Title
Multiple Objective Stormwater Management For the Coliseum Complex

Authors
Jones, Jesse
Kraai, Rachel

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Jesse Jones and Rachel Kraai
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Abstract

The Coliseum Complex and its associated parking lot create almost four million square feet of continuous impermeable surface. This vast expanse of pavement extends all the way to the edge of two adjacent drainage channels, Damon Slough and Arroyo Viejo Creek. Existing site conditions indicate that the stormwater that falls on this surface runs untreated directly into these adjacent waterbodies. This paper analyzes the site's conditions based on available data and proposes strategic actions and a concept plan for stormwater management. The proposals incorporate both hydrologic and cultural constraints of the site, including the presence of underlying soil contaminants, a planned bicycle and pedestrian path to the north of the site, and the use of the parking lot as a major social gathering spot for cultural groups associated with the sports arena. In addition this paper discusses the regulatory context for this stormwater retrofit as well as mechanisms which could be used to negotiate the redesign of both the Coliseum and similar sites throughout the urban landscape.

Introduction and Problem Statement

The current strategy for managing stormwater at the Oakland Coliseum Complex is the product of outdated problem solving that neglects to consider the environmental impacts of stormwater pollutants on receiving waterbodies. The strategy for managing stormwater on the Coliseum site is emblematic of the "pave it, pipe it paradigm" resulting in over 4 million feet of nearly continuous asphalt and concrete surfaces drained by subsurface storm sewers directly into adjacent creeks and sloughs. Figure 1 shows an aerial view of the site and the surrounding area.

The Coliseum Complex presents daunting issues for environmentally sound stormwater management both due to its large size and multiple site constraints including soil type, shallow groundwater, and contamination issues. This paper investigates stormwater management for a portion of the site and proposes a concept plan incorporating low-impact design strategies with current and future uses. The goals of the proposed treatment controls are multiple-objective; the proposed controls cleanse and slow stormwater, and also serve recreational and aesthetic purposes as well as additional ecological functions. Many of the issues addressed in our research and proposals are common to large parking lots developed prior to stormwater regulations. These sites present critical challenges to efforts to reduce pollutant levels and revitalize urban waterbodies.

Coliseum Complex Footprint

The Coliseum Complex site occupies approximately 4,200,000 square feet (sq ft), of which 4,000,000 sq ft is covered with impermeable surfaces. To put the magnitude of this space into perspective, we compared the site to the Walmart Supercenter located several blocks away on Hegenberger Road. Including the parking lot and surrounding buildings, the Supercenter's footprint is approximately 637,000 sq ft. Over 6½ of these Walmart Supercenters would fit into the Coliseum Complex footprint. Figure 2 presents a visual comparison of these two sites.

Effects of Urban Stormwater Runoff on Waterbody Health

Urban stormwater runoff negatively effects waterbody hydrology and health. Urban waterways experience more extreme surges of runoff as water flows faster and in larger amounts over impervious surfaces, such as roofs, parking lots, and streets, causing increased levels of erosion and downcutting in receiving waterways. (Minick 2004, 2). These stormwater flows also carry high concentrations of contaminants, such as organic compounds from car oils, heavy metals from brake pads and construction materials, pesticides, fertilizers, herbicides, and bacteria from dumpsters. These pollutants can decrease species diversity and impair plant and fish growth (Minick 2004, 2).

Stormwater at the Oakland Coliseum

In addition to organic petroleum compounds and heavy metals from brake pads, stormwater running off the Coliseum parking lot also carries other byproducts caused by regular use of the lot as a community gathering space by sports fans. Pollutants resulting from these day-long tailgating parties include significant amounts of trash (see section below) and potentially other byproducts such as lighter fluid and residue from charcoal and chemical briquettes used in barbequing. Figure 3 shows photographs of oil stains on the parking lot and charcoal disposal cans.

Effects of Trash on Waterbody Health

One of the primary sources of trash in waterways is urban runoff from nearshore areas (SWRCB 2007, 6). Trash moves with runoff across impervious surfaces and through storm sewers to receiving waterbodies, unless it is screened out by coarse metal grates in urban gutters (SWRCB 2007, 6). In addition to the negative visual effects of trash in waterways, trash imparts harm to aquatic and shore wildlife, primarily through entanglement or ingestion of floatable debris. (SWRCB 2007, 2). Entanglement is harmful to wildlife because it can cause wounds that lead to infections and/or loss of limbs, and also cause strangulation, suffocation, drowning, or limited escape from predators (EPA 2002, 1-2). Ingestion can lead to starvation or malnutrition and can damage the mouth, digestive tract and stomach lining. Ingested items can also block air passages resulting in death (EPA 2002, 1-3).

Documented Trash Levels in Damon Slough

In early 2009, the San Francisco Bay Regional Water Quality Control Board staff released a report listing Damon Slough as one of twenty-three Bay Area waterways heavily impacted by trash. In order to make this determination, staff used a Rapid Trash Assessment tool which evaluates waterway impairment based on the impact of trash on non-contact recreation and wildlife habitat (SFBRWQCB 2009b, 8). The tool scored Damon Slough as "poor" in both categories, indicating that levels of trash create a threat to aquatic life and are not supportive of recreational uses (SFBRWQCB 2008). The resulting staff report recommends that Damon Slough be added to the region's 303(d) list of impaired water bodies (SFBRWQCB 2009b, 14). If the slough is approved for 303(d) listing, the State will be required to develop a Total Maximum Daily Load (TMDL) to address the trash impairment. A TMDL would require local agencies to comply with an implementation plan describing how pollution prevention and control will be accomplished and who is responsible for these actions. Save the Bay, a local non-profit, recently listed Damon Slough as one of their "Top 10 Bay Trash Hotspots." On their website they indicate that one of the sources of the trash are sports fans using the Coliseum parking lot. Other possible sources include homeless encampments and upstream deposits (C. Pon, City of Oakland Public Works Agency, personal communication, April 26, 2009). Figure 4 shows photographs of trash in Damon Slough.

Research Approach and Methods

The methods we used to inform our concept plan for stormwater treatment controls can be divided into three sections: 1) research and application of the current regulatory framework for stormwater management to the site; 2) site analysis; and 3) research on design solutions for stormwater retrofits, specifically focusing on implementation and sizing of low-impact design (LID) solutions. After completing these steps we compiled a list of potential strategies and produced a concept plan demonstrating how these strategies could be put in place on site.

Regulatory Context Analysis: To determine the conditions that would require a stormwater retrofit, we consulted the proposed National Pollutant Discharge Elimination System (NPDES) permit for the San Francisco Bay Region (SFBRWQCB 2009a). We also met with Keith Lichten of the San Francisco Bay Regional Water Quality Control Board for advice on current and proposed regulatory standards applicable to the site.

Site Analysis: We visited the site on two occasions to document conditions using photography and hand sketches. We located visible storm drains and estimated existing drainage patterns on the section of the site where we chose to focus our study. To further study site topography, we used spatial contour data from UC Berkeley's Geographic Information Science Center (GISC) to create a triangulated irregular network (TIN). Unfortunately, we were unable to obtain detailed construction documents from the site, and had to make assumptions about change in elevation based on GIS data that does not show the micrograding of the site or detailed contour lines. Future consideration of the strategies proposed in our concept plan need to locate this missing data and incorporate a more detailed study of topography, as it could significantly affect the configuration of the controls proposed. We also used GIS data on Bay Area creeks from the Oakland Museum's website to characterize historic marshland and artificially filled areas. We consulted the California State Water Resources Control Board's GeoTracker website, the California Department of Toxic Substances Envirostor website, and the Alameda County Environmental Health website to locate historical contamination sites in the area. We used aerial photography and ArcMap to determine the total site area and the areas of drainage basins within the site.

