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RESTORING CONVERTED WETLANDS: A CASE STUDY IN WATSONVILLE, CALIFORNIA

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ABSTRACT

RESTORING CONVERTED WETLANDS:
A CASE STUDY IN WATSONVILLE, CALIFORNIA

by Karl F. Schwing

"Prior converted croplands" are wetlands converted to agricultural uses prior to December 23, 1985. Prior converted croplands are exempted from protection under the Clean Water Act and the Food Security Act. This exemption may hinder efforts to achieve net gains in wetland habitat. This study researched how the prior converted cropland exemption could affect restoration efforts in the Watsonville Wetlands Complex, Santa Cruz County, California.

This research was conducted using a geographic information system to analyze changes in wetland extent over time. Historical cartographic data, aerial photographs, and land use plans served as data sources for tracking changes between 1881, 1985, and 1994.

This study found that 61% to 70% of the Watsonville Wetlands Complex were converted prior to December 23, 1985, and may be considered restorable prior converted cropland. However, analysis of land use plans showed that 6% to 40% of converted wetland areas are targeted for urbanization.

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INTRODUCTION

Background

There is broad concern about wetland habitat loss because wetlands perform beneficial environmental services. Wetlands are important to coastal hydrology by providing groundwater recharge and flood water storage. Wetlands filter pollutants and regulate water chemistry. In addition, wetlands provide food, cover, and breeding grounds for aquatic and terrestrial wildlife (Mitsch and Gosselink 1993).

Unfortunately, wetland function is being degraded globally. While reliable published data are not readily available on the worldwide extent of wetland habitat loss, it is known the figure approaches 100% in many of the most densely populated regions (Mitsch and Gosselink 1993). In the conterminous United States, at least 44.5 million hectares (110 million acres) have been lost, or 50%, between the 1780's and the mid-1980's (Dahl 1990). Despite wetland regulation and protection efforts, losses continue. The latest figures show a net loss of 1 million hectares (2.6 million acres) in the United States, an additional 2.5%, occurred between the mid-1970's and the mid-1980's (Dahl and Johnson 1991), and a net loss of 315,000 hectares (779,000

acres), an additional 0.53%, occurred between 1985 and 1995 (Dahl, Young, and Caldwell 1997). In California, these losses have amounted to the destruction of at least 90 percent of the wetlands present in the 1700's (Dennis and Marcus 1984; Dahl 1990).

Wetlands restoration is viewed by some researchers and resource managers as both a way to offset ongoing wetland destruction and a means of repairing the function of existing wetlands. Indeed, wetlands restoration is the only way to achieve the net gains called for by present wetlands policy (Beck 1994; Tolman 1995, 1997).

Americans are literally eating away at their wetlands. Since 1950, up to 87 percent of the wetlands destroyed in the United States were converted for agricultural purposes (Dahl and Johnson 1991; Dahl, Young, and Caldwell 1997). The loss of so much wetland habitat is having negative social and ecological impacts. As people have destroyed wetlands and built closer to water courses, flooding becomes more common. The decline in wetland habitat is also resulting in species declines.

In 1993, the Clinton Administration committed itself to halting further wetland loss and achieving net gains in wetland quality and quantity. "Prior converted croplands," which are former wetlands transformed for agricultural purposes before December 23, 1985, represent approximately 21 million hectares of converted wetlands nationwide (U.S. Environmental Protection Agency 1993). In urbanizing coastal areas, such as Watsonville,

California (Figure 1), cultivated areas, including former wetlands, represent the most readily available developable land. These former wetland areas also represent the most likely places to perform the wetland enhancement and restoration necessary to achieve a net gain in wetland quality and quantity. However, an exemption for prior converted croplands from regulatory authority under the Section 404 program of the Clean Water Act and the Swampbuster provisions of the Food Security Act may interfere with restoration efforts.

This study examined the implications of the prior converted cropland exemption within a series of wetlands, the Watsonville Wetlands Complex, located along the Pacific Coast, approximately 12 miles south of the City of Santa Cruz and 12 miles west of the Santa Cruz Mountains on the northerly third of the Monterey Bay coastline in Santa Cruz County, California (Figure 2). This thesis research identified the quantity of converted Watsonville wetland habitat that may be considered prior converted cropland and then examined how the exemption affects the efforts of municipalities and other public and private entities to pursue wetland restoration within the watershed.

Clean Water Act and the Food Security Act

Regulation of wetland resources occurs most directly through the U.S. Federal Water Pollution Control Act of 1972 as amended by the Clean Water

Act of 1977, now known as the Clean Water Act (CWA), and through the Food Security Act of 1985, as amended in 1990 and 1996 (FSA). The CWA directly regulates activity in all wetlands through a permit system, while the FSA, which applies only to wetlands found in agricultural settings, uses economic sanctions for regulatory purposes (National Research Council 1995).

More specifically, section 404 of CWA empowers the administrative and regulatory agencies, the U.S. Environmental Protection Agency (USEPA) and the U.S. Army Corps of Engineers (USACE) respectively, to regulate the dredging and filling of navigable waters in the United States. Any activity which will result in the dredging or filling of navigable waters, including wetlands, must either be exempt from the CWA or receive a CWA Section 404 permit. Of particular interest to this study is the regulation of wetlands found in agricultural settings. In such cases, the CWA provides several exemptions from permit requirements. Dredging or filling of agricultural wetlands may be exempt if such activity is for: 1) routine construction and maintenance of farm roads; 2) drainage ditches; 3) artificial agricultural catch ponds; or 4) routine plowing, seeding, cultivating, and minor drainage related to cultivation of food, fiber, or forest products (Blumm and Zaleha 1989; Hofer 1988; Rouvalis 1988; Liebesman 1985; National Research Council 1995).

A second level of regulation relevant to wetlands in agricultural settings is a result of the FSA. Wetland resources are most directly managed by the FSA through the so-called "Swampbuster" provisions. This program is

the responsibility of two agencies within U.S. Department of Agriculture: the Natural Resources Conservation Service (NRCS), which handles wetland determinations, and the Agricultural Stabilization and Conservation Service (ASCS), which determines farmers' eligibility for exemptions. The Swampbuster provisions direct farmers not to convert wetlands for agricultural purposes or they will be disqualified from government benefits, including crop subsidies and low interest loans. However, as with the CWA, the FSA includes a number of clauses which exempt farmers from disqualification. One important exemption allows farmers to continue cultivating wetland habitat that was converted prior to December 23, 1985. Wetland and former wetland areas designated prior converted cropland are exempt from penalties associated with their cultivation (National Research Council 1995).

The wetland conservation provisions of the Food Security Act of 1985 provide that an agricultural producer will be ineligible for production flexibility contract payments, marketing assistance loans, price supports or payments, and Consolidated Farm Service Agency loans, if an agricultural commodity is produced during any crop year on a converted wetland (16 U.S.C. 3821). The language of the provision, Title 16, Chapter 58, Subchapter III, Section 3821, states in relevant part:

> *(a) Production on converted wetland*
> *Except as provided in this subchapter and notwithstanding any other provision of law, any person who in any crop year produces*

an agricultural commodity on converted wetland, as determined by the Secretary, shall be -

(1) in violation of this section; and

(2) ineligible for loans or payments in an amount determined by the Secretary to be proportionate to the severity of the violation.

(b) Ineligibility for certain loans and payments

If a person is determined to have committed a violation under subsection (a) of this section during a crop year, the Secretary shall determine which of, and the amount of, the following loans and payments for which the person shall be ineligible:

(1) Contract payments under a production flexibility contract, marketing assistance loans, and any type of price support or payment made available under the Agricultural Market Transition Act (7 U.S.C. 7201 et seq.), the Commodity Credit Corporation Charter Act (15 U.S.C. 714 et seq.), or any other Act.

(2) A loan made or guaranteed under the Consolidated Farm and Rural Development Act (7 U.S.C. 1921 et seq.) or any other provision of law administered by the Consolidated Farm Service Agency, if the Secretary determines that the proceeds of the loan will be used for a purpose that will contribute to conversion of a wetland (other than as provided in this subchapter) to produce an agricultural commodity.

(3) During the crop year:

(A) A payment made pursuant to a contract entered into under the environmental quality incentives program under part IV of subchapter IV of this chapter.

(B) A payment under any other provision of subchapter IV of this chapter.

(C) A payment under section 2201 or 2202 of this title.

(D) A payment, loan, or other assistance under section 1003 or 1006a of this title.

(c) Wetland conversion

Except as provided in section 3822 of this title and notwithstanding any other provision of law, any person who in any crop year beginning after November 28, 1990, converts a wetland by draining, dredging, filling, leveling, or any other means for the purpose, or to have the effect, of making the production of an agricultural commodity possible on such converted wetland shall be ineligible for those payments, loans, or programs specified in subsection (b) of this section for that crop year and all subsequent crop years.

(d) Prior loans

This section shall not apply to a loan described in subsection (b) of this section made before December 23, 1985.

Interestingly, as originally adopted in 1985, a person who converted an agricultural wetland, but did not produce an agricultural commodity on that converted wetland, would not be subject to Swampbuster sanctions. However, an amendment to the law in 1990 changed the provision so that, if any person simply converts a wetland for purposes of agricultural production, after November 28, 1990, that person is not eligible for agricultural assistance programs until and unless the conversion is mitigated. Notwithstanding these provisions, a person is exempt from Swampbuster sanctions if the wetland conversion occurred prior to December 23, 1985, the date the law became effective, and the converted wetland meets specific criteria based on its physical state and the field conditions.

The physical state of a converted wetland may vary depending on field conditions. For instance, some converted wetland areas may have undergone such substantial physical alteration that wetland characteristics would not return to the site in the event cropping of the area was halted. In other instances, a converted wetland area may retain wetland hydrology during some parts of the year and allow cropping during other times of the year. There also are varying statutory provisions which dictate how a particular wetland is treated for Food Security Act purposes. For instance, if substantial alteration of a wetland was underway, but not completed, at the time the law was passed by Congress, the statute allows the producer to complete the conversion and production of an agricultural commodity on the wetland

without sanction. Swampbuster regulations define the type of converted wetland that is exempt based upon specific field conditions.

Section 12.2 of the regulations defines the types of agricultural wetlands and former wetlands and the sanction-free, allowable uses that can occur. These types of agricultural and former wetlands include: "prior converted cropland," "wetland," "artificial wetland," "commenced conversion wetland," "converted wetland," "farmed wetland," and "farmed wetland pasture." Criteria such as the date of conversion, length of inundation, degree of hydrologic alteration, and cropping history are used to characterize the wetland or former wetland. According to the regulations, a prior converted cropland is defined as follows (7 CFR 12.2):

> *(8) Prior-converted cropland is a converted wetland where the conversion occurred prior to December 23, 1985, an agricultural commodity had been produced at least once before December 23, 1985, and as of December 23, 1985, the converted wetland did not support woody vegetation and met the following hydrologic criteria:*
>
> *(i) Inundation was less than 15 consecutive days during the growing season or 10 percent of the growing season, whichever is less, in most years (50 percent chance or more); and*
>
> *(ii) If a pothole, playa or pocosin, ponding was less than 7 consecutive days during the growing season in most years (50 percent chance or more) and saturation was less than 14 consecutive days during the growing season most years (50 percent chance or more).*

Under these regulations, labeling a converted wetland area as "prior converted cropland" gives special status to that area. For instance, any area labeled prior converted cropland will always retain that label regardless of the physical condition of the converted wetland. Therefore, if a prior converted

cropland area is neglected and wetland characteristics return to that area, there is no sanction for eliminating those wetland characteristics in the future for purposes of agricultural commodity production. The statutory provision allowing this to occur was implemented in the 1996 amendments to the Food Security Act (i.e., FAIRA 1996). Legislators and other interested persons labeled this provision the "once a prior converted cropland, always a prior converted cropland" allowance. Due to this allowance, growers do not need to clear, plow, or remove wetland characteristics from prior converted cropland areas to retain that status. Prior to implementation of the provision, if a grower did not produce a commodity crop on a prior converted cropland area for five years, the area was considered "abandoned" and could be re-labeled under one of the more use-restrictive wetland definitions based upon the return of wetland characteristics to the area. In order to avoid re-labeling, some growers would plow and plant these prior converted cropland areas within the five year time period, regardless of any economic or practical need to farm the converted wetland. Therefore, legislators expunged the abandonment provision of the law as it related to prior converted cropland so that growers would not resort to elimination of wetland areas simply to retain the advantages of the prior converted cropland label (McBeth 1997).

Effort Toward Integration of CWA and FSA

In 1993, the Clinton Administration announced a wetland policy reform package promising a more fair and flexible approach to wetland regulation (U.S. Environmental Protection Agency 1993). As part of these reforms, and an ongoing coordination effort, the USACE and the NRCS/ASCS carried out two actions to coordinate and reconcile their regulatory procedures related to their shared jurisdiction over agricultural wetlands. First, the USACE and USEPA issued new regulations stating that prior converted croplands were no longer considered waters of the United States and were thus exempt from CWA permit procedures (33 CFR 328). Second, a memorandum of agreement was signed between the Department of Agriculture, Environmental Protection Agency (USEPA), Department of Defense, and Department of the Interior establishing the Soil Conservation Service (now called the Natural Resources Conservation Service) as the lead agency for wetland determinations in agricultural landscapes.

In 1993, the U.S. Department of Defense, Corps of Engineers, Department of the Army (USACE) announced their final rule on a clarification to the meaning of waters of the United States as the regulatory definition relates to implementation of Clean Water Act wetland regulatory programs in agricultural areas (U.S. Department of Defense 1993). The clarification states that waters of the United States do not include prior

converted cropland. Section 328.3 of the federal regulations was revised to state, in relevant part (33 CFR 328):

> *For the purpose of this regulation these terms are defined as follows:*
> *(a) The term waters of the United States means...*
> *(8) Waters of the United States do not include prior converted cropland. Notwithstanding the determination of an area's status as prior converted cropland by any other Federal agency, for the purposes of the Clean Water Act, the final authority regarding Clean Water Act jurisdiction remains with EPA.*

Accordingly, if the NRCS designates a converted wetland area as a prior converted cropland, then, under most circumstances, the USACE will not consider that area waters of the United States for purposes of Clean Water Act jurisdiction.

In 1994, a memorandum of agreement between the USDA, USEPA, USACE, and U. S. Department of the Interior (USDI) established the Soil Conservation Service (now NRCS) as the lead agency for wetland determinations in agricultural landscapes. A lead agency was assigned to reduce redundant and sometimes conflicting agricultural wetland determinations which previously were prepared by several agencies utilizing different wetland determination methods and to clarify for agricultural producers which agency was responsible for wetland determinations in agricultural areas (USDA 1994). As a result, the USEPA, USACE, and USDI have agreed, under most circumstances, to use the wetland determination prepared by the NRCS for any agricultural wetland determination required in

carrying out their respective responsibilities under federal wetland regulatory programs.

Implications of CWA and FSA within the Watsonville Wetlands Complex

Several analysts have found this move by the USACE and USEPA ill conceived (McElfish and Adler 1990; Risley and Budzik 1988; Robinson 1993). Others have found the exemption legally suspicious (Babcock 1991; Theis 1991). Finally, some say the exemption offers an opportunity for real estate developers to purchase easily developable, poorly producing, drained and filled wetlands at bargain prices from farmers (Eggers 1996). During an era where federal policy calls for wetland restoration and a net gain in wetland quantity (U.S. Environmental Protection Agency 1993), this policy deserves scrutiny as it allows the unregulated destruction of almost half of America's restorable former wetland resource (Holland et al. 1995; Shabman 1991). Studies by Dahl and Johnson (1991) and Dahl, Young, and Caldwell (1997) and the trends noticed by Eggers (1996) and Sullivan (1996) show the quantity of former wetlands which may succumb to development because of the prior converted cropland exemption is significant --approximately 21 million hectares (U.S. Environmental Protection Agency 1993).

The Watsonville Wetlands Complex is one area susceptible to the problems associated with the prior converted cropland exemption. This wetlands complex is an impaired agricultural wetland system that requires

wetland restoration as part of the recovery plan called for by the Association of Monterey Bay Area Governments (AMBAG 1995). The region, however, is rapidly urbanizing. It is estimated the human population in Santa Cruz County will increase by 50% between 1988 and 2010 (Culliton et al. 1990). In addition, the City of Watsonville's population is expected to increase by 62% between 1990 and 2005 (City of Watsonville 1994). New development will be required to support this new population. Due to the nature of the region, however, most of this development must occur on land which is currently in agricultural production. Watsonville's most recent land annexation allows a development corridor that leads directly to the slough system (City of Watsonville 1994). This study determined how much of the agricultural lands surrounding the wetlands complex may once have been wetland habitat. Since restoration of wetland habitat is important to improving the quality of the Watsonville Wetlands Complex, this identification of former wetland habitat areas can assist planning efforts to restore this impaired wetland system.

National and local studies show that this research which identified historically present wetland habitat is necessary (AMBAG 1995; Shabman 1991; Holland et al. 1995). The Association of Monterey Bay Area Governments (AMBAG), through the Watsonville Slough Water Resources Management Plan (1995), and the California Coastal Commission, through the Regional Cumulative Assessment Project (ReCAP 1995), state the

importance and need to understand the historical extent of wetland resources in the Monterey Bay region so future efforts to restore wetlands in the region may be properly guided. Other local and regional planning agencies, such as the City of Watsonville and the County of Santa Cruz, can use the data collected in this study for their own regional wetland management planning needs. The Monterey Bay National Marine Sanctuary, California Department of Fish and Game, and the U.S. Fish and Wildlife Service can also use these data as baseline information relating to water quality and biological conditions for the purpose of impact and biodiversity assessment. Flood control management agencies can use these data to understand if current flood patterns have any relationship to the now absent flood control capacity of historically present wetlands. Finally, local citizen groups and potential developers can use the data to pro-actively design development projects which avoid environmental impacts and restore historical wetland habitat.

This research into how federal wetland policy is manifested at the local level can help policy makers decide how to improve these policies. More specifically, this research into policies that affect restoration efforts creates a context which can explain observed restoration patterns. For instance, wetland managers may be able to explain why restoration is not occurring in their jurisdiction by gaining an understanding of the laws individuals consider when they decide whether to pursue development or wetlands restoration on their property. The research performed in this study helps

illuminate how the prior converted cropland exemption is antithetical to accomplishment of local restoration initiatives. More broadly, this research has provided a case study with implications that the exemption of prior converted croplands is contrary to present wetland policy goals. A repertoire of case studies, such as this one, which demonstrate the problems associated with the prior converted cropland exemption provides data illustrating that there is a need to either reform this feature of the FSA and CWA or seek new legislation targeted at wetland restoration.

The results of this work show how existing cartographic data and a geographic information system (GIS) may be used to identify valuable wetland restoration sites in advance of urbanization. It also provides a case study demonstrating how the prior converted wetland exemption may shape efforts to restore wetlands. This study of the potential for restoration of prior converted croplands in an urbanizing, coastal, agricultural setting in Santa Cruz County, California, is also useful as a case study. Urbanization of prior converted croplands has occurred or is anticipated to occur in places such as Minnesota, Wisconsin, and Washington (Eggers 1996, Sullivan 1996). The information these case studies provide may be considered by legislators and citizen participants when reauthorization of the Clean Water Act is pursued (Zinn and Copeland 1996).

Objectives

The main purpose of this project has been to quantitatively determine how much converted wetland exists in the Watsonville Wetlands Complex. First, this research quantified how many hectares of wetland habitat have been lost in the wetlands complex; this information also creates an understanding of the quantity and location of former wetland habitat in the area that may be restored. Second, this study helps wetland managers understand how many hectares of former wetland habitat may be subject to the prior converted cropland exemption. This understanding has been gained by investigating currently proposed uses of converted wetland.

The role the prior converted cropland exemption plays in shaping future efforts to perform wetland restoration can best be analyzed at the local level. The Watsonville Wetlands Complex provides an important case study. The following questions have been answered to complete this analysis:

1) How much wetland habitat has been converted to human use within the Watsonville Wetlands Complex between the pre-development period and 1985?

2) How much wetland habitat has been converted in this same area between 1985 and the present?

3) What are the current and planned future uses of converted wetland habitat based upon the Santa Cruz County and City of Watsonville general plans?

4) How much historical wetland habitat may be identified as prior converted cropland?

5) Could the prior converted cropland exemption play a significant role in future efforts to restore wetland habitat in the Watsonville Wetlands Complex?

6) What implications do the findings of this study have upon wetland restoration efforts nationwide?

CHAPTER 2

RELATED RESEARCH

In 1993, the Clinton Administration reaffirmed America's commitment to cease wetland habitat loss and reverse the trend through enhancement and restoration of degraded and converted wetland habitat. The Watsonville Wetlands Complex is an example of an impaired wetland system that stands to benefit from such a policy. An exemption from the Clean Water Act and Food Security Act for prior converted cropland, however, may threaten the possibility of restoration in many agricultural landscapes, including the Watsonville Wetlands Complex. The potential use of prior converted croplands and the exemption of these areas from regulatory control are debated by public agencies, policy experts and wetland resource specialists (Babcock 1991; Eggers 1996; Evans 1998; McBeth 1997; Sullivan 1996; Theis 1991; U.S. Department of Agriculture 1999a).

Implementation of federal wetland policy primarily rests upon the Section 404 program established by the Federal Water Pollution Control Act (FWPCA) of 1972, as amended by the Clean Water Act of 1977, and the Food

Security Act Swampbuster program, as amended by Food, Agriculture, Conservation and Trade Act (FACTA) of 1990, and the Federal Agricultural Improvement and Reform Act (FAIRA) of 1996. The goal of the FWPCA is "...to restore and maintain the chemical, physical, and biological integrity of the Nation's waters..." (FWPCA §101 (a) 33 U.S.C. § 1251 (a) (U.S. Congress 1972). Section 404 of the Clean Water Act authorized the U.S. Army Corps of Engineers (USACE) to implement this goal by regulating discharges into waters of the United States. Congress intended the definition of "waters of the United States" to be defined as broadly as possible so as to include all water bodies, including agricultural wetlands such as those found in the Watsonville Wetlands Complex (Thompson 1977). The Swampbuster program was created in 1985 as part of the Food Security Act, as amended in 1990 and 1996, to counteract the conversion of wetlands for agricultural purposes. This activity was essentially subsidized by federal price support programs, which guaranteed farmers a crop price, especially in cases where a crop surplus created low crop prices on the open market. Some attributed the agricultural wetland conversion problem to farmers who sowed as much land as possible, including wetlands, regardless of market demand in expectation of benefiting from the guaranteed price system. Swampbuster threatened disqualification for price supports, and other subsidies such as crop insurance if wetlands were converted by the farmer. However, Swampbuster also allowed farmers to continue to farm prior converted croplands (i.e.,

wetlands converted to agricultural use prior to December 23, 1985) without penalty (Bianucci and Goodenow 1991; Cylinder et al. 1995; McBeth 1997).

Implementation of the Swampbuster program was given to the U.S. Department of Agriculture (USDA), who delegated authority to the Natural Resources Conservation Service (NRCS) and the Agricultural Stabilization and Conservation Service (ASCS). Since the USACE regulated activity in all wetlands, there was a jurisdictional overlap between the USDA and the USACE. Many farmers were concerned that continued use of prior converted croplands, under the then-existing regulatory program, would result in a CWA violation (Reilly 1991). The USACE clarified their position regarding this concern by issuing Regulatory Guidance Letter 90-07 stating prior converted croplands would be exempt from Clean Water Act jurisdiction (U.S. Army Corps of Engineers 1990).

In 1993, the Clinton Administration announced the elevation of the prior converted cropland exemption from regulatory guidance to a formal regulation. The announcement was a part of the Administration's overall wetland management strategy. This plan updated and reaffirmed former President Bush's policy of "no net loss" of wetland habitat. The Clinton Administration's plan established as policy a short-term goal of no further net loss of wetlands, with the addition of a long-term goal of positive gain in the quality and quantity of habitat. The plan included a package of reforms, including changes to USACE and USEPA regulations that exempted prior

converted croplands from wetland regulation. Specifically, the regulatory change excluded prior converted croplands from the definition of waters of the United States. This formal articulation of a policy in place, ad-hoc since 1990 via Regulatory Guidance Letter 90-07 (U.S. Army Corps of Engineers 1990), removed approximately 21 million hectares (53 million acres) of wetland and former wetland from America's base of wetland habitat, including some quantity in the Watsonville Wetlands Complex (U.S. Environmental Protection Agency 1993).

Some researchers argue that prior converted croplands represent an important resource which must be identified and protected so wetland restoration projects may be pursued. Shabman (1991), an agricultural economist, argues that converted agricultural wetlands represent the largest and best source of potentially restorable wetlands. Since converted wetlands tend to be easier to restore in agricultural landscapes than urban ones, wetland managers should be identifying converted agricultural wetlands to restore as a means to repair damaged wetland systems. These restored agricultural wetlands could also be used to create mitigation banks to offset impacts caused when urban areas take over agricultural landscapes. Use of converted wetland resources in this manner maximizes benefits to both wetland systems and development values (Shabman 1991).

Advance identification of potentially restorable wetlands and the protection of prior converted cropland resources would be necessary to

implement the ideas of Kilborn (1991) and Searchinger (1993). Kilborn and Searchinger call for the implementation of advance identification of existing and former wetlands on properties during real estate transactions in the same manner Phase 1 Environmental Site Investigations are performed to disclose the presence of toxic substances on the subject property. Searchinger argues the implementation of this system would alert potential property owners to the restrictions that accompany use of the land (Searchinger 1993). Kilborn argues this same system would provide knowledge to prospective buyers of the presence of altered or illegally filled or altered wetlands. This information would increase awareness of wetland function and value as well as prevent property owners who have illegally altered wetlands from gaining through the development and/or sale of them. Kilborn goes on to state the idea is supported by evaluating Congressional intent, statutory language, and case law related to the Clean Water Act (Kilborn 1991).

Hanson (1987) argues for taking advance identification of restorable wetlands one step further. He evaluated the possibility of drawing upon the extremely successful drainage district model, in terms of establishment, financing, construction, and benefit assessment, to create wetland districts. These wetland districts would be designed to facilitate the restoration of needed wetlands, especially in agricultural areas where so much conversion has taken place (Hanson 1987). Advance identification of prior converted

croplands would be required to evaluate the needs and benefits that would warrant establishment of the district.

There are several documented examples where prior converted croplands have been successfully restored. Evans (1998) documents an ongoing restoration of prior converted cropland to wetland habitat in North Carolina. The Natural Resources Conservation Service cites at least seven successful wetland restorations of prior converted cropland in Indiana, Louisiana, Michigan, Missouri, Oregon, South Carolina, and Wisconsin. These restoration efforts occurred as part of the USDA's Wetlands Reserve Program targeting prior converted cropland and farmed wetland for restoration and long term or permanent conservation. The program is voluntary and provides funding to landowners for restoration and the purchase of 30 year and permanent conservation easements (U.S. Department of Agriculture 1999a).

It is evident that prior converted croplands represent an important resource from the standpoint of restoration. However, the process by which prior converted croplands are identified by regulatory agencies and the legal validity of the exemption itself is challenged by some experts.

Some authors are concerned about the legality of the prior converted cropland exemption as used by the USDA while executing their duties under the Food Security Act Swampbuster provisions. The issues they raise may also have ramifications when the exemption is activated for Clean Water Act

purposes. McElfish and Adler (1990), for instance, find the prior converted cropland exemption is given too frequently and easily. The authors attribute this problem to the appeals process growers can undertake if they disagree with a prior converted cropland exemption determination. This process places review and decision authority for appeals with a county committee composed of local electives who are typically growers themselves. The authors contend that a ruling against the grower appealing a decision could have negative consequences, both politically and socially, for the elected board members. Therefore, growers who appeal for a prior converted cropland exemption are usually granted the exemption even in cases where factual evidence indicates the exemption is not warranted (McElfish and Adler 1990). Robinson (1993) agrees with McElfish and Adler when she declares exemptions such as the prior converted cropland exemption are overused by USDA officials for purposes of expediency (Robinson 1993).

Concern regarding the quality of the work performed by the USDA is also raised by Risley and Budzik (1988). They cite at least two instances where wetland determinations were performed incorrectly resulting in needless wetland conversion. In one case, a wetland determination that was made without a field inspection showed that there was not a wetland on a particular farm, whereas a field check showed that there was a well established wetland on that farm. In the other case, a prior converted

cropland exemption was granted even though agency records clearly showed that the wetland had not been converted prior to December 23, 1985.

Robinson (1996) notes that recent changes made to the FSA by FAIRA (U.S. Congress 1996) make it nearly impossible to remedy inaccurate wetland determinations made by USDA officials. According to Robinson, once the USDA has made a wetland determination, that determination cannot be revisited by anyone with the exception of the landowner who typically will only call for re-visitation of the issue if the determination is detrimental to the growers operation (Robinson 1996). The concerns raised by McElfish and Adler (1990), Robinson (1993), Risley and Budzik (1988), and Robinson (1996) demonstrate there are concerns that the USDA abuses the prior converted cropland exemption and makes incorrect wetland determinations all in the absence of basic oversight conventions that would allow for correction. Since the Section 404 prior converted cropland exemption is activated based upon a determination made by the USDA, it is possible to extrapolate that the Section 404 exemption may be falsely utilized under some circumstances.

