*The free Adobe Reader may be used to view and complete this form. However, software must be purchased to complete, save, and reuse a saved form.

File Original with DWR

State of California

Well Completion Report

Refer to Instruction Pamphlet

No. e0213859

DWR Use Only – Do Not Fill In

State Well Number/Site Number

N Latitude — W Longitude

APN/TRS/Other

Page One of One

Owner's Well Number MW3

Date Work Began 04/17/2014 Date Work Ended 5/5/2014

Local Permit Agency SD DEH

Permit Number LWELL000839 Permit Date 1/23/14

Geologic Log

Orientation ⦿ Vertical ○ Horizontal ○ Angle Specify ____

Drilling Method Direct Rotary Drilling Fluid Bentonite mud

Depth from Surface Feet	to Feet	Description (Describe material, grain size, color, etc)
0	12	Brown Medium to Fine Sand
12	15	Clay w/ Medium to Fine Sand
15	22	Brown Medium to Fine Sand
22	37	Clay w/ Medium to Fine Sand
37	75	Grey Clay and Silt
75	88	Black Clay
88	105	Grey Clay w/ Fine Sand and Silt
105	108	Medium Sand w/ Clay
108	112	Fine to Medium Sand and Clay
112	128	Compacted Sand with Clay
128	158	Clay and Silt
158	175	Weathered Rock
175	191	Bedrock/Granite

Total Depth of Boring 191 Feet

Total Depth of Completed Well 150 Feet

Well Owner

Name Rancho Guejito Corporation

Mailing Address 17224 San Pasqual Valley Road

City Escondido State CA Zip 92029

Well Location

Address 17224 San Pasqual Valley Road

City San Pasqual County San Diego

Latitude ___ Deg. ___ Min. ___ Sec. N Longitude ___ Deg. ___ Min. ___ Sec. W

Datum ____ Dec. Lat. 33.0948 Dec. Long. 116.9585

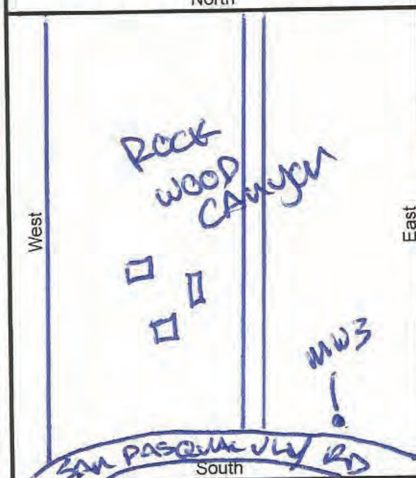
APN Book 242 Page 110 Parcel 01

Township ____ Range ____ Section ____

Location Sketch

(Sketch must be drawn by hand after form is printed.)

North



Illustrate or describe distance of well from roads, buildings, fences, rivers, etc. and attach a map. Use additional paper if necessary. Please be accurate and complete.

Activity

⦿ New Well
○ Modification/Repair
○ Deepen
○ Other ____
○ Destroy
Describe procedures and materials under "GEOLOGIC LOG"

Planned Uses

○ Water Supply
☐ Domestic ☐ Public
☐ Irrigation ☐ Industrial
○ Cathodic Protection
○ Dewatering
○ Heat Exchange
○ Injection
⦿ Monitoring
○ Remediation
○ Sparging
○ Test Well
○ Vapor Extraction
○ Other ____

Water Level and Yield of Completed Well

Depth to first water ____ (Feet below surface)

Depth to Static Water Level 54 (Feet) Date Measured 05/02/2014

Estimated Yield * 75 (GPM) Test Type Air Lift

Test Length 7.5 (Hours) Total Drawdown ____ (Feet)

*May not be representative of a well's long term yield.

Casings

Depth from Surface Feet	to Feet	Borehole Diameter (Inches)	Type	Material	Wall Thickness (Inches)	Outside Diameter (Inches)	Screen Type	Slot Size if Any (Inches)
0	50	10	Blank	PVC F-480	.237	4.5		
50	130	10	Screen	PVC F-480	.237	4.5	Milled Slots	0.032
130	150	10	Blank	PVC F-480	.237	4.5		

Annular Material

Depth from Surface Feet	to Feet	Fill	Description
1	20	Cement	
20	25	Bentonite	
25	170	Filter Pack	
170	191	Native	

Attachments

☐ Geologic Log
☑ Well Construction Diagram
☑ Geophysical Log(s)
☐ Soil/Water Chemical Analyses
☑ Other Site Map

Attach additional information, if it exists.

Certification Statement

I, the undersigned, certify that this report is complete and accurate to the best of my knowledge and belief

Name Fain Drilling and Pump Company, Inc.
Person, Firm or Corporation

12029 Old Castle Road (Address) Valley Center (City) CA (State) 92082 (Zip)

Signed [signature] C-57 Licensed Water Well Contractor

Date Signed 5/16/2014 C-57 License Number 328287

DWR 188 REV. 1/2006

IF ADDITIONAL SPACE IS NEEDED, USE NEXT CONSECUTIVELY NUMBERED FORM

*The free Adobe Reader may be used to view and complete this form. However, software must be purchased to complete, save, and reuse a saved form.

File Original with DWR

State of California

Well Completion Report

Refer to Instruction Pamphlet

No. e0361105

Page ________ of ________

Owner's Well Number RC-8

Date Work Began 11/19/2014 Date Work Ended ________

Local Permit Agency COUNTY OF SAN DIEGO

Permit Number LWELL-000731 Permit Date 11/10/14

DWR Use Only – Do Not Fill In

State Well Number/Site Number

Latitude N Longitude W

APN/TRS/Other

Geologic Log

Orientation ○ Vertical ○ Horizontal ○ Angle Specify ________

Drilling Method ________ Drilling Fluid ________

Depth from Surface Feet	to Feet	Description (Describe material, grain size, color, etc)
0	24	TOP SOIL
24	44	SAND,CLAY STREAK
44	84	CLAY,COBBLE
84	104	SAND, CLAY
104	124	SAND, CLAY, COBBLE
124	164	SAND
164	184	SAND, DG
184	206	GRANITE
		PERFORATIONS:
		55'-85'
		95'-185'

Total Depth of Boring 206 Feet

Total Depth of Completed Well 205 Feet

Well Owner

Name RANCHO GUEJITO CORP

Mailing Address 17224 SAN PASQUAL VALLEY RD

City ESCONDIDO State CA Zip 92027

Well Location

Address 17224 SAN PASQUAL VALLEY RD

City ESCONDIDO County San Diego

Latitude ____ ____ ____ N Longitude ____ ____ ____ W (Deg. Min. Sec.)

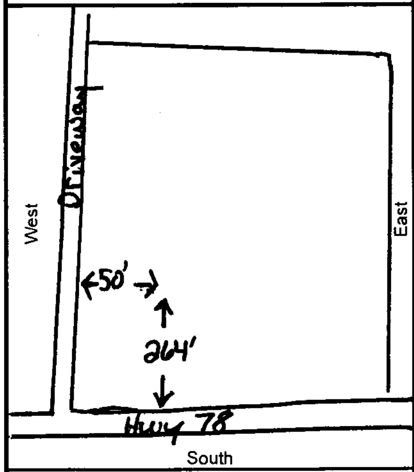
Datum ________ Dec. Lat. ________ Dec. Long. ________

APN Book 242 Page 070 Parcel 07

Township ________ Range ________ Section ________

Location Sketch

(Sketch must be drawn by hand after form is printed.)



Illustrate or describe distance of well from roads, buildings, fences, rivers, etc. and attach a map. Use additional paper if necessary. Please be accurate and complete.

Activity

◉ New Well
○ Modification/Repair
○ Deepen
○ Other ________
○ Destroy
Describe procedures and materials under "GEOLOGIC LOG"

Planned Uses

◉ Water Supply
☐ Domestic ☐ Public
☑ Irrigation ☐ Industrial
○ Cathodic Protection
○ Dewatering
○ Heat Exchange
○ Injection
○ Monitoring
○ Remediation
○ Sparging
○ Test Well
○ Vapor Extraction
○ Other ________

Water Level and Yield of Completed Well

Depth to first water ________ (Feet below surface)

Depth to Static Water Level 64' (Feet) Date Measured ________

Estimated Yield * 350 (GPM) Test Type Test Pumped

Test Length 24 (Hours) Total Drawdown ______ (Feet)

*May not be representative of a well's long term yield.

Casings

Depth from Surface Feet	to Feet	Borehole Diameter (Inches)	Type	Material	Wall Thickness (Inches)	Outside Diameter (Inches)	Screen Type	Slot Size if Any (Inches)
0	20	30			5/16	24		
20	200	22						
0	195				.25	12ID	Louver	0.055

Annular Material

Depth from Surface Feet	to Feet	Fill	Description
0	20	Cement	10 SACK
0	205	Filter Pack	TACNA 8 X 20

Attachments

☐ Geologic Log
☐ Well Construction Diagram
☐ Geophysical Log(s)
☐ Soil/Water Chemical Analyses
☐ Other ________

Attach additional information, if it exists.

Certification Statement

I, the undersigned, certify that this report is complete and accurate to the best of my knowledge and belief

Name L O LYNCH QUALITY WELLS & PUMPS INC
Person, Firm or Corporation

856 W SEVENTH STREET SAN JACINTO CA 92582
Address City State Zip

Signed Kenneth S Swartdout 1-30-2015 740156
C-57 Licensed Water Well Contractor Date Signed C-57 License Number

DWR 188 REV. 1/2006

IF ADDITIONAL SPACE IS NEEDED, USE NEXT CONSECUTIVELY NUMBERED FORM

Well 2H

ORIGINAL OCT 31 1976
File with DWR

STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES

WATER WELL DRILLERS REPORT

Do Not Fill In
№ 100632
State Well No. 12S/1W-26
Other Well No.

(1) OWNER:
Name George A. Hillebrecht, Inc.
Address 2170 Skyline Drive
Escondido, California

(2) LOCATION OF WELL:
County San Diego Owner's number, if any
Township, Range, and Section 12-S 1W Sec 26
Distance from cities, roads, railroads, etc. San Pasqual Valley Rd. San Pasqual

(3) TYPE OF WORK (check):
New Well [X] Deepening [ ] Reconditioning [ ] Destroying [ ]
If destruction, describe material and procedure in Item 11.

(4) PROPOSED USE (check):
Domestic [ ] Industrial [ ] Municipal [ ]
Irrigation [X] Test Well [ ] Other [ ]

(5) EQUIPMENT:
Rotary [X]
Cable [ ]
Other [ ]

(6) CASING INSTALLED:
STEEL: SINGLE [X] DOUBLE [ ] OTHER:

From ft.	To ft.	Diam.	Gage or Wall	Diameter of Bore (If gravel packed)	From ft.	To ft.
0	20	16"	.250	18"	0	203
0	203	10"	.250			

Size of shoe or well ring: None Size of gravel: 1/8 Inch
Describe joint Welded

(7) PERFORATIONS OR SCREEN:
Type of perforation or name of screen Johnson Irrigator #50 Slot

From ft.	To ft.	Perf. per row	Rows per ft.	Size in. x in.
99	109	Well	Screen	.050 Screen Opening Size
119	129	"	"	
139	149	"	"	
159	169	"	"	
179	189	"	"	

(8) CONSTRUCTION:
Was a surface sanitary seal provided? Yes [X] No [ ] To what depth 20 ft.
Were any strata sealed against pollution? Yes [ ] No [X] If yes, note depth of strata
From ft. to ft.
From ft. to ft.
Method of sealing Puddled Clay & Steel Cased

(9) WATER LEVELS:
Depth at which water was first found, if known UKN ft.
Standing level before perforating, if known UKN ft.
Standing level after perforating and developing 32 ft.

(10) WELL TESTS: air pumped w/rig
Was pump test made? Yes [ ] No [X] If yes, by whom?
Yield: 800+ gal./min. with 100 ft. drawdown after 6 hrs.
Temperature of water ukn Was a chemical analysis made? Yes [ ] No [X]
Was electric log made of well? Yes [ ] No [X] If yes, attach copy

(11) WELL LOG:
Total depth 210 ft. Depth of completed well 210 ft.
Formation: Describe by color, character, size of material, and structure
ft. to ft.

0-60 Fine, silty sand - dark brown color

60-90 "Tule" Bed, black, silty sand with pieces of wood and vegatation embedded within

90-140 Fine to coarse sand - dark brown color

140-165 Partly cemented sand with some gravel dark brown color

165-208 Residuum (decomposed granite) with granite nodules - brown color

208-210 Hard rock - Granite

~~CONFIDENTIAL NOT FOR PUBLIC RELEASE~~

Work started 8/18 1976, Completed 8/21 1976

WELL DRILLER'S STATEMENT:
This well was drilled under my jurisdiction and this report is true to the best of my knowledge and belief.

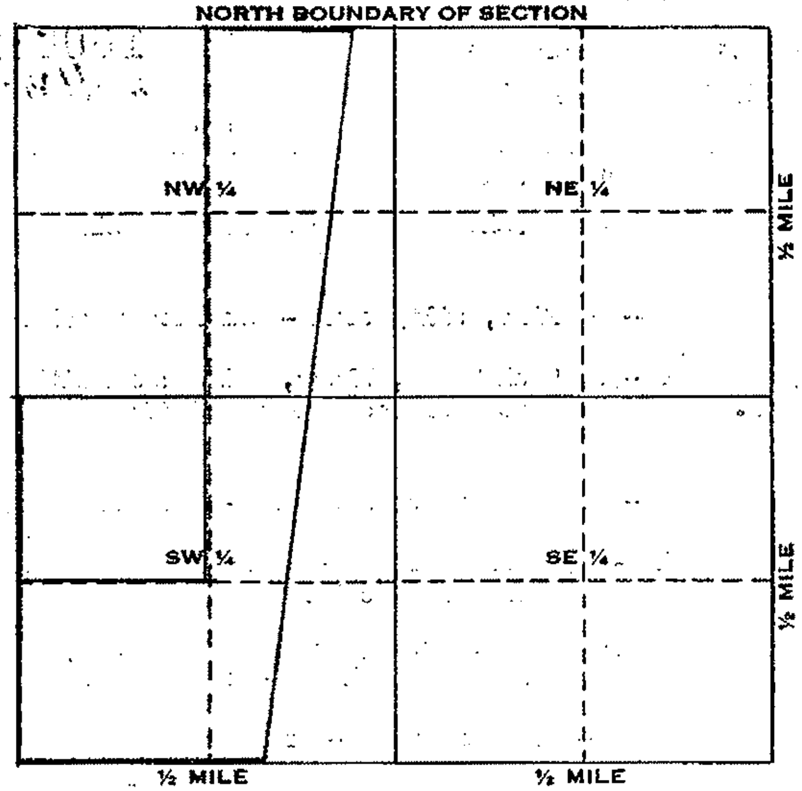
NAME Fain Drilling Co.
(Person, firm, or corporation) (Typed or printed)
Address P.O. Box 603
Valley Center, California 92082
[SIGNED] [signature]
(Well Driller)
License No. 252357 Dated 8/23, 1976

SKETCH LOCATION OF WELL ON REVERSE SIDE

REV. 9-68

67(58-750 8-72 30M TRIP OSP

WELL LOCATION SKETCH

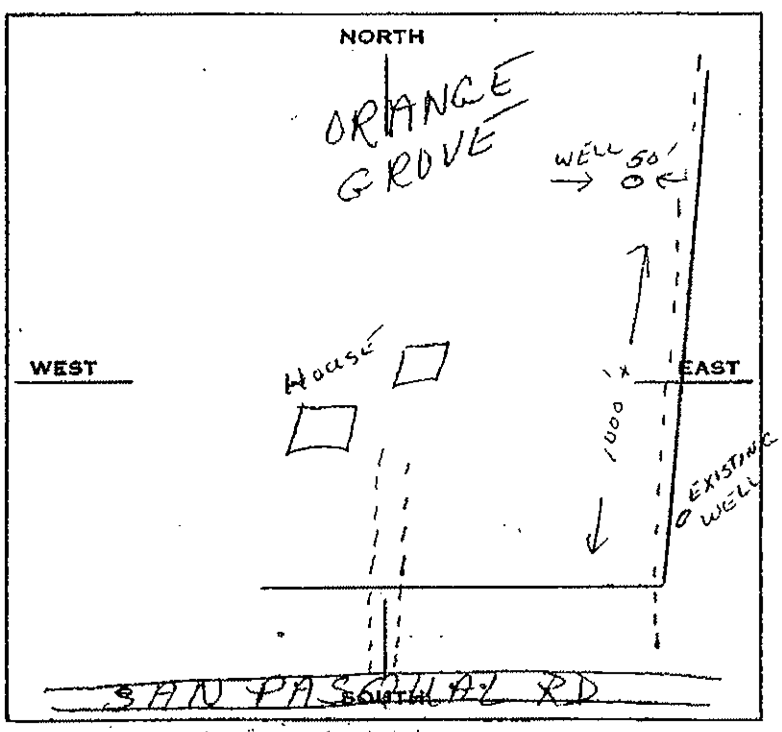


Township 12-S N/S

Range 1-W E/W

Section No. 26

A. Location of well in sectionized areas.
Sketch roads, railroads, streams, or other features as necessary.



B. Location of well in areas not sectionized.
Sketch roads, railroads, streams, or other features as necessary.
Indicate distances.

RECEIVED
7 35 AM '76

RECEIVED
OCT 32 8 33 AM '76

COUNTY OF SAN DIEGO
DEPARTMENT OF ENVIRONMENTAL HEALTH
WELL PERMIT APPLICATION

DEH USE ONLY
PERMIT # W LWHL 16379
WELL COMPUTER #
FEE: ~~[illegible]~~ 390.00
WATER DIST: ________

RECEIVED DEC 13 2004 Dept. of Env. Health

1. Property Owner: TYSON SHORT Phone: ________
17331 SAN PASQUAL Vly Rd. (Mailing Address) ESCONdido (City) 92027 (Zip)
2. Well Location - Assessors Parcel Number 242-110-10
17331 SAN PASQUAL VLY RD (Site Address) ESCondido (City) 92027 (Zip)
3. Well Contractor - Well Driller Joe EDWARDS Company Name: FAIN DRilling
12029 old CAStle Rd (Mailing Address) VAlley CENTER (City) 92082 (Zip)
Phone#: 760-749-0701 C-57#: 328281 ☐ Cash Deposit ☒ Bond Posted
4. Use: ☒ Private ☐ Public ☐ Industrial ☐ Cathodic ☐ Other ________
5. Type of Work: ☒ New ☐ Reconstruction ☐ Destruction Time Extension: ☐ 1st ☐ 2nd
6. Type of Equipment: ROTARY
7. Depth of Well: Proposed: 140'-160' Existing: —0—
8. Proposed:

Casing	Conductor Casing	Filter/Filler Material	Perforations
Type: PVC	☒ Yes ☐ No	☒ Yes ☐ No	
Depth: 140-160	Depth: 20 ft.	From: 20 To: 140	From: 90 To: 140
Diameter 8 in.	Diameter 16 in.	Type: PEA GRAVEL	From: ____ To: ____
Wall/Gauge: .500	Wall/Gauge: .250	~~Wall/Gauge:~~	From: ____ To: ____

9. Annular Seal: Depth: 20 ft. Sealing Material: CEMENT
Borehole diameter: 22 in. Conductor diameter: 16 in. Annular Thickness 3+ in.
10. Date of Work: Start: Dec-2004 Complete: Dec-2004

On sites served by public water, contact the local water agency for meter protection requirements.

I hereby agree to comply with all regulations of the Department of Environmental Health, and with all ordinances and laws of the County of San Diego and the State of California pertaining to well construction, repair, modification and destruction. Immediately upon completion of work, I will furnish the Department of Environmental Health with a complete and accurate log of the well. I accept responsibility for all work done as part of this permit and all work will be performed under my direct supervision.

Contractor's Signature: [signature] Date: 12-10-04

DISPOSITION OF APPLICATION (Department of Environmental Health Use only)

☒ **Approved** ☐ **Denied** Special Conditions: Grading and clearing associated with access to, or the construction, maintenance or destruction of water wells, may require additional permits from the County of San Diego and/or other agencies. City of San Diego

Specialist: [signature] Date: 13 DEC 04

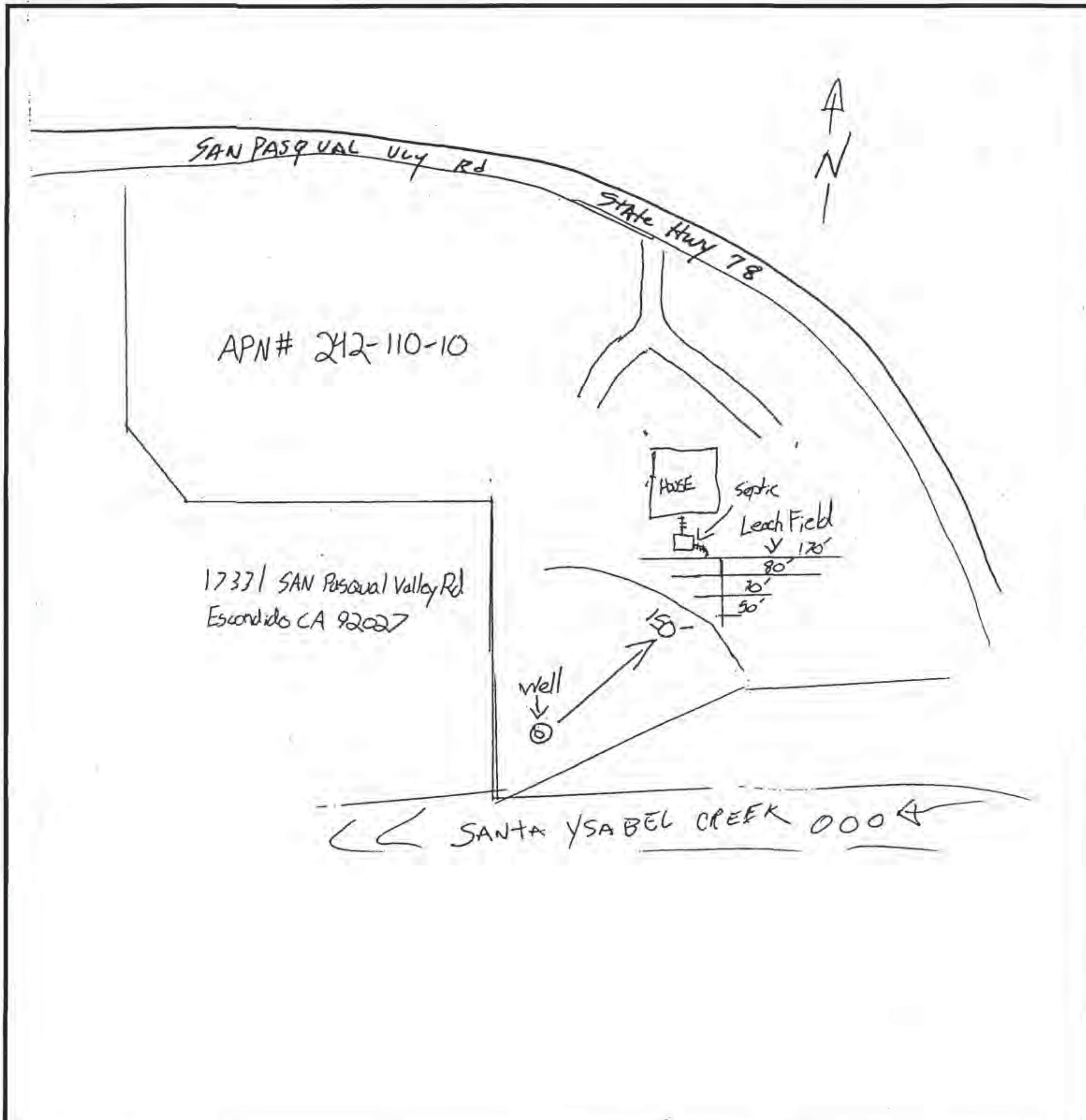
COUNTY OF SAN DIEGO
DEPARTMENT OF ENVIRONMENTAL HEALTH

RECEIVED
DEC 13 2004

Control #: LW2L 16379
Assessor's Parcel Number: 242-110-10

LOCATION

Indicate below the vicinity and exact location of well with respect to the following items: Property lines, water bodies or water courses, drainage pattern, easements, roads, existing wells, sewers and private sewage disposal systems and other potential contamination sources, including dimensions.



QUADRUPLICATE
For Local Requirements

STATE OF CALIFORNIA

WELL COMPLETION REPORT

Refer to Instruction Pamphlet

No. 0909553

DWR USE ONLY — DO NOT FILL IN
STATE WELL NO./STATION NO.
LATITUDE / LONGITUDE
APN/TRS/OTHER

Page 1 of 1
Owner's Well No. ~~Two~~
Date Work Began ~~12/21/04~~, Ended ~~1/6/05~~
Local Permit Agency ~~DEH~~
Permit No. ~~16379~~ Permit Date ~~12/13/04~~

GEOLOGIC LOG

ORIENTATION (✓) X VERTICAL ___ HORIZONTAL ___ ANGLE ___ (SPECIFY)
DRILLING METHOD Rotary FLUID Gel & Air

DEPTH FROM SURFACE Ft. to Ft.		DESCRIPTION Describe material, grain size, color, etc.
~~0~~	~~70~~	~~Sand, fine grained, partly cemented~~
~~70~~	~~110~~	~~Decomposed granite, hard Brown turning to grey color~~
~~110~~	~~113~~	~~Hard bed rock - granite grey color~~
~~113~~	~~189~~	~~Granite, hard~~
~~189~~	~~192~~	~~Fracture - water 10 gpm~~
~~192~~	~~360~~	~~Hard, rigging, granidiorite grey color with black and white minerals~~
~~360~~	~~385~~	~~Fracture zone - most water approx 150 GPM obtained here~~
~~385~~	~~410~~	~~Granidiorite~~

TOTAL DEPTH OF BORING 410 (Feet)
TOTAL DEPTH OF COMPLETED WELL 410 (Feet)

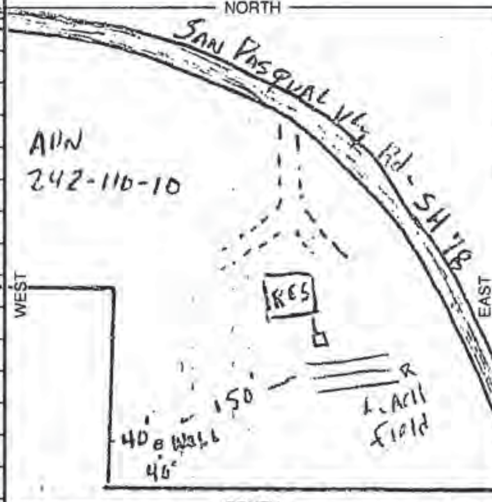
The information in this grayed area has been blocked from public viewing pursuant to section 13752 of the Water Code and the Information Practice Act of 1977, to protect personal information.

NOT FOR PUBLIC CONFIDENTIAL WATER CODE SEC. 13752

WELL LOCATION

Address ~~17331 San Pasqual Valley Rd.~~
City ~~Escondido~~
County ~~San Diego~~
APN Book ~~242~~ Page ~~110~~ Parcel ~~10~~
Township ~~12 S~~ Range ~~1 W~~ Section ~~35~~
Lat ~~33°~~ ~~05~~ ~~601~~ N (DEG. MIN. SEC.) Long ~~116°~~ ~~57~~ ~~475~~ W (DEG. MIN. SEC.)

LOCATION SKETCH



Illustrate or Describe Distance of Well from Roads, Buildings, Fences, Rivers, etc. and attach a map. Use additional paper if necessary. PLEASE BE ACCURATE & COMPLETE.

ACTIVITY (✓)

X NEW WELL
MODIFICATION/REPAIR
___ Deepen
___ Other (Specify)
___ DESTROY (Describe Procedures and Materials Under "GEOLOGIC LOG")

USES (✓)

WATER SUPPLY
X Domestic ___ Public
___ Irrigation ___ Industrial
MONITORING ___
TEST WELL ___
CATHODIC PROTECTION ___
HEAT EXCHANGE ___
DIRECT PUSH ___
INJECTION ___
VAPOR EXTRACTION ___
SPARGING ___
REMEDIATION ___
OTHER (SPECIFY) ___

WATER LEVEL & YIELD OF COMPLETED WELL

DEPTH TO FIRST WATER ~~80~~ (Ft.) BELOW SURFACE
DEPTH OF STATIC WATER LEVEL 68 (Ft.) & DATE MEASURED 1/6/05
ESTIMATED YIELD * 150+ (GPM) & TEST TYPE airlift
TEST LENGTH 4 (Hrs.) TOTAL DRAWDOWN 300 (Ft.)
** May not be representative of a well's long-term yield.*

CASING (S)

DEPTH FROM SURFACE Ft.	to Ft.	BORE-HOLE DIA. (Inches)	BLANK	SCREEN	CON-DUCTOR	FILL PIPE	MATERIAL / GRADE	INTERNAL DIAMETER (Inches)	GAUGE OR WALL THICKNESS	SLOT SIZE IF ANY (Inches)
0	20	22	X				steel	15.5	.250	
0	75	15	X				PVCF480	7.8	.500	
75	115	15		X			PVCF480	7.8	.500	.032
115	410	6.5					Open Hole			

ANNULAR MATERIAL

DEPTH FROM SURFACE Ft.	to Ft.	CE-MENT (✓)	BEN-TONITE (✓)	FILL (✓)	FILTER PACK (TYPE/SIZE)
0	20	X			
20	113				6/16 [illegible]

ATTACHMENTS (✓)

___ Geologic Log
X Well Construction Diagram
___ Geophysical Log(s)
___ Soil/Water Chemical Analyses
___ Other
ATTACH ADDITIONAL INFORMATION, IF IT EXISTS.

CERTIFICATION STATEMENT

I, the undersigned, certify that this report is complete and accurate to the best of my knowledge and belief.

NAME Fain Drilling & Pump Co Inc
(PERSON, FIRM, OR CORPORATION) (TYPED OR PRINTED)
12029 Old Castle Rd. Valley Center, Ca 92082
ADDRESS CITY STATE ZIP

Signed [signature] 1-8-05 372227
C-57 LICENSED WATER WELL CONTRACTOR DATE SIGNED C-57 LICENSE NUMBER

DWR 188 REV. 05-03

IF ADDITIONAL SPACE IS NEEDED, USE NEXT CONSECUTIVELY NUMBERED FORM

15 of 07

COUNTY OF SAN DIEGO
DEPARTMENT OF HEALTH SERVICES

WELL PERMIT APPLICATION

Loc# 828

APN 242-070-07

Control # W08874

TYPE OF WORK (Check)		USE (Check)		EQUIPMENT (Check)	
New Well	[X]	Individual Domestic	[X]	Rotary	[X]
Repair or Modification	[ ]	Agricultural [ ]	Community [ ]	Cable Tool	[ ]
Time Extension	[ ]	Industrial [ ]	Other ____	Other	[ ]
Destruction	[ ]				

PROPOSED WELL DEPTH: Max. 100 Min. 80 (Feet)

PROPOSED CASING: Type F480 PVC Depth 100' Diameter 5" Wall or Gage .25 C-200

PROPOSED SEALING ZONE(S)

From 0 to 20 Feet
From ____ to ____ Feet
From ____ to ____ Feet

SEALING MATERIAL (Check)

Neat Cement Grout [X] Bentonite Clay [ ]
Sand Cement Grout [ ] Concrete [ ]
Other-Specify: ____

PROPOSED PERFORATIONS OR SCREEN

From 60 to 100 Feet
From ____ to ____ Feet
From ____ to ____ Feet
From ____ to ____ Feet

DATE OF WORK

Start Dec-9-94
Completion Dec-13-94

NAME OF WELL OWNER 714-661-1755
Ron Hansen - Rockwood Ranch

NAME OF WELL DRILLER
Randy Stevens

LOCATION OF WELL
Hwy 78 - San Pasqual Vly Rd - ESC

COMPANY 749-0701
Fain Drilling & Pump Co. Inc.

BUSINESS ADDRESS
12029 Old Castle Rd - Valley Center

LICENSE NUMBER
328287

Cash Deposit [ ]
Bond Posted [ ]

$135 Fee paid on 12/7/94 CB

DISPOSITION OF APPLICATION
(FOR HEALTH OFFICERS USE ONLY)

[ ] APPROVED [ ] DENIED

[X] APPROVED WITH CONDITIONS

Report Reason(s) for Denial or Necessary Conditions Here:

On sites served with public water, contact the local water agency for meter protection requirements.

* This area is known for high nitrate levels, it is recommended that a 50 ft. seal be applied

* Final Pending on approved H_2O sample

M. Sedgh
HEALTH OFFICER

12-7-94
DATE

I hereby agree to comply with all regulations of the Department of Health Services and with all ordinances and laws of the County of San Diego and of the State of California pertaining to well construction, repair, modification and destruction. Immediately upon completion of work I will furnish the Department of Health Services with a complete and accurate log of the well.

Joe R. Fain
APPLICANT'S SIGNATURE

12-7-94
DATE

242-070-15 34032 Blue Lantern - Dana Point, CA 92629

WEL - 5346

242-070-06

HANSEN, RON

COUNTY OF SAN DIEGO
DEPARTMENT OF HEALTH SERVICES

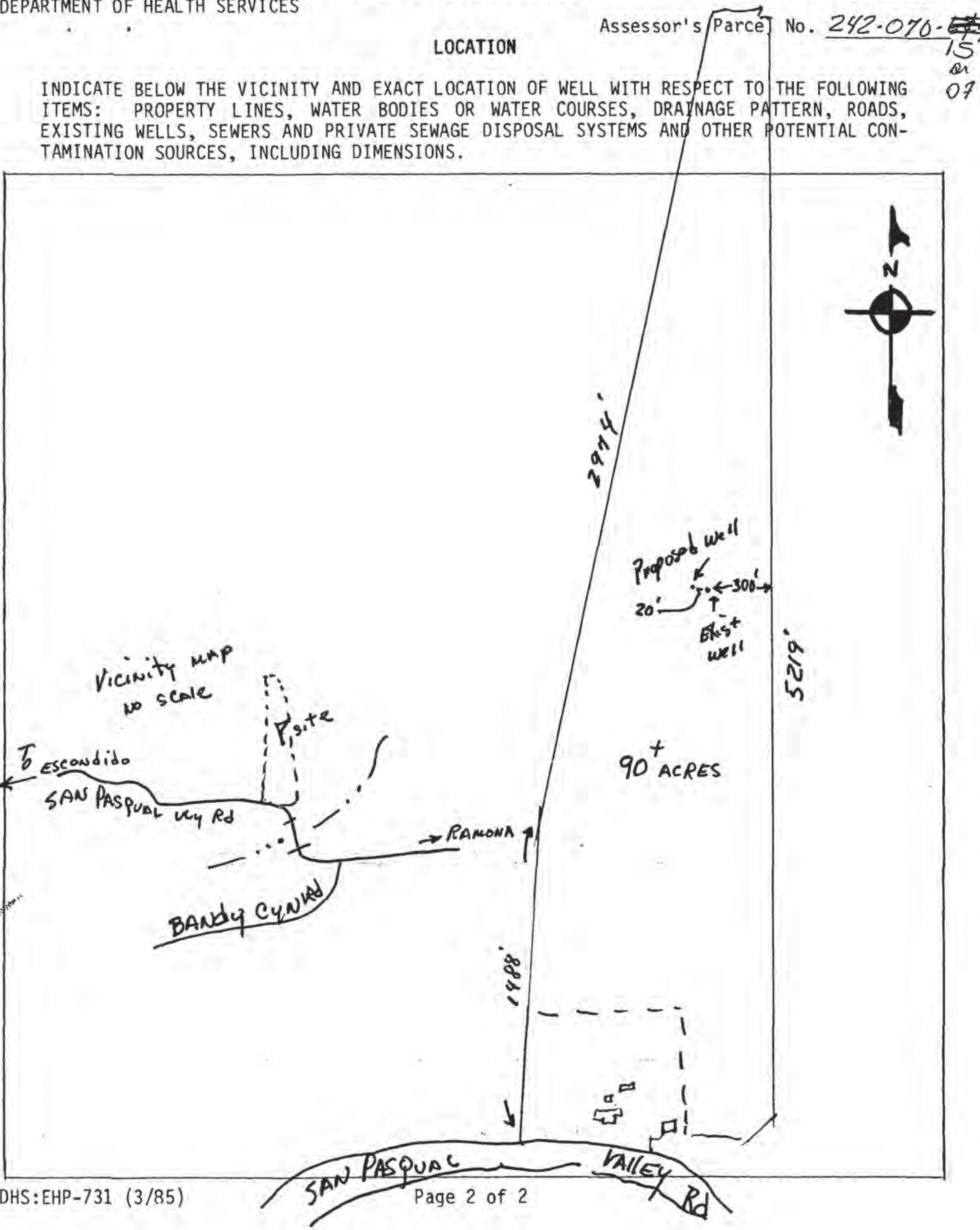
WELL PERMIT APPLICATION

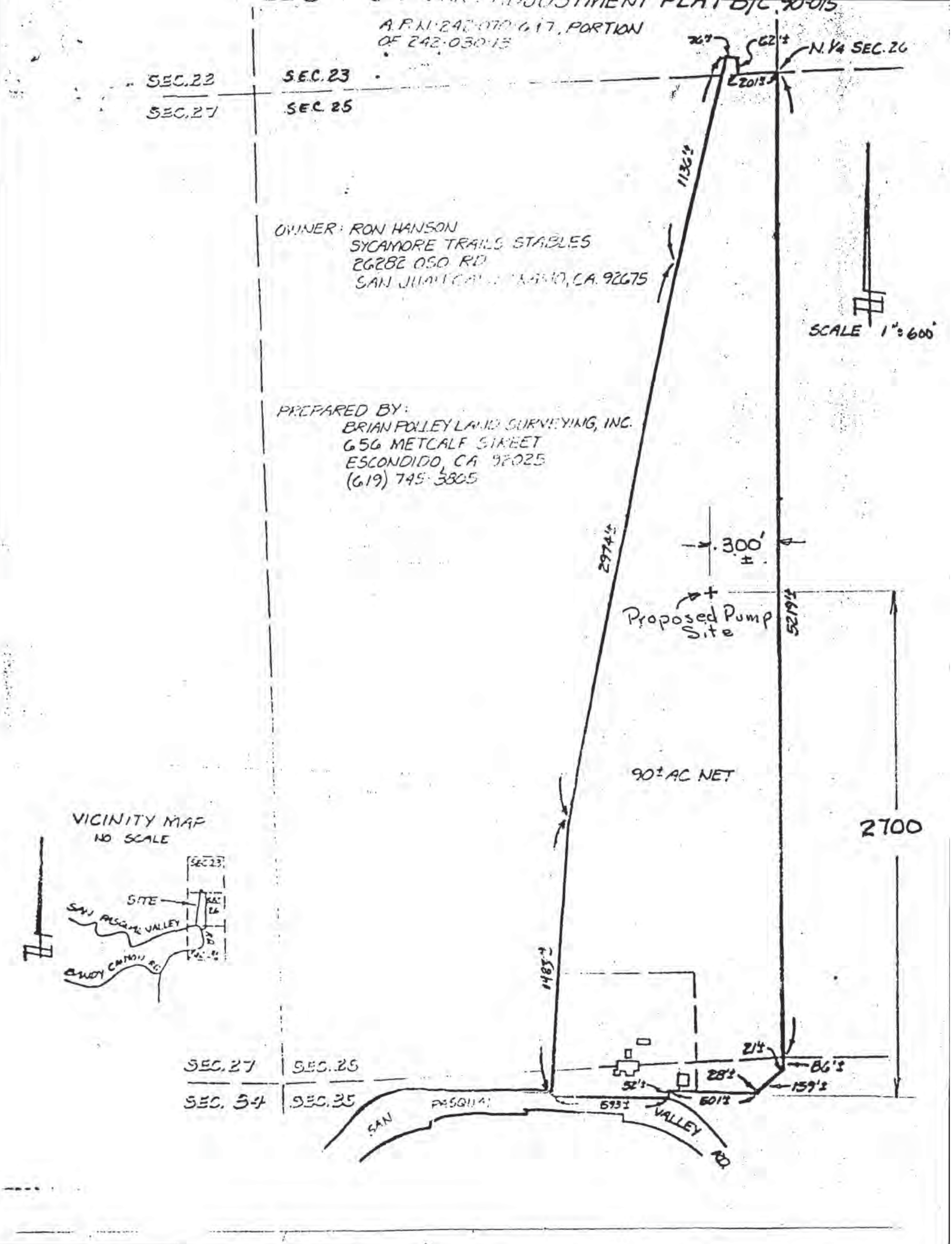
Control # W62874

Assessor's Parcel No. 242-070-15 or 07

LOCATION

INDICATE BELOW THE VICINITY AND EXACT LOCATION OF WELL WITH RESPECT TO THE FOLLOWING ITEMS: PROPERTY LINES, WATER BODIES OR WATER COURSES, DRAINAGE PATTERN, ROADS, EXISTING WELLS, SEWERS AND PRIVATE SEWAGE DISPOSAL SYSTEMS AND OTHER POTENTIAL CONTAMINATION SOURCES, INCLUDING DIMENSIONS.





ADJUSTMENT PLAT B/C 90-015
OF 242-030-13
N. 1/4 SEC. 26
SEC. 22
SEC. 23
SEC. 27
SEC. 25
1136±
OWNER: RON HANSON
SYCAMORE TRAILS STABLES
26282 OSO RD
SCALE 1" = 600'
PREPARED BY:
BRIAN POLLEY LAND SURVEYING, INC.
656 METCALF STREET
ESCONDIDO, CA 92025
(619) 745-3805
2974±
300' ±
Proposed Pump Site
5219±
90± AC NET
VICINITY MAP
NO SCALE
SEC 23
SITE
SAN PASQUAL VALLEY
2700
1483±
SEC. 27
SEC. 26
SEC. 34
SEC. 35
28±
52'±
593±
601±
159'±
86'±
SAN PASQUAL VALLEY RD

WDR CB WSM
4-18-95

QUADRUPLICATE
For Local Requirements

Page 1 of 1

Owner's Well No. Three

Date Work Began 12-14-94, Ended 12-19-94

Local Permit Agency Environmental Health Dept

Permit No. W62874 Permit Date 12-7-94

STATE OF CALIFORNIA
WELL COMPLETION REPORT
Refer to Instruction Pamphlet

No. 463662

DWR USE ONLY — DO NOT FILL IN

STATE WELL NO./STATION NO.	
LATITUDE	LONGITUDE
APN/TRS/OTHER	

GEOLOGIC LOG

ORIENTATION (✓) X VERTICAL ___ HORIZONTAL ___ ANGLE ___ (SPECIFY)

DEPTH TO FIRST WATER 50 (Ft.) BELOW SURFACE

DEPTH FROM SURFACE Ft.	to Ft.	DESCRIPTION Describe material, grain size, color, etc.
0	45	alluvial fill as follows: fine grained, sand and silt dark brown color
45	74	fine to coarse sand - partly cemented - brown color
74	116	Fine to coarse sand with some small rocks - partly cemented brown to grey color

Completed Well Construction

Date 5-4-95

Date Inspected 5-3-95

Comments Final Pending on approved water sample

Water Sample Taken? NO

Reviewed By M. Sedghi

TOTAL DEPTH OF BORING 116 (Feet)

TOTAL DEPTH OF COMPLETED WELL 116 (Feet)

WELL OWNER

The information in this grayed area has been blocked from public viewing pursuant to section 13752 of the Water Code and the Information Practice Act of 1977, to protect personal information.

The information in

The information in this grayed

ZIP

WELL LOCATION

Address

City Same

County San Diego

APN Book 242 Page 070 Parcel 6 8 7

or Township Range Section

or Latitude 12S 1W NORTH DEG. MIN. SEC. Longitude 25 WEST DEG. MIN. SEC.

LOCATION SKETCH

NORTH

WEST

EAST

ORANGE GROVE

200

NEW WELL

EXIST

dirt road

ORANGE GROVE

SOUTH

Illustrate or Describe Distance of Well from Landmarks such as Roads, Buildings, Fences, Rivers, etc.
PLEASE BE ACCURATE & COMPLETE.

ACTIVITY (✓)

X NEW WELL

MODIFICATION/REPAIR

___ Deepen

___ Other (Specify)

___ DESTROY (Describe Procedures and Materials Under "GEOLOGIC LOG")

PLANNED USE(S) (✓)

___ MONITORING

WATER SUPPLY

X Domestic

___ Public

___ Irrigation

___ Industrial

___ "TEST WELL"

___ CATHODIC PROTECTION

___ OTHER (Specify)

DRILLING METHOD Rotary FLUID Gel

WATER LEVEL & YIELD OF COMPLETED WELL

DEPTH OF STATIC WATER LEVEL 29 (Ft.) & DATE MEASURED 12-17-94

ESTIMATED YIELD* 50+ (GPM) & TEST TYPE airlift

TEST LENGTH 3 (Hrs.) TOTAL DRAWDOWN 70 (Ft.)

* *May not be representative of a well's long-term yield.*

CASING(S)

DEPTH FROM SURFACE Ft.	to Ft.	BORE-HOLE DIA. (Inches)	BLANK	SCREEN	CON-DUCTOR	FILL PIPE	MATERIAL / GRADE	INTERNAL DIAMETER (Inches)	GAUGE OR WALL THICKNESS	SLOT SIZE IF ANY (Inches)
0	20	14	X				A-53	8	.188	
0	56	10	X				F480	5	.250	
56	116	10		X			F480	5	.250	

ANNULAR MATERIAL

DEPTH FROM SURFACE Ft.	to Ft.	CE-MENT (✓)	BEN-TONITE (✓)	FILL (✓)	FILTER PACK (TYPE/SIZE)
0	20	X			
20	115				Pea Gravel 5/16x7

ATTACHMENTS (✓)

___ Geologic Log

___ Well Construction Diagram

___ Geophysical Log(s)

___ Soil/Water Chemical Analyses

X Other Map

ATTACH ADDITIONAL INFORMATION, IF IT EXISTS.

CERTIFICATION STATEMENT

I, the undersigned, certify that this report is complete and accurate to the best of my knowledge and belief.

NAME Fain Drilling & Pump Co Inc.
(PERSON, FIRM, OR CORPORATION) (TYPED OR PRINTED)

ADDRESS 12029 Old Castle Rd. Valley Center, Ca 92082 CITY STATE ZIP

Signed [illegible]
WELL DRILLER/AUTHORIZED REPRESENTATIVE

DATE SIGNED 12/19/94 C-57 LICENSE NUMBER 528287

TT 1.8

DWR 188 REV. 7-90

IF ADDITIONAL SPACE IS NEEDED, USE NEXT CONSECUTIVELY NUMBERED FORM

COUNTY OF SAN DIEGO
DEPARTMENT OF HEALTH SERVICES

WELL PERMIT APPLICATION

WC #5915 APN 242 070 1300
Control # W61615

242-070-13 WELL-5915

TYPE OF WORK (Check)		USE (Check)		EQUIPMENT (Check)	
New Well	☐	Individual Domestic ☐		Rotary	☒
Repair or Modification	☒	Agricultural ☒	Community ☐	Cable Tool	☐
Time Extension	☐	Industrial ☐	Other	Other	☐
Destruction	☐	DEEPEN EXISTING WELL			

PROPOSED WELL DEPTH
Max. 1000 Min. 150 (Feet)

PROPOSED CASING
Type STEEL Depth 160 Diameter 10" Wall or Gage 250

PROPOSED SEALING ZONE(S)
From 0 to 20 Feet
From ______ to ______ Feet
From ______ to ______ Feet

SEALING MATERIAL (Check)
Neat Cement Grout ☐ Bentonite Clay ☐
Sand Cement Grout ☐ Concrete ☒
Other-Specify: ______

PROPOSED PERFORATIONS OR SCREEN
From NONE. to ______ Feet
From ______ to ______ Feet
From ______ to ______ Feet
From ______ to ______ Feet

DATE OF WORK
Start 3-25-91
Completion 4-1-91

NAME OF WELL OWNER 745-4948 call to get Gate unlocked
BEN HILLEBRECHT.

NAME OF WELL DRILLER
Art Widner

LOCATION OF WELL
17204 San Pasqual Valley Rd.
ESCONDIDO CA.

COMPANY
Hidden Valley Pump Systems

BUSINESS ADDRESS
27932 Valley Center Rd VC

DISPOSITION OF APPLICATION
(FOR HEALTH OFFICERS USE ONLY)

☐ APPROVED ☐ DENIED

☒ APPROVED WITH CONDITIONS

LICENSE NUMBER
487325.

Cash Deposit ☒
Bond Posted ☐

180 Fee paid on 03-21-91

Report Reason(s) for Denial or Necessary Conditions Here:
1. Well is to be deepened per Bulletin 74-81
2. Well is for agricultural use only. This well will not meet the minimal standards of a public water supply source and shall not be used as a source of water for uses requiring an approved public water supply.

I hereby agree to comply with all regulations of the Department of Health Services and with all ordinances and laws of the County of San Diego and of the State of California pertaining to well construction, repair, modification and destruction. Immediately upon completion of work I will furnish the Department of Health Services with a complete and accurate log of the well.

[signature]
HEALTH OFFICER
3-25-91
DATE

[signature]
APPLICANT'S SIGNATURE
3-21-91
DATE

COUNTY OF SAN DIEGO
DEPARTMENT OF HEALTH SERVICES

03-21-91

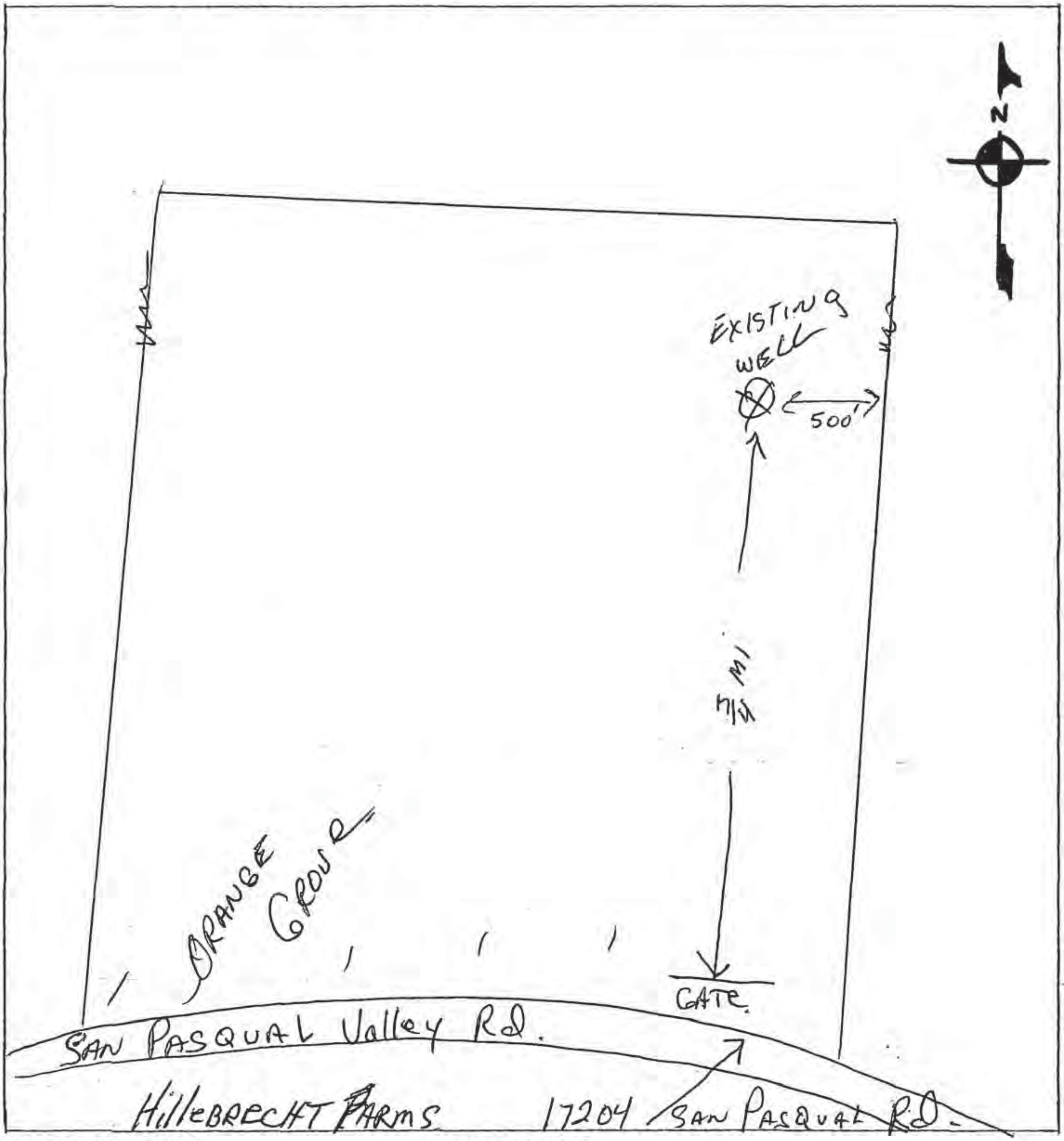
WELL PERMIT APPLICATION

Control # 061615

Assessor's Parcel No. 242-070-13-00

LOCATION

INDICATE BELOW THE VICINITY AND EXACT LOCATION OF WELL WITH RESPECT TO THE FOLLOWING ITEMS: PROPERTY LINES, WATER BODIES OR WATER COURSES, DRAINAGE PATTERN, ROADS, EXISTING WELLS, SEWERS AND PRIVATE SEWAGE DISPOSAL SYSTEMS AND OTHER POTENTIAL CONTAMINATION SOURCES, INCLUDING DIMENSIONS.



County Mail Station — A-21

FIRST CARBON COPY

WDR to SM
4/29/91 JSD

COUNTY OF SAN DIEGO
DEPARTMENT OF HEALTH SERVICES
1700 PACIFIC HIGHWAY, SAN DIEGO, CA 92101-2417

ASSESSORS PARCEL NUMBER: 242-070-13

WATER WELL DRILLERS REPORT

Notice of Intent No. ______
Local Permit No. or Date L16165 (INSERT under ORIGINAL PAGE w/carbon of State Form)

State Well No. ______
Other Well No. ______

The information in this grayed area has been blocked from public viewing pursuant to section 13752 of the Water Code and the Information Practice Act of 1977, to protect personal information.

(2) LOCATION OF WELL (See instructions):
County San Diego Owner's Well Number ______
Well address if different from above 17204 San Pasqual Valley Rd.
Township 1W Range 12S Section 26
Distance from cities, roads, railroads, fences, etc. ______

DEPARTMENT USE ONLY
Completed Well Construction:
Date ______
Date Inspected 5-9-91
Comments approval is for deepening only
Water Sample Taken? NO
Sanitarian's Approval: [signature]

(3) TYPE OF WORK:
New Well ☐ Deepening ☒
Reconstruction ☐
Reconditioning ☐
Horizontal Well ☐
Destruction ☐ (Describe destruction materials and procedures in Item (12)

(4) PROPOSED USE:
Domestic ☐
Irrigation ☒
Industrial ☐
Test Well ☐
Stock ☐
Municipal ☐
Other ☐

(5) Equipment:
Rotary ☒ Reverse ☐
Cable ☐ Air ☐
Other ☐ Bucket ☐

(6) Gravel Pack:
Yes ☐ No ☐ Size ______
Diameter of above ______
Packed from ______ to ______ ft.

(7) Casing Installed:
Steel ☒ Plastic ☐ Concrete ☐

(8) Perforations:
Type of perforation or size of screen ______

From ft.	To ft.	Dia. in.	Gage or Wall	From ft.	To ft.	Slot Size
0	151	10	.188			

(12) WELL LOG: Total depth 638 ft. Depth of completed well 638 ft.

from ft.	to ft.	Formation (Describe by color, character, size or material)
122	140	cemented sand & clay formation
140	149	broken granite
149	167	cont. broken granite, 167' hard granite
167	200	hard granite w/fractures at 170, 174, 183, 188, 193, 194
200	240	fractured B & W with red colored rock.
240	275	B & W, many fracs.
275	278	very large frac. B & W
278	300	fractured B & W, some green clay at 289'
300	378	hard B & W, some small fracs, grey clay layer at 377', picked up 250 gpm in frac at 377'
378	490	hard B & W, fracs at 423', 449', 474'.
490	491	B & W frac, picked up 75 gpm
491	638	B & W, fracs at 529, 530, 553, 568, 575. Picked up 205 gpm at 575'. More fracs at 582, 610, hard B & W to 638'.
		Deepened existing well 122' to 638'. Existing well had 14" casing 0' to 122'.

(9) WELL SEAL:
Was surface sanitary seal provided? Yes ☒ No ☐ If yes, to depth 20 ft.
Were strata sealed against pollution? Yes ☐ No ☐ Interval ______ ft.
Method of sealing ______

(10) WATER LEVELS:
Depth of first water, if known 60 ft.
Standing level after well completion 60 ft.

(11) WELL TESTS:
Was well test made? Yes ☐ No ☒ If yes, by whom?
Type of test Pump ☐ Bailer ☐ Air lift ☐
Depth to water at start of test ______ ft. At end of test ______ ft.
Discharge ______ gal/min after ______ hours Water temperature ______
Chemical analysis made? Yes ☐ No ☐ If yes, by whom?
Was electric log made? Yes ☐ No ☐ If yes, attach copy to this report

Work Started 3/23 1991 Completed 4/2 1991

WELL DRILLERS STATEMENT: I hereby declare under penalty of perjury that the information provided in this report is true. This water well was installed in compliance with San Diego County Code and State of California, Department of Water Resources, Bulletin No. 74.

SIGNED [signature] (Well Driller)
NAME HIDDEN VALLEY PUMP SYSTEMS INC.
(Person, firm, or Corporation) (Type or Print)
ADDRESS 27932 Valley Center Road
CITY Valley Center ZIP 92082
LICENSE NO. 487325 DATE THIS REPORT 4/23/91

DHS:EHP-732 (83) CONFIDENTIAL — NOT FOR PUBLIC USE — WATER CODE SEC. 13752

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Appendix H
Groundwater Quality
Representative Monitoring Network
Chemographs with Thresholds

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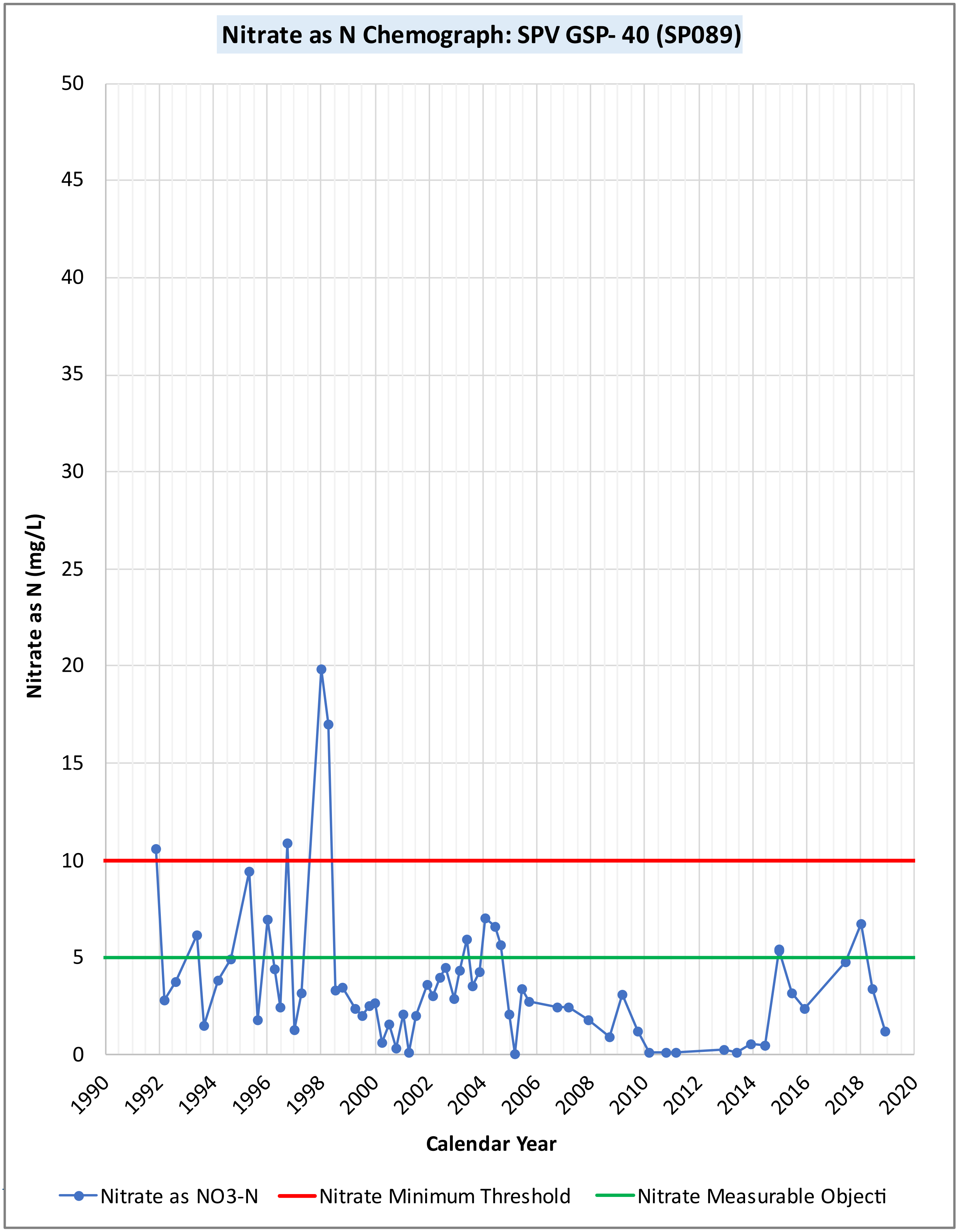
Nitrate as N Chemograph: SPV GSP- 40 (SP089)
Nitrate as N (mg/L)
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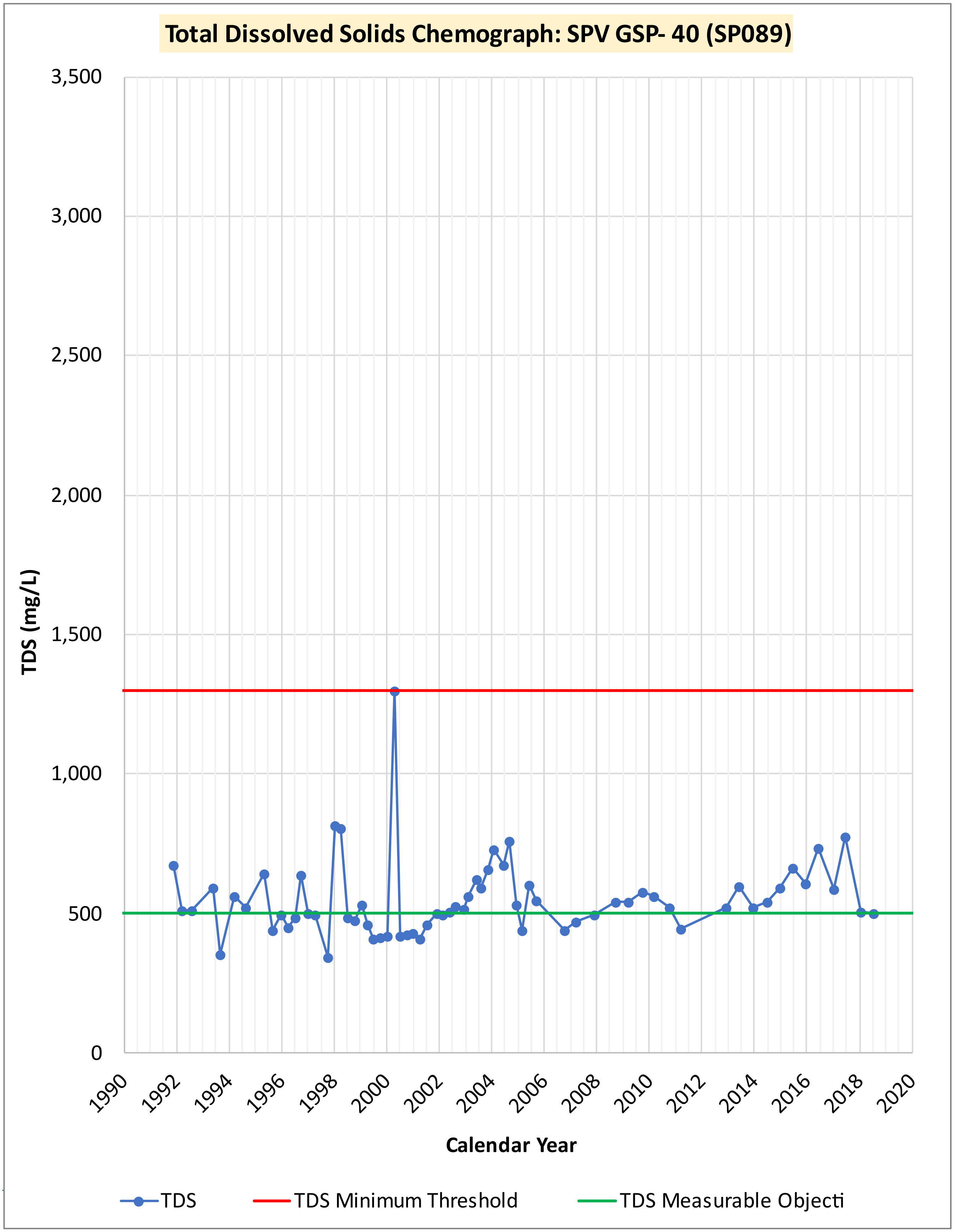
Nitrate as NO3-N
Nitrate Minimum Threshold
Nitrate Measurable Objecti


Total Dissolved Solids Chemograph: SPV GSP- 40 (SP089)
3,500
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TDS (mg/L)
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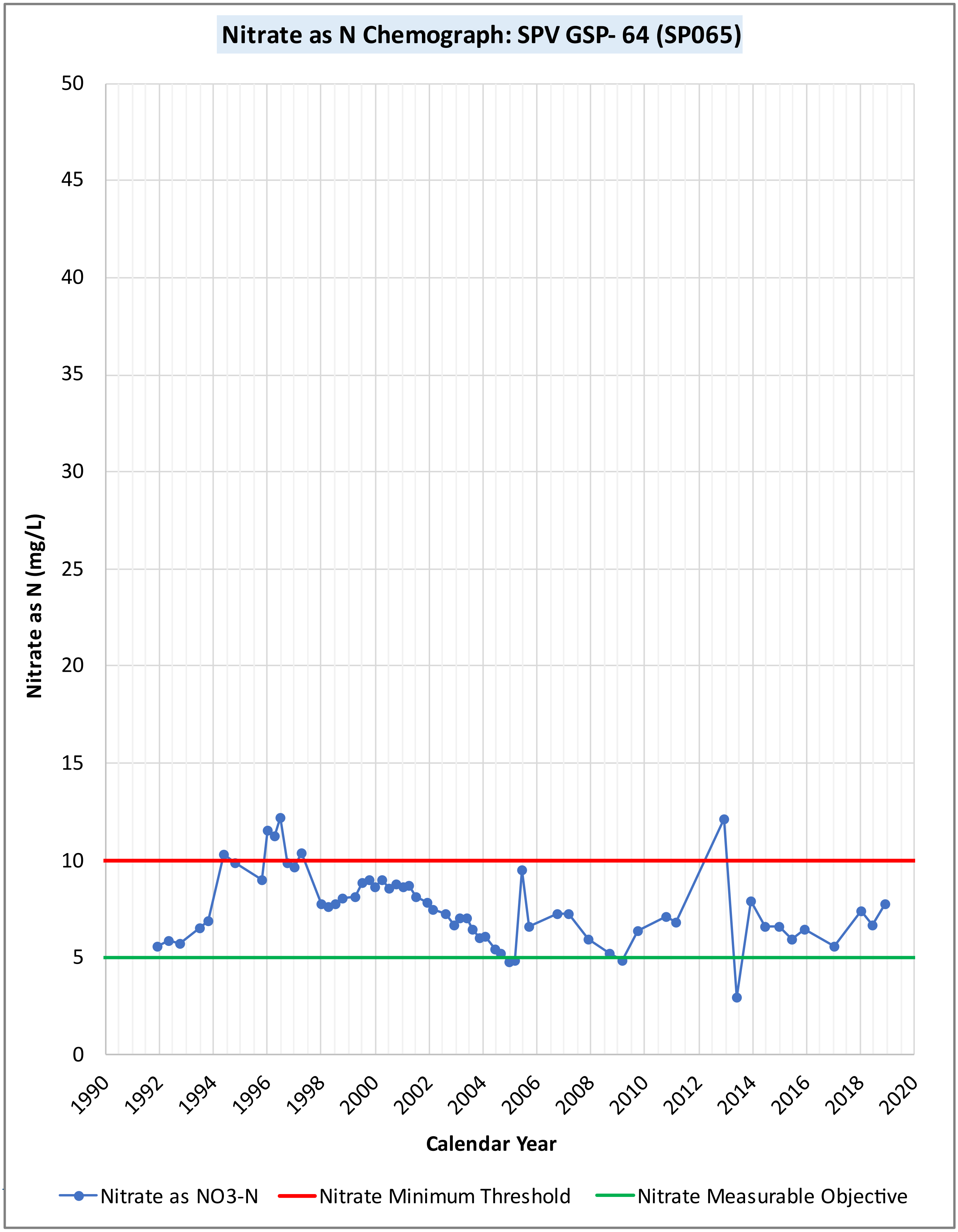
TDS Minimum Threshold
TDS Measurable Objecti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Nitrate as N (mg/L)
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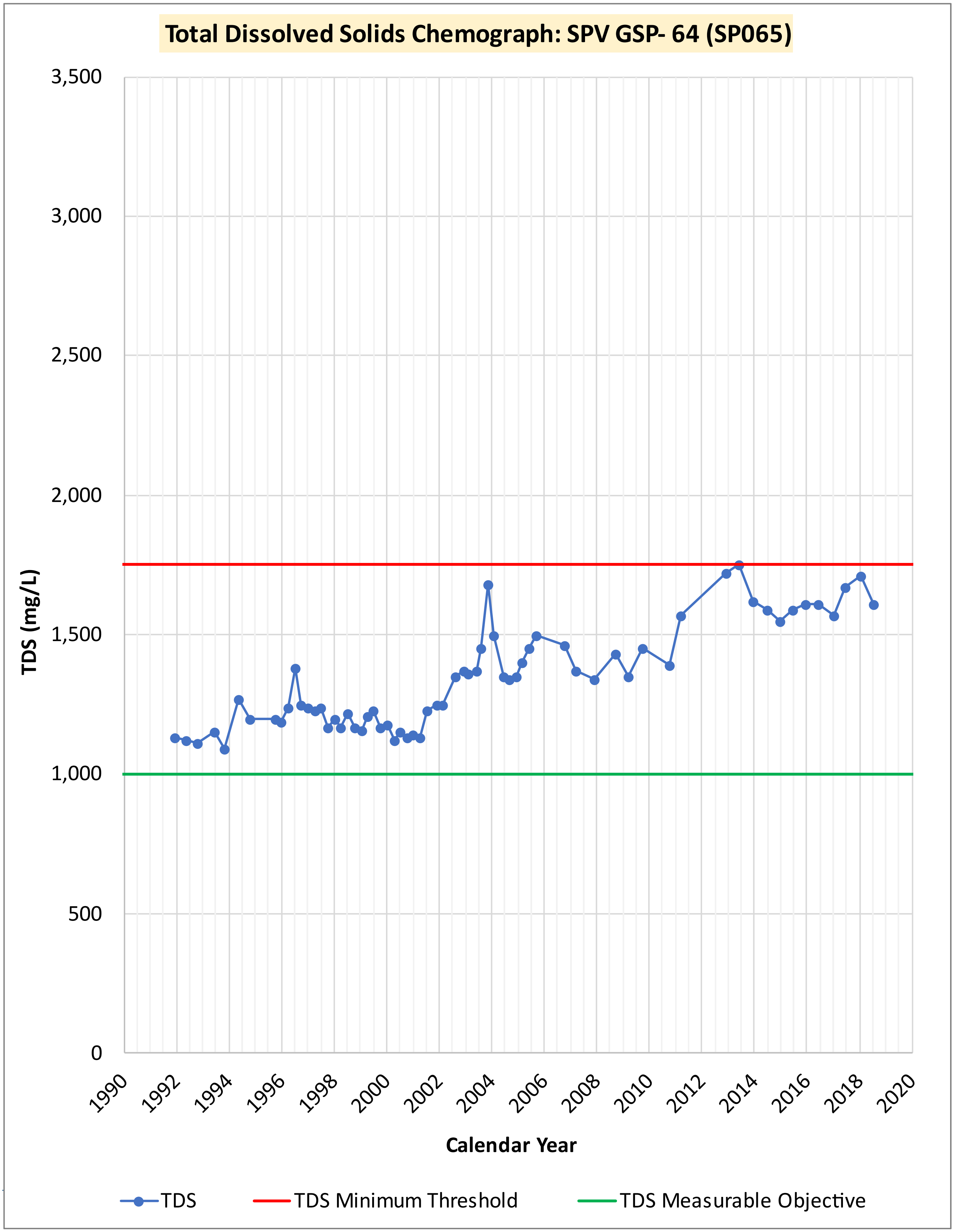
Calendar Year
Nitrate as NO3-N
Nitrate Minimum Threshold
Nitrate Measurable Objective


Total Dissolved Solids Chemograph: SPV GSP- 64 (SP065)
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TDS (mg/L)
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Calendar Year
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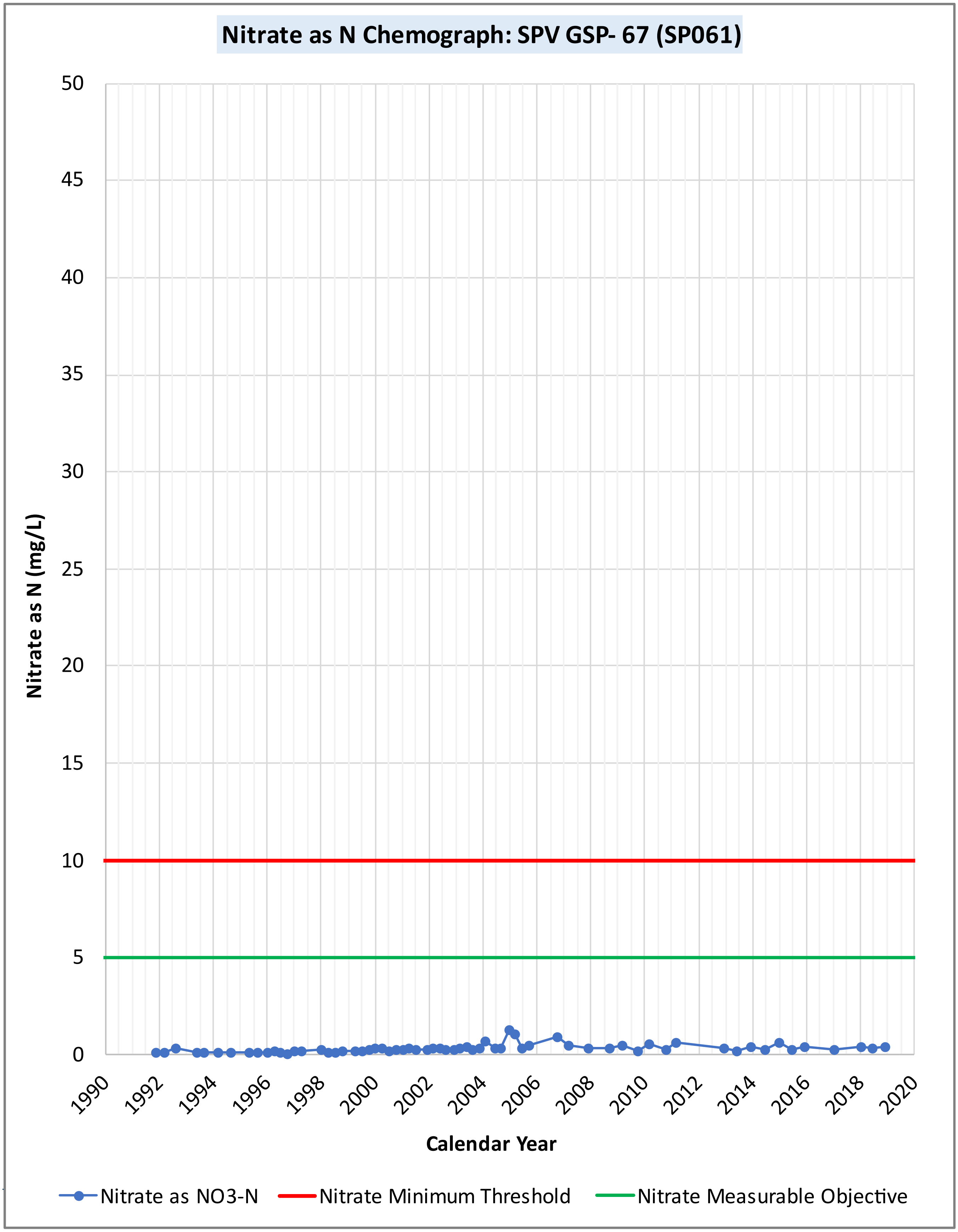
TDS Minimum Threshold
TDS Measurable Objective


Nitrate as N Chemograph: SPV GSP- 67 (SP061)
Nitrate as N (mg/L)
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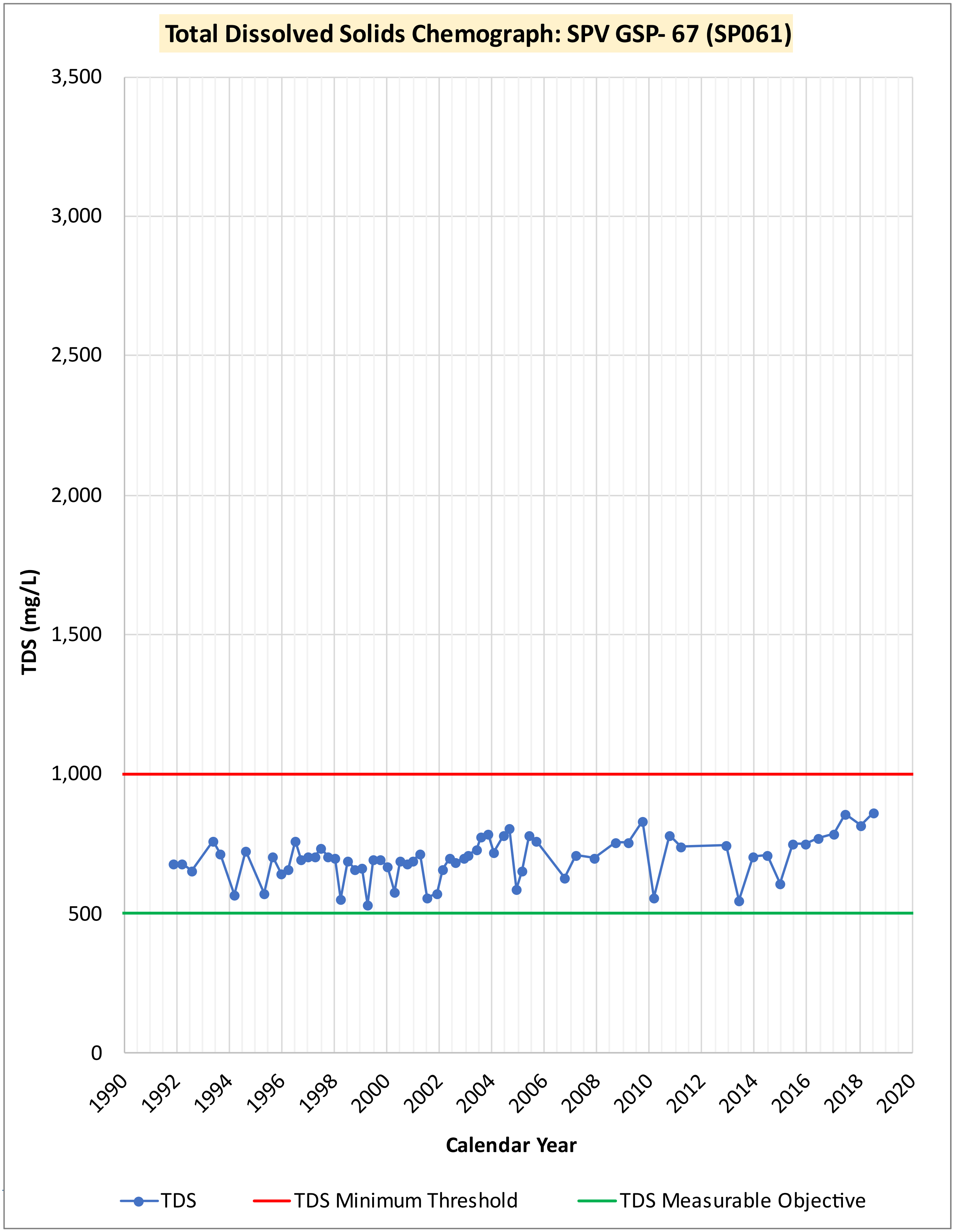
Nitrate as NO3-N
Nitrate Minimum Threshold
Nitrate Measurable Objective


Total Dissolved Solids Chemograph: SPV GSP- 67 (SP061)
TDS (mg/L)
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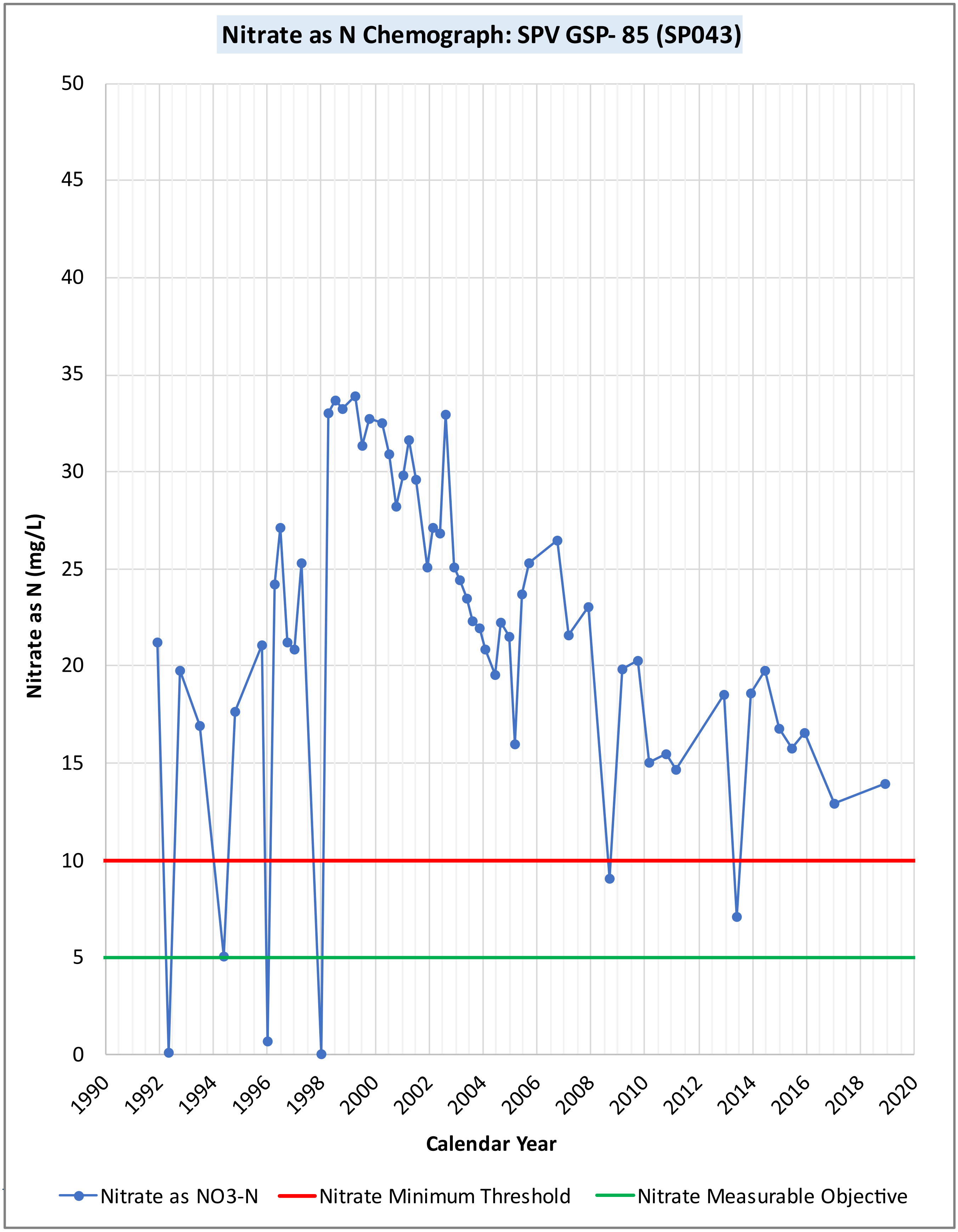
TDS Measurable Objective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Nitrate as N (mg/L)
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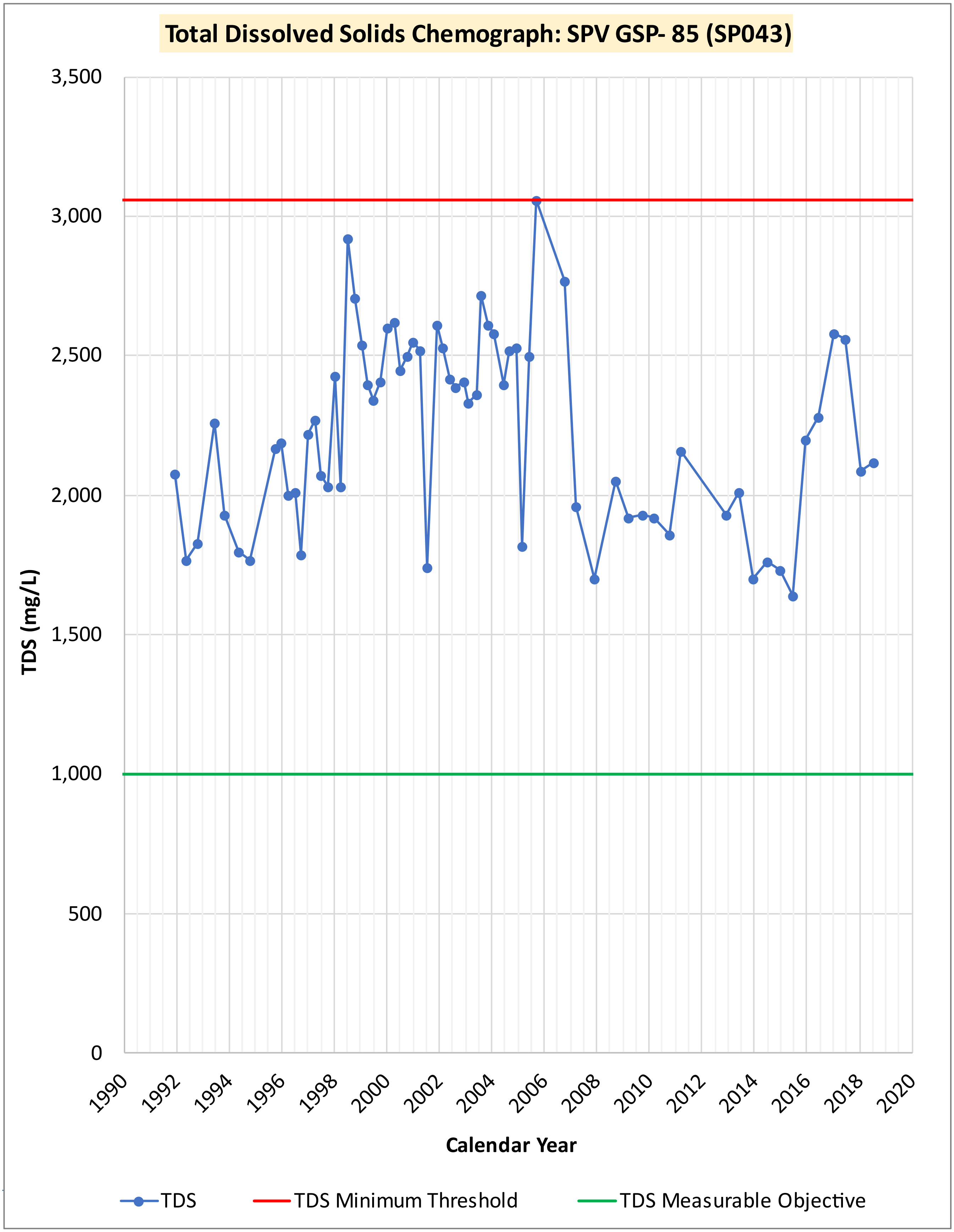
Calendar Year
Nitrate as NO3-N
Nitrate Minimum Threshold
Nitrate Measurable Objective


Total Dissolved Solids Chemograph: SPV GSP- 85 (SP043)
TDS (mg/L)
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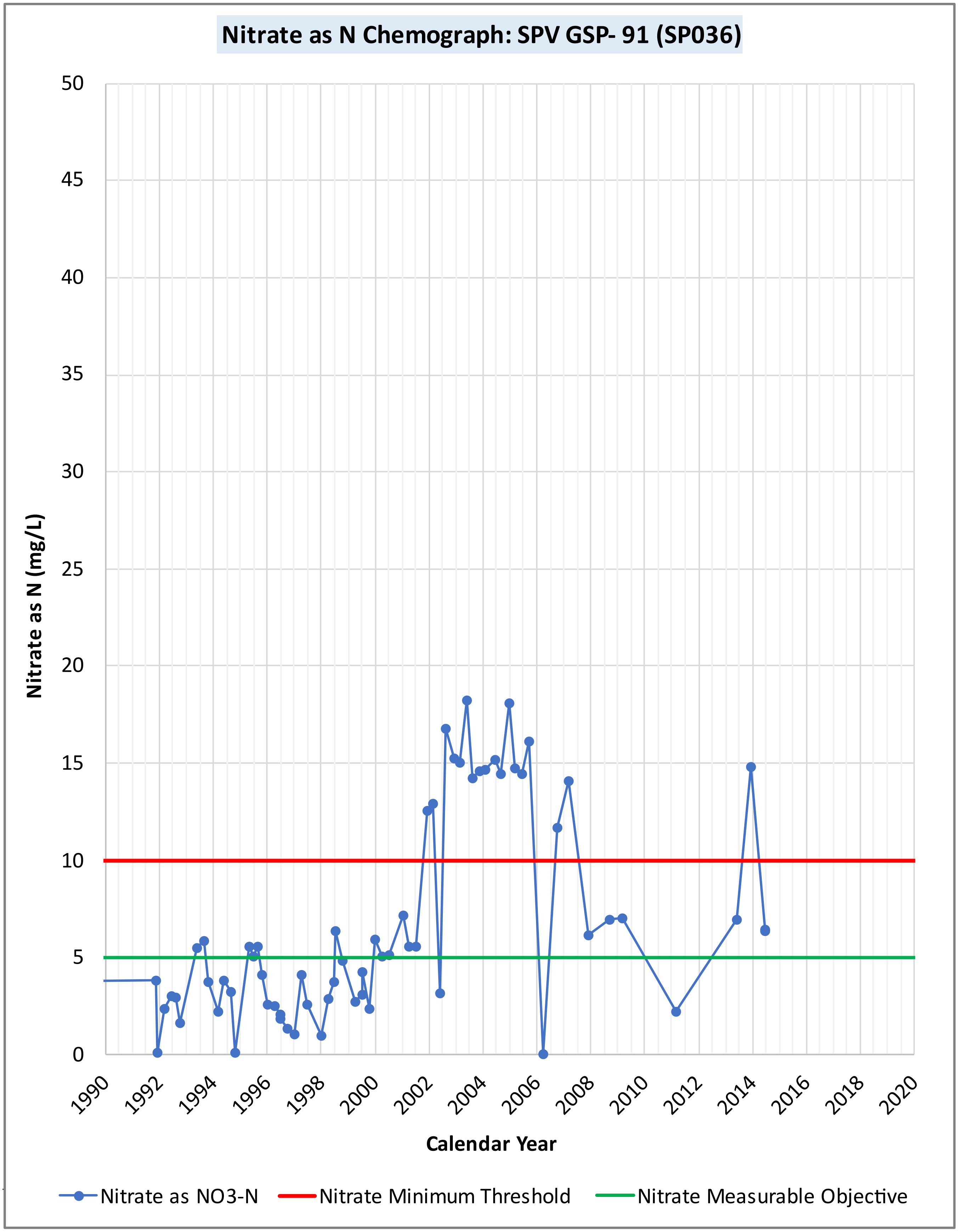
TDS Measurable Objective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Nitrate as N (mg/L)
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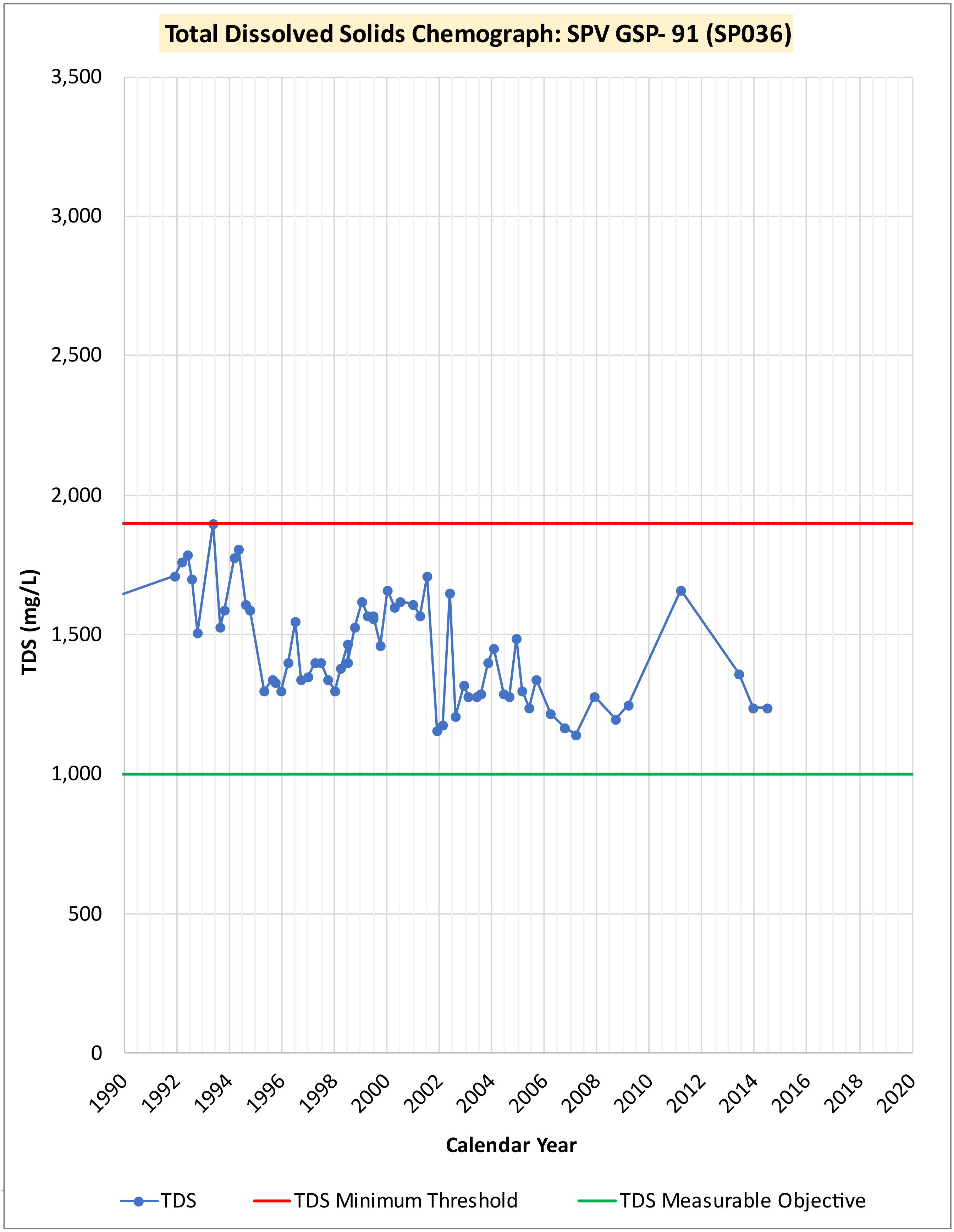
Calendar Year
Nitrate as NO3-N
Nitrate Minimum Threshold
Nitrate Measurable Objective


