

**Impervious Surface Area Thresholds  
for Control of Hydromodification:  
An Evaluation Using Data from the Santa Clara Basin**

**FINAL**

**Prepared for  
Santa Clara Valley  
Urban Runoff Pollution  
Prevention Program**



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## I. Introduction

In 2005, the San Francisco Bay Regional Water Quality Control Board (Water Board) staff raised the issue of whether impervious surface area thresholds for implementation of Bay Area National Pollutant Discharge Elimination System (NPDES) Stormwater Permit Provision C.3. requirements (i.e., stormwater treatment and control of hydromodification) should be lowered. At the Water Board staff's request, the Santa Clara Valley Urban Runoff Pollution Prevention Program (SCVURPPP) provided data on the amount of created/replaced impervious area created in their Program area. These data were collected from April 2002 through August 2003 by SCVURPPP Co-Permittees for the purpose of potentially submitting an alternative definition of "Group 2" projects per Provision C.3.ciii (SCVURPPP 2005)

On October 11, 2005, Water Board staff held a workshop with representatives from Bay Area Stormwater Programs and raised the following management questions (SFRWQCB 2005a):

- ❖ What is the appropriate impervious surface area threshold for stormwater treatment requirements?
- ❖ What is the appropriate impervious surface area threshold for hydromodification control requirements?

At this workshop, Water Board staff presented the results of an analysis they conducted on the SCVURPPP total/replaced impervious area data described above (SFRWQCB 2005b). They concluded that their analysis supported the idea of lowering current C3 thresholds. In later discussions of this issue with the Municipal Regional Permit New Development Work Group, Water Board staff and environmental group representatives proposed several options for lowering the thresholds.<sup>1</sup> The BASMAA position on this issue was to maintain the current C.3. thresholds.

Current C.3. requirements are, and future modifications to the requirements would be, implemented equally across the entire Santa Clara Basin. However, it is useful to explore alternatives to this assumption, including the possibility of implementing policy alternatives on a location-specific basis rather than on a "blanket", basin-wide basis. Examples of this type of approach include:

- ❖ Concentrate development in more highly developed watersheds and cluster development within watersheds (Schueler 1994, White and Greer 2006).
- ❖ Use impervious thresholds as a policy tool to limit or deflect development from occurring in sensitive and/or less-developed areas and drainages (Town of Brunswick Maine 1991, Booth et al., 2002, City of Olympia 2002, Jones et al., 2005, Homsey et al., 2006).

Investigation along these lines is also warranted because alternatives that involve lowering the current C.3. project threshold could have fiscal ramifications for Co-Permittees, as well as for developers and other community members. However, at this point, it is unclear what relative

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<sup>1</sup>New and Redevelopment Performance Standard Table Options for Municipal Regional Permit (For Steering Committee Meeting on April 24, 2006), April 7, 2006.

ecological value might be associated with lowering thresholds basin-wide or with alternative, location-specific policies. To address this question, SCVURPPP has evaluated patterns of increase in impervious area that could result from future growth throughout the portion of the Santa Clara Valley Basin (Basin) covered under its NPDES Permit. This report addresses a different set of management questions, listed below, based on analyses using the SCVURPPP data (the same data used by the Water Board staff) as well as additional data.

### **Questions for analysis:**

- ❖ What is the potential increase in impervious area in the Basin?
  - What is the potential increase in impervious Basin area due to projects not subject to C.3. requirements (i.e., below current thresholds)?
  - What is the potential increase in impervious Basin area at build-out (all project sizes)?
- ❖ Where will the greatest increases in impervious area occur in the Basin?
  - Is future growth projected to be distributed homogeneously across the landscape, or is growth concentrated in certain areas?
  - What is the condition of the natural resource base where the greatest growth is expected to occur; are some of these drainages less-developed, and/or deemed to be sensitive, warranting more protection from development than others?
- ❖ In areas of potential high growth, particularly those that may occur in drainages deemed to be more sensitive, do plans already exist to manage the way these areas are developed and prevent such development from negatively impacting the natural resource base?

## **II. Analyses**

### **II.1 What is the potential increase in impervious area in the Basin?**

The potential increase in impervious area in the Basin was calculated using two different methods (Appendix A). First, the data collected by SCVURPPP Co-Permittees for the amount of impervious area created and replaced in their jurisdictions within the 2002-2003 timeframe were analyzed, focusing on the data for projects smaller than the Group 2 threshold size (less than 10,000 sq. ft. of impervious area). This enabled a direct comparison to the Water Board staff analysis (2005b), and provided a means for estimating an annual rate of increase of impervious area in the Basin. Second, the potential increase in impervious area at build-out was estimated for the Basin using data for all ownership parcels classified as vacant/undeveloped by Co-Permittees as of 2005, and provided to SCVURPPP as part of the effort to assess the applicability of hydromodification control requirements in certain areas for the Hydromodification Management Plan (SCVURPPP 2005).

#### **II.1.a. What is the potential increase in impervious Basin area (in the 2002-2003 timeframe) due to projects not subject to C.3. requirements (i.e., below current thresholds)?**

The Water Board staff estimated that 34.1 acres of impervious surface area would be created and/or replaced from projects that were smaller than the Group 2 threshold size (e.g., less than 10,000 sq ft of impervious area) within the 17-month time frame covered by the SCVURPPP impervious surface data set. A cross-check of this estimate by SCVURPPP using the Board staff’s methodology (Appendix A) resulted in a similar value (Table 1). Calculated as an annual rate (assuming a constant rate over the 17-month data collection period), the estimated rate of creation and/or replacement of impervious surface is 23.8 acres/year (0.005% of the total Basin area) (Table 1).

Hydromodification impacts resulting from impervious area, however, are most accurately described based on **net increase in impervious area**, rather than the category of created and/or replaced used by the Water Board staff. To calculate the net increase in total impervious area from the SCVURPPP data set<sup>2</sup>, the existing impervious area for each reported project was subtracted from the total post-project impervious area. Analyzing only the net increase in impervious data resulted in a lower effective rate of impervious area increase -- 14.7 acres/year (0.003% of the total Basin area) (Table 1). Of these 14.7 impervious acres, 11.4 (78%) were derived from redevelopment projects; the remaining 3.3 acres (22%) were attributed to new development, indicating a development pattern of “Smart Growth” (USEPA 2006). Another indication of moving towards smart growth is that 15% of the redevelopment projects classified as creating/replacing less than 10,000 square feet of impervious area, resulted in a zero-balance or net *decrease* in impervious area, e.g., fewer square feet of impervious area existed once the project was completed than existed prior to the project.

