DOCKETED	
Docket Number:	24-OPT-03
Project Title:	Soda Mountain Solar
TN #:	257946
Document Title:	Appendix K Stormwater Drainage Report
Description:	In this Appendix, hydrologic conditions were analyzed to understand the existing and future flood hazards for the proposed Project site; determine inundation areas and spatial distribution of stormwater depths and velocities for the 2-year, 10-year, and 100-year 24-hour storm events; and identify any flood hazard areas within the site.
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Organization:	Resolution Environmental
Submitter Role:	Applicant Consultant
Submission Date:	7/22/2024 5:19:38 PM
Docketed Date:	7/23/2024

Soda Mountain Solar Project
Stormwater Drainage Report
San Bernardino County, California

JUNE 2024

PREPARED FOR

Soda Mountain Solar, LLC

PREPARED BY

SWCA Environmental Consultants

SODA MOUNTAIN SOLAR PROJECT
STORMWATER DRAINAGE REPORT
SAN BERNARDINO, CALIFORNIA

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SWCA Project No. 68347

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1 BACKGROUND AND OBJECTIVES

Soda Mountain Solar, LLC, is proposing a solar power production facility in the Soda Mountain area of San Bernardino County, California, and is currently seeking an Incidental Take Permit and Streambed Alteration Agreement from the California Department of Fish and Wildlife, along with a Title 27 Discharge Permit and Clean Water Act Section 401 Permit from the Lahontan Regional Water Quality Control Board. In support of those permit applications, SWCA Environmental Consultants (SWCA) conducted a stormwater drainage analysis.

Hydrologic conditions were analyzed to understand the existing and future flood hazards for the proposed Soda Mountain Solar Project (project) site; determine inundation areas and spatial distribution of stormwater depths and velocities for the 2-year, 10-year, and 100-year 24-hour storm events; and identify any flood hazard areas within the site. The project site is located on federal land managed by Bureau of Land Management. It is approximately 2,670 acres and is located 3.83 miles northwest of Zzyzx, California, and 6 miles southwest of Baker, California, along Interstate 15. The study area contains numerous alluvial fans that drain toward the proposed site. The site is located in Federal Emergency Management Agency (FEMA) Zone D, meaning that the area has not been studied using detailed methods and existing flood risk is unknown (Appendix A).

2 CALCULATION METHODOLOGIES

A 2-dimensional (2-D) rain-on-grid hydrodynamic model was prepared for this study area using HEC-RAS v. 6.3.1, developed by the U.S. Army Corps of Engineers, Hydrologic Engineering Center. The program is capable of modeling rainfall-runoff and surface water hydraulics. For this study, the area of interest (AOI) modeled in HEC-RAS included the site of proposed solar facility and the contributing drainage area. Existing and proposed conditions were modeled to understand the effect of the proposed solar development on stormwater drainage. The proposed conditions were based on 30% civil design plans dated August 8, 2023, and provided by QCells and Kleinfelder, Inc. The 30% civil design plans that are incorporated into the proposed conditions are the berm outlines, drainage channels, catchment basins, and solar panels. The proposed land cover layer within the model was adjusted to delineate the proposed design features and represent the impervious conditions of the solar array coverage. However, the proposed condition in the model did not include the 12 box culverts and eight low-water crossings due to the assumptions that the culverts will be designed to allow the channels to withstand the flow capacity. The following section describes the available data used and assumptions made by SWCA to develop the model.

2.1 Topographic Data

Existing terrain conditions were based on a digital elevation model (DEM) with 1-meter resolution from the U.S. Geological Survey (USGS) merged with the detailed topographic survey data of the site provided by Michael Baker, Inc. The DEM was reprojected to North American Datum of 1983 (NAD 83) California Zone 5, converted to units of U.S. survey feet, and imported to the HEC-RAS to build the topographic surface for the existing condition model. A rectilinear mesh was created for the AOI using 100-foot grid cells. The mesh was refined by adding additional computation points within the known areas of concentrated flow, creating a mesh of 50-foot grid cells within these areas. The proposed terrain was created by modifying the existing conditions DEM to represent conditions shown in the 30% civil design, which included multiple berms, channels, and sediment basins.

2.2 Rainfall Data

A hyetograph was developed based on the Soil Conservation Service (SCS) dimensionless curve and Type II rainfall data derived from National Oceanic and Atmospheric Administration (NOAA) Atlas 14 precipitation data for the 2-year, 10-year, and 100-year 24-hour storm events over the Soda Mountain location coordinates 35.1575 degrees North, 116.1821 degrees West, near Baker, California. The hyetograph illustrates the intensity of rainfall over time; the horizontal axis of the hyetograph represents time, while the vertical axis represents rainfall depth. Each storm event was run as an individual unsteady flow model with a precipitation value added to the meteorological data encompassing the entire AOI and normal depth downstream conditions with friction slopes measured from the topographic data in HEC-RAS. The hyetographs are provided in Appendix B.

Meantime, a monthly mean precipitation summary was obtained from the National Weather Service (NWS) past weather record (NWS, 2024). Precipitation at NWS Baker Station from 1996 – 2013 was used for analysis the pattern of the monthly precipitation because Baker Station is close to the project site. The monthly mean precipitation is shown in Figure 1 below. Precipitation information from California Irrigation Management Information System (CIMIS) was used for comparison. The three closest CIMIS stations 117-Victorville, 221-Cadiz Valley, and 257-Ridgecrest shows similar precipitation patterns as the NWS Baker Station precipitation data. The CIMIS stations are further away compared to the NWS Baker Station so the CIMIS stations information are not included in this report. The construction and operation of project is not anticipated to alter the monthly precipitation patterns.

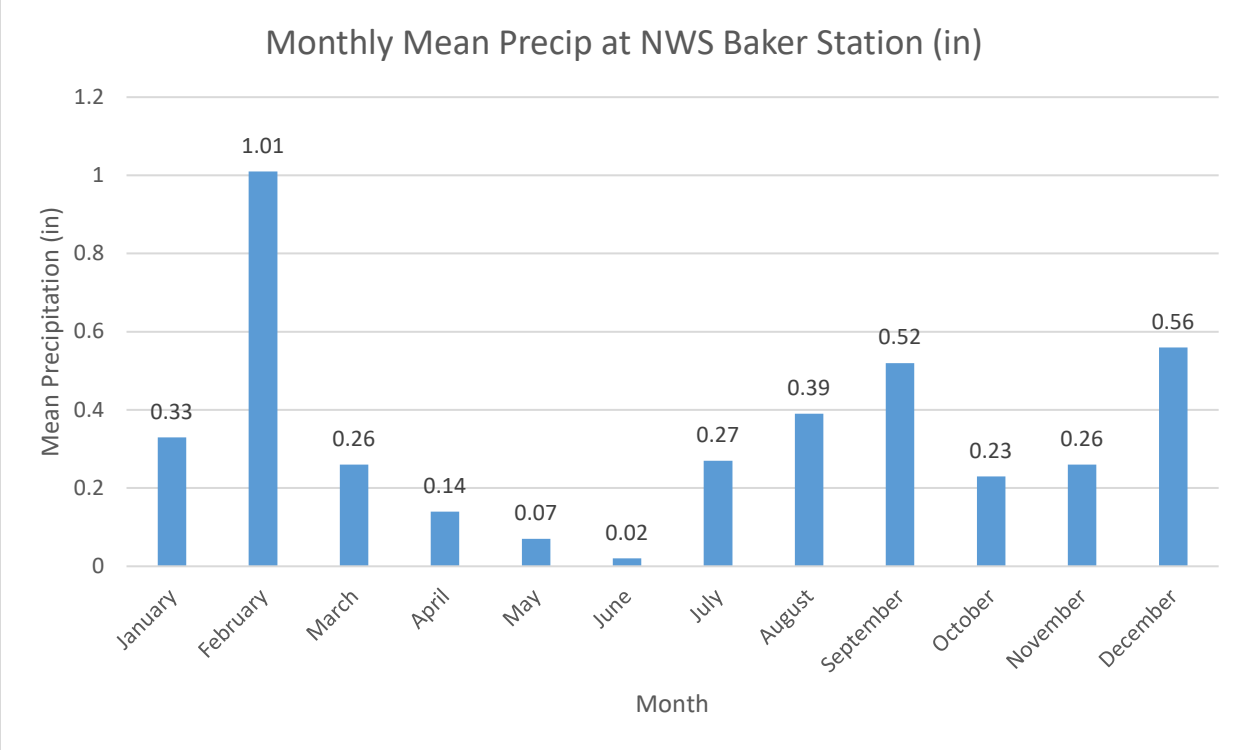

Figure 1: Monthly Mean Precipitation at NWS Baker Station

2.3 Soils and Land Cover Data

The study area soil types consist of gravel with silt and sand. Therefore, the hydrologic soil groups (HSGs) were determined to be A, B, and C for this site based on information from the soil watershed study and the Jurisdictional Determination Report by the URS Land Management Consulting Group (2009) and the Natural Resource Conservation Service (NRCS). See Appendix C and Table 1 below for descriptions of individual HSGs. Group D soils were not present based on the NRCS soil survey information.

Table 1. Hydrologic Soil Groups

HSG	Description
Group A	Sand, loamy sand or sandy loam types of soils. These soils have low runoff potential and high infiltration rates even when thoroughly wetted. They consist chiefly of deep, well-drained to excessively drained sands or gravels and have a high rate of water transmission.
Group B	Silt loam or loam. Soils in this HSG have a moderate infiltration rate when thoroughly wetted and consist chiefly of moderately deep to deep, moderately well-drained to well-drained soils with moderately fine to moderately coarse textures.
Group C	Sandy clay loam. These soils have low infiltration rates when thoroughly wetted and consist chiefly of soils with a layer that impedes downward movement of water and soils with moderately fine to fine structure.
Group D	Clay loam, silty clay loam, sandy clay, silty clay or clay. This HSG has the highest runoff potential. These soils have very low infiltration rates when thoroughly wetted and consist chiefly of clay soils with a high swelling potential, soils with a permanent high-water table, soils with a claypan or clay layer at or near the surface and shallow soils over nearly impervious material.

A 30-meter land cover raster was retrieved from the National Land Cover Database (Multi-Resolution Land Characteristics Consortium 2019).

The land cover and soils data were reprojected to NAD 83 California Zone 5, converted to units of U.S. survey feet, and imported to HEC-RAS to build the existing condition model. The infiltration dataset was created in HEC-RAS using a parametrization of the soils and land cover layers. Manning's n roughness values were assigned based on land cover conditions. The existing land cover condition at the site is predominantly classified "Shrub-Scrub". Areas of proposed solar areas were assumed to be converted to "Developed, Medium Intensity," with increased SCS curve numbers and impervious areas to account for site development. See Appendix C for further information.

2.4 Floodplain Data

According to the FEMA, the area in which the project site is located is classified as Zone D, which indicates possible but undetermined flood hazards. The flood insurance study and map for the Soda Mountain San Bernardino County, California, incorporated areas by FEMA were used to determine the extent of the zone and the regulations within the zone (FEMA 2023). The coordinate points used to generate the Soda Mountain flood insurance rate map project site were 35.1575 degrees North, 116.1821 degrees West. Based on Best Available Map (BAM) provided by California Department of Water Resources indicated the location of the project site is not within the floodplain (BAM 2024). SWCA obtained a second FEMA study map that had a larger coverage area of the Soda Mountain region and the town of Baker, California (FEMA 2023). Between Baker and east of Soda Mountain lies a floodplain Zone A, which indicates areas with a 1% annual chance of flooding. The FEMA maps are provided in Appendix A.

3 MODEL RESULTS

Hydrographs were generated for each simulation at two locations where flow leaves the site, as shown in Figure 2. Figure 3 and Figure 4 show the change in stormwater runoff to the south and north of the site, respectively, for the 2-year storm event. No grading of the proposed condition was conducted by the site development engineer for the 30% design milestone. Proposed berms and channels were added directly into the hydraulic model terrain by SWCA based on the alignments and section geometries provided in the 30% design. Future refinement of the site design to include grading of the proposed solar array areas to drain into the detention basins will be required to mitigate these increases in stormwater runoff. Peak flows for a 10-year events of the proposed condition are expected to be the same to the existing condition (Figure 5Figure 6. A decrease in peak flow for the proposed condition is predicted in the 100-year hydrographs at south side of the site, due to the capacity of the retention ponds, while no significant change at the north side (Figure 7 and Figure 8).

Exhibits were prepared illustrating the predicted spatial distributions of depth and velocity for existing and proposed conditions under the 2-year, 10-year, and 100-year storm events (Appendix D). These maps clearly indicate areas where hazardous flow depths and velocities are expected to be present in the site and surrounding area during these events.

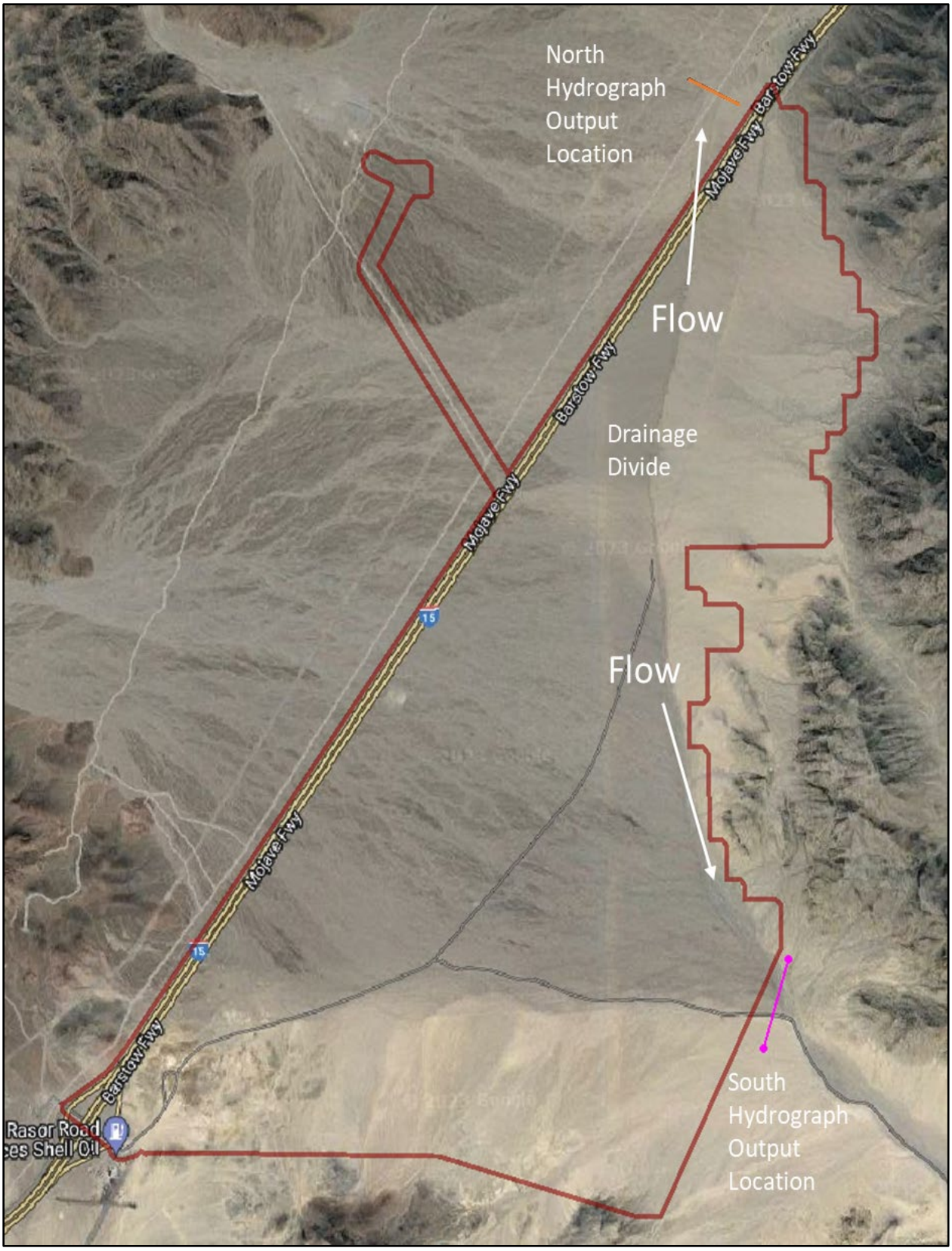

Figure 2. Overview of project site showing locations of hydrograph output locations and drainage divide.

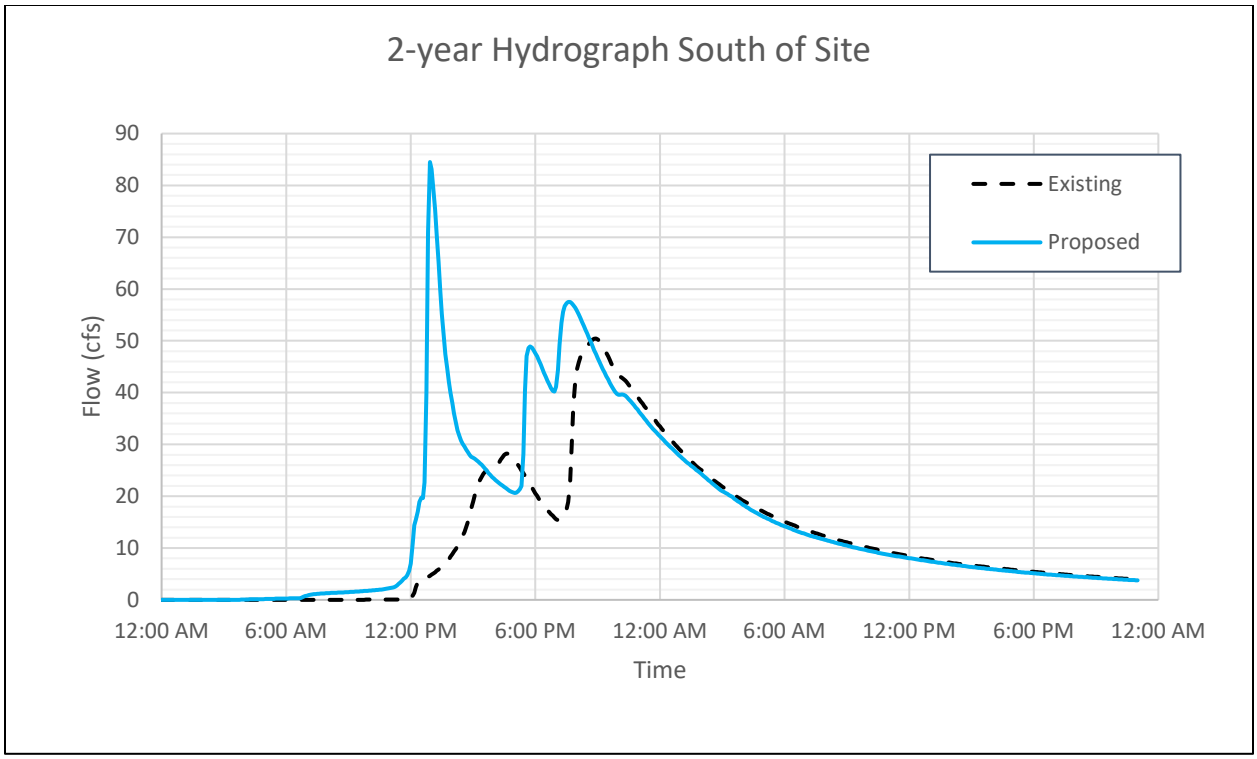

Figure 3. 2-year hydrograph of flow exiting the site to the south, proposed condition showing a significant increase and change in timing in stormwater runoff compared to existing condition.

