Technical Memorandum

201 N. Civic Drive, Suite 115
Walnut Creek, CA 94569-3864

Prepared for: Monterey County

Project Title: Salinas River Groundwater Basin Investigation

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Technical Memorandum 5

Subject: Interim Progress Summary on Model Development

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To: Howard Franklin, Senior Hydrologist, MCWRA
Amy Woodrow, Hydrologist, MCWRA

cc: James Graydon, Vice President, Brown and Caldwell

From: Les Chau, Principal Investigator

Prepared by: Matthew Baillie, Principal Hydrogeologist
Alex Johnson, IT Program Manager
Nathan Foged, Supervising Engineer
Les Chau, Managing Geologist

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Section 1: Introduction

Brown and Caldwell (BC) is working with the Monterey County Water Resources Agency (MCWRA) to provide technical assistance to the County of Monterey (County) in response to Settlement Agreement M109451. BC is currently developing a baseline surface/groundwater model of the Salinas River basin.

The technical memorandum (TM) presented herein provides an interim summary of progress made to date on model development. This TM contains the additional four sections as follows:

- Section 2 describes input data development for the rainfall-runoff model.
- Section 3 discusses land use mapping.
- Section 4 discusses the status of data development for the model.
- Section 5 summarizes next steps and upcoming modeling activities.

Note that the model development process is ongoing; data and information presented in this document should be considered preliminary in nature and are provided to facilitate suggestions and feedback from the Technical Advisory Committee (TAC). As model development activities continue input values, data sources, software packages, and overall model setup may need to change to achieve the overarching goals of the project.

Section 2: Rainfall-Runoff Model Development

Hydrologic Simulation Program – Fortran (HSPF; Bicknell et al. 1997) is a comprehensive surface water model that uses long-term continuous meteorological data to simulate hydrologic processes, including rainfall-runoff from pervious and impervious land surfaces, evapotranspiration, and baseflow discharge to streams. The physical conditions of the Salinas River watershed are represented by a basin model that consists of land surface elements aggregated into drainage sub-basins in combination with a network of stream flow routing reaches. Climatic conditions are represented by meteorological time series data that are based on long-term records for precipitation, evaporation, and evapotranspiration. The following subsections describe the model setup and input data development.

2.1 Basin Model

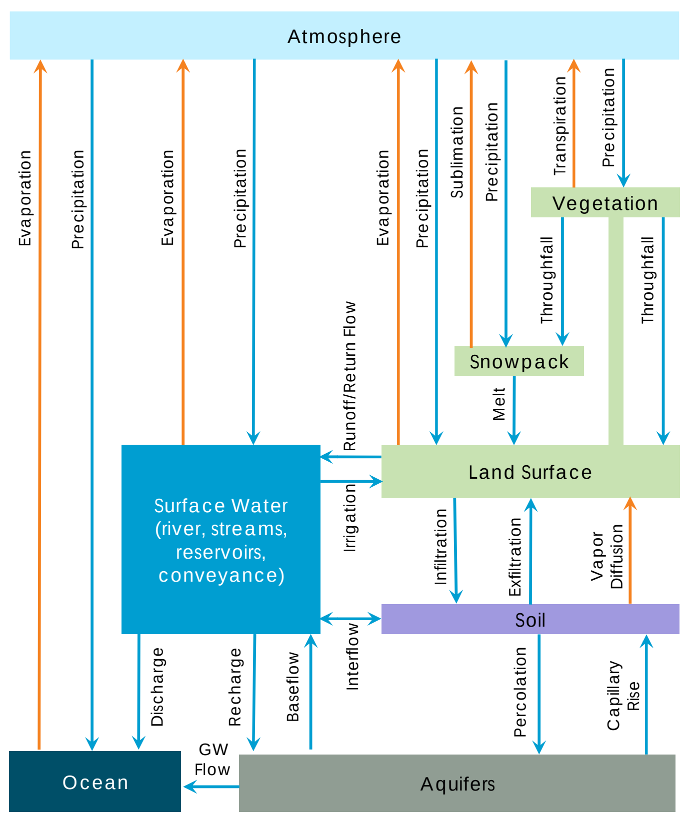

Figure 1. Schematic of hydrologic cycle

Adapted from Eagleson (1970)

Figure 1 is a schematic representation of the hydrologic cycle of a river basin. For this study, HSPF will be used to simulate rainfall-runoff processes and calculate streamflow hydrographs. As such, the primary focus of model is in the development of hydrologic response units (HRUs). Hydrologic processes simulated at the HRU level include interception, infiltration, soil storage, generation of direct surface runoff, near-surface interflow to streams, deep aquifer percolation, and evapotranspiration. Direct runoff, interflow, and baseflow return rates from

HRUs are multiplied by respective drainage areas to obtain total discharge rates to the stream network for each sub-basin within the model. The following subsections describe input data development for HRUs, sub-basins, and the network of stream flow routing reaches.

2.1.1 Hydrologic Response Units

HRUs are typically defined based on land surface conditions such as slope, surficial soils, and vegetated or impervious land cover. BC collected data, developed geospatial datasets, and prepared maps to assess slope, soil, and land cover conditions throughout the watershed, including the following:

- **Land surface slope.** BC developed a digital elevation model (DEM) for the Salinas River watershed using topographic data from the U.S. Geological Survey (USGS) National Elevation Dataset (NED; Gesch et al. 2002). NED data were obtained in a raster (gridded) format and used to develop shaded topographic relief (i.e., hillshade) and surface slope calculations (i.e., the maximum rate of change between each grid cell and its neighbors). The NED contains seamless topographic data at resolutions of 10 and 30 meters throughout the continental United States, built from about 54,000 individual DEM files covering 7.5-minute quadrangles. The data are provided in a consistent projection (the user can select the reference system). The elevation data are provided as a raster, with an elevation value provided for each cell of the raster.

  Two surface slope categories were identified: one representing shallow valley slopes (less than 2 percent) and a second representing steeper mountainous terrain (greater than 2 percent). Figure A-1 (Attachment A) shows the areas mapped as “valley” and “mountain” slopes.

- **Surficial soils.** BC developed a continuous coverage of surficial soils data for the Salinas River watershed using digitized soil survey data from the U.S. Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS). The NRCS has collected soil survey data for more than a century through the National Cooperative Soil Survey. Spatial and tabular data have been digitized in recent years and made available through the Soil Survey Geographic (SSURGO) database (1995). Delineated soil map units are classified into one of four hydrologic soil groups defined by the NRCS (USDA 1997; see Table 1). Figure A-2 (Attachment A) shows hydrologic soil group mapping for the Salinas River watershed. The digital data are based on soil surveys published for Monterey County in 1978 (USDA, 1978) and San Luis Obispo County in 1983, 1984, and 2003 (USDA, 1983, 1984, and 2003); digital data are considered by USDA to be current.

Table 1. NRCS Hydrologic Soil Groups		
Hydrologic Soil Group	Description	Water transmission rates
A	Low runoff potential and high infiltration rates even when thoroughly wetted; consist chiefly of deep, well to excessively drained sands or gravels and have a high rate of water transmission	greater than 0.30 inches per hour
B	Moderate infiltration rates when thoroughly wetted and consist chiefly of moderately deep to deep, moderately well to well drained soils with moderately fine to moderately coarse textures; moderate rate of water transmission	0.15 to 0.30 inches per hour
C	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 texture; low rate of water transmission	0.05 to 0.15 inches per hour
D	High runoff potential; 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; very low rate of water transmission	0 to 0.05 inches per hour

- **Land cover.** USGS's Multi-Resolution Land Characteristics (MRLC) Consortium developed the National Land Cover Database for the United States (NLCD; Homer et al., 2012). This dataset uses remote sensing data from the Landsat family of satellites, with a selected amount of ground-truthing to confirm the accuracy of the algorithms transforming the remotely sensed data into land use classifications. Classifications are quite broad, including open water, evergreen forest, deciduous forest, cultivated crops, developed land, and others; information on crop types, crop rotations, and irrigation methods are not available from NLCD. In addition to the 2011 data, land use coverages were also produced for 1992, 2001, and 2006. BC obtained 2011 NLCD mapping in a raster (gridded) format at a resolution of 30 meters; general land cover categories are listed in Table 2. Figure A-3 (Attachment A) shows the 2011 NLCD mapping for the Salinas River watershed.

Table 2. NLCD Land Cover Categories	
Raster Code	Land Cover
11	Open water
21	Developed, Open Space
22	Developed, Low Intensity
23	Developed, Medium Intensity
24	Developed, High Intensity
31	Barren Land
41	Deciduous Forest
42	Evergreen Forest
43	Mixed Forest
51	Scrub/Shrub
52	Grassland/Herbaceous
81	Pasture/Hay
82	Cultivated Crops
94	Woody Wetlands
95	Emergent/Herbaceous Wetlands

Although any number of land surface categories can be created in HSPF, each HRU must be defined as one of two fundamental surface types:

- **Pervious land surfaces** (or *PERLND* elements in HSPF) are conceptually defined with three possible routing layers; surface, shallow subsurface, and deeper subsurface, controlling flow runoff and pollutant SSURGO generation. Transmission through these layers is interdependent on rainfall intensity and duration on the surface, storage capacity, and infiltration rates among all three layers.
- **Impervious land surfaces** (or *IMPLND* elements in HSPF) are defined as one layer with potential surface storage and zero infiltration capacity. Runoff rates and pollutant generation depend on rainfall intensity, duration, and storage.