To characterize the cultural landscape at the Oakland Coliseum, we consulted a number of fan websites dedicated to Oakland teams. We also watched "Oakland Raider Parking Lot," a film that documents "Raider Nation" behavior on the site.

Design Considerations

For guidance on stormwater design strategies, we consulted the *California State Best Management Practices Handbook* (the "Handbook"), the *Draft San Francisco Stormwater Design Guidelines* from the San Francisco Public Utilities Commission and the Port of San Francisco, and *Green Streets*, a stormwater guidance document developed by Portland Metro Regional Government. We followed sizing requirements for redevelopment sites designated in the proposed Municipal Regional Stormwater NPDES Permit for the San Francisco Bay Region (SFBRWQCB 2009a). We used both volume-based and flow-based approaches to size our treatment controls.

We sized volume based controls using the "Urban Runoff Quality Management Approach" (California Stormwater Quality Association, 2003a, 5-15), one of two volume-based methods specified by the NPDES permit. This sizing methodology corresponds to approximately the 85th percentile runoff event and is dictated by the following equation:

$$P_0 = (a \cdot C) \cdot P_6$$

where P_0 is the maximized detention volume (or volume equal to 85^{th} percentile runoff event), a is regression constant of 1.963 for the 48 hour drawn down level, C is a runoff coefficient (see below), and P_6

is the mean annual runoff-producing rainfall depth. P_6 is calculated from rain gauge data; we used the value of 0.55 inches calculated by the *Handbook* for the Oakland WSO airport location. We used the following calculation from the *Handbook* to calculate C:

$$C = 0.858i^3 - 0.78i^2 + 0.774i + 0.04$$

where C is the runoff coefficient and i is the watershed imperviousness ratio (the percent total imperviousness of the total drainage area divided by 100).

We sized flow based controls using the "California Stormwater BMP Handbook Approach" (California Stormwater Quality Association, 2003a, 5-17). This method estimates flow amounts based on two times the 85th percentile hourly rainfall intensity. Multiplying by two is suggested as a factor of safety. The calculation is based on the Rational Method, which is determined as follows:

$$Q = CiA$$

where Q is the flow (cubic feet/second), C is the runoff coefficient, i is the design rainfall intensity (inches/hour) and A (acres) is the drainage area. C is calculated using the same method applied in the Urban Runoff Quality Management Approach. We used a rain intensity level of 0.1 inches per hour calculated by the Handbook for the Oakland WSO airport location.

Regulatory Context for a Coliseum Stormwater Redesign: Redevelopment Scenario

Stormwater Requirements Under a Redevelopment Scenario

Stormwater pollution is regulated under Section 402(p) of the federal Clean Water Act. The Clean Water Act requires compliance with National Pollutant Discharge Elimination System (NPDES) permits for stormwater discharges from separate municipal storm drain systems, such as the system used in Oakland (SFBRWQCB 2009a). Under Section C.3. of the proposed NPDES permit for the San Francisco Bay Region, Oakland's Coliseum Complex would be required to design and install stormwater treatment systems if relatively minor changes are undertaken on the site. If 10,000 sq ft or more of any impervious surface on the site is redeveloped, the project is required to "implement Low Impact Development management techniques and design and install stormwater treatment systems" that will reduce the discharge of pollutants to the "maximum extent possible" (SFBRWQCB 2009a, 17). While routine maintenance of the parking lot (such as resurfacing or tarring the cracks) does not count as a redevelopment project, any redevelopment that takes the parking lot down to base gravel would require treatment controls for the disturbed area.

In addition, the Coliseum facility is required to design treatment controls to accommodate runoff from the entire existing development site if more than 50% of the impervious surface of the existing project is altered. If less than 50% of the previously existing impervious surface is altered, only runoff from the new and/or replaced impervious surface must be accommodated in the project (SFBRWQCB 2009a, 17).

While we consider it reasonable to assume that the Coliseum Complex will eventually undertake some level of redevelopment project, it is unclear whether the scope of near-term projects would be significant enough to require a retrofit of the entire site. Without a significant redevelopment scenario, the NPDES standards do not require comprehensive treatment of the serious stormwater issues on the site. The next sections of this paper briefly explore a possible mechanism for incentivizing a retrofit, and discuss directions for regulators to look for future innovation in stormwater management policy.

Equivalent Offsite Treatment

Under the NPDES standards, projects which cannot fill their stormwater requirements are allowed to install "equivalent offsite treatment" at an offsite project in the same watershed (SFBRWQCB 2009a, 28). Using this mechanism, the Coliseum parking lot could become an "equivalent offsite treatment" location for a project that has no possibility for onsite stormwater treatment. For example, Caltrans utilizes this option for projects that have limited right-of-way and are unable to manage stormwater repercussions onsite. Caltrans has funded offsite treatment projects in the Pleasanton/Livermore/Dublin area and in Marin County. (K. Lichten, San Francisco Bay Regional Water Quality Control Board, personal communication, April 16, 2009.)

Developing Innovative Policy: The European Water Framework Directive

Planners and regulators should also look across both state and national borders for policy innovations that may be appropriate for inclusion in local standards. One direction to look is the European Union's developing Water Framework Directive. The EU's Water Framework Directive requires that member states and river basin districts achieve "good" ecological and chemical quality status for all waters (surface, underground, and coastal) by 2015 (Kallis and Butler 2001, 129). Article 5 of the Directive requires a characterization of *non-point source discharges* based on land-use activity in order to assess whether waters will achieve appropriate environmental quality standards (Ellis and Revitt, 2008, 577). In addition, Article

16 of the Directive sets limits on the concentrations of 33 priority substances and 8 other pollutants in surface waters (European Commission Directorate-General for the Environment). This list includes several of the contaminants found in urban stormwater runoff. Part of the WFD's potential for innovative stormwater solutions lies in its decentralized implementation structure. While the WFD outlines EU-wide goals for water quality, federal/national level agencies will set strategic directions to meet these goals, and operational implementation in respect to urban drainage will happen primarily at the level of many diverse local municipalities (Ellis et al 2008). This decentralized implementation structure may ultimately result in a wider diversity of stormwater management solutions because of the different countries and regulatory cultures that will be addressing treatment. US policymakers should look to the EU member states for innovative stormwater management policy as the 2015 deadline for achieving "good" ecological and chemical quality status for waterbodies approaches.

Site Analysis: Relevant Soil Information, Hydrology, and Contamination History

To determine the opportunities and constraints for LID stormwater treatment interventions on Coliseum Complex facility grounds, we considered soil type and groundwater levels and also investigated the site for underlying contamination.

Soil and Groundwater Levels

Soil type and groundwater levels on site appear to be unsuitable for infiltration to subsurface soils. Underlying soil is bay fill and drained marsh (Oakland Museum of California GIS) with a likely composition of "silty sand and clayey sand." (Alameda County Health Care Services Agency 2000). The California Stormwater Quality Association's Handbook indicates that infiltration strategies are not appropriate for sites located on fill (California Stormwater Quality Association 2003b, 2). The groundwater levels at the site are also assumed to be high, due to site history as bay marsh and proximity to the San Francisco Bay, reducing the feasibility of interventions relying on deep infiltration.

Contamination History

A contaminant history search using the Alameda County Online Heath Map revealed soil contaminants on the north side of the property from an underground 1000 gallon UL gasoline tank. Although the tank was removed in 1999, an ensuing study showed that 5.8 ppm methyl tertiary butyl ether (MTBE) remain in the soil around the tank, and that 94 ppb gasoline, .54 ppb toluene, 8.0 ppb ethylbenzene, 5.2 ppb xylenes, and 160 ppb MTBE remain in the groundwater beneath a portion of the site (Alameda County Health Care Services Agency 2000). The study determined that the groundwater in the polluted area is traveling at an estimated velocity of .008 ft/day. Based on this velocity and an estimated northeasterly groundwater hydraulic gradient, it would take 300 years for the contaminants to reach a line of supply wells within the Coliseum site. Damon Slough is just beyond this line of wells (Figure 5). Alameda County Environmental Health Care Services Agency determined contamination levels to be low enough to issue a closure letter for the case, indicating that no further remedial action is required.

