Scoping Study, Retrofit Pilot Program, Caltrans District 7

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RESEARCH OBJECTIVES

The objectives of the stormwater retrofit pilot studies include an evaluation of the constituent removal efficiency, technical feasibility, and costs of retrofitting Caltrans facilities with chemical constituent controls. This study will document the effectiveness of a wide range of stormwater controls through a comprehensive chemical constituent, sediment and litter monitoring program. The monitoring program will be supplemented with detailed records of siting, design, construction, and operational and maintenance issues and problems. Operational problems and will be documented, along with solutions to such problems. Operational procedures that promote or maintain the effectiveness of the BMP will also be documented. In addition, the site selection process will help define the feasibility of retrofit project installations in Caltrans right-of-way. Construction of a number of these devices will allow Caltrans to develop accurate cost estimates for BMP retrofit. The costs will be assessed through detailed records kept on the process of designing, building, operating, and maintaining each of the retrofit devices.

SITE SELECTION

Stormwater retrofit controls will be installed at a maximum of 28 sites in Caltrans District 7 and at 7 sites (10 installations) in Caltrans District 11 based on the following criteria: (1) appropriateness for the capabilities of the control; (2) presence of a realistic opportunity to install, operate, and observe the device; and (3) the ability to address an identified water quality problem. The sites in District 7 will be located in three major watersheds–Ballona Creek, the Los Angeles River and the San Gabriel River. Ballona Creek discharges into Santa Monica Bay immediately south of Marina Del Rey. The Los Angeles River discharges through Queensway Bay and Outer Long Beach Harbor into San Pedro Bay. The San Gabriel River discharges into San Pedro Bay just south of Long Beach Harbor. Both San Pedro Bay and Santa Monica Bay have been identified as receiving several constituents of concern from urban storm water runoff that could adversely impact the beneficial uses of the receiving waters. The BMPs installed in District 11 will be sited in a single watershed, Carlsbad Hydrological Unit, if possible; however, other sites will be considered if all of the selected BMPs cannot be placed in the selected watershed.

Each prospective pilot project site will be evaluated to match physical site characteristics and the types of potential constituents present in runoff to the requirements and performance characteristics of the BMPs being evaluated. Each site will also be evaluated for adequate space and access to safely construct, maintain and monitor the retrofit pilot project proposed for the site.

Specific sites must be carefully selected to assure that the data collected in this program are accurate and transferable. This requires that the monitoring program adhere to well-developed protocols established for other Caltrans programs. In addition, a number of

logistical and safety related issues must be included in the selection criteria. Criteria included in the Caltrans *Guidance Manual: Stormwater Monitoring Protocols* (LWA, 1997), and described in detail in Appendix A as appropriate, will help ensure selection of the most appropriate monitoring locations and data transferability. Specific siting guidelines are also provided with the retrofit pilot study descriptions which follow.

BEST MANAGEMENT PRACTICES

Several types of stormwater controls have been identified which have the potential for improving the quality of runoff from Caltrans facilities. A list of the controls scheduled to be evaluated and the number of projects is shown in Table 1.

Table 1: Retrofit Pilot Studies

Retrofit Pilot Project	**Number of Installations** District 7	**Number of Installations** District 11
Trapping Catch Basin	2	0
Catch Basin Insert	6	0
Extended Detention Basin	2	0
Infiltration Basin	1	2
Infiltration Trench	4	2
Biofiltration Swale	4	2
Biofiltration Strip	2	1
Media Filter	4	2
Oil/Water Separator	3	1
Totals	**28**	**10**

The devices selected for evaluation in the BMP Retrofit Pilot Study will be designed, installed, operated, and maintained at state-of-the-art levels. The designs will be selected following a review of the technical literature and interviews with persons familiar with the performance of these devices.

In general and as applicable, the selected BMPs will be designed in accordance with the *Caltrans Planning and Design Staff Guide*, dated September 1997. One of the goals of the retrofit pilot program is to investigate the feasibility and effectiveness of the design and installation of BMPs as a part of typical Caltrans facilities.

Since an important element of this study is to develop an understanding of problems (and solutions to those problems) and issues which might be encountered in implementing a stormwater retrofit program, the design, bidding, and construction of these facilities will

be conducted in a manner compatible with Caltrans procedures. The level of maintenance for each device will be consistent with what might reasonably be expected under normal operating conditions, such maintenance practices will be at 'state-of-the-art' levels for each BMP pilot project. Installation and monitoring of these devices under realistic conditions will result in a more accurate assessment of constituent removal performance and identification of operational and maintenance issues. The publication entitled, *Operation, Maintenance and Management of Stormwater Management Systems*, published by the Watershed Management Institute and the USEPA dated August 1997 will serve as the primary guide and reference for the maintenance and operation program for the Pilot Projects.

Regulatory Status of Created 'Wetland' Areas

There is justified concern that stormwater BMPs that create 'wetland' areas may become jurisdictional and subject to control by the California Department of Fish and Game, and the U.S. Army Corps of Engineers by way of Section 1601 of the State Fish and Game Code, and Section 404 of the Clean Water Act respectively. These regulatory agencies are beginning to establish procedures whereby structural BMPs may be differentiated from jurisdictional wetlands.

Both the State Department of Fish and Game and the U.S. Army Corps of Engineers were contacted relative to the issue of stormwater BMPs becoming jurisdictional wetlands. Each agency indicated that constructed stormwater BMPs that may accrue wetlands characteristics (hydric soils, standing water for a period of longer than seven days each year, or wetland type vegetation) can be considered exempt from regulation providing the following conditions apply:

1. The area is not currently a regulated wetland or jurisdictional waters.

2. A maintenance program is developed for the stormwater BMP indicating the type of maintenance that will be performed, and the frequency of such maintenance.

3. The maintenance program is not abandoned. Should the established maintenance schedule of the BMP be abandoned, each agency reserves the right to declare the location jurisdictional, and subsequently regulate future activity (disturbance) of the site.

4. The agency is notified in writing of the location of the BMP, the responsible entity for maintenance, the nature of the maintenance activity. The schedule is identified and an agreement is reached.

Maintenance programs for each of the BMPs described in the Retrofit Program that may develop wetlands characteristics will be developed and forwarded to the State and U.S. Army Corps of Engineers under the procedure described above. The procedure for

exempting stormwater BMPs from jurisdictional control will be further clarified during the Retrofit Pilot Projects.

STORM SIZE AND SAMPLING FREQUENCY

Storm water samples for the appropriate BMPs will be collected from four storms per year, weather permitting, with a maximum of a total of eight storms over a two year period. Samples taken will be representative of the discharge resulting from a storm with greater than 0.1 inch of rainfall. Storm events that are separated by at least 72 hours of dry weather from the previous storm event and having greater than 0.1 inch of accumulation will be sampled. The minimum separation between events will be at least 48 hours.

LABORATORY ANALYSIS

The stormwater BMPs will be monitored to determine their constituent removal effectiveness. Each of the designs is focused on the removal of certain constituents present in highway runoff; consequently, the type of analyses performed will depend on the runoff control under consideration. Water quality samples from runoff controls which are designed to remove a wide range of constituents will be analyzed for solids, heavy metals, nutrients, and oil & grease. A list of these constituents is contained in Table 2. The samples from other, more specialized controls will be analyzed for the appropriate subset of these constituents.

Since many of these constituents can impair beneficial uses of receiving waters at extremely low concentrations, it is important that analytical methods be selected which have appropriate detection limits. In addition, many of the water quality samples will be collected after treatment by a BMP and will have concentrations below what is normally found in untreated highway runoff. The analytical methods recommended in Table 2 should provide accurate results at concentrations that might be expected in the discharge from retrofit BMPs.

Table 2: Methods for Analyzing Stormwater Constituents

Parameter	Detection Limit (mg/L)	Analytical Method (USEPA, 1979;1994)
Total suspended solids	1	160.2
Zinc	0.001	289.2/200.8
Lead	0.001	239.2/200.8
Copper	0.001	220.2/200.8
Nitrate nitrogen	0.01	353.3
Total Kjedahl nitrogen	0.1	351.3
Total Phosphorus	0.002	365.2
Fecal Coliform	200 CFU	SM 909C*
Total Recoverable Petroleum Hydrocarbons**	0.25 to 0.75	8015 mod/ext.

*Standard Methods **Includes diesel and gasoline fractions when referenced throughout this report

Note that testing for metals includes total and dissolved fractions.

SITE STORMWATER SAMPLING EQUIPMENT

Many of the pilot retrofit sites will be equipped with flow measuring devices, automatic samplers and rain gauges. A comprehensive maintenance plan must be followed to assure that measurements of flow and rainfall are accurate and that water quality samples are representative of the runoff.

The flow monitoring equipment must be calibrated according to manufacturer specifications. Flow meters typically contain moisture indicators that should be checked during each site visit, or at least once between each monitoring event. Any time a moisture indicator reads above the acceptable level, the desiccant should be replaced with new packets. The sensor should be inspected prior to each monitoring event and calibrated at any time the calibration appears to be needed based on observance of recorded flow data. The sensor cable will be inspected prior to each stormwater monitoring season.

Automatic sampling equipment will be calibrated according to manufacturer specifications to collect the desired sample aliquot. At a minimum, the calibration will be checked prior to each stormwater monitoring season. After each monitored event, the sample bottles will be checked to verify that the programmed sample volume was delivered to the sample bottles. If the volume is incorrect, the sampler will be recalibrated prior to the next monitoring event. Pump tubing in the samplers will be replaced annually.

Rain gauges will be installed and maintained according to manufacturer specifications. At a minimum, the gauge should be inspected, cleared of debris, and calibrated following the manufacturer-specified procedure prior to each stormwater monitoring season.

Each of the monitoring sites will be inspected after runoff events to evaluate the condition of the equipment and perform routine maintenance. The samplers will be inspected to verify that trash and other debris are not obstructing the intake to the sampler. Solar panels will be inspected to ensure dirt and other debris are not limiting the amount of sunlight and batteries will be checked to determine that they are fully charged. Trash and other debris which collect in the storm drain near the sampling point will be removed so that flow estimates will not be affected.

MOSQUITO AND VECTOR CONTROL

Mosquitoes inhabit almost all wetland areas but the population size and associated problems vary considerably with the location and local site conditions. For these reasons, mosquito and vector control procedures will be developed concurrent with the pilot program design process. The assistance of a vector control specialist will be obtained to assist in the preparation of a program to address proper operation and maintenance procedures to minimize mosquito and vector problems. Specific details of this program will be formulated and agreed upon between Caltrans and the NRDC. Vector control issues will be examined, at a minimum, for the following Pilot Projects: infiltration ponds, biofilters and trapping catchbasins.

The vector control program will initially consist of a monitoring component to assess the potential for mosquitoes and related problems at the pilot sites. The monitoring program will also define appropriate abatement procedures (if any are required) to be used at the pilot sites. The NRDC will participate in the program formulation process and be updated relative to vector monitoring activities through quarterly reports.

BENEFIT ASSESSMENT PROGRAM AND REPORTING

Detailed records will be maintained for each site to document siting, design, construction, operation and maintenance experience. Many of the stormwater BMPs that will be monitored during this study, have been the subject of numerous research efforts. Consequently, the constituent removal for some of these devices is well established for properly designed and maintained systems. Therefore, much of the effort of this study will be directed to recording and analyzing the siting, design, construction, and operation and maintenance experience. Forms will be developed for each phase of the project so that engineers and support staff can record their observations in a common format to facilitate compilation of this information.

A site visit log will be developed prior to visiting potential sites. It will be based on a list of criteria, specific to the BMP objectives and will be filled out during each site inspection. Criteria to be documented during a site visit may include the type of site, drainage area characteristics, type of runoff, whether an appropriate sampling location exists, potential safety issues, site access, and whether accurate flow measurement is achievable.

Other forms will be developed in support of the Benefit Assessment Program. The observational and narrative description of the process will identify the problems encountered in siting, designing, constructing, operating and maintaining the facilities. In addition, it will document whether the design guidelines could be fully implemented and how that affected BMP performance. An analysis of these data will form a central part of the final research report for each of the selected BMPs. Emphasis in the final reports will be placed on identifying solutions to problems discovered during the implementation of the pilot projects, and documenting procedures that were determined to be beneficial in maintaining the effectiveness of the BMP. Specifically, the Benefit Assessment Program for the pilot projects will include the following elements:

1. Collection of stormwater samples (influent and effluent) for each pilot project except as modified herein using autosampler equipment. This will form the "Sampling Program."
2. Implementation of a "Maintenance Program" to ensure each of the pilot projects are maintained at state-of-the-art levels throughout the monitoring period. Specific maintenance checklists will be developed for each BMP and each site, to ensure that improper maintenance does not impair the operation of the BMP.
3. Implementation of an "Assessment Program" documenting: the deviations from standard design; compromises in design-based, on-site constraints; and deviations from standard maintenance practices due to unusual weather, site conditions or failures.
4. Observation of BMP operation during storm and post storm periods (a minimum of four times per year) to assess such factors as: functioning of the outlet works; estimation of residence time, visual observations regarding 'short circuiting;' and drain time for infiltration BMPs. These observations will be a part of the "Assessment Program".
5. Comparison of the performance of the pilot projects to that of other BMPs in similar projects, analyzing the reasons for differences where they occur. This will be presented in the Final Report.
6. Documentation of complete process including siting, design, construction and monitoring in a final report.

Sampling results and site conditions will be described for each sampled storm event. This data will be compiled in a database and presented in the final project reports to be prepared during Years 3 and 4 of this study.

Appendix C provides a discussion of the proposed methodology for estimating constituent loadings and BMP efficiency for the pilot studies. The procedure indicated will be used to calculate average annual loads and removal efficiencies for the pilot projects, where paired influent and effluent samples are collected.

SCHEDULE/COST

A master schedule has been prepared indicating the general timeline for BMP retrofit siting, design, construction bid, construction, monitoring, and final report development. This master schedule is contained in Appendix B. The master schedule has been developed in two forms, a primary or target schedule, and a contingency schedule. The primary schedule is a four-year target schedule designated for the BMP Retrofit Projects. The second, or contingency schedule indicates monitoring beginning in the Fall of 1999 rather than 1998 as shown on the primary schedule. It is anticipated that there will be technical or construction issues that would necessitate a delay in delivery of pilot projects to the contingency schedule. The specific pilot projects that will follow the contingency schedule track will be determined on a case-by-case basis. Specific pilot projects will be shifted to the contingency schedule if technical problems arise that would otherwise compromise the scientific value of the study. Use of the contingency schedule will provide flexibility within the program to deliver the entire project within the Stipulated five-year period while maintaining good research practices.

The determination of the specific pilot projects that will be moved to the contingency schedule will be made mutually by Caltrans and NRDC at established decision points. The decision points are defined as: 1) at the completion of design (June 1998, see Appendix D); and 2) prior to monitoring (estimated November 1998). A formal staging plan, defining the decision points and the criteria used to review the specific pilot project schedule track at each decision point, is provided in Appendix D.

Further, for those pilots on the primary or target schedule, a third year of monitoring (during the 2000/2001 storm season) is also a stated option. Should problems be encountered in either of the first two years of monitoring or operation of pilots on the primary (target) schedule, a third year of monitoring will be included. This third-year monitoring option will not be available for those pilots initially operating according to the contingency schedule. The third year of monitoring would proceed according to the timeline established on the contingency schedule. The decision to move pilot projects from the primary schedule track to the contingency schedule may be made at any time during the first two years of monitoring (1998/1999 or 1999/2000 winter seasons) by mutual agreement between Caltrans and NRDC. The total study time will not exceed the stipulated five-year period. As shown in the master schedule, the total cost of the retrofit program, including siting, design, construction and monitoring is estimated to be about $15,000,000. Actual costs for the program will be accumulated as each of the scheduled milestones is completed. The actual program costs will be reported in the retrofit pilot

project Final Report. The siting, design and monitoring of the projects will be completed by Caltrans as indicated on the master schedule. It is estimated that the projects will be constructed by contractors through six construction bid packages, completed through a standard bid process. Additional construction bid packages may be developed to accommodate projects shifted to the contingency track.

The program schedules call for six milestone events over the next four years as follows:

Milestone	Completion Date (Mast. Sched)	Completion Date (Cont. Sched)
1. BMP Siting	January 26, 1998	May 11, 1998
2. BMP Design	May 12, 1998	September 2, 1998
3. Bid Projects	August 27, 1998	May 5, 1999
4. Construction	November 30, 1998	August 23, 1999
5. Monitoring	April 1, 2000	April 1, 2001
6. Final Report	July, 2001	July, 2002

Other intermediate milestones are shown on the master schedule. Estimated costs for each of the milestones and the associated components are provided in the schedule. The master schedule also indicates the timing of periodic status reports and meetings between Caltrans and NRDC.

Periodic status reports and meetings will be held to update the NRDC on the progress of the program and to receive input as to changes or modifications in the program. Status meetings have been scheduled on a regular basis to coincide with general project milestones or periods of significant activity. The status meetings will also be used as an opportunity to achieve consensus relative to the Benefit Assessment Programs previously described. The scheduled periodic status meetings (per the Target Schedule) and the primary topic of each meeting are:

Scheduled Date	Primary Topic
March 30, 1998	Pilot Project Design
September 1, 1998	Review Bids/Sampling Program
December 1, 1998	Maintenance Program/Assessment Program
March 30, 1999	Review First Season Monitoring Data
September 1, 1999	Review Benefit Assessment Programs[1]
December 1, 1999	Review Benefit Assessment Programs[1]
March 30, 2000	Review Second Season Monitoring Data
September 1, 2000	Review Final Report Format
December 1, 2000	Review Report Progress
March 30, 2001	Review Draft Report

[1]As needed/appropriate

Status reports will be prepared prior to each meeting to provide background for discussion. The status reports will be provided to NRDC two to three weeks prior to the meeting to allow for discussion of comments on the report at the meeting. Meeting minutes will be prepared for the status meetings, documenting the discussion and the agreed modifications to the program. One of the purposes of the status meetings is to provide flexibility within the program to respond to information as it is developed to allow the program to evolve in a systematic manner.

A detailed project schedule will be prepared and maintained by Caltrans to track the: 1) major decision points of the BMP Retrofit Pilot Program defined herein; 2) deliverables to the Plaintiff; 3) internal project deadlines; and 4) delivery and response dates for work items to the Plaintiffs. Further, the detailed project schedule will include other projects proceeding under the terms of the Caltrans Districts 7 and 11 litigation to provide a more comprehensive view of the overall program activities. The detailed project schedule will be regularly updated and available through the quarterly reports and the internet. Items specifically addressed at the periodic status meetings and/or on the detailed project schedule are as follows:

- Detailed design basis reports, with date for final approval of construction plans

- Construction status reports (monthly during construction periods)

- Operational plans (by project site or site group of the same project type), including--

  -- Operating procedures

  -- Maintenance plan (procedures and schedule)

  -- Benefits assessment plan (observations, measurements, water quality monitoring, etc.), including methods, schedules, anticipated data analysis techniques, etc.

- Operational status reports--covering operating actions, maintenance performed, and benefits assessment activities (quarterly during operational periods)

- Reports on problems encountered--description, potential solutions considered, solutions attempted, results of attempts, conclusions and recommendations (quarterly)

- Cost accounting (by site and categorized by site selection, design, construction, operation, maintenance, benefits assessment)

- Compilation of correspondence with external parties such as special consultants (quarterly)

Except for operational plans, reports on these elements can be submitted with status reports prepared for meetings.

Workload Allocation

The design, construction management, maintenance, monitoring and operation of the retrofit projects will be divided between four consulting firms as shown on the Master Schedule. The projects have initially been grouped into six construction bid packages to create discrete construction projects that will attract reputable construction firms.

Robert Bein, William Frost and Associates (RBF) and Kinnetic Laboratories will oversee the two construction packages in San Diego (District 11). RBF will provide design services as well as construction management for the District 11 projects. Kinnetic Laboratory will assume responsibility for the District 11 Projects following construction, completing the monitoring tasks and final report. Brown and Caldwell and Montgomery Watson -Chaudhary will oversee two construction packages each in Los Angeles (District 7). These firms will provide services from design to monitoring, and preparation of the final report for their respective construction packages. The total program, consisting of six construction packages comprised of the 38 retrofit studies, will be managed at the program level by RBF. Each of the three consulting firms involved in monitoring will have the responsibility to monitor an average of 13 pilot projects allowing for sufficient, manpower to service the sites during storm periods.

RETROFIT STUDIES

TRAPPING CATCH BASINS

Caltrans will identify and retrofit two catchments in District 7 representing highway or freeway land uses with trapping catch basins. Each catchment will consist of a minimum of four and maximum of ten drain inlets that direct stormwater to a single discharge point. Two additional catchments will be identified for use as baseline controls to estimate the overall effectiveness of the trapping catch basin retrofit program.

Site Selection

The catchments (retrofit and non-retrofit) should be located near each other and drain comparable highway or freeway segments. The segments will ideally be about the same size, have approximately the same average daily vehicle count, and contain about the same vehicle mix. The greater the dissimilarity between the watersheds, the less appropriate the use of non-retrofitted catchments as controls. Watershed outlets should have a stable channel and cross section for discharge monitoring. Each catchment should be unaltered for a number of years prior to the study so that they are at a steady state (EPA, 1993). This will assure that the only change that will occur in the water quality of either the control or retrofitted catchment will be the result of BMP implementation. Ongoing or recent construction projects could increase sediment loads or alter traffic patterns resulting in changes in runoff quality during the study period. The area served by an individual trapping catchbasin should generally be less than 0.4 ha (1.0 ac.) (Schueler, 1987).

The available land evaluated for this retrofit opportunity requires adequate space to provide access and egress for service vehicles. Space should also be available to allow ease of maintenance for operational inspections, periodic maintenance, and replacement of damaged equipment.

Design Guidance

The following design guidelines are based on information prepared for the Federal Highway Administration by Young et al (1996) except where superceded by Caltrans design criteria.. Final design details may be refined based on a further literature review and/or interviews with other agencies that have installed or tested this type of stormwater BMP. A schematic of a typical trapping catchbasin is shown in Figure 1.

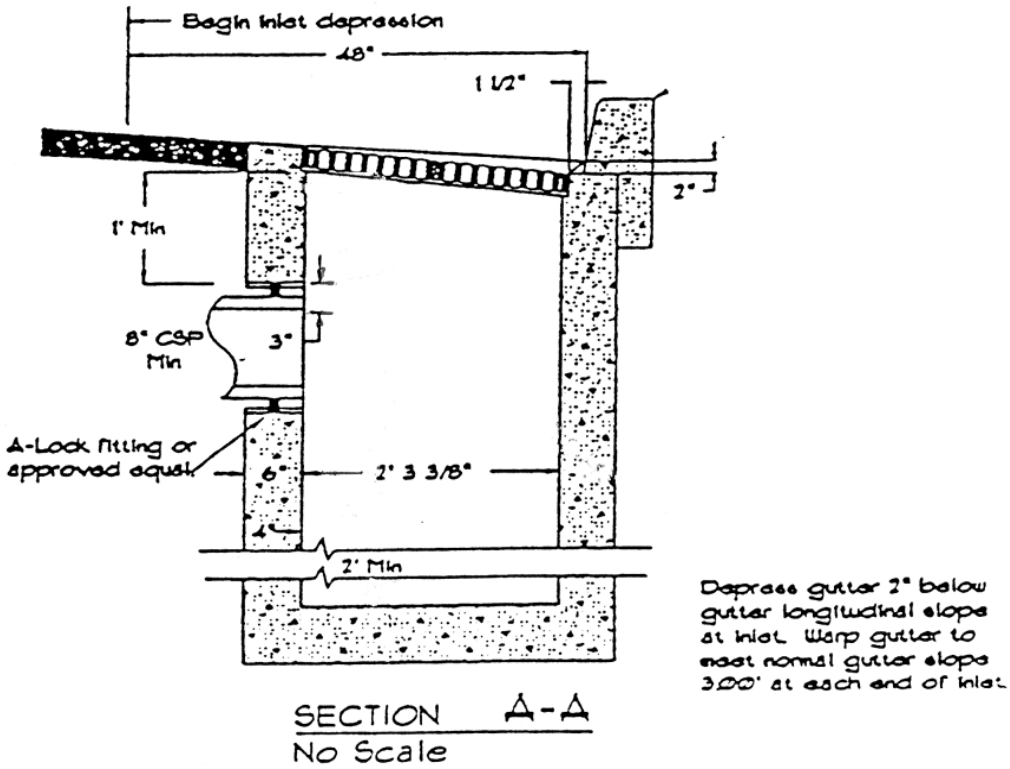

Figure 1 Schematic of Trapping Catchbasin (City of Portland, 1995)

Depth. The depth of the permanent pool will be 1.2 m (4 ft) as suggested by Schueler (1987).

Volume. The volume of the permanent pool will be determined by the design depth and the size of the standard Caltrans inlet (Type G1, p. 62 Caltrans Standard Plans, 1992).

Access. Manholes or grates will be provided for easy access to clean and maintain the trapping catchbasin. Step rings will be installed for access to the chamber floor.

Hydraulic Design. The units will be sized to meet Caltrans drainage criteria, which will be for a storm with a recurrence interval of 25 years in most instances. The structure will be constructed of reinforced concrete.

Water Table. If the groundwater table is high, the structures will be designed to avoid floatation.

Maintenance

The sumps will be cleaned when they are approximately 25 to 50% full but in all cases before they are 50% full. Normal maintenance will entail removal and disposal of material that has accumulated in the sump. It may also be necessary to remove any standing water in the sump prior to removal of the trapped solids.

Water Quality Monitoring

Each of the four identified catchments will be outfitted with automated flow monitoring and sample collection equipment similar to that manufactured by ISCO and Sigma. A solar panel or marine battery will power the equipment where access to power lines is difficult. The flow monitoring equipment will be connected to a cellular or conventional telephone line so that activity of the equipment can be monitored from a central location. This will also allow records of flow rates and sampling times to be downloaded for analysis. It is anticipated that the monitoring point will be located in the storm drain system or at the discharge point to the receiving water. Water depth will be measured using a bubble meter type-measuring device and flow will be estimated using Manning's equation, so that a control structure will not have to be installed.

Water quality data collected at each site with automatic sampling equipment will be used to characterize the average concentrations of the following constituents:

- total suspended solids (TSS),
- zinc,
- lead,
- copper,
- nitrate nitrogen,
- total Kjedahl nitrogen, and
- total phosphorus.

The concentrations of these constituents will be determined from flow weighted composite samples collected from each catchment. Attempts will be made to sample four storms per year. The water quality data will be analyzed in accordance with the methodology contained in Appendix C.

Grab samples will be collected during selected storm events (a maximum of two per year) and analyzed for total petroleum hydrocarbons (including diesel and gasoline fractions), and fecal coliform.

One of the more important elements of the monitoring program involves assessing the rate of accumulation of material in the trapping catchbasin relative to self-cleaning drain inlets. In addition, it will be necessary to determine the proper method of disposal for this material. To ensure that the data collected here is comparable to other ongoing Caltrans studies, the final procedures to be developed by CDM for the Solid Transport and Deposition Study (Draft, 1997) will be used in this study as well. Some modifications of the CDM procedures may be necessary for trapping catchbasins. If required, the specific changes will be formulated and agreed upon between Caltrans and NRDC before field application.

Schedule/Cost

Following is a list of milestone dates for the Trapping Catch Basin Retrofit Pilot Project:

1. Design complete: 5/13/98
2. Project Bid Complete: 8/13/98
3. Construction Complete: 12/1/98
4. Monitoring: 12/1/98 through 3/30/00
5. Final Report Complete: 7/2000

The total cost for the design, construction, monitoring and report preparation for the trapping catch basin analysis is $1,400,000. The total construction cost is estimated to be $638,000.

CATCH BASIN INSERTS

Caltrans will identify and retrofit with catch basin inserts six drain inlets located at Caltrans maintenance or weighing stations in District 7. Catch basin inserts are defined as containers with some filtering and/or sorbing medium to be installed in existing inlets. The catch basin inserts manufactured to date typically have been configured to remove sediment (according to the King County, Washington, Design Manual), constituents adsorbed to sediment, and oil & grease.

Site Selection

Two different designs of commercially available catch basin inserts will be installed at three sites each. The inlets will be selected that receive stormwater runoff from areas of the stations that are most likely to generate oil & grease and other constituents commonly found in maintenance station runoff. These areas would include locations where vehicles are commonly parked, where heavy equipment is stored, or where vehicle maintenance is performed. The area that drains to an inlet must be large enough so that typical stormwater flows can be easily sampled. The proposed inserts are the 'Fossil Filter' by Kristar Enterprises, and the Hydro-Kleen by Bamcom Engineering. Further investigations of other commercially available catch basin inserts that are marketed in California will be completed by Caltrans prior to final design. The brand of insert filters used in the study will be agreed upon between Caltrans and NRDC following a more detailed comparison between various units.

Design Guidance (King County, 1996)

The inserts will be installed in either curb or drain inlets according to the manufacturer's recommendations. A typical design is shown in Figure 2.

The insert will have the ability to pass high flows without causing excessive ponding, with no ponding to occur for the 1-year peak flow rate. A high-flow bypass will be provided to prevent resuspension and washout.

The insert will have the means for preventing media from escaping the unit.

The insert will have the ability to create a positive seal around the grate to prevent low-flow bypass.

The catch basin insert will be accessible as needed for maintenance and not limited by continuous vehicle parking. This may require elimination of a parking stall for these retrofit pilot projects.

Maintenance

The inserts will be replaced as noted in the following section. Periodic removal of trash and debris from 'bag' type inserts will be necessary to maintain flow capacity through the filter and the inlet. Maintenance of 'tray' type inlets will generally consist of inspection to ensure the filter media is not clogged with sediment, and that the screens are clear to allow flow to pass through the media.