The slope, soil, and land cover conditions described previously apply mainly to pervious land surfaces, with the exceptions of the "developed" land cover categories, which inherently include both pervious and impervious surfaces. BC developed a list of pervious HRU categories based on observed combinations of land cover type, hydrologic soil group, and slope conditions (see Table 3).

Table 3. HRU Categories for Pervious Land Surfaces

PERLND Code	Land Use	Hydrologic Soil Groups (Table 1)	Slopes
101	Open water	NA	NA
105	Woody wetlands	NA	NA
106	Emergent herbaceous wetland	NA	NA
210	Developed (pervious areas)	A	valley
220	Developed (pervious areas)	B	valley
230	Developed (pervious areas)	C	valley
240	Developed (pervious areas)	D	Valley
310	Barren land (no vegetation)	A	Valley
320	Barren land (no vegetation)	B	Valley
330	Barren land (no vegetation)	C	Valley
340	Barren land (no vegetation)	D	Valley
350	Barren land (no vegetation)	A	Mountain
360	Barren land (no vegetation)	B	Mountain
370	Barren land (no vegetation)	C	Mountain
380	Barren land (no vegetation)	D	Mountain
410	Forested (deciduous, evergreen, mixed)	A	Valley
420	Forested (deciduous, evergreen, mixed)	B	Valley
430	Forested (deciduous, evergreen, mixed)	C	Valley
440	Forested (deciduous, evergreen, mixed)	D	Valley
450	Forested (deciduous, evergreen, mixed)	A	Mountain
460	Forested (deciduous, evergreen, mixed)	B	Mountain
470	Forested (deciduous, evergreen, mixed)	C	Mountain
480	Forested (deciduous, evergreen, mixed)	D	Mountain

Table 3. HRU Categories for Pervious Land Surfaces			
PERLND Code	Land Use	Hydrologic Soil Groups (Table 1)	Slopes
510	Scrub/shrub/grassland	A	Valley
520	Scrub/shrub/grassland	B	Valley
530	Scrub/shrub/grassland	C	Valley
540	Scrub/shrub/grassland	D	Valley
550	Scrub/shrub/grassland	A	Mountain
560	Scrub/shrub/grassland	B	Mountain
570	Scrub/shrub/grassland	C	Mountain
580	Scrub/shrub/grassland	D	Mountain
610	Pasture	A	Valley
620	Pasture	B	Valley
630	Pasture	C	Valley
640	Pasture	D	Valley
650	Pasture	A	Mountain
660	Pasture	B	Mountain
670	Pasture	C	Mountain
680	Pasture	D	Mountain
610	Cultivated crops	A	Valley
620	Cultivated crops	B	Valley
630	Cultivated crops	C	Valley
640	Cultivated crops	D	Valley

Preliminary input parameters for all HRU categories were selected based on recommendations from BASINS Technical Note 6 (EPA, 2000), professional experience with modeling similar watersheds in the region, and other relevant hydrologic studies. Table 4 describes HRU parameters for pervious surfaces. Table 5 describes HRU parameters for impervious surfaces.

Note that the HRU categories for the HSPF model will likely change as specific land use data are developed for the study (see Section 3).

Table 4. HSPF Modeling Parameter Descriptions and Selected Values for Pervious Land Surfaces

Parameter	Units	Description	Selected Value
FOREST	None	Fraction of land covered by forest that will continue to transpire in winter (i.e. coniferous). This is only relevant if snow is being considered (i.e., CSNOFG=1 in PWATER-PARM1).	0.0
LZSN	Inches	Lower zone nominal soil moisture storage. This parameter affects the proportion of water going to surface runoff, interflow and active groundwater	8.7
INFILT	in/hr	INFILT is the parameter that controls the overall division of the available moisture from precipitation (after interception) into surface runoff. This is NOT equivalent to a field-measured infiltration rate.	Varies based on land cover/soil condition
LSUR	Feet	Length of assumed overland flow plane. LSUR approximates the average length of travel for water to reach any drainage path such as streams, swales, ditches, etc.	400
SLSUR	ft/ft	Average slope of assumed overland flow path. Average SLSUR values for each land use being simulated can often be estimated directly with GIS capabilities.	0.05
KVARY	1/inches	Groundwater recession flow parameter used to describe non-linear groundwater recession rate	0.0
AGWRC	None	Groundwater recession rate, or ratio of current groundwater discharge to that from 24 hours earlier	0.99
PETMAX	Degrees F	Temperature below which ET will be reduced to 50% of that in the input time series	40.0
PETMIN	Degrees F	Temperature at and below which ET will be zero. PETMIN represents the temperature threshold where plant transpiration is effectively suspended	35.0
INFEXP	None	Exponent that determines how much a deviation from nominal lower zone storage affects the infiltration rate. This parameter is commonly set to a value of 2.	2.0
INFILD	None	Ratio of maximum and mean soil infiltration capacities. This parameter is commonly set to a value of 2.	2.0
DEEPFR	None	The fraction of infiltrating water that is lost to deep/inactive aquifers with the remaining fraction assigned to active groundwater storage that contributes base flow to the stream.	0.15
BASETP	None	ET by riparian vegetation as active groundwater enters streambed; specified as a fraction of potential ET, which is fulfilled only as outflow exists.	0.0
AGEWTP	None	Fraction of PERLND that is subject to direct evaporation from groundwater storage, e.g. wetlands or marsh areas.	0.0
CEPSC	inches	Amount of rainfall, in inches, which is retained by vegetation, never reaches the land surface, and is eventually evaporated.	Varies based on land cover/soil condition
UZSN	inches	Nominal upper zone soil moisture storage. UZSN is related to land surface characteristics, topography, and LZSN.	Varies based on land cover/soil condition
NSUR	None	Manning's friction coefficient, n, for overland flow plane.	Varies based on land cover/soil condition
INTFW	None	Coefficient that determines the amount of water that enters the ground from surface detention storage and becomes interflow	10.0
IRC	None	Interflow recession coefficient IRC is the ratio of the current daily interflow discharge to the interflow discharge on the previous day.	0.80
LZETP	None	Index to lower zone evapotranspiration LZETP affects ET from the lower zone, which represents the primary soil moisture storage and root zone of the soil profile.	Varies based on land cover/soil condition

Note: parameter descriptions were obtained from the EPA BASINS Technical Note 6.

Table 5. HSPF Modeling Parameters for Impervious HRUs			
Parameter	Units	Description	Selected Value
LSUR	feet	Length of assumed overland flow plane	500
SLSUR	dimensionless	Average slope of the assumed overland flow path	0.005
NSUR	dimensionless	Manning's n for overland flow plane	0.300
RETSC	inches	Retention (interception) storage of the impervious surface	0.300
PETMAX	Degrees F	Temperature below which ET will be reduced to 50% of that in the input time series	40.0
PETMIN	Degrees F	Temperature at and below which ET will be zero. PETMIN represents the temperature threshold where plant transpiration is effectively suspended	35.0
RETS	inches	initial value for storage of water in retention	0.0
SURS	inches	initial value for storage of water in surface ponding	0.0

Note: Input parameters were not varied by impervious surfaces type

2.1.2 Subbasin Areas

As a lumped-element, or lumped-parameter model, input parameters describing the land surface conditions of the watershed are averaged over discrete areas (i.e., sub-basins) and thus do not retain detailed information pertaining to their spatial distribution. HRU outputs, such as runoff rates, are assigned to sub-basins in HSPF using a coded *SCHEMATIC* block where calculated areas for each HRU category (i.e., area factors) are multiplied by the outputs from the corresponding HRU process, assuming the HRU represents one area unit. An example is shown below in Figure 2.

```
SCHEMATIC
*** SCHEMATIC BLOCK - PERLND (SURO, IFWO, AGEO) PERO AND IMPLND ***
<-Source->                  <--Area-->     <-Target >   MSLK      ***
<Name>   #                  <-factor->     <Name>   #   Tbl#      ***

*** SUB-BASIN 212
PERLND 110                           0     RCHRES 212      5
PERLND 120                           0     RCHRES 212      5
PERLND 130                      78.581     RCHRES 212      5
PERLND 140                       7.956     RCHRES 212      5
PERLND 210                           0     RCHRES 212      5
PERLND 220                           0     RCHRES 212      5
PERLND 230                      56.992     RCHRES 212      5
PERLND 240                       2.247     RCHRES 212      5
PERLND 310                           0     RCHRES 212      5
PERLND 320                           0     RCHRES 212      5
PERLND 330                      80.478     RCHRES 212      5
PERLND 340                       1.875     RCHRES 212      5
PERLND 410                       0.011     RCHRES 212      5
PERLND 420                      16.888     RCHRES 212      5
PERLND 421                      11.375     RCHRES 212      5
PERLND 500                      45.316     RCHRES 212      5
IMPLND 910                           0     RCHRES 212      6
IMPLND 920                      40.037     RCHRES 212      6
IMPLND 921                      45.718     RCHRES 212      6
IMPLND 922                       6.456     RCHRES 212      6
IMPLND 923                      23.871     RCHRES 212      6
IMPLND 924                       5.054     RCHRES 212      6
IMPLND 925                        5.22     RCHRES 212      6
```

Figure 2. Example SCHEMATIC block inputs from HSPF User Control Input (UCI) file

Input for Subbasin 212 shows the number of acres associated with each PERLND and IMPLND code

The breakdown of the full basin into smaller sub-basins depends on the size and complexity of the basin model. In particular, sub-basins must be delineated for smaller sub-watersheds or drainage areas where specific outputs (e.g., discharge hydrographs) are needed. For this study, the HSPF model needs to provide streamflow hydrographs as boundary inputs to the groundwater model, thus sub-basins will need to be created near the groundwater model domain boundary for tributary streams.