Despite this closure determination, the presence of these underground contaminants remains a concern in the design of stormwater treatment controls. Controls that depend on infiltration into deeper soils could speed migration of this contaminated groundwater towards the wells and the slough. Based on this information as well as the information on incompatible soil type and groundwater levels, we recommend that stormwater treatment interventions be kept hydraulically separate from the groundwater system. Additionally, further research should be done on the historical uses of the site prior to the Coliseum. Although we were able to find the above contamination information, the Coliseum Complex is located in an area with a history of contaminating industrial uses, and there is a possibility that additional polluting land uses existed prior to the county's record.

Site Analysis: Recreational Uses

Tailgating Parties

The Coliseum Complex is currently used for football games, baseball games, basketball games, and concerts and other major events. During many of these events, the Coliseum parking lot serves as an important community gathering place where residents come together to cook, eat, and share appreciation for the city's sports teams in advance of games. The "Raider Nation" is an especially devout fan group that utilizes the lot before Oakland Raiders football games. People typically drive into the space and set up elaborate "tailgating" communities. We consider this use to be important culturally for the site and believe mitigation of its effects should be incorporated into any retrofit scenario. Figure 6 shows a diagram from the Raiders official website which describes the spatial layout for tailgating. This diagram shows how several feet in each parking space can be used for tables, chairs, and grills. This configuration informed our development of stormwater treatment controls which also accommodate and enhance the tailgating use.

Future Multi-Use Path Along Damon Slough

The Coliseum site is also located along the future site of the proposed Coliseum BART to Bay Trail Connector path, which runs adjacent to the parking lot and Damon Slough, linking the transit center with an important regional recreation destination. Proposals for the path alignment by the Alameda County Department of Public Works are shown in Figure 7 in the appendix. Although the exact alignment of the path has not been determined, future design plans for the area should consider improving the site for this recreational use. Stormwater treatment controls can improve the aesthetic quality of the site both through trash reduction and increasing green recreational space around the slough.

Site Analysis: Current Site Drainage and Stormwater Flows

Due to the size of the Coliseum site and the time limitations of this project, we focused our analysis of drainage flows specifically on the section of the site directly adjacent to Damon Slough. This section includes the northern half of the Coliseum's parking lot and occupies approximately 3,272,327 sq ft. Our observations suggest that the grading creates three separate "drainage management areas" (DMAs) on the site. Figure 8 shows these areas and estimated water flow patterns. Figure 9 shows photographs of existing drains.

We estimate that under existing conditions, stormwater treatment controls for these three DMAs need to accommodate approximately 117,993 cubic feet (882,649 gallons) of runoff using calculations from the *California Stormwater Best Management Practices Handbook*. Calculations for the individual basins are found in Table 1.

Design Toolbox

Based on our research, the primary tools we considered for stormwater management on the site are:

Engineered Liners

Although soil, shallow groundwater and historical contamination on the site significantly limit opportunities for infiltration based strategies, low impact design solutions are still feasible if the stormwater is “hydraulically isolated” from existing soil types and groundwater contamination. The San Francisco Public Utilities Commission and the Port of San Francisco recommend the use of “engineered liners to prevent the mobilization of subsurface contaminants” (CCSF, SFPUC, and PSF 2009a, 62). These impermeable liners must be coupled with a system for subsurface flow. This can be achieved by creating a sloping subsurface to a natural outlet or piping.

Treatment Trains: Swales and Filtration Basins

Since the liner depth limits capacity for vertical infiltration, lateral distribution of treatment is necessary. “Treatment Trains” are stormwater treatment controls installed in a series to increase performance (CCSF, SFPUC, and PSF 2009a, 82). An example of this approach is a swale flowing into a filtration basin or large rain garden. By increasing the treatment area and the type of cleansing, the system is more effective at removing metals, sediments, oils, bacteria, and nutrients. Additionally, treatment basins or rain gardens often require pretreatment by a swale to avoid clogging (CCSF, SFPUC, and PSF 2009b, 8). These systems can also capture trash blown across the site, although regular maintenance will be required to maintain treatment control effectiveness (California Stormwater Quality Association 2003b, 1).

Trees as Stormwater, Trash Mitigation, and Phytoremediation Controls

Trees can provide a multitude of onsite services, including stormwater management, wind breaks preventing trash dispersion, phytoremediation of underlying contaminants, mitigation for the urban heat island effect, and improved aesthetic and recreational value. *Green Streets*, Portland Metro’s handbook for stormwater treatment strategies, indicates that street trees serve important stormwater management functions as they capture rainwater on leaves and trunks, preventing it from reaching the ground and entering storm sewer systems. They also attenuate ground flows (Portland Metro 2002, 17). We hypothesize that tree breaks across the parking lot site could serve as a trash mitigation strategy as they could dissipate the strong easterly winds traveling across the site which currently direct trash towards Damon Slough. Rows of trees could also serve for phytoremediation of underlying contaminants. Edward G. Gatliff of Applied Natural Sciences, Inc. popularized a method of “TreeMediation,” which utilizes phreatophyte species, specifically poplar (*Populus*) and willow (*Salix*) trees, in a process to pump contaminated groundwater up through the tree’s root system into the plant body where it is broken down and stored in a benign form or volatilized (Gatliff 1994). If trees are used for these purposes, additional study should be done to ensure that the amount of water that naturally falls in a tree basin is not beyond the capacity of the trees to absorb, while still mitigating groundwater pollution. The tree basins would also need to be hydraulically isolated from the lined stormwater controls both to make room for tree root growth and so as not to concentrate stormwater in the basins beyond the trees capacity to mitigate.

Concept Plan for Multipurpose Stormwater Management:

After considering the regulatory framework, site conditions, and available design tools, we developed a concept plan for the site, incorporating a set of intervention strategies. The future implementation of this plan would necessarily require further examination of site specifics, however the plan is presented here as a means of stimulating discussion on future site management. The concept plan is presented in Figure 10. This plan reorganizes the study portion of the site into two drainage management areas. These areas are presented in Figure 11 with approximate water flow directions. The calculations of area and estimated runoff are shown in Table 2. The plan incorporates the following strategies:

- *Strategy 1: Create vegetated swales with engineered liners that serve as tailgating spaces during sporting events.*
- *Strategy 2: Create a "Treatment Train" which directs stormwater through swales, and then into filtration basins along the slough for improved treatment of contaminants.*
- *Strategy 3: Filtration basins along the slough also serve to green the area around the channel and increase recreational value for future uses such as the proposed multi-use path.*
- *Strategy 4: Alternate swale basins in parking lot with rows of trees to serve multiple purposes, including stormwater management, phytoremediation, and to improve the visual appearance of the site.*
- *Strategy 5: Increase trash receptacles onsite, incorporating their placement into the new tailgating spaces created by swales.*
- *Strategy 6: Create trash mitigation public education campaign around pride of Raider Nation and other sports teams. Public service announcements during games should highlight improvements to the parking lot and urge use of trash and recycling receptacles.*

Swale Design: Swales in the concept plan are approximately 400 feet long and 12 feet wide. Table 3 shows estimated flow levels and swale sizing calculations. For these calculations, we assumed a water depth of approximately 0.417 feet (5 inches). Construction of the swales would include the excavation of the existing soil to a depth of approximately three feet. A plastic liner would be placed along the bottom of the excavated area and the displaced soil would be replaced with engineered soil and planted with a low grass. To encourage people to use the swale for gathering during tailgating events, the channel would not have the standard trapezoidal design, but rather include a concrete edge and step to bring people down into the swale bed. The step would be approximately 0.66 feet (8 inches) and the grassy swale bed would have a relatively flat bottom. Because of this step down, the swales could accomodate far more water than our design flow. Picnic tables and trash cans could be located within the swale to be used during these events. Figure 12 provides a cross sectional representation of swale design.

