FINAL REPORT | June 2021

Annual Report of the Prado Basin Habitat Sustainability Committee

Water Year 2020

PREPARED FOR

Chino Basin Watermaster and the
Inland Empire Utilities Agency

PREPARED BY

WEST YOST
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Annual Report of the Prado Basin Habitat Sustainability Committee Water Year 2020

Prepared for

Chino Basin Watermaster and the Inland Empire Utilities Agency

Project No. 941-80-20-24

Project Manager: Veva Weamer | Date: 6/3/2021

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LIST OF ACRONYMS AND ABBREVIATIONS

ACOE	US Army Corps of Engineers
af	acre-feet
afy	acre-feet per year
AMP	Adaptive Management Plan for the PBHSP
Annual Report	Annual Report of the Prado Basin Habitat Sustainability Committee
CAL FIRE	California Department of Forestry and Fire Protection
CBMWD	Chino Basin Municipal Water District
CBWM	Chino Basin Watermaster
CCWF	Chino Creek Well Field
CDA	Chino Basin Desalter Authority
CDFM	Cumulative Departure from the Mean
CDFW	California Department of Fish and Wildlife
CEQA	California Environmental Quality Act
Chino Basin	Chino Groundwater Basin
CIMIS	California Irrigation Management Information System
DBH	Diameter at Breast Height
EC	Electrical Conductivity
EROS	Earth Resources Observation and Science
ESPA	Center Science Processing Architecture
FD	Fusarium Dieback
ft-amsl	Feet above mean sea level
ft-bgs	feet below ground surface
FRAP	Fire and Resource Assessment Program
GIS	Geographic Information System
GMP	Groundwater Monitoring Program
HCMP	Hydraulic Control Monitoring Program
IEUA	Inland Empire Utilities Agency
In/yr	Inches per year
LEDAPS	Landsat Ecosystem Disturbance Adaptive Processing System
mi^2	square miles
MWD	Metropolitan Water District of Southern California
NDVI	Normalized Difference Vegetation Index
NASA	National Aeronautics and Space Administration
NEXRAD	Next Generation Radar

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OBMP	Optimum Basin Management Program
OC-59	The OCWD's imported water turnout tributary to Prado Basin
OCWD	Orange County Water District
Parties	Parties to the Chino Basin Judgment
PBHSC	Prado Basin Habitat Sustainability Committee
PBHSP	Prado Basin Habitat Sustainability Program
POTWs	Publicly Owned Treatment Works
ppm	Parts Per Million
Prado Basin	Prado Basin Management Zone
PSHB	Polyphagous Shot Hole Borer - *Euwallacea fornicates*
QA/QC	Quality Assurance and Quality Control
RHMP	Riparian Habitat Monitoring Program
SAWA	Santa Ana Watershed Association
SAR	Santa Ana River
SARWM	Santa Ana River Watermaster
SEIR	Subsequent Environmental Impact Report
SWMP	Surface-Water Monitoring Program
TDS	Total Dissolved Solids
USBR	United States Bureau of Reclamation
USGS	United States Geological Survey
USDA	United State Department of Agriculture
USFWS	United States Fish and Wildlife Service
VOCs	Volatile Organic Compounds
Watermaster	Chino Basin Watermaster
WEI	Wildermuth Environmental Inc.
WRCRWA	Western Riverside County Regional Wastewater Authority
WY	Water Year

1.0 BACKGROUND AND OBJECTIVES

This *Annual Report of the Prado Basin Habitat Sustainability Committee for Water Year 2020* (Annual Report) was prepared on behalf of the Prado Basin Habitat Sustainability Committee (PBHSC), convened by the Inland Empire Utilities Agency (IEUA) and the Chino Basin Watermaster (Watermaster) pursuant to the mitigation monitoring and reporting requirements of the Peace II Subsequent Environmental Impact Report (SEIR) (Tom Dodson, 2010).

This introductory section provides background on the general hydrologic setting of the Prado Basin Management Zone (Prado Basin); the Chino Basin Judgment; the Optimum Basin Management Program (OBMP), its Programmatic EIR, and the Peace Agreement; the Peace II Agreement and its SEIR; and the formation of the PBHSC and the development of the adaptive management plan (AMP) for the Prado Basin Habitat Sustainability Program (PBHSP).

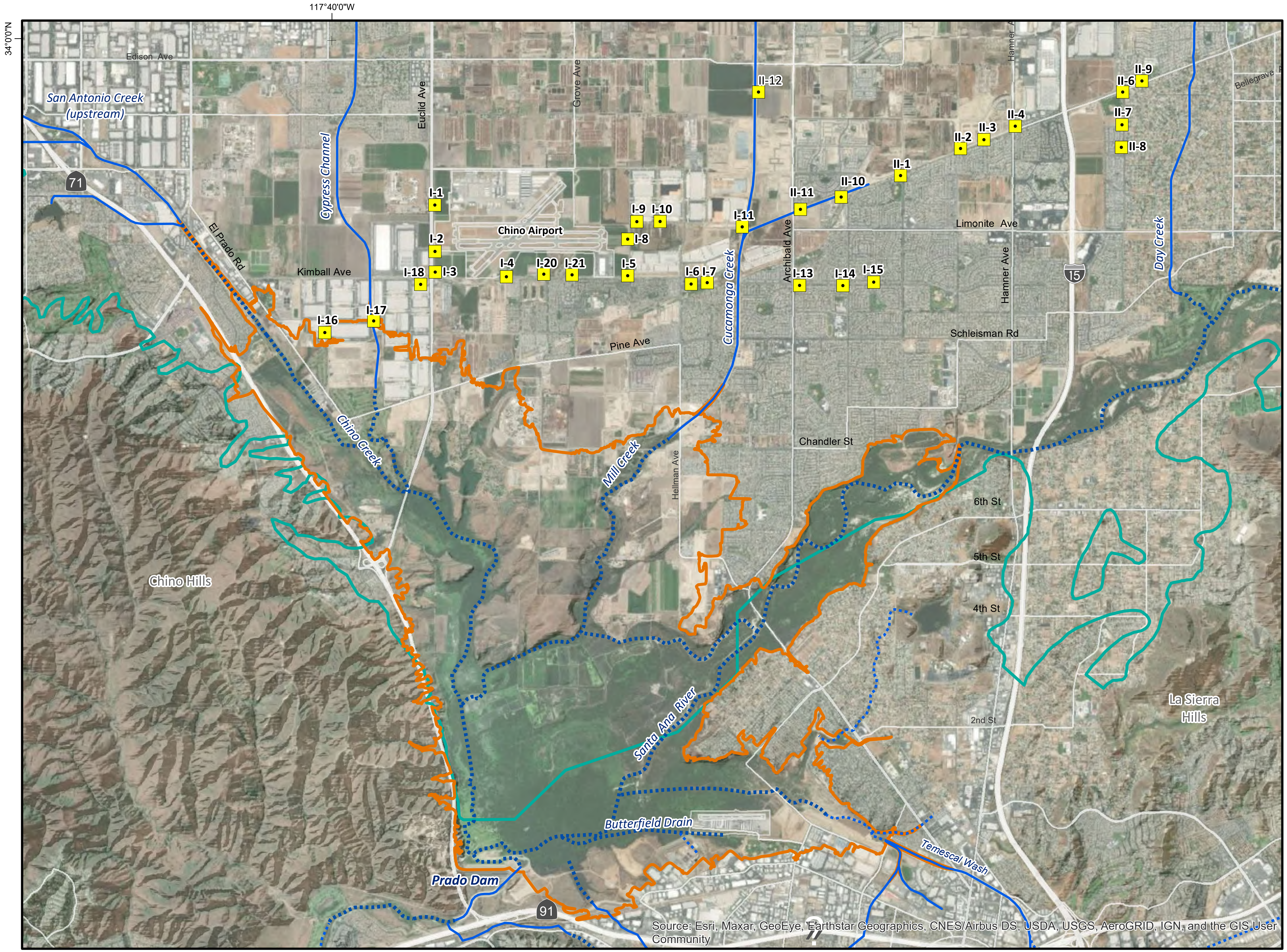
1.1 Prado Basin

The Prado Basin is the flood control area behind Prado Dam, which was constructed in 1941 as the major flood-control facility within the Santa Ana River (SAR) Watershed. The US Army Corps of Engineers (ACOE) regulates releases of water from Prado Dam for both purposes of flood control and groundwater recharge in Orange County. Releases of water temporarily held in storage in the Prado Basin for groundwater recharge in Orange County is coordinated with the Orange County Water District (OCWD). Figure 1-1 shows the location of the Prado Basin in the southern portion of the Chino Groundwater Basin (Chino Basin). The Prado Basin boundary shown on Figure 1-1 is the Prado Basin Management Zone boundary as defined in the Santa Ana Region Basin Plan (Regional Board, 2016), which approximately follows the 566 feet above mean sea level (ft-amsl) elevation contour behind Prado Dam.

Approximately 4,300 acres of riparian habitat have developed within the Prado Basin, creating the largest riparian habitat in Southern California. Portions of the riparian habitat have been designated as critical habitat to several endangered or threatened species. Figure 1-2 shows the locations of the critical habitat, as defined by the United States Fish and Wildlife Service (USFWS). Most of the riparian habitat in Prado Basin is designated as critical habitat for one or multiple species, including the Santa Ana Sucker, the Southwestern Willow Flycatcher, and Least Bell's Vireo.

The SAR flows through the Prado Basin from east to west. The tributaries of the SAR that flow into the Prado Basin include San Antonio/Chino, Cucamonga/Mill, and Temescal Creeks. The major components of flow within the SAR and its tributaries are: runoff from precipitation, discharge of tertiary-treated effluent from wastewater treatment plants, rising groundwater, discharge of untreated imported water from the OC-59 turnout conveyed through the Prado Basin for groundwater recharge in Orange County, and dry-weather runoff.[1]

1 Dry-weather runoff consists of excess irrigation runoff, purging of wells, dewatering discharges, etc.



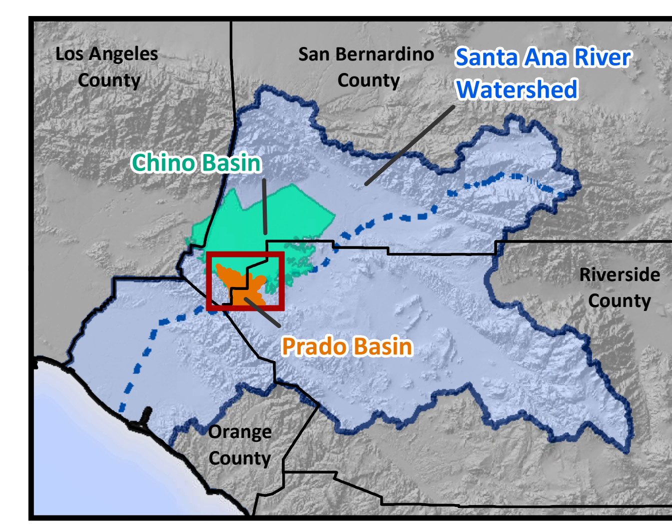
Prado Basin Management Zone (Prado Basin) - as defined in the Santa Ana Region Basin Plan (Regional Board, 2016) which approximately follows the 566 feet above mean sea level elevation contour in the flood control area behind Prado Dam.

Hydrologic Boundary of the Chino Groundwater Basin (Chino Basin)

Concrete-Lined Channels

Unlined Rivers and Streams

Chino Basin Desalter Authority Well



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Date: 4/14/2021

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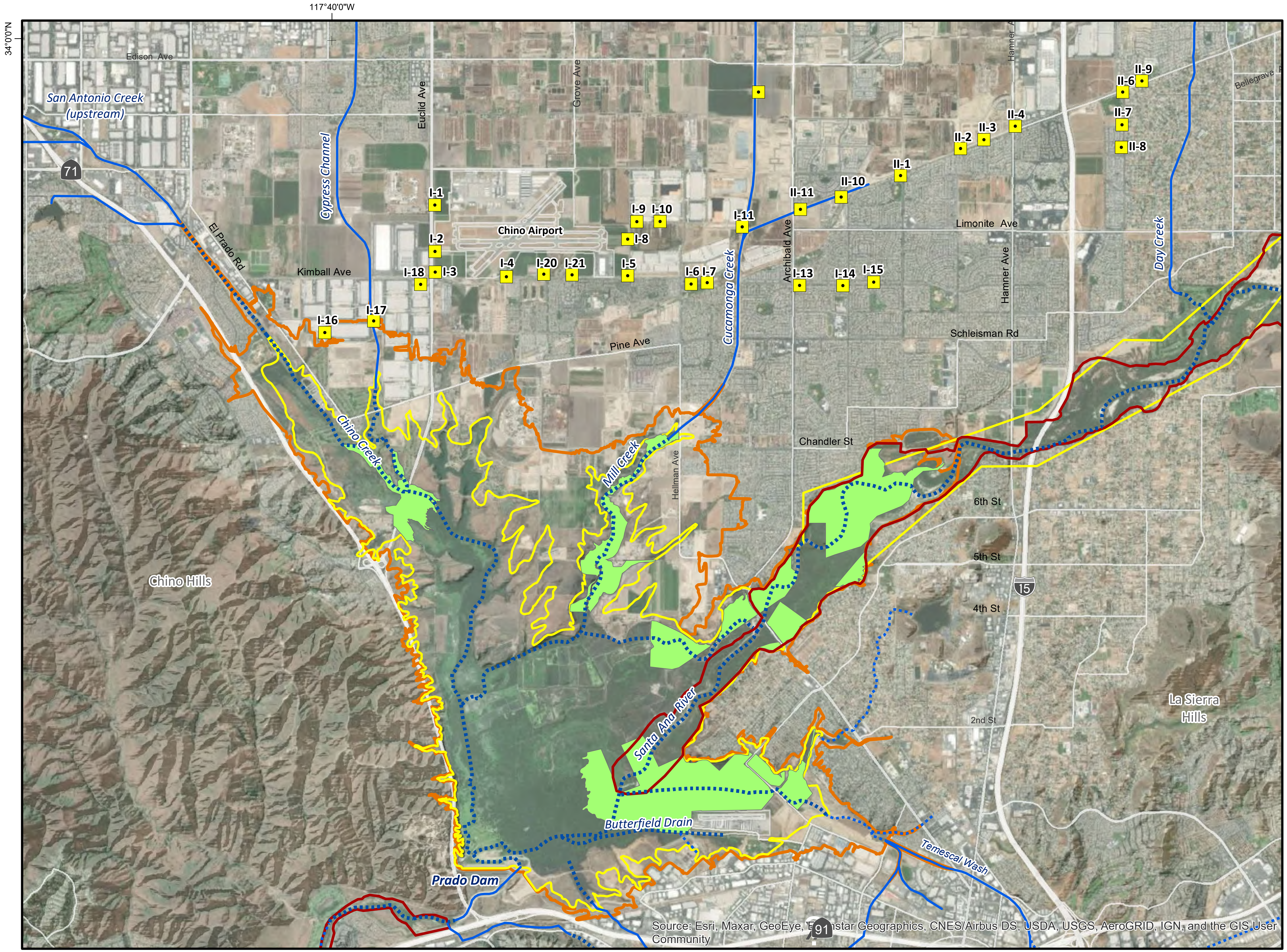
Prado Basin Area

Figure 1-1



Critical Habitat

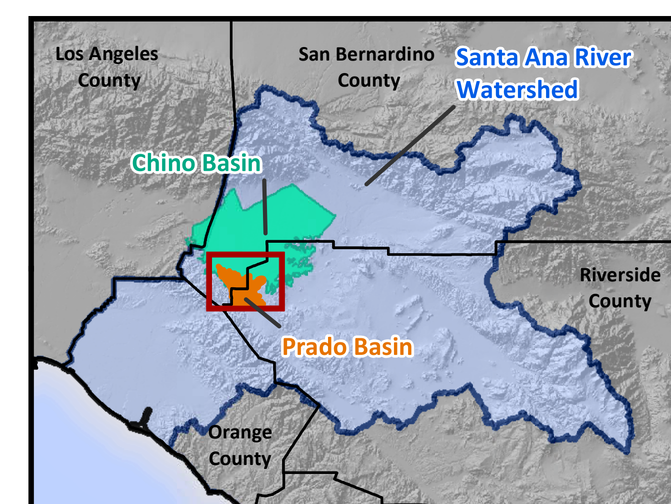
- Santa Ana Sucker
- Southwestern Willow Flycatcher
- Least Bell's Vireo

Prado Basin Management Zone (Prado Basin)

Concrete-Lined Channels

Unlined Rivers and Streams

Chino Basin Desalter Authority Well



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Critical Habitat for Endangered or Threatened Species in the Prado Basin Area

Figure 1-2

The Prado Basin is a hydrologically complex region of the lower Chino Basin. Groundwater in the Chino Basin generally flows from the forebay regions in the north towards the Prado Basin in the south. Depth to groundwater is relatively shallow in the Prado Basin area, and the SAR and its tributaries are unlined across the Prado Basin, which allows for groundwater/surface-water interaction. Groundwater outflows in the Prado Basin occur via evapotranspiration by riparian vegetation and rising-groundwater discharge to the SAR and its tributaries.

To the north of the Prado Basin, the Chino Basin Desalter Authority (CDA) owns and operates a municipal well field. Figure 1-1 shows the locations of existing CDA wells. The well field pumps groundwater with high concentrations of total dissolved solids (TDS), nitrate, and volatile organic compounds (VOCs). The CDA treats the groundwater at two regional facilities using reverse osmosis, ion exchange, and blending to produce a potable water supply for the region. VOCs are currently treated through blending, and new treatment processes are being added to increase their removal. CDA operations are fundamental to achieving many of the management goals outlined in the OBMP and both Peace Agreements, which are discussed below.

1.2 Chino Basin Judgment, OBMP, and Peace Agreement

A 1978 Judgment entered in the Superior Court of the State of California for the County of San Bernardino (Chino Basin Municipal Water District vs*.* City of Chino et al.) established pumping and storage rights in the Chino Basin. The Judgment established the Chino Basin Watermaster to oversee the implementation of the Judgment and provided Watermaster with the discretionary authority to develop an OBMP to maximize the beneficial use of the Chino Basin. The OBMP was developed by Watermaster and the parties to the Judgment (Parties) in the late 1990s (WEI, 1999). The OBMP maps a strategy to enhance the yield of the Chino Basin and provide reliable high-quality water supplies for the development expected to occur in the region. The goals of the OBMP are: to enhance basin water supplies, to protect and enhance water quality, to enhance the management of the Basin, and to equitably finance the OBMP.

In 2000, the Parties executed the Peace Agreement (Watermaster, 2000), which documented their intent to implement the OBMP. The Peace Agreement included an OBMP Implementation Plan, which outlined the time frame for implementing tasks and projects in accordance with the Peace Agreement and the OBMP. The OBMP Implementation Plan is a comprehensive, long-range water-management plan for the Chino Basin and includes: the use of recycled water for direct reuse and artificial recharge, the capture of increased quantities of high-quality storm-water runoff, the recharge of imported water when TDS concentrations are low, the desalting of poor-quality groundwater in impaired areas of the basin, the support of regulatory efforts to improve water quality in the basin, subsidence management, storage management, and the implementation of management activities to reduce the discharge of high-TDS/high-nitrate groundwater to the SAR, thus ensuring the protection of downstream beneficial uses in Orange County.

The Chino Basin Municipal Water District (CBMWD) was the plaintiff in the legal action that resulted in the Judgment. The CBMWD was formed in 1950 to supply supplemental, imported water purchased from the Metropolitan Water District of Southern California (MWD) to the Chino Basin. On July 1, 1998, the CBMWD changed its name to the IEUA and expanded its role to become the regional supplier of recycled water for most of the Chino Basin. For OBMP implementation, the IEUA has served as the lead agency for compliance with the California Environmental Quality Act (CEQA). A Program Environmental Impact Report for the OBMP (SCH#2000041047) was certified by the IEUA in July 2000 (Tom Dodson, 2000).

1.3 The Peace II Agreement and its Subsequent EIR

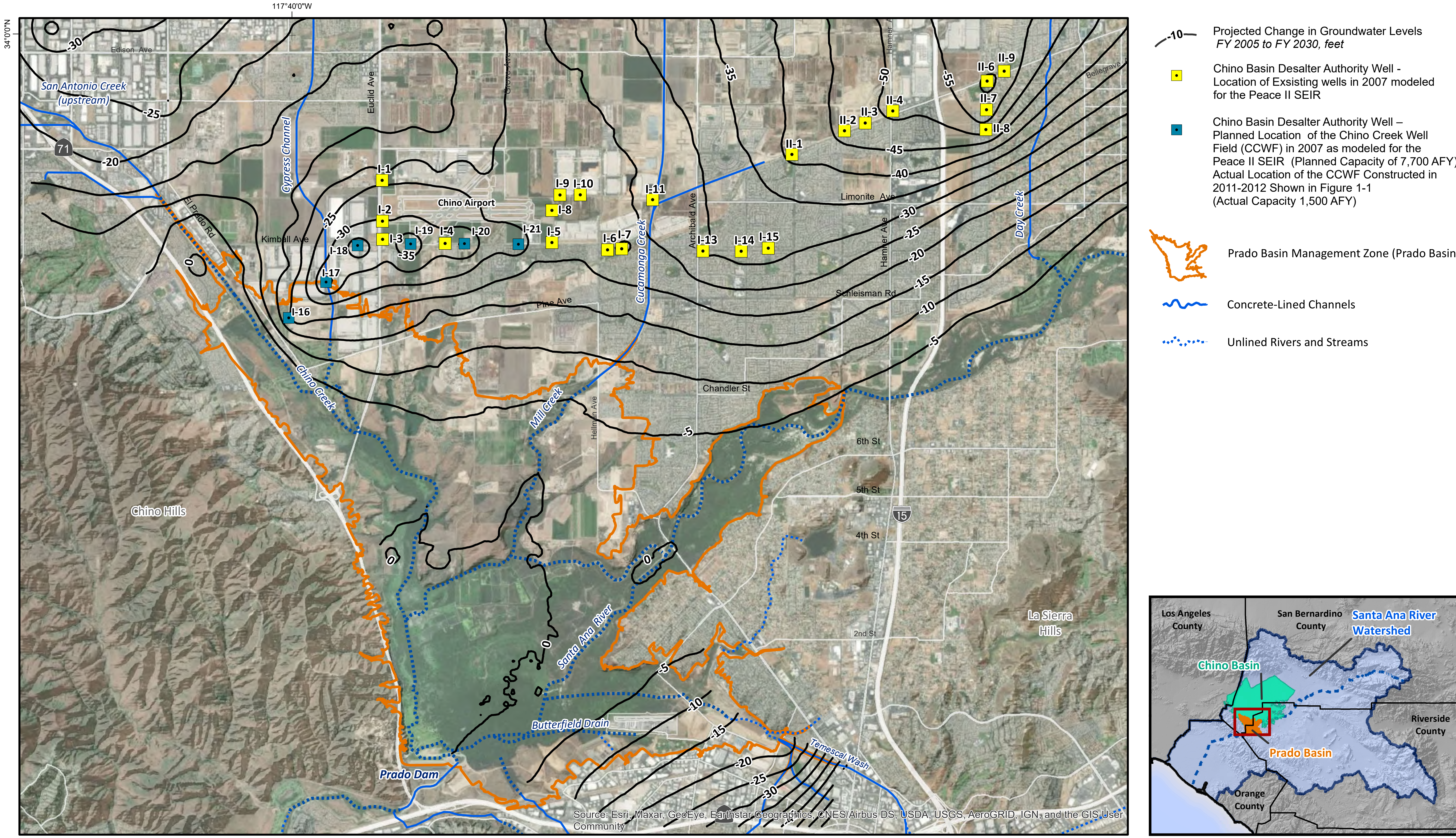
To further implement the goals and objectives of the OBMP, the Parties executed the Peace II Agreement in 2007, which modified the OBMP Implementation Plan (Watermaster, 2007). The two main activities of the Peace II Agreement are: (i) increasing the controlled overdraft of the Chino Basin, as defined in the Judgment,[2] by 400,000 acre-feet (af) through 2030 (re-operation), and (ii) refining the planned expansion facilities of the Chino Basin Desalter program from about 30,000 to 40,000 acre-feet per year (afy) of groundwater production. Re-operation is allocated specifically to offset the production of the Chino Basin Desalters. Both re-operation and desalter expansion contribute to the attainment of "hydraulic control" of groundwater outflow from the Chino Basin to the SAR. The attainment and maintenance of hydraulic control is a requirement of Watermaster and the IEUA, as defined in the Water Quality Control Plan for the Santa Ana River Basin (California Regional Water Quality Control Board, Santa Ana Region, 2008). Hydraulic control ensures that the water management activities in the Chino Basin will not impair the beneficial uses designated for SAR water quality downstream of Prado Dam.

The expansion of the Chino Basin Desalters, described in the Peace II Agreement, was accomplished, in part, by the construction and operation of the Chino Creek Well Field (CCWF) in the southwest portion of Chino Basin (see Figure 1-3). During Peace II Agreement planning, the estimated capacity of the CCWF was about 5,000 to 7,700 afy (WEI, 2007). The CCWF wells were constructed in 2011-2012, and their actual capacity is about 1,500 afy.

In 2010, the IEUA certified the Peace II SEIR (Tom Dodson, 2010) to evaluate the environmental impacts that could result from implementing the Peace II Agreement. One of the potential impacts evaluated was the possible lowering of groundwater levels (drawdown) in the Prado Basin area, which could impact riparian vegetation that is dependent upon shallow groundwater. Watermaster performed modeling studies to predict the extent and magnitude of the drawdown associated with the implementation of the Peace II Agreement, using the planned capacity of 7,700 afy of the CCWF (WEI, 2007). Figure 1-3 (modified from Figure 4.4-10 from the Peace II SEIR) shows the model-predicted drawdown in the Prado Basin area for the period of 2005 to 2030. The drawdown throughout most of the Prado Basin area was predicted to be less than five feet by 2030.

Although the available modeling work indicated that implementing the Peace II Agreement would not cause significant adverse effects on Prado Basin riparian habitat, a contingency measure to address the potential for drawdown of groundwater levels and its impact on riparian vegetation was included in the Peace II SEIR as Mitigation Measure 4.4-3 (Biological Resources/Land Use & Planning section of the Mitigation Monitoring and Reporting Program).

[2] The Judgment established 200,000 AF of controlled overdraft over the period of 1978 to 2017. Re-operation increases the controlled overdraft to 600,000 acre-ft through 2030.



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Projected Change in Groundwater Levels
FY 2005 to 2030 - Peace II Alternative

Figure 1-3

Mitigation Measure 4.4-3 was developed to ensure that the riparian habitat will not incur unforeseeable significant adverse effects from the Peace II implementation and to contribute to the long-term sustainability of the riparian habitat. Mitigation Measure 4.4-3 calls for:

- Watermaster, the IEUA, the OCWD, and other stakeholders that choose to participate to jointly fund the development of an adaptive management program to monitor the extent and quality of the Prado Basin riparian habitat and investigate and identify essential factors to its long-term sustainability.
- Watermaster and the IEUA to convene the PBHSC, comprised of representatives from all interested parties to implement the adaptive management program.
- The PBHSC to prepare annual reports pursuant the adaptive management program. Annual reports are to include recommendations for ongoing monitoring and any adaptive management actions required to mitigate any measured or prospective loss of riparian habitat resulting from Peace II activities.

1.4 Adaptive Management Plan for the PBHSP

Pursuant to Mitigation Measure 4.4-3 in the SEIR, Watermaster and the IEUA convened four meetings of the PBHSC, starting in late-2012, to develop the adaptive management plan for the PBHSP and facilitate its implementation. Watermaster and the IEUA adopted the final *2016 Adaptive Management Plan for the Prado Basin Habitat Sustainability Program* (AMP) in August 2016 (WEI, 2016).

The AMP was designed to answer the following questions to satisfy the monitoring and mitigation requirements of the Peace II SEIR:

- What are the factors that potentially can affect the extent and quality of the riparian habitat?
- What is a consistent, quantifiable definition of "riparian habitat quality," including metrics and measurement criteria?
- What has been the historical extent and quality of the riparian habitat in the Prado Basin?
- How has the extent and quality of the riparian habitat changed during implementation of Peace II?
- How have groundwater levels and quality, surface-water discharge, weather, and climate changed over time? What were the causes of the changes? And, did those changes result in an adverse impact to riparian habitat in the Prado Basin?
- Are there other factors besides groundwater levels, surface-water discharge, weather, and climate that affect riparian habitat in the Prado Basin? What are those factors? And, did they (or do they) result in an adverse impact to riparian habitat in the Prado Basin?
- Are the factors that result in an adverse impact to riparian habitat in the Prado Basin related to Peace II implementation?
- Are there areas of prospective loss of riparian habitat that may be attributable to the Peace II Agreement?
- What are the potential mitigation actions that can be implemented if Peace II implementation results in an adverse impact to the riparian habitat?

The AMP outlines a process for monitoring, modeling, and annual reporting to answer and address the questions listed above. Appendix A to the AMP is the initial monitoring program: *2016 Monitoring Program for the Prado Basin Habitat Sustainability Program*. Annual reports are intended to document monitoring and modeling activities, the analysis and interpretation of the monitoring and modeling results, and recommendations for changes to the PBHSP, which may include monitoring, modeling, and/or mitigation, if deemed necessary. Any future mitigation measures that are deemed necessary will be developed jointly by Watermaster and the IEUA.

1.5 Annual Report Organization

This Annual Report for water year (WY) 2020 is the fifth annual report of the PBHSC. It documents the collection, analysis, and interpretations of the data and information generated by the PSHSP through September 30, 2020 and is organized into the following sections:

Section 1.0 – Introduction. This section describes the background and objectives of the PBHSP and the Annual Report.

Section 2.0 – Monitoring, Data Collection, and Methods. This section describes the collection of historical information and recent monitoring data and describes the groundwater-modeling activities performed during WY 2020 for the PBHSP.

Section 3.0 – Results and Interpretations. This section describes the results and interpretations that were derived from the information, data, and groundwater-modeling.

Section 4.0 – Conclusions and Recommendations. This section summarizes the main conclusions derived from the PBHSP through the prior water year and describes the recommended activities for the subsequent fiscal year as a proposed scope-of-work, schedule, and budget.

Section 5.0 – References. This section lists the publications cited in the report.

2.0 MONITORING, DATA COLLECTION, AND METHODS

The PBHSP was designed, in part, to answer Question 1 from the AMP:

- *What are the factors that potentially can affect the extent and quality of the riparian habitat?*

The main hydrologic factors that can potentially affect the extent and quality of the riparian habitat in the Prado Basin include, but are not limited to, groundwater levels, surface-water discharge, weather events, and long-term climate. As such, the PBHSP includes integrated monitoring and analysis programs for riparian habitat, groundwater, surface water, climate, and other potential factors (e.g. wildfire, pests, etc.).

Since the implementation of the AMP in WY 2016, data collection efforts included the compilation of historical data through present. The period of data available for each data type varies, but all span both pre- and post-Peace II implementation. Data collection efforts for historical data were described in the first two annual reports for WY 2016 and WY 2017. Data collection efforts for subsequent water years have focused on recent water year monitoring data. All data collected and compiled for this effort were uploaded to Watermaster's centralized relational database, HydroDaVE^{SM}, and used in the analyses.

This section describes the collection of recent monitoring data and the groundwater-modeling activities performed for the PBHSP during WY 2020.

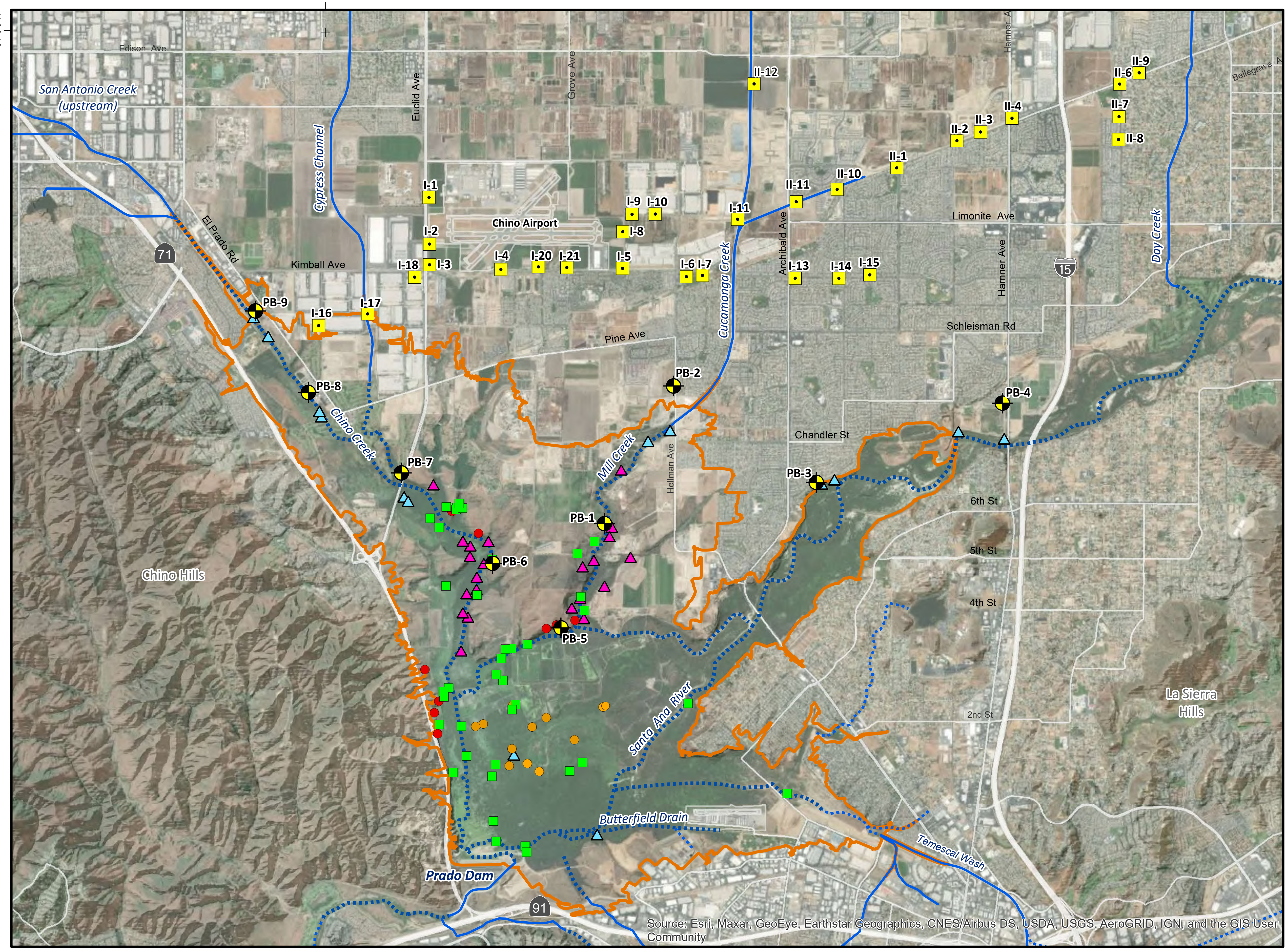
2.1 Riparian Habitat Monitoring

The objective of the Riparian Habitat Monitoring Program (RHMP) is to collect data to help answer questions 2, 3, and 4 from the AMP:

- What is a consistent quantifiable definition of "riparian habitat quality," including metrics and measurement criteria?
- What has been the historical extent and quality of the riparian habitat in the Prado Basin?
- How has the extent and quality of the riparian habitat changed during the implementation of Peace II?

To answer these questions, the RHMP includes time series data and information on the extent and quality of riparian habitat in the Prado Basin over a historical period, including both pre- and post-Peace II implementation.

Figure 2-1 displays the features of the RHMP. Two types of monitoring and assessment are performed: regional and site-specific. Regional monitoring and assessment is appropriate because the main potential stress associated with Peace II activities is the regional drawdown of groundwater levels. The intent of site-specific monitoring and assessment is to verify and complement the results of regional monitoring.



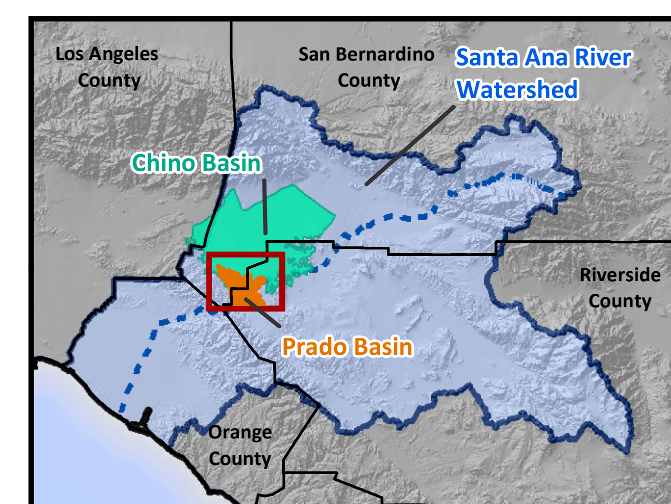
Riparian Habitat Monitoring Program

USBR Site-Specific Monitoring

- USBR Vegetation Surveys 2007, 2013, 2016, and 2019
- USBR Vegetation Surveys 2016 and 2019

OCWD Site-Specific Monitoring

- Understory Photo Stations
- Canopy Photo Stations
- Stacked-Cube Monitoring Site (Spring and Summer)
- PBHSP Monitoring Well
- Prado Basin Management Zone (Prado Basin)
- Concrete-Lined Channels
- Unlined Rivers and Streams
- Chino Basin Desalter Authority Well



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Riparian Habitat Monitoring Program

Figure 2-1

2.1.1 Regional Monitoring of Riparian Habitat

Regional monitoring and assessment of the riparian habitat is performed by mapping the extent and quality of riparian habitat over time using: (i) multi-spectral remote-sensing data and (ii) air photos.

2.1.1.1 Multi-Spectral Remote Sensing Data

The Normalized Difference Vegetation Index (NDVI), derived from remote sensing measurements by Landsat Program satellites, is used to assess the extent and quality of the riparian vegetation in the Prado Basin over a long-term historical period. NDVI is a commonly used numerical indicator of vegetation health that can be calculated from satellite remote-sensing measurements (Ke et al., 2015; Xue, J. and Su, B., 2017). NDVI is calculated from visible and near-infrared radiation reflected by vegetation, is an index of greenness correlated with photosynthesis, and can be used to assess spatial and temporal changes in the distribution and productivity of vegetation (Pettorelli, 2013). Appendix A provides background information on NDVI, explains why NDVI was chosen as an analytical tool for the PBHSP, discusses its advantages and limitations, and describes how NDVI estimates were used for the PBHSP.

For the current reporting period, NDVI estimates were collected from the United States Geological Survey (USGS) using the Earth Resources Observation and Science (EROS) Center Science Processing Architecture (ESPA) On Demand Interface[3] (USGS, 2017b) over the period November 2019 through October 2020 to span the entire growing-season period (March-October 2020). To obtain complete spatial coverage of the Prado Basin area, NDVI estimates were requested for all Landsat scenes for Path 040, Rows 036 and 037 from the Landsat 7 and Landsat 8 satellites. The NDVI were processed and uploaded to Watermaster's centralized relational database, HydroDaVE[SM], which includes tools to manage, review, and extract NDVI estimates. The frequency of NDVI estimates from the Landsat 7 and 8 satellites is about every eight days. However, not all NDVI estimates are useable due to disturbances that can be caused by cloud cover, unfavorable atmospheric conditions, or satellite equipment malfunction. NDVI estimates were reviewed for these disturbances and excluded from analysis if they were determined erroneous. Appendix A describes the how the NDVI estimates were collected, reviewed, and assembled for the PBHSP.

2.1.1.2 Collection and Analysis of Air Photos

Georeferenced air photos are used to visually characterize the spatial extent and quality of the riparian habitat in the Prado Basin. The air photos also serve as an independent check on interpretations of NDVI, which involves visual comparison of the extent and density of the riparian habitat, as shown in the air photos, to the NDVI maps. For ongoing monitoring, a high-resolution (3-inch pixel) image of the visible spectrum for the entire Prado Basin is acquired at the approximate peak of each growing season, typically in July.

For the current reporting period, the acquisition of the 2020 air photo included a custom flight that was performed by Digital Mapping Inc. on July 7 and 8, 2020. The cost to acquire the 2020 air photo was shared with the OCWD. This was the third annual high-resolution air photo acquired for the PBHSP.

2.1.2 Site-Specific Monitoring of Riparian Habitat

The objective of the site-specific monitoring of riparian habitat is to collect data that can be used to ground-truth the interpretations derived from the regional monitoring and assessment of the riparian

[3] ESPA USGS

habitat (Pettorelli, 2013). Prior to the implementation of the AMP, site-specific monitoring performed in the Prado Basin included vegetation surveys performed by the United States Bureau of Reclamation (USBR) in 2007 and 2013 (USBR, 2008b; 2015). Since the implementation of the AMP, the USBR conducted vegetation surveys for the PBHSP in 2016 and 2019. The USBR vegetation surveys performed for the PBHSP in 2016 and 2019 consist of 37 sites in the Prado Basin: 24 previously established USBR sites during the 2007 and 2013 sampling and 14 new sites established in 2016 that are primarily located near the PBHSP monitoring wells. The OCWD performs site-specific monitoring in the southern portion of Prado Basin to monitor for effects of the operation of Prado Dam on riparian habitat. OCWD site-specific monitoring includes: seasonal monitoring at nine canopy photo stations located along the edge of Prado Basin, seasonal monitoring at 11 understory photo stations within different surface elevations of the inundation zone behind the dam, 40 stacked-cube monitoring sites monitored in the spring and summer throughout different surface elevation ranges of the inundation zone, and 40 stacked-cube monitoring sites in Least Bell's Vireo nesting and territory locations in the riparian habitat. The most recent OCWD results performed during this reporting period are described in the *Prado Basin Water Conservation and Habitat Assessment 2019-2020* report (OCWD, 2021).

Figure 2-1 shows the locations of the USBR vegetation surveys and the OCWD photo and stacked-cube monitoring sites.

2.2 Factors that Potentially Affect the Riparian Habitat

The main factors that can potentially affect riparian habitat in Prado Basin include, but are not limited to: groundwater levels, surface-water discharge, weather/climate, wildfires, and pests. This section describes the methods employed to collect and analyze information on these factors to help answer questions 5, 6, and 7 from the AMP:

- How have groundwater levels and quality, surface-water discharge, weather, and climate changed over time? What were the causes of the changes? And, did those changes result in an adverse impact to riparian habitat in the Prado Basin?
- Are there other factors besides groundwater levels, surface-water discharge, weather, and climate that affect riparian habitat in the Prado Basin? What are those factors? And, did they (or do they) result in an adverse impact to riparian habitat in the Prado Basin?
- Are the factors that result in an adverse impact to riparian habitat in the Prado Basin related to Peace II implementation?

2.2.1 Groundwater Monitoring Program

A primary result of implementation of the Peace II Agreement is the lowering of groundwater levels (drawdown) in the southern portion of Chino Basin. Hence, drawdown is a factor that is potentially related to Peace II implementation and could adversely impact riparian habitat.

The Groundwater Monitoring Program (GMP) includes the collection of three types of data: groundwater production, groundwater level, and groundwater quality. Watermaster has been implementing a groundwater monitoring program across the entire Chino Basin to support various basin management initiatives and activities, and all data within Watermaster's centralized relational database are available to the GMP.

Watermaster's groundwater monitoring network was expanded in 2015 specifically for the PBHSP with the construction of 16 new monitoring wells at nine sites located along the fringes of the riparian habitat and between the riparian habitat and the CDA well field. These wells, along with two existing monitoring wells, HCMP-5/1 and RP2-MW3, are specifically monitored for the PBHSP and are called the "PBHSP monitoring wells."

Figure 2-2 shows the extent of the study area for which the GMP data are compiled and used for the PBHSP. The area covers the Prado Basin and the upgradient areas to the north that encompass the CDA well field. Figure 2-2 also shows the wells in the study area where groundwater data were available in WY 2020.

2.2.1.1 Groundwater Production

Groundwater production influences groundwater levels and groundwater-flow patterns. Groundwater-production data are analyzed together with groundwater-level data to characterize the influence of groundwater production on groundwater levels. Groundwater-production data are also used as an input to the Chino Basin groundwater-flow model to evaluate past and future conditions in the Chino Basin, which, for the PBHSP, supports the analysis of prospective losses of riparian habitat (see Section 2.3).

Watermaster collects quarterly groundwater-production data for all active production wells within the Chino Basin. The data are checked for quality assurance and quality control (QA/QC) and uploaded to Watermaster's centralized relational database. The active production wells within the study area include CDA wells and privately owned wells used for agricultural, dairy, or domestic purposes.

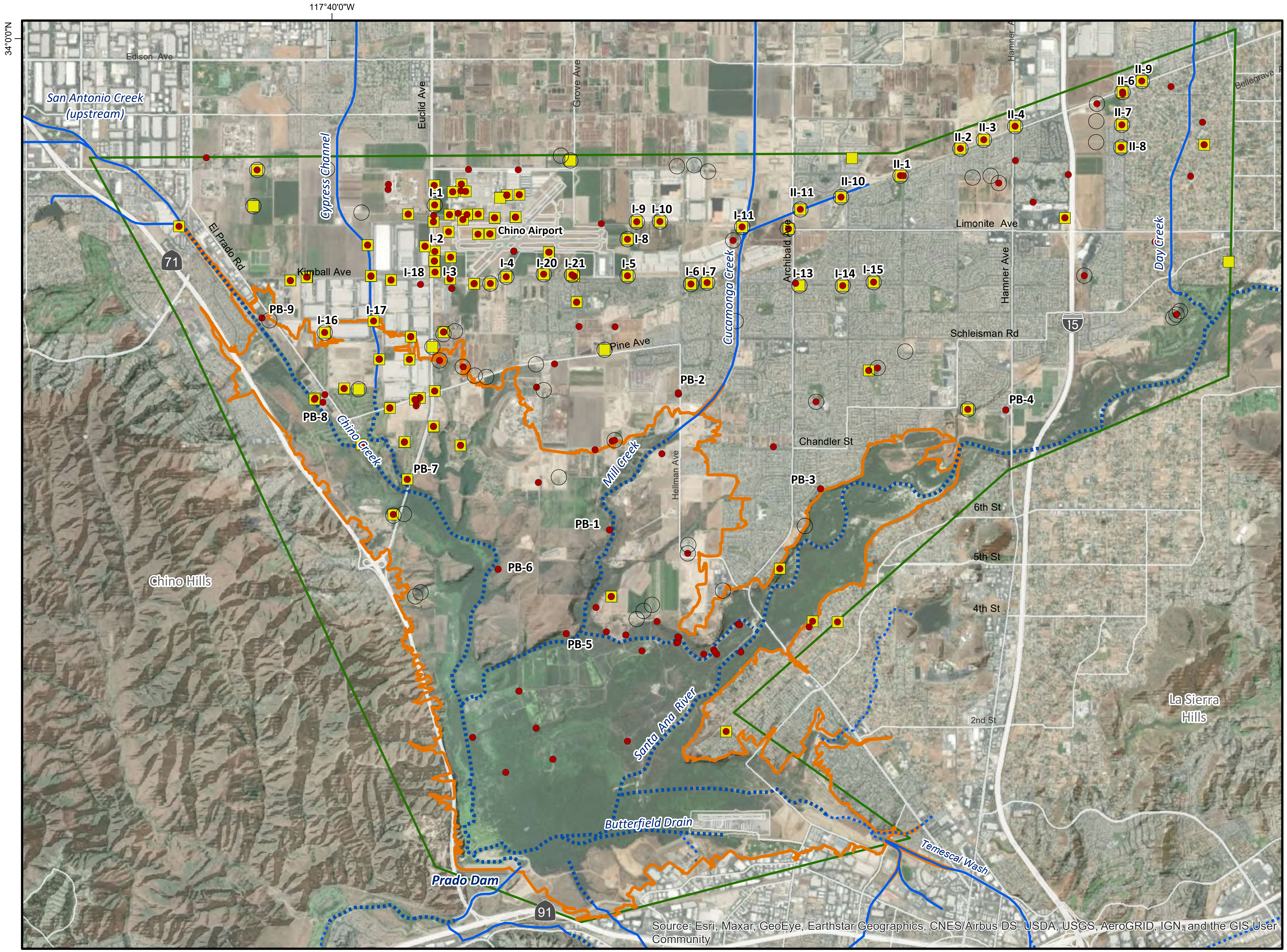
During WY 2019, Watermaster collected groundwater-production data at about 95 wells in the GMP study area.