Total Dissolved Solids Chemograph: SPV GSP- 91 (SP036)
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TDS (mg/L)
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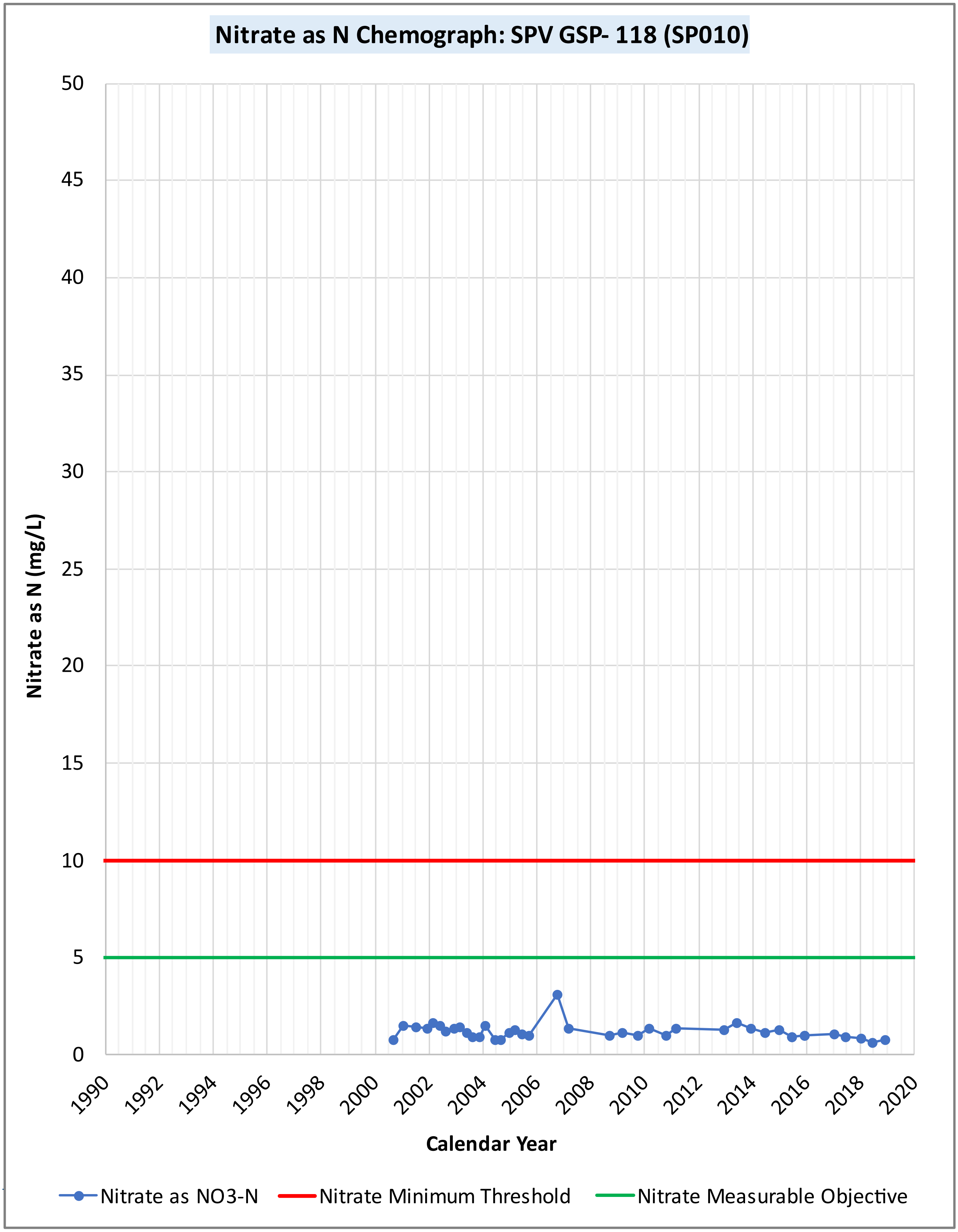
TDS Minimum Threshold
TDS Measurable Objective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Nitrate as N (mg/L)
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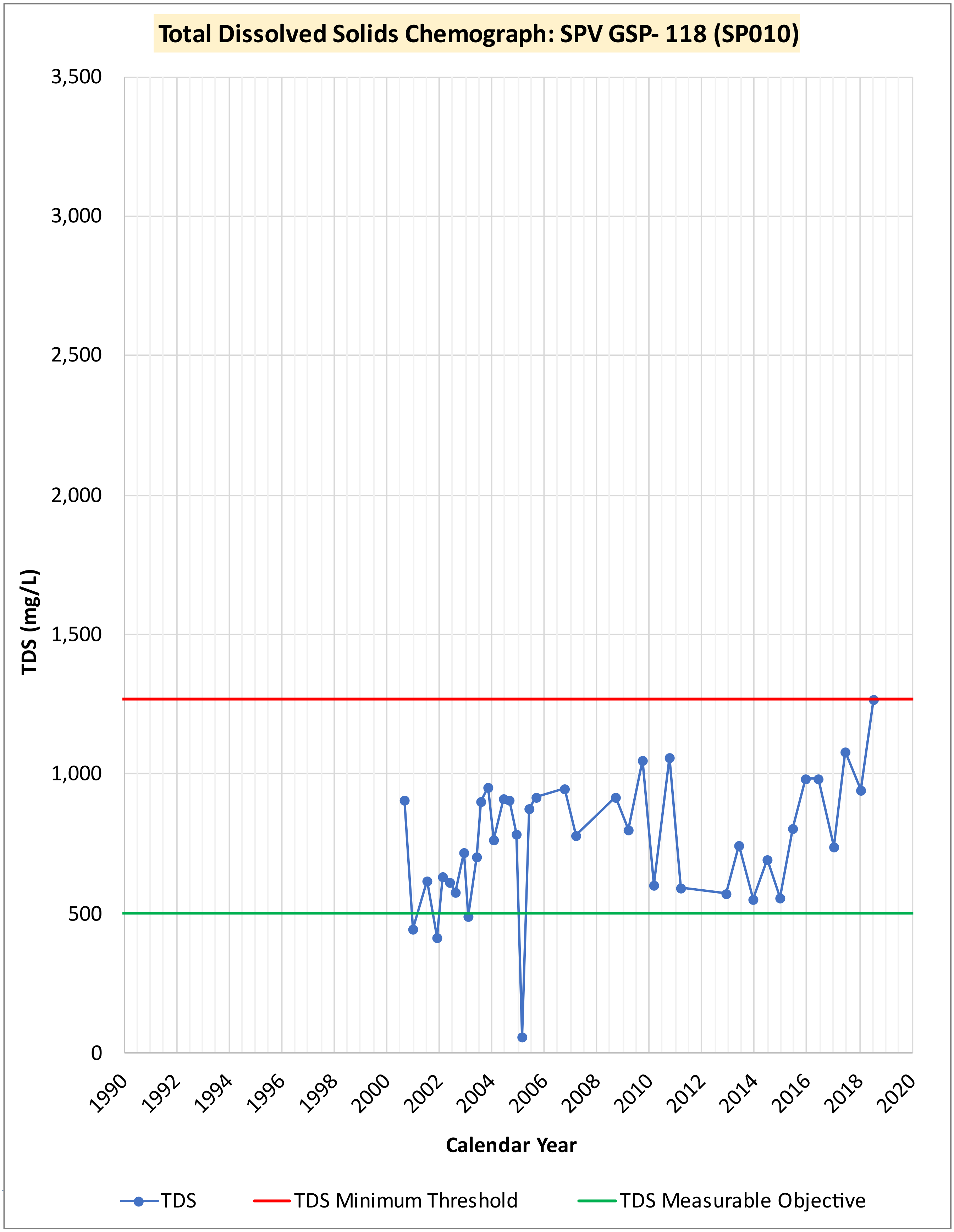
Calendar Year
Nitrate as NO3-N
Nitrate Minimum Threshold
Nitrate Measurable Objective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TDS (mg/L)
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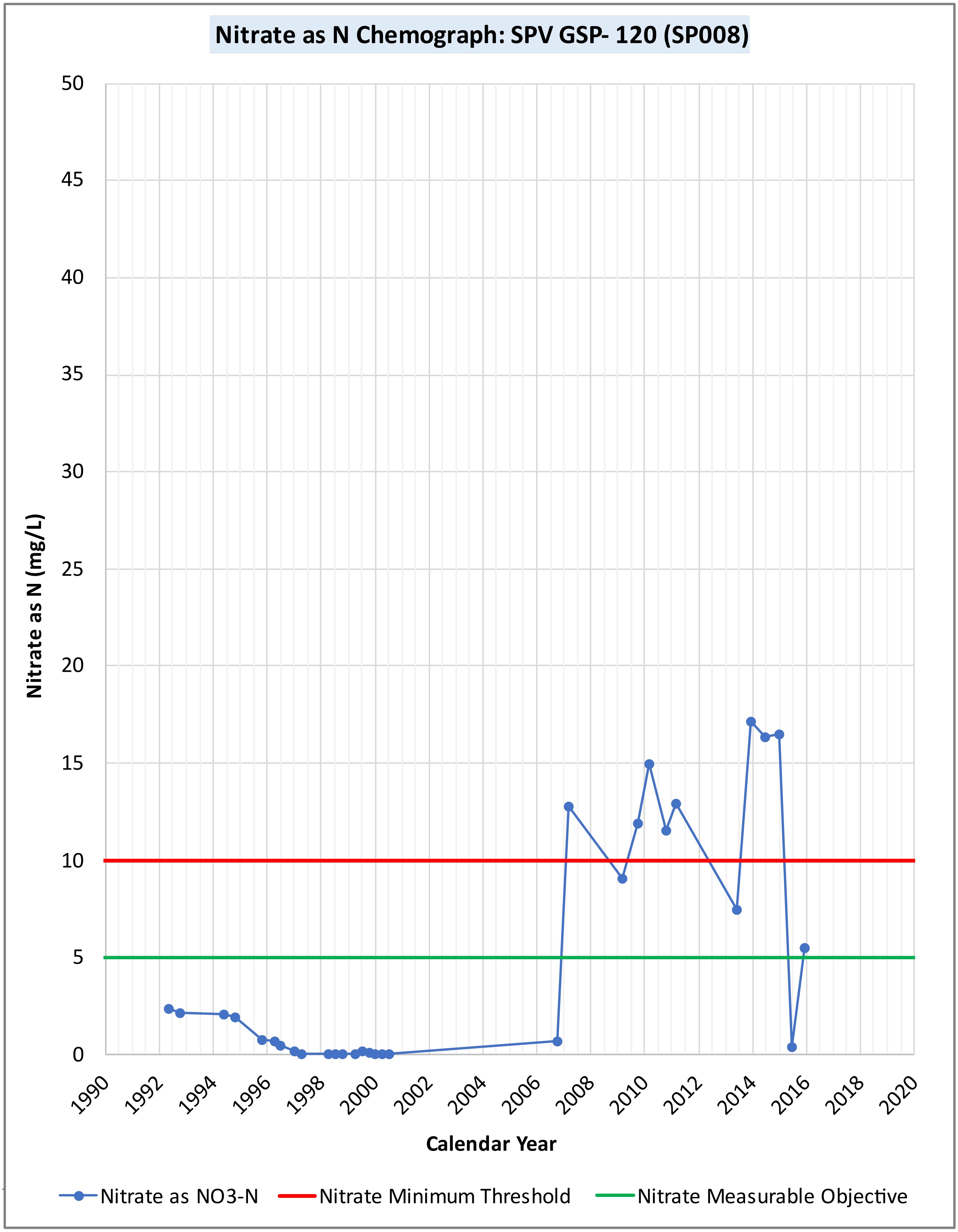
TDS Minimum Threshold
TDS Measurable Objective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Nitrate as N (mg/L)
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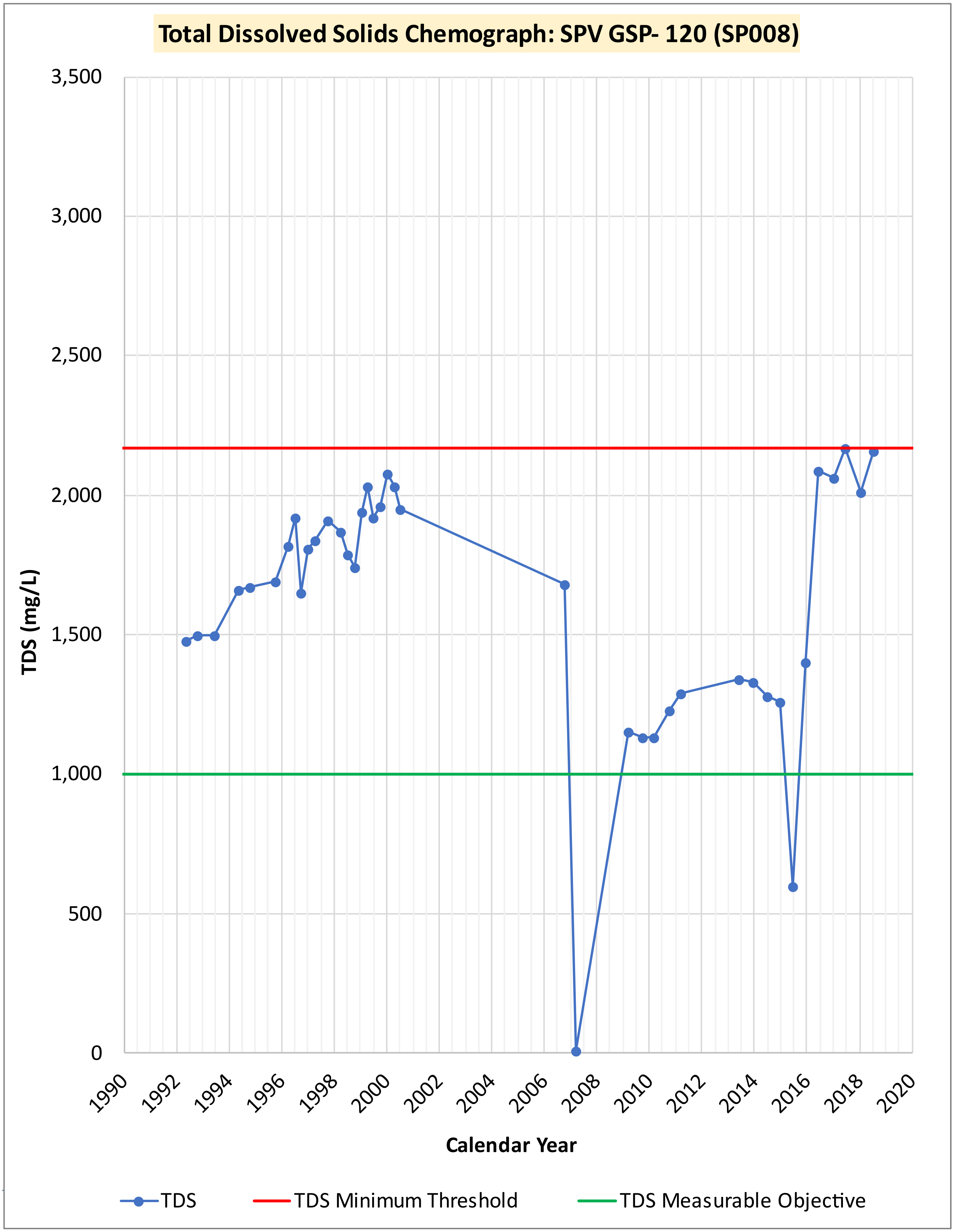
Nitrate as NO3-N
Nitrate Minimum Threshold
Nitrate Measurable Objective


Total Dissolved Solids Chemograph: SPV GSP- 120 (SP008)
TDS (mg/L)
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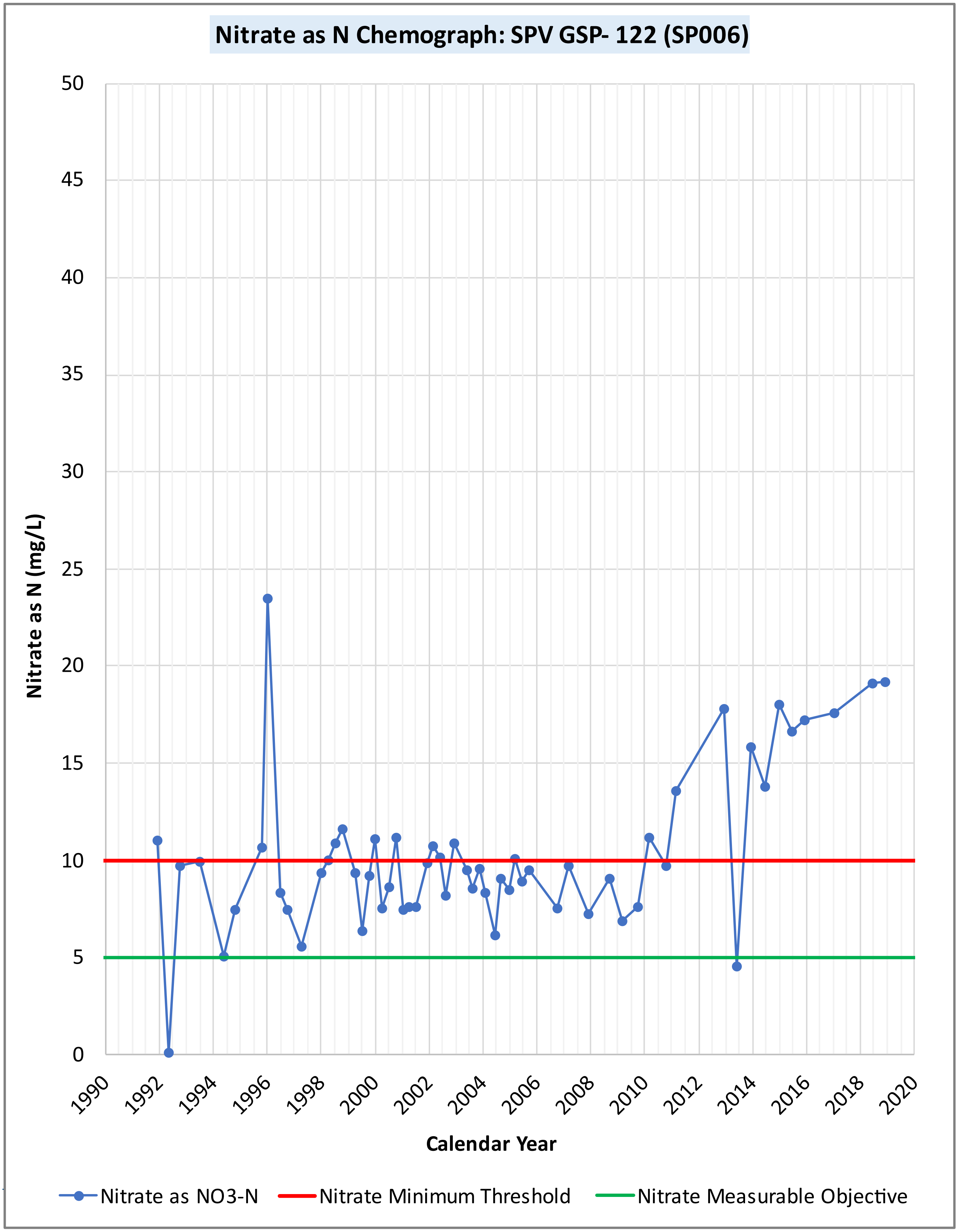
TDS Minimum Threshold
TDS Measurable Objective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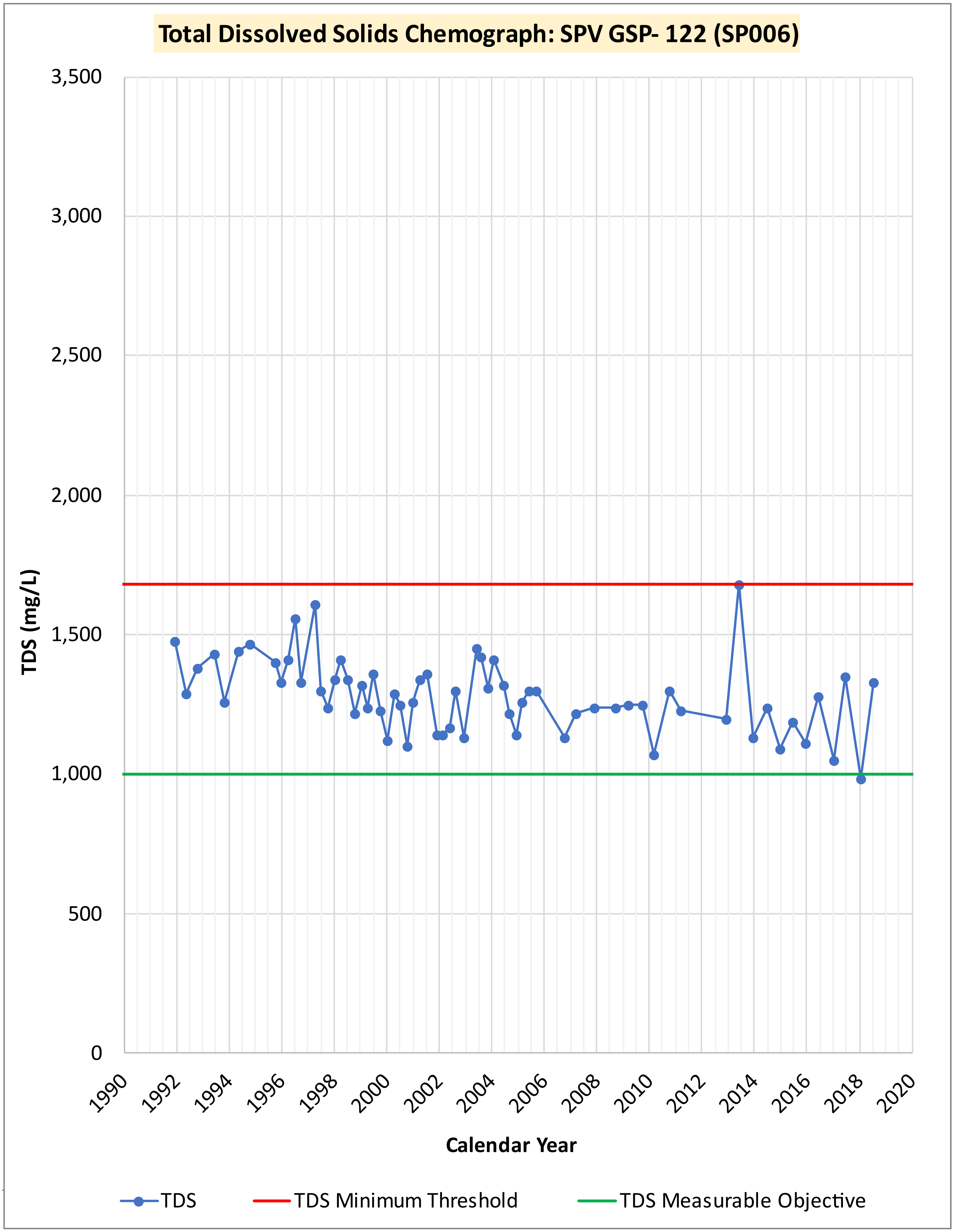
Calendar Year
Nitrate as NO3-N
Nitrate Minimum Threshold
Nitrate Measurable Objective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TDS (mg/L)
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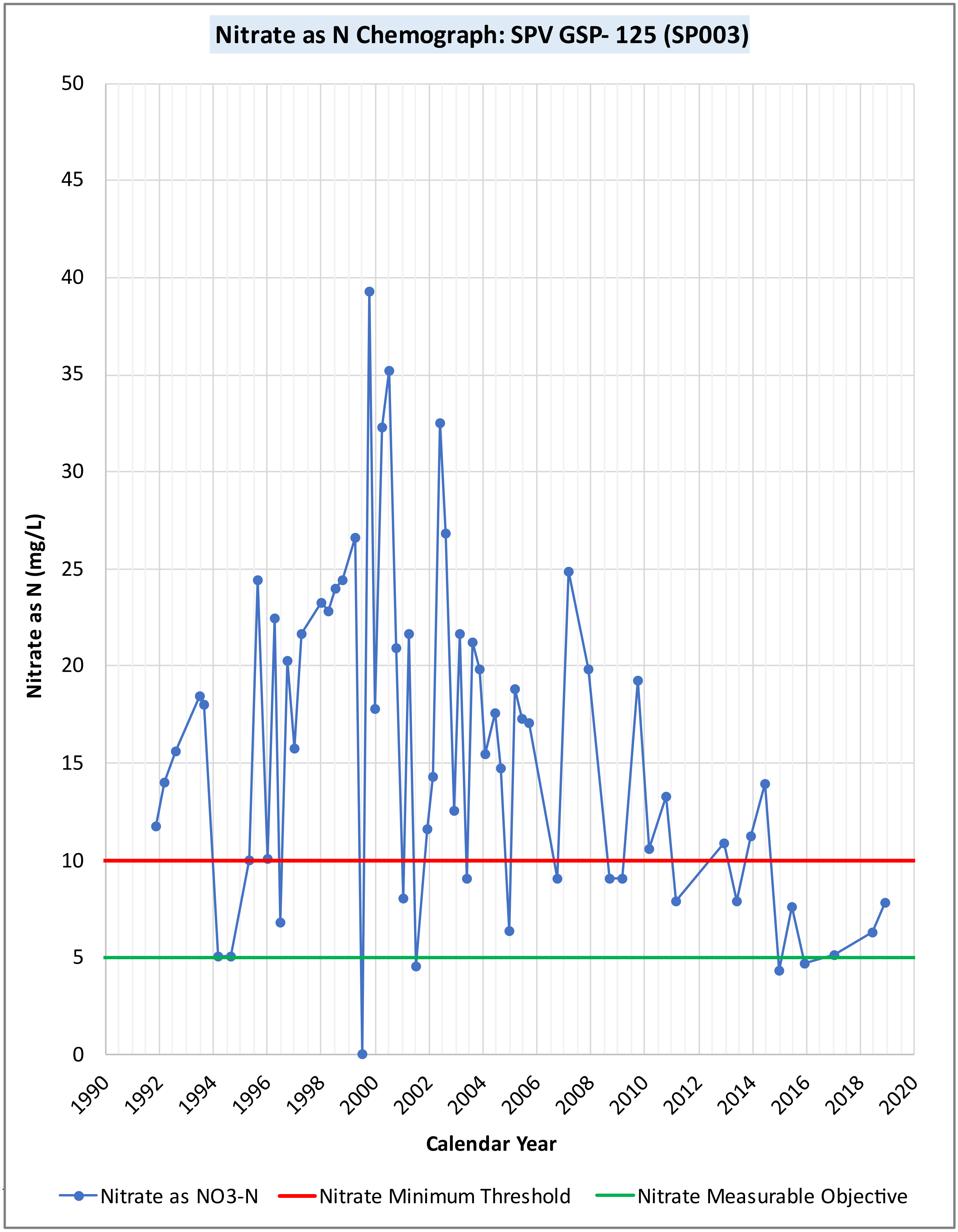
Calendar Year
TDS
TDS Minimum Threshold
TDS Measurable Objective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Nitrate as N (mg/L)
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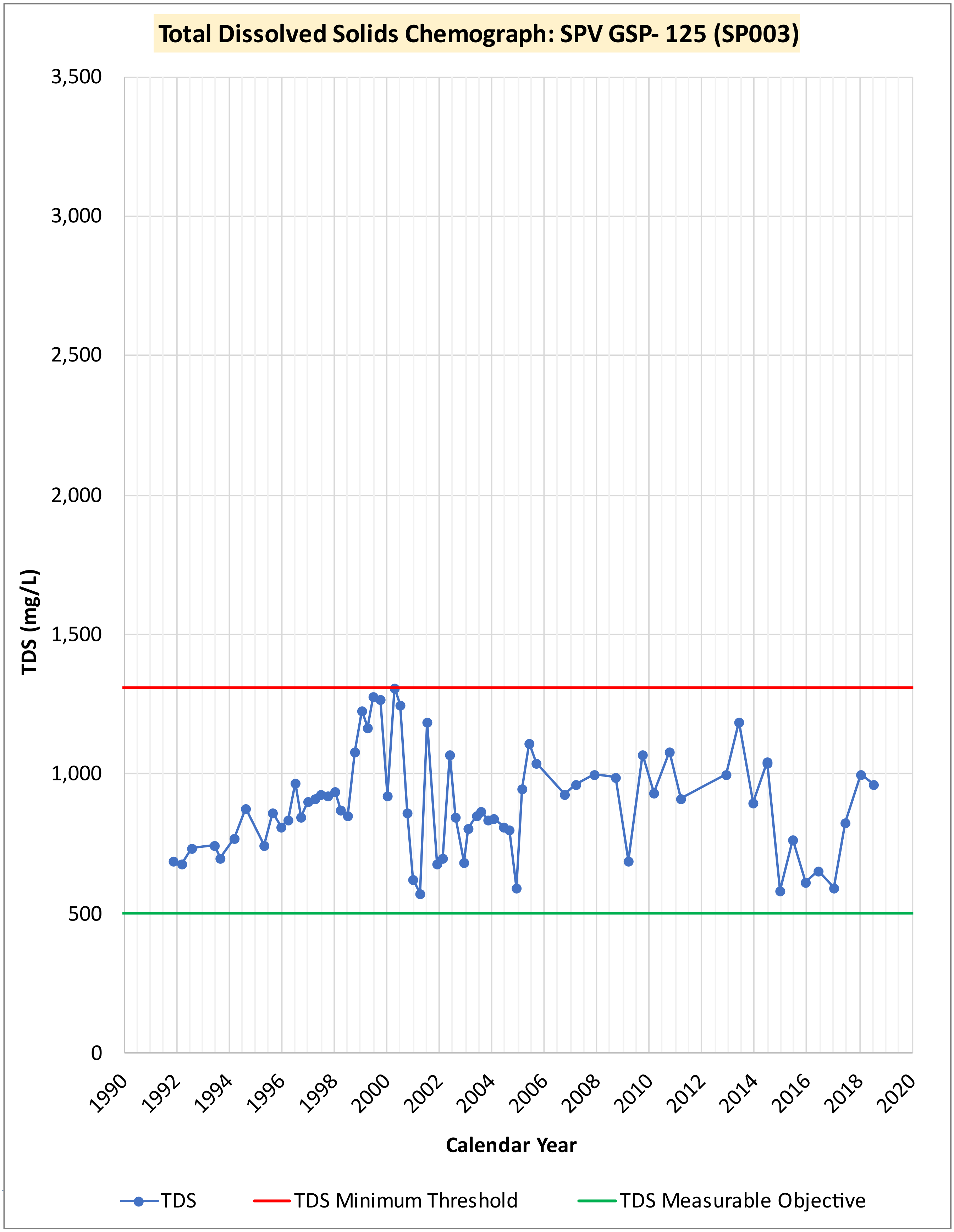
Calendar Year
Nitrate as NO3-N
Nitrate Minimum Threshold
Nitrate Measurable Objective


Total Dissolved Solids Chemograph: SPV GSP- 125 (SP003)
TDS (mg/L)
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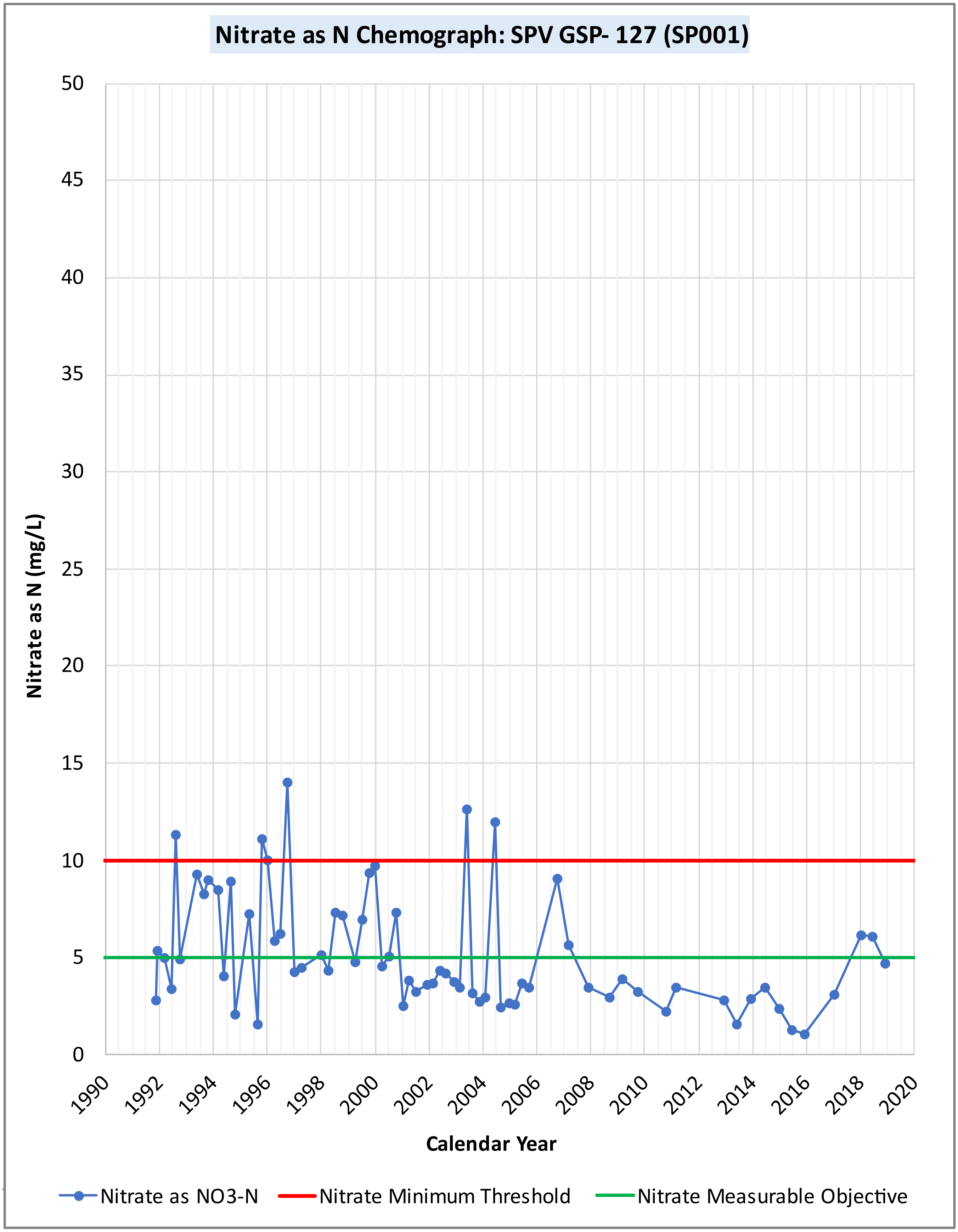
Calendar Year
TDS
TDS Minimum Threshold
TDS Measurable Objective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Nitrate as N (mg/L)
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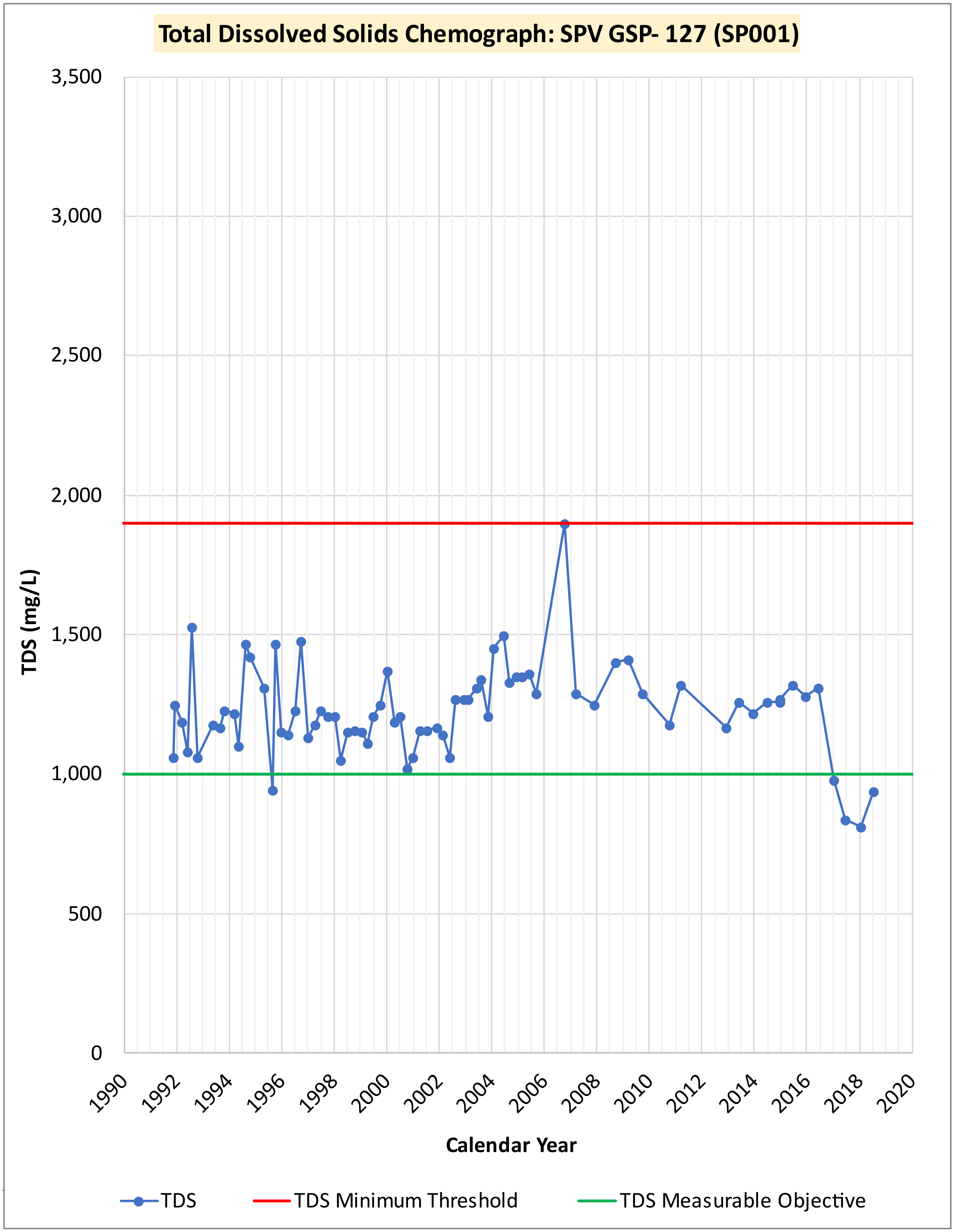
2020
Calendar Year
Nitrate as NO3-N
Nitrate Minimum Threshold
Nitrate Measurable Objective


Total Dissolved Solids Chemograph: SPV GSP- 127 (SP001)
TDS (mg/L)
3,500
3,000
2,500
2,000
1,500
1,000
500
0
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
2018
2020
Calendar Year
TDS
TDS Minimum Threshold
TDS Measurable Objective

Appendix I
Numerical Flow Model Documentation

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SD Public Utilities

San Pasqual Valley Groundwater Basin

Groundwater Sustainability Plan Draft

APPENDIX I

Numerical Flow Model Documentation

Presented by

Jacobs

Our Region's Trusted Water Leader
San Diego County Water Authority

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Acronyms

3D	three dimensional
AF	acre-feet
AFY	acre-feet per year
ASCII	American Standard Code for Information Interchange
Basin	San Pasqual Valley Groundwater Basin
bgs	below ground surface
BCM	Basin Characterization Model
BMP	Best Management Practice
CCTAG	Climate Change Technical Advisory Group
CDM	Camp, Dresser, & McKee, Inc.
CH2M	CH2M HILL Engineers, Inc.
CIMIS	California Irrigation Management Information System
City	City of San Diego
cm/s	centimeters per second
County	County of San Diego
DEM	digital elevation model
DRT	Drain Return
DSOD	Division of Safety of Dams
DWR	California Department of Water Resources
ESI	Environmental Simulations Inc.
ET	evapotranspiration
ET0	reference evapotranspiration
FMP	Farm Process
ft-1	per foot
ft/d	feet per day
GCM	global climate model
GIS	geographic information system
GHB	general head boundary
gpcd	gallons per capita per day

gpm	gallons per minute
GSP	Groundwater Sustainability Plan
IPCC	Intergovernmental Panel on Climate Change
Jacobs	Jacobs Engineering Group, Inc.
Kc	crop coefficient
Kh	horizontal hydraulic conductivity
Kh:Kv	vertical anisotropy
Kv	vertical hydraulic conductivity
MAP	mean annual precipitation
mi^2	square miles
MNW2	multi-node well 2
MO	measurable objective
MR	mean residual
MT	minimum threshold
NA	not applicable
NAVD88	North American Vertical Datum of 1988
NRCS	National Resources Conservation Service
NRD	non-routed delivery
OneWater	MODFLOW-OWHM: One Water Hydrologic Flow Model
PRISM	Parameter-elevation Relationships on Independent Slopes Model
R^2	coefficient of determination
RCP	Representative Concentration Pathway
RMSR	root mean squared residual
RMSR/Range	root mean squared residual divided by the range of target head values
SDWA	San Diego Water Authority
SFR	Streamflow Routing
SMC	sustainable management criteria
SNMP	Salt and Nutrient Management Plan
SPV GSP Model	San Pasqual Valley Groundwater Sustainability Plan Integrated Groundwater/Surface Water Flow Model
Ss	specific storage

SSURGO	Soil Survey Geography
Sy	specific yield
TFDR	Total Farm Delivery Requirement
TPR	Technical Peer Review
USDA	United States Department of Agriculture
USGS	United States Geological Survey
VHD	vertical head difference
WBS	water balance subarea
WY	water year
WYT	water year type

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SECTION 1. INTRODUCTION

On behalf of the City of San Diego (City) and County of San Diego (County), Jacobs Engineering Group, Inc. (Jacobs) has developed an integrated groundwater/surface-water flow model of an area encompassing the San Pasqual Valley (SPV) in San Diego County, California. This report was prepared by Jacobs and documents the development, calibration, and application of this numerical model to support the SPV Groundwater Sustainablity Agency (GSA) in the preparation of its Groundwater Sustainability Plan (GSP). This model is hereafter referred to as the SPV GSP Integrated Groundwater/Surface Water Flow Model (SPV GSP Model) to differentiate it from other numerical models developed in recent years for this area and to emphasize its intended use to support development of the SPV GSP.

The SPV GSP Model, which was used to develop the water budgets, was developed in consultation with members of the Technical Peer Review (TPR) group, which includes three independent groundwater practitioners with expertise in technical groundwater evaluations. The GSA hosted seven TPR meetings (i.e., November 9, 2019; January 9, 2020; May 14, 2020; July 9, 2020; October 8, 2020; December 17, 2020; and January 14, 2021) during the development of the GSP and SPV GSP Model. These meetings provided opportunities for TPR members to review and comment on major aspects of model and GSP development.

The SPV GSP Model integrates the three-dimensional (3D) groundwater and surface-water systems, land surface processes, and operations. Development of this model included the assimilation of information on land use, water infrastructure, hydrogeologic conditions, agricultural water demands and supplies, and population. The SPV GSP Model was built upon an existing numerical groundwater flow and transport model developed as part of the SPV Salt and Nutrient Management Plan (SNMP) (City of San Diego, 2014). The SPV GSP Model is based on the best available data and information as of January 2020. It is expected that this model will be updated as additional monitoring data are collected and analyzed and as knowledge of the hydrogeologic conceptual model evolves during implementation of the GSP.

The center of the SPV is located at latitude 33°5.0'N and longitude 116°59.5'W, approximately 25 miles north of downtown San Diego and approximately 5 miles southwest of City of Escondido. **Figure 1-1** (figures are located at the end of their respective sections) show the location of the SPV .The study area boundary (shown in yellow in **Figure 1-1**) was selected to coincide with natural hydrologic features, such as subcatchment and SPV Groundwater Basin (Basin) (defined as 09-010 in Bulletin 118) boundaries, to help establish a hydrologic framework for the SPV GSP Model.

1.1 Background

In 2014, in response to continued overdraft of many of California's groundwater basins, the State of California enacted SGMA to provide local and regional agencies the authority to sustainably manage groundwater. The SPV Basin is subject to SGMA, because it is one of 127 basins and subbasins identified in 2014 by the California Department of Water Resources (DWR) as being medium- or high-priority, based on population, groundwater use, and other factors. Under SGMA, high- and medium-priority basins not identified as critically overdrafted must be managed according to a GSP by January 31, 2022. DWR has identified the SPV Basin as a medium-priority basin. SGMA requires medium-priority groundwater basins being managed by a GSA to reach sustainability within 20 years of implementing its GSP. Within the framework of SGMA, sustainable groundwater management is defined as the management and use of groundwater in a manner that can be maintained during the planning and implementation period without causing undesirable results. The SPV GSP Model has been developed to help prepare water budgets and guide planning efforts associated with the GSP.

1.2 Modeling Objectives

The modeling objectives include the following:

- Support development of surface water and groundwater budgets for historical, current, and future conditions for the GSP.
- Help guide the development of sustainable management criteria (SMC) as part of the GSP process.
- Support refinement of monitoring networks during implementation of the GSP, if needed.
- Provide insights into how implementation of project and management actions, if needed, could potentially affect groundwater conditions during implementation of the GSP.

The SPV GSP Model is only one line of analysis being used to help the GSA develop and implement its GSP. This model will not ultimately "decide" whether the Basin is being managed sustainably. Collection, reporting, and analysis of field data during GSP implementation will be used in conjunction with SMC to demonstrate to DWR whether the Basin is being managed sustainably. One of the main purposes of the model is to provide plausible water budgets to alert the GSA to potential future conditions, so it can develop a plan for the continued responsible management of the Basin.

1.3 Model Function

To achieve the modeling objectives, the SPV GSP Model was developed and calibrated using available data and professional judgment. This 3D model was constructed and calibrated to simulate monthly groundwater and surface-water flow conditions within a 42 square mile (mi^2) area encompassing the Basin. The United States Geological Survey (USGS) codes MODFLOW-OWHM: One Water Hydrologic Flow Model version 2 (Boyce et al., 2020) and the Basin Characterization Model version 8 (Flint et al., 2013; Flint and Flint, 2014) were used in conjunction with the graphical-user-interface Groundwater Vistas version 8 (Environmental Simulations Inc. [ESI], 2020) and other custom utilities to develop and use the SPV GSP Model to achieve the modeling objectives. Subsequent sections of this report provide additional details regarding the development and application of the SPV GSP Model.

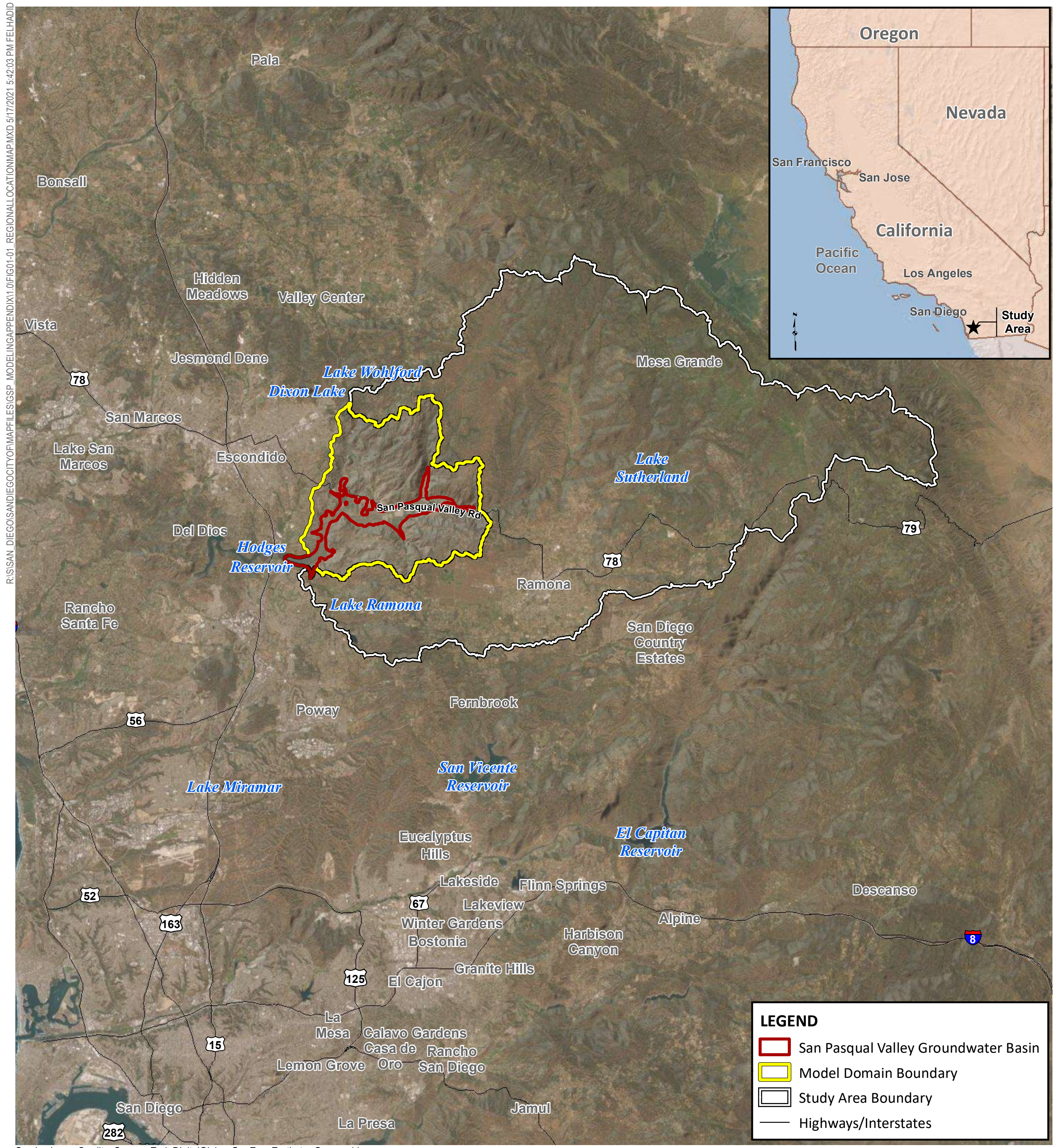
1.4 Model Assumptions and Limitations

The development of the SPV GSP Model included the following assumptions and limitations:

- Subsurface geologic materials, including granular unconsolidated material (e.g., gravel, sand, silt, and clay) and crystalline rock with varying degrees of fracturing, are all modeled as an equivalent porous media.
- Groundwater and surface water are modeled as a single-density fluid.
- No-flow conditions are assumed along portions of the lateral boundary and at the bottom of the SPV GSP Model.
- Monthly stress periods have been incorporated into the simulations. As such, variations in flow processes that occur within a given month are not explicitly simulated; instead, monthly average flow rates are implemented.
- In the absense of detailed well logs, assumptions had to be made regarding well construction and locations for some of the pumping wells represented in the model.
- Although the SPV GSP Model provides estimates of the groundwater flow exchange between the Basin and surrounding rock, these estimates include varying degrees of uncertainty. This is because of the limited information regarding groundwater levels and weathering and fracture characteristics in the surrounding rock.
- Mathematical models like the SPV GSP Model described herein can only approximate surface and subsurface flow processes, despite their high degree of precision. A major cause of uncertainty in these types of models is the discrepancy between the coverage of measurements needed to understand site conditions and the coverage of measurements generally made under the constraints of limited time and budget (Rojstaczer, 1994).

- Because the SPV GSP Model is a flow model, it cannot perform solute transport calculations. Therefore, it cannot directly provide estimates or forecasts of constituent concentrations in the modeled environment. Other tools, such as the flow and transport model developed to support the SPV SNMP (City of San Diego, 2014), could be used as companion tools to address questions related to water quality.

Given these assumptions and limitations, numerical flow models like the SPV GSP Model should be considered tools to provide insight and qualitative projections of future conditions. Therefore, important planning decisions that use output from the SPV GSP Model must be made with an understanding of the uncertainty in and sensitivity to model input parameters. These planning decisions should also consider other site data, local and regional drivers, professional judgment, and the inclusion of safety factors.



Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

The City of SAN DIEGO

FIGURE 1-1
Regional Location Map
Numerical Flow Model Documentation
San Pasqual Valley Groundwater Basin
Groundwater Sustainability Plan
San Pasqual Valley, California

Jacobs

Third Party GIS Disclaimer: This map is for reference and graphical purposes only and should not be relied upon by third parties for any legal decisions. Any reliance upon the map or data contained herein shall be at the users' sole risk. **Data Sources:**

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SECTION 2. CONCEPTUAL MODEL OVERVIEW

The study area lies within the Peninsular Range Province in a central portion of San Diego County, California, within the San Dieguito Drainage Basin. The San Dieguito Drainage Basin, which is the fourth largest drainage basin in San Diego County, starts in the Laguna Mountains, slopes west-southwest, and ultimately terminates at the Pacific Ocean. The study area is a 42 mi^2 (26,816-acre) subcatchment that includes the 5.5-mi^2 (3,500-acre) Basin (**Figure 1-2**). As shown on **Figure 1-1**, the Basin is near the southern coast of California, approximately 25 miles north of downtown San Diego, and approximately 5 miles southeast of the city of Escondido. The study area includes the SPV and several canyons—most notably Rockwood Canyon, Bandy Canyon, and Cloverdale Canyon. Santa Ysabel Creek in the SPV, Guejito Creek in Rockwood Canyon, Santa Maria Creek in Bandy Canyon, and Cloverdale Creek in Cloverdale Canyon drain most of the study area. San Dieguito River is formed at the confluence of Santa Ysabel Creek and Santa Maria Creek, and flows into Hodges Reservoir downgradient from the southwest boundary of the Basin (**Figure 1-2**). Of these streams, only Cloverdale Creek and San Dieguito River in the downgradient portion of the Basin have perennial streamflow. The groundwater recharge of applied water on hillside avocado groves in Cloverdale Canyon has turned Cloverdale Creek from an intermittent stream into a perennial stream (Izbicki, 1983).

The City owns the land over approximately 90 percent of the Basin. The City leases much of this land for agricultural and residential uses, for which groundwater from the Basin serves as the primary source of water supply. Much of the land in the SPV is designated as an agricultural and open space preserve.

The climate is characteristic of a Mediterranean-type climate with dry hot summers and mild winters. The average precipitation in the study area is approximately 14 inches per year (PRISM Climate Group, 2020) with most of the precipitation falling December through March.

The primary water-bearing materials in the study area are alluvium and residuum within the Basin. The permeable alluvium consists of poorly consolidated deposits of gravel, sand, silt, and clay and can be more than 200 feet thick in some areas. The residuum has varying degrees of permeability, depending on the weathering and fracture characteristics of the crystalline rock from which it formed. The alluvium and residuum form an unconfined aquifer, which is surrounded by low-permeability crystalline rocks with varying degrees of weathering and fracturing.

Groundwater in the study area generally converges on the Basin and flows westward toward Hodges Reservoir. The eastern end of the Basin is generally a groundwater recharge area, where the aquifer receives water primarily from streambed infiltration of Guejito, Santa Maria, and Santa Ysabel Creeks. As groundwater moves along its flow path, some of it is intercepted by groundwater wells or is partially consumed by evaporation and transpiration (the combined process of shallow groundwater evapotranspiration [ET]) within riparian or groundwater discharge areas. Groundwater that is extracted through pumping is used for irrigation and domestic potable water and is partially consumed through the ET process. The portion of this pumped flow that is not consumed by ET reenters the aquifer as groundwater recharge from applied water or recharge from wastewater ponds or septic tanks. The process of groundwater being intercepted by groundwater wells and then reapplied to the land surface for irrigation continues along its generally westward flow path, with some groundwater eventually exiting the Basin as subsurface outflow. Thus, groundwater flowing from the Basin has been "recycled" several times to sustain the predominantly agricultural land uses within the study area before emerging from the Basin as subsurface outflow.

SECTION 3. NUMERICAL MODEL CONSTRUCTION

The mathematical model was designed to translate the hydrogeologic conceptual model into a form that is suitable for numerical modeling. The following steps were included in the development of the mathematical model:

1. Selecting numerical codes for groundwater and surface-water flow
2. Establishing a model domain and developing a model grid
3. Spatially distributing surface parameter values
4. Spatially distributing subsurface parameter values
5. Selecting a time-discretization approach appropriate for evaluating the field problem and achieving the modeling objectives (see Section 1.2)
6. Establishing initial flow conditions for groundwater and surface-water flow
7. Establishing boundary conditions for groundwater and surface-water flow

The following subsections describe the methodology for executing these design steps.

3.1 Code Selection

The USGS code MODFLOW-OWHM: One Water Hydrologic Flow Model (OneWater) version 2 (Boyce et al., 2020) was selected for this modeling effort, in conjunction with the graphical-user-interface Groundwater Vistas version 8 (ESI, 2020) and other custom utilities to develop the SPV GSP Model. OneWater is an updated formulation, built upon the MODFLOW-2005 (Harbaugh, 2005) framework. OneWater accommodates the development of a 3D, physically based, spatially distributed, integrated groundwater/surface-water flow model. The OneWater code was selected for the following reasons:

- OneWater is based on MODFLOW-2005, which has been used extensively in groundwater evaluations worldwide for many years and is well-documented. OneWater contains an improved solution scheme that can handle a variety of complex, variably saturated flow conditions, which are relevant to groundwater conditions in the Basin.
- OneWater has been benchmarked and verified, so the numerical solutions generated by the code have been compared with analytical solutions, subjected to scientific review, and used on other modeling projects. Verification of the code confirms that OneWater can accurately solve the governing equations that constitute the mathematical model.
- OneWater accommodates a comprehensive suite of groundwater and surface-water boundary conditions.

In addition to using OneWater as the primary mathematical code upon which the SPV GSP Model is built, version 8 of the Basin Characterization Model (BCM) (Flint et al., 2013; Flint and Flint, 2014) was also selected for use as a companion rainfall–runoff model. The BCM has been used to help provide runoff estimates to the SPV GSP Model domain from contributing catchments located outside the SPV GSP Model domain. The use of the BCM to support the modeling effort is described in more detail in Section 3.7.

3.1.1 Numerical Assumptions

OneWater is conceptualized mathematically into two hydrologic flow regimes: surface flow and subsurface flow. The surface-flow regime, as configured for the SPV GSP Model described herein, includes runoff, channel flow, and interaction with the subsurface. The subsurface-flow regime underlies the surface-flow regime and includes variably saturated zones representing porous media through which groundwater flows and can interact with the surface-flow regime.

3.1.2 Scientific Basis

The theory and numerical techniques that are incorporated into OneWater and the BCM have been scientifically tested. The governing equations for rainfall-runoff, streamflow, and variably saturated subsurface flow have been solved by several modeling codes over the past few decades, on a wide range of field problems. Therefore, the scientific basis of the theory and the numerical techniques for solving these equations have been well-established. The OneWater user's manual (Boyce et al., 2020) and the BCM documentation (Flint et al., 2013; Flint and Flint, 2014) detail the governing equations and other information on the codes.

3.1.3 Data Formats

Several American Standard Code for Information Interchange (ASCII) data files were used to parameterize the SPV GSP Model. **Table 3-1** shows the grouping of various data items in the SPV GSP Model input files.

Table 3-1. OneWater Input File Description

File Extension	Version	Purpose[a]	Parameters[a,b]
BAS	6	• Basic Package establishes active and inactive cells and initial heads	• IBOUND array by layer (active domain) • Initial heads by layer
DIS	NA	• Discretization Package establishes information on how time and space are subdivided • Establishes whether the numerical solution is steady state or transient	• Grid cell dimensions • Layer interface elevations • Stress period durations • Number of time steps per stress period • Time step multiplier • Stress period type (steady state or transient)
UPW	1	• Upstream Weighting Package contains aquifer hydraulic parameters, which constrain flow between model cells	• Horizontal and vertical hydraulic conductivity • Groundwater storage parameters
FMP	4	• Farm Process contains soil, vegetation, water source, and water use information • Controls supply and demand to facilitate computation of runoff, groundwater recharge from precipitation and applied water, and agricultural pumping	• Consumptive use terms • Soil type • Rooting depths • Irrigation efficiency • Groundwater root flag and root pressures • Capillary fringe • Vadose zone options • ET factors • Water source and delivery information • Irrigation fractions
SFR	7	• Streamflow Routing Package constrains streamflow and groundwater/stream interaction	• Segment and reach information • Channel geometry and elevation information • Slope and resistance terms • Optional flow rules and constraints • Flow tolerance terms • Streambed properties
GHB	NA	• General-Head Boundary Package controls groundwater outflow from the	• Boundary head and conductance by stress period • Model layer designations

File Extension	Version	Purpose[a]	Parameters[a,b]
		Basin toward Hodges Reservoir	
WEL	v1	• Well Package v1 establishes septic system discharges	• Specified injection rate by stress period • Model layer designations
WEL	v2	• Well Package v2 establishes subsurface inflow from contributing catchments	• Specified inflow rate by stress period • Model layer designations
DRT	7	• Drain Return Package directs rejected recharge to streams	• Drain head and conductance • Recipient SFR nodes for drained groundwater
MNW	2	• Multi-Node Well Package simulates agricultural groundwater pumping	• Well dimension and construction information • Groundwater pumping rate by stress period • Model layer(s) designations
NWT	1.2.0	• Newton Solver solves the governing flow equations	• Solver iteration and closure terms • Backtracking and other solver options
NAM	NA	• Name File specifies names of input and output files	• No parameters are included
OC	NA	• Output Control File specifies the type of runtime information to write to output files	• User-defined print and save statements

[a] As implemented in the SPV GSP Model. Alternative uses of the package are also possible.
[b] Not intended to be an exhaustive list of input parameters. Please see the model code documentation and online resources for additional information.
NA = not applicable, because it is built into the main OneWater code

Output from the SPV GSP Model also follows the USGS MODFLOW output file formats and includes ASCII as well as binary files. Although a variety of optional output files can be generated with the OneWater code, **Table 3-2** summarizes the main output files used for this modeling effort.

Table 3-2. Selected OneWater Output File Description

File Name or Extension	Content
LST	• ASCII listing file containing runtime information included in the simulation
FB-Details	• ASCII file containing Farm Process inflows and outflows by water balance subregions for all output times
FDS	• ASCII file containing supply and demand information for all output times
SFRBUD	• ASCII file containing reach-specific stream inflows, outflows, and other physical parameters of the stream reach for all output times
HDS	• Binary file containing cell-by-cell modeled groundwater elevations for all output times
CBB	• Binary file containing cell-by-cell subsurface flows for all output times

3.2 Model Domain

A numerical model must use discrete space to represent the hydrologic system. The simplest way to discretize space is to subdivide the study area into many subregions (i.e., grid blocks) of the same size. This grid-building strategy was implemented for this modeling effort and is described in the following subsections.

3.2.1 Areal Characteristics of Model Grid

CH2M HILL Engineers, Inc. (now Jacobs) developed as part of the SPV SNMP (City of San Diego, 2014) a numerical model grid that mathematically represents the 42-mi^2 study area, which is a subcatchment encompassing the 5.5-mi^2 Basin and vicinity. The areal extents and lateral dimensions of the model grid for the SPV GSP Model described herein remain unchanged from the lateral dimensions of the grid developed for the SNMP (City of San Diego, 2014). This was done to facilitate making comparisons back and forth between the two models, given that these models are both useful for different purposes. **Figure 3-1** illustrates the numerical grid of the SPV GSP Model. This grid is areally discretized into uniform grid-block (i.e., cell) spacings on 100-foot centers. The locations of the lateral model domain boundaries shown in **Figure 3-1** were selected to mostly coincide with natural hydrologic features, such as subcatchment boundaries and to help establish a regional hydrologic framework around the Basin.

3.2.2 Vertical Characteristics of Model Grid

Four vertically stacked layers have been developed by Jacobs to provide a 3D representation of the subsurface system. Elevation datasets for the ground surface and the top of indurated bedrock were used to define the layers of the model grid. The top elevation of Model Layer 1 was set equal to the ground surface elevation, which was derived from 10-meter digital elevation model (DEM) data. Model Layers 1 and 2 within the Basin generally represent the unconsolidated alluvium and friable residuum, respectively, whereas Model Layers 3 and 4 within the Basin represent more indurated bedrock. Two indurated bedrock layers were included to allow screened intervals at clustered monitoring well locations to have unique model layers assigned to each screened interval.

The 3D geometry of the alluvial aquifer was specified by assigning alluvial aquifer hydraulic conductivities representative of alluvium to the appropriate cells and layers using the estimated alluvium thickness at each grid cell location within the Basin boundary. If the alluvium depth was estimated to extend more than half the thickness of a cell in a particular layer, then that cell was assigned a hydraulic conductivity value representative of alluvium. **Table 3-3** lists the model layer designations, layer thicknesses, and layer depths. **Figure 3-2** illustrates the geologic cross sections develop by Snyder Geologic that were used along with well completion reports and professional judgment to establish the model layers within the Basin. Outside of the Basin, model layers more generally subdivide the indurated rock to provide adequate mathematical resolution and allow for continuous model layers. Hydraulic conductivity values indicative of crystalline rock are assigned to model cells outside the Basin.

Table 3-3. Summary of Model Layers

Model Layer	Description	Model Layer Thickness (feet)	Depth of Layer Bottom (feet bgs)
1	• Generally alluvium within the Basin • Alluvium/Residuum/Indurated rock outside the Basin	36 to 190	36 to 190
2	• Generally residuum within the Basin • Residuum/Indurated rock outside the Basin	6 to 110	85 to 230
3	• Shallower indurated rock	150	235 to 380
4	• Deeper indurated rock	1,416	216 to 2,159

bgs = below ground surface
Model Layers 1 and 2 are set as unconfined, convertible layers to allow transmissivity to vary temporally and spatially according to the layer's saturated thickness and horizontal hydraulic conductivity. Model Layers 3 and 4 are set as confined, so transmissivity only varies spatially according to the cell thickness and horizontal hydraulic conductivity therein.

3.3 Surface Parameters

The surface parameters required by the SPV GSP Model are the land surface elevations, stream channel characteristics.

3.3.1 Topography

A 10-meter DEM raster dataset forms the basis for land surface elevations covering the modeling domain. These land surface elevations were assigned to the top of Model Layer 1. Elevation data were processed using ArcGIS Version 10 software. **Figure 3-3** illustrates the land surface elevations incorporated into the top of the model grid.

3.3.2 Stream Channel Characteristics

The stream channel network used in the SPV GSP model was adapted from the SNMP (City of San Diego, 2014) to serve as the starting point for development of the Streamflow Routing (SFR) package. **Figure 3-4** presents the stream network used in the SPV GSP Model. The SFR package requires definition of stream channel segments that are intersected with the model grid to obtain stream channel networks. Stream channel parameters that define information necessary for the calculation of streamflow routing are specified throughout the SFR network. As a starting point parameter values were idealized for all stream segments. With this setup stream channel width was set to 50 feet, streambed hydraulic conductivity was set to 10 feet per day (ft/d) (3.5×10^{-3} centimeters per second [cm/s]) (Freeze and Cherry, 1979), and the Manning's roughness coefficient was set to 0.025 (Chow, 1959).

3.3.3 Land Cover

Land cover parameters provide an important component to the modeling framework because they participate in hydraulic calculations that affect irrigation pumping rates and areal groundwater recharge rates in the SPV GSP Model.

Soils

Soil survey information was compiled from the United States Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) Soil Survey Geography (SSURGO) geodatabase for the study area. The primary parameter utilized from the SSURGO database is a texture classification that defines the soil type assigned in the SPV GSP Model. **Figure 3-5** presents the four soil categories that were defined throughout the SPV GSP Model domain. Each model grid cell is assigned a unique soil type classification that links the soil type to capillary fringe depths. Initially, capillary fringe depths were set equal to 1.0 foot for each of the four soil types and were refined during the calibration process (see Section 4.3.5).

Land use and Vegetation

Land use in the SPV GSP Model is based on a combination of different data sources, including City lease information, DWR and county land use surveys, and satellite imagery from 2009, 2012, and 2018; however, the primary sources of information used for the final assignment of land cover types were the recent satellite imagery and stakeholder input. Areas were first classified into different land use categories that were developed to align with specific land uses within the Basin, because they relate to differences in hydrology and irrigation. Maps of the 2005 and 2018 land uses developed from this effort are presented in **Figures 3-6 and 3-7**. **Table 3-4** summarizes the crops assigned in the SPV GSP Model. Land use acreages presented for the areas within the Basin and the SPV GSP Model domain represent conditions for the 2018 land use dataset. The largest changes in land use acreage between 2005 and 2018 were a reduction of approximately 121 acres of nursery crops and an increase in approximately 104 acres of citrus crops within the Basin. Additionally, there was a 22-acre reduction in riparian area and an increase in 13 acres of truck crops, 12 acres of grapevines, and 15 acres of rural landscape. Changes in water use associated with these land use changes were directly reflected in the simulation of consumptive use in the SPV GSP Model. The details of the consumptive use assumptions will be discussed further under Section 3.7.1.

Irrigation efficiency values were specified based on the irrigation method for each crop category simulated in the SPV GSP Model. Efficiency values are presented in the footnote of **Table 3-4**. Irrigation efficiency values were translated into "on-farm efficiency" parameters in the SPV GSP Model by calculating an area-weighted irrigation efficiency based on the percentage of each crop within each unique water balance subarea (WBS).

Table 3-4 - Summary of Crop Categories and Associated Parameter Assumptions

Crop	Irrigated?	Rooting Depth (inches)	Irrigation Method	2018 Area within Basin (acres)	2018 Area within SPV GSP Model Domain (acres)
Truck Crops	Yes	36	Sprinkler	100	240
Nursery	Yes	24	Sprinkler	318	601
Avocado	Yes	40	Drip	1	2,451
Citrus	Yes	48	Drip	481	762
Grapevines	Yes	60	Drip	12	55
Turfgrass	Yes	30	Sprinkler	631	633
Winter Forage	No	36	None	153	329
Summer Forage	Yes	36	Flood	149	157
Golf Course	Yes	36	Sprinkler	0	171
Feedlot	Yes	36	Flood	51	372
Rural Landscape	Yes	36	Sprinkler	65	1,749
Urban Landscape	Yes	36	Sprinkler	22	1,422
Riparian	No	72	None	1,422	1,509
Greenhouse	Yes	24	Drip	4	8
Native Shrub	No	72	None	73	16,457
Irrigation Efficiencies for flood, sprinkler, and drip irrigation are 0.65, 0.75, and 0.80, respectively.					

Water Infrastructure

Local residents are dependent on a network of groundwater production wells that provide water for agricultural and domestic use throughout the Basin. Pumping wells were identified based on several sources including the SNMP (City of San Diego, 2014), the City's well database, County information, and local stakeholder input. A critical aspect of this effort was to identify not only the locations of wells, but also the subareas to which those wells provide water as a source of supply. **Figure 3-8** depicts the pumping well locations throughout the Basin along with parcels that define land where residents maintain agricultural operations. These parcels were related spatially using geographic information system (GIS) software to specific well locations, based on the ownership and infrastructure of wells and adjacent parcels. The linkage between pumping wells and parcels allows for estimation of production well pumping rates based on the applied-water demand computed by the OneWater code for each distinct parcel during each month of the simulation period. The outdoor water demand associated with these parcels is defined by a consumptive use dataset described in Section 3.7.1. In the case of well locations not being identified, three virtual wells were modeled in Parcel #35 (see Figure 3-8) to improve the consistency between the numerical and conceptual models for that irrigated parcel. Attachment 1 presents the annual status of each pumping well during the simulation period based on stakeholder input.

The Farm Process (FMP) package of the SPV GSP Model requires the delineation of WBSs to define unique subareas of the model that receive water from the same source. The parcel boundaries served as the starting point for WBS delineation in the SPV GSP Model, thereby allowing the model to mathematically route pumped groundwater to the appropriate parcel. Additional considerations were made in the delineation of WBSs including areas receiving imported water, and areas of native or non-irrigated lands. Additionally, the model reports WBS-specific outputs. Thus, to develop water budgets at the Basin scale, the WBSs were clipped to the Basin extent to provide flexibility in summarizing model output at the Basin scale. **Figure 3-9** illustrates the WBSs within the SPV GSP Model domain.

3.4 Subsurface Parameters

The subsurface hydraulic parameters required by the SPV GSP Model are the horizontal hydraulic conductivity (K_h), vertical hydraulic conductivity (K_v), specific yield (S_y), and specific storage (S_s).

3.4.1 Hydraulic Conductivity

Data from previous studies and models of the area (Izbicki, 1983; CH2M HILL Engineers, Inc. [CH2M], 2001; Camp Dresser & McKee, Inc. [CDM], 2010; City of San Diego, 2014) and professional judgment formed the basis for the initial K_h and K_v values incorporated into the

SPV GSP Model. **Figures 3-10 and 3-11** present the basis for the initial distributions of K_h and K_v in the SPV GSP Model, which were obtained from the five-layer SNMP model (City of San Diego, 2014). As described in Section 3.2.2, the SPV GSP Model has only four model layers, so the values presented in Figures 3-10 and 3-11 were not distributed vertically as shown, but rather the range of values served as the initial basis for the appropriate materials in the SPV GSP Model prior to calibration. Initial K_h values ranged from 37.5 to 85 feet per day (ft/d) (1.3×10^{-2} to 3.0×10^{-2} cm/s) in the alluvial aquifer and residuum and 1.5×10^{-2} to 250 ft/d (5.3×10^{-6} to 8.8×10^{-2} cm/s) in the rock and creek beds surrounding the alluvial aquifer. Initial K_v values ranged from 3.75 to 8.5 ft/d (1.3×10^{-3} to 3.0×10^{-3} cm/s) in the alluvial aquifer and 1.5×10^{-2} to 25 ft/d (5.3×10^{-6} to 8.8×10^{-3} cm/s) in the rock and riparian aquifers surrounding the alluvial aquifer. Section 4 describes the modification of these values during the calibration process.

3.4.2 Groundwater Storage

Groundwater storage (i.e., storativity) is handled through the assignment of two parameters, including the S_y and S_s. Model Layers 1 and 2 are set as unconfined, convertible layers to allow transmissivity to vary temporally and spatially according to the layer's saturated thickness and K_h. These model layers require the user to input both S_y and S_s values, which can vary on a cell-by-cell basis. If a model cell during a given stress period in Model Layers 1 or 2 is fully saturated, then the model computes a storativity as the product of the S_s and cell thickness. If a model cell during a given stress period in Model Layers 1 or 2 is partially saturated, then the model uses the S_y. Model Layers 3 and 4 are set as confined, so the model computes for each stress period a storativity value as the product of the S_s and cell thickness for these model layers. Thus, groundwater storage properties do not very temporally in Model Layers 3 and 4. The SPV GSP Model was initially assigned uniform S_y and S_s values of 10 percent and 1×10^{-6} per foot (ft^{-1}), respectively, based on literature values and professional judgement. Section 4 describes the modification of these values during the calibration process.

3.5 Time Discretization

3.5.1 Climate Period Analysis

Historical Period

An analysis was performed to analyze recent historical trends to determine the most appropriate time-period to use for the historical simulation period. The chart at the top of **Figure 3-12** presents the annual precipitation totals for the Basin for a 40-year period, including water years [WY][1] 1980 through 2019. The Parameter-elevation Relationships on

[1] A water year runs from October 1st of one calendar year through September 30th of the following calendar year. For example October 1, 2019 and September 30, 2020 would mark the first and last day of water year 2020, respectively.

Independent Slopes Model (PRISM) (PRISM Climate Group, 2020) interpolation method was used to develop data sets that reflect the current state of knowledge of spatial climate patterns in the SPV and surrounding vicinity. The precipitation data presented in **Figure 3-12** represent the spatial averages of PRISM precipitation grid values located in the SPV GSP Model domain. The mean annual precipitation (MAP) over the 40-year historical period is 14.57 inches. This historical period was considered when establishing a historical model calibration period, which would also serve as the historical water budget period. After consideration of climatic variability and available data regarding land and water use and groundwater levels, a 15-year period including WYs 2005 through 2019 was selected for the historical model calibration and water budget period. A MAP of 13.80 inches for the WYs 2005 through 2019 model calibration period is about 5 percent lower than the longer-term WYs 1980 through 2019 MAP of 14.57 inches.

A water year classification scheme was developed using a quantile-based approach to develop a water year type (WYT) for each WY to characterize annual climate variability for use in time-period selection and water budget reporting. **Figure 3-13** presents a quantile-style chart used to rank annual precipitation values into WYTs. First, the quantile-based approach ranks annual precipitation from the historical 40-year analysis period from largest to smallest and assigns a percent rank to each annual precipitation value.

A 20th percentile rank was used to subdivide the ranked precipitation into five percentile categories, as follows:

- Critically Dry (C): WYs with a percent rank less than or equal to 20 percent
- Dry (D): WYs with a percent rank greater than 20 percent and less than or equal to 40 percent
- Normal (N): WYs with a percent rank greater than 40 percent and less than or equal to 60 percent
- Above Normal (AN): WYs with a percent rank greater than 60 percent and less than or equal to 80 percent
- Wet (W): WYs with a percent rank greater than 80 percent

Annual departures from the WYs 2005 through 2019 MAP are displayed as yellow bars in the top chart of **Figure 3-12** and are calculated by subtracting the MAP value of 13.80 inches from each annual precipitation value. Above normal and wet WYs have positive annual departure values above the dashed line, whereas normal, dry, and critically dry years have negative annual departure values below the dashed line. The cumulative departure from the WYs 2005 through 2019 MAP is also provided in the top chart of **Figure 3-12** (shown as the black solid line) and is computed by accumulating the annual departures (i.e., the yellow bars) from WY

2005 forward in time. The annual departures and cumulative departure data indicate a reasonable balance of wet, normal, and dry conditions for model calibration. Additionally, because the availability and reliability of hydrologic and water budget data are more favorable for this recent period as compared with earlier periods, the recent 15-year period was selected for model and water budget development. SGMA Regulations Section 354.18 requires not only a historical water budget, but also a current water budget. The current water budget has been developed using the last five years of this historical period, including WYs 2015 through 2019, as the current averaging period. Historical and current water budgets are discussed in Section 4.4.

Future Period

SGMA Regulations Section 354.18 also requires the projected precipitation and ET_0 to incorporate assumptions regarding climate change. However, these regulations do not require any particular climate change approach, as long as the chosen approach is based on the best available science and is technically defensible. Two climate change approaches were considered for developing projected precipitation and ET_0 for the SPV GSP. The first approach considered is based on a "time-period analysis" as offered by DWR. With this approach, 50 years of historical monthly precipitation and ET_0 data are selected by the modeler and then processed through a DWR tool that adjusts these datasets to account for climate change. The second approach considered is based on a "transient analysis". With this approach, precipitation and air temperature projections from a global climate model (GCM) are used along with a rainfall-runoff model to establish projected precipitation and ET_0 datasets. Available GCMs include projected climate conditions out to the year 2100 under a variety of climatic and greenhouse-gas-emission assumptions made by atmospheric scientists (e.g., Climate Change Technical Advisory Group [CCTAG], 2015; Pierce et al., 2018). This second approach was selected for the projection simulations, based on the reasons that follow:

- Past climatic patterns over the last several decades may not necessarily reflect future projected climatic patterns over the next several decades. Thus, although the regulations indicate that the projected water budget be based on 50 years of historical hydrology to reflect long-term hydrologic conditions, selecting an appropriate historical hydrologic period on which to base climate change factors is not as straightforward as it may seem.
- Considerable research on climate change has been and will continue to be undertaken by dedicated atmospheric scientists with appropriate technical backgrounds. Thus, the GCMs developed by these specialists are based on the best available science and are technically defensible and therefore comply with the intent of SGMA Regulations Section 354.18.

- This particular approach allowed the GSP technical team to maintain consistency with the modeling tools, assumptions, and workflow associated with the development of the historical, current, and projected water budgets.

To account for future hydrologic conditions associated with potential changes in climate, various datasets and reports were analyzed to determine the appropriate set of climate change assumptions and methodology best suitable for incorporation into the projection version of the SPV GSP model. As part of the California Fourth Climate Change Assessment (Pierce et al., 2018), a suite of 10 GCMs previously identified by CCTAG (2015) was reduced to four GCMs representing warm/dry, average, and cool/wet conditions, and a complement (identified as a "diversity" scenario). Through this process, the following four GCMs were identified as representative of the projected climate variability in California:

- HadGEM2-ES (warm/dry)
- CanESM2 (average)
- MIROC5 (complement)
- CNRM-CM5 (cool/wet)

Each of these GCMs also considers Representative Concentration Pathway (RCP) scenarios that describe potential greenhouse-gas and aerosol-emission conditions (Intergovernmental Panel on Climate Change [IPCC], 2013). Two RCP scenarios have been analyzed with "RCP 4.5" representing a medium scenario in which a reduction in greenhouse gas emissions is considered, versus "RCP 8.5", which assumes a "business as usual" emissions scenario (Pierce et al., 2018). A recent study conducted by Schwalm et al. (2020) identified that the RCP 8.5 emissions scenario closely tracks historical total cumulative carbon dioxide emissions and is the best match for mid-century projections of greenhouse-gas emissions, based on current and stated policies. Thus, annual precipitation projections were processed for the SPV area from the four GCMs identified by Pierce et al. (2018) with the RCP 8.5 emissions scenario to review how these projections compare and to recommend a GCM as an appropriate climate-change scenario for the SPV GSP.

Monthly precipitation data for WYs 2020 through 2100 from each of the four recommended GCMs were initially processed into average annual precipitation values across the SPV GSP Model domain. For the purposes of the SPV GSP, the GSP planning period includes WYs 2020 through 2071 to create a continuous simulation run from historical years into projected years to include the 50-year GSP implementation horizon starting from 2022. Thus, projected precipitation summaries presented herein span this 52-year time period.

Figure 3-14 presents the cumulative departure from the most recent 30-year normal (i.e., WYs 1981 through 2010) MAP value of 14.4 inches for the model domain. Overall, the four GCMs indicate different outlooks as compared with the historical 30-year precipitation normal, especially after the 2060 time frame. The CNRM-CM5 scenario indicates the most increase in precipitation during the projection period with the CanESM2 reaching a similar level of departure by the end of the projection period. Conversely, the MIROC5 scenario shows the most decrease in precipitation during the projection period. The annual precipitation associated with the HadGEM2-ES scenario remains relatively close to the historical 30-year precipitation normal (as evidenced by the cumulative departure of the HadGEM2-ES scenario being close to the zero line in **Figure 3-14**) until around 2060, when this scenario begins to show a declining trend.

Another important aspect to consider is the magnitude and timing of precipitation during a given year. **Figure 3-15** presents the average monthly precipitation for each of the four GCMs during the projection period, along with the monthly average precipitation values for the historical 30-year precipitation normal. The two "wetter" scenarios (i.e., CanESM2 and CNRM-CM5) show greater peak precipitation rates with earlier shifts in the timing of peak precipitation rates during the winter (see January and February peaks in **Figure 3-15**), as compared with rates associated with the MIROC5 and HadGEM2-ES scenarios.

The HadGEM2-ES, RCP 8.5 (IPCC, 2013) scenario was ultimately selected to develop projected water budgets for the projection period. This dataset assumes "business as usual" greenhouse gas emissions and represents climatic conditions that plot within the range of the ensemble, but on the drier side of the four California-specific GCMs. Although within the range of climate change projections, this dataset was selected as a potentially conservative scenario for water budget development. The lower chart in **Figure 3-12** presents the annual precipitation totals for the Basin for the projection period, including WYs 2020 through 2071, along with annual and cumulative departures from the MAP of the most recent historical precipitation normal of WYs 1981 through 2010. Projected precipitation for the HadGEM2-ES, RCP 8.5 GCM includes two 4-year droughts in (WYs 2029 through 2032 and WYs 2040 through 2043), one 3-year drought (WYs 2054 through 2056), and one 9-year drought (WYs 2062 through 2070). More substantial wet years are projected to occur only one to two times every 10 to 20 years with the HadGEM2-ES, RCP 8.5 scenario. The projected precipitation and departure data indicate a variety of wet, normal, and dry conditions that are suitable for aiding in the GSP planning process.

3.5.2 Simulation Period

The calibration version of the SPV GSP Model simulates historical hydrologic conditions from January 2004 through September 2019, whereas the projection version of the SPV GSP Model simulates future hydrologic conditions from October 2019 through September 2071. All versions of the SPV GSP Model include monthly stress periods to adequately simulate seasonal hydrologic processes.

3.6 Initial Flow Conditions

The establishment of a transient SPV GSP Model necessitates establishment of initial flow conditions in the hydrologic system. Initial conditions refer to the initial distribution of heads (i.e., groundwater elevations) throughout the model domain. Initial conditions for the calibration simulations were established in a "spin-up" manner. This step involved assigning initial heads intended to approximate December 2003 conditions and then allowing the monthly stress periods to "work through" the monthly conditions through September 2004 (i.e., the end of the spin-up period). This spin-up period is necessary, because it is not possible to assign initial conditions in the surface water boundary conditions of the SPV GSP Model. As such, the surface-water boundary conditions start out dry and must be allowed some simulation time to "wet up" and begin routing water in a manner that is consistent with the intended month-to-month hydrologic variations. Therefore, model output data from the spin-up period are not included in the assessment of calibration or water budgets. Thus, presentation of calibration results and water budgets described in Sections 4 and 5 are representative of October 1, 2004 through September 30, 2019 (i.e., WYs 2005 through 2019).

3.7 Boundary Conditions

Boundary conditions are mathematical statements (i.e., rules) that specify groundwater elevation (i.e., head) or water flux at particular locations within the model domain. The following three types of boundary conditions were used in the SPV GSP Model during calibration.

- **Specified flux:** Water fluxes are assigned to selected model cells and remain unchanged during a monthly stress period. A specified-flux boundary condition is a two-way boundary condition, whereby values indicate either water inflow or outflow rates.
- **Head-dependent flux:** Groundwater elevation (i.e., head) and hydraulic-conductance values are assigned to selected model cells, and water fluxes are computed by the model code across the boundary using an appropriate governing-flow equation. A head-dependent-flux boundary condition is also a two-way boundary condition, depending on the direction of the hydraulic gradient (into or out of the modeled aquifer system).
- **No flow:** Water can flow parallel to the boundary, but not across it.

Table 3-5 summarizes these boundary conditions and **Figure 3-16** depicts locations and types of boundary conditions used to calibrate the SPV GSP Model.

Table 3-5. Summary of Boundary Conditions for Calibration

Hydrologic Process	Specified Flux	Head-dependent Flux
Stream Inflow from Contributing Catchments	X	
Subsurface Inflow from Contributing Catchments	X	
Precipitation	X[a]	
Applied Water	X[a]	X[a]
Groundwater Recharge from Precipitation, Applied Water, and Septic Systems	X[a]	X[a]
Groundwater/Surface-water Interaction		X
Evapotranspiration		X[a]
Groundwater Pumping	X[a]	X[a]
San Dieguito River Outflow to Hodges Reservoir Area		X
Subsurface Outflow to Hodges Reservoir Area		X

[a] *Processed and managed through the Farm Process, which includes some aspects of both specified flux and head-dependent flux boundary conditions*

No-flow boundaries are simulated at lateral boundaries of active surface and subsurface nodes not already assigned specified fluxes and at the bottom of the deepest model layer (i.e., Model Layer 4).

3.7.1 Specified Fluxes

The following section describes boundary conditions in the SPV GSP Model where either a volumetric or linear flux is used to simulate various flow processes.

Precipitation and Reference Evapotranspiration

With use of the FMP, fluxes of precipitation and reference evapotranspiration (ET_0) are specified directly for each model cell. Grass is the reference crop for the ET_0 term. Monthly precipitation and ET_0 estimates were processed from the USGS BCM v8 (Flint et al., 2013, Flint et al., 2014), 270 square meter raster data for the historical simulation period. Additionally, measured ET_0 data from the California Irrigation Management Information System (CIMIS) Escondido SPV #153 station was utilized to correct the BCM ET_0 data to better reflect climate conditions in the Basin. For this correction, a monthly factor was calculated for each month in the historical simulation period as the ratio of BCM ET_0 to CIMIS ET_0. **Figure 3-17** presents the historical average monthly precipitation and CIMIS station ET_0 across the SPV GSP Model domain. In general, peak precipitation throughout the model domain occurs in the December through February time frame, with peak rainfall occurring in the month of February at just under 4 inches (**Figure 3-17**). On average, there is approximately less than one inch of rain from April through September, during which time the ET_0 is near annual maximum values. The seasonal timing of greater ET_0 with lower precipitation highlights the reason that water deliveries are needed as an additional source of water to irrigate agricultural lands throughout the summer and fall months.

Consumptive Use

Monthly estimates of consumptive use of water were developed for each land use polygon, as shown in **Figures 3-6 and 3-7**, based on a dataset called "CalETa", which contains actual crop ET values on a 30-meter by 30-meter grid estimated through processing of Landsat satellite data and ground-based climate data, and performing a land surface energy budget (Formation, 2020). The CalETa values are equivalent to consumptive use values and are related to the crop coefficient (Kc) and ET_0, as shown in **Equation 3-1**, as follows:

$$\text{Consumptive Use} = \text{CalETa} = Kc \times ET_0 \quad (3\text{-}1)$$

The CalETa (and therefore, consumptive use) values were associated with a unique identification number for each land use polygon throughout the model domain (**Figures 3-6 and 3-7**). These data, along with areal fractions of each unique land use per cell, serve as input to the SPV GSP Model to define the consumptive use of water for each WBS. CalETa data for this project are available as monthly raster datasets for calendar years 2005, 2010 through 2017, and 2019. To fill the gap years associated with the historical simulation period, site-specific Kc values were calculated, for each land use polygon shown in **Figures 3-6 and 3-7**, based on the bounding years of available CalETa data and rearrangement of **Equation 3-1** using the CIMIS station ET_0. For 2006 through 2009, monthly Kc values were computed based on the average consumptive use and CIMIS station ET_0 for 2005 and 2010. For 2018, Kc values were computed based on the average consumptive use and CIMIS station ET_0 for 2017 and 2019.

Stream Inflows from Contributing Catchments

As shown in **Figure 3-18**, there are significant contributing catchments upstream from and outside of the SPV GSP Model domain. Thus, surface water inflows from these contributing catchments need to be accounted for as a boundary condition in the model. Three USGS gage locations are available within the model area and provide measured streamflow rates for use in the SPV GSP Model. There are three other contributing catchments in the model area that do not have associated stream gages. Stream inflows from ungaged watersheds are estimated for the historical period by aggregating the BCM runoff in the contributing watersheds on a monthly scale upgradient from the inflow points to the model domain. To account for potential biases in the BCM estimates of runoff, a bias-correction process was implemented to refine the estimates of stream inflows for ungaged watersheds.

The bias-correction process described herein includes the development of monthly and annual adjustment factors to modify the simulated response of the contributing catchments to be more consistent with historical measured monthly and annual streamflows, where available. These adjustment factors are then used to develop historical stream inflows from ungaged catchments. Where historical records of stream inflows are available, these data are used directly as stream inflows in the historical SPV GSP Model simulation. The following subsections describe the bias-correction process in more detail.

Monthly and Annual Adjustment Factor Development

The implemented bias-correction process requires measured streamflow data and BCM runoff aggregated across the contributing catchment area corresponding to the USGS stream gage location. An approach was implemented to develop monthly and annual WYT adjustment factors for the gaged Santa Ysabel Creek catchment (green), Guejito Creek catchment (orange), and the Santa Maria Creek catchment (purple) as shown in **Figure 3-18**. These catchments were selected because of the existence of the associated stream gages and the measured streamflow data available for these locations. The WYT includes designating each WY as wet, above normal, normal, dry, or critical, as described in Section 3.5.1.

The first step in the bias-correction process is to apply a monthly average adjustment factor for each month in the historical simulation period (i.e., WYs 2005 through 2019). Applying monthly adjustments to the BCM runoff estimates results in better alignment of the modeled timing and magnitude of streamflows with the measured streamflows. Monthly average adjustment factors are developed by calculating the monthly average values of measured streamflow and the BCM runoff. A ratio is then calculated for each month as the measured monthly average streamflow divided by the BCM monthly average runoff. This ratio is then multiplied against the original BCM runoff for every month in the historical simulation period, resulting in a monthly adjusted BCM runoff dataset. **Table 3-6** lists the monthly adjustment factors.

Table 3-6. Monthly BCM Adjustment Factors

Month	Santa Ysabel Creek Monthly Adjustment Factor	Guejito Creek Monthly Adjustment Factor	Santa Maria Creek Monthly Adjustment Factor
Oct	0.82	0.82	0.44
Nov	0.50	0.50	0.29
Dec	0.27	0.27	0.32
Jan	0.20	0.20	0.57
Feb	0.33	0.33	0.52
Mar	0.45	0.45	0.57

Month	Santa Ysabel Creek Monthly Adjustment Factor	Guejito Creek Monthly Adjustment Factor	Santa Maria Creek Monthly Adjustment Factor
Apr	2.41	2.41	1.85
May	5.00	5.00	5.00
Jun	5.00	5.00	1.00
Jul	5.00	5.00	5.00
Aug	5.00	5.00	5.00
Sep	5.00	5.00	5.00

The second step in the bias-correction process is to calculate WYT-specific annual averages of measured streamflow and BCM monthly adjusted runoff for the historical simulation period. An adjustment factor is then calculated for each WYT based on the ratio of measured streamflow to BCM monthly adjusted runoff. WYT annual adjustment factors are then applied to the corresponding WYTs of the BCM monthly-adjusted runoff to adjust the overall annual volume. **Table 3-7** lists the annual adjustment factors by WYT.

Figures 3-19 through 3-21 present various summary plots that illustrates results from the two-step bias-correction approach for Santa Ysabel Creek, Guejito Creek, and Santa Maria Creek. The two-step approach seeks to strike a balance between matching the measured monthly timing and annual volume of streamflow. Although bias-correction methods never result in perfect matches on a monthly and annual basis, there is much improved consistency between bias-corrected and measured total cumulative streamflows, which is an important aspect of long-term water supply planning.

Table 3-7. Annual BCM Adjustment Factors

Water Year Type	Santa Ysabel Creek Annual Adjustment Factor	Guejito Creek Annual Adjustment Factor	Santa Maria Creek Annual Adjustment Factor
Wet	0.56	0.56	0.32
Above Normal	1.39	1.39	0.65
Normal	0.89	0.89	0.37
Dry	0.41	0.41	0.45
Critical	1.37	1.37	1.52

Application of Adjustment Factors to Ungaged Catchments

To develop stream inflows for ungaged catchments, the monthly and WY adjustment factors, developed for gaged catchments, are applied to the original BCM runoff from ungaged catchments. For the SPV GSP Model, the Santa Ysabel Creek adjustment factors are applied to the catchment contributing to the Santa Ysabel inflow location downstream from the USGS stream gage (see **Figure 3-18**), Guejito Creek adjustment factors are applied to the Cloverdale Creek inflow location, and Santa Maria adjustment factors are applied to the Sycamore Creek inflow location. **Figures 3-22 through 3-24** present the final-adjusted BCM runoff after applying the monthly and annual-adjustment factors to the ungaged catchments. Through application of adjustment factors the streamflow characteristics from the ungaged watersheds are assumed to be similar to the neighboring watershed. However, the overall magnitudes of stream inflows are scaled based on the ungaged catchment area.

Subsurface Inflows from Contributing Catchments

Along with surface inflows from contributing catchments, a boundary condition was incorporated in the SPV GSP Model to account for potential subsurface inflows from each of the contributing catchments upgradient from the SPV GSP Model domain. The BCM-derived subsurface inflow estimates were processed through time for each contributing catchment to get monthly estimates of potential subsurface inflow across the northern, eastern, and southern SPV GSP Model boundaries (see **Figure 3-16**). The catchment recharge estimates were incorporated in the Well package as a specified flux in the northern, eastern, and southern boundary cells in Model Layers 3 and 4 (i.e., deeper bedrock layers). **Figure 3-25** presents the groundwater recharge in the contributing catchments, as computed by the BCM. These recharge estimates provide an indication of the potential range of subsurface inflows for the SPV GSP Model domain. In reality, the magnitudes and locations of subsurface inflows from contributing catchments are highly uncertain due to the incomplete information regarding recharge-runoff characteristics in the contributing catchments and the nature and extent of weathering and fracturing of the bedrock near the SPV GSP Model domain boundaries. As such, values for subsurface inflows at these boundary cells were initially set to zero to assess whether subsurface inflows were needed to adequately calibrate the model. Variations on the subsurface inflow estimates were explored and modified during the calibration process (see Section 4.2).

Groundwater Pumping

Because most of the wells in the SPV are either not metered or have not been metered for very long, the magnitude and distribution of pumpage was calculated using the FMP package based on a OneWater code variable called the Total Farm Delivery Requirement (TFDR). Within the

SPV GSP Model, the FMP assumes a hierarchy of shallow groundwater uptake as the first source of supply, precipitation as the secondary source of supply, and finally a user-specified source of water (i.e., deliveries) for each WBS. The TFDR is calculated as the total consumptive use minus the available shallow groundwater uptake and precipitation for that WBS during a given month (i.e., stress period). In the case where a WBS is dependent on groundwater pumping, the final source of water is provided through well infrastructure, as previously discussed in Section 3.3.3. The FMP distributes the WBS TFDR evenly across each of the pumping wells assigned to that WBS. Individual well pumping rates are then passed to the multi-node well 2 (MNW2) package to simulate the pumping of groundwater. Well locations and available construction information, were incorporated into the MNW2 package to define the location and vertical extent of well screens for each pumping well. **Figure 3-8** depicts the locations of the modeled pumping wells.

Groundwater pumping associated with domestic water use was implemented separately using the Well package. Locations of residences and their associated groundwater pumping infrastructure were adapted from information provided by the City, County, and stakeholders during the model development process. Domestic water use was assumed to be 55 gallons per capita per day (gpcd) (Bennett, 2020) with an assumed 2.5 people per household, based on census data. **Figure 3-26** depicts the locations of domestic wells simulated in the SPV GSP Model.

Imported Water

Figure 3-27 illustrates the subareas within the SPV GSP Model domain that receive imported water deliveries from the City of Escondido, City of Poway, Ramona, and Rincon Del Diablo Municipal Water District. There is a small area of land in the Basin that receives imported water from the City of Escondido in the Basin "finger", west of Cloverdale Creek between Old San Pasqual Road and San Pasqual Valley Road (Highway 78). Additionally, as indicated in Figure 3-8, Parcel #8 in the southwestern portion of the Basin is designated to receive water from a groundwater well located outside of the SPV GSP Model domain. Water deliveries associated with water sources outside of the model domain are modeled as imported water. Imported water is incorporated in the model as a non-routed delivery (NRD) in the FMP package, which essentially specifies a monthly volume of water that is available to meet consumptive use of water in each WBS. These NRDs are the third and final source of water (after shallow groundwater uptake and precipitation) for each WBS that receives imported water to meet the TFDR. The imported water volumes were determined through an iterative process, whereby an initial model simulation was run to compute monthly TFDR values to be satisfied by imported water. This TFDR was then provided in the next model iteration as a NRD for each of the imported water areas.

