0.033 sec	1 : 5969252	1 : 5977614
		ΔHt.	-23.443 m	0.009 m		
		ΔElev.	-23.409 m	0.009 m		
		Ellip Dist.	11491.744 m	0.002 m		
UCD1	P271	**Az.**	13°21'33"	0.029 sec	1 : 9593411	1 : 9578680
		ΔHt.	-17.824 m	0.008 m		
		ΔElev.	-18.311 m	0.008 m		
		Ellip Dist.	13818.769 m	0.001 m		

APPENDIX D – STAR*NET NETWORK ADJUSTMENT REPORT

Summary of Unadjusted Input Observations

Number of Entered Stations (Meters) = 10
(Elevations Marked with (*) are Ellipsoid Heights)

Partially Fixed	N StdErr	E StdErr	Elev StdErr	Description
15	608777.2764	2029032.5965	10.8178	CONTROL
	0.0100	0.0100	FREE	
16 MARK	608797.8742	2028884.0119	10.0000	CONTROL AZ
	FREE	FREE	FIXED	

Partially Fixed	Latitude N-StdErr	Longitude E-StdErr	Elev StdErr	Description
UCD1	38-32-10.449890	121-45-04.379830	0.0140*	UCD1
	0.0010	0.0010	0.0010	
P268	38-28-24.681090	121-38-47.027850	-23.4310*	P268
	0.0010	0.0010	0.0010	
P271	38-39-26.447910	121-42-52.326100	-17.7980*	P271
	0.0010	0.0010	0.0020	
COD1	38-35-28.114870	121-39-28.223000	-24.4600*	COD1
	0.0010	0.0010	0.0020	
COY1	38-35-28.054260	121-41-31.836460	-22.5980*	COY1
	0.0010	0.0010	0.0020	
S16A	38-40-35.753130	121-38-40.255180	-22.2020*	S16A
	0.0010	0.0010	0.0020	
SM08	38-37-04.450370	121-38-44.384080	-24.3660*	SM08
	0.0010	0.0010	0.0020	
SM10	38-38-47.114480	121-39-58.691660	-21.3290*	SM10
	0.0010	0.0010	0.0020	

Number of Measured Angle Observations (DMS) = 2

From	At	To	Angle	StdErr	t-T
16	15	EX11	0-00-01.00	4.76	-0.00
16	15	SM10	107-06-31.00	12.67	-0.02

Number of Measured Distance Observations (Meters) = 3

From	To	Distance	StdErr	HI	HT	Comb Grid	Type
15	16	121.9202	FIXED	0.000	0.000	0.9999470	S
15	EX11	89.6510	0.0031	1.524	2.121	0.9999472	S
15	SM10	37.9205	0.0030	1.524	2.121	0.9999470	S

Number of Zenith Observations (DMS) = 2

From	To	Zenith	StdErr	HI	HT
15	EX11	91-45-28.00	5.35	1.524	2.121
15	SM10	91-11-33.00	11.89	1.524	2.121

APPENDIX D – STAR*NET NETWORK ADJUSTMENT REPORT

Note: In order to effectively incorporate the trigonometric leveling data, approximate positions for the instrument and backsight stations were determined in order to provide the adjustment engine with adequate seed data. This pertains to stations 15 and 16 referenced in the adjustment report. These station were ephemeral and are not marked on the ground.

Summary of Files Used and Option Settings

Project Folder and Data Files

Project Name		1037-001-201409
Project Folder		C:\STAR
Data File List	1.	1037-001-201409.dat
	2.	1037-001-201409.gps

Project Option Settings

STAR*NET Run Mode	: Adjust with Error Propagation
Type of Adjustment	: 3D
Project Units	: Meters; DMS
Coordinate System	: Lambert NAD83; CA Zone 2 0402
Geoid Height Model	: GEOID12A-5.GHT
Longitude Sign Convention	: Positive West
Input/Output Coordinate Order	: North-East
Angle Data Station Order	: From-At-To
Distance/Vertical Data Type	: Slope/Zenith
Convergence Limit; Max Iterations	: 0.010000; 99
Default Coefficient of Refraction	: 0.070000
Create Coordinate File	: Yes
Create Geodetic Position File	: Yes
Create Ground Scale Coordinate File	: No
Create Dump File	: No
GPS Vector Standard Error Factors	: 1.9600
GPS Vector Centering (Meters)	: 0.00100
GPS Vector Transformations	: None

Company Library Instrument TCRA1102
Note: Leica TCRA1102plus Robot

Distances (Constant)	:	0.002012 Meters
Distances (PPM)	:	2.000000
Angles	:	2.000000 Seconds
Directions	:	2.000000 Seconds
Azimuths & Bearings	:	2.000000 Seconds
Zeniths	:	2.000000 Seconds
Elevation Differences (Constant)	:	0.001524 Meters
Elevation Differences (PPM)	:	0.000000
Differential Levels	:	0.002403 Meters / Km
Centering Error Instrument	:	0.001524 Meters
Centering Error Target	:	0.001524 Meters
Centering Error Vertical	:	0.001524 Meters

```
(V14 PostProcessed 03-SEP-2014 19:22:14.0 1037-001-201409.asc)
COY1                      2547.2854          0.0060          0.8504
COD1                     -1568.6208          0.0097         -0.8142
                             0.2983          0.0099         -0.9366
(V15 PostProcessed 04-SEP-2014 15:27:29.0 1037-001-201409.asc)
COY1                      2547.2770          0.0065          0.8404
COD1                     -1568.6355          0.0092         -0.8049
                             0.3121          0.0086         -0.9157
(V16 PostProcessed 04-SEP-2014 15:14:29.0 1037-001-201409.asc)
COY1                      2604.5800          0.0133          0.9524
CAST                     -3801.2848          0.0202         -0.9250
                         -2346.9131          0.0184         -0.9437
(V17 PostProcessed 03-SEP-2014 19:18:44.0 1037-001-201409.asc)
COY1                      2604.5616          0.0102          0.8826
CAST                     -3801.2998          0.0140         -0.8777
                         -2346.8893          0.0151         -0.9073
(V18 PostProcessed 04-SEP-2014 17:13:59.0 1037-001-201409.asc)
COY1                       715.9736          0.0121          0.9492
CR27                      1796.2033          0.0180         -0.9334
                          2386.4675          0.0168         -0.9689
(V19 PostProcessed 03-SEP-2014 21:14:44.0 1037-001-201409.asc)
COY1                       715.9592          0.0102          0.8935
CR27                      1796.1763          0.0196         -0.8967
                          2386.4945          0.0164         -0.9413
(V20 PostProcessed 03-SEP-2014 15:05:29.0 1037-001-201409.asc)
1031                      2562.2871          0.0102          0.9425
SM11                     -2016.5094          0.0153         -0.9188
                          -466.8788          0.0140         -0.9408
(V21 PostProcessed 04-SEP-2014 19:25:29.0 1037-001-201409.asc)
1031                      2562.2768          0.0079          0.8726
SM11                     -2016.5252          0.0116         -0.8632
                          -466.8624          0.0121         -0.8995
(V22 PostProcessed 04-SEP-2014 14:06:29.0 1037-001-201409.asc)
SM10                       493.8504          0.0050          0.6902
SM08                     -2623.5621          0.0075         -0.7181
                         -2474.8491          0.0070         -0.9094
(V23 PostProcessed 03-SEP-2014 18:54:29.0 1037-001-201409.asc)
SM10                       493.8347          0.0051          0.7938
SM08                     -2623.5967          0.0086         -0.7315
                         -2474.8189          0.0078         -0.7422
(V24 PostProcessed 03-SEP-2014 14:11:29.0 1037-001-201409.asc)
SM10                       493.8397          0.0060          0.8761
SM08                     -2623.5852          0.0085         -0.8403
                         -2474.8345          0.0078         -0.8801
(V25 PostProcessed 04-SEP-2014 21:01:44.0 1037-001-201409.asc)
SM10                      3341.5544          0.0190          0.9476
SM09                     -4140.8760          0.0454         -0.9398
                         -2224.0729          0.0390         -0.9803
(V26 PostProcessed 03-SEP-2014 15:05:29.0 1037-001-201409.asc)
SM10                       488.7758          0.0093          0.9400
SM11                      1776.4598          0.0139         -0.9163
                          2207.0288          0.0128         -0.9392
(V27 PostProcessed 04-SEP-2014 19:25:29.0 1037-001-201409.asc)
SM10                       488.7640          0.0078          0.8854
SM11                      1776.4406          0.0111         -0.8866
                          2207.0449          0.0120         -0.9117
```

APPENDIX D – STAR*NET NETWORK ADJUSTMENT REPORT

Number of GPS Vector Observations (Meters) = 60

From To	DeltaX DeltaY DeltaZ	StdErrX StdErrY StdErrZ	CorrelXY CorrelXZ CorrelYZ
(V1 PostProcessed 04-SEP-2014 14:32:59.0 1037-001-201409.asc)			
P271	-752.9454	0.0096	0.8572
COY1	-4923.8725	0.0144	-0.8403
	-5746.0067	0.0129	-0.9366
(V2 PostProcessed 03-SEP-2014 19:18:44.0 1037-001-201409.asc)			
P271	-752.9585	0.0077	0.8068
COY1	-4923.8892	0.0119	-0.7546
	-5745.9901	0.0119	-0.9140
(V3 PostProcessed 03-SEP-2014 21:14:44.0 1037-001-201409.asc)			
P271	-36.9762	0.0203	0.9595
CR27	-3127.6721	0.0414	-0.9651
	-3359.5302	0.0347	-0.9799
(V4 PostProcessed 04-SEP-2014 17:13:59.0 1037-001-201409.asc)			
P271	-36.9872	0.0109	0.9386
CR27	-3127.6915	0.0178	-0.9311
	-3359.5126	0.0164	-0.9652
(V5 PostProcessed 03-SEP-2014 14:32:29.0 1037-001-201409.asc)			
P271	1102.4947	0.0069	0.9266
1031	945.1001	0.0101	-0.8967
	1724.5077	0.0090	-0.9279
(V6 PostProcessed 04-SEP-2014 19:09:29.0 1037-001-201409.asc)			
P271	1102.4868	0.0059	0.8670
1031	945.0878	0.0086	-0.8554
	1724.5196	0.0089	-0.8984
(V7 PostProcessed 04-SEP-2014 13:46:59.0 1037-001-201409.asc)			
P271	3176.0059	0.0050	0.6951
SM10	-2847.8650	0.0080	-0.7264
	-949.3992	0.0073	-0.9107
(V8 PostProcessed 03-SEP-2014 18:54:29.0 1037-001-201409.asc)			
P271	3175.9814	0.0049	0.7317
SM10	-2847.9006	0.0080	-0.6591
	-949.3669	0.0074	-0.6651
(V9 PostProcessed 03-SEP-2014 14:11:29.0 1037-001-201409.asc)			
P271	3175.9888	0.0061	0.8707
SM10	-2847.8932	0.0088	-0.8237
	-949.3755	0.0081	-0.8704
(V10 PostProcessed 03-SEP-2014 15:05:29.0 1037-001-201409.asc)			
P271	3664.7827	0.0117	0.9458
SM11	-1071.4086	0.0175	-0.9222
	1257.6282	0.0161	-0.9429
(V11 PostProcessed 04-SEP-2014 19:25:29.0 1037-001-201409.asc)			
P271	3664.7711	0.0086	0.8781
SM11	-1071.4269	0.0128	-0.8669
	1257.6467	0.0133	-0.9039
(V12 PostProcessed 03-SEP-2014 23:59:44.0 1037-001-201409.asc)			
P271	-7136.3762	0.0041	0.7048
UCD1	-5464.3203	0.0058	-0.7371
	-10496.2575	0.0052	-0.8683
(V13 PostProcessed 02-SEP-2014 23:59:44.0 1037-001-201409.asc)			
P271	-7136.3806	0.0040	0.6686
UCD1	-5464.3285	0.0054	-0.7259
	-10496.2503	0.0049	-0.8473

```
(V42 PostProcessed 03-SEP-2014 19:18:44.0 1037-001-201409.asc)
SM08          -4422.8140      0.0069       0.8125
COY1            547.5408      0.0108      -0.7640
              -2321.7369      0.0110      -0.9201
(V43 PostProcessed 03-SEP-2014 19:22:14.0 1037-001-201409.asc)
SM08          -1875.5191      0.0061       0.8700
COD1          -1021.0666      0.0098      -0.8321
              -2321.4527      0.0100      -0.9349
(V44 PostProcessed 04-SEP-2014 15:27:29.0 1037-001-201409.asc)
SM08          -1875.5279      0.0068       0.8490
COD1          -1021.0749      0.0096      -0.8110
              -2321.4456      0.0089      -0.9174
(V45 PostProcessed 04-SEP-2014 15:14:29.0 1037-001-201409.asc)
SM08          -1818.2287      0.0137       0.9509
CAST          -3253.7289      0.0210      -0.9212
              -4668.6679      0.0190      -0.9414
(V46 PostProcessed 03-SEP-2014 19:18:14.0 1037-001-201409.asc)
SM08          -1818.2387      0.0106       0.8813
CAST          -3253.7435      0.0145      -0.8756
              -4668.6457      0.0157      -0.9062
(V47 PostProcessed 03-SEP-2014 17:11:44.0 1037-001-201409.asc)
SM08           2847.7158      0.0133       0.9484
SM09          -1517.2889      0.0198      -0.9268
                250.7560      0.0184      -0.9711
(V48 PostProcessed 04-SEP-2014 21:01:44.0 1037-001-201409.asc)
SM08           2847.7052      0.0056       0.6116
SM09          -1517.3030      0.0080      -0.4736
                250.7710      0.0095      -0.7819
(V49 PostProcessed 03-SEP-2014 17:05:29.0 1037-001-201409.asc)
S16A           4292.9231      0.0180       0.9434
RIVE          -5026.6381      0.0260      -0.9171
              -2533.0286      0.0243      -0.9685
(V50 PostProcessed 04-SEP-2014 21:14:44.0 1037-001-201409.asc)
S16A           4292.9099      0.0114       0.8342
RIVE          -5026.6715      0.0230      -0.8259
              -2532.9959      0.0210      -0.9687
(V51 PostProcessed 03-SEP-2014 15:12:29.0 1037-001-201409.asc)
S16A          -4786.4011      0.0139       0.9489
1031           3006.2012      0.0209      -0.9268
                 58.6424      0.0192      -0.9429
(V52 PostProcessed 04-SEP-2014 19:21:29.0 1037-001-201409.asc)
S16A          -4786.4137      0.0107       0.8819
1031           3006.1814      0.0146      -0.8793
                 58.6612      0.0161      -0.9070
(V53 PostProcessed 04-SEP-2014 21:01:44.0 1037-001-201409.asc)
S16A            628.6664      0.0203       0.9486
SM09          -4927.6479      0.0486      -0.9408
              -4839.3318      0.0417      -0.9807
(V54 PostProcessed 03-SEP-2014 17:11:44.0 1037-001-201409.asc)
S16A            628.6564      0.0116       0.9211
SM09          -4927.6607      0.0201      -0.8980
              -4839.3232      0.0186      -0.9624
(V55 PostProcessed 04-SEP-2014 19:21:29.0 1037-001-201409.asc)
S16A          -2712.8863      0.0072       0.8236
SM10           -786.7665      0.0125      -0.7790
              -2615.2619      0.0129      -0.9360
```

APPENDIX D – STAR*NET NETWORK ADJUSTMENT REPORT

```
(V28 PostProcessed 04-SEP-2014 17:13:59.0 1037-001-201409.asc)
SM10                -3212.9788        0.0139         0.9485
CR27                 -279.8002        0.0206        -0.9317
                    -2410.1374        0.0194        -0.9685
(V29 PostProcessed 03-SEP-2014 15:12:29.0 1037-001-201409.asc)
SM11                 2224.1149        0.0087         0.9387
S16A                 -989.6889        0.0130        -0.9162
                      408.2336        0.0120        -0.9374
(V30 PostProcessed 04-SEP-2014 19:25:29.0 1037-001-201409.asc)
SM11                 2224.1034        0.0072         0.8861
S16A                 -989.7031        0.0102        -0.8874
                      408.2518        0.0110        -0.9131
(V31 PostProcessed 02-SEP-2014 23:59:44.0 1037-001-201409.asc)
UCD1                 5511.3999        0.0042         0.6963
P268                -8476.2458        0.0059        -0.7509
                    -5462.4091        0.0053        -0.8662
(V32 PostProcessed 03-SEP-2014 23:59:44.0 1037-001-201409.asc)
UCD1                 5511.3951        0.0040         0.6703
P268                -8476.2542        0.0056        -0.7107
                    -5462.4011        0.0050        -0.8494
(V33 PostProcessed 04-SEP-2014 14:32:59.0 1037-001-201409.asc)
UCD1                 6383.4259        0.0097         0.8587
COY1                  540.4438        0.0145        -0.8420
                     4750.2535        0.0130        -0.9373
(V34 PostProcessed 03-SEP-2014 19:18:44.0 1037-001-201409.asc)
UCD1                 6383.4106        0.0078         0.8154
COY1                  540.4248        0.0123        -0.7643
                     4750.2699        0.0125        -0.9217
(V35 PostProcessed 04-SEP-2014 15:14:29.0 1037-001-201409.asc)
UCD1                 8988.0084        0.0149         0.9521
CAST                -3260.8461        0.0229        -0.9223
                     2403.3439        0.0208        -0.9421
(V36 PostProcessed 03-SEP-2014 19:18:14.0 1037-001-201409.asc)
UCD1                 8987.9863        0.0111         0.8819
CAST                -3260.8604        0.0156        -0.8757
                     2403.3619        0.0153        -0.9377
(V37 PostProcessed 03-SEP-2014 19:22:14.0 1037-001-201409.asc)
COD1                   57.2949        0.0105         0.9256
CAST                -2232.6530        0.0150        -0.9247
                    -2347.2158        0.0159        -0.9419
(V38 PostProcessed 04-SEP-2014 15:27:29.0 1037-001-201409.asc)
COD1                   57.2859        0.0083         0.9145
CAST                -2232.6724        0.0126        -0.8701
                    -2347.2029        0.0117        -0.8995
(V39 PostProcessed 03-SEP-2014 21:14:44.0 1037-001-201409.asc)
SM08                -3706.8335        0.0196         0.9591
CR27                 2343.7568        0.0399        -0.9646
                       64.7268        0.0334        -0.9796
(V40 PostProcessed 04-SEP-2014 17:13:59.0 1037-001-201409.asc)
SM08                -3706.8425        0.0124         0.9315
CR27                 2343.7488        0.0183        -0.9157
                       64.7293        0.0167        -0.9674
(V41 PostProcessed 04-SEP-2014 14:32:59.0 1037-001-201409.asc)
SM08                -4422.8070        0.0086         0.8601
COY1                  547.5590        0.0128        -0.8409
                    -2321.7556        0.0114        -0.9342
```

APPENDIX D – STAR*NET NETWORK ADJUSTMENT REPORT

Adjustment Statistical Summary

Iterations	=	4
Number of Stations	=	17
Number of Observations	=	213
Number of Unknowns	=	50
Number of Redundant Obs	=	163

Observation	Count	Sum Squares of StdRes	Error Factor
Coordinates	26	21.798	1.047
Angles	2	0.000	0.000
Distances	3	0.000	0.006
Zeniths	2	0.000	0.000
GPS Deltas	180	154.960	1.061
Total	213	176.758	1.041

The Chi-Square Test at 5.00% Level Passed
Lower/Upper Bounds (0.891/1.108)

```
(V56 PostProcessed 03-SEP-2014 15:12:29.0 1037-001-201409.asc)
S16A                  -2712.8948        0.0070        0.8909
SM10                   -786.7763        0.0103       -0.8603
                      -2615.2551        0.0095       -0.8868
(V57 PostProcessed 04-SEP-2014 15:14:29.0 1037-001-201409.asc)
P268                   3476.6114        0.0152        0.9531
CAST                   5215.4185        0.0233       -0.9239
                       7865.7445        0.0211       -0.9431
(V58 PostProcessed 03-SEP-2014 19:18:14.0 1037-001-201409.asc)
P268                   3476.5897        0.0119        0.8956
CAST                   5215.3857        0.0169       -0.8890
                       7865.7733        0.0163       -0.9442
(V59 PostProcessed 03-SEP-2014 17:11:44.0 1037-001-201409.asc)
RIVE                  -3664.2397        0.0159        0.9502
SM09                     99.0115        0.0236       -0.9285
                      -2306.3269        0.0220       -0.9724
(V60 PostProcessed 04-SEP-2014 21:14:44.0 1037-001-201409.asc)
RIVE                  -3664.2659        0.0095        0.8675
SM09                     98.9699        0.0164       -0.8395
                      -2306.2899        0.0156       -0.9609
```

APPENDIX D – STAR*NET NETWORK ADJUSTMENT REPORT

Convergence Angles (DMS) and Grid Factors at Stations
(Grid Azimuth = Geodetic Azimuth - Convergence)
(Elevation Factor Includes a Geoid Height Correction at Each Station))

Station	Convergence Angle	------- Factors ------- Scale	x Elevation	= Combined
UCD1	0-09-24.66	0.99996018	1.00000000	0.99996018
P268	0-13-22.57	0.99997117	1.00000368	0.99997484
P271	0-10-47.92	0.99994232	1.00000279	0.99994511
COD1	0-12-56.60	0.99995153	1.00000384	0.99995537
COY1	0-11-38.66	0.99995154	1.00000355	0.99995508
S16A	0-13-26.84	0.99993988	1.00000348	0.99994337
SM08	0-13-24.24	0.99994765	1.00000382	0.99995147
SM10	0-12-37.39	0.99994375	1.00000335	0.99994709
15	0-12-36.97	0.99994379	1.00000313	0.99994692
16	0-12-33.82	0.99994377	1.00000326	0.99994702
EX11	0-12-34.65	0.99994377	1.00000365	0.99994743
CR27	0-11-29.95	0.99994755	1.00000343	0.99995097
1031	0-10-59.42	0.99993980	1.00000323	0.99994303
SM11	0-12-23.91	0.99994047	1.00000371	0.99994418
CAST	0-13-28.38	0.99995568	1.00000405	0.99995973
SM09	0-14-48.17	0.99994724	1.00000395	0.99995119
RIVE	0-16-10.88	0.99994362	1.00000295	0.99994657
Project Averages:	0-12-37.94	0.99994786	1.00000329	0.99995115

APPENDIX D – STAR*NET NETWORK ADJUSTMENT REPORT

Adjusted Station Information
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Adjusted Coordinates (Meters)

Station	N	E	Elev	Description
UCD1	596557.2693	2021690.2957	31.2765	UCD1
P268	589626.2665	2030856.1207	7.8651	P268
P271	610010.1580	2024846.1584	12.9705	P271
COD1	602678.4883	2029808.4221	6.4637	COD1
COY1	602665.9217	2026817.0537	8.3753	COY1
S16A	612168.5942	2030932.1104	8.4498	S16A
SM08	605652.9391	2030857.7158	6.4636	SM08
SM10	608811.6582	2029048.5679	9.4302	SM10
15	608777.2764	2029032.5965	10.8179	CONTROL
16	608793.8378	2028911.8157	10.0000	CONTROL AZ MARK
EX11	608789.4494	2028943.8232	7.4716	EX11
CR27	605717.8829	2026472.2946	9.0378	
1031	612222.3164	2025280.2267	10.1305	
SM11	611637.8060	2028521.6330	7.0497	
CAST	599681.9537	2031040.2322	5.1830	
SM09	605987.7372	2034076.6317	5.6389	
RIVE	608949.2090	2037236.2768	11.9588	

Adjusted Positions and Ellipsoid Heights (Meters)

Station	Latitude	Longitude	Ellip Ht	Geoid Ht
UCD1	38-32-10.449924	121-45-04.379784	0.0144	-31.2621
P268	38-28-24.681149	121-38-47.027881	-23.4309	-31.2960
P271	38-39-26.447882	121-42-52.326075	-17.8044	-30.7749
COD1	38-35-28.114860	121-39-28.223014	-24.4590	-30.9227
COY1	38-35-28.054244	121-41-31.836450	-22.5974	-30.9728
S16A	38-40-35.753116	121-38-40.255181	-22.2021	-30.6520
SM08	38-37-04.450378	121-38-44.384113	-24.3643	-30.8279
SM10	38-38-47.114446	121-39-58.691662	-21.3277	-30.7579
15	38-38-46.001294	121-39-59.357372	-19.9412	-30.7590
16	38-38-46.552748	121-40-04.349716	-20.7598	-30.7598
EX11	38-38-46.406630	121-40-03.026719	-23.2880	-30.7596
CR27	38-37-07.071749	121-41-45.661002	-21.8468	-30.8845
1031	38-40-38.146911	121-42-34.079974	-20.5680	-30.6985
SM11	38-40-18.832764	121-40-20.061430	-23.6302	-30.6799
CAST	38-33-50.779180	121-38-37.806580	-25.8065	-30.9894
SM09	38-37-14.880094	121-36-31.260494	-25.1625	-30.8014
RIVE	38-38-50.462947	121-34-20.065279	-18.7741	-30.7330
			Average:	-30.8548

APPENDIX D – STAR*NET NETWORK ADJUSTMENT REPORT

Adjusted GPS Vector Observations (Meters)

From To	Component	Adj Value	Residual	StdErr	StdRes
(V1 PostProcessed 04-SEP-2014 14:32:59.0 1037-001-201409.asc)					
P271	Delta-N	-7350.7564	0.0002	0.0037	0.1
COY1	Delta-E	1947.9035	-0.0007	0.0043	0.2
	Delta-U	-9.3378	-0.0001	0.0208	0.0
	Length	7604.4747			
(V2 PostProcessed 03-SEP-2014 19:18:44.0 1037-001-201409.asc)					
P271	Delta-N	-7350.7564	0.0004	0.0040	0.1
COY1	Delta-E	1947.9035	0.0017	0.0040	0.4
	Delta-U	-9.3378	-0.0270	0.0176	1.5
	Length	7604.4747			
(V3 PostProcessed 03-SEP-2014 21:14:44.0 1037-001-201409.asc)					
P271	Delta-N	-4297.5852	-0.0005	0.0052	0.1
CR27	Delta-E	1612.7244	0.0012	0.0071	0.2
	Delta-U	-5.6979	0.0092	0.0570	0.2
	Length	4590.2234			
(V4 PostProcessed 04-SEP-2014 17:13:59.0 1037-001-201409.asc)					
P271	Delta-N	-4297.5852	-0.0003	0.0033	0.1
CR27	Delta-E	1612.7244	0.0004	0.0033	0.1
	Delta-U	-5.6979	-0.0192	0.0261	0.7
	Length	4590.2234			
(V5 PostProcessed 03-SEP-2014 14:32:29.0 1037-001-201409.asc)					
P271	Delta-N	2210.9071	0.0003	0.0027	0.1
1031	Delta-E	441.0401	-0.0004	0.0022	0.2
	Delta-U	-3.1631	0.0063	0.0148	0.4
	Length	2254.4703			
(V6 PostProcessed 04-SEP-2014 19:09:29.0 1037-001-201409.asc)					
P271	Delta-N	2210.9071	0.0001	0.0028	0.0
1031	Delta-E	441.0401	-0.0001	0.0025	0.1
	Delta-U	-3.1631	-0.0126	0.0131	1.0
	Length	2254.4703			
(V7 PostProcessed 04-SEP-2014 13:46:59.0 1037-001-201409.asc)					
P271	Delta-N	-1211.7696	0.0003	0.0023	0.1
SM10	Delta-E	4198.8460	0.0014	0.0033	0.4
	Delta-U	-5.0190	-0.0029	0.0112	0.3
	Length	4370.2080			
(V8 PostProcessed 03-SEP-2014 18:54:29.0 1037-001-201409.asc)					
P271	Delta-N	-1211.7696	0.0021	0.0044	0.5
SM10	Delta-E	4198.8460	0.0035	0.0031	1.1
	Delta-U	-5.0190	-0.0567	0.0107	5.3*
	Length	4370.2080			
(V9 PostProcessed 03-SEP-2014 14:11:29.0 1037-001-201409.asc)					
P271	Delta-N	-1211.7696	0.0024	0.0031	0.8
SM10	Delta-E	4198.8460	0.0011	0.0025	0.4
	Delta-U	-5.0190	-0.0434	0.0128	3.4*
	Length	4370.2080			
(V10 PostProcessed 03-SEP-2014 15:05:29.0 1037-001-201409.asc)					
P271	Delta-N	1616.1754	0.0009	0.0042	0.2
SM11	Delta-E	3680.7745	-0.0008	0.0032	0.2
	Delta-U	-7.0918	0.0088	0.0259	0.3
	Length	4019.9719			
(V11 PostProcessed 04-SEP-2014 19:25:29.0 1037-001-201409.asc)					
P271	Delta-N	1616.1754	-0.0000	0.0042	0.0
SM11	Delta-E	3680.7745	-0.0005	0.0035	0.1

APPENDIX D – STAR*NET NETWORK ADJUSTMENT REPORT

Adjusted Observations and Residuals

Adjusted Coordinate Observations (Meters)
(Stations with Partially Fixed Coordinate Components)
(Elevations Marked with (*) are Ellipsoid Heights)

