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November 14, 2018

Ms. Barcy F. McNeal, Secretary
Ohio Power Siting Board
Docketing Division
180 East Broad Street, 11th Floor
Columbus, Ohio 43215-3793

Re: Supplement to Application
Case No. 18-1360-EL-BGN
In the Matter of the Application of Hardin Solar Energy II LLC for a Certificate of Environmental Compatibility and Public Need to Construct a Solar-Powered Electric Generation Facility in Hardin County, Ohio.

Dear Ms. McNeal:

On October 12, 2018, Hardin Solar Energy II LLC ("Applicant") filed an application with the Ohio Power Siting Board ("Board") for a Certificate of Environmental Compatibility and Public Need to Construct a Solar-Powered Electric Generation Facility in Hardin County, Ohio ("Application"). At this time, the Applicant is filing this supplement, in order to provide the Board with additional information regarding the items listed below. The Applicant requests that the Board consider the following supplemental information as part of the Application in this matter:

1. **<u>Attachment 1</u>**: In response to O.A.C. Rules 4906-4-03(B)(2)(i) and 4906-4-06(F)(3) (pages 16 and 35 of the Application, respectively), the Applicant stated that the Road Survey Report would be provided shortly following the filing of the Application. At this time, the Applicant is providing, as Attachment 1, the Road Survey Report completed by Barr dated October 2018.

2. **<u>Attachment 2</u>**: In response to O.A.C. Rule 4906-4-06(F)(5) (page 36 of the Application), the Applicant stated that the Decommissioning Report completed by Stantec Consulting Services would be provided shortly following submittal of the Application. At this time, the Applicant is providing, as Attachment 2, the Decommissioning Report dated November 12, 2018.

3. **<u>Attachment 3</u>**: In response to O.A.C. Rule 4906-4-08(A)(3)(a) through (d) (pages 50 through 52 of the Application), the Applicant stated that it would provide a report from Hankard Environmental Inc. addressing the sound levels for construction and operation of the Facility. At this time, the Applicant is providing, as Attachment 3, the Sound Analysis dated November 12, 2018.

4. **Attachment 4**: In response to O.A.C. Rule 4906-4-08(D)(4) (beginning at page 81), the Applicant provided Exhibit R to the Application, the Summary of the Viewshed Analysis and Aesthetic Resources Inventory conducted by TRC Environmental Corporation ("TRC") dated October 2018. At this time, the Applicant is providing an update to Exhibit R dated November 2018. This updated Exhibit R includes an analysis by TRC based on the most current proposed layout for the Facility that was filed with the Application. This updated Exhibit R supersedes and replaces the Exhibit R that was filed with the Application on October 12, 2018.

5. **Attachment 5**: In response to O.A.C. Rule 4906-4-03, the Applicant provided Figure 03-2, the Project Area Aerial Map dated October 3, 2018. At this time, the Applicant is providing an update to Figure 03-2 dated November 9, 2018, which includes an additional right-of-way. This right-of-way was considered in the studies and reports already submitted with the Application. This updated Figure 03-2 supersedes and replaces the Figure 03-2 that was filed with the Application on October 12, 2018.

The original of this supplement to the Application has been filed electronically. In addition, 5 complete paper copies and 10 USB drives containing the supplemental information to the Application have been provided.

We are available, at your convenience, to answer any questions you may have.

Respectfully submitted,

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CMTP:ap
Enclosures

Cc: Jim O'Dell

CERTIFICATE OF SERVICE

The Ohio Power Siting Board's e-filing system will electronically serve notice of the filing of this document on the parties referenced in the service list of the docket card who have electronically subscribed to this case. In addition, the undersigned certifies that a copy of the foregoing document is also being served upon the person below via electronic mail this 14th day of November, 2018.

<u>/s/ Christine M.T. Pirik</u>
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COLUMBUS 39579-24 101257v2

Hardin Solar Energy II LLC
Case No. 18-1360-EL-BGN
Supplement to Application
November 14, 2018

Attachment 1

Road Survey Report

by Barr
October 2018

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Hardin Solar - Phase 2

Road Survey Report

Prepared for
Invenergy, LLC

October 2018

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Road Survey Report

October 2018

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Certifications

I hereby certify that this report was prepared by me or under my direct supervision and that I am a duly licensed Professional Engineer under the laws of the State of Ohio.

Matthew B. Johnson
E-74181

11/09/18
Date

1.0 Executive Summary

A road survey consisting of a video survey, a pavement visual assessment, and identification of areas of concern from visual inspection was performed for Hardin Solar, a proposed solar power development located in Hardin County, Ohio.

Hardin Solar roads were divided into sections and each section was inspected with at least two sample units. The existing pavement visual assessments using ASTM Pavement Condition Index (PCI) survey are generally as follows:

- County Road 110 – good condition.
- Township Road 120
  - From OH-235 to east 7,800 feet – satisfactory to good condition.
  - From 7,800 feet to 11,700 feet – very poor to poor condition.
  - From 11,700 feet to OH-195 – aggregate road not subject to pavement condition indexing.
- County Road 130
  - From OH-235 to OH-195 – satisfactory to good condition.
  - From OH-195 to CR-65 – fair to good condition.
  - From CR-65 to CR-75 – good condition.
- Township Road 65 – satisfactory condition.
- County Road 65 – good condition.
- County Road 75 – satisfactory condition.
- County Road 150 – satisfactory to good condition.

1.1 Recommendations

Access to the project site from TR-120 is adequate only up to the western edge of the project boundary. The section of road within the project boundary is in poor condition with extensive block cracking and pavement weathering. Due to the extents of the damage, localized corrections cannot be implemented. It is recommended to avoid these areas.

Access to the project site from the remainder of the roads is adequate. There are no mitigations expected for these roads. It is recommended to monitor the edge cracking along the roads during project construction to ensure there is no additional deterioration created with construction traffic.

2.0 Introduction

Invenergy, LLC (Invenergy) is planning to construct Hardin Solar, a proposed solar power development located in Hardin County, Ohio. See Appendix A – Figure 1 for site layout

Invenergy requested a road survey to identify areas of concern and possible mitigation measures which will allow them to permit the site with Ohio Power Siting Board. The road survey consists of a video survey, a pavement visual assessment, and identification of areas of concern from visual inspection. Road surveys are limited to township and local roads. State Highways are not evaluated under this report.

The studies described in this report were performed in at different times and represent the road conditions at the time of the survey. Portions of CR-110 were completed in November 2016, CR-75 and roads leading to substation were completed in August 2017, and the remainder of the roads were completed in December 2017.

3.0 Project information

The project site is located south of the town of Alger, OH in Hardin County. It is expected that delivery vehicles will access the project from State Highway 235 (OH-235).

The following roads were surveyed as part of the Hardin Solar project:

- County Road 110 (CR-110) from OH-235 to OH-195.
- Township Road 120 (TR-120) from OH-235 to OH-195.
- County Road 130 (CR-130) from OH-235 to CR-75.
- Township Road 65 (TR-65) from CR-130 to approximately 1,500 feet to the south of the road's 90º bend.
- County Road 65 (CR-65) from CR-130 to approximately 4,500 feet to the north.
- County Road 75 (CR-75) from OH-67 to CR-130.
- County Road 150 (CR-150) from OH-237 to OH-195.

See Appendix A – Figure 2 for road survey location.

Additional to the roads mentioned above, Township Road 45 (TR-45) from TR-120 to CR-110 was to be included in the analysis. However, upon visual inspection it was determined that there was no asphalt or gravel present for the road and the road was not included in the report.

4.0 Road Study

4.1 General

The conditions of existing pavement were assessed visually and rated using ASTM D 6433 Road and Parking Lots Pavement Condition Index Surveys (See Appendix B). This method divides the pavement into branches that are divided into sections. Each section is then divided into sample units. The units are inspected, and the severity of the distress is assessed visually. The quantity of each distress is estimated to calculate the pavement condition index (PCI). The PCI of the inspected section is determined based on the PCI of the units inspected within the section. Once the PCI of the section is determined, the PCI is used to rate the road using Table 4-1.

In addition to the PCI rating, a video survey was performed for each one of the roads to document the current conditions of the roads. These videos are provided separately and are not part of this report, however, the videos can be used to confirm the distresses described in this document.

Table 4-1 Standard PCI Rating Scale

PCI RANGE	RATING
85 - 100	GOOD
70 - 85	SATISFACTORY
55 - 70	FAIR
40 – 55	POOR
25 – 40	VERY POOR
10 – 25	SERIOUS
0 - 10	FAILED

It is important to note that the PCI does not measure structural capacity, it only provides an objective and rational basis for determining maintenance and repair needs.

Sample units within a section were randomly selected depending on the homogeneity of the pavement section. For roads where more distresses were observed, more sections were selected for measurement. Barr did not find necessary to run a statistical analysis for determining the minimal number of sample units, due to the homogeneity on the number and types of distresses observed.

4.2 Results

Hardin Solar roads were divided into sections. Each section was inspected with at least two sample units.

4.2.1 County Road 110

CR-110 was inspected from the intersection with OH-235 to the intersection with OH-195. CR-110 was divided into two sections for the inspection.

Section 1 from OH-235 to 114+00 was generally in good condition. Minimal distresses such as shoulder drop-off, sags and bumps were observed, specifically on the bridge at the intersection with CR-35 and at the irrigation ditch crossings by the Van Deurzen Dairy site. Heavy traffic from harvesting activities was observed coming in and out of the Van Deurzen Dairy site, and travelling east on CR-110 to the adjacent fields. During the site visit no significant distresses were observed in this section of road product of the heavy traffic. Two sample units were selected within the section.

Table 4-2 CR-110 Section 1 – PCI Summary

SAMPLE UNIT	PCI	RATING
1	97	GOOD
2	97	GOOD

Figure 4-1 CR-110 Section 1

Section 2 from 114+00 to OH-195 was observed in good condition. No signs of distresses other than shoulder drop-offs and a slight depression cause by traffic at a field entrance.

Two sample units were selected within the section.

Table 4-3 CR-110 Section 2 – PCI Summary

SAMPLE UNIT	PCI	RATING
1	88	GOOD
2	77	SATISFACTORY

Figure 4-2 CR-110 Section 2

4.2.2 Township Road 120

TR-120 was inspected from the intersection with OH-235 to OH-195 (Scioto River). TR-120 was divided into six sections for the inspection.

Section 1 from OH-235 to 25+00 was observed generally in good condition. The pavement has minimal distresses such as bleeding.

Two sample units were selected within the section.

Table 4-4 TR-120 Section 1 – PCI Summary

SAMPLE UNIT	PCI	RATING
1	97	GOOD
2	97	GOOD

Figure 4-3 TR-120 Section 1

Section 2 from 25+00 to 51+50 was observed generally in good condition. The pavement has minimal distresses such as bleeding and edge cracking. One small area had patching and a slight depression.

Two sample units were selected within the section.

Table 4-5 TR-120 Section 2 – PCI Summary

SAMPLE UNIT	PCI	RATING
1	72	SATISFACTORY
2	90	GOOD

Figure 4-4 TR-120 Section 2

Section 3 from 51+50 to 78+00 was observed generally in satisfactory condition. The pavement has some distress such as bleeding, edge cracking, and small depressions. There are two areas where the asphalt was removed to place culverts. One of the areas was patched with bituminous asphalt and is in good condition, while the other was only filled with gravel and is starting to erode creating a dip.

Three sample units were selected within the section.

Table 4-6 TR-120 Section 3 – PCI Summary

SAMPLE UNIT	PCI	RATING
1	78	SATISFACTORY
2	70	SATISFACTORY
3	92	GOOD

Figure 4-5 TR-120 Section 3

Section 4 from 78+00 to 104+00 was observed generally in poor condition. The pavement has several patches, bumps and dips, and block cracking throughout the section. The ride quality for this section is poor. Driving at posted speeds presents vehicle vibration. Some areas require slight reduction in speed due to the size of the bumps and dips.

Four sample units were selected within the section.

Table 4-7 TR-120 Section 4 – PCI Summary

SAMPLE UNIT	PCI	RATING
1	12	SERIOUS
2	68	FAIR
3	34	VERY POOR
4	42	POOR

Figure 4-6 TR-120 Section 4

Section 5 from 104+00 to 117+00 was observed generally in poor condition. The pavement has several patches, bumps and sags, shoulder drop-off, pavement weathering, and block cracking throughout the section. The ride quality for this section is poor. Driving at posted speeds presents vehicle vibration. Some areas require slight reduction in speed due to the size of the bumps and dips.

