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FINAL REPORT

DAYLIGHTED DRAINABLE BASE RESEARCH

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KANSAS DEPARTMENT OF TRANSPORTATION

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16 Abstract

Modern highways are built with flat grades and gentle side slopes. The flat grades and shallow ditches that result are not conducive to the construction of edge drains and outlet structures. The Kansas Department of Transportation proposed using a drainable base to enhance the performance of pavements and to evaluate the performance of drainage features such as edge drains and daylighted Bound Drainable Base without edge drains.

The objective of this research project was to study the effects of moisture content and drainage characteristics of the daylighted Bound Drainable Base and edge drain sections on pavement performance under less than ideal conditions.

The test sections were constructed on two lane highways with 10’ PCC shoulders. The surface was Portland Cement Concrete Pavement (PCCP) that was non-reinforced with doweled joints (NRDJ). Beneath the PCCP was 4” of Bound Drainable Base (BDB) and 6” of Lime Treated Subgrade (LTSG). The LTSG was supposed to act as a separator layer. Four test sections were constructed at each location:

1. Bound Drainable Base with edge drains and outlet pipes
2. partially daylighted Bound Drainable Base using denser aggregate wedge
3. fully daylighted Bound Drainable Base using BDB material for the wedge
4. partially daylighted BDB with a filter fabric above and below the BDB outside of the shoulder.

The test section performance indicates that a daylighted drainage system can perform as well as a drainage system using edge drain pipes and outlets. Both types of drainage systems are susceptible to freezing weather causing ice buildup in the drainable material resulting in reduced flow. The vibrating strip piezometers were not reliable for measuring the effectiveness of the drainage layer’s ability to remove moisture by measuring pore pressure. Several of the test sections on the US-50 site failed to maintain open drainage when the fines from the LTSG migrated upward into the drainable base layer. There needs to be a separator layer below the drainable layer to prevent the migration of fines. It is suspected that the LTSG on the US-50 site was not thoroughly mixed which resulted in incomplete hydration. This weakened the stabilized base and, when exposed to moisture, resulted in the fines migrating upward into the drainable layer.

Bound Drainable Base, BDB, Daylighted, Edge Drains, Lime Treated Subgrade, LTSG, Pavement, PCC and Portland Cement Concrete	**18 Distribution Statement** No restrictions. This document is available to the public through the National Technical Information Service, Springfield, Virginia 22161

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DAYLIGHTED DRAINABLE BASE RESEARCH

Final Report

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A Report on Research Sponsored By

THE KANSAS DEPARTMENT OF TRANSPORTATION
TOPEKA, KANSAS

September 2004

ACKNOWLEDGMENTS

The Soils Section would like to extend a special thanks to: District Two for their assistance in installing the instrumentation for the test sections on US-50 in Marion County; District Four for their assistance in installing the instrumentation for the test sections on US-400 in Montgomery County; and the Soils Section Personnel for the installation of the instrumentation and the collection of the water level information.

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1.1 Introduction

During the Decade of the 1990's, US Route 50 was reconstructed from the North Junction of K-15 in Newton, east to the Junction of US-77 in Florence. This 26-mile stretch of two-lane highway was constructed in six segments totaling ten projects. In order to carry traffic through construction, the majority of these pavements were reconstructed on an offset alignment.

The typical pavement section on US- 50 is a 9"-10" Portland Cement Concrete Pavement (PCCP) on a 4" Bound Drainable Base (BDB) or a 4" Portland Cement Treated Base (PCTB). These sections are underlain with a 6" Lime Treated Subgrade (LTSG). Due to the flat profile grade, the section from Peabody to Florence was approved as a test section for "daylighted" bound drainable base. A section with the conventional edge drain and outlet system was also constructed for comparison purposes.

US-400, formerly K-96, was designated as a super-two highway from Wichita to Joplin, Missouri. A super-two is a two-lane highway designed on four-lane right of way with criteria to allow upgrading to an expressway or freeway design in the future. This required the reconstruction of several sections of the existing K-96 corridor and new construction of several sections under the US-400 designation. Two of these projects were slated for inclusion in the study of daylighted drainable bases.

The first US-400 Project, constructed under project number 96-63 K-4892-02, extended from the Wilson County Line south and east to the Labette County Line. This section consisted of a 9" Portland Cement Concrete Pavement with a 4" Daylighted Bound Drainable Base on a 6" Lime Treated Sub-grade. This project included a section with edge drains and outlets and five other drainage configurations.

The final selected Project was also on US-400. It was constructed on Project 96-103 K-3294-02 near Fredonia in Wilson County. This Project was not instrumented and was dropped from the research Project.

1.2 Background

Drainable bases under concrete pavements are being constructed to enhance their performance. An effective pavement drainage system relies on positive methods to remove moisture from the base. This requires a base with adequate cross slope to promote drainage; edge drains with adequate longitudinal slope to carry water away and outlet pipes with adequate headroom to allow egress of the water. Modern highways are built with flat grades and gentle side slopes. The flat grades and shallow ditches that result are not conducive to the construction and operation of edge drains and outlet structures.

It became apparent in 1994 that the drainage policy for the Kansas Department of Transportation did not address two conditions. Many projects experienced flat profile grades or shallow ditches. These factors alone or in combination contributed to poor performance and extensive maintenance activities for pavements with drainage systems. To improve the performance of the system and decrease the maintenance that needs to be performed, the Kansas Department of Transportation developed an alternate method to incorporate a "daylighted" drainage system into a pavement section.

The practice of the Kansas Department of Transportation in 1994 called for edge drains and outlet pipes. As an alternate KDOT used a "daylighted" section when drainage was needed where the profile grade was less than 0.35% and/or the ditches were less than 3.0 feet in depth and no reasonable alternate method existed to outlet the drainage pipes. A project could contain both a section with edge drains and outlet pipes and a "daylighted" section. A project had to contain significant lengths of both conditions before both were be used. The prevalent condition dictated the selected alternate.

The original "daylighted" section detail that was submitted to FHWA, Federal Highway Administration, is shown in Figure 1. The section consisted of drainable base construction two feet beyond the pavement edge and a three-foot wide rock wedge over the base and adjacent to the shoulder pavement. The rock wedge was to be dense graded to reduce erosion and prevent water infiltration into the drainage layer. Water from the drainable base was to be removed by evaporation and transpiration.

This section would not rapidly remove water from the pavement structure. KDOT's observation of in-place systems indicated that few outlet pipes drain appreciable quantities of water. It was further observed that pipes on flat slopes generally resulted in plugged to partially plugged conditions. This daylighted section had a continuous path for water egress. On flat grades the primary drainage component is the direction of the pavement cross slope. This design resulted in a short flow path. The water concentrates at the edge of the shoulder, away from the traffic loading, until it dissipates. This proposal was rejected by FHWA because it did not provide for positive drainage and could have problems associated with water ponding on the lime treated sub-grade.

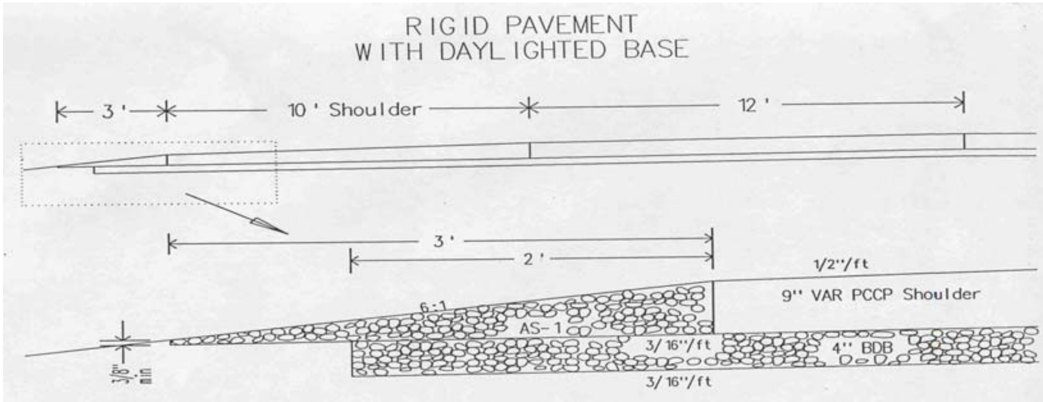


FIGURE 1

A revision to this original design, illustrated in Figure 2, was submitted in May of 1995. This design extended the bound drainable base material to the shoulder slope providing the positive drainage system desired. Thus the term "daylighted" was applied. The positive drainage was achieved by constructing the lime treated subgrade at a 3/16-inch per foot slope. This method of continuous positive drainage would also prevent the ponding of water on the lime treated subgrade. Aggregate, with minimal fine material, would be used adjacent to the shoulder above the daylighted base material, in lieu of soil, to reduce the infiltration of fine material into the drainable base material.

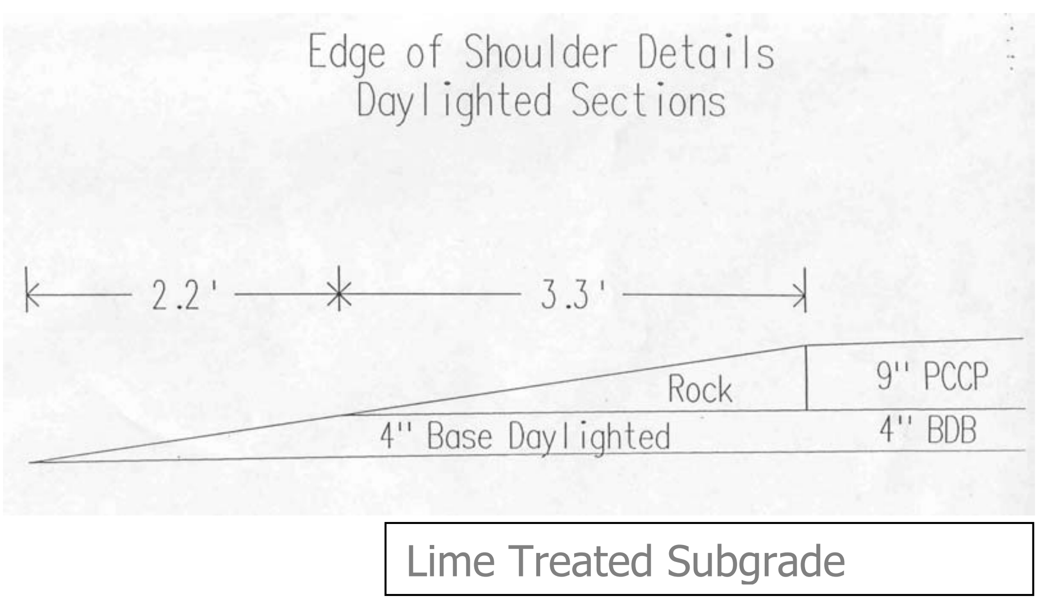


FIGURE 2

This design met with FHWA's approval. Test Projects were selected and variations of the design were prepared to be field tested on these Projects.