Due to the size of the basin and the large number of sub-basins needed around groundwater model domain, BC decided to use automated geospatial techniques to perform sub-basin delineations. The basic data needed to perform automated delineations are a hydrologically-conditioned DEM[1] and a set of discharge nodes, or "pourpoints."

BC performed initial work on delineating the interface between the surface and ground water models. The interface will occur at "discharge nodes" of the surface water model. The nodes will be used as "pourpoints" for the surface water model, which will delineate the surface water sub-basins. Generally speaking, the nodes will be located where significant surface water flow lines intersect the groundwater study area boundary, though some will likely be adjusted from these locations (see more discussions below). Flow lines being used are taken from the NHD. Surface water flows will be modeled at these nodes, and those flows will be used as input to the surface water routing package of the groundwater/surface water model. The surface water study area currently being considered includes the NHD HUC 8 zones 18060005 (Salinas) and 18060004 (Estrella), and the portions of zone 18060015 (Monterey Bay) south of Elkhorn Slough.

Horizon Systems Corporation developed a geospatial data for the US Environmental Protection Agency called NHDPlus (Horizon Systems 2015). The NHDPlus dataset includes hydrologically-conditioned DEM data derived from 30-meter NED data. BC used these data to perform an initial auto-delineation for the Salinas River watershed. Given a set of selected pourpoints, the auto-delineation process created a preliminary set of approximately 200 sub-basins (see Attachment A, Figure A-4). Based on our initial review of the data some corrections, manual adjustments, and post-processing of the sub-basins will be necessary.

2.1.3 Stream Network

HRUs generate direct runoff, interflow, and in some cases groundwater outflow (i.e., baseflow), which are aggregated to obtain sub-basin outflows and routed into a network of stream flow routing reaches that represent the Salinas River and its tributaries. BC obtained geospatial stream data from the USGS National Hydrography Dataset (NHD; Simley and Carswell 2009). The NHD includes line, point, and polygon features representing a wide array of features, including streams, canals, flumes, weirs, reservoirs, and others, as well as watershed boundaries for individual streams. Figure A-5 (Attachment A) shows the NHD data. NHD data are provided un-projected in the Geographic Coordinate System, in decimal degrees. The horizontal datum is the North American Datum of 1983 (NAD83), and the vertical datum is the National Geodetic Vertical Datum of 1929 (NGVD29).

Stream channels will be divided into reaches at sub-basin boundaries such that each sub-basin contains one reach. Stream reaches (or *RCHRES* elements in HSPF) require some basic input parameters (e.g., length, slope) and a stage-storage-discharge routing table (or *F-Table* in HSPF).

2.2 Meteorological Time Series

HSPF requires time-variable precipitation and potential evapotranspiration (ET) data covering the simulation period. BC downloaded hourly precipitation data for selected National Oceanic and Atmospheric Administration (NOAA) stations via the National Centers for Environmental Information (NCEI). Precipitation records are available from more than 50 weather stations within the Salinas River watershed. A map of weather stations with precipitation data is provided in Attachment A, Figure A-6.

[1] A hydrologically-conditioned DEM refers to preprocessing steps needed to enforce flow direction and flow accumulation rules.

BC prepared a graph of hourly precipitation data periods of record (Figure 3, below) for selected weather stations. Hourly precipitation data from various stations may need to be extended or gaps may need to be filled based on inferred data from other nearby stations. In addition, the precipitation data used for the HSPF model will need to be reconciled with the monthly precipitation data records to be used for groundwater modeling. The precipitation data time series will ultimately be stored in a Watershed Data Management (WDM) file, which is a direct-access binary file used by HSPF for time series data inputs.

ID	Name	Begin Date	End Date
040790	BIG SUR STATION CA US	12/1/1996	12/7/2013
040322	ARROYO SECO CA US	12/1/1948	12/7/2013
041864	COALINGA CA US	7/1/1948	12/1/2013
041867	COALINGA 1 SE CA US	7/1/1948	5/1/1979
042362	DEL MONTE CA US	7/1/1948	12/7/2013
044555	KING CITY CA US	7/1/1948	2/1/1999
044706	PARKFIELD 7 NNW CA US	7/1/1948	12/18/2013
044762	LA PANZA CA US	10/1/1975	3/24/1994
044767	LA PANZA RANCH CA US	7/1/1948	7/1/1975
045017	LOCKWOOD 1 N CA US	7/1/1948	1/1/1980
045802	MONTEREY NWSFO CA US	7/1/1995	12/7/2013
046703	PARKFIELD CA US	2/1/1970	7/1/1975
046708	PARKFIELD 8 NNW CA US	5/1/1952	9/1/1959
046742	PASO ROBLES MUNICIPAL AIRPORT CA US	7/1/1948	12/18/2013
047669	SALINAS MUNICIPAL AIRPORT CA US	7/1/1948	12/7/2013
047834	SAN JUAN BAUTISTA CA US	7/1/1948	2/1/1988
047933	SANTA MARGARITA BOOST CA US	1/1/1971	1/1/2013

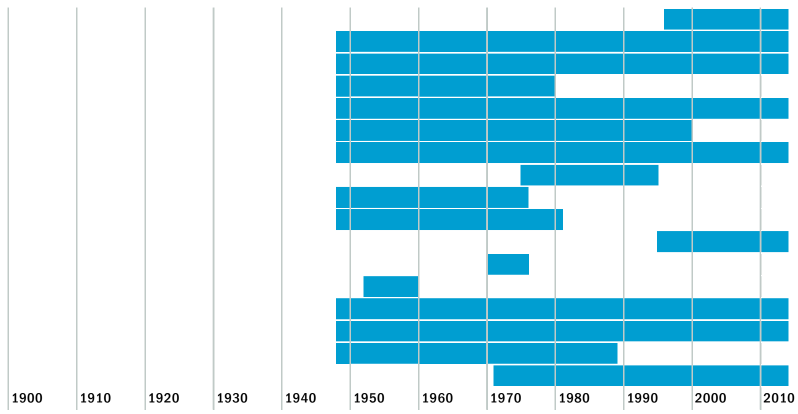

Figure 3. Periods of record for NOAA Co-op Weather Stations

In addition to the measurements at individual weather stations, BC will use spatial climate coverages from the USGS Basin Characterization Model (BCM), which utilized a statistical downscaling process to produce monthly rainfall throughout California at a 270-meter resolution from coarser (4-km resolution) maps. These coverages are available starting in 1895, and were created using measurements from weather stations as calibration data. These coverages have been compared to measurements at NOAA stations, and there is an excellent correlation between the two sets of data.

2.3 Streamflow Time Series

BC collected and reviewed USGS daily streamflow data[2] for use in model calibration. Streamflow data are collected automatically using telemetric dataloggers that measure stream stages and translate them into discharges, using a stage-discharge relationship established and maintained through a program of field measurements.

Figure A-7 (Attachment A) shows 39 gages located within the Salinas River watershed. Of the 39 gages, 30 were active for all or part of the baseline simulation period from October 1966 through 2014 (see Figure 4). Gages that were active for only part of the baseline simulation period are still useful for calibration because calibration simulations can be performed for smaller periods within the full baseline period.

[2] USGS streamflow data available from the National Water Information System (NWIS): http://nwis.waterdata.usgs.gov/nwis/.