Station	Component	Adj Coordinate	Residual	StdErr	StdRes
UCD1	N	596557.2693	0.0011	0.0010	1.1
	E	2021690.2957	0.0011	0.0010	1.1
	Elev	0.0144*	0.0004	0.0010	0.4
P268	N	589626.2665	0.0018	0.0010	1.8
	E	2030856.1207	-0.0008	0.0010	0.8
	Elev	-23.4309*	0.0001	0.0010	0.1
P271	N	610010.1580	-0.0008	0.0010	0.8
	E	2024846.1584	0.0006	0.0010	0.6
	Elev	-17.8044*	-0.0064	0.0020	3.2*
COD1	N	602678.4883	-0.0003	0.0010	0.3
	E	2029808.4221	-0.0003	0.0010	0.3
	Elev	-24.4590*	0.0010	0.0020	0.5
COY1	N	602665.9217	-0.0005	0.0010	0.5
	E	2026817.0537	0.0002	0.0010	0.2
	Elev	-22.5974*	0.0006	0.0020	0.3
S16A	N	612168.5942	-0.0004	0.0010	0.4
	E	2030932.1104	-0.0000	0.0010	0.0
	Elev	-22.2021*	-0.0001	0.0020	0.1
SM08	N	605652.9391	0.0003	0.0010	0.3
	E	2030857.7158	-0.0008	0.0010	0.8
	Elev	-24.3643*	0.0017	0.0020	0.8
SM10	N	608811.6582	-0.0010	0.0010	1.0
	E	2029048.5679	-0.0000	0.0010	0.0
	Elev	-21.3277*	0.0013	0.0020	0.7
15	N	608777.2764	0.0000	0.0100	0.0
	E	2029032.5965	0.0000	0.0100	0.0

Adjusted Measured Angle Observations (DMS)

From	At	To	Angle	Residual	StdErr	StdRes
16	15	EX11	0-00-01.00	0-00-00.00	4.76	0.0
16	15	SM10	107-06-31.00	0-00-00.00	12.67	0.0

Adjusted Measured Distance Observations (Meters)

From	To	Distance	Residual	StdErr	StdRes
15	16	121.9202	-0.0000	FIXED	0.0
15	EX11	89.6510	0.0000	0.0031	0.0
15	SM10	37.9206	0.0000	0.0030	0.0

Adjusted Zenith Observations (DMS)

From	To	Zenith	Residual	StdErr	StdRes
15	EX11	91-45-28.00	0-00-00.00	5.35	0.0
15	SM10	91-11-33.00	-0-00-00.00	11.89	0.0

APPENDIX D – STAR*NET NETWORK ADJUSTMENT REPORT

(V23 PostProcessed	03-SEP-2014	18:54:29.0 1037-001-201409.asc)			
SM10	Delta-N	-3165.5026	-0.0029	0.0041	0.7
SM08	Delta-E	1797.6244	-0.0008	0.0029	0.3
	Delta-U	-4.0774	-0.0471	0.0117	4.0*
	Length	3640.3127			
(V24 PostProcessed	03-SEP-2014	14:11:29.0 1037-001-201409.asc)			
SM10	Delta-N	-3165.5026	0.0015	0.0029	0.5
SM08	Delta-E	1797.6244	0.0010	0.0025	0.4
	Delta-U	-4.0774	-0.0277	0.0125	2.2
	Length	3640.3127			
(V25 PostProcessed	04-SEP-2014	21:01:44.0 1037-001-201409.asc)			
SM10	Delta-N	-2842.5232	-0.0007	0.0060	0.1
SM09	Delta-E	5017.9052	0.0008	0.0100	0.1
	Delta-U	-6.4414	-0.0030	0.0617	0.0
	Length	5767.0922			
(V26 PostProcessed	03-SEP-2014	15:05:29.0 1037-001-201409.asc)			
SM10	Delta-N	2828.2165	-0.0020	0.0034	0.6
SM11	Delta-E	-516.5828	0.0005	0.0027	0.2
	Delta-U	-2.9522	0.0126	0.0206	0.6
	Length	2875.0087			
(V27 PostProcessed	04-SEP-2014	19:25:29.0 1037-001-201409.asc)			
SM10	Delta-N	2828.2165	-0.0005	0.0035	0.1
SM11	Delta-E	-516.5828	0.0005	0.0031	0.2
	Delta-U	-2.9522	-0.0150	0.0175	0.9
	Length	2875.0087			
(V28 PostProcessed	04-SEP-2014	17:13:59.0 1037-001-201409.asc)			
SM10	Delta-N	-3084.4557	-0.0005	0.0039	0.1
CR27	Delta-E	-2587.7428	0.0007	0.0038	0.2
	Delta-U	-1.7913	0.0220	0.0311	0.7
	Length	4026.1996			
(V29 PostProcessed	03-SEP-2014	15:12:29.0 1037-001-201409.asc)			
SM11	Delta-N	522.1173	0.0010	0.0032	0.3
S16A	Delta-E	2412.5126	-0.0005	0.0025	0.2
	Delta-U	0.9510	-0.0062	0.0192	0.3
	Length	2468.3647			
(V30 PostProcessed	04-SEP-2014	19:25:29.0 1037-001-201409.asc)			
SM11	Delta-N	522.1173	-0.0019	0.0032	0.6
S16A	Delta-E	2412.5126	0.0018	0.0028	0.6
	Delta-U	0.9510	-0.0317	0.0161	2.0
	Length	2468.3647			
(V31 PostProcessed	02-SEP-2014	23:59:44.0 1037-001-201409.asc)			
UCD1	Delta-N	-6956.3437	-0.0027	0.0020	1.4
P268	Delta-E	9147.0438	0.0026	0.0026	1.0
	Delta-U	-33.7999	0.0033	0.0083	0.4
	Length	11491.7479			
(V32 PostProcessed	03-SEP-2014	23:59:44.0 1037-001-201409.asc)			
UCD1	Delta-N	-6956.3437	-0.0029	0.0020	1.5
P268	Delta-E	9147.0438	0.0023	0.0026	0.9
	Delta-U	-33.7999	-0.0093	0.0078	1.2
	Length	11491.7479			
(V33 PostProcessed	04-SEP-2014	14:32:59.0 1037-001-201409.asc)			
UCD1	Delta-N	6094.8219	0.0042	0.0037	1.2
COY1	Delta-E	5143.6920	0.0017	0.0043	0.4
	Delta-U	-27.6034	0.0045	0.0210	0.2
	Length	7975.2858			

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                    Delta-U           -7.0918        -0.0197   0.0197    1.0
                    Length          4019.9719
 (V12 PostProcessed 03-SEP-2014 23:59:44.0 1037-001-201409.asc)
 P271               Delta-N       -13443.5655        -0.0024   0.0020    1.2
 UCD1               Delta-E        -3198.2322        -0.0003   0.0025    0.1
                    Delta-U            2.8103        -0.0110   0.0082    1.3
                    Length         13818.7608
 (V13 PostProcessed 02-SEP-2014 23:59:44.0 1037-001-201409.asc)
 P271               Delta-N       -13443.5655        -0.0022   0.0019    1.2
 UCD1               Delta-E        -3198.2322        -0.0009   0.0026    0.3
                    Delta-U            2.8103        -0.0228   0.0076    3.0
                    Length         13818.7608
 (V14 PostProcessed 03-SEP-2014 19:22:14.0 1037-001-201409.asc)
 COY1               Delta-N            2.4283         0.0008   0.0028    0.3
 COD1               Delta-E         2991.5273         0.0023   0.0028    0.8
                    Delta-U           -2.5622         0.0013   0.0146    0.1
                    Length          2991.5294
 (V15 PostProcessed 04-SEP-2014 15:27:29.0 1037-001-201409.asc)
 COY1               Delta-N            2.4283         0.0006   0.0028    0.2
 COD1               Delta-E         2991.5273         0.0017   0.0030    0.6
                    Delta-U           -2.5622        -0.0206   0.0136    1.5
                    Length          2991.5294
 (V16 PostProcessed 04-SEP-2014 15:14:29.0 1037-001-201409.asc)
 COY1               Delta-N        -2998.3944        -0.0002   0.0048    0.0
 CAST               Delta-E         4213.2164        -0.0018   0.0034    0.5
                    Delta-U           -5.3056         0.0121   0.0299    0.4
                    Length          5171.2271
 (V17 PostProcessed 03-SEP-2014 19:18:44.0 1037-001-201409.asc)
 COY1               Delta-N        -2998.3944        -0.0048   0.0046    1.0
 CAST               Delta-E         4213.2164         0.0059   0.0041    1.5
                    Delta-U           -5.3056        -0.0203   0.0221    0.9
                    Length          5171.2271
 (V18 PostProcessed 04-SEP-2014 17:13:59.0 1037-001-201409.asc)
 COY1               Delta-N         3053.2549         0.0034   0.0033    1.0
 CR27               Delta-E         -334.4359        -0.0003   0.0032    0.1
                    Delta-U            0.0090         0.0187   0.0271    0.7
                    Length          3071.5163
 (V19 PostProcessed 03-SEP-2014 21:14:44.0 1037-001-201409.asc)
 COY1               Delta-N         3053.2549         0.0014   0.0042    0.3
 CR27               Delta-E         -334.4359        -0.0023   0.0047    0.5
                    Delta-U            0.0090        -0.0220   0.0268    0.8
                    Length          3071.5163
 (V20 PostProcessed 03-SEP-2014 15:05:29.0 1037-001-201409.asc)
 1031               Delta-N         -594.9093         0.0007   0.0037    0.2
 SM11               Delta-E         3239.7019         0.0000   0.0029    0.0
                    Delta-U           -3.9117         0.0013   0.0226    0.1
                    Length          3293.8732
 (V21 PostProcessed 04-SEP-2014 19:25:29.0 1037-001-201409.asc)
 1031               Delta-N         -594.9093        -0.0003   0.0038    0.1
 SM11               Delta-E         3239.7019         0.0005   0.0033    0.2
                    Delta-U           -3.9117        -0.0237   0.0178    1.3
                    Length          3293.8732
 (V22 PostProcessed 04-SEP-2014 14:06:29.0 1037-001-201409.asc)
 SM10               Delta-N        -3165.5026        -0.0028   0.0022    1.3
 SM08               Delta-E         1797.6244         0.0040   0.0032    1.2
                    Delta-U           -4.0774         0.0012   0.0107    0.1
                    Length          3640.3127
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(V45 PostProcessed 04-SEP-2014 15:14:29.0 1037-001-201409.asc)
SM08               Delta-N       -5971.9156      0.0013   0.0051   0.3
CAST               Delta-E         159.2403     -0.0012   0.0036   0.3
                   Delta-U          -4.2478      0.0094   0.0308   0.3
                   Length         5974.0398
(V46 PostProcessed 03-SEP-2014 19:18:14.0 1037-001-201409.asc)
SM08               Delta-N       -5971.9156     -0.0050   0.0048   1.0
CAST               Delta-E         159.2403     -0.0004   0.0043   0.1
                   Delta-U          -4.2478     -0.0183   0.0230   0.8
                   Length         5974.0398
(V47 PostProcessed 03-SEP-2014 17:11:44.0 1037-001-201409.asc)
SM08               Delta-N         322.2540      0.0008   0.0037   0.2
SM09               Delta-E        3220.3539     -0.0001   0.0036   0.0
                   Delta-U          -1.6183      0.0299   0.0297   1.0
                   Length         3236.4378
(V48 PostProcessed 04-SEP-2014 21:01:44.0 1037-001-201409.asc)
SM08               Delta-N         322.2540      0.0001   0.0049   0.0
SM09               Delta-E        3220.3539      0.0016   0.0040   0.4
                   Delta-U          -1.6183      0.0068   0.0121   0.6
                   Length         3236.4378
(V49 PostProcessed 03-SEP-2014 17:05:29.0 1037-001-201409.asc)
S16A               Delta-N       -3244.2216      0.0009   0.0051   0.2
RIVE               Delta-E        6291.8603     -0.0022   0.0051   0.4
                   Delta-U          -0.4987     -0.0019   0.0392   0.0
                   Length         7079.0169
(V50 PostProcessed 04-SEP-2014 21:14:44.0 1037-001-201409.asc)
S16A               Delta-N       -3244.2216     -0.0026   0.0043   0.6
RIVE               Delta-E        6291.8603     -0.0085   0.0067   1.3
                   Delta-U          -0.4987     -0.0499   0.0322   1.6
                   Length         7079.0169
(V51 PostProcessed 03-SEP-2014 15:12:29.0 1037-001-201409.asc)
S16A               Delta-N          75.8166     -0.0014   0.0049   0.3
1031               Delta-E       -5651.9516      0.0012   0.0038   0.3
                   Delta-U          -0.8673      0.0090   0.0310   0.3
                   Length         5652.4602
(V52 PostProcessed 04-SEP-2014 19:21:29.0 1037-001-201409.asc)
S16A               Delta-N          75.8166     -0.0014   0.0049   0.3
1031               Delta-E       -5651.9516      0.0016   0.0043   0.4
                   Delta-U          -0.8673     -0.0211   0.0233   0.9
                   Length         5652.4602
(V53 PostProcessed 04-SEP-2014 21:01:44.0 1037-001-201409.asc)
S16A               Delta-N       -6193.4399     -0.0027   0.0064   0.4
SM09               Delta-E        3120.4721     -0.0020   0.0106   0.2
                   Delta-U          -6.7382     -0.0112   0.0660   0.2
                   Length         6935.1344
(V54 PostProcessed 03-SEP-2014 17:11:44.0 1037-001-201409.asc)
S16A               Delta-N       -6193.4399      0.0006   0.0041   0.2
SM09               Delta-E        3120.4721     -0.0002   0.0041   0.0
                   Delta-U          -6.7382     -0.0291   0.0292   1.0
                   Length         6935.1344
(V55 PostProcessed 04-SEP-2014 19:21:29.0 1037-001-201409.asc)
S16A               Delta-N       -3349.7281     -0.0032   0.0038   0.8
SM10               Delta-E       -1896.7596     -0.0014   0.0038   0.4
                   Delta-U          -0.2893     -0.0020   0.0186   0.1
                   Length         3849.4643
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APPENDIX D – STAR*NET NETWORK ADJUSTMENT REPORT

(V34 PostProcessed 03-SEP-2014 19:18:44.0 1037-001-201409.asc)					
UCD1	Delta-N	6094.8219	0.0065	0.0040	1.6
COY1	Delta-E	5143.6920	0.0047	0.0040	1.2
	Delta-U	-27.6034	-0.0246	0.0183	1.3
	Length	7975.2858			
(V35 PostProcessed 04-SEP-2014 15:14:29.0 1037-001-201409.asc)					
UCD1	Delta-N	3099.1291	0.0032	0.0055	0.6
CAST	Delta-E	9358.8291	-0.0049	0.0039	1.3
	Delta-U	-33.4332	0.0121	0.0337	0.4
	Length	9858.6714			
(V36 PostProcessed 03-SEP-2014 19:18:14.0 1037-001-201409.asc)					
UCD1	Delta-N	3099.1291	0.0040	0.0040	1.0
CAST	Delta-E	9358.8291	0.0063	0.0045	1.4
	Delta-U	-33.4332	-0.0178	0.0238	0.7
	Length	9858.6714			
(V37 PostProcessed 03-SEP-2014 19:22:14.0 1037-001-201409.asc)					
COD1	Delta-N	-3001.2791	-0.0035	0.0039	0.9
CAST	Delta-E	1220.5684	0.0014	0.0034	0.4
	Delta-U	-2.1722	0.0210	0.0237	0.9
	Length	3239.9797			
(V38 PostProcessed 04-SEP-2014 15:27:29.0 1037-001-201409.asc)					
COD1	Delta-N	-3001.2791	-0.0004	0.0040	0.1
CAST	Delta-E	1220.5684	-0.0011	0.0029	0.4
	Delta-U	-2.1722	-0.0036	0.0185	0.2
	Length	3239.9797			
(V39 PostProcessed 03-SEP-2014 21:14:44.0 1037-001-201409.asc)					
SM08	Delta-N	82.0340	-0.0054	0.0051	1.1
CR27	Delta-E	-4385.3494	-0.0023	0.0068	0.3
	Delta-U	1.0114	0.0062	0.0549	0.1
	Length	4386.1167			
(V40 PostProcessed 04-SEP-2014 17:13:59.0 1037-001-201409.asc)					
SM08	Delta-N	82.0340	-0.0001	0.0035	0.0
CR27	Delta-E	-4385.3494	0.0011	0.0038	0.3
	Delta-U	1.0114	-0.0043	0.0272	0.2
	Length	4386.1167			
(V41 PostProcessed 04-SEP-2014 14:32:59.0 1037-001-201409.asc)					
SM08	Delta-N	-2971.3896	-0.0001	0.0033	0.0
COY1	Delta-E	-4052.4597	0.0008	0.0038	0.2
	Delta-U	-0.2129	0.0006	0.0185	0.0
	Length	5025.0956			
(V42 PostProcessed 03-SEP-2014 19:18:44.0 1037-001-201409.asc)					
SM08	Delta-N	-2971.3896	-0.0027	0.0035	0.8
COY1	Delta-E	-4052.4597	-0.0028	0.0035	0.8
	Delta-U	-0.2129	-0.0261	0.0161	1.6
	Length	5025.0956			
(V43 PostProcessed 03-SEP-2014 19:22:14.0 1037-001-201409.asc)					
SM08	Delta-N	-2970.4759	-0.0011	0.0029	0.4
COD1	Delta-E	-1060.9306	-0.0016	0.0026	0.6
	Delta-U	-0.8765	-0.0032	0.0147	0.2
	Length	3154.2513			
(V44 PostProcessed 04-SEP-2014 15:27:29.0 1037-001-201409.asc)					
SM08	Delta-N	-2970.4759	0.0006	0.0029	0.2
COD1	Delta-E	-1060.9306	0.0016	0.0031	0.5
	Delta-U	-0.8765	-0.0168	0.0142	1.2
	Length	3154.2513			

APPENDIX D – STAR*NET NETWORK ADJUSTMENT REPORT

Adjusted Bearings (DMS) and Horizontal Distances (Meters)

(Relative Confidence of Bearing is in Seconds)

From	To	Grid Bearing	Grid Dist Grnd Dist	95% RelConfidence Brg	Dist	PPM
15	16	N82-11-32.53W	121.9110 121.9175	137.07	0.0000	0.3822
15	EX11	N82-11-31.54W	89.6041 89.6088	137.57	0.0075	83.9499
15	SM10	N24-54-58.45E	37.9103 37.9123	133.52	0.0070	185.6037
1031	P271	S11-06-05.39W	2254.3425 2254.4686	0.29	0.0036	1.6145
1031	S16A	S89-27-19.47E	5652.1390 5652.4599	0.14	0.0034	0.6095
1031	SM11	S79-46-40.53E	3293.6860 3293.8718	0.26	0.0035	1.0720
CAST	COD1	N22-20-47.39W	3239.8419 3239.9794	0.21	0.0037	1.1303
CAST	COY1	N54-45-22.14W	5171.0059 5171.2261	0.15	0.0034	0.6576
CAST	P268	S01-02-56.12W	10057.3726 10057.7026	0.07	0.0039	0.3829
CAST	SM08	N01-45-02.98W	5973.7742 5974.0396	0.11	0.0038	0.6324
CAST	UCD1	S71-31-14.62W	9858.2435 9858.6375	0.08	0.0034	0.3470
COD1	COY1	S89-45-33.50W	2991.3948 2991.5288	0.17	0.0024	0.8089
COD1	SM08	N19-25-52.52E	3154.1044 3154.2513	0.15	0.0025	0.7853
COY1	CR27	N06-26-41.96W	3071.3720 3071.5163	0.26	0.0037	1.2135
COY1	P271	N15-01-18.95W	7604.0933 7604.4731	0.07	0.0023	0.3024
COY1	SM08	N53-31-36.20E	5024.8605 5025.0953	0.09	0.0025	0.4882
COY1	UCD1	S40-00-19.61W	7974.9157 7975.2537	0.06	0.0025	0.3151
CR27	P271	N20-44-57.42W	4589.9831 4590.2216	0.17	0.0037	0.8041
CR27	SM08	S89-09-05.64E	4385.9021 4386.1160	0.18	0.0038	0.8756
CR27	SM10	N39-47-06.34E	4025.9943 4026.1995	0.19	0.0040	0.9924
P268	UCD1	N52-54-15.12W	11491.3510 11491.7240	0.04	0.0024	0.2103
P271	SM10	S74-04-55.91E	4369.9711 4370.2066	0.10	0.0021	0.4894
P271	SM11	N66-06-51.52E	4019.7452 4019.9677	0.17	0.0030	0.7536
P271	UCD1	S13-12-07.50W	13818.0926 13818.7493	0.03	0.0021	0.1550
RIVE	S16A	N62-56-51.72W	7078.6267 7079.0161	0.20	0.0055	0.7776
RIVE	SM09	S46-51-15.57W	4330.5511	0.22	0.0067	1.5371