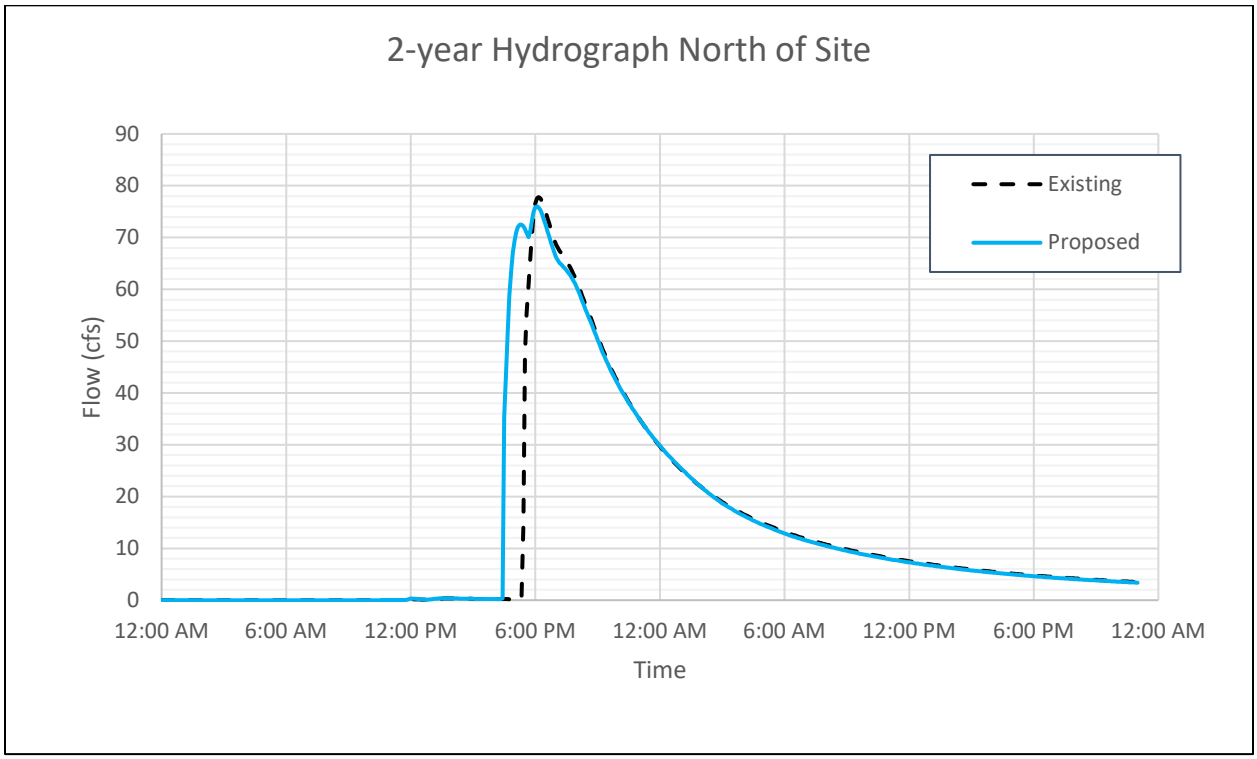

Figure 4. 2-year hydrograph of flow existing to the north of the site, proposed condition showing a small decrease in peak flow.

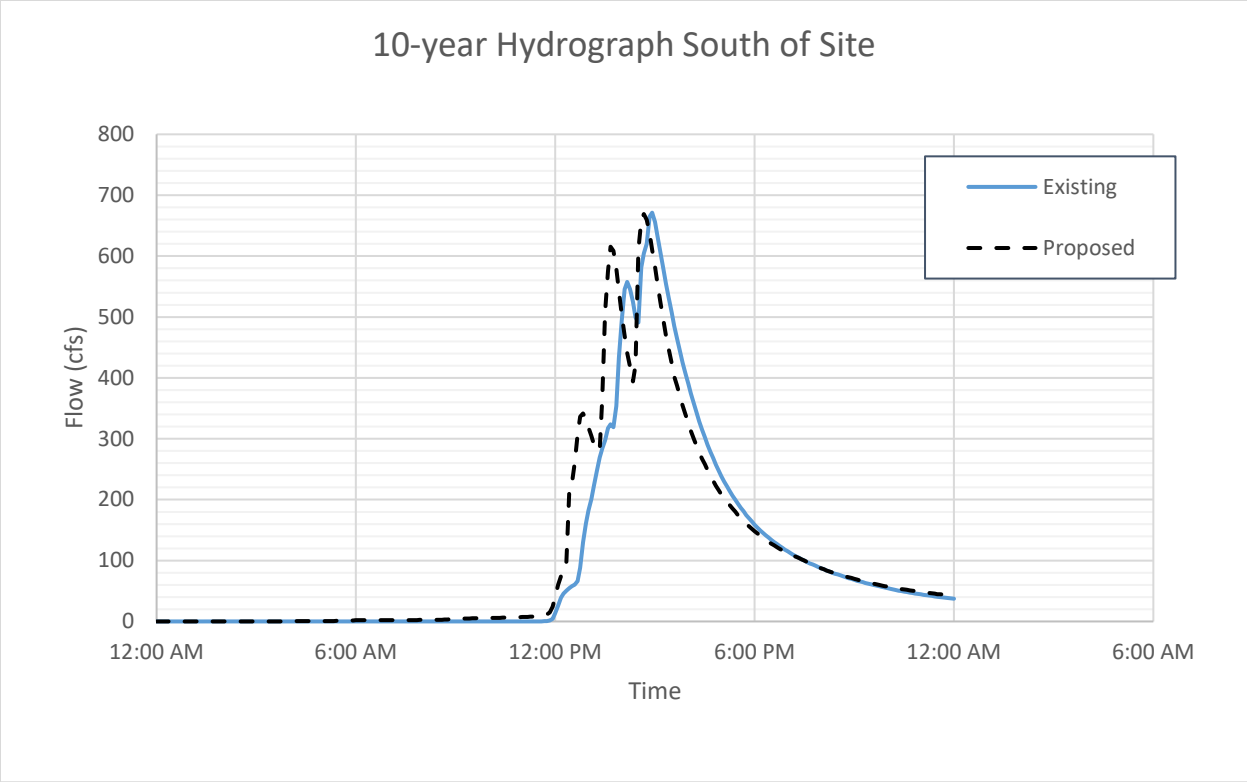

Figure 5. 10-year hydrograph of flow exiting the site to the south, showing no change in peak stormwater runoff among existing and proposed conditions.

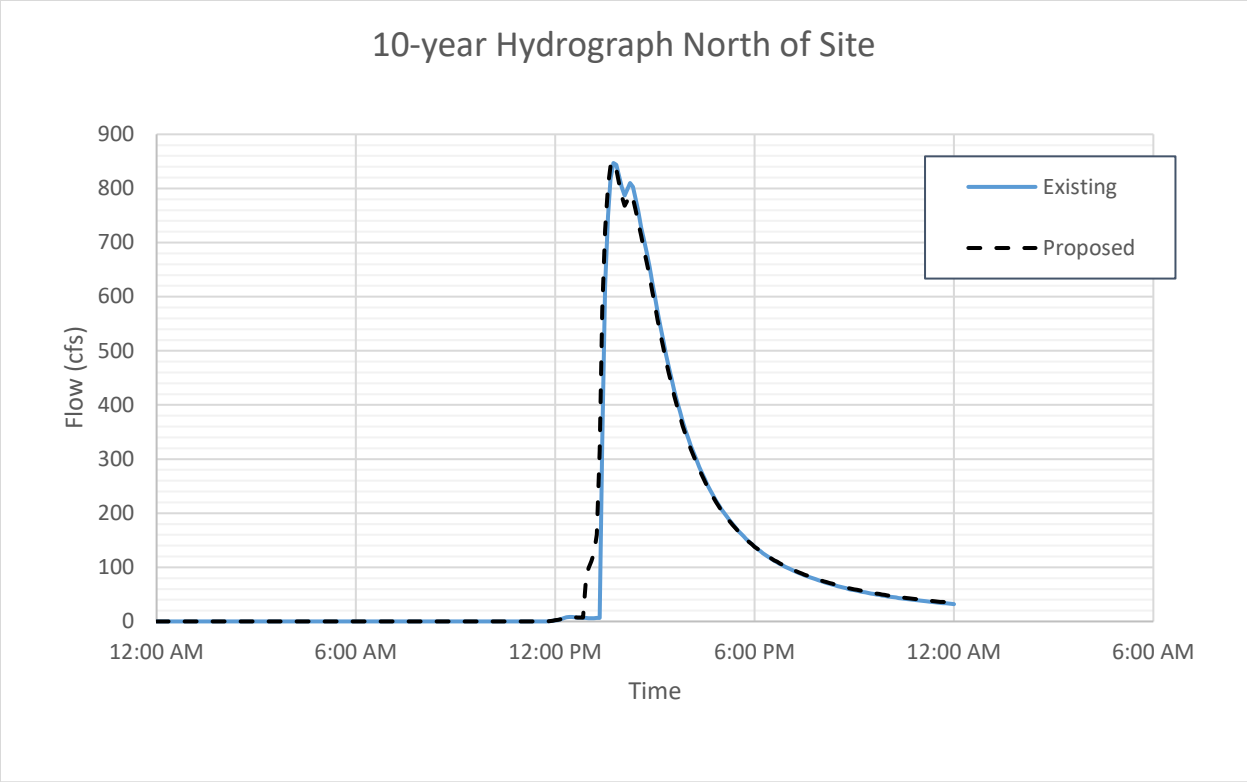

Figure 6. 10-year hydrograph of flow exiting the site to the north, showing no change in peak stormwater runoff among existing and proposed conditions.

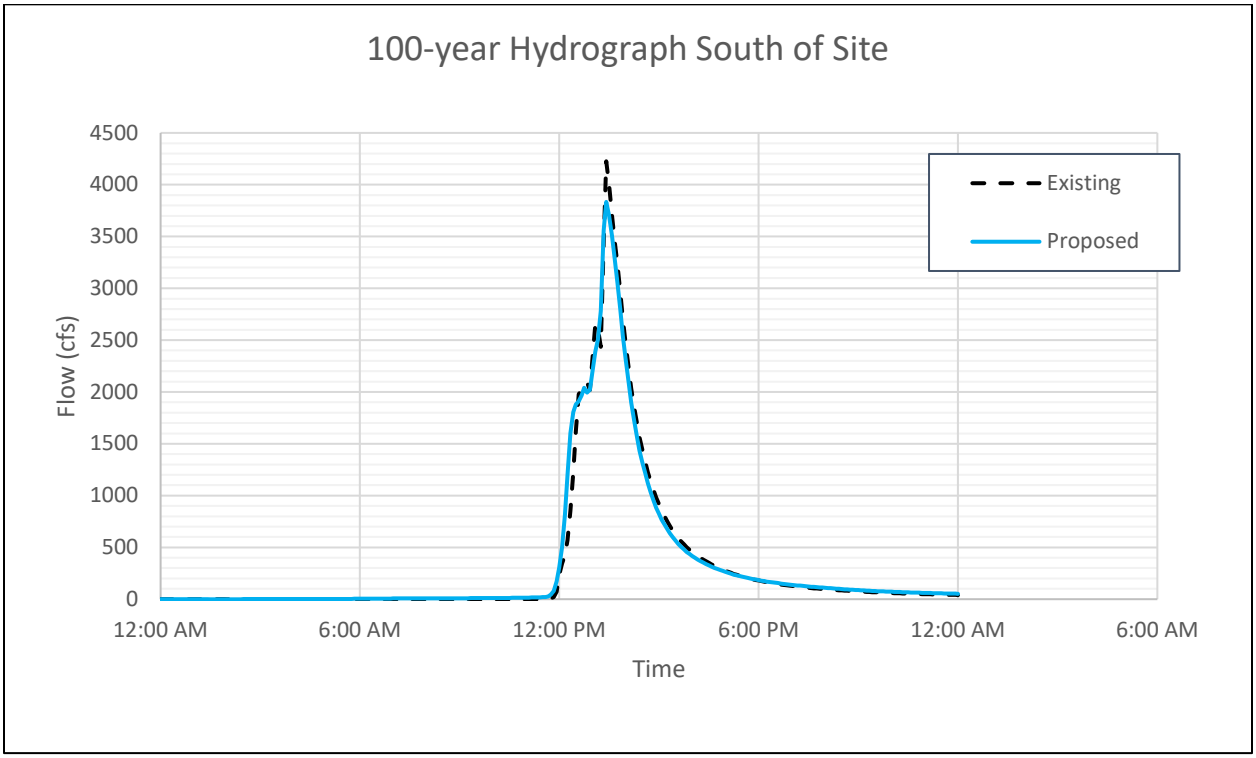

Figure 7. 100-year hydrograph of flow exiting the site to the south, proposed condition showing decrease in peak stormwater runoff compared to existing condition.

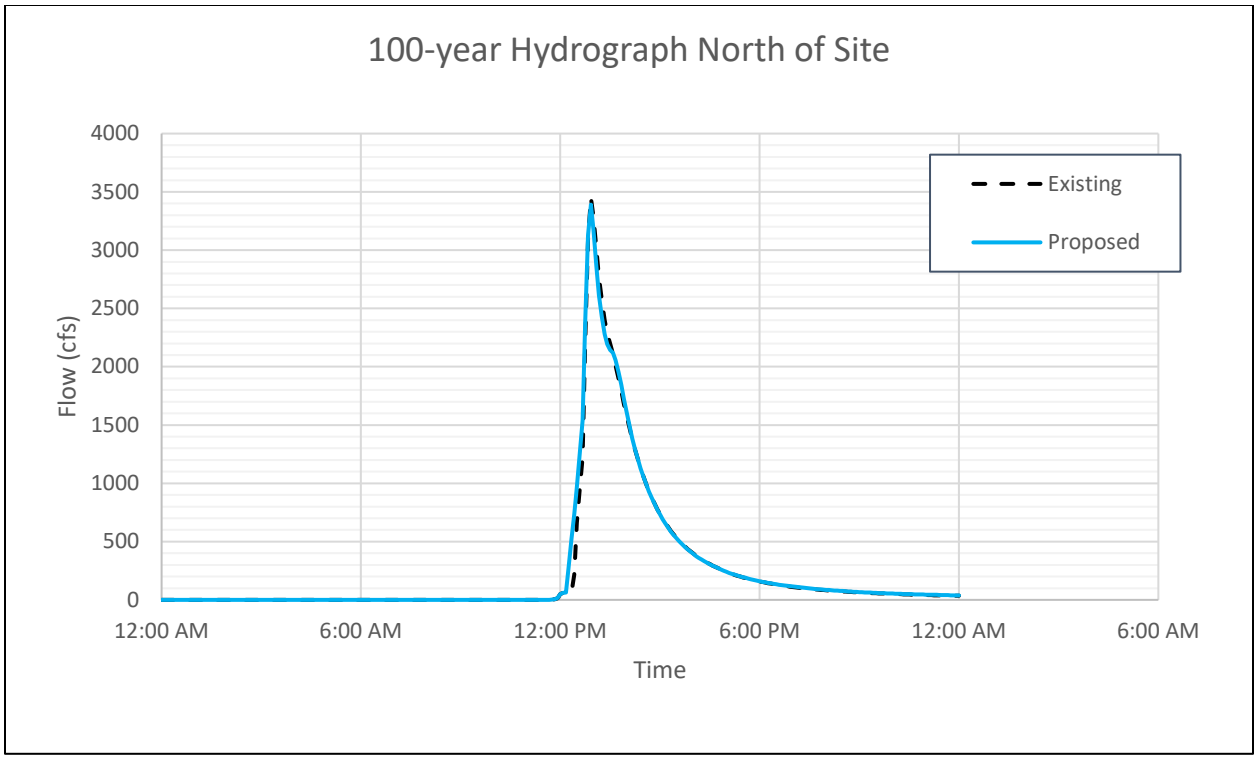

Figure 8. 100-year hydrograph of flow exiting the site to the north, showing no significant change in stormwater runoff.