Grass Species Selection: We recommend planting swales with a low grass, such as red fescue (*Festuca rubra*). Red fescue grows well in full sun and is drought tolerant. It is also recommended in the SFPUC's Design Guidelines as suitable plant for use in swales (CCSF, SFPUC, and PSF 2009c, 12). Red fescue also creates a lawn-like sensation, which would facilitate use of the space during sporting events.

Filtration Basin Design: The two filtration basins in the concept plan are approximately 50,000 sq ft and 69,000 sq ft. Table 4 shows filtration basin sizing calculations. Construction of the filtration basins would include the excavation of the existing soil to a depth of three feet. A plastic liner would be placed along the bottom of the excavated area. The displaced soil would be replaced with engineered soil with an infiltration rate of 0.5 inches/hour. Outflows at the bottom of the filtration basin would discharge treated water into Damon Slough.

Tree Species Selection: We recommend investigation of planting rows of *Populus fremontii,* commonly known as the Fremont Cottonwood. This tree has a wide canopy that will intercept rainfall, as well as serve as a windbreak, help shade the lot, and mitigate the urban heat island effect. Additionally, species from the *Populus* genus are recommended for phytoremediation.

Conclusion

The Coliseum site presents a complicated myriad of constraints to be considered in the design of ecological stormwater management systems. Bay fill, shallow groundwater levels, underlying contaminants, and a lack of significant slope all severely limit the controls that can be used.

This report outlines the regulatory mechanisms that could be used to impel a stormwater retrofit, as well as a concept plan that could be used to meet these requirements. This report was necessarily limited by the lack of detailed construction documents for the site. This lack of data necessitated assumptions about topography that should be researched before any of these strategies are developed. Further investigation into this missing data could result in significant change to the proposed configurations. We also want to stress that this report sets out a concept plan, and not a specific site design. Any work building upon this project should explore other configurations of these swale/basin systems that could enhance public recreational use of the lot while serving the parking needs of the Complex to the most reasonable extent possible. Additionally, plans could be developed which would phase in these controls in sections, as smaller stormwater retrofits could take place over time. Nonetheless, we consider the strategies presented here to demonstrate an important symbiosis of several current and future uses of the site with appropriate stormwater management controls.

As our review of the NPDES standards indicated, current regulations require sites like the Coliseum Complex to redesign for stormwater in the case of significant redevelopment scenarios, however there is still work to be done to compel these giant sites to manage for stormwater in the absence of these redevelopment scenarios. Our hope is that public agencies, designers, and community members will all take on the challenge of understanding these sites, and develop both the regulatory mechanisms and integrative design solutions that will mitigate the environmental hazards these locations present to urban waterbodies today.

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Figures

Figure 1: Oakland Coliseum in Context

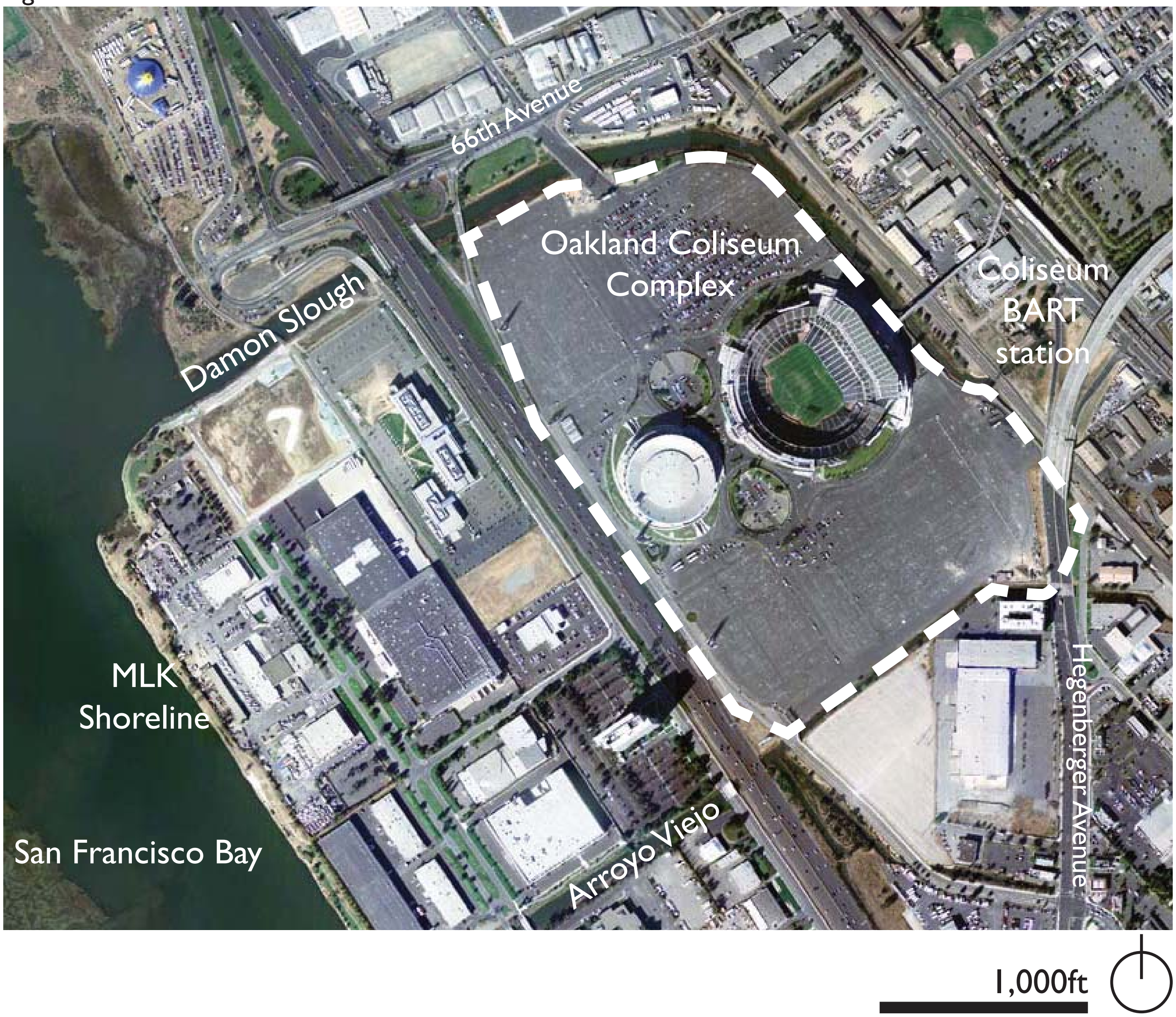
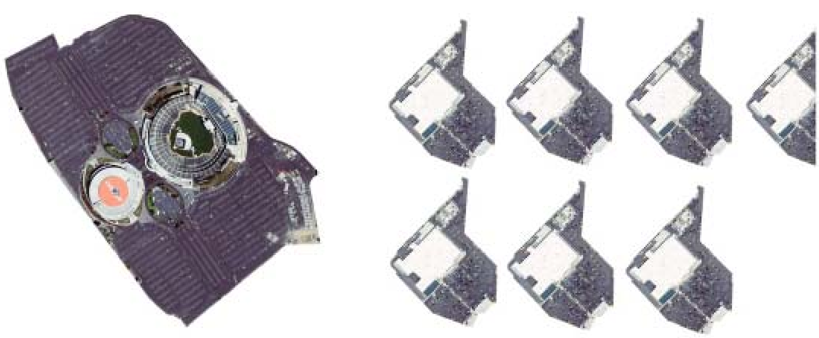