Water Quality Monitoring

Each of the two insert designs will be installed in three drain inlets. The constituent removal efficiency of the inserts will be determined by extracting the sediment, metals, and hydrocarbons from the inserts. The amount of material trapped will be estimated by comparing the results from these tests with results from analyses performed on new insert materials.

Flow weighted samples will also be collected from the catchment discharge and analyzed for sediment, metals, and total petroleum hydrocarbons. Knowledge of the effluent quality and quantity will allow calculation of the influent quality by performing a mass balance on the catch basin inserts. The amount of material retained in the inserts plus the amount of material that is discharged from the catch basin must be equal to the amount of material entering the basin. Collection of samples from the basin outlet is generally easier than collecting influent samples; consequently, influent concentration will be calculated from the other two known values. Constituent removal efficiency will be estimated as the difference between calculated influent mass and measured effluent mass.

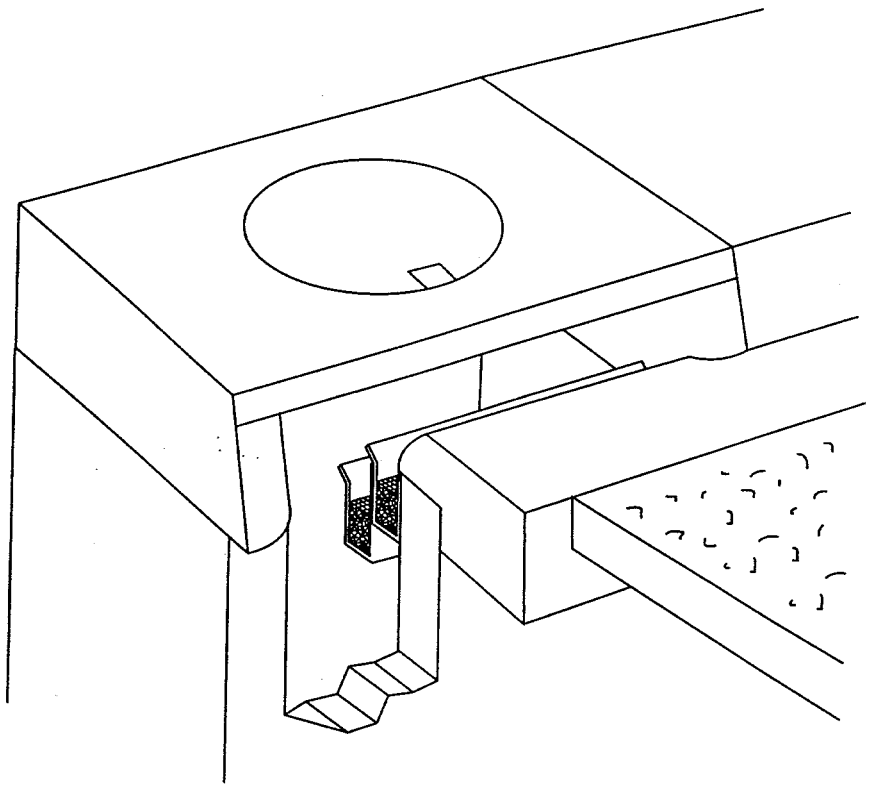

Figure 2 Schematic of Catch Basin Insert

Two of the more important issues which must be understood are the service life of the inserts under typical operating conditions and how constituent removal is affected by the age of the insert material. To resolve these questions, the media in each of the inserts will be replaced at different intervals based on the cumulative runoff treated. The insert material in one of the inlets for each of the designs selected will be replaced and analyzed for sediment, metals, and hydrocarbons following a cumulative rainfall of 13 mm (0.5 in). The insert material will be replaced and analyzed in two other inlets following a total of 100 mm (4 in) of rainfall. The material in the last pair of inlets will be replaced and analyzed annually at the end of the rainy season unless more frequent replacement will be required for maintenance proposes. Rainfall will be measured at another fully instrumented site in the vicinity.

The sites selected for installation of these devices will be nearly 100% paved so the total rainfall can be easily used to calculate the total volume of runoff treated. The concentration reduction resulting from the use of these devices will be calculated as the mass of material retained in the insert divided by the total volume of runoff.

The catch basin inserts will be analyzed for the following constituents:

- total suspended solids (TSS),
- zinc,
- lead,
- copper, and
- total recoverable petroleum hydrocarbons.

Schedule/Cost

Following is a list of milestone dates for the Catchbasin Insert Pilot Project:

1. Design complete: 6/8/98/98
2. Project Bid Complete: 8/01/98
3. Construction Complete: 12/1/98
4. Monitoring: 12/1/98 through 3/30/00
5. Final Report Complete: 7/2000

The total cost for the design, construction, monitoring and report preparation for the catchbasin insert is $820,000. The total construction cost is estimated to be $44,700.

EXTENDED DETENTION BASINS

As required by the stipulation, Caltrans will conduct an Initial Investigation of the feasibility and performance of extended detention basins for treating freeway and highway runoff in the Los Angeles District 7 area. The Initial Investigation will identify data gaps and determine the feasibility of constructing extended detention basins along Caltrans right-of-way. The Initial Investigation will address the following issues:

- Availability of existing right-of-way
- Availability of other land
- Suitability of soils and other site conditions
- How the basin slopes can be stabilized
- Definition of design criteria
- Operation and maintenance requirements
- Regulatory wetlands issues
- Efficiency in removing constituents in stormwater
- Minimum hydraulic residence time for designated basin performance

If it is mutually agreed by NRDC and Caltrans that the issues listed above have been resolved following completion of the Initial Investigation, then the extended detention basin portion of the Retrofit Pilot Program will terminate. Should either party determine that the Initial Investigation is incomplete due to lack of field experience and prototype specific data, the retrofit pilot program will continue with one of the following two options: 1) the construction of one extended detention basin in District 7 and the monitoring of the existing detention basin in District 12 or 2) the construction of two extended detention basins in District 7.

The decision between the two options will be made by Caltrans and NRDC based on the information collected during the Initial Investigation. If it is decided to construct one new extended detention basin and monitor the existing basin in District 12, maintenance to the existing basin will be provided. At minimum, vegetation at the bottom of the basin will be managed before the start of the monitoring period per the California Department of Fish and Game permit #5-261-97 to prevent classification of the basin as a wetland.

The objective of extended detention basins is to remove particulate constituents. The water quality benefits are the removal of sediment and buoyant materials. Furthermore, nutrients, heavy metals, toxic materials, and oxygen-demanding particles are also removed with associated particles. The control of the maximum runoff levels serves to protect drainage channels below the device from erosion and to reduce downstream flooding. However, the subject basins will not be designed for peak flow attenuation and control of peak discharge, rather they will be designed using guidance relative to water quality operation.

Site Selection (Young et al, 1996)

Normally, the land required for an extended detention basin is approximately 0.5 to 2.0 percent of the total tributary development area. Although the soil types beneath the pond seldom prevent the use of this BMP, they should be considered during design. Any exfiltration capacity should be considered a short-term characteristic because exfiltration will decrease over time as the soil is clogged with fine sediment. In areas with very coarse soils, detention basins can be constructed of concrete or lined with compacted clay.

The runoff that is subject to this BMP should originate as much as possible within the highway right-of-way. Since rights-of-way are typically narrow, highway extended detention dry ponds are likely to be long and narrow. They can be located to the sides next to the shoulders. They can also be located in the lands around intersections where not precluded by safety considerations.

Curb and gutter sections are ideal catchments to maximize on-site and minimize off-site drainage to highway BMPs, as are bridge deck systems. Rest areas and weigh stations can also be located with this BMP. Extra area may be needed to accommodate this BMP, and this requirement should be factored into preliminary design and retrofit activities. Figure 3 shows how an extended detention pond may be located within a highway right-of-way.

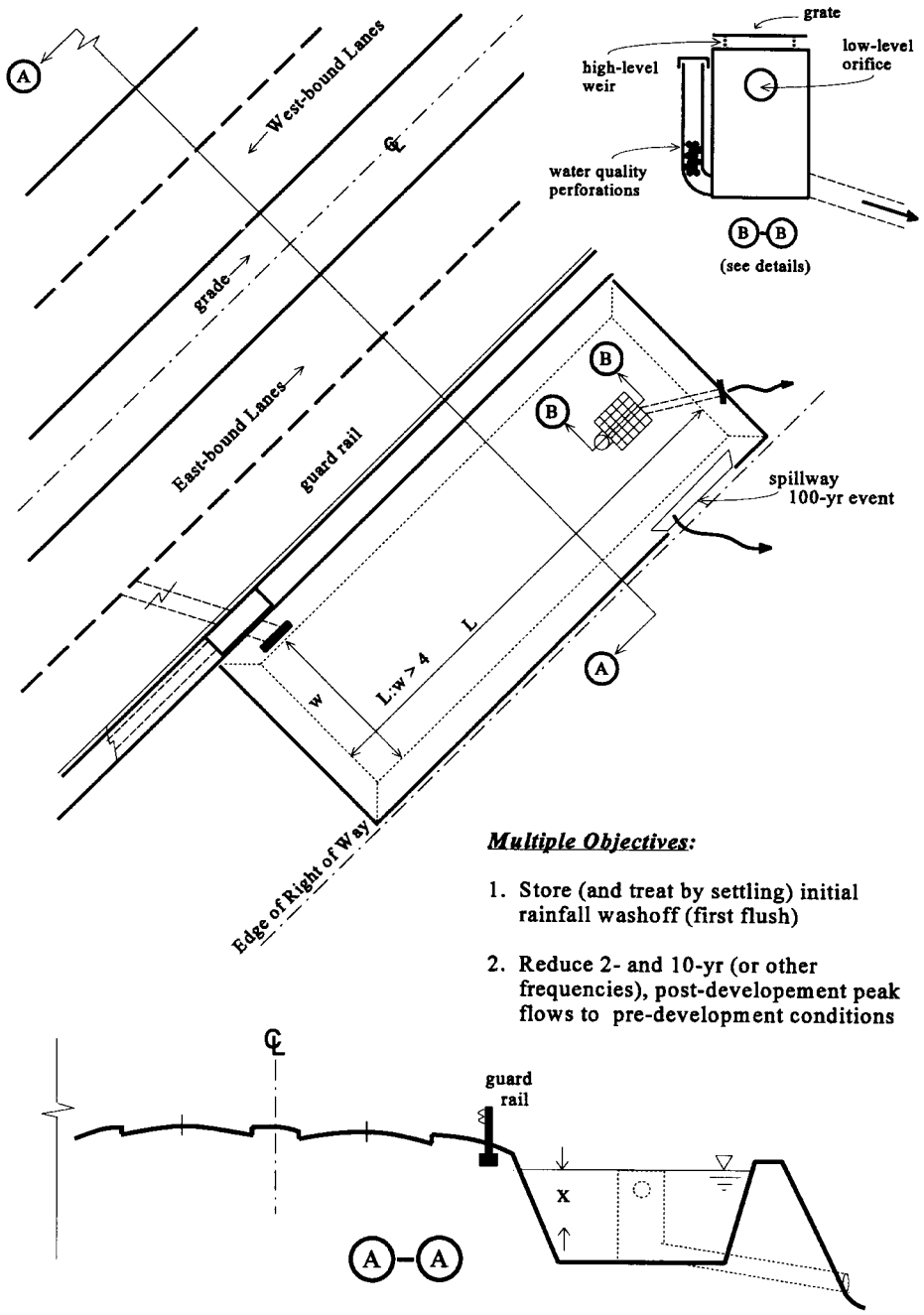

Figure 3 Schematic of an Extended Detention Pond

Design Guidance

Estimating the appropriate dimensions of a BMP facility is largely based on a trial and error process in which the designer tries to fit the required BMP volume so that it works well with the site. Each site has its own unique limiting factors. Some constraints other

than the existing topography include, but are not limited to, the location of existing and proposed utilities, depth to bedrock, and location and number of existing trees. The designer can analyze possible basin configurations by varying the surface area and depth and then determining the corresponding available storage (Young et al, 1996).

In order to enhance the effectiveness of BMP basins, the dimensions of the basin must be sized appropriately. Merely providing the required storage volume will not ensure maximum constituent removal. By effectively configuring the basin, the designer will create a long flow path, promote the establishment of low velocities, and avoid having stagnant areas of the basin. To promote settling and to attain an appealing environment, the design of BMP basin should consider the length to width ratio, cross-sectional areas, basin slopes and pond configuration, and aesthetics (Young et al, 1996).

Caltrans has identified a number of criteria to be applied to basin design (CDM et al, 1997):

Access: A permanent area will be provided around the perimeter of the impoundment to allow maintenance. Provisions will also be made for emptying the basin as necessary for maintenance.

Volume: Caltrans has adopted a maximum design goal of sizing detention basins to capture the entire runoff from a one-year, 24-hour storm event. Determine the one-year, 24-hour storm event for either the closest rain gauge to the project site, or the average of the closest 2-3 gauges, particularly where there is a significant elevation difference between the closest gauge and the project site (see Sheet 1, Appendix C, Staff Planning and Design Guide). The runoff produced by this storm based upon the characteristics of the project drainage area after completion of the project should then be calculated and the resulting volume used as a maximum design target. A smaller design storm may be used based on site specific conditions.

Detention Time: Extended detention basins require longer detention times to provide the opportunity for sediment particles in the runoff to settle out of the water column. Detention facility studies indicate that effective detention basins should be designed for a detention time of 24 hours for <u>average</u> conditions rather than full basin conditions. In California, a 24-hour average detention time for the full range of storms up to and including the water quality design storm is generally achieved with a full-basin drawdown time of 72 hours, where the drawdown time is the time required for a full basin to empty. Although longer detention times improve constituent removal in the basins, there is a tendency for the smaller outlet structures to clog with litter, grass clippings and other debris (Barrett et al, 1997).

Basin Geometry: The configuration of the basin, as well as the location of the associated facilities (inlet, outlet structures, baffles, etc.), will significantly impact the desired function of the basin. In order to enhance constituent removal, the hydraulic flow length

of the basin will be maximized. The length to width ratio of the basin will be on the order of 3:1 or greater depending on the site configuration. Pond depths range from 1.2 m (4 ft) to 1.8 m (6 ft) (CDM et al, 1997).

Basin Side Slopes: Embankment slopes will be stable and gentle enough to limit rill erosion and facilitate maintenance access and needs. Although limited by the stability of the soil, basin slopes should be 4:1 or flatter. Steeper slopes may require that the facility be fenced for safety, although basin side slopes should not exceed 2:1. Embankment slopes will be compacted and stabilization of slopes provided to assist in preventing erosion. Height limitations should be in accordance with HDM Index 829.9 and verified by the Division of Dam Safety.

Inlets: Inlet structures will be designed to dissipate flow energy at the inlet point to limit erosion and promote particle sedimentation. They will be located as far as possible from the outlet structure to maximize the hydraulic flow length (CDM et al, 1997).

Maintenance Considerations: Maintenance procedures also will be considered during the design stage. Basins will be located such that safe and easy access for maintenance is provided. Debris in empty basins may be unsightly and require more frequent maintenance. In some areas, mosquitoes and other insects may require additional maintenance requirements (CDM et al, 1997).

Safety: Safety is a major consideration when planning retention/ detention basins. Basins will be located where failure would not cause loss of life or property damage. Basins will be fenced to prevent public access. The size of the basins will be kept below the threshold that would require approval from the State Division of Safety of Dams, which is less than 50 acre-feet of storage and a 25 foot embankment height, or unlimited storage and a maximum 6 foot embankment height.

Maintenance

Periodic removal of sediments will be required to maintain the basin stormwater capture volume and to remove undesirable or excessive vegetation growth. Maintenance access to the basin invert for this purpose. The outlet structure and debris rack should also be inspected prior to each storm event.

Water Quality Monitoring

Constituent removal in the extended detention basin will be determined by comparison of the average water quality of runoff entering the facility with that leaving (see Appendix C). Automatic sampling equipment will be installed at the inlet and outlet of the device to collect flow weighted composite samples. These sites will be designed to incorporate flow measurement structures.

The most appropriate flow measurement structures for basin inlets are Parshall flumes and H flumes. An advantage of these devices is their ability to pass trash and other debris, which tend to accumulate in structures such as V-notch weirs. The high velocity through the flume prevents sediment accumulation from runoff with high suspended solids concentrations. In addition, these devices operate with a much smaller head loss than a weir. Depending on the size of the contributing watershed, an H flume is preferred because of its ability to accurately measure a wider range of flows.

Flow measurement at the basin outlet is subject to different constraints than at the inlet. Because of the long detention times, flow rates will necessarily be much lower and most of the trash and debris will have been removed from the runoff. Therefore, a V-notch weir is the preferred option for measuring flow at this location. The type and size will be determined by the size of the watershed and expected discharge rate from the basin.

An attempt will be made to sample five storms per year following construction of the facilities. The runoff samples collected by the automatic sampling equipment will be analyzed for:

- total suspended solids (TSS),
- zinc,
- lead,
- copper,
- nitrate nitrogen,
- total Kjedahl nitrogen, and
- total phosphorus.

Manual grab samples will also be collected during two events each year to determine the instantaneous concentrations of:

- total petroleum hydrocarbons, and
- fecal coliforms.

At the end of the monitoring period, samples of the sediment that has been retained by the basin will be collected and analyzed to determine the proper disposal method.

Vegetation changes in the basins will be documented over the monitoring period. Standard botanical techniques will be used to record vegetation cover once during each growing season.

Schedule/Cost

Following is a list of milestone dates for the Extended Detention Basin Pilot Project:

1.
2. Design complete: 5/06/98
3. Project Bid Complete: 8/6/98
4. Construction Complete: 12/01/98
5. Monitoring: 12/01/98 through 3/30/00
6. Final Report Complete: 7/2000

The total cost for the design, construction, monitoring and report preparation for the extended detention basin project is $ 1,800,000. The total construction cost is estimated to be $ 564,800.

INFILTRATION BASINS

Infiltration basins are similar to detention ponds, except that they have a high flow spillway only and no standard outlet structure. The incoming stormwater runoff is stored until it gradually exfiltrates through the soil of the basin floor. Subject to the results of an Initial Investigation, three basins may be constructed to treat stormwater discharge from freeways or highways.

The stipulation requires that an Initial Investigation be prepared to identify data gaps and determine the feasibility of constructing infiltration basins along Caltrans right-of-way. The Initial Investigation will address the following issues:

- Availability of existing right-of-way
- Availability of other land
- Suitability of soils and other site conditions
- How the basin slopes can be stabilized
- Definition of design criteria
- Operation and maintenance requirements
- Regulatory wetlands issues
- Rates of infiltration under typical storm water runoff conditions
- The tendency for clogging
- The potential for groundwater contamination and associated regulatory implications

If it is mutually agreed by NRDC and Caltrans that the issues listed above have been resolved following completion of the Initial Investigation, then the infiltration basin portion of the Retrofit Pilot Program will terminate. Should either party determine that the Initial Investigation is incomplete due to lack of field experience and prototype specific data, the retrofit pilot program will continue with the construction of one infiltration basin in District 7 and the construction of two infiltration basins in District 11.

Site Selection (Young et al, 1996)

The location for placement of an infiltration basin must be carefully chosen. One of the most important aspects of a site is the type of soil. Other factors which are important in the site selection include slope, bedrock depth, and depth to the water table. In general, only SCS Type A and B soils have high enough infiltration rates to permit drainage of the basin without excessive clogging. Soils composed of more than 30% clay or 40% combined silt and clay are undesirable. Soil cores should be taken to a depth of at least 1.5 m (5 ft) below the proposed basin floor elevation to determine which kinds of soils are prevalent at the potential sites. The basins should also be a minimum of 0.6 to 1.2 m (2 to 4 ft) above the seasonally high water table. They should not be located within 30 m (100 ft) of drinking water wells to avoid any possible contamination (Schueler, 1987).

The basins should also be a minimum of 3-m (10-ft) down-gradient and 30 m (100 ft) up gradient from building foundations because of possible seepage problems. In addition, the basins should be located down gradient from highway pavement to avoid infiltration to the pavement edgedrain system.

Design Guidance (Young et al, 1996)

Drainage Area. Drainage areas between 2 and 20 ha (5 to 50 ac) are good candidates for infiltration basins. Smaller areas are better served by infiltration trenches (Schueler, 1987).

Volume. The basin will be able to exfiltrate the design storm volume (see Sheet 1, Appendix C, Caltrans Planning and Design Staff Guide) from the contributing watershed (smaller storms can be considered based on site specific conditions). The optimum configuration places the basin off-line so that additional runoff is routed around the basin, rather than displacing the captured first flush volume.

Slope. The basin floor will be as flat as possible to ensure an even infiltration surface. Side slopes will have a maximum slope of 2:1.

Avoidance of Compaction. Compaction during construction will be avoided if possible by excavating from the sides of the basin as opposed to from the basin floor. If using equipment on the basin floor is unavoidable, light equipment will be used, and the floor will be deeply tilled with a rotary tiller or disc harrow upon completion of excavation. This should be followed by a pass with a leveling drag (Schueler, 1987).

Vegetation. Vegetation will be established if possible. Root penetration and thatch formation maintains and sometimes improves infiltration capacity of the basin floor. In addition, the vegetation helps to trap the constituents by growing through the accumulated sediment and preventing resuspension.

Inlet. An energy dissipation device will be installed to reduce inflow velocities, trap sediment upon entrance to the basin, and distribute flow evenly over the floor. The inlet pipe or channel will enter the basin at floor level to prevent erosion.

A schematic of an off-line infiltration basin is shown in Figure 4.

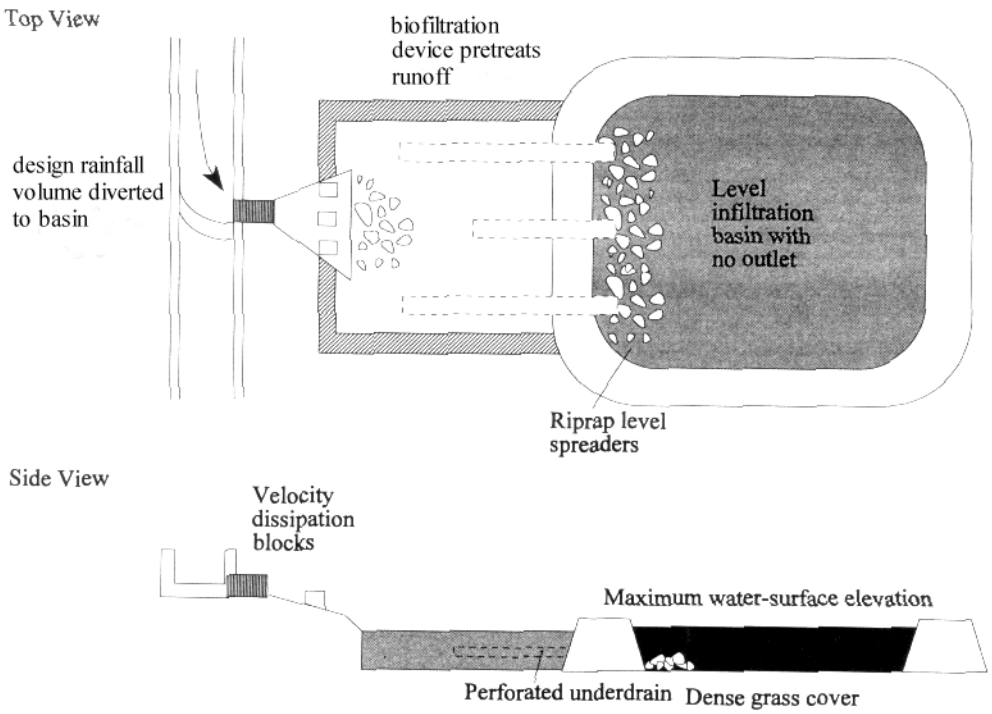

Figure 4 Schematic of Infiltration Basin Design

Maintenance

Infiltration basins must be periodically cleaned to remove trapped sediments and restore permeability. Over the course of operation, fines will accumulate on the basin invert creating a relatively impervious veneer that reduces the average infiltration rate. The deposits must be removed from the basin when the infiltration time for the design storm volume exceeds 72 hours. Vegetation must also be managed to prohibit excessive amounts that would reduce the stormwater volume, moderate vegetation is generally seen as a positive attribute for infiltration devices as it can aide in maintaining permeability of the soil and assist in the uptake of some soluble constituents.

Water Quality Monitoring

The monitoring program is designed to address three main questions related to the use of infiltration basins: 1) What is the degree and rate of infiltration? 2) Is constituent removal sufficiently high in the basin to avoid contamination of groundwater? and 3) How should the material that collects in basins be disposed?

The rate of stormwater infiltration will be measured by installing an automated flow meter in the basin. The meter will be a bubbler type device, which is available from a number of manufacturers. The meter will record changes in water depth in the basin so that infiltration rate can be calculated. These data will also indicate how the infiltration rate changes over the course of the study period and indicate when maintenance is required to remove material that has accumulated on the surface of the basin.

The method for determining the threat to groundwater supplies will depend on the depth to groundwater at the site. If the groundwater level is within about 10 m (33 ft) of the basin floor, a monitoring well will be constructed to allow water quality samples to be collected twice a year from the saturated zone. The well will be installed adjacent to the basin to prevent possible short-circuiting down the annulus of the well and to facilitate access and sampling. The samples will be analyzed for:

- zinc,
- lead,
- copper,
- nitrate nitrogen,
- total Kjedahl nitrogen,
- total phosphorus
- total petroleum hydrocarbons, and
- fecal coliform.

If the normal groundwater level is deep, then samples will have to be collected from the vadose zone. This type of sampling requires a pressure-vacuum lysimeter. The lysimeter will be installed according to the manufacturer's recommendations and placed so that samples are collected at a depth of 1-2 m (3-6 ft) below the basin floor. This type of sampling is only appropriate for the analysis of dissolved constituents, because the water must be drawn through a ceramic or Teflon cup.

Collection of sufficient sample volumes from the unsaturated zone is normally only possible following significant rainfall. Groundwater quality changes relatively slowly in response to changes in the characteristics of the recharged water, so an intensive monitoring program is not necessary. Samples will be collected twice each year, in December and February. Based on previous water quality monitoring of runoff from highways in the Los Angeles area, the main dissolved constituents that are of concern are heavy metals. Therefore, the samples will be analyzed for the zinc, lead and copper.

The rate of accumulation of material in the infiltration basins will be determined by making annual measurements at the end of the rainy season of depth of material in the basins. Sediment samples will be collected from the surface of the infiltration basin at the same time. The samples of sediment will be analyzed for particle size distribution,

zinc, lead, copper, and total petroleum hydrocarbons. The sediment will be subjected to the appropriate analyses to determine the proper method of disposal.

Core samples in the infiltration basin will be collected to determine the rate at which constituents are transported into the subsurface. Samples of soil will be collected from depths of 0.3 m and 0.6 m (1 ft and 2 ft) in the infiltration basin and analyzed for zinc, lead, copper, and total petroleum hydrocarbons. Similar samples will also be collected and analyzed immediately following completion of construction for comparison.

Vegetation changes in the basin will be documented over the monitoring period. Standard botanical techniques will be used to record vegetation cover once during each growing season.

Schedule/Cost

Following is a list of milestone dates for the Infiltration Basin Retrofit Pilot Project:

1.
2. Design complete: 5/13/98
3. Project Bid Complete: 8/13/98
4. Construction Complete: 12/1/98
5. Monitoring: 12/1/98 through 3/30/00
6. Final Report Complete: 7/2000

The total cost for the design, construction, monitoring and report preparation for the infiltration basin analysis is $ 2,700,000. The total construction cost only is estimated to be $ 352,200.

INFILTRATION TRENCH

Caltrans will identify four sites in District 7 and two sites in District 11 and construct infiltration trenches in the drainage pathway from Caltrans maintenance yards. These devices will be designed to infiltrate the majority of runoff to the saturated zone.

Site Selection

The following criteria suggested by Young et al (1996) will be used to site the infiltration trenches.

Several factors need to be considered when a potential infiltration site is being examined. The soil type and drainage area are two of the most important aspects of the site. A drainage area of between 0.4 and 4 ha (1 to 10 ac) is recommended. Other factors to examine include the slope of the watershed, the depth to bedrock and the seasonally high water table. The distance to wells and foundations must also be examined (Schueler, 1987). The bottom of the facility should be at least 1.2 m (4 ft) above the underlying bedrock and at least 0.6 to 1.2 m (2 to 4 ft) above the seasonally high water table (Yu and Kaighm, 1992).

Soil should have an infiltration rate greater than or equal to 7 mm/h (0.27 in/h) for practical design. Some suggest a minimum infiltration rate of 13 mm/h (0.5 in/h) (Yu and Kaighm, 1992; Schueler, 1992). This rate is associated with the sand, loamy sand, sandy loam, loam, and silt loam soil groups. Soils should be tested at the site by taking a core to a depth of at least 1.5 m (5 ft) below the anticipated level of the stone reservoir bottom. The cores should be examined for anything that might inhibit infiltration, such as localized clay lenses, hardpans, or fragipans. Trenches should not be placed on "D" soils (soils with infiltration rates of less than 0.27 in/h), or on soils with a clay content greater than 30 percent. Placing an infiltration trench on C and D soils is questionable, and should only be considered if the trench is of the partial-infiltration type. Soils with a combined silt/clay percentage greater than 40 are also not good sites for infiltration trenches (Schueler, 1987). In-field infiltration tests are being conducted on potential infiltration basin sites for this pilot program.

Trenches should not be placed in sites where the incoming drainage area has a slope greater than 20 percent. The slope of the trench bottom should be approximately zero, unless an outlet placed at the bottom of the trench is part of the design (Schueler, 1987).

