Task Deliverable 3.8

Porous Pavement and Model Municipal Operations Center Demonstration Project

Final Report

SWRCB Agreement No. 03-264-559-2

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San Diego River Watershed

Project Type: **Proposition 13 Nonpoint Source Control**

Funding Sources: **State Water Resources Control Board**
County of San Diego

Cost of Project: **$1,705,000**

Grantee: **County of San Diego Department of General Services**
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1.0 EXECUTIVE SUMMARY

The County of San Diego, Department of General Services (Department or DGS) sought Proposition 13 Nonpoint Source Grant Program funds to demonstrate the use of porous pavements and to initiate development of a model municipal operations center by installing a treatment train consisting of two treatment control best management practices (BMPs), replacing approximately 64,000 square feet of traditional impervious pavement with porous pavement, conducting training and public outreach related to the installations, and monitoring water quality improvements associated with the installation of porous pavement and treatment control BMPs. The activities included in this project were proposed to help make the County Operations Center (COC) into a regional model operations center, increase the awareness of the value of porous pavement and water quality treatment control devices, and contribute to long-term water quality improvements within the San Diego River Watershed.

The concept for the proposed project evolved out of DGS efforts to strengthen the Department's stormwater program. DGS staff reviewed 78 facilities in preparation of both required Facility Pollution Prevention Plans and a Stormwater Guidance Manual, which includes a prioritized inventory of County facilities for which DGS has stormwater quality management responsibility. The facility assessment confirmed that the Department is responsible for many highly impervious facilities. Much of this imperviousness is associated with high-volume public parking lots at many County facilities, particularly at several large regional centers and the COC. Because of its position as a large regional operations center, and the potential for a project there to draw attention to the problems inherent in impervious surfaces, the COC was selected as the best location to conduct a Porous Pavement and Model Municipal Operations Center Demonstration Project.

A Technical Advisory Committee (TAC) for this project was formed to review plans and reports, and contribute information from member organizations about potential applications of porous pavement and enhanced treatment BMPs within the watershed. The TAC included representation from the County Department of Public Works, San Diego River Watershed Urban Runoff Management Plan Workgroup, the San Diego River Foundation, and the University of California Cooperative Extension (UCCE). The TAC met quarterly for the duration of the demonstration project.

Approximately 64,000 square feet of existing pavement at the COC was removed and replaced with porous pavement. Three types of porous pavement were selected and installed in order to compare infiltration and runoff reduction effectiveness. The Demonstration Project also included installation of a "treatment train," comprised of a Continuous Deflective Separation (CDS) stormwater pollution control device and a media filtration system. The Department conducted a monitoring program to assess results, and conducted training and outreach to increase awareness of the problems of impervious surfaces and the potential benefits of installing best management practices to address the problem.

2.0 PROBLEM STATEMENT

The basic problem is that public and private development within urban watersheds has continuously increased the area of impervious built structures. Approximately two-thirds of the built structure area in these watersheds is pavement. Impervious pavements reduce infiltration of stormwater and non-stormwater discharges, such as run-off from over irrigation, thus increasing urban runoff that entrains and transports pollutants to lakes, creeks, rivers, and the ocean. These pavements also reduce times of concentration, thereby increasing flood potential and hydromodification of creeks and unlined channels. They also contribute to the urban "heat island" effect that results in higher temperatures in and adjacent to urban centers.

The concept for the proposed Porous Pavement and Model Municipal Operations Center Demonstration Project evolved out of an effort the that the County of San Diego Department of General Services (DGS) had undertaken to strengthen its stormwater quality program. During preparation of a Stormwater Guidance Manual and Facility Pollution Prevention Plans and related extensive facility review, it became apparent that the Department is responsible for stormwater quality management at many facilities that are highly impervious. Much of this imperviousness is associated with the large public parking lots. Two problems were discussed: how to reduce the adverse impacts of large impervious surfaces at the facilities and how best to remove constituents of concern that are not fully addressed through pollution prevention and source control.

