CDM

Memorandum

To: *Stormwater Quality Standards Task Force*

From: *CDM*

Date: *November 29, 2007*

Subject: *Economic Analysis of Compliance Alternatives for the Trapezoidal Segment of the Santa Ana Delhi Channel*

This technical memorandum presents the results of a preliminary economic analysis of compliance alternatives for compliance with REC-1 water quality objectives for bacterial indicators in a segment of the Santa Ana Delhi Channel in the Santa Ana River Basin. An analysis of two potential compliance alternatives is presented, including an estimation of the economic impact of the alternatives.

The location and physical characteristics of the channel segment analyzed, conceptual design of selected compliance alternatives, and estimated costs and economic impacts are described below.

Channel Location and Physical Characteristics

This analysis was conducted on the trapezoidal configured, rip-rap lined segment of the Santa Ana Delhi Channel, which extends along Flower Avenue in the City of Santa Ana from the Southern Pacific Railroad crossing downstream to Sunflower Avenue. Upstream from the Southern Pacific Railroad and downstream from Sunflower Avenue, the Santa Ana Delhi Channel is a vertical side-walled, concrete lined channel.

The Santa Ana Delhi Channel watershed (approximately 20 mi^2) is located in Orange County within the Santa Ana River Basin. The portion of the watershed that drains to the trapezoidal segment, hereafter referred to as the Upper Santa Ana Delhi Channel watershed, has a drainage area of approximately 6 mi^2 (Figure 1). Figure 2 shows the land uses of the watershed draining to the trapezoidal segment.