Figure 2: Size Comparison: Oakland Coliseum and Wal-Mart Supercenter



1 Oakland Coliseum = 6.5 Wal-Mart Supercenters

Figure 3: Photographs of Oil Stains and Evidence of Charcoal Use at Oakland Coliseum

Images by authors

Figure 4: Photographs of Trash in Damon Slough

Image from SF Chronicle, 2009

Image from Save the Bay

Figure 5: Proximity of Contamination to Damon Slough

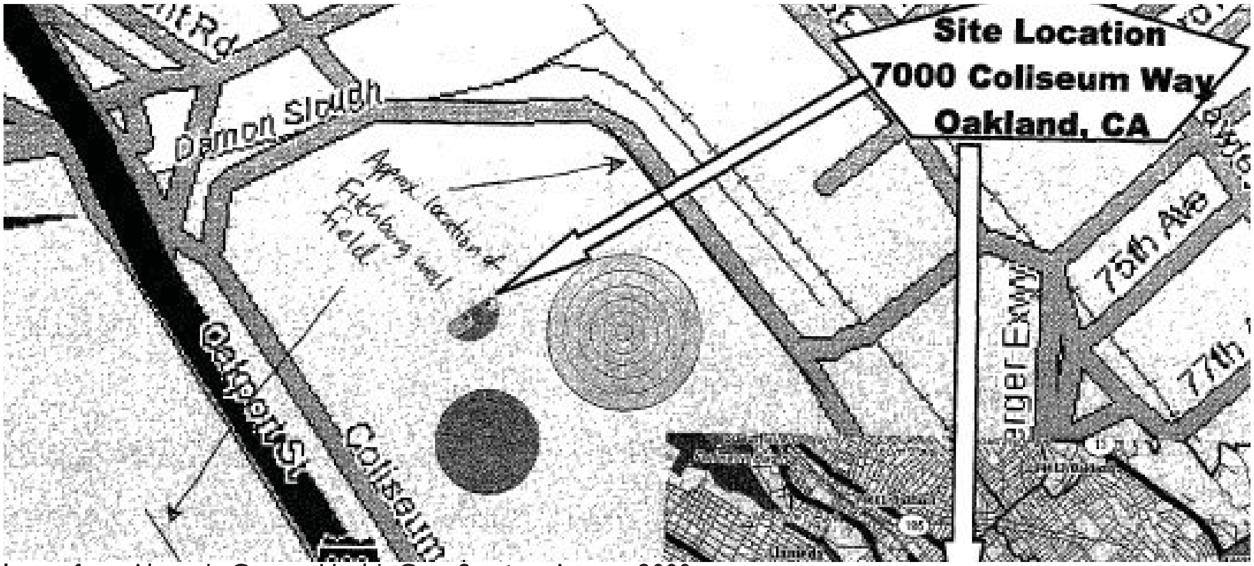


Image from Alameda County Health Care Services Agency, 2000.

Figure 6: Tailgating Protocol at the Oakland Coliseum

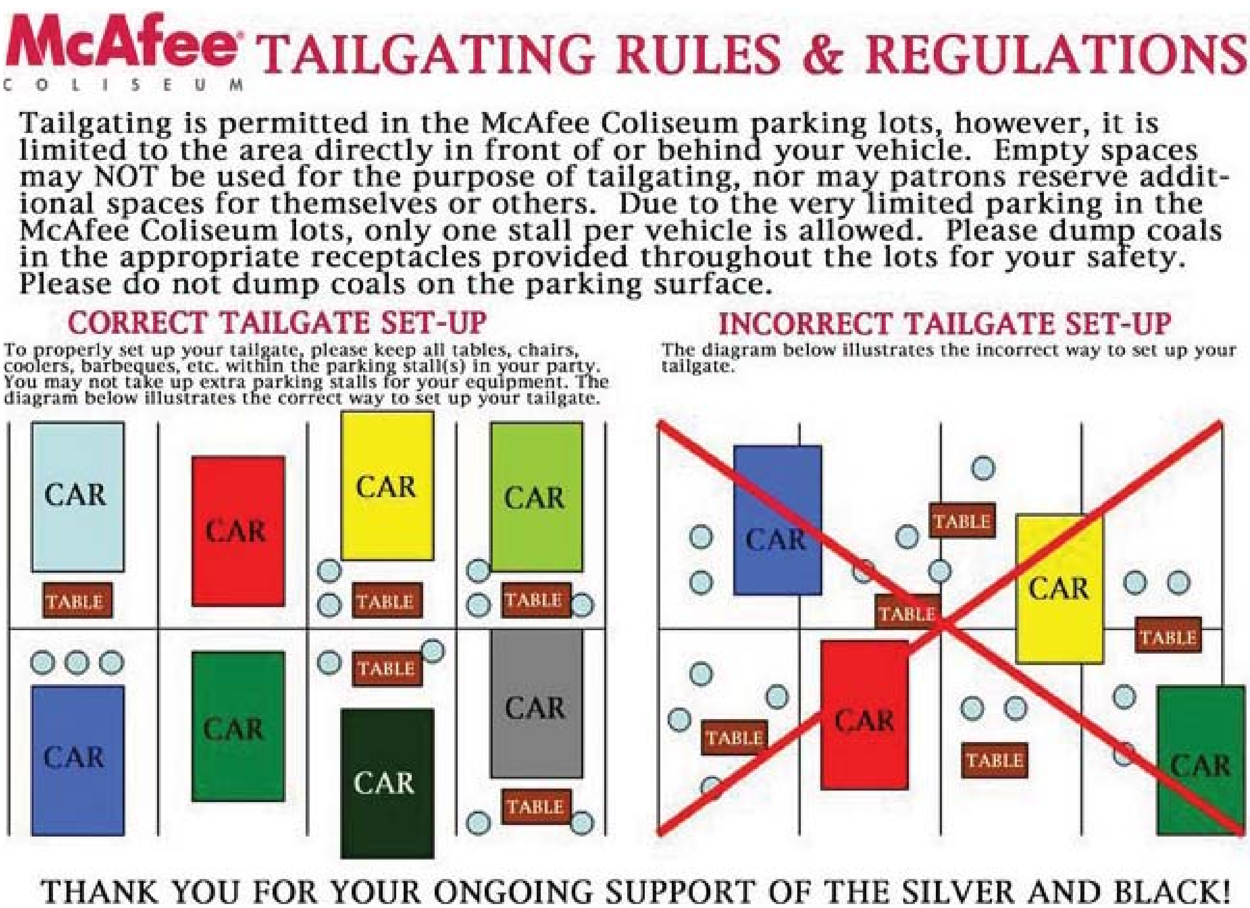


Image from Oakland Raiders Official Website

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Figure 7: Potential Right-of-Way for Coliseum BART to Bay Trail Connector Path

Image from Alameda County Department of Public Works, 2004

Figure 8: Estimated Existing Drainage Management Areas (DMAs) and Flow Directions

