# APPENDIX 3.G. MONITORING NETWORK

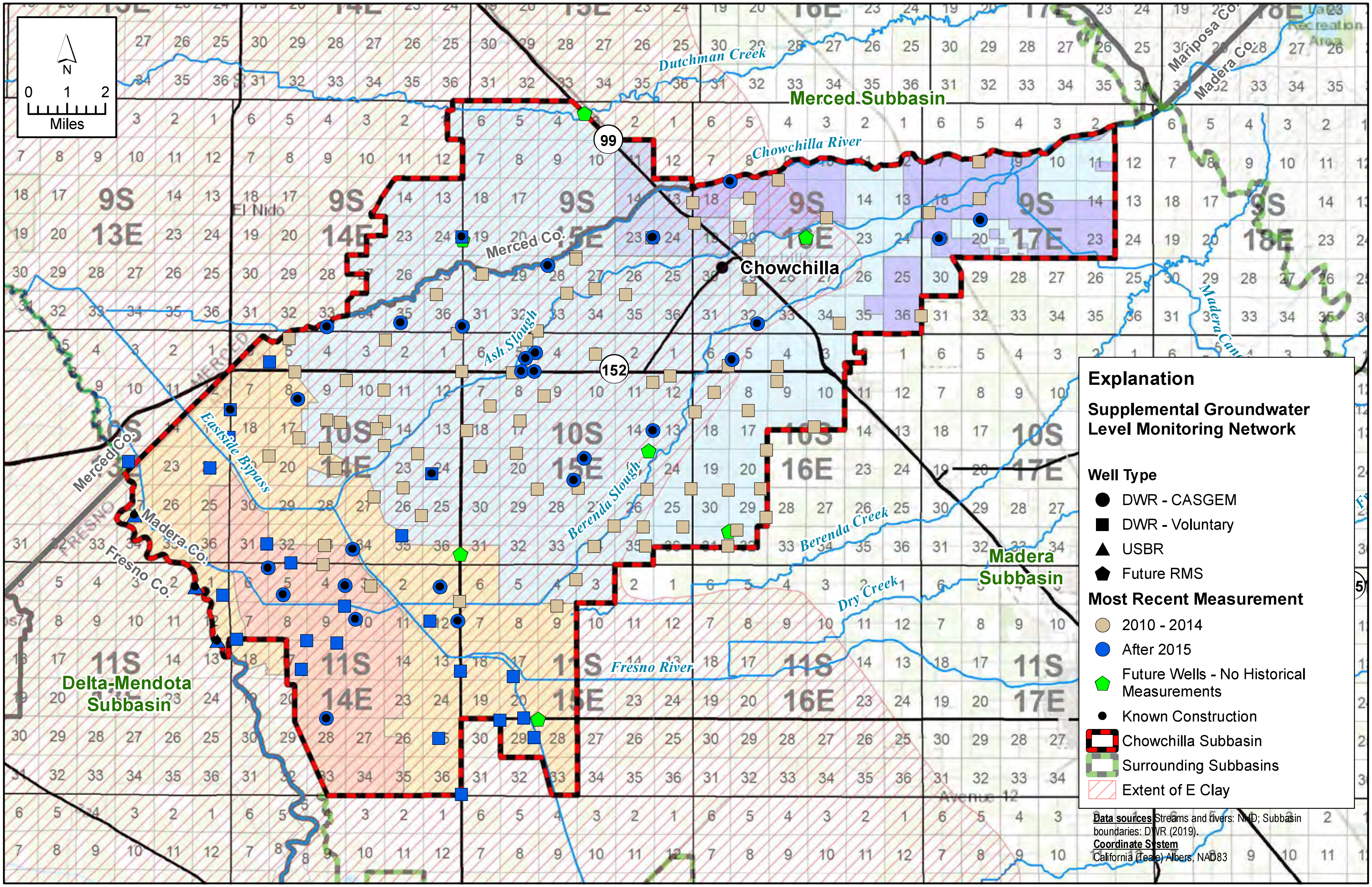
Prepared as part of the

**Groundwater Sustainability Plan**
**Chowchilla Subbasin**

January 2020


**GSP Team:**

Davids Engineering, Inc
Luhdorff & Scalmanini
ERA Economics
Stillwater Sciences and
California State University, Sacramento




X:\2018\18-017 Chowchilla GSP Development\GIS\Map files\Report Figures\Figure 3.D-1 Chowchilla Subbasin Supplemental Groundwater Level Monitoring Network.mxd

DAVIDS ENGINEERING, INC

Luhdorff & Scalmanini Consulting Engineers

**FIGURE 3.G-1**

**Supplemental Groundwater Level Monitoring Network**

*Chowchilla Subbasin*
*Groundwater Sustainability Plan*

**Table 3.G-1 - Supplemental Groundwater Level Monitoring Network, Chowchilla Subbasin**

| Well ID | Well Type | Latitude | Longitude | T/R/S | Well Depth | Screen Interval | Earliest Groundwater Level Measurement Date | Most Recent Groundwater Level Measurement Date | Count of Groundwater Level Measurements |
|---|---|---|---|---|---|---|---|---|---|
| 09S14E24H | Voluntary | 37.1343 | -120.3831 | 9S/14E/24 | 900 | 324-828 | 11/3/2015 | 3/14/2019 | 8 |
| 09S14E33L | CASGEM | 37.1001 | -120.4467 | 9S/14E/33 | 290 | 265-285 | 10/28/2015 | 3/14/2019 | 8 |
| 09S14E35P | CASGEM | 37.1018 | -120.4120 | 9S/14E/35 | 452 | 257-447 | 5/9/2019 | 5/9/2019 | 0 |
| 09S14E36C001M | Voluntary | 37.1124 | -120.3952 | 9S/14E/36 | | | 2/9/1967 | 3/9/2011 | 83 |
| 09S14E36R1 | CASGEM | 37.1004 | -120.3828 | 9S/14E/36 | 490 | 130-270 | 5/10/2019 | 5/10/2019 | 0 |
| 09S15E23J | CASGEM | 37.1343 | -120.2929 | 9S/15E/23 | 291 | | 10/17/2016 | 3/14/2019 | 6 |
| 09S15E23J2 | Voluntary | 37.1341 | -120.2935 | 9S/15E/23 | 291 | 290.5-291 | 2/23/1968 | 2/19/2014 | 85 |
| 09S15E27Q001M | Voluntary | 37.1149 | -120.3202 | 9S/15E/27 | | | 2/25/2013 | 2/18/2014 | 2 |
| 09S15E28A001M | Voluntary | 37.1268 | -120.3293 | 9S/15E/28 | | | 10/29/1935 | 2/22/2010 | 54 |
| 09S15E28A002M | Voluntary | 37.1260 | -120.3293 | 9S/15E/28 | | | 2/15/1963 | 2/18/2014 | 74 |
| 09S15E28C | CASGEM | 37.1236 | -120.3427 | 9S/15E/28 | 736 | 502-722 | 5/11/2019 | 5/11/2019 | 0 |
| 09S15E28R001M | Voluntary | 37.1132 | -120.3335 | 9S/15E/28 | | | 7/6/1939 | 2/18/2014 | 133 |
| 09S15E30G001M | Voluntary | 37.1202 | -120.3735 | 9S/15E/30 | | | 11/8/1939 | 2/22/2010 | 127 |
| 09S15E32R001M | Voluntary | 37.0988 | -120.3474 | 9S/15E/32 | | | 10/24/1952 | 2/22/2010 | 74 |
| 09S15E35C001M | Voluntary | 37.1127 | -120.3057 | 9S/15E/26 | | | 3/4/2013 | 2/18/2014 | 2 |
| 09S16E15Q001M | Voluntary | 37.1418 | -120.2110 | 9S/16E/15 | | | 2/6/1980 | 2/20/2014 | 56 |
| 09S16E16D001M | Voluntary | 37.1560 | -120.2338 | 9S/16E/16 | | | 1/30/1987 | 3/5/2010 | 41 |
| 09S16E17F001M | Voluntary | 37.1491 | -120.2474 | 9S/16E/17 | | | 2/6/1980 | 2/20/2014 | 58 |
| 09S16E18A | CASGEM | 37.1554 | -120.2565 | 9S/16E/18 | 800 | 320-762 | 10/30/2015 | 3/14/2019 | 8 |
| 09S16E18M001M | Voluntary | 37.1474 | -120.2741 | 9S/16E/18 | | | 2/6/1980 | 2/28/2011 | 56 |
| 09S16E19D001M | Voluntary | 37.1396 | -120.2732 | 9S/16E/19 | | | 2/25/2013 | 2/19/2014 | 2 |
| 09S16E20E001M | Voluntary | 37.1382 | -120.2521 | 9S/16E/20 | | | 10/14/1964 | 2/20/2014 | 82 |
| 09S16E20P002M | Voluntary | 37.1296 | -120.2477 | 9S/16E/20 | | | 3/7/1969 | 2/20/2014 | 83 |
| 09S16E29Q001M | Voluntary | 37.1149 | -120.2468 | 9S/16E/29 | | | 10/10/1941 | 2/20/2014 | 49 |
| 09S16E29Q002M | Voluntary | 37.1149 | -120.2474 | 9S/16E/29 | | | 2/21/1958 | 2/28/2011 | 73 |
| 09S16E32Q | CASGEM | 37.1019 | -120.2434 | 9S/16E/32 | 400 | 200-400 | 10/28/2015 | 3/14/2019 | 8 |
| 09S16E34J001M | Voluntary | 37.1021 | -120.2049 | 9S/16E/34 | | | 12/3/1959 | 2/20/2014 | 106 |
| 09S16E36J001M | Voluntary | 37.1049 | -120.1663 | 9S/16E/36 | | | 11/3/1952 | 2/20/2014 | 104 |
| 09S17E08F001M | Voluntary | 37.1630 | -120.1391 | 9S/17E/08 | | | 2/13/2013 | 2/19/2014 | 2 |
| 09S17E17F001M | Voluntary | 37.1491 | -120.1388 | 9S/17E/17 | | | 2/6/1980 | 3/1/2011 | 55 |
| 09S17E18N002M | Voluntary | 37.1438 | -120.1624 | 9S/17E/18 | | | 2/6/1980 | 3/1/2011 | 44 |
| 09S17E19L001M | CASGEM | 37.1341 | -120.1577 | 9S/17E/19 | 648 | 240-620 | 10/9/1964 | 3/14/2019 | 99 |
| 09S17E20C | CASGEM | 37.1411 | -120.1384 | 9S/17E/20 | 720 | 200-720 | 10/29/2015 | 3/14/2019 | 8 |
| 10S13E13J001M | Voluntary | 37.0582 | -120.4927 | 10S/13E/13 | | | 2/8/2012 | 3/11/2019 | 9 |
| 10S13E22F002M | Voluntary | 37.0489 | -120.5400 | 10S/13E/22 | | | 1/22/1999 | 10/16/2018 | 11 |
| 10S13E24L001M | Voluntary | 37.0468 | -120.5016 | 10S/13E/24 | | | 2/12/1964 | 3/8/2017 | 89 |
| 10S14E01A001M | Voluntary | 37.0977 | -120.3852 | 10S/14E/01 | | | 3/1/2013 | 2/28/2014 | 2 |
| 10S14E01R002M | Voluntary | 37.0835 | -120.3829 | 10S/14E/12 | | | 2/22/1968 | 2/28/2014 | 82 |
| 10S14E03A001M | Voluntary | 37.0952 | -120.4191 | 10S/14E/03 | | | 10/1/1928 | 2/11/2014 | 138 |
| 10S14E05C003M | Voluntary | 37.0955 | -120.4646 | 10S/14E/05 | | | 10/6/1976 | 2/11/2014 | 66 |
| 10S14E06R001M | Voluntary | 37.0868 | -120.4738 | 10S/14E/06 | | | 10/8/1976 | 3/11/2019 | 66 |
| 10S14E08B003M | Voluntary | 37.0830 | -120.4616 | 10S/14E/08 | | | 7/21/1961 | 2/26/2010 | 157 |
| 10S14E08D | CASGEM | 37.0728 | -120.4603 | 10S/14E/08 | 410 | 230-360 | 10/29/2015 | 3/15/2019 | 8 |
| 10S14E09A003M | Voluntary | 37.0799 | -120.4374 | 10S/14E/09 | | | 2/22/1968 | 2/12/2014 | 81 |
| 10S14E10H001M | Voluntary | 37.0763 | -120.4196 | 10S/14E/10 | | | 2/21/2013 | 2/12/2014 | 2 |
| 10S14E15H001M | Voluntary | 37.0646 | -120.4193 | 10S/14E/15 | | | 10/29/1935 | 2/12/2014 | 135 |
| 10S14E15J001M | Voluntary | 37.0618 | -120.4232 | 10S/14E/15 | | | 2/1/1999 | 2/26/2010 | 17 |
| 10S14E15R001M | Voluntary | 37.0555 | -120.4193 | 10S/14E/15 | | | 11/30/1937 | 3/1/2011 | 131 |
| 10S14E16F002M | Voluntary | 37.0649 | -120.4466 | 10S/14E/16 | | | 10/14/1964 | 2/12/2014 | 85 |
| 10S14E16H001M | Voluntary | 37.0641 | -120.4402 | 10S/14E/16 | | | 12/28/1950 | 2/12/2014 | 110 |
| 10S14E17J001M | Voluntary | 37.0582 | -120.4596 | 10S/14E/17 | | | 2/6/1980 | 2/12/2014 | 58 |
| 10S14E18D | Voluntary | 37.0688 | -120.4922 | 10S/13E/13 | 516 | 265-506 | 10/29/2015 | 3/15/2019 | 8 |
| 10S14E19A002M | Voluntary | 37.0513 | -120.4738 | 10S/14E/19 | | | 2/6/1980 | 2/11/2014 | 58 |
| 10S14E21C003M | Voluntary | 37.0543 | -120.4471 | 10S/14E/21 | | | 2/6/1980 | 3/1/2013 | 58 |
| 10S14E21G001M | Voluntary | 37.0468 | -120.4421 | 10S/14E/21 | | | 2/6/1980 | 2/21/2013 | 58 |
| 10S14E23A001M | Voluntary | 37.0524 | -120.4035 | 10S/14E/23 | | | 11/26/1941 | 2/13/2014 | 122 |
| 10S14E24M | Voluntary | 37.0449 | -120.3969 | 10S/14E/24 | 696 | 255-636 | 10/29/2015 | 3/15/2019 | 8 |
| 10S14E26C002M | Voluntary | 37.0396 | -120.4104 | 10S/14E/26 | | | 2/18/1963 | 2/12/2014 | 91 |
| 10S14E26R001M | Voluntary | 37.0291 | -120.4018 | 10S/14E/26 | | | 2/21/2013 | 2/28/2014 | 2 |
| 10S14E27H001M | Voluntary | 37.0360 | -120.4241 | 10S/14E/27 | | | 2/2/1999 | 2/25/2010 | 17 |
| 10S14E31H001M | Voluntary | 37.0182 | -120.4746 | 10S/14E/31 | | | 2/8/2012 | 3/18/2016 | 5 |
| 10S14E32Q001M | Voluntary | 37.0110 | -120.4632 | 11S/14E/05 | | | 10/16/1961 | 3/20/2019 | 93 |
| 10S14E33L002M | Voluntary | 37.0177 | -120.4474 | 10S/14E/33 | | | 2/6/1980 | 2/12/2014 | 58 |
| 10S14E34M001M | CASGEM | 37.0163 | -120.4341 | 10S/14E/34 | 870 | 295-850 | 10/8/2015 | 10/17/2017 | 2 |
| 10S14E35F001M | Voluntary | 37.0216 | -120.4110 | 10S/14E/35 | | | 2/13/1964 | 3/11/2019 | 133 |
| 10S15E03L001M | Voluntary | 37.0902 | -120.3199 | 10S/15E/03 | | | 2/28/2013 | 2/18/2014 | 2 |
| 10S15E05B001M | Voluntary | 37.0955 | -120.3524 | 10S/15E/05 | | | 3/21/1944 | 2/14/2014 | 120 |
| 10S15E05J-2 | CASGEM | 37.0906 | -120.3483 | 10S/15E/05 | 104 | 84-104 | 10/29/2015 | 3/15/2019 | 8 |
| 10S15E05K | CASGEM | 37.0885 | -120.3528 | 10S/15E/05 | 105 | 85-105 | 10/29/2015 | 3/15/2019 | 8 |
| 10S15E05Q | CASGEM | 37.0836 | -120.3549 | 10S/15E/05 | 100 | 80-100 | 10/29/2015 | 3/15/2019 | 8 |
| 10S15E05R | CASGEM | 37.0837 | -120.3488 | 10S/15E/05 | 100 | 80-100 | 10/29/2015 | 3/15/2019 | 8 |

**Table 3.G-1 - Supplemental Groundwater Level Monitoring Network, Chowchilla Subbasin**

| Well ID | Well Type | Latitude | Longitude | T/R/S | Well Depth | Screen Interval | Earliest Groundwater Level Measurement Date | Most Recent Groundwater Level Measurement Date | Count of Groundwater Level Measurements |
|---|---|---|---|---|---|---|---|---|---|
| 10S15E07Q001M | Voluntary | 37.0705 | -120.3696 | 10S/15E/07 | | | 12/6/1961 | 2/25/2010 | 87 |
| 10S15E08C001M | Voluntary | 37.0830 | -120.3591 | 10S/15E/08 | | | 12/6/1961 | 2/14/2014 | 88 |
| 10S15E09M001M | Voluntary | 37.0743 | -120.3441 | 10S/15E/09 | | | 12/6/1961 | 3/4/2011 | 89 |
| 10S15E11H001M | Voluntary | 37.0796 | -120.2927 | 10S/15E/11 | | | 2/11/1963 | 2/14/2014 | 86 |
| 10S15E12C002M | Voluntary | 37.0821 | -120.2846 | 10S/15E/12 | | | 2/19/2013 | 2/14/2014 | 2 |
| 10S15E13F | CASGEM | 37.0614 | -120.2928 | 10S/15E/14 | 390 | 150-390 | 10/29/2015 | 3/15/2019 | 8 |
| 10S15E17G001M | Voluntary | 37.0649 | -120.3554 | 10S/15E/17 | | | 12/6/1961 | 2/14/2014 | 89 |
| 10S15E18M002M | Voluntary | 37.0613 | -120.3804 | 10S/15E/18 | | | 3/4/1960 | 2/14/2014 | 92 |
| 10S15E19F001M | Voluntary | 37.0477 | -120.3741 | 10S/15E/19 | | | 12/5/1961 | 2/28/2014 | 92 |
| 10S15E20C004M | Voluntary | 37.0527 | -120.3571 | 10S/15E/20 | | | 1/12/1979 | 2/14/2014 | 61 |
| 10S15E21R001M | CASGEM | 37.0427 | -120.3300 | 10S/15E/21 | 600 | 280-600 | 10/8/2015 | 3/28/2019 | 7 |
| 10S15E22D | CASGEM | 37.0509 | -120.3251 | 10S/15E/22 | 800 | 360-800 | 10/29/2015 | 3/15/2019 | 8 |
| 10S15E23K001M | Voluntary | 37.0471 | -120.3016 | 10S/15E/23 | | | 10/26/1920 | 2/13/2014 | 150 |
| 10S15E25A001M | Voluntary | 37.0396 | -120.2746 | 10S/15E/25 | | | 2/19/2013 | 2/13/2014 | 2 |
| 10S15E26A001M | Voluntary | 37.0393 | -120.2954 | 10S/15E/26 | | | 3/1/1927 | 2/13/2014 | 146 |
| 10S15E27D001M | Voluntary | 37.0396 | -120.3279 | 10S/15E/27 | | | 10/1/1928 | 3/3/2011 | 51 |
| 10S15E27R001M | Voluntary | 37.0255 | -120.3107 | 10S/15E/27 | | | 10/1/1928 | 2/13/2014 | 144 |
| 10S15E29A002M | Voluntary | 37.0393 | -120.3471 | 10S/15E/29 | | | 1/12/1979 | 2/13/2014 | 60 |
| 10S15E34L001M | Voluntary | 37.0177 | -120.3202 | 10S/15E/34 | | | 2/19/2013 | 2/13/2014 | 2 |
| 10S15E35A002M | Voluntary | 37.0252 | -120.2971 | 10S/15E/35 | | | 3/6/1969 | 2/13/2014 | 80 |
| 10S15E35J001M | Voluntary | 37.0180 | -120.2960 | 10S/15E/35 | | | 2/25/2013 | 2/13/2014 | 2 |
| 10S15E36A001M | Voluntary | 37.0252 | -120.2785 | 10S/15E/36 | | | 3/15/2002 | 3/15/2012 | 11 |
| 10S16E04N001M | Voluntary | 37.0857 | -120.2341 | 10S/16E/04 | | | 12/22/1934 | 3/1/2011 | 131 |
| 10S16E05M | CASGEM | 37.0884 | -120.2554 | 10S/16E/05 | 440 | 240-440 | 10/30/2015 | 3/15/2019 | 8 |
| 10S16E06R001M | Voluntary | 37.0860 | -120.2571 | 10S/16E/06 | | | 3/22/1944 | 2/21/2014 | 126 |
| 10S16E07K001M | Voluntary | 37.0760 | -120.2638 | 10S/16E/07 | | | 12/11/1961 | 2/25/2010 | 88 |
| 10S16E09E001M | Voluntary | 37.0802 | -120.2343 | 10S/16E/09 | | | 2/19/2013 | 2/21/2014 | 2 |
| 10S16E15F001M | Voluntary | 37.0630 | -120.2166 | 10S/16E/15 | | | 2/14/2013 | 2/20/2014 | 2 |
| 10S16E17C001M | Voluntary | 37.0691 | -120.2477 | 10S/16E/08 | | | 10/24/1952 | 2/21/2014 | 101 |
| 10S16E18D002M | Voluntary | 37.0685 | -120.2727 | 10S/16E/18 | | | 12/5/1961 | 2/21/2014 | 89 |
| 10S16E20A001M | Voluntary | 37.0543 | -120.2391 | 10S/16E/20 | | | 3/8/1969 | 3/2/2010 | 77 |
| 10S16E29A001M | Voluntary | 37.0396 | -120.2418 | 10S/16E/29 | | | 2/6/1980 | 2/13/2014 | 58 |
| 10S16E29R002M | Voluntary | 37.0288 | -120.2393 | 10S/16E/29 | | | 1/19/1979 | 3/2/2011 | 58 |
| 10S16E30A001M | Voluntary | 37.0391 | -120.2571 | 10S/16E/30 | | | 11/26/1941 | 2/28/2014 | 122 |
| 10S16E31J001M | Voluntary | 37.0180 | -120.2571 | 10S/16E/31 | | | 2/6/1980 | 2/21/2014 | 58 |
| 10S16E32D002M | Voluntary | 37.0241 | -120.2529 | 10S/16E/32 | | | 2/6/1980 | 2/25/2010 | 55 |
| 11S13E01Q001M | Voluntary | 36.9988 | -120.4952 | 11S/13E/01 | | | 10/16/1961 | 3/20/2019 | 94 |
| 11S14E01R001M | Voluntary | 36.9968 | -120.3835 | 11S/14E/01 | | | 10/15/2001 | 10/15/2010 | 19 |
| 11S14E03G001M | Voluntary | 37.0024 | -120.4254 | 11S/14E/03 | | | 10/26/2011 | 2/12/2014 | 6 |
| 11S14E04C001M | Voluntary | 37.0105 | -120.4479 | 11S/14E/04 | | | 3/13/1959 | 2/21/2014 | 91 |
| 11S14E04J001M | CASGEM | 37.0025 | -120.4377 | 11S/14E/04 | 900 | | 10/8/2015 | 3/28/2019 | 7 |
| 11S14E05P | CASGEM | 36.9991 | -120.4667 | 11S/14E/05 | 860 | 290-840 | 5/13/2019 | 5/13/2019 | 0 |
| 11S14E06A | CASGEM | 37.0092 | -120.4738 | 11S/14E/06 | 840 | 170-230 | 5/14/2019 | 5/14/2019 | 0 |
| 11S14E07N001M | Voluntary | 36.9821 | -120.4885 | 11S/14E/18 | | | 2/13/1964 | 3/20/2019 | 67 |
| 11S14E08R001M | Voluntary | 36.9818 | -120.4554 | 11S/14E/17 | | | 10/16/1961 | 3/20/2019 | 94 |
| 11S14E09A003M | Voluntary | 36.9949 | -120.4377 | 11S/14E/09 | | | 10/16/1961 | 3/20/2019 | 95 |
| 11S14E10F | CASGEM | 36.9899 | -120.4326 | 11S/14E/10 | 710 | 170-690 | 5/15/2019 | 5/15/2019 | 0 |
| 11S14E12E001M | Voluntary | 36.9893 | -120.3974 | 11S/14E/12 | | | 10/5/1976 | 3/20/2019 | 68 |
| 11S14E12H1 | CASGEM | 36.9894 | -120.3844 | 11S/14E/12 | 420 | | 11/2/2015 | 3/14/2019 | 8 |
| 11S14E13R001M | Voluntary | 36.9705 | -120.3829 | 11S/14E/13 | | | 2/19/1963 | 3/13/2019 | 104 |
| 11S14E16A001M | Voluntary | 36.9810 | -120.4413 | 11S/14E/16 | | | 10/16/1961 | 3/20/2019 | 105 |
| 11S14E17J001M | Voluntary | 36.9710 | -120.4579 | 11S/14E/17 | | | 2/9/2012 | 3/9/2017 | 7 |
| 11S14E25L002M | Voluntary | 36.9452 | -120.3932 | 11S/14E/25 | | | 10/5/1976 | 3/13/2019 | 70 |
| 11S14E28C | CASGEM | 36.9524 | -120.4461 | 11S/14E/28 | 840 | 320-680 | 5/16/2019 | 5/16/2019 | 0 |
| 11S14E36R001M | Voluntary | 36.9241 | -120.3824 | 11S/14E/36 | | | 2/14/1964 | 3/10/2017 | 87 |
| 11S15E04H001M | Voluntary | 37.0052 | -120.3288 | 11S/15E/04 | | | 2/19/2013 | 2/28/2014 | 2 |
| 11S15E06L | CASGEM | 37.0022 | -120.3929 | 11S/14E/01 | 390 | 120-390 | 10/30/2015 | 3/19/2019 | 8 |
| 11S15E09C001M | Voluntary | 36.9952 | -120.3377 | 11S/15E/09 | | | 3/22/1950 | 2/13/2014 | 112 |
| 11S15E17P001M | Voluntary | 36.9685 | -120.3582 | 11S/15E/17 | | | 2/9/2012 | 3/10/2017 | 7 |
| 11S15E20Q001M | Voluntary | 36.9530 | -120.3532 | 11S/15E/20 | | | 2/9/2012 | 3/13/2019 | 9 |
| 11S15E29H001M | Voluntary | 36.9457 | -120.3482 | 11S/15E/29 | | | 7/28/1949 | 3/20/2019 | 105 |
| 11S15E30A001M | Voluntary | 36.9521 | -120.3643 | 11S/15E/30 | | | 2/14/1964 | 3/13/2019 | 91 |
| Clayton WD Shallow Ag Well #2 | Other | 37.0051 | 120.5040 | 11S/13E/01 | | | 10/1/2001 | 4/1/2018 | 19 |
| Site 1 | Future RMS | 37.1332 | -120.3827 | 9S/15E/19 | | | | | |
| Site 2 | Future RMS | 37.1811 | -120.3254 | 9S/15E/03 | | | | | |
| Site 3 | Future RMS | 37.1347 | -120.2206 | 9S/16E/21 | | | | | |
| Site 5 | Future RMS | 37.0539 | -120.2947 | 10S/15E/23 | | | | | |
| Site 6 | Future RMS | 37.0148 | -120.3833 | 13S/16E/03 | | | | | |
| Site 7 | Future RMS | 36.9527 | -120.3463 | 11S/15E/20 | | | | | |
| Site 9 | Future RMS | 37.0236 | -120.2567 | 10S/16E/31 | | | | | |
| SJRRP_MW-10-78 | USBR | 36.9817 | -120.4978 | 11S/13E/13 | 28 | 43763 | 4/14/2010 | 10/31/2018 | 295 |

