California Spatial Reference Center
Dr. Yehuda Bock, Director and Principal Investigator
Greg Helmer, Chairperson CSRC Coordinating Council
Cecil H. and Ida M. Green Institute of Geophysics and Planetary Physics, MC 0225
University of California San Diego (USCD)
9500 Gilman Drive
La Jolla, CA 92093-0225
Website: http://csrc.ucsd.edu

California Spatial Reference Center

A MASTER PLAN for a MODERN CALIFORNIA GEODETIC CONTROL NETWORK

Approved By: CSRC Coordinating Council – October 18, 2002
Approved By: National Geodetic Survey – March 12, 2003

Prepared by the CSRC Committee for developing a California Spatial Reference Network Master Plan:

- Don D'Onofrio, Chairperson
  Retired NGS, CSRC Geodetic Consultant,
  & Private geodetic consultant
- Larry Fenske, RCE, PLS, retired Caltrans
- Greg Helmer, PLS, RBF Consulting
- Fred Henstridge, PLS, Psomas and Associates
- Marti Ikehara, NGS State Geodetic Advisor
- Dr. Nancy King, USGS
- Dr. Glenn Sasagawa, UCSD

A MASTER PLAN for a MODERN CALIFORNIA GEODETIC CONTROL NETWORK

TABLE of CONTENTS

TABLE of CONTENTS (cont.)

A MASTER PLAN for a MODERN CALIFORNIA GEODETIC CONTROL NETWORK

ABSTRACT

Modern society is becoming increasingly dependent on geographic data that is accurately and reliably spatially referenced. In response to this increasing demand for dependable spatially referenced data and the decreasing availability of "up-to-date" control (reference) data from the federal government, the California Spatial Reference Center (CSRC) has developed a "master plan" for a modern statewide geodetic control network for California. The plan specifies that each network station shall have at least the following geodetic values – latitude (northings, Y), longitude (eastings, X), height (elevation, orthometric, ellipsoidal), velocity (magnitude/direction), and a stated accuracy for each value. This planned network also will achieve the goals of the federal National Height Modernization initiative as determined by the CSRC Coordinating Council in consultation with NGS.

CSRC's ultimate goal is to establish a geodetic control network consisting entirely of Continuously Operating Reference Stations (CORS); i.e., a "CORS-only" statewide control network. However, the proposed initial implementation includes passive (in-ground) stations, as well as CORS, primarily because of funding limitations. Exceptions are the greater Los Angeles and San Francisco areas where it is now feasible to establish CORS-only networks. The master plan includes systematic network maintenance procedures that minimize the unique challenges within California to maintain control values up to date; i.e., procedures that monitor temporal changes in geodetic coordinates due to tectonic motion, seismic activity, volcanic deformation, and land subsidence.

The described statewide network fully utilizes the existing CORS and related data-processing infrastructure that have been established by a decade of investments, totaling over $25 million, in earthquake-related science. Thus, the planned network not only provides an accurate, consistent foundation for California's spatial referencing needs, but also facilitates the continuation of this vital scientific research.

The initial implementation of the statewide geodetic network, as detailed in the master plan, consists of approximately 275 CORS of which 210 exist from the previously noted geophysical research. Outside of the Los Angeles and San Francisco CORS-only areas, the CORS are to be located throughout the state in a grid-like pattern with a nominal spacing of 80 kilometers. About 1,500 passive stations (in-ground monuments) also are included in the network to supplement these CORS. The passive stations are to be established along selected transportation corridors and other critical infrastructures at an average spacing of seven kilometers. For the next several years, the focus will be on passive stations. *However, as the actual implementation occurs, some passive stations are likely to be replaced by CORS, through partnership efforts, as the demands for a denser real-time CORS network increase, and as GPS and other GNSS technologies and programs evolve.*

The initial implementation, as outlined, can be completed over a three-year period, if sufficient funds are available. The total estimated cost is $8.8 million. This includes constructing 65 new CORS, installing 500 new passive station monuments, and performing observations, data processing, and adjustments for the entire network. Nearly 40 percent of the resources are allocated for improving

the accuracies of GPS-derived elevations (orthometric heights). Approximately $7.7 million of the initial implementation is to be accomplished through contracts with private industry.

The “on-going” support and network maintenance efforts for the initial implementation are estimated to cost $2.8 million, annually. These annual (on-going) funds are critical to the long-term success of the network because of the significant crustal motion and subsidence issues throughout California. The on-going support and maintenance efforts will be accomplished by CSRC staff and through contracts with private firms. The latter is estimated to be about $400,000 annually.

The planned, modern statewide geodetic control network, including access to the basic geodetic data, is to be available at no charge to all users.

A MASTER PLAN for a MODERN CALIFORNIA GEODETIC CONTROL NETWORK

INTRODUCTION:

Introduction: Traditionally and historically, California users have depended on the National Geodetic Survey (NGS), and its predecessor agencies, for geodetic control – 18,000 horizontal stations and 50,000 benchmarks were established by NGS in California. But, in the last 10 to 15 years, the direction of NGS has changed (largely due to budget constraints) from maintaining relatively dense control networks to maintaining a basic "framework" system consisting primarily of Continuously Operating Reference Stations (CORS). NGS's published strategic goals state that NGS will observe, monitor, and maintain a network of high-accuracy stations at a spacing of one degree by one degree (75 km to 125 km) – *and even this commitment is becoming questionable*. Any additional geodetic control is to be established and maintained either through cooperative agreements, with NGS or by independent, local efforts.

Unfortunately, the decline in NGS's geodetic control efforts has occurred just as the need for an accurate, seamless statewide control network has greatly increased. This expanded need has been, and continues to be, created by GPS – its positioning capabilities and its many diverse applications including numerous non-surveying applications. Modern society is becoming increasingly dependent upon accurate spatial information for making critical decisions regarding such varied activities as environmental monitoring, civil infrastructure management, earthquake research, and emergency response operations. The increased spatial positioning capabilities, uses, and dependency are demanding the use of an accurate geodetic control network that is seamless throughout California for all spatial referencing activities.

National Height Modernization Study: In 1998, NGS prepared and submitted a *"National Height Modernization Study"* to Congress. This study recommends a state-by-state implementation of a "National Height Modernization Program" that would establish three-dimensional control monuments at a 10-kilometer spacing, each with a NAVD88 elevation. The study provides a five-year implementation schedule; however, California and North Carolina are designated as demonstration states since "both states are subject to extreme seismic activity, subsidence, floodplain management, coastal erosion, and heavy urbanization." The study estimated the cost for California's height modernization to be $4.6 million using GPS technologies (1998 cost figures). If conventional surveying technologies were to be used, the cost estimate is $41.2 million. However, to date, the program has received only minor funding. The network described in this master plan achieves the National Height Modernization goals for California as determined by the CSRC Coordinating Council in consultation with NGS.

Master Plan Objective: The objective of this master plan is to specify (detail) a modern statewide geodetic control network as envisioned by the California Spatial Reference Center (CSRC). However, readers should be aware that a statewide control network is but one component (but a key component) of a "complete" spatial reference **system.** Other components of an **overall** spatial reference system include the following:

- Guidelines and specifications.

- Observation data archives.
- Metadata records.
- Data processing infrastructure.
- Geodetic models and formulas.
- Data portal (database and user interface).
- Support services (user assistance).
- Outreach and education programs.
- Real-time positioning infrastructure.

These other components will not be discussed in this master plan document. As appropriate, these components will be addressed in CSRC's annual work plans as funding becomes available to improve these items. For example, the FY 01/02 "Work Plan" includes funding and statements of work for improving the data portal and the real-time positioning infrastructure. *Note: The latter effort is a demonstration project that is being funded jointly by CSRC and Orange County in collaboration with the Southern California Integrated GPS Network (SCIGN).*

Master Plan Review and Modifications: This master plan is the result of work that began in the fall of 2001. In February 2002, an initial draft was approved by the CSRC Executive Committee and released to users and others for review and comment. The draft was widely distributed and comments were strongly encouraged.

