R E P O R T

GEOTECHNICAL ENGINEERING PEER REVIEW I-5/LACOSTA AVENUE INFILTRATION BASIN CALTRANS BMP RETROFIT PROGRAM CARLSBAD, CALIFORNIA

Prepared for
California Department of Transportation
Environmental Program, District 11, MS-8
2829 Juan Street
San Diego, CA 92110

URSGWC Project No. 58-977001NP.00-RR001

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URS Greiner Woodward Clyde

1615 Murray Canyon Road, Suite 1000
San Diego, CA 92108-4314
619-294-9400 Fax: 619-293-7920

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California Department of Transportation
Environmental Program, District 11, MS-8
2829 Juan Street
San Diego, CA 92110

Attention: Marcelo Peinado

Subject: Geotechnical Engineering Peer Review
I-5/LaCosta Avenue Infiltration Basin
Caltrans BMP Retrofit Program
Carlsbad, California
URSGWC Project No. 58-977001NP.00-RR001

Dear Mr. Peinado:

In accordance with the authorization set forth in Task Order No. 15 of Caltrans Contract No. 43A0004C, authorized on April 21, 1999, URS Greiner Woodward Clyde (URSGWC) is pleased to submit this report of our geotechnical engineering peer review for the subject infiltration basin. The purpose of our work was to evaluate why the basin is not functioning as it was originally intended, and to develop recommendations to improve the performance or design criteria, as necessary. The scope of our work consisted of reviewing various documents related to design and construction of the basin, reviewing other technical publications, performing computer modeling to evaluate design assumptions, and preparing this report of our findings, conclusions, and recommendations.

We appreciate the opportunity to be of service to you on this interesting project.

Very truly yours,

URS GREINER WOODWARD CLYDE

Leo D. Handfelt, P.E.
Senior Associate

REGISTERED PROFESSIONAL ENGINEER
LEO DAVID HANDFELT
GE373
EXP 12/31/00
GEOTECHNICAL
STATE OF CALIFORNIA

Ronald S. Johnson, P.E.
Senior Project Engineer

REGISTERED PROFESSIONAL ENGINEER
RONALD S. JOHNSON
No. GE 2356
Exp. 9-30-00
GEOTECHNICAL
STATE OF CALIFORNIA

LDH/RSJ:rwt/lh

Attachments

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The LaCosta Infiltration Basin (LCIB) was constructed as part of the Caltrans Best Management Practices (BMP) Retrofit Pilot Program. The basin is located west of the southbound lanes of Interstate 5 just north of LaCosta Avenue in Carlsbad, California. Standing water has remained in the basin since construction was completed in December 1998. The purpose of this study was to evaluate and address the possible reasons why the observed basin performance differs from the design expectations. Also, our study addressed the design criteria and provides suggestions for improving the basin performance and future selection criteria. The scope of our work consisted of reviewing LCIB reports, technical publications, performing additional engineering analyses, and preparing this report.

Site selection and basin design for the LCIB was performed in 1997 and 1998 according to BMP criteria established by Robert Bein, William Frost & Associates (RBF), with reviews by representatives from Caltrans, Natural Resources Defense Council (NRDC), Bay Keeper, and US Environmental Protection Agency (USEPA). Geotechnical investigations for evaluating the groundwater conditions and soil percolation were performed by LKR Group (later acquired by Group Delta Consultants).

Early in the basin design and throughout basin construction, high groundwater conditions were observed at the site. Initial explorations by the LKR Group (LKR) revealed groundwater elevations between 1.31 and 1.48 meters below the proposed basin invert. The initial readings were taken shortly after excavation of the explorations, and probably did not represent stabilized groundwater elevations. In a separate boring, percolation tests were performed to evaluate the hydraulic conductivity of the soil. The high groundwater conditions were noted in a separate monitoring well (SDMW-1), the percolation test hole (SD-7) and within the basin invert. Remedial measures were implemented to address the high groundwater, which consisted of raising the basin invert, and placing pervious materials around the invert. Despite these remedial actions, the LCIB continues to hold water.

The manual used for basin design, published by the Federal Highway Administration (FHWA), recommends a minimum separation from seasonally high groundwater of 2 feet (0.61 m) and a soil permeability greater than 1.94×10^{-4} cm/sec. A SEEP/W finite element model was developed to evaluate this design criteria as well as the soil parameters provided by LKR. The model indicates that a separation greater than 0.61 m would be required to drain the basin within a three-day period. It appears that the lack of infiltration at the LCIB is resulting primarily from the proximity of the basin invert to groundwater. Additionally, the permeability of materials beneath the basin may be lower than the values reported by LKR. In several instances, the adjacent groundwater elevations have been either above the basin invert, or within close proximity to the invert. Remedial action such as applying permeable materials near the basin invert, are not likely to significantly improve the performance. In the absence of high groundwater, the permeability values recommended by the FHWA Manual and those measured by LKR, would be adequate to drain the basin within three days.

The basin performance could be improved by raising the invert to provide a greater separation from groundwater and enlarging the basin surface area. Site constraints may restrict these modifications.

Many useful protocols for evaluating future basin sites can be developed from assessing the circumstances and performance with the LCIB. Elements of the geotechnical field investigations which should be modified include: the location and quantity of borings and wells, the monitoring of groundwater elevations over both wet and dry seasons, and increasing the quantity of insitu hydraulic conductivity measurements. Additionally, numerical groundwater modeling should be considered if site infiltration conditions are deemed marginal.

1.1 PURPOSE AND SCOPE

The purpose of this study is to provide a peer review of the geotechnical component of the La Costa Infiltration Basin Report prepared by Robert Bein, William Frost & Associates (RBF, 1999). That report addresses the project investigation for design and construction of the La Costa Infiltration Basin (LCIB) as part of the Best Management Practices (BMP) Retrofit Pilot Program. The purpose of URS Greiner Woodward Clyde's (URSGWC's) evaluation is to address possible reasons why the basin performance differs from the designed performance. Additionally, this study addresses the remedial measures taken during construction, and provides recommendations for improving the performance, as necessary, and suggestions for future geotechnical evaluations of basin sites.