2.2.1.2 Groundwater Level

Monitoring groundwater levels in the Prado Basin is a key component of the PBHSP, as the potential for declining groundwater levels related to Peace II implementation could be a factor that adversely impacts riparian habitat. Groundwater-level data are analyzed together with production data to characterize how groundwater levels have changed over time in the GMP study area and to explore the relationship(s) to any observed changes that occurred in the extent and quality of the riparian habitat. Groundwater-level and production data are also used as input to the Chino Basin groundwater flow model to evaluate past and future conditions in the Chino Basin, which, for the PBHSP, supports the analysis of prospective losses of riparian habitat (see Section 2.3).

Watermaster collects groundwater-level data at various frequencies at wells in the GMP study area to support various groundwater-management initiatives. The data are checked for QA/QC and uploaded to Watermaster's centralized relational database.

During WY 2020, Watermaster collected groundwater-level data from 230 wells in the study area (see Figure 2-2). At 130 of these wells, water levels were measured by well owners at varying frequencies and provided to Watermaster. The remaining 100 wells are CDA wells, dedicated monitoring wells, or private wells that are monitored by Watermaster using manual methods once per month or with pressure transducers that record water levels once every 15 minutes. Groundwater-levels at the 18 PBHSP monitoring wells have been measured with pressure transducers since May 2015.



Wells with Groundwater Data - Water Year 2020

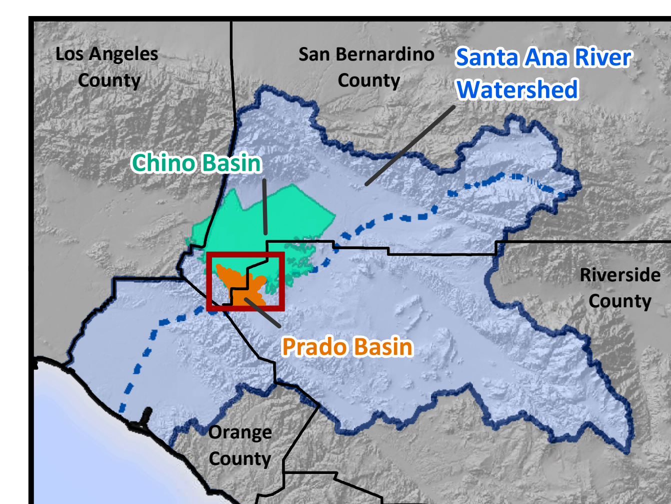
- Wells with Production Data
- Wells with Water Level Data
- Wells with Water Quality Data

Wells Labeld on the Map:

Chino Basin Desalter Authority Well - Labled with **"I-" or "II-"**

PBHSP Monitoring Well - Labled with **"PB-"**

- Groundwater Monitoring Program (GMP) Study Area
- Prado Basin Management Zone (Prado Basin)
- Concrete-Lined Channels
- Unlined Rivers and Streams



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K:\Clients\941 Chino Basin Watermaster\00-00-00 Master\PE1 - Data_Monitoring\GIS\MXD\Prado\Annual Report\Figure 2-2_Groundwater Monitoring Program.mxd

0 1 2 Miles

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Groundwater Monitoring Program

Figure 2-2

2.2.1.3 Groundwater Quality

Water-quality data can be used to understand the various potential sources of shallow groundwater in the Prado Basin. Groundwater-quality data are compared to surface-water-quality data to characterize groundwater/surface-water interactions in the Prado Basin and assess the importance of those interactions to the extent and quality of the riparian habitat.

Watermaster collects groundwater-quality data from wells in the GMP study area to support various groundwater-management initiatives. These data are checked for QA/QC and uploaded to Watermaster's centralized relational database.

During WY 2020, groundwater-quality data were collected from 132 wells in the study area (see Figure 2-2). Of these wells, 98 were sampled by the well owners at varying frequencies. The remaining 34 wells are dedicated monitoring wells or private wells sampled by Watermaster either quarterly, annually, or triennially (every three years).

Watermaster has performed groundwater-quality monitoring at the PBHSP monitoring wells since they were constructed in 2015, and the monitoring program has been tailored to discern the groundwater/surface-water interactions important to the sustainability of the riparian habitat. During WY 2020, Watermaster sampled four of the 18 PBHSP monitoring wells quarterly as part of a pilot monitoring program that was initiated in July 2018. The pilot program is designed to enhance the understanding of groundwater/surface-water interactions in this area. Data loggers with probes were installed in the four monitoring wells to measure and record electrical conductivity (EC), temperature, and water levels at a 15-minute frequency. Samples of groundwater were collected and analyzed quarterly (fiscal year 2020) or semiannually (fiscal year 2021) for EC, temperature, and the parameters listed in Table 2-1. The same monitoring methods and protocols were performed at nearby surface-water sites in Chino Creek for comparison with the groundwater data. Watermaster conducted the quarterly download of the data loggers at the four PBHSP monitoring wells in December 2019, March 2020, June 2020, and September 2020. Groundwater quality samples were collected and analyzed in December 2019, March 2020, and September 2020.

Table 2-1. Parameter List for the Groundwater and Surface Water Quality Monitoring Program		
Chemical Parameter	Method Detection Limit	Method
Alkalinity in CaCO3 units	2 mg/L	SM2320B
Ammonia Nitrogen	0.05 mg/L	EPA 350.1
Bicarbonate as HCO3 *Calculated*	2 mg/L	SM2320B
Calcium Total ICAP	1 mg/L	EPA 200.7
Carbonate as CO3 *Calculated*	2 mg/L	SM2320B
Chloride	1 mg/L	EPA 300.0
Hydroxide as OH *Calculated*	2 mg/L	SM2320B
Magnesium Total ICAP	0.1 mg/L	EPA 200.7
Nitrate as Nitrogen by IC	0.1 mg/L	EPA 300.0
Nitrate as NO3 *Calculated*	0.44 mg/L	EPA 300.0
Nitrite as Nitrogen by IC	0.05 mg/L	EPA 300.0
Nitrate plus Nitrite as Nitrogen *Calculated*	0.1 mg/L	EPA 300.0
PH (H3=past HT not compliant)	0.1 Units	SM4500-HB
Potassium Total ICAP	1 mg/L	EPA 200.7
Silica	0.5 mg/L	EPA 200.7
Sodium Total ICAP	1 mg/L	EPA 200.7
Specific Conductance, 25 C	2 umhos/cm	SM2510B
Sulfate	0.5 mg/L	EPA 300.0
Total Dissolved Solids (TDS)	10 mg/L	E160.1/SM2540C
Total Hardness as CaCO3 by ICP *Calculated*	3 mg/L	SM 2340B
Total Organic Carbon	0.3 mg/L	SM5310C/E415.3
Turbidity	0.05 NTU	EPA 180.1

2.2.2 Surface-Water Monitoring Program

Surface-water discharge in the Prado Basin is another factor that can influence the extent and quality of riparian habitat and can influence groundwater levels. Surface-water discharge data are evaluated for the PBHSP to characterize historical and current trends in the discharge of the SAR and its tributaries in the Prado Basin and to explore the relationship(s) to any observed changes that occurred in the extent and quality of the riparian habitat. Surface-water discharge data are also used as input to the Chino Basin groundwater-flow model to evaluate past and future conditions in the Chino Basin, which for the PBHSP, supports the analysis of prospective losses of riparian habitat (see Section 2.3). Surface-water quality is compared to groundwater-quality data to characterize groundwater/surface-water interactions in the Prado Basin and the importance of those interactions to the extent and quality of the riparian habitat.

The surface-water monitoring program (SWMP) for the PBHSP involves collecting existing, publicly available, surface-water discharge and quality data from sites within or tributary to the Prado Basin. Figure 2-3 shows the location of the surface-water monitoring sites used in the PBHSP. These sites include discharge locations for publicly owned treatment works (POTWs), USGS stream gaging stations, Watermaster and the IEUA Maximum-Benefit Monitoring Program surface-water-quality monitoring sites, ACOE's storage levels and inflow to Prado Dam, and the OCWD's discharge of untreated imported water from the OC-59 turnout tributary to Prado Basin. All surface-water discharge and quality data were collected for WY 2019, checked for QA/QC, and uploaded to Watermaster's relational database.

As noted in Section 2.2.1.3 above, a pilot monitoring program was initiated July 2018 at two locations along Chino Creek near monitoring wells PB-7 and PB-8 to help characterize groundwater/surface-water interactions. Data loggers with probes were installed in Chino Creek adjacent to PB-7 and PB-8 to measure and record EC, temperature, and stage at a 15-minute frequency. Surface-water samples were collected and analyzed quarterly or semiannually for EC, temperature, and the parameters listed in Table 2-1. Watermaster conducted the quarterly download of the data loggers at the four PBHSP monitoring wells in December 2019, March 2020, June 2020, and September 2020 Groundwater-quality samples were collected and analyzed in December 2019, March 2020, and September 2020.

2.2.3 Climatic Monitoring Program

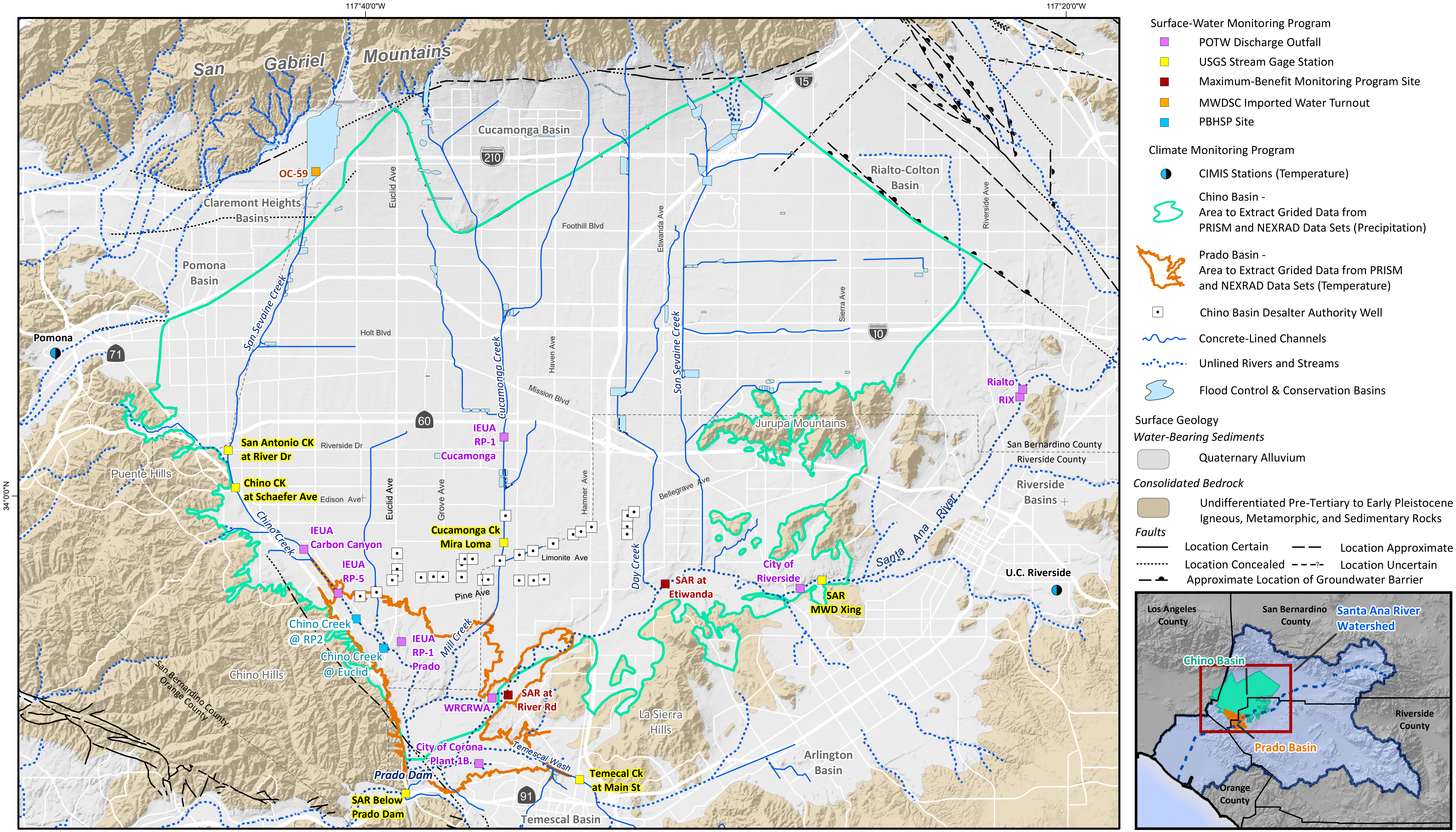
Climatic data are used to characterize how the climate has changed over time in the study area and to explore the relationship(s) to any observed changes that occurred in the extent and quality of the riparian habitat. Climatic data are also used for the Chino Basin groundwater-flow model to evaluate past and future conditions in the Chino Basin, which for the PBHSP, supports the analysis of prospective losses of riparian habitat (see Section 2.3).

The climatic monitoring program for the PBHSP involves collecting existing, publicly available precipitation and temperature data in the vicinity of the Prado Basin. Figure 2-3 shows the location of the stations where data are available and collected for the PBHSP. These sites include monitoring stations for the California Irrigation Management Information System (CIMIS) for temperature data, spatially gridded climate datasets from Next-Generation Radar (NEXRAD), and the PRISM Climate Group for regional precipitation and temperature data. The Chino Basin boundary was used to extract the spatially gridded data for precipitation, and the Prado Basin boundary was used to extract the spatially gridded data for maximum and minimum temperature. Climatic data are collected annually and uploaded to Watermaster's relational database.

2.2.4 Other Factors That Can Affect Riparian Habitat

The AMP recognizes that there are potential factors other than groundwater, surface water, and climate that can affect riparian habitat in the Prado Basin. These factors include, but are not limited to: wildfire, disease, pests, and invasive species. To the extent necessary, data and information on these factors are collected and analyzed to explore for relationships to changes in the extent and quality of the riparian habitat.

In WY 2016, during the analysis for the first Annual Report, two specific factors were identified as potential impacts to the Prado Basin riparian habitat: wildfires and an invasive pest known as the Polyphagous Shot-Hole Borer (*Euwallacea fornicates*; PSHB hereafter). In WY 2018, the removal of the non-native invasive weed *Arundo donax* (Arundo) was identified as a factor to impact riparian habitat in the Prado Basin. The following describes the information that was collected for these three factors and how they are used to explore for relationships to changes that have occurred in the extent and quality of riparian habitat.



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K:\Clients\941 Chino Basin Watermaster\00-00-00 Master\PE1 - Data_Monitoring\GIS\MXD\Prado\Annual Report\Figure 2-3_Surface Water and Climate Monitoring.mxd

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Surface Water and Climate
Monitoring Programs

Figure 2-3

2.2.4.1 Wildfires

Wildfires occur periodically in the Prado Basin and can reduce the extent and quality of riparian habitat. For the PBHSP, the occurrence and locations of wildfires are used to help understand and explain the trends observed in the extent and quality of the riparian vegetation.

To map the extent of any wildfires that have occurred in the study area, fire-perimeter data were collected from the Fire and Resource Assessment Program (FRAP) of the California Department of Forestry and Fire Protection (CAL FIRE).[4]

For the current reporting period, wildfire data were obtained from the FRAP database for the Prado Basin region for calendar year 2019[5] and from the mapped extent of 2020 wildfire documented in the OCWD's *Prado Basin Water Conservation and Habitat Assessment Report for 2019-2020* (OCWD, 2021).

2.2.4.2 Polyphagous Shot-Hole Borer (PSHB)

The PSHB is a beetle that burrows into trees, introducing a fungus (*Fusarium euwallacea*) into the tree bark that spreads the disease Fusarium Dieback (FD).[6,7] FD destroys the food and water conducting systems of the tree, eventually causing stress and tree mortality. The PSHB was first discovered in Southern California in 2003 and has been recorded to have caused branch die-back and tree mortality for various tree specimens throughout the Southern California region (USDA, 2013). Since 2016, the PSHB is an identified pest within the Prado Basin that has the potential to negatively impact riparian habitat vegetation (USBR, 2016; Palenscar, K., personal communication, 2016; McPherson, D., personal communication, 2016).

Information on PSHB occurrence in the Prado Basin has been obtained during the USBR vegetation surveys of riparian habitat in the Prado Basin for the PBHSP during 2016 and 2019, and also from the University of California, United States Department of Agriculture (USDA) and Natural Resources' online PSHB/FD Distribution Map[8], and the OCWD's PSHB trap deployment and monitoring. For the PBHSP, the occurrences of the PSHB in the Prado Basin are used to help understand and explain the trends observed in the extent and quality of the riparian vegetation. There was no new information on the PSHB occurrence in the Prado Basin collected for the current reporting period.

2.2.4.3 Arundo Removal

Non-native Arundo is prominent throughout riparian habitat in the Prado Basin. Arundo consumes significantly more water than native plants, can out-compete native vegetation, and is flammable in nature increasing the risk of wildfire. There are several SAR watershed stakeholders that remove Arundo in the riparian habitat to restore native habitat to aid in the recovery of the threated and endangered species, such as the Least Bell's Vireo and Santa Ana Sucker. For the PBHSP, the occurrence and locations of habitat restoration activities that include the removal of Arundo can help understand and explain trends in the extent and quality of the riparian habitat. The OCWD and Santa Ana Watershed Association

[4] Frap.fire.ca.gov

[5] Data for the previous year is available each year in April.

[6] UCANR.edu

[7] Cisr.Ucr.Edu

[8] Ucanr.edu

(SAWA) in coordination with others, are the main entities in the watershed that implement habitat restoration programs that include removing Arundo.

In WY 2020, information on Arundo removal and management activities that have occurred recently in the Prado Basin were obtained to track these programs and explore if there is a connection between these activities and trends observed in the extent and quality of riparian habitat. This effort involved coordinating with the OCWD and SAWA to obtain information on the location and timing of these programs.

2.3 Prospective Loss of Riparian Habitat

Monitoring and mitigation requirement 4.4-3 in the Peace II SEIR calls for annual reporting for the PBHSP.

Annual reports will be prepared and will include recommendations for ongoing monitoring and any adaptive management actions required to mitigate any measured loss or **prospective loss** of riparian habitat that may be attributable to the Peace II Agreement (emphasis added).

The meaning of “prospective loss” in this context is “future potential losses” of riparian habitat. Predictive modeling of groundwater levels can be used to answer question 8 from the AMP:

- Are there areas of prospective loss of riparian habitat that may be attributable to the Peace II Agreement?

Watermaster’s most recent groundwater-modeling results can be used to evaluate forecasted groundwater-level changes within the Prado Basin under current and projected future conditions in the Basin, including, but not limited to, plans for pumping, storm-water recharge, and supplemental water recharge. To perform this evaluation, the predictive model results are mapped and analyzed to identify areas (if any) where groundwater levels are projected to decline to depths that may negatively impact riparian habitat in the Prado Basin.

For this Annual Report, Watermaster’s most recent groundwater model projections were used to characterize future groundwater-level conditions in the PBHSP study area. This model projection was the simulation of planning scenario “2020 SYR1” for the 2020 recalculation of Safe Yield using the updated Chino Basin groundwater-flow model (WEI, 2020)

3.0 RESULTS AND INTERPRETATIONS

3.1 Trends in Riparian Habitat Extent and Quality

This section describes the analysis and interpretation of the monitoring data and groundwater-modeling results for the PBHSP. Analyzed data span various historical periods, based on data availability, and include both pre- and post-Peace II implementation (2007).

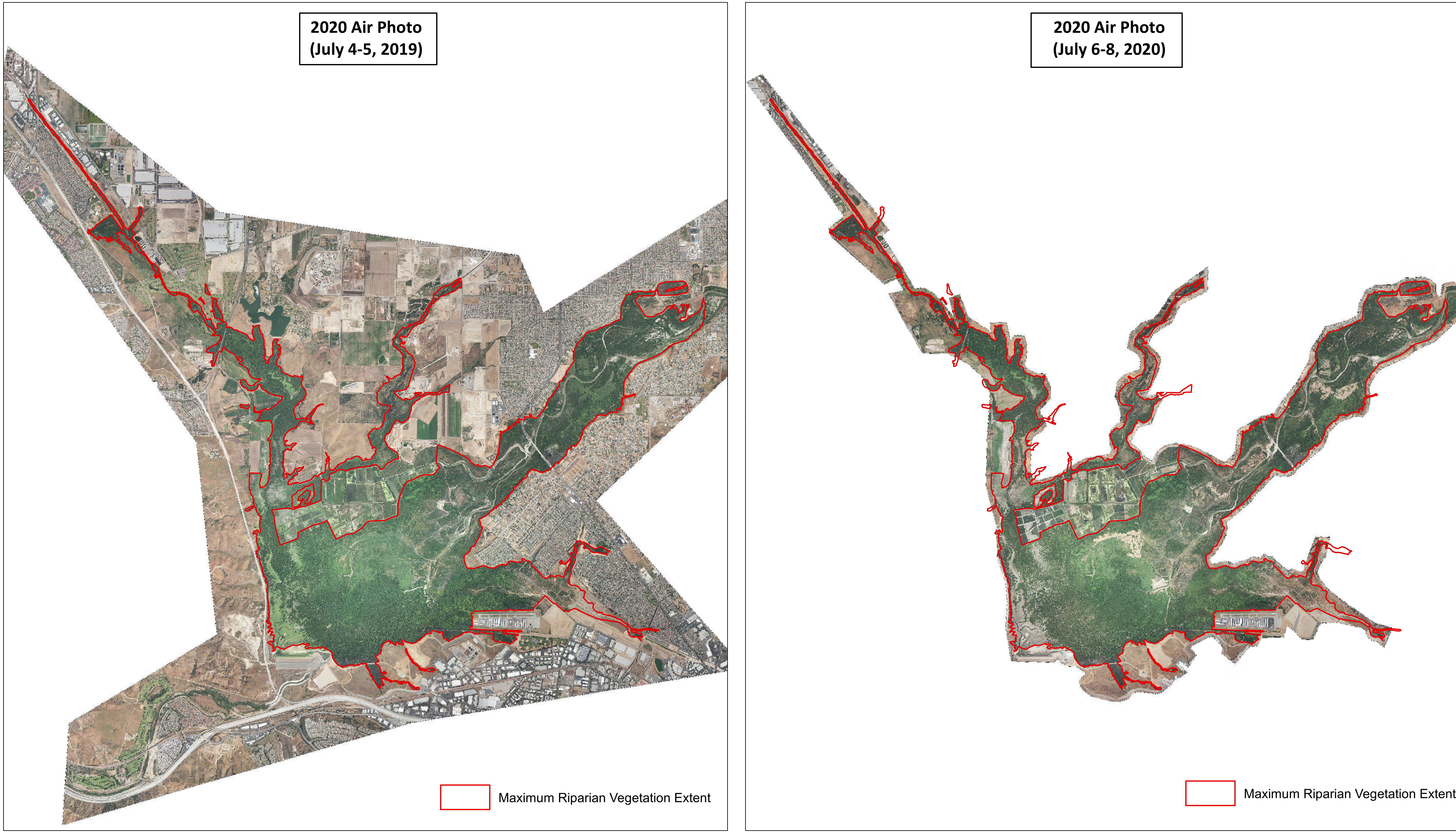
More specifically, this section describes the trends in the extent and quality of the riparian habitat, describes the trends in factors that can impact the riparian habitat, and evaluates potential cause-and-effect relationships—particularly any cause-and-effect relationships that may be associated with Peace II implementation. The factors that could have potentially impacted the extent and quality of the riparian habitat, including changes in groundwater levels, surface-water discharge, climate, and other factors, such as pests, wildfires, and habitat management activities. Declining groundwater levels is the primary factor that is potentially related to Peace II implementation and could adversely impact the riparian habitat.

This section also includes a review of Watermaster's most recent predictive Chino Basin groundwater modeling results to identify areas of potential future drawdown that could impact the riparian habitat.

3.1.1 Extent of the Riparian Habitat

Previous Annual Reports include an analysis of the riparian vegetation using historical air photos to map the density and extent of the vegetation in the Prado Basin (WEI, 2017; 2018; 2019; 2020). The analysis concluded in general, from 1960 to 1999, the mapped extent of the riparian habitat increased from about 1.8 to 6.7 square miles (mi^2), and its vegetated density increased. Since 1999, the extent and vegetated density of the riparian habitat has remained relatively constant.

Figure 3-1a compares air photos that were acquired for the PBHSP in July 2019 and July 2020. Both of these air photos are high resolution (3-inches pixels), which allows for a side-by-side visual comparison of riparian vegetation extent and quality from 2019 to 2020.



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Author: SO

Date: 4/26/2021

K:\Clients\941 Chino Basin Watermaster\00-00-00 Master\PE1 - Data_Monitoring\GIS\MXD\Prado\Annual Report\Figure 3-1a_2019-2020 AirPhoto.mxd

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Prepared for:

Air Photos and Extent of the Riparian Vegetation
2019 and 2020

Figure 3-1a

Figure 3-1b compares the 2020 air photo and the mapped extent of the riparian habitat to the NDVI estimates for the Prado Basin area on a date that corresponds to the maximum of the spatial average of NDVI during the growing season for 2020.[9] Four main observations and interpretations are derived from this figure:

- Generally, the following ranges in NDVI during the growing season correspond to these land cover types:
  - < 0: Water
  - 0 - 0.2: Non-vegetated surfaces, such as urbanized land cover and barren land
  - 0.3 - 1.0: Vegetated land cover: higher NDVI values indicate greater photosynthetic activity
- Prado Basin riparian vegetation areas have NDVI estimates of about 0.3 to 0.9 during the growing season. Active agricultural lands in the Prado Basin region can also have NDVI values of a similar range during the growing season.
- The NDVI estimates support the delineation of the extent of the riparian habitat as drawn from the air photos.
- The consistency of NDVI values to land cover observed in the air photo indicates that the processing of NDVI estimates for this study were performed accurately, which supports subsequent analyses and interpretations.

3.1.2 Quality of the Riparian Habitat

As discussed, and referenced in Section 2.0, NDVI is an indicator of the photosynthetic activity of vegetation and therefore can be used to interpret the health or "quality" of the riparian vegetation. In this section, NDVI is spatially and temporally analyzed in maps and time-series charts for defined areas throughout Prado Basin to characterize changes in the quality of riparian habitat over the period 1984 to 2020.

3.1.2.1 Spatial Analysis of NDVI

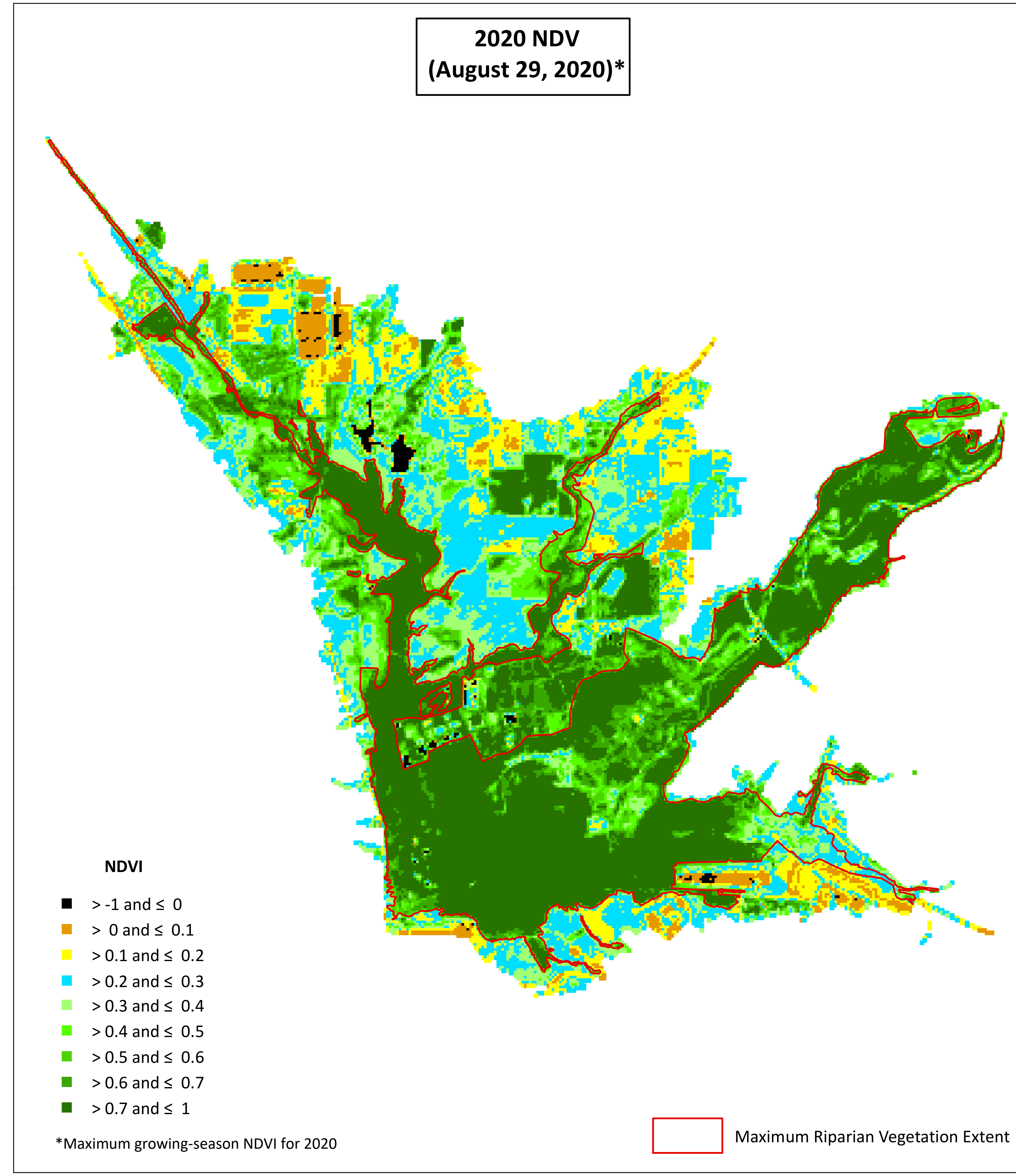
Figure 3-2 compares maps of NDVI across the entire Prado Basin area for 2019 and 2020 on the dates that correspond to the maximum growing-season NDVI as a spatial average across the entire extent of the riparian vegetation in the Prado Basin. Figure 3-3 is a map of change in NDVI from 2019 to 2020 that was prepared by subtracting the 2019 NDVI map from the 2020 NDVI map on Figure 3-2. These figures identify areas that may have experienced a change in the quality of riparian habitat from 2019 to 2020:

- About half of the riparian vegetation extent area showed no change in NDVI from 2019 to 2020.
- NDVI decreased in small patches along Mill Creek. Figure 3-1a corroborates these observations, showing a decrease in green land cover in these same areas from 2019 to 2020.
- NDVI decreased in large patches along the SAR and below the OCWD wetlands. Inspection of the air photos in Figure 3-1a corroborates these observations, showing a decrease in green land cover in these same areas from 2019 to 2020. Most of these areas align with areas where there was Arundo removal projects in 2019 and 2020 that is the cause of the NDVI decreases (see Section 3.6.3).

[9] The growing season for the Prado Basin riparian vegetation is from March through October (Merkel, 2007; USBR, 2008). The maximum NDVI for the 2019 growing season occurred on July 10, 2019.

- NDVI increased in the southern portion of Chino Creek above the OCWD wetlands and along portions of the SAR.

These spatial changes in NDVI will be analyzed along with the factors that can impact riparian habitat in Sections 3.2 through 3.6 of this report.



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K:\Clients\941 Chino Basin Watermaster\00-00-00 Master\PE1 - Data_Monitoring\GIS\MXD\Prado\Annual Report\Figure 3-1b_2020 AirP_NDVI.mxd

N

0 1 2 Miles

0 1 2 Km

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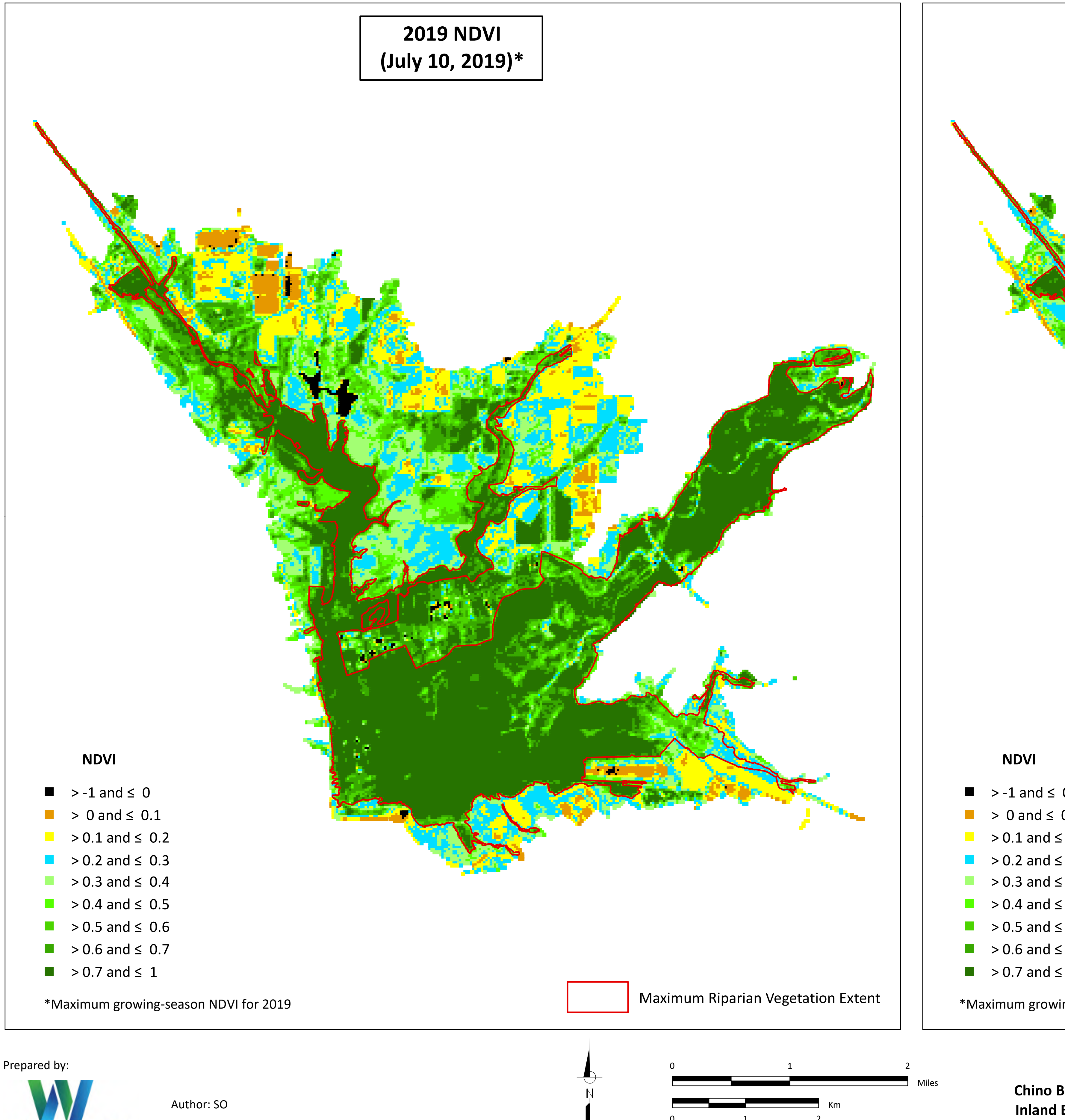
Air Photo and Spatial NDVI for the Prado Basin
2020

Figure 3-1b



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Author: SO

Date: 4/13/2021

K:\Clients\941 Chino Basin Watermaster\00-00-00 Master\PE1 - Data_Monitoring\GIS\MXD\Prado\Annual Report\Figure 3-2_2019_2020_NDVI.mxd

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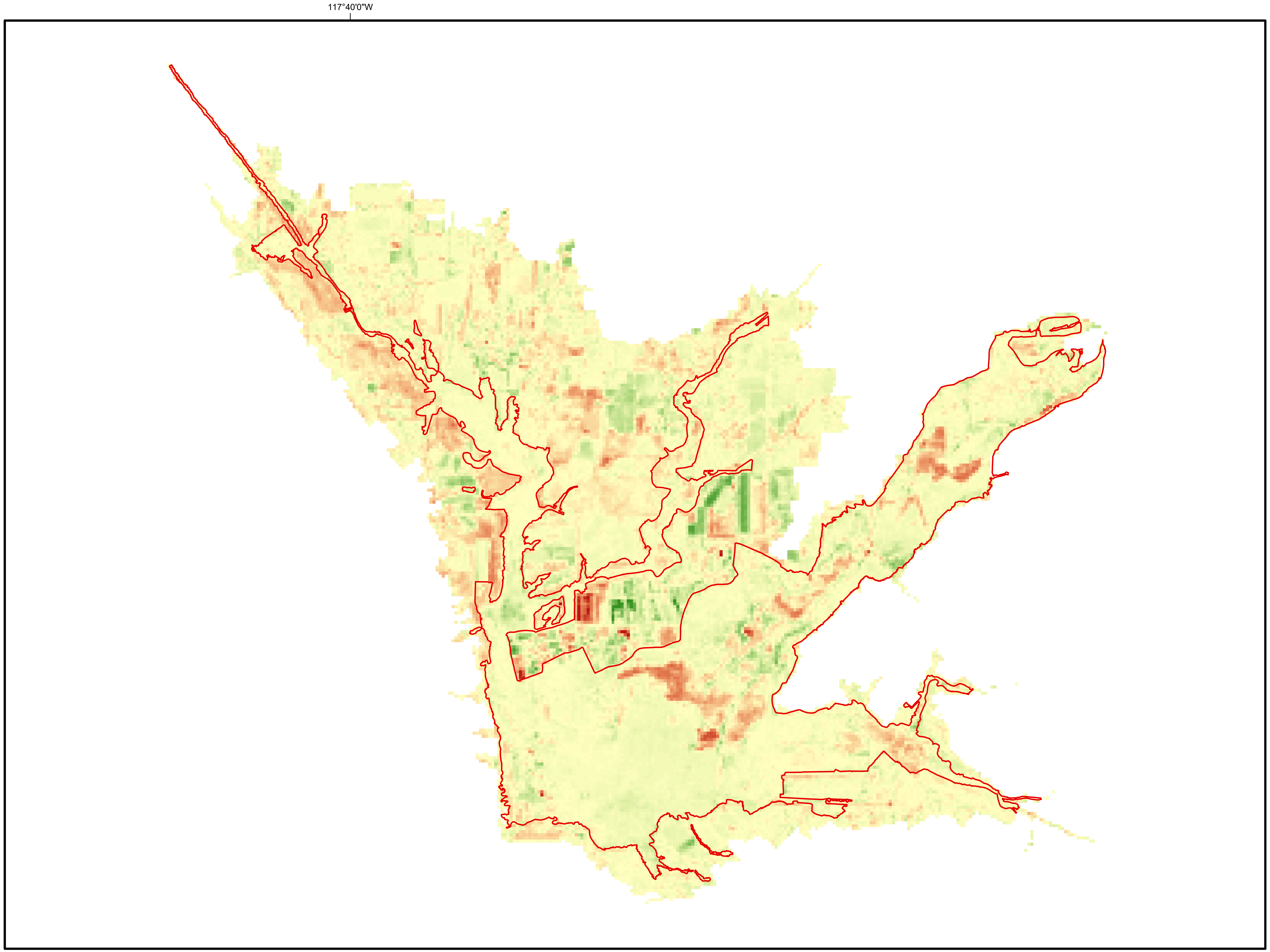
Prepared for:

Spatial NDVI for the Prado Basin
2019 and 2020

Figure 3-2

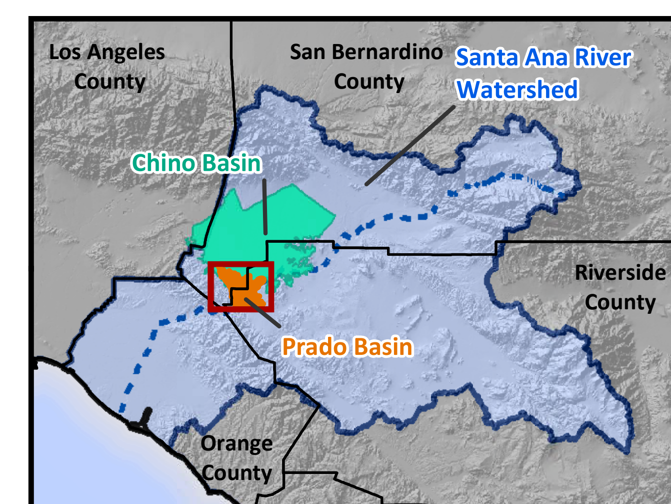


Change in Maximum Growing-Season NDVI Values
2019 to 2020

0.8 Increase

-0.8 Decrease

Maximum Riparian Vegetation Extent in Prado Basin



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Author: SO

Date: 5/5/2021

K:\Clients\941 Chino Basin Watermaster\00-00-00 Master\PE1 - Data_Monitoring\GIS\MXD\Prado\Annual Report\Figure 3-3_Change NDVI2019_2020.mxd

0 1 2 Miles

0 1 2 Km

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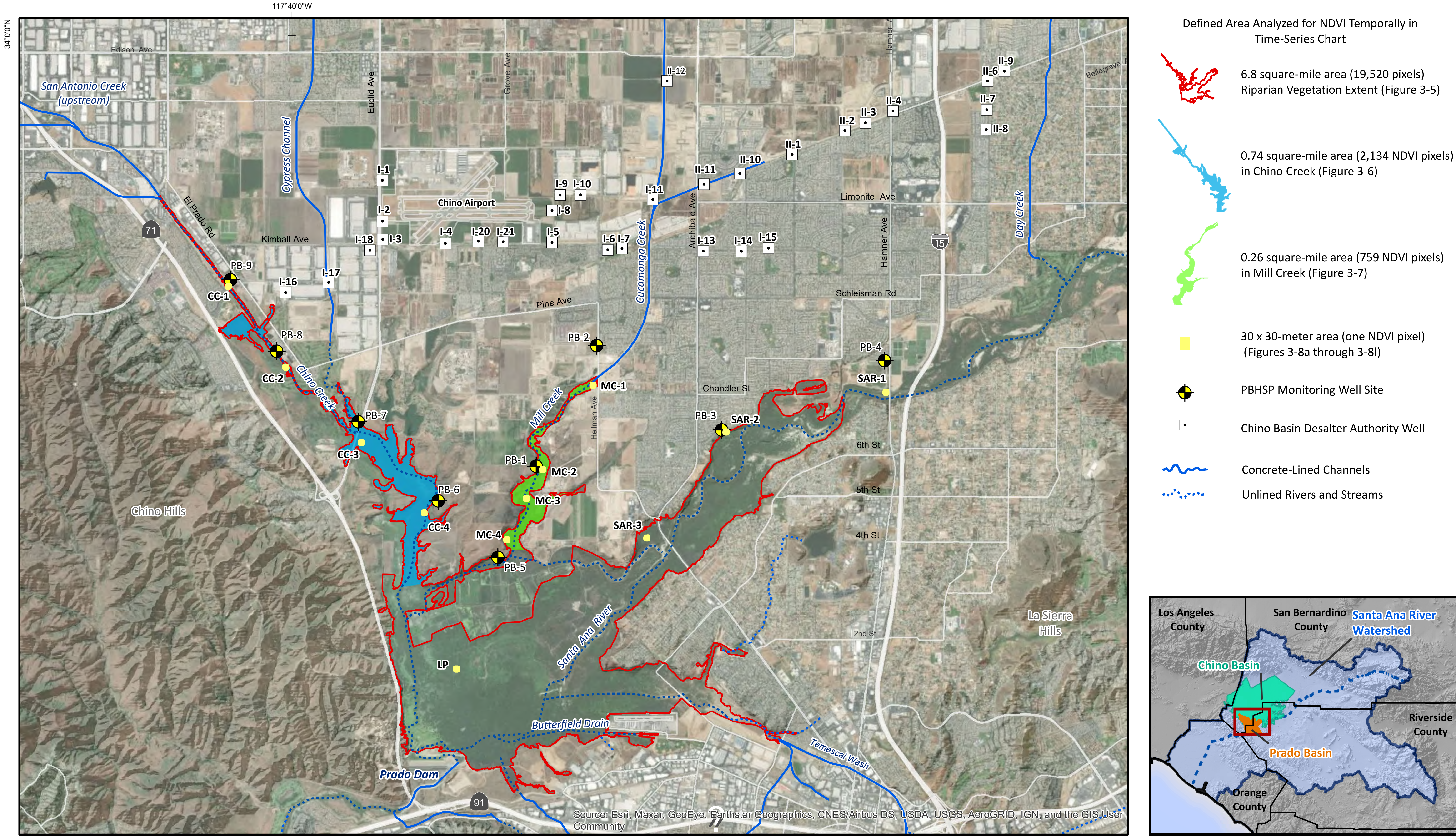
Spatial Change in NDVI for the Prado Basin
2019 and 2020

Figure 3-3



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Author: VWW

Date: 4/14/2021

K:\Clients\941 Chino Basin Watermaster\00-00-00 Master\PE1 - Data_Monitoring\GIS\MXD\Prado\Annual Report\Figure 3-4 Veg Monitoring_NDVI_Sites.mxd

