1.0 Summary
The objective of this water quality narrative is to review existing literature from Tomales Bay and tributaries in order to understand the status and trends for contaminants found by these studies. The emphasis is on the water quality parameters that have exceeded the Regional Water Quality Control Board’s (RWQCB) Basin Plan standards and has caused the listing of Tomales Bay as impaired under the Clean Water Act. Most of the report relies on existing data analysis and conclusions drawn by the responsible authors. Data was extracted from a number of studies that used bivalve to bioconcentrate contaminants from Tomales Bay. This data was complied and plotted to indicate the status and possible trends over time. The status and trends, when possible, was presented for each of four contaminants. These included pathogens, nutrients, mercury contamination and sediment inputs into tributaries and the bay. The outcome of this review is the listing of data gaps and recommendation on studies that could obtain additional data that will further the understanding of the bay and watershed processes. Recommendations were proposed for issues that need to be addressed by organizations involved with Tomales Bay watershed management.

2.0 Introduction
2.1 Scope
This status and trends report is focused on the water quality of Tomales Bay and tributary streams. Emphasis of this report is on the four parameters (pathogens, nutrients, heavy metals and sedimentation) that exceed the standards established for the bay in the RWQCB Basin Plan, and the Department of Health Services and the National Shellfish Sanitation Programs. The fact that these parameters do not meet established standards and could affect the beneficial uses presented in the Basin Plan has resulted in Tomales Bay being listed as impaired under the Clean Water Act section 303(d). However, it is important not to lose sight of the fact that the bay and adjacent watershed makes up an interrelated ecosystem and that these factors of concern are only part of a complex system. Thus, other aspects of the Tomales Bay ecosystem must also be studied, evaluated and perhaps monitored to protect the beneficial uses of the estuary.

2.2 Objectives
The objectives of the narrative are: 1) to review relevant studies of the bay dating back to 1960, 2) to summarize existing conditions based upon historical and current monitoring data, 3) to identify water quality problems and pollutants of concern based on the literature review and discussions with leaders of ongoing programs in the bay, 4) based upon this review and evaluation develop a data gap matrix and an overview of the necessary studies and information needed to fill the data gaps.

2.3 Limitations
The narrative addresses primarily water quality issues. References to impacts on biological communities and/or species are presented only if well documented and important to understanding the stated objectives. Since the emphasis is on water quality
the majority of the data reviewed will relate to materials in suspension in the water column or found in bivalve tissue. Thus, stream bedload transport, erosion patterns, and sediment transport from tributaries or within the bay is not evaluated except as they relate to the mercury contamination problem. Because of the time and financial limitations very little analysis of the data is attempted in this report. No evaluation of current or past BMPs, or restoration actions within the watershed is presented nor is ground water contamination addressed in this narrative. There is no attempt to evaluate the quality of the data, status of the QA/QC protocol for data analysis and presentation, or any attempt to evaluate the validity of the conclusions of the information reviewed. Because of the lack of data analysis only the most apparent data gaps are presented.

3.0 Tomales Bay

3.1 Description

3.1.1 Geological
Tomales Bay exists because of two natural phenomena: the San Andreas Fault, and high sea level. The linear valley that extends from Bolinas Lagoon north to Tomales Bay coincides with the San Andreas Fault, a 0.7 to 1.5 km- wide zone of concentrated geologic activity (Grove 1992). In the region of Tomales Bay the zone is broadly defined by the present width of the bay. The fault zone widens somewhat to the north, and in the vicinity of Bodega Head it is 1.5 miles (2.4 km) wide (Gallaway 1962).

A discontinuous, center rift ridge is developed throughout the length of Tomales Bay. The Pleistocene (Millerton formation) core of Tom’s point, Hog Island, the bay floor outcrop southeast of Hog Island, and an acoustically delineated mid bay topographic high developed south-east of Reynolds, are all expressions of this rift feature (Daetwyler 1966).

Earthquakes have and still do play a role in the ever-changing geology along the active San Andreas Fault. Data from most of the paleoseismic investigations indicate that a large earthquake occurred about 350 years ago and another earthquake occurred about 700 years ago (Knudsen 2001). This earthquake activity is also evidenced in the profiles of marine terraces along the coast showing progressive tilting of older terraces and warping of the entire terrace sequence consistent with localized folding adjacent to the San Andreas fault (Hitchcock 1998). Investigation of the terrace surfaces along the Point Reyes Peninsula shows that the deformation of these terraces indicate that the uplift process is currently active. Hitchcock (1998) found that the northeast southwest directed shortening between the San Andreas and Rogers Creek fault deformed the Wilson Grove Formation and younger marine terraces. This factor suggests uplift rates between 0.03 to 0.15 m/ka. Early work on earthquake frequency in the region near Tomales Bay and Bodega Bays indicated that the area is remarkably free of small to moderate-sized earthquakes (Koenig 1963), however, earthquake activity reporting was not as well developed at that time so it is likely that Koenig underestimated the frequency of smaller earthquakes (a look at the Seismo-Watch section of the Press Democrat paper shows weekly activity). It was observed that a sequence of closely timed, smaller earthquakes
would have produced a similar set of paleoseismic data to that generated by the larger earthquakes which might indicate that the area has a long history of small to moderate-sized earthquake activity (Knudsen 2001). The effects of the 1906 earthquake resulted in crater-like depressions in Tomales Bay that developed along the surface fault trace on Sand Point, and gently undulating ridges and troughs covering the tidal mud flats at the southern end of the bay. Horizontal shifting of mud was also observed near the bay-shore in the vicinity of Inverness (Smith 1971).

While earthquake related tsunami activity is rare along the Pacific Coast, the effects of the Alaskan earthquake of 1964 and resulting tsunamis were noted for Tomales Bay. The Alaskan earthquake was the largest recorded in North America (9.2 Richter magnitude) and the second largest ever recorded. The tsunamis generated by the 6:36 pm earthquake on March 27, 1964 (epicenter in Prince William Sound) were recorded throughout the Pacific. On March 28th a 1-meter amplitude wave reached the mouth of Tomales Bay (Sokolowski 1990). The Pacific Marine Station operated a tidal gage located on the pier at Lawson’s Landing just inside the bay on the northwest side of the bay entrance (Smith 1971). This gage recorded the wave time as it moved down the bay and returned to the gauging station. The time recorded was just over 22 minutes for the wave to osculate back and forth within the bay (Johnson 1965). The Pacific Marine Station also maintained two time stations, one at Lawson’s sand flat and the other at White Gulch. Sediment height was measured from the top of ten separate pipes driven into the sand and surveyed to a tidal benchmark at each time station every two weeks. The sediment height was measured the day before the tsunami reached Tomales Bay. Sediment was re-deposited to a depth of 1.5 cm at Lawson’s sand flat and to a depth of just under 1 cm in White Gulch. This type of information might be useful in developing predictive circulation models for Tomales Bay.

3.1.2 Hydrographic Observations
Tomales Bay, a small estuary, is located in Marin County about 40 miles (64 kilometers) north of San Francisco and is part of the Gulf of the Farallones National Marine Sanctuary. It opens at the southern end of Bodega Bay and extends in a southeasterly direction. The bay is 12 miles (20 kilometers) long and ranges from 720 yards to 2,900 yards (658 to 2,651 meters) wide (Smith 1971). The bay has an area at mean lower low water of 10.9 square miles (28.4 square kilometers). The average depth is approximately 12 feet (3.7 meters) at sea level; its greatest depth is 61 feet with a total volume of 48 x 10^6 cubic meters.

The physical environment of the bay was divided into three major regions based upon hydrographic observations made in the 1960s (Johnson 1960). These divisions are the lower bay (north of Pelican Point) with strong oceanic influence, and mid-bay (Pelican Point to Tomasini Point) and the upper bay (Tomasini Point to Point Reyes Delta) both with slower currents and less oceanic exchange. Water mixing in the lower bay is slow and is driven predominantly by tidal currents. Mixing in the upper reaches of the bay is primarily by wind driven turbulence (Smith 1987). In the summer, water exchange between the bay and ocean is slower with resident times of the water exceeding a month while in the winter, with freshwater inflow; the exchange is faster and the resident time is
decreased to a few days. With the combination of slow water mixing and exchange and net evaporation in the summer the bay becomes slightly more saline than the adjacent ocean (Smith 2000). Baroclinic (density-driven) processes are important to the flushing processes in Tomales Bay (Hearn 1997). These processes are generally dominant over tidal dispersion and other mechanisms that transport salt along the estuary (Lewis 1983). The occurrence of hypersalinity in late summer is indicative of weak ocean exchange during that season, and this is a consequence of the longitudinal density gradients being at an annual minimum (Hearn 1997). During the winter freshwater runoff mixes with coastal ocean water to modify the salinity levels. Salinity studies indicated that bay waters were stratified during winter runoff periods. As the summer approaches, salinities rise gradually and stratification of the water column decreases. Generally, at most areas sampled, stratification occurred when salinity decreased below 30% (Smith 1971).

3.1.3 Meteorological
The Tomales Bay watershed is indicative of the Mediterranean climate of the central coast of California and receives intense rain during the winter months (November through March), with 85% of the annual rain usually falling during this period. Another 10% of the annual precipitation falls during October and April, with the remaining 5% during the other five months of the dry season. Average annual rainfall ranges from 26 inches per year in the north and east part of the watershed to 39 inches per year in the south (Fischer 1996).

3.2 Overview of the Tomales Watershed
The estimated size of the Tomales Bay watershed ranges from 216 square miles (560 sq. km) (Smith 2000) to 236 square miles (611 sq. km) (Storm 1972) depending on the boundaries selected to determine the watershed. The watershed is rugged with the maximum elevation of 794 meters (Mt. Tamalpais) and several other peaks that exceed 300 meters. About 40% of the watershed is covered by clay-loam soils that support grasslands. Much of the grasslands consist of introduced annual grasses used for pastures (Smith 2000). Roughly 20% of the watershed is covered by brush and the remainder is forested woodland. About 80% of the watershed is used for agriculture, primarily the grazing of dairy and beef cattle. The remaining portion is in federal or local parkland.