Four sample units were selected within the section.

Table 4-8 TR-120 Section 5 – PCI Summary

SAMPLE UNIT	PCI	RATING
1	12	SERIOUS
2	32	VERY POOR
3	60	FAIR
4	38	VERY POOR

Figure 4-7 TR-120 Section 5

Section 6 from 117+00 to OH-195 is gravel with no bituminous asphalt. Gravel roads are not subject to pavement assessment. Gravel section seems in good shape. Areas measured show over 6 inches of new gravel over a subgrade that appears to be a base for the old road section. There are no visible washout areas. Ride is consistent without any mayor bumps.

Figure 4-8 TR-120 Section 6

4.2.3 County Road 130

CR-130 was inspected from the intersection with OH-235 to CR-75. CR-130 was divided into seven sections for the inspection.

Section 1 from OH-235 to 29+00 was observed generally in good condition. The pavement has minimal distresses such as bleeding, edge cracking and some small bumps.

Four sample units were selected within the section.

Table 4-9 CR-130 Section 1 – PCI Summary

SAMPLE UNIT	PCI	RATING
1	90	GOOD
2	92	GOOD
3	82	SATISFACTORY
4	82	SATISFACTORY

Figure 4-9 CR-130 Section 1

Section 2 from 29+00 to 56+00 was observed generally in good condition. The pavement has minimal distresses such as edge cracking, transverse cracking and shoulder drop-off.

Four sample units were selected within the section.

Table 4-10 CR-130 Section 2 – PCI Summary

SAMPLE UNIT	PCI	RATING
1	90	GOOD
2	96	GOOD
3	88	GOOD
4	80	SATISFACTORY

Figure 4-10 CR-130 Section 2

Section 3 from 56+00 to 82+00 was observed generally in satisfactory condition. The pavement has some distress such as edge cracking, shoulder drop-off and small area of raveling.

Four sample units were selected within the section.

Table 4-11 CR-130 Section 3 – PCI Summary

SAMPLE UNIT	PCI	RATING
1	76	SATISFACTORY
2	96	GOOD
3	78	SATISFACTORY
4	78	SATISFACTORY

Figure 4-11 CR-130 Section 3

Section 4 from 82+00 to OH-195 was observed generally in good condition. The pavement has minimal distresses such as edge cracking, transverse cracking, shoulder drop-off and raveling.

Three sample units were selected within the section.

Table 4-12 CR-130 Section 4 – PCI Summary

SAMPLE UNIT	PCI	RATING
1	88	GOOD
2	72	SATISFACTORY
3	90	GOOD

Figure 4-12 CR-130 Section 4

Section 5 from OH-195 to CR-65 road conditions varied along its length from fair to good with the majority of the distresses at the intersections with other roads, bridges or at farm entrances. Such distresses were mainly classified as low, with few areas where the severity was deemed as medium.

Eight sample units were selected within the section.

Table 4-13 CR-130 Section 5 – PCI Summary

SAMPLE UNIT	PCI	RATING
1	76	SATISFACTORY
2	89	GOOD
3	87	GOOD
4	72	SATISFACTORY
5	67	FAIR
6	70	SATISFACTORY
7	64	FAIR
8	68	FAIR

Figure 4-13 CR-130 Section 5

Section 6 from CR-65 to TR-65 was observed generally in good condition. The pavement has minimal distresses such as bleeding. The road differs from previous sections with a width of 17 feet compared to 20 feet.

Two sample units were selected within the section.

Table 4-14 CR-130 Section 6 – PCI Summary

SAMPLE UNIT	PCI	RATING
1	90	GOOD
2	93	GOOD

Figure 4-14 CR-130 Section 6

Section 7 from TR-65 to CR-75 was observed generally in good condition. The pavement has minimal distresses such as edge cracking.

Three sample units were selected within the section.

Table 4-15 CR-130 Section 7– PCI Summary

SAMPLE UNIT	PCI	RATING
1	79	SATISFACTORY
2	92	GOOD
3	92	GOOD

Figure 4-15 CR-130 Section 7

4.2.4 Township Road 65

TR-65 was inspected from CR-130 to approximately 1,500 feet to the south of the road's 90º bend. TR-65 was divided into two sections for the inspection.

Section 1 from CR-130 to the road's 90º bend was observed generally in satisfactory condition. The pavement has minimal distresses such as bleeding and edge cracking. Some areas had small potholes and corrugation resulting in lower rating. Five sample units were selected within the section.

Table 4-16 TR-65 Section 1 – PCI Summary

SAMPLE UNIT	PCI	RATING
1	69	FAIR
2	69	FAIR
3	84	SATISFACTORY
4	92	GOOD
5	92	GOOD

Figure 4-16 TR-65 Section 1

Section 2 from the road's 90º bend to 1,500 feet to the south was observed generally in satisfactory condition, except for the curve section, where fair conditions were observed due to a depression at the internal lane, and therefore the ride quality was noticeably affected. The rest of the inspected section had low distresses such as bleeding and edge cracking.

Three sample units were selected within the section.

Table 4-17 TR-65 Section 2 – PCI Summary

SAMPLE UNIT	PCI	RATING
1	59	FAIR
2	84	SATISFACTORY
3	82	SATISFACTORY

Figure 4-17 TR-65 Section 2

4.2.5 County Road 65

CR-65 was inspected from the intersection with CR-130 to approximately 4,500 feet the north. CR-95 was measured at 20-foot wide and was observed in good condition. Low severity distresses such as shoulder drop-off and patching were observed, especially near the intersection with CR-130.

Three sample units were selected for this road.

Table 4-18 CR-65 – PCI Summary

SAMPLE UNIT	PCI	RATING
1	87	GOOD
2	87	GOOD
3	86	GOOD

Figure 4-18 CR-65

4.2.6 County Road 75

CR-75 was inspected from the intersection with OH-67 to CR-130. CR-75 was divided into four sections for the inspection.

Section 1 from OH-67 to 33+50 was observed generally in satisfactory condition. The pavement has minimal distresses such as edge cracking. Six sample units were selected within the section.

Table 4-19 CR-75 Section 1 – PCI Summary

SAMPLE UNIT	PCI	RATING
1	78	SATISFACTORY
2	86	GOOD
3	91	GOOD
4	78	SATISFACTORY
5	78	SATISFACTORY
6	80	SATISFACTORY

Figure 4-19 CR-75 Section 1

Section 2 from 33+50 to TR-154 was observed generally in satisfactory condition. The pavement has minimal distresses such as edge cracking. There are small areas with longitudinal and transverse cracking as well as patching.

Four sample units were selected within the section.

Table 4-20 CR-75 Section 2 – PCI Summary

SAMPLE UNIT	PCI	RATING
1	79	SATISFACTORY
2	80	SATISFACTORY
3	78	SATISFACTORY
4	88	GOOD

Figure 4-20 CR-75 Section 2

Section 3 from TR-154 to the north intersection with CR-150 was observed generally in satisfactory condition. The pavement has minimal distresses such as bleeding and edge cracking. One sample unit had potholes, bleeding and edge cracking and seemed only in "fair" condition.

Six sample units were selected within the section.

Table 4-21 CR-75 Section 3 – PCI Summary

SAMPLE UNIT	PCI	RATING
1	60	FAIR
2	80	SATISFACTORY
3	88	GOOD
4	86	GOOD
5	78	SATISFACTORY
6	77	SATISFACTORY

Figure 4-21 CR-75 Section 3

Section 4 from the north intersection with CR-150 to CR-130 was observed generally in satisfactory condition. The pavement has minimal distresses such as longitudinal cracking, transverse cracking and edge cracking. There were a couple of areas with patching that resulted in a “fair” rating for one sample unit. Six sample units were selected within the section.

Table 4-22 CR-75 Section 4 – PCI Summary

SAMPLE UNIT	PCI	RATING
1	70	SATISFACTORY
2	67	FAIR
3	75	SATISFACTORY
4	88	GOOD
5	84	SATISFACTORY
6	93	GOOD

Figure 4-22 CR-75 Section 4

4.2.7 County Road 150

CR-150 was inspected from the intersection with OH-235 to OH-195. The road was measured with a 20 foot with, and it was averaged in satisfactory condition with low severity distresses such as edge cracking, patching and shoulder drop-offs.

Four sample units were selected for this road.