0 1 2 Miles

0 1 2 Km

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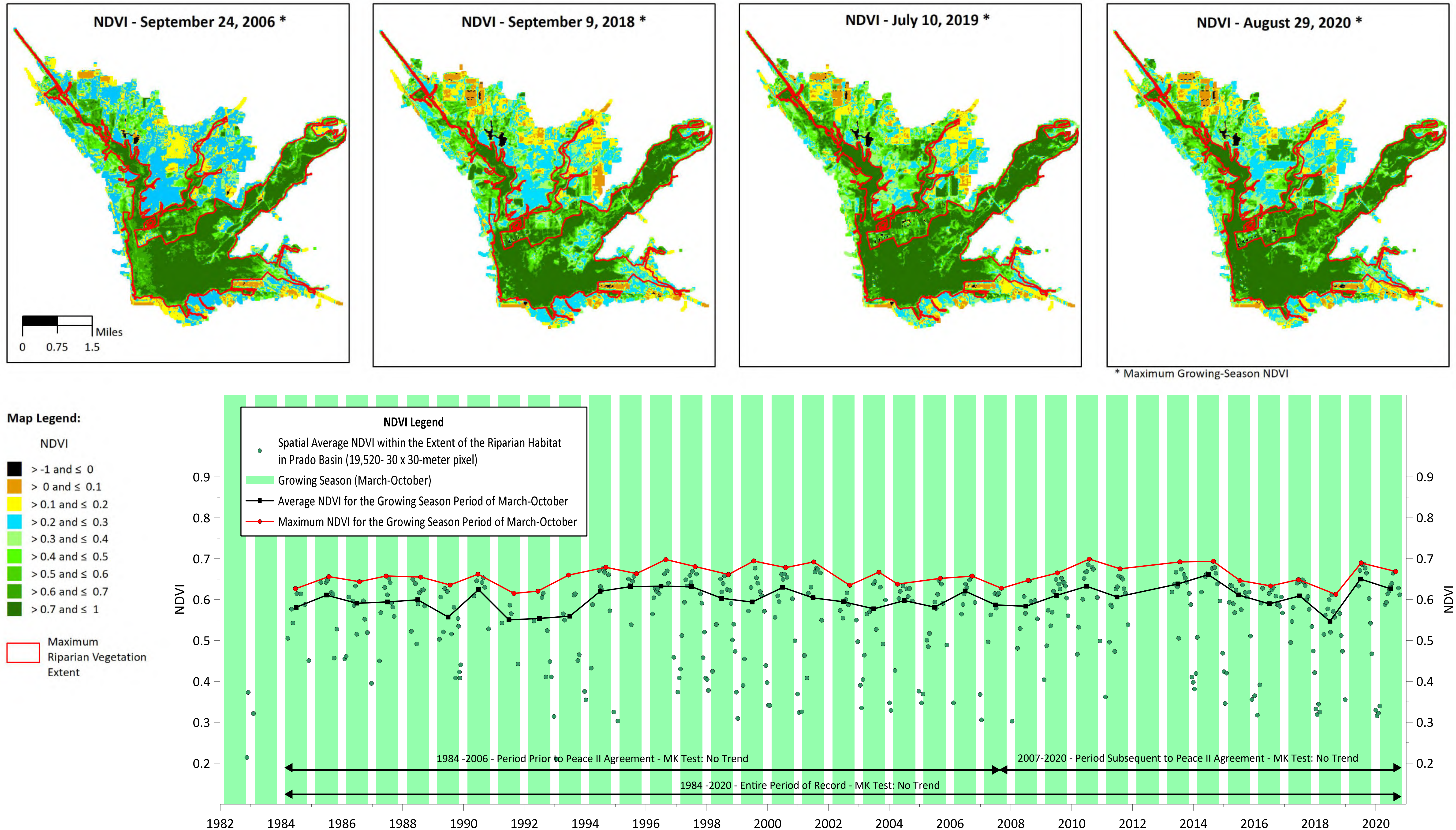
Areas for Analysis of NDVI Time Series

Figure 3-4



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Author: VMW
Date: 1/21/2020
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Prado Basin Habitat Sustainability Committee
2020 Annual Report

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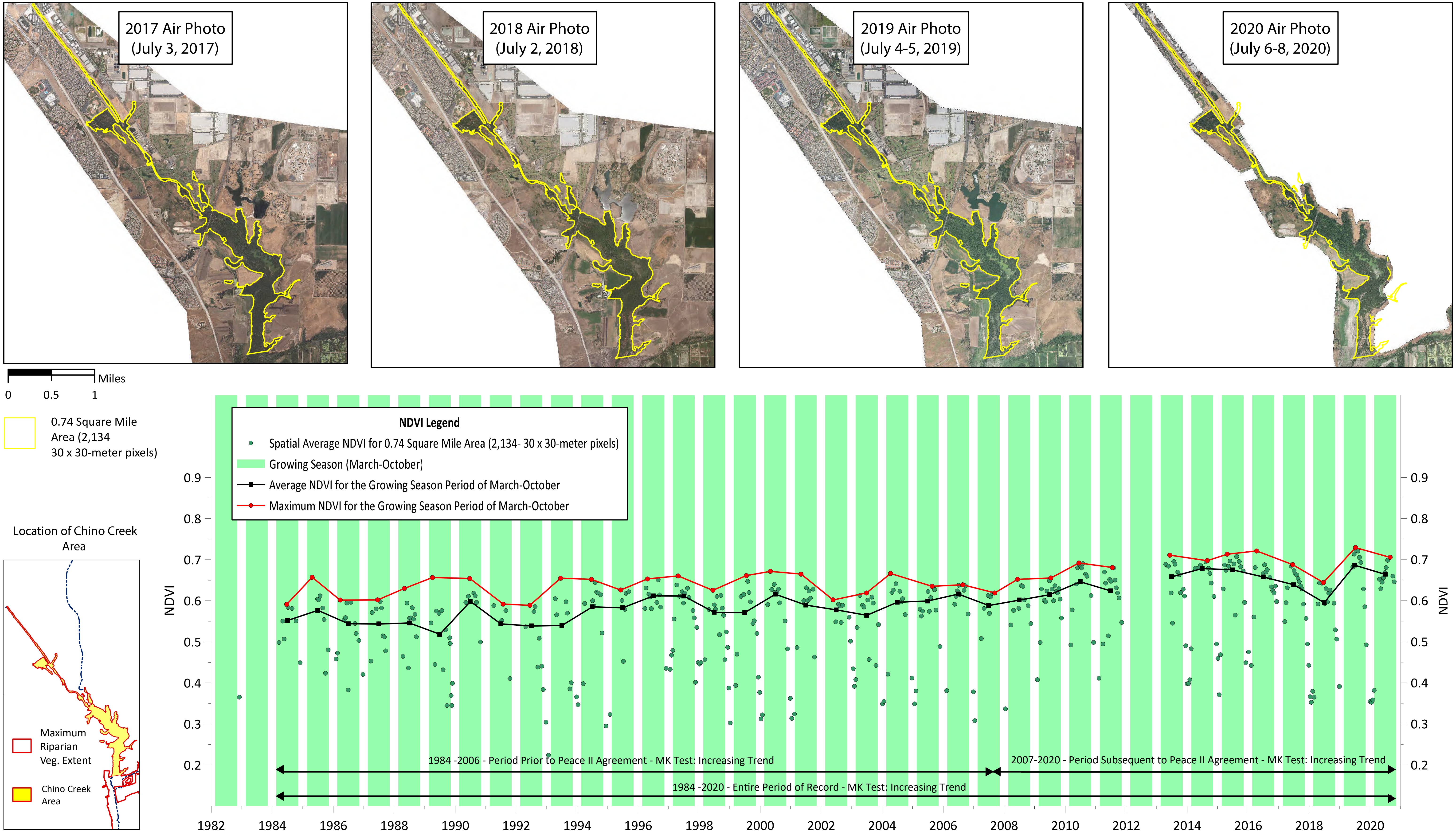
Time Series of NDVI for the Riparian Vegetation Extent for 1984 to 2020

Figure 3-5



Prepared by:

WEST YOST Water. Engineered

Author: VMW
Date: 1/21/2020
K:\Clients\Chino Basin Watermaster\00-00-00 Chino Basin Master Project\PE1\PBHSP\GRAPHER\GRF\AnnualR\Figure3-9a_NDVI_CC-1

Prado Basin Habitat Sustainability Committee
2020 Annual Report

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CHINO BASIN WATERMASTER Partners in Basin Management

Time Series of NDVI and Air Photos
Along Chino Creek Area for 1984 to 2020

Figure 3-6

3.1.2.2 Temporal Analysis of NDVI

NDVI pixels[10] within defined areas throughout the Prado Basin were spatially averaged and temporally analyzed in time-series charts. The defined areas include large and small areas within Prado Basin and are shown in Figure 3-4. The large areas include the entire extent of the riparian habitat (6.8 mi^2 – 19,520 NDVI pixels), the extent of the riparian habitat along the upper portion of Chino Creek (0.74 mi^2 – 2,134 NDVI pixels), and the extent of the riparian habitat along Mill Creek (0.26 mi^2 – 759 NDVI pixels). The small areas are located along the northern reaches of the Prado Basin riparian habitat near the PBHSP monitoring wells and align with a location of a USBR vegetation survey (10-meter radius plot). All the small areas are one NDVI pixel (30 x 30-meter pixel – 900 square meters).[11]

Figures 3-5 through 3-8l are time-series charts of the NDVI for each of the defined areas that indicate changes in the quality of riparian habitat over time. These figures are used to characterize long- and short-term changes in NDVI in specific areas, which provide context for interpreting the trends and changes in NDVI that have been occurring during Peace II implementation. Each figure shows three datasets that illustrate trends in the NDVI estimates:

- **Spatial Average NDVI** (green dots). Spatial Average NDVI are the spatial average of the NDVI pixels within the defined area. These data characterize the seasonal and long-term trends in NDVI for each defined area. The NDVI exhibit an oscillatory pattern caused by seasonal changes in the riparian habitat. The NDVI time-series are typical for a deciduous forest, where NDVI values are higher in the growing season from March through October and lower in the dormant season from November through February when plants and trees shed their leaves.
- **Average Growing-Season NDVI** (black squares and black curve). The Average Growing-Season NDVI is the annual average of the Spatial Average NDVI for each growing season from March through October. This curve shows the annual changes and long-term trends in the NDVI for the growing season. This metric is used to analyze year-to-year changes and long-term trends in NDVI.
- **Maximum Growing-Season NDVI** (red squares and red curve). The Maximum Growing-Season NDVI is the annual maximum of the Spatial Average NDVI for each growing season from March through October. Maximum Growing-Season NDVI typically occurs during summer months. This curve shows the annual changes and long-term trends in the maximum NDVI.

NDVI maps or air photos are included on the time-series charts for spatial reference and as a visual check on the interpretations derived from the time-series charts. These air photos are for 2017, 2018, 2019, and 2020— showing the last four years using the high-resolution air photos collected for the PBHSP.

To statistically characterize long-term trends in NDVI, the Mann-Kendall statistical trend test (Mann-Kendall test) was performed on the Average Growing-Season NDVI for all defined areas over the following three periods:

[10] Each NDVI pixel is 30 x 30 meters.

[11] In previous annual reports these small areas were four NDVI pixels in this same general area. During WY 2020, these areas were modified to one NDVI pixel that aligned with the USBR vegetation survey to that the field vegetation survey data can better correlate with the NDVI time-series data.

- 1984 to 2019: the entire period of record
- 1984 to 2006: period prior to Peace II Agreement implementation
- 2007 to 2020: period subsequent to Peace II Agreement implementation

The Mann-Kendall test utilizes a ranking formula to statistically analyze if there is an increasing trend, decreasing trend, or no trend in the NDVI time-series. Appendix B describes the Mann-Kendall test methods and results. The final Mann-Kendall test results for the Average Growing-Season NDVI are shown on each time-series chart and are summarized in Table 3-1.

Table 3-1. Mann-Kendall Test Results of the Average-Growing Season NDVI Trends for Defined Areas in the Prado Basin

Defined Area	Figure Number	Mann Kendal Test Result[(a)]		
		Period of Record 1984 - 2020	Prior to Peace II 1984 - 2006	Post Peace II 2007 - 2020
Riparian Vegetation Extent	3-5	No Trend	No Trend	No Trend
Chino Creek Area	3-6	Increasing	Increasing	Increasing
Mill Creek Area	3-7	No Trend	Decreasing	No Trend
CC-1	3-8a	Increasing	No Trend	No Trend
CC-2	3-8b	Increasing	Increasing	Increasing
CC-3	3-8c	Increasing	Increasing	Increasing
CC-4	3-8d	Increasing	No Trend	Increasing
MC-1	3-8e	Increasing	No Trend	Increasing
MC-2	3-8f	No Trend	No Trend	Increasing
MC-3	3-8g	No Trend	No Trend	Increasing
MC-4	3-8h	Increasing	No Trend	No Trend
SAR-1	3-8i	No Trend	No Trend	Increasing
SAR-2	3-8j	No Trend	Decreasing	Increasing
SAR-3	3-8k	Increasing	No Trend	Increasing
LP	3-8l	Increasing	No Trend	Increasing

(a) See Appendix B for a description of the Mann-Kendall statistical trend test and results.

To characterize the short-term trends in NDVI, Table 3-2 summarizes the one-year change in the Average Growing-Season NDVI from 2019 to 2020 at the 15 defined areas and compares to the changes and variability in Average Growing-Season NDVI over the historical period of 1984 to 2019 at each area. During WY 2020, there were variable trends in the NDVI from 2019 to 2020 at each area; seven areas increased; seven areas decreased; and one area showed no trend. These one-year changes in the Average Growing-Season NDVI were all within the range of long-term annual variability of the NDVI at each area.

Table 3-2. Characterization of Variability in the Average-Growing Season NDVI for Defined Areas in the Prado Basin

Defined Area	Figure Number	Historical NDVI Statistics 1984 - 2019		One-Year Change in NDVI1 from 2019-2020
		Average Annual Change in NDVI (Absolute Value)	Maximum One-Year Change in NDVI (Absolute Value)	
Riparian Vegetation Extent	3-5	0.03	0.10	-0.02
Chino Creek Area	3-6	0.02	0.09	-0.02
Mill Creek Area	3-7	0.07	0.57	-0.01
CC-1	3-8a	0.03	0.11	-0.02
CC-2	3-8b	0.03	0.13	0.01
CC-3	3-8c	0.03	0.13	-0.02
CC-4	3-8d	0.03	0.12	-0.02
MC-1	3-8e	0.04	0.31	0.06
MC-2	3-8f	0.05	0.14	0.03
MC-3	3-8g	0.03	0.12	-0.05
MC-4	3-8h	0.03	0.13	0.00
SAR-1	3-8i	0.06	0.44	0.04
SAR-2	3-8j	0.04	0.21	0.02
SAR-3	3-8k	0.03	0.10	0.03
LP	3-8l	0.03	0.10	0.02

3.1.2.2.1 Temporal Analysis of NDVI in Prado Basin

Figure 3-5 is a time-series chart from 1984 to 2020 of the spatial average of all 19,520 NDVI pixels that are within the maximum delineated extent of the riparian habitat in the Prado Basin.[12] The intent of the time series is to characterize the trends in NDVI for the Prado Basin as a whole, which is used as a basis of comparison to the trends in the NDVI for each of the smaller defined areas shown in subsequent figures. Figure 3-5 also includes NDVI maps from, 2017, 2018, 2019, and 2020 to visually compare to the NDVI time-series.

Figure 3-5 and Tables 3-1 and 3-2 show that the Average Growing-Season NDVI varies from year-to-year by no more than 0.10 with no apparent long-term trends. The Mann-Kendall test result on the Average Growing-Season NDVI indicates “no trend” over the 1984 to 2020 period, “no trend” over the 1984 to 2006 period, and “no trend” over the 2007 to 2020 period.

[12] The extent of the riparian habitat in the Prado Basin has been relatively stable since 1999, and has been verified by inspection of the 2017, 2018, 2019, and 2020 high-resolution air photos.

From 2019 to 2020, the Average Growing-Season NDVI decreased by 0.02. This recent one-year decrease in Average Growing-Season NDVI is within the historical range of the annual Average Growing-Season NDVI variability for the extent of the riparian vegetation.

This time-series analysis of NDVI suggests that the riparian habitat in Prado Basin, analyzed as a whole, has not experienced statistically significant declines in NDVI in the recent water year, nor during the post-Peace II Agreement period from 2007 to 2020.

3.1.2.2.2 Temporal Analysis of NDVI within Large Areas along Chino Creek and Mill Creek

Figure 3-6 and Figure 3-7 are time-series charts from 1984-2020 of the spatial average for all NDVI pixels within large areas of riparian habitat located along the reaches of Chino Creek and Mill Creek. These charts characterize trends and changes in NDVI for these northern reaches of the riparian habitat in the Prado Basin, and provide a basis for comparison to the NDVI trends and changes for each of the smaller defined areas. These figures include a series of air photos for spatial reference and as a visual check on the interpretations derived from the NDVI time-series charts. The air photos are for 2017, 2018, 2019, and 2020— showing the last four years using the high-resolution air photos collected for the PBHSP.

Chino Creek

Figure 3-6 is an NDVI time-series chart for 1984-2020 of the spatial average of all 2,134 NDVI pixels along the northern reach of Chino Creek in the Prado Basin. This reach of Chino Creek is susceptible to impacts from declining groundwater levels associated with Peace II implementation.

Figure 3-6 and Tables 3-1 and 3-2, show that over the period of record, the Average Growing-Season NDVI varied from year-to-year by no more than 0.09 with no long-term declining trends. The Mann-Kendall test result on the Average Growing-Season NDVI indicates an "increasing trend" over the 1984 to 2020 period, an "increasing trend" over the 1984 to 2006 period, and "increasing trend" over the 2007 to 2020 period.

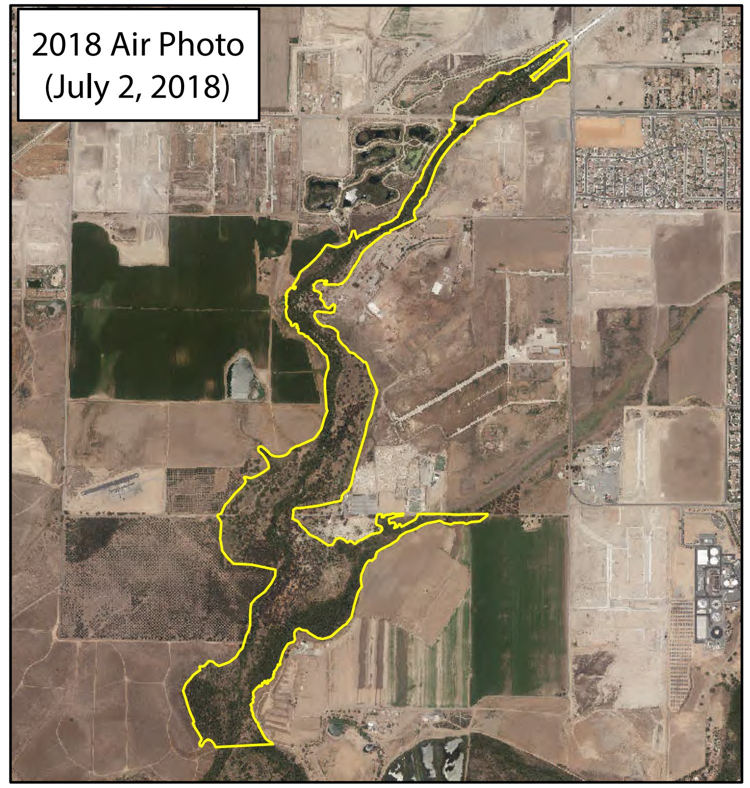
From 2019 to 2020, the Average Growing-Season NDVI decreased by 0.02, which is within the historical range of variability for the annual Average Growing-Season NDVI. Visual inspection of the 2019 and 2020 air photos show a slight decrease in greenness along the southern portion of Chino Creek.

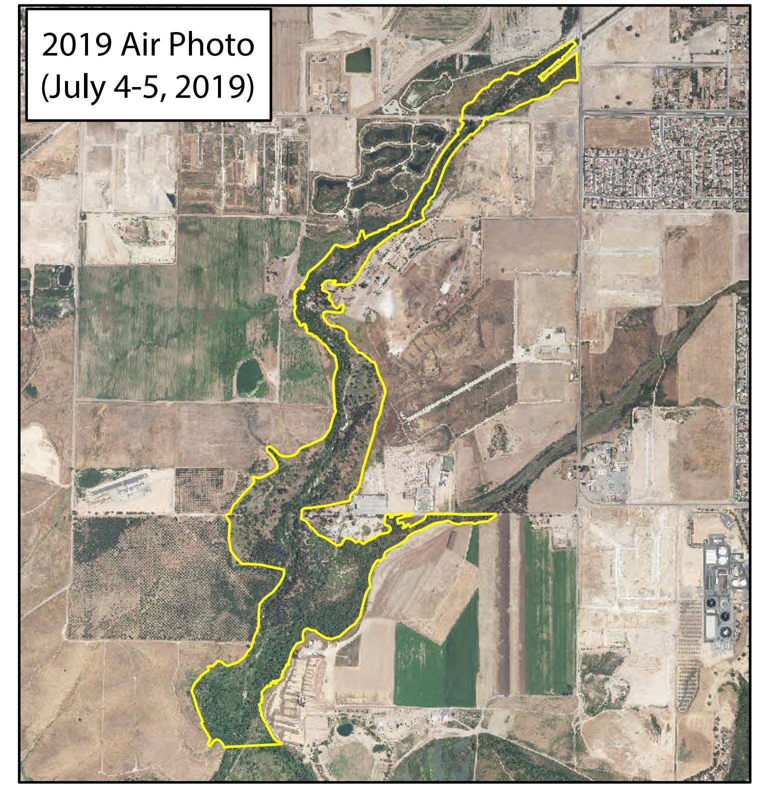
Mill Creek

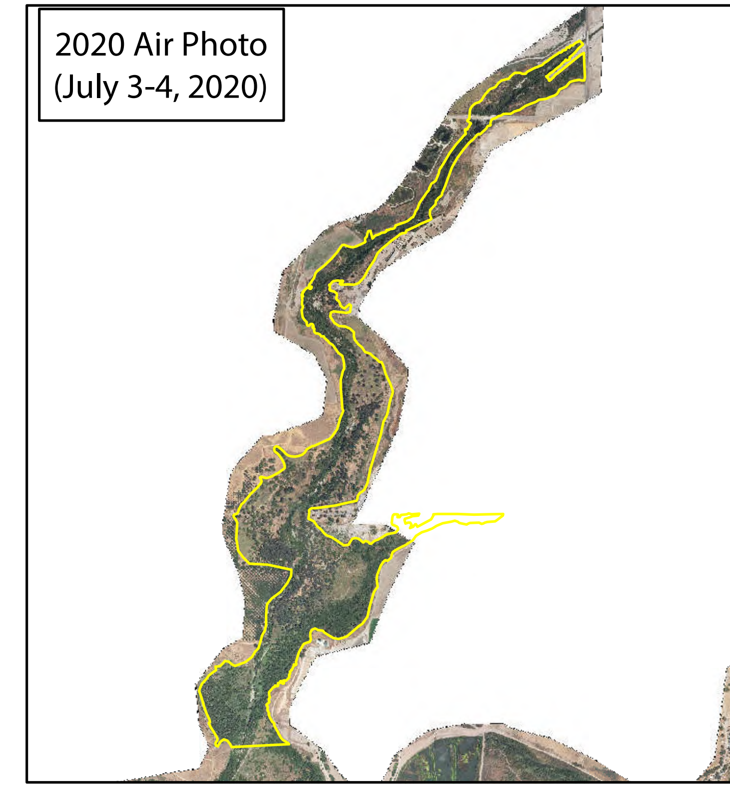
Figure 3-7 is a NDVI time-series chart for 1984-2020 of the spatial average of all 759 NDVI pixels along the northern reach of Mill Creek in the Prado Basin. This reach of Mill Creek is susceptible to impacts from declining groundwater levels associated with Peace II implementation.

Figure 3-7 and Tables 3-1 and 3-2, show that over the period of record, the Average Growing-Season NDVI varied from year-to-year by no more than 0.57. The Mann-Kendall test result on the Average Growing-Season NDVI indicates "no trend" over the 1984 to 2020 period, "decreasing trend" over the 1984 to 2006 period, and "no trend" over the 2007 to 2020 period.

From 2019 to 2020, the Average Growing-Season NDVI decreased by 0.01, which is within the historical range of variability for the annual Average Growing-Season NDVI. Visual inspection of the 2019 and 2020 air photos show a slight decrease in greenness within the central portion of Mill Creek.



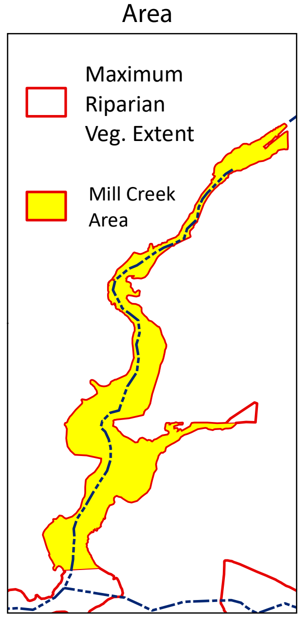


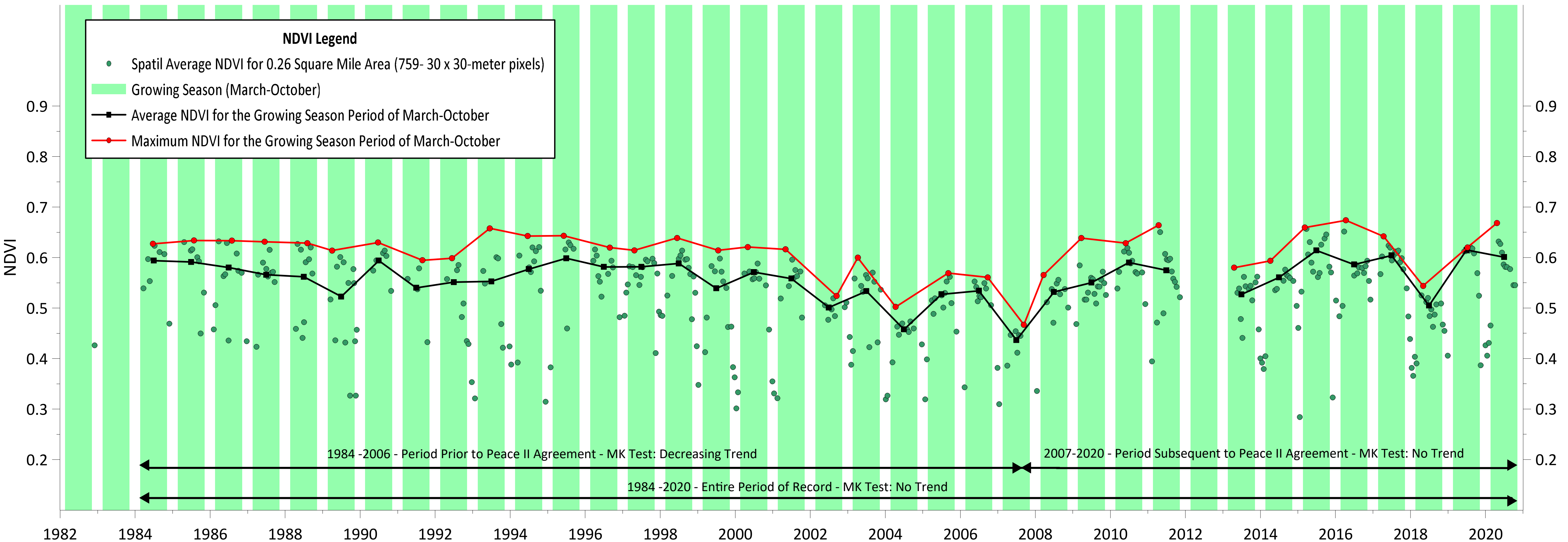


Miles
0 0.425 0.85

0.26 Square Mile Area (759 30 x 30 -meter pixels)

Location of Mill Creek Area





Prepared by:

WEST YOST
Water. Engineered

Author: VMW
Date: 1/21/2020
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Prado Basin Habitat Sustainability Committee
2020 Annual Report

Prepared for:

Time Series of NDVI and Air Photos Along Mill Creek Area for 1984 to 2020

Figure 3-7

3.1.2.2.3 Temporal Analysis of NDVI within Small Areas along Chino Creek, Mill Creek, and the Santa Ana River

Figures 3-8a through 3-8l are time-series charts of the NDVI for one NDVI pixel for small defined areas located along Chino Creek, Mill Creek, and the SAR near the PBHSP monitoring wells from 1984 to 2020. The areas are located near a PBHSP monitoring well to facilitate the comparison of changes in groundwater levels versus changes in the riparian habitat. These small areas also align with a location of a 10-meter radius plot where vegetation surveys are conducted by the USBR every three years so that the field measurements from the surveys can be compared to the NDVI.

The purpose of these charts is to characterize long-term trends and short-term changes in NDVI for smaller areas primarily located along the northern stream reaches of the Prado Basin riparian habitat—areas that are most susceptible to potential impacts from declining groundwater levels associated with Peace II implementation, and provide a basis for comparison to the NDVI trends and changes for each of the larger defined areas. Each figure includes a series of air photos for spatial reference and as a visual check on the interpretations derived from the NDVI time-series charts. The air photos are for 2017, 2018, 2019, and 2020—showing the last four years using the high-resolution air photos collected for the PBHSP.

***Chino Creek* (Figures 3-8a to 3-8d)**. Four vegetated areas were analyzed along Chino Creek just southwest of the CDA well field: CC-1, CC-2, CC-3, and CC-4 (see Figure 3-4 for locations).

These figures, and Tables 3-1 and 3-2, show that over the period of record the Average Growing-Season NDVI varied from year-to-year by up to 0.13 with no long-term declining trends. For all four areas, the Mann-Kendall test result on the Average Growing-Season NDVI indicates an "increasing trend" over the 1984 to 2020 period, "no trend" or "increasing trend" over the 1984 to 2006 period, and "no trend" or "increasing trend" over the 2007 to 2020 period.

For these four areas along Chino Creek, the Average Growing-Season NDVI from 2019 to 2020 decreased for three of the areas (CC-1, CC-2, CC-4) and increased for one of the areas (CC-3). At all of the areas, these one-year changes in the Average Growing-Season NDVI are relatively minor and within the historical ranges of one-year NDVI variability (see Table 3-2). Visual inspection of the 2019 and 2020 air photos do not show significant changes in the riparian vegetation.

***Mill Creek* (Figures 3-8e to 3-8h).** Four vegetated areas were analyzed along Mill Creek just south of the CDA well field: MC-1, MC-2, MC-3, and MC-4 (see Figure 3-4 for locations).

These figures, and Tables 3-1 and 3-2, show that over the period of record the Average Growing-Season NDVI varied year-to-year by up to 0.31 with no long-term declining trends. For all four areas, the Mann-Kendall test result on the Average Growing-Season NDVI indicates an "increasing trend" or "no trend" for the 1984 to 2020 period, "no trend" for the 1984 to 2006 period, and "increasing trend" or "no trend" for the 2007 to 2020 period.

For these four areas along Mill Creek, the Average Growing-Season NDVI from 2019 to 2020: increased for two of the areas (MC-1, MC-2), decreased for one of the areas (MC-3), and did not change for one of the areas (MC-4). At all of the areas these recent changes in the Average Growing-Season NDVI are within their historical ranges of the one-year NDVI variability. Visual inspection of the 2019 and 2020 air photos for the MC-3 area, where NDVI decreased from 2019 to 2020, shows a noticeable decrease in green vegetated areas.

***Santa Ana River* (Figures 3-8i to 3-8l).** Four vegetated areas were analyzed along the floodplain of the SAR south of the CDA well field: SAR-1, SAR-2, SAR-3, and LP (see Figure 3-4 for locations).

These figures, and Tables 3-1 and 3-2, show that over the period of record the Average Growing-Season NDVI varied by up to 0.44 from year-to-year. For all four areas, the Mann-Kendall test result on the Average Growing-Season NDVI indicates an “increasing trend” or “no trend” for the 1984 to 2020 period, “no trend” or “decreasing trend” for the 1984 to 2006 period, and an “increasing trend” for the 2007 to 2020 period.

At all four areas along the SAR, the Average Growing-Season NDVI from 2019 to 2020 increased. At all the areas, these one-year increases in the Average Growing-Season NDVI are relatively minor and within the historical ranges of one-year NDVI variability (see Table 3-2). Visual inspection of the 2019 and 2020 air photos do not show significant changes in the riparian vegetation.

3.1.3 Analysis of Vegetation Surveys

Vegetation surveys are performed for the PBHSP once every three years. The most recent vegetation survey was performed in 2019 by the USBR which was a continuation of the surveys performed in 2007, 2013, and 2016. Preliminary findings and results from the 2019 vegetation survey were published in the final report in June 2020 (USBR, 2020).

Table 3-3 summarizes some of the measured parameters for all areas surveyed in 2007, 2013, 2016, and 2019. The measurements of percent canopy cover from the USBR vegetation surveys are the most appropriate measured data for ground-truthing the NDVI. Percent canopy cover is a measurement of the percentage of the ground surface area that is directly covered by the vertical projections of tree crowns (USDA, 1999). Although there is no direct quantitative relationship between percent canopy cover and NDVI, percent canopy cover is a metric of the areal density of the vegetation that is reflecting visible and near-infrared light and therefore can be used for comparison with the NDVI analysis. The percent canopy cover at the survey location within the small areas of NDVI analysis in Figures 3-8a through 3-8l are charted with the NDVI time-series data. Where percent canopy cover measurements are available for more than one year, they typically show stable or increasing trends, consistent with the increasing trends in NDVI since 2007. Table 3-3a shows that overall the percent canopy cover for all surveyed areas each year has increased: the average percentages of canopy cover at all areas surveyed in 2007, 2013, 2016, and 2019 were 75-, 76-, 86-, and 82-percent, respectively.

Table 3-3. Summary of USBR Vegetation Surveys in 2007, 2013, 2016, and 2019 in the Prado Basin - Canopy Cover, Tree Condition, and Occurrence of Polyphagous Shot-Hole Borer

Site	Canopy Cover (%)[a]					Tree Condition (% trees surveyed per plot)[b]															Polyphagous Shot-Hole Borer[c]				
						Not Stressed (Live)					Stressed					Dead									
	2007	2013	2016	2019	Change Through 2019	2007	2013	2016	2019	Change Through 2019	2007	2013	2016	2019	Change Through 2019	2007	2013	2016	2019	Change Through 2019	Present in 2016	% of Trees in 2016	Present in 2019	% of Trees in 2019	% Change in 2019
Chino Creek Sites																									
Chino 3	59%	NM	NM	NM	-	NM	NM	NM	NM	--	NM	NM	NM	NM	--	NM	NM	NM	NM	--	NM	NM	NM	NM	--
Chino 3B	NM	97%	96%	96%	--	NM	100%	0%	33%	-67%	NM	0%	100%	44%	44%	NM	0%	0%	22%	22%	no	0%	no	0%	0%
Chino 4	80%	94%	98%	84%	4%	NM	100%	7%	55%	-45%	NM	0%	80%	40%	40%	NM	0%	13%	5%	5%	no	0%	no	0%	0%
Chino 9	92%	96%	95%	96%	4%	NM	100%	0%	23%	-77%	NM	0%	100%	59%	59%	NM	0%	0%	18%	18%	no	0%	no	0%	0%
Chino 11	94%	96%	96%	98%	4%	NM	100%	50%	69%	-31%	NM	0%	42%	0%	0%	NM	0%	8%	31%	31%	no	0%	no	0%	0%
Chino 16	46%	61%	81%	52%	7%	NM	NM	27%	50%	23%	NM	NM	64%	50%	-14%	NM	NM	9%	0%	--	no	0%	no	0%	0%
Chino 18	38%	87%	90%	77%	39%	NM	100%	7%	15%	-85%	NM	0%	67%	69%	69%	NM	0%	27%	15%	15%	yes	40%	no	0%	-40%
Chino 21	98%	94%	88%	17%	-81%	NM	100%	0%	73%	-27%	NM	0%	100%	0%	0%	NM	0%	0%	27%	27%	yes	17%	no	0%	-17%
Chino 24	93%	93%	98%	94%	1%	NM	100%	6%	32%	-68%	NM	0%	94%	56%	56%	NM	0%	0%	12%	12%	yes	6%	no	0%	-6%
Chino 30	79%	88%	NM	NM	--	NM	NM	NM	NM	--	NM	NM	NM	NM	--	NM	NM	NM	NM	--	NM	NM	NM	NM	--
Chino 30B	NM	NM	89%	74%	-15%	NM		0%	20%	20%	NM	NM	89%	50%	-39%	NM	NM	11%	30%	19%	yes	100%	no	0%	-100%
Chino 31	82%	93%	97%	91%	9%	NM	100%	7%	4%	-96%	NM	0%	93%	72%	72%	NM	0%	0%	24%	24%	yes	7%	no	0%	-7%
Chino 34	96%	97%	89%	75%	-21%	NM	100%	0%	33%	-67%	NM	0%	67%	33%	33%	NM	0%	33%	33%	33%	no	0%	no	0%	0%
Chino 78	95%	98%	87%	98%	3%	NM	100%	0%	45%	-55%	NM	0%	80%	55%	55%	NM	0%	20%	0%	0%	yes	80%	no	0%	-80%
Chino 81	92%	0%	NM	NM	-	NM	NM	NM	NM	--	NM	NM	NM	NM	--	NM	NM	NM	NM	--	NM	NM	NM	NM	--
Chino 85	89%	0%	NM	NM	--	NM	NM	NM	NM	--	NM	NM	NM	NM	--	NM	NM	NM	NM	--	NM	NM	NM	NM	--
Chino X3	NM	NM	93%	94%	1%	NM	NM	25%	83%	58%	NM	NM	75%	17%	-58%	NM	NM	0%	0%	0%	no	0%	no	0%	0%
Chino X4	NM	NM	92%	94%	2%	NM	NM	0%	43%	43%	NM	NM	100%	14%	-86%	NM	NM	0%	43%	43%	yes	100%	yes	71%	-29%
Chino X5	NM	NM	96%	95%	-1%	NM	NM	75%	89%	14%	NM	NM	25%	11%	-14%	NM	NM	0%	0%	0%	yes	25%	no	0%	-25%
Chino X6	NM	NM	98%	99%	1%	NM	NM	87%	47%	-40%	NM	NM	13%	47%	34%	NM	NM	0%	7%	7%	yes	13%	no	0%	-13%
Chino X7	NM	NM	88%	66%	-22%	NM	NM	0%	43%	43%	NM	NM	70%	43%	-27%	NM	NM	30%	14%	-16%	yes	70%	no	0%	-70%
Chino X8	NM	NM	85%	99%	14%	NM	NM	0%	71%	71%	NM	NM	62%	24%	-38%	NM	NM	38%	6%	-32%	yes	46%	yes	6%	-40%
Average	**81%**	**78%**	**92%**	**83%**	**-3%**	**-**	**100%**	**16%**	**46%**	**-21%**	**-**	**0%**	**73%**	**38%**	**10%**	**-**	**0%**	**11%**	**16%**	**12%**	**yes**	**28%**	**no**	**4%**	**-24%**
Mill Creek Sites																									
Mill 1	40%	0%	NM	NM	--	NM	NM	NM	NM	--	NM	NM	NM	NM	--	NM	NM	NM	NM	--	NM	NM	NM	NM	--
Mill 3	8%	13%	NM	NM	--	NM	NM	NM	NM	--	NM	NM	NM	NM	--	NM	NM	NM	NM	--	NM	NM	NM	NM	--
Mill 4	38%	6%	0%	0%	-38%	NM	0%	0%	100%	100%	NM	63%	50%	0%	-63%	NM	37%	50%	0%	-37%	yes	50%	no	0%	-50%
Mill 8	66%	88%	82%	79%	13%	NM	33%	33%	0%	-33%	NM	67%	0%	50%	-17%	NM	0%	67%	50%	50%	yes	33%	no	0%	-33%
Mill 11	75%	80%	NM	NM	--	NM	90%	NM	NM	--	NM	0%	NM	NM	--	NM	10%	NM	NM	--	NM	NM	NM	0%	--
Mill 18	62%	68%	78%	90%	28%	NM	100%	38%	10%	-90%	NM	0%	38%	80%	80%	NM	0%	25%	10%	10%	yes	38%	no	0%	-38%
Mill 22	89%	93%	96%	93%	4%	NM	86%	0%	43%	-43%	NM	0%	79%	43%	43%	NM	14%	21%	14%	0%	yes	64%	no	0%	-64%
Mill 30	63%	63%	NM	NM	--	NM	NM	NM	NM	--	NM	NM	NM	NM	--	NM	NM	NM	NM	--	NM	NM	NM	0%	--
Mill 35	81%	95%	NM	NM	--	NM	100%	NM	NM	--	NM	0%	NM	NM	--	NM	0%	NM	NM	--	NM	NM	NM	0%	--
Mill 39	94%	87%	96%	96%	2%	NM	92%	0%	13%	-79%	NM	0%	67%	63%	63%	NM	8%	33%	25%	17%	yes	44%	yes	38%	-6%
Mill 60	76%	90%	83%	51%	6%	NM	86%	0%	0%	-86%	NM	0%	93%	69%	69%	NM	14%	7%	31%	17%	yes	29%	no	0%	-29%
Mill 62	66%	96%	96%	63%	30%	NM	100%	0%	6%	-94%	NM	0%	94%	25%	25%	NM	0%	6%	69%	69%	yes	94%	yes	25%	-69%
Mill 63	70%	97%	78%	43%	8%	NM	100%	0%	15%	-85%	NM	0%	68%	23%	23%	NM	0%	32%	62%	62%	yes	41%	yes	23%	-18%
Mill 67	75%	95%	NM	NM	--	NM	100%	NM	NM	--	NM	0%	NM	NM	--	NM	0%	NM	NM	--	NM	NM	NM	0%	--
Mill 69	92%	84%	75%	98%	6%	NM	90%	0%	67%	-23%	NM	0%	64%	0%	0%	NM	10%	36%	33%	23%	yes	64%	yes	22%	-42%
Mill 82	92%	96%	56%	91%	-1%	NM	100%	0%	69%	-31%	NM	0%	75%	15%	15%	NM	0%	25%	15%	15%	yes	25%	yes	8%	-17%
Mill 101	90%	94%	83%	88%	-2%	NM	96%	0%	26%	-70%	NM	0%	87%	48%	48%	NM	4%	13%	26%	22%	yes	83%	no	0%	-83%
Mill X9	NM	NM	94%	94%	0%	NM	NM	70%	42%	-28%	NM	NM	30%	58%	28%	NM	NM	0%	0%	0%	yes	10%	no	0%	-10%
Mill X10	NM	NM	89%	95%	6%	NM	NM	0%	70%	70%	NM	NM	50%	30%	-20%	NM	NM	50%	0%	-50%	yes	50%	no	0%	-50%
Average	**69%**	**73%**	**77%**	**75%**	**5%**	**-**	**84%**	**11%**	**35%**	**-38%**	**-**	**9%**	**61%**	**39%**	**23%**	**-**	**7%**	**28%**	**26%**	**15%**	**yes**	**48%**	**no**	**7%**	**-39%**
Santa Ana River Sites																									
SAR X1	NM	NM	58%	86%	28%	NM	NM	76%	75%	-1%	NM	NM	5%	13%	8%	NM	NM	19%	13%	-6%	yes	3%	no	0%	-3%
SAR X2	NM	NM	93%	79%	-14%	NM	NM	11%	60%	49%	NM	NM	89%	30%	-59%	NM	NM	0%	10%	10%	yes	17%	no	0%	-17%
SAR X11	NM	NM	88%	94%	6%	NM	NM	27%	44%	17%	NM	NM	64%	11%	-53%	NM	NM	9%	44%	35%	yes	82%	no	0%	-82%
SAR X12	NM	NM	96%	100%	4%	NM	NM	9%	44%	35%	NM	NM	91%	44%	-47%	NM	NM	0%	13%	13%	yes	91%	no	0%	-91%
SAR X13	NM	NM	87%	100%	13%	NM	NM	0%	17%	17%	NM	NM	67%	67%	0%	NM	NM	33%	17%	-16%	yes	67%	no	0%	-67%
SAR X14	NM	NM	88%	97%	10%	NM	NM	0%	75%	75%	NM	NM	100%	25%	-75%	NM	NM	0%	0%	0%	yes	100%	no	0%	-100%
Average	**-**	**-**	**85%**	**93%**	**8%**	**-**	**-**	**21%**	**53%**	**32%**	**-**	**-**	**69%**	**32%**	**-38%**	**-**	**-**	**10%**	**16%**	**6%**	**yes**	**60%**	**no**	**0%**	**-60%**
Average all Sites	**75%**	**76%**	**86%**	**82%**	**8%**	**-**	**91%**	**15%**	**43%**	**-19%**	**-**	**5%**	**68%**	**37%**	**7%**	**-**	**4%**	**17%**	**19%**	**12%**	**yes**	**40%**	**no**	**5%**	**-35%**

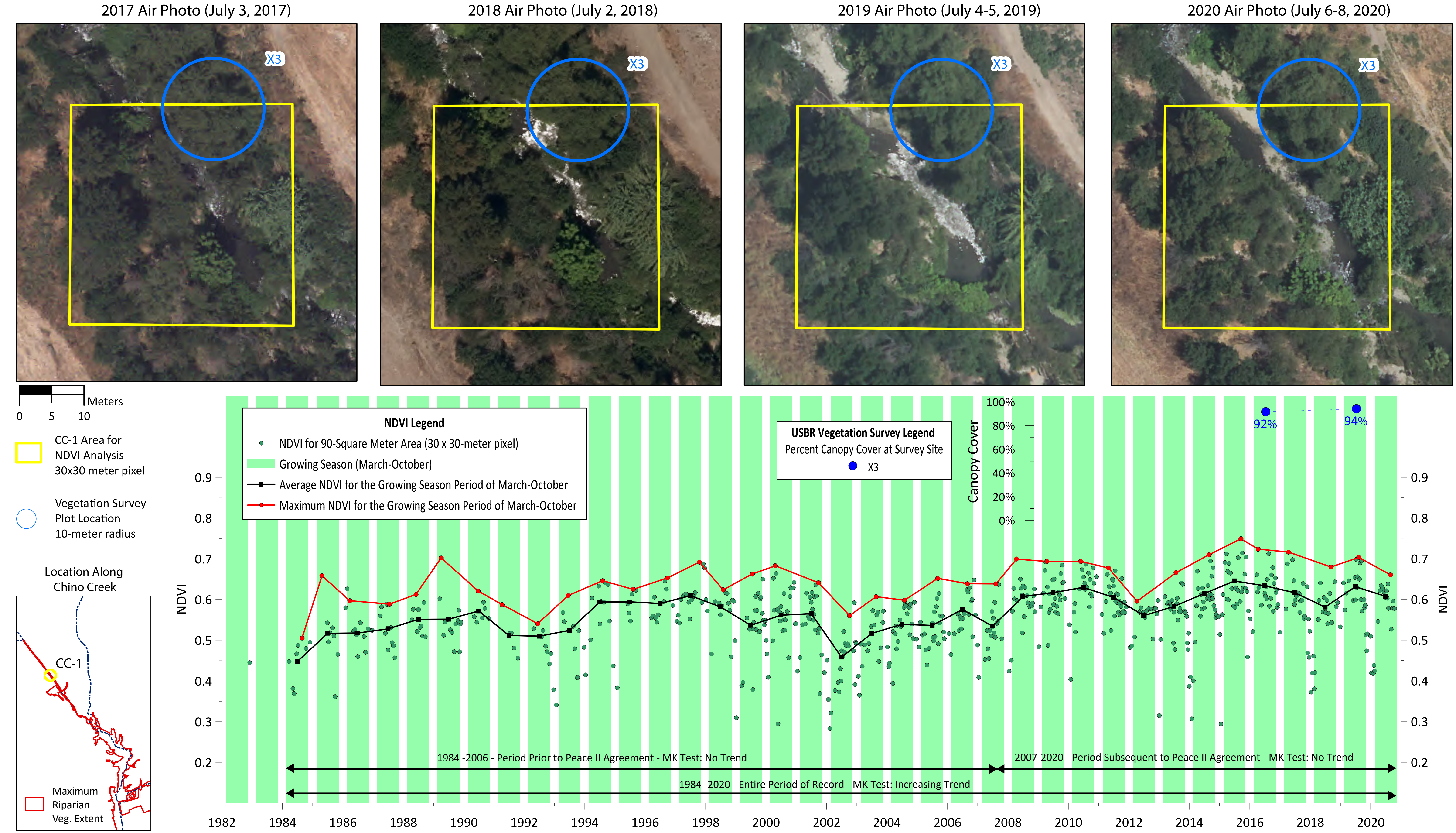
Notes:

NM - Not Measured

(a) Canopy cover is a measurement of the percentage of a ground area directly covered by vertical projections of tree crowns. In the field, canopy cover is measured using a spherical densiometer standing five meters from the center of the plot in the four cardinal directions (north, south, east, west). Canopy Cover percent herein is the average of the four measurements.