A number of comments were received. Many were informal comments obtained during face-to-face discussions with individuals and at various master plan presentations. The California Department of Transportation (Caltrans) submitted an extensive compilation of formal comments from various departmental offices. CSRC formally responded to Caltrans. Additional formal comments were received from other individuals and agencies. (See Attachment D for a summary of the formal comments.) However, most of the comments received regarded general control issues. Comments regarding specific or technical aspects of the proposed statewide geodetic control network were sparse. As a result, this final document does not include significant modifications from the draft, although all comments were thoroughly considered.

Several respondents requested additional CORS installations. For cost reasons, such requests were not accepted, unless it was shown that the spacing in the draft exceeded the originally established policies on CORS spacing. (This was the case in northern California.) In communities where a greater number of CORS are desired than shown in the initial implementation, users are encouraged to form consortiums to garner the necessary funding to realize their goals.

The following actions were employed by CSRC to make users and others aware of the draft master plan and to encourage comments.

- Provided an extended review period (February 2002 to August 2002).
- Posted the draft master plan on the websites of CSRC and the California Land Surveyors Association (CLSA).
- Participated in an all-day forum and workshop regarding the status of SCIGN, NGS, and CSRC – key topics were height modernization and the CSRC draft master plan.
- Made presentations to a) CLSA's annual conference attendees, b) California Department of Transportation Surveys Management Board, c) CLSA's Board of Directors, d) several local CLSA chapters, e) the CSRC Coordinating Council, f) Surveying and Land Use Committee of

the County Engineers Association of California, and g) League of California Surveying Organizations.
- Provided an e-mail address, as well as a telephone number and mail address, for comments.

The intent of the master plan is to establish an overall plan for a modern, statewide geodetic control network – its basic policies and scope (funding needs and the type and number of stations). Details of the network, such as the actual station locations, are flexible and will be determined based on user needs during the actual network implementation. In general, CSRC will not consider modifications to the basic network policies and scope unless the requesting user provides cost-sharing funds. CSRC will consider alternative geodetic control schemes (e.g., exchanging passive stations for CORS), if the overall funding needs are not significantly increased or additional funds are provided.

The master plan provides various tasks for improving orthometric heights (elevations) – conventional geodetic leveling, gravity measurements, etc. However, the extent and costs of these tasks are rough estimates as no definitive study has been made to estimate these needs accurately. Thus, it is likely that these master plan tasks will require modification when such needs are known.

The master plan will be updated to meet future technology improvements as the users adopt these improvements. (See next section.) Updates and revisions to the master plan will be made through a committee appointed by the CSRC Coordinating Council.

Prior to the beginning of each fiscal year, CSRC shall prepare an annual work plan for the next fiscal year that describes the various tasks to be performed, the planned expenditures for each task, and the anticipated funding source for each task. A CSRC Work Plan Committee will prepare the annual work plans with assistance from CSRC staff. The Work Plan Committee shall be appointed by the CSRC Coordinating Council Chairperson and approved by the entire Council. The annual work plans will be highly dependent upon funding received and the priorities established for each task. Each annual Work Plan Committee, shall a) review the status of on-going each tasks, b) examine the availability of current and future funds, c) solicit work suggestions from NGS and other funding agencies ("Funding Agencies"), CSRC partners, and interested users (both GPS and non-GPS users), and d) prepare and recommend next year's plan to the funding agencies and UCSD according to the information gathered. The Funding Agencies shall review and approve (or modify) the portion of the annual work plan that is funded by the anticipated allocations, before any monies from such allocations are expended. If the Funding Agencies suggest modifications to the prepared annual work plan, CSRC and the Funding Agencies shall work in good faith to develop a compromise work plan that is acceptable to both.

Technological Advances: The design of the statewide geodetic control network described in this master plan is based upon current positioning capabilities and the anticipated utilization of the network by today's users. It is fully recognized that future advances will likely affect the requirements and demands for this control network. Examples include the GPS modernization program, which will offer increased accuracy and reliability by increasing the number and signal strength of civilian frequencies. This program, when fully implemented, will most certainly attract additional and more diverse GPS users. Real-time GPS positioning, to which CSRC is currently devoting a significant portion of its available resources, has the potential to decrease dramatically the need for passive stations. These advanced technologies, and others, will occur incrementally over time. Their ultimate implementation will be based upon sound and proven geodetic surveying practices. While future versions of this master plan and their corresponding statewide geodetic

control networks may have a different appearance, the planned network outlined in this document provides the necessary geodetic infrastructure to support both current and future applications and users.

NETWORK ISSUES:

Specific critical California geodetic control issues are:

- Secular crustal motions (a constant, consistent differential movement of the tectonic plates throughout most of California) – up to five centimeters per year along the coast (the Pacific plate) relative to the North American plate.
- Episodic crustal motions (earthquakes) – deformations resulting from a specific event, with measured horizontal displacements sometimes exceeding five meters (e.g., the 1992 Landers earthquake) and vertical displacement sometimes exceeding one meter (e.g., the 1992 Cape Mendocino earthquake).
- Aseismic deformations (fault creep) – Coastal Range east of Paso Robles, Imperial Valley, etc.
- Many large areas of subsidence (Central Valley, Lancaster/Edwards Air Force Base, Long Beach, etc.). *An NGS station (benchmark) near Mendota in the San Joaquin Valley had a measured subsidence from 1943 to 1966 of 24 feet; the elevation today is unknown.*
- No releveling in much of California, including the Central Valley, since the 1970's.
- Two vertical datums in use in California: NGVD29 and NAVD88.
- Incomplete implementation of NAVD88 – only 30 percent of California's NGVD29 benchmarks were included in the NAVD88 readjustment and many of these are either lost to construction or unreliable because of subsidence.
- Extensive coastal infrastructure facilities (harbors, international boundaries, offshore leases, etc.) – these facilities generally are referenced to tidal datums, which are not necessarily referenced to a national geodetic vertical datum.
- Use of numerous local vertical datums – information from different sources cannot be related.
- Incorrect (obsolete) published values for many geodetic control stations – due to crustal motions, subsidence, etc.
- Limited or no station maintenance during the last 20 to 30 years (monitoring, updating values, station replacement, etc.).
- Reduced NGS assistance – today, NGS does not have any dedicated resources for the acquisition of field data; e.g., field personnel to perform vertical control surveys.

The result of these issues is that many of today's geodetic control (reference) values are incorrect or questionable, particularly in the vertical component! A critical consequence is that the State of California is poorly positioned to realize the opportunities and benefits available from emerging spatial information science.

NETWORK SOLUTIONS:

Long-Term Goal: As a long-term goal, CSRC envisions a statewide geodetic control network that ultimately will consist entirely of CORS; i.e., a "CORS-only" statewide network. A network of only CORS would ensure that the geodetic values for all stations are valid and current (up to date) at all times and eliminate the need for any resurveys of the statewide control network; i.e., surveys required after earthquakes and to monitor secular crustal motion and subsidence. The envisioned CORS-only network would include the following components:

1. Framework CORS spaced, statewide, on a nominal 80-kilometer grid.
2. Regional CORS spaced on an approximately 15-kilometer grid in densely populated regions. Candidate regions are the Los Angeles area, San Francisco Bay area, western San Bernardino and Riverside Counties, and portions of San Diego and Sacramento Counties.
3. Corridor CORS spaced 15 to 20 kilometers along major infrastructure corridors. (The selected corridors would be similar to those identified for passive stations in this document. See section entitled "Station Spacing," below.)
4. Real-time infrastructure systems that provide "real-time" GPS capabilities for a regional or corridor area. Such systems would be similar to the CSRC demonstration project now being developed for Orange County. Implementation of real-time capabilities is dependent, however, on the availability of emerging third-generation wireless communication networks and the cooperative and financial support of others; e.g., a state agency, county and/or city. *(Note: The third-generation communications systems are developed and established by others.)*

Each CORS within a CORS-only network would have the capability of providing data at a high sample rate (once a second or greater).