Design Guidance

Infiltration trenches and infiltration basins follow similar design logic. The differences are that the former is for small drainage areas and stores runoff out of sight, within a

gravel or aggregate matrix, whereas the latter is for larger drainage areas and water is stored in a visible surface pond.

Infiltration trenches can be categorized both by trench type, and as surface or below ground. Trench types include *complete, partial, and water quality* infiltration trenches. A schematic of a typical infiltration trench is shown in Figure 5.

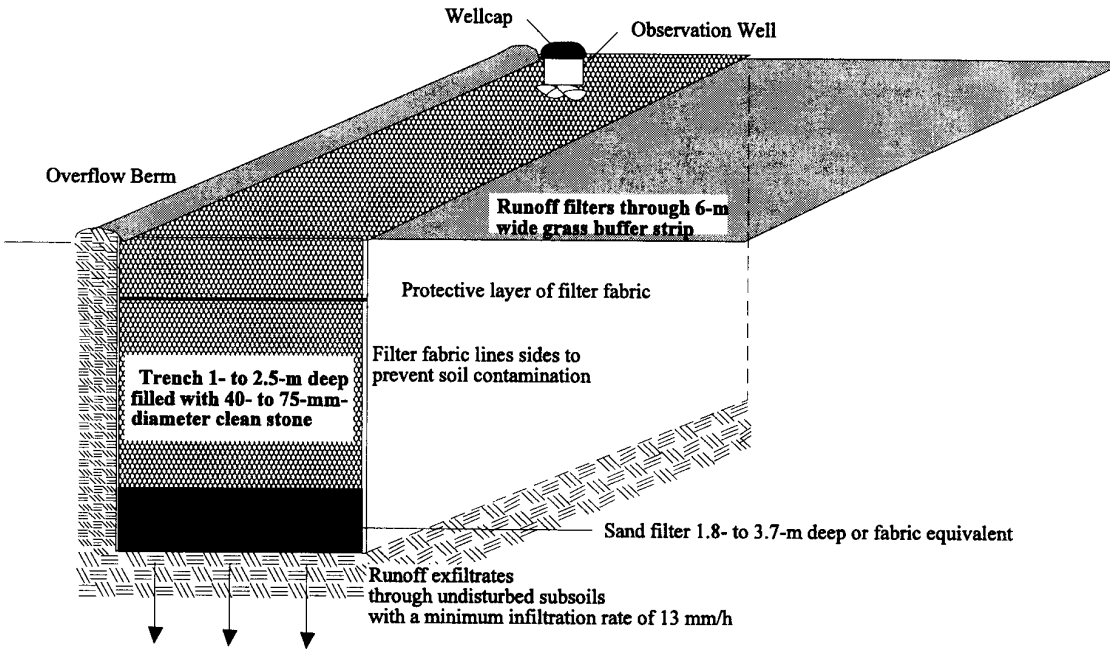

Figure 5 Cross-section of an Infiltration Trench

Volume. Trenches will be sized using the design storm approach (see Sheet 1, Appendix C of the Caltrans Planning and Design Staff Guide for volume calculation).

Dimensions. Generally, soils with low infiltration rates require a higher ratio of bottom surface area to storage volume (Northern Virginia Planning District Commission and Engineers and Surveyors Institute, 1992).

The actual storage volume of the facility is the void ratio multiplied by the total volume of the trench. Constraints such as available land, depth to bedrock, and height of the water table are used to determine the final dimensions of the trench.

Buffer Strip/Special Inlet. A grass filter strip a minimum of 6-m (20 ft) wide should surround the trench on all sides over which surface flow reaches the trench. A special inlet can be used to prevent floatable material, solids, grease, and oil from entering trenches that are located below ground (Young et al, 1996).

Filter Fabric. The bottom and sides of the trench will be lined with filter fabric soon after the trench is excavated. The fabric will be flush with the sides, overlap on the order of 0.6 m (2 ft) over the seams, and not have trapped air pockets. As an alternative, 150 mm (6 in) of clean, washed sand may be placed on the bottom of the trench instead of filter fabric (Young et al, 1996).

Grass Cover. If the trench is grass covered, at least 0.3 m (1 ft) of soil will be over the trench for grass substrate (Young et al, 1996).

Surface Area. The surface area of the trench can be engineered to the site with the understanding that a larger surface area of the bottom of the trench increases infiltration rates and helps to reduce clogging. The depth may be limited by seasonal groundwater (Young et al, 1996).

Surface Area of the Trench Bottom. Constituent removal in a trench can be improved by increasing the surface area of the trench bottom. This can be done by adjusting the geometry of the trench to make it shallow and broad, rather than deep and narrow. Greater bottom surface area increases exfiltration rates and provides more area and depth for soil filtering. In addition, broader trench bottoms reduce the risk of clogging at the soil/filter cloth interface by spreading exfiltration over a wider area (Young et al, 1996).

Groundwater Table. The groundwater table should be at least 0.6 to 1.2 m (2 to 4 ft) below the bottom of the trench (Young et al, 1996).

Distance from Wells and foundations. The trench will be at least 30 m (100 ft) away from any drinking water supply well, and at least 3 m (10 ft) down-gradient and 30 m (100 ft) up-gradient from building foundations (Schueler, 1987).

Drain Time. The drain time will be between two and three days. The total volume of the trench, if greater than the water quality volume, should drain in 72 hours, while the calculated water quality volume should drain in 48 hours (Young et al, 1996).

Backfill Material. The backfill material in the trench will be D50 sized between 40 and 80 mm (1.5 and 3 in) and the clay content will be limited to less than 30 percent. The porosity of the material should be between 0.3 and 0.4 (Young et al, 1996).

Observation Well. An observation well of 100-mm to 150-mm (4-in to 6-in) diameter PVC will be located in the center of the trench and the bottom will rest on a plate. The top should be capped (Young et al, 1996).

Overflow Berm. A 50-mm to 75-mm (2-in to 3-in) emergency overflow berm on the downstream side of the trench serves a twofold purpose. First, it detains surface runoff

and allows it to pond and infiltrate to the trench. The berm also promotes uniform sheet flow for runoff overflow (Young et al, 1996).

Slope. Surface trenches are not recommended when contributing slopes are greater than five percent. The slope of the bottom of the trench will be near zero to evenly distribute exfiltration, unless the design includes a positive outlet (Young et al, 1996).

Maintenance

The infiltration trench will be monitored via the observation well to ensure that acceptable permeability is maintained over the life of the project. The trench must be completely drained within 72 hours. Maintenance of the trench would entail removal of the gravel matrix and the filter fabric, and replacement of these components.

Water Quality Monitoring

Water quality samples will be collected from the vadose zone below the trenches. This type of sampling requires a pressure-vacuum lysimeter. The lysimeter will be installed according to the manufacturer's recommendations and placed so that samples are collected at a depth of 1-2 m (3-6 ft) below the trench floor. This type of sampling is only appropriate for the analysis of dissolved constituents, because the water must be drawn through a ceramic or Teflon cup.

Collection of sufficient sample volumes from the unsaturated zone is normally only possible following significant rainfall. Groundwater quality changes relatively slowly in response to changes in the characteristics of the recharged water, so an intensive monitoring program is not necessary. Samples will be collected twice each year, in December and February. Based on previous water quality monitoring of runoff from highways in the Los Angeles area, the main dissolved constituents of concern are heavy metals. Therefore, the samples will be analyzed for the zinc, lead and copper.

The trenches will be visually monitored for two years to determine the following:

- Trench surface stabilization methods to promote infiltration,
- Rates of infiltration under typical stormwater runoff conditions,
- Operation and maintenance requirements, and
- Tendency for clogging.

A monitoring well will be constructed in each of the infiltration trenches to monitor the rate of infiltration into the soil and to determine whether the trenches are draining in the recommended time. Measurements of water level in the monitoring well will be made twice a year following rainfall events of at least 12 mm (0.5 inches). These data will

indicate the rate of infiltration under typical conditions and assess how that rate changes during the monitoring period.

Project personnel will observe the performance of the infiltration trenches during four storms each year. Logs will be kept to indicate the degree to which clogging of the trench surfaces is restricting the flow of runoff into the trench.

Schedule/Cost

Following is a list of milestone dates for the Infiltration Trench Pilot Project:

1. Design complete: 6/8/98
2. Project Bid Complete: 8/1/98
3. Construction Complete: 12/1/98
4. Monitoring: 12/1/98 through 3/30/00
5. Final Report Complete: 7/2000

The total cost for the design, construction, monitoring and report preparation for the infiltration trench is $ 1,300,000. The total construction cost is estimated to be $310,000.

BIOFILTRATION SWALES AND STRIPS

Caltrans will construct biofiltration swales at four sites in District 7 and two sites in District 11. Biofiltration strips will be constructed at two sites in District 7 and one site in District 11. There are two key elements to investigate related to the use of vegetative controls for treating highway runoff in this area. The first is the identification of appropriate vegetation for an area with little rainfall and prolonged dry spells. The second is the evaluation of the constituent removal, which will be associated with this vegetation.

Caltrans will identify a suitable seed mix for use in the filter strips and swales. Criteria used for the selection of the mix will include: 1) vegetation stays below a maximum height of six inches to avoid mandatory mowing, 2) vegetation is drought tolerant and does not require irrigation, 3) vegetation is compatible with adjacent landscape and Caltrans policy relative to Integrated Vegetation Management (IVM) principles, 4) vegetation is suitable for a BMP type application (e.g., provide adequate 'filtering' of runoff). Relevant available information on the environmental requirements of the potential vegetation selections will be reviewed and considered to make choices and develop planting and maintenance plans best suited for conditions at the study sites.

The biofiltration devices will be constructed in conjunction with the infiltration devices (trenches and basins) wherever possible to provide pretreatment, and a 'treatment train' approach. The total number of each biofiltration device (swales and strips), as shown in Table 1, will be preserved and the constituent removal performance of the biofiltration devices will be determined independently of any other associated BMP.

Site Selection (Young et al, 1996)

Swales

The suitability of a swale at a site will depend on land use, size of the area serviced, soil type, slope, imperviousness of the contributing watershed, and dimensions and slope of the swale system. (Schueler, 1992). In general, swales can be used to serve small areas, less than 4 ha (10 ac) in size, with slopes no greater than 5 percent. The seasonal high water table should be at least 0.3 to 0.6 m (1 to 2 ft) below the surface and buildings should be at least 3 m (10 feet) from the site. Use of natural topographic lows is encouraged, and natural drainage courses should be regarded as significant local resources to be kept in use.

Drainage patterns and contributing areas can be determined from contour maps generated from surveys. Roadside ditches should be regarded as potential sites as well. The

suitability of swales may be reduced as the number of culverts increases, and they are not especially compatible with extensive sidewalk systems.

Swale systems require dry soils with good drainage and high infiltration rates for better constituent removal (Yousef, et al., 1985). It is desirable for the permeability or final infiltration rate of the underlying soil to be at least 4.3 mm/h (0. 17 in/h). The suitable textural classes of the soil underlying the swale are sand, loamy sand, sandy loam, loam, silt loam, and sandy clay loam. Heavy clays that would not support good vegetation and would promote ponding should be avoided. Soil types in the area will be determined through soil survey maps.

The area required for a swale system varies, depending on area to be served, soil types, and design. A length of 61 m (200 ft) is often recommended, although some swale designs have been effective with lengths between 30 and 38 m (100 to 125 ft). Width varies from 0.6 to 2.4 m (2 to 8 ft), and can be adjusted to a maximum of 3.1 m (10 ft) to increase the area of the swale system if an acceptable length cannot be achieved (Washington State Department of Transportation, 1995).

The topography of the site should permit the design of a channel with a slope and cross sectional area sufficient to maintain an appropriate flow velocity. Site topography may also dictate a need for additional structural controls. Recommendations for longitudinal slopes range between 2 and 6 percent (Khan, 1993). Shallower slopes can be used, if sufficient to provide adequate conveyance. Steep slopes increase flow velocity and decrease detention time, and may require energy dissipating and grade check. Steep slopes can also be managed through the use of a series of check dams to terrace the swale and reduce the slope to within acceptable limits. The use of check dams with swales also promotes additional infiltration.

Filter Strips

The most important criteria for selection and use of this BMP for highways are soils, space, and slope, where:

Soils and moisture are adequate to grow relatively dense vegetative stands. Underlying soils should be similar to that required for swales so that much of the runoff will be infiltrated. The presence of clay and organic matter in soils improves the ability of filter strips to remove constituents from the surface runoff (Schueler, 1992).

Sufficient space is available. Because filter strip effectiveness depends on having an evenly distributed sheet flow, the size of the contributing area and the associated volume runoff have to be limited (Urbonas, 1992). To prevent concentrated flows from forming, it is advisable to have each filter strip adjacent to the highway pavement so that they are subjected only to low flow rates.

Slope. When filter strips are used on steep or unstable slopes, the formation of rills and gullies can disrupt sheet flow (Urbonas, 1992). As a result filter strips will not function at all on slopes greater than 15 percent and may have reduced effectiveness on slopes between 6 and 15 percent. Simple, V-shaped highway medians or shoulder areas with length of at least 8 meters (27 feet), full vegetative cover, and slopes less than 12% are effective at reducing concentrations of many highway stormwater constituents.

Design Guidance

Swales

Several criteria should be kept in mind relative to swale design. These provisions presented in Table 3 have been developed through a series of studies conducted on swale performance. A typical swale cross-section is shown in Figure 6.

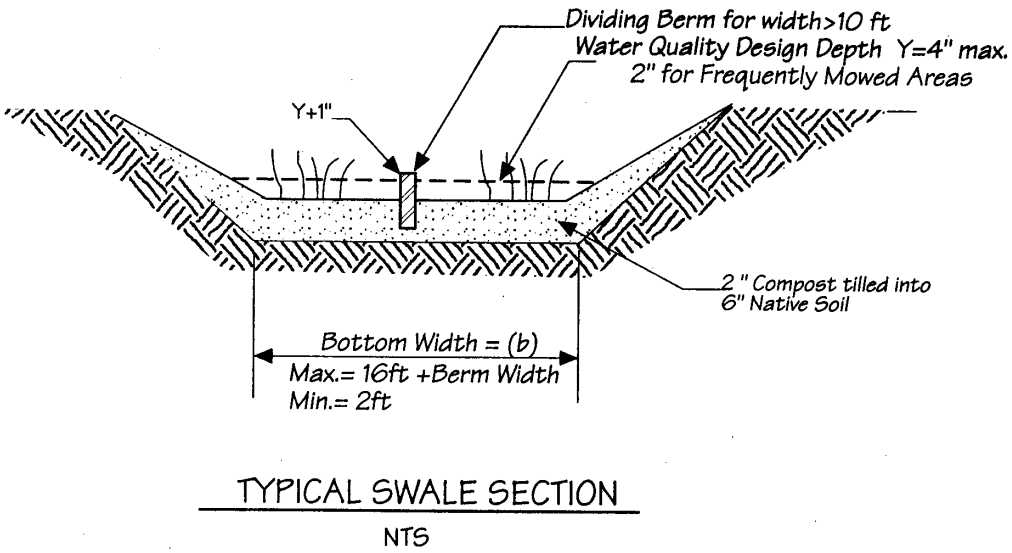

Figure 6 Schematic of a Typical Swale

Table 3: Criteria for Swale Design (Young et al, 1996)

Parameter	Optimal Criteria	Minimum Criteria
Hydraulic Residence Time	9 min	> 5 min
Average Velocity	< 0.27 m/s	-
Width	2.4 m (8 feet)	0.6 m (2 feet)
Slope	2 – 6%	1 %
Side Slope	4:1	2:1

The maximum flow velocity in the swale under drainage design conditions (25-year event) shall be limited to 1.2 m/s (4 ft/s), consistent with the Caltrans Highway Design Manual. Velocities for the water quality storm event will be much lower, due to the lower discharge.

There are a number of ways to apply the design procedure, depending on the order in which the steps are performed and the variables established at the beginning of the process. The procedures described below were set forth by Horner, and unless otherwise cited, are set forth in *Biofiltration for Stormwater Runoff Quality Control*, published in 1993. Horner's procedure reverses Chow's order, designing first for capacity, to emphasize the promotion of biofiltration, rather than the simple conveyance of stormwater. The following steps are recommended to be conducted in order to complete a swale design:

(1) Determine peak flow rate to the system (water quality and drainage design storm).
(2) Determine the slope of the system (from site geometry).
(3) Select a swale shape (skip if filter strip design).
(4) Determine required channel width (based on hydraulic requirements).
(5) Calculate the cross-sectional area of flow for the channel.
(6) Calculate the velocity of channel flow.
(7) Calculate swale length (based on site geometry).
(8) Select swale location based on the design parameters.
(9) Select vegetation cover for the swale.
(10) Check for swale stability.

Filter Strips

1. Filter strips are effective with slopes of up to 12 percent. Filter strips with greater slopes may not reliably treat runoff from highways; therefore, the maximum recommended slope for vegetated buffer strips is 12% (Barrett et al, 1997).

2. The minimum recommended length of a filter strip when used to treat highway runoff is 8 meters (27 feet), if the slope of the strip is less than 12% and there is full vegetative cover (Barrett et al, 1997).

3. The area to be used for the strip will be free of gullies or rills that can concentrate overland flow (Schueler, 1987).

4. The top edge of the filter strip along the pavement will be designed to avoid the situation where runoff would travel along the top of the filter strip, rather than through it. Berms may be placed at 15 to 30 m (50 to 100 ft) intervals perpendicular to the top edge of the strip to prevent runoff from bypassing it (Washington State Department of Transportation, 1995).

5. Top edge of the filter strip will be level, otherwise runoff will tend to form a channel in the low spot.

6. Filter strips will be landscaped after other portions of the project are completed (Washington State Department of Transportation, 1995).

A schematic of a combination filter strip and grassy swale is shown in Figure 7.

Maintenance

Biofilters require maintenance of the vegetation including limiting the height of the growth to about 6 inches and ensuring good coverage. Standing water must be eliminated through regrading or sediment removal and debris must be removed from the surface areas. Any condition that promotes the concentration of flow across a strip-type biofilter must be corrected.

Water Quality Monitoring

The effectiveness of these vegetative controls for reducing the concentrations of various constituents in highway runoff will be evaluated during a two year monitoring program. Depending upon the type of vegetation and amount of rainfall/irrigation, these sites may require a period of time for the vegetation to become completely established. Caltrans will conduct two years of water quality monitoring if adequate vegetation is established at the site.

Planting time will be chosen to provide time for vegetation establishment before the beginning of the rainy season. To determine whether climatological, soil and topographical conditions allow for adequate vegetation establishment, the irrigation of the sites during the establishment stage will be specified according to the requirements of the selected vegetation. The sites will be evaluated to determine whether they have sufficient vegetative cover. The degree to which vegetation has become established will be determined by performing a vegetation survey at least every month during the period of October through April and every other month from May through September. An established protocol will be followed to determine the amount and type of vegetative coverage.

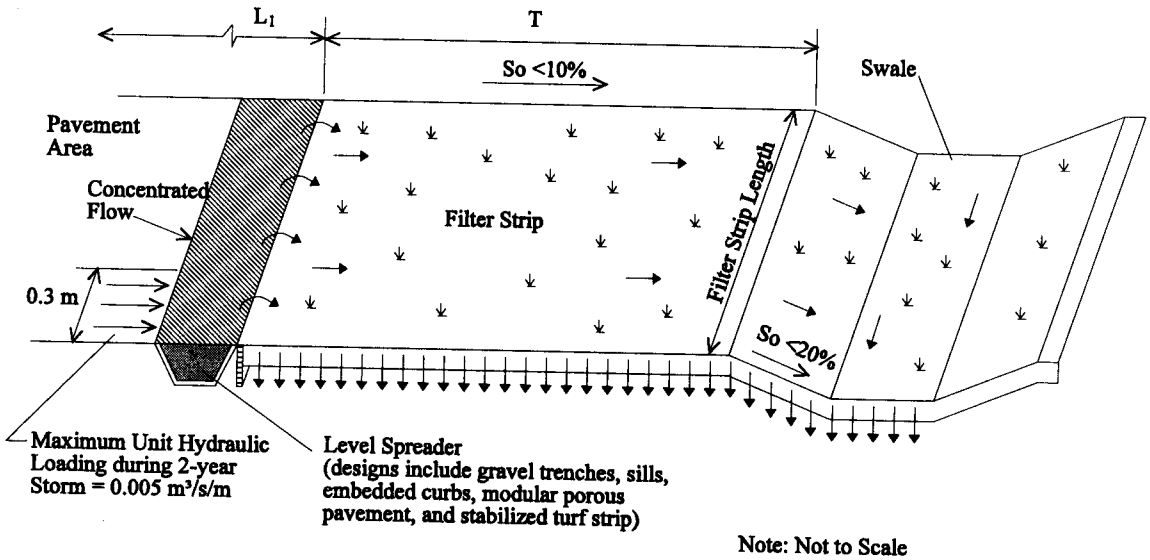

Figure 7 Schematic of Biofiltration Filter Strip

Constituent removal effectiveness will be determined by comparing the water quality of untreated highway runoff with that discharged from the vegetative control. Highway runoff data will be determined by sampling highway runoff as it leaves the pavement in the vicinity of the experimental sites. A sampling setup similar to that shown in Figure 8 could be used to collect sufficient runoff for sampling four times per year.

Flow weighted composite samples will be collected a maximum of four times per year where runoff is discharged from the vegetative controls. These samples will be analyzed for the following constituents:

- total suspended solids (TSS),
- zinc,
- lead,
- copper,
- nitrate nitrogen,
- total Kjedahl nitrogen, and
- total phosphorus.

Manual grab samples will be collected during selected events to determine the instantaneous concentrations of

- total petroleum hydrocarbons, and
- fecal coliform.

Several published studies relate constituent removal effectiveness to hydraulic residence time of runoff in grassy swales. The residence time for the constructed swales will be calculated for the average storm using Manning's equation, dye tracing, or some other appropriate technique. The relationship between residence time and constituent removal will be established and compared to previous work.

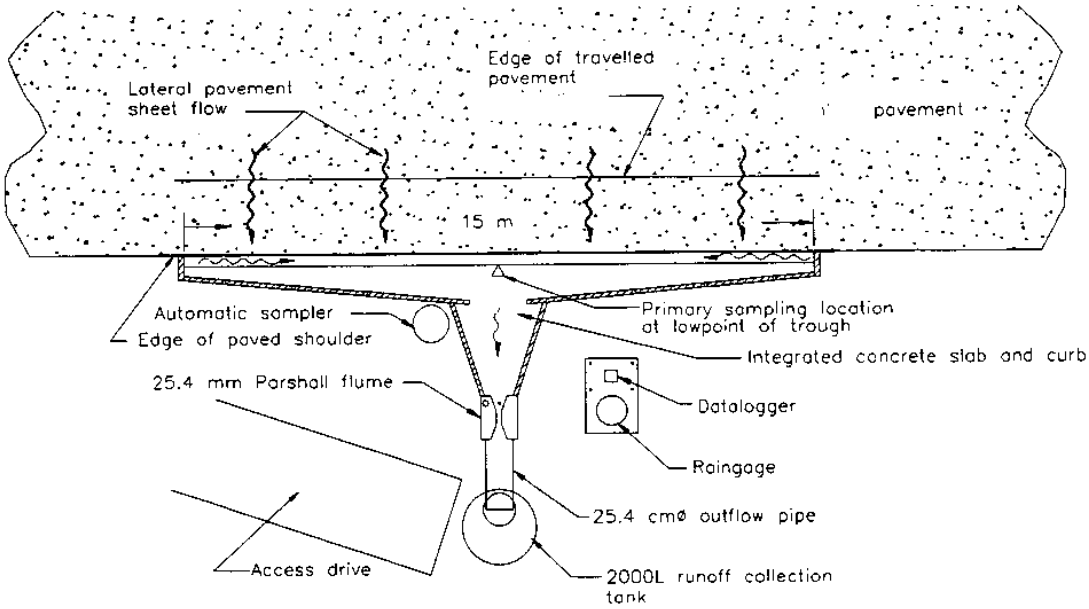

Figure 8 Sampling Design for Swale and Filter Strips (after Sansalone et al, 1997)

Schedule/Cost

Following is a list of milestone dates for the Biofiltration Swales and Strips Pilot Project:

1. Design complete: 6/8/98
2. Project Bid Complete: 8/1/98
3. Construction Complete: 12/1/98
4. Monitoring: 12/1/98 through 3/30/00
5. Final Report Complete: 7/2000

The total cost for the design, construction, monitoring and report preparation for biofiltration swales and strips pilot project is $ 4,700,000. The total construction cost is estimated to be $ 757,700.

MEDIA FILTERS

Caltrans will construct six media filters at maintenance stations or park-and-ride lots. Four of the filters will be located in District 7 and two will be located in District 11. Media filters are defined as chambers containing filtering medium such as sand, compost, or sand/peat layers that discharge to an underdrain system.

Site Selection (Young et al, 1996)

Sand filter BMPs may provide effective treatment in areas where conventional BMPs fail or cannot be applied at all, including:

Space-Limited Areas	Sand filters can be applied in confined urban areas or in any instance where space is limited. Since they can be completely self-contained in underground vaults, a sand filter can be placed underneath pavement to maximize land use.
Arid Climates	BMPs such as ponds, wetlands, and vegetative filter strips require relatively moist environments to be effective. No such limitation exists for sand filter BMPs, as they can be completely self-contained and can function on an intermittent basis.

While sand filters can provide options in areas where the application of more conventional BMPs is limited, there are a number of site considerations that must be recognized in order to maximize the effectiveness of the unit. Aside from needed vertical clearances, the most important consideration is the extent to which runoff from bare soil will be able to enter the filter. The biggest threat to the long-term successful operation of any filter is the introduction of excessive amounts of sediment that cause premature clogging of the filter media. For this reason, it is recommended that sand filter BMPs be applied to treat stormwater runoff from relatively small, impervious watersheds (e.g., parking lots, roadways, etc.). It is important to ensure all construction activities up-gradient from the filter have been completed and all areas of erosion stabilized before bringing the filter on-line.

These facilities need enough vertical clearance to operate hydraulically (a minimum of about 3 feet). The elevation difference between the inlet and outlet must include clearance for the depth of the settling chamber, water on top of the filter, the filter media, and the underdrains. If the site plan constraints preclude such clearances, then pumping is needed.

Filters in residential areas can present aesthetic and safety problems. Filters designed with open beds can be the source of objectionable odors and can be unsightly. The concrete walls that comprise the filter structure can present safety hazards. Fences should be included around all such structures to reduce hazards.

Design Guidance

There have been several types of sand filter designs for the treatment of stormwater runoff introduced since the original one was developed over ten years ago. Some of the more common designs include the Austin Sand Filter, the D. C. Underground Sand Filter, Alexandria Dry Vault Sand Filter, and the Slotted Curb Delaware Sand Filter.

The Austin design (Figure 9) has open-air filters, a full sedimentation basin, and requires the largest amount of space. It is the best design for treating runoff from larger watersheds and where adequate space is available. The Delaware unit (Figure 10) operates on the curbside edge of paved areas and parking lots. It is available as a precast completely self contained unit and requires the least area for installation. The choice between these two designs will be made after selection of available sites.

If the Austin sand filter is selected, it will be designed according to the guidelines specified by the City of Austin (1988). The Delaware unit will be designed and installed according to the guidelines described by Young et al (1996).