This field test allowed KDOT to utilize drainage layers on these critical roadways. This experiment tested the need for positive drainage features such as edge drains. KDOT constructed a minimum of four sections on each Project. One site incorporated KDOT's typical edge drain section. Figure 14 in Appendix C provides the design details for this section. A second site incorporated a partially daylighted section similar to the original submittal shown in Figure 1. A third site incorporated a fully daylighted section similar to the design shown in Figure 2. The photo in Figure 3 illustrates the expected appearance of the daylighted drainable base shoulder. A fourth site repeated the fully daylighted section, but incorporated an alternate edge wedge shoulder material for economy.

FIGURE 3: Expected aggregate appearance of a daylighted drainable base. This is the right shoulder on US-50 at Station 242+00

1.3 Objective

The objective is to measure the moisture content and drainage characteristics of the daylighted and edge drain sections. The construction and maintenance costs will be measured for each of the alternate materials used in the edge wedge shoulder. Falling Weight Deflectometer and roughness measurements will be obtained. The instrumentation will establish drainage characteristics while the deflection and roughness measurements will track the performance of the pavement structure. The information obtained will provide an understanding of the movement and quantity of moisture in the base.

This information is being used to decide if a drainage system can perform in less than ideal conditions, presently defined as flat grades and/or shallow ditches. The information may be used to establish new criteria for the design of drainage layers. If the performance of the daylighted section is satisfactory, then KDOT has the opportunity to utilize a drainage system where it was not practical before. Positive drainage, when properly designed and maintained, increases pavement performance and can prevent costly premature pavement failures caused by moisture damage.

The primary purpose of the investigation is to document the design and performance of the daylighted drainable base systems and provide a comparison of the performance of the various designs.

1.4 The Projects

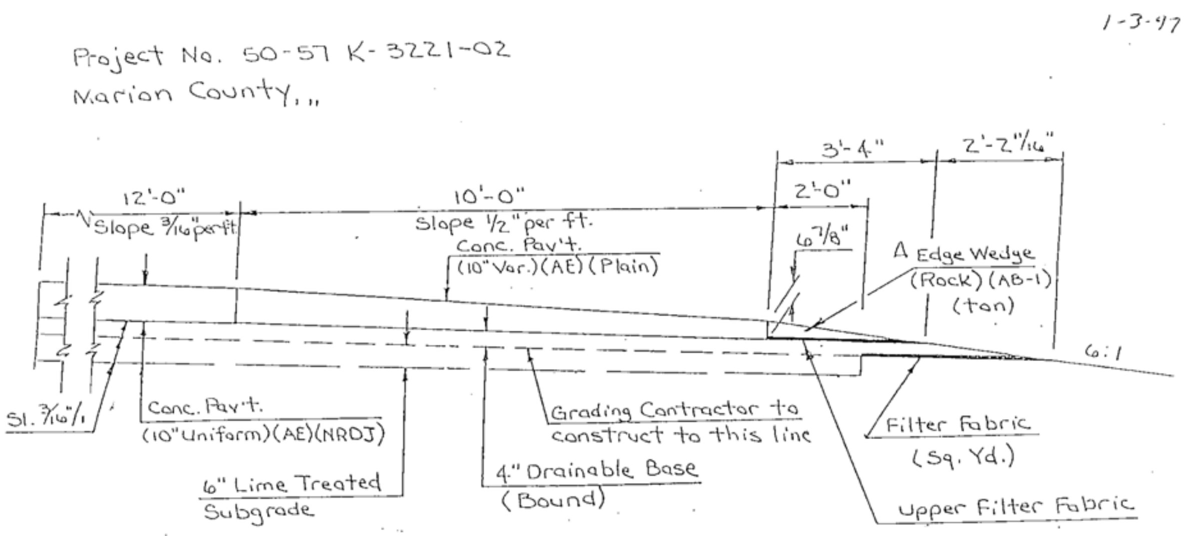
Wittwer Construction Company was contracted to do the surfacing portion of the US-50 Project in Marion County. The notice to proceed was issued in December 1997. The actual completion date of the paving project was November of 1998. Included in their contract was the lime treatment of the top 6" of the subgrade. This layer would serve as the separator layer. The typical section is 10” PCCP (NRDJ, non-reinforced with doweled joints) (15’ joint spacing) + 4” Daylighted BDB + 6” LTSG. The use of the daylighted bound drainable base (BDB) was a new concept to Kansas, and this was selected as one of three projects in the state to install and monitor the daylighted bound drainable base.

Koss Construction was contracted to construct the K-96 (US-400) section in Montgomery County. The project was completed in late 1998. The typical section for this project is 9” PCCP (NRDJ, non-reinforced with doweled joints) (15’ joint spacing) + 4” Daylighted BDB + 6” LTSG.

The typical method of daylighting the BDB was to run the BDB to the shoulder side slope. Above the BDB outside the shoulder, a denser aggregate base wedge was constructed over the BDB. Three other sections were also constructed on the US-50 Project. They are: (1) fully daylighted BDB with bound drainable base material being used as the wedge, (2) edge drains with outlets, and (3) a partially daylighted BDB using a denser aggregate base, AB-1, for the wedge outside of the shoulder. The K-96 (US-400) added three more versions of the partially daylighted system. These were (1) using a denser aggregate, AS-1, for the wedge aggregate, (2) using unbound drainable base aggregate for the shoulder wedge and (3) using the AB-1 aggregate for the shoulder wedge, but adding filter fabric to prevent infiltration of the fines into the bound drainable base.

1.5 Design of Drainage

As noted above, the US-50 Project tested four different drainage systems. The first was a fully daylighted drainable base section with the cement treated drainable base material carried to the shoulder slope as shown in Figure 4. A filter fabric was placed below and above this drainage layer from the shoulder edge out. This filter fabric was used to prevent infiltration of the untreated soil from below and the fines from the aggregate wedge above. Aggregate of the AB-1 designation was used in the shoulder wedge. Figures illustrating the other drainage designs being investigated are shown in Appendix C.



FULLY DAYLIGHTED HALF-SECTION

STA. 219+75 to STA. 300+00 (8,025')
STA. 300+00 to STA. 325+00 (2,500')
STA. 377+00 to STA. 732+11.98 (35,511.98')

FIGURE 4

The second design section was compared to an edge drain system, a partially daylighted section and a fully daylighted system using the bound drainable base aggregate as the shoulder wedge. The edge drain system used the same cement bound drainable base material. This base was connected to a drainage trench at the shoulder. The drainage trench contained a four-inch drainage pipe with a coarse drainage aggregate. The trench was lined with a filter fabric to allow infiltration of water, but to prevent the infiltration on soil particles. This design is illustrated in Appendix C under Figure 14.

The third design section used on the US-50 Project consisted of a partially daylighted section. This design consists of the same cement treated drainable base material. However, in this design the base material is stopped two feet outside of the shoulder. The water would then pass through a shoulder wedge of AB-1 material. This aggregate wedge would give the shoulder slope a more consistent appearance, as only one material would be visible instead of the two materials visible in the fully daylighted section. It is believed that the AB-1 aggregate gradation will allow the egress of moisture. The AB-1 aggregate gradation specification is shown in Table 1 below. This design is shown in Appendix C under Figure 15.

The final design section used on US-50 provided a fully daylighted drainable base. The modification to this section was the use of the bound drainable base material as the shoulder wedge. This provided just one visible material after paving on the shoulder. However, the wedge had to be added in a separate machine pass since the underlying drainable base layer was used as the equipment track lane for placement of the concrete pavement.

The US-400 incorporated these four designs and added three additional variations of the partially daylighted section design. These designs modified the partially daylighted design by changing the aggregate used in the wedge. This original design used AB-1 for the wedge material. This material was changed to AS-1 for the section from Station 226+00 to 249+85.25. The wedge material was changed to unbound drainable base aggregate on the left side from Station 101+40 to 126+00. Bound drainable base aggregate was installed on the right side in this same section. The gradations for these aggregates are shown in Table 1. The fourth design section used the original AB-1 material. However, it called for placing a filter fabric over the extended bound drainable base similar to the installation on US-50. These designs are shown in Appendix C as Figure 16 through Figure 18.

TABLE 1: Edge Wedge Aggregate Gradations

Aggregate	2 inch	1 ½ inch	1 inch	¾ inch	3/8 inch	No. 4	No. 40	No. 200
AB – 1	0	0 – 5		5 – 30		35 – 60	78 – 90	90 – 98
AS – 1	0	0 – 5		5 – 30		35 – 60	60 – 84	80 – 92
BDB(50)			0	5 – 15	51 – 62	80 – 88	92 – 96	93 - 100
BDB(96)			0	5 - 21	49 - 65	72 - 86		94 - 100

1.6 Construction

The specification for Bound Drainable Base in place during 1998 was 90M-144-R1. This specification is included in this report as Appendix D. This material consisted of mineral aggregate with a binder of asphalt cement, Portland cement or fly ash. Portland cement and fly ash could also be used in combination.

The permeability of the mixture was specified to exceed 300 meters per day (1,000 feet per day). The seven-day compressive strength for mixtures bound with fly ash or cement was to be between 4.1 MPa (600 psi), and 8.3 MPa (1,000 psi). This strength requirement was for six-inch specimens six inches in height as described in Kansas Test Method MR1.

The Contractor submitted a mix design for approval from an accredited laboratory. This mix design was verified in the State's laboratory prior to approval. Actual field verification of the mixture was not required at that time.

Wittwer Construction, the US-50 Contractor, submitted a mixture using limestone from Florence Rock Company, a quarry within two miles of the east end of the Project. This mixture was bound with 264 pounds of cementatious material consisting of 40% cement from Heartland Cement and 60% fly ash from the Jeffery Energy Power Plant. This material was placed with an ABG paver and compacted with two coverages of a steel flat-faced roller. Fourteen field specimens of this material were prepared for strength testing. The strengths varied from 185 psi to 1,159 psi. The average strength was 561 psi with a standard deviation of 297 psi.

Koss Construction also submitted a mixture consisting of limestone, cement and fly ash for the K-96 Project. Nelson Quarries, with their Cherryvale, Kansas plant, quarried the limestone. Heartland Cement supplied the cement from their Independence, Kansas plant. Boral Materials supplied the fly ash from their Oolagah plant in Oolagah, Oklahoma. This mixture used 145 pounds of cementatious material. This consisted of 40% cement and 60% fly ash. The design strength of this mixture was 665 psi. The permeability of the mixture tested at the lower gradation tolerances was 1,025 feet per day.

1.7 Field Instrumentation

Two types of instrumentation were used to document the performance of the daylighted drainable base. The first was a standpipe system. A standpipe consisted of one-inch diameter pipe with a five foot slotted section. The slotted section was buried at the interface of the base with the lime treated subgrade. The pipe was then extended to the ditch with a vertical standpipe for elevation readings. One of these standpipes was placed at each test section. The standpipe was used to determine the elevation of water in the drainage system. A reading greater than the reference elevation would indicate the presence of standing water in the base drainage system. Conversely, a reading less than the reference elevation would indicate the absence of water in the base. One standpipe was located at each of the stations listed in Table 2. A detail of the standpipe design is shown in Figure 5.

