Work Plans for Estimating Non-Brake Releases of Copper In the San Francisco Bay Area Watershed

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1 Introduction

Many human activities result in the release of copper to the environment. The work plans described in this document will be used to estimate releases of copper (including the copper in copper compounds) from non-brake sources in the San Francisco Bay area. The magnitude of these releases must be understood before their potential impact on ambient copper levels can be determined.

This report contains separate work plans for the following categories of releases of copper:

- architectural copper
- copper in pesticides
- copper in fertilizer
- copper releases from industrial operations (including releases in runoff)
- copper in domestic water discharged to storm drains

These categories of releases are taken from “Copper Sources in Urban Runoff and Shoreline Activities” (hereafter referred to as the urban runoff report) prepared by TDC Environmental for the Clean Estuary Partnership in November of 2004. Work plans for sources estimated to contribute less than one thousand pounds of copper per year in urban runoff (those from fuel combustion, wood burning, and vehicle fluid leaks) will not be developed. Also, copper released from soil erosion is calculated by the runoff model and will not be estimated. A work plan for estimating copper releases from fertilizer use will be developed.

In many cases, approaches for estimating releases that are described in the urban runoff report will be adopted.

2 Work Plans for Individual Categories of Releases

Some of the ideas presented in these work plans apply to all or most of the release categories. These commonalities are presented in this section.

Multimedia Estimates

Multimedia emission estimates of copper will be presented, so that releases to land, water, and air will be identified. When releases to land occur, an attempt will also be made to quantify the portion of releases that fall on impervious surfaces as opposed to pervious surfaces. Direct releases to storm drains and to surface waters will be provided as point sources for the purposes of modeling, rather than as releases to pervious or impervious surfaces. Releases will be estimated for the more than 20 sub-watersheds that lie within the greater Bay watershed; this will provide the best possible inputs for the runoff model.

Study Area

Releases in the San Francisco Bay area watershed, pictured in Figure 1, will be estimated. The values in the legend for this figure are expressed in people per square mile. The sub-watersheds in the study are outlined in red and county boundaries appear in black. Note that some county lines are drawn along divides. Also note that single-family housing tracts have a population density on the order of 10,000 people per square mile, and they appear as one of the two darkest colors in this map. This figure shows that a substantial portion of the study area has a population density of less than 80 people per square mile.

Figure 2 is an aerial photograph of a portion of the watershed, again with the watershed boundaries overlaid in red. Urban areas are white in this photograph.

General Methodology

Information that can be used to estimate releases is almost without exception available for areas bordered by political boundaries as opposed to physical ones such as watersheds. Data for estimating emissions will be gathered with the highest geographic resolution possible. For some categories of releases, the data will be county-based; for others, they will be state- or nationally-based. Emissions for the portion of the county (or state or country) within the watershed will then be parceled out based on population, land use, or some other appropriate factor.

Population counts and other weighting factors such as land use areas will be provided by the Bay modeling team for each sub-watershed area by county, for the counties, and for the state. Tables 1a through 1g include some of the data that will be needed to estimate releases by sub-watershed.

A number of assumptions will be made in order to conduct the inventories of copper releases described in these work plans. These assumptions will be clearly stated during execution of the work plans. In cases where there is more than one source of data for a given value, the value judged to be superior in terms of factors including peer-review of the reference, geography, sample size, and timeliness will be used. If several values are available in different references that are determined to be of equal quality, a value that is representative of all of them will be chosen.

Standard uncertainties will be estimated for each of the values obtained, following the strategies outlined by the National Institute of Standards and Technology (NIST, 2005). In a few cases, a standard deviation will be calculated and used as the standard uncertainty. However, in most cases, it will be possible to determine only a potential range of possible values for a given variable, where the true value is equally likely to be anywhere in the range (a uniform distribution). In these cases, the point value will be calculated to be the midpoint of the range and the standard uncertainty will be estimated as being equal to half of the range divided by the square root of three. This is a means of estimating the standard deviation of a uniform distribution.

Developing a standard uncertainty for each variable will be onerous, but it is necessary so that the uncertainties in each intermediate value can be combined in order to develop a sense for the standard uncertainty in the final calculated results. One way to estimate the standard uncertainty in a value that is calculated using the function $f(x_1, x_2, \ldots, x_n)$ is to apply the Kline-McClintock equation to that function. The Kline-McClintock equation is the first term in the Taylor series approximation for the propagation of uncertainty and can be used when variables are not co-related. It is

$$u_R = \sqrt{\left(u_1 \frac{\partial f}{\partial x_1}\right)^2 + \left(u_2 \frac{\partial f}{\partial x_2}\right)^2 + \cdots + \left(u_n \frac{\partial f}{\partial x_n}\right)^2},$$

where u is uncertainty, R is the resulting value, and n is the number of variables in the function. The Kline-McClintock equation will be used to estimate the uncertainty in calculated results for this project.

Standard uncertainties are also useful in that they can be used to provide a range of values that apply to a desired confidence interval. If a 95% confidence interval is desired, that means that it is desired that the range of values provided for the final result are 95% likely to contain the true (actual) value. This 95% confidence interval would be described as a point value plus or minus two times the standard uncertainty for that value. A 67% confidence interval is one that includes the point value plus or minus the standard uncertainty. (This assumes that the probability distribution characterized by a function's result and its standard uncertainty is approximately normal, and the uncertainty result is a reliable estimate of the standard deviation of the result.)

2.1 Architectural Copper

This category of releases will be estimated using the approach taken in the urban runoff report. Using this methodology, the surface area of copper roofs, composite shingles containing copper biocide, and copper gutters is calculated and then multiplied by factors that identify the amount of copper released per unit of surface area for each type of material.

Roofing is estimated to occupy 30% of residential land use and 50% of other developed land (Barron, 2001). Copper roofs are used in 0.05% of residences and 0.3% of industrial buildings (Barron, 2001). It is estimated that 0.03% of residential roofs are covered in composite shingles treated with copper biocide (Barron, 2001). Additionally, copper gutters are used on 0.06% of residences and 0.3% of industrial buildings (Barron, 2001). The estimated surface area of gutters is 3.25% of roof area (Barron, 2001).

The uncertainty in these values is judgment-based. The standard uncertainty in surface areas devoted to each type of land use will be assumed to be 10% of the land use area and the standard uncertainty in the fraction of surface area taken by each type of architectural feature will be assumed to be 50% of the fraction.

The loss of copper in runoff from architectural fixtures decreases with increasing rainfall pH until the pH reaches a level of 4.8, where further increases in pH have no effect on the loss rate (CDA, 2003). Another strong influence on copper runoff rates from architectural features is the atmospheric concentration of chloride ions. The copper in runoff is higher in marine environments where chloride concentrations are high both because the corrosion rate is faster and because the dominant corrosion products are more soluble in water than the corrosion products found in inland areas (He et al, 2001). Similarly, the copper in runoff from architectural features is higher in urban areas than in rural areas because pollutants in urban areas increase the rate of corrosion (Wallinder and Leygraf, 2001). Finally, copper in runoff from architectural features increases as annual precipitation increases.

Figure 3 shows that the Bay area has elevated atmospheric chloride concentrations. Also, most of the copper roofs in the Bay area are found in urbanized areas. However, the pH of rainfall in the Bay area is generally higher than 6 and the precipitation rate is low (35 cm/yr).

For this inventory of releases, the copper emission factor selected for copper roofs is 1.8 g/m^2/yr. This factor is based on the concentration of copper in runoff from a roof exposed to marine conditions (He et al, 2001) and the rainfall rate in the Bay area. The potential range of release rates will be assumed to be 1.0 to 2.6 g/m^2/yr. The standard uncertainty in this value is half of the range divided by the square root of three, or 0.5 g/m^2/yr.