**Table 3.G-1 - Supplemental Groundwater Level Monitoring Network, Chowchilla Subbasin**

| Well ID | Well Type | Latitude | Longitude | T/R/S | Well Depth | Screen Interval | Earliest Groundwater Level Measurement Date | Most Recent Groundwater Level Measurement Date | Count of Groundwater Level Measurements |
|---|---|---|---|---|---|---|---|---|---|
| SJRRP_MW-10-80 | USBR | 37.0018 | -120.5081 | 11S/13E/01 | 27.9 | 43763 | 4/14/2010 | 7/27/2016 | 226 |
| SJRRP_MW-11-162 | USBR | 37.0287 | -120.5370 | 10S/13E/27 | 30 | | 1/11/2012 | 10/31/2018 | 205 |

*NOTE:*
T/R/S location corresponds to Township/Range/Section grid on Figure A-X

# APPENDIX 3.H. SUBSIDENCE DATA GAPS WORKPLAN

Prepared as part of the

**Groundwater Sustainability Plan**
**Chowchilla Subbasin**

January 2020
Revised January 2025

**GSP Team:**

Davids Engineering, Inc (Revised GSP Team)
Luhdorff & Scalmanini (Revised GSP Team)
ERA Economics
Stillwater Sciences and
California State University, Sacramento

Luhdorff & Scalmanini
Consulting Engineers

# TECHNICAL MEMORANDUM

DATE: May 3, 2023 Project No. 21-1-166

TO: Chowchilla Subbasin GSAs

FROM: LSCE and DE

**SUBJECT: Chowchilla Subbasin Revised GSP (May 2023) - Land Subsidence Workplan**

## Introduction and Background

Some areas of the Chowchilla Subbasin (Subbasin) have experienced considerable historical land subsidence, as documented in the Revised Groundwater Sustainability Plan (GSP) for the Subbasin. Much of the historical land subsidence in the Subbasin is believed to be caused by declining groundwater levels or piezometric head within the Lower Aquifer below the Corcoran Clay[1], and associated release of water from fine-grained sediments, ultimately resulting in compaction of these fine-grained sediments. In other areas of the San Joaquin Valley with long-term historical monitoring of both land subsidence and groundwater levels, land subsidence has been correlated with declining groundwater levels in the Lower Aquifer. Furthermore, considerable lag time between declining groundwater levels and land subsidence has been observed in other areas of the San Joaquin Valley.

Within the Subbasin, limited long-term data are available for land subsidence, including data to evaluate potential relationships between land subsidence and groundwater levels. As a result, there are gaps in the understanding of mechanisms and conditions related to land subsidence in the Subbasin, especially as it relates to how historical groundwater level decline may continue to cause ongoing residual land subsidence in the Subbasin, even as groundwater levels stabilize or rise in the future, as is planned for in the Revised GSP.

The Revised GSP establishes sustainable management criteria (SMC) for land subsidence with consideration of DWR review and input received in the initial GSP consultation letter and the March 2022 inadequate determination. The revised SMC for subsidence are all established as rates of subsidence, measured from subsidence benchmarks, with consideration for the total rate of subsidence. Groundwater levels are no longer used as a proxy for subsidence in the Subbasin.

[1] The Corcoran Clay (E-Clay of the Tulare Formation) is a laterally extensive and thick layer of clay present across large areas of the Subbasin and functions as a confining layer hydraulically separating the Upper Aquifer from the Lower Aquifer, where it exists.

Additional characterization of land subsidence conditions – including the relationship between groundwater levels and land subsidence – and evaluation of mechanisms for mitigating future land subsidence are important for ensuring that the GSAs successfully achieve the Subbasin sustainability goal. This Workplan is intended to provide additional field data and technical analyses as input to better characterizing land subsidence for the 2025 GSP Update (and beyond).

The Workplan outlines future efforts intended to address data gaps identified in the Revised GSP through enhanced monitoring and improving understanding of relationships between groundwater conditions and land subsidence in the Subbasin. The workplan also includes tasks to further evaluate sustainable management criteria (SMC) for land subsidence and support development of a coordinated approach to implementation of projects and management actions (PMAs) presented in the Revised GSP to address land subsidence and achieve sustainable groundwater management.

## Information Summarized in Revised GSP

As summarized in the Revised GSP, historical documentation of land subsidence in the Subbasin indicated limited land subsidence prior to the early 1970s (see Revised GSP Figure 2-66). More recent monitoring using remote sensing information and data collected from benchmark surveys conducted for the San Joaquin River Restoration Program (SJRRP) has shown an increase in land subsidence in parts of the Subbasin since the mid-2000s. Over the period from 2007 through 2021, cumulative vertical displacement ranged from almost zero to more than six feet, with most land subsidence during this period focused in the western part of the Subbasin (see Revised GSP Figure 2-67). The Revised GSP identifies a Western Management Area (WMA) where greater amounts of historical subsidence have occurred and where more focused management of groundwater is planned to mitigate impacts to critical infrastructure from future land subsidence.

Although there is considerable historical monitoring of land subsidence in the Subbasin, most of this monitoring has occurred at infrequent temporal intervals and with varying spatial resolution and distribution. Historical monitoring of groundwater levels, especially to support understanding of relationships between groundwater levels and land subsidence, has also been limited in most of the Subbasin. The Revised GSP summarizes historical groundwater level and land subsidence monitoring and available data to directly compare groundwater levels and land subsidence (see Revised GSP Figures 2-70a and 2-70b). The available data do not indicate clear and consistent relationships between groundwater levels and land subsidence in the Subbasin, largely because of limitations in the temporal and spatial distribution of available historical monitoring data, and also because of the ongoing occurrence of residual land subsidence, which is discussed more below.

Under the Revised GSP, the GSAs will evaluate land subsidence by monitoring the vertical displacement of the land surface. The land subsidence monitoring network is comprised of elevation benchmark survey points monitored by the United States Bureau of Reclamation (USBR) as part of the SJRRP.

## Data Gaps Identified in Revised GSP

As discussed in the Revised GSP, key aspects of land subsidence in the Subbasin that are not well understood or quantified relate to:

- The mechanisms and conditions causing land subsidence in the Subbasin, including the relationship between land subsidence and declining groundwater levels, especially in the Lower Aquifer, within the local context of the Subbasin; and
- Residual land subsidence, specifically differentiating residual land subsidence caused by historical conditions from new land subsidence caused by current conditions.

Robust land subsidence monitoring coupled with well-defined groundwater level monitoring will be important for tracking the different mechanisms related to land subsidence. Expansion of the land subsidence monitoring network will fill the temporal data gap noted in the Revised GSP and benefit the understanding and monitoring of potential subsidence in the Subbasin.

The Revised GSP noted the potential opportunities and benefits related to improving the understanding of relationships between groundwater levels and land subsidence from:

- Continued monitoring of existing benchmarks, including the many land subsidence benchmarks in the Subbasin that are monitored by the United States Bureau of Reclamation (USBR) as part of the SJRRP, and
- Potential installation of continuous GPS or other monitoring facilities, in conjunction with coupling groundwater level monitoring in the vicinity of sites with historical and ongoing land subsidence monitoring.

## Workplan Objectives and Overview

This Workplan outlines a proposed scope of work to compile and review additional data and reports pertaining to land subsidence in the Subbasin, improve understanding of active production wells, establish or construct additional monitoring facilities, and conduct additional technical analyses. The Workplan incorporates consideration of comments and guidance provided by DWR during the initial GSP review and consultation stages. The purpose of this scope of work is to provide sufficient data and analyses to:

- Enhance monitoring and understanding of relationships between land subsidence and groundwater levels at different depths within the western part of the Subbasin;
- Expand land subsidence monitoring network throughout Subbasin (i.e., new elevation benchmark survey points);
- Refine mapping of geologic conditions related to land subsidence, including the thickness and extent of the Corcoran Clay and other clay units;
- Improve quantification of groundwater pumping within each of the two principal aquifers (Upper and Lower Aquifer);
- Develop estimates of the amount of expected residual land subsidence caused by historical groundwater conditions that cannot be avoided;
- Assess the adequacy of the Revised GSP PMAs and sustainable management criteria (SMC) to address undesirable results related to land subsidence in the Subbasin; and

- Provide technical analyses to support the development of approaches to managing pumping in the WMA to mitigate additional future land subsidence through shifting groundwater pumping from the Lower Aquifer to the Upper Aquifer in conjunction with enhanced recharge efforts, in accordance with the GSP.

## Scope of Work

The scope of work involved in completion of this Workplan includes seven main tasks, including collection and analysis of existing data (beyond data compiled for the Revised GSP) and review of data gaps, installation of new monitoring facilities and collection of additional field data, completion of additional technical analyses, stakeholder outreach, and preparation of an updated assessment of the adequacy of the Revised GSP SMC and PMAs to address land subsidence. The scope of work to implement the Workplan is described in more detail below. Implementation of the potential work set-forth herein is predicated on Groundwater Sustainability Agency (GSA) approval and allocation of the necessary funds as may be required (local funding and/or grants).

### *Task 1: Compile Additional Existing Data and Update Assessment of Available Data*

#### Compile and Review Supplemental Existing Data

In this task, data collected during preparation of the Revised GSP will be supplemented with other newly available data related to groundwater levels and land subsidence in the Subbasin and surrounding areas, with specific focus on the WMA. Available supplemental data may include the following:

- information presented in GSPs for other subbasins;
- data related to the Subsidence Control Measures Agreement (Subsidence Agreement) between certain landowners in the WMA of the Subbasin, the Central California Irrigation District (CCID), and San Luis Canal Company;
- new data from specific local landowners or entities previously not available for incorporation into the Revised GSP;
- DWR Well Completion Reports (WCRs) for the WMA;
- additional data compiled by USBR for the SJRRP for areas in the Subbasin;
- additional data from the United States Geological Survey (USGS) and modeling information for their study of the San Joaquin River; and
- other reports and data.

The available data will be compiled and reviewed to inform subsequent field work (Task 2) and used as inputs for technical analyses (Task 3). This task can be performed in coordination with similar efforts planned as part of implementation of the Interconnected Surface Water (ISW) Workplan proposed for the Subbasin.

## AEM Data

Data from airborne electromagnetic (AEM) surveys conducted in Spring 2022 to support additional characterization of subsurface conditions in the Subbasin and surrounding areas are expected to be available around the end of 2022. AEM data can provide helpful information on hydrogeologic conditions through measurements of the resistivity of subsurface materials. These surveys have the potential to improve the understanding of the configuration and composition of different subsurface materials. To the extent that AEM data were collected in the Subbasin and within the WMA, these data will be evaluated for their potential usefulness in helping to supplement the delineation of stratigraphy, especially within the Lower Aquifer where most of the historical and ongoing compaction is believed to occur. A quality assurance/quality control (QA/QC) analysis of the data will be conducted by comparing AEM hydrostratigraphic interpretations to existing and new field data collected as described in this Workplan and in coordination with efforts related to implementation of the ISW Workplan developed for the Subbasin. Lithologic data from borehole logs along AEM section lines will be compared to evaluate if AEM interpretations are consistent with field data. If AEM data interpretations are found to be consistent and the resolution of stratigraphic interpretations from the AEM data are sufficient, the AEM data will be combined with field borehole lithologic data to develop refined characterization of subsurface geologic materials and stratigraphic configuration, including the depth and thickness of prominent clay layers, including the Corcoran Clay.

## *Task 2: Complete Additional Field Work*

Enhancements to groundwater level monitoring facilities and activities, specifically within the WMA and in proximity to sites with historical land subsidence monitoring (e.g., SJRRP benchmarks) and planned future land subsidence monitoring, are important for improving the understanding of the relationships between groundwater levels and land subsidence across the Subbasin. Developing continuous groundwater level monitoring at finer temporal scales and at different depths in key areas where land subsidence monitoring is conducted will support understanding of the relationship between groundwater levels at different depths and any associated land subsidence, and will help differentiate residual land subsidence caused by historical groundwater conditions from active land subsidence related to current and future conditions. Instrumentation of suitably-located existing wells and installation of additional dedicated monitoring wells are two approaches that will be pursued to enhance the groundwater level monitoring in key areas for relating with land subsidence. Use of existing wells provides a cost-effective approach to enhancing the groundwater monitoring program and can reduce the need for installation of new monitoring wells, which can be more costly.

Historical and current land subsidence monitoring in the Subbasin consists of periodic benchmark surveys and remote sensing data collection. These land subsidence monitoring techniques do not differentiate the depth interval at which land subsidence is occurring. Data from nearby land subsidence monitoring sites near Mendota conducted with a combination of extensometer readings and continuous GPS readings together with data from land subsidence monitoring across the San Joaquin Valley suggests the inelastic compaction that is leading to land subsidence is likely occurring in fine-grained materials within the Lower Aquifer. Field work to install land subsidence monitoring facilities at a key location in the Subbasin would benefit the understanding of how compaction at different depth zones (i.e., Upper and Lower Aquifer) contributes to the total land subsidence occurring in the Subbasin.

## Identification and Instrumentation of Existing Wells

This task will include identifying and prioritizing existing wells in key land subsidence monitoring locations for instrumentation with automated continuous groundwater level monitoring equipment. Potential use of existing wells to enhance groundwater level monitoring in key areas of interest, especially near SJRRP land subsidence monitoring benchmarks, will be considered as the first step in efforts to improve groundwater monitoring for developing information to inform the assessment of the dynamics between groundwater levels and land subsidence. Use of existing wells for groundwater level monitoring is a cost-effective way to monitor groundwater conditions for the purpose of relating to land subsidence. This task involves working to identify existing wells with suitable well construction characteristics (e.g., well depth, screen interval) in key areas of interest for potential instrumentation and continuous groundwater level monitoring. Existing wells of interest for instrumentation in key areas will target wells completed (screened) within the Lower Aquifer since land subsidence in the Subbasin is believed to be primarily a result of lowered groundwater levels in the Lower Aquifer. However, wells representing conditions within the Upper Aquifer will also be considered as potential opportunities to evaluate any relationships between groundwater levels in the Upper Aquifer and observed land subsidence. Additionally, existing wells should be evaluated for inclusion in the land subsidence monitoring network. Wells that would be beneficial for inclusion in this network should be surveyed on a bi-annual basis. The identification and instrumentation of existing wells will enhance the understanding of relationships between groundwater levels and land subsidence for the purpose of evaluating land subsidence SMC and use of groundwater levels as a proxy, as defined in the Revised GSP. Furthermore, this work will also support enhancements to the Subbasin's RMS network (if necessary and beneficial) and other ongoing groundwater level monitoring activities used to support GSP annual reporting efforts in the future.

The task involves working with the owners of suitable wells in key monitoring areas to prioritize and implement instrumentation of existing wells with automated pressure transducers for collecting continuous groundwater level data to limit the need for constructing new monitoring wells. As part of this task the feasibility and benefits of instrumenting RMS wells that are already part of the GSP groundwater level monitoring network will be considered. It is assumed for purposes of estimating the cost of implementing the Workplan that a total of up to four existing wells (RMS and other) will be identified and selected for instrumentation.

## New Monitoring Facilities

This task will identify and install new monitoring wells and new land subsidence monitoring facilities in key areas of the Subbasin where data gaps exist. Providing robust coupled groundwater level and land subsidence monitoring is important in establishing appropriate groundwater level metrics as a proxy for land subsidence. The presence of critical surface infrastructure in the WMA also warrants enhanced monitoring of groundwater conditions in this area. Enhancements to existing land subsidence monitoring in the Subbasin also have the objective of differentiating land subsidence by depth zone, and would also benefit the understanding of relationships between groundwater levels and land subsidence. Current and continuing land subsidence monitoring being conducted by DWR using remote sensing and also as part of the SJRRP benchmark surveying provide broad spatial and temporal coverage of land subsidence, although they do not differentiate the depth where land subsidence is occurring and relationships to groundwater levels. Proposed field efforts related to addressing these objectives are described in more detail below.

## *New Monitoring Wells*

Monitoring wells are recommended for installation at five locations based on considerations related to locations of critical infrastructure, historical land subsidence, existing SJRRP benchmark survey sites, and existing groundwater level monitoring (especially groundwater level RMS and dedicated monitoring well locations). These monitoring wells will augment existing groundwater level monitoring for enhanced monitoring of groundwater conditions in key areas of the Subbasin and to support improved understanding of the dynamics between groundwater levels and land subsidence. Four proposed locations are within the WMA where the greatest amount of historical land subsidence has occurred in the Subbasin. One additional proposed location is more central to the Subbasin, and although located outside of the WMA, is in an area where more than four feet of land subsidence has been measured since 2007 and where dedicated groundwater level monitoring facilities in proximity to an existing SJRRP benchmark survey site will provide high-resolution monitoring of groundwater level conditions within different parts of the groundwater system to support sustainable groundwater management objectives. New monitoring wells will be designed to include nested monitoring wells for independent monitoring of conditions in the Upper and Lower Aquifers. The new monitoring wells are anticipated to extend to depths of approximately 700 to 800 feet and consist of three independent casing strings screened at different depths, depending on unique site conditions. Additionally, new monitoring wells should be surveyed upon installation, and on a bi-annual basis, for inclusion in the land subsidence monitoring network. Preliminarily identified priority locations for potential new nested wells are shown in **Figure 1** along with key information considered in preliminary site identification. Final site selection will consider the outcome from review of additional data and evaluation of site suitability relating to access for construction and ongoing monitoring.

The monitoring wells are planned to be drilled using the direct rotary drilling method with sediment samples collected every ten feet and downhole geophysical logging completed over the entire depth of the boreholes. A lithologic log of the borehole will be prepared based on samples collected and results from geophysical logging under the supervision and guidance of a Professional Geologist, who will also provide recommendations regarding well construction details such as depth intervals for placement of well screen, filter pack, blank casing, and surface sanitary seal. Preliminarily, the new monitoring wells are planned to be constructed using 2-inch diameter Schedule 40 PVC materials, which will enable installation of automated groundwater level monitoring instrumentation and also provide access for groundwater quality sampling equipment. The new monitoring wells, and any existing wells instrumented as described above, will be surveyed to a consistent elevation datum. Water quality samples will be collected from the new monitoring wells for the purpose of characterizing general geochemical conditions, and they will be outfitted with pressure transducers for ongoing automated collection of groundwater level data.

## *New Land Subsidence Monitoring Facilities*

One location for potential installation of new land subsidence monitoring facilities has been identified along the Eastside Bypass within the WMA. The new land subsidence monitoring facilities would be intended to track land subsidence conditions with high-quality and continuous monitoring of land subsidence at one of the new monitoring well sites through installation of facilities for continuous Global Positioning System (GPS) monitoring or depth-specific monitoring of compaction using an extensometer. The possible location of this potential land subsidence monitoring site is shown on **Figure 1**. The planning of this site should be coordinated with other land subsidence monitoring efforts occurring in the area, including work being conducted as part of the Subsidence Agreement between certain landowners in the WMA of the Subbasin, CCID, and San Luis Canal Company. Furthermore, planning of this monitoring facility should include coordination with other potential cooperators, including the USGS, the California Department of Water Resources (DWR), USBR, and any other interested entities. There may be opportunities to support these monitoring facilities through acquisition of grants or technical support services provided by DWR or through other avenues. The details of the potential land subsidence monitoring facilities should be developed in coordination with any cooperators and with consideration of any new data compiled and evaluated as part of implementation of this Workplan.