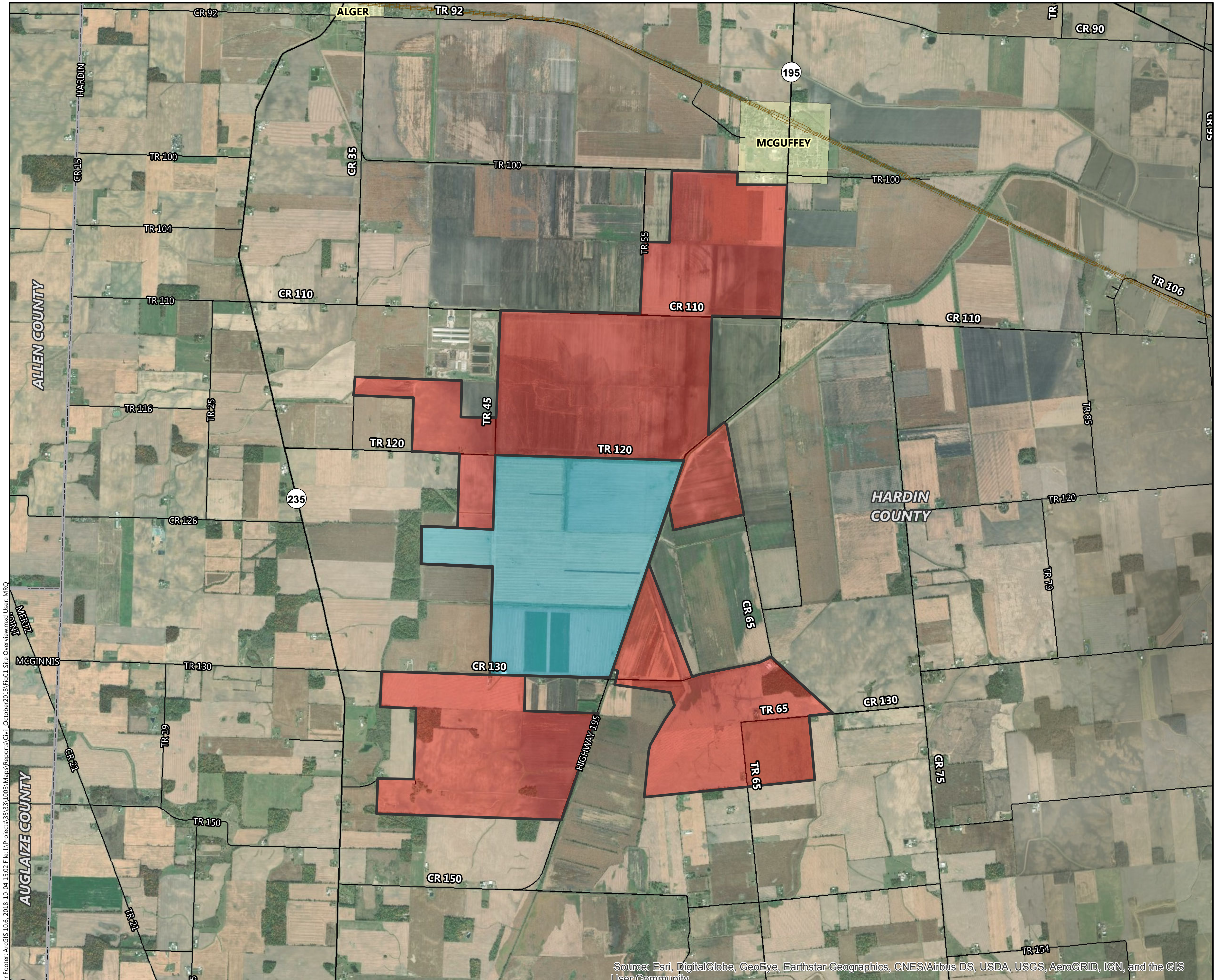
Table 4-23 CR-150 – PCI Summary

SAMPLE UNIT	PCI	RATING
1	88	GOOD
2	77	SATISFACTORY
3	90	GOOD
4	71	SATISFACTORY

Figure 4-23 CR-150

Appendix A

Figures



Phase 1 Boundary
Phase 2 Boundary
City Boundary
County Boundary

Feet
3,500 0 3,500

Meters
1,000 0 1,000

Figure 1

SITE OVERVIEW
Hardin Solar Project - Phase 2
Invenergy LLC
Hardin County, Ohio

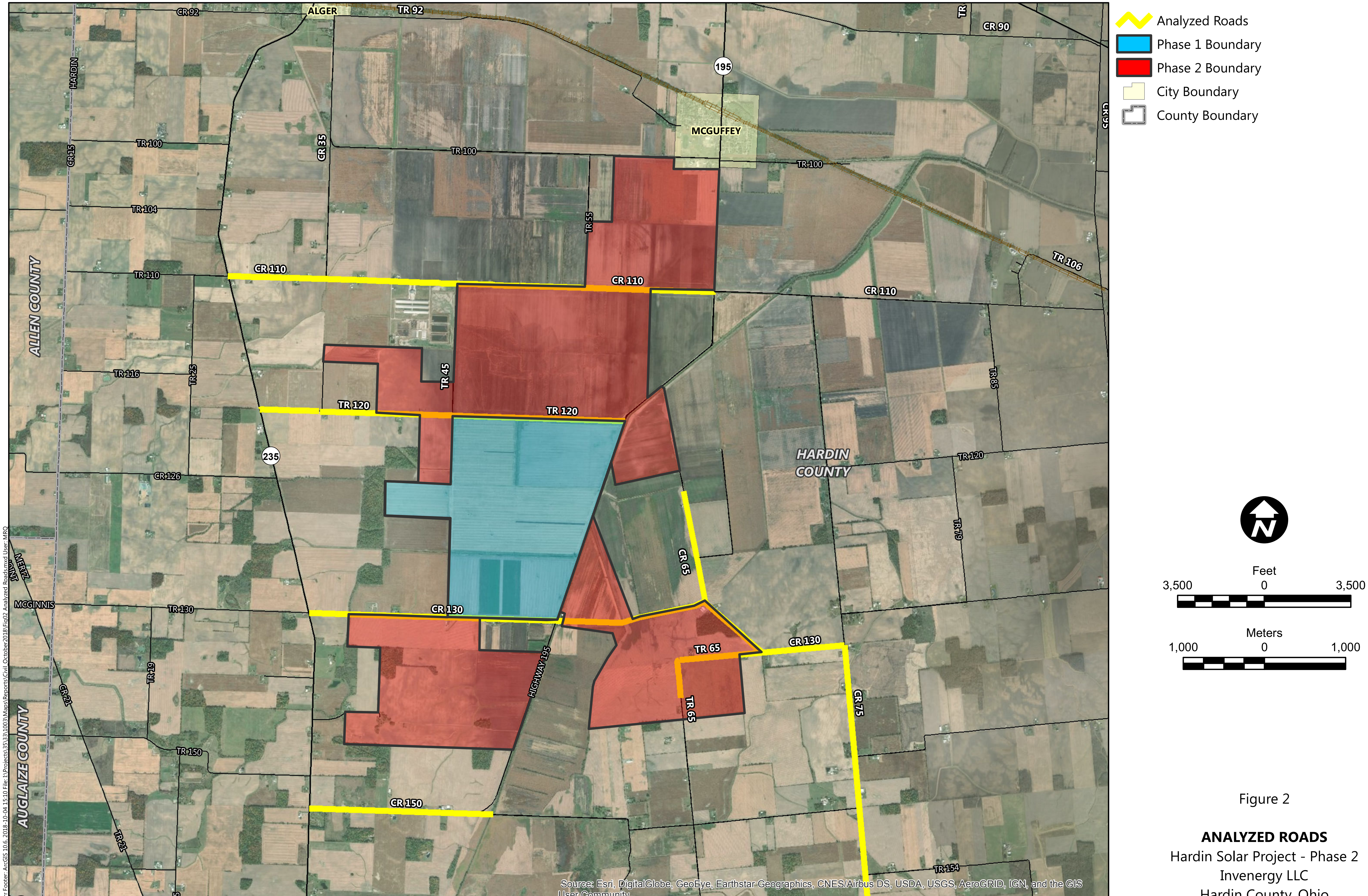


Figure 2

ANALYZED ROADS

Hardin Solar Project - Phase 2

Invenergy LLC

Hardin County, Ohio

Appendix B

ASTM D 6433-07

Standard Practice for Roads and Parking Lots Pavement Condition Index Surveys

Designation: D 6433 – 07

Standard Practice for Roads and Parking Lots Pavement Condition Index Surveys[1]

This standard is issued under the fixed designation D 6433; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This practice covers the determination of roads and parking lots pavement condition through visual surveys using the Pavement Condition Index (PCI) method of quantifying pavement condition.

1.2 The PCI for roads and parking lots was developed by the U.S. Army Corps of Engineers (**1, 2**).[2] It is further verified and adopted by DOD and APWA.

1.3 The values stated in inch-pound units are to be regarded as the standard. The SI units given in parentheses are for information only.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* Specific precautionary statements are given in Section 6.

2. Terminology

2.1 *Definitions of Terms Specific to This Standard:*

2.1.1 *additional sample*—a sample unit inspected in addition to the random sample units to include nonrepresentative sample units in the determination of the pavement condition. This includes very poor or excellent samples that are not typical of the section and sample units, which contain an unusual distress such as a utility cut. If a sample unit containing an unusual distress is chosen at random it should be counted as an additional sample unit and another random sample unit should be chosen. If every sample unit is surveyed, then there are no additional sample units.

2.1.2 *asphalt concrete (AC) surface*—aggregate mixture with an asphalt cement binder. This term also refers to surfaces constructed of coal tars and natural tars for purposes of this practice.

2.1.3 *pavement branch*—a branch is an identifiable part of the pavement network that is a single entity and has a distinct function. For example, each roadway or parking area is a separate branch.

2.1.4 *pavement condition index (PCI)*—a numerical rating of the pavement condition that ranges from 0 to 100 with 0 being the worst possible condition and 100 being the best possible condition.

2.1.5 *pavement condition rating*—a verbal description of pavement condition as a function of the PCI value that varies from "failed" to "excellent" as shown in Fig. 1.

2.1.6 *pavement distress*—external indicators of pavement deterioration caused by loading, environmental factors, construction deficiencies, or a combination thereof. Typical distresses are cracks, rutting, and weathering of the pavement surface. Distress types and severity levels detailed in Appendix X1 for AC, and Appendix X2 for PCC pavements must be used to obtain an accurate PCI value.

2.1.7 *pavement sample unit*—a subdivision of a pavement section that has a standard size range: 20 contiguous slabs (±8 slabs if the total number of slabs in the section is not evenly divided by 20 or to accommodate specific field condition) for PCC pavement, and 2500 contiguous square feet, ± 1000 ft^2 (225 ± 90 m^2), if the pavement is not evenly divided by 2500 or to accommodate specific field condition, for AC pavement.

2.1.8 *pavement section*—a contiguous pavement area having uniform construction, maintenance, usage history, and condition. A section should have the same traffic volume and load intensity.

2.1.9 *portland cement concrete (PCC) pavement*—aggregate mixture with portland cement binder including nonreinforced and reinforced jointed pavement.

2.1.10 *random sample*—a sample unit of the pavement section selected for inspection by random sampling techniques, such as a random number table or systematic random procedure.

3. Summary of Practice

3.1 The pavement is divided into branches that are divided into sections. Each section is divided into sample units. The type and severity of pavement distress is assessed by visual

[1] This practice is under the jurisdiction of ASTM Committee E17 on Vehicle - Pavement Systems and is the direct responsibility of Subcommittee E17.41 on Pavement Testing, Evaluation, and Management Methods.

Current edition approved Dec. 1, 2007. Published January 2008. Originally approved in 1999. Last previous edition approved in 2003 as D 6433 – 03.

[2] The boldface numbers in parentheses refer to the list of references at the end of this standard.

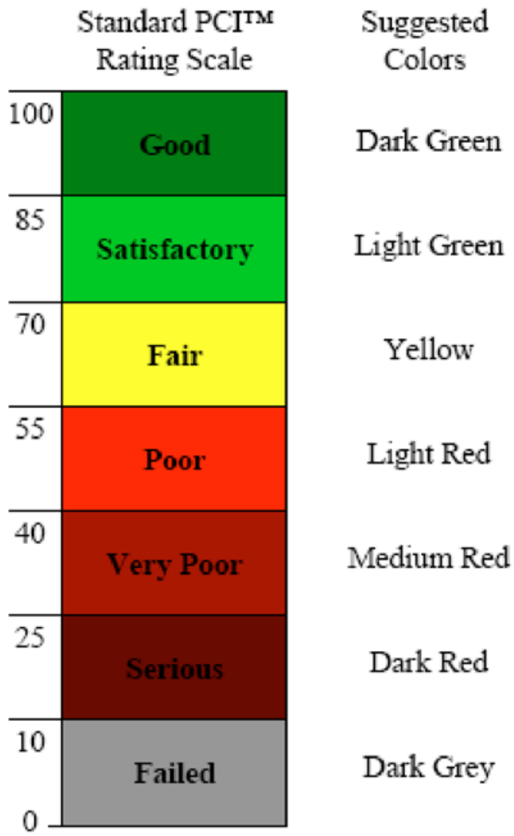


FIG. 1 Pavement Condition Index (PCI), Rating Scale, and Suggested Colors

inspection of the pavement sample units. The quantity of the distress is measured as described in Appendix X1 and Appendix X2. The distress data are used to calculate the PCI for each sample unit. The PCI of the pavement section is determined based on the PCI of the inspected sample units within the section.

4. Significance and Use

4.1 The PCI is a numerical indicator that rates the surface condition of the pavement. The PCI provides a measure of the present condition of the pavement based on the distress observed on the surface of the pavement, which also indicates the structural integrity and surface operational condition (localized roughness and safety). The PCI cannot measure structural capacity nor does it provide direct measurement of skid resistance or roughness. It provides an objective and rational basis for determining maintenance and repair needs and priorities. Continuous monitoring of the PCI is used to establish the rate of pavement deterioration, which permits early identification of major rehabilitation needs. The PCI provides feedback on pavement performance for validation or improvement of current pavement design and maintenance procedures.

5. Apparatus

5.1 *Data Sheets*, or other field recording instruments that record at a minimum the following information: date, location, branch, section, sample unit size, slab number and size, distress types, severity levels, quantities, and names of surveyors. Example data sheets for AC and PCC pavements are shown in Figs. 2 and 3.

5.2 *Hand Odometer Wheel*, that reads to the nearest 0.1 ft (30 mm).

5.3 *Straightedge or String Line*, (AC only), 10 ft (3 m).

5.4 *Scale*, 12 in. (300 mm) that reads to ⅛ in. (3 mm) or better. Additional 12-in. (300 mm) ruler or straightedge is needed to measure faulting in PCC pavements.

5.5 *Layout Plan*, for network to be inspected.

6. Hazards

6.1 Traffic is a hazard as inspectors may walk on the pavement to perform the condition survey.

7. Sampling and Sample Units

7.1 Identify branches of the pavement with different uses such as roadways and parking on the network layout plan.

7.2 Divide each branch into sections based on the pavements design, construction history, traffic, and condition.

7.3 Divide the pavement sections into sample units. If the pavement slabs in PCC have joint spacing greater than 25 ft (8 m) subdivide each slab into imaginary slabs. The imaginary slabs all should be less than or equal to 25 ft (8 m) in length, and the imaginary joints dividing the slabs are assumed to be in perfect condition. This is needed because the deduct values developed for jointed concrete slabs are less than or equal to 25 ft (8 m).

7.4 Individual sample units to be inspected should be marked or identified in a manner to allow inspectors and quality control personnel to easily locate them on the pavement surface. Paint marks along the edge and sketches with locations connected to physical pavement features are acceptable. It is necessary to be able to accurately relocate the sample units to allow verification of current distress data, to examine changes in condition with time of a particular sample unit, and to enable future inspections of the same sample unit if desired.