The copper emission factor selected for composite shingles with copper biocide is 0.2 g/m^2/yr. This is based on field tests of seven rainfall events in Palo Alto (Barron, 2001). The standard uncertainty in this value is the standard deviation of the average values for the seven rainfall events and is 0.1 g/m^2/yr.

A rate of 4 g/m^2/yr for copper released in runoff from copper gutters was estimated based on a study of gutters of varying ages in the Palo Alto area in the late 1990s (Uribe and

Associates, 1999). This will be the point value for estimating copper runoff in copper gutters. Note that it is larger than the precipitation-adjusted copper release rates found in copper gutters in Switzerland (Zobrist et al, 2000), where chloride concentrations are low. It will be assumed that the actual value for the release rates has a 100% likelihood of falling between 2 and 6 g/m^2/yr, so that the standard uncertainty is 1 g/m^2/yr.

The surface area of each watershed that is devoted to residential and industrial/commercial structures will be required in order to make these calculations.

It will be assumed that all of the releases of architectural copper are released directly to runoff, even for residential applications. They will be estimated as a point source for the purposes of modeling because they are almost always hard-piped to storm drains.

The details for calculating architectural copper releases from residences will be shown here in order to give a clear understanding of the methodology.

First of all, the releases of architectural copper from residences is going to be the sum of the releases from copper roofs, copper gutters, and copper biocide in composite shingles. These are equal to the surface area of those features in residential areas multiplied by the emission factor for that type of feature, or

$$Q_{\text{res, arch Cu}} = A_{\text{res Cu roof}}\text{EF}_{\text{roof}} + A_{\text{res Cu gutt}}\text{EF}_{\text{gutt}} + A_{\text{res Cu comp}}\text{EF}_{\text{comp}}$$

Here, EF is emission factor and A is surface area.

The surface area of copper roofs in residential areas is equal to the surface area of residential areas multiplied by the fraction of residential areas that is covered by roofs, multiplied by the fraction of residential roofs that are copper.

$$A_{\text{res Cu roof}} = A_{\text{res}}F_{\text{res roof}}F_{\text{res Cu roof}}$$

The surface area of copper gutters in residential areas is the surface area of residential areas multiplied by the fraction of residential areas that is covered by roofs, multiplied by the fraction of roof area that gutters comprise, multiplied by the fraction of gutters that are copper:

$$A_{\text{res Cu gutt}} = A_{\text{res}}F_{\text{res roof}}F_{\text{roof gutt}}F_{\text{res Cu gutt}}$$

Finally, the surface area of composite shingles that contain copper biocides in residential areas is

$$A_{\text{res Cu comp}} = A_{\text{res}}F_{\text{res roof}}F_{\text{res Cu comp}}$$

Substituting values gives

$$\begin{aligned} Q_{\text{res, arch Cu}} &= 0.3A_{\text{res}}\left(\left(0.0005\right)\left(\frac{1.8\text{ g}}{\text{m}^2}\right) + \left(0.0006\right)\left(0.0325\right)\left(\frac{4\text{ g}}{\text{m}^2}\right) + \left(0.0003\right)\left(\frac{0.17\text{ g}}{\text{m}^2}\right)\right) \\ &= \left(\frac{0.0003\text{ g}}{\text{m}^2}\right)A_{\text{res}} \end{aligned}$$

Similarly, copper releases from architectural copper used on industrial structures is

$$
\begin{aligned}
Q_{\text{ind, arch Cu}} &= 0.5A_{\text{ind}}\left((0.003)\left(\frac{2\text{ g}}{\text{m}^2}\right)+(0.003)(0.0325)\left(\frac{4\text{ g}}{\text{m}^2}\right)\right)\\
&= \left(\frac{0.003\text{ g}}{\text{m}^2}\right)A_{\text{ind}}
\end{aligned}
$$

Releases of copper from architectural copper to storm drains are

$$
\begin{aligned}
Q_{\text{imp, arch Cu}} &= Q_{\text{res, arch Cu}} + Q_{\text{ind, arch Cu}}\\
&= \left(\frac{0.0003\text{ g}}{\text{m}^2}\right)A_{\text{res}} + \left(\frac{0.003\text{ g}}{\text{m}^2}\right)A_{\text{ind}}
\end{aligned}
$$

The uncertainty in these estimates depends on the uncertainty in the value for the surface area of each type of land use, the uncertainty in the fraction of surface area taken by each type of architectural feature (copper roofs, copper gutters, and composite shingles with copper biocide), and the uncertainty in the emission factors.

2.2 Copper in Pesticides

Pesticide use reports are available statewide (CA DPR, 2005a) and by county (CA DPR, not dated, various counties) and pesticide sales are available statewide (CA DPR, 2005b). Data in these reports are generally given in terms of active ingredient.

In the pesticide sales reports, sales are disclosed only for pesticides that have 3 or more registrants. Eight copper-based pesticides in California have reported use with no reported sales. The sales for these pesticides can be estimated either based on their sales history or based on their labeling information, coupled with information on usage. Unfortunately, sales of some retail products sold at “big box” stores are inadequately disclosed (CA DPR, 2004). These stores dominate sales of pesticides to consumers. Estimated consumer sales will be adjusted upwards by a factor of 20% in order to correct for unreported sales (Brank, 2005). This will be taken as the midpoint of a range from 0-40%. The standard uncertainty in this correction factor is 10%.

Use is also known to be under-reported. Reported uses will be adjusted upwards by 10% of reported usage to correct for under-reporting. This correction factor is taken from a study by the California Department of Pesticide Regulation, where it was found that about 90% of the sales were reported used over a five-year period for a group of pesticides whose usage was required to be entirely reported (Wilhoit, 2005). For calculating the standard uncertainty, it will be assumed that 67% of pesticides fall within a range of 80-100% fully reported, so that the standard uncertainty in the correction factor is 10%.

Note that all currently registered copper-based pesticide products appear in the California use and/or sales reports.

Pesticide use reporting applies to agricultural use and to use by licensed professional pesticide applicators. The difference between sales and use can be assumed to include everything else, including the amount of active ingredient applied by commercial, institutional, and household consumers. There are a few cases where usage is known to be un-reported and in these cases a usage estimate will be developed.

2.2a Pesticides Applied to Land in Urban Areas

This approach assumes copper-based pesticides sold in California that are not used in agriculture, for pressure treating wood, as algaecides, as antifouling coatings, or as root killer are applied to land in urban areas. It is assumed that adjusted reported uses in agriculture and pressure treated wood are adequate estimates of those uses. Algaecide and antifouling coating uses as well as root killer uses are not necessarily required to be reported and must be estimated.

A statewide estimate of cuprous oxide use in antifouling paints for boats can be made by assuming that any unreported uses of cuprous oxide are used in antifouling coatings (paints). Adjusted reported sales of this pesticide in California were 1,800,000 lb copper in 2003, while adjusted reported use on boats and piers is approximately 6,100 lb Cu/yr. Other adjusted reported uses of this active ingredient, most of which are agricultural, totaled 310,000 lb copper. Thus, use of cuprous oxide in antifouling coatings on boats and piers will be estimated to be 1,500,000 lb Cu, which is 240 times larger than adjusted reported use.

Sales are not reported for cuprous thiocyanate because there is only one registrant. In order to estimate use of this active ingredient, it will be assumed that the use of cuprous thiocyanate as an antifouling coating is reported at the same rate as use of cuprous oxide as an antifouling coating. Adjusted reported statewide use of cuprous thiocyanate for boats and piers was 6.5 lb copper in 2003. Multiplying this value by 240 yields an estimate of 1,500 lb Cu/yr.

Copper hydroxide is registered for antifoulant paint use, but is used for that purpose in only two products where it is present in small quantities (TDC, 2004). Therefore, its use as a marine antifouling coating will be neglected.