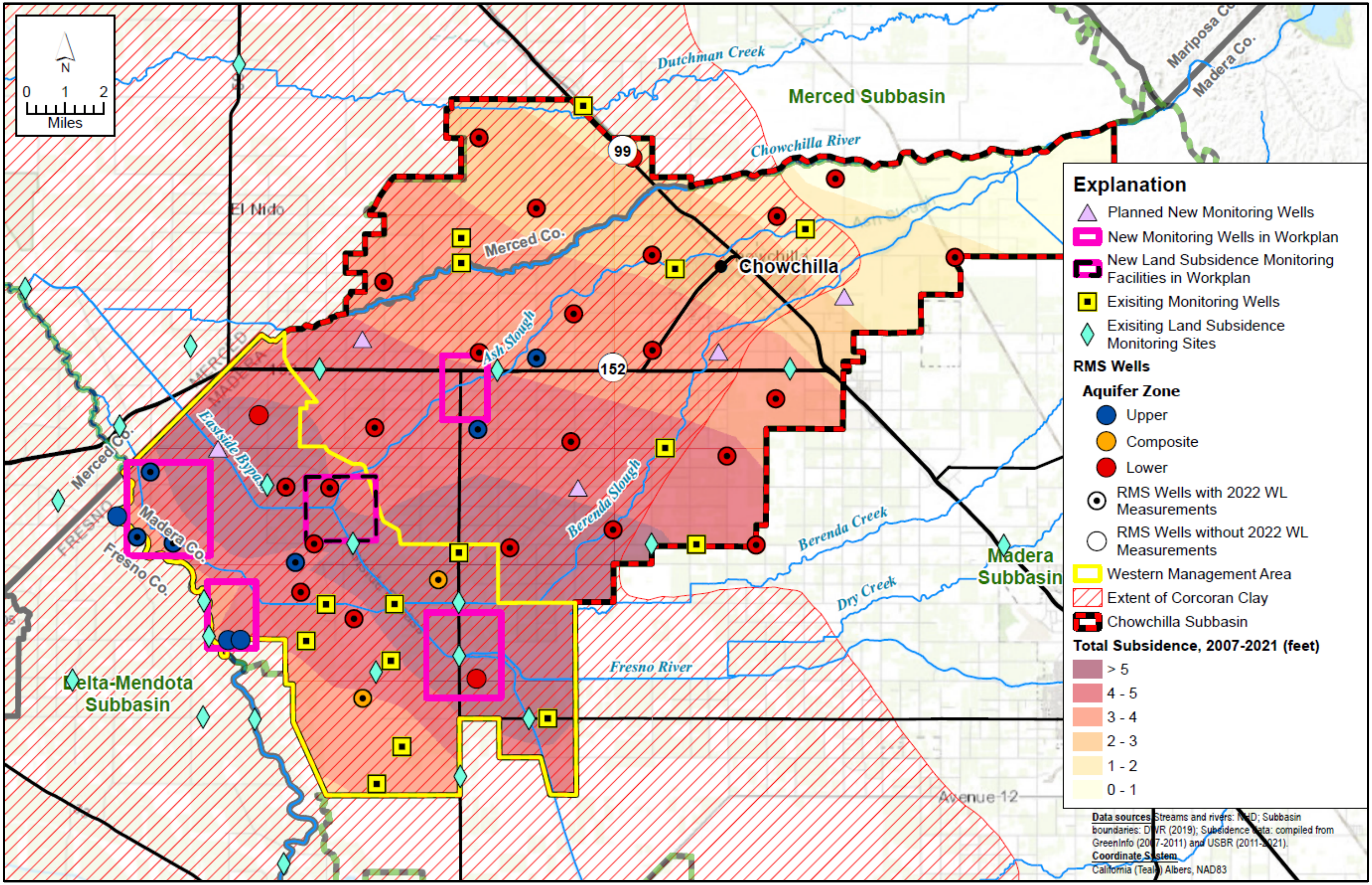



**Figure 1. Potential New Nested Monitoring Well and Land Subsidence Monitoring Sites**

## *Task 3: Technical Analyses*

In this task, technical analyses will be conducted to synthesize the available information on dynamics between groundwater levels and land subsidence in the WMA by evaluating fluctuations in groundwater levels and land subsidence and by evaluating relationships between groundwater pumping and land subsidence. This task will be completed in coordination with and utilizing new information from compilation of additional available data (Task 1) and field work related to additional monitoring and characterization of groundwater conditions and land subsidence (Task 2).

Field and monitoring data will be evaluated relative to the relationship between groundwater levels in both the Upper and Lower Aquifers and land subsidence and consideration of ongoing residual land subsidence. Available information suggests that the lack of clear and consistent relationships between groundwater levels and land subsidence may be partly a result of the continued residual land subsidence resulting from historical conditions. Analyses presented in the Revised GSP based on the limited available historical data suggest that there is limited correlation between shorter-term groundwater level changes and land subsidence, although historical groundwater conditions and the persistence of conditions over longer periods may be the most important drivers related to land subsidence.

Technical analyses will also include conducting refinements to existing available information on the mapped extent and thickness of the Corcoran Clay and other clay layers. This task will involve review of new lithologic information collected through construction of new monitoring wells, including new wells installed at key land subsidence monitoring sites as described in Task 2, and also wells constructed for the ISW Workplan and for other the Subbasin monitoring efforts conducted through Proposition 1 and Proposition 68 grant projects. The ability to incorporate any data developed from the AEM surveys conducted by DWR in the Subbasin will also be considered in these refinements.

## *Task 4: Groundwater Modeling (in Conjunction with 5-Year GSP Update)*

Distinguishing between residual land subsidence resulting from historical groundwater conditions and active land subsidence caused by current conditions is a challenging aspect of evaluating appropriate metrics for ensuring sustainable groundwater management. Modeling techniques represent one of the most robust approaches available for evaluating this aspect of groundwater conditions. Key objectives of the modeling to be conducted under this task include 1) estimating the amount, rate, and duration of residual land subsidence likely to occur resulting from historical groundwater conditions, and 2) estimating total anticipated future land subsidence. Additional modeling to be completed as part of Task 7 will assist in evaluating approaches and mechanisms for ensuring groundwater sustainability is achieved in accordance with the Revised GSP through transitioning of groundwater pumping from the Lower Aquifer to the Upper Aquifer in coordination with projects planned to augment water supplies and enhance recharge. The modeling planned for completion as part of this Workplan is separate from, but will occur in coordination with, other modeling efforts to be completed for the purpose of the first five-year update of the Revised GSP, which are anticipated to focus on general updates to the numerical groundwater flow model developed to support preparation of the GSP (MCSim) involving extending the historical simulation period, updating hydrology, and updating simulations of PMAs included in the Revised GSP.

Two potential modeling approaches would help in evaluating historical and projected land subsidence in the Subbasin and differentiation of residual land subsidence from active land subsidence.

The first modeling approach involves using MCSim. At the time the GSP was initially developed, MCSim did not include the ability to simulate subsurface compaction or land subsidence because the Integrated Water Flow Model (IWFM) modeling platform, upon which MCSim is built, did not include this capability. The ability to simulate land subsidence has since been added to IWFM. The modeling task will include implementing the IWFM subsidence module in MCSim and conducting updated model scenarios to evaluate historical and projected future land subsidence. Groundwater modeling scenarios would be conducted with the primary purpose of estimating future land subsidence under varying future conditions, including varying levels of groundwater pumping and under conditions with and without PMAs described in the Revised GSP.

Updating MCSim with the subsidence module and refined information on active production well distribution developed in previous tasks will improve the accuracy of all model simulations. The MCSim modeling efforts will assist further in understanding the relationship between groundwater levels and land subsidence, both within the Upper Aquifer and Lower Aquifer, continued assessment of mechanisms to limit future land subsidence and avoid adverse impacts, and evaluation of land subsidence SMC to ensure they are appropriate for defining sustainable groundwater management.

The second modeling approach would consider more simplified, one-dimensional modeling techniques to better quantify residual and active land subsidence in localized areas. Such modeling approaches would support a better understanding of site-specific subsidence mechanisms and projections and could assist in evaluation of the use of groundwater levels as an appropriate proxy for land subsidence, although this modeling method presents limitations with respect to the ability to simulate groundwater conditions at the subbasin scale. One-dimensional modeling would complement the use of MCSim to estimate residual land subsidence; the need for this additional modeling will be evaluated during the course of implementation of the Workplan and evaluation of results from technical analyses and MCSim modeling efforts. However, one-dimensional modeling is included for the purpose of estimating the level of effort to implement this Workplan.

### *Task 5: Stakeholder Outreach and Interbasin Coordination*

Implementation of the Workplan should involve outreach and coordination with key stakeholders and interested parties. This would include communication with stakeholders associated with critical infrastructure in and around the WMA. Outreach efforts should focus on efforts related to the need and benefit from additional groundwater level or land subsidence monitoring and prioritization of efforts to expand monitoring. An additional objective of outreach efforts includes coordination related to the understanding of critical land subsidence thresholds related to damage to infrastructure or other adverse impacts to infrastructure. Furthermore, outreach efforts may also benefit considerations related to the feasibility of potential PMAs to achieve sustainability. Outreach and coordination with adjacent subbasins about land subsidence issues will be a continuing aspect of tracking of groundwater level and land subsidence conditions.

### *Task 6: Assess the Adequacy of Revised GSP SMC*

An important outcome from efforts conducted as part of this Workplan will be an assessment of the adequacy of current land subsidence SMC and the need for any revisions to these SMCs as part of updates to the Revised GSP. The assessment will consider data and analyses developed through implementation of Tasks 1 through 5 of the Workplan and relationships between groundwater levels and land subsidence and the differentiation of residual land subsidence from new active subsidence established through that work. The continued occurrence of residual land subsidence is an important consideration related to how land subsidence SMC are established for the Subbasin, since impacts from residual land subsidence are largely unavoidable. The amount of residual land subsidence is something the Revised GSP cannot address or prevent, although the Revised GSP does outline an approach to minimize future land subsidence in an effort to avoid adverse impacts.

The review and assessment of SMC completed under this task will inform decisions on revisions to land subsidence SMC for incorporation in updates to the Revised GSP. Future GSP updates will draw upon the most recent data and technical analyses developed through implementation of this Workplan with consideration for the complexities of the impacts of residual land subsidence resulting from historical conditions that preceded submittal or implementation of the Revised GSP. The outcomes from assessment of SMC will be summarized in deliverable documents to be prepared as part of Task 8. Some data generated through the completion of the field activities outlined in the Workplan may not be available until after completion of the five-year update of the GSP. As described in the scope of work for Task 8, an initial assessment of the SMC will be conducted to support the five-year update of the GSP to be completed by January 2025. A subsequent deliverable document prepared after completion of all field work will include a summary of all Workplan activities.

## *Task 7: Technical Support for Development of a Strategy for Managing Groundwater Pumping and Recharge in the WMA*

An integral aspect of achieving sustainability in the Subbasin involves mitigating future land subsidence to the extent possible, which will require management of groundwater pumping in coordination with enhancing groundwater recharge in the WMA. Task 7 of the Workplan will involve efforts to refine the understanding of existing groundwater pumping and the vertical and lateral distribution of pumping in the WMA as the foundation for developing management approaches to mitigate additional land subsidence caused by pumping. These efforts will include inventorying existing active wells in the WMA through desktop review and field verification coupled with technical analyses to support groundwater management planning in the Subbasin related to reducing pumping from the Lower Aquifer with the intent to mitigate future land subsidence. Key components of this effort are described below.

### Desktop Inventory of Wells in WMA

Documentation of active production wells in the WMA is important for accurately assessing and planning groundwater management activities as they relate to mitigating land subsidence. Achieving groundwater sustainability in the Subbasin, especially in relation to land subsidence, involves ensuring that groundwater extractions do not cause chronic lowering of groundwater levels, especially in the Lower Aquifer. Accurately documenting the locations and construction characteristics of active production wells in the WMA will provide important information for ensuring appropriate management actions are developed and implemented to address this issue. A desktop evaluation of available information on active production wells in the WMA will seek to identify likely active production wells and their construction characteristics, especially as they relate to screened interval and zone of production. The desktop well inventory will utilize data from WCRs, well permits, or other sources and will outline appropriate field work activities to be completed as part of Task 2 to refine information developed through the desktop inventory. To the extent possible, this task will coordinate with work being conducted for the ISW Workplan and will build on previous evaluations performed during the initial development and later revision of the GSP and the domestic well inventory completed as part of a Proposition 68 grant project for the Subbasin along with ongoing mapping of wells conducted by the GSAs.

## Field Survey of Active Production Wells in WMA

The desktop inventory of active production wells in the WMA will provide the basis for outlining field work efforts to refine or confirm the information developed from the desktop inventory (Task 1). The surveying of active production wells in the WMA is anticipated to include targeted efforts to in the WMA utilizing outreach and field reconnaissance. The field survey will likely focus on areas with higher well densities and/or greater levels of uncertainty relating to existing well status and construction characteristics as informed by evaluation of available data and results from the desktop inventory. The field survey may include focused review of aerial photographs, personal communication with landowners, field visits or other field reconnaissance activities, and other approaches to refine information developed from the desktop inventory.

## Refined Analyses of Pumping Distribution in the WMA

Using information assembled through the well inventory tasks in conjunction with data related to groundwater demands derived from groundwater modeling and other water budget analyses, refinements to the assessments of the volumes and spatial distribution (laterally and vertically) of pumping in the WMA will be conducted. The primary objective of this task will be to refine estimates of the amount of groundwater pumping that is occurring in the Lower Aquifer as it relates to the sustainability planning for the Subbasin. The results from this task will inform efforts related to assessing PMAs planned to achieve groundwater sustainability.

## Evaluation of Scenarios for PMA Implementation to Mitigate Land Subsidence

Task 7 will include conducting evaluations of approaches and mechanisms for redistributing pumping in the WMA in a manner that is consistent with sustainability goals and metrics defined in the Revised GSP, analysis of costs and other considerations relating to the feasibility of different approaches, and assessing the timing needs associated with implementation of potential management actions. These technical analyses will consider the lateral distribution of pumping within the WMA and the vertical distribution between the Upper and Lower Aquifers. A key aspect of these technical analyses will involve consideration of management approaches that recognize the existing or planned groundwater recharge efforts, which focus on enhancing recharge in the Upper Aquifer, to achieve a distribution of groundwater pumping in the WMA that is consistent with sustainability objectives defined in the Revised GSP. Numerical groundwater modeling will be used to test PMA implementation scenarios and evaluate the effectiveness of different implementation strategies for mitigating land subsidence in the WMA.

## Prepare a Technical Summary Document to Inform Policymaking

A technical summary document will be provided at the conclusion of this task for use by the GSAs in developing management strategies in the WMA to mitigate future subsidence. This document will synthesize technical information developed through completion of the task (and information available from completion of other tasks outlined in the Workplan) relating to how much, where, and when PMAs may be appropriate to achieve necessary reductions of Lower Aquifer pumping in the WMA and potential mechanisms to achieve these reductions. The goal is to provide the GSAs with a technical basis for their development of policies and a plan related to implementation of PMAs to avoid undesirable results related to land subsidence in the WMA. The assessment conducted under this task will consider the importance of developing a strategy that coordinates the management of groundwater pumping in the WMA in conjunction with enhanced groundwater recharge efforts. The technical summary document for Task 7 will be provided as an interim deliverable intended to support the GSA development of management policies, which may need to be implemented prior to the completion of the entire Workplan.

### *Task 8: Prepare a Technical Memorandum or Report*

A technical memorandum (TM) or report will be prepared to document all the tasks completed as part of implementation of this Workplan. An interim TM/Report deliverable will be prepared to inform the five-year GSP update efforts occurring prior to January 2025. A Final TM/Report will be prepared and submitted at the time of completion of all field work outlined in the Workplan. For each of the deliverables prepared as part of Task 8, a draft TM/Report will be submitted to the GSAs (and their technical representatives) for review. Comments and suggested edits received from the GSAs will be reviewed and incorporated as appropriate into final versions of the deliverable documents. The deliverable documents will include documentation of all data compiled, field work completed, technical analyses performed, modeling results, and evaluation of the nature of relationships between groundwater levels and land subsidence, and recommended updates to the Revised GSP SMC and potential management actions to ensure sustainable groundwater management is maintained in the Subbasin. In addition, the deliverable documents will include a review and summary of any remaining data gaps and recommendations for future monitoring and assessment, as needed.

## Schedule

The overall implementation of this Workplan is envisioned as a longer-term effort to develop important monitoring data and facilities for tracking and understanding groundwater conditions related to land subsidence in the Subbasin. However, several tasks are intended to support shorter-term objectives, including the development of a plan for managing groundwater pumping and recharge in the WMA. Additional tasks are geared towards completion in time for incorporation into the first five-year update of the Revised GSP. However, some tasks described in the Workplan will likely extend beyond January 2025, including ongoing data collection. These longer-term tasks include field work involving installation of monitoring facilities, which should be phased with consideration of funding and cooperation from other entities needed to support these efforts. Implementation of the Workplan is planned to start in 2023 with commencement of the additional data review and compilation task. Similarly, field work is also planned to begin in 2023, primarily with well inventory survey efforts and review of opportunities to instrument existing wells. Planning related to field work including the installation of new dedicated monitoring facilities for groundwater levels and land subsidence should begin in early 2023, although the completion of this work is anticipated to extend over multiple years. As a result, not all of the field work described in this Workplan is anticipated to be completed prior to January 2025 when the first five-year update of the Revised GSP is to be submitted. A general planned schedule for implementation of the Workplan is outlined below in Table 1.

**Table 1. Summary of Proposed Schedule for Implementation of the Land Subsidence Workplan**

| Task No. | Task Description | Task Completion Timeframe |
|---|---|---|
| 1 | Compile Additional Existing Data and Update Assessment of Available Data | Mid 2023 - Late 2023 |
| 2 | Complete Additional Field Work | Late 2023 - 2026+ (field work may be phased depending on available funding) |
| 3 | Technical Analyses | Mid 2023 - Late 2024 |
| 4 | Groundwater Modeling (in Conjunction with 5-Year GSP Update) | Early 2024 - Late 2024 |
| 5 | Stakeholder Outreach and Interbasin Coordination | Early 2023 - Late 2024+ |
| 6 | Assess the Adequacy of Revised GSP SMC | Late 2023 - Late 2024 |
| 7 | Technical Support for Development of a Strategy for Managing Groundwater Pumping and Recharge in the WMA | Early 2023 - Early/Mid 2024 |
| 8 | Prepare a Technical Memorandum or Report | Mid 2024 - Late 2024 for interim deliverable; 2026+ for final deliverable |

Luhdorff & Scalmanini
Consulting Engineers

# TECHNICAL MEMORANDUM

DATE: July 18, 2024 Project No. 23-1-048

TO: Chowchilla Subbasin GSAs

FROM: LSCE and DE

**SUBJECT: Chowchilla Subbasin Revised GSP (July 2024) - Land Subsidence Workplan**

## Introduction and Background

Some areas of the Chowchilla Subbasin (Subbasin) have experienced considerable historical land subsidence, as documented in the Revised Groundwater Sustainability Plan (GSP) for the Subbasin. Much of the historical land subsidence in the Subbasin is believed to be caused by declining groundwater levels or piezometric head within the Lower Aquifer below the Corcoran Clay[2], and associated release of water from fine-grained sediments, ultimately resulting in compaction of these fine-grained sediments. In other areas of the San Joaquin Valley with long-term historical monitoring of both land subsidence and groundwater levels, land subsidence has been correlated with declining groundwater levels in the Lower Aquifer. Furthermore, considerable lag time between declining groundwater levels and land subsidence has been observed in other areas of the San Joaquin Valley.

Within the Subbasin, limited long-term data are available for land subsidence. As a result, there are gaps in the understanding of mechanisms and conditions related to land subsidence in the Subbasin, especially as it relates to how historical groundwater level decline may continue to cause ongoing residual land subsidence in the Subbasin, even as groundwater levels stabilize or rise in the future, as is planned for in the Revised GSP.

The Revised GSP establishes sustainable management criteria (SMC) for land subsidence with consideration of DWR review and input received in the initial GSP consultation letter, the DWR March 2022 inadequate determination, and SWRCB review and input received in 2023/2024. The revised SMC for subsidence are all established as rates of subsidence, measured from subsidence benchmarks, with consideration for the cumulative amount of subsidence. Groundwater levels are no longer used as a proxy for subsidence in the Subbasin.

[2] The Corcoran Clay (E-Clay of the Tulare Formation) is a laterally extensive and thick layer of clay present across large areas of the Subbasin and functions as a confining layer hydraulically separating the Upper Aquifer from the Lower Aquifer, where it exists.

Additional characterization of land subsidence conditions – including the relationship between groundwater levels and land subsidence – and evaluation of mechanisms for mitigating future land subsidence are important for ensuring that the GSAs successfully achieve the Subbasin sustainability goal. This Workplan is intended to provide additional field data and technical analyses as input to better characterizing land subsidence for future GSP updates.

The Workplan outlines future efforts intended to address data gaps identified in the Revised GSP through enhanced monitoring and improving understanding of relationships between groundwater conditions and land subsidence in the Subbasin. The workplan also includes tasks to further evaluate sustainable management criteria (SMC) for land subsidence and support development of a coordinated approach to implementation of projects and management actions (PMAs) presented in the Revised GSP to address land subsidence and achieve sustainable groundwater management.

## Information Summarized in Revised GSP

As summarized in the Revised GSP, historical documentation of land subsidence in the Subbasin indicated limited land subsidence prior to the early 1970s (see Revised GSP Figure 2-66). More recent monitoring using remote sensing information and data collected from benchmark surveys conducted for the San Joaquin River Restoration Program (SJRRP) has shown an increase in land subsidence in parts of the Subbasin since the mid-2000s. Over the period from 2007 through 2021, cumulative vertical displacement ranged from almost zero to more than six feet, with most land subsidence during this period focused in the western part of the Subbasin (see Revised GSP Figure 2-67). The Revised GSP identifies a Western Management Area (WMA) where greater amounts of historical subsidence have occurred and where more focused management of groundwater is planned to mitigate impacts to critical infrastructure from future land subsidence.

Although there is considerable historical monitoring of land subsidence in the Subbasin, most of this monitoring has occurred at infrequent temporal intervals and with varying spatial resolution and distribution. Historical monitoring of groundwater levels, especially to support understanding of relationships between groundwater levels and land subsidence, has also been limited in most of the Subbasin. The Revised GSP summarizes historical groundwater level and land subsidence monitoring and available data to directly compare groundwater levels and land subsidence (see Revised GSP Figures 2-70a and 2-70b). The available data do not indicate clear and consistent relationships between groundwater levels and land subsidence in the Subbasin, largely because of limitations in the temporal and spatial distribution of available historical monitoring data, and also because of the ongoing occurrence of residual land subsidence, which is discussed more below.

Under the Revised GSP, the GSAs will evaluate land subsidence by monitoring the vertical displacement of the land surface. The land subsidence monitoring network is comprised of elevation benchmark survey points monitored by the United States Bureau of Reclamation (USBR) as part of the SJRRP. However, it is important to understand the relationship between groundwater levels and land subsidence in order to evaluate PMA implementation and ongoing basin management, and to evaluate the potential for historical groundwater level decline to continue to cause ongoing residual land subsidence in the Subbasin, even as groundwater levels stabilize or rise in the future.

## Data Gaps Identified in Revised GSP

As discussed in the Revised GSP, key aspects of land subsidence in the Subbasin that are not well understood or quantified relate to:

- The mechanisms and conditions causing land subsidence in the Subbasin, including the relationship between land subsidence and declining groundwater levels, especially in the Lower Aquifer, within the local context of the Subbasin; and
- Residual land subsidence, specifically differentiating residual land subsidence caused by historical conditions from new land subsidence caused by current conditions.

Robust land subsidence monitoring coupled with well-defined groundwater level monitoring will be important for tracking the different mechanisms related to land subsidence. Expansion of the land subsidence monitoring network will fill the spatial data gap noted in the Revised GSP and benefit the understanding and monitoring of potential subsidence in the Subbasin.