ID	Name	Begin Date	End Date
11143300	ARROYO DEL REY A DEL REY OAKS CA	10/1/1966	9/30/1978
11143500	SALINAS R NR POZO CA	10/1/1942	9/30/1983
11144000	TORO C NR POZO CA	10/1/1960	9/30/1983
11144200	SALSIPUEDES C NR POZO CA	10/1/1969	9/30/1983
11144600	SALINAS R BL SALINAS DAM NR POZO CA	10/1/1973	4/9/1986
11145000	SALINAS R AB PILITAS C NR SANTA MARGARITA CA	7/28/1942	10/3/1975
11145500	SALINAS R NR SANTA MARGARITA CA	4/1/1922	9/30/1949
11147000	JACK C NR TEMPLETON CA	10/1/1949	9/30/1978
11147040	SANTA RITA C TRIB NR TEMPLETON CA	8/1/1967	9/30/1972
11147070	SANTA RITA C NR TEMPLETON CA	10/1/1961	9/30/1994
11147500	SALINAS R A PASO ROBLES CA	11/1/1939	6/16/2015
11147600	HUERHUERO C NR CRESTON CA	10/1/1958	9/30/1972
11147700	CHOLAME C TRIB NR CHOLAME CA	10/1/1958	9/30/1965
11147800	CHOLAME C NR SHANDON CA	10/1/1958	9/30/1972
11148000	ESTRELLA R NR PASO ROBLES CA	10/1/1939	9/30/1941
11148500	ESTRELLA R NR ESTRELLA CA	10/1/1954	9/30/1996
11148800	NACIMIENTO R NR BRYSON CA	10/1/1955	9/30/1971
11148900	NACIMIENTO R BL SAPAQUE C NR BRYSON CA	9/16/1971	6/16/2015
11149400	NACIMIENTO R BL NACIMIENTO DAM NR BRADLEY CA	10/1/1957	6/16/2015
11149500	NACIMIENTO R NR SAN MIGUEL CA	10/1/1939	9/30/1957
11149650	SULPHUR SPRINGS CYN NR JOLON CA	10/1/1967	9/30/1969
11149700	SAN ANTONIO R A SAM JNS BR NR LOCKWOOD CA	7/1/1958	9/30/1965
11149900	SAN ANTONIO R NR LOCKWOOD CA	10/1/1965	6/16/2015
11150000	SAN ANTONIO R A PLEYTO CA	10/1/1929	9/30/1965
11150500	SALINAS R NR BRADLEY CA	10/1/1948	6/16/2015
11150800	COW C NR SAN ARDO CA	10/1/1960	9/30/1964
11151000	SAN LORENZO C NR KING CITY CA	4/1/1940	9/30/1942
11151300	SAN LORENZO C BL BITTERWATER C NR KING CITY CA	10/1/1958	6/16/2015
11151500	SAN LORENZO C A KING CITY CA	10/1/1942	9/30/1945
11151700	SALINAS R A SOLEDAD CA	10/1/1968	6/16/2015
11151870	ARROYO SECO NR GREENFIELD CA	10/1/1961	9/30/1986
11152000	ARROYO SECO NR SOLEDAD CA	10/1/1901	6/16/2015
11152050	ARROYO SECO BL RELIZ C NR SOLEDAD CA	10/1/1994	6/16/2015
11152300	SALINAS R NR CHUALAR CA	10/1/1976	6/16/2015
11152540	EL TORO C NR SPRECKELS CA	10/1/1961	9/30/2001
11152500	SALINAS R NR SPRECKELS CA	10/1/1929	6/16/2015
11152570	ALISAL C NR SALINAS CA	10/1/1970	9/30/1974
11152600	GABILAN C NR SALINAS CA	10/1/1970	9/30/2014
11152650	RECLAMATION DITCH NR SALINAS CA	10/1/1970	6/16/2015

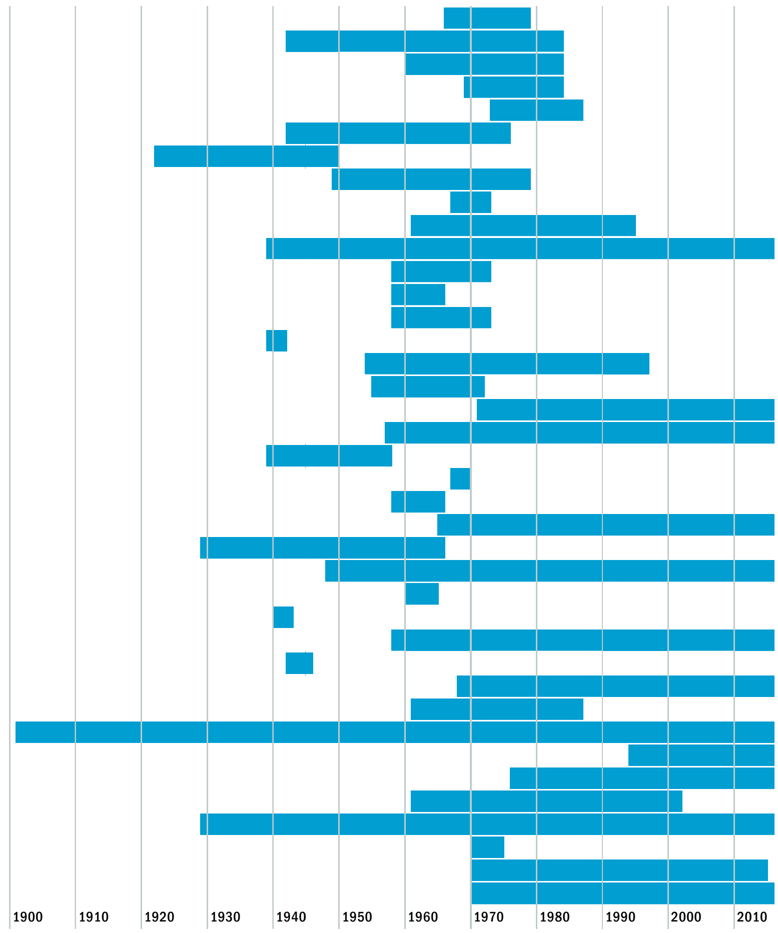

Figure 4. Periods of record for USGS Streamflow Gages

Section 3: Land Use Map Development

BC is developing the current land use map for use in the groundwater model, paying specific attention to the crop types and cropping patterns in the basin. The requirements of the final land use map for this effort include adequate spatial and temporal coverages, as well as adequate agricultural land use detail for input into the MODFLOW Farm Process (FMP; Schmid et al., 2006; Schmid and Hanson, 2009; Hanson et al., 2014). The purpose of FMP is to quantify the components of water supply and demand in agricultural settings; it does this by estimating crop water demand using crop types, crop-specific parameters, and irrigation methods, then meeting the crop demand using local precipitation and available surface water and groundwater supply. While broad classifications of crop type can be used in FMP, greater accuracy can be achieved if more specific information on the spatial and temporal variability of crop type is known.

The following data sources were reviewed for potential use in developing the land use map:

- California Department of Water Resources (DWR) Land Use Surveys (1997): DWR has collected land use data throughout California since 1976, with most of the surveys covering a single county each. Monterey County was last surveyed in 1997. The DWR survey for Monterey County categorized land use into 18 classifications, with agricultural areas broken up into broad crop categories (field crops, truck crops, vine-yards, etc.) and separated from native vegetation, urban areas, and others. Unless a category correlates directly to a single crop type (e.g. vineyards), the DWR land use information does not contain crop types, nor does it provide insight into irrigation methods or crop rotation. (http://www.water.ca.gov/landwateruse/lusrvymain.cfm)

- 2010 California Water Service Company (Cal Water) Urban Water Management Plan (UWMP; Cal Water, 2011): The Cal Water UWMP for the Salinas District includes a listing of the percentage of Cal Water's Salinas District covered by several land use types, with the bulk of the area classified as residential. Land use is determined based on the connection category of each service connection. The Salinas District connections do not include any agricultural users, so the UWMP can only be used to categorize land use within the urban area around Salinas.
- USDA Aerial Imagery: The USDA Farm Service Agency provides aerial imagery covering the study area that was collected during 2014 (and in previous years). While the aerial imagery does not have land use information attached to the imagery, the aerial photographs can be used to confirm land use data from other sources and to identify areas with observed changes in land use (by comparison with aerial photographs from previous years). (http://www.fsa.usda.gov/programs-and-services/aerial-photography/index)
- USDA National Agricultural Statistics Service (NASS) Cropland Data Layer (CDL): Hosted on CropScape, the CDL is a raster dataset of crop type that has been collected in the study area annually from 2007 to 2014. The crop type data are derived from the Thematic Mapper (TM) and Enhanced Thematic Mapper Plus (ETM+) sensors on the Landsat family of satellites, ground-truthed by the USDA. The 2014 CDL data have a resolution of 30 meters. The CDL data are categorized into a large variety of individual crop types as well as non-agricultural categories. However, the accuracy of the crop type classifications is highly questionable. For example, there are many examples of crop type varying on a pixel-by-pixel basis (indicating crops covering an area of only about a quarter acre), and there are several areas just southeast of Salinas given a crop type of rice. Therefore, the CDL crop type data will not be used to inform the 2014 land use map. (http://nassgeodata.gmu.edu/CropScape/)
- Salinas Valley Integrated Ground and Surface Water Model (SVIGSM) Land Use Maps: Land use maps were prepared for the SVIGSM so that it could estimate water supply and demand in an integrated groundwater/surface water system. Land use was categorized into 10 different classifications, including several different broad categories of agriculture (including field crops, orchard, vineyard, grain, and others). In addition, non-irrigated and idle areas were noted. BC was provided with land use maps for 1995 (the end of the period of the SVIGSM model documented by MW, 1997) and 2030.
- SVIGSM 2012 Update (LSCE, 2015): Luhdorff and Scalmanini Consulting Engineers (LSCE), in association with Environmental Science Associates (ESA), prepared a map of land use representing 2012 conditions for use in the update of the SVIGSM. Land use was updated based on the existing 1997 land use provided by MCWRA and aerial photography from 2012. Land use updates were concentrated in the Pressure and East Side Subareas, with less emphasis placed on modifying land use in the Forebay and Upper Valley Subareas. Land use was categorized using the classifications already used in the existing SVIGSM, consisting of 10 fairly broad land use categories, including truck crops, field crops, vineyards, native vegetation, urban areas, and others. Land use over the period from 1995 (the end of the duration of the SVIGSM in MW, 1997) to 2011 was determined using linear interpolation between the 1994 and 2012 land use maps.
- Adopted 2010 Monterey County General Plan: The Adopted General Plan contained maps of land use throughout Monterey County. These maps classify land use into about 18 categories, including 4 different agricultural categories. The General Plan land use data are not associated with any kind of crop type information. (http://www.co.monterey.ca.us/planning/gpu/gpu_2007/2010_mo_co_general_plan_adopted_102610/2010_mo_co_general_plan_adopted_102610.htm)