Indeed, some analysts challenge the legal validity of the Section 404 prior converted cropland exemption. Theis (1991) finds that Section 404 jurisdiction over agricultural wetlands has been severely curtailed by the Section 404 prior converted cropland exemption. He analyses the ramifications of the forerunner to the existing exemption, Regulatory Guidance Letter (RGL) 90-07. Theis argues that RGL 90-07, and therefore,

current regulation, are both scientifically and legally unsound. RGL 90-07 was issued to clarify the definition of normal circumstances as used in the regulatory definition of wetlands. This regulatory definition states wetlands are "areas that are inundated or saturated by surface or groundwater at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions" (33 CFR Section 328.3 (b)). RGL 90-07 stated wetlands which were manipulated and cropped prior to December 23, 1985, defined as prior converted cropland were exempt from Section 404 of the CWA based on the assumption that all prior converted cropland had undergone extensive alteration and would not support wetland vegetation upon cessation of cropping. Theis argues RGL 90-07 presumes, without verification, that prior converted croplands are not wetlands. Theis stated this presumption is not scientifically sound because some prior converted croplands continue to perform wetland functions such as floodwater retention, groundwater recharge, and water filtration. Theis found the presumption not only unscientific, but arbitrary because a date, December 23, 1985, not field verification, is the trigger for the exemption. Furthermore, the presumption is contrary to the definition of 'normal circumstances' as interpreted by the courts and inconsistent with the definition found in the Federal Manual for Identifying and Delineating Jurisdictional Wetlands (Theis 1991).

Babcock (1991) echoed some of the ideas delivered by Theis (1991). RGL 90-07 and the existing prior converted cropland exemption are legally invalid, according to Babcock, because the Clean Water Act has been in place since 1972. There is nothing in the legislation according to Babcock which allows the USACE to exempt wetlands converted prior to December 23, 1985. Babcock believed the exemption is not legally sound and was only created to relieve political pressure placed on the USACE by the farming community. Babcock noted this exemption could be particularly odious because it relies on a definition created by the Natural Resources Conservation Service who have, in some areas, mistakenly identified vast tracks of farmed wetland as prior converted cropland, within the San Francisco Bay region in particular. As a result, some farmed wetlands which are unmistakably wetlands by definition and function are exempt from Section 404 permit requirements (Babcock 1991).

Eggers (1996) explains how the prior converted cropland exemption has been taken too far under some circumstances. Eggers traced the construction of the prior converted cropland exemption from its inception in the Food Security Act to integration of the concept into the Clean Water Act Section 404 regulatory program. Eggers explained many compromises were made between the NRCS and the USACE in order to clarify regulation of wetlands in agricultural landscapes. Eggers argues the assumption of CWA jurisdictional duties for wetlands located in agricultural landscapes, typically

the USACE's charge, by the NRCS compromises the effectiveness of the CWA program because the methods of regulation used by the NRCS to implement the FSA Swampbuster provisions are not compatible with the methods or purpose of regulation in the Section 404 program of the CWA. Eggers explains that a FSA determination of an area as prior converted cropland is largely based upon whether an area has been manipulated prior to December 23, 1985. According to Eggers, NRCS defines 'manipulated' as any change to hydrology and/or the removal of woody vegetation from a wetland. In the case of prior converted croplands, Eggers states, "FSA interpretations of 'manipulated' have become so all-encompassing that areas labeled prior converted have little validity as a means for determining CWA jurisdiction" (Eggers 1996, 25). Even so, prior converted croplands were exempted from CWA jurisdiction through a 1993 regulatory change which categorically excluded prior converted croplands from the definition of waters of the United States. Eggers derided the change in policy for its role in creating a real estate market for prior converted cropland property at the rural-urban fringe of metropolitan areas in Minnesota and Wisconsin. Evidently, land speculators recognized that prior converted cropland tracts may be dredged, filled, or drained to accommodate development without regulatory interference because of the exemption (Eggers 1996).

Sullivan (1996) recognized that prior converted cropland areas, providing important potential waterfowl habitat in the Snohomish River

Valley in the State of Washington, may be threatened by the suburban expansion of nearby Seattle. Sullivan's study finds that prior converted cropland areas within Seattle's urban growth boundary will likely be converted to urban use since the Clean Water Act and Food Security Act provide no protection to prior converted cropland areas. However, Sullivan also finds those prior converted cropland areas outside Seattle's urban growth boundary will likely be protected from development by local development controls despite Clean Water Act and Food Security Act shortcomings regarding protection of prior converted cropland areas.

Some of the concerns raised by McElfish and Adler (1990), Robinson (1993), Risley and Budzik (1988), Robinson (1996), Theis (1991), Babcock (1991), and Eggers (1996) were addressed in part when the USACE published their rationale for the removal of prior converted cropland from the definition of waters of the United States (U.S. Department of Defense 1993). The USACE explains the primary motivation in issuing the rule is to provide consistency with other federal programs regarding wetlands in agricultural areas. These changes, according to USACE, were designed to reduce public confusion with respect to wetland regulation and ultimately aid achievement of Clean Water Act goals. In keeping with their rationale published in RGL 90-07, the USACE found their decision had no adverse effect upon wetland resources because any wetland values associated with prior converted croplands were so severely degraded that such areas should not be considered wetlands for

Clean Water Act purposes. In addition, the USACE found exempting prior converted cropland from CWA authority did not constitute a retroactive grandfathering of illegal wetland alteration activities occurring between 1977 and 1985 as suggested by Theis (1991) and Babcock (1991). USACE stated no illegal activity could exempt any area from CWA jurisdiction. Once again, the USACE reiterated the rationale originally issued in RGL 90-07. Accordingly, Theis's (1991) and Babcock's (1991) comments on RGL 90-07 remain applicable to the position taken by USACE in 1993.

The USACE acknowledged that although making a technical distinction between wetlands and non-wetlands in agricultural areas is difficult, the manner and rationale used by NRCS in identifying certain areas as prior converted croplands is also a reasonable manner and rationale for determining which such areas are subject to Clean Water Act jurisdiction (U.S. Department of Defense 1993). The USACE acknowledged their method for identifying wetlands varies from that used by NRCS to determine which areas would be considered prior converted cropland and found there may be some cases where the prior converted cropland label would not be consistent with determining whether or not the same resource would be considered waters of the United States. In such cases, the USACE stated the final authority on such determinations remain with the USEPA and USACE. Therefore, the authority for determining Clean Water Act jurisdiction ultimately was not delegated to any other agency. This declaration on final

authority addresses some of the concerns regarding liberal granting of the exemption raised by McElfish and Adler (1990) and Robinson (1993). Contrary to the USACE's assertions on final authority, the observations made by Eggers (1996) suggest areas labeled prior converted cropland are excluded wholesale from CWA permit requirements and that any determination on final authority tends to favor exemption rather than a determination that CWA permit requirements should be asserted.

In order to reduce the number of situations where a prior converted cropland determination would not be consistent with a determination on Clean Water Act jurisdiction, the USACE stated they would expand efforts to provide cross training on wetland identification with NRCS personnel as well as work toward integrating the wetland identification manuals used by each agency (i.e., NRCS's National Food Security Act Manual and the USACE's 1987 Federal Manual for Identifying and Delineating Jurisdictional Wetlands) (U.S. Department of Defense 1993). The USACE acknowledged there may be some cases where NRCS prior converted cropland determinations are inconsistent or unreliable. However, USACE was confident their cross-training and effort toward integrating wetland identification manuals would reduce the number of such cases. It appears then USACE recognized the same problem Risley and Budzik (1988) found regarding inconsistent and unreliable wetland determinations. However, Robinson's (1996) comments suggest the interagency coordination effort

promoted by USACE in 1993 had not been effective when evaluated three years later. While interagency coordination efforts to reduce inaccurate determinations were to be undertaken, no method for a concerned party, outside the cooperating agencies, to challenge an inconsistent or unreliable wetland determination was established. Therefore, Risley and Budzik's (1988) and Robinson's (1996) concern that an improper prior converted cropland determination could stand unchallenged remains a concern.

Finally, in their 1993 findings regarding the elimination of prior converted cropland from the definition of waters of the United States, the USACE found that the abandonment provision of Swampbuster would allow the USACE to assert jurisdiction over those prior converted croplands which clearly exhibit wetland characteristics and which were taken out of agricultural production (U.S. Department of Defense 1993). Therefore, USACE was confident in their ability to re-assert jurisdiction over wetland areas which were labeled prior converted cropland when these areas were no longer in agricultural production. However, in 1996 Congress eliminated the abandonment provision of Swampbuster and subsequently eliminated the USACE's clear ability to recapture regulatory authority over prior converted croplands no longer in agricultural production. This situation may be the cause for some concern as described below by the U.S. Environmental Protection Agency, Office of Federal Activities (1996).

As noted previously, the change to the definition of waters of the United States was followed up with a Memorandum of Agreement (MOA) between the USDA, USEPA, USACE, and USDI establishing the NRCS as the lead agency for wetland determinations in agricultural landscapes (USDA 1994). This MOA reiterated the USACE assertion that USEPA and USACE would defer to NRCS on wetland determinations. However, any final determination on CWA jurisdiction remained with USEPA. Therefore, the effect any prior converted cropland determination would have on CWA jurisdiction ultimately remains up to whether the USEPA and USACE choose to concur with the NRCS wetland determination or choose to assert CWA jurisdiction. As noted previously, the USACE apparently remained confident in their ability to regain CWA jurisdiction where necessary, given that the abandonment provisions in the FSA allowed for the recapture of certain prior converted cropland areas where wetland characteristics return and the site was taken out of agricultural production (U.S. Department of Defense, Department of the Army, Corps of Engineers 1993).

In 1996, FAIRA (1996) amended the Swampbuster provisions of the Food Security Act to eliminate the abandonment clause as it related to prior converted cropland. Accordingly, there is no longer any provision in the law by which a prior converted cropland which reverts to wetland can be re-labeled a more use-restrictive label under the FSA. When this change was made, Congress intended the change would have no effect upon the USEPA's

and USACE's ability to assert CWA jurisdiction as appropriate (U.S. Congress, House 1996). However, in light of their policy which eliminates prior converted croplands from CWA jurisdiction, USEPA expressed some concern that changes to FSA policy regarding abandonment may have an adverse effect on the USEPA's ability to assert CWA jurisdiction when it is required. Specifically, the USEPA requested the USDA establish clear rules which explicitly state the prior converted cropland label is only valid while the subject land is used for agricultural purposes (U.S. Environmental Protection Agency, Office of Federal Activities 1996). This request suggests that USEPA is unclear whether assertion of CWA authority in prior converted cropland areas is legally feasible given the elimination of the abandonment provision in the FSA. If USEPA were unable to assert CWA jurisdiction in cases where it is appropriate, the kind of development described by Eggers (1996) might occur without regulatory review upon cessation of agricultural activity at the site.

Zinn and Copeland (1996) noted that recent legislative proposals intend to elevate the prior converted cropland exemption from 'regulation' to 'congressional intent' by making changes at the legislative level. Two bills, H.R. 961 and S.851, related to Clean Water Act reauthorization were passed in 1995 making it a legislative mandate to eliminate prior converted croplands from the definition of waters of the United States. This elevation is important because judicial decisions made by the courts often rely heavily

upon Congressional intent articulated through mandates when regulatory decisions, based upon regulations or regulatory guidance documents, are challenged in court. These bills also proposed to authorize the USACE to create a nationwide permit specifically exempting wetland conversions which are exempt per Swampbuster from Section 404 of the CWA (Zinn and Copeland 1996). While these bills have made no further progress, a trend toward permanent elimination of prior converted croplands from regulatory oversight is apparent.

Zinn (1997) noted that wetland protection advocates have been critical of the administrative and regulatory changes proposed to Section 404 of the CWA. This criticism is compounded by changes made recently to the Food Security Act by FAIRA (U.S. Congress 1996). The expanded definition of agricultural lands now including pasturelands, rangelands, and tree farms is of most interest because this change substantially expands the quantity of wetlands which may be considered prior converted (Zinn 1997).

At least one state, Pennsylvania, has expanded the federal level effort to provide consistency between the CWA and FSA regarding prior converted croplands to state level wetland policy. The Pennsylvania Department of Environmental Protection has issued a policy statement which provides that prior converted cropland are not subject to the State's Wetland Protection Program (Pennsylvania Department of Environmental Protection 1995). This is evidence federal wetland policy changes are being accompanied by state

level wetland protection policy changes regarding the treatment of areas designated prior converted croplands.

Overall, the Clinton Administration has declared the need and intention to initiate restoration of America's wetlands (U.S. Environmental Protection Agency 1993). Prior converted croplands represent the most likely place to pursue the implementation of that policy and therefore represent a resource deserving protection (Shabman 1991; Holland et al. 1995). Identification of these prior converted cropland resources in advance of urbanization is integral to the success of America's stated policy (Searchinger 1993; Kilborn 1991; Hanson 1987). The structure and implementation of the prior converted wetland exemption in the Food Security Act and the Clean Water Act, however, may hinder the progress of wetland restoration efforts (McElfish and Adler 1990; Robinson 1993; Risley and Budzik 1988). Indeed, some believe the exemption is illegal (Babcock 1991; Theis 1991) and in some cases may be contributing to the urbanization of the resource (Eggers 1996; Reilly 1991). The concerns raised by critics have been addressed in some manner by various public entities (U.S. Department of Defense, Department of the Army, Corps of Engineers 1993; U.S. Congress, House 1996; USDA 1994). However, there is still some concern about the USEPA's and USACE's ability to assert CWA jurisdiction when necessary given changes implemented by FAIRA (1996) (U.S. Environmental Protection Agency, Office of Federal Activities 1996). Furthermore, recent legislative indicators show the prior

converted cropland exemption may become a permanent feature of America's regulatory structure for wetlands (Zinn and Copeland 1996). The scope of the exemption may already be expanded beyond that previously estimated (Zinn 1997). In fact, federal level efforts at harmonizing policy regarding prior converted cropland is expanding to state level wetland policy (Pennsylvania Department of Environmental Protection 1995). While there are studies which explore the prior converted cropland issue at a national level, there are few studies which investigate the implications of this national policy upon restoration plans at the local level.

CHAPTER 3

METHODS

Study Site

This study was carried out within the Watsonville Wetlands Complex, Santa Cruz County, California (Figure 1). This wetlands system includes Gallighan, Harkins, Hanson, West Struve, Struve, and Watsonville Sloughs which drain a 54 square kilometer (21 square mile) watershed (Figure 2). The Watsonville Wetlands Complex is the largest salt, brackish, and freshwater wetland system between Elkhorn Slough in Monterey County and Pescadero Marsh in San Mateo County. The slough complex provides habitat for migratory and resident waterfowl and raptors, as well as numerous aquatic and terrestrial amphibians, reptiles and mammals. Especially notable are habitat areas supporting endangered populations of tidewater goby (*Eucyclogobius newberry*), Santa Cruz long-toed salamander (*Ambystoma macrodactylum croceum*), California tiger salamander (*Ambystoma tigrinum californiense*), California red-legged frog (*Rana aurora draytonnii*), Southwestern pond turtle (*Clemmys marmorata pallida*), tricolored blackbird (*Agelaius tricolor*), black-shoulder kite (*Elanus leucurus*), and Santa Cruz

tarplant (*Holocarpha macradenia*) (AMBAG 1995).

Even though the Watsonville Wetlands Complex currently supports diverse biota, it is considered an impaired ecosystem (AMBAG 1995). The complex is labeled 'impaired' because of the dominant presence of invasive and exotic plant species, land use encroachment upon wetland areas, blanketing of wetland vegetation due to sedimentation, and vegetation removal. As part of planned repairs to wetland function, historically present wetlands will need to be restored.

Restoration of wetland habitat in the Watsonville Wetlands Complex is considered important in order to improve the system's water purification capabilities, increase flood attenuation capacity, and to enhance plant and animal habitats as well as opportunities for human recreation. Such efforts would seek to restore some portion of the large shallow freshwater and saltwater wetland habitat that historical data indicate were once present. Restoration of wetland habitat is considered a major component to efforts to improve water quality within the Watsonville Wetlands Complex watershed (AMBAG 1995).

Research on using prior converted croplands for restoration purposes necessitates study of wetlands located in agricultural landscapes. This study focused upon the Watsonville Wetlands Complex because the watershed is primarily an agricultural wetlands complex. The slough complex was

additionally suited for this study because wetlands are known to have been converted to agricultural purposes prior to 1985 (Lydon 1985). Furthermore, there is a sense of urgency to perform this study because the region is rapidly urbanizing (City of Watsonville 1994) and there is a need to identify restorable wetland areas in advance of such urbanization (AMBAG 1995; Shabman 1991).

This study was conducted within the Watsonville Slough System Watershed Basin as described in AMBAG (1995). The watershed is an appropriate study region as this basin delineates the entire region which may harbor historically present wetland areas hydraulically connected to the contiguous wetland system known as the Watsonville Wetlands Complex. Limiting this research to this watershed basin is also appropriate as the scope of the study matches that analyzed by AMBAG (1995). The AMBAG (1995) study was a broad based documentation of wetland resources and the hydraulic mechanisms of the wetlands complex. The AMBAG (1995) study also analyzed sources of polluted run-off and provided a basic work plan toward a comprehensive wetlands management strategy for the Watsonville Wetlands Complex. This study adds to research previously conducted by AMBAG (1995) by providing mapping of the historical wetland extent of the Watsonville Wetlands Complex. This historical mapping effort and the subsequent identification of areas potentially suitable for wetland restoration

may serve as a component of the Watsonville Slough System Master Plan described by AMBAG (1995).

Study Design

This research was performed in five phases: data collection, data input, data error evaluation and correction, data analysis, and case study evaluation of the data. The source data analyzed included the following: aerial photographs, historical land survey maps, soil maps, a base topographic map, digital elevation models, land use and zoning maps, a ground control point map, and ground truth verification map. Data not already in digital format were input to a computer system through a digital image scanner. Aerial photographic images and historical maps were manipulated at this point to correct distortions and to homogenize the map projection and datum on all data layers. GPS technology was used to collect information about the position of important objects in the field. The GPS data were also used to verify the accuracy of maps created in this study and guided the correction of inaccuracies. Once the data were input and manipulated, prior converted croplands were identified and their planned use cataloged using the analytical capabilities of the GIS. Finally, a case study evaluated the results of the mapping effort.

The use of aerial photography, historical maps, and geographic information systems (GIS) to study changes to wetland systems is well documented in the literature. This study used methods described by Lee and Lunetta (1995). The same methods used in this study were used variously in studies performed by Grossinger (1995); Kuzila, Rundquist, and Green (1991); Lyon and Adkins (1995); McCreary et. al. (1992); Niedzwiedz and Batie (1984); Niemi and Hall (1996); and Welch, Remillard, and Alberts (1992) among others. Grossinger (1995) used a GIS to compile and catalog historical data to reconstruct the historical extent and structure of tidal marshlands in the San Francisco Bay. Sources of information used included historical United States Coastal Survey topographic maps as the primary data source, corroborated by a myriad of historical evidence including maps, photographs, sketches, and written accounts. Kuzila, Rundquist, and Green (1991) successfully used historical soils maps to reconstruct the pre-development wetland landscape of Clay County, Nebraska. Lyon and Adkins (1995) similarly used historical soils maps in combination with aerial photography and a GIS to perform their study of wetland change in St. Clair Flats, Michigan. McCreary et. al. (1992) used some of these same techniques with the addition of city and county land use plans to predict the future use of wetland areas in the San Francisco Bay region. Niedzwiedz and Batie (1984) utilized historical aerial photography as the primary source for reconstructing historical coastal wetland patterns in

Virginia. Niemi and Hall (1996) reconstructed the historical extent of wetlands in Marin County, California through the use of historical cartographic data. Finally, Welch, Remillard, and Alberts (1992) use aerial photography, a GIS and a global positioning system (GPS) to study wetland change on Sapelo Island off the Georgia coast. The GPS was used as a primary means of collecting ground control points and as a means of ground-truthing.

Data Collection and Preparation

Data for this research were gathered from aerial photography, compilation of digital maps and digitization of paper maps, data collection in the field and through a literature review.

In order to provide a framework on which to build a geographic information system (GIS) database, it was necessary to obtain a digital base map of the Watsonville Wetlands Complex watershed. The base map used was a digitized portion of the U.S. Geological Survey 7.5 minute topographic quadrangles identified as Watsonville West (U.S. Department of the Interior, Geological Survey 1980), Watsonville East (U.S. Department of the Interior, Geological Survey 1993a) and Moss Landing (U.S. Department of the Interior, Geological Survey 1994). In addition, a map of field verified ground control points was constructed using a global positioning system (GPS). Road intersections and other structures were used as these ground control points.

Aerial photographs from 1931, 1985 and 1994 were collected, digitized and registered to ground control points on the base map. The historical survey maps, soil maps, and land use maps were also registered to the base map.

Base Map and Ground Control Point Collection and Processing

A base map provided the framework upon which to organize and create map layers within a geographic information system. The base map established the general geographic vicinity in which data were collected and it established the map projections and datum to be used in the database. In this study several digital, georeferenced United States Geological Survey (USGS) 7.5 minute topographic quadrangle maps were used as the base map. Three map quadrangles, Watsonville West, Watsonville East, and Moss Landing, provided coverage for the entire study area. These maps were available in digital format from the map publisher in a format called a digital raster graphic. The projection for this digital base map is the Universal Transverse Mercator (UTM) map projection for zone 10. The datum is the 1927 North American Datum (NAD). Features on this map included topography, roads, railroads, waterways, buildings, political boundaries, and land survey lines (i.e., township range and land grant lines). The published accuracy of these maps are ± 12 meters. Data collected in this study were registered to this base map by identifying common features or points (ground control points)

between the base map and target data layer, such as a road intersection or building, that could be used to link information in the data layers to one another.

A second, more accurate ground control point (GCP) map was also constructed. Features such as road intersections, railway intersections, buildings, and water storage towers common among the data layers being prepared were identified. Upon visitation, the latitude and longitude of the features were obtained using a global positioning system (GPS). The equipment used was a Trimble GeoExplorer II Global Positioning System hand-held data collector. Field visits occurred on January 30, January 31, February 4, February 22, February 27, February 28, March 1, and March 2, 1998.

A data dictionary was designed to aid in the collection of those points. Several categories of point types were outlined including road intersections, structures, water tanks, water courses, water pumps, and miscellaneous other intersections. A point collected at each type of intersection could have an attribute showing the position within the intersection where the point was collected, including northwest, northeast, southwest, southeast, or centerline of intersection. In total, 70 points were collected throughout the 54 square kilometer (21 square mile) watershed. These 70 points provided the minimum quantity of reference points necessary to perform the geometric transformation of the images used in this study (MicroImages, Inc. 1997).

Data collected without correction using the Trimble GeoExplorer II may have a positional accuracy of between ± 30 to 100 meters. This means the latitude and longitude obtained for a target object by the Trimble GeoExplorer II is accurate within ± 30 to 100 meters of the actual latitude and longitude of the target object. Sources of error include inaccurate satellite clocks, atmospheric interference with the satellite signal, multi-path errors (signal reflection off nearby objects), receiver errors, and errors due to selective availability (an error intentionally introduced to the satellite signal by the United States Department of Defense) (Hurn 1993). In order to increase the degree of accuracy of the data collected, a process called differential correction was used. During collection of data using the hand held Trimble GeoExplorer II, data were also collected at a second stationary GPS, otherwise known as a GPS base station, located at the California State University, Monterey Bay. The stationary GPS has a known location, calculated using highly accurate surveying techniques. Using the stationary location as a reference point, a data correction factor was calculated and used to factor out any errors introduced to the data.

The data collected from January 30, 1998, through March 2, 1998, were downloaded from the Trimble GeoExplorer II to a personal computer. In addition, data collected by the stationary GPS were transferred to the same personal computer. These data were then imported into Trimble Pathfinder,

a software package designed to perform differential correction. Using the Trimble Pathfinder software, the differential correction was performed. Upon completion of the differential correction, the data, based upon estimates by Trimble Navigation, are spatially accurate to within ± 2 to 5 meters of the actual position. Upon completion of the differential correction, a ground control point map was created using the newly corrected data.

Obtaining ground control points using GPS was limited in this study by the data collector's ability to visit a particular location, by technical limitations, and by time and access to equipment. A majority of the study area is in private ownership and not accessible without landowner authorization. The scope of this study did not include a systematic request for authorization from individual property owners. Accordingly, collection of ground control points was primarily limited to publicly accessible locations. However, in some instances, access to private land was granted by the tenant or landowner. In addition, site conditions at some ground control locations prevented proper operation of the GPS. In some locations, the presence of tall trees or a closed tree canopy interfered with the signal transmitted by the GPS satellite network. Therefore, collection of the ground control point was not possible. With these limitations, as well as time and access to equipment, 70 points were collected. Although additional points would have improved the overall spatial accuracy of the maps used to identify wetlands, this quantity of

points was adequate to perform the required geometric transformation of the images and maps. Improved spatial accuracy of the maps would not have changed the outcome and conclusion of this study.

Aerial Image Collection and Processing

At least one set of aerial images covering the Watsonville Wetlands Complex watershed was located for 1931, 1985 and 1994. Special effort focused upon gathering image sets which were taken during the same time of year and preferably during the wet season.

Seventy-two black and white aerial photographs total were identified for the years 1931, 1985 and 1994 in the Map Collection of the McHenry Library at the University of California, Santa Cruz. Thirty-two photographs were taken by Fairchild Aerial Surveys, Inc. on May 27, 1931 (Fairchild Aerial Photography Collection 1931). Twelve photographs were taken by W.A.C. Corporation on April 12, 1985 and April 13, 1985 (W.A.C. Corporation 1985). Twenty-eight photographs were taken by Air Flight Service on June 22, 1994 (Air Flight Service 1994). In addition, a set of sixteen color aerial images were obtained from the library of the Elkhorn Slough Foundation. These photographs were taken by the National Ocean Service, National Geodetic Survey on March 7, 1994 (National Ocean Service 1994). The characteristics of

these photographs including the scale, elevation, print size and type are included in Table 1.

Each of the eighty-eight photographic prints was scanned into digital format using an image scanner and desktop personal computer. The scanner used was a Hewlett Packard ScanJet 4C. The software used to perform the scan was Hewlett Packard DeskScan II v2.4. The photographic prints were scanned at resolutions ranging from 220 to 400 dots per inch (DPI). Resolution was selected based upon a balance between the detail visible at a particular resolution and the quantity of space available to digitally store the image. Each digital image was stored as a Tagged Image File Format (TIFF) version 5.0, 16 bit file with no compression.

Digital processing of digitized aerial photographs. A map is "[a] representation of the surface of the earth, or of some portion of it, showing the relative position of the parts represented; -- usually on a flat surface" (Webster 1998, 765). The aerial photographs collected lacked the qualities of a map because they did not show "the relative position of the parts represented." In order to create a single map from each set of aerial photographs, several processes occurred. First, the relative location with respect to the earth's surface, or latitude and longitude, of the elements in the image were located. Second, distortions due to relief displacement were

removed from the image. Images produced using aerial photography are often affected by terrain and tilt distortions. Terrain distortions are caused by changes in topography resulting in radial displacement away from the center of the photograph. Tilt distortions are caused by changes in camera angle (Bolstad and Smith 1995). Using photogrammetric principles and digital image warping mathematical algorithms, these displacements were corrected in digital images. Third, the individual photographs were mosaicked to form a single image.

The digitized aerial photographs were imported into a computer software package called TNTmips® by MicroImages, Inc. of Lincoln, Nebraska. TNTmips® is a Geographic Information System (GIS) capable of manipulating raster and vector data.

Georeferencing. Georeferencing is the process of linking features visible on the digital photograph to real world coordinates, or ground control points. Georeferencing was performed, both to provide real world coordinates for the digital images, as well as to provide ground control necessary to perform the digital image warping required to remove distortions from the digitized photographs. TNTmips® Professional software was used to accomplish this process. A minimum of three points on each image were georeferenced to ground control points collected using GPS. In

some cases, if more than three points collected using the GPS were available, more than three points were utilized. As many as 30 control points were georeferenced on each photograph. The balance of ground control points used for georeferencing were obtained from the USGS topographic quadrangle base map.

Digital image processing (warping). After the digital images were georeferenced, the images were transformed into maps with a map projection and coordinates. The transformation occurred in two steps, orthorectification and piecewise affine transformation. These processes were implemented using TNTmips® Professional software.

Orthorectification is a process which uses photogrammetric principles and digital image warping mathematical algorithms to remove image distortions. Variables that describe the photogrammetric properties of each digital image must be obtained and input to the orthorectification module in TNTmips®. These properties include the focal length of the camera used to obtain the photograph and the pixel cell address of the principal point of the photograph.

In addition, a digital elevation model containing information about the topography (i.e., elevation) of the study area is required. A digital elevation model of the study area was constructed using two sources: airborne

side-looking aperture radar (SLAR) data, and USGS digital elevation models. Airborne SLAR data is information collected about topography using a radar imaging device mounted on an airborne platform (i.e., airplane). Radar signals are emitted from the transmitter toward the earth. These signals are then reflected back to a receiver. A calculation is performed giving the elevation of the reflected object. The SLAR data used in this study had a resolution of 1.5 square meters (i.e., an elevation was recorded for every 1.5 square meters of surface encountered by the radar signal).