The reported uses of the six copper pesticides that are applied to water along with reported uses that preclude algaecide applications can be used to arrive at statewide estimates of the amount of these pesticides that are used as algaecides. These six pesticides are copper, copper carbonate (basic), copper ethanolamine complexes (mixed), copper ethylenediamine complex, copper sulfate (pentahydrate), and copper triethanolamine complex. Many uses of these pesticides are not reported, and some of the uses are reported in categories that may or may not be algaecide applications. Thus, the fraction of each pesticide used as an algaecide can only be found in terms of a fairly wide range.

Table 2 shows this range, along with the estimated statewide use of these compounds as algaecides and their adjusted reported uses to water. Footnotes for Table 2 explain calculations for each column that is not taken directly from adjusted reported use values. For the purposes of estimating releases of copper-based pesticides to urban land, only the column titled “Estimated Use as Algaecide” is used. The uncertainty in these values is large, mostly because the range of possible use as algaecide is large. It is calculated based on the standard uncertainty in the fraction of pesticide used as algaecide as well as the standard uncertainty in sales.

Finally, the use of copper in copper sulfate (pentahydrate) as a root killer must be estimated. The sale of root killer products containing this compound have been banned in the nine counties surrounding the bays but are still allowed in the remainder of California. Use of these products as root killer can be estimated by using the reduction in sewered copper in Palo Alto after the ban on sales of root killer products containing this product was instituted. A reduction of 370 lb of copper per year was observed for a population base of 226,300 (Moran, 2005). The population of California outside of the nine-county Bay area is 26,637,987, so the statewide estimated use of copper for root control in products containing copper sulfate (pentahydrate) is 44,000 lb Cu/yr.

Table 3 shows the statewide values for reported sales and use of copper-containing pesticides. The second-to-the-last column in this table represents estimated copper in copper pesticides applied to urban land. The ratio of population in each sub-watershed to total state population will be applied to this column in order to determine the portion of copper in unreported copper pesticides that is used in urban areas in the sub-watershed.

It should be noted that uses of copper for structural pest control are included in the urban land use estimate. Statewide, adjusted reported use of copper in copper pesticides for structural pest control was 4,700 lb in 2003. These uses are included with the urban land estimate because it is expected that they would behave much more like landscaping uses than uses of copper in treated lumber.

There is uncertainty inherent in using pesticide sales and use data, not only because of errors in reporting and data management, but because reported sales and reported uses do not always occur during the same year. In order to account for this uncertainty, it will be assumed that 67% of the products are 80-100% matched in terms of sales and usage each year. For this category of uncertainty, this results in a standard uncertainty of 10% of sales. Uncertainty in the estimated statewide use of antifouling paints, treated lumber, and root killer is insignificant compared to the uncertainty in adjusted sales, agricultural uses, and (especially) algaecide uses and are not included in the calculated standard uncertainty for urban land uses. Because of the way antifouling coating use is estimated, the uncertainty in urban land applications of cuprous oxide and cuprous thiocyanate is based on the uncertainty in total adjusted reported usage, adjusted reported agricultural usage, and adjusted reported usage on boats/piers. The final column of Table 3 gives the standard uncertainty for urban land applications of copper in copper based pesticides.

2.2b Agricultural Applications

The next step in estimating copper releases from copper-containing pesticides in the watershed is to estimate agricultural applications of copper pesticides within each sub-watershed. Copper use reports for the eight counties in the watershed will be used. Adjusted usage values (excluding use as algaecide, if any) are shown in Table 4. The portion of agricultural area in each county that falls within each sub-watershed will be used to assign agricultural releases to the sub-watersheds, and total estimated releases for the entire watershed will be somewhat lower than the values shown in Table 4.

Uncertainties in the values in Table 4 are based on the uncertainty in the correction factor for reported use and can be neglected because they are far outweighed by uncertainties in apportioning them to the sub-watersheds. The uncertainty in basing sub-watershed use on land use that falls within each sub-watershed in each county will be estimated as half of the range of possible values (from zero to the adjusted reported use for the entire county), divided by the square root of three.

2.2c Algaecide Treatment of Surface Waters

This is the same group of pesticides as is listed in Table 2. Reported usage in industrial water will not be included in this category, because it is assumed that those uses are captured in the section on industrial runoff and industrial releases to surface waters.

Usage of copper-based algaecides in nonagricultural water areas in the eight-county area will be assumed to occur entirely within the watershed and along the shoreline of the bays in the watershed. Uses of algaecides in agricultural water areas will be treated as point sources and will be apportioned amongst the sub-watersheds based on land use area. Adjusted reported water area uses of copper-based algaecides in the 8-county region are given in Table 5. The uncertainty in these values is based on the uncertainty in the correction factor for usage reporting. For uses in agricultural water areas, this uncertainty can be neglected because it is far outweighed by the uncertainty associated with apportioning the values among the sub-watersheds. This apportioning uncertainty will be equal to half of the range of possible values (from zero to the adjusted reported use for the entire county), divided by the square root of three.

A portion of the reported public health, rights of way (nonagricultural), regulatory pest control, recreation area, and uncultivated (nonagricultural) applications are used as surface water algaecides, as explained in the section on estimating algaecide uses and in the footnotes for Table 2. However, in the eight-county area, there are no reported uses of any copper-based algaecides for regulatory pest control or in uncultivated (nonagricultural) applications.

Estimates for those portions of adjusted reported uses in rights of way (nonagricultural), public health, and recreation area categories will be taken as the midpoint of a range from zero to total adjusted reported use in these categories. These values will be apportioned amongst the sub-watersheds based on population. Table 5 shows surface water values for each county.

The uncertainty for estimates of algaecides used in rights of way (nonagricultural), public health, and recreation areas is based on half of the possible range (from zero to 100% of adjusted reported usage) divided by the square root of three. This uncertainty must be combined with the uncertainty in apportioning the releases by population, which will be taken as half of the range of half the population to 1.5 times the population of each sub-watershed, divided by the square root of three.

2.2d Wood Preservatives

This category includes copper released from treated lumber. The amount of treated lumber that is used in California is not necessarily related to the amount of treatment applied in California. Therefore, treated lumber releases are based on total copper applied to treated lumber in the nation adjusted by the fraction of the nation's population that is in each sub-watershed.

Each year in the United States, approximately 13 million cubic meters of wood are treated with water-based preservatives, most of which contain copper. If the copper concentration in treated wood is on the order of 1 kg/m^3 (CDA, 2003), then approximately 13 million kilograms or 29 million pounds of copper are applied to treated wood in the United States each year.

Only a portion of the copper used to treat lumber is released during product use. Loss rates depend on the type of preservative used, the type of wood, the surface area of the wood, and environmental factors including acidity, exposure to moisture, temperature, and salinity. Researchers have estimated that it would take about 180 years to leach all the copper from treated wood posts and pilings submerged in water (Rice et al., 2002). An equation describing the rate of copper leaching from treated lumber could not be found, but it is known that larger losses occur at the beginning of use (CDA, 2003), and that most of the copper remains in the lumber after 10 to 20 years in service (Rice et al, 2002). A first order equation can be used to fit these constraints, and can be developed by assuming that 1% of the copper remains in the treated lumber after 180 years. The resulting equation for the rate of copper loss from CCA-treated wood is

$$\frac{C}{C_0} = e^{-0.025t}$$

The average lifetime for pressure-treated lumber is 15 to 25 years (CDA, 2003; Rice et al, 2002). Using the rate equation, the copper released during the first 20 years of use is approximately 40% of the initial copper used to treat the wood. If the use of treated lumber has remained constant, then 40% of the total copper used to treat lumber each year is released into the environment each year. This amounts to 12 million pounds of copper in the United States.

It is difficult to assess the uncertainty in this value. Not all applications of treated lumber are submerged in water, where leaching rates would be higher, so the above value represents something of an upper bound estimate. However, CCA has been largely banned, and some of the copper-containing substitutes for pressure-treating wood leach copper at rates that are an order of magnitude larger than CCA (CDA, 2003). If 29 million pounds of copper were applied to pressure-treated lumber annually, and the copper leaches at a rate that is an order of magnitude higher than suggested by the above equation, and the lumber is removed from service after 15 years, the estimated releases of copper from pressure treated lumber are 28 million pounds of copper per year.