The scope of our services including reviewing the infiltration basin report (RBF, 1999), reviewing additional technical publications, performing additional engineering analyses, and preparing this report presenting our findings, conclusions, and recommendations. Also, occasional site visits were performed to observe and document the existing conditions at the infiltration basin site.

1.2 BACKGROUND

The infiltration basin is designed to capture a portion of storm water runoff and allow the runoff to percolate into the ground. The LCIB was constructed as part of the Caltrans BMP Retrofit Pilot Program. LCIB is located west of the southbound lanes of Interstate 5, just north of La Costa Avenue in Carlsbad, California. The basin is approximately 30 meters (m) by 15 m in plan dimensions (at top of slope), with 1:4 (vertical:horizontal) side slopes 1 m high (Figure 1). The bottom of the basin was designed to be at +2 m Mean Sea Level (MSL). The LCIB site selection was performed in 1997 and 1998, according to BMP criteria established by RBF, with reviews by representatives from Caltrans, Natural Resources Defense Counsel (NRDC), Baykeeper, and the United States Environmental Protection Agency (USEPA), (RBF, 1998a). LCIB was constructed during September through December 1998. Standing water has remained in the LCIB since December 1998 (RBF, 1999).

High groundwater and low infiltration rates have been observed at LCIB before, during, and following construction. Standing water remains in the basin for a significant period of time following storms. The basin should be generally dry, except for a short time immediately following precipitation. The Federal Highway Administration's (FHWA's) suggested performance criteria indicates that the basin should be dry in approximately 264 hours (11 days) following a runoff event (Young, et al. 1996). However, because of the potential vector issues, the LCIB was to be designed to drain within 72 hours (3 days), (RBF, 1998b).

Both during and following construction, various remedial measures were taken to improve the basin percolation, including raising the basin invert elevation and replacing portions of the subgrade soil with coarse aggregate. These measures were implemented because higher-than-expected groundwater conditions were identified before and during construction.

2.1 INFILTRATION BASIN FUNCTION

An infiltration basin is a surface water pond designed to capture first-flush storm water runoff from a small catchment and treat it by allowing percolation into the ground. The basins remove soluble pollutants through biological processes. The basin should generally remain dry, except for periods immediately following storms. The Design Report indicates that basins are designed to percolate the captured storm water runoff within three days (RBF, 1998b). Infiltration basins require periodic maintenance to remove accumulations of sediment and debris that may restrict the flow of water into the soil. Several technical publications address the details of siting, design, construction, and maintenance of infiltration basins (Young et. al, 1996; Urbonas, 1993; and Stahre, 1990).

2.2 SITE OBSERVATIONS

URSGWC performed periodic site visits during the course of our post-construction study. The site visits were performed on April 30, May 11, 12, and 17, 1999. The primary purpose of the site visits were to observe the existing basin and site conditions immediately following the storm on April 29, 1999, and to record the infiltration rate of storm water. During each site visit, standing water was observed in the basin. The relative water surface elevation in the basin was measured at the inlet headwall on an existing survey rule, graduated in 0.01 feet increments. The measurements and observations were intended to provide a relative indication of the time that water remains in the basin. Corresponding hydraulic conductivity was not computed from these measurements, since pan evaporation rates were not measured during the same period of time. The relative water surface elevations recorded during our site visits are as follows:

Date	Time	Headwall Reading (feet)	Notes
4-30-1999	10:30 am	2.17	Rainfall on 4-29-99. Photos taken.
5-11-1999	12:30 pm	1.85	
5-12-1999	12:35 pm	1.82	
5-17-1999	12:45 pm	1.70	Minnows observed in basin. Photos taken.

The invert of the basin was not visible due to the low visibility of the retained water. No readings were collected in the locked monitoring well SDMW-1. Photographs depicting the general LCIB conditions during our May 17, 1999 site visit are shown on Figure 4.

The immediate areas adjacent to the LCIB were supporting some vegetation which appeared to have been hydro-seeded following construction. Surface drainage from the adjacent southern and eastern areas was directed toward the basin. It appeared that some of the surface drainage originating south of the basin may be directed around the western side of the LCIB by a gently sloping swale. The surface soil was visibly moist during the April 30 site visit. Surface soil appeared relatively dry during subsequent site visits. The basin appeared to have been generally constructed according to the drawings provided to our office (RBF, 1999). No measurements or surveys were performed by URSGWC to verify the design elevations and dimensions shown on the construction drawings.

2.3 GEOTECHNICAL INVESTIGATION BY LKR GROUP

Geotechnical investigations and consultation for designing the LCIB were performed by the LKR Group (LKR) during December 1997 through approximately April 1998. LKR was acquired by Group Delta Consultants who then provided geotechnical consultation services during construction and post-construction evaluations of the basin.

2.3.1 Explorations

On December 12, 1997, LKR performed two shallow borings at the LCIB site (LKR, 1997). The borings, WW-1 and WW-2, were excavated to 4.6 m (15 feet) below the ground surface to determine the approximate location of groundwater. Groundwater was measured in the borings at a depth of approximately 2.43 to 2.74 m (8 to 9 feet), or +0.69 and +0.52 meters (m) MSL. According to a telephone conversation on May 27, 1999 with the LKR's project geologist, Steve Kolthoff, the groundwater readings were collected approximately 30 minutes after excavation of the borings.

Both WW-1 and WW-2 encountered approximately 1.52 m (5 feet) of silty to clayey sand fill that was underlain by a light gray fine sand. The preliminary geotechnical indication from these groundwater readings was that the LaCosta site was a potential candidate for an infiltration basin. One of the two initial borings is located within the limits of the existing infiltration basin. The approximate locations of the borings are shown on the Site Plan (Figure 1).

2.3.2 Permeability Evaluation

On December 23 and 24, 1997, LKR performed an investigation to evaluate the in-drill hole permeability at the LCIB site (LKR, 1998a). The investigation consisted of excavating a 0.25 m (10-inch) diameter boring (SD-7) to 1.8 m (6 feet) below the ground surface (bgs). The bottom of the boring was located at approximately +1.5 m MSL. A 100 mm (4-inch) diameter slotted PVC casing was inserted into the excavation and the annular spaced filled with a medium aquarium gravel. Bentonite chips were placed above and below the slotted section of casing. Reportedly, the slotted casing was placed entirely within the sandy fill, from the ground surface to 1.52 m (5 feet) bgs (elevation +1.8 m MSL). A saturated silty to clayey fine- to medium-grained sand was reportedly encountered from 1.5 to 1.8 m (5 to 6 feet bgs). Caving in the boring was noted between 1.75 to 1.8 m (5.8 and 6.0 feet) bgs. The approximate location of SD-7 is indicated on the Site Plan (Figure 1).