Since the SLAR data available did not provide coverage for the entire study area, a second source of information on topography was required. This second source was provided by a USGS 7.5 minute digital elevation model. In this case, the 7.5 minute Watsonville West digital elevation model was used. These data were produced using a variety of automated photogrammetric instruments as well as through manual photogrammetric techniques. The resolution of these data are 30 square meters (U.S. Department of the Interior, Geological Survey 1993b).

A mosaic of the SLAR data and USGS 7.5 minute digital elevation models was created using the Mosaic process in TNTmips®. During this process, the USGS data was resampled to match the higher resolution SLAR data. This process did not increase the actual resolution of the USGS 7.5 digital elevation model. It only created a data layer with uniform cell size.

Using the newly prepared digital elevation model, the orthorectification process was run on the digitized, georeferenced, aerial images from 1931, 1985 and 1994. Upon completion of the process, the images were examined for irregularities which may have been introduced to the image during the orthorectification process. If an image showed any unusual deformities, the input parameters such as the georeferencing, camera focal length, and location of the principal point were reexamined. Additional ground control points were added where feasible. The orthorectification process was then run again on the source image using the updated parameters.

Upon completion of the orthorectification process, the images were reexamined for conformity with real world coordinates. This was accomplished by comparing the location of the ground control points collected with the GPS to their anticipated position within the images. In some cases, the ground control points did not occur in the anticipated position within the images. Through trial and error, it was discovered that running the piecewise affine image warping transformation algorithm was successful at increasing conformity between the ground control points and their anticipated position within the images. A piecewise affine transformation was utilized on all the images processed using the orthorectification process.

Since distortions in images taken from vertical platforms tend to increase as one moves away from the principal point (center point) of the image, the central portion of an image will tend to have less distortion. The images used as data sources in this study were stereopairs with overlapping coverage. In order to reduce the opportunity for distortion in the aerial image mosaic, the most central portion of each image was extracted for use in the mosaic. This was accomplished using tools within TNTmips® software designed for this purpose.

Upon completion of the orthorectification, piecewise affine transformation, and central image portion extraction, the images were mosaicked into single image maps using the mosaic process in TNTmips®. The accuracy of the aerial image maps for 1985 and 1994 are reported in Tables 2 through 4 (see also Error Evaluation in this chapter). These completed aerial image maps were utilized to identify wetlands within the study area.

Historical Map Collection and Processing

In order to identify the presence of wetlands prior to 1931, historical maps of the study area were collected, digitized, and transformed into maps compatible (i.e., having the same projection and coordinate system) with the base map. Information present on the maps which likely represented

wetland area were then digitized to create a map of wetlands present at the time the map was compiled.

A collection of maps of the study area was identified at the County of Santa Cruz Assessor's Office. This collection was reviewed to identify those maps which contained information indicating the presence of wetlands, had information that could be used to georeference the map to the base map and provided coverage for the entire study area.

The most complete map set identified was a County survey performed by Wright, Bennett, and Healy (1881a, 1881b, 1881c, 1881d, 1881e, 1881f, 1881g, 1881h). These maps clearly showed the outline of wetland areas with notations identifying the area as "slough" or "marsh." In addition, these maps contained clear information such as township-range survey lines, roadways, and property boundaries which could be used for georeferencing. The maps were original prints, paper on cloth, hand-drawn ink. Furthermore, this map set provided complete coverage of the study area.

A second map source identified included rancho land grant survey maps compiled in the 1860's. These maps were not compiled by the same surveyors but did represent a common theme, contained the requisite information regarding wetlands and contained information common with the base map that could be used for georeferencing. The rancho survey maps also provided complete coverage of the study area, but no single map or set of

maps (prepared by the same surveyor) could be located which covered the entire study area. In addition, the land grant survey maps did not consistently depict drainage or wetland areas. Therefore, the rancho maps do not provide a complete, synoptic view of wetland extent in the 1860's. Accordingly, the maps were utilized only as reference to corroborate the results from Wright, Bennett, and Healy (1881a, 1881b, 1881c, 1881d, 1881e, 1881f, 1881g, 1881h).

The maps were scanned into digital format using a large format OCE 7700 binary scanner and printer running OCE 7700 Upload Application version 1.1 software. The digital files were essentially images of the source map, similar in format to the photographic images. As images, these source maps were transformed into maps with modern coordinate systems using the same kinds of image warping algorithms used to transform the photographic images into a map. The map image files were imported into TNTmips® Software for processing including georeferencing and transformation.

Georeferencing. Georeferencing was accomplished using the ground control point map created from the points collected by global positioning system. Additional ground control was provided by the USGS topographic quadrangles. Once georeferenced, the maps were projected into Universal Transverse Mercator, zone 10 using the 1927 North American Datum. This

was first accomplished using a plane projective transformation. Then, the newly projected maps were compared to the ground control reference points. Since some error was identified, the piecewise affine transformation was used to decrease error. Upon completion of this process the maps were found to be substantially compliant with the ground control reference points. However, errors were still present. Possible error sources include errors by the original surveyors, warping of the source map media (i.e., stretching, contracting, folding, etc.), warping of the image during scanning, inaccurate georeferencing, and limitations of the image warping algorithms.

Since the map sets included several maps, the maps were mosaicked into a single map using the TNTmips® mosaic process. Based upon this map, a second map showing only wetland areas was created. Symbols including outlines, along with notes printed on the map, indicated where wetlands occurred. These areas were digitized to create the wetland-only map (Figures 3 and 4). The accuracy of these maps is reported in Tables 2, 5 and 6 (see also Error Evaluation in this chapter).

Reliability of selected historical maps as a data source. Drainage and cultivation of wetland area within the Watsonville Wetlands Complex was not documented until the late 1880's, when a shortage of cultivatable land was experienced and drainage of such areas became economically prudent.

The Pajaro Valley and vicinity, within which the Watsonville Wetlands Complex occurs, became known to European colonists in 1769, when Don Gaspar Portola's land expedition entered the valley in that year. The first mission in the area, while not within the immediate boundaries of the Pajaro Valley, was established in 1791 at Santa Cruz. Within ten years, the pueblo Branciforte was established across the San Lorenzo River from Mission Santa Cruz and a second mission was established at San Juan Bautista. In addition to the Monterey Presidio, founded in 1770, each of these establishments utilized some portion of the Pajaro Valley as pastureland for cattle, horses, sheep and other livestock. The Monterey Presidio and Mission Santa Cruz utilized areas within the study area in the vicinity of Corralitos Creek. Cultivation was limited to sustenance and largely occurred adjacent to the settlements, which were outside the study area. An abundance of rangeland and absence of settlement within the study area would largely preclude any need to convert wetlands for human use at that time (Hornbeck 1969).

Mexican independence from Spain in 1822, the Mexican Colonization Act of 1824 and the Secularization Act of 1833 brought about the rise of the Mexican rancho land grants in the region. Between the 1820's and 1840's, portions of the study area were divided into four ranchos: Bolsa del Pajaro, Los Corralitos, San Andres, and Laguna de Las Calabasas. These ranchos were settled by the rancho owner's family and, in some cases, by lessee's of the

rancho. However, the settlers continued to use their land to raise livestock during this period. Accordingly, cultivation of the land was largely limited to sustenance purposes (Hornbeck 1969). Pastureland and cultivatable land were still in abundance and precluded any large scale need to drain wetland areas for human use.

Mexican control of the region shifted to the American government in the late 1840's. Between 1850 and the 1880's the Mexican rancho system was gradually dismantled through legislative action. As a result, the large Mexican rancho holdings were divided into smaller parcels owned by individual American settlers or leased by immigrant laborers. Other factors, including the elimination of laws which favored ranching, a population influx from displaced gold miners and immigrant laborers and local improvements in shipping technology such as the construction of a narrow gauge railway in 1876 between the towns of Santa Cruz and Watsonville led to a shift from a ranching to a cultivation-based economy. The first documented large scale cultivation for economic gain occurred in the early 1850's. From the 1850's to the 1880's, cropping intensified from grain crops which did not require intense cultivation efforts to more intensive crops including flax, hops, apples, tobacco, pumpkins, cucumbers, and strawberries (Atkinson 1935, Hornbeck 1969, U.S. Department of Agriculture 1910).

The first documented conversion of wetland for agricultural purposes in the study area occurred in the late 1880's and early 1890's. During this period American landowners and Chinese farm workers established an arrangement by which Chinese farm workers would drain and farm wetland areas in exchange for a four or five season no-cost lease from the landowner. Accordingly, the Chinese farm worker could cultivate a crop, typically strawberries, with no land cost and the landowner would gain newly drained farmland upon conclusion of the lease. These kinds of arrangements occurred particularly in Struve and Hanson sloughs (Lydon 1985).

It has been historically documented that large scale agricultural production did not occur in the study area until the latter part of the 1800's. Furthermore, the earliest documented wetland conversions occurred in the late 1880's and early 1890's. Therefore, the maps of the study area produced by Wright, Bennett, and Healy (1881a, 1881b, 1881c, 1881d, 1881e, 1881f, 1881g, 1881h) depict a period in time prior to the conversion of wetland areas for human use.

Soil Map Collection and Processing

A soil survey conducted by the U.S. Department of Agriculture was identified which covered the study area (U.S. Department of Agriculture, Soil Conservation Service 1980). The maps and associated data from this survey

were available in digital format. These data were obtained and transformed to match the projection and datum of the other data layers used in this study. TNTmips® was used to perform this transformation.

Land Use Map Collection and Processing

The study area is within unincorporated Santa Cruz County and within the limits of the City of Watsonville. Land use maps were obtained in digital format from these local governments (City of Watsonville 1994, County of Santa Cruz 1994). The data were imported to TNTmips® and transformed to match the projection and datum used in this study.

The land use designations within each local government's jurisdiction were compatible but not identical. For instance, the County of Santa Cruz land use plan (1994) designates important environmental resource areas as "Resource Conservation" while the City of Watsonville's land use plan (1994) designates these areas as "Environmental Management." Similarly, the County of Santa Cruz has four gradations to identify urban residential areas ranging from "Urban Residential, Very Low Density" to "Urban Residential, High Density," while the City of Watsonville only has three gradations ranging from low to high density. In order to simplify the analysis, compatible land use designations were assigned a more generic, all-inclusive descriptive land use designation. For instance, the County of Santa Cruz land

use plan designation for "Resource Conservation" and the City of Watsonville's land use plan designation for "Environmental Management" were combined to form the "Environmental Management" designation used in this study. Assignment of city and county land use designations to this study's generalized land use designation is detailed in Table 7.

Creation of Wetland Probability Map

Limited resources for this study required the use of photography which could be obtained at no charge. As a result, with the exception of some photographs available for the year 1994, only black and white photographs were available. In addition, the selection of photograph scale was limited. Since mapping from black and white photographs can be difficult, a predictive model was created to identify the most reasonable location for wetlands to be present. Five parameters were used to construct the model including slope, elevation, soil type, soil clay content, and soil drainage.

In order to create this model, several maps were constructed. A slope map was constructed by interpolating the slope using elevation values in the digital elevation model. Elevation was provided in the digital elevation model. The soil survey map was used to identify soil type. Soil clay content and drainage characteristic maps were generated from data available in the soil survey map.

Using the information in these maps, a probability map was constructed identifying those areas where conditions would be most conducive to wetland development with gradations toward those areas least likely to have wetland conditions. The model parameters for the areas most likely to have wetland conditions were areas with low elevation, less than a 2% grade, hydric soils (as defined by the U.S. Department of Agriculture 1991), soils with high clay content, and soils with poor drainage. Areas least likely to have wetland conditions were those areas at higher elevation, more than a 2% grade, non-hydric soils, soils with low clay content, and soils with good drainage. This probability map was then used as a guide during visual identification of wetland areas on the aerial images.

The methodology used by the Natural Resources Conservation Service to identify agricultural wetlands and former agricultural wetlands, including prior converted cropland, is established in the National Food Security Act Manual (NFSAM) (U.S. Department of Agriculture, Natural Resources Conservation Service, Conservation and Ecosystem Assistance Division 1996). Additional refinements, developed to accommodate regional variations in wetland habitat types, are found in California Inter-Agency Mapping Conventions for Waters of the United States (i.e., Mapping Conventions) (USDA et al. 1994b). The NFSAM and Mapping Conventions allow for off-site determinations regarding the presence or absence of

agricultural wetlands. On-site determinations are required when necessary documentation is not available and when other circumstances necessitate an on-site determination. Acceptable documentation for off-site determinations include aerial photographs at a scale of 1:12,000 or less, climate and hydrologic data, and a Soil Conservation Service soil survey. Additional documentation recommended include U.S. Fish and Wildlife Service National Wetland Inventory maps, U.S. Geological Survey maps and topographic surveys, and other information as available.

The methodology utilized in this study to identify prior converted cropland areas is based upon, but does not precisely replicate, the methods established by the USDA. Limitations including cost and availability prevented use of 1:12,000 scale photographs. However, wetland areas and evidence of cropping were clearly visible on the 1:15,840 to 1:31,680 scale photographs used in this study. In addition, a Soil Conservation Service soil survey, digital topographic data prepared by the U.S. Geological Survey, and historical maps were used as a basis for prior converted cropland identification. Furthermore, U.S. Fish and Wildlife Service National Wetland Inventory maps were referred to in confirming the presence and location of agricultural wetlands.

Creation of Wetland Map

Wetland habitat areas were mapped for 1931, 1985, and 1994 using the aerial image maps created as part of this study (Figures 5 and 6). Wetland habitat visible on the aerial images was identified using image interpretation methods based upon recognition of pattern keys, such as tone, pattern, mottling, site, shape, and size. Visual identification was aided with the wetland habitat probability map created as part of this study. The probability map masked terrain unlikely to harbor wetland habitat. A visual inspection of the terrain filtered out by the probability map was performed to confirm the validity of the masking. Corrections were made as appropriate.

Since the goal of this study was to identify historical wetland habitat in the context of a policy analysis, attention was not focused upon the kinds of wetland habitat present. Areas were either designated wetland or not given a designation. The kinds of wetland present ranged from salt to fresh water inclusive of shallow flats to open water.

The wetland maps produced for the years 1985 and 1994 were utilized in the data analysis. However, the wetland map produced for the year 1931 was not used in the data analysis. This map was instead used to corroborate observations made about the presence of wetlands in 1881 and 1908 and the state of agricultural production in the region in the early 1900's. Therefore, no results are reported based upon the 1931 wetland map.

Miscellaneous Reference Sources

In order to corroborate the presence and location of historical wetland areas, several additional sources of information were referenced. These sources include historical soil surveys published in 1910 (U.S. Department of Agriculture 1910) and 1944 (U.S. Department of Agriculture 1944), U.S. Fish and Wildlife Service National Wetland Inventory maps, a historical U.S. Geological Survey topographic quadrangle (U.S. Department of the Interior, Geologic Survey 1912), a U.S. Coast and Geodetic Survey map (U.S. Department of Commerce and Labor, Coast and Geodetic Survey 1910), and several miscellaneous maps from the County of Santa Cruz Assessor's Office. Selected maps were scanned, georeferenced, and transformed to match the projection and datum used in this study. Others were already available in digital format. These maps were referenced but not directly used to generate the data upon which the findings of this study are based.

Error Evaluation

Errors using GIS mapping technology which could occur in this study include two forms; positional and attribute. Positional errors are those which create a difference between the actual versus mapped location of features, such as roads and structures. Positional errors occur during field

measurement are part of source maps, are generated during the digitizing process, occur during coordinate registration, and are an inherent part of imagery due to the function and operation of equipment used to obtain the images. Attribute errors are essentially labeling errors, such as mislabeling non-wetland areas as wetland areas in the GIS database. Fortunately, errors can be measured to determine how they influence data outcome (Bolstad and Smith 1995).

The positional accuracy of the maps constructed in this study was evaluated using a root mean-square error analysis (RMSE). RMSE analysis is a commonly used statistical evaluation of the average positional accuracy of any single point within a map based upon an average of the calculated accuracy of several selected points within the map (Bolstad and Smith 1995). The error is calculated by comparing the coordinates of an object read from the subject map (sample coordinate) with the actual coordinates of that same object (reference coordinate). In this study, the reference coordinates of the selected objects were obtained by visiting the target objects in the field and collecting the coordinates of those objects using a GPS with differential correction capability. The RMSE is calculated by obtaining the difference between the sample and reference coordinate. The difference is calculated in both the X coordinate direction (rms_x) and the Y coordinate direction (rms_y). The calculations are as follows:

$$rms_x = \sqrt{\frac{X^2}{n}}$$

$$rms_y = \sqrt{\frac{Y^2}{n}}$$

where $X^2 = dx_1^2 + dx_2^2 + dx_3^2 + \ldots dx_n^2$

dx = the difference in the X coordinate direction: $X_{reference} - X_{sample}$

where $Y^2 = dy_1^2 + dy_2^2 + dy_3^2 + \ldots dy_n^2$

dy = the difference in the Y coordinate direction: $Y_{reference} - Y_{sample}$

n = the number of points sampled

The overall accuracy of the map may be expressed as the RMSE of planimetry (rms_p) and is calculated:

$$rms_p = \sqrt{[(rms_x)^2 + (rms_y)^2]}$$

Errors were evaluated by comparing the coordinates of selected objects depicted on the newly constructed maps with the coordinates of the same objects obtained in the field using GPS technology. Upon completion of data

input to the GIS, coordinates of map features were calculated using GIS analysis. These coordinates were then compared to positional information collected about those same map features in the field using a GPS. The coordinate collected by the GPS was assumed to be the "actual" position of the target object. The difference between the GIS calculated feature location and actual feature location was then calculated. The resulting values were analyzed using a root mean-square error (RMSE) analysis. The resulting error value was reported (Tables 2 through 6) (Bolstad and Smith 1995).

Attribute error, wetland mis-identification in this case, was also tested using GPS technology. In this study, since all data analyzed were historical in nature, it was not possible to make direct comparisons between information observed in the field and information extracted from the historical data sets. As an alternative, the probability model was tested for accuracy in the field since the probability model was used to guide identification of wetland areas. The coordinate locations of wetland features were downloaded to the GPS receiver. The GPS was then used to guide field personnel to the expected wetland locations. Two questions were answered for each location tested: based upon observation 1) are wetland conditions now present?; 2) given site conditions (e.g., topography) and proximity to existing wetlands, is there a high, medium, or low probability of historical wetland presence? The results are noted and reported in Table 8 (Bolstad and Smith 1995).

Data Analysis

Data compiled depicting the quantity of wetland habitat historically present, and the quantity of wetland habitat present in 1985 and 1994 were used to construct maps depicting potential prior converted cropland and the planned use of those areas based upon county and city land use plans. An overlay analysis was used to generate these maps as well as to produce basic descriptive statistics, such as acreage, of the wetland present in each data layer.

Potential prior converted cropland was identified using two historical information sources as the historical wetland baseline. These sources were Wright, Bennett, and Healy (1881a, 1881b, 1881c, 1881d, 1881e, 1881f, 1881g, 1881h) and Lewis (1908).

Wetlands which were converted prior to December 23, 1985 were identified by using the overlay capabilities of the GIS. This overlay analysis produced the following data: quantity of historical wetland habitat, quantity of wetland habitat in 1985, quantity of wetland habitat in 1994, change in the quantity of wetland habitat between the pre-development period and 1985 (prior converted cropland), the change in the quantity of wetland habitat between 1985 and 1994, and quantity of converted wetland planned for future development.

These data were then interpreted qualitatively through a case study of the impact of the prior converted cropland exemption upon restoration plans for the Watsonville Wetlands Complex. The purpose was to understand how many acres of prior converted cropland exist, how many of those acres had been developed or plan to be developed, and how many acres of prior converted cropland remain in agricultural production which may be potentially restored to wetland habitat. The impact of the prior converted cropland policy was then analyzed through an explanation of how many acres of former wetland habitat may be subject to the exemption. This information provided an understanding of how the exemption may affect efforts to restore the Watsonville Wetlands Complex.

CHAPTER 4

RESULTS

The implications of the prior converted cropland exemption upon restoration plans for the Watsonville Wetlands Complex were analyzed using quantitative and qualitative methods. Quantitative methods involved obtaining information about the quantity of wetlands in the study area present at selected intervals. In addition, information was obtained and used to generate the quantity of wetlands subject to particular types of land use in the study area. A geographic information system (GIS) was used as a tool to catalog, manipulate, and interpret the data. An overlay analysis using the GIS revealed the quantity of prior converted cropland present in the slough complex and the planned use for those areas. These data were interpreted next through a qualitative case study of how the prior converted cropland exemption may shape the use of prior converted cropland in the watershed.

Quantity of Wetland Converted Prior to 1985

Two primary sources of information were used to identify the pre-development quantity of wetland habitat. These sources include historical

maps dated 1881 and 1908. The total area of wetland depicted on the maps by Wright, Bennett, and Healy (1881a, 1881b, 1881c, 1881d, 1881e, 1881f, 1881g, 1881h) is 415 hectares (1,026 acres) (Figure 3). The total quantity of wetland depicted on the map by Lewis (1908) is 480 hectares (1,187 acres) (Figure 4).

Quantity of Wetland Converted: 1985 to 1994

Evaluation of aerial photography showed there were 202 hectares (500 acres) of wetland present in 1985 (Figure 5).

A comparison between the pre-development landscape and wetlands present in 1985 provided information on the quantity of converted wetland within the Watsonville Wetlands Complex. The wetland areas depicted on the maps by Wright, Bennett, and Healy (1881a, 1881b, 1881c, 1881d, 1881e, 1881f, 1881g, 1881h) showed that 255 hectares (629 acres) of a total of 415 hectares depicted may be considered converted wetland (Figure 7). The wetland areas depicted on the map by Lewis (1908) revealed that 334 hectares (826 acres) may be considered converted wetland (Figure 8).

Using each individual source of data as a baseline, the change in the quantity of wetland present between 1985 and the pre-development landscape, using Wright, Bennett, and Healy (1881a, 1881b, 1881c, 1881d, 1881e, 1881f, 1881g, 1881h) is –213 hectares (-526 acres). Using Lewis (1908) as the

baseline the change between pre-development and 1985 is -278 hectares (-687 acres).

Evaluation of aerial photography showed the quantity of wetland habitat in the Watsonville Wetlands Complex increased between 1985 and 1994 from a total of 202 hectares (500 acres) (Figure 5) to 264 hectares (652 acres) (Figure 6). This is an increase of 62 hectares (153 acres).

Uses of Converted Wetland Based Upon General Plans

The current zoned land uses of prior converted wetlands were quantified using these City of Watsonville General Plan (1994) and Santa Cruz County General Plan (1994) land use categories: Environmental management, Agriculture, Residential - rural, Public facility/infrastructure, Residential - urban, Commercial, Industrial, Specific plan area, and Coastal zone (see Table 7 for land use designation grouping).

Using the maps produced by Wright, Bennett, and Healy (1881a, 1881b, 1881c, 1881d, 1881e, 1881f, 1881g, 1881h) and the Santa Cruz County Land Use Plan (1994) the zoned uses of prior converted wetlands and area used are as follows (Figure 9, Tables 9 and 10): Environmental management - 11 hectares (27 acres); Agriculture - 182 hectares (450 acres); Residential - rural - less than a hectare (less than an acre); Public facility/infrastructure - 16 hectares (40 acres); Residential - urban - 0 hectares (0 acres); Commercial - 0 hectares (0 acres);

Industrial- 0 hectares (0 acres); Specific plan area - 0 hectares (0 acres); and Coastal zone - 0 hectares (0 acres). There were 69 hectares (170 acres) of converted wetland habitat which were not given any land use designation by the Santa Cruz County Land Use Plan (1994).

The same analysis using the City of Watsonville Land Use Plan (1994) produced the following results by category (Figure 10, Table 9 and 11): Environmental management - 129 hectares (320 acres); Agriculture - 34 hectares (84 acres); Residential - rural - 0 hectares (0 acres); Public facility / infrastructure - 15 hectares (38 acres); Residential - urban -23 hectares (56 acres); Commercial -6 hectares (16 acres); Industrial -5 hectares (13 acres); Specific plan area - 36 hectares (89 acres); and Coastal zone - 2 hectares (5 acres). There were 13 hectares (31 acres) of converted wetland habitat which were not given any land use designation by the City of Watsonville Land Use Plan (1994).

Converted wetland habitat identified using the maps produced by Lewis (1908) and the Santa Cruz County Land Use Plan (1994) produced the following results by category (Figure 11, Tables 9 and 12): Environmental management - 25 hectares (61 acres); Agriculture - 223 hectares (550 acres); Residential - rural - 0 hectares (0 hectares); Public facility / infrastructure - 26 hectares (64 acres); Residential- urban - less than a hectare (less than an acre); Commercial - 0 hectares (0 acres); Industrial - 0 hectares (0 acres); Specific plan

area - 0 hectares (0 acres); and Coastal zone - 0 hectares (0 acres). There were 86 hectares (210 acres) of converted wetland habitat which were not given any land use designation by the Santa Cruz County Land Use Plan (1994).

Comparison of the City of Watsonville Land Use Plan (1994) and the Lewis (1908) maps produced the following results by category (Figure 12, Tables 9 and 13): Environmental management - 140 hectares (340 acres); Agriculture - 39 hectares (96 acres); Residential - rural - 0 hectares (0 acres); Public facility/infrastructure - 25 hectares (62 acres); Residential - urban - 26 hectares (65 acres); Commercial - 10 hectares (24 acres); Industrial - 9 hectares (21 acres); Specific plan area - 65 hectares (160 acres); and Coastal zone - 1 hectares (3 acres). There were 31 hectares (76 acres) of converted wetland habitat which were not given any land use designation by the City of Watsonville Land Use Plan (1994).

USDA Designation of Prior Converted Cropland

As described in the limitations section of this study, a very specific methodology has been constructed by the USDA to identify areas which can be designated prior converted croplands. In as much, the USDA is the only entity authorized to make a regulatory determination as to whether an area is a prior converted cropland. Thus, the methods of this study do not give the

regulatory boundaries of prior converted cropland in the Watsonville Wetlands Complex.

The methods of this study identify areas which might be, but are not necessarily, designated prior converted cropland. Thus, the result is a population of areas which might be considered prior converted cropland. If USDA were requested to make wetland determinations on all agricultural lands within the study area, it is probable those areas identified as converted wetlands in this study would also be identified by the USDA as prior converted cropland.

CHAPTER 5

DISCUSSION

Quantity of Wetland Converted Prior to 1985

The maps from 1881 and 1908 were compared to the map of the wetland areas constructed for 1985 (Figures 7 and 8). The comparison indicated there had been a loss of wetland habitat in the Watsonville Wetlands Complex during the study period. Based upon the quantity of wetland areas depicted on the maps by Wright, Bennett, and Healy (1881a, 1881b, 1881c, 1881d, 1881e, 1881f, 1881g, 1881h) showing 415 hectares and Lewis (1908) showing 480 hectares, in 1985 there were between 255 hectares and 334 hectares, respectively, of converted wetland in the Watsonville Wetlands Complex. Using this information, it was evident that between 61% and 70% of the total quantity of former wetland areas depicted on the historical maps used in this study were converted before December 23, 1985.

The loss of wetland habitat observed in this study was consistent with the findings of more generalized estimations of wetland losses statewide and nationwide prepared by Dahl (1990), Dahl and Johnson (1991), Dahl, Young, and Caldwell (1997), and Dennis and Marcus (1984). These authors variously

estimate wetland habitat losses of approximately 50% nationwide and 90% statewide.

Wetlands identified as historically present in this study were contiguous with currently existing wetland habitat. In addition, the location and extent of the wetland areas identified on the historical maps was consistent with the location and extent of hydric soils identified on maps of soil type produced by the U.S. Department of Agriculture (1910, 1944, and 1991). Finally, the location and extent of historical wetland areas were consistent with topography conducive to the development of wetland areas in this region, such as little or no slope in combination with low elevation. Therefore, the depiction of wetland habitat on the historical maps used for reference in this study was coincident with existing wetland areas and independently mapped features indicative of wetland habitat including soil type and topography. Accordingly, site conditions and independently documented sources corroborated the location and extent of the historically present wetland habitat mapped in this study.

Quantity of Wetland Converted: 1985 to 1994

The results from this study showed that the quantity of wetland habitat increased from 202 hectares in 1985 to 264 hectares in 1994. The 62 hectare increase of wetland habitat was mapped based upon aerial photographs taken

in March of 1994 after a period of heavy winter rain. The photographs indicated large expanses of open water lacking vegetation. The presence of vegetation would tend to indicate some longevity to the open water areas. It is possible that areas mapped as wetland in 1994 may have been open water habitat areas for a short duration. Field investigations in 1997 indicated the areas mapped as open water in 1994 south of and adjacent to the present day Watsonville Slough drainage ditch located between San Andreas Road and Lee Road were in agricultural production and no longer open water habitat. Existing drainage systems likely provided drainage to remove ponded waters. While the photographs from 1994 showed an overall increase in the quantity of wetland habitat, there were strong indications some ponded open water areas in the wetlands complex were not lasting features and such areas were subject to existing drainage systems. However, it is interesting to note that the location of the ponded areas south of and adjacent to the Watsonville Slough drainage ditch, as described above, were consistent with the location and extent of those wetland areas mapped as historically present.