Vibrating strip piezometers were the second type of instrumentation used for this study. They were used to attempt to detect the presence of pore pressure. It was initially believed that pore pressure would develop in the presence of heavy loads if the permeable drainage layer was saturated. At least one piezometer was installed in each test section in the wheel path at the soil sub-grade and base interface. These were attached to a readout station in the ditch. A data collector was used to collect the readings. Several test sections had two piezometers installed since Project 96-103 K-3294-02 was not instrumented. The locations of these piezometers are listed in Table 2. One piezometer was installed at each of the offsets listed in this table.

Table 2

Instrumentation Locations		
Project	**Project Station**	**Offset for Piezometers**
Project 50-57 K-3221-02	Station 365+03	3.2' Left
		11.8' Left
	Station 339+97.5	3.5' Left
		11.0' Left
	Station 312+95	2.6' Left
		10.0' Left
	Station 241+83.7	3.0' Right
Project 96-63 K-4892-02 (US-400)	Station 349+95	4.0' Right
		15.5' Right
	Station 342+90	4.2' Right
		13.4' Right
	Station 259+55.4	3.5 Right
	Station 236+47.4	3.5' Right WB
	Station 115+03	3.2' Right NB
	Station 115+02.8	4.2' Left SB

1.8 Processing of Field Instrumentation Data

The standpipe water levels were observed from June 22, 1998 until May 29, 2003. Initially, only readings of the standpipe water elevation and piezometer pressure were taken. Once pavement distress became apparent on one of the projects, the project technicians also documented any pavement distress that appeared at the test sections.

Generally, water levels in the standpipes remained below the entry elevations of the slotted section of the pipe. This indicates that there was not an over abundance of water moving through the drainable base material or ponding in it. The standpipes were bailed after the water levels were recorded, unless ice prevented bailing. Ice was encountered on several occasions. The standpipes were easily bailed on the other occasions further indicating the lack of water ponding in the drainable base. During winter freezing occasions when ice was encountered, the water level in some standpipes did reach the entry level of the base or slightly exceed it. Virtually all of the water level records at each test section indicate a rising water level during winter freeze conditions. This rise in water level during winter conditions was greater than those recorded during the higher rainfall periods of the spring and fall. This indicates that freezing conditions did prevent the free flow of water in the drainage material. Graphic interpretation of the information obtained from the standpipes is contained in Appendix E.

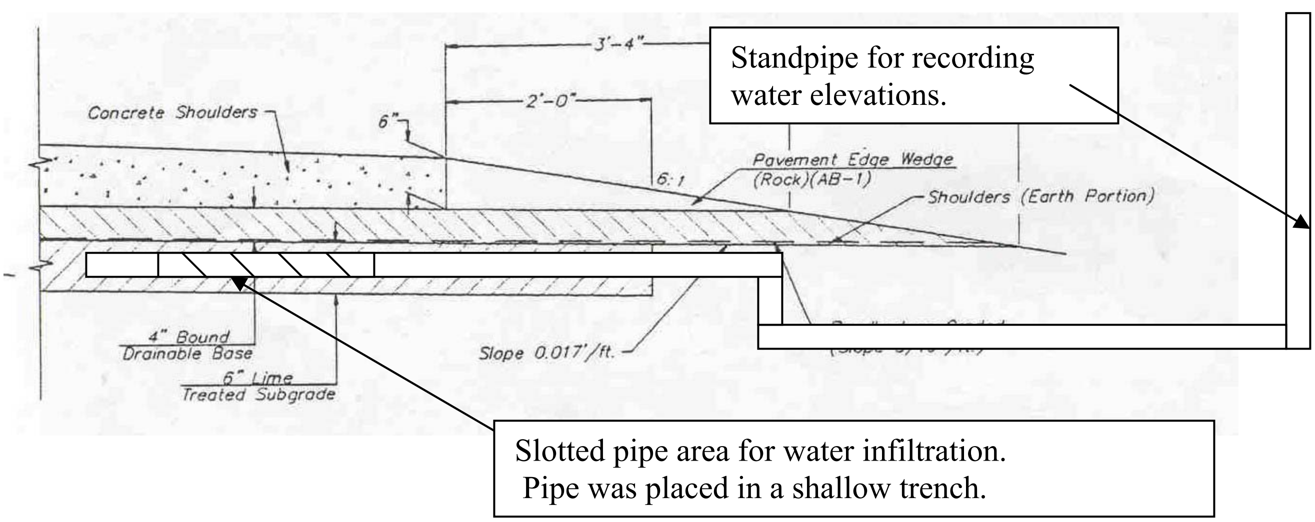


Figure 2

FIGURE 3: Dennis Estes and Kirk Fredrichs Performing Standpipe Water Elevation Reading

The vibrating strip piezometers were the other type of instrumentation installed. These were located in the wheel paths at the soil sub-grade and base interface. These were connected to a readout station on the side-slope. Technician observations during data recordings of the vibrating strip piezometers indicated wide variances in the vibrating strip responses due to traffic. This made it impossible to detect any residual pore pressures in the base material or increased pressures caused by the traffic as it passed over the sensors. Therefore, the vibrating strip piezometers were unreliable for measuring the effectiveness of the drainage layer and the conclusions of this report will be based on the standpipe analysis.

Figure 4

Typical standpipe setup for testing. The PVC tube is the standpipe.
The black tubes access the piezometers for reading purposes.

CURRENT CONDITIONS

The US-50 Project has experienced serious distress. See the "Special Pavement Investigation" report by Richard A. Barezinsky, P. E. dated June of 2002. This report indicates the failure of the Lime Treated Subgrade separator layer and its infiltration into the drainable base. This is leaving voids in the subgrade allowing the pavement slab to settle. See the photo in Figure 8 below. Jim Brennan's report of July 7, 1999 did indicate that all of the test sections were performing as expected except for the section with the bound drainable base wedge prior to this failure of the subgrade.

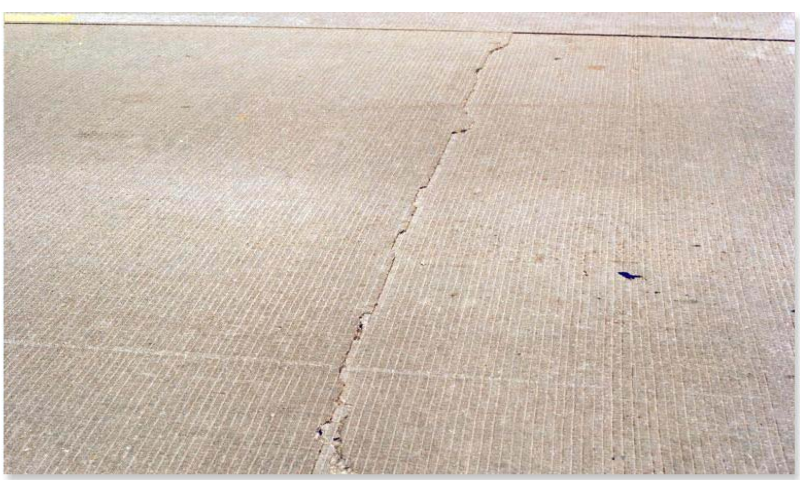


Figure 5

Typical Mid-Panel Crack on the US-50 Project. This one is at Station 339+98.

The US-400 Project is still performing in the expected manner. The final readings taken in 2003 indicate the absence of water in the base indicating the daylighted drainable base is functioning. Jim Brennan's July 7, 1999 report indicated similar performance between the partially daylighted system using AS-1 aggregate wedge as the edge drain system with one exception. The edge drain system was plugged initially and required cleaning to perform properly, a typical requirement for edge drain systems. The photos of this project illustrate a vast difference from the US-50 photos as this Lime Treated Sub-grade is still performing as designed.

Figure 6

Condition of US-400 at Station 349+95 viewed to the East.

CONCLUSIONS

Several conclusions can be drawn from this investigation of various drainage systems. The first is that a daylighted drainage system of various configurations can perform as well as a system using a positive drainage system of pipes and outlets. The second is that a partially daylighted system can also perform in a like manner. Both of these systems do not have the inherent problems of a pipe system plugging. However, the winter freeze condition can affect the outflow of water from the base and may not be desirable in harsh freeze environments. This could also be true for an edge drain system.

Another conclusion is the inadequacy of piezometers to detect pore pressures in a drainable base environment. Our technicians observed wide variances in the vibrating strip responses due to traffic. This made it impossible to detect any residual pore pressures in the base material or increased pressures caused by the traffic as it passed over the sensors. Therefore, the vibrating strip piezometers were unreliable for measuring the effectiveness of the drainage layer. Further study is needed to find a method of determining pore pressure and moisture content of a drainable base environment.

Any future study of daylighted drainable bases should also incorporate a tipping bucket system in the edge drain system control section. This is desirable to obtain approximate quantities of moisture actually being removed by the drainage system. We could accept on theory that the daylighted sections are removing approximately the same amount of water as the edge drain and outlet section. This assumption is based on the pavement having the same infiltration rate since the drainage system should not affect infiltration.

A final conclusion is the need for an acceptable separator layer. This layer, whether aggregate, fabric or cemented soils, must prevent the infiltration of fine particles into the drainable base layer. The US-50 project illustrates the failure possible if fines move into the base plugging the drainage system and removing the constant support that a subgrade is to provide to the pavement section.