- California Department of Conservation Farmland Mapping and Monitoring Program (FMMP) Maps (Biannual 1984-2012): FMMP publishes land use data on a county-by-county basis throughout California every two years. The data are provided as GIS files, maps, and spreadsheets quantifying the area of changes in land use type between surveys. Land is classified into uses based on current aerial photos, correspondence with locals, related GIS data, and ground-truthing. Areas are classified into one of 8 land use categories, including four different types of farmland; these four categories are not associated with crop types, so there is no crop-type information included in FMMP. (http://www.conservation.ca.gov/dlrp/FMMP/Pages/Index.aspx)
- California Department of Pesticide Regulation (DPR) CalAgPermits Ranch Maps (2012-2015; irregular period, usually every few months): The CalAgPermits program produces ranch maps made up of polygons representing individual ranches throughout California. There is no land use or crop type information associated with the spatial data, but the tabular data do include permit and site numbers that are used in the pesticide use data (see below). (https://www.calagpermits.org/)
- Monterey County Office of the Agricultural Commissioner Ranch Maps (electronic versions available for 2008, 2011, and 2014; paper copies also available for earlier years): The Office of the Agricultural Commissioner develops its own set of ranch maps based on those of the CalAgPermits. The Agricultural Commissioner cleans up the polygons produced by CalAgPermits, making sure that polygons do not overlap, and that boundaries line up together. Therefore, they are considered more useful for the spatial analysis of land use. Also unlike the CalAgPermits ranch maps, the data for these ranch maps are associated with crop type information, although this can be categorized quite broadly (e.g. "Rotational Crops"). The Office of the Agricultural Commissioner ranch map data are associated with permit and site numbers used by DPR, as with the CalAgPermits maps. (http://www.co.monterey.ca.us/government/departments-a-h/agricultural-commissioner/forms-publications/ranch-maps)
- DPR California Pesticide Information Portal (CalPIP) Pesticide User Reporting Database (1990-2013): The CalPIP database includes copious data on pesticide applications throughout California, including planting location, crop type, crop acreage, pesticide amount applied, and permit number, among others. All pesticide use in California has to be reported by the users to the CalPIP system each year, with pesticide use provided on a monthly time step. In recent years, the permit number included in the CalPIP database has corresponded to the permit number used in the AgComm ranch maps (see above); however, until recently permit numbers were recycled and changed from year to year, so current permit numbers for a given agricultural area will not necessarily correspond to that same agricultural area in previous years.

Based on this review, BC has identified the following as the most appropriate for development of the baseline 2014 land use map:

- DWR 1997 Land Use Survey, which covers the entirety of Monterey County, including areas outside of the groundwater basin;
- The adopted 2010 General Plan (for Urban and Vegetation Land Uses)
- The Agricultural Commissioner Ranch Maps (2014)
- CalPIP Data (2013)

These sources, when combined, will provide the most complete spatial coverage throughout the model domain, will satisfy the temporal coverage requirements, and the CalPIP data will provide the necessary crop type detail for agricultural land use.

The Urban and Vegetation Layers from the 2010 General Plan will be used directly for these two land use classifications. The CalPIP data will be integrated with the Ranch Maps from the Agricultural Commissioner for the agricultural land use in FMP as follows:

The CalPIP pesticide application data includes the crop to which the pesticide was applied. These applications are correlated to individual ranch polygons from the Ranch Maps. These two sources will be combined to create a set of polygons (the ranches) and their planted crops through time. Figure 5 illustrates this process as; a) GIS thematic layers (Farms, Crop Types, etc) and, b) GIS layers of changes in crop patterns through time (vertical two-headed arrows on the right edges). The individual crops will be aggregated into cropping categories (e.g. vineyard, truck crops, berries, orchard, etc.), resulting in a set of polygons and their planted cropping categories through time. The actual ranch boundaries may be further aggregated into areas of similar crop type, as may be convenient, which will become the "Farms" used in FMP. The groundwater model will then apply these cropping categories to each model grid cell and stress period.

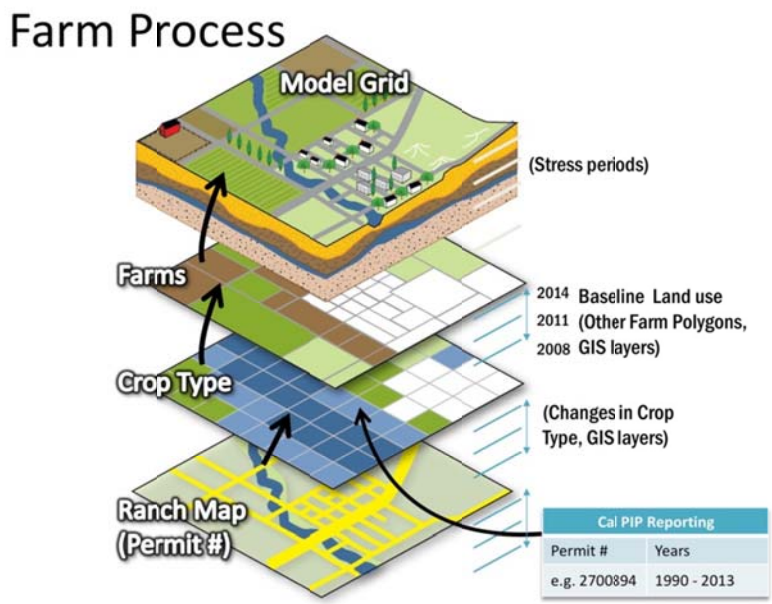

Figure 5. FMP spatial data relationships

BC anticipates that the CalPIP data will not provide complete spatial coverage of the model area; for example, it does not include data for areas where pesticides were not used, such as farms growing organic crops. Once BC develops this CalPIP-derived crop coverage dataset, a gap analysis will be done to determine the extent of the datagaps that exist. BC will then determine how to most effectively fill the remaining data gaps using the other data sources reviewed, or through another method, for example interpolating based on surrounding crop types. Additional data on crop patterns will also be sought from stakeholders during upcoming public meetings.

Section 4: Data Management

BC is finalizing our understanding of the outstanding data needs for the various model efforts, and identifying the data sources. Table 6 below provides a listing of data needs for the groundwater/surface water model, along with an indication of whether or not they are still outstanding, and a potential source for the data if they have not been acquired. The geodatabase structure of the data for linkage into the GW/SW model is being developed. As discussed in the preceding sections, data sources BC is compiling include:

- Land Use: NLCD, 2011 (http://www.mrlc.gov/)
- Soils: SSURGO database (http://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/survey/geo/?cid=nrcs142p2_053627)
- Elevation: NED (http://nationalmap.gov/elevation.html)
- Hydrography: NHD (http://nhd.usgs.gov/)
- Historical Weather Information: USGS BCM (http://ca.water.usgs.gov/projects/reg_hydro/projects/dataset.html) and NCEI (http://www.ncdc.noaa.gov/)
- Historical Streamflow: USGS National Water Information System (NWIS) (http://waterdata.usgs.gov/nwis)

Table 6. Data Compilation Status			
Data Description	Model Package	Acquisition	Source
Reservoir Operation Rules	WaterOps	No	MCWRA
Reservoir Storage-Stage-Area Relationship	WaterOps	No	MCWRA
Precipitation	WaterOps, FMP3, HSPF	Yes	USGS
Open-Water Evaporation	WaterOps	?	USGS
Historical Reservoir Releases	WaterOps, SFR2	Yes	MCWRA
Reservoir Inflow	WaterOps	No	BC
Stream Locations	SFR2	Yes	USGS
Streambed Shape	SFR2	No	TNC, MCWRA?
Streambed Thickness	SFR2	No	TNC?, MCWRA?
Streambed Material	SFR2	No	TNC?, MCWRA?
Historical Streamflow	SFR2	Yes	USGS
Engineered Structure Locations	SWR1	Part	NHD/Aerial Imagery/Stakeholders
Engineered Structure Shapes	SWR1	No	MCWRA/Stakeholders?
Engineered Structure Materials	SWR1	No	MCWRA/Stakeholders?
Timing of Construction/Modification of Engineered Structures	SWR1	No	MCWRA/Aerial Imagery/Stakeholders
Engineered Structure Diversion Rates	SWR1	No	MCWRA?
Drain Locations	DRT	No	Stakeholders
Drain Shapes	DRT	No	Stakeholders
Drain Materials	DRT	No	Stakeholders
Timing of Construction/Modification of Drains	DRT	No	Stakeholders
Well Locations	MNW2	Part	MCWRA
Well Construction Information	MNW2	Part	MCWRA
Well Destruction Information	MNW2	No?	MCWRA
Pumping Data	MNW2	Yes	MCWRA
Fault Locations	HFB	Yes	USGS
Fault Transmissivities	HFB	No	??
Offshore Locations of Model Layer Outcrops	SWI2	Part	Studies
Initial Locations of Isoconcentration Surfaces	SWI2	Part	MCWRA
Land Use (Including Crops; Variable in Space & Time)	FMP3	Part	SVIGSM, CalPIP, AgComm, MCWRA, Stakeholders, etc.
Irrigation Practices (Variable in Space & Time)	FMP3	No	Stakeholders
Water Rights	FMP3	No	State Water Resources Control Board
Surface Water Diversions	FMP3	No	MCWRA, Stakeholders
Well-Farm Relationships	FMP3	No	BC