APPENDIX D – STAR*NET NETWORK ADJUSTMENT REPORT

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(V56 PostProcessed 03-SEP-2014 15:12:29.0 1037-001-201409.asc)
S16A                Delta-N        -3349.7281       -0.0005   0.0034   0.1
SM10                Delta-E        -1896.7596        0.0007   0.0027   0.2
                    Delta-U           -0.2893       -0.0163   0.0151   1.1
                    Length          3849.4643
(V57 PostProcessed 04-SEP-2014 15:14:29.0 1037-001-201409.asc)
P268                Delta-N        10055.2196        0.0017   0.0055   0.3
CAST                Delta-E          223.2452       -0.0002   0.0039   0.1
                    Delta-U          -10.3280        0.0278   0.0343   0.8
                    Length         10057.7028
(V58 PostProcessed 03-SEP-2014 19:18:14.0 1037-001-201409.asc)
P268                Delta-N        10055.2196        0.0036   0.0041   0.9
CAST                Delta-E          223.2452        0.0011   0.0045   0.2
                    Delta-U          -10.3280       -0.0209   0.0256   0.8
                    Length         10057.7028
(V59 PostProcessed 03-SEP-2014 17:11:44.0 1037-001-201409.asc)
RIVE                Delta-N        -2946.7218       -0.0020   0.0043   0.5
SM09                Delta-E        -3173.7044       -0.0031   0.0043   0.7
                    Delta-U           -7.8596        0.0267   0.0355   0.8
                    Length          4330.7772
(V60 PostProcessed 04-SEP-2014 21:14:44.0 1037-001-201409.asc)
RIVE                Delta-N        -2946.7218       -0.0002   0.0037   0.0
SM09                Delta-E        -3173.7044       -0.0026   0.0043   0.6
                    Delta-U           -7.8596       -0.0348   0.0239   1.5
                    Length          4330.7772
```

APPENDIX D – STAR*NET NETWORK ADJUSTMENT REPORT

Error Propagation

Station Coordinate Standard Deviations (Meters)

Station	N	E	Elev
UCD1	0.000718	0.000771	0.000968
P268	0.000829	0.000867	0.000984
P271	0.000703	0.000721	0.001779
COD1	0.000809	0.000802	0.001914
COY1	0.000749	0.000756	0.001882
S16A	0.000850	0.000821	0.001937
SM08	0.000731	0.000728	0.001844
SM10	0.000728	0.000716	0.001808
15	0.004991	0.009154	0.002838
16	0.036994	0.004977	0.000000
EX11	0.028416	0.006769	0.003668
CR27	0.001499	0.001520	0.011151
1031	0.001556	0.001354	0.007579
SM11	0.001393	0.001203	0.007017
CAST	0.001463	0.001255	0.007831
SM09	0.001940	0.001902	0.009146
RIVE	0.002461	0.002671	0.015661

Station Coordinate Error Ellipses (Meters)
Confidence Region = 95%

Station	Semi-Major Axis	Semi-Minor Axis	Azimuth of Major Axis	Elev
UCD1	0.001891	0.001754	79-43	0.001898
P268	0.002122	0.002027	84-26	0.001929
P271	0.001770	0.001715	70-44	0.003487
COD1	0.002030	0.001912	40-17	0.003751
COY1	0.001913	0.001770	48-24	0.003688
S16A	0.002085	0.002005	13-58	0.003797
SM08	0.001832	0.001737	42-42	0.003614
SM10	0.001786	0.001747	20-55	0.003544
15	0.024477	0.007223	114-55	0.005562
16	0.091157	0.006216	173-23	0.000000
EX11	0.070845	0.009660	168-56	0.007190
CR27	0.003825	0.003559	50-39	0.021856
1031	0.003809	0.003313	179-32	0.014854
SM11	0.003412	0.002942	174-53	0.013754
CAST	0.003581	0.003072	1-43	0.015349
SM09	0.005241	0.004095	42-39	0.017925
RIVE	0.007201	0.005213	52-34	0.030694

			4330.7724			
S16A	SM09	S26-57-53.25E	6934.7680 6935.1338	0.15	0.0042	0.6104
S16A	SM10	S29-17-46.82W	3849.2533 3849.4642	0.13	0.0025	0.6465
S16A	SM11	S77-34-53.86W	2468.2255 2468.3643	0.29	0.0030	1.2100
SM08	SM09	N84-03-43.34E	3236.2802 3236.4377	0.30	0.0047	1.4669
SM08	SM10	N29-48-06.51W	3640.1268 3640.3114	0.13	0.0022	0.5970
SM09	SM10	N60-40-48.16W	5766.7977 5767.0909	0.19	0.0043	0.7476
SM10	SM11	N10-33-41.47W	2874.8515 2875.0078	0.21	0.0035	1.2037

The OPUS Projects adjustment produced a SEUW of 0.500, which is in the middle of the acceptable range. The OPUS Projects adjustment report is attached as Appendix B.

Following the OPUS Projects adjustment, GPS data taken at 14 stations (including the CORS P268, P271 and UCD1) was processed in Trimble Business Center (TBC) v2.81 using precise orbits and NGS absolute antenna models. This was done primarily to produce vector data for use in a combined GPS-terrestrial adjustment using Star*Net v6.0. However, a minimally-constrained adjustment of the GPS data was performed in TBC to ensure data quality. This adjustment produced a SEUW of 1.96, indicating that the accuracy of the data is somewhat lower than predicted by the baseline processor. However, the Trimble baseline processor is known to be optimistic, and this value is acceptable for the project. (Note that the acceptable SEUW range for OPUS Projects is based on a different set of parameters and is not directly comparable to the SEUW value produced by TBC.) The minimally-constrained adjustment report is attached as Appendix C.

The adjusted positions from the OPUS Projects adjustment for the 8 stations closest to the project area were used as constraints in the Star*Net adjustment, using the standard errors for these station positions (latitude, longitude and ellipsoid height) as reported by OPUS Projects. This adjustment incorporated both GPS and terrestrial measurements, and produced a SEUW of 1.041 after scaling the GPS vector standard errors by the SEUW of the TBC adjustment (1.96).

A high-resolution hybrid geoid model (GEOID12A) produced by NGS was applied during the adjustment to produce NAVD88 orthometric heights (elevations).

The final positions from the Star*Net adjustment are shown in the tables below. Values are shown in geographic format with ellipsoid height in meters (Table C), California Coordinate System of 1983 (CCS83) meters (Table D) and CCS83 feet (Table E). The complete Star*Net adjustment report is attached as Appendix D. Note that there is no Table A or Table B so that table designations remain consistent between this report and the June report, and that Tables C, D and E do not include positions for LNC2, P267, PLSB and SACR, as these were not used in the Star*Net adjustment.

APPENDIX D – STAR*NET NETWORK ADJUSTMENT REPORT

Relative Error Ellipses (Meters)
Confidence Region = 95%

Stations From	To	Semi-Major Axis	Semi-Minor Axis	Azimuth of Major Axis	Vertical
15	16	0.081014	0.000047	7-48	0.005562
15	EX11	0.059760	0.007522	7-48	0.004557
15	SM10	0.024540	0.007036	114-55	0.004286
1031	P271	0.003658	0.003127	0-02	0.014715
1031	S16A	0.003973	0.003444	178-55	0.015068
1031	SM11	0.004163	0.003494	177-12	0.017284
CAST	COD1	0.003747	0.003223	2-13	0.015519
CAST	COY1	0.003764	0.003266	4-48	0.015591
CAST	P268	0.003852	0.003465	5-07	0.015433
CAST	SM08	0.003782	0.003276	3-48	0.015594
CAST	UCD1	0.003752	0.003350	5-44	0.015425
COD1	COY1	0.002545	0.002289	44-36	0.005147
COD1	SM08	0.002507	0.002280	41-18	0.005105
COY1	CR27	0.003926	0.003630	49-13	0.021921
COY1	P271	0.002457	0.002277	54-32	0.005017
COY1	SM08	0.002456	0.002228	46-59	0.005082
COY1	UCD1	0.002539	0.002325	60-40	0.004127
CR27	P271	0.003911	0.003669	52-06	0.021986
CR27	SM08	0.003958	0.003652	51-55	0.021996
CR27	SM10	0.004001	0.003713	47-39	0.022040
P268	UCD1	0.002540	0.002258	84-57	0.002665
P271	SM10	0.002185	0.002136	27-50	0.004761
P271	SM11	0.003456	0.002970	175-52	0.013864
P271	UCD1	0.002349	0.002109	81-59	0.003876
RIVE	S16A	0.007083	0.005049	53-13	0.030667
RIVE	SM09	0.006669	0.004690	51-44	0.029732
S16A	SM09	0.005229	0.004095	43-45	0.018131
S16A	SM10	0.002499	0.002356	13-38	0.005093
S16A	SM11	0.003473	0.002978	174-49	0.013871
SM08	SM09	0.005252	0.004060	41-40	0.017762
SM08	SM10	0.002247	0.002160	37-10	0.004856
SM09	SM10	0.005356	0.004249	42-15	0.018191
SM10	SM11	0.003465	0.002977	175-32	0.013910

LA15

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Prepared at the Request of Counsel

TECHNICAL MEMORANDUM

TO: John Herrick, South Delta Water Agency
Dante Nomellini, Central Delta Water Agency

DATE: December 1, 2014

FROM: Jack Dahl, EIT
Nathan Jacobsen, PE
John Lambie, PE, PG, CEG

PROJ. NO. 0611-001-01

SUBJECT:___Review and Comments to Long-Term Water Transfers Environmental Impact Statement/Environmental Impact Report (EIS/EIR) - Public Draft

Executive Summary of Comments

The analysis in the EIS/EIR of Groundwater Substitution Measures considered within Alternatives 2 and 3 for Long-Term Water Transfers does not properly account the water available. The analysis of the Groundwater Substitution Measures in the EIS/EIR: 1

- improperly quantifies the groundwater depletions that would result from groundwater extraction;
- fails to properly account for the timing and quantity of groundwater flow that would have accreted to the rivers as baseflow absent the groundwater extraction;
- fails to accurately quantify the effects of exfiltration from the river to groundwater; and
- as a result significant quantities of water are being double counted as between available surface water and extracted groundwater.

The proposed mitigation measures are inadequate to offset the impacts, in some cases this is due to the inaccurate accounting of water and in other cases it is because the proposed mitigation is too ill-defined to provide substantive protection against impacts.

Groundwater Resources

The SACFEM 2013 groundwater model utilized for analysis in the EIS/EIR for Groundwater Substitution Measures does not properly account the losses of water in the rivers. This is true due to a number of deficiencies in the model's simulation code, MicroFEM and the SACFEM2013 model's construction. 2

- SACFEM2013 uses a river stage that does not vary over each time step which in effect makes the river an infinite source of water for each time step.

- SACFEM2013 does not accurately account the losses of water in the rivers because it does not contain a mathematical algorithm for accounting the flow or quantity of water in the rivers. 3
- SACFEM2013 does not accurately account the water because it treats flow between the river and aquifer as fully-saturated flow even when the model conditions recognize that hydraulically they are detached. 4
- SACFEM2013 has been configured such that extraction from Groundwater Substitution Measures are hydraulically isolated from the river (for example a vertical anisotropy of 500:1 in hydraulic conductivity at the wells in the model substantially isolates them from the rivers) 5
- SACFEM2013 does not represent accurately the depletions to groundwater that must be refilled by natural recharge or other sources due to its handling the rivers as infinite sources during each model time interval 6

SACFEM2013 is not well calibrated to actual conditions of groundwater elevation near rivers and streams. Due to its lack of calibration to actual groundwater elevation conditions, the predictive outcomes are not reliable as a basis for assessing the locations of impact and the degree of impact to Water Supply, Groundwater Resources, Water Quality, and Terrestrial Resource considerations. 7

Neither the quantity of water nor the timing of its removal from surface water is calculated correctly in SACFEM2013 due to the structural deficiencies identified in our review. One of the essential needs in an EIS/EIR on Groundwater Substitution Measures is accurate estimating of the timing of impacts to the flowing rivers and streams; SACFEM2013 does not provide accurate monthly estimates of when peak streamflow depletions will occur if Groundwater Substitution Measures are imposed in large part because of the hydraulic isolation of the pumping from the rivers configured into the model. 8

The magnitude of groundwater depletion is underestimated in SACFEM2013 due to its use of infinite river sources. 9

The Proposed Mitigation GW-1 for aquifer desaturation resulting from Groundwater Substitution Measures, GW-1, will not adequately mitigate the impacts to groundwater users in the Seller's Area. This is due in part to the improper accounting of the exchange of surface water and groundwater in SACFEM2013 which attributes too much of the groundwater elevation variability to seasonal recharge and discharge and does not attribute enough of the variability to long term desaturation. However, the Proposed Mitigation, GW-1, will not adequately mitigate for changes in groundwater storage due to the mitigation measure's reliance upon local groundwater-subbasin management-objectives; those objectives are insufficiently quantified and thereby cannot enable timely mitigation of project impacts from Groundwater Substitution Measures. 10

The mitigation proposed for decreases in groundwater saturation of the uppermost aquifer, GW-1, are inadequately considered. SACFEM2013 does not correctly calculate the drawdown of the unsaturated aquifer and its corresponding increase in the weight of the overburden on under consolidated lithologic layers. This will result in greater impacts from Groundwater Substitution Measures than are recognized in the EIS/EIR due to inelastic subsidence and the resulting permanent loss of aquifer storage in the Seller's Area. The proposed mitigation, GW-1, will only recognize or acknowledge inelastic subsidence 11

due to Groundwater Substitution Measures after it has occurred; thus it cannot restore or offset the 11
permanent impact of subsidence.

Water Supply

The "post-processing tool" referred to under evaluations of Water Supply for Water Operations
Assessment does not properly account for water as it uses SACFEM2013, CalSim II, and a spreadsheet 12
model called the Transfer Operations Model (TOM). The potential impacts to Water Supply from Groundwater Substitution Measures do not properly account the water the sources available and depleted in the Water Operations Assessment.

The CalSim II model utilized for analysis in the EIS/EIR does not properly account the losses of water in the rivers nor the quantities of accretionary flow of groundwater to rivers within the area modeled.
Calsim II provides limited useful information to assess potential surface water impacts as the model 13
contains unfounded assumptions, errors, and outdated simulation codes. The very poor precision of the surface water delivery model (CalSim II) used for the baseline assessment on quantities of water moving in and around the CVP and SWP leads to problems in accounting for water losses due to existing groundwater extraction and proposed groundwater extraction as Groundwater Substitution Measures.

TOM is utilized in the EIS/EIR to assess Impacts to Water Supply from Groundwater Substitution Measures does not and by virtue of its underpinnings of SACFEM2013 and CalSim II cannot properly account the losses of water in the rivers induced by Groundwater Substitution Measures. TOM simulates water made available under each transfer mechanism, subject to various constraints. TOM uses an
assumed priority for transfer mechanisms used to make water available under Project alternatives in the 14
following order:

- Groundwater substitution – for alternatives that include this mechanism
- Reservoir release
- Conserved water
- Crop idling – for alternatives that include this mechanism

Priorities for transfer mechanisms are necessary to develop groundwater pumping inputs to
SACFEM2013 and simulate all transfers in TOM. Thus TOM appears to bookkeep errors in available 15
water derived in SACFEM2013 and CalSim II. It takes input from SACFEM2013 and CalSim II to bookkeep their inaccurate information but provides no feedback to those models

The methodology by which Groundwater Substitution Measures for Long-Term Water Transfers are
being considered and analyzed within the EIS/EIR, improperly accounts quantities of water and as a 16
result significant quantities of water are being double counted as between available surface water and extracted groundwater.

Due to the improper accounting of water in Water Supply, the proposed mitigation, WS-1, is inadequate
to mitigate the impacts to water availability and water flows into and through the Delta during three 17
important periods of time: (1) the period of Groundwater Substitution pumping, April thru September; (2) the Water Transfers window, July thru September; and, (3) the period following the Water Transfers window, October to April.

Due to the lack of a specific formulation for the proposed Water Supply mitigation, WS-1, it is unpredictable how the mitigation will be applied. The EIS/EIR references Draft documents on Technical Information for Preparing Water Transfer Proposals (October 2013).[1] Those documents identify the need for estimating the effects of transfer operations on streamflow and describe the use of a streamflow depletion factor; however they provide no basis for Project Agency approval nor for transfer proponents to submit site-specific technical analysis supporting a streamflow depletion factor. That document which is completely relied upon in establishing proposed mitigation, WS-1, states that:

> *"Project Agencies are developing tools to more accurately evaluate the impacts of groundwater substitution transfers on streamflow. These tools may be implemented in the near future and may include a site-specific analysis that could be applied to each transfer proposal."*[2]

This future action provides no established or predictable basis for the mitigation of streamflow depletions due to Groundwater Substitution Measures. Due to the improper accounting of water in both the groundwater and surface water supply models utilized for Water Supply analysis, reliance upon these models or the analysis in this EIS/EIR by the Project Agencies would result in inappropriate estimation of the streamflow depletion factors (SDF) utilized. Examples of appropriate methodologies for quantifying SDF for Water Supply are provided in Appendices A and B. They result in short-term SDF ranging from 8% to 22% of the Groundwater Substitution Measures after the onset of pumping proposed in the EIS/EIR and long-term cumulative SDF ranging from 34% to 108.5% of annual pumping based on evaluation of the 6-year drought from 1987 to 1992. 18

The mitigation proposed for loss of Water Supply, WS-1, due to Groundwater Substitution transfers is insufficient. It does not adequately account for the impact from the resulting reductions of water available in the rivers and groundwater due to the improper accounting of water in the EIS/EIR analyses. As detailed in our analysis the mitigation measure proposed has no basis in fact, and if it did the project proponents would find that mitigation of the impacts from Groundwater Substitution Measures are not likely to meet the Project Purpose and Need and the Project Objectives.

Water Quality

Groundwater Substitution Measures for Long-Term Water Transfers effects on Delta outflows and water quality are not properly considered in the EIR/EIS. The EIS/EIR rates the effects on Delta outflows and the impact to Delta Water Quality as Less Than Significant based on improper accounting of water. The effects and impacts are likely to be Significant and thus will require mitigation.

Reservoir Releases for meeting regulatory requirements and or deliveries to Project Contractors may be diminished by streamflow depletions from <u>current and proposed</u> pumping conditions in areas where groundwater saturation falls below the adjoining river stage. These depletions of water available for transfer via Reservoir Releases are not quantified in the EIS/EIR. The effect of these baseline conditions impacts the availability of water to be transferred down the Sacramento River and through the 19

[1] Department of Water Resources and Bureau of Reclamation, 2013. DRAFT Technical Information for Preparing Water Transfer Proposals – Information to Parties Interested in Making Water Available for Water Transfers in 2014, October.

[2] Ibid, at p. 33.

Sacramento San-Joaquin River Delta to the CVP and SWP pumping stations that pump water south via their respective aqueducts, the Delta-Mendota Canal, and the California Aqueduct. 19

Terrestrial Resources

Terrestrial Resource impacts are not properly accounted in the EIS/EIR due in part to the imprecision and inability of the models to assess dehydration of the soils and groundwater aquifer adjoining both small streams and large rivers.

The Proposed Mitigation, GW-1, for potential impacts to Terrestrial Resources is insufficient to mitigate the impacts since it too is not sufficiently quantified in the EIS/EIR nor in the Groundwater Management Plans (GWMPs) referenced. Existing GWMPs do not contain quantified year on year metrics for subbasin depletion and refill. These GWMPs do not identify acceptable ranges of groundwater elevations for short-term or long-term groundwater that will to sustain primary functions like support for natural riparian communities upon which several endangered species rely. 20

Summary of Impact Statements Addressed from the Review Performed of the EIS/EIR Analyses