Research by the Center for Watershed Protection has demonstrated the importance of imperviousness as an indicator by which to measure the impact of land development on aquatic systems. Research on how to control both the quantity and quality of stormwater discharges from impervious surfaces led DGS to consider the installation of porous pavement that would increase infiltration, thereby reducing excess runoff associated with highly impervious corporation yards and other surface parking. Temporary storage of stormwater within the porous pavement and underlying stone reservoir will allow the water to either infiltrate into the soil or be slowly released after a storm event. Implementation of this approach to parking lot design could reduce discharges from DGS facilities and, if implemented widely, help to bring runoff levels within developed watersheds closer to natural levels.

Porous pavements can be installed in low and moderate traffic areas to promote infiltration and reduce urban runoff. This increases ground water supplies while reducing the transport of pollutants that accumulate on pavements from atmospheric deposition, automobile exhaust, tire wear, brake pad wear, leaking vehicles and other sources. However, San Diego architects, civil engineers, contractors, and batch plant operators have little experience with porous pavements and have been hesitant to specify or install them. Until porous pavements are widely accepted and used, development within the San Diego River Watershed and other watersheds in the county will continue to utilize impervious pavement and increase urban runoff.

3.0 PROJECT GOALS

The primary purpose of the Porous Pavement and Model Municipal Operations Center Demonstration Project was two-fold; first, to assess and demonstrate the potential water quality benefits of installing enhanced source control (porous paving) and treatment control best management practices, and second, to establish the COC as a regional Model Municipal Operations Center. The Department of General Services' overall goal for this project was to demonstrate to municipal managers and elected officials the benefits and feasibility of installing porous paving and enhanced treatment facilities at municipal parking lots and corporation yards and to educate municipal employees and contractors - especially architects and engineers - about the installation of porous paving and the use of structural best management practices (BMPs) at municipal facilities. DGS intended that as a result of this project it would be able to better contribute to improved water quality in the San Diego River Watershed and elsewhere in the county, an objective that would be accomplished by retrofitting existing County facilities, designing and constructing future County facilities, and influencing other jurisdictions and private entities to incorporate appropriate source control and treatment control best management practices.

In addition to operating existing facilities, DGS is the agency responsible for supervising the planning, design, and construction of new facilities and remodeling and refurbishing of existing facilities. As the Department conducted focused stormwater training for its various Divisions and began the process of transforming itself into a more water quality conscious organization, the Project Manager in charge of the DGS Stormwater Program, together with a stormwater expert brought in to assist the Department, began to evaluate how to change the culture and day to day operations within the Department so that water quality considerations become fully integrated into ongoing facility planning, design, construction, and management operations.

4.0 PROJECT DESCRIPTION

The Porous Pavement and Model Municipal Operations Center Demonstration Project has consisted of the installation of three types of porous paving materials at the County Operations Center (COC) (64,000 square feet). It also has included the installation of a treatment train of control devices at the COC. The project was designed to demonstrate how municipalities can provide leadership in improving water quality by making changes in existing facilities and improving the design and construction of future facilities. In order to enhance the value of the COC as a regional training site, the construction and assessment work was concentrated at the COC.

4.1 Project Type

This project was a Proposition 13 Nonpoint Source Control project. It was devised by DGS as a demonstration to municipal managers and elected officials of the benefits and feasibility of installing porous paving and enhanced treatment facilities at municipal parking lots and corporation yards. It was designed to educate municipal employees and contractors about the installation of porous paving and the use of structural best management practices at municipal facilities.

4.2 Project Costs

Grant funds:	$1,400,000
Match funds:	305,000
Total:	$1,705,000

Match funds were provided by the County of San Diego.

4.3 Project Methodology

4.3.1 Overview of Porous Pavement Component of Demonstration Project

The County replaced approximately 64,000 square feet of traditional impervious pavement with three different types of porous paving materials at the COC. The Project Team, design engineers and monitoring team reviewed several products and selected Uni Eco-Stone Pavers, Porous Asphalt and Pervious Concrete as the three types of porous pavement to be installed. These products are considered to be the most practical application for public parking areas. Design engineers and monitoring consultants for the for the porous pavement project met at the COC with the Project Team to address final site selection. During this two-day visit, four test trenches were constructed to assess infiltration. Since the results indicated that infiltration is poor, the bottom of the stone reservoir was ripped to facilitate infiltration. After the site review, the County Department of Public Works surveyed the site to provide more detailed topographic information needed for design. The final site was along the west central edge of the COC, southwest of Building 7 and north of buildings 11 and 12.