SD-7 was presaturated on December 23, 1997. The in-hole permeability test was performed on December 24, 1997, apparently during a high tide period. No groundwater was present in the casing prior to testing on December 24, 1997. The permeability was evaluated according to the U.S. Bureau of Reclamation (USBR) methods that involve placing a volume of water in the boring between sealed depth intervals in an exploration and recording the rate of infiltration. Four intervals of filling and recording the infiltration were performed by LKR. Water from the first two intervals was dissipated rapidly in to the soil. The third interval provided the lowest rate of infiltration, and the fourth interval was invalid due to a ruptured seal. LKR used the third interval of infiltration data in their analysis of permeability. The in-drill hole and laboratory

hydraulic conductivity reported by LKR were 6.2×10^{-4} cm/s and 1.3×10^{-6} cm/s, respectively. Laboratory permeability was determined by LKR from a tube sample collected at 1.5 m to 1.8 m (5 to 6 feet) bgs, in materials logged as natural clayey to silty sand. LKR used ASTM D5804-90 test method to evaluate the laboratory permeability.

LKR reported that after a series of storms, on February 10, 1998, the water level in SD-7 was measured at 0.9 m (3 feet) bgs (2.4 m MSL). LKR recommended that the upper fill soils be removed during construction to allow infiltration into the natural sands.

2.3.3 Groundwater Elevations

The groundwater readings recorded by RBF, Group Delta Consultants (formerly LKR Group), and Kinnetic Laboratories, Inc., are summarized in the project investigation report (RBF, 1999). Various groundwater and surface water readings were collected over the site during December 1997 through April 1999. These groundwater readings were reduced to elevations and summarized graphically on Cross Section A-A' (Figure 2).

The groundwater elevations in Borings WW-1 and WW-2 were recorded within approximately 30 minutes after excavation. The readings indicate that groundwater in Borings WW-1 and WW-2 was approximately 1.31 m and 1.48 m below the basin invert, respectively.

Boring SD-7 was excavated to evaluate the percolation characteristics of the soil. No water was encountered during the December 23, 1997 excavation. The bottom of Boring SD-7 was located approximately 0.58 m below the basin invert. On February 10, 1998, after a series of rainstorms ponded water was observed on the ground surface, and the water elevation in Boring SD-7 was recorded at 2.41 m MSL, approximately 0.41 m above the basin invert. LKR indicated that the condition appeared temporary and was resulting from the above average rainfall. LKR continued that the condition should subside quickly between periods of precipitation, and a more realistic groundwater elevation would be at approximately 8 feet bgs or +0.8 m MSL (LKR, 1998b).

Monitoring well SDMW-1 was installed by the LKR on April 21, 1998. The highest and lowest stabilized groundwater elevations recorded in SDMW-1 were approximately +1.92 m and +1.28 m MSL, respectively. These elevations correspond to 0.08 m (0.26 feet) and 0.72 m (2.36 feet) beneath the basin invert.

Wet and unsuitable materials were encountered during the early stages of construction excavation. The excavation was apparently near the southern basin boundary. Standing water was observed in the excavation and initially recorded at an elevation of +1.453 m MSL on September 28, 1998 (Caltrans, 1998b). These elevations correspond to approximately 0.55 m (1.79 feet) and 0.22 m (0.73 feet) below the basin invert, respectively. On October 1, 1998, the water surface elevation in the trench was located at +1.779 m MSL (Caltrans, 1998a). According to Caltrans, the groundwater surface elevation observed in the excavation was at least 0.5 m above the projected flowline (Caltrans, 1998c).

Several readings were collected at the headwall to record the water surface elevation after construction was completed. Monitoring at the headwall was apparently initiated in February 1999 and has continued, through May 1999, with URSGWC's readings for this study. Over that

time, the water surface elevation has not varied by more than 0.36 m. We understand that the basin has contained water continuously since it was constructed in December 1998.

2.4 INFILTRATION BASIN DESIGN, CONSTRUCTION, AND REMEDIAL ACTIONS

The infiltration basin was designed in accordance with criteria outlined in the FHWA manual (Young, et al., 1996) and with the separate project specific requirements of RBF. The basin was designed to capture and infiltrate storm water from the adjacent Interstate 5 freeway within three days based upon the infiltration rate of 6.2×10^{-4} cm/s provided by the LKR. The basin invert was designed to have a minimum separation of 2 feet (0.61 m) from the seasonally high groundwater. RBF sized the basin to a depth of 0.8 m based on the hydrologic calculations. An evaluation of the surface hydrologic design was not part of our work scope.

Construction began in September 1998 and was completed in December 1998. During construction, the basin invert elevation was raised from +1.7 m to +2.0 m MSL in order to provide a greater separation from groundwater[1]. Water was accumulating in the basin during and shortly after construction. The apparent lack of infiltration was investigated by Group Delta Consultants, who recommended that marine cells be placed in and around the basin and filled with pervious material. Marine cells are a cellular system of high-density polyethylene "baskets" filled with gravel and cobble. The cells are designed to provide confinement to the gravel and cobbles, similar to gabions.

The basin invert was overexcavated approximately 0.3 m and backfilled with "pervious material" defined by Caltrans Specifications Section 19-3.065. At the same time, two excavations were advanced in the basin invert to a depth of 2.5 m below the invert. Reportedly, organic materials and clays were removed from the two backhoe excavations. Also, no groundwater was observed in the backhoe excavations while they remained open. These excavations were filled with ¾ inch rock and pervious materials. Water was then introduced into the basin with a water truck. Water from the first truck was reported to infiltrate; however, water from the second truck remained in the basin. A permanent pool of water has been present in the basin since the second infiltration test (RBF, 1999).