The fundamental concept of water accounting errors in the models and conceptualizations applied to six specific evaluations made in the EIS/EIR are addressed herein under four topic headings Groundwater Resources, Water Supply, Water Quality and Terrestrial Resources.

Potential Impact Statements from Table ES-4	Related Alternative(s)	Significance to CEQA	Proposed Mitigation	Significance After Mitigation Pursuant to CEQA
Groundwater substitution transfers could cause a reduction in groundwater levels in the Seller Service Area.	2, 3	S	GW-1: Mitigation and Monitoring Plans	LTS
Groundwater substitution transfers could cause subsidence in the Seller Service Area.	2, 3	S	GW-1: Mitigation and Monitoring Plans	LTS
Groundwater substitution transfers could decrease flows in surface water bodies following a transfer while groundwater basins recharge, which could decrease pumping at Jones and Banks Pumping Plants and/or require additional water releases from upstream CVP reservoirs.	2, 3	S	WS-1: Streamflow Depletion Factor	LTS

Potential Impact Statements from Table ES-4	**Related Alternative(s)**	**Significance to CEQA**	**Proposed Mitigation**	**Significance After Mitigation Pursuant to CEQA**
Water transfers could change Delta outflows and could result in water quality impacts.	2, 3, 4	LTS	None	LTS
Groundwater substitution could reduce stream flows supporting natural communities in small streams	2, 3	S	GW-1	LTS
Transfer actions could alter flows in large rivers, altering habitat availability and suitability associated with these rivers	2, 3, 4	LTS	None	LTS

EPUR Safe Water for All

Detailed Comments to EIS/EIR Analyses

Groundwater Resources

The EIS/EIR evaluates at Section 3.3.2 on Environmental Consequences/Environmental Impacts on Groundwater Levels from the Long-Term Water Transfers lists: (1) increased groundwater pumping costs due to increased pumping depth (i.e. increased depth to water in an extraction well); (2) decreased yields from groundwater due to reduction in the saturated thickness of the aquifer; (3) lowered groundwater table elevation to a level below the vegetative root zone, which could result in environmental effects. It then sets out to evaluate Item (1) under Regional Economics and (3) under Vegetation and Wildlife. Further it states that for Environmental Consequences/Environmental Impacts on Land Subsidence that excessive groundwater extraction from confined and unconfined aquifers could lower groundwater levels and decrease pore-water pressure. It notes that compression of fine-grained deposits is largely permanent and lists various negative consequences that could result. 21

Our review finds the evaluation in the EIS/EIR of impacts to Groundwater Resources from Groundwater Substitution Measures does not properly account for water and as a result is either inaccurate or insufficient to evaluate the potential environmental impacts associated with Groundwater Substitution.

Potential Impact Statements from Table ES-4	Related Alternative(s)	Significance to CEQA	Proposed Mitigation	Significance After Mitigation Pursuant to CEQA
Groundwater substitution transfers could cause a reduction in groundwater levels in the Seller Service Area.	2, 3	S	GW-1: Mitigation and Monitoring Plans	LTS

The two assessment methods utilized for Groundwater Resources in the EIS/EIR are a numerical groundwater model, SACFEM2013, and a qualitative assessment for groundwater conditions in the Redding Area Groundwater Basin outside of the numerical groundwater limits.

The SACFEM 2013 groundwater model does not properly account water in an integrated groundwater to surface water system. This is due in part to the shortcomings in the underlying simulation code used, MicroFEM, to construct the SACFEM 2013 groundwater model.[3] The MicroFEM simulation code selected for evaluation of the significance of potential impacts to groundwater lacks some essential mathematics for evaluation of the issues presented by Groundwater Substitution Measures. MicroFEM is a simulation code only for fully saturated groundwater systems whereas to evaluate the potential impacts and 22

[3] The following terms, referenced herein, are typical of industry nomenclature: Algorithm - an operation or calculation (e.g., the Darcy equation); Simulation Code - a sequence of programming language commands that encapsulates one or more algorithms (e.g., California DWR's IWFM program); and, Model - an application of a simulation code to a site-specific question (e.g., in this EIS/EIR-evaluation the use of MicroFEM and its construction into the groundwater model SACFEM2013)

effects of groundwater extraction near rivers in the Sacramento River Basin it is necessary to properly formulate the discharge of water from the rivers when the river at the bottom of its streambed hydraulically detaches from the groundwater aquifer due to aquifer desaturation. While MicroFEM mathematically notes the transition from saturated to unsaturated it calculates the condition of discharge as if it is fully saturated. This is incorrect and produces substantive miscalculation of the rate and quantity of movement of surface water into groundwater and thus the magnitude of the resulting groundwater depletion. 22

As can be seen in the following illustration (Figure 1) aquifer desaturation and streamflow detachment, will influence the rate of change in groundwater elevations, groundwater flow, and groundwater interaction with surface water bodies, particularly rivers and streams. We address streamflow under Water Supply.

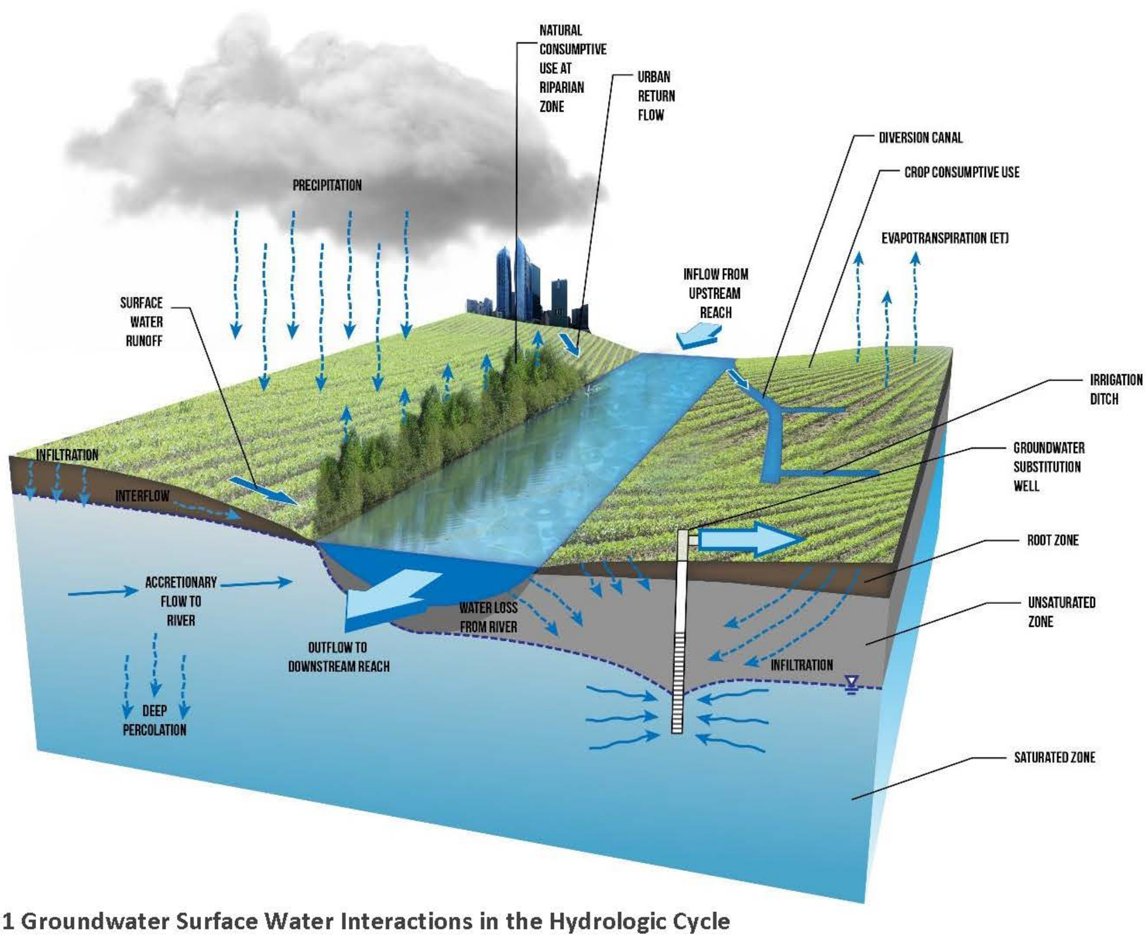

Figure 1 Groundwater Surface Water Interactions in the Hydrologic Cycle

The MicroFEM simulation code lacks the algorithm that would account the water loss from the river under unsaturated and partially saturated conditions. In order to properly account water in the groundwater system and represent the changes in the groundwater elevations as well as the streamflow depletion from the rivers and streams induced by Groundwater Substitution Measures, unsaturated or

partially saturated groundwater flow algorithms are essential components of the simulation code and/or the quantitative analysis. Since the MicroFEM simulation code does not have proper algorithms 22
to represent streamflow detachment and the resulting flux to groundwater, then as a result neither does SACFEM2013 model, the model upon which Groundwater Resource evaluations are based.

As far as potential impacts to river stage heights induced by decreases in groundwater elevations from Groundwater Substitution Measures, MicroFEM has no algorithm to calculate a change in river stage height that governs the rate of accretion or depletion to the river. Thus calculation of fluxes into and out of a river are inaccurate. They are either overestimated or underestimated based on the relative head difference between groundwater and surface water. The flow into or out of the groundwater system (called groundwater surface-water flux hereinafter) is never correct in MicroFEM due to this missing algorithm and capability in the simulation code.

For each time step the SACFEM2013 model has a user-input river stage that is invariant for the monthly time step. This results in substantive problems in properly accounting the depletion of water in the groundwater aquifer and in the groundwater surface-water flux. First with regard to accounting the depletion of groundwater SACFEM2013 does not account for the origin of surface water flowing into the groundwater domain. Surface water flowing into the groundwater domain during each monthly time- 23
step is treated as an infinite source of water; there is no formulation of river flow in the MicroFEM simulation code and hence the SACFEM2013 model has no river flow accounting to provide proper accounting of this lost surface water (That water loss accounting appears to be attempted later under the Transfer Operations Model which we address under Water Supply). A useful publication from the U.S. Geological Survey (USGS) from 1998, <u>Ground Water and Surface Water A Single Resource,</u> identifies that the hydrologic cycle demonstrates that groundwater surface-water flux behaves dynamically and that groundwater is not a source but rather the system of surface water and groundwater is a finite resource defined and governed by local and regional hydrologic and hydrogeologic conditions.[4] This dynamic interaction of groundwater surface-water fluxes within the context that it is finite in quantity and temporally controlled is not the manner in which groundwater modeling has been done for use in the EIS/EIR. Since the source of surface water in SACFEM2013 that satisfies the model estimated drawdown is mathematically infinite, an improper accounting of water available in the system occurs. This results in the double counting of available water as between available groundwater for substitution transfer and available surface water to transfer. In summary the accounting of surface water available to recharge an aquifer in SACFEM2013 is not correct due to the fundamental construct of the model.

Due to the SACFEM2013 model requirement of groundwater surface-water flux being calculated as a fully saturated flow condition, groundwater surface-water flux where the model calculated head near a river reach is below the bottom of the streambed is not properly calculated in SACFEM2013. Rates of inflow to groundwater where this occurs within the model domain for a particular model stress period 24
are overestimated due to both the incorrect mathematical formulation as fully saturated flow and the invariant stage height in that river reach for that stress period (or the following stress period if there were some model carryover of surface water depletions). Furthermore the underestimation of groundwater depletion from that same stress period is error that is carried over to the next stress

[4] Winter, T.C., J.W. Harvey, O.L. Franke, and W.M. Alley 1998. Ground Water and Surface Water A Single Resource, USGS Circular 1139, pp. 79, p. 2.

period. This cumulative error in accounting the temporal depletion of groundwater in SACFEM2013 is significant because the model then subsequently does not have correct quantification of the amount of 24
required refill water to replenish groundwater from both natural recharge and delivery and application of irrigation water. Thus there are problems in accounting water correctly in the connected groundwater and surface water system due to errors in SACFEM2013.

Unlike surface water depletions to groundwater, the accretionary flow of groundwater to the river is 25
calculated in SACFEM 2013, but the calculation is inaccurate due to the invariant stage height during each monthly time step in the model.

SACFEM2013 contains an unusual model construction feature with respect to natural or crop consumptive use and evapotranspirational loss of water. It utilizes a calculation module in MicroFEM called Drains to simulate evapotranspirational losses and groundwater discharge to land surface outside 26
of a recognized and model surface water course. Drains were set at land surface rather than at root zone depth. This is altogether an unusual construction and one that reduces the quantity of water removed by vegetation as constructed. Additional details on SACFEM2013 model review and issues noted are provided in Attachment C herein.

SACFEM2013 is not well calibrated to actual conditions of groundwater elevation near rivers and streams. There is almost no mention of model calibration in the EIS/EIR; those two words appear once at page D-13. There are a number of standard references on numerical groundwater modelling that emphasize the importance of model calibration.[5,6,7] The lack of documentation in the EIS/EIR of model calibration such as how it was conducted and what the degree of precision achieved to which outcomes, is a significant omission. Through sources cited in the EIS/EIR we were able to locate calibration information for SACFEM.[8] The peer review cited in the EIS/EIR stated:

> *"Review of the representative and other calibration hydrographs reveals that significant* 27
> *calibration issues exists in areas that rely mostly on surface water. This is mainly due to the issues of SacFEM's estimation of stream-aquifer interaction. Calibration quality improves in areas that rely mostly on groundwater."*[9]

The model documentation we reviewed demonstrated local errors in predicting groundwater elevation heads that are greater than 65 feet (see Attachment C).[10] Calibration errors of this magnitude signify that the groundwater elevations for the water table would fall below the bottom of the uppermost layer in SACFEM2013; the significance of this is that MicroFEM simulation code only calculates unconfined flow conditions in the uppermost layer of a particular model such as SACFEM2013. When actual

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[5] Reilly, T.E., and Harbaugh, A.W., 2004, Guidelines for evaluating ground-water flow models: U.S. Geological Survey Scientific Investigations Report 2004-5038, 30 p.

[6] ASTM 2001, D 5981-96 (Reapproved 2002), "Standard Guide for Calibrating a Ground-Water Flow Model Application". Published November 1996, 6 p.

[7] ASTM 1994, D 5490-93,"Standard Guide for Comparing Ground-Water Flow Model Simulations to Site-Specific Information"Published January 1994, 7 p.

[8] WRIME, 2011. Peer review of Sacramento valley Finite Element Groundwater Model (SACFEM2013), October.

[9] Ibid, p. 16.

[10] Lawson, Peter, 2009. Documentation of the SacFEM Groundwater Flow Model. CH2MHill Technical Memorandum. Prepared for Bob Niblack, California Department of Water Resources, February. This document is relied upon heavily in the peer review document cited for Section 3.3 of the EIS/EIR: WRIME,2011.

groundwater elevations fall below the bottom of Layer 1 in a number of locations, the model is miscalculating the groundwater flux. This demonstrates that the SACFEM2013 model was improperly constructed as well as poorly calibrated. Due to its lack of calibration to actual groundwater elevation conditions, the predictive outcomes are not reliable as a basis for assessing the locations of impact and the degree of impact to Water Supply, Groundwater Resources, Water Quality, and Terrestrial Resource considerations. Attachment C herein highlights further critique of the SACFEM2013 based on information found in the EIS/EIR as to the model's construction and documentation that the EIS/EIR relies upon in regard to the model's construction and calibration. 27

Neither the quantity of water nor the timing of water's removal from surface water is calculated correctly in SACFEM2013 due to the structural deficiencies identified in our review. One of the essential needs in an EIS/EIR on Groundwater Substitution Measures is accurate estimating of the timing of impacts to the flowing rivers and streams; SACFEM2013 does not provide accurate monthly estimates of when peak streamflow depletions will occur if Groundwater Substitution Measures are imposed in large part because of the hydraulic isolation of the pumping from the rivers configured into the model. 28

Accurately quantifying the changes in groundwater storage and groundwater elevations associated with Groundwater Substitution Measures is foundational to defining the potential impacts and their magnitude, and the metrics for the proposed mitigation measure GW-1.

Qualitative Assessments for Groundwater Resources

In section 3.3.1.3.1 Redding Area Groundwater Basin the discussion of Groundwater Production, Levels and Storage does not quantify the quantity of current groundwater pumping or the basin safe-yield without mining out groundwater in any of the six subbasins recognized in DWR Bulletin 118. There is no identification of what impacts to base flows occur from current groundwater extractions for either current Municipal & Industrial (M&I) or applied irrigation. The EIS/EIR does not quantify those groundwater levels (i.e. drawdowns) associated with existing extractions in order to establish what the acceptable groundwater levels (i.e. drawdowns) associated with Groundwater Substitution Measures in this area might be. This is foundational to establish a basis for the proposed mitigation, GW-1, to avoid impacts to existing groundwater users and to avoid impacts to the seasonal base flows in the Sacramento River reaches in the Redding Area Groundwater Basin and those seasonal base flows of the 7 major tributaries to the Sacramento River within the basin. For example our review of the groundwater elevation contours on Figure 3.3-4 indicate that the Sacramento River are between 420 feet and 400 feet above Mean Sea Level between the Clear Creek join and the crossing of the I-5 freeway over the Sacramento at Anderson, CA; since the stream bottom profile of the Sacramento River is approximately 430 feet to 403 feet over this same reach the Sacramento River was losing water in this reach during the Spring of 2013. In addition our review finds that the Sacramento River streambed elevation is above the groundwater elevations of Spring 2013 depicted on Figure 3.3-4 at Colusa, California and southward to the edge of that figure; this means that the Sacramento River from Colusa, California and southward to perhaps Tyndall Landing, California is not only exfiltrating to groundwater, but it is also not gaining the accretionary flow of groundwater that historically occurred in these river reaches. 29

In Section 3.3.1.3.2 Sacramento Valley Groundwater Basin the discussion of Geology, Hydrogeology and Hydrology notes that it was estimated by the USGS that from 1962 to 2003 that streamflow leakage 30

(also called direct exfiltration) amounted to 19% of total basin recharge and equated to 2,527,000 acre-feet per year (AFY) or 3,490 cubic feet per second of surface-water flow. This quantity of water does not 30
denote the entirety of the streamflow depletion from the basin which is the: denied accretionary groundwater flow to the rivers and streams within the basin. However, it is noted that this USGS estimated leakage-loss that discharges from the rivers and streams to groundwater is accounted in their CVHM model as surface water removed.[11]

The impact from surface water leakage to support the groundwater elevations reviewed in Section 3.3 is not quantified and the available response of groundwater elevations to Groundwater Substitution Measures is not quantifiable as a result. In other words if one of the principal sources to groundwater is surface water leakage and that leakage has already reached its maximum rate then the impact from further groundwater extraction must take into account that removal from storage and upgradient flow must meet the demand from Groundwater Substitution Measures.

It appears that neither quantitative nor qualitative evaluation of inflow or outflow to rivers and streams 31
has been done in the EIS/EIR using empirical groundwater and surface water elevation data. Our requests for the database of groundwater elevations used in the EIS/EIR did not yield the Spring 2013 groundwater elevation data used to generate Figure 3.3-4. Further neither the report nor the data provided to our request reveal groundwater elevation data for 2013 in the southerly portions of the Sacramento Valley beyond the extent of Figure 3.3.-4. Comparison of empirical (actual) data to mathematical representations in models is essential to assess whether the models are adequately representing the physics of the real-life system being mathematically modeled. Evaluation of empirical data such as land surface, groundwater elevations, and stream stage heights and rated flow rates, enables assessment of the direction of flux and with more sophisticated tools the probable magnitude of flux.

Proposed Mitigation for Potential Effects on Groundwater Resources

The Proposed Mitigation GW-1 for groundwater pressure decreases (a.k.a. groundwater elevations) resulting from Groundwater Substitution Measures, GW-1, will not adequately mitigate the impacts to groundwater users in the Seller's Area. Proposed Mitigation GW-1 is not quantified or quantifiable as to what groundwater pressure decreases will constitute an impact to water users in the Seller's Area. 32

The groundwater elevations necessary to mitigate streamflow depletions under proposed mitigation, GW-1, as well as the stated impact of lowered groundwater levels for existing groundwater users must be quantifiable or else the proposed mitigation is insufficient to reduce the impacts from Groundwater Substitution Measures. For example in the Spring 2013, the Sacramento River streambed elevations are below groundwater elevations from Red Bluff, California to roughly Princeton, California (i.e. the Sacramento River is gaining flow from accretionary flows of groundwater in this lengthy reach) as depicted on Figure 3.3-4 of the EIS/EIR.