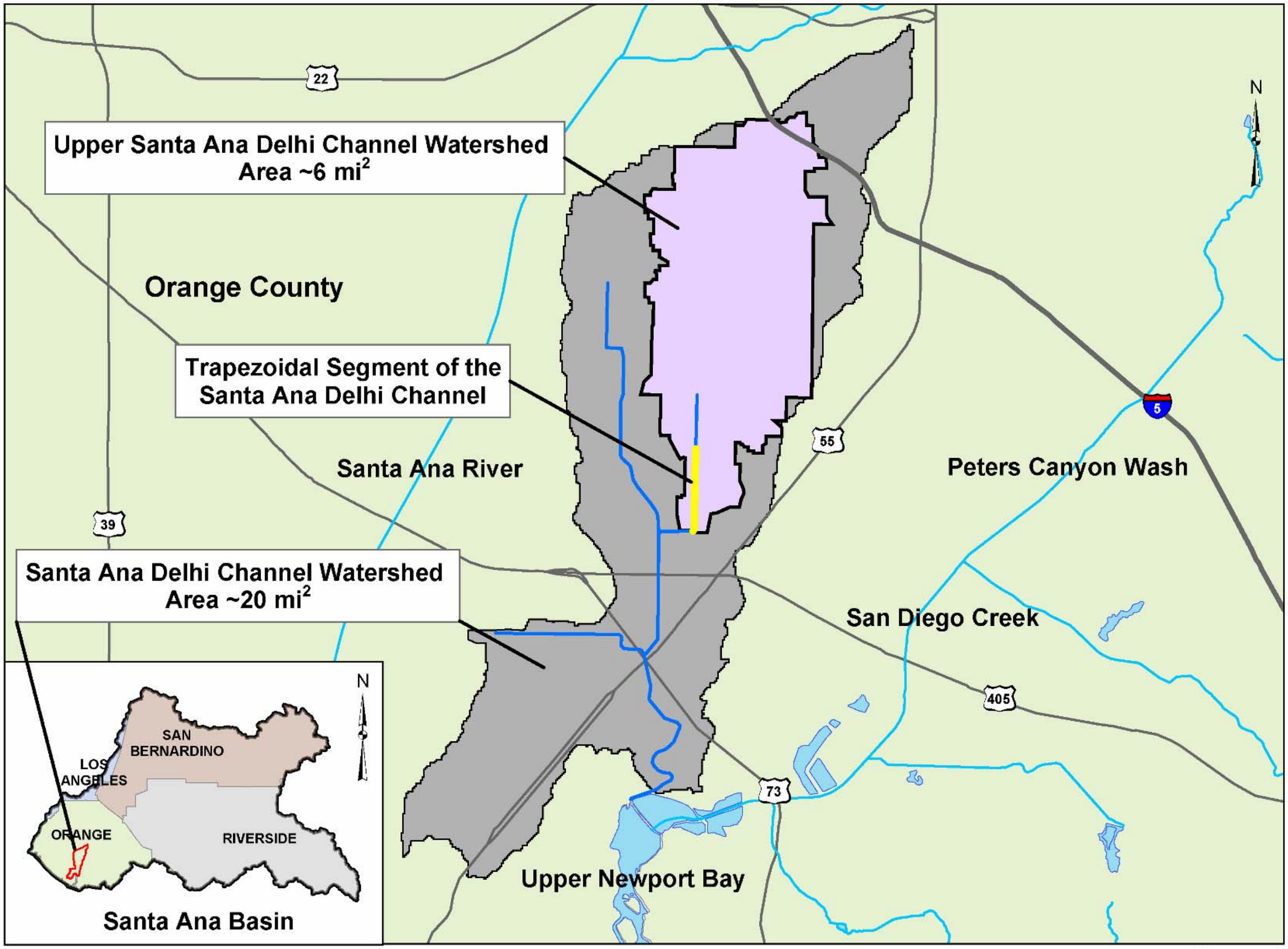

Figure 1
Upper Santa Ana Delhi Channel Watershed

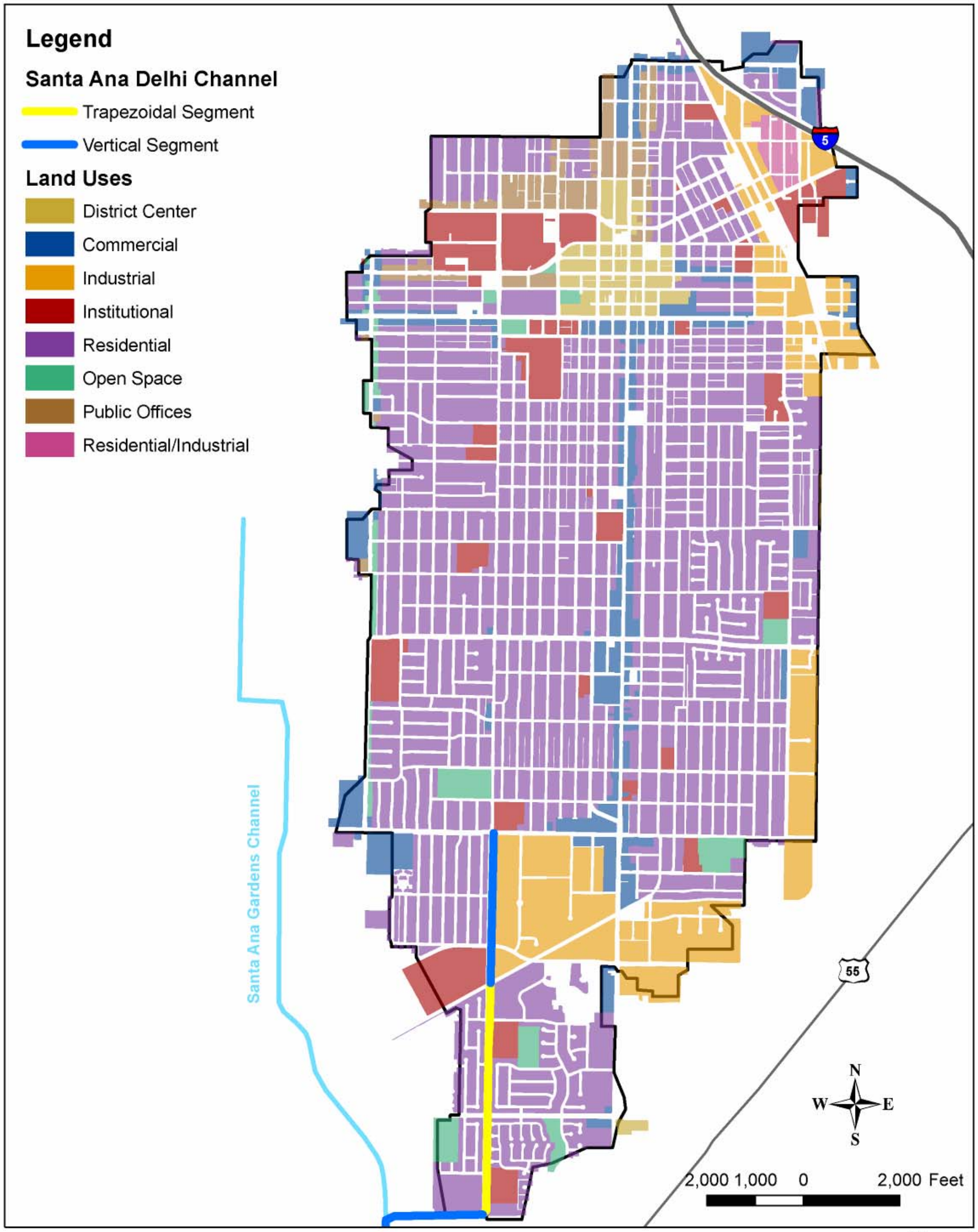

Figure 2
Upper Santa Ana Delhi Channel Watershed Land Uses

Conceptual Design of Compliance Alternatives

A conceptual design of the compliance alternatives was completed to provide a basis for the economic analysis. The configuration of the design was not explicitly optimized for cost efficiency, but was intended to represent one potential technically feasible solution towards achieving compliance with REC-1 bacteria water quality objectives.

Compliance Alternatives

Compliance alternatives were evaluated and selected as technically feasible approaches for collecting and treating the runoff from subwatersheds of the Upper Santa Ana Delhi Channel watershed. Structural best management practices (BMPs) or treatment devices that have been shown to be effective at reducing bacteria concentrations were selected as follows:

- Alternative 1 consists of treatment of dry weather flows via diversion to an existing publicly owned treatment works (POTW) and treatment of a portion of wet weather flows using ultraviolet (UV) treatment facilities, with pre-treatment as necessary.

- Alternative 2 consists of treatment of both dry weather flows and a portion of wet weather flows using UV treatment facilities, with pre-treatment as necessary.

Treatment facilities would be configured off-line to provide flow attenuation, and facilitate settling and pre-filtration, requiring diversion of flow from the channel to the treatment facility and conveyance of the treated flow back to the channel.

For this analysis, it was assumed that there would be no re-growth of bacteria downstream of proposed treatment facilities. In addition, the use of non-structural distributed source control measures to possibly reduce the amount of treatment required was not assessed for this analysis. The effectiveness of such measures is difficult to quantify in large urbanized watersheds and in other investigations has been estimated to only reduce on the order of 5 to 15 percent of bacteria load. However, these approaches should be considered in future watershed plans.

Dry Weather Diversions to Existing POTW

To achieve compliance with water quality objectives during dry weather only, diversion structures at individual points of discharge to the channel would be designed to divert only the dry weather runoff from the City of Santa Ana’s municipal storm sewer system (MS4) to the Orange County Sanitation District (OCSD) sanitary interceptor sewer system. In comparison to existing domestic sanitary flows, the urban dry weather flows that would be diverted from the MS4 are relatively small, and there is sufficient capacity within the OCSD sanitary sewer network to handle the diverted dry weather flows (personal communication, Bob Chenowith, OCSD).