In order to estimate an annual rate of potential increase in total impervious acres for the entire Basin, the impervious data collected by the City of Sunnyvale were used to estimate impervious acreages for the three jurisdictions<sup>3</sup> that had not collected data for projects with less than 10,000 square feet of impervious surface (Appendix A). The revised annual estimate of net increase in impervious acres for the Basin was 39.3 acres/year (0.009% of the Basin) (Table 1).

**Table 1. Comparative Statistics of Total Impervious Acres Created and/or Replaced versus Net Increase in Impervious Area in Santa Clara Valley Cities and County, 2002 – 2003.**

| Development Category                    | Impervious Area Created and/or Replaced (acres) |                   | Net Increase in Impervious Area (acres)       |                                                  |
|-----------------------------------------|-------------------------------------------------|-------------------|-----------------------------------------------|--------------------------------------------------|
|                                         | Water Board Staff Estimate                      | SCVURPPP Estimate | Net Increase Impervious Area, All Development | Net Increase Impervious Area, Redevelopment Only |
| Residential (17-month period)           | 31.86                                           | 32.40             | 19.82                                         | 15.87                                            |
| Industrial/Commercial (17-month period) | 2.01                                            | 1.57              | 0.79                                          | 0.26                                             |
| Residential (Annual rate)               | 22.60                                           | 22.99             | 14.10                                         | 11.20                                            |

<sup>2</sup> The SCVURPPP data set did not cover areas where three Co-Permittees did not collect data for projects creating less than 10,000 square feet of impervious area.

<sup>3</sup> Cities of San Jose, Santa Clara, and Mountain View.

|                                                            |       |       |                            |                            |
|------------------------------------------------------------|-------|-------|----------------------------|----------------------------|
| Industrial/Commercial<br>(Annual rate)                     | 1.19  | 0.87  | 0.56                       | 0.18                       |
| Residential + Ind/Comm<br>(Annual Rate)                    | 23.79 | 23.86 | 14.66 <sup>1</sup>         | 11.38 <sup>2</sup>         |
| Residential + Ind/Comm<br>Revised Annual Rate <sup>3</sup> |       |       | 39.33<br>(0.009% of Basin) | 30.53<br>(0.007% of Basin) |

Note: Estimates based on data collected by SCVURPPP Co-Permittees for projects that created and/or replaced less than 10,000 square feet of impervious surface, April 2002 – August 2003.

<sup>1</sup> Net increase in impervious area attributable to new development is 3.28 acres (14.66 – 11.38), 22% of the total net increase.

<sup>2</sup> The net increase in impervious area resulting from redevelopment equates to 78% of the net increase in impervious area for all development (e.g., new development and redevelopment).

<sup>3</sup> Annual rate revised to include estimates of impervious area for the Cities of San Jose, Santa Clara, and Mountain View<sup>3</sup> based on data from the City of Sunnyvale

### II.1.b. What is the potential increase in impervious area at build-out of the Basin (all project sizes)?

SCVURPPP estimated the potential increase in the amount of total impervious area (TIA) and directly connected impervious area (DCIA) in each catchment that would be generated if all the ownership parcels that have the potential to be developed, were fully developed to their current zoning potential, e.g., a build-out scenario (Table 2) (methodology described in Appendix A). The difference between these two measures of impervious area is that DCIA reflects the amount of runoff expected to be discharged to a receiving water, whereas some runoff generated by TIA is expected to infiltrate. Under such build-out conditions, less than two percent of the Basin would be developed as impervious area (1.6% total impervious area, or 0.6% directly connected impervious area).

**Table 2. Potential Increase in Basin Impervious Area at Build-Out.**

| Area                                                                                 | # Acres | % of Basin |
|--------------------------------------------------------------------------------------|---------|------------|
| Entire Basin                                                                         | 443774  | 100        |
| Vacant/Undeveloped Parcels                                                           | 78,034  | 18         |
| Vacant/Undeveloped Parcels, as Total Impervious Area, at Current Zoning              | 7029    | 1.6        |
| Vacant/Undeveloped Parcels, as Directly Connected Impervious Area, at Current Zoning | 2720    | 0.6        |

### II.2 Where will the greatest increases in impervious area occur in the Basin?

To understand ecological impacts at a watershed scale, the statistics presented in the previous sections do not provide enough information. From an ecological perspective, it is important to examine *where* the increases in impervious surface area are projected to occur. For example, all things being equal, development higher up in a watershed will impact a larger area due to the greater downstream distance than will development occurring lower in the same watershed (Brabec et al. 2002). As well, increases in the amount of impervious area have been shown by

numerous studies to have a greater impact on habitat and biological assemblages in undeveloped and less-developed watersheds than in more highly developed watersheds (Brabec et al. 2002). As Jones et al. stated,

“The issue is not that impervious area exists; rather, the issue is the arrangement of impervious area within a landscape....”(p178)

A report published by the City of Olympia, Washington (2002) that involved extensive scientific study and review, concluded that the goal of both accommodating projected growth and protecting habitat throughout their entire jurisdiction was not realistic in the long term. The approach the City suggested was to design management tools and make investment decisions based on the potential for effective habitat protection in individual drainages. Drainages were classified as sensitive, impacted, and degraded using a suite of criteria. In sensitive basins where habitat is still intact, habitat protection was defined as the primary goal to be met by implementing low-impact development standards. For impacted basins, where habitat is still intact, but vulnerable to strong development pressure, the City’s goal is to attempt to protect habitat while accommodating growth, realizing the outcome is uncertain. In drainages with degraded habitats, their goal is to accommodate growth.