3.3 Major Fresh Water Sources
Stream flow provides the major linkage between the watershed and Tomales Bay. Two major stream systems drain into the bay. Walker Creek system is made up of Chileno, Arroyo Sausal, Salmon, and Keyes Creeks and includes 35% of the Tomales Bay watershed area. This drainage system supplies about 25% of the annual runoff into the Bay (Fischer 1996). The Lagunitas-Olema Creek drainage contributes about two-thirds of the runoff into Tomales Bay, but includes only about half of the watershed. The remainder of the runoff into the Bay (about 10%) comes from the local bay shore drainages, which make up the remaining 13% of the watershed area. Rainfall over the past century has averaged about 90 cm/yr, with considerable interannual and seasonal variation. Groundwater discharge is of the same order of magnitude as summer streamflow into the bay or less than 1% of the freshwater input (Oberdorfer 1990). Over an 8-year study between 1987 and 1995, runoff into the system averaged 90 x 10^6 m^3/yr;
direct precipitation on the inner bay averaged $19 \times 10^6$ m$^3$/yr and evaporation averaged $9 \times 10^6$ m$^3$/yr (Smith 2002).

3.4 The Impairment of Tomales Bay

Tomales Bay has been listed under the Clean Water Act section 303(d) as being impaired due to pathogens, nutrient levels, mercury contamination and sedimentation. For the above listed parameters Tomales Bay exceeds the water quality objectives contained in the California Regional Water Quality Control Plan (Basin Plan). Because it is listed as impaired the RWQCB and/or the USEPA must determine the Total Maximum Daily Load for each of the listed parameters that Tomales Bay and the tributaries can maintain without causing impairment of beneficial uses. So far only the TMDL process for pathogens has been started with a completion date of 2004. The remaining parameters have completion dates of 2007 (RWQCB, 1995).

3.5 Water Quality

3.5.1 Bacterial Contamination

3.5.1.1 Statement of the Problem

Under section 303(d) of the Clean Water Act Tomales Bay has been listed as impaired due to pathogens (Taberski, 2000) for the following reasons:

- Tomales Bay is closed to shellfish harvesting for an estimated 90 days a year, therefore it is assumed that the standards set by the RWQCB (basin plan), DHS and FDA are exceeded 90 days per year.
- Under the state’s Shellfish Protection Act (California Water Code), Tomales Bay is considered “threatened” due to the shellfish harvesting closures listed above.
- DHS prohibits shellfish harvesting during periods of rainfall based upon the results of bacteriological studies. In 1997, closure rules for shellfish harvesting were made more stringent. Thus, the beneficial use of shellfish harvesting is not protected during the wet weather season.
- During periods without rainfall and when bacteriological objectives were met there was a major human illness outbreak of a virus of human origin from consumption of oysters. This fact shows that the beneficial uses of Tomales Bay were not protected even when water quality objectives were met.

On October 10, 1993, legislation was passed by the California legislature that enacted the Shellfish Protection Act of 1993. This bill requires the RWQCB to form a technical advisory committee for any commercial shellfish growing area that is determined to be threatened. One of the criteria for the formation of the committee was that if a shellfish harvesting area is closed for more than thirty days in each of three consecutive years a committee must be organized. Tomales Bay met this requirement and the Tomales Bay Shellfish Advisory Committee (TBSTAC) was formed on February 15, 1994 (TBSTAC, 2001).
3.5.1.2 Overview of the Supportive Documentation

As early as 1967 when the Pacific Marine Station and the North Marin Water District undertook water quality studies it was found that Tomales Bay had fecal coliform levels that were high during the winter runoff periods (Smith, 1971). During this four-year water column study surface coliform did not always exceed coliform levels near the bottom. This may have been due to the association of coliform bacteria with settling detritus. Even under the shellfish harvesting standards in effect during the study period, the requirements were only met between July and September of each year (Smith, 1971).

The California Department of Health Services conducted a detailed water quality survey of Tomales Bay and tributary streams during wet weather conditions to evaluate the bacteriological quality of the shellfish grown in the bay (Sharpe, 1974). Dry conditions in the watershed during the study period resulted in runoff that was not great enough to result in significant degradation of the Bay surface water quality. The study was started after a three-day rainfall of 1.98 inches with only some shoreline sampling stations affected by runoff. Water quality stations were located at 17 bay sampling stations, 19 shoreline stations and 49 stream stations. The sampling effort continued for 12 days in December. Shellfish tissue samples were also analyzed for coliforms and heavy metals.

Samples from the bay did not exceed the median standard of 14 MPN/100 mL required for shellfish harvesting, although a few stations did exceed the required 90th percentile of 43 NPM/100 mL. Stations along the shoreline had elevated levels of total and fecal coliform. Sharp (Sharpe, 1974) considered the tributary streams to be the major pathway of coliform entering the bay he attributed the source of the coliform bacteria to waste material from dairy cattle in the watershed. Other sources of potential contamination were investigated including raw sewage from the town of Tomales (this study was conducted before the town of Tomales completed construction of a sewage treatment plant), faulty septic systems, boats and boating facilities, the park systems, and ducks and other birds. None of these possible sources of contamination were considered to be major factors in the bacteria degradation of the bay waters. Only 5 of the 22 (22.7%) shellfish samples analyzed met the recommended standard for harvesting. The results of this study indicated the need for a “Conditionally Approved” shellfish growing area for Tomales Bay.

A two-year study was conducted during the winters of 1976-77 and 1977-78 by the San Francisco Regional Water Quality Control Board (Jarvis, 1978) to evaluate the effectiveness of the RWQCB’s requirements for dairy waste practices. Twenty stream stations and six shoreline stations were established for the study. Not all the stations were sampled both years and during each survey period. An analysis of total and fecal coliforms, ammonia and total organic carbon were completed for the samples collected.

The results indicated that the coliform quality of streams that are tributaries to Tomales Bay seemed to have improved between 1974, before the implementation of the “Minimum Guidelines for Protection of Water Quality from Animal Wastes” and the period after the guidelines were established and covered by the study period (1976-77/1977-78) (Jarvis, 1978). Creeks that had dairies in their drainage areas had higher
coliform levels than creeks without dairies. Some areas of the watershed that had no dairies also had substantial levels of coliform during rainfall runoff in 1977-78. The authors attribute that to animals on pasturage, wild animals, and naturally occurring coliform from the soil and vegetation. Ammonia concentrations did not exceed water quality standards, except for two stations (affected by dairy wastes) during 1976-77. Shellfish harvesting was affected when coliform levels exceeded the allowable limit and resulted in the closure of one aquaculture facility for two months. The authors also observed that: “it is unlikely that Tomales Bay will ever meet coliform objectives for shellfish harvesting during periods of substantial rainfall runoff even if all the dairies met the Minimum Guidelines”.

An FDA sanitary survey was conducted from February 24 through March 12, 1980. The primary objectives of the study were to collect water quality data during and following a period of rainfall from which the following could be determined: how much rainfall requires a closure to shellfishing and in what period of time; how long the Bay takes to recover from such a contamination event; and what portions of the bay are most affected (Musselman, 1980)? In addition, the study was to determine what the sources of pollutions were and to assess the hazard level, and to compare data from DHS’s routine monitoring program with the results of this study. Forty-five stations were established in the bay and on tributaries near where they empty into the bay. A total of 393 samples were collected and analyzed for total and fecal coliform and fecal streptococci. Shellfish tissue was collected at two stations in the bay and tested for total and fecal coliform.

The results indicated that intermittent periods of rainfall caused large variations in the water flowing in the streams during the survey. These flow changes were accompanied by wide variations in the bacterial levels with total coliform ranging from 230 NPM/100 ml in Bear Valley Creek after a few days of dry weather to 97,000 NPM/100 ml in Tomasini Creek during a heavy runoff event. The portions of the bay most seriously affected by bacteria contamination resulting from rainfall and runoff are the head of the bay (Millerton Point) south and the east side of the Bay inside the bay mouth (Walker Creek Delta). Seven out of eight shellfish tissue samples exceeded market standards. Bacterial ratio analysis in stream and bay waters indicated that a mixture of rural and livestock non-point pollution was the most likely source of high bacterial counts in the bay.

A small study was conducted by DHS in 1982 with 21 boat stations in Tomales Bay and 19 stations in tributary streams that were sampled during a rainstorm from March 1 through March 5 (Hultquist, 1982). Samples were analyzed for total and fecal coliform and fecal streptococcus. The results of this unpublished report follows the established pattern in earlier studies of high coliform levels during the storm runoff and then rapidly declining concentrations during the following drying period.

The Department of Health Services (DHS) conducted studies during 1994-95 to evaluate indicator species, test sampling methods and laboratory analyses and to finalize site selection of watershed sampling stations for a later investigation in 1995-96. During this pilot study a total of 352 samples were collected from 12 stations in the Tomales Bay and
from 35 watershed locations. Samples were collected from this array of stations nine separate times covering periods when the shellfish harvesting was both open and closed. These samples were analyzed for total and fecal coliform, *Enterococci*, Bacteroides species, *Clostridium perfringens* and Methylene Blue-Active Substances (MBAS), which are common surfactants in detergent. These indicator species were selected by TBSTAC as a preliminary effort to evaluate the use of more selective test procedures (TBSTAC, 2001). Shellfish tissue was sampled from 26 organisms and analyzed for total and fecal coliform (DHS, 1996). Results of this investigation were similar to earlier studies and verified that during periods of rain the tributaries entering Tomales Bay contributed bacteria to the bay system. Two seasonal patterns of fecal coliform concentrations were noted: 1) sites that showed declining fecal coliform densities throughout the winter, that suggested a nonrenewable source as the runoff declined and, 2) sites that exhibited high fecal coliform concentrations throughout the winter season, suggesting a renewable source (Taberski, 2000).