2.5 EVALUATION OF PERMEABILITY AND GROUNDWATER

One of the primary objectives of our study was to assess the interpretations of groundwater elevations, techniques for measuring the soil permeability, and the appropriateness of design criteria presented by FHWA design manuals with respect to groundwater separation and soil permeability. Groundwater elevations, soil permeability, and design manual guidelines were evaluated through the use of numerical modeling and our experience.

[1] There are discrepancies in the referenced documents as to the adjusted basin invert elevation. Profiles in Caltrans Field Memorandum No. 10 indicate an invert elevation of +2.1 m MSL. Caltrans Field Memorandum No. 11 and subsequent basin contours, indicate a basin invert elevation of +2.0 m MSL (RBF, 1999).

2.5.1 Groundwater Elevations

The readings in the initial Borings WW-1 and WW-2 were taken within 30 minutes of excavation. It is likely that these readings were not indicative of stabilized groundwater levels. A common practice is to allow at least 24 hours after excavation before stabilized groundwater readings are measured. In fine grained materials such as silts and clays, more than 24 hours may be necessary. From these measurements, one can only infer that the groundwater elevations are at least as high as the levels recorded in the explorations.

The groundwater elevation of +2.41 m MSL recorded in Boring SD-7 on February 10, 1998, is 0.41 m higher than the basin invert. The 0.61 m minimum separation from groundwater recommended by the FHWA manuals is clearly exceeded. Under these conditions there is very little head differential to facilitate infiltration.

As previously mentioned, the highest and lowest stabilized groundwater readings in SDMW-1 are 0.08 and 0.72 m below the basin invert. Most of the readings collected in SDMW-1 are higher than the two-foot separation recommended in the FHWA manuals. Groundwater readings from SDMW-1 indicate that the highest groundwater generally occurs in the winter months. The LCIB requires the greatest percolation during the winter months, when storms are frequent. Consequently, the design separation should be from the maximum groundwater level that is anticipated during the winter months.

2.5.2 Hydraulic Conductivity

Slug testing is commonly performed to evaluate the insitu permeability of soil and rock, by making a rapid removal or addition of water to a well, and recording the subsequent rise or fall of the piezometric surface. From a slug test, it is only possible to determine the characteristics of a small volume of aquifer material surrounding the well, and this volume may have been disturbed during drilling (Kruseman and de Redder, 1991). Slug testing has been recommended as a means for assessing infiltration basin hydraulically conductivity (Kessler and Osterbaan, 1974). There are many equations that have been developed to calculate the permeability of soil from slug-type testing such as the Hvorslev, Bouwer-Rice, and USBR methods.

The method used by LKR was that outlined in the USBR Ground Water Manual (1985). This method requires the use of packers or seals to isolate infiltration within a portion of the boring. The Bouwer-Rice method is a more conventional slug test, performed through an established well where the groundwater surface is known or can be reasonably approximated (Bouwer and Rice, 1976). The Hvorslev method (Hvorslev, 1949) is an electric analog method, similar to the USBR method in that both tests are performed on non-saturated aquifer materials; however, Hvorslev's method is generally regarded as highly variable and is not commonly used today.

One of the greatest shortcomings of vadose zone permeability testing is the attempt to measure saturated hydraulic conductivity in unsaturated materials. Saturated permeabilities are generally lower than unsaturated conditions. Generally, an evaluation of the insitu hydraulic conductivity for free-draining soil requires ground saturation. As such, a large volume constant head test would likely provide more representative results than a falling head test. A large volume test such as the USBR test method 7300-89, may yield more stable results than small volume slug-

type testing (USBR, 1990). Some researchers believe that unsaturated vadose zone permeability testing should be considered a measure of the relative permeability rather than the hydraulic conductivity (Kaplan, 1991).

URSGWC utilized the data collected by LKR during their hydraulic conductivity testing to evaluate the permeability calculations by the Hvorslev and Bouwer-Rice methods as a comparison to the USBR method. The third set of readings collected by LKR in SD-7 were used to assess the infiltration rate. Accordingly, the following hydraulic conductivities were computed:

Method	Calculation Performed By	Hydraulic Conductivity (cm/sec)
USBR	LKR Group	6.2×10^{-4}
Hvorslev	URSGWC	9.9×10^{-2}
Bouwer-Rice	URSGWC	4.5×10^{-3}

Based on these calculations, it is apparent that the USBR method provides the most conservative estimate of permeability, but that widely varying results can be obtained by various methods of calculations. The laboratory permeability reported by LKR is approximately two orders of magnitude lower than their reported field permeability. The test was performed on a tube sample we obtained from Boring SD-7 at 1.5 to 1.8 m (5 to 6 feet) bgs, in materials logged as a natural clayey to silty sand. The material located above this interval is logged as a clayey to silty sand fill. Hence, the field permeability appears to have been performed in fill materials, and the laboratory permeability in natural materials. We understand that LKR used ASTM D5084-90 test method to evaluate laboratory permeability.

2.5.3 SEEP/W Finite Element Model

In order to assess the minimum permeability and groundwater separation criteria recommended in the FHWA manual, URSGWC constructed a finite element model (FEM) to estimate the time for basin drainage under various scenarios of groundwater and permeability. The model did not consider evaporation as a means for reducing the volume of water in the basin.

SEEP/W is a finite element software developed by Geo-Slope International (1998) that is used for analyzing groundwater seepage and excess pore-water pressure dissipation problems. The comprehensive formulation makes it possible to analyze both simple and highly complex seepage problems in soil and rock, and to consider analyses ranging from simple saturated steady-state problems to sophisticated saturated/unsaturated time-dependent problems. This transient feature of SEEP/W makes it possible to analyze seepage as a function of time and to consider such processes as infiltration. This provides an ideal model to assess the mounding of the groundwater table beneath water retention structures such as the LCIB.

The FEM mesh developed for LCIB consists of approximately 2100 nodes. The two-dimensional mesh extends for a distance of approximately 55 m beyond the basin in each direction. The mesh used in the analysis is presented as Figure 3.