The University of Delaware’s Institute for Public Administration - Water Resources Agency has assisted New Castle County develop Water Resource Protection Area zoning ordinances to protect water quantity and quality by limiting impervious surfaces in sensitive areas, and is similarly assisting other municipalities and counties in Delaware. In New Castle County, their approach (Homsey et al. 2006) was to develop a methodology that designated priority watersheds as those having superior watershed health with low amounts of impervious cover and high amounts of natural resources such as wetlands, forests, and riparian areas. Such “sensitive” watersheds may receive a higher degree of protection from development under the provisions of the Unified Development Code.

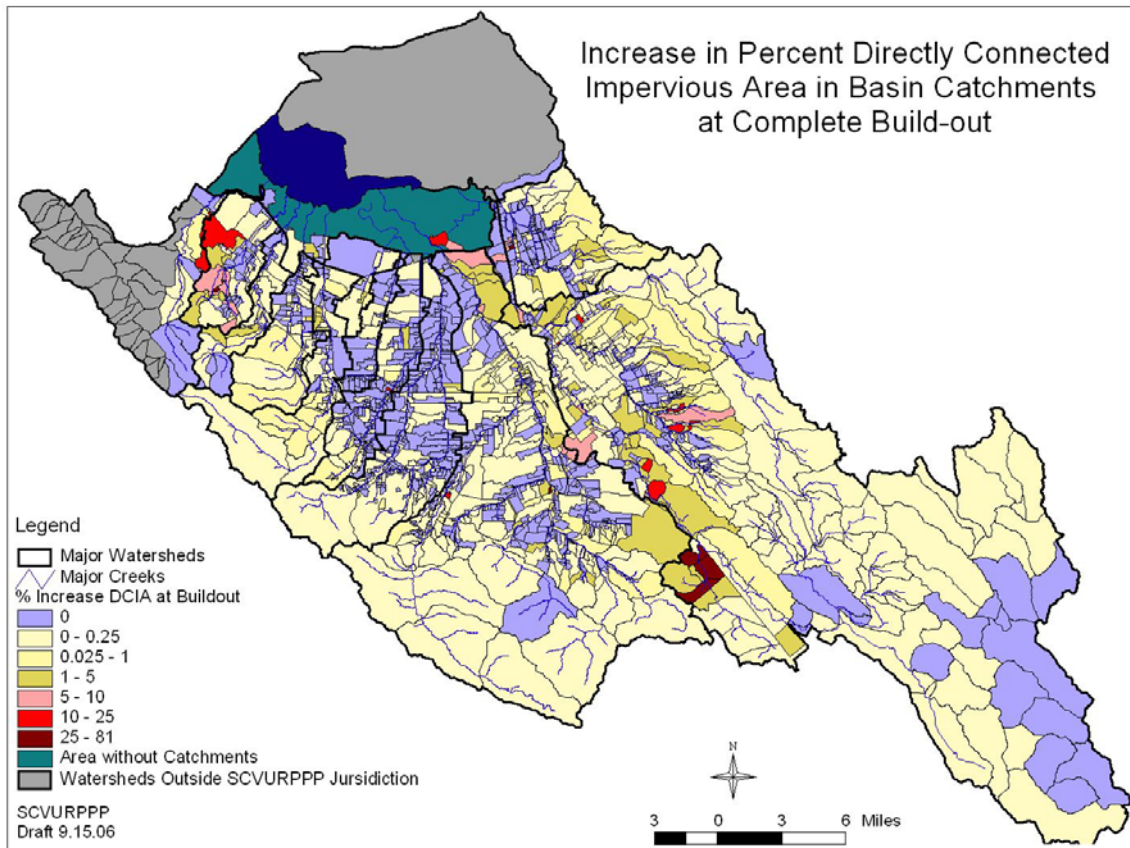
Following the line of reasoning exhibited by the aforementioned cases, SCVURPPP has examined the patterns of expected increases in impervious area and identified where such increases may occur in less-developed, and more sensitive drainages, and where they may occur in drainages that can be classified as degraded or impacted. Along this line of inquiry, the first question addressed was:

**II.2.a. Is future growth distributed homogeneously across the landscape, or is growth concentrated in certain areas?**

To answer this question, the projected increases in the percent DCIA by catchment area were examined and mapped to identify where the greatest expected increases would occur (Figure 1). The analysis focused on identifying DCIA rather than total impervious area (TIA) because estimates of DCIA are likely to be most informative for identifying potential effects of increased impervious surface on runoff volumes since they measure only runoff that will enter receiving waters and do not account for the volume expected to infiltrate (as does the measure of TIA).<sup>4</sup>

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<sup>4</sup> Alley and Veenhuis (1983) found that ratios of total impervious area to effective impervious area indicated that as development intensity increased, DCIA increased at a greater rate than TIA, indicating



**Figure 1. Projected increase in percent directly connected impervious area if ownership parcels that are currently classified by municipalities as vacant or undeveloped are developed to current zoning potential.**

The next questions that SCVURPPP addressed were:

**II.2.b. What is the condition of the natural resource base where the greatest growth is expected to occur? Are some of these drainages less-developed now, and/or deemed to be sensitive, perhaps warranting more protection from development than others?**

To identify catchments that were currently less-developed, could support more intact habitat, and could contain natural resources more sensitive to development impacts, SCVURPPP developed a suite of potential criteria to evaluate catchment conditions. These catchment criteria included the following: less than 25% DCIA; channels that are not hardened on all three sides; located upstream of dryback zones and have perennial flow; are located upstream of identified downstream channel erosion limits; steep slopes and erosion-prone soils; many mapped slumps, translational slides, and earthflows; designated coldwater fisheries management zones; intact native fish assemblages; relatively high richness of sensitive macroinvertebrate taxa (Ephemeroptera, Plecoptera, and Trichoptera); presence of red-legged frogs; and presence of

