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Urban Retrofit: A Whole-Watershed Approach to Urban Stormwater Management

Author
Lithander, Becky

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Becky Lithander
LA 222, UC Berkeley

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Urban growth has not been favorable to streams. Urban watersheds disrupted by the increase in impervious surfaces of roadways and roofs and the decrease in vegetation associated with development, suffer increased runoff, leading to elevated flood risks, and greater concentrations of runoff pollution. The conventional response to these problems has been the development of a complex network of storm channels and culverts that function to drain stormwater away from built sites as quickly as possible, sending it quickly to the nearest waterway. While this approach greatly reduces the risk of flood (until the system is overloaded), it has proven to have many adverse effects on the ecology of our urban watersheds, including increased erosion, concentration of pollutants in waterways, and loss of habitat.

In order to understand the problems of disrupted urban watersheds, it is important to understand how they differ from natural watersheds. Essential to this is an understanding of the hydrologic cycle. In a continuous pattern, water is constantly recycled through evaporation from the ocean into water vapor in the atmosphere that condenses and falls to the ground as precipitation, collecting into surface waterways or infiltrating into groundwater before eventually flowing back to the ocean to repeat the process. In a natural watershed, much precipitation from storms is intercepted by vegetation before even reaching the ground. The water that reaches the ground is often detained through the "roughness" of vegetation and soils, slowing runoff and reducing the total amount of runoff that reaches waterways, and the main pollutant in the cycle is sediment. In such a system, there is a certain lag time between the time a storm event begins and the time it takes to reach peak runoff, as seen in the hydrograph below. In an urban system, vegetation is reduced, and open ground is replaced by impermeable surfaces such as pavement and roofs, leading to increased runoff traveling at higher velocities. In addition, this runoff concentrates not just sediment, but also urban pollutants such as oil, heavy metals, pesticides and fertilizers associated with urban environments. This results in higher levels of erosion and pollution in waterways, as well as increased risk of flooding downstream during large storm events.

In recent years, the paradigm has been shifting from one of stormwater as a problem to stormwater as an opportunity, and the need for strategic stormwater planning has been growing. There are a growing number of exciting case studies on smart stormwater planning and design that have created a foundation from which to improve upon. Often a network of decentralized green infrastructure solutions can be implemented to have a net reduction in construction and maintenance costs in addition to a net gain in wildlife habitat and social benefit. While changing systems is costly and resource intensive, it is important to note that all infrastructure has a finite lifespan, and as stormwater infrastructure ages and needs replacing, opportunities will arise to implement stormwater management BMPs (Best Management Practices). To ensure such alternatives exist, it is essential to plan for such opportunities by assessing entire watersheds, and determining appropriate strategies for different situations.

In this paper, I will lay out potential strategies for one particular urban watershed, the Derby Creek/Potter Creek watershed in Berkeley, California (Diagram 1, Appendix A). Derby/Potter Creek watershed begins in the Berkeley Hills, near Claremont Canyon, and continues roughly 3½ miles west to the San Francisco Bay. Historically, Derby and Potter Creeks collected stormwater runoff into surface waterways that followed the natural topography flowing downhill to gradually reach the bay. But today, the entire watershed is completely engineered into storm channel culverts that flow underground, except for the very top of Derby Creek, where its intermittent beginnings still flow above ground during the wet winter months. (See diagram, Appendix A) Because the system is completely engineered, stream channel erosion is not a concern, but urban runoff pollution and flooding in the lower watershed remain issues of concern. Because stormwater runoff is sent directly to the culverted system, runoff pollution is concentrated in the channels and delivered quickly to the bay, where pollution toxins have resulted in bioaccumulation in the aquatic life there, to the degree it is recommended to eat no more than two fish per month from the bay to avoid accumulation of toxins in our selves. In addition, the culvert system has a limited capacity that becomes overburdened in large storm events, causing flooding in the lower watershed. While flooding has been a minor issue to this point, not overtopping street curbs, this issue can potentially be exacerbated by the increasing intensity of storms that may occur as a result of climate change. For these reasons it is necessary to implement better stormwater management solutions here as opportunities arise.

In order to strategize stormwater management for this watershed, I have used a two-pronged approach. The first deals with recommending green infrastructure solutions that can be applied generally in any watershed, the second deals with specific opportunities that are presented when looking more closely at this particular watershed. Specific opportunities and strategies will necessarily vary from one watershed to the next, and from one area of a watershed to the next, based on climate patterns, land use, slope, and other factors, and many potential opportunities require community support to implement. What I have laid out here is a guide for exploring these potential opportunities.

There are numerous and growing case studies of green infrastructure and their associated stormwater management benefits. Many of these interventions provide benefits beyond stormwater management, such as increased pedestrian safety, improved wildlife habitat, beautified city streets, water use reduction and heat island mitigation. These strategies vary in size and scope from simple and inexpensive to complex and resource-intensive. Interventions such as creating curb-outs with flow-through planters along streets are cost-effective means of slowing runoff, beautifying city streets, and increasing pedestrian safety. Cities such as Seattle, Portland, San Francisco, and Emeryville have been implementing these interventions with great success.[1] These systems have proven effectiveness at reducing runoff rates and removing some amount of runoff pollution, and monitoring has begun on long-term maintenance procedures and costs. Another intervention that builds naturally from curb-outs is to implement rain gardens in street medians along large streets. This strategy could further reduce runoff and remove pollutants with little cost to implement.

[1] "Sustainable Stormwater Management."

Capturing rainwater runoff from roofs is another important strategy for managing stormwater. Rainwater catchment can be stored in large amounts for future use for non-potable indoor pluming such as flushing toilets, or for irrigation during the dry season. In 2008, San Francisco began allowing residents to capture rainwater and use it for non-potable indoor plumbing without treating it to potable standards.[2] There are a growing number of large-scale examples of this type of innovative low-impact development (LID), such as the Taylor 28 apartment complex in Seattle designed by Mithun, in which rainwater is captured from the roof of the mixed-use complex and used for toilet-flushing and irrigation, and the sidewalk design includes beautiful flow-through planters as part of the design of the public social space.[3] In smaller systems, captured rain can be drained between large storms, provided much-needed relief for over-burdened stream and engineered channel systems. If every household had one 50-gallon barrel that captured 5o gallons of roof rainwater runoff in every large storm, the reduction in peak flow volume to the storm channel system would be incredibly significant. In a moderate-density residential watershed such as Derby Creek, with an average of over 500 houses per square mile, more than 25,000 gallons of stormwater runoff could be detained from each storm event, significantly reducing the impact on the channel system. If this captured water were released into a garden swale between storm events, urban runoff pollution could be drastically reduced and groundwater recharge increased. The Los Angeles-based non-profit Tree People has retrofitted a single-family home with stormwater runoff strategies to demonstrate simple, effective residential-scale stormwater strategies such as these. [4]

Green roofs are also a growing urban strategy, providing urban heat-island mitigation which reduces summer cooling costs, increasing urban wildlife habitat, improving air quality, and reducing stormwater runoff. Chicago City Hall's model green roof is estimated to capture 75% of a 1-inch storm before overflowing to the

[2] "ZyPDF.pdf | nepis.epa.gov/Exe/ZyPURL.cgi?Dockey=P1005FN2.txt"
[3] "Taylor 28 - Projects - Mithun."
[4] "Hall House | www.treepeople.org."

storm channel system.[5] Meanwhile, the California Academy of Science's green roof in San Francisco's Golden Gate Park, designed with dramatic slopes and valleys that mimic the topography of its surroundings, drastically reduces heating and cooling costs, and provides an expanse of native wildflowers for local insects and birds in the area, in addition to reducing stormwater runoff.[6] These and other green infrastructure solutions need to be implemented throughout urbanized watersheds as opportunities arise. A valuable blueprint for such opportunities exists in Rosey Jencks' 2005 report, "Finding Room for Stormwater: a Review of Site and Design Opportunities in San Francisco".[7]