Underground Storage and UV Disinfection Treatment System
UV treatment facilities use ultraviolet radiation to destroy bacteria. UV disinfection differs from conventional chemical disinfection methods in that no toxic byproducts are produced. In order for the UV treatment to be effective, the water must be of low turbidity; therefore filtration is required upstream of the UV treatment unit.

For Alternative 1, the conceptual design assumes that the UV treatment facilities would operate only during wet weather events and be sized to treat wet weather runoff from up to a typical 0.5-inch storm event. Runoff from larger storm events would be routed directly to the channel with no treatment. This flow routing would be accomplished using diversion structures at discharge points to the channel. Designs for each of these diversion structures would require detailed hydraulic modeling of the drainage system and flows, and is therefore not included in this preliminary analysis. An underground storage tank would be used to capture and equalize flows for release to the treatment system over an extended period of time, allowing the treatment system to be sized smaller than that otherwise necessary to meet the short-term peak flow from the storm hydrograph.

Under Alternative 2, the wet weather storage and treatment facilities would be identical to those under Alternative 1, but the pumping and treatment facilities would have a low-flow component that would essentially operate year-round to treat dry weather flow, bypassing the storage reservoir.

Target Flow Estimation

For the purpose of the conceptual design, the Upper Santa Ana Delhi Channel watershed was subdivided into three subwatersheds (Figure 3):

- Subwatershed A is a 3,247-acre portion of the watershed that lies north of Warner Avenue.
- Subwatershed B is a 578-acre portion of the watershed that lies south of Warner Avenue and east of the channel.
- Subwatershed C is a 230-acre portion of the watershed that lies south of Warner Avenue and west of the channel.

As indicated by the layout of the major storm drains shown in Figure 3, Subwatershed A drains to the vertical side-walled segment of the channel, north of the trapezoidal segment. Subwatersheds B and C drain to both the vertical and trapezoidal side-walled segments via multiple discharge points to the channel.

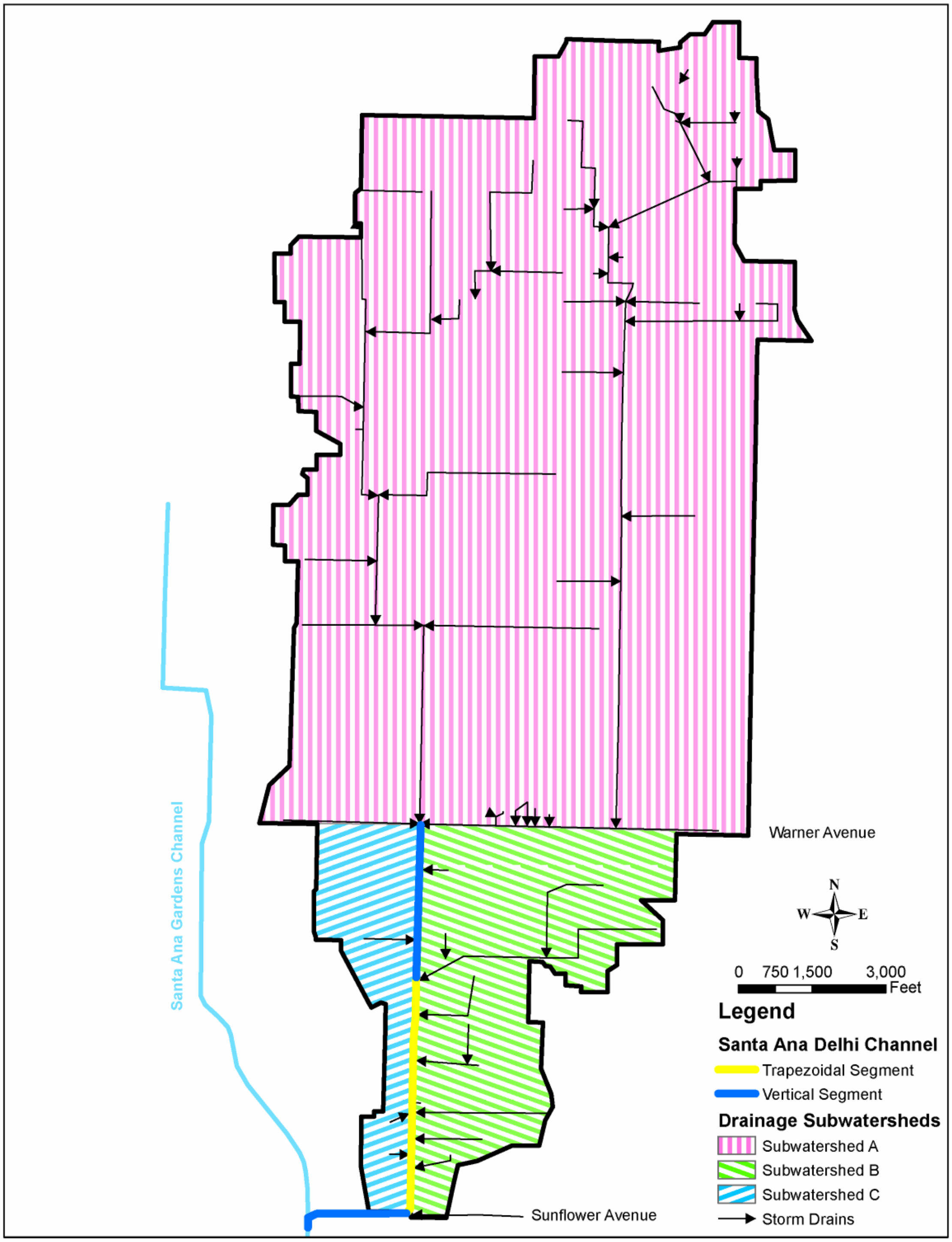

Figure 3
Drainage Features and Subwatersheds of the Upper Santa Ana Delhi Channel

Flow monitoring data was not available for the trapezoidal segment of the Santa Ana Delhi Channel, so dry and wet weather flows from the three subwatersheds were estimated. Continuous flow monitoring of four predominantly urban watersheds in southern California showed that an average daily flow of approximately 0.2 cfs per square mile of watershed can be expected during dry weather conditions (SCCWRP, 2005). Using this estimate, dry weather flow rates were estimated to be 1.0 cfs, 0.2 cfs, and 0.1 cfs, for Subwatersheds A, B, and C, respectively.