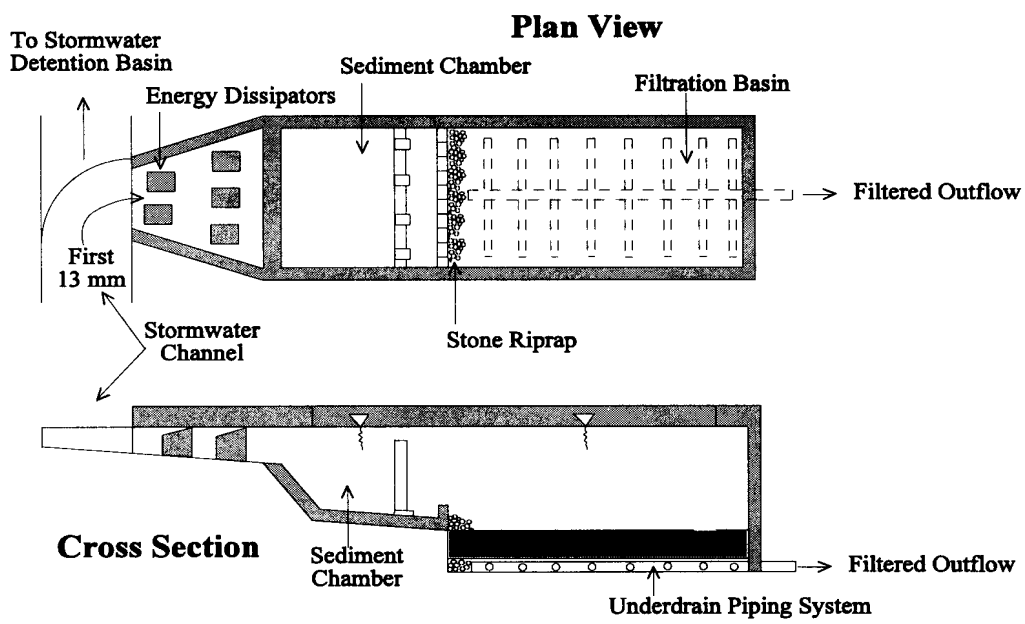

Figure 9 Schematic of an Austin Sand Filter

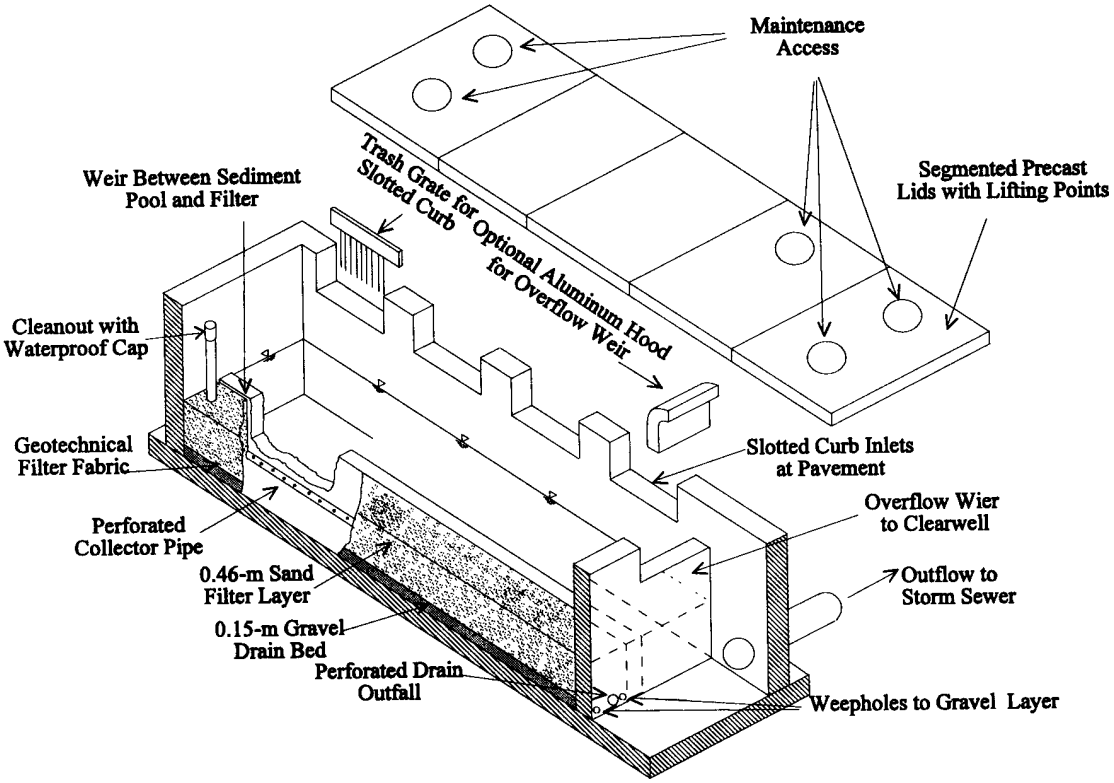

Figure 10 Schematic of a Delaware Sand Filter

Maintenance

General maintenance practices will include ensuring that the vaults are free from debris that would otherwise block discharge. The filter surface must be maintained to ensure that flow can pass through the media at the design rate. As with infiltration BMPs, a veneer of sediment will accumulate on the media which must be periodically removed.

Water Quality Monitoring

Constituent removal in the media filters will be determined by comparison of the average water quality of runoff entering the facility with that leaving (see Appendix C). Automatic sampling equipment will be installed at the inlet and outlet of the device to collect flow weighted composite samples. These sites will be designed to incorporate flow measurement structures.

The most appropriate flow measurement structures for filter inlet are Parshall flumes and H flumes. An advantage of these devices is their ability to pass trash and other debris which tend to accumulate in structures such as V-notch weirs. The high velocity through the flume prevents sediment accumulation from runoff with high suspended solids concentrations. In addition, these devices operate with a much smaller head loss than a weir. Depending on the size of the contributing watershed, an H flume is preferred because of its ability to accurately measure a wider range of flows.

Flow measurement at the filter outlet is subject to different constraints than at the inlet. Because of the long detention times, flow rates will necessarily be much lower and most of the trash and debris will have been removed from the runoff. Therefore, a V-notch weir is the preferred option for measuring flow at this location. The type and size will be determined by the size of the watershed and expected discharge rate from the filter.

Two years of water quality monitoring will be conducted following construction of the facilities. The runoff samples collected by the automatic sampling equipment four times per year, contingent upon rainfall events, will be analyzed for:

- total suspended solids (TSS),
- zinc,
- lead,
- copper,
- nitrate nitrogen,
- total Kjedahl nitrogen, and
- total phosphorus.

Manual grab samples will also be collected during two storms per year to determine the instantaneous concentrations in the treated and untreated runoff for

- total petroleum hydrocarbons, and
- fecal coliform.

At the end of the monitoring period, samples of the sediment which has been retained by the filter will be collected and analyzed to determine the proper disposal method.

Schedule/Cost

Following is a list of milestone dates for the Media Filter Retrofit Pilot Project:

1. Design complete: 5/30/98
2. Project Bid Complete: 8/15/98
3. Construction Complete: 12/1/98
4. Monitoring: 12/1/98 through 3/30/00
5. Final Report Complete: 7/2000

The total cost for the design, construction, monitoring and report preparation for the media filter pilot project is $ 1,600,000. The total construction cost is estimated to be $890,000.

OIL/WATER SEPARATORS

Subject to a preliminary sampling program to determine the concentrations of oil & grease in runoff from Caltrans maintenance stations, Caltrans will construct and monitor four of these devices, three in District 7 and one in District 11. The oil/water separators will be of the coalescing-plate or equivalent type.

Coalescing plate separators are typically manufactured units consisting of a baffled vault containing several inclined corrugated plates stacked and bundled together. The plates are equally spaced (typical plate spacing ranges from 6 mm to 25 mm (1/4 inch to 1 inch) and are made of a variety of materials such as fiberglass, stainless steel, and polypropylene. Efficient separation results because the plates reduce the vertical distance oil droplets must rise in order to separate from the stormwater. As oil droplets migrate along the plates, they agglomerate from collisions between droplets having different migration rates. This coalescing of oil droplets into larger-diameter oil droplets results in an increased rate of efficiency of oil separation. Therefore, coalescing plate separators result in a smaller vault size than that of a gravity separator for comparable removal performance.

Coalescing plate separators may be used to treat stormwater runoff from high-use developments and facilities that can produce relatively high concentrations of oil and grease. Current technology and design of coalescing plate separators achieve effluent concentrations as low as 10 mg/L with removal of oil droplet sizes as small as 20 to 60 microns.

Site Selection

Coalescing plate separators are designed to remove free oil and are not generally effective in separating oil that has become either chemically or mechanically emulsified and dissolved in water. Therefore, it is important that separators be installed upstream of facilities and conveyance structures that introduce turbulence and consequently promote emulsification. Emulsification of oil can also result if surfactants or detergents are used to wash parking areas. Detergents should not be used to clean parking areas unless the wash water is collected and disposed of to a sanitary sewer or septic tank (King County, 1996).

Oil/water separators are best located in areas where the tributary drainage area is nearly all impervious, to minimize the amount of larger solids and sediment entering the vault. Solids and sediment interfere with the separation function. Coalescing plate bundles can clog due to solids loading, requiring more frequent maintenance. A unit that fails and ceases to function can result in release of previously trapped oil to the downstream receiving water. The separator should also be located so that floating debris entering the vault is not excessive, since it can result in clogging (King County, 1996).

Siting has been completed for the three locations in District 7 and the single location in District 11. The site selection is detailed for District 7 in a report entitled, "*Site selection Analysis, Oil/Water separator Feasiblitiy Investigation, Retrofit Pilot Program, Caltrans District 7"*, dated October, 1997. The three selected maintenance stations in District 7 are Alameda, Altadena and Metro. The site selection for District 11 is detailed in a report entitled, *"Site Selection Analysis, Oil/Water Separator Feasibility Investigation, Retrofit Pilot Program, Caltrans District 11"*, dated October, 1997, the selected site is in Escondido.

Design Guidance (King County, 1996)

Coalescing plate separators are designed using the same basic principles as gravity separators. The major difference is that a separator's treatment area is increased by installing parallel plates in the vault. The surface area is increased by the sum of the horizontal projections of the plates being added, referred to as the plate "effective separation area."

The basic procedure for designing a coalescing plate separator is to determine the "effective separation area" required for the plate media under a given design flow. The specific vault sizing will then depend on the manufacturer's plate media design. The specific design, analysis, configuration, and specifications for coalescing plates are empirically based and variable. Manufacturers recommendations may be used to vary the recommendations given in this section.

Coalescing plate oil/water separator details are shown in Figure 11. Other designs and configurations of separator units and vaults may be selected, if it can be shown that they can produce equivalent treatment results.

<u>General Siting</u> (King County, 1996)

1. The oil/water separator must be installed off-line, bypassing flows greater than the Water Quality design flow. The design flow will be a 3-month storm event per the *Caltrans Planning and Design Staff Guide*, Appendix C, Oil/Water Separators.

2. When a separator is required, it shall precede all other water quality treatment facilities (except wetvaults) and should also precede flow control facilities, if possible.

3. In moderately pervious soils where seasonal groundwater may induce flotation, buoyancy tendencies shall be balanced by ballasting or other methods as appropriate.

4. Any pumping devices shall be installed downstream of the separator to prevent oil emulsification in stormwater.

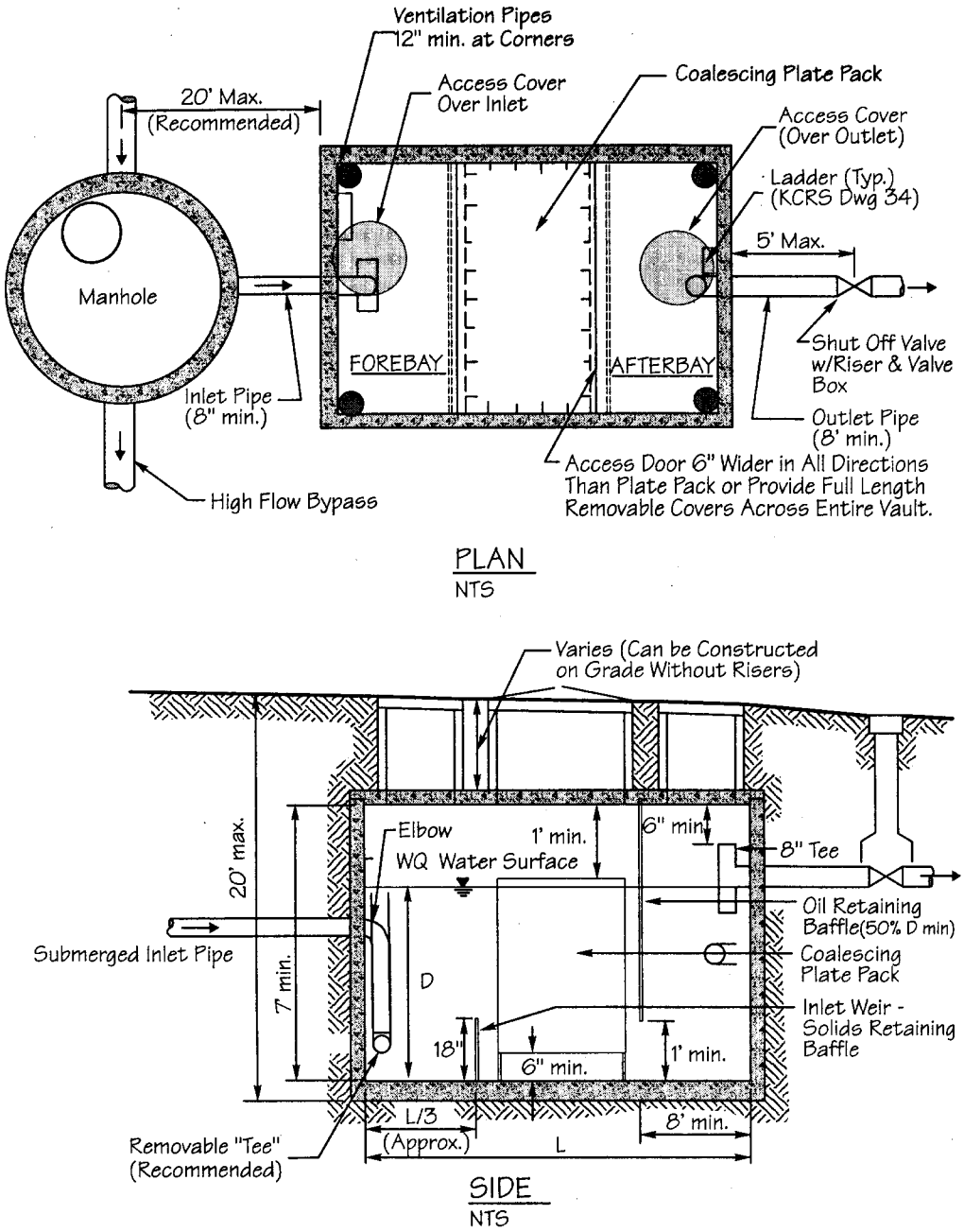

Figure 11 Schematic of a Coalescing Plate Oil/Water Separator

Vault Structure (King County, 1996)

1. The separator shall be divided into three compartments by baffles or berms: a forebay, an oil separation cell which houses the plate pack, and an afterbay. The forebay is primarily to trap and collect sediments. The oil separation cell is to capture and hold oil. The afterbay provides a relatively oil-free exit cell before the outlet.

2. The length of the forebay shall be approximately 1/3 to 1/2 of the length of the vault (L). In addition, it is recommended that the surface area of the forebay be at least 20 m^2 (200 ft^2) per 10,000 m^2 (100,000 ft^2) of impervious area draining to the separator.

3. An oil retaining baffle shall be provided and located approximately 1/4 L from the outlet wall or a minimum of 8 inches, whichever is greater (the 8-inch minimum is for maintenance purposes). The oil-retaining baffle shall extend from the water surface to a depth of at least 50% of the design water depth, and shall be at least 1 foot (minimum) from the vault bottom.

4. A bottom sediment retaining baffle shall be provided upstream of the plate pack. The minimum height of the sludge-retaining baffle shall be 18 inches.

5. The separator plates shall be as follows:

   - plates shall be inclined at 45° to 60° from the horizontal (this range of angles exceeds the angle of repose of many solids and therefore provides more effective droplet separation while minimizing the accumulation of solids on the individual plates).

   - Plate media shall have a minimum plate spacing of 3/4-inch and have corrugations.

   - Plate media material shall be fiberglass, stainless steel, or polypropylene.

   - The plate pack shall be a minimum of 6 inches from the vault bottom.

6. The vaults shall be watertight and shall be coated to protect from corrosion.

7. Separator vaults shall have a shutoff mechanism on the outlet pipe to prevent oil discharges during maintenance and to provide emergency shut-off capability in case of a spill. A valve box and riser shall also be provided.

Inlet and Outlet (King County, 1996)

1. The inlet to the separator shall be submerged. A "tee" section may be used to submerge the incoming flow. The "tee" must be at least 0.6 m (2 feet) from the bottom of the tank. A removable "tee" placed horizontally at the bottom of the inflow "tee" is recommended to dissipate flow velocity.

2. The outlet pipe shall be sized to pass the water quality design flow before overflow. The outlet pipe shall be back-sloped or have a turn-down elbow extending 0.3 m (1 foot) below the design water surface to provide for trapping of oils and floatables in the wetpond.

Material Requirements (King County, 1996)

1. All metal parts shall be corrosion-resistant. Zinc and galvanized materials are to be avoided when substitutes are available because of aquatic toxicity potential. Painting metal parts shall not be allowed due to lack of longevity. Acceptable examples include parts made of aluminum and stainless steel, fiberglass or plastic.

2. Vault baffles shall be concrete, stainless steel, fiberglass reinforced plastic, or other acceptable material and shall be securely fastened to the vault.

3. Gate valves, if used, shall be designed for seating and unseating heads appropriate for the design conditions.

Access Requirements (King County, 1996)

Access to each compartment is required. If the length or width of any compartment exceeds 15 m (50 feet), an additional access point for each 15 m is required.

1. Access points for the forebay and afterbay shall be positioned partially over the inlet or outlet tee to allow visual inspection as well as to allow physical access into the bottom of the vault.

2. Access to the compartment containing the plate pack shall be removable or open completely over an area a minimum of 150 mm (6 inches) greater in all directions than the dimensions of the plate pack and be adequate to remove the coalescing plate bundle from the cell for cleaning. Doors or panels shall have stainless steel lifting eyes, and panels shall weigh no more than 4500 kg (5 tons) per panel.

3. An access pad shall be provided near the coalescing plate bundles to allow for removal of coalescing plate bundles from the vault by a truck-mounted crane or

backhoe, and to allow for extracting accumulated solids and oils from the vault using a vactor truck.

Maintenance

General maintenance for oil/water separators will include cleaning the separator plates when sufficient oil and grease has accumulated on them to reduce their effectiveness or begin to interrupt the hydraulic operation of the unit. The plates must be periodically inspected and cleaned per manufacturers recommendations.

Water Quality Monitoring

The performance of the oil/water separators will be evaluated by comparing the concentrations of hydrocarbons entering and leaving the device. Since grab samples are required for analysis of oil and grease concentrations, with efficiency based on a comparison of paired samples. Samples will be collected from eight storms (weather permitting) during the two year monitoring period and analyzed for oil & grease. Samples collected from two storms each year will also be analyzed to determine the specific petroleum hydrocarbon fractions.

Schedule/Cost

Following is a list of milestone dates for the Oil/Water Separator Retrofit Pilot Project:

1. Preliminary Investigation complete: 2/1/98
2. Design complete: 5/30/98
3. Project Bid Complete: 8/15/98
4. Construction Complete: 12/1/98
5. Monitoring: 10/21/98 through 3/30/00
6. Final Report Complete: 7/2000

The total cost for the design, construction, monitoring and report preparation for the oil/water separator pilot project is $ 930,000. The total construction cost is estimated to be $ 290,000.

MULTI-CHAMBERED TREATMENT TRAIN (MCTT)

The MCTT consists of three chambers: a catchbasin (initial chamber) for removal of larger particulates and litter, a settling chamber for quiescent settling of fine settleable solids, and a media filter for final polishing. A cross section of the MCTT is shown in Figure 12. The catchbasin functions primarily as a screening process for the other two units by removing large, grit-sized material. The settling chamber is the primary treatment chamber for removing settleable solids and associated constituents. The media filter is for final polishing of the effluent, using a combination of sorption and ion exchange for the removal of soluble constituents.

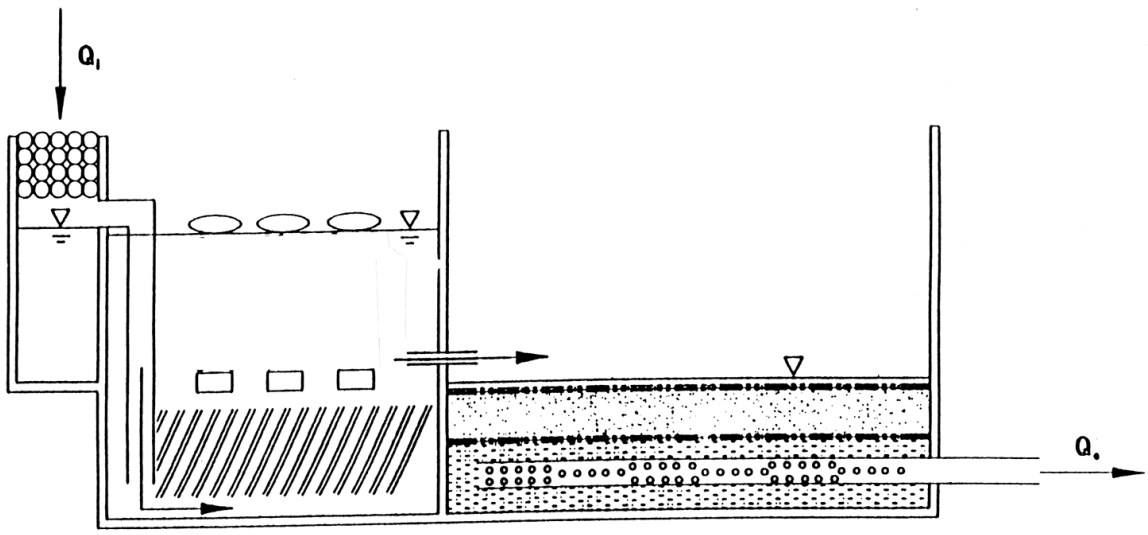

Figure 12 Cross Section of the MCTT

Site Selection

The MCTT was developed for treatment of stormwater at critical source areas. The target area for use of this particular device includes vehicle service facilities, parking area, paved storage area and fueling stations from about 0.1 to 1 ha (0.25 to 2.5 acres) in area. Space is extremely limited for these typically small areas and these critical source areas are therefore left with few alternatives.

Design Guidelines

Design guidelines are based on an report entitled, *Stormwater Treatment at Critical Areas, Volume 1: The Multi-Chambered Treatment Train (MCTT)*, by Robert Pitt, et. al., dated October 1997, EPA/600/X-97/XXX. The design of the MCTT can be separated into the following general steps:

- conduct a site survey to determine drainage area and character, subsurface conflicts (existing buried utilities and bedrock), and special surface loading conditions (such as from heavy public works vehicles or sediment sources)

- determine the needed hydraulic grade line for the drainage system receiving the MCTT effluent

- select a series of candidate MCTT tank depths and holding periods for the desired constituent removal rate in the main settling chamber using the design curves for the area nearest to the site that meets the above site restraints and goals

- determine critical runoff volumes that need to be captured for the alternative tank depths and holding times for the main settling chamber

- investigate alternative available tank components and select the most appropriate tank size

- select the most appropriate filtration/sorption media (usually a peat/sand mixture, with activated carbon, if possible)

- size the filtration/sorption chamber to obtain the desired flow rate and mass of media

- size the catchbasin/grit chamber as a pre-treatment unit. This can be located adjacent to the MCTT, or it can be located at inlets upstream to the MCTT.

Catchbasin/Grit Chamber Design

The catchbasin can be located adjacent to the MCTT, or it can be located at inlets upstream to the MCTT. The MCTT catchbasin/grit chamber design is based upon previous studies of catchbasins. A circular catchbasin with a diameter 4 times the diameter of the circular outlet should be used. The outlet is then placed 1.5 times its diameter from the top and 4 times its diameter from the bottom of the catchbasin, thus providing a total depth of 6.5 times the outlet diameter. The volume of the catchbasin is determined based on the desired maintenance frequency of the sump. The total settleable solids per year are estimated, and the sump sized accordingly to achieve the desired maintenance interval. It is recommended that the sump be sized to provide a maintenance interval of about 1-year. The sump volume may be determined by estimating the total

annual sediment load to the device for the given watershed. A schematic of the catchbasin is shown in Figure 13.

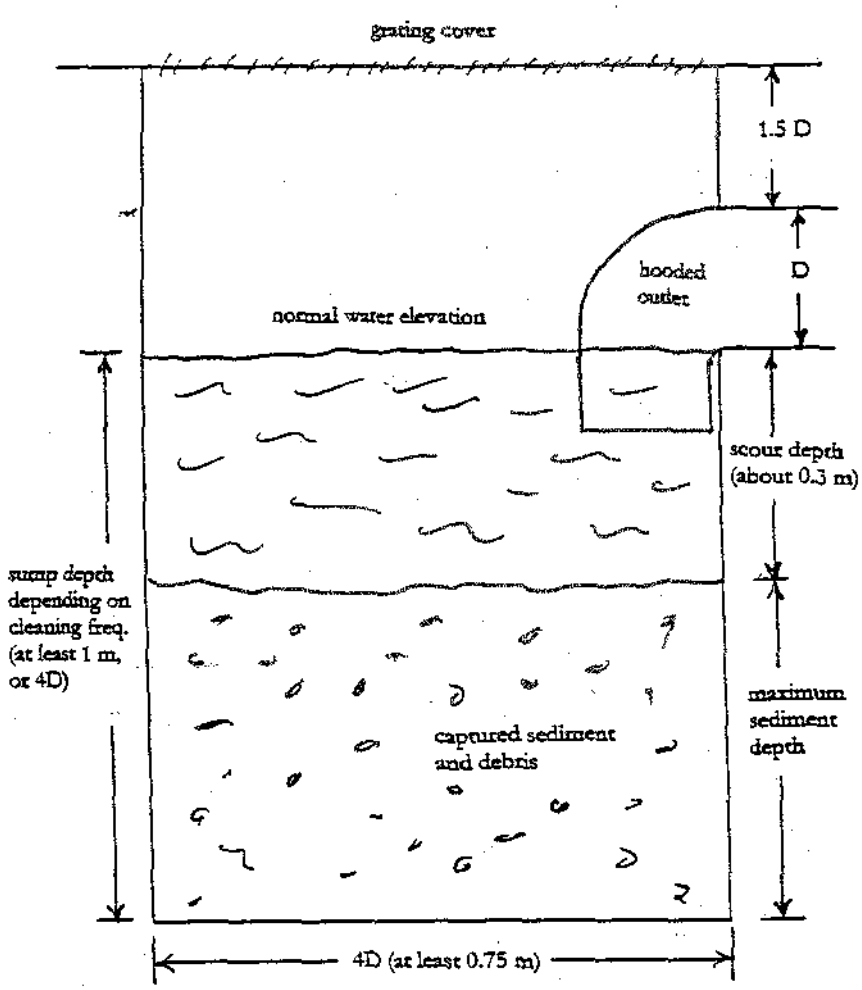

Figure 13 Schematic of MCTT Catchbasin

Main Settling Chamber Design

The design volume of the MCTT is highly dependent on local rainfall characteristics. A computer model was used to analyze rainfall data from Los Angeles. The rainfall analysis together with monitoring data from other installations indicates that a capacity in the main chamber of about 1.1 cm (0.45 in) of runoff will result in a 90% reduction in toxicity (Pitt, 1997, Op. Cit.). An orifice will be used to control water drainage from the main settling chamber to the filtration chamber. The orifices will be sized using the

equation developed by Pitt et al (1997, pg. 128).

Filtration Chamber

Effluent from the main settling chamber is directed towards a media filter chamber, which should provide a surface hydraulic loading rate of between 1.5 and 6 m per day (5 and 20 ft per day), and have a media depth of at least 0.5 m (18 in.).

The selection of the filter media will be based on the desired constituent reduction performance and the associated site conditions. If based on a wide range of constituents for pretreated stormwater (such as provided in the main settling chamber), then the rankings (best media listed first) for the tested media are as follows:

1) peat moss-sand (with degradation in color, turbidity, and pH)

2) activated carbon-sand (no degradation, but fewer benefits)

3) Enretech-sand, forest/sand, filter fabrics, or sand alone (few changes, either good or bad)

4) compost-sand (many negative changes)

Preliminary Material Specifications

- A removable grid needs to be placed in the catchbasin inlets a few inches above any possible water surface to support a nylon mesh bag (locally available) which contains about a foot thickness of Jaeger 25 mm (1 in.) Tri-Pack High Performance column packing balls (available from W. J. May & Assoc. of Nashville, TN (615) 662-1276, or from Jaeger Products of Houston at (800) 678-0345). Several of these bags need to be made for rotating during cleaning. The support needs to be made of material and constructed so as not to snag and tear the mesh bags.

- The inclined tube settlers can be purchased from Meurer Research (Golden, CO, 303-279-8373) (or alternative). These are about 0.6-m (2 ft) thick and have 0.1-m (4 in.) tubes. The estimated cost for these is about \$25 per ft^2 (for 1.2 m, or 4 ft tall units). They will have to be supported on some type of grid about 0.15 m (6 in.) off the bottom of the tank. Do not use any galvanized metal or treated wood in the installation where water contact is possible (stainless steel, aluminum or plastic are acceptable).

- Floating sorbent pillows can be purchased from New Pig Corp. (Tipton, PA, 800-643-6465) (or alternative). 75 mm x 3.0 m (3 in. x 10 ft) "Spaghetti Socks" float and are about \$12 each. About 5 to 10 should be placed in the MCTT main settling chamber

at one time.

- The MCTT tank accesses needs to be sufficient in size for entry, clean-out and installation. For example, the inclined tube settler sections need to be able to fit through the accesses easily (large 1.8 m x 1.8 m, or 6 ft x 6 ft accesses with hinged steel covers may be better than smaller round manhole covers).

- There should be no direct connection between the main settling chamber and the filtration tank chambers (such as over the top of a tank divider) besides the orifice, because overtopping water would easily scour the filter media. A suitable bypass/overflow should be provided to prevent flooding if the orifice clogs. This bypass/overflow should bypass the last filter/sorption chamber, connecting the downstream discharge directly with the main settling chamber.

- The 0.3 - 0.45 m (12 - 18 in.) of mixed filter media is comprised of 1/2 sand mixed with 1/2 peat moss. The surface of the mixed filter media is to be covered with a "Gunderboom" fabric material (Amoco 4557, available from Ray Bauer Assoc. in New York at (516) 671-6535 or from Polar Supply, Co. of Anchorage at (907) 563-5000, or from a local Amoco filter fabric distributor). The fabric needs to be one piece (or carefully seamed) and is to cover the top of the media and extend about 0.15-m (6 in.) up the sides of the tank to minimize leakage at the edges. The edges should be anchored to the walls of the MCTT, or weighted with concrete cinder blocks. Do not use loose stone to weigh down the filter fabric because of difficulties in removing the fabric for cleaning or replacement. The water jet coming from the orifice will need to be directed to a splash plate to diffuse the water before it hits the fabric. It can be directed into a perforated pipe laying on the top of the fabric, extending the length of the filter, to serve as a rough flow distributor. The mixed media filter material is laid over another filter fabric and then 0.15 m (6 in.) of sand. The sand is also above another filter fabric and then gravel underdrain material. These bottom two layers of filter fabric also need to extend up the tank several inches and preferably be one piece (or carefully sewn). The top filter fabric acts as a flow distributor and the Amoco fabric also tends to sorb dissolved oils.