Field investigations of the wetlands complex between San Andreas Road and Lee Road during February and March of 1998 also showed there was a recurrence of ponding in the same areas which were mapped as historical wetlands and which were ponded in 1994 and 1997. This indicates that historical wetland areas pond recurrently. Therefore, there was an indication

that a reduction in the capacity of existing drainage systems could cause some historically present wetland areas to re-emerge as more permanent features in the Watsonville Wetland Complex.

Uses of Converted Wetlands Based Upon General Plans

Land use designations from the Santa Cruz County and City of Watsonville general plan land use plans were applied to the maps of converted wetland areas in an effort to understand the planned use for converted wetland areas in the Watsonville Wetlands Complex. This study found that 86 to 135 hectares of converted wetland areas are designated for intense urban uses while 163 to 248 hectares of converted wetlands are designated for agricultural use or environmental management (Tables 9, 10, 11, 12, and 13).

It was anticipated that the land use plan for each governmental entity, the County of Santa Cruz and the City of Watsonville, would cover areas that were mutually exclusive, but combined, would be wholly inclusive of the study area. However, the City of Watsonville Land Use Plan (1994) was not limited to those areas within the city boundary, but also included land uses for areas falling within the sphere of influence of the city, beyond the city boundary. These areas within the city's sphere of influence are areas where the city does not have regulatory authority, but which the city anticipates may

become part of the city in the future or which are integrally related to the city's planning effort.

Uses allowed in environmental management areas according to the City of Watsonville General Plan and Santa Cruz County General Plan included those compatible with the preservation and beneficial management of the environmental resources. These uses include recreational use, habitat restoration, and flood/drainage control (City of Watsonville 1994, County of Santa Cruz 1994). Environmental resources generally granted the environmental management designation include wetlands, sloughs, wildlife habitat, and archeological and mineral resources. Accordingly, any use approved in an area designated for environmental management must not adversely affect any wetlands, sloughs or other environmental resources.

Generally, a larger percentage of converted wetland area in the Watsonville Wetlands Complex was designated for environmental management purposes under the City of Watsonville Land Use Plan (1994) than the Santa Cruz County Land Use Plan (1994). The City of Watsonville Land Use Plan designates between 40 and 50 percent of the converted wetland areas identified in this study as environmental management areas. Only between 4 and 7 percent of converted wetland areas were designated environmental management under the Santa Cruz County Land Use Plan (1994). Therefore, based upon the land use plans from the city and county, it

appears the city has more generously granted protection to converted wetland areas in the Watsonville Wetlands Complex. However, many of the areas designated environmental management by the City of Watsonville Land Use Plan (1994) were within the city's sphere of influence which is not under direct regulatory control of the city. These areas included Gallighan Slough, Harkins Slough, and Hanson Slough, and a majority of the historically present Watsonville Slough. The county's agriculture designation is the controlling land use designation in these areas (Tables 9, 10, 11, 12, and 13). Accordingly, there is an indication that the city's generous assignment of the environmental management designation on converted wetland areas does not mean that use of such areas can be controlled by the city at this time. However, given the opportunity to control use of the area through annexation, the present land use plan indicated the city would manage those areas in a fashion which would be compatible with preservation of environmental resources.

Those areas designated environmental management by the City of Watsonville were largely within the same area the county designates for agricultural use. Allowable uses in areas designated for agricultural areas include the cultivation of crops for food, fiber, and livestock and placement of buildings and infrastructure to support that cultivation. Approximately 62 to 66 percent of converted wetland areas in the Watsonville Wetlands Complex

were designated for agricultural use under the Santa Cruz County Land Use Plan (1994). The City of Watsonville Land Use Plan (1994) identified between 11 and 13 percent of converted wetlands as agricultural. The agricultural use designation is primarily assigned to converted wetland areas within Gallighan Slough, Harkins Slough, Hanson Slough, and the Watsonville Slough (Figures 10 and 12). The use of these areas is largely controlled by county policy, not city policy.

Public facilities and infrastructure ranged between 6 and 7 percent of converted wetland area in the Watsonville Wetlands Complex on both the City of Watsonville Land Use Plan (1994) and the Santa Cruz County Land Use Plan (1994). These areas are used for city and county services such as garbage disposal and wastewater treatment.

Generally, more intense urban uses of converted wetland areas in the Watsonville Wetlands Complex were identified in the City of Watsonville Land Use Plan (1994) than the Santa Cruz County Land Use Plan (1994). For instance, while the Santa Cruz County Land Use Plan (1994) identified no converted wetland areas for urban residential, commercial, or industrial use, the City of Watsonville Land Use Plan (1994) assigned between 7 and 9 percent of converted wetland for urban residential use and between 2 and 3 percent of converted wetland areas for both commercial and industrial uses. In addition, the City of Watsonville Land Use Plan (1994) has a specific plan

land use overlay for between 14 and 19 percent of the converted wetland areas. A specific plan overlay in the City of Watsonville (1994) general plan indicates that the area has been targeted for more intense urban use, such as residential and commercial use, than presently designated or used. Consequently, converted wetland areas within the city's jurisdiction would tend to be developed by more intense urban uses than converted wetland areas in the county's jurisdiction.

Five to nine percent of converted wetland areas were not designated for any use under the City of Watsonville Land Use Plan (1994). The City of Watsonville Land Use Plan (1994) did not give a land use designation for areas that are presently roads. In addition, the City of Watsonville Land Use Plan (1994) did not give a land use designation for those areas beyond both the city boundary and the city's sphere of influence. Accordingly, the City of Watsonville Land Use Plan (1994) indicated that between 5 percent and 9 percent of converted wetlands in the Watsonville Wetlands Complex are used for roads or are not given a use designation because the area is outside the city boundary and sphere of influence.

The Santa Cruz County Land Use Plan (1994) did not provide a land use designation for between 24 and 25 percent of converted wetland areas in the Watsonville Wetlands Complex. Unlike the City of Watsonville Land Use Plan (1994), the county did not identify a sphere of influence. The

county's land use plan only provided land use designations for those areas that are distinctly within the County's jurisdiction. Therefore, this information indicated between 24 and 25 percent of converted wetland areas in the Watsonville Wetlands Complex are not within the county's jurisdiction. Also, unlike the City of Watsonville Land Use Plan (1994), the Santa Cruz County Land Use Plan (1994) did not specify whether certain areas are roads. Therefore, it was indeterminate whether any portion of the 24 to 25 percent of undesignated converted wetland area is roadway.

In summary, the City of Watsonville Land Use Plan (1994) designated 51 percent to 62 percent of the converted wetland areas in the Watsonville Wetlands Complex for non-urban use and 33 percent to 40 percent for urban use (Tables 9, 10, 11, 12, and 13). The Santa Cruz County Land Use Plan (1994) designated 69 percent to 70 percent of the converted wetlands identified in this study for non-urban use and 6 to 7 percent for urban use.

Role of Exemption in Restoration of Watsonville Wetlands Complex

AMBAG (1995) and California Coastal Commission (1995) have stated that the Watsonville Wetlands Complex is an important but degraded wetland system which may be restored by increasing the quantity of wetland in the complex. Other studies (Evans 1998, U.S. Department of Agriculture 1999a, U.S. Department of Agriculture 1999b) have shown that prior

converted cropland areas (i.e., historical wetland areas) represent a logical and often successful area for wetland restoration to occur. This is because, as former wetlands, the proper soils and hydrology still exist. Proper soils and hydrology are critical elements for successful wetland restoration. Therefore, prior converted cropland areas in the Watsonville Wetlands Complex are logical areas where wetlands might be successfully restored.

Without federal regulatory control over prior converted cropland, converted wetland habitat in the Watsonville Wetlands Complex would not receive federal protection under the Food Security Act or Clean Water Act. This means between 61 and 70 percent of pre-development wetland habitat in the Watsonville Wetland Complex may be developed without interference from Food Security Act and Clean Water Act policies. According to the City of Watsonville General Plan (1994), 33 to 44 percent of these potential prior wetland restoration areas are designated for urban use (City of Watsonville 1994). In addition, the planned use of prior converted cropland in the Watsonville Wetlands Complex is trending toward more intense urbanized uses.

This study also showed converted wetland areas in the Watsonville Wetlands Complex exhibit a tendency toward re-emergence. Aerial photography from 1994 depicted ponding on cultivated areas which are also prior converted cropland. These ponded areas provide ecological services

including holding floodwater and providing waterfowl habitat. Despite their value in performing wetland functions, Food Security Act and Clean Water Act policies would not protect these areas from conversion to urban use if the USDA officially designated such areas as prior converted cropland.

The results from this study showed some converted wetland areas exhibit wetland characteristics under certain conditions. For example, the photographs of wetland conditions in 1994 showed open water ponding where Harkins, Hanson, and Struve sloughs intersect with the Watsonville Slough channel. The historical maps show that the Watsonville Slough channel is the remnant of a much more extensive Watsonville Slough. The prior converted cropland exemption could apply to the converted wetland areas that were formerly part of the Watsonville Slough. These same areas have been targeted by the City of Watsonville Land Use Plan (1994) for urban development. Overall, there is evidence that, due to the prior converted cropland exemption, Food Security Act and Clean Water Act policies may not interfere with plans to urbanize 86 to 135 hectares of former wetland areas that were converted prior to December 23, 1985, but which exhibit wetland characteristics. Efforts to improve the Watsonville Wetlands Complex by restoring converted wetland areas are hindered by Food Security Act and Clean Water Act policies which exempt prior converted cropland from regulatory oversight.

While this study focuses on the effect a Food Security Act and Clean Water Act exemption may have upon restoration efforts at the local level, there are state and local laws and policies which may mitigate the shortcomings of federal wetland law. For instance, the study area is a coastal watershed located partially within California's coastal zone as defined by the California Coastal Act. The Coastal Act contains strong wetland protection policies which may affect efforts to develop prior converted cropland areas in the Watsonville Wetlands Complex. Coastal Act definitions of wetland areas are generally more inclusive than Food Security Act and Clean Water Act definitions of wetland areas. Therefore, there may be areas which could be designated prior converted cropland which also meet the Coastal Act definition of a wetland. In such cases, while urban development of these prior converted croplands may be allowable under Food Security Act and Clean Water Act policies, urban development may not be allowable under California's Coastal Act.

Implications For Wetland Restoration Efforts Nationwide

This study found that 255 to 334 hectares of converted wetland habitat in the Watsonville Wetlands Complex may be considered prior converted cropland and currently, 32.6% to 39.5 % of these prior converted croplands are likely to be urbanized according to the City of Watsonville Land Use Plan

(1994). This finding is consistent with patterns observed by Eggers (1996) in Minnesota and Wisconsin where the absence of federal protection of areas designated prior converted cropland have resulted in the conversion of 445 hectares (1,100 acres) of land to urban uses despite indications that such areas were functioning wetlands. The observations of this study are also consistent with findings made by Sullivan (1996) which demonstrate that the absence of federal legal protection of prior converted croplands in a suburban area of Seattle, Washington, will likely result in the urbanization of 32.45% of the 191 hectares (473 acres) of prior converted cropland located within Seattle's urban growth boundary. In this case, 62 hectares (153 acres) of functioning wetlands, in an area where such wetlands provide important waterfowl habitat and flood water retention capacity, will be destroyed due to allowances made by the prior converted cropland exemption. The problems associated with the prior converted cropland exemption in the Watsonville Wetlands Complex have been recognized in other urbanizing agricultural watersheds in the United States. The problems associated with the prior converted cropland exemption in the Watsonville Wetlands Complex are not limited to the study area, but are occurring at the larger national scale as well.

Theis (1991) and Babcock (1991) argue that the policy of exempting areas identified as prior converted cropland from Clean Water Act permit requirements is unsound because the exemption presumes that prior

converted cropland areas do not perform wetland functions. Theis (1991) and Babcock (1991) argue some areas designated prior converted cropland in fact do exhibit wetland characteristics. Since some areas mapped in this study as prior converted cropland were also mapped as wetland from aerial photographs taken in 1994, Theis (1991) and Babcock's (1991) concern may be realized in the Watsonville Wetlands Complex.

The results from this study showed that some converted wetland areas in the Watsonville Wetlands Complex exhibit a tendency toward wetland re-emergence. They retain wetland soil characteristics and exhibit wetland hydrology, two of the three criteria for delineating an area as wetland. More detailed investigations of individual re-emergent wetlands may show these same areas could be considered waters of the United States, if, for example, such areas were inundated for the minimum quantity of days required by Clean Water Act regulations for areas to be delineated as wetlands. Therefore, some prior converted cropland areas, which may be urbanized according to the City of Watsonville Land Use Plan (1994), may be waters of the United States. Thompson (1977) asserts that Congress intended for waters of the United States to be interpreted as broadly as possible such that important wet resources would be subject to federal regulatory authority. However, it appears that Food Security Act and Clean Water Act policies regarding prior converted cropland may limit the federal government's ability to assert

jurisdiction. Accordingly, the Food Security Act and Clean Water Act policies regarding prior converted croplands result in a failure to manage a resource which might otherwise be labeled waters of the United States consistent with Congressional intent to broadly cast that label. These exemptions may contribute to continuous wetland loss and hinder efforts to restore wetlands to meet national goals and policies.

Bianucci and Goodenow (1991), Cylinder et. al. (1995) and McBeth (1997) recount the history and intent of Swampbuster. In all of these examinations, the authors found Swampbuster was originally designed to discourage wetland conversion and to provide that agricultural wet resource areas remain rightfully considered as waters of the United States. It is clear from this study that the prior converted cropland exemption, as presently constructed, may be problematic to wetland restoration efforts in urbanizing agricultural areas where wetland habitat was converted prior to December 23, 1985. It is apparent that USDA and the USACE have recognized, to some degree, the problems associated with the prior converted cropland exemption and the integration of Food Security Act and Clean Water Act policies regarding those areas. Efforts are underway to correct those problems through the refinement of regulatory language and interpretive guidance documents.

Another implication of this exemption on the national level is that it may undercut the Clinton Administration's federal policy to achieve a net

increase in wetlands. Converted wetland areas in agricultural landscapes such as those identified in this study represent important restorable wetland resource areas. Wetland policy experts such as Evans (1998), Shabman (1991), Sullivan (1996), and U.S. Department of Agriculture (1999b) recognized this in their own studies showing that converted agricultural wetlands are important restorable wetland resources. Their importance should be recognized through enforceable federal regulations by ensuring the prior converted cropland exemption is applied in a manner which retains flexibility while the converted wetlands are in agricultural use, but which are re-evaluated for their restoration potential prior to conversion to more intense urbanized uses.

Finally, the overall importance of the prior converted cropland exemption in efforts to restore America's wetlands is somewhat uncertain. There are varying opinions regarding the legality of the prior converted cropland exemption, the reliability of prior converted cropland determinations made by the USDA, questions regarding an interested person's ability to challenge a prior converted cropland determination, and the prudence of integrating Food Security Act and Clean Water Act policies. Refinements to the law, regulations, and agency guidance documents related to the prior converted cropland exemption are underway. The success of these refinements will determine the degree of impact the exemption will

have upon restoration efforts nationwide. Actions taken by USDA and the USACE related to the exemption must be monitored to evaluate whether the prior converted cropland exemption is being utilized as intended to assist growers in flexibly and predictably managing prior converted cropland areas, or whether the exemption is being deliberately used to circumvent federal wetland regulation by those attempting to urbanize agricultural areas. These uncertainties will likely be decided through litigation rather than regulation.

Limitations

Although this study was able to document wetland loss and the effect of the prior converted cropland exemption on the study area, there were several limitations of the study. The first possible limitation of this study relates to the identification of historical wetland areas based on documentation rather than field investigation. An area is commonly defined as wetland when saturated or flooded soil conditions exist, hydrophytic vegetation is present, and hydric soils are present. In absence of an ability to know definitively that such conditions were historically present in any particular area, one must rely upon available data and take into account the weight this evidence bears. This study described the presence of historical wetland habitat based upon historical maps, soil types, topography, and historical photography. This method of data interpretation is not meant to

replace site specific field investigations, however such investigations were beyond the scope of this thesis work. The presence of hydrophytic vegetation and wetland hydrology could not be definitively confirmed in this study. However, historical maps depicting "slough" or "marsh" strongly suggested the presence of wetland characteristics. In addition, hydric soils are a strong indicator of wetland habitat because hydric soils only develop in water saturated conditions. Therefore, the depiction of a soil unit as containing hydric soils strongly suggested the presence of saturated soil conditions in the past and that hydrophytic vegetation would have dominated the area.

The data and analysis methods of this study also have limitations. The data were produced using historical cartographic data and aerial photographs which have limited accuracy. The maps created in this study are only as accurate as the data upon which they were based. The data are designed for use as management level planning information which could alert planners to the location of possible restoration sites. Specific field investigations should be performed as restoration plans are implemented.

While the conclusions from this study were based upon robust data sources providing valuable information on the historical presence of wetland habitat in the study area, the data produced may provide a solid framework upon which additional research upon historical wetland habitat in the study area may be founded. Additional research will reveal more site-specifically

the boundary of historical wetland habitat and any future ability to restore such wetland areas.

Another limitation of this study involves identifying with certainty the quantity of converted wetlands in the Watsonville Wetlands Complex which would be labeled prior converted croplands by the USDA. The methods used in this study mimicked but did not precisely replicate the USDA's method for identifying prior converted cropland areas. Dissimilarities between the methods included the USDA's requirement to perform a field investigation for all areas to be designated prior converted cropland, whereas this study provided a field investigation limited to those areas that were publicly accessible. Thus some areas which may be designated prior converted cropland by this study were not verified in the field. In addition, USDA requires the use of photographs at a scale of 1:12,000 or larger, whereas this study used photographs ranging in scale from 1:15,840 to 1:31,680.

One alternative to investigating and identifying prior converted croplands would have been to compile existing data produced by the USDA regarding prior converted cropland determinations, similar to Sullivan (1996). Evidence of these determinations is contained within USDA's form NRCS-CPA-38, which is filed by the producer to request a wetland determination. A Freedom of Information Act request was made to review

all records of wetland determinations relevant to the study area on file in the Santa Cruz County Resource Conservation District office of the Natural Resources Conservation Service. This public records search revealed only three farms in the study area had requested and obtained a wetland determination. These three determinations occurred within portions of Harkins Slough and southwest of San Andres Road adjacent to the existing Watsonville Slough drainage canal. Accordingly, existing data did not provide full coverage of the study area.

The results from USDA's wetland determinations for certain farms in the study area were compared to the converted wetland areas identified in this study for those same areas. This comparison showed some areas identified as converted wetlands in this study were also identified by USDA as prior converted cropland. While this study could not state with certainty that all converted wetlands identified in this study were also prior converted cropland, it could be stated that those areas identified as converted wetlands represent the pool of potential prior converted croplands in the study area. Accordingly, this area is equal to the quantity of converted wetlands previously identified. Site specific field investigations of each individual farm by the USDA would be required to confirm this information. Such information was beyond the scope of this study.

Finally, the policy analysis did not indicate a causal relationship between the presence of prior converted cropland and planned future development. Instead, the policy analysis can alert wetland management experts that federal policies guiding the use of prior converted croplands may affect local restoration planning efforts. The data and analysis are intended to guide local level efforts to produce a wetland restoration plan for the Watsonville Wetlands Complex while also providing a case study which demonstrates how a federal wetland exemption affects local efforts to achieve net wetland gains.

CHAPTER 6

IMPLICATIONS AND RECOMMENDATIONS

This study found that 255 to 334 hectares of converted wetland habitat are available in the Watsonville Wetlands Complex which could potentially be used for restoration purposes. These converted wetland areas exhibited a regular tendency toward re-emergence. However, most, if not all, of the converted wetland areas in the Watsonville Wetlands Complex were converted prior to December 23, 1985 and may be considered prior converted cropland. Land use plans demonstrated some of the converted wetland area in the Watsonville Wetlands Complex is targeted for urbanization. The presence of the prior converted cropland exemption likely means that Food Security Act and Clean Water Act policies will not interfere with the development of converted wetland habitat in the Watsonville Wetlands Complex.

The results of this study lead to the following recommendations:

1. Identify converted wetland areas which are critically important from a resource management standpoint to the success of efforts to restore the

Watsonville Wetlands Complex.

2. Perform detailed, site specific investigations of these important areas to evaluate whether NRCS has labeled those areas as prior converted croplands and whether site conditions are amenable to wetland restoration efforts. If such areas are labeled prior converted croplands, work with NRCS and the USACE to evaluate the effect the exemption may have upon efforts to restore those areas. Work with USDA officials to enroll critically important converted wetland areas in the Wetlands Reserve Program. Alternatively, consider fee title acquisition or purchase of a conservation easement on critically important converted wetland areas.

3. Utilize state and local policies to preserve converted wetland areas. More specifically, modify local planning documents to specifically identify converted wetland areas as a resource to be protected and enhanced for environmental purposes including wildlife habitat, open space and recreation, and flood attenuation.

4. Utilize mechanisms described by Kilborn (1991) and Searchinger (1993) to ensure converted wetland resources in the Watsonville Wetlands

Complex are recognized for their value as restorable wetland areas. Kilborn (1991) and Searchinger (1993) developed the idea of requiring a wetlands assessment as part of any real estate transaction so potential property owners are aware that existing or former wetland habitat is present on the property. Disclosure of the presence of these resources may decrease a potential landowners' expectations regarding development on properties containing restorable wetland areas. City and county ordinances could be crafted such that any real estate transaction in the Watsonville Wetlands Complex includes a wetlands assessment.

5. Encourage the development of a Watsonville Wetlands Complex wetlands restoration district as described by Hanson (1987). Utilize the information compiled in this study to design a comprehensive wetlands restoration plan as the basis for the wetlands restoration district. The wetlands restoration district could be used as the framework for acquiring important resource areas and obtaining private and public funding to implement the comprehensive plan.

6. Seek legislative changes to the Food Security Act and Clean Water Act to ensure that the prior converted cropland exemption is limited to exempting converted wetland areas in agricultural landscapes only and

specifically disallow application of the exemption to uses other than agricultural production. Ensure that Congressional intent is clear that the prior converted cropland label is only allowed while the subject area is in agricultural production and that the label is extinguished upon conversion of the area to a non-agricultural use.

Overall, this study identified, with some certainty, the location and extent of converted wetland habitat in the Watsonville Wetlands Complex. These converted wetland areas represent the most logical and likely successful places for the wetland restoration efforts called for in AMBAG (1995). Maintaining these areas as open space is vital to efforts to restore the Watsonville Wetlands Complex. Therefore, the information gathered in this study should be made available to relevant resource managers responsible for reviewing applications for development so they may evaluate any opportunity for wetland restoration that may be obtained as a result of the proposed development.

LIST OF REFERENCES

AMBAG. 1995. See Association of Monterey Bay Area Governments. 1995.

Air Flight Service. 1994. Flight line identification Big creek lumber. Vertical aerial photographs obtained June 22, 1994, black and white, paper prints. Photograph scale 1:15,840. Camera focal length 6.0 inches. Photograph identification no. 5-1 to 5-3; 5-6; 6-1 to 6-6; 7-1 to 7-2; 7-4 to 7-7; 7-9 to 7-10; 8-4 to 8-9; 9-3 to 9-6. Santa Clara, California: Air Flight Service.

Association of Monterey Bay Area Governments. 1995. Water resources management plan for Watsonville Slough System Santa Cruz County. Prepared by Questa Engineering Corporation, Point Richmond, California for the Association of Monterey Bay Area Governments, Seaside, California.

Atkinson, Fred W. 1935. 100 years in the Pajaro Valley: From 1769 to 1868. Watsonville: Register and Pajaronian Press.

Babcock, Hope. 1991. Federal wetlands regulatory policy: Up to its ears in alligators. Pace Environmental Law Review 8 (Spring): 307-353.

Beck, Robert E. 1994. The movement in the United States to restoration and creation of wetlands. Natural Resources Journal 34 (4): 781-822.

Bianucci, Larry R. and Rew R. Goodenow. 1991. The impact of section 404 of the Clean Water Act on agricultural land use. Journal of Environmental Law 10 (1): 41-65.

Blumm, Michael C. and D. Bernard Zaleha. 1989. Federal wetlands protection under the Clean Water Act: Regulatory ambivalence, intergovernmental tension, and call for reform. University of Colorado Law Review 60 (4): 695-772.

Bolstad, Paul V. and James L. Smith. 1995. Errors in GIS: Assessing spatial data accuracy. In Wetland and environmental applications of GIS, ed. J. G. Lyon and J. McCarthy, 301-312. Boca Raton: CRC Press.

California Coastal Commission. 1995. ReCAP pilot project findings and recommendations: Monterey Bay region. California Coastal Commission.

City of Watsonville. 1994. Watsonville 2005 general plan. City of Watsonville.

City of Watsonville Land Use Plan. 1994. See City of Watsonville. 1994.

County of Santa Cruz. 1994. General plan and local coastal program for the County of Santa Cruz, California. County of Santa Cruz.

County of Santa Cruz Land Use Plan. 1994. See County of Santa Cruz. 1994.

Culliton, Thomas J., Maureen A. Warren, Timothy R. Goodspeed, Davida G.; Remer, Carol M. Blackwell and John J. McDonough III. 1990. 50 years of population change along the Nation's coasts, 1960-2010. National Oceanic and Atmospheric Administration, Rockville, Maryland.

Cylinder, Paul D., Kenneth M. Bogdan, Ellyn Miller Davis and Albert I. Herson. 1995. Wetland regulation: A complete guide to Federal and California programs. Point Arena: Solano Press Books.

Dahl, Thomas E. 1990. Wetlands losses in the United States 1780's to 1980's. U.S. Department of the Interior, Fish and Wildlife Service, Washington, D.C.

Dahl, Thomas E. and Craig E. Johnson. 1991. Wetlands status and trends in the conterminous United States mid-1970's to mid-1980's. U.S. Department of the Interior, Fish and Wildlife Service, Washington, D.C.

Dahl, T.E., R.D. Young and M.C. Caldwell. 1997. Status and trends of wetlands in the conterminous United States: Projected trends 1985 to 1995. U.S. Department of the Interior, Fish and Wildlife Service.

Dennis, N.B. and M.L. Marcus. 1984. Status and trends of California wetlands. Final report prepared for the California Assembly, Resources subcommittee.

Eggers, Steve. 1996. The PC exemption taken too far. National Wetlands Newsletter 18 (May-June): 9-12, 25.

Evans, Robert O. 1998. Wetland restoration of prior converted cropland. Available from: http://www5.bae.ncsu.edu/bae/programs/extension/wqg/kevin/ wetrest/index.htm [accessed 6 May 1999].

FAIRA. 1996. See U.S. Congress. 1996.

Fairchild Aerial Photography Collection. 1931. Flight line identification C-1550. Vertical aerial photographs obtained May 27, 1931, black and white, paper prints. Photograph scale 1:20,000. Camera focal length 8.25 inches. Photograph identification no. 15 to 24; 29 to 38; 46 to 54; 64 to 65; 76. Whittier, California: Fairchild Aerial Photography Collection at Whittier College.

Grossinger, Robin M. 1995. Historical evidence of freshwater effects on the plan form of tidal marshlands in the Golden Gate Estuary. M.S. Thesis, University of California, Santa Cruz.

Hanson, Mark J. 1987. Damming agricultural drainage: the effect of wetland preservation and federal regulation of agricultural drainage in Minnesota. William Mitchell Law Review 13 (1): 135-191.

Hofer, Stewart L. 1988. Federal regulation of agricultural drainage activity in prairie potholes: The effect of section 404 of the Clean Water Act and the Swampbuster provisions of the 1985 Farm Bill. South Dakota Law Review 33 (3): 511-527.

Holland, Cindy C., JoEllen Honea, Stephanie E. Gwin and Mary E. Kentula. 1995. Wetland degradation and loss in the rapidly urbanizing area of Portland, Oregon. Wetlands 15 (December): 336-345.

Hornbeck, David. 1969. Landscape change in the Pajaro Valley, 1840-1800: A study in change processes. M.A. Thesis, Fresno State College.

Hurn, Jeff. 1993. Differential GPS explained. Sunnyvale: Trimble Navigation.

Kilborn, John Webster. 1991. Purchaser liability for the restoration of illegally filled wetlands under section 404 of the clean water act. Boston College Environmental Affairs Law Review 18 (Winter): 319-355.

Kuzila, Mark S., Donald C. Rundquist and Jeffrey A. Green. 1991. Methods for estimating wetland loss: The Rainbasin region of Nebraska, 1927-1981. Journal of Soil and Water Conservation 46 (6): 441-446.

Lee, K.H. and R.S. Lunetta. 1995. Wetlands detection methods. In Wetland and environmental applications of GIS, ed. J. G. Lyon and J. McCarthy, 249-284. Boca Raton: CRC Press, Inc.

Lewis, C.B. 1908. Map of the Pajaro Valley, Santa Cruz County, California. Map scale 40 chains to an inch. Santa Cruz: Santa Cruz County Assessors Office.