Installation of porous pavement was completed October 1, 2005. Three porous pavement product types were installed: pervious concrete (approx. 14,936 s.f.), porous asphalt (approx. 41,092 s.f.) & concrete pavers (approx. 7,896 s.f.). In addition, approximately 37,600 sq. ft. was reserved and prepared to function as a “reference area” for baseline monitoring purposes. Since some runoff was expected from the pavers, a catch basin was installed at the southwestern end to redirect any runoff from intense events back to the infiltration bed.

4.3.2 Overview of Treatment Train Component of Demonstration Project

In planning for the demonstration project, the Department looked at various treatment controls to address constituents of concern at the COC that were not fully addressed through pollution prevention and source control. Because of an initial emphasis on retrofitting devices into existing facilities, the focus was on proprietary structural treatment controls that could be installed underground. Several vendors were asked to make presentations and provide the Department with information concerning the capabilities, effectiveness, and costs of their products.

The first phase of this Demonstration Project involved the installation of a "treatment train" to capture gross pollutants from stormwater discharges from rainfall events up to 0.2 inches per hour and to filter out very small suspended solids and dissolved constituents of concern from the first flush of these stormwater discharges. This phase of the project included the installation of a Continuous Deflective Separation (CDS) stormwater pollution control device and a media filtration system, both manufactured by CDS Technologies, Inc.

In the COC treatment train, the CDS unit functions as a pre-treatment device for the media filter, which treats first flush flows to remove suspended solids, petroleum hydrocarbons, and particulate-bound contaminants. The media filtration system installed as part of the demonstration project involves 42 media cartridges, each operating at approximately 18 gallons per minute. Initially, these cartridges were filled with Perlite, which has a strong affinity for total suspended solids and hydrocarbons and some affinity for metals. This material is expected to remove 80% of fine particulates (smaller than 100 microns) of the design flow. These constituents of concern are common in stormwater discharges from operations centers like the COC. The media can be changed or blended with other media if the monitoring program indicates that other specific constituents need to be filtered out of the runoff discharges from the COC.

After several significant weather-triggered delays, construction and installation of the centralized treatment controls was completed on February 9, 2005. The CDS unit installed at the COC uses a 2,400-micron screen that permanently captures material down to about the size of a match head (about 2.4 mm). Floatables and neutrally buoyant materials are trapped in a separation chamber by the screen while negatively buoyant debris settles into a catchment sump that extends to a depth almost eight feet below the storm drain. In this case, the bottom of the sump is almost 20 feet below the surface of the parking lot because the storm drain is so deep. The unit also has an oil baffle capable of capturing up to 80% of free oil and grease. In addition, sorbent booms were installed on the water surface to capture free oil. Use of these booms is expected to result in removal of up to 90% of the free oil and grease in stormwater runoff from the site.

4.3.3 Project Monitoring

Although the duration of monitoring pursuant to the grant project was insufficient to make definitive statements about the water quality improvements possible through the installation of porous pavement and treatment trains, the three types of porous pavement and the CDS/media filtration treatment train were monitored to develop preliminary information on their performance. This monitoring program has assisted the County and the San Diego Regional Water Quality Control Board in assessing how effective the treatment control devices are in removing oil and grease, sediment, trash and debris, and dissolved constituents such as soluble metals, organics, nitrogen, and phosphorus. The monitoring program has been conducted in accordance with plans approved by the Regional Water Quality Control Board.

Monitoring stations were established at locations where subsurface drains exit each of the three porous pavement test sites and at a reference site that drains a similar section of parking area with standard impervious paving. Monitoring compared discharges from the three types of porous pavement and the reference area in order to measure flow reductions, hydrograph modification, and reductions in both pollutant loads and concentrations. Rain gauges were incorporated into monitoring stations at two of the sites to provide accurate measure of stormwater volumes associated with each site. A rain gauge installed at the nearby treatment train BMP test site and an ALERT Kearney Mesa rain gauge on the COC site were used to supplement measurements at the porous pavement sites and provide back up, if necessary.