The 1995-96 sampling program was designed by Tomales Bay Shellfish Technical Advisory Committee (TBSTAC) and conducted by the Department of Health Services (Taberski, 2000; TBSTAC, 2001). This study was a joint effort of DHS, RWQBC and funded by SWRCB. Samples were analyzed for total and fecal coliform, enterococcus and *Escherichia coli*. In addition to the parameters measured in the earlier study, several sites were analyzed for coliphage and the anaerobic bacterium *Bacteriodes vulgatus*, which is an indicator that is thought to be more specific for human fecal sources than the standard indicator organisms (Taberski, 2000). A limited number of samples were analyzed for the pathogenic bacteria *Salmonella typhirium* and *E. coli*:0157. The study was conducted in the winter of 1995-96 and samples were obtained from 40 stations located in the bay and watershed. The collecting periods covered two dry phases and four rainfall events. Sample collection during wet events extended past the period when the bay would be opened for shellfish harvesting (day 10 after the first rainfall).

The results from this intensive study were used, in part, to establish numeric targets for the TMDL process (Taberski, 2000; TBSTAC, 2001). These results are summarized below:

- Bacterial densities usually exceeded the standards within the first one or two days of each rainfall event and then decreased to within requirements by the end of sampling. This fact follows the finding of all the earlier studies reviewed for this report.
- High bacterial levels were consistently recorded for the Walker/Keyes/Chileno watershed and along the eastern shoreline of the watershed. The stations on the eastern shoreline that high levels were recorded included Mileposts 40.35, 34.95, 32.12, Millerton Creek, Grand Canyon Creek and Tomasini Creek. Slightly lower levels of fecal coliform were detected throughout the Lagunitas/Olema subwatershed with Lagunitas Creek contributing the largest share of fecal coliform to the bay, followed by Olema Creek. Bear Valley drainage contributed the lowest amount from this sub watershed. The fecal coliform concentrations along the western shoreline were 10-100 times lower than in the other watershed.
• Samples collected in the bay were also affected and were above standards within the first two days following significant rainfall. The fecal coliform levels remained above requirements for three days after the rainfall event and did not always return to levels below the standard for shellfish growing regions after bay waters were open for harvesting (day 10). A station (34) directly influenced by outflow from the Walker Creek drainage around Preston Point had the highest levels of fecal coliform. Stations sampled in mid-bay had fecal coliform levels that were usually lower than those stations located in the outer bay or inner bay although all were elevated. Inner-bay samples during rainfall event number three showed a greatly elevated concentration of fecal coliform after day 10. A possible explanation for this sharp peak would be some type of contamination pulse originating from the watershed or along the bay’s near shore areas (Taberski, 2000).

• Samples taken from oyster tissue collected at outer bay stations reached extremely high levels following significant rainfall and followed the pattern seen in the water column analysis where levels did not return to the NSSP market standards after the bay was opened for harvesting. The data also indicated a pattern of increasing fecal coliform levels throughout the winter period. At some of the outer bay stations samples were taken from oysters growing in floating bags (top culture) and bottom-cultured bags. Those oysters raised under surface conditions had significantly higher levels of fecal coliform (above NSSP standards) during the first dry period sampling, which might be related to local contamination sources possibly from birds (Taberski, 2000). What portion of the increasing fecal coliform levels that occur throughout the winter period in the bay come from the watershed and/or local sources near the shellfish growing areas was not clear in the report.

• The pilot study and the later, more intensive study indicated that more refined tests were used to differentiate bacteria that was of human origin from the general category of fecal coliform which can come from any warm-blood animal. The four commonly used indicator organisms were monitored during this study to evaluate if any single indicator was more source-specific than others. Levels of *E. coli* tended to drop more slowly than the other indicators, and was often the only indicator exceeding the acceptable standard by day 3 of the monitored rainfall events. Based on these results, *enterococcus* was determined to be the most sensitive and fecal coliform was the least sensitive indicator organism relative to their respective water quality objectives.

A joint study in 2000-2001 was undertaken by the RWQCB and NPS to investigate water quality in the Lagunitas Creek and Olema Creek sub-watersheds (Ketcham, 2001). For the Tomales Bay Pathogen Study, 25 stations were sampled during the rainfall events. Other water quality parameters were also collected and included ammonia, DO, pH, conductivity, TSS and temperature. At these sites one or two samples were collected in a given day. Two time series stations were designated (Olema Creek at Bear Valley Road Bridge and Lagunitas Creek at the USGS gauging station). At these stations the sampling was much more intense and was intended to document the response of *E. coli* levels in relation to the monitored hydrograph. Collections were spread across the rising and
falling limb of the hydrograph to determine pathogen delivery response in relation to the stream flow. Thus, samples were collected every one to four hours for the duration of the study (up to four days).

Analysis of the data demonstrated that Olema Creek watershed had one of the lowest fecal coliform and \textit{E. coli} loadings to the bay. Loading results from Lagunitas Creek indicated that it was a larger contributor of fecal coliform and \textit{E. coli} to the bay than Olema Creek. Even though bacterial concentrations were always lower in Lagunitas Creek than Olema Creek, the stream flow affected the calculations of loading so that Lagunitas was higher than Olema. The report also concluded that agricultural sources are the major contributors of fecal coliform and \textit{E. coli} to the bay. However, high levels of these pollutant parameters observed in San Geronimo Creek and from Point Reyes Station storm drains indicates that developed areas cannot be discounted as a source (Ketcham, 2001). Toxic ammonia was not a problem except for one sample taken from pasture runoff in the Giacomini tributary to Olema Creek.

### 3.5.1.3 Stream Runoff and Watershed Contributions

All of the bacterial studies reviewed in this document have indicated that animal based agricultural runoff plays a major role in the high levels of fecal coliform recorded in tributaries from the watershed and in Tomales Bay during the rainy season. In order to address this problem and to assist the agricultural community maintain a viable enterprise the Tomales Bay Agriculture Group (TBAG) was formed in 1999. To assist with these water quality efforts, the University of California Tomales Bay Water Quality Project (UCTBWQP) has implemented a “systems approach” to study animal agricultural facilities (Lewis, 2001). This systems approach was designed to evaluate possible links between animal agriculture and fecal coliform, nutrients, and sediment loading to the Bay. Facility evaluations were conducted in a four-step process; which included a facility tour and sampling site selection, first storm-event sampling, second storm-event sampling and on site discussion of the preliminary results with participating members of TBAG. With ten participating producers and a limited number of storms during the two-year period of the study 19 first-storm event samplings and 6 second-storm events were studied for a total of 25 sampling events. Sampling locations during storm events for facility scale investigations were selected to compare management practices with respect to water quality for the investigated parameters. The loading units were grouped into subcategories that included; waste management systems (WMS) such as retention ponds and flush systems, pasture, lots used during the summer, manure stockpiles, drains not in contact with animals facilities, runoff from impervious surfaces and roof runoff before it entered subsurface drains. In addition to the facility loading unit evaluation, tributary scale sampling and analysis was conducted to establish a water quality baseline. Control watersheds were selected which did not have dairy facilities or development and had limited rangeland usage by cattle or wildlife. Tributaries that represent upstream conditions just before the stream entered a facility unit that was to be evaluated were selected. Stations were located downstream on the tributary that past through the facilities. Bay sediment samples were also collected during low tide periods near leased shellfish growing tidal flats. Six transects with random samples were taken before rains (September, 2000), during rains (March, 2001) and after winter rains (late May, 2001).
In addition to these samples sediment was also collected from tributary streams and Tomales Bay shoreline.

This study showed that mean fecal coliform instantaneous load and storm load for control and upstream were not significantly different. This is important given that upstream units were managed for grazing and received spread and irrigated manure (Lewis, 2001). Mean fecal coliform concentration, instantaneous load and storm load were significantly greater downstream from facilities than the control. Both fecal coliform concentrations and storm load were significantly greater downstream than upstream of facilities. Data from the sediment analysis shows a significantly greater mean fecal coliform concentration in tidal flat sediments during the winter than during pre-or post- winter periods. Fecal coliform concentrations in bay and stream sediments were lower than tributary concentrations indicating that they were not a reservoir of sufficient size to load the bay if re-suspended (Lewis, 2001).

The major objective of this narrative is to address water quality in Tomales Bay and its tributaries and not evaluate animal agricultural operations. Obviously, water quality in tributary streams is closely tied to the operational aspects of dairies, and other animal intensive agriculture. However, with limited time and budget only a brief review of waste management systems and remediation efforts by animal agricultural operations will be presented. Specific loading units, in order of concern, for fecal coliform include stockpiles, lots, storm drains, and facility runoff (Lewis, 2001). Tributary stream results indicate the control and upstream unit instantaneous loads for fecal coliform and nutrients are significantly different. The importance of this observation is that existing grazing and manure applications in upstream units does not appear to have a large impact on water quality. Potential fecal coliform loading in runoff from stockpile areas and lots is two and in some cases three orders of magnitude greater than loading from other units (Lewis, 2001). In comparison, fecal coliform loading from pastures is not significantly different from upstream or runoff loading units. Focusing efforts to reduce or store this volume of runoff, or lowering the concentration of fecal coliform from lots and stockpiles, would contribute to a reduction of the overall potential loading within agricultural tributaries.

Staff from the Department of Fish and Game has been involved since the early 1970s with the dairy industry to assist in the promulgation of guidelines to reduce the waste material that enters streams near confined animal operations (Rugg, R. C. B. Wyatt, L. Sauter 1992). Most of the attention has been focused on bacterial contamination moving down tributaries and entering Tomales Bay and effecting the harvesting of shellfish during wet weather periods. However, in response to dairy waste pond failures, CDFG has found that soluble organics, principally ammonia, are of even greater importance than the bacterial levels because ammonia is extremely toxic to aquatic organisms. Based upon this information a program was started in 1991 and continued through 2001 (Rugg, 2000; Rugg, 2002). The program consists of 20 stations in the Tomales Bay (20 more stations were located in Sonoma County, outside the area of interest) that were monitored from the onset of sustained flow in most watersheds, through the middle of June, or whenever flows became intermittent. At each sampling station a number of parameters were measured including dissolved oxygen, total ammonia, un-ionized ammonia and
conductivity. The stations were located along the south and eastern shoreline of Tomales Bay at bridges or culverts under Hwy 1, wherever flow could be sampled.