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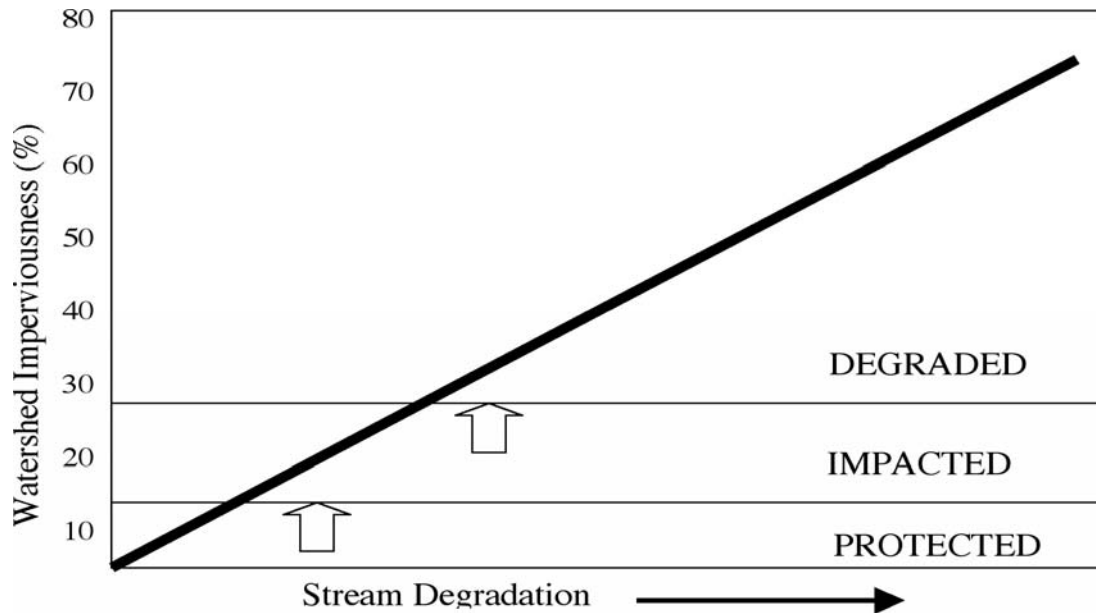
the appropriateness of using DCIA rather than TIA, as a more accurate indicator of runoff generation in areas such as the Santa Clara Basin, where land development intensity is increasing. CWP (2003) states that many researchers have repeatedly made the case that DCIA is a superior metric to TIA, yet most researchers continue to measure TIA because it is quicker to calculate.

other threatened and sensitive species (see Appendix A). Implementation of these criteria in Basin catchments revealed that they were highly spatially correlated with the percent of existing catchment imperviousness. Therefore, to take a “proof-of-concept” approach and demonstrate where additional regulation of development might be most effective, the criterion that provided the most complete geographic coverage of the Basin, percent catchment impervious area, was the primary factor used to identify those catchments that are less-developed and more likely to have intact habitat that can be protected.

A wealth of literature indicates relationships between the condition of habitat and biota relative to levels of impervious area (Karr and Chu 1999). Generally this literature supports the Impervious Cover Model (ICM) (Schueler 1994), which characterizes drainages with less than 10% total impervious surface area as “protecting” stream health, those with 10 – 30% total impervious surface as “impacted”, and those with more than 30% total impervious surface area as “degraded” (Figure 2). Numerous researchers, including the authors of the ICM (CWP 2003), remind those considering using percent imperviousness as a policy tool to recognize that the values represented by the ICM model are not sharp breakpoints, but instead reflect an expected transition of a composite of individual indicators within the range of impervious cover indicated in the model. Moreover, because uncertainty exists in both estimates of impervious surface area (depending on methods used), as well as in watershed condition, e.g., underlying geology, soils, forest cover, rainfall, etc., it is inappropriate to expect that the thresholds indicated in the ICM model strictly apply to every watershed (Booth et al. 2002, Brabec et al. 2002, Jones et al. 2002). A limited discussion of a local example is provided in Appendix A, however, the ICM model has not been widely tested in California (CWP 2003). In accordance with these perspectives, the upper limit used to define a class of “sensitive” catchments was 25% DCIA, (corresponds to ~38% total impervious area (TIA). This threshold was chosen as a conservative approach that could account for potential uncertainty in estimates of impervious area (Brabec et al. 2002), and differences in watershed characteristics that can influence the impact of impervious area (Booth et al. 2002, Jones et al. 2005). Catchments that drain to channels that are completely hardened<sup>5</sup> (both banks and bottom) and tidally influenced were subsequently eliminated from the subset of catchments having less than or equal to 25% DCIA (Table 3), as they are not considered to be more sensitive to future development (from an erosion potential standpoint).

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<sup>5</sup> These are the same catchments that have been identified as areas exempt from the Hydromodification Plan (SCVURPPP 2005).



**Figure 2. Relationship between percent watershed imperviousness and stream degradation (adapted from Schueler 1994). Y axis measures total impervious area.**