(b) Tree condition is a qualitative measurement of the health of the tree. Trees were assessed and classified as "live," "stressed," or "dead". The percentage of each classification per plot is shown here.

(c) In 2016 and 2019 trees were assessed for the presence of polyphagous shot-hole borers (PSHB). If a tree showed signs of the beetle it was noted. The percent of trees in each plot that showed signs of beetle infestation was then calculated.



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Water. Engineered

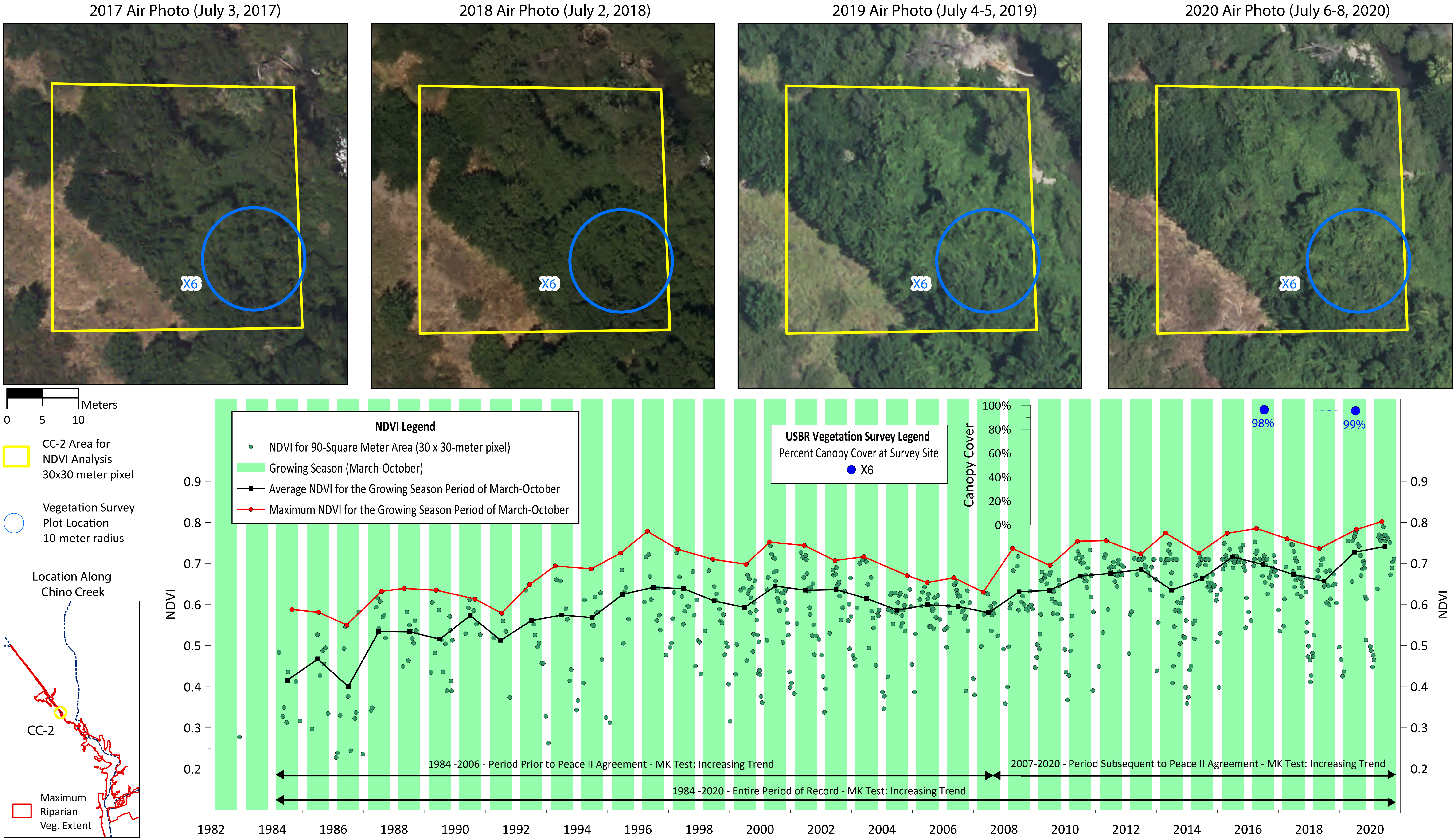
Author: VMW
Date: 1/21/2020
K:\Clients\Chino Basin Watermaster\00-00-00 Chino Basin Master Project\PE1\PBHSP\GRAPHER\GRF\AnnualR\Figure3-9a_NDVI_CC-1

Prado Basin Habitat Sustainability Committee
2020 Annual Report

Prepared for:

Time Series of NDVI and Air Photos
CC-1 Area for 1984 to 2020

Figure 3-8a



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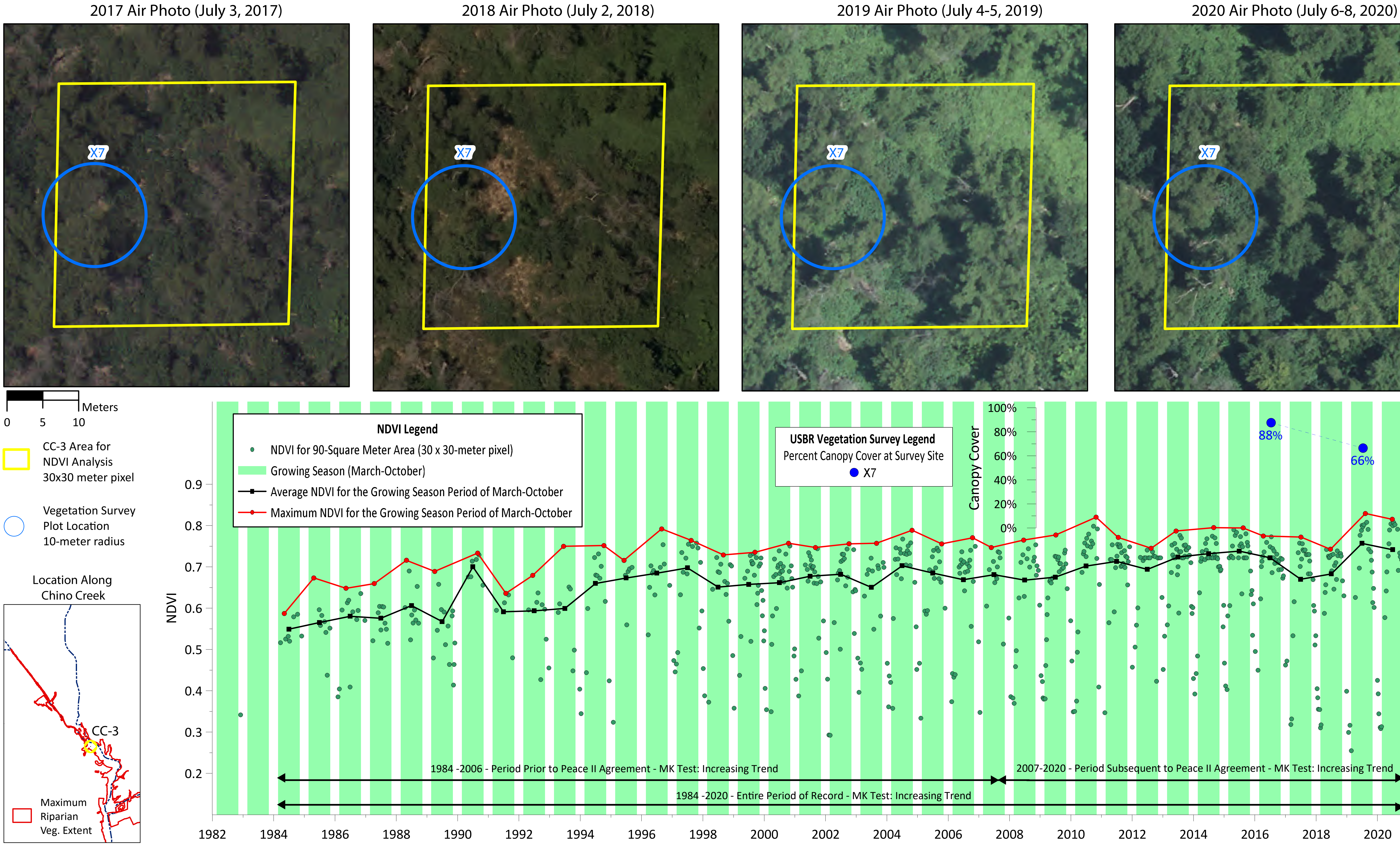
Time Series of NDVI and Air Photos
CC-2 Area for 1984 to 2020

Figure 3-8b



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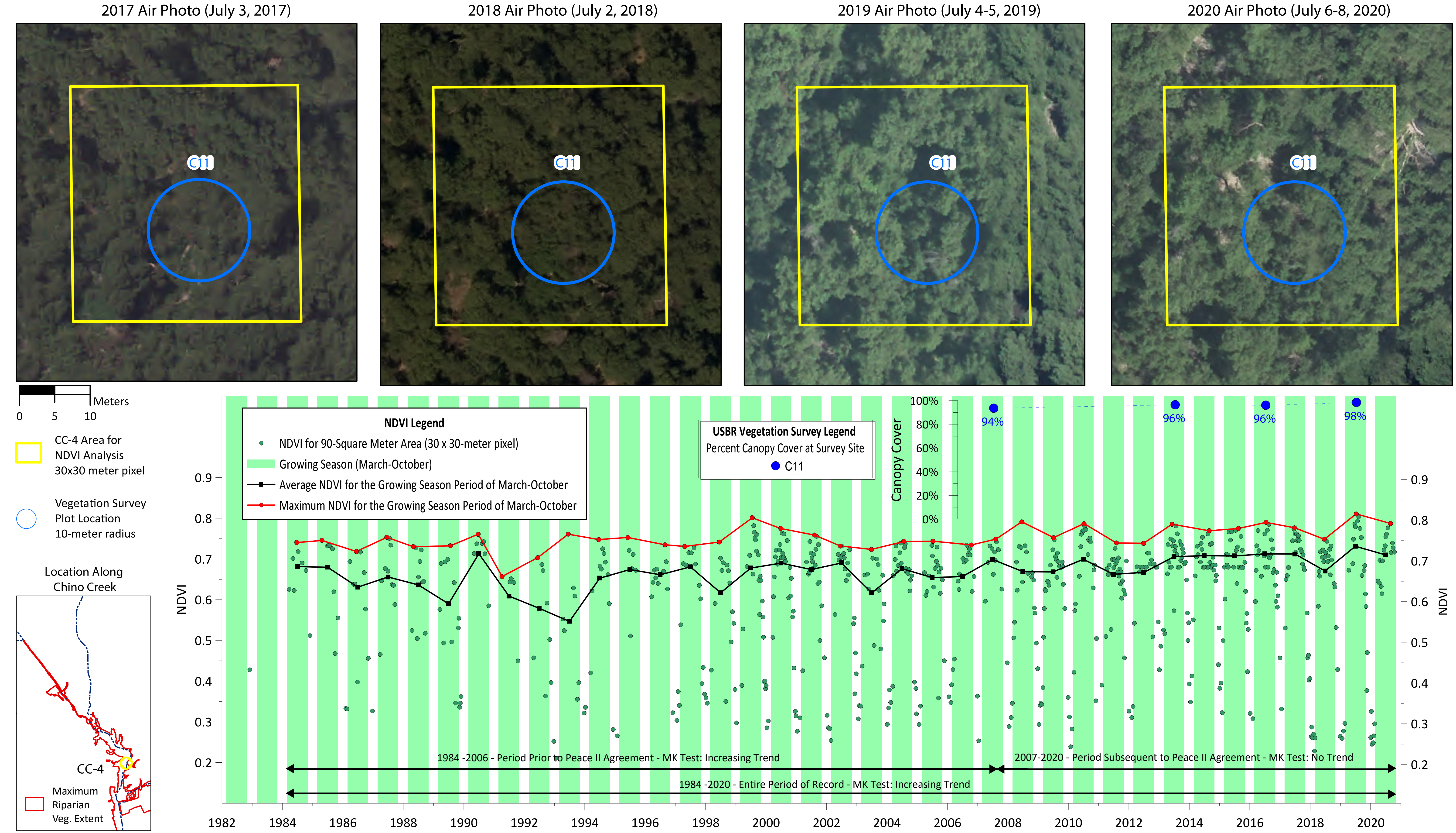
Time Series of NDVI and Air Photos
CC-3 Area for 1984 to 2020

Figure 3-8c



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Time Series of NDVI and Air Photos
CC-4 Area for 1984 to 2020

Figure 3-8d

2017 Air Photo (July 3, 2017)

2018 Air Photo (July 2, 2018)

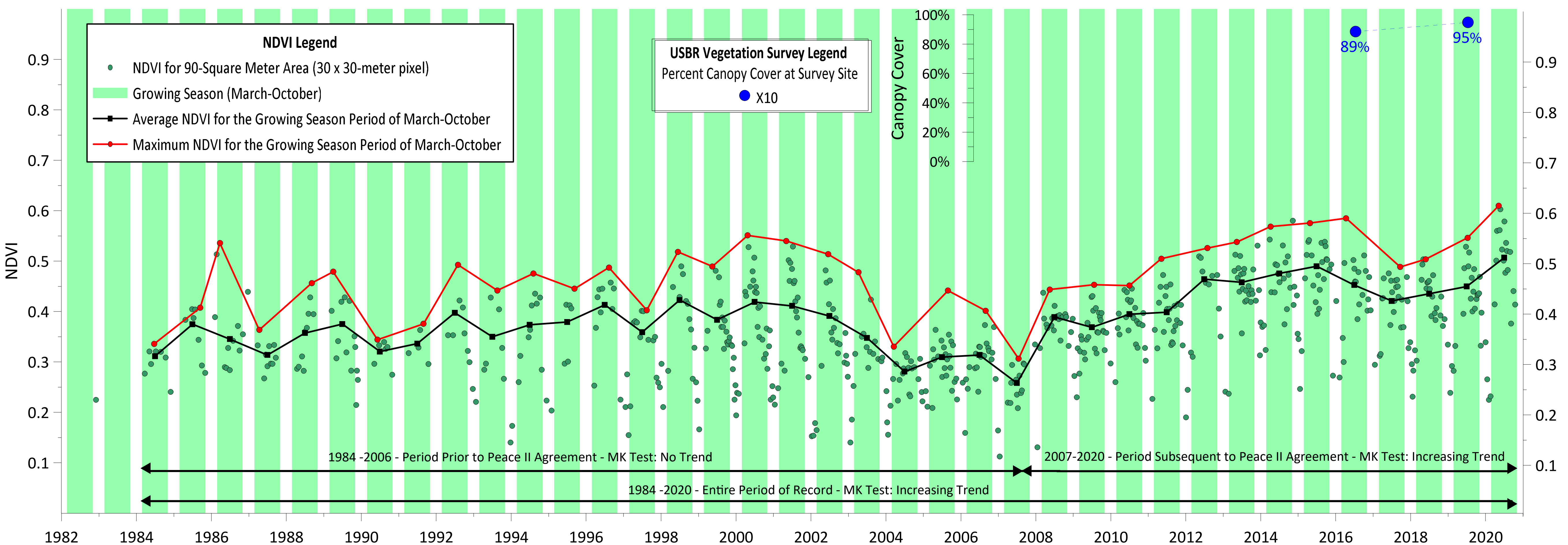
2019 Air Photo (July 4-5, 2019)

2020 Air Photo (July 6-8, 2020)

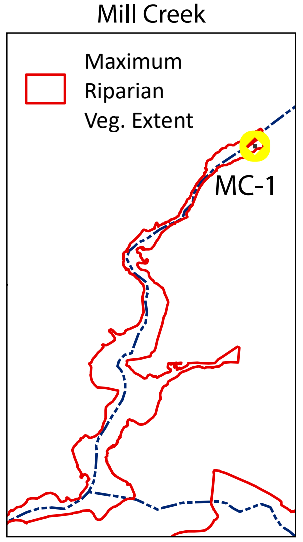
Meters
0 5 10

MC-1 Area for NDVI Analysis 30x30 meter pixel

Vegetation Survey Plot Location 10-meter radius



Location Along Mill Creek



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Date: 1/21/2020
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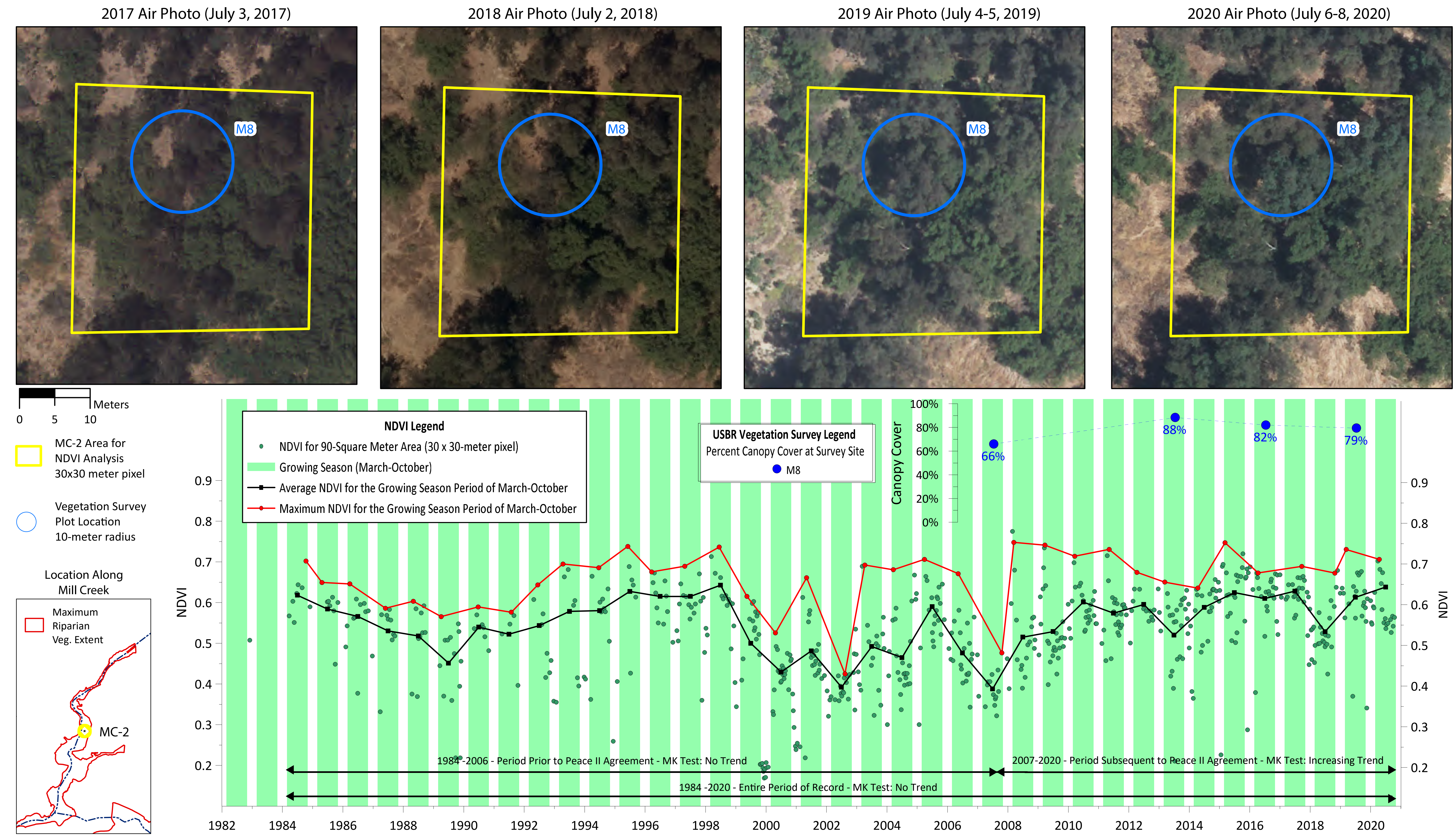
Prepared for:

Time Series of NDVI and Air Photos
MC-1 Area for 1984 to 2020

Figure 3-8e



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2020 Annual Report

Time Series of NDVI and Air Photos
MC-2 Area for 1984 to 2020

Figure 3-8f

2017 Air Photo (July 3, 2017)

2018 Air Photo (July 2, 2018)

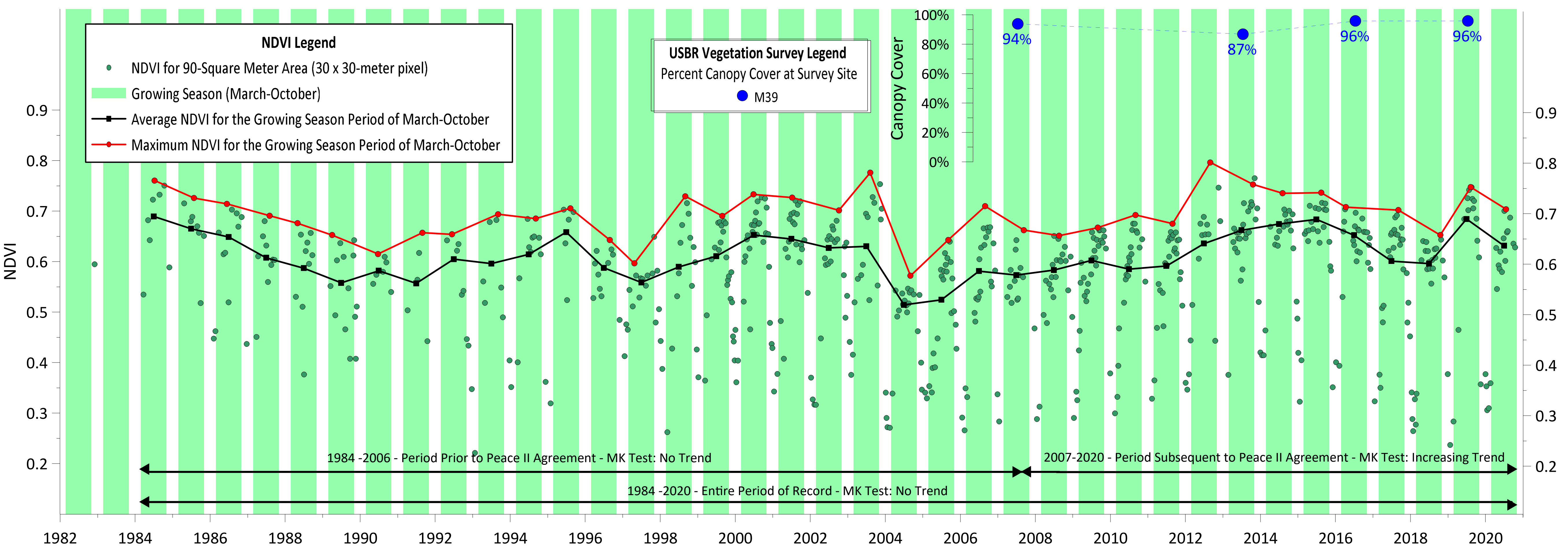
2019 Air Photo (July 4-5, 2019)

2020 Air Photo (July 6-8, 2020)

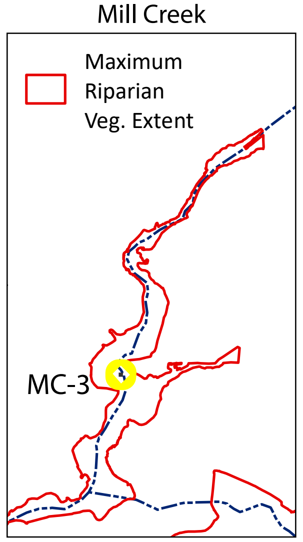
Meters
0 5 10

MC-3 Area for NDVI Analysis 30x30 meter pixel

Vegetation Survey Plot Location 10-meter radius



Location Along Mill Creek



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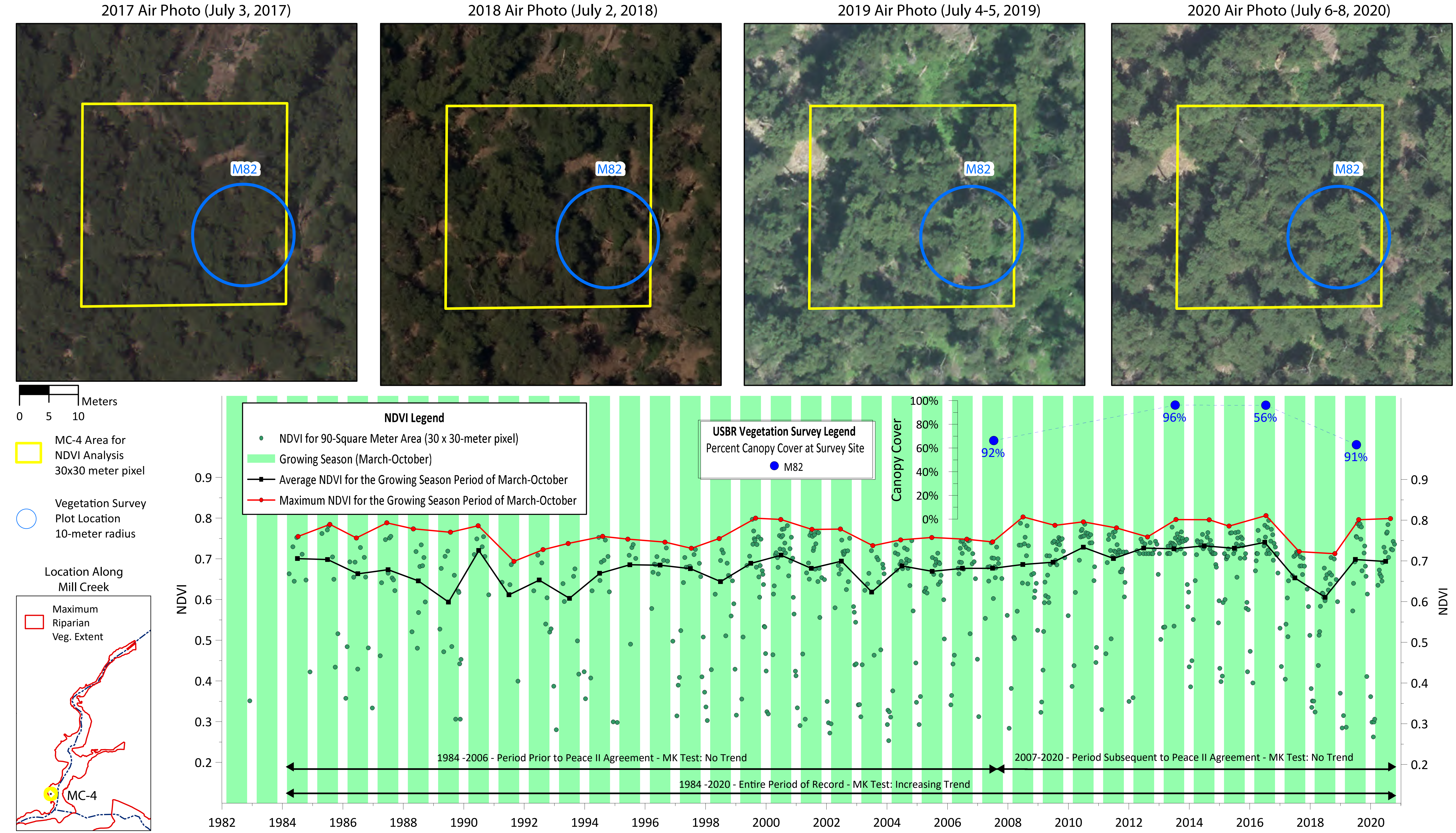
Time Series of NDVI and Air Photos
MC-3 Area for 1984 to 2020

Figure 3-8g



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Prado Basin Habitat Sustainability Committee
2020 Annual Report

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CHINO BASIN WATERMASTER
Partners in Basin Management

Time Series of NDVI and Air Photos
MC-4 Area for 1984 to 2020

Figure 3-8h

2017 Air Photo (July 3, 2017)

2018 Air Photo (July 2, 2018)

2019 Air Photo (July 4-5, 2019)

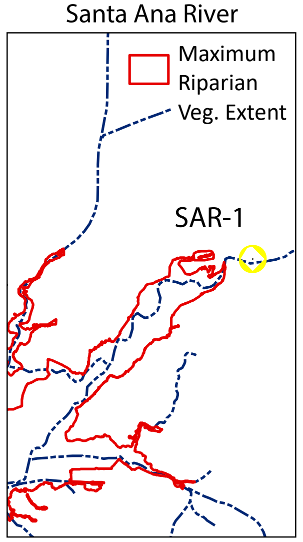
2020 Air Photo (July 6-8, 2020)

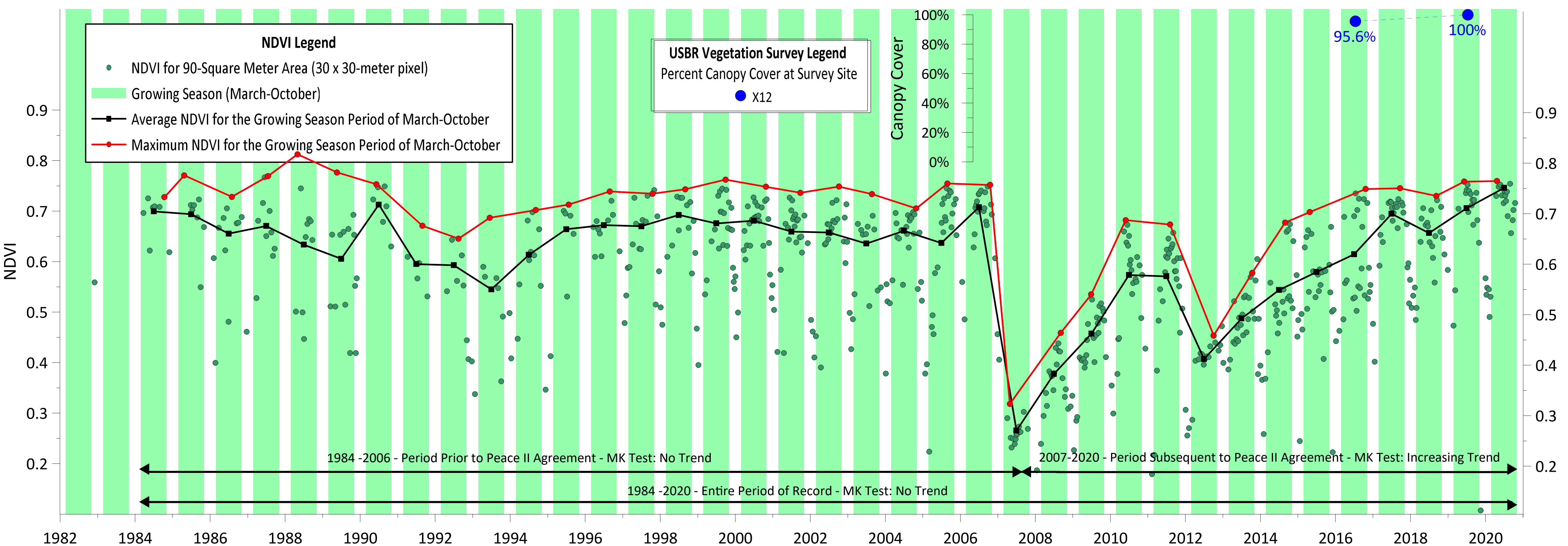
Meters
0 5 10

SAR-1 Area for NDVI Analysis 30x30 meter pixel

Vegetation Survey Plot Location 10-meter radius

Location Along Santa Ana River





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Prado Basin Habitat Sustainability Committee
2020 Annual Report

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Time Series of NDVI and Air Photos
SAR-1 Area for 1984 to 2020

Figure 3-8i

2017 Air Photo (July 3, 2017)

2018 Air Photo (July 2, 2018)

2019 Air Photo (July 4-5, 2019)

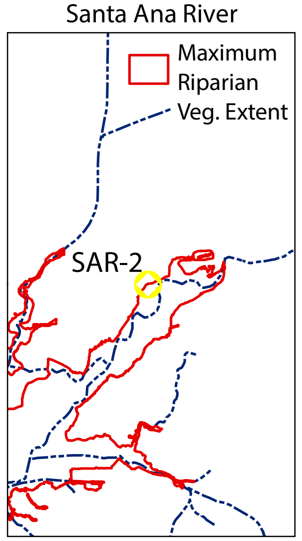
2020 Air Photo (July 6-8, 2020)

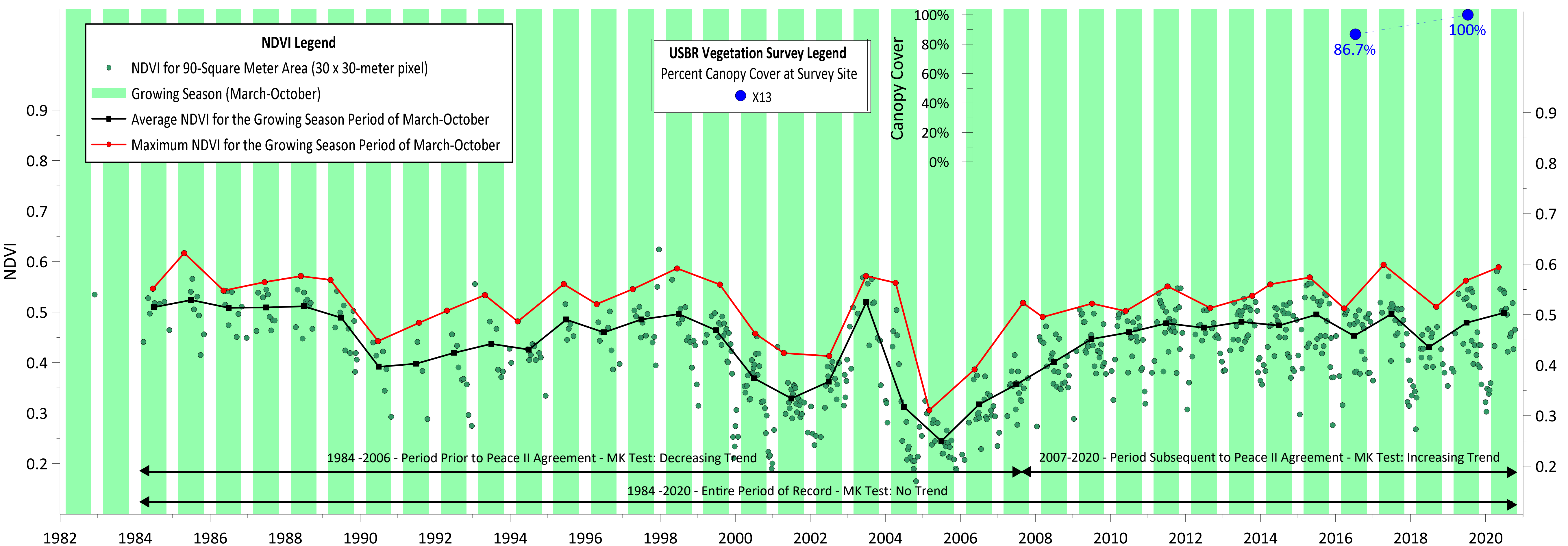
Meters
0 5 10

SAR-2 Area for NDVI Analysis 30x30 meter pixel

Vegetation Survey Plot Location 10-meter radius

Location Along Santa Ana River





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Prado Basin Habitat Sustainability Committee
2020 Annual Report

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Time Series of NDVI and Air Photos
SAR-2 Area for 1984 to 2020

Figure 3-8j

2017 Air Photo (July 3, 2017)

2018 Air Photo (July 2, 2018)

2019 Air Photo (July 4-5, 2019)

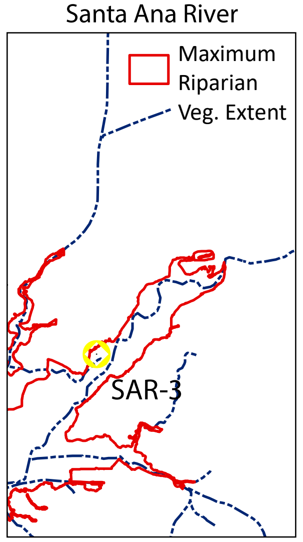
2020 Air Photo (July 6-8, 2020)

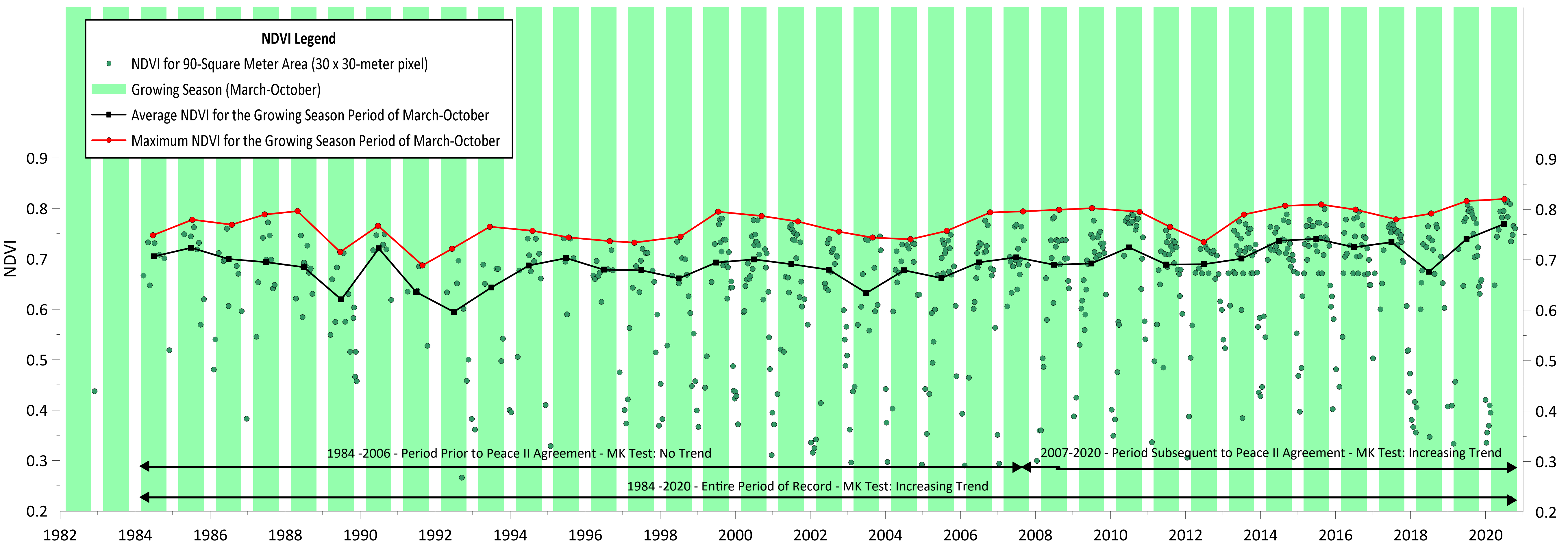
Meters
0 5 10

SAR-3 Area for NDVI Analysis 30x30 meter pixel

Vegetation Survey Plot Location 10-meter radius

Location Along Santa Ana River





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Date: 1/21/2020
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Prado Basin Habitat Sustainability Committee
2020 Annual Report

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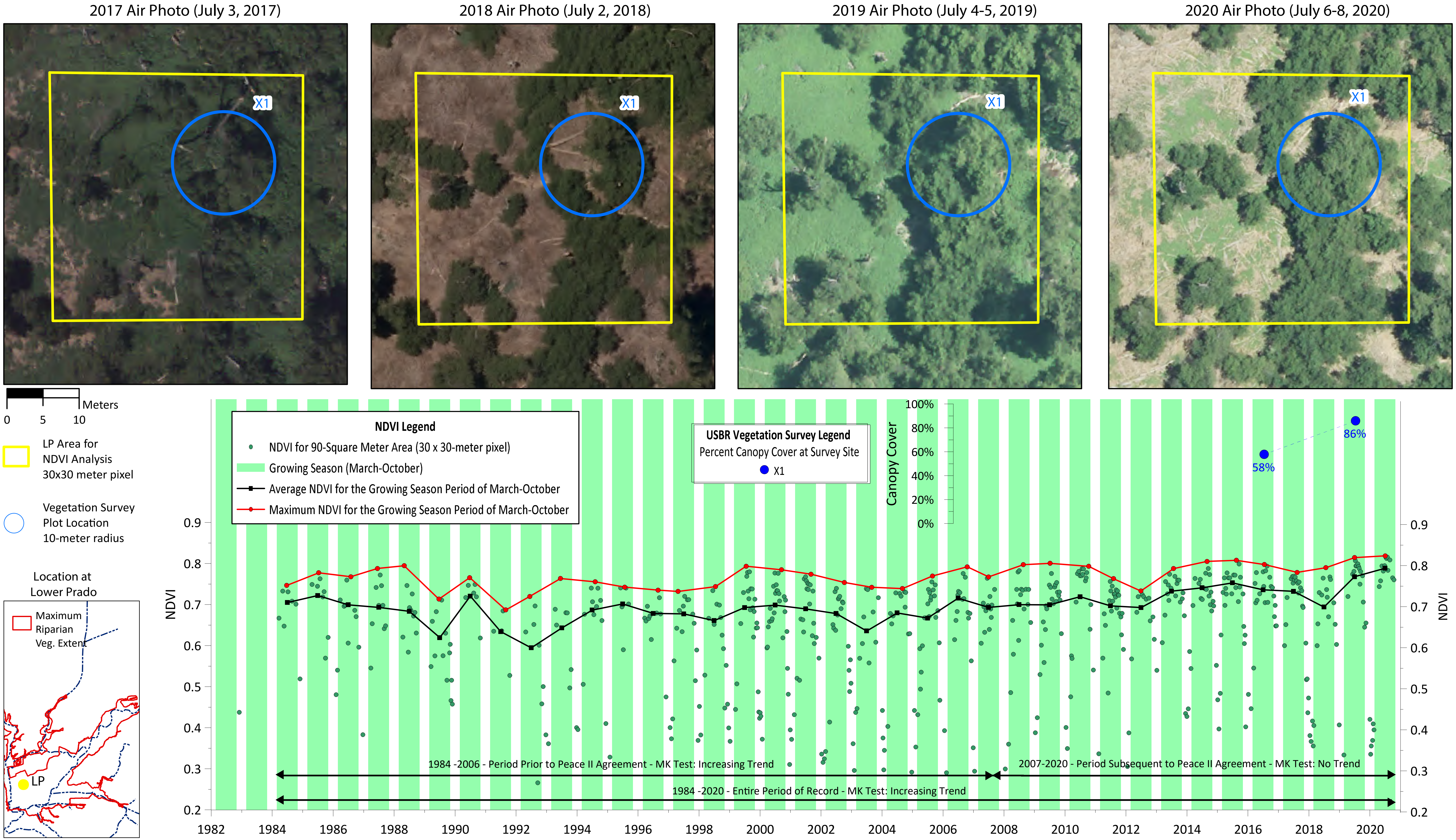
Time Series of NDVI and Air Photos
SAR-3 Area for 1984 to 2020

Figure 3-8k



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Prado Basin Habitat Sustainability Committee
2020 Annual Report

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Time Series of NDVI and Air Photos
Lower Prado Area for 1984 to 2020

Figure 3-8l

The USBR vegetation surveys in 2016 and 2019 noticed the presence of the invasive pest—the PSHB. Overall, the presence of the PSHB decreased in 2019 at all of the sites where it was noted in 2016, and some of the sites no longer indicated the presence of the PSHB in 2019 where noted in 2016. The vegetation surveys provide a measurement of the change in riparian habitat health from 2016 to 2019 for those survey locations impacted by the PSHB. This is discussed in further detail in Section 3.6.2.

3.1.4 Summary

The extent of the riparian habitat in the Prado Basin has been delineated from air photos and maps of NDVI. The extent increased from about 1.85 mi^2 in 1960 to about 6.7 mi^2 by 1999 and has remained relatively constant through 2020.

The quality of riparian habitat has been characterized through the analysis of air photos, maps of NDVI, and time-series charts of NDVI for large and small areas located throughout the Prado Basin. The analyses indicate that from 2019 to 2020 there was a slight decrease in the greenness of the riparian vegetation across the Prado Basin when analyzed as a whole and the along the Chino Creek and Mill Creek reaches. Throughout the riparian vegetation extent, there were varying levels of increasing and decreasing trends in the greenness of the vegetation from 2019 to 2020 as indicated by NDVI maps and time series. However, at all the areas where NDVI time series are analyzed these one-year changes in the Average Growing-Season NDVI are relatively minor and within the historical ranges of one-year NDVI variability, and most were less than the average annual change in NDVI.

The NDVI change map shows notable decreases in the NDVI spatially in large patches along the SAR and below the OCWD wetlands. Most of these decreases are areas where there was Arundo removal projects in 2019 and 2020 that is the cause of the NDVI decreases (see Section 3.6.3).

Visual inspection of the 2019 and 2020 air photos for the MC-3 area, where NDVI decreased from 2019 to 2020, shows a notable decrease in green vegetated areas. More information and research are required to understand the cause of the observed decrease in green riparian vegetation at MC-3.

The remainder of Section 3.0 describes the factors that can affect the riparian habitat, how these factors have changed over time, and how the changes in these factors may explain the changes that are being observed in the riparian habitat described above.

3.2 Groundwater and Its Relationship to Riparian Habitat

Peace II Agreement implementation was projected to change groundwater pumping patterns and reduce artificial recharge through 2030, both of which would change groundwater levels in the Chino Basin. These groundwater level changes caused by Peace II Agreement implementation and other unrelated water management activities[13] have the potential to impact the extent and quality of Prado Basin riparian habitat.

[13] Other water management activities unrelated to Peace II Agreement implementation include changes in wastewater discharge to the SAR due to conservation, recycling, and drought response; increases in storm water diverted and recharged; increases in recycled water recharge; management of groundwater in storage; and the implementation of the Dry-Year Yield Program with the Metropolitan Water District of Southern California.

This section characterizes the history of groundwater pumping and changes in groundwater-levels in the GMP study area and compares this history to the trends in the extent and quality of the riparian habitat described in Section 3.1.

3.2.1 Groundwater Pumping

Table 3-4 lists the groundwater pumping estimates for the GMP study area for WY 1961 to 2020.[14] Figure 3-9 is a map and illustrates the spatial distribution of groundwater pumping from wells within the GMP study area for WY 2020, the extent of the riparian habitat, and the mix of agricultural and urban overlying land uses in 2019. This figure includes a bar chart of the annual groundwater pumping in the GMP study area (from Table 3-4). Figure 3-9 illustrates the following history of groundwater pumping within the GMP study area:

- From 1961 to 1990, groundwater pumping averaged about 45,900 afy. Pumping mainly occurred at private domestic and agricultural wells distributed throughout the area.
- From 1991 to 1999, groundwater pumping steadily declined, primarily due to conversions of agricultural land uses to urban. By WY 1999, groundwater pumping was estimated to be about 23,600 afy—about 49 percent less than average annual pumping from 1961-1990.
- From 2000 to 2020, CDA pumping commenced and increased to replace the declining agricultural groundwater pumping—as envisioned in the OBMP/Peace Agreement and Peace II Agreement. By WY 2020, total groundwater pumping was about 43,800 afy—an increase of about 87 percent from 1999.
- Over the last year from 2019 to 2020, the CDA pumping increased by about 6,000 afy. In mid-2020 the CDA pumping reached its intended pumping rate of 40,000 afy to maintain hydraulic control of the Chino Basin.