Liebesman, Lawrence R. 1985. The farming exemption under section 404 (f) of the Clean Water Act-Congressional intent and judicial construction. National Wetlands Newsletter 7 (July-August): 14-17.

Lydon, Sandy. 1985. Chinese gold: The Chinese in the Monterey Bay region. Capitola: Capitola Book Company.

Lyon, John G. and Kirt F. Adkins. 1995. Use of a GIS for wetland identification, the St. Clair Flats, Michigan. In Wetland and environmental applications of GIS, ed. J. G. Lyon and J. McCarthy, 49-60. Boca Raton: CRC Press, Inc.

McBeth, Daryn. 1997. Wetlands conservation and federal regulation: Analysis of the Food Security Act's "Swampbuster" provisions as amended by the Federal Agriculture Improvement and Reform Act of 1996. Harvard Environmental Law Review 21: 201-263.

McCreary, Scott, Robert Twiss, Bonita Warren, Carolyn White, Susan Huse, Kenneth Gardels and Dominic Roques. 1992. Land use change and impacts on the San Francisco Estuary: A regional assessment with national policy implications. Coastal Management 20: 219-253.

McElfish, James M., Jr. and Kenneth J. Adler. 1990. Swampbuster implementation: Missed opportunities for wetland protection. Journal of Soil and Water Conservation 45 (3): 383-385.

MicroImages, Inc. 1997. Reference manual for TNTmips® and TNTview®. Lincoln, Nebraska: MicroImages, Inc.

Mitsch, William J. and James G. Gosselink. 1993. Wetlands. New York: Van Nostrand Reinhold.

National Ocean Service. 1994. Flight line identification NOS ACN. Vertical aerial photographs obtained March 7, 1994, color, paper prints. Photograph scale 1:23,000. Camera focal length 153 millimeters. Photograph identification no. 993; 1021 to 1025; 1058 to 1066. Silver Spring, Maryland: National Ocean Service.

National Research Council. 1995. Wetlands characteristics and boundaries. Washington, D.C.: National Academy Press.

Niedzwiedz, William R. and Sandra S. Batie. 1984. An assessment of urban development into coastal wetlands using historical aerial photography: A case study. Environmental Management 8 (3): 205-214.

Niemi, Tina M. and N. Timothy Hall. 1996. Historical changes in the tidal marsh of Tomales Bay and Olema Creek, Marin County, California. Journal of Coastal Research 12 (1): 90-102.

Pennsylvania Department of Environmental Protection. 1995. Statements of Policy, Department of Environmental Protection, 25 Pa. Code Chapter 105, Dam Safety and Waterway Management, Statement of Policy: Revision to 105.451 - Identification and Delineation of Wetlands and Statement of Policy: 105.452 - Status of Prior Converted Cropland in the Commonwealth. Issued December 5, 1995. Available from: http://www.WQP_WWEC/GENERAL/WETLANDS/policy.htm [accessed 6 May 1999].

ReCAP. 1995. See California Coastal Commission. 1995.

Reilly, William K. 1991. A new way with wetlands. Journal of Soil and Water Conservation 46 (3): 192-194.

Risley, David L. and Michael J. Budzik. 1988. Implementing swampbuster and conservation easements: An Ohio perspective. Journal of Soil and Water Conservation 43 (1): 33-34.

Robinson, Ann Y. 1993. Wetlands protection: What success? Journal of Soil and Water Conservation 48 (4): 267-270.

_____. 1996. A wetland-friendly Farm Bill? National Wetlands Newsletter 18 (May-June): 1, 28-31.

Rouvalis, Mark C. 1988. Restoration of wetlands under section 404 of the Clean Water Act: An analytical synthesis of statutory and case law principles. Boston College Environmental Affairs Law Review 15: 295-347.

Searchinger, Timothy D. 1993. Wetlands issues 1993: challenges and a new approach. Maryland Journal of Contemporary Legal Issues 4 (1): 13-72.

Shabman, Leonard. 1991. Integrating agricultural reconversion of wetlands into achieving environmental goals in urbanizing regions. In A national policy of "no net loss" of wetlands: What do agricultural economists have to contribute?, ed. R. E. Heimlich, 23-28. Washington, D.C.: United States Department of Agriculture

Sullivan, Sean P. 1996. Assessing prior converted cropland in an urbanizing agricultural landscape. M.L.A. thesis, University of Washington.

Theis, Joseph G. 1991. Wetlands loss and agriculture: the failed federal regulation of farming activities under section 404 of the Clean Water Act. Pace Environmental Law Review 9 (Fall): 1-54.

Thompson, Edward, Jr. 1977. Section 404 of the Federal Water Pollution Control Act Amendments of 1977: Hydrologic modification, wetlands protection and the physical integrity of the nations waters. Harvard Environmental Law Review 2: 264-287.

Tolman, Jonathan. 1995. Achieving no net loss. National Wetlands Newsletter 17 (May-June): 5-7.

_____. 1997. How we achieved no net loss. National Wetlands Newsletter 19 (4): 1, 19-22.

U.S. Army Corps of Engineers. 1990. Regulatory Guidance Letter No. 90-07. Subject: Clarification of the phrase 'normal circumstances' as it pertains to cropped wetlands. Washington, D.C.: Office of the Chief of Engineers.

U.S. Congress. 1972. Federal Water Pollution Control Act, 33 U.S.C. §§ 1251-1376 (Supp. V 1975).

_____. 1996. Federal Agriculture Improvement and Reform Act of 1996, Pub. L. No. 104-127. U.S. Congress.

U.S. Congress. House. Conference Committee. 1996. Conference report on H.R. 2854. 104th Cong., 25 March.

U.S. Department of Agriculture. 1910. Soil survey of the Pajaro Valley, California, by W. W. Mackie. Washington, D.C.: Government Printing Office.

_____. 1944. Soil survey: The Santa Cruz Area, California, by R. Earl Storie, Ralph C. Cole, Bruce C. Owen and L.F. Koehler. Washington, D.C.: Government Printing Office.

_____. 1991. Hydric soils of the United States, Third Edition. Washington, D.C.: Soil Conservation Service.

U.S. Department of Agriculture, Natural Resources Conservation Service. 1999a. Wetlands reserve program. Available from: http://www.wl.fb-net.org/ [accessed 23 May 1999].

_____. 1999b. Wetlands reserve program: Success stories. Available from: http://www.wl.fb-net.org/success.htm [accessed 23 May 1999].

U.S. Department of Agriculture, Natural Resources Conservation Service, Conservation and Ecosystem Assistance Division. 1996. National Food Security Act Manual. 3d ed., 2d Amendment. Washington, D.C.: U.S. Department of Agriculture.

U.S. Department of Agriculture, Soil Conservation Service. 1980. Soil survey of Santa Cruz County, California. Washington, D.C.: Soil Conservation Service.

U.S. Department of Agriculture, Soil Conservation Service; U.S. Department of Defense, Corps of Engineers, Department of the Army; U.S. Environmental Protection Agency; U.S. Department of the Interior, Fish and Wildlife Service. 1994a. Memorandum of Agreement Concerning Wetlands Determinations on Agricultural Lands; Notice. Interagency Memorandum of Agreement Concerning Wetlands Determinations for Purposes of Section 404 of the Clean Water Act and

Subtitle B of the Food Security Act. Federal Register, January 19, 1994, Doc. 94-1311. Washington, D.C.: U.S. Government Printing Office.

U.S. Department of Agriculture, Soil Conservation Service; U.S. Department of Defense, Corps of Engineers, Department of the Army; U.S. Environmental Protection Agency; U.S. Department of the Interior, Fish and Wildlife Service. 1994b. California Inter-Agency Mapping Conventions for Waters of the United States. Washington, D.C.: U.S. Department of Agriculture.

U.S. Department of Commerce and Labor, Coast and Geodetic Survey. 1910. Monterey Bay north of Pajaro River, California. Map. Scale 1:10,000. Washington, D.C.: U.S.: U.S. Coast Survey.

U.S. Department of Defense, Department of the Army, Corps of Engineers. 1993. Final rule. Federal Register, August 25, 1993. Washington, D.C.: U.S. Government Printing Office.

U.S. Environmental Protection Agency, Office of Federal Activities. 1996. Letter from Richard Sanderson to Lloyd E. Wright, Conservation Ecosystems Assistance Division, Natural Resources Conservation Service, 21 November.

U.S. Environmental Protection Agency. 1993. Protecting America's wetlands: A fair, flexible, and effective approach. U.S. Environmental Protection Agency, Office of Wetlands, Oceans, Watersheds.

U.S. Department of the Interior, Geological Survey. 1912. California, Capitola quadrangle. Map. Scale 1:62,500. 1912 - Reprint 1960. Washington, D.C.: U.S. Geological Survey.

_____. 1980. Watsonville West quadrangle. Map. Scale 1:24,000. Washington, D.C.: U.S. Geological Survey.

_____. 1993a. Watsonville East quadrangle. Map. Scale 1:24,000. Washington, D.C.: U.S. Geological Survey.

_____. 1993b. US Geodata digital elevation models data users guide. Data users guide number 5. Reston, Virginia: U.S. Geological Survey.

_____. 1994. Moss Landing quadrangle. Map. Scale 1:24,000. Washington, D.C.: U.S. Geological Survey.

USDA. 1994. See U.S. Department of Agriculture, Soil Conservation Service; U.S. Department of Defense, Corps of Engineers, Department of the Army; U.S. Environmental Protection Agency; U.S. Department of the Interior, Fish and Wildlife Service. 1994a.

W.A.C. Corporation. 1985. Flight line identification WAC-85-CA. Vertical aerial photographs obtained April 12, 1985 and April 13, 1985, black and white, paper prints. Photograph scale 1:31,680. Cameral focal length 6.0 inches. Photograph identification no. 12-204 to 12-211; 12-250 to 12-252; 14-101 to 14-102. Eugene, Oregon: W.A.C. Corporation.

Webster, Merriam. 1998. Webster's Revised Unabridged Dictionary. Version published 1913 by the C. & G. Merriam Co., Springfield, Mass. Under the direction of Noah Porter, D.D., LL.D.

Welch, R., M. Remillard and J. Alberts. 1992. Integration of GPS, remote sensing, and GIS techniques for coastal resource management. Photogrammetric Engineering and Remote Sensing 58 (November): 1571-1578.

Wright, T. W., M.V. Bennett and L.B. Healy. 1881a. S. E. 1/4 T. 12 S. R 1 E. Map, hand drawn ink, paper on cloth. Map scale, 10 chains to an inch. Santa Cruz: Santa Cruz County Assessors Office.

_____. 1881b. N. E. 1/4 T. 12 S. R. 1 E. Map, hand drawn ink, paper on cloth. Map scale 10 chains to an inch. Santa Cruz: Santa Cruz County Assessors Office.

_____. 1881c. S. E. 1/4 R. 11 S. R. 1 E. Map, hand drawn ink, paper on cloth. Map scale 10 chains to an inch. Santa Cruz: Santa Cruz County Assessors Office.

_____. 1881d. N. E. 1/4 T. 12 S. R. 2 E. Map, hand drawn ink, paper on cloth. Map scale 10 chains to an inch. Santa Cruz: Santa Cruz County Assessors Office.

_____. 1881e. S. W. 1/4 T. 11 S. R. 2 E. Map, hand drawn ink, paper on cloth. Map scale 10 chains to an inch. Santa Cruz: Santa Cruz County Assessors Office.

_____. 1881f. N. W. 1/4 T. 11 S. R. 1 E. Map, hand drawn ink, paper on cloth. Map scale 10 chains to an inch. Santa Cruz: Santa Cruz County Assessors Office.

_____. 1881g. N. E. 1/4 T. 11 S. R. 1 E. Map, hand drawn ink, paper on cloth. Map scale 10 chains to an inch. Santa Cruz: Santa Cruz County Assessors Office.

_____. 1881h. N. W. 1/4 T. 12 S. R. 2 E. Map, hand drawn ink, paper on cloth. Map scale 10 chains to an inch. Santa Cruz: Santa Cruz County Assessors Office.

Zinn, Jeffrey. 1997. Soil and water conservation: Implementing the 1996 Farm Bill. Congressional Research Service. Washington, D.C.: Library of Congress.

Zinn, Jeffery and Claudia Copeland. 1996. Agricultural wetlands: Current programs and legislative proposals. Congressional Research Service. Washington, D.C.: Library of Congress.

APPENDIX 1

TABLES

TABLE 1

CHARACTERISTICS OF AERIAL
PHOTOGRAPHS UTILIZED IN THIS STUDY

Photographer	Year	Scale	Type
Fairchild Aerial Surveys, Inc.	1931	1:20,000	Black and White
W.A.C. Corporation	1985	1:31,680	Black and White
National Ocean Service	1994	1:23,100	Color
Air Flight Service	1994	1:15,840	Black and White

TABLE 2

SUMMARY OF PLANAR ROOT MEAN SQUARE ERROR FOR DIGITALLY PROCESSED MAPS

Map	Year	Root Mean Square Error Planar (RMSp)
Wright, Bennett, Healy	1881	11.829
Lewis	1908	50.913
Aerial Photographic Image Mosaic	1985	10.497
Aerial Photographic Image Mosaic	1994	9.121

TABLE 3

ROOT MEAN SQUARE ERROR ANALYSIS
OF 1985 AERIAL IMAGE MAP
AFTER COMPLETION OF DIGITAL PROCESSING

Test Location Number	Difference in Direction X (dx)	Difference in Direction Y (dy)	Root Mean Square Error (RMSE)
1	0.199	0.221	0.297
2	1.775	1.204	2.145
3	-8.583	9.490	12.796
4	-0.642	5.076	5.116
5	-8.930	6.785	11.215
6	-8.144	8.040	11.445
7	-22.593	1.811	22.665
8	-29.927	-7.000	30.735
9	-2.723	4.807	5.525
10	-13.213	2.941	13.536
11	-10.962	11.230	15.693
12	3.034	4.880	5.746
13	0.259	5.279	5.285
14	-8.511	7.457	11.316
15	-3.779	-2.232	4.389
16	-6.017	1.732	6.261
17	-3.905	2.728	4.763
18	-3.991	7.066	8.116
19	-4.922	3.930	6.299
20	-2.682	3.197	4.173
21	-4.965	3.565	6.112
22	-2.920	2.016	3.548
23	-0.411	7.889	7.900
24	-3.807	3.483	5.160
25	-3.534	3.654	5.084
26	-7.423	13.630	15.520
27	-5.245	4.027	6.612
28	-2.729	3.897	4.758
29	1.772	3.581	3.996

TABLE 4

ROOT MEAN SQUARE ERROR ANALYSIS
OF 1994 AERIAL IMAGE MAP
AFTER COMPLETION OF DIGITAL PROCESSING

Test Location Number	Difference in Direction X (dx)	Difference in Direction Y (dy)	Root Mean Square Error (RMSE)
1	-4.517	-4.292	6.231
2	-6.163	6.910	9.259
3	-7.037	6.884	9.844
4	-7.298	7.924	10.773
5	-6.501	6.660	9.307
6	-3.241	5.365	6.268
7	-33.572	-5.375	33.999
8	-9.276	6.520	11.338
9	-7.657	6.168	9.832
10	0.922	2.424	2.594
11	-6.005	7.170	9.353
12	-6.852	7.547	10.193
13	-3.673	2.678	4.546
14	-3.142	1.860	3.651
15	-3.626	2.972	4.689
16	-1.110	2.554	2.785
17	-2.753	2.000	3.403
18	-3.444	2.475	4.241
19	-1.720	2.904	3.375
20	-3.220	2.897	4.331
21	-2.016	2.974	3.593
22	2.251	3.723	4.350
23	-2.363	2.004	3.099
24	-3.219	2.809	4.272
25	-2.425	2.830	3.727
26	-1.581	3.386	3.737
27	-7.328	1.085	7.408
28	-3.966	2.228	4.549

TABLE 5

ROOT MEAN SQUARE ERROR ANALYSIS
OF MAPS BY WRIGHT, BENNETT, HEALY (1881)
AFTER COMPLETION OF DIGITAL PROCESSING

Test Location Number	Difference in Direction X (dx)	Difference In Direction Y (dy)	Root Mean Square Error (RMSE)
1	6.975	-1.645	7.167
2	-2.873	6.259	6.887
3	-1.459	-6.071	6.243
4	2.655	2.719	3.800
5	-5.297	-1.262	5.446
6	-1.671	-2.195	2.759
7	14.566	2.881	14.848
8	0.517	-1.577	1.660
9	-12.392	-4.271	13.107
10	3.683	14.038	14.513
11	-12.351	-0.739	12.374
12	7.65	-8.137	11.169
13	-0.279	-4.107	4.116
14	15.373	-4.011	15.888
15	-2.854	-5.618	6.302
16	-20.75	-6.449	21.729
17	-9.307	23.353	25.140
18	7.531	-1.725	7.726
19	-4.188	2.788	5.031
20	14.473	-4.232	15.079

TABLE 6

ROOT MEAN SQUARE ERROR ANALYSIS
OF MAPS BY LEWIS (1908)
AFTER COMPLETION OF DIGITAL PROCESSING

Test Location Number	Difference in Direction X (dx)	Difference In Direction Y (dy)	Root Mean Square Error (RMSE)
1	-66.806	-47.851	82.175
2	-25.953	29.99	39.661
3	6.239	5.992	8.65
4	-35.93	41.561	54.939
5	-26.849	-30.301	40.484
6	13.618	60.485	61.999
7	26.979	41.932	49.862
8	7.311	3.291	8.018
9	-13.199	-47.506	49.305
10	28.135	-3.177	28.313
11	-8.163	64.668	65.182
12	-51.151	-6.728	51.591
13	-5.379	-55.969	56.227
14	17.934	41.645	45.342
15	-22.693	-18.562	29.318
16	-46.327	39.182	60.675
17	41.865	-71.389	82.759
18	32.911	42.448	53.711
19	36.926	13.191	39.211
20	-10.905	-33.158	34.905

TABLE 7

ASSIGNMENT OF CITY AND COUNTY LAND USE PLAN
DESIGNATIONS TO GENERALIZED STUDY DESIGNATIONS

County/City Land Use Designation	Code	Land Use Plan	Generalized Study Designation
Urban-open space	O-U	Santa Cruz County	Environmental management
Resource conservation	O-C	Santa Cruz County	Environmental management
Lake, reservoir, lagoon	O-L	Santa Cruz County	Environmental management
Parks, recreation and open space	O-R	Santa Cruz County	Environmental management
Environmental management	EM	City of Watsonville	Environmental management
Agriculture	AG	Santa Cruz County	Agriculture
Agriculture	AG	City of Watsonville	Agriculture
Mountain residential	R-M	Santa Cruz County	Residential - rural
Rural residential	R-R	Santa Cruz County	Residential - rural
Public facility	P	Santa Cruz County	Public facility/infrastructure
Public/quasi-public	P/QP	City of Watsonville	Public facility/infrastructure
Transportation, communication, and utilities	TCU	City of Watsonville	Public facility/infrastructure
Suburban residential	R-S	Santa Cruz County	Residential - urban
Urban residential, very low density	R-UVL	Santa Cruz County	Residential - urban

TABLE 7 (continued)

County/City Land Use Designation	Code	Land Use Plan	Generalized Study Designation
Urban residential, low density	R-UL	Santa Cruz County	Residential - urban
Urban residential, medium density	R-UM	Santa Cruz County	Residential - urban
Urban residential, high density	R-UH	Santa Cruz County	Residential - urban
Residential, low density	R-LD	City of Watsonville	Residential - urban
Residential, medium density	R-MD	City of Watsonville	Residential - urban
Residential, high density	R-HD	City of Watsonville	Residential - urban
Office commercial	C-O	Santa Cruz County	Commercial
Neighborhood commercial	C-N	Santa Cruz County	Commercial
Community commercial	C-C	Santa Cruz County	Commercial
Visitor accommodations	C-V	Santa Cruz County	Commercial
Service commercial/light industrial	C-S	Santa Cruz County	Commercial
General commercial	CG	City of Watsonville	Commercial
Central commercial	CC	City of Watsonville	Commercial
Heavy industrial	I	Santa Cruz County	Industrial
Industrial	I	City of Watsonville	Industrial
Specific plan area	SPA	City of Watsonville	Specific plan area
Coastal zone	CZ	City of Watsonville	Coastal zone

TABLE 8

RESULTS FROM FIELD VERIFICATION
OF WETLAND PROBABILITY MAP

Line	Coordinate Location		Wetlands Present? (Yes/No/Maybe)	Probability of Historical Wetland Presence (High/Med./Low)
	Easting	Northing		
1	609489.378	4086633.75	Maybe	Medium
2	609592.579	4086417.69	No Access	No Access
3	609615.512	4086255.35	Maybe	Medium
4	609726.558	4086211.29	Maybe	Medium
5	609731.990	4086095.42	Maybe	Medium
6	609569.531	4086030.39	No	Medium
7	609828.439	4086046.08	Yes	Medium
8	609972.277	4085945.40	Yes	High
9	610089.963	4086352.07	Maybe	Medium
10	610027.197	4086214.77	No Access	No Access
11	610317.488	4086413.52	Yes	High
12	610099.116	4086107.54	Maybe	Medium
13	609427.327	4085816.27	No	Medium
14	609799.998	4085659.35	Maybe	Medium
15	609688.851	4085788.48	Yes	High
16	609623.470	4085566.19	Yes	High
17	609679.044	4085450.14	Yes	High
18	609644.719	4085271.97	Yes	High
19	609672.506	4085038.24	Yes	High
20	609615.297	4084958.14	Yes	High
21	609450.210	4084891.13	Yes	High
22	609177.245	4084685.18	No Access	No Access
23	608181.003	4084453.48	Yes	Medium
24	609225.566	4087382.35	Yes	High
25	609046.790	4086976.27	Maybe	High
26	608985.495	4086641.70	Yes	High
27	608977.833	4086521.67	Yes	High
28	608645.821	4086079.84	No	High
29	608847.582	4086171.78	Yes	High
30	608630.497	4085714.62	Yes	High

TABLE 8 (continued)

Line	Coordinate Location Easting	Northing	Wetlands Present? (Yes/No/Maybe)	Probability of Historical Wetland Presence (High/Med./Low)
31	608676.468	4085576.71	Yes	High
32	608880.783	4085357.07	Maybe	Medium
33	608592.188	4085037.83	Yes	High
34	608009.889	4085318.76	Yes	High
35	608186.111	4085254.91	Yes	High
36	607345.864	4085576.71	Yes	High
37	607665.107	4085178.29	No	High
38	607391.835	4084795.20	No Access	No Access
39	607700.862	4085019.95	No Access	No Access
40	607598.704	4084603.66	No Access	No Access
41	607928.163	4084330.38	No Access	No Access
42	607333.094	4084018.80	No Access	No Access
43	607409.712	4083972.83	No Access	No Access
44	606988.312	4083674.02	Maybe	Medium
45	606669.069	4087300.62	Maybe	Medium
46	606692.055	4087091.20	Yes	High
47	606669.069	4086608.50	Yes	High
48	606628.206	4086442.50	Yes	High
49	606829.968	4085420.92	Yes	High
50	606541.372	4085040.38	Yes	High
51	606661.407	4085035.27	Yes	Medium
52	606745.687	4083686.79	Yes	High
53	607373.957	4083127.48	Yes	High
54	606916.802	4081510.19	Yes	High
55	607015.767	4082068.87	Yes	High
56	607350.972	4082882.94	Yes	High
57	607216.890	4081730.47	Yes	High

TABLE 9

SUMMARY OF LAND USES ASSIGNED TO
CONVERTED WETLANDS FOR TWO LAND USE PLANS

Generalized Study Designation	Santa Cruz County Land Use Plan			City of Watsonville Land Use Plan		
	Hectares WBH (1881)	Hectares Lewis (1908)	Percent Range	Hectares WBH (1881)	Hectares Lewis (1908)	Percent Range
Environmental mgmt.	11	25	3.9 - 6.9	129	136	39.8 - 49.0
Agriculture	182	223	61.9 - 65.5	34	39	11.3 -12.9
Residential - rural	>1	0	0 - >1	0	0	0.0
Public facility/ infrastructure	16	26	5.8 - 7.2	15	25	5.8 - 7.3
Residential - urban	0	0	0 - 0.1	23	26	7.7 - 8.6
Commercial	0	0	0	6	10	2.4 - 2.9
Industrial	0	0	0	5	9	2.0 - 2.5
Specific plan area	0	0	0	36	65	13.7 - 19.1
Coastal zone	0	0	0	2	1	0.3 - 0.7
No designation	69	86	23.9 - 24.6	13	31	4.8 - 9.0

TABLE 10

SUMMARY OF LAND USES ASSIGNED TO CONVERTED WETLANDS
USING SANTA CRUZ COUNTY LAND USE PLAN AND
WRIGHT, BENNETT, HEALY (1881)
AS BASELINE FOR CONVERTED WETLANDS

Generalized Study Designation		Hectares	Percent of Total
Environmental management		11	3.9
Agriculture		182	65.5
Residential - rural		>1	>1
	Total non-urban	**193**	**69.5**
Public facility / infrastructure		16	5.8
Residential - urban		0	0.0
Commercial		0	0.0
Industrial		0	0.0
Specific plan area		0	0.0
	Total urban	**16**	**5.8**
Coastal zone		0	0.0
No designation		69	24.6
	Total unspecified	**69**	**24.6**

TABLE 11

SUMMARY OF LAND USES ASSIGNED TO CONVERTED WETLANDS
USING CITY OF WATSONVILLE LAND USE PLAN AND
WRIGHT, BENNETT, HEALY (1881)
AS BASELINE FOR CONVERTED WETLANDS

Generalized Study Designation		Hectares	Percent of Total
Environmental management		129	49.0
Agriculture		34	12.9
Residential-rural		0	0.0
	Total non-urban	**163**	**61.9**
Public facility/infrastructure		15	5.8
Residential-urban		23	8.6
Commercial		6	2.4
Industrial		5	2.0
Specific plan area		36	13.7
	Total urban	**86**	**32.6**
Coastal zone		2	0.7
No designation		13	4.8
	Total unspecified	**15**	**5.6**

TABLE 12

SUMMARY OF LAND USES ASSIGNED TO CONVERTED WETLANDS USING SANTA CRUZ COUNTY LAND USE PLAN AND LEWIS (1908) AS BASELINE FOR CONVERTED WETLANDS

Generalized Study Designation		Hectares	Percent of Total
Environmental management		25	6.9
Agriculture		223	61.9
Residential - rural		0	0.0
	Total non-urban	**248**	**68.8**
Public facility / infrastructure		26	7.2
Residential - urban		0	0.1
Commercial		0	0.0
Industrial		0	0.0
Specific plan area		0	0.0
	Total urban	**26**	**7.3**
Coastal zone		0	0.0
No designation		86	23.9
	Total unspecified	**86**	**23.9**

TABLE 13

SUMMARY OF LAND USES ASSIGNED TO CONVERTED WETLANDS USING CITY OF WATSONVILLE LAND USE PLAN AND LEWIS (1908) AS BASELINE FOR CONVERTED WETLANDS

Generalized Study Designation		Hectares	Percent of Total
Environmental management		136	39.8
Agriculture		39	11.3
Residential - rural		0	0.0
	Total non-urban	**175**	**51.1**
Public facility / infrastructure		25	7.3
Residential - urban		26	7.7
Commercial		10	2.9
Industrial		9	2.5
Specific plan area		65	19.1
	Total urban	**135**	**39.5**
Coastal zone		1	0.3
No designation		31	9.0
	Total unspecified	**32**	**9.3**

APPENDIX 2

MAPS

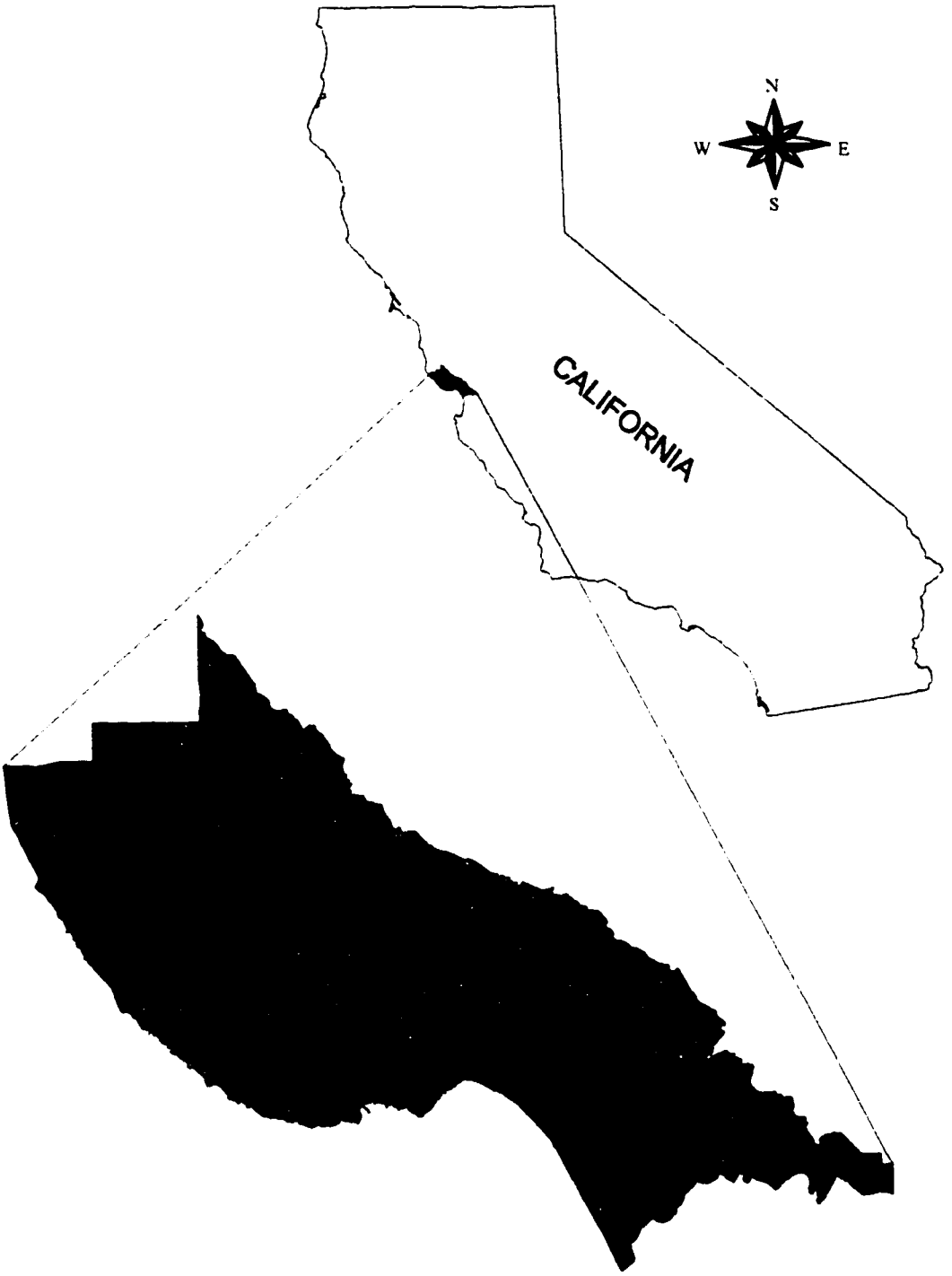


Figure 1. General location of study area.