In order to discern opportunities specific to the Derby Creek watershed, I have broken it up into four categories: upper watershed hills, middle watershed residential, middle watershed commercial, and lower watershed industrial. (Diagram 5, Appendix A) The upper watershed is characterized by steep slopes resulting from uplift along the Hayward fault, becoming gentler west of the fault zone. While this pattern can be traced throughout the length of the East Bay, what is of particular interest in the Derby Creek watershed is that much of the land along the fault, where the slope flattens out from an average 100% to an average 8-9% slope, is University of California, Berkeley property (Diagram 6, Appendix A). This presents an interesting opportunity to work with the university to implement stormwater management strategies that slow runoff from the steepest part of the watershed and increase interception and infiltration at its upper end. The university properties include the Smyth-Fernwald student housing complex and the Clark Kerr campus. The Smyth-Fernwald property, an historic farm bequeathed to the university that abuts the only remaining open stream channel in the watershed, was built out as graduate student family housing in the 1950s. The property is now condemned due to failure to meet seismic safety regulations and will be demolished in the next few years. While the university withdrew its most recent plans to

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[5] "City of Chicago: Chicago's City Hall Rooftop Garden."
[6] "The Living Roof: California Academy of Sciences."
[7] "Finding Room for Stormwater: A Review of Site and Design Opportunities in ... - Rosey A. Jencks - Google Books."

develop new student housing on site, it maintains the intent to rebuild student housing at a higher density in 10-15 years. Work can be done now to implement LID strategies for this redevelopment such that the resulting housing goes beyond California Law to not only avoid increasing runoff from the site, but to also further reduce current runoff volume. Just south of Smyth Fernwald is the Clark Kerr campus. This undergraduate housing and gym complex covers a large expanse of the Hayward fault terrace, and includes a lot of turf. While much of the turf is used for athletics, like the soccer field in the upper track, much of the turf on the site is under-utilized, and offers opportunities for rain gardens and detention ponds. Further, a small chunk of the southeastern portion of the main campus is also in the Derby Creek watershed. This area includes Wurster Hall, which houses the College of Environmental Design. This provides a unique opportunity to challenge the hundreds of architecture, landscape architecture, planning, and urban design students to seek better stormwater management solutions for Derby Creek watershed and other similar urbanized watersheds. Currently, the university's stormwater sustainability efforts center around slowing runoff and reducing pollution to Strawberry Creek, as it runs through the main campus, and the bay marshlands adjacent to the Richmond Field Station. However, the campus sustainability report sets clear guidelines for water quality stewardship in the Strawberry Creek watershed that set a precedent to build upon for better stormwater stewardship of the properties in the Derby Creek watershed.[8]

Moving west to the middle watershed, the land use changes to moderate-density residential, consisting of a mix of apartment buildings and single-family homes on the eastern side of this area and mostly single-family homes on the western side (Diagram 7, Appendix A). Along with residential communities, come schools, parks, and churches: ideal places to demonstrate stormwater stewardship because of the built-in communities associated with these spaces. Overlaying the current city map with the Oakland Museum's historic creek map[9], reveals that historically stretches of Potter and Derby Creeks flowed through current-day parks

[8] "2011_Campus_Sustainability_Report.pdf: http://sustainability.berkeley.edu"
[9] "Potter/Derby Creeks Watershed Map."

and schools including People's Park, San Pablo Park, Grove Park, and Malcolm X Elementary School (Diagram 8, Appendix A). These places provide potential opportunities for daylighting sections of the creeks to provide public interface with flowing creek water and increase education and awareness of stormwater stewardship. There are nearby examples of successful daylighting projects along nearby Berkeley streams, most closely, along Strawberry Creek, at Strawberry Creek Park and through the UC Berkeley campus, and city council-approved plans are underway to daylight a section of the creek right in the heart of downtown Berkeley as well.[10] Where actual creek daylighting isn't an option, creek features may provide a close alternative. Successful projects such as the Temescal Creek Feature adjacent to the Oakland DMV on Claremont Avenue prove that these alternative creeks can be exciting and powerful additions to communities as well.[11] Daylighting creeks has proven to not only build community interest around creek and watershed stewardship—a powerful motivator for better stormwater management—but has actually proven to raise real estate values for properties located near such daylighting projects.[12]

Daylighting creeks is a big, expensive project that requires ongoing maintenance. While numerous case studies exist demonstrating success, such projects would require local champions. This would mean identifying teachers/parents/residents of the school or park community that would champion the cause and help build a grassroots movement of support. Even where daylighting or building creek features is implausible, schools and parks provide important public spaces for demonstration stormwater management strategies. A growing number of schools are implementing rainwater harvesting and rain garden techniques that not only improve stormwater management, but also provide living classrooms where students can learn about the water cycle and water stewardship. Groundbreaking examples include Tabor elementary school in Portland, Oregon,[13]

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[10] "Center Street Plaza, Berkeley |."
[11] "ABOUT FROG PARK | FROG Park."
[12] Pinkham, "Daylighting."
[13] "Designing Our Future: Sustainable Landscapes."

where an under-utilized parking lot has been transformed into a beautiful rain garden that manages over 30,000 square feet of parking and rooftop runoff, and is estimated to have saved the city over $100,000 in infrastructure upgrades. While Oregon has set the early examples, the practice is quickly spreading, and through a partnership with SPAWN (Salmon Protection and Watershed Network) and MMWD (Marin Municipal Water District) now includes many schools in nearby Marin County as well.[14] In addition to schoolyard demonstration gardens there are a growing number of public park projects as well. An exciting recent project in South Carolina at Cleveland Park features a beautiful rain garden that filters runoff before it enters the stormwater system. This project was carried out by Clemson University's horticulture extension (Diagram 10, Appendix A). Projects of this scale would be easy to replicate and could serve to inform and inspire the general public, as in the project I proposed in the earlier stormwater design exercise (Diagram 9, Appendix A).

The commercial district that runs through the middle watershed includes the southern portion of downtown Berkeley and runs to the Oakland /Berkeley border along Shattuck and Adeline avenues. This area would be an ideal location to install curb-outs, especially near the Ashby BART station, and Berkeley Bowl supermarket, where pedestrian-motor vehicle traffic is already contentious. In addition, the entire strip features wide medians that could easily be retrofitted as rain gardens to further decrease stormwater runoff volume and pollution (Diagram 12, Appendix A).. If designed well, these median strips could provide beautiful seasonal accents to draw attention to the impressive seasonal patterns of precipitation here, with known wet winters and yearly summer droughts.

At the base of the watershed, in the Berkeley flatlands, is the industrial sector. This area of the watershed is the flattest and the last stretch before hitting Berkeley Aquatic Park and the bay. A brief glance at aerial photos of this area immediately reveals a lot of parking lots. It takes live visits to these lots to determine if they're implementing stormwater BMPs, which most, if not all, are not.

[14] "10,000 Rain Gardens Project - Home," 000.

Even the recent addition of Berkeley Bowl West, adjacent to a wide strip of unused gravel, has a parking lot full of storm drains that lead directly to the bay (Diagram 1f4, Appendix A). Implementing change in this area will require stricter regulations and better incentives at the city level. While Berkeley's creek ordinance sets a base line for protecting open and culverted creeks, it doesn't go nearly far enough to incentivize stormwater management practices.[15] Better incentives for LID approaches coupled with long-term visioning of incorporating freshwater detention ponds as land use changes will serve the city and the bay well.

Just before hitting the actual bay, this watershed ends at Berkeley Aquatic Park, an artificial lagoon that marks the historical edge of the bay shoreline. Aquatic Park is influenced by tide and does also receive some of the stormwater outlet form the upper watershed, though most of it flows past, directly into the bay. Aquatic Park is the one area of the watershed that has received significant attention. As an important habitat and recreation area, it has been studied in depth, and some areas have undergone restoration. While overall water quality has improved slightly over the years, it continues to suffer from poor circulation, with limited culvert capacity to let the bay tide flush it out. The 1990 Aquatic Park Master Plan was prepared for prepared for the City of Berkeley by MPA Design with input from PWA hydrologic consultants, recommending widening of the culverts between Aquatic Park and the bay to improve circulation.[16] This recommendation was not followed through as it was determined incompatible with water sport recreational use, which would be diminished by the daily low tides. This is an important indicator of the sometimes-conflicting interests that are met in seeking to implement better watershed and stormwater management approaches.

In summary, Derby Creek watershed, like most urbanized watersheds, functions very differently from a natural watershed. Stormwater runoff quickly collects in culverted channels and delivers high concentrations of runoff pollution

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[15] "Creeks Ordinance - City of Berkeley, CA."
[16] "City of Berkeley Aquatic Park Master Plan: Prepared for Joint Subcommittee ... - Berkeley (Calif.). Parks/Marina Division, Berkeley (Calif.). Joint Subcommittee on Waterfront Parks - Google Books."

directly to the bay. A typical hydrograph of this watershed would indicate very little lag time between peak intensity of a storm enevnt and peak runoff flow caused by the event, in contrast to a natural watershed,in which runoff is intercepted, slowed, and filtered by vegetation and soil. But urban watersheds can function more like natural watersheds by implementing decentralized stormwater management approaches, by moving from “gray” to “green” infrastructure. The Derby Creek watershed, with its ties to the University of California, Berkeley, and the long tradition of creek activism in the area, presents a unique opportunity for demonstrating a whole-watershed green infrastructure approach to stormwater management.