It is estimated that a CORS-only statewide geodetic control network, as described above, would require about 900 CORS, including the existing CORS established by the scientific community. The total installation cost is estimated to be roughly $30 million, of which the scientific community has completed a portion valued at $12 million. (The $30 million installation cost includes about $4 million for conventional leveling and other efforts to improve GPS-derived elevations.) The support/maintenance costs for the envisioned CORS-only statewide network are estimated to be $5 to $6 million each year. These costs are expected to decrease in the future with reductions in equipment and installation costs – the latter primarily the result of less extensive monumentation requirements. With the development of better models, the need for 900 CORS will become less important for surveying and mapping, which will decrease maintenance costs.

Since the initial costs of CORS-only networks and real-time capabilities are still comparatively high, implementation of these capabilities within each region or corridor area will be dependent on the willingness of others (local entities, state agencies, etc.) to collaborate (partner) with CSRC and share the cost of such installations.

The CORS-only network is a CSRC goal – the ultimate network to work towards and achieve. It provides a guide for improving the existing network and identifying opportunities to complete portions of the ultimate network.

Initial Implementation: Today, the establishment of a "CORS-only" geodetic control network throughout the state, the goal, is not feasible for various reasons – comparatively high costs, absence of sufficient conventional leveling and gravity data, an inadequate geoid model in some areas, lack of developed CSRC partnerships, increased difficulty and time to establish a CORS-only network, uncertainties of future GPS capabilities and their effect on control needs, unfamiliarity of users with CORS usage, etc. Thus, to address California's immediate spatial referencing needs as quickly as feasible, CSRC has formulated an initial implementation plan that expands and improves the existing statewide geodetic control network.

This initial effort is designed so it does not conflict with the ultimate CORS-only network concepts. On the contrary, it implements portions of the ultimate network goal. CSRC will outline, explain, and provide means to obtain project control for classical surveys for non-GPS users.

Nearly 40 percent of the initial implementation is for conventional leveling and other work that is necessary to improve the accuracy of elevations derived by GPS survey techniques – a crucial need for this evolving and expanding GPS usage.

The initial implementation is described in detail throughout the remainder of this master plan. In brief, the network consists of approximately 275 CORS, of which 210 are existing scientific CORS. A CORS-only network is planned for the Los Angeles and San Francisco areas. In the Los Angeles area, the scientific community has established sufficient CORS to implement a CORS-only network. In the San Francisco area, as many as14 new CORS are required to enable a CORS-only network and avoid the need for conventional surveys in this highly congested area. The additional costs are offset partially by the reduction in passive stations. CSRC will continue to seek partners and financial support to establish a CORS-only network in other urban and corridor areas as opportunities permit. Outside of the Los Angeles and San Francisco areas, the CORS are to be located throughout the state in a grid-like pattern with a nominal spacing of 80 kilometers. This fulfills another portion of the CORS-only network goal. In addition, about 1,500 passive stations (in-ground monuments) are included in the network, initially, to supplement the CORS outside the CORS-only areas. The passive stations are to be established along selected transportation corridors and other critical infrastructures at an average spacing of seven kilometers. This spacing is dictated by the NGS *"Guidelines for Establishing GPS-Derived Ellipsoid Heights"* for the two-centimeter accuracy standard. See attachment A for a map of the planned network.

The statewide geodetic control network described in this document provides both horizontal and vertical control at each station. However, the primary considerations that were adhered to in the network design are the NGS guidelines for performing vertical GPS surveys. It is well known that GPS vertical surveys require more stringent specifications than horizontal surveys to achieve the same degree of accuracy. **Thus, the needs of the vertical component have determined the overall design of the network.**

NETWORK POLICIES:

The planned statewide geodetic control network shall observe the following policies.

a. The network shall be part of the "National Spatial Reference System" and comply with the national spatial data infrastructure standards.
b. The network shall conform to the datum, accuracy classifications, guidelines, and methodologies accepted by NGS.
c. The network shall meet the goals and objectives of the federal National Height Modernization initiative as determined by the CSRC Coordinating Council in consultation with NGS.
d. The basis of the network shall be CORS that have NGS-sanctioned geodetic values.
e. The network design shall facilitate establishment, maintenance, and monitoring through GPS survey procedures.
f. The network design also shall facilitate the utilization of other modern surveying and remote sensing technologies; e.g., InSAR.
g. The accuracies of the network stations shall be the "best" that are technically and fiscally feasible.
h. Stations shall have, at a minimum, values for horizontal position, ellipsoidal and orthometric heights (vertical values), horizontal velocity (also vertical velocity on certain CORS), and a stated accuracy standard for each value.
i. The stations in the network shall be maintained (repaired or replaced if destroyed, disturbed, or, in the case of CORS, failed).
j. The network stations shall be monitored and their geodetic values kept current or supplemental information shall be provided to enable the user to determine the current geodetic values. *In certain subsidence or unstable areas, this might be impossible for passive stations. In such cases, an appropriate note will be included with the published geodetic values. These areas will be subject to additional monitoring.*
k. The network shall provide stations suitable for GPS positioning techniques; and the related database and Internet data portal shall provide appropriate geodetic data in a user-friendly, convenient manner.
l. The statewide geodetic control network, including access to the basic geodetic data, is to be available "free of charge" to all users.
m. The network shall provide a statewide geodetic control network; it is not intended to provide specific project-related control monuments. *CSRC will outline, explain, and provide means to obtain project control for classical surveys for non-GPS users.*

NETWORK SPECIFICATIONS:

Station Accuracies: The minimum accuracies of the network stations, at their published epoch date, shall conform to those shown in the table below. The accuracies listed are at the 95 percent confidence level and shall be defined and documented in accordance with the specifications given in the Federal Geographic Data Committee's "Geospatial Positioning Accuracy Standards, Part 2: Standards for Geodetic Networks," "http://www.fgdc.gov/standards/standards.html," (FGDC-STD-007.2-1998), or an officially-sanctioned successor document that replaces the referenced publication.

Value	Minimum Station Accuracy		Comment
	CORS	Passive	
Horizontal Position[1]	3 mm	10 mm	CORS are assumed to be the network's absolute basis.
Ellipsoidal Height	10 mm	20 mm	CORS are assumed to be the network's absolute basis.
Orthometric Height	20 mm	20 mm	Or as feasible with the latest, sanctioned geoid model.
Horizontal Velocity	1 mm/yr	3 mm/yr	

Note: 1) Based on station accuracy by SCIGN and BARD studies.

Station Specifications: The physical architecture of the stations included in the statewide geodetic control network shall comply with the requirements noted below.

CORS: The CORS specifications (site conditions, equipment, communications, and installation procedures) will be modeled after the following:

i. The "SCIGN Station" as developed by the SCIGN organization. Refer to "http://www.scign.org" for detailed information regarding the SCIGN project. For a catalog of CORS equipment and monument specifications, see "http://unavco.ucar.edu/project_support/permanent/permanent.html."
ii. The "Cooperative CORS" as published by NGS. For additional details, refer to "www.ngs.noaa.gov/CORS/Coop/Coop_details.html."

To avoid any confusion, the geodetic values of all CORS will be referenced to an official "Geodetic Reference Point" that is published in CSRC's database along with the appropriate offsets to the GPS antenna. In some cases, the Geodetic Reference Point may be a physical point on the antenna due to constraints upon the site construction.