The EPA Storm Water Management Model (SWMM) was used to estimate the peak flow rate and volume of runoff generated from up to a typical 0.5-inch storm event. To select an appropriate duration for this event, an intensity-duration-frequency analysis was performed on historical rainfall data from a precipitation gauge at Laguna Beach. The analysis results showed that approximately 85 percent of 0.45- to 0.54-inch storms had a 6-hour duration or greater. Therefore, an event duration of 6 hours was selected to ensure that 85 percent of targeted storms would be fully captured and treated by the treatment facilities in the conceptual design. In shorter high intensity, storm events, it is possible that a small volume of runoff would have to be bypassed due to rapid filling of the storage reservoir at the peak of the hydrograph. The SWMM model allows for the input of rainfall data in the form of a hyetograph (rainfall versus time). A hyetograph was constructed by taking a 24-hour unit hyetograph for southern California (Los Angeles County Department of Public Works, 2006) and scaling it for a 0.5-inch, 6-hour rainfall event. Along with the hyetograph time-series, characteristics for the three subwatersheds were used as inputs to the SWMM model. The simulated peak flows and runoff volumes from each of the subwatersheds are listed in Table 1. The input hyetograph and output hydrographs generated from the modeling are shown in Figure 4.

Table 1
Estimated Peak Flows and Runoff Volumes from the 0.5-inch, 6-hour Rainfall Event

Subwatershed	Peak Flow (cfs)	Runoff Volume (ac-ft)
Subwatershed A	87	57
Subwatershed B	23	13
Subwatershed C	12	6

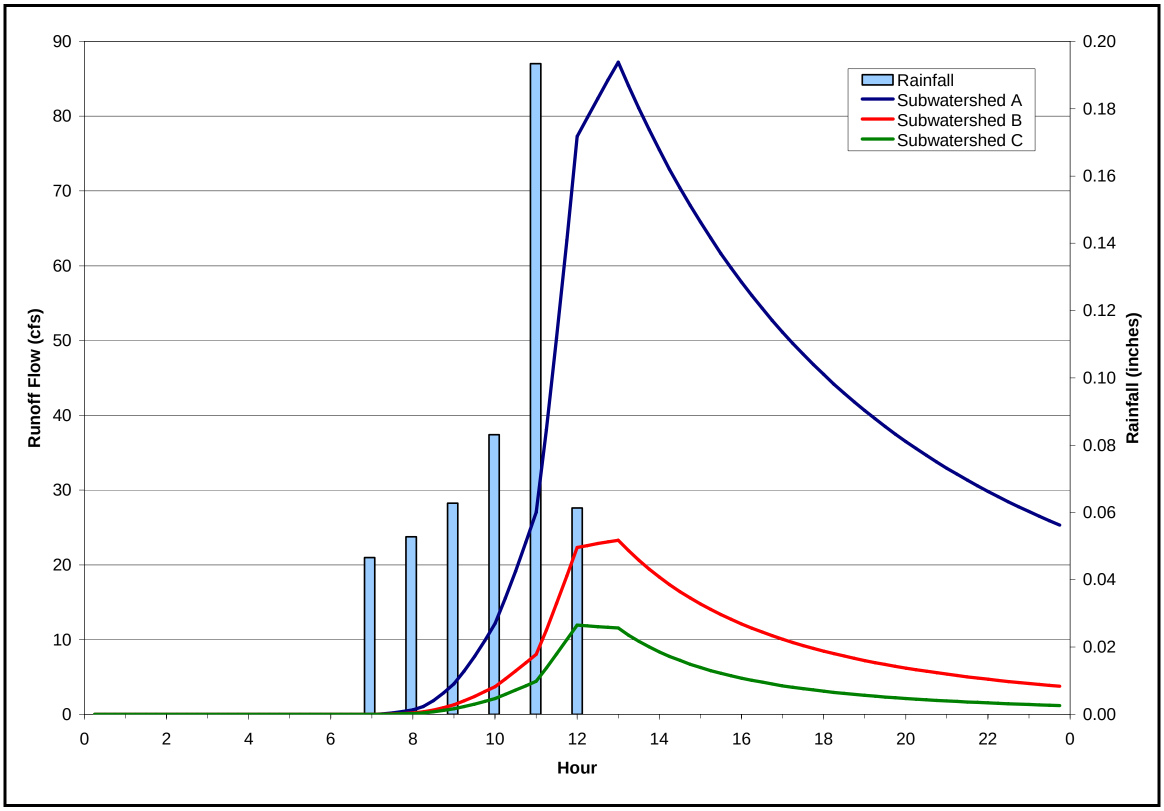

Figure 4
Estimated Peak Runoff Flows from the 0.5-inch, 6-hour Rainfall Event

Proposed Facilities

Dry Weather Diversions to Existing POTW

Dry weather runoff could be diverted away from the Santa Ana Delhi Channel to the OCSD Fountain Valley facility. The dry weather diversion treatment option would not require separate land acquisition. The main component of the dry weather diversion treatment option would be the installation of diversion structures at each location where flows from Subwatersheds A, B, and C would otherwise enter the Santa Ana Delhi Channel. For Subwatershed A, an inflatable dam would be installed in the vertical section of the Santa Ana Delhi Channel, just south of Warner Avenue, to temporarily store water in the channel so that it could be diverted. For Subwatersheds B and C, 10 specialized manholes at MS4 discharge points along Flower Road would be installed with structural components that would divert low flows. The diversion structures would be designed such that only dry weather flows would be routed to the sanitary sewer system and subsequently to the POTW. The structures would also be sized and designed to divert wet weather flows to the underground storage and UV treatment facilities as described below.