Recycled Water/Wastewater Reuse

Within the SPV GSP Model domain there are a few locations that utilize recycled water for irrigation purposes. **Figure 3-28** illustrates the regions where recycled water is assumed to be utilized. The Safari Park utilizes water from multiple sources including imported water from Escondido, on-site recycled water, and groundwater pumping from the Basin. Groundwater pumping associated with the Safari Park is incorporated in the SPV GSP Model based on the previous discussion of groundwater pumping. Limited information was available at the time of development of the SPV GSP Model to define the magnitude and timing of imported water and recycled water use at the Safari Park. Any shortfall in the consumptive use estimate was assumed to be met by imported water or recycled water. Therefore these two sources of water were combined in the implementation of the NRD volume for the Safari Park WBS.

According to the SNMP (City of San Diego, 2014), treated wastewater effluent from the San Pasqual Academy is conveyed to a nearby aeration pond that is then utilized to irrigate a 1-acre grass strip adjacent to the pond. During the development of the SPV GSP Model, little information was known to characterize the volume and timing of recycled water use along the 1-acre grass strip. With the configuration of consumptive use from the CalETa dataset and the well-to-parcel relationships obtained from stakeholders, the 1-acre grass strip was incorporated into a WBS associated with the San Pasqual Academy and its pumping wells. Thus, any consumptive use, and therefore groundwater pumping, associated with the 1-acre grass strip is accounted for without directly computing the recycled water volume.

Groundwater Recharge from Septic Systems

Groundwater recharge from septic systems within the Basin is incorporated in the SPV GSP Model using the "Direct Recharge" feature of the FMP package. Through this feature, the recharge flux associated representing the volume of water entering the groundwater system through septic systems was specified directly on a cell-by-cell basis through time. Housing locations and corresponding septic systems were identified through the assessment of rural domestic groundwater pumping (see **Figure 3-26**). As previously discussed, domestic (i.e., indoor) water use was assumed to be 55 gpcd (Bennett, 2020) with an assumed 2.5 people per household, based on census data. Without specific knowledge of septic system locations, septic systems were assumed to be within 100 feet of the residence from which the water was used. Because the SPV GSP Model grid has 100-foot cell centers, the septic recharge flux associated with a specific residence was specified in the model grid cell representing the residence. The magnitude of the groundwater recharge flux for septic systems was set equal to the assumed rural domestic (i.e., indoor) pumping rates.

3.7.2 Head-dependent Fluxes

The following section describes boundary conditions in the SPV GSP Model where the flux used to simulate various hydrologic processes that are dependent on groundwater elevations (i.e., heads) in the aquifer.

Groundwater Recharge from Precipitation

Groundwater recharge from precipitation is computed by the FMP package, whereby the water that is not consumed through consumptive use is available for either recharge or overland runoff. Recharge of precipitation is rejected and routed through the drain return (DRT) package to the nearest SFR segment, if the modeled water table is at land surface during a given month of the simulation. This boundary condition is applied areally across the top of the entire model domain (see **Figure 3-16**).

Groundwater Recharge from Applied Water

Groundwater recharge from applied water is derived through the FMP package, based on the on-farm efficiency term. The inefficient losses, like precipitation, can either recharge the aquifer or become overland runoff, which is routed through the DRT package to the nearest SFR segment. This boundary condition only applies to irrigated crops.

Shallow Groundwater Uptake

Shallow groundwater uptake is simulated through the FMP package, whereby crops can utilize shallow groundwater as a source of supply to meet consumptive use water demands. Access to shallow groundwater is determined based on the crop rooting depths, capillary fringe height, and the elevation of the water table during a given month in the simulation. This boundary condition is applied areally across the top of the entire model domain (see **Figure 3-16**).

Groundwater/Surface-water Interaction

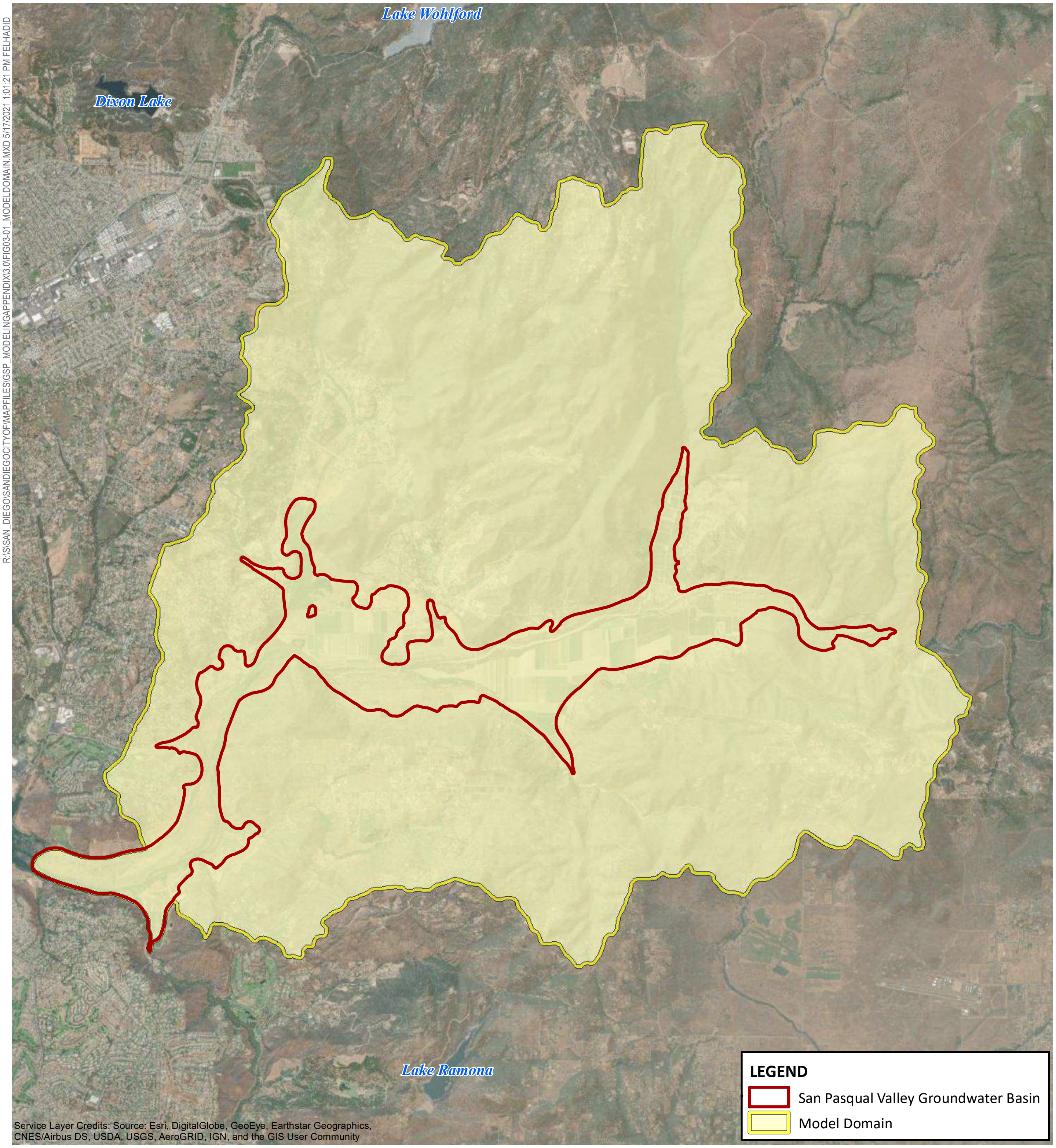
Groundwater and surface water interaction at streams is simulated with the SFR package (see **Figure 3-16**). The SFR package accounts for stream segments that can gain water from and lose water to the underlying aquifer, based on the hydraulic gradient between the modeled water table and modeled stage (i.e., surface water elevation) in the SFR reach during a given month in the simulation. The monthly gaining or losing flux is computed based on the hydraulic gradient, streambed hydraulic conductivity, channel geometry, and thickness of the stream bed. Section 3.3.2 discussed the initial stream channel characteristics.

Subsurface Interaction with Hodges Reservoir

Subsurface interaction with Hodges Reservoir is configured through the general head boundary (GHB) package in the SPV GSP Model (see **Figure 3-16**). The GHB package requires the user to assign a monthly head value, a distance term to the location of that head value, and the effective hydraulic conductivity of the porous medium between the boundary and the location of the head value. The GHB cells are located along the lateral boundary cells where the San Dieguito River exits the model domain. The monthly stage of Hodges Reservoir is used as the head term. A distance of 2,900 feet is used as the distance term between the GHB cells at the model boundary and Hodges Reservoir. A hydraulic conductivity ranging from 0.01 ft/d (3.5×10^{-6} cm/s) in the bedrock to 4 ft/d (1.4×10^{-3} cm/s) in the residuum to 40 ft/d (1.4×10^{-2} cm/s) in the alluvium is assigned in the GHB cells to represent assumed permeability characteristics of the porous medium between the GHB cells and Hodges Reservoir.

3.7.3 No-flow Boundaries

The lateral model boundary cells depicted in **Figure 3-16** that are not assigned other boundary conditions and the bottom of the deepest model layer (i.e., Model Layer 4) are assigned the no-flow boundary condition. Inherent with the assignment of no-flow boundaries is the assumption that these boundaries coincide with locations of groundwater divides. These lateral and deep model boundaries were purposely located far enough from cells representing the Basin to avoid adverse boundary effects that could result from conceptual errors along the margin of the model domain.



NOTES:

Model cells have uniform dimensions of 100 by 100 feet.

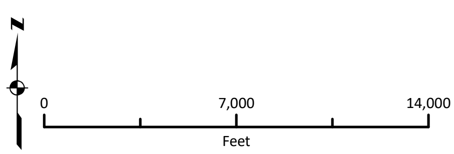


FIGURE 3-1

Model Domain: Plan View

Numerical Flow Model Documentation
San Pasqual Valley Groundwater Basin
Groundwater Sustainability Plan
San Pasqual Valley, California

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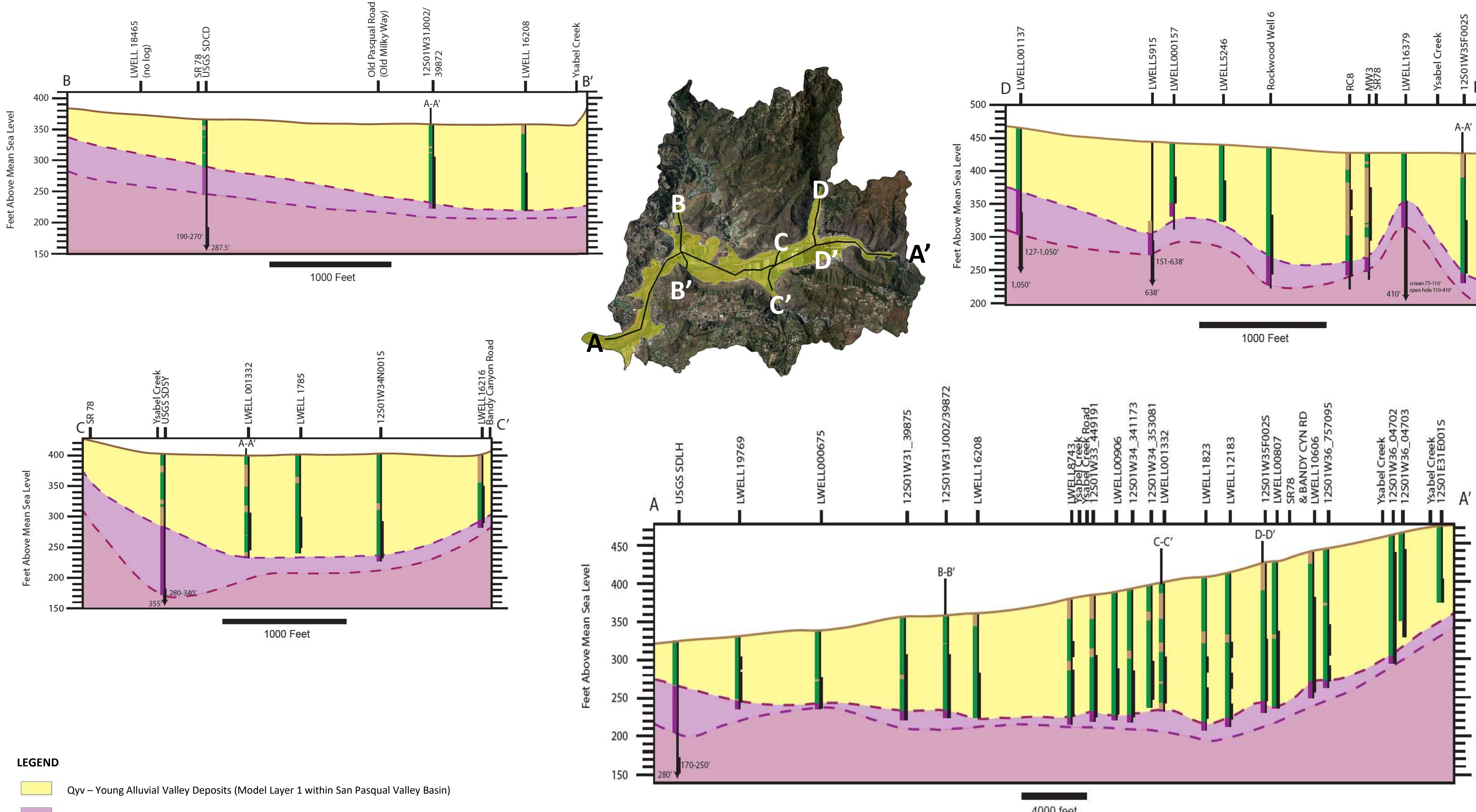

LEGEND

Qyv – Young Alluvial Valley Deposits (Model Layer 1 within San Pasqual Valley Basin)

Weathered Bedrock (granite/granodiorite) (Model Layer 2 within San Pasqual Valley Basin)

Kg – Woodson Mountain Granodiorite (Model Layers 3 and 4 within San Pasqual Valley Basin)

Source for Cross Sections: Snyder Geologic

FIGURE 3-2
Model Domain: Profile Views
Numerical Flow Model Documentation
San Pasqual Valley Groundwater Basin
Groundwater Sustainability Plan
San Pasqual Valley, California

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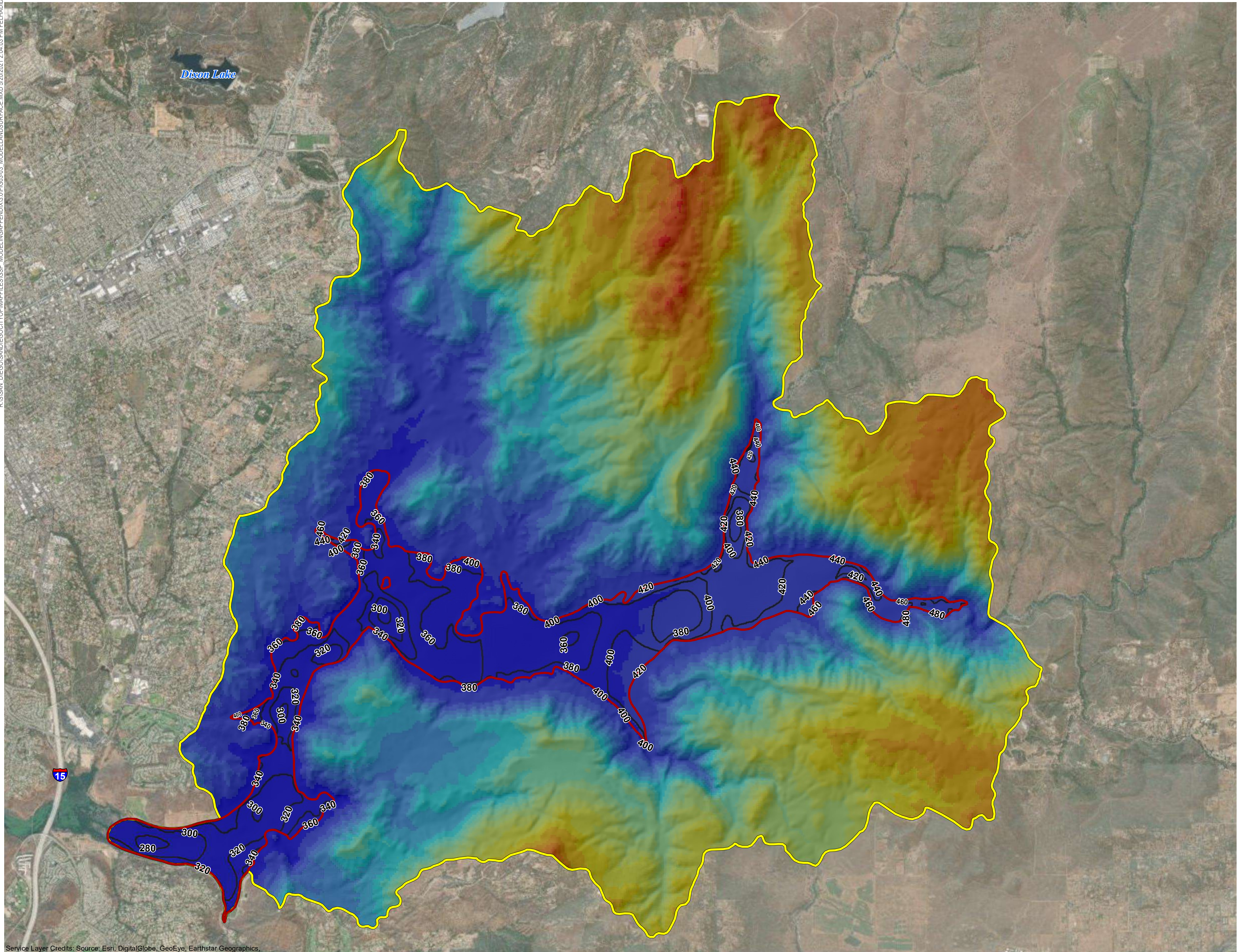

LEGEND

- Land Surface Elevation 20-foot Contour (feet NAVD88)
- Model Domain Boundary
- San Pasqual Valley Groundwater Basin

Modeled Land Surface Elevation (feet NAVD88)

- 2,200 to 2,260
- 2,100 to 2,200
- 2,000 to 2,100
- 1,900 to 2,000
- 1,800 to 1,900
- 1,700 to 1,800
- 1,600 to 1,700
- 1,500 to 1,600
- 1,400 to 1,500
- 1,300 to 1,400
- 1,200 to 1,300
- 1,100 to 1,200
- 1,000 to 1,100
- 900 to 1,000
- 800 to 900
- 700 to 800
- 600 to 700
- 500 to 600
- 400 to 500
- 315 to 400

NOTES:

Elevations based on 10-meter digital elevation model data.

NAVD88 = North American Vertical Datum of 1988.

N

0 5,000 10,000
Feet

The City of SAN DIEGO

FIGURE 3-3
Modeled Land Surface Elevations
Numerical Flow Model Documentation
San Pasqual Valley Groundwater Basin
Groundwater Sustainability Plan
San Pasqual Valley, California

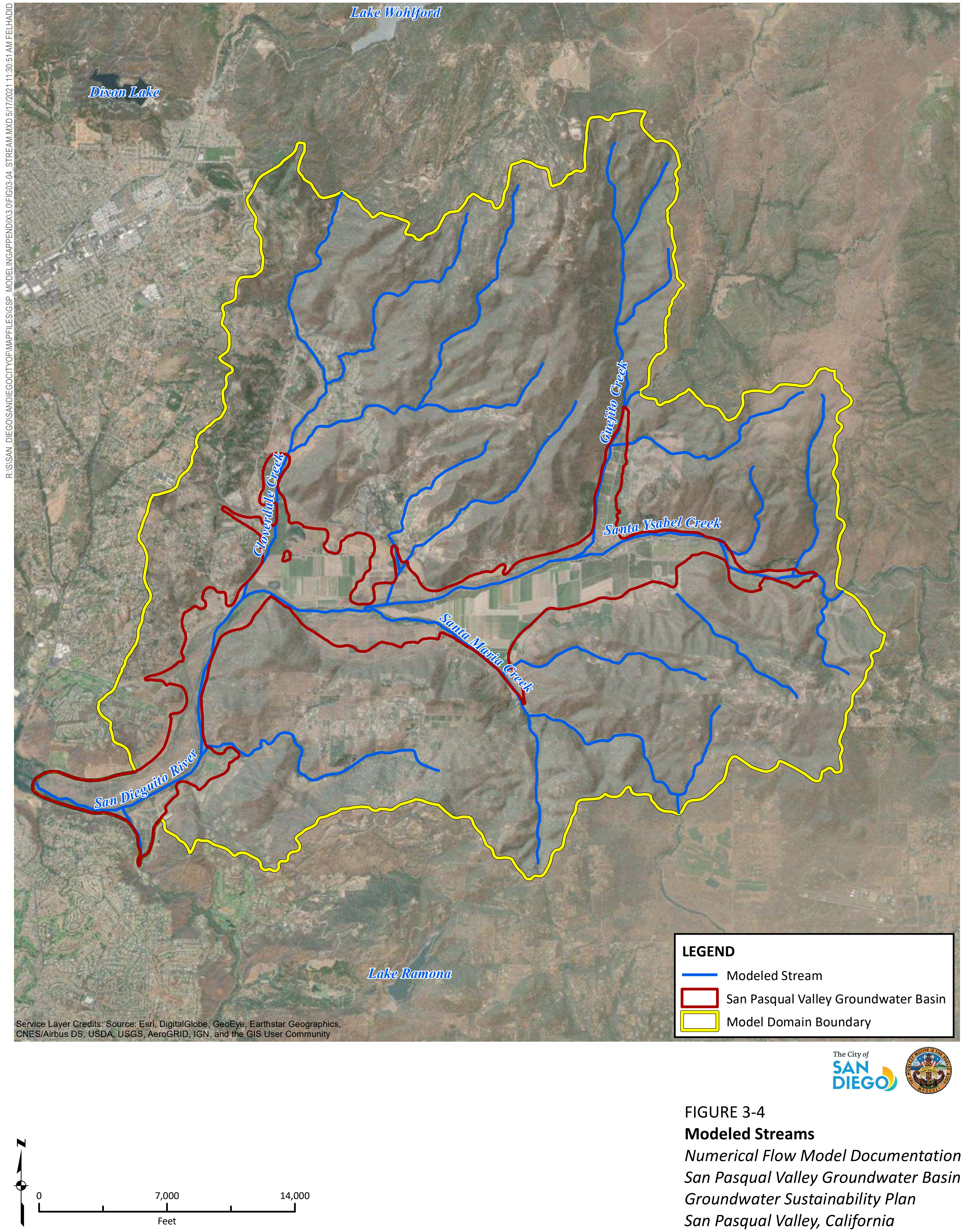

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FIGURE 3-4

Modeled Streams

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San Pasqual Valley Groundwater Basin
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San Pasqual Valley, California

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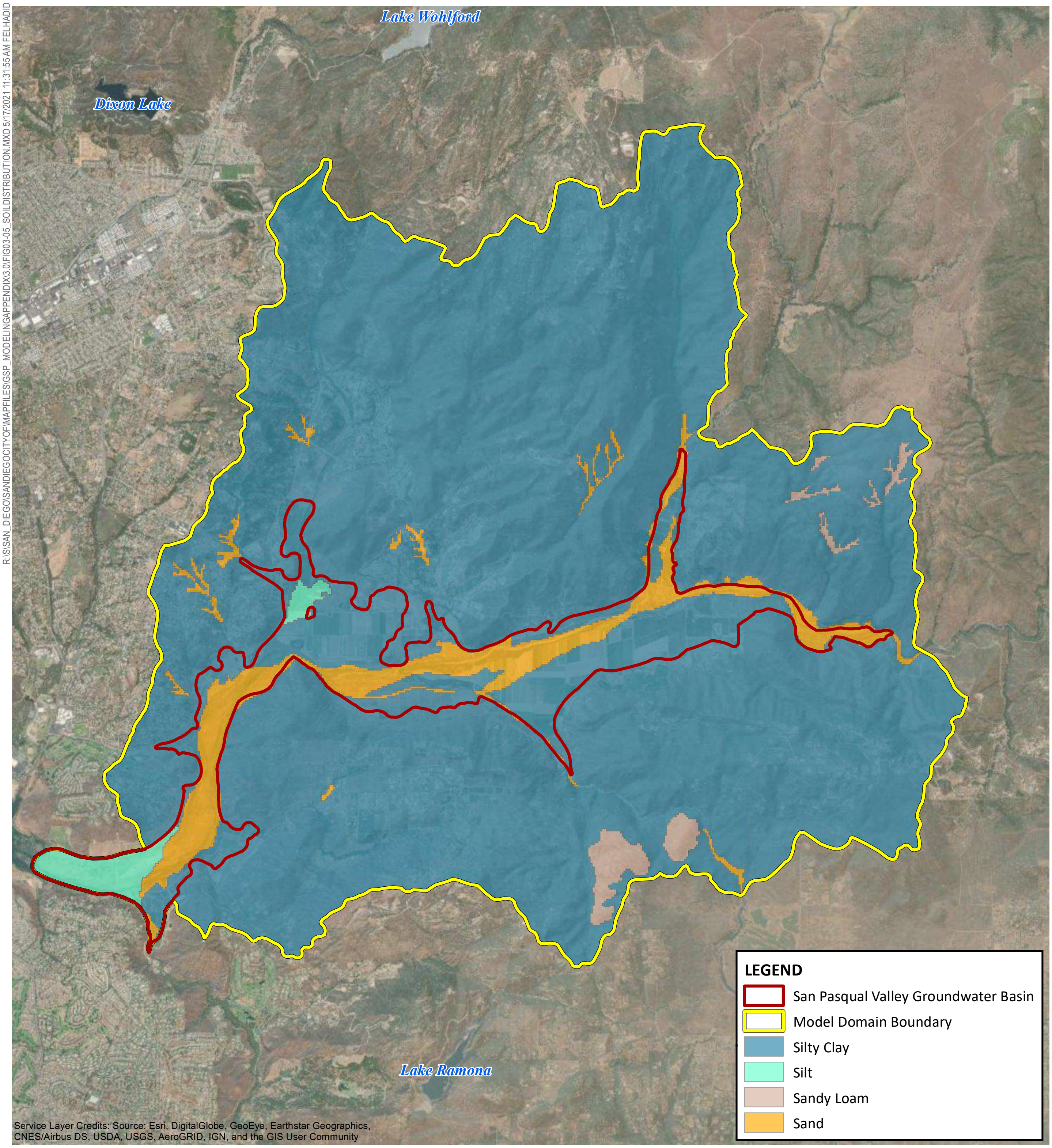

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FIGURE 3-5
Modeled Distribution of Soil Types
Numerical Flow Model Documentation
San Pasqual Valley Groundwater Basin
Groundwater Sustainability Plan
San Pasqual Valley, California

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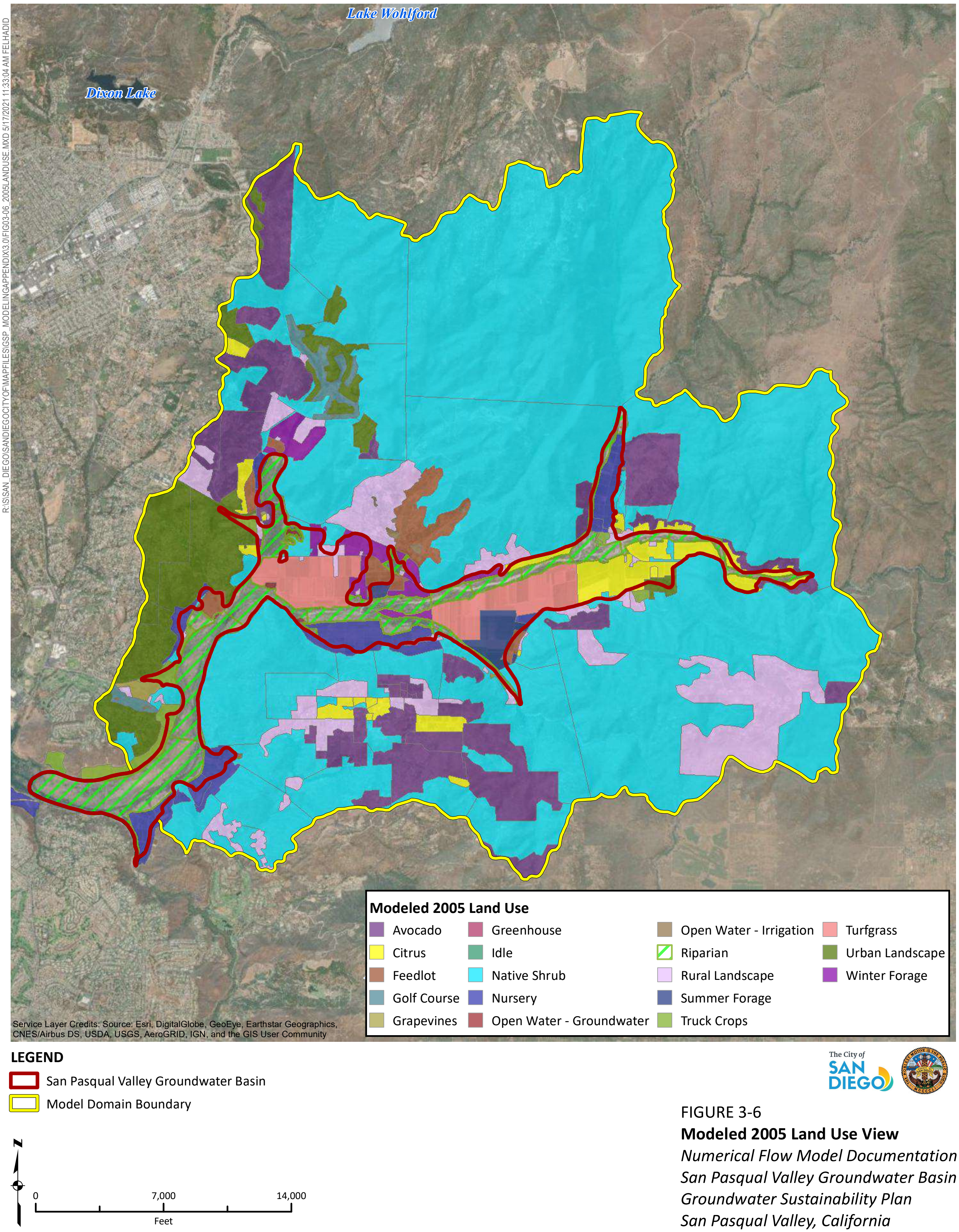

FIGURE 3-6

Modeled 2005 Land Use View

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Groundwater Sustainability Plan
San Pasqual Valley, California

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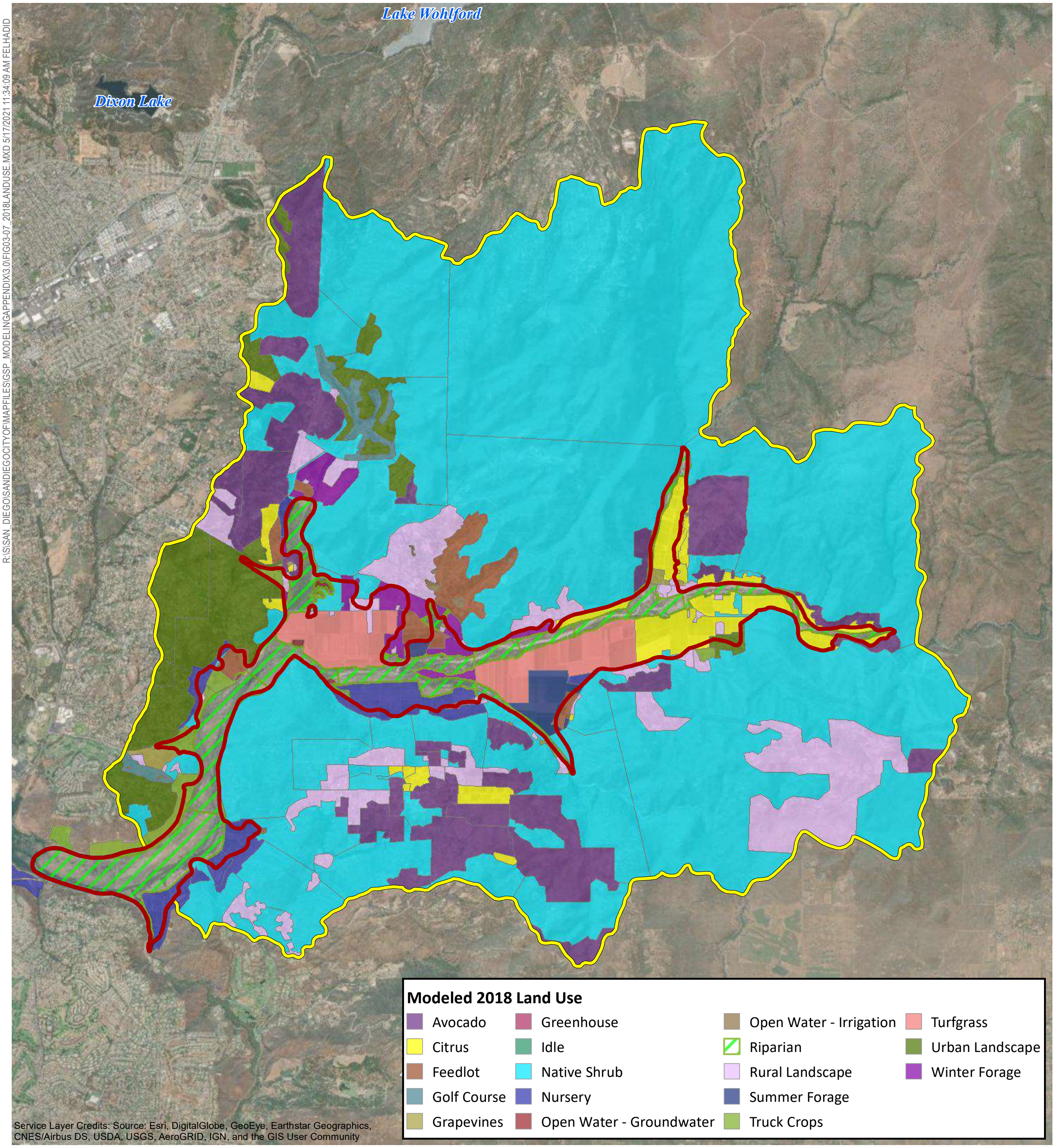

LEGEND

San Pasqual Valley Groundwater Basin

Model Domain Boundary

N

0 7,000 14,000

Feet

FIGURE 3-7

Modeled 2018 Land Use View

Numerical Flow Model Documentation
San Pasqual Valley Groundwater Basin
Groundwater Sustainability Plan
San Pasqual Valley, California

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Parcel ID	Associated Pumping Wells	Parcel ID	Associated Pumping Wells
1	SP002, SP076, SP079	20	SP052, SP053
2	Not Irrigated	21	SP083, SP089, SP090, SP098, SP121, SP125
3	SP003, SP004	22	SPA002, SPA005, SPA006, SPA010
4	Escondido Water	23	SP061
5	SP008	24	SP011, SP065
6	SP008	25	SP067, SP071
7	SP043	26	SP072, SP092, SP095, SP096, SP126
8	Imported Water	27	SP084, SP127
9	SP021, SP022, SP023	28	Not Irrigated
10	SP103	29	SPA108, SPA130, CONS1
11	SP026, SP027, SP028	30	Well 3, Well 4, Well 5, Well 6, RK-8, RK-9, RK-10, RK-11, RK-12, RK-13, RK-DOM, RK-DOM-2
12	SP029	31	Not Irrigated
13	SP003, SP004, SP012, SP013	32	SP041, SP042
14	SP009, SP031, SP032, SP033, SP034	33	SP049, SP050, SP051, SP055, 1/2 SP057, SP059, New Well #5
15	SP035	34	Well 3, Well 4, Well 5, Well 6
16	SP036, SP084, SP127	35	VW001, VW002, VW003
17	SP043	36	Not Irrigated
18	SP046, Escondido Recycled Water, Escondido Drinking Water	37	SP013
19	1/2 SP057		

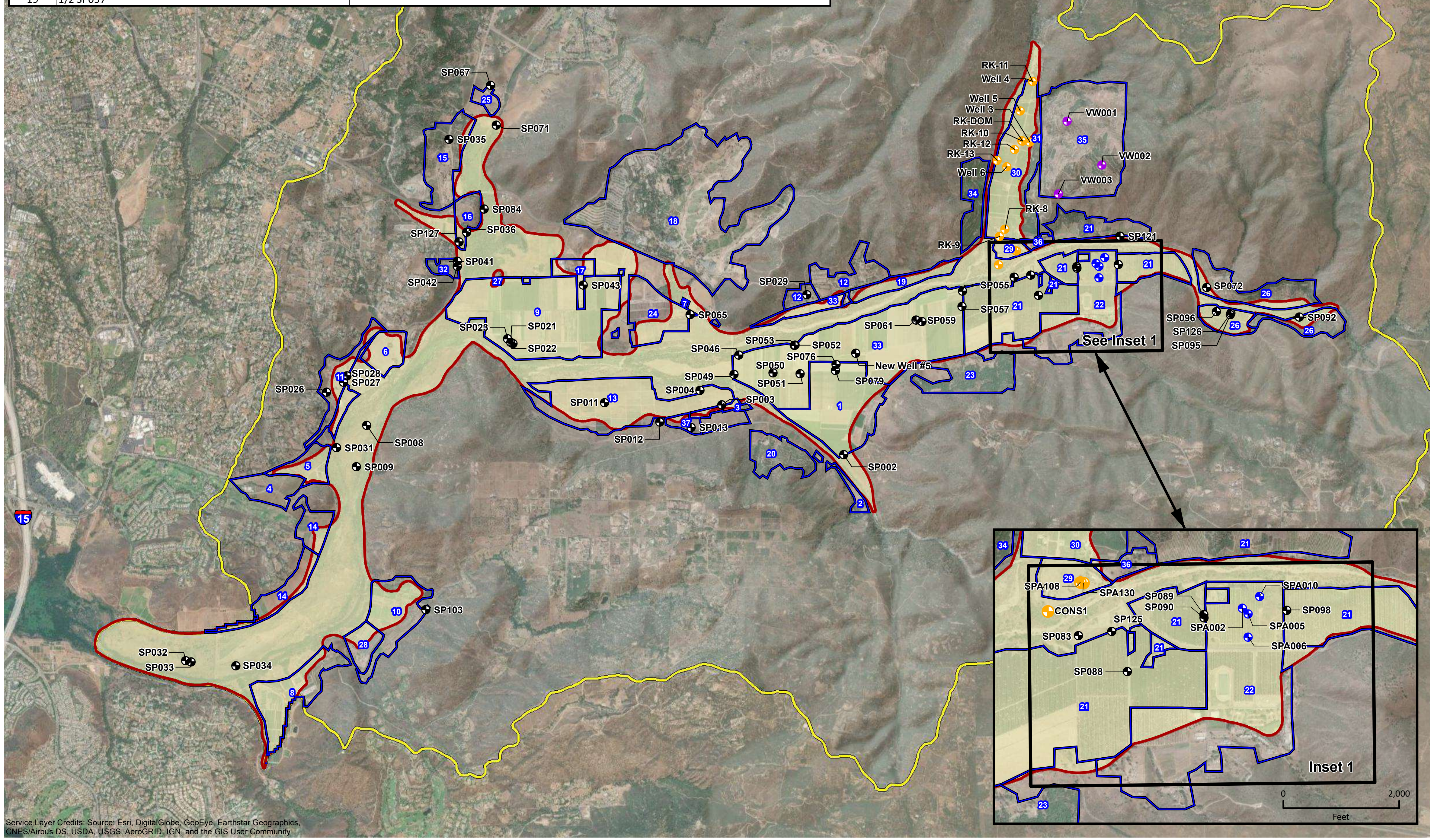

FIGURE 3-8

Modeled Pumping Well Locations

Numerical Flow Model Documentation
San Pasqual Valley Groundwater Basin
Groundwater Sustainability Plan
San Pasqual Valley, California

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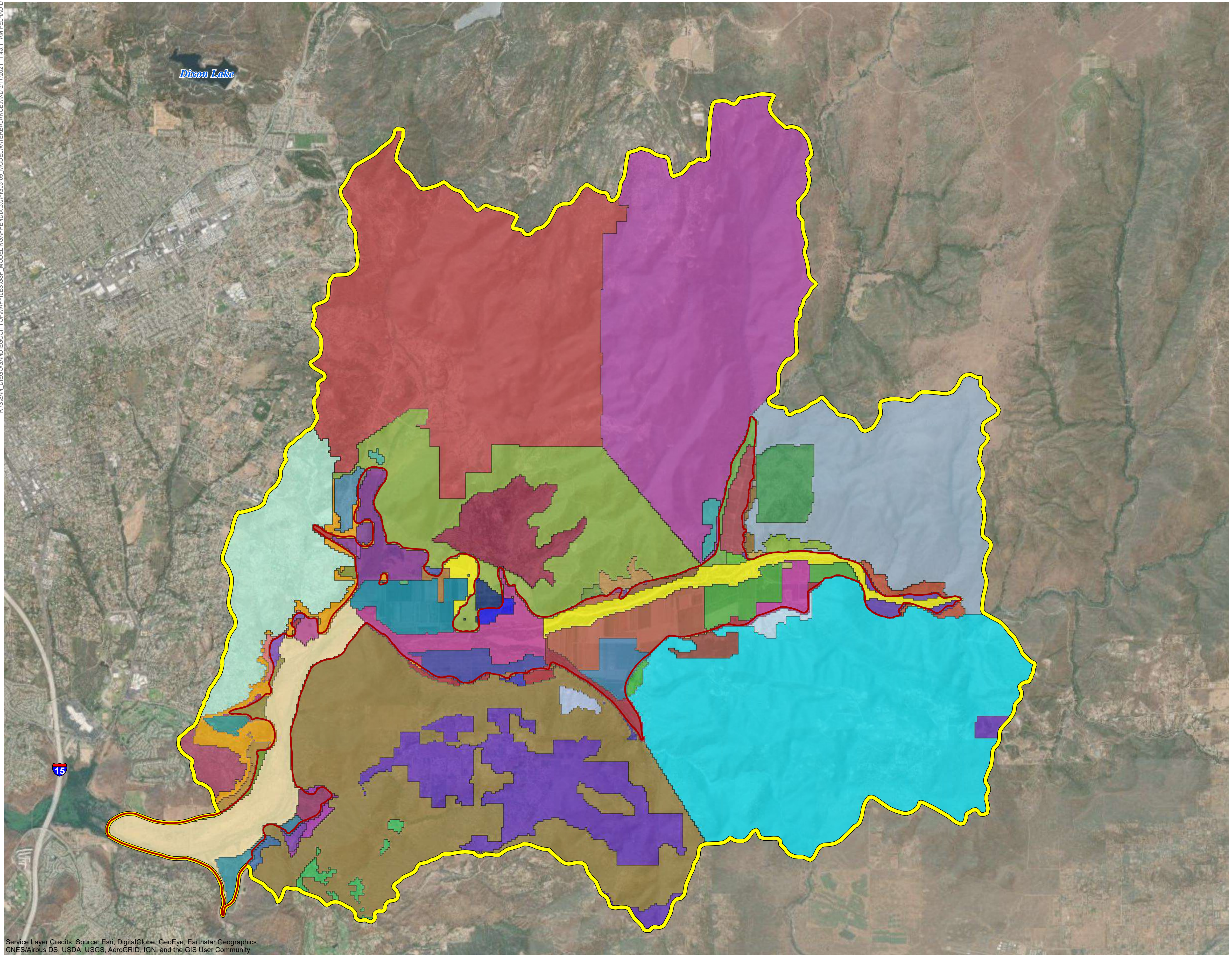

LEGEND

- San Pasqual Valley Groundwater Basin
- Model Domain Boundary

NOTE:

The intent of this figure is only to provide a general sense of the spatial distribution of water balance subareas, which are displayed as color-filled polygons. It is not intended to provide a detailed association with specific statements made in the report.

N

0 5,000 10,000
Feet

The City of SAN DIEGO

FIGURE 3-9
Modeled Water Balance Subareas
Numerical Flow Model Documentation
San Pasqual Valley Groundwater Basin
Groundwater Sustainability Plan
San Pasqual Valley, California

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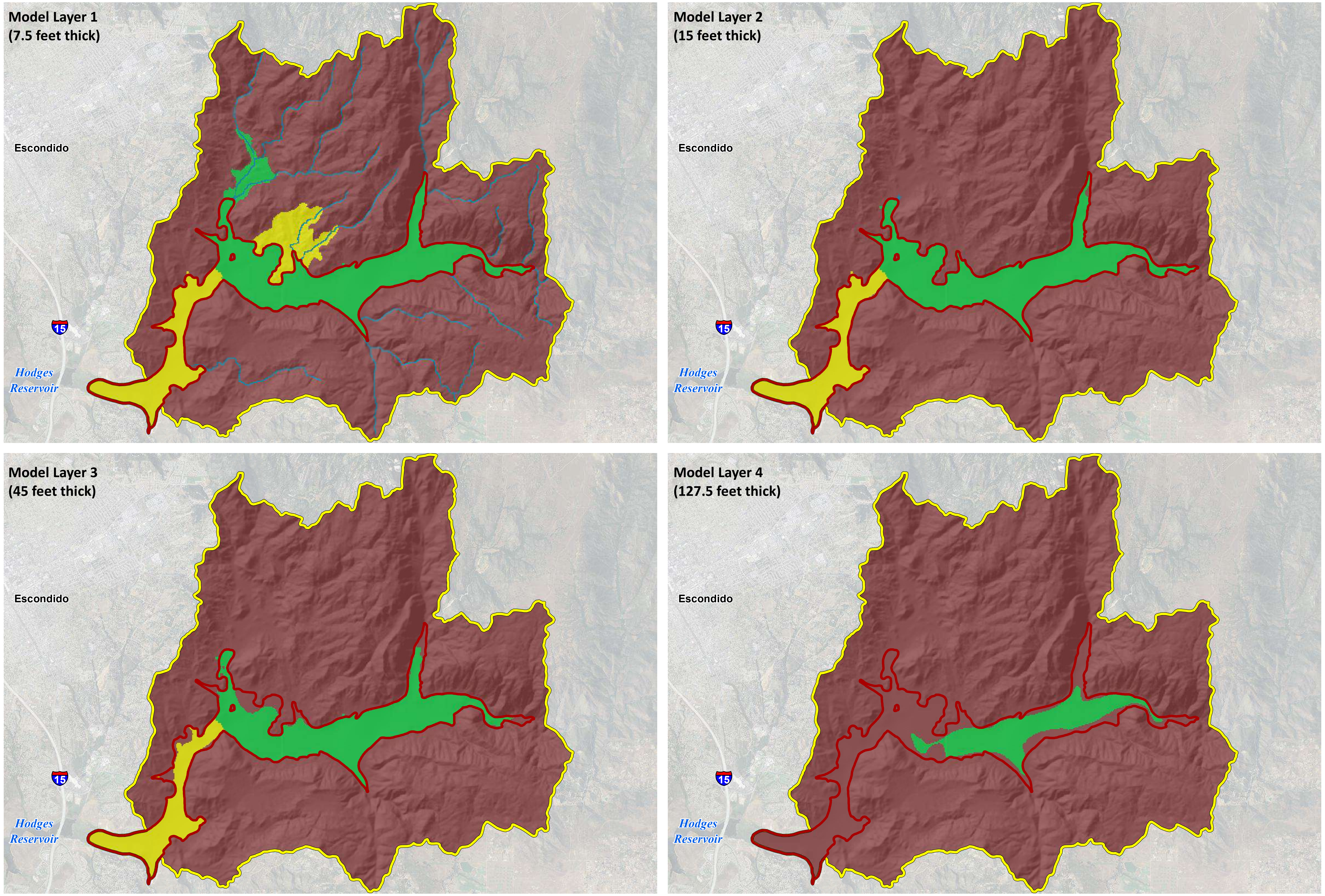

LEGEND

- San Pasqual Valley Groundwater Basin
- Model Domain Boundary

Horizontal Hydraulic Conductivity (feet/day)

- 100 to 250
- 50 to 100
- 10 to 50
- 5 to 10
- 1 to 5
- 0.07 to 1

NOTE:

The displayed distribution of horizontal hydraulic conductivity is from the San Pasqual Valley Salt and Nutrient Management Plan model (City of San Diego, 2014), which has five model layers.

Model Layer 5 has a uniform horizontal hydraulic conductivity of 0.015 feet/day and a uniform thickness of 255 feet.

0 2 4
Miles

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FIGURE 3-10
Initial Distribution of Horizontal Hydraulic Conductivity
Numerical Flow Model Documentation
San Pasqual Valley Groundwater Basin
Groundwater Sustainability Plan
San Pasqual Valley, California

Jacobs

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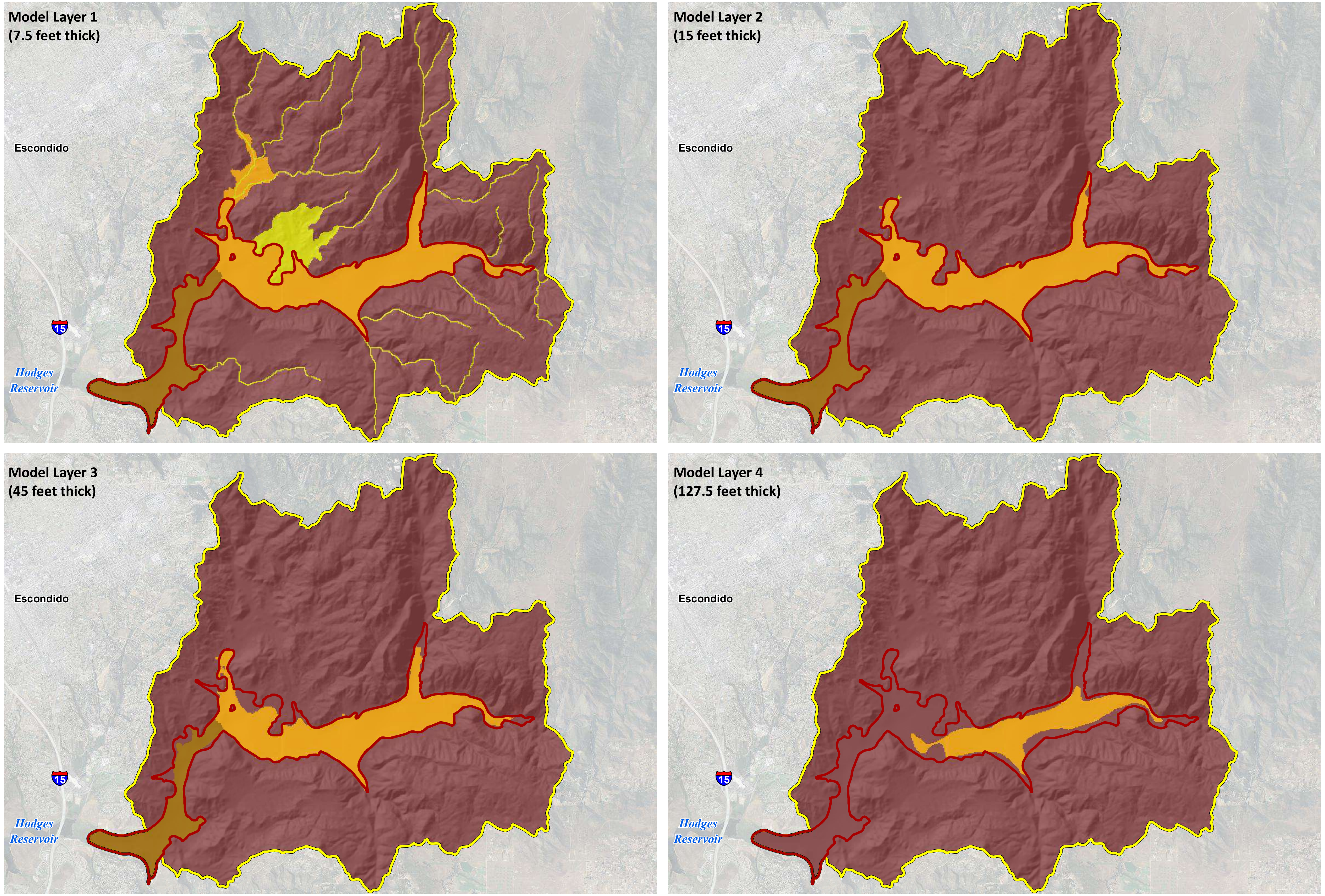

LEGEND

- San Pasqual Valley Groundwater Basin
- Model Domain Boundary

Vertical Hydraulic Conductivity (feet/day)

- 100 to 250
- 50 to 100
- 10 to 50
- 5 to 10
- 1 to 5
- 0.07 to 1

NOTE:

The displayed distribution of vertictal hydraulic conductivity is from the San Pasqual Valley Salt and Nutrient Management Plan model (City of San Diego, 2014), which has five model layers.

Model Layer 5 has a uniform vertical hydraulic conductivity of 0.015 feet/day and a uniform thickness of 255 feet.

0 2 4
Miles

The City of SAN DIEGO

FIGURE 3-11

Initial Distribution of Vertical Hydraulic Conductivity

Numerical Flow Model Documentation

San Pasqual Valley Groundwater Basin

Groundwater Sustainability Plan

San Pasqual Valley, California

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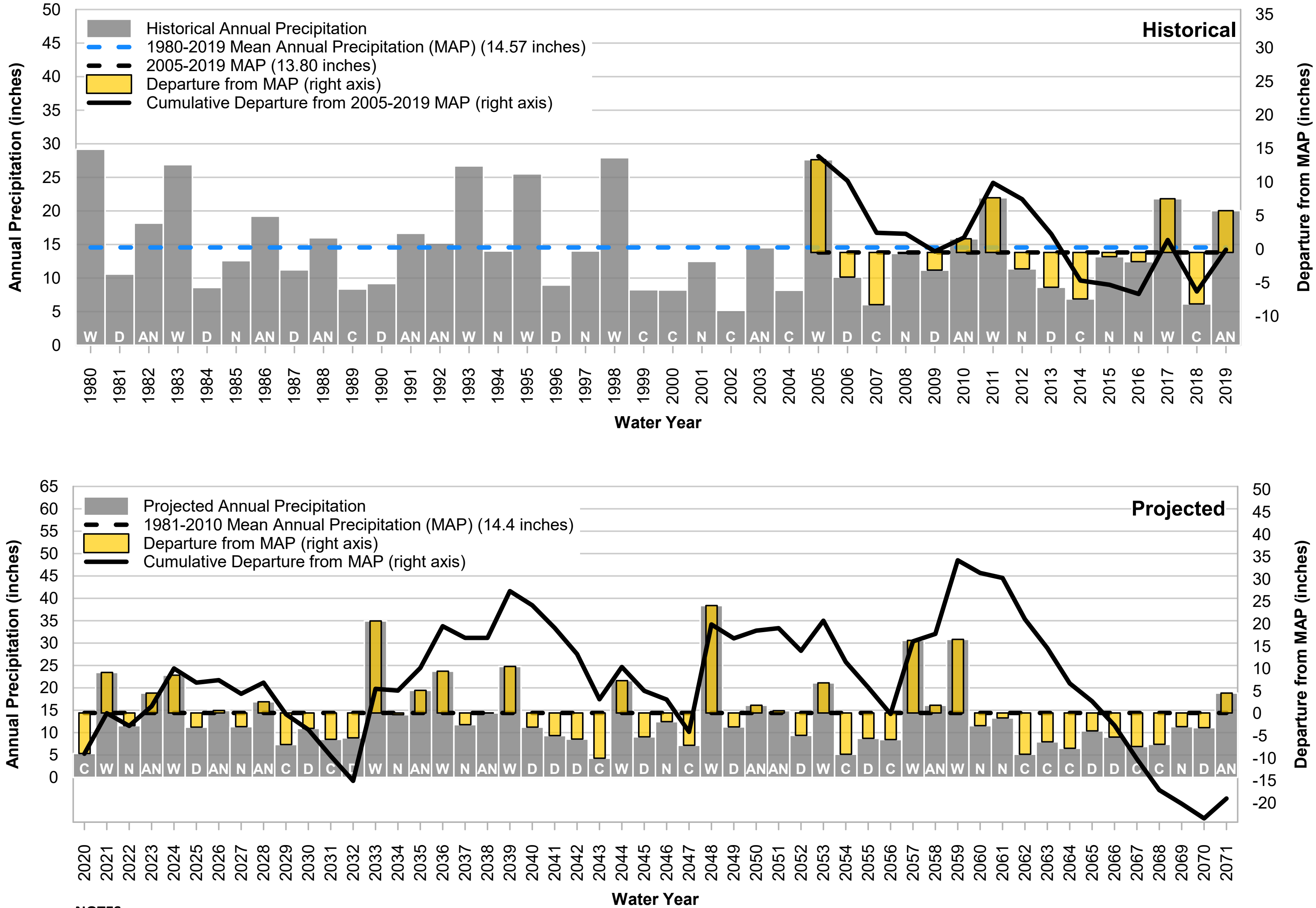

NOTES:

MAP = mean annual precipitation

Projected precipitation represents the HadGEM2-ES, RCP 8.5 global climate model.

FIGURE 3-12

Historical and Projected Annual Precipitation

Numerical Flow Model Documentation

San Pasqual Valley Groundwater Basin

Groundwater Sustainability Plan

San Pasqual Valley, California

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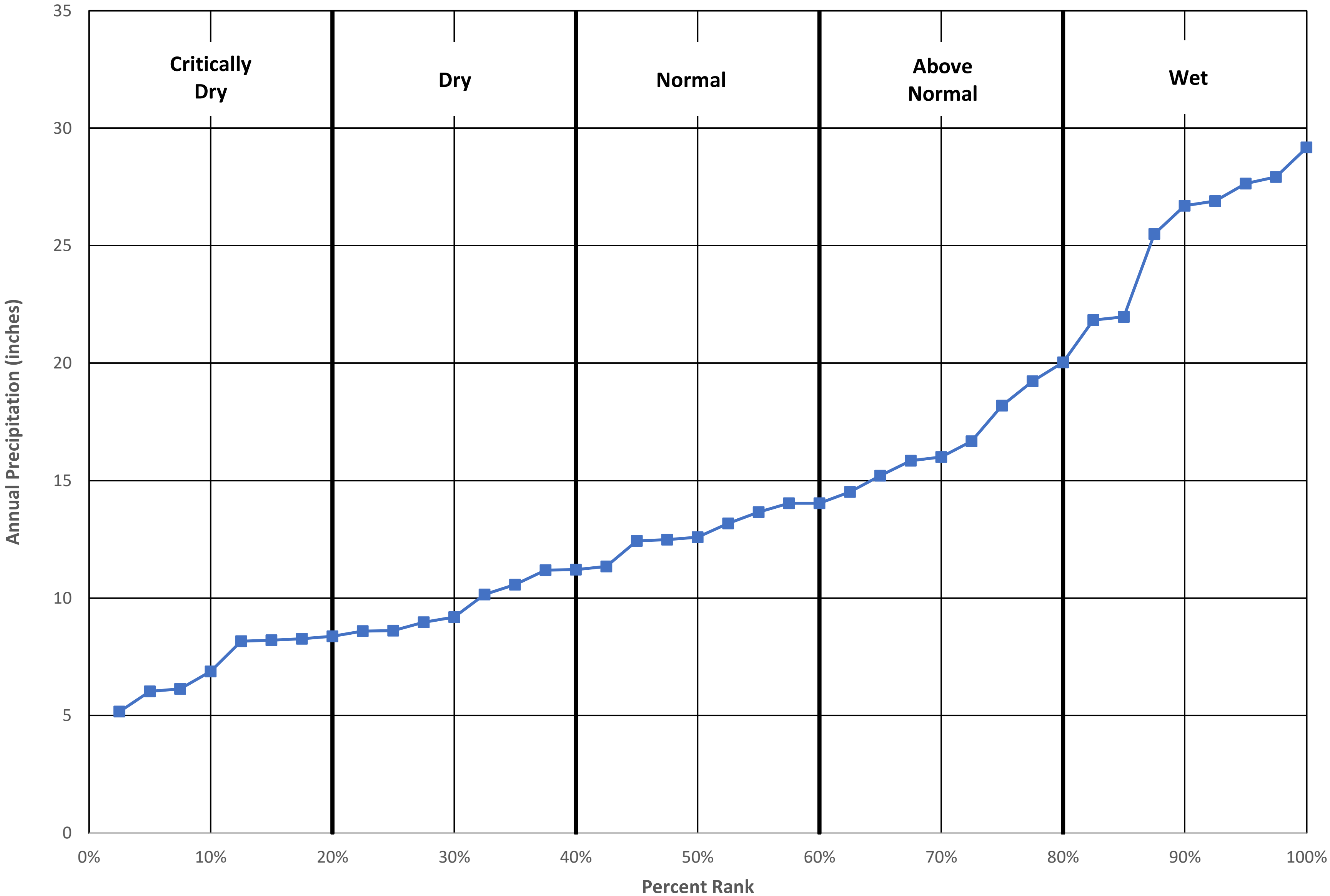

FIGURE 3-13

Quantile-based Water Year Type Ranking of Annual Precipitation

San Pasqual Valley Groundwater Basin
Groundwater Sustainability Plan
San Pasqual Valley, California

O:\SanDiegoCityof\CommonFiles\SGMA\2022_GSP\GSP\ModelingAppendix\Figures\XLSX\3.0\FIG03-13_Quantile_WYT_Dev.xlsx\FIG03-13

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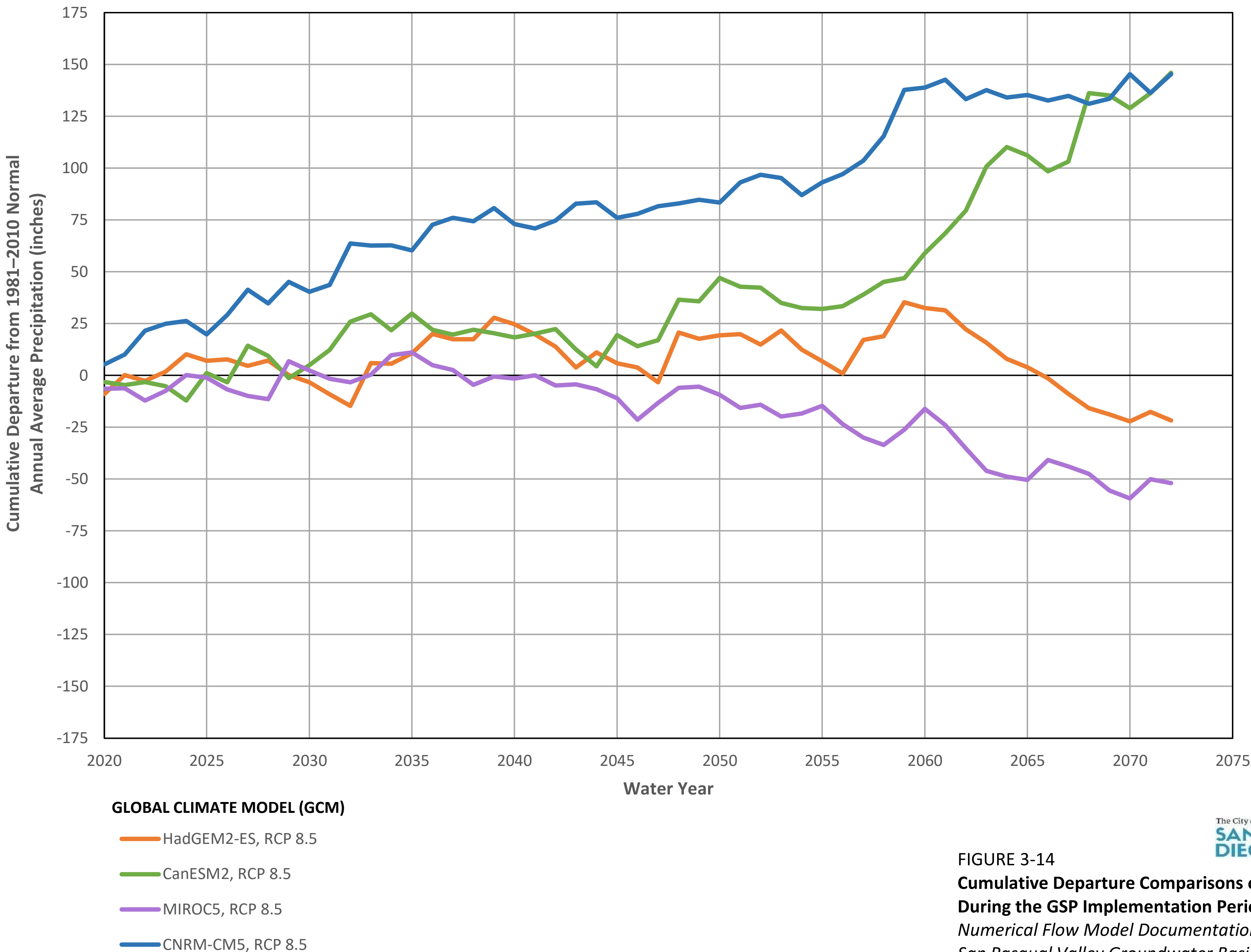

FIGURE 3-14

Cumulative Departure Comparisons of GCMs During the GSP Implementation Period

Numerical Flow Model Documentation
San Pasqual Valley Groundwater Basin
Groundwater Sustainability Plan
San Pasqual Valley, California

\\odin\proj\SanDiegoCityof\CommonFiles\SGMA\2022_GSP\GSP\ModelingAppendix\Figures\XLSX\3.0\FIG03-14_15_AnnMonthlyAvg_Proj_Precip.xlsx\FIG03-14

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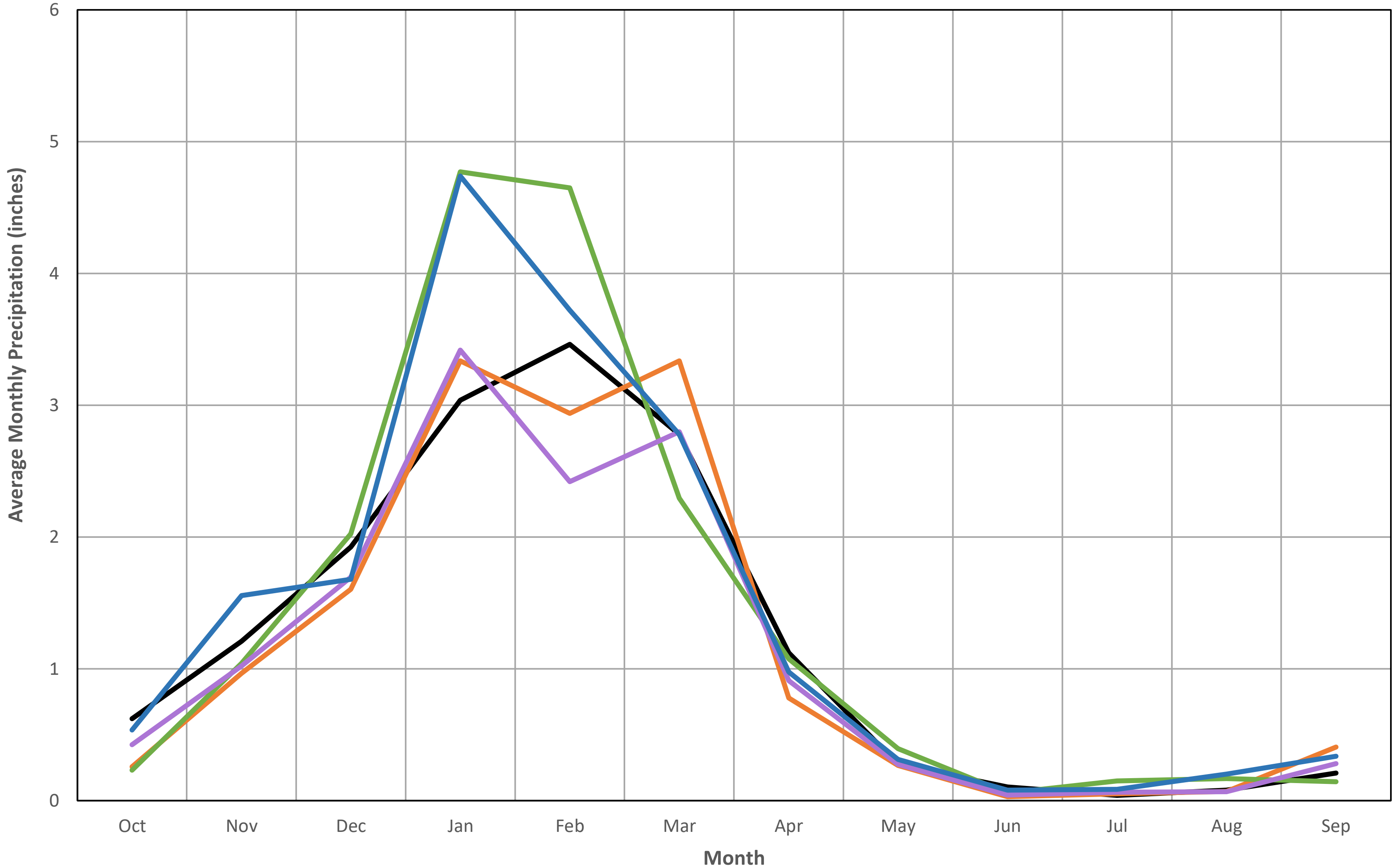

LEGEND

- Historical 30-Year Normal
- HadGEM2-ES, RCP 8.5
- CanESM2, RCP 8.5
- MIROC5, RCP 8.5
- CNRM-CM5, RCP 8.5

NOTE:
Average monthly values are representative of water years 2020 through 2071.

\\odin\proj\SanDiegoCityof\CommonFiles\SGMA\2022_GSP\GSP\ModelingAppendix\Figures\XLSX\3.0\FIG03-14_15_AnnMonthlyAvg_Proj_Precip.xlsx\FIG03-15

FIGURE 3-15
Average Monthly Precipitation of GCMs During the GSP Implementation Period
Numerical Flow Model Documentation
San Pasqual Valley Groundwater Basin
Groundwater Sustainability Plan
San Pasqual Valley, California

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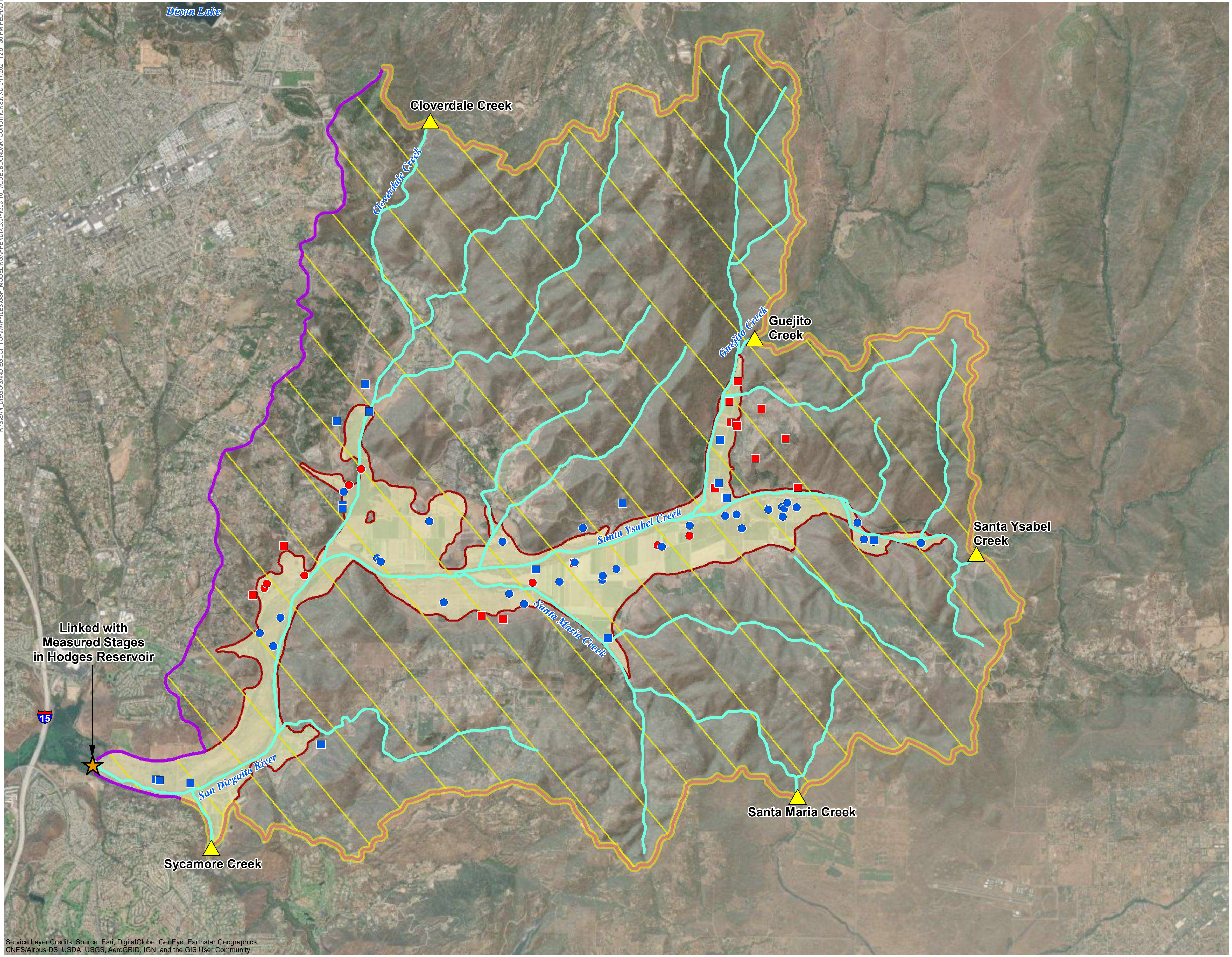

LEGEND

San Pasqual Valley Groundwater Basin

BOUNDARY CONDITION CATEGORIES

Specified Flux

Groundwater Pumping Well (FMP and MNW2)

- Alluvium/Residuum (more reliable well construction)
- Alluvium/Residuum (less reliable well construction)
- Bedrock (more reliable well construction)
- Bedrock (less reliable well construction)
- Stream Inflows (SFR)
- Subsurface Inflow in Model Layers 3 and 4 (WEL)
- Precipitation and Surface Evapotranspiration (FMP)

Head-dependent Flux

- Subsurface Exchange (GHB)
- Streams (SFR)
- Groundwater Recharge from Precipitation and Applied Water; Subsurface Evapotranspiration; and Rejected Recharge (FMP and DRT)

No Flow

- Located Along Model Domain Boundary Where Specified Fluxes are Not Assigned and at the Bottom of Model Layer 4

NOTES:

Farm Process package (FMP) computes applied water demand based on the deficit after accounting for precipitation and groundwater uptake (yellow hatched area).

DRT = Drain Return package

GHB = General Head Boundary package

MNW2 = Multi-Node Well 2 package

SFR = Streamflow Routing package

WEL = Well package

N

0 5,000 10,000
Feet

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FIGURE 3-16
Modeled Boundary Conditions for Calibration
Numerical Flow Model Documentation
San Pasqual Valley Groundwater Basin
Groundwater Sustainability Plan
San Pasqual Valley, California

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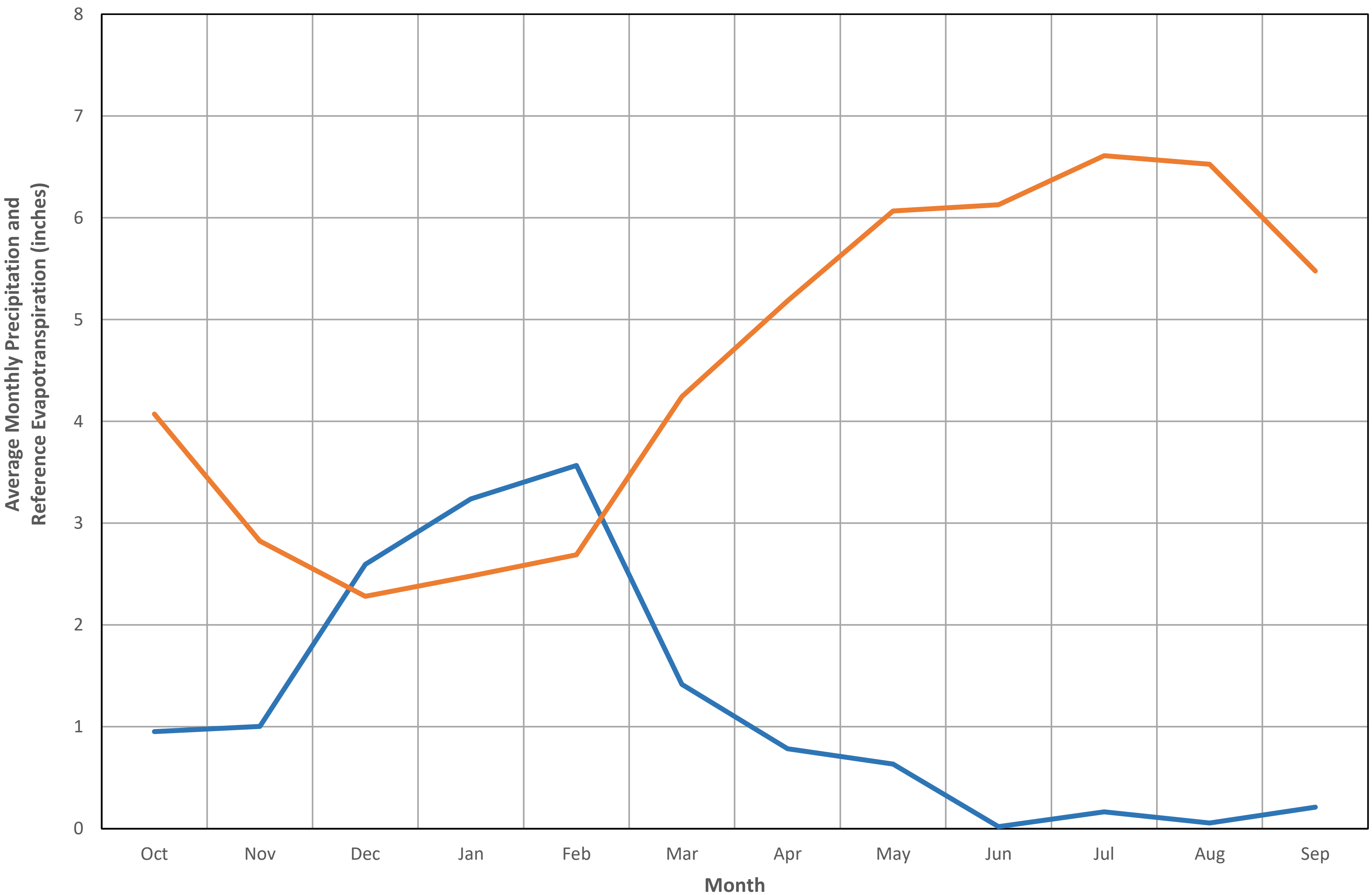

LEGEND

Precipitation

Reference Evapotranspiration

NOTE:

Average monthly values are representative of water years 2005 through 2019.

FIGURE 3-17

Average Monthly Precipitation and Reference Evapotranspiration

San Pasqual Valley Groundwater Basin
Groundwater Sustainability Plan
San Pasqual Valley, California

\\odin\proj\SanDiegoCityof\CommonFiles\SGMA\2022_GSP\GSP\ModelingAppendix\Figures\XLSX\3.0\FIG03-17_AvgMonthlyPrecip.xlsx\FIG03-17

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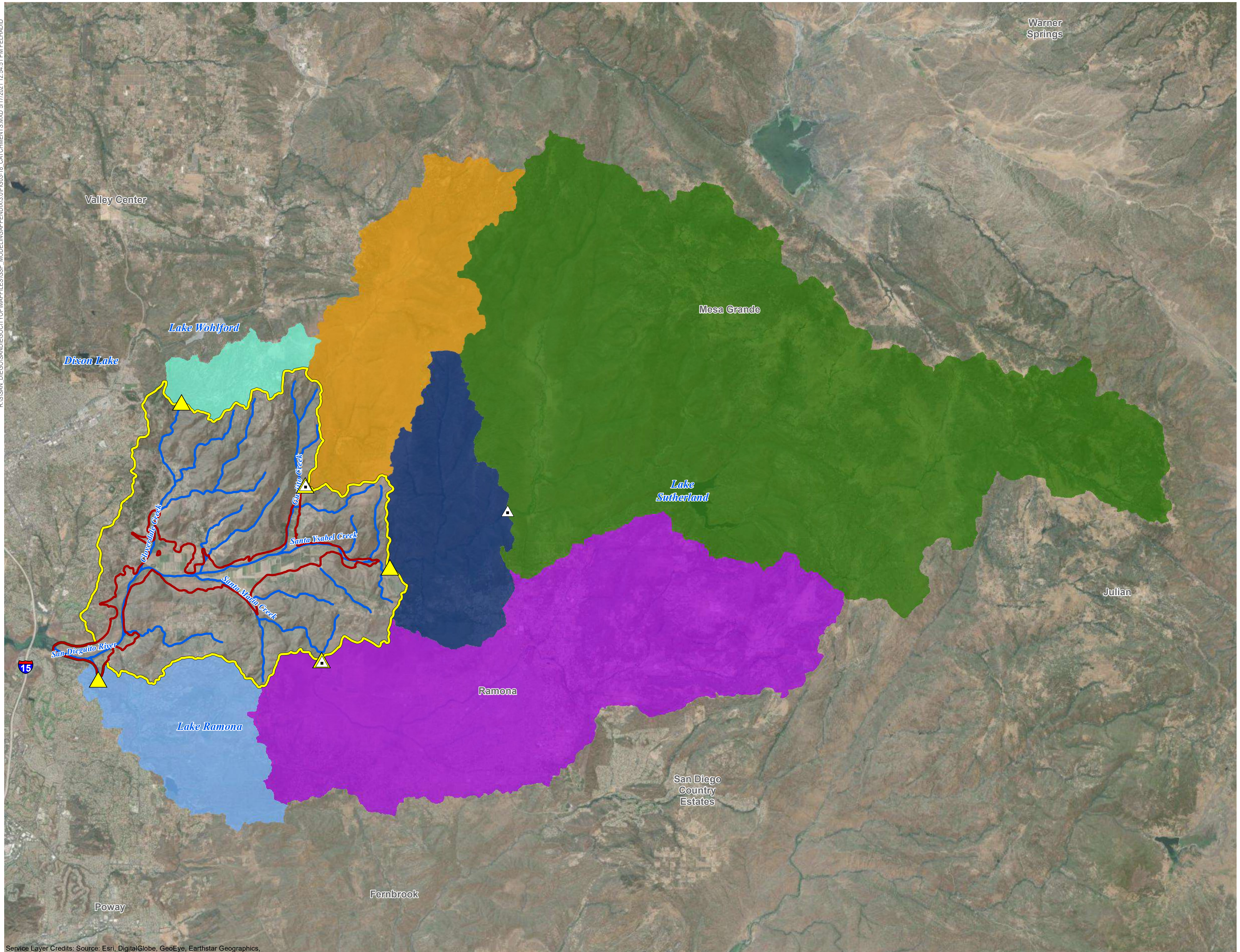
R:\S\SAN_DIEGO\SANDIEGOCITYOF\MAPFILES\GSP_MODELINGAPPENDIX\3.0\FIG03-18_CATCHMENTS.MXD 5/17/2021 12:54:51 PM FELHADID



LEGEND

- USGS Stream Gage
- Stream Inflow Location
- Modeled Stream
- San Pasqual Valley Groundwater Basin
- Model Domain Boundary

Contributing Catchment

- Cloverdale Creek-Ungaged
- Guejito Creek
- Santa Maria Creek
- Santa Ysabel Creek
- Santa Ysabel Creek-Ungaged
- Sycamore Creek-Ungaged

N

0 2.5 5
Miles

The City of SAN DIEGO

FIGURE 3-18
Contributing Catchments Upgradient from Model Domain
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San Pasqual Valley Groundwater Basin
Groundwater Sustainability Plan
San Pasqual Valley, California

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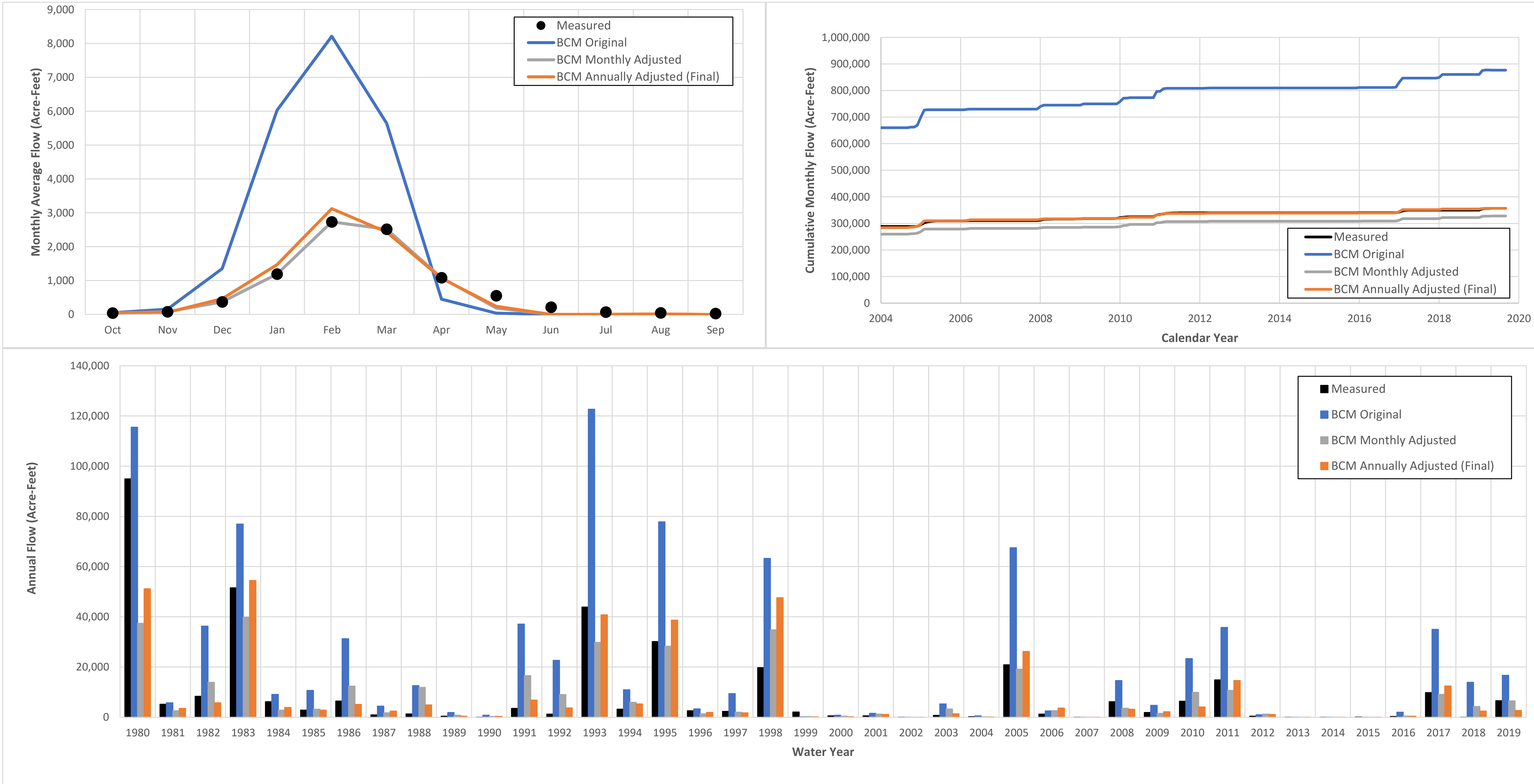

Note:

BCM = Basin Characterization Model

FIGURE 3-19

Adjusted Santa Ysabel Creek Monthly and Annual Stream Inflows

Numerical Flow Model Documentation

San Pasqual Valley Groundwater Basin

Groundwater Sustainability Plan

San Pasqual Valley, California

\\odin\proj\SanDiegoCityof\CommonFiles\SGMA\2022_GSP\GSP\ModelingAppendix\Figures\XLSX\3.0\FIG03-19_03-24_BCM_Historical_BiasCorrection.xlsx\FIG03-19

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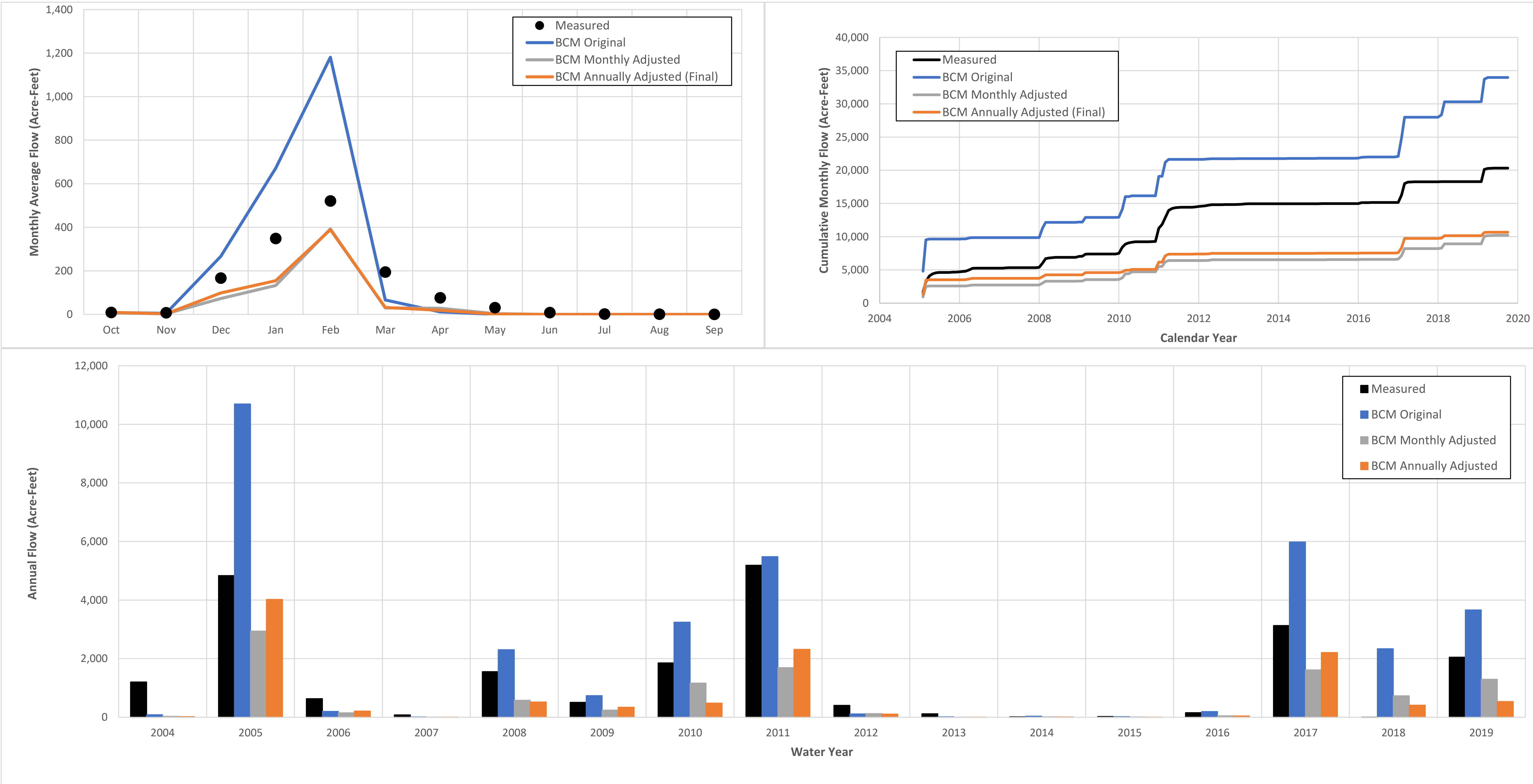

Note:

BCM = Basin Characterization Model

FIGURE 3-20

Adjusted Guejito Creek Creek Monthly and Annual Stream Inflows

Numerical Flow Model Documentation
San Pasqual Valley Groundwater Basin
Groundwater Sustainability Plan
San Pasqual Valley, California

\\odin\proj\SanDiegoCityof\CommonFiles\SGMA\2022_GSP\GSP\ModelingAppendix\Figures\XLSX\3.0\FIG03-19_03-24_BCM_Historical_BiasCorrection.xlsx\FIG03-20

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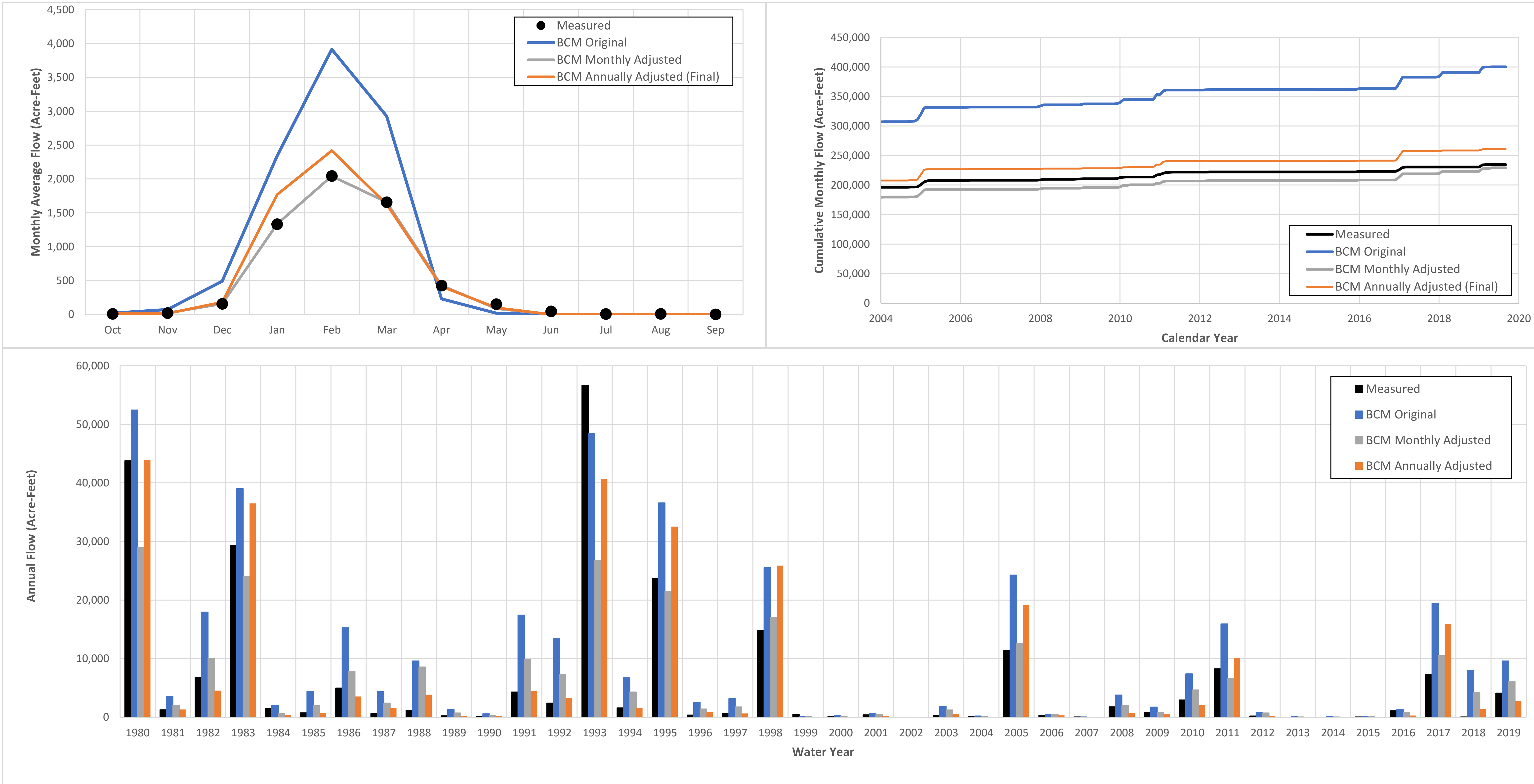

Note:

BCM = Basin Characterization Model

FIGURE 3-21

Adjusted Santa Maria Creek Monthly and Annual Stream Inflows

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San Pasqual Valley Groundwater Basin
Groundwater Sustainability Plan
San Pasqual Valley, California

\\odin\proj\SanDiegoCityof\CommonFiles\SGMA\2022_GSP\GSP\ModelingAppendix\Figures\XLSX\3.0\FIG03-19_03-24_BCM_Historical_BiasCorrection.xlsx\FIG03-21