7.5 Select the sample units to be inspected. The number of sample units to be inspected may vary from the following: all of the sample units in the section, a number of sample units that provides a 95 % confidence level, or a lesser number.

7.5.1 All sample units in the section may be inspected to determine the average PCI of the section. This is usually precluded for routine management purposes by available manpower, funds, and time. Total sampling, however, is desirable for project analysis to help estimate maintenance and repair quantities.

7.5.2 The minimum number of sample units (n) that must be surveyed within a given section to obtain a statistically adequate estimate (95 % confidence) of the PCI of the section

ASPHALT SURFACED ROADS AND PARKING LOTS CONDITION SURVEY DATA SHEET FOR SAMPLE UNIT

SKETCH:

BRANCH ____________ SECTION _________ SAMPLE UNIT _________

SURVEYED BY ___________ DATE _________ SAMPLE AREA _________

1. Alligator Cracking
2. Bleeding
3. Block Cracking
4. Bumps and Sags
5. Corrugation
6. Depression
7. Edge Cracking
8. Jt. Reflection Cracking
9. Lane/Shoulder Drop Off
10. Long & Trans Cracking
11. Patching & Util Cut Patching
12. Polished Aggregate
13. Potholes
14. Railroad Crossing
15. Rutting
16. Shoving
17. Slippage Cracking
18. Swell
19. Weathering/Raveling

DISTRESS SEVERITY	QUANTITY									TOTAL	DENSITY %	DEDUCT VALUE

FIG. 2 Flexible Pavement Condition Survey Data Sheet for Sample Unit

CONCRETE SURFACED ROADS AND PARKING LOTS
CONDITION SURVEY DATA SHEET FOR SAMPLE UNIT

BRANCH______________ SECTION______________ SAMPLE UNIT______________
SURVEYED BY____________ DATE______________ SAMPLE AREA______________

Distress Types

21. Blow up/Buckling
22. Corner Break
23. Divided Slab
24. Durability Crack
25. Faulting
26. Joint Seal
27. Lane/Shoulder
28. Linear Cracking
29. Patching (Large)
30. Patching (Small)
31. Polished Aggregate
32. Popouts
33. Pumping
34. Punchout
35. Railroad Crossing
36. Scaling
37. Shrinkage
38. Spalling Corner
39. Spalling Joint

DIST TYPE	SEV	NO. SLABS	DENSITY %	DEDUCT VALUE

SKETCH:

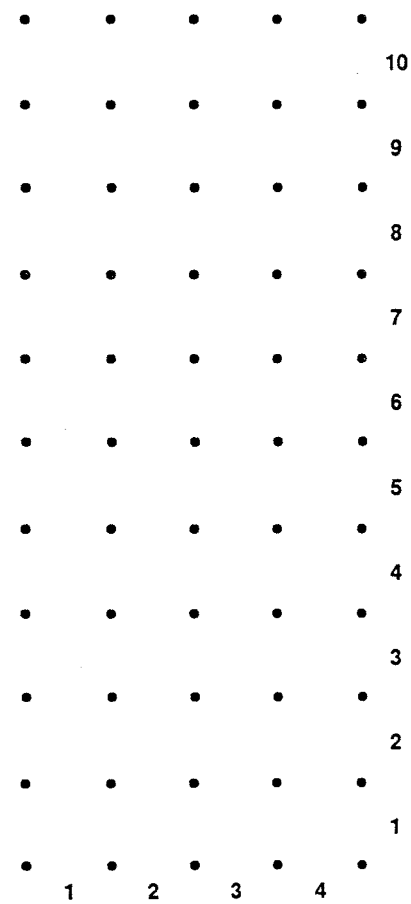


FIG. 3 Joint Rigid Pavement Condition Survey Data Sheet for Sample Unit

is calculated using the following formula and rounding n to the next highest whole number (see Eq 1).

$$n = Ns^2/((e^2/4)(N-1) + s^2) \tag{1}$$

where:

e = acceptable error in estimating the section PCI; commonly, $e=\pm 5$ PCI points;
s = standard deviation of the PCI from one sample unit to another within the section. When performing the initial inspection the standard deviation is assumed to be ten for AC pavements and 15 for PCC pavements. This assumption should be checked as described below after PCI values are determined. For subsequent inspections, the standard deviation from the preceding inspection should be used to determine n; and,
N = total number of sample units in the section.

7.5.2.1 If obtaining the 95 % confidence level is critical, the adequacy of the number of sample units surveyed must be confirmed. The number of sample units was estimated based on an assumed standard deviation. Calculate the actual standard deviation (s) as follows (see Eq 2):

$$s = \left(\sum_{i=1}^{n}(PCI_i - PCI_s)^2/(n-1)\right)^{1/2} \tag{2}$$

where:

PCI_i = PCI of surveyed sample units i,
PCI_s = PCI of section (mean PCI of surveyed sample units), and
n = total number of sample units surveyed.

7.5.2.2 Calculate the revised minimum number of sample units (Eq 1) to be surveyed using the calculated standard deviation (Eq 2). If the revised number of sample units to be surveyed is greater than the number of sample units already surveyed, select and survey additional random sample units. These sample units should be spaced evenly across the section. Repeat the process of checking the revised number of sample units and surveying additional random sample units until the total number of sample units surveyed equals or exceeds the minimum required sample units (n) in Eq 1, using the actual total sample standard deviation.

7.5.3 Once the number of sample units to be inspected has been determined, compute the spacing interval of the units using systematic random sampling. Samples are spaced equally throughout the section with the first sample selected at random. The spacing interval (i) of the units to be sampled is calculated by the following formula rounded to the next lowest whole number:

$$i = N/n \tag{3}$$

where:
N = total number of sample units in the section, and
n = number of sample units to be inspected.

The first sample unit to be inspected is selected at random from sample units 1 through i. The sample units within a section that are successive increments of the interval i after the first randomly selected unit also are inspected.

7.6 A lessor sampling rate than the above mentioned 95 % confidence level can be used based on the condition survey objective. As an example, one agency uses the following table for selecting the number of sample units to be inspected for other than project analysis:

Given	Survey
1 to 5 sample units	1 sample unit
6 to 10 sample units	2 sample units
11 to 15 sample units	3 sample units
16 to 40 sample units	4 sample units
over 40 sample units	10 %

7.7 Additional sample units only are to be inspected when nonrepresentative distresses are observed as defined in 2.1.1. These sample units are selected by the user.

8. Inspection Procedure

8.1 The definitions and guidelines for quantifying distresses for PCI determination are given in Appendix X1 for AC pavements. Using this test method, inspectors should identify distress types accurately 95 % of the time. Linear measurements should be considered accurate when they are within 10 % if remeasured, and area measurements should be considered accurate when they are within 20 % if remeasured. Distress severities that one determines based on ride quality are considered subjective.

8.2 *Asphalt Concrete (AC) Surfaced Pavement*—Individually inspect each sample unit chosen. Sketch the sample unit, including orientation. Record the branch and section number and the number and type of the sample unit (random or additional). Record the sample unit size measured with the hand odometer. Conduct the distress inspection by walking over the sidewalk/shoulder of the sample unit being surveyed, measuring the quantity of each severity level of every distress type present, and recording the data. Each distress must correspond in type and severity to that described in Appendix X1. The method of measurement is included with each distress description. Repeat this procedure for each sample unit to be inspected. A copy of a Blank Flexible Pavement Condition Survey Data Sheet for Sample Unit is included in Fig. 2.

8.3 *PCC Pavements*—Individually inspect each sample unit chosen. Sketch the sample unit showing the location of the slabs. Record the sample unit size, branch and section number, and number and type of the sample unit (random or additional), the number of slabs in the sample unit and the slab size measured with the hand odometer. Perform the inspection by walking over the sidewalk/shoulder of the sample unit being surveyed and recording all distress existing in the slab along with their severity level. Each distress type and severity must correspond with that described in Appendix X2. Summarize the distress types, their severity levels and the number of slabs in the sample unit containing each type and severity level. Repeat this procedure for each sample unit to be inspected. A copy of a Blank Jointed Rigid Pavement Condition Survey Data Sheet for Sample Unit is included in Fig. 3.

9. Calculation of PCI for Asphalt Concrete (AC) Pavement

9.1 Add up the total quantity of each distress type at each severity level, and record them in the "Total Severities" section. For example, Fig. 4 shows five entries for the Distress Type 1, "Alligator Cracking": 5L, 4L, 4L, 8H, and 6H. The distress at each severity level is summed and entered in the "Total Severity" section as 13 ft^2 (1.2 m^2) of low severity and 14 ft^2 (1.3 m^2) of medium severity. The units for the quantities may be either in square feet (square meters), linear feet (meters), or number of occurrences, depending on the distress type.

9.2 Divide the total quantity of each distress type at each severity level from 9.1 by the total area of the sample unit and multiply by 100 to obtain the percent density of each distress type and severity.

9.3 Determine the deduct value (DV) for each distress type and severity level combination from the distress deduct value curves in Appendix X3.

9.4 Determine the maximum corrected deduct value (CDV). The procedure for determining maximum CDV from individual DVs is identical for both AC and PCC pavement types.

9.5 The following procedure must be used to determine the maximum CDV.

9.5.1 If none or only one individual deduct value is greater than two, the total value is used in place of the maximum CDV in determining the PCI; otherwise, maximum CDV must be determined using the procedure described in 9.5.2-9.5.5.

9.5.2 List the individual deduct values in descending order. For example, in Fig. 4 this will be 25.1, 23.4, 17.9, 11.2, 7.9, 7.5, 6.9, and 5.3.

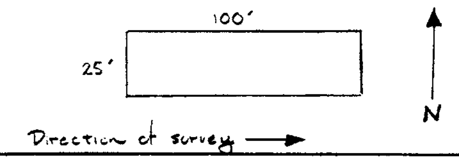
9.5.3 Determine the allowable number of deducts, m, from Fig. 5, or using the following formula (see Eq 4):

$$m = 1 + (9/98)(100–\mathrm{HDV}) \leq 10 \tag{4}$$

ASPHALT SURFACED ROADS AND PARKING LOTS CONDITION SURVEY DATA SHEET FOR SAMPLE UNIT

BRANCH SPRINGFIELD SECTION 001 SAMPLE UNIT 1
SURVEYED BY KAK DATE 10 Jul 93 SAMPLE AREA 2500 sf

SKETCH:



1. Alligator Cracking
2. Bleeding
3. Block Cracking
4. Bumps and Sags
5. Corrugation
6. Depression
7. Edge Cracking
8. Jt. Reflection Cracking
9. Lane/Shoulder Drop Off
10. Long & Trans Cracking
11. Patching & Util Cut Patching
12. Polished Aggregate
13. Potholes
14. Railroad Crossing
15. Rutting
16. Shoving
17. Slippage Cracking
18. Swell
19. Weathering/Raveling

DISTRESS SEVERITY	QUANTITY									TOTAL	DENSITY %	DEDUCT VALUE
1L	1×5	1×4	1×4							13	0.52	7.9
1H	1×8	1×6								14	0.56	23.4
7L	32	15	18	24	41					130	5.20	7.5
8M	20	15	35	27	23	10	13			143	5.72	25.1
11H	3×4	2×5								22	0.88	17.9
13L	1									1	0.04	11.2
15L	4	9	8							21	0.84	6.9
19L	250									250	10.0	5.3