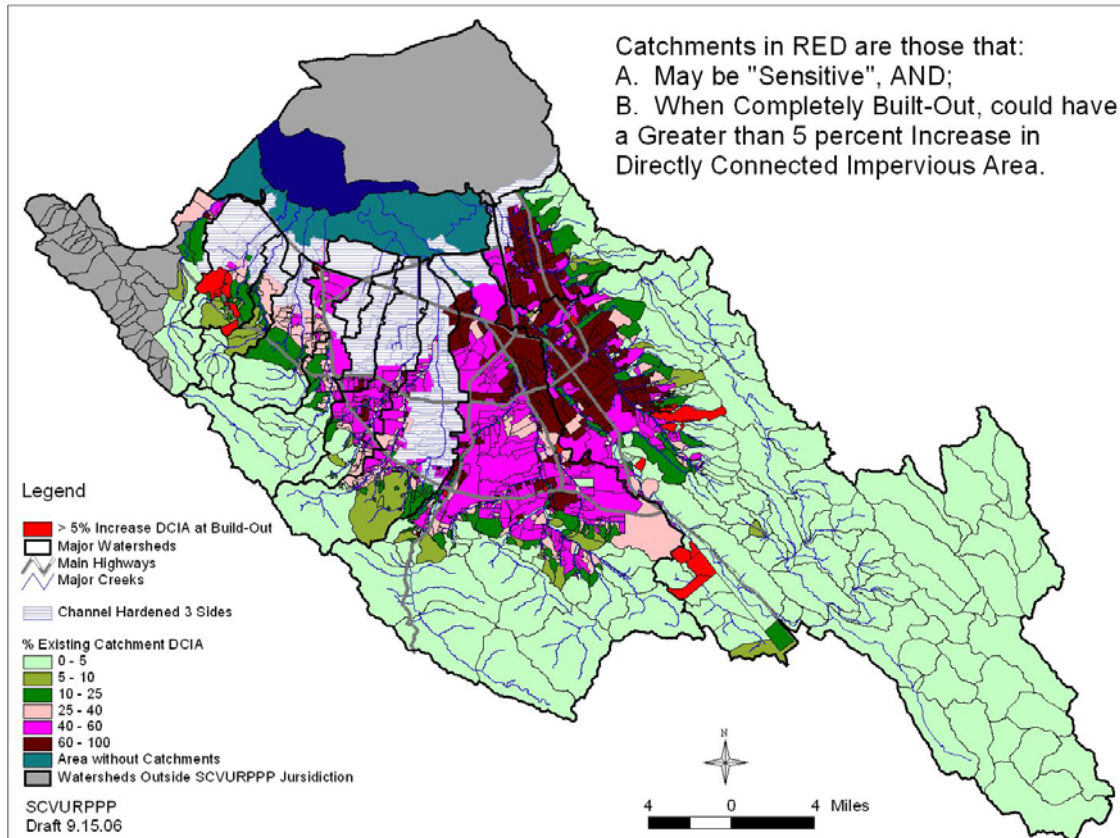
**Table 3. Number of catchments where impervious area is projected to increase if ownership parcels currently designated as vacant/undeveloped are developed to their full current zoning potential.**

| Projected Percent Increase in Catchment Impervious Area | Number Catchments | Number Catchments NOT Draining to Hardened Channel (HC) | Catchments NOT Draining to HC, as Percent of Total Number Catchments |
|---------------------------------------------------------|-------------------|---------------------------------------------------------|----------------------------------------------------------------------|
| All Catchments                                          | 1578              | 1289                                                    | 81.6%                                                                |
| TIA Increase > 0%                                       | 678               | 573                                                     | 36.3%                                                                |
| DCIA Increase > 0%                                      | 618               | 549                                                     | 34.8%                                                                |
| DCIA Increase > 5%                                      | 41                | 37                                                      | 2.3%                                                                 |
| DCIA Increase > 5% AND Existing DCIA ≤ 25%              | 24                | 23                                                      | 1.5%                                                                 |

Of the 1578 catchments in the Santa Clara Basin, 23 (1.5%) indicate an existing level of relatively low development (less than or equal to 25% DCIA), do not drain to hardened channels **and** are projected to have a greater than 5% increase in DCIA if vacant/undeveloped parcels are developed to their current zoning potential (Table 3). Therefore, these catchments represent locations<sup>6</sup> where development policies may be most effective to protect habitat from the

<sup>6</sup>It was not possible to conduct a parallel analysis to identify the location of catchments where future growth from redevelopment would be expected due to difference in the redevelopment data set. Unlike

influence of increased impervious surface area. The locations of these catchments are shown on Figure 3.



**Figure 3. Catchments in Santa Clara County Basin that currently have less than or equal to 25% directly connected impervious area (DCIA), and are projected to have a greater than five percent increase in DCIA if ownership parcels classified as vacant/undeveloped (2005) are fully developed to current zoning potential.**

The 5% increase threshold used to identify catchments where more DCIA may be generated due to future growth is not based on local watershed analysis, but does correspond to the ICM model, in that a 5% increase to a catchment with an existing level of 25% DCIA, places that catchment in the transition zone between the impacted and degraded categories. Therefore, for the purposes of this investigation it is a reasonable number to use.

the vacant/undeveloped data used to project future new growth by catchment, the SCVURPPP 2002-2003 data set only contains a snapshot of redevelopment projects from a 17-month period, and therefore, cannot be used to predict where future redevelopment projects will occur with catchment-level specificity. However, it is interesting to note that the majority of the redevelopment tracked in the SCVURPPP 2002-2003 data set occurred in catchments classified as “non-sensitive” in this analysis. Of the projects tracked by Co-Permittees during the 2002-2003 timeframe, 77% occurred in catchments having existing levels of DCIA greater than 25%, and thus according to the ICM model, are considered to be “degraded”, whereas only 23% occurred in “sensitive” catchments. These data again demonstrate a tendency towards an existing pattern of “smart” growth in the Santa Clara Basin.

Amongst the group of 23 “sensitive” catchments with greatest development potential, it is feasible to further distinguish those that may be more highly sensitive on the basis of additional attributes. For example, in 22 of the 23 catchments, “few or no landslides” have been observed (Wentworth et al. 1997). In the upper end of one of the Thompson Creek catchments, however “many” landslides have occurred (Wentworth et al. 1997). Therefore, on this basis, this Thompson Creek catchment could qualify as being more highly sensitive to development than other “sensitive” catchments that have more stable lithology. As another example, one of the catchments draining to Matadero Creek has been classified as having the potential to support a native, warmwater fishery (Smith 1996), whereas none of the other 22 “sensitive” catchments were reported to support a native fishery. Therefore, on this basis, this catchment could be classified as being highly sensitive in comparison to the other “sensitive” catchments.

### **II.3 In areas of potential high growth, do plans already exist to carefully manage the way these areas are developed in order to protect the natural resource base?**

Having identified 23 “sensitive” catchments with potential for impervious surface area to increase substantially (greater than 5%) in the future, an important question becomes, do any plans exist to carefully manage the anticipated growth in these areas in order to protect the natural resource base from hydromodification impacts? In this case, the answer to this question is largely “yes”; it is evident that municipal and county planning agencies are not only aware of where significant development may occur within their jurisdictions, but are actively planning to manage impacts on stormwater quality and quantity in those areas under the current C.3. provisions for stormwater treatment and hydromodification control.. It turns out that 94% of the total area represented by these 23 catchments is clustered in three main areas of potential development that are being addressed by the development plans listed below (Appendix A).

- ❖ **North Coyote Valley:** Draft Specific Plan development in progress; draft expected Fall, 2006 (City of San Jose 2006a). Hydrology studies are being conducted to locate and size onsite and regional stormwater treatment and flow control facilities as part of the Specific Plan.
  