Passive Stations: Passive stations shall conform to the specifications and installation procedures specified by NGS for bedrock marks or Class B rod marks (aluminum rods may be substituted for stainless steel rods). See NOAA Manual NOS NGS 1, "Geodetic Bench Marks," 1978.

Station Spacing: The spacing of the network stations shall be as stated below. Existing stations will be utilized to achieve the specified station spacing. See the subsection below entitled "Stations Established by Others."

Station Type	Spacing	Location	Comment
Framework CORS	80 km (nominal) grid.	Established where security, power, and communications are conveniently available, if feasible.	Besides the Framework CORS spaced at 80-km, 16 additional Framework CORS will be established throughout the San Joaquin Valley in the initial implementation. These additional CORS, together with the 80-km CORS, provide a CORS spacing of about 40 km in this general area of subsidence.
Regional CORS	15 km (nominal) grid.	See above.	
Corridor CORS	15 to 20 km, generally linear.	See above for CORS locations.	The linear configuration is similar to the original NGS vertical control surveys.
Passive Stations	7 km (average) generally linear.	Established along selected transportation corridors and other critical infrastructures, as supported by population, economic, terrain, and crustal motion needs.	

Attachment B shows a county-by-county tally of existing and new CORS that are included in the initial implementation. See Attachment C for a tally of planned passive stations in the initial implementation.

Survey Method: GPS survey methods, using the specifications and procedures that achieve the station accuracies specified above, shall be utilized to establish the entire statewide geodetic control network. Conventional geodetic vertical survey methods are simply too costly to employ. *(The NGS "National Height Modernization Study" reported that, for a statewide effort, conventional surveys were nine times more costly than GPS surveys. See previous section entitled "National Height Modernization Study.")* GPS survey methods also facilitate the subsequent monitoring of stations in an efficient and timely manner.

Orthometric Height Improvements: To improve the vertical values (heights) of the network stations and the geoid model in California, conventional geodetic vertical surveys and other efforts shall be performed to supplement the GPS surveys. It is estimated that these efforts will require a significant portion (nearly 40 percent) of the total initial implementation effort. The planned efforts include:

a. Perform conventional geodetic vertical surveys to establish NAVD88 elevations on selected CORS.

b. Perform additional conventional vertical surveys and GPS observations at selected locations to improve California's geoid model.
c. Develop models with real and simulated data, which then can be used to test the sensitivity of orthometric heights to data coverage, network configurations, and single-point errors. The results will be used to determine additional observational needs.
d. Measure gravity at selected CORS sites and in sparsely sampled areas, as guided by the effort described in item "c," above.

For additional information, refer to the table included in the section below entitled "Estimated Initial Implementation Costs."

Stations Established by Others: Stations that are established by others and meet the adopted specifications may be included in the statewide geodetic control network to reduce initial implementation costs and to subsequently densify the network. However, the number of stations incorporated into the network (beyond the minimum spacing requirements) adversely affects the annual maintenance costs (e.g., station, data portal, and database maintenance costs). Thus, policies are required that "balance" the need/value of such stations with the additional annual maintenance costs. The CSRC policies regarding stations established by others are outlined in the table below.

Responsibility	**Approved Stations Established By Others [1]**	
	CORS [2]	**Passive Stations**
Station Included as part of statewide geodetic control network.	Yes, provided the spacing is not less than 10 km from another "network" CORS.	Yes, provided the average spacing is not less than 7 km.
Station Maintained; i.e.; physical facilities replaced if destroyed, disturbed, or, in the case of CORS, failed.	Generally yes, if cost effective and provided the spacing is not less than 10 km from another "network" CORS.	No.
Station Values Monitored; i.e., geodetic values are monitored and updated as appropriate.	Yes, provided the spacing is not less than 10 km from another "network" CORS.	No.
Station Data Distributed as part of the statewide geodetic control network.	Yes, provided the spacing is not less than 10 km from another "network" CORS.	Yes, provided the average spacing is not less than 7 km. All such data will be noted as being for a station that is not maintained or monitored by CSRC.

Notes: 1) Stations that meet the specifications and requirements specified for the statewide geodetic control network.
2) Agreements may be executed with others to make additional CORS (CORS less than 10 kilometers from an existing "network" CORS) part of the statewide geodetic control network. Generally, such agreements will specify that the other party will be responsible for the additional costs associated with the added CORS.

CSRC will encourage surveyors to file "records of survey" for control surveys that establish stations at a denser spacing than shown in the table; i.e., a spacing less than that acceptable for inclusion in the statewide geodetic control network.

It is anticipated that the location and monumentation of many existing passive stations will be satisfactory for inclusion into the initial implementation of the planned network (e.g., California High Precision Geodetic Network, HPGN, stations, NAVD88 benchmarks, etc.). However, new geodetic values will be established for all stations included. For cost estimating purposes, it was estimated that two thirds of the passive stations already exist. See subsection below entitled "Estimated Initial Implementation Costs."

Existing Geodetic Control: NGS has published values for 18,000 horizontal control monuments and 50,000 vertical control benchmarks in California. However, most of this original, published control is unreliable for the reasons outlined above in the "Network Issues" section. There are two notable exceptions: 1) horizontal control included in the "California Spatial Reference System – Horizontal" as defined by the Public Resources Code, section 8801(e) and 2) NAVD88 benchmarks in stable areas.

Existing stations (monuments and benchmarks) will be incorporated into the initial implementation of the planned statewide geodetic control network as outlined in the previous section, "Stations Established by Others."

Selected existing stations that are **not** included in the initial implementation shall be updated (geodetic values and epoch) to be consistent with the master plan network adjustment, providing they meet all of the following criteria:

a. The station is included in the "California Spatial Reference System – Horizontal" or is a NGS NAVD88 benchmark.
b. The station (monument or benchmark) is stable.
c. The station is essential to users.

The update (adjustment) of these selected stations will occur after the adjustment of the initially implemented network is completed and the horizontal velocity model has been updated. The stations will be selected, in cooperation with NGS and local users, based on the above criteria. These selected updated stations shall **not** be maintained or monitored (see policies outlined in the previous section, "Stations Established by Others").

Existing "National Spatial Reference System" stations (i.e., NGS database stations) that are not included in the initial implementation and are not selected for updating will remain in NGS database. Data and other information for such stations will remain available through NGS. Caution: These stations might not be acceptable for use as control for a survey using the California Coordinate System of 1983.

INITIAL IMPLEMENTATION:

Estimated Initial Implementation Costs: The estimated cost for initially implementing the statewide geodetic control network, as outlined in this master plan, is $8.8 million. Details, including how the various tasks are anticipated to be accomplished, are shown in the following table.