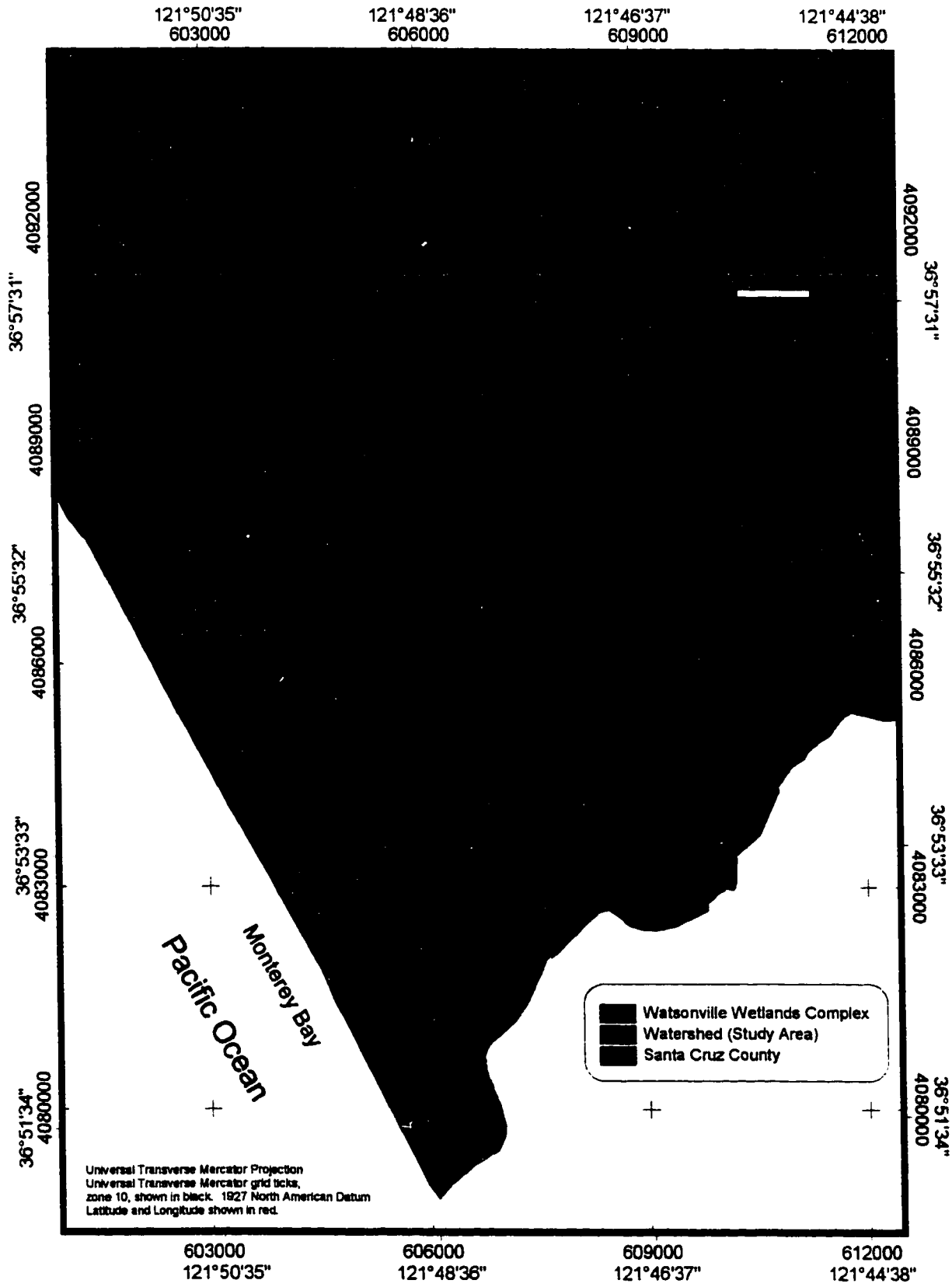
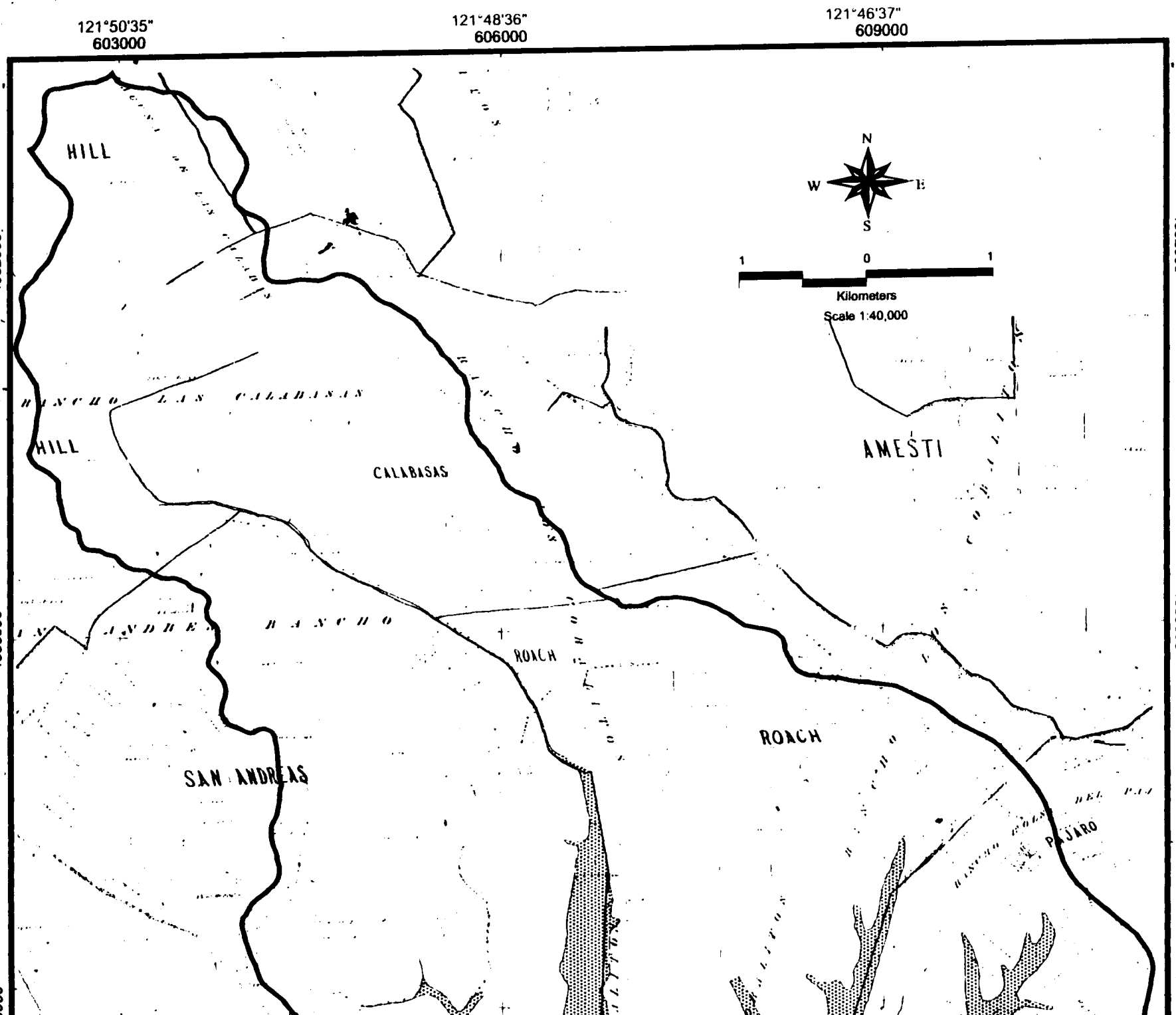


Figure 2. Study area boundary.


121°50'35"
603000
121°48'36"
606000
121°46'37"
609000
4092000
4089000
4086000
36°57'31"
36°55'32"
N
W
E
S
1
0
1
Kilometers
Scale 1:40,000
HILL
HILL
CALABASAS
AMESTI
ROACH
ROACH
SAN ANDREAS
PAJARO

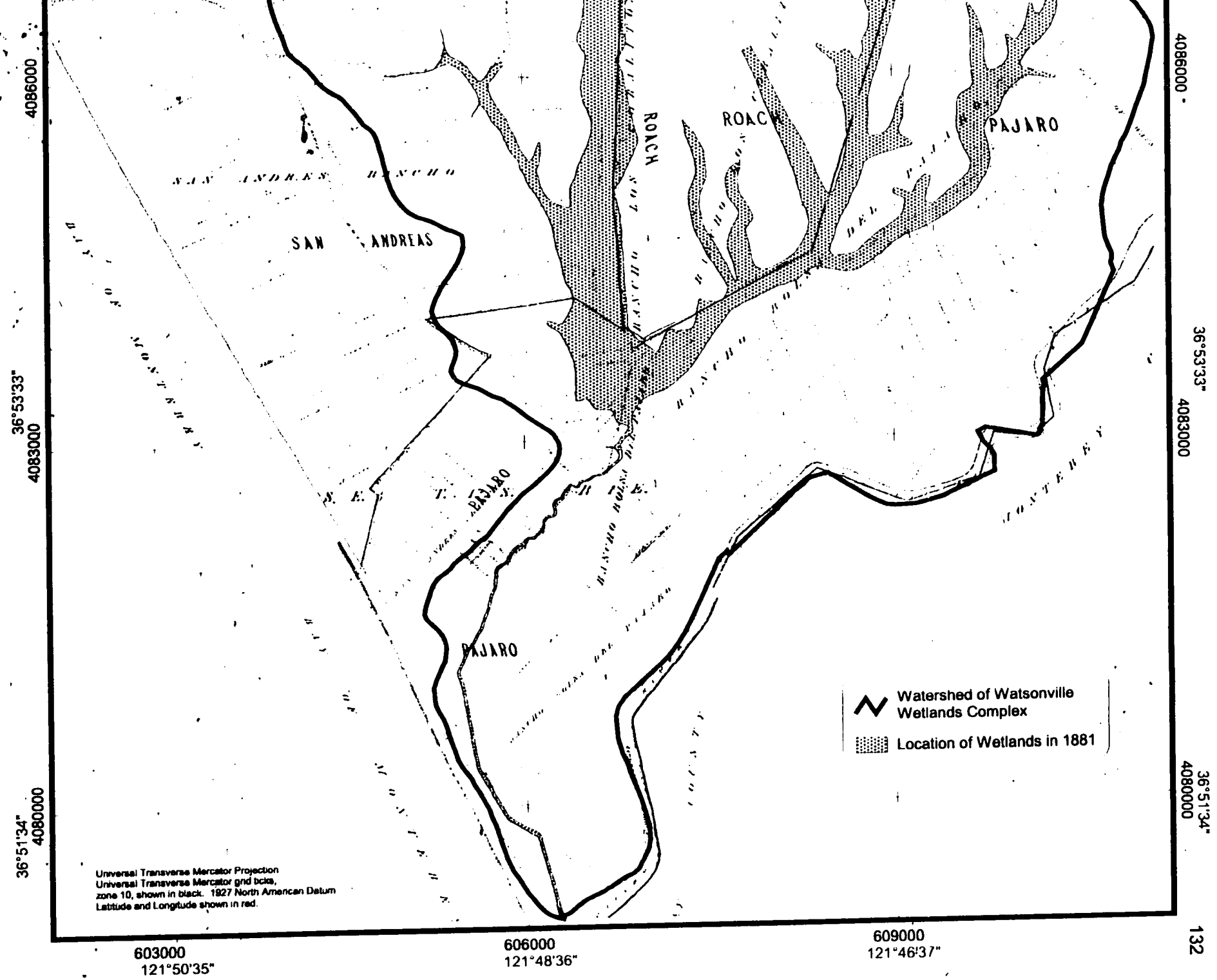
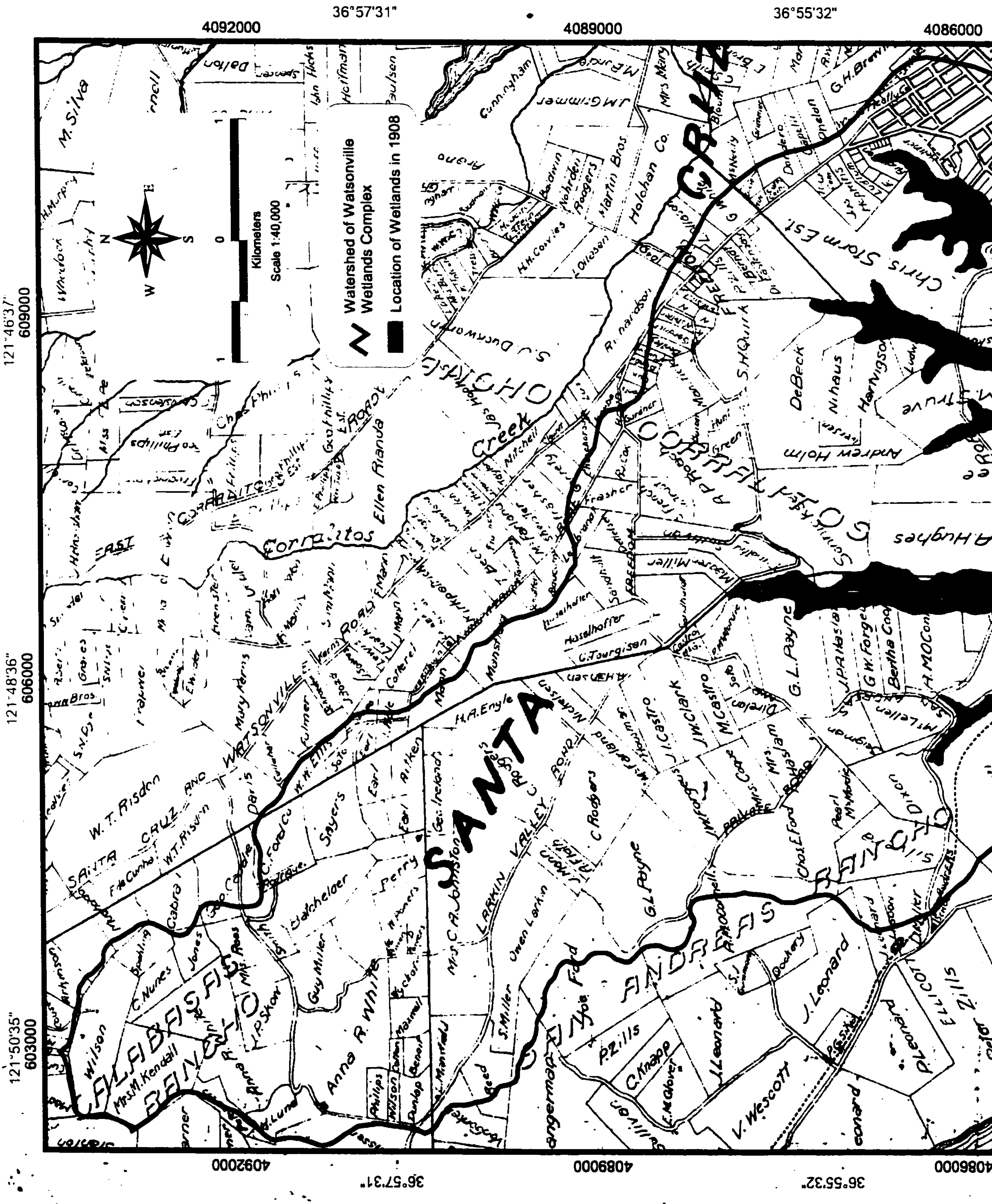


Figure 3. Location of wetlands in 1881 based upon Wright, Bennett, and Healy (1881).



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Watershed of Watsonville Wetlands Complex
Location of Wetlands in 1908
Kilometers
Scale 1:40,000

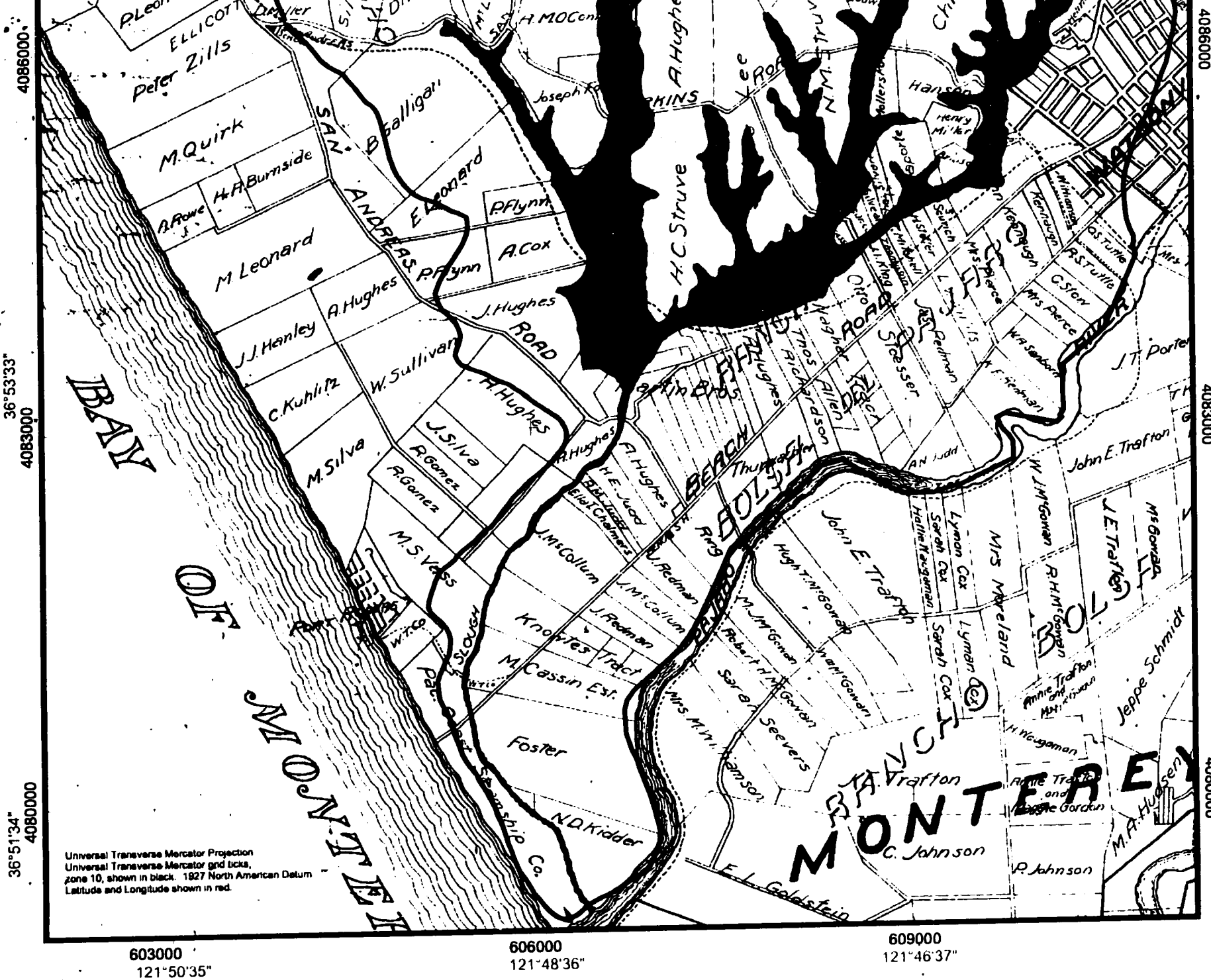
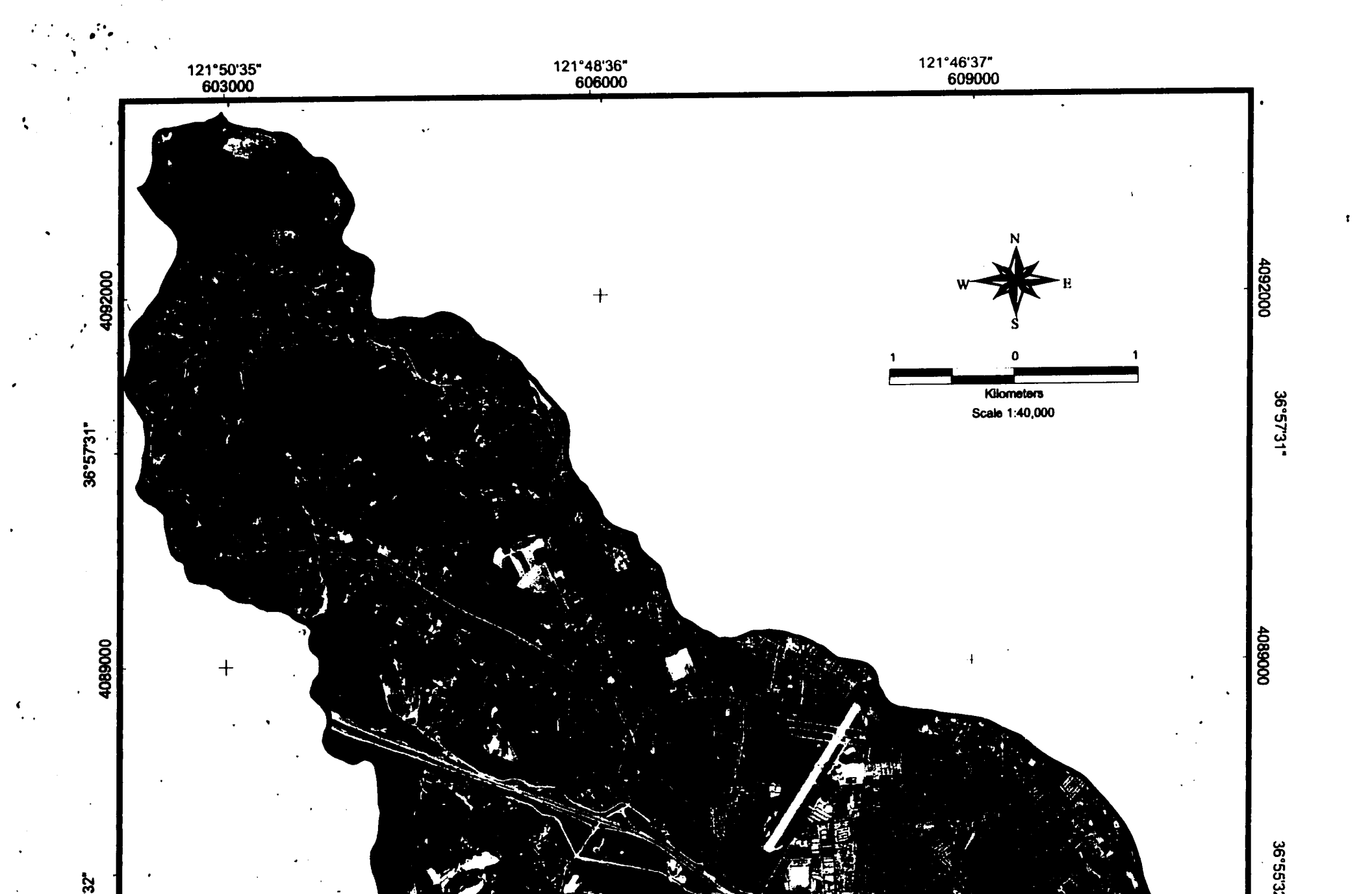


Figure 4. Location of wetlands in 1908 based upon Lewis (1908).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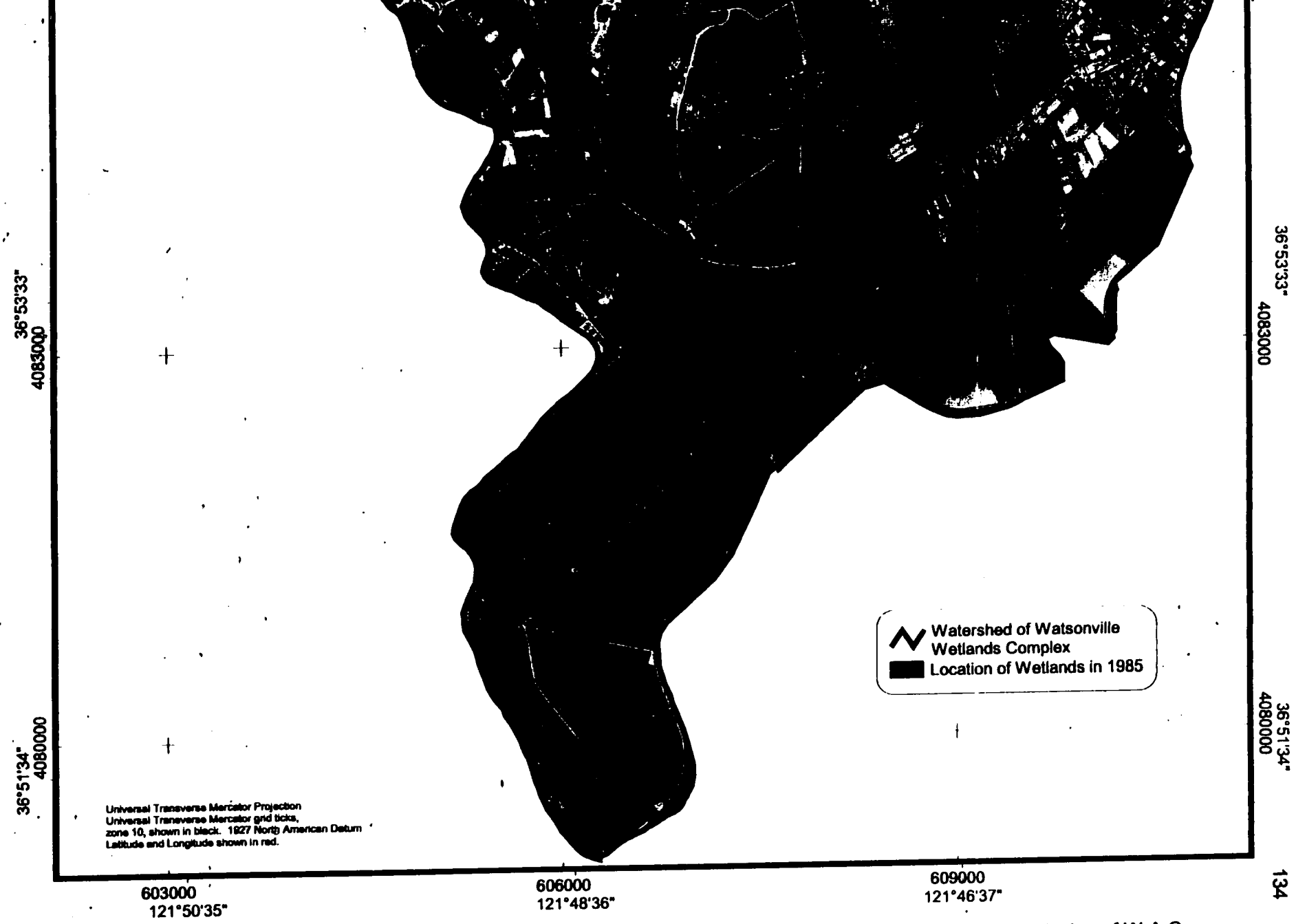
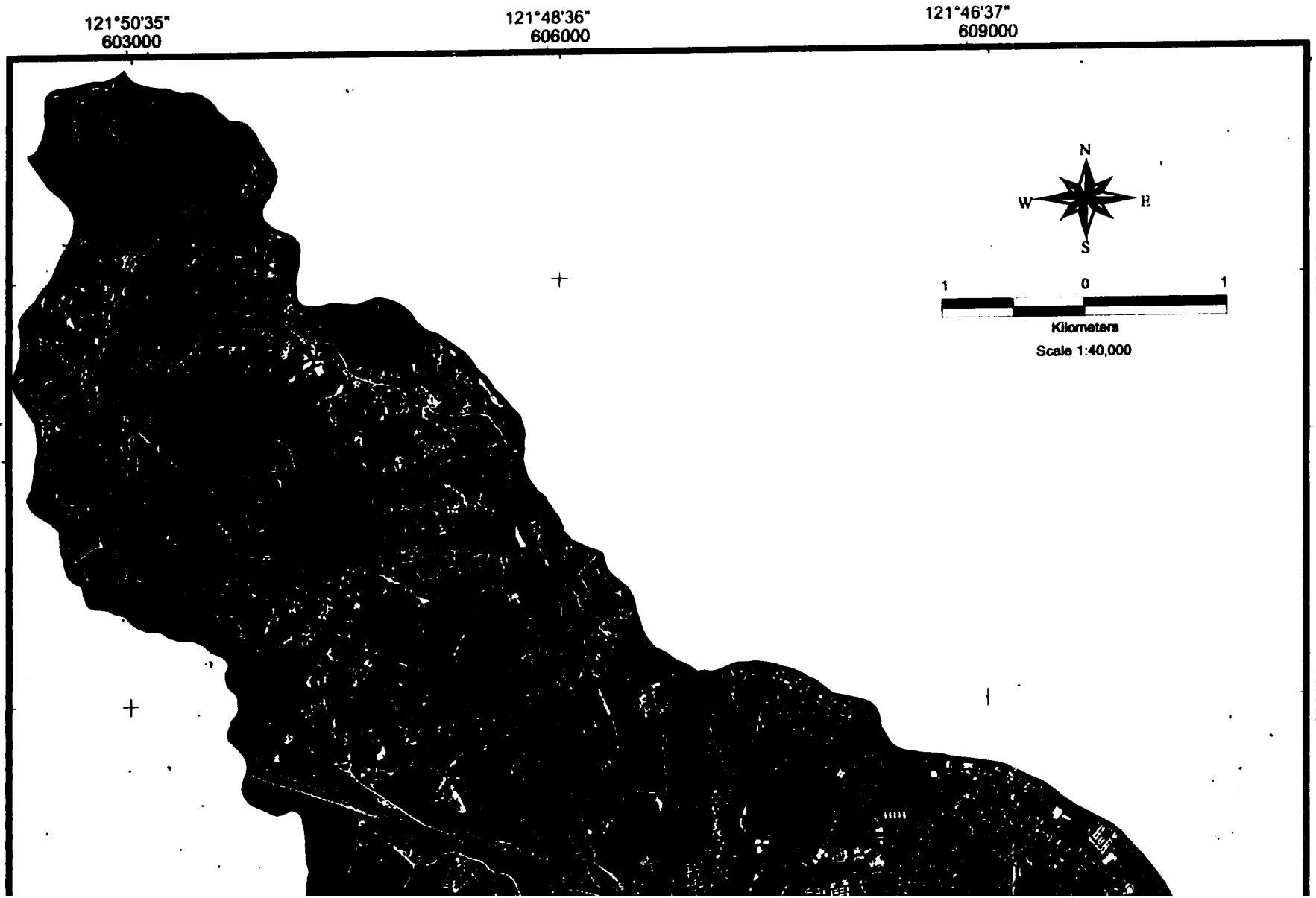