4 LITERATURE CITED

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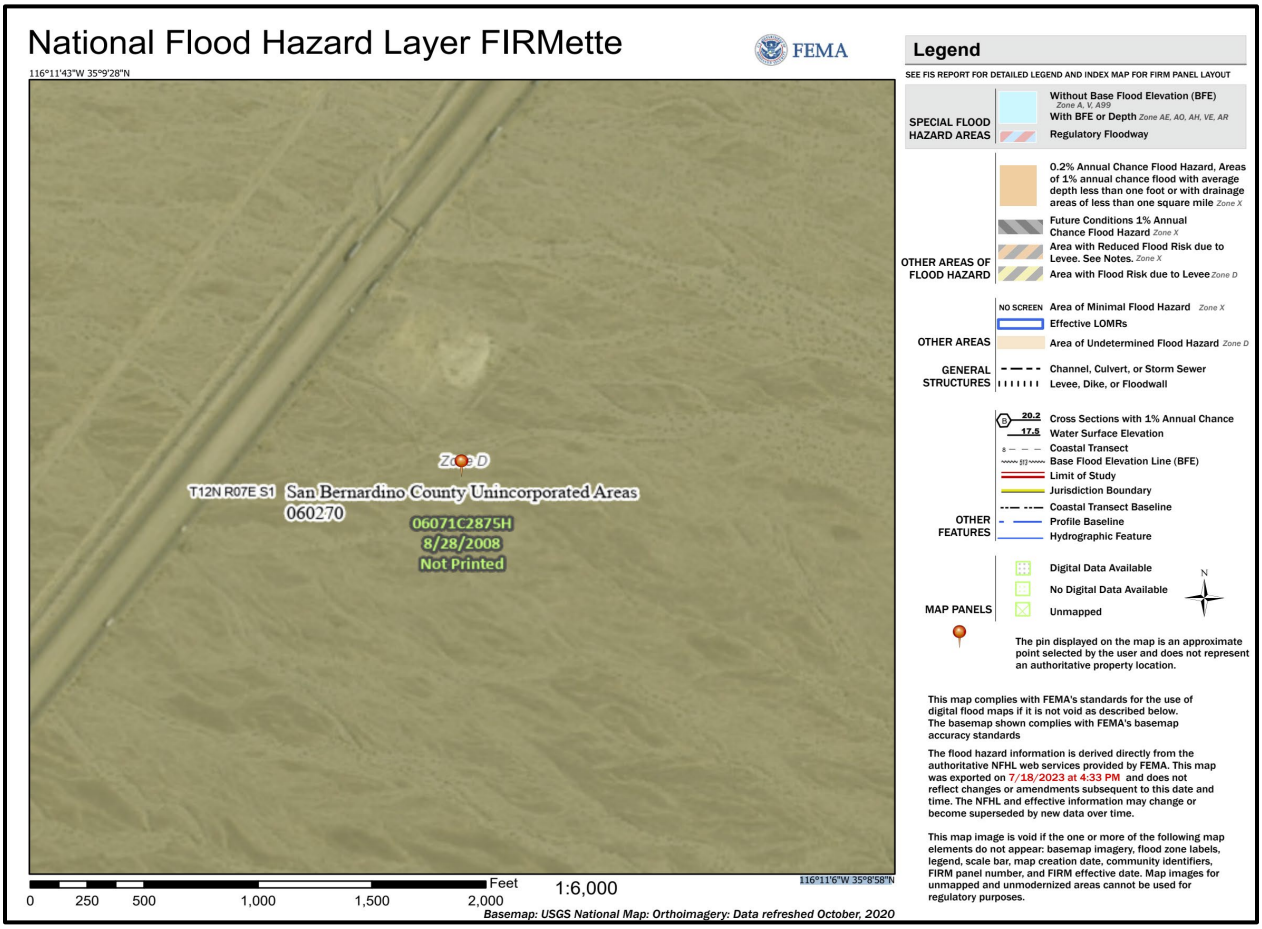
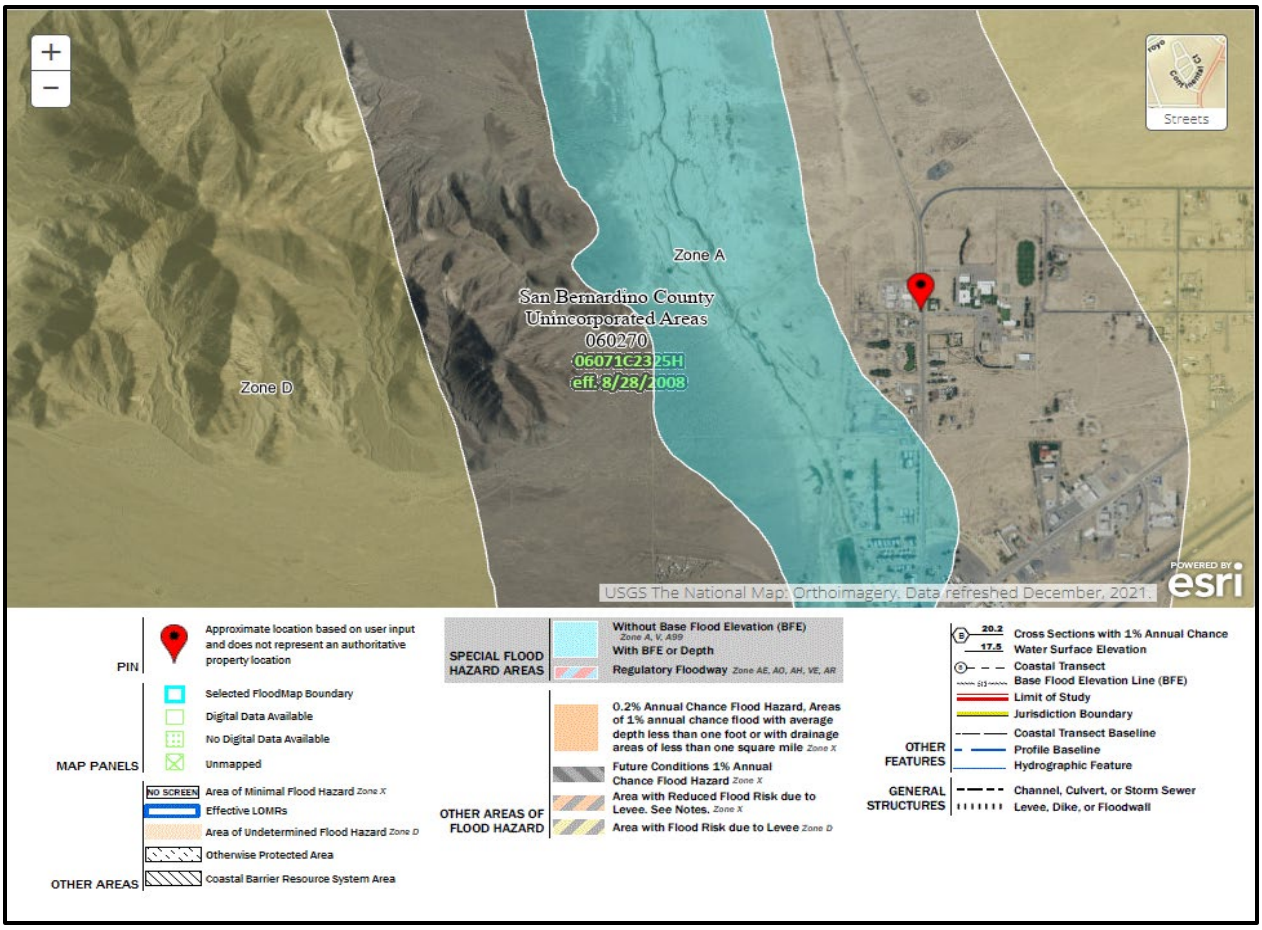
APPENDIX A

Miscellaneous Site Data

FEMA Flood Hazard



Source: FEMA (2023)



Source: FEMA (2023)

APPENDIX B

Rainfall Data

Point Precipitation Frequency Estimates by NOAA

PF tabular

PDS-based point precipitation frequency estimates with 90% confidence intervals (in inches)[1]

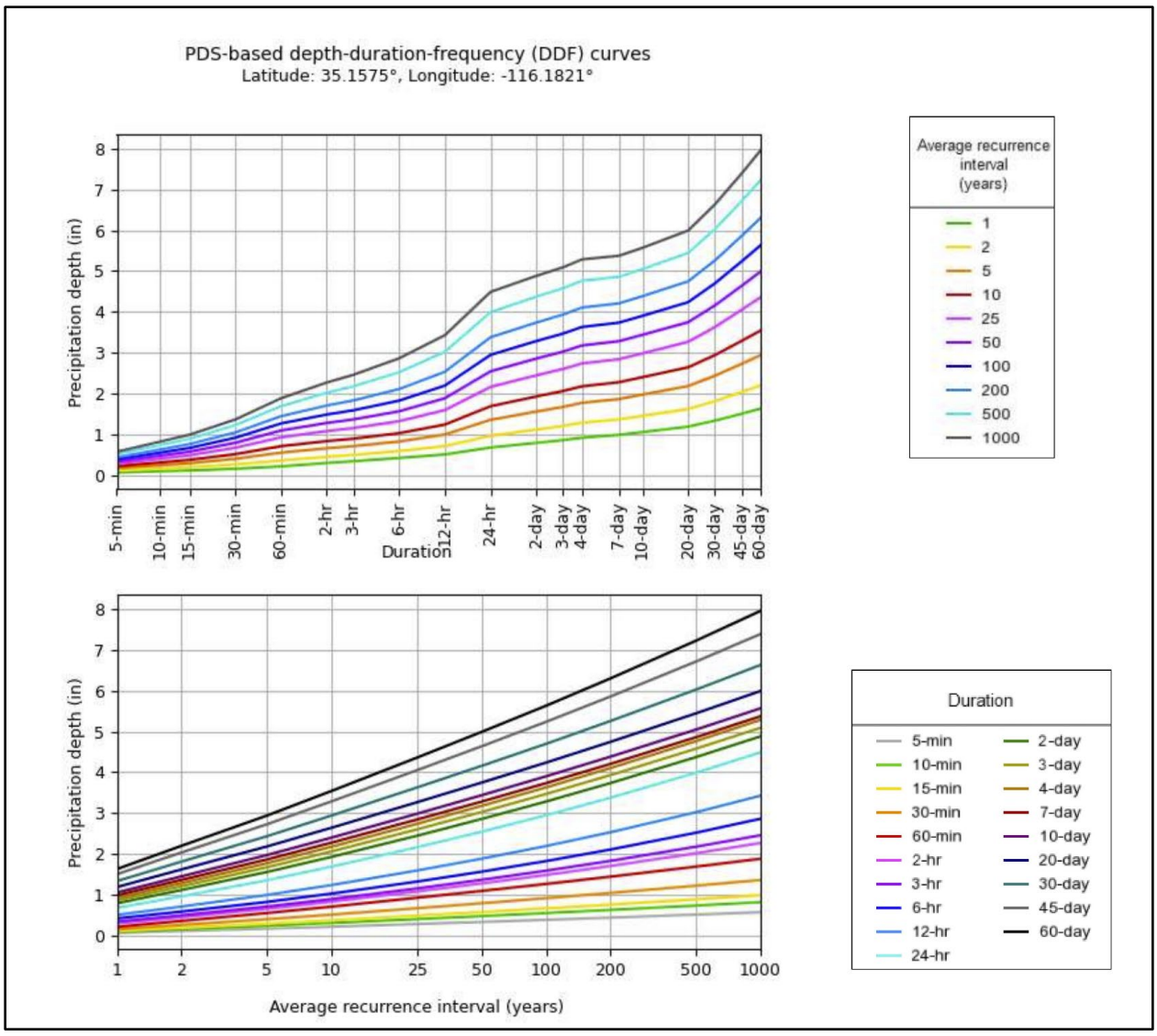
Duration	Average recurrence interval (years)									
	1	2	5	10	25	50	100	200	500	1000
5-min	0.063 (0.052-0.078)	0.108 (0.088-0.133)	0.166 (0.135-0.205)	0.214 (0.173-0.267)	0.279 (0.219-0.360)	0.330 (0.254-0.434)	0.382 (0.287-0.514)	0.436 (0.319-0.603)	0.511 (0.359-0.734)	0.569 (0.387-0.846)
10-min	0.091 (0.074-0.112)	0.154 (0.126-0.191)	0.238 (0.194-0.294)	0.306 (0.248-0.382)	0.400 (0.314-0.516)	0.473 (0.364-0.622)	0.548 (0.411-0.737)	0.625 (0.457-0.864)	0.732 (0.514-1.05)	0.816 (0.555-1.21)
15-min	0.110 (0.090-0.136)	0.186 (0.152-0.230)	0.287 (0.234-0.356)	0.370 (0.300-0.462)	0.484 (0.379-0.624)	0.572 (0.440-0.752)	0.662 (0.497-0.891)	0.756 (0.553-1.04)	0.885 (0.622-1.27)	0.987 (0.671-1.47)
30-min	0.151 (0.124-0.187)	0.257 (0.210-0.317)	0.396 (0.323-0.490)	0.510 (0.413-0.637)	0.666 (0.522-0.859)	0.788 (0.605-1.04)	0.912 (0.685-1.23)	1.04 (0.761-1.44)	1.22 (0.857-1.75)	1.36 (0.924-2.02)
60-min	0.209 (0.171-0.258)	0.355 (0.290-0.439)	0.548 (0.447-0.678)	0.705 (0.571-0.881)	0.922 (0.723-1.19)	1.09 (0.837-1.43)	1.26 (0.947-1.70)	1.44 (1.05-1.99)	1.69 (1.18-2.42)	1.88 (1.28-2.79)
2-hr	0.294 (0.241-0.363)	0.447 (0.365-0.552)	0.654 (0.533-0.810)	0.829 (0.671-1.04)	1.08 (0.844-1.39)	1.27 (0.979-1.67)	1.48 (1.11-1.99)	1.70 (1.24-2.35)	2.01 (1.42-2.90)	2.27 (1.54-3.37)
3-hr	0.337 (0.276-0.416)	0.492 (0.402-0.608)	0.706 (0.576-0.875)	0.889 (0.719-1.11)	1.15 (0.902-1.48)	1.36 (1.05-1.79)	1.59 (1.19-2.13)	1.83 (1.34-2.53)	2.17 (1.53-3.12)	2.46 (1.67-3.65)
6-hr	0.417 (0.341-0.514)	0.585 (0.478-0.723)	0.820 (0.669-1.02)	1.02 (0.828-1.28)	1.32 (1.03-1.70)	1.56 (1.20-2.05)	1.82 (1.37-2.45)	2.11 (1.54-2.91)	2.52 (1.77-3.62)	2.86 (1.94-4.25)
12-hr	0.503 (0.412-0.621)	0.707 (0.578-0.873)	0.991 (0.808-1.23)	1.24 (1.00-1.54)	1.59 (1.25-2.05)	1.88 (1.44-2.47)	2.19 (1.64-2.95)	2.53 (1.85-3.50)	3.02 (2.12-4.34)	3.43 (2.33-5.09)
24-hr	0.673 (0.594-0.778)	0.959 (0.846-1.11)	1.35 (1.19-1.57)	1.68 (1.47-1.97)	2.16 (1.83-2.60)	2.54 (2.11-3.12)	2.94 (2.39-3.69)	3.38 (2.68-4.34)	3.99 (3.05-5.33)	4.49 (3.32-6.19)
2-day	0.786 (0.694-0.909)	1.11 (0.982-1.29)	1.55 (1.37-1.80)	1.92 (1.68-2.25)	2.44 (2.07-2.94)	2.85 (2.37-3.50)	3.28 (2.67-4.12)	3.74 (2.96-4.81)	4.37 (3.34-5.84)	4.88 (3.61-6.73)
3-day	0.854 (0.753-0.987)	1.20 (1.06-1.39)	1.67 (1.47-1.94)	2.06 (1.80-2.40)	2.60 (2.20-3.13)	3.02 (2.51-3.71)	3.47 (2.82-4.35)	3.93 (3.12-5.06)	4.58 (3.49-6.12)	5.09 (3.77-7.02)
4-day	0.912 (0.805-1.06)	1.28 (1.13-1.48)	1.77 (1.56-2.05)	2.17 (1.90-2.54)	2.73 (2.32-3.29)	3.17 (2.64-3.90)	3.63 (2.95-4.55)	4.10 (3.25-5.28)	4.76 (3.64-6.36)	5.28 (3.91-7.29)
7-day	0.982 (0.867-1.14)	1.36 (1.20-1.58)	1.86 (1.64-2.16)	2.27 (1.98-2.66)	2.84 (2.40-3.42)	3.28 (2.73-4.02)	3.73 (3.04-4.68)	4.21 (3.34-5.41)	4.86 (3.71-6.49)	5.37 (3.98-7.41)
10-day	1.05 (0.927-1.22)	1.45 (1.28-1.68)	1.97 (1.73-2.28)	2.40 (2.09-2.80)	2.98 (2.53-3.59)	3.44 (2.86-4.22)	3.90 (3.17-4.89)	4.38 (3.48-5.64)	5.05 (3.85-6.74)	5.57 (4.12-7.68)
20-day	1.18 (1.05-1.37)	1.62 (1.42-1.87)	2.18 (1.92-2.53)	2.64 (2.30-3.08)	3.26 (2.76-3.93)	3.74 (3.11-4.60)	4.24 (3.44-5.32)	4.75 (3.76-6.11)	5.44 (4.16-7.28)	5.99 (4.43-8.26)
30-day	1.33 (1.18-1.54)	1.81 (1.60-2.09)	2.43 (2.14-2.82)	2.94 (2.56-3.43)	3.62 (3.07-4.37)	4.16 (3.46-5.10)	4.70 (3.82-5.89)	5.26 (4.17-6.77)	6.03 (4.60-8.05)	6.63 (4.91-9.15)
45-day	1.50 (1.32-1.74)	2.03 (1.79-2.35)	2.72 (2.40-3.16)	3.29 (2.87-3.84)	4.05 (3.43-4.88)	4.64 (3.85-5.69)	5.24 (4.26-6.57)	5.86 (4.64-7.54)	6.71 (5.13-8.97)	7.39 (5.47-10.2)
60-day	1.63 (1.44-1.88)	2.20 (1.94-2.54)	2.94 (2.58-3.41)	3.54 (3.09-4.14)	4.36 (3.69-5.25)	4.99 (4.15-6.12)	5.63 (4.58-7.06)	6.30 (5.00-8.11)	7.22 (5.52-9.66)	7.96 (5.89-11.0)

[1] Precipitation frequency (PF) estimates in this table are based on frequency analysis of partial duration series (PDS).

Numbers in parenthesis are PF estimates at lower and upper bounds of the 90% confidence interval. The probability that precipitation frequency estimates (for a given duration and average recurrence interval) will be greater than the upper bound (or less than the lower bound) is 5%. Estimates at upper bounds are not checked against probable maximum precipitation (PMP) estimates and may be higher than currently valid PMP values.