[11] Faunt, C.C., ed., 2009, Groundwater Availability of the Central Valley Aquifer, California: U.S. Geological Survey Professional Paper 1766, 225 p.

The proposed framework for GW-1 is based upon a draft application for preparing water transfer proposals for 2014 from DWR and U.S. Bureau of Reclamation and with the statement that this will be updated as appropriate.[12]

The framework provided for groundwater monitoring and the subsequent proposed mitigation in the EIS/EIR provides no substantive criteria for either monitoring or mitigation. With regard to groundwater monitoring for example at page 3.3-88 under Section 3.3.4.1.2 it states

> *"The monitoring program will incorporate a sufficient number of monitoring wells to accurately characterize groundwater levels and response in the area before, during, and after transfer pumping takes place."*

There is no attempt at defining the minimum number of wells, a spatial resolution laterally or vertically, nor a timeframe. The subsequent subsection on groundwater level measurement requires measurement of groundwater elevations until March of the year following the transfer; this would imply that impacts from one year's transfer are not anticipated to carry over into the following year or it implies that this is the new baseline for the subsequent year's transfer withdrawal. There is no discussion or mention of a multi-year monitoring program in the EIS/EIR with year over year metrics nor are in the draft application guidance for groundwater transfer proposals. A typical application of such a monitoring program using best available science and practice is to establish groundwater elevations in a base year and then metric changes as relative drawdown; in this manner groundwater depletion within a basin or subbasin can be assessed if it is occurring and this would encompass protections against injurious harm to Groundwater Resources if natural recharge is less than normal or slower than one seasonal cycle in providing recovery of the depletion from Groundwater Substitution Measures coupled with other groundwater uses or fluxes. With regard to proposed mitigation for example at Section 3.3.4.1.3, the EIS/EIR states: 33

"If the seller's monitoring efforts indicate that the operation of wells for groundwater substitution pumping are causing substantial adverse impacts, the seller will be responsible for mitigating any significant environmental impacts that occur."

There is no definition provided of what constitutes a substantial adverse impact. Looking back to Section 3.3.2.2 Significance Criteria one finds:

> *"A net reduction in groundwater levels that would result in adverse environmental effects or effects to non-transferring parties"*

There is no benchmark criterion for mitigation and in fact the EIS/EIR at page 3.3-90 then states:

> *"To ensure that mitigation plans will be feasible, effective, and tailored to local conditions, the plan must include the following elements:*
>
> - *A procedure for the seller to receive reports of purported environmental or effects to non-transferring parties;*
> - *A procedure for investigating any reported effect;*
> - *Development of mitigation options, in cooperation with the affected parties, for legitimate significant effects; and*

[12] Department of Water Resources and Bureau of Reclamation, 2013. DRAFT Technical Information for Preparing Water Transfer Proposals – Information to Parties Interested in Making Water Available for Water Transfers in 2014, October

- *Assurances that adequate financial resources are available to cover reasonably anticipated mitigation needs."*

This text is extremely unclear as to: technically what is the procedure for investigation of effects; what is the meaning of "legitimate significant effects" when a multitude of overlapping influences on groundwater will occur from natural to man-made; and who would be monitoring and reporting on adverse environmental effects if not the Seller's and if so then who would be compensating for that monitoring. Our review finds the GW-1 does not provide adequate mitigation for groundwater decreases in the Seller Service Area as it relies upon poorly defined future actions with no established, reliable, or predictable basis for the monitoring and mitigation. 33

Potential Impact Statements from Table ES-4	**Related Alternative(s)**	**Significance to CEQA**	**Proposed Mitigation**	**Significance After Mitigation Pursuant to CEQA**
Groundwater substitution transfers could cause subsidence in the Seller Service Area.	2, 3	S	GW-1: Mitigation and Monitoring Plans	LTS

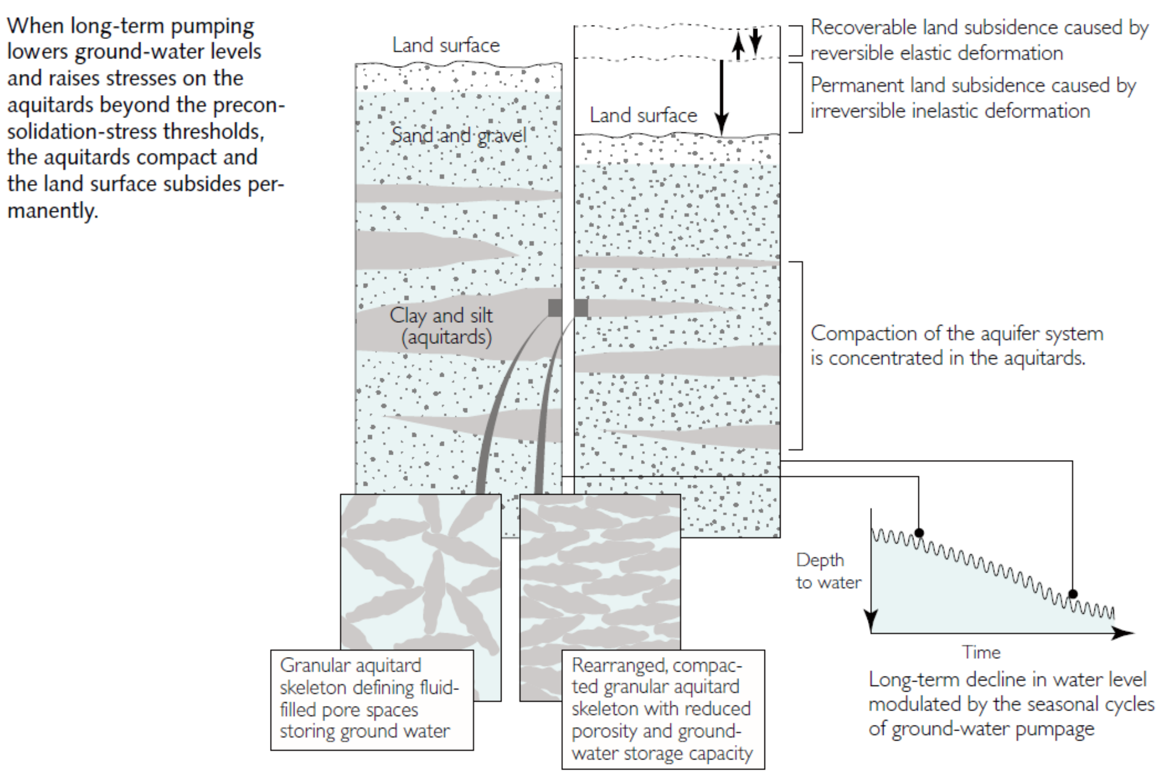

Figure 2 The mechanics of land subsidence due to changes in groundwater elevations, USGS Circular 1182

The groundwater formation in the Seller Service Area west of the Sacramento River is composed of the Tehama Formation.[13] The Tehama Formation has exhibited subsidence in Yolo County. According to the EIS/EIR similar formational and hydrogeologic characteristics exist in the Redding Area Groundwater Basin.

Groundwater elevation changes due to long term pumping can increase the effective stress on subsurface materials that are under-consolidated. This is typical of some aquitards whose skeletal materials are typically composed of fine-grained sediments and when deposited by lower-energy hydraulic processes their ionic mineral boundaries keep them under-consolidated. When the effective stress of the soil column on these aquitards is increased due to dehydration of the aquifers above them, their skeletons compact. This is known as inelastic subsidence and it causes both a permanent loss of groundwater aquifer storage capacity and a depression at the land surface (Figure 2). 34

The groundwater elevations depicted on Figures 3.3-8 and 3.3-9 demonstrate that groundwater elevations in three of the eleven wells selected are at historic lows and under existing hydrogeologic and hydrologic conditions are on decadal declining trends. Specifically wells 11N05E32R001M, 21N03W33A004M, and 15N03W01N001M are all at historic lows at their last measurement discounting for seasonality. Each of these wells is in the western half of the Sacramento Valley Basin and thus would be expected to be overlying the Tehama Formation with its known under-consolidated units. Further groundwater extraction by Groundwater Substitution Measures will further lower groundwater elevations in both the Redding Area Groundwater Basin and the Sacramento Valley Basin. The assessment of changes in groundwater elevations reported at Table 3.3-5 is based on SACFEM2013 modeling and is incorrect due to the deficiencies and built-in errors noted for SACFEM2013 to accurately represent cumulative drawdown from Groundwater Substitution Measures. Moreover without specific well depth information and screened intervals for the handful of monitoring wells noted it is impossible in our review to assess whether they monitor the groundwater table portions of the aquifers; the unit where desaturation occurs and effective stresses that induce permanent land subsidence generally occur.

Proposed Mitigation

The mitigation proposed for the potential impacts of land subsidence due to decreases in groundwater saturation of the uppermost aquifer, GW-1, is inadequate. The monitoring measures for land subsidence in the EIS/EIR are stated at page 3.3-89 as:

> *"Subsidence monitoring will include determination of land surface elevation in strategic (determined by Reclamation) locations throughout the transfer area at the beginning and end of each transfer year. If the land surface elevation survey indicates an elevation decrease, then the area will require more extensive monitoring…"* 35

Under this monitoring program approach, permanent inelastic subsidence will have occurred prior to detection. Mitigation is offered in the form of reimbursement for infrastructure (e.g. roadway) structural damage due to permanent subsidence (albeit elastic reversible subsidence would likely also cause infrastructural damage). No mitigation is offered for the permanent loss of aquifer storage capacity.

[13] US Bureau of Reclamation, 2014. "Long-Term Water Transfers Environmental Impact Statement/Environmental Impact Report Public Draft, September, at p. 3.3-17.

Under this program of monitoring and mitigation it has to be noted at Section 3.3.5 Potentially Significant Unavoidable Impacts that this permanent impact of lost aquifer storage capacity is not mitigated by GW-1. Under Sections 3.3.6.1 and 3.3.6.2 for Cumulative Effects for Alternatives 2 and 3, respectively, which include Groundwater Substitution Measures the cumulative effects noted for land subsidence are stated as:

> *"The groundwater substitution pumping associated with the SWP transfers would occur in an area that is historically not subject to significant land subsidence. In the overall area of analysis, land subsidence is occurring in several areas, as described in Section 3.3.1.3.2."*

The statement is inaccurate. The juxtaposition of Seller locations next to historic subsidence in Yolo County makes the statement inaccurate. The EIS/EIR then goes on to say:

> *"…however, the existing subsidence along with future increases in groundwater pumping in the cumulative condition could cause potentially significant cumulative effects. The impacts of the Proposed Action would be reduced through Mitigation Measure GW-1 (Section 3.3.4.1) to less than significant. Therefore, with implementation of Mitigation Measure GW-1, the Proposed Action's incremental contribution to subsidence impacts would not be cumulatively considerable."* 35

The analysis of changes to groundwater elevations leading to this statement is inaccurate and hence the impacts anticipated are underestimated. Perhaps more to the point the Mitigation Measure, GW-1, as defined will not adequately address the impacts of groundwater drawdown on inelastic subsidence and the resulting permanent loss of aquifer storage in the Seller's Area. The proposed observation of subsidence as mitigation cannot restore or offset the impact of subsidence once it has already occurred.

It is however possible to define a monitoring and mitigation program for the risks and potential impacts of permanent Land Subsidence. Such a program of monitoring and mitigation would require evaluation of historic and current groundwater elevations in the upper groundwater aquifer units over a series of decades long cyclical hydrologic and land use conditions in each Seller Area to determine whether groundwater elevations are at historic lows. If so then mitigation for permanent land subsidence due to Groundwater Substitution Measures would require no Groundwater Substitution Measures for Long Term Water Transfers be approved until groundwater elevations increase above historic lows and within a range that accurate groundwater modeling could demonstrate would not create cumulative lowering of groundwater elevations during the period of approved water transfers.

Water Supply

At Section 3.1.2 on Environmental Consequences/Environmental Impacts on Water Supply the Assessment Methods states:

> *"Impacts to surface water supplies are analyzed by comparing the conditions in water bodies and surface supplies without implementing transfers to the expected conditions of supplies with implementation"* 36

The quantitative tool to be used in assessing impacts to supplies but not water bodies from water transfers and exports from the Delta is referred to in the EIS/EIR as a "post-processing tool." The "post-processing tool" referred to under evaluations of Water Supply for Water Operations Assessment consists of the use of the SACFEM2013 groundwater model, CalSim II, and a spreadsheet model called the Transfer Operations Model (TOM). Our review will focus on these assessment tools to evaluate potential environmental impacts and consequences from the proposed Long-Term Water Transfers Alternatives.

Section 3.1.2.2 Significance Criteria states:

> *"Impacts on surface water supplies would be considered potentially significant if the long term transfers would:*
>
> - *Result in substantial long-term adverse effects to water supply for beneficial uses"* 36

Putting aside the substantive issue of why short-term adverse effects to water supply for beneficial uses is not considered as a criterion, our review finds the evaluation in the EIS/EIR of impacts to Water Supply from Groundwater Substitution Measures to this criterion is either inaccurate or insufficient to evaluate the potential environmental impacts associated with Groundwater Substitution as the methods of Assessment in the EIS/EIR do not properly account water and as a result cannot be relied upon to assess potential impacts and the means of mitigation or the timing of mitigation needs. Analysis of streamflow depletions due to Groundwater Substitution Measures is not analyzed accurately in the EIS/EIR and the loss of surface water to meet Water Supply needs is not properly accounted. This inaccurate accounting results in a fraction of the groundwater extracted being double counted as available surface water for transfer.

No Action Alternative Evaluations in EIS/EIR

It is notable that the No Action Alternative is to look at the Environmental Consequences/Environmental Impacts in water bodies (presumably rivers and reservoirs) <u>and</u> surface supplies while the evaluation for implementing Long-Term Water Transfers is to look at surface supplies with no mention of evaluating impacts to water bodies such as rivers or reservoirs.

The quantitative tool to be used to aid in assessing impacts to surface water supplies and water bodies is CalSim II for the No Action Alternative. 37

CalSim II works on a monthly time-step to assess SWP and CVP operations. CalSim II generates flows as a water system operational decision support tool. CalSim II is not a hydraulic model and does not include channel characteristics such as channel roughness or cross-section geometry to simulate the water routing. As a result of CalSim II's limitations, the models inability to schedule reservoir releases on a daily basis creates water accounting inaccuracies of losses caused by routing and attenuation of upstream reservoir releases to phenomena such as streamflow depletions. Additionally, CalSim II uses simplified flow routing rules (on a monthly time-step) which result in inaccuracies associated with how the SWP and CVP operate in extreme hydrologic conditions, especially in the driest years (DWR and USBOR, 2004 & Ford et al., 2006).[14,15]

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[14] Department of Water Resources and U.S. Bureau of Reclamation (DWR and USROR, 2004). Peer Review Response: A Report by DWR/Reclamation in Reply to the Peer Review of the CalSim-II Model Sponsored by the CALFED Science Program In December 2003, August, 2004

[15] Ford, D., Grober, L., Harmon, T., Lund, J.(Chair), McKinney, D. (Ford et al., 2006). Review Panel Report San Joaquin River Valley CalSim II Model Review. CALFED Science Program – California Water and Environment Modeling Forum. January 12, 2006.

CalSim II was developed over a decade ago to assess new storage and conveyance facilities in the CVP & SWP systems on a monthly time-step. Use of CalSim II has yielded significant scrutiny on its ability to provide relevant data to assess potential future impacts (Close, A. et al, 2003).[16] The CalSim II model presented in the EIS was used for the baseline conditions (2014 planning horizon) and was not used to assess potential changes resulting in future land use and hydrologic/metrological conditions. The baseline assessment can only assess how the Long-Term Transfer Project would impact the environment if it was in-place from 1970-2003 and therefore cannot assess potential impacts of future conditions that are different than the baseline conditions such as various climate change scenarios. 37

Alternative 2 and 3 Evaluations in EIS/EIR

The EIS/EIR reaches the following conclusion with regard to Potential Impacts to Water Supply from Groundwater Substitution Measures.

Potential Impact Statements from Table ES-4	**Related Alternative(s)**	**Significance to CEQA**	**Proposed Mitigation**	**Significance After Mitigation Pursuant to CEQA**
Groundwater substitution transfers could decrease flows in surface water bodies following a transfer while groundwater basins recharge, which could decrease pumping at Jones and Banks Pumping Plants and/or require additional water releases from upstream CVP reservoirs.	2, 3	S	WS-1: Streamflow Depletion Factor	LTS

The analysis of Environmental Consequences/Environmental Impacts is not done accurately nor with a complete conceptual model of the interactive groundwater and surface water system that constitute the Water Supply. At page 3.1.5 in Section 3.1.2.4.1 the analysis states that groundwater basins are naturally recharged after drawdown by rainfall and surface water to groundwater flux, thereby depleting available in stream flow. It goes on to state that the accretionary flow of groundwater to surface water can be intercepted by groundwater extraction; however, it fails to note that this is a depletion of available surface water and water for other beneficial uses such as the health of the riparian and hyporheic zones. As detailed further in our review that follows a proper conceptual model of the hydrologic system for Water Supply demonstrates that the water deprived for the natural consumptive use, evapotranspiration and potentially evaporation via Groundwater Substitution Measures is the likely conserved-water available. The analysis of Water Supply is improperly conceptualized. 38

Additionally at page 3.1.6 in Section 3.1.2.4.1 the EIS/EIR states:

> *"Transfers would not affect whether the water flow and quality standards are met… but only Reclamation and DWR water supplies"*

[16] Close, A., Haneman, W.M., Labadie, J.W., Loucks D.P. (Chair), Lund, J.R., McKinney, D.C., and Stedinger, J.R. (Close, A. et al.). Strategic Review of CALSIM II and its Use for Water Planning, Management, and Operations in Central California. Submitted to the California Bay Delta Authority Science Program Association of Bay Governments. Oakland, California. December 4, 2003.

38

The EIS/EIR notes that it is the State and Federal projects responsibility to maintain water quality standards in the Sacramento River, its tributaries, and the Delta. It then anticipates hypothetically that if the streamflow depletion resulting from Groundwater Substitution Measures results in decreased river flows then USBOR and DWR would modify operations by decreasing Delta exports or release of additional water from reservoirs to meet Delta outflow and/or water quality standards; however as documented in Attachment D herein the Federal and State projects were unable to maintain these standards in 2013 due to dry year conditions and a lack of available in-stream flow and releases of water.

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The quantitative tool used in assessing impacts to supplies but not water bodies from water transfers and exports from the Delta is referred to in the EIS/EIR as a post-processing tool. From Appendix B,

> *"The post-processing tool also includes changes in flows in waterways caused by streamflow depletion from groundwater substitution. Data for the post-processing tool was provided by the SACFEM2013 model, which includes highly variable hydrology (from very wet periods to very dry periods) was used as a basis for simulating groundwater substitution pumping."*

The EIS/EIR used two other models, CalSim II and a spreadsheet accounting model referred to as TOM, to attempt to properly account streamflow depletions. A general technical reference from the U.S. Geological Survey (USGS) published in 1998 entitled Ground Water and Surface Water - A Single Resource identifies that the hydrologic cycle demonstrates that groundwater is not a source of water but rather behaves as a reservoir, receiving and releasing water as governed by local and regional hydrologic and hydrogeologic conditions.[17] The use of the combination of three models does not properly account for water and thus the evaluation of *"how long-term transfers could benefit or adversely affect water supplies"* does not accurately identify potential impacts to available-water for Water Supply.

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[17] Winter, T.C., J.W. Harvey, O.L. Franke, and W.M. Alley 1998. Ground Water and Surface Water A Single Resource, USGS Circular 1139, pp. 79, p. 2.

Figure 3 depicts the overall hydrologic cycle in Water Supply. The only source of true supply is precipitation in the form of rain, snow, or dew. Groundwater is not a source but an interactive reservoir.

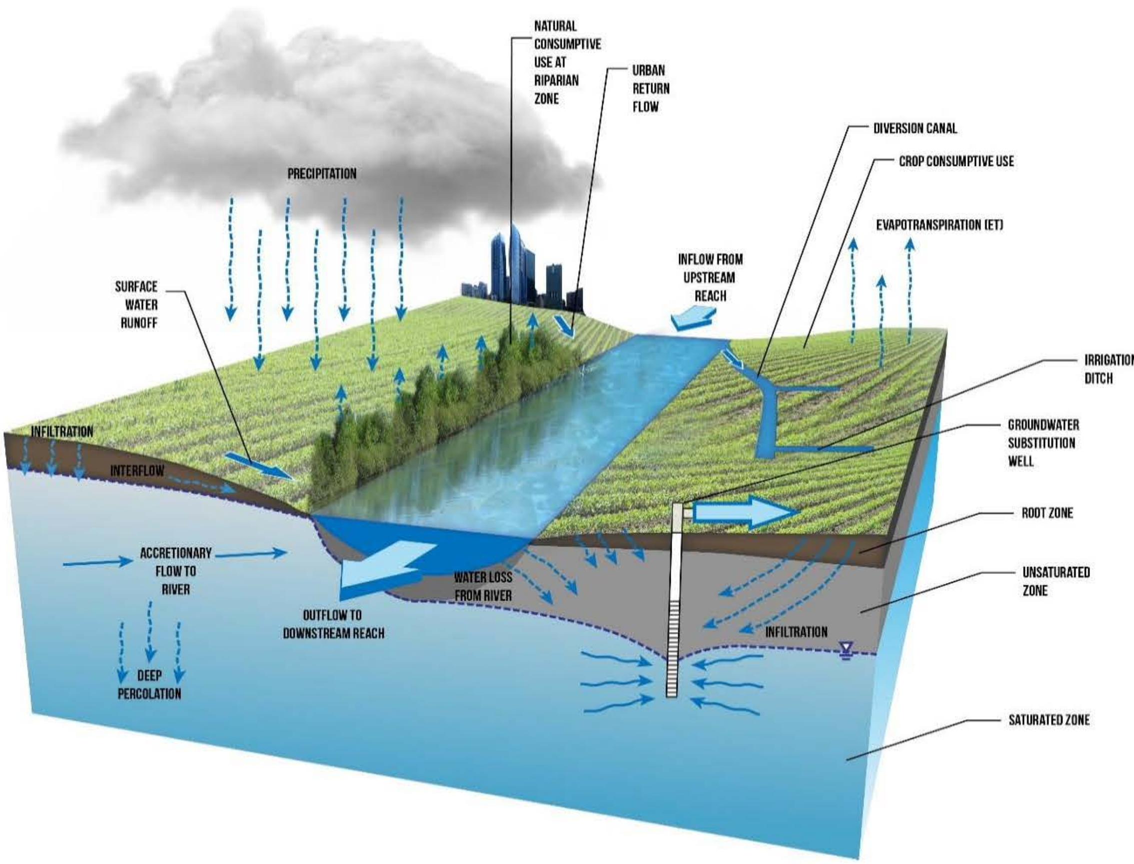