Figure 5. Location of wetlands in 1985 based upon W.A.C. Corporation aerial images. Images reprinted by permission of W.A.C. Corporation (www.waccorp.com). Digital modifications to aerial images by author.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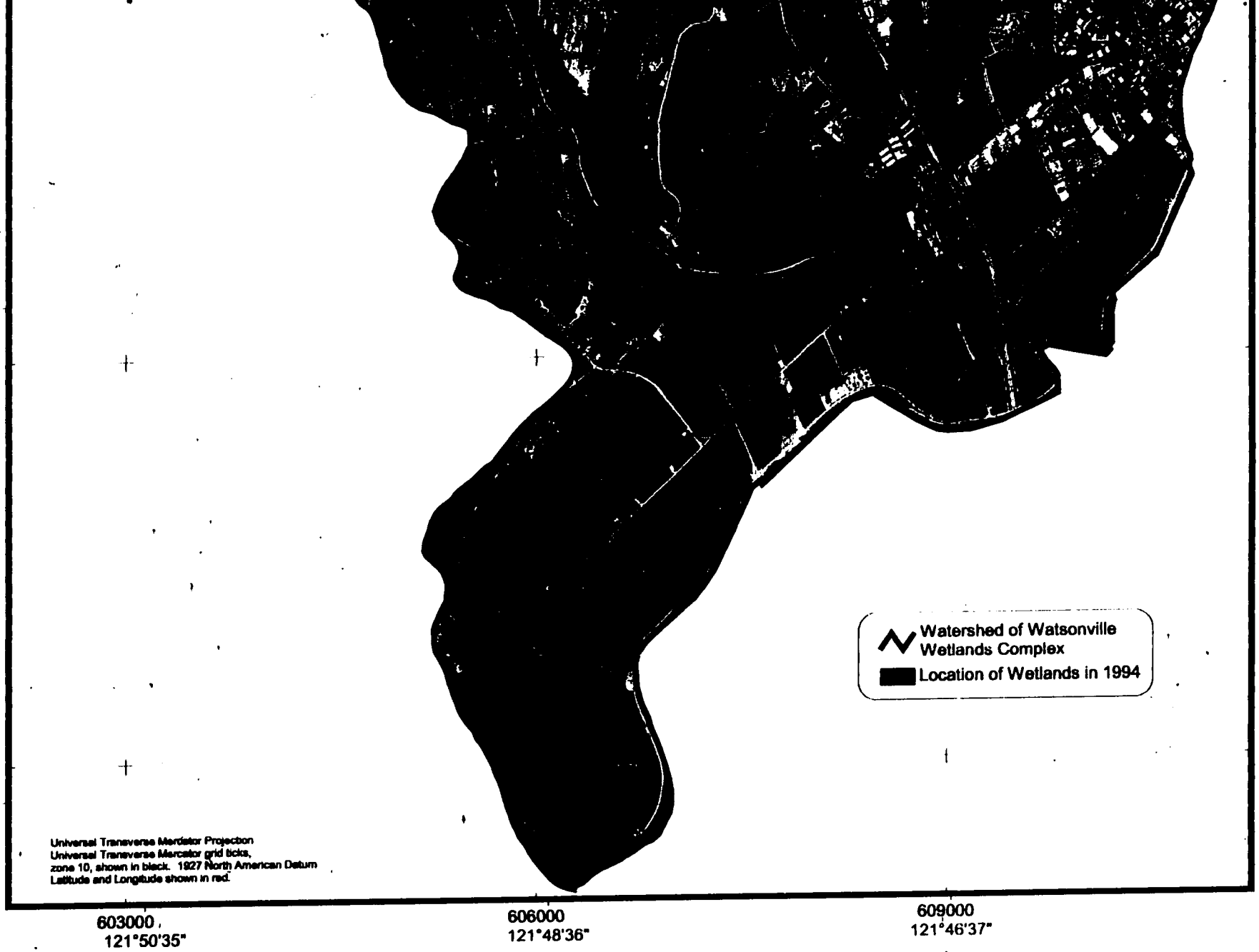
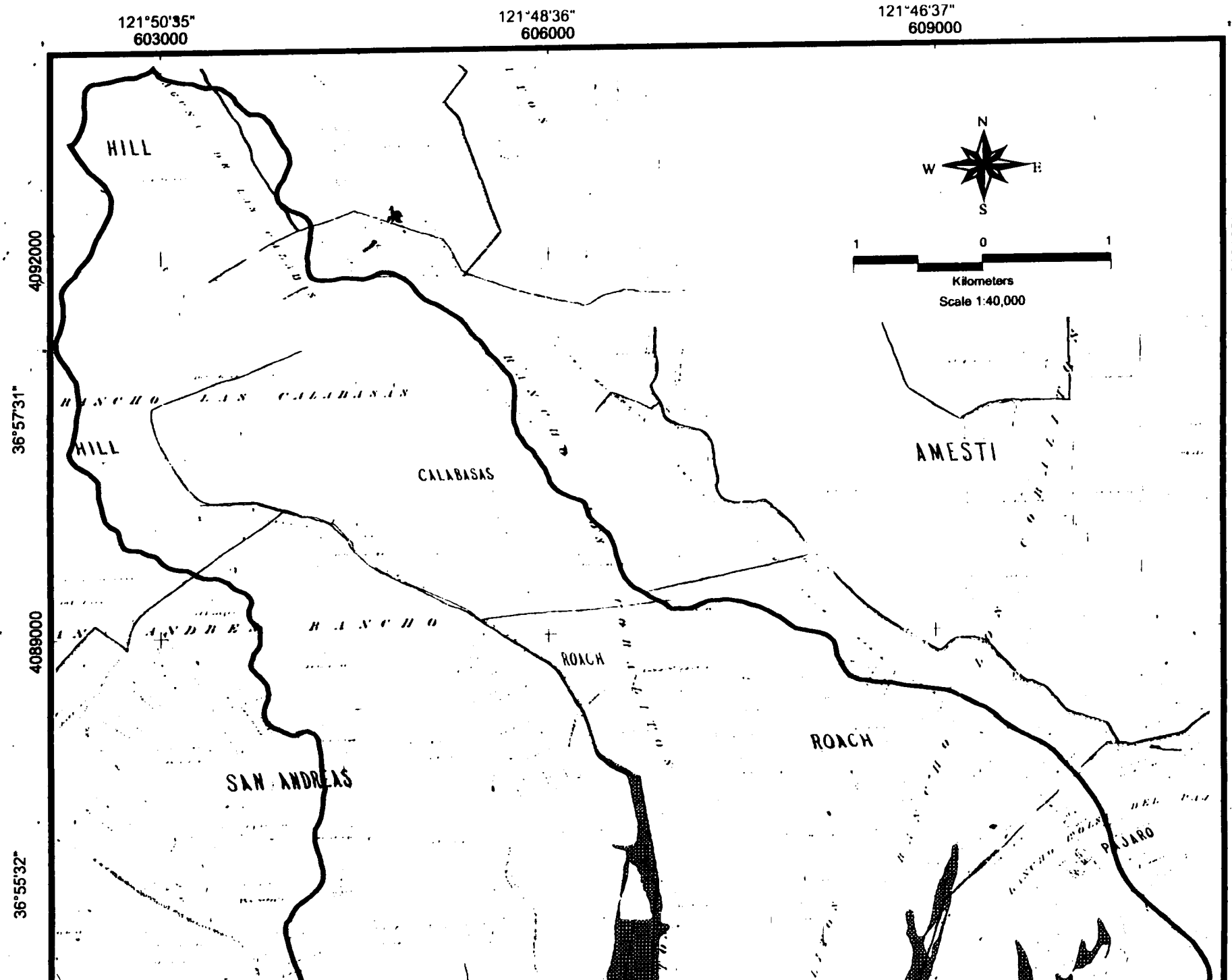


Figure 6. Location of wetlands in 1994 based upon Air Flight Service aerial images. Images reprinted by permission of Air Flight Service. Digital modifications to aerial images by author.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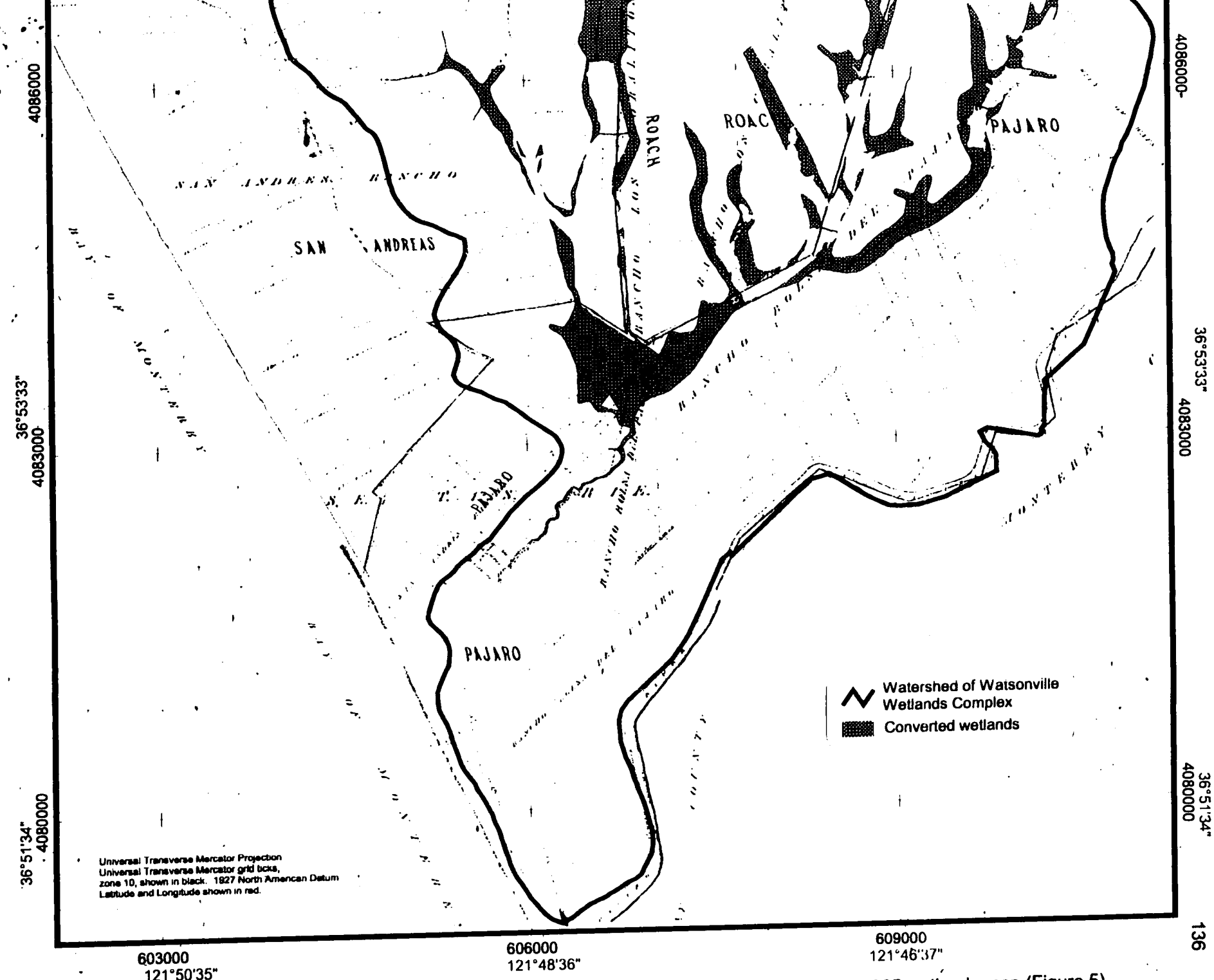
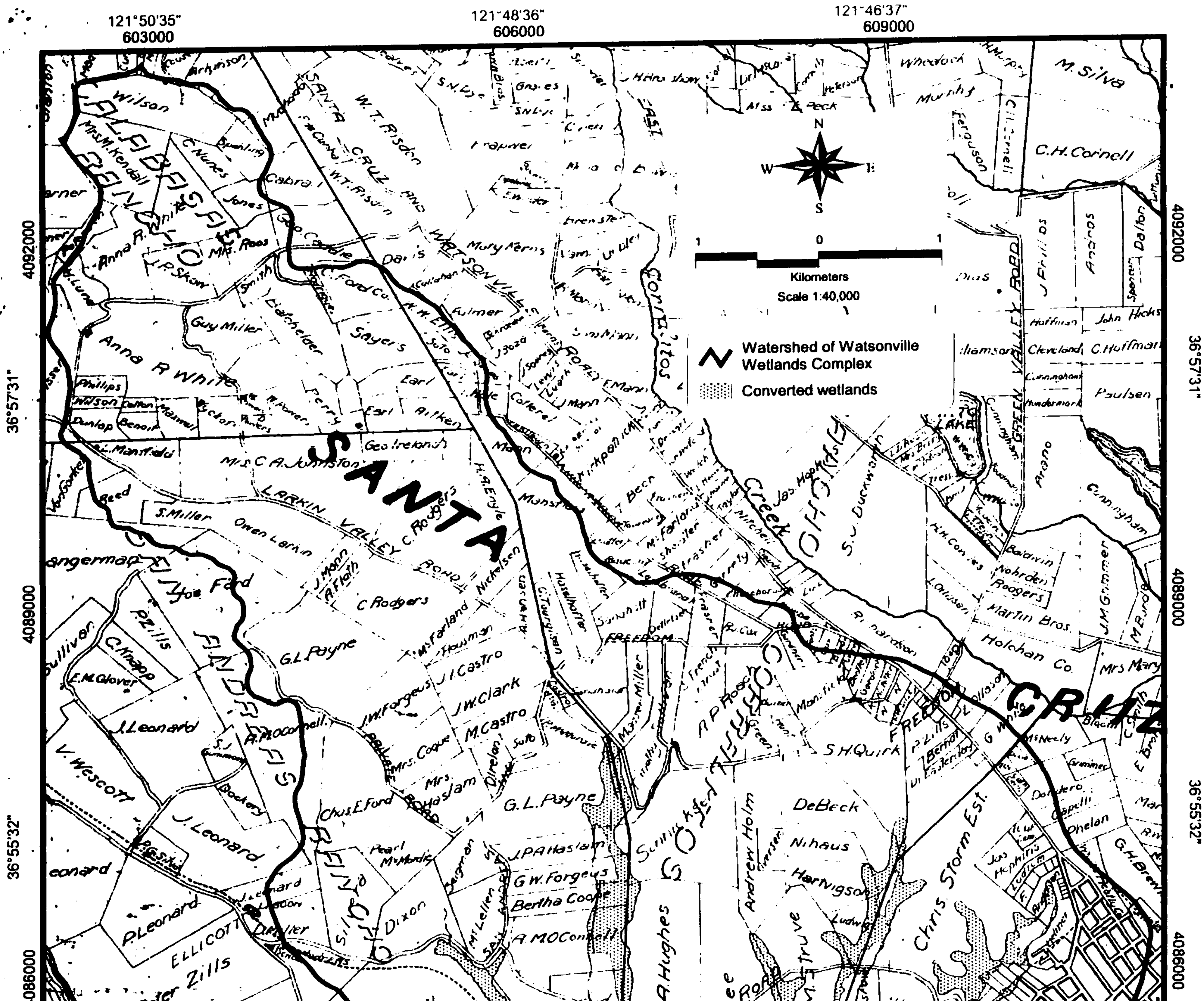


Figure 7. Location of converted wetlands based upon Wright, Bennett, Healy (1881), compared to 1985 wetlands map (Figure 5).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Scale 1:40,000
Watershed of Watsonville Wetlands Complex
Converted wetlands
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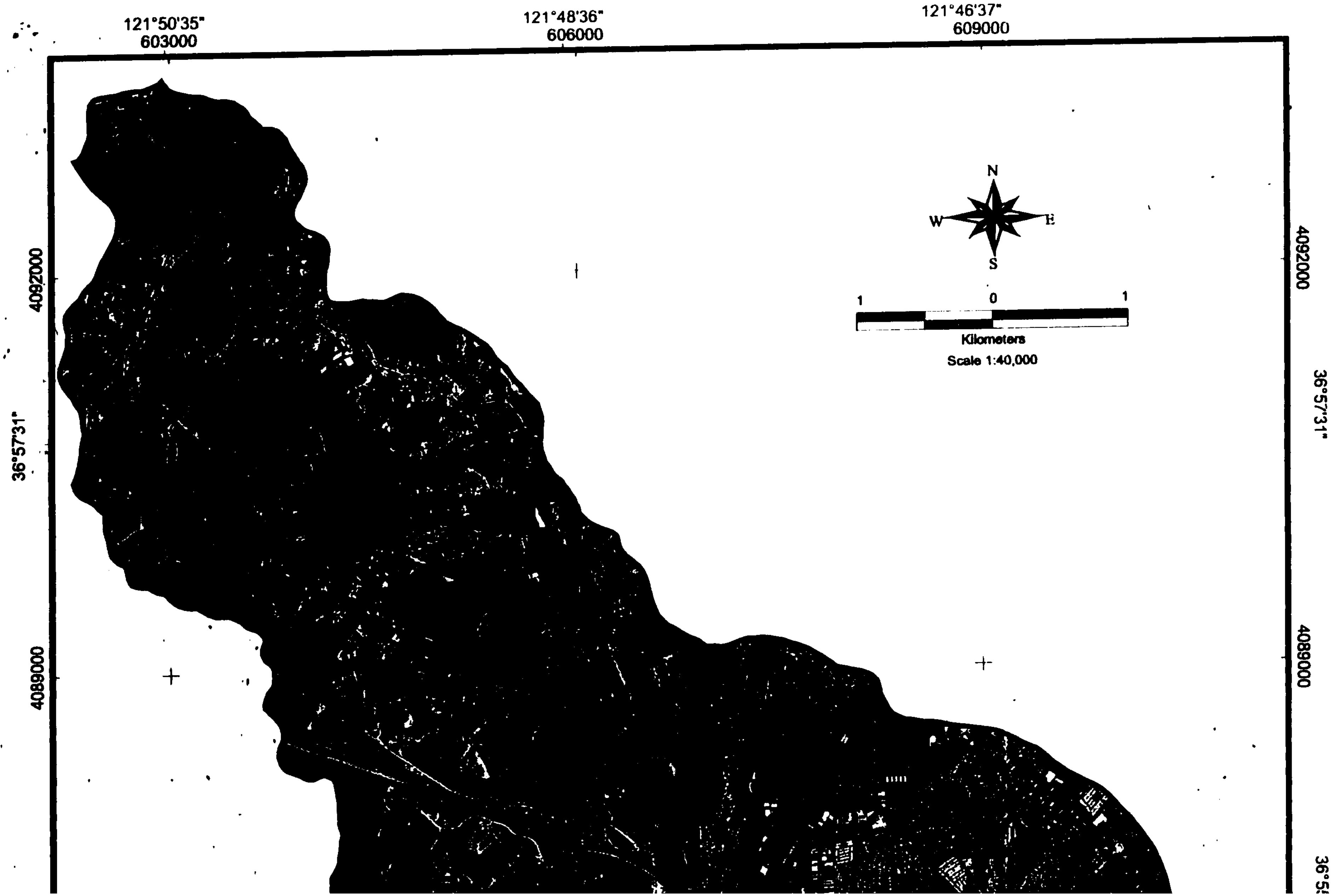
CRUZ
SANTA CRUZ AND WATSONVILLE ROAD
LARKIN VALLEY ROAD
GREEN VALLEY ROAD
FREEDOM
Corralitos
Creek
Chris Storm Est.

Figure 8. Location of converted wetlands based upon Lewis (1908), compared to 1985 wetlands map (Figure 5).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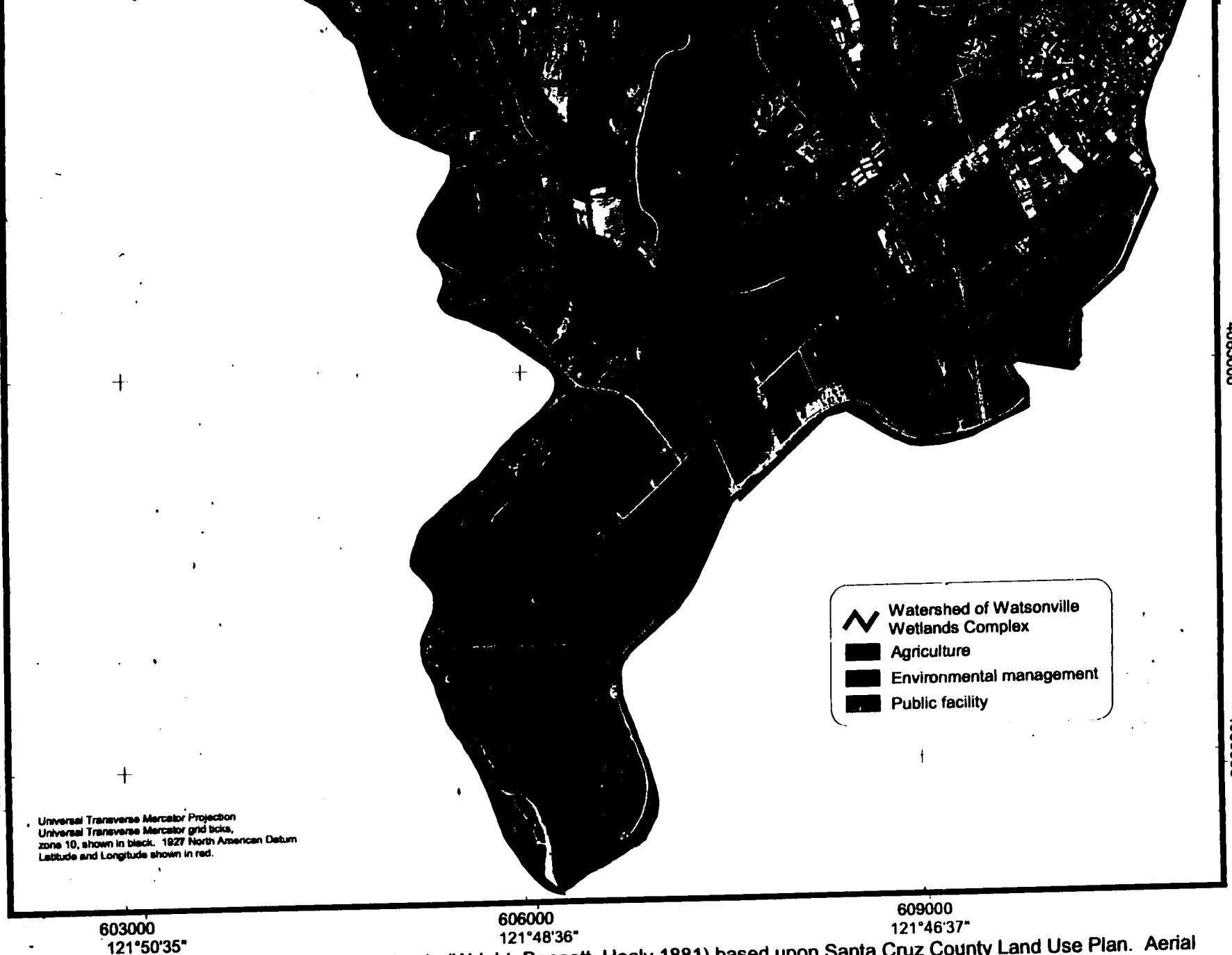
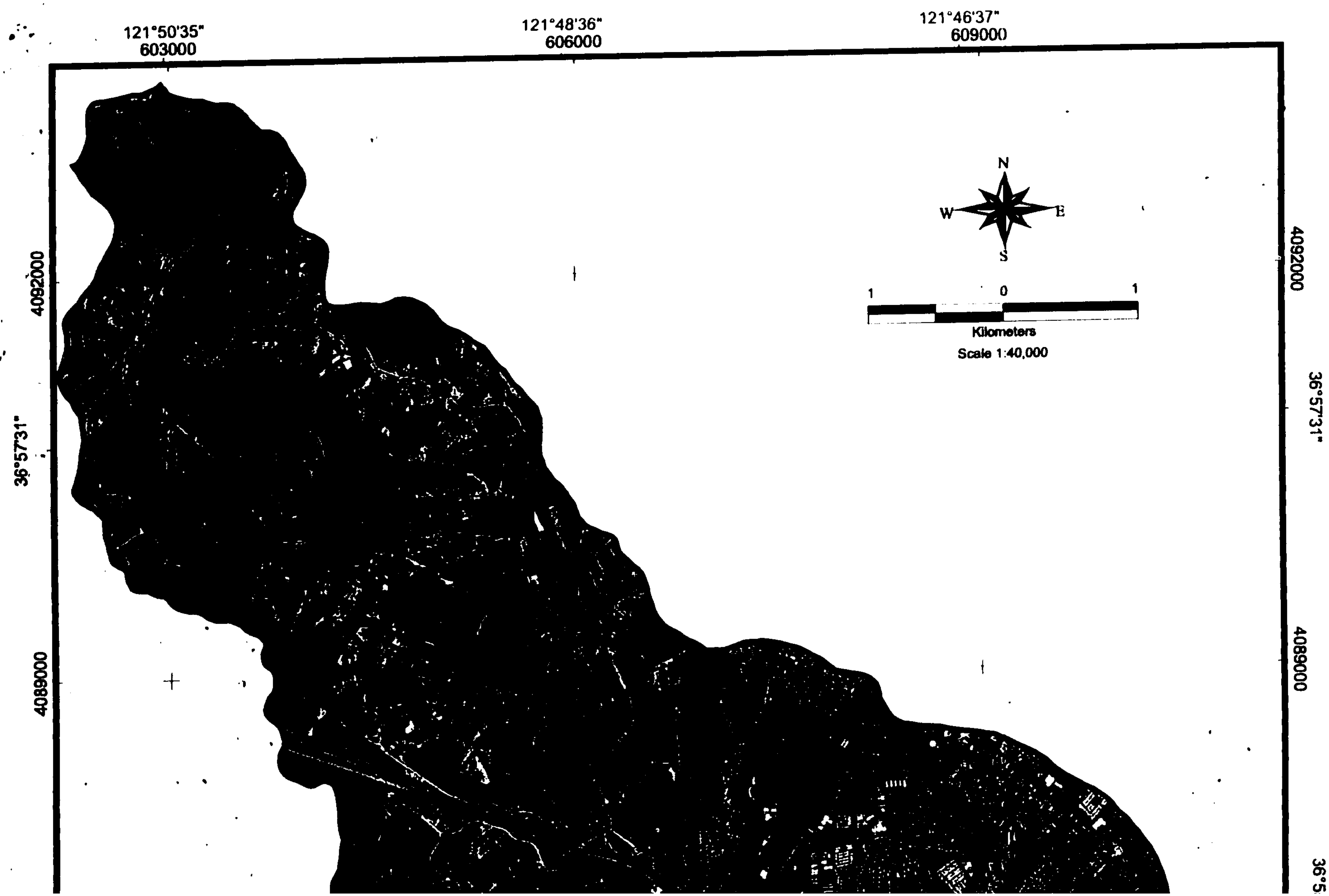