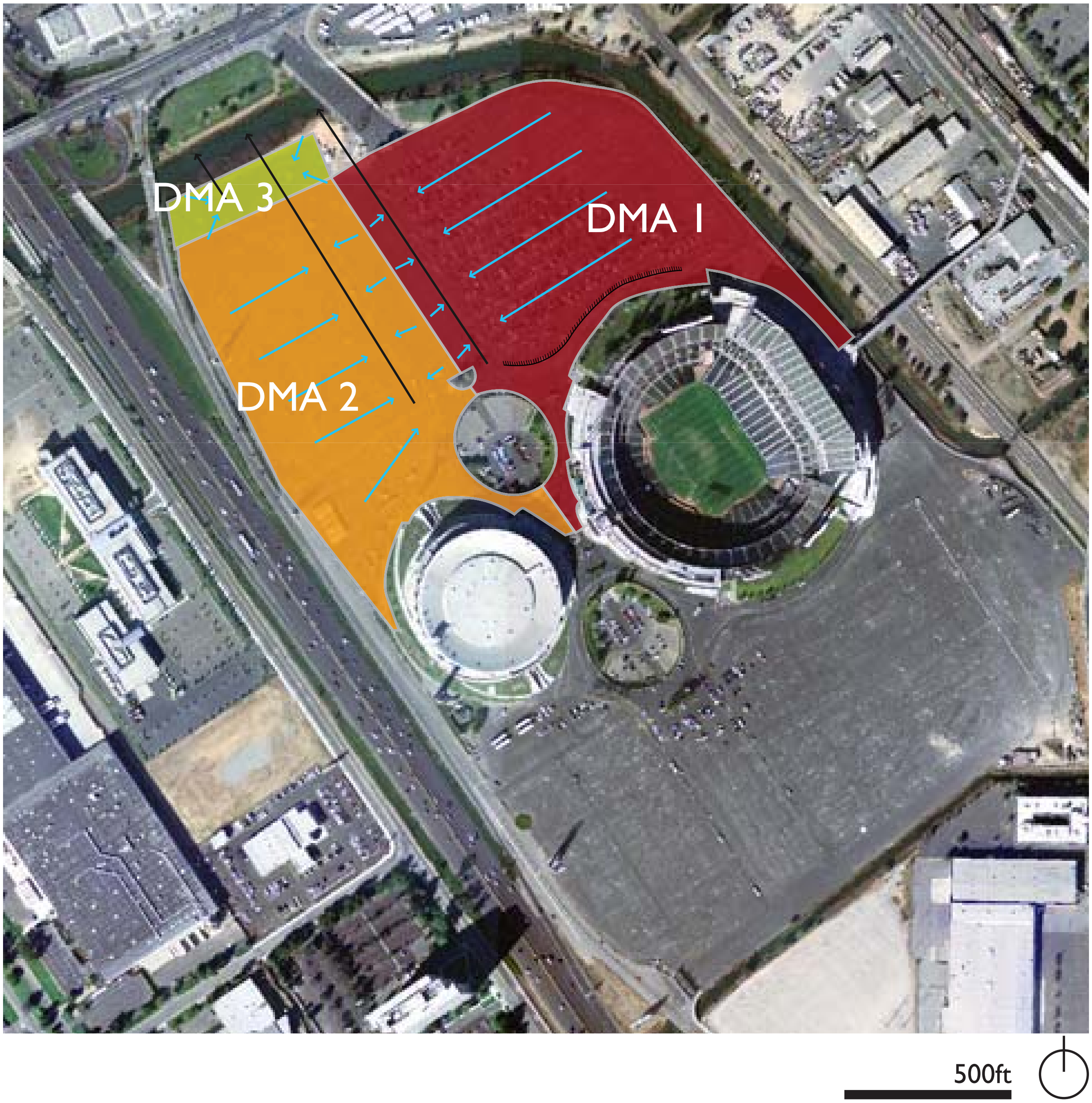


Figure 9: Photographs of Existing Drainage

Images by authors

Figure 10: Conceptual Plan

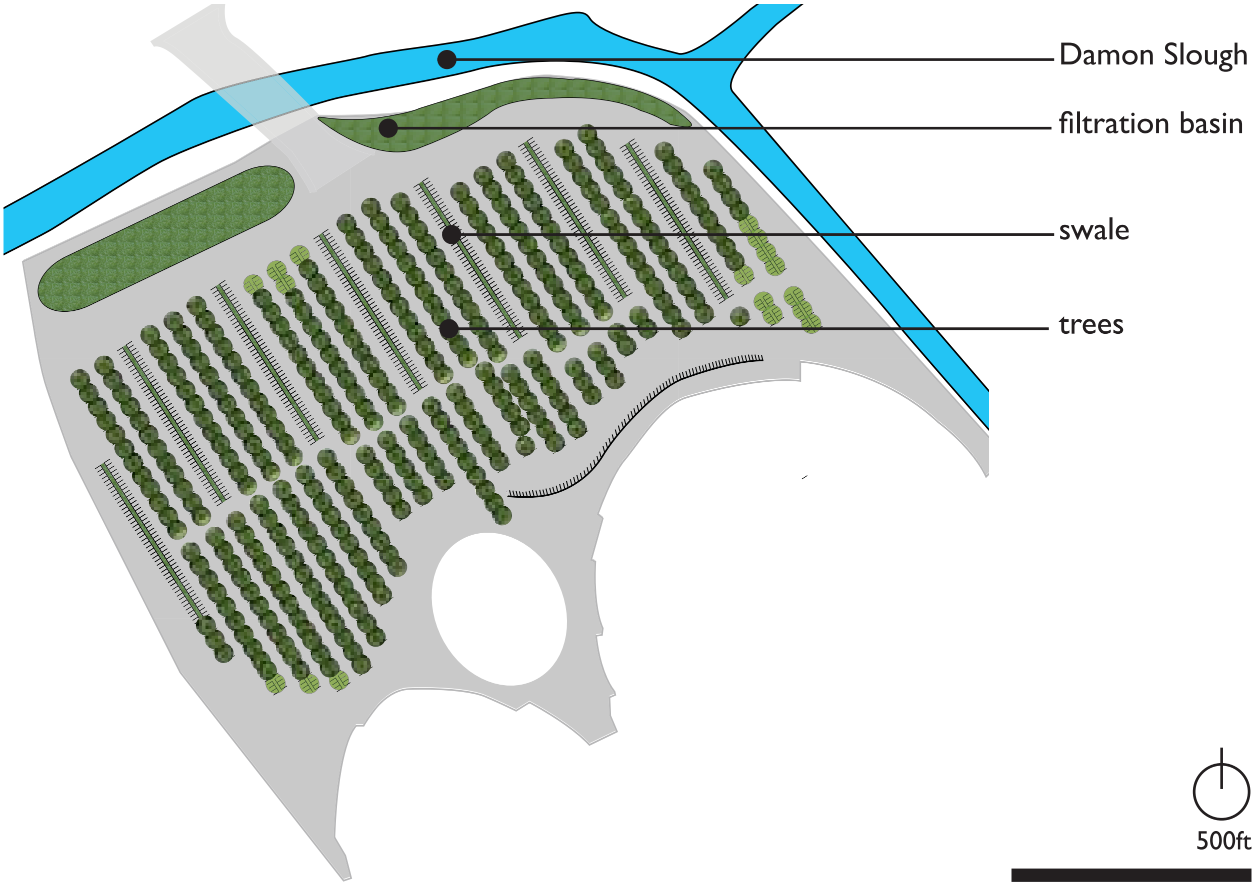


Figure 11: Proposed Drainage Management Areas (DMAs)