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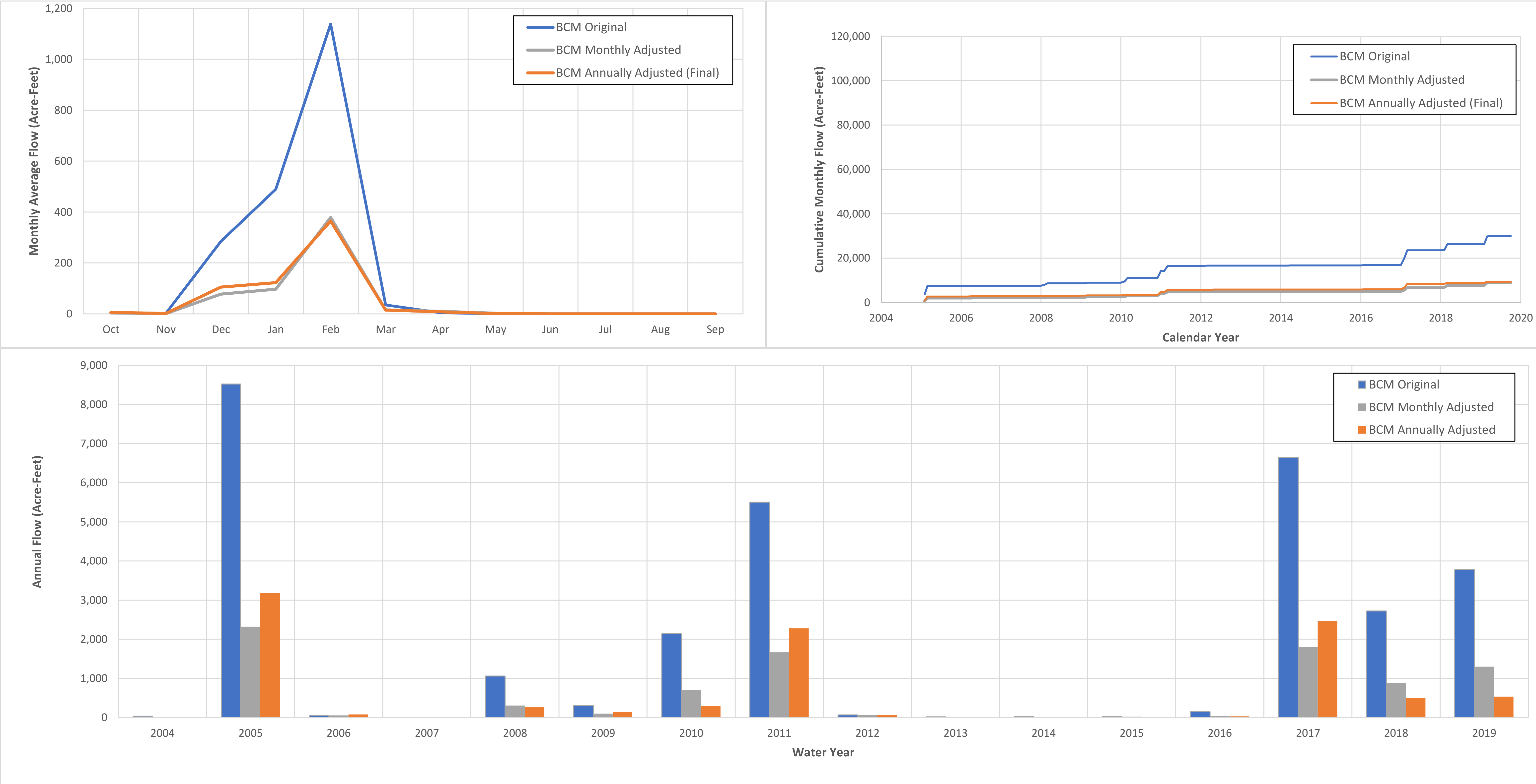

Note:

BCM = Basin Characterization Model

FIGURE 3-22

Adjusted Ungaged Santa Ysabel Creek Monthly and Annual Stream Inflows

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San Pasqual Valley Groundwater Basin
Groundwater Sustainability Plan
San Pasqual Valley, California

\\odin\proj\SanDiegoCityof\CommonFiles\SGMA\2022_GSP\GSP\ModelingAppendix\Figures\XLSX\3.0\FIG03-19_03-24_BCM_Historical_BiasCorrection.xlsx\FIG03-22

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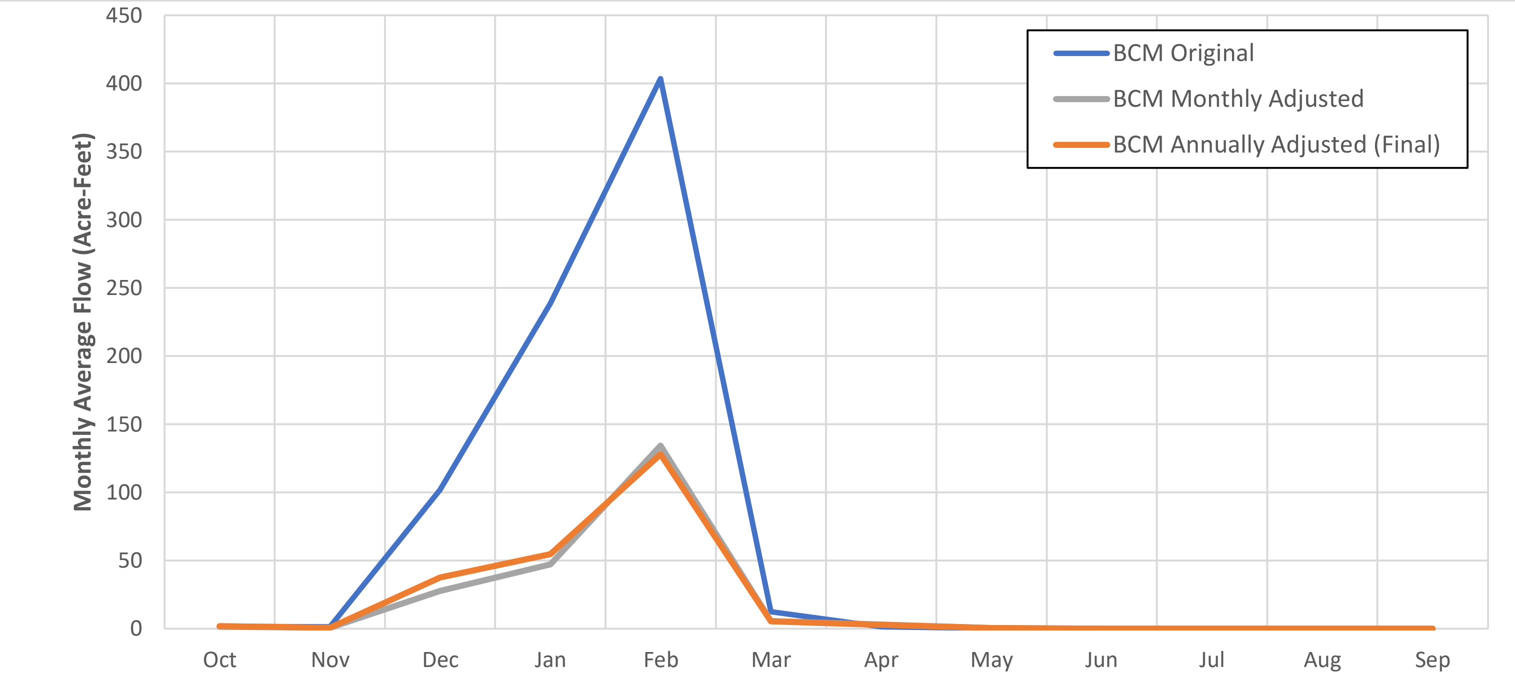

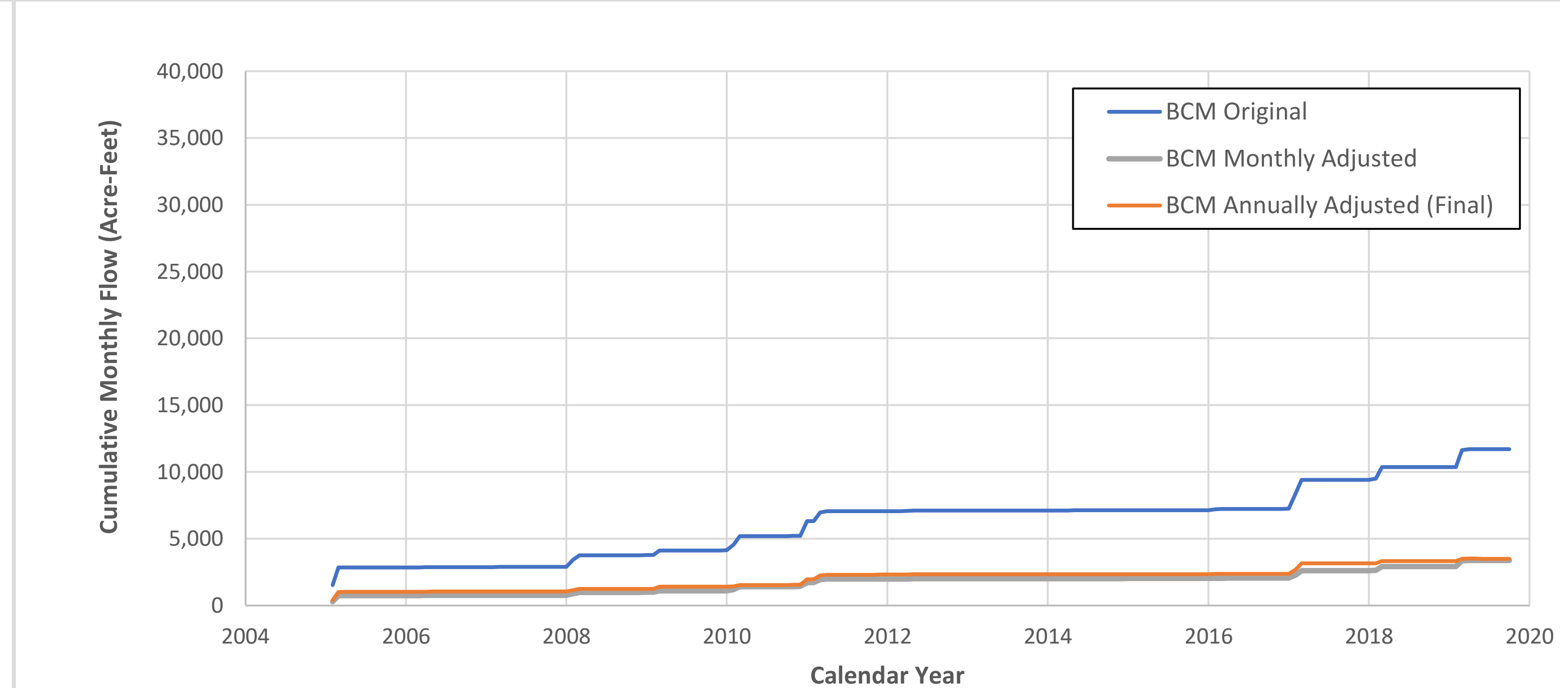

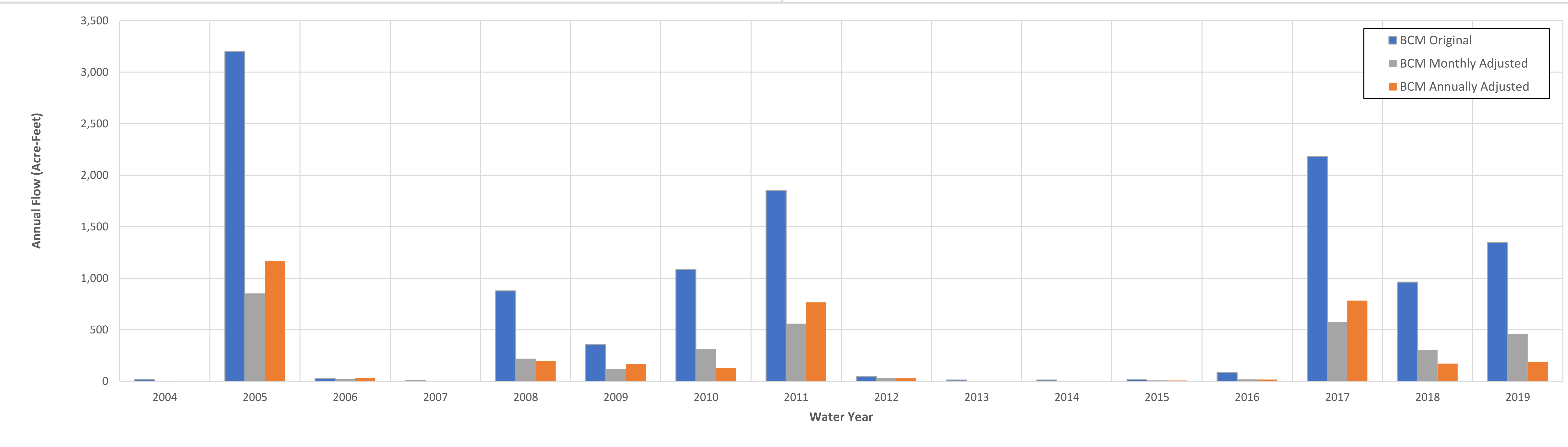

Note:
BCM = Basin Characterization Model

FIGURE 3-23
Adjusted Cloverdale Creek Monthly and Annual Stream Inflows
Numerical Flow Model Documentation
San Pasqual Valley Groundwater Basin
Groundwater Sustainability Plan
San Pasqual Valley, California

\\odin\proj\SanDiegoCityof\CommonFiles\SGMA\2022_GSP\GSP\ModelingAppendix\Figures\XLSX\3.0\FIG03-19_03-24_BCM_Historical_BiasCorrection.xlsx\FIG03-23

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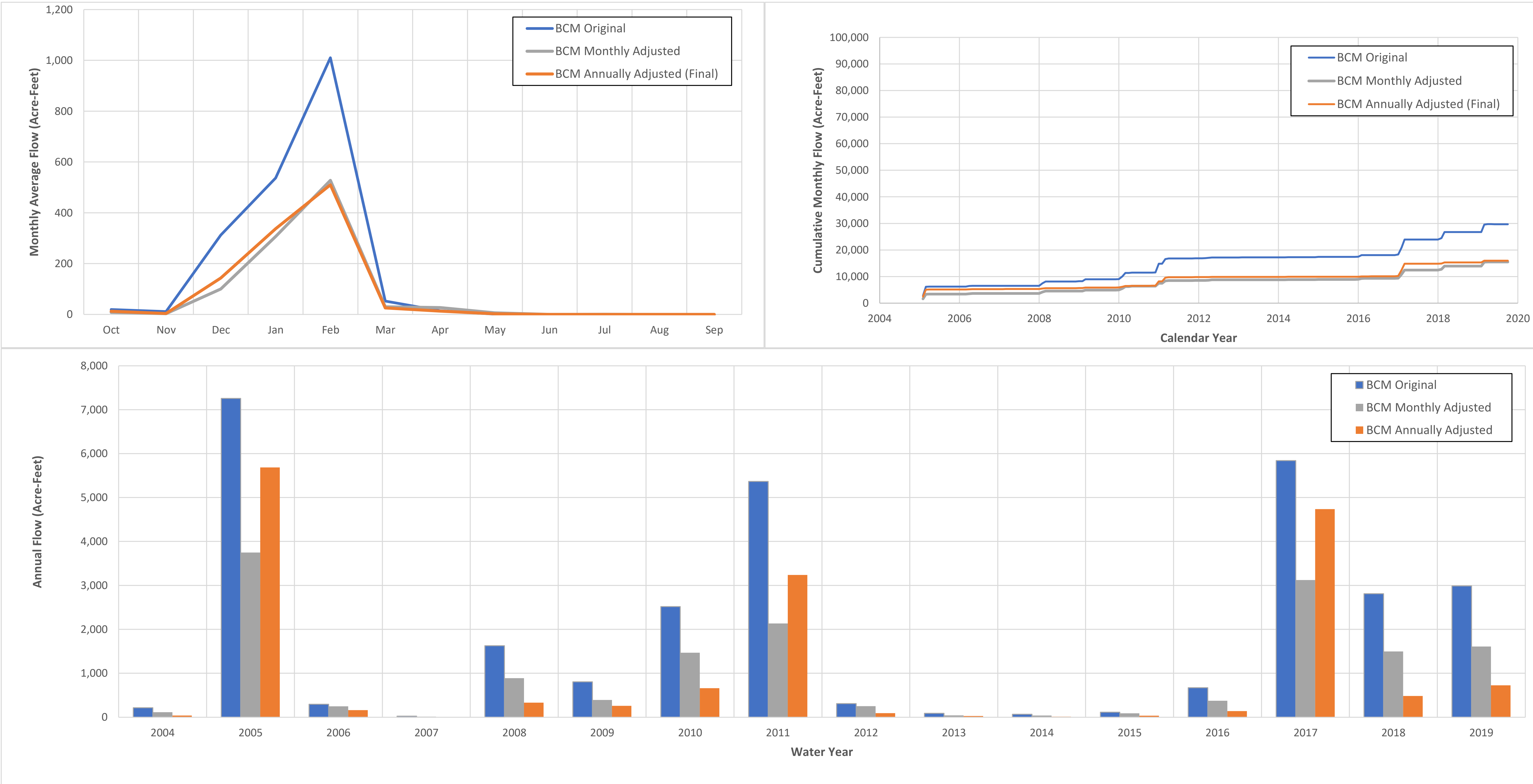

Note:

BCM = Basin Characterization Model

FIGURE 3-24

Adjusted Sycamore Creek Monthly and Annual Stream Inflows

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San Pasqual Valley Groundwater Basin
Groundwater Sustainability Plan
San Pasqual Valley, California

\\odin\proj\SanDiegoCityof\CommonFiles\SGMA\2022_GSP\GSP\ModelingAppendix\Figures\XLSX\3.0\FIG03-19_03-24_BCM_Historical_BiasCorrection.xlsx\FIG03-24

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LEGEND

- Santa Ysabel Creek Catchment
- Guejito Creek Catchment
- Cloverdale Creek Catchment
- Santa Maria Creek Catchment
- Sycamore Creek Catchment

FIGURE 3-25
Groundwater Recharge in Contributing Catchments Computed with the BCM
Numerical Flow Model Documentation
San Pasqual Valley Groundwater Basin
Groundwater Sustainability Plan
San Pasqual Valley, California

\\odin\proj\SanDiegoCityof\CommonFiles\SGMA\2022_GSP\GSP\ModelingAppendix\Figures\XLSX\3.0\FIG03-25_Ann RCH_Watershed.xlsx\FIG03-25

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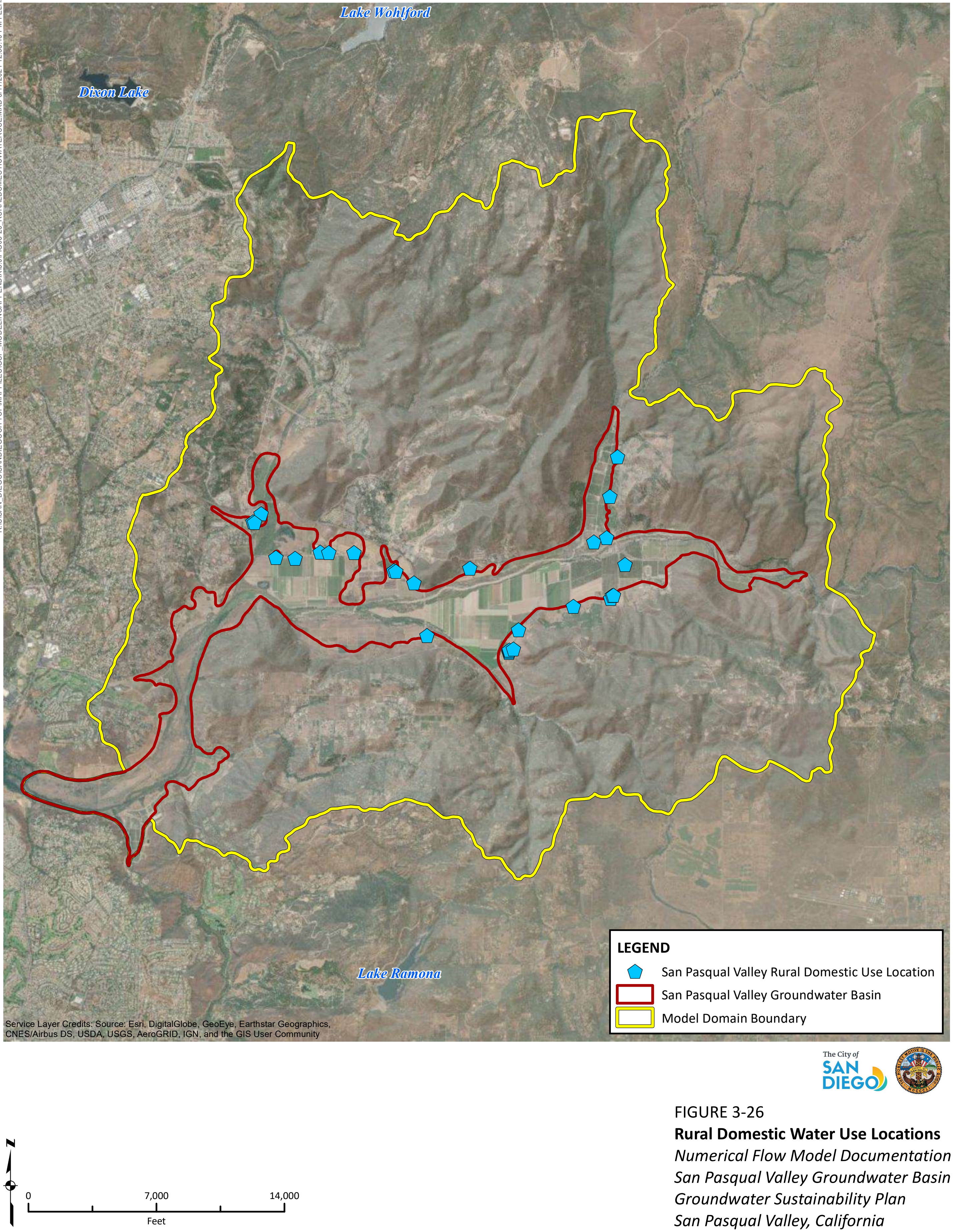

The City of SAN DIEGO

FIGURE 3-26

Rural Domestic Water Use Locations

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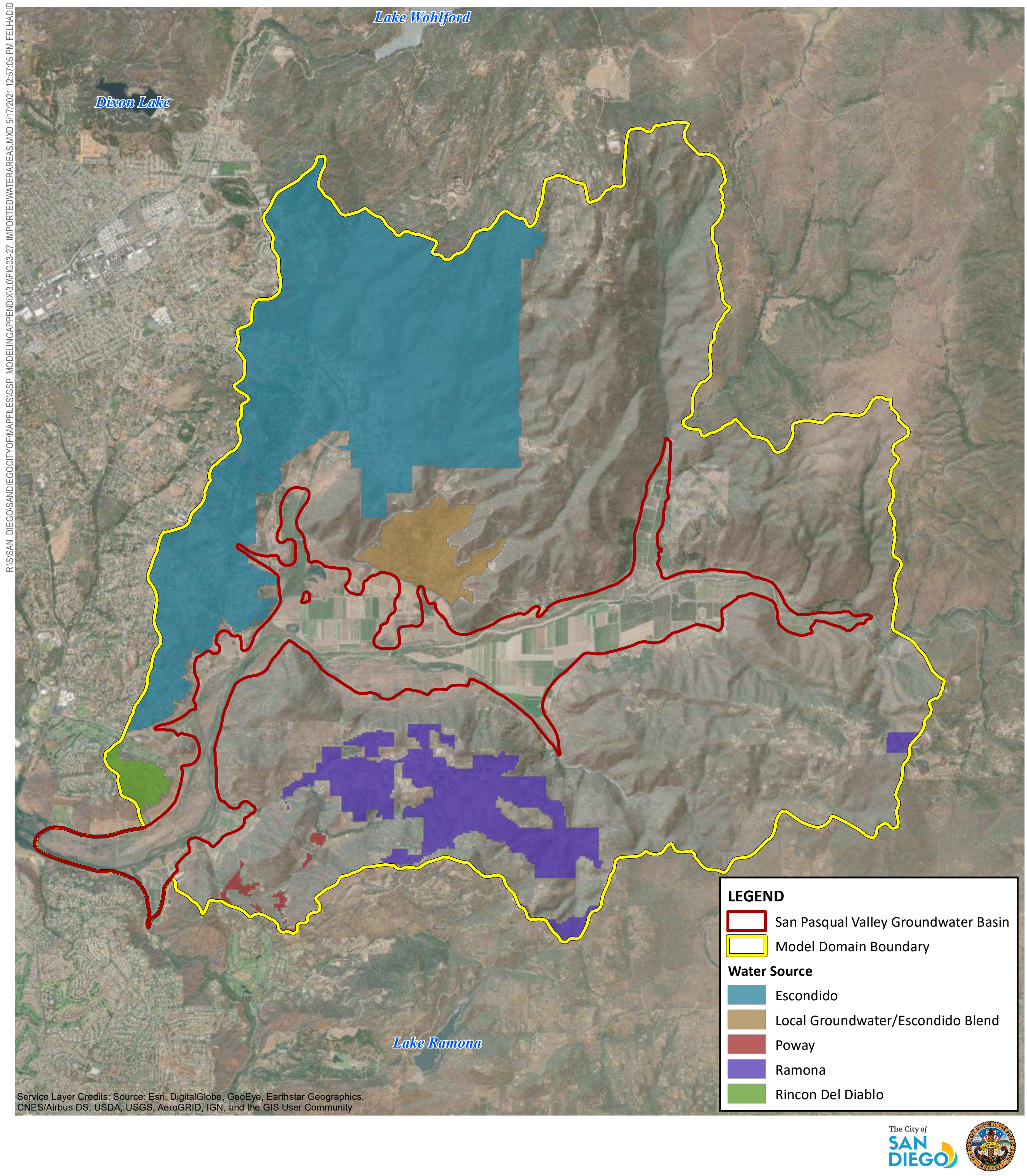

FIGURE 3-27
Areas of Imported Water Use
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San Pasqual Valley Groundwater Basin
Groundwater Sustainability Plan
San Pasqual Valley, California

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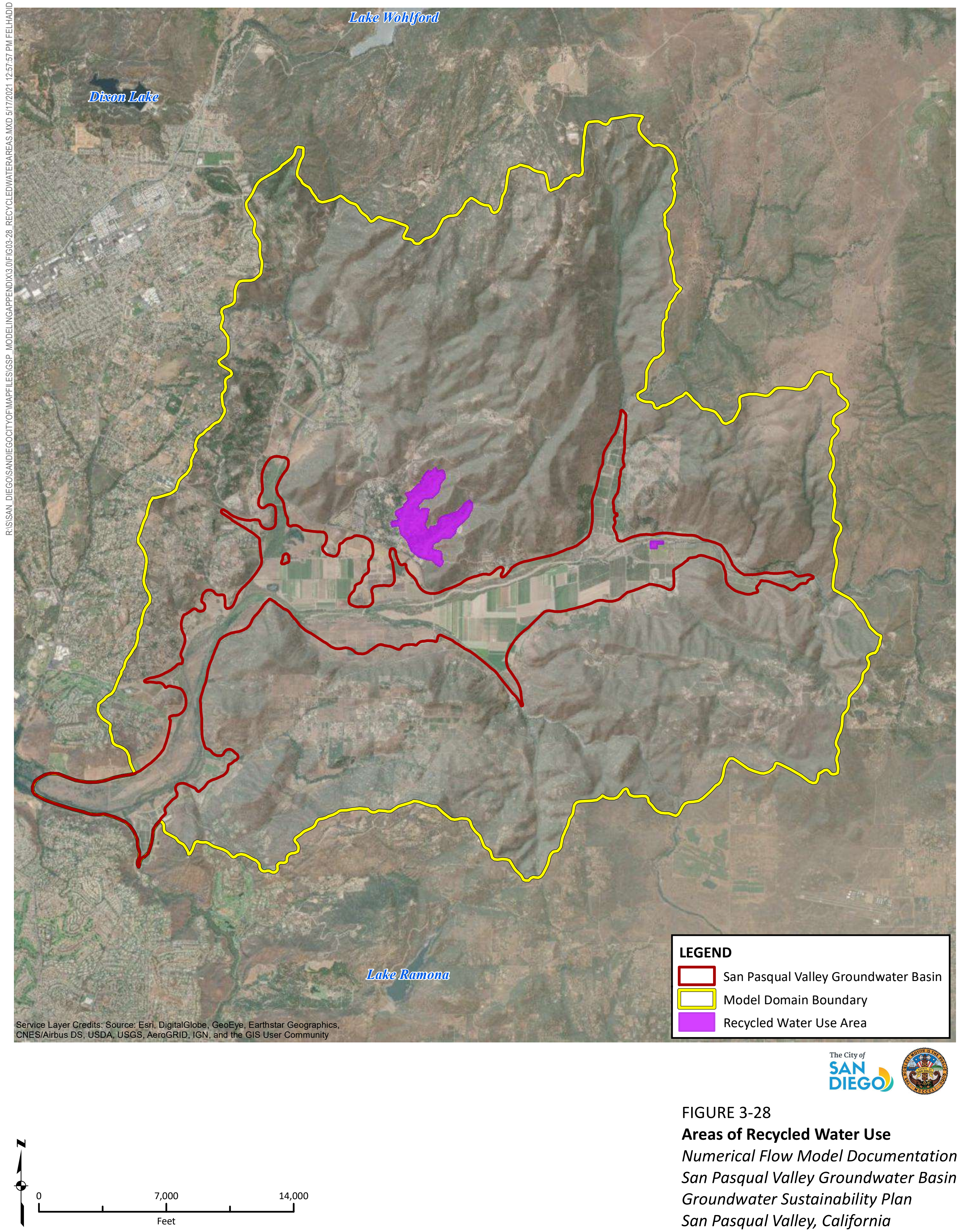

FIGURE 3-28

Areas of Recycled Water Use

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San Pasqual Valley Groundwater Basin
Groundwater Sustainability Plan
San Pasqual Valley, California

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SECTION 4. MODEL CALIBRATION

Model calibration is a process of tuning numerical model parameters to adequately replicate measured field conditions of interest. The numerical models described herein were calibrated in accordance with the *Standard Guide for Calibrating a Ground-Water Flow Model Application* (American Society for Testing and Materials, 1996) and the *Modeling BMP* (DWR, 2016a). As described in Section 3.5, WYs 2005 through 2019 was selected as the historical water budget period and is therefore also the model calibration period. This period includes a reasonable balance of wet, normal, and dry conditions for model calibration and more reliable hydrologic and water budget data, as compared with earlier periods. This section discusses the calibration targets, process, and results, including the historical and current water budgets.

4.1 Calibration Targets

Quantitative and qualitative calibration targets were selected to evaluate progress during calibration of the SPV GSP Model. Time-varying heads served as quantitative calibration targets. Calibration involved adjusting K_h, K_v, storativity, and FMP parameters within reasonable ranges until there was adequate consistency between modeled and calibration target values. Calibration summary statistics were computed for head targets to provide a quantitative measure of the SPV GSP Model's ability to replicate head target values. Head calibration was evaluated using the following summary statistics:

- Residual, computed as the modeled head value minus the target (i.e., measured) head value
- Mean residual (MR), computed as the sum of all residuals divided by the number of observations
- Root mean squared residual (RMSR), computed as the square root of the mean of all squared residuals
- RMSR divided by the range of target head values (RMSR/Range)
- Coefficient of determination (R^2), computed as the square of the correlation coefficient

During the quantitative calibration effort, Jacobs executed work with the following general goals:

- Minimize global bias in heads (e.g., all heads being too high or too low as compared with the target heads)
- Minimize the spatial bias of residuals in key subareas of the model domain
- Minimize residuals, MR, RMSR, and RMSR/Range values
- Strive for R^2 values as close to 1.00 as possible

In addition to calibrating to transient heads, qualitative targets were also used to aid in the calibration process. Calibration summary statistics were not computed for qualitative calibration targets. The qualitative targets used for the modeling effort are as follows:

- General groundwater flow patterns throughout the model domain
- Transient vertical head difference (VHD) values at three USGS monitoring well locations with shallow, intermediate, and deeper well screens
- Outflows from the model domain as compared with independent estimates of inflows to Hodges Reservoir

Targets classified as "qualitative" should not be interpreted as being unimportant. The main distinction is that summary statistics are not computed for qualitative targets, because doing so is not a requirement or is even typical for groundwater flow model documentation. **Figure 4-1** shows the 18 calibration target locations.

4.2 Calibration Process

The calibration process focused on defining FMP parameter values, surface and subsurface parameter distributions, and boundary-condition values until there was a reasonably close match to both quantitative and qualitative targets. The main parameters adjusted during the calibration process were the K_h and K_v values within and outside of the Basin. The main boundary condition evaluated during the calibration process was the subsurface inflow from contributing catchments. The focus on this aspect of the model was in response to feedback from members of the TPR group, which included three independent groundwater practitioners with expertise in technical groundwater evaluations. The GSA hosted seven public TPR meetings (i.e., November 9, 2019; January 9, 2020; May 14, 2020; July 9, 2020; October 8, 2020; December 17, 2020; and January 14, 2021) during the development of the SPV GSP Model. These meetings provided opportunities for TPR members to review and comment on major aspects of model and GSP development.

As previously discussed in Section 3.7.1, the BCM provides estimates of groundwater recharge in the contributing catchments. These recharge estimates provide an indication of the potential range of subsurface inflows for the SPV GSP Model domain. In reality, the magnitudes and locations of subsurface inflows from contributing catchments are highly uncertain due to the incomplete information regarding recharge-runoff characteristics in the contributing catchments and the nature and extent of weathering and fracturing of the bedrock near the SPV GSP Model domain boundaries. Thus, five different scenarios were simulated during the calibration effort including 0 percent, 25 percent, 50 percent, 75 percent, and 100 percent of the BCM recharge estimates as subsurface inflow.

The product resulting from this calibration process was an integrated groundwater/surface-water flow model that incorporates important aspects of the hydrogeologic conceptual model and the professional judgment of engineers and scientists familiar with the study area. The following section describes the results of the calibration effort.

4.3 Calibration Results

The following subsections describe the calibration results for time-varying groundwater levels, general groundwater flow patterns, VHDs, outflows to Hodges Reservoir, and groundwater pumping rates. Calibrated values for key parameters and boundary conditions are also presented.

4.3.1 Groundwater Levels

Figure 4-2 presents the modeled versus target (i.e., measured) groundwater levels to evaluate potential global biases and the overall ability of the SPV GSP Model to replicate historical groundwater level. In general, points trend along the one-to-one correlation line with some points falling above and below the line. This highlights that the SPV GSP model does not contain a global bias where all modeled groundwater levels are either always above or always below this line. Global calibration statistics for the data presented in **Figure 4-2** are listed in **Table 4-1** and are within industry standards for adequate model calibration (e.g., small MR with an RMSR/Range < 10 percent with an R^2 close to 1).

Table 4-1. Calibration Summary Statistics for Groundwater Elevations

Calibration Statistic	Value	Unit
Mean Residual (MR)	6.3	feet
Standard Deviation	23.2	feet
Root Mean Squared Residual (RMSR)	12.1	feet
Range of Measured Values (Range)	150.0	feet
RMSR/Range	8.0	percent
Coefficient of Determination (R^2)	0.81	unitless
Number of Values	28,119	unitless
Residual is computed by subtracting the target (i.e., measured) groundwater level from the modeled groundwater level.		

Although there is no indication of global bias in modeled groundwater levels, there is an indication of some degree of spatial bias. For example, there is also a cluster of points in the x-axis range of 320 to 350 feet above the North American Vertical Datum of 1988 (NAVD88) in **Figure 4-2** where the model tends to overestimate groundwater levels, whereas modeled groundwater levels in the target head range 380 feet NACD88 and greater tend to underestimate measured groundwater levels. **Figure 4-3** is provided to further evaluate spatial biases in modeled groundwater levels by displaying a spatial distribution of MR values for each calibration target well. According to this figure, there is some spatial bias in the eastern portion of the Basin where modeled heads tend to underestimate the target heads.

Figure 4-4 shows hydrograph comparisons on a map to show how the transient modeled and target groundwater levels compare. The horizontal and vertical axes on the hydrographs presented in **Figure 4-4** have been standardized to facilitate making comparisons among the hydrographs. The Basin has two distinct zones in which the behavior of the aquifer system is quite different. Inspection of hydrographs from east to west in a downstream direction reveals that modeled and target groundwater levels show short- and long-term trends, which diminish around SP110 and SP107. The general trends in modeled groundwater levels are reasonably consistent with target trends, as evidenced by the hydrograph comparisons and the R^2 statistic of 0.81 listed in **Table 4-1**.

Figure 4-5 illustrates the modeled water table during May 2016, which has been classified as a normal WYT. It is provided to illustrate general patterns of groundwater flow. Because of sharp contrast in the slope of the water table in the Basin versus outside of the Basin in the surrounding rock, **Figure 4-5** provides two sets of contour intervals with a 5-foot contour interval in the Basin and a 50-foot contour interval in the surrounding rock. This figures shows that the water table is steeper in the narrow canyons of the Basin, as evidenced by the more closely spaced blue contours therein. Groundwater generally moves from east to west, but flattens out in the central portion of the Basin where agricultural groundwater pumping flattens out the Basin hydraulic gradient. The overall groundwater flow pattern being illustrated in **Figure 4-5** is reasonable based on the understanding of groundwater use in the Basin and local hydrogeologic characteristics.

4.3.2 Vertical Head Difference

There are three multi-completion wells that have been installed and are monitored by the USGS. Groundwater levels representative of three distinct depth intervals are measured and recorded, providing an opportunity to evaluate vertical head difference at those well locations. As described in Section 3.2.2 the SPV GSP Model layering was developed with the aid of geologic cross-sections prepared by Snyder Geologic, well completion reports, and professional judgment. The model layering accounts for the multi-completion well-screen intervals and lithologic descriptions at those depths. Thus, the SPV GSP Model layering allows for extraction of modeled heads for each interval to compute VHDs.

Figure 4-6 presents the modeled and target VHD hydrographs. The horizontal and vertical axes on the VHD hydrographs presented in **Figure 4-6** have been standardized to facilitate making comparisons among the VHD hydrographs. For each multi-completion well, a VHD is calculated between Model Layer 1 (i.e., alluvium) and Model Layer 2 (i.e., residuum) (see "_L1-L2" designation), between Model Layer 2 and Model Layer 3 (i.e., bedrock) (see "_L2-L3" designation), and between Model Layer 1 and Model Layer 3 (see "_L1-L3" designation). Positive VHD values in **Figure 4-6** indicate a downward hydraulic gradient with groundwater moving from shallower to deeper layers, whereas negative VHD values indicate an upward hydraulic gradient with groundwater moving from deeper to shallower layers. In general, the measured data associated with these multi-completion wells indicate downward hydraulic gradients, meaning the vertical component of the 3D groundwater flow at those particular locations is from the alluvium and residuum down into the bedrock below the Basin. The largest positive VHDs tend to occur at the SDLH well, which is closest to the outlet of the Basin and Hodges Reservoir. At SDSY, modeled VHDs show vertical gradients of similar magnitude as the measured VHDs across each of the layers indicating that the model simulates similar downward gradients from alluvium to residuum and bedrock at that location. For SDCD, the model typically simulates upward hydraulic gradients and does not capture the downward trends observed in the measured VHDs. There are some modeled pumping wells in the Cloverdale Canyon area with unknown well construction details. It is possible that the SPV GSP Model could be modified to improve the fits to VHDs, if there was more reliable information on bedrock pumping well construction in the Cloverdale Canyon area. At SDLH, the SPV GSP Model tends to overestimate the peak VHD from the alluvium to residuum as compared to measured data and tends to underestimate the VHD from residuum to bedrock and from alluvium to bedrock. However, the timing of the modeled alluvium to bedrock VHDs tends to correlate well with measured values. It was noted during calibration that assigning larger K_v values in the bedrock near the USGS multi-completion wells and bedrock pumping wells resulted in improved matches to the larger downward hydraulic gradients at the USGS multi-completion wells.

4.3.3 Outflows to Hodges Reservoir

Surface and subsurface outflows to Hodges Reservoir are computed by the SPV GSP Model through the SFR and GHB packages, respectively. No measured flow data are available to characterize the magnitude and timing of contributions of inflow to Hodges Reservoir from the SPV GSP Model domain. The best estimate available of net inflow to Hodges Reservoir is a derived inflow to the reservoir. As part of previous long-range planning efforts, the San Diego Water Authority (SDWA) compiled local surface water supply data at inflow locations of Hodges Reservoir and nine other reservoirs for the period of 1888 through 1989. These flow data include measured or synthesized daily and monthly flow records. The reservoir inflow data were extended from 1990 through 2011 as part of the 2013 Regional Water Facilities Optimization and Master Plan (San Diego County Water Authority, 2014). The associated evaluation was conducted using information from the SDWA and member agencies and focused on preparing modeling inputs for a water balance model called CWASim (San Diego County Water Authority, 2014). This model has been recently updated and used for the San Diego Watershed Basin Study conducted in partnership between the City of San Diego Public Utilities Department and the United States Bureau of Reclamation. Due to the lack of measured flow data, CWASim estimates the inflows to Hodges Reservoir as a closure term of the reservoir water balance, accounting for all other measured inflows and outflows and the relationship of surface water elevation and reservoir storage.

Although there are limitations with CWASim's estimate of inflows to Hodges Reservoir, an analysis was conducted to compare SPV GSP Model outflow estimates to CWASim estimates of total inflow to Hodges Reservoir. One such limitation is that there are contributing areas upgradient from Hodges Reservoir that are downgradient from the SPV GSP Model domain (see area immediately west of the SPV GSP Model domain in **Figure 3-18**); therefore, there are areas contributing inflow to Hodges Reservoir that are not related to the SPV GSP Model domain. Another important consideration in comparing SPV GSP Model outflow estimates to CWASim's estimate of inflows to Hodges Reservoir is the consumption of water in the vegetated area between the SPV GSP Model domain and Hodges Reservoir (see **Figure 4-7**). CalETa data were processed for the vegetated area to compute an annual estimate of consumptive use ranging from approximately 770 acre-feet per year (AFY) in wet years to 381 AFY in critically dry years. The monthly estimates of consumptive use in the vegetated area were subtracted from the SPV GSP Model outflows (i.e., sum of the outflows from the San Dieguito River SFR and GHB cells) to make them more comparable to the CWASim estimates of inflow to Hodges Reservoir during non-wet years.

Figure 4-8 presents an annual comparison of ET-adjusted outflows to Hodges Reservoir from the SPV GSP Model and the estimated inflows to Hodges Reservoir from the CWASim model for WYs 2005 through WY 2011 (i.e., the only years with estimates from both CWASim and the SPV GSP Model) for the five different scenarios previously described (i.e., 0 percent, 25 percent, 50 percent, 75 percent, and 100 percent of the BCM recharge estimates as subsurface inflow). Considering the limitations of CWASim estimates previously discussed, the goal of this comparison from a calibration perspective is for the SPV GSP Model to underestimate inflows in wet years and to match the CWASim estimates more closely during other years.

The MRs of the non-wet WYTs for each scenario are as follows:

- 0 Percent of the ET-adjusted BCM Recharge: -1,048 AFY
- 25 Percent of the ET-adjusted BCM Recharge: 453 AFY
- 50 Percent of the ET-adjusted BCM Recharge: 1,897 AFY
- 75 Percent of the ET-adjusted BCM Recharge: 3,414 AFY

- 100 Percent of the ET-adjusted BCM Recharge: 4,967 AFY

Of the five scenarios, the 25 percent of the ET-adjusted BCM recharge scenario resulted in the closest fit to the CWASim estimates for the non-wet WYTs.

Table 4-2 presents the suite of calibration statistics for groundwater levels at the 18 target well locations, based on the historical simulation of each of the five scenarios. In general, the head-calibration statistics did not change substantially with the inclusion of subsurface inflow; however, as the subsurface inflow volume increased, the head-calibration statistics generally became worse. For example, the MR ranged from 4.3 feet with the 0-percent BCM recharge scenario to 8.4 feet for the 100-percent BCM recharge scenario.

Table 4-2. Sensitivity of Head-calibration Statistics to Subsurface Inflows

Calibration Statistic	0% of BCM Recharge	25% of BCM Recharge	50% of BCM Recharge	75% of BCM Recharge	100% of BCM Recharge
MR	4.3	6.3	7.2	7.8	8.4
RMSR	10.0	12.1	13.1	13.7	14.4
RMSR/Range	6.68%	8.02%	8.71%	9.12%	9.59%
R^2	0.85	0.81	0.79	0.78	0.77
Standard Deviation	22.8	23.2	23.4	23.6	23.8

Additionally, agricultural pumping rates in the Basin were evaluated under the five scenarios to understand the potential implications of subsurface inflow on this water budget term. The modeled historical (i.e., WYs 2005 through 2019) agricultural pumping rates were as follows:

- 0 Percent BCM Recharge: 5,868 AFY
- 25 Percent BCM Recharge: 5,861 AFY
- 50 Percent BCM Recharge: 5,862 AFY
- 75 Percent BCM Recharge: 5,862 AFY
- 100 Percent BCM Recharge: 5,861 AFY

In general, groundwater pumping was not significantly sensitive to changes in subsurface inflow with values ranging from a minimum of 5,861 AFY to 5,868 AFY.

Due the head-dependent nature of ET, the TFDR is affected by the ability of a crop to access shallow groundwater. As groundwater levels increase, the potential for increased groundwater uptake occurs, which would reduce the need to supplement supply through groundwater pumping. However, the changes in groundwater levels were minor based on the calibration statistics presented in **Table 4-2**. Therefore, the modeled agricultural groundwater pumping was not sensitive to the range of subsurface inflows evaluated.

Another important consideration is how groundwater storage in the Basin is affected by changes in subsurface inflow from contributing catchments. The historical (i.e, WYs 2005 through 2019) average changes in modeled groundwater storage in the Basin with the five scenarios were as follows:

- 0 Percent BCM Recharge: -300 AFY
- 25 Percent BCM Recharge: -245 AFY
- 50 Percent BCM Recharge: -220 AFY
- 75 Percent BCM Recharge: -203 AFY
- 100 Percent BCM Recharge: -187 AFY

Although all five of the scenarios result in average declines in groundwater storage during the historical period, these declines become less steep with increasing subsurface inflows from contributing catchments. Thus, the range of subsurface inflows from contributing catchments evaluted has some implication on changes in groundwater storage, but not enough to eliminate the general declines in groundwater storage during the historical period.

Although the model could be reasonably calibrated without including the subsurface inflows from contributing catchments, the 25 percent scenario was retained as the final calibrated model. The global head-calibration statistics were slightly worse with this inclusion; however, some fits to individual groundwater-level hydrographs for wells located in the eastern portion of the Basin were slightly improved. Further, including 25 percent of the BCM recharge as subsurface inflows provided the best fit to CWASim estimates of inflows to Hodges Reservoir during non-wet WYs. All calibration results discussed in Sections 4.3.1 and 4.3.2 and hereafter in this report include the 25 percent of the BCM recharge as subsurface inflow from contributing catchments.

4.3.4 Groundwater Pumping Rates

Groundwater pumping rates were estimated by the FMP package based on CalETa data and the well-to-parcel relationships discussed in Section 3.3.3. Attachment 2 presents time-weighted annual average groundwater pumping rates for each pumping well for the historical simulation period. The annual average pumping rates range from 0 to approximately 300 gallons per minute (gpm). Non-zero annual average pumping rates are more typically in the 50 to 85 gpm range, according to the model. Although actual pumping rates at many of the pumping wells are not known with certainty, the estimates listed in Attachment 2 provide a good starting point for estimated pumping rates.

4.3.5 Surface Parameters

Stream channel parameters were refined during the calibration process to better represent local channel geometries and to improve model stability. Better estimates of channel widths were obtained and specified for each of the major creeks and rivers through review of Google Earth™ imagery. Additionally, stream channel conditions were evaluated during the review process to note the general state of the channel and whether the channels contained significant vegetation, larger rocks or boulders, or were generally "clean". These channel descriptions were used to assign Manning's roughness coefficient values based on estimates from Chow (1959). **Table 4-3** presents the calibrated SFR parameters by stream.

Ranges of streambed hydraulic conductivity were attempted during the calibration effort. However, the SPV GSP Model was not very sensitive to this parameter and more importantly, adequate numerical mass balances were only possible when the streambed hydraulic conductivity values were set no higher than 0.1 ft/d (3.5×10^{-5} cm/s). The lack of sensitivity to this particular parameter is likely due to the fact that most streams in the Basin do not regularly flow. Thus, simulations with different streambed hydraulic conductivity values for mostly dry stream beds did not provide substantially different results.

The capillary fringe length parameters were also updated during the calibration effort to be more consistent with soil type. Capillary fringe values in the SPV GSP Model range from 1 foot to 9 feet and are in the range of literature values (Boyce et al., 2020). After evaluation of various parameter values associated with land use and vegetation, the parameter values listed in **Table 3-4** in Section 3.3.3 were ultimately retained in the calibrated version of the model.

Table 4-3. Calibrated Stream Parameters

Stream	Channel Width (feet)	Manning's Roughness Coefficient
Santa Ysabel Creek	50 to 150	0.035 to 0.05
Guejito Creek	15 to 40	0.05 to 0.08
Santa Maria Creek	15 to 80	0.035 to 0.08
Cloverdale Creek	20 to 60	0.05 to 0.08
Sycamore Creek	40	0.08
Other Creeks	15 to 100	0.03 to 0.08
San Dieguito River	100 to 100	0.08 to 0.08

Streams are modeled with rectangular channel geometries, a streambed thickness of 1 foot, and a streambed hydraulic conductivity of 0.1 ft/d (3.5×10^{-5} cm/s).

4.3.6 Subsurface Parameters

Hydraulic conductivity zones were modified during the calibration process to account for variability in lithologic conditions throughout the Basin and to improve the fits to calibration targets. **Figures 4-9 and 4-10** present the calibrated distributions of K_h and K_v for each model layer (shown in text boxes on upper left side of each model layer frame), respectively. Calibrated K_h values are in the range of 40 to 100 ft/d (1.4×10^{-2} to 3.5×10^{-2} cm/s) in the alluvium, 2 to 10 ft/d (7.1×10^{-4} to 3.5×10^{-3} cm/s) in the residuum, and generally 0.004 to 0.006 ft/d (1.4×10^{-6} to 2.1×10^{-6} cm/s) in the bedrock. Calibrated K_v values are in the range of 0.4 to 10 ft/d (1.4×10^{-4} to 3.5×10^{-3} cm/s) in the alluvium, 0.04 to 1,000 ft/d (1.4×10^{-5} to 3.5×10^{-1} cm/s) in the residuum, and generally 0.4 to 0.6 ft/d (1.4×10^{-4} to 2.1×10^{-4} cm/s) in the bedrock. These values are reasonable based on experience at other sites, in the range of reported aquifer parameters in Rockwood Canyon (Richard C. Slade and Associates, LLC, 2015) and Bandy Canyon (Ogden Environmental and Energy Services, 1992), and are within the range of literature values for the materials present in the study area (Freeze and Cherry, 1979). The vertical anisotropy (K_h:K_v) ranges from 10 to 100 in the alluvium, 0.01 to 100 in the residuum, and is 0.01 in the bedrock. Areas with K_v values that are larger than the co-located K_h values was needed to improve the fit to VHDs, as discussed in Section 4.3.2. Values of K_h:K_v ratios that are less than one are possible in geologic settings with fractured crystalline rock.

The bedrock K_h was one of the more sensitive parameters that controlled bulk subsurface flow contributions to the Basin and the temporal trends of the groundwater level hydrographs. Thus, inclusion of the bedrock area surrounding and underlying the Basin proved to be an important step in the learning process and gaining insights into the potential hydraulic interplay between the Basin and its surrounding environment.

Refinements were made to the S_y and S_s value during the calibration process. Calibrated values of S_y range from 0.05 to 0.10 in the residuum and alluvium, whereas the calibrated S_s values range from 1×10^{-6} to 1×10^{-7} per foot (ft^{-1}) in the residuum and bedrock. These values are reasonable based on experience at other sites and are within the ranges of literature values.

4.3.7 Numerical Mass Balance

It is important to review the numerical mass balance of model simulations to ensure that good mathematical closure is achieved. The percent discrepancy in the mass balance for each stress period ranged from -0.02 to 0.01 percent in the calibration simulation. The cumulative percent discrepancy in the numerical mass balance was 0.00 percent in the calibration simulation. Thus, the transient historical model achieved excellent numerical mass balances associated with the water budgets described in the following sections.

4.4 Historical and Current Water Budgets

SGMA Regulations (i.e., Title 23 CCR Section 354.18) requires the SPV GSA to develop historical, current, and projected water budgets for the Basin. The historical water budget evaluates the availability and reliability of past surface water supplies and agricultural demands relative to WYT. The 15-year hydrologic period of WYs 2005 through 2019 was selected for developing the historical water budget to include a period of representative hydrology, while capturing recent Basin operations. The current water budget evaluates the availability and reliability of more recent surface water supplies and agricultural demands relative to WYT. The 5-year hydrologic period of WYs 2015 through 2019 was selected for developing the current water budget to include a period of recent hydrology and Basin operations since 2015, the WY coinciding with the January 1, 2015 effective date of the SGMA regulations.

Figure 4-11 illustrates the water budget reference volume for water budget values presented in this report. The reference volume includes the alluvium and residuum within the DWR definition of the Basin. Thus, water budget values are summarized for only the alluvium and residuum layers (i.e., Model Layers 1 and 2) within the footprint of the Basin. Model Layers 3 and 4 (i.e., bedrock layers) and portions of the domain that fall outside of the Basin footprint are not included in the water budgets; however, the exchange of flows across the Basin boundary with these outer areas is included in the water budgets. This means that stream inflows reported in the surface water budget represent the stream inflows to the Basin (see the white circles in **Figure 4-11**) rather than the stream inflows at locations along the SPV GSP Model domain (see the yellow triangles in **Figure 4-11**).

The water budgets described herein have been developed in accordance with the general guidelines provided in DWR's *Water Budget BMP* (DWR, 2016b) to help quantify the volumetric rate of water entering and leaving the Basin. Water enters and leaves the Basin naturally, such as through precipitation and streamflow, and through human activities, such as pumping and groundwater recharge from irrigation. Separate historical, current, and projected water budgets have been developed for three different "systems", including the land system, surface water system, and groundwater system. **Figure 4-12** presents a generalized depiction showing how these different systems relate to each other and **Table 4-4** lists the water budget components for each of these systems.

As shown in **Figure 4-12** and **Table 4-4**, an outflow from one system can be an inflow to another system. There is unavoidable uncertainty associated with these water budget estimates, which is inherent in any numerical flow model. Further, these estimates are subject to change as the understanding of Basin conditions evolves during implementation of the GSP.

Table 4-5 lists the assumptions for information incorporated into the SPV GSP Model, which was used to develop the historical and current water budgets.

Table 4-4. Land, Surface Water, and Groundwater Systems Water Budget Components

Land System Inflow Components	Land System Outflow Components
Precipitation	Runoff to Streams
Imported Applied Water[a]	ET of Precipitation
Groundwater Deliveries for Irrigation	ET of Shallow Groundwater
Shallow Groundwater Uptake	ET of Applied Water
Groundwater Discharge to Land Surface	Groundwater Recharge from Precipitation, Applied Water, and Septic Systems
Surface Water System Inflow Components	**Surface Water System Outflow Components**
Runoff to Streams	Stream Outflow to Hodges Reservoir Area
Stream Inflow from Adjacent Areas	Groundwater Recharge from Streams
Groundwater Discharge to Streams	
Groundwater System Inflow Components	**Groundwater System Outflow Components**
Groundwater Recharge from Precipitation, Applied Water, and Septic Systems	Shallow Groundwater Uptake (ET of Shallow Groundwater)
Groundwater Recharge from Streams	Groundwater Discharge to Streams
Subsurface Inflow from Hodges Reservoir Area	Groundwater Pumping
Subsurface Inflow from Adjacent Rock	Subsurface Outflow to Hodges Reservoir Area
	Subsurface Outflow to Adjacent Rock
	Groundwater Discharge to Land Surface

[a] A small portion of the Basin receives imported water from the City of Escondido as well as from groundwater pumping wells outside of the SPV GSP Model domain (City of San Diego, 2014).

Table 4-5. Water Budget Assumptions

Water Budget Item	Assumption/Basis for Historical and Current Water Budgets
Hydrologic Period	• Historical: WYs 2005 through 2019 • Current: WYs 2015 through 2019 • Monthly time intervals
Precipitation	• Downscaled PRISM (PRISM Climate Group, 2020) precipitation dataset, as processed using the BCM (Flint et al., 2013)
Reference Evapotranspiration [a]	• California Irrigation Management Information System Station 153 in the SPV
Stream Inflows	• Guejito Creek USGS stream gage 11027000 • Santa Ysabel Creek USGS stream gage 11025500 • Santa Maria Creek USGS stream gage 11028500 • Inflows for ungauged streams are based runoff estimates computed by the BCM (Flint et al., 2013) and bias corrected by Jacobs
Subsurface Inflows	• 25 percent of the groundwater recharge in contributing catchments as computed by the BCM (Flint et al., 2013)
Land Use/Cropping	• Built upon land use dataset developed for the SNMP (City of San Diego, 2014) • Updated based on 2014 and 2016 DWR land use datasets, Google Earth™ imagery, and stakeholder input
Well Infrastructure	• Stakeholder input for WYs 2005 through 2019
Evapotranspiration	• CalETa (Formation, 2020) dataset provides actual monthly crop ET values for calendar years 2005, 2010 through 2017, and 2019
Domestic Water Use	• Stakeholder input and census data

Notes:
BCM = California Basin Characterization Model
Formation = Formation Environmental
CalETa = California Actual Evapotranspiration
[a] The crop associated with the reference evapotranspiration is grass.

Figure 4-13 presents three sets of charts showing historical and current water budgets. The top, middle, and bottom charts show the land system, surface water system, and groundwater system water budget summaries, respectively. **Figure 4-14** presents three sets of charts, one for each Basin water budget system, with the annual time series of the historical and current water budgets. The colors of the water budget components in **Figures 4-13 and 4-14** have been standardized to facilitate making comparisons between figures. Water budget estimates are described below; these budgets are subject to change in future GSP updates as understanding of Basin conditions evolves during GSP implementation.

4.4.1 Land System

Table 4-6 and **Figure 4-13a** present averages of the individual Basin components of the historical and current land system water budgets, whereas **Figure 4-14a** presents the annual time series of the historical and current land system water budgets. Attachment 3 provides the annual values for the land system water budget components. Tabulated water budget values presented herein are reported to the nearest whole number from the SPV GSP Model. This has been done out of convenience. It is not the intention of the authors to imply that the values are accurate to the nearest AF.

Table 4-6. Historical and Current Average Annual Land System Budget

Water Budget Component	Historical Average Annual Flow (AFY) WYs 2005–2019	Current Average Annual Flow (AFY) WYs 2015–2019
Precipitation	3,864	4,126
Imported Applied Water[(a)]	76	92
Groundwater Deliveries for Irrigation	4,679	4,818
Shallow Groundwater Uptake	1,107	1,088
Groundwater Discharge to Land Surface	119	102
Total Inflow	9,845	10,226
Runoff to Streams	130	115
ET of Precipitation[(b)]	1,974	2,000
ET of Shallow Groundwater[(b)]	1,107	1,088
ET of Applied Water	3,583	3,704
Groundwater Recharge from Precipitation, Applied Water, and Septic Systems	3,052	3,320
Total Outflow	9,846	10,227

[(a)] A small portion of the Basin receives imported water from the City of Escondido as well as from groundwater pumping wells outside of the SPV GSP Model domain (City of San Diego, 2014).
[(b)] Native vegetation (that is, native shrubs plus riparian vegetation) water demand is met through precipitation and shallow groundwater uptake. The ET of native vegetation is a portion of the sum of the ET of precipitation and the ET of shallow groundwater. The ET of native vegetation alone within the Basin averages 2,328 to 2,387 AFY during the two averaging periods indicated.

According to the SPV GSP Model results, the Basin experienced an average of about 9,900 acre-feet per year (AFY) of land inflows and outflows during the 15-year historical period mostly from groundwater deliveries for irrigation, followed by precipitation, and shallow groundwater uptake by vegetation. During this same period, the largest outflow from the land system was ET of applied water (3,600 AFY) followed by groundwater recharge from precipitation, applied water, and septic system flows that recharged the underlying Basin aquifer.

In the SPV GSP Model, the hierarchy of inflow and outflows under current conditions is the same as that under the historical period. That is, the relative order of the most dominant land system water budget components is identical with the 15-year versus the most recent 5-year averaging periods. Total inflows and outflows under current conditions are about 4 percent higher than the total inflows and outflows under historical conditions.

4.4.2 Surface Water System

Table 4-7 and **Figure 4-13b** present averages of the historical and current surface water system water budgets, whereas **Figure 4-14b** presents the annual time series of the historical and current surface water system water budgets. Attachment 4 provides the annual values for the surface water system water budget components.

According to the SPV GSP Model results, the Basin experienced an average of about 15,000 AFY of surface-water inflows during the 15-year historical period; most stream inflow is from contributing catchments north, east, and south of the Basin. During this same period, approximately 14,000 AFY of streamflow in the San Dieguito River exited the Basin and flowed toward Hodges Reservoir.

Table 4-7. Historical and Current Average Annual Surface Water System Budget

Water Budget Component	Historical Average Annual Flow (AFY) WYs 2005–2019	Current Average Annual Flow (AFY) WYs 2015–2019
Runoff to Streams	130	115
Stream Inflow from Adjacent Areas	13,907	12,796
Groundwater Discharge to Streams	921	861
Total Inflow	14,958	13,772
Stream Outflow to Hodges Reservoir Area	13,714	12,641
Groundwater Recharge from Streams	2,276	2,303
Total Outflow	15,990	14,944

4.4.3 Groundwater System

Table 4-8 and **Figure 4-13c** present averages of the historical and current groundwater system water budgets, whereas **Figure 4-14c** presents the annual time series of the historical and current groundwater system water budgets. Attachment 5 provides the annual values for the groundwater system water budget components.

Table 4-8. Historical and Current Average Annual Groundwater System Budget

Water Budget Component	Historical Average Annual Flow (AFY) WYs 2005–2019	Current Average Annual Flow (AFY) WYs 2015–2019
Groundwater Recharge from Precipitation, Applied Water, and Septic Systems	3,052	3,320
Groundwater Recharge from Streams	2,276	2,303
Subsurface Inflow from Hodges Reservoir Area	18	0
Subsurface Inflow from Adjacent Rock	2,983	3,031
Total Inflow	8,329	8,654
Shallow Groundwater Uptake (ET of Shallow Groundwater)	1,107	1,088
Groundwater Discharge to Streams	921	861
Groundwater Pumping	5,861	6,021
Subsurface Outflow to Hodges Reservoir Area	98	149
Subsurface Outflow to Adjacent Rock	468	486
Groundwater Discharge to Land Surface	119	102
Total Outflow	8,574	8,707
Average of Total Inflows and Outflows	8,452	8,681
Change in Groundwater Storage	-245	-53
Change in Groundwater Storage as a Percent of the Average of Total Inflows and Outflows	2.9%	0.6%

According to SPV GSP Model results, the Basin experienced an average of about 8,300 AFY of groundwater inflows during the 15-year historical period; most of which was in the form groundwater recharge from precipitation, applied water, and septic systems, subsurface inflow from adjacent rock, and groundwater recharge from streams. During this same period, the largest outflow from the groundwater system was groundwater pumping, which serves as the primary source for irrigation in the Basin with pumping rates totaling around 5,900 AFY.

The historical and current groundwater system water budgets indicate an average deficit in the cumulative change in groundwater storage ranging from -53 AFY under current conditions up to -245 AFY under historical conditions. This deficit range represents 0.6 to 3 percent of the average of the groundwater inflows and outflows during the historical and current periods and is more likely than not, within the uncertainty of the estimates of the water budgets. Thus, the estimated deficit is "within the noise" of the groundwater budget, meaning small changes to individual water budget estimates could potentially result in no deficit in the cumulative change in groundwater storage.

4.4.4 Water Supply and Demand

Table 4-9 summarizes annual average supply and demand by water year type within the Basin for the historical and current water budgets. Groundwater serves as the dominant supply source in the Basin, placing a higher demand on pumping during critically dry and dry WYs due to less precipitation. Although surface water that flows through the system is not generally used directly as supply for irrigation, surface water does provide an important source of groundwater recharge to the Basin (see groundwater recharge from streams component in **Figures 4-13c and 4-14c**), making water potentially available to help meet agricultural pumping demands. Annual applied water demands are highest under critically dry and dry years due to the lack of precipitation, lower groundwater levels (and therefore less groundwater uptake), and the need to irrigate to sustain agriculture in the Basin. Changes in groundwater storage vary between WY types with increases in groundwater storage during wet and above normal years and decreases in groundwater storage during normal, dry, and critically dry years.

Table 4-9. Historical and Current Supply and Demand by Water Year Type

Water Budget Component	Wet (AFY)	Above Normal (AFY)	Normal (AFY)	Dry (AFY)	Critically Dry (AFY)
Historical Period (WYs 2005–2019)					
Annual Groundwater Supply	5,199	5,904	5,618	6,237	6,428
Annual Imported Applied Water	67	68	69	65	87
Annual Surface Water Supply	1,110	1,886	1,653	1,269	933
Annual Total Supply	6,376	7,858	7,340	7,571	7,448
Annual Applied Water Demand	3,760	4,223	4,018	4,415	4,570
Change in Stored Groundwater	1,835	683	-405	-1,332	-1,639
Current Period (WYs 2015–2019)					
Annual Groundwater Supply	5,934	6,521	5,484	N/A	6,669
Annual Imported Applied Water	79	114	68	N/A	67
Annual Surface Water Supply	1,864	1,877	1,476	N/A	519
Annual Total Supply	7,877	8,512	7,028	N/A	7,255
Annual Applied Water Demand	4,294	4,686	3,933	N/A	4,834
Change in Stored Groundwater	1,664	18	-573	N/A	-790

N/A = Not applicable because no dry year occurred during the current period
Annual Groundwater Supply = groundwater pumped from the Basin
Annual Imported Water = water imported to the Basin used to meet applied water demand
Annual Surface Water Supply = the net groundwater recharge from streams in the Basin

Water Budget Component	Wet (AFY)	Above Normal (AFY)	Normal (AFY)	Dry (AFY)	Critically Dry (AFY)
Annual Total Supply = sum of the groundwater, imported applied water, and surface water supply *Annual Applied Water Demand = the applied water demand within the Basin*					

Observations of the current supply and demand are consistent with those of the 15-year historical period, except that a dry water year did not occur in WYs 2015 through 2019 (**Table 4-9**).

4.4.5 Sustainable Yield Estimates

Table 4-10 presents the annual agricultural groundwater pumping from the historical groundwater system water budget. According to the SPV GSP Model, agricultural pumping ranged from 4,740 AFY in the wet WY of 2011 to 6,741 AFY in the critically dry WY of 2007. Year-to-year variability plays an important role in the health of the Basin. Sustainable yield is defined in the SGMA regulations as follows:

> *"…the maximum quantity of water calculated over a base period representative of long-term conditions in a basin, including any temporary surplus that can be withdrawn annually from a groundwater supply without causing an undesirable result."*

As described in Section 8 of the Basin GSP, Minimum Thresholds and Measurable Objectives, groundwater levels will be used as a proxy to determine whether an undesirable result has occurred for both chronic lowering of groundwater levels and depletion of groundwater storage. Groundwater levels during the historical water budget period (i.e., WYs 2005 through 2019) do not indicate an undesirable result based on the sustainable management criteria described in Section 8. Therefore, the Basin's sustainable yield is at least higher than historical agricultural pumping (i.e., above the average of the modeled historical pumping rate in the Basin; see statistical summaries at the bottom of Table 4-10.

Table 4-10. Historical Agricultural Pumping Summary

Water Year	Water Year Type	Agricultural Groundwater Pumping (AFY) [(a)]
2005	Wet	4,925
2006	Dry	5,875
2007	Critically Dry	6,741
2008	Normal	5,933
2009	Dry	6,480

Water Year	Water Year Type	Agricultural Groundwater Pumping (AFY) [(a)]
2010	Above Normal	5,287
2011	Wet	4,740
2012	Normal	5,569
2013	Dry	6,356
2014	Critically Dry	5,875
2015	Normal	5,403
2016	Normal	5,565
2017	Wet	5,934
2018	Critically Dry	6,669
2019	Above Normal	6,521
2005–2019 Minimum	N/A	4,740
2005–2019 Average	N/A	5,858
2005–2019 Median	N/A	5,875
2005–2019 Maximum	N/A	6,741

[(a)] *Values do not include groundwater pumping for domestic indoor uses.*

The SPV GSP Model is only one line of analysis being used to help the GSA develop its GSP. The SPV GSP Model does not and will not ultimately decide whether the Basin is being managed sustainably. Field data collection, reporting, and analysis during GSP implementation will be used in conjunction with the established sustainable management criteria to establish a more definitive sustainable yield for the Basin.

4.4.6 Surface Water Depletion

To further evaluate the interaction of surface water and groundwater in the Basin, surface water depletions from streams were evaluated. **Figure 4-15** depicts the surface water depletion summary reaches within the Basin that were analyzed. Modeled estimates of groundwater recharge from streams and groundwater discharge to streams were processed for each summary reach to gain insight into whether these reaches were primarily gaining water from or losing water to the underlying aquifer during the historical calibration period. The annual net gain of groundwater in the stream reaches was calculated as shown in **Equation 4-1**, as follows:

Net Gain = Groundwater Discharge to Stream Reach – Groundwater Recharge from Stream Reach (4-1)

Thus, positive values indicate primarily gaining conditions in the stream reach and negative values indicate primarily losing conditions in the stream reach during a given year. **Table 4-11** lists the annual net gain of groundwater for each summary reach for the historical calibration period. In general on an annual basis, stream reaches in the eastern portion of the Basin primarily lose water to the aquifer and are potentially disconnected from the water table, whereas stream reaches in the western portion of the Basin are interconnected with groundwater and primarily gain water from the aquifer. Because losing stream reaches can still be interconnected with groundwater, the modeled stream bottoms were also intersected with the average monthly, modeled water table from WY 2005 through 2019 to help assess locations of interconnected streams. This analysis showed good consistency with the interpretation of interconnect streams depicted in Figure 4-15.

To aid in the development of sustainable management criteria (see Section 8 of the GSP for more details), estimates of surface water depletion due to groundwater pumping were needed. To achieve this, two model simulations were utilized including the historical calibration simulation, which includes agricultural and domestic groundwater pumping, and an identical simulation, but with the following processes turned off:

- Agricultural groundwater pumping and irrigation in parcels served by those associated pumping wells
- Domestic groundwater pumping for indoor use and the associated groundwater recharge from septic systems

All other processes remained consistent with the historical calibration simulation. Next, total annual streamflows at the downstream ends of each stream summary reach shown in **Figure 4-15** were compiled for each simulation and the differences in these streamflows between the two different simulations (i.e., with and without pumping-related processes) were compiled.

Table 4-12 lists the estimated annual depletions of surface water due to groundwater pumping from each stream summary reach. As inferred from **Figure 4-15**, if there is any remaining surface water in each summary stream reach, that water would be routed to the next downgradient reach until the San Dieguito River-West summary reach, which is the final reach of the modeled stream system. Thus, the overall depletion of surface water in the Basin due to groundwater pumping is best estimated using the outflows from the San Dieguito River-West summary reach. As shown in **Table 4-12**, the estimated annual average depletion of surface water from the San Dieguito River-West summary reach is approximately 3,500 AFY. Thus, on average during the historical calibration period, a depletion of surface water from the Basin streams of about 3,500 AFY results from about 5,900 AFY (see **Table 4-8** in Section 4.4.3) of groundwater pumping in the Basin.

Table 4-11. Net Gain of Groundwater by Stream Summary Reach

	Disconnected Streams					Interconnected Streams			
Water Year	Santa Ysabel Creek–East	Guejito Creek	Santa Ysabel Creek–West	Safari Park Outlet	Santa Maria Creek	San Dieguito River–East	Cloverdale Creek	Sycamore Creek	San Dieguito River–West
	Disconnected Streams					Interconnected Streams			
2005 (W)	-1,138	-353	0	-2	40	603	246	7	486
2006 (D)	-652	-247	-346	0	-347	295	69	-23	-62
2007 (C)	-254	-162	-64	-1	-257	86	13	-4	-137
2008 (N)	-864	-266	-808	-9	-413	69	52	-13	-83
2009 (D)	-580	-203	-396	-8	-351	146	60	-14	42
2010 (AN)	-837	-321	-684	-10	-504	228	100	-16	157
2011 (W)	-1,201	-391	-637	-8	-345	478	202	13	575
2012 (N)	-680	-291	-442	-2	-410	397	94	-27	51
2013 (D)	-454	-264	-215	-7	-426	228	65	-16	-84
2014 (C)	-459	-289	-107	-4	-464	79	36	-9	-276
2015 (N)	-502	-268	-146	-5	-412	32	39	-18	-153
2016 (N)	-586	-251	-317	-8	-462	58	56	-14	24
2017 (W)	-948	-287	-837	-15	-605	284	142	1	418
2018 (C)	-472	-156	-248	-10	-352	326	110	1	293
2019 (AN)	-850	-229	-640	-9	-532	194	88	-16	124
Historical Average (2005–2019)	-698	-265	-392	-7	-389	234	91	-10	92

Net gains of groundwater in the stream reaches were calculated by subtracting the annual groundwater recharge from the stream reach from the annual groundwater discharge to the stream reach. Thus, positive values indicate primarily gaining conditions, whereas negative values indicate primarily losing conditions.

Table 4-12. Annual Depletion of Surface Water from Groundwater Pumping by Stream Summary Reach

	Disconnected Streams					Interconnected Streams			
Water Year	Santa Ysabel Creek–East	Guejito Creek	Santa Ysabel Creek–West	Safari Park Outlet	Santa Maria Creek	San Dieguito River–East	Cloverdale Creek	Sycamore Creek	San Dieguito River–West
	Disconnected Streams					Interconnected Streams			
2005 (W)	1,367	121	2,843	5	661	3,860	47	13	4,295
2006 (D)	560	34	1,433	1	609	2,522	43	2	2,698
2007 (C)	91	8	456	1	453	1,517	47	0	1,626
2008 (N)	816	60	2,270	3	752	3,715	70	5	4,093
2009 (D)	619	50	1,698	3	706	3,067	65	4	3,306
2010 (AN)	991	92	2,601	4	945	4,183	81	8	4,550
2011 (W)	1,620	174	3,597	7	917	4,913	50	7	5,259
2012 (N)	638	59	1,674	1	689	2,778	51	1	3,014
2013 (D)	364	38	1,073	2	683	2,314	66	1	2,521
2014 (C)	289	38	797	2	687	2,160	87	1	2,423
2015 (N)	407	41	1,058	2	694	2,526	106	1	2,810
2016 (N)	543	58	1,432	2	764	2,957	98	1	3,132
2017 (W)	1,267	131	3,316	11	1,177	5,125	83	6	5,470
2018 (C)	690	58	1,913	5	849	3,391	64	3	3,629
2019 (AN)	929	64	2,378	4	930	3,942	63	4	4,144
Historical Average (2005–2019)	746	68	1,903	4	768	3,265	68	4	3,531

4.5 Calibration Sensitivity Overview

During the model calibration effort, numerous simulations were run to refine parameter estimates and improve fits to the target groundwater levels, VHDs, and inflows to Hodges Reservoir. As with any numerical flow model, improvements to some calibration targets resulted in worse fits to other calibration targets, forcing the modeler to try and strike a reasonable balance when deciding on final sets of parameter values. Through this calibration process, sensitivities of various parameters were noted relative to calibration targets. **Table 4-13** provides a high-level summary of observations related to parameter sensitivities during the calibration effort.

Table 4-13. Overview of Parameter and Process Sensitivities to Calibration Targets

Parameter or Process	Sensitivity
Bedrock K_h	Groundwater levels and temporal groundwater-level trends are sensitive to K_h values assigned in the bedrock. Lower values of bedrock K_h tend to steepen temporal declines in modeled hydrographs. Thus, inclusion of the bedrock area surrounding and underlying the Basin proved to be an important step in the learning process and gaining insights into the potential hydraulic interplay between the Basin and its surrounding environment.
Bedrock K_v	VHDs are not sensitive to K_h in the Basin but are moderately sensitive to bedrock K_v values. Larger K_v values near bedrock pumping wells result in larger downward hydraulic gradients that more closely match VHDs at USGS multi-completion wells.
Subsurface Inflow from Contributing Catchments	Basin groundwater levels from wells in the western portion of the Basin are not sensitive to these subsurface inflows; however, groundwater levels from eastern wells are moderately sensitive to these subsurface inflows. Outflows to Hodges Reservoir have low to moderate sensitivity to these subsurface inflows during non-wet WYTs.
Storativity	Groundwater-level hydrographs have low to moderate sensitivities to S_y and S_s.
FMP Parameters	Although some aspects of the water budgets change in response to changes in the FMP input assumptions, the modeled hydrographs had low to moderate sensitivity to these parameters.
Streambed Hydraulic Conductivity	Global calibration statistics are not very sensitive to this parameter. The lack of sensitivity is likely due to the fact that most streams in the Basin do not regularly flow. Thus, simulations with different streambed hydraulic conductivity values for mostly dry stream beds did not provide substantially different results.

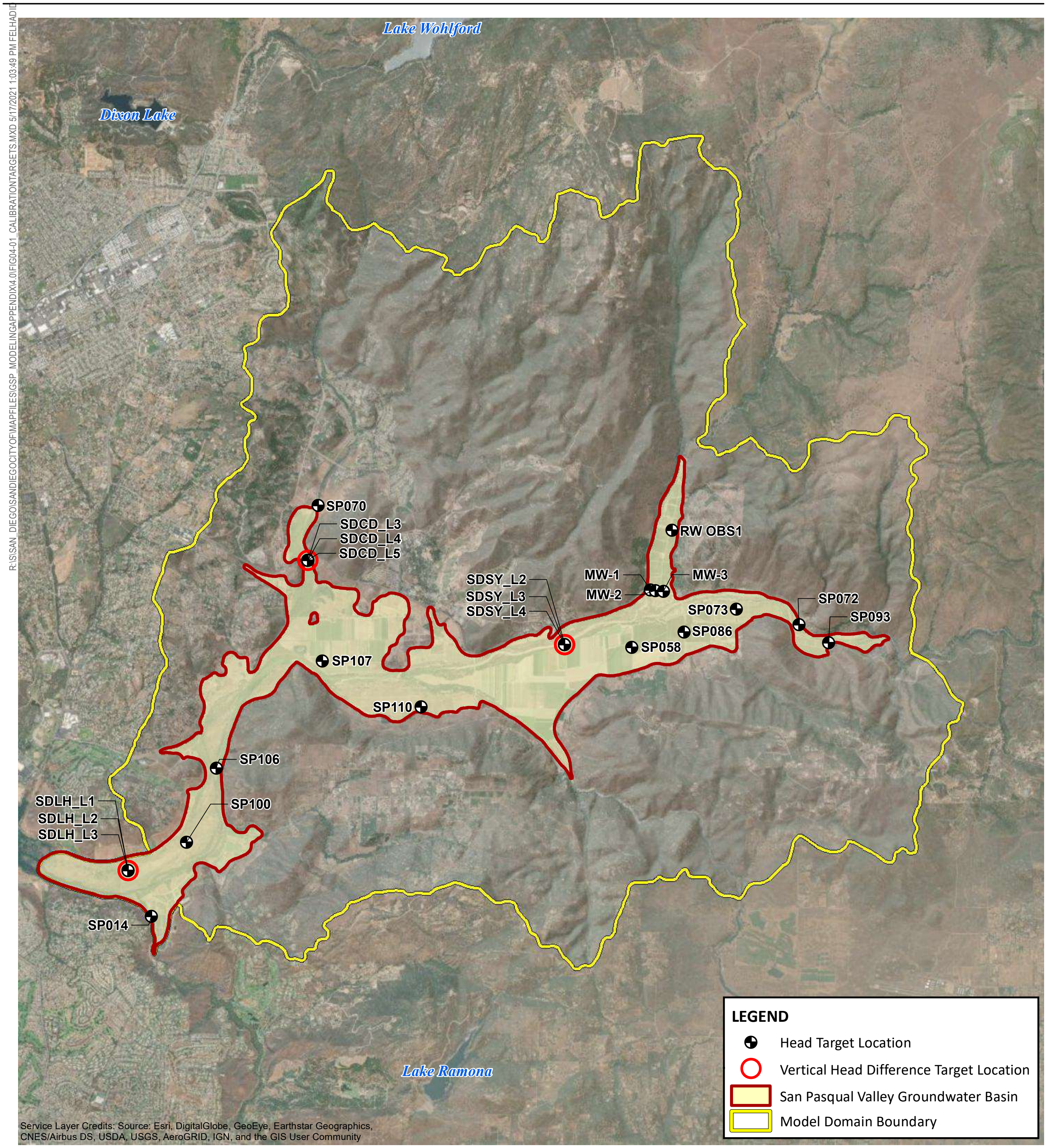

FIGURE 4-1
Calibration Target Locations
Numerical Flow Model Documentation
San Pasqual Valley Groundwater Basin
Groundwater Sustainability Plan
San Pasqual Valley, California

Jacobs

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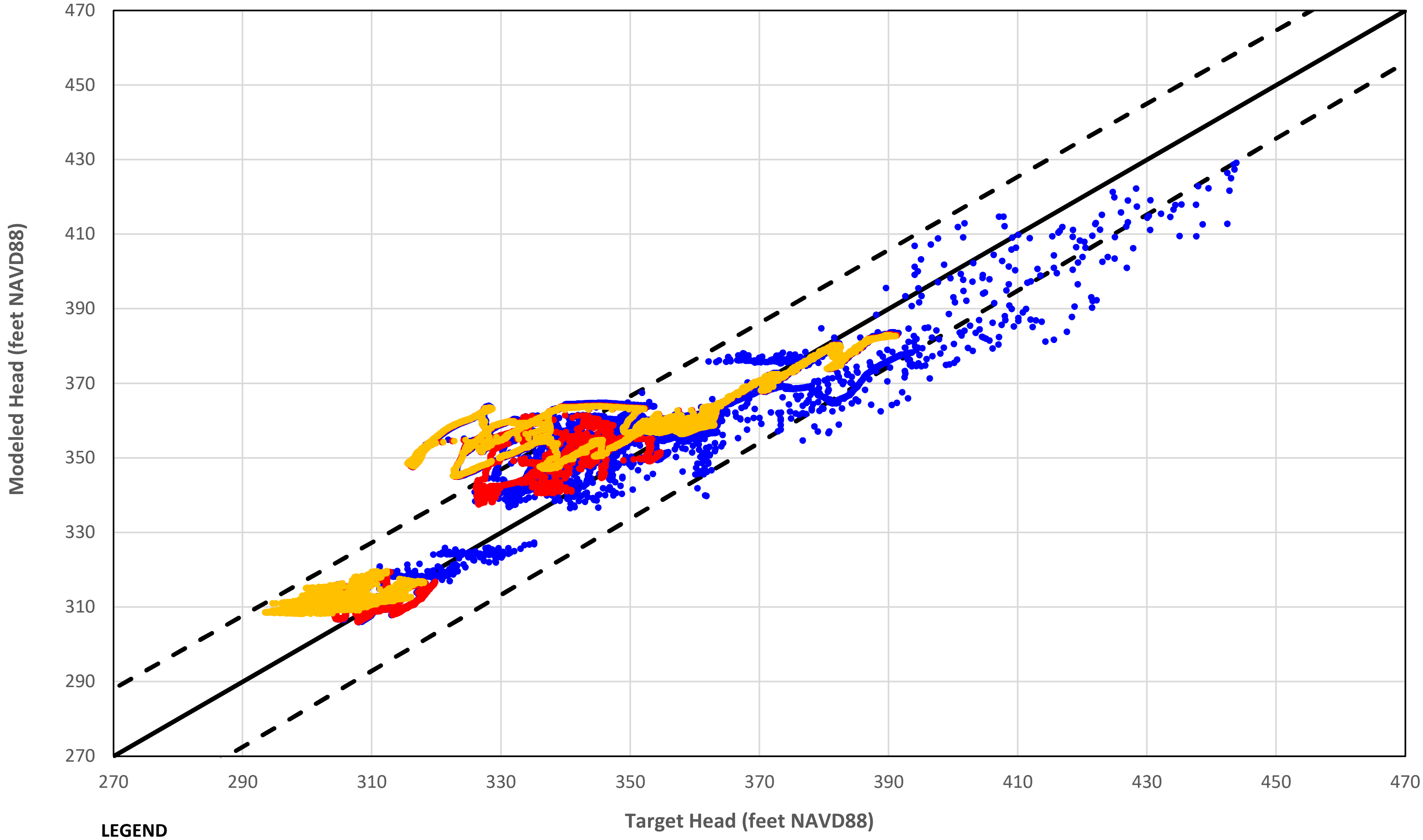

LEGEND

- Model Layer 1
- Model Layer 2
- Model Layer 3
- One-to-One Correlation Line
- ± 1 Standard Deviation Line

NOTE:

NAVD88 = North American Vertical Datum of 1988.

FIGURE 4-2

Modeled Versus Target Groundwater Elevations

Numerical Flow Model Documentation
San Pasqual Valley Groundwater Basin
Groundwater Sustainability Plan
San Pasqual Valley, California

\\Odin\proj\SanDiegoCityof\CommonFiles\SGMA\2022_GSP\GSP\ModelingAppendix\Figures\XLSX\4.0\FIG04-02_25Perc_BCMRCH_GlobalScatter.xlsx\FIG04-2

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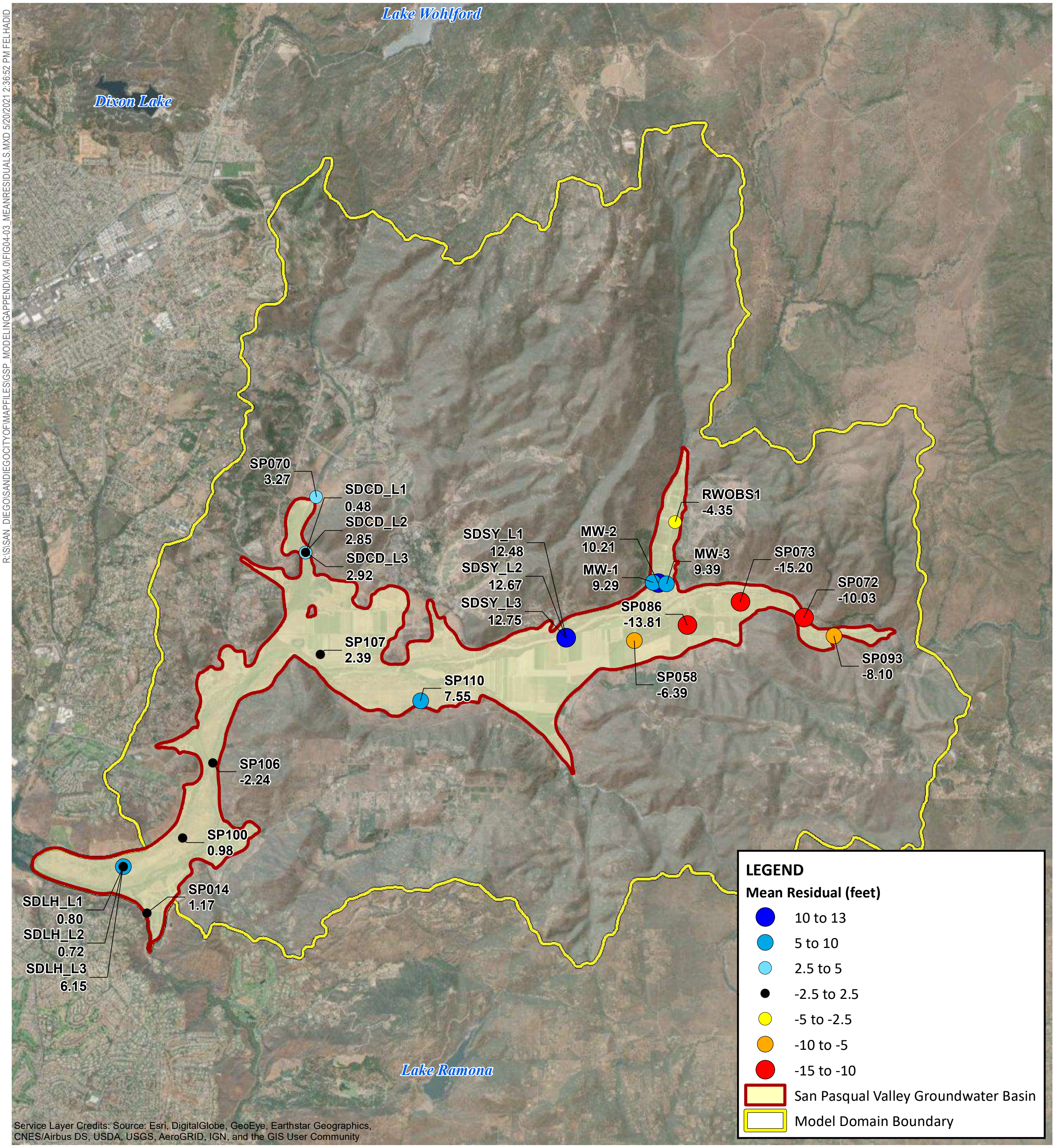

NOTE:
The residual is computed by subtracting the target (measured) groundwater elevation from the modeled groundwater elevation. The mean residual values represent the average of the residuals from all measurement times at a given target well during the calibration period.