Table 6. Data Compilation Status			
Data Description	Model Package	Acquisition	Source
Reference Evapotranspiration	FMP3, HSPF	Part	CIMIS, BCM
Topography	FMP3, HSPF	Yes	USGS
Soil Type	FMP3, HSPF	Yes	USDA
Soil Hydrologic Information	FMP3, HSPF	Yes	USDA
Root Zone Depth	FMP3	Part	USGS
Crop Coefficients (By Crop; Variable In Time)	FMP3	Part	USGS
Other Crop Info...	FMP3	Part	USGS

Section 5: Future Steps

Although effort in August focused strongly on development and construction of the rainfall-runoff model, BC continues to also develop the groundwater/surface water model in parallel. BC has prepared templates for input files for some of the packages utilized by MODFLOW-OWHM, including the Farm Process (FMP3), Streamflow Routing (SFR2), Surface-Water Routing (SWR1), and Drain-Return Flow (DRT1). These template files will increase the efficiency of model construction when information specific to the study area is compiled, including streamflow output from the rainfall-runoff model, surface water body physical data, land use distribution, and others. The templates are based in part on the structures of input files used in the USGS Pajaro Valley Hydrologic Model, and make use of calling of external input files (such as precipitation time series) to reduce the size of the MODFLOW input files.

In the coming months, the rainfall-runoff model output and the Baseline (2014) land use information will become available for inclusion into the groundwater/surface water model. Groundwater/surface water model construction will accelerate once these steps are completed. Figure 6 presents a current schedule for model development and TAC meetings.

Task	Start	Finish	May	June	July	Aug	Sep	Oct	Nov	Dec
Task 3 - Conceptual Model	1/1/2015	9/31/2015								
Task 4 - Modeling Tools Assessment/Selection	4/1/2015	5/31/2015								
Task 5 - GW/SW Model Development	5/1/2015	10/30/2015								
Task 6 - Model Calibration (Baseline 2014 & Sensitivity Run)	10/1/2015	12/30/2015								
Task 10 TAC Meetings			12-May	9-Jun	14-Jul			13-Oct	10-Nov	8-Dec
Proposed TAC meeting Topic			Model Selection	Model Construction /BC/ IC	Model Boundary Conditions	No Meeting	No Meeting	Model Calibration	Model Calibration	Sensitivity & Uncertainty analyses/ Simulation

Figure 6. Current 2015 Schedule

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Appendix A: Model Development Data

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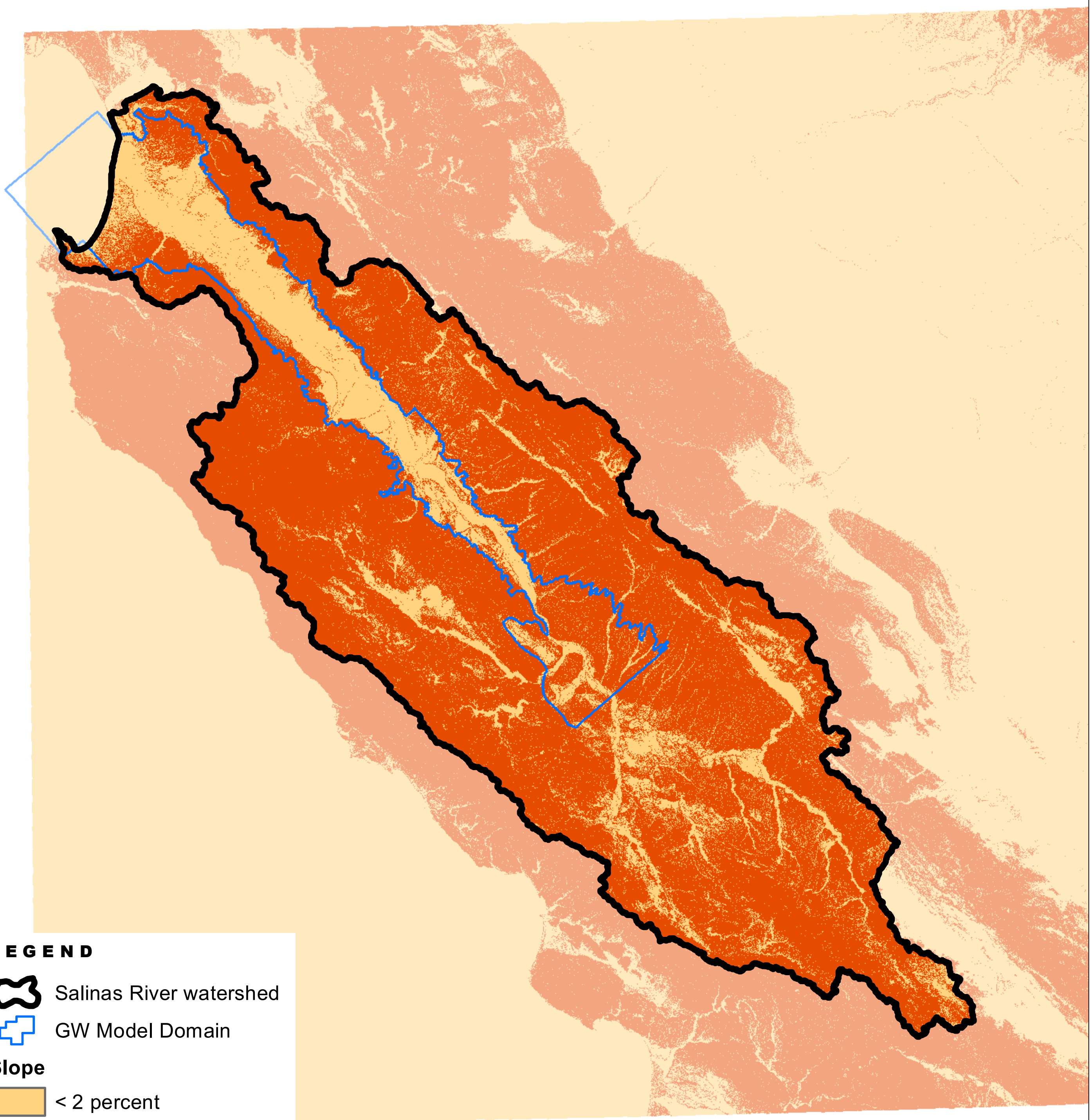

Source: slope calculated as the maximum rate of change between each grid cell and its neighbors using USGS NED data

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1 inch = 100,000 feet

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FIGURE A-1

LAND SURFACE SLOPE CATEGORIES FOR RAINFALL-RUNOFF MODEL

Salinas River Groundwater Basin Investigation
Monterey County

Project Number 146430

DRAFT

Brown AND Caldwell

9/10/2015

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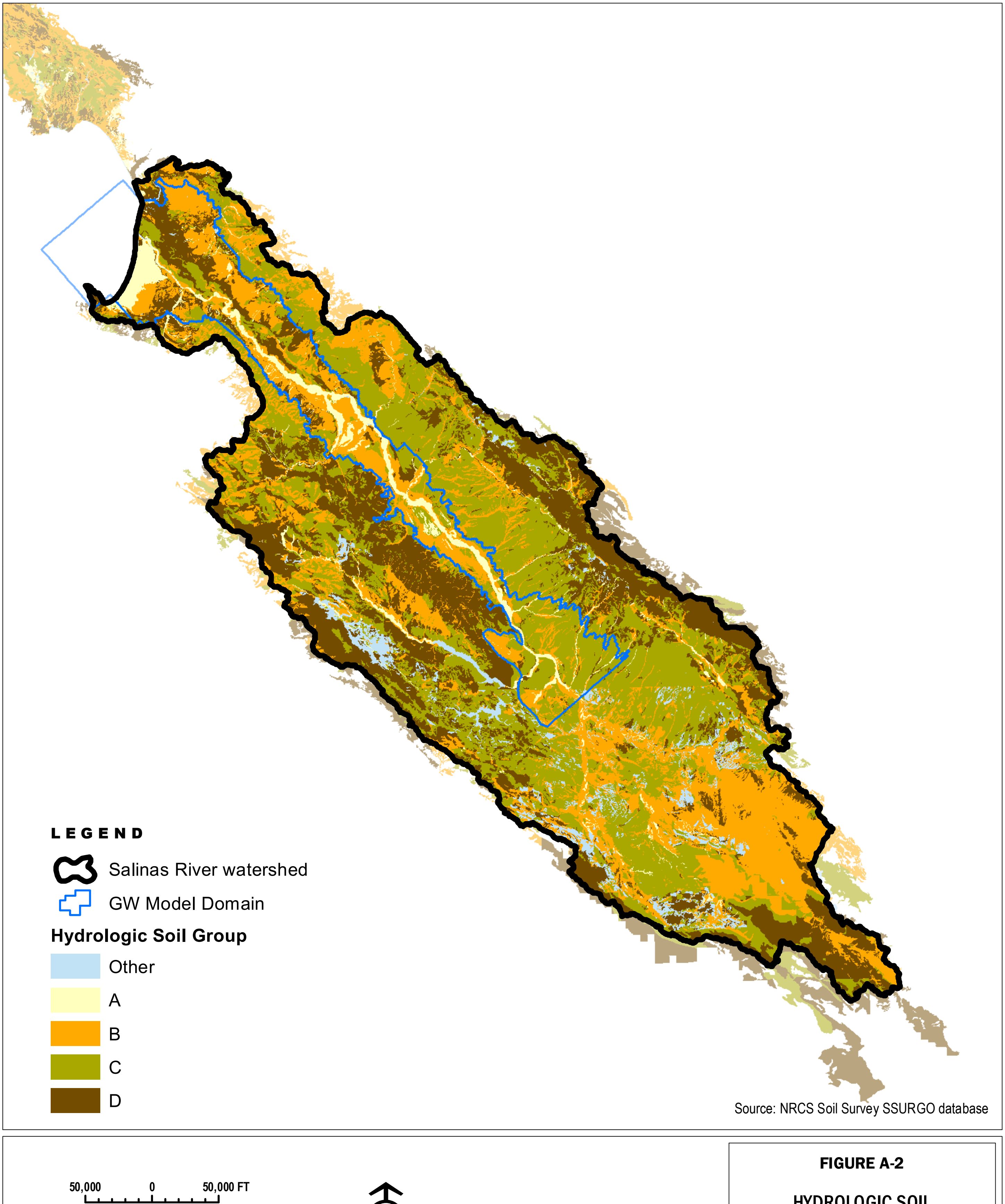