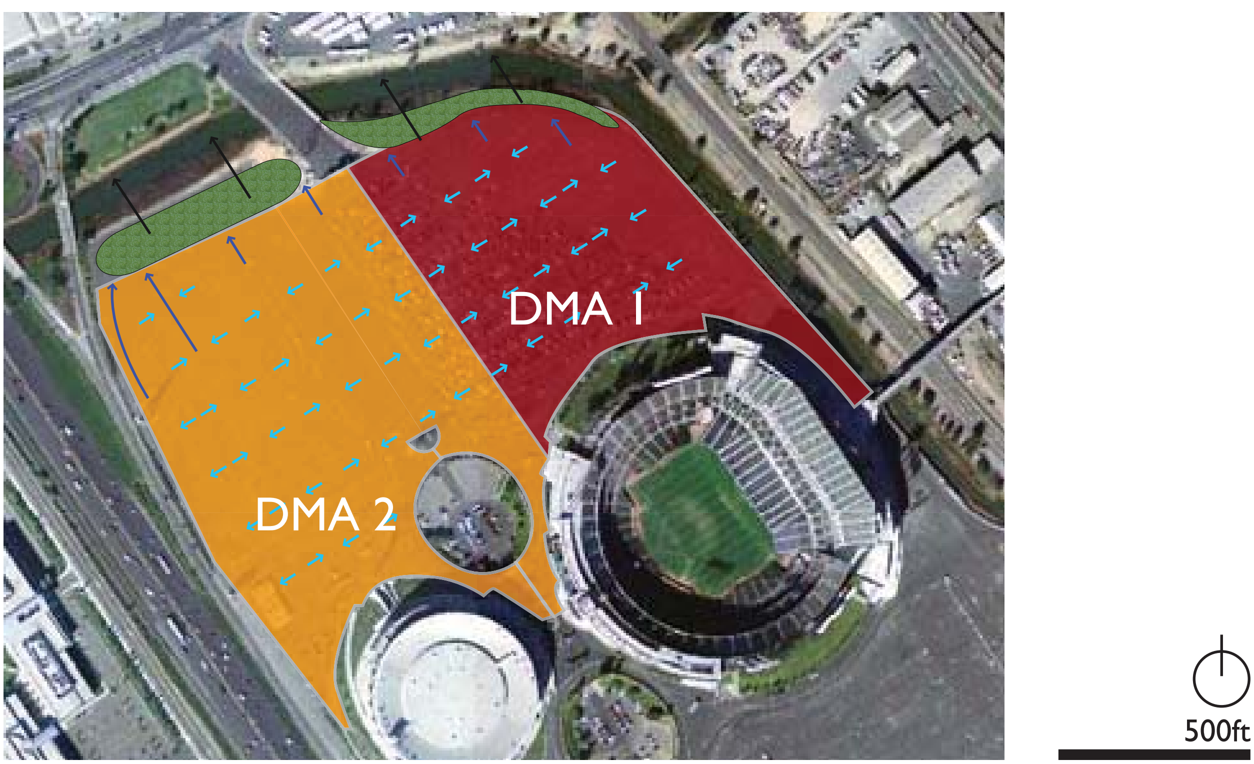
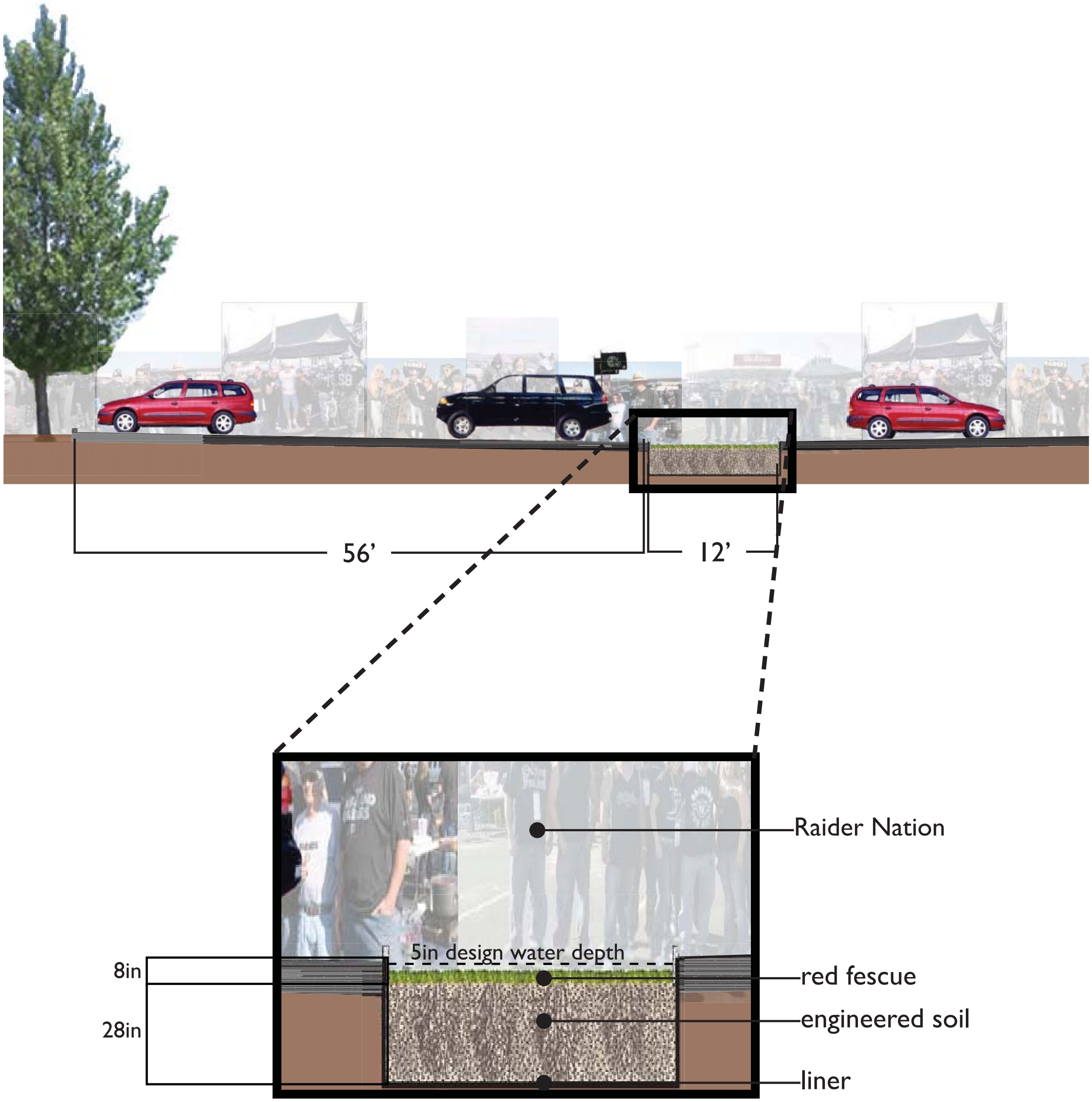


Figure 12: Swale Cross Section



* not to scale

Tables

Table 1: Estimated Existing Conditions

Existing Total Runoff Volume

equation: $V = P_0 A$

V = volume

P_0 = maximized detention volume

A = area

Basin Name	P_0 (feet)	A (feet^2)	**V (feet^3)**
DMA 1	0.08025	773,730.95	**62,094.99**
DMA 2	0.08025	626,975.84	**50,317.31**
DMA 3	0.08025	69,538.49	**5,580.74**

Supplement: Maximized Detention Volume Calculation

equation: $P_0 = (a \cdot C) \cdot P_6$

P_0 = maximized detention volume

a = regression constant for 48 hour draw down

C = runoff coefficient

P_6 = mean annual runoff-producing rainfall depth

a	C	P6 (feet)	**P_0 (feet)**
1.963	0.892	0.0458	**0.08025**

Supplement: Runoff Coefficient Calculation

equation: $C = 0.858i^3 - 0.78i^2 + 0.774i + 0.04$

C = runoff coefficient

i = watershed imperviousness ratio (the percent total imperviousness divided by 100)

i	**C**
1	**0.892**

Table 2: New Drainage Management Areas

New Total Runoff Volume

equation: $V = P_0 A$

V = volume

P_0 = maximized detention volume

A = area

Name	P_0 (feet)	A (feet^2)	**V (feet^3)**
DMA 1	0.06523	627,298.21	**40,920.01**
DMA 2	0.06523	886,408.58	**57,822.34**