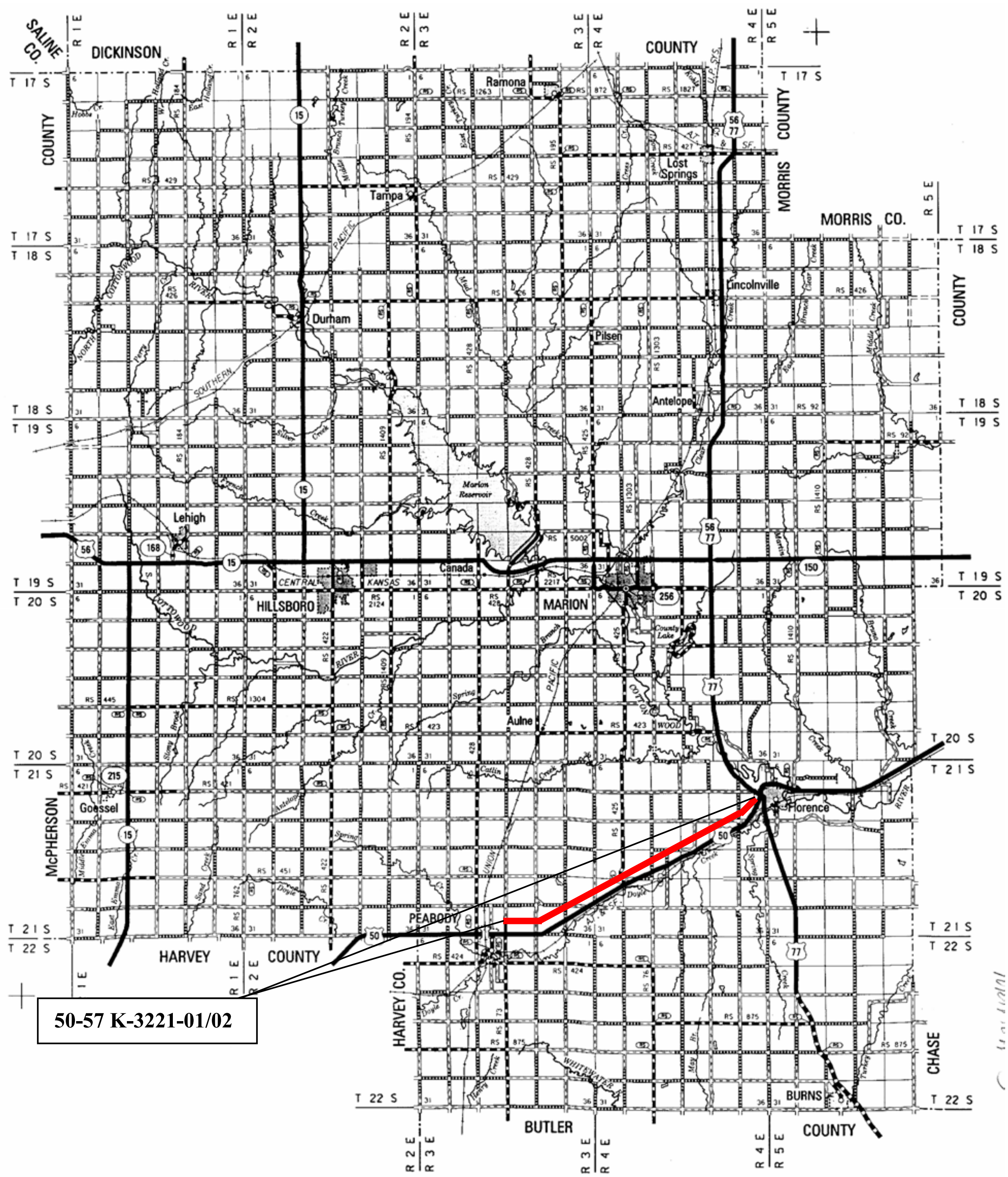
REFERENCES

Barezinsky, Richard 2002 *US-50 Special Pavement Investigation* Kansas Department of Transportation, Topeka, Kansas

Brennan, James J. 1999 *Drainable Base Efficiencies* Kansas Department of Transportation, Topeka, Kansas

APPENDIX A: PROJECT LOCATIONS

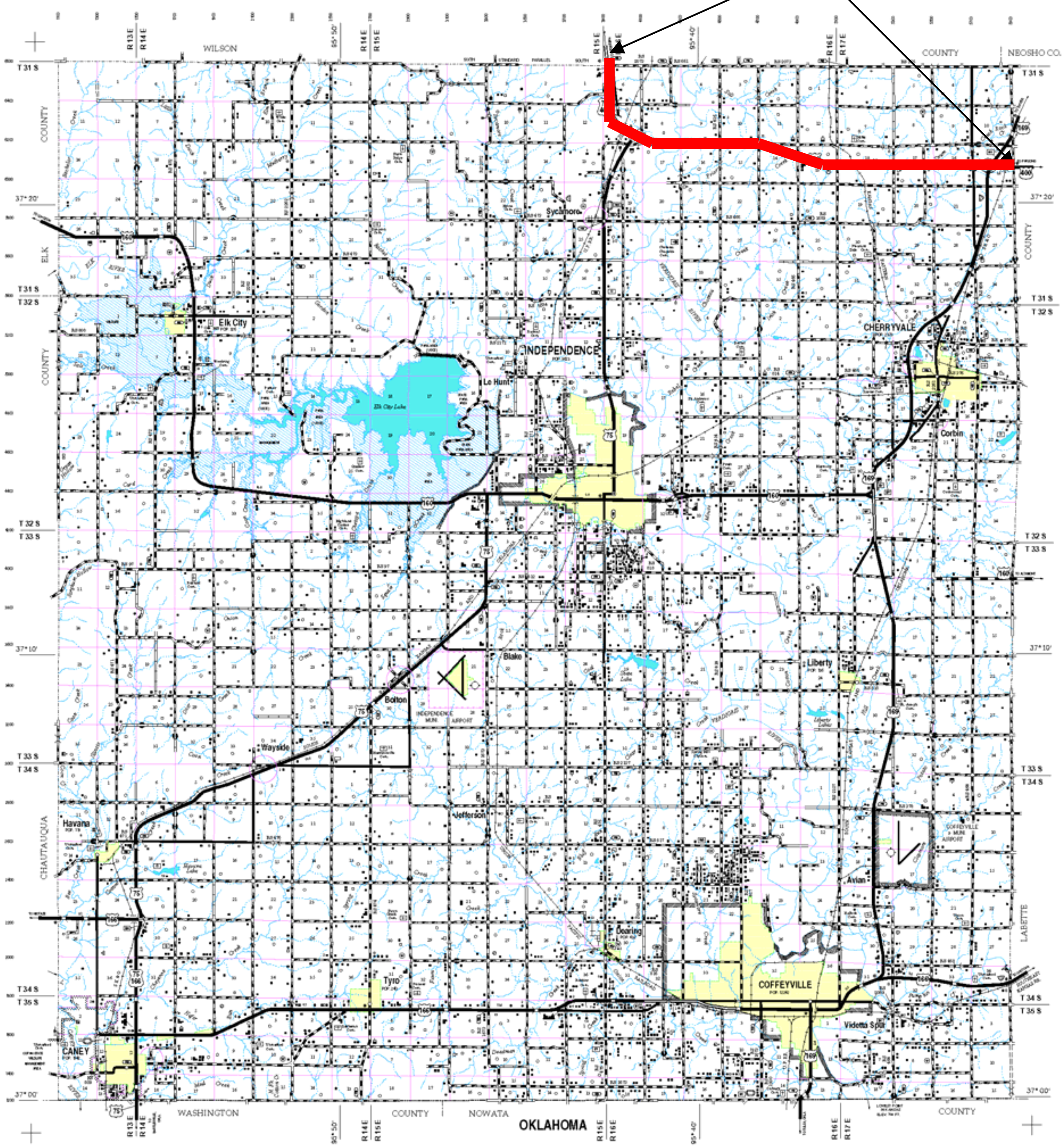
Figure 10
Marion County Map
Project 50-57 K-3221-02 Location



APPENDIX A: PROJECT LOCATIONS (continued)

Figure 11
Montgomery County Map

Project: 96-63 K-4892-02



APPENDIX B: PROJECT PROFILES

Figure 12
US-50 Profile Indicating Areas of Distress

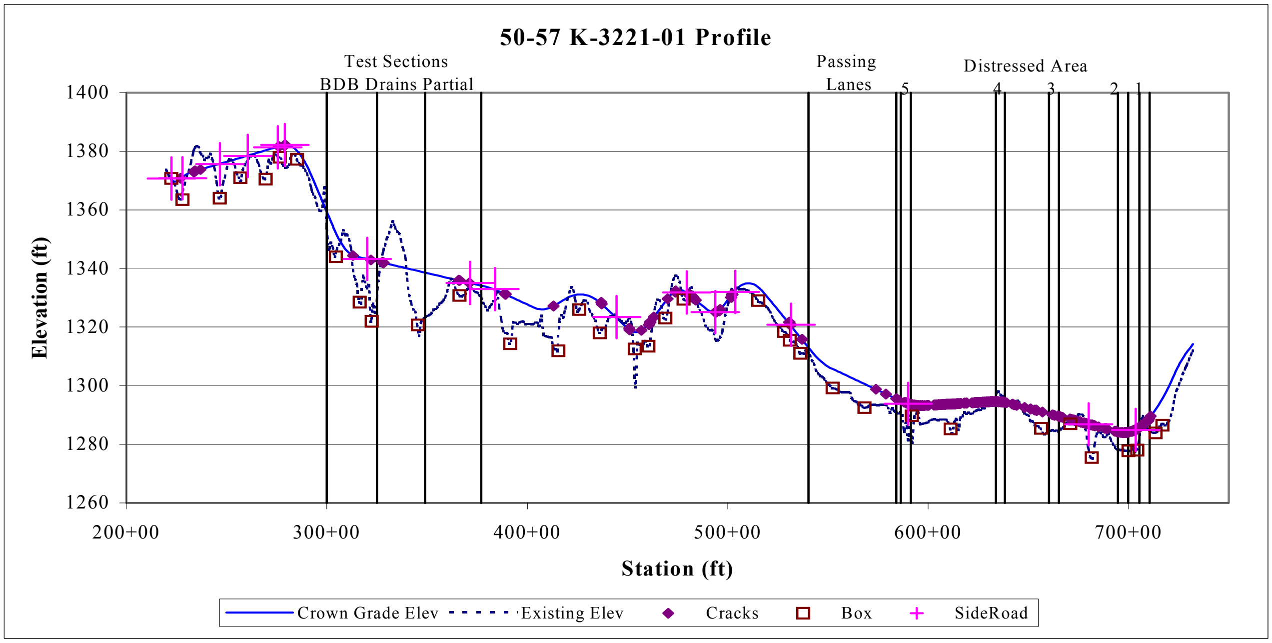
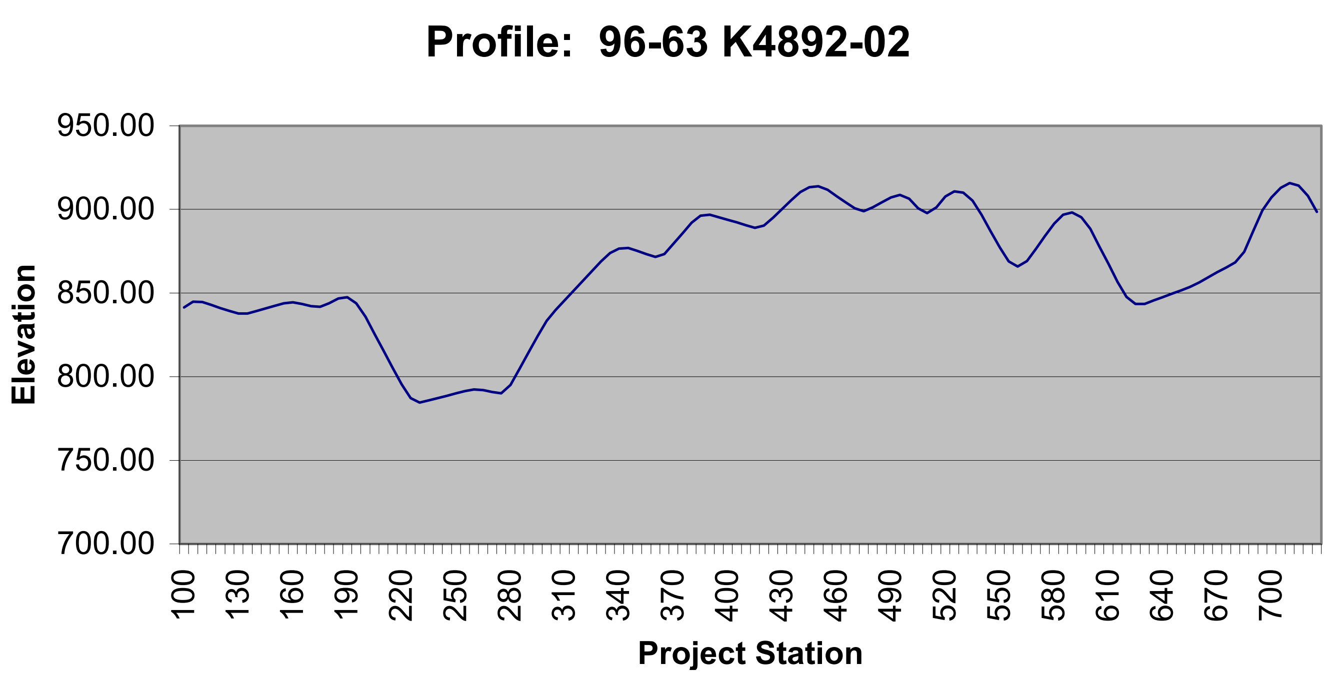