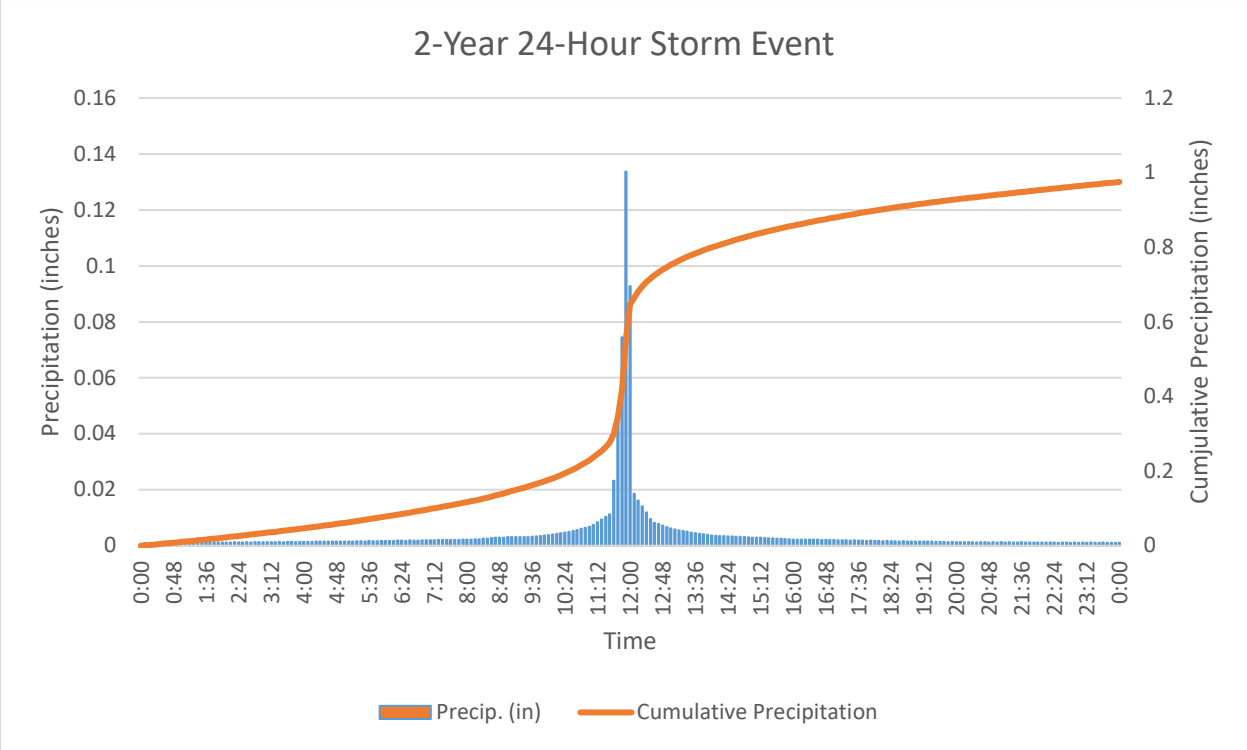
Please refer to NOAA Atlas 14 document for more information.

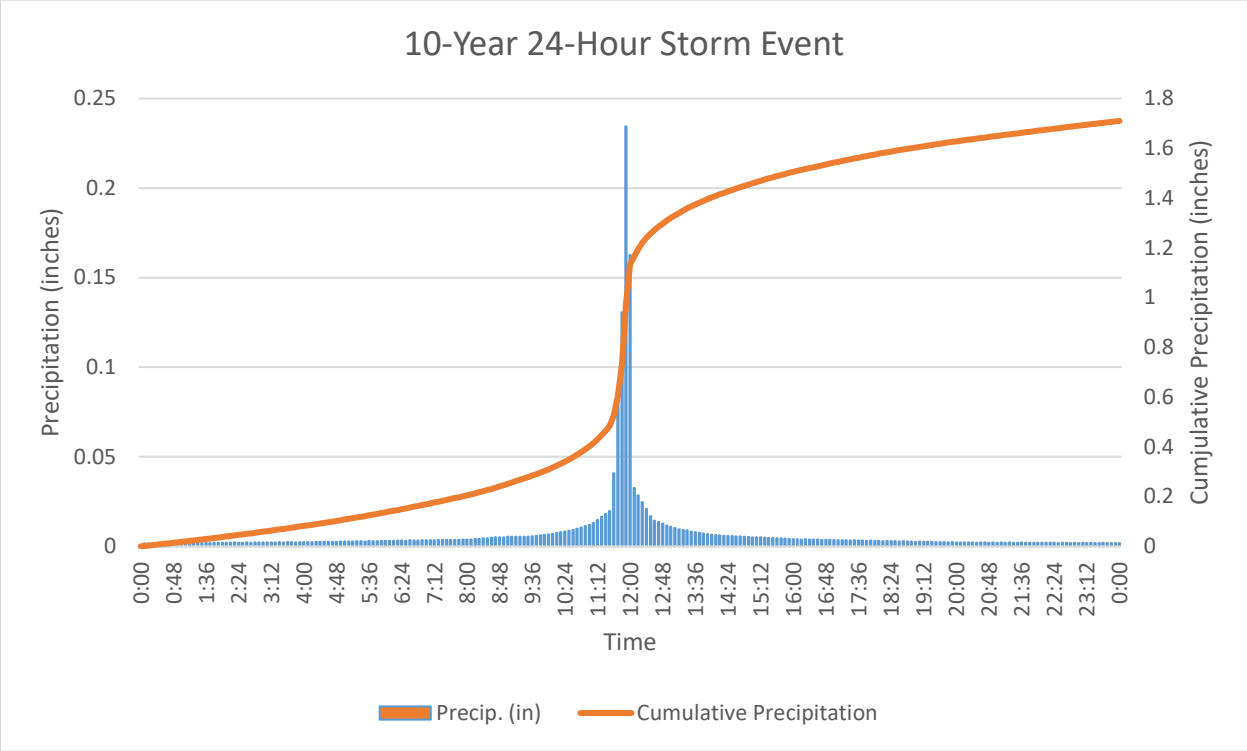
Source: NOAA (2023)



Source: NOAA (2023)

Precipitation Hyetograph

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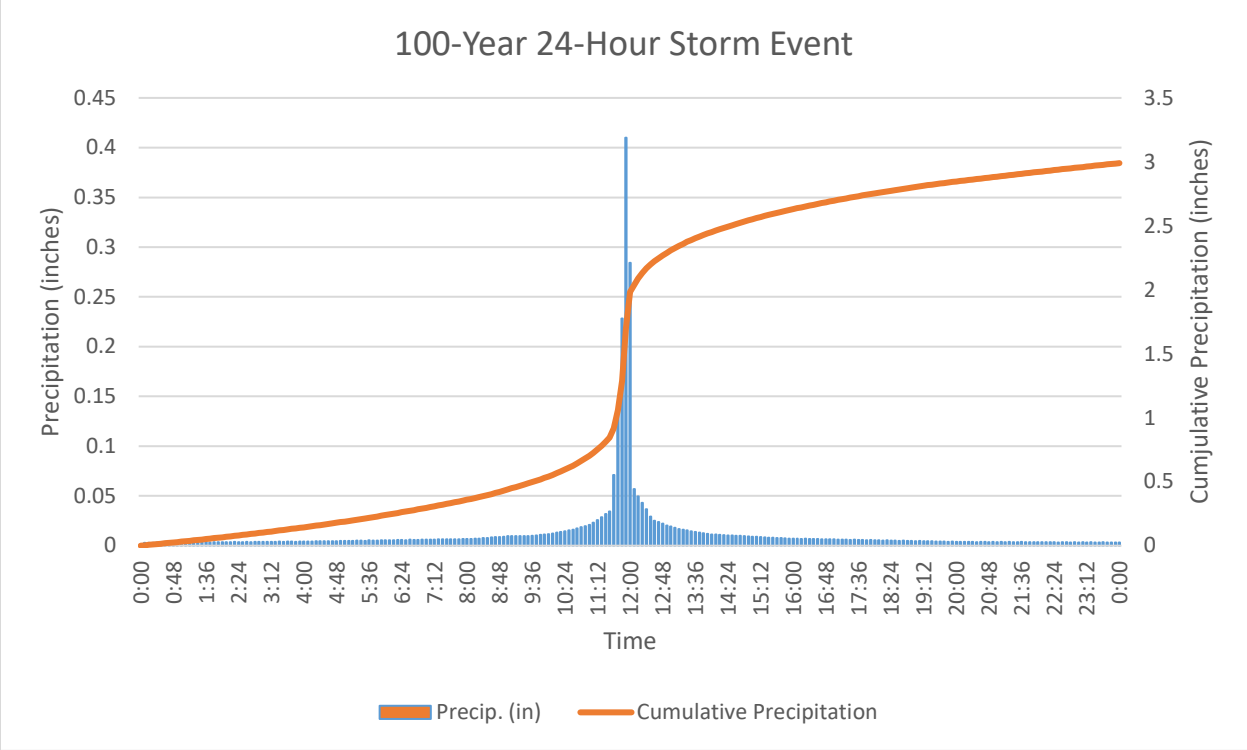
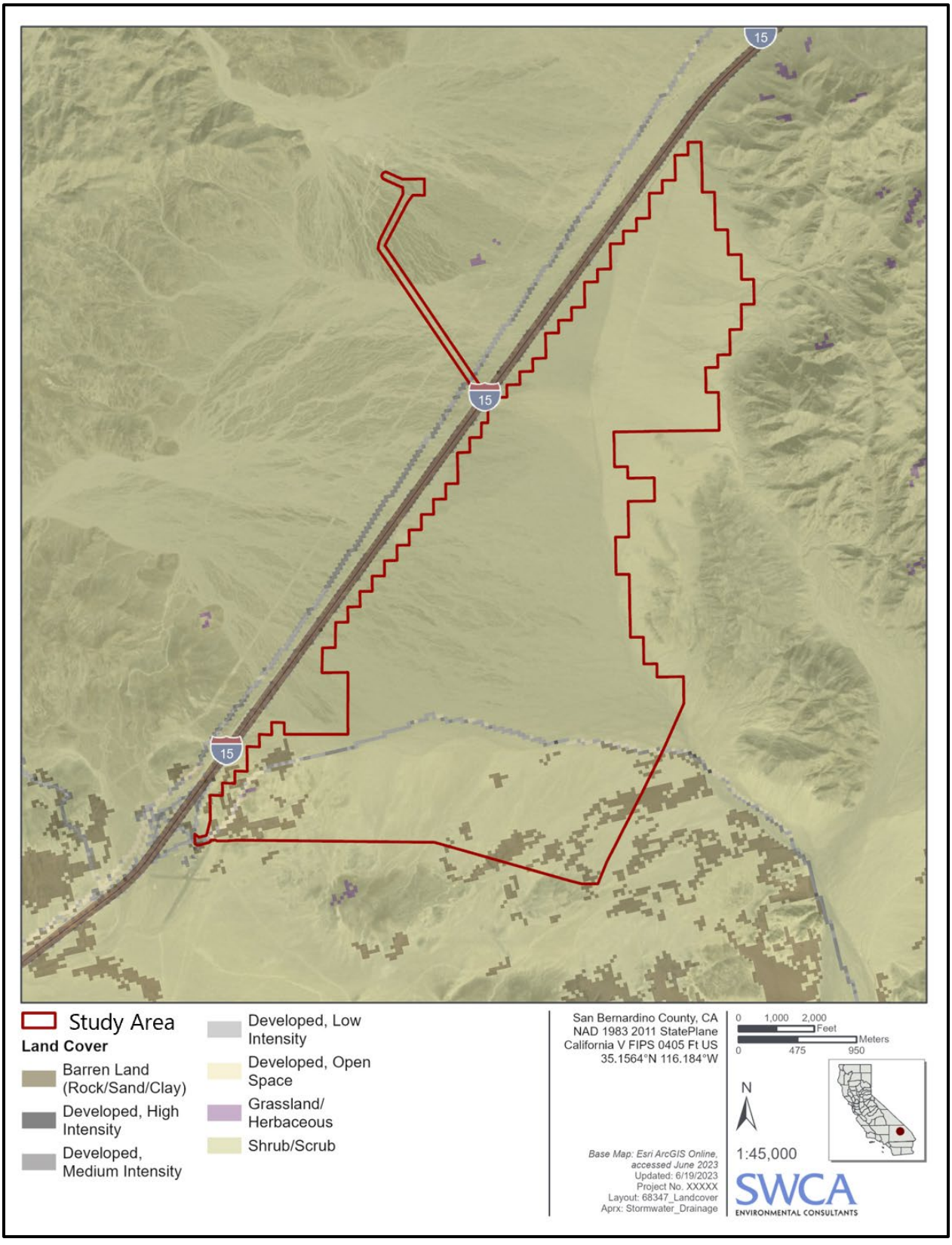
Precipitation (inches)
Cumjulative Precipitation (inches)
0.25
0.2
0.15
0.1
0.05
0
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0:00 0:48 1:36 2:24 3:12 4:00 4:48 5:36 6:24 7:12 8:00 8:48 9:36 10:24 11:12 12:00 12:48 13:36 14:24 15:12 16:00 16:48 17:36 18:24 19:12 20:00 20:48 21:36 22:24 23:12 0:00
Time
Precip. (in)
Cumulative Precipitation


100-Year 24-Hour Storm Event
Precipitation (inches)
Cumjulative Precipitation (inches)
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
3.5
3
2.5
2
1.5
1
0.5
0
0:00 0:48 1:36 2:24 3:12 4:00 4:48 5:36 6:24 7:12 8:00 8:48 9:36 10:24 11:12 12:00 12:48 13:36 14:24 15:12 16:00 16:48 17:36 18:24 19:12 20:00 20:48 21:36 22:24 23:12 0:00
Time
Precip. (in)
Cumulative Precipitation