- The filter sand material needs to be clean and have an effective size (D_{10}) of about 0.3 mm and uniformity coefficient (D_{60}/D_{10}) of about 1.5. After the filter media installation is complete, it needs to be carefully rinsed using clean water until the water runs clear to remove any fines.

Maintenance

The chambers of the MCTT should be vented, mosquito proofed, and be made easily accessible for maintenance. Maintenance for the MCTT would consist of inspections, cleaning of the catchbasin, and renewing of the sorbent pillows after each rainy season. The MCTT is designed to operate without maintenance for at least 6 months, with major maintenance activities every several years. However during this study, the MCTT will be inspected monthly to document the performance of the system.

The ion exchange/sorption capacity of the sand-peat media should last from 3 - 5 years before requiring replacement. Specific site conditions may warrant more frequent maintenance, which should be evident after the first few site examinations.

Water Quality Monitoring

Constituent removal in the MCTT will be determined by comparison of the average water quality of runoff entering the facility with that leaving. Automatic sampling equipment will be installed at the inlet and outlet of the device to collect flow weighted composite samples. These sites will be designed to incorporate flow measurement structures.

The most appropriate flow measurement structures for the MCTT inlet are Parshall flumes and H flumes. An advantage of these devices is their ability to pass trash and other debris, which tend to accumulate in structures such as V-notch weirs. The high velocity through the flume prevents sediment accumulation from runoff with high suspended solids concentrations. In addition, these devices operate with a much smaller head loss than a weir. Depending on the size of the contributing watershed, an H flume is preferred because of its ability to accurately measure a wider range of flows.

Flow measurement at the basin outlet is subject to different constraints than at the inlet. Average flow rates will necessarily be lower because of the media filtration chamber and most of the trash and debris will have been removed from the runoff. However, during large storms, runoff will bypass the filter chamber and discharge rates will be equal to the influent rate. Therefore, a compound V-notch weir is the preferred option for measuring flow at this location. The type and size will be determined by the size of the watershed and expected discharge rate from the MCTT.

Four storms per year will be sampled following construction of the facilities. The runoff samples collected by the automatic sampling equipment will be analyzed for:

- total suspended solids (TSS),
- zinc,
- lead,

- copper,
- nitrate nitrogen,
- total Kjedahl nitrogen,
- total phosphorus

Manual grab samples will also be collected during two events each year to determine the instantaneous concentrations of:

- total petroleum hydrocarbons
- bacteria.

At the end of the monitoring period, samples of the sediment that has been retained by the basin will be collected and analyzed to determine the proper disposal method.

Monitoring of the MCTT will also include general observation during storm events to ensure that the device is functioning as designed, and to discover and correct any operational problems that may occur. Observation and inspection following the storm event will also be important to assess the maintenance requirements of the system. A specific maintenance, operation and observation program will be developed as the subject of a separate document.

Schedule/Cost

Following is a list of milestone dates for the Multi-Chamber Treatment Train Retrofit Pilot Project. The schedule dates for both the Target and Contingency schedules are shown for information.

Target Schedule	*Contingency Schedule*
Design Complete: 5/5/98	Design Complete: 8/26/98
Project Bid Complete: 8/20/98	Project Bid Complete: 3/23/99
Construction Complete: 11/30/98	Construction Complete: 6/28/99
Monitoring: 12/1/98 through 3/31/00	Monitoring: 10/1/99 through 3/31/01
Final Report Complete: 7/01	Final Report Complete: 7/02

Three MCTT units will be constructed as a part of the retrofit pilot program. The total cost for the design, construction, monitoring and report preparation for the MCTT pilot project is $ 525,000. The total construction cost is estimated to be $150,000 or $50,000 per unit for 3 expected installations. The construction cost will be refined during the design process as this is a relatively new BMP with few prototype installations.

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APPENDIX A: SITE SELECTION CRITERIA

Representativeness

Types of sampling sites specified by Caltrans may include highway sites (freeways, expressways and/or conventional highways), maintenance yards, park-and-ride lots, border check points and weigh stations. It is important to select specific monitoring sites that are representative of typical Caltrans operations for these site types. The following discussions provide guidance on site characteristics to consider when selecting representative monitoring sites.

Highway Sites

Several criteria must be used in the selection of appropriate highway stormwater sampling sites, including traffic volume, grade, and location relative to other land uses. Although certain monitoring areas may appear favorable according to these factors, the following considerations will help to ensure selection of sites that are representative of highway runoff:

Traffic Volume

The selected sampling site should be located where the traffic volume is comparable to the average range of daily traffic volumes in Caltrans District 7 for the type of highway being studied. Selecting sites with typical traffic volumes may help ensure that the sites are representative of normal conditions.

Uniform Flow

Sampling sites should be located where stormwater flows are relatively well mixed, yet tend to be relatively “stable” or “uniform.” To better approach uniform flows, avoid steep slopes (i.e., select sites with pipe slope less than 2% to achieve uniform flows in the subcritical range), junctions, grade changes, and areas of irregular channel shape due to breaks, repairs, roots, debris, etc. Sites should be located where the channel or storm drain is soundly constructed.

Erosion Potential

Avoid areas where the potential for erosion is high, such as areas where land has recently been disturbed by construction or other activities, areas with excessively steep slopes, or cut and fill areas where the land surface has not been fully stabilized.

Surrounding Land Uses

Select sites that are not influenced by surrounding land uses (e.g., atmospheric deposition or flows from non-Caltrans areas). For example, do not select sites in close proximity to agricultural fields that may be sprayed with pesticides, industrial sites that may contribute airborne constituents, or residential areas.

Backwater or Tidal influences

Select sampling sites where the runoff will be free flowing (gravity flow). Avoid areas likely to be affected by backwater and tidal conditions, as these factors can complicate the reliable measurement of flow and the interpretation of data.

High Groundwater Table

A high groundwater table may influence stormwater runoff if groundwater reaches the surface and mixes with stormwater runoff; therefore, avoid sites where there is a potential for this to occur.

Illegal Discharges/Illicit Connections

An inspection of the site should include identification of any signs of illegal discharges, which generally include illegal discharge/dumping of wastes (e.g., used oil and other automotive fluids, trash and debris, etc.) and illicit connections (e.g. sanitary sewer lines) to the storm drainage system. Selected sites should be free of illegal discharges and illicit connections.

To adequately assess illegal discharges and illicit connections, sites should be visited during dry weather to observe any non-stormwater discharge. The following on-site observations should be made to identify illegal discharges and illicit connections:

Presence of debris, or rubbish piles on roadway shoulders, at turnouts, in open channels or other areas of the potential monitoring site. Solid waste dumping often occurs on roadways with light traffic loads or in areas not easily visible from the traveled way. Approach containers, such as bottles or barrels, with caution as they may contain hazardous liquids or solids.

Visible signs of staining or unusual colors to the pavement or surrounding adjacent soils.

Pungent odors coming from the drainage system.

Discoloration or oily substances in the water or stains and residues on ditches, channels or drain boxes.

Flow during dry weather.

Unusual flows in subdrain systems used for dewatering.

Excessive sediment deposits, particularly adjacent or near active off-site construction projects.

All observations should be documented for potential future use. If an illegal discharge or illicit connection is observed on a Caltrans right-of-way, the Caltrans Stormwater Coordinator will be notified. If the nature of an observed discharge is unknown or suspected of being a hazardous substance, no further investigation should be conducted and the incident reported to the Caltrans Stormwater Coordinator.

Significant Transitions

When considering representative highway sampling sites, it is generally desirable to select areas that are unlikely to undergo significant transition in the near future. This is to prevent the intrusion of contaminants from construction activities, or other alterations to the monitored area that may cause changes in the quality of the runoff (i.e., cause the quality of the runoff to be atypical of the site being monitored).

Maintenance Yard

Locations where highway maintenance vehicles and equipment are stored and serviced will be selected as stormwater monitoring sites. Maintenance activities, including vehicle and equipment cleaning, fueling, and repair, may all contribute constituents to stormwater runoff.

Effective monitoring of maintenance yards requires selection of sampling sites that adequately represent typical runoff from the site, prior to mixing with off-site sources. Select sampling sites that have the following characteristics:

Runoff from the facility has combined to form a definable runoff stream of adequate depth to sample.

The runoff stream represents the full range of activities at the facility.

On-site runoff has not combined with runoff from off-site sources.

Adequate grade or a drop-off exists (e.g., into a drain inlet) to enable collection of runoff samples by placing a sample bottle or automatic sampler intake in the runoff stream (if manual sampling is planned).

Park-and-Ride Lots

Monitoring at park-and-ride lots may be included in the Caltrans retrofit pilot study. Effective monitoring of park-and-ride lots requires selection of sampling locations that adequately represent typical runoff from the site prior to mixing with off-site sources. Select sampling sites that have the following characteristics:

Runoff from the area has combined to form a definable runoff stream of adequate depth to sample.

On-site runoff has not combined with runoff from off-site sources.

Illicit connections are not present (refer to highway site section, above).

Trash receptacles are provided and the area is routinely checked for trash and debris (including illegal dumping).

Personnel Safety

It is essential to ensure monitoring crew safety from such hazards as traffic, explosive or toxic gases, possible injury due to poor footing in slippery conditions, and hazards posed by poor visibility or other challenging conditions during adverse weather, especially at night.

To help avoid hazards, personnel should be physically capable of performing all tasks required for sample collection and be familiar with the program's Health and Safety Plan. The Health and Safety Plan must be developed prior to the initiation of any sample collection activities and should include information on at least the following: hazard evaluation (e.g. chemical, physical, etc.), contingency plan, personal protective equipment, and emergency information.

Site Access

Ease of vehicle and personnel access to the monitoring sites for equipment installation and sample collection activities should be assured for the full range of weather conditions that may be encountered. Safe access must be confirmed, especially during wet-weather

conditions. For example, ensure that the access point and available parking are at a safe distance from traffic, that any roads to the sampling location are adequate and reliable (e.g., limited potential to be muddy or flooded during wet weather), and that access does not require crossing private property.

For stormwater outfall monitoring sites, access into the drainage line/outfall for the flow measuring and sample collection equipment must be feasible and practical. Where practical, access to monitoring sites and equipment should be possible without confined space apparatus or exposure to fast moving traffic, for ease of servicing.

Equipment Security

It is necessary to minimize the susceptibility of automated sampling and flow measurement equipment to vandalism or other possible damage. To ensure security, automated monitoring equipment should be installed in a protective enclosure that is lockable and resistant to vandalism and tampering. Sites should be selected that have a flat, accessible area that is large enough for installation of any necessary enclosures, including fencing if necessary.

Flow Measurement Capability

Obtaining accurate flow measurements at monitoring stations is necessary to ensure representativeness of flow-weighted composite samples, to determine constituent mass loadings, and to assess the relationship between rainfall and runoff to support mathematical modeling. The hydraulic characteristics necessary to allow for accurate flow measurement include a relatively straight and uniform length of pipe or channel with no confluences (i.e., wyes or tees in the storm drain lines) or grade changes, and the absence of backwater effects.

Monitoring sites should be selected at locations where flow rate will be adequate under typical storm conditions to provide for both accurate flow measurement and automatic sample collection. This can be checked in advance by roughly calculating the runoff flow depth expected in the pipe during a storm of typical intensity for the study area.

Flow measurement stations should be located sufficiently downstream from inflows to the drainage system to achieve well-mixed conditions across the channel, and to favor the likelihood of "uniform" flow conditions. In the vicinity of a confluence, the flow sensor and sample collection inlet should be placed a minimum of five pipe diameters upstream and ten pipe diameters downstream of any confluence to minimize turbulence and ensure well-mixed flow.

Backwater effects should be avoided especially where sampling protocols make use of depth-based flow measurement. Specifically, backwater effects will result in non-uniform flow conditions, which compromise the ability to measure flow when using depth-based methods. In addition, sampling stations in pipes, culverts, or tunnels should be located to avoid surcharging over the normal range of precipitation expected during monitoring events.

Telephone lines can be used for remote communication with automated equipment. Telephone access provides a convenient mode of rapidly accessing information from field equipment during field activities. Cellular telephones are a possible alternative if telephone lines are not available. However, cellular telephone operations should be thoroughly checked prior to any monitoring activities (e.g., ensure that there is a reliable provider in the area and test reception).

Non-Caltrans Sources

Monitoring sites should be selected such that the monitored stormwater runoff originates solely within Caltrans freeway systems or facilities. Any site whose drainage area includes other land use types (e.g., commercial, residential, agricultural, etc.) should be avoided to eliminate collection of non-Caltrans flows.

Site Evaluation

Each potential monitoring site will be visited, to confirm the expected site characteristics and verify whether the site is suitable for the needs of the program. The visit should be conducted preferably during or after a storm, when the discharge can be observed. A wet-weather visit can provide valuable information regarding logistical constraints that may not be readily apparent during dry weather. However, a dry weather visit should also be conducted to observe any illegal discharges.

A list of criteria, specific to the program objectives and including the considerations discussed in this section, should be developed prior to visiting potential sites. These criteria should be used to produce a site visit log form, which should be filled out during each site inspection.

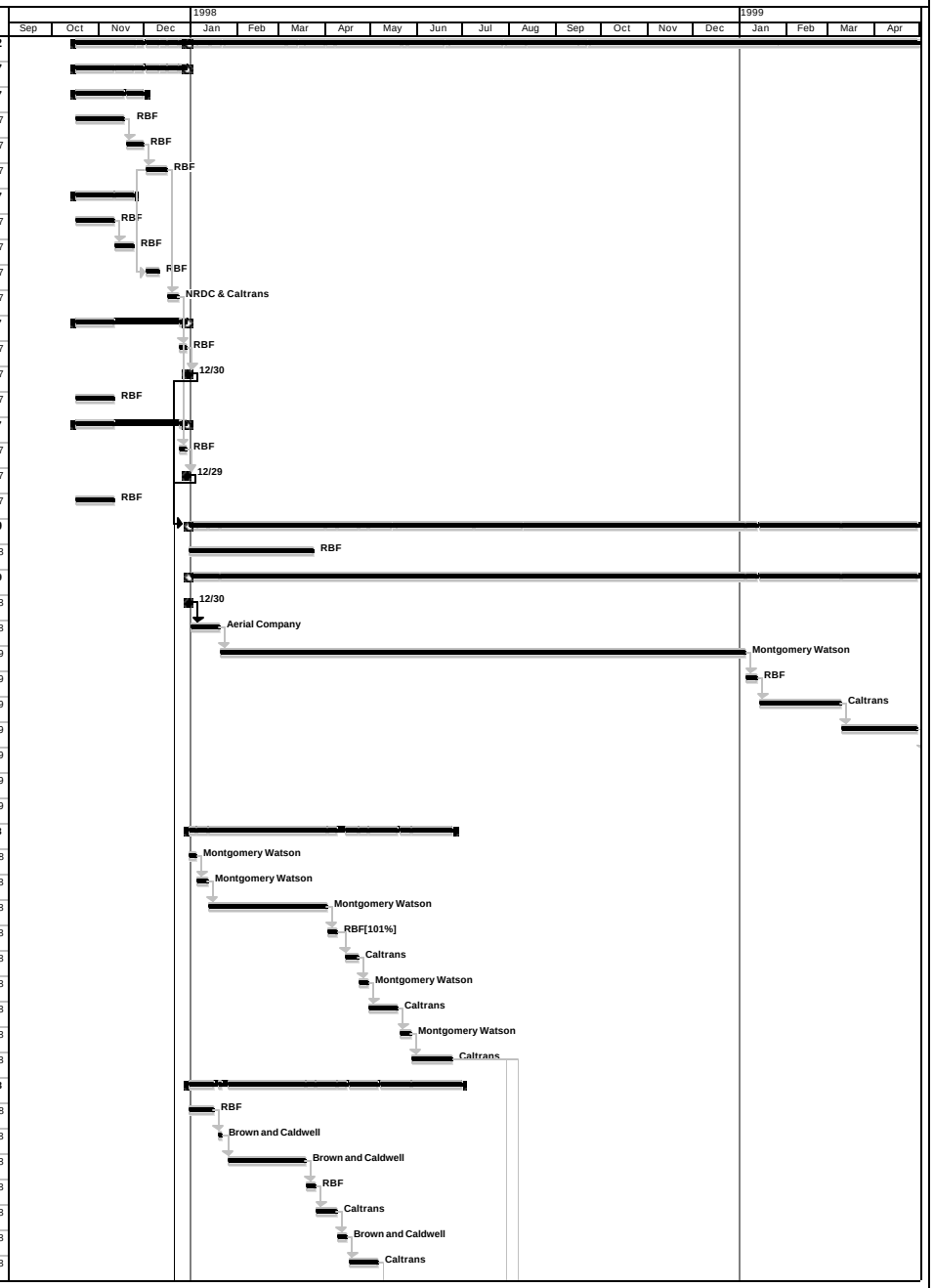
Criteria to be documented during a site visit may include type of site, drainage area characteristics, type of runoff, whether an appropriate sampling location exists, potential safety issues, site access, whether accurate flow measurement is achievable, and if telephone and electrical power are available.

In addition, a check list may be useful to record whether certain conditions exist at a given site, such as: tidal influences, illegal dumping, illicit connections, high groundwater table, erosion, runoff from landscaped areas, adjacent commercial farming, contributing residential runoff, or nearby industrial sites. Once these observations have been made, it is possible to determine if the site is representative and appropriate for the objectives of this project.

APPENDIX B: MASTER SCHEDULE

Caltrans Pilot BMP Project
Master Schedule

ID	Task Name	Duration	Start	Finish
1	**Retrofit Pilot Program - District 7 Master Schedule**	**954 days**	**Thu 10/16/97**	**Tue 7/2/02**
2	**Preliminary Investigation**	**38 days**	**Thu 10/16/97**	**Tue 12/30/97**
3	**Site Selection Field Visits - LA**	**24 days**	**Thu 10/16/97**	**Mon 12/1/97**
4	Identify Candidate Sites	23 days	Thu 10/16/97	Tue 11/18/97
5	Refine to Preliminary Sites	7 days	Wed 11/19/97	Mon 12/1/97
6	Site Selection Presentations/Develop Reports	11.3 days	Tue 12/2/97	Wed 12/17/97
7	**Site Selection Field Visits - SD**	**20.5 days**	**Thu 10/16/97**	**Mon 11/24/97**
8	Identify Candidate Sites	18 days	Thu 10/16/97	Tue 11/11/97
9	Refine to Preliminary Sites	8.5 days	Wed 11/12/97	Mon 11/24/97
10	Site Selection Presentations/Develop Reports	6.63 days	Tue 12/2/97	Thu 12/11/97
11	NRDC Review	4 days	Wed 12/17/97	Wed 12/24/97
12	**Final Site Selection - LA**	**38 days**	**Thu 10/16/97**	**Tue 12/30/97**
13	Revise Site Selection Studies	0.53 days	Wed 12/24/97	Tue 12/30/97
14	Final Reports	0 hrs	Tue 12/30/97	Tue 12/30/97
15	Project Management	18 days	Thu 10/16/97	Tue 11/11/97
16	**Final Site Selection - SD**	**38 days**	**Thu 10/16/97**	**Tue 12/30/97**
17	Revise Site Selection Studies	0.53 days	Wed 12/24/97	Mon 12/29/97
18	Final Reports	0 hrs	Mon 12/29/97	Tue 12/30/97
19	Project Management	18 days	Thu 10/16/97	Tue 11/11/97
20	**Project Design - Los Angeles**	**341 days**	**Tue 12/30/97**	**Tue 9/14/99**
21	Design Management/Assistance	55.99 days	Tue 12/30/97	Tue 3/24/98
22	**1. Continuous Deflective Separators (2 Sites)**	**341 days**	**Tue 12/30/97**	**Tue 9/14/99**
23	Site Aerial Controls	0 days	Tue 12/30/97	Thu 1/1/98
24	Fly Aerial Photo/Compile to Map	10 days	Thu 1/1/98	Tue 1/20/98
25	Plan Preparation/Hold	191 days	Wed 1/21/98	Tue 1/5/99
26	Internal QA/QC	4.94 days	Wed 1/6/99	Wed 1/13/99
27	Plan Review	30 days	Thu 1/14/99	Tue 3/9/99
28	Plan Revision	30 days	Wed 3/10/99	Thu 4/29/99
29	Plan Review	29 days	Mon 5/3/99	Tue 6/22/99
30	Plan Revision	30 days	Wed 6/23/99	Mon 8/16/99
31	Plans Signed	16 days	Tue 8/17/99	Tue 9/14/99
32	**2. Catch Basin Inserts (3 Sites)**	**97 days**	**Tue 12/30/97**	**Wed 6/24/98**
33	Site Topography	0.99 days	Tue 12/30/97	Mon 1/5/98
34	Topography Compilation	4 days	Mon 1/5/98	Mon 1/12/98
35	Plan Preparation	45 days	Tue 1/13/98	Wed 4/1/98
36	Internal QA/QC	4.94 days	Thu 4/2/98	Thu 4/9/98
37	Plan Review	6 days	Tue 4/14/98	Wed 4/22/98
38	Plan Revision	4 days	Thu 4/23/98	Wed 4/29/98
39	Plan Review	11 days	Thu 4/30/98	Tue 5/19/98
40	Plan Revision	4 days	Wed 5/20/98	Wed 5/27/98
41	Plans Signed	16 days	Thu 5/28/98	Wed 6/24/98
42	**3. Extended Detention Basin (2 Sites)**	**100 days**	**Tue 12/30/97**	**Tue 6/30/98**
43	Site Topography	10 days	Tue 12/30/97	Fri 1/16/98
44	Topography Compilation	4 days	Mon 1/19/98	Thu 1/22/98
45	Plan Preparation	30 days	Mon 1/26/98	Wed 3/18/98
46	Internal QA/QC	4 days	Thu 3/19/98	Wed 3/25/98
47	Plan Review	8 days	Thu 3/26/98	Wed 4/8/98
48	Plan Revision	4 days	Thu 4/9/98	Wed 4/15/98
49	Plan Review	12 days	Thu 4/16/98	Wed 5/6/98



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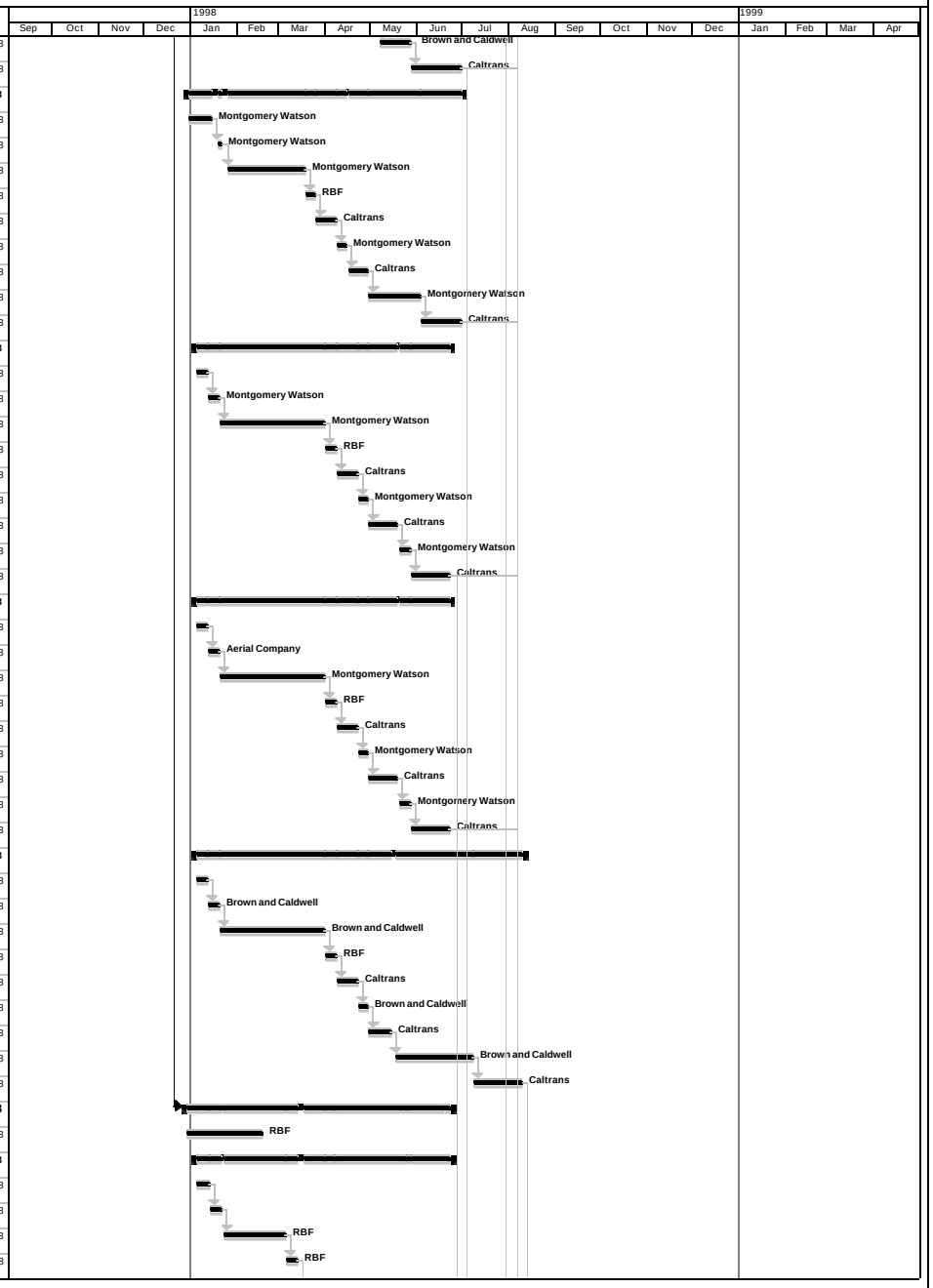
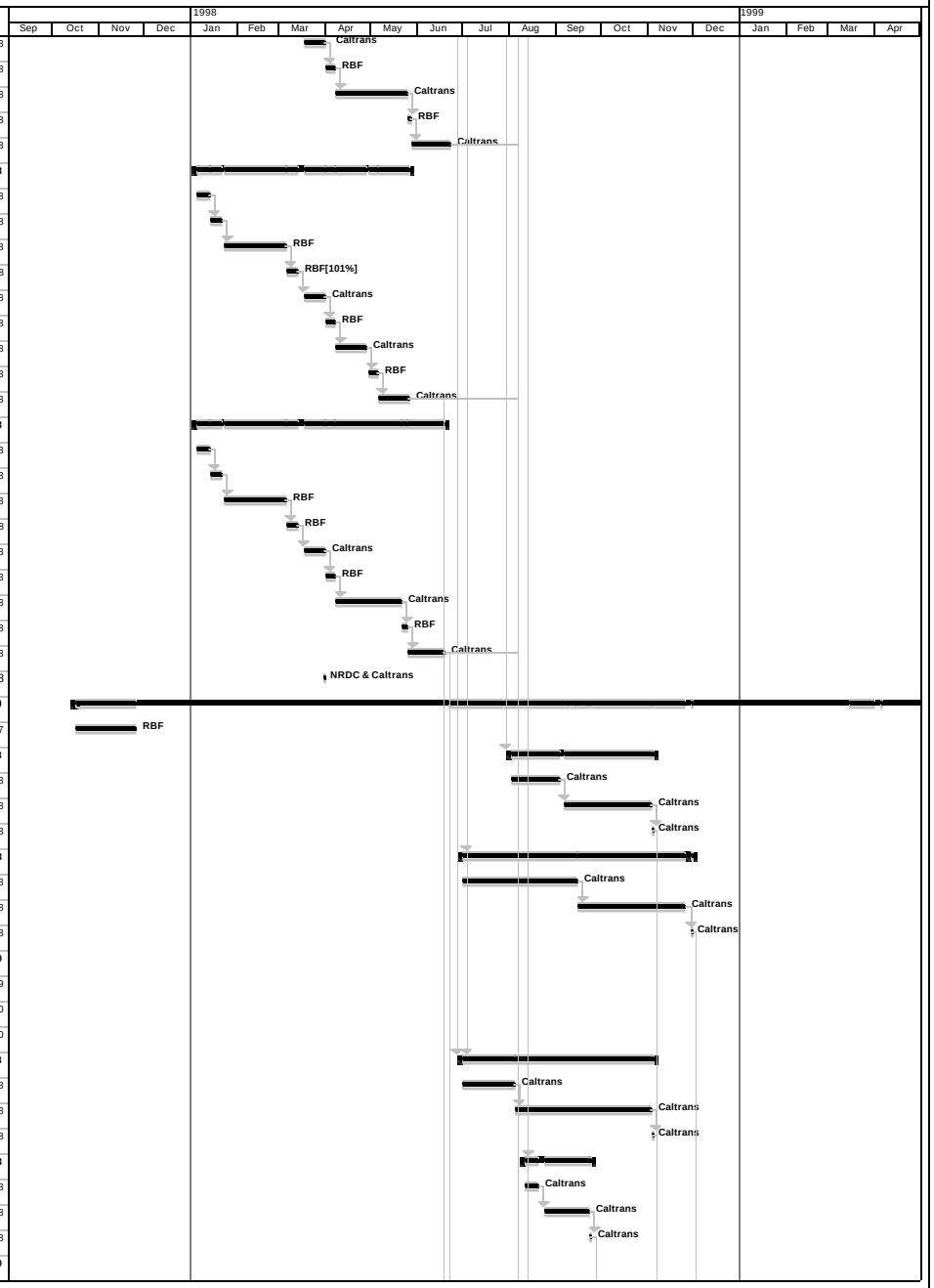
Caltrans Pilot BMP Project
Master Schedule