The Revised GSP noted the potential opportunities and benefits related to improving the understanding of relationships between groundwater levels and land subsidence from:

- Continued monitoring of existing benchmarks, including the many land subsidence benchmarks in the Subbasin that are monitored by the United States Bureau of Reclamation (USBR) as part of the SJRRP, and addition of new benchmark locations throughout the Subbasin, and
- Potential installation of continuous GPS or other monitoring facilities, in conjunction with coupling groundwater level monitoring in the vicinity of sites with historical and ongoing land subsidence monitoring.

## Workplan Objectives and Overview

This Workplan outlines a proposed scope of work to compile and review additional data and reports pertaining to land subsidence in the Subbasin, improve understanding of active production wells, establish or construct additional monitoring facilities, and conduct additional technical analyses. The Workplan incorporates consideration of comments and guidance provided by DWR (during the initial GSP review and consultation stages) and comments provided by the SWRCB in 2023/2024 after the DWR Inadequate Determination. The purpose of this scope of work is to provide sufficient data and analyses to:

- Enhance monitoring and understanding of relationships between land subsidence and groundwater levels at different depths within the western part of the Subbasin;
- Expand land subsidence monitoring network throughout Subbasin (i.e., new elevation benchmark survey points);
- Refine mapping of geologic conditions related to land subsidence, including the thickness and extent of the Corcoran Clay and other clay units;
- Improve quantification of groundwater pumping within each of the two principal aquifers (Upper and Lower Aquifer), particularly in the western portion of the subbasin;
- Develop estimates of the amount of expected residual land subsidence caused by historical groundwater conditions that cannot be avoided;

- Assess the adequacy of the Revised GSP PMAs and sustainable management criteria (SMC) to address undesirable results related to land subsidence in the Subbasin; and
- Provide technical analyses to support the development of approaches to managing pumping in the WMA to mitigate additional future land subsidence through shifting groundwater pumping from the Lower Aquifer to the Upper Aquifer in conjunction with enhanced recharge efforts, in accordance with the GSP.

## Scope of Work

The scope of work involved in completion of this Workplan includes seven main tasks, including collection and analysis of existing data (beyond data compiled for the Revised GSP) and review of data gaps, installation of new monitoring facilities and collection of additional field data, completion of additional technical analyses, stakeholder outreach, and preparation of an updated assessment of the adequacy of the Revised GSP SMC and PMAs to address land subsidence. The scope of work to implement the Workplan is described in more detail below. Implementation of the potential work set-forth herein is predicated on Groundwater Sustainability Agency (GSA) approval and allocation of the necessary funds as may be required (local funding and/or grants).

### *Task 1: Compile Additional Existing Data and Update Assessment of Available Data*

#### Compile and Review Supplemental Existing Data

In this task, data collected during preparation of the Revised GSP will be supplemented with other newly available data related to groundwater levels and land subsidence in the Subbasin and surrounding areas. Available supplemental data may include the following:

- information presented in GSPs for other subbasins;
- data related to the Subsidence Control Measures Agreement (Subsidence Agreement) between certain landowners in the WMA of the Subbasin, the Central California Irrigation District (CCID), and San Luis Canal Company;
- new data from specific local landowners or entities previously not available for incorporation into the Revised GSP, including recent (mid-2024) critical infrastructure interviews with infrastructure operators/managers in Madera County;
- DWR Well Completion Reports (WCRs) for the WMA;
- additional data compiled by USBR for the SJRRP for areas in the Subbasin;
- additional data from the United States Geological Survey (USGS) and modeling information for their study of the San Joaquin River; and
- other reports and data.

The available data will be compiled and reviewed to inform subsequent field work (Task 2) and used as inputs for technical analyses (Task 3). This task can be performed in coordination with similar efforts planned as part of implementation of the Interconnected Surface Water (ISW) Workplan proposed for the Subbasin.

## AEM Data

Data from airborne electromagnetic (AEM) surveys conducted in Spring 2022 to support additional characterization of subsurface conditions in the Subbasin and surrounding areas first became available in April 2023. AEM data can provide helpful information on hydrogeologic conditions through measurements of the resistivity of subsurface materials. These surveys have the potential to improve the understanding of the configuration and composition of different subsurface materials. To the extent that AEM data were collected in the Subbasin, these data will be evaluated for their potential usefulness in helping to supplement the delineation of stratigraphy, especially within the Lower Aquifer where most of the historical and ongoing compaction is believed to occur. A quality assurance/quality control (QA/QC) analysis of the data will be conducted by comparing AEM hydrostratigraphic interpretations to existing and new field data collected as described in this Workplan and in coordination with efforts related to implementation of the ISW Workplan developed for the Subbasin. Lithologic data from borehole logs along AEM section lines will be compared to evaluate if AEM interpretations are consistent with field data. If AEM data interpretations are found to be consistent and the resolution of stratigraphic interpretations from the AEM data are sufficient, the AEM data will be combined with field borehole lithologic data to develop refined characterization of subsurface geologic materials and stratigraphic configuration, including the depth and thickness of prominent clay layers, including the Corcoran Clay.

## *Task 2: Complete Additional Field Work*

Historical and current land subsidence monitoring in the Subbasin consists of periodic benchmark surveys and remote sensing data collection. While there is an existing benchmark survey network monitored by the SJRRP, there is an interest in expanding the benchmark survey network. Nested monitoring wells have been constructed throughout the Subbasin as part of the GSP implementation process. Field work to survey these nested well sites and incorporate some or all of these locations within the benchmark survey network is planned.

However, these land subsidence monitoring techniques do not differentiate the depth interval at which land subsidence is occurring. Data from nearby land subsidence monitoring sites near Mendota conducted with a combination of extensometer readings and continuous GPS readings together with data from land subsidence monitoring across the San Joaquin Valley suggests the inelastic compaction that is leading to land subsidence is likely occurring in fine-grained materials within the Lower Aquifer. Field work to install continuous land subsidence monitoring facilities at a key location in the Subbasin would benefit the understanding of how compaction at different depth zones (i.e., Upper and Lower Aquifer) contributes to the total land subsidence occurring in the Subbasin.

Additionally, enhancements to groundwater level monitoring facilities and activities, specifically in proximity to sites with historical land subsidence monitoring (e.g., SJRRP benchmarks) and planned future land subsidence monitoring, are important for improving the understanding of the relationships between groundwater levels and land subsidence across the Subbasin. Developing continuous groundwater level monitoring at finer temporal scales and at different depths in key areas where land subsidence monitoring is conducted will support understanding of the relationship between groundwater levels at different depths and any associated land subsidence, and will help differentiate residual land subsidence caused by historical groundwater conditions from active land subsidence related to current and future conditions.

Instrumentation of suitably-located existing wells and installation of subsidence benchmark stations at existing dedicated monitoring wells are two approaches that will be pursued to enhance the understanding between groundwater levels and rates of land subsidence. Use of existing wells provides a cost-effective approach to enhancing the groundwater monitoring program and helps reduce the need for installation of new monitoring wells (to correlate with land subsidence measurements), which can be more costly.

## Identification and Instrumentation of Existing Wells

This task will include identifying and prioritizing existing wells in key land subsidence monitoring locations for surveying for inclusion in the benchmark survey network or for instrumentation with automated continuous groundwater level monitoring equipment.

The current nested monitoring well network (shown in relationship to the current benchmark survey network in **Figure 1**) provides an existing and accessible location for establishing new benchmark survey locations. This task involves conducting an official GPS survey of these nested monitoring locations and establishing a benchmark to serve as the surveying point for future monitoring. The number of nested monitoring wells that will be surveyed is subject to cost and usefulness for filling in data gaps within the Subbasin benchmark survey network.

Additionally, potential use of existing wells to enhance groundwater level monitoring in key areas of interest, especially near SJRRP land subsidence monitoring benchmarks, will be considered as the first step in efforts to improve groundwater monitoring for developing information to inform the assessment of the dynamics between groundwater levels and land subsidence. Use of existing wells for groundwater level monitoring is a cost-effective way to monitor groundwater conditions for the purpose of relating to land subsidence. This task involves working to identify existing wells with suitable well construction characteristics (e.g., well depth, screen interval) in key areas of interest for potential instrumentation and continuous groundwater level monitoring. Existing wells of interest for instrumentation in key areas will target wells completed (screened) within the Lower Aquifer since land subsidence in the Subbasin is believed to be primarily a result of lowered groundwater levels in the Lower Aquifer. However, wells representing conditions within the Upper Aquifer will also be considered as potential opportunities to evaluate any relationships between groundwater levels in the Upper Aquifer and observed land subsidence. Additionally, existing wells will be evaluated for inclusion in the land subsidence monitoring network. Wells that would be beneficial for inclusion in this network should be surveyed on a bi-annual basis. The identification and instrumentation of existing wells will enhance the understanding of relationships between groundwater levels and land subsidence for the purpose of evaluating land subsidence SMC. Furthermore, this work will also support enhancements to the Subbasin's RMS network (if necessary and beneficial) and other ongoing groundwater level monitoring activities used to support GSP annual reporting efforts in the future.

The task involves working with the owners of suitable wells in key monitoring areas to prioritize and implement instrumentation of existing wells with automated pressure transducers for collecting continuous groundwater level data. As part of this task the feasibility and benefits of instrumenting RMS wells that are already part of the GSP groundwater level monitoring network will be considered. It is assumed for purposes of estimating the cost of implementing the Workplan that a total of up to four existing wells (RMS and other) will be identified and selected for instrumentation.

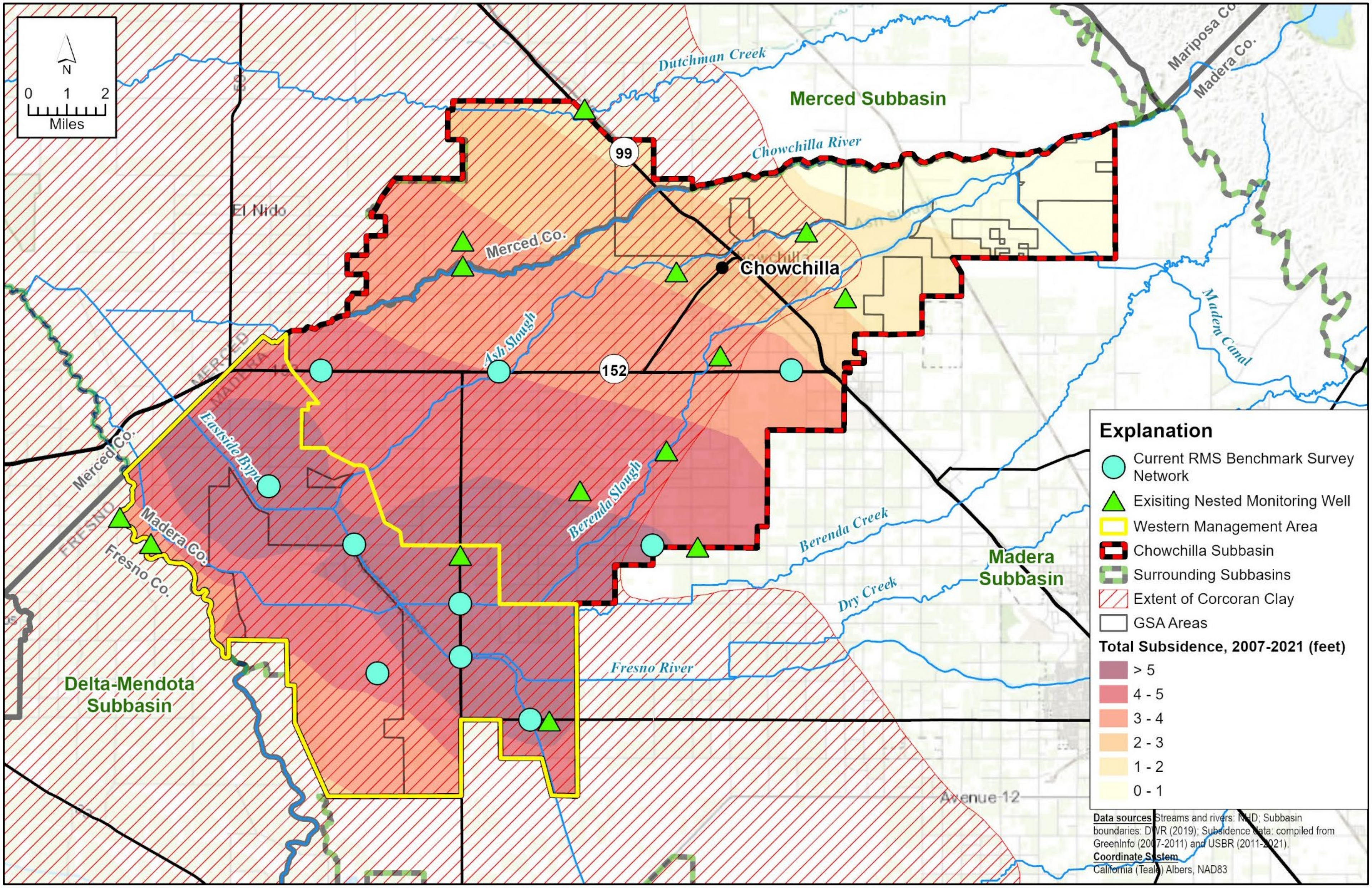



**Figure 1. Current Land Subsidence RMS Monitoring Sites and Nested Monitoring Well Locations**

## New Land Subsidence Monitoring Facilities

This task will identify and install new land subsidence monitoring facilities in key areas of the Subbasin where data gaps exist. Providing robust coupled groundwater level and land subsidence monitoring is important in evaluating the mechanisms of residual subsidence and differentiating residual subsidence caused by historical conditions from new subsidence. The presence of critical surface infrastructure in the subbasin also warrants enhanced monitoring of groundwater conditions in certain areas. Understanding the relationships between groundwater levels and subsidence, in particular residual subsidence, will help implementation of PMAs near critical infrastructure to be the most effective. Proposed field efforts related to addressing these objectives are described in more detail below.

The Chowchilla Subbasins GSAs are currently involved in discussions with DWR to install between one to three continuous GPS subsidence monitoring stations within the Subbasin. The new land subsidence monitoring facilities would be intended to track land subsidence conditions with high-quality and continuous monitoring of land subsidence at one of the new monitoring well sites through installation of facilities for continuous Global Positioning System (GPS) monitoring. Possible locations of potential land subsidence monitoring sites are shown on **Figure 2**. The planning of these sites should be coordinated with other land subsidence monitoring efforts occurring in the area, including work being conducted as part of the Subsidence Agreement between certain landowners in the WMA of the Subbasin, CCID, and San Luis Canal Company. Furthermore, planning of new monitoring facilities should include coordination with other potential cooperators, including the USGS, the California Department of Water Resources (DWR), USBR, and any other interested entities. The details of the potential land subsidence monitoring facilities should be developed in coordination with any cooperators and with consideration of any new data compiled and evaluated as part of implementation of this Workplan.

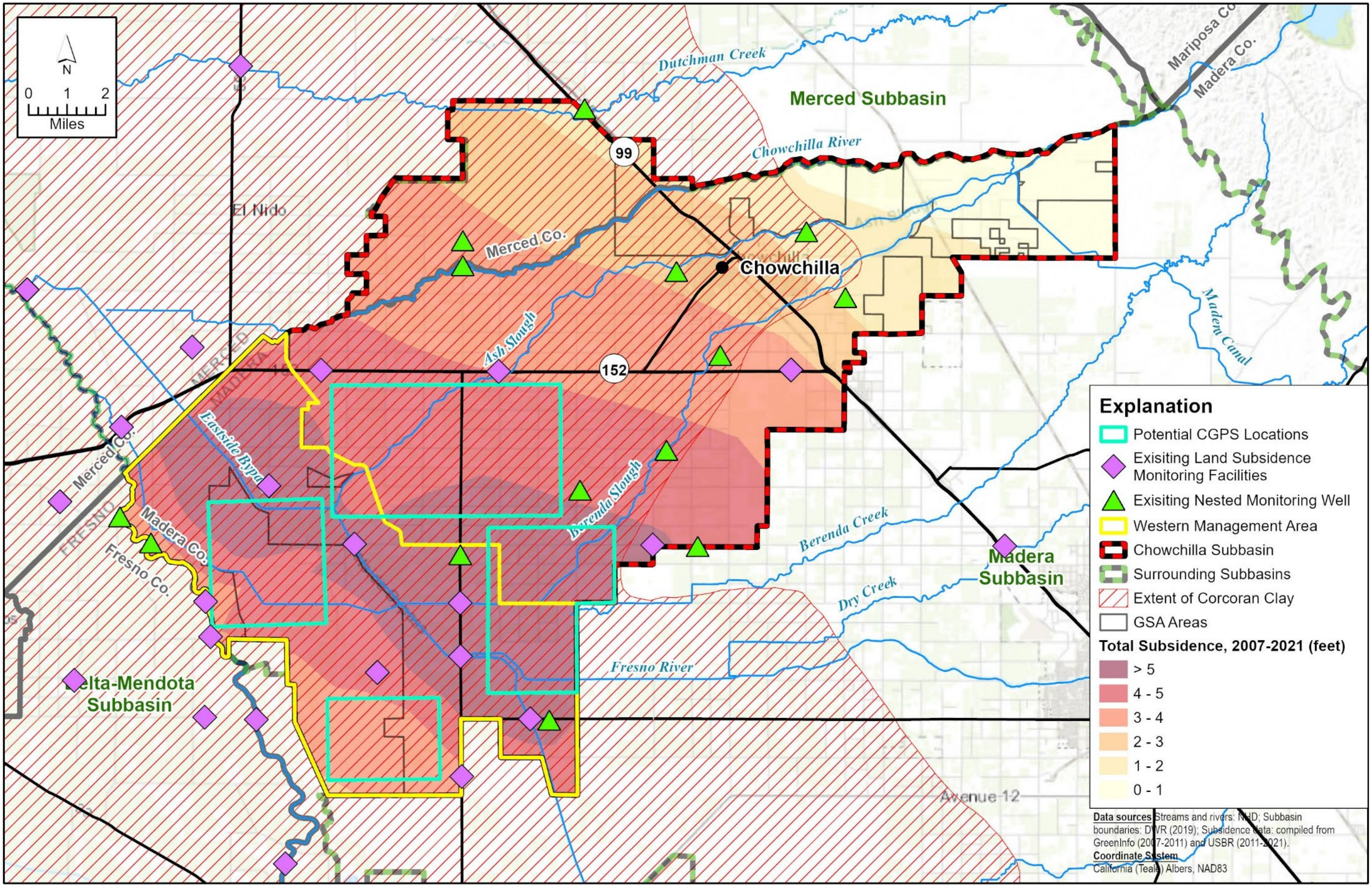



**Figure 2. Potential New Land Subsidence Monitoring Sites**

## *Task 3: Technical Analyses*

In this task, technical analyses will be conducted to synthesize the available information on dynamics between groundwater levels and land subsidence by evaluating fluctuations in groundwater levels and land subsidence and by evaluating relationships between groundwater pumping and land subsidence. This task will be completed in coordination with and utilizing new information from compilation of additional available data (Task 1) and field work related to additional monitoring and characterization of groundwater conditions and land subsidence (Task 2).

Field and monitoring data will be evaluated relative to the relationship between groundwater levels in both the Upper and Lower Aquifers and land subsidence and consideration of ongoing residual land subsidence. Available information suggests that the lack of clear and consistent relationships between groundwater levels and land subsidence may be partly a result of the continued residual land subsidence resulting from historical conditions. Analyses presented in the Revised GSP based on the limited available historical data suggest that there is limited correlation between shorter-term groundwater level changes and land subsidence, although historical groundwater conditions and the persistence of conditions over longer periods may be the most important drivers related to land subsidence.

Technical analyses will also include conducting refinements to existing available information on the mapped extent and thickness of the Corcoran Clay and other clay layers. This task will involve review of new lithologic information collected through construction of dedicated monitoring wells for monitoring efforts conducted through Proposition 1 and Proposition 68 grant projects. The ability to incorporate any data developed from the AEM surveys conducted by DWR in the Subbasin will also be considered in these refinements.

## *Task 4: Groundwater Modeling (in Conjunction with 5-Year GSP Update)*

Distinguishing between residual land subsidence resulting from historical groundwater conditions and active land subsidence caused by current conditions is a challenging aspect of evaluating appropriate metrics for ensuring sustainable groundwater management. Modeling techniques represent one of the most robust approaches available for evaluating this aspect of groundwater conditions. Key objectives of the modeling to be conducted under this task include 1) estimating the amount, rate, and duration of residual land subsidence likely to occur resulting from historical groundwater conditions, and 2) estimating total anticipated future land subsidence. Additional modeling to be completed will assist in evaluating approaches and mechanisms for ensuring groundwater sustainability is achieved in accordance with the Revised GSP through transitioning of groundwater pumping from the Lower Aquifer to the Upper Aquifer in coordination with projects planned to augment water supplies and enhance recharge. The modeling planned for completion as part of this Workplan is separate from, but will occur in coordination with, other modeling efforts to be completed for the purpose of the first periodic evaluation of the Revised GSP.

Two potential modeling approaches would help in evaluating historical and projected land subsidence in the Subbasin and differentiation of residual land subsidence from active land subsidence.

The first modeling approach involves using MCSim. At the time the GSP was initially developed, MCSim did not include the ability to simulate subsurface compaction or land subsidence because the Integrated

Water Flow Model (IWFM) modeling platform, upon which MCSim is built, did not include this capability. The ability to simulate land subsidence has since been added to IWFM. The modeling task will include implementing and calibrating the IWFM subsidence module in MCSim and conducting updated model scenarios to evaluate historical and projected future land subsidence, and is currently underway. Additional groundwater modeling scenarios may be conducted in the future with the primary purpose of estimating future land subsidence under varying future conditions, including varying levels of groundwater pumping and under conditions with and without PMAs described in the Revised GSP.

Updating MCSim with the subsidence module and refined information on active production well distribution developed in previous tasks will improve the accuracy of all model simulations. The MCSim modeling efforts will assist further in understanding the relationship between groundwater levels and land subsidence, both within the Upper Aquifer and Lower Aquifer, continued assessment of mechanisms to limit future land subsidence and avoid adverse impacts, and evaluation of land subsidence SMC to ensure they are appropriate for defining sustainable groundwater management.

The second modeling approach would consider more simplified, one-dimensional modeling techniques to better quantify residual and active land subsidence in localized areas. Such modeling approaches would support a better understanding of site-specific subsidence mechanisms and projections and could assist in evaluation of the use of groundwater levels as an appropriate proxy for land subsidence, although this modeling method presents limitations with respect to the ability to simulate groundwater conditions at the subbasin scale. One-dimensional modeling would complement the use of MCSim to estimate residual land subsidence; the need for this additional modeling will be evaluated during the course of implementation of the Workplan and evaluation of results from technical analyses and MCSim modeling efforts. However, one-dimensional modeling is included for the purpose of estimating the level of effort to implement this Workplan.

## *Task 5: Stakeholder Outreach and Interbasin Coordination*

Implementation of the Workplan should involve outreach and coordination with key stakeholders and interested parties. This would include communication with stakeholders associated with critical infrastructure in the Subbasin. Outreach efforts should focus on efforts related to the need and benefit from additional groundwater level or land subsidence monitoring and prioritization of efforts to expand monitoring. An additional objective of outreach efforts includes coordination related to the understanding of critical land subsidence thresholds related to damage to infrastructure or other adverse impacts to infrastructure. Furthermore, outreach efforts may also benefit considerations related to the feasibility of potential PMAs to achieve sustainability. Outreach and coordination with adjacent subbasins about land subsidence issues will be a continuing aspect of tracking of groundwater level and land subsidence conditions.