Table 3-4. Annual Groundwater Pumping in the Groundwater Monitoring Program Study Area

Water Year	Non-CDA Pumping, afy[(a)]	CDA Pumping, afy	Total Pumping, afy[(a)]
1961	48,577	0	48,577
1962	43,811	0	43,811
1963	43,293	0	43,293
1964	45,170	0	45,170
1965	43,294	0	43,294
1966	46,891	0	46,891
1967	42,709	0	42,709
1968	47,180	0	47,180
1969	37,754	0	37,754
1970	45,849	0	45,849
1971	45,492	0	45,492

[14] Production for years prior to WY 2001 were estimated in the calibration of the 2013 Chino Basin groundwater model (WEI, 2015). Production estimates for WY 2001 and thereafter are based on metered production data and water-duty estimates compiled by Watermaster.

Water Year	Non-CDA Pumping, afy[a]	CDA Pumping, afy	Total Pumping, afy[a]
1972	47,541	0	47,541
1973	38,427	0	38,427
1974	47,014	0	47,014
1975	44,606	0	44,606
1976	44,847	0	44,847
1977	45,710	0	45,710
1978	46,881	0	46,881
1979	48,829	0	48,829
1980	46,402	0	46,402
1981	53,326	0	53,326
1982	41,719	0	41,719
1983	42,200	0	42,200
1984	52,877	0	52,877
1985	46,876	0	46,876
1986	54,501	0	54,501
1987	46,875	0	46,875
1988	46,277	0	46,277
1989	46,835	0	46,835
1990	45,732	0	45,732
1991	42,266	0	42,266
1992	44,617	0	44,617
1993	43,186	0	43,186
1994	37,390	0	37,390
1995	32,604	0	32,604
1996	35,200	0	35,200
1997	33,340	0	33,340
1998	22,366	0	22,366
1999	23,632	0	23,632
2000	24,299	523	24,822
2001	21,249	9,470	30,719
2002	20,271	10,173	30,445
2003	18,600	10,322	28,922
2004	18,606	10,480	29,086
2005	13,695	10,595	24,290
2006	14,261	19,819	34,079
2007	12,988	28,529	41,517
2008	12,293	30,116	42,409
2009	11,694	28,456	40,150

Table 3-4. Annual Groundwater Pumping in the Groundwater Monitoring Program Study Area

Table 3-4. Annual Groundwater Pumping in the Groundwater Monitoring Program Study Area

Water Year	Non-CDA Pumping, afy[(a)]	CDA Pumping, afy	Total Pumping, afy[(a)]
2010	10,452	28,964	39,416
2011	10,460	28,941	39,401
2012	11,193	28,230	39,423
2013	11,433	27,380	38,813
2014	9,059	29,626	38,685
2015	6,985	29,877	36,862
2016	5,900	28,249	34,148
2017	5,899	28,351	34,250
2018	7,504	29,191	36,695
2019	5,348	32,004	37,352
2020	5,875	37,973	43,848
Average: 1961-1990	45,917	0	45,917
Average: 1991-1999	34,956	0	34,956
Average: 2000-2020	12,289	23,203	35,492

(a) Prior to water year 2001 production is estimated with the calibrated 2013 Chino Basin groundwater model (WEI, 2015).

3.2.2 Groundwater Levels

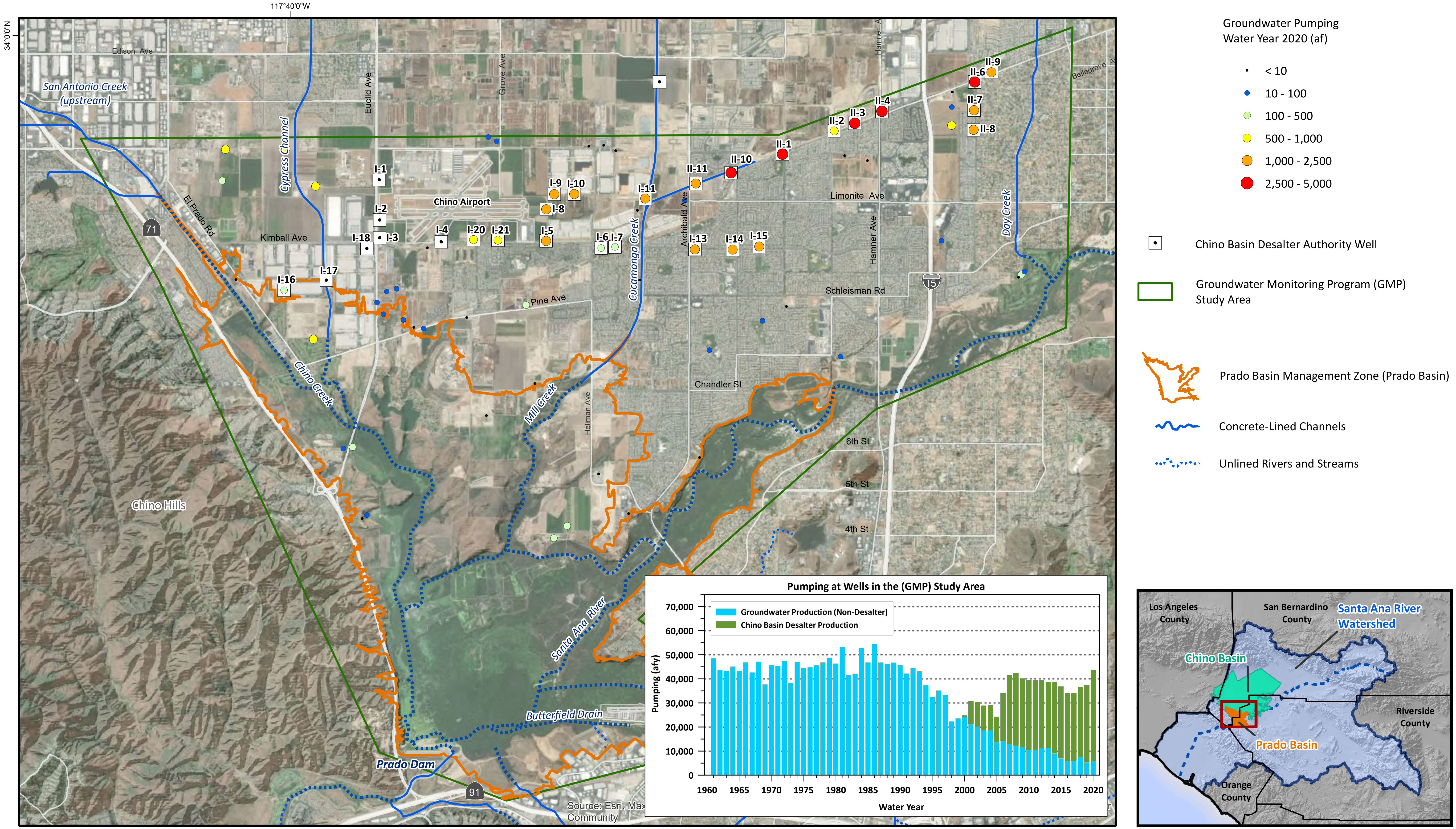
Figures 3-10a and 3-10b are groundwater-elevation contour maps of the GMP study area for the shallow aquifer system in September 2016 (first Annual Report condition) and September 2020 (current condition).[15] The contours were drawn based on measured groundwater elevations at wells. These contours were used to create rasterized surfaces of groundwater elevation for September 2016 and September 2020. The raster for September 2016 was subtracted from the raster for September 2020 to create a raster of change in groundwater elevation from 2016 to 2020 (Figure 3-11). Figure 3-11 shows that groundwater levels changed by up to +/- 15 feet across the GMP study area from 2016 to 2020. The greatest areas of change in groundwater elevation occurred near the CDA well field. Groundwater levels decreased by up to 15 feet near the central portion of CDA well field (Wells I-20 to II-10) and increased by up to 15 feet along the western portion the CDA well field (Wells I-16, I-17, I-18). Within the extent of the riparian vegetation, groundwater elevations have remained relatively stable throughout most of the extent from 2016-2020. However there are three notable areas were groundwater levels have declined: the upper reach of Mill Creek south of PB-2 (decline of about 2 feet); the middle reaches of Chino Creek and Mill Creek near PB-6 and PB-1 (decline of 1.5 to 0.5 feet); and northeastern portion of SAR near PB-3 (decline of about 0.5 feet).

Figure 3-12 is a map of depth-to-groundwater in September 2020. It was created by subtracting a one-meter horizontal resolution digital elevation model of the ground surface (Associated Engineers, 2007) from the raster of groundwater elevation for September 2020. An outline of the Prado Basin riparian

[15] Historical groundwater-elevation data for the Prado Basin are scarce due to a lack of wells and/or monitoring. As such, the discussion and interpretation of measured groundwater elevations focuses on the GMP's period of record.

habitat extent is superimposed on the 2020 depth-to-groundwater raster. With few exceptions,[16] the riparian habitat overlies areas where the depth-to-groundwater is less than 15 feet below the ground surface. The shallow groundwater could contribute to rising groundwater discharge to the SAR and its tributaries and evapotranspiration by the riparian vegetation in the Prado Basin.

[16] Exceptions include: the upstream reach of Temescal Wash in the Prado Basin, and some limited areas west of the southern reach of Chino Creek.



Prepared by:

WEST YOST
Water. Engineered.

Author: VWW

Date: 4/14/2021

K:\Clients\941 Chino Basin Watermaster\00-00-00 Master\PE1 - Data_Monitoring\GIS\MXD\Prado\Annual Report\Figure 3-9_ Production_WY 2020.mxd

0 1 2 Miles

0 1 2 Km

N

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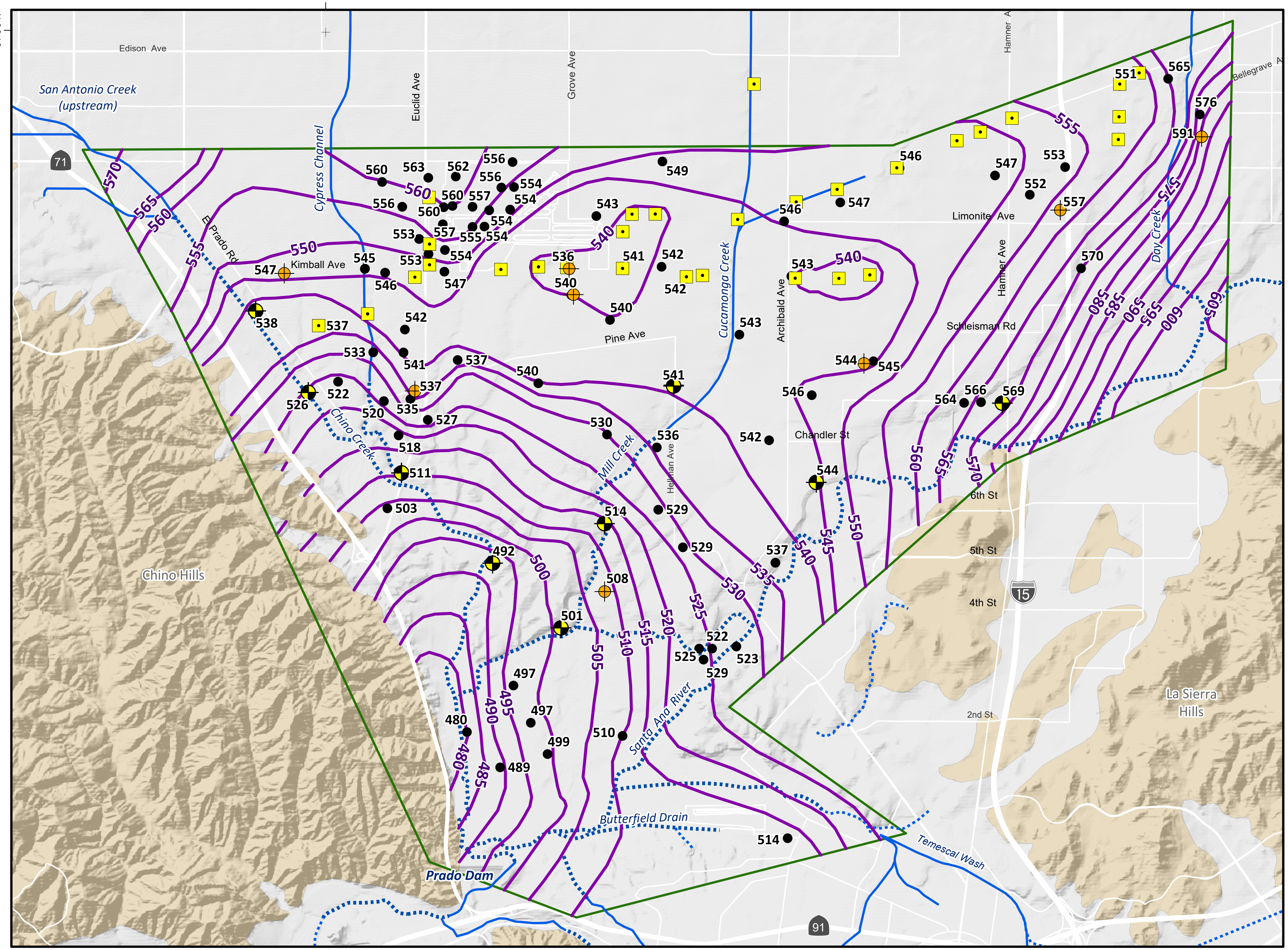
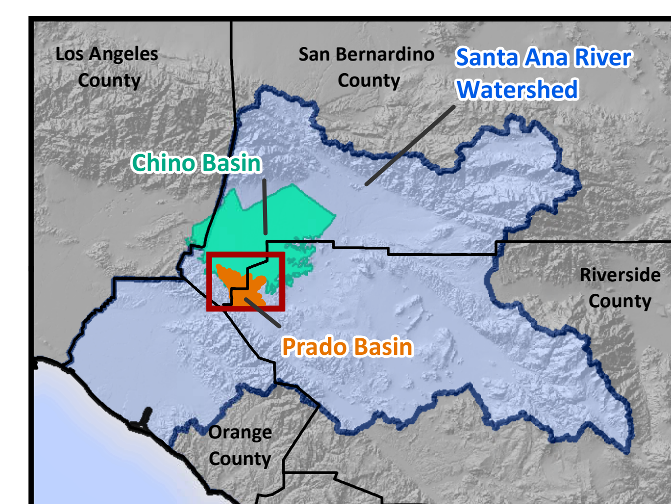
Chino Basin Watermaster and
Inland Empire Utilities Agency
2020 Annual Report of the
Prado Basin Habitat Sustainability Committee

Groundwater Pumping
Water Year 2020

Figure 3-9





Equal Elevation Contour of Groundwater Elevation (feet above mean sea level)

505 Measured Groundwater Elevation in September 2016 used to draw contours (feet above mean sea level)

PBHSP Monitoring Well

HCMP Monitoring Well

Other Well

Chino Basin Desalter Authority Well

Groundwater Monitoring Program (GMP) Study Area

Concrete-Lined Channels

Unlined Rivers and Streams

Surface Geology

Consolidated Bedrock

Quaternary Alluvium

Water-Bearing Sediments

Undifferentiated Pre-Tertiary to Early Pleistocene Igneous, Metamorphic, and Sedimentary Rocks

Prepared by:

WEST YOST Water. Engineered.

Author: TSA

Date: 4/23/2021

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0 1 2 Miles

0 1 2 Km

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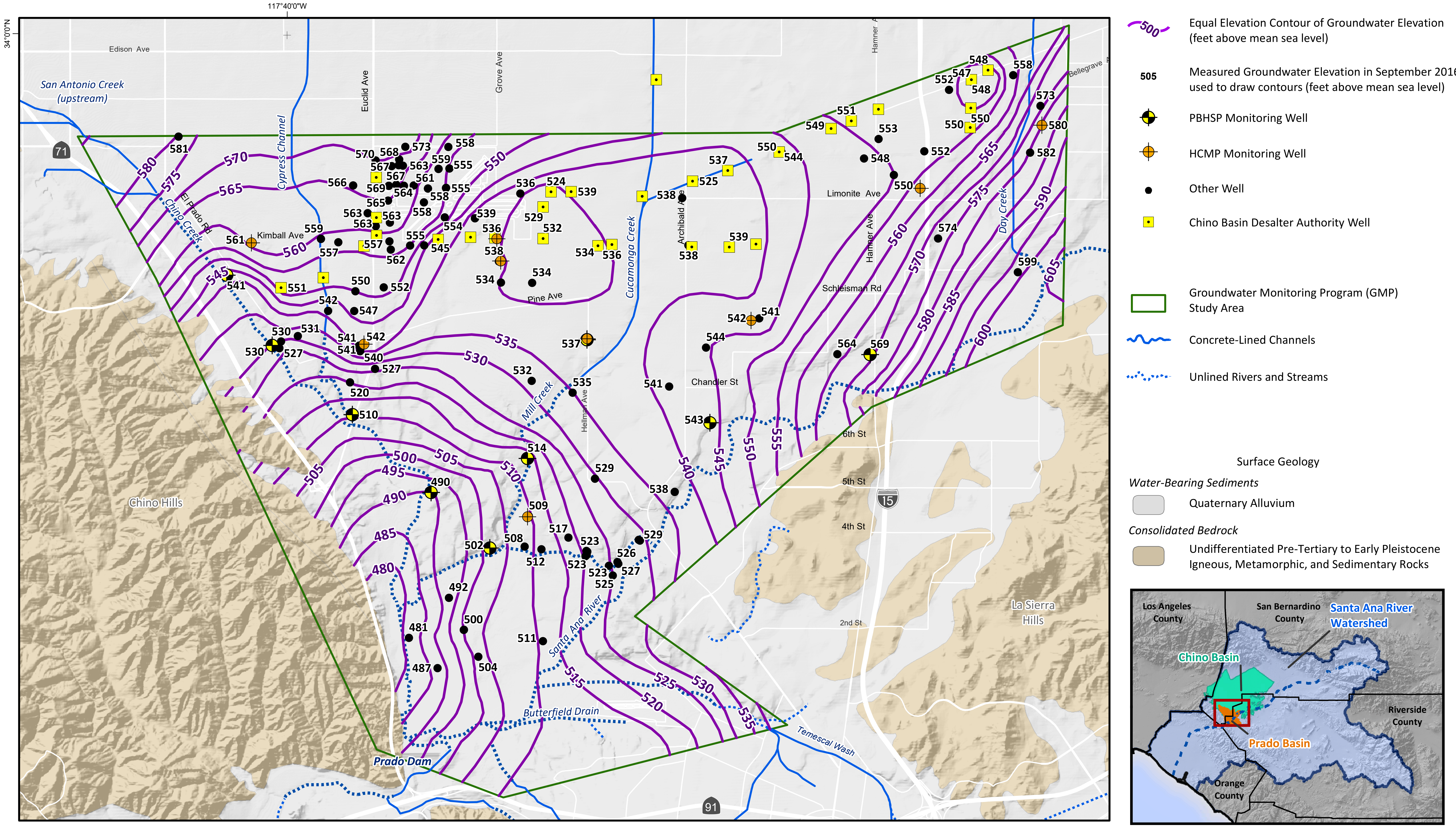
Map of Groundwater Elevation
September 2016 - Shallow Aquifer System

Figure 3-10a



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0 1 2 Miles

0 1 2 Km

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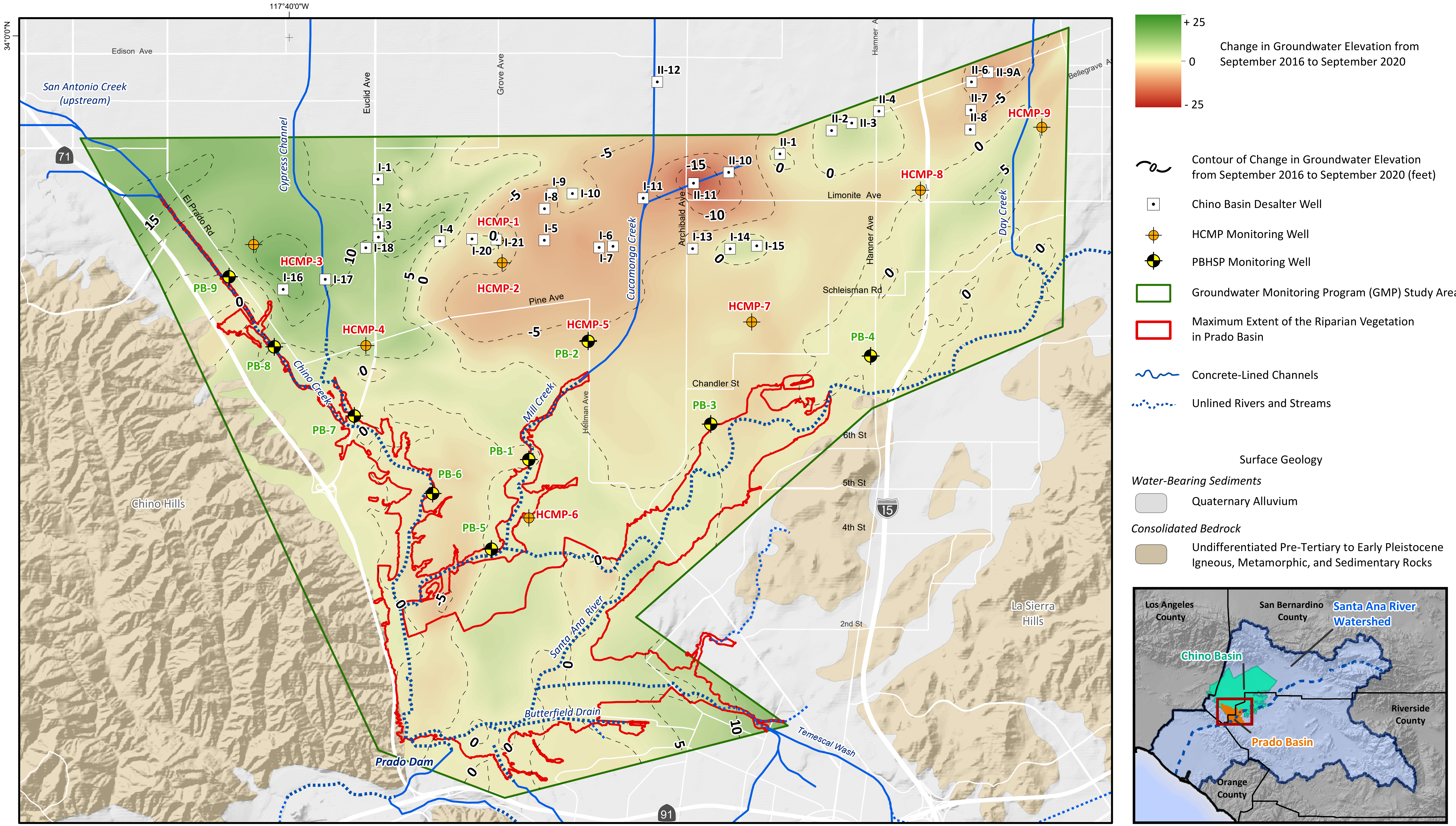
Map of Groundwater Elevation
September 2020 - Shallow Aquifer System

Figure 3-10b



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Date: 5/5/2021

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0 1 2 Miles

0 1 2 Km

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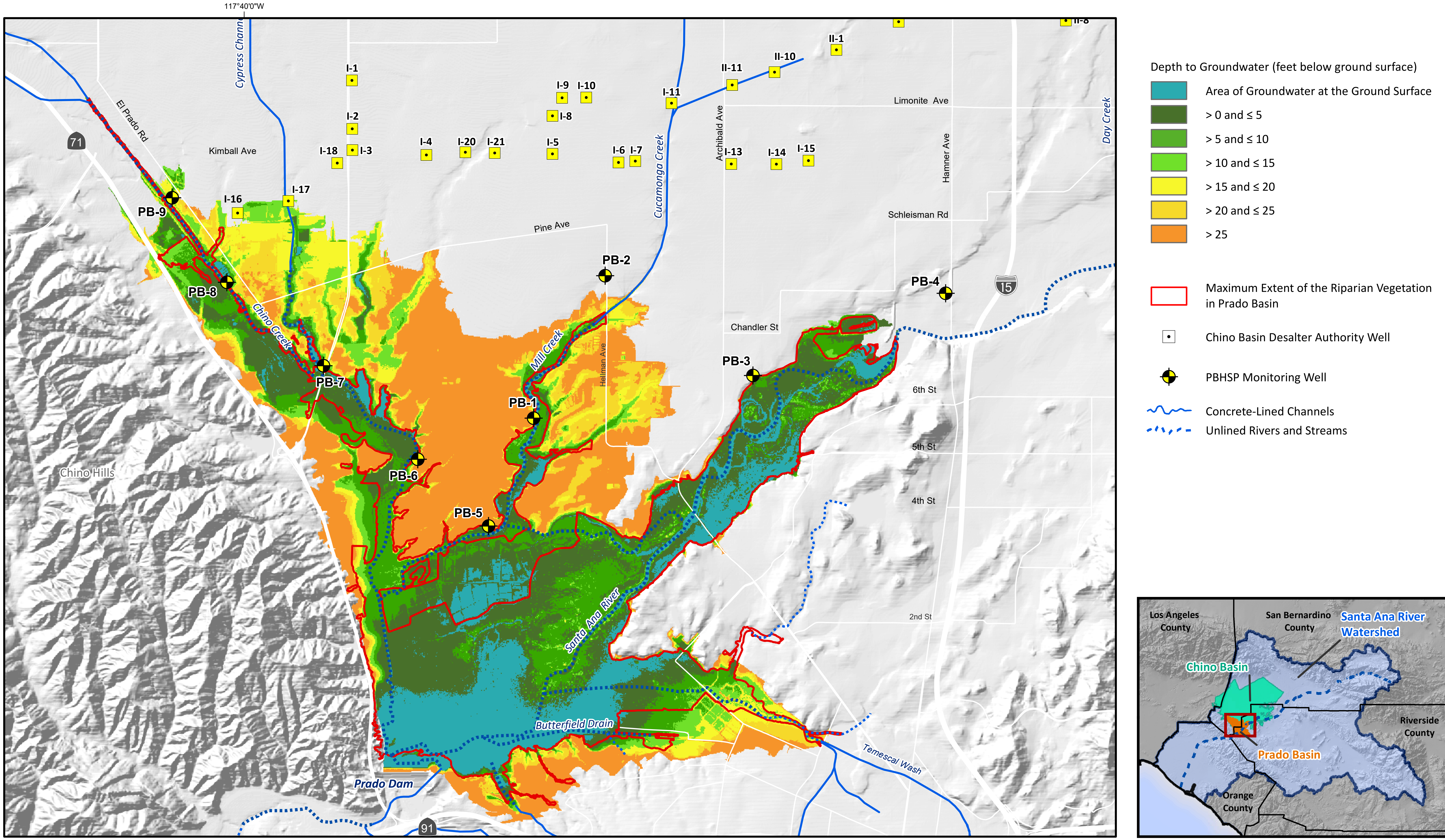
Change in Groundwater Elevation
September 2016 to September 2020

Figure 3-11



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Date: 4/23/2021

K:\Clients\941 Chino Basin Watermaster\00-00-00 Master\PE1 - Data_Monitoring\GIS\MXD\Prado\Annual Report\Figure 3-12.mxd

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Depth to Groundwater
September 2020

Figure 3-12

3.2.3 Groundwater Levels Compared to NDVI

Figures 3-13a through 3-13c are time-series charts that compare long-term trends in groundwater pumping and groundwater elevations to the trends in the quality of the riparian vegetation as indicated by the NDVI for three areas in the Prado Basin: Chino Creek, Mill Creek, and the SAR. The period of analysis for these charts is 1984 to 2020—the period of NDVI availability. The upper chart in these figures compares changes in groundwater levels for each respective area to long-term trends in groundwater pumping within the study area. Groundwater-elevation estimates for the period of 1984 to 2018 were extracted from Watermaster's most recent calibration of its groundwater-flow model at the monitoring well locations (WEI, 2020). The more recent groundwater-elevation data shown on these charts were measured at monitoring wells constructed by Watermaster and the IEUA to support the Hydraulic Control Monitoring Program (HCMP) (beginning in 2005) and the PBHSP (beginning in 2015). Where the measured and model-estimated groundwater elevations overlap in time, the model-estimated elevations mimic the seasonal fluctuations and longer-term trends of the measured elevations and are typically no more than 10 feet different. This supports the use of these model-estimated groundwater elevations in this analysis.

The lower chart in Figures 3-13a through 3-13c displays the time series of the Average Growing-Season NDVI for the defined areas (discussed in Section 3.1) along Chino Creek, Mill Creek, and the SAR. For reference, the Mann-Kendall test results for trends in the Average Growing-Season NDVI for 1984-2020, 1984-2006, and 2007-2020 are shown in the legend.

The NDVI observations and interpretations below focus on recent changes in Average Growing-Season NDVI (Section 3.1) and whether observed groundwater level trends may be contributing to recent NDVI changes.

Chino Creek (Figure 3-13a). During the 1990s, groundwater levels along Chino Creek increased, particularly along the north reach of Chino Creek, where groundwater levels increased by over 30 feet. The increase in groundwater levels was most likely due to reduced pumping in the area. Since 2000, groundwater levels have remained relatively stable, even as CDA pumping increased.

From 2015-2020, the measured groundwater levels at the PBHSP monitoring wells along Chino Creek show an increasing trend along the northern portion of Chino Creek (PB-9/1, PB-8, and RP2-MW3) and a relatively stable or slight decreasing trend along the southern portion (PB-7/1 and PB-6/1). Groundwater levels fluctuate seasonally, in some cases by more than 15 feet, under the seasonal stresses of pumping and recharge. During the winter months of WY 2017 and 2019, groundwater levels at the PBHSP monitoring wells increased to their highest recorded levels, likely in response to the recharge of stormwater discharge in unlined creeks and the associated surface-water reservoir that ponds behind Prado Dam. Over the last year (September 2019 to September 2020) groundwater levels remained stable along the northern reach of Chino Creek (PB-9/1, PB-8, and RP3-MW3) and decreased by up to one foot along the southern reach of Chino Creek (PB-7/1 and PB-6/1).

The Average Growing-Season NDVI and the air photo analyses along Chino Creek show that changes in the vegetation were relatively minor (discussed in Section 3.1) during 2019-2020. Hence, the main observations and conclusions for the period of 2019 to 2020 in this area are that groundwater levels remained relatively stable and the riparian vegetation did not change significantly.

Mill Creek*. *(Figure 3-13b). During the 1990s, groundwater levels along Mill Creek increased, particularly along the north reach of Mill Creek where groundwater levels increased by about 10 feet, most likely due to reduced agricultural pumping in the area. Since 2000, groundwater levels have declined, particularly along the north reach of Mill Creek where groundwater levels have declined by up to 15 feet. The decline in groundwater levels was most likely due to the onset and progressive increase in CDA pumping.

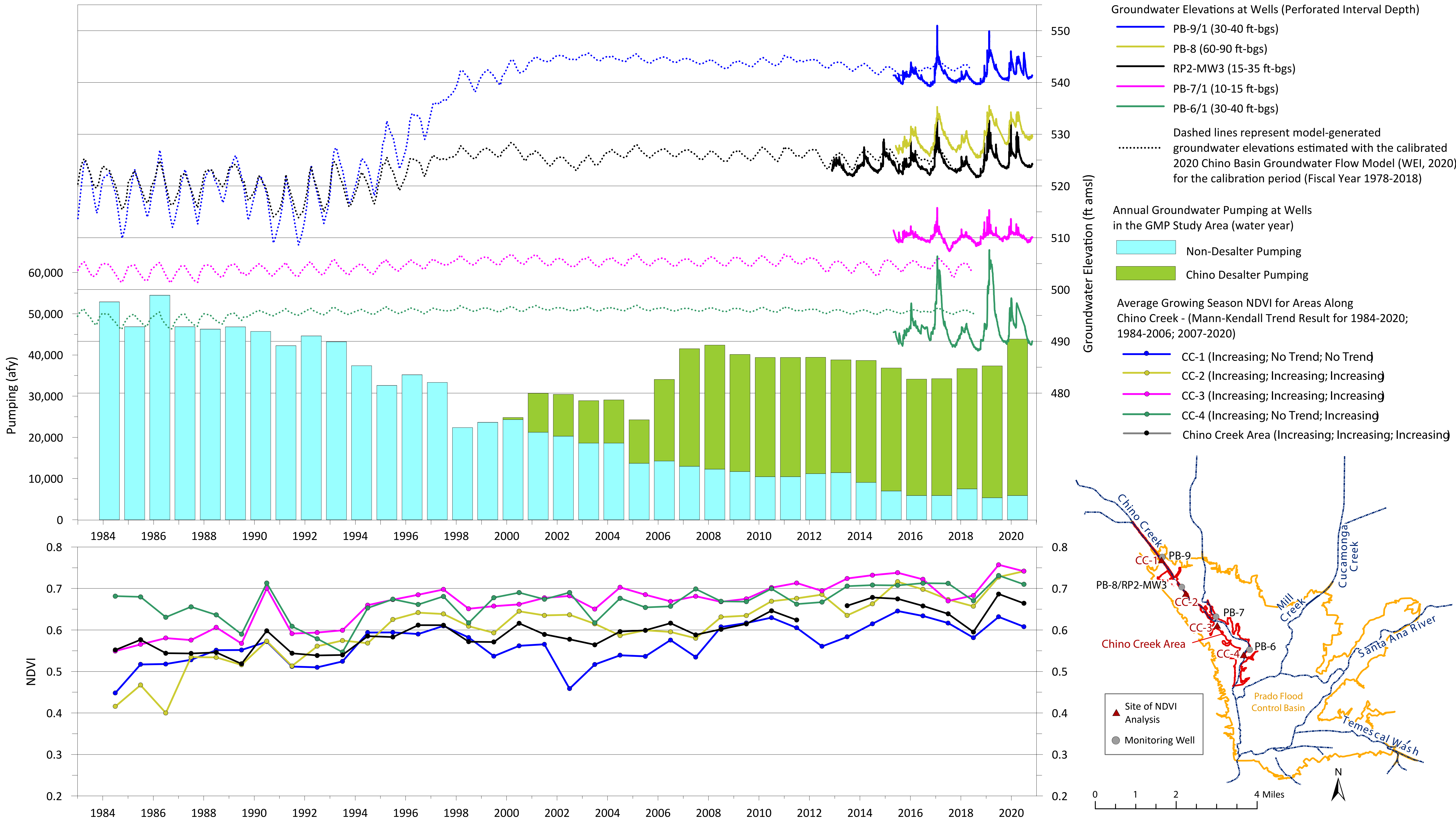
From 2015-2020, the measured groundwater levels at the PBHSP monitoring wells along Mill Creek show a decreasing trend in the northern portion of Mill Creek (PB-2 and HCMP-5/1), a slight decreasing trend in the central reach (PB-1/1), and relatively stable trend throughout the southern portion. Groundwater levels fluctuate seasonally, in some cases by more than 10 feet, under the seasonal stresses of pumping and recharge. During the winter months in WY 2017 and WY 2019, groundwater levels at most of the PBHSP monitoring wells increased to their highest recorded levels, likely in response to the recharge of stormwater discharge in unlined creeks and the associated surface-water reservoir that ponds behind Prado Dam. Over the last year (September 2019 to September 2020) groundwater levels at the monitoring wells along Mill Creek decreased by about two feet just north of the top of Mill Creek (PB-2 and HCMP-5/1), decreased about 0.5 feet along the central portion (HCMP-6/1 and PB-1/2), and remained the same along the southern portion (PB-5/1).

The Average Growing-Season NDVI analyses along Mill Creek show that changes in the vegetation were relatively minor during 2019-2020 (discussed in Section 3.1). The analyses of the air photos at MC-3 indicate that there is a notable decrease in the vegetation from 2019-2020. Hence, the main observations and conclusions for the period of 2019 to 2020 in this area are that groundwater levels decreased in the northern and central portions of Mill Creek and remained stable in the southern portion, and the riparian vegetation did not change significantly except for a notable decrease at MC-3 in the central portion of Mill Creek. The MC-3 area is within the central portion of Mill Creek where groundwater levels slightly declined by about 0.5 feet during 2019 to 2020. These changes in groundwater levels are within the range of the long-term variability for these areas and not likely the cause of the decrease in the green vegetation observed at MC-3 from 2019 to 2020. Where groundwater levels decreased by 2 feet from 2019 to 2020 at PB-2, the NDVI for the MC-1 area in the northern portion of Mill Creek closest to this well increased.

Santa Ana River (***Figure 3-13c***). During the 1990s, the groundwater levels along SAR increased in response to a decline in pumping from 1990 to 2000. These responses were greatest along the eastern portion of SAR where they increased up to five feet. Since 2000, groundwater levels have declined by a similar magnitude along the eastern portion of the SAR due to the onset and progressive increase in CDA pumping, while groundwater levels remained relatively stable along the western portion of the SAR near the Archibald well.

From 2015-2020, the measured groundwater levels at the PBHSP monitoring wells show a slight increasing trend along the northeastern portion near PB-4, a slightly decreasing trend along the center portion near PB-3, and an increasing trend along the southwestern portion near the Archibald 1 well. Groundwater levels fluctuate seasonally, in some cases by up to three feet under the seasonal stresses of pumping and recharge. During this past year, from September 2019 to September 2020, groundwater levels at the monitoring wells along the SAR remained the same along the eastern portion and increased by about 0.5 to 1 foot along the western portion (PB-3 and Archibald).

The Average Growing-Season NDVI and air photo analyses along SAR show that changes in the vegetation were relatively minor (discussed in Section 3.1) during 2019-2020. Hence, the main observations and conclusions for the period of 2019 to 2020 in this area are that groundwater levels remained relatively stable and the riparian vegetation did not change significantly.



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K:\Clients\Chino Basin Watermaster\00-00-00 Chino Basin Master Project\PE1\PBHSP\GRAPHER\GRF\AnnualR\Figure3-2a SW vs NDVI Chino CK

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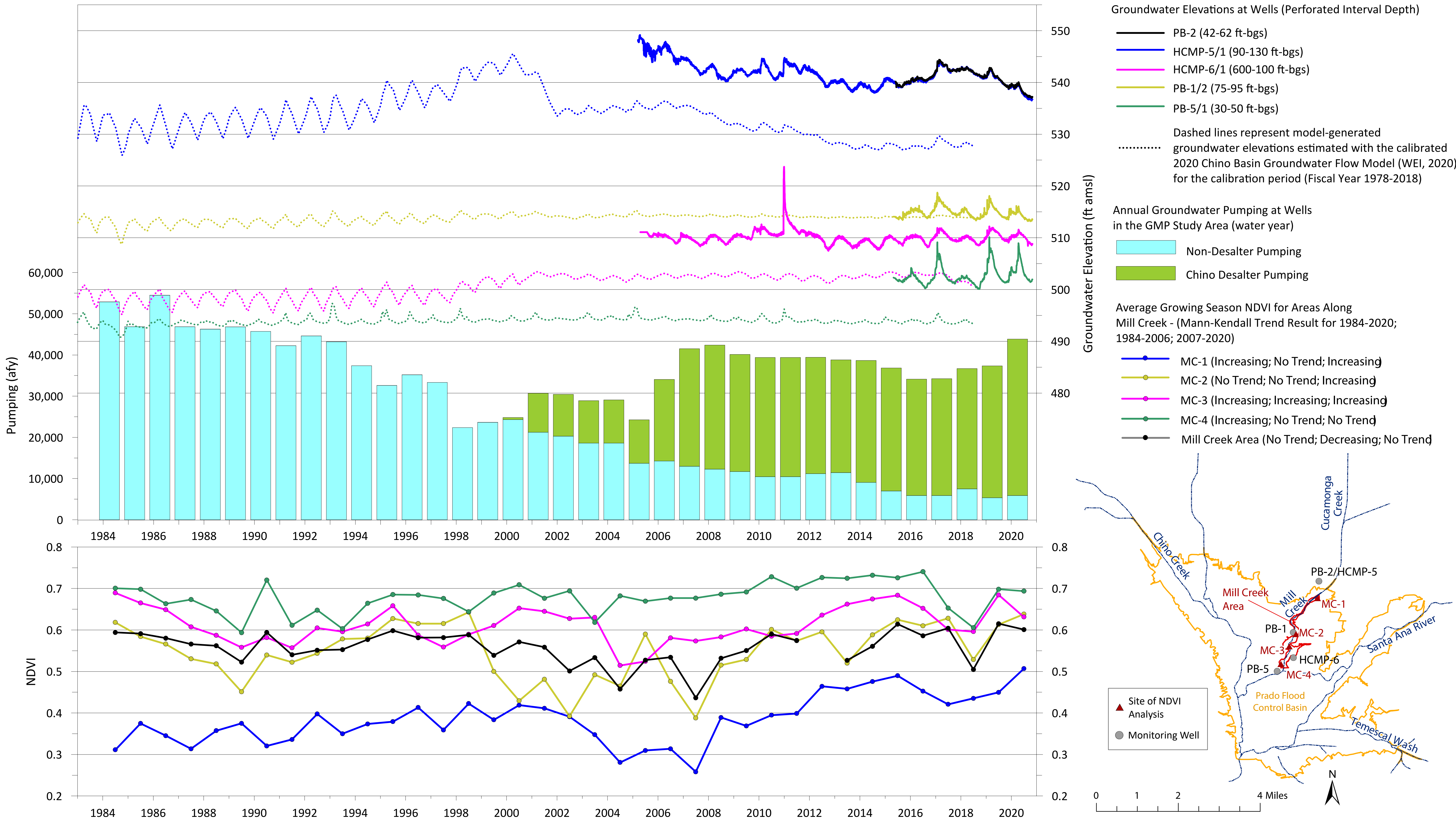
Groundwater Levels and Production versus NDVI
Chino Creek Area for 1984-2020

Figure 3-13a



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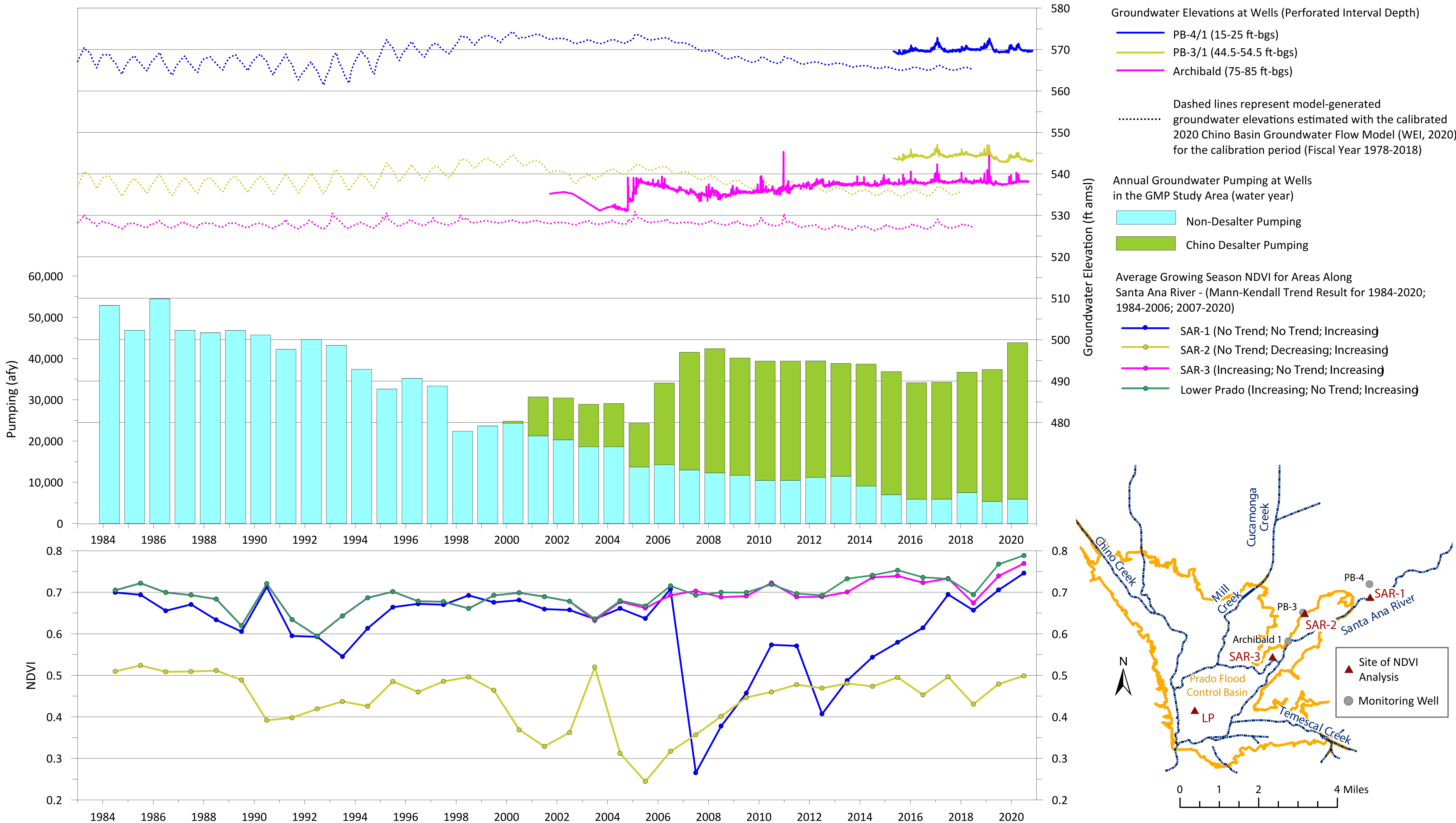
Groundwater Levels and Production versus NDVI
Mill Creek Area for 1984-2020

Figure 3-13b



Groundwater Levels and Production versus NDVI
Santa Ana River Area for 1984-2020

Figure 3-13c

3.2.4 Summary

The following observations and interpretations were derived from the analysis of groundwater pumping, groundwater levels, and NDVI:

- From 1961 to 1990, groundwater pumping from private domestic and agricultural wells in the study area averaged about 45,900 afy. From 1991 to 1999, groundwater pumping steadily declined to about 23,600 afy primarily due to conversions from agricultural to urban land uses. In 2000, CDA pumping commenced to replace the declining agricultural production. From WY 2019 to WY 2020, total groundwater pumping in the study area increased by about 6,000 afy to 43,800 afy due to an increase in the CDA pumping.
- Depth to groundwater in the Prado Basin area is relatively shallow—typically less than 15 feet below ground surface (ft-bgs) where riparian habitat exists. The shallow groundwater exits the Prado Basin via rising groundwater discharge to the SAR and its tributaries and evapotranspiration by riparian vegetation.
- Groundwater levels across the study area fluctuate seasonally, in some cases by up to 15 feet, under the seasonal stresses of pumping and recharge. During the winter months of WY 2017 and WY 2019, groundwater levels at some of the PBHSP monitoring wells increased to their highest recorded levels, likely in response to the recharge of stormwater discharge in unlined creeks and the surface-water reservoir that ponds behind Prado Dam.
- Since groundwater level measurements commenced at the PBHSP monitoring wells in 2015, there have been some slight increasing and decreasing trends in groundwater levels observed along the reaches of Chino Creek, Mill Creek, and SAR. From September 2016 to September 2020, groundwater levels near the edges of the riparian habitat have changed up to +/- 3 feet. Groundwater levels have declined the most at the PB-2 monitoring well near the upper reach of Mill Creek. Other areas of minor declines in groundwater levels since 2015 include the central reach of Mill Creek, the southern reach of Chino Creek, and the eastern reach of the SAR.
- In Section 3.1, the analysis of air photos and NDVI in Prado Basin indicate that the riparian vegetation did not change significantly throughout the Prado Basin over the 2019-2020 period, except for the MC-3 area where the air photo shows a notable decrease in the green riparian vegetation from 2019-2020. Groundwater levels have remained relatively stable across the Prado Basin from September 2019 to September 2020, except for the northern portion of Mill Creek (decrease up to 2 feet), central portion of Mill Creek (decrease up to 0.5 feet), and southern portion of SAR (increase up to 1 foot). This slight change in groundwater levels of 0.5 feet along the center portion of Mill Creek near MC-3 is within the historical range of variability in groundwater levels in this region, and is not likely the cause of the decreased green vegetation observed there in 2020. More information and research are needed to understand the cause of the decrease in green vegetation at the MC-3 site.