Underground Storage and UV Disinfection Treatment System

Aerial photographs were reviewed and open space areas that could potentially be acquired and utilized to locate UV disinfection facilities and underground equalizing storage facilities were identified. The primary criterion was to identify open land in the general vicinity of the channel that does not currently already have significant fixed development. Potential land areas meeting these criteria include Memorial Park in Subwatershed A and an agricultural field south of Sunflower Avenue (Figures 5, 6, and 7). For this conceptual analysis, the owners (one public, one private) of these properties were not contacted to discuss land availability.

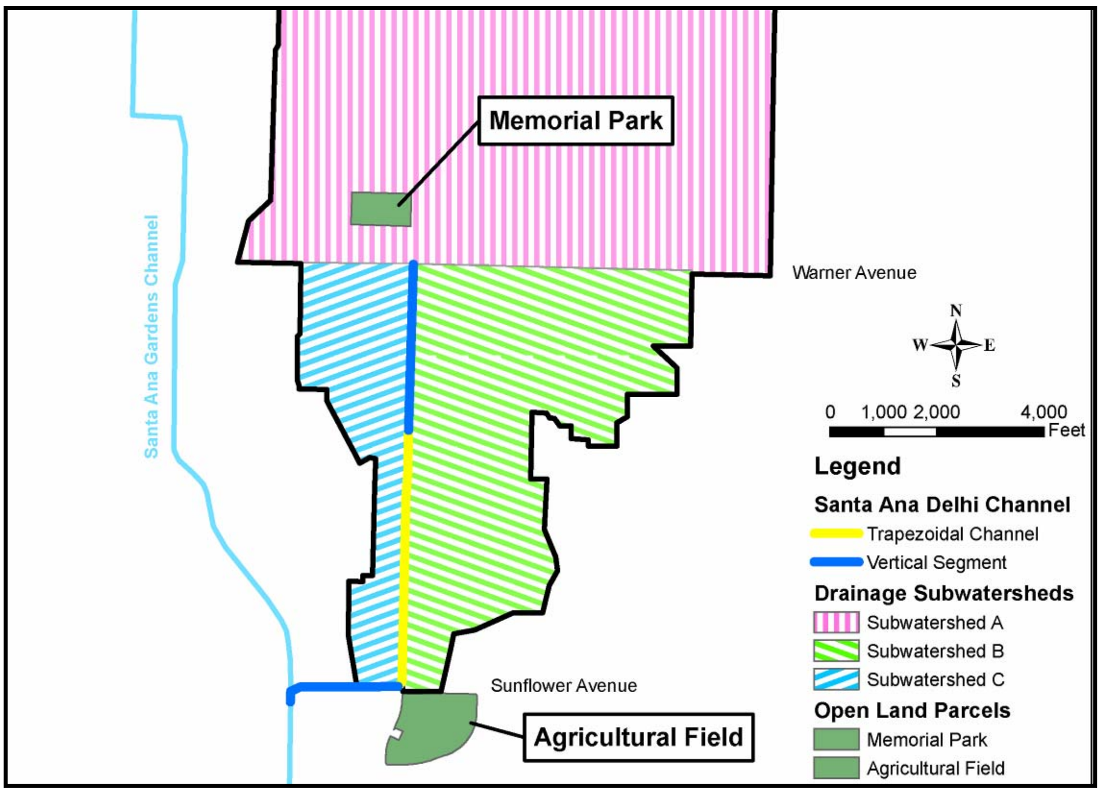

Figure 5
Potential Land to Locate Underground Storage and UV Treatment Facilities

Figure 6

Potential Location for Storage and Treatment System at Memorial Park

Figure 7
Potential Location for Storage and Treatment System at Agricultural Field

The runoff from Subwatershed A would be diverted from the upper end of the vertical concrete channel just below Warner Avenue by installing an inflatable rubber dam in the channel, and constructing a diversion structure and pipeline to the proposed site. It is assumed that a low-head pump station will be needed to pump the flow to an underground storage tank located at the southeast corner of Memorial Park. The flow would then be pumped from the storage tank to a sand filtration unit upstream of the UV treatment system. After treatment, the flow would be conveyed by gravity to the Santa Ana Delhi Channel below the diversion point. When peak flows in the channel exceeded a pre-determined rate consistent with the peak flow from the 0.5-inch storm event, the dam would deflate and flows would pass downstream untreated. A conceptual diagram illustrating the Subwatershed A underground storage and UV treatment system is presented in Figure 8.