Figure 13



APPENDIX C: TEST SECTION DESIGNS

Edge Drain System Design

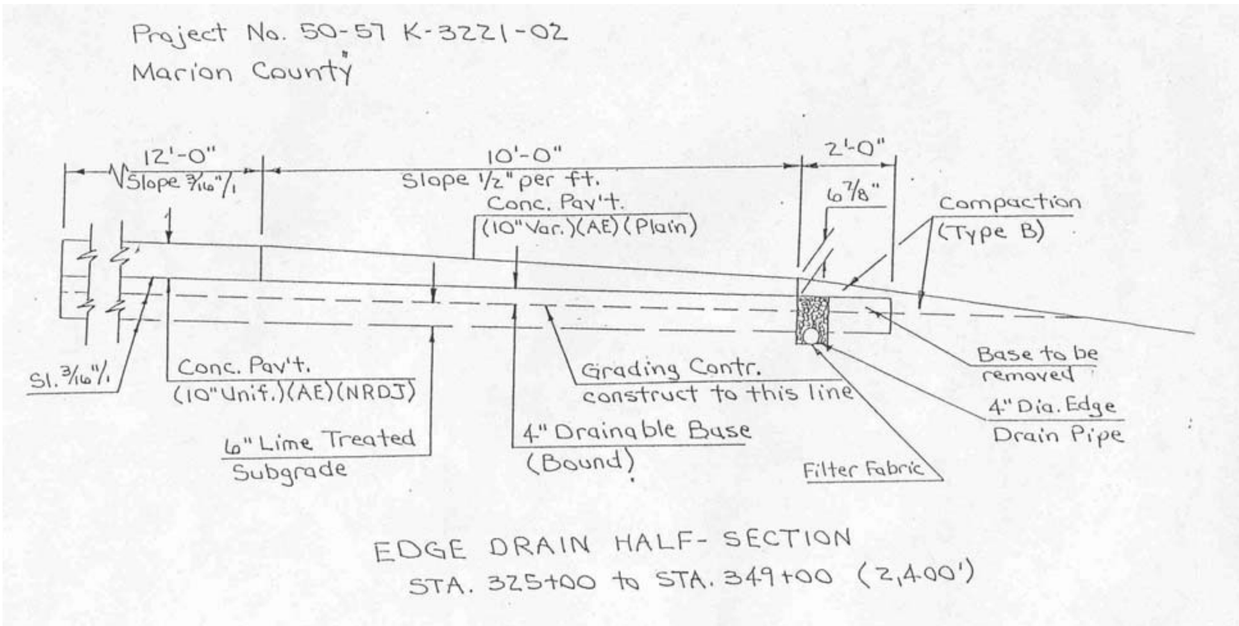


Figure 14

Partially Daylighted Drainable System (AB-1 with Fabric)

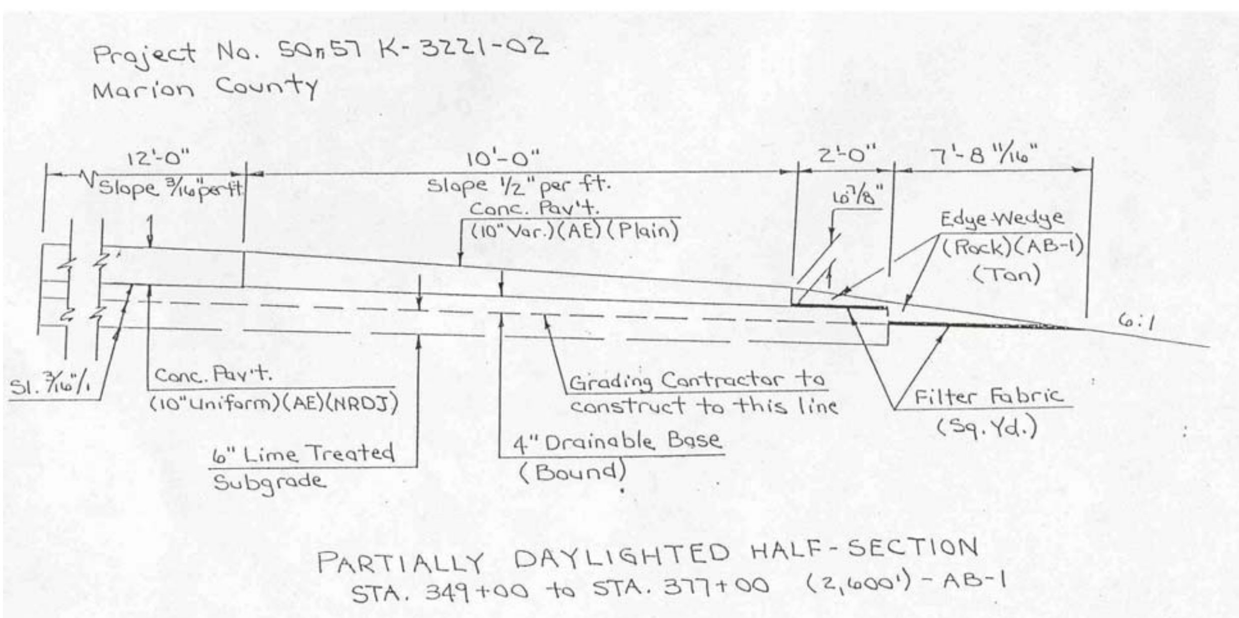


Figure 15

APPENDIX C: (continued)

Partially Daylighted System (AB-1 without Fabric)

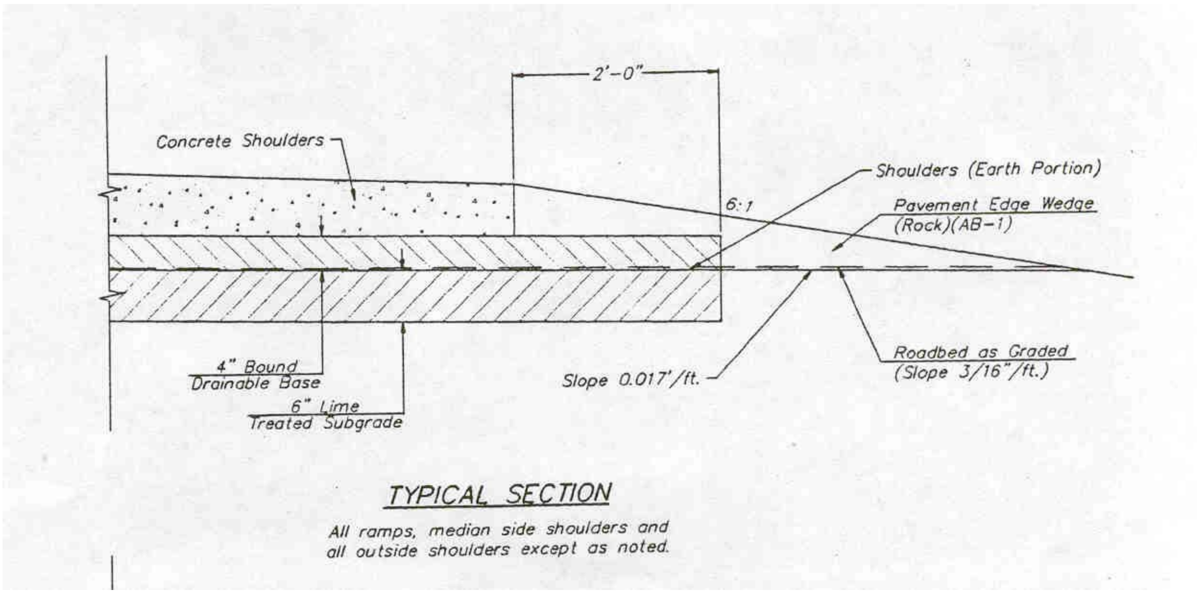


Figure 16

Partially Daylighted Drainable System (AS-1)

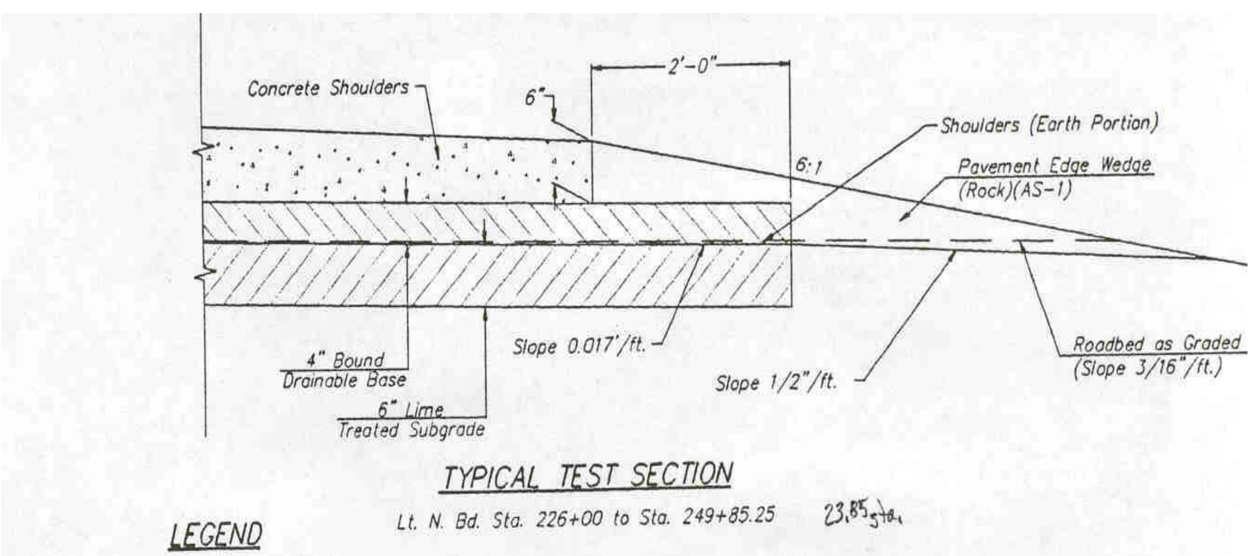


Figure 17

APPENDIX C (continued)