FIGURE A-2

HYDROLOGIC SOIL GROUPS FOR RAINFALL-RUNOFF MODEL

Salinas River Groundwater Basin Investigation
Monterey County

Project Number 146430

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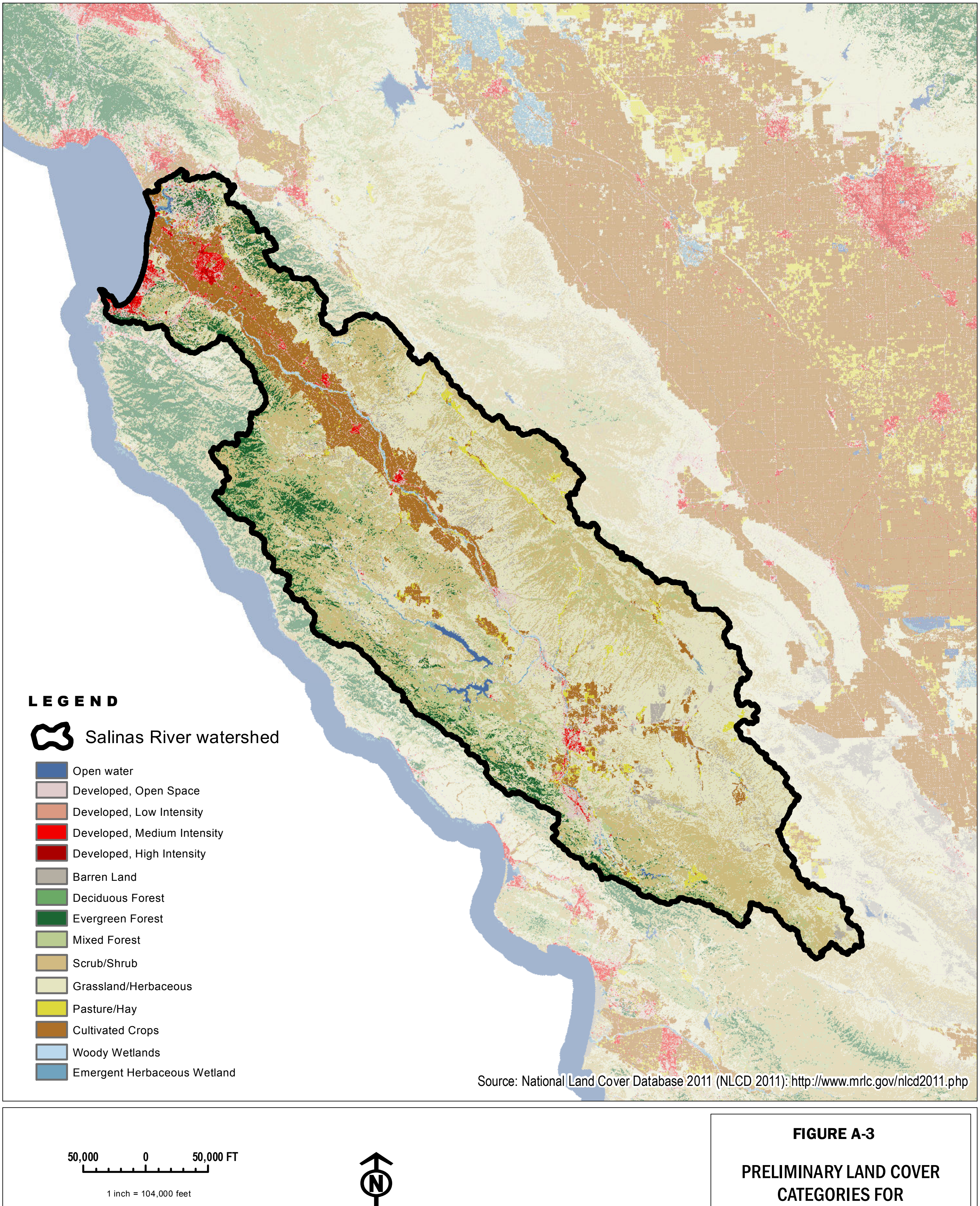

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FIGURE A-3

PRELIMINARY LAND COVER CATEGORIES FOR RAINFALL-RUNOFF MODEL

Salinas River Groundwater Basin Investigation
Monterey County

Project Number 146430

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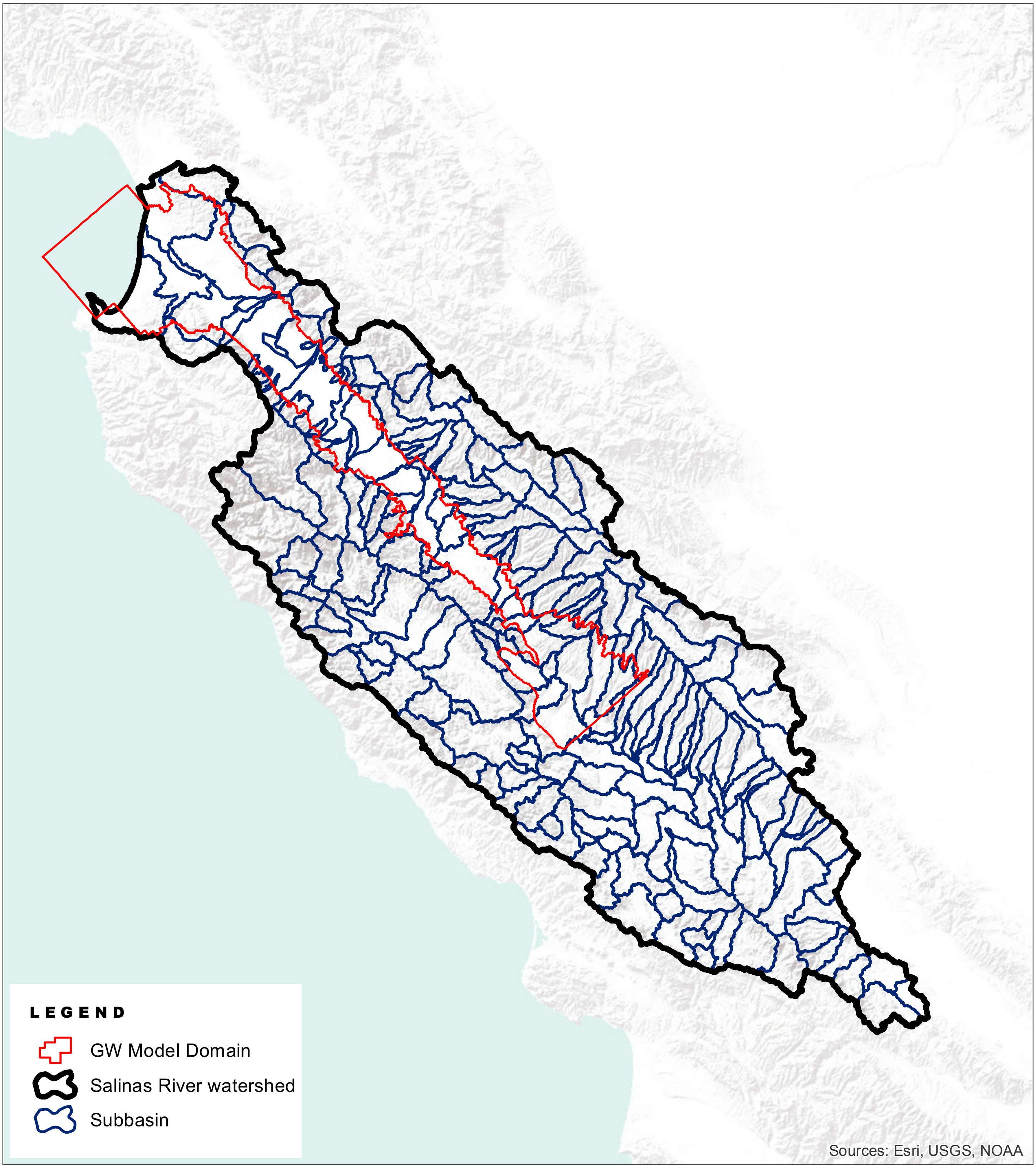