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Appendix A - diagrams and case studies

Diagram 1

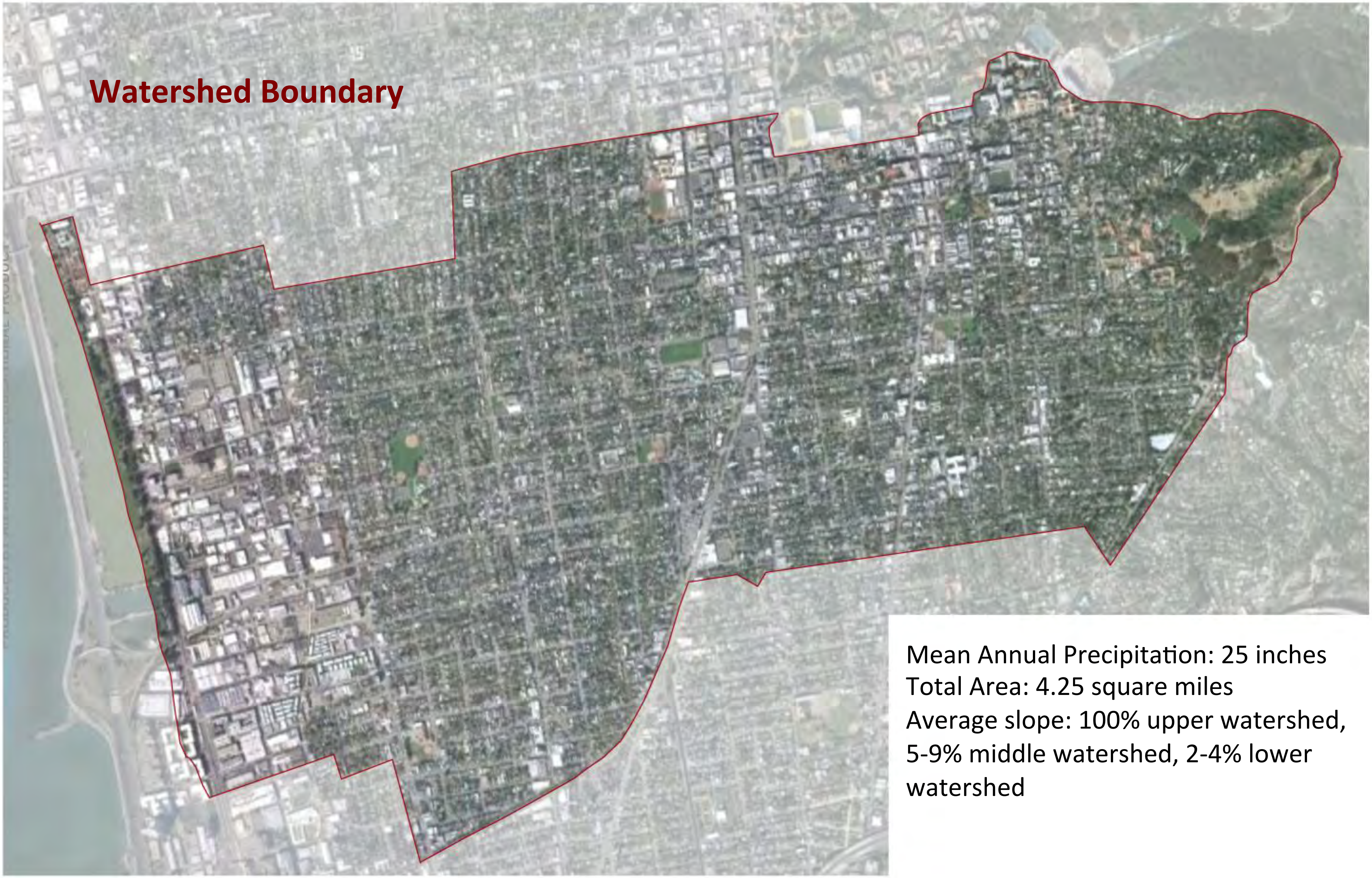
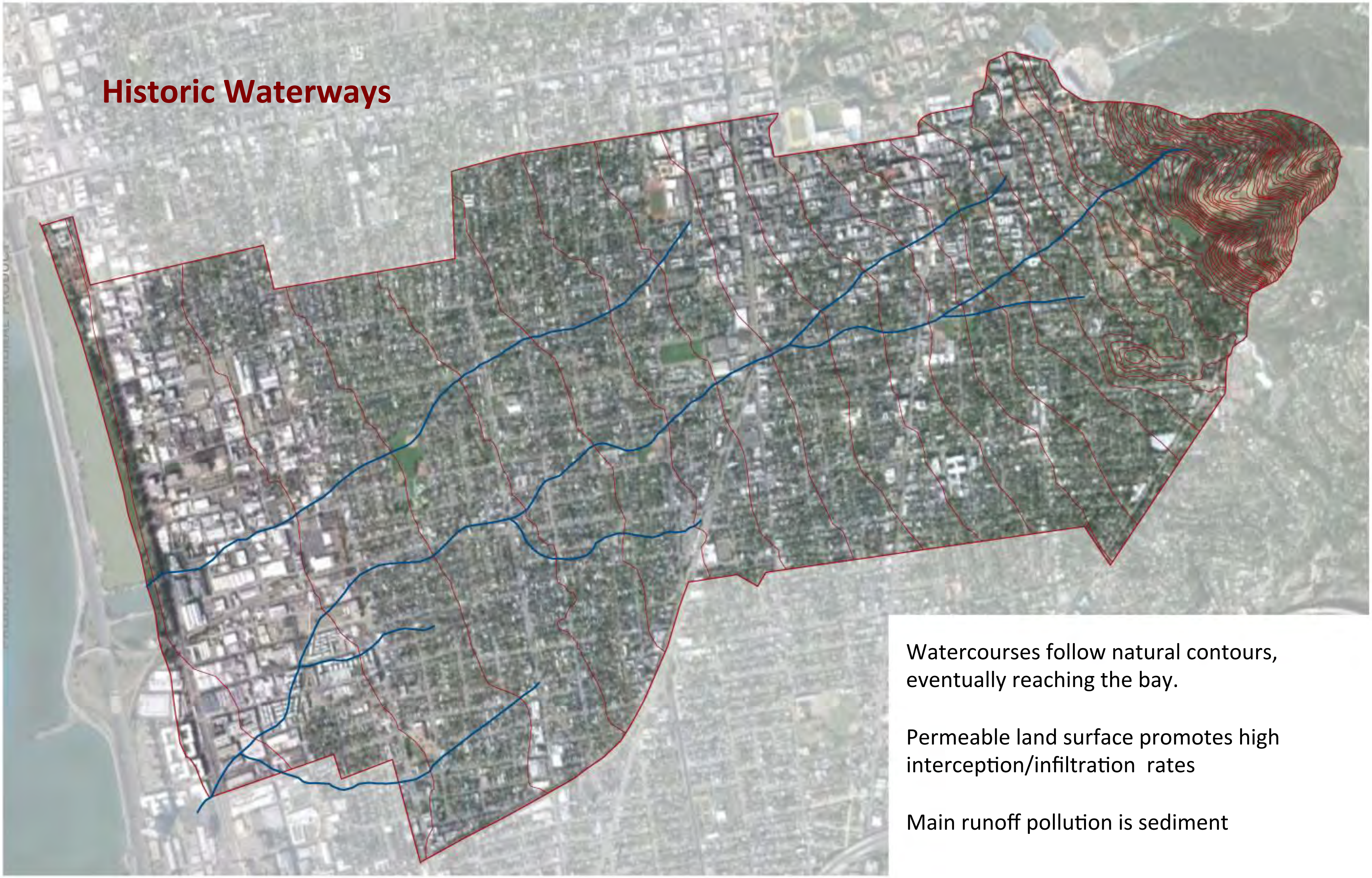