Data was evaluated for the periods from 1998 through 2001 in this agricultural runoff investigation. Results from the 1998-99 period indicated that out of 329 measurements the water quality parameters in the watershed were very good, with only three exceptions being recorded (D.O. levels and un-ionized ammonia). D.O. was consistently at or near saturation; total ammonia was low, with a notable exception of one elevated ammonia reading. The toxic form of ammonia was low and conductivity showed some slight improvement from earlier studies (Rugg, 2000). The nearly normal winter did not create any serious water quality problems in most streams within the study area. Water quality problems encountered were principally the result of runoff of animal wastes from loading areas, walkways, disposal areas, or the resultant eutrophication and disruptive effects upon oxygen dynamics.

Results for the periods from 1999-2000 indicated that the streams in the watershed were in very good condition. Dissolved oxygen was consistently at or near saturation, total ammonia was low and conductivity was extremely low. It should be noted that the conductivity data might be somewhat ambiguous as some sampling locations within the watershed are periodically subject to tidal inundation (Rugg, 2002). There were no recorded samples that exceeded the ammonia criteria for the year, and only two for dissolved oxygen, a dramatic improvement over the year before.

3.5.2 Management of Sewage Waste

3.5.2.1 Point Sources
There are nine small towns within the watershed. All of the towns are served by onsite sewage disposal systems except the town of Tomales, which is served by a centralized wastewater treatment plant (TBSTAC, 2001). There are eight small sewage treatment systems within the watershed, and one facility that accept septage waste. Four of the facilities discharge effluent onto the land, and five facilities utilize leach fields for dispersing effluent in the ground. Since most of these facilities are located near streams there is always the chance of a plant accident that could cause an effluent discharge to a local tributary and possibly into Tomales Bay. The only preventive steps that can be taken in case of a spill is to have response plans in place to reduce the effect of the spill and to notify such activities as shellfish harvesting of the potential danger. During the review of files and site inspections DHS noticed considerable variability in waste discharge requirements, operator certifications, and site regulations for various permitted waste facilities (TBSTAC, 2001).

3.5.2.2 Non-point Sources
There are a number of non-point sources for potential release of effluent into tributaries or directly into Tomales Bay. The potential for failing septic systems in areas around the Bay has been of concern to public officials for a number of years particularly in regions where growth would cause expansion of septic system usage. As far back as 1978 there was concern that nitrate pollutions could occur from Inverness housing developments
using septic systems and located near Brook Ness, Alder Creek and other locations (Clark, 1978). Leakage into the creek drainage areas could cause nutrients to enter Tomales Bay. The unincorporated areas around the Bay are served entirely by various types of onsite sewage disposal systems including septic tank and leach-field systems, holding tanks, and seepage pits (TBSTAC, 2001). These systems are most likely to fail during times of heavy rainfall with resulting high groundwater.

In May of 1998 there was an illness outbreak associated with the consumption of oysters from Tomales Bay. This event was linked to human virus that came from human sewage released into Tomales Bay. A preliminary survey of houses along 7 miles of the east side shoreline of the Bay was conducted. This survey found two houses within 1.5 miles of the harvest sites associated with the disease outbreak that might discharge directly into the bay. In 2000 additional shoreline survey work was conducted by DHS along 35.5 miles of shoreline. A visual survey conducted on foot found no obvious signs of failing septic systems or discharges to the surface of Tomales Bay (TBSTAC, 2001). No conclusive evidence was found as to the source of contamination, DHS determined that the two most likely causes for the outbreak were substandard and potentially failing septic systems or overboard discharge(s) of toilet waste from a boat.

Wildlife including waterfowl and marine mammals as well as terrestrial animals contributes bacteria to Tomales Bay either directly to bay waters or through the tributaries. The amount of “background” contamination that comes from these wild stocks is not known. However, large populations of wintering water birds (e.g., 11,800 in winter of 1998-1999, not including gulls) occur in the vicinity of shellfish growing areas (Kelley and Etienne, 1999). In addition, some 7,400 were observed roosting on the Walker Creek Delta encompassing an area of about 2 hectares of tidal flat (Kelly, 1996). Marine mammals mostly harbor seals have haul out sites in Tomales Bay around Hog Island and in the Lawson’s flat area near the bay mouth. Surveys by the NPS estimate that populations range from 400 to 650 year round with between 100 and 200 individuals that are resident in Tomales Bay. The haul out areas are not directly in the any commercial shellfish growing area (TBSTAC, 2001) but they are about ½ mile away. Of course floating structures that support shellfish culture bags are attractive to both birds and marine mammals.

Cattle and other livestock also use the watershed, but here better population estimates can be made and data is available on the manure production characteristics of different livestock. Estimates have been made on a pounds per day of total waste (fecal and urine) production by a typical animal. A survey in 1990 (Bennett, R. C. B. Wyatt, L. Sauter 1992) estimated that there were approximately 10,970 head of dairy animals and 1,320 head of beef and 1000 sheep that utilized the Tomales Bay watershed (includes Chileno Creek, Keyes Creek, Walker Creek, Marshall to Pt. Reyes Stations and the Lagunitas/Nicasio Reservoir). The total count of 11,254 animals produce 1,448,018 lbs/day of manure (Taberski, 2000).

Pleasure and fishing boats are found distributed throughout the bay. Boating activities have increased in recent years with large numbers of kayakers now using the bay. There
are a few live aboard vessels moored in the bay and only one true marina. There is a lack of vessel sewage pump-out facilities in the bay. Commercial fishing occurs for a short time during the annual herring run. In 2000 CDFG issued 38 permits for fishing rights to the fishery with about 22 boats on the bay for about 40 days.

3.5.3 Shellfish Harvesting
There are currently six certified active commercial shellfish harvesters in Tomales Bay with a combined aquaculture lease area of 483 acres (TBSTAC, 2001). All the active commercial growers in Tomales Bay operate on the eastern shoreline on leases granted by CDFG. Shellfish production is primarily devoted to the Pacific oysters (*Crassostrea gigas*) and bay mussels (*Mytilus edulis* and *M. galloprovincialis*). A small number of Eastern oysters (*C. virginica*), European oyster (*Ostrea edulis*), Kumamoto oyster (*C. gigas kumomoto*) and Manila clams (*Tapes semidecussata*) are also grown. The Department of Health Services has classified Tomales Bay for commercial shellfish production in accordance with the National Shellfish Sanitation Program (NSSP) Model Ordinance (FDA, 2000). All commercial shellfish growing areas are in regions of the bay that are classified as Conditionally Approved. This classification means that the area meets NSSP standards except for short periods of time (during rainfall events) when the bay is closed to shellfish harvesting.

A large effort over the last 20 years has gone into investigating the cause, frequency and sources of bacteria contamination that effect the harvesting of shellfish in Tomales Bay. These efforts (12 studies) have dealt primarily with total and fecal coliform potentially coming from a number of possible sources including dairy and cattle operations and from substandard or failing sewage systems and natural populations of wildlife that live in or visit the bay and surrounding watershed. Each certified grower was in compliance with the conditions of their respective self-monitoring water quality programs (Commandatore, 2000).

In May of 1998 there was a virus infestation of Tomales Bay oysters that affected 171 people and was determined to be from human fecal origin. Shellfish harvested at the time that the contaminated oysters were collected met both the water and shellfish fecal coliform standards. In 2000, four cases of food borne illnesses associated with *Vibrio parahaemolyticus* prompted DHS to issue warnings to consumers against eating raw or undercooked oysters (Commandatore, 2000). *V. parahaemolyticus* is a naturally occurring halophilic (salt-requiring) bacterium that inhabits the coastal waters of the United States and is present in higher numbers during the summer. These food borne illnesses resulted in a cooperative monitoring plan between DHS and the shellfish growers. Weekly samples are collected between May and September of each year. In 2001 there were no tissues samples that were detected as contaminated with *V. parahaemolyticus* in oysters from Tomales Bay.

The event of human pathogens contaminating Tomales Bay oysters during times when the coliform standard was met in both the water column and in shellfish tissue brings into question the validity of fecal coliform as the sole indicator of safe conditions for harvesting. While monitoring for selected pathogens, as is now done in Tomales Bay,
focuses on a known virus it does not assure that the tissue is safe from other forms of human pathogens. This same argument can also apply to concerns that some pathogens from animal waste could affect humans since reduced fecal coliform still does not protect humans. As long as fecal coliform is the indicator used for public health and water quality standards (FDA, 2000), animal agricultural sources will merit management attention (Lewis, 2001). Since there is no simple or routine test to separate human pathogens from fecal coliform measurements and thus, there is no simple way to determine what percentage of the fecal coliform levels come from different sources the use of this standard will no doubt continue. As one of the early studies pointed out (Jarvis, 1978) it is unlikely that Tomales Bay will ever meet coliform objectives for shellfish harvesting during periods of substantial rainfall runoff even if all the dairies met the RWQCB Minimum Guidelines. While we know more about coliform sources now than in 1978 information is still lacking as to the role natural sources (e.g., large, over-wintering and resident bird populations, marine mammals) and the extend of human waste input (failing septic systems, boat and recreational uses) play in this process. These concluding statements are not intended to indicate that efforts should not continue to address fecal coliform but to warn that additional efforts to understand sources is necessary.