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FIGURE 4-3
Map of Mean Residuals
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Groundwater Sustainability Plan
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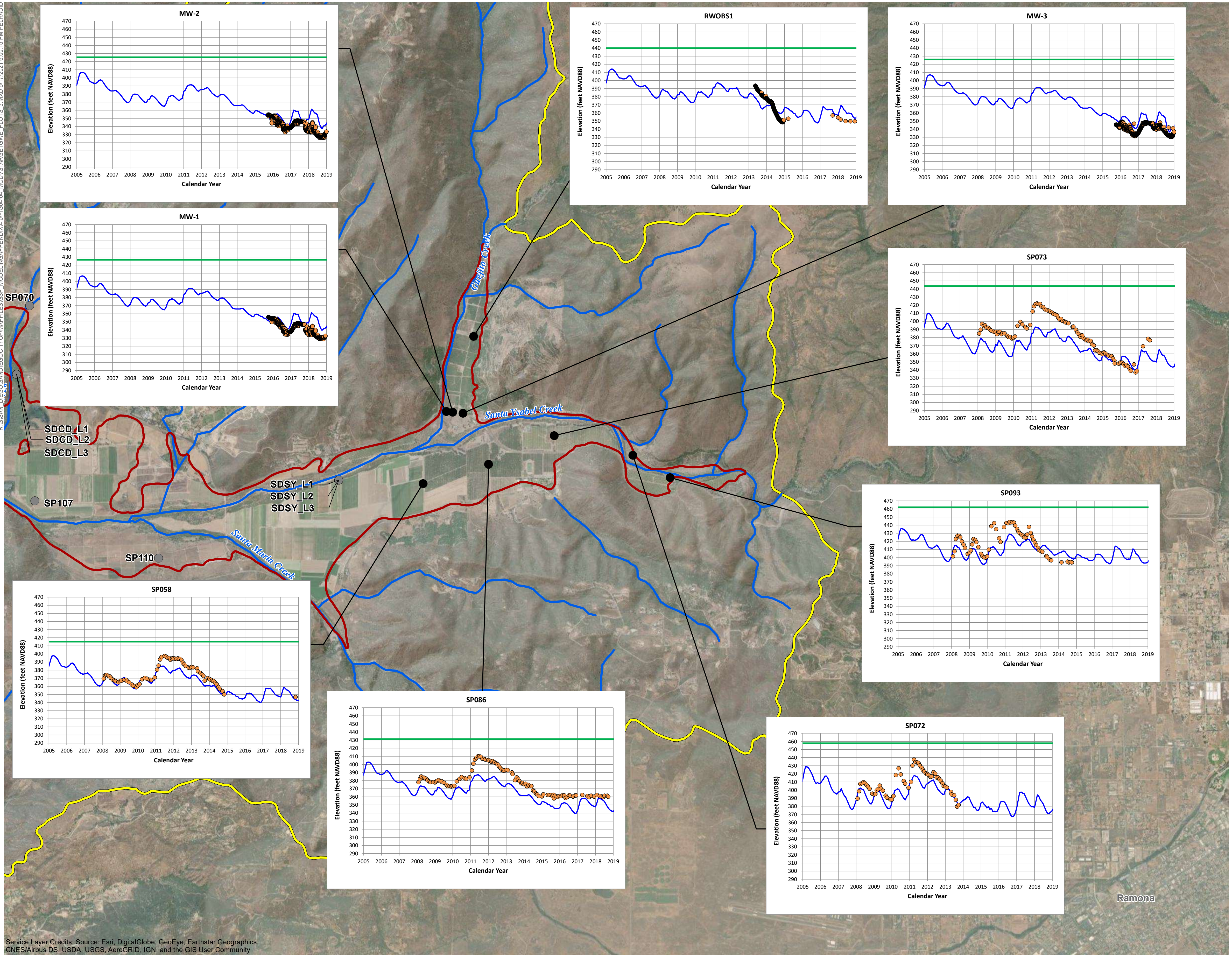
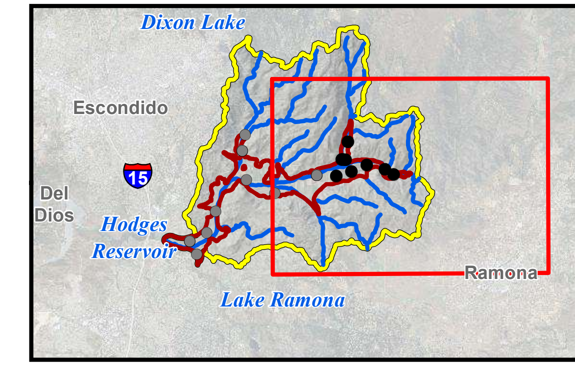


EXTENT INDICATOR



MAP LEGEND

- Calibration Target Well Location
- Modeled Stream
- San Pasqual Valley Groundwater Basin
- Model Domain Boundary

GRAPH LEGEND

- Target Groundwater Elevation (feet NAVD88)
- Modeled Groundwater Elevation (feet NAVD88)
- Ground Surface Elevation (feet NAVD88)

N

0 4,000 8,000
Feet

FIGURE 4-4 (PAGE 1 OF 3)

Modeled Versus Target Groundwater-level Hydrographs

Numerical Flow Model Documentation
San Pasqual Valley Groundwater Basin
Groundwater Sustainability Plan
San Pasqual Valley, California

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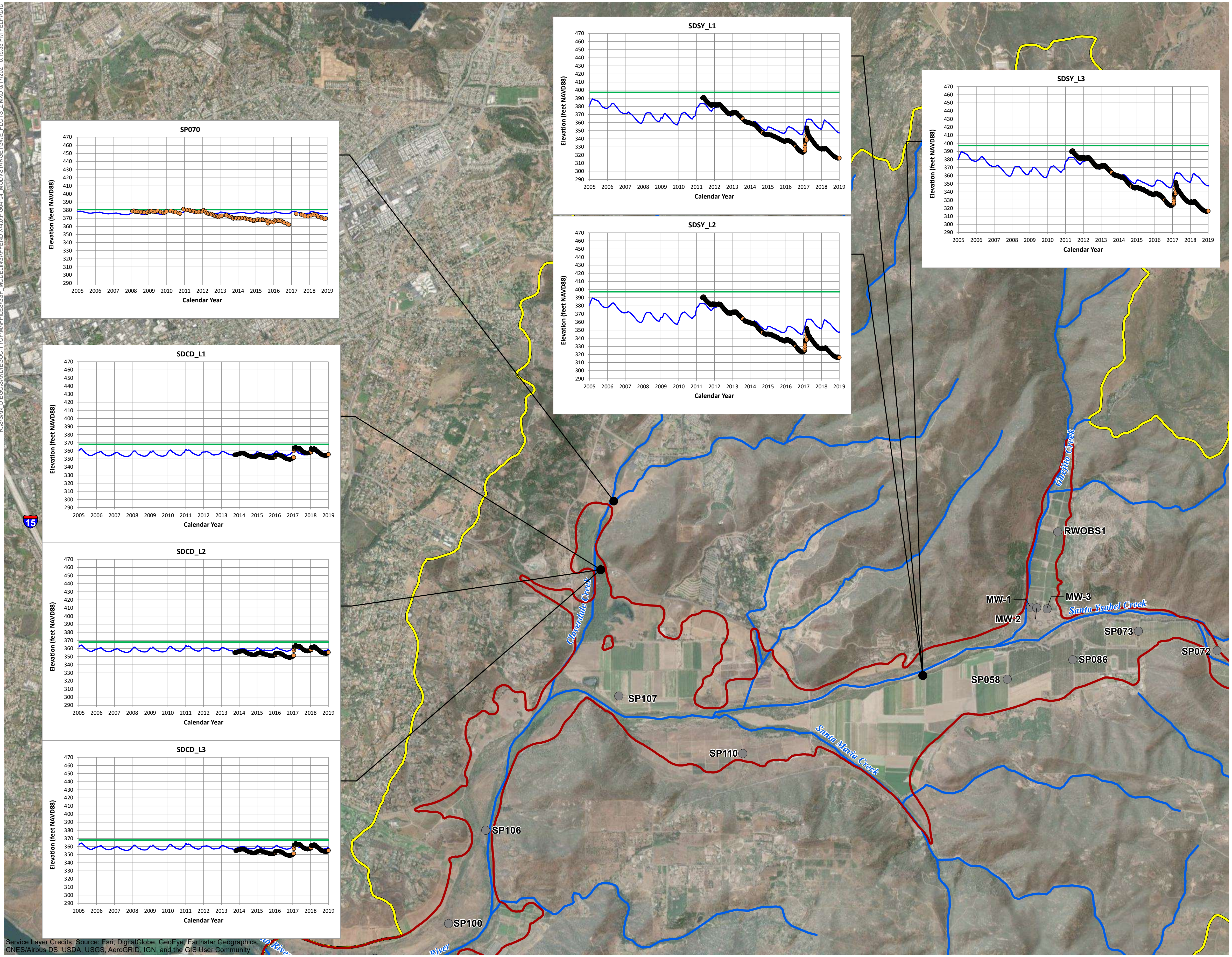
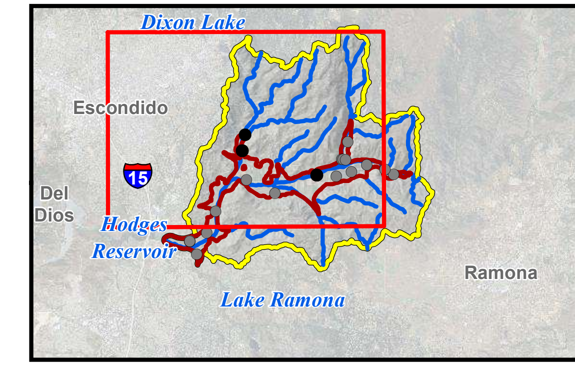


EXTENT INDICATOR



MAP LEGEND

- Calibration Target Well Location
- Modeled Stream
- San Pasqual Valley Groundwater Basin
- Model Domain Boundary

GRAPH LEGEND

- Target Groundwater Elevation (feet NAVD88)
- Modeled Groundwater Elevation (feet NAVD88)
- Ground Surface Elevation (feet NAVD88)

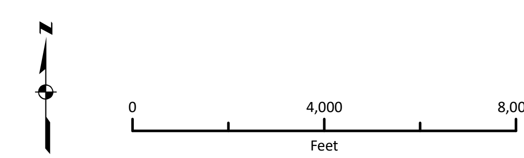


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FIGURE 4-4 (PAGE 2 OF 3)

Modeled Versus Target Groundwater-level Hydrographs

Numerical Flow Model Documentation
San Pasqual Valley Groundwater Basin
Groundwater Sustainability Plan
San Pasqual Valley, California

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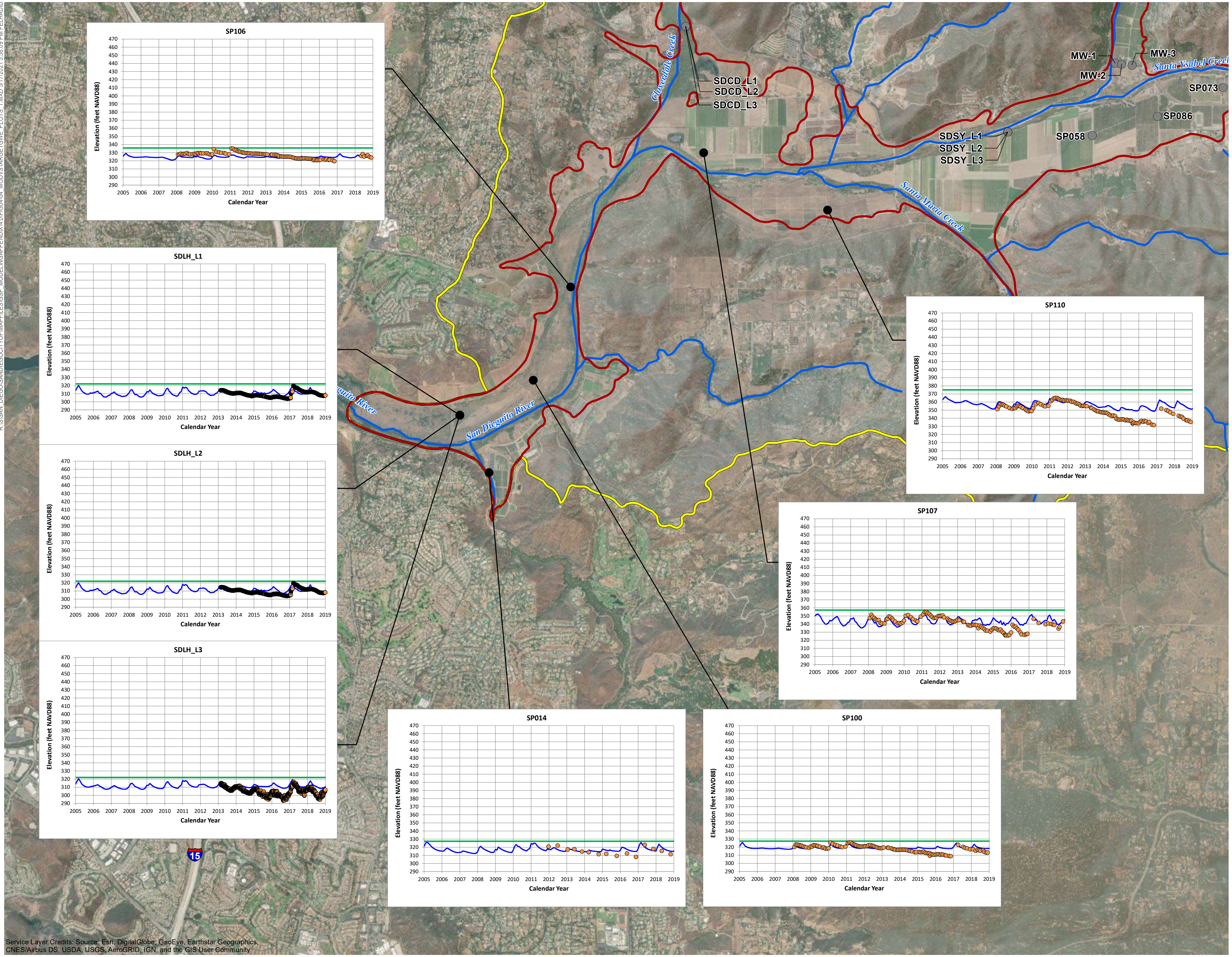
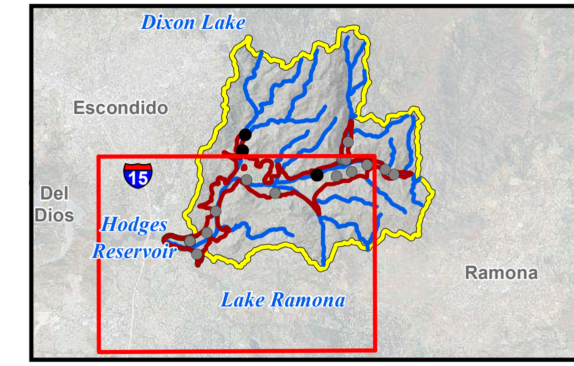


EXTENT INDICATOR



MAP LEGEND

- Calibration Target Well Location
- Modeled Stream
- San Pasqual Valley Groundwater Basin
- Model Domain Boundary

GRAPH LEGEND

- Target Groundwater Elevation (feet NAVD88)
- Modeled Groundwater Elevation (feet NAVD88)
- Ground Surface Elevation (feet NAVD88)

N

0 4,000 8,000
Feet

The City of SAN DIEGO

FIGURE 4-4 (PAGE 3 OF 3)
Modeled Versus Target Groundwater-level Hydrographs
Numerical Flow Model Documentation
San Pasqual Valley Groundwater Basin
Groundwater Sustainability Plan
San Pasqual Valley, California

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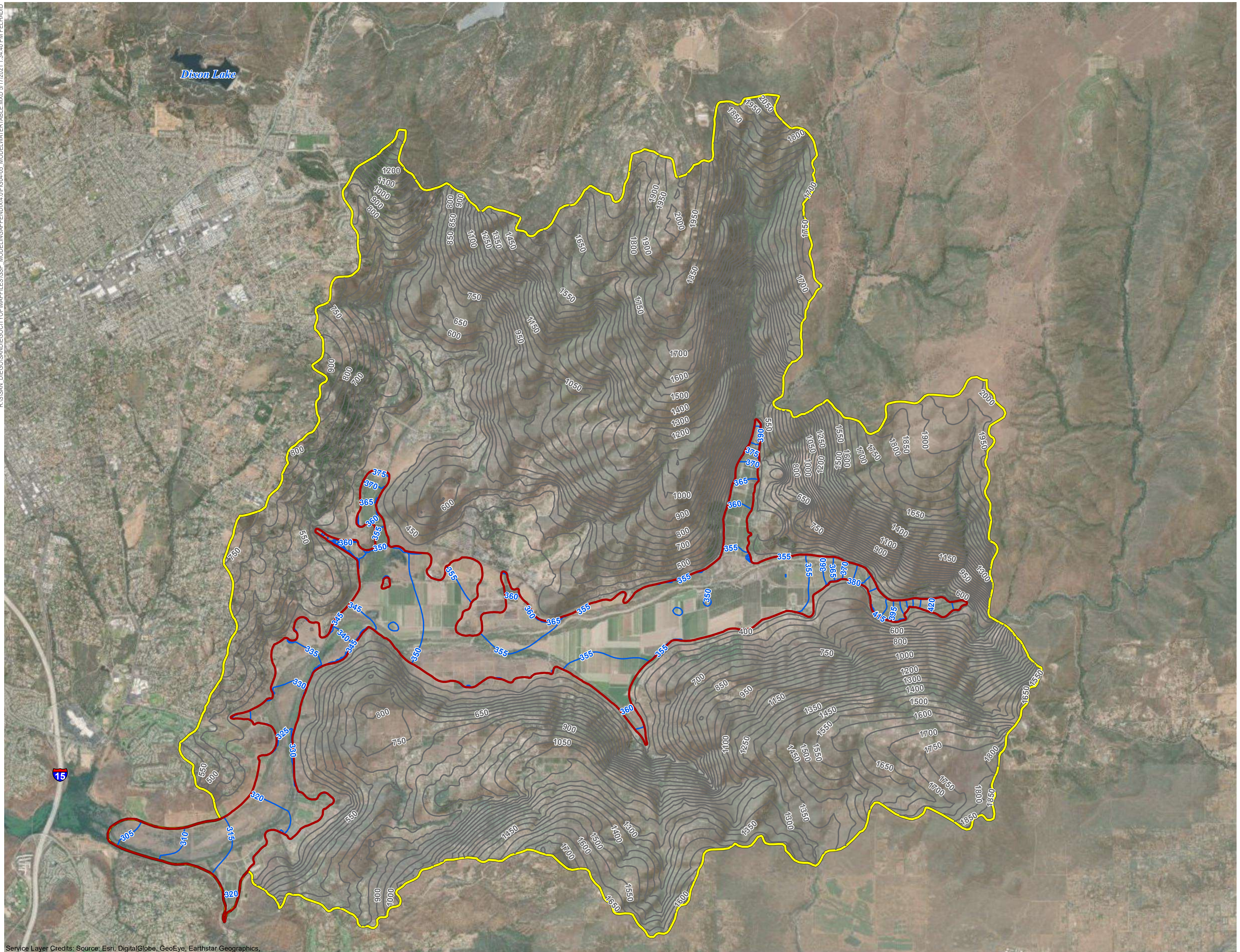

LEGEND

- Model Domain Boundary
- San Pasqual Valley Groundwater Basin

Water Table Elevation Contour (feet NAVD88)

- Contour Interval = 5 feet
- Contour Interval = 50 feet

NOTES:

Contours represent May 2016 conditions, which is a normal precipitation year.

NAVD88 = North American Vertical Datum of 1988.

N

0 5,000 10,000
Feet

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FIGURE 4-5

Modeled Water Table During a Normal Water Year

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San Pasqual Valley Groundwater Basin

Groundwater Sustainability Plan

San Pasqual Valley, California

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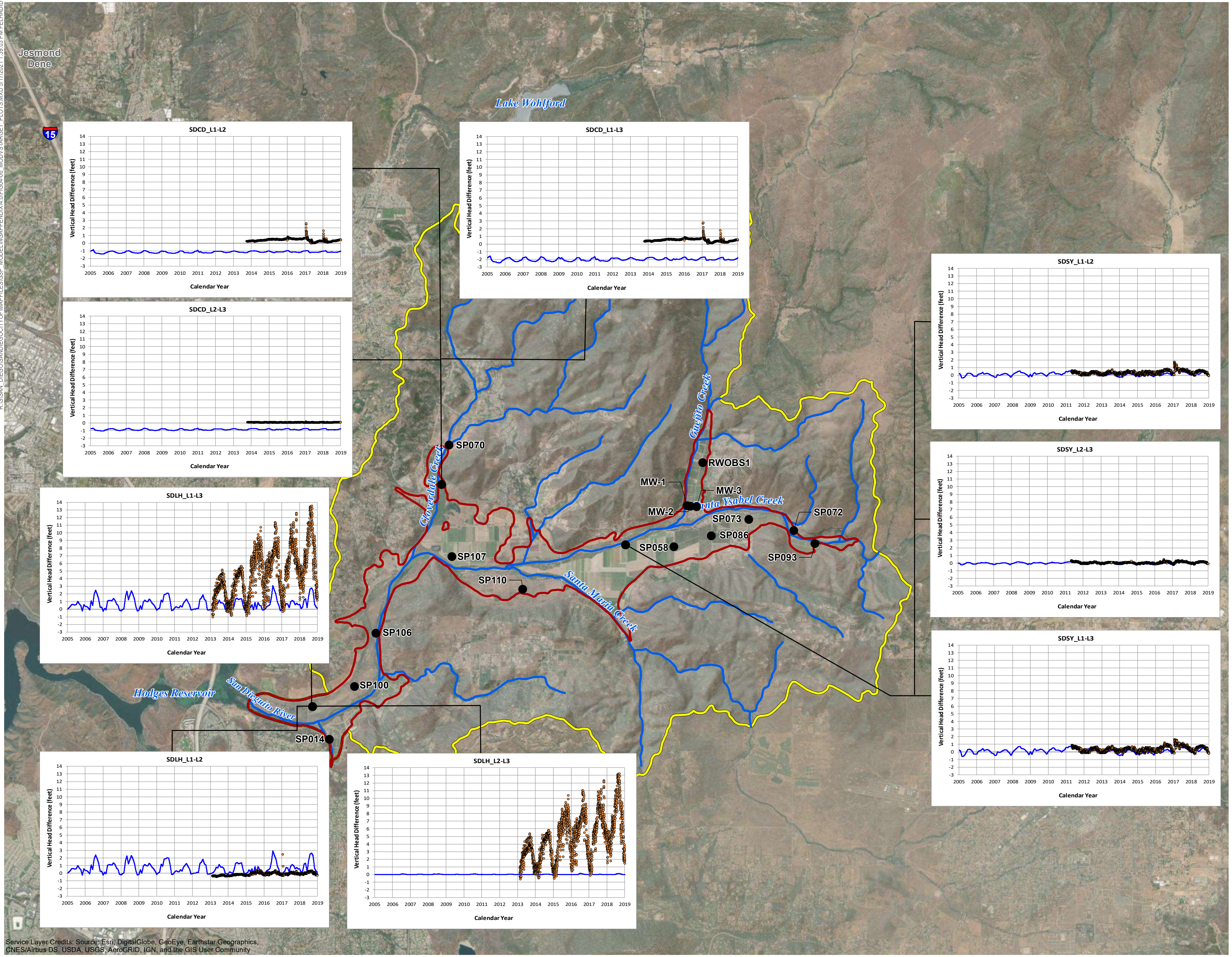

MAP LEGEND

- Calibration Target Well Location
- Modeled Stream
- San Pasqual Valley Groundwater Basin
- Model Domain Boundary

GRAPH LEGEND

- Target Vertical Head Difference (feet)
- Modeled Vertical Head Difference (feet)

N

0 7,000 14,000
Feet

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FIGURE 4-6

Modeled Versus Target Vertical Head Difference Hydrographs

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San Pasqual Valley Groundwater Basin

Groundwater Sustainability Plan

San Pasqual Valley, California

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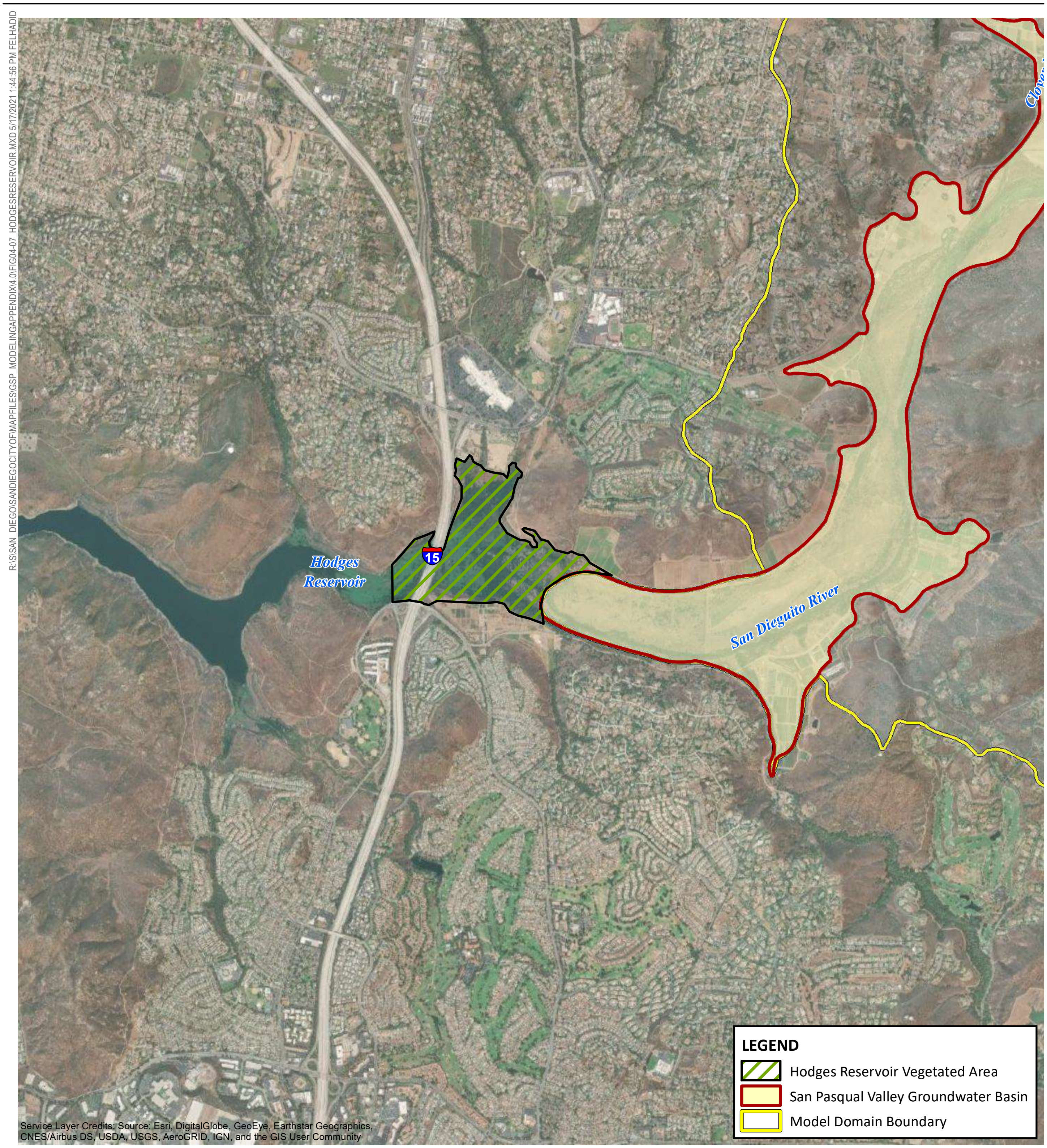

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FIGURE 4-7
Hodges Reservoir Vegetated Area
Numerical Flow Model Documentation
San Pasqual Valley Groundwater Basin
Groundwater Sustainability Plan
San Pasqual Valley, California

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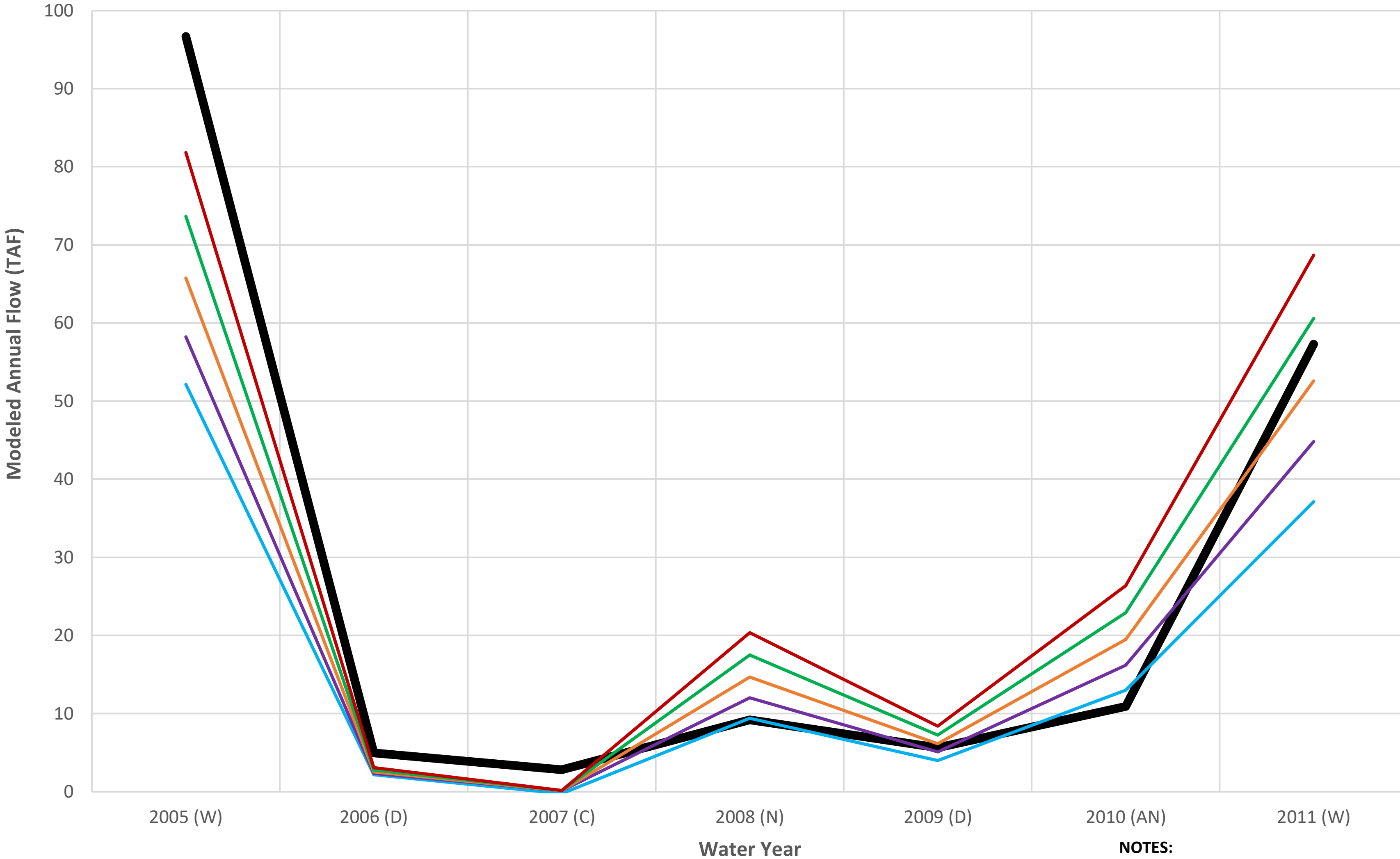

LEGEND

- CWASim Inflow to Hodges Reservoir
- 0% ET-adjusted BCM Recharge
- 25% ET-adjusted BCM Recharge
- 50% ET-adjusted BCM Recharge
- 75% ET-adjusted BCM Recharge
- 100% ET-adjusted BCM Recharge

NOTES:
BCM = Basin Characterization Model
ET = evapotranspiration
TAF = thousand acre-feet

FIGURE 4-8
Comparison of Modeled Inflows to Hodges Reservoir
Numerical Flow Model Documentation
San Pasqual Valley Groundwater Basin
Groundwater Sustainability Plan
San Pasqual Valley, California

\\odin\proj\SanDiegoCityof\CommonFiles\SGMA\2022_GSP\GSP\ModelingAppendix\Figures\XLSX\4.0\FIG04-08_CompModeled_IF_Hodges.xlsx\FIG04-8

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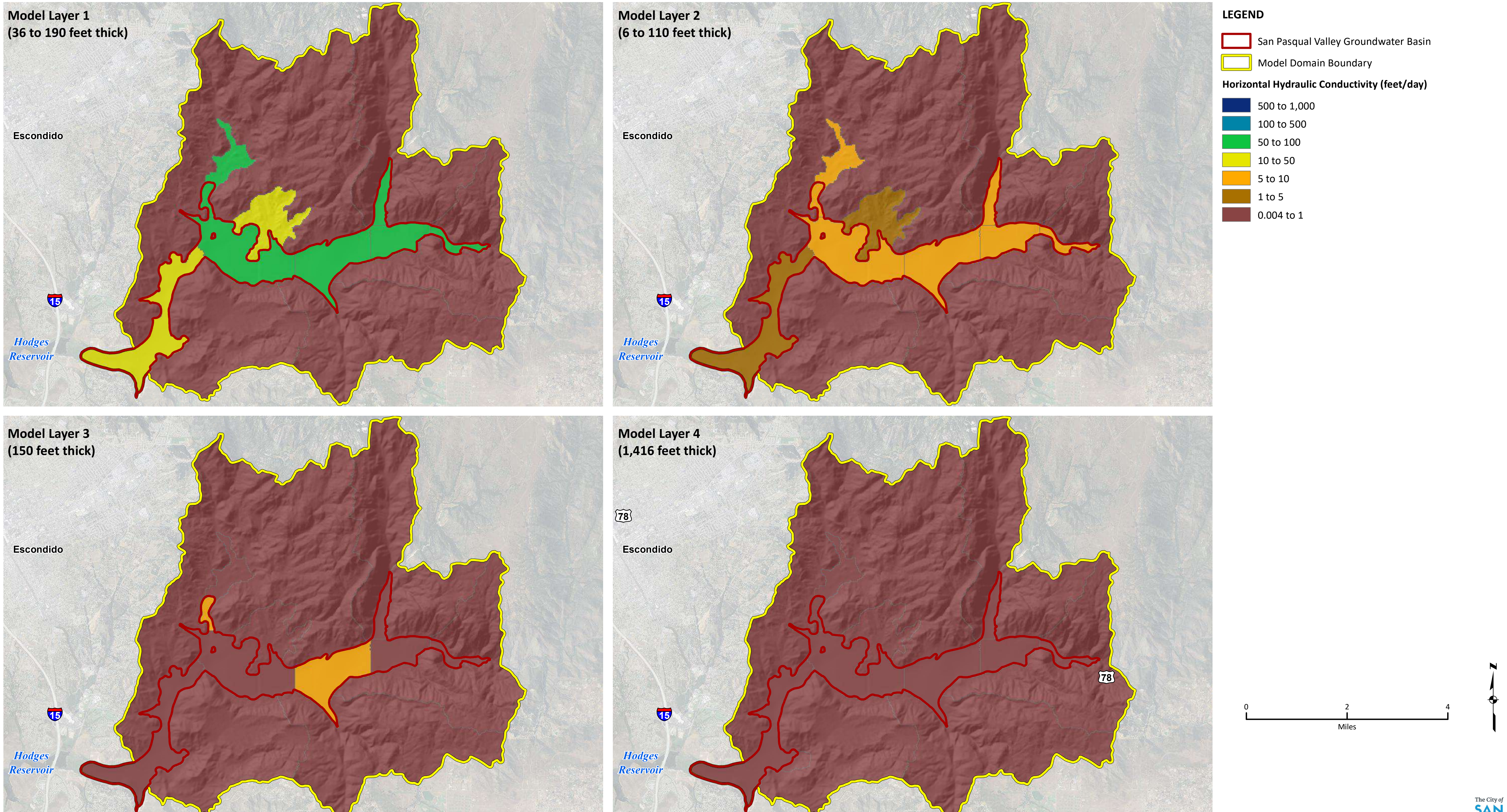

FIGURE 4-9
Calibrated Horizontal Hydraulic Conductivity
Numerical Flow Model Documentation
San Pasqual Valley Groundwater Basin
Groundwater Sustainability Plan
San Pasqual Valley, California

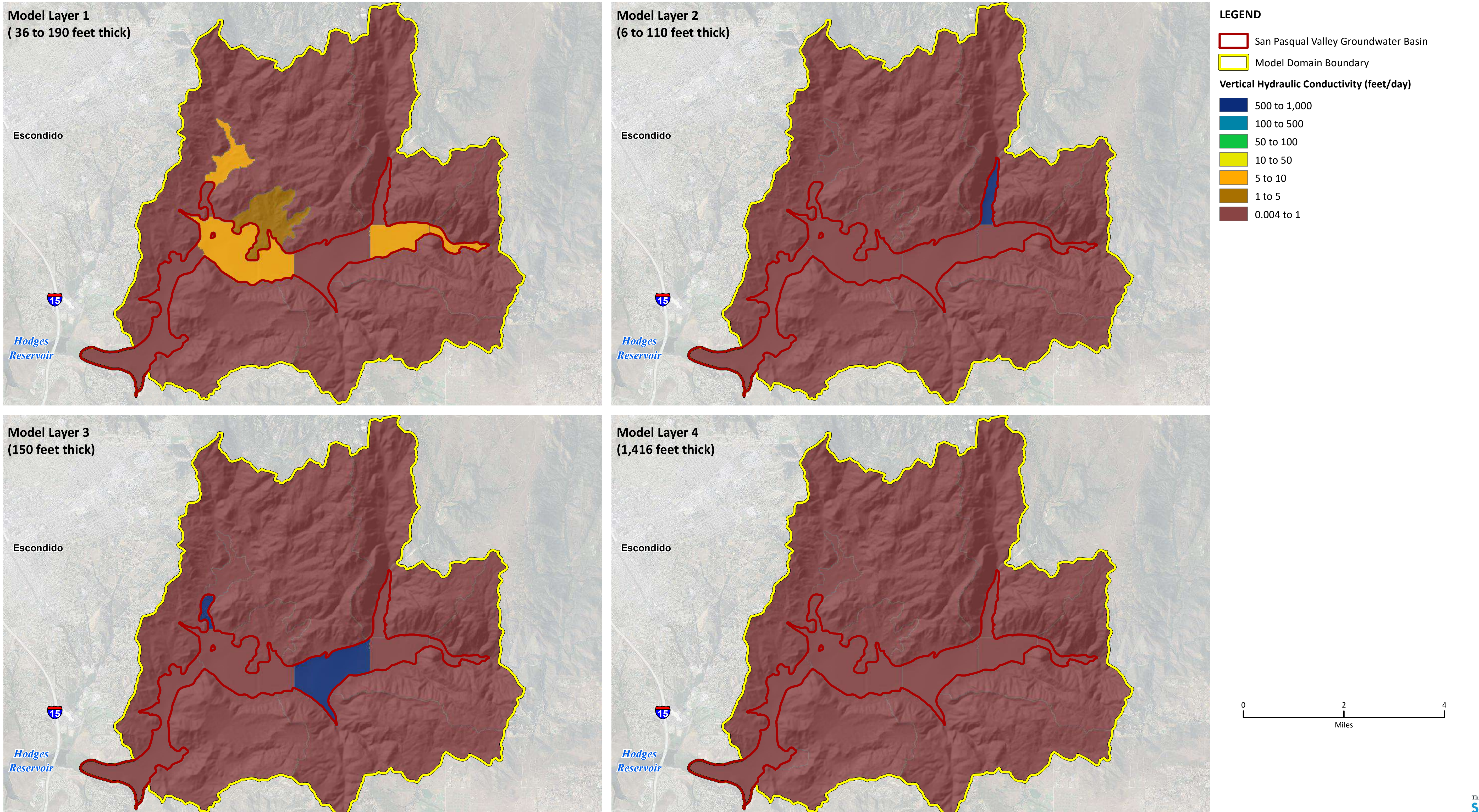

FIGURE 4-10
Calibrated Vertical Hydraulic Conductivity
Numerical Flow Model Documentation
San Pasqual Valley Groundwater Basin
Groundwater Sustainability Plan
San Pasqual Valley, California

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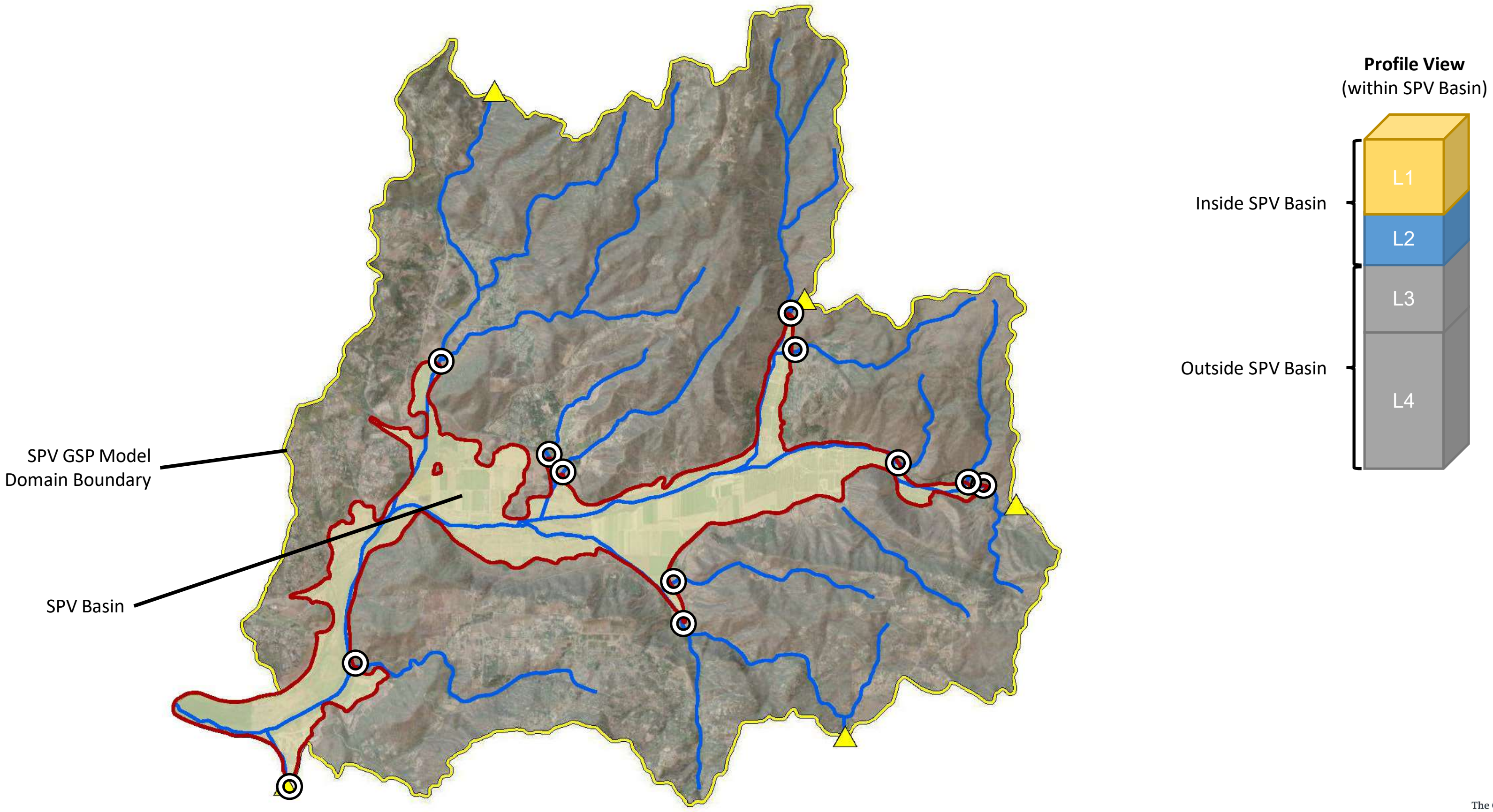
LEGEND

△ Location of Stream Inflow to SPV GSP Model Domain

◎ Location of Stream Inflow to SPV Basin

━ Modeled Stream



NOTE:
The water budget reference volume includes Model Layers 1 and 2 within the lateral limits of the San Pasqual Valley (SPV) Basin.

FIGURE 4-11
Water Budget Reference Volume
Numerical Flow Model Documentation
San Pasqual Valley Groundwater Basin
Groundwater Sustainability Plan
San Pasqual Valley, California

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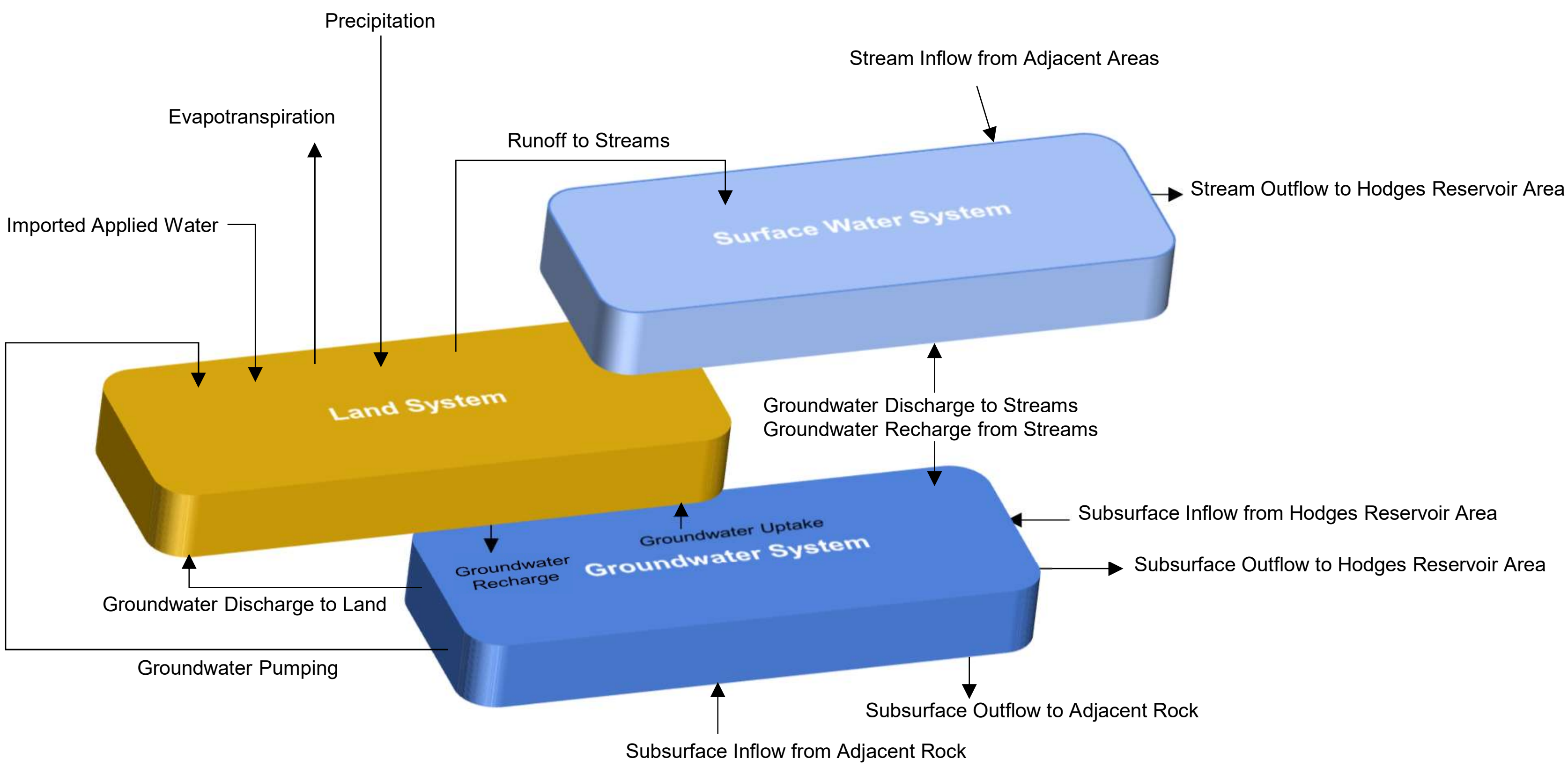

FIGURE 4-12

Generalized Water Budget Diagram

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San Pasqual Valley Groundwater Basin
Groundwater Sustainability Plan
San Pasqual Valley, California

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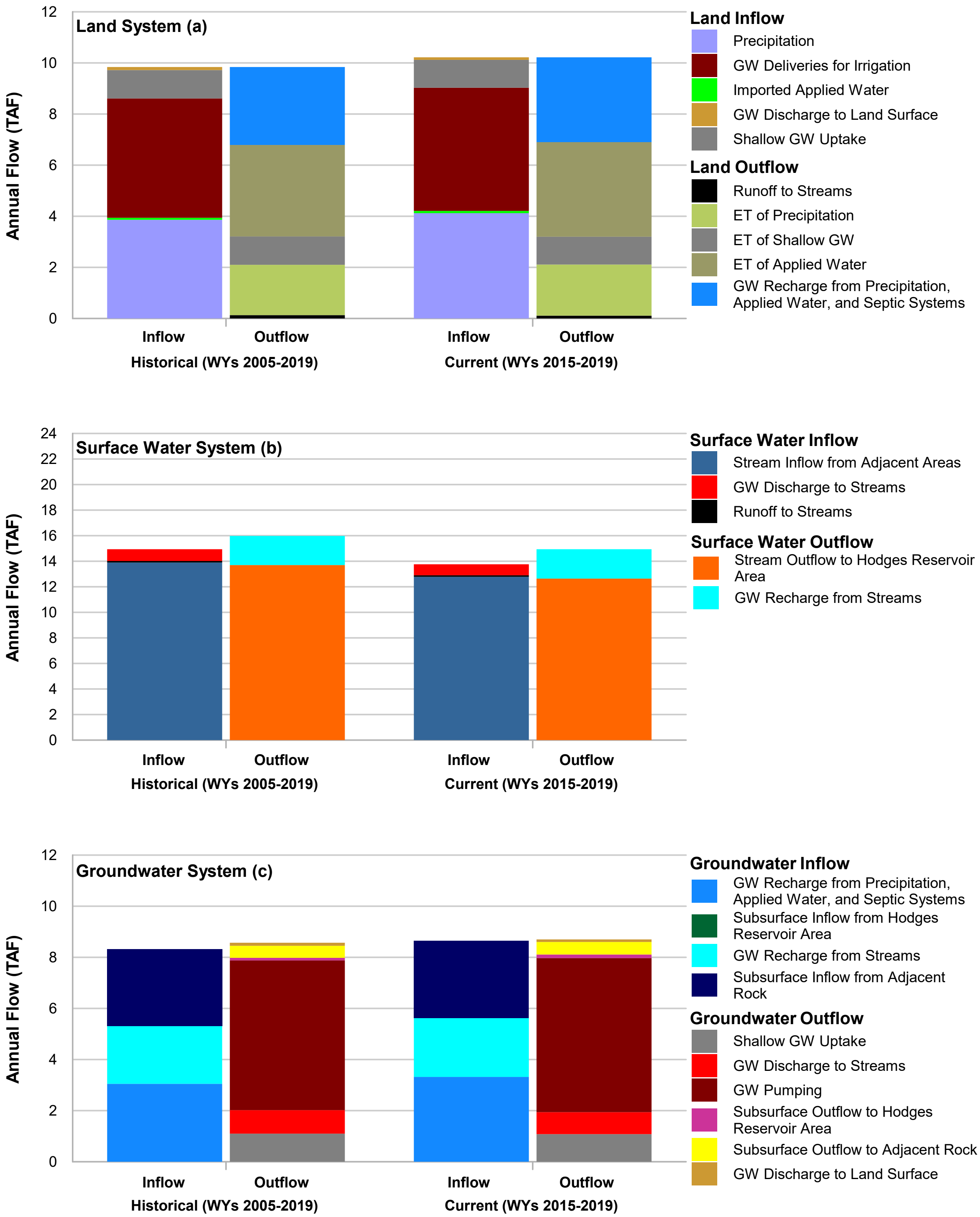

NOTES:

ET = Evapotranspiration
GW = Groundwater
TAF = thousand acre-feet
WY = Water Year

FIGURE 4-13

Historical and Current Average Annual Water Budgets

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San Pasqual Valley Groundwater Basin
Groundwater Sustainability Plan
San Pasqual Valley, California

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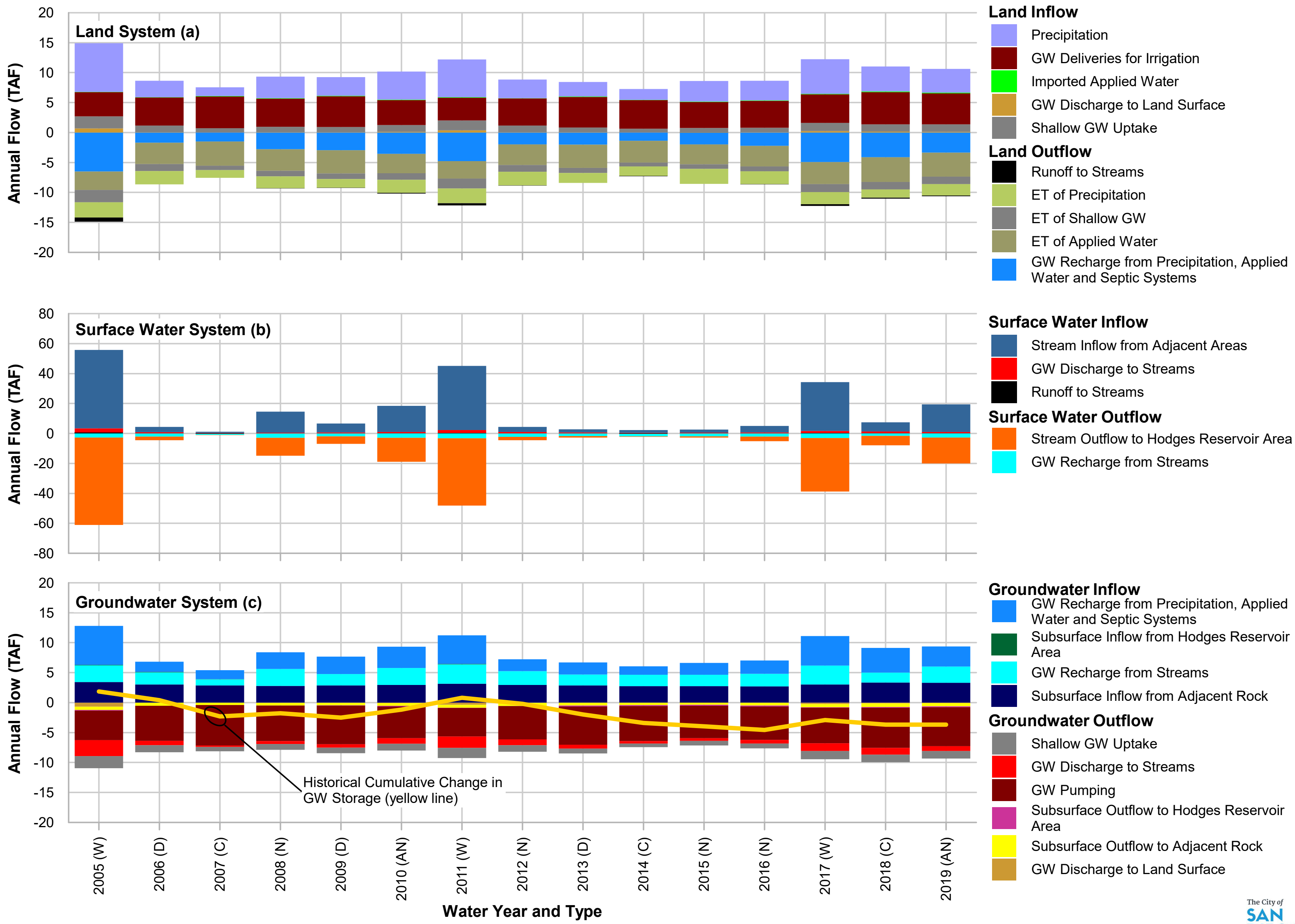

NOTES:

ET = Evapotranspiration
GW = Groundwater
TAF = thousand acre-feet

FIGURE 4-14
Time-series Annual Water Budgets
Numerical Flow Model Documentation
San Pasqual Valley Groundwater Basin
Groundwater Sustainability Plan
San Pasqual Valley, California

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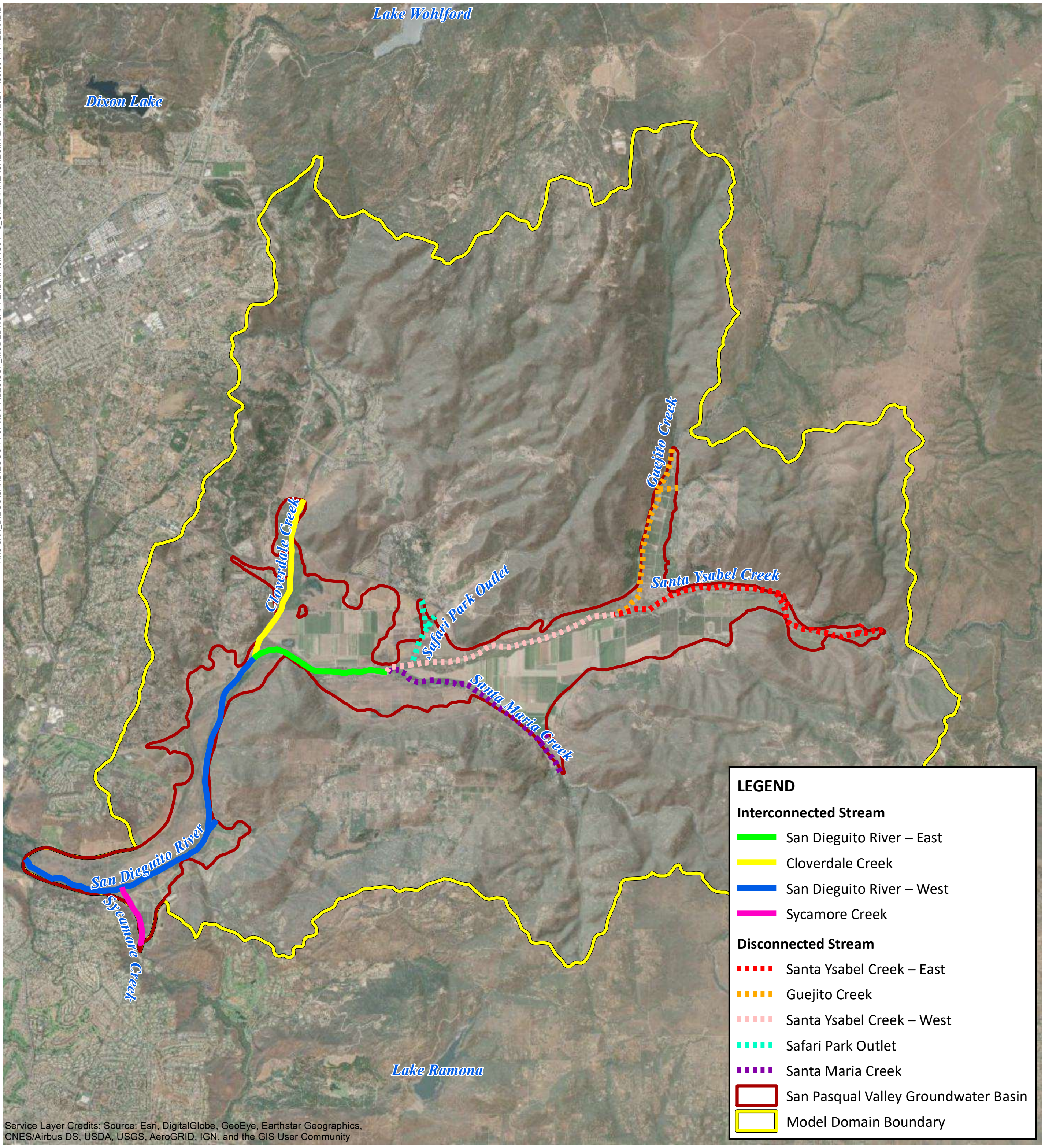

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FIGURE 4-15

Stream Surface Water Depletion Summary Reaches

Numerical Flow Model Documentation
San Pasqual Valley Groundwater Basin Groundwater Sustainability Plan
San Pasqual Valley, California

N

0 7,000 14,000
Feet

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SECTION 5. MODEL PROJECTIONS

Although it is impossible to predict future hydrology with certainty, the SPV GSP Model is the best available tool to forecast the response of the Basin aquifer to potential future conditions. Application of this tool as described in this section is intended to provide projected water budgets under assumed climate conditions to support development of the GSP.

5.1 Assumed Future Conditions

SGMA Regulations (i.e., Title 23 CCR Section 354.18) requires the SPV GSA to develop historical, current, and projected water budgets for the Basin. Section 4.4 discusses the historical and current water budgets. To develop the projected water budget, certain boundary conditions needed to be modified from the calibration version of the model, which was used to evaluate historical conditions, to convert it into a projection tool configured to simulate assumed future climatic conditions. The following sections describe the process of converting the historical model into a projection model.

5.1.1 Climate Change

SGMA Regulations (i.e. Title 23 CCR Section 354.18) also requires projected water budgets to incorporate assumptions regarding climate change. As discussed in Section 3.5.1 an analysis was performed to establish a compliant future period and associated climate change approach. Based on this analysis, climate change projections from the HadGEM2-ES, RCP 8.5 GCM were selected to serve as the basis for future precipitation and ET_0 data simulated in the SPV GSP Model. Precipitation and ET_0 raster datasets were intersected with the SPV GSP Model grid cells, based on the BCM v8 simulation of the HadGEM2-ES, RCP 8.5 GCM. Projected ET_0 data for the SPV GSP Model domain were corrected to reflect the historical monthly adjustment applied to historic BCM ET_0 estimates to better reflect SPV climate conditions as discussed in Section 3.7.1. These factors were averaged into long-term monthly average adjustment factors and were applied to each corresponding month in the future simulation period to eliminate biases inherit in BCM's ET_0 estimates.

Figure 5-1 presents the historical and projected annual precipitation and bias-corrected ET_0 for the SPV GSP Model. As previously discussed, the projected precipitation is taken directly from the HadGEM2-ES, RCP8.5 GCM. According to this GCM, annual precipitation is projected to vary from year to year with a low of 4 inches in WY 2043 to a maximum of about 39 inches in WY 2048. Although there are a few years where the maximum precipitation is greater than any year in the historical simulation period, the variability of precipitation in the future is generally within the historical variability. However, the year-to-year variability highlights the potential sequencing of wet years and dry years. For example, beyond 2060 a significant drought with seven consecutive critically dry or dry years is projected to occur, according to this particular GCM. In contrast, projected ET_0 exhibits very minor fluctuations from year-to-year; however, there is a clear warming trend in the projected ET_0 as indicated by the early part of the projected period as compared with the later part period. This is a direct result of the changes in temperature simulated by the HadGEM2-ES, RCP 8.5 GCM. However, the projected ET_0 is within the historical variability of the CIMIS station ET_0.

5.1.2 Stream Inflows from Contributing Catchments

The methodology described in Section 3.7.1 for the development of stream inflows from contributing catchments from ungaged watersheds was adapted for the development of projected stream inflows for the SPV GSP Model. Initially, the BCM-derived runoff was aggregated across each of the contributing catchments through the projection period (i.e., WYs 2020 through 2071). These runoff estimates were then adjusted using the same bias-correction technique on a monthly and annual scale. Adjustment factors presented in **Tables 3-6 and 3-7** in Section 3.7.1 were applied to the projected runoff, based on the same contributing catchment relationship. **Figure 5-2** presents the historical and projected stream inflows for each contributing catchment of the SPV GSP Model. Stream inflows to Santa Ysabel and Santa Maria Creeks are the two largest contributors of stream inflows to the SPV GSP Model and exhibit similar streamflow responses. For Santa Ysabel Creek, there are number of stream inflow events greater than the historical simulation period maximum of approximately 24,000 AFY in WY 2005 with a peak event occurring in WY 2048 at around 90,000 AF. Santa Maria Creek exhibits a similar peak event in WY 2048 of around 60,000 AFY, which is greater than the maximum event in the historical period of around 11,000 AF in WY 2005. Although the two stream inflow events in WY 2048 are significantly greater than the historical maximum values, similar events have been measured at the associated gage locations in WY 1980. For Santa Ysabel Creek, an annual stream inflow of approximately 95,000 AF was measured in WY 1980 (**Figure 3-19**). Similarly for Santa Maria Creek, an annual inflow of approximately 45,000 AF was measured in WY 1980 (**Figure 3-21**). Although the frequency of peak events is projected to change, the overall magnitudes of events are projected to be within similar ranges as has been measured since around 1980.

5.1.3 Subsurface Inflows from Contributing Catchments

Subsurface inflows from contributing catchments under future conditions were processed from BCM-derived recharge estimates, based on the HadGEM2-ES, RCP 8.5 GCM. The approach utilized for the historical simulation period of developing subsurface inflow estimates from contributing catchments was applied in the same manner for the projected subsurface inflows (i.e., 25 percent of the BCM-derived recharge in the contributing catchments, as discussed in Section 4.3.3.). **Figure 5-3** presents on a logarithmic y-axis the historical and projected subsurface inflow estimates for each contributing catchment of the SPV GSP Model. Overall, general magnitudes of subsurface inflows for the projected period are similar to the historical subsurface inflows; however the sequencing of climate variability leads to differences in the year-to-year magnitudes. Similar to stream inflows, the contributing catchments associated with Santa Ysabel and Santa Maria Creeks are the two largest contributors of subsurface inflow to the SPV GSP Model domain. The projected post-2060 drought is evident in the declining trends of the subsurface inflow plots for each contributing catchment.

5.1.4 Subsurface Flow Interaction with Hodges Reservoir Area

To simulate subsurface flow interactions with Hodges Reservoir under future conditions, the SPV GSP Model required monthly projected water surface elevations (i.e., stages) for Hodges Reservoir to be specified in the GHB package. It was assumed that Hodges Reservoir would be operated into the future in a manner that reflects historical operations. Based on this assumption a monthly and WYT average stage was calculated from historical measured stages for each month and associated WYT of the projected simulation period. An additional consideration that needed to be accounted for is a recent Division of Safety of Dams (DSOD) requirement that defines the maximum pool elevation in Hodges Reservoir as 295 feet NAVD88. Thus, the projected monthly stage values were capped to the maximum pool elevation of 295 feet to reflect the DSOD operational constraint. **Figure 5-4** presents the historical and projected monthly Hodges Reservoir stage included in the model projections.

Projected Hodges Reservoir stages range from year-to-year based on the WYT associated with the projected climate data and is within the range of historical measured stages due to the WYT sampling of the historical data. The projected stages often exceed the DSOD maximum pool elevation. As a result, the capping methodology reduces the stage to 295 feet NAVD88 in many of the months of the projection period.

5.1.5 Land Use and Population

Through discussions with local stakeholders, land use will remain as primarily agricultural, while preserving native and riparian areas with little to no urban expansion. Based on these discussions, the land use conditions were assumed to be fixed at 2018 conditions (**Figure 3-7**) for the projection period.

Given the desire to maintain the SPV as an agricultural preserve in City jurisdiction, the population has not experienced much growth historically and anticipated SPV population growth is negligible. Similarly in County-only jurisdiction the population has remained steady in the Basin. Therefore, the population within the Basin was fixed at 2020 conditions with 2018 land use characteristics for the future baseline projection.

5.1.6 Consumptive Use

To develop consumptive use estimates under future conditions, site-specific Kc values computed for 2018 based on the ET_0 recorded at the CIMIS station and the CalETa dataset were utilized along with the projected ET_0 discussed in Section 5.1.1. Thus, site-specific monthly 2018 Kc values for each unique land use polygon were used in conjunction with the projected monthly ET_0 to compute future consumptive use, according to **Equation 3-1**.

5.1.7 Groundwater Pumping

Agricultural groundwater pumping under future conditions follow a similar methodology as was implemented for the historical simulation period. However, the status of pumping wells under future conditions was refined, based on stakeholder input to include more recent well installations and the pumping wells they plan to continue using into the future (see Attachment 1). Projected agricultural groundwater pumping rates are computed based on the TFDR for each WBS and the associated well-to-parcel relationship defined through local stakeholder input (**Figure 3-8**).

Rural domestic pumping was assumed to be fixed at the 55 gpcd and 2.5 people per household assumed for the historical conditions, as discussed in Section 3.7.1 (Bennett, 2020). Well infrastructure associated with rural domestic water use was assumed to remain the same as historical conditions, given the lack of potential growth in the Basin.

5.1.8 Imported Water

Under future conditions, the imported water areas were assumed to not expand beyond the historical areas incorporated into the SPV GSP Model (**Figure 3-27**). Imported water flows were determined using the same iterative approach of quantifying the TFDR in the imported water areas and then providing those flows as a NRD for the final projection simulation. See Section 3.7.1 for more details.

5.1.9 Recycled Water/Wastewater Reuse

Under future conditions, the recycled water use areas were assumed to not expand beyond the historical areas incorporated in the SPV GSP Model (**Figure 3-28**). A similar methodology to the historical recycled water use configuration was assumed for the future conditions. The Safari Park is provided a NRD in addition to imported water and groundwater pumping to offset the TFDR for its WBS. The San Pasqual Academy's recycled water use was assumed to be captured in the projected consumptive use and ultimate TFDR determined for its associated WBS. See Section 3.7.1 for more details.

5.1.10 Groundwater Recharge from Septic Systems

Groundwater recharge from septic systems was assumed to occur in the same locations that were utilized for the historical simulation (**Figure 3-26**). Septic system recharge was assumed to reflect the rural domestic groundwater pumping quantities. See Section 3.7.1 for more details.

5.2 Model Setup for Projection Simulations

For the future baseline simulation, the SPV GSP Model was configuered to run the historical and projected simulation periods as one continuous simulation. Simulating the historic and projected periods as a continous simulation ensures that there are no discontinuities in Basin conditions between the end of the historical period and the start of the projection period. Although modeled groundwater levels at the end of the historical simulation could be used as initial conditions of the projected simulation, other boundary conditions, such as the SFRs do not allow the user to specify initial conditions. Thus, a continuous simulation would allow any potential surface water storage at the end of the historical simulation to be retained for the start of the projection simulation. **Table 5-1** presents a comparison of the assumptions associated with the historical and projection simulations.

5.3 Projected Groundwater Levels

Figure 5-5 presents the historical and projected groundwater-level hydrographs at each of the target wells. The horizontal and vertical axes on the hydrographs presented in **Figure 5-5** have been standardized to facilitate making comparisons among the hydrographs. Also included in the figures are the various SMC thresholds presented in Section 8 of the GSP for each of the target wells included as a representative monitoring point. Three thresholds have been included representing the minimum threshold (MT), planning threshold, and the measurable objective (MO). Refer to Section 8 of the GSP for further discussion of what these thresholds represent and how they were derived. For comparison, the hydrographs also include the ground surface elevation and the modeled Basin bottom elevation to help characterize the modeled saturated thickness at each of the wells.

Table 5-1. Overview of Assumptions for the Historical and Projection Periods

Simulation Item	Assumption/Basis for Historical Simulation Period	Assumption/Basis for Projection Simulation Period
Hydrologic Period	• Historical: WYs 2005 through 2019 • Monthly time intervals	• WYs 2020 through 2071 • Monthly time intervals
Precipitation	• Downscaled PRISM (PRISM Climate Group, 2020) precipitation dataset, as	• Downscaled PRISM (PRISM Climate Group, 2020) precipitation dataset that incorporates climate

Simulation Item	Assumption/Basis for Historical Simulation Period	Assumption/Basis for Projection Simulation Period
	processed using the BCM (Flint et al., 2013)	change based on the HadGEM2-ES, RCP 8.5 (IPCC, 2013) GCM, as process using the BCM (Flint et al., 2013)
Reference Evapotranspiration [(a)]	• California Irrigation Management Information System Station 153 in the SPV	• Downscaled PRISM (PRISM Climate Group, 2020) air temperature dataset that incorporates climate change based on the HadGEM2-ES, RCP 8.5 (IPCC, 2013) GCM, as processed using the BCM • ET_0 is computed using the BCM (Flint et al., 2013) based on air temperature projections
Stream Inflows	• Guejito Creek USGS stream gage 11027000 • Santa Ysabel Creek USGS stream gage 11025500 • Santa Maria Creek USGS stream gage 11028500 • Inflows for ungauged streams are based runoff estimates computed by the BCM (Flint et al., 2013) and bias corrected by Jacobs	• Runoff projections computed by the BCM (Flint et al., 2013) based on the HadGEM2-ES, RCP 8.5 (IPCC, 2013) GCM and bias corrected by Jacobs
Subsurface Inflows	• 25 percent of the groundwater recharge in contributing catchments as computed by the BCM (Flint et al., 2013)	• 25 percent of the groundwater recharge in contributing catchments as computed by the BCM (Flint et al, 2013) based on the HadGEM2-ES, RCP 8.5 (IPCC, 2013) GCM
Land Use/Cropping	• Built upon land use dataset developed for the SNMP (City of San Diego, 2014) • Updated based on 2014 and 2016 DWR land use datasets, Google Earth™ imagery, and stakeholder input	• Built upon land use dataset developed for the SNMP (City of San Diego, 2014) • Updated based on 2014 and 2016 DWR land use datasets, Google Earth™ imagery, and stakeholder input • Held constant at 2018 conditions based on low likelihood of future changes in land use
Well Infrastructure	• Stakeholder input for WYs 2005 through 2019	• Stakeholder input for 2020 conditions
Evapotranspiration	• CalETa (Formation, 2020) dataset provides actual monthly crop ET values for calendar years 2005, 2010 through 2017, and 2019	• 2018 land use and crop coefficients and projected ET_0 computed by the BCM (Flint et al, 2013) that incorporates climate change based on the HadGEM2-ES, RCP 8.5 (IPCC, 2013) GCM
Domestic Water Use	• Stakeholder input and census data	• Held constant at 2020 conditions based on stakeholder input and 2018 land use and population characteristics • Given the desire to maintain the SPV as an agricultural preserve, the population has not experienced much growth historically and anticipated SPV population growth is negligible

Notes:
BCM = California Basin Characterization Model
Formation = Formation Environmental
CalETa = California Actual Evapotranspiration
[a] The crop associated with the reference evapotranspiration is grass.

In general, groundwater levels in the eastern portion of the Basin continue in a declining trend into the future, but eventually bottom out at lower levels. While groundwater levels tend to decline, there are instances where groundwater levels rebound during wetter years when significant groundwater recharge events occur. There are instances where groundwater levels tend to drop below the planning threshold and MT, but often rebound above those thresholds in subsequent years (e.g., see SP093, SP073, and MW-2). In other cases, such as at SP086, the groundwater levels decrease below the MT around year 2025 and are not able to recover to a level above that MT.

An important consideration in analyzing these hydrographs and trends is the bias that the SPV GSP Model has in replicating historical groundwater levels. Based on the discussion in Section 4.3.1, the SPV GSP Model does not perfectly replicate groundwater levels and tends to underestimate groundwater levels in the eastern portion of the Basin. Therefore, head values displayed in **Figure 5-5**, particularly for the projection period, should not be viewed as fact. However, the groundwater-level trends at the target wells are often consistent with measured groundwater-level trends and are therefore useful for guiding decisions related to SMC.

Groundwater levels in the western portion of the Basin have been more stable throughout the past and are projected to be mostly stable until around 2065, when some of these wells start to show declines in groundwater levels because of the projected extended drought that occurs later in the projection period. Although the certainty in the projections decreases with increasing time, it is important to consider the potential impacts of longer-term consecutive dry years when developing planning thresholds. However, even with the later period drought, none of the modeled hydrographs for wells in the western portion of the Basin decrease below the planning threshold or MT.

5.4 Projected Water Budgets

SGMA Regulations (i.e., Title 23 CCR Section 354.18) requires the SPV GSA to develop historical, current, and projected water budgets for the Basin. Section 4.4 discusses the historical and current water budgets. **Figure 5-6** presents three sets of charts showing historical, current, and projected water budgets. The top, middle, and bottom charts show the land system, surface water system, and groundwater system water budget summaries, respectively. **Figure 5-7** presents three sets of charts, one for each component, with the annual time series of the historical, current, and projected water budgets. The colors of the water budget components in **Figure 5-6** and **Figure 5-7** have been standardized to facilitate making comparisons between figures. Following is a description of the water budget estimates, which are subject to change in future GSP updates as the understanding of Basin conditions evolves during implementation of the GSP.

5.4.1 Land System

Table 5-2 and **Figure 5-6a** present averages of the individual historical, current, and projected land system budgets, whereas **Figure 5-7a** presents the annual time series of each Basin component of the historical, current, and projected land system budgets. Attachment 3 provides the annual values for the land system water budget components. Tabulated water budget values presented herein are reported to the nearest whole number from the SPV GSP Model. This has been done out of convenience. It is not the intention of the authors to imply that the values are accurate to the nearest AF. Because projections assume a similar water demand, the projected time series, land system water budget looks similar to the historical land system estimates. Although there is a greater projected amount of groundwater deliveries for irrigation, as compared to historical amounts, it is not enough to offset the reduction of the other land system inflow terms.

Table 5-2. Average Annual Historical, Current, and Projected Land System Water Budgets

Water Budget Component	Historical Average Annual Flow (AFY) WYs 2005–2019	Current Average Annual Flow (AFY) WYs 2015–2019	GSP Implementation Period Average Annual Flow (AFY) WYs 2020-2042	Projected Average Annual Flow (AFY) WYs 2020–2071
Inflows				
Precipitation	3,864	4,126	3,872	3,638
Imported Applied Water	76	92	128	135
Groundwater Deliveries for Irrigation	4,679	4,818	5,145	5,162
Shallow Groundwater Uptake	1,107	1,088	1,079	887
Groundwater Discharge to Land Surface	119	102	120	119
Total Inflow	9,845	10,226	10,344	9,941
Outflows				
Runoff to Streams	130	115	130	128
ET of Precipitation[a]	1,974	2,000	2,301	2,182
ET of Shallow Groundwater[a]	1,107	1,088	1,079	887
ET of Applied Water	3,583	3,704	3,975	3,985
Groundwater Recharge from Precipitation, Applied Water, and Septic Systems	3,052	3,320	2,861	2,759

Water Budget Component	Historical Average Annual Flow (AFY) WYs 2005–2019	Current Average Annual Flow (AFY) WYs 2015–2019	GSP Implementation Period Average Annual Flow (AFY) WYs 2020-2042	Projected Average Annual Flow (AFY) WYs 2020–2071
Total Outflow	9,846	10,227	10,346	9,941

[(a)] Native vegetation (that is, native shrubs plus riparian vegetation) water demand is met through precipitation and shallow groundwater uptake. The ET of native vegetation is a portion of the sum of the ET of precipitation and the ET of shallow groundwater. The ET of native vegetation alone within the Basin averages 2,328 to 2,556 AFY during the four averaging periods indicated.

5.4.2 Surface Water System

Table 5-3 and **Figure 5-6b** present averages of individual Basin historical, current, and projected surface water system water budgets, whereas **Figure 5-7b** presents an annual time series of the historical, current, and projected surface water system water budgets. Attachment 4 provides the annual values for the surface water system water budget components. Model projections for WYs 2020-2071 indicate larger average stream inflows and outflows than historical averages; however, as shown in **Figure 5-7b**, the larger projected averages are influenced by relatively fewer extreme wet years.

5.4.3 Groundwater System

Table 5-4 and **Figure 5-6c** present averages of the historical, current, and projected groundwater system water budgets, whereas **Figure 5-7c** presents the annual time series of the historical, current, and projected groundwater system water budgets. Attachment 5 provides the annual values for the groundwater system water budget components.

Table 5-3. Average Annual Historical, Current, and Projected Surface Water System Budgets

Water Budget Component	Historical Average Annual Flow (AFY) WYs 2005–2019	Current Average Annual Flow (AFY) WYs 2015–2019	GSP Implementation Period Average Annual Flow (AFY) WYs 2020-2042	Projected Average Annual Flow (AFY) WYs 2020–2071
Inflows				
Runoff to Streams	130	115	130	128
Stream Inflow from Adjacent Areas	13,907	12,796	24,752	23,537

Water Budget Component	Historical Average Annual Flow (AFY) WYs 2005–2019	Current Average Annual Flow (AFY) WYs 2015–2019	GSP Implementation Period Average Annual Flow (AFY) WYs 2020-2042	Projected Average Annual Flow (AFY) WYs 2020–2071
Groundwater Discharge to Streams	921	861	590	438
Total Inflow	14,958	13,772	25,472	24,103
Outflows				
Stream Outflow to Hodges Reservoir Area	13,714	12,641	24,656	23,506
Groundwater Recharge from Streams	2,276	2,303	2,431	2,169
Total Outflow	15,990	14,944	27,086	25,675

Table 5-4. Average Annual Historical, Current, and Projected Groundwater System Water Budgets

Water Budget Component	Historical Average Annual Flow (AFY) WYs 2005–2019	Current Average Annual Flow (AFY) WYs 2015–2019	GSP Implementation Period Average Annual Flow (AFY) WYs 2020-2042	Projected Average Annual Flow (AFY) WYs 2020–2071
Inflows				
Groundwater Recharge from Precipitation, Applied Water, and Septic Systems	3,052	3,320	2,861	2,759
Groundwater Recharge from Streams	2,276	2,303	2,431	2,169
Subsurface Inflow from Hodges Reservoir Area	18	0	0	0
Subsurface Inflow from Adjacent Rock	2,983	3,031	3,110	3,145
Total Inflow	8,329	8,654	8,402	8,073
Outflows				
Shallow Groundwater Uptake (ET of Shallow Groundwater)	1,107	1,088	1,079	887
Groundwater Discharge to Streams	921	861	590	438
Groundwater Pumping	5,861	6,021	6,198	6,233

Water Budget Component	Historical Average Annual Flow (AFY) WYs 2005–2019	Current Average Annual Flow (AFY) WYs 2015–2019	GSP Implementation Period Average Annual Flow (AFY) WYs 2020-2042	Projected Average Annual Flow (AFY) WYs 2020–2071
Subsurface Outflow to Hodges Reservoir Area	98	149	112	99
Subsurface Outflow to Adjacent Rock	468	486	500	545
Groundwater Discharge to Land Surface	119	102	120	119
Totals				
Total Outflow	8,574	8,707	8,600	8,321
Average of Total Inflows and Outflows	8,452	8,681	8,501	8,197
Change in Groundwater Storage	-245	-53	-199	-248
Change in Groundwater Storage as a Percent of the Average of Total Inflows and Outflows	2.9%	0.60%	2.3%	3.0%

Because SPV GSP Model projections assume a similar water demand, the projected time series, groundwater system water budget looks similar to the historical groundwater system estimates (see **Figure 5-7c**). SPV GSP Model results indicate that the total projected groundwater inflows could be slightly lower than historical groundwater inflows due to less groundwater recharge from precipitation and applied water and less groundwater recharge from streams. This is because the hydrology under modeled climate change conditions during the projection period is generally drier as compared to the last few decades. Although there is more projected subsurface inflow from adjacent rock, as compared with historical rates, this inflow is not enough to offset the projected reduction in groundwater recharge terms.

The historical, current, and projected groundwater system budgets all indicate an average deficit in the cumulative change in groundwater storage ranging from -53 AFY under current conditions to -248 AFY under projected conditions. The projected deficit results from lower groundwater recharge rates and lower groundwater levels (equating to reduced groundwater uptake) and increased ET_0 under climate change conditions. These conditions exacerbate the need for increased groundwater pumping to meet future water demands. Thus, even with little to no change in cropping patterns or population, reductions in precipitation and groundwater uptake and increases in ET_0 under climate change conditions could result in greater reliance on groundwater pumping and/or imported water. This deficit range represents 0.60 to 3 percent of the average of the groundwater inflows and outflows and is more likely than not, within the uncertainty of the estimates of the water budgets. This means small changes to individual water budget estimates could potentially result in no deficit in the cumulative change in groundwater storage. Further, given the substantial uncertainty associated with climate projections using drier than average projected values, it is possible that future climate conditions could be different than those inherent in the GCM selected for use in the SPV GSP Model.

DWR's Water Budget BMP indicates that reductions of groundwater storage in wet and above normal years could be an indication of overdraft conditions. As discussed in Section 5.4.4 and shown in Table 5-5, the average changes in stored groundwater during historical, current, and projected years are positive numbers under wet and above normal WY types. It is also common for outflows to exceed inflows during drought conditions; for example, WYs 2012 through 2014 coincide with a substantial drought. Thus, it would be premature to identify a small deficit in the cumulative change in groundwater storage over WYs 2005 through 2019 as overdraft. Additional years of groundwater level data are needed to develop a more definitive statement about whether the Basin is in a long-term overdraft condition. The water budgets described here will be revaluated during GSP implementation.

5.4.4 Water Supply and Demand

Table 5-5 summarizes annual average supply and demand by WY type within the Basin for the historical, current, and projected water budgets. Groundwater is the dominant supply source in the Basin, placing a higher demand on pumping during critically dry and dry WYs due to less precipitation. Although surface water flowing through the system is not generally used directly for irrigation, surface water does provide an important source of groundwater recharge to the Basin (refer to groundwater recharge from streams Figure 5-6 and 5-7), making water potentially available to help meet agricultural pumping demands. Annual applied water demands are highest during critically dry and dry WYs due to a lack of precipitation, lower groundwater levels (and therefore less groundwater uptake), and the need for irrigation to sustain agriculture in the Basin. Changes in groundwater storage vary between WY types, with increases in groundwater storage during wet and above normal years and decreases in groundwater storage during normal, dry, and critically dry years.

Observations of current supply and demand are consistent with those of the 15-year historical period, except that a dry WY did not occur in WYs 2015 through 2019 (Table 5-5).

As with the historical and current groundwater conditions, projected groundwater pumping serves as the dominant supply source in the Basin, with a higher demand on pumping required under critically dry and dry WYs due to less precipitation (Table 5-5). Projections indicate that surface water and imported water will be increasingly important sources of supply to meet projected agricultural demands in the Basin. Annual applied water demands are projected to be highest under critically dry and dry years due to the lack of precipitation, lower groundwater levels (and therefore less groundwater uptake), and the need to irrigate to sustain agriculture in the Basin. Changes in groundwater storage vary between WY types, with increases during wet and above normal years and decreases during normal, dry, and critically dry years. Overall, the positive and negative changes in groundwater storage are projected to be greater during the projected period compared to the current period, suggesting the possibility of more dramatic changes in groundwater levels in the future (Table 5-5). More dramatic changes in future modeled groundwater levels and groundwater storage are the result of future sequencing and magnitudes of wetter and drier WYs as compared to historical conditions.

Table 5-5. Summary of Historical, Current, and Projected Supply and Demand by Water Year Type

Water Budget Component	Wet (AFY)	Above Normal (AFY)	Normal (AFY)	Dry (AFY)	Critically Dry (AFY)
Historical Period (WYs 2005–2019)					
Annual Groundwater Supply	5,199	5,904	5,618	6,237	6,428
Annual Imported Applied Water	67	68	69	65	87
Annual Surface Water Supply	1,110	1,886	1,653	1,269	933
Annual Total Supply	6,376	7,858	7,340	7,571	7,448
Annual Applied Water Demand	3,760	4,223	4,018	4,415	4,570
Change in Stored Groundwater	1,835	683	-405	-1,332	-1,639
Current Period (WYs 2015–2019)					
Annual Groundwater Supply	5,934	6,521	5,484	N/A	6,669
Annual Imported Applied Water	79	114	68	N/A	67
Annual Surface Water Supply	1,864	1,877	1,476	N/A	519
Annual Total Supply	7,877	8,512	7,028	N/A	7,255
Annual Applied Water Demand	4,294	4,686	3,933	N/A	4,834
Change in Stored Groundwater	1,664	18	-573	N/A	-790
Projection Period (WYs 2020–2071)					
Annual Groundwater Supply	5,603	6,047	6,235	6,413	6,694
Annual Imported Applied Water	127	137	134	141	139
Annual Surface Water Supply	2,942	1,972	1,551	1,517	894
Annual Total Supply	8,672	8,156	7,920	8,071	7,727

Water Budget Component	Wet (AFY)	Above Normal (AFY)	Normal (AFY)	Dry (AFY)	Critically Dry (AFY)
Annual Applied Water Demand	4,243	4,616	4,886	5,088	5,464
Change in Stored Groundwater	3,276	398	-831	-1,234	-2,211

N/A = Not applicable because no dry year occurred during the current period
Annual Groundwater Supply = groundwater pumped from the Basin
Annual Imported Water = water imported to the Basin used to meet applied water demand
Annual Surface Water Supply = the net groundwater recharge from streams in the Basin
Annual Total Supply = sum of the groundwater, imported applied water, and surface water supply
Annual Applied Water Demand = the applied water demand within the Basin

5.5 Model Projection Sensitivity Analysis

A sensitivity analysis was performed to assess the sensitivity of groundwater levels and groundwater storage to the selected climate-change scenario. For this analysis, the CanESM2, RCP 8.5 scenario was selected. This particular GCM was selected because it is generally in the mid-range of the four GCMs evaluated (**Figure 3-14**) and discussed in **Section 3.5.1**, but exhibits a more favorable sequence of future hydrology than the HadGEM2-ES GCM and can therefore provide some insight into how the Basin might respond to a different sequence of future hydrology. The same approach used for the HadGEM2-ES scenario was used for the CanESM2 datasets.

Figure 5-8 presents historical and future groundwater-level hydrographs from the HadGEM2-ES and CanESM2 scenarios. The HadGEM2-ES groundwater-level hydrograph lines on the charts fall directly underneath the CanESM2 hydrographs throughout the historical simulation period, because the two simulations are identical during this historical time frame. However, the two different simulations begin to diverge at the start of the projection period in WY 2020, due to the differences in projected climate and boundary conditions. In general, the two projection simulations trend above and below each other throughout the projection period until around 2060 when the two diverge. As previously dicussed, the HadGEM2-ES GCM forecasts a severe post-2060 drought, whereas the CanESM2 forecasts wetter consecutive years in the post-2060 time frame. As a result, the CanESM2 simulation shows substantial rebounds in the eastern wells in the Basin (**Figure 5-8**).

Table 5-6 presents average annual groundwater budget results for the HadGEM2-ES and the CanESM2 projection scenarios. In general, the CanESM2 scenario exhibits greater inflows and outflows as compared to the HadGEM2-ES scenario. Greater inflows occur from more groundwater recharge, which allows for groundwater-levels to rebound, providing more water to flow out from the system through the various outflow terms. The most notable difference in the comparison of water budgets is the average annual change in groundwater storage. The CanESM2 scenario indicates a slightly positive value of 26 AFY, rather than being in a deficit or overdraft. This outcome is consistent with the projected groundwater-level hydrographs for the CanESM2 scenario; particularly for the the post-2060 period, which includes substantial rebounds of groundwater levels back to historical levels (**Figure 5-8**).

Table 5-6. Projected Groundwater Budget Sensitivity

Water Budget Component	HadGEM2-ES, RCP 8.5 Average Annual Flow (AFY) WYs 2020–2071	CanESM2, RCP 8.5 Average Annual Flow (AFY) WYs 2020-2071
Groundwater Recharge from Precipitation, Applied Water, and Septic Systems	2,759	3,416
Groundwater Recharge from Streams	2,169	2,428
Subsurface Inflow from Hodges Reservoir Area	0	0
Subsurface Inflow from Adjacent Rock	3,145	3,300
Total Inflow	8,073	9,144
Shallow Groundwater Uptake (ET of Shallow Groundwater)	887	1,162
Groundwater Discharge to Streams	438	746
Groundwater Pumping	6,233	6,355
Subsurface Outflow to Hodges Reservoir Area	99	114
Subsurface Outflow to Adjacent Rock	545	526
Groundwater Discharge to Land Surface	119	212
Total Outflow	8,321	9,118
Average of Total Inflows and Outflows	8,197	9,131
Change in Groundwater Storage	-248	26
Change in Groundwater Storage as a Percent of the Average of Total Inflows and Outflows	3%	0.3%

As previously discussed in Sections 4.4.3 and 5.4.3, the modeled deficit with the HadGEM2-ES scenario represents 0.6 to 3 percent of the average of the groundwater inflows and outflows and is more likely than not, "within the noise" of the groundwater budget, meaning small changes to individual water budget estimates could potentially result in no deficit in the cumulative change in groundwater storage. As shown in this section, the GCM selected can make the difference between projecting an overdrafted or balanced Basin.

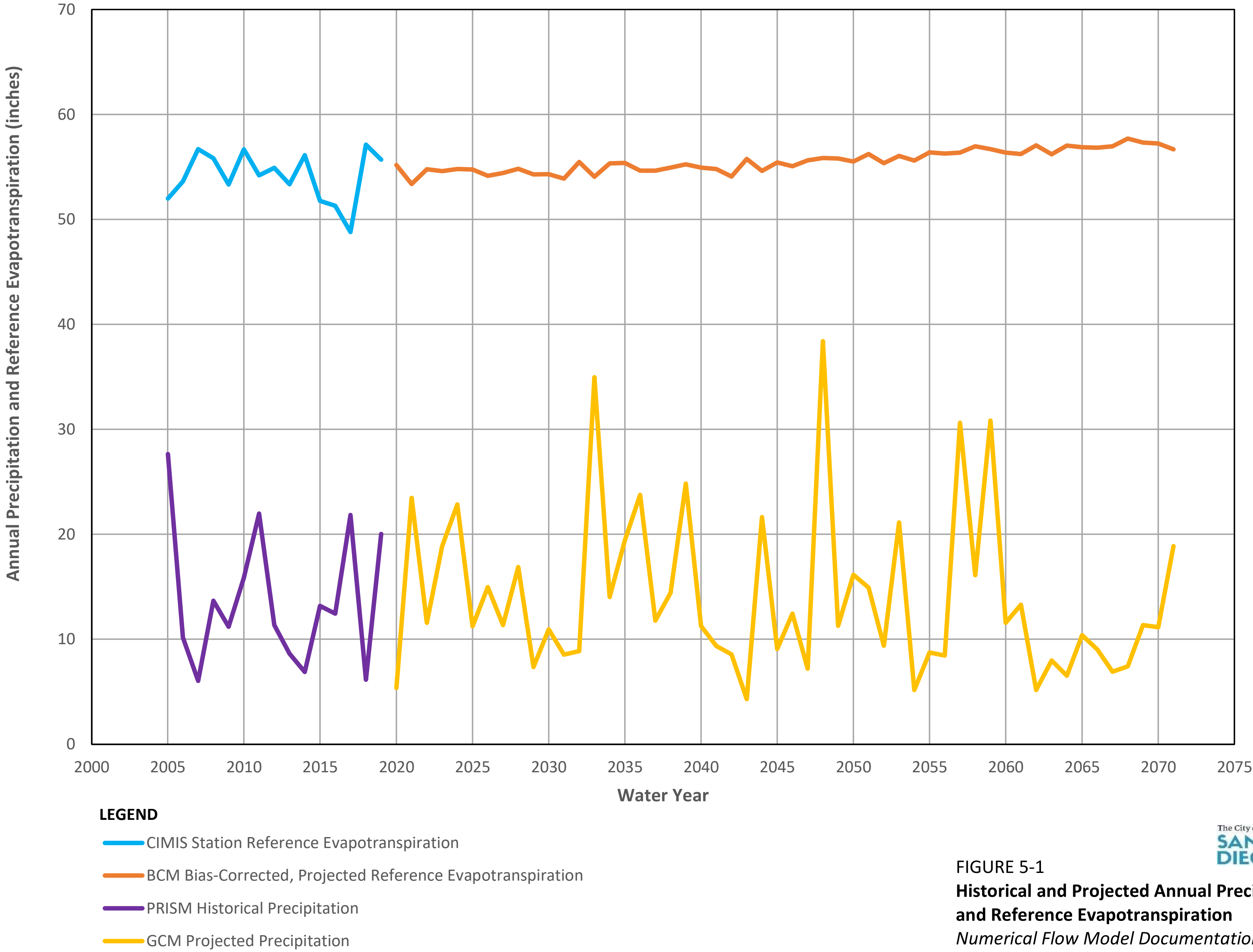

FIGURE 5-1
Historical and Projected Annual Precipitation and Reference Evapotranspiration
Numerical Flow Model Documentation
San Pasqual Valley Groundwater Basin
Groundwater Sustainability Plan
San Pasqual Valley, California

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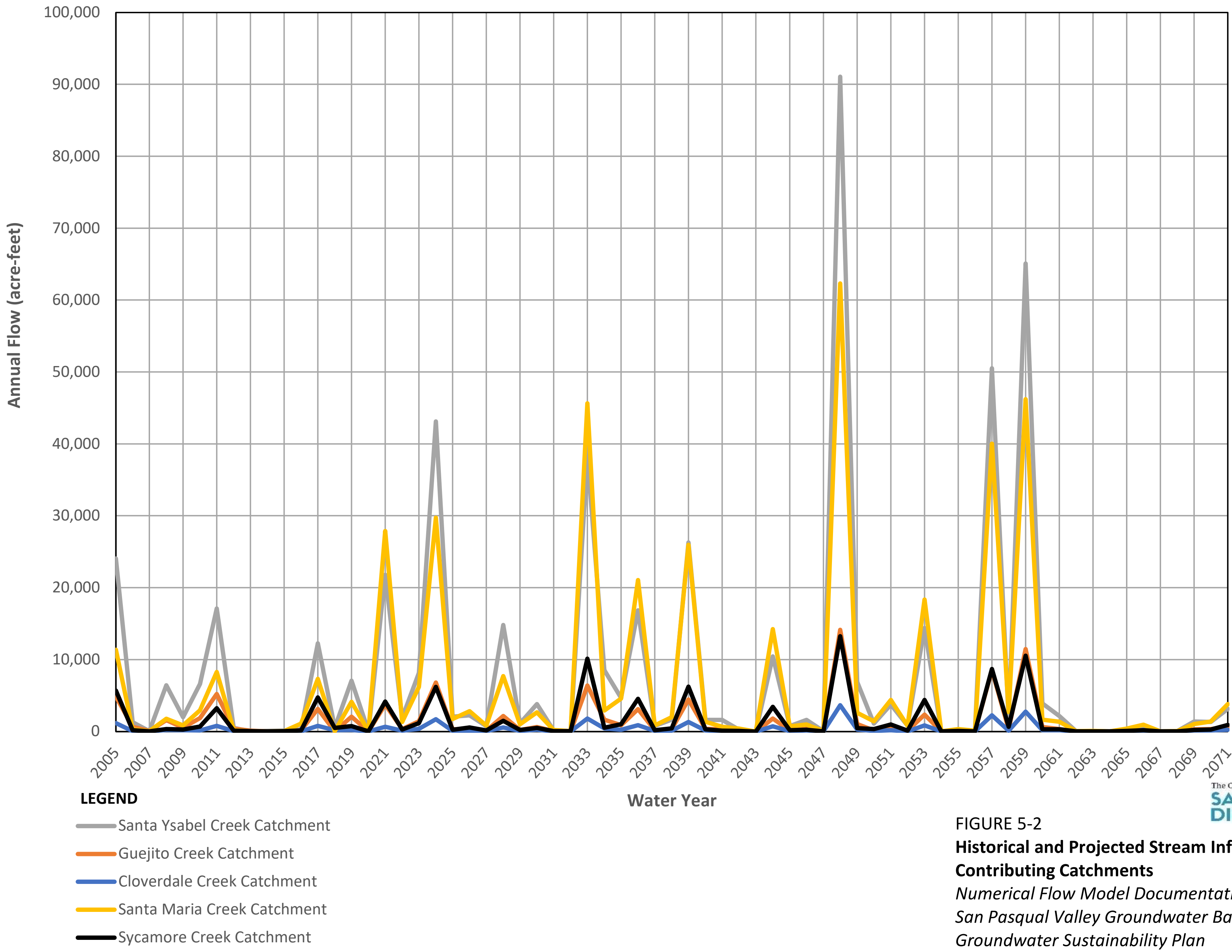

FIGURE 5-2

Historical and Projected Stream Inflows from Contributing Catchments

Numerical Flow Model Documentation
San Pasqual Valley Groundwater Basin
Groundwater Sustainability Plan
San Pasqual Valley, California

\\odin\proj\SanDiegoCityof\CommonFiles\SGMA\2022_GSP\GSP\ModelingAppendix\Figures\XLSX\5.0\FIG05-02_Annual_BCM_RCH_Contributing_Areas_Historic&Future.xlsx\FIG05-2

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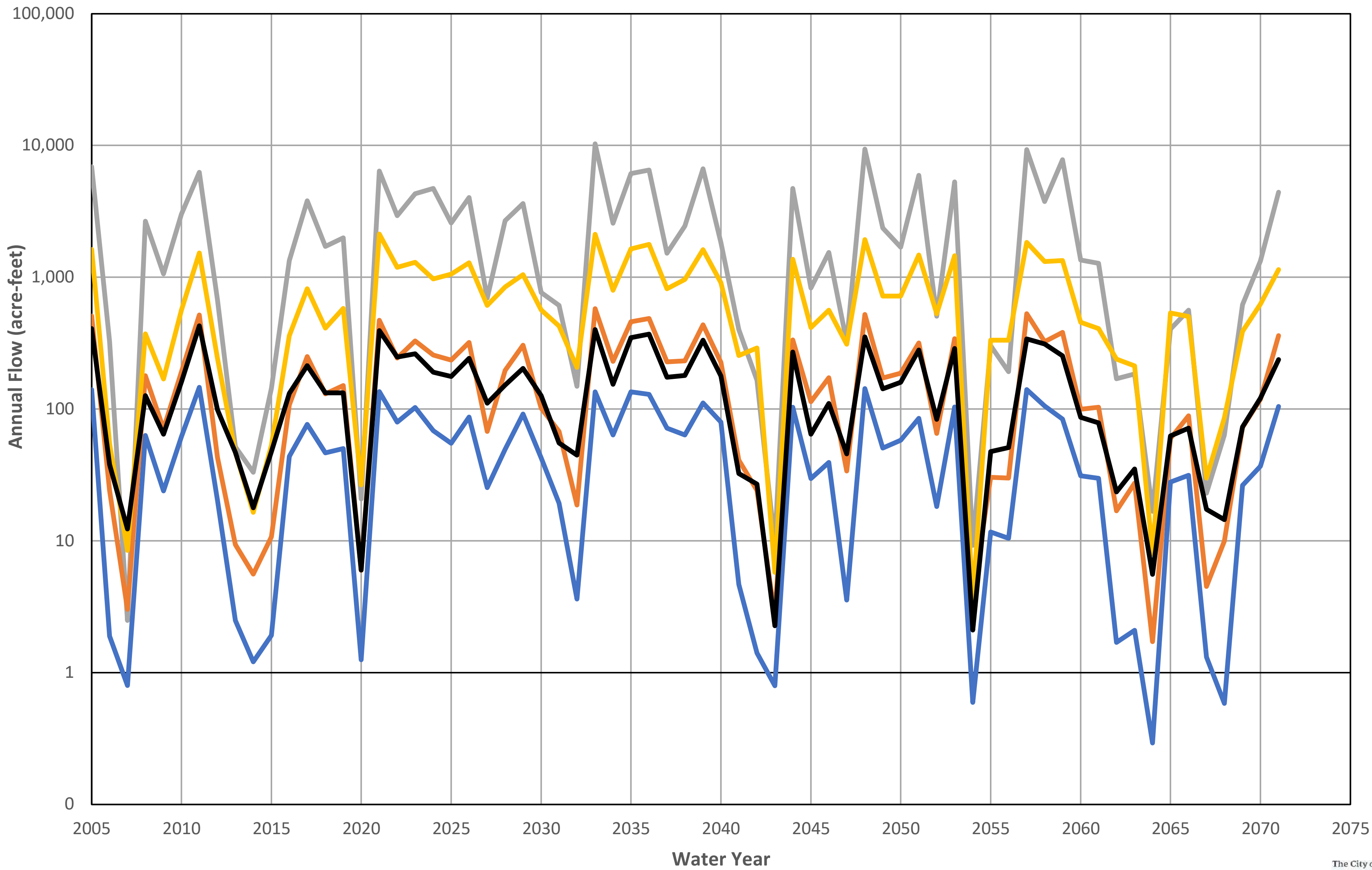

LEGEND

- Santa Ysabel Creek Catchment
- Guejito Creek Catchment
- Cloverdale Creek Catchment
- Santa Maria Creek Catchment
- Sycamore Creek Catchment

FIGURE 5-3

Historical and Projected Subsurface Inflows from Contributing Catchments

Numerical Flow Model Documentation
San Pasqual Valley Groundwater Basin
Groundwater Sustainability Plan
San Pasqual Valley, California

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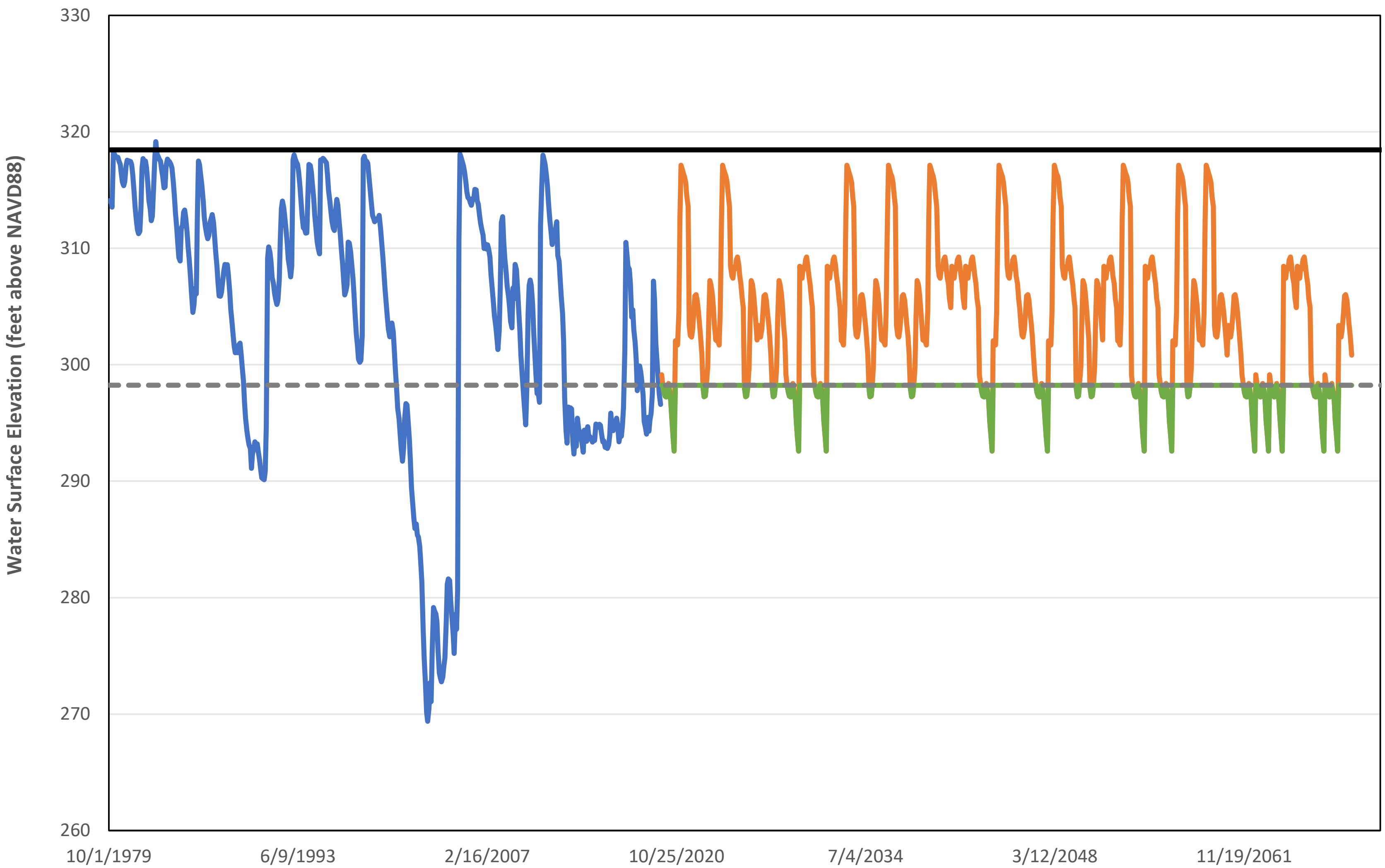