Initial groundwater conditions at two and four feet below the basin were evaluated to assess the minimum separation recommended by FHWA (Young, et al. 1996). At the same time hydraulic conductivity of the soil was varied. The results of the FEM analysis are as follows:

Hydraulic Conductivity Criteria	Time Required for Basin Drainage	
	Groundwater at 2 Feet Below Basin Invert	Groundwater at 4 Feet Below Basin Invert
Young, et. al, 1996 minimum 1.94×10^{-4} cm/sec	5.3 days	3.3 days
LKR Group In-Hole 6.2×10^{-4} cm/sec	1.6 days	1.1 days
LKR Group Laboratory 1.3×10^{-6} cm/sec	1450 days	160 days

The results of the analysis indicate that approximately 5.3 days would be required to drain the basin with the minimum groundwater separation and soil permeability recommended by FHWA. Additionally, we determined that a permeability of approximately 3.0×10^{-4} cm/sec would allow drainage of the basin in three days with the groundwater level 2 feet (0.61 m) below the invert. Based on this information, it is apparent that the time required to drain the basin depends not only on the permeability of the soil, but also on the separation of the basin invert from groundwater. The greater separation provides a greater differential head, less mounding, and a correspondingly shorter time to drain.

3.1 BASIN FUNCTION

The primary function of the infiltration basin is to temporarily capture storm water runoff and allow it to percolate into the soil within a short period of time. The LCIB fails to meet the basic performance criteria of percolating water into the soil within a reasonable amount of time. According to the reports by other firms, water has remained in the LCIB since it was constructed. Therefore it does not appear that the basin performance has degraded with time, as might be expected with sediment inflow. Rather, it appears that the basin, as designed and constructed, is not functional. Our findings indicate that the primary factor that inhibits the basin from performing as it was designed is the proximity of the invert to groundwater. Additionally, the permeability measured by LKR is primarily in the near surface fill materials outside of the basin. It is possible that the materials located beneath the basin have a lower permeability than that reported by LKR.

3.2 FIELD INVESTIGATION

The geotechnical site investigations were performed by LKR (now known as Group Delta Consultants). Initial borings were advanced to evaluate the approximate elevation of groundwater. Groundwater measurements made in Borings WW-1 and WW-2 were not representative of the stabilized groundwater elevation as they were obtained approximately 30 minutes after drilling. It is common to wait at least 24 hours or more to obtain a stabilized reading. The preliminary geotechnical indication from these groundwater readings was that the La Costa site was a potential candidate for an infiltration basin.

In-hole permeability testing was performed in boring SD-7 located just north of the existing basin. The test was isolated to the zone of 0 to 1.5 m (0 to 5 feet) bgs, that was logged primarily as fill. Assuming horizontal and continuous subsurface stratigraphy, percolation testing was therefore performed on materials located in the basin side slopes, and materials within 0.28 m below the basin invert. It appears that Boring SD-7 may have been terminated just above groundwater. Similar to Borings WW-1 and WW-2, the initial findings from Boring SD-7 indicated that the site geotechnical conditions were commensurate with the minimum basin design criteria. However, Boring SD-7 was located outside of the proposed basin area and penetrated a relatively small zone beneath the basin invert.

The permanent monitoring well SDMW-1 provided an indication of groundwater fluctuations during design, construction, and post construction monitoring. Prior to construction, groundwater levels were recorded in Boring SD-7 and SDMW-1 which indicated that the seasonally high groundwater was either near or above the LCIB invert. The consultants exercised a reasonable approach in attempting to locate a solution to the design deficiency; however, greater attention should have been directed at monitoring the groundwater condition, rather than addressing it as a short-term transient issue. It is our opinion that the high groundwater at the site is the primary reason the basin is not performing as it was intended or designed.

In addition to Young, et al, (1996) other researchers have addressed the critical factors affecting the performance of an infiltration basin. According to Urbonas and Stahre, (1993) there are

several conditions that would rule out a site as a candidate for an infiltration facility. One of the key conditions is that the seasonal high groundwater is less than 4 feet (1.2m) below the infiltrating surface. Urbonas and Stahre (1993) further recommend that the practical approach in assessing infiltration is to make several infiltration tests and then use the lowest measured rates in the design.

3.3 BASIN DESIGN, CONSTRUCTION, AND REMEDIAL ACTIONS

The basin was designed by RBF to capture and infiltrate storm water runoff. The basin was sized to catch the anticipated storm water load and to drain within three days. Actions were taken to modify the design such as raising the basin invert and applying more permeable materials below the invert as high groundwater conditions were identified. These recommendations were helpful; however, the high groundwater condition persisted and only small separations from the groundwater were realized. As groundwater elevations were at or near the basin invert, the addition of permeable materials at the basin invert did not significantly increase infiltration rates. If groundwater was lower, then this action would have likely increased the basin infiltration rates. The basin configuration with the adjacent Interstate 5 freeway is restrictive on the allowable fall to the LCIB. As such, there is very little vertical elevation available to raise the basin invert.

3.4 HYDRAULIC CONDUCTIVITY AND GROUNDWATER ELEVATION

As previously mentioned in Section 3.2, the hydraulic conductivity testing was performed in Boring SD-7, located just north of the existing basin. Also, the materials tested for conductivity would likely comprise the basin sides and a small portion of the materials below the basin invert. The USBR test method provides a reasonable approximation of the hydraulic conductivity for materials located in the vadose zone. When compared to similar methods of computation, the USBR method provides the most conservative value for the circumstances at the LCIB and for the conditions of LKR Group's test. Also, the clayey materials located near the base of Boring SD-7, that were later tested for laboratory permeability, provided some indication that subsurface conditions were not uniform, and that less permeable materials may be present below the basin invert. Further exploration and in-hole permeability testing may have been warranted.

The minimum permeability (1.94×10^{-4} cm/sec) and separation from groundwater (2 feet) recommended by Young, et al., (1996) will not result in a 3-day maximum basin drain time, as indicated in the SEEP/W modeling. A separation of four feet from groundwater appears to generally meet the selected design criteria for drainage within three days. The LKR in-hole permeabilities also meet the 3-day criteria for both groundwater conditions. The LKR laboratory permeability is much lower than the in-hole, and drainage times are excessive for an infiltration basin, regardless of either groundwater condition. Laboratory permeability was determined by LKR in Boring SD-7 from a tube sample collected at 1.5 m to 1.8 m (5 to 6 feet) bgs, in materials logged as natural clayey to silty sand. The laboratory permeability was approximately two orders of magnitude lower than the field permeability. It is possible that the permeability of materials beneath LCIB have a lower permeability than 6.2×10^{4} cm/sec. Therefore, in the absence of the high groundwater, the permeability values recommended by Young, et al., (1996) and those measured in the field by LKR would be adequate to drain the basin within three days.