The uncertainty in the amount of copper leached from treated lumber each year in the United States will be based on a range of possible values from 2 million pounds per year to 22 million pounds per year. The standard uncertainty is 6 million pounds per year, or half of the range divided by the square root of three.

Some of the releases of copper from pressure-treated lumber occur from portions of the lumber that are buried underground or that are in service in areas protected from precipitation. These releases are not likely to be entrained in runoff. It will be assumed that a range from 10% to 40% of the copper leached from treated lumber cannot reach surface runoff, with a point value of 25%. The uncertainty in this estimate is half of the range divided by the square root of three, or 9%.

The uncertainty in apportioning nationwide releases of copper to the sub-watersheds based on population will be based on a range of half the population to 1.5 times the population.

2.2e Antifouling Coatings

Antifouling coatings (paints) are designed to deter growth of aquatic life on submerged boat and structure surfaces. Table 3 shows that the statewide estimate of the copper portion of the coatings used in 2003 is 1,500,000 lb. However, along with the pesticides used in treated lumber and unlike most other pesticides, all of the copper in these coatings is not released directly to the environment. Instead, it leaches out of the coating over time in a process that does not go to completion.

The urban runoff report estimates the copper releases from antifouling coatings to be 20,000 lb Cu per year (TDC Environmental, 2004). This value is arrived at by multiplying the number of boats berthed in the bays (10,000 to 12,000; TDC Environmental, 2004) by copper releases per boat from a study of San Diego’s Shelter Island Yacht Harbor (1.8 lb Cu/boat/yr) (CA RWQCB, 2005). The values used to derive the emission factor of 1.8 lb Cu/boat/yr vary over a range of approximately 1.3 lb Cu/boat/yr to 2.3 lb Cu/boat/yr (CA RWQCB, 2005), and half of this range divided by the square root of three will be the estimate of the standard uncertainty in this emission factor. The uncertainty in the number of boats berthed in the bays will be estimated as half of the range from 10,000 to 12,000 divided by the square root of three.

Other reported studies of copper released from boats provide an estimate of copper releases per boat of 3 lb/yr (CDA, 2003). This emission factor would result in an estimate of 30,000 to 40,000 lb/yr of copper released to the bays from antifouling coating.

The release rate used in the San Diego study are the most appropriate for the purpose of estimating copper releases from antifouling coatings in the bays because it represents newer data obtained using more modern analytical methods, because the value is based on measurements taken in California waters, and because they represent exclusively salt water releases.

The Copper Development Association estimates an emission factor for copper from copper-based antifouling coatings of 60 to 80 $g/m^2/yr$ for well-maintained boats (CDA, 2003). This emission factor can be used as a check on the reasonableness of the other estimates. If the average surface area of coating per boat is 35 m^2, and it is assumed that all boats are treated with copper-based antifouling coatings, then releases of copper to the bays from antifouling coatings are 50,000 to 70,000 lb/yr.

Another way to estimate copper releases from antifouling coatings is to estimate the number of gallons of antifouling paint that correspond to the pounds of copper used for boat coatings in the state, and then to apply the CDA emission factor in combination with the surface area coverage per gallon and the fraction of boats registered in the bay area. If each gallon of these paints weighs ten pounds, and cuprous oxide-based paints are assumed to be 50% copper while cuprous thiocyanate-based paints are assumed to be 8.5% copper (these are the midpoint values from the urban runoff report), then 290,000 gallons of cuprous oxide-based paint and 1800 gallons of cuprous thiocyanate-based paint were used in California in 2003. If each gallon of antifouling paint covers 40 square meters, then there are 12 million square meters of boat surfaces in California's waters that have been painted with a copper-based antifouling coating. The fraction of California boat ownership in the nine counties surrounding the bays is 176,483/963,379, or 18% (TDC Environmental, 2004). If the fraction of boat ownership in the bay area counties corresponds with the fraction of antifouling coated boat surface area that is in marine wet storage in the bay area counties, this gives an estimate of two million square meters of copper-based antifouling coating treated surfaces in the bay area. Applying the CDA emission factor yields an estimated copper release of 300,000 to 400,000 lb/yr. Note that boat ownership and boat location do not necessarily coincide.

The total copper used in antifouling coatings in the entire state is estimated to be 1,500,000 lb. If 18% of that copper was poured directly into the bays (without having to leach out of paint), it would amount to 300,000 lb/yr of copper released. What this final estimation method essentially divulges, therefore, is that the CDA-reported emission factor for copper released from boats is high.

2.2f Pool, Spa, and Fountain Algaecides

The final two columns in Table 2 are estimated use of copper-based algaecides in pools, spas, and fountains in California along with their associated standard uncertainty. This table shows that the estimate for pool, spa, and fountain use, which is based on possible fractions of use of these compounds as algaecides, is highly uncertain. The fraction of

California's population in each sub-watershed will be used to estimate the total pool, spa, and fountain algaecide used in each sub-watershed.

Copper algaecides used in swimming pools can be released to storm drains when pools are emptied. However, this is not a common event. It is believed to be illegal in California to discharge swimming pool filter backwash (which would have much higher concentrations of copper than swimming pool water in general) to storm drains, but a casual inspection of one 1960s-era neighborhood in southern California revealed that almost all homes with pools were equipped with a drain from the pool to the curb or to another area that empties to storm drains.

The frequency with which pool filters are backwashed and the quantity of water used per filter backwash event vary depending on the type of filter, whether backwashing is automated, and other pool maintenance factors. In general, filters are backwashed on the order of once every five days, with a reverse flow of water lasting three minutes. However, even in circumstances where filter backwash is routed to storm drains, not all of the algaecides used in swimming pools are released to the storm drains because much of the copper adheres to the filter media.

It will be assumed that 5% of the total watershed use of pool, spa, and fountain algaecides is released as a point source to storm drains. This is a midpoint of a range from 0-10%, with a standard uncertainty of 3%. A better estimate could be made if measurements of copper concentration in swimming pool filter backwash were available along with information on the ratio of pools that drain filter backwash to the storm drains.

The uncertainty in the estimate of releases of copper from pool, spa, and fountain algaecides includes the uncertainty in the use estimate along with the uncertainty in the fraction that is released as a point source to storm drains and the error in assuming that swimming pools, spas, and fountains are uniform throughout California on a per capita basis. The uncertainty in basing values on sub-watershed population will be assumed to reflect a range from half the sub-watershed population to 1.5 times the sub-watershed population.

2.3 Copper in Fertilizers

Approximately 10% of the 54 million tons of commercial fertilizers used in the United States in 1996 were used in California (US EPA. 1999).

The amount of copper in fertilizer varies from 0% to 39 g/kg. The Copper Development Association has a publication that describes the copper content of 20 fertilizer products, and the state of Connecticut analyses over 100 fertilizer products for copper every year. These sources of data will be used to determine an estimate of the amount of copper typically contained in fertilizer products, and the standard deviation in the values will be used the estimate the standard uncertainty for copper concentration in fertilizers.

If information on the breakdown of agricultural and non-agricultural uses of fertilizer is available, it will be used to apportion copper releases from fertilizer to the watershed. Agricultural uses will be estimated using land use fraction and non-agricultural uses will be estimated using population.

In some agricultural applications, fertilizers are tilled into the soil after application and are not entirely available for incorporation into runoff. If agricultural applications can be estimated separately, the fraction available for runoff will be based on a range from 50-100%, and uncertainty will be half of this range divided by the square root of three.

The uncertainties in apportioning according to land use fraction and population will be estimated as half of a range of 0.5 to 1.5 of land use or population, whichever is appropriate, divided by the square root of three. The uncertainty in the amount of fertilizer used in California will be based on the assumption that the range of potential values is 5-15% of fertilizer use in the nation.