FIG. 4 Example of a Flexible Pavement Condition Survey Data Sheet

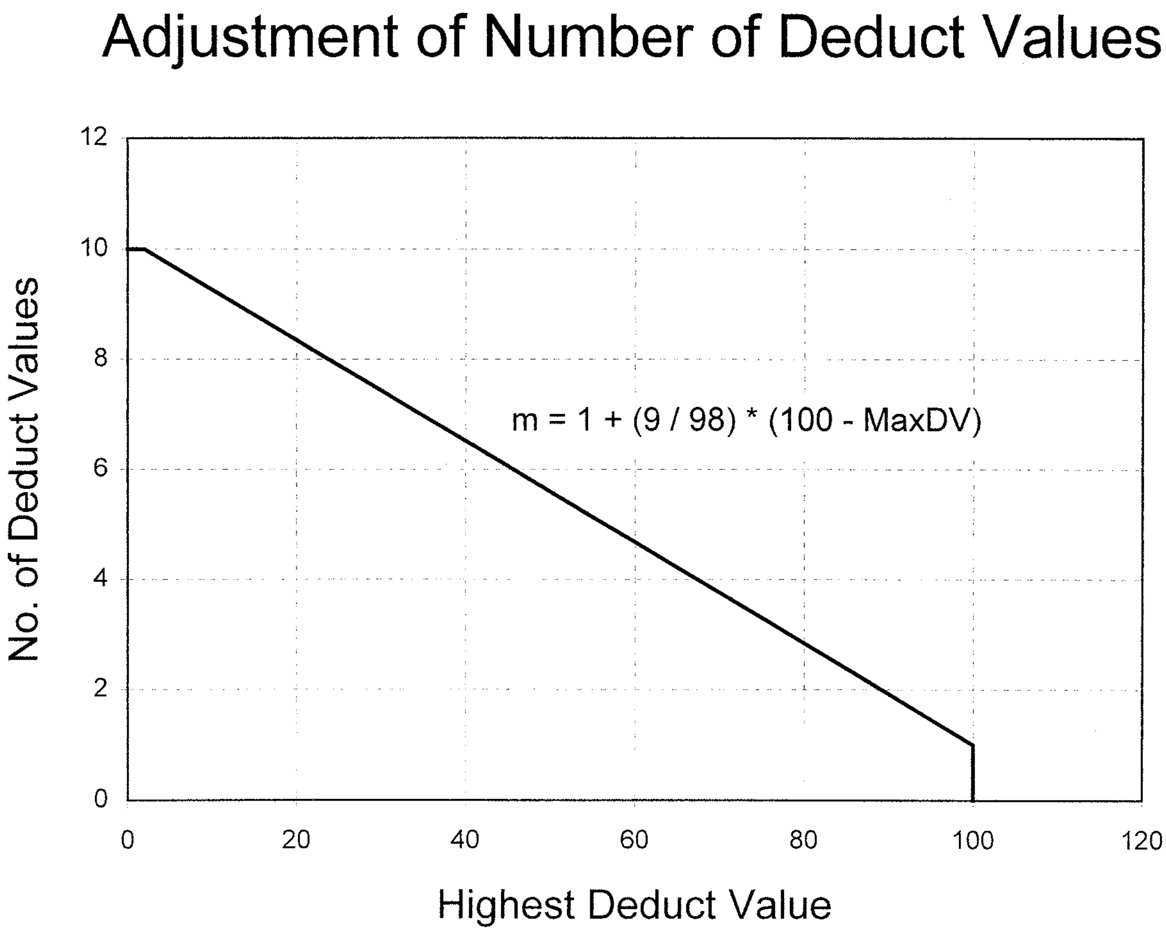


FIG. 5 Adjustment of Number of Deduct Values

where:

m = allowable number of deducts including fractions (must be less than or equal to ten), and
HDV = highest individual deduct value.

(For the example in Fig. 4, m = 1 + (9/98)(100-25.1) = 7.9).

9.5.4 The number of individual deduct values is reduced to the m largest deduct values, including the fractional part. For the example in Fig. 6, the values are 25.1, 23.4, 17.9, 11.2, 7.9, 7.5, 6.9, and 4.8 (the 4.8 is obtained by multiplying 5.3 by (7.9 – 7 = 0.9)). If less than m deduct values are available, all of the deduct values are used.

9.5.5 Determine maximum CDV iteratively, as shown in Fig. 6.

9.5.5.1 Determine total deduct value by summing individual deduct values. The total deduct value is obtained by adding the individual deduct values in 9.5.4, that is, 104.7.

9.5.5.2 Determine q as the number of deducts with a value greater than 2.0. For example, in Fig. 6, q = 8.

9.5.5.3 Determine the CDV from total deduct value and q by looking up the appropriate correction curve for AC pavements in Fig. X4.15 in Appendix X3.

9.5.5.4 Reduce the smallest individual deduct value greater than 2.0 to 2.0 and repeat 9.5.5.1-9.5.5.3 until q = 1.

9.5.5.5 Maximum CDV is the largest of the CDVs.

9.6 Calculate PCI by subtracting the maximum CDV from 100: PCI = 100-max CDV.

9.7 Fig. 6 shows a summary of PCI calculation for the example AC pavement data in Fig. 4. A blank PCI calculation form is included in Fig. 2.

10. Calculation of PCI for Portland Cement Concrete (PCC) Pavement

10.1 For each unique combination of distress type and severity level, add up the total number of slabs in which they occur. For the example in Fig. 7, there are two slabs containing low-severity corner break (Distress 22L).

10.2 Divide the number of slabs from 10.1 by the total number of slabs in the sample unit and multiply by 100 to obtain the percent density of each distress type and severity combination.

10.3 Determine the deduct values for each distress type severity level combination using the corresponding deduct curve in Appendix X4.

10.4 Determine PCI by following the procedures in 9.5 and 9.6, using the correction curve for PCC pavements (see Fig. X4.20 in Appendix X4) in place of the correction curve for AC pavements.

m = 1 + (9/98) (100 - 25.1) = 7.9 < 8

Use highest 7 deducts and 0.9 of eighth deduct.

0.9 x 5.3 = 4.8

#	Deduct Values										Total	q	CDV
1	25.1	23.4	17.9	11.2	7.9	7.5	6.9	4.8			104.7	8	51.0
2	25.1	23.4	17.9	11.2	7.9	7.5	6.9	2			101.9	7	50.0
3	25.1	23.4	17.9	11.2	7.9	7.5	2	2			96.0	6	46.0
4	25.1	23.4	17.9	11.2	7.9	2	2	2			90.5	5	47.0
5	25.1	23.4	17.9	11.2	2	2	2	2			84.6	4	48.0
6	25.1	23.4	17.9	2	2	2	2	2			75.4	3	48.0
7	25.1	23.4	2	2	2	2	2	2			59.5	2	44.0
8	25.1	2	2	2	2	2	2	2			38.1	1	38.0
9													
10													

Max CDV = 51

PCI = 100 - Max CDV = 49

Rating = FAIR

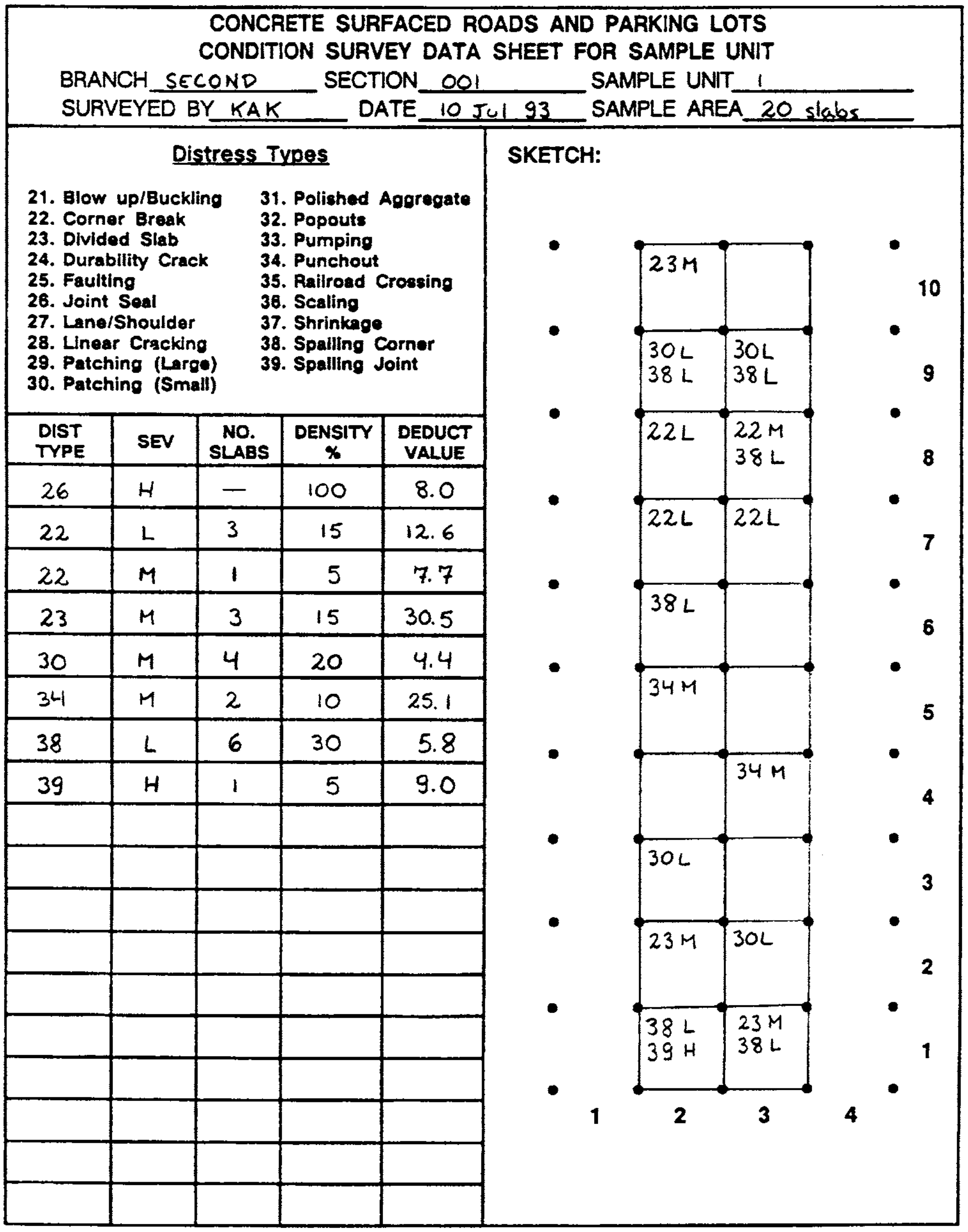
FIG. 6 Calculation of Corrected PCI Value—Flexible Pavement

10.5 Fig. 7 shows a summary of PCI calculation for the example PCC pavement distress data in Fig. 8.

11. Determination of Section PCI

11.1 If all surveyed sample units are selected randomly, then the PCI of the section (PCI_s) is calculated as the area weighted PCI of the randomly surveyed sample units ($\overline{PCI_r}$) using equation 5:

$$PCI_S = \overline{PCI_r} = \frac{\sum_{i=1}^{n}(PCI_{ri} \cdot A_{ri})}{\sum_{i=1}^{n} A_{ri}} \tag{5}$$



CONCRETE SURFACED ROADS AND PARKING LOTS
CONDITION SURVEY DATA SHEET FOR SAMPLE UNIT

BRANCH SECOND SECTION 001 SAMPLE UNIT 1
SURVEYED BY KAK DATE 10 JUL 93 SAMPLE AREA 20 slabs

Distress Types

21. Blow up/Buckling
22. Corner Break
23. Divided Slab
24. Durability Crack
25. Faulting
26. Joint Seal
27. Lane/Shoulder
28. Linear Cracking
29. Patching (Large)
30. Patching (Small)
31. Polished Aggregate
32. Popouts
33. Pumping
34. Punchout
35. Railroad Crossing
36. Scaling
37. Shrinkage
38. Spalling Corner
39. Spalling Joint

DIST TYPE	SEV	NO. SLABS	DENSITY %	DEDUCT VALUE
26	H	—	100	8.0
22	L	3	15	12.6
22	M	1	5	7.7
23	M	3	15	30.5
30	M	4	20	4.4
34	M	2	10	25.1
38	L	6	30	5.8
39	H	1	5	9.0

SKETCH:

	2	3
10	23M	
9	30L 38L	30L 38L
8	22L	22M 38L
7	22L	22L
6	38L	
5	34M	
4		34M
3	30L	
2	23M	30L
1	38L 39H	23M 38L

1 2 3 4

FIG. 7 Example of a Jointed Rigid Pavement Condition Survey Data Sheet

where:

$\overline{PCI_r}$ = area weighted PCI of randomly surveyed sample units,
PCI_{ri} = PCI of random sample unit i,
A_{ri} = area of random sample unit i,
n = number of random sample units surveyed.