The basin drainage time is a function of basin size, soil hydraulic conductivity, and the separation from groundwater. A small change in hydraulic conductivity can have a significant impact on the basin percolation. Therefore, it is not only important to determine the permeability of materials above and below the basin invert, but also the groundwater elevations over both seasonally wet and dry periods. A larger basin (in area) may overcome deficiencies in the desired minimum permeability.

4.1 EXISTING BASIN

The existing LCIB performance could be improved by raising the invert to provide a greater separation from groundwater and simultaneously enlarging the invert percolation area of the basin. The size and separation distance from seasonal groundwater could be determined once the subsurface profile and hydraulic conductivities beneath the basin are known. Site constraints with elevation may restrict further adjustments to the basin invert. A subsurface investigation would be required to develop specific modifications to the basin. A geotechnical investigation would not be necessary if the site constraints restrict raising the basin invert beyond 2.0 m MSL.

4.2 FIELD INVESTIGATION

Many useful concepts and protocols for future investigations can be developed from assessing the circumstances and performance of the LCIB. Aspects of the geotechnical field investigations which should be revised include: location and quantity of borings and wells, monitoring programs, and the quantity and location of in-hole hydraulic conductivity measurements.

All explorations should be carefully logged to determine variations in the subsurface profile that may result in lower infiltration rates. Of greatest importance is the presence of fine-grained materials such as silts and clay. A small fraction of these materials can result in a substantial reduction in permeability. For example, an approximate addition of two percent of minus #100 material can reduce the permeability of a clean sand by one to two orders of magnitude (Cedergren, 1989).

At least two monitoring wells should be established adjacent to a proposed basin. One of the wells should be located near the basin, but down-gradient by no more than approximately 10 m. The other should be placed within the proposed basin. The wells should extend at least 5 m below the invert of the proposed basin. The wells should be monitored at least monthly over both a wet and dry season. Monitoring over multiple seasons may be necessary in the event of an unusually wet or dry season. Obviously, wet season monitoring is of paramount importance, since this is when the basin will be receiving and percolating storm water.

4.3 HYDRAULIC CONDUCTIVITY

At least three in-hole hydraulic conductivity tests should be performed (Urbonas and Sathre, 1993). Two of the tests should be located within the proposed basin, and the third down gradient no more than approximately 10 m. Permeability tests should be measuring the materials located in both the side slopes and materials within a depth of 3 m of the basin invert. It is recommended that either the USBR 7300-89 or Bouwer-Rice test procedures be used. Bouwer-Rice is an appropriate method where the groundwater is encountered within the boring. The lowest value of permeability obtained from the three tests should be used to design the basin.

Laboratory permeability testing has the advantage that materials can be tested in a saturated state. However, these tests are performed on a very small sample of the soil and are subject to disturbance. We recommend that additional field permeability tests be performed in lieu of laboratory permeability testing.

4.4 GENERAL BASIN DESIGN

Basin percolation rates are primarily a function of basin size, soil permeability, and the separation of the basin invert from groundwater. According to our FEM analysis, the minimum criteria recommended by Young, et al. (1996) should not be used if the basin is to drain within three days. We recommend a minimum hydraulic conductivity of 3×10^{-4} cm/sec be utilized if the basin needs to be drained in three days and when there is a minimum separation of approximately two feet. If the separation is four feet or greater, then a lower hydraulic conductivity, such as 2×10^{-4} cm/sec, appears to provide reasonable drainage times. It is recommended that groundwater modeling be performed if the site infiltration conditions are considered marginal. A larger basin (in area) may be required if the minimum criteria can not be met at a selected site.

Some researchers suggest that the infiltration be designed only at the sides of the basin, as the bottom is likely to become clogged with sediment over time. Provided that periodic maintenance is performed that includes removing fine-grained materials and debris from the basin, this design assumption should not be necessary. If site conditions suggest marginal percolation characteristics, then modeling should be considered to assist with the basin design.

Our findings and conclusions are based on the documentation provided to us by RBF, Caltrans, Group Delta Consultants, telephone conversations with their representatives, and our experience. URSGWC has not performed independent subsurface investigation and laboratory testing. Our recommendations are general suggestions for future geotechnical investigations of infiltration basin sites. The geotechnical conditions at basin sites will be different, and engineering judgement will be necessary to investigate and evaluate the conditions specific to each site.

Geotechnical engineering and the geologic sciences are characterized by uncertainty. Professional judgments presented herein are based partly on our understanding of the proposed construction, and partly on our general experience. Our engineering work and judgments rendered meet current professional standards; we do not guarantee the performance of the project in any respect.