ESTIMATED INITIAL IMPLEMENTATION COSTS

Operation	How Accomplished	Stations (Estimate)		Unit Cost (Estimate)	Total Cost Estimate	Percent of Total Cost
		New	Exist			
CORS:		65	210			
Installation	Contract	65	0	$40,000 per sta.	$2,600,000	29.5
Oversight – 1 FTE [1]	CSRC Consultant			n.a.	$100,000	1.1
Observations/Process Data	CSRC	275		Incl. w/ adj.	$0	0.0
Final Adjustment	CSRC	275		$250 per sta.	$68,750	0.8
Subtotal					*$2,768,750*	*31.4*
Passive Stations:		500	1,000			
Monument Installation [2]	Contract	500	0	$1,000 per sta.	$500,000	5.7
Observations/Process Data [3]	Contract	1,500		$1,000 per sta.	$1,500,000	17.0
Oversight – 2 FTE [1]	CSRC Consultant			n.a.	$200,000	2.3
Final Adjustment	CSRC	1,500		$250 per sta.	$375,000	4.3
Subtotal					*$2,575,000*	*29.3*
Improved Heights:		**Units As Shown**				
CORS NAVD88 Ties [4]	Contract	1,500 km		$1,000 per km	$1,500,000	17.0
Geodetic Vertical Surveys[5]	Contract	1,500 km		$1,000 per km	$1,500,000	17.0
Gravity Surveys [6]	Contract	500 points		$300 per point	$150,000	1.7
Oversight – 1 FTE [1]	CSRC Consultant			n.a.	$100,000	1.1
Analysis – 1/2 FTE [7]	CSRC			n.a.	$60,000	0.7
Subtotal					*$3,310,000*	*37.5*
UCSD Indirect Costs [8]				n.a.	$156,500	1.8
Total					**$8,810,250**	**100.0**

Notes:
1) CSRC Consultant rates include all costs (labor, equipment, overhead, and profit); FTE is full time equivalent.
2) It is estimated that suitable existing monuments will be available for about two thirds of the passive stations.
3) Cost estimates for "Observation/Process Data" include preparing data in a format acceptable by CSRC and NGS ("bluebooking").
4) Conventional geodetic vertical surveys required to establish NAVD88 elevations at **selected** CORS to improve the overall accuracy of the orthometric heights for the entire network. The unit cost includes required monumentation efforts.
5) Conventional geodetic vertical surveys required to develop a sufficiently accurate California geoid model. The unit cost includes required monumentation efforts.
6) Gravity surveys (relative and absolute) required to develop a sufficiently accurate California geoid model.
7) NGS also will provide analysis efforts.
8) UCSD indirect costs are 13 percent of direct, less equipment and contracts over $25,000.

Although the table above indicates how the various tasks will be accomplished (CSRC staff, CSRC Consultant, Contract, etc.), this does not preclude, by any means, a state or local agency from collaborating with CSRC to implement a portion of the planned network. For example, a county agency might assume the responsibility for installing the passive stations within the county or a state agency might implement selected CORS throughout the state. Such partnership proposals are welcomed (encouraged) by CSRC.

Implementation Contracts: Contracts shall be issued to private firms to perform the CORS installations (excluding certain equipment), establish the passive stations (i.e., install monuments as required, perform observations, and process data), and perform surveys to improve the geodetic heights. CSRC will perform the final adjustment for the entire network (approximately 275 CORS and 1,500 passive stations). It is anticipated that, in total, there will be one CORS installation contract, about eight contracts to establish the passive stations, and several contracts for surveys to improve the geodetic heights. Each passive station contract will involve about 175 stations, for which new values will be established, plus about 25 reference (control) stations. The number of contracts awarded each year will depend on available funding. CSRC, with the assistance of others, is seeking sufficient funds to complete the initial implementation within three years.

All contracts will be issued and administered by the University of California at San Diego (UCSD). The contracting procedures, rules, and regulations of the University will be observed. The CSRC Coordinating Council strongly recommends that a "qualification based selection" (QBS) process be employed for selecting and awarding all professional surveying contracts. In addition, all contracts shall conform to the terms of funding organizations; e.g., contracts involving NGS funds will conform to the federal "Brooks Act" if specified by NGS.

It is anticipated that selection committees will consist of selected CSRC Coordinating Council members and others.

SUPPORT and MAINTENANCE:

Policies: All stations in the described statewide geodetic control network shall be maintained and their geodetic values kept current (up to date) through systematic monitoring. See policies "i" and "j" under the section entitled "Network Policies" in this document. The policy to monitor and update station values is critical in California – a state in which the Earth's surface is literally "on the move" because of extensive seismic activity and many areas of subsidence.

Procedures: Planned maintenance procedures are listed below.

a. Volunteers through an "Adopt-A-CORS and Adopt-A-Station" program shall perform minor maintenance and annual station checks. *In past discussions, the community has been receptive to such programs.*
b. CORS will be maintained by CSRC.
c. Passive stations that are disturbed or destroyed shall be repaired or replaced through an "on-call" contract. The on-call contract will be for a multi-year period and shall be awarded through a process similar to those outlined for the initial implementation (see above).
d. Approximately 15 percent of the passive stations shall be resurveyed each year. The resurveys shall be performed through contracts similar to the initial implementation contracts (see above).
e. The resurvey results shall be used to update the station's geodetic values (i.e., a new epoch) and/or used to update the horizontal velocity model. If feasible, results from the resurveys will be used also to develop a vertical velocity model.
f. A **statewide** network adjustment with a new statewide epoch shall be made each decade.
g. CSRC shall aggressively seek FEMA funding to perform resurveys after earthquakes or major floods.

Estimated Annual Support and Maintenance Costs: The estimated cost for supporting and maintaining the statewide geodetic control network, based on the initial implementation as outlined in this master plan, is $2.8 million, **annually**. Details, including how the various tasks are anticipated to be accomplished, are shown on the next page.

ESTIMATED ANNUAL SUPPORT and MAINTENANCE COSTS

Operation	How Accomplished	Stations (Estimate)	Unit Cost Per Station (Estimate)	Total Cost Estimate
CORS:				
Maintenance, Minor	User (Adopt-A-CORS)	275	$0	$0
Maintenance/Download Data [1]	CSRC	275	$1,700	$467,500
Utilities [2]	Various	275	$700	$192,500
Monitor (observe/process data)	CSRC	275	w/ below	$0
Daily Processing/Adjustments [2]	CSRC	275	$1,600	$440,000
User Support Services (data portal) *(20 % Programmer, 1/2 FTE [3])*	CSRC and CSRC Consultant			$20,000 $50,000
Support/Maintenance, Added CORS [4]	CSRC	15	$6,200	$93,000
Receiver/Antenna Replacement [5]	CSRC	55	$11,000	$605,000
Subtotal				*$1,868,000*
Passive Stations:				
Annual Station Check	User (Adopt-A-Station)	1,500	$0	$0
Maintenance (repair/replace) [6]	Contract (statewide)	75	$2,000	$150,000
Monitor (reobserve, process data) [7]	Contract (project)	225	$1,200	$270,000
Oversight – 1/2 FTE [3]	CSRC Consultant		n.a.	$50,000
Resurvey Final Adj. (update values)	CSRC	300	$270	$81,000
User Support Services (data portal) *(10 % Programmer, 1/2 FTE [3])*	CSRC and CSRC Consultant			$10,000 $50,000
Subtotal				*$611,000*
Education/Outreach – 1 FTE [3]	CSRC Consultant		n.a.	$100,000
UCSD Indirect Costs [8]			n.a.	$202,500
Total				**$2,781,500**

Notes:
1) Costs are based on SCIGN's experience plus 25 percent for equipment and miscellaneous. Most of SCIGN repair data was during a warranty period.
2) Costs are based on SCIGN's experience.
3) CSRC Consultant rates include all costs (labor, benefits, equipment, overhead, and profit). FTE is full time equivalent
4) After the initial implementation, it is expected that additional CORS will be established and accepted into the network. See section entitled "Stations Established by Others." The annual support/maintenance cost for these future, new CORS is difficult to estimate and will vary each year.

5) Replacement costs are based on a five-year replacement cycle – $2,200 ($11,000/5) per station per year.
6) Costs are based somewhat on Caltrans experience with the HPGN. A conservative loss rate of about five percent per year is used in the cost estimate.
7) Cost estimates for "Monitor (reobserve, process data)" include preparing data in a format acceptable by CSRC and NGS ("bluebooking"). The estimate is based on a 15 percent resurvey effort each year (see text above).
8) UCSD indirect costs are 13 percent of direct, less equipment and contracts over $25,000.