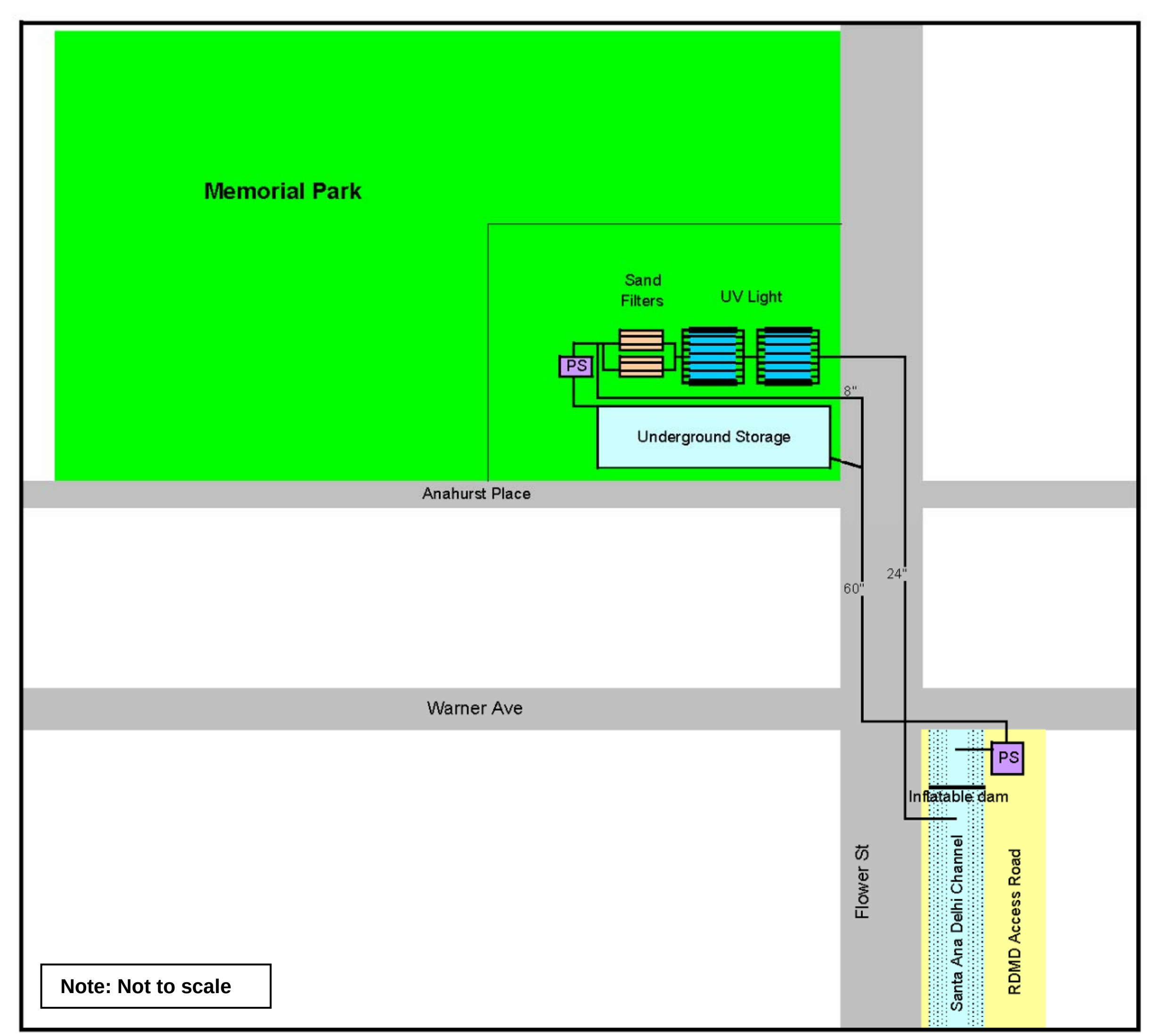

Figure 8
Subwatershed A Underground Storage and Treatment System

Using diversion structures upstream of each discharge point to the Santa Ana Delhi Channel, the runoff from Subwatershed B would be diverted to a proposed gravity storm sewer located in the right-of-way along the east side of the Santa Ana Delhi Channel. Likewise, the runoff from Subwatershed C would be diverted to a proposed gravity storm sewer located along Flower Street on the west side of the Channel. The two parallel storm sewers would be combined at the northeast corner of Sunflower Ave and Flower Street and flow to a low head pump station, which would pump the flow to an underground storage tank located at the northwest corner of the proposed site. The flow would then be pumped from the storage tank to the sand filtration unit upstream of the UV treatment system. After treatment, the flow would be conveyed by gravity to the Santa Ana Delhi Channel via a storm sewer in Sunflower Avenue. The diversion facilities at each outfall would be designed to pass runoff rates exceeding the estimated peak flow for the 0.5-inch storm event. A conceptual diagram illustrating the Subwatersheds B/C underground storage and UV treatment system is presented in Figure 9.