LEGEND

- Historical Water Surface .Elevation
- Projected Water Surface Elevation
- Projected Capped Water Surface Elevation
- Maximum Reservoir Elevation
- Division of Safety of Dams Maximum Pool Elevation

FIGURE 5-4

Historical and Projected Hodges Reservoir Water Surface Elevations

Numerical Flow Model Documentation
San Pasqual Valley Groundwater Basin
Groundwater Sustainability Plan
San Pasqual Valley, California

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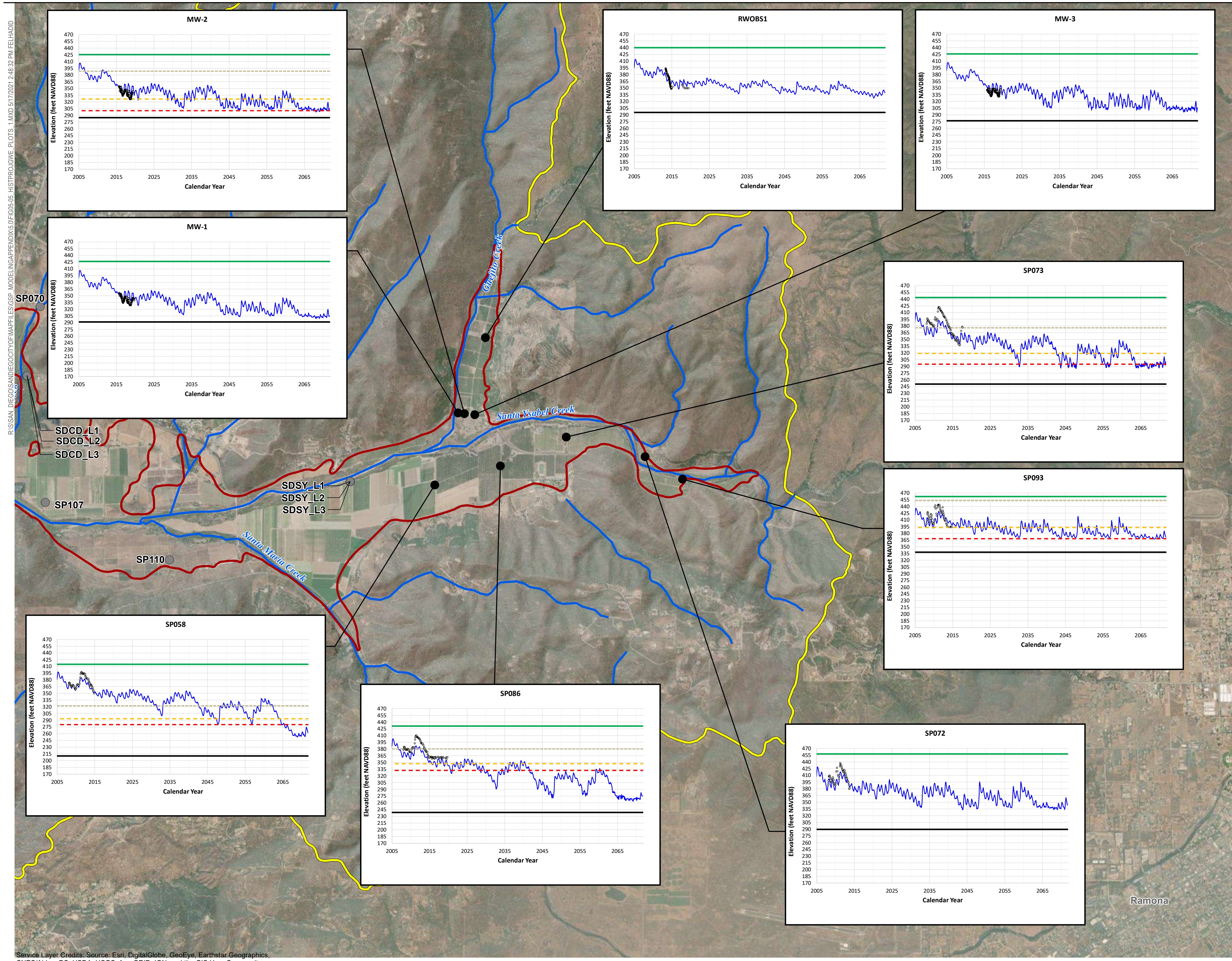

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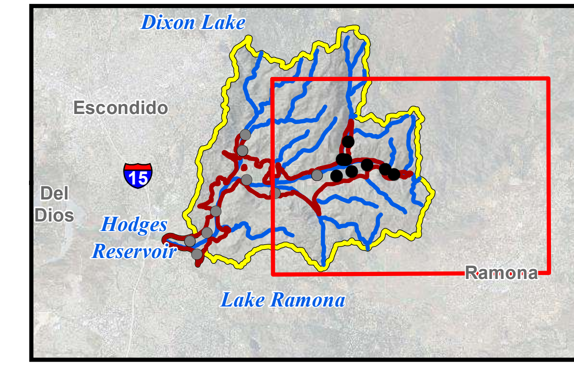

MAP LEGEND

- Calibration Target Well Location
- Modeled Stream
- San Pasqual Valley Groundwater Basin
- Model Domain Boundary

GRAPH LEGEND

- Measured Groundwater Elevation (feet NAVD88)
- Modeled Groundwater Elevation (feet NAVD88)
- Ground Surface Elevation (feet NAVD88)
- Modeled Basin Bottom Elevation (feet NAVD88)
- Minimum Threshold (feet NAVD88)
- Planning Threshold (feet NAVD88)
- Measurable Objective (feet NAVD88)

N

0 4,000 8,000
Feet

FIGURE 5-5 (PAGE 1 OF 3)

Historical and Projected Groundwater-level Hydrographs

Numerical Flow Model Documentation
San Pasqual Valley Groundwater Basin
Groundwater Sustainability Plan
San Pasqual Valley, California

Jacobs

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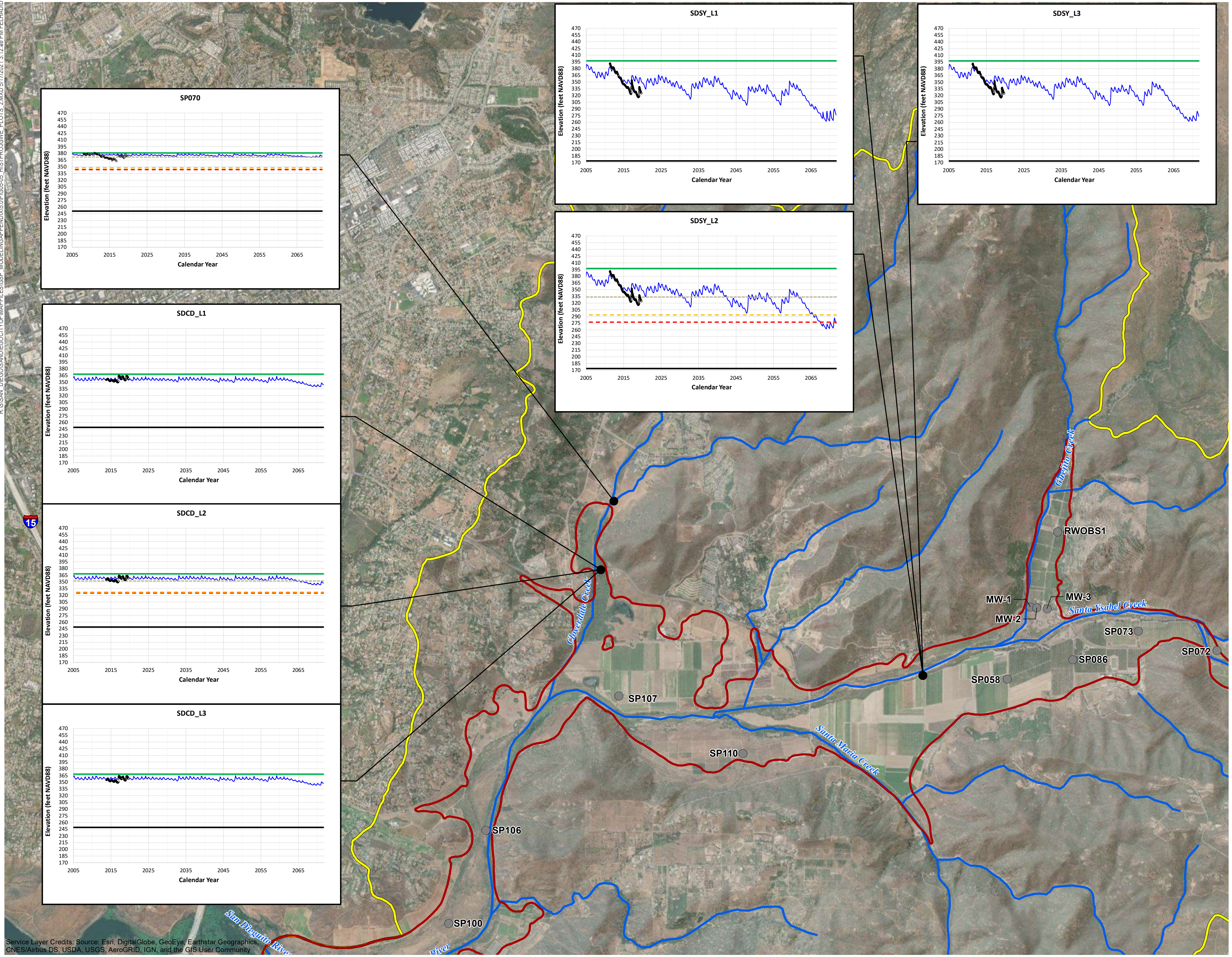

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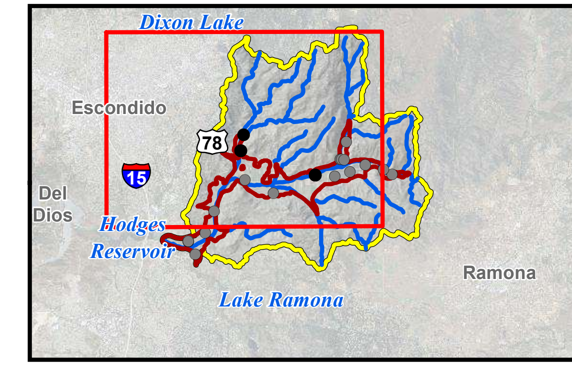

MAP LEGEND

- Calibration Target Well Location
- Modeled Stream
- San Pasqual Valley Groundwater Basin
- Model Domain Boundary

GRAPH LEGEND

- Measured Groundwater Elevation (feet NAVD88)
- Modeled Groundwater Elevation (feet NAVD88)
- Ground Surface Elevation (feet NAVD88)
- Modeled Basin Bottom Elevation (feet NAVD88)
- Minimum Threshold (feet NAVD88)
- Planning Threshold (feet NAVD88)
- Measurable Objective (feet NAVD88)

N

0 4,000 8,000
Feet

The City of SAN DIEGO

FIGURE 5-5 (PAGE 2 OF 3)
Historical and Projected Groundwater-level Hydrographs
Numerical Flow Model Documentation
San Pasqual Valley Groundwater Basin
Groundwater Sustainability Plan
San Pasqual Valley, California

Jacobs

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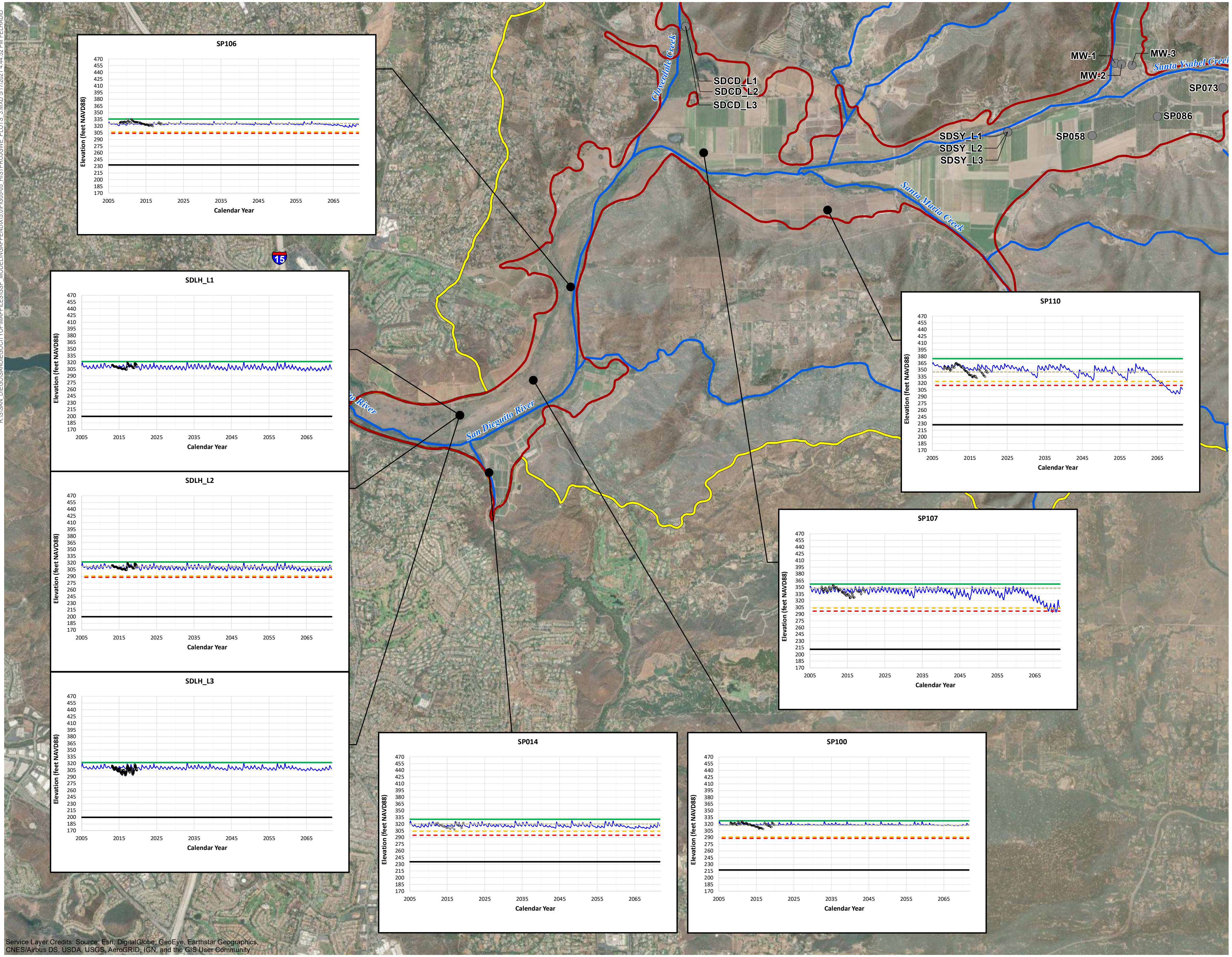

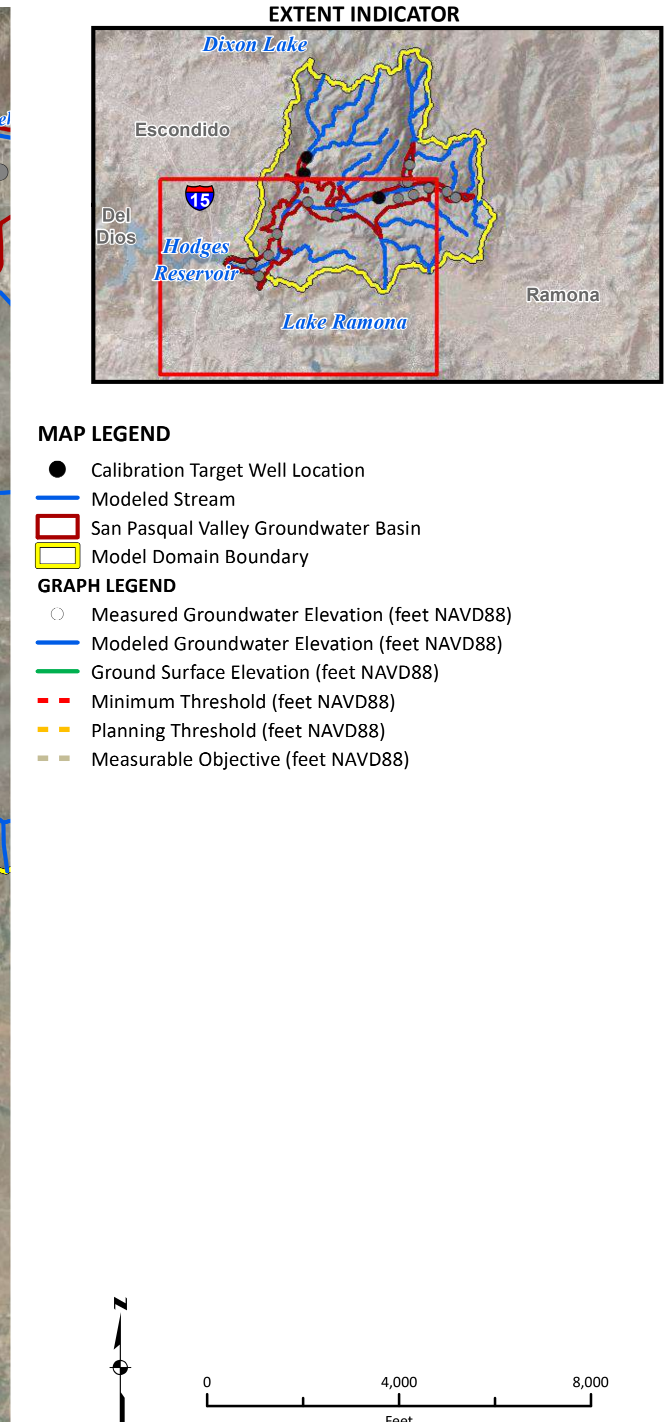

FIGURE 5-5 (PAGE 3 OF 3)

Historical and Projected Groundwater-level Hydrographs

Numerical Flow Model Documentation

San Pasqual Valley Groundwater Basin

Groundwater Sustainability Plan

San Pasqual Valley, California

Jacobs

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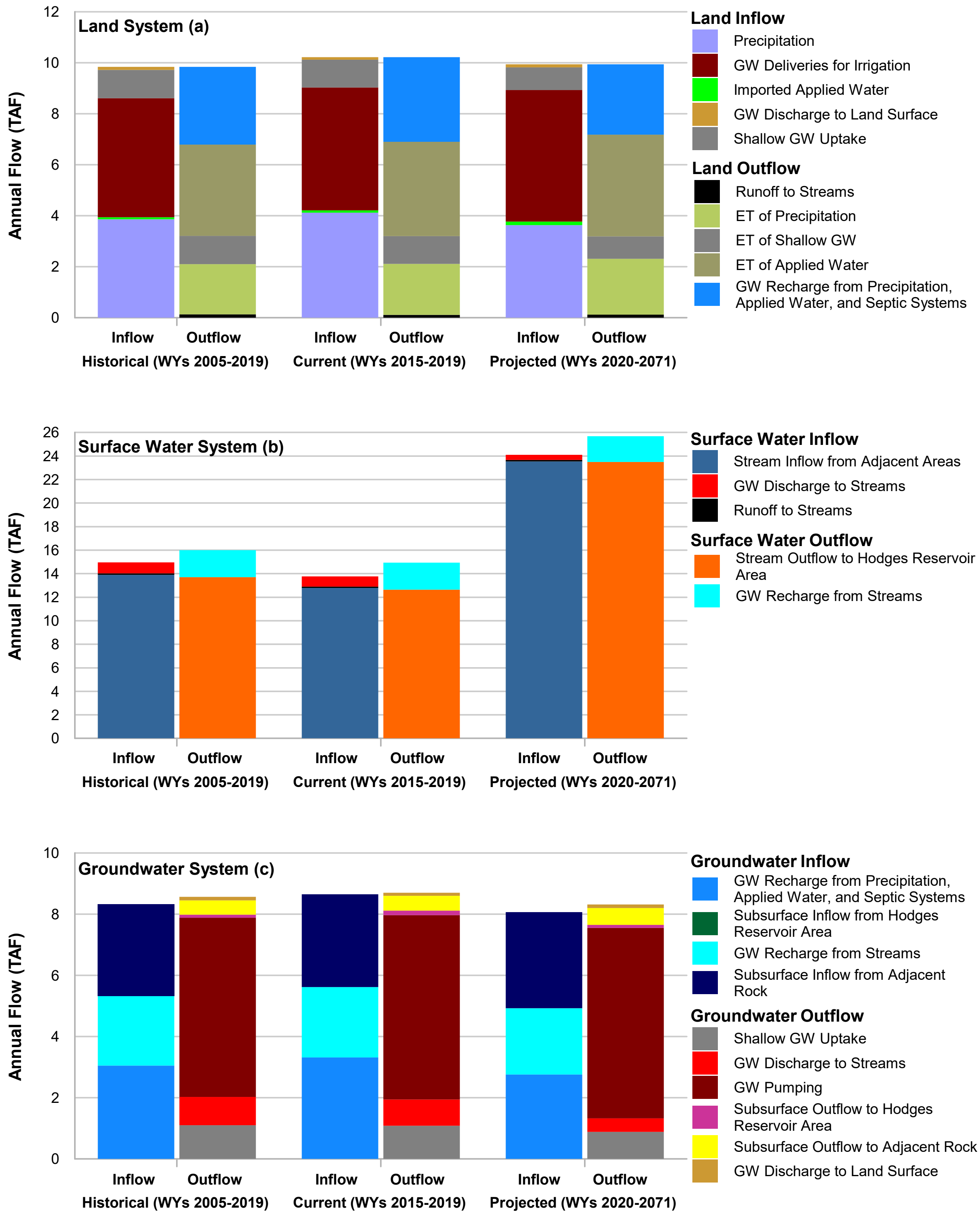

NOTES:

ET = Evapotranspiration
GW = Groundwater
TAF = thousand acre-feet
WY = Water Year

FIGURE 5-6

Historical, Current, and Projected Average Annual Water Budgets

Numerical Flow Model Documentation
San Pasqual Valley Groundwater Basin
Groundwater Sustainability Plan
San Pasqual Valley, California

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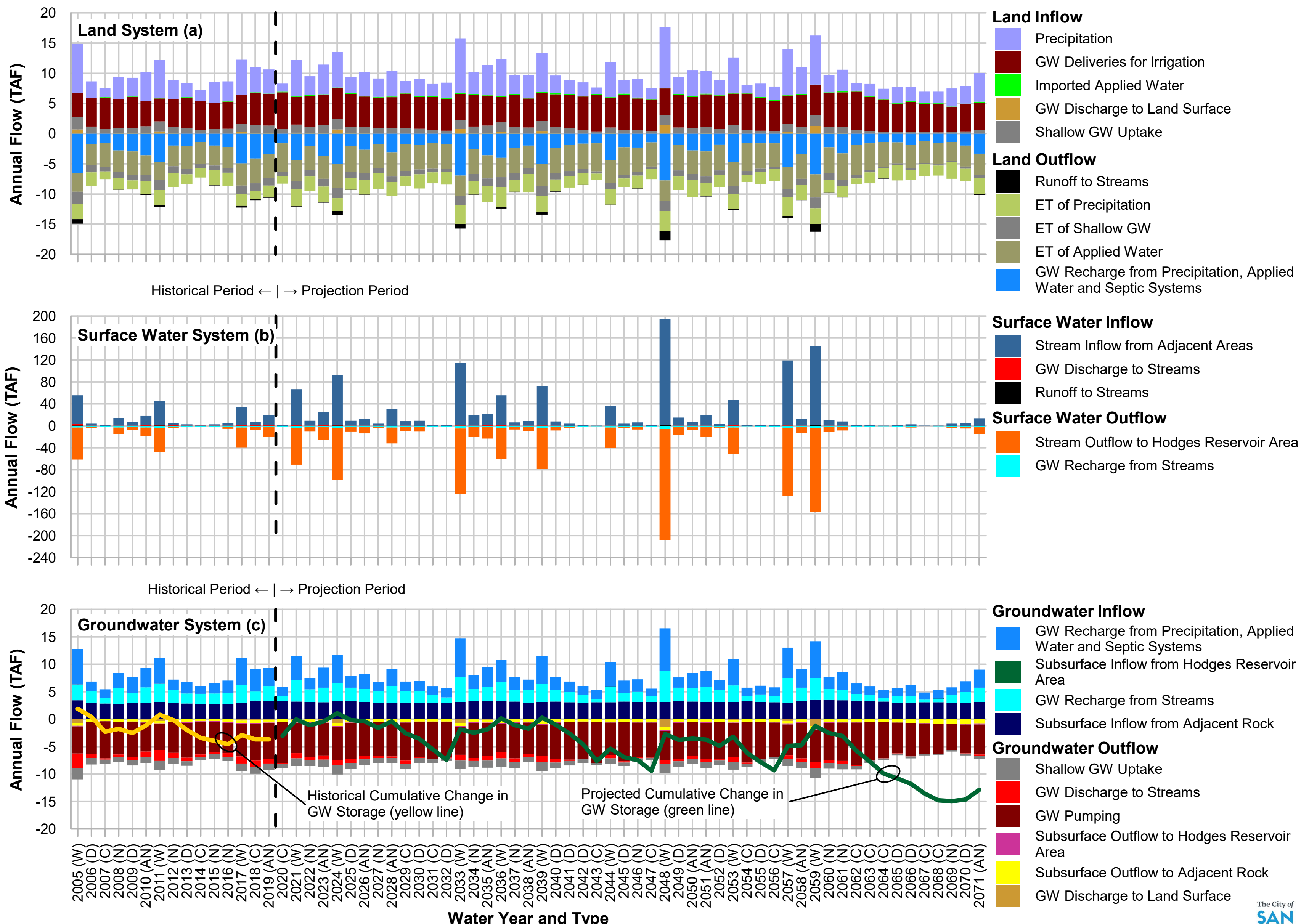

NOTES:

ET = Evapotranspiration
GW = Groundwater
TAF = thousand acre-feet

FIGURE 5-7
Historical, Current, and Projected Average Annual Water Budgets
Numerical Flow Model Documentation
San Pasqual Valley Groundwater Basin
Groundwater Sustainability Plan
San Pasqual Valley, California

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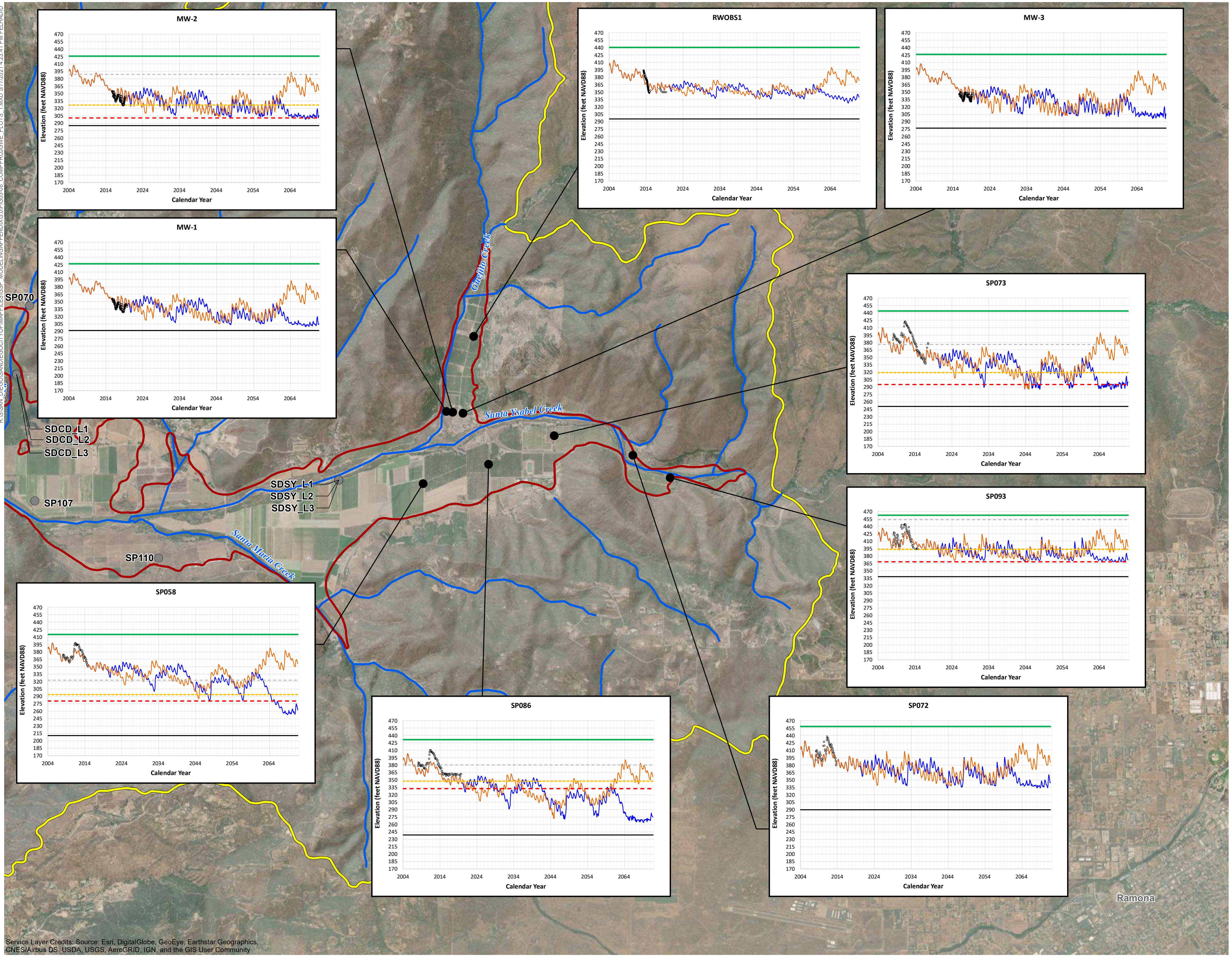

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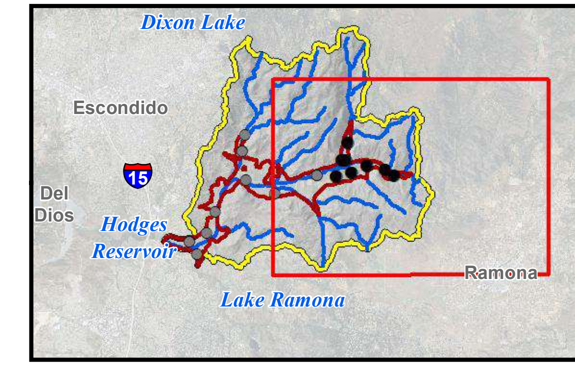

MAP LEGEND

- Calibration Target Well Location
- Modeled Stream
- San Pasqual Valley Groundwater Basin
- Model Domain Boundary

GRAPH LEGEND

- Measured Groundwater Elevation(feet NAVD88)
- HadGEM2-ES, RCP 8.5
- CanESM2, RCP 8.5
- Ground Surface (feet NAVD88)
- Modeled Basin Bottom Elevation (feet NAVD88)
- Minimum Threshold (feet NAVD88)
- Planning Threshold (feet NAVD88)
- Measurable Objective (feet NAVD88)

N

0 4,000 8,000

Feet

FIGURE 5-8 (PAGE 1 OF 3)

Comparison of Projected Groundwater-level Hydrographs

Numerical Flow Model Documentation

San Pasqual Valley Groundwater Basin

Groundwater Sustainability Plan

San Pasqual Valley, California

Jacobs

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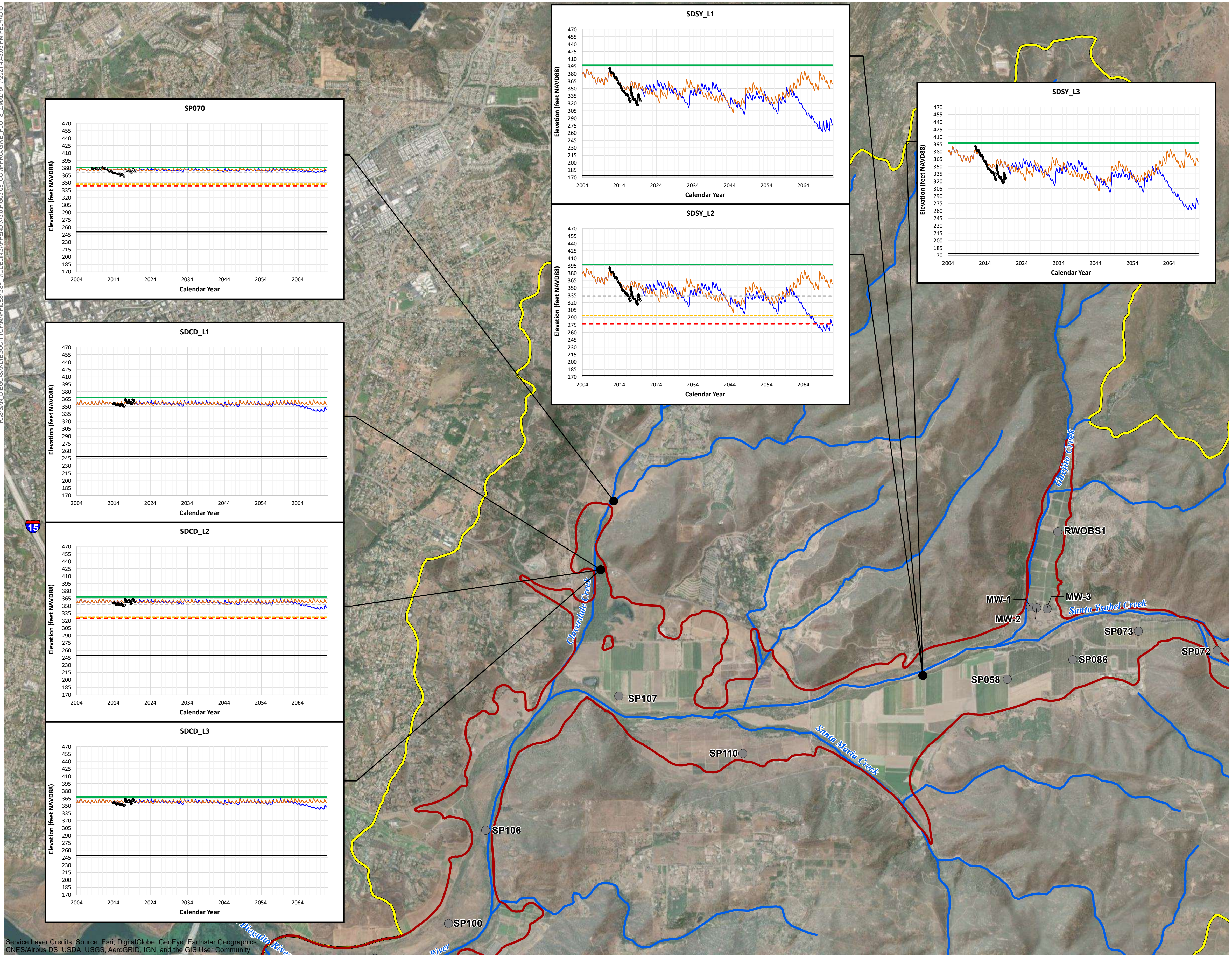

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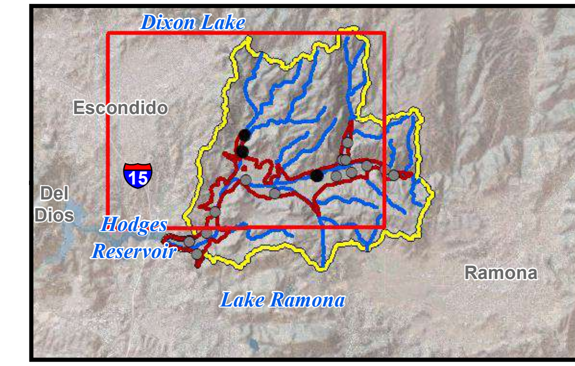

CHART LEGEND

- Calibration Target Well Location
- Modeled Stream
- San Pasqual Valley Groundwater Basin
- Model Domain Boundary

GRAPH LEGEND

- Measured Groundwater Elevation (feet NAVD88)
- HadGEM2-ES, RCP 8.5
- CanESM2, RCP 8.5
- Ground Surface (feet NAVD88)
- Modeled Basin Bottom Elevation (feet NAVD88)
- Minimum Threshold (feet NAVD88)
- Planning Threshold (feet NAVD88)
- Measurable Objective (feet NAVD88)

N

0 4,000 8,000

Feet

The City of SAN DIEGO

FIGURE 5-8 (PAGE 2 OF 3)

Comparison of Projected Groundwater-level Hydrographs

Numerical Flow Model Documentation

San Pasqual Valley Groundwater Basin

Groundwater Sustainability Plan

San Pasqual Valley, California

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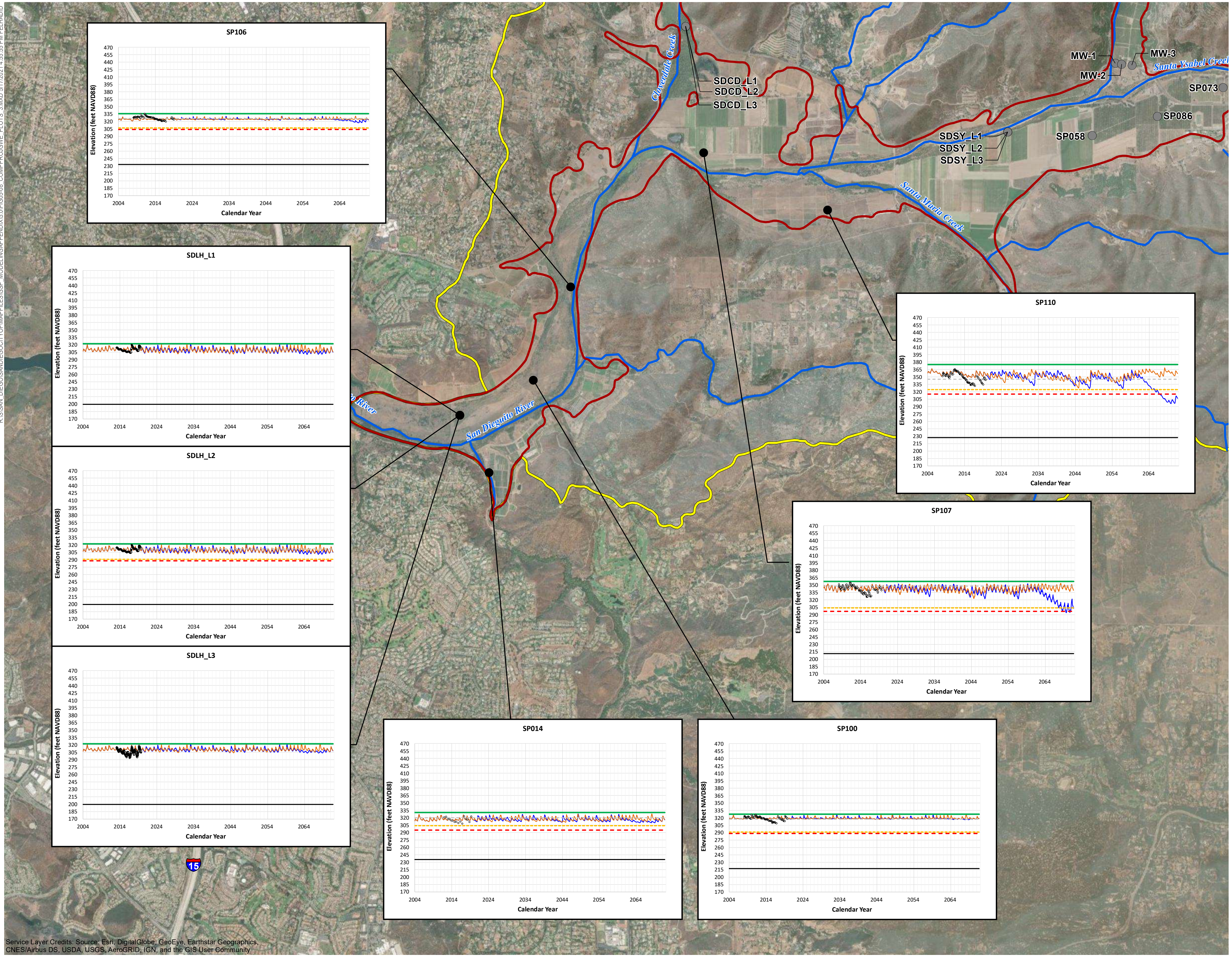
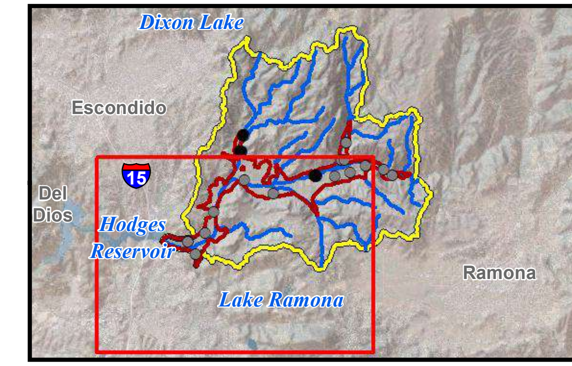


EXTENT INDICATOR



MAP LEGEND

- Calibration Target Well Location
- Modeled Stream
- San Pasqual Valley Groundwater Basin
- Model Domain Boundary

GRAPH LEGEND

- Measured Groundwater Elevation (feet NAVD88)
- HadGEM2-ES, RCP 8.5
- CanESM2, RCP 8.5
- Ground Surface (feet NAVD88)
- Modeled Basin Bottom Elevation (feet NAVD88)
- Minimum Threshold (feet NAVD88)
- Planning Threshold (feet NAVD88)
- Measurable Objective (feet NAVD88)

0 4,000 8,000
Feet

FIGURE 5-8 (PAGE 3 OF 3)
Comparison of Projected Groundwater-level Hydrographs
Numerical Flow Model Documentation
San Pasqual Valley Groundwater Basin
Groundwater Sustainability Plan
San Pasqual Valley, California

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SECTION 6. CONCLUSIONS AND RECOMMENDATIONS

Jacobs has developed an integrated groundwater/surface-water flow model called the SPV GSP Model of an area encompassing the SPV in San Diego County, California. This report was prepared by Jacobs to support the SPV GSA in the preparation of its GSP. This model integrates the 3D groundwater and surface-water systems, land surface processes, and operations and was built upon an existing numerical groundwater flow and transport model developed as part of the SPV SNMP (City of San Diego, 2014). The model was constructed and calibrated to simulate groundwater and surface-water flow conditions within a 42 mi^2 area encompassing the Basin using the USGS OneWater code (Boyce et al., 2020) and the USGS BCM (Flint et al., 2013; Flint and Flint, 2014). The calibration version of the SPV GSP Model simulates historical hydrologic conditions from January 2004 through September 2019, whereas the projection version of the SPV GSP Model simulates future hydrologic conditions from October 2019 through September 2071. Projections are based on the HadGEM2-ES GCM with the RCP 8.5 emissions scenario. All versions of the model include monthly stress periods to adequately simulate seasonal hydrologic processes.

The historical and projected groundwater system budgets all indicate small deficits in the cumulative change in groundwater storage ranging from -53 AFY under current conditions to -248 AFY under projected conditions. The projected deficit results from lower groundwater recharge rates and lower groundwater levels (equating to reduced groundwater uptake) and increased ET_0 under climate change conditions, thereby exacerbating the need for increased groundwater pumping to meet future water demands. Thus, even with little to no change in cropping patterns or population, reductions in precipitation and groundwater uptake and increases in ET_0 under climate change conditions could result in greater reliance on groundwater pumping. This potential deficit range represents 0.60 to 3 percent of the average of the groundwater inflows and outflows and is more likely than not, within the uncertainty of the estimates of the water budgets. Thus, the estimated deficit is "within the noise" of the groundwater budget, meaning small changes to individual water budget estimates could potentially result in no deficit in the cumulative change in groundwater storage. Because the estimated deficit in the cumulative change in groundwater storage is small enough to be considered within the uncertainty of the water budget, and because there have been no undesirable results identified for the historical period, a midrange of 4,740 to 6,741 AFY of agricultural groundwater pumping serves as an initial estimate of sustainable yield. This estimated range would suggest that the sustainable yield likely cannot increase much, if at all, beyond the historically observed range of agricultural groundwater pumping without a more favorable sequence of future hydrology.

A sensitivity analysis was performed to assess the sensitivity of groundwater levels and groundwater storage to the selected climate-change scenario. For this analysis, the CanESM2 GCM with the RCP 8.5 emissions scenario was selected. This particular GCM was selected because it is generally in the mid-range of the four GCMs evaluated, but exhibits a more favorable sequence of future hydrology than the HadGEM2-ES GCM and can therefore provide some insight into how the Basin might respond to a different sequence of future hydrology. Results from this sensitivity analysis indicate that the GCM selected can make the difference between projecting an overdrafted or balanced Basin.

Now that the SPV GSP Model has been developed to support the GSA in the preparation of its GSP, it could also be used during the implementation of the GSP to aid in the following:

- Help prioritize and refine the monitoring well network used to demonstrate whether the Basin is being managed sustainably
- Forecast potential outcomes to potential conditions or actions not evaluated herein
- Test hypotheses about interrelationships among different hydrologic processes of interest
- Support the City and County with decisions related to managing their water supply portfolios resulting in capital investments for projects and management actions, if necessary
- Provide technical graphics to support public outreach efforts
- Aid in the development of annual SGMA-related reports to DWR, as needed
- Support constructive dispute resolution on the basis of objective scientific analyses, if necessary

In addition to the possible model uses listed above, the following recommendations are also offered:

- Assumptions had to be made for well construction for several of the pumping wells included in the SPV GSP Model. It would be helpful to conduct video-log surveys of higher-priority wells with unknown well construction, so such details could be incorporated into the model and provide the opportunity to improve its accuracy and utility.
- Totalizing flow meters have been installed at some wells throughout the Basin. Expanding the list of wells with flow meters and recording the flow volumes monthly would provide more detailed information on pumping rates, which could be incorporated more directly into the modeling process. Doing so would provide the opportunity to reduce uncertainty in the modeled pumping rates.
- It will be important for the SPV GSP Model to be periodically updated as additional monitoring data are analyzed and as knowledge of the hydrogeologic conceptual model evolves.

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Attachment 1
Activity of Known Pumping Wells

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Activity of Known Pumping Wells

Pumping Well	Well Activity During the Historical Simulation Period (WYs 2005–2019)	Well Activity During the Projection Simulation Period (WYs 2020–2071)
CONS1	2008–2019	Not Active
New Well #5	2019	Active
RK-10	2017–2019	Active
RK-11	Not Active	Active
RK-12	Not Active	Active
RK-13	Not Active	Active
RK-8	2015–2019	Active
RK-9	2016–2019	Active
RK-DOM	2005–2015	Not Active
RK-DOM-2	2016–2019	Active
SP002	2005–2019	Active
SP003	2005–2019	Active
SP004	2005–2019	Active
SP008	2005–2019	Active
SP009	2005, 2007, 2009, 2011, 2013, 2015, 2017, 2019	Not Active
SP011	2005–2019	Active
SP012	2005–2019	Active
SP013	2005–2019	Active
SP021	2005–2019	Active
SP022	2005–2019	Active
SP023	2005–2019	Active
SP026	2005–2019	Active
SP027	2005–2019	Active
SP028	2005–2019	Active
SP029	2005–2019	Active
SP031	2005, 2007, 2009, 2011, 2013, 2015, 2017, 2019	Not Active
SP032	2005–2014	Not Active
SP033	2005–2019	Active
SP034	2005–2019	Active

Pumping Well	Well Activity During the Historical Simulation Period (WYs 2005–2019)	Well Activity During the Projection Simulation Period (WYs 2020–2071)
SP035	2005–2019	Active
SP036	2005–2019	Active
SP041	2005–2019	Active
SP042	2005–2019	Active
SP043	2005–2019	Active
SP046	2013–2019	Active
SP049	2005–2019	Active
SP050	2005–2019	Active
SP051	Not Active	Active
SP052	2016–2019	Active
SP053	2005–2019	Active
SP055	2005–2019	Active
SP057	2005–2019	Active
SP059	2005–2019	Active
SP061	2005–2019	Active
SP065	2005–2019	Active
SP067	2005–2019	Active
SP071	2005–2012	Not Active
SP072	2005–2007	Not Active
SP076	2005–2019	Active
SP079	2005–2019	Active
SP083	2005–2019	Active
SP084	2005–2019	Active
SP088	2005–2015	Active
SP089	2005–2019	Active
SP090	2005–2019	Active
SP092	2005–2006; 2008–2012; 2017; 2019	Active
SP095	2005–2012; 2017; 2019	Active
SP096	2005–2019	Active
SP098	2005–2019	Active
SP103	2005–2019	Active
SP121	2005–2019	Active

Pumping Well	Well Activity During the Historical Simulation Period (WYs 2005–2019)	Well Activity During the Projection Simulation Period (WYs 2020–2071)
SP125	2015–2019	Active
SP126	2017–2019	Active
SP127	2017–2019	Active
SPA002	2016–2019	Active
SPA005	2011–2019	Active
SPA006	2010–2019	Active
SPA010	2005–2019	Active
SPA108	2005–2019	Active
SPA130	2005–2019	Active
VW001	2005–2019	Active
VW002	2005–2019	Active
VW003	2005–2019	Active
Well 3	2005–2019	Not Active
Well 4	2005–2011	Not Active
Well 5	2005–2019	Not Active
Well 6	2005–2016	Not Active
Only those wells that stakeholders indicated as having some activity within the historical and projected simulation periods are listed.		

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Attachment 2
Time-weighted Annual Average Modeled Groundwater Pumping by Well (2005–2019)

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Time-weighted Annual Average Modeled Groundwater Pumping by Well (2005–2019)

Well	Minimum (gpm)	Average (gpm)	Maximum (gpm)
CONS1	0	2	3
New Well #5	0	7	110
RK-10	0	2	11
RK-11	0	0	0
RK-12	0	0	0
RK-13	0	0	0
RK-8	0	32	135
RK-9	0	29	135
RK-DOM	0	27	73
RK-DOM-2	0	2	8
SP002	100	126	151
SP003	73	110	159
SP004	73	110	159
SP008	70	113	150
SP009	0	13	33
SP011	22	34	44
SP012	8	10	14
SP013	20	23	28
SP021	132	161	207
SP022	132	161	207
SP023	132	161	207
SP026	7	8	11
SP027	7	13	18
SP028	7	13	18
SP029	0	0	0
SP031	0	13	33
SP032	0	22	54
SP033	19	33	55
SP034	19	33	55
SP035	1	1	1
SP036	0	0	0
SP041	0	1	1
SP042	0	1	1

Well	Minimum (gpm)	Average (gpm)	Maximum (gpm)
SP043	16	22	28
SP046	0	45	154
SP049	86	119	145
SP050	86	119	145
SP051	0	0	0
SP052	0	11	43
SP053	39	67	98
SP055	86	119	145
SP057	126	168	205
SP059	86	119	145
SP061	126	163	191
SP065	22	34	44
SP067	1	3	5
SP071	0	1	2
SP072	0	12	71
SP076	100	126	151
SP079	100	126	151
SP083	74	93	111
SP084	14	25	38
SP088	0	66	108
SP089	74	93	111
SP090	74	93	111
SP092	0	50	106
SP095	0	57	115
SP096	64	146	294
SP098	74	93	111
SP103	3	4	5
SP121	47	83	106
SP125	0	32	111
SP126	0	20	152
SP127	0	3	16
SPA002	0	14	56
SPA005	50	74	117
SPA006	0	40	70
SPA010	50	74	117

Well	Minimum (gpm)	Average (gpm)	Maximum (gpm)
SPA108	2	3	5
SPA130	2	3	5
VW001	22	25	29
VW002	24	29	35
VW003	25	29	33
Well 3	28	65	100
Well 4	0	18	46
Well 5	28	64	95
Well 6	0	49	113
Minimum	***0***	***0***	***0***
Median	***7***	***29***	***70***
Average	***31***	***50***	***79***
Maximum	***132***	***168***	***294***
Figure 3-8 depicts the locations of the modeled groundwater pumping wells.			

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Attachment 3
Land System Annual Water Budget

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Land System Annual Water Budget

Water Year(a)	Precipitation (AF)	Imported Applied Water (AF)	Agricultural GW Pumping (AF)	Shallow GW Uptake (AF)	GW Discharge to Land Surface (AF)	Total Inflow (AF)	Runoff to Streams (AF)	ET of Precipitation (AF)	ET of Shallow GW (AF)	ET of Applied Water (AF)	GW Recharge from Precipitation and Applied Water (AF)	Total Outflow (AF)
2005 (W)	8,096	58	4,019	2,043	674	14,890	702	2,549	2,043	3,072	6,525	14,891
2006 (D)	2,740	67	4,665	1,163	18	8,653	21	2,210	1,163	3,568	1,693	8,655
2007 (C)	1,470	80	5,260	737	0	7,547	2	1,281	737	4,024	1,504	7,548
2008 (N)	3,604	72	4,689	938	41	9,344	51	1,982	938	3,588	2,787	9,346
2009 (D)	3,120	79	5,110	912	28	9,249	38	1,449	912	3,910	2,943	9,252
2010 (AN)	4,694	63	4,180	1,126	103	10,166	118	2,148	1,126	3,202	3,575	10,169
2011 (W)	6,304	59	3,785	1,663	366	12,177	386	2,464	1,663	2,895	4,770	12,178
2012 (N)	3,112	65	4,529	1,121	29	8,856	35	2,275	1,121	3,453	1,974	8,858
2013 (D)	2,398	69	5,100	835	17	8,419	22	1,659	835	3,888	2,017	8,421
2014 (C)	1,797	70	4,760	628	0	7,255	2	1,595	628	3,633	1,398	7,256
2015 (N)	3,430	64	4,313	774	1	8,582	7	2,524	774	3,303	1,977	8,585
2016 (N)	3,278	77	4,481	800	17	8,653	25	2,166	800	3,446	2,217	8,654
2017 (W)	5,755	104	4,747	1,366	256	12,228	277	1,991	1,366	3,655	4,941	12,230
2018 (C)	4,175	114	5,349	1,250	136	11,024	153	1,384	1,250	4,117	4,122	11,026
2019 (AN)	3,993	100	5,199	1,248	100	10,640	112	1,935	1,248	3,998	3,348	10,641
2020 (C)	1,320	148	6,099	717	0	8,284	3	1,259	717	4,708	1,599	8,286
2021 (W)	6,013	108	4,571	1,369	147	12,208	165	2,793	1,369	3,528	4,354	12,209
2022 (N)	3,136	129	5,156	1,050	35	9,506	41	2,350	1,050	3,983	2,083	9,507
2023 (AN)	4,936	129	4,936	1,323	110	11,434	125	2,533	1,323	3,819	3,637	11,437
2024 (W)	5,861	128	5,100	1,731	686	13,506	707	2,103	1,731	3,942	5,026	13,509
2025 (D)	2,630	132	5,442	1,100	41	9,345	47	1,895	1,100	4,201	2,104	9,347
2026 (AN)	3,914	125	4,976	1,098	55	10,168	65	2,488	1,098	3,846	2,675	10,172
2027 (N)	3,002	119	5,079	920	3	9,123	8	2,551	920	3,918	1,728	9,125
2028 (AN)	4,228	126	5,122	886	3	10,365	15	2,370	886	3,954	3,143	10,368
2029 (C)	1,911	141	5,709	919	14	8,694	19	1,565	919	4,409	1,785	8,697
2030 (D)	2,910	133	5,231	830	0	9,104	5	2,340	830	4,044	1,888	9,107
2031 (C)	2,027	133	5,457	618	0	8,235	3	1,811	618	4,212	1,593	8,237
2032 (D)	2,499	134	5,318	481	0	8,432	4	2,103	481	4,104	1,740	8,432
2033 (W)	9,023	108	4,277	1,558	741	15,707	773	3,131	1,558	3,307	6,941	15,710
2034 (N)	3,576	141	5,264	1,141	50	10,172	59	2,302	1,141	4,075	2,597	10,174
2035 (AN)	4,948	129	4,963	1,249	96	11,385	111	2,593	1,249	3,839	3,596	11,388

Water Year(a)	Precipitation (AF)	Imported Applied Water (AF)	Agricultural GW Pumping (AF)	Shallow GW Uptake (AF)	GW Discharge to Land Surface (AF)	Total Inflow (AF)	Runoff to Streams (AF)	ET of Precipitation (AF)	ET of Shallow GW (AF)	ET of Applied Water (AF)	GW Recharge from Precipitation and Applied Water (AF)	Total Outflow (AF)
2036 (W)	6,242	103	4,231	1,583	260	12,419	277	3,312	1,583	3,269	3,980	12,421
2037 (N)	3,066	133	5,372	1,062	40	9,673	48	1,997	1,062	4,150	2,418	9,675
2038 (AN)	3,765	118	4,814	992	22	9,711	28	2,986	992	3,718	1,988	9,712
2039 (W)	6,554	123	4,688	1,655	406	13,426	427	2,703	1,655	3,629	5,014	13,428
2040 (D)	2,943	137	5,410	1,067	44	9,601	52	1,949	1,067	4,181	2,355	9,604
2041 (D)	2,331	141	5,605	839	0	8,916	5	1,836	839	4,331	1,907	8,918
2042 (D)	2,222	136	5,522	622	0	8,502	4	1,962	622	4,265	1,651	8,504
2043 (C)	1,098	159	6,033	368	0	7,658	3	1,030	368	4,661	1,599	7,661
2044 (W)	5,782	123	4,900	983	34	11,822	53	2,576	983	3,787	4,426	11,825
2045 (D)	2,196	151	5,812	660	0	8,819	6	1,388	660	4,490	2,275	8,819
2046 (N)	3,145	137	5,174	657	0	9,113	8	2,155	657	3,999	2,297	9,116
2047 (C)	1,807	138	5,215	400	0	7,560	2	1,714	400	4,011	1,435	7,562
2048 (W)	10,057	113	4,374	1,643	1,468	17,655	1,504	3,367	1,643	3,385	7,759	17,658
2049 (D)	2,751	138	5,431	1,009	19	9,348	24	2,226	1,009	4,197	1,893	9,349
2050 (AN)	4,315	121	5,077	966	19	10,498	30	2,786	966	3,920	2,800	10,502
2051 (AN)	3,776	139	5,364	1,081	49	10,409	60	2,169	1,081	4,148	2,953	10,411
2052 (D)	2,394	138	5,517	773	0	8,822	5	1,948	773	4,261	1,836	8,823
2053 (W)	5,812	138	5,168	1,345	131	12,594	151	2,368	1,345	4,001	4,730	12,595
2054 (C)	1,274	150	6,011	608	0	8,043	2	1,204	608	4,640	1,591	8,045
2055 (D)	2,243	142	5,447	471	0	8,303	3	1,999	471	4,205	1,626	8,304
2056 (C)	2,208	141	5,047	398	0	7,794	3	1,913	398	3,883	1,598	7,795
2057 (W)	7,567	120	4,662	1,333	320	14,002	345	3,153	1,333	3,606	5,567	14,004
2058 (AN)	4,451	130	5,347	1,064	35	11,027	48	2,444	1,064	4,129	3,345	11,030
2059 (W)	8,103	130	4,938	1,787	1,278	16,236	1,308	2,570	1,787	3,822	6,751	16,238
2060 (N)	2,911	146	5,581	1,092	30	9,760	37	2,074	1,092	4,317	2,242	9,762
2061 (N)	3,612	141	5,775	1,021	41	10,590	52	1,809	1,021	4,459	3,251	10,592
2062 (C)	1,298	162	6,301	652	0	8,413	4	977	652	4,867	1,915	8,415
2063 (C)	2,004	143	5,659	432	0	8,238	3	1,832	432	4,369	1,604	8,240
2064 (C)	1,704	148	5,313	286	0	7,451	2	1,661	286	4,085	1,418	7,452
2065 (D)	2,773	129	4,561	305	0	7,768	3	2,528	305	3,497	1,436	7,769
2066 (D)	2,303	148	4,922	342	0	7,715	5	1,702	342	3,780	1,887	7,716
2067 (C)	1,913	146	4,678	234	0	6,971	2	1,875	234	3,585	1,278	6,974

Water Year(a)	Precipitation (AF)	Imported Applied Water (AF)	Agricultural GW Pumping (AF)	Shallow GW Uptake (AF)	GW Discharge to Land Surface (AF)	Total Inflow (AF)	Runoff to Streams (AF)	ET of Precipitation (AF)	ET of Shallow GW (AF)	ET of Applied Water (AF)	GW Recharge from Precipitation and Applied Water (AF)	Total Outflow (AF)
2068 (C)	1,946	156	4,647	211	0	6,960	3	1,660	211	3,574	1,514	6,962
2069 (N)	2,997	141	4,067	267	0	7,472	3	2,692	267	3,142	1,369	7,473
2070 (D)	2,889	144	4,482	359	0	7,874	5	2,068	359	3,462	1,982	7,876
2071 (AN)	4,787	141	4,575	576	0	10,079	11	2,658	576	3,534	3,301	10,080
Historical Average (2005–2019)	3,864	76	4,679	1,107	119	9,845	130	1,974	1,107	3,583	3,052	9,846
Current Average (2015–2019)	4,126	92	4,818	1,088	102	10,226	115	2,000	1,088	3,704	3,320	10,227
Projected Average (2020–2071)	3,638	135	5,162	887	119	9,941	128	2,182	887	3,985	2,759	9,941

[a] *Water year types are shown in parentheses and defined as follows: W=wet, AN=above normal, N=normal, D=dry, and C=critically dry.*

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Attachment 4

Surface Water System Annual Water Budget

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Surface Water System Annual Water Budget

Water Year(a)	Runoff From Precipitation (AF)	Santa Ysabel Creek Inflow (AF)	Santa Maria Creek Inflow (AF)	Guejito Creek Inflow (AF)	Sycamore Creek Inflow (AF)	Cloverdale Creek Inflow (AF)	Other Streams Inflow (AF)	GW Discharge to Streams (AF)	Total Inflow (AF)	Stream Outflow to Lake Hodges (AF)	GW Recharge from Streams (AF)	Total Outflow (AF)
2005 (W)	702	25,184	13,189	5,659	763	3,463	4,204	2,653	55,817	58,224	2,788	61,012
2006 (D)	21	1,448	604	859	115	340	228	719	4,334	2,453	2,039	4,492
2007 (C)	2	148	244	227	73	119	122	248	1,183	164	1,025	1,189
2008 (N)	51	6,837	2,438	1,939	276	985	1,552	490	14,568	12,047	2,829	14,876
2009 (D)	38	2,298	1,272	802	206	797	731	562	6,706	5,082	1,869	6,951
2010 (AN)	118	7,258	3,916	2,370	432	1,209	2,141	933	18,377	16,145	2,829	18,974
2011 (W)	386	18,314	10,344	5,921	907	2,442	4,917	1,921	45,152	44,879	3,253	48,132
2012 (N)	35	758	673	693	232	418	643	965	4,417	2,221	2,285	4,506
2013 (D)	22	250	431	436	212	377	346	643	2,717	924	1,824	2,748
2014 (C)	2	260	407	370	210	315	306	384	2,254	398	1,886	2,284
2015 (N)	7	351	435	371	231	469	328	470	2,662	801	1,913	2,714
2016 (N)	25	633	1,610	503	275	563	799	611	5,019	3,045	2,120	5,165
2017 (W)	277	13,318	8,875	3,824	853	2,574	3,261	1,271	34,253	35,722	3,135	38,857
2018 (C)	153	1,211	959	451	540	1,401	1,656	1,142	7,513	6,248	1,662	7,910
2019 (AN)	112	7,671	5,032	2,458	473	1,172	1,714	810	19,442	17,417	2,686	20,103
2020 (C)	3	137	229	114	105	59	179	190	1,016	16	999	1,015
2021 (W)	165	23,053	30,135	4,386	1,009	2,041	4,854	924	66,567	66,682	3,966	70,648
2022 (N)	41	2,488	2,433	621	450	595	2,215	622	9,465	7,405	2,301	9,706
2023 (AN)	125	9,026	7,698	1,843	658	1,367	3,288	775	24,780	23,215	2,650	25,865
2024 (W)	707	44,234	31,473	7,425	881	3,232	3,940	939	92,831	95,385	3,312	98,697
2025 (D)	47	2,585	2,741	595	411	581	1,997	718	9,675	7,411	2,481	9,892
2026 (AN)	65	2,977	4,188	721	566	786	3,027	672	13,002	11,163	2,360	13,523
2027 (N)	8	1,015	1,297	299	224	298	572	374	4,087	2,121	2,100	4,221
2028 (AN)	15	15,359	8,577	2,468	405	1,293	1,819	301	30,237	28,641	3,074	31,715
2029 (C)	19	1,732	2,177	478	449	376	2,733	593	8,557	6,695	2,054	8,749
2030 (D)	5	4,068	3,067	789	203	428	510	216	9,286	7,655	2,121	9,776
2031 (C)	3	349	532	174	160	187	396	132	1,933	441	1,520	1,961
2032 (D)	4	195	262	123	118	148	144	109	1,103	132	1,003	1,135
2033 (W)	773	40,563	49,244	7,633	1,904	4,758	8,343	1,058	114,276	119,639	4,624	124,263
2034 (N)	59	9,131	3,925	2,003	446	1,185	2,060	556	19,365	17,570	2,288	19,858
2035 (AN)	111	5,799	6,581	1,476	858	1,471	4,744	877	21,917	20,297	2,580	22,877
2036 (W)	277	18,182	23,382	3,863	1,055	2,399	5,303	1,175	55,636	56,503	3,519	60,022

Water Year(a)	Runoff From Precipitation (AF)	Santa Ysabel Creek Inflow (AF)	Santa Maria Creek Inflow (AF)	Guejito Creek Inflow (AF)	Sycamore Creek Inflow (AF)	Cloverdale Creek Inflow (AF)	Other Streams Inflow (AF)	GW Discharge to Streams (AF)	Total Inflow (AF)	Stream Outflow to Lake Hodges (AF)	GW Recharge from Streams (AF)	Total Outflow (AF)
2037 (N)	48	1,240	1,641	461	369	649	1,342	695	6,445	4,507	2,074	6,581
2038 (AN)	28	2,141	2,907	620	396	605	1,816	453	8,966	7,154	2,215	9,369
2039 (W)	427	27,698	28,331	5,231	1,130	3,115	5,425	1,126	72,483	75,186	3,285	78,471
2040 (D)	52	2,087	2,199	651	382	668	1,508	688	8,235	6,381	2,123	8,504
2041 (D)	5	1,811	934	449	161	287	330	253	4,230	2,468	1,868	4,336
2042 (D)	4	384	644	162	126	135	179	119	1,753	410	1,395	1,805
2043 (C)	3	119	157	82	80	60	97	57	655	0	645	645
2044 (W)	53	11,467	15,814	2,324	774	1,989	3,352	612	36,385	36,903	2,917	39,820
2045 (D)	6	1,019	1,138	327	210	422	610	248	3,980	2,589	1,545	4,134
2046 (N)	8	1,993	1,575	604	291	640	1,088	236	6,435	4,866	1,808	6,674
2047 (C)	2	173	281	119	114	78	183	84	1,034	6	1,030	1,036
2048 (W)	1,504	93,530	66,032	15,548	2,083	7,106	8,151	811	194,765	202,147	5,647	207,794
2049 (D)	24	7,372	3,424	1,306	355	724	1,763	428	15,396	13,425	2,409	15,834
2050 (AN)	30	1,582	2,201	423	368	662	1,340	474	7,080	5,030	2,381	7,411
2051 (AN)	60	4,757	6,213	1,077	738	1,108	4,441	678	19,072	17,313	2,703	20,016
2052 (D)	5	1,058	1,151	276	186	243	409	233	3,561	1,434	2,219	3,653
2053 (W)	151	15,557	20,226	2,903	886	2,246	4,125	872	46,966	48,282	2,984	51,266
2054 (C)	2	132	207	101	99	48	164	140	893	18	872	890
2055 (D)	3	371	576	161	131	180	214	87	1,723	397	1,393	1,790
2056 (C)	3	192	340	125	125	133	162	76	1,156	62	1,107	1,169
2057 (W)	345	52,347	43,073	9,595	1,489	4,567	7,239	648	119,303	123,594	4,402	127,996
2058 (AN)	48	2,362	4,109	691	636	971	2,971	722	12,510	10,762	2,384	13,146
2059 (W)	1,308	67,105	49,332	12,732	1,745	5,767	7,069	991	146,049	152,243	3,923	156,166
2060 (N)	37	4,298	2,288	879	313	725	1,180	501	10,221	8,520	1,966	10,486
2061 (N)	52	2,596	1,992	615	334	835	1,133	527	8,084	6,402	1,968	8,370
2062 (C)	4	207	333	144	141	194	289	202	1,514	323	1,198	1,521
2063 (C)	3	205	314	139	124	137	203	81	1,206	84	1,133	1,217
2064 (C)	2	123	177	87	84	19	109	41	642	0	632	632
2065 (D)	3	431	654	171	122	147	177	38	1,743	585	1,226	1,811
2066 (D)	5	706	1,255	218	158	262	295	55	2,954	1,870	1,233	3,103
2067 (C)	2	111	147	75	72	3	60	12	482	0	477	477
2068 (C)	3	168	172	91	85	142	64	5	730	56	674	730
2069 (N)	3	1,592	1,273	413	130	327	174	5	3,917	2,661	1,422	4,083

Water Year(a)	Runoff From Precipitation (AF)	Santa Ysabel Creek Inflow (AF)	Santa Maria Creek Inflow (AF)	Guejito Creek Inflow (AF)	Sycamore Creek Inflow (AF)	Cloverdale Creek Inflow (AF)	Other Streams Inflow (AF)	GW Discharge to Streams (AF)	Total Inflow (AF)	Stream Outflow to Lake Hodges (AF)	GW Recharge from Streams (AF)	Total Outflow (AF)
2070 (D)	5	1,546	1,787	445	175	181	552	49	4,740	3,035	1,939	4,974
2071 (AN)	11	3,784	5,055	1,019	521	515	2,836	276	14,017	12,293	2,629	14,922
Historical Average (2005–2019)	130	5,728	3,361	1,792	387	1,109	1,530	921	14,958	13,714	2,276	15,990
Current Average (2015–2019)	115	4,634	3,381	1,521	474	1,235	1,551	861	13,772	12,641	2,303	14,944
Projected Average (2020–2071)	128	9,487	8,577	1,833	481	1,098	2,061	438	24,103	23,506	2,169	25,675

[(a)] *Water year types are shown in parentheses and defined as follows: W=wet, AN=above normal, N=normal, D=dry, and C=critically dry.*

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Attachment 5
Groundwater System Annual Water Budget

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Groundwater System Annual Water Budget

Water Year(a)	GW Recharge from Precipitation and Applied Water (AF)	GW Recharge from Septic Systems (AF)	GW Recharge from Streams (AF)	Subsurface Inflow from Lake Hodges Area (AF)	Subsurface Inflow from Adjacent Rock (AF)	Total Inflow (AF)	ET of Shallow GW (AF)	GW Discharge to Streams (AF)	Agricultural GW Pumping (AF)	GW Pumping for Domestic (AF)	Subsurface Outflow to Lake Hodges Area (AF)	Subsurface Outflow to Adjacent Rock (AF)	GW Discharge to Land Surface (AF)	Total Outflow (AF)	Change in GW Storage (AF)
2005 (W)	6,523	2	2,788	73	3,434	12,820	2,043	2,653	4,925	3	127	540	674	10,965	1,855
2006 (D)	1,691	2	2,039	81	3,025	6,838	1,163	719	5,875	3	0	501	18	8,279	-1,441
2007 (C)	1,502	2	1,025	19	2,867	5,415	737	248	6,741	3	3	394	0	8,126	-2,711
2008 (N)	2,785	2	2,829	13	2,768	8,397	938	490	5,933	3	34	428	41	7,867	530
2009 (D)	2,941	2	1,869	0	2,877	7,689	912	562	6,480	3	51	403	28	8,439	-750
2010 (AN)	3,573	2	2,829	0	2,931	9,335	1,126	933	5,287	3	96	439	103	7,987	1,348
2011 (W)	4,768	2	3,253	66	3,133	11,222	1,663	1,921	4,740	3	53	493	366	9,239	1,983
2012 (N)	1,972	2	2,285	11	2,945	7,215	1,121	965	5,569	3	14	521	29	8,222	-1,007
2013 (D)	2,015	2	1,824	0	2,858	6,699	835	643	6,356	3	175	474	17	8,503	-1,804
2014 (C)	1,396	2	1,886	0	2,754	6,038	628	384	5,875	3	170	394	0	7,454	-1,416
2015 (N)	1,975	2	1,913	0	2,745	6,635	774	470	5,403	3	175	349	1	7,175	-540
2016 (N)	2,215	2	2,120	0	2,699	7,036	800	611	5,565	3	193	452	17	7,641	-605
2017 (W)	4,939	2	3,135	0	3,033	11,109	1,366	1,271	5,934	3	90	525	256	9,445	1,664
2018 (C)	4,120	2	1,662	0	3,361	9,145	1,250	1,142	6,669	3	158	575	136	9,933	-788
2019 (AN)	3,346	2	2,686	0	3,318	9,352	1,248	810	6,521	3	125	529	100	9,336	16
2020 (C)	1,597	2	999	0	3,251	5,849	717	190	7,407	3	96	481	0	8,894	-3,045
2021 (W)	4,352	2	3,966	0	3,187	11,507	1,369	924	5,455	3	127	493	147	8,518	2,989
2022 (N)	2,081	2	2,301	0	3,104	7,488	1,050	622	6,208	3	116	515	35	8,549	-1,061
2023 (AN)	3,635	2	2,650	0	3,082	9,369	1,323	775	5,885	3	114	504	110	8,714	655
2024 (W)	5,024	2	3,312	0	3,291	11,629	1,731	939	6,050	3	141	542	686	10,092	1,537
2025 (D)	2,102	2	2,481	0	3,275	7,860	1,100	718	6,520	3	122	584	41	9,088	-1,228
2026 (AN)	2,673	2	2,360	0	3,135	8,170	1,098	672	5,940	3	109	535	55	8,412	-242
2027 (N)	1,726	2	2,100	0	2,968	6,796	920	374	6,111	3	105	487	3	8,003	-1,207
2028 (AN)	3,141	2	3,074	0	2,985	9,202	886	301	6,213	3	108	464	3	7,978	1,224
2029 (C)	1,783	2	2,054	0	3,021	6,860	919	593	6,912	3	138	479	14	9,058	-2,198
2030 (D)	1,886	2	2,121	0	2,936	6,945	830	216	6,386	3	79	424	0	7,938	-993
2031 (C)	1,591	2	1,520	0	2,907	6,020	618	132	6,649	3	101	449	0	7,952	-1,932
2032 (D)	1,738	2	1,003	0	2,944	5,687	481	109	6,502	2	65	457	0	7,616	-1,929
2033 (W)	6,939	2	4,624	0	3,114	14,679	1,558	1,058	5,083	2	152	527	741	9,121	5,558
2034 (N)	2,595	2	2,288	0	3,227	8,112	1,141	556	6,367	3	124	500	50	8,741	-629

Water Year(a)	GW Recharge from Precipitation and Applied Water (AF)	GW Recharge from Septic Systems (AF)	GW Recharge from Streams (AF)	Subsurface Inflow from Lake Hodges Area (AF)	Subsurface Inflow from Adjacent Rock (AF)	Total Inflow (AF)	ET of Shallow GW (AF)	GW Discharge to Streams (AF)	Agricultural GW Pumping (AF)	GW Pumping for Domestic (AF)	Subsurface Outflow to Lake Hodges Area (AF)	Subsurface Outflow to Adjacent Rock (AF)	GW Discharge to Land Surface (AF)	Total Outflow (AF)	Change in GW Storage (AF)
2035 (AN)	3,594	2	2,580	0	3,273	9,449	1,249	877	5,964	3	124	507	96	8,820	629
2036 (W)	3,978	2	3,519	0	3,246	10,745	1,583	1,175	5,030	3	141	550	260	8,742	2,003
2037 (N)	2,416	2	2,074	0	3,190	7,682	1,062	695	6,462	3	113	528	40	8,903	-1,221
2038 (AN)	1,986	2	2,215	0	3,013	7,216	992	453	5,808	3	110	470	22	7,858	-642
2039 (W)	5,012	2	3,285	0	3,130	11,429	1,655	1,126	5,555	3	135	544	406	9,424	2,005
2040 (D)	2,353	2	2,123	0	3,195	7,673	1,067	688	6,505	3	112	549	44	8,968	-1,295
2041 (D)	1,905	2	1,868	0	3,064	6,839	839	253	6,796	3	86	478	0	8,455	-1,616
2042 (D)	1,649	2	1,395	0	2,983	6,029	622	119	6,735	3	57	423	0	7,959	-1,930
2043 (C)	1,597	2	645	0	3,048	5,292	368	57	7,415	2	61	484	0	8,387	-3,095
2044 (W)	4,424	2	2,917	1	3,054	10,398	983	612	5,910	2	108	466	34	8,115	2,283
2045 (D)	2,273	2	1,545	0	3,213	7,033	660	248	7,092	2	90	494	0	8,586	-1,553
2046 (N)	2,295	2	1,808	0	3,153	7,258	657	236	6,309	2	92	509	0	7,805	-547
2047 (C)	1,433	2	1,030	0	3,104	5,569	400	84	6,373	2	73	568	0	7,500	-1,931
2048 (W)	7,757	2	5,647	0	3,152	16,558	1,643	811	5,213	2	151	565	1,468	9,853	6,705
2049 (D)	1,891	2	2,409	0	3,306	7,608	1,009	428	6,599	3	120	514	19	8,692	-1,084
2050 (AN)	2,798	2	2,381	0	3,204	8,385	966	474	6,128	3	98	462	19	8,150	235
2051 (AN)	2,951	2	2,703	0	3,134	8,790	1,081	678	6,531	3	132	486	49	8,960	-170
2052 (D)	1,834	2	2,219	0	3,094	7,149	773	233	6,755	3	96	466	0	8,326	-1,177
2053 (W)	4,728	2	2,984	0	3,170	10,884	1,345	872	6,233	3	125	484	131	9,193	1,691
2054 (C)	1,589	2	872	0	3,277	5,740	608	140	7,339	2	84	504	0	8,677	-2,937
2055 (D)	1,624	2	1,393	0	3,092	6,111	471	87	6,656	2	52	500	0	7,768	-1,657
2056 (C)	1,596	2	1,107	0	3,055	5,760	398	76	6,196	2	78	549	0	7,299	-1,539
2057 (W)	5,565	2	4,402	0	3,046	13,015	1,333	648	5,622	2	132	515	320	8,572	4,443
2058 (AN)	3,343	2	2,384	0	3,337	9,066	1,064	722	6,474	3	120	511	35	8,929	137
2059 (W)	6,749	2	3,923	0	3,529	14,203	1,787	991	5,877	3	145	578	1,278	10,659	3,544
2060 (N)	2,240	2	1,966	0	3,497	7,705	1,092	501	6,728	3	121	555	30	9,030	-1,325
2061 (N)	3,249	2	1,968	0	3,427	8,646	1,021	527	6,972	3	102	497	41	9,163	-517
2062 (C)	1,913	2	1,198	0	3,386	6,499	652	202	7,700	3	92	512	0	9,161	-2,662
2063 (C)	1,602	2	1,133	0	3,248	5,985	432	81	6,899	2	54	515	0	7,983	-1,998
2064 (C)	1,416	2	632	1	3,199	5,250	286	41	6,507	2	28	564	0	7,428	-2,178
2065 (D)	1,434	2	1,226	4	3,020	5,686	305	38	5,592	2	31	609	0	6,577	-891

Water Year(a)	GW Recharge from Precipitation and Applied Water (AF)	GW Recharge from Septic Systems (AF)	GW Recharge from Streams (AF)	Subsurface Inflow from Lake Hodges Area (AF)	Subsurface Inflow from Adjacent Rock (AF)	Total Inflow (AF)	ET of Shallow GW (AF)	GW Discharge to Streams (AF)	Agricultural GW Pumping (AF)	GW Pumping for Domestic (AF)	Subsurface Outflow to Lake Hodges Area (AF)	Subsurface Outflow to Adjacent Rock (AF)	GW Discharge to Land Surface (AF)	Total Outflow (AF)	Change in GW Storage (AF)
2066 (D)	1,885	2	1,233	0	3,046	6,166	342	55	5,973	2	59	707	0	7,138	-972
2067 (C)	1,276	2	477	0	3,084	4,839	234	12	5,541	2	41	785	0	6,615	-1,776
2068 (C)	1,512	2	674	2	3,071	5,261	211	5	5,384	2	40	866	0	6,508	-1,247
2069 (N)	1,367	2	1,422	2	2,970	5,763	267	5	4,721	2	37	870	0	5,902	-139
2070 (D)	1,980	2	1,939	0	2,988	6,909	359	49	5,262	2	82	880	0	6,634	275
2071 (AN)	3,299	2	2,629	0	3,115	9,045	576	276	5,482	2	106	853	0	7,295	1,750
Historical Average (2005–2019)	3,050	2	2,276	18	2,983	8,329	1,107	921	5,858	3	98	468	119	8,574	-245
Current Average (2015–2019)	3,318	2	2,303	0	3,031	8,654	1,088	861	6,018	3	149	486	102	8,707	-53
Projected Average (2020–2071)	2,757	2	2,169	0	3,145	8,073	887	438	6,231	2	99	545	119	8,321	-248

[(a)] *Water year types are shown in parentheses and defined as follows: W=wet, AN=above normal, N=normal, D=dry, and C=critically dry.*

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Appendix J
Groundwater-Dependent Ecosystems Technical Memorandum

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Groundwater-Dependent Ecosystems Study for the San Pasqual Valley Groundwater Basin

Prepared for:

SD Public Utilities

Prepared by:

WOODARD & CURRAN

September 2020

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Acronyms and Abbreviations

Term	Abbreviation
CDFW	California Department of Fish and Wildlife
CNDDB	California Natural Diversity Database
DWR	California Department of Water Resources
GDE	Groundwater Dependent Ecosystem
GIS	geographic information systems
GSA	Groundwater Sustainability Agency
GSP	Groundwater Sustainability Plan
HCM	hydrogeologic conceptual model
NCCAG	Natural Communities Commonly Associated with Groundwater
TM	Technical Memorandum
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey

SECTION 1. INTRODUCTION AND REGULATORY FRAMEWORK

As part of the California Sustainable Groundwater Management Act (SGMA), Groundwater Sustainability Agencies (GSAs) are required to develop a Groundwater Sustainability Plan (GSP) to help ensure that groundwater is available for long-term, reliable water supply uses. SGMA was signed into law in 2014.

Identifying groundwater-dependent ecosystems (GDEs) is a required component of a GSP. SGMA defines GDEs as "ecological communities or species that depend on groundwater emerging from aquifers or on groundwater occurring near the ground surface." This Technical Memorandum (TM) specifically focuses on GDEs identified in the San Pasqual Valley Groundwater Basin (Basin).

SECTION 2. SAN PASQUAL VALLEY GROUNDWATER BASIN ECOLOGICAL SETTING

An ecoregion is an area with generally similar ecosystems with similar quantity, quality, and type of environmental resources. Ecoregions are an important geospatial mapping system that are used by many local, state, and federal regulatory agencies and non-governmental organizations as a frame of reference for assessment and management of ecosystems across the United States. In the context of GDEs, it is important to consider the ecoregion where the GDEs are being assessed because biotic and abiotic processes may vary widely between localities.

The Basin is located in Southern California southeast of the City of Escondido, in San Diego County, California. The Basin sits entirely within the Southern California/Northern Baja Coast Level III ecoregion (85). The Southern California/Northern Baja Coast ecoregion is made up of coastal and alluvial plains, marine terraces, and foothills along the coast of Southern California. The ecoregion also extends southward for over 200 miles along the coast of Baja California. Dominant communities of coastal sage shrub and chaparral plants once characterized much of the area; however, large-scale urbanization and agricultural land clearing activities have altered the landscape (Griffith et al. 2016).

Much of the Basin is within the Diegan Coastal Valleys and Hills (85f) Level IV ecoregion. This ecoregion is characterized by terraces and some steep foothills. Numerous canyons exist along with a few wide valleys and the geology primarily consists of sedimentary and granitic rocks. Oceanic influence drives and changes the climate in this ecoregion. Soils are typically hot and dry, and the native vegetative communities include coastal scrub, chaparral, grasslands and meadows, and some small areas of coastal oak woodland.

The westernmost extents of the Basin are located within the Diegan Western Granitic Foothills (85g) Level IV ecoregion. This ecoregion consists of low, somewhat steep, foothills that are part of the lower Peninsular Ranges. Valleys in the ecoregion vary in width. Marine air does not affect the climate as much as in the neighboring ecoregions to the west, however, soil temperature and moisture regimes and vegetative communities are similar. Refer to Figure 1 at the end of this TM for more information about the project location and the Level IV ecoregion.

The Basin is in a wide valley situated between Highland Valley and Starvation Mountain to the south, and Rockwood Canyon to the north. According to U.S. Geological Survey (USGS) 7.5-minute topographic map Escondido, California (1975) and San Pasqual, California (1988) quadrangles, the approximate elevation of the eastern extent of the Basin is approximately 480 feet above mean sea level and the approximate elevation of the western extent of the Basin is 300 feet above mean sea level. Surface drainage in the eastern portion of San Pasqual Valley is mainly comprised of Guejito and Santa Ysabel Creeks. Guejito Creek flows southward through Rockwood Canyon and into Santa

Ysabel Creek which then flows westward through the valley eventually draining into the San Dieguito River. The San Dieguito River then continues flowing west-southwest through the Basin, eventually entering Hodges Reservoir. Refer to Figure 2 at the end of this TM for USGS 7.5-minute topography in the Basin's vicinity.

SECTION 3. THREATENED AND ENDANGERED SPECIES IN SAN PASQUAL VALLEY

As part of GDE assessment, Woodard & Curran conducted a preliminary review of special-status species in the Basin. Study for this TM focused on state- and federally listed species designated as threatened and/or endangered by the California Department of Fish and Wildlife (CDFW) or the U.S. Fish and Wildlife Service (USFWS). Other listed or otherwise unlisted special-status species were excluded from the evaluation. The purpose of this review was to support the determination of ecological value for GDEs in the Basin.

The San Pasqual Valley is covered by the City of San Diego Multiple Species Conservation Program (MSCP) Planning Area (City of San Diego, 1997). The MSCP is designed to conserve regional sensitive ecological habitat by coordinating project impacts and compensatory mitigation through the issuance of take permits for special-status species. The conservation area, or preserve, is known as the Multi-Habitat Planning Area (MHPA). Significant portions of the San Pasqual Valley are located within the MHPA.

Woodard & Curran conducted a literature review of the latest versions of the California Natural Diversity Database (CNDDB) (CDFW, 2020), and the California Native Plant Society (CNPS) Electronic Inventory of Rare and Endangered Plants (CNPS, 2020) for the USGS Topographic Quadrangles covering the San Pasqual Valley. Additionally, Woodard & Curran reviewed the USFWS Critical Habitat Mapper and Information, Planning and Consultation (IPaC) database for the area covering San Pasqual Valley.

A Woodard & Curran senior field biologist surveyed 15 representative locations in the field to document the Basin's vegetative community and general habitat conditions from March 2 through 4, 2020. Field survey locations were selected during the preliminary desktop assessment of GDEs for the Basin. The senior field biologist observed and documented plant and wildlife species during the field visit(s), and took representative photographs. Protocol-level or presence-absence surveys were not conducted as part of this project; they were not in the scope of work. Refer to Figure 3 for a map of state and federal protected species potentially occurring in the Basin. Table 1 below describes state- and federally listed threatened and endangered species in the Basin.

Table 1. State and Federally Threatened and Endangered Species in the San Pasqual Valley Groundwater Basin

Common Name/ Scientific Name	Status	Habitat	Potential to Occur Within the Project Area	Reliance on Groundwater	Individual(s) Observed
Fauna					
Stephen's kangaroo rat *Dipodomys stephensi*	USFWS: Endangered CDFW: Threatened MSCP Coverage: No	Annual grassland and coastal sage scrub with sparse cover.	Presumed absent based on CNDDB (2020) data. However, potential habitat exists within the project area.	No	No
Swainson's hawk *Buteo swainsoni*	USFWS: None CDFW: Threatened MSCP Coverage: Yes	Open grasslands and cultivated areas; deserts, savannas, and pine-oak woodlands.	Presumed extant based on CNDDB (2020) data. Potential habitat exists within the project area.	Indirect. Species relies on GDE vegetation in riparian woodlands for nesting.	No
tricolored blackbird *Agelaius tricolor*	USFWS: None CDFW: Threatened MSCP Coverage: Yes	Grasslands and other open cultivated areas; freshwater marshes.	Presumed extant based on CNDDB (2020) data. Potential habitat exists within the project area.	Direct. Species relies on GDE vegetation for breeding and roosting, especially emergent marsh wetlands.	No
southwestern willow flycatcher *Empidonax traillii extimus*	USFWS: Endangered CDFW: Endangered MSCP Coverage: Yes	Riparian and wetland thickets.	Presumed extant based on CNDDB (2020) data. Potential habitat exists within the project area.	Indirect. Species relies on GDE riparian vegetation.	No
coastal California gnatcatcher *Polioptila californica californica*	USFWS: Threatened CDFW: None MSCP Coverage: Yes	Coastal sage scrub; dry slopes, washes, mesas.	Presumed extant based on CNDDB (2020) data. Potential habitat exists within the project area.	No	No
least Bell's vireo *Vireo bellii pusillus*	USFWS: Endangered CDFW: Endangered MSCP Coverage: Yes	Willow-cottonwood forest, streamside thickets, and scrub oak.	Presumed extant based on CNDDB (2020) data. Potential habitat exists within the project area.	Indirect. Species relies on GDE vegetation in riparian areas for breeding.	No

Table 1. State and Federally Threatened and Endangered Species in the San Pasqual Valley Groundwater Basin

Common Name/ Scientific Name	Status	Habitat	Potential to Occur Within the Project Area	Reliance on Groundwater	Individual(s) Observed
arroyo toad *Anaxyrus californicus*	USFWS: Endangered CDFW: None MSCP Coverage: Yes	Washes, streams, arroyos, and adjacent riparian uplands; shallow gravelly pools.	Presumed absent based on CNDDB (2020) data. Potential habitat exists within the project area. USFWS critical habitat designated in project area.	Direct and indirect. Species relies on groundwater for breeding and on GDE vegetation for foraging.	No
quino checkerspot *Euphydryas editha quino*	USFWS: Endangered CDFW: None MSCP Coverage: No	Chaparral; coastal sage scrub with Plantago spp.	Presumed absent based on CNDDB (2020) data. However, potential habitat exists within the project area.	N/A*	No
Riverside fairy shrimp *Streptocephalus woottoni*	USFWS: Endangered CDFW: None MSCP Coverage: Yes	Vernal pool complexes in patches of grassland or coastal sage scrub that are hydrologically connected.	Presumed absent based on CNDDB (2020) data. Habitat was not observed within the project area.	N/A*	No
Branchinecta sandiegonensis San Diego fairy shrimp	USFWS: Endangered CDFW: None MSCP Coverage: Yes	Vernal pools and ephemeral wetlands that are hydrologically connected.	Presumed absent based on CNDDB (2020) data. Habitat was not observed within the project area.	N/A*	No
Flora					
San Diego thornmint *Acanthomintha ilicifolia*	USFWS: Threatened CDFW: Endangered MSCP Coverage: Yes	Heavy clay soils in coastal sage scrub and chaparral; often in open depressions or vernal pools.	Presumed absent based on CNDDB (2020) data. Habitat was not observed within the project area.	N/A*	No
San Diego ragweed *Ambrosia pumila*	USFWS: Endangered CDFW: None MSCP Coverage: Yes	Coastal scrub, grasslands, floodplains, and low valleys; persists in disturbed soils.	Presumed absent based on CNDDB (2020) data. However, potential habitat exists within the project area.	N/A*	No

Table 1. State and Federally Threatened and Endangered Species in the San Pasqual Valley Groundwater Basin

Common Name/ Scientific Name	Status	Habitat	Potential to Occur Within the Project Area	Reliance on Groundwater	Individual(s) Observed
coastal dunes milk-vetch *Astragalus tener var. titi*	USFWS: Endangered CDFW: Endangered MSCP Coverage: Yes	Sand/dunes; shallow swales on coastal terraces.	Presumed absent based on CNDDB (2020) data. Habitat was not observed within the project area.	N/A*	No
Encinitas baccharis *Baccharis vanessae*	USFWS: Threatened CDFW: Endangered MSCP Coverage: Yes	Shrubland, chaparral; typically found on steep slopes.	Presumed absent based on CNDDB (2020) data. Habitat was not observed within the project area.	N/A*	No
threadleaf brodiaea *Brodiaea filifolia*	USFWS: Threatened CDFW: Endangered MSCP Coverage: Yes	Grasslands, floodplains; vernal pools.	Presumed extant based on CNDDB (2020) data. Potential habitat exists within the project area.	N/A*	No
salt-marsh bird's beak *Cordylanthus maritimum spp. Maritimum*	USFWS: None CDFW: Endangered MSCP Coverage: Yes	Coastal salt marshes.	Presumed absent based on CNDDB (2020) data. Habitat was not observed within the project area.	N/A*	No
Orcutt's spineflower *Chorizanthe orcuttiana*	USFWS: Endangered CDFW: Endangered MSCP Coverage: No	Open areas within coastal, maritime shrubland/chaparral.	Presumed absent based on CNDDB (2020) data. Habitat was not observed within the project area.	N/A*	No
San Diego button-celery *Eryngium aristulatum var. parishii*	USFWS: Endangered CDFW: Endangered MSCP Coverage: Yes	Vernal pools.	Presumed absent based on CNDDB (2020) data. Habitat was not observed within the project area.	N/A*	No
spreading navarretia *Navarretia fossalis*	USFWS: Threatened CDFW: None MSCP Coverage: Yes	Vernal pools, alkali playas and sinks; may be found in man-made ditches/depressions with clay soils.	Presumed absent based on CNDDB (2020) data. Habitat was not observed within the project area.	N/A*	No

Table 1. State and Federally Threatened and Endangered Species in the San Pasqual Valley Groundwater Basin

Common Name/ Scientific Name	Status	Habitat	Potential to Occur Within the Project Area	Reliance on Groundwater	Individual(s) Observed
willowy monardella *Monardella viminea*	USFWS: Endangered CDFW: Endangered MSCP Coverage: Yes	Rocky coastal drainages; sandy benches along streambeds.	Presumed absent based on CNDDB (2020) data. However, potential habitat exists within the project area.	N/A*	No
California Orcutt grass *Orcuttia californica*	USFWS: Endangered CDFW: Endangered MSCP Coverage: Yes	Grasslands and chaparral; often found in dried beds of vernal pools.	Presumed absent based on CNDDB (2020) data. Habitat was not observed within the project area.	N/A*	No
San Diego mesa mint *Pogogyne abramsii*	USFWS: Endangered CDFW: Endangered MSCP Coverage: Yes	Vernal pools on coastal mesas/terraces.	Presumed absent based on CNDDB (2020) data. Habitat was not observed within the project area.	N/A*	No
Otay mesa mint *Pogogyne nudiuscula*	USFWS: Endangered CDFW: Endangered MSCP Coverage: Yes	Vernal pools; chaparral and coastal sage scrub.	Presumed absent based on CNDDB (2020) data. Habitat was not observed within the project area.	N/A*	No

Notes:
N/A = Reliance on groundwater unknown or otherwise not fully understood based on species omission from the Critical Species LookBook (2019).*
Source: California Natural Diversity Database (CDFW, 2020); California Native Plant Society Inventory Results (2020); IPaC Trust Resources List (USFWS, 2020).

SECTION 4. GROUNDWATER DEPENDENT ECOSYSTEM ASSESSMENT

4.1 Preliminary Desktop Assessment

Using a geographic information system (GIS), Woodard & Curran completed a preliminary desktop analysis of the California Department of Water Resources' (DWR's) Natural Communities Commonly Associated with Groundwater (NCCAG) database for the Basin. The NCCAG database includes a set of GIS data for vegetative communities and a separate dataset for wetlands. Additional relevant environmental and hydrogeological GIS datasets were also reviewed as part of the desktop assessment. Woodard & Current developed a Basin using these publicly available statewide and regional data layers to understand the extent of the NCCAG dataset within the Basin. Refer to Figure 4 for a map of GDE indicators in Basin. Once the Basin map of GDE indicators was developed, Woodard & Curran then reviewed the Basin and attempted to identify NCCAG polygons that appeared to be probable GDEs based on the following criteria:

- Presence of a USGS-mapped stream, spring, seep, or other waterbody
- Presence of USFWS National Wetlands Inventory (NWI) mapped wetlands
- Inundation visible on aerial imagery
- Saturation visible on aerial imagery
- Dense riparian and/or wetland vegetation visible on aerial imagery
- CNDDB and/or CNPS vegetative community data indicating a concentration of phreatophytes
- California Protected Areas and/or Areas of Conservation Emphasis

If an NCCAG polygon, or a portion of a polygon, included one or multiple of the above characteristics, then it was tentatively marked as a probable GDE for further evaluation and validation as part of the field study. NCCAG polygons that did not appear to exhibit the above criteria (or similar) were considered probable non-GDEs for the purposes of the desktop study, and were subject to further review as part of the field study.