Supplement: Maximized Detention Volume Calculation

equation: $P_0 = (a \cdot C) \cdot P_6$

P_0 = maximized detention volume

a = regression constant for 48 hour draw down

C = runoff coefficient

P_6 = mean annual runoff-producing rainfall depth

a	C	P6 (feet)	**P_0 (feet)**
1.963	0.73	0.0458	**0.06523**

Supplement: Runoff Coefficient Calculation

equation: $C = 0.858i^3 - 0.78i^2 + 0.774i + 0.04$

C = runoff coefficient

i = watershed imperviousness ratio (the percent total imperviousness divided by 100)

Name	i	**C**
DMA 1	0.90	**0.73**
DMA 2	0.90	**0.73**

Table 2 con't

Supplement: Drainage Management Cover Breakdown

Drainage Management Area 1

Feature	Area	Percentage of Total Area	Cover Material	Cover Factor*
parking lot	562,298	90%	asphalt	0.8
filtration basin 1	47,000	7%	landscaping	0.2
swale 1	6,000	1%	lawns and grass; sandy soil, slope <2%	0.08
swale 2	6,000	1%	lawns and grass; sandy soil, slope <2%	0.08
swale 3	6,000	1%	lawns and grass; sandy soil, slope <2%	0.08

Drainage Management Area 2

Feature	Area	Percentage of Total Area	Cover Material	Cover Factor*
parking lot	796,409	90%	asphalt	0.8
filtration basin 2	66,000	7%	landscaping	0.2
swale 4	6,000	1%	lawns and grass; sandy soil, slope <2%	0.08
swale 5	6,000	1%	lawns and grass; sandy soil, slope <2%	0.08
swale 6	6,000	1%	lawns and grass; sandy soil, slope <2%	0.08
swale 7	6,000	1%	lawns and grass; sandy soil, slope <2%	0.08

* Cover factor from CCSF, SFPUC, and PSF, 2009, p 87.

Table 3: Swale Sizing Calculations

BMP Sizing for Vegetated Swales (Flow-Based Sizing)

using California Stormwater BMP Handbook Approach (incorporates the Rational Method)

equation: Q =C(i*S)A

Q = flow

C = composite runoff coefficient
(asphalt)

i = rainfall intensity

S = safety factor

A = drainage area

Name	C	i (in/hr)	S	A (acres)	**Q (cfs)**
DMA1					
Sub-DMA A	0.85	0.1	2	4.44	**0.75**
Sub-DMA B	0.85	0.1	2	4.44	**0.75**
Sub-DMA C	0.85	0.1	2	4.44	**0.75**
DMA 2					
Sub-DMA D	0.85	0.1	2	4.71	**0.80**
Sub-DMA E	0.85	0.1	2	4.71	**0.80**
Sub-DMA F	0.85	0.1	2	4.71	**0.80**
Sub-DMA G	0.85	0.1	2	4.71	**0.80**

Table 3 con't

Supplement: Runoff Coefficient Calculation

equation: $C = 0.858i^3 - 0.78i^2 + 0.774i + 0.04$

C = runoff coefficient

i = watershed imperviousness ratio (the percent total imperviousness divided by 100)

Name	i	**C**
DMA 1		
Sub-DMAs	0.975	**0.85**
DMA 2		
Sub-DMAs	0.977	**0.85**

Supplement: Drainage Management Cover Breakdown

Sub-Drainage Management Areas in DMA 1

Feature	Area	Percentage of Total Area	Cover Material	Cover Factor*
parking lot	188,633	97.5%	asphalt	0.8
swale	4,800	2.5%	lawns and grass; sandy soil, slope <2%	0.08

Supplement: Drainage Management Cover Breakdown

Sub-Drainage Management Areas in DMA 2

Feature	Area	Percentage of Total Area	Cover Material	Cover Factor*
parking lot	200,302	97.7%	asphalt	0.8
swale	4,800	2.3%	lawns and grass; sandy soil, slope <2%	0.08

* Cover factor from CCSF, SFPUC, and PSF, 2009, p 87.

Table 3 con't

Designed Flow Capacity for Vegetated Swales

equation: $Q = VA$

Q = flow

V = velocity

A = channel area

Name	V	A (square feet)	**Q (cfs)**	**Q needs**
swale 1	0.22	5.0	**1.12**	**0.75**
swale 2	0.22	5.0	**1.12**	**0.75**
swale 3	0.22	5.0	**1.12**	**0.75**
swale 4	0.22	5.0	**1.12**	**0.80**
swale 5	0.22	5.0	**1.12**	**0.80**
swale 6	0.22	5.0	**1.12**	**0.80**
swale 7	0.22	5.0	**1.12**	**0.80**

Supplement: Velocity Calculation using Manning's Equation

equation: $V = c(s^{0.5}\ R\ 0^{.67}) / n$

V = velocity

c = coefficient 1.49

s = slope

R = hydraulic radius

n = Manning's roughness coefficient (0.25 as per CA Stormwater BMP Handbook)

DMA 1

feature	c	s	R	n	**V**
swale 1	1.49	0.005	0.39	0.25	**0.22**
swale 2	1.49	0.005	0.39	0.25	**0.22**
swale 3	1.49	0.005	0.39	0.25	**0.22**

DMA 2

feature	c	s	R	n	**V**
swale 4	1.49	0.005	0.39	0.25	**0.22**
swale 5	1.49	0.005	0.39	0.25	**0.22**
swale 6	1.49	0.005	0.39	0.25	**0.22**
swale 7	1.49	0.005	0.39	0.25	**0.22**

Table 3 con't

Supplement: Hydraulic Radius Calculation

equation: hydraulic radius = cross sectional area/wetted perimeter

DMA 1

feature	W (feet)	depth (feet)	**cross sectional area (square feet)**	**wetted perimeter (feet)**	**hydraulic radius (feet)**
swale 1	12	0.417	**5**	**12.8**	**0.39**
swale 2	12	0.417	**5**	**12.8**	**0.39**
swale 3	12	0.417	**5**	**12.8**	**0.39**

DMA 2

feature	W (feet)	depth (feet)	**cross sectional area (square feet)**	**wetted perimeter (feet)**	**hydraulic radius (feet)**
swale 4	12	0.417	**5**	**12.8**	**0.39**
swale 5	12	0.417	**5**	**12.8**	**0.39**
swale 6	12	0.417	**5**	**12.8**	**0.39**
swale 7	12	0.417	**5**	**12.8**	**0.39**

Estimate of Longitudal Drop of Swales

equation: longtitudal drop = l*s

l = length (assume approx 400 feet for all swales)

s = slope (0.5%)

	L (feet)	S (percent)	**Longitudal Drop (feet)**
swale	400	0.5%	**2**

Area of Swales

	L (feet)	W (feet)	A (square feet)	
swale 1	400	12	4800	
swale 2	400	12	4800	
swale 3	400	12	4800	
swale 4	400	12	4800	
swale 5	400	12	4800	
swale 6	400	12	4800	
swale 7	400	12	4800	

Table 4: Filtration Basin Sizing Calculations

Stormwater Management Needs

	Runoff Volume
Drainage Management Area 1	**41,234**
Drainage Management Area 2	**58,185**
TOTAL	**99,419**

Stormwater Management Achieved

	Runoff Volume
Filtration Basin 1	**41,667**
Filtration Basin 2	**57,500**
TOTAL	**99,167**

LID Volume

equation: $V=A*d$

A = area

d = depth

	A (square feet)	d (feet)	V (cubic feet)
filtration basin 1	50,000	0.833	41,667
filtration basin 2	69,000	0.833	57,500

LID Capacity

capacity $= V_B + (A*I)$

Vb = basin volume

A = area

I = infiltration rate (assume 0.5 in/hr)

	VB (cubic feet)	A (square feet)	I (ft/hr)	**capacity (cubic feet)**
filtration basin 1	41,667	50,000	0.042	**43,750**
filtration basin 2	57,500	69,000	0.042	**60,375**
			TOTAL	**104,125**