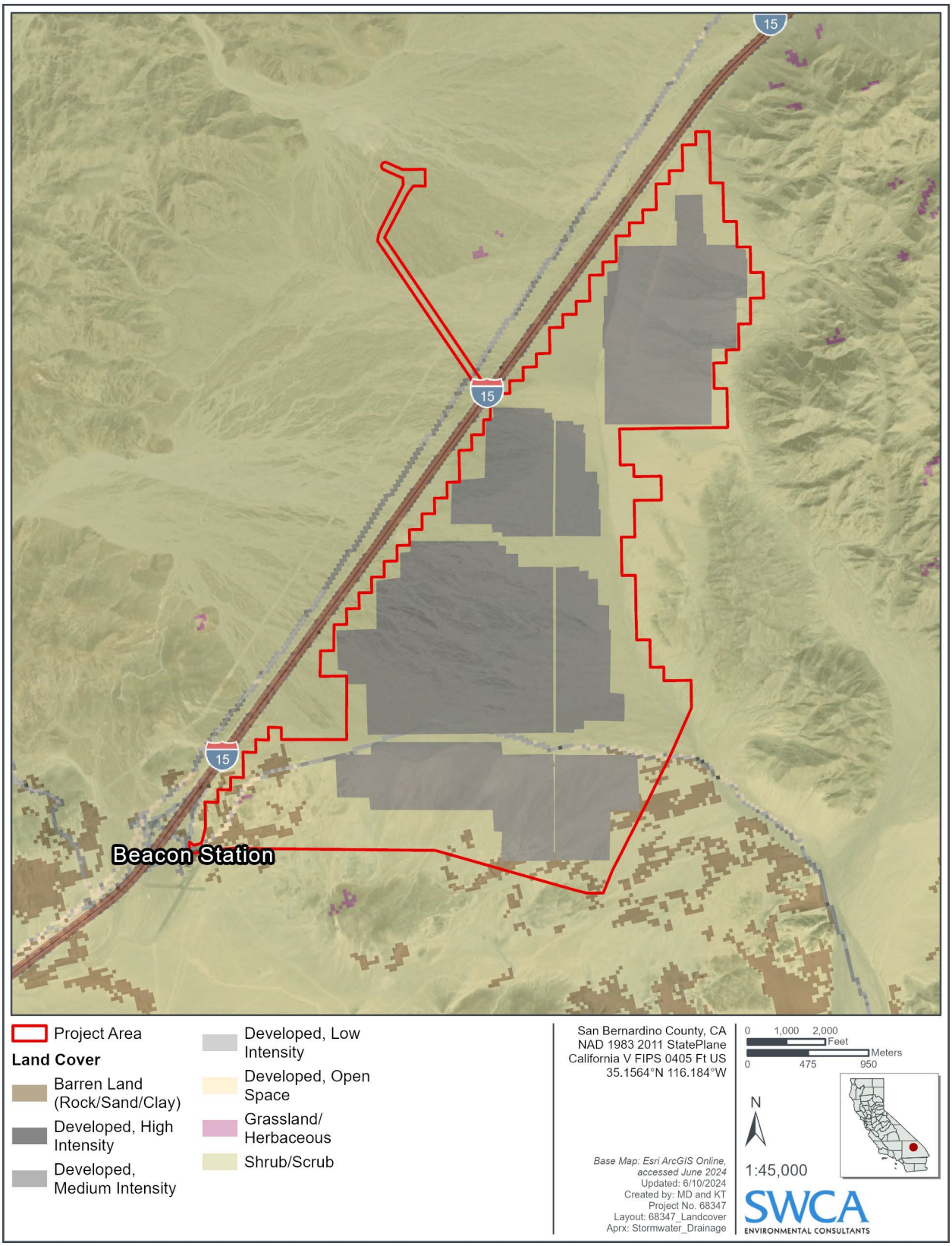
APPENDIX C

Soils and Land Cover Data

Pre-Development Land Cover Exhibit



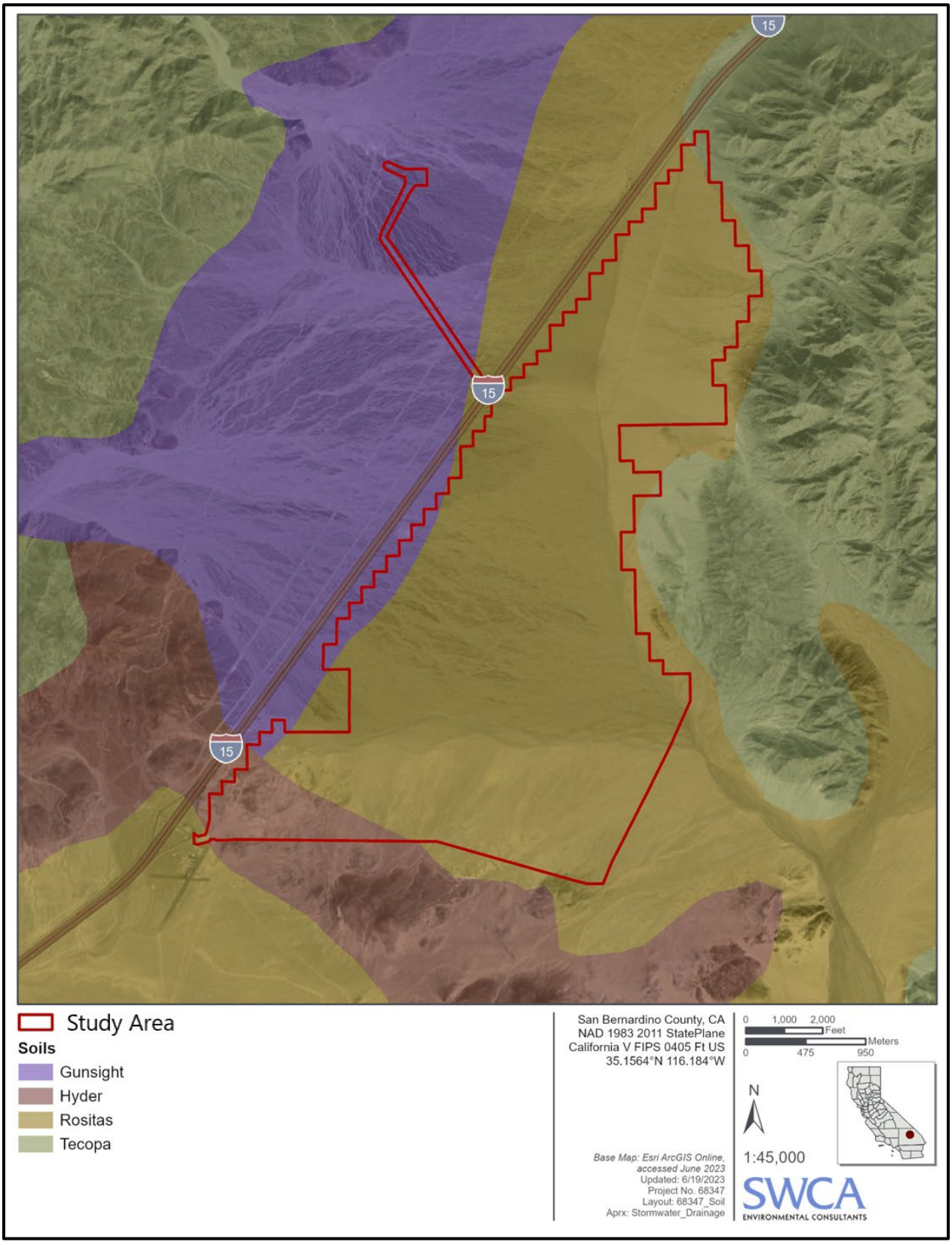
Post-Development Land Cover Exhibit

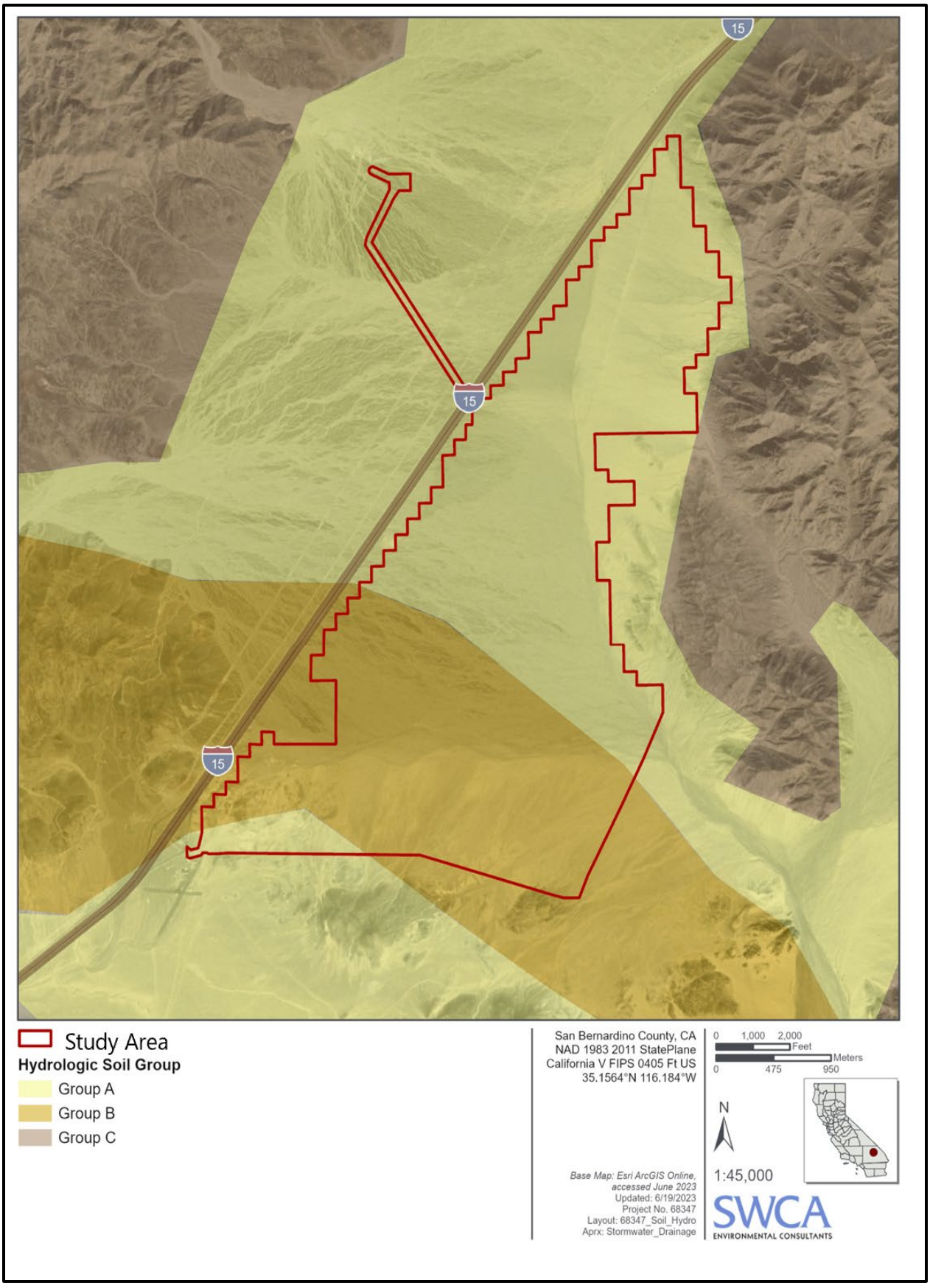


Pre-Development and Post-Development Land Cover Roughness and Percent Impervious Area

ID	Name	ManningsN	Percent Impervious
0	NoData	0.066	0
52	Shrub-Scrub	0.06	0
31	Barren Land Rock-Sand-Clay	0.025	0
22	Developed, Low Intensity	0.09	20
21	Developed, Open Space	0.03	10
71	Grassland-Herbaceous	0.04	0
23	Developed, Medium Intensity	0.1	40
24	Developed, High Intensity	0.15	80
90	Woody Wetlands	0.09	0
11	Open Water	0.035	100
42	Evergreen Forest	0.15	0
43	Mixed Forest	0.1	0
95	Emergent Herbaceous Wetlan...	0.075	0
81	Pasture-Hay	0.035	0
82	Cultivated Crops	0.035	0
41	Deciduous Forest	0.15	0

Natural Resources Conservation Service Soils Information




15
15
15
Study Area
Hydrologic Soil Group
Group A
Group B
Group C
San Bernardino County, CA
NAD 1983 2011 StatePlane
California V FIPS 0405 Ft US
35.1564°N 116.184°W
0 1,000 2,000
Feet
Meters
0 475 950
N
1:45,000
Base Map: Esri ArcGIS Online,
accessed June 2023
Updated: 6/19/2023
Project No. 68347
Layout: 68347_Soil_Hydro
Aprx: Stormwater_Drainage
SWCA
ENVIRONMENTAL CONSULTANTS

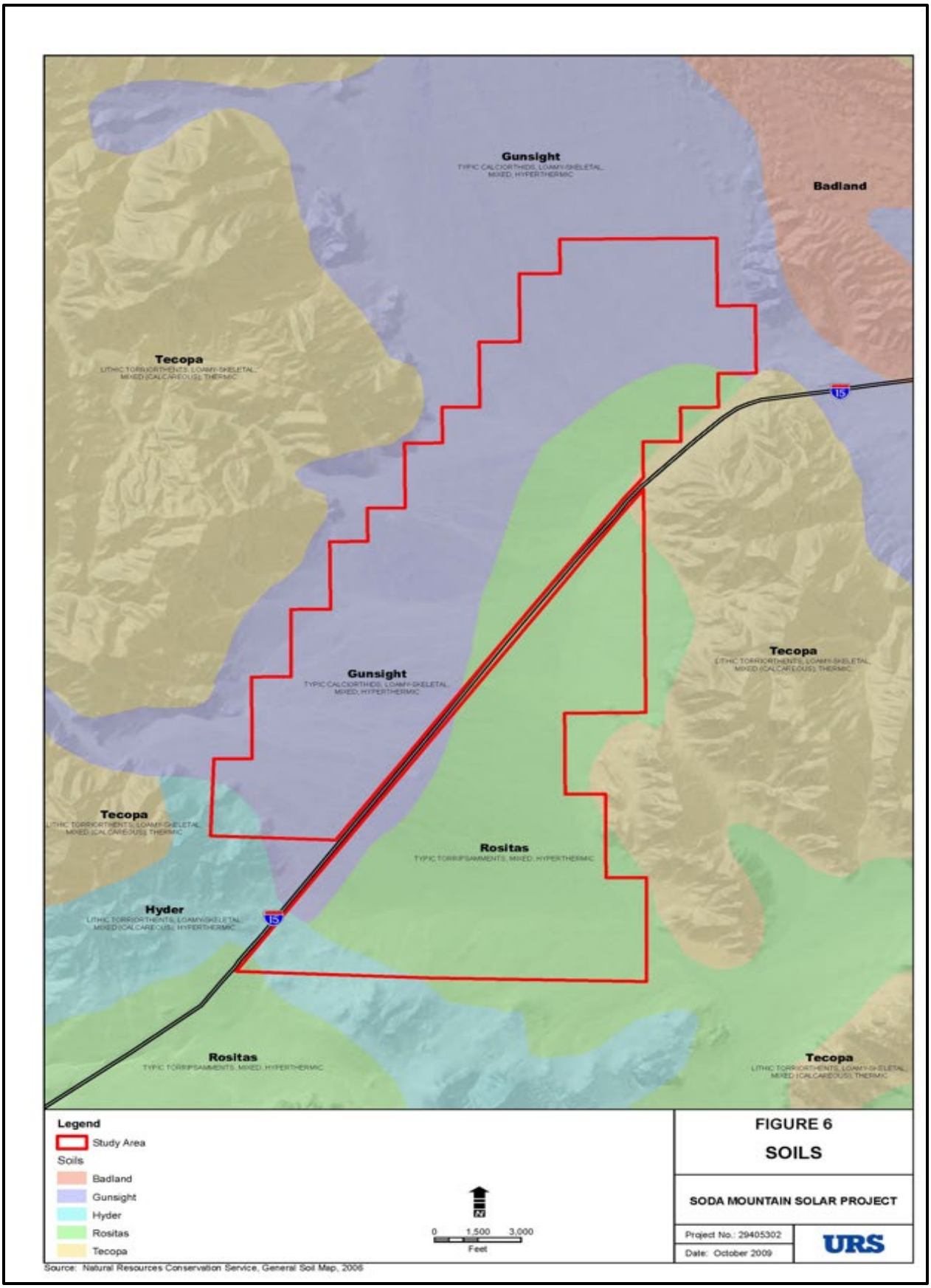

Gunsight
TYPIC CALCIORTHIDS, LOAMY-SKELETAL, MIXED, HYPERTHERMIC
Badland
Tecopa
LITHIC TORRIORTHENTS, LOAMY-SKELETAL, MIXED (CALCAREOUS), THERMIC
15
Gunsight
TYPIC CALCIORTHIDS, LOAMY-SKELETAL, MIXED, HYPERTHERMIC
Tecopa
LITHIC TORRIORTHENTS, LOAMY-SKELETAL, MIXED (CALCAREOUS), THERMIC
Tecopa
LITHIC TORRIORTHENTS, LOAMY-SKELETAL, MIXED (CALCAREOUS), THERMIC
Rositas
TYPIC TORRIPSAMMENTS, MIXED, HYPERTHERMIC
Hyder
LITHIC TORRIORTHENTS, LOAMY-SKELETAL, MIXED (CALCAREOUS), HYPERTHERMIC
15
Rositas
TYPIC TORRIPSAMMENTS, MIXED, HYPERTHERMIC
Tecopa
LITHIC TORRIORTHENTS, LOAMY-SKELETAL, MIXED (CALCAREOUS), THERMIC
Legend
Study Area
Soils
Badland
Gunsight
Hyder
Rositas
Tecopa
N
0 1,500 3,000
Feet
FIGURE 6
SOILS
SODA MOUNTAIN SOLAR PROJECT
Project No.: 29405302
Date: October 2009
URS
Source: Natural Resources Conservation Service, General Soil Map, 2006

Table 2. Permissible Shear and Velocity for Selected Lining Materials[1]

Boundary Category	Boundary Type	Permissible Shear Stress (lb/sq ft)	Permissible Velocity (ft/sec)	Citation(s)
Soils	Fine colloidal sand	0.02 - 0.03	1.5	A
	Sandy loam (noncolloidal)	0.03 - 0.04	1.75	A
	Alluvial silt (noncolloidal)	0.045 - 0.05	2	A
	Silty loam (noncolloidal)	0.045 - 0.05	1.75 – 2.25	A
	Firm loam	0.075	2.5	A
	Fine gravels	0.075	2.5	A
	Stiff clay	0.26	3 – 4.5	A, F
	Alluvial silt (colloidal)	0.26	3.75	A
	Graded loam to cobbles	0.38	3.75	A
	Graded silts to cobbles	0.43	4	A
	Shales and hardpan	0.67	6	A
Gravel/Cobble	1-in.	0.33	2.5 – 5	A
	2-in.	0.67	3 – 6	A
	6-in.	2.0	4 – 7.5	A
	12-in.	4.0	5.5 – 12	A
Vegetation	Class A turf	3.7	6 – 8	E, N
	Class B turf	2.1	4 - 7	E, N
	Class C turf	1.0	3.5	E, N
	Long native grasses	1.2 – 1.7	4 – 6	G, H, L, N
	Short native and bunch grass	0.7 - 0.95	3 – 4	G, H, L, N
	Reed plantings	0.1-0.6	N/A	E, N
	Hardwood tree plantings	0.41-2.5	N/A	E, N
Temporary Degradable RECPs	Jute net	0.45	1 – 2.5	E, H, M
	Straw with net	1.5 – 1.65	1 – 3	E, H, M
	Coconut fiber with net	2.25	3 – 4	E, M
	Fiberglass roving	2.00	2.5 – 7	E, H, M
Non-Degradable RECPs	Unvegetated	3.00	5 – 7	E, G, M
	Partially established	4.0-6.0	7.5 – 15	E, G, M
	Fully vegetated	8.00	8 – 21	F, L, M
Riprap	6 – in. d_{50}	2.5	5 – 10	H
	9 – in. d_{50}	3.8	7 – 11	H
	12 – in. d_{50}	5.1	10 – 13	H
	18 – in. d_{50}	7.6	12 – 16	H
	24 – in. d_{50}	10.1	14 – 18	E
Soil Bioengineering	Wattles	0.2 – 1.0	3	C, I, J, N
	Reed fascine	0.6-1.25	5	E
	Coir roll	3 - 5	8	E, M, N
	Vegetated coir mat	4 - 8	9.5	E, M, N
	Live brush mattress (initial)	0.4 – 4.1	4	B, E, I
	Live brush mattress (grown)	3.90-8.2	12	B, C, E, I, N
	Brush layering (initial/grown)	0.4 – 6.25	12	E, I, N
	Live fascine	1.25-3.10	6 – 8	C, E, I, J
	Live willow stakes	2.10-3.10	3 – 10	E, N, O
Hard Surfacing	Gabions	10	14 – 19	D
	Concrete	12.5	>18	H

[1] Ranges of values generally reflect multiple sources of data or different testing conditions.

A. Chang, H.H. (1988).
B. Florineth. (1982)
C. Gerstgraser, C. (1998).
D. Goff, K. (1999).
E. Gray, D.H., and Sotir, R.B. (1996).
F. Julien, P.Y. (1995).
G. Kouwen, N.; Li, R. M.; and Simons, D.B., (1980).
H. Norman, J. N. (1975).
I. Schiechtl, H. M. and R. Stern. (1996).
J. Schoklitsch, A. (1937).
K. Sprague, C.J. (1999).
L. Temple, D.M. (1980).
M. TXDOT (1999)
N. Data from Author (2001)
O. USACE (1997).