3.3 Analysis of Groundwater/Surface Water Interactions

One of the objectives of the PBHSP is to identify factors that contribute to the long-term sustainability of Prado Basin riparian habitat. The depth to groundwater analysis shown in Figure 3-12 indicates that the riparian vegetation exists in areas of shallow groundwater, where groundwater levels are typically 15 ft-bgs or less, and that the riparian vegetation is likely dependent, at least in part, upon the shallow groundwater.

The previous Annual Reports for WY 2017 and WY 2018 (Section 3.3) included a comprehensive analysis to understand the sources of the shallow groundwater in the Prado Basin and the groundwater/surface-water interactions that may be important to the long-term sustainability of the riparian habitat (WEI, 2018; 2019). The analysis included using surface-water discharge and quality, groundwater quality, groundwater levels, and groundwater modeling as multiple lines of evidence to analyze the groundwater/surface water interactions at the nine PBHSP well locations—along the fringes of the riparian habitat and adjacent to Chino Creek, Mill Creek, and the SAR. In general, the analysis concluded that the SAR and northern portion of Mill Creek are losing reaches, characterized by streambed recharge. Most other areas along Chino and Mill Creeks are gaining reaches, characterized by groundwater discharge. That said, at most locations in the Prado Basin, there appear to be multiple and transient sources that feed the shallow groundwater, and the groundwater/surface-water interactions are complex. Additional monitoring is needed to better characterize the sources of shallow groundwater and groundwater/surface-water interactions. This additional monitoring began in 2018 as a pilot program, which included:

- High-frequency water-quality monitoring at two PBHSP monitoring well sites along Chino Creek: PB-7 and PB-8 (two wells at each site). Each monitoring well was equipped with data logger to measure and record EC, temperature, and water levels at a 15-minute frequency. The wells were visited quarterly to download data from the data loggers and measure water levels. Groundwater quality samples were collected quarterly then semiannually for laboratory analyses of TDS and general mineral chemistry to validate and support the high-frequency data.
- High-frequency water-quality monitoring at two surface-water sites along Chino Creek adjacent to the monitoring well sites. Each site was equipped with a data logger to measure and record EC, temperature, and stage at a 15-minute frequency. The surface-water sites were visited quarterly to download data from the data loggers. Groundwater quality samples were collected quarterly then semiannually for laboratory analyses of TDS and general mineral chemistry to validate and support the high-frequency data.

The data loggers were installed at the groundwater and surface-water sites in July 2018. Since installation there has been periodic disruptions of the data collected in the surface water data loggers: in late-2018, the data loggers were lost during large storm events; and the casing that house the data loggers experienced accumulation of mud which periodically compromised the accuracy of the collected data. These monitoring challenges have been resolved. The high-frequency data collected thus far for the pilot monitoring program shows promise and has provided more data to support the characterization of groundwater/surface water interactions at these locations and warrants the continuation of the pilot program. More high-frequency surface-water data needs to be collected along Chino Creek to order to collect enough data to draw defensible conclusions.

3.4 Climate and Its Relationship to the Riparian Habitat

Precipitation and temperature are climatic factors that can affect the extent and quality of riparian habitat. Precipitation can provide a source of water for consumptive use by the riparian vegetation via the direct infiltration of precipitation and runoff, which increases soil moisture that can be directly used by the vegetation, or by maintaining groundwater levels underlying the vegetation for its subsequent use. Temperatures affect the rate of plant growth and productivity. Both factors are unrelated to the implementation of the Peace II Agreement. This section characterizes the time series of precipitation and temperature in the Prado Basin area and compares that time series to trends in the quality of the riparian habitat, as indicated by NDVI, to help determine if these factors have influenced the riparian habitat in the Prado Basin.

3.4.1 Precipitation

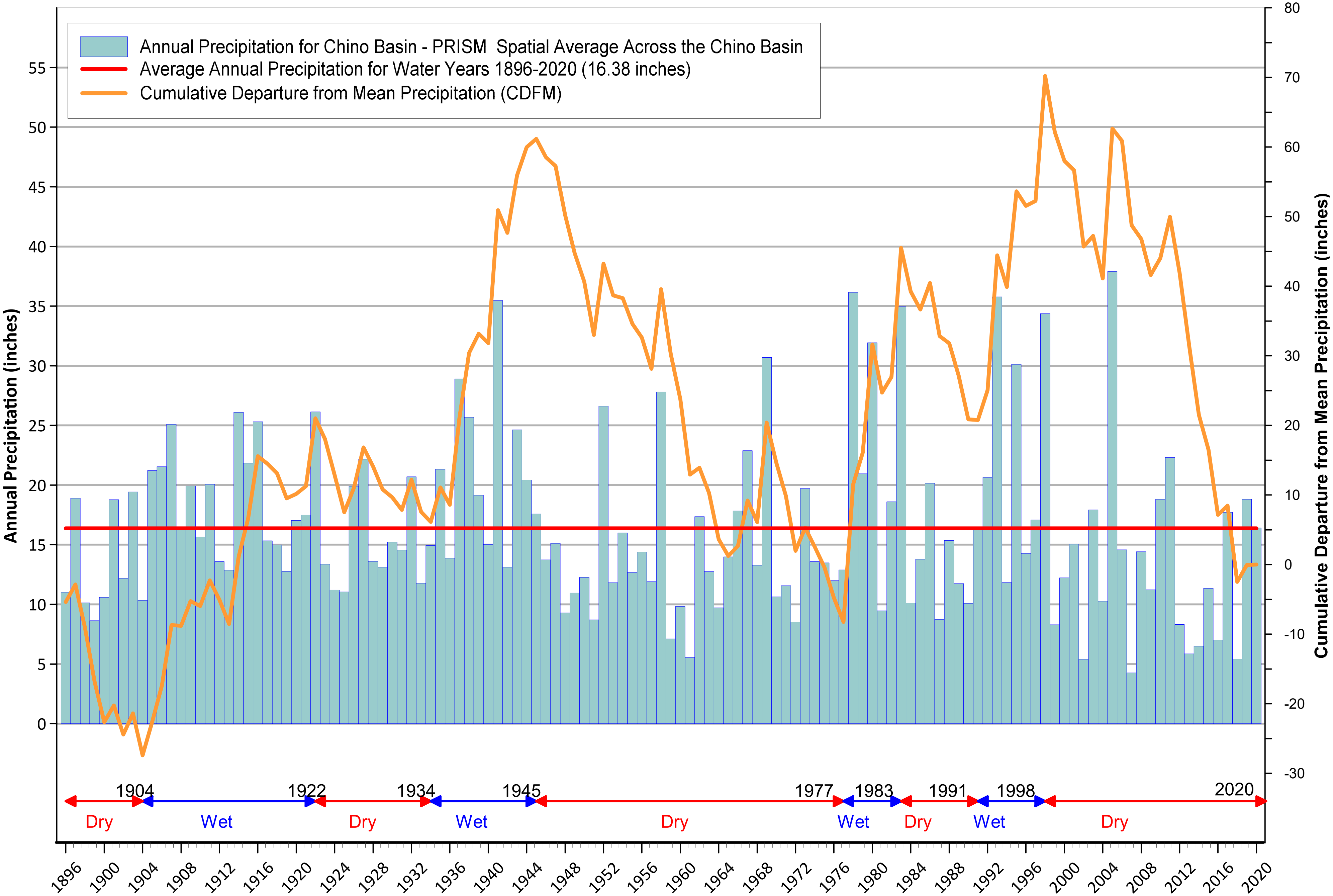
Figure 3-14 is a time-series chart that shows annual precipitation estimates within the Chino Basin for WY 1896 to 2020. These estimates were computed as a spatial average across the Chino Basin using rasterized data from the PRISM Climatic Group (an 800-meter by 800-meter grid). The long-term average annual precipitation in the Chino Basin is 16.38 inches per year (in/yr). The chart includes a cumulative departure from mean (CDFM) precipitation curve, which characterizes the occurrence and magnitude of wet and dry periods: positive sloping segments (trending upward to the right) indicate wet periods, and negative sloping segments (trending downward to the right) indicate dry periods.

Review of the CDFM precipitation curve indicates that the Chino Basin experienced several prolonged wet and dry periods from WY 1896 to 2020. Typically, dry periods are longer in duration than wet periods. The longest dry period occurred between 1946 through 1977 (32 years). The current dry period is a 22-year period, starting in WY 1999, and includes the Peace/Peace II Agreement period (2001 through 2020). Over the 124-year record, about 40 percent of the years had precipitation greater than the average, and 60 percent had below average precipitation. In the 20-year period since the Peace Agreement was implemented, 35 percent of the years had precipitation greater than the average, and 65 percent had below average precipitation. Precipitation in WY 2020 was 16.42 inches, which is about equal to the long-term average.

3.4.2 Temperature

Maximum and minimum temperatures during the growing season are the temperature metrics used in this analysis because plant growth and development are dependent upon the temperatures surrounding the plant (Hatfield and Prueger, 2015). Maximum temperatures during the growing season directly influence photosynthesis, evapotranspiration, and breaking of the dormancy of vegetation (Pettorelli, 2015). Minimum temperatures affect nighttime plant respiration rates and can potentially have an effect on plant growth that occurs during the day (Hatfiled et. al, 2011). Hence, both temperature metrics can influence NDVI. All species of plants have a range of maximum and minimum temperatures necessary for growth (Hatfield and Prueger, 2015). Climate change is more likely to increase minimum temperatures while maximum temperatures are affected more by local conditions (Knowles et al., 2006; Alfaro et al., 2006).

Figure 3-15 is a time-series chart that shows the average maximum and minimum Prado Basin temperatures for the growing-season months of March through October from 1896 to 2020 (growing-season maximum and minimum temperatures). These temperature estimates were computed as a spatial average across the Prado Basin using rasterized data from the PRISM Climatic Group (an 800-meter by 800-meter grid) of monthly maximum and minimum temperature estimates. This chart also shows the five-year moving average of the growing-season maximum and minimum temperatures for the Prado Basin. The five-year moving average is a smoothing technique used to reveal trends over time.



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2020 Annual Report

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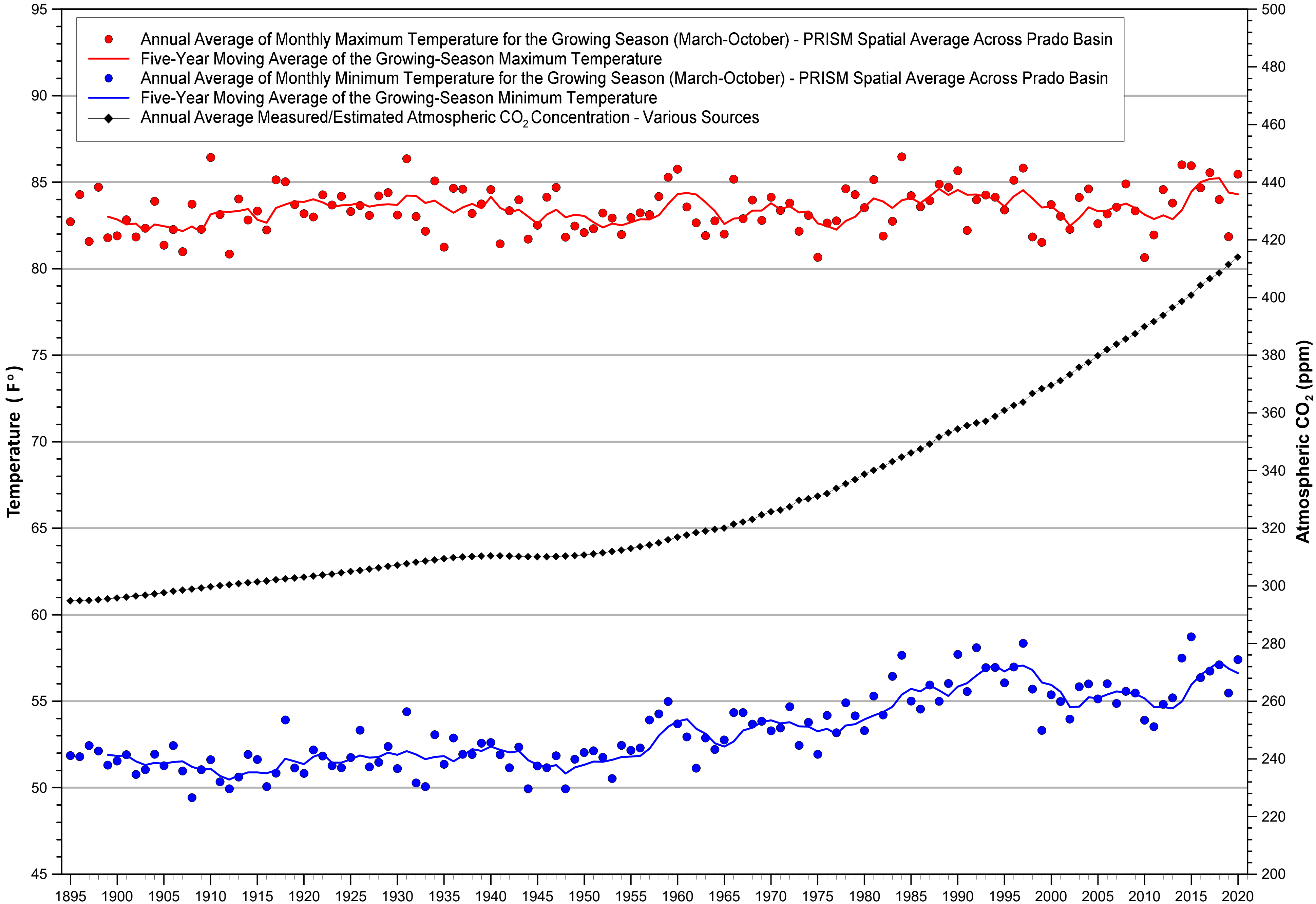
Chino Basin Watermaster — Partners in Basin Management

Annual Precipitation in the Chino Basin
Water Year 1986 - 2020

Figure 3-14



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Maximum and Minimum Temperature in Prado Basin

1895 - 2020

Figure 3-15

This chart also shows a complete record of atmospheric carbon dioxide (CO2) concentrations assembled from multiple sources:

- Values prior to 1959 were estimated from an analysis of the Law Dome DE08 and DE08-2 ice cores in Antarctica. (Acquired from the Carbon Dioxide Information Analysis Center, http://cdiac.ornl.gov/trends/co2/lawdome.html. Accessed on June 6, 2017).
- Values after 1959 are from measured CO2 concentration data at the Mauna Loa Observatory in Hawaii. (Acquired from the National Oceanic and Atmospheric Association's Earth Systems Research Laboratory, https://www.esrl.noaa.gov/gmd/ ccgg/trends/full.html. Accessed on June 5, 2017).

The time history of atmospheric CO2 concentrations shows a slight increasing trend from about 290 parts per million (ppm) in the late 1890s to about 310 ppm in 1950. After 1950, the CO2 concentration shows an amplified increasing trend and exceeds 400 ppm by 2015.

From 1896 to 2020, the growing-season maximum temperature fluctuates between 80° F to 86° F and does not appear to have a prominent long-term increasing or decreasing trend. From 1896 to 2020, the growing-season minimum temperature fluctuates between 49° F to 59° F and has an increasing trend starting in 1950 of about five degrees Fahrenheit through 2020. This increasing trend in the growing-season minimum temperature beginning 1950 appears to correlate with the increase in atmospheric CO2 concentrations. The five-year moving averages of both the growing-season minimum and maximum temperatures display an increasing trend over the recent six-year period of 2013-2018 and in 2018 had the highest calculated values over the entire period of record. In 2019 and 2020, the growing-season minimum and maximum temperatures and the five-year moving averages all decreased slightly from the previous period with the highest values historically.

3.4.3 Climate Compared to NDVI

Figures 3-16a through 3-16c are time-series charts that compare long-term trends in precipitation and temperature to trends in the quality of the riparian vegetation, as indicated by NDVI, for three areas in the Prado Basin: Chino Creek, Mill Creek, and the SAR. The period of analysis is 1984-2020—the period of NDVI availability. The upper chart on the figures displays the time series of annual precipitation in Chino Basin, the CDFM precipitation curve, and the five-year moving average for the growing-season maximum and minimum temperatures in the Prado Basin. The lower chart displays the time series of the Average Growing-Season NDVI for the defined areas discussed in Section 3.1 along Chino Creek, Mill Creek, and the SAR. For reference, the Mann-Kendall test results for trends in the Average Growing-Season NDVI for 1984-2020, 1984-2006, and 2007-2020 are shown in the legend.

The observations and interpretations below are focused on recent changes in Average Growing-Season NDVI during 2020 described in Section 3.1 and whether observed trends in temperature and precipitation may be contributing to recent increases in NDVI.

Chino Creek (Figure 3-16a). From 2019 to 2020, Average Growing-Season NDVI for the five areas along Chino Creek decreased at four areas and increased at one area. For all these areas, the one-year changes in NDVI were relatively minor and within the historical ranges of one-year NDVI variability (see Table 3-2). These recent changes in NDVI occurred during a year of average precipitation and slightly lower minimum and maximum temperatures in the Prado Basin then what has occurred the seven prior years. Hence, the main observations and conclusions for the 2019 to 2020 period are that there were slightly cooler and drier conditions in 2020 and the riparian vegetation did not change significantly along Chino Creek.

Mill Creek (Figure 3-16b). From 2019 to 2020, the Average Growing-Season NDVI of the five areas along Mill Creek: decreased at three areas, increased at one area, and did not change at one area. At all the areas, the one-year NDVI changes are within their historical ranges of the one-year NDVI variability (see Table 3-2). However, the air photo for the MC-3 area shows a notable decrease in green vegetation. These recent changes in NDVI and vegetation occurred during a year of average precipitation and slightly lower minimum and maximum temperatures in the Prado Basin then what has occurred the prior seven years. Hence, the main observations and conclusions for the 2019 to 2020 period are that there were slightly cooler and drier conditions and the riparian vegetation did not change significantly along Mill Creek, except in the area near MC-3. The decrease in the green vegetation observed at MC-3 is likely not caused by the slightly cooler and drier conditions during 2020 and is likely related to some other factor.

Santa Ana River (Figure 3-16c). From 2019 to 2020, the Average Growing-Season NDVI increased at all four areas along the SAR. For all these areas, the one-year NDVI changes were relatively minor and within the historical ranges of one-year NDVI variability (see Table 3-2). These recent changes in NDVI occurred during a year of average precipitation and slightly lower minimum and maximum temperatures in the Prado Basin then what has occurred the seven years prior. Hence, the main observations and conclusions for the 2019 to 2020 period are that there were slightly cooler and drier conditions in 2020, and the riparian vegetation did not change significantly along the SAR.

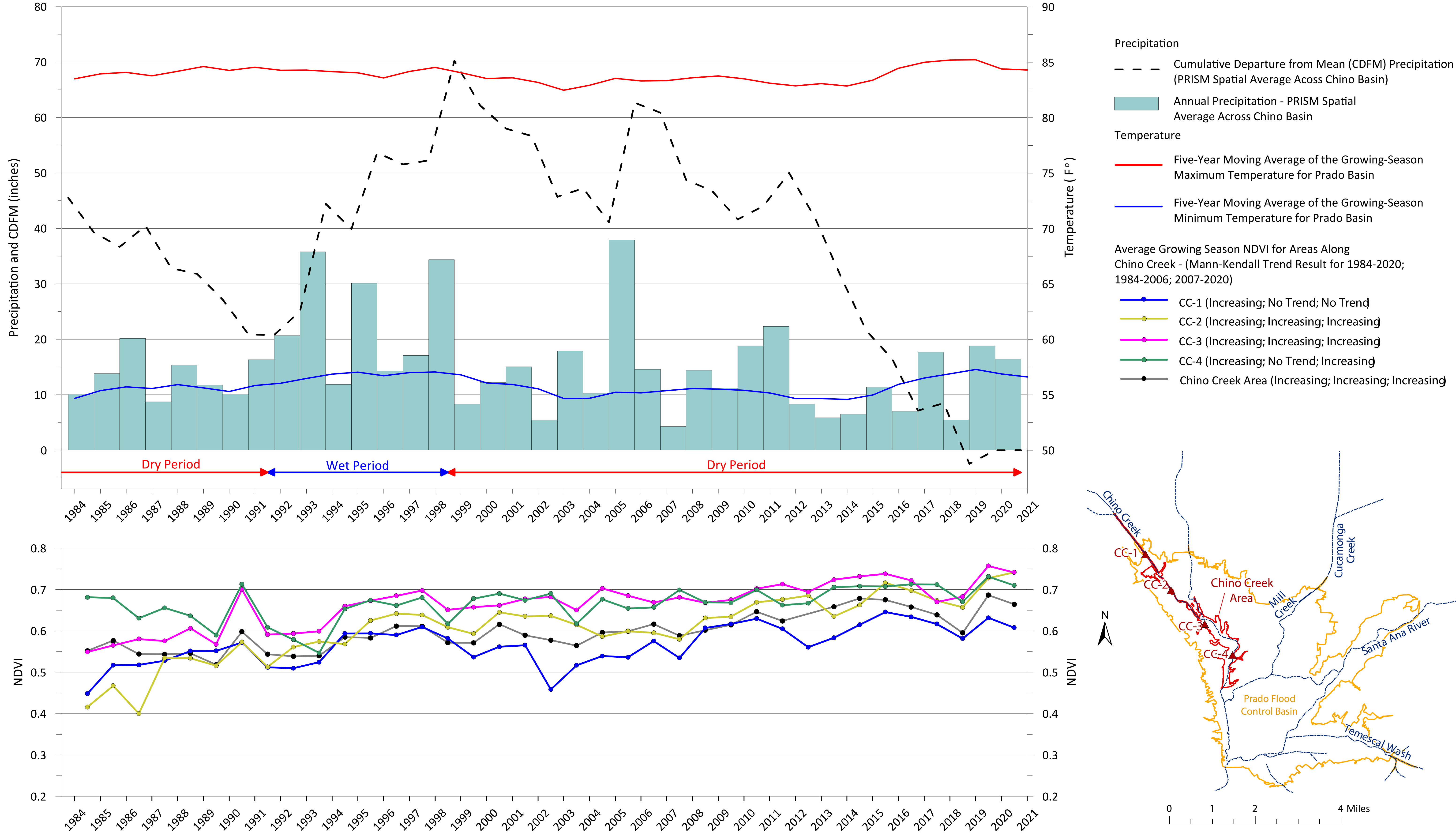
3.5 Stream Discharge and Its Relationship to the Riparian Habitat

Stream discharge in the SAR and its tributaries that flow through the Prado Basin is a factor that can affect the extent and quality of Prado Basin riparian habitat Basin. Stream discharge can recharge the groundwater system along losing stream reaches and supply water through the groundwater system to riparian vegetation. Stream discharge is also important to fauna living within the stream system. Flooding events and flood-control/water-conservation operations at Prado Dam can scour and inundate areas of the riparian habitat and potentially cause adverse impacts.

This section characterizes the time series of stream discharge within the Prado Basin and compares that time series to trends in the extent and quality of the riparian habitat, as indicated by NDVI, to help determine whether changes in stream discharge have influenced the riparian habitat in the Prado Basin.

3.5.1 Stream Discharge

There are three primary components of stream discharge in the SAR and its tributaries: storm discharge, non-tributary discharge, and base-flow discharge. Storm discharge is rainfall runoff. Non-tributary discharge typically originates from outside the watershed, such as imported water discharged from the OC-59 turnout on San Antonio Creek. Base-flow discharge, as used herein and by the Santa Ana River Watermaster (SARWM), includes tertiary-treated wastewater discharge from POTWs, rising groundwater, and dry-weather runoff.



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2020 Annual Report

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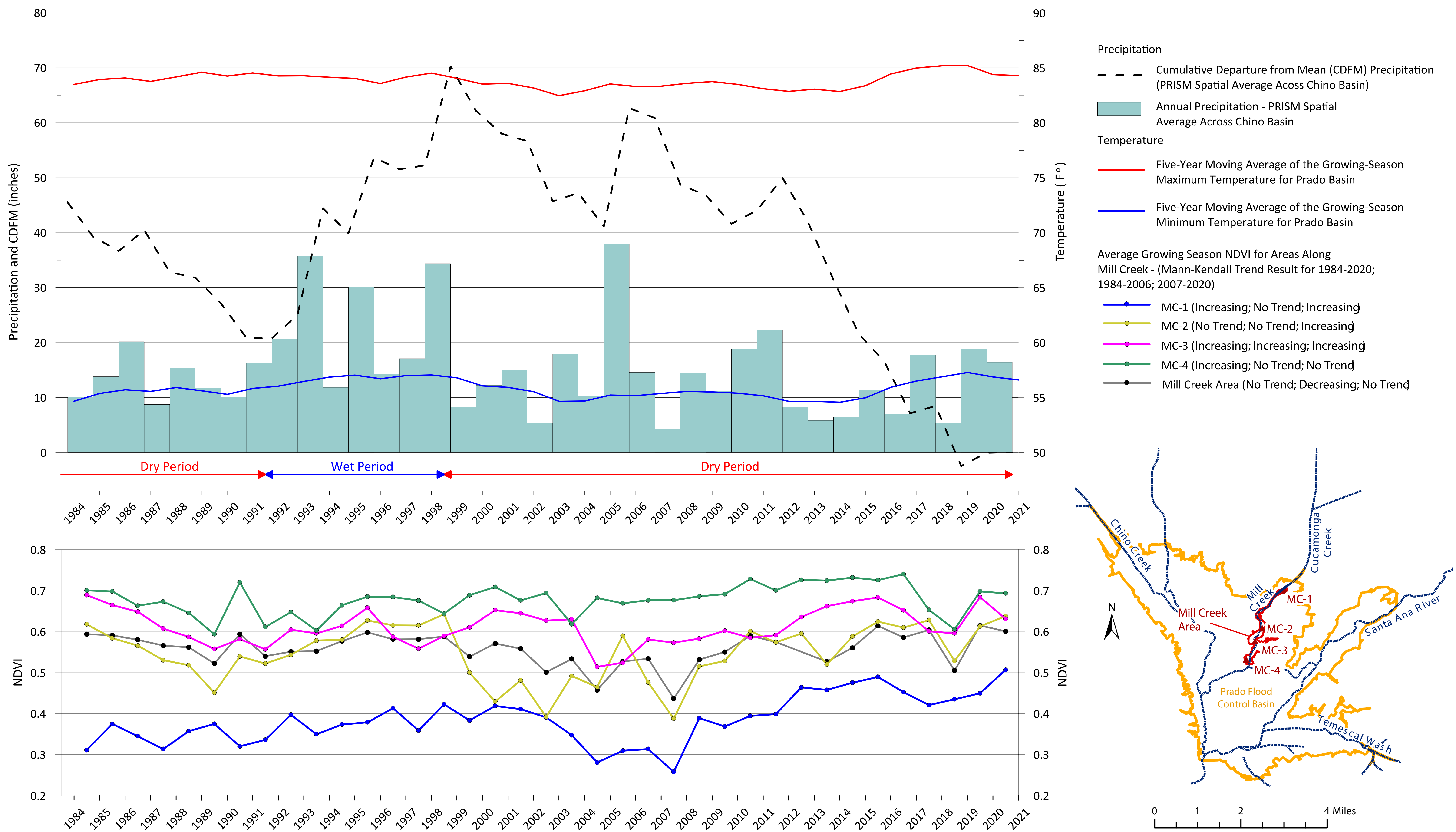
Climate verus NDVI
Chino Creek Area for 1984-2020

Figure 3-16a



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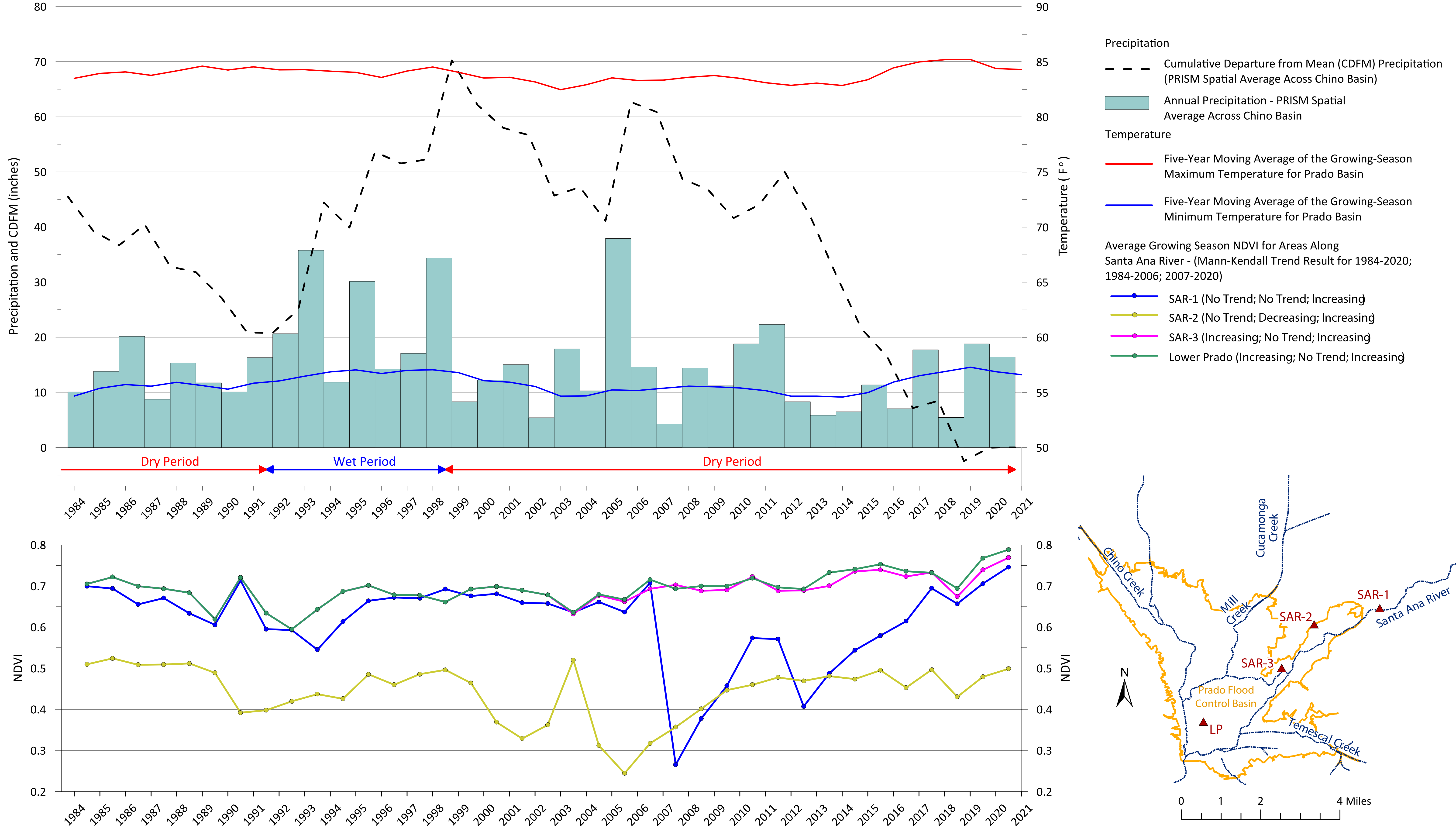
2020 Annual Report

Climate verus NDVI
Mill Creek Area for 1984-2020

Figure 3-16b



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Climate verus NDVI
Santa Ana River and Lower Prado Area for 1984-2020

Figure 3-16c

Figure 3-17 includes time-series charts that summarize important annual discharges within the upper SAR watershed that are tributary to Prado Dam from water years 1971 to 2020 (SARWM, 2021). The upper chart on Figure 3-17 characterizes the annual outflow from the Prado Basin as total measured SAR discharge at USGS gage *SAR at below Prado Dam*. The upper chart also shows the base-flow component of total measured discharge as estimated by the SARWM. This chart shows that base-flow discharge declined from about 154,000 afy in 2005 to an average of about 76,000 afy over the period 2012-2020. The decline in base-flow discharge is primarily related to declines in POTW effluent discharges that are tributary to Prado Basin. In WY 2020, the total discharge at below Prado Dam was above average and base-flow discharge was average, following a wet year in WY 2019 where the discharge was the highest values since 2011:

- *Total Discharge at below Prado Dam in WY 2020.* Total discharge in WY 2020 was about 161,000 af, which is about 29,000 afy greater than the average total discharge over the previous eight years (2012 to 2019), and a 91,000 afy decrease from total discharge in WY 2019.
- *Base-Flow Discharge at below Prado Dam in WY 2020*. Base-flow discharge was about 74,500 afy, which is about 1,300 afy less than the average base-flow discharge over the previous eight years (2012 to 2019), and about 23,500 afy less than base-flow discharge in WY 2019.

The lower chart on Figure 3-17 shows the combined POTW discharges that are tributary, at least in part, to Prado Dam. The POTW discharges declined from about 192,000 afy in 2005 to an average of about 97,300 afy for the last eight years (2012-2019). This decrease is mostly attributed to decreases in effluent discharge from the IEUA and the POTWs that discharge to Temescal Creek. The post-2005 decrease in POTW effluent discharge was caused by increased recycled-water reuse, decreased water use due to the economic recession that began in 2008, and the implementation of emergency water-conservation measures during the recent drought since 2012. In WY 2020, POTW discharge was about 98,900 afy, which is about 1,600 afy greater than the average POTW discharge over the previous eight years, and about 8,100 afy less than POTW discharge in WY 2019.

3.5.2 Stream Discharge Compared to NDVI

Figures 3-18a through 3-18c are time-series charts that compare long-term trends in stream discharge to trends in the quality of the riparian vegetation, as indicated by NDVI, for three areas in Prado Basin: Chino Creek, Mill Creek, and the SAR. The period of analysis for these charts is 1984-2020—the period of NDVI availability. The upper chart on the figures displays the annual volumes of measured discharge to each stream during the growing season (March-October), including: measurements at USGS gaging stations located upstream of the Prado Basin and POTW discharges.[17] The lower chart displays the time series of the Average Growing-Season NDVI for defined areas, as discussed in Section 3.1, along Chino Creek, Mill Creek, and the SAR. For reference, the Mann-Kendall test results for trends in the Average Growing-Season NDVI for 1984-2020, 1984-2006, and 2007-2020 are shown in the legend.

[17] These charts do not describe other hydrologic processes that affect surface-water discharge within the Prado Basin, including evaporation, evapotranspiration, the infiltration of water along unlined stream segments, and rising groundwater discharge.

The observations and interpretations below are focused on the recent (2020) changes in Average Growing-Season NDVI, as described in Section 3.1, and whether observed trends in surface-water discharge may be contributing to recent changes in NDVI.

Chino Creek (Figure 3-18a). Chino Creek is a concrete-lined, flood-control channel that transitions into an unlined stream channel at the Prado Basin boundary and flows south to merge with Mill Creek and the SAR behind Prado Dam (see Figure 2-3). The upper chart on Figure 3-18a shows discharge to Chino Creek during the growing season, including: measured discharge at USGS gage *Chino Creek at Schaefer* and the POTW discharges downstream of the USGS gage, including discharges from the IEUA Carbon Canyon, RP-2, RP-5, and RP-1 plants. Measured discharge at *Chino Creek at Schaefer* includes storm-water and dry-weather runoff in the concrete-lined channel upstream of the IEUA discharge locations and imported water discharge from the OC-59 turnout. Discharges not characterized in this figure are storm-water runoff, dry-weather runoff, and rising-groundwater discharge downstream of the *Chino Creek at Schaefer* gage. From 1984 to 2020, discharge in Chino Creek during the growing season progressively increased through 1999 and then decreased. The decreasing trend in growing-season discharge since about 1999 was caused by dry climatic conditions, water conservation in response to drought, and decreases in effluent discharge from the IEUA plants. During the recent eight-year period, from 2012 to 2019, growing-season discharge in Chino Creek averaged about 7,900 afy. In 2020, growing-season discharge was about 9,100 afy, which is about 1,100 af greater than the average growing-season discharge over the last eight years, and about 170 af greater than growing-season discharge in 2019. This minor increase in growing-season discharge in Chino Creek during 2020 is attributed to increases in the storm-water/dry-weather runoff and POTW discharges.

From 2019 to 2020, Average Growing-Season NDVI at the five areas along Chino Creek: decreased at four of the areas and increased at one area. For all these areas, the one-year NDVI changes were relatively minor and within the historical ranges of one-year NDVI variability (see Table 3-2). These recent changes in NDVI occurred during a year of above average discharge in Chino Creek. Hence, the main observations and conclusions for the 2020 period are that there were above average discharge conditions in Chino Creek and the riparian vegetation did not change significantly along Chino Creek.

Mill Creek (Figure 3-18b). Cucamonga Creek is a concrete-lined flood-control channel and transitions into an unlined stream channel at the Prado Basin boundary, and at that point, its name changes to Mill Creek (see Figure 2-3). The upper chart on Figure 3-18b shows discharge to Mill Creek during the growing season, including: POTW effluent discharge from the IEUA RP-1 plant to Cucamonga Creek and measured discharge downstream at USGS gage *Cucamonga Creek near Mira Loma* (less the RP-1 discharge). The measured discharge at *Cucamonga Creek near Mira Loma* (less the RP-1 discharge) is representative of storm-water and dry-weather runoff in Cucamonga Creek upstream of this gaging station during the growing season. Discharges not characterized on this figure are storm-water runoff, dry-weather runoff, and rising-groundwater discharge downstream of the *Cucamonga Creek near Mira Loma* gage. From 1984 to 2020, growing-season discharge in Mill Creek progressively increased through 2004 and then decreased. The decreasing trend in growing-season discharge since about 2004 was caused by dry climatic conditions, water conservation in response to drought conditions after 2012, and the decrease in effluent discharge from the IEUA RP-1 plant. During the recent eight-year period from 2012 to 2019, growing-season discharge averaged about 8,000 afy. In 2020, the growing-season discharge was about 15,200 afy, which is about 7,200 af greater than the average growing-season discharge over the last eight years, and about 1,100 af greater than growing-season discharge in 2019.

From 2019 to 2020, Average Growing-Season NDVI at the five areas along Mill Creek: decreased at three areas, increased at one area, and remained the same at one area. At all the areas, these recent changes in NDVI are within their historical ranges of the one-year NDVI variability (see Table 3-2). However, the air photo for the MC-3 area shows a notable decrease in green vegetated area. These recent changes in NDVI occurred during a year of above average discharge in Mill Creek. Hence, the main observations and conclusions for the 2020 period are that there were above average discharge conditions in Mill Creek and the riparian vegetation did not change significantly along Mill Creek, except in the area observed near MC-3. The decrease in NDVI and green vegetation observed at MC-3 is likely not caused by the above average discharge conditions in Mill Creek during 2020 but is likely related to some other factor.

Santa Ana River (Figure 3-18c). The SAR is an unlined stream channel from the Riverside Narrows to Prado Dam—its entire reach across the Chino Basin (see Figure 2-3). The upper chart on Figure 3-18c shows the annual growing-season discharge at the USGS gage *Santa Ana River at MWD Crossing* (Riverside Narrows) and the annual growing-season discharges to the SAR downstream of the Riverside Narrows, including POTW effluent from the City of Riverside's Regional Water Quality Control Plant and the Western Riverside County Regional Wastewater Authority (WRCRWA) plant that is conveyed in an unlined channel (along with a portion of SAR discharge) to the OCWD Wetlands. The measured discharge at the *Santa Ana River at MWD Crossing* gage represents storm-water runoff and base-flow discharge in the SAR upstream of the gaging station at the Riverside Narrows. The base-flow discharge includes POTW discharge from the RIX and Rialto treatment plants, dry-weather runoff, and rising groundwater. Discharges not characterized on this figure are storm-water runoff, dry-weather runoff, and rising-groundwater discharge downstream of the *Santa Ana River at MWD Crossing* gage.

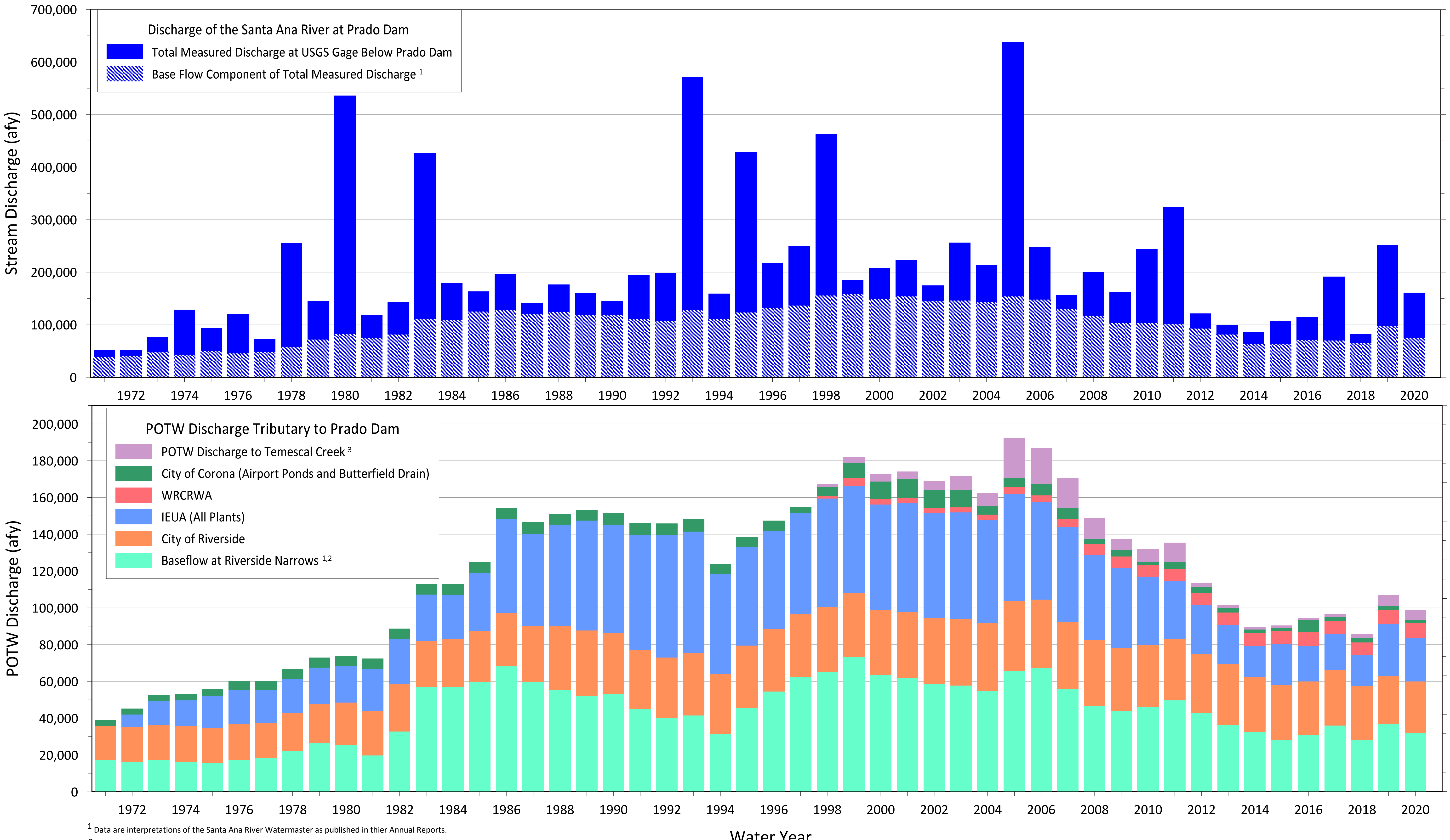
From 1984 to 2011, growing-season discharge in the SAR averaged about 78,100 afy with episodic increases in storm-water discharge during wet years. During the recent eight-year period, from 2012 to 2019, growing-season discharge in the SAR gradually declined and averaged about 48,600 afy. The decreasing trend in growing-season discharge was caused by dry climatic conditions, water conservation in response to drought, and decreasing base flow at the Riverside Narrows. In 2020, the growing-season discharge in the SAR was about 59,900 af, which is about 11,300 af greater than the average growing-season discharge during 2012 to 2018, and about 7,900 af greater than growing-season discharge in 2019.

From 2019 to 2020, the Average Growing-Season NDVI increased at all four areas along the SAR. For all these areas, the one-year NDVI increases were relatively minor and within the historical ranges of one-year NDVI variability (see Table 3-2). These recent changes in NDVI occurred during a year of above average discharge in the SAR. Hence, the main observations and conclusions for the 2020 period are that there was above average discharge in the SAR during the growing season and the riparian vegetation did not change significantly along the SAR.

3.6 Other Factors and Their Relationships to Riparian Habitat

Other factors that can affect the extent and quality of riparian habitat in the Prado Basin analyzed in this Annual Report include wildfire, pests, and Arundo management. These factors are unrelated to Peace II Agreement implementation.

This section characterizes what is known about these factors and compares them to trends in the extent and quality of the riparian habitat to determine their impacts, as characterized by the NDVI.



[1] Data are interpretations of the Santa Ana River Watermaster as published in thier Annual Reports.