3.5.4 Status of Bacterial Contamination

The review of twenty-five years of studies and data on bacteria (1967 to 2001, not taken continuously) demonstrates that fecal coliform consistently increased above the NSSP and DHS shellfish harvesting standard during rainfall runoff. These conditions still exist and still require closing shellfish harvesting during rainfall runoff events. The same conclusions were presented in the TMDL document (Taberski, 2000). Recent incidents of human illness caused by oysters collected while meeting current fecal coliform standards have been taken into consideration in forming thresholds for pathogen TMDLs. Based upon the current status of pathogen contamination in Tomales Bay and adjacent tributaries the RWQCB has proposed numeric targets for the TMDL. The board staff has proposed using three different numeric targets; the fecal coliform objectives for water found in the RWGCB Basin Plan to protect shellfish harvesting, the fecal coliform shellfish tissue standard used by DHS to determine if shellfish have been contaminated by fecal waste and used by FDA as a market standard, and a zero discharge of human waste in order to protect the public from human viruses.

3.5.5 Trends in Bacterial Contamination

No trend analysis was attempted on the bacterial contamination data in this report because of time constraints and the fact that the data generated by many of the studies was not comparable. Time of year, level of effort, station locations, rainfall variability, stream flows data and rainfall records were not consistent between investigations making trends difficult to detect. An attempt was made in the TMDL report (Taberski, 2000) to make comparisons of fecal coliform results between studies. The author found many of the same problems of data incompatibility or incomplete data, however some trends were described. Because of the variability of the data only the highest, lowest, and median
fecal coliform values were used from each study. Data from the 1995-96 pre and post-wet period samples were not included in the trend analysis. Four stations were selected from the watershed (Walker Creek, Millerton Creek, Grand Canyon Creek, and Olema Creek) and four stations from Tomales Bay (Walker Creek Delta, Marconi Cove, Blake’s Landing and Tomales Bay Oyster Company). Because of the issues discussed above, it was difficult to make any clear conclusion about fecal coliform trends over the years from 1974 to 1996. However, stations in the bay indicated that fecal coliform was lowest in the low rainfall years and that over the past twenty years levels of fecal coliform have stayed high during moderate to high rainfall periods, especially at the Walker Creek and Tomales Bay Oyster Company locations. The watershed stations, however, indicated that the highest fecal coliform concentrations remained elevated in all studies. Over the long term there were no clear overall trends of increasing or decreasing fecal coliform levels at watershed stations with the exception of Millerton Creek where coliform levels increased over the time period represented by the studies. Later studies conducted on streams in the Lagunitas Creek and Olema Creek sub-watersheds (Ketcham, 2001) indicated that runoff from Olema Creek had one of the lowest fecal coliform loading to the Bay.

3.6.1 Nutrient Levels
Tomales Bay was listed as impaired under the Clean Water Act section 303(d) (RWQCB, 1995) due to elevated nutrient levels in the tributary streams. At first glance a review of the existing data suggests that this nutrient impairment determination seems to be closely related to the high levels of total and fecal coliform in streams and the bay associated with animal agriculture and possibly with failing septic systems. However, a recent study indicates that nutrient loading and more specifically, their fate and transport, may not be as closely associated with fecal coliform as first thought (Lewis, 2001). Nutrient loading needs to be investigated as an issue separate from fecal coliform. Most of the studies of tributary streams to date have concentrated on coliform with some nutrient measurements made but with little analysis of the results or understanding of their direct impact on Tomales Bay. Nutrient levels and their transport to the bay are likely closely linked to sediment movement. For example, phosphorus may be bound to fine particles and moved down stream with the sediment to the bay. Emphasis has often been placed on monitoring total and un-ionized ammonia levels that have a direct and rapid effect on aquatic organism in the stream systems. Nitrogen and phosphorus do not necessarily have a direct effect upon entering the aquatic system but are nutrients that concentrate over time in the water column and sediments where they interact with other chemicals and can effect plankton production and benthic flux at a later time. Because balanced nutrient levels are critical in maintaining the bay ecosystem it is important to distinguish natural levels from elevated concentrations coming from animal and human activities in the watershed. This is not a simple tasks since nutrient levels often involve complex relationships between sediment and the water column, storage in ponds and sediment sinks and seasonal variability.

3.6.1.1 Watershed Nutrient Levels
A number of recent watershed studies have taken measurements of nutrients although the emphasis was on other water quality factors. The most extensive study seems to be
focused on the effects of animal agriculture on Tomales Bay tributaries (Lewis, D. M. P. Olin 2000; Lewis, 2001). This study found that mean total nitrogen concentrations/loads, ammonium concentrations/loads, nitrate instantaneous load, and phosphate concentration/loads for the control sites and sites upstream of agricultural facilities were not significantly different. Mean total nitrogen, nitrate and phosphate concentrations were significantly greater downstream from facilities than were the concentrations at the control watershed. Mean ammonium concentration downstream was not significantly greater than the control. Mean nitrate and phosphate levels were significantly greater downstream from the facilities. Tributary scale results indicate the control and upstream unit instantaneous leads for fecal coliform and nutrients are not significantly different. Downstream fecal coliform loads are significantly greater than control loads but not upstream loads, indicating that animal agriculture practices within the facility areas have the potential to impact water quality with regard to fecal coliform (Lewis, 2001). The authors do not make the same comparison for nutrients, but they may also follow a similar pattern.

Studies conducted in the Lagunitas Creek Watershed by the National Park Service found that nutrients and ammonia were not a concern in this watershed (Ketcham, 2001). Nearly all of the samples collected from the larger stream systems, and most of the tributary samples were below detection limits. As Lewis observed, the nutrient cycling within the watershed must be better understood (Lewis, D. M. P. Olin 2000). This cycling includes plant uptake, soil microbial and chemical processes and exchanges with the atmosphere. There is some indication from these two studies that nutrient loading from animal agriculture may not be as high as previously indicated (RWQCB, 1995; Lewis, D. M. P. Olin 2000). Nutrient concentrations in the ground water were determined through extensive well sampling; groundwater discharge was estimated using both Darcy’s Law calculations and soil moisture budget. Results indicate that ground water discharge is of the same order of magnitude as summer stream flows. Dissolved nutrients concentrations in groundwater were consistently higher than surface water discharges (Oberdorfer, 1990).

3.6.1.2 Nutrients in Tomales Bay
Because of the NSF Land Margin Ecosystem Research (LMER) program Tomales Bay has been subjected to intensive study on water quality, bay water mixing and nutrient dynamics (Kimmerer, 1993; Joye, 1995; Largier, 1997). This large data set provides an excellent understanding into the complex nutrient cycling found in estuaries. Tomales Bay is influenced by water exchange with the coastal ocean. Coastal seawater composition shows significant variation over an annual cycle, largely because of varying strength of coastal upwelling (Smith, 2000). Direct inorganic nutrient delivery from upwelling is not of major importance to the bay, but may be important indirectly by effecting nutrient dynamics within the bay. Particulate organic matter is delivered to the bay by tides and particle settling. Ecosystem respiration appears to exceed primary production by about 10% (Smith, 1997). This implies that the net ecosystem metabolism of the bay is supported to a significant extent by the import and oxidation of organic matter produced outside the system. The organic matter supporting the net heterotrophy of the bay (Smith, 2000) comes from land (about ½) and from the coastal ocean (the other
The activity of filter feeders (e.g., oysters and mussels) can alter the composition of available nutrients in the water column, impacting phytoplankton based food webs. Excreted material from large populations of bivalves may be returned to nutrient cycling systems, in such forms as NH$_4$, which is readily taken up by bacteria (Judah, 2000).

Eutrophication has been defined as an increase in the rate of supply of organic matter to an ecosystem. Studies in 1985-1986 indicated that spatial and temporal variations in primary productivity were similar to variations in phytoplankton biomass. During summer months productivity was highest in the seaward and central regions of the bay and lowest in the shallow landward region (Cole, 1989). This lack of sustained high phytoplankton concentrations suggests that the shallowness of the southern region, its shallow photic depths, wind-induced turbidity and feeding of benthic organisms keeps the populations at a lower level that other parts of the bay (Cole, 1989). Research has shown that the external supply of organic matter to Tomales Bay varies over seasonal and annual time scales (Chambers, D. M. P. Olin 2000). The rates of external inputs of organic matter to Tomales Bay may change in the future in response to regional changes in land use and/or the response to climate-driven changes in the watershed, estuary, and ocean complex. Internal generation of organic matter in the bay (algal blooms) could be stimulated by increased runoff of dissolved or sediment attached inorganic nutrients. The current state of the bay remains fairly pristine with the major impact of terrestrial runoff being the sediment transport and infilling of the bay (Chambers, D. M. P. Olin 2000). However, little is known about the phytoplankton dynamics in Tomales Bay and the shifting location of the maximum chlorophyll-a concentrations at different times indicates the dominant processes controlling phytoplankton biomass vary (Cole, 1989). Thus, more effort is needed in understanding primary productivity in Tomales Bay before much can be said about winter nutrient loading and summer algal growth as contaminants problems in the bay.

3.6.2 Status of Nutrient Concentrations

A review of the current literature indicates that the nutrient levels in the watershed could be elevated but the database is not very extensive. There is some indication that nutrient loading from animal agriculture may not be as extensive as once thought. Additional studies on nutrient transport to the bay from agricultural operations needs to be completed before a clear understanding of the role of agriculture in nutrient enrichment is obtained. It is important to understand nutrient (C, N, P) reservoirs to clarify how this system responds to the influences of cattle and humans (Freifelder, R, et. al. 1998). As the authors conclude understanding the linkages between land and water remains incomplete if fluxes from the land to the ocean are treated as outputs from a black box whose contents and internal reaction characteristics are unknown. Tomales Bay shows no indication of eutrophication with the current level of nutrient input from the watershed (Cole, 1989; Chambers, D. M. P. Olin 2000). As stated earlier in this report more effort is needed to really understand primary productivity in Tomales Bay. The role of nutrient runoff in winter and the perceived increase in primary productivity (lower end of the bay) in the summer should be investigated to determine if the concern is really a problem and if it does occur, to establish the spatial and temporal patterns.
3.6.3 Trends in Nutrient Levels

Time series sampling was undertaken to describe seasonal, annual and interannual variations of fluxes of C, N and P over 8 years (1987-1995) by the Land Margin Ecosystems Research Program L.M.E.R. (Smith, S, J.T. Hollibaugh 2002). They observed that the ocean in general and many systems in the coastal ocean in particular tend to oxidize more organic carbon than they produce. Tomales Bay is an example of this phenomenon called “net heterotrophy” (production: respiration ratio). The does not imply a low rate of primary production, but rather that respiration tends to exceed primary production. In addition, the authors suggest that anthropogenic activities are tending to increase, rather than to decrease, this net heterotrophy globally. With so little seasonal data on nutrient loading from the watershed and nutrient levels in Tomales Bay trends cannot be determined. In addition, most of the 12 water quality studies conducted in the watershed and bay have emphasized total and fecal coliform measurements and not nutrient levels. While a large number of scientific papers address various monitoring results, hydrological models and geochemical reconstruction there remains limited data on eutrophication or the extent of anthropogenic nutrient loading from the watershed to Tomales Bay.