- ❖ **Evergreen Valley:** The Evergreen • East Hills Vision Strategy is a comprehensive land use and transportation planning effort that is expected to guide infill development in the Evergreen and East Hills area to create housing in balance with transportation improvements and amenities (City of San Jose, 2006b). The Strategy addresses the future development of several non-contiguous properties. The development of these properties will comprise more than 500 acres and could include approximately 6,000 homes. The Evergreen-East Hills Strategy provided a unique opportunity to address stormwater treatment and HMP issues early in the planning stages of this community development. The City of San Jose, Water District and SCVURPPP staff have met with the team of consultants representing the property owners to evaluate how to meet the treatment/HMP requirements for the proposed developments, and the consultants have developed draft facility plans.

❖ **Stanford Lands:** In lieu of permanent protection of the foothill lands owned by Stanford, Stanford University entered into an agreement with Santa Clara County that established an Academic Growth Boundary that is in effect until 2025, and conducted a Sustainable Build-Out Study, which requires the development of a Conservation Plan. Some of the key planning documents include the following:

- ❑ Stanford University Community Plan: An amendment to the County’s General Plan that refines the policies of the General Plan as they apply to Stanford lands within the County (Santa Clara County 2006).
- ❑ Stanford University General Use Permit: This permit describes the distribution of additional building area, procedures under which construction may occur, and associated measures which must be accomplished before, during and after construction (Santa Clara County 2000).

### **III. Considerations**

#### **III.1 Regulation using impervious thresholds is in its infancy.**

Regulatory tools using impervious thresholds are typically implemented at a municipal or county level (City of Olympia 2002, King County 2005). The use of imperviousness as a policy tool, however, is in its infancy, and some difficulties associated with implementing impervious-related policies on the ground are becoming apparent. For example, to date, the City of Olympia has piloted low-impact development standards in one drainage and has found that the site-design review process for a drainage designated as sensitive is time-consuming and can overwhelm staff resources (pers comm. Andrew Haub, City of Olympia, 2002). Currently, the City has no plans to implement this model of low-impact development in another drainage (pers comm. Andrew Haub, City of Olympia, 2002).

#### **III.2 Not all impervious areas are created equal.**

As Bledsoe, in his paper on relationships of stream responses to hydrologic changes (2002), states, not all impervious areas are created equal. Regulating potential impacts of urbanization by focusing policy tools solely on changes in the amount of impervious area may miss some very important influences on stream condition, including: soil characteristics, slopes and topography, landcover/vegetation type, climate/rainfall, landscape position, and stream order (Booth et al. 2002, Brabec et al. 2002, Jones et al. 2002). In some cases, these factors may have a greater influence on stream condition than impervious area alone. Booth et al. (2002), for example, found that in rural areas, clearing and converting forest cover to suburban vegetation (mainly lawns), had a far more significant effect on peak discharge increases than the increases in impervious area that were occurring in low-density developments.

#### **III.3. The analyses of increases in impervious area do not address questions associated with lowering thresholds for stormwater treatment requirements.**

Current C.3. stormwater treatment requirements apply to projects that create and/or replace 10,000 square feet. These include redevelopment projects that may replace but not increase (and may even decrease) the amount of impervious surface on the site. It is essentially a mechanism to require existing development to “upgrade” to treat stormwater from impervious surfaces whenever major redevelopment is planned. Analyses of appropriate thresholds for stormwater treatment need to take into account pollutant loads from impervious surfaces and the costs and benefits of regulating smaller projects.

### **III.4 Majority of DCIA in Santa Clara Valley Consists of Road Surface Area**

In the Central Santa Clara Valley, a Brake Pad Partnership study (URS Greiner 2006) found that road surface area accounted for 76-79% of the estimated directly connected impervious area. This indicates that it may make sense to focus on reducing impervious surface associated with roads in catchments that are likely to be most sensitive to substantial increases in percent DCIA.

## **IV. Summary/Conclusions**

The current C.3. provisions ensure that control measures will be implemented for Group 2 projects that create and/or replace at least 10,000 square feet of impervious area. If the Group 2 project size threshold is lowered below 10,000 square feet, it would require the expenditure of additional public agency resources. From the standpoint of hydromodification management, the greatest ecological benefit to support consideration for the expenditure of additional resources could be gained in less-developed/impervious watersheds where there is potential to maintain, protect, and possibly enhance existing aquatic habitat and assemblages. Using a proof-of-concept approach, this study has provided an example of how such “sensitive” areas may be identified and within such areas, where projected increases in impervious area will occur. In many of these areas, municipalities have already developed plans to manage the stormwater quantity and quality impacts of anticipated growth.

In the interest of gaining the greatest ecological benefit for the expenditure of additional public agency resources that could be incurred from a change to current C.3. policy, it is prudent to consider investigating the implementation of location-specific policy changes in such sensitive areas rather than considering implementing a blanket-policy approach that requires the same level of effort regardless of landscape position and resource condition.

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## **Appendix A.**

### **Methods used to Address Questions Raised in Section II. Analyses**

The methods used to generate estimates of the relative amount and rate of impervious increase throughout the Santa Clara Basin are described following the subheadings presented in the report.

#### **II.1 What is the potential increase in impervious area in the Basin?**

##### **Quality assurance/quality control (QA/QC) of impervious surface data collected by SCVURPPP and used by Water Board staff.**

As a first step in this investigation, a QA/QC procedure was implemented on the data collected in 2002-2003 by SCVURPPP Co-Permittees that was used by Water Board staff in their analysis. This QA/QC procedure included identifying and correcting typographic errors, and omissions where possible (e.g., if two of three pieces of data were provided, the third was calculated using the two provided). In the case of the City of Cupertino, 26 of the records were missing data for the amount of impervious area created, however, most of the data set was otherwise useable. To address this data gap, an average value for the amount of imperviousness created, was calculated using records that provided complete information and this value was applied to the 26 records with missing data. Statistics calculated as a percent of Basin area were based on a value of 443,774 acres, which includes all catchments in Santa Clara County, and several at the base of San Francisquito Creek, which span both sides of the Creek.