[2] Baseflow at Riverside Narrows includes POTW discharge from RIX and Rialto plants, rising groundwater, and dry weather runoff

[3] Includes discharge from EVMWD, EMWD, and LLWD plants

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PBHSP\GRAPHER\GRF\AnnualR\Figure3-18 Flow Tributary to Prado Dam

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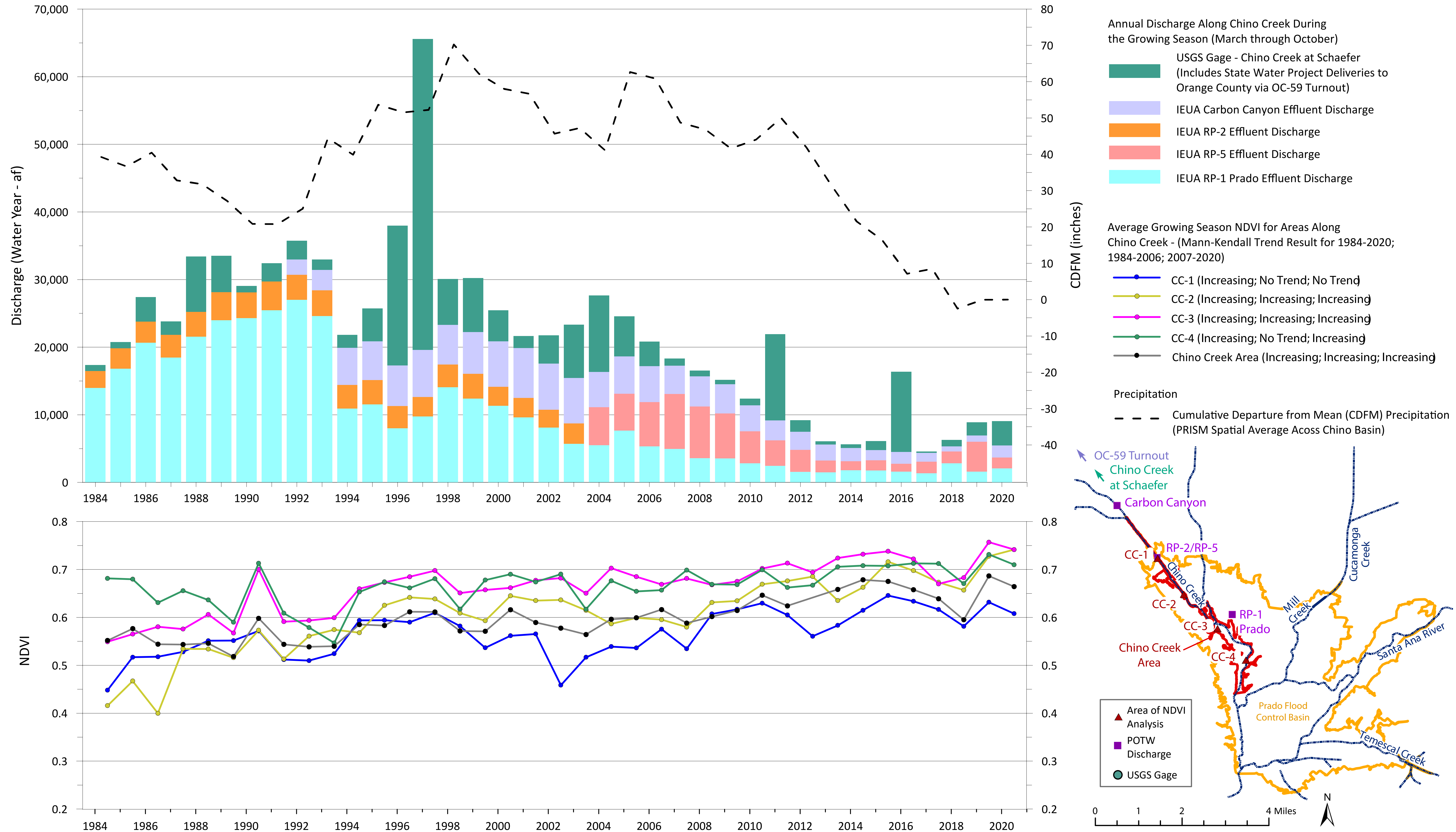
2020 Annual Report

Discharge Tributary to Prado Dam
Water Year 1960-2020

Figure 3-17



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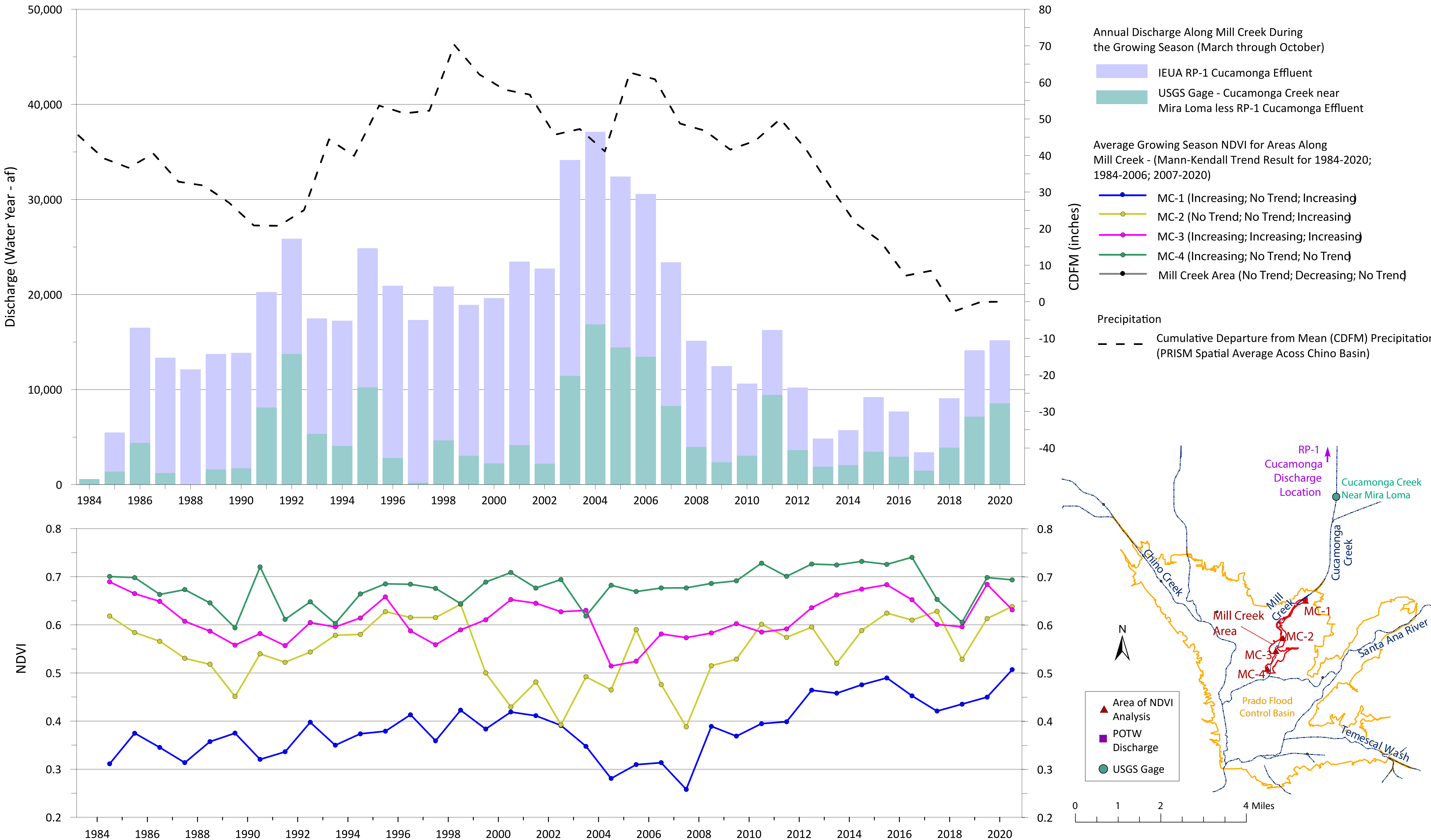
Surface-Water Discharge versus NDVI
Chino Creek Area for 1984-2020

Figure 3-18a



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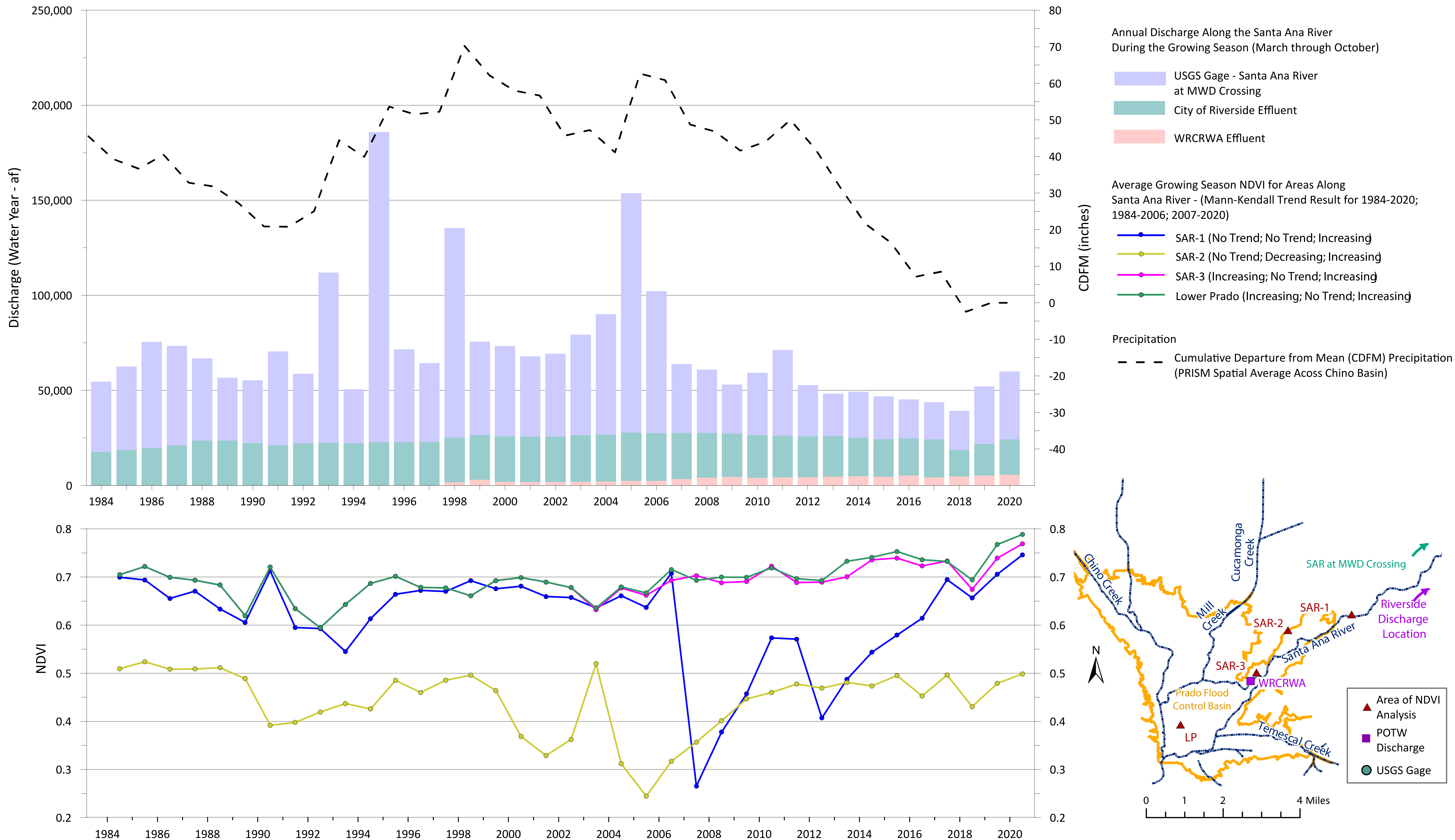
Surface-Water Discharge versus NDVI
Mill Creek Area for 1984-2020

Figure 3-18



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Surface-Water Discharge versus NDVI
Santa Ana River and Lower Prado Area for 1984-2020

Figure 3-18c

3.6.1 Wildfire

Available wildfire perimeter data from the FRAP database[18] were compiled within the Prado Basin extent for the period of 1950-2019.[19] The FRAP database shows that wildfires occurred in the Prado Basin in 1985, 1989, 2007, 2015, and 2018. Figure 3-19 shows the spatial extent of these wildfires, mapped over the 2020 air photo. The most recent wildfire was along the southern reach of Chino Creek in 2018. Portions of the 2018 wildfire area are still identifiable in the air photo by small areas of brownish land cover that lack vegetation.

Figures 3-20a through 3-20c are time-series charts that explore the relationship between other factors that can impact riparian vegetation and NDVI for three reaches in the Prado Basin: Chino Creek, Mill Creek, and the SAR. The figures show the Average Growing-Season NDVI for 14 defined areas of riparian habitat discussed in Section 3.1 and shown in Figures 3-6, 3-7, and 3-8a through 3-8l. Wildfire occurrences, annotated by date, are shown on the charts if their extent intersects with the extent of the defined area of NDVI analysis. The most recent wildfire was in 2018 and burned the southern portion of Chino Creek. The Chino Creek area, which includes the northern portion of the 2018 wildfire, showed a decrease in the Average Growing-Season NDVI of about 0.05 following the wildfire. There are other notable declines in the NDVI for some of the defined areas impacted by the 2007 and 1985 wildfires, and the NDVI for the entire vegetation extent after the 2015 fire which have been described in previous annual reports.

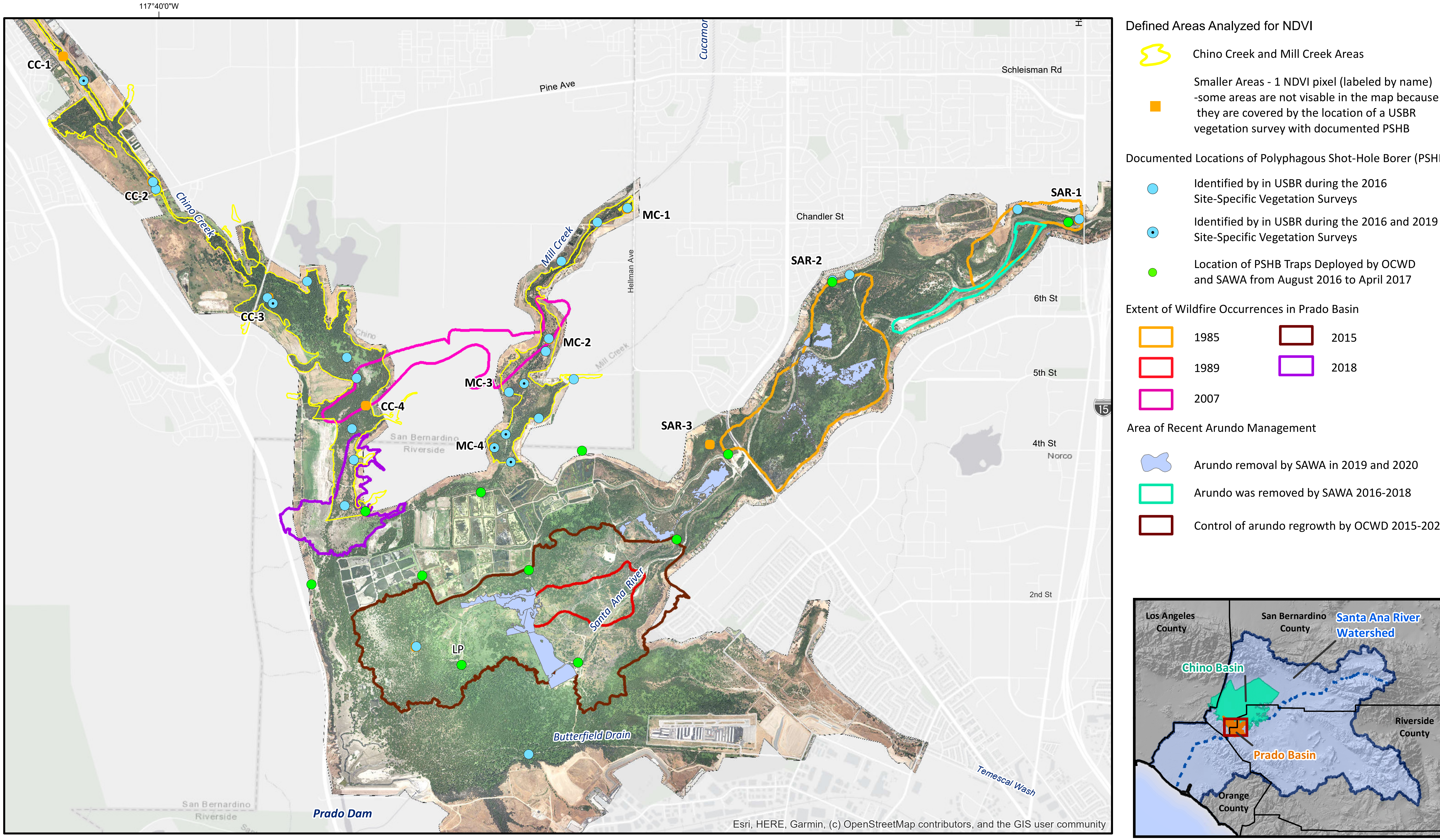
3.6.2 Polyphagous Shot Hole Borer

PSHB, from the group known as ambrosia beetles, is a relatively new pest in Southern California. PSHB burrows into trees and introduces fungi that assists in establishing colonies. Infection caused by the fungi can cause a dark stain surrounding the entry holes, discolored bark, leaf discoloration and wilting, and die off of entire branches or trees.

In spring 2016, OCWD biologists observed die off of riparian trees in patches throughout the Prado Basin, especially arroyo and black willows, and confirmed that the cause was from PSHB (ACOE and OCWD, 2017; OCWD 2020). Although PSHB arrived prior to 2016, this was the first notable die off in the Prado Basin. Since 2016, OCWD biologists have noted that the presence of PSHB is widespread throughout the Prado Basin and has reduced tree canopy cover, but tree mortality has remained confined to small local patches (Zembal, R., personal communication, 2018). OCWD biologists observed that the affected trees that had not died were showing signs of severe infestation, exhibiting branch failure, significant staining, and crown sprouting after the upper branches had died back. (ACOE and OCWD, 2017). In infected trees, crown sprouting allows some of the trees to persist, but the PSHB have been observed to attack the recently emerged limbs once they grow to two to three inches in diameter, causing the sprouting to be temporary. The die back and crown sprouting has resulted in a reduction of canopy in many areas (OCWD, 2020). Canopy loss in heavily infested areas may allow faster-growing invasive non-native species to colonize and out-compete native trees and shrubs in the understory (OCWD, 2020).

[18] Link (Website for California Department of Forestry and Fire Protection's Fire and Resource Assessment Program).

[19] Data is updated in late April for the previous year; 2019 data were not available for this annual report.



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Date: 6/3/2021

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Chino Basin Watermaster and Inland Empire Utilities Agency
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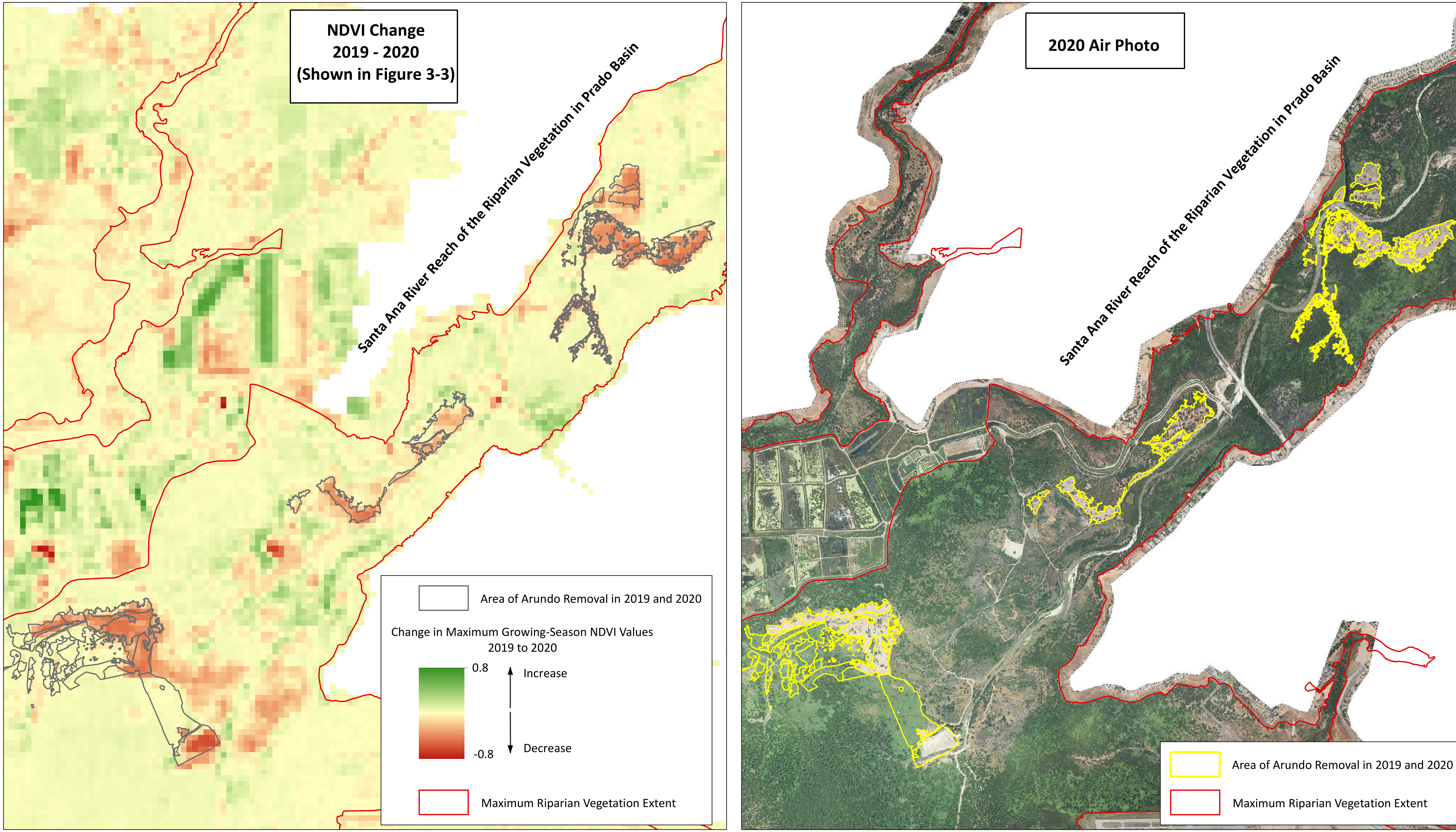
Location Map of Other Factors That Can Affect Riparian Habitat

Figure 3-19a



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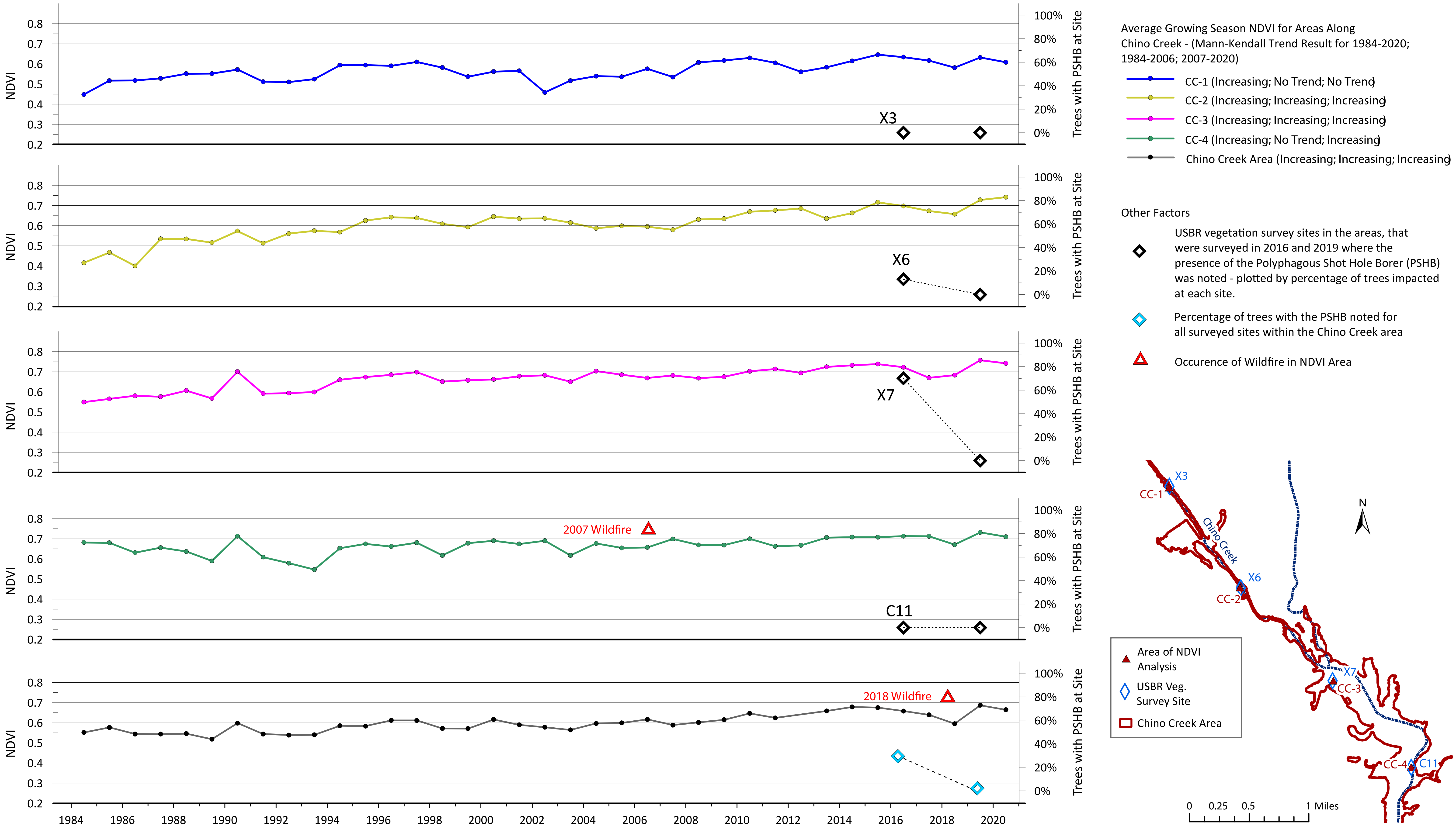
Areas of Arundo Removal and the
Santa Ana River Reach and Lower Prado
2019 and 2020

Figure 3-19b



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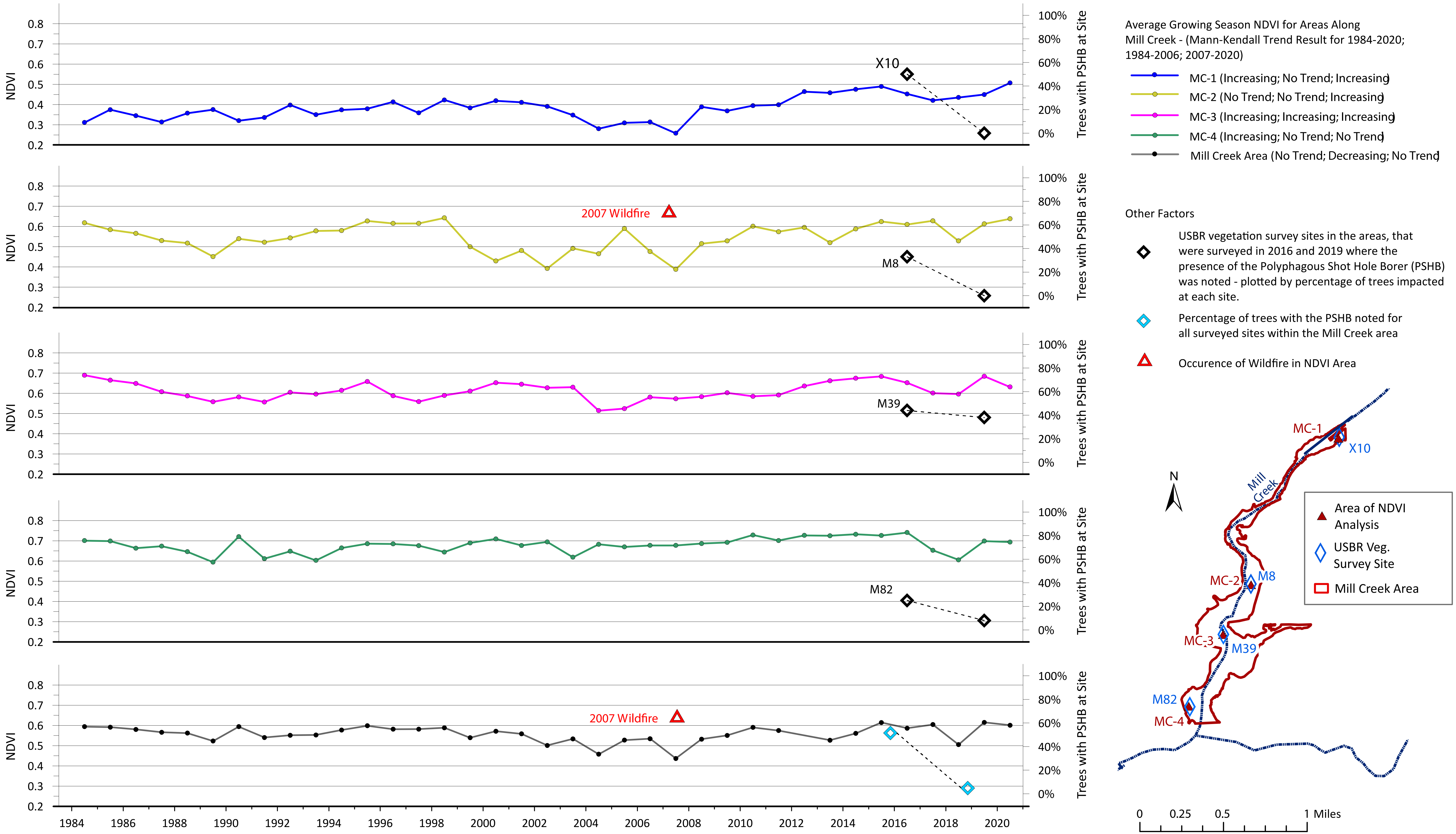
Other Factors that Affect Riparian Habitat verus NDVI
Chino Creek Area for 1984-2020

Figure 3-20a



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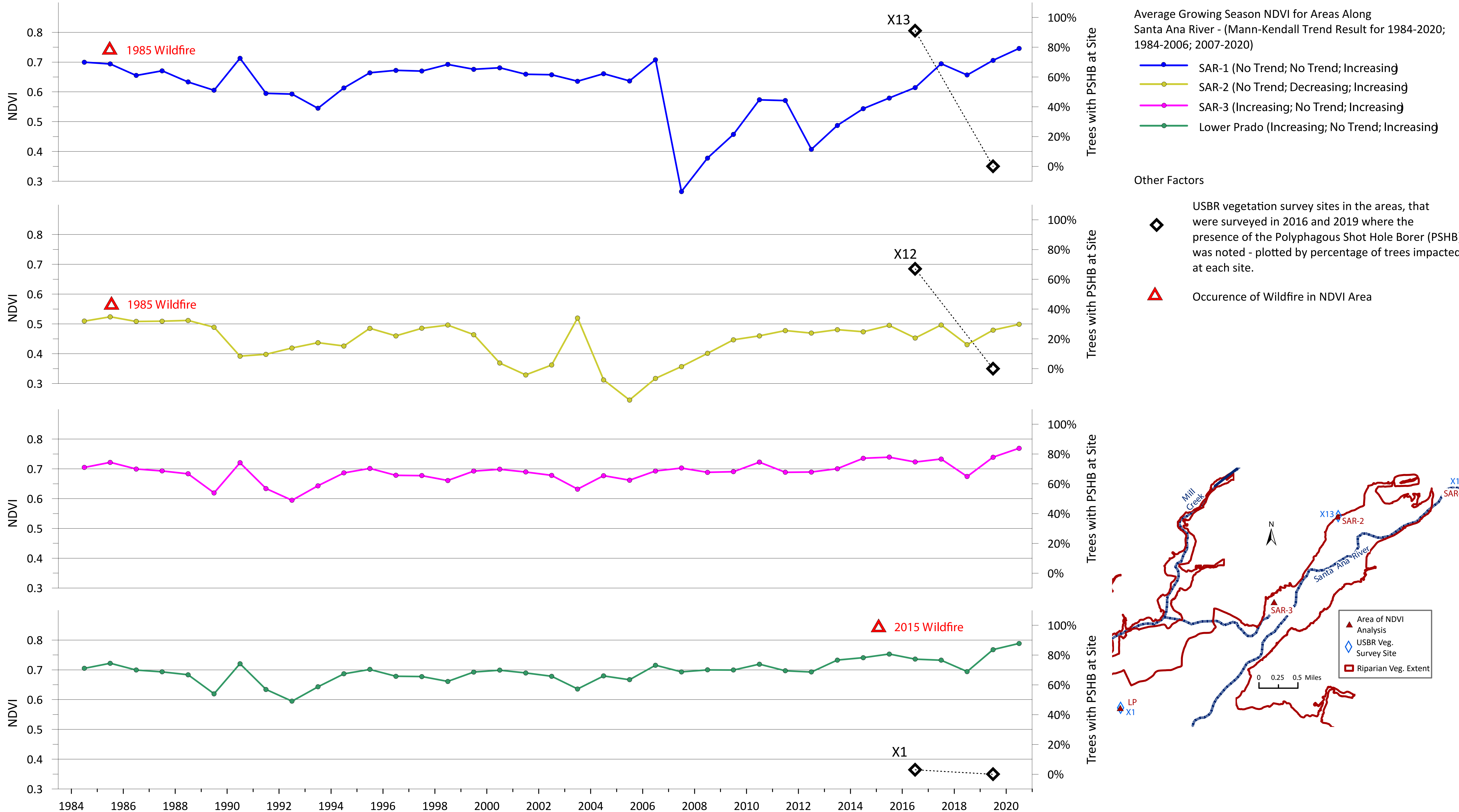
Other Factors that Affect Riparian Habitat verus NDVI
Mill Creek Area for 1984-2020

Figure 3-20b



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Prado Basin Habitat Sustainability Committee
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Other Factors that Affect Riparian Habitat verus NDVI
Santa Ana River and Lower Prado Area for 1984-2020

Figure 3-20c

In 2016 and 2017, OCWD biologists in the Prado Basin worked with the University of California, Riverside, the USFWS, and SAWA to actively monitor the occurrence and impact of PSHB within Prado Basin riparian habitat. These agencies conducted studies on how to potentially protect certain areas of the Prado Basin from PSHB using attractants and deterrents; however, there were too many trees to effectively protect the entire forest (Zembal, R., personal communication, 2018). Traps were placed throughout the lower portion of Prado Basin and along the SAR by the OCWD and SAWA. The total number of PBHB beetles trapped at each location between August 2016 and April 2017 ranged from seven to 2,092.

Figure 3-19 shows the locations where the presence of PSHB has been documented within the Prado Basin from 2016 to 2019 by: PSHB traps deployed by the OCWD and SAWA between August 2016 and April 2017; and the USBR vegetation surveys performed in 2016 and 2019.

During the 2016 USBR vegetation surveys, the presence of the PSHB was identified at 30 of the 37 survey sites. At these sites, all the trees identified with the presence of PSHB were noted as “stressed,” except one which was noted as “dead.” The 2016 USBR surveys were the first site-specific surveys that documented the presence and abundance of PSHB for the PBHSP.

During the 2019 USBR vegetation surveys, the presence of the PSHB was identified at only seven of the 30 sites that were originally identified with PSHB presence in 2016—a 61 percent decrease. In 2019, the presence was only noted at sites along Chino and Mill Creeks; no presence was noted at sites along the SAR. The percentage of trees with the noted presence of the PSHB decreased from 28 to three percent at sites along Chino Creek; and decreased from 57 to nine percent at sites along Mill Creek. OCWD biologists have suggested that the wet year of 2019 may have allowed the riparian trees to better resist PSHB burrowing and fungal disease impacts (USBR, 2020). The reduced presence of the PSHB from 2016 to 2019 correlated to less stressed trees at each of the survey sites; however, the PSHB had an adverse impact from 2016 to 2019, as evidenced by the increased percentage of dead trees and some reductions in percent canopy cover at the survey sites (see Table 3-3 and the 2019 Annual Report Section 3.6.2).

As the table indicates, the reduced presence of the PSHB has reduced tree stress across the Prado Basin; however, the PSHB had an adverse impact from 2016 to 2019, as evidenced by the increased percentage of dead trees and some reductions in percent canopy cover.

Figures 3-20a through 3-20c are time-series charts that explore the relationship between PSHB occurrence and NDVI for three reaches in Prado Basin: Chino Creek, Mill Creek, and the SAR. These figures show the Average Growing-Season NDVI for 14 defined areas of riparian habitat discussed in Section 3.1 and shown in Figures 3-6, 3-7 and 3-8a through 3-8l. For each defined area, the percentage of infected trees relative to the total of all trees within each survey site that is within the area are plotted on the charts. At all of these sites, the percentage of trees impacted decreased from 2016 to 2019, and the Average Growing-Season NDVI in the nearby defined areas increased from 2018 to 2020. These observations indicate that the reduced presence of the PSHB in 2019 is a contributing cause of the observed increases in NDVI along Chino Creek, Mill Creek, and the SAR.

3.6.3 Arundo Removal

The OCWD and SAWA[20] are the main entities that implement habitat restoration programs, including the removal and management of Arundo in the SAR watershed for the promotion of native habitat for endangered or threatened species. The OCWD and SAWA sometimes work collaboratively with each other on these programs and with other stakeholders in the watershed, such as the USFWS, California Department of Fish and Wildlife (CDFW), ACOE, Regional Board, Counties of Riverside and San Bernardino, and several cities. There are many ongoing programs throughout the Prado Basin for the management and maintenance of riparian habitat, which include Arundo management. SAWA publishes an annual report on the status of all habitat restoration projects they are involved with in the watershed (SAWA, 2020). Figure 3-20a shows the locations of known areas where habitat restoration activities have occurred recently in the Prado Basin, including the management and removal of Arundo. The current known habitat restoration activities in 2020 include the area of the 2015 wildfire in the lower Prado area, where the OCWD is controlling the regrowth of Arundo following the fire, and various patches along the SAR and lower Prado Basin area, where SAWA is leading efforts to remove Arundo. These areas and activities are not inclusive of all activities currently occurring in the Prado Basin but are the known locations identified for the PBHSP where there are current Arundo management activities and notable impacts to vegetation in the PBHSP.

In 2020, there are no identified areas of Arundo removal within the 14 defined areas analyzed in Section 3.1 and shown in Figures 3-6, 3-7, and 3-8a through 3-8l. All of the Arundo removal areas from 2019-2020 are along the SAR and the lower Prado Area below the OCWD wetlands. The location of these Arundo removal projects in 2019 and 2020 align with the notable areas of NDVI decrease from 2019 to 2020 shown on the NDVI change map in Figure 3-3 along the SAR reach and lower Prado Basin below the OCWD wetlands. To demonstrate this observation, Figure 3-20b shows the NDVI change map for 2019 to 2020 and the 2020 air photo side by side for the area along the SAR and lower Prado overlain by the areas of Arundo removal in 2019 and 2020. Most of the areas where there is a notable decrease in the NDVI from 2019 to 2020 include these Arundo removal areas and are a brown land cover in the 2020 air photo.

3.7 Analysis of Prospective Loss of Riparian Habitat

The meaning of "prospective loss" of riparian habitat in this context is the "future potential loss" of riparian habitat. Watermaster's recent predictive modeling results[21] were used to identify areas of prospective loss of riparian habitat that may be attributable to the Peace II Agreement by projecting future groundwater level conditions in the Prado Basin area through 2030. To perform this evaluation, the

[20] SAWA is a non-profit agency with a five-member board, consisting of one member from the OCWD and the remaining from four resource conservation districts (RCDs) in the watershed, including the Riverside-Corona RCD, Temecula-Elsinore-Anza RCD, San Jacinto RCD, and Inland Empire RCD.

[21] The predicted groundwater level changes through 2030 were made with the 2020 Chino Basin Groundwater Model for Scenario 2020 SYR1 for Layer 1 of the aquifer. The results of this model scenario were used to recalculate the 2020 Safe Yield of the Chino Basin (WEI, 2020). Scenario SYR1 is based on the water demands and water supply plans provided by the Watermaster parties, planning hydrology that incorporates climate change impacts on precipitation and ET_0, and assumptions regarding cultural conditions and future replenishment.

predictive model results were mapped and charted to identify areas, if any, where groundwater levels are projected to decline to depths that may adversely impact the riparian habitat in the Prado Basin.

Figure 3-21 is a map that shows the model-predicted change in groundwater levels in the Prado Basin area over the period of 2018-2030 from the planning scenario used to recalculate the Safe Yield of the Chino Basin in 2020 using Watermaster's updated groundwater-flow model (WEI, 2020). The map shows that groundwater levels are predicted to remain steady across most of the Prado Basin area through 2030. The stability in groundwater levels is explained in part by projected declines in groundwater production from private wells in the area, the IEUA's delivery of treated recycled water to this area for direct uses (such as outdoor irrigation), and the fact that most of the CDA production will occur to the north and northeast. Figure 3-21 shows that the most likely area where groundwater levels are projected to decline by 2030 is the northern portions of Mill Creek and the SAR.

Figure 3-22 is a time-series chart of model-predicted groundwater levels at the PBHSP monitoring wells for the period of 2018 to 2030. These wells are strategically located adjacent to the riparian habitat south of the CDA well field to understand the potential impacts of Peace II implementation on groundwater levels and riparian habitat. The chart shows:

- Groundwater levels are projected to fluctuate seasonally at the PBHSP monitoring wells by about one to two feet.
- Groundwater levels are projected to remain stable at most of the PBHSP monitoring wells through the duration of the Peace II Agreement (through 2030) with no significant periods of increasing or decreasing groundwater levels.
- Some of the PBHSP monitoring wells are projected to experience declines in groundwater levels of about one to three feet by 2030: PB-2 along northern portion Mill Creek (~three feet of decline) and PB-3 and PB-4 along the SAR (~one foot of decline).

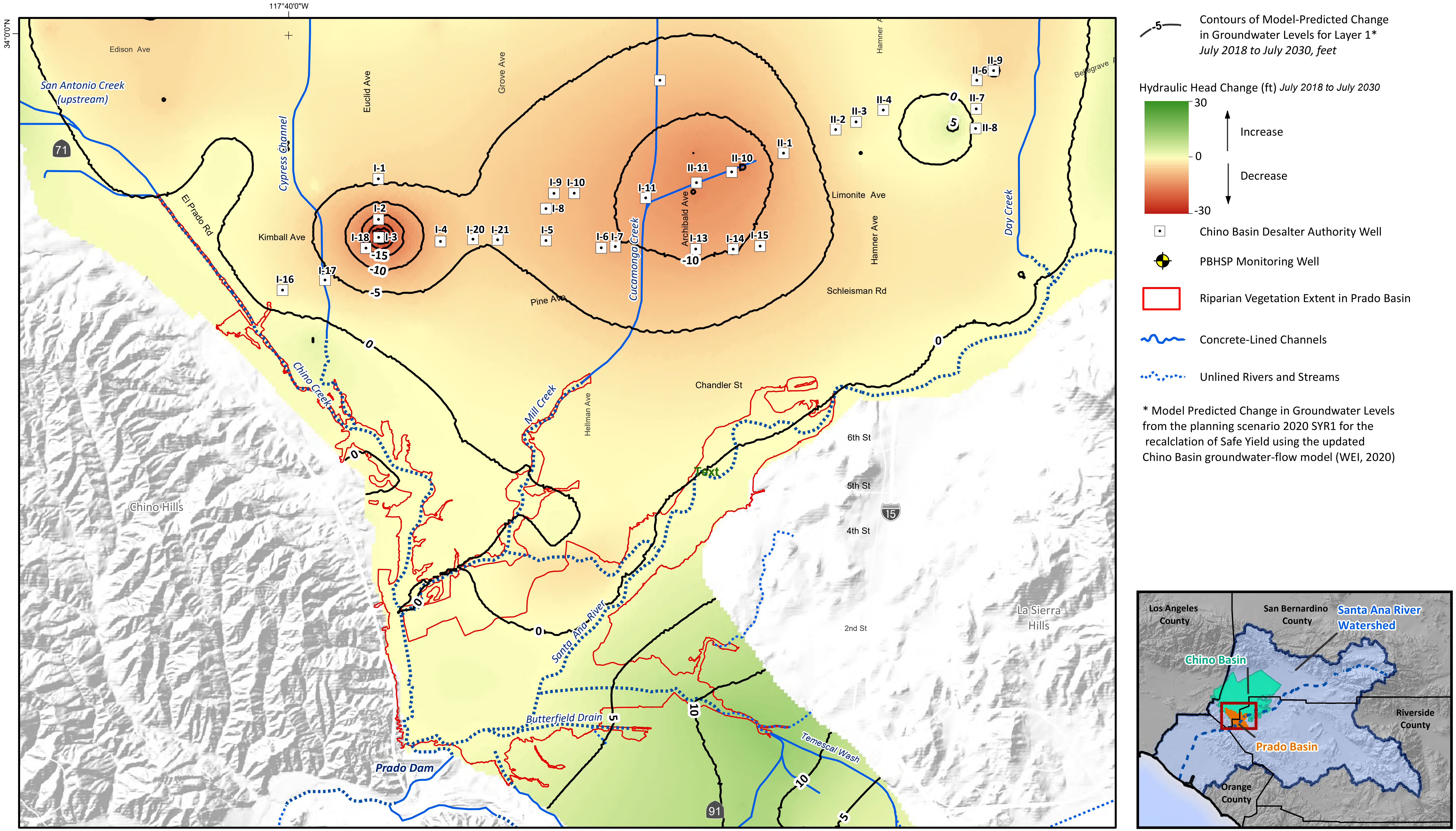
With regard to prospective loss of riparian habitat:

- Across most of the Prado Basin where riparian habitat exists, there are no projected declines in groundwater levels through 2030 that indicate a threat for prospective loss of riparian habitat.
- The two areas within the Prado Basin where groundwater levels are projected to decline by 2030 that indicate a threat for prospective loss of riparian habitat are the northernmost reaches of Mill Creek and the SAR:

    - Figure 3-11 shows that in 2020 groundwater levels have declined to the north of the upper portion of Mill Creek near PB-2 by about 3 feet which is equal to the predicted drawdown by the model. Figure 3-12 shows the current depth-to-groundwater (Fall 2020) across the Prado Basin. Where the riparian vegetation is growing along the northernmost reaches of Mill Creek, the maximum depth to water ranges from 5-13 ft-bgs. Hence, if the groundwater levels continue to decline along Mill Creek, more then what the model projects, then it could result in adverse impacts to riparian habitat in this area.

    - Figure 3-11 shows that in 2020 groundwater levels along the SAR near PB-3 have declined by about 0.5 feet which is about half of the predicted drawdown by the model. Figure 3-12 shows the current depth-to-groundwater (Fall 2020) across the Prado Basin. Where the riparian vegetation is growing along the northernmost reaches of the SAR, the maximum depth to water ranges from 3-7 ft-bgs. Figure 3-12 shows that riparian vegetation in the Prado Basin grows in areas where depth-to-groundwater is up to 15 feet-bgs. Hence if groundwater levels decline along the SAR, by up to one foot as the model projects, it is unlikely that it will result in adverse impacts to Prado Basin riparian habitat in this area.

- The projected changes in groundwater levels in the Prado Basin study area are predicated on the Chino Basin parties pumping groundwater and conducting recharge operations consistent with their planning assumptions incorporated in the model scenario.



Prepared by:

WEST YOST Water. Engineered.