ID	Task Name	Duration	Start	Finish
50	Plan Revision	11 days	Thu 5/7/98	Wed 5/27/98
51	Plans Signed	19 days	Thu 5/28/98	Tue 6/30/98
52	**4. Infiltration Basin (1 Site)**	**100 days**	**Tue 12/30/97**	**Tue 6/30/98**
53	Site Topography	8 days	Tue 12/30/97	Thu 1/15/98
54	Topography Compilation	4 days	Mon 1/19/98	Thu 1/22/98
55	Plan Preparation	30 days	Mon 1/26/98	Wed 3/18/98
56	Internal QA/QC	4 days	Thu 3/19/98	Wed 3/25/98
57	Plan Review	8 days	Thu 3/26/98	Wed 4/8/98
58	Plan Revision	4 days	Thu 4/9/98	Wed 4/15/98
59	Plan Review	8 days	Thu 4/16/98	Wed 4/29/98
60	Plan Revision	19 days	Thu 4/30/98	Wed 6/3/98
61	Plans Signed	15 days	Thu 6/4/98	Tue 6/30/98
62	**5. Infiltration Trench (1 Site)**	**95 days**	**Mon 1/5/98**	**Mon 6/22/98**
63	Site Topography	5 days	Mon 1/5/98	Mon 1/12/98
64	Topography Compilation	5 days	Tue 1/13/98	Tue 1/20/98
65	Plan Preparation	39 days	Wed 1/21/98	Tue 3/31/98
66	Internal QA/QC	4.94 days	Wed 4/1/98	Wed 4/8/98
67	Plan Review	8 days	Thu 4/9/98	Wed 4/22/98
68	Plan Revision	4 days	Thu 4/23/98	Wed 4/29/98
69	Plan Review	11 days	Thu 4/30/98	Tue 5/19/98
70	Plan Revision	4 days	Wed 5/20/98	Wed 5/27/98
71	Plans Signed	14 days	Thu 5/28/98	Mon 6/22/98
72	**6. Biofiltration (6 Sites)**	**95 days**	**Mon 1/5/98**	**Mon 6/22/98**
73	Site Aerial Controls	5 days	Mon 1/5/98	Mon 1/12/98
74	Fly Aerial Photo/Compile to Map	5 days	Tue 1/13/98	Tue 1/20/98
75	Plan Preparation	39 days	Wed 1/21/98	Tue 3/31/98
76	Internal QA/QC	4.94 days	Wed 4/1/98	Wed 4/8/98
77	Plan Review	8 days	Thu 4/9/98	Wed 4/22/98
78	Plan Revision	4 days	Thu 4/23/98	Wed 4/29/98
79	Plan Review	11 days	Thu 4/30/98	Tue 5/19/98
80	Plan Revision	4 days	Wed 5/20/98	Wed 5/27/98
81	Plans Signed	14 days	Thu 5/28/98	Mon 6/22/98
82	**7. Media Filter and MCTT (5 Sites)**	**123 days**	**Mon 1/5/98**	**Mon 8/10/98**
83	Site Topography	5 days	Mon 1/5/98	Mon 1/12/98
84	Topography Compilation	5 days	Tue 1/13/98	Tue 1/20/98
85	Plan Preparation	39 days	Wed 1/21/98	Tue 3/31/98
86	Internal QA/QC	4.94 days	Wed 4/1/98	Wed 4/8/98
87	Plan Review	8 days	Thu 4/9/98	Wed 4/22/98
88	Plan Revision	4 days	Thu 4/23/98	Wed 4/29/98
89	Plan Review	9 days	Thu 4/30/98	Thu 5/14/98
90	Plan Revision	30 days	Mon 5/18/98	Wed 7/8/98
91	Plans Signed	18 days	Thu 7/9/98	Mon 8/10/98
92	**Project Design - San Diego**	**96 days**	**Tue 12/30/97**	**Tue 6/23/98**
93	Project Management/Environmental	31.87 days	Tue 12/30/97	Wed 2/18/98
94	**Biofilter (3 Sites)**	**96 days**	**Mon 1/5/98**	**Tue 6/23/98**
95	Site Topography	6 days	Mon 1/5/98	Tue 1/13/98
96	Topography Compilation	6 days	Wed 1/14/98	Thu 1/22/98
97	Plan Preparation	29 days	Fri 1/23/98	Thu 3/5/98
98	Internal QA/QC	4 days	Fri 3/6/98	Fri 3/13/98



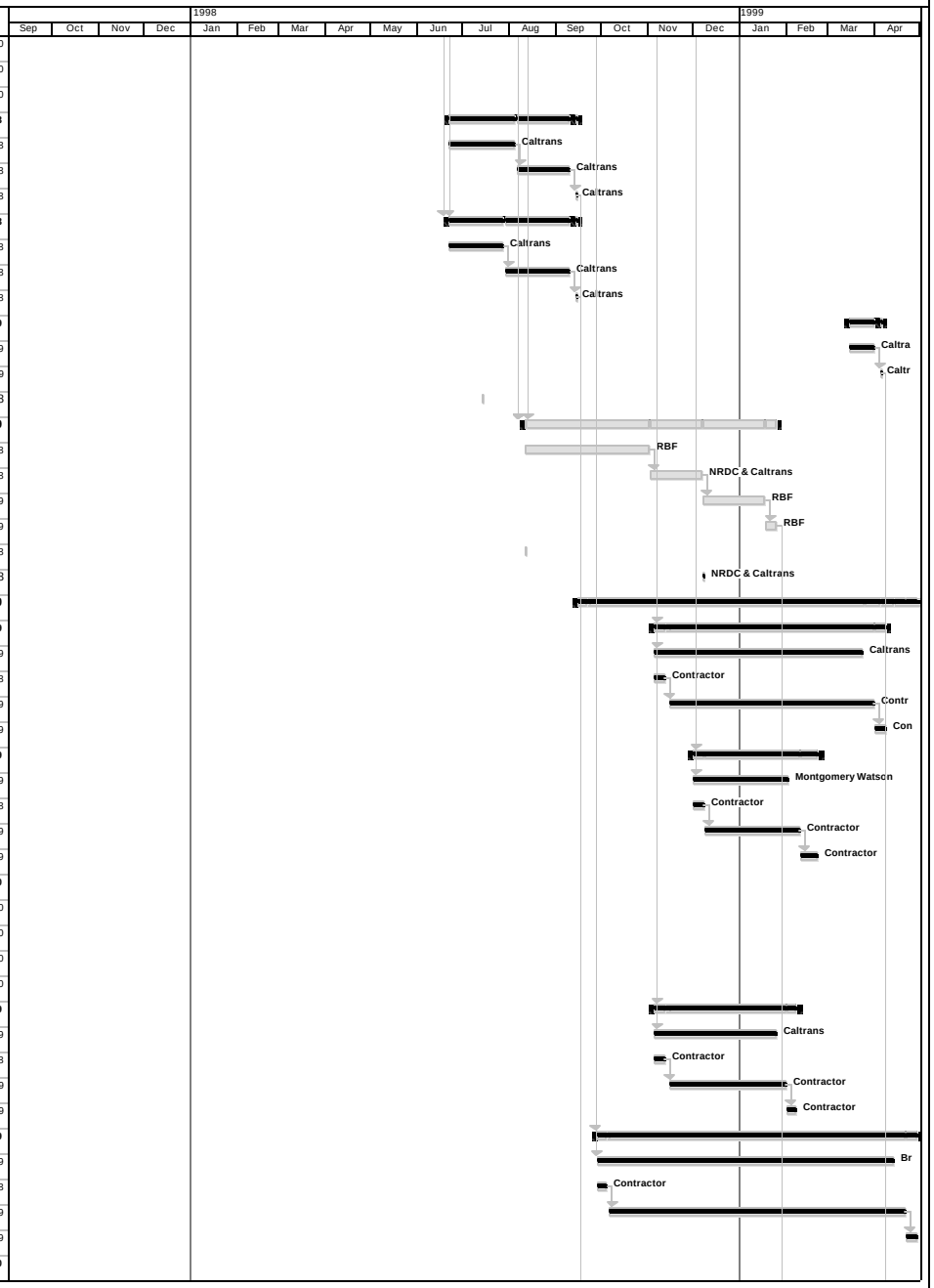
Caltrans Pilot BMP Project
Master Schedule

ID	Task Name	Duration	Start	Finish
99	Plan Review	9 days	Tue 3/17/98	Tue 3/31/98
100	Plan Revision	5 days	Wed 4/1/98	Tue 4/7/98
101	Plan Review	26 days	Wed 4/8/98	Mon 5/25/98
102	Plan Revision	2 days	Tue 5/26/98	Wed 5/27/98
103	Plans Signed	15 days	Thu 5/28/98	Tue 6/23/98
104	**Infiltration Basin (1 Site)**	**80 days**	**Mon 1/5/98**	**Tue 5/26/98**
105	Site Topography	6 days	Mon 1/5/98	Tue 1/13/98
106	Topography Compilation	6 days	Wed 1/14/98	Thu 1/22/98
107	Plan Preparation	29 days	Fri 1/23/98	Thu 3/5/98
108	Internal QA/QC	4 days	Fri 3/6/98	Fri 3/13/98
109	Plan Review	9 days	Tue 3/17/98	Tue 3/31/98
110	Plan Revision	5 days	Wed 4/1/98	Tue 4/7/98
111	Plan Review	12 days	Wed 4/8/98	Tue 4/28/98
112	Plan Revision	5 days	Wed 4/29/98	Tue 5/5/98
113	Plans Signed	11 days	Wed 5/6/98	Tue 5/26/98
114	**Media Filter (3 Sites)**	**94 days**	**Mon 1/5/98**	**Thu 6/18/98**
115	Site Topography	6 days	Mon 1/5/98	Tue 1/13/98
116	Topography Compilation	6 days	Wed 1/14/98	Thu 1/22/98
117	Plan Preparation	29 days	Fri 1/23/98	Thu 3/5/98
118	Internal QA/QC	4 days	Fri 3/6/98	Fri 3/13/98
119	Plan Review	9 days	Tue 3/17/98	Tue 3/31/98
120	Plan Revision	5 days	Wed 4/1/98	Tue 4/7/98
121	Plan Review	26 days	Wed 4/8/98	Thu 5/21/98
122	Plan Revision	1 day	Fri 5/22/98	Mon 5/25/98
123	Plans Signed	15 days	Tue 5/26/98	Thu 6/18/98
124	**STATUS MEETING NO. 1**	1 day	Mon 3/30/98	Mon 3/30/98
125	**Bid Projects**	**478 days**	**Thu 10/16/97**	**Thu 3/9/00**
126	Construction Management	28 days	Thu 10/16/97	Tue 11/25/97
127	**Montgomery-Watson PS&E**	**54 days**	**Mon 8/3/98**	**Wed 11/4/98**
128	Advertisement	20 days	Mon 8/3/98	Thu 9/3/98
129	Award	33 days	Mon 9/7/98	Tue 11/3/98
130	Construction Begins	1 day	Wed 11/4/98	Wed 11/4/98
131	**Montgomery-Watson Procurement**	**84 days**	**Wed 7/1/98**	**Mon 11/30/98**
132	Advertisement	43 days	Wed 7/1/98	Tue 9/15/98
133	Award	40 days	Wed 9/16/98	Thu 11/26/98
134	Construction Begins	1 day	Mon 11/30/98	Mon 11/30/98
135	**Montgomery-Watson CDS Sites**	**31 days**	**Tue 11/16/99**	**Mon 1/10/00**
136	Advertisement	15 days	Tue 11/16/99	Mon 12/13/99
137	Award	15 days	Tue 12/14/99	Thu 1/6/00
138	Construction Begins	1 day	Mon 1/10/00	Mon 1/10/00
139	**Brown and Caldwell PS&E**	**72 days**	**Wed 7/1/98**	**Wed 11/4/98**
140	Advertisement	20 days	Wed 7/1/98	Tue 8/4/98
141	Award	51 days	Wed 8/5/98	Tue 11/3/98
142	Construction Begins	1 day	Wed 11/4/98	Wed 11/4/98
143	**Brown and Caldwell Procurement**	**26 days**	**Tue 8/11/98**	**Thu 9/24/98**
144	Advertisement	7 days	Tue 8/11/98	Thu 8/20/98
145	Award	18 days	Mon 8/24/98	Wed 9/23/98
146	Construction Begins	1 day	Thu 9/24/98	Thu 9/24/98
147	**Brown and Caldwell PS&E - Metro MS and Paxton PR**	**31 days**	**Mon 1/17/00**	**Thu 3/9/00**



Caltrans Pilot BMP Project
Master Schedule

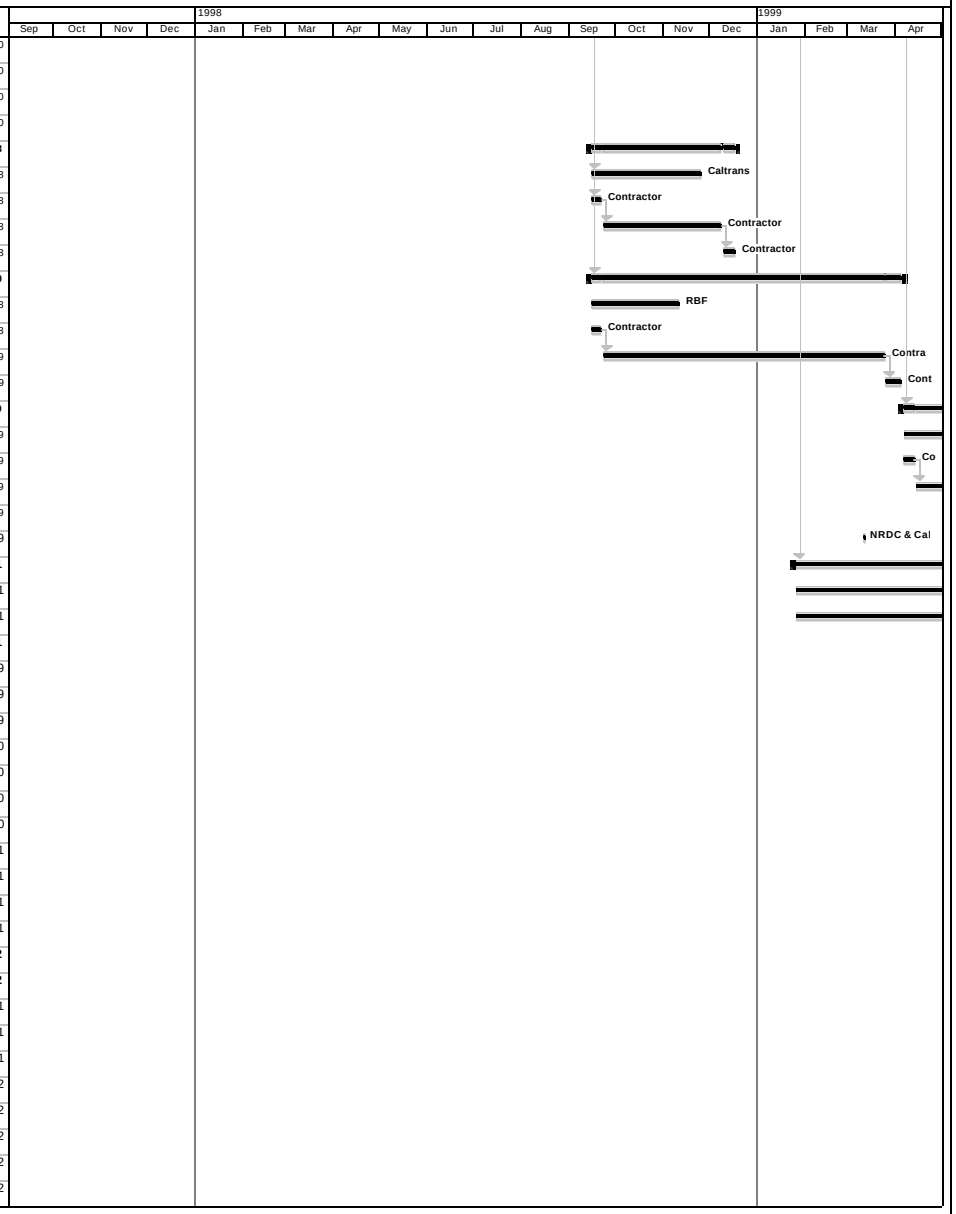
ID	Task Name	Duration	Start	Finish
148	Advertisement	15 days	Mon 1/17/00	Wed 2/9/00
149	Award	15 days	Thu 2/10/00	Wed 3/8/00
150	Construction Begins	1 day	Thu 3/9/00	Thu 3/9/00
151	**RBF PS&E**	**48 days**	**Mon 6/22/98**	**Mon 9/14/98**
152	Advertisement	27 days	Mon 6/22/98	Wed 8/5/98
153	Award	20 days	Thu 8/6/98	Thu 9/10/98
154	Construction Begins	1 day	Mon 9/14/98	Mon 9/14/98
155	**RBF Procurement**	**48 days**	**Mon 6/22/98**	**Mon 9/14/98**
156	Advertisement	22 days	Mon 6/22/98	Tue 7/28/98
157	Award	25 days	Wed 7/29/98	Thu 9/10/98
158	Construction Begins	1 day	Mon 9/14/98	Mon 9/14/98
159	**RBF PS&E - La Costa East and Manchester East**	**13 days**	**Mon 3/15/99**	**Mon 4/5/99**
160	Award	12 days	Mon 3/15/99	Thu 4/1/99
161	Construction Begins	1 day	Mon 4/5/99	Mon 4/5/99
162	**STATUS MEETING NO. 2**	1 day	Tue 7/14/98	Tue 7/14/98
163	**Operation, Maintenance and Monitoring Program**	**89 days**	**Tue 8/11/98**	**Mon 1/25/99**
164	Draft Maintenance, Monitoring and Reporting Program	59 days	Tue 8/11/98	Mon 11/2/98
165	NRDC Review	18 days	Tue 11/3/98	Mon 12/7/98
166	Program Revisions	26 days	Tue 12/8/98	Mon 1/18/99
167	Final Maintenance, Monitoring and Reporting Program	5 days	Tue 1/19/99	Mon 1/25/99
168	O&M Begins	1 day	Tue 8/11/98	Tue 8/11/98
169	**STATUS MEETING NO. 3**	1 day	Tue 12/8/98	Tue 12/8/98
170	**Construction**	**362 days**	**Tue 9/15/98**	**Mon 6/26/00**
171	**Montgomery-Watson PS&E**	**82 days**	**Thu 11/5/98**	**Thu 4/8/99**
172	Construction Management	73 days	Thu 11/5/98	Wed 3/24/99
173	Mobilization	4 days	Thu 11/5/98	Thu 11/12/98
174	Construction	73 days	Mon 11/16/98	Wed 3/31/99
175	Demobilization/Final Project	5 days	Thu 4/1/99	Thu 4/8/99
176	**Montgomery-Watson Procurement**	**43 days**	**Tue 12/1/98**	**Mon 2/22/99**
177	Construction Management	33 days	Tue 12/1/98	Tue 2/2/99
178	Mobilization	5 days	Tue 12/1/98	Tue 12/8/98
179	Construction	33 days	Wed 12/9/98	Wed 2/10/99
180	Demobilization/Final Project	5 days	Thu 2/11/99	Mon 2/22/99
181	**Montgomery-Watson CDS Sites**	**59 days**	**Tue 1/11/00**	**Mon 4/24/00**
182	Construction Management	22 days	Tue 1/11/00	Mon 2/21/00
183	Mobilization	5 days	Tue 1/11/00	Tue 1/18/00
184	Construction	49 days	Wed 1/19/00	Thu 4/13/00
185	Demobilization/Final Project	5 days	Mon 4/17/00	Mon 4/24/00
186	**Brown and Caldwell PS&E**	**48 days**	**Thu 11/5/98**	**Mon 2/8/99**
187	Construction Management	40 days	Thu 11/5/98	Mon 1/25/99
188	Mobilization	4 days	Thu 11/5/98	Thu 11/12/98
189	Construction	40 days	Mon 11/16/98	Mon 2/1/99
190	Demobilization/Final Project	4 days	Tue 2/2/99	Mon 2/8/99
191	**Brown and Caldwell Procurement**	**117 days**	**Mon 9/28/98**	**Thu 4/29/99**
192	Construction Management	107 days	Mon 9/28/98	Tue 4/13/99
193	Mobilization	5 days	Mon 9/28/98	Mon 10/5/98
194	Construction	107 days	Tue 10/6/98	Wed 4/21/99
195	Demobilization/Final Project	5 days	Thu 4/22/99	Thu 4/29/99
196	**Brown and Caldwell PS&E - Metro MS and Paxton PR**	**64 days**	**Mon 3/13/00**	**Mon 6/26/00**



Mon 3/10/03

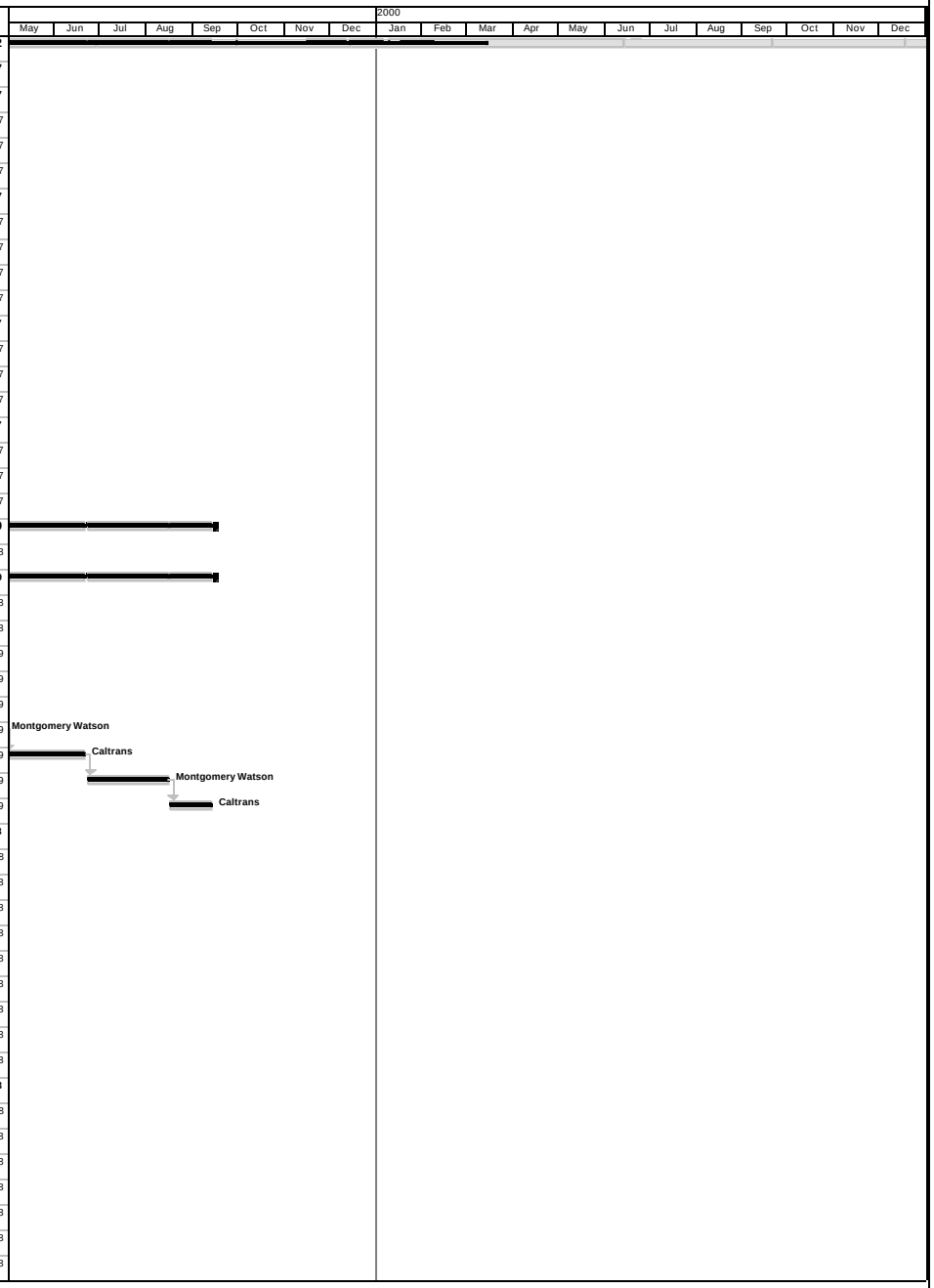
Caltrans Pilot BMP Project
Master Schedule

ID	Task Name	Duration	Start	Finish
197	Construction Management	54 days	Mon 3/13/00	Wed 6/7/00
198	Mobilization	5 days	Mon 3/13/00	Mon 3/20/00
199	Construction	54 days	Tue 3/21/00	Thu 6/15/00
200	Demobilization/Final Project	5 days	Mon 6/19/00	Mon 6/26/00
201	**RBF PS&E**	**53 days**	**Tue 9/15/98**	**Thu 12/17/98**
202	Construction Management	41 days	Tue 9/15/98	Thu 11/26/98
203	Mobilization	5 days	Tue 9/15/98	Tue 9/22/98
204	Construction	43 days	Wed 9/23/98	Wed 12/9/98
205	Demobilization/Final Project	5 days	Thu 12/10/98	Thu 12/17/98
206	**RBF Procurement**	**109 days**	**Tue 9/15/98**	**Mon 4/5/99**
207	Construction Management	41.88 days	Tue 9/15/98	Thu 11/12/98
208	Mobilization	5 days	Tue 9/15/98	Tue 9/22/98
209	Construction	99 days	Wed 9/23/98	Thu 3/25/99
210	Demobilization/Final Project	5 days	Thu 3/25/99	Mon 4/5/99
211	**RBF PS&E - La Costa East and Manchester East**	**45 days**	**Tue 4/6/99**	**Wed 6/23/99**
212	Construction Management	34 days	Tue 4/6/99	Thu 6/3/99
213	Mobilization	5 days	Tue 4/6/99	Tue 4/13/99
214	Construction	35 days	Wed 4/14/99	Tue 6/15/99
215	Demobilization/Final Project	5 days	Wed 6/16/99	Wed 6/23/99
216	**STATUS MEETING NO. 4**	1 day	Thu 3/11/99	Thu 3/11/99
217	**Operation, Maintenance and Monitoring**	**462 days**	**Tue 1/26/99**	**Mon 4/30/01**
218	District 7 Pilots	462 days	Tue 1/26/99	Mon 4/30/01
219	District 11 Pilots	462 days	Tue 1/26/99	Mon 4/30/01
220	**QUARTERLY STATUS MEETINGS**	**503 days**	**Tue 6/29/99**	**Wed 12/12/01**
221	**STATUS MEETING NO. 5**	1 day	Tue 6/29/99	Tue 6/29/99
222	**STATUS MEETING NO. 6**	1 day	Thu 9/30/99	Thu 9/30/99
223	**STATUS MEETING NO. 7**	1 day	Wed 12/15/99	Wed 12/15/99
224	**STATUS MEETING NO. 8**	1 day	Wed 3/15/00	Wed 3/15/00
225	**STATUS MEETING NO. 9**	1 day	Wed 6/14/00	Wed 6/14/00
226	**STATUS MEETING NO. 10**	1 day	Wed 9/20/00	Wed 9/20/00
227	**STATUS MEETING NO. 11**	1 day	Mon 12/18/00	Mon 12/18/00
228	**STATUS MEETING NO. 12**	1 day	Wed 3/14/01	Wed 3/14/01
229	**STATUS MEETING NO. 13**	1 day	Wed 6/13/01	Wed 6/13/01
230	**STATUS MEETING NO. 14**	1 day	Wed 9/19/01	Wed 9/19/01
231	**STATUS MEETING NO. 15**	1 day	Wed 12/12/01	Wed 12/12/01
232	**Final Reports**	**216 days**	**Mon 6/18/01**	**Tue 7/2/02**
233	**Retrofit Pilot Projects**	**216 days**	**Mon 6/18/01**	**Tue 7/2/02**
234	Summary of Water Quality Monitoring Data	63 days	Mon 6/18/01	Fri 9/14/01
235	NRDC Review	20 days	Mon 9/17/01	Thu 10/18/01
236	Discussion Meeting	1 day	Mon 10/22/01	Mon 10/22/01
237	Final Report (1st Draft)	70 days	Tue 10/23/01	Mon 1/28/02
238	NRDC Review/Meetings	20 days	Tue 1/29/02	Mon 3/4/02
239	Revised Final Report	60 days	Tue 3/5/02	Mon 5/27/02
240	NRDC Review	20 days	Tue 5/28/02	Mon 7/1/02
241	Publish Final Report	1 day	Tue 7/2/02	Tue 7/2/02