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1 inch = 100,000 feet

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FIGURE A-4

PRELIMINARY SUBBASIN DELINEATIONS FOR RAINFALL-RUNOFF MODEL

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FIGURE A-5

NHD STREAM NETWORK FOR RAINFALL-RUNOFF MODEL

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Monterey County

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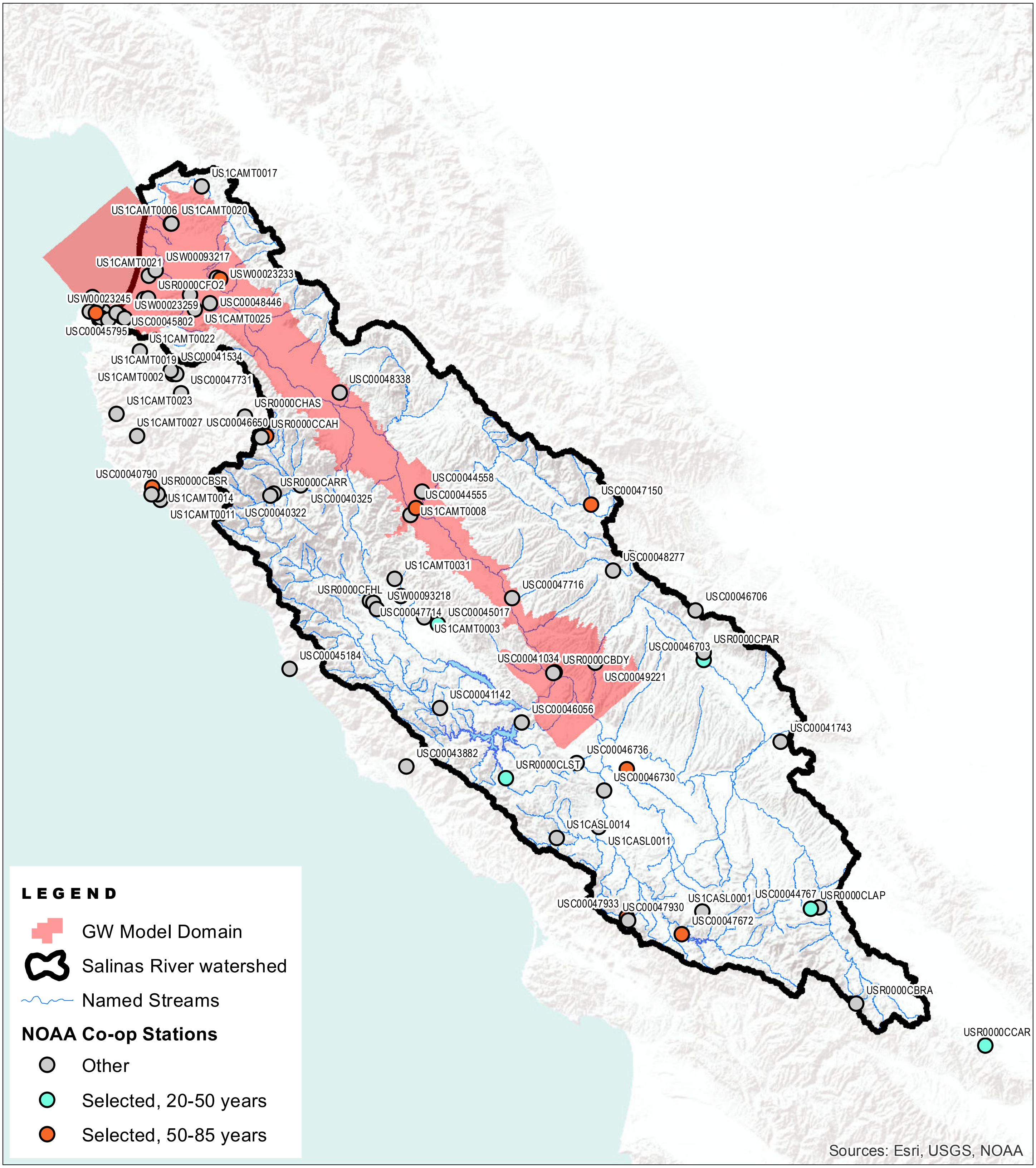

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1 inch = 100,000 feet

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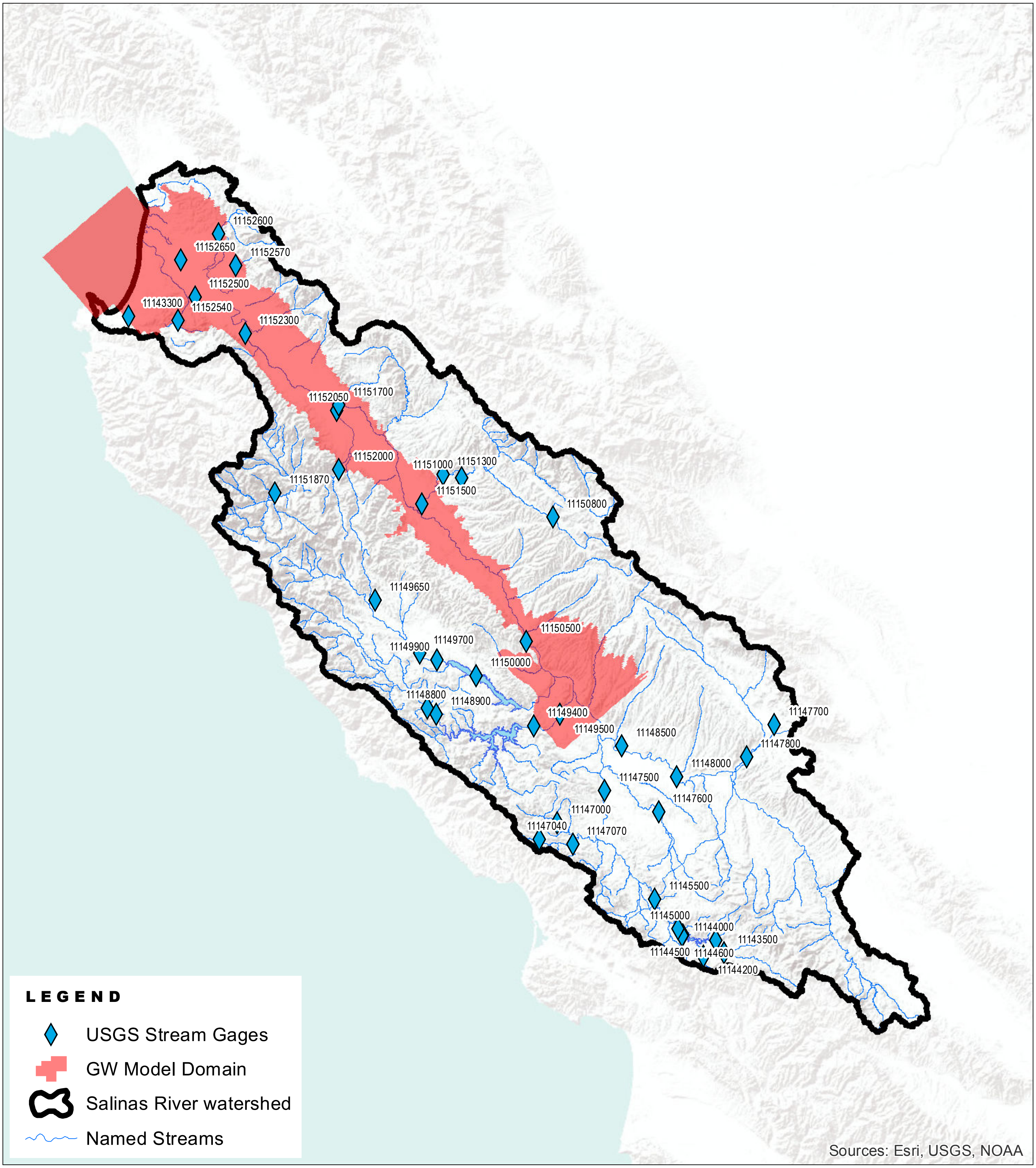
FIGURE A-6

NOAA CO-OP STATION LOCATIONS FOR RAINFALL-RUNOFF MODEL

Salinas River Groundwater Basin Investigation
Monterey County

Project Number 146430



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1 inch = 100,000 feet

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FIGURE A-7

USGS STREAM GAGE LOCATIONS FOR RAINFALL-RUNOFF MODEL

Salinas River Groundwater Basin Investigation
Monterey County

Project Number 146430