2.4 Copper Releases from Industrial Operations

2.4a Industrial Runoff and Industrial Releases to Surface Waters

The methodology from the urban runoff report will be used. This approach extrapolates copper released in industrial runoff as measured in a study in Santa Clara County to the bay area sub-watersheds based on industrial acreage within each sub-watershed. Copper in industrial runoff in the Santa Clara County study was found to be 0.04 lb Cu/industrial acre/yr (derived from Grotte, 1996; SCVURP, 1997). The monitoring data this value is based on was collected nearly a decade ago and the uncertainty in this value must reflect this, along with the inherent uncertainty in applying monitored data to long-term estimates of releases. This uncertainty will be estimated as half of a range from 0.01 to 0.07 lb Cu/industrial acre/yr. Industrial runoff releases will be treated as a point source because they go directly to storm water drains.

The Toxic Chemical Release Inventory (TRI) is a database containing facility-reported release data for many chemicals. One of the reported chemicals is copper, either as elemental copper or copper in copper compounds. TRI-reported releases capture only a subset of industrial releases. Facilities are not required to report copper releases to the TRI unless they fall into manufacturing and certain other industrial classifications, have more than ten employees, and either process more than 25,000 lb/yr of copper or "otherwise use" more than 10,000 lb/yr of copper. TRI data include information on receiving streams and facility addresses, and TRI-reported releases could be gathered by sub-watershed, if desired. In 2002, TRI-reported releases to surface waters in the 8-county region were 320 lb (US EPA, 2005).

The uncertainty in the urban runoff value includes uncertainty in the monitoring data that the emission factor is based on, uncertainty in land use values, and uncertainty in extrapolating the monitored sites to all industrial sites. The uncertainty in land use values is negligible compared to the other uncertainties. The uncertainty in extrapolating monitored sites to all industrial sites will be based on half of a range of half of industrial acreage within each sub-watershed to 1.5 times the industrial acreage, divided by the square root of three.

2.4b Industrial Air Emissions

TRI-reported air emissions of copper from 17 facilities in the 9-county region were 1700 lb in 2002. This is several times larger than the value of 410 lb copper from 53 facilities reported by the Bay Area Air Quality Management District (BAAQMD) for 2001. Part of the explanation for the discrepancy between these two sources of data is caused by differences in reporting requirements. For example, only facilities releasing more than 463 lb/yr of copper are required to report releases to the BAAQMD. TRI-reported releases also capture only a subset of industrial releases. Facilities are not required to report copper releases to the TRI unless they fall into manufacturing and certain other industrial classifications, have more than ten employees, and either process more than 25,000 lb/yr of copper or “otherwise use” more than 10,000 lb/yr of copper.

Table 6 summarizes the TRI air emission data. Of the 17 facilities that reported copper releases to air, four were refineries, one was an organic chemical manufacturer, one was a secondary nonferrous metals manufacturer, one was a maker of aluminum die-cast parts, one was a non-electronic transformer manufacturer, one was a commercial lighting fixture manufacturer, one was an electron tube manufacturer, four made cathode ray television picture tubes, one made electronic components not elsewhere classified, one made motor vehicles and car bodies, and one was a ship building and repair facility. Clearly, not all facilities in these industrial classification categories are reporting releases of copper to air.

The 1700 lb reported in the TRI for 2002 most likely underestimates the amount of copper released to air from industrial. A comparison of BAAQMD estimates and TRI-reported releases might shed further light on air emissions of copper from industrial sources.

TRI data includes facility addresses and sub-watershed values could be obtained. BAAQMD data is not available by sub-watershed. Apportioning air releases amongst the sub-watersheds will range from time-consuming to impossible.

A comparison between TRI data on air releases and air toxics data reported to the Great Lakes Commission for states whose air toxics data is more complete than TRI data would shed light on the uncertainty in industrial air emissions. However, the logistics of applying this uncertainty of point source air emission values within the sub-watersheds must be discussed before Great Lakes Commission air toxics data are examined, because the effort may not be worthwhile.

2.5 Copper in Domestic Water Discharged to Storm Drains

This source consists of domestic water that contains copper because it has passed through copper pipes. An example of these discharges is domestic water that is lost to storm drains during irrigation. The methodology from the urban runoff report will be used for estimating these releases. This approach is to extrapolate copper discharged to storm drains as measured in a study in Santa Clara County to the bay area based on population. Copper in domestic water discharged to storm drains in the Santa Clara County study was found to be 0.004 lb Cu/person/yr (derived from TDC Environmental, 2004). This emission factor can be applied to population within the sub-watersheds.

Note that this methodology is expected to produce an upper bound estimate because it is based on tap water concentrations of copper. It is likely that domestic water discharges to storm drains pass through less copper piping than tap water does. In fact, in many cases, irrigation water passes through no copper piping. A lower bound for the emission factor will be assumed to be an order of magnitude smaller, or 0.0004 lb Cu/person/yr. The midpoint of this range (0.002 lb Cu/person/yr) will be used to produce the estimate of copper released to storm drains from domestic water discharges, and the standard uncertainty will be half of the range divided by the square root of three, or 0.001 lb Cu/person/yr.

3 Sources Not Included in the Inventory

Work plans for sources whose estimates in the urban runoff report contribute minimally to copper runoff to the bay were not developed. These sources include fuel combustion, which is estimated to release 10 lb/yr to 200 lb/yr of copper to air in the nine Bay area counties each year (TDC Environmental, 2004). Another source that falls into this category is wood burning, which is estimated to release 340 lb/yr of copper to air in the nine Bay area counties (TDC Environmental, 2004). The final source identified as minor in the urban runoff report is vehicle fluid leaks. An estimated 600 lb/yr of copper is released due to vehicle fluid leaks (mostly coolant dumping, but some coolant leaks as well) in the nine-county Bay area (TDC Environmental, 2004).

Also, copper released from soil erosion is calculated by the runoff model and will not be estimated.

Copper runoff from landfills is not included in this inventory work plan because modern landfills are regulated under the Resource Conservation and Recovery Act (RCRA) and landfill leachate is managed and treated either on-site or routed to sewer. Old landfills in the Bay area are regulated under programs for closed landfills and have been controlled since the 1980s. Demolition debris that was dumped around the edges of the city after the Loma Prieta earthquake is now covered and paved, and is surrounded by engineered fill.

There is a potential for copper to be released from the exposed copper that provides power to electrically powered public transit systems, either as mechanically abraded particles or as very small particulate matter that is generated when arcing occurs between the contacts. The only location in the Bay area where public transit relies on exposed overhead copper wires is a small area in San Francisco where runoff drains to sewer and is treated before discharge.

Copper releases from electrically powered public transit systems will not be inventoried because they are expected to be small. BART has not conducted any studies of the losses of copper from its conducting surfaces, and to the author’s knowledge, no such studies exist in the literature. Also, BART is required to treat the wash off water from their trains before discharging it to the sewer, so copper that adheres to the trains is removed and treated before discharge.

Copper losses from the brake lining materials of electrically powered public transit systems are also expected to be small. The manufacturer of the brake pads used for BART trains has indicated that the copper/brass content of the pads is less than one percent by weight (Kahr, 2004).