If additional sample units, as defined in 2.1.1, are surveyed, the area weighted PCI of the surveyed additional units ($\overline{PCI_a}$) is calculated using equation 6. The PCI of the pavement section is calculated using equation 7.

$$\overline{PCI_a} = \frac{\sum_{i=1}^{m}(PCI_{ai} \cdot A_{ai})}{\sum_{i=1}^{m} A_{ai}} \qquad (6)$$

$$PCI_s = \frac{\overline{PCI_r}\left(A - \sum_{i=1}^{m} A_{ai}\right) + \overline{PCI_a}\left(\sum_{i=1}^{m} A_{ai}\right)}{A} \qquad (7)$$

m = 1 + (9/98) (100 - 30.5) = 7.4 < 8

Use highest 7 deducts and 0.4 of eighth deduct.

0.4 x 4.4 = 1.76

#	Deduct Values										Total	q	CDV
1	30.5	25.1	12.6	9.0	8.0	7.7	5.8	1.76			100.5	7	50.0
2	30.5	25.1	12.6	9.0	8.0	7.7	2	1.76			96.7	6	49.5
3	30.5	25.1	12.6	9.0	8.0	2	2	1.76			91.0	5	51.0
4	30.5	25.1	12.6	9.0	2	2	2	1.76			85.0	4	49.0
5	30.5	25.1	12.6	2	2	2	2	1.76			78.0	3	50.0
6	30.5	25.1	2	2	2	2	2	1.76			67.4	2	50.0
7	30.5	2	2	2	2	2	2	1.76			44.3	1	44.3
8													
9													
10													

Max CDV = 51

PCI = 100 - Max CDV = 49

Rating = FAIR

FIG. 8 Calculation of Corrected PCI Value—Jointed Rigid Pavement

$\overline{PCI_a}$ = area weighted PCI of additional sample units,
PCI_{ai} = PCI of additional sample unit *i*,
A_{ai} = area of additional sample unit *i*,
A = area of section,
m = number of additional sample units surveyed, and
PCI_s = area weighted PCI of the pavement section.

11.2 Determine the overall condition rating of the section by using the section PCI and the condition rating scale in Fig. 1.

12. Report

12.1 Develop a summary report for each section. The summary lists section location, size, total number of sample units, the sample units inspected, the PCIs obtained, the average PCI for the section, and the section condition rating.

APPENDIXES

(Nonmandatory Information)

X1. Distress in Asphalt Pavements

X1.1 During the field condition surveys and validation of the PCI, several questions are commonly asked about the identification and measurement of some of the distresses. The answers to these questions for each distress are included under the heading "How to Measure." For convenience, however, the most frequently raised issues are addressed below:

X1.1.1 If alligator cracking and rutting occur in the same area, each is recorded separately at its respective severity level.

X1.1.2 If bleeding is counted, polished aggregate is not counted in the same area.

X1.1.3 Spalling as used herein is the further breaking of pavement or loss of materials around cracks or joints.

X1.1.4 If a crack does not have the same severity level along its entire length, each portion of the crack having a different severity level should be recorded separately. If, however, the different levels of severity in a portion of a crack cannot be easily divided, that portion should be rated at the highest severity level present.

X1.1.5 If any distress, including cracking and potholes, is found in a patched area, it is not recorded; its effect on the patch, however, is considered in determining the severity level of the patch.

X1.1.6 A significant amount of polished aggregate should be present before it is counted.

X1.1.7 A distress is said to be raveled if the area surrounding the distress is broken (sometimes to the extent that pieces are removed).

X1.2 The reader should note that the items above are general issues and do not stand alone as inspection criteria. To properly measure each distress type, the inspector must be familiar with its individual measurement criteria.

X1.3 Nineteen distress types for asphalt-surfaced pavements are listed alphabetically in this manual.

RIDE QUALITY

X1.4 Ride quality must be evaluated in order to establish a severity level for the following distress types:

X1.4.1 Bumps.
X1.4.2 Corrugation.
X1.4.3 Railroad crossings.
X1.4.4 Shoving.
X1.4.5 Swells.

X1.4.6 To determine the effect these distresses have on ride quality, the inspector should drive at the normal operating speed and use the following severity-level definitions of ride quality:

X1.4.6.1 **L**—Low. Vehicle vibrations, for example, from corrugation, are noticeable, but no reduction in speed is necessary for comfort or safety. Individual bumps or settlements, or both, cause the vehicle to bounce slightly, but create little discomfort.

X1.4.6.2 **M**—Medium. Vehicle vibrations are significant and some reduction in speed is necessary for safety and comfort. Individual bumps or settlements, or both, cause the vehicle to bounce significantly, creating some discomfort.

X1.4.6.3 **H**—High. Vehicle vibrations are so excessive that speed must be reduced considerably for safety and comfort. Individual bumps or settlements, or both, cause the vehicle to bounce excessively, creating substantial discomfort, safety hazard, or high potential vehicle damage.

X1.4.7 The inspector should drive at the posted speed in a sedan that is representative of cars typically seen in local traffic. Pavement sections near stop signs should be rated at a deceleration speed appropriate for the intersection.

ALLIGATOR CRACKING (FATIGUE)

X1.5 *Description*—Alligator or fatigue cracking is a series of interconnecting cracks caused by fatigue failure of the asphalt concrete surface under repeated traffic loading. Cracking begins at the bottom of the asphalt surface, or stabilized base, where tensile stress and strain are highest under a wheel load. The cracks propagate to the surface initially as a series of parallel longitudinal cracks. After repeated traffic loading, the cracks connect, forming many sided, sharp-angled pieces that develop a pattern resembling chicken wire or the skin of an alligator. The pieces are generally less than 0.5 m (1.5 ft) on the longest side. Alligator cracking occurs only in areas subjected to repeated traffic loading, such as wheel paths. Pattern-type cracking that occurs over an entire area not subjected to loading is called "block cracking," which is not a load-associated distress.

X1.5.1 *Severity Levels*:

X1.5.1.1 **L**—Fine, longitudinal hairline cracks running parallel to each other with no, or only a few interconnecting cracks. The cracks are not spalled (Fig. X1.1).

FIG. X1.1 Low-Severity Alligator Cracking

X1.5.1.2 **M**—Further development of light alligator cracks into a pattern or network of cracks that may be lightly spalled (Fig. X1.2).

X1.5.1.3 **H**—Network or pattern cracking has progressed so that the pieces are well defined and spalled at the edges. Some of the pieces may rock under traffic (Fig. X1.3).

X1.5.2 *How to Measure*—Alligator cracking is measured in square meters (square feet) of surface area. The major difficulty in measuring this type of distress is that two or three levels of severity often exist within one distressed area. If these portions can be easily distinguished from each other, they should be measured and recorded separately; however, if the different levels of severity cannot be divided easily, the entire area should be rated at the highest severity present. If alligator cracking and rutting occur in the same area, each is recorded separately as its respective severity level.

BLEEDING

X1.6 *Description*—Bleeding is a film of bituminous material on the pavement surface that creates a shiny, glasslike, reflecting surface that usually becomes quite sticky. Bleeding is caused by excessive amounts of asphaltic cement or tars in the mix, excess application of a bituminous sealant, or low air void content, or a combination thereof. It occurs when asphalt fills the voids of the mix during hot weather and then expands onto the pavement surface. Since the bleeding process in not reversible during cold weather, asphalt or tar will accumulate on the surface.

X1.6.1 *Severity Levels*:

X1.6.1.1 **L**—Bleeding only has occurred to a very slight degree and is noticeable only during a few days of the year. Asphalt does not stick to shoes or vehicles (Fig. X1.4).

X1.6.1.2 **M**—Bleeding has occurred to the extent that asphalt sticks to shoes and vehicles during only a few weeks of the year (Fig. X1.5).

X1.6.1.3 **H**—Bleeding has occurred extensively and considerable asphalt sticks to shoes and vehicles during at least several weeks of the year (Fig. X1.6).

X1.6.2 *How to Measure*—Bleeding is measured in square meters (square feet) of surface area. If bleeding is counted, polished aggregate should not be counted.

FIG. X1.2 Medium-Severity Alligator Cracking

FIG. X1.3 High-Severity Alligator Cracking

FIG. X1.4 Low-Severity Bleeding

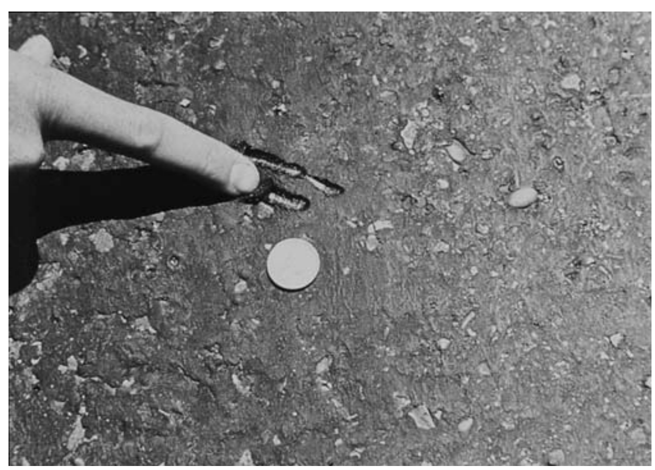


FIG. X1.5 Medium-Severity Bleeding

BLOCK CRACKING

X1.7 *Description*—Block cracks are interconnected cracks that divide the pavement into approximately rectangular pieces. The blocks may range in size from approximately 0.3 by 0.3 m (1 by 1 ft) to 3 by 3 m (10 by 10 ft). Block cracking is caused mainly by shrinkage of the asphalt concrete and daily

FIG. X1.6 High-Severity Bleeding

temperature cycling, which results in daily stress/strain cycling. It is not load-associated. Block cracking usually indicates that the asphalt has hardened significantly. Block cracking normally occurs over a large portion of the pavement area, but sometimes will occur only in nontraffic areas. This type of distress differs from alligator cracking in that alligator cracks form smaller, many-sided pieces with sharp angles. Also, unlike block, alligator cracks are caused by repeated traffic loadings, and therefore, are found only in traffic areas, that is, wheel paths.

X1.7.1 *Severity Levels*:

X1.7.1.1 **L**—Blocks are defined by low-severity[3] cracks (Fig. X1.7).

X1.7.1.2 **M**—Blocks are defined by medium-severity[3] cracks (Fig. X1.8).

X1.7.1.3 **H**—Blocks are defined by high-severity[3] cracks (Fig. X1.9).

X1.7.2 *How to Measure*—Block cracking is measured in m^2 (ft^2) of surface area. It usually occurs at one severity level in a given pavement section; however, if areas of different severity levels can be distinguished easily from one another, they should be measured and recorded separately.

BUMPS AND SAGS

X1.8 *Description*:

X1.8.1 Bumps are small, localized, upward displacements of the pavement surface. They are different from shoves in that shoves are caused by unstable pavement. Bumps, on the other hand, can be caused by several factors, including:

X1.8.1.1 Buckling or bulging of underlying PCC slabs in AC overlay over PCC pavement.

X1.8.1.2 Frost heave (ice, lens growth).

X1.8.1.3 Infiltration and buildup of material in a crack in combination with traffic loading (sometimes called "tenting").

X1.8.1.4 Sags are small, abrupt, downward displacements of the pavement surface. If bumps appear in a pattern perpendicular to traffic flow and are spaced at less than 3 m (10 ft), the distress is called corrugation. Distortion and displacement that occur over large areas of the pavement surface, causing large or long dips, or both, in the pavement should be recorded as" swelling."

X1.8.2 *Severity Levels*:

X1.8.2.1 **L**—Bump or sag causes low-severity ride quality (Fig. X1.10).

X1.8.2.2 **M**—Bump or sag causes medium-severity ride quality (Fig. X1.11).

X1.8.2.3 **H**—Bump or sag causes high-severity ride quality (Fig. X1.12).

X1.8.3 *How to Measure*—Bumps or sags are measured in linear meters (feet). If the bump occurs in combination with a crack, the crack also is recorded.

[3] See definitions of longitudinal transverse cracking within Appendix X2.10.