USER INFORMATION:

Epochs: An epoch date is the **effective** date of a geodetic value (northing/easting coordinate value, latitude, longitude, ellipsoid height, orthometric height/elevation, etc.) for a given datum and adjustment; i.e., ***the date the geodetic values are valid***. Epoch dates are necessary because points (control stations) move over time as a result of tectonic plate motions, subsidence, and other factors. Currently, the use of epoch dates is essentially limited to horizontal values. Although the vertical values of some control stations do vary, the changes are a function of a number of underlying issues such as soil characteristics, water withdrawal, etc. Generally, there is insufficient information to develop a useful model of the vertical changes; thus, epochs are not noted – at least today (2002). In California, the use of epoch dates is critical for horizontal values because of extensive crustal motions (secular and episodic tectonic plate motions) within California. This need has been recognized by the State. Section 8815.1 of California's Public Resources Code (PRC) – the "California Coordinate System" – **requires** that the epoch be noted whenever coordinate values for the California Coordinate System of 1983 (CCS83) are shown on a map or other survey document.

Epoch dates are established (determined) as follows:

- For surveys that establish the positions of "primary" geodetic control (reference) stations, such as those included in the "California Spatial Reference System – Horizontal," HPGN, etc., the epoch date is the mean date of the survey observation period.
- For local surveys, including most project control surveys, the epoch date is the same as the epoch date of the controlling (reference) stations. See below for additional information.

The year and the decimal portion of the year identify epoch dates. The original HPGN has an epoch date of 1991.35. The decimal portion of the epoch date refers, in this case, to May 8, 1991, the mean date of the four-month HPGN survey. Other significant epoch dates are 1992.88 (Landers/Big Bear earthquake), 1995.00 (Northridge earthquake), 1998.50 (HPGN re-observation), and 2000.35 (Hector Mine earthquake). Section 8815.2 of the PRC, states that the epoch for a survey using CCS83 coordinates shall be the NGS-published epoch of a controlling station for the survey.

Secular crustal motions are uniform over time and thus can be accurately predicted (determined) by historical data (models). However, episodic crustal motions (earthquakes) cannot be predicted; thus, a new geodetic survey is required, of the affected primary geodetic control, after each major earthquake (magnitude generally greater than about 6.0) to measure the movements. In recent history, these required "new" surveys have been performed in California. NGS has incorporated the available crustal motion data (secular crustal motion data and data from surveys performed after major earthquakes) into a computer-modeling program called "Horizontal Time Dependent Positioning" (HTDP). The model is updated after each major earthquake upon completion of the post-earthquake survey. The accuracy of HTDP is currently about ± 0.5 centimeter per year.

HTDP can be used to convert (adjust) data from one epoch date to another epoch date. *Note that the program accounts for both the uniform secular motion, as well as episodic motion caused by earthquakes.* For example, if the primary geodetic control stations have different epochs (this is not unusual), HTDP can be used to adjust the control stations to a consistent epoch date; i.e., the same date. HTDP also can be used to relate a survey to a required date such as might be mandated by a local agency (see also PRC 8815.2). HTDP is available from NGS at "www.ngs.noaa.gov."

A sample epoch calculation is illustrated below.

- Epochs for the Controlling Stations
  of a Survey to Establish Project Control: CORS A …..…… 2000.35
  Passive Station B … 1992.88
  Passive Station C … 1995.00

- Desired Epoch of the Project Control Being Established: 2000.35
  (And the desired epoch of the project's detailed surveys.)

  The surveyor uses the NGS HTDP modeling program to adjust the positions of controlling stations B and C from their various epochs to epoch 2000.35, prior to computing the positions of the project control stations. By performing this epoch adjustment initially, the project control *(and all subsequent detail project surveys based on the project control)* will be on a 2000.35 epoch.

It is anticipated, that eventually GPS vendors will incorporate HTDP into their software. When this occurs, the user will simply input the epoch of the controlling station and the desired epoch of the survey, and the software will automatically compute the necessary corrections. Of course, the "responsible charge" surveyor will remain responsible for the validity of such corrections and the overall survey results.

The use of epoch dates and a seamless, statewide geodetic control reference network permit various surveys, conducted at various times, to be related to each other. This is a huge benefit to the surveyors and other spatial referencing professionals – and, in general, to the public.

Geodetic Heights: The vertical value (or height) of a point is commonly expressed in terms of "orthometric" height, or elevation, and is the primary "height" value used for mapping, surveying, GIS, and engineering applications. An orthometric height is referenced to the "geoid' – in simple terms, the surface obtained if the entire Earth was covered by water. This surface is not a smooth, mathematical spheroid; instead, it is an irregular surface that varies with the changes in the direction of the gravity force. Such changes are caused by differences in the Earth's mass at different locations; e.g., mountains as opposed to flat surfaces. Conversely, GPS height values are referenced to an ellipsoid – a mathematical figure that is selected to represent the earth. The difference, or displacement, between the orthometric height (H) and the ellipsoidal height (*h*) is termed the "geoid height" (N).

$$\mathbf{N = h - H}$$

In California, the magnitude of geoid heights ranges from about -20 meters to about -35 meters.

NGS and others have developed geoid height models that can be used to derive orthometric heights from a GPS survey; i.e., H = *h* - N, where N is obtained from the model. The current NGS geoid model is GEOID99. It has an accuracy, at the national scale, of about five centimeters (root mean square error); however, the relative accuracy over 10 kilometers is generally about one centimeter according to NGS officials. Although desirable, an accuracy map of the modeled geoid heights in

California is not a simple product to develop. Geoid heights are sensitive to gravity and other data coverage and, currently, there is a lack of data in various areas of California.

Network Usage: All data for the described statewide geodetic control network will be available from CSRC's data portal, which is found at CSRC's website, "http://csrc.ucsd.edu." (See header entitled *"Enter CSRC Data Portal"* on the home page.) The basic data will be sanctioned by NGS and available to all users free of charge.

The primary objective of the planned statewide geodetic control network (and CSRC) is to provide a seamless, statewide geodetic control reference (basic, framework) network. Refer to Item "m" under "Network Policies." However, for some surveys, the network data obtainable through CSRC might be used for other purposes beyond providing basic control data; e.g., positioning data for detailed survey points. See below for additional explanation.

Users have various options to utilize the statewide geodetic control network data from CSRC, depending on the type and accuracy of the data required and the availability of such data. Users having questions regarding CSRC data or comments are encouraged to contact CSRC. The three basic methods are described below.

1. Real-time positioning data.

   Usage: To determine the position of detailed survey points in **real time**.

   Comments:
   - This option is only available where a RTK GPS infrastructure system has been established; e.g. Orange County. *(The Orange County Real-Time Network (OCRTN) demonstration project is a jointly funded effort by Orange County and CSRC, in collaboration with SCIGN.)*
   - If the real-time CORS epoch is different from the desired survey epoch, the surveyor must apply an epoch adjustment to the real-time positioning data. See discussion on epochs above.

2. CORS control data for positioning detailed project data.

   Usage: To provide control data for post processing the positions of detailed points for a project survey.

   Comments:
   - This utilization is only feasible where CORS are close enough to the survey to yield valid results with reasonable observation times.
   - As funding becomes available, CSRC in cooperation with NGS intends to develop guidelines for this type of work. Until such guidelines are developed, contact CSRC staff or California's NGS State Geodetic Advisor for advice. Example: NGS guidelines for GPS-derived ellipsoid heights (two-centimeter standard) currently state that two 30-minute observation periods are required for baselines less than 10 kilometers. *Note: This observation procedure continues to be investigated by NGS and others and might be revised to two 45-minute periods in the future.*

- If the published CORS epoch and the desired survey epoch are different, the surveyor must apply the adjustment for the epoch difference to the CORS and the detailed survey points. See discussion on epochs above.