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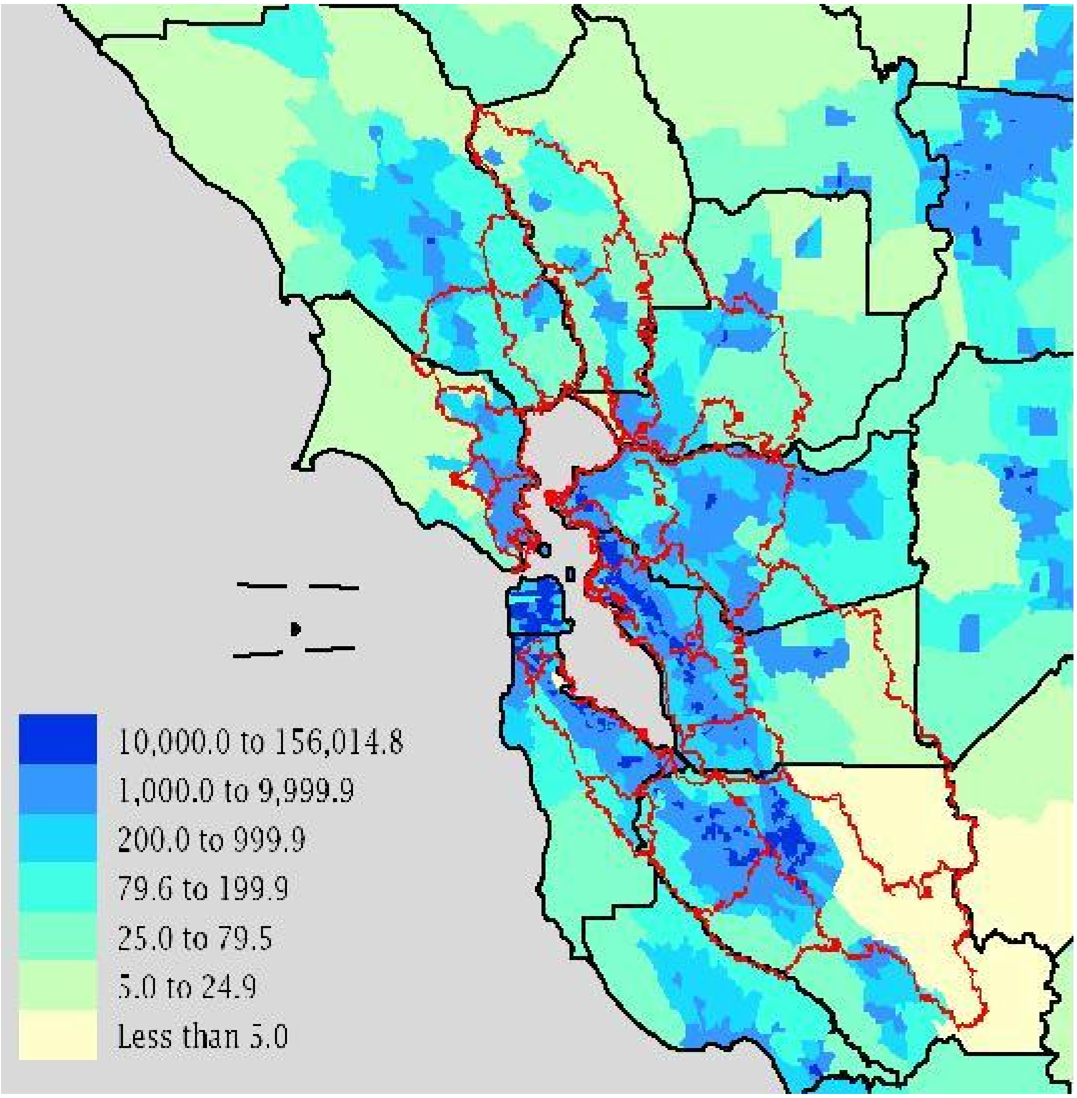

Figure 1. Population density in the San Francisco Bay area watershed. Starting at the south end of the Golden Gate and going counterclockwise, counties are San Francisco (which falls outside of the watershed), San Mateo, Santa Clara, Alameda, Contra Costa, Solano, Napa, Sonoma, and Marin. (Population density map for 2000 taken from US Census Bureau, not dated.)

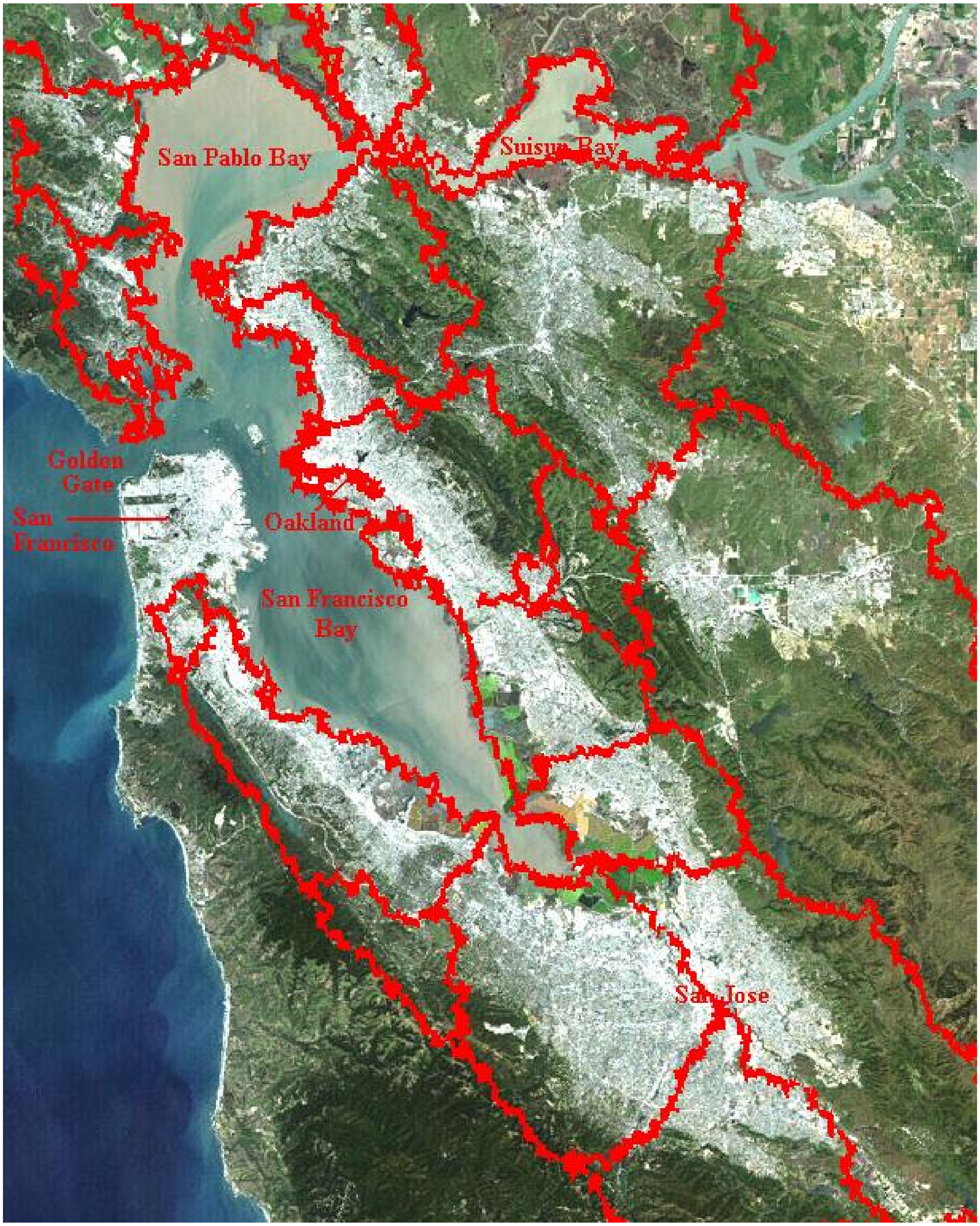

Figure 2. An aerial photograph of a portion of the study area.