The design engineer and site project manager coordinated to assure that slight design and configuration changes required during the construction process did not impair hydraulic isolation of the sites and the ability to obtain precise measurements of stormwater discharge. This included oversight during installation of a concrete approach channel and Parshall flume that was used to monitor flow from the reference area.

Monitoring of the treatment train included characterization of the gross pollutants and sediment load removed by the CDS unit and any reduction in pollutant concentrations and loads by the media filtration system. The details of the project monitoring were included in two Sampling and Analysis Plans submitted to the Regional Board and are presented in Appendix I.

5.0 TRAINING AND OUTREACH

The Department's training and outreach component was undertaken after installation and monitoring of the treatment train and porous pavement were completed. DGS staff and consultant Richard Watson presented slide shows to identified outreach groups and other interested parties. Because of increased interest in the grant program from the community and the industry, five versions of the slide show presentation were completed in order to communicate as effectively as possible the benefits of centralized treatment units and low impact development best management practices.

Presentations were made to members of the Technical Advisory Committee, San Diego County staff, the San Diego River Coalition, the San Diego Municipal NPDES Permit Co-Permittees, El Cajon and other San Diego River Watershed municipalities, and the Water Committee of the Industrial Environmental Association. These presentations stimulated interest, particularly in porous pavements, and resulted in visits to the COC to see the installations. There were many questions about specifications, costs, maintenance, monitoring results, and durability.

6.0 CONCLUSIONS

6.1 Runoff Reduction/Infiltration

6.1.1 Porous Pavement

Water levels in the infiltration beds of all porous pavement treatment sites were continuously monitored throughout the project to determine how the infiltration basins would respond to both individual events and the effects of multiple events throughout the season. Given initial measurements taken with a double-ring infiltrometer during the design phase, it was expected that water levels within the basins might gradually increase due to a series of events due to minimal infiltration rates.

Evidence of water levels increasing within the infiltration basins of the porous pavers and porous asphalt did not occur until an intense, late season storm event on April 4th and 5th, 2006. This event yielded 1.07 inches of rain and reached a maximum intensity of 0.68 inches per hour. Infiltration was slowest at the porous paver site but the maximum water level in the basin only reached 0.15 feet, 0.76 feet below the discharge level. After approximately 15 hours, water was no longer measurable in the infiltration basin. Water levels in the porous asphalt infiltration bed came within 0.2 feet of the discharge level but decreased rapidly. Within 8 hours after water levels peaked at 0.38 feet in the infiltration bed, water levels were no longer measurable. Water in the porous concrete infiltration bed increased to a maximum level of 0.48 feet leaving another 0.44 feet before reaching the level necessary to produce a discharge. Fifteen hours after reaching a level of 0.48 feet, the water level in the porous concrete bed had dropped to zero.

Based upon the April 4th and 5th, 2006 event, infiltration rates for both the porous concrete and asphalt sites were on the order of 0.04 feet per hour or roughly 0.5 inches per hour. Much lower infiltration rates of 0.006 feet per hour (0.08 inches per hour) were observed at the porous paver site. Despite the lower infiltration rates measured at the porous paver site, the water levels reached in the infiltration basin were minimal, leaving a substantial storage volume before discharges would ever occur.

6.1.2 Treatment Train

A total of eight storm events were monitored for rainfall and flow volumes during the 2005/2006 storm season. Flow was monitored through the CDS unit for a ninth event that occurred after the end of the official monitoring season. Monitoring was continued at this site to allow all runoff to be quantified prior to removal and assessment of gross pollutants from the CDS sump. Full analytical testing was conducted on the first three events. All subsequent events that occurred up through the end of the monitoring season on April 30, 2006 were monitored for rainfall and flow.