Diagram 2

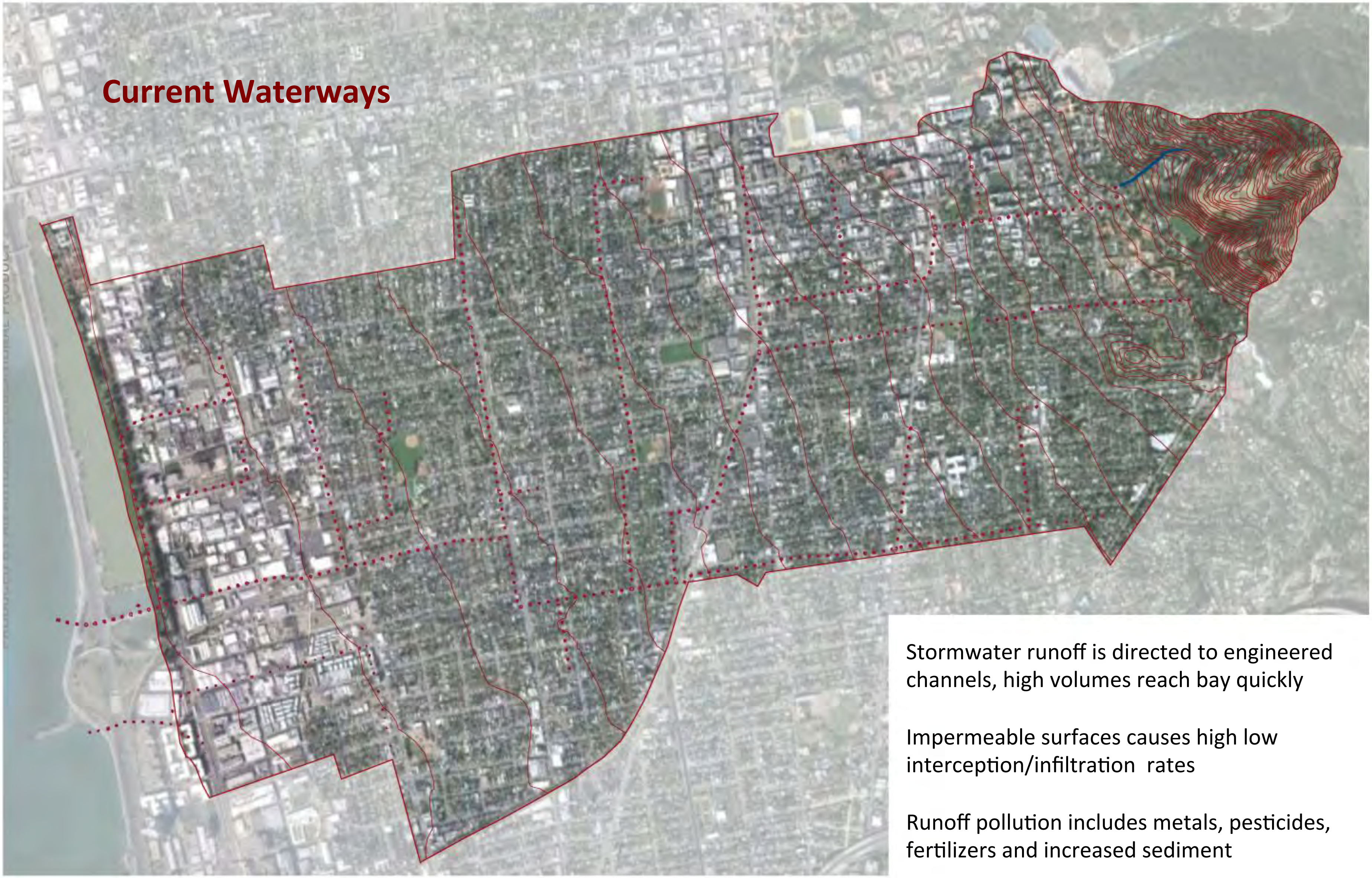


Watercourses follow natural contours, eventually reaching the bay.

Permeable land surface promotes high interception/infiltration rates

Main runoff pollution is sediment

Diagram 3

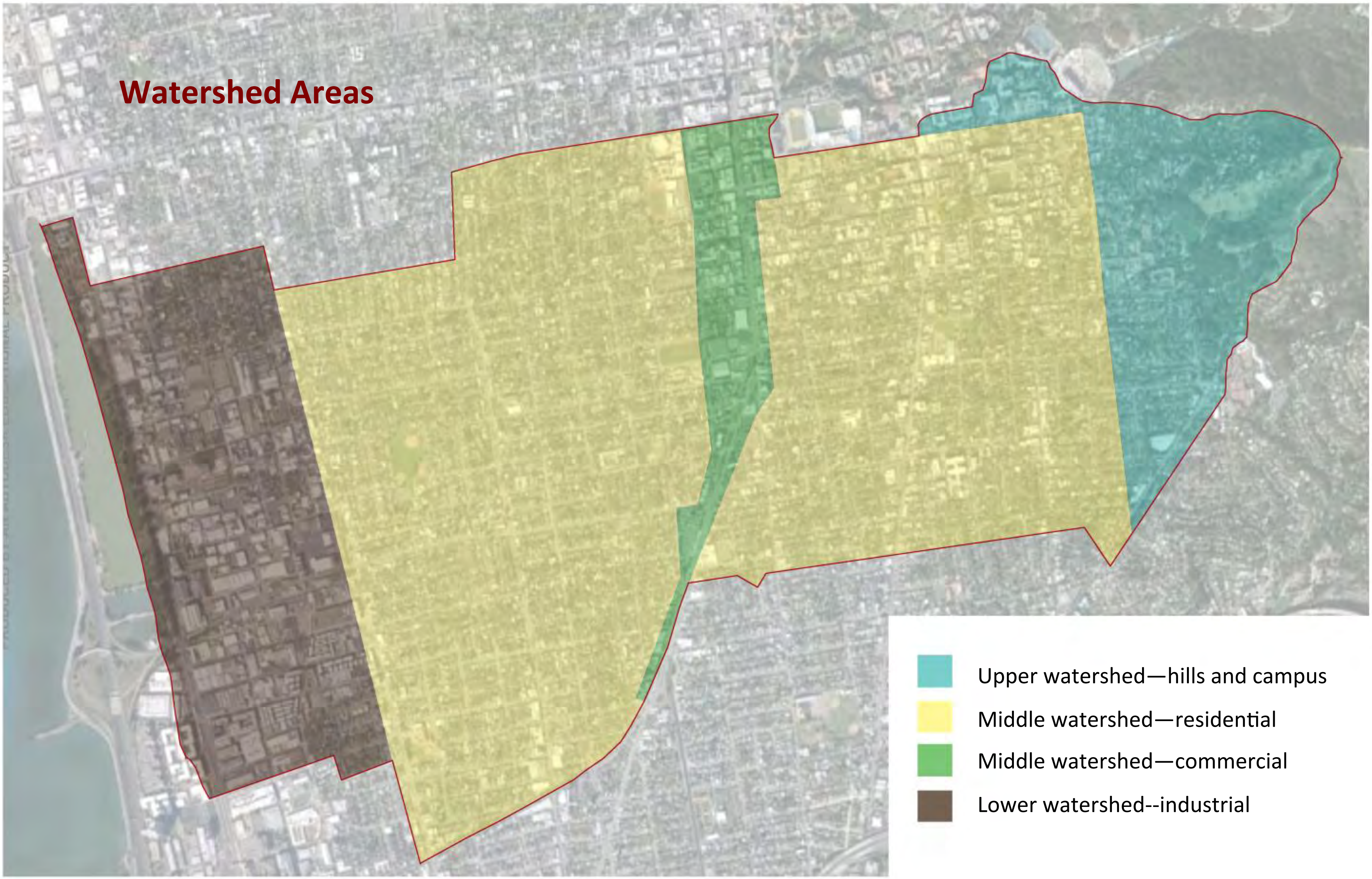


Stormwater runoff is directed to engineered channels, high volumes reach bay quickly

Impermeable surfaces causes high low interception/infiltration rates

Runoff pollution includes metals, pesticides, fertilizers and increased sediment

Diagram 4



Watershed Areas
Upper watershed—hills and campus
Middle watershed—residential
Middle watershed—commercial
Lower watershed--industrial