3.7.1 Toxic Contamination

This section discusses toxic contamination found in bivalve tissue (both heavy metals and synthetic organics), mercury contaminated sediments and toxicity found in some sediments from Tomales Bay that are unknown. Ammonia toxicity has been discussed in the section on nutrients only because it is frequently determined from the same samples as those collected for nutrient analysis.

3.7.1.1 Bivalve Tissue Concentrations

Tomales Bay has been recognized for many years as one of the most pristine estuaries remaining in the United States. No doubt this is true to some level when compared to most of the estuaries in the country even though the bay has now been listed as impaired. The fact that Tomales Bay has been considered pristine in the past is a mixed blessing in some cases. It is extremely important from an environmental standpoint, but has traditionally been a draw back to obtaining long term funding to establish a baseline of natural fluctuations in a lightly impacted estuary system. Funding organizations often are reluctant to provide funds for long term monitoring because the bay is not polluted and the funds are “needed” to study high visibility estuaries with serious pollution problems. Sporadic data on toxic contamination has been generated primarily because the bay has been and is still being used as a control site. Unfortunately, the data generated from control sampling programs does not provide us with long-term, uninterrupted information on toxic contamination levels in Tomales Bay. The sampling protocols often reflect the needs of programs studying San Francisco Bay or other estuaries and do not address the needs of a Tomales Bay database on potential toxic contaminants.
Figure 3.1 Metal concentrations in mussel tissue (*M. edulis*) from California Mussel Watch Program. Sp=Spring, Fa=Fall, Re=Resident, Tr=Transplant.

Figure 3.2 Selected metal concentrations in mussel tissue (*M. edulis*) from Tomales Bay collect by the California Mussel Watch Program. Sp=Spring, Fa=Fall, Re=Resident, Tr=Transplant.
Figure 3.3 Synthetic organic compounds in mussel tissue (*M. edulis*) from Tomales Bay collected by the California Mussel Watch Program.

Figure 3.4 Metal concentrations in oyster tissue (*C. gigas*) from Tomales Bay collected by the Regional Monitoring Program.
Figure 3.5 Selected metal concentrations in oyster tissue (C. gigas) from Tomales Bay collected by the Regional Monitoring Program.

Figure 3.6 Selected metal concentrations in oyster tissue (C. gigas) from Tomales Bay collected by the Regional Monitoring Program.
Figure 3.7 Butyltin concentrations in oyster tissue (C. gigas) from Tomales Bay collected by the Regional Monitoring Program.

Figure 3.8 Selected metal concentrations in mussel tissue (M. edulis) from Tomales Bay collected by the National Mussel Watch Program.
Figure 3.9  Metal concentrations in mussel tissue (*M. edulis*) from Tomales Bay collected by the National Mussel Watch Program.

Figure 3.10  Synthetic organic concentrations in mussel tissue (*M. edulis*) from Tomales Bay collected by the National Mussel Watch Program.
The best archival data sets that we have on Tomales Bay water column toxic contaminate levels is from the California Mussel Watch Program, the National Mussel Watch Program and the San Francisco Bay Regional Monitoring Program (SFEI). More recently the RWQCB has taken bivalve tissue samples from suspended organism (5 year period) to study uptake of mercury (Whyte, 2002) although the data has not be published. These programs used bivalves as an organism to bioaccumulate contaminants from the water column over time. Both transplanted and resident bivalves have been used as control organisms for toxic uptake studies in other bays. Both heavy metals and anthropogenically produced organic compounds were analyzed in the tissues of the test organisms.

The California Mussel Watch collected trace contaminate levels in the tissue of the mussel *Mytilus edulis* in Tomales Bay from 1980 to 1984. A number of observation were made on levels of some heavy metals observed from mussels collected in or transplanted to Tomales Bay. During the 1979-80 sampling periods mussel transplants had elevated levels of manganese that might be an indication that the mussels contained a substantial amount of sediment in their digestive tracts (Stephenson, 1980). Low trace metal concentrations and little seasonal variation were noted during the 1980-81 period (Stephenson, 1981) although manganese remained elevated (Fig. 3.1). During the 1981 to 1983 period some changes were noted (Ladd, 1984). At the time of this mussel watch
program no significant sources of toxic pollutants had been identified entering the Bay. At the Tomales Bay station (203), resident Bay mussels were sampled. Synthetic organics were analyzed in 1983 and found in low levels as in the past although DDT and PCBs were present in the mussel tissue as were some pesticides (Fig. 3.2). In contrast, concentrations of the trace metals silver and cadmium (Fig. 3.3) were among the highest found in resident Bay mussels from along the California coast (Ladd, 1984). The 1983-84 (Hayes, 1985) period showed arsenic, cadmium, lead and manganese to be elevated (Fig. 3.2) when compared to other metals from Tomales Bay.

The San Francisco Estuary Institute (SFEI) has collected trace element data from oysters (Crassostrea gigas) in Tomales Bay from 1993 through 2000 (SFEI, 2002). Here again, Tomales Bay organisms were used for transplanting to San Francisco Bay. This data shows elevated levels for copper (in most years) and for cadmium during 1994 (Figs. 3.4, 3.5, 3.6). Selenium and cadmium were present at slightly elevated levels throughout the sampling period. Manganese was not sampled in this program. Butyltin was also sampled with TBT and DBT (found in antifouling paint used on boats) found in the oyster tissue at higher levels in 1993 and 1994 (Fig. 3.7).

The National Mussel Watch Program sampled bay mussels (Mytilus edulis) at Spenger’s residence from 1986 through 1998 with the exception of years 1993 and 1996 (NOAA, 2001). This program noted that nickel was elevated and that selenium levels increased over the nine-year period that samples were collected as shown in Figure 3.8 (O'Conner, 1990; O'Conner, 1995). Manganese levels increased during 1995, 1997 and 1998 (Fig. 3.9). Also cadmium and arsenic levels were higher than other trace metals analyzed. Synthetic organic compounds were also sampled with increases in PAHs (which are associated with petroleum products) in 1992, 97 and in 1998 (Fig. 3.10). PCBs and DDT were also found in mussel tissue along with lower levels of Dieldrin (Fig. 3.11).

3.7.2 Mercury Contaminated Sediment
The Gambonini mercury mine was operated from 1964 to 1970 and generated over 300,000 m³ of waste with an average concentration of 320 ng/kg of mercury that was dumped on the slope at the mine site (Whyte, 2000). Approximately 5000 flasks of mercury were extracted from the high-grade cinnabar deposits. In an attempt to reduce mine waste discharge and protect water quality, the mining company constructed a dam 400 meters downstream from the waste pile. By 1990 the dam failed and mass wasting incurred down slope releasing the waste material into an adjacent stream that ran into Walker Creek a major tributary to Tomales Bay (Whyte, 2000). In order to mitigate the mercury transport from the mine site, the USEPA and the San Francisco Regional Water Quality Control Board initiated an emergency Superfund Cleanup in 1998 (Whyte, 2000). Water column samples were collected and analyzed. Total mercury concentrations ranged from 485 to 1,040,000 ng/l grossly exceeding the water quality objective of 12 ng/l. Much of the mercury laden deposits may potentially be stored along Walker Creek and in the salt marsh and the sediments of the Walker Creek Delta while some mercury contaminated sediments may have moved down bay. Studies conducted by Whyte and Ganguli measured mercury concentrations in the Walker Creek delta as high as 13 ppm in 1999. During studies in 2000, 11 sites were sampled in the Walker Creek Delta where
individual samples ranged from 7.6 to 0.06 ppm (Whyte, 2000). Methylmercury concentrations (a highly toxic organic form) were not correlated with high mercury concentrations. Methylmercury concentrations averaged 0.0015 ppm and ranged from 0.0114 to 0.00001 ppm. Much of the data collected during the mercury sediment studies has not been completely analyzed and/or the quality control review has not be completed, thus, this data is not ready for public review at this time (Whyte, 2002).

In addition to the sediment measurement, a number of bay invertebrate tissues were also analyzed for mercury. Resident bivalves (cockles) collected in the sediments of Walker Creek Delta contained up to 0.34-ppm (wet wt.) mercury while cockles harvested at McDonald sampling site (11 km south of Walker Creek) contained only 0.055 ppm mercury (Whyte, 2000). This fact may indicate that the down bay transport of contaminated sediment has not moved quickly. Mercury concentrations in commercial oysters were also measured and ranged from 0.029-0.049 ppm, below FDA action levels. These tissue values compare to the levels reported by the RMP study that also used oysters from Tomales Bay. As Whyte (Whyte, 2000) points out the oysters are feeding out of the water column and have lower levels than mollusks (cockles and mud snails) that are in direct contact with the contaminated sediment. In addition to mollusc tissue, the burrowing ghost shrimp (*Callianassa californiensis*) was also sampled and contained relatively high mercury levels (0.39-0.45 ppm). Shore crabs (*Pachygrapsus crassipes*) from the Walker Creek Delta area had 6 times more mercury than shore crabs from McDonald. An early study in 1973 (Swanson, 1973) of mercury accumulation in the purple shore crab (*Hemigrapsus nudus*) measured mercury levels in the near shore water column just North of the mouth of Tomales Bay and found mean levels of 0.24 ppb. These values most likely reflect the natural background levels in Bodega Bay at that time.