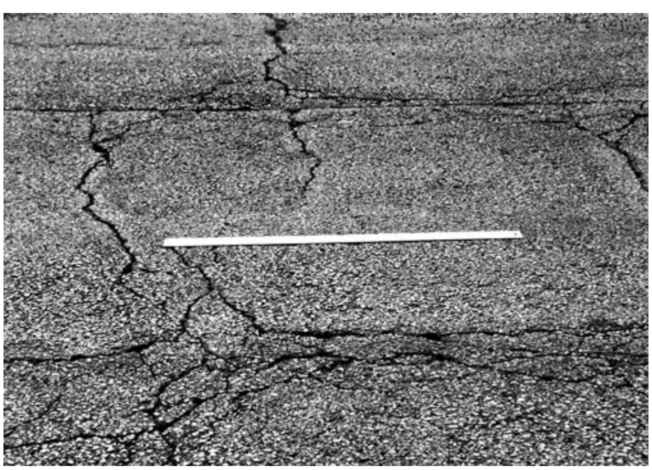


FIG. X1.7 Low-Severity Block Cracking

FIG. X1.8 Medium-Severity Block Cracking

FIG. X1.9 High-Severity Block Cracking

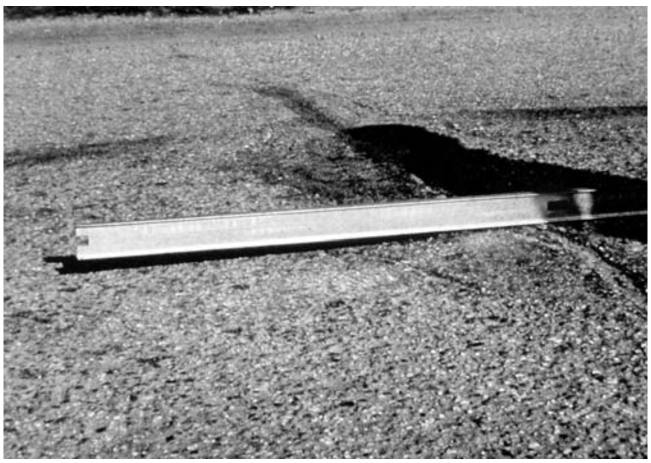


FIG. X1.10 Low-Severity Bumps and Sags

FIG. X1.11 Medium-Severity Bumps and Sags

CORRUGATION

X1.9 *Description*—Corrugation, also known as "washboarding", is a series of closely spaced ridges and valleys (ripples) occurring at fairly regular intervals, usually less than 3 m (10 ft) along the pavement. The ridges are perpendicular to

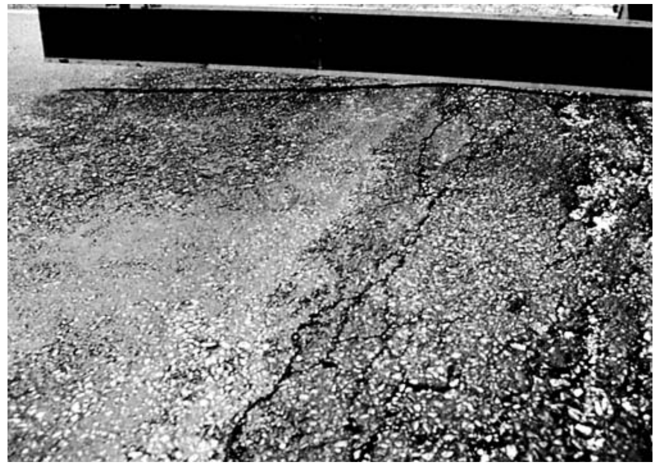


FIG. X1.12 High-Severity Bumps and Sags

the traffic direction. This type of distress usually is caused by traffic action combined with an unstable pavement surface or base.

X1.9.1 *Severity Levels*:

X1.9.1.1 **L**—Corrugation produces low-severity ride quality (Fig. X1.13).

X1.9.1.2 **M**—Corrugation produces medium-severity ride quality (Fig. X1.14).

X1.9.1.3 **H**—Corrugation produces high-severity ride quality (Fig. X1.15).

X1.9.2 *How to Measure*—Corrugation is measured in square meters (square feet) of surface area.

DEPRESSION

X1.10 *Description*—Depressions are localized pavement surface areas with elevations slightly lower than those of the surrounding pavement. In many instances, light depressions are not noticeable until after a rain, when ponding water creates a "birdbath" area; on dry pavement, depressions can be spotted by looking for stains caused by ponding water. Depressions are created by settlement of the foundation soil or are a result of

FIG. X1.13 Low-Severity Corrugation

FIG. X1.14 Medium-Severity Corrugation

FIG. X1.15 High-Severity Corrugation

improper construction. Depressions cause some roughness, and when deep enough or filled with water, can cause hydroplaning.

X1.10.1 *Severity Levels (Maximum Depth of Depression)*:

X1.10.1.1 **L**–13 to 25 mm (½ to 1 in.) (Fig. X1.16).

X1.10.1.2 **M**–25 to 50 mm (1 to 2 in.) (Fig. X1.17).

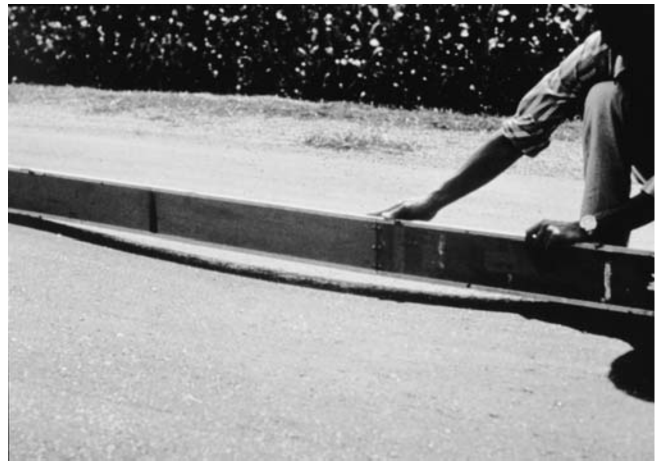


FIG. X1.17 Medium-Severity Depression

X1.10.1.3 **H**—More than 50 mm (2 in.) (Fig. X1.18).

X1.10.2 *How to Measure*—Depressions are measured in square meters (square feet) of surface area.

EDGE CRACKING

X1.11 *Description*—Edge cracks are parallel to and usually within 0.3 to 0.5 m (1 to 1.5 ft) of the outer edge of the pavement. This distress is accelerated by traffic loading and can be caused by frost-weakened base or subgrade near the edge of the pavement. The area between the crack and pavement edge is classified as raveled if it is broken up (sometimes to the extent that pieces are removed).

X1.11.1 *Severity Levels*:

X1.11.1.1 **L**—Low or medium cracking with no breakup or raveling (Fig. X1.19).

X1.11.1.2 **M**—Medium cracks with some breakup and raveling (Fig. X1.20).

X1.11.1.3 **H**—Considerable breakup or raveling along the edge (Fig. X1.21).

X1.11.2 *How to Measure*—Edge cracking is measure in linear meters (feet).

FIG. X1.16 Low-Severity Depression

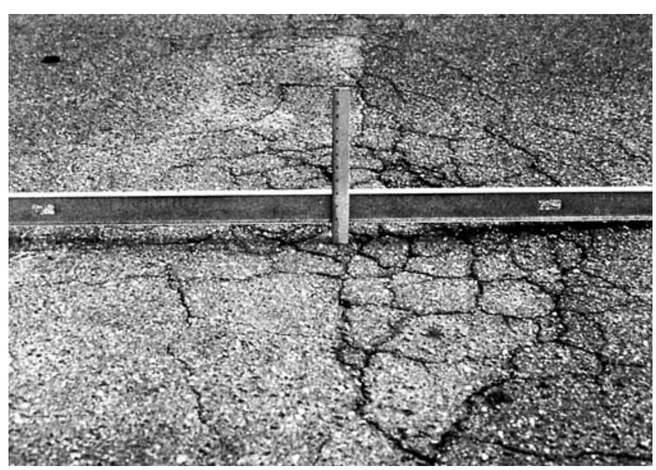


FIG. X1.18 High-Severity Depression

FIG. X1.19 Low-Severity Edge Cracking

FIG. X1.20 Medium-Severity Edge Cracking

FIG. X1.21 High-Severity Edge Cracking

JOINT REFLECTION CRACKING (From Longitudinal and Transverse PCC Slabs)

X1.12 *Description*—This distress occurs only on asphalt-surfaced pavements that have been laid over a PCC slab. It does not include reflection cracks from any other type of base, that is, cement- or lime-stabilized; these cracks are caused mainly by thermal- or moisture-induced movement of the PCC slab beneath the AC surface. This distress is not load-related; however, traffic loading may cause a breakdown of the AC surface near the crack. If the pavement is fragmented along a crack, the crack is said to be spalled. A knowledge of slab dimension beneath the AC surface will help to identify these distresses.

X1.12.1 *Severity Levels*:

X1.12.1.1 **L**—One of the following conditions exists (Fig. X1.22): Nonfilled crack width is less than 10 mm (3⁄8 in.), or filled crack of any width (filler in satisfactory condition).

X1.12.1.2 **M**—One of the following conditions exists (Fig. X1.23): Nonfilled crack width is greater than or equal to 10 mm (3⁄8 in.) and less than 75 mm (3 in.); nonfilled crack less than or equal to 75 mm (3 in.) surrounded by light secondary cracking; or, filled crack of any width surrounded by light secondary cracking.

X1.12.1.3 **H**—One of the following conditions exists (Fig. X1.24): Any crack filled or nonfilled surrounded by medium- or high-severity secondary cracking; nonfilled cracks greater than 75 mm (3 in.); or, a crack of any width where approximately 100 mm (4 in.) of pavement around the crack are severely raveled or broken.

X1.12.2 *How to Measure*—Joint reflection cracking is measured in linear meters (feet). The length and severity level of each crack should be identified and recorded separately. For example, a crack that is 15 m (50 ft) long may have 3 m (10 ft) of high severity cracks, which are all recorded separately. If a bump occurs at the reflection crack, it is recorded also.

LANE/SHOULDER DROP-OFF

X1.13 *Description*—Lane/shoulder drop-off is a difference in elevation between the pavement edge and the shoulder. This distress is caused by shoulder erosion, shoulder settlement, or by building up the roadway without adjusting the shoulder level.

X1.13.1 *Severity Levels*:

X1.13.1.1 **L**—The difference in elevation between the pavement edge and shoulder is > 25 mm (1 in.) and< 50 mm (2 in.) (Fig. X1.25).

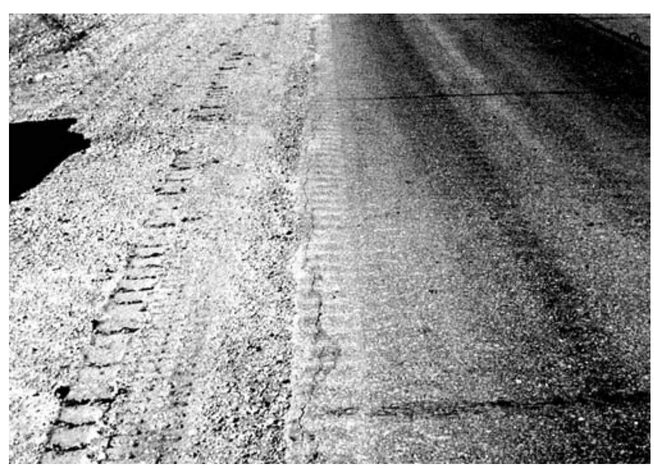


FIG. X1.22 Low-Severity Joint Reflection Cracking

FIG. X1.23 Medium-Severity Joint Reflection Cracking

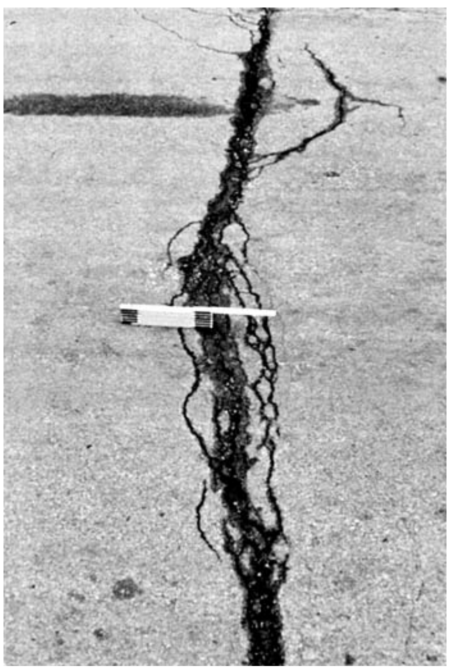


FIG. X1.24 High-Severity Joint Reflection Cracking

X1.13.1.2 **M**—The difference in elevation is > 50 mm (2 in.) and < 100 mm (4 in.) (Fig. X1.26).