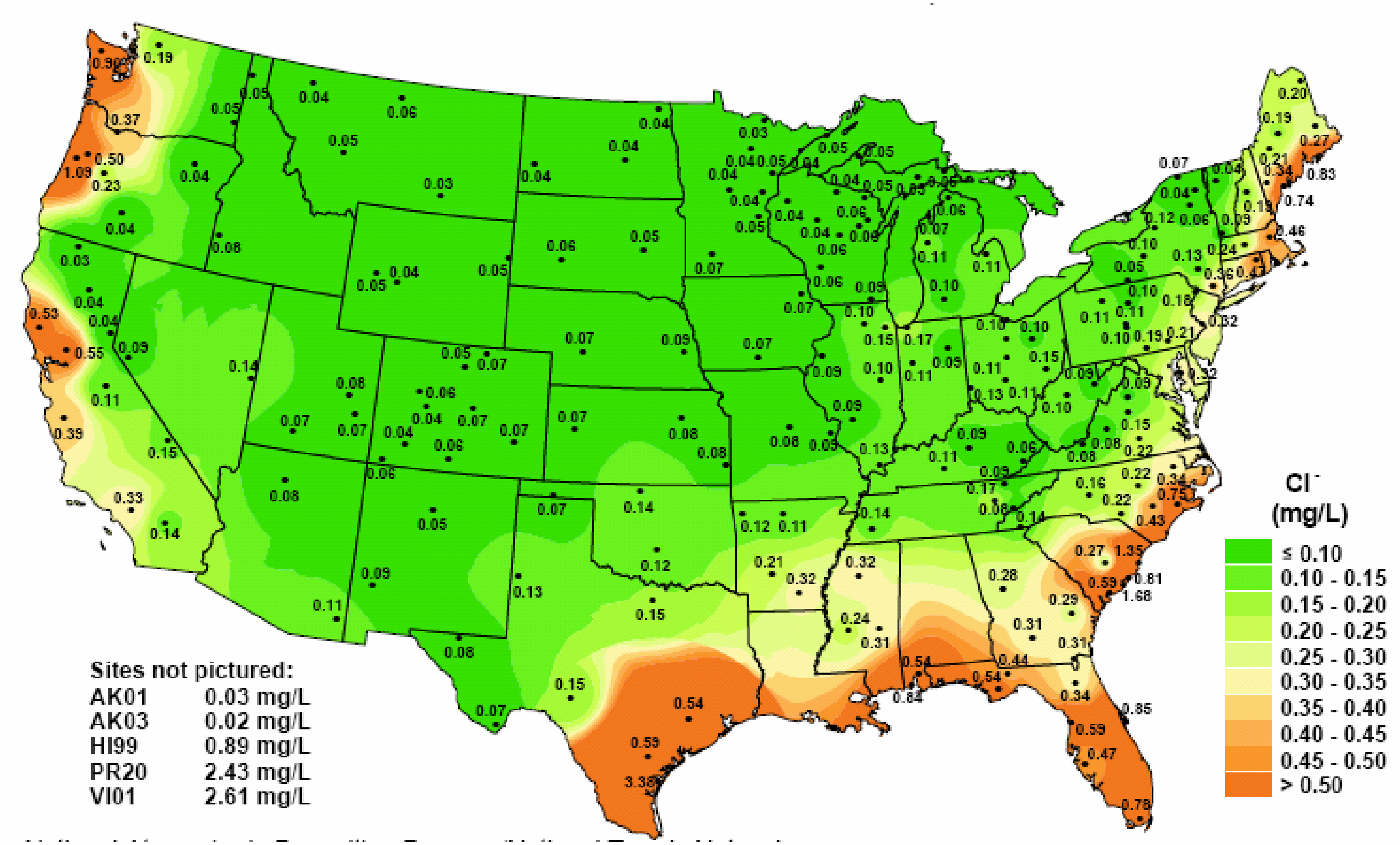

Figure 3. Chloride ion concentrations, 2003 (National Atmospheric Deposition Program, 2005).

Table 1a. Data potentially useful in assigning releases to the San Francisco Bay area watershed.

Area	Population (% in watershed)	Area, acre (% in watershed)	Area by Land Use Category, acre		
			Agricultural (% in watershed)	Urban (% in watershed)	Industrial (% in watershed)
United States	290,809,777				
California	33,484,453				
San Francisco County	751,682				
San Mateo County	697,456				
Santa Clara County	1,678,421				
Alameda County	1,461,030				
Contra Costa County	1,001,136				
Solano County	412,336				
Napa County	131,607				
Sonoma County	466,725				
Marin County	246,073				
8-County area	6,094,784				
9-County area	6,846,466				
San Francisco Bay area watershed		2,236,011	205,707		

Table 1b. Population by sub-watershed.

Sub-watershed	POPULATION, 2003								
	San Mateo County	Santa Clara County	Alameda County	Contra Costa County	Solano County	Napa County	Sonoma County	Marin County	8-County Area (Sub-watershed Total)
1									
2									
3									
4									
5									
6									
7									
8									
9									
10									
11									
12									
13									
14									
15									
16									
17									
18									
19									
20									
21									
22									
23									
24									
WATERSHED TOTAL									
COUNTY TOTAL	697,456	1,678,421	1,461,030	1,001,136	412,336	131,607	466,725	246,073	6,094,784

Table 1c. Land area by sub-watershed.

Sub-watershed	AREA (unit)								
	San Mateo County	Santa Clara County	Alameda County	Contra Costa County	Solano County	Napa County	Sonoma County	Marin County	8-County Area (Sub-watershed Total)
1									
2									
3									
4									
5									
6									
7									
8									
9									
10									
11									
12									
13									
14									
15									
16									
17									
18									
19									
20									
21									
22									
23									
24									
WATERSHED TOTAL									
COUNTY TOTAL									

Table 1d. Agricultural land use in the sub-watersheds.

Sub-watershed	AGRICULTURAL AREA (unit)								
	San Mateo County	Santa Clara County	Alameda County	Contra Costa County	Solano County	Napa County	Sonoma County	Marin County	8-County Area (Sub-watershed Total)
1									
2									
3									
4									
5									
6									
7									
8									
9									
10									
11									
12									
13									
14									
15									
16									
17									
18									
19									
20									
21									
22									
23									
24									
WATERSHED TOTAL									
COUNTY TOTAL									

Table 1e. Urban land use in the sub-watersheds.

Sub-watershed	URBAN AREA (unit)								
	San Mateo County	Santa Clara County	Alameda County	Contra Costa County	Solano County	Napa County	Sonoma County	Marin County	8-County Area (Sub-watershed Total)
1									
2									
3									
4									
5									
6									
7									
8									
9									
10									
11									
12									
13									
14									
15									
16									
17									
18									
19									
20									
21									
22									
23									
24									
WATERSHED TOTAL									
COUNTY TOTAL									

Table 1f. Industrial land use in the sub-watersheds.

Sub-watershed	INDUSTRIAL AREA (unit)								
	San Mateo County	Santa Clara County	Alameda County	Contra Costa County	Solano County	Napa County	Sonoma County	Marin County	8-County Area (Sub-watershed Total)
1									
2									
3									
4									
5									
6									
7									
8									
9									
10									
11									
12									
13									
14									
15									
16									
17									
18									
19									
20									
21									
22									
23									
24									
WATERSHED TOTAL									
COUNTY TOTAL									

Table 1g. Commercial land use in the sub-watersheds.

Sub-watershed	COMMERCIAL AREA (unit)								
	San Mateo County	Santa Clara County	Alameda County	Contra Costa County	Solano County	Napa County	Sonoma County	Marin County	8-County Area (Sub-watershed Total)
1									
2									
3									
4									
5									
6									
7									
8									
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24									
WATERSHED TOTAL									
COUNTY TOTAL									

Table 2. Estimated applications of copper-based algaecides in California in 2003. Values are in pounds of copper.