## *Task 6: Assess the Adequacy of Revised GSP SMC*

An important outcome from efforts conducted as part of this Workplan will be an assessment of the adequacy of current land subsidence SMC and the need for any revisions to these SMCs as part of updates to the Revised GSP. The assessment will consider data and analyses developed through implementation of Tasks 1 through 5 of the Workplan and relationships between groundwater levels and land subsidence and the differentiation of residual land subsidence from new active subsidence established through that work. The continued occurrence of residual land subsidence is important to understand in relation to the land subsidence SMC established for the Subbasin. The amount of residual land subsidence expected to occur under a given future scenario of PMA and groundwater level conditions may be better understood following application of use of the modeling tools described in this workplan.

The review and assessment of SMC completed under this task will inform decisions on potential revisions to land subsidence SMC for incorporation in updates to the Revised GSP. Future GSP updates will draw upon the most recent data and technical analyses developed through implementation of this Workplan with consideration for the complexities of the impacts of residual land subsidence resulting from historical conditions that preceded submittal or implementation of the Revised GSP. The outcomes from assessment of SMC will be summarized in deliverable documents to be prepared as part of Task 8.

## *Task 7: Technical Support for Development of a Strategy for Managing Groundwater Pumping and Recharge in the WMA*

An integral aspect of achieving sustainability in the Subbasin involves mitigating future land subsidence to the extent possible, which will require management of groundwater pumping in coordination with enhancing groundwater recharge in the WMA. Task 7 of the Workplan will involve efforts to refine the understanding of existing groundwater pumping and the vertical and lateral distribution of pumping in the WMA as the foundation for developing management approaches to mitigate additional land subsidence caused by pumping. These efforts will include inventorying existing active wells in the WMA through desktop review and field verification coupled with technical analyses to support groundwater management planning in the Subbasin related to reducing pumping from the Lower Aquifer with the intent to mitigate future land subsidence. Key components of this effort are described below.

### Desktop Inventory of Wells in WMA

Documentation of active production wells in the WMA is important for accurately assessing and planning groundwater management activities as they relate to mitigating land subsidence. Achieving groundwater sustainability in the Subbasin, especially in relation to land subsidence, involves ensuring that groundwater extractions do not cause chronic lowering of groundwater levels, especially in the Lower Aquifer. Accurately documenting the locations and construction characteristics of active production wells in the WMA will provide important information for ensuring appropriate management actions are developed and implemented to address this issue. A desktop evaluation of available information on active production wells in the WMA will seek to identify likely active production wells and their construction characteristics, especially as they relate to screened interval and zone of production. The desktop well inventory will utilize data from WCRs, well permits, or other sources and will outline appropriate field work activities to be completed as part of Task 2 to refine information developed through the desktop inventory. To the extent possible, this task will coordinate with work being conducted for the ISW Workplan and will build on previous evaluations performed during the initial development and later revision of the GSP and the domestic well inventory completed as part of a Proposition 68 grant project for the Subbasin along with ongoing mapping of wells conducted by the GSAs.

## Field Survey of Active Production Wells in WMA

The desktop inventory of active production wells in the WMA will provide the basis for outlining field work efforts to refine or confirm the information developed from the desktop inventory (Task 1). The surveying of active production wells in the WMA is anticipated to include targeted efforts in the WMA utilizing outreach and field reconnaissance. The field survey will likely focus on areas with higher well densities and/or greater levels of uncertainty relating to existing well status and construction characteristics as informed by evaluation of available data and results from the desktop inventory. The field survey may include focused review of aerial photographs, personal communication with landowners, field visits or other field reconnaissance activities, and other approaches to refine information developed from the desktop inventory.

## Refined Analyses of Pumping Distribution in the WMA

Using information assembled through the well inventory tasks in conjunction with data related to groundwater demands derived from groundwater modeling and other water budget analyses, refinements to the assessments of the volumes and spatial distribution (laterally and vertically) of pumping in the WMA will be conducted. The primary objective of this task will be to refine estimates of the amount of groundwater pumping that is occurring in the Lower Aquifer as it relates to the sustainability planning for the Subbasin. The results from this task will inform efforts related to assessing PMAs planned to achieve groundwater sustainability.

## Evaluation of Scenarios for PMA Implementation to Mitigate Land Subsidence

Task 7 will include conducting evaluations of approaches and mechanisms for redistributing pumping in the WMA in a manner that is consistent with sustainability goals and metrics defined in the Revised GSP, analysis of costs and other considerations relating to the feasibility of different approaches, and assessing the timing needs associated with implementation of potential management actions. These technical analyses will consider the lateral distribution of pumping within the WMA and the vertical distribution between the Upper and Lower Aquifers. A key aspect of these technical analyses will involve consideration of management approaches that recognize the existing or planned groundwater recharge efforts, which focus on enhancing recharge in the Upper Aquifer, to achieve a distribution of groundwater pumping in the WMA that is consistent with sustainability objectives defined in the Revised GSP. Numerical groundwater modeling will be used to test PMA implementation scenarios and evaluate the effectiveness of different implementation strategies for mitigating land subsidence in the WMA.

## Prepare a Technical Summary Document to Inform Policymaking

A technical summary document will be provided at the conclusion of this task for use by the GSAs in developing management strategies in the WMA to mitigate future subsidence. This document will synthesize technical information developed through completion of the task (and information available from completion of other tasks outlined in the Workplan) relating to how much, where, and when PMAs may be appropriate to achieve necessary reductions of Lower Aquifer pumping in the WMA and potential mechanisms to achieve these reductions. The goal is to provide the GSAs with a technical basis for their development of policies and a plan related to implementation of PMAs to avoid undesirable results related to land subsidence in the WMA. The assessment conducted under this task will consider the importance of developing a strategy that coordinates the management of groundwater pumping in the WMA in conjunction with enhanced groundwater recharge efforts. The technical summary document for Task 7 will be provided as an interim deliverable intended to support the GSA development of management policies, which may need to be implemented prior to the completion of the entire Workplan.

### *Task 8: Prepare a Technical Memorandum or Report*

A technical memorandum (TM) or report will be prepared to document all the tasks completed as part of implementation of this Workplan. An interim TM/Report deliverable will be prepared, if needed, to inform the periodic evaluation efforts. A Final TM/Report will be prepared and submitted at the time of completion of tasks outlined in the Workplan. For each of the deliverables prepared as part of Task 8, a draft TM/Report will be submitted to the GSAs (and their technical representatives) for review. Comments and suggested edits received from the GSAs will be reviewed and incorporated as appropriate into final versions of the deliverable documents. The deliverable documents will include documentation of all data compiled, field work completed, technical analyses performed, modeling results, and evaluation of the nature of relationships between groundwater levels and land subsidence, and recommended updates to the Revised GSP SMC and potential management actions to ensure sustainable groundwater management is maintained in the Subbasin. In addition, the deliverable documents will include a review and summary of any remaining data gaps and recommendations for future monitoring and assessment, as needed.

## Schedule

The overall implementation of this Workplan is envisioned as a longer-term effort to develop important monitoring data and facilities for tracking and understanding groundwater conditions related to land subsidence in the Subbasin. However, several tasks are intended to support shorter-term objectives, including the development of a plan for managing groundwater pumping and recharge in the WMA. Additional tasks are geared towards completion in time for incorporation into the first periodic evaluation of the Revised GSP. However, some tasks described in the Workplan will extend beyond the first periodic evaluation, including ongoing data collection. These longer-term tasks include field work involving installation of monitoring facilities, which should be phased with consideration of funding and cooperation from other entities needed to support these efforts. Implementation of the Workplan has already begun and is ongoing.  A general planned schedule for implementation of the Workplan is outlined below in **Table 1**.

| Table 1. Summary of Proposed Schedule for Implementation of the Land Subsidence Workplan | | |
|---|---|---|
| **Task No.** | **Task Description** | **Task Completion Timeframe** |
| 1 | Compile Additional Existing Data and Update Assessment of Available Data | Mid 2024 - Late 2025 |
| 2 | Complete Additional Field Work | Late 2024 - 2026+ (field work may be phased depending on available funding) |
| 3 | Technical Analyses | Mid 2024 - Late 2026 |
| 4 | Groundwater Modeling (in Conjunction with Periodic GSP Update) | Early 2024 - Late 2025 |
| 5 | Stakeholder Outreach and Interbasin Coordination | Mid 2024 - Late 2026+ |
| 6 | Assess the Adequacy of Revised GSP SMC | Late 2024 - Late 2026 |
| 7 | Technical Support for Development of a Strategy for Managing Groundwater Pumping and Recharge in the WMA | Early 2024 - Early/Mid 2026 |
| 8 | Prepare a Technical Memorandum or Report | Mid 2025 - Late 2025 for interim deliverable; 2026+ for final deliverable |

# APPENDIX 3.I. INTERCONNECTED SURFACE WATER DATA GAPS WORKPLAN

Prepared as part of the

**Groundwater Sustainability Plan**
**Chowchilla Subbasin**

January 2020,
Revised May 2023

**GSP Team:**

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# DRAFT TECHNICAL MEMORANDUM

DATE: December 5, 2022 Project No. 21-1-166

TO: Chowchilla Subbasin GSAs

FROM: LSCE and DE

**SUBJECT: Chowchilla Subbasin Revised GSP – Interconnected Surface Water Draft Workplan**

## Introduction and Background

The relationship between the San Joaquin River (SJ River) and shallow groundwater along the western boundary of Chowchilla Subbasin (Subbasin) is complex and data to characterize the groundwater-surface water relationship in this area of the Subbasin are limited. Hydrogeologic conditions at shallow depths appear to vary significantly on different sides of the SJ River, resulting in very shallow groundwater levels west of the river in Delta-Mendota Subbasin and deeper groundwater levels east of the river within Chowchilla Subbasin. Available data suggest shallow clay layers are more prevalent west of and beneath the river, but these shallow clay layers may not be as extensive to the east of the river. Differences between the presence and configuration of shallow clay layers on the west and east sides of the river likely contribute to the occurrence of higher groundwater levels in the shallow zone west of and immediately adjacent to the river compared to east of the river. It may be possible to draw different conclusions regarding the occurrence of interconnected surface water (ISW) on either side of the river, but further studies should be considered to better characterize the following conditions:

- Shallow subsurface conditions,
- The relationship between streamflow and fluctuations of shallow groundwater levels, and
- The relationship between groundwater pumping and streamflow.

Shallow monitoring wells (typically less than 30 feet deep, although some extend to greater depths) installed in areas along the San Joaquin River as part of the San Joaquin River Restoration Program (SJRRP) provide much of the existing monitoring information related to shallow groundwater adjacent to the River. These wells were initially installed to monitor for potential increases in shallow groundwater levels west of the river due to increased reservoir releases to and flows in the San Joaquin River as part of implementing the San Joaquin River Restoration Program (SJRRP). Additional field data collection and technical analyses should be considered at depths greater than 30 feet to better characterize the shallow subsurface along the SJ River at the western boundary of Subbasin, which is likely to improve overall understanding of the relationship between groundwater in the (upper 30 feet), the zone between 30 and

100 feet below ground surface (bgs), and the remaining portion of the Upper Aquifer below a depth of 100 feet where most groundwater pumping currently occurs.

This Workplan outlines potential plans and a related scope of work to compile and review existing data and reports pertaining to the study area, construct/install new monitoring facilities, collect additional field data, and conduct additional technical analyses. The purpose of this scope of work is to provide sufficient data and analyses to:

- Make a more informed determination of whether or not ISW is present along the SJ River at the western boundary of the Subbasin;
- Improve understanding of the relationship between streamflow and fluctuations in shallow groundwater levels;
- Improve understanding of the relationship between shallow groundwater and regional groundwater pumping from deeper zones within the Upper Aquifer that may be separated from shallowest groundwater by intervening clay layers;
- Improve understanding of the relationship between streamflow and regional groundwater pumping; and
- Provide an improved basis for setting sustainable management criteria (SMC) if it is determined that interconnected surface water conditions exist.

## Previous Work Summarized in GSP

As summarized in the Revised Groundwater Sustainability Plan (GSP) for the Subbasin, comparison of historical maps of unconfined groundwater elevations prepared by the Department of Water Resources (DWR) and the SJ River thalweg elevation indicated a connection between groundwater and surface water likely existed from 1958 (and likely before) through 2008. Subsequent data appeared to indicate groundwater elevations below (and disconnected from) the SJ River thalweg from 2009 to 2016. This analysis was based on contour maps of unconfined groundwater elevation prepared by DWR for the following years: Spring 1958, Spring 1962, Spring 1969, Spring 1970, Spring 1976, Spring 1984, Spring 1989 through Spring 2011 (see Revised GSP Appendix 2.E), Spring 2014 (Revised GSP Figure 2-47), and Spring 2016 (Revised GSP Figure 2-48).

Maps of depths to shallowest groundwater (including perched groundwater) for 2014 and 2016 are displayed on Revised GSP Figures 2-71 and 2-72. These maps incorporate very shallow monitoring wells (i.e., less than 50 feet deep), including SJRRP wells (many of which have well screens in the upper 30 feet). Depth to shallow groundwater maps were generated by contouring groundwater surface elevation and subtracting the contoured groundwater surface from the ground surface elevation as represented by the United States Geological Survey (USGS) National Elevation Dataset Digital Elevation Model. Some of the areas in western Subbasin along/adjacent to the SJ River are underlain by the "C-clay" unit of the Tulare Formation and other shallow clay layers that occur above the more laterally and vertically extensive Corcoran Clay ("E-Clay of the Tulare Formation). These clay layers impede the vertical movement of water within the shallowest part of the groundwater system and shallow groundwater in these areas can be considered perched/mounded as a result of the shallow clay layers, although there may be no unsaturated zone beneath them as exists in what is conventionally considered a perched groundwater condition. It is likely that seepage of water from the SJ River (when water is present) combined with the presence of shallow clay layers, serves to maintain shallow groundwater levels in these areas. The depth to the Corcoran Clay becomes relatively shallow farther east in the Subbasin (Eastern Management Area), where it creates a zone of perched groundwater. While shallow perched groundwater levels may be approximately 50 to 90 feet below ground surface, the underlying regional groundwater surface is typically at depths exceeding 200 feet. This is illustrated by new monitoring wells MW-1A and MW-10 installed in the north central portion of the Subbasin near the Chowchilla River, where depths to perched groundwater above the Corcoran Clay are 60 to 70 feet below ground surface (bgs) and depths to unconfined regional groundwater below the Corcoran Clay are 200 to 230 feet bgs.

The SJRRP involves augmenting flow releases from Friant Dam with restoration flows. SJRRP restoration flows were initiated in October 2009 and referred to as "Interim" flows, while SJRRP "Restoration" flows were initiated in January 2014. The commencement of the SJRRP flows complicates the historical review and understanding of surface water – groundwater interaction and the potential effects (or lack thereof) on surface water flow from groundwater pumping. A more detailed assessment of the timing and magnitude of SJRRP flow releases and relationships to shallow groundwater levels is something that should be taken into consideration.

Review of Revised GSP Figures 2-71 and 2-72 indicates that the SJ River was disconnected from the shallow perched/mounded groundwater during these time periods (Spring 2014 and Spring 2016). The 2014 and 2016 water years were considered Critical and Dry water years, respectively, according to the San Joaquin Valley Hydrologic Index (although water year 2016 was on the border of being classified as a Below Normal year). However, review of groundwater elevation hydrographs for wells screened in the Upper Aquifer (see Revised GSP Sections 3.2.5 and 3.3.5) also indicate there may be some interconnection between shallow groundwater and the SJ River during certain discrete time periods when shallow groundwater levels are high, typically during spring in certain Wet and Above Normal index years and sometimes in spring of dry or critical years following a sequence of wet/above normal years. The relationship between stream seepage in the SJ River along the western boundary of Subbasin and groundwater pumping along this portion of the SJ River within the Subbasin (i.e., within approximately 0.75 miles of the San Joaquin River) is shown in Revised GSP Figure 2-73. The relationship between groundwater pumping from the Upper Aquifer throughout the entire Western Management Area and stream seepage is shown in Revised GSP Figure 2-74. These figures indicate no distinct and consistent relationships between the amount of groundwater pumping and stream seepage. On the other hand, the relationship between streamflow entering this reach of the SJ River and stream seepage presented in Revised GSP Figure 2-75 suggests an apparent strong relationship where increasing streamflow correlates with increasing stream seepage. This relationship between the magnitudes of streamflow and stream seepage is expected because this segment of the SJ River (known in the SJRRP as Reach 4A) has been characterized as a losing reach (United States Bureau of Reclamation (USBR), December 2020). These relationships between various factors are discussed further in Revised GSP Sections 3.2.5 and 3.3.5.

Available data and analyses (see Revised GSP Section 2.2.2.5) suggest shallow groundwater occurring along the SJ River is a result of stream seepage and regional groundwater does not support streamflow along this reach of the SJ River adjacent to the western boundary of Subbasin. Nonetheless, based on guidance received from DWR and because of limitations in available information to evaluate the interconnected nature of groundwater and surface water on the SJ River, for the Revised GSP it is assumed that conditions along the SJ River in the Subbasin constitute an ISW condition as defined by SGMA and under the GSP regulations. As a result, the Revised GSP established interim SMC for ISW until the shallow hydrogeologic conditions along the SJ River are more fully characterizing and a final determination regarding the presence/absence of ISW can be made.

In the Subbasin, an area identified as having a Groundwater Dependent Ecosystem (GDE) is located adjacent to the SJ River (see Revised GSP Figure 2-76). As noted above, the SJ River is in a net-losing condition and infiltrating surface water flows (stream seepage) likely contributes directly to the shallow groundwater system that supports the vegetation in the GDE unit (San Joaquin River GDE Unit). While it appears the source of shallow groundwater adjacent to the SJ River is stream seepage from the SJ River (when water is present) and shallow groundwater does not support surface water flows, there nevertheless is some potential for surface water flows and the shallow groundwater system supporting GDEs to be affected by regional pumping during certain times when shallow groundwater is present below the stream thalweg but within the root zone of GDEs. These GDEs/beneficial users include environmental users such as riparian vegetation along the SJ River and the wildlife habitat and ecosystem functions it provides. The potential effects on the San Joaquin River Riparian GDE Unit are presented in Revised GSP Appendix 2.B.

As summarized above, the revised Chowchilla Subbasin GSP established interim SMC for ISW based on DWR review/input received in the initial consultation letter. However, additional characterization of the relationship between groundwater and surface water along the San Joaquin River is needed to provide an improved basis for making a final determination of the nature of the interconnection and appropriate SMC (if needed). This Workplan is intended to provide additional field data and technical analyses as input to better characterizing ISW for the 2025 GSP Update (and beyond).

## Proposed Scope of Work

The proposed scope of work involves seven main tasks including collection and analysis of existing data (beyond data compiled for the Revised GSP), installation of new monitoring facilities and collection of additional field data, completion of additional technical analyses, and completion of an updated assessment of presence/absence of ISW with recommendations for updated SMC (if necessary). The proposed scope of work is described in more detail below. It should be noted that implementation of the potential work set-forth herein is predicated on Groundwater Sustainability Agency (GSA) approval and allocation of the necessary funds as may be required (local funding and/or grants).

### *Task 1. Compile Additional Existing Data/Analyses (Supplemental to GSP)*

#### Compile and Review Supplemental Existing Data

In this task, data collected during preparation of the Revised GSP will be supplemented with other newly available data related to ISW along the SJ River including:

- information presented in GSPs for other subbasins adjacent to the San Joaquin River in the area, such as the GSP prepared by the San Joaquin River Exchange Contractors;
- available data related to the Subsidence Control Measures Agreement (Subsidence Agreement);

- new data available from specific local landowners or entities previously not available for incorporation into the Revised GSP;
- DWR Well Completion Reports (WCRs) for the area immediately adjacent to the San Joaquin River (i.e., a zone extending approximately one mile on either side of the River along the western boundary of Chowchilla Subbasin);
- additional data compiled by USBR for the SJRRP for areas in the Subbasin;
- additional data from USGS and modeling information for their study of the San Joaquin River;
- and other reports and data that may now be available.

The available data will be compiled and reviewed to inform subsequent field work (Task 2) and as input for technical analyses (Task 3).

## AEM Data

Data from airborne electromagnetic (AEM) surveys conducted in Spring 2022 to support additional characterization of subsurface conditions in the Subbasin and surrounding areas are expected to be available around the end of 2022. AEM data can provide helpful information on hydrogeologic conditions through measurements of the resistivity of subsurface materials. These surveys have the potential to improve the understanding of the configuration and composition of different subsurface materials. To the extent that AEM data was collected in the vicinity of the western boundary of Subbasin along the San Joaquin River, these data will be evaluated for their potential usefulness in helping to supplement the delineation of shallow stratigraphy along the portion of San Joaquin River that forms a portion of the western boundary of Subbasin. One potential application of AEM that is of particular interest related to potential interconnectedness of surface water is delineation of any shallow clay layers under and adjacent to the SJ River. A quality assurance/quality control (QA/QC) analysis of the data will be conducted by comparing AEM hydrostratigraphic interpretations to existing and new field data collected as described in this Workplan. Lithologic data from borehole logs along AEM section lines will be compared to evaluate if AEM interpretations are consistent with field data. If AEM data interpretations are found to be consistent and the resolution of shallow aquifer stratigraphy from AEM data interpretations is sufficient, the AEM data will be combined with field borehole lithologic data to develop refined hydrogeologic cross-sections along the San Joaquin River (as described below in Task 3).

## *Task 2. Complete Additional Field Work*

## Instrumentation of Existing Wells

The monitoring frequency in some of the Representative Monitoring Site (RMS) wells designated for the ISW minimum thresholds (MTs) and measurable objectives (MOs) in the Revised GSP presents some limitations for characterizing groundwater level fluctuations and development of appropriate SMC. The RMS wells related to ISW include MCW RMS-1, MCW RMS-2, MCW RMS-3, MCW RMS-10, MCW RMS-11, and MCW RMS-12 (**Figure 1**). These wells do not currently have continuous and automated groundwater level monitoring with pressure transducers. This task involves working with the owners of key RMS wells to prioritize and implement instrumentation of wells with transducers for collecting continuous groundwater data. As part of this task, if the assessment and monitoring of ISW would benefit from more continuous monitoring at other RMS well locations, other RMS wells could be considered and prioritized for automated monitoring. If further characterization and evaluation of ISW during implementation of this Workplan determines there are important benefits to continuous monitoring of other (non-ISW SMC) RMS wells, and arrangements can be made with the well owner(s), additional well instrumentation could be prioritized for implementation. It is assumed for purposes of estimating the cost of implementing the Workplan that two additional RMS wells will be selected for instrumentation.

## New Monitoring Facilities and Field Data Collection.

Several key data gaps related to ISW in the Subbasin include coupled monitoring of groundwater levels at different depths within the Upper Aquifer (including very shallow groundwater and more regional groundwater zone) and stream conditions of stage, flow, and channel configuration at locations adjacent to the San Joaquin River. Construction of new monitoring facilities and additional field data collection efforts are anticipated to focus on, but are not limited to: supplemental monitoring wells; stream stage and flow; stream elevation profile/thalweg profiles; and possible aquifer or well pump testing if cooperation can be obtained from landowners with wells at suitable locations near the SJ River. Potential field efforts are described in more detail below.

## Install New Monitoring Wells

Monitoring wells are recommended for installation at four locations near the San Joaquin River to augment existing groundwater level monitoring to understand dynamics between surface water conditions in the SJ River, groundwater conditions at very shallow depths where there is greater potential for interconnection between groundwater and surface water, and groundwater conditions in the regional groundwater system where groundwater is extracted by wells for irrigation and other uses. Two locations will target sites near existing SJRRP monitoring wells MCW RMS-10 and MCW RMS-11, which are approximately 30 feet deep; the new monitoring wells at these two locations will be screened slightly deeper in a coarse-grained zone between depths of 50 to 90 feet below ground surface (bgs). In addition, two new locations will be selected for installation of nested monitoring wells: one screened in the upper 30 feet and one screened at depths between 50 and 90 feet. Preliminarily identified locations for potential new nested wells are shown in **Figure 1**, pending the outcome from review of additional data and evaluation of site suitability relating to access for construction and ongoing monitoring. Target well locations may also include consideration of proximity to existing production wells that might be used in evaluating shallow groundwater level responses to pumping from deeper zones.