Diagram 5

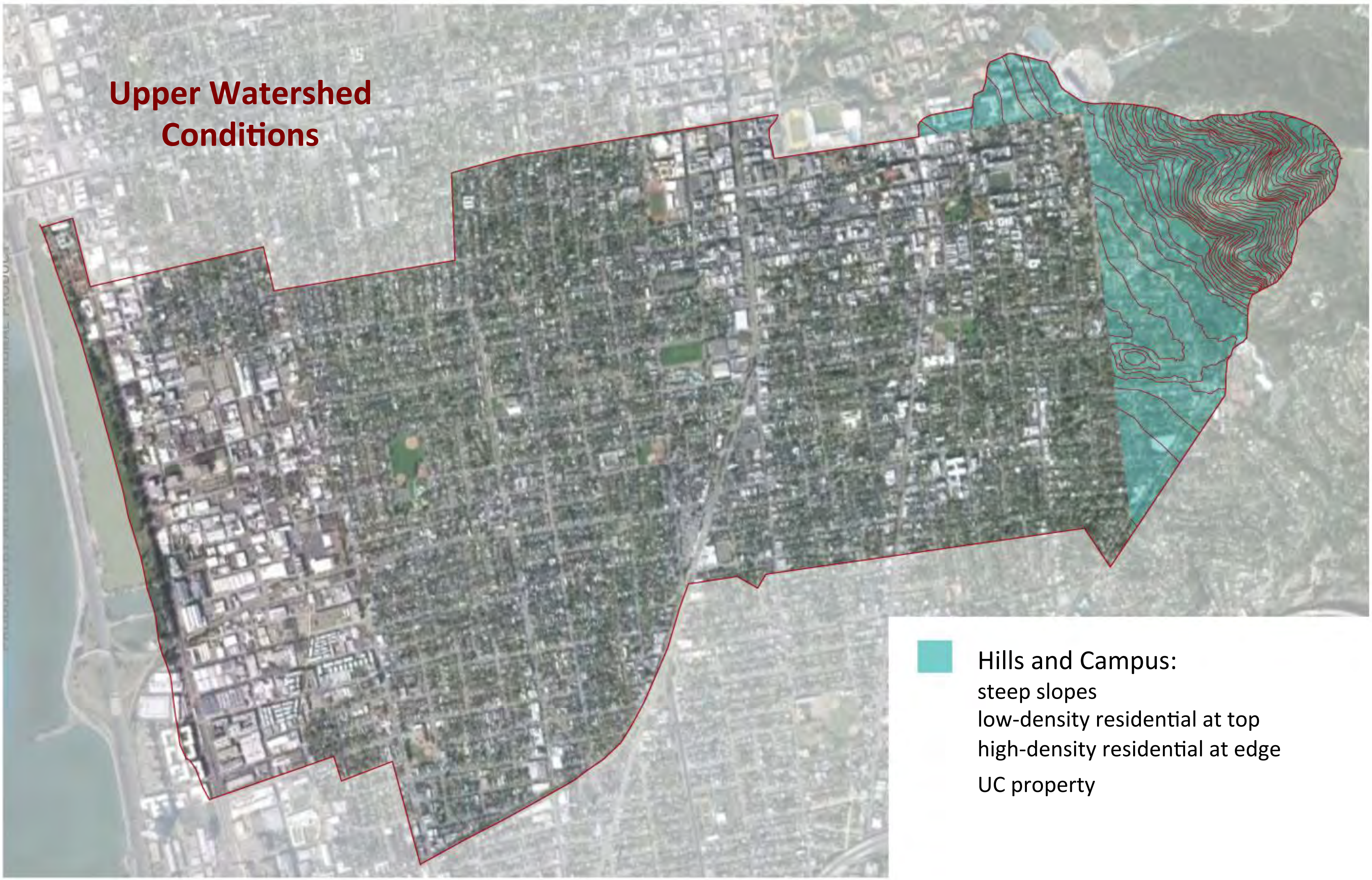
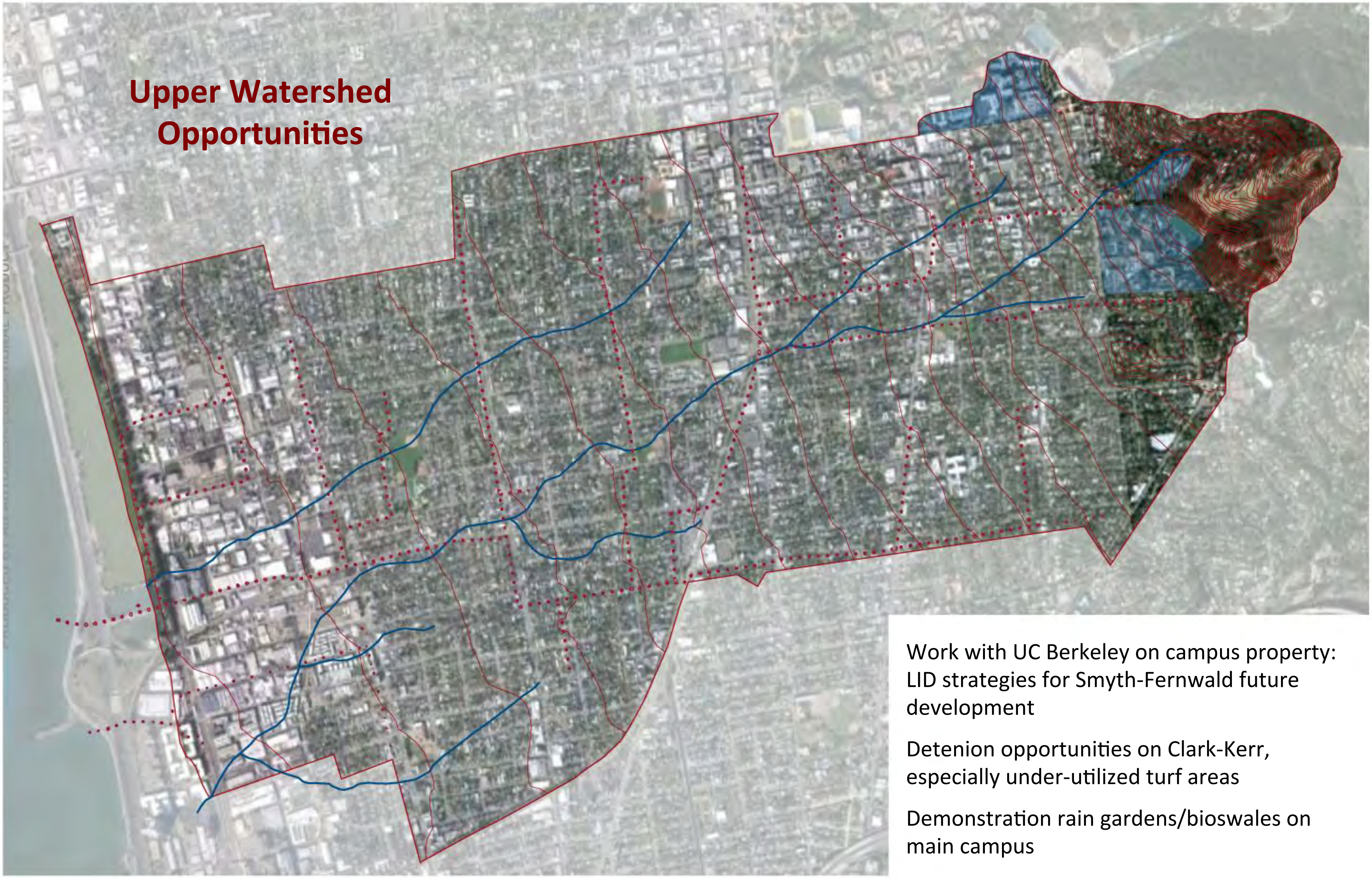

Upper Watershed
Conditions
Hills and Campus:
steep slopes
low-density residential at top
high-density residential at edge
UC property