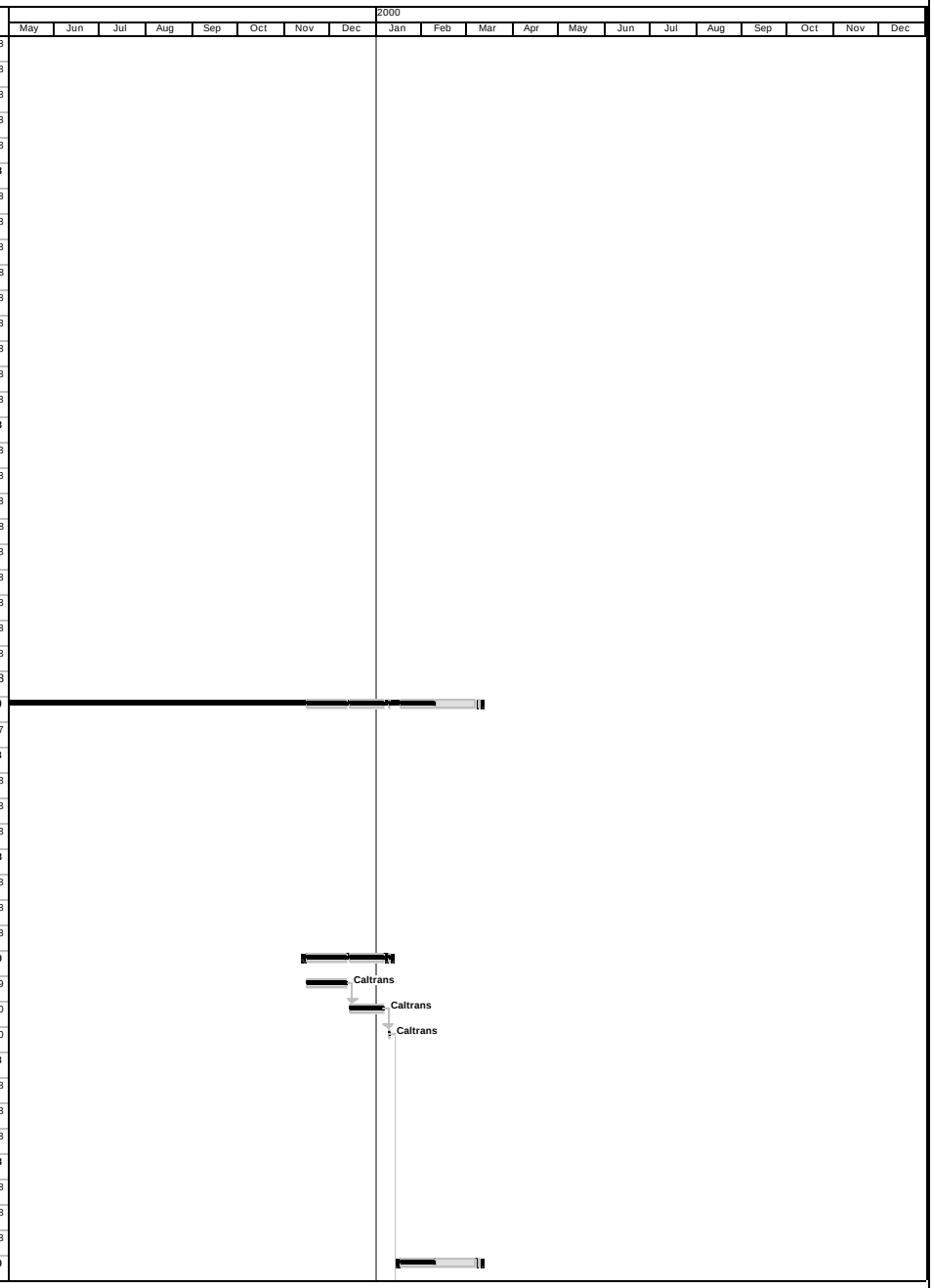
Caltrans Pilot BMP Project
Master Schedule

ID	Task Name	Duration	Start	Finish
1	**Retrofit Pilot Program - District 7 Master Schedule**	**954 days**	**Thu 10/16/97**	**Tue 7/2/02**
2	**Preliminary Investigation**	**38 days**	**Thu 10/16/97**	**Tue 12/30/97**
3	**Site Selection Field Visits - LA**	**24 days**	**Thu 10/16/97**	**Mon 12/1/97**
4	Identify Candidate Sites	23 days	Thu 10/16/97	Tue 11/18/97
5	Refine to Preliminary Sites	7 days	Wed 11/19/97	Mon 12/1/97
6	Site Selection Presentations/Develop Reports	11.3 days	Tue 12/2/97	Wed 12/17/97
7	**Site Selection Field Visits - SD**	**20.5 days**	**Thu 10/16/97**	**Mon 11/24/97**
8	Identify Candidate Sites	18 days	Thu 10/16/97	Tue 11/11/97
9	Refine to Preliminary Sites	8.5 days	Wed 11/12/97	Mon 11/24/97
10	Site Selection Presentations/Develop Reports	6.63 days	Tue 12/2/97	Thu 12/11/97
11	NRDC Review	4 days	Wed 12/17/97	Wed 12/24/97
12	**Final Site Selection - LA**	**38 days**	**Thu 10/16/97**	**Tue 12/30/97**
13	Revise Site Selection Studies	0.53 days	Wed 12/24/97	Tue 12/30/97
14	Final Reports	0 hrs	Tue 12/30/97	Tue 12/30/97
15	Project Management	18 days	Thu 10/16/97	Tue 11/11/97
16	**Final Site Selection - SD**	**38 days**	**Thu 10/16/97**	**Tue 12/30/97**
17	Revise Site Selection Studies	0.53 days	Wed 12/24/97	Mon 12/29/97
18	Final Reports	0 hrs	Mon 12/29/97	Tue 12/30/97
19	Project Management	18 days	Thu 10/16/97	Tue 11/11/97
20	**Project Design - Los Angeles**	**341 days**	**Tue 12/30/97**	**Tue 9/14/99**
21	Design Management/Assistance	55.99 days	Tue 12/30/97	Tue 3/24/98
22	**1. Continuous Deflective Separators (2 Sites)**	**341 days**	**Tue 12/30/97**	**Tue 9/14/99**
23	Site Aerial Controls	0 days	Tue 12/30/97	Thu 1/1/98
24	Fly Aerial Photo/Compile to Map	10 days	Thu 1/1/98	Tue 1/20/98
25	Plan Preparation/Hold	191 days	Wed 1/21/98	Tue 1/5/99
26	Internal QA/QC	4.94 days	Wed 1/6/99	Wed 1/13/99
27	Plan Review	30 days	Thu 1/14/99	Tue 3/9/99
28	Plan Revision	30 days	Wed 3/10/99	Thu 4/29/99
29	Plan Review	29 days	Mon 5/3/99	Tue 6/22/99
30	Plan Revision	30 days	Wed 6/23/99	Mon 8/16/99
31	Plans Signed	16 days	Tue 8/17/99	Tue 9/14/99
32	**2. Catch Basin Inserts (3 Sites)**	**97 days**	**Tue 12/30/97**	**Wed 6/24/98**
33	Site Topography	0.99 days	Tue 12/30/97	Mon 1/5/98
34	Topography Compilation	4 days	Mon 1/5/98	Mon 1/12/98
35	Plan Preparation	45 days	Tue 1/13/98	Wed 4/1/98
36	Internal QA/QC	4.94 days	Thu 4/2/98	Thu 4/9/98
37	Plan Review	6 days	Tue 4/14/98	Wed 4/22/98
38	Plan Revision	4 days	Thu 4/23/98	Wed 4/29/98
39	Plan Review	11 days	Thu 4/30/98	Tue 5/19/98
40	Plan Revision	4 days	Wed 5/20/98	Wed 5/27/98
41	Plans Signed	16 days	Thu 5/28/98	Wed 6/24/98
42	**3. Extended Detention Basin (2 Sites)**	**100 days**	**Tue 12/30/97**	**Tue 6/30/98**
43	Site Topography	10 days	Tue 12/30/97	Fri 1/16/98
44	Topography Compilation	4 days	Mon 1/19/98	Thu 1/22/98
45	Plan Preparation	30 days	Mon 1/26/98	Wed 3/18/98
46	Internal QA/QC	4 days	Thu 3/19/98	Wed 3/25/98
47	Plan Review	8 days	Thu 3/26/98	Wed 4/8/98
48	Plan Revision	4 days	Thu 4/9/98	Wed 4/15/98
49	Plan Review	12 days	Thu 4/16/98	Wed 5/6/98



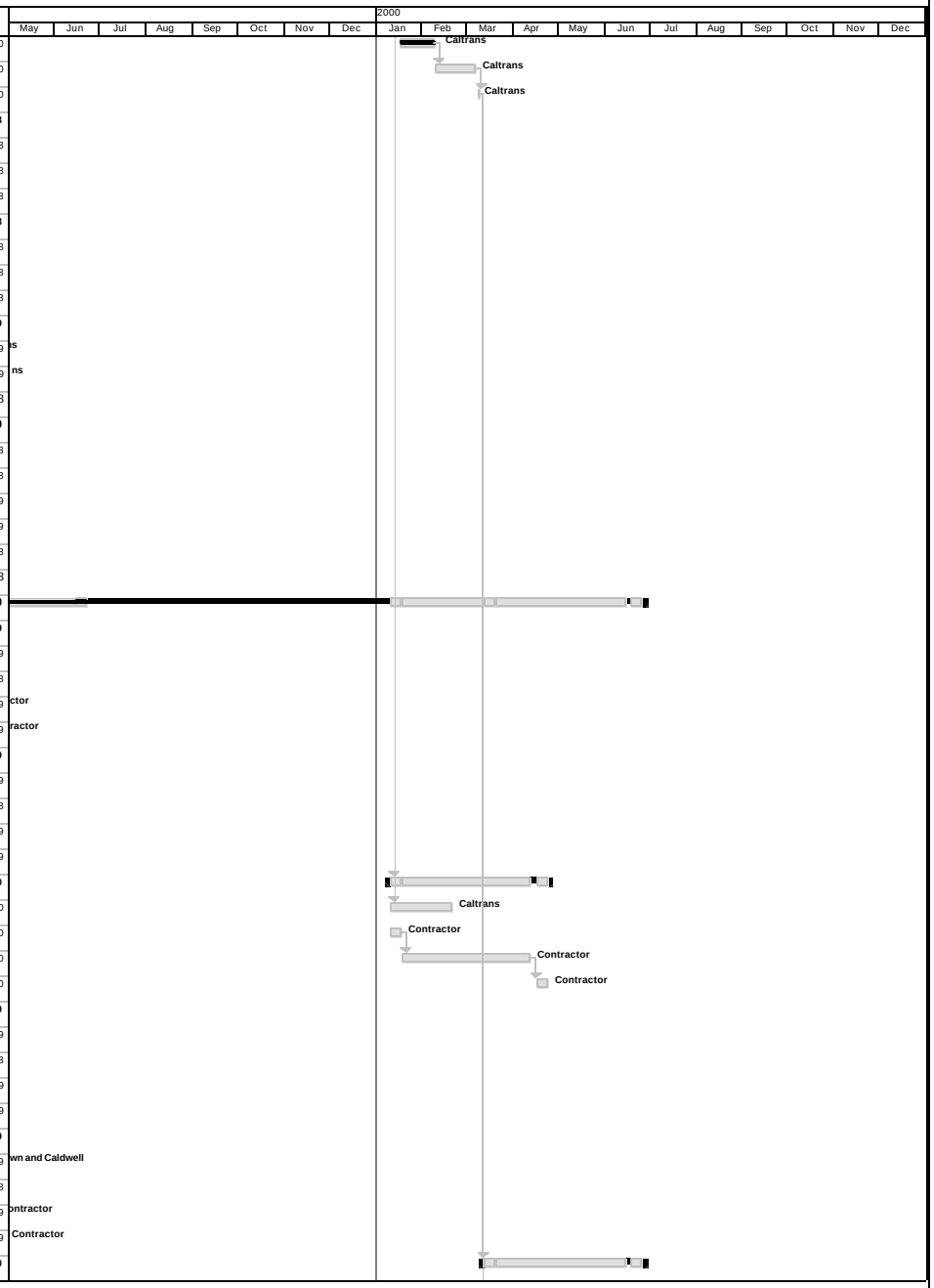
Caltrans Pilot BMP Project
Master Schedule

ID	Task Name	Duration	Start	Finish
99	Plan Review	9 days	Tue 3/17/98	Tue 3/31/98
100	Plan Revision	5 days	Wed 4/1/98	Tue 4/7/98
101	Plan Review	26 days	Wed 4/8/98	Mon 5/25/98
102	Plan Revision	2 days	Tue 5/26/98	Wed 5/27/98
103	Plans Signed	15 days	Thu 5/28/98	Tue 6/23/98
104	**Infiltration Basin (1 Site)**	**80 days**	**Mon 1/5/98**	**Tue 5/26/98**
105	Site Topography	6 days	Mon 1/5/98	Tue 1/13/98
106	Topography Compilation	6 days	Wed 1/14/98	Thu 1/22/98
107	Plan Preparation	29 days	Fri 1/23/98	Thu 3/5/98
108	Internal QA/QC	4 days	Fri 3/6/98	Fri 3/13/98
109	Plan Review	9 days	Tue 3/17/98	Tue 3/31/98
110	Plan Revision	5 days	Wed 4/1/98	Tue 4/7/98
111	Plan Review	12 days	Wed 4/8/98	Tue 4/28/98
112	Plan Revision	5 days	Wed 4/29/98	Tue 5/5/98
113	Plans Signed	11 days	Wed 5/6/98	Tue 5/26/98
114	**Media Filter (3 Sites)**	**94 days**	**Mon 1/5/98**	**Thu 6/18/98**
115	Site Topography	6 days	Mon 1/5/98	Tue 1/13/98
116	Topography Compilation	6 days	Wed 1/14/98	Thu 1/22/98
117	Plan Preparation	29 days	Fri 1/23/98	Thu 3/5/98
118	Internal QA/QC	4 days	Fri 3/6/98	Fri 3/13/98
119	Plan Review	9 days	Tue 3/17/98	Tue 3/31/98
120	Plan Revision	5 days	Wed 4/1/98	Tue 4/7/98
121	Plan Review	26 days	Wed 4/8/98	Thu 5/21/98
122	Plan Revision	1 day	Fri 5/22/98	Mon 5/25/98
123	Plans Signed	15 days	Tue 5/26/98	Thu 6/18/98
124	**STATUS MEETING NO. 1**	1 day	Mon 3/30/98	Mon 3/30/98
125	**Bid Projects**	**478 days**	**Thu 10/16/97**	**Thu 3/9/00**
126	Construction Management	28 days	Thu 10/16/97	Tue 11/25/97
127	**Montgomery-Watson PS&E**	**54 days**	**Mon 8/3/98**	**Wed 11/4/98**
128	Advertisement	20 days	Mon 8/3/98	Thu 9/3/98
129	Award	33 days	Mon 9/7/98	Tue 11/3/98
130	Construction Begins	1 day	Wed 11/4/98	Wed 11/4/98
131	**Montgomery-Watson Procurement**	**84 days**	**Wed 7/1/98**	**Mon 11/30/98**
132	Advertisement	43 days	Wed 7/1/98	Tue 9/15/98
133	Award	40 days	Wed 9/16/98	Thu 11/26/98
134	Construction Begins	1 day	Mon 11/30/98	Mon 11/30/98
135	**Montgomery-Watson CDS Sites**	**31 days**	**Tue 11/16/99**	**Mon 1/10/00**
136	Advertisement	15 days	Tue 11/16/99	Mon 12/13/99
137	Award	15 days	Tue 12/14/99	Thu 1/6/00
138	Construction Begins	1 day	Mon 1/10/00	Mon 1/10/00
139	**Brown and Caldwell PS&E**	**72 days**	**Wed 7/1/98**	**Wed 11/4/98**
140	Advertisement	20 days	Wed 7/1/98	Tue 8/4/98
141	Award	51 days	Wed 8/5/98	Tue 11/3/98
142	Construction Begins	1 day	Wed 11/4/98	Wed 11/4/98
143	**Brown and Caldwell Procurement**	**26 days**	**Tue 8/11/98**	**Thu 9/24/98**
144	Advertisement	7 days	Tue 8/11/98	Thu 8/20/98
145	Award	18 days	Mon 8/24/98	Wed 9/23/98
146	Construction Begins	1 day	Thu 9/24/98	Thu 9/24/98
147	**Brown and Caldwell PS&E - Metro MS and Paxton PR**	**31 days**	**Mon 1/17/00**	**Thu 3/9/00**



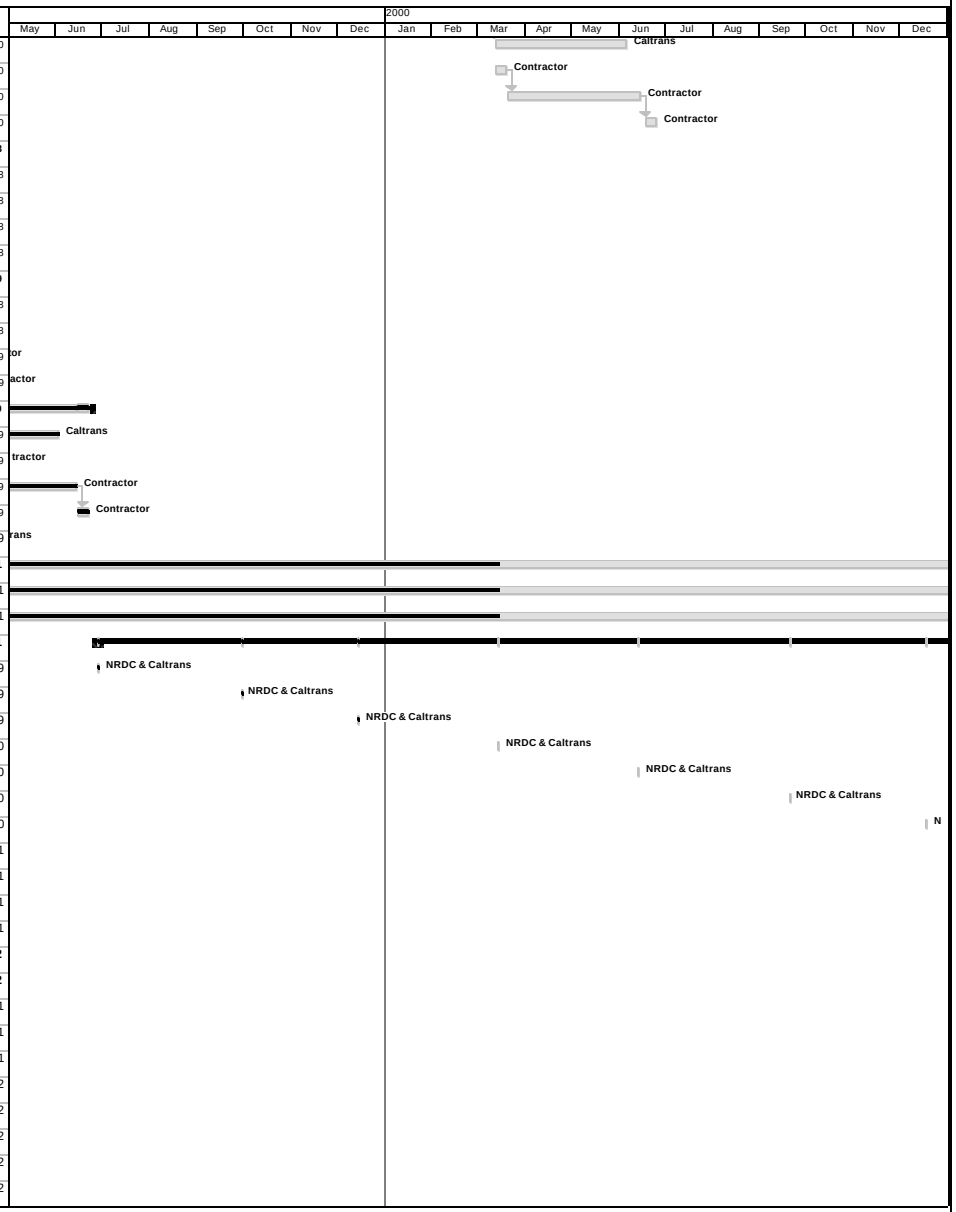
Caltrans Pilot BMP Project
Master Schedule

ID	Task Name	Duration	Start	Finish
148	Advertisement	15 days	Mon 1/17/00	Wed 2/9/00
149	Award	15 days	Thu 2/10/00	Wed 3/8/00
150	Construction Begins	1 day	Thu 3/9/00	Thu 3/9/00
151	**RBF PS&E**	**48 days**	**Mon 6/22/98**	**Mon 9/14/98**
152	Advertisement	27 days	Mon 6/22/98	Wed 8/5/98
153	Award	20 days	Thu 8/6/98	Thu 9/10/98
154	Construction Begins	1 day	Mon 9/14/98	Mon 9/14/98
155	**RBF Procurement**	**48 days**	**Mon 6/22/98**	**Mon 9/14/98**
156	Advertisement	22 days	Mon 6/22/98	Tue 7/28/98
157	Award	25 days	Wed 7/29/98	Thu 9/10/98
158	Construction Begins	1 day	Mon 9/14/98	Mon 9/14/98
159	**RBF PS&E - La Costa East and Manchester East**	**13 days**	**Mon 3/15/99**	**Mon 4/5/99**
160	Award	12 days	Mon 3/15/99	Thu 4/1/99
161	Construction Begins	1 day	Mon 4/5/99	Mon 4/5/99
162	**STATUS MEETING NO. 2**	1 day	Tue 7/14/98	Tue 7/14/98
163	**Operation, Maintenance and Monitoring Program**	**89 days**	**Tue 8/11/98**	**Mon 1/25/99**
164	Draft Maintenance, Monitoring and Reporting Program	59 days	Tue 8/11/98	Mon 11/2/98
165	NRDC Review	18 days	Tue 11/3/98	Mon 12/7/98
166	Program Revisions	26 days	Tue 12/8/98	Mon 1/18/99
167	Final Maintenance, Monitoring and Reporting Program	5 days	Tue 1/19/99	Mon 1/25/99
168	O&M Begins	1 day	Tue 8/11/98	Tue 8/11/98
169	**STATUS MEETING NO. 3**	1 day	Tue 12/8/98	Tue 12/8/98
170	**Construction**	**362 days**	**Tue 9/15/98**	**Mon 6/26/00**
171	**Montgomery-Watson PS&E**	**82 days**	**Thu 11/5/98**	**Thu 4/8/99**
172	Construction Management	73 days	Thu 11/5/98	Wed 3/24/99
173	Mobilization	4 days	Thu 11/5/98	Thu 11/12/98
174	Construction	73 days	Mon 11/16/98	Wed 3/31/99
175	Demobilization/Final Project	5 days	Thu 4/1/99	Thu 4/8/99
176	**Montgomery-Watson Procurement**	**43 days**	**Tue 12/1/98**	**Mon 2/22/99**
177	Construction Management	33 days	Tue 12/1/98	Tue 2/2/99
178	Mobilization	5 days	Tue 12/1/98	Tue 12/8/98
179	Construction	33 days	Wed 12/9/98	Wed 2/10/99
180	Demobilization/Final Project	5 days	Thu 2/11/99	Mon 2/22/99
181	**Montgomery-Watson CDS Sites**	**59 days**	**Tue 1/11/00**	**Mon 4/24/00**
182	Construction Management	22 days	Tue 1/11/00	Mon 2/21/00
183	Mobilization	5 days	Tue 1/11/00	Tue 1/18/00
184	Construction	49 days	Wed 1/19/00	Thu 4/13/00
185	Demobilization/Final Project	5 days	Mon 4/17/00	Mon 4/24/00
186	**Brown and Caldwell PS&E**	**48 days**	**Thu 11/5/98**	**Mon 2/8/99**
187	Construction Management	40 days	Thu 11/5/98	Mon 1/25/99
188	Mobilization	4 days	Thu 11/5/98	Thu 11/12/98
189	Construction	40 days	Mon 11/16/98	Mon 2/1/99
190	Demobilization/Final Project	4 days	Tue 2/2/99	Mon 2/8/99
191	**Brown and Caldwell Procurement**	**117 days**	**Mon 9/28/98**	**Thu 4/29/99**
192	Construction Management	107 days	Mon 9/28/98	Tue 4/13/99
193	Mobilization	5 days	Mon 9/28/98	Mon 10/5/98
194	Construction	107 days	Tue 10/6/98	Wed 4/21/99
195	Demobilization/Final Project	5 days	Thu 4/22/99	Thu 4/29/99
196	**Brown and Caldwell PS&E - Metro MS and Paxton PR**	**64 days**	**Mon 3/13/00**	**Mon 6/26/00**



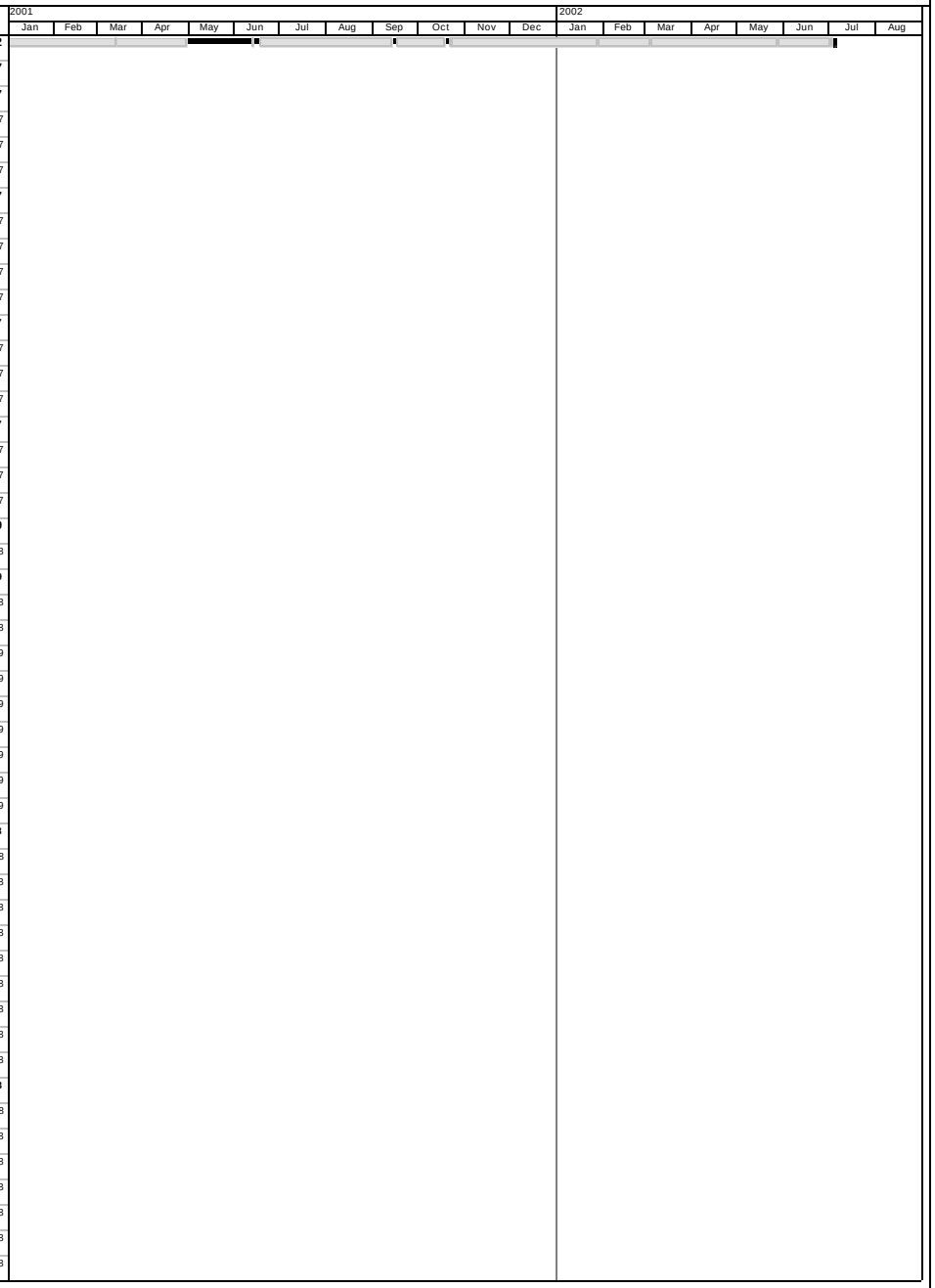
Caltrans Pilot BMP Project
Master Schedule