The ten most commonly caught and consumed fish species from Tomales Bay were collected and the tissue analyzed for mercury (Whyte, 2000). Mean mercury concentrations were highest in brown smooth hound sharks (1.31 ppm wet wt.) and leopard sharks (1.09 ppm), followed by bat rays (0.56 ppm), angel sharks (0.43) with lower levels in halibut, redtail surf perch, shiner surf perch and jack smelt. These results instigated an interim public health advisory for sport fish from Tomales Bay (MCDHHS, 2000). The advisory recommendations included not eating leopard and brown smooth hound sharks and limited consumption of surfperch, halibut, pacific angel sharks and bat rays. Because many of these fish species do move around and some leave the bay for undetermined time periods it is more difficult to directly relate the mercury concentrations in Tomales Bay sediments with the tissue burden of these fish species without more research. These types of advisories often raise public concerns and also result in added questions about the findings (Baty, 2000).

A study of mercury and selenium in diving ducks from the San Francisco Bay region used Tomales Bay as a reference site (Hoffman, 1998). Both the greater scaup and surf scoters collected from the site were found to have elevated hepatic mercury concentrations. These differences correspond to higher mercury levels found in sediments from Tomales Bay than from sites in San Pablo Bay near Suisun Bay ((Long, 1990). Both species of ducks feed on shellfish and crabs and migrate from more northern...
locations to over winter along the west coast (Udvardy, S. Rayfield 1984). While the authors indicate that the higher mercury concentration in Tomales Bay sediments may play a role in the elevated hepatic levels in the ducks studied, direct connection is difficult with these migratory duck species since part of their time is spent feeding in other areas that could have mercury in bivalves or sediment. Also information is lacking on the pathway of mercury through the food web that the ducks are using.

3.7.3 Unknown Source of Sediment Toxicity
Toxicity tests were conducted on homogenized Tomales Bay sediments collected at Marconi Cove (Hunt, 1998). This site was selected as a reference for evaluating the toxicity of San Francisco Bay sediments. Survival of the amphipod *Eohaustorius* was found to be poor when the Tomales Bay sediments were tested. The Tomales Bay site had the highest percentage of clay particles, among the reference sites used in the study, with greater than 69% of the sample mass composed of particles less than 4 \( \mu m \). In a comparative study between San Francisco Bay and Tomales Bay sediments several of the test endpoints for three samples from Tomales Bay were among the most toxic (Long, 1990). The samples were collected from a boat using a 0.1 m\(^2\) Young grab sampler with the upper 1 cm taken from the surface of 6 to 10 samples at each station. The location of the Tomales Bay samples were near 38°09'02"N, 122°53'55"W which was located in the vicinity of the Marshall Boat Works and close to the TB-WC-mid station sampled by Whyte (Whyte, 2000). Several of the endpoints used in the toxicity tests, for example, the mussel *M. edulis* and echinoderm *S. purpuratus* showed abnormal development and the survival of the amphipod *R. abronius* was below control values. As the authors state these results are not easily explained. The concentrations of chromium and nickel in two of the samples were elevated somewhat relative to the other sites in the study. The other chemicals analyzed in the Tomales Bay samples were not elevated. Benthic samples collected synoptically with the sediments tested were dominated by hardy polychaetes and mollusks with an absence of more sensitive crustaceans that might indicate some level of toxicity. Using a model (DeWitt, 1988) for interpreting the results of measuring *R. abronius* survival in uncontaminated fine-grained sediments did not account entirely for the toxicity observed. Based on the outcome of these two studies the cause of the relatively inhospitable sediment from parts of Tomales Bay remains unsolved and is due to some unknown factor(s) (Long, 1990). Based upon these results and reference sites identified within San Francisco Bay the use of remote reference sites like Tomales Bay has diminished (Hunt, 1998).

3.7.4 Status of Toxic Contamination

3.7.4.1 Trace Elements and Synthetic Organics in Bivalve Tissue
Unfortunately, the bivalve tissue data is not continuous, with wide gaps and few water column measurements to relate to the uptake values found in the tissue samples. Data collection in Tomales Bay has been reduced as the bay is less frequently used as a reference site for studies in San Francisco Bay. More recently the RWQCB has deployed bagged bivalves for 5 years as part of the mercury studies. At the present time there is very little data being gathered on trace element and synthetic organic compounds in sediments or in the water column in the Tomales Bay with the exception of mercury.
This archival data is presented as the best available background information we have on trace element levels and synthetic organics from the water column. The data presented here was not adjusted against controls nor were bioconcentration factors (BCF) calculated for the bivalve tissue. Also measurement levels are reported in parts per million (ug/g, mg/kg) and in part per billion (ng/g). No attempt was made to normalize the data so that figures represent the levels reported by the various agencies producing the data. Thus caution should be taken when comparing the figures. It is also inappropriate to compare concentrations of some elements between species. Tests were conducted by the National Mussel Watch program (O'Conner, 1995) at one site in Long Island Sound to investigate the uptake by two different species. The results indicate that, despite being exposed to the same environment, the species, mussels (Mytilus edulis) and oysters (Crassostrea virginica) do not accumulate all chemicals to the same extent. For example, concentrations of copper, zinc, and silver were more than 10 times higher in oysters than in mussels, while the concentrations for chromium and lead were threefold higher in mussels. Therefore it is important to use the same species if annual comparisons are going to be made to establish trends in the bioconcentration of trace elements and synthetic organics.

In most cases no attempt was made to compare the levels of trace elements and synthetic organic compounds to past or current thresholds promulgated by regulatory agencies since most of the data is archival and not current. Some comparisons were made between recorded levels of contaminants from Tomales Bay and other sites along the west coast to provide some insight on the relative height of the tissue burden of native and transplanted bivalves. However, care must be taken in comparing levels from studies that were many years apart in sampling periods. Mercury, cadmium, chromium, silver, nickel and manganese were noted to be elevated between studies or had reached high levels when compared to other reference sites. Mercury in transplanted and resident mussels (M. edulis) tissue during the 1985-86 studies from Tomales Bay had levels of 0.3 ppm (Hayes, 1987) which is similar or slightly higher than levels found in some parts of San Francisco Bay (Mare Island, Treasure Island, Oakland inner harbor, San Mateo Bridge). When compared to 53 other stations sampled along the west coast Tomales Bay ranked 9th highest for mercury in mussel tissue (NOAA, 1986).

In a recent study mercury levels recorded at designated “hot spots” in Humboldt Bay (mercury was not the chemical of concern) were within (0.0.07-0.155 ppm) the range found by the National Mussel Watch (O'Conner, 1995) tissue levels in Tomales Bay (0.02 ppm for 1998) as was Bodega Harbor at 0.127 ppm (Jacobi, 1998). Mercury levels in Tomales Bay oysters (Fig. 3.5) were low (0.23 ppm) in 1998 (SFEI, 2002). Cadmium concentrations in transplanted and resident mussel tissue (1985-86) showed that, at 5.5, ppm Tomales Bay had similar or slightly elevated levels to some stations in San Francisco Bay (Mare Island, Point Pinole, Treasure Island, Oakland back harbor). Tomales Bay ranked 12th highest in cadmium out of the 53 west coast sites studied by the National Status and Trend program (NS&T) (NOAA, 1986). Again Tomales Bay levels (0.0237 ppm) were slightly lower than those found in Humboldt Bay (0.09-0.157 ppm) and much lower than Bodega Harbor (0.960 ppm). Cadmium levels in Tomales Bay
oysters were much higher with concentrations reaching a level of 50 ppm in 1994 and then dropping to 5.7 ppm in 1999 (SFEI, 2002). The National Mussel Watch Program noted that nickel (Fig. 3.8) was elevated in Tomales Bay and reached a high of 0.84 ppm in 1997 (NOAA, 2001). At this level Tomales Bay tissue concentrations are well below those found in Humboldt Bay (126-167 ppm) or Bodega Harbor (71 ppm). Using the information on chronic shellfish consumption and typical levels of nickel in shellfish, it is possible to estimate nickel intake on a chronic basis for consumers of shellfish (FDA, 1993). Assuming that mean nickel levels in tissue range from 0.6 µg/g (ppm) to 0.9 µg/g for molluscan shellfish (Tomales Bay levels in oysters range from 2.0 to 0.29 ppm), consumer exposures (molluscan eaters-only) would be 7 µg/person/day. Selenium was measured in tissue from mussels in Tomales Bay (Fig. 3.1) by the California Mussel Watch over three years (1979-80, 1980-81, 1983-84). This small data set does not provide a strong database for analysis. Recent data (1998) from the National Mussel Watch recorded selenium levels at 0.6 ppm for tissue from Tomales Bay (Fig. 3.8) while levels in San Francisco Bay reached 5.5 ppm at some stations. In comparison to Humboldt Bay where tissue concentrations in mussels ranged from 0.2 to 0.45 ppm, Tomales Bay levels were only slightly higher. Manganese was noted to be higher than other metals in both mussel watch programs in Tomales Bay. Levels reached 13 ppm in 1997 in mussel tissue (NOAA, 2001). Early levels reached 28 ppm in Tomales Bay mussel tissue (Fig. 3.1) during the 1980s (Stephenson, 1980; Stephenson, 1981). These levels are well below those recorded from Humboldt Bay where tissue concentrations in mussels reached 323-770 ppm (Jacobi, 1998). Synthetic organic compounds in Tomales Bay were generally low. However, in 1994 tributyltin levels reached over 100 ppm in oyster tissue (Fig. 3.7) that was well above the USEPA screening guidelines for human consumption of shellfish (2.1 ppm) (USEPA, 1998).