##### **Calculating Net Increase in Total Impervious Area (TIA) based on SCVURPPP data**

To calculate the net increase in total impervious area from the SCVURPPP data set, the existing impervious area for each reported project was subtracted from the total post-project impervious area.

##### **Calculating Annual Rate of Increase in (TIA)**

The period of data collection for SCVURPPP Co-Permittees ranged from 12 – 17 months. To estimate an annual rate of increase in TIA, the total net increases for Co-Permittees that collected data over a 17-month period were divided by 17 and multiplied by 12, and then added to the totals for Co-Permittees that collected over a 12-month period.

##### **Revising the Annual Rate of Increase in TIA to include area within the three jurisdictions that did not collect data for projects < 10,000 square feet in size.**

In order to use the 2002-2003 SCVURPPP data to estimate an annual rate of increase in impervious surface area for the entire portion of the Santa Clara Basin within Santa Clara County, the data collected by the City of Sunnyvale was extrapolated to the areas included in the cities of San Jose, Santa Clara, and Mountain View. The following ratio was applied to the total area represented by each of these three municipalities: annual net increase in percent impervious area for the City of Sunnyvale, divided by the total acreage in the City of Sunnyvale. The City of Sunnyvale data was used because the relative proportion of major land uses in that City was similar to the other three municipalities shown in Table 1.

Appendix A, Table 1. Percent of major land use categories in selected municipalities in Santa Clara County. Source: SCBWMI 2001.

| Community        | Residential | Commercial | Industrial |
|------------------|-------------|------------|------------|
| <b>Sunnyvale</b> | <b>44</b>   | <b>16</b>  | <b>18</b>  |
| Mountain View    | 44          | 20         | 19         |
| Santa Clara      | 36          | 15         | 21         |
| San Jose         | 50          | 13         | 9          |

**Estimating the increase in percent impervious area for each catchment at total build-out using parcel data classified by Co-Permittees as vacant/undeveloped.**

During the development of the Hydromodification Management Plan (SCVURPPP 2005), the percent of each catchment comprised of vacant/undeveloped parcels that could be developed in the future, and could result in increased imperviousness was estimated. For this project, the zoning potential for each of these parcels was identified from individual municipal plans. A lookup table was created and each zoning code was assigned a coefficient of imperviousness (CI) based on prior analyses<sup>7</sup> (Bredehorst 1981, SCVURPPP 2001, SCBWMI 2001). The CIs were multiplied by parcel area to estimate the potential increase in impervious acres for each catchment assuming that the parcel was fully developed to the designated zoning potential. These estimates of increase in future imperviousness differ from those calculated by Mattern et al. (2003) in that: 1) the Mattern et al. methodology incorporated estimates of redevelopment into the estimate of total future impervious area; and 2) they did not estimate future imperviousness for all catchments in the Basin. SCVURPPP’s estimates are based on parcel-level data provided by individual municipal planning departments, so these data should result in estimates that quite accurately represent potential increases in impervious area due to new development.

The potential increase in directly connected impervious area (DCIA) was calculated by applying the same equation used by the Brake Pad Partnership (BPP) to estimate DCIA for impervious surface area throughout the San Francisco Bay Region (URS Greiner 2006). URS Greiner compared three methods published in literature to calculate DCIA (Alley and Veenhuis, 1983, Lee and Heaney 2003, and Sutherland 1995) and calculated uncertainties associated with estimates derived from each of these methods. URS Greiner concluded their study by recommending that the BPP use the empirical equation from Alley and Veenhuis (1983) to estimate DCIA for BPP-modeled watersheds:

$$\text{Effective Impervious Area} = 0.15 * \text{Total Impervious Area}^{1.41}$$

<sup>7</sup> A literature search was conducted to identify studies that had the most accurate imperviousness estimates (based on their methods and data sources), and were in regions with similar climate and land use patterns. Most imperviousness coefficients were drawn from Bredehorst (1981), who studied a statistically representative random sample of land use classes within the Los Angeles Flood Control District’s jurisdiction (Appendix B). These coefficients were rounded to two significant digits (Iraj Nasser, Chief Hydrologist, Los Angeles Flood Control District, personal communication, 1999). Bredehorst (1981) found that the 95-percent confidence interval was less than +/- 8.5 percent, with average interval of +/- 3.7 percent. For land use classes that were not sampled by Bredehorst (1981) (some subclasses of public parks, schools and right-of-way land uses), coefficients were based on those developed by SCBWMI (2001). CIs for “unknown”, land uses were assigned by overlaying the parcel boundaries on orthophotographs in a GIS and visually identifying the land use, and assigning the corresponding CI.

Effective impervious area as used here is analogous to directly connected impervious area. The R-square coefficient was 0.98 and the standard error of estimate was 7.5%.

The ratios of total impervious area to effective impervious area, as measured in the Alley and Veenhuis study (1983), indicated that as the intensity of land development increased, DCIA increased at a greater rate than TIA, indicating the appropriateness of using DCIA rather than TIA, as a more accurate indicator of runoff generation in areas such as the Santa Clara Basin, where land development intensity is increasing.

**Identified number of redevelopment projects included in the 2002-2003 SCVURPPP data set that occur in catchments likely to be more sensitive to increases in impervious area associated with projected growth.**

The individual records from the 2002-2003 SCVURPPP data set that documented change in impervious area resulting from redevelopment projects, were georeferenced using the assessor's parcel number in a geographic information system (GIS). The GIS was used to query whether these georeferenced records were located in catchments classified as having less than or equal to 25% DCIA, and therefore, likely to be more sensitive to hydromodification associated with projected growth.