Stormwater discharges exceeding 7.5 cfs were intended to bypass the entire Treatment Train. Since the current configuration of the Treatment Train has only a single MFS unit with a design capacity of 1.75 cfs, much of the stormwater treated by the initial CDS unit also had to be redirected around the MFS unit. This condition will be changed during Phase II when three additional MFS units will be installed. Bypasses of the Treatment Train during the nine events were uncommon and only occurred during brief periods when flow spiked due to particularly intense rainfall. Over the season, 96.5 percent of the stormwater runoff from the COC was treated by the CDS unit. Roughly 33 percent of the water treated by the CDS unit entered the MFS unit (the second component of the Treatment Train). The remainder was discharged back to the main storm drain and discharged to the municipal storm sewer system.

The MFS unit also experienced internal bypasses that may have been partially influenced by backpressure from the downstream weir. The MFS unit treated 73 percent of the water that entered the system. Overall approximately 25 percent of all stormwater runoff from the COC received full treatment by the CDS and MFS units. A modified control box has now been installed in the MFS unit to provide the ability to make the fine adjustments needed to limit bypasses. The new MFS units being installed under Phase II of the program will also have the modified control boxes.

During individual storm events, the percent of influent flow to the MFS that was effectively treated ranged from 64 to 95 percent of the water entering the unit. These percentages varied due to differences in duration and intensity of storm events. CDS has modified the MFS unit to improve performance of the system.

6.2 Water Quality Benefits

6.2.1 Porous Pavement

Stormwater quality was measured during six events at the Reference Site. The Event Mean Concentrations (EMCs), statistical summaries of data for the 2005/06 storm season, estimates of pollutant load reductions, and a comparison of mean runoff quality from the reference site to other studies and to the California Toxics Rule (CTR) acute water quality criteria are presented in Tables 6-9 in Appendix I: Porous Paving and Treatment Train Water Quality Monitoring Program Final Report.

The study protocol used in the Demonstration Project used both Suspended Sediment Concentration (SSC) and TSS methods to measure solids present in the runoff. Both tests produced similar results in terms of the total mass of particles in the runoff. The SSC method provided additional information on the size composition. Results (Table 6 and 7 of Appendix I) indicate that fine sediments (less than 63 microns) were the dominant size class of particles present in the stormwater discharge. The mean concentration of the coarse fraction (greater than 63 microns) was 10.5 mg/L compared to an average of 51.3 mg/L for the fine fraction (Table 7 of Appendix I).

Concentrations of nutrients (Total P, Ortho-P, Ammonia-N, TKN, and Nitrate-N) measured in runoff from the six monitored events were generally highest during the first three events and lowest during the latter three events. This may be indicative of seasonal effects or simply an artifact of the characteristics of the 2005/2006 wet season. Early storms were widely spaced providing time for buildup of nutrients on the parking lot surface. Later storms occurred more frequently (Appendix I, Table 4) with fewer days between events, which may have limited the time for buildup of nutrients on the parking lot surface.

All three porous paving BMPs examined were successful in preventing 100 percent of the metals and other contaminants from discharging to the San Diego River through the municipal storm drains. The seasonal mean Event Mean Concentrations (EMC) for runoff from the Reference Area was used to estimate load reductions achieved by each type of porous pavement (Table 8 of Appendix I). In addition, the porous pavement prevented the discharge of nearly 34,000 cubic feet of water that would have been associated with the 8.15 inches of rainfall experienced during the 2005/2006 season.

6.2.2 Treatment Train

Soon after construction was complete, a previous consultant attempted to monitor two storm events. As a result of this effort, several problems were identified that required a re-evaluation of the configuration and monitoring approach. The major issues were primarily related to quantification of the flow regime under less than ideal conditions resulting, in part, from last minute changes in the configuration of the Treatment Train.

An assessment of the flow data from these events determined that data from these events could not be considered valid. A complete reevaluation of the methods was necessary to modify both the Treatment Train and overall monitoring strategy to improve measurement of water quantity and quality. The modified approach resulted from extensive consultation and support from CDS Technologies. The final approach used to instrument and monitor the Treatment Train is described in Appendix I, Section 3.2.