X1.13.1.3 **H**—The difference in elevation is > 100 mm (4 in.) (Fig. X1.27).

X1.13.2 *How to Measure*—Lane/shoulder drop-off is measured in linear meters (feet).

LONGITUDINAL AND TRANSVERSE CRACKING (Non-PCC Slab Joint Reflective)

X1.14 *Description*:

FIG. X1.25 Low-Severity Lane/Shoulder Drop-Off

FIG. X1.26 Medium-Severity Lane/Shoulder Drop-Off

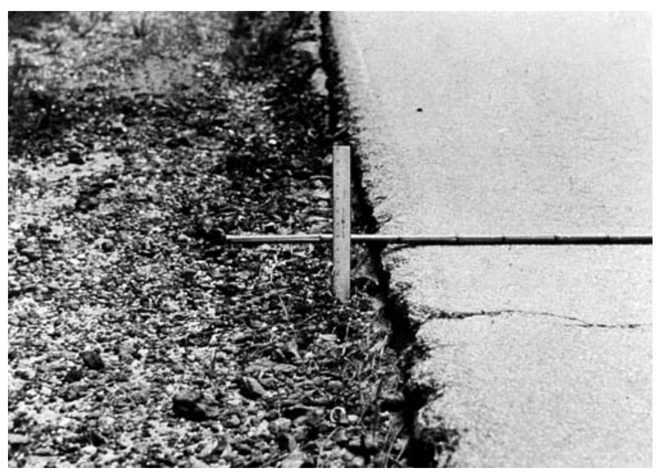


FIG. X1.27 High-Severity Lane/Shoulder Drop-Off

X1.14.1 Longitudinal cracks are parallel to the pavement's centerline or laydown direction. They may be caused by:

X1.14.1.1 A poorly constructed paving lane joint.

X1.14.1.2 Shrinkage of the AC surface due to low temperatures or hardening of the asphalt, or daily temperature cycling, or both.

X1.14.1.3 A reflective crack caused by cracking beneath the surface course, including cracks in PCC slabs, but not PCC joints.

X1.14.1.4 Transverse cracks extend across the pavement at approximately right angles to the pavement centerline or direction of laydown. These types of cracks are not usually load-associated.

X1.14.2 *Severity Levels*:

X1.14.2.1 **L**—One of the following conditions exists (Fig. X1.28): nonfilled crack width is less than 10 mm (3⁄8 in.), or filled crack of any width (filler in satisfactory condition).

X1.14.2.2 **M**—One of the following conditions exists (Fig. X1.29): nonfilled crack width is greater than or equal to 10 mm and less than 75 mm (3⁄8 to 3 in.); nonfilled crack is less than or equal to 75 mm (3 in.) surrounded by light and random cracking; or, filled crack is of any width surrounded by light random cracking.

X1.14.2.3 **H**—One of the following conditions exists (Fig. X1.30): any crack filled or nonfilled surrounded by medium- or high-severity random cracking; nonfilled crack greater than 75 m (3 in.); or, a crack of any width where approximately 100 mm (4 in.) of pavement around the crack is severely broken.

X1.14.3 *How to Measure*—Longitudinal and transverse cracks are measured in linear meters (feet). The length and severity of each crack should be recorded. If the crack does not have the same severity level along its entire length, each portion of the crack having a different severity level should be recorded separately.

PATCHING AND UTILITY CUT PATCHING

X1.15 *Description*—A patch is an area of pavement that has been replaced with new material to repair the existing pavement. A patch is considered a defect no matter how well it is performing (a patched area or adjacent area usually does not perform as well as an original pavement section). Generally, some roughness is associated with this distress.

X1.15.1 *Severity Levels*:

X1.15.1.1 **L**—Patch is in good condition and satisfactory. Ride quality is rated as low severity or better (Fig. X1.31).

X1.15.1.2 **M**—Patch is moderately deteriorated, or ride quality is rated as medium severity, or both (Fig. X1.32).

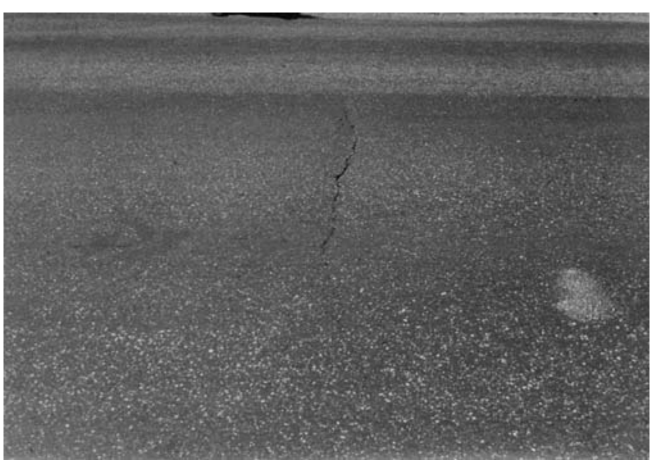


FIG. X1.28 Low-Severity Longitudinal and Transverse Cracking

FIG. X1.29 Medium-Severity Longitudinal and Transverse Cracking

FIG. X1.30 High-Severity Longitudinal and Transverse Cracking

FIG. X1.31 Low-Severity Patching and Utility Cut Patching

X1.15.1.3 **H**—Patch is badly deteriorated, or ride quality is rated as high severity, or both; needs replacement soon (Fig. X1.33).

X1.15.2 *How to Measure*—Patching is rated in ft^2 of surface area; however, if a single patch has areas of differing

FIG. X1.32 Medium-Severity Patching and Utility Cut Patching

FIG. X1.33 High-Severity Patching and Utility Cut Patching

severity, these areas should be measured and recorded separately. For example, a 2.5 m^2 (27.0 ft^2) patch may have 1 m^2 (11 ft^2) of medium severity and 1.5 m^2 (16 ft^2) of low severity. These areas would be recorded separately. Any distress found in a patched area will not be recorded; however, its effect on the patch will be considered when determining the patch's severity level. No other distresses, for example, are recorded within a patch. Even if the patch material is shoving or cracking, the area is rated only as a patch. If a large amount of pavement has been replaced, it should not be recorded as a patch but considered as new pavement, for example, replacement of a complete intersection.

POLISHED AGGREGATE

X1.16 *Description*—This distress is caused by repeated traffic applications. Polished aggregate is present when close examination of a pavement reveals that the portion of aggregate extending above the asphalt is either very small, or there are no rough or angular aggregate particles to provide good skid resistance. When the aggregate in the surface becomes smooth to the touch, adhesion with vehicle tires is considerably reduced. When the portion of aggregate extending above the surface is small, the pavement texture does not significantly contribute to reducing vehicle speed. Polished aggregate should be counted when close examination reveals that the aggregate extending above the asphalt is negligible, and the surface aggregate is smooth to the touch. This type of distress is indicated when the number on a skid resistance test is low or has dropped significantly from a previous rating.

X1.16.1 *Severity Levels*—No degrees of severity are defined; however, the degree of polishing should be clearly evident in the sample unit in that the aggregate surface should be smooth to the touch (Fig. X1.34).

X1.16.2 *How to Measure*—Polished aggregate is measured in square meters (square feet) of surface area. If bleeding is counted, polished aggregate should not be counted.

POTHOLES

X1.17 *Description*—Potholes are small—usually less than 750 mm (30 in.) in diameter—bowl-shaped depressions in the pavement surface. They generally have sharp edges and vertical sides near the top of the hole. When holes are created by high-severity alligator cracking, they should be identified as potholes, not as weathering.

X1.17.1 *Severity Levels*:

X1.17.1.1 The levels of severity for potholes less than 750 mm (30 in.) in diameter are based on both the diameter and the depth of the pothole, according to Table X1.1.

X1.17.1.2 If the pothole is more than 750 mm (30 in.) in diameter, the area should be determined in square feet and divided by 0.5 m^2 (5.5 ft^2) find the equivalent number of holes. If the depth is 25 mm (1 in.) or less, the holes are considered medium-severity. If the depth is more than 25 mm (1 in.), they are considered high-severity (Figs. X1.35-X1.37).

X1.17.2 *How to Measure*—Potholes are measured by counting the number that are low-, medium-, and high-severity and recording them separately.

RAILROAD CROSSING

X1.18 *Description*—Railroad crossing defects are depressions or bumps around, or between tracks, or both.

X1.18.1 *Severity Levels*:

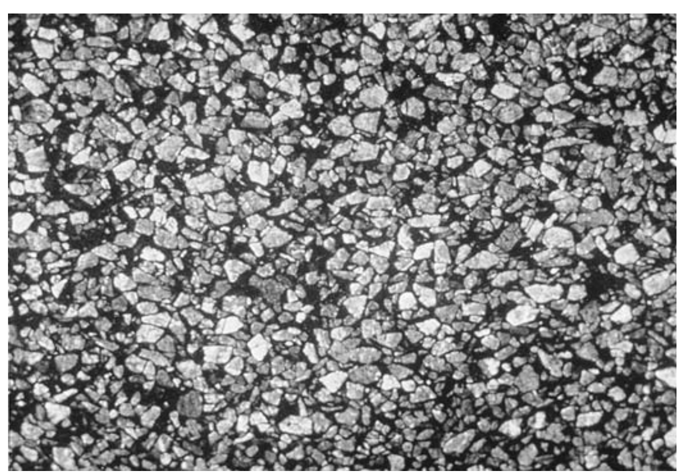


FIG. X1.34 Polished Aggregate

TABLE X1.1 Levels of Severity for Potholes

	Average Diameter (mm) (in.)		
Maximum Depth of Pothole	100 to 200 mm (4 to 8 in.)	200 to 450 mm (8 to 18 in.)	450 to 750 mm (18 to 30 in.)
13 to ≤25 mm (½ to 1 in.)	**L**	**L**	**M**
>25 and ≤50 mm (1 to 2 in.)	**L**	**M**	**H**
>50 mm (2 in.)	**M**	**M**	**H**

FIG. X1.35 Low-Severity Pothole

FIG. X1.36 Medium-Severity Pothole

X1.18.1.1 **L**—Railroad crossing causes low-severity ride quality (Fig. X1.38).

X1.18.1.2 **M**—Railroad crossing causes medium-severity ride quality (Fig. X1.39).

X1.18.1.3 **H**—Railroad crossing causes high-severity ride quality (Fig. X1.40).

X1.18.2 *How to Measure*—The area of the crossing is measured in square meters (square feet) of surface area. If the crossing does not affect ride quality, it should not be counted. Any large bump created by the tracks should be counted as part of the crossing.

FIG. X1.37 High-Severity Pothole

FIG. X1.38 Low-Severity Railroad Crossing

FIG. X1.39 Medium-Severity Railroad Crossing

RUTTING

X1.19 *Description*—A rut is a surface depression in the wheel paths. Pavement uplift may occur along the sides of the rut, but, in many instances, ruts are noticeable only after a

FIG. X1.40 High-Severity Railroad Crossing

FIG. X1.42 Medium-Severity Rutting

rainfall when the paths are filled with water. Rutting stems from a permanent deformation in any of the pavement layers or subgrades, usually caused by consolidated or lateral movement of the materials due to traffic load.

X1.19.1 *Severity Levels (Mean Rut Depth)*:

X1.19.1.1 **L**—6 to 13 mm (¼ to ½ in.) (Fig. X1.41).

X1.19.1.2 **M**—>13 to 25 mm (>½ to 1 in.) (Fig. X1.42).

X1.19.1.3 **H**—>25 mm (>1 in.) (Fig. X1.43).

X1.19.2 *How to Measure*—Rutting is measured in square meters (square feet) of surface area, and its severity is determined by the mean depth of the rut (see X1.19.1.1-X1.19.1.3). The mean rut depth is calculated by laying a straight edge across the rut, measuring its depth, then using measurements taken along the length of the rut to compute its mean depth in millimeters.

SHOVING

X1.20 *Description*:

X1.20.1 Shoving is a permanent, longitudinal displacement of a localized area of the pavement surface caused by traffic loading. When traffic pushes against the pavement, it produces a short, abrupt wave in the pavement surface. This distress