4.2 GDE Field Assessment and Validation

Woodard & Curran completed a GDE field assessment and validation study at representative locations throughout the Basin. Woodard & Curran originally selected 16 representative locations based on geographic position in the Basin, vegetative community/habitat type, land use, topography, and other environmental factors determined via remote sensing. Prior to field work, Woodard & Curran coordinated with the City of San Diego Public Utilities Department to review the selected GDE field assessment sites and property lease information as well as physical access to the sites. Survey permissions were obtained from the appropriate stakeholders prior to mobilization for the field effort.

The field study was conducted from March 2 to 4, 2020. Woodard & Curran Senior Biologist Will Medlin and City of San Diego Public Utilities Department Civil Engineer Michael Bolouri worked together to complete the field study. GDE field assessment Sites 1 through 14 and 16 were visited during the field study. Site 15 was not accessible at time of field deployment and was eliminated from assessment.

Field observations were made at NCCAG-mapped seeps, springs, wetlands, and other riparian habitats to document plant communities, aquatic or semi-aquatic wildlife, indicators of surface and subsurface hydrology, soil-based evidence of a high water table, and other relevant ecological and hydrological data. Soils were sampled to an approximate depth of between 12 and 20 inches depending on restrictive layer to determine moisture content and texture. The soil profile was assessed and classified based on color using a Munsell soil color chart. Photographs were taken in the four cardinal directions (i.e., north, east, south, west) at each GDE field assessment site to document general habitat conditions. Field notes and additional photographs were taken of plant species, wildlife, and other relevant ecological data to support the GDE assessment at each site. Global positioning system (GPS) data points were also collected using a submeter Trimble Geo 7x GPS unit at each GDE field assessment site. Refer to Figure 5 at the end of this TM for GDE field assessment site locations.

Upon completion of the GDE field assessment, Woodard & Curran refined the preliminary desktop GDE assessment data and revised the mapping for probable GDEs and probable non-GDEs based on field observations and further research.

SECTION 5. RESULTS AND DISCUSSION

Out of 72 NCCAG-mapped polygons (i.e., 53 GDE wetland polygons and 19 GDE vegetation polygons), the combined desktop and field assessment yielded 64 potential GDEs and eight potential non-GDEs. In addition, during the desktop assessment, 1,062 individual locations were viewed and a determination of potential GDE status was made for a point on the landscape. Out of 1,062 assessment locations, 285 points were determined to be probable GDEs, 197 points were determined to be probable non-GDEs, and 580 points were determined to be wetland and/or riparian communities. Probable GDEs largely consisted of dense riparian and wetland communities along mapped drainage systems where monitoring well data showed the depth to groundwater at 30 feet or less relative to the ground surface. Probable non-GDEs largely consisted of dry upland areas dominated by shallow-rooted grasses and/or invasive species. Areas that consisted of wetland and/or riparian phreatophytes (i.e., deep-rooted plant species) along drainageways where depth to groundwater was greater than 30 feet were classified as wetland and riparian communities. Refer to Figure 6 at the end of this TM for the draft GDE assessment map.

For the field study, 15 representative locations were assessed for GDE indicators, functions, and values. Of the 15 sites reviewed in the field, one appeared to be a non-GDE, nine appeared to be GDEs, and five appeared to be wetland/riparian communities but not GDEs. The 14 GDE and wetland/riparian community sites had deep-rooted woody riparian or wetland species growing there. Further, five sites (i.e., Sites 5, 7, 9, 10 and 16) had either standing or flowing water observed at the surface. The one potential non-GDE location was Site 1, which did not have any deep-rooted woody riparian or wetland species and was dominated by grasses and other non-native herbaceous species. Table 2 below describes each of the field assessment sites in more detail.

Table 2. Woodard & Curran GDE Field Assessment Sites in the San Pasqual Valley Groundwater Basin

GDE Field Assessment Site	Latitude/ Longitude	NCCAG-Mapped Polygon?	NCCAG Vegetation/ Wetland Type[a]	Dominant Plant Species Observed	Field Assessment Notes
1	33.056556 N/ 117.054057 W	Yes	Vegetation—Tule-Cattail Wetland—Palustrine, emergent, persistent, seasonally flooded	• *Avena fatua* • *Conium maculatum* • *Rumex crispus* • *Bromus carinatus*	Site is an upland terrace within the floodplain of the San Dieguito River. Soils at data point are low-chroma yet dry and somewhat friable. Site appears to be dominated by non-native grasses and other invasive herbaceous plants. This location does not appear to be a GDE.
2	33.052368 N/ 117.049115 W	Yes	Vegetation—Willow (Shrub)	• *Salix laevigata* • *Tamarisk ramosissima* • *Baccharis salicifolia* • *Schoenoplectus californicus* • *Urtica dioica*	Site is a forested riparian corridor with many large willows. Soils at data point are low-chroma with some organic content. Multiple songbirds were observed/heard at this site. This location appears to be a GDE.
3	33.046929 N 117.042083 W	Yes	Wetland—Palustrine, scrub-shrub, forested, seasonally flooded	• *Eucalyptus globulus* • *Baccharis salicifolia* • *Salix laevigata* • *Eriogonum sp.* • *Conium maculatum* • *Carex sp.*	Site is a forested drainage with a small intermittent/ephemeral stream channel; sediment is deposited throughout the floodplain; soils are low-chroma. Multiple songbirds were observed/heard at this site. This location appears to be a GDE.
4	33.053996 N/ 117.039712 W	Yes	Wetland - Palustrine, emergent, persistent, seasonally flooded	• *Salix laevigata* • *Baccharis salicifolia* • *Rumex crispus*	Site is a dense willow thicket with little herbaceous vegetation; soils are low-chroma with some organic content. This location appears to be a GDE.
5	33.069208N/ 117.031547W	Yes	Vegetation—Willow (Shrub)	• *Salix lasiolepis* • *Salix laevigata* • *Urtica dioica* • *Typha domingensis* • *Schoenoplectus californicus*	Site is a riparian willow thicket. Soils are saturated at the surface by what appears to be groundwater; high organic content observed. Surface water, drainage patterns, drift deposits, and iron-oxidizing bacteria observed. This location appears to be a GDE.

Table 2. Woodard & Curran GDE Field Assessment Sites in the San Pasqual Valley Groundwater Basin

GDE Field Assessment Site	Latitude/ Longitude	NCCAG-Mapped Polygon?	NCCAG Vegetation/ Wetland Type[a]	Dominant Plant Species Observed	Field Assessment Notes
6	33.081393 N/ 117.028357 W	No	N/A	• *Salix lasiolepis* • *Baccharis salicifolia* • *Schoenoplectus californicus* • *Rumex crispus*	Site is an emergent marsh adjacent to an excavated pond/basin that is holding water. Soils are saturated and low-chroma. Dense wetland vegetation. Several waterfowl observed in the open water. This location appears to be a GDE.
7	33.081120 N/ 117.013124 W	Yes	Vegetation—Riparian mixed shrub	• *Tamarisk ramosissima* • *Polygonum sp.* • *Rumex crispus* • *Silybum marianum* • *Plantago sp.*	Site is within what appears to be an excavated pond/basin. Soils are saturated and low-chroma. Standing water observed in western portion of basin. Vegetation favors disturbed sites. Multiple songbirds heard/observed. This location appears to be a GDE.
8	33.091726 N 117.019165 W	Yes	Vegetation—Willow (shrub) Wetland—Palustrine, forested, seasonally flooded	• *Washingtonia filifera* • *Salix laevigata* • *Baccharis salicifolia* • *Urtica dioica* • *Anemopsis californica*	Site is a forested floodplain with a dense understory. Soils are low-chroma through the profile with some organic content. Multiple songbirds heard/observed as well as small mammal. This location appears to be a GDE.
9	33.093791 N/ 117.016029 W	Yes	Wetland—Palustrine, forested, seasonally flooded	• *Salix laevigata* • *Baccharis salicifolia* • *Urtica dioica* • *Schoenoplectus californicus*	Site is an inundated pond/basin with thick scrub-shrub wetland vegetation surrounding and extending into deeper, open water areas. Significant waterfowl and other songbirds heard/observed. This location appears to be a GDE.

Table 2. Woodard & Curran GDE Field Assessment Sites in the San Pasqual Valley Groundwater Basin

GDE Field Assessment Site	Latitude/ Longitude	NCCAG-Mapped Polygon?	NCCAG Vegetation/ Wetland Type[a]	Dominant Plant Species Observed	Field Assessment Notes
10	33.099183 N/ 117.019179 W	Yes	Wetland—Palustrine, emergent, persistent, seasonally saturated	• *Salix laevigata* • *Tamarisk ramosissima* • *Nasturtium officinale* • *Eleocharis palustris* • *Lobelia sp.* • *Rumex crispus* • *Schoenoplectus californicus*	Site is a wet meadow in a pasture adjacent to a perennial drainage feature. Soils are low-chroma and have a dense upper clay layer that appears to help pond surface water. Surface water is approximately 4-6 inches deep. Algae and macroinvertebrates observed in standing water. This location appears to be a GDE.
11	33.089156 N/ 116.995885 W	Yes	Vegetation—Riparian mixed hardwood Wetland—Palustrine, emergent, persistent, seasonally flooded	• *Washingtonia filifera* • *Salix laevigata* • *Eucalyptus globulus* • *Baccharis salicifolia* • *Urtica dioica* • *Anemopsis californica*	Site is a mature riparian forest. A small intermittent stream was observed just west of the data point and was flowing at time of field survey. Soils are low-chroma in the upper part but become high-chroma below. Soils are very sandy and appear to be well drained. Songbirds heard/observed. This location appears to be a wetland/riparian community, but not a GDE.
12	33.083919 N/ 116.995362 W	Yes	Vegetation—Riparian mixed shrub Wetland—Palustrine, emergent, persistent, seasonally flooded	• *Tamarisk ramosissima* • *Salix lasiolepis* • *Baccharis salicifolia* • *Arundo donax* • *Xanthium strumarium* • *Conium maculatum* • *Madia exigua*	Site is a dry creek bed and adjacent riparian zone. Some vegetated mid-channel bars are present. No evidence of recent flow. Soils are very dry, friable sands. Butterflies and a lizard were observed. This location appears to be a wetland/riparian community, but not a GDE.

Table 2. Woodard & Curran GDE Field Assessment Sites in the San Pasqual Valley Groundwater Basin

GDE Field Assessment Site	Latitude/ Longitude	NCCAG-Mapped Polygon?	NCCAG Vegetation/ Wetland Type[a]	Dominant Plant Species Observed	Field Assessment Notes
13	33.073991 N/ 116.977904 W	Yes	Vegetation—Riversidean alluvial scrub	• *Tamarisk ramosissima* • *Sambucus nigra spp.* • *Caerulea* • *Salix lasiolepis* • *Baccharis salicifolia* • *Xanthium strumarium* • *Arundo donax*	Site is a dry creek bed just downstream from a roadway bridge. Lots of shrubby vegetation growing in channel and wrack lines are present from past flooding events. Soils are low-chroma and moist in the upper part, but quickly become dry sand below. Bees and songbirds heard/observed; swallow nests were observed under bridge. This location appears to be a wetland/riparian community, but not a GDE.
14	33.092898 N/ 116.956288 W	Yes	Vegetation—Riparian mixed shrub Wetland—Palustrine, scrub-shrub, seasonally flooded	• *Tamarisk ramosissima* • *Sambucus nigra spp.* • *Caerulea* • *Baccharis salicifolia* • *Conium maculatum* • *Galium aparine* • *Xanthium strumarium* • *Madia exigua* • *Bromus diandrus*	Site is a riparian scrub-shrub upland along Santa Ysabel Creek. Streambed is dry and banks are steep and eroded. Soils are somewhat low-chroma, but dry throughout profile. This location appears to be a wetland/riparian community, but not a GDE.

Table 2. Woodard & Curran GDE Field Assessment Sites in the San Pasqual Valley Groundwater Basin

GDE Field Assessment Site	Latitude/ Longitude	NCCAG-Mapped Polygon?	NCCAG Vegetation/ Wetland Type[a]	Dominant Plant Species Observed	Field Assessment Notes
16	33.088564 N/ 116.923676 W	Yes	Vegetation—Willow (shrub)	• *Populus fremontii* • *Platanus racemose* • *Tamarisk ramosissima* • *Salix lasiolepis* • *Salix laevigata, Eucalyptus globulus* • *Baccharis salicifolia* • *Arundo donax* • *Xanthium strumarium* • *Ricinus communis* • *Mirabilis laevis var. crassifolia*	Site is the streambed of Santa Ysabel Creek with adjacent riparian scrub-shrub and forest. Stream was flowing at time of field survey. Aquatic macroinvertebrates were observed in stream. Soils were moist coarse sands. Wild turkey, wading birds, and songbirds heard/observed. This location appears to be a wetland/riparian community, but not a GDE.

GDEs are present in the Basin as indicated in Table 2. Groundwater monitoring well data from 2015 for depth to water ranges from 8 feet below surface along Cloverdale Creek in the northwestern portion of the Basin to greater than 80 feet below surface along Santa Ysabel Creek near the eastern extent of the Basin. Surface water base flow was observed in the field at five of the GDE assessment sites in March 2020, including in Santa Ysabel Creek near the eastern extent of the Basin. This may suggest that there is a separate shallow, perched groundwater table that was discharging at the time of the field study. This shallow water-bearing zone may be comprised of a type of rock that allows groundwater to exist within interstitial pore spaces and discharge to localized receiving streams prior to connecting to the regional groundwater table or aquifer. Additionally, some GDEs and wetland/riparian communities may be supported by surface waters resulting from storm flows and (possibly) flowing springs outside the Basin boundary.

The major drainages in the San Pasqual Valley have significant riparian or wetland vegetative communities with an abundance of woody phreatophytes such as willows (*Salix* spp.), salt cedar (*Tamarisk ramosissima*), Fremont cottonwood (*Populus fremontii*), California sycamore (*Platanus racemosa*) and California fan palm (*Washingtonia filifera*). These drainageways and their associated riparian communities provide valuable ecological habitat for many species to shelter, feed, and breed. They also provide wildlife corridors for movement and migration through the large agricultural fields and orchards located on the adjacent valley floor.

GDEs in the Basin may also provide habitat for certain state and federal protected species. Of the 23 state- or federally listed threatened and endangered species that have the potential to occur in the Basin, six species (i.e., Swainson's hawk, tricolored blackbird, southwestern willow flycatcher, coastal California gnatcatcher, least Bell's vireo, and threadleaf brodiaea) are presumed extant based on CNDDB (2020) data. Additionally, potential suitable habitat was observed for 11 species (i.e., Stephen's kangaroo rat, Swainson's hawk, tricolored blackbird, southwestern willow flycatcher, coastal California gnatcatcher, least Bell's vireo, arroyo toad, quino checkerspot, San Diego ragweed, threadleaf brodiaea, and willowy monardella) during the field study. Many of these special-status species rely on the riparian scrub-shrub found along drainageways and other wetland ecosystems present in the valley for all or part of their life cycle.

5.1 Conclusion

GDEs and wetland/riparian communities present in the Basin do not appear to depend solely on the regional groundwater table. Many of the GDEs and wetland/riparian communities observed rely on surface flows and stormwater runoff to influence soil moisture requirements for vegetative communities. Further study is recommended to understand if and where a shallow, perched groundwater table exists and if there is an aquitard or other rock layer in the subsurface geology that would influence groundwater discharge at the surface. Also, additional work is recommended to refine and revise the extents of the NCCAG datasets, as this may yield a more realistic map of GDEs for the Basin. Special attention should be given to human-made excavated basins that have naturalized into semi-permanently inundated wetlands and/or open waters where waterfowl and other wetland-dependent species are present. These ecosystems may or may not have a direct connection to groundwater and that should be confirmed.

SECTION 6. REFERENCES

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FIGURES

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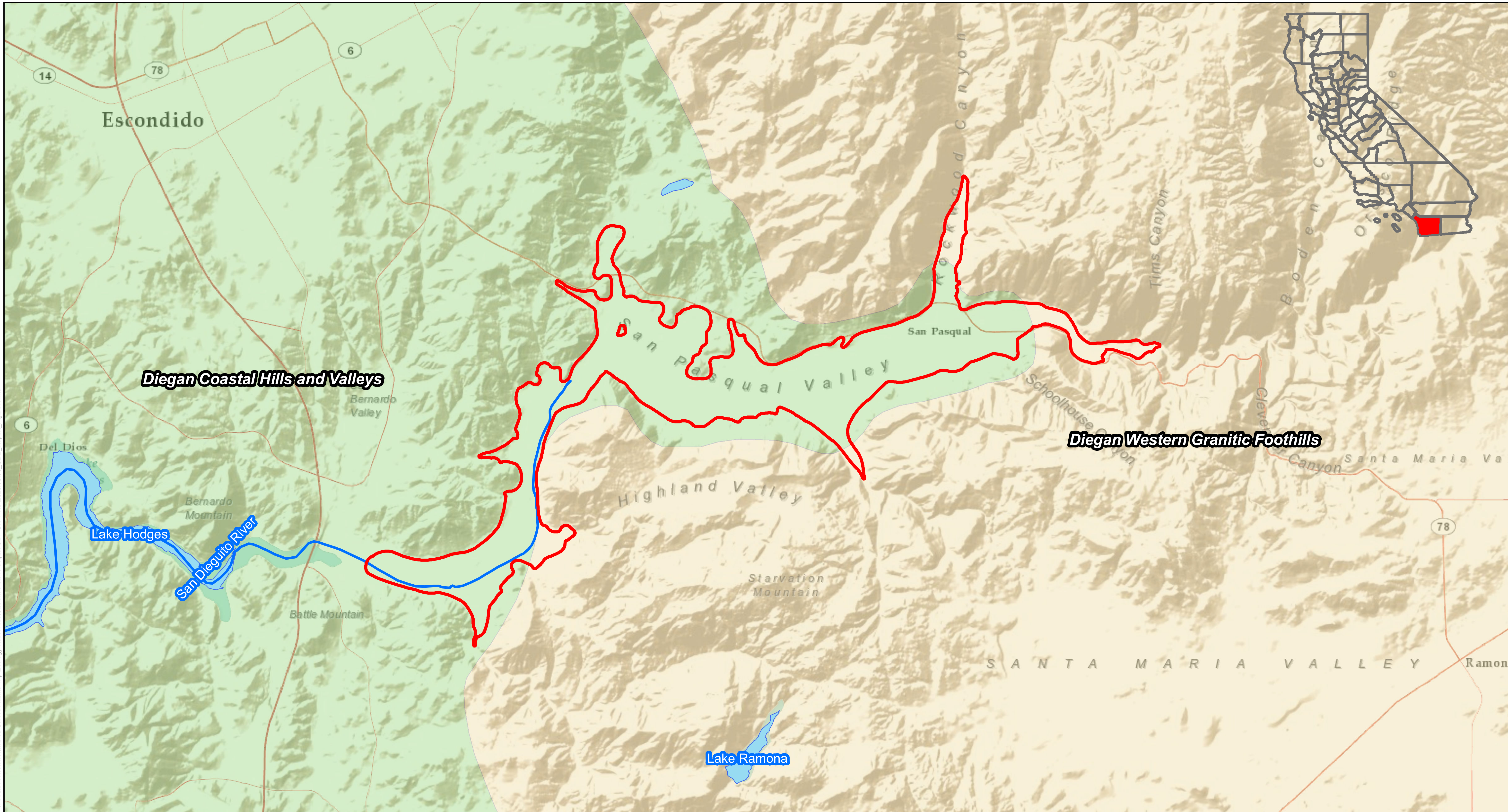

Figure 1

Project Location and Ecoregions

San Pasqual Valley Groundwater Basin

San Diego Public Utilities

San Diego County, CA

Legend

- San Pasqual Valley Groundwater Basin
- USGS National Hydrography Data
- CA DWR Lakes Data

Ecoregion

- Diegan Coastal Hills and Valleys
- Diegan Western Granitic Foothills

1 inch = 6,000 feet

0 3,000 6,000 12,000 Feet

N

Project #: 0011197.00

Map Created: May 2020

Third Party GIS Disclaimer: This map is for reference and graphical purposes only and should not be relied upon by third parties for any legal decisions.
Any reliance upon the map or data contained herein shall be at the users' sole risk. **Data Sources: ESRI World Terrain Basemap; USEPA Level III Ecoregions; USGS NHD Hydrography; CA DWR Lakes.**

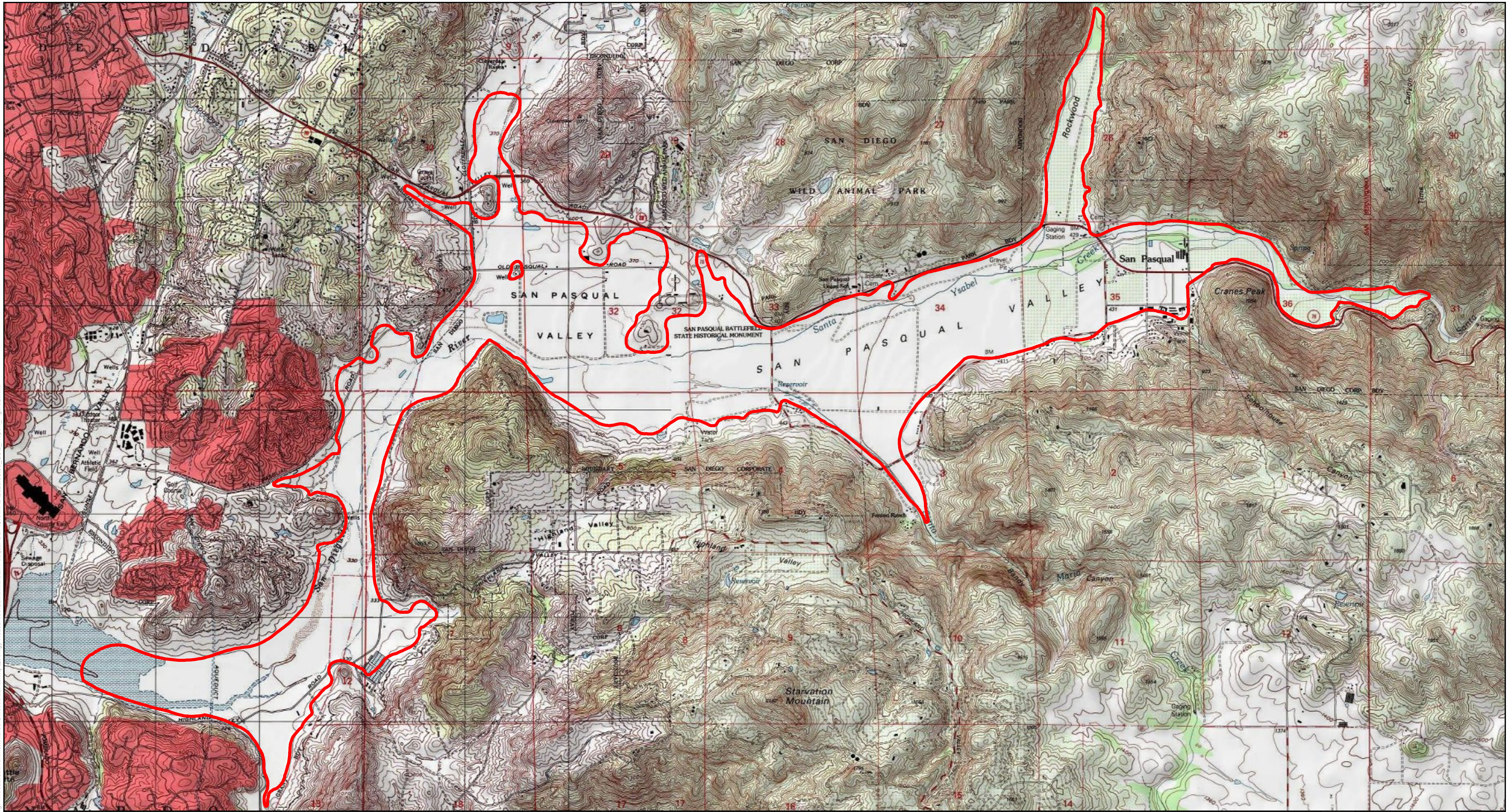

Figure 2
USGS Topography

San Pasqual Valley Groundwater Basin
San Diego Public Utilities

San Diego County, CA

Legend

San Pasqual Valley Groundwater Basin

SD Public Utilities

1 inch = 3,500 feet

0 1,750 3,500 7,000 Feet

N

WOODARD & CURRAN

Project #: 0011197.00
Map Created: May 2020

Third Party GIS Disclaimer: This map is for reference and graphical purposes only and should not be relied upon by third parties for any legal decisions.
Any reliance upon the map or data contained herein shall be at the users' sole risk. **Data Sources: ESRI USA Topomaps.**

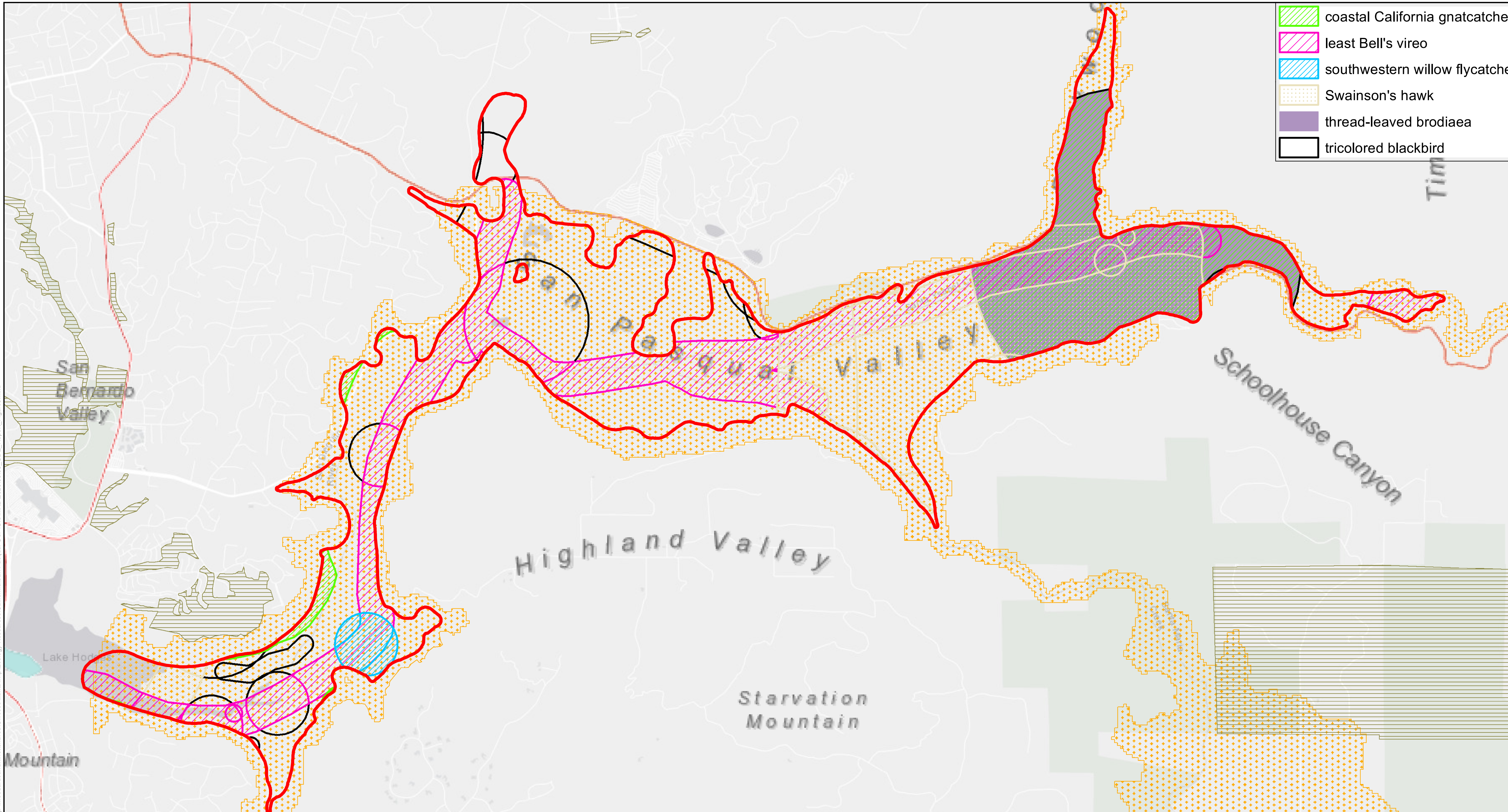

Figure 3

State and Federal Protected Species

San Pasqual Valley Groundwater Basin
San Diego Public Utilities

San Diego County, CA

Project #: 0011197.00
Map Created: May 2020

Third Party GIS Disclaimer: This map is for reference and graphical purposes only and should not be relied upon by third parties for any legal decisions. Any reliance upon the map or data contained herein shall be at the users' sole risk. **Data Sources: ESRI World Light Gray Canvas Base; CA Natural Diversity Database 2020; USFWS Critical Habitat.**

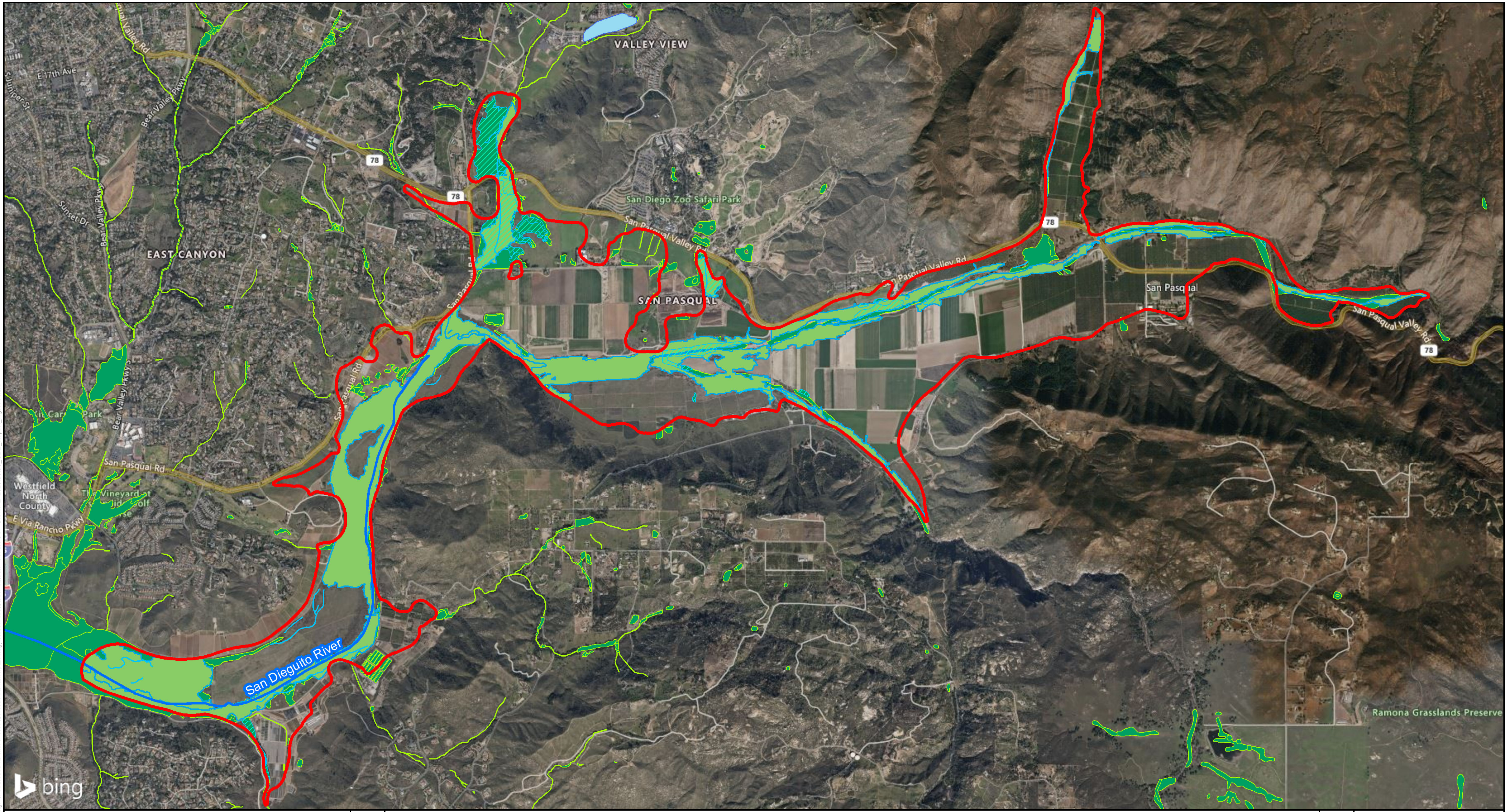

Figure 4
Groundwater Dependent Ecosystem (GDE) Indicators
San Pasqual Valley Groundwater Basin
San Diego Public Utilities
San Diego County, CA

Legend

- San Pasqual Valley Groundwater Basin
- USGS National Hydrography Data
- CA DWR Lakes Data
- NCCAG Wetlands (San Pasqual Valley)
- NCCAG Vegetation (San Pasqual Valley)
- USFWS National Wetlands Inventory

SD Public Utilities

1 inch = 3,500 feet

0 1,750 3,500 7,000 Feet

N

WOODARD & CURRAN

Project #: 0011197.00
Map Created: May 2020

Third Party GIS Disclaimer: This map is for reference and graphical purposes only and should not be relied upon by third parties for any legal decisions.
Any reliance upon the map or data contained herein shall be at the users' sole risk. **Data Sources: Bing Maps Hybrid; USGS NHD; CA DWR Lakes; CA DWR Natural Communities Commonly Associated with Groundwater; USFWS NWI.**

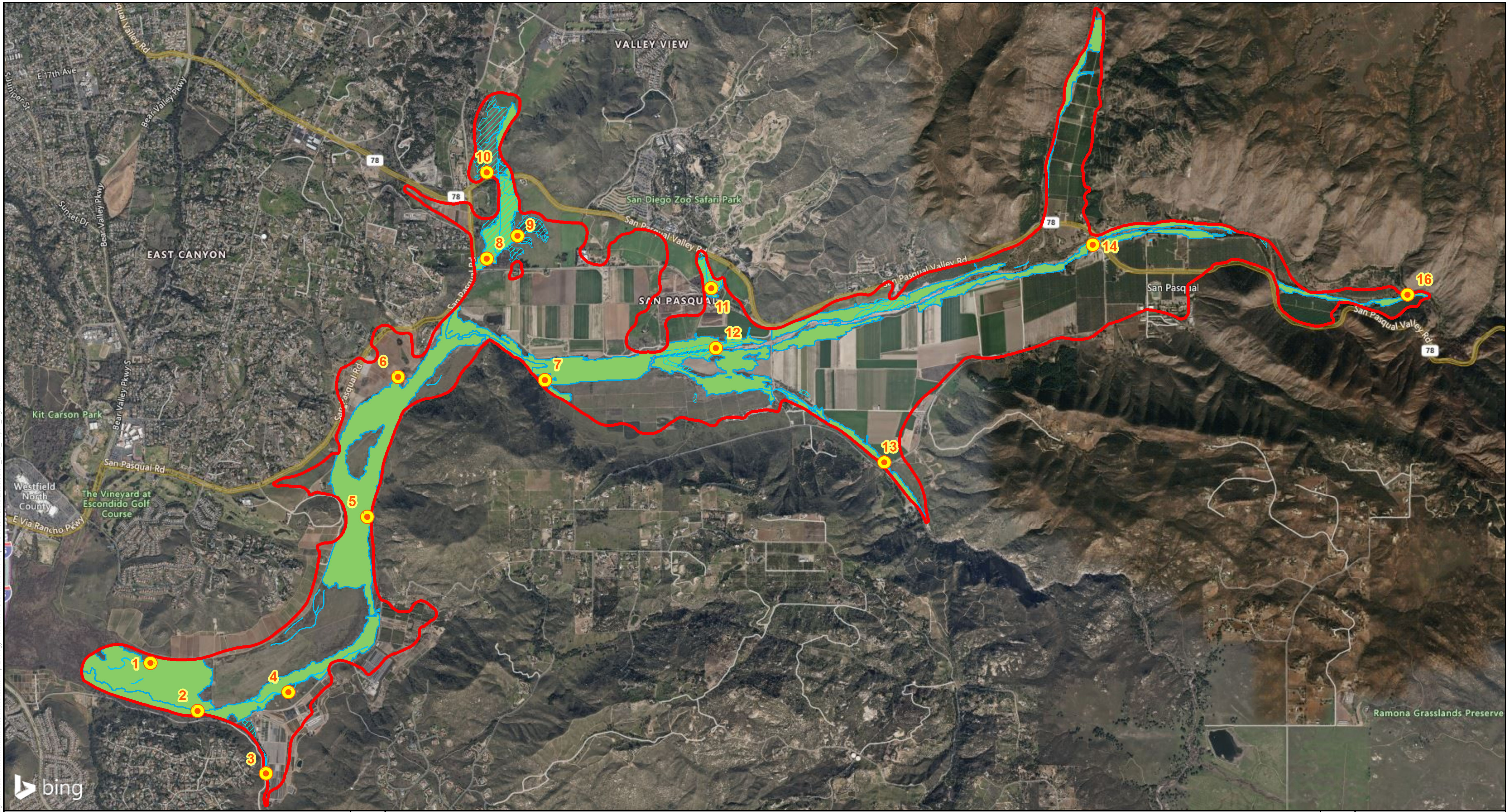

Figure 5
Completed GDE Field Assessments

San Pasqual Valley Groundwater Basin
San Diego Public Utilities

San Diego County, CA

Legend

- San Pasqual Valley Groundwater Basin
- NCCAG Wetlands (San Pasqual Valley)
- NCCAG Vegetation (San Pasqual Valley)
- Completed GDE Field Assessment

SD Public Utilities

1 inch = 3,500 feet

0 1,750 3,500 7,000 Feet

N

WOODARD & CURRAN

Project #: 0011197.00
Map Created: May 2020

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Any reliance upon the map or data contained herein shall be at the users' sole risk. **Data Sources: Bing Maps Hybrid; USGS CA DWR Natural Communities Commonly Associated with Groundwater.**

Figure 6
GDE Assessment
San Pasqual Valley Groundwater Basin
San Diego Public Utilities
San Diego County, CA

Legend

- San Pasqual Valley Groundwater Basin
- NCCAG Wetlands (San Pasqual Valley)
- NCCAG Vegetation (San Pasqual Valley)
- Groundwater Contours
- Probable GDE
- Probable Non-GDE
- Wetland & Riparian Vegetation

SD Public Utilities

1 inch = 3,500 feet

0 1,750 3,500 7,000 Feet

N

WOODARD & CURRAN

Project #: 0011197.00
Map Created: August 2020

Third Party GIS Disclaimer: This map is for reference and graphical purposes only and should not be relied upon by third parties for any legal decisions.
Any reliance upon the map or data contained herein shall be at the users' sole risk. **Data Sources: Bing Maps Hybrid; CA DWR Natural Communities Commonly Associated with Groundwater.**

Attachment 1
Photographic Log of GDE Field Assessment Sites

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Photo Number: 1 | **View Direction:** West | **Date:** March 2, 2020

Description: Representative photograph taken of confirmed probable groundwater dependent ecosystem (NCCAG 2020). Photo taken at GDE field assessment site 2.

Photo Number: 2 | **View Direction:** South | **Date:** March 2, 2020

Description: Representative photograph taken of confirmed probable groundwater dependent ecosystem (NCCAG 2020). Photo taken at GDE field assessment site 3.

Photo Number: 3 | **View Direction:** West | **Date:** October 23, 2018
Description: Representative photograph taken of confirmed probable groundwater dependent ecosystem (NCCAG 2020). Photo taken at GDE field assessment site 4.

Photo Number: 4 | **View Direction:** West | **Date:** March 2, 2020
Description: Representative photograph taken of potential incorrectly mapped groundwater dependent ecosystem (NCCAG 2020). Photo taken GDE field assessment site 1.

Photo Number: 5 | **View Direction:** North | **Date:** March 2, 2020

Description: Representative photograph taken of confirmed probable groundwater dependent ecosystem (NCCAG 2020). Photo taken GDE field assessment site 5.

Photo Number: 6 | **View Direction:** North | **Date:** March 2, 2020

Description: Representative photograph taken of unmapped potential groundwater dependent ecosystem (NCCAG 2020). Photo taken at GDE field assessment site 6.

Photo Number: 7 | **View Direction:** South | **Date:** March 2, 2020
Description: Representative photograph taken of confirmed probable groundwater dependent ecosystem (NCCAG 2020). Photo taken at GDE field assessment site 10.

Photo Number: 8 | **View Direction:** West | **Date:** March 3, 2020
Description: Representative photograph taken of confirmed wetland and riparian vegetation . Photo taken at GDE field assessment site 11.

Photo Number: 9 | **View Direction:** West | **Date:** March 3, 2020
Description: Representative photograph taken of confirmed wetland and riparian vegetation. Photo taken at GDE field assessment site 12.

Photo Number: 10 | **View Direction:** South | **Date:** March 3, 2020
Description: Representative photograph taken of confirmed wetland and riparian vegetation. Photo taken at GDE field assessment site 13.

Photo Number: 11 | **View Direction:** West | **Date:** March 3, 2020

Description: Representative photograph taken of confirmed probable groundwater dependent ecosystem (NCCAG 2020). Photo taken at GDE field assessment site 7.

Photo Number: 12 | **View Direction:** West | **Date:** March 3, 2020

Description: Representative photograph taken of confirmed probable groundwater dependent ecosystem (NCCAG 2020). Photo taken at GDE field assessment site 14.

Photo Number: 13 | **View Direction:** North | **Date:** March 4, 2020

Description: Representative photograph taken of confirmed wetland and riparian vegetation. Photo taken at GDE field assessment site 16.

Photo Number: 14 | **View Direction:** South | **Date:** March 4, 2020

Description: Representative photograph taken of confirmed probable groundwater dependent ecosystem (NCCAG 2020). Photo taken at GDE field assessment site 8.

Photo Number: 15 | **View Direction:** West | **Date:** March 4, 2020

Description: Representative photograph taken of confirmed probable groundwater dependent ecosystem (NCCAG 2020). Photo taken at GDE field assessment site 9.

Appendix K
Stakeholder Input Matrix—
Tabulated Workshop Results

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Stakeholder Input Matrix: Undesirable Results and Sustainable Management Criteria

Sustainability Indicator [1]	I. STORAGE	II. GROUNDWATER ELEVATION	III. WATER QUALITY	IV. SURFACE WATER CONNECTIVITY
Undesirable Results Consideration [2]	Unreasonable reduction of groundwater storage, which results in: a. Adverse impacts to the viability of agriculture, and the agricultural economy. b. Unusable and stranded groundwater extraction infrastructure. c. Need to deepen or construct new wells. d. Adverse impacts to domestic wells users. e. Adverse impacts on connected ecosystems.	Chronic lowering of groundwater levels indicating unreasonable depletion of supply, which results in: a. Adverse impacts to the viability of agriculture, and the agricultural economy. b. Unusable and stranded groundwater extraction infrastructure. c. Need to deepen or construct new wells. d. Adverse impacts to domestic wells users. e. Adverse impacts on connected ecosystems.	Significant and unreasonable degraded water quality that adversely impacts drinking, irrigation, industrial, and environmental uses, resulting from: a. Adverse impacts to the viability of agriculture, and the agricultural economy. b. Adverse impacts to ecosystems and habitat. c. Adverse impacts to the viability of drinking water.	Significant and unreasonable depletions of interconnected surface water that results in: a. Adverse impacts on downstream neighbors. b. Adverse impacts on the natural stream environment.
Minimum Threshold Consideration [3]	• TBD	• Local well infrastructure depths • Groundwater dependent ecosystems	• Maintain and sustain water quality • Trend or exceedance of historic baseline of water quality indicators at representative sites (TDS, Nitrate)	• Understand historic rates of stream depletion for comparison
Measurable Objective Consideration [4]	*Example* • Maintain groundwater storage (*within the limits of basin sustainable yield*) that provide for sustainable use of the groundwater basin.	*Example* • Maintain groundwater elevations (*within xx at locations y, z*) that provide for sustainable use of the groundwater basin.	*Example* • Maintain groundwater quality in the San Pasqual Valley Basin for the benefit of groundwater users.	*Example* • Manage groundwater to protect against adverse impacts to surface water flows in creeks flowing through the San Pasqual Valley Basin.
Interim Milestones Consideration [5]	• TBD	• TBD	• TBD	• TBD
Projects & Management Actions Consideration	• Lean and efficient management of groundwater • Use recycled water for recharge or direct use • Agricultural Best Management Practices (BMPs)	• Manage streambeds to increase percolation • Maximize stormwater capture • Work with RWQCB on runoff • Limit new users if needed • Allow alternate dust control methods	• Use recycled water for recharge or direct use • Protect habitat restoration areas • Limit contamination of groundwater due to stormwater infiltration	• TBD
Planning Principles [6]	• Consistent, reliable supplies of water desired • Seek grant funds for conservation improvements • Maintain ability to market crops		• Collaboration and cooperation • Consider effects of west end pumping on east end groundwater levels • Avoid economic impacts where possible • Limit invasive species	

Notes:

1. **Sustainability Indicator** refers to any of the effects caused by groundwater conditions occurring throughout the basin that, when significant and unreasonable, cause undesirable results
2. **Undesirable Result** means one or more of the following effects caused by groundwater conditions occurring throughout the basin: (1) Chronic lowering of groundwater levels indicating a significant and unreasonable depletion of supply if continued over the planning and implementation horizon. (2) Significant and unreasonable reduction of groundwater storage. (3) Significant and unreasonable seawater intrusion. (4) Significant and unreasonable degraded water quality, including the migration of contaminant plumes that impair water supplies. (5) Significant and unreasonable land subsidence that substantially interferes with surface land uses. (6) Depletion of interconnected surface water that have significant and unreasonable adverse impacts on beneficial uses of the surface water. Seawater Intrusion and Subsidence are not occurring in the San Pasqual Valley Basin and are not included in this matrix
3. **Minimum Threshold** refers to a numeric value for each sustainability indicator used to define undesirable results
4. **Measurable Objective** refers to specific, quantifiable goals for the maintenance or improvement of specified groundwater conditions that have been included in an adopted Plan to achieve the sustainability goal for the basin within 20 years. Uses the same metric as defined by the minimum threshold for the same sustainability indicator.
5. **Interim Milestones** refers to a target value representing measurable groundwater conditions, in increments of five years using the same metric as the measurable objective.
6. **Planning Principles** describes "how" the planning process will be conducted and provide overall guidance.

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Appendix L
Groundwater-Level Representative Monitoring Network Well Hydrographs with Thresholds

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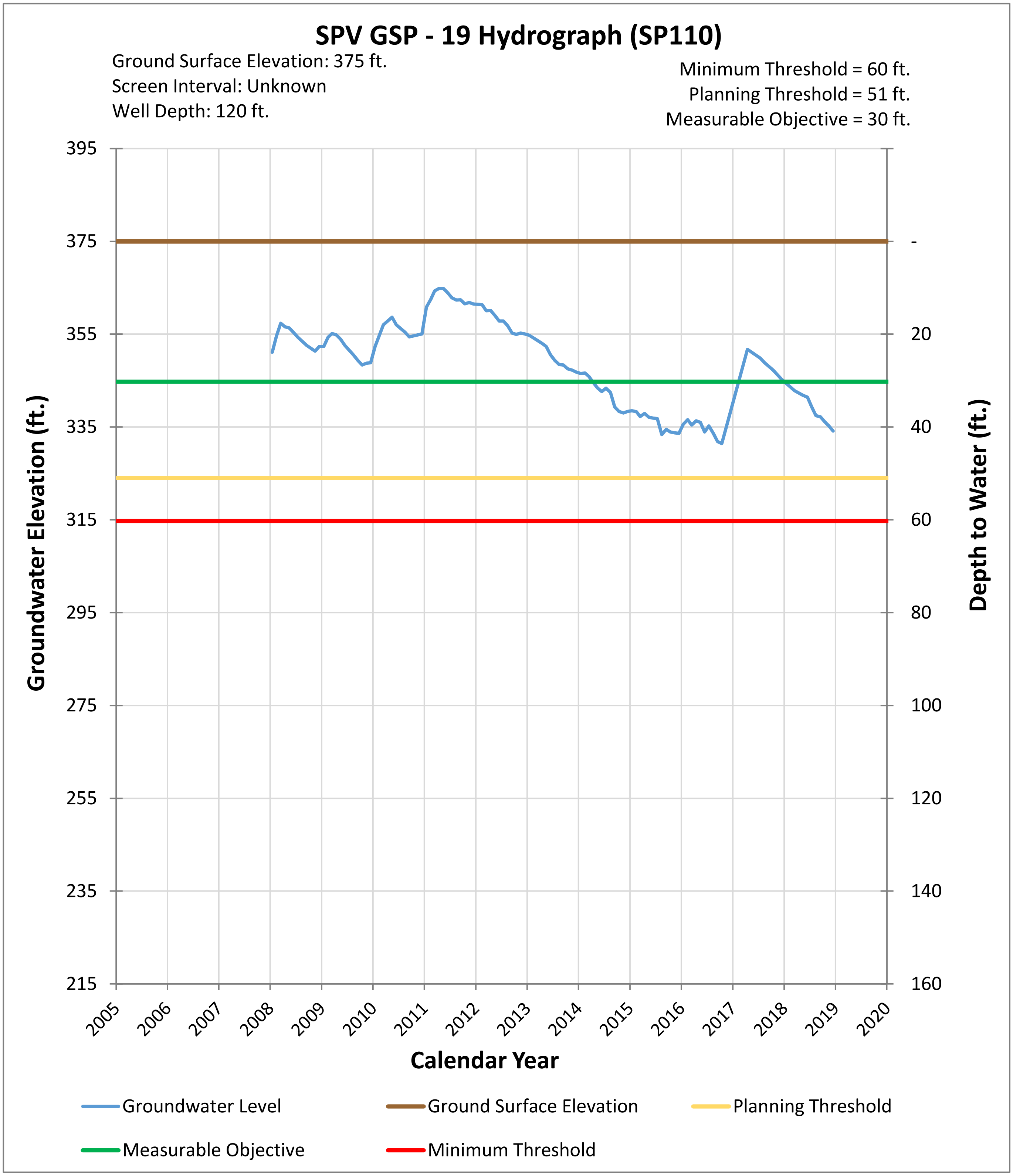
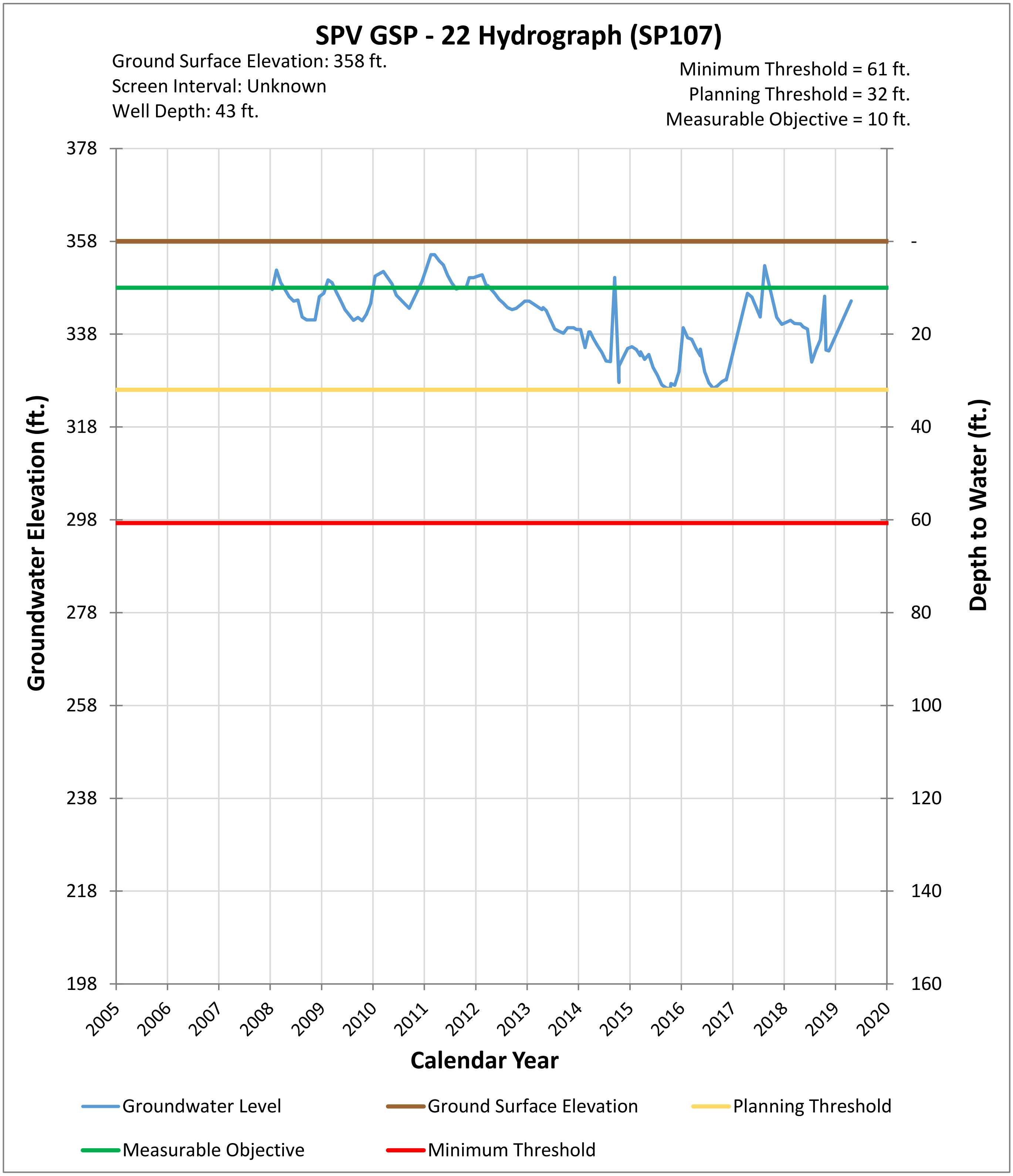
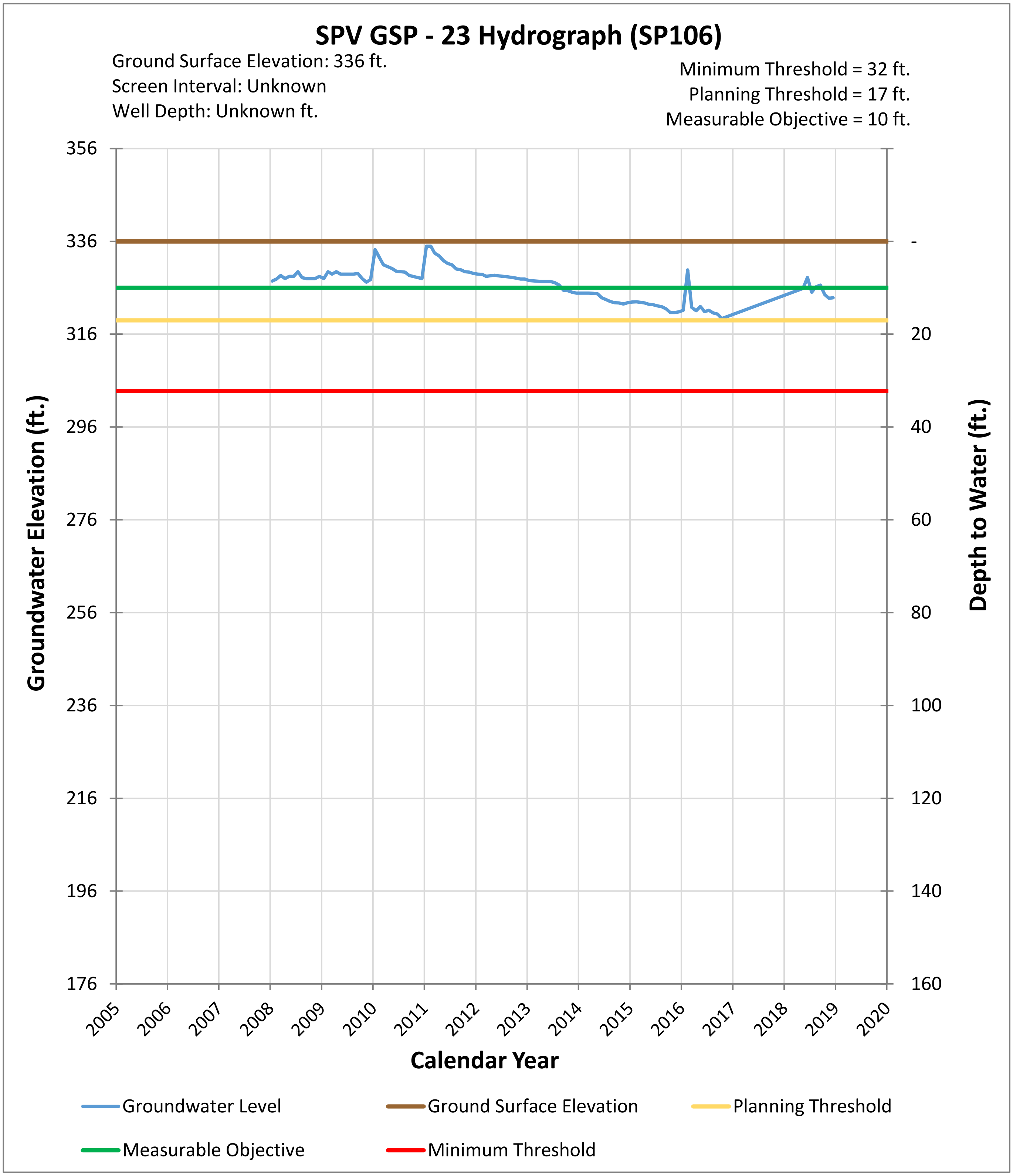
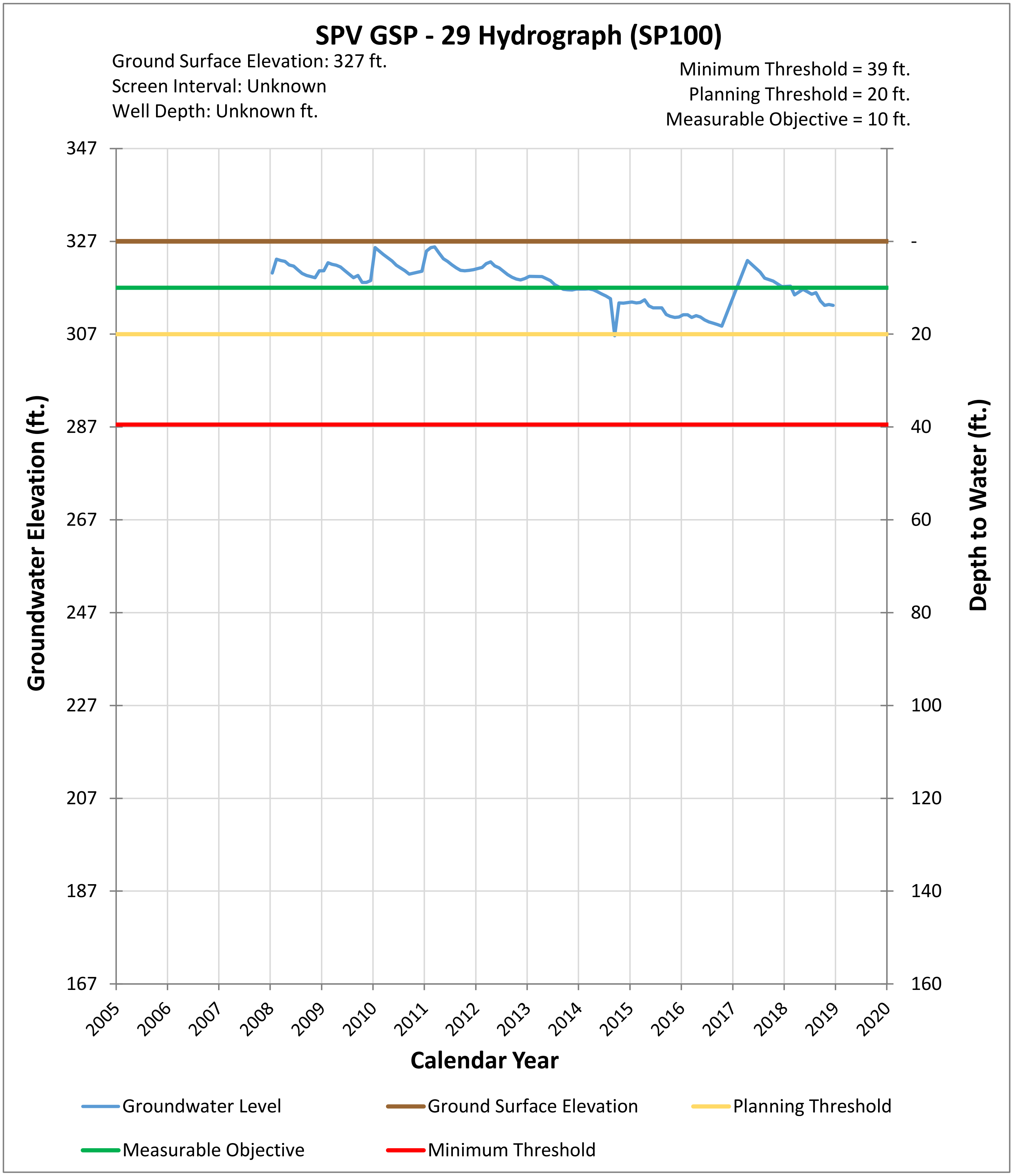
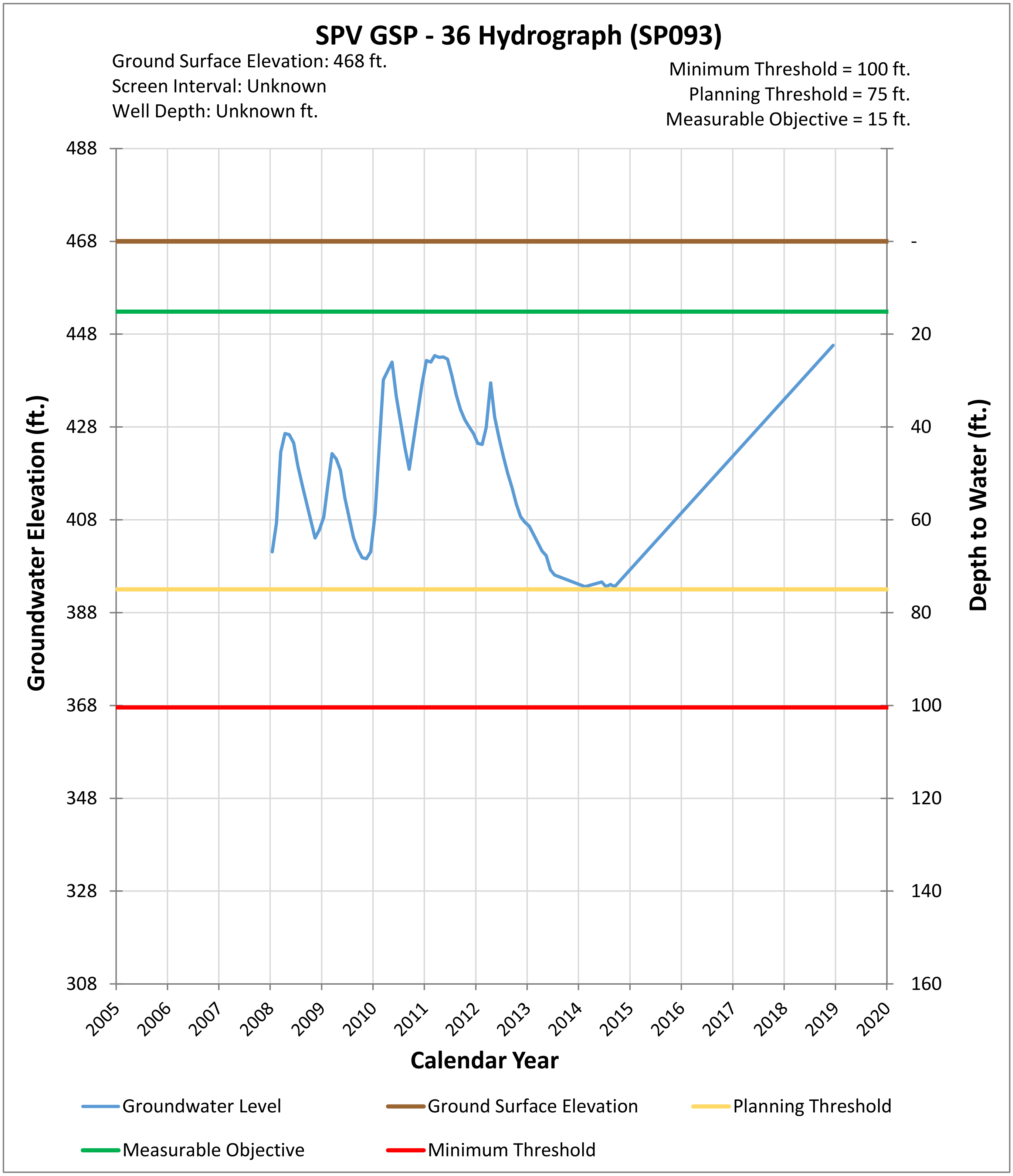

SPV GSP - 19 Hydrograph (SP110)
Ground Surface Elevation: 375 ft.
Screen Interval: Unknown
Well Depth: 120 ft.
Minimum Threshold = 60 ft.
Planning Threshold = 51 ft.
Measurable Objective = 30 ft.
Groundwater Elevation (ft.)
Depth to Water (ft.)
Calendar Year
395
375
355
335
315
295
275
255
235
215
-
20
40
60
80
100
120
140
160
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
Groundwater Level
Ground Surface Elevation
Planning Threshold
Measurable Objective
Minimum Threshold


SPV GSP - 22 Hydrograph (SP107)
Ground Surface Elevation: 358 ft.
Screen Interval: Unknown
Well Depth: 43 ft.
Minimum Threshold = 61 ft.
Planning Threshold = 32 ft.
Measurable Objective = 10 ft.
Groundwater Elevation (ft.)
378
358
338
318
298
278
258
238
218
198
Depth to Water (ft.)
-
20
40
60
80
100
120
140
160
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
Calendar Year
Groundwater Level
Ground Surface Elevation
Planning Threshold
Measurable Objective
Minimum Threshold

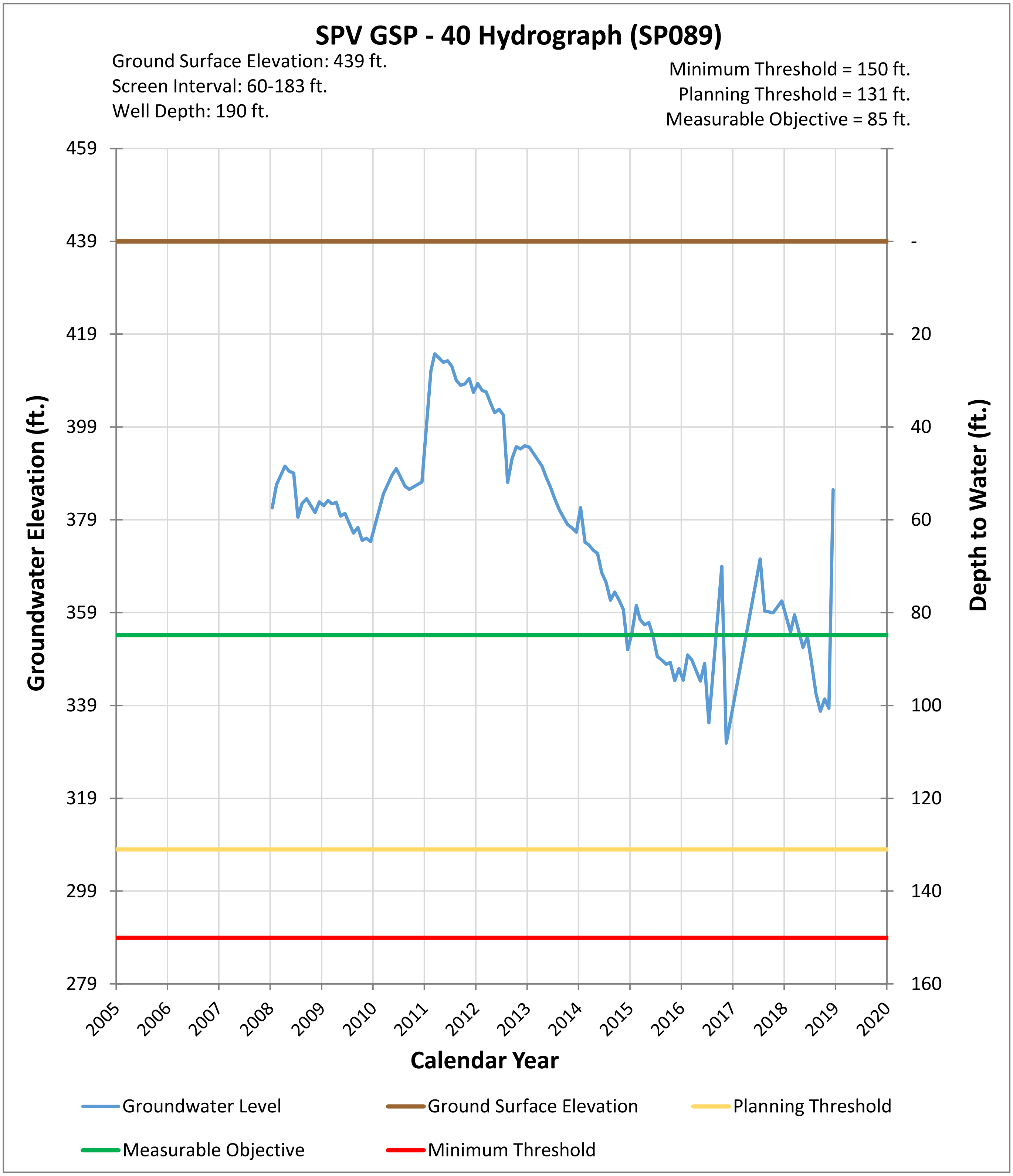

SPV GSP - 23 Hydrograph (SP106)
Ground Surface Elevation: 336 ft.
Screen Interval: Unknown
Well Depth: Unknown ft.
Minimum Threshold = 32 ft.
Planning Threshold = 17 ft.
Measurable Objective = 10 ft.
Groundwater Elevation (ft.)
Depth to Water (ft.)
356
336
316
296
276
256
236
216
196
176
-
20
40
60
80
100
120
140
160
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
Calendar Year
Groundwater Level
Ground Surface Elevation
Planning Threshold
Measurable Objective
Minimum Threshold



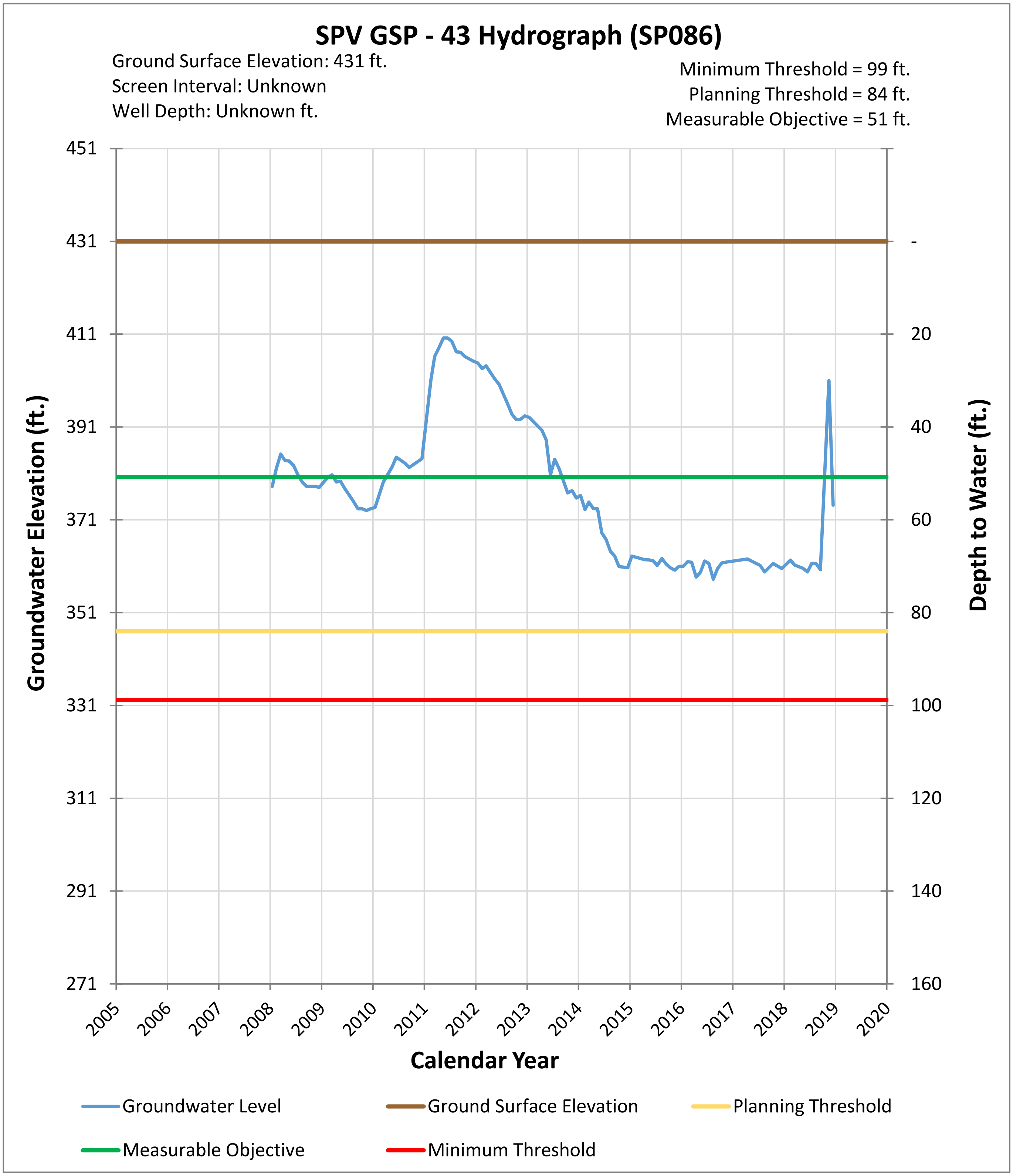
SPV GSP - 29 Hydrograph (SP100)
Ground Surface Elevation: 327 ft.
Screen Interval: Unknown
Well Depth: Unknown ft.
Minimum Threshold = 39 ft.
Planning Threshold = 20 ft.
Measurable Objective = 10 ft.
Groundwater Elevation (ft.)
Depth to Water (ft.)
Calendar Year
347
327
307
287
267
247
227
207
187
167
-
20
40
60
80
100
120
140
160
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
Groundwater Level
Ground Surface Elevation
Planning Threshold
Measurable Objective
Minimum Threshold



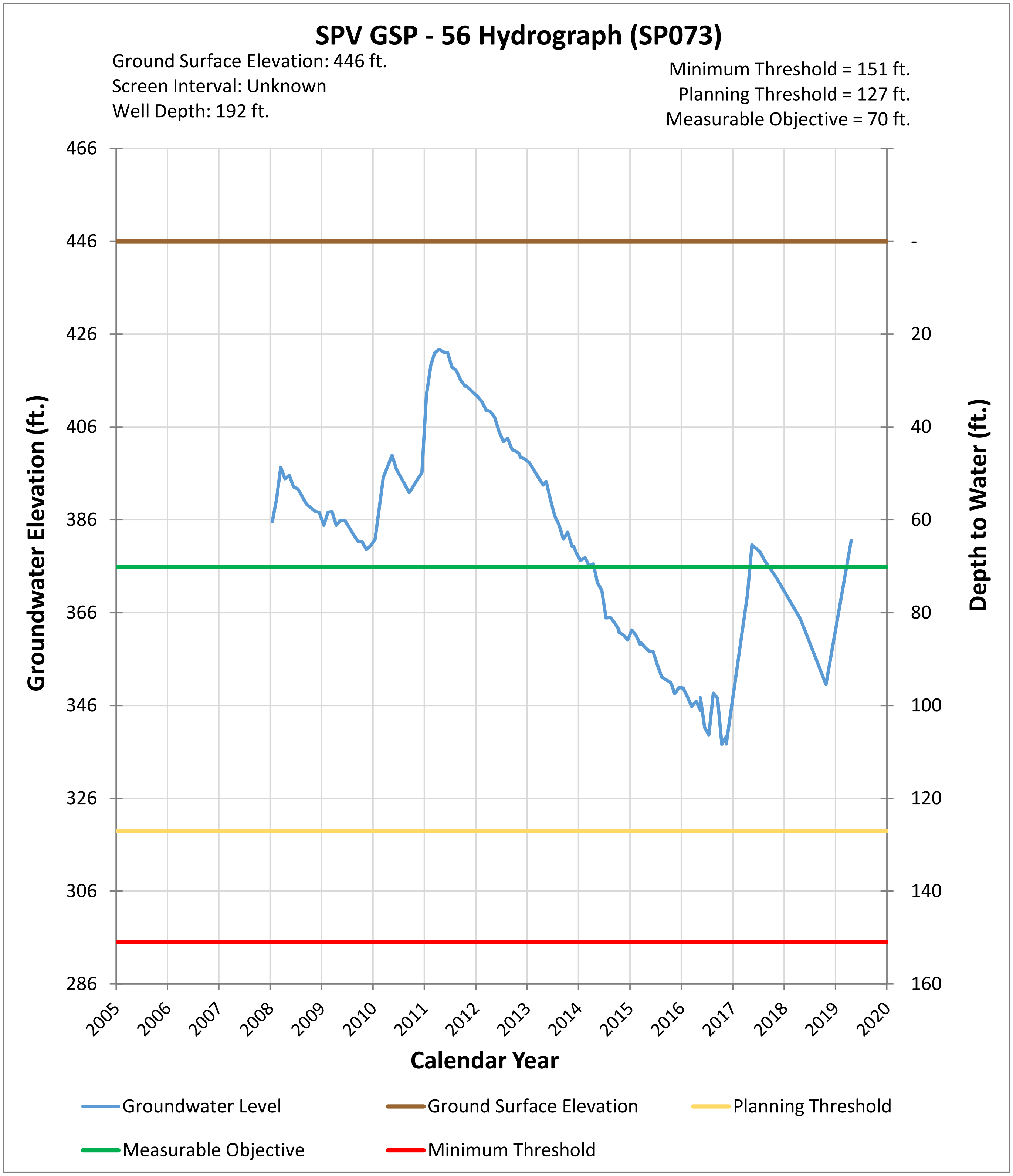
SPV GSP - 36 Hydrograph (SP093)
Ground Surface Elevation: 468 ft.
Screen Interval: Unknown
Well Depth: Unknown ft.
Minimum Threshold = 100 ft.
Planning Threshold = 75 ft.
Measurable Objective = 15 ft.
Groundwater Elevation (ft.)
Depth to Water (ft.)
488
468
448
428
408
388
368
348
328
308
-
20
40
60
80
100
120
140
160
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
Calendar Year
Groundwater Level
Ground Surface Elevation
Planning Threshold
Measurable Objective
Minimum Threshold



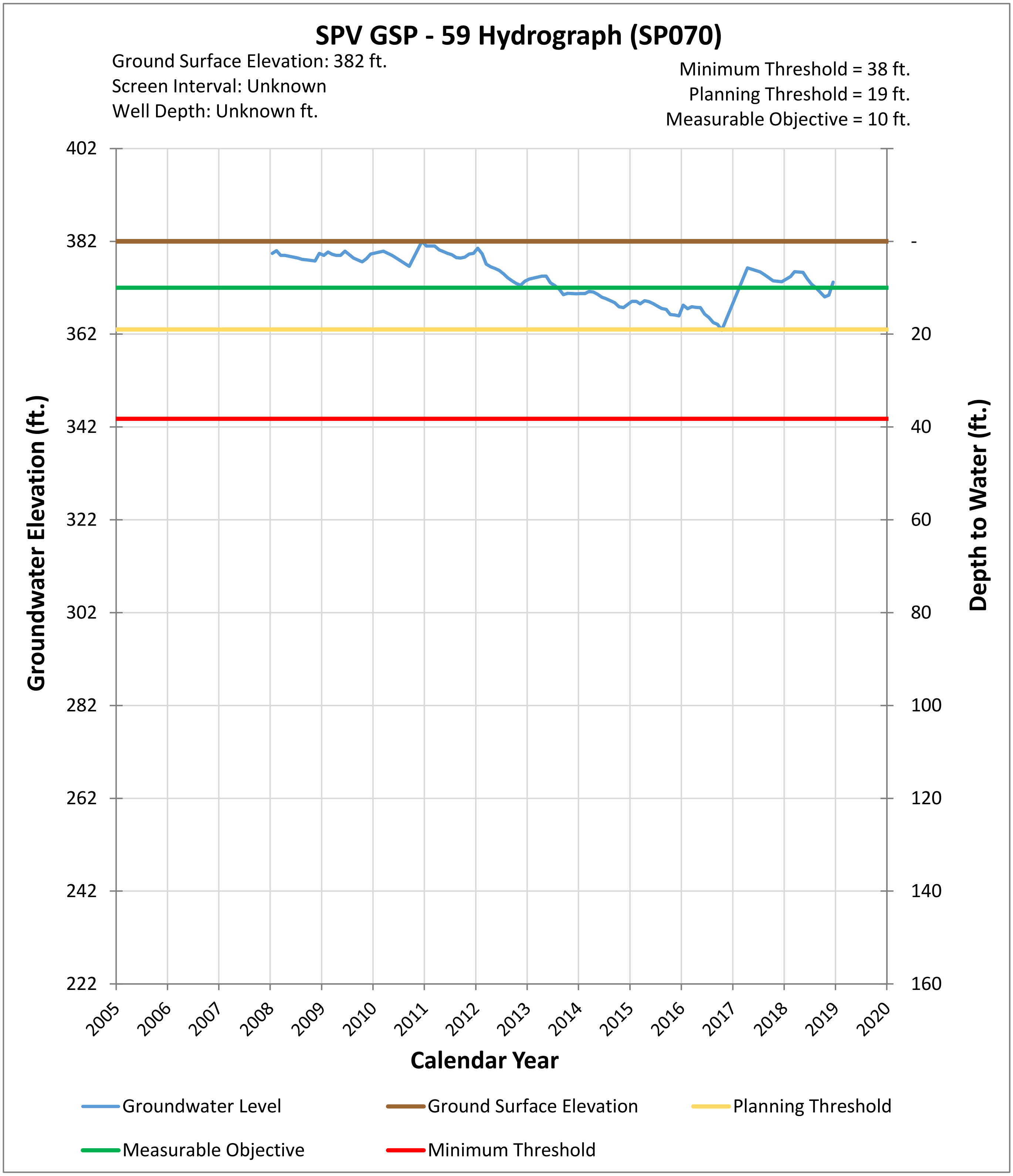
SPV GSP - 40 Hydrograph (SP089)
Ground Surface Elevation: 439 ft.
Screen Interval: 60-183 ft.
Well Depth: 190 ft.
Minimum Threshold = 150 ft.
Planning Threshold = 131 ft.
Measurable Objective = 85 ft.
Groundwater Elevation (ft.)
459
439
419
399
379
359
339
319
299
279
Depth to Water (ft.)
-
20
40
60
80
100
120
140
160
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
Calendar Year
Groundwater Level
Ground Surface Elevation
Planning Threshold
Measurable Objective
Minimum Threshold

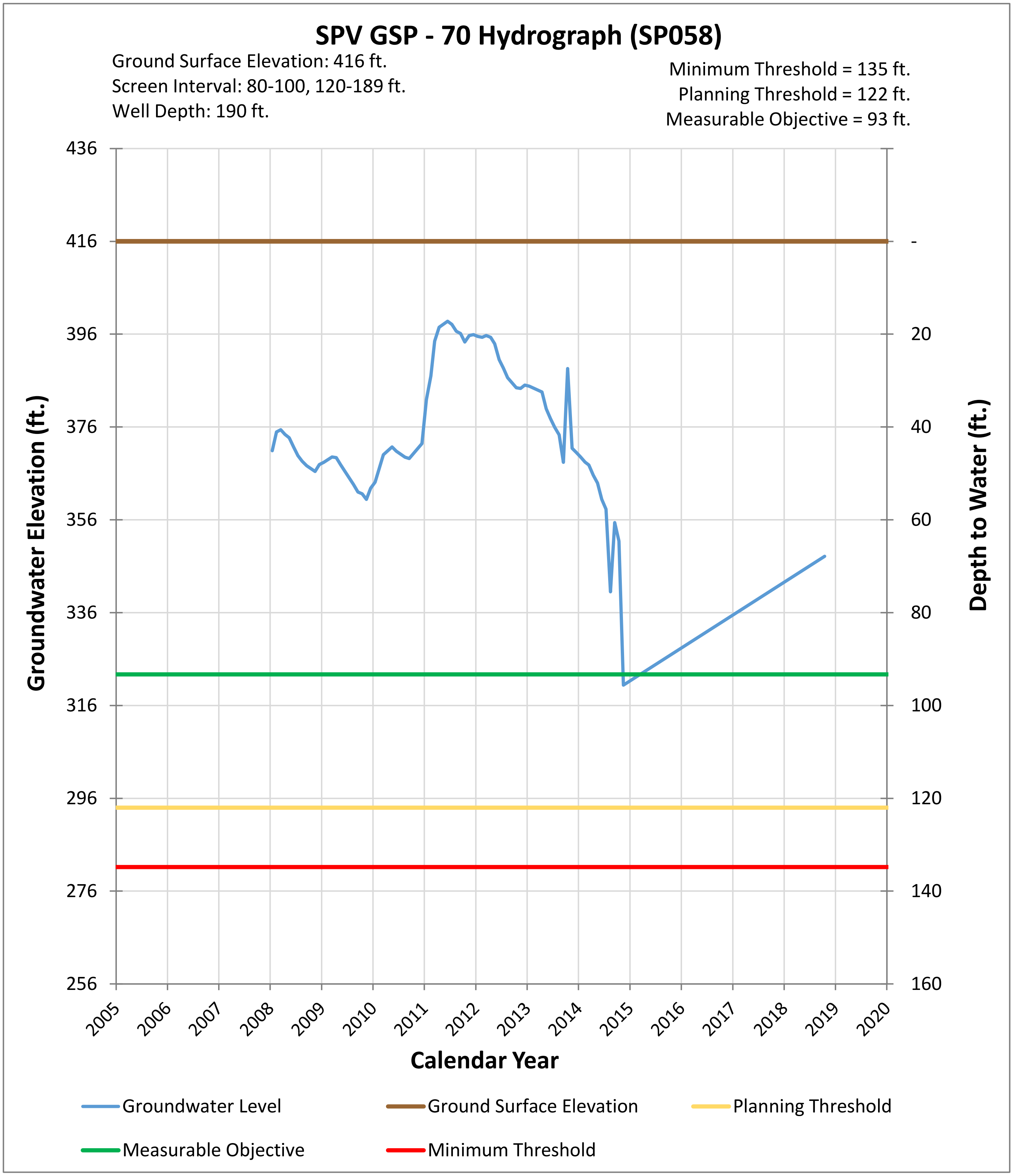


SPV GSP - 43 Hydrograph (SP086)
Ground Surface Elevation: 431 ft.
Screen Interval: Unknown
Well Depth: Unknown ft.
Minimum Threshold = 99 ft.
Planning Threshold = 84 ft.
Measurable Objective = 51 ft.
451
431
411
391
371
351
331
311
291
271
-
20
40
60
80
100
120
140
160
Groundwater Elevation (ft.)
Depth to Water (ft.)
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
Calendar Year
Groundwater Level
Ground Surface Elevation
Planning Threshold
Measurable Objective
Minimum Threshold



SPV GSP - 56 Hydrograph (SP073)
Ground Surface Elevation: 446 ft.
Screen Interval: Unknown
Well Depth: 192 ft.
Minimum Threshold = 151 ft.
Planning Threshold = 127 ft.
Measurable Objective = 70 ft.
Groundwater Elevation (ft.)
Depth to Water (ft.)
466
446
426
406
386
366
346
326
306
286
-
20
40
60
80
100
120
140
160
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
Calendar Year
Groundwater Level
Ground Surface Elevation
Planning Threshold
Measurable Objective
Minimum Threshold


SPV GSP - 59 Hydrograph (SP070)
Ground Surface Elevation: 382 ft.
Screen Interval: Unknown
Well Depth: Unknown ft.
Minimum Threshold = 38 ft.
Planning Threshold = 19 ft.
Measurable Objective = 10 ft.
Groundwater Elevation (ft.)
402
382
362
342
322
302
282
262
242
222
Depth to Water (ft.)
-
20
40
60
80
100
120
140
160
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
Calendar Year
Groundwater Level
Ground Surface Elevation
Planning Threshold
Measurable Objective
Minimum Threshold



SPV GSP - 70 Hydrograph (SP058)
Ground Surface Elevation: 416 ft.
Screen Interval: 80-100, 120-189 ft.
Well Depth: 190 ft.
Minimum Threshold = 135 ft.
Planning Threshold = 122 ft.
Measurable Objective = 93 ft.
Groundwater Elevation (ft.)
Depth to Water (ft.)
436
416
396
376
356
336
316
296
276
256
-
20
40
60
80
100
120
140
160
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
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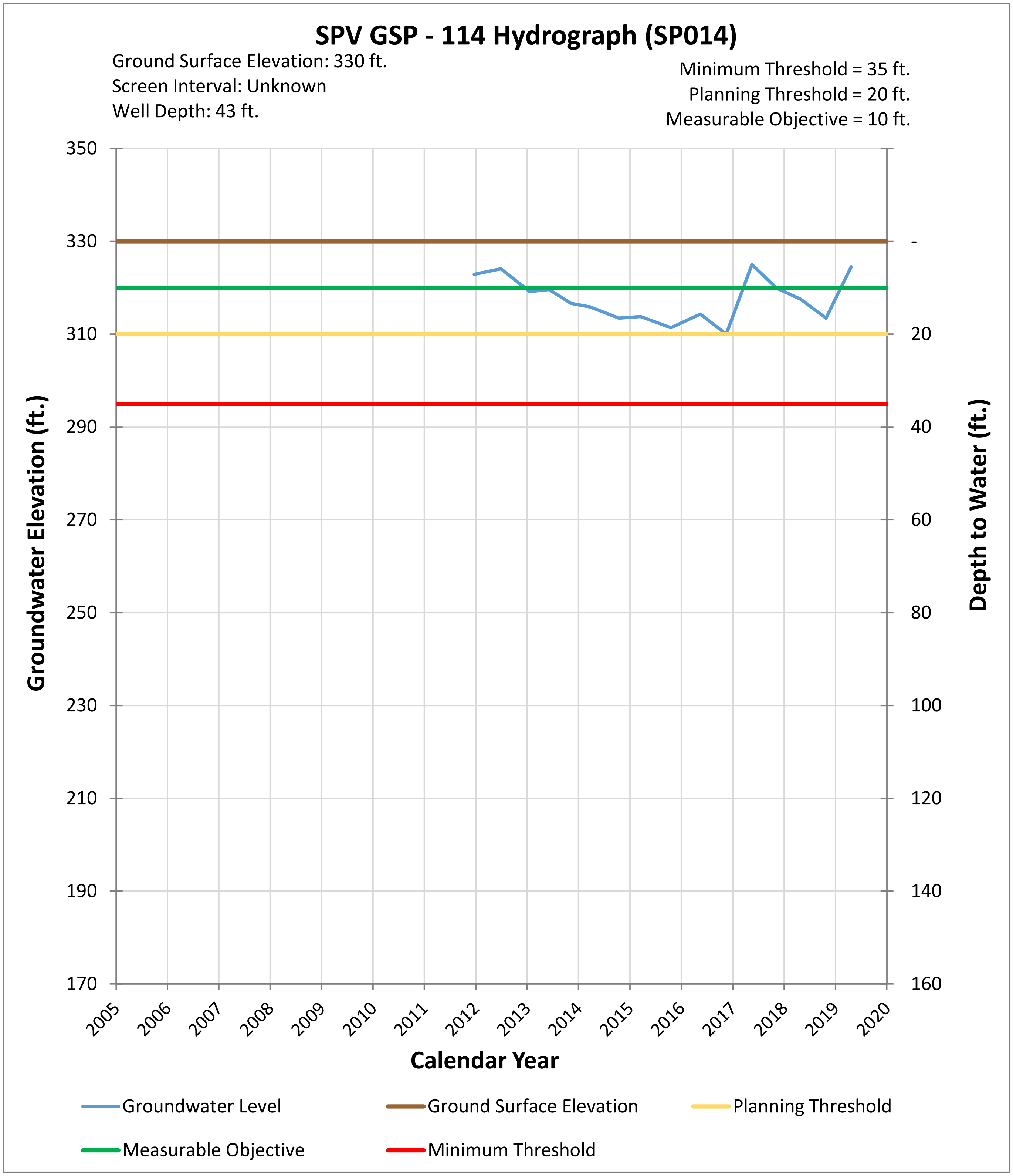
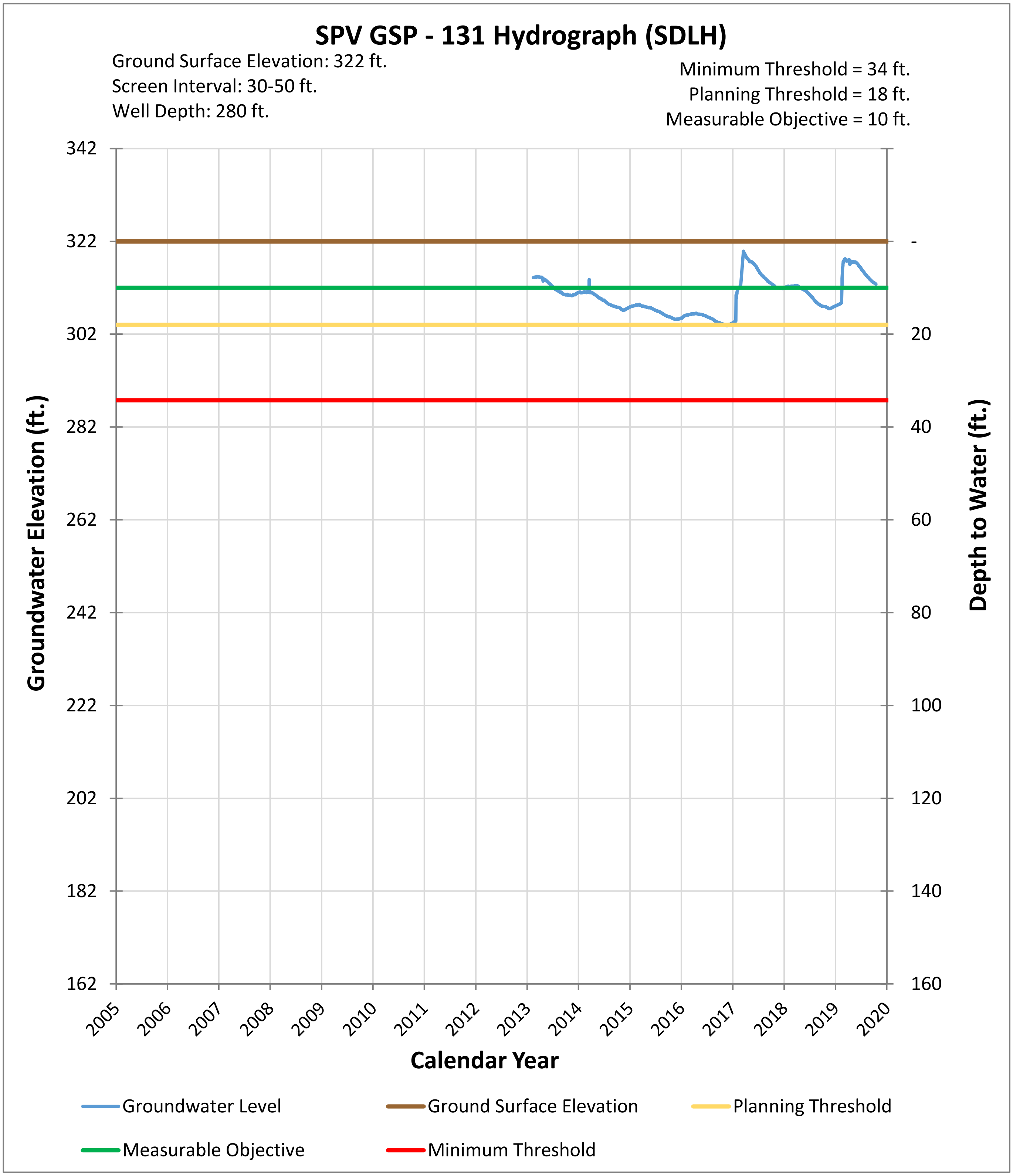
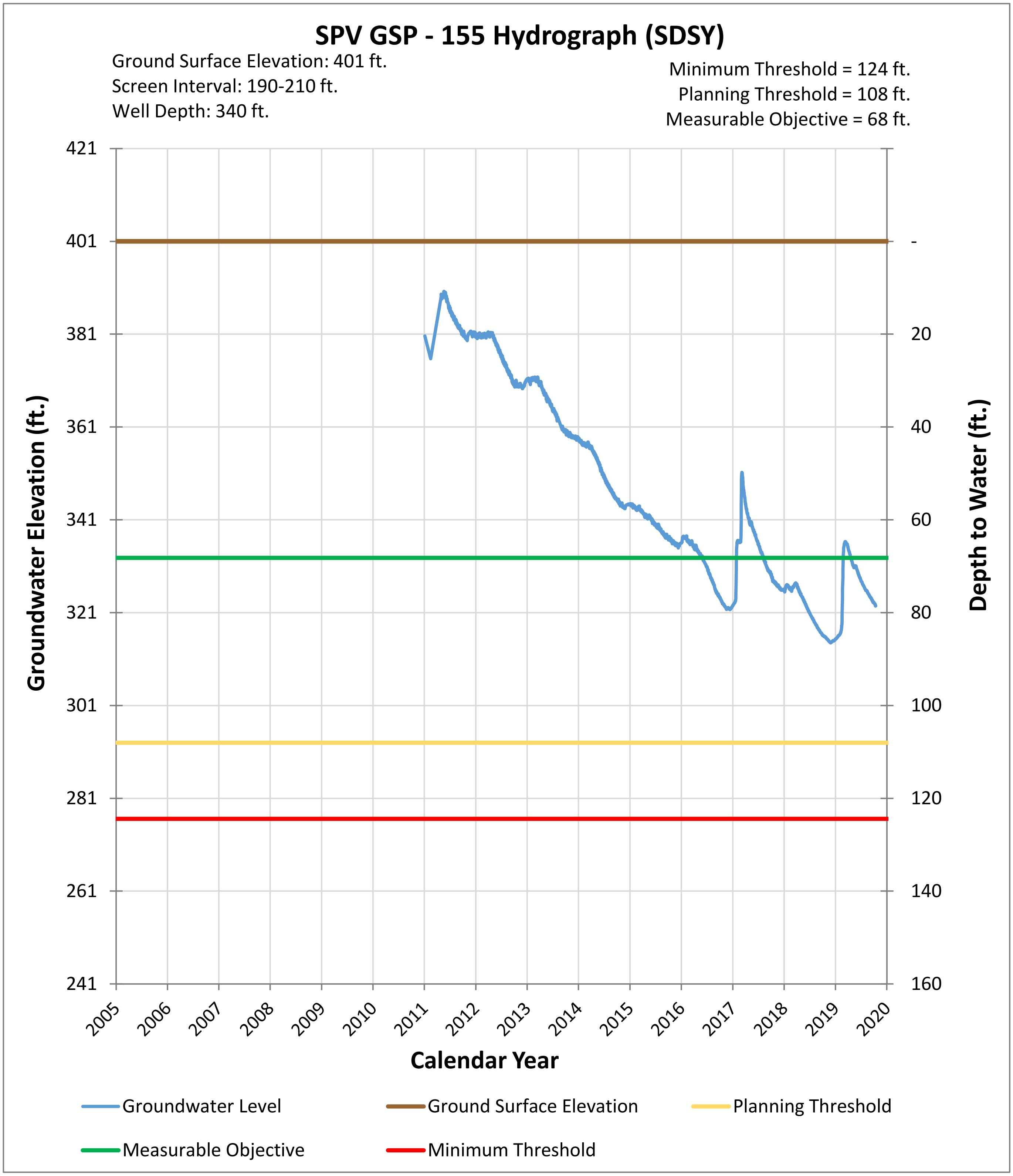
2016
2017
2018
2019
2020
Calendar Year
Groundwater Level
Ground Surface Elevation
Planning Threshold
Measurable Objective
Minimum Threshold