SCS Curve Numbers and Infiltration Rates

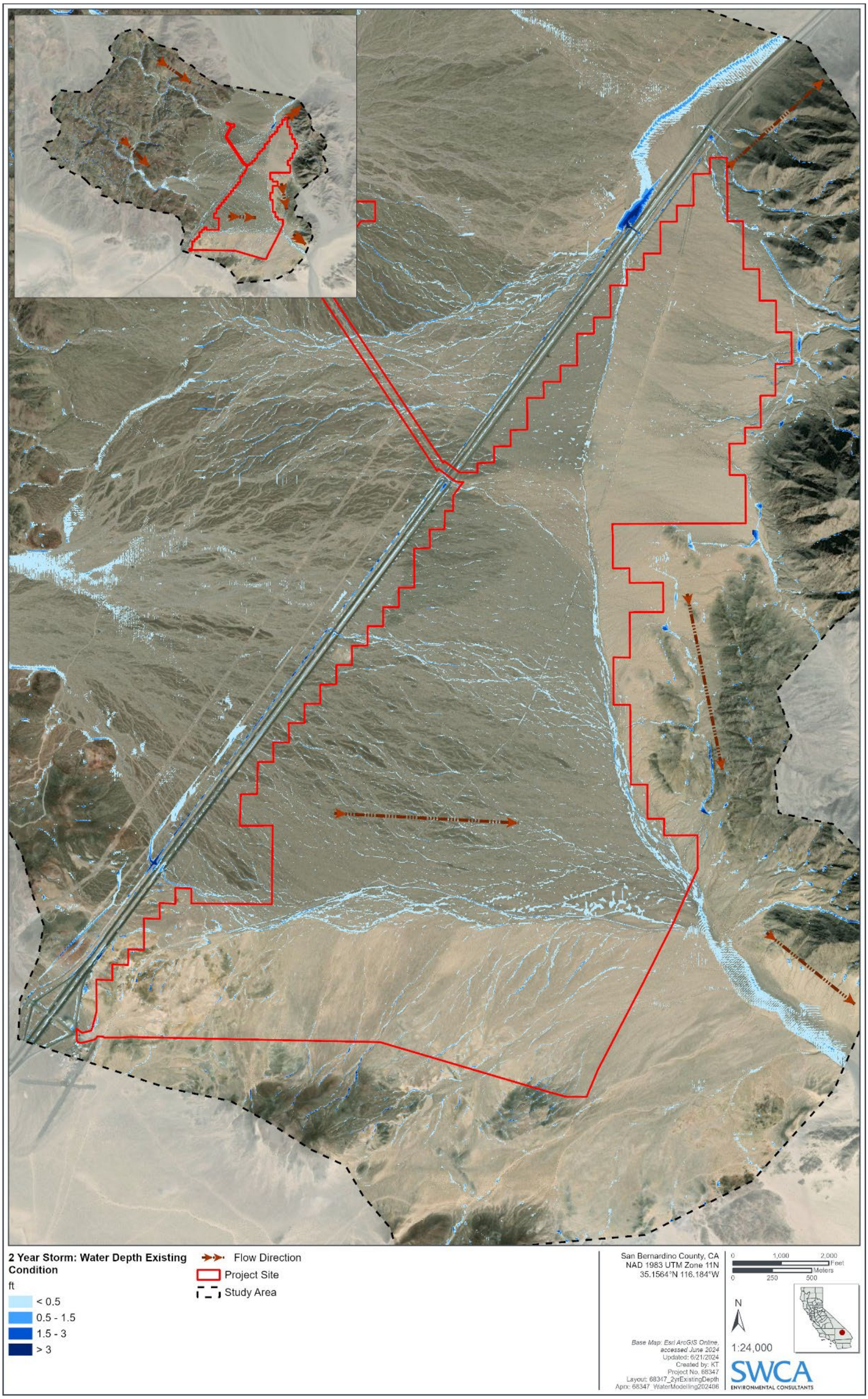
ID	Name	Curve Number	Abstraction Ratio	Minimum Infiltration Rate (in/hr)
0	NoData	90	0.2	0.14
1	NoData : C	80	0.2	0.18
2	NoData : A	60	0.2	0.41
3	NoData : B	70	0.2	0.27
4	Shrub-Scrub : NoData	92	0.2	0.14
5	Shrub-Scrub : C	92	0.2	0.18
6	Shrub-Scrub : A	83	0.2	0.41
7	Shrub-Scrub : B	89	0.2	0.27
8	Barren Land Rock-Sand-Clay : NoData	92	0.2	0.14
9	Barren Land Rock-Sand-Clay : C	92	0.2	0.18
10	Barren Land Rock-Sand-Clay : A	83	0.2	0.41
11	Barren Land Rock-Sand-Clay : B	89	0.2	0.27
12	Developed, Low Intensity : NoData	90	0.2	0.37
13	Developed, Low Intensity : C	80	0.2	0.45
14	Developed, Low Intensity : A	50	0.2	0.6
15	Developed, Low Intensity : B	65	0.2	0.78
16	Developed, Open Space : NoData	70	0.2	0.8
17	Developed, Open Space : C	70	0.2	0.8
18	Developed, Open Space : A	50	0.2	0.8
19	Developed, Open Space : B	60	0.2	0.8
20	Grassland-Herbaceous : NoData	80	0.2	0.31
21	Grassland-Herbaceous : C	80	0.2	0.4

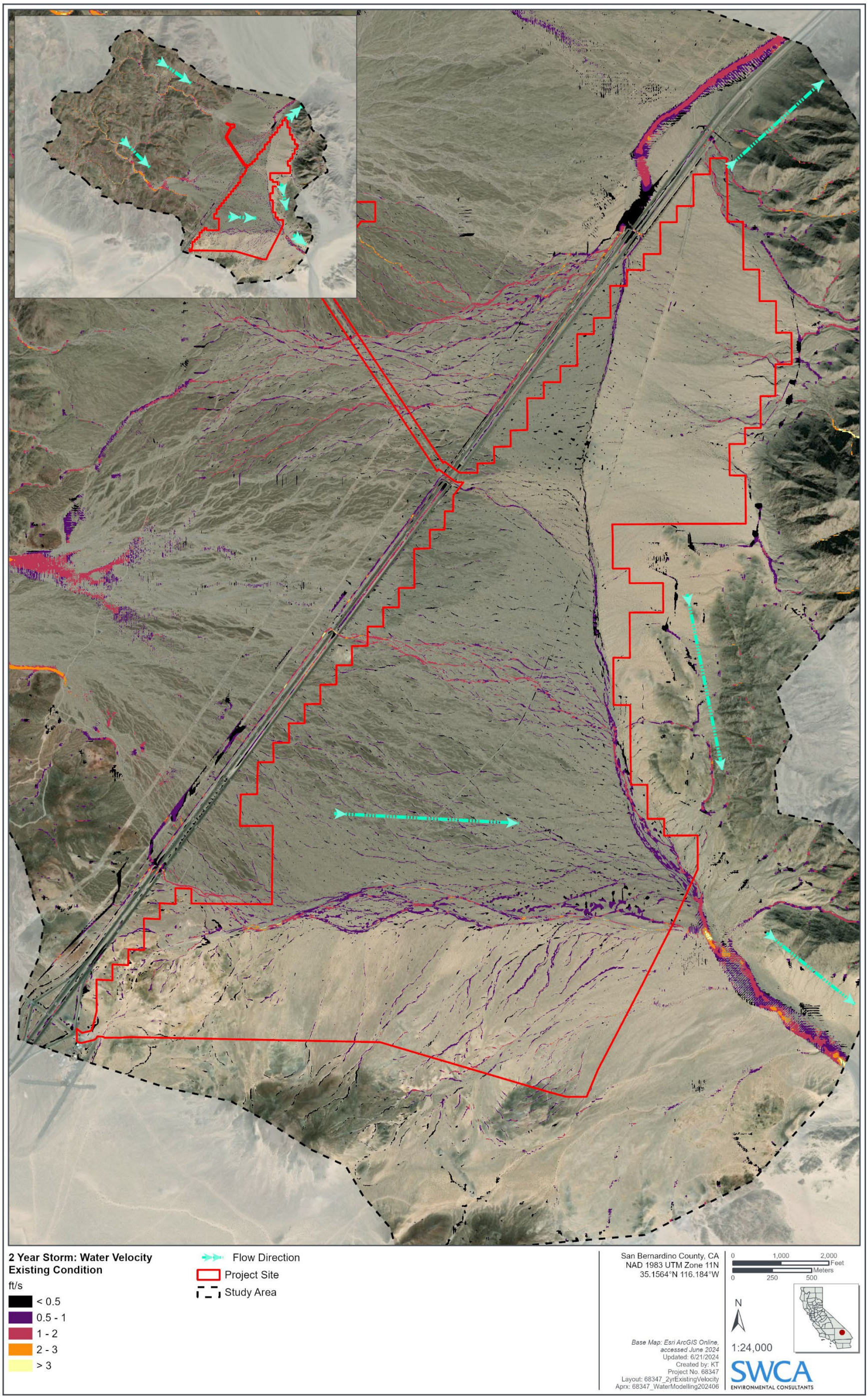
22	Grassland-Herbaceous : A	70	0.2	0.82
23	Grassland-Herbaceous : B	60	0.2	0.56
24	Developed, Medium Intensity : NoData	85	0.2	0.28
25	Developed, Medium Intensity : C	85	0.2	0.34
26	Developed, Medium Intensity : A	60	0.2	0.58
27	Developed, Medium Intensity : B	77	0.2	0.45
28	Developed, High Intensity : NoData	95	0.2	0.18
29	Developed, High Intensity : C	95	0.2	0.22
30	Developed, High Intensity : A	65	0.2	0.39
31	Developed, High Intensity : B	80	0.2	0.3
32	Woody Wetlands : NoData	75	0.2	0.4
33	Woody Wetlands : C	75	0.2	0.5
34	Woody Wetlands : A	60	0.2	0.95
35	Woody Wetlands : B	45	0.2	0.69
36	Open Water : NoData	98	0.2	0.01
37	Open Water : C	98	0.2	0.01
38	Open Water : A	98	0.2	0.01
39	Open Water : B	98	0.2	0.01
40	Evergreen Forest : NoData	70	0.2	0.4
41	Evergreen Forest : C	70	0.2	0.5
42	Evergreen Forest : A	40	0.2	0.95

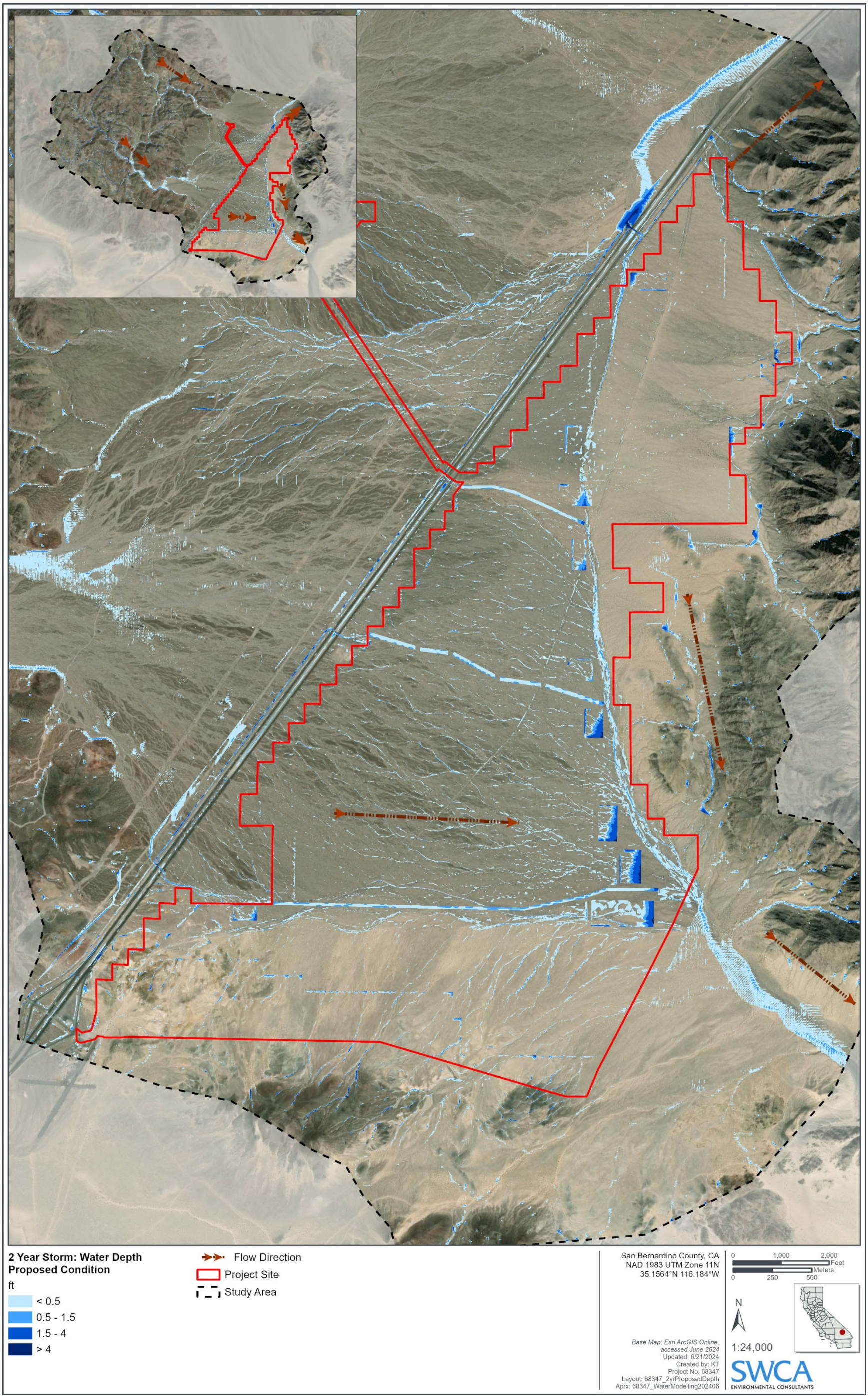
43	Evergreen Forest : B	55	0.2	0.69
44	Mixed Forest : NoData	75	0.2	0.4
45	Mixed Forest : C	75	0.2	0.5
46	Mixed Forest : A	60	0.2	0.95
47	Mixed Forest : B	68	0.2	0.69
48	Emergent Herbaceous Wetlands : NoD...	80	0.2	0.4
49	Emergent Herbaceous Wetlands : C	80	0.2	0.5
50	Emergent Herbaceous Wetlands : A	60	0.2	0.95
51	Emergent Herbaceous Wetlands : B	70	0.2	0.69
52	Pasture-Hay : NoData	80	0.2	0.22
53	Pasture-Hay : C	80	0.2	0.29
54	Pasture-Hay : A	60	0.2	0.59
55	Pasture-Hay : B	70	0.2	0.41
56	Cultivated Crops : NoData	80	0.2	0.22
57	Cultivated Crops : C	80	0.2	0.29
58	Cultivated Crops : A	60	0.2	0.59
59	Cultivated Crops : B	70	0.2	0.41
60	Deciduous Forest : NoData	75	0.2	0.4
61	Deciduous Forest : C	75	0.2	0.5
62	Deciduous Forest : A	60	0.2	0.95
63	Deciduous Forest : B	68	0.2	0.69