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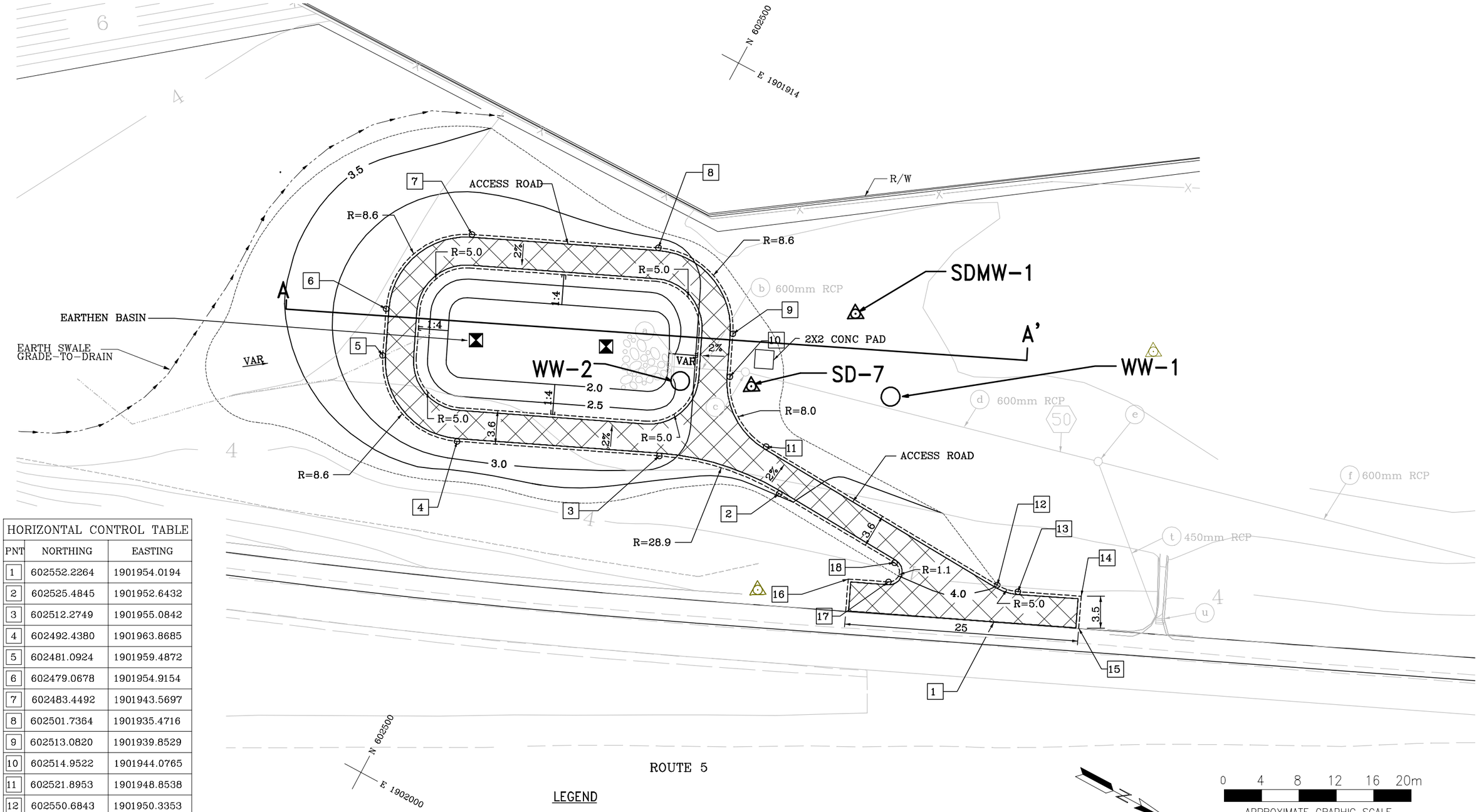


HORIZONTAL CONTROL TABLE		
PNT	NORTHING	EASTING
1	602552.2264	1901954.0194
2	602525.4845	1901952.6432
3	602512.2749	1901955.0842
4	602492.4380	1901963.8685
5	602481.0924	1901959.4872
6	602479.0678	1901954.9154
7	602483.4492	1901943.5697
8	602501.7364	1901935.4716
9	602513.0820	1901939.8529
10	602514.9522	1901944.0765
11	602521.8953	1901948.8538
12	602550.6843	1901950.3353
13	602552.9657	1901949.9137
14	602559.1682	1901947.1672
15	602560.5540	1901950.3073
16	602536.2903	1901957.2395
17	602540.2472	1901955.4872
18	602539.8583	1901953.3829

ALL DIMENSIONS ARE IN METERS UNLESS OTHERWISE SHOWN

LEGEND

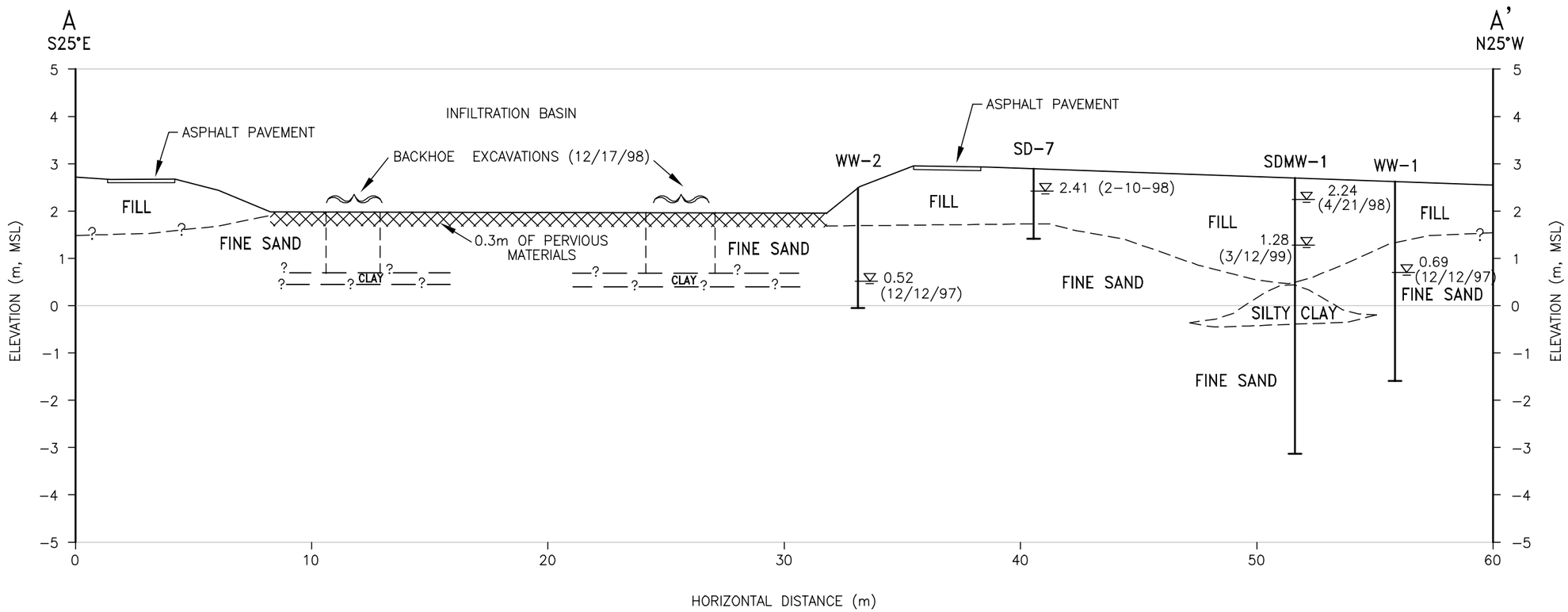
- BORING LOCATION (LKR, 1997)
- BORING/MONITORING WELL LOCATION (LKR, 1997, 1998)
- BACKHOE TRENCHES EXCAVATED ON 12/17/98

REFERENCE:
"PROJECT INVESTIGATION, I-5/LA COSTA AVE., INFILTRATION BASIN, CALTRANS REPORT ID# CTSW-RT-99-008, EXHIBIT A," DATED APRIL 6, 1999, PREPARED BY RBF & ASSOCIATES.