**II.2 Where will the greatest increases in impervious area occur in the Basin?**

- ❖ **What is the condition of the natural resource base where the greatest growth is expected to occur; are some of these drainages less-developed, and/or deemed to be sensitive, perhaps warranting more protection from development than others?**

To identify the resource areas in the Basin that might be most “sensitive” to increases in impervious surface area, a suite of proposed criteria were applied to data available for the Basin (Table 2). When displayed in a GIS, the data associated with these criteria were highly spatially correlated with the catchments that have less than or equal to 25% DCIA. As well, many of these correlated data sets did not provide as complete geographic coverage of the Basin as did the impervious data set, and some were not highly accurate (see example below). Therefore, for the purpose of this study to define areas that might be more “sensitive” to further development, the less than 25% DCIA criterion was used alone. For this study, using less than or equal to 25% DCIA as the threshold value for defining “sensitive” catchments, rather than a lower level that would correspond to the ICM model threshold for degraded waters (30% TIA would equal 18% DCIA) was a way of ensuring that the classification was more likely to include all catchments that might be more sensitive to development from an erosion potential standpoint, e.g., by accounting for variability inherent in the impervious data sets, the DCIA model (URS Greiner 2006), and the way that different watersheds respond to impervious area (Booth et al. 2002, Brabec et al., Jones et al. 2002).

The following example illustrates the concern expressed in literature about the difficulties of using absolute thresholds of impervious area as policy tools, and underlines the importance of conducting watershed assessments to understand the condition of the resource base before blanket-implementation of policy. In Saratoga, Upper Penitencia, and Guadalupe Creeks, the

extent of the predicted coldwater native fisheries (Smith 1996) extended further downstream than the 25% DCIA catchment threshold, e.g., extending downstream of catchments that were greater than 25% DCIA. It is important to realize, however, that this fisheries map is not empirically-based, but rather, is based on the best professional judgement of a single fisheries professional. Therefore, its boundaries were not considered to be highly accurate nor taken as absolutes. In the case of Saratoga Creek, Smith's map indicated potential habitat for a coldwater trout community downstream of catchments with 0 – 10% DCIA for approximately 5.25 miles, passing through catchments in the range of 25-60% DCIA. Preliminary analysis of fisheries sampling on Saratoga Creek (SCVURPPP 2006 *in progress*), indicates that the trout community is likely productive in only the approximately upper 1.75 mile of the stream segment indicated by Smith. It is also relevant to note that the large upper watershed area with colder, perennial flows and significant amounts of forest cover and intact riparian cover may exert a positive influence on biological assemblages that continues further downstream than in other watersheds that for example, have smaller headwaters that contribute less and warmer flows.

For the Saratoga Creek watershed, SCVURPPP explored calculating cumulative imperviousness as a way of accounting for the discrepancy observed between fishery condition and percent catchment DCIA, however, the cumulative impervious values were very low due to the large upstream drainage areas and points of reference from literature are not available for this approach, therefore, it was not further pursued.

Appendix A, Table 2. Potential Criteria to identify areas that might most benefit from changes in existing policy regulating development in the Santa Clara Basin

| Category | Variable                                   | Criteria                                                             | Rationale                                                                                                                          | Comments                                                                                                                                                                                      |
|----------|--------------------------------------------|----------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Physical | Percent Directly Connected Impervious Area | ≤ 25%                                                                | Lower % Imperviousness means the channel and biological communities are likely in better condition and are valuable to protect.    | Criterion is highly spatially correlated with all the other criteria and may be sufficient to use alone, though the others could be used to distinguish highly sensitive from just sensitive. |
| Physical | Channel Modification                       | Catchments draining to channels that are not hardened on all 3 sides | Channels that are not hardened on both banks and the bottom can provide habitat to support native aquatic species.                 | Accepted in our HMP already. Good way to define areas that are not completely impacted.                                                                                                       |
| Physical | Downstream Limit Channel Erosion           | Upstream of MDL                                                      | Indicates potential for channel instability upstream                                                                               | Limited utility – just shows what is unstable but not necessarily sensitive.                                                                                                                  |
| Physical | Flow Regime                                | Upstream dryback zones; perennial flow                               | Perennially flowing stream segments upstream of summer dryback zones support intact and sensitive biological communities. Tidally- | Correlates strongly with fish communities.                                                                                                                                                    |

|                      |                                     |                                                     |                                                                                                                                                                                                                                      |                                                                                                                                                   |
|----------------------|-------------------------------------|-----------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------|
|                      |                                     |                                                     | influenced areas, which also support sensitive communities do not need to be considered from a hydromodification perspective.                                                                                                        |                                                                                                                                                   |
| Physical             | Surface Erosion Risk                | Steep Slopes and Erosion-prone soils                | Erosion-prone areas are more likely to deliver sediment to stormdrain system when developed.                                                                                                                                         | Indicates more area is at risk of erosion than evidenced by Landslide data.                                                                       |
| Physical             | Landslide Areas                     | Mapped slumps, translational slides, and earthflows | Future landslides are most likely to occur in areas where landslides have previously occurred.                                                                                                                                       | Correlates to Surface Risk Erosion but covers Eastern Basin as well.                                                                              |
| Biological, Physical | FAHCE Management Zones              | Includes FAHCE Management Zones                     | The FAHCE Project evaluated biological and physical parameters to identify management zones where habitat for two sensitive fish species (steelhead – listed as Threatened under the Federal ESA – and chinook) needs to be managed. | Useful management perspective.                                                                                                                    |
| Biological           | Fish Assemblages                    | Intact Native Assemblages                           | Stream segments supporting intact native fish assemblages indicate higher quality habitat that is valuable to protect.                                                                                                               | Correlates strongly with DCIA. Exceptions are creeks in large watersheds reaching the ridges having colder, perennial flows and tributaries.      |
| Biological           | Macroinvertebrate Assemblages       | Relatively high EPT richness                        | Stream segments supporting intact native fish assemblages indicate higher quality habitat that is valuable to protect.                                                                                                               | Not as complete data set as fishes nor developed to point to make it as useful for this purpose as fish data.                                     |
| Biological           | Red Legged Frogs                    | Presence                                            | Red-legged frogs are sensitive amphibian species listed as Threatened under the Federal ESA. Their presence indicates habitat that should be protected.                                                                              | Partial Basin area covered by surveys.                                                                                                            |
| Biological           | Other Threatened, Sensitive species | Presence                                            | Locations could be indicators of sensitive habitats.                                                                                                                                                                                 | Santa Clara Valley Habitat Conservation Plan likely more complete coverage than California Natural Diversity Database but plan not available yet. |

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