Partially Daylighted Drainable System (BDB)

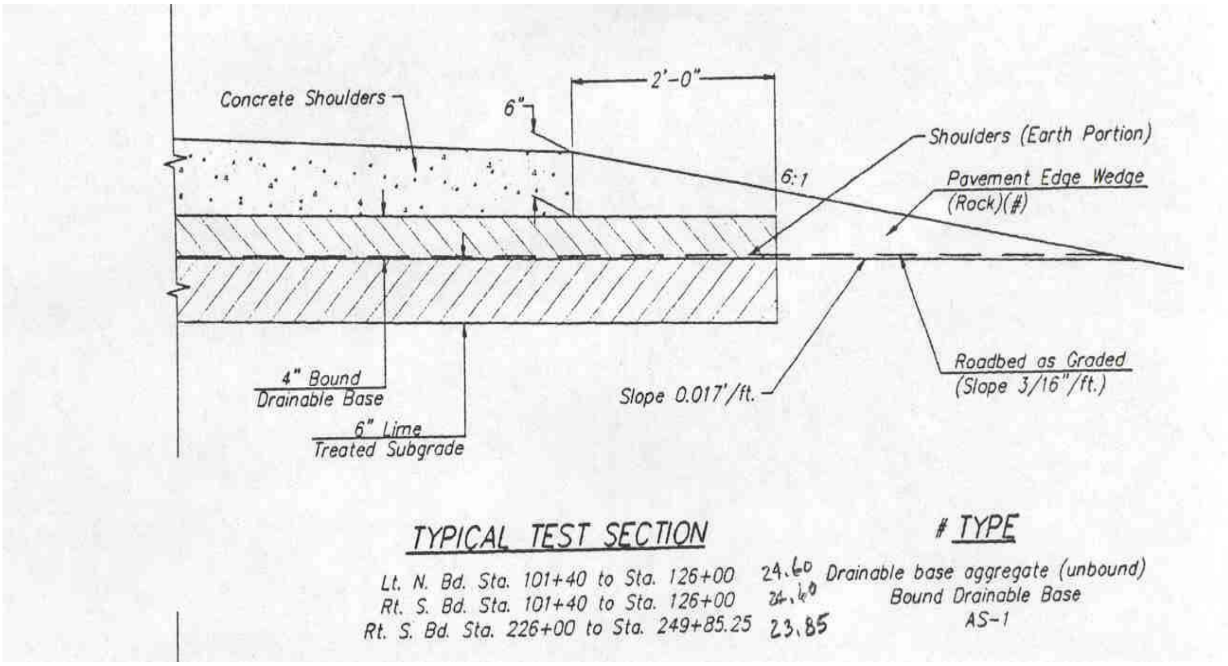


Figure 18

APPENDIX D (Bound Drainable Base Specification)

KANSAS DEPARTMENT OF TRANSPORTATION
SPECIAL PROVISION TO THE
STANDARD SPECIFICATIONS, 1990 EDITION

DIVISION 300

BOUND DRAINABLE BASE

1.0 DESCRIPTION.

This item shall consist of an open-graded drainable base composed of mineral aggregate and a binder of asphalt cement, Portland cement or fly ash. The aggregates and binder shall be uniformly mixed and placed on a prepared foundation in accordance with these specifications and shall conform to the lines, grades, thickness and typical cross sections shown on the Plans.
This special provision is intended to allow Contractors the widest latitude in selecting a drainable base that will meet the drainage needs for the project. Contractors are to select the binder type that is best suited to provide a working platform commensurate with the Contractor's individual needs or desires. The Contractor shall assume full responsibility for the suitability of the mix design to provide a stable working platform for subsequent paving operations.

BID ITEM
Drainable Base (Bound) (*)
* Denotes Thickness

2.0 MATERIALS.

2.1 Materials shall comply with the requirements specified below:

Fly Ash	Section 2005
Asphalt Cement	Section 1201
Portland Cement (Type I, II, III)	Section 2001
Water	Section 2400
Aggregates for Drainable Base	Spec. Prov. 90M-126 (latest revision)

2.2 Mix Design

(a) The drainable base mix design shall comply with the permeability and strength requirements that follow:

Permeability for the mixture shall be 300 meters per day or greater. Permeability test specimens shall be prepared and permeability tests shall be performed in accordance with KDOT laboratory test method KT-MR5, Permeability for Base Course Materials.

APPENDIX D (Bound Drainable Base Specification)

The acceptable range of seven (7) day compressive strengths for mix designs bound with fly ash or Portland cement shall be 4.1 MPa to 8.3 MPa. The test specimens shall be 150 mm x 150 mm cylinders prepared and tested in accordance with KT-MR1 procedures, modified to account for the rapid curing of the sample.

Drainable bases that are bound with asphalt cement shall have a minimum Marshall stability value of 2.75 MPa. The test specimens shall be prepared and tested in accordance with KT-14.

(b) Tests to determine compliance of the mix design with the above requirements shall be the responsibility of the Contractor and shall be performed by a qualified laboratory.

The Contractor shall submit the final mix design, permeability test results, and compressive strength or Marshall stability results as appropriate, to the Geotechnical Engineer for approval prior to placing the drainable base material on the project. The Department may choose to verify any or all of the Contractors test results prior to approving the mix design. After approval of the mix design, any proposed changes to the approved mix design must be submitted to the Geotechnical Engineer for approval prior to implementing such changes. The Geotechnical Engineer may require the Contractor to provide permeability tests results before approving any design changes.

Note: The Engineer may choose to test the permeability of the actual mix being used on the project. If it is determined that the permeability is less than the specified minimum then the Engineer may require the Contractor to suspend placement of the drainable base material and submit a new mix design.

3.0 CONSTRUCTION REQUIREMENTS.

Construction requirements shall be in accordance with the standard specifications except for the following:

3.1 Spreading of the Base Material - The base material shall be spread to the lines and grades shown on the Plans. Any material which becomes mixed with soil or other contaminants shall be removed and replaced with fresh mixture.

3.2 Compaction of the Drainable Base Material - After spreading and/or trimming, the base material shall be uniformly compacted by making a minimum of 2 coverages with a steel wheeled roller. The compaction process may be adjusted on the project by the Contractor with approval of the Engineer to assure uniform compaction of the drainable base material. In areas not accessible by the roller, the base material shall be compacted by hand methods.

If after spreading and compacting the base is not to the required lines and grade, the Contractor shall trim the base by means of an electronically controlled machine utilizing string line controls for grade. The Engineer reserves the right to direct the Contractor to suspend all operations if the Contractor produces excessive fines in the trimming process which are viewed by the Engineer to be detrimental to the permeability of the base. Appropriate corrections to the trimming process shall be made by the Contractor prior to beginning again.

After compaction of the drainable base, the Contractor shall protect the surface from damage and/or contamination. If, during anytime prior to placement of the succeeding pavement course the integrity of the drainable base is disturbed, the area shall be removed and replaced with

APPENDIX D (Bound Drainable Base Specification)

new material and compacted to conform to the original lines and grades. Any removed material shall not be reincorporated into the drainable base or other drainage features.

3.3 Curing of the Drainable Base Material - If the Contractor chooses to use fly ash or Portland cement as a binder then uniform curing procedures will be necessary. The Contractor will be required to provide a curing plan to the Engineer so that the Engineer can monitor the procedure to assure that the drainable base is receiving a uniform cure throughout the project.

4.0 METHOD OF MEASUREMENT.

Drainable base shall be measured by the square meter complete in place.

5.0 BASIS OF PAYMENT.

The amount of completed and accepted work, measured as provided above, shall be paid for at the Contract unit price per square meter for "Drainable Base (Bound) (*)", which price shall be full compensation for furnishing all aggregates, binder, preparation, mixing, placing, curing of the drainable base and for all labor, equipment, tools and incidentals necessary to complete this item.

Water used in the preparation of the subgrade, in the drainable base material and for curing the completed base will be subsidiary to the bid item "Drainable Base, (Bound) (*)".

NOTE: Very open mixes may necessitate that the Contractor supply additional concrete since the surface voids of the drainable base will create an additional concrete demand. The Contractor may at his expense, choose to place a permeable separation fabric/paper over the base to reduce the need for additional concrete.

03-20-96 M&R(SP) (AJG)
typographical correction 03-05-99

007030017	Drainable Base Aggregate (LS)	TONS	90M/P-126-R*PRQA

APPENDIX E (Standpipe Water Elevations)
A reading of 0.00 indicates the water elevation is at the bottom of the base at the shoulder pavement edge.

US-50 Station 242+00
Fully Daylighted Bound Drainable Base with AB-1 Rock Shoulder Wedge

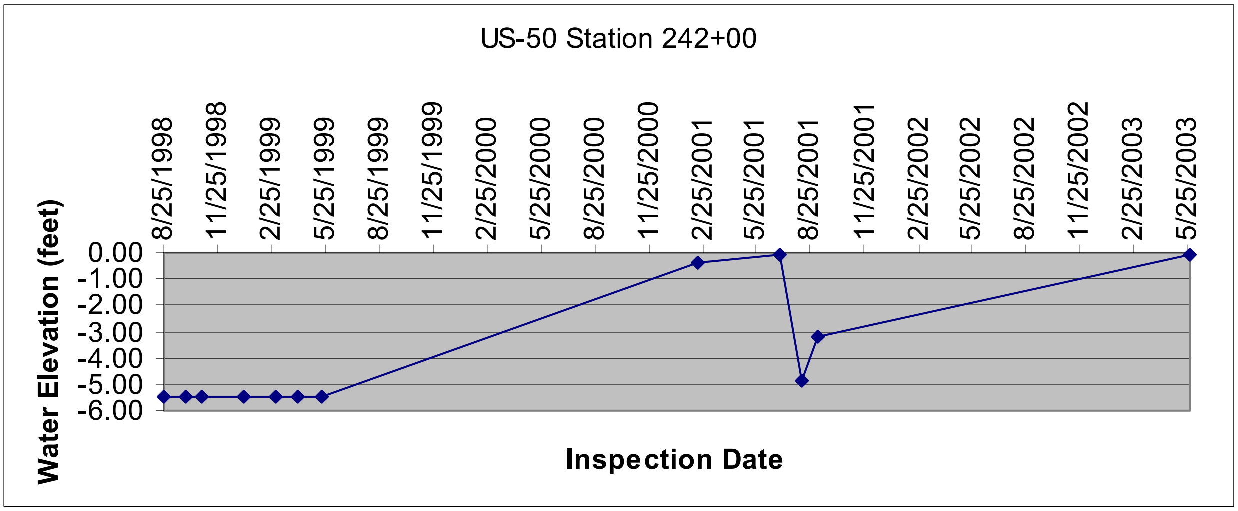


Figure 19

US-50 Station 312+95
Fully Daylighted Bound Drainable Base with Bound Drainable Base Shoulder Wedge