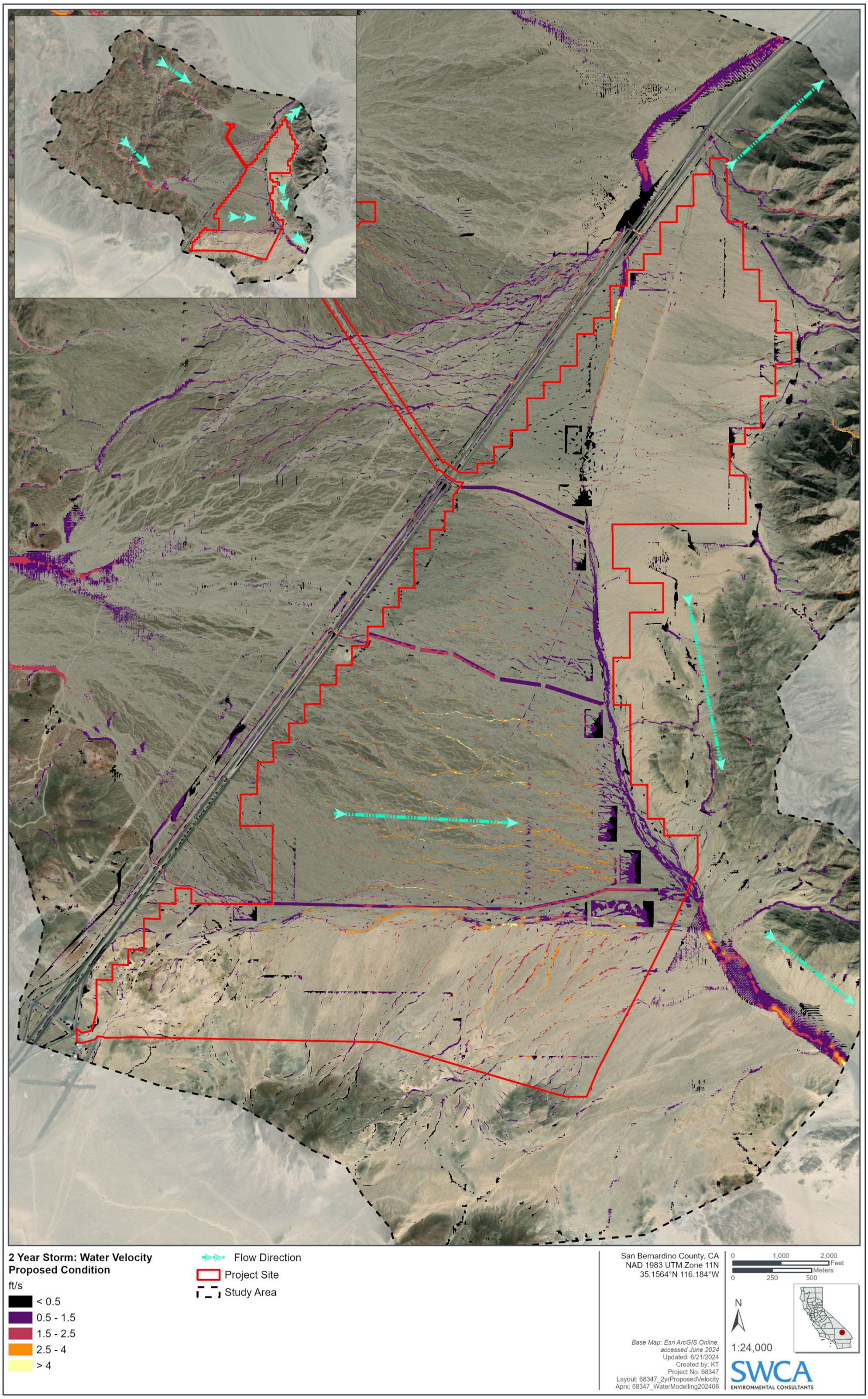
APPENDIX D

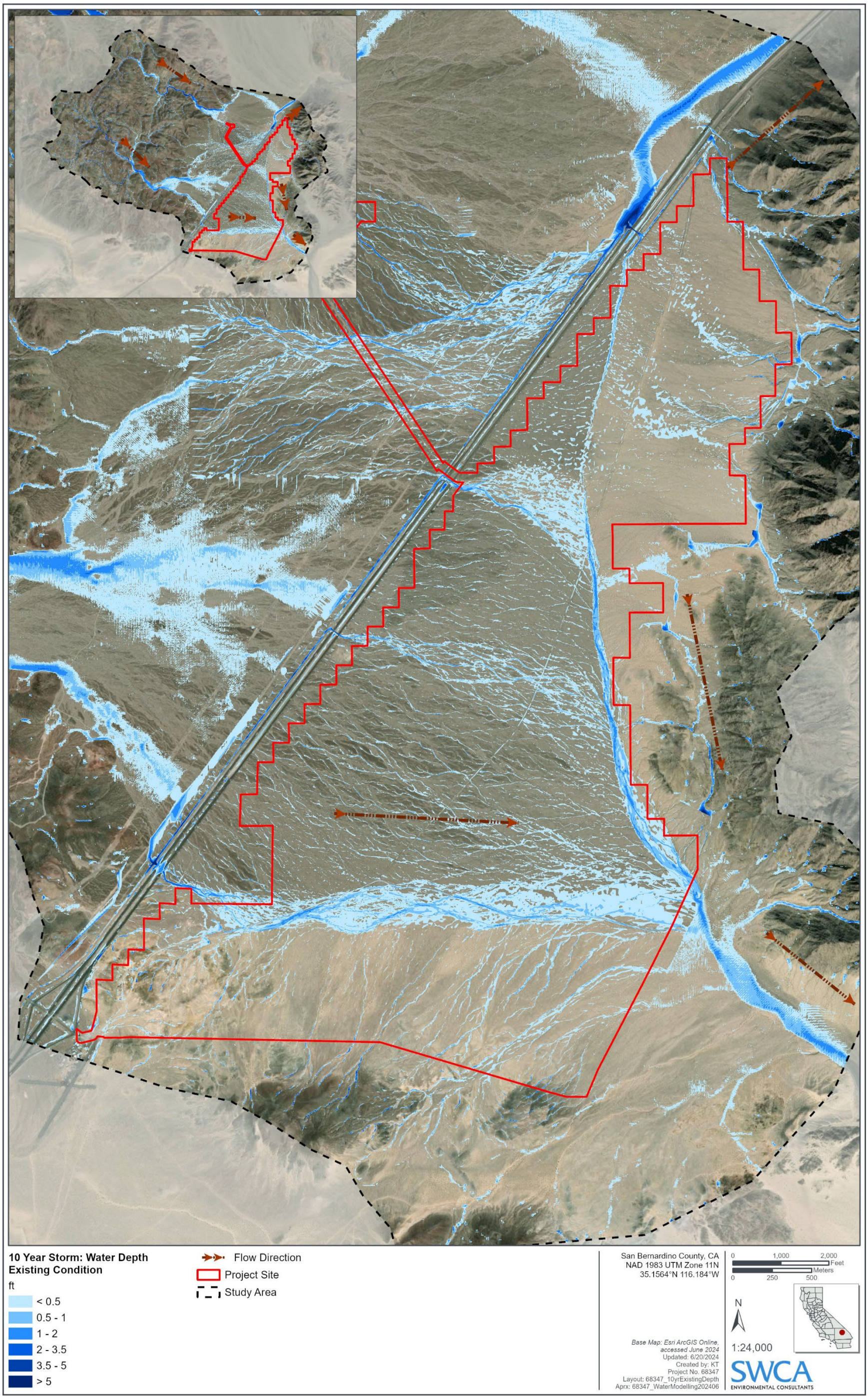
HEC-RAS Model Results

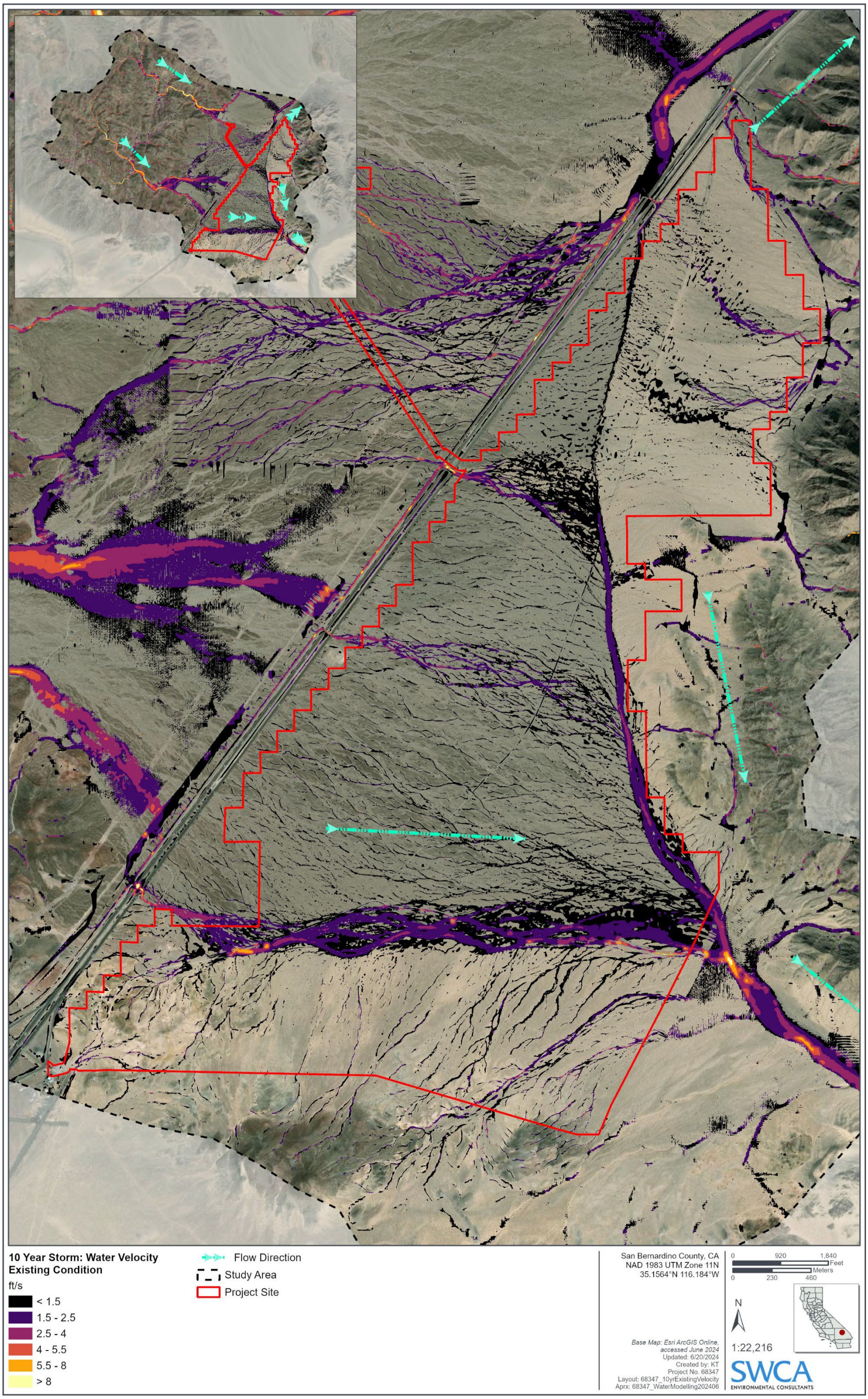

2 Year Storm: Water Depth Existing Condition
ft
< 0.5
0.5 - 1.5
1.5 - 3
> 3
Flow Direction
Project Site
Study Area
San Bernardino County, CA
NAD 1983 UTM Zone 11N
35.1564°N 116.184°W
0
1,000
2,000
Feet
Meters
0
250
500
N
1:24,000
Base Map: Esri ArcGIS Online, accessed June 2024
Updated: 6/21/2024
Created by: KT
Project No. 68347
Layout: 68347_2yrExistingDepth
Aprx: 68347_WaterModelling202406
SWCA
ENVIRONMENTAL CONSULTANTS

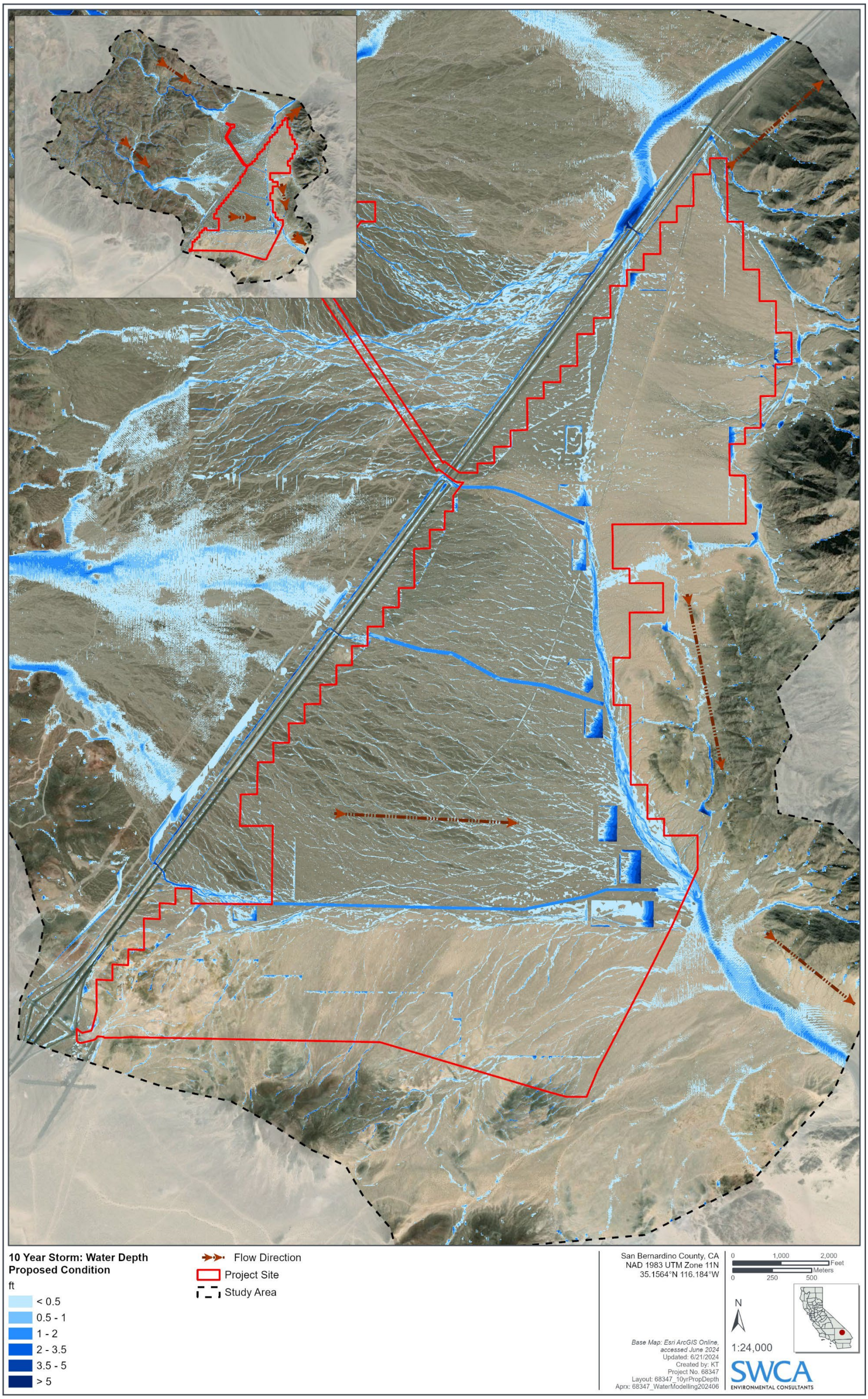

2 Year Storm: Water Velocity
Existing Condition
ft/s
< 0.5
0.5 - 1
1 - 2
2 - 3
> 3
Flow Direction
Project Site
Study Area
San Bernardino County, CA
NAD 1983 UTM Zone 11N
35.1564°N 116.184°W
0 1,000 2,000 Feet
0 250 500 Meters
N
1:24,000
Base Map: Esri ArcGIS Online, accessed June 2024
Updated: 6/21/2024
Created by: KT
Project No. 68347
Layout: 68347_2yrExistingVelocity
Aprx: 68347_WaterModelling202406
SWCA
ENVIRONMENTAL CONSULTANTS

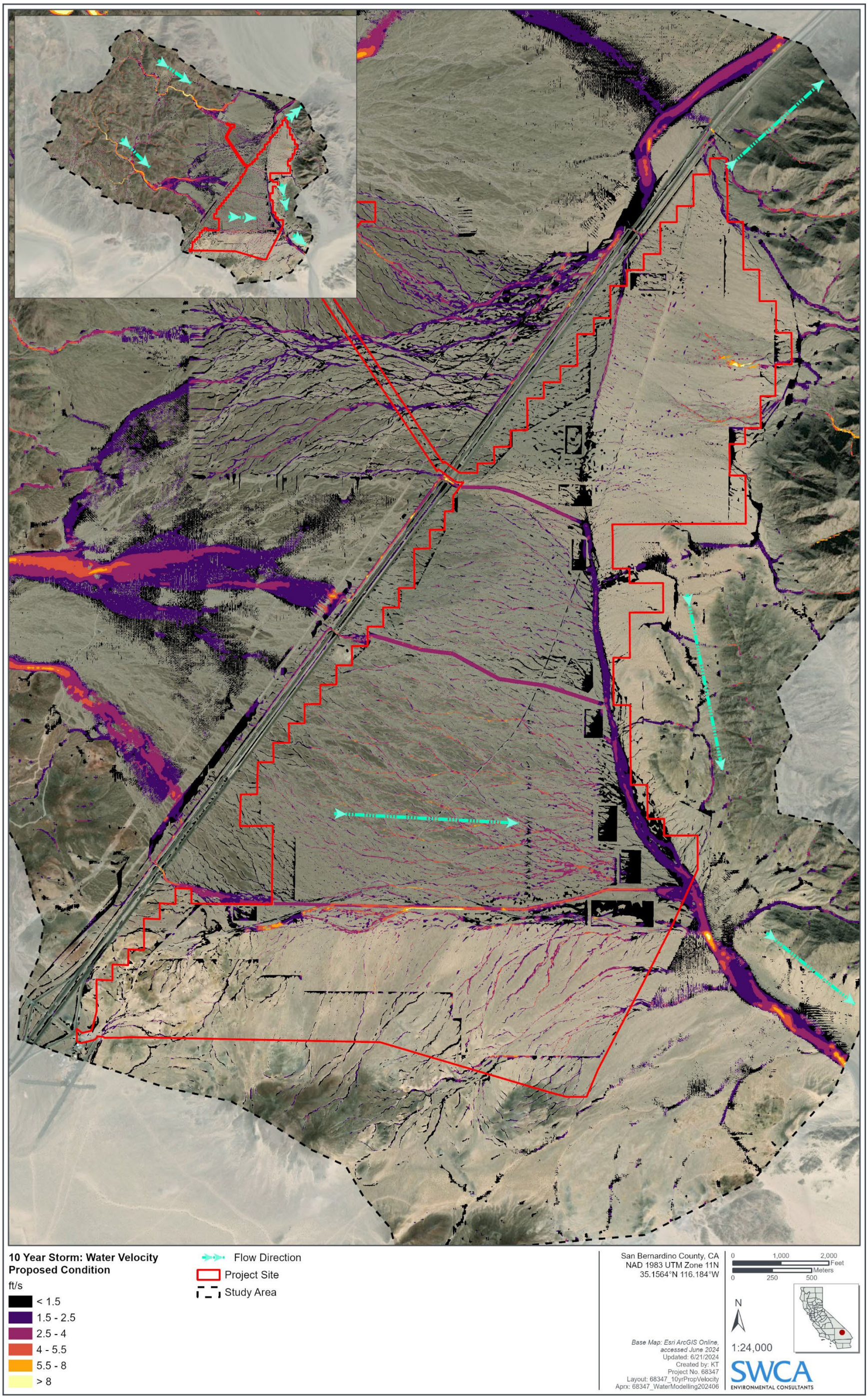

2 Year Storm: Water Depth
Proposed Condition
ft
< 0.5
0.5 - 1.5
1.5 - 4
> 4
Flow Direction
Project Site
Study Area
San Bernardino County, CA
NAD 1983 UTM Zone 11N
35.1564°N 116.184°W
0 1,000 2,000 Feet
0 250 500 Meters
N
1:24,000
Base Map: Esri ArcGIS Online, accessed June 2024
Updated: 6/21/2024
Created by: KT
Project No. 68347
Layout: 68347_2yrProposedDepth
Aprx: 68347_WaterModelling202406
SWCA
ENVIRONMENTAL CONSULTANTS

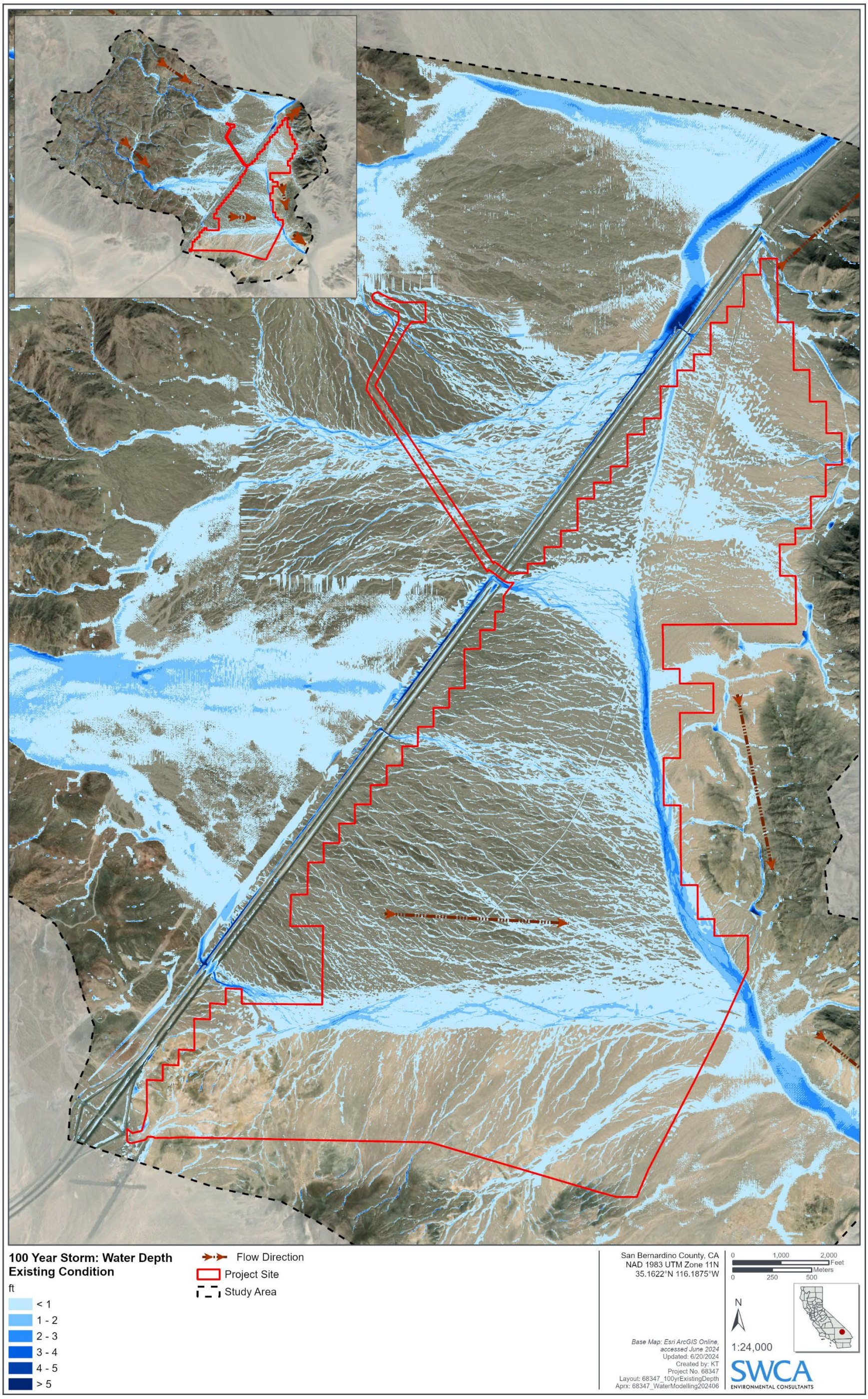

2 Year Storm: Water Velocity
Proposed Condition
ft/s
< 0.5
0.5 - 1.5
1.5 - 2.5
2.5 - 4
> 4
Flow Direction
Project Site
Study Area
San Bernardino County, CA
NAD 1983 UTM Zone 11N
35.1564°N 116.184°W
0 1,000 2,000 Feet
0 250 500 Meters
N
1:24,000
Base Map: Esri ArcGIS Online, accessed June 2024
Updated: 6/21/2024
Created by: KT
Project No. 68347
Layout: 68347_2yrProposedVelocity
Aprx: 68347_WaterModelling202406
SWCA
ENVIRONMENTAL CONSULTANTS