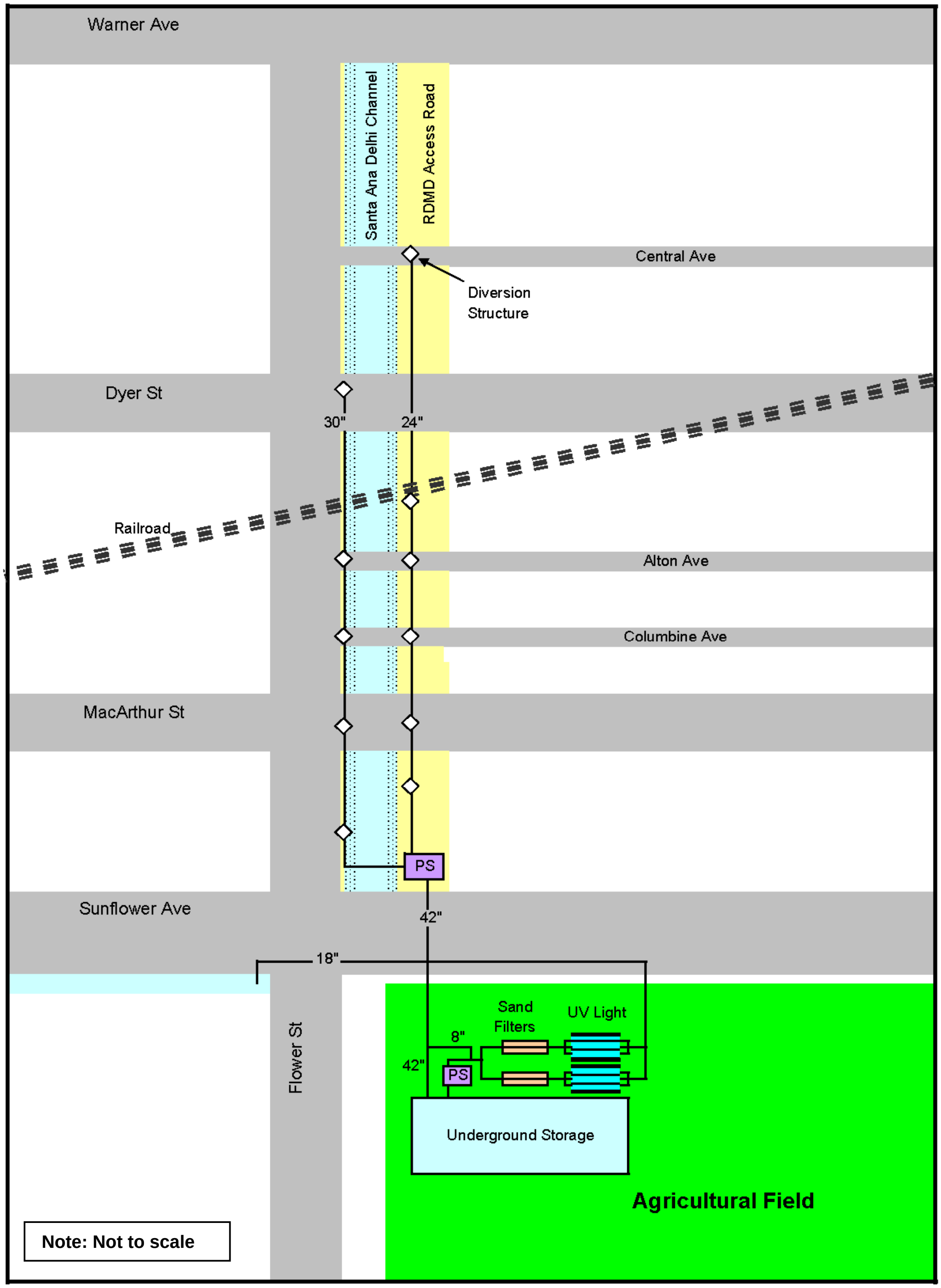

Figure 9
Subwatersheds B/C Underground Storage and Treatment System

Site constraints for off-channel UV treatment systems are primarily a function of the space available to provide detention storage of the volume of flow that is diverted during the part of a storm event when the hydrograph exceeds the capacity of the treatment system. The treatment plant footprint was assumed to be approximately 2 acres for the Subwatershed A system and ½ acre for the Subwatersheds B/C system. Based on the proposed site layout, there is sufficient space (assuming the required land can be acquired) to capture and treat runoff from all targeted flow conditions for Subwatershed A and Subwatersheds B/C.

The capacities of the two treatment systems were determined by assuming that the target volumes calculated using the SWMM model would be stored and pumped out to the treatment system over a 48-hour time period. Based on this assumption, the UV treatment systems were sized at 10 MGD for the Subwatershed A system and 3 MGD for the Subwatershed B/C system.

The peak flows calculated by the SWMM model were used to size the pipelines that convey the runoff to the underground storage tanks. Conveyance pipe diameters were determined by finding the size of pipeline required to limit peak velocities to less than five feet per second. A head loss of 30 ft and projected maximum flow capacities at each of the proposed pumps in the treatment system design were used to estimate the horsepower, assuming pumping efficiency will not exceed 70% on average.

Storage tank volumes for each of the treatment locations were designed by using the Detention Storage Volume computation approach presented in Technical Release 55 (USDA Soils Conservation Service Engineering Division, 1986) to calculate the storage necessary to route hydrographs given varying treatment outflow rates. Table 2 presents the storage volumes that would be necessary to capture and treat runoff from a 0.5-inch storm event, when the treatment system is designed to provide a 48-hour drawdown of the stored volume. The footprint area for the Subwatershed A treatment system storage tank located under Memorial Park is proposed to be 1.7 acres based on the amount of open space visible from the aerial photograph. A footprint area of 0.5 acres is proposed for the Subwatershed B/C treatment system storage tank located under the agricultural field. Based on the required storage volume and proposed tank footprints, tank depths were calculated and are also presented in Table 2.

Table 2
Storage Volumes Necessary to Capture Runoff from the 0.5-inch Storm Event

Subwatershed	Storage Volume (ac-ft)	Storage Footprint Area (ac)	Storage Depth (ft)
Subwatershed A	25.8	1.7	15.2
Subwatersheds B and C	8.3	0.5	16.6

Estimated Costs and Economic Impacts

Planning level capital and operation and maintenance (O&M) costs were developed for the alternatives, assuming that the land required for underground storage and the UV treatment system can be acquired and assuming there are no insurmountable engineering or environmental constraints with either of the alternatives. Costs were developed by compiling quotes obtained from an equipment vendor and obtaining probable cost of construction estimates prepared by CDM Constructors, Inc. (CCI). Land acquisition cost was estimated by researching current properties for sale in the region of each subwatershed, and applying a unit cost per acre.

Construction costs were estimated on both a total and per capita level based on an estimate of the population within each subwatershed. Additionally, a factor of 3.1 persons/household was used to estimate the cost per household for each of the feasible alternatives (University of Southern California, Southern California Studies Center, 2001). The population of the entire Santa Ana Delhi Channel watershed was estimated based on 2000 Census data for the portion of the City of Santa Ana that lies within the Upper Santa Ana Delhi Channel watershed. The population for the Upper Santa Ana Delhi Channel watershed was estimated to be approximately 63,750, which equates to approximately 20,570 households. The costs reported here were developed based on conceptual level designs and are intended to be used only as a general planning tool. The costs are only intended to provide the Task Force with an order-of-magnitude estimate of the potential costs for complying with REC-1 bacteria water quality objectives in the trapezoidal segment of the Santa Ana Delhi Channel.