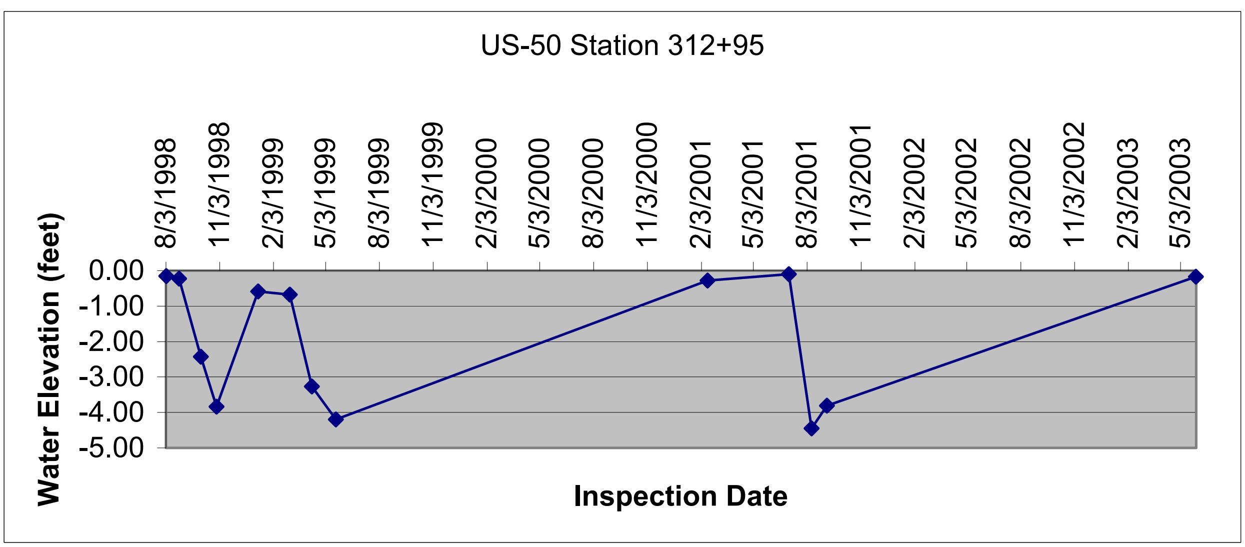


Figure 20

APPENDIX E (Standpipe Water Elevations continued)
A reading of 0.00 indicates the water elevation is at the bottom of the base at the shoulder pavement edge.

US-50 Station 339+97.5
Bound Drainable Base with Edge Drains

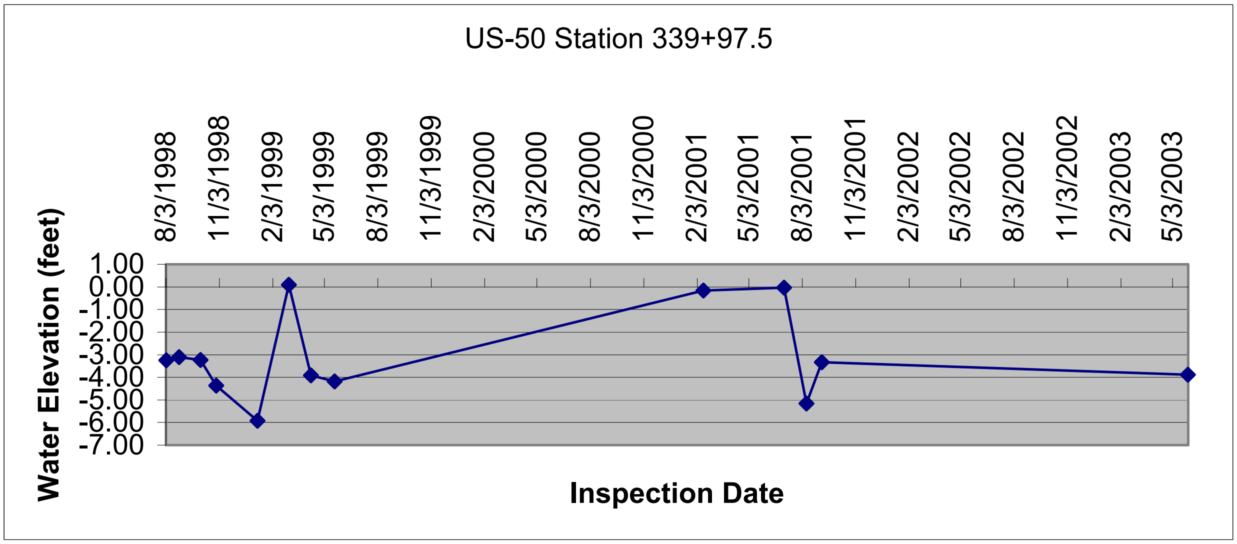


Figure 21

US-50 Station 365+03
Partially Daylighted Bound Drainable Base with AB-1 Shoulder Wedge

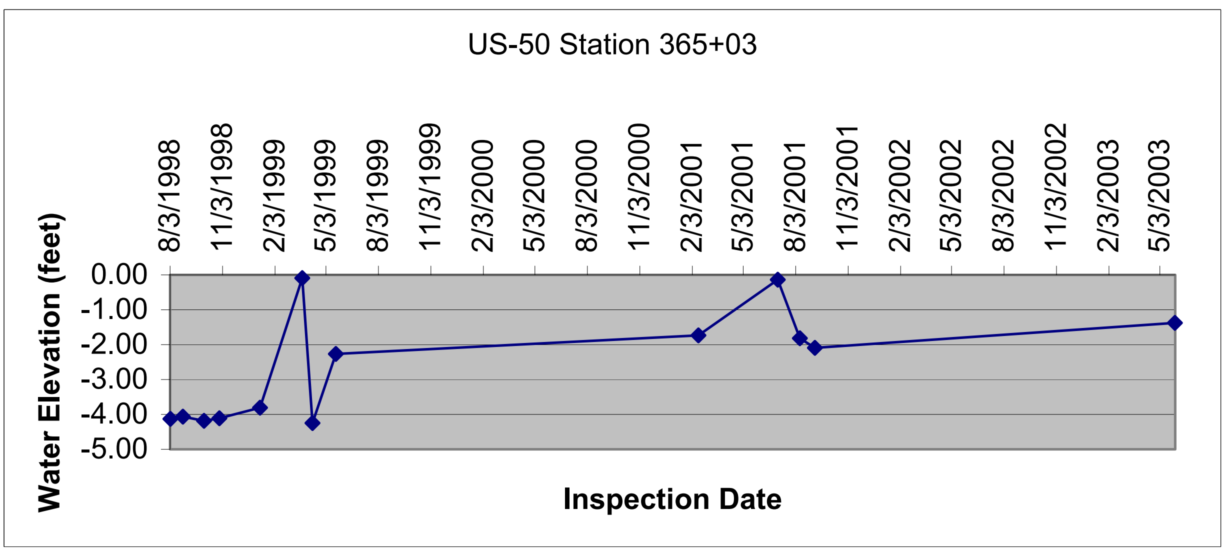


Figure 22

APPENDIX E (Standpipe Water Elevations continued)
A reading of 0.00 indicates the water elevation is at the bottom of the base at the shoulder pavement edge.

K-96 Station 115+00 Northbound
Partially Daylighted Bound Drainable Base Section with the Wedge Aggregate being Unbound Drainable Base Aggregate

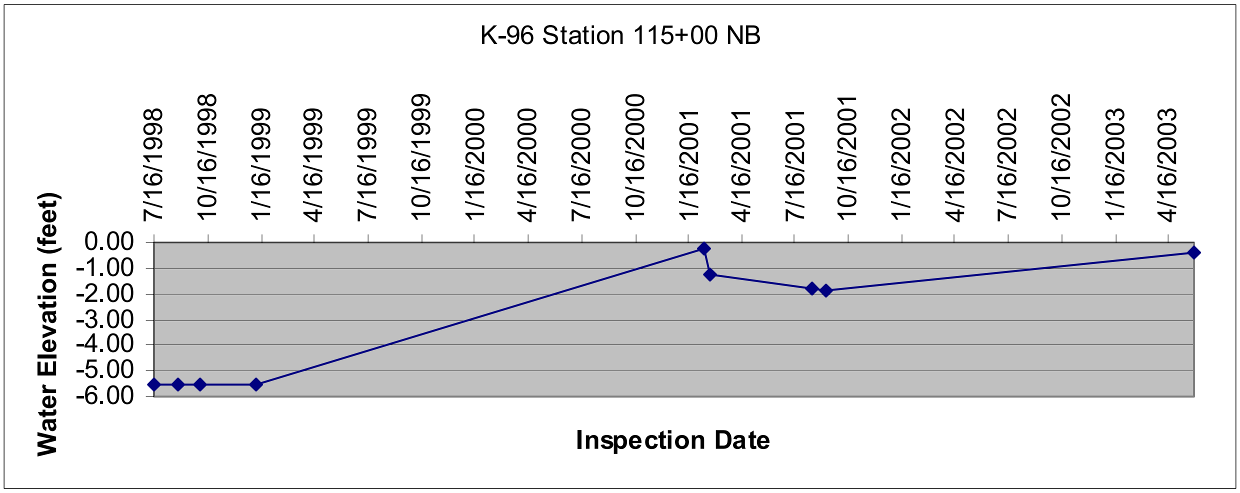


Figure 23

K-96 Station 115+00 Southbound
Partially Daylighted Bound Drainable Base Section with the Wedge Bound Drainable Base

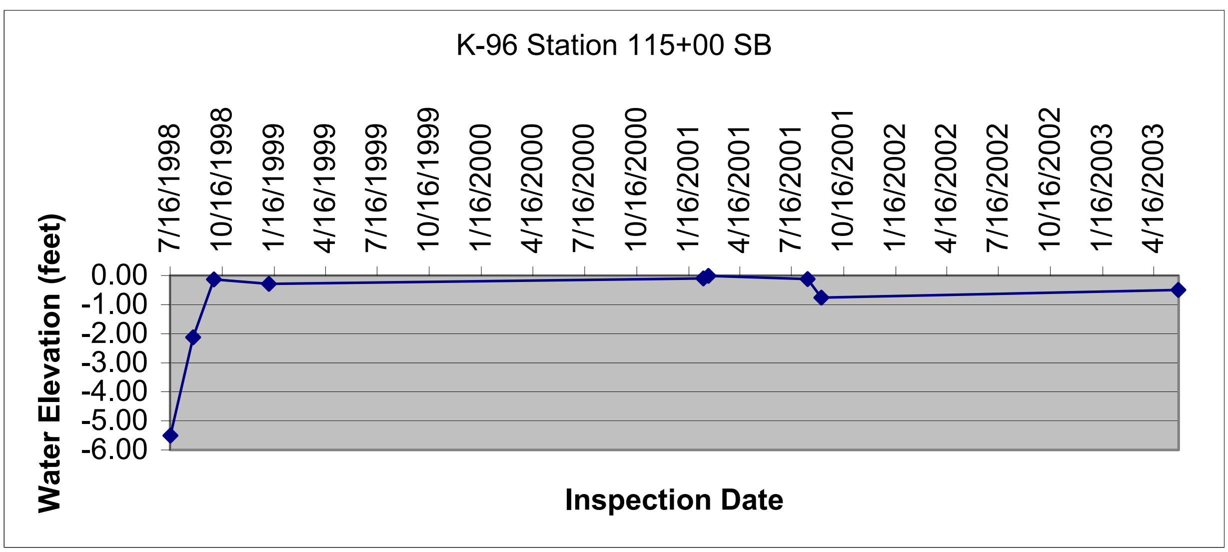


Figure 24

APPENDIX E (Standpipe Water Elevations continued)
A reading of 0.00 indicates the water elevation is at the bottom of the base at the shoulder pavement edge.