Diagram 6

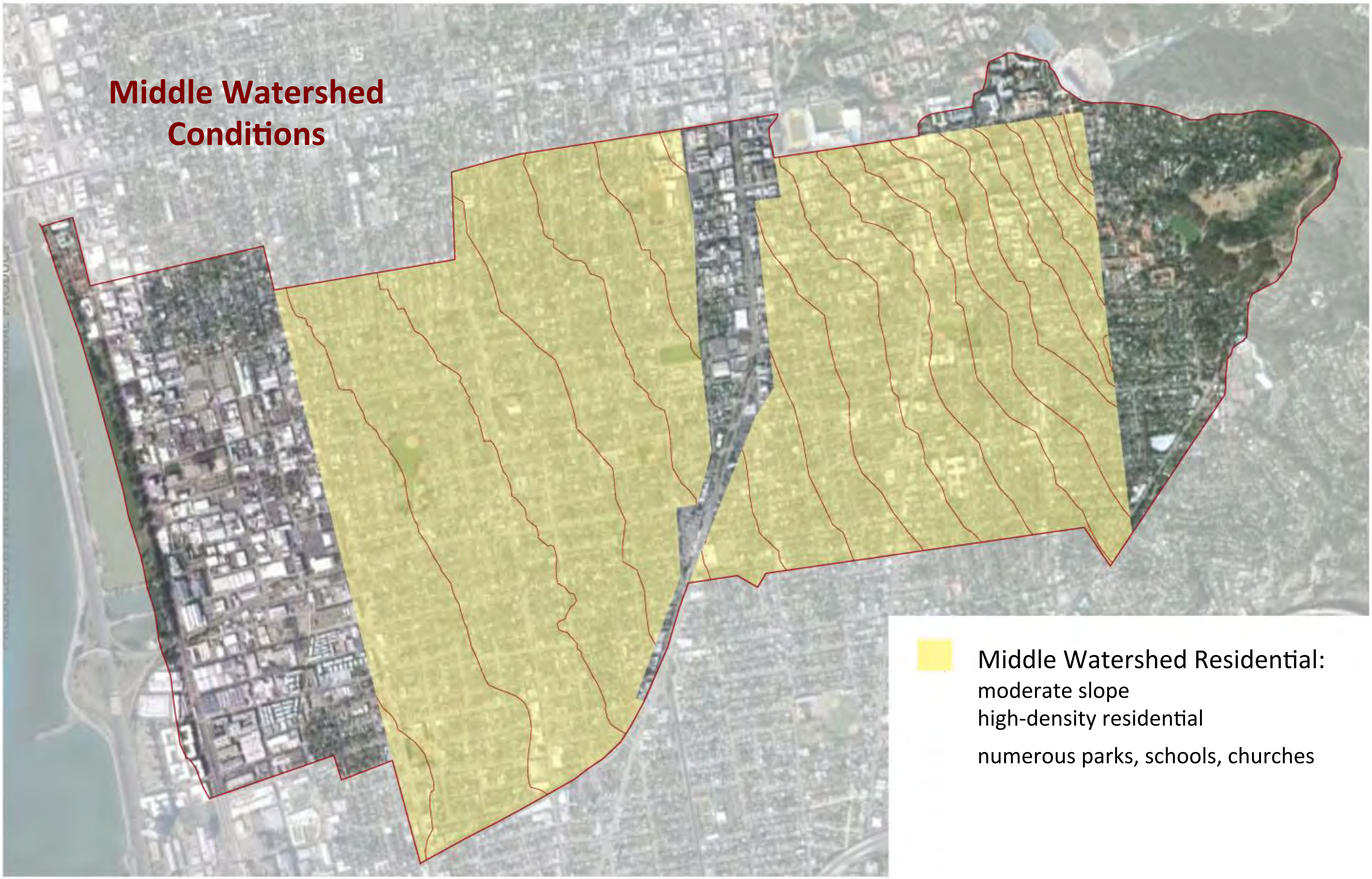


Work with UC Berkeley on campus property: LID strategies for Smyth-Fernwald future development

Detenion opportunities on Clark-Kerr, especially under-utilized turf areas

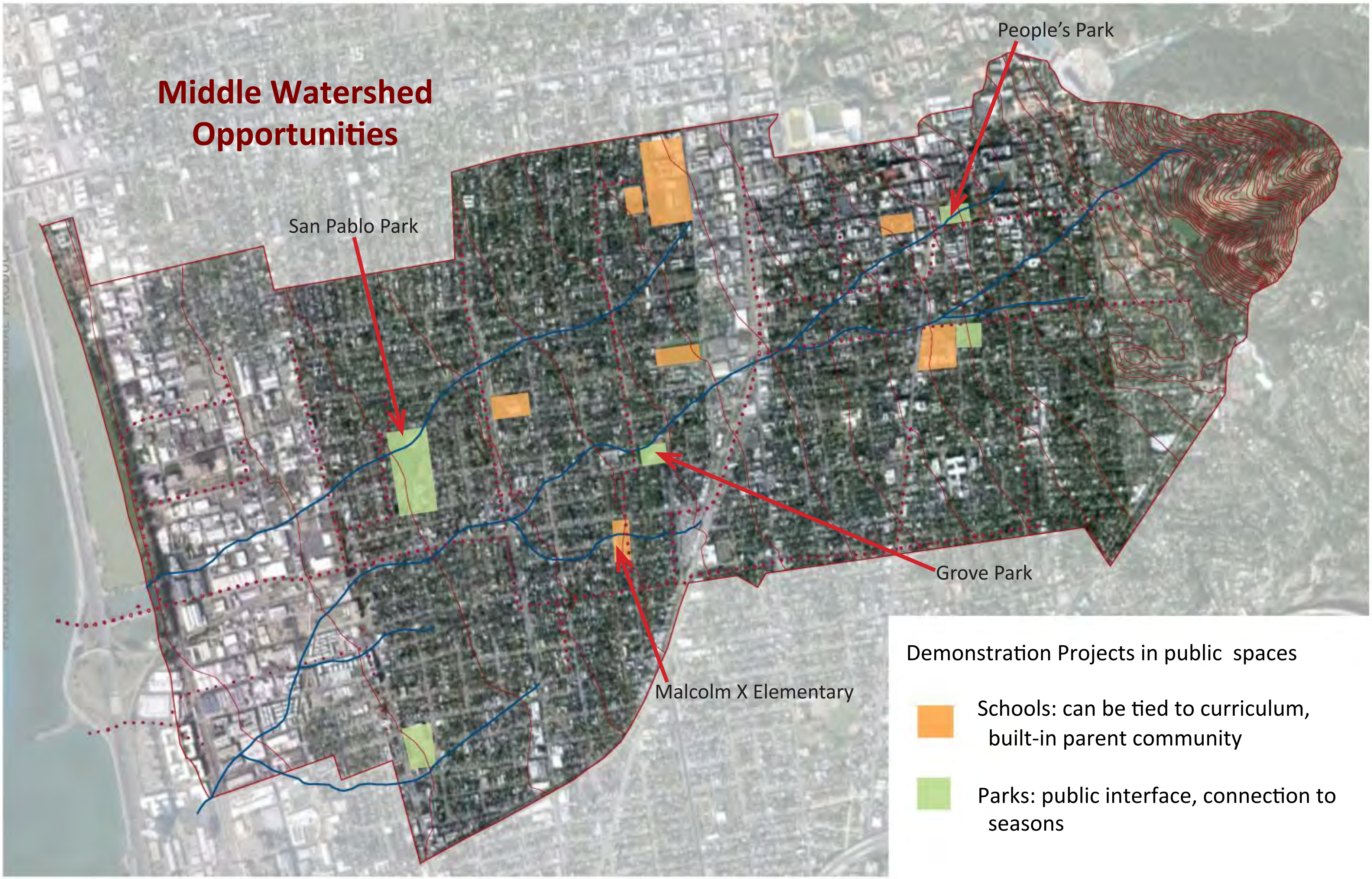
Demonstration rain gardens/bioswales on main campus

Diagram 7



Middle Watershed Conditions
Middle Watershed Residential:
moderate slope
high-density residential
numerous parks, schools, churches

Diagram 8


Middle Watershed
Opportunities
People's Park
San Pablo Park
Grove Park
Malcolm X Elementary
Demonstration Projects in public spaces
Schools: can be tied to curriculum, built-in parent community
Parks: public interface, connection to seasons

Proposed Stormwater Design for LA 222 exercise

Diagram 9

San Pablo Park: Proposed Site Retrofits

- Install bioswales along periphery, behind community center, and along periphery of basketball courts/restrooms

- Lower main baseball fields by 6”, but improve drainage with infiltration base of gravel

- Excavate central turf area by 3.5’ to create seasonal retention pond

- Direct bioswale drains to detention pond instead of storm drain system

- Replace impervious pathways with pervious material and incorporate educational signage