Dry Weather Diversions to Existing POTW

Dry weather diversion to an existing OCSD POTW is considered feasible for up to 1 cfs of flow from the Santa Ana Delhi Channel watershed. Cost considerations include:

- Capital costs of buying capacity at OCSD Plant No. 1 in Fountain Valley, and construction of diversion structures and local drainage pipes to convey dry weather runoff from the City of Santa Ana's MS4 to the closest locations in the OCSD sanitary sewer system. This would include construction of an inflatable dam across the upper end of the concrete lined reach of the channel.

- O&M costs are based on annual POTW charges.

Table 3 summarizes the capital and O&M costs for dry weather diversion of a total of 0.79 MGD (1.2 cfs) for all three subwatersheds to the OCSD Fountain Valley POTW from the Santa Ana Delhi Channel study site.

Diversion, Conveyance, Underground Storage and UV Disinfection Treatment System

Costs for these systems include land acquisition costs, capital costs, and O&M costs. Capital costs include diversion structures, conveyance pipelines, filtration systems, detention tanks, pump stations, screens, and the UV system. Capital costs for proposed storm sewers, pumping stations, manholes, and storage reservoirs were developed by estimators at CDM Constructors Inc (CCI). The CCI estimates included vendor supplied quotes for the filtration and UV disinfection treatment facilities. Low Pressure High Output (LPHO) lamps, quartz sleeves for lamps, ballasts, power supplies for ballasts, and mechanical and chemical cleaning systems. Capital costs for underground detention storage tanks, influent and effluent channels, and pump stations were estimated by assuming the tanks would be reinforced concrete. Contingencies for construction, field and home office overhead, and insurance were included in the estimates. Table 3 summarizes the costs for conventional UV disinfection systems at Memorial Park and the agricultural field.

Annual O&M costs include labor, maintenance, and energy costs. For Alternative 1, under which the treatment system would treat wet weather runoff only, labor costs were estimated assuming that the facility would require the equivalent labor from ½ person per year. Although the systems would only operated during and following wet weather events, the operations would require more intense attention during these periods, and periodic maintenance and inspections would still be required between storm events. Under Alternative 2, because the treatment facility would treat both dry and wet weather runoff, labor costs were estimated assuming that the facility would require 1 person per year. Maintenance costs were estimated to be 1 percent of the unburdened capital costs (capital costs minus overhead and contingencies). Energy costs for UV radiation were estimated based on peak power draw unit costs provided by the UV vendor and an assumed rate of 15 cents per kWh. Average annual energy costs for the pump stations were estimated by calculating energy usage over a typical year using the assumed rate of 15 cents per kWh.

In addition, a review of available properties in the City of Santa Ana was also conducted. It was found that listed unimproved properties are on average $2,800,000 per acre. This was accounted for in the estimate of project costs, as shown in Table 3.

Summary of Costs

Two alternatives were developed to achieve compliance with REC-1 water quality objectives for the trapezoidal segment of the Upper Santa Ana Delhi Channel, which involved diversion dry weather runoff to OCSD (Alternative 1) or to an off-line underground storage and stormwater UV treatment facility. Both alternatives would capture and treat runoff from rain events up to the ½ inch storm in an off-line underground storage and stormwater UV treatment facility. The total capital costs are approximately $45 million and $44 million for Alternatives 1 and 2, respectively. This capital cost was amortized to estimate an approximate annual cost for the capital projects. In addition, annual O&M costs were also estimated to be $590,000 and $390,000 for Alternatives 1 and 2, respectively. Thus the total annual cost of compliance was estimated to be approximately $3.6 million for Alternative 1 and $3.3 million for Alternatives 2. When converted to a per capita cost for watershed residents, the cost of compliance could be between $52 to $56 per year per person, or approximately $161 to $174 per year per household.

Table 3
Summary of Opinion of Probable Costs of Compliance with REC-1 Water Quality Objectives for the Upper Santa Ana Delhi Channel

	Alternative 1	Alternative 2
Capital Cost		
Dry Weather Diversion		
Plant Capacity - 0.79 MGD	$420,000	$0
Pipeline Construction - 3,000 ft	$600,000	$0
Diversion Structures	$100,000	$0
Subwatershed A Underground Storage and UV Disinfection Treatment System		
Land Acquisition	$2,800,000	$2,800,000
Excavation / Earthwork	$3,010,000	$3,010,000
Storage Reservoir	$16,080,000	$16,080,000
Diversion Structures/Conveyance Pipelines	$1,000,000	$1,000,000
Runoff Treatment / Pumping	$5,100,000	$5,100,000
Subwatershed B and C Underground Storage and UV Disinfection Treatment System		
Land Acquisition	$2,800,000	$2,800,000
Excavation / Earthwork	$990,000	$990,000
Storage Reservoir	$5,280,000	$5,280,000
Diversion Structures/Conveyance Pipelines	$4,420,000	$4,420,000
Runoff Treatment / Pumping	$2,380,000	$2,380,000
Total Capital Cost	$44,980,000	$43,860,000
O&M Costs		
OCSD Treatment Fees	$280,000	$0
Facility Maintenance (1% of unburdened capital)	$250,000	$240,000
Labor (Assumes cost of $100,000 per FTE)	$50,000	$100,000
Energy Usage	$40,000	$50,000
Annualized Costs		
Amortized Capital Cost [1]	$2,990,000	$2,930,000
O&M	$590,000	$390,000
Total Annual Cost	$3,580,000	$3,320,000
Annual Spread Cost		
Per Person	$56	$52
Per Household	$174	$161

1) Assumes bonding for 30 years at a 4.4% interest rate

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