K-96 Station 236+47.4 Northbound
Partially Daylighted Bound Drainable Base Section with the Wedge Aggregate being AS-1

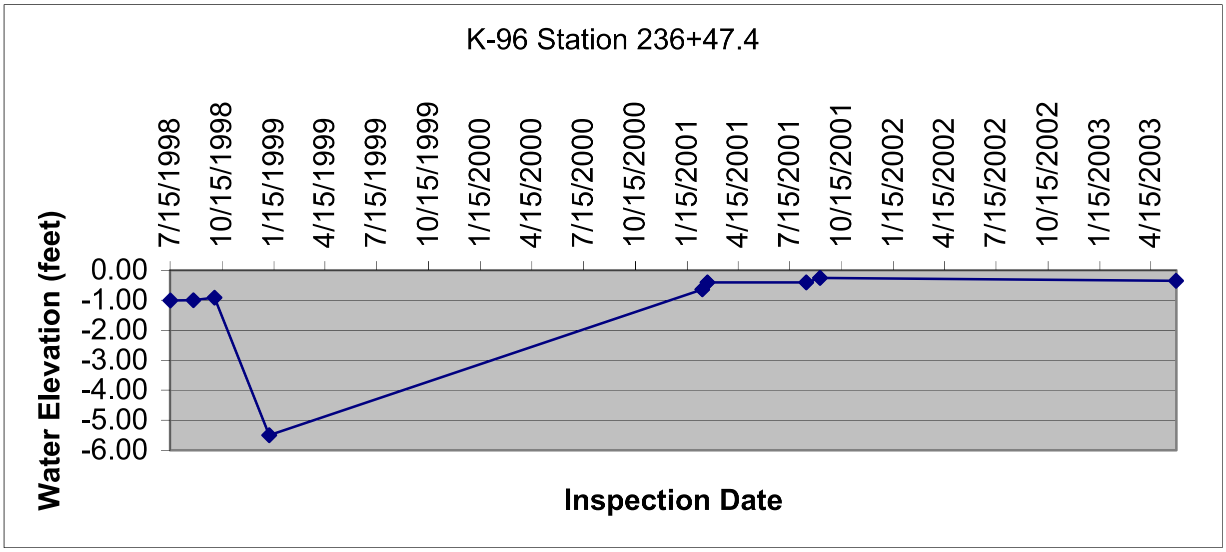


Figure 25

K-96 Station 259+55.4 Northbound (Standpipe Destroyed)
Partially Daylighted Bound Drainable Base Section with the Wedge Aggregate being AB-1

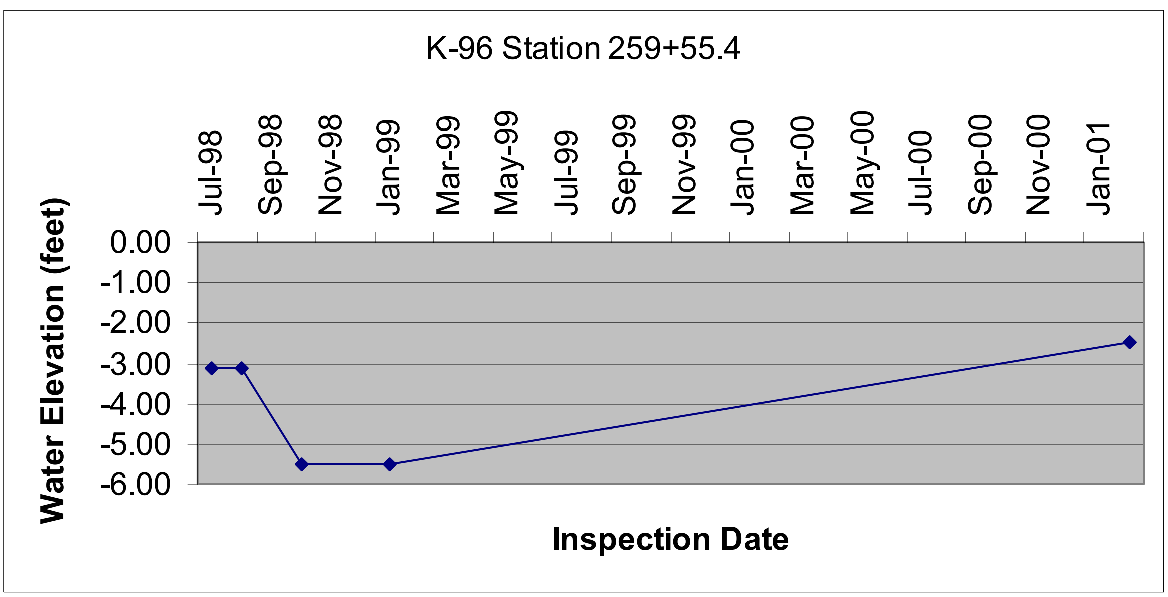


Figure 26

APPENDIX E (Standpipe Water Elevations continued)
A reading of 0.00 indicates the water elevation is at the bottom of the base at the shoulder pavement edge.

K-96 Station 342+90
Bound Drainable Base with Edge Drain System

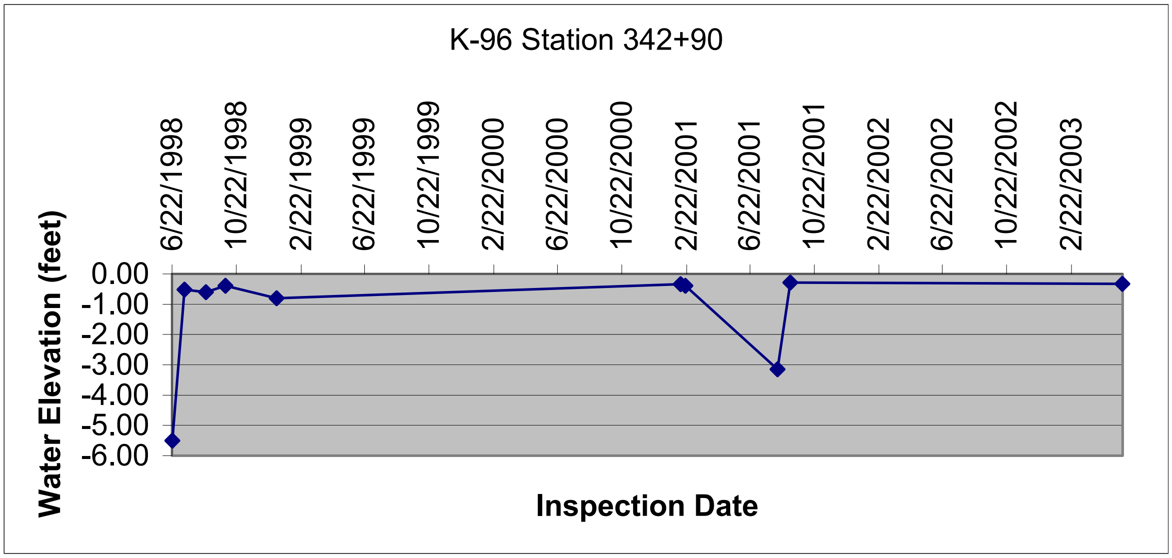


Figure 27

K-96 Station 349+95
Fully Daylighted Bound Drainable Base System

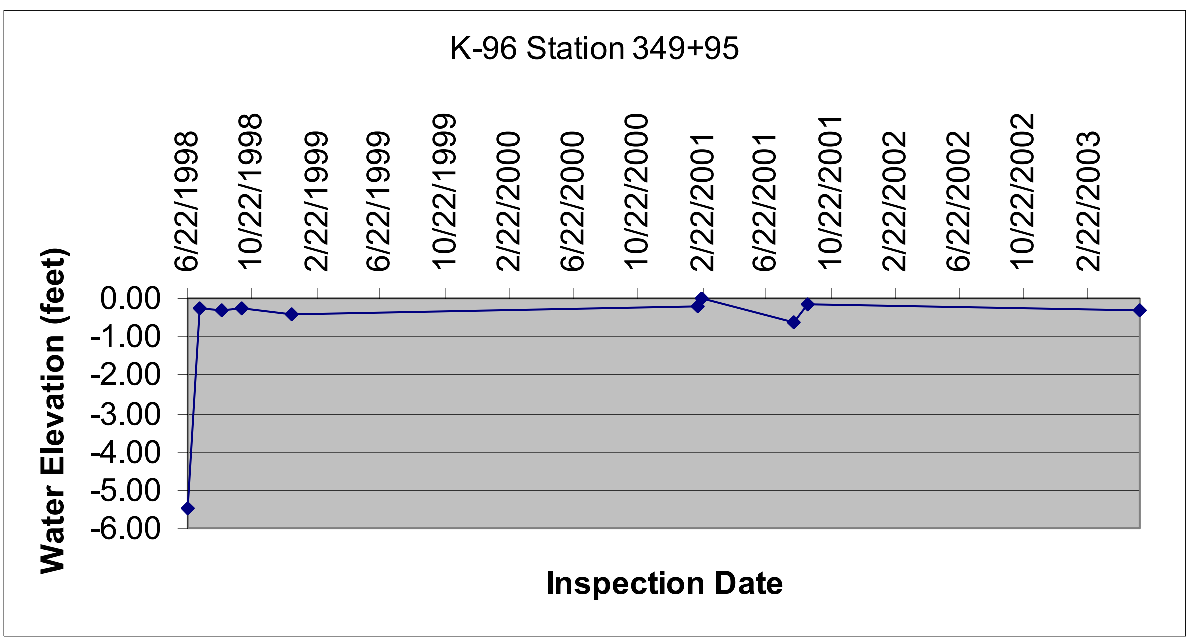


Figure 28