The results of chemical analysis of the MFS influent and effluent are summarized in Appendix I, Table 13. Results from the first three events indicate that the MFS unit was effective in further removing solids from the stormwater. SSC and TSS measured in the effluent from the unit were reduced by 40-75 percent from concentrations in the influent. Nearly all particles in the >63 micron size fraction were removed in the final effluent. Residual concentrations of the <63 micron size fraction were ranged from 0.9 to 1.8 mg/L in the effluent. The fine particles (<63 microns) were reduced by 27 to 65 percent in the final effluent.

The effectiveness of the MFS unit in removing solids was also very evident in visual comparisons of flow composited samples of the influent and effluent from the second (Appendix I, Figure 40) and third (Appendix I, Figure 41) storm events. These photographs show the flow composited samples with all sediment suspended by a magnetic stir bar that is used to assure that the samples are well mixed during the subsampling process.

Stormwater contaminants that are strongly associated with the particulate fraction also demonstrated partial removal. Among the most notable were reductions in total lead and total zinc (Appendix I, Table 13). As expected, concentrations of contaminants that are primarily present in the dissolved form were not affected by the MFS unit. Perlite, the current media being used in the MFS, serves primarily as a filter for fine particles and would only be expected to remove contaminants associated with particles. Expanded testing scheduled to be conducted in 2007/2008 as part of the Phase II Demonstration Project will explore alternative media that have the potential to remove various dissolved contaminants.

Due to the number of storm events, it is not appropriate to conduct a critical examination of the performance of the MFS unit. Ultimately, data will be evaluated using the "effluent probability method" recommended by USEPA/ASCE (2002). This method provides a more robust measure of performance than just reporting efficiency as percent removal. Simple use of percent removal based on the difference between influent and effluent concentrations will always make a BMP that treats stormwater with high concentrations appear to be more efficient than one treating stormwater with low concentrations of contaminants.

6.3 Next Steps

The County of San Diego Department of General Services has been awarded a Proposition 40 Nonpoint Source Pollution Control Grant under the 2005-2006 Consolidated Grant Program for Phase II of the Porous Pavement and Model Municipal Operations Center Demonstration Project. The Phase II project includes two years of additional monitoring of both the porous pavement and treatment train constructed during Phase I of the Demonstration Project. This additional monitoring will help to develop a more statistically valid database for evaluating runoff reduction and constituent removal.

Phase II also includes the construction of three additional porous asphalt plots that will test two grades of porous asphalt, asphalt reinforced with polymer, grid reinforcement, and a deeper stone reservoir to accept roof runoff as well as parking lot drainage. Phase II also includes the installation of three additional media filtration units to permit the treatment train to fully treat 7 cfs of runoff from the County Operations Center. The inclusion of three additional media filtration units will permit DGS to test and demonstrate the use of alternative filtration media.

The continuation of the Porous Pavement and Model Municipal Operations Center Demonstration Project includes an expanded Stakeholder Advisory Group (SAG) in order to increase outreach to builders and developers as well as industries operating sites with significant amounts of impervious surfaces such as parking lots and roof tops. The environmental community also will be included in the new SAG. The Department will continue educating its own staff and reaching out to other municipalities to promote use of porous pavement to reduce urban runoff and use of both porous pavement and treatment trains to reduce the discharge of pollutants into the County's receiving waters.

One immediate step that DGS has undertaken is to work with CONTECH Stormwater Solutions (Successor to CDS Technologies) and Kinnetic Laboratories to resolve the issue of bypasses in the media filtration unit. Although several adjustments were made to the existing unit during Phase I, unexpected bypasses are still occurring. DGS is focusing on this issue now so that the problem can be resolved before the three additional media filtration units are installed.

The short duration of Phase II will permit only one year of monitoring the performance of the newly installed porous pavement and media filtration units. The Department recommends that the State Water Board consider reserving a portion of future grant program funds for continued monitoring of previously installed demonstration projects.

APPENDIX I:

County of San Diego Model Municipal Operations Center, Porous Paving and Treatment Train Water Quality Monitoring Program, Final Report

APPENDIX II:

Photo Documentation

APPENDIX III:

Porous Pavement Operation and Maintenance Protocol

APPENDIX IV:
COC Maintenance Experience

APPENDIX V:
Deliverables