SITE PLAN
I-5/LA COSTA AVENUE INFILTRATION BASIN

FN: LACSITE	PM: RSJ	CHECKED BY:	DATE: 6-8-99
PROJECT NO: 58-977001NP.00-RR001			FIGURE NO: 1

URS Greiner Woodward Clyde



—?— —?— DENOTES ORGANIC MATERIALS

NOTE: SEE FIGURE 1 FOR LOCATION OF SECTION

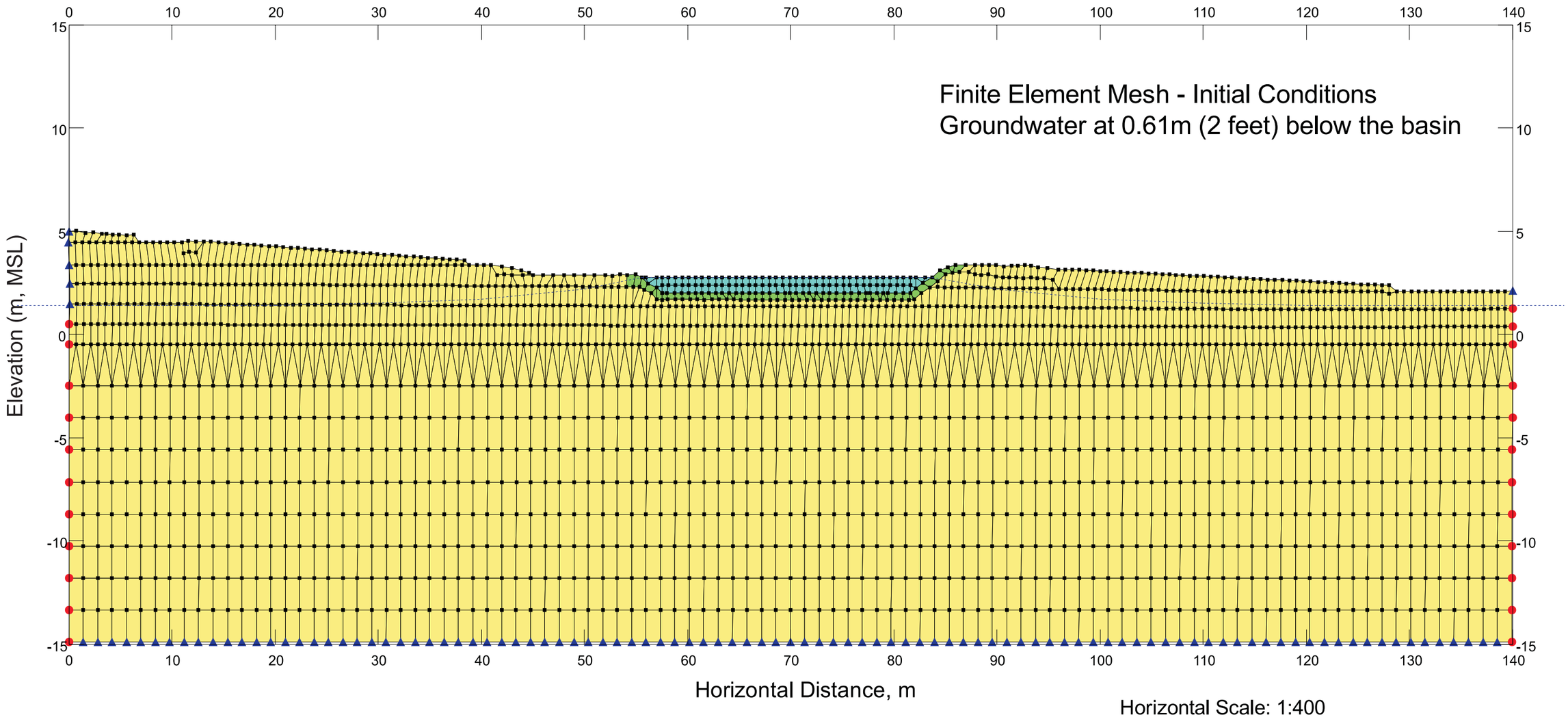
0 2 4 6 8 10m

APPROXIMATE GRAPHIC SCALE
1:200
VERTICAL EXAGGERATION = 2

CROSS SECTION A-A'
I-5/LA COSTA AVENUE INFILTRATION BASIN

FN: LACSECT	PM: RSJ	CHECKED BY:	DATE: 6-8-99
PROJECT NO: 58-977001NP.00-RR001			FIGURE NO: 2

URS Greiner Woodward Clyde



Horizontal Scale: 1:400

Vertical Scale: 1:200

FINITE ELEMENT MESH - INITIAL CONDITIONS
I-5/LA COSTA AVENUE INFILTRATION BASIN

FN: LACMESH	PM: RSJ	CHECKED BY:	DATE: 6-7-99
PROJECT NO: 58-977001NP.00-RR001			FIG. NO: 3

URS Greiner Woodward Clyde

INFILTRATION BASIN LOOKING SOUTH

INFILTRATION BASIN LOOKING NORTH

SITE CONDITIONS ON MAY 17, 1999
I-5/LA COSTA AVENUE INFILTRATION BASIN

FN: LACFOTO1	PM: RSJ	CHECKED BY:	DATE: 6-8-99	PROJECT NO: 58-977001NP.00-RR001	FIG. NO: 4

URS Greiner Woodward Clyde

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