The monitoring wells are planned to be drilled using the hollow-stem auger drilling method with split spoon core sediment samples collected every five feet. A lithologic log of the borehole will be prepared based on samples collected and under the supervision and guidance of a Professional Geologist, who will also provide recommendations regarding well construction details such as depth intervals for placement of well screen, filter pack, blank casing, and surface sanitary seal. Preliminarily, the new monitoring wells are planned to be constructed using 2-inch diameter Schedule 40 PVC materials, which will enable installation of automated groundwater level monitoring instrumentation and also provide access for groundwater quality sampling equipment. The new monitoring wells and existing RMS wells listed above will be surveyed to a consistent elevation datum to ensure there are no recent changes in groundwater surface or reference point elevations related to any recent ISW that may have occurred in the area. Water quality samples will be collected from the new monitoring wells, and they will be outfitted with pressure transducers for ongoing automated collection of groundwater level data.

## Install Stream Stage Recording Device(s)

Accurate assessment of dynamics related to surface water-groundwater interaction requires detailed information on river stage for relating to groundwater levels. There is only one currently active stream stage monitoring location along the San Joaquin River within the Chowchilla Subbasin (**Figure 2**). Installation of stream stage recorders are recommended at four locations corresponding to the locations of nested monitoring wells described in this Workplan (assuming permission/access can be obtained). Various options for instrumentation should be considered, but options include constructing the stream stage recorders from small-diameter (1- or 2-inch) PVC slotted pipe, which could be secured to the riverbank and extended into the low flow channel to enable the pipe to remain submerged during low-flow conditions and also provide access to monitoring instrumentation during higher flow conditions. A transducer would be installed in the PVC pipe for automated collection of river stage at all flow conditions. The river stage recorders will be coupled with a staff gage for periodic manual readings of stage to ensure accuracy of all data collected through automated instrumentation. The staff gage and stream stage recorder will be surveyed to the same elevation datum as the new monitoring wells.

## Complete Stream Profile Surveys

Stream channel elevation profiles will improve characterization of the San Joaquin River channel elevation and shape, which relates to potential for interconnectivity between surface water and groundwater when compared with groundwater levels. To better characterize the potential surface water-groundwater interconnectivity along the San Joaquin River, stream channel elevation profiles perpendicular to the river channel orientation will be obtained at key locations through surveying, using the same elevation datum used for the monitoring wells and river stage recorders. The stream channel profiles will be conducted near each of the four new nested monitoring well locations and will extend perpendicularly from the new/existing monitoring well locations on the east side of the river and across the San Joaquin River to the opposite riverbank (and possibly to any existing nearby monitoring wells on the west side of the river). The stream channel surveys should be conducted at a time of low flow (or no flow) in the river in an effort to accurately survey as much of the streambed as possible.

## Complete Aquifer Testing

One of the key aspects related to ISW that is not well characterized in the areas along the San Joaquin River includes understanding of how groundwater pumping from the regional aquifer may influence groundwater levels in the very shallow part of the groundwater system (and in turn surface water), especially in areas where the movement of water between the shallow part of the groundwater and the deeper regional groundwater system may be impeded to a great degree by the presence of clay layers. Aquifer testing conducted through pumping of existing production wells while monitoring conditions in the shallow part of the groundwater system and in the nearby SJ River would help understand the cross-communication between different depth zones of the groundwater system and potential communication between shallow groundwater and streamflow. One of the goals of the proposed aquifer testing is to evaluate how clay layers located between the top of the pumping well screen and bottom of the streambed do or do not impede a connection between groundwater pumping and streamflow. If cooperation can be obtained with one or more landowners having a suitable production well near the San Joaquin River in Chowchilla Subbasin, one or more pumping tests will be performed to evaluate pumping effects on shallow groundwater levels and streamflow. A suitable production well for this testing would be screened in the Upper Aquifer at a location sufficiently close to the San Joaquin River and to adjacent shallow monitoring wells to potentially have an effect on streamflow and shallow groundwater levels in close proximity to the River within the planned pumping duration (if there is a connection between groundwater and surface water). The timing of the test will also be important with considerations being given to performing the test at a time with higher shallow groundwater elevations (to maximize chances of having a connection between streamflow and shallow groundwater levels) while having a lower range of stream discharge (to maximize opportunity to see effects on streamflow).

If cooperation with existing production well owners cannot be obtained, consideration will be given to implementing “passive” aquifer testing. This type of testing would involve conducting continuous groundwater level monitoring in proximity to a production well to observe whether influences from normal pumping cycles can be discerned in nearby shallow groundwater and surface water. In this type of testing there will be no controlled/coordinated start and stop of pumping or attempts to maintain a consistent pumping rate, but rather the well would be operated in accordance with normal use without any coordinated pumping period.

## *Task 3. Technical Analyses*

In coordination with and utilizing new information from compilation of additional available data and field work related to additional monitoring and characterization of surface and subsurface conditions related to the potential for interconnectivity between groundwater and surface water, technical analyses involving construction of detailed hydrogeologic cross sections along the San Joaquin River, evaluation of fluctuations in shallow groundwater levels and river stage/flow, and evaluating relationships between groundwater pumping and streamflow are also planned to synthesize the available information and groundwater-surface water dynamics along the River.

Hydrogeologic cross-sections will be constructed using geologic/lithologic logs, geophysical logs, and AEM data relating to the stratigraphy within the Upper Aquifer, with particular focus on the upper 100 feet where there is potential for interconnectivity between groundwater and surface water. These cross-sections will include the most recent available data on groundwater levels, stream thalweg elevation (stream profiles conducted for this Workplan and available LiDAR data), and stream stage in conjunction with subsurface stratigraphy. The specific locations and orientation of the cross-sections will depend on where available data exist, including new data collected through Tasks 1 and 2, but are expected to include cross-sections oriented both parallel to and perpendicular to the San Joaquin River. The perpendicular cross-sections will focus on locations aligned with new monitoring well locations.

Field data will be evaluated relative to the dynamic relationship between surface water and groundwater levels within the Upper Aquifer (in both the shallow and deeper zones of the Upper Aquifer). Available information indicates these dynamics vary over time and space depending on climatic/hydrologic conditions within a year (seasonal fluctuations) and from year to year (variations from wet years to dry years). Analyses presented in the Revised GSP based on the limited available historical data suggest that periods with greater streamflow correspond with higher rates of stream infiltration (seepage) that provide a source of water to the shallow zone resulting in higher groundwater levels where shallow clay layers are present to impede downward flow of infiltrating surface water. During time periods of no or minimal river flows, previous analyses suggest that lower rates and very little or no stream infiltration occur that reduce the available source of water to the shallow zone that and lead to rapidly declining groundwater levels in the shallow zone. These additional technical analyses will focus on providing further assessment of the surface water-groundwater dynamics along four key profiles perpendicular to the river (at new monitoring well locations) where the San Joaquin River forms the boundary of Chowchilla Subbasin to improve understanding of groundwater conditions in relation to surface water.

## *Task 4. Outreach*

To be determined, but likely to involve NOAA-NMFS, USBR, and others.

## *Task 5. Groundwater Modeling (in Conjunction with 5-Year GSP Update)*

The groundwater model developed for the GSP (MCSim) will be updated and recalibrated as necessary as part of the 5-Year Update Report. This updated modeling will be used to further evaluate ISW conditions, both historically as well as current and expected future conditions, with the objective of characterizing groundwater-surface water interaction at a broader spatial scale within the western part of the Subbasin. The groundwater model will be used to assist in evaluation of the potential for ISW to be present along the San Joaquin River, and to further evaluate the potential for connection between regional groundwater pumping and surface water flows.

Pending the results from analyses conducted as part of Task 3 and the model update planned as part of the five-year update of the Revised GSP, it is anticipated that additional model scenarios may need to be developed to enable more detailed assessment of stream-aquifer interaction via model simulations of conditions and mechanisms across the entire Subbasin, especially the western Subbasin. Potential additional model runs could include simulation of 50 years of future hydrology while varying the amount and distribution of groundwater pumping. Comparisons between such hypothetical model runs could be used to improve understanding of the influence of groundwater pumping in the Subbasin on shallow groundwater levels, stream flow/stage, and dynamics of connectivity between groundwater and surface water, including frequency, duration, and percent of time any interconnectivity occurs. A key aspect of additional groundwater model simulations will be to further evaluate the percentage of time connectivity between groundwater and surface water existed along the San Joaquin River prior to 2015 compared to current and expected future conditions with implementation of projects and management actions (PMA) and the ongoing SJRRP. These analyses will directly support the evaluation and determination of appropriate SMC related to ISW (as described in the Revised GSP) under Task 5.

## *Task 6. Assessment of Presence of Interconnected Surface Water and Possible Revisions to SMC*

The ultimate outcome from efforts conducted as part of this Workplan will be an assessment and establishment of appropriate SMC related to ISW as part of the five-year update of the Revised GSP. This will include potential refinements or modifications to interim SMC established in the Revised GSP, if determined appropriate. In conducting this assessment, the data and analyses developed through implementation of Tasks 1 through 4 of the Workplan will be used to evaluate whether ISW exists along the western boundary of Chowchilla Subbasin and if there is need to include SMC for ISW in the Revised GSP for the Chowchilla Subbasin. An important consideration related to ISW and how and whether SMC are established for ISW is that once shallow aquifer groundwater levels fall to a point where they are disconnected from the river, additional declines in groundwater levels will no longer affect the rate and amount of stream infiltration/depletion. This fact, combined with the difference between historical and current/future San Joaquin River flow releases from Friant Dam as part of the SJRRP, likely means that rate or amount of stream depletion are not appropriate metrics for defining ISW SMC, including undesirable results. Additionally, groundwater levels as a proxy for stream depletion is also not an appropriate SMC metric for two key reasons: 1) elevations of shallow groundwater levels below the threshold when groundwater and surface water become disconnected will make not affect the rate/amount of stream depletion, and 2) historical shallow groundwater level data suggest that shallow groundwater levels have commonly been below the threshold when they become disconnected from surface water and such conditions are likely to continue to occur under future conditions. As described in the Revised GSP and used as an interim ISW SMC metric in the GSP, a potential SMC metric relating to the percent of time ISW occurs based on the occurrence during historical conditions (prior to 2015), likely provides the most appropriate ISW SMC metric for future management of groundwater in the Subbasin. However, because interconnectivity of surface water may only occur under limited hydrologic circumstances (i.e., brief periods during the winter or spring and/or during wet water years) implementing this metric necessitates that ISW conditions be evaluated over an extended period of time (e.g., 5 years as currently used as part of the interim SMC or more) to ensure the SMC assessment period spans a representative range of climatic/hydrologic conditions.

Establishing final SMC for ISW for inclusion in the five-year update of the Revised GSP will draw upon the most recent data and technical analyses developed through implementation of this Workplan with consideration for the complexities of the dynamic relationship between groundwater and surface water along the San Joaquin River in the Subbasin under conditions prior to and after initiation of the SJRRP.

### *Task 7. Prepare a Technical Memorandum or Report*

A technical memorandum (TM) or report will be prepared to document all the tasks completed as part of implementation of the ISW Workplan. A Draft TM/Report will be submitted for review by the GSAs (and their technical representatives). Comments and suggested edits received from GSAs will be reviewed and incorporated as appropriate into a Final TM/Report. The Report will include documentation of all data compiled, field work completed, technical analyses performed, modeling results, and evaluation of the nature of groundwater – surface water interactions and recommended updates to SMC. In addition, the TM/Report will include a review and summary of any remaining data gaps and recommendations for future monitoring and assessment, as needed.

## Schedule

The overall implementation of this Workplan is envisioned as a longer-term effort to develop important monitoring data and facilities for tracking and understanding groundwater conditions related to ISW in the Subbasin. Additional tasks are geared towards completion in time for incorporation into the first five-year update of the Revised GSP. However, some tasks described in the Workplan will likely extend beyond January 2025, including ongoing data collection. These longer-term tasks include field work involving installation of monitoring facilities, which should be phased with consideration of funding and cooperation from other entities needed to support these efforts. Implementation of the Workplan is planned to start in 2023 with commencement of the additional data review and compilation task. Similarly, field work is also planned to begin in 2023, primarily with well inventory survey efforts and review of opportunities to instrument existing wells. As a result, not all of the field work described in this Workplan is anticipated to be completed prior to January 2025 when the first five-year update of the Revised GSP is to be submitted. A general planned schedule for implementation of the Workplan is outlined below in **Table 1**.

| Table 1. Summary of Proposed Schedule for Implementation of the Interconnected Surface Water Workplan | | |
|---|---|---|
| **Task No.** | **Task Description** | **Task Completion Timeframe** |
| 1 | Compile Additional Existing Data/Analyses (Supplemental to GSP) | Mid 2023 - Late 2023 |
| 2 | Complete Additional Field Work | Late 2023 - 2026+ (field work may be phased depending on available funding) |
| 3 | Technical Analyses | Mid 2023 - Late 2024 |
| 4 | Outreach | Early 2024 - Late 2024 |
| 5 | Groundwater Modeling (in Conjunction with 5-Year GSP Update) | Early 2024 - Late 2024+ |
| 6 | Assessment of Presence of Interconnected Surface Water and Possible Revisions to SMC | Late 2023 - Late 2024 |
| 7 | Prepare a Technical Memorandum or Report | Mid 2024 - Late 2024 for interim deliverable; 2026+ for final deliverable |

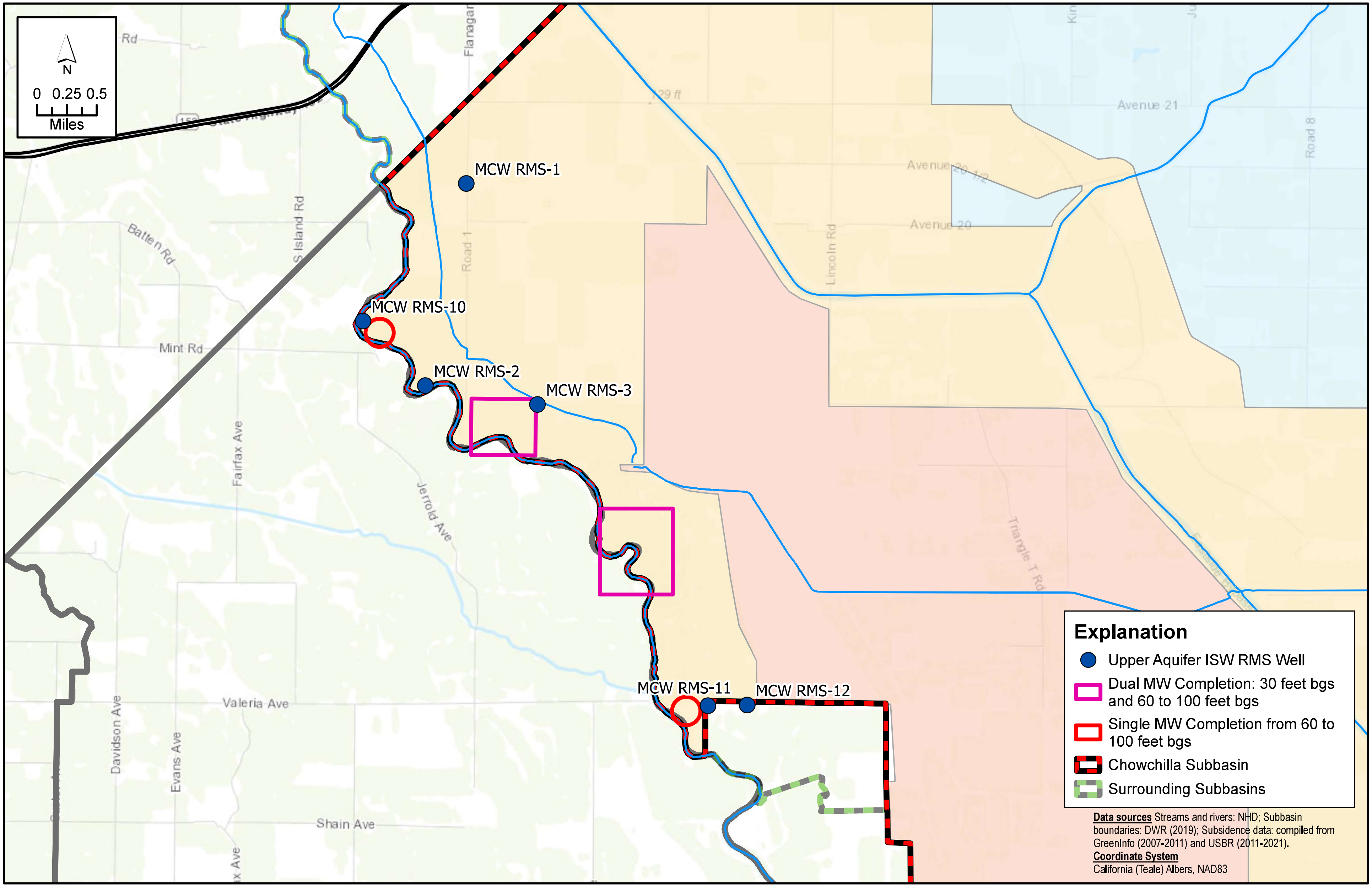


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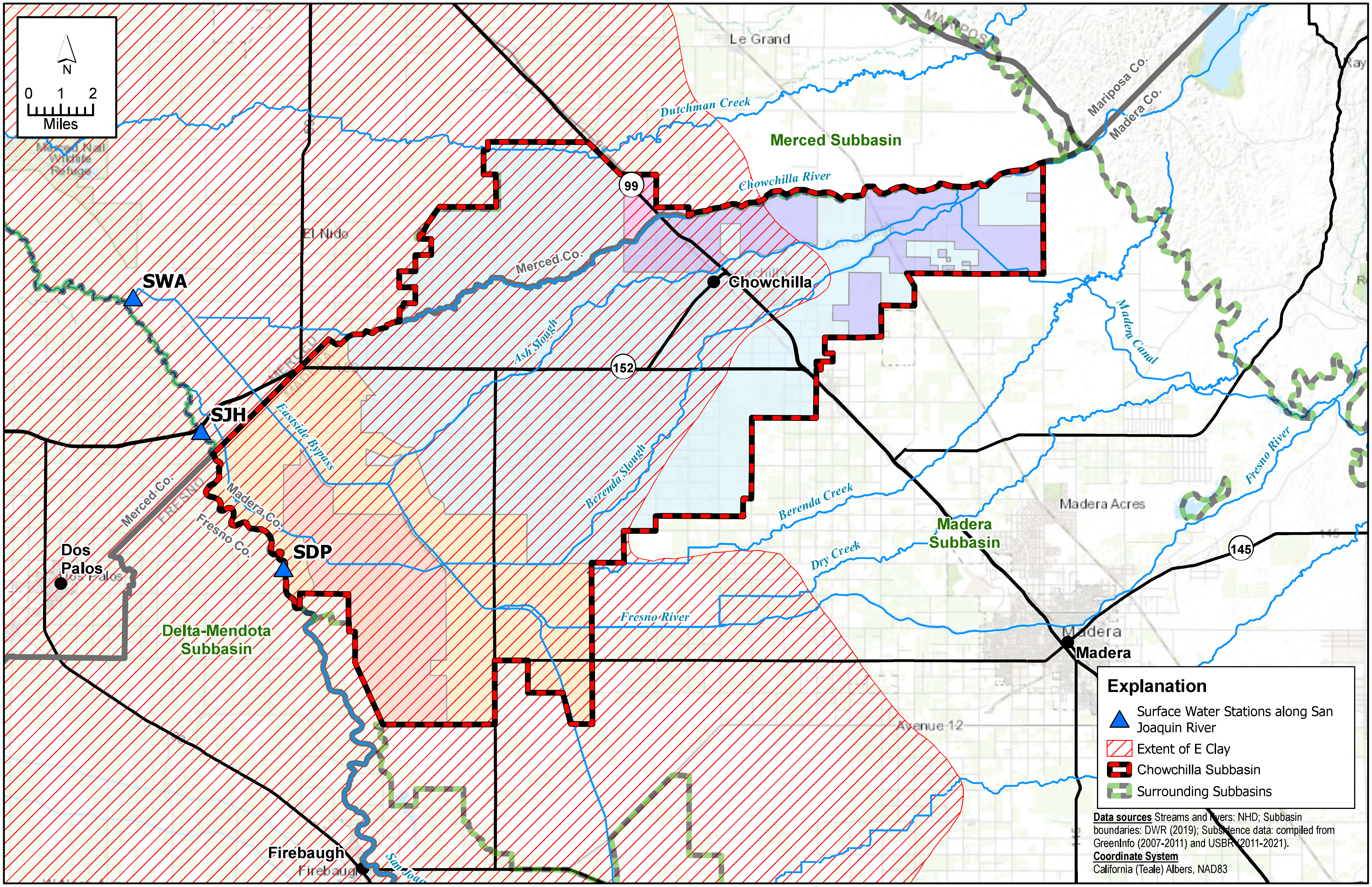
**FIGURE 1**

**Proposed Monitoring Well Locations for ISW Workplan**

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DAVIDS ENGINEERING, INC

Luhdorff & Scalmanini Consulting Engineers

**FIGURE X-X**

**Surface Water Stations along San Joaquin River in Madera Subbasin**

*Chowchilla Subbasin*
*Groundwater Sustainability Plan*

# APPENDIX 3.J. DETAILED PROCESS FOR SETTING GROUNDWATER LEVEL INTERIM MILESTONES

Prepared as part of the

**Groundwater Sustainability Plan**
**Chowchilla Subbasin**

January 2020',
Revised May 2023

**GSP Team:**

Davids Engineering, Inc (Revised GSP)
Luhdorff & Scalmanini (Revised GSP)
ERA Economics
Stillwater Sciences and
California State University, Sacramento

# TECHNICAL MEMORANDUM

DATE: May 2, 2023 Project No. 23-1-048

TO: Chowchilla Subbasin GSAs

FROM: LSCE and DE

**SUBJECT: Chowchilla Subbasin Revised GSP - Detailed Process for Setting Groundwater Level Interim Milestones**

## Methodology for Calculating Interim Milestones

Interim milestones (IMs) for chronic lowering of groundwater levels were established at five-year intervals over the Implementation Period from 2020 to 2040, at years 2025, 2030, and 2035. IMs were established through review and evaluation of measured groundwater level data and consideration of the SMCs (e.g., Measurable Objectives (MOs) and Minimum Thresholds (MTs)) defined for the Sustainability Period (starting in 2040). During the Implementation Period, some level of continued decline in groundwater levels is expected in the Subbasin. Additionally, some Representative Monitoring Sites (RMS) are currently below their minimum threshold. IMs are set to allow for some further decline below the minimum threshold in the early part of the Implementation Period, while increasing toward sustainability in the latter part of the Implementation Period. IMs were developed specific to individual RMS wells based on a range of simulated conditions at each RMS over five-year intervals during the implementation period. The range of simulated conditions includes variability in levels between wet (at the high value of the range) and dry (at the low value of the range) periods. The interim milestones for each five-year interval were based on a percentage between the high and low values.

The methodology for calculating the range of high and low values used in determining the IMs is described in this TM. A general description of each value is provided, followed by a step-by-step methodology.

### *2025 Interim Milestone*

The 2025 IM continues historical trends while beginning to slow continued groundwater level declines.

### 2025 Low Value

The 2025 low value was determined by calculating the average annual slope between the MT (based on Fall 2015 measurement) and MO (based on Fall 2011 measurement) and projecting the 2025 level forward starting from the Fall 2021 measurement using the average slope (if an RMS did not have a Fall 2021 measurement, the simulated water level from the model for that RMS was used).