Pesticide	Range of Possible Use as Algaecide[a], %	Estimated Use as Algaecide[b]	Adjusted Reported Agricultural Use in Water Area	Estimated Algaecide Use for Rights-of-Way, Regulatory Pest Control, Recreation Areas, and Public Health	Adjusted Reported Non-Agricultural Use in Water Area	Adjusted Reported Use in Industrial Water	Estimated Use as Pool, Spa, and Fountain Algaecide[c]	Standard Uncertainty in Estimated Use as Pool, Spa, and Fountain Algaecide
Copper	0-80	165,364	259	52	0	0	165,053	93,737
Copper carbonate, basic	0-100	4,458	322	1,402	0	104	2,629	1,177
Copper ethanolamine complexes, mixed	0-100	114,148	1,229	4,003	711	15	108,187	60,437
Copper ethylenediamine complex[d]	40-100	3,634	1,970	699	45	0	518	299
Copper sulfate (pentahydrate)	0-50	476,871	15,533	42,790	49,617	1,152	366,464	205,213
Copper triethanolamine complex	0-100	70	0	0	0	0	70	40
TOTAL		764,545	19,314	48,946	50,372	1,271	642,921	233,566

[a] The lower bound in this column represents reported uses to water; the upper bound is based on reporting in usage categories that preclude use as an algaecide.

[b] Total algaecide use is adjusted reported sales multiplied by the midpoint of the range of possible use as algaecide.

[c] Pool, spa, and fountain algaecide use is estimated by subtracting adjusted reported agricultural and non-agricultural applications to water areas, industrial water use, and estimated other algaecide uses from total estimated algaecide use. Use of copper algaecides in drinking water reservoirs, which is unreported, is small and not expected to be important.

[d] Copper ethylenediamine complex had no reported sales. Its sales were estimated to be equal to adjusted reported use, as labeling information on products containing this active ingredient indicated that all use should be reported.

Table 3. Estimated urban land application of copper-containing pesticides in California in 2003. Values are in pounds of copper.

Chemical	Adjusted Sales	Adjusted Use in Agriculture, Excluding Application to Water Areas	Estimated Use as Marine Antifouling Coating	Estimated Use as Algaecide	Adjusted Use for Pressure-Treating Lumber	Estimated Use as Root Killer	Estimated Release to Urban Land	Standard Uncertainty In Release To Urban Land
Copper	414,717	84,236	0	165,364	0	0	165,375	111,565
Copper 8-quinolinoleate[1]	98	0	0	0	0	0	98	14
Copper ammonium carbonate[2]	3	0	0	0	0	0	3	0
Copper ammonium complex	16,302	4,529	0	0	0	0	11,773	2,080
Copper carbonate, basic[3]	8,716	26	0	4,458	200	0	4,354	2,603
Copper ethanolamine complexes, mixed	226,341	0	3	114,148	0	0	113,419	73,256
Copper ethylenediamine complex[2]	5,252	0	0	3,634	0	0	3,589	1,209
Copper hydroxide	2,823,913	2,080,643	0	0	0	0	743,270	381,922
Copper naphthenate	19,288	0	0	0	0	0	19,288	2,445
Copper octanoate	68	0	0	0	0	0	68	9
Copper oxide (ic)[2]	79,889	0	0	0	77,143	0	2,747	9,587
Copper oxide (ous)	1,758,864	307,555	1,450,881	0	0	0	428	39,968
Copper oxychloride	87,187	63,385	0	0	0	0	23,802	11,754
Copper oxychloride sulfate[2]	283,829	283,829	0	0	0	0	0	42,730
Copper salts of fatty and rosin acids[2]	1,286	1,285	0	0	0	0	0	194
Copper sulfate (basic)	620,584	561,387	0	0	0	0	59,197	89,527
Copper sulfate (pentahydrate)[4]	1,866,483	979,245	0	476,871	0	43,553	382,347	340,540
Cuprous thiocyanate[5]	1,632	0	1,544	0	0	0	88	9
Copper triethanolamine complex	139	0	0	70	0	0	70	46
Total	8,214,592	4,366,121	1,452,428	764,545	77,343	43,553	1,529,916	539,752

[1] Reported sales of copper 8-quinolinoleate were 455 lb active ingredient in 2001, or 80 lb of copper. This value is used to estimate 2003 sales of this product (in any event, this is not a high-volume pesticide).

[2] Because labeling information indicates that all usage is reported and because sales of these active ingredients are not reported, total adjusted statewide reported uses or total statewide estimated uses are used to estimate sales of these products.

[3] Copper carbonate sales estimated using ratio of sales (8,136 lb copper) to total reported usage (4,490 lb copper) from 2002 and applying to 2003 reported usage (4,905 lb copper).

[4] Corrected for 533 pounds of nonagricultural water area usage that were reported for copper sulfate (basic) but that should have been reported for copper sulfate (pentahydrate).

[5] Adjusted sales for boat/pier usage estimated as 240 multiplied by adjusted reported use on boat/pier (this is the ratio of estimated cuprous oxide use on boats to reported cuprous oxide use on boats).

Table 4. Reported agricultural use of copper-containing pesticides in the watershed counties, 2003.

Species	Adjusted Reported Agricultural Usage, lb Cu								TOTAL
	San Mateo	Santa Clara	Alameda	Contra Costa	Solano	Napa	Sonoma	Marin	
Copper								18	18
Copper ammonium complex				0			68	1	70
Copper hydroxide	256	3,431	74	13,075	279	2,673	19,312	23,204	62,306
Copper oxide (ous)		92		449			388	2,750	3,679
Copper oxychloride			149				57	441	647
Copper oxychloride sulfate		256		1,758		23		8,962	10,999
Copper salts of fatty and rosin acids	3	39		2	4		18	95	161
Copper sulfate (basic)		18	26			1	27	144	215
Copper sulfate (pentahydrate)		22		0	5	6		2	35
Total	259	3,857	249	15,285	288	2,703	19,870	35,618	78,128

Table 5. Releases of copper-based pesticides to surface waters in the 8-county area in 2003. Values are in pounds of copper.

County	Use in Nonagricultural Rights of Way, Recreation Areas, and Public Health			Adjusted Reported Use in Nonagricultural Water Area (Assumed to Be Entirely Released to Shoreline Surface Waters)	Adjusted Reported Use in Agricultural Water Area
	Total Adjusted Reported Usage for Six Algaecides	Estimated Use as Algaecide	Uncertainty in Estimated Use as Algaecide		
Alameda	45	22	13	0	0
Santa Clara	0	0	0	11	0
San Mateo	0	0	0	1,284	0
Contra Costa	4,603	2,302	832	0	2
Solano	0	0	0	1,863	0
Sonoma	276	138	77	939	0
Napa	1,586	793	340	0	0
Marin	3	1	1	0	254
TOTAL	6,513	3,256	902	4,097	256

Table 6. TRI-reported air emissions of copper in the 9-county region in 2002 (US EPA, 2005).

Facility Name	SIC Code Description	Air Emissions, lb/yr
Shell Chemical Co. Martinez Catalyst Plant	Industrial organic chemicals nec	0.03
Chevron Products Co Richmond Refinery	Petroleum refining	71
ConocoPhillips San Francisco Refinery	Petroleum refining	250
Shell Oil Products US Martinez Refinery	Petroleum refining	104
Valero Refining Co California Benicia Refinery	Petroleum refining	1
ECS Refining	Secondary nonferrous metals	14
Pressure Cast Products Corp	Aluminum die-castings (1987)	5
Waukesha Electric Sys. Inc.	Transformers except electronic	250
Shaper Lighting	Commercial lighting fixtures	1.5
Communications & Power Industries Inc Eimac Div	Electron tubes	60
Pycon Inc	Cathode ray television picture tubes (disc. 1987 3671)	5
South Bay Circuits Inc	Cathode ray television picture tubes (disc. 1987 3671)	255
Sprig Circuits Inc	Cathode ray television picture tubes (disc. 1987 3671)	2
Viko Technology Inc Adaptive Circuits Div	Cathode ray television picture tubes (disc. 1987 3671)	5
Isola USA Corp	Electronic components nec	5
New United Motor Manufacturing Inc	Motor vehicles and car bodies	250
San Francisco Drydock Inc	Ship building and repairing	429
TOTAL		1,707