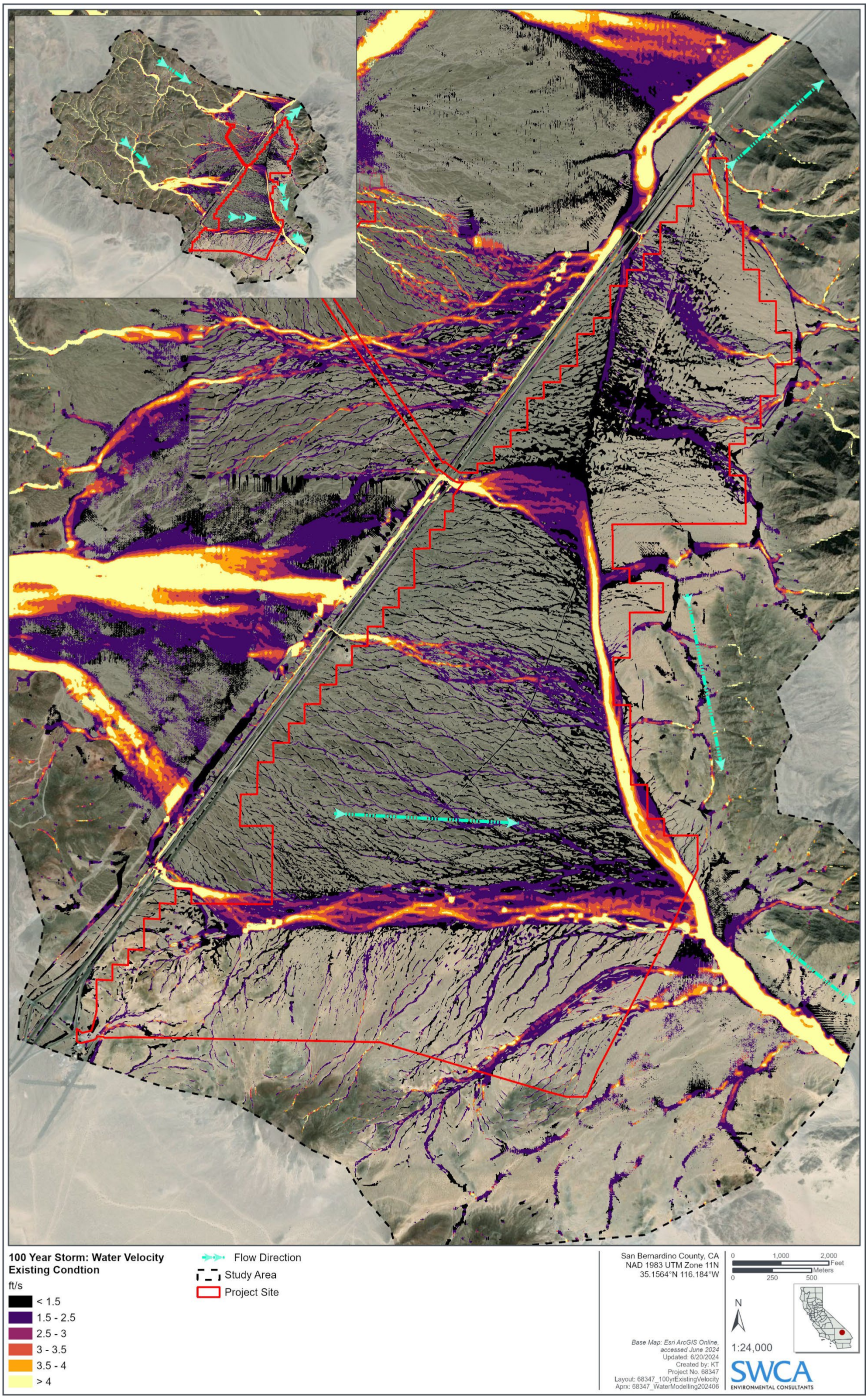

10 Year Storm: Water Depth
Existing Condition
ft
< 0.5
0.5 - 1
1 - 2
2 - 3.5
3.5 - 5
> 5
Flow Direction
Project Site
Study Area
San Bernardino County, CA
NAD 1983 UTM Zone 11N
35.1564°N 116.184°W
0 1,000 2,000 Feet
0 250 500 Meters
N
1:24,000
Base Map: Esri ArcGIS Online, accessed June 2024
Updated: 6/20/2024
Created by: KT
Project No. 68347
Layout: 68347_10yrExistingDepth
Aprx: 68347_WaterModelling202406
SWCA
ENVIRONMENTAL CONSULTANTS

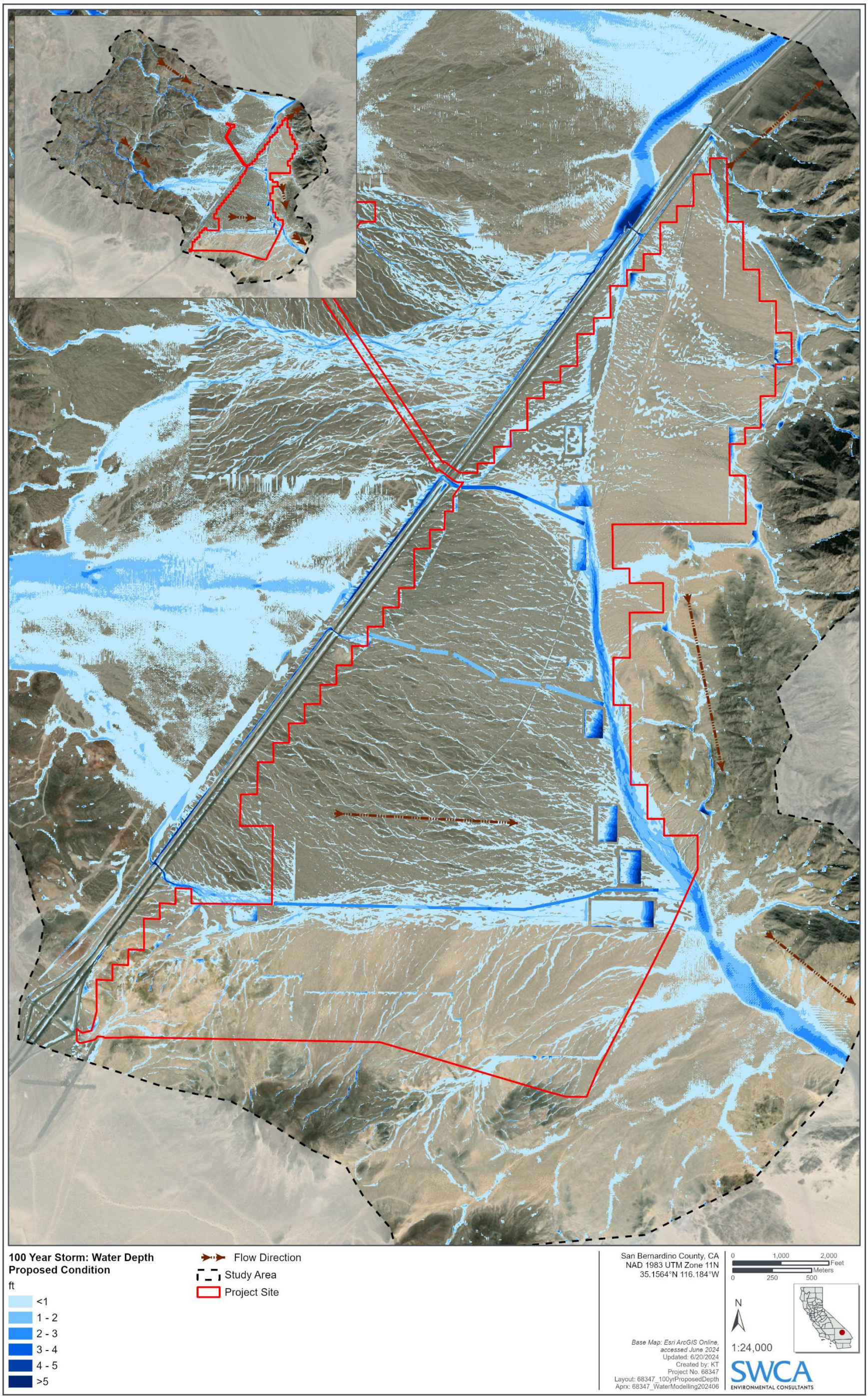

10 Year Storm: Water Velocity
Existing Condition
ft/s
< 1.5
1.5 - 2.5
2.5 - 4
4 - 5.5
5.5 - 8
> 8
Flow Direction
Study Area
Project Site
San Bernardino County, CA
NAD 1983 UTM Zone 11N
35.1564°N 116.184°W
0 920 1,840
Feet
0 230 460
Meters
N
1:22,216
Base Map: Esri ArcGIS Online, accessed June 2024
Updated: 6/20/2024
Created by: KT
Project No. 68347
Layout: 68347_10yrExistingVelocity
Aprx: 68347_WaterModelling202406
SWCA
ENVIRONMENTAL CONSULTANTS

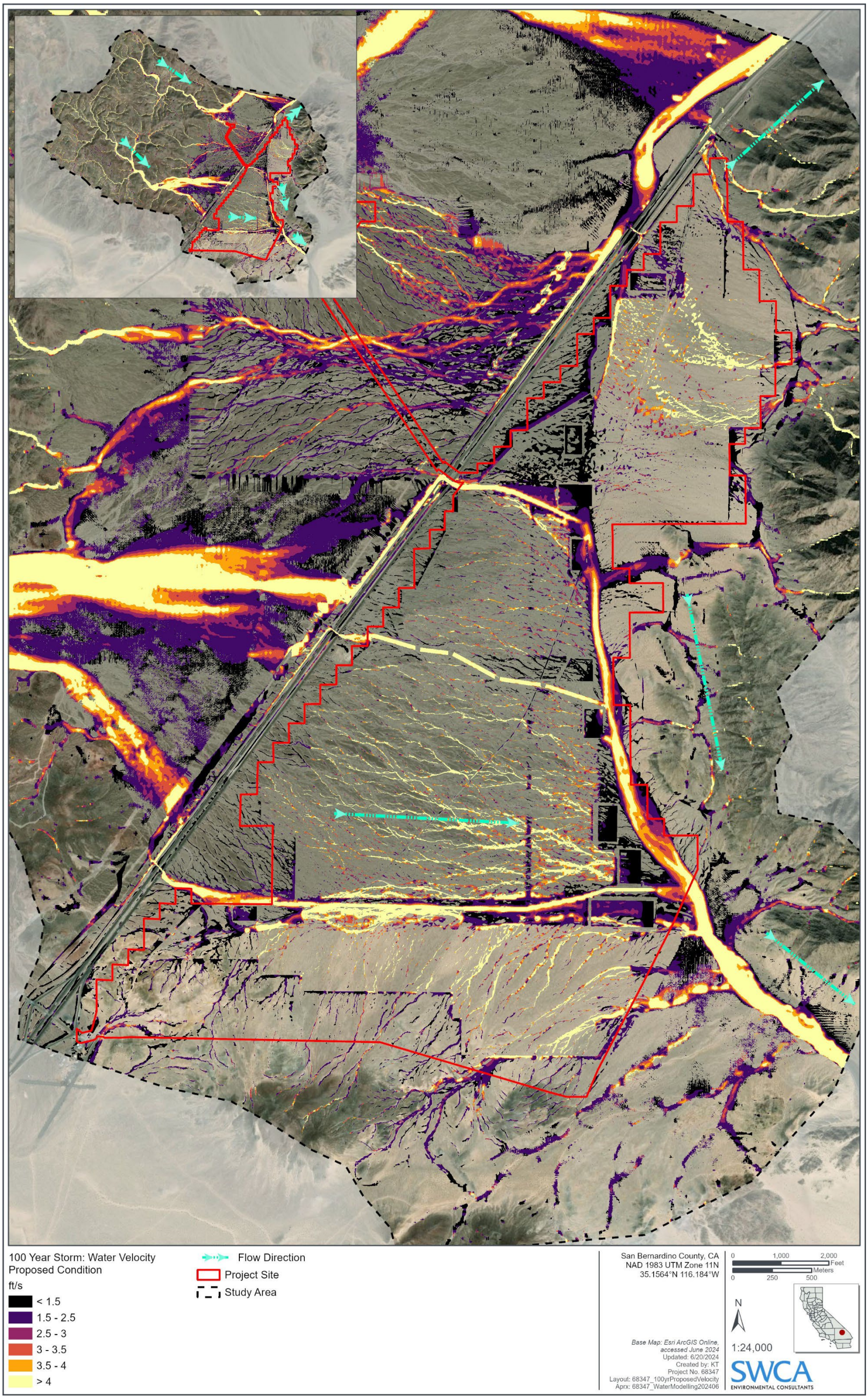

10 Year Storm: Water Depth
Proposed Condition
ft
< 0.5
0.5 - 1
1 - 2
2 - 3.5
3.5 - 5
> 5
Flow Direction
Project Site
Study Area
San Bernardino County, CA
NAD 1983 UTM Zone 11N
35.1564°N 116.184°W
0 1,000 2,000 Feet
0 250 500 Meters
N
1:24,000
Base Map: Esri ArcGIS Online, accessed June 2024
Updated: 6/21/2024
Created by: KT
Project No. 68347
Layout: 68347_10yrPropDepth
Aprx: 68347_WaterModelling202406
SWCA
ENVIRONMENTAL CONSULTANTS


10 Year Storm: Water Velocity
Proposed Condition
ft/s
< 1.5
1.5 - 2.5
2.5 - 4
4 - 5.5
5.5 - 8
> 8
Flow Direction
Project Site
Study Area
San Bernardino County, CA
NAD 1983 UTM Zone 11N
35.1564°N 116.184°W
0 1,000 2,000 Feet
0 250 500 Meters
N
1:24,000
Base Map: Esri ArcGIS Online, accessed June 2024
Updated: 6/21/2024
Created by: KT
Project No. 68347
Layout: 68347_10yrPropVelocity
Aprx: 68347_WaterModelling202406
SWCA
ENVIRONMENTAL CONSULTANTS


100 Year Storm: Water Depth
Existing Condition
ft
< 1
1 - 2
2 - 3
3 - 4
4 - 5
> 5
Flow Direction
Project Site
Study Area
San Bernardino County, CA
NAD 1983 UTM Zone 11N
35.1622°N 116.1875°W
0 1,000 2,000
Feet
Meters
0 250 500
N
1:24,000
Base Map: Esri ArcGIS Online, accessed June 2024
Updated: 6/20/2024
Created by: KT
Project No. 68347
Layout: 68347_100yrExistingDepth
Aprx: 68347_WaterModelling202406
SWCA
ENVIRONMENTAL CONSULTANTS


100 Year Storm: Water Velocity
Existing Condtion
ft/s
< 1.5
1.5 - 2.5
2.5 - 3
3 - 3.5
3.5 - 4
> 4
Flow Direction
Study Area
Project Site
San Bernardino County, CA
NAD 1983 UTM Zone 11N
35.1564°N 116.184°W
0 1,000 2,000 Feet
0 250 500 Meters
N
1:24,000
Base Map: Esri ArcGIS Online, accessed June 2024
Updated: 6/20/2024
Created by: KT
Project No. 68347
Layout: 68347_100yrExistingVelocity
Aprx: 68347_WaterModelling202406
SWCA
ENVIRONMENTAL CONSULTANTS


100 Year Storm: Water Depth
Proposed Condition
ft
<1
1 - 2
2 - 3
3 - 4
4 - 5
>5
Flow Direction
Study Area
Project Site
San Bernardino County, CA
NAD 1983 UTM Zone 11N
35.1564°N 116.184°W
0 1,000 2,000 Feet
0 250 500 Meters
N
1:24,000
Base Map: Esri ArcGIS Online, accessed June 2024
Updated: 6/20/2024
Created by: KT
Project No. 68347
Layout: 68347_100yrProposedDepth
Aprx: 68347_WaterModelling202406
SWCA
ENVIRONMENTAL CONSULTANTS


100 Year Storm: Water Velocity
Proposed Condition
ft/s
< 1.5
1.5 - 2.5
2.5 - 3
3 - 3.5
3.5 - 4
> 4
Flow Direction
Project Site
Study Area
San Bernardino County, CA
NAD 1983 UTM Zone 11N
35.1564°N 116.184°W
0 1,000 2,000 Feet
0 250 500 Meters
N
1:24,000
Base Map: Esri ArcGIS Online, accessed June 2024
Updated: 6/20/2024
Created by: KT
Project No. 68347
Layout: 68347_100yrProposedVelocity
Aprx: 68347_WaterModelling202406
SWCA
ENVIRONMENTAL CONSULTANTS