Case Studies of Rain Gardens and Creek Features

Diagram 10

Rain Garden at Tabor Elementary School, Portland

Bioswale at Clevleland Park, South Carolina

Temescal Creek Feature, Oakland

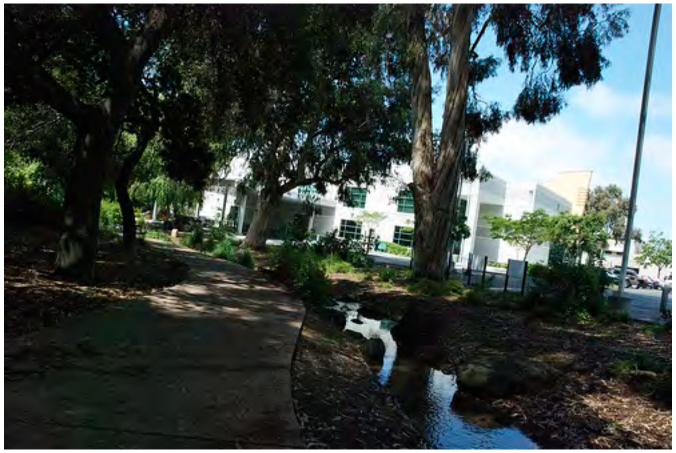


Diagram 11

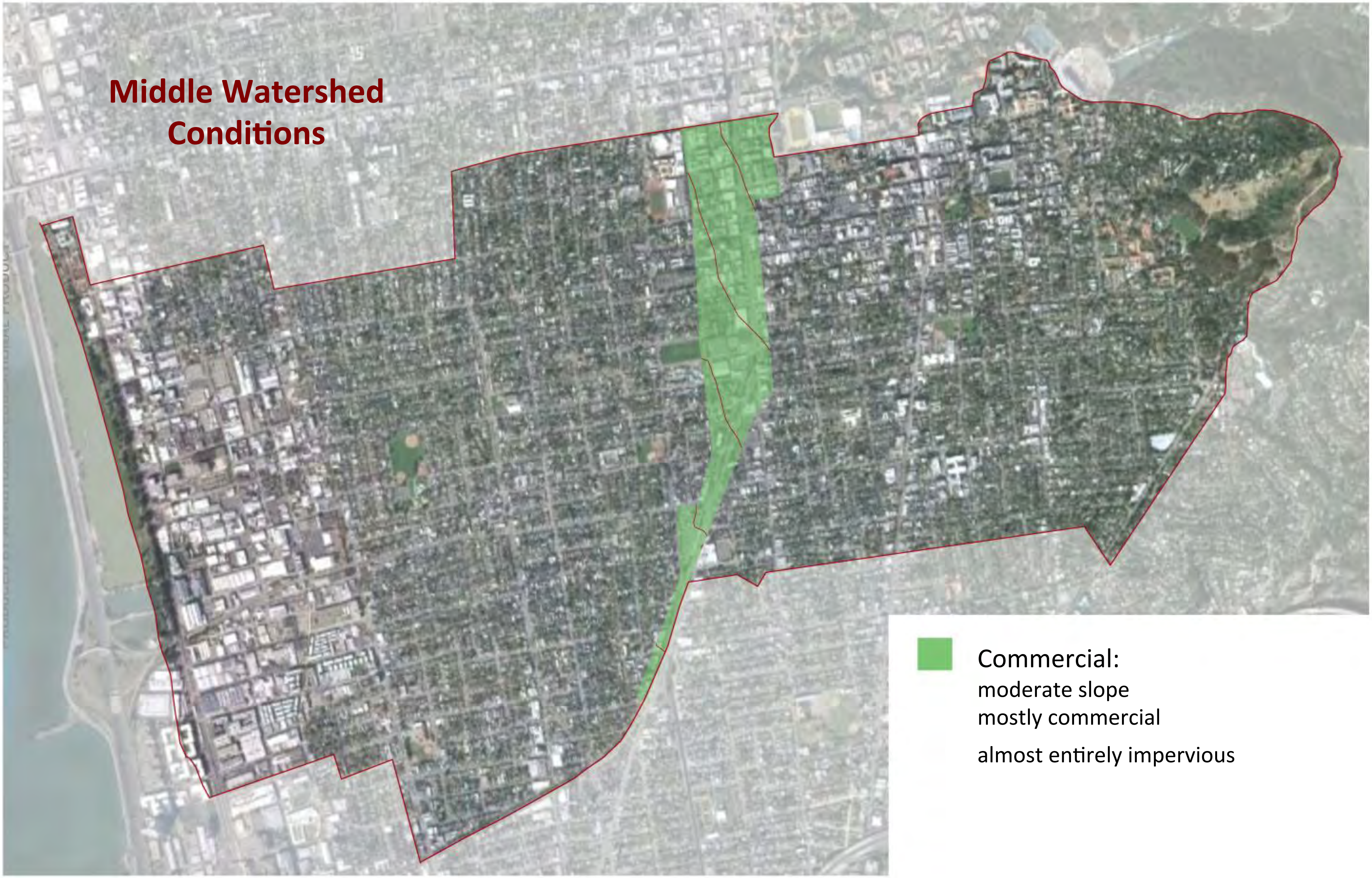
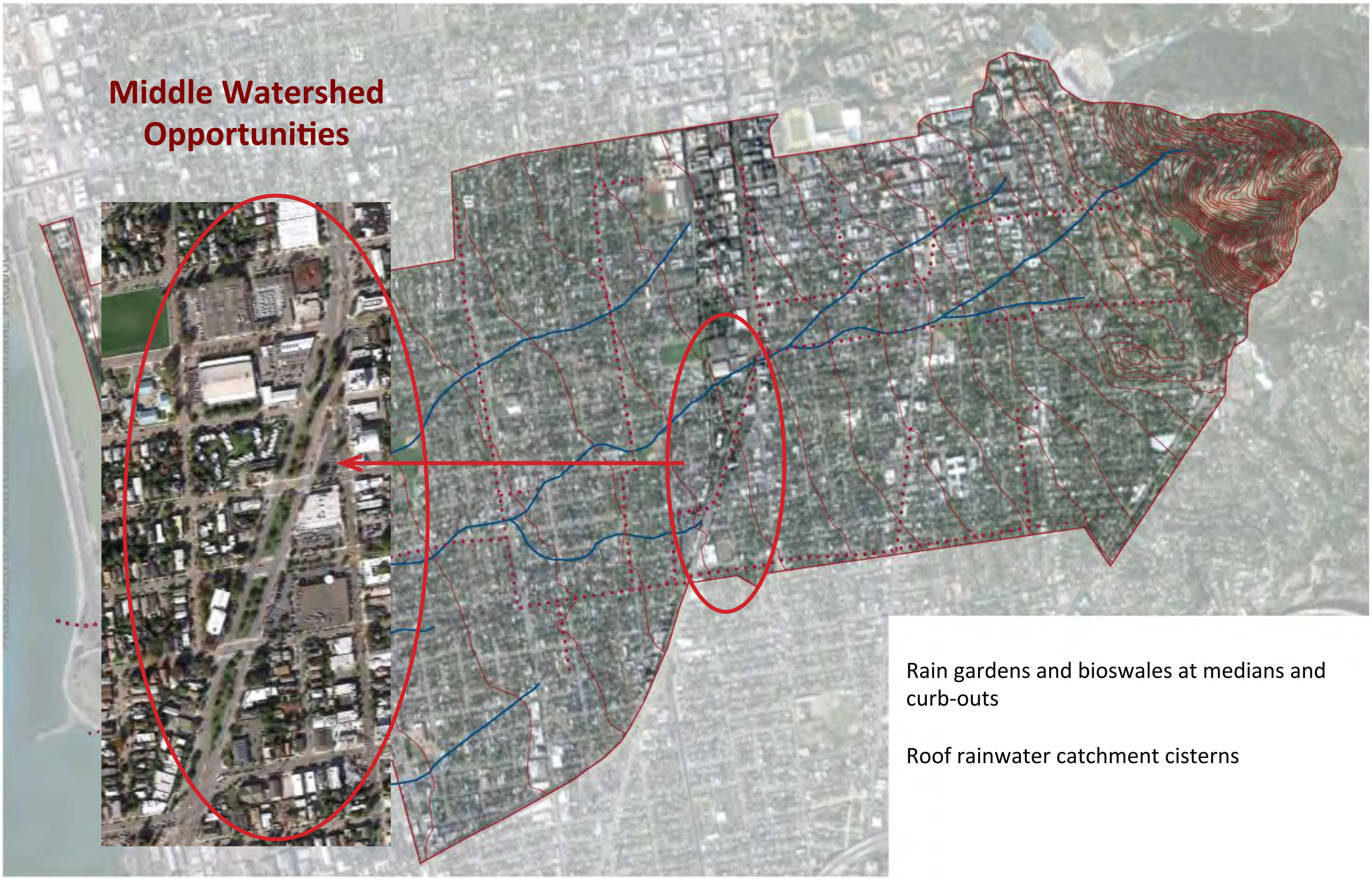