Figure 9. Zoned land uses of converted wetlands (Wright, Bennett, Healy 1881) based upon Santa Cruz County Land Use Plan. Aerial images by Air Flight Service (1994) as digitally modified by author. Aerial images reprinted by permission of Air Flight Service.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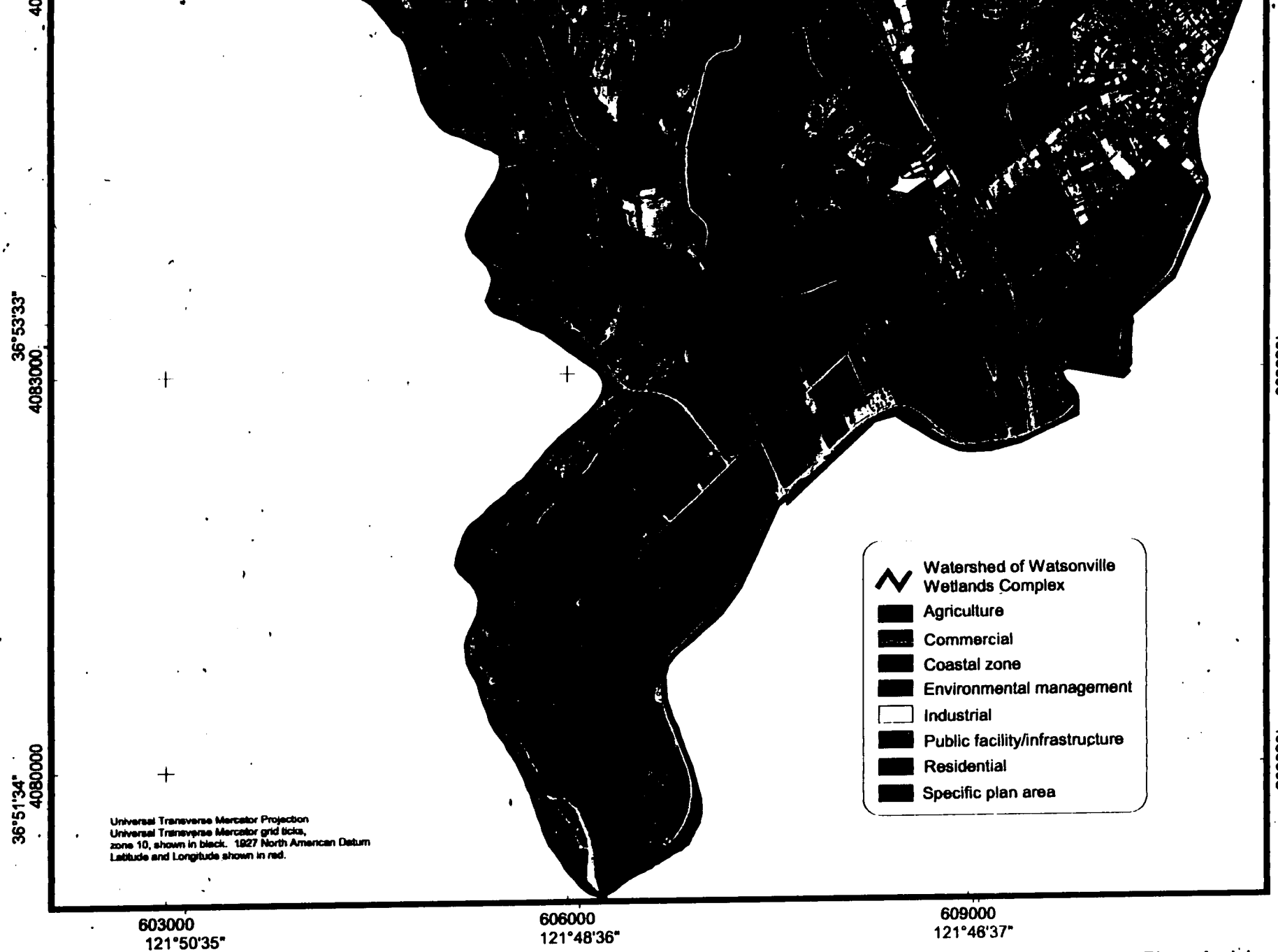
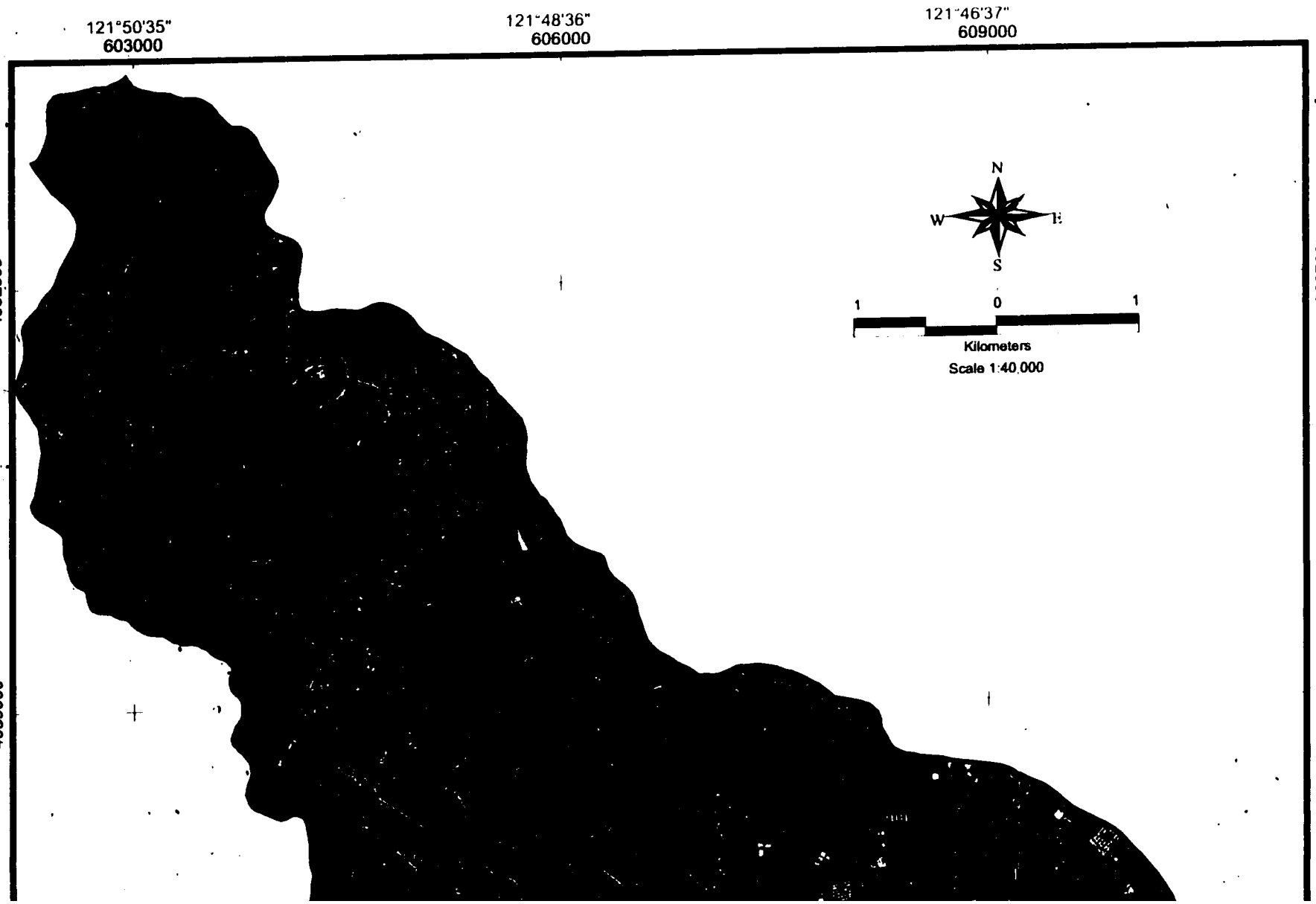


Figure 10. Zoned land uses of converted wetlands (Wright, Bennett, Healy 1881) based upon City of Watsonville Land Use Plan. Aerial images by Air Flight Service (1994) as digitally modified by author. Aerial images reprinted by permission of Air Flight Service.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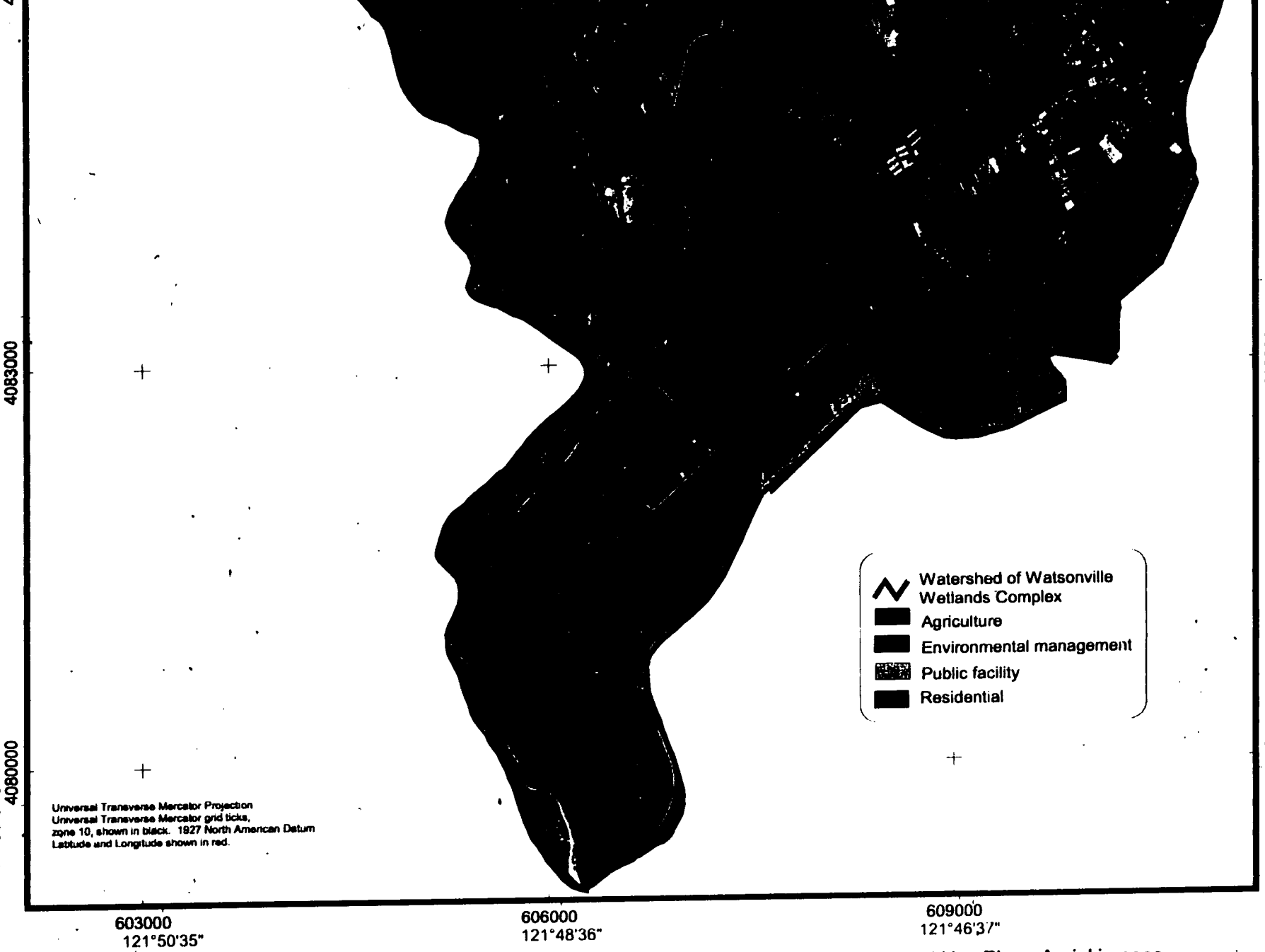
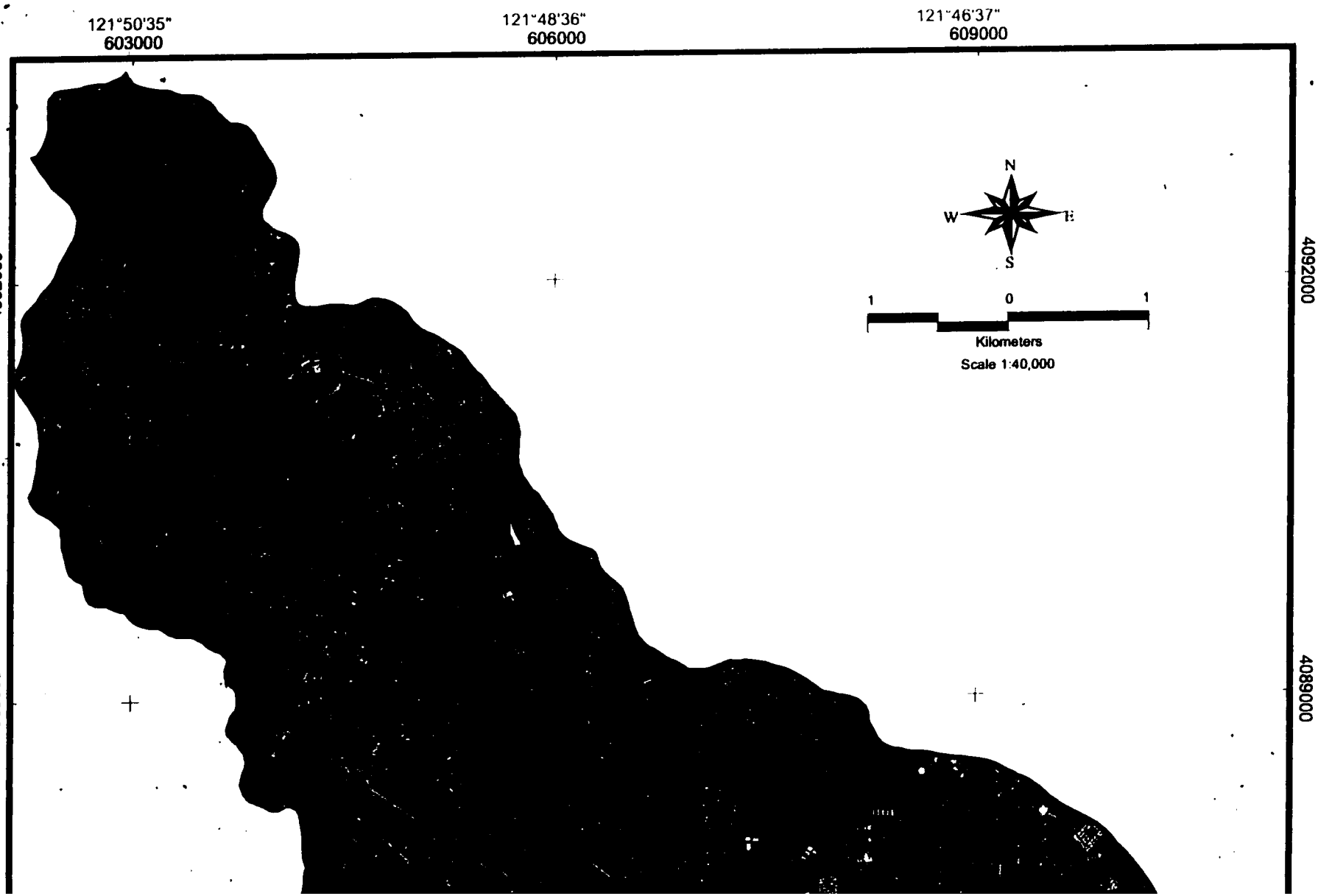


Figure 11. Zoned land uses of converted wetlands (Lewis 1908) based upon Santa Cruz County Land Use Plan. Aerial images by Air Flight Service (1994) as digitally modified by author. Aerial images reprinted by permission of Air Flight Service.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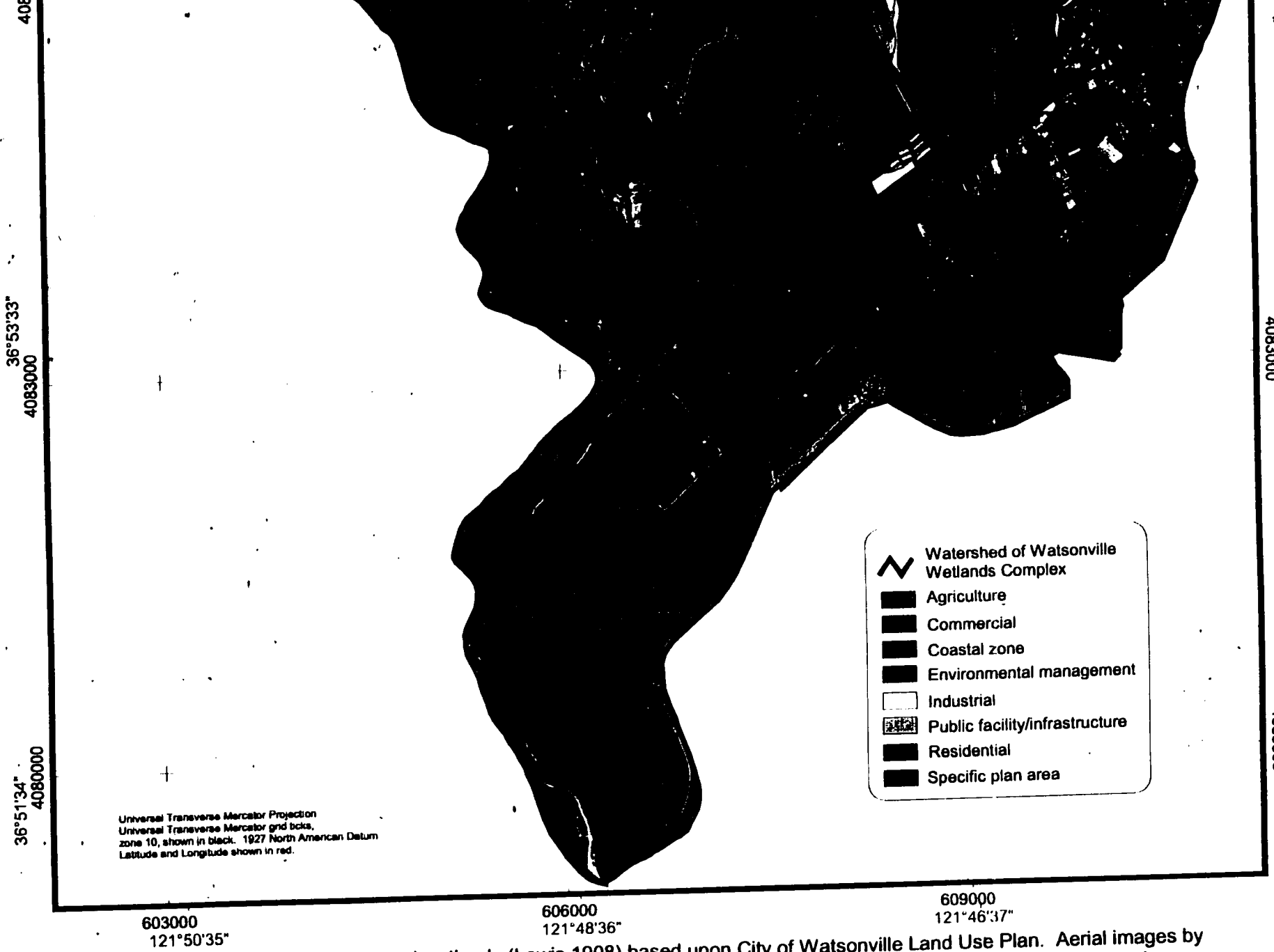


Figure 12. Zoned land uses of converted wetlands (Lewis 1908) based upon City of Watsonville Land Use Plan. Aerial images by Air Flight Service (1994) as digitally modified by author. Aerial images reprinted by permission of Air Flight Service.

February 17, 1999

WAC Corporation
520 Conger Street
Eugene, OR 97402-2795

Subject: **REQUEST FOR AUTHORIZATION**
TO USE COPYRIGHTED MATERIALS
Aerial Photographs
WAC Corporation
Flight WAC-85-CA-12 and WAC-85-CA-14
Date of Flights: April 12, 1985 and April 13, 1985

Dear Sirs:

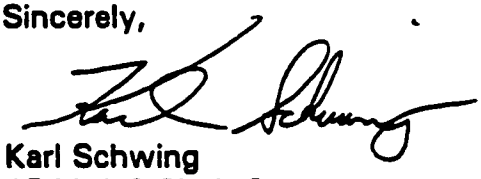
It is my understanding that the WAC Corporation is the copyright holder of the subject aerial photographs. Please accept this letter as request to publish value added reproductions of the subject aerial photographs.

I am a graduate student with the Department of Environmental Studies, San Jose State University, San Jose, California. I wish to use the subject photographs as research materials for my master's thesis. Utilization of these photographs includes scanning the photographs into digital format, manipulation of the photographs (georectification) to correct distortions, and input to a geographic information system (GIS) for use as a digital map. Publication of the value added photographs will include printed duplication for the thesis manuscript. In addition, a CD-ROM, or other form of storage media, containing GIS data, including the digitized photographs, will accompany the thesis manuscript.

The use of the subject photographs and their reproduction in paper and digital formats, is intended solely for academic purposes. Accordingly, the photographs will not be sold for profit. May I have your written authorization to use the materials in the above described manner?

If you have any questions, I can be reached via telephone, mail, or e-mail, as shown below. Thank you for your time and attention.

Sincerely,



Karl Schwing
1541-1/2 Sixth Street
Manhattan Beach, CA 90266
(310) 372-1893
kschwing@pacbell.net

WAC
CORPORATION

March 8th, 1999

Karl Schwing
1541 1/2 Sixth Street
Manhattan Beach, CA 90266

Dear Mr. Schwing:

This letter may be used as a copyright release under the following conditions:

Copyright release is granted for the express purposes as stated in the letter to WAC Corporation from Mr. Schwing dated 2/17/99. In addition WAC is requesting a line of credit for the photography as follows: "Aerial photography by WAC Corporation. (www.waccorp.com)"

I appreciate your concern in this matter. If you have any further questions, please feel free to call.

Sincerely,

Jody Wilkinson

Jody Wilkinson
WAC Corporation, Inc.

Aerial Photography, Photo Lab Services, Stock Photography
541.342.5169
541.485.1258 (FAX)
520 Conger Street
Eugene, Oregon 97402-2795

February 17, 1999

Air Flight Service
2220 Calle de Luna
Santa Clara, CA 95054

Subject: **REQUEST FOR AUTHORIZATION TO USE COPYRIGHTED MATERIALS**
Aerial Photographs
Big Creek Lumber Series
Flight Line 5-1 through 9-6
Date of Flight: June 22, 1994

Dear Sirs:

It is my understanding that Air Flight Service is the copyright holder of the subject aerial photographs. Please accept this letter as request to publish value added reproductions of the subject aerial photographs.

I am a graduate student at San Jose State University, San Jose, California. I wish to use the subject photographs as research materials for my master's thesis. Utilization of these photographs includes scanning the photographs into digital format, manipulation of the photographs (georectification) to correct distortions, and input to a geographic information system (GIS) for use as a digital map. Publication of the value added photographs will include printed duplication for the thesis manuscript. In addition, a CD-ROM, or other form of storage media, containing GIS data, including the digitized photographs, will accompany the thesis manuscript.

The use of the subject photographs and their reproduction in paper and digital formats, is intended solely for academic purposes. Accordingly, the photographs will not be sold for profit. May I have your written authorization to use the materials in the above described manner?

If you have any questions, I can be reached via telephone, mail, or e-mail, as shown below. Thank you for your time and attention.

Sincerely,

Karl Schwing
1541-1/2 Sixth Street
Manhattan Beach, CA 90266
(310) 372-1893
kschwing@pacbell.net

Air Flight Service

Mapping Photography
GPS Positioning
Digital Imagery
Airborne Sensor Platforms
Photo Library

2220 Calle De Luna Santa Clara, California 95054 (408) 988-0107 Fax:(408) 988-0729

February 22, 1999

Karl Schwing
1541-1\2 Sixth Street
Manhattan Beach, CA 90266

RE: COYYRIGHT

This letter is to confirm authorization for the use and reproduction of Air Flight Service aerial photography. Flown 6/24/94, line 5-1 thru 9-6 for academic purposes.

Jack Barcelona
President Air Flight Service

February 17, 1999

Fairchild Aerial Surveys, Inc.
c/o Department of Geology
Whittier College
13406 Philadelphia Street
P.O. Box 634
Whittier, California 90608

Subject: **REQUEST FOR AUTHORIZATION TO USE MATERIALS COVERED BY COPYRIGHT**
Aerial Photographs
Fairchild Aerial Survey, Inc.
Flight C-1550; May 27, 1931

Dear Sirs:

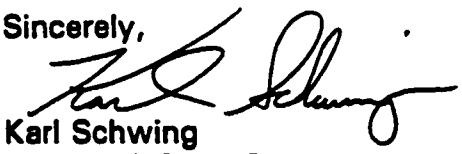
It is my understanding that the Department of Geology, Whittier College is the caretaker and copyright holder of the subject aerial photographs taken by Fairchild Aerial Survey, Inc. in 1931. Please accept this letter as request to publish value added reproductions of the subject aerial photographs.

I am a graduate student with the Department of Environmental Studies, San Jose State University, San Jose, California. I wish to use the subject photographs as research materials for my master's thesis. Utilization of these photographs includes scanning the photographs into digital format, manipulation of the photographs (georectification) to correct distortions, and input to a geographic information system (GIS) for use as a digital map. Publication of the value added photographs will include printed duplication for the thesis manuscript. In addition, a CD-ROM, or other form of storage media, containing GIS data, including the digitized photographs, will accompany the thesis manuscript.

The use of the subject photographs and their reproduction in paper and digital formats, is intended solely for academic purposes. Accordingly, the photographs will not be sold for profit. May I have your written authorization to use the materials in the above described manner?

If you have any questions, I can be reached via telephone, mail, or e-mail, as shown below. Thank you for your time and attention.

Sincerely,



Karl Schwing
1541-1/2 Sixth Street
Manhattan Beach, CA 90266
(310) 372-1893
kschwing@pacbell.net

FAIRCHILD AERIAL PHOTOGRAPHY COLLECTION
Whittier College
Whittier, California 90608

PERMISSION FOR PUBLICATION

TO: Karl Schwing
Department of Environmental Studies
San Jose State University
San Jose, CA 95192

The organization or individual named above is granted permission to publish certain photographs from the Fairchild Aerial Photography Collection at Whittier College (as specified below) in the work entitled:

Restoring Converted Wetlands: A Case Study in Watsonville, CA

on the following conditions:

(1) Each photograph will be credited to The Fairchild Aerial Photography Collection at Whittier College.

(2) The flight number(s) and frame number(s), as shown below, will be referenced in either the text or the figure caption.

(3) The photographic image will not be altered in any way other than enlargement or reduction.

This permission includes all future revisions and editions of the same work and world-wide distribution of the work in any language.

On these conditions, the above named organization or individual is granted permission to publish the following photographs:

Date	Flight Number	Frame Number(s)
5-1931	C-1550	15-24, 29-38, 46-54, 64-65, 76

To acknowledge acceptance of the conditions listed above, a representative of the publisher should sign both copies of this agreement in the space provided and return one copy to the Fairchild Aerial Photography Collection.

For the user:

Name: Karl Schwing

Title:

Date: 5/12/99

For the Fairchild Collection:

Stephanie Breaux
Stephanie Breaux
Director

April 23, 1999