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Figure 3 Hydrologic Cycle Overview with regard to Water Supply Evaluation

For groundwater in the wells near enough to a river to have the cone of depression reach the river within the hydraulic capture zone of the well the following statement applies:

> *"When pumping of a well near a river begins, water is drawn, at first, from the water table in the immediate neighborhood of the well. As the zone of influence widens, however, it begins to draw a part of its flow from the river and, ultimately, the river supplies the entire flow"*
>
> - Robert Glover and Glenn Balmer[18]

This clear statement on the depletion of a river flow by the same rate as that withdrawn from the well is the opening of Glover and Balmer's 1954 paper on their mathematical analysis of river depletion by extraction from a nearby well. Glover and Balmer's work followed upon the first analysis of the

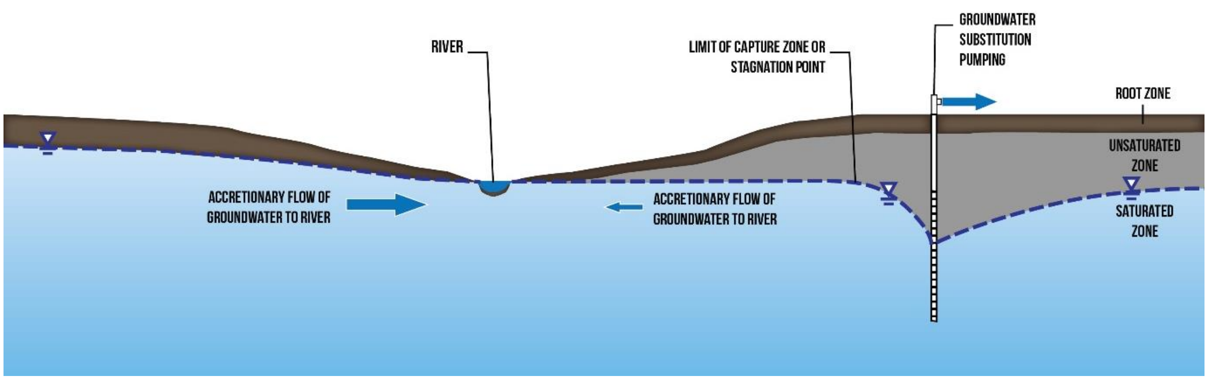
[18] Glover, R.E. and G.G Balmer. (1954). River depletion resulting from pumping a well near a river. *Transactions, American Geophysical Union,* v. 35

depletion of streamflow induced by an extraction well and its zone of capture done by C.V. Theis of the USGS in 1941.[19]

Dr. Theis commented in his 1941 paper on one aspect of the analysis of the overall effects of extraction in an alluvial river valley on the flow into and from a river:

> *"…the flux 'from the river' will be spoken of in the following treatment, the flux may be either an actual movement of water from the river or a decrease of the customary movement of water to the river"*
>
> \- C.V. Theis

This customary movement of water is also commonly known as the accretionary flow of groundwater to the river; it is accretionary flow of groundwater to a river that provides the observable and measurable flow of water in a free-flowing stream during lengthy dry periods when no rain or snowmelt provides the baseflow in a river or stream (i.e. not an ephemeral stream or arroyo). In the illustration below (Figure 4) it can be seen that consistent with Dr. Theis observation on the flux "from the river" the impact to the river is due to loss of accretionary flow to the river and not as a result of direct streamflow 39



depletion by way of river exfiltration. This phenomena from a well located some distance from the river results in streamflow depletion; the principal difference between this case and the one where the zone of capture to the well reaches the streambed of the river is the timing of the streamflow depletion.

L.K. Wenzel of the USGS in the peer-reviewed Discussion of this seminal paper by Dr. Theis from 1941 offered this observation:

> *"It is possible that in some localities all or a part of the water removed from the well may be obtained indirectly by reducing the amount of water that is transpired by plants from the zone of saturation. This is accomplished, of course, through the lowering of the water-table and capillary fringe to some depth below the roots of the plants."*
>
> \- L.K. Wenzel[20]

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[19] Theis, C.V., 1941, The effect of a well on the flow of a nearby stream: *Transactions, American Geophysical Union*, v. 22, part 3, p. 734-737.

[20] Wenzel, L.K., 1941, Discussion re: The effect of a well on the flow of a nearby stream: *Transactions, American Geophysical Union*, v. 22, part 3, p. 737-738.

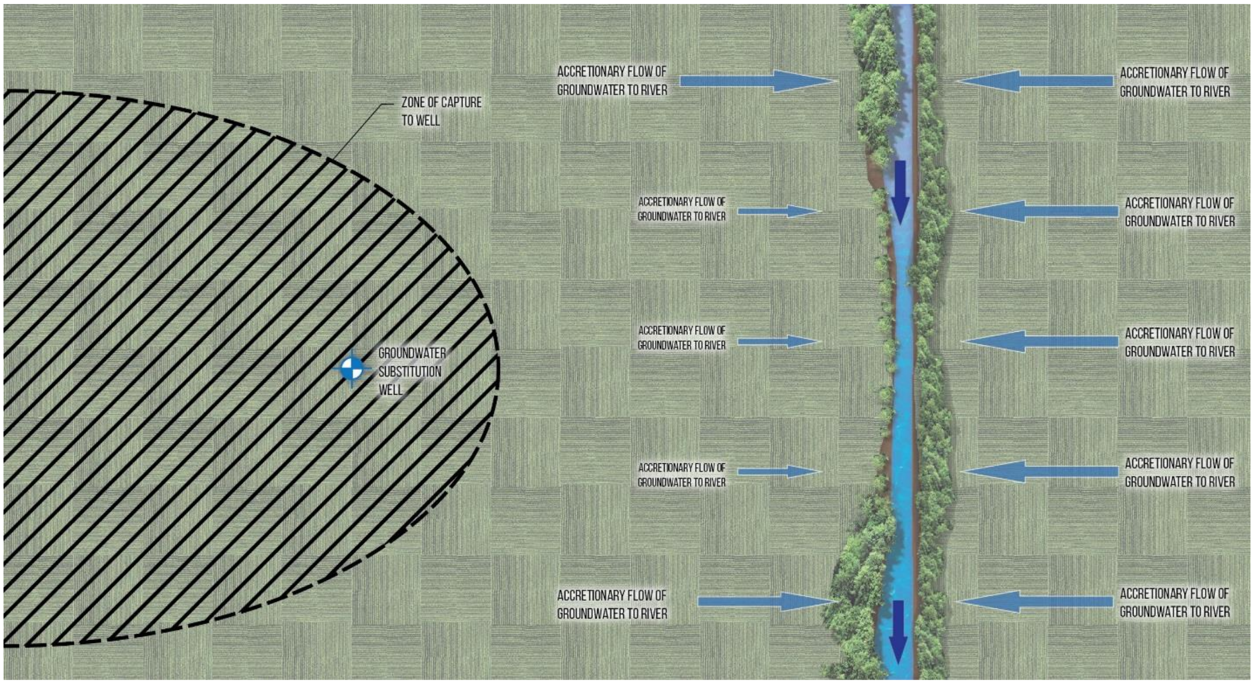

Figure 5 Plan View of Extraction of Groundwater via a Groundwater Substitution Well from which the Zone of Capture to the Well Does not reach the River

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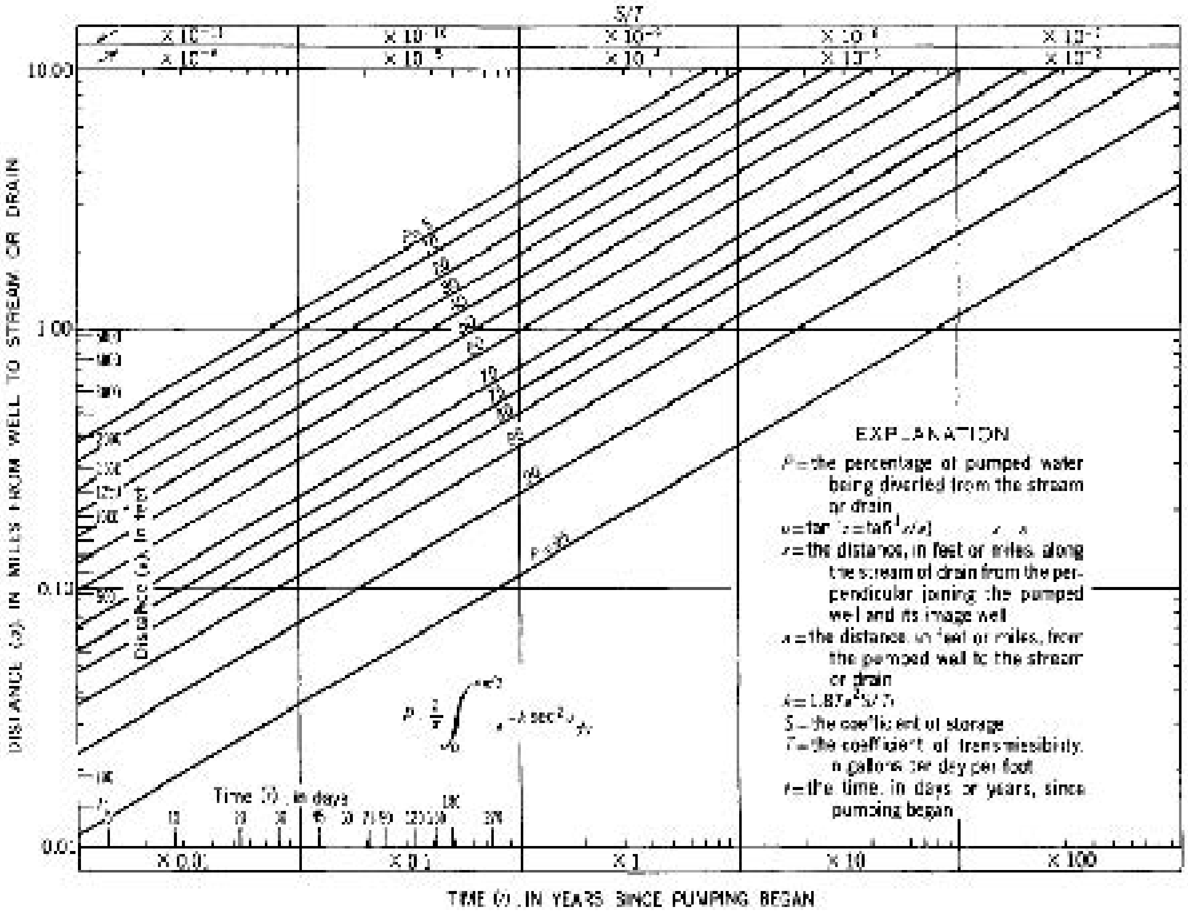
Figure 5 illustrates that extraction pumping far back from a river's edge (e.g. perhaps more than 1-mile) does not capture water directly from the river but instead results in a loss of accretionary flow of groundwater to the river as depicted by the reduced accretionary flow arrows and the diminished riparian zone flora (and in all likelihood impacts the hyporheic fauna near and beneath the riparian zone that supports the food chain for pelagic fish such as salmonids and the habitat for other threatened species). The deprivation of flow to the river from a groundwater extraction well located some distance from the river is ultimately equal to the quantity of extraction; if the flow to the well is drawn from storage then that storage will be replaced eventually by an equivalent quantity of groundwater via direct recharge and indirect groundwater recharge. As Dr. Wenzel's comment notes the only water not deprived to the river or stream is that water that would otherwise have been withdrawn for consumptive use and evapotranspiration by vegetation that is/was able to utilize water from the zone of saturation (i.e. the water table aquifer).

Evaluation of the timing of streamflow depletion due to groundwater extraction wells was made simpler by a further paper by Dr. Theis and his co-author in 1963. The following graphic (Figure 6) describes the timing of impact to a stream or river's quantity of flow based upon two primary criteria, the ration of the aquifer storage coefficient to the aquifer transmissivity, S/T, and the distance between the extraction well and the river.[21] The coefficients are as described in the Explanation in the chart with the X-axis denoting the time since pumping began.

[21] Theis, C.V. and C.S Conover. 1963 "Chart for Determination of the Percentage of Pumped Water being Diverted from a Stream or Drain" *USGS Water Supply Paper 1545-C*. pp. C106-C109.



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This method of analysis was then added to by Mahdi Hantush in 1965 by incorporating to the mathematical solution a simplified concept of streambed resistance laterally to groundwater flow by way of a vertical layer of impedance to flow.[22]

This group of two general methods was improved upon further by Jenkins in 1968 in several ways but also in describing the residual effects of "streamflow depletion" (a phrase first coined in Jenkins paper) after pumping ceases.[23] Jenkins' addition to the field of groundwater and surface-water interconnection at river boundaries, enabled season-to-season carryover of depletions of groundwater storage and the resulting streamflow depletion that can take place over more than one annual hydrologic cycle. Wallace et al. (1990) carried out a similar analysis for cyclic pumping of wells.[24]

[22] Hantush, M.S., 1965. Wells near streams with semi-pervious beds. *Journal of Geophysical Research*, v. 70, no. 12. pp2829-2838

[23] Jenkins, C.T., 1968. Techniques for computing rate and volume of stream depletion by wells. *Ground Water*, v. 6, no. 2. pp37-46.

[24] Wallace, R.B., Y. Darama, and M.D. Annable, 1990. Stream Depletion by Cyclic Pumping. *Water Resources Research* v. 26, no. 6, 1263-1270.

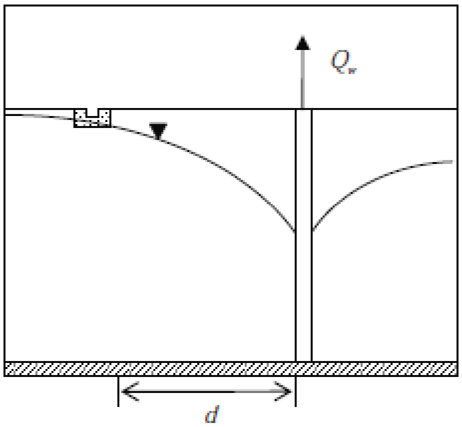

Figure 7 Definition Sketch for a partially penetrating well and a river with semi-pervious layer Hunt (1999)

Subsequently Bruce Hunt (1999) developed an analytical solution to the question of what is the response in a river that has a lower permeability streambed surrounding it than the permeability of the groundwater aquifer to which it is connected including the conceptualization of an extraction well which only partially penetrates the aquifer adjoining the stream.[25] While the bounding conditions of a homogeneous aquifer of infinite extent are applied to each of the aforementioned methods in order to solve the equations of unsteady flow in which a well or wells are actively extracting constitute an idealized case, the inclusion of a semi-pervious streambed fully to the solution provides an even more realistic estimate of the timing of impact on flow in a river or stream (Figure 7).

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Lastly, Bruce Hunt (2003) developed an analytical solution to the case of a stream incised into a low permeability layer or formation over top of a more permeable aquifer (Figure 8).[26]

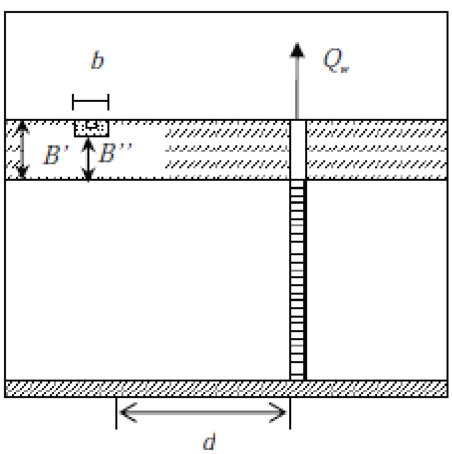

Figure 8 Definition Sketch for flow to well in semipermeable aquifer Hunt (2003)

Each of the four analytical mathematical solutions to the question of the impact of extraction well pumping on flow in a stream and the genesis of the water captured by an extraction well remain valid, particularly where the bounding assumptions are met well by the aquifer being pumped. Various mathematical solvers are available to look at streamflow depletion by the appropriate analytical method for each case including some provide by Dr. Bruce Hunt[27]; the most recent set of solvers for each of these groundwater to surface-water analytical methods was developed by the USGS (2008).[28] The USGS program STRMDEPL08 enables a sequence of time varying pumping during an irrigation season and it allows for year on year carryover of aquifer depletion to be retained in a subsequent year. This program represents "best available science" for near field assessment of groundwater extraction on the flow in nearby streams. Based upon the information provided in the EIS/EIR with regard to stream aquifer relationships our review determined that the conceptual model of Figure 7, Hunt (1999) best fits the conditions described for the Sacramento Valley. An evaluation of streamflow depletions for select wells near rivers was undertaken for the extended drought period of 1987 to 1992

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[25] Hunt, B., 1999.. Unsteady stream depletion from ground water pumping. *Ground Water, 37*(1), pp. 98–102.

[26] Hunt, B. 2003. Unsteady Stream Depletion when Pumping from Semiconfined Aquifer. *Journal of Hydrologic Engineering, Vol. 8*, No. 1, pp. 12-19.

[27] http://www.civil.canterbury.ac.nz/staff/bhunt.asp

[28] Reeves, H.W., 2008,STRMDEPL08—An extended version of STRMDEPL with additional analytical solutions to calculate streamflow depletion by nearby pumping wells: U.S. Geological Survey Open-File Report 2008–1166, 22 p.

noted in the EIS/EIR was undertaken and the method and results are presented in Attachment A. These analyses result in a range of streamflow depletion factors (SDF) from in short-term SDF ranging from 8% to 22% by the end of a 1987 extraction scenario proffered in the EIS/EIR and long-term cumulative SDF 39
ranging from 34% to 108.5% of annual pumping based on evaluation of the 6-year drought from 1987 to 1992 again following the extraction scenario proffered in the EIS/EIR due to the cumulative depletion of aquifer storage and the available accretionary flow of groundwater to the river as compared to stream flow from the river to satisfy the capture of water by a groundwater extraction well.

Assessment of SACFEM2013 Model for Water Supply Analysis in the Post Processing Tool

The SACFEM2013 model in the EIR/EIS does not account for the streamflow depletions induced by groundwater pumping along the lines of any of the analytical methods identified above from the literature. SACFEM2013 has no river flow accounting to account water flow depletions. As for potential impacts to surface water flow rates due to groundwater accretions or depletions SACFEM2013 does not account the quantity of water flowing within a river. There simply is no algorithm in the MicroFEM code to account for changing rates of streamflow and dynamically changing river stage associated with streamflow. Hence these potential impacts are not accounted in the SACFEM2103 model.[29] As a result of this missing algorithm in the model the outflow of surface water to groundwater in a river reach where 40
Groundwater Substitution Measures lower the modeled head in the upper aquifer (ignoring the numerous errors in the formulation of well extractions and in the SACFEM2013 model hydraulic parameters)[30] below the river bottom water is not properly accounted in SACFEM2013. The loss of surface water flowing into the groundwater domain to satisfy the extraction well demand via streamflow depletion is not accounted. Thus the available Water Supply will not be properly accounted using SACFEM2013 with respect to both the magnitude of the impacts to Water Supply due to Groundwater Substitution pumping and the timing of such impacts to Water Supply and surface water flow in the rivers. This holds for extraction from any of the 327 groundwater extraction wells proposed as a part of Alternatives 2 and 3. This lack of water accounting affects the ability of the "post-processing tool" to properly evaluate water availability under Water Supply due to the shortcomings of the SACFEM2013 model to calculate changes in river flow.

Further as to the poor accounting of water available to the "post-processing tool," the river outflow is not accounted properly in the SACFEM2013 groundwater model at the river nodes. As mentioned under Groundwater Resources SACFEM2013 sets each river reach's stage height as invariant during a month, 41
irrespective of the groundwater withdrawals. This river stage invariance means that SACFEM2013 calculates as though there is an infinite amount of water in the nearby river (i.e. no streamflow depletion impact on the predicted outflow of water).

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[29] SACFEM2013's agricultural groundwater extraction terms were reportedly developed using the Irrigation Demand Calculator (IDC) within the California Dept. of Water Resources, Integrated Water Flow Model (simulation code). The use of only a portion of the IWFM, simulation code and the manner in which it was done leaves the soil moisture model and the groundwater model uncoupled with no feedback between the two models except that perhaps carried by the user from SACFEM back to the IDC model .

[30] SACFEM 2013 formulation places all extraction wells into Layers 2, 3, and 4 and then artificially imposes a vertical anisotropy of 500:1 at each flow layer.

The river inflow (i.e. gaining reaches) is calculated in SACFEM2013. However it is done inaccurately due to the invariant stage height during each monthly time step in the model. This imprecision results in an improper accounting of water. Not surprisingly the peer review for the model done in 2011 found:

> *"Review of the representative and other calibration hydrographs reveals that significant calibration issues exists in areas that rely mostly on surface water. This is mainly due to the issues of SacFEM's estimation of stream-aquifer interaction. Calibration quality improves in areas that rely mostly on groundwater."*[31] 42

Using this mathematical formulation in the algorithm for groundwater to surface water flux, the degree of exfiltration in each month from the river to groundwater is too high if flow and stage in the river decrease due to Groundwater Substitution Measures or alternatively the degree of exfiltration is too low if Water Transfer flows increase river stage during the transfer period of July to September as more of that water would be depleted from the stream and not available to the Buyer's Area. Thus inputs from SACFEM2013 to TOM for subsequent analysis of Water Supply, are inaccurate.

Review of SACFEM2013 by the aforementioned peer review found that SacFEM2013 deep percolation rates are not supported by the fundamental Irrigation Demand Calculation (IDC) module's methodology (a subcomponent of DWR's Integrated Water Flow Model, IWFM simulation code) and parameters. This results in a disconnection between SacFEM2013 and IDC. They recommended incorporating a feedback loop between the two models (IDC as constructed for SACFEM2013 input, and SACFEM2013) and subjecting them to convergence criteria. Their review states: 43

> *"SACFEM deep percolation rates are not consistent with other data sets and it should be ensured that they are supported by historical land use, crop mix, and agricultural practices."*

It is unknown whether these recommendations from 2011 to SACFEM2013 were incorporated to SACFEM2013 based on the documentation provided in the EIS/EIR and on the documents requested and received from the project proponents. Further review of SACFEM2013 is provided in Attachment C herein.

Lastly with regard to SACFEM2013 and Water Supply considerations we note that unlike Appendix B of the EIS/EIR on the uncertainties and limitations of TOM and CalSim II, there are no statements in Appendix D of the EIS/EIR or the main body of the EIS/EIR as to the uncertainties in the modeling assumptions or stated limitations on the utility and intended uses of the SACFEM2013 groundwater model.

Looking at "Best Available Science" for evaluation of potential impacts in the EIS/EIR there is a simulation code available from DWR, IWFM, which can better evaluate the time varying mass balance between surface water and groundwater inclusive of losses or gains in soil moisture to crop demand and precipitation. The IWFM simulation code's capabilities are summarized in Attachment B herein and documented for the current release by DWR.[32] However, the simulation code with these general capabilities was first publicly released in 2003. Further there is an existing model of the Central Valley in IWFM, C2VSim, which is calibrated for the period 1922 to 2009, which was initially released to the public in 2011. The C2VSim model can be run with either a coarse finite element grid (C2VSim-CG with 1,392 44

[31] WRIME. 2011. Peer review of Sacramento valley Finite Element Groundwater Model (SACFEM2013), October at page 16

[32] http://baydeltaoffice.water.ca.gov/modeling/hydrology/IWFM/IWFMv4_0/v4_0_331/downloadables/IWFMv4.0.331_TheoreticalDocumentation.pdf.

elements, run-time 6 minutes) or with a fine finite element grid (C2VSim-FG with over 35,000 elements, run-time 6 hours). For both versions, the elements are grouped into 21 water-budget sub-regions. [33] The C2VSim-CG model was utilized in our review to assess the cumulative impacts.[34] DWR notes that both C2VSim versions will also be useful tools for integrated regional water management plans, planning studies, groundwater storage investigations, assessing infrastructure improvements, evaluating ecosystem enhancement scenarios, conducting climate change studies, and assessing the impacts of changes to water operations. The results of our assessment of relative streamflow depletions in several river reaches brought about by projected use of available transfer volumes in the extended drought of suggest that streamflow depletions of 8% to 22% depending upon the year and the river reach will result from a mass balanced model. In our review the use of C2VSim-CG provides a reasonable estimate of what best available science would reveal. Use of C2VSim-FG would likely improve upon the accuracy of the estimated streamflow depletions resulting from Groundwater Substitution Measures on Water Supply. 44

Assessment of the CalSim II Model for Water Supply Analysis in the Post Processing Tool

As stated previously for the No Action Alternative, the use of CalSim II has yielded significant scrutiny on its ability to provide relevant data to assess potential future impacts (Close, A. et al, 2003).[35] The CalSim II model presented in the EIS was used for the baseline conditions (2014 planning horizon) and was not used to assess potential changes resulting in future land use and hydrologic/metrological conditions. The baseline assessment can only assess how the Long-Term Transfer Project would impact the environment if it was in-place from 1970-2003 and therefore cannot assess potential impacts of future conditions that are different than the baseline conditions such as various climate change scenarios. 45

CalSim II does not provide adequate loss factors to assess potential project impacts. The CalSim II model describes the physical system (e.g., reservoirs, channels, pumping plants), basic operational rules (e.g., flood-control diagrams, channel capacity, evaporation, minimum flows, salinity requirements), and priorities for allocating water to different uses (water quality, ecosystems, etc.). As a result of CalSim II's complexity, very important water loss characteristics such as stream reaches losses, deep groundwater percolation, and stream-aquifer interactions are generalized as basin "efficiencies" rather than losses for specific reaches or stream-aquifer interactions. The lack of specific loss characteristics within CalSim II yields inaccuracies specific to even seasonal and annual water accounting losses (e.g., stream-aquifer interactions) that have been identified as potential impacts from the proposed Long Term Water Transfers. 46

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[33] As reported by the DWR at http://baydeltaoffice.water.ca.gov/modeling/hydrology/C2VSim/index_C2VSIM.cfm on November 30, 2014