Author: VWW

Date: 4/26/2021

K:\Clients\941 Chino Basin Watermaster\00-00-00 Master\PE1 - Data_Monitoring\GIS\MXD\Prado\Annual Report\Figure 3-21_Model 2018-30.mxd

0 1 2 Miles

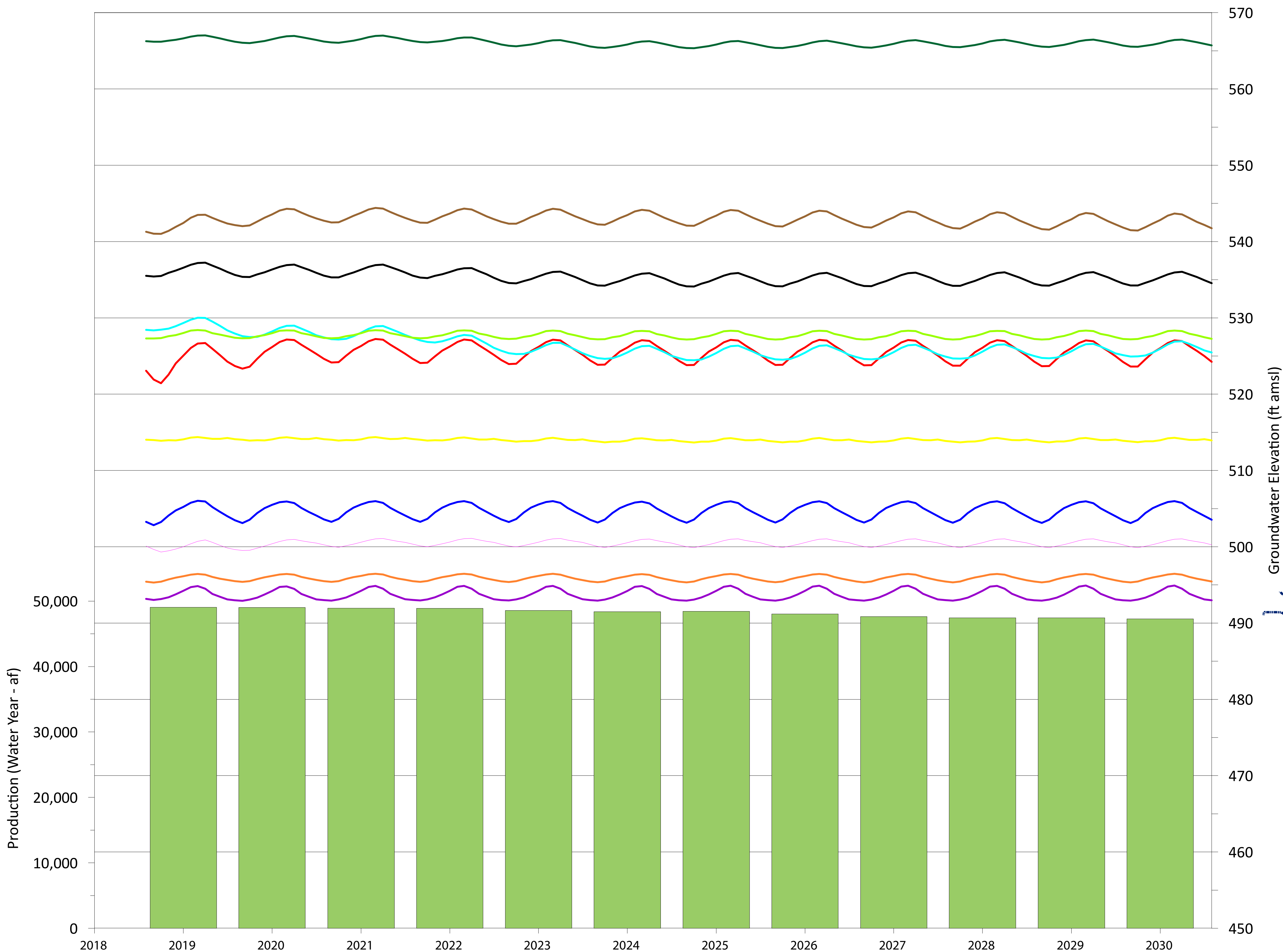
0 1 2 Km

Prepared for:

Chino Basin Watermaster and Inland Empire Utilities Agency
2020 Annual Report of the
Prado Basin Habitat Sustainability Committee

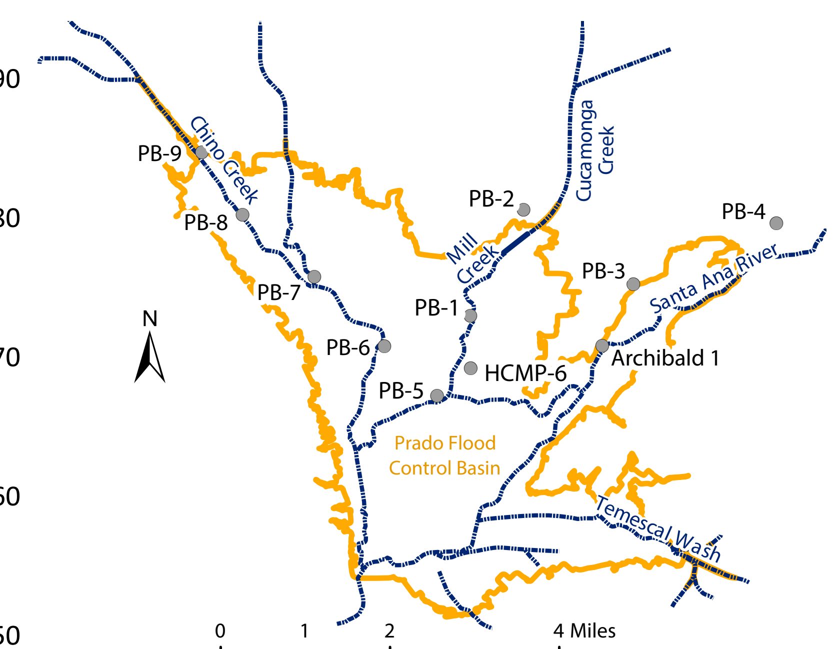
Predicted Change in Groundwater Levels
2018 to 2030 - Scenario 2020 SYR1

Figure 3-21



*Model Simulated Groundwater Elevations and Pumping from the planning scenario 2020 SYR1 for the 2020 recalculation of Safe Yield using the updated Chino Basin groundwater-flow model (WEI, 2020)

Well Locations



WEST YOST Water. Engineered

Author: VW
Date: 4/19/2021
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Prepared for:

Prado Basin Habitat Sustainability Committee
2020 Annual Report

Predicted Groundwater Pumping and Groundwater Levels - 2018 to 2030 - Scenario 2020 SYR1

Figure 3-22

4.0 CONCLUSIONS AND RECOMMENDATIONS

The monitoring and mitigation requirements in the Peace II SEIR call for annual reporting for the PBHSP. Annual reports will be prepared and will include recommendations for ongoing monitoring and any adaptive management actions required to mitigate any measured loss or prospective loss of riparian habitat that may be attributable to the Peace II Agreement.

The following describes the main conclusions of this annual report and provides recommendations for future monitoring, reporting, and mitigation, if any.

4.1 Main Conclusions and Recommendations

4.1.1 Conclusions

The main conclusions of the PBHSC Annual Report for WY 2020 are:

- The quality of riparian habitat throughout the Prado Basin has been characterized through analyses of air photos, NDVI maps, and NDVI time-series charts. The NDVI time-series analyses indicate that there were varying levels of changes in the greenness of the vegetation from 2019 to 2020. Typically, the one-year NDVI changes were relatively minor and within the historical ranges of one-year NDVI variability. However, there were some areas where there were notable decreases in green vegetation. At the MC-3 area, there was a notable decrease in green vegetation evident from the comparison of the 2019 and 2020 air photos. There are also notable NDVI decreases in the NDVI change map from 2019 to 2020 for large patches along the SAR and below the OCWD wetlands at are associated with Arundo removal habitat restoration projects.
- Groundwater production has increased in the PBHSP study area by 6,000 afy from 2019 to 2020 mainly due to an increase in the CDA pumping.
- Since monitoring began for the PBHSP, groundwater levels within the riparian habitat extent in the Prado Basin have shown some slight increasing and decreasing trends along the reaches of Chino Creek, Mill Creek, and SAR from 2016 to 2020. Of note is a groundwater-level decline of about three feet at the PB-2 monitoring well near the upper reach of Mill Creek. There were also some lesser declines in groundwater levels from 2016 to 2020 in the central reach of Mill Creek, the southern reach of Chino Creek, and along the eastern reach of the SAR. Except for the groundwater levels changes at PB-2, the changes in groundwater levels over the last year are within the historical range of short-term and long-term variability. The Mann-Kendall test results for all the areas analyzed for NDVI indicate an increasing trend or no trend for the Peace II Agreement period. Hence, there is no trend in degradation of the riparian habitat that is contemporaneous with decreasing groundwater levels during Peace II Agreement.
- During WY 2020, the Prado Basin area experienced average precipitation, slightly lower temperatures then the previous seven years, slightly above average discharge conditions in Chino Creek, Mill Creek, and SAR, while there were no significant changes observed in the riparian vegetation based on the NDVI. The decrease in green vegetation noted at the MC-3 area in the air photos is likely not attributable to the wetter and cooler conditions in WY 2020.
- In 2020, all available data was collected on the other factors that could potentially impact riparian vegetation in the Prado Basin, including wildfires, the PSHB, and Arundo removal. In

WY 2020, there were no wildfires within the Prado Basin, and there was no new information collected on the presence and effect of the PSHB on the riparian habitat. There were various areas along the SAR and lower Prado area where Arundo removal occurred from 2019-2020. At these locations, there are notable NDVI decreases in the NDVI change map from 2019-2020.

- The most recent Chino Basin groundwater-model projections indicate two areas within the Prado Basin where groundwater levels are projected to decline during the 2018-2030 period: the northernmost reaches of Mill Creek (declines of three feet) and the SAR (declines of about one foot). From WY 2016 to 2020, groundwater levels declined in these areas that were predicted by the model: at PB-2 groundwater levels declined by about three feet which is equal to the predicted drawdown by the model; and along the SAR near PB-3, groundwater levels declined by about 0.5 feet which is about half of the predicted drawdown by the model. Based on the current (2020) analysis of depth to groundwater in these areas, these declines in groundwater levels are not a concern for the prospective loss of riparian habitat, however if groundwater levels continue to decline along the northern portion of Mill Creek (by more than what the model predicts), it could result in adverse impacts to riparian habitat in this area.

4.1.2 Recommendations

The monitoring and analyses of the riparian habitat, groundwater levels, precipitation, temperature, and surface-water discharge should continue with no change in scope. The monitoring and analysis of other factors—such as wildfires, the PSHB, Arundo removal, and additional factors as needed—should also continue. Continued monitoring and analysis are required to identify the relationships between the riparian habitat and factors that can influence it during Peace II Agreement implementation.

There are two areas where the monitoring and analysis should focus over this next year to track the notable changes observed in WY 2020 that are a concern for the quality and quantity of the riparian habitat:

- *Groundwater levels in the upper reach of Mill Creek.* High-frequency groundwater levels will continue to be monitored at the PBHSP wells just to the north of the top of the Mill Creek reach and used with other groundwater level data in the area to track the trends in the groundwater levels in this region. If groundwater levels continue to decline, the PBHSC should consider additional monitoring in this area and/or explore mitigation measures to sustain groundwater levels and protect the riparian habitat in this area.
- *Riparian vegetation at the MC-3 area.* A site visit should be performed to the MC-3 area to inspect and document the state of the vegetation. Based on the results of the site visit, the PBHSC may consider revised monitoring if needed to characterize the changes in the riparian habitat and identify the causes of those changes.

The pilot monitoring program initiated in WY 2018 to characterize groundwater/surface water interactions along Chino Creek should continue, at least for the next water year. This includes monitoring groundwater at the four PBHSP monitoring wells and two adjacent surface-water sites using probes and collecting semi-annual grab samples.

The periodic riparian vegetation surveys at sites throughout the Prado Basin should continue at a frequency of every three years. The vegetation surveys will be used to quantitatively characterize the current state of riparian vegetation at the sites, to ground-truth the interpretations derived from regional riparian habitat monitoring, and to note the occurrence and effects of the PSHB. The next vegetation survey is scheduled for the summer of 2022. The OCWD also performs required monitoring of the flora and fauna in the Prado Basin. Future vegetation surveys for the PBHSP should be planned and performed in coordination with the OCWD, and the Watermaster, the IEUA and OCWD should work to achieve efficiencies for this element of the monitoring program.

4.2 Recommended Mitigation Measures and/or Adjustments to the AMP

This annual report documented no trend in the degradation of the extent or quality of riparian habitat along Chino Creek, Mill Creek, or the SAR that is contemporaneous with decreasing groundwater levels during the implementation of the Peace II Agreement. As such, no mitigation measures are proposed at this time.

No adjustments to the AMP are recommended at this time.

4.3 Recommended PBHSP for Fiscal Year 2021/22

Based on preliminary analysis of the PBHSP data for WY 2020, a draft *Technical Memorandum Recommended Scope and Budget of the Prado Basin Habitat Sustainability for FY 2021/22* was submitted to the PBSHC in February 2021. In March 2021, Watermaster's Engineer presented the recommended scope and budget for FY 2021/22 to the PBHSC for consideration. There were no changes recommended by the PBHSC on the proposed FY 2021/22 scope of work, and a final scope of work and budget was submitted to the PBHSC and will go through the Watermaster and the IEUA FY 2020/21 budgeting process in May and June of 2021. The scope of work for the PBHSP for FY 2021/22 is shown in Table 4-1 as a line-item cost estimate.

Table 4-1. Work Breakdown Structure and Cost Estimate
Prado Basin Habitat Sustainability Program: FY 2021/22

				Labor Total		Other Costs							Totals				
	Task Description	No. of sites	Task Rep Multiplier	Person Days	Total	Travel	Equipment Rental	Lab	Outside Pro	Equipment	Total	Notes	Recommended Budget 2021/22	Budget 2020/21	Varience from Prior FY	IEUA Share 2021/22	CBWM Share 2021/22
Task 1: Groundwater Level Monitoring Program				**10.8**	**$13,125**						**$660**		**$13,785**	**$14,678**	**-$893**	-	**$13,785**
1.1	Collect Transducer Data from PBHSP Wells (Quarterly)	17	4	4.8	$4,878	$500	$160				$660		$5,538	$5,910			
1.2	Collect, Check, and Upload Transducer Data from PBHSP Wells (Quarterly)	17	4	6.0	$8,246						$0		$8,246	$8,768			
Task 2: Groundwater Quality Monitoring Program				**0.0**	**$5,188**						**$185**		**$5,373**	**$10,140**	**-$4,767**	-	**$5,373**
2.1	Collect, Check, and Upload High-Frequency Probe Data from Pilot Monitoring Program (Quarterly)	4	4	4.4	$5,188	$125	$60				$185		$5,373	$4,475			
2.2	Collect, Check, and Upload Grab Sample General Mineral Chemistry Data (Semi-annually)	4	2	0.0	$0						$0		$0	$5,665			
Task 3: Surface Water Monitoring Program				**2.6**	**$9,622**						**$185**		**$9,807**	**$14,252**	**-$4,445**	-	**$9,807**
3.1	Collect, Check, and Upload Surface Water Discharge and Quality Data from POTWs, and Dam Level data from the ACOE (Annual)		1	1.8	$2,346						$0		$2,346	$2,559			
3.2	Collect, Check, and Upload Surface Water Discharge and Quality Data from USGS gaging stations (Annual)		1	0.9	$1,216						$0		$1,216	$1,096			
3.3	Collect, Check, and Upload High-Frequency Probe Data for Chino Creek from Pilot Monitoring Program (Quarterly)	2	4	5.0	$6,060	$125	$60				$185		$6,245	$5,794			
3.4	Collect, Check, and Upload Grab Surface Water Quality Field and Lab Data for Chino Creek from Pilot Monitoring Program (Semi-annually)	2	2	0.0	$0						$0		$0	$4,802			
Task 4: Climate Monitoring Program				**1.3**	**$1,806**						**$275**		**$2,081**	**$2,039**	**$42**	**$1,040.50**	**$1,040.50**
4.1	Collect, Check, and Upload Climatic Data (Annual)		1	1.3	$1,806				$275		$275		$2,081	$2,039			
Task 5: Riparian Habitat Monitoring Program				**21.0**	**$23,696**						**$9,000**		**$32,696**	**$34,738**	**-$2,042**	**$16,348.00**	**$16,348.0**
5.1	Perform a Custom Flight to Acquire a High-Resolution 2021 Air Photo of the Prado Basin		1	1.3	$2,386				$9,000		$9,000	1	11,386	12,860			
5.2	Catalog, Check, and Review the Extent of the Riparian Vegetation in the 2020 Air Photo of the Prado Basin		1	3.5	$6,104						$0		6,104	7,642			
5.3	Collect, Check, and Upload 2021 Landsat NDVI Data to the PBHSP Database		1	9.3	$15,206						$0		$15,206	$14,236			
Task 6: Prepare Annual Report of the PBHSC				**54.0**	**$88,448**						**$180**		**$88,628**	**$91,224**	**-$2,596**	**$44,314.00**	**$44,314.0**
6.1	Analyze Data and Prepare Admin Draft Report for CBWM/IEUA		1	39.5	$63,060						$0		$63,060	$66,268			
6.2	Meet with CBWM/IEUA to Review Admin Draft Report		1	2.0	$4,000	$90					$90		$4,090	$4,002			
6.3	Incorporate CBWM/IEUA Comments and Prepare Draft Report: Submit Draft Report to PBHSC		1	5.0	$7,904						$0		$7,904	$7,680			
6.4	Meet with PBHSC to Review Draft Report		1	3.0	$5,848	$90					$90		$5,938	$5,810			
6.5	Incorporate PBHSC Comments and Finalize Report		1	4.5	$7,636						$0		$7,636	$7,464			
Task 7: Project Management and Administration				**10.5**	**$20,012**						**$90**		**$20,102**	**$20,751**	**-$649**	**$10,051.00**	**$10,051.00**
7.1	Prepare Scope and Budget for FY 2022/23		1	4.0	$7,696						$0		$7,696	$7,528			
7.2	Meet with PBHSC to Review Scope and Budget for FY 2022/23		1	3.5	$6,772	$90					$90		$6,862	$6,714			
7.3	Project Administration and Financial Reporting		12	3.0	$5,544						$0		$5,544	$6,509			
	Totals			**208**	**$161,896**	**$790**	**$120**	**$0**	**$9,275**	**$0**	**$10,575**		**$172,471**	**$187,821**	**-$15,350**	**$71,754**	**$100,718**

1 - This is half of the cost for the outside professional. OCWD will pay the other half.

The following describes the scope-of-work by major task for the PBHSP for FY 2021/22:

Task 1. Groundwater-Level Monitoring Program

The monitoring of groundwater levels in the Prado Basin is a key component of the PBHSP because declining groundwater levels could be a factor related to Peace II implementation that adversely impacts riparian vegetation. Sixteen monitoring wells were installed specifically for the PBHSP in 2015. These wells, plus monitoring wells HCMP-5/1 and RP3-MW3, are monitored for groundwater levels. The 18 monitoring wells are equipped with integrated pressure-transducers/data-loggers that measure and record water-level measurements every 15 minutes. This task includes quarterly field visits to all 18 PBHSP monitoring wells to download data. All data will be checked and uploaded to the PBHSP database. This task is consistent with the work performed during the previous FY.

Task 2. Groundwater-Quality Monitoring Program

Since the PBHSP monitoring wells were constructed in 2015, groundwater-quality monitoring has been tailored to discern the groundwater/surface-water interactions that are important to the sustainability of the riparian habitat in Prado Basin. From FY 2015/16 through 2017/18, quarterly groundwater samples were collected from the 18 PBHSP monitoring wells and analyzed at a minimum for general minerals. The general mineral chemistry data collected was analyzed along with groundwater-level data, model-generated groundwater-flow directions, and surface-water quality and flow data to help characterize groundwater/surface-water interactions in the Prado Basin and determine the source of the shallow groundwater that is available for consumptive use by the riparian vegetation.

During FY 2018/19, a pilot monitoring program was initiated at four monitoring wells at two locations along Chino Creek (PB-7 and PB-8) where the data loggers that measure groundwater levels at 15-minute intervals were replaced with data loggers that measure and record EC, temperature, and water levels at 15-minute intervals. The same high-frequency monitoring was initiated at two nearby surface water sites in Chino Creek (Task 3.3). Additionally, groundwater-quality samples were collected at these wells quarterly in FY 2018/19, and semi-annually in FY 2019/20, and were analyzed for EC, temperature, and general minerals to validate and support the high-frequency data, along with the collection of field measurements of EC and temperature. The purpose of the pilot monitoring program is to determine if the high-frequency data better reveals the groundwater/surface-water interactions and enhances the interpretation of the general mineral data derived from grab sampling. The data collected thus far for the pilot monitoring program shows promise, has provided more data to support the characterization of groundwater/surface water interactions at these locations, and warrants the continuation of the pilot program. In addition, more high-frequency surface-water data needs to be collected along Chino Creek. Periodically, the data loggers within the creek have been lost during large storm events and the casing that house the probes have sometimes experienced the accumulation of mud which has compromised the accuracy of the collected data. These monitoring challenges in the field have resulted in extended periods of no data or erroneous data and have necessitated additional field work to resolve. The pilot program should continue for at least another year to collect enough data to draw defensible conclusions.

Tasks 2.1 is to continue the pilot monitoring program in FY 2021/22 to collect the high-frequency data in groundwater to help discern the groundwater/surface water interactions near PB-7 and PB-8. The monitoring wells will be visited quarterly to download the data from the data loggers and all data will be checked and uploaded to the PBHSP database. In FY 2021/22, groundwater quality samples will not be collected at the four wells for laboratory analyses of EC, temperature, and general mineral analytes as was done the prior two fiscal years, as this data is no longer required to validate and support the high-frequency data.

Task 3. Surface-Water Monitoring Program

Surface-water discharge data from the SAR and the tributaries that cross Prado Basin are evaluated to characterize the influence of surface-water discharge on the riparian habitat. The SWMP utilizes publicly-available data sets which include: the USGS daily discharge measurements at six sites along the SAR and its tributaries; daily discharge and water-quality data from POTWs that are tributary to Prado Basin; ACOE daily measurements of reservoir elevation and releases from the reservoir at Prado Dam; and Watermaster's quarterly surface-water-quality monitoring at two sites along the SAR.

Tasks 3.1 and 3.2 include the annual collection of the USGS, POTW, and ACOE data for water year 2021, and the processing, checking, and uploading of these data to the PBHSP database. These tasks do not include the processing, checking, and uploading of the Watermaster-collected SAR data, which is performed for another Watermaster task. The scope of these tasks is consistent with the work performed for the previous fiscal year.

Surface water-quality data are also collected and analyzed in the pilot monitoring program to help characterize groundwater/surface water interactions. During FY 2018/19, a pilot monitoring program was initiated at two locations along Chino Creek adjacent to wells PB-7 and PB-8. At these locations, data loggers were installed in Chino Creek to measure and record EC, temperature, and stage at 15-minute intervals in coordination with the similar high-frequency monitoring at PB-7 and PB-8 (Task 2). Grab samples of surface water were also collected quarterly for EC, temperature, and general mineral analyses, along with field measurements of EC and temperature. As described above for *Task 2 – Groundwater-Quality Monitoring Program*, the purpose of the pilot monitoring program is to determine if the high-frequency data better reveals the groundwater/surface-water interactions and enhances the interpretation of the general mineral data derived from grab sampling. Periodically, the data loggers within the creek have been lost during large storm events and the casing that house the probes have sometimes experienced the accumulation of mud which has compromised the accuracy of the collected data. These monitoring challenges in the field have resulted in extended periods of no data or erroneous data, and have necessitated additional field work to resolve. The pilot program should continue for at least another year to collect enough data to draw defensible conclusions.

Tasks 3.3 is to continue the pilot monitoring program in FY 2021/22 to collect the high-frequency data in the surface water to help discern the groundwater/surface water interactions near wells PB-7 and PB-8. The probes will be visited quarterly to download the data, collect field measurements for temperature and EC, and routinely clean the probes to prevent the buildup of residue. All data will be checked and uploaded to the PBHSP database. In FY 2021/22, surface water quality samples will not be collected at the two surface water sites for laboratory analyses of EC, temperature, and general mineral analytes as was done the prior two fiscal years, as these data are no longer needed to validate and support the high-frequency data.

Task 4. Climate Monitoring Program

Climatic data are evaluated in the vicinity of the Prado Basin to characterize trends, and to determine if these trends contribute to impacts on the riparian habitat. The climate monitoring program utilizes publicly-available datasets. Two types of datasets are compiled: time-series data measured at weather stations and spatially-gridded datasets. Task 4 includes the annual collection of the time-series data and spatially-gridded datasets for water year 2021 (October 2020 – September 2021), and the checking and uploading of the data to the PBHSP database. The scope of this task is consistent with the work performed for the previous fiscal year.

Task 5. Riparian Habitat Monitoring Program

Monitoring the extent and quality of the riparian habitat in the Prado Basin is a fundamental component of the PBHSP to characterize how the riparian habitat changes over time. To characterize the impacts of Peace II implementation on the riparian habitat (if any) it is necessary to understand the long-term historical trends of its extent and quality and the factors that have affected it. The current riparian habitat monitoring program consists of both regional and site-specific components. The proposed riparian habitat monitoring program for FY 2021/22 is described in the subsections below.

Regional Monitoring: The regional monitoring of riparian habitat is performed via two independent methods that complement each other: mapping and analysis of the riparian habitat using (i) air photos and (ii) the normalized difference vegetation index (NDVI) derived from the Landsat remote-sensing program. Tasks 5.1, 5.2, and 5.3 are for the collection and compilation of the regional monitoring data, including:

- Perform a custom flight (via outside professional services) to acquire a high-resolution air photo (three-inch pixel) of the Prado Basin during summer 2021. The cost for the air photo is shared with OCWD.
- Catalog and review the 2021 high-resolution air photo in ArcGIS and digitize the extent of the riparian habitat.
- Collect, review, and upload the Landsat NDVI data for water year 2021.

Site-Specific Monitoring: The site-specific monitoring of the riparian habitat consists of periodic field surveys of the riparian vegetation at selected locations. These surveys provide an independent measurement of vegetation quality that can be used to "ground truth" the regional monitoring of the riparian habitat. To date, the United States Bureau of Reclamation (USBR) along with the OCWD[22] has conducted field surveys once every three years. The most recent triennial field survey was conducted in the summer of 2019. The next field survey is scheduled for the summer of 2022. There is no scope or budget proposed for site-specific monitoring for FY 2021/22.

Task 6. Prepare Annual Report of the PBHSC

This task involves the analysis of the data sets collected by the PBHSP through water year 2021. The results and interpretations generated from the data analysis will be documented in the *Annual Report for Prado Basin Habitat Sustainability Committee for Water Year 2021*. This task includes the effort to prepare an administrative draft report for Watermaster and the IEUA staff review, a draft report for the review by the PBHSC, and a final report including comments and responses. A PBHSC meeting will be conducted in May 2022 to review the draft report and facilitate comments on the report. The scope of this task is consistent with the work performed for the previous fiscal year.

[22] OCWD staff provides assistance to the USBR in the field as in-kind services.

Task 7. Project Management and Administration

This task includes the effort to prepare the PBHSP scope, schedule, and budget for the subsequent fiscal year. A draft *Technical Memorandum Recommended Scope and Budget of the Prado Basin Habitat Sustainability Program for FY 2022/23* will be submitted to the PBHSC in February 2022. A PBHSC meeting will be conducted in March 2022 to review the draft recommended scope and budget and facilitate comments. Also included in this task is project administration, including management of staffing and monthly financial reporting. The scope of this task is consistent with the work performed for the previous fiscal year.

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Appendix A

NDVI

A.1 Background

Multi-spectral remote-sensing measurements of the Earth's surface from satellites are a verifiable means of deriving complete spatial coverage of environmental information. Remote-sensing measurements have been collected in a consistent manner over time. They are updated regularly and can be analyzed retrospectively, which has made these measurements useful in various types of ecological and environmental monitoring, including vegetation monitoring (USDA, 1996; Schidt and Karnieli, 2000; Campbell, 2007; Lillesand et al., 2008; Xie et al., 2008; Jones and Vaughnan, 2010).

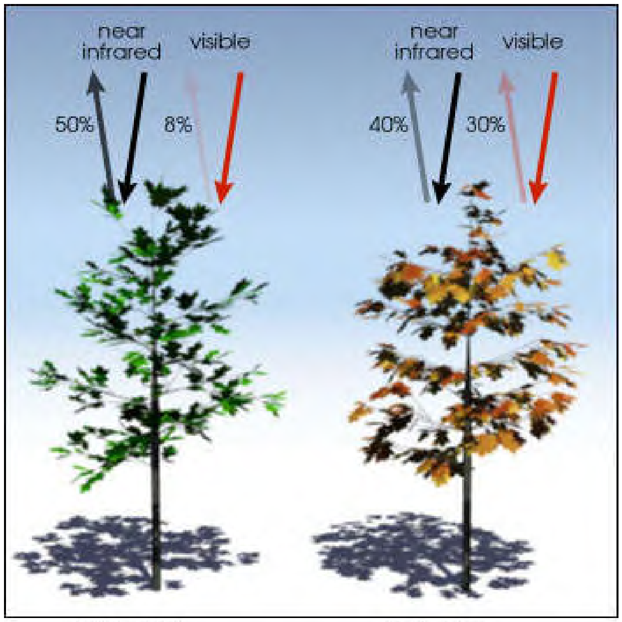
Remote sensing-based methods of vegetation monitoring commonly use vegetation indices that can be calculated from the wavelengths of light absorbed and reflected by vegetation (Jensen, 2007). NDVI is a widely used numerical indicator of vegetation extent and quality that is calculated from remote-sensing measurements (Ke et al., 2015; Xue,J and Su, B., 2017). Moreover, NDVI is an index of greenness correlated with photosynthesis and can be used to assess temporal and spatial changes in the distribution, productivity, and dynamics of vegetation (Pettorelli, 2013). NDVI is calculated from visible and near-infrared radiation reflected by vegetation using the following formula:

$$NDVI = \frac{(NIR - VIS)}{NIR + VIS}$$

Where: **NIR** = the spectral reflectance of near infrared radiation.
VIS = the spectral reflectance of visible (red) radiation.

During photosynthesis, healthy vegetation absorbs incoming visible light and reflects a large portion of near-infrared radiation. Unhealthy or dormant vegetation absorbs less visible light and reflects less near-infrared radiation. The figure[1] below is illustrates NDVI:

[1] Nasa.gov



$$\frac{(0.50 - 0.08)}{(0.50 + 0.08)} = 0.72 \qquad \frac{(0.4 - 0.30)}{(0.4 + 0.30)} = 0.14$$

Near-infrared radiation and visible light spectral reflectance are both expressed as ratios of the reflected radiation over the incoming radiation (values between 0 and 1); therefore, NDVI estimates range between -1.0 and 1.0. Negative NDVI estimates correspond to standing water, and low positive values (0 to 0.1) correspond to non-vegetated areas, such as barren rock and sand, snow, and water. NDVI estimates ranging from 0.1 to 1.0 correspond to vegetated areas, with very low-end estimates indicating sparse, unhealthy, or dormant vegetation, and increasing estimates towards 0.9 indicating higher amounts of dense, healthy green vegetation.

Advantages and Limitations.

NDVI was chosen as a method for characterizing and monitoring the riparian habitat for the PBHSP for the following reasons:

- Peace II activities could cause regional changes in groundwater levels, which potentially could result in regional impacts to the riparian habitat that is dependent on shallow groundwater. The regional scale of NDVI makes it an appropriate "first indicator" of regional changes in the extent and quality of riparian vegetation. And, it has been widely used in the past to support similar environmental monitoring and management programs (Peters et al., 2002; Pinzon et al., 2004; Wang et al., 2004; Weiss et al., 2004; Intera, 2014; Verbesselt et al, 2010; Gandhi et al. 2015).
- There is a long time-series of historical NDVI (early 1980s to present) that spatially covers the entire Prado Basin. These datasets can be used to characterize the history of the spatial extent and quality of the riparian vegetation prior to and after the implementation of Peace II activities (2007).

- In the future, it is likely that multi-spectral remote sensing will continue to collect the commonly measured spectral bands that are used to calculate NDVI (red and near-infrared) and that these data will be available for use as part of the PBHSP at a low cost.

Like most monitoring tools, NDVI has its limitations, which can reduce its reliability and usefulness. Important examples include:

- Cloud cover, water vapor, and atmospheric contaminants can lead to false decreases in NDVI estimates compared to clear days (Tanre et al., 1992; Achard and Estreguil, 1995; Chen et. al., 2004; Hird and McDermid, 2009).
- Satellite degradation, sensor errors, and data transmission errors can lead to false increases in NDVI estimates (James and Kalluri, 1994).
- Changes in soil moisture can lead to changes in NDVI estimates that are not necessarily related to changes in vegetation (Pettorelli, 2013).
- NDVI is a composite view of plant species diversity, form, structure, density, and vigor. As such, changes in NDVI may be caused by various changes in riparian habitat (Markon et al., 1995; Markon and Peterson, 2002). In other words, NDVI does not provide a complete picture of how and why vegetative changes are occurring; it simply indicates a change in vegetation.
- In densely vegetated areas, NDVI estimates have been shown to plateau during the growing season, indicating that NDVI can underestimate the green biomass in densely vegetated areas (Tucker et al., 1986).

These limitations demand that NDVI data be screened and filtered to identify or remove errors and noise. To reduce or eliminate noise, processing algorithms can be applied to "smooth" the time-series data and reveal patterns of change over time. For example, a smoothing technique applied in this report was the averaging of all NDVI from the growing season months. The average values are then plotted on time-series charts to display long-term trends in growing season vegetation quality.

The limitations also demand that NDVI not be interpreted in isolation. Interpretations of NDVI (vegetative changes) should be (i) verified with other georeferenced datasets, such as air photos and field vegetation surveys, and (ii) explained by comparison to datasets of causal factors of vegetative changes, such as water availability.

A.2 Landsat Program and NDVI

The USGS and the National Aeronautics and Space Administration (NASA) jointly manage the Landsat Program,2 a series of Earth-observing satellite missions that began in 1972 with sensors that observe the Earth's surface and transmit information to ground stations that receive and process multi-spectral, remote-sensing data. Landsat satellites use technology that collects scenes of remote sensing measurements at the same time and location on the Earth's surface at a temporal frequency of about every two weeks. Landsat remote sensing measurements (Landsat imagery) is acquired in scenes that are

[2] Nasa.gov

approximately 106 by 115 miles. Landsat imagery is the only data source with more than thirty-years of continuous records of global land surface conditions at a spatial resolution of tens of meters (Tuck et al. 2004). Landsat imagery is among the most widely used satellite imagery in ecology and conservation studies (Pettorelli, 2013), and the data have been available for no cost since about 2010.

The United States Geological Survey (USGS), in compliance with the Global Climate Observing System,[3] produces spectral indices products from Landsat imagery to support land surface change studies, which includes NDVI from 1982 to present (USGS, 2016). The USGS uses remote sensing imagery from the Landsat satellites—*Landsat 4, Landsat 5, Landsat 7, and Landsat 8* (*Landsat 4, 5, 7, and 8*)—to generate NDVI estimates of the Earth's surface at a 30 x 30-meter pixel resolution. To apply the necessary atmospheric corrections and generate a surface reflectance product, the USGS uses a specialized software called Landsat Ecosystem Disturbance Adaptive Processing System (LEDAPS) to post-process the Landsat imagery (USGS 2015; 2017a). This surface reflectance product is then used to determine NDVI, among the other spectral indices.

A.3 Collection, Review, and Analysis of NDVI for the PBHSP

Collection

NDVI from the Landsat imagery for the period 1982 to 2020 were collected from the USGS, using the Earth Resources Observation and Science (EROS) Center Science Processing Architecture (ESPA) On Demand Interface[4] (USGS 2017b). The interface requires a bulk request in the form of a text file list of specific Landsat scenes using the Landsat scene identifier ID.[5] To obtain complete spatial coverage of the Prado Basin area, NDVI was requested for all Landsat scenes for Path 040, Rows 036 and 037.[6] Table 1 below summarizes the Landsat satellites and periods for which NDVI was obtained to produce a near-continuous NDVI record.

[3] Link

[4] USGS LINK

[5] Landsat imagery is captured in scenes that are about 106 by 114 miles. Each Landsat scene has a unique scene ID based on the specific Landsat satellite, Landsat path number, Landsat row number, and date the image was collected.

[6] The Prado Basin is in an area of the Landsat path 040 that straddles Rows 036 and 037. Landsat scenes from Path 040 Row 036 and Path 040 Row 037 overlap each other throughout most of the Prado Basin region, but both are required to obtain complete spatial coverage of the Prado Basin.

Table 1. Landsat Satellites

Satellite	Instrument	Launched	Ended	Period of NDVI Data Obtained from USGS
Landsat 4	Thematic Mapper	July 16, 1982	December 14, 1993	1982 - 1983
Landsat 5	Thematic Mapper	March 1, 1984	June 5, 2013	1984 - 2011
Landsat 7	Enhanced Thematic Mapper	April 15, 1999	Still active	2012 - 2016
Landsat 8	Operational Land Imager	February 11, 2013	Still active	2013 - 2020

NDVI from scenes produced from the *Landsat 4*, *5, 7,* and *8* satellites were obtained from the USGS for the period 1982 through 2020. The source and frequency of availability of NDVI from the USGS varies over the period of record:

- From 1982 to 1989, NDVI is from *Landsat 4 and 5* and is patchy, ranging from a frequency of eight days to one year.
- From 1990 to 1999, NDVI is from *Landsat 5* at a frequency of 16 days.
- From 1999 to 2012, NDVI is from *Landsat 5 and 7* at a frequency of eight days.
- From 2013 to 2020, NDVI is from *Landsat 7 and 8* at a frequency of eight days.

NDVI were cataloged, processed, and uploaded into HydroDaVE^{SM}, a database management software that manages gridded datasets and features tools for viewing and extracting data.[7] There is some overlap of NVDI data in areas where there is NVDI from Landsat scenes from Rows 036 and 037. HydroDaVE has the ability to compute a stacked average for Landsat scenes from Rows 036 and 037 for each NDVI pixel they overlay[8] when viewing and extracting NDVI data.

Review

Spatial NDVI were reviewed for disturbances that can be caused by cloud cover, unfavorable atmospheric conditions, or satellite equipment malfunction. In HydroDaVESM, maps were prepared of spatial NDVI for the entire Prado Basin region for each date. The maps were reviewed and documented to identify specific dates for exclusion due to cloud cover or other disturbances. Erroneous NDVI estimates were discernable because NDVI patterns of permanent landscape features were distorted and/or NDVI estimates were

[7] Hydrodave Link

[8] Not all dates will have Landsat scenes for both Rows 036 and 037 if cloud cover was greater than 20 percent in one of them; Landsat scenes with a percent cloud cover greater than 20 percent were not obtained from the USGS for this study.

clearly not consistent with estimates typically observed for a particular area both seasonally and over time. On average, about 21 percent of the NDVI were identified as erroneous and excluded from the analysis. Most of which were rejected because of cloud coverage, which was further verified by referencing and viewing the specific Landsat scene on the USGS *EarthExplorer* website.[9]

After excluding erroneous NDVI estimates, there was one date for 1982, and there were no dates for 1983; as such, the time-series data discussed throughout Section 3 of the report include NDVI estimates for 1984-2020.

NDVI estimates derived from *Landsat 7* satellite imagery since mid-2003 have to be further reviewed date-by-date for the occurrence of spatial data gaps, resulting from the failure of the Scan Line Corrector (SLC) on the *Landsat 7* satellite, which accounts for the satellite's forward motion. SLC failure results in data gaps along scan line paths of variable widths and occurrences. An estimated 22 percent of any given *Landsat 7* scene is lost because of SLC failure; however, the imagery acquired between these gaps is valid and useable for analysis.[10] All NDVI estimates derived from *Landsat 7* satellite imagery since 2003 were evaluated spatially date-by-date to determine if the valid portion of the data covers the defined areas of interest used for the temporal analysis of NDVI in the time series discussed in Section 3 of this report. Date-by-date analysis is necessary because the spatial position and size of the data gaps from the *Landsat 7* satellite vary for each date. Generally, areas of interest for NDVI analysis that are larger than about 400 square meters cannot use any NDVI determined from *Landsat 7* satellite imagery because it would include data gaps within the area; while areas of interest less than 400 square meters can use NDVI determined from the *Landsat 7* satellite imagery if the data gap area is not within the area of interest.

Analyses of Time-series Data

HydroDaVE[SM] contains features to calculate and extract a spatial average NDVI for a designated area and time period. The NDVI spatial average for each available date is plotted in time-series charts to analyze seasonal and temporal changes for a defined area. Time-series charts of NDVI for various areas in the Prado Basin are first introduced in Section 3.1 of this report.

When viewing time-series charts of NDVI for the period of record, it should be noted that a methodological factor that can affect observed NDVI trends is the difference between the technology of the *Landsat 4, 5, and 7* satellites*,* and the *Landsat 8* satellite. The *Landsat 4, 5, and 7* satellites use thematic mapper technology to scan the land surface, whereas *Landsat 8* uses operational land imager sensors. It has been well documented that the NDVI estimates obtained from the operational land imager sensors used on the *Landsat 8* satellite generates slightly higher index values for vegetated land cover (Xu and Guo 2014; She et al., 2015). The *Landsat 8* satellite was launched in orbit in 2013, and since, NDVI has been available from both the *Landsat 7 and 8* satellites. In order to analyze the time-series of NDVI derived across all Landsat satellites for the period of record, a bias-correction factor of -0.05, derived from literature review

[9] Earthexplorer Link

[10] Landsat Link

(Li et al., 2014; Flood, 2014: and Ke et al., 2015), was used to transform all *Landsat 8* NDVI estimates such that all historical NDVI estimates could be analyzed collectively (Roy et al., 2016).

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Appendix B

Mann-Kendall Analysis of NDVI

B.1 Introduction

The Mann-Kendall statistical trend test (Mann-Kendall test) was performed on the average growing-season NDVI metrics (NDVI) for the period of 1984 to 2020 for all 15 areas where NDVI are analyzed for the *Annual Report of the Prado Basin Habitat Sustainability Committee Water Year 2020*. The Mann-Kendall test was utilized to evaluate whether the average growing-season NDVI increased, decreased, or remained stable over time.

B.2 Methods

The Mann-Kendall test is a non-parametric statistical trend test. It is analogous to parametric trend testing such as regression (linear regression) except the data do not need to have a particular probability distribution (normal) and be accurately described by a particular measure of centrally tendency (mean, standard deviation, etc.) (Helsel and Hirsch, 2002).

To perform the test, the NDVI values are ordered chronologically and the signs (+/–) are recorded for all of the possible differences between a given NDVI value and every NDVI value that preceded it in the time series. The Mann-Kendall test statistic **S** is defined as the number of positive differences (+) minus the number of negative differences (–). From **S** and the number of NDVI values, **n**, the **τ** coefficient (analogous to the **r** correlation coefficient in linear associations) is then calculated. The **τ** coefficient represents the strength of the monotonic relationship between time and NVDI values with a possible range of -1 to 1. A perfect positive trend would yield a **τ** coefficient equal to 1, and a perfect negative trend would yield a **τ** coefficient equal to -1.

The Mann-Kendall test utilizes the null hypothesis that there is no trend. If the **S** test statistic and **τ** coefficient are significantly different than zero, the null hypothesis is rejected, and a trend exists. The level of statistical significance is expressed as a p-value between 0 and 1. The smaller the p-value the stronger the evidence that the null hypothesis should be rejected. In this study, a p-value of less than or equal to 0.05 was used to determine if a trend existed. In summary, the three possible outcomes of the test are

- Increasing trend (p-value ≤ 0.05, **τ** > 0)
- No trend (p-value > 0.05)
- Decreasing trend (p-value ≤ 0.05, **τ** < 0)

B.4 Data Analysis and Results

The Mann-Kendall **S** test statistic, **τ** coefficient and p-value were computed for average-growing season NDVI from 1984 to 2020 for the 15 areas in Prado Basin, using the python package pyMannKendall (Hussain, 2019). Table B-1 through B-3 lists the results of the Mann-Kendall test for the three time periods of interest: 1984 through 2020; 1984 through 2006; and 2007 through 2020.

Table B-1. 1984 to 2020					
Area	n (number of NDVI values)	S Test Statistic	τ coefficient	p-value	Trend
Riparian Vegetation Extent	36	132	0.21	7.44E-02	No Trend
Chino Creek Area	36	390	0.62	1.17E-07	Increasing
Mill Creek Area	36	-20	-0.03	7.96E-01	No Trend
CC-1	37	320	0.48	3.02E-05	Increasing
CC-2	37	462	0.69	1.65E-09	Increasing
CC-3	37	430	0.65	2.01E-08	Increasing
CC-4	37	270	0.41	4.34E-04	Increasing
MC-1	37	304	0.46	7.40E-05	Increasing
MC-2	37	88	0.13	2.55E-01	No Trend
MC-3	37	78	0.12	3.14E-01	No Trend
MC-4	37	206	0.31	7.34E-03	Increasing
SAR-1	37	-86	-0.13	2.66E-01	No Trend
SAR-2	37	-52	-0.08	5.05E-01	No Trend
SAR-3	37	182	0.27	1.79E-02	Increasing
LP	37	244	0.37	1.48E-03	Increasing

Table B-2. 1984 to 2006					
Area	n (number of NDVI values)	S Test Statistic	τ coefficient	p-value	Trend
Riparian Vegetation Extent	23	33	0.13	3.98E-01	No Trend
Chino Creek Area	23	99	0.39	9.65E-03	Increasing
Mill Creek Area	23	-97	-0.38	1.12E-02	Decreasing
CC-1	23	49	0.19	2.05E-01	No Trend
CC-2	23	137	0.54	3.28E-04	Increasing
CC-3	23	143	0.57	1.77E-04	Increasing
CC-4	23	19	0.08	6.35E-01	No Trend
MC-1	23	33	0.13	3.98E-01	No Trend
MC-2	23	-53	-0.21	1.70E-01	No Trend
MC-3	23	-47	-0.19	2.24E-01	No Trend
MC-4	23	13	0.05	7.51E-01	No Trend
SAR-1	23	1	0.00	1.00E+00	No Trend
SAR-2	23	-119	-0.47	1.83E-03	Decreasing
SAR-3	23	-55	-0.22	1.54E-01	No Trend
LP	23	-37	-0.15	3.42E-01	No Trend

Table B-3. 2007 to 2020					
Area	n (number of NDVI values)	S Test Statistic	τ coefficient	p-value	Trend
Riparian Vegetation Extent	13	14	0.18	4.28E-01	No Trend
Chino Creek Area	13	34	0.44	4.41E-02	Increasing
Mill Creek Area	13	34	0.44	4.41E-02	Increasing
CC-1	14	19	0.21	3.24E-01	No Trend
CC-2	14	55	0.60	3.11E-03	Increasing
CC-3	14	43	0.47	2.15E-02	Increasing
CC-4	14	45	0.49	1.60E-02	Increasing
MC-1	14	49	0.54	8.60E-03	Increasing
MC-2	14	53	0.58	4.42E-03	Increasing
MC-3	14	43	0.47	2.15E-02	Increasing
MC-4	14	5	0.05	8.27E-01	No Trend
SAR-1	14	73	0.80	8.09E-05	Increasing
SAR-2	14	49	0.54	8.60E-03	Increasing
SAR-3	14	39	0.43	3.75E-02	Increasing
LP	14	43	0.47	2.15E-02	Increasing

B.5 References

Helsel, D.R., and Hirsch R.M. 2002. *Statistical Methods in Water Resources*. Techniques of Water Resource Investigations of the United States Geological Survey, Book, 4 Hydrological Analysis and Interpretation. September 2002.

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