3. CORS and/or passive station control (reference) data for establishing project control.

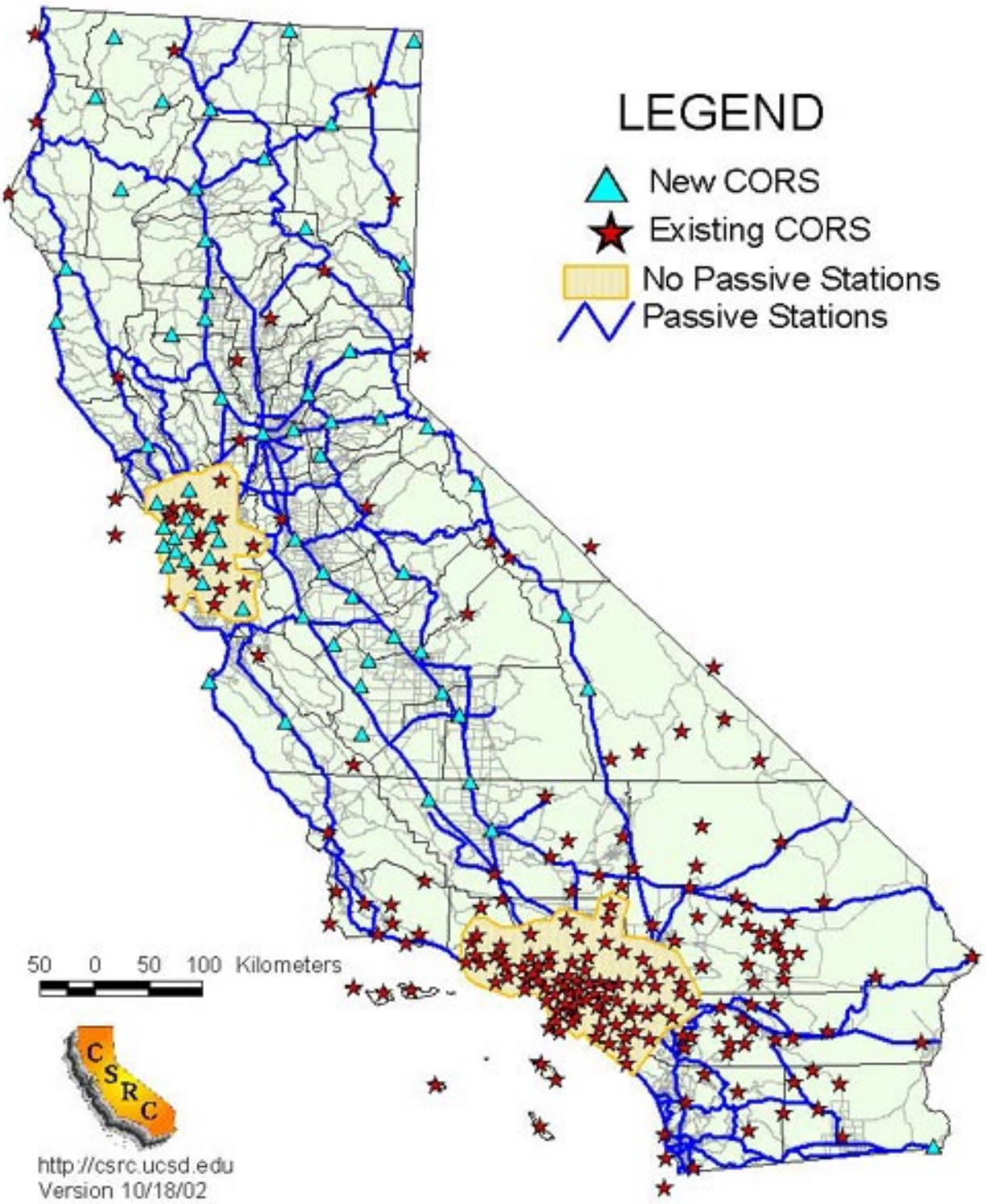
   Usage: To establish detailed project control for a specific project or projects.

   Comments:
   - Initially, CSRC anticipates that this will be the primary use of the statewide geodetic control network.
   - CSRC is in the process of developing detailed instructions for such usage, as this will be (is) a common use of CORS data. In addition, CSRC staff is available to conduct "CORS usage" training for groups.
   - If the desired project control epoch is different from the published epochs of the controlling stations (CORS and/or passive stations), which would not be unusual, or if the controlling stations themselves have different published epochs, the surveyor must adjust the controlling stations and project control data to a consistent, valid epoch. For additional information, refer to the discussion on epochs above. See also the sample epoch calculation in the "Epochs" section, above.
   - Once the project control is established for a project, that project control can be used to control all subsequent surveys throughout the duration of the project; i.e., from preliminary survey work, through the final land, design, and construction surveys. Additional reference to the statewide geodetic control network is not necessary for other project-related surveys, except for replacing destroyed project control or for checking the project control – in which case, corrections for the differences in epochs must be made (the controlling statewide network station epochs versus the project control epoch).
   - For long, linear work involving several projects, it might be advantageous to establish a common project control, on a single epoch, for all projects.

Contacting CSRC: For general information or comments regarding CSRC, this master plan, or other CSRC matters, contact the CSRC "Coordinator" at (858) 534-8031 telephone, (858) 534-9873 fax, or "spike@ucsd.edu" e-mail. Additional information regarding CSRC also can be found at CSRC's website, "http://csrc.ucsd.edu." CSRC's address is shown on the front cover of this document. Specific questions or comments on technical issues should be referred to CSRC staff. (The Coordinator can direct you to the proper staff person.)

(blank)

Statewide Geodetic Control Network (Initial Implementation)



Note: This map is available in color from CSRC in hard copy and electronic file formats.

Continuously Operating Reference Stations in the Statewide Geodetic Control Network (Initial Implementation)

County	Exist	New		Total
		No.	Location	
Alameda	4	4	Alameda (e) Berkeley (e) Dublin (e) Fremont (e)	8
Alpine	0	1	Markleeville	1
Amador	0	1	Ione (f)	1
Butte	1	0		1
Calaveras	0	0		0
Colusa	0	1	Stonyford	1
Contra Costa	4	1	Danville (e)	5
Del Norte	1	0		1
El Dorado	0	2	Kyburz Placerville (f)	2
Fresno	1	6	Coalinga (f) Fresno Kingsburg (f) Mendota Oro Loma Three Rocks (f)	7
Glenn	0	2	Orland Willows (f)	2
Humboldt	2	1	Orleans	3
Imperial	6	1	Andrade	7
Inyo (a)	6	2	Big Pine Lone Pine	8
Kern	8	3	Bakersfield (f) Delano (f) Lost Hills	11
Kings	0	0		0
Lake	0	0		0
Lassen	1	1	Doyle	2
Los Angeles (b)	47	0		47
Madera	0	1	Madera (f)	1
Marin	2	1	Fairfax (e)	3
Mariposa	0	1	Mariposa	1
Mendocino	1	2	Ft. Bragg Leggett	3
Merced	0	2	Merced (f) San Luis Reserv. (f)	2
Modoc	1	2	Adin Fort Bidwell	3
Mono (a)	3	1	Bridgeport	4
Monterey	1	2	Carmel King City	3
Napa	0	0		0
Nevada	0	0		0
Orange	10	0		10
Column Subtotal	*99*	*38*		*137*