[34] Informal telephonic requests to DWR's Bay Delta Office for C2VSim-FG on November 13, 2014 revealed that they view the model as not ready yet for public release.

[35] Close, A., Haneman, W.M., Labadie, J.W., Loucks D.P. (Chair), Lund, J.R., McKinney, D.C., and Stedinger, J.R. (Close, A. et al.). Strategic Review of CALSIM II and its Use for Water Planning, Management, and Operations in Central California. Submitted to the California Bay Delta Authority Science Program Association of Bay Governments. Oakland, California. December 4, 2003.

Hydrology modeling within CalSim II uses a "depletion analysis" to estimate the historical and projected level flows (Ford 2006).[36] As a result of this, CalSim II requires a calculation to estimate the aggregate stream inflow for each sub-watershed. This calculation is identified as the "closure term" of the hydrologic mass balance and is also how the model encompasses errors resulting from over/under estimates of water losses. In recent documentation regarding future development of CalSim II into version III, DWR and Reclamation provided a graphic of "closure term" magnitudes. [37]

In this graphic from Draper 2008 (Figure 9), the "closure term" represents a significant amount of error in CalSim that has to be accounted for to create a hydrologic mass balance. Note that this graph is in thousands of acre-feet/year. Thus the "closure term" necessary to correct for water budget errors in CalSim ranges from (2,000,000) AFY in deficit to 3,000,000 AFY in surplus. CalSim II does not account for water on an annual basis with precision. 47

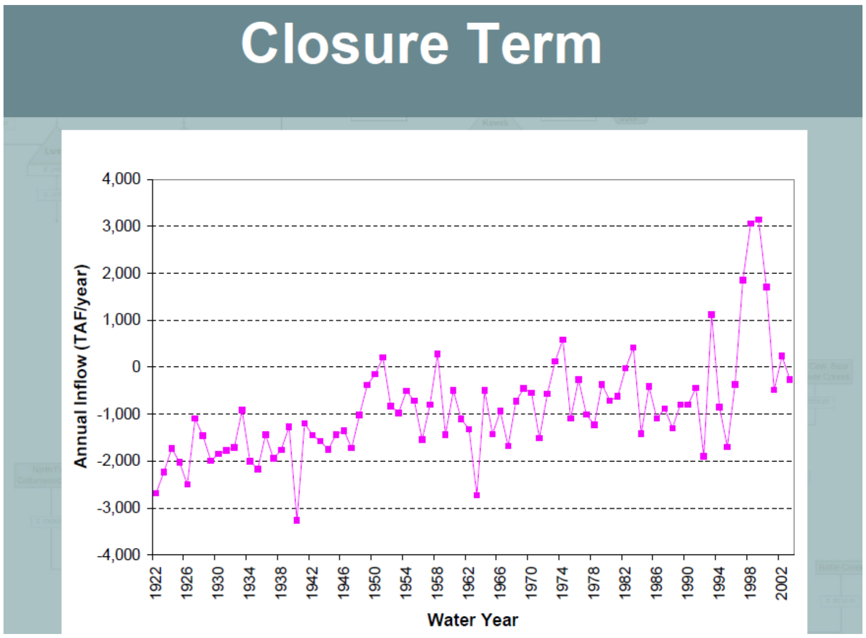

Figure 9 Closure Terms to Correct Accounting Problems in CalSim for Annual Quantities of Water

CalSim II cannot assess how "Long-Term" water transfers would impact future water demands, water supplies, and required water quality and ecosystem management requirements. Hence the analysis of potential impacts to Water Supply based upon CalSim II is insufficient. CalSim II does not provide adequate detail to assess project impacts. The very poor precision of the surface water delivery model (CalSim II) used for the baseline assessment on quantities of water moving in and around the CVP and SWP leads to problems in accounting for water losses due to existing and proposed groundwater extractions.

As noted in the review of CalSim II in Draper (2008) there is a version of CalSim referred to alternately as CalSim III or CalSim 3 that appears to have been in development and use since approximately 2006. 48

[36] Ford, D., Grober, L., Harmon, T., Lund, J.(Chair), McKinney, D. (Ford et al., 2006). Review Panel Report San Joaquin River Valley CalSim II Model Review. CALFED Science Program – California Water and Environment Modeling Forum. January 12, 2006.

[37] Draper, A. CalSim-III Hydrology Development Project, CalSim III Implementation, MWH Americas, California Water and Environmental Modeling Forum Annual Meeting, 2008

> *"The C2VSim-CG model is being used as the basis for the groundwater flow component of CalSim 3, and has also been used to investigate how Sacramento Valley water transfers may affect Delta flows and how an extended drought may impact groundwater levels."*[38]

It would appear that CalSim III represents "Best Available Science" with its focus on improving the significant shortcomings in CalSim II identified in our review and that of others. However, CalSim III was 48
not utilized for the EIS/EIR. An analysis of the outcomes for the project by way of CalSim III use would appear to represent something approaching best available science on the available windows of water for transfer prior to 2003 and post 2003 to present and beyond. The availability and uses of CalSim III by USBOR for the CVP could not be determined during our review.

Assessment of the Transfer Operations Model for Water Supply Analysis in the Post Processing Tool

TOM was developed to analyze effects of the Long-Term Water Transfer Project on the CVP, SWP, major rivers, and the Delta. TOM does not provide a specialized groundwater, hydrology, or hydraulic 49
simulations of the Long-Term Water Transfer Project but rather provides water accounting based upon inputs from SACFEM2013 and CalSim II. As a result of the water accounting approach, the inaccuracies within CalSim II (e.g., water losses, closure term error, etc.) and SACFEM2013 (e.g., stream-aquifer interactions, groundwater elevation predictions, etc.) are carried over into TOM to quantify and assess potential impacts resulting from the Long-Term Water Transfer Project.

Our review of the TOM model provided by the project proponents at our request yielded a number of errors that were also included in the EIS text. Table 1 presents two examples water transfer volumes that were presented in the EIS/EIR Executive Summary Table 2, EIS/EIR descriptive text of each text from section 3.1.1.3, and TOM.

Table 1 – Comparison of Transfer Volumes Within Long-Term Water Transfer Project Documentation				
Transfer Description	Table ES-2 (AF)	EIS Section 3.1.1.3 (AF)	TOM (AF)	
Anderson-Cottonwood Irrigation District (Maximum Groundwater Substitution Volume)	5,225	5,225	5,938	50
Garden Highway Mutual Water Company (Maximum Groundwater Substitution Volume)	14,000	12,287	14,000	
Conaway Preservation Group (Maximum Cropland Idling or Crop Shifting Volume)	9,239	9,239	21,349	

Upon review of Table 1, how specific transfer volumes of water are applied in TOM, CalSim II, and SACFEM2013 is neither understood nor constant. Additionally, specific model descriptions of how CalSim II, SACFEM2013 and TOM account for each water transfers are vague. The EIS states that there is a priority of transfer volumes *("…groundwater substitution and reservoir release are more likely transfer mechanisms than crop idling…",* Section B.4.3.1.2) but specifically how each transfer was applied to the

[38] As reported by the DWR at http://baydeltaoffice.water.ca.gov/modeling/hydrology/C2VSim/index_C2VSIM.cfm on November 30, 2014

time series and into each model are not documented. To understand how each transfer volume is applied in each model is essential to properly assess the validity of the analysis of potential impacts. 50

Within TOM, adjustments in delivered water through the Delta include a portion lost as carriage water which is defined as extra water needed to carry water across the Delta to export facilities. Carriage water is a critical part of the water modeling analyses because the additional water is needed to maintain Delta water quality. Because the majority of the transfer water is made available and diverted upstream of the Delta, TOM assumes carriage percentage adjustments based on the location of the transfer:

- Transfers from the Sacramento River assume a 20 percent carriage water adjustment; 51
- Transfers to Contra Costa Water District assume a 20 percent carriage water adjustment;
- Transfers from Merced Irrigation District assume a 10 percent carriage water adjustment for water flowing from the San Joaquin River into the Delta.

The use of a single carriage percentage based on location does not adequately address potential impacts to Delta water quality. The concept of carriage water is a complex concept that would require appropriate hydrodynamic models coupled with a hydrology and groundwater model to identify appropriate carriage water volumes over time. The EIS states that the initial estimates for carriage water should later be verified and adjusted and therefore water quality impacts cannot be assessed with the models presented in the EIS/EIR for Long-Term Water Transfers. Additionally, significant stream flow depletion associated with pumping will likely reduce water transfers to the Delta and result in significant water quality impacts and/or limited transfers to water buyers. Therefore, statements with the EIS/EIR claiming limited changes in Delta outflow as well as water quality impacts are unfounded.

Carryover of storage water within reservoirs is one of many factors within the EIS/EIR, TOM and CalSim II that lacks a description of application. In other words there is no detail provided on where each of the water volumes in TOM are derived (e.g. groundwater vs. stored water). As a result of streamflow depletion from Groundwater Substitution Measures, the EIS/EIR identifies that small decreases in water supplies to users could occur when the stored reservoir release transfers decrease carryover storage in 52
reservoirs. These operational controls are very important to how storage facilities would operate during extended dry periods. These operational assumptions within the modeling are not described in the EIS/EIR text or models. Therefore, carryover along with other operational assumptions associated with the Long-Term Water Project is not properly assessed and the resulting operational Water Supply impacts could be significant; these potential and probable impacts to Water Supply are not analyzed in the EIS/EIR for Groundwater Substitution Measures.

Summary of Impact Assessment

Impacts to Water Supply from the Water Operations Assessment are not fully quantified. The improper accounting of water under Groundwater Substitution Measures results in insufficient control on water accounting such that water lost from river flow due to both the impairment of accretionary groundwater flow to support Project operations and the direct losses from river flow to groundwater extraction wells 53
in the Groundwater Substitution program may be counted twice or more. Evaluation of the effects on Water Supply from the Groundwater Substitution Measures requires adequate and accurate analysis of what the sources of water in Water Supply and what appropriate streamflow depletions are for

Groundwater Substitution Measures on top of existing conditions to assess short-term and long-term effects on Water Supply from Long-Term Water Transfers. Further the use of Groundwater Substitution 53 Measures has important impacts to Water Supply in regard to operational flexibility. These have been rated to be Less Than Significant in the EIS/EIR but given the substantive errors noted in assessing available water for Long-Term Water Transfers this likely deserves re-examination.

Proposed Mitigation

Due to the improper accounting of water in Water Supply, the proposed mitigation WS-1 is inadequate to mitigate the likely impacts to water availability and water flows into and through the Delta during 54 three important periods of time: (1) the period of Groundwater Substitution pumping, April thru September; (2) the Water Transfers window, July thru September; and, (3) the period following the Water Transfers window, October to April.

The Proposed Mitigation WS-1 to address streamflow depletion resulting from Groundwater 55 Substitution Measures is ill defined and will not adequately mitigate the impacts to Water Supply.

Due to the lack of a specific formulation for the proposed Water Supply mitigation, WS-1, it is unpredictable how the mitigation will be applied. The EIS/EIR references Draft documents on Technical Information for Preparing Water Transfer Proposals (October 2013).[39] Those documents identify the need for estimating the effects of transfer operations on streamflow and describe the use of a streamflow depletion factor; however they provide no basis for Project Agency approval nor for transfer 56 proponents to submit site-specific technical analysis supporting a streamflow depletion factor. That document which is completely relied upon in establishing proposed mitigation, WS-1, states that:

> *"Project Agencies are developing tools to more accurately evaluate the impacts of groundwater substitution transfers on streamflow. These tools may be implemented in the near future and may include a site-specific analysis that could be applied to each transfer proposal."*[40]

This future action provides no established or predictable basis for the mitigation of streamflow depletions due to Groundwater Substitution Measures. Due to the improper accounting of water in both the groundwater and surface water supply models utilized for Water Supply analysis, reliance upon these models or the analysis in this EIS/EIR by the Project Agencies would result in inappropriate 57 estimation of the streamflow depletion factors utilized. Examples of best available science methodologies for quantifying streamflow depletion factors for Water Supply are provided in Attachment A . They result in short-term streamflow depletion factors ranging from in short-term SDF ranging from 8% to 22% of the Groundwater Substitution Measures proposed in the EIS/EIR and long-term cumulative SDF ranging from 34% to 108.5% of annual pumping based on evaluation of the 6-year drought from 1987 to 1992

The mitigation proposed for loss of Water Supply, WS-1, due to Groundwater Substitution transfers is insufficient. It does not adequately account for the impact from the resulting reductions of water 58 available in the rivers and groundwater due to the improper accounting of water in the EIS/EIR analyses.

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[39] Department of Water Resources and Bureau of Reclamation, 2013. DRAFT Technical Information for Preparing Water Transfer Proposals – Information to Parties Interested in Making Water Available for Water Transfers in 2014, October.
[40] Ibid, at p. 33.

As detailed in our analysis the mitigation measure proposed has no basis in fact, and if it did the project proponents would find that mitigation of the impacts from Groundwater Substitution Measures are not likely to meet the Project Purpose and Need and the Project Objectives. 58

Water Quality

Groundwater Substitution Measures for Long-Term Water Transfers effects on Delta outflows and water quality are not properly considered in the EIR/EIS. The EIS/EIR rates the effects on Delta outflows and the impact to Delta Water Quality as Less Than Significant based on improper accounting of water. The effects and impacts are likely to be Significant and thus will require mitigation. 59

Potential Impact Statements from Table ES-4	Related Alternative(s)	Significance to CEQA	Proposed Mitigation	Significance After Mitigation Pursuant to CEQA
Water transfers could change Delta outflows and could result in water quality impacts.	2, 3, 4	LTS	None	LTS

The analysis of Environmental Consequences/Environmental Impacts is not done accurately nor with a complete conceptual model of the interactive groundwater and surface water system depletions that would affect the Federal and State water projects, CVP and SWP, to meet Water Quality requirements. As noted previously the analysis of components for Water Supply is improperly conceptualized and yet finds that streamflow depletion of significance can occur and must be mitigated by application of an appropriately calculated SDF. 60

Again from page 3.1.6 in Section 3.1.2.4.1 the EIS/EIR states:

> *"Transfers would not affect whether the water flow and quality standards are met…" but only Reclamation and DWR water supplies"*

The EIS/EIR anticipates hypothetically that if the streamflow depletion resulting from Groundwater Substitution Measures results in decreased river flows then USBOR and DWR would modify operations by decreasing Delta exports or release of additional water from reservoirs to meet Delta outflow and/or water quality standards; however as documented in Attachment D herein the Federal and State projects were unable to maintain these standards in 2013 due to dry year conditions and a lack of available in-stream flow and releases of water.

Under Assessment Methods at page 3.2-27 in Section 3.2.2.1.1 states that quantitative analysis relies on hydrologic modeling estimated changes in river flow rates and reservoir storage for the CVP and SWP reservoirs and the rivers they influence. The quantitative analysis is left to Appendix B but the main body states that: 61

> *"If the changes are small and within the normal range of fluctuations (similar to the No Action/No Project Alternative) for that time period, it is … assumed that any water quality impacts would be less than significant"*

According to the EIS/EIR:

> *"CalSim II is the latest version of CalSim available for general use. It represents the Central Valley with a node and link structure to simulate natural and managed flows in rivers and canals. It generates monthly flows showing the effect of land use, potential climate change, and water operations on flows throughout the Central Valley."* [41]

With Closure Terms to rectify storage and flow on the order of millions of acre-feet per year (as much as 3,000,000 AFY during the model periods simulated for the EIS/EIR), CalSim II is not an adequate tool for 61
assessing whether flow and required storage changes under the proposed Groundwater Substitution Measures are small, normal or significant to enable the assumption of insignificant water quality impacts. Further CalSim II works on a coarse monthly time-step to assess SWP and CVP operations. However, water quality and ecosystem management decisions require a more detailed weekly or daily time-steps to properly account for potential water availability and timing impacts. CalSim II is not the appropriate modeling system to assess the Long-Term Transfer Project which will cause daily flow changes that require water quality and ecosystem management decisions to mitigate impacts before they occur and does not represent best available science (see earlier comment on CalSim III under Water Supply).

Contracted Reservoir Releases by the Sellers may be diminished by streamflow depletions from current pumping conditions in areas where groundwater saturation falls below the river stage adjoining under existing conditions. These depletions of water available for transfer via Reservoir Releases and are not 62
quantified in the EIS/EIR. The effect of these baseline conditions impacts the availability of water to be transferred down the Sacramento River and through the Sacramento San-Joaquin Rivers Delta to the CVP and SWP pumping stations that pump water south via their respective aqueducts, the Delta-Mendota Canal, and the California Aqueduct.

The quantitative analysis of potential Water Quality impacts to the Sacramento-San Joaquin Delta is provided in Appendix C. Appendix C states at page C-2 that:

> *"The Delta Conditions analysis is performed with the Delta Simulation Model 2 (DSM2). DSM2 setup relies on the output of three additional tools for this Project: CalSim II, the Transfer Operations Model (TOM), and the Delta Island Consumptive Use model (DICU model). CalSim II outputs simulating California's water delivery system to the Delta are used* 63
> *to supply inflow and export boundary conditions to DSM2."*

Use of a CalSim II model with monthly outputs that are crude approximations of actual system performance at best renders use of these outputs to create daily approximations that are supplied to DSM2 useless in assessing the potential for water quality impacts from proposed Groundwater Substitution Measures that will impair the actual timing of surface-water baseflow as a result of streamflow depletion and the quantity of water available to meet Delta Water Quality requirements.

Proposed Mitigation

Our review finds that the Less Than Significant assessment in the EIS/EIR lacks sufficiently accurate analysis as to available flows and storage of water in the Sacramento River watershed by virtue of the 64
precision of the models used in the quantitative assessment. Mitigation is likely required to assure

[41] EIS/EIR Public Draft Under Review at page C-5

sufficient baseflow and stored water availability for CVP and SWP operating requirements for Water Quality. 64

Terrestrial Resources

Potential Impact Statements from Table ES-4	Related Alternative(s)	Significance to CEQA	Proposed Mitigation	Significance After Mitigation Pursuant to CEQA
Groundwater substitution could reduce stream flows supporting natural communities in small streams	2, 3	S	GW-1	LTS

Assessment methods in the EIS/EIR for riparian, wetland, and natural in-stream community (e.g. fauna in the hyporheic zone such as Caddis fly larvae) impacts include SACFEM2013. Reportedly SACFEM2013 predicted changes in groundwater elevations over time were used to assess the potential impacts of groundwater depletion on stream flows in small tributaries and associated natural communities. However, it should be noted that in wetland and riparian habitats, groundwater typically ranges from eight feet to just below the ground surface Faunt (2009).[42] As noted previously under the discussion of Groundwater Resources evaluations, SACFEM2013 contains an unusual model construction feature using model "Drains" with respect to riparian habitats consumptive use of water, its evapotranspiration of water, and groundwater discharge to land surface outside of a recognized and model surface water course. Drains were set at land surface rather than at root zone depth. Thus SACFEM2013 is highly imprecise in its ability to discern where and how much a riparian or riverine habitat is utilizing groundwater or residual soil moisture (see earlier commentary on the decoupling of the soil moisture model from the SACFEM2013 groundwater model) 65