3.7.4.2 Mercury in Sediments
Studies on the mercury concentration in bay sediments and in selected organisms are still under way by the staff of the Regional Water Quality Control Board. The board has just recently awarded a grant for studies on the water circulation and sediment movement in the Walker Creek Delta to better understand sediment transport characteristics in Tomales Bay.

3.7.4.3 Unknown Source of Potentially Toxic Sediments
At this time there does not seem to be any follow up studies being conducted on the toxic sediments found in some sections of Tomales Bay. It is still not clear what caused the toxic response to bioassay organisms when exposed to some bay sediment. Sediment size class, unmeasured chemicals and/or other sediment conditions could play a role in the response of the test organisms.

3.7.5 Trends in Toxic Contamination

3.7.5.1 Trace Elements and Synthetic Organic Compounds.
Transplanted and resident bivalves are valuable in the assessment of long-term trends because they provide an integrated measure of contamination over a three month period (normal transplant time) or longer for resident samples. This interval is more appropriate
for the assessment of interannual trends than the one-hour representation of a water
column grab sample or the longer-term sediment accumulation period (20+ years).
However, because of time and funding constraints and mixed data sets no trend analysis
or formal evaluation of the data was conducted for this narrative. Some general
statements can be made as to visual trends taken from the figures presented in this
section. Mercury levels have remained low both in oyster and mussel tissue collected
from Tomales Bay in all the years sampled. Cadmium levels were elevated in 1994 in
oysters and then have steadily declined through 2000 (Fig. 3.6). The same trend can be
seen in cadmium levels in mussel tissue (Fig. 3.2). Nickel increased in mussel tissue in
1997 while declining in 1998. Nickel in oysters has remained low during the more recent
sampling periods. Copper levels in oysters have declined from 1997 to 2000 (Fig. 3.4).
Figure (3.9) for trace elements indicate that manganese has increased in recent years in
mussel tissue. These elevated levels may reflect increased sediment loads coming from
old mining operations or maybe a byproduct of sediment movement out of the watershed
in general. Manganese in not particularly toxic to aquatic life and is slowly precipitated
as a dioxide as it reacts with dissolved oxygen. The synthetic organics are low in bivalve
tissue from Tomales Bay, however, the fact that PCBs, DDT and dieldrin have been
recorded indicates that they are present in the watershed. PAH has increased in recent
years to a high in 1998 (Fig. 3.10). This fact might suggest that boat traffic has increased
with more petroleum products entering the bay. The butyltin products have declined
from a high in 1994 to very low levels in 1998. This fact may indicate that the removal
of this compound from antifouling paints has reduced available levels for
bioaccumulation.

Metal and synthetic organic contaminants in bivalve tissue still generally remain low.
However, at various points in time, levels have been high when compared to other west
coast regions. The fact that these contaminants can bioaccumulate in Tomales Bay
bivalve tissue is a strong argument for continued measurements.

4.0 Sediment Loading in Tomales Bay
It is beyond the scope of this water quality narrative to address sediment loading from
tributary streams into Tomales Bay this issue is covered in another section of the main
report. But some discussion is warranted because sediment is often a carrier of toxic
chemicals, coliform bacteria and nutrients. Sedimentation is rapidly occurring in
Tomales Bay. Comparisons were made between 1861 and 1957 using hydrographic
charts with corrections made for changing sea levels (Rooney, 1999). These calculations
showed a bay wide average infilling rate of 5mm/yr. This is equivalent to a watershed
erosion rate of approximately 80,000 tons per year. The largest sediment influx seems to
have occurred between about 1930 and 1960. The physical filling of the bay reduces the
water volume, alters circulation patterns, changes nutrient levels, effects benthic
communities and estuary habitat in general, and it also can effect the contaminate load in
the bay. As discussed in 3.7 above, mercury attached to fine particles has and most likely
will continues to move into Tomales Bay. Phosphate and coliform bacteria can be
attached to particles and also be transported and deposited into bay sediment. Re-
suspension can occur during high winds and winter runoff, thus exposing the system to
new pulses of contamimates.
5.0 Data Gaps
The recommendations in this section are intended to identify gaps in information and suggest methods and studies to fill these gaps. These recommendations are not to be confused with a Plan of Action. Because the TMDL process will be driving a number of studies related to designated contaminants it will be important to collect the necessary information to select thresholds that are protective to beneficial uses but not prohibitive to legitimate uses of the bay and watershed. The TMDL analysis can be divided into four components: source analysis, loading capacity estimates, development of numeric targets and load allocations. Some indications of data needs can be addressed by describing the Total Maximum Daily Load as: $\text{TMDL} = \Sigma \text{WLAs} + \Sigma \text{Las} + \text{NB}$ Where: $\Sigma$= the sum, WLAs= waste load allocations, Las= load allocation and NB= Natural Background. The data gaps outlined in this narrative address information that is simply missing, information needed for the TMDL process, or data that, if collected, could provide a better understanding of the bay and watershed. Some of the recommendations are based on input from agency reports (Taberski, 2000; Lewis, 2001; Workplan, 2001), research studies and observations based on this review.

5.1 Watershed and Bay Wide Monitoring
In order to establish a baseline of present conditions in Tomales Bay and tributaries a monitoring plan should be designed to follow important parameters through time. Based upon existing data stations could be selected to monitor temporal and spatial changes in the bay. Water flow from the tributaries along with water quality parameters would provide important information on watershed changes. This program could include measurement for nutrients, salinity, temperature, suspended solids, suspended particulate matter, dissolved oxygen, light penetration and chlorophyll concentrations. With new techniques many of these parameters can be measured directly with an automated CTD instrument package. These basic elements of water quality define the suitability of the bay as a habitat for marine life and for the support of aquaculture.

5.2 Site Specific Recommendations
The RWQC has developed recommendations for study and monitoring programs (SWAMP) for Walker Creek and Lagunites Creek drainages (Workplan, 2001). There is some overlap to the more general data gaps and program design recommendations made in sections 5.0 and 5.3 of this report.

- Develop a monitoring program to study nutrient, pathogens and sediment movement in Keys, Chileno, Arroyo Sausal, Salmon, and Walker Creek to evaluate the effects of grazing.
- Develop a monitoring program for pathogens and nutrients at Laguna Lake to determine the input from the headwaters of Chileno Creek.
- Develop a monitoring program for pathogens and nutrients below the town of Tomales to evaluate the septic system leaks into Keys Creek.
• Develop a monitoring program to evaluate the impact of flow, temperature, dissolved oxygen and sediment on the salmonid fishery below Soulejoule Reservoir.
• Design a sampling program above Peters Dam to establish reference conditions in a protected upper watershed for flow, temperature, dissolved oxygen, and biological indicators.
• Develop a monitoring program to evaluate water quality (DO, temperature and sediment) in Lagunitas Creek below Peters Dam, in Nicasio Creek below Seeger Dam and San Geronimo and Olema Creeks.
• Develop a monitoring program for sediment deposition up and downstream from the confluence of Lagunitas and San Geronimo Creeks to evaluate erosion control programs.
• Monitor for pathogens and nutrients from septic tank leaks along San Geronimo Creek.
• Conduct nutrient and pesticide testing below the golf courses on Bon Tempe Lake and on San Geronimo Creek.

5.3 Role of Watershed Management Group(s)
As the watershed and bay programs develop and expand there are critical roles that Tomales Bay organizations must play if an ecosystem wide approach is to work and if identified problems are to be solved. Organizations can:
• An organization should serve as a repository for data, publications, reports and information on Tomales Bay for the general public, researchers, educators, and regulatory agencies. A web site and a well-organized library could disseminate this information.
• Assist in the TMDL process by providing a forum for stakeholders, the public, regulatory agencies and research groups to interact and come to consensus on threshold levels and action plans.
• Support and encourage needed studies by agencies, research groups and others in Tomales Bay and tributaries. Augment these efforts and monitoring programs by assistance from a well-organized and well-trained volunteer group.
• Encourage interaction between stakeholders and provide a neutral forum to help resolve conflicts between diverse uses of the bay and watershed. Highlight programs that offer solutions to stakeholder issues to encourage long-term comment to work on watershed and bay problems.
• Support, by educational outreach, the importance of Tomales Bay resources and the issues that impact the ecosystem. Develop methods to educate the public, agriculture, aquaculture, media, schools, local communities and visitors about the importance of a balanced system and how fragile the bay and watershed really is.
• Provide and support the biannual State of the Bay Conference as a means to keep the public, research groups, environmental organizations, regulatory agencies, shellfish growers, and agricultural interests informed about what the important issues are in the bay and watershed.
• Play an advocacy role in supporting programs, regulatory actions or administrative recommendations that protect the bay and watershed without adversely impacting other uses.

• Support honest action by groups that want to reduce the impact of their operations on the watershed and bay through learning and applying the best management techniques available.

6.0 New Programs and Studies
A number of studies on Tomales Bay and tributaries that are just beginning or are in the scheduled stage for action this year have come to light during this review.

• The USEPA has awarded a four-year grant to the Bodega Marine Station, UCD and UCSB to develop a suite of ecological indicators to rapidly assess the integrity and sustainability of wetlands in West Coast estuaries. The Walker Creek Delta area of Tomales Bay has been selected by the team for study because of the mercury contaminated sediment. Tom’s Point has been selected as a reference site. A wide range of parameters will be investigated (although all of them may not be applied at each site) including physiochemical monitoring, biological monitoring, toxicity biomarkers and statistical analysis and modeling. Indicators are now being evaluated and final stations in Tomales Bay are being selected.

• The RWQCB has a contract with Mark Stacy and Ed Gross of UCB to study sediment transport, bay circulation and historical levels of mercury in deep sediment in the Walker Creek Delta. The project will study mercury contaminated sediment movement in the delta and Tomales Bay.

• A study is proposed by the RWQCB for this spring to investigate natural levels of mercury in sediments coming from the Lagunitas watershed.
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