County	Exist	New		Total
		No.	Location	
Placer (a)	1	2	Auburn (f) Nyack	3
Plumas	1	1	Chester	2
Riverside	23	0		23
Sacramento	0	2	Rancho Cordova Sacramento	2
San Benito	1	0		1
San Bernardino	35	0		35
San Diego (c)	8	0		8
San Francisco (d)	2	2	S.F. NW point (e) S.F. SE point (e)	4
San Joaquin	1	1	Ripon (f)	2
San Luis Obispo	1	0		1
San Mateo	1	4	Burlingame (e) Half Moon Bay (e) Pacifica (e) San Carlos (e)	5
Santa Barbara (b)	12	0		12
Santa Clara	4	2	Cupertino (e) Morgan Hill (e)	6
Santa Cruz	0	0		0
Shasta	0	2	Burney Redding	2
Sierra	0	0		0
Siskiyou	1	4	Callahan Dunsmuir Happy Camp Tulelake	5
Solano	1	1	Vallejo (f)	2
Sonoma	0	1	Santa Rosa	1
Stanislaus	0	1	Turlock	1
Sutter	1	0		1
Tehama	0	1	Red Bluff (f)	1
Trinity	0	1	Hayfork	1
Tulare	0	1	Visalia	1
Tuolumne	1	0		1
Ventura (b)	15	0		15
Yolo	1	1	Dunnigan (f)	2
Yuba	0	0		0
TBD/Rounding	1	0		1
Column Subtotal	*111*	*27*		*138*
Total	**210**	**65**		**275**

a) Includes one existing CORS (each) in the State of Nevada.
b) Includes Channel Island existing CORS – 3 Los Angeles, 3 Santa Barbara, and 1 Ventura.
c) Includes one existing CORS on Islas Coronado, Mexico.
d) Includes one existing CORS on the Farallon Islands.
e) San Francisco area CORS to enable a CORS-only network.
f) Added Framework CORS for the Central Valley.

THE LOCATIONS OF ALL NEW CORS ARE PRELIMINARY.
Actual locations will be determined by specific needs and user comments.

Attachment C

Passive Stations in the Statewide Geodetic Control Network (Initial Implementation)

County	Location	No. Sta.
Alameda		0
Alpine	SH 89	6
Amador	SH 49	5
Butte	SH 70 & 99	16
Calaveras	SH 12 & 49	10
Colusa	I 5 & SH 20	13
Contra Costa	SH 4; Sacramento River	1
Del Norte	US 101	10
El Dorado	US 50; SH 49 & 89	29
Fresno	I 5; SH 41, 63, 99, 180, & 198	33
Glenn	I 5	7
Humboldt	US 101; SH 299	36
Imperial	I 8; US 78, 86, & 98	52
Inyo	US 395	29
Kern	I 5; US 395; SH 14, 58, 99, & 178; California Aqueduct	96
Kings	I 5; SH 99 & 198	16
Lake	SH 20 & 29	22
Lassen	US 395; SH 299	37
Los Angeles	I 5; SH 14; California Aqueduct	11
Madera	SH 41, 49, 99, & 152	20
Marin	US 101; SH 1	7
Mariposa	SH 49 & 120	15
Mendocino	US 101; SH 1 & 20	45
Merced	I 5; SH 99 & 152	26
Modoc	US 395; SH 299	31
Mono	US 395; SH 89 & 120	30
Monterey	US 101; SH 1	41
Napa	SH 12 & 29	10
Nevada	I 80; SH 49 & 89	14
Orange		0
Column Subtotal		*668*

County	Location	No. Sta.
Placer	I 80; SH 49 & 89; Baseline Rd	24
Plumas	SH 70 & 89	23
Riverside	I 10, 15, & 215; SH 79 & 86; Colorado River Aqueduct	93
Sacramento	I 5 & 80; US 50; SH 12, 99, & 116; Dillard Rd	32
San Benito	US 101; SH 152	1
San Bernardino	I 15 & 40; US 395; SH 58; Colorado River Aqueduct	110
San Diego	I 8, 15, & 905; SH 1, 52, 78, 79, 94, & 125; Palomar Airport Rd., Rancho Santa Fe Rd, & San Ysidro Border Crossing	111
San Francisco		0
San Joaquin	I 5, 205, & 580; SH 12, 99, & 120; Stockton Channel	36
San Luis Obispo	US 101; SH 1	34
San Mateo	SH 1	0
Santa Barbara	US 101; SH 1	29
Santa Clara	US 101; SH 152	10
Santa Cruz	SH 1 & 152	10
Shasta	I 5; SH 89 & 299	53
Sierra	I 80; US 395; SH 89	7
Siskiyou	I 5; US 97; SH 89	36
Solano	I 80 & 505; SH 12; Sacramento River	14
Sonoma	US 101; SH 1 & 12	32
Stanislaus	I 5; SH 99 & 120	19
Sutter	SH 99; Baseline Rd	11
Tehama	I 5; SH 89 & 99	20
Trinity	SH 299	14
Tulare	SH 63, 99, & 198	25
Tuolumne	SH 49 & 120	24
Ventura	SH 1	2
Yolo	I, 5, 80, & 505; US 50; Baseline Rd & Sacramento River	22
Yuba		0
TBD/Rounding		40
Column Subtotal		*792*
Total		**1,500**

THE LOCATIONS OF ALL PASSIVE STATIONS ARE PRELIMINARY.
Actual locations will be determined by specific needs and user comments

Attachment D

Comments Received Regarding the Draft Master Plan (February 1, 2002)

1. **San Diego County:** Suggested that the number of CORS be increased by 6 to 8 in the county.

2. **Sonoma County Water District:** a) Expressed concerns regarding a CORS-only network and frequent changes in the epoch of statewide datums. *(Note: A master plan maintenance procedure states that the statewide epoch is to be changed once each decade, assuming no major earthquake activity.)* b) Also expressed were concerns regarding public access to stations, lack of azimuth pairs, and usage of a CORS-only network.

3. **Dr. Duncan Agnew, University of California – San Diego:** a) Recommended using bedrock monuments instead of Type B rod monuments where feasible. b) Presented a concept in which state plane coordinate values would be fixed (held) at a particular epoch until a statewide adjustment was necessary (say every 10 years), but latitude and longitude values and their corresponding epochs would change with time.

4. **Caltrans, District 2 (Redding):** a) Requested nine additional CORS in northern California and suggested locating the CORS at Caltrans maintenance stations to offset the added cost. b) Asked that the number of passive stations and highway routes be increased in northern California. c) Suggested using HPGN and HPGN-densification monuments when available. *(Note: The master plan estimates that roughly two thirds of the passive monuments will be HPGN, NAVD88, etc. marks.)*

5. **Caltrans:** Caltrans compiled and submitted a detailed and lengthy tabulation of comments and questions from various Caltrans users and departmental organizations. The comments and questions included the following major categories of issues:

    a. Height modernization.
    b. User-friendly website.
    c. CORS sampling rate.
    d. RTK (also related to CORS spacing and sampling rate).
    e. CORS benefits.
    f. Caltrans participation.

    Specific issues that were included in the Caltrans response are listed below:

    - When to change CORS epochs.
    - Vertical velocities.
    - CORS versus HPGN stations.
    - Leveling and geoid model needs.
    - Basic network (master plan network) versus project control.
    - HTDP and its use.
    - CORS location and spacing.
    - Voluntary CORS maintenance.
    - Funding and sources of funding.
    - The "legitimacy" of CSRC.
    - Involvement of licensed land surveyors in CSRC and the master plan preparation.
    - Caltrans input regarding the plan's preparation.
    - Training and CSRC's data portal.

6. **Land Surveyor A:** Stated that the master plan fails to address the key issues surrounding the National Height Modernization Program and that the cost of implementing the master plan is excessive.

7. **Land Surveyor B:** a) Remarked that the master plan "focuses" on the future of California's geodetic network – when sufficiently densified, the use of CORS will make horizontal and vertical positioning "easier." b) Suggested that, in the interim, the plan should address the issue of HPGN epoch compatibility, the location of data, ease of data usage, and a CORS selection program. c) Also, suggested a five-second sampling rate for CORS.