Middle Watershed Conditions
Commercial:
moderate slope
mostly commercial
almost entirely impervious

Diagram 12



Rain gardens and bioswales at medians and curb-outs

Roof rainwater catchment cisterns

Diagram 13

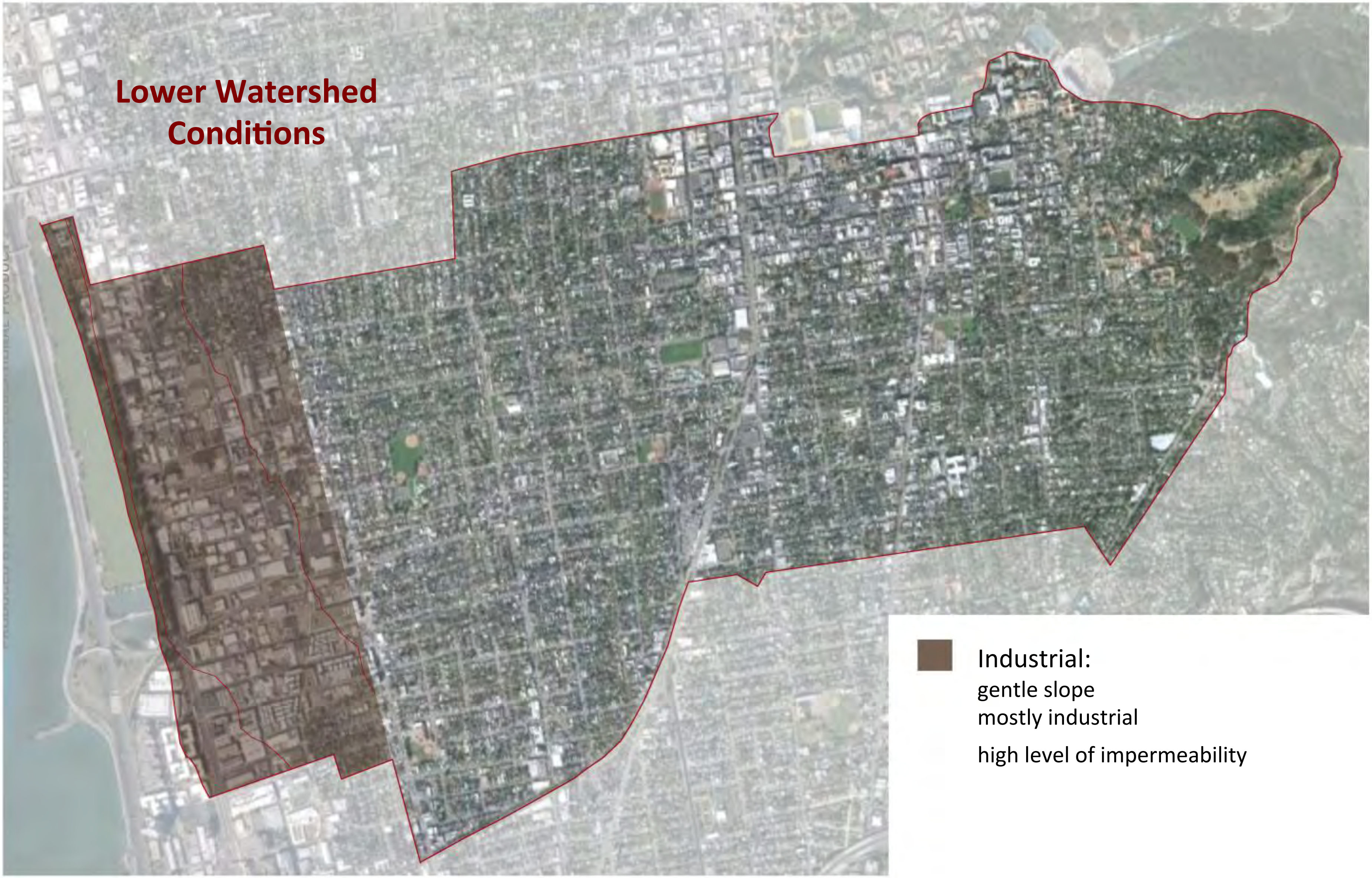
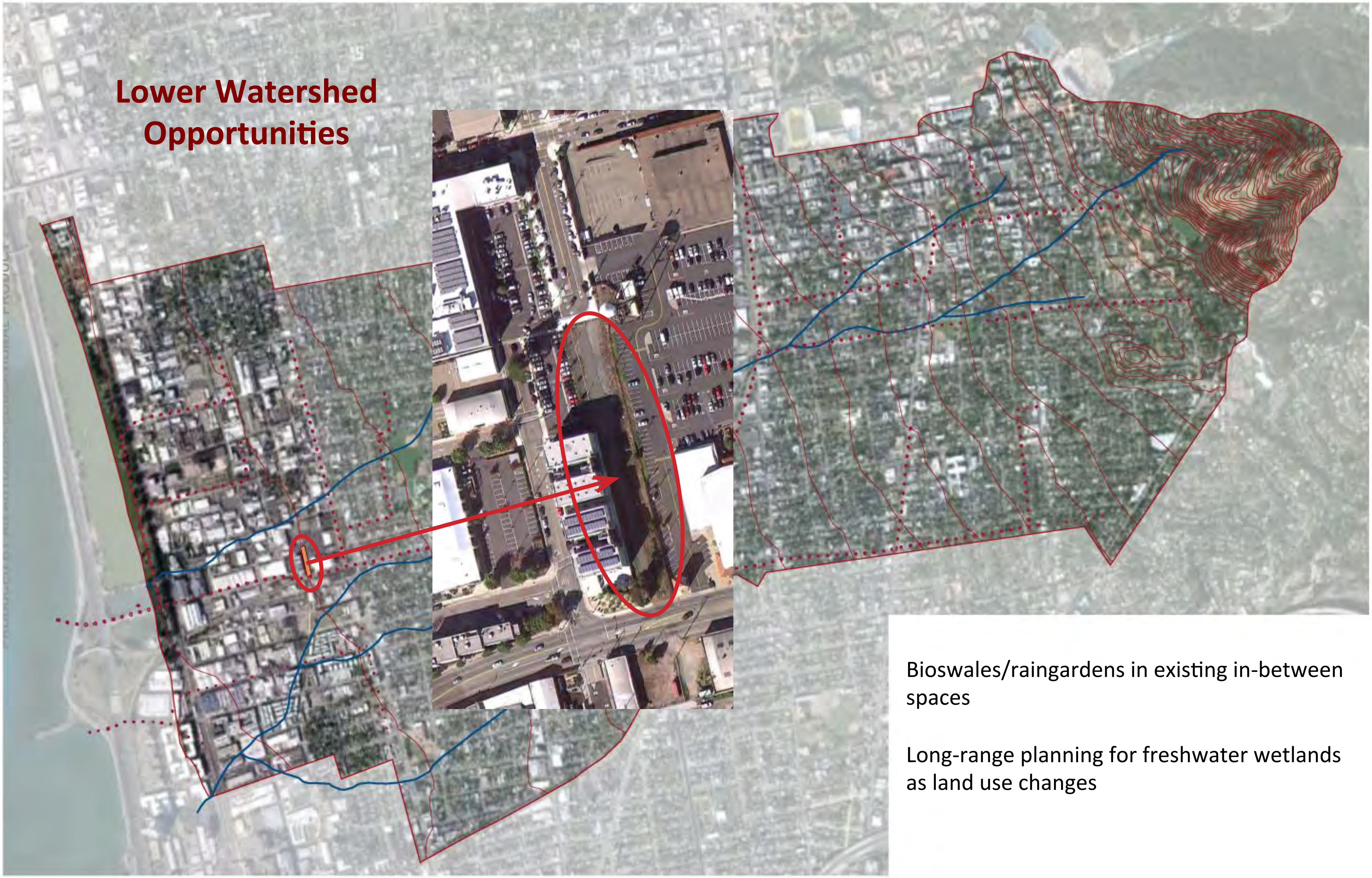

Lower Watershed Conditions
Industrial:
gentle slope
mostly industrial
high level of impermeability

Diagram 14



Bioswales/raingardens in existing in-between spaces

Long-range planning for freshwater wetlands as land use changes