ID	Task Name	Duration	Start	Finish
197	Construction Management	54 days	Mon 3/13/00	Wed 6/7/00
198	Mobilization	5 days	Mon 3/13/00	Mon 3/20/00
199	Construction	54 days	Tue 3/21/00	Thu 6/15/00
200	Demobilization/Final Project	5 days	Mon 6/19/00	Mon 6/26/00
201	**RBF PS&E**	**53 days**	**Tue 9/15/98**	**Thu 12/17/98**
202	Construction Management	41 days	Tue 9/15/98	Thu 11/26/98
203	Mobilization	5 days	Tue 9/15/98	Tue 9/22/98
204	Construction	43 days	Wed 9/23/98	Wed 12/9/98
205	Demobilization/Final Project	5 days	Thu 12/10/98	Thu 12/17/98
206	**RBF Procurement**	**109 days**	**Tue 9/15/98**	**Mon 4/5/99**
207	Construction Management	41.88 days	Tue 9/15/98	Thu 11/12/98
208	Mobilization	5 days	Tue 9/15/98	Tue 9/22/98
209	Construction	99 days	Wed 9/23/98	Thu 3/25/99
210	Demobilization/Final Project	5 days	Thu 3/25/99	Mon 4/5/99
211	**RBF PS&E - La Costa East and Manchester East**	**45 days**	**Tue 4/6/99**	**Wed 6/23/99**
212	Construction Management	34 days	Tue 4/6/99	Thu 6/3/99
213	Mobilization	5 days	Tue 4/6/99	Tue 4/13/99
214	Construction	35 days	Wed 4/14/99	Tue 6/15/99
215	Demobilization/Final Project	5 days	Wed 6/16/99	Wed 6/23/99
216	**STATUS MEETING NO. 4**	1 day	Thu 3/11/99	Thu 3/11/99
217	**Operation, Maintenance and Monitoring**	**462 days**	**Tue 1/26/99**	**Mon 4/30/01**
218	District 7 Pilots	462 days	Tue 1/26/99	Mon 4/30/01
219	District 11 Pilots	462 days	Tue 1/26/99	Mon 4/30/01
220	**QUARTERLY STATUS MEETINGS**	**503 days**	**Tue 6/29/99**	**Wed 12/12/01**
221	**STATUS MEETING NO. 5**	1 day	Tue 6/29/99	Tue 6/29/99
222	**STATUS MEETING NO. 6**	1 day	Thu 9/30/99	Thu 9/30/99
223	**STATUS MEETING NO. 7**	1 day	Wed 12/15/99	Wed 12/15/99
224	**STATUS MEETING NO. 8**	1 day	Wed 3/15/00	Wed 3/15/00
225	**STATUS MEETING NO. 9**	1 day	Wed 6/14/00	Wed 6/14/00
226	**STATUS MEETING NO. 10**	1 day	Wed 9/20/00	Wed 9/20/00
227	**STATUS MEETING NO. 11**	1 day	Mon 12/18/00	Mon 12/18/00
228	**STATUS MEETING NO. 12**	1 day	Wed 3/14/01	Wed 3/14/01
229	**STATUS MEETING NO. 13**	1 day	Wed 6/13/01	Wed 6/13/01
230	**STATUS MEETING NO. 14**	1 day	Wed 9/19/01	Wed 9/19/01
231	**STATUS MEETING NO. 15**	1 day	Wed 12/12/01	Wed 12/12/01
232	**Final Reports**	**216 days**	**Mon 6/18/01**	**Tue 7/2/02**
233	**Retrofit Pilot Projects**	**216 days**	**Mon 6/18/01**	**Tue 7/2/02**
234	Summary of Water Quality Monitoring Data	63 days	Mon 6/18/01	Fri 9/14/01
235	NRDC Review	20 days	Mon 9/17/01	Thu 10/18/01
236	Discussion Meeting	1 day	Mon 10/22/01	Mon 10/22/01
237	Final Report (1st Draft)	70 days	Tue 10/23/01	Mon 1/28/02
238	NRDC Review/Meetings	20 days	Tue 1/29/02	Mon 3/4/02
239	Revised Final Report	60 days	Tue 3/5/02	Mon 5/27/02
240	NRDC Review	20 days	Tue 5/28/02	Mon 7/1/02
241	Publish Final Report	1 day	Tue 7/2/02	Tue 7/2/02



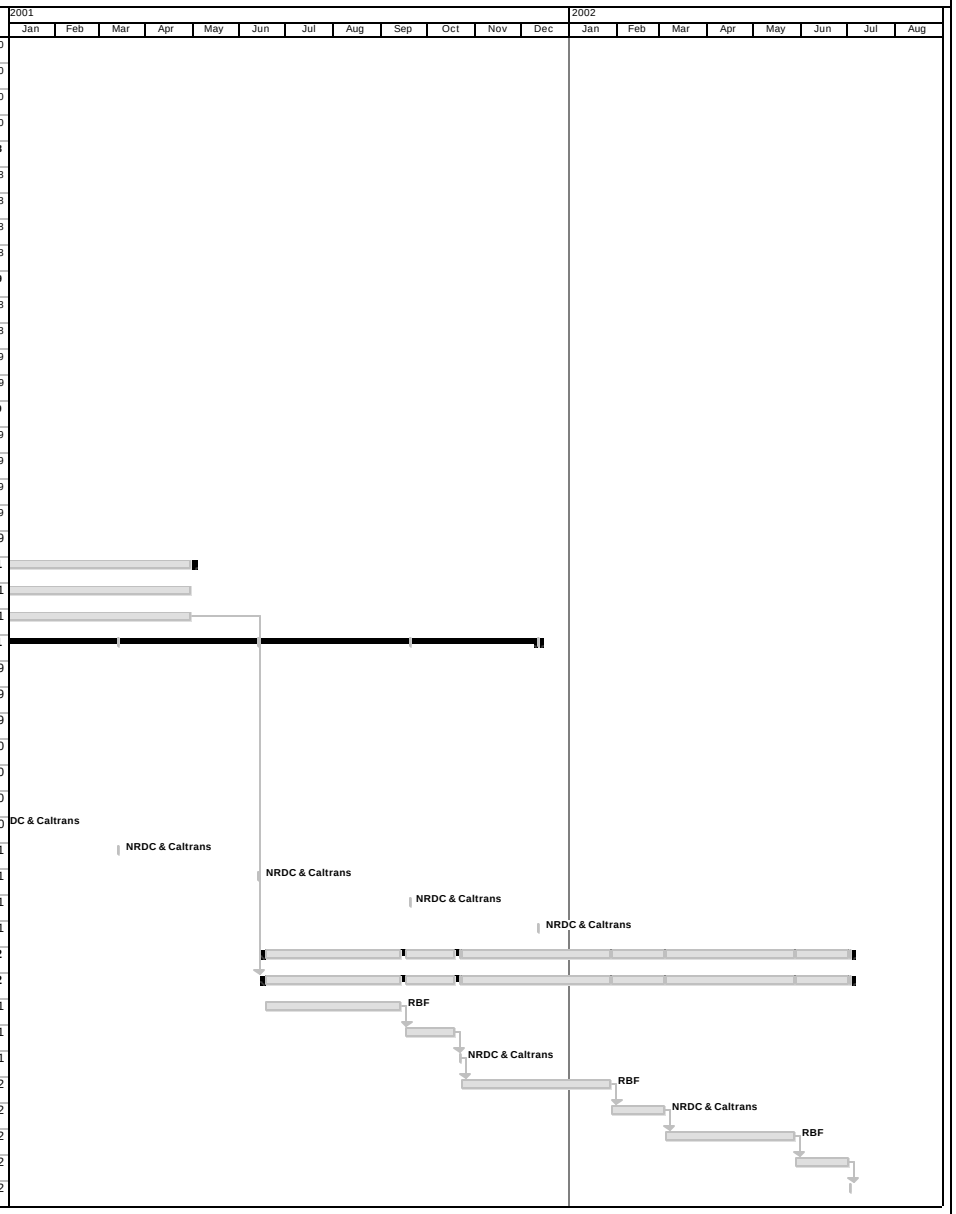
Caltrans Pilot BMP Project
Master Schedule

ID	Task Name	Duration	Start	Finish
1	**Retrofit Pilot Program - District 7 Master Schedule**	**954 days**	**Thu 10/16/97**	**Tue 7/2/02**
2	**Preliminary Investigation**	**38 days**	**Thu 10/16/97**	**Tue 12/30/97**
3	**Site Selection Field Visits - LA**	**24 days**	**Thu 10/16/97**	**Mon 12/1/97**
4	Identify Candidate Sites	23 days	Thu 10/16/97	Tue 11/18/97
5	Refine to Preliminary Sites	7 days	Wed 11/19/97	Mon 12/1/97
6	Site Selection Presentations/Develop Reports	11.3 days	Tue 12/2/97	Wed 12/17/97
7	**Site Selection Field Visits - SD**	**20.5 days**	**Thu 10/16/97**	**Mon 11/24/97**
8	Identify Candidate Sites	18 days	Thu 10/16/97	Tue 11/11/97
9	Refine to Preliminary Sites	8.5 days	Wed 11/12/97	Mon 11/24/97
10	Site Selection Presentations/Develop Reports	6.63 days	Tue 12/2/97	Thu 12/11/97
11	NRDC Review	4 days	Wed 12/17/97	Wed 12/24/97
12	**Final Site Selection - LA**	**38 days**	**Thu 10/16/97**	**Tue 12/30/97**
13	Revise Site Selection Studies	0.53 days	Wed 12/24/97	Tue 12/30/97
14	Final Reports	0 hrs	Tue 12/30/97	Tue 12/30/97
15	Project Management	18 days	Thu 10/16/97	Tue 11/11/97
16	**Final Site Selection - SD**	**38 days**	**Thu 10/16/97**	**Tue 12/30/97**
17	Revise Site Selection Studies	0.53 days	Wed 12/24/97	Mon 12/29/97
18	Final Reports	0 hrs	Mon 12/29/97	Tue 12/30/97
19	Project Management	18 days	Thu 10/16/97	Tue 11/11/97
20	**Project Design - Los Angeles**	**341 days**	**Tue 12/30/97**	**Tue 9/14/99**
21	Design Management/Assistance	55.99 days	Tue 12/30/97	Tue 3/24/98
22	**1. Continuous Deflective Separators (2 Sites)**	**341 days**	**Tue 12/30/97**	**Tue 9/14/99**
23	Site Aerial Controls	0 days	Tue 12/30/97	Thu 1/1/98
24	Fly Aerial Photo/Compile to Map	10 days	Thu 1/1/98	Tue 1/20/98
25	Plan Preparation/Hold	191 days	Wed 1/21/98	Tue 1/5/99
26	Internal QA/QC	4.94 days	Wed 1/6/99	Wed 1/13/99
27	Plan Review	30 days	Thu 1/14/99	Tue 3/9/99
28	Plan Revision	30 days	Wed 3/10/99	Thu 4/29/99
29	Plan Review	29 days	Mon 5/3/99	Tue 6/22/99
30	Plan Revision	30 days	Wed 6/23/99	Mon 8/16/99
31	Plans Signed	16 days	Tue 8/17/99	Tue 9/14/99
32	**2. Catch Basin Inserts (3 Sites)**	**97 days**	**Tue 12/30/97**	**Wed 6/24/98**
33	Site Topography	0.99 days	Tue 12/30/97	Mon 1/5/98
34	Topography Compilation	4 days	Mon 1/5/98	Mon 1/12/98
35	Plan Preparation	45 days	Tue 1/13/98	Wed 4/1/98
36	Internal QA/QC	4.94 days	Thu 4/2/98	Thu 4/9/98
37	Plan Review	6 days	Tue 4/14/98	Wed 4/22/98
38	Plan Revision	4 days	Thu 4/23/98	Wed 4/29/98
39	Plan Review	11 days	Thu 4/30/98	Tue 5/19/98
40	Plan Revision	4 days	Wed 5/20/98	Wed 5/27/98
41	Plans Signed	16 days	Thu 5/28/98	Wed 6/24/98
42	**3. Extended Detention Basin (2 Sites)**	**100 days**	**Tue 12/30/97**	**Tue 6/30/98**
43	Site Topography	10 days	Tue 12/30/97	Fri 1/16/98
44	Topography Compilation	4 days	Mon 1/19/98	Thu 1/22/98
45	Plan Preparation	30 days	Mon 1/26/98	Wed 3/18/98
46	Internal QA/QC	4 days	Thu 3/19/98	Wed 3/25/98
47	Plan Review	8 days	Thu 3/26/98	Wed 4/8/98
48	Plan Revision	4 days	Thu 4/9/98	Wed 4/15/98
49	Plan Review	12 days	Thu 4/16/98	Wed 5/6/98



Caltrans Pilot BMP Project
Master Schedule

ID	Task Name	Duration	Start	Finish
197	Construction Management	54 days	Mon 3/13/00	Wed 6/7/00
198	Mobilization	5 days	Mon 3/13/00	Mon 3/20/00
199	Construction	54 days	Tue 3/21/00	Thu 6/15/00
200	Demobilization/Final Project	5 days	Mon 6/19/00	Mon 6/26/00
201	**RBF PS&E**	**53 days**	**Tue 9/15/98**	**Thu 12/17/98**
202	Construction Management	41 days	Tue 9/15/98	Thu 11/26/98
203	Mobilization	5 days	Tue 9/15/98	Tue 9/22/98
204	Construction	43 days	Wed 9/23/98	Wed 12/9/98
205	Demobilization/Final Project	5 days	Thu 12/10/98	Thu 12/17/98
206	**RBF Procurement**	**109 days**	**Tue 9/15/98**	**Mon 4/5/99**
207	Construction Management	41.88 days	Tue 9/15/98	Thu 11/12/98
208	Mobilization	5 days	Tue 9/15/98	Tue 9/22/98
209	Construction	99 days	Wed 9/23/98	Thu 3/25/99
210	Demobilization/Final Project	5 days	Thu 3/25/99	Mon 4/5/99
211	**RBF PS&E - La Costa East and Manchester East**	**45 days**	**Tue 4/6/99**	**Wed 6/23/99**
212	Construction Management	34 days	Tue 4/6/99	Thu 6/3/99
213	Mobilization	5 days	Tue 4/6/99	Tue 4/13/99
214	Construction	35 days	Wed 4/14/99	Tue 6/15/99
215	Demobilization/Final Project	5 days	Wed 6/16/99	Wed 6/23/99
216	**STATUS MEETING NO. 4**	1 day	Thu 3/11/99	Thu 3/11/99
217	**Operation, Maintenance and Monitoring**	**462 days**	**Tue 1/26/99**	**Mon 4/30/01**
218	District 7 Pilots	462 days	Tue 1/26/99	Mon 4/30/01
219	District 11 Pilots	462 days	Tue 1/26/99	Mon 4/30/01
220	**QUARTERLY STATUS MEETINGS**	**503 days**	**Tue 6/29/99**	**Wed 12/12/01**
221	**STATUS MEETING NO. 5**	1 day	Tue 6/29/99	Tue 6/29/99
222	**STATUS MEETING NO. 6**	1 day	Thu 9/30/99	Thu 9/30/99
223	**STATUS MEETING NO. 7**	1 day	Wed 12/15/99	Wed 12/15/99
224	**STATUS MEETING NO. 8**	1 day	Wed 3/15/00	Wed 3/15/00
225	**STATUS MEETING NO. 9**	1 day	Wed 6/14/00	Wed 6/14/00
226	**STATUS MEETING NO. 10**	1 day	Wed 9/20/00	Wed 9/20/00
227	**STATUS MEETING NO. 11**	1 day	Mon 12/18/00	Mon 12/18/00
228	**STATUS MEETING NO. 12**	1 day	Wed 3/14/01	Wed 3/14/01
229	**STATUS MEETING NO. 13**	1 day	Wed 6/13/01	Wed 6/13/01
230	**STATUS MEETING NO. 14**	1 day	Wed 9/19/01	Wed 9/19/01
231	**STATUS MEETING NO. 15**	1 day	Wed 12/12/01	Wed 12/12/01
232	**Final Reports**	**216 days**	**Mon 6/18/01**	**Tue 7/2/02**
233	**Retrofit Pilot Projects**	**216 days**	**Mon 6/18/01**	**Tue 7/2/02**
234	Summary of Water Quality Monitoring Data	63 days	Mon 6/18/01	Fri 9/14/01
235	NRDC Review	20 days	Mon 9/17/01	Thu 10/18/01
236	Discussion Meeting	1 day	Mon 10/22/01	Mon 10/22/01
237	Final Report (1st Draft)	70 days	Tue 10/23/01	Mon 1/28/02
238	NRDC Review/Meetings	20 days	Tue 1/29/02	Mon 3/4/02
239	Revised Final Report	60 days	Tue 3/5/02	Mon 5/27/02
240	NRDC Review	20 days	Tue 5/28/02	Mon 7/1/02
241	Publish Final Report	1 day	Tue 7/2/02	Tue 7/2/02



APPENDIX C: ESTIMATING POLLUTANT LOADINGS

Estimating Pollutant Loadings and BMP Efficiency

Background

This section provides a brief literature review and background information on constituent loading calculation and estimation techniques which were used in selecting the appropriate methods for analyzing data obtained from the BMP monitoring program. Several documents outlining constituent load estimation methods and/or related topics were reviewed. The techniques are generally very similar, and a few representative documents will be briefly discussed here. Summaries from a few key studies are also provided.

The EPA's Nationwide Urban Runoff Program (1982) measured constituent concentrations at 85 sites for 200 storms throughout the United States, and the results were published in 1983. This study is probably the most comprehensive study of its type available. The study began by testing the assumed log-normal distribution of the data, which was determined to be valid. Site specific rainfall/runoff characteristics were found to be very important to the results. Federal Highway Administration (FHWA) has outlined a procedure for estimating impacts to streams and lakes receiving highway stormwater runoff in a three volume report entitled as, "Pollutant Loadings and Impacts from Highway Stormwater Runoff" (1990). Volume III of the report, entitled as "Analytical Investigation and Research Report", tested the validity of the lognormal distribution, which is then used in presenting the methodology used in data analysis. Results indicated that when an underlying population has a lognormal distribution, the mean and variance of the population should be obtained by computing the mean and standard deviation of the logarithmic transforms of the data.

Volume I of the FHWA 1990 report, entitled as "Design Procedure", provides worksheets to calculate runoff and constituent loading parameters from inputs such as drainage area, rainfall data, streamflow, Event Mean Concentration (EMC), and soluble fractions (defined as soluble fraction of each measured constituent). One worksheet is provided to calculate runoff from the site characteristics, and another is given to calculate constituent mass load in pounds per year from highway runoff characteristics. The annual mass load is computed according to the following equation:

$$AML = EMC * MVR * N * 0.00006245$$

where: AML is the annual mass load in pounds per year,
EMC is the event mean concentration in mg/L,
MVR is the mean volume of runoff from a storm event at the specified site in cubic feet,
N is the average number of storms per year,

0.00006425 is a conversion factor to convert results to annual mass in pounds per year,

The Flint Creek Watershed Project (1995) was initiated by the Morgan County Soil and Water Conservation District to improve and protect the water quality of Flint Creek, located in Northwestern Alabama. To determine the best approach, annual constituent loadings were estimated for Total Suspended Solids, BOD5, Total Kjedahl Nitrogen, Phosphorous, and Nitrogen for land uses including, industrial and commercial, residential, cropland, pasture, and grazing type uses. For industrial and commercial land uses, the following equation was used to estimate annual constituent loads:

$$M = R * K * A * C * 0.227$$

where: M = Constituent Loading (lbs/yr)
R = Rainfall (in/yr)
K = Runoff Coefficient
A = Drainage Area (acres)
C = Pollutant Concentration in Runoff (mg/L)
0.227 = Unit Conversion Factor

The Santa Monica Bay Restoration Project included annual estimates of constituent loading to Santa Monica Bay from stormwater runoff. The constituent loadings were tabulated for various land uses, including residential, commercial, industrial, and open spaces. Water quality measurements were taken at 22 selected locations. Pollutant loads were obtained by multiplying the stormwater flow rate by a constituent concentration. The runoff is affected by land use, so the following load estimating model was used to account for variation in land use:

$$\text{Load} = \Sigma M_a * X_a$$

where: M is concentration of constituents for land use a, and
X is runoff from land use a.

Finally, in review of the "1996-1997 Caltrans Detention Basin Monitoring Plan", NRDC outlined a loading estimation method which is very similar to the FHWA method discussed above and recommended to arrange the loading calculations on one or more computerized spreadsheets for convenience (November 12, 1996 Memorandum from Richard Horner to Ed Dammel and Bob Smith). The recommended method can be used to estimate wet season and annual loading given calculated event loadings. If possible, NRDC suggested to obtain continuously recorded local flow data and a series of representative local EMC readings. Assuming log-normal distribution of EMCs, the mean of the EMCs can be calculated using an applicable statistical relationship. In addition to the constituent load estimations, NRDC recommended that BMP efficiencies be evaluated from a comparison of effluent and influent loadings (over a period of time)

from the following relationship:

Efficiency (%) = [(Loading in - Loading out)/Loading in] x 100

Methodology

The recommended methodology for estimating effluent and influent constituent loadings for the subject detention basins was obtained from FHWA report *Pollutant Loadings and Impacts from Highway Stormwater Runoff*. This method is very similar to the NRDC recommended procedure discussed above. Caltrans and NRDC acknowledge the limitations of the procedure when it is applied to small data sets. Statistical analysis will be performed for each year of the program and for the overall monitoring period of two years. Other numerical techniques will be employed as needed to make the most effective use of the data set.

Estimating Pollutant Loading

The following is a step-by-step guide in estimating constituent loadings using the FHWA method:

1. Collect stormwater runoff samples from five representative storms.

2. Analyze water samples for desired water quality parameters and obtain EMCs.

3. Tabulate EMCs.

4. Measure runoff volume per storm. If problems occur with obtaining flow data, multiply runoff coefficient (unitless) by watershed area (in acres) and rainfall depth per storm (in inches) to obtain runoff volume (acre-in).

5. Convert runoff volume from acre-in to liters using the conversion factor: acre-in = 102,790 liters.

For single event constituent loading calculation, perform Steps 6a and 7a, otherwise skip to Step 6b:

6a. Multiply EMCs (in μg/l or mg/l) from Step 2 by runoff volume (in liters) from Step 5 to obtain constituent load in μg or mg.

7a. Convert constituent load from μg or mg to pounds (lbs) using the conversion factors: 1 mg = 0.00000220 lbs and 1 μg = 0.00000000220 lb.

For average wet season loading estimations, perform Steps 6b and 7b:

6b. Take natural log of EMCs from Step 2.

7b. Compute mean *(μ)* and variance *(s^2)* of natural logs obtained from Step 6b from the following equations:

$$\mu = \frac{x}{n}$$

$$s^2 = \frac{\left(n \quad x^2 - \left(\quad x\right)^2\right)}{n(n-1)}$$

where: x is the natural log of EMCs.
Σx represents the summation of data points (x).
n is the number of data points (x).

8. Compute expected value a (also known as mean of the EMC) using the following formula:

$$a = e^{(\mu + s^2/2)}$$

9. Compute upper and lower confidence limits x_{hi} and x_{lo} from μ, s, and standardized normal deviate, z, using the equation:

$$x = e^{(\mu +/- zs)}$$

The value of z corresponds to a given probability of exceedence, which can be converted to a confidence level. For a confidence level of 90%, for example, the z value corresponding to 0.90 is 1.28. Values for z can be obtained from a standard normal distribution table.

10. Compute runoff volume per wet season by multiplying runoff coefficient (unitless) by watershed area (in acres) and rainfall depth per wet season (in inches) to obtain runoff volume (acre-in), and converting to liters by using the conversion factor from step 5 above.

11. To obtain expected constituent load in the wet-season, multiply expected value (mean of the EMC) from Step 8 by the runoff volume obtained from Step 10. Convert to pounds (lbs) using the conversion factor provided in Step 7a.

12. To obtain the 90% confidence limits for expected constituent loadings in the wet-season, repeat Step 11, substituting the confidence limits from Step 9 for the expected value.

Computing BMP Efficiency

As mentioned previously, BMP (detention basin and CSF) efficiencies may be evaluated by comparing effluent and influent loadings over the entire wet season from the following equation:

$$\text{Efficiency (\%)} = [(\text{Loading in} - \text{Loading out})/\text{Loading in}] \times 100$$

For the detention basins, since the residence times are expected to be fairly long (longer than a typical event duration), cumulative loadings over a series of events should be used in estimating BMP efficiency. When using a multiple events for basin efficiency calculations, it is necessary to have a complete loading record or representative loadings. Since the CSF residence times are expected to be fairly short and the CSFs should be operating under steady state conditions, the EMC (or the mean EMC for a series of events) can be substituted for loading in the efficiency equation above.

APPENDIX D

Project Staging Plan

DISTRICT 7 BMP RETROFIT PILOT PROJECTS

Project Staging Plan

OVERVIEW

It is recognized by Caltrans and NRDC that technical or construction issues may arise in the development of the BMP Retrofit Pilot projects that would necessitate the delay in the delivery of a pilot project. Accordingly, the project master schedule has been developed in two forms, a primary or target schedule, and a contingency schedule. The primary schedule is a four-year target schedule designated for the Retrofit Pilot Projects. The contingency schedule provides flexibility within the program to deliver some of the projects on a delayed basis as compared to the primary schedule to accommodate project delays while still delivering the entire project within the Stipulated five-year period.

PROJECT STAGING

Three 'decision points' have been identified where discrete pilot projects may be shifted from the primary schedule to the contingency schedule. Discussion of the projects relative to the stated criteria will be initiated in the March 30, 1998 status meeting. Each of these decision points, along with the criteria to be used to identify candidate contingency schedule projects is given as follows:

Decision Point No. 1- Post Design, Preconstruction

Date: June 10, 1998 (PSE Projects)
June 10, 20 and 30 (Procurement Dist 11, Dist 7-Project 3, Dist 7-Project 4 respectively)

Decision Point Criteria

- Pilot has fundamental design/siting flaw
- Design/plans/specifications not complete
- Siting not complete

Discussion

This will be the primary decision point for deferring pilots to the Contingency Schedule. Pilots that proceed beyond this decision point will be 'committed' for the bid and construction process, with relatively fewer options for delay at the second decision point.

Issues indicating delay at this decision point will be design related, focusing on incomplete, delayed or other design problems. Pilots may be delayed within this decision point time frame should bid problems occur, such as contractor bids not in substantial agreement with the engineer's estimate.

Decision Point No. 2 – Pre-monitoring

Date: November 18, 1998

Decision Point Criteria

- Pilot construction delayed (construction delays)
- Pilot construction flawed
- Pilot not ready for monitoring
- Delays/problems installing/configuring sampling equipment
- Bid process problem

Discussion

This decision point will occur post-construction but prior to commencement of monitoring. Primary issues indicating delay to the contingency schedule at this point are related to the suitability of the site to begin monitoring. Examples could include incomplete construction, site not properly stabilized, incomplete growth of biofilters, or problems with monitoring equipment. Pilots may also be delayed within this decision point time frame should bid problems occur, such as contractor bids not in substantial agreement with the engineer's estimate. Pilots delayed at this decision point would track with the monitoring portion of the Contingency schedule once construction problems were completed. Note that no substantial construction of the pilots will occur during the winter season (December through March).

Decision Point 3 – End of First Year of Monitoring

Date: June 1, 1999

Decision Point Criteria

- First year monitoring data unsatisfactory
- Substantial sampling equipment failures
- Operational problems with Pilot
- Maintenance problems with pilot

Discussion

This decision point will occur following the first year of monitoring and following a sufficient amount of time to assess the first-year monitoring data. This decision point is not an option for those pilots on the Contingency schedule. Pilots that are agreed to meet the criteria listed above at this decision point will track with the monitoring portion of the Contingency schedule for a third year of monitoring. It is expected that the primary reason for a third year of monitoring would be problems associated with storm water sampling/monitoring or maintenance and operation of the pilot.

PROCUREMENT PROJECTS	DISTRICT 7 PROJECT 3 (MW) Procurement	DISTRICT 7 PROJECT 4 (B&C) Procurement	DISTRICT 11 PACKAGE 2 (AEI-CASC) Procurement
SUBMITTAL TO DISTRICT (MEETING)	4/8/98	4/8/98	3/16/98
DISTRICT COMMENTS TO CONSULTANTS (MEETING)	4/22/98	4/22/98	3/31/98
REVISED SUBMITTAL TO DISTRICT, NRDC, and EPA (District 11)	**4/29/98**	**4/29/98**	**4/7/98**
NRDC and EPA COMMENTS TO CALTRANS	**5/22/98**	**5/22/98**	**5/1/98**
PACKAGE TO ENCROACHMENT PERMITS	5/29/98	5/29/98	5/8/98
PERMITS ISSUED	6/8/98	6/8/98	5/15/98
Supplemental Report - Complete Design Assumptions Submitted to NRDC	**6/30/98**	**6/30/98**	**6/10/98**
1st DECISION POINT (Post Design - Pre-Construction)	**7/10/98**	**7/10/98**	**6/19/98**
BEGIN CONSTRUCTION (BC)	**8/15/98**	**8/15/98**	**8/1/98**
Supplemental Report - Construction Status and Problems Submitted to NRDC	**11/11/98**	**11/11/98**	**11/11/98**
2nd DECISION POINT (Pre-Monitoring)	**11/18/98**	**11/18/98**	**11/18/98**
START STORMWATER MONITORING	**12/1/98**	**12/1/98**	**12/1/98**

PS&E PROJECTS	DISTRICT 7 PROJECT 1 (MW) PS&E	DISTRICT 7 PROJECT 2 (B&C) PS&E	DISTRICT 11 PACKAGE 1 (RBF) PS&E
PS&E SUBMITTAL TO DISTRICT (MEETING)	3/25/98	3/25/98	3/16/98
DISTRICT COMMENTS TO CONSULTANTS (MEETING)	4/8/98	4/8/98	3/31/98
REVISED PS&E TO DISTRICT OFFICE ENGINEER, NRDC, and EPA (District 11)	**4/15/98**	**4/15/98**	**4/7/98**
NRDC and EPA COMMENTS TO CALTRANS	**4/22/98**	**4/22/98**	**4/14/98**
DISTRICT OFFICE ENGINEER COMMENTS TO CONSULTANTS	4/29/98	4/29/98	4/21/98
FINAL PS&E TO DISTRICT OFFICE ENGINEER	5/6/98	5/6/98	4/28/98
PS&E	**5/13/98**	**5/13/98**	**5/5/98**
READY TO LIST (RTL)	5/18/98	5/18/98	5/11/98
Supplemental Report - Complete Design Assumptions Submitted to NRDC	**6/1/98**	**6/1/98**	**6/1/98**
1st DECISION POINT (Post Design - Pre-Construction)	**6/10/98**	**6/10/98**	**6/10/98**
ADVERTISE (ADV)	6/29/98	6/29/98	6/22/98
BID OPENING (BO)	7/23/98	7/23/98	7/16/98
AWARD (AW)	8/13/98	8/13/98	8/6/98

EXECUTION (EX)	8/20/98	8/20/98	8/13/98
BEGIN CONSTRUCTION (BC)	**8/25/98**	**8/25/98**	**8/18/98**
Supplemental Report - Construction Status and Problems Submitted to NRDC	**11/11/98**	**11/11/98**	**11/11/98**
2nd DECISION POINT (Pre-Monitoring)	**11/18/98**	**11/18/98**	**11/18/98**
START STORMWATER MONITORING	**12/1/98**	**12/1/98**	**12/1/98**