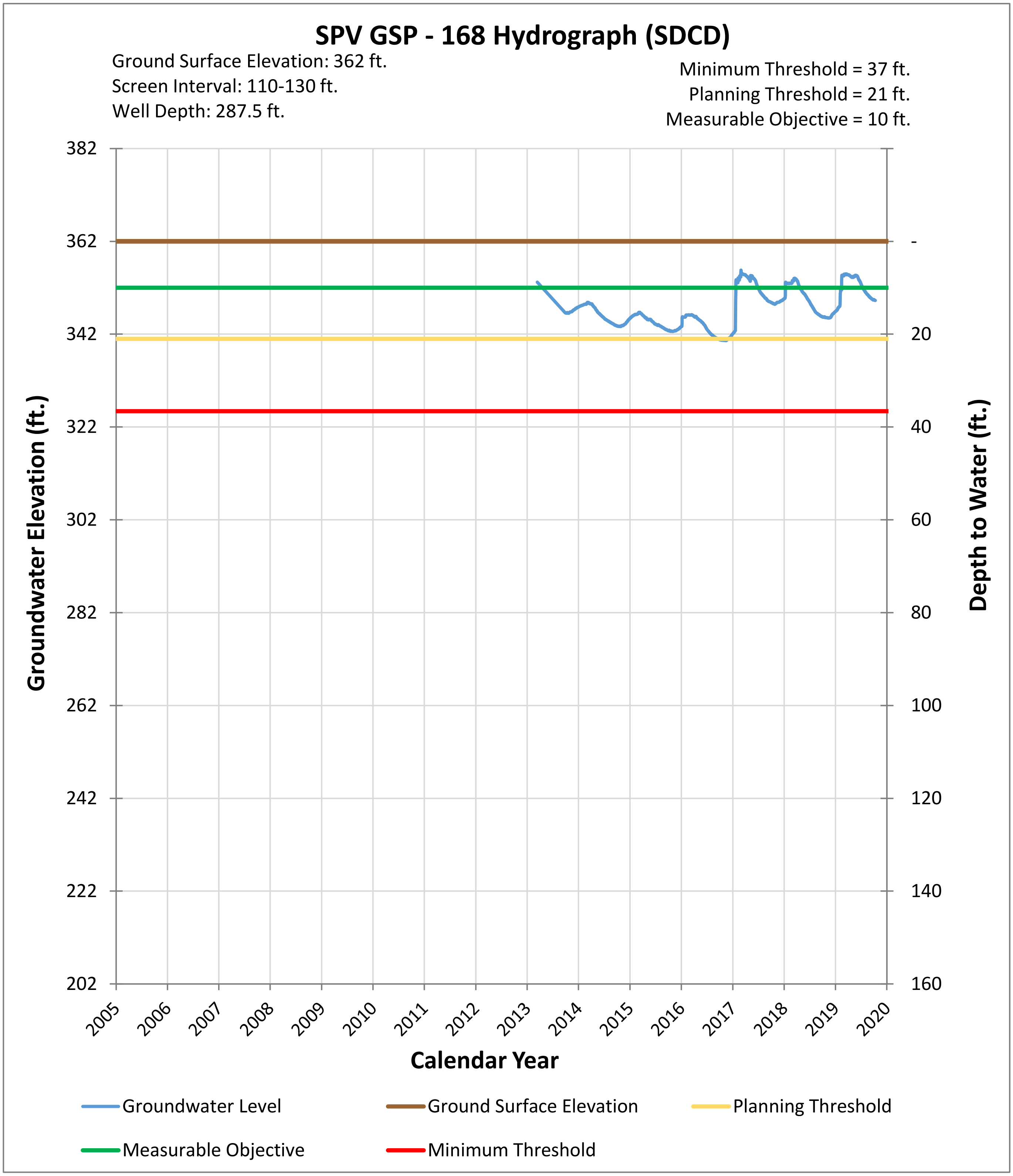
SPV GSP - 114 Hydrograph (SP014)
Ground Surface Elevation: 330 ft.
Screen Interval: Unknown
Well Depth: 43 ft.
Minimum Threshold = 35 ft.
Planning Threshold = 20 ft.
Measurable Objective = 10 ft.
Groundwater Elevation (ft.)
Depth to Water (ft.)
350
330
310
290
270
250
230
210
190
170
-
20
40
60
80
100
120
140
160
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
Calendar Year
Groundwater Level
Ground Surface Elevation
Planning Threshold
Measurable Objective
Minimum Threshold



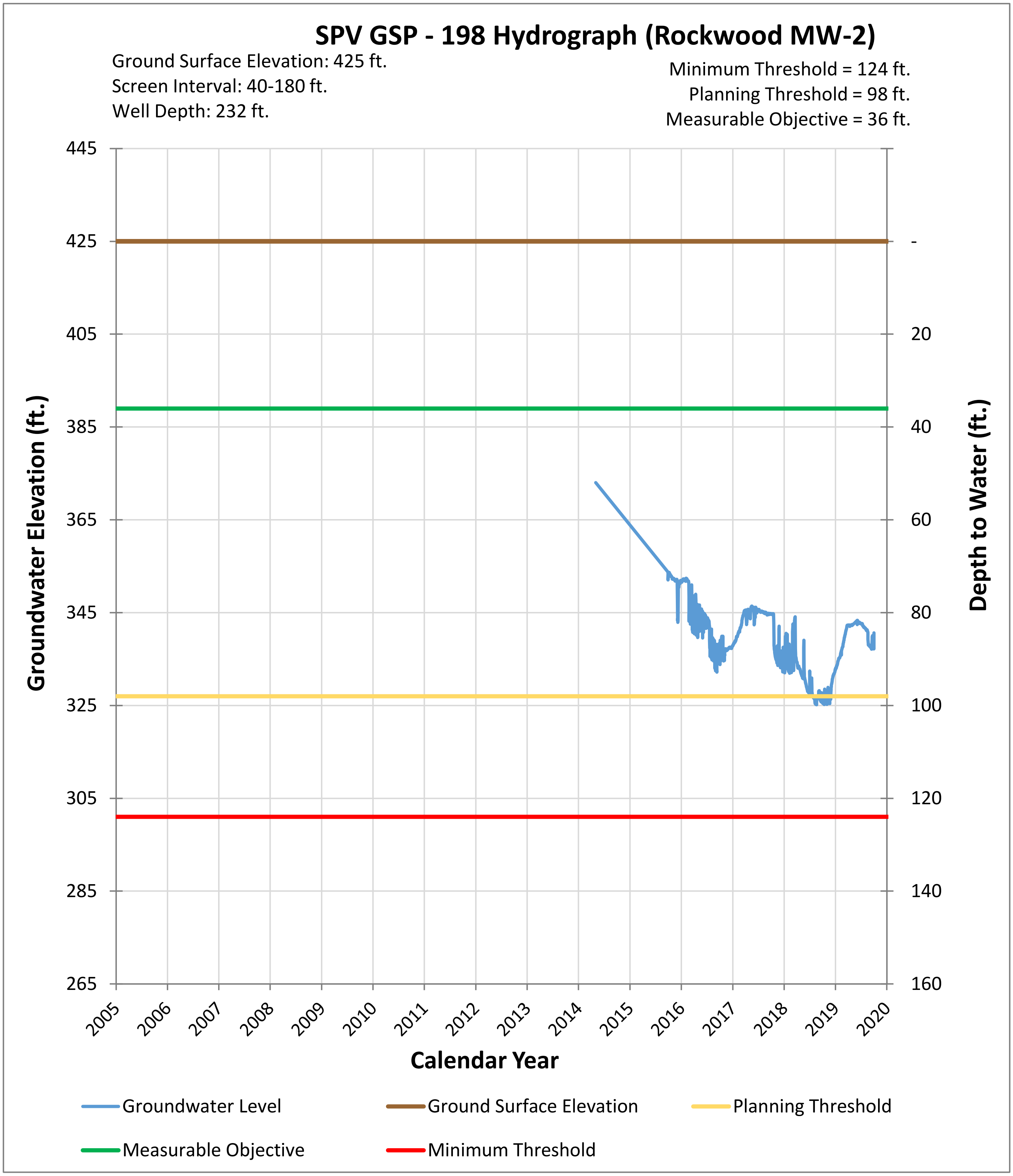
SPV GSP - 131 Hydrograph (SDLH)
Ground Surface Elevation: 322 ft.
Screen Interval: 30-50 ft.
Well Depth: 280 ft.
Minimum Threshold = 34 ft.
Planning Threshold = 18 ft.
Measurable Objective = 10 ft.
Groundwater Elevation (ft.)
Depth to Water (ft.)
342
322
302
282
262
242
222
202
182
162
-
20
40
60
80
100
120
140
160
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
Calendar Year
Groundwater Level
Ground Surface Elevation
Planning Threshold
Measurable Objective
Minimum Threshold



SPV GSP - 155 Hydrograph (SDSY)
Ground Surface Elevation: 401 ft.
Screen Interval: 190-210 ft.
Well Depth: 340 ft.
Minimum Threshold = 124 ft.
Planning Threshold = 108 ft.
Measurable Objective = 68 ft.
Groundwater Elevation (ft.)
Depth to Water (ft.)
421
401
381
361
341
321
301
281
261
241
-
20
40
60
80
100
120
140
160
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
Calendar Year
Groundwater Level
Ground Surface Elevation
Planning Threshold
Measurable Objective
Minimum Threshold



SPV GSP - 168 Hydrograph (SDCD)
Ground Surface Elevation: 362 ft.
Screen Interval: 110-130 ft.
Well Depth: 287.5 ft.
Minimum Threshold = 37 ft.
Planning Threshold = 21 ft.
Measurable Objective = 10 ft.
Groundwater Elevation (ft.)
Depth to Water (ft.)
382
362
342
322
302
282
262
242
222
202
-
20
40
60
80
100
120
140
160
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
Calendar Year
Groundwater Level
Ground Surface Elevation
Planning Threshold
Measurable Objective
Minimum Threshold



SPV GSP - 198 Hydrograph (Rockwood MW-2)
Ground Surface Elevation: 425 ft.
Screen Interval: 40-180 ft.
Well Depth: 232 ft.
Minimum Threshold = 124 ft.
Planning Threshold = 98 ft.
Measurable Objective = 36 ft.
Groundwater Elevation (ft.)
Depth to Water (ft.)
445
425
405
385
365
345
325
305
285
265
-
20
40
60
80
100
120
140
160
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
Calendar Year
Groundwater Level
Ground Surface Elevation
Planning Threshold
Measurable Objective
Minimum Threshold

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Appendix M
California Department of Water Resources: Best Management Practices for the Sustainable Management of Groundwater—Monitoring Protocols, Standards and Sites

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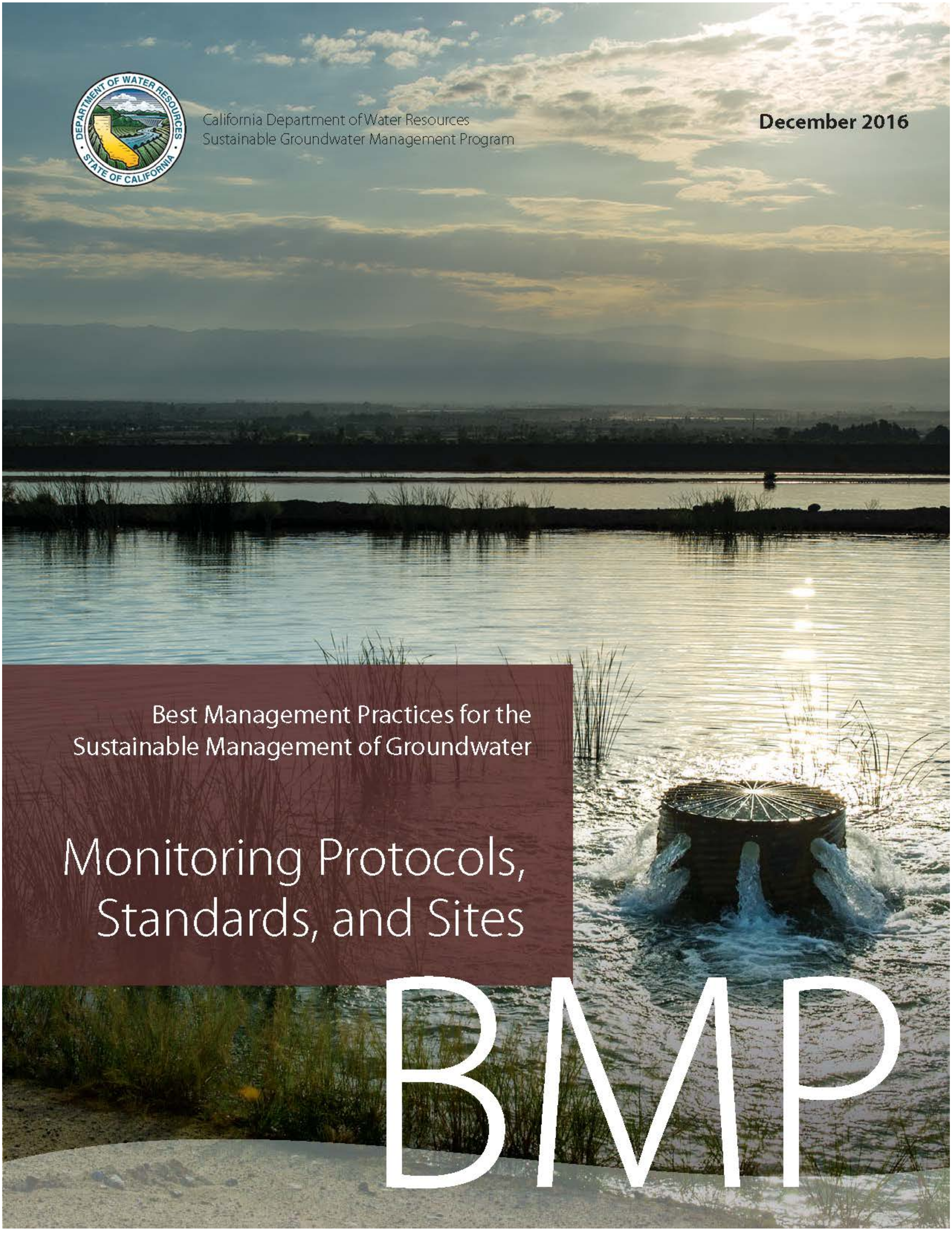
California Department of Water Resources
Sustainable Groundwater Management Program

December 2016

Best Management Practices for the Sustainable Management of Groundwater

Monitoring Protocols, Standards, and Sites

BMP



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California Natural Resources Agency
John Laird, Secretary for Natural Resources

Department of Water Resources
Mark W. Cowin, Director

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Groundwater Monitoring Protocols, Standards, and Sites Best Management Practice

1. OBJECTIVE

The objective of this *Best Management Practice* (BMP) is to assist in the development of Monitoring Protocols. The California Department of Water Resources (the Department or DWR) has developed this document as part of the obligation in the Technical Assistance chapter (Chapter 7) of the Sustainable Groundwater Management Act (SGMA) to support the long-term sustainability of California's groundwater *basins*. Information provided in this BMP provides technical assistance to Groundwater Sustainability Agencies (GSAs) and other stakeholders to aid in the establishment of consistent data collection processes and procedures. In addition, this BMP can be used by GSAs to adopt a set of sampling and measuring procedures that will yield similar data regardless of the monitoring personnel. Finally, this BMP identifies available resources to support the development of monitoring protocols.

This BMP includes the following sections:

1. Objective. A brief description of how and where monitoring protocols are required under SGMA and the overall objective of this BMP.
2. Use and Limitations. A brief description of the use and limitations of this BMP.
3. Monitoring Protocol Fundamentals. A description of the general approach and background of groundwater monitoring protocols.
4. Relationship of Monitoring Protocols to other BMPs. A description of how this BMP is connected with other BMPS.
5. Technical Assistance. Technical content providing guidance for regulatory sections.
6. Key Definitions. Descriptions of definitions identified in the GSP Regulations or SGMA.
7. Related Materials. References and other materials that provide supporting information related to the development of Groundwater Monitoring Protocols.

2. USE AND LIMITATIONS

BMPs developed by the Department provide technical guidance to GSAs and other stakeholders. Practices described in these BMPs do not replace the GSP Regulations, nor do they create new requirements or obligations for GSAs or other stakeholders. In addition, using this BMP to develop a GSP does not equate to an approval determination by the Department. All references to GSP Regulations relate to Title 23 of the California Code of Regulations (CCR), Division 2, Chapter 1.5, and Subchapter 2. All references to SGMA relate to California Water Code sections in Division 6, Part 2.74.

3. MONITORING PROTOCOL FUNDAMENTALS

Establishing data collection protocols that are based on best available scientific methods is essential. Protocols that can be applied consistently across all basins will likely yield comparable data. Consistency of data collection methods reduces uncertainty in the comparison of data and facilitates more accurate communication within basins as well as between basins.

Basic minimum technical standards of accuracy lead to quality data that will better support implementation of GSPs.

4. RELATIONSHIP OF MONITORING PROTOCOL TO OTHER BMPS

Groundwater monitoring is a fundamental component of SGMA, as each GSP must include a sufficient network of data that demonstrates measured progress toward the achievement of the sustainability goal for each basin. For this reason, a standard set of protocols need to be developed and utilized.

It is important that data is developed in a manner consistent with the basin setting, planning, and projects/management actions steps identified on **Figure 1** and the GSP Regulations. The inclusion of monitoring protocols in the GSP Regulations also emphasizes the importance of quality empirical data to support GSPs and provide comparable information from basin to basin.

Figure 1 provides a logical progression for the development of a GSP and illustrates how monitoring protocols are linked to other related BMPs. This figure also shows the context of the BMPs as they relate to various steps to sustainability as outlined in the GSP Regulations. The monitoring protocol BMP is part of the Monitoring step identified in **Figure 1**.

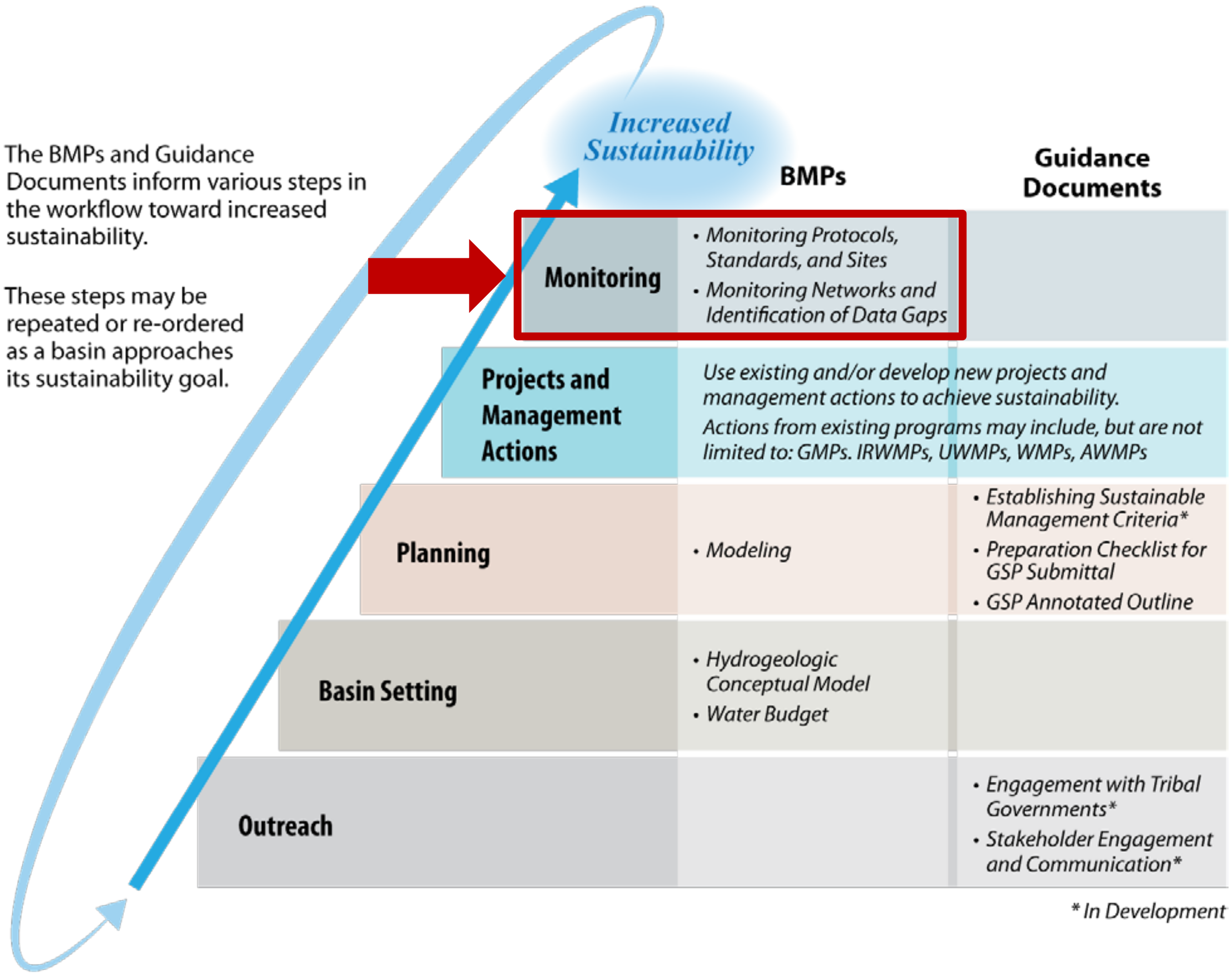

Figure 1 – Logical Progression of Basin Activities Needed to Increase Basin Sustainability

5. TECHNICAL ASSISTANCE

23 CCR §352.2. Monitoring Protocols. Each Plan shall include monitoring protocols adopted by the Agency for data collection and management, as follows:
(a) Monitoring protocols shall be developed according to best management practices.
(b) The Agency may rely on monitoring protocols included as part of the best management practices developed by the Department, or may adopt similar monitoring protocols that will yield comparable data.
(c) Monitoring protocols shall be reviewed at least every five years as part of the periodic evaluation of the Plan, and modified as necessary.

The GSP Regulations specifically call out the need to utilize protocols identified in this BMP, or develop similar protocols. The following technical protocols provide guidance based upon existing professional standards and are commonly adopted in various groundwater-related programs. They provide clear techniques that yield quality data for use in the various components of the GSP. They can be further elaborated on by individual GSAs in the form of standard operating procedures which reflect specific local requirements and conditions. While many methodologies are suggested in this BMP, it should be understood that qualified professional judgment should be used to meet the specific monitoring needs.

The following BMPs may be incorporated into a GSP's monitoring protocols section for collecting groundwater elevation data. A GSP that adopts protocols that deviate from these BMPs must demonstrate that they will yield comparable data.

PROTOCOLS FOR ESTABLISHING A MONITORING PROGRAM

The protocol for establishment of a monitoring program should be evaluated in conjunction with the *Monitoring Network and Identification of Data Gaps* BMP and other BMPs. Monitoring protocols must take into consideration the *Hydrogeologic Conceptual Model, Water Budget, and Modeling* BMPs when considering the data needs to meet GSP objectives and the sustainability goal.

It is suggested that each GSP incorporate the Data Quality Objective (DQO) process following the U.S. EPA *Guidance on Systematic Planning Using the Data Quality Objectives Process* (EPA, 2006). Although strict adherence to this method is not required, it does provide a robust approach to consider and assures that data is collected with a specific purpose in mind, and efforts for monitoring are as efficient as possible to achieve the objectives of the GSP and compliance with the GSP Regulations.

The DQO process presents a method that can be applied directly to the sustainability criteria quantitative requirements through the following steps.

1. State the problem – Define sustainability indicators and planning considerations of the GSP and sustainability goal.
2. Identify the goal – Describe the quantitative measurable objectives and minimum thresholds for each of the sustainability indicators.
3. Identify the inputs – Describe the data necessary to evaluate the sustainability indicators and other GSP requirements (i.e. water budget).
4. Define the boundaries of the study – This is commonly the extent of the Bulletin 118 groundwater basin or subbasin, unless multiple GSPs are prepared for a given basin. In that case, evaluation of the coordination plan and specifically how the monitoring will be comparable and meet the sustainability goals for the entire basin.
5. Develop an analytical approach – Determine how the quantitative sustainability indicators will be evaluated (i.e. are special analytical methods required that have specific data needs).
6. Specify performance or acceptance criteria – Determine what quality the data must have to achieve the objective and provide some assurance that the analysis is accurate and reliable.
7. Develop a plan for obtaining data – Once the objectives are known determine how these data should be collected. Existing data sources should be used to the greatest extent possible.

These steps of the DQO process should be used to guide GSAs to develop the most efficient monitoring process to meet the measurable objectives of the GSP and the sustainability goal. The DQO process is an iterative process and should be evaluated regularly to improve monitoring efficiencies and meet changing planning and project needs. Following the DQO process, GSAs should also include a data quality control and quality assurance plan to guide the collection of data.

Many monitoring programs already exist as part of ongoing groundwater management or other programs. To the extent possible, the use of existing monitoring data and programs should be utilized to meet the needs for characterization, historical record documentation, and continued monitoring for the SGMA program. However, an evaluation of the existing monitoring data should be performed to assure the data being collected meets the DQOs, regulatory requirements, and data collection protocol described in this BMP. While this BMP provides guidance for collection of various regulatory based requirements, there is flexibility among the various methodologies available to meet the DQOs based upon professional judgment (local conditions or project needs).

At a minimum, for each monitoring site, the following information or procedure should be collected and documented:

- Long-term access agreements. Access agreements should include year-round site access to allow for increased monitoring frequency.
- A unique identifier that includes a general written description of the site location, date established, access instructions and point of contact (if necessary), type of information to be collected, latitude, longitude, and elevation. Each monitoring location should also track all modifications to the site in a modification log.

PROTOCOLS FOR MEASURING GROUNDWATER LEVELS

This section presents considerations for the methodology of collection of groundwater level data such that it meets the requirements of the GSP Regulations and the DQOs of the specific GSP. Groundwater levels are a fundamental measure of the status of groundwater conditions within a basin. In many cases, relationships of the sustainability indicators may be able to be correlated with groundwater levels. The quality of this data must consider the specific aquifer being monitored and the methodology for collecting these levels.

The following considerations for groundwater level measuring protocols should ensure the following:

- Groundwater level data are taken from the correct location, well ID, and screen interval depth
- Groundwater level data are accurate and reproducible
- Groundwater level data represent conditions that inform appropriate basin management DQOs
- All salient information is recorded to correct, if necessary, and compare data
- Data are handled in a way that ensures data integrity

General Well Monitoring Information

The following presents considerations for collection of water level data that include regulatory required components as well as those which are recommended.

- Groundwater elevation data will form the basis of basin-wide water-table and piezometric maps, and should approximate conditions at a discrete period in time. Therefore, all groundwater levels in a basin should be collected within as short a time as possible, preferably within a 1 to 2 week period.
- Depth to groundwater must be measured relative to an established Reference Point (RP) on the well casing. The RP is usually identified with a permanent marker, paint spot, or a notch in the lip of the well casing. By convention in open casing monitoring wells, the RP reference point is located on the north side of the well casing. If no mark is apparent, the person performing the measurement should measure the depth to groundwater from the north side of the top of the well casing.
- The elevation of the RP of each well must be surveyed to the North American Vertical Datum of 1988 (NAVD88), or a local datum that can be converted to NAVD88. The elevation of the RP must be accurate to within 0.5 foot. It is preferable for the RP elevation to be accurate to 0.1 foot or less. Survey grade global navigation satellite system (GNSS) global positioning system (GPS) equipment can achieve similar vertical accuracy when corrected. Guidance for use of GPS can be found at USGS http://water.usgs.gov/osw/gps/. Hand-held GPS units likely will not produce reliable vertical elevation measurement accurate enough for the casing elevation consistent with the DQOs and regulatory requirements.
- The sampler should remove the appropriate cap, lid, or plug that covers the monitoring access point listening for pressure release. If a release is observed, the measurement should follow a period of time to allow the water level to equilibrate.
- Depth to groundwater must be measured to an accuracy of 0.1 foot below the RP. It is preferable to measure depth to groundwater to an accuracy of 0.01 foot. Air lines and acoustic sounders may not provide the required accuracy of 0.1 foot.
- The water level meter should be decontaminated after measuring each well.

Where existing wells do not meet the base standard as described in the GSP Regulations or the considerations provided above, new monitoring wells may need to be constructed to meet the DQOs of the GSP. The design, installation, and documentation of new monitoring wells must consider the following:

- Construction consistent with California Well Standards as described in Bulletins 74-81 and 74-90, and local permitting agency standards of practice.
- Logging of borehole cuttings under the supervision of a California Professional Geologist and described consistent with the Unified Soil Classification System methods according to ASTM standard D2487-11.
- Written criteria for logging of borehole cuttings for comparison to known geologic formations, principal aquifers and aquitards/aquicludes, or specific marker beds to aid in consistent stratigraphic correlation within and across basins.
- Geophysical surveys of boreholes to aid in consistency of logging practices. Methodologies should include resistivity, spontaneous potential, spectral gamma, or other methods as appropriate for the conditions. Selection of geophysical methods should be based upon the opinion of a professional geologist or professional engineer, and address the DQOs for the specific borehole and characterization needs.
- Prepare and submit State well completion reports according to the requirements of §13752. Well completion report documentation should include geophysical logs, detailed geologic log, and formation identification as attachments. An example well completion as-built log is illustrated in **Figure 2.** DWR well completion reports can be filed directly at the Online System for Well Completion Reports (OSWCR) http://water.ca.gov/oswcr/index.cfm.

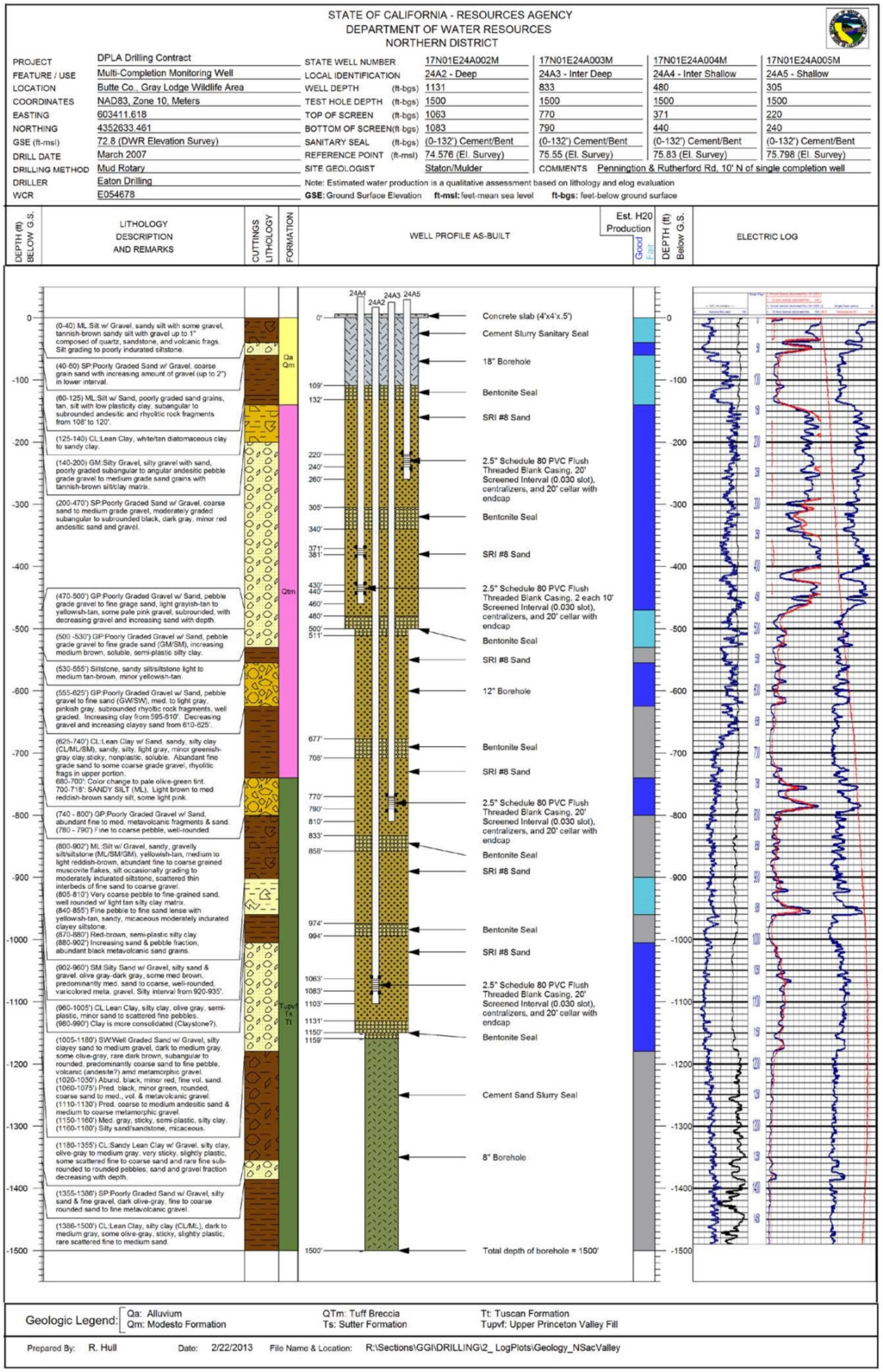

Figure 2 – Example As-Built Multi-Completion Monitoring Well Log

Measuring Groundwater Levels

Well construction, anticipated groundwater level, groundwater level measuring equipment, field conditions, and well operations should be considered prior collection of the groundwater level measurement. The USGS *Groundwater Technical Procedures* (Cunningham and Schalk, 2011) provide a thorough set of procedures which can be used to establish specific Standard Operating Procedures (SOPs) for a local agency. **Figure 3** illustrates a typical groundwater level measuring event and simultaneous pressure transducer download.

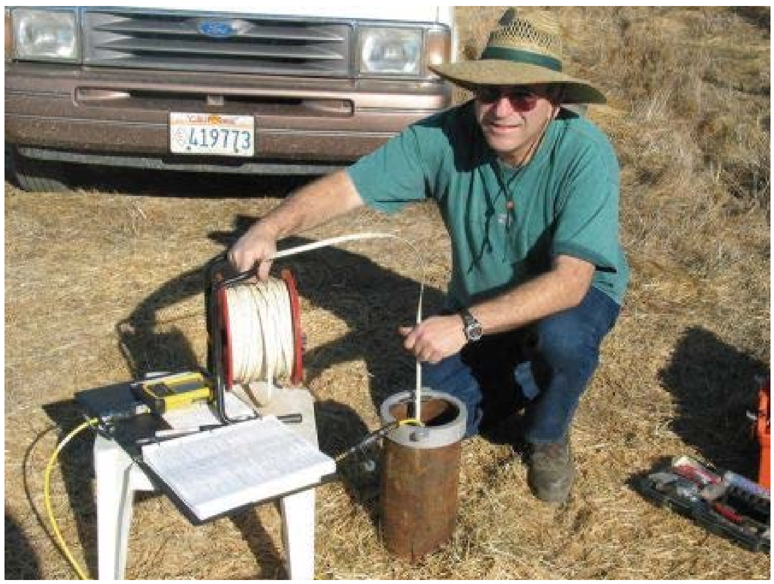

Figure 3 – Collection of Water Level Measurement and Pressure Transducer Download

The following points provide a general approach for collecting groundwater level measurements:

- Measure depth to water in the well using procedures appropriate for the measuring device. Equipment must be operated and maintained in accordance with manufacturer's instructions. Groundwater levels should be measured to the nearest 0.01 foot relative to the RP.
- For measuring wells that are under pressure, allow a period of time for the groundwater levels to stabilize. In these cases, multiple measurements should be collected to ensure the well has reached equilibrium such that no significant changes in water level are observed. Every effort should be made to ensure that a representative stable depth to groundwater is recorded. If a well does not stabilize, the quality of the value should be appropriately qualified as a

questionable measurement. In the event that a well is artesian, site specific procedures should be developed to collect accurate information and be protective of safety conditions associated with a pressurized well. In many cases, an extension pipe may be adequate to stabilize head in the well. Record the dimension of the extension and document measurements and configuration.

- The sampler should calculate the groundwater elevation as:

$$GWE = RPE - DTW$$

Where:

GWE = Groundwater Elevation
RPE = Reference Point Elevation
DTW = Depth to Water

The sampler must ensure that all measurements are in consistent units of feet, tenths of feet, and hundredths of feet. Measurements and RPEs should not be recorded in feet and inches.

Recording Groundwater Levels

- The sampler should record the well identifier, date, time (24-hour format), RPE, height of RP above or below ground surface, DTW, GWE, and comments regarding any factors that may influence the depth to water readings such as weather, nearby irrigation, flooding, potential for tidal influence, or well condition. If there is a questionable measurement or the measurement cannot be obtained, it should be noted. An example of a field sheet with the required information is shown in **Figure 4**. It includes questionable measurement and no measurement codes that should be noted. This field sheet is provided as an example. Standardized field forms should be used for all data collection. The aforementioned USGS *Groundwater Technical Procedures* offers a number of example forms.
- The sampler should replace any well caps or plugs, and lock any well buildings or covers.
- All data should be entered into the GSA data management system (DMS) as soon as possible. Care should be taken to avoid data entry mistakes and the entries should be checked by a second person for compliance with the DQOs.

STATE OF CALIFORNA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES

WELL DATA

STATE WELL NUMBER	COUNTY	REFERENCE POINT ELEV.	MEASURING AGENCY
			DWR

NO MEASUREMENT	QUESTIONABLE MEASUREMENT
0. Measurement discontinued	0. Caved or deepened
1. Pumping	1. Pumping
2. Pump house locked	2. Nearby pump operating
3. Tape hung up	3. Casing leaky or wet
4. Can't get tape in casing	4. Pumped recently
5. Unable to locate well	5. Air or pressure gauge measurement
6. Well has been destroyed	6. Other
7. Special	7. Recharge operation at or nearby well
8. Casing leaky or wet	8. Oil in casing
9. Temporarily inaccessible	

DATE	N M	Q M	TAPE AT RP	TAPE AT WS	RP to WS	OBSR VR	COMMENTS

DWR 1213

Figure 4 – Example of Water Level Well Data Field Collection Form

Pressure Transducers

Groundwater levels and/or calculated groundwater elevations may be recorded using pressure transducers equipped with data loggers installed in monitoring wells. When installing pressure transducers, care must be exercised to ensure that the data recorded by the transducers is confirmed with hand measurements.

The following general protocols must be followed when installing a pressure transducer in a monitoring well:

- The sampler must use an electronic sounder or chalked steel tape and follow the protocols listed above to measure the groundwater level and calculate the groundwater elevation in the monitoring well to properly program and reference the installation. It is recommended that transducers record measured groundwater level to conserve data capacity; groundwater elevations can be calculated at a later time after downloading.
- The sampler must note the well identifier, the associated transducer serial number, transducer range, transducer accuracy, and cable serial number.
- Transducers must be able to record groundwater levels with an accuracy of at least 0.1 foot. Professional judgment should be exercised to ensure that the data being collected is meeting the DQO and that the instrument is capable. Consideration of the battery life, data storage capacity, range of groundwater level fluctuations, and natural pressure drift of the transducers should be included in the evaluation.
- The sampler must note whether the pressure transducer uses a vented or non-vented cable for barometric compensation. Vented cables are preferred, but non-vented units provide accurate data if properly corrected for natural barometric pressure changes. This requires the consistent logging of barometric pressures to coincide with measurement intervals.
- Follow manufacturer specifications for installation, calibration, data logging intervals, battery life, correction procedure (if non-vented cables used), and anticipated life expectancy to assure that DQOs are being met for the GSP.
- Secure the cable to the well head with a well dock or another reliable method. Mark the cable at the elevation of the reference point with tape or an indelible marker. This will allow estimates of future cable slippage.
- The transducer data should periodically be checked against hand measured groundwater levels to monitor electronic drift or cable movement. This should happen during routine site visits, at least annually or as necessary to maintain data integrity.

- The data should be downloaded as necessary to ensure no data is lost and entered into the basin's DMS following the QA/QC program established for the GSP. Data collected with non-vented data logger cables should be corrected for atmospheric barometric pressure changes, as appropriate. After the sampler is confident that the transducer data have been safely downloaded and stored, the data should be deleted from the data logger to ensure that adequate data logger memory remains.

PROTOCOLS FOR SAMPLING GROUNDWATER QUALITY

The following protocols can be incorporated into a GSP's monitoring protocols for collecting groundwater quality data. More detailed sampling procedures and protocols are included in the standards and guidance documents listed at the end of this BMP. A GSP that adopts protocols that deviate from these BMPs must demonstrate that the adopted protocols will yield comparable data.

In general, the use of existing water quality data within the basin should be done to the greatest extent possible if it achieves the DQOs for the GSP. In some cases it may be necessary to collect additional water quality data to support monitoring programs or evaluate specific projects. The USGS *National Field Manual for the Collection of Water Quality Data* (Wilde, 2005) should be used to guide the collection of reliable data. **Figure 5** illustrates a typical groundwater quality sampling setup.

Figure 5 – Typical Groundwater Quality Sampling Event

All analyses should be performed by a laboratory certified under the State Environmental Laboratory Accreditation Program. The specific analytical methods are beyond the scope of this BMP, but should be commiserate with other programs evaluating water quality within the basin for comparative purposes.

Groundwater quality sampling protocols should ensure that:

- Groundwater quality data are taken from the correct location
- Groundwater quality data are accurate and reproducible
- Groundwater quality data represent conditions that inform appropriate basin management and are consistent with the DQOs
- All salient information is recorded to normalize, if necessary, and compare data
- Data are handled in a way that ensures data integrity

The following points are general guidance in addition to the techniques presented in the previously mentioned USGS *National Field Manual for the Collection of Water Quality Data.*

Standardized protocols include the following:

- Prior to sampling, the sampler must contact the laboratory to schedule laboratory time, obtain appropriate sample containers, and clarify any sample holding times or sample preservation requirements.
- Each well used for groundwater quality monitoring must have a unique identifier. This identifier must appear on the well housing or the well casing to avoid confusion.
- In the case of wells with dedicated pumps, samples should be collected at or near the wellhead. Samples should not be collected from storage tanks, at the end of long pipe runs, or after any water treatment.
- The sampler should clean the sampling port and/or sampling equipment and the sampling port and/or sampling equipment must be free of any contaminants. The sampler must decontaminate sampling equipment between sampling locations or wells to avoid cross-contamination between samples.
- The groundwater elevation in the well should be measured following appropriate protocols described above in the groundwater level measuring protocols.
- For any well not equipped with low-flow or passive sampling equipment, an adequate volume of water should be purged from the well to ensure that the groundwater sample is representative of ambient groundwater and not stagnant water in the well casing. Purging three well casing volumes is generally

considered adequate. Professional judgment should be used to determine the proper configuration of the sampling equipment with respect to well construction such that a representative ambient groundwater sample is collected. If pumping causes a well to be evacuated (go dry), document the condition and allow well to recover to within 90% of original level prior to sampling. Professional judgment should be exercised as to whether the sample will meet the DQOs and adjusted as necessary.

- Field parameters of pH, electrical conductivity, and temperature should be collected for each sample. Field parameters should be evaluated during the purging of the well and should stabilize prior to sampling. Measurements of pH should only be measured in the field, lab pH analysis are typically unachievable due to short hold times. Other parameters, such as oxidation-reduction potential (ORP), dissolved oxygen (DO) (in situ measurements preferable), or turbidity, may also be useful for meeting DQOs of GSP and assessing purge conditions. All field instruments should be calibrated daily and evaluated for drift throughout the day.
- Sample containers should be labeled prior to sample collection. The sample label must include: sample ID (often well ID), sample date and time, sample personnel, sample location, preservative used, and analytes and analytical method.
- Samples should be collected under laminar flow conditions. This may require reducing pumping rates prior to sample collection.
- Samples should be collected according to appropriate standards such as those listed in the *Standard Methods for the Examination of Water and Wastewater*, USGS *National Field Manual for the Collection of Water Quality Data,* or other appropriate guidance. The specific sample collection procedure should reflect the type of analysis to be performed and DQOs.
- All samples requiring preservation must be preserved as soon as practically possible, ideally at the time of sample collection. Ensure that samples are appropriately filtered as recommended for the specific analyte. Entrained solids can be dissolved by preservative leading to inconsistent results of dissolve analytes. Specifically, samples to be analyzed for metals should be field-filtered prior to preservation; do not collect an unfiltered sample in a preserved container.
- Samples should be chilled and maintained at 4 °C to prevent degradation of the sample. The laboratory's Quality Assurance Management Plan should detail appropriate chilling and shipping requirements.

- Samples must be shipped under chain of custody documentation to the appropriate laboratory promptly to avoid violating holding time restrictions.
- Instruct the laboratory to use reporting limits that are equal to or less than the applicable DQOs or regional water quality objectives/screening levels.

Special protocols for low-flow sampling equipment

In addition to the protocols listed above, sampling using low-flow sample equipment should adopt the following protocols derived from EPA's *Low-flow (minimal drawdown) ground-water sampling procedures* (Puls and Barcelona, 1996). These protocols apply to low-flow sampling equipment that generally pumps between 0.1 and 0.5 liters per minute. These protocols are not intended for bailers.

Special protocols for passive sampling equipment

In addition to the protocols listed above, passive diffusion samplers should follow protocols set forth in USGS Fact Sheet 088-00.

PROTOCOLS FOR MONITORING SEAWATER INTRUSION

Monitoring seawater intrusion requires analysis of the chloride concentrations within groundwater of each principal aquifer subject to seawater intrusion. While no significant standardized approach exists, the methodologies described above for degraded water quality can be applied for the collection of groundwater samples. In addition to the protocol described above, the following protocols should be followed:

- Water quality samples should be collected and analyzed at least semi-annually. Samples will be analyzed for dissolved chloride at a minimum. It may be beneficial to include analyses of iodide and bromide to aid in determination of salinity source. More frequent sampling may be necessary to meet DQOs of GSP. The development of surrogate measures of chloride concentration may facilitate cost-effective means to monitor more frequently to observe the range of conditions and variability of the flow dynamics controlling seawater intrusion.
- Groundwater levels will be collected at a frequency adequate to characterize changes in head in the vicinity of the leading edge of degraded water quality in each principal aquifer. Frequency may need to be increased in areas of known preferential pathways, groundwater pumping, or efficacy evaluation of mitigation projects.
- The use of geophysical surveys, electrical resistivity, or other methods may provide for identification of preferential pathways and optimize monitoring well placement and evaluation of the seawater intrusion front. Professional judgment

should be exercised to determine the appropriate methodology and whether the DQOs for the GSP would be met.

PROTOCOLS FOR MEASURING STREAMFLOW

Monitoring of streamflow is necessary for incorporation into water budget analysis and for use in evaluation of stream depletions associated with groundwater extractions. The use of existing monitoring locations should be incorporated to the greatest extent possible. Many of these streamflow monitoring locations currently follow the protocol described below.

Establishment of new streamflow discharge sites should consider the existing network and the objectives of the new location. Professional judgment should be used to determine the appropriate permitting that may be necessary for the installation of any monitoring locations along surface water bodies. Regular frequent access will be necessary to these sites for the development of ratings curves and maintenance of equipment.

To establish a new streamflow monitoring station special consideration must be made in the field to select an appropriate location for measuring discharge. Once a site is selected, development of a relationship of stream stage to discharge will be necessary to provide continuous estimates of streamflow. Several measurements of discharge at a variety of stream stages will be necessary to develop the ratings curve correlating stage to discharge. The use of Acoustic Doppler Current Profilers (ADCPs) can provide accurate estimates of discharge in the correct settings. Professional judgment must be exercised to determine the appropriate methodology. Following development of the ratings curve a simple stilling well and pressure transducer with data logger can be used to evaluate stage on a frequent basis. A simple stilling well and staff gage is illustrated in **Figure 6**.

Streamflow measurements should be collected, analyzed, and reported in accordance with the procedures outlined in USGS Water Supply Paper 2175, *Volume 1. – Measurement of Stage Discharge* and *Volume 2. – Computation of Discharge.* This methodology is currently being used by both the USGS and DWR for existing streamflow monitoring throughout the State.

Figure 6 – Simple Stilling Well and Staff Gage Setup

PROTOCOLS FOR MEASURING SUBSIDENCE

Evaluating and monitoring inelastic land subsidence can utilize multiple data sources to evaluate the specific conditions and associated causes. To the extent possible, the use of existing data should be utilized. Subsidence can be estimated from numerous techniques, they include: level surveying tied to known stable benchmarks or benchmarks located outside the area being studied for possible subsidence; installing and tracking changes in borehole extensometers; obtaining data from continuous GPS (CGPS) locations, static GPS surveys or Real-Time-Kinematic (RTK) surveys; or analyzing Interferometric Synthetic Aperture Radar (InSAR) data. No standard procedures exist for collecting data from the potential subsidence monitoring approaches. However, an approach may include:

- Identification of land subsidence conditions.
    - Evaluate existing regional long-term leveling surveys of regional infrastructure, i.e. roadways, railroads, canals, and levees.
    - Inspect existing county and State well records where collapse has been noted for well repairs or replacement.
    - Determine if significant fine-grained layers are present such that the potential for collapse of the units could occur should there be significant depressurization of the aquifer system.

  - Inspect geologic logs and the hydrogeologic conceptual model to aid in identification of specific units of concern.
  - Collect regional remote-sensing information such as InSAR, commonly provided by USGS and NASA. Data availability is currently limited, but future resources are being developed.
- Monitor regions of suspected subsidence where potential exists.
  - Establish CGPS network to evaluate changes in land surface elevation.
  - Establish leveling surveys transects to observe changes in land surface elevation.
  - Establish extensometer network to observe land subsidence. An example of a typical extensometer design is illustrated in **Figure 7**. There are a variety of extensometer designs and they should be selected based on the specific DQOs.

Various standards and guidance documents for collecting data include:

- Leveling surveys must follow surveying standards set out in the California Department of Transportation's Caltrans Surveys Manual.
- GPS surveys must follow surveying standards set out in the California Department of Transportation's Caltrans Surveys Manual.
- USGS has been performing subsidence surveys within several areas of California. These studies are sound examples for appropriate methods and should be utilized to the extent possible and where available:
  - http://ca.water.usgs.gov/land_subsidence/california-subsidence-measuring.html
- Instruments installed in borehole extensometers must follow the manufacturer's instructions for installation, care, and calibration.
- Availability of InSAR data is improving and will increase as programs are developed. This method requires expertise in analysis of the raw data and will likely be made available as an interpretative report for specific regions.

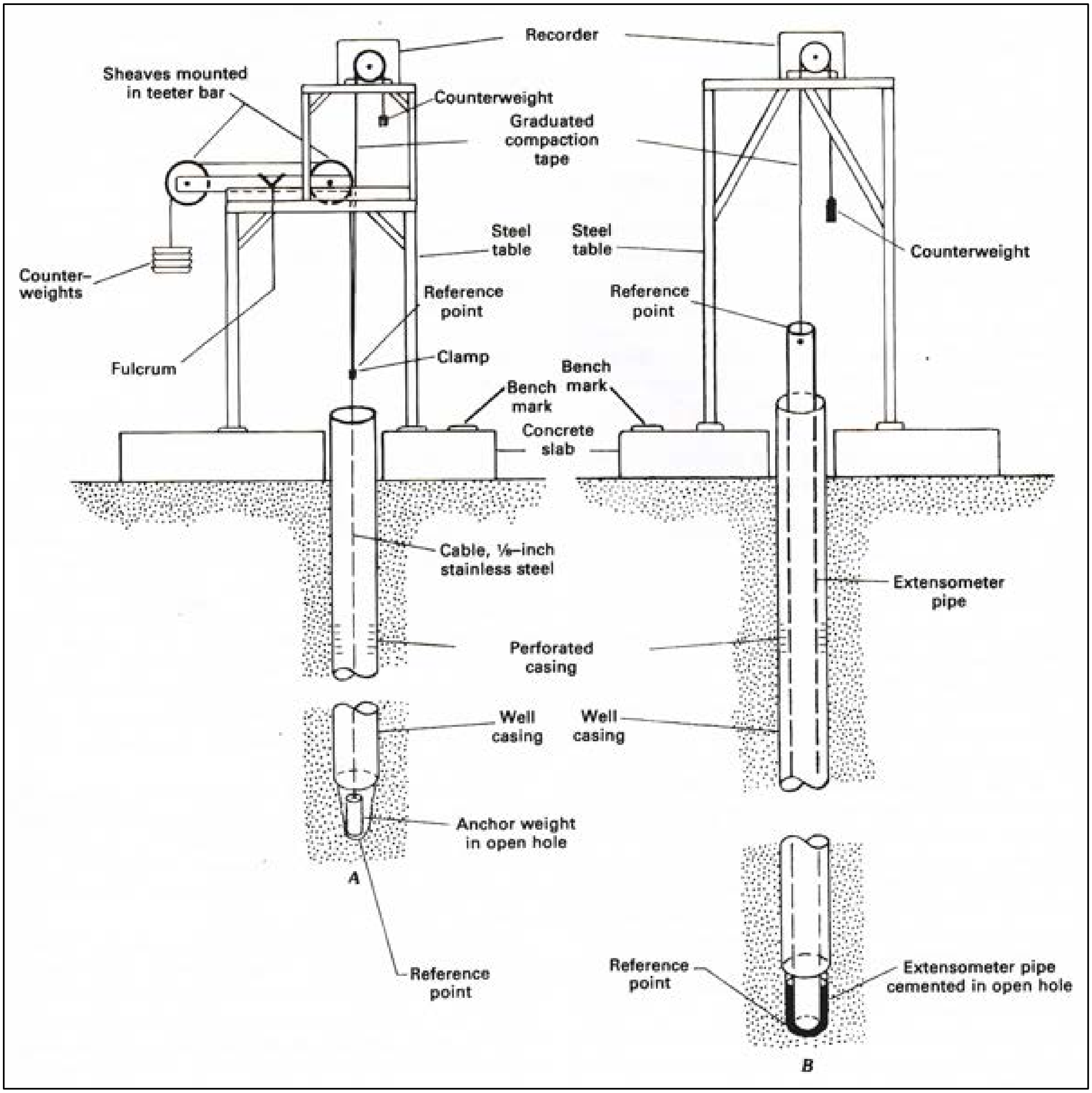

Figure 7 – Simplified Extensometer Diagram

6. KEY DEFINITIONS

The key definitions and sections related to Groundwater Monitoring Protocols, Standards, and Sites outlined in applicable SGMA code and regulations are provided below for reference.

Groundwater Sustainability Plan Regulations (California Code of Regulations §351)

- §351(h) "Best available science" refers to the use of sufficient and credible information and data, specific to the decision being made and the time frame available for making that decision, that is consistent with scientific and engineering professional standards of practice.
- §351(i) "Best management practice" refers to a practice, or combination of practices, that are designed to achieve sustainable groundwater management and have been determined to be technologically and economically effective, practicable, and based on best available science.

Monitoring Protocols Reference

§352.2. Monitoring Protocols

Each Plan shall include monitoring protocols adopted by the Agency for data collection and management, as follows:

(a) Monitoring protocols shall be developed according to best management practices.

(b) The Agency may rely on monitoring protocols included as part of the best management practices developed by the Department, or may adopt similar monitoring protocols that will yield comparable data.

(c) Monitoring protocols shall be reviewed at least every five years as part of the periodic evaluation of the Plan, and modified as necessary.

SGMA Reference

§10727.2. Required Plan Elements

(f) Monitoring protocols that are designed to detect changes in groundwater levels, groundwater quality, inelastic surface subsidence for basins for which subsidence has been identified as a potential problem, and flow and quality of surface water that directly affect groundwater levels or quality or are caused by groundwater extraction in the basin. The monitoring protocols shall be designed to generate information that promotes efficient and effective groundwater management.

7. Related Materials

CASE STUDIES

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Measuring Land Subsidence web page. U.S. Geological Survey. http://ca.water.usgs.gov/land_subsidence/california-subsidence-measuring.html

USGS Global Positioning Application and Practice web page. U.S. Geological Survey. http://water.usgs.gov/osw/gps/

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Appendix N
Screening Analysis Results

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TECHNICAL MEMORANDUM

TO: San Pasqual Valley GSP Core Team

DATE: Revised September 2021

RE: Projects and Management Actions Screening Process

The purpose of this Technical Memorandum is to describe the screening process for inclusion of projects and management actions in the GSP.

1. OVERVIEW OF SCREENING PROCESS

The consultant team first met with the GSA Core Team on August 26, 2020 to discuss the strategy for the development of projects and management actions. All GSP program management tasks would be implemented throughout the GSP implementation period, while projects and management actions may be implemented by the GSA as determined through the adaptive management process.

The consultant team prepared a comprehensive list of implementation tasks, management actions, and projects that could potentially be implemented in the San Pasqual Valley (SPV) Basin, based on our knowledge of SGMA regulations and regional infrastructure. During a GSA Core Team meeting on November 18, 2020, the consultant team provided an overview of each proposed implementation task, project, and management action, as well as an initial recommendation on whether it should be included in the GSP. Recommendations were based on a preliminary high-level cost-benefit analysis.

The GSA Core Team reviewed the recommendations and provided revisions that were incorporated into Section 9, *Projects and Management Actions* of the GSP. The proposed final list of projects and management actions was reviewed by the GSA Core Team on December 10, 2020. The proposed final list of projects and management actions was presented to both the Technical Peer Review Group and Advisory Committee on January 14, 2021.

This list was reviewed by the Advisory Committee again on February 18, 2021. At that Advisory Committee meeting, stakeholders raised the possibility of additional surface water recharge projects that had not been previously included in the list of projects and management actions. On May 4, 2021, additional analysis related to potential surface water releases from Sutherland Reservoir were completed (see Section 2 below) and an additional management action related to further study of surface water recharge was added to Section 9, *Projects and Management Actions*.

Table 1 shows the projects and management actions that were excluded during the screening process (**Table 1**).

Table 1: Projects and Management Actions Excluded During the Screening Analysis

Activity Name	Reason for Screening Out
Limitations on new well construction: limiting the installation of new wells over a certain size or capacity unless they are replacing an existing well	Well construction permits are an existing County function and not a GSA authority.
Surface water or stormwater capture and storage: capture surface water or stormwater flows in the eastern end of the Basin and use the water to recharge groundwater levels.	Environmental permitting requirements are high, and cost is high relative to the amount of water gained.
Discharge excess advanced treated reclaimed water, available in nonpeak growing season and winter months, from Hogback Reservoir to Cloverdale Creek	High cost and uncertain benefit.
Recharge excess reclaimed water from Hogback Reservoir to the eastern portion of the Basin	High cost.
Recharge basin with advanced treated recycled water from a new San Pasqual Water Reclamation Facility in the West Basin	High cost.
Recharge basin with Advanced treated recycled water from New San Pasqual Water Reclamation Facility in the East Basin	High cost.
Recharge with raw water from Ramona Mutual Water District	Ramona is discontinuing its raw water services at the end of 2021.
Recharge with City of San Diego recycled water	High cost.
Pump-and-treat system for nitrate	High cost.
Hodges Reservoir natural treatment system: wetlands and detention basins to treat discharge before entering to Hodges	High cost and uncertain benefit.
Household water treatment for domestic users	Infeasible implementation due to regulations.

2. PRELIMINARY EVALUATION OF SURFACE WATER RECHARGE

As part of the screening analysis to evaluate potential projects and management actions to help maintain Basin sustainability, a preliminary analysis of surface water releases from Sutherland Reservoir was conducted.

Sutherland Context and History

Sutherland Reservoir is on Santa Ysabel Creek, a tributary to the San Dieguito River, located upstream of San Pasqual Valley. Sutherland Reservoir has 557 surface acres, a maximum water depth of 145 feet, a minimum pool of 2,680 acre-feet, and usable storage capacity of 29,400 acre-feet[1].

Stream flow in Santa Ysabel Creek below Sutherland Reservoir is intermittent, and with the exception of very high rainfall years, the creek has no flow during later summer and fall months. Santa Ysabel Creek, at the USGS gage near Ramona, flows approximately 100 days during the year with an average annual discharge of 510 acre-feet per year (AFY) (see Section 3, *Hydrogeologic Conceptual Model*, Section 3.1.2 Surface Water Bodies).

Reservoir operations are influenced by the City of San Diego (City) in a Water Exchange and Water Transportation Agreement (Agreement) with Ramona Municipal Water District (RMWD) (Originally agreed upon May 4, 1953 and most recently revised July 17, 2000 and amended August 27, 2010) which is due to expire in 2025. Operations under this agreement optimize storage and allow for cooperative management between the City and RMWD. The Agreement (which ends in 2025) provides that RMWD may purchase a portion of the water the City transfers from Sutherland Reservoir to San Vicente Reservoir, provided storage capacity is available. Up to 65 million gallons per day (MGD) of water can be transferred from Sutherland Reservoir through the Sutherland-San Vicente Pipeline to either the RMWD Barger Water Treatment Plant (WTP) or discharged into San Vicente Creek at Daney Canyon. Due to the RMWD Barger WTP not being in use, 2005-2006 is the only year on record of the City selling water to RMWD in last 20 years. Generally, all water above RMWD's contract pool is released and the volume and timing of this water transfer is optimized to minimize streambed erosion; accommodate bass spawning (April 1 through May 15) in Sutherland Reservoir, and the federally endangered arroyo toad (Bufo californicus) breeding (March 15 through July 1) in the streambed.

[1] Sutherland reservoir specifications. https://www.sandiego.gov/reservoirs-lakes/sutherland-reservoir

Sutherland Reservoir Releases

To evaluate the benefit of increasing Santa Ysabel Creek inflows into the Basin from releasing additional water from Sutherland Reservoir, a preliminary groundwater system budget was developed using the historical SPV GSP Integrated Groundwater/Surface Water Flow Model (SPV GSP Model) simulation. The historical version of this model simulates hydrologic and operational conditions from water years (WYs) 2005 - 2019. The average change in groundwater storage, as calculated by the SPV GSP Model, is -245 AFY over the 15-year historical period (refer to Table 5-5 in Section 5, *Water Budgets*). The preliminary analysis included simulating an additional 300 acre-feet (AF) per month of inflow from Santa Ysabel Creek at the Basin boundary during the months of March through September (or 2,100 AFY of additional streamflow), to assess its potential impact on changes in Basin groundwater storage. Reservoir discharge was modeled for the summer months when irrigation demand is highest and there is less likelihood of shallower groundwater levels to potentially reject recharge from the stream. A more thorough and comprehensive evaluation could be done to explore potential benefits from different reservoir release scenarios.

Table 2 shows a comparison of historical water budgets from two simulations including the historical simulation (WYs 2005 - 2019) and the same simulation, but with an additional 300 AF per month of Santa Ysabel Creek inflow at the Basin boundary during the months of March through September, totaling an additional 2,100 AFY of additional stream inflow. This second simulation is referred to in Table 2 as "Sutherland Scenario". The last column of Table 2 computes the difference between the water budget flow rates by subtracting the historical flow rate from the Sutherland Scenario flow rate.

The preliminary modeling exercise indicates that if the Santa Ysabel Creek inflows were to have been 2,100 AFY greater on average during the historical 15-year period from WYs 2005 - 2019, the average change in groundwater storage could have potentially been 188 AFY higher. This increase in groundwater storage would have removed most of the 245 AFY deficit in groundwater storage from the historical simulation (57 AFY of groundwater storage deficit remains in the Sutherland Scenario).

Note that a positive change in groundwater storage of 188 AFY does not equate to 188 AFY of groundwater recharge from Santa Ysabel Creek. As shown in Table 2, of the 5,278 to 7,828 AFY of Santa Ysabel Creek inflows into the Basin for the historical simulation and Sutherland Scenario, groundwater recharge from the Santa Ysabel Creek is estimated to range from 1,144 to 2,001 AFY. The reason groundwater storage only increases by 188 AFY in the Sutherland Scenario is because increases in groundwater inflows to the Basin cause increases in groundwater outflows from the Basin. So, not all of the additional Sutherland releases introduced to the Basin results in an equivalent increase in groundwater storage. This hydrologic response is not unique to the SPV Basin. Increases in groundwater inflows to an aquifer causes increases in groundwater outflows from that aquifer.

Examination of the individual water budget components and flow rates in Table 2 shows how an increase of 2,100 AFY of Santa Ysabel Creek inflows to the Basin influences the flow rates of the other water budget components (see the "Difference" column in Table 2). An increase of Santa Ysabel Creek inflows would result in some increase in Basin groundwater levels, because of an increase in groundwater recharge from Santa Ysabel Creek. An increase in groundwater levels would be limited by increases in groundwater discharge to streams and the land surface in portions of the Basin, increases in groundwater ET, and increases in subsurface outflows from the Basin. A more comprehensive evaluation would need to be completed to better understand the cost-benefit and operational feasibility of surface water recharge projects via reservoir releases. Such an evaluation would need to consider operational rules and priority setting to balance competing demands of Sutherland Reservoir.

As a result of this preliminary analysis, Management Action 7—Initial Surface Water Recharge Evaluation was added to Section 9, *Projects and Management Actions*.

Table 2: Comparison of Water Balance Components and Flow Rates

Water Budget Component	Historical Flow Rate (AFY)	Sutherland Scenario Flow Rate (AFY)	Difference (AFY)(a)
Santa Ysabel Creek Inflow into Basin	5,728	7,828	+2,100
San Dieguito River Outflow from Basin to Lake Hodges	13,714	15,284	+1,570
Groundwater Inflow Components			
Groundwater Recharge from Precipitation and Applied Water	3,050	3,100	+50
Groundwater Recharge from Septic Systems	2	2	0
Groundwater Recharge from Santa Ysabel Creek	1,144	2,001	+857
Groundwater Recharge from Other Streams	1,132	1,220	+88
Subsurface Inflow from Lake Hodges Area	18	16	-2
Subsurface Inflow from Adjacent Rock	2,983	2,902	-81
Total Groundwater Inflow	8,329	9,241	+912
Groundwater Outflow Components			
ET of Shallow Groundwater	1107	1347	+240
Groundwater Discharge to Santa Ysabel Creek	54	139	+85
Groundwater Discharge to Other Streams	867	1169	+302
Agricultural Groundwater Pumping	5858	5830	-28
Domestic Groundwater Pumping	3	3	0
Subsurface Outflow to Lake Hodges Area	98	127	+29
Subsurface Outflow to Adjacent Rock	468	525	+57
Groundwater Discharge to Land Surface	119	158	+39
Total Groundwater Outflow	8574	9298	+724
Groundwater Storage			
Change in Groundwater Storage	-245	-57	+188

(a) Computed by subtracting the historical flow rate from the Sutherland Scenario flow.

3. IMPLEMENTATION STRATEGY

Section 9, *Projects and Management Actions* includes all of the projects and management actions that could be implemented by the GSA, as needed to maintain Basin sustainability. The implementation strategy was defined in a GSA Core Team meeting on January 28, 2021 by three tiers of implementation dependent on thresholds (Tier 0, Tier 1, and Tier 2).

- **Tier 0:** these projects and management actions can be implemented by the GSA at any time after GSP adoption.
- **Tier 1:** these projects and management actions can be implemented when Planning Thresholds for groundwater levels (described in Section 8, *Minimum Thresholds and Measurable Objectives*) are exceeded. Tier 1 actions can potentially be initiated when at least five wells in the Basin exceed their planning threshold. Potential Tier 1 management actions include a well inventory, development of a pumping restrictions and enforcement plan, and a basin-wide metering program.
- **Tier 2:** these projects and management actions can be implemented when Minimum Thresholds for groundwater levels (described in Section 8, *Minimum Thresholds and Measurable Objectives*) are exceeded. Tier 2 actions can potentially be initiated when at least five wells in the Basin exceed their minimum threshold. The potential Tier 2 management action currently included in the GSP is implementation of pumping restrictions and enforcement.

See the attached **Table 3** for the complete list of GSP implementation tasks, projects, and management actions reviewed by the GSA Core Team for inclusion in the GSP. Note that Table 3 also includes the full list of excluded projects not incorporated into the SPV GSP.

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Table 3: Projects and Management Actions

Name and Description							Screening and Reason for Screening			
Tier	Goal	Activity Name	Description	Potential Partner	When it Starts	Implementation Period	Benefits	Potential Challenges	Estimated Cost	Recommendation for Inclusion in GSP?
Tier Zero										
Tier Zero	Successfully implement GSP	**Continue Groundwater Level Monitoring**	The GSA will continue monitoring groundwater levels using the existing monitoring network. This task is required under SGMA.	None	Immediately after GSP adoption	Ongoing	Monitors groundwater levels to avoid undesirable results	None	\$20,000 - \$30,000 per year	Yes
Tier Zero	Successfully implement GSP	**Continue Groundwater Quality Monitoring**	The GSA will continue monitoring groundwater quality using the existing monitoring network. This task is required under SGMA.	None	Immediately after GSP adoption	Ongoing	Monitors groundwater quality	None	\$20,000 - \$30,000 per year	Yes
Tier Zero	Successfully implement GSP	**Public Meetings**	The Core Team will hold an annual public meeting around the release of the annual report	None	Immediately after GSP adoption	Ongoing	Public involvement and engagement	None	\$15,000 - \$30,000 per year	Yes
Tier Zero	Successfully implement GSP	**GSA Core Team Meetings**	The Core Team will meet biannually or annually	None	Immediately after GSP adoption	Ongoing	The Core Team will continue to actively manage basin sustainability	None	\$20,000- \$40,000 per year	Yes
Tier Zero	Successfully implement GSP	**Annual Reporting**	Prepares annual reports for submittal to DWR to report on GSP implementation by April 1 of each year following adoption	None	Annually	Annually	Will ensure groundwater management continues to be sustainable	None	\$40,000 - \$65,000 per year	Yes
Tier Zero	Successfully implement GSP	**5 Year Evaluation Reports**	Prepares 5 year updates of the GSP in accordance with SGMA regulations.	None	Every 5 years	Every 5 years	Will ensure groundwater management continues to be sustainable	None	\$100,000- \$300,000	Yes
Tier Zero	Successfully implement GSP	**Numerical Model Updates As Needed**	Before a 5 year evaluation report, the Core Team would assess the need to update the numerical model with recent data.	None	May occur every 5 years	Every 5 years	Improved GSP projections	May be costly, up to \$300,000.	\$75,000 - \$300,000	Yes
Tier Zero	Successfully implement GSP	**Pursue Funding Opportunities**	GSA would pursue implementation funding for applicable projects and management actions. This may include grant or loan assistance from State or Federal agencies.	None	Dependent on timing of applicable opportunities	Ongoing	Grant or loan assistance for projects and management action implementation, reducing cost to GSA	Grant program timing is variable, and award is not guaranteed.	By application type: \$45,000- \$60,000 (State) \$50,000+ (Federal)	Yes
Tier Zero	Successfully implement GSP	**Groundwater Monitoring Improvements**	Groundwater monitoring improvements may include expanding the monitoring network through the installation of additional monitoring wells or addition of continuous measurement devices, for example.	None	May be implemented at any time	Ongoing	Improved understanding of basin; addresses gaps in monitoring network	Identification of locations for new monitoring wells	\$150,000 - \$200,000 per new well construction	Yes

Table 3: Projects and Management Actions

Name and Description							Screening and Reason for Screening			
Tier	**Goal**	**Activity Name**	**Description**	**Potential Partner**	**When it Starts**	**Implementation Period**	**Benefits**	**Potential Challenges**	**Estimated Cost**	**Recommendation for Inclusion in GSP?**
Tier Zero	Understand land use in the basin	**Annual Land Use Inventory**	An annual land use inventory will ensure any changes to land use that could impact the basin are being addressed. The inventory will be performed once every five years to support the five-year GSP update.	None	Every 5 years	Every 5 years	Better understanding of land use in the basin and any changes	None	$10,000 - $20,000 per year	Yes
Tier Zero	Successfully implement GSP	**Public Outreach and Website Maintenance**	The GSAs intend to continue public outreach during the GSP implementation period. This may include providing access to GSP information online or continued coordination with entities conducting outreach to diverse communities in the Basin.	None	Ongoing	Ongoing	Continued public engagement with the GSP process	None	$5,000-$15,000 annually	Yes
Tier Zero	Improve Groundwater Quality	**Project 1: Coordinate with the City of San Diego on the Construction of Infiltration Basins at San Pasqual Union Elementary School**	A draft of the 2020 San Dieguito Water Quality Improvement Plan Update (WQIP) was released in September 2020 (City of San Diego, 2020). The WQIP lists a number of potential jurisdictional strategies. One of the identified projects involves constructing infiltration and detention basins at San Pasqual Union Elementary School, sited directly north of the Basin adjacent to Cloverdale Creek. If this project was triggered and implemented by the City's Transportation & Stormwater Department through the WQIP, the GSA Core Team would support its implementation.	City of San Diego Transportation & Stormwater Department (TSW) may implement as part of their WQIP	May be implemented at any time	The WQIP indicates the implementation of this project may take 4 to 6.5 years.	Constructing infiltration basins could improve groundwater quality through additional infiltration prior to reaching the Basin. Specifically, the western portion of the basin historically has high concentration of TDS and nitrate; the new infiltration basins would help reduce bacteria, nitrate, metals, trash, and sediment prior to entering this area of the Basin.	Implementation of this project is outside of GSA Authority and would require coordination with the City's Transportation & Stormwater Department.	No cost to the GSA. It is expected that the MS4 and WQIP co-permittees would fund this project	Yes

Table 3: Projects and Management Actions

Name and Description							Screening and Reason for Screening			
Tier	Goal	Activity Name	Description	Potential Partner	When it Starts	Implementation Period	Benefits	Potential Challenges	Estimated Cost	Recommendation for Inclusion in GSP?
Tier Zero	Improve Groundwater Levels	**Project 2: Coordinate on the implementation of Invasive Species Removal**	A draft of the 2020 Draft WQIP Update includes information on the Northern San Diego County Invasive Non-Native Species Control Program. The Northern San Diego County Invasive Non-Native Species Control Program is an existing project that began in 2012 and is located in SPV. If this project were implemented, the GSA Core Team would coordinate with existing partners to support invasive non-native plant removal in the SPV Basin.	This project is implemented through partnerships with the City of San Diego Public Utilities Department, Dendra Inc., Mission Resource Conservation District, and the San Diego County Water Authority.	May be implemented at any time	Ongoing	Invasive non-native plant removal protects and enhances habitat, conserves water resources, protects water delivery and storage systems by reducing flood risk and damage, improves water quality by reducing erosion, and reduces risk of fire. Arundo donax and Cortaderia selloana (pampas grass) in particular are large groundwater water users. Eradication of these invasive species in SPV will reduce groundwater use and therefore increase groundwater levels.	The GSA Core Team would coordinate with existing project partners on project implementation. Details of implementation are currently unknown.	No cost to the GSA	Yes
Tier Zero	Improve Groundwater Quality and Levels	**MA 1: Farming Best Management Practices**	The GSA would support changes in irrigation practices to encourage efficiency, including irrigation efficiency or sustainable agriculture practices to reduce groundwater quality impacts. Sustainable agriculture practices may include crop rotation, planting cover crops, reducing or eliminating tillage, applying integrated pest management, or adopting agroforestry practices. Because the GSA have limited authority to implement these best management practices (BMPs), the GSA would encourage use of BMPs through education and outreach or encourage collaboration with other entities in the region, including the Farm Bureau and San Diego County Water Authority as needed.	Farm Bureau, City Lease Department, San Diego County Water Authority	May be implemented at any time	Ongoing	Land use changes would positively impact groundwater use, and improve irrigation efficiency, increasing groundwater supply. Through partnering with existing programs, the GSA could encourage participation in regional programs that would directly benefit the Basin	Challenges will vary by BMP. GSA authority to implement BMPs is limited.	$40,000 - $50,000 per year dependent on BMP	Yes
Tier Zero	Improve Groundwater Levels	**MA 2: Education and Outreach to Encourage Demand Softening**	To encourage water use efficiency in the Basin, the GSA would conduct education and outreach to its water users. The outreach program would encourage landowners to reduce acreage of permanent crops, or encourage converting high water use crops to low water use crops. Participation in the program be voluntary.	Farm Bureau, San Diego Water Authority	May be implemented at any time	Ongoing	Reduces total agricultural water use by encouraging the reduction of the proportion of high water use crops (AFY of water savings is dependent on crop type)	Cost to stakeholders is high, and could potentially be >$10,000 per acre for stakeholders. The GSA would research local, state, and federal funding opportunities that could complement/support an outreach program and lower the barrier to entry for stakeholders.	$10,000-$15,000 per year	Yes
Tier Zero	Improve Groundwater Quality	**MA 3: Support WQIP Actions**	The GSA would support strategies identified in the 2020 Draft Water Quality Improvement Plan (WQIP) that aims to address discharges of nutrients and other pollutants through activities in the GSA area. Example strategies include agricultural lease renewals and enhanced golf course inspections.	City of San Diego Transportation & Stormwater Department (TSW) may implement as part of their WQIP	Expected to be implemented FY2022	Ongoing	This action may be implemented through the WQIP and therefore provides benefit to the Basin without a large additional cost to the GSA	GSA does not have the authority to implement. Requires implementation by City of San Diego TSW.	No cost to the GSA	Yes

Table 3: Projects and Management Actions

Name and Description							Screening and Reason for Screening			
Tier	**Goal**	**Activity Name**	**Description**	**Potential Partner**	**When it Starts**	**Implementation Period**	**Benefits**	**Potential Challenges**	**Estimated Cost**	**Recommendation for Inclusion in GSP?**
Tier Zero	Improve Groundwater Levels and Improve Groundwater Quality	**MA 4: Coordinate and Collaborate Regionally with Other Entities to Perform Monitoring and Implement Regional Projects**	The GSA would collaboration with other entities in the region on projects that would benefit the Basin. This management action would involve coordinating with other monitoring entities or encouraging the implementation of regional projects.	For example, this may include the San Diego Regional Water Quality Control Board or the San Diego Integrated Regional Water Management Program.	May be implemented at any time	Ongoing	This management action leverages the efforts of other monitoring and regional entities for increased benefits to the GSA's area. Improved coordination could leverage the efforts of other monitoring entities and improve knowledge of the Basin.	Requires ongoing effort to achieve alignment with other agencies	$10,000-$15,000 per year	Yes
Tier Zero	Improve Groundwater Quality	**MA 5: Education and Outreach about TDS and Nitrate**	The GSA would conduct outreach and education to water users in the Basin to provide an update on water quality monitoring results and to provide a forum to discuss potential water quality issues and options.	Farm Bureau, San Diego Water Authority	May be implemented at any time	Ongoing	This education and outreach program has the potential to provide information to Basin residents about the potability of their wells. Benefits would be measured by stakeholder participation in the Basin.	GSA could find it difficult to engage stakeholders, and have no authority to enforce changes	$10,000-$15,000 per year	Yes
Tier Zero	Improve Groundwater Levels and Improve Groundwater Quality	**MA 6: Coordinate with City on Hodges Watershed Improvement Project**	This project consists of two subprojects 1) a San Pasqual Valley Resource Management Plan (SPVRMP) and associated Best Management Practices (BMP) Implementation Project, and 2) San Dieguito Watershed Habitat Restoration (SDWHR) for ecosystem enhancement. The Hodges Watershed Improvement Project is being managed by the City's Public Utilities Department as part of an IRWM Planning grant in coordination with the San Diego County Water Authority.	City of San Diego Public Utilities Department and San Diego County Water Authority	Began in 2021	Began in 2021, expected completion in 2026	The primary benefit of the SPVRMP is the implementation of a minimum of five (5) BMPs. The primary benefit of the SDWHR project is the restoration of a minimum of 17 acres of habitat. This Management Action would use habitat restoration and BMPs to improve water quality and reduce soil salinity by removing invasive salt cedar and reducing sediment and nutrient loading in Basin and downstream in Hodges Reservoir.	GSA does not have the authority to implement. Requires implementation by City of San Diego Public Utilities Department and San Diego County Water Authority.	No cost to the GSA	Yes
Tier Zero	Improve Groundwater Levels	**MA 7: Initial Surface Water Recharge Evaluation**	The GSA would complete an initial investigation to identify potential surface water recharge projects that warrant further analysis, and conduct a preliminary feasibility analysis study.	City of San Diego Public Utilities Department	May be implemented at any time	1- to 2-year evaluation to identify potential recharge projects that warrant further analysis	An Initial Surface Water Recharge Evaluation would help the Basin achieve desired groundwater levels, groundwater storage, groundwater quality, and reductions in negative impacts to surface water flows through direct replenishment.	Institutional challenges, substantial modeling and analysis needed to identify recharge potential, cost to stakeholders is high	$300,000-$500,000	Yes

Table 3: Projects and Management Actions

Name and Description							Screening and Reason for Screening			
Tier	Goal	Activity Name	Description	Potential Partner	When it Starts	Implementation Period	Benefits	Potential Challenges	Estimated Cost	Recommendation for Inclusion in GSP?
Tier One										
Tier One	Improve understanding of Groundwater Dependent Ecosystems (GDEs)	**MA 8: Study of Groundwater Dependent Ecosystems (GDEs)**	GDEs are defined in the GSP regulations as "ecological communities or species that depend on groundwater emerging from aquifers or on groundwater occurring near the ground surface." Because GDEs are considered a beneficial user of groundwater in the Basin, it is important to definitively identify where they are located. This management action would entail developing a detailed study for this purpose.	None	May be implemented at any time	6 months - 1 year implementation	Better understanding of GDE locations	None	\$100,000-\$200,000	Yes
Tier One	Improve GSA's Ability to Manage	**MA 9: Well Inventory**	The GSA would inventory monitoring wells in the Basin to improve its ability to manage the Basin. The well inventory would identify and compile information about wells that are located inside the Basin. Compilation of the well inventory may include the following: review of records to obtain well construction information, coordination with landowners/leaseholders, field visits to verify well location and size, compilation of estimates or meter readings of water pumped, or investigation of conditions wells might need to meet to determine if pumping of that well affects Basin conditions.	None	May be implemented during Tier 1	1-3 year implementation	Provides a more accurate understanding of the wells located within the basin for increasingly accurate monitoring and pumping measurement	High level of effort. Requires water user cooperation; May be contentious with water users.	\$100,000-200,000	Yes
Tier One	Improve Groundwater Use Monitoring	**MA 10: Basinwide Metering Program**	The GSA would require installation of pumping flow meters on non-de minimis extraction wells in the Basin	None	May be implemented during Tier 1	1-2 year implementation	Improves understanding of Basin groundwater extractions with groundwater pumping data for each well in the Basin.	High cost. Requires water user cooperation; May be contentious with water users.	\$50,000-200,000	Yes
Tier One	Improve Groundwater Levels	**MA 11: Develop a Pumping Reduction Plan**	The GSA would plan and prepare the details of a pumping restriction program. The program would include enforcement could be through fee assessments and/or penalties. Pumping restriction planning would consider the sustainable yield of the Basin and the allocation of that sustainable yield to groundwater users based on historical use, land use, and an assessment of how new supplies would be allocated. A timeline would be developed for reducing pumping to achieve pumping allocations over time.	None	May be implemented during Tier 1	1-2 year implementation	Helps the Basin achieve sustainable pumping levels through direct reductions in groundwater overdraft.	Would require an accurate pumping quantification	\$100,000-\$200,000	Yes
Tier Two										
Tier Two	Improve Groundwater Levels	**MA 12: Pumping Restrictions and Enforcement**	Under this action, the GSA would implement pumping restrictions to limit groundwater use in accordance with the pumping reduction plan created in Tier 1. Enforcement would be through fee assessments and/or penalties.	None	May be implemented during Tier 2	Ongoing	Implementation and enforcement of a pumping reduction plan would directly reduce groundwater pumping. Benefits would be measured by the change in total volume of groundwater pumped from the Basin and by how many users were complying with their pumping allocations.	Would require enforcement techniques	\$50,000-\$100,000 per year based on implementation costs from other basins	Yes

Table 3: Projects and Management Actions

Name and Description							Screening and Reason for Screening			
Tier	Goal	Activity Name	Description	Potential Partner	When it Starts	Implementation Period	Benefits	Potential Challenges	Estimated Cost	Recommendation for Inclusion in GSP?
Projects and Management Actions Not Included in GSP										
Excluded	Improve Groundwater Levels	**Limitation on New Well Construction**	GSA would limit the installation of new wells in some way. This may include limiting the installation of new wells over a certain size or capacity unless they are replacing an existing well	County of San Diego Department of Environmental Health	May be implemented under adaptive management	Ongoing	Would reduce groundwater extraction from new wells	Well permitting is currently under County jurisdiction and not within GSA Authority.	$10,000-$30,000 per year	No, the GSA does not have the authority to implement this management action
Excluded	Improve Groundwater Levels	**Surface Water / Stormwater Capture and Storage**	Project would capture surface water or stormwater flows in the eastern end of the Basin and use the water to recharge groundwater levels. This include the construction of small berms (18-24 inches) to slow stream flows and encourage groundwater recharge.	US Army Corps of Engineers, San Diego Regional Water Quality Control Board, California Department of Fish and Wildlife	May be implemented under adaptive management	2-3 years	Would increase groundwater recharge into the aquifer through infiltration of surface water flows.	The amount of benefit in AFY is dependent on precipitation, recharge capacity, and location of flows and is therefore uncertain. Implementation requires additional study for feasibility (modeling, pilot studies, etc.). There may be a downstream water rights claim for less flow to Lake Hodges in dry years that would need to be resolved. Streambed alteration permits are challenging and expensive.	$1-3 million	No, the benefits are uncertain and do not justify the relatively high cost
Excluded	Improve Groundwater Quality	**Discharge Excess Advanced Treated Reclaimed Water from Hogback Reservoir to Cloverdale Creek**	The Hogback Reservoir, managed by the City of Escondido, stores advanced treated recycled water for avocado farmers in the area. The highest demand for this water is during the spring to summer months. Excess water is available in non-peak growing season and winter months. This excess water could be discharged and diverted to Cloverdale Creek, a tributary to the Basin. This would require the construction of a 1 mile pipeline from Hogback Reservoir southeast to Cloverdale Creek at Rockwood Road.	City of Escondido US Army Corps of Engineers, San Diego Regional Water Quality Control Board, California Department of Fish and Wildlife	May be implemented under adaptive management	2-3 years	May improve quality of water in Cloverdale creek as it enters the SPV Basin. Currently this creek measures 1,500 mg/L TDS.	A transfer purchase agreement must be negotiated with the City of Escondido. Water may only be available for purchase during the winter and may be expensive. This project would be located in the western Basin which has limited recharge capacity. Benefits are unknown: groundwater quality is improved but by unknown amount. Streambed alteration permits are challenging and expensive.	$2-3 million	No, the benefits are uncertain and do not justify the relatively high cost
Excluded	Improve Groundwater Levels and Improve Groundwater Quality	**Recharge Excess Advanced Treated Reclaimed Water from Hogback Reservoir to Eastern Basin**	This project would build upon the pipeline construction from Hogback Reservoir to Cloverdale Creek, described above, and extend the pipeline to the eastern end of the Basin for groundwater recharge due to limited recharge capacity in the western Basin. At least 6 miles of pipeline from Cloverdale Creek would be constructed to a recharge area in the eastern portion of the Basin, potentially to the area south of Rockwood Canyon.	City of Escondido US Army Corps of Engineers, San Diego Regional Water Quality Control Board, California Department of Fish and Wildlife	May be implemented under adaptive management	2-3 years for implementation	Would increase groundwater recharge in the eastern Basin, increasing groundwater supply	This project faces the same challenges listed above and includes the construction of additional pipeline to eastern Basin. Pipeline construction would include crossing difficult terrain and creeks, greatly increasing cost and increasing environmental permitting needs.	$10-15 million	No, the benefits are uncertain and do not justify the relatively high cost

Table 3: Projects and Management Actions

Name and Description							Screening and Reason for Screening			
Tier	Goal	Activity Name	Description	Potential Partner	When it Starts	Implementation Period	Benefits	Potential Challenges	Estimated Cost	Recommendation for Inclusion in GSP?
Excluded	Improve Groundwater Quality	**Inject Advanced Treated Recycled Water from New San Pasqual Water Reclamation Facility in the West Basin**	This project would involve the construction of a new Water Reclamation Facility (WRF) at the site of the former Aqua III WRF in order to produce advanced treated recycled water for groundwater recharge. Raw wastewater would be pumped from Pump Station 77A to the new WRF using existing infrastructure. To achieve the water quality required for groundwater recharge, the new treatment process would be a tertiary treatment plant. A brine line would need to be constructed to convey solids and reverse osmosis concentrate produced at the new WRF back to Pump Station 77A for handling at HARRF. Advanced treated recycled water would be injected into the western basin for groundwater quality improvement. However, available capacity for recharge in the western portion of the Basin is low, a potential limiting factor for this project.	City of San Diego	May be implemented under adaptive management	6-10 years	Would improve groundwater quality in western Basin with injection of advanced treated recycled water. Utilizes some existing infrastructure for beneficial use. The Escondido Land Outfall may have capacity issues in the winter. This project would be an alternative disposal option to treat and inject wastewater from Pump Station 77a, rather than dispose of it.	May be difficult to secure approval to construct at site as there is existing infrastructure. May require management of Lake Hodges with agency agreements. Will not greatly impact supply reliability due to shallow depth to groundwater in the western Basin. The amount of water that may be available to purchase is currently unknown. The amount of benefit provided by groundwater quality improvement is currently unknown.	$75-100 million	No, the benefits are uncertain and do not justify the relatively high cost
Excluded	Improve Groundwater Levels	**Recharge Basin with Advanced Treated Recycled Water from New San Pasqual Water Reclamation Facility in the East Basin**	This project would utilize the WRF constructed in the project described above, and construct a pipeline to convey the advanced treated recycled water to the eastern Basin. Pipeline alignment is currently unknown and requires further consideration; it may be over 6 miles.	City of San Diego	May be implemented under adaptive management	2-3 years	Would improve groundwater levels in the eastern Basin where more storage is available, therefore improving supply reliability. Utilizes some existing infrastructure for beneficial use. The Escondido Land Outfall may have capacity issues in the winter. This project would be an alternative disposal option to treat and inject wastewater from Pump Station 77a, rather than dispose of it.	Pipeline construction would include crossing difficult terrain and creeks, greatly increasing cost and increasing environmental permitting needs. May be difficult to secure approval to construct at site as there is existing infrastructure. May require management of Lake Hodges with agency agreements. The amount of water that may be available to purchase is currently unknown.	$8-20 million in addition to $75-100 million for Water Reclamation Facility construction	No, the benefits are uncertain and do not outweigh the cost
Excluded	Improve Groundwater Levels and Improve Groundwater Quality	**Recharge Basin with Raw San Diego County Water Authority Water from Ramona Municipal Water District**	Ramona MWD has a raw water pipeline (Ramona's untreated water system) from San Diego First Aqueduct to Lake Ramona. This project would convey raw water from this pipeline to the eastern Basin for recharge. Raw water is a blend of Colorado River and State Water Project water that has not yet been treated. There is some existing Ramona MWD raw water infrastructure, which will be discontinued in December 2021.	Ramona MWD, SDCWA	May be implemented under adaptive management	2-3 years	Would provide increased groundwater recharge in the eastern Basin where storage is available. Utilizes existing infrastructure for beneficial use.	A purchase agreement would need to be negotiated. Would require discussion with Ramona MWD to determine feasibility of utilizing existing infrastructure. Would need to confirm that the current blended TDS levels of the raw water would be lower than the SPV Basin to ensure groundwater quality does not deteriorate.	$1-5 million, dependent on additional infrastructure needed	No, the benefits are uncertain and do not justify the relatively high cost

Table 3: Projects and Management Actions

Name and Description							Screening and Reason for Screening			
Tier	Goal	Activity Name	Description	Potential Partner	When it Starts	Implementation Period	Benefits	Potential Challenges	Estimated Cost	Recommendation for Inclusion in GSP?
Excluded	Improve Groundwater Levels and Improve Groundwater Quality	**Recharge Basin with City of San Diego Recycled Water**	Deliver Title 22 recycled water from the City of San Diego located south of the basin. The existing non-potable system would need to be extended from South Poway to the eastern Basin for recharge with the construction of approximately 3-4 miles of pipeline.	Ramona MWD, SDCWA	May be implemented under adaptive management	2-3 years	Would provide increased groundwater recharge in the eastern Basin where storage is available.	There may not be recycled water available to purchase; supplies are limited following Pure Water commitment. Difficult terrain for pipeline construction in the eastern Basin.	$4-6 million for pipeline construction	No, the benefits are uncertain and do not justify the relatively high cost
Excluded	Improve Groundwater Quality	**Pump and Treat system for Nitrate**	GSA would drill a well where nitrate concentrations are high and install a treatment system at the wellhead. This may include blending, ion exchange, gas chromatography (GC), electrodialysis/electrodialysis reversal, or biological treatment. Following treatment, the water will be injected back into the groundwater basin.	City of San Diego	May be implemented under adaptive management	2-4 years	Improve groundwater quality through water treatment and injection; reducing nitrates in the Basin.	This project would only treat nitrate and would not be viable to develop for treatment of TDS due to the need for brine disposal. Requires ongoing maintenance, such as changing filters.	$10-15 million for 1,000 AFY (single ion exchange +GC). Requires feasibility study to determine best treatment method in the SPV Basin.	No, the benefits are uncertain and do not outweigh the cost
Excluded	Improve Groundwater Quality	**Lake Hodges Natural Treatment System**	Dudek (2013) conducted a preliminary analysis of nutrient loading to Lake Hodges and presented two conceptual-level options for the natural treatment system (NTS) for Lake Hodges. The first NTS option consists of a large wetland upstream from Lake Hodges and a series of detention basins along the main stem of Santa Ysabel Creek. The second NTS option consists of a series of smaller wetlands and detention basins at the confluences of the three tributaries that drain the urban watersheds directly into Lake Hodges	City of San Diego	May be implemented under adaptive management	TBD	Detention basins would treat discharge before it enters Lake Hodges, improving water quality.	The study was conducted in 2013 and may need to be updated for implementation.	Currently unknown	No, the benefits are uncertain and do not justify the relatively high cost
Excluded	Improve Groundwater Quality at Point of Use	**Household Water treatment or alternative potable supply for Domestic Users**	To best manage the local groundwater resource to meet needs of all Valley residents, household desalters may be installed to address water quality issues for domestic use at the point of use. The GSA would conduct an assessment of various treatment options to determine if household desalters would be appropriate to install.	None	May be implemented at any time	1 to 2 year implementation	Improved groundwater quality through treatment at point of use, in wells where it is an issue	This project would require outreach and coordination with domestic users	$250,000 - $400,000 if required in all domestic wells in the Basin. Cost is dependent on commercially available point of use reverse osmosis treatment units.	Yes

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