1. MO is Fall 2011 measurement (or October 2011 modeled value (with any necessary offsets[1])).
2. MT is Fall 2015 measurement (or October 2015 modeled value (with any necessary offsets)).
3. Calculate the slope between these two measurements.
4. Determine the Fall 2021 GW elevation measurement (or October 2021 modeled value (with any necessary offsets)).
5. Calculate the equation of the line through the Fall 2021 measurement using the slope calculated in step 3.
6. Using the line calculated in step 5, calculate the value for the groundwater level at Fall 2025.
7. **The value calculated in step 6 is the 2025 IM low value.**

An example of the determination of the 2025 low value is presented in **Figure 1**.

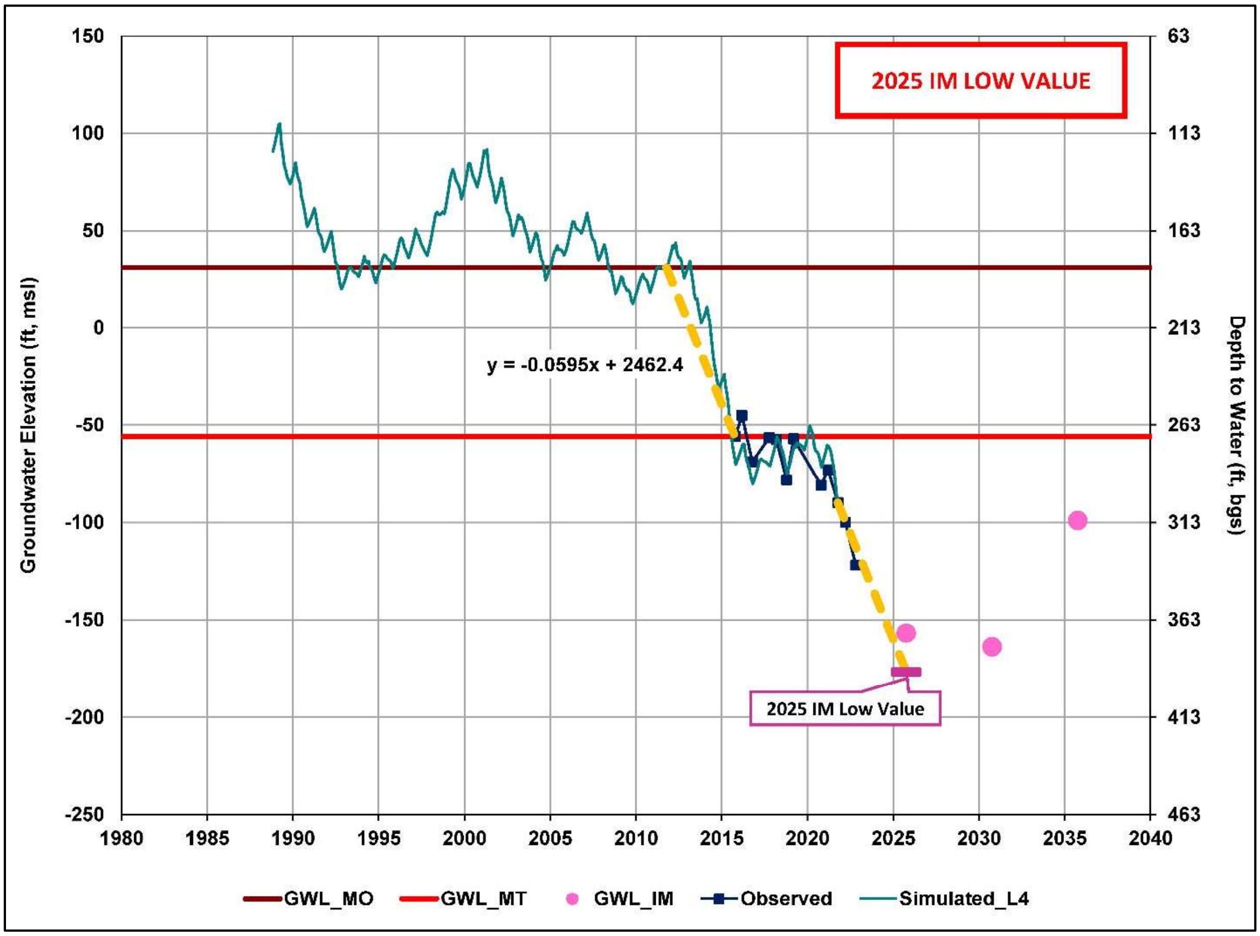


**Figure 1. Example of the determination of the 2025 IM low value**

[1] Offsets were used to account for any discrepancies between observed and simulated groundwater levels.

## 2025 High Value

The 2025 high value was determined by calculating the average annual slope in Fall groundwater levels from 2015 through 2019 (a relatively wet period), then projecting the 2025 level using the average slope from the Fall 2021 measurement (if an RMS did not have a Fall 2021 measurement, the simulated water level from the model for that RMS was used). If the resulting value was greater than 25% of the distance from the MT to the MO, then it was placed at 25% of the way from the MT to the MO.

1. Determine the Fall 2015 measurement (or October 2015 modeled value (with any necessary offsets)).
2. Determine the Fall 2019 measurement (or October 2019 modeled value (with any necessary offsets)).
3. Calculate the slope between these two measurements.
4. Determine the Fall 2021 GW elevation measurement (or October 2021 modeled value (with any necessary offsets)).
5. Calculate the equation of the line through the Fall 2021 measurement using the slope calculated in step 3.
6. Using the line calculated in step 5, calculate the value for the groundwater level at Fall 2025.
7. Calculate the value of the groundwater elevation that is 25% of the distance from the MT to the MO.
8. **If the value calculated in step 6 is less than the value calculated in step 7, the value calculated in step 6 is the 2025 IM high value.**
9. **If the value calculated in step 6 is greater than the value calculated in step 7, the value calculated in step 7 is the 2025 IM high value.**

An example of the determination of the 2025 high value is presented in **Figure 2**.

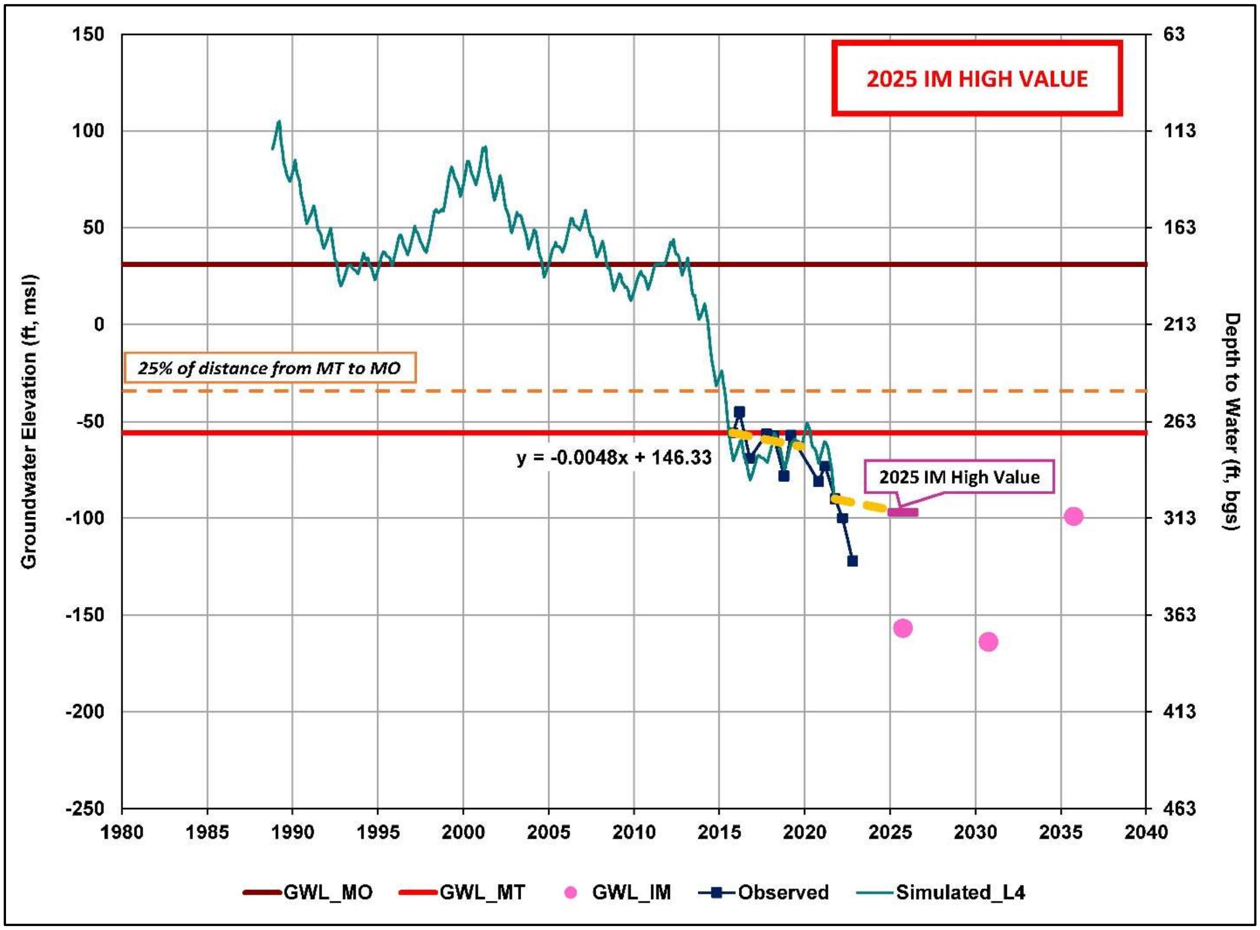


**Figure 2. Example of the determination of the 2025 IM high value**

## 2025 Interim Milestone

The final 2025 interim milestone was set 25% of the distance between the 2025 low value and the 2025 high value, and was calculated as follows:

[2025 IM low value] + 25% * ([2025 IM high value] – [2025 IM low value])

An example of the determination of the final 2025 interim value is presented in **Figure 3**.

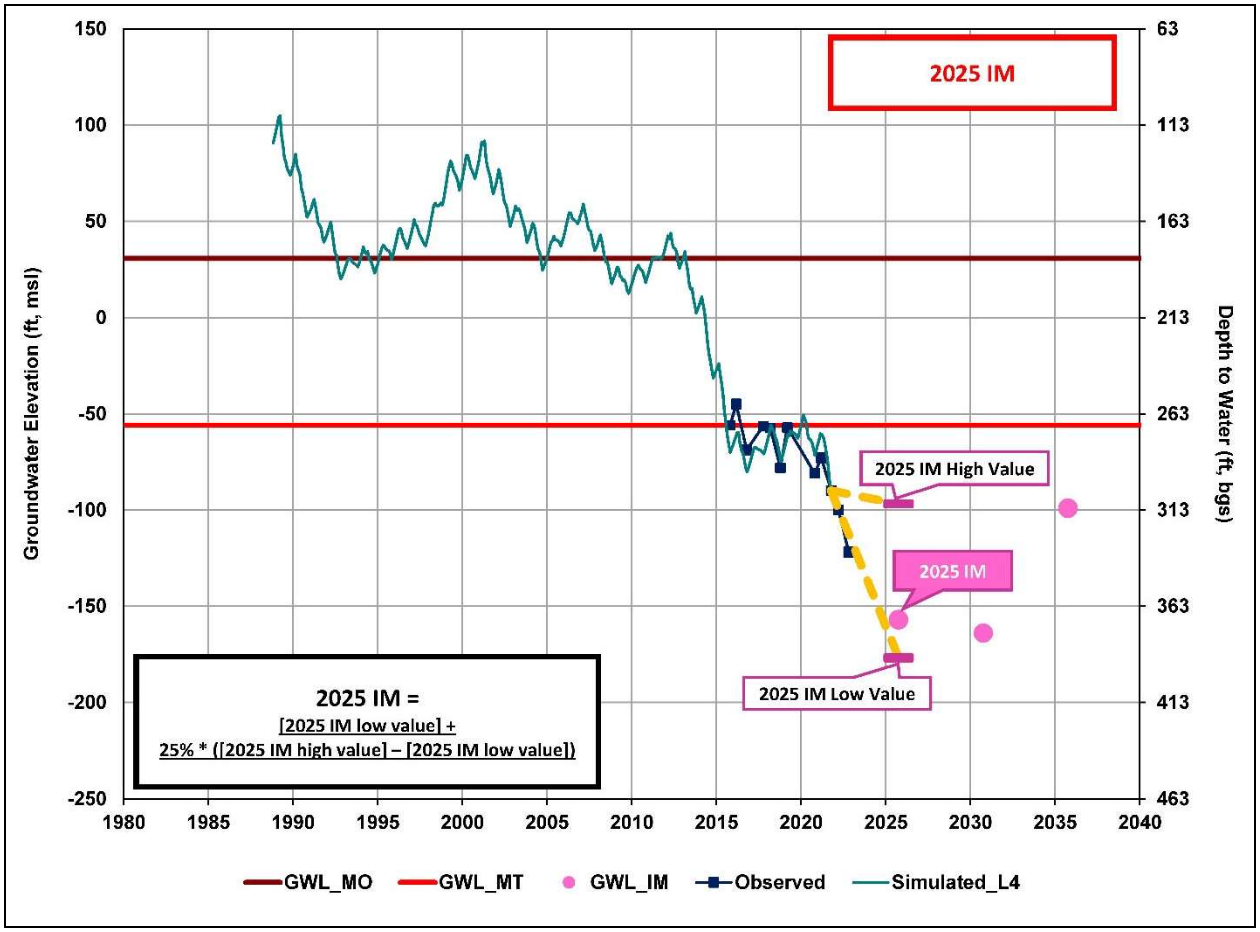


**Figure 3. Example of the determination of the final 2025 IM**

## *2030 Interim Milestone*

The 2030 IM flattens out groundwater level declines and begins an upward trend towards the MO.

### 2030 Low Value

The 2030 low value was determined by calculating the average annual slope between the MT and MO, then projecting the 2030 measurement using half the average slope from the 2025 IM low value.

1. MO is Fall 2011 measurement (or October 2011 modeled value (with any necessary offsets)).
2. MT is Fall 2015 measurement (or October 2015 modeled value (with any necessary offsets)).
3. Calculate the slope between these two measurements, then divide this slope value in half.
4. Calculate the equation of the line through the 2025 IM low value using the slope calculated in step 3.
5. Using the line calculated in step 4, calculate the value for the groundwater level at Fall 2030.
6. **The value calculated in step 5 is the 2030 IM low value.**

An example of the determination of the 2030 low value is presented in **Figure 4**.

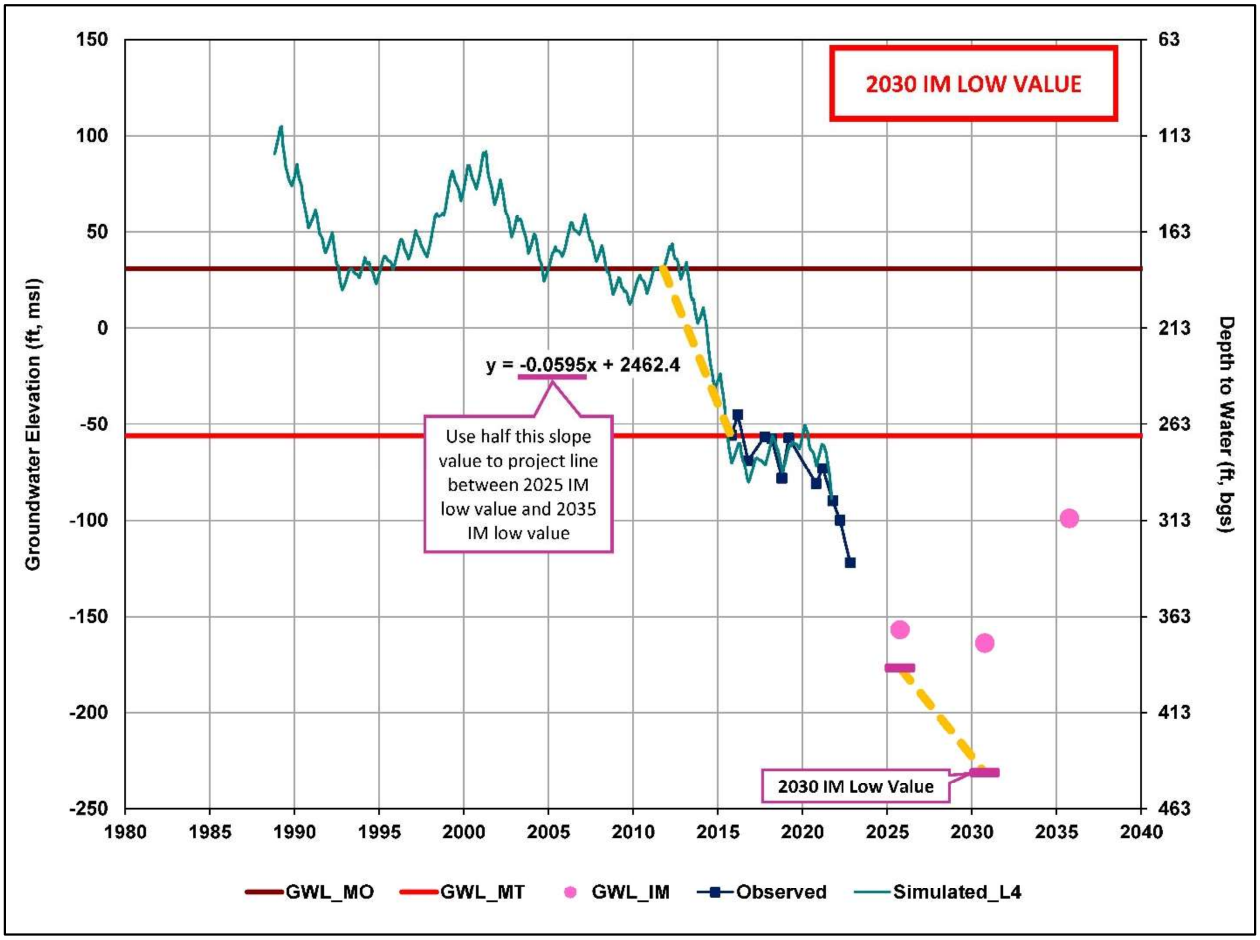


**Figure 4. Example of the determination of the 2030 IM low value**

## 2030 High Value

The 2030 high value was determined by calculating the average annual slope in Fall groundwater levels from 2015 through 2019 (a relatively wet period). If the slope was negative, then the 2025 IM high value was used as the 2030 IM high value. If the slope was positive, then the 2030 IM high value was determined by projecting the average slope from the 2025 IM high value. If the resulting value was greater than 50% of the distance from the MT to the MO, then it was placed at 50% of the way from the MT to the MO.

1. Determine the Fall 2015 measurement (or October 2015 modeled value (with any necessary offsets)).
2. Determine the Fall 2019 measurement (or October 2019 modeled value (with any necessary offsets)).
3. Calculate the slope between these two measurements.
4. **If the slope calculated in step 1 is negative (declining), the 2025 IM high end is set as the 2030 IM high end.**
5. If the slope calculated in step 1 is positive (rising), then calculate the equation of the line through the 2025 IM high value using the slope calculated in step 3.

6. Using the line calculated in step 5, calculate the value for the groundwater level at Fall 2030.
7. **If the slope calculated in step 1 is positive, then the value calculated in step 6 is the 2030 IM high value.**

An example of the determination of the 2030 high value if slope between Fall 2015 and Fall 2019 measurements is negative is presented in **Figure 5a**. An example of the determination of the 2030 high value if slope between Fall 2015 and Fall 2019 measurements is positive is presented in **Figure 5b**.

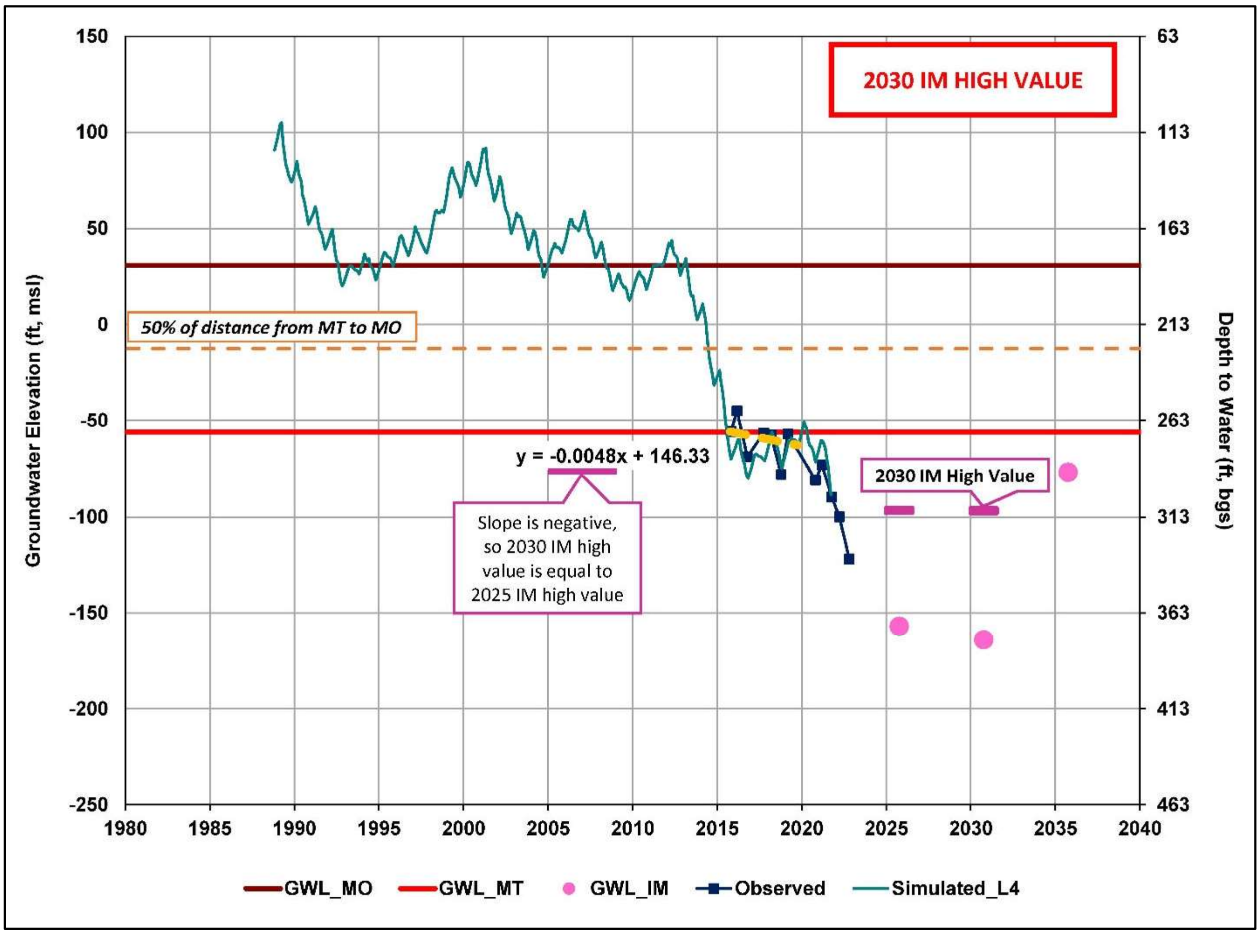


**Figure 5a. Example of the determination of the 2030 IM high value if slope between Fall 2015 and Fall 2019 measurements is negative (i.e., groundwater levels are declining)**