The EIS/EIR notes that:

> *"…groundwater modeling results indicate that shallow groundwater is typically deeper than 15 feet in most locations under existing conditions, and often substantially deeper…"*[43]

Modeling is not the best available science for this analysis when empirical data are available to assess actual or anticipatable depth to a phreatic surface or the capillary fringe of water rising above the phreatic surface in native sediments and soils. For example groundwater elevations of Spring 2013 depicted on Figure 3.3-4 along the Sacramento River main stem from Red Bluff, California to roughly Princeton, California are above the streambed elevations. This indicates that the Sacramento River is gaining flow from accretionary flows of groundwater in this lengthy reach, and the phreatic surface of groundwater would be expected to be eight feet or less below ground surface along the riparian corridor of the river with possible wetlands. Similarly groundwater elevations depicted on Figure 3.3-4

[42] Faunt, C.C., ed., 2009, Groundwater Availability of the Central Valley Aquifer, California: U.S. Geological Survey Professional Paper 1766, 225 p

[43] EIS/EIR Public Draft at page 3.8-32

along the Feather River from Oroville to Live Oak are above the streambed elevations. Conditions for the riparian corridor and potential wetlands may exist based on these data. The areas where groundwater elevations are below the elevation of the bottom of river courses was noted in the discussion of Groundwater Resources; yet an analysis of near river and stream course depths to groundwater or the capillary fringe can be reasonably estimated from the data. Data are better than models for current or historic conditions analysis. 65

Terrestrial Resource impacts are not properly accounted in the EIS/EIR due in part to the imprecision and inability of the models to assess dehydration of the soils and groundwater aquifer adjoining streams and large rivers.

Proposed Mitigation

Proposed Mitigation GW-1 is not quantified or quantifiable as to what groundwater pressure decreases will constitute an impact to natural communities in and near small streams in the Seller Service Area.

The groundwater elevation changes within a conceptual monitoring plan that would be necessary to mitigate stream flows supporting natural communities in small streams under proposed mitigation, GW-1, must be quantifiable or else the proposed mitigation is insufficient to reduce the impacts from Groundwater Substitution Measures. The proposed mitigation, GW-1, is not sufficiently quantified in the EIS/EIR nor in the Groundwater Management Plans (GWMPs) referenced. Existing GWMPs do not contain quantified year on year metrics for subbasin depletion and refill within acceptable ranges to sustain primary functions like support for natural communities. 66

Potential Impact Statements from Table ES-4	Related Alternative(s)	Significance to CEQA	Proposed Mitigation	Significance After Mitigation Pursuant to CEQA
Transfer actions could alter flows in large rivers, altering habitat availability and suitability associated with these rivers	2, 3, 4	LTS	None	LTS

Much of the discussion of small streams is applicable to large rivers. Additional considerations are noted in the following discussion that demonstrate a finding of Less Than Significant is apparently due to a faulty analysis of the type of impacts, and their foreseeable magnitude and likelihood of creating Significant impact to habitat supported by large rivers.

Water transfers would affect flows in the rivers and creeks adjacent to and downstream of the areas where transfer activities (of all kinds) would occur. Changes in stream flows that would result within the Seller Service Area may affect natural communities, such as riverine, riparian, seasonal wetland, and managed wetland natural communities, which are reliant on CVP and SWP operational outcomes with Water Transfers such as surface-water flow velocity, surface-water quality (in particular water temperature both released and exchanged with groundwater), and the accretion or depletion of 67 groundwater near surface. These operational outcomes and effects could propagate downstream of the areas/locations where pumping occurs. 67

The extraction scenarios proffered in the EIS/EIR will cumulatively over time and space reduce the available accretionary flow of groundwater to the large rivers in addition to the loss of water directly from the adjoining large river, where proximate to a well or wells, to satisfy the capture of water by groundwater extraction wells used for Long-Term Water Transfers as Groundwater Substitution Measures. 68

Releases of storage water within reservoirs is one of many factors within TOM and CalSim II that lack a sufficient description for the analyses required here for natural habitat flow requirements. An adequate form of model would incorporate anticipated timing of natural flow impacts and controlled releases for Water Transfers. Again the best available science would include implementation of the IWFM simulation code to an appropriately configured model. Due to the IWFM codes ability to account stream flows dynamically in the simulation code's algorithms the timing and magnitude of flows could be quantified. From this foundational quantification additional models on river flow velocities, bed scour, temperatures and other attributes of Seasonally Varying Flow (SVF) that has been found to be essential to riverine habitat.[44] In other words there is no detail provided on where each of the water volumes in TOM are derived (e.g. groundwater vs. stored water). As a result of streamflow depletion from Groundwater Substitution Measures, the EIS identifies that small decreases in water supplies to users could occur when the stored reservoir release transfers decrease carryover storage in reservoirs. These operational controls are very important to how storage facilities would operate during extended dry periods. 69

Proposed Mitigation

A reanalysis of the potential impacts of Water Transfers is required using best available science to ascertain the magnitude of potential impacts, system operational constraints on those impacts, and the method and implementation of mitigation, if needed. 70

Fisheries

The findings of Less Than Significant for Fisheries is not supported by the analytical tools based upon the preceding analyses of Groundwater Resources and Water Supply and should be revisited as to availability of water to support riparian and hyporheic zones along the waterways for habitat support for species of special interest identified in Section 3.7.1.2 and as to timing and quantity impacts of river flows due to streamflow depletions evaluated under Water Supply. 71

[44] Risley, John, Wallick, J.R., Waite, Ian, and Stonewall, Adam, 2010, Development of an environmental flow framework for the McKenzie River basin, Oregon: U.S. Geological Survey Scientific Investigations Report 2010-5016, 94 p.

ATTACHMENT A

STREAMFLOW DEPLETION CALCULATIONS USING USGS STRMDEPL08 FOR SELECT GROUNDWATER SUBSTITUTION TRANSFER WELLS

Development of Streamflow Depletion Factors for Select Wells

The USGS released in 2008 a numerical code, STRMDEPL08, that solves the analytical solutions of Theis, 1941, Hantush 1954, Hunt 1999, and Hunt 2003 for groundwater interaction with nearby streams. One of the key advantages to STRMDEPL08 is the ability to use time varying flow rates and shorter time steps down to one half of a calendar month.

Six wells in close proximity to streams based upon the input arrays provided for SACFEM2013. The distance to the nearest stream or river was calculated in GIS to the polylines for surface water bodies provided in response to the Delta Water Agency for model input datasets. This was generally found to be a greater distance than represented by the nodal structure of surface water nodes in SACFEM2013 vs. the groundwater extraction well nodes. Hence this is a conservative estimate of configuration with regard to expected streamflow impact (the distance of an extraction well from a stream is a key determinant in the timing and magnitude of the streamflow depletion)

Streambed thickness was set at 1 meter per the model documentation. Stream widths were as provided. Additionally the streambed vertical conductivity was as specified in the SACFEM2013 model dataset. These values were found to range from 1 meter/day to 0.1 meter/day which does not correspond to the Appendix D documentation but was used anyway.

The pumping stress was applied for the extended drought period of 1987 to 1992 for each well. The pumping rate applied for each well was derived from the information provided by the Bureau of Reclamation for their TOM operational analysis model. The total water available for extraction and transfer by the six entities (Sellers) for which a well was evaluated was used. The rate for the well was estimated by dividing the total quantity transferable by the number of wells owned (e.g. Pelger Mutual Water Company). It was then further modified by applying an estimate of Evapotranspiration on the average climatic zone of Yuba City. Groundwater extraction was thereby curved from April to September, the period of water demand for crops in that climate.

The results for 6 wells are depicted on the following pages, first by fraction of annual pumping per month, and then by cumulative extraction by pumping year. The carryover of depletions produces cumulative losses of more than 100% in certain years based upon the annual variability in pumping rates.

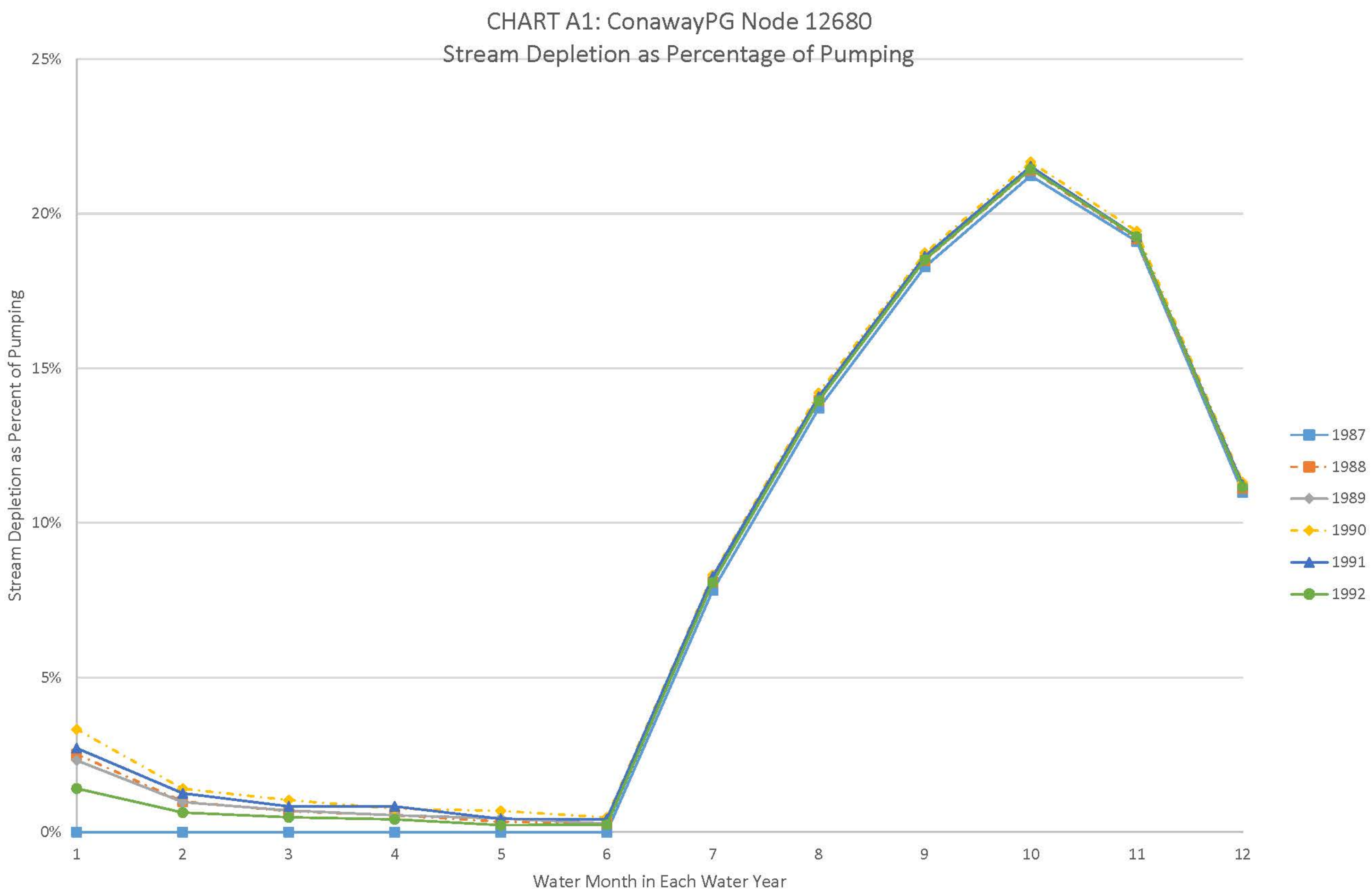


CHART A1: ConawayPG Node 12680
Stream Depletion as Percentage of Pumping
Stream Depletion as Percent of Pumping
25%
20%
15%
10%
5%
0%
1
2
3
4
5
6
7
8
9
10
11
12
Water Month in Each Water Year
1987
1988
1989
1990
1991
1992

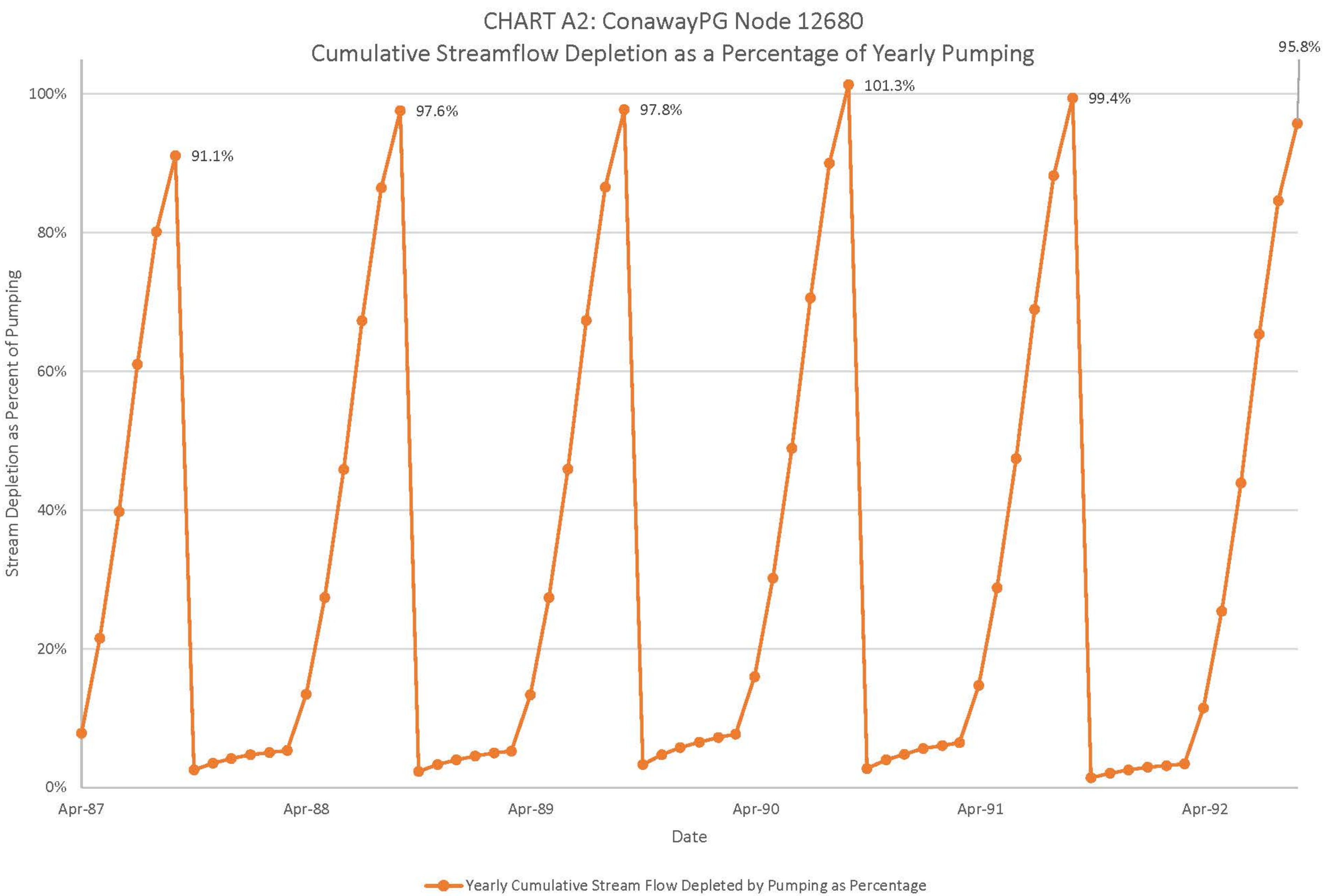


CHART A2: ConawayPG Node 12680
Cumulative Streamflow Depletion as a Percentage of Yearly Pumping
Stream Depletion as Percent of Pumping
100%
80%
60%
40%
20%
0%
91.1%
97.6%
97.8%
101.3%
99.4%
95.8%
Apr-87
Apr-88
Apr-89
Apr-90
Apr-91
Apr-92
Date
Yearly Cumulative Stream Flow Depleted by Pumping as Percentage

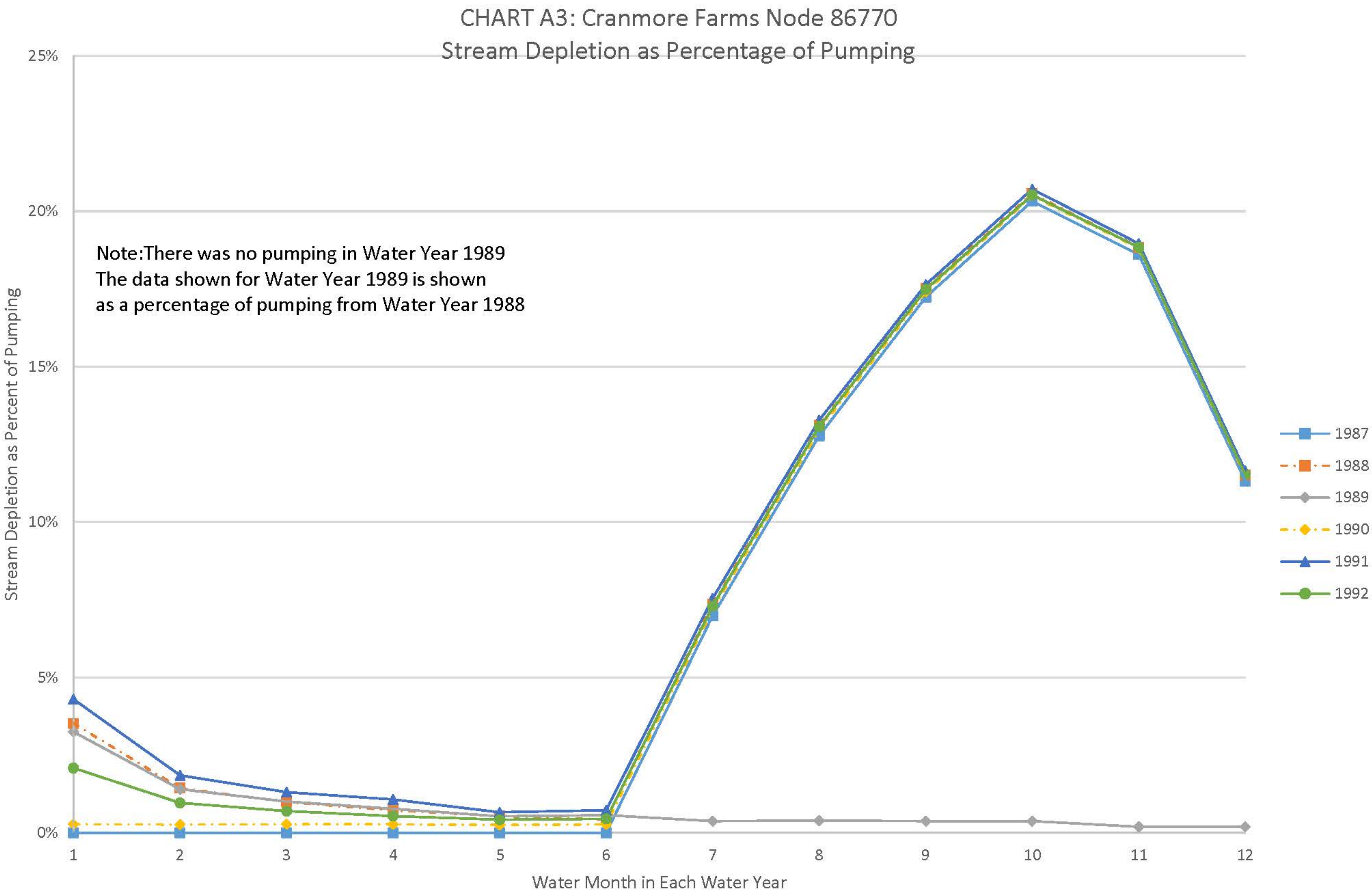


CHART A3: Cranmore Farms Node 86770
Stream Depletion as Percentage of Pumping
Note:There was no pumping in Water Year 1989
The data shown for Water Year 1989 is shown
as a percentage of pumping from Water Year 1988
Stream Depletion as Percent of Pumping
25%
20%
15%
10%
5%
0%
1
2
3
4
5
6
7
8
9
10
11
12
Water Month in Each Water Year
1987
1988
1989
1990
1991
1992

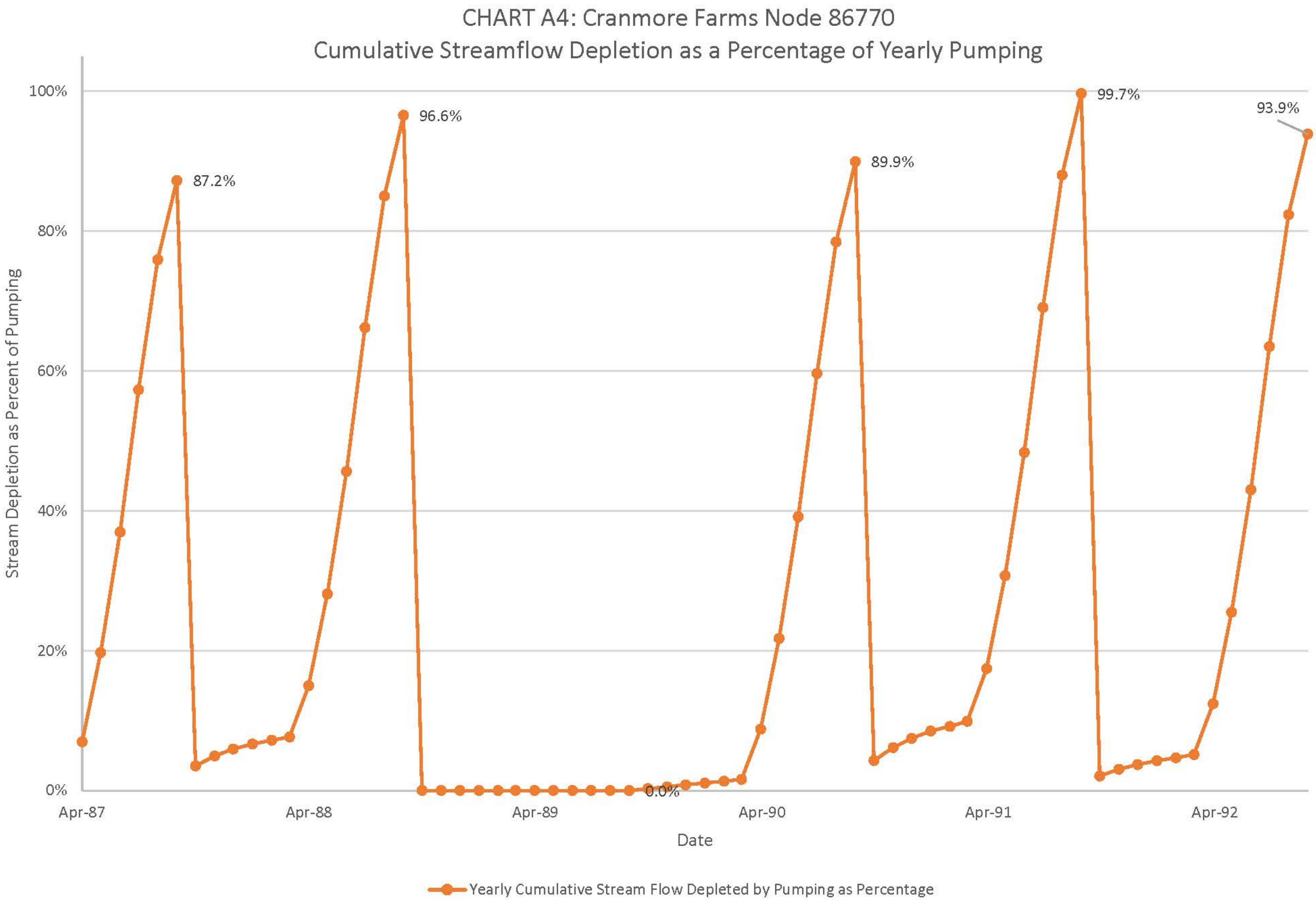


CHART A4: Cranmore Farms Node 86770
Cumulative Streamflow Depletion as a Percentage of Yearly Pumping
100%
80%
60%
40%
20%
0%
Stream Depletion as Percent of Pumping
87.2%
96.6%
0.0%
89.9%
99.7%
93.9%
Apr-87
Apr-88
Apr-89
Apr-90
Apr-91
Apr-92
Date
Yearly Cumulative Stream Flow Depleted by Pumping as Percentage

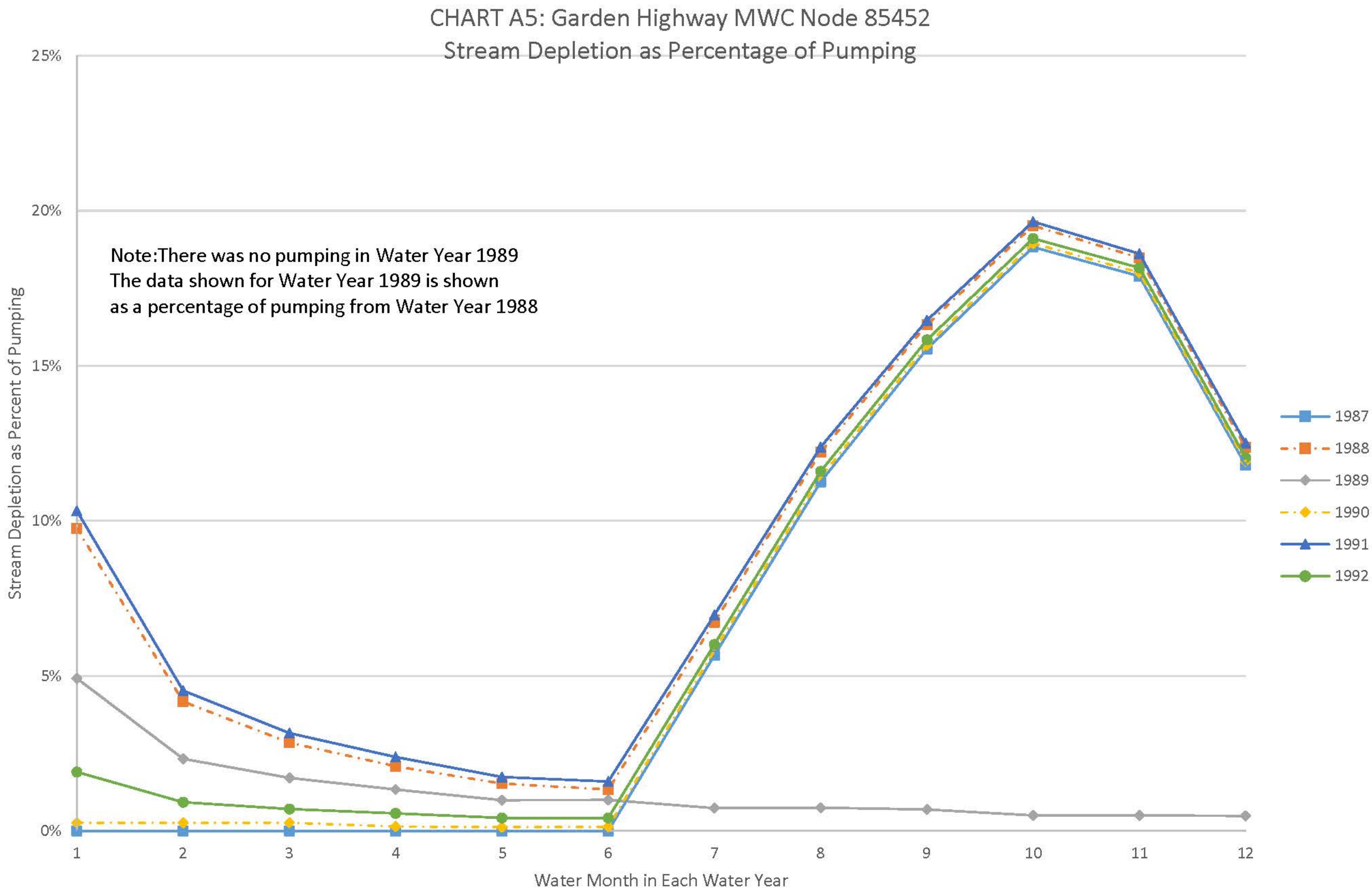


CHART A5: Garden Highway MWC Node 85452
Stream Depletion as Percentage of Pumping
Note:There was no pumping in Water Year 1989
The data shown for Water Year 1989 is shown
as a percentage of pumping from Water Year 1988
Stream Depletion as Percent of Pumping
25%
20%
15%
10%
5%
0%
1
2
3
4
5
6
7
8
9
10
11
12
Water Month in Each Water Year
1987
1988
1989
1990
1991
1992

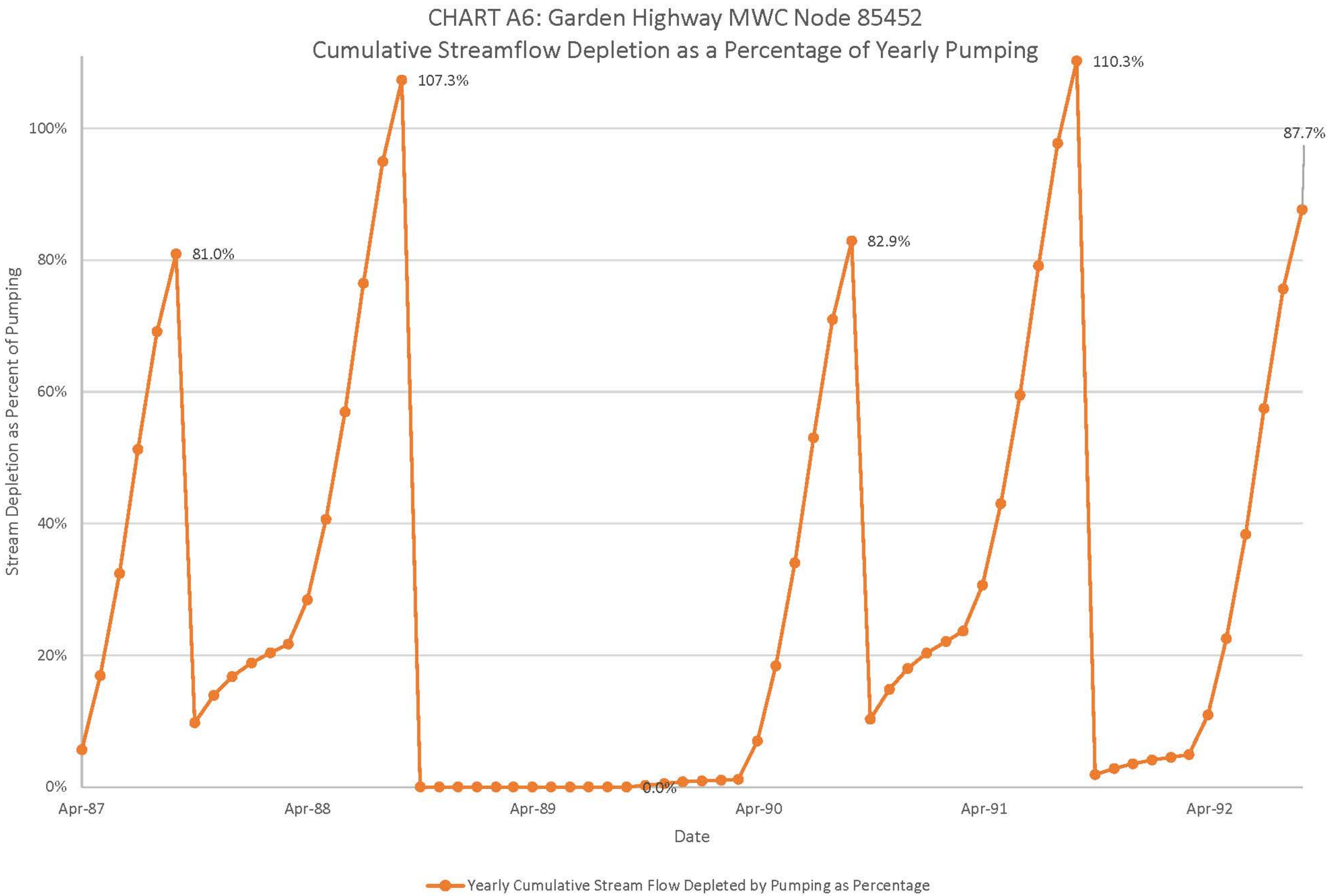


CHART A6: Garden Highway MWC Node 85452
Cumulative Streamflow Depletion as a Percentage of Yearly Pumping
Stream Depletion as Percent of Pumping
100%
80%
60%
40%
20%
0%
81.0%
107.3%
0.0%
82.9%
110.3%
87.7%
Apr-87
Apr-88
Apr-89
Apr-90
Apr-91
Apr-92
Date
Yearly Cumulative Stream Flow Depleted by Pumping as Percentage

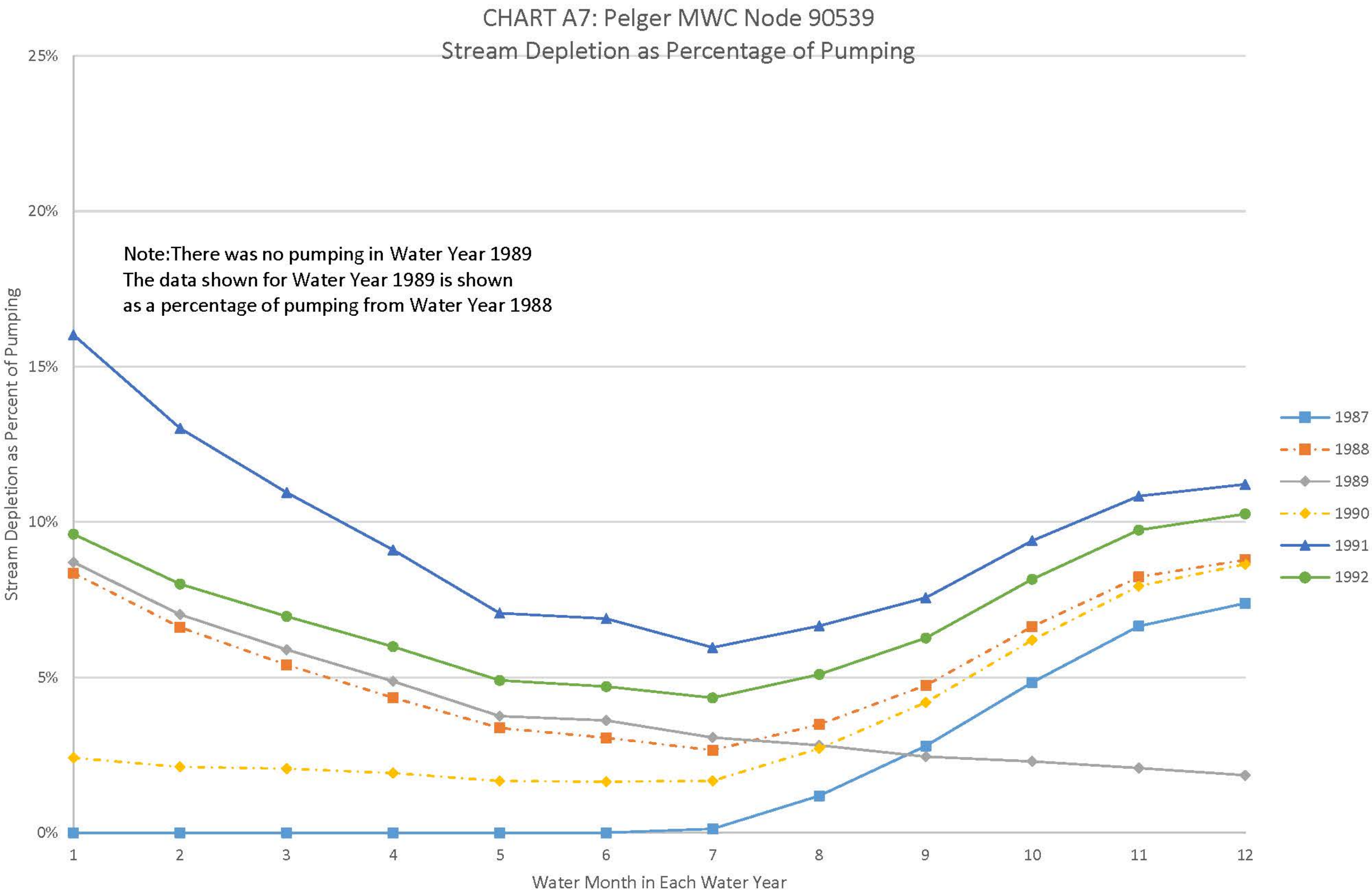


CHART A7: Pelger MWC Node 90539
Stream Depletion as Percentage of Pumping
Note:There was no pumping in Water Year 1989
The data shown for Water Year 1989 is shown
as a percentage of pumping from Water Year 1988
Stream Depletion as Percent of Pumping
25%
20%
15%
10%
5%
0%
1
2
3
4
5
6
7
8
9
10
11
12
Water Month in Each Water Year
1987
1988
1989
1990
1991
1992

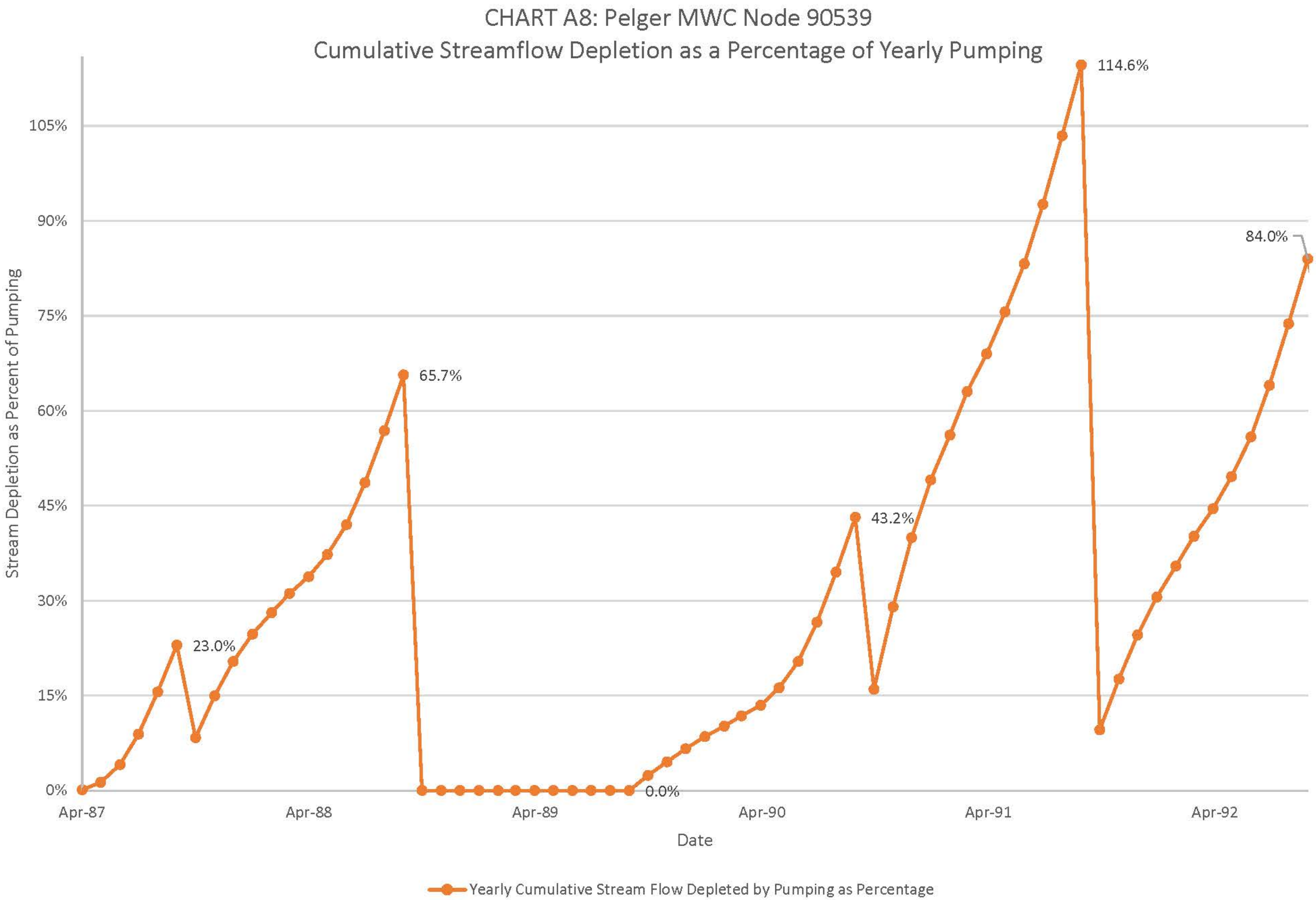


CHART A8: Pelger MWC Node 90539
Cumulative Streamflow Depletion as a Percentage of Yearly Pumping
Stream Depletion as Percent of Pumping
105%
90%
75%
60%
45%
30%
15%
0%
114.6%
84.0%
65.7%
43.2%
23.0%
0.0%
Apr-87
Apr-88
Apr-89
Apr-90
Apr-91
Apr-92
Date
Yearly Cumulative Stream Flow Depleted by Pumping as Percentage

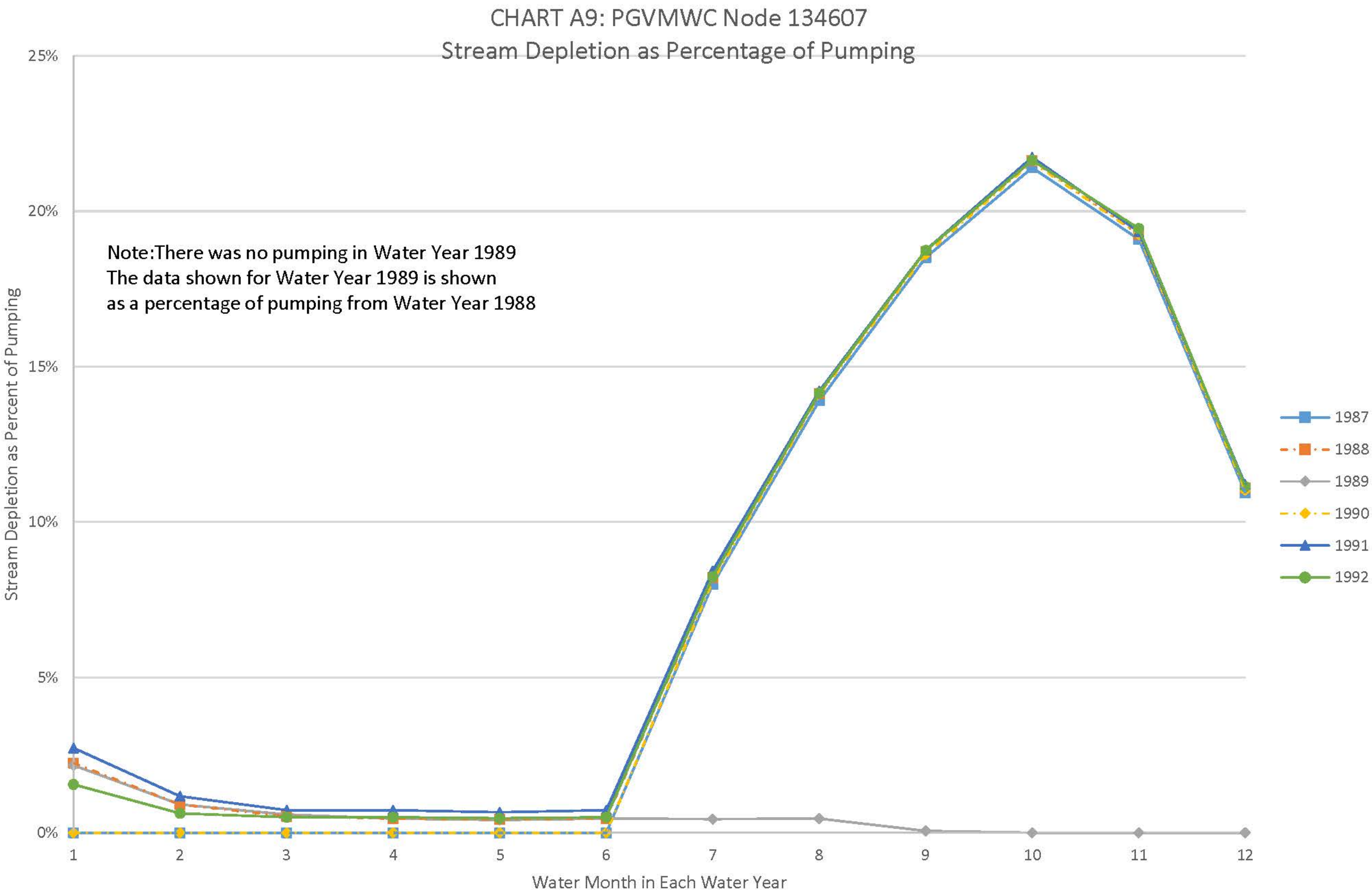


CHART A9: PGVMWC Node 134607
Stream Depletion as Percentage of Pumping
25%
20%
15%
10%
5%
0%
Stream Depletion as Percent of Pumping
Note:There was no pumping in Water Year 1989
The data shown for Water Year 1989 is shown
as a percentage of pumping from Water Year 1988
1
2
3
4
5
6
7
8
9
10
11
12
Water Month in Each Water Year
1987
1988
1989
1990
1991
1992

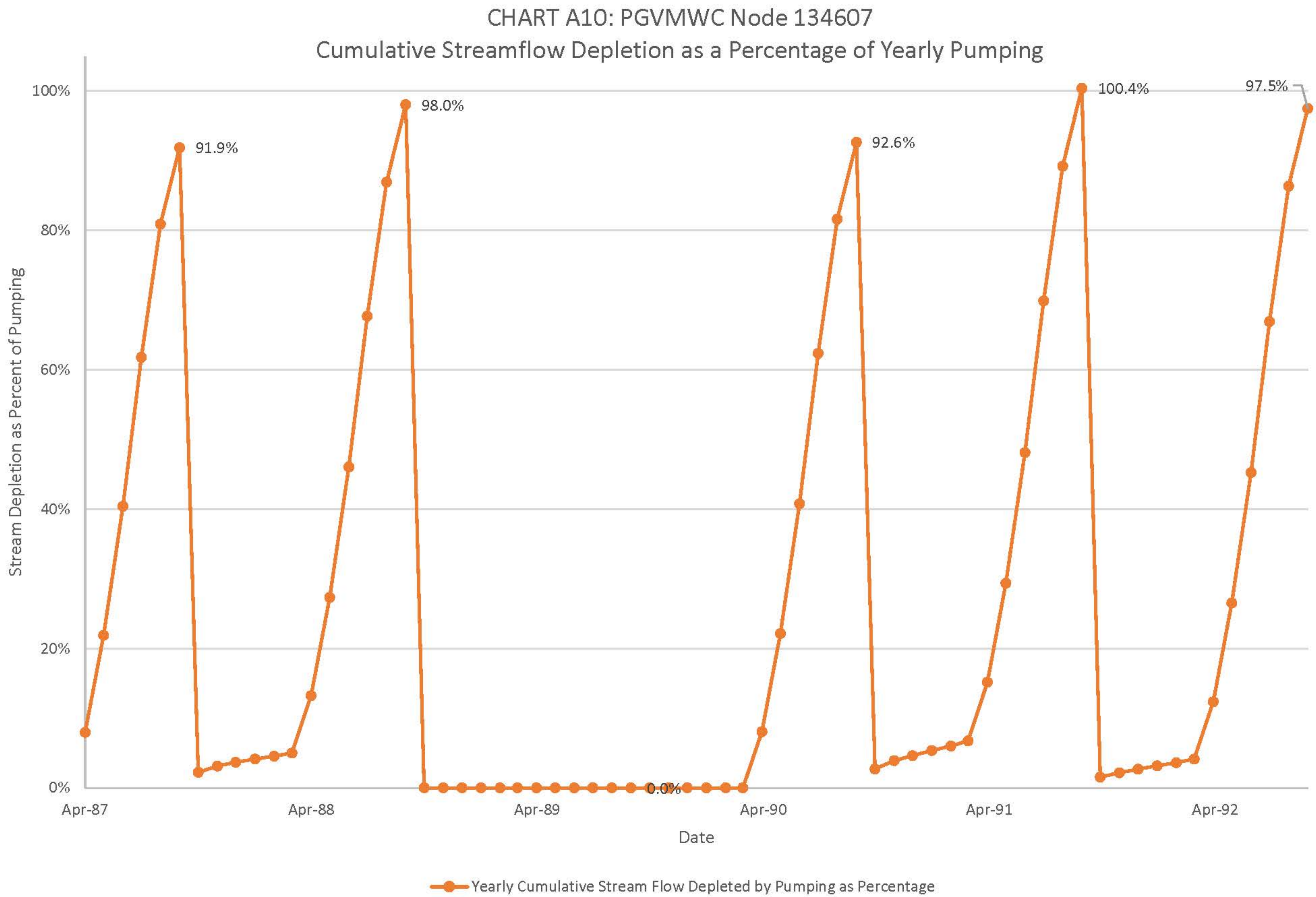


CHART A10: PGVMWC Node 134607
Cumulative Streamflow Depletion as a Percentage of Yearly Pumping
Stream Depletion as Percent of Pumping
100%
80%
60%
40%
20%
0%
91.9%
98.0%
0.0%
92.6%
100.4%
97.5%
Apr-87
Apr-88
Apr-89
Apr-90
Apr-91
Apr-92
Date
Yearly Cumulative Stream Flow Depleted by Pumping as Percentage

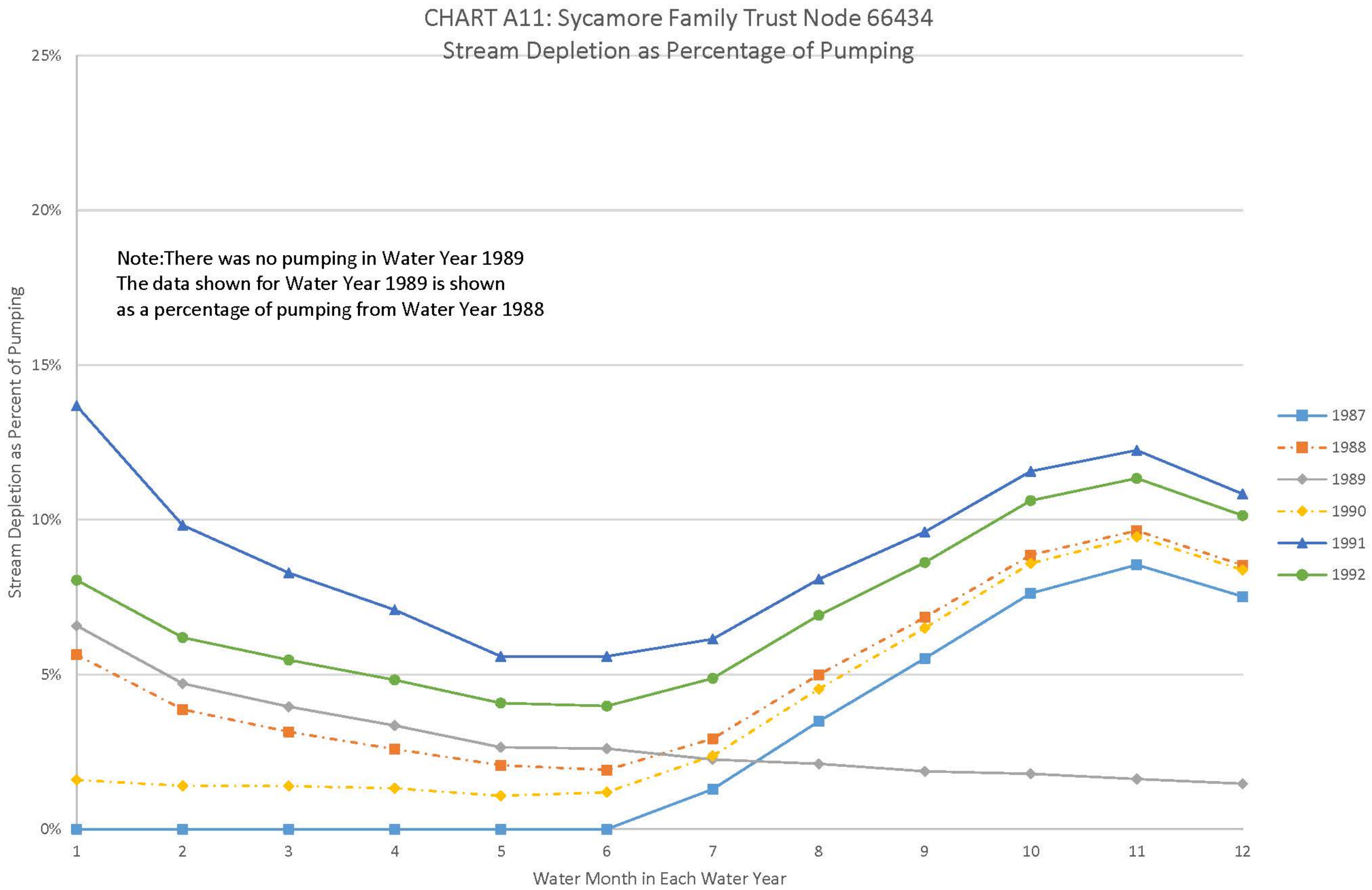


CHART A11: Sycamore Family Trust Node 66434
Stream Depletion as Percentage of Pumping
Note:There was no pumping in Water Year 1989
The data shown for Water Year 1989 is shown
as a percentage of pumping from Water Year 1988
Stream Depletion as Percent of Pumping
25%
20%
15%
10%
5%
0%
1
2
3
4
5
6
7
8
9
10
11
12
Water Month in Each Water Year
1987
1988
1989
1990
1991
1992

EPUR
Safe Water for All

ATTACHMENT B

OVERVIEW OF IWFM SIMULATION CODE CAPABILITIES
AND C2VSIM-CG MODEL CONDITIONS ASSESSMENT FOR STREAMFLOWS

Overview of IWFM

The Integrated Water Flow Model (IWFM) is a fully documented FORTRAN based computerized mathematical model that simulates ground water flow, stream flow, and surface water – ground water interactions. IWFM was developed by staff at the California Department of Water Resources (DWR). IWFM is GNU licensed software, and all the source codes, executables, documentation, and training material, are freely available on DWR's website.

The hydrological processes that are simulated in IWFM are the groundwater heads in a multi-layer aquifer system, stream flows, lakes (open water bodies), direct runoff of precipitation, return flow from irrigation water, infiltration, evapotranspiration, vertical moisture movement in the root zone and the unsaturated zone that lies between the root zone and the saturated groundwater system.

The interaction between the aquifer, streams and lakes as well as land subsidence, tile drainage, subsurface irrigation and the runoff from small watersheds adjacent to model domain are also modeled by IWFM.

IWFM is a water resources management and planning model that simulates groundwater, surface water, groundwater-surface water interaction, as well as other components of the hydrologic system. Preserving the non-linear aspects ofthe surface and subsurface flow processes and the interactions among them is an important aspect of the current version of IWFM.

Simulation of groundwater elevations in a multi-layer aquifer system and the flows among the aquifer layers lies in the core of IWFM. Galerkin finite element method is used to solve the conservation equation for the multi-layer aquifer system. Stream flows and lake storages are also modeled in IWFM. Their interaction with the aquifer system is simulated by solving the conservation equations for groundwater, streams and lakes simultaneously.

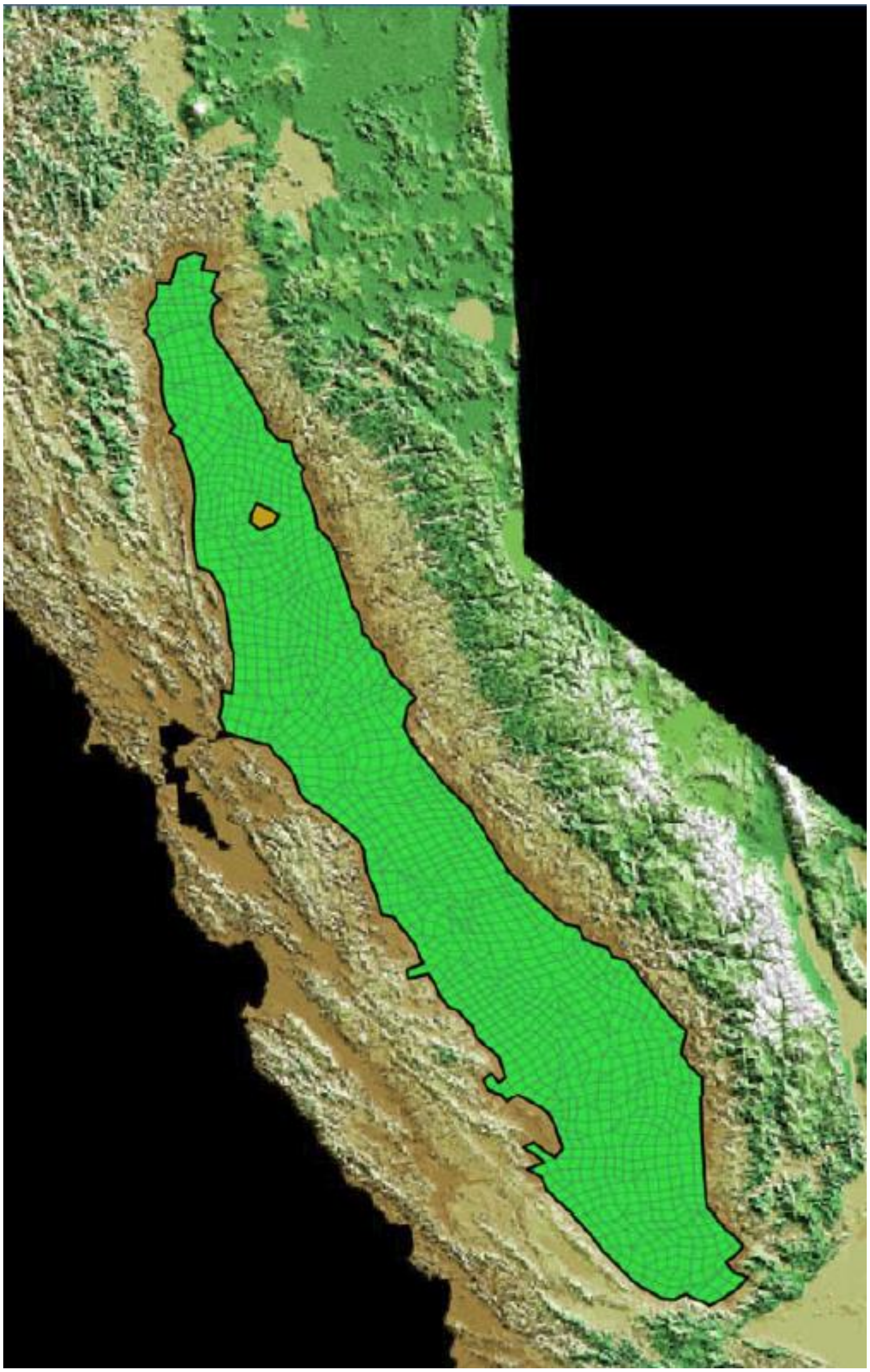
An important aspect of IWFM that differentiates it from the other models in its class is its capability to simulate the water demand as a function of different land use and crop types, and compare it to the historical or projected amount of water supply. The user can specify stream diversion and pumping locations for the source of water supply.

User-specified diversion and pumping amounts can be distributed over the modeled area for agricultural irrigation or urban municipal and industrial use. Based on the precipitation and irrigation rates, and the distribution of land use and crop types over the model domain, the infiltration, evapotranspiration and surface runoff can be computed. Vertical movement of the soil moisture through the root zone and the unsaturated zone that lies between the root zone and the saturated groundwater system can be simulated, and the recharge rates to the groundwater can be computed.

Overview of C2VSim- CG

C2VSIM-CG Boundaries and Grid

The model encompasses approximately 20,000 square miles. The finite-element grid has 1393 nodes, 1392 elements.



Model Layering

There are three explicit groundwater layers in C2VSim with two aquitards layers between the three layers. The bottom of layer 1 was specified to attempt to maintain a minimum saturated thickness of 100 ft except at the model lateral boundaries. The bottoms of layers 1 and 2 were set to incorporate the depth of most groundwater extraction well screens into one or both layers. The bottom of layer 3 was set at the base of fresh water

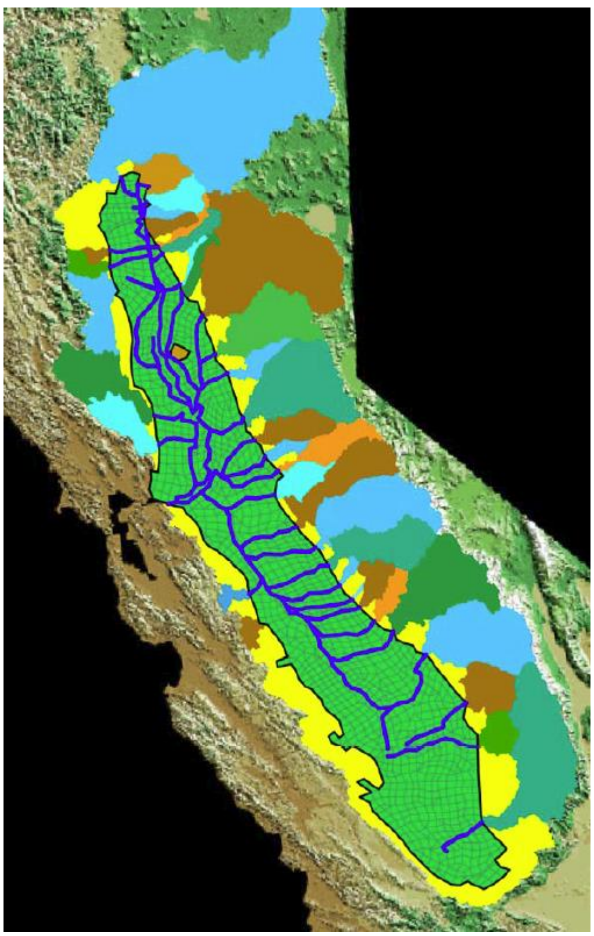
C2VSIM Land Use Process

For the land use process module C2VSIM defines 21 subregions that correspond to the Joint DWR-USBR Depletion Study Drainage Areas (DSAs)

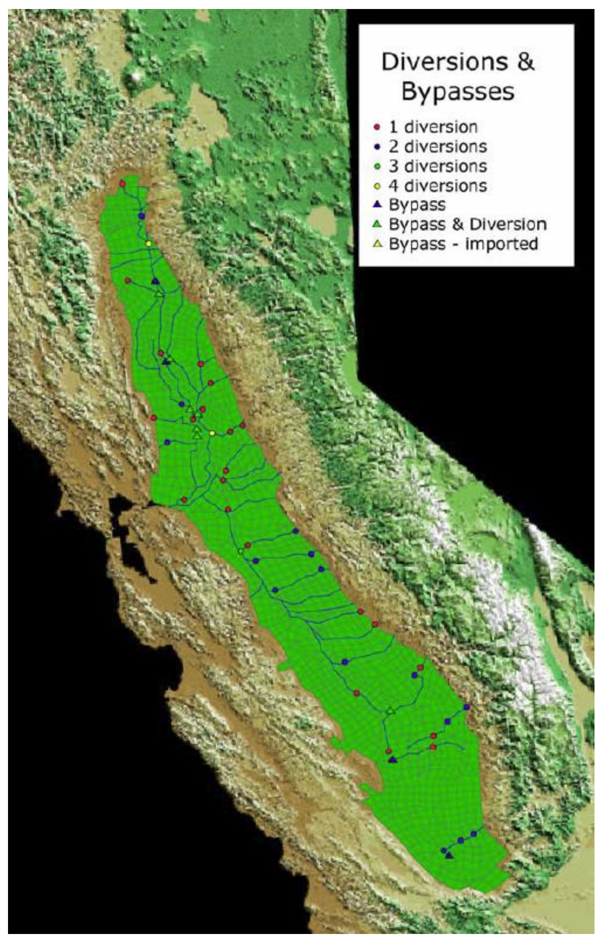
The land use type modules that are simulated in the model are:

- Agriculture
- Urban
- Native
- Riparian

Watersheds and Streams



Major watersheds have gaged flows to C2VSIM streams. Minor watersheds are treated using IWFM Small Watersheds process module.



The model incorporates 72 stream reaches and 97 surface water diversion points. There are two lakes within the model domain. There are also eight flood water bypass canals modeled as surface water diversions in the domain but with their own hydraulic characteristics to differentiate them from other diversion points.

Model Input Parameters

Precipitation Stations and Zones

The model inputs were derived from 32 precipitation stations. Monthly precipitation data from October 1921 to September 2009 were input to the model. Elemental multipliers were used to match the monthly precipitation arrays from the Precipitation Regression Inverse Slope Model (PRISM) 1971-2000 from Oregon State University

Hydraulic Parameters

Horizontal hydraulic conductivity

- 20 – 80 ft/day in layers 1 and 2
- 5 ft/day in layer 3

Vertical hydraulic conductivity

- $5x10^{-5}$ – $1x10^{-3}$ ft/day

Specific yield

- 0.12 – 0.18

Specific storage

- $2x10^{-5}$ ft^{-1}

C2VSIM calibration

C2VSIM calibration was done in an organized sequence of steps. The first step was to update the Conceptual Model for:

- Small watershed delineation
- Precipitation data and stations
- Model Layering and Thicknesses
- Initial heads
- Stream-bed elevations
- Rainfall Runoff Uniform Curve Numbers
- Agricultural root-zone process

The calibration data used included:

- 1976 water level maps for layers 1 & 2
- Head observations at 221wells
- Single screen coincides with model layering
- Measurements before 1977 and after 1997
- No more than one well per model element
- Vertical head gradients at 9 locations
- Average stream accretions and depletions

Calibration was done using PEST with Pilot Points to do inverse parameter fitting to achieve best estimates of parameters to fit through observations (i.e. field data). The calibration sequence used was:

1. Land use process

- Agricultural root-zone process
- Curve numbers

2. Groundwater flow system

- Hydraulic conductivity of layers 1 & 2
- Vertical anisotropy
- Specific yield in layer 1

3. Surface water flow system

- Stream-bed conductivity

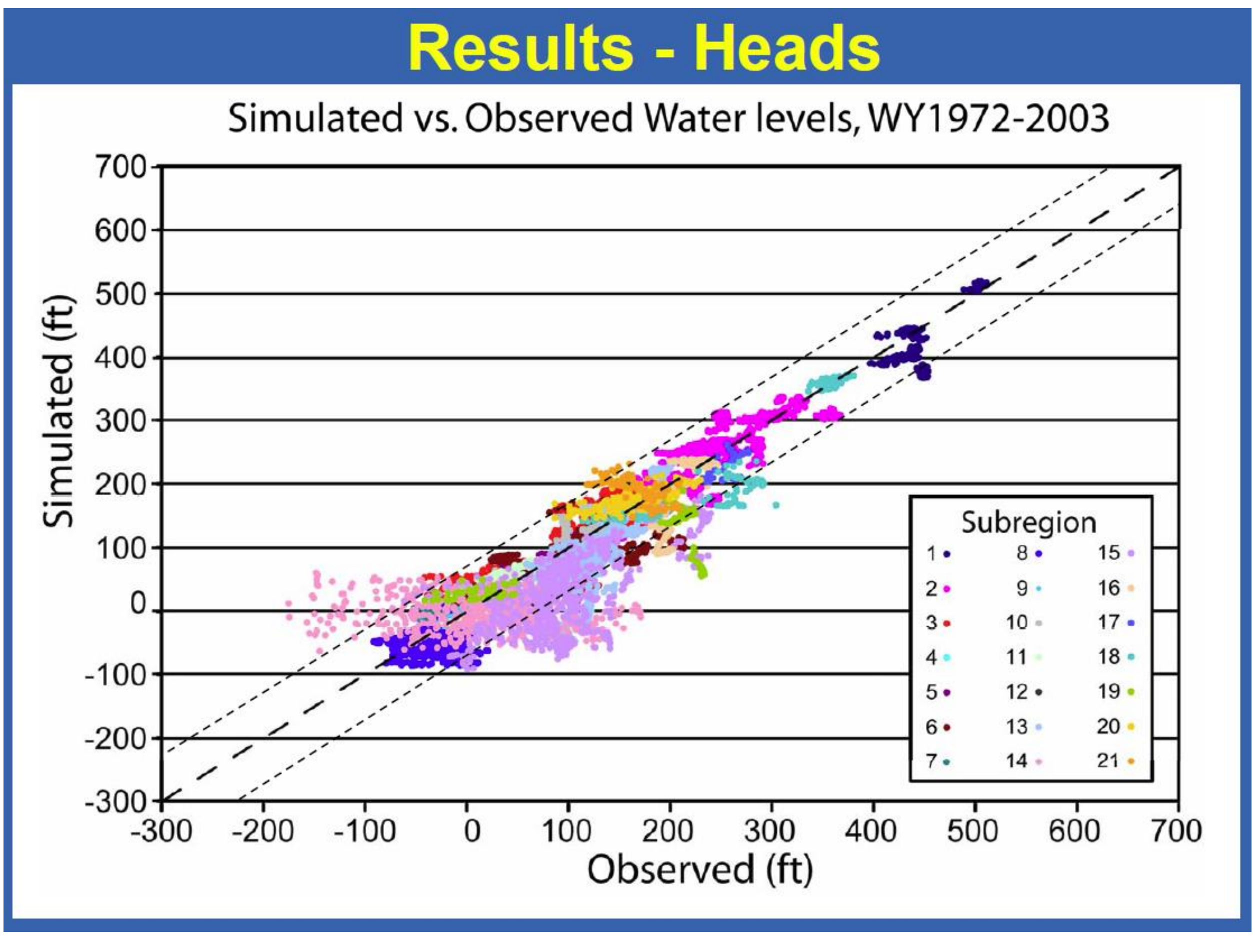
Calibration Results

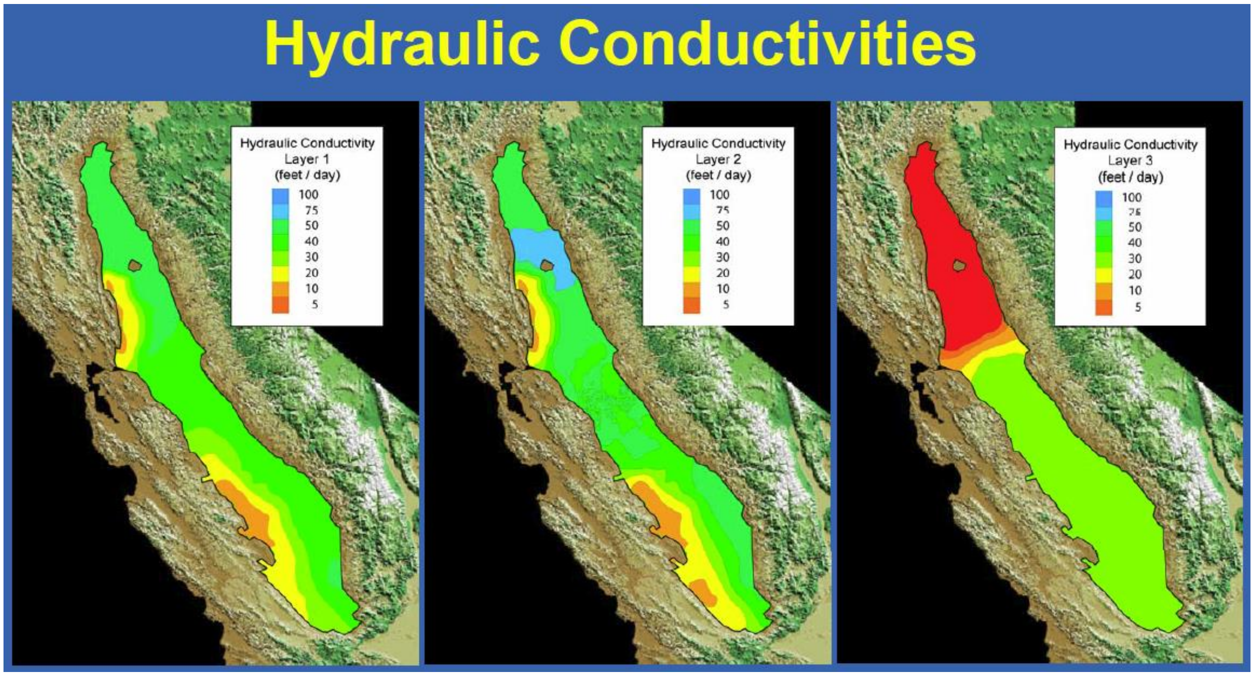
Water Levels:

- Layer 1 generally good
- Layer 2 high beneath Corcoran Clay

Spatial correlation of head residuals

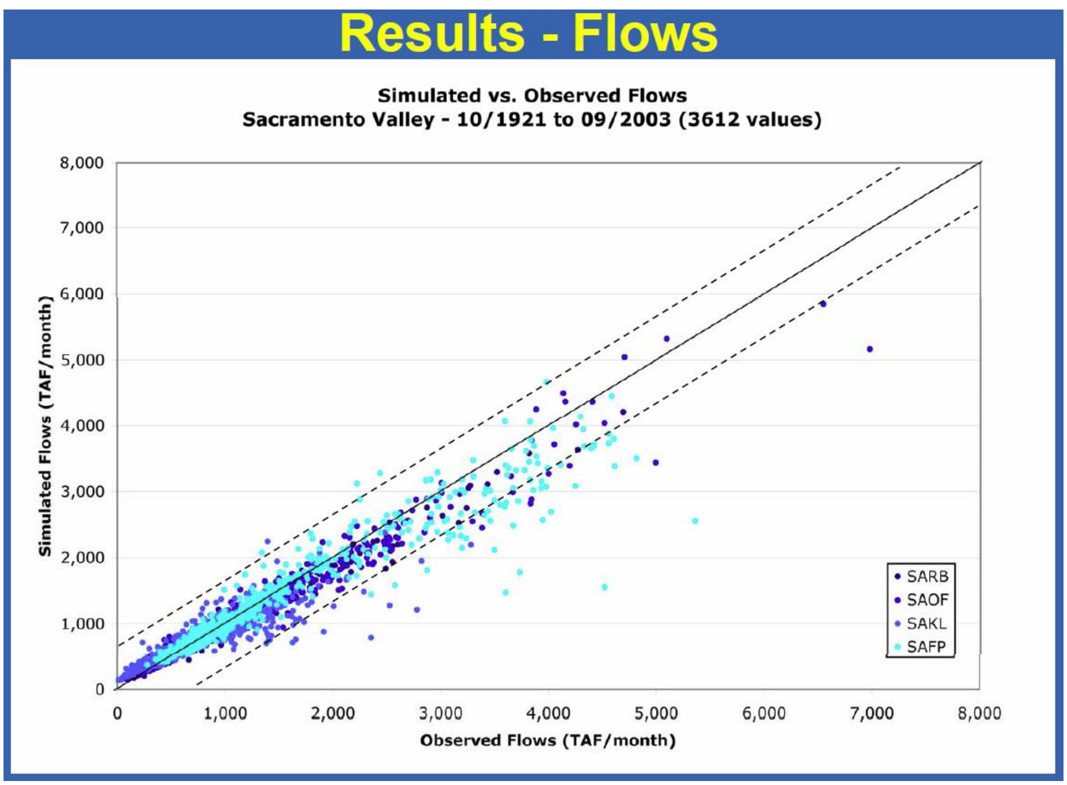
- Reasonable in Sacramento Valley (low on western edge)
- Low in western San Joaquin Valley
- High beneath Corcoran Clay
- Simulated water level trends match observed water level trends on a regional basis





Water Budget Items

C2VSIM shows net groundwater discharge to streams. C2VSIM simulated stream accretions and depletions have same sign as observed, and magnitude is close



Results - Flows