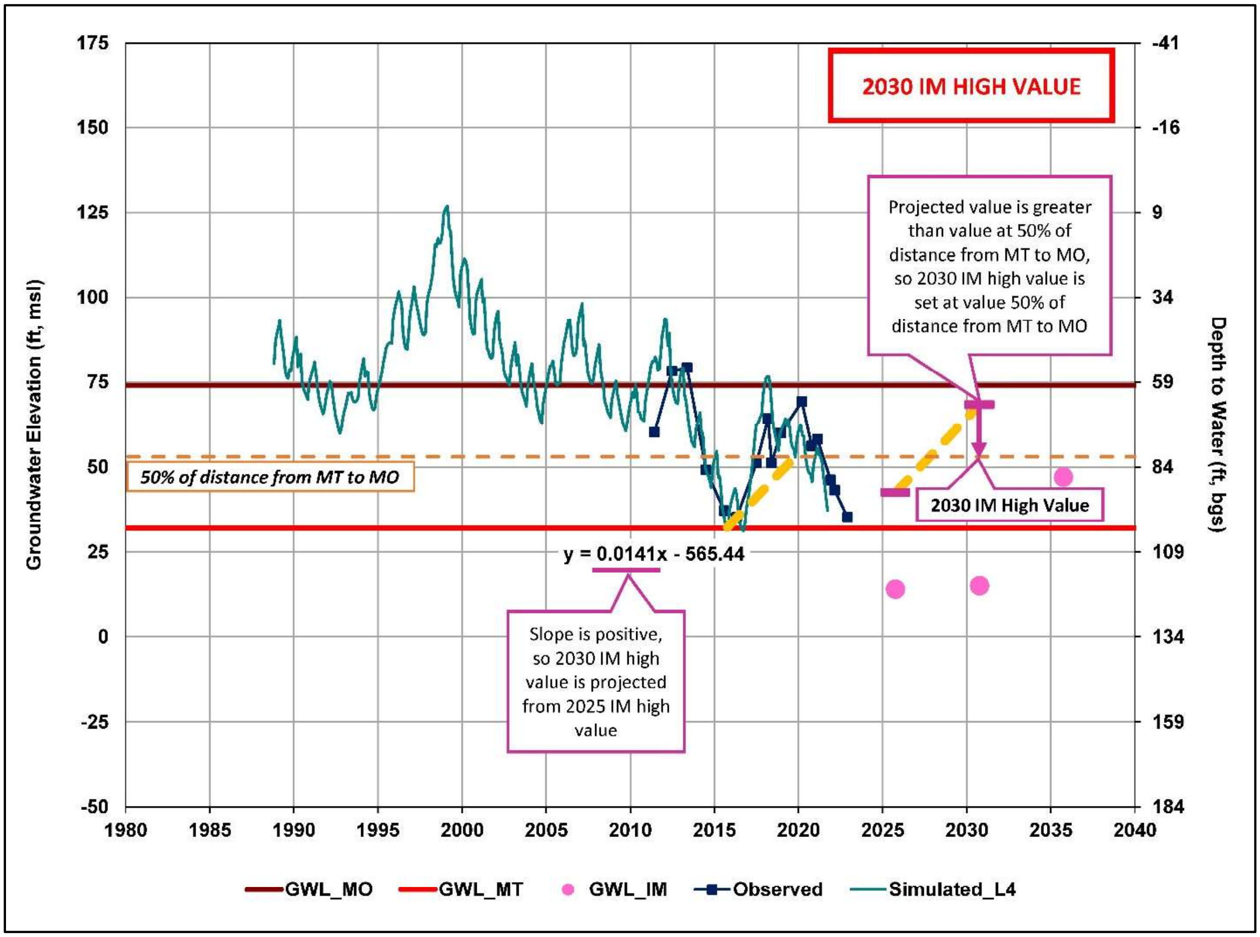


**Figure 5b. Example of the determination of the 2030 IM high value if slope between Fall 2015 and Fall 2019 measurements is positive (i.e., groundwater levels are recovering)**

## 2030 Interim Milestone

The final 2030 interim milestone was set 50% of the distance between the 2030 low value and the 2030 high value, and was calculated as follows:

[2030 IM low value] + 50% * ([2030 IM high value] – [2030 IM low value])

An example of the determination of the final 2030 interim value is presented in **Figure 6**.

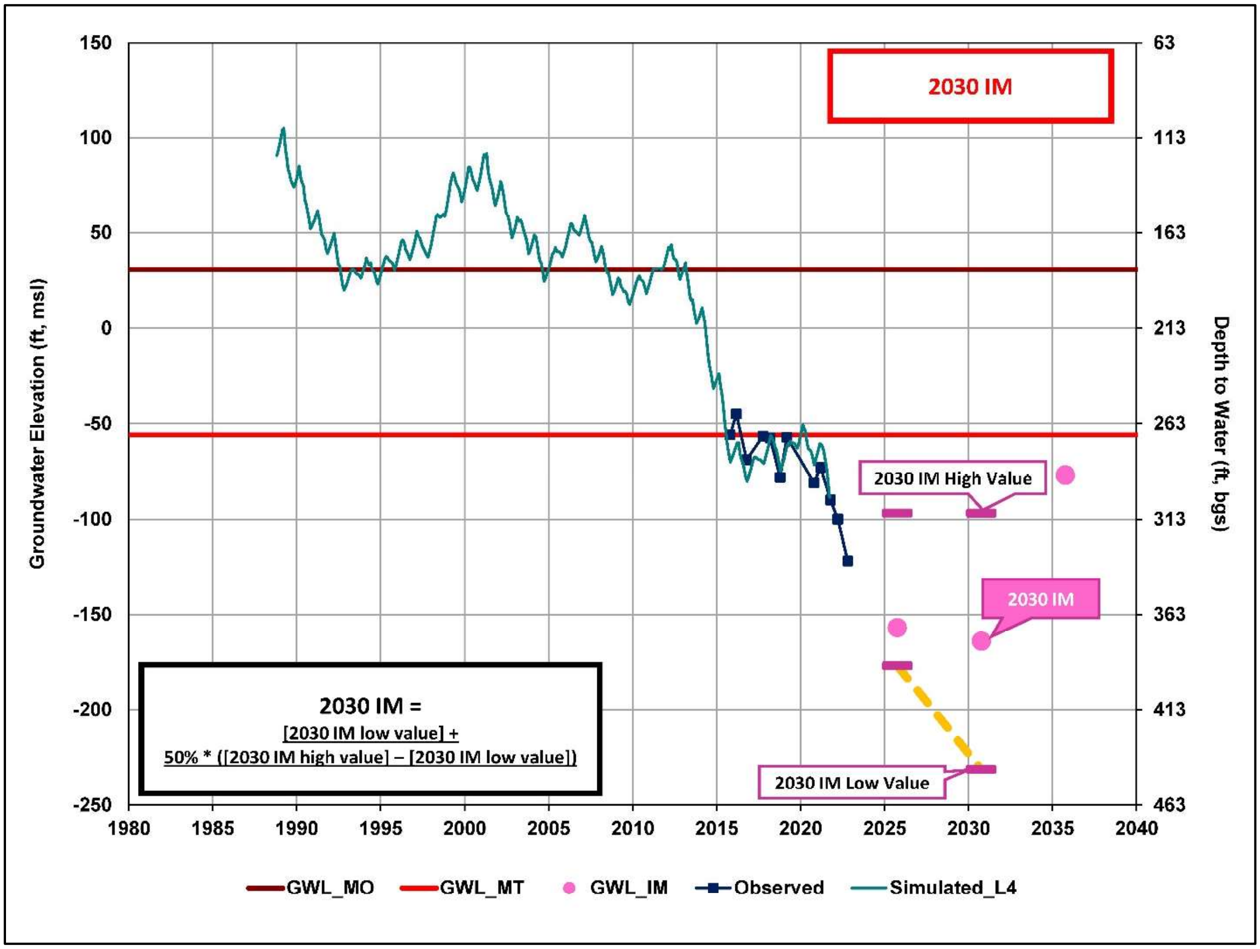


**Figure 6. Example of the determination of the final 2030 IM**

## *2035 Interim Milestone*

The 2035 IM continues upward trend in groundwater levels towards the MO.

### 2035 Low Value

The 2035 low value was determined by calculating the value one third of the way between the 2030 IM low value and the MO. If the resulting value is less than the MT, then the resulting value was set as the 2035 low value. If the resulting value is greater than the MT, then the MT was set as the 2035 low value.

1. Calculate the groundwater elevation value that is 1/3 of the distance from the 2030 IM low value to the MO.
2. **If the value calculated in step 1 is less than the MT, the value calculated in step 1 is the 2035 IM low value.**
3. **If the value calculated in step 1 is greater than the MT, then the MT is the 2035 IM low value.**

An example of the determination of the 2035 low value is presented in **Figure 7**.

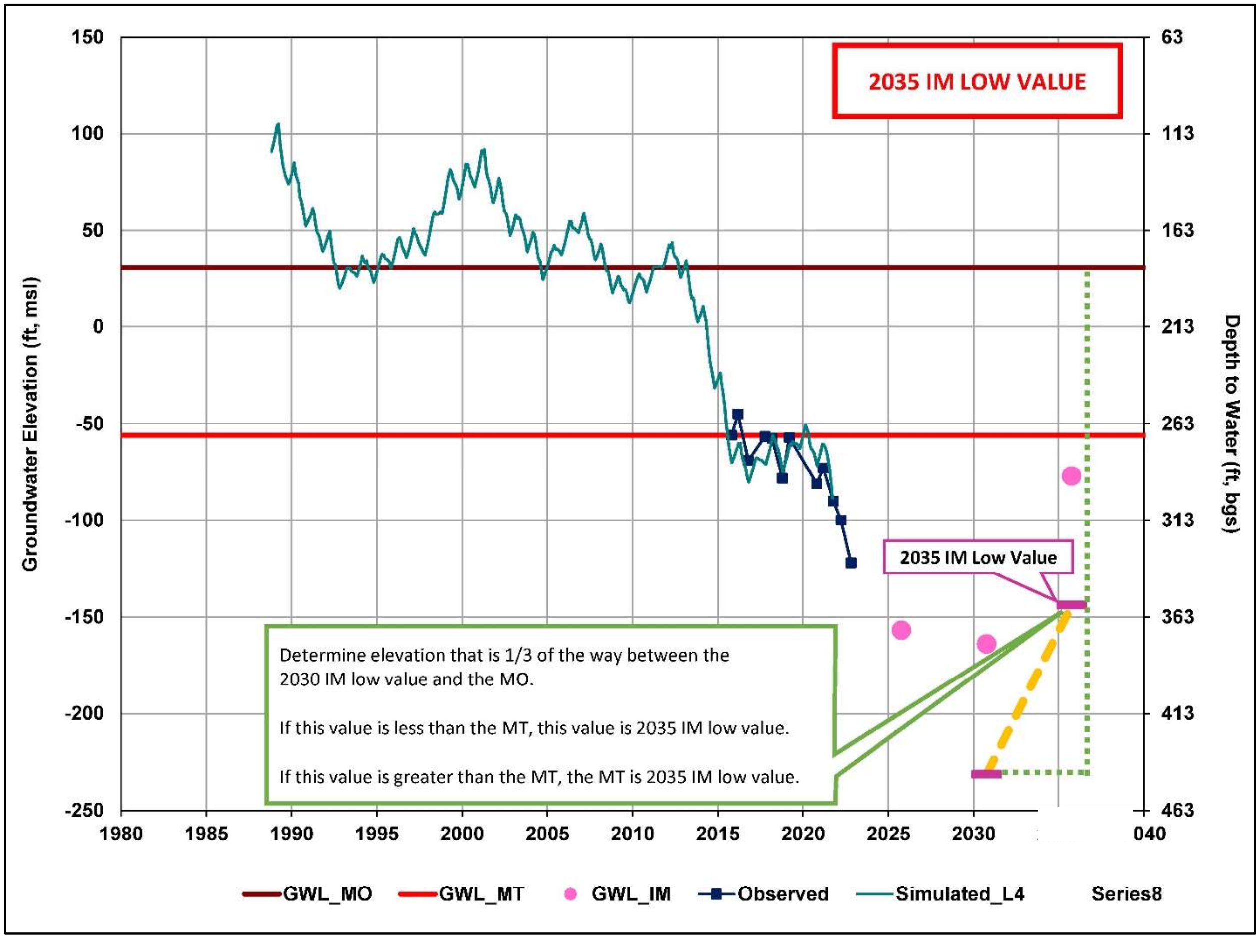


**Figure 7. Example of the determination of the 2035 IM low value**

## 2035 High Value

The 2035 high value was determined by calculating the value one third of the way between the 2030 IM high value and the MO. The resulting value was set as the 2035 high value.

1. Calculated the groundwater elevation value that is 1/3 of the distance from the 2030 IM high value to the MO.
2. **The value calculated in step 1 is the 2035 IM high value.**

An example of the determination of the 2035 high value is presented in **Figure 8**.

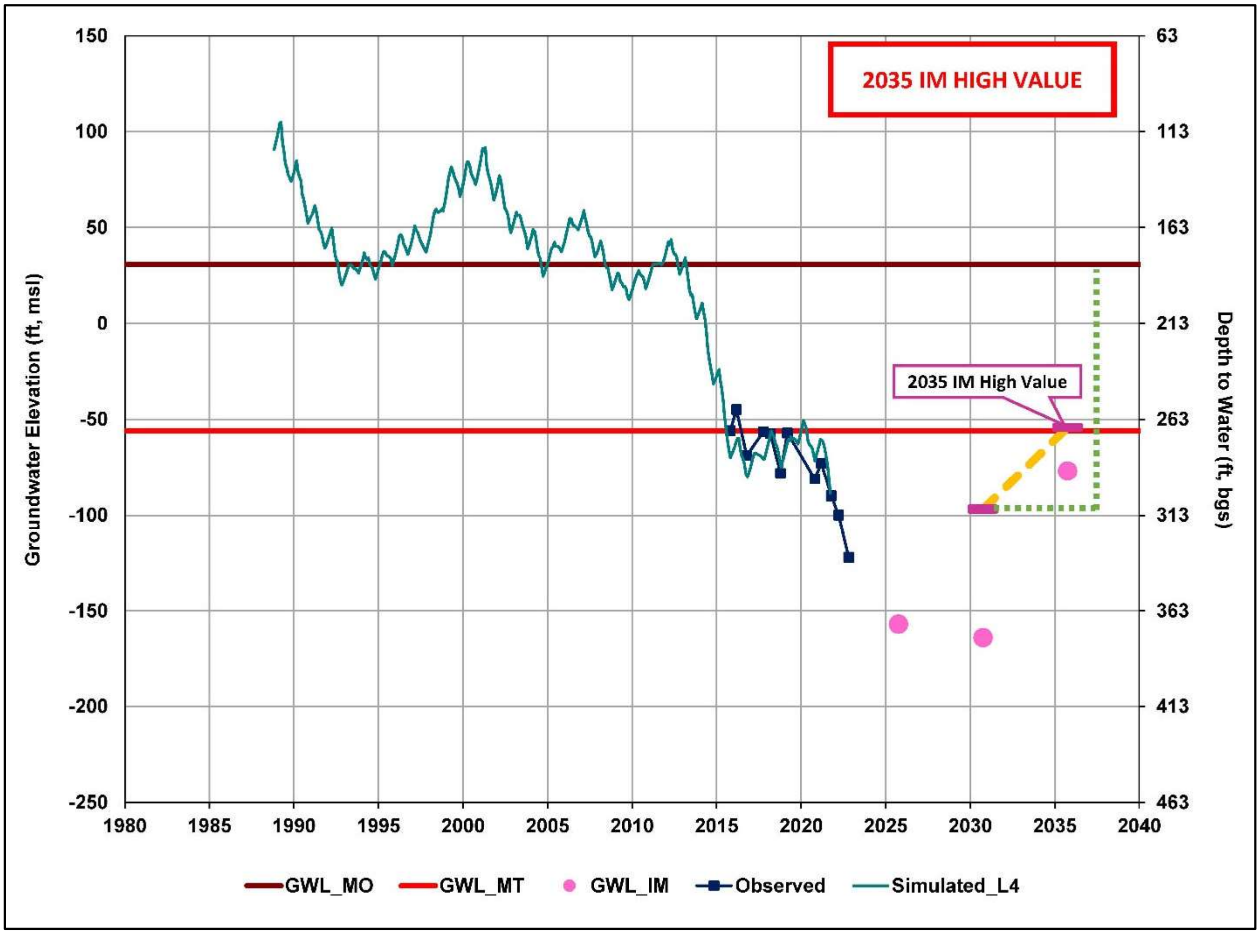


**Figure 8. Example of the determination of the 2035 IM high value**

## 2035 Interim Milestone

The final 2035 interim milestone was set 75% of the distance between the 2035 low value and the 2035 high value, and was calculated as follows:

[2035 IM low value] + 75% * ([2035 IM high value] – [2035 IM low value])

An example of the determination of the final 2035 interim value is presented in **Figure 9**.

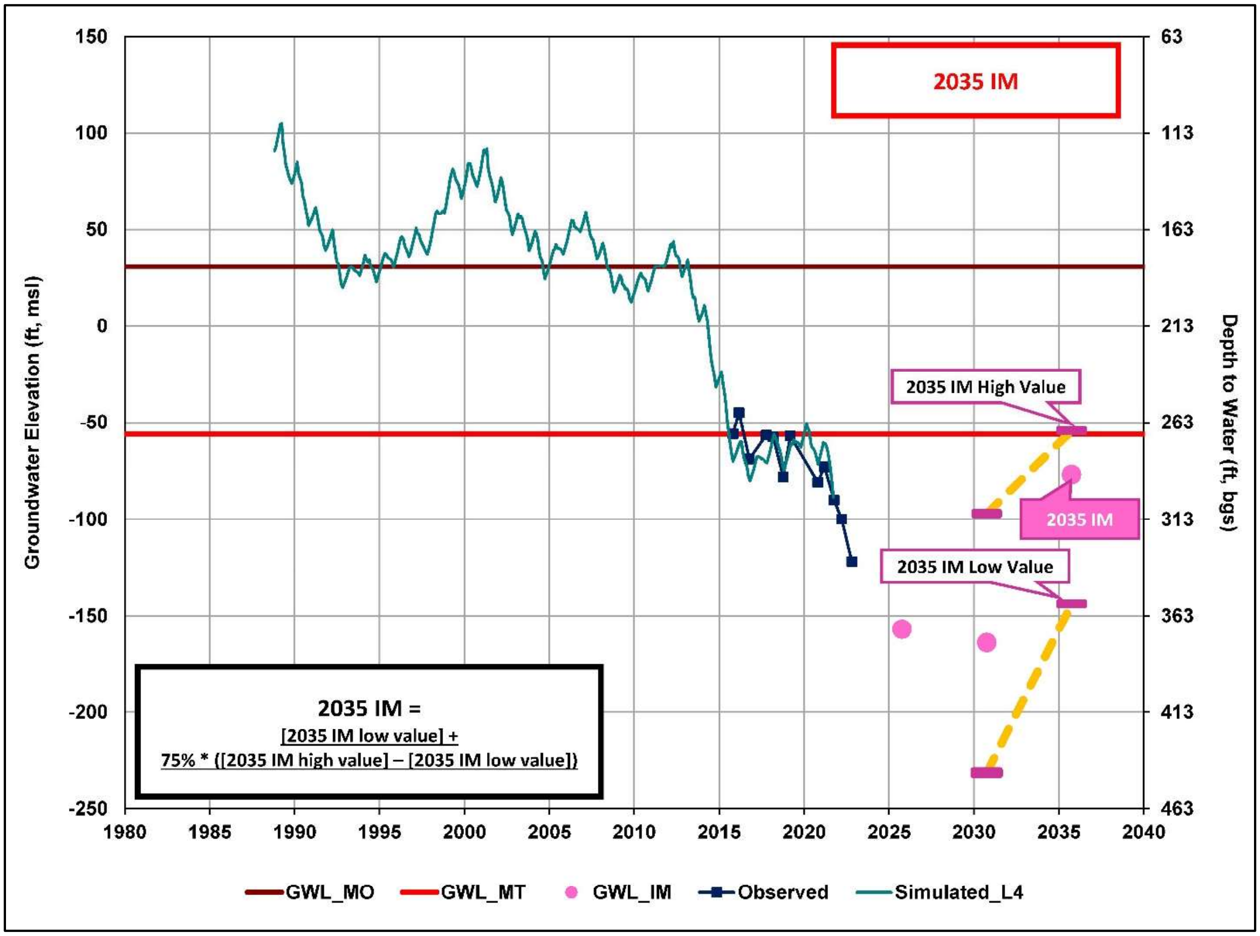


**Figure 9. Example of the determination of the final 2035 IM**

## *Final Interim Milestones*

Interim milestones for groundwater levels for each RMS are summarized in **Table 1**.

**Table 1. Summary of Groundwater Level Interim Milestones for Representative Monitoring Sites**

| Well I.D. | 2025 IM Groundwater Elevation (ft, msl) | 2030 IM Groundwater Elevation (ft, msl) | 2035 IM Groundwater Elevation (ft, msl) | Aquifer Designation |
|---|---|---|---|---|
| CWD RMS-1 | -98 | -86 | -22 | Lower |
| CWD RMS-2 | -107 | -102 | -46 | Lower |
| CWD RMS-3 | -139 | -132 | -47 | Lower |
| CWD RMS-4 | -125 | -135 | -70 | Lower |

| Table 1. Summary of Groundwater Level Interim Milestones for Representative Monitoring Sites | | | | |
|---|---|---|---|---|
| Well I.D. | 2025 IM Groundwater Elevation (ft, msl) | 2030 IM Groundwater Elevation (ft, msl) | 2035 IM Groundwater Elevation (ft, msl) | Aquifer Designation |
| CWD RMS-5 | -82 | -72 | 1 | Lower |
| CWD RMS-6 | -105 | -99 | -46 | Lower |
| CWD RMS-7 | -72 | -70 | -10 | Lower |
| CWD RMS-8 | -127 | -120 | -34 | Lower |
| CWD RMS-9 | 73 | 72 | 75 | Upper |
| CWD RMS-10 | -151 | -143 | -48 | Lower |
| CWD RMS-11 | 76 | 76 | 81 | Lower |
| CWD RMS-12 | 35 | 32 | 54 | Upper |
| CWD RMS-13 | -77 | -82 | -13 | Lower |
| CWD RMS-14 | -179 | -189 | -87 | Lower |
| CWD RMS-15 | -157 | -164 | -77 | Lower |
| CWD RMS-16 | -148 | -133 | -34 | Lower |
| CWD RMS-17 | -166 | -149 | -47 | Lower |
| MCE RMS-1 | -84 | -69 | -16 | Lower |
| MCE RMS-2 | -91 | -96 | -59 | Lower |
| MCW RMS-1 | 19 | 20 | 52 | Upper |
| MCW RMS-2 | 76 | 78 | 91 | Upper |
| MCW RMS-3 | 67 | 63 | 82 | Upper |
| MCW RMS-4 | -90 | -79 | -18 | Lower |
| MCW RMS-5 | -110 | -105 | -38 | Lower |
| MCW RMS-6 | -84 | -75 | -11 | Lower |
| MCW RMS-7 | -12 | -30 | -1 | Lower |
| MCW RMS-8 | -36 | -41 | 3 | Composite |
| MCW RMS-9 | -122 | -112 | -43 | Lower |

**Table 1. Summary of Groundwater Level Interim Milestones for Representative Monitoring Sites**

| Well I.D. | 2025 IM Groundwater Elevation (ft, msl) | 2030 IM Groundwater Elevation (ft, msl) | 2035 IM Groundwater Elevation (ft, msl) | Aquifer Designation |
|---|---|---|---|---|
| MCW RMS-10 | 94 | 96 | 105 | Upper |
| MCW RMS-11 | 88 | 91 | 107 | Upper |
| MCW RMS-12 | 78 | 80 | 100 | Upper |
| MER RMS-1 | -129 | -117 | -37 | Lower |
| TRT RMS-1 | 14 | 15 | 47 | Upper |
| TRT RMS-2 | -3 | -17 | 24 | Lower |
| TRT RMS-3 | -63 | -66 | -25 | Lower |
| TRT RMS-4 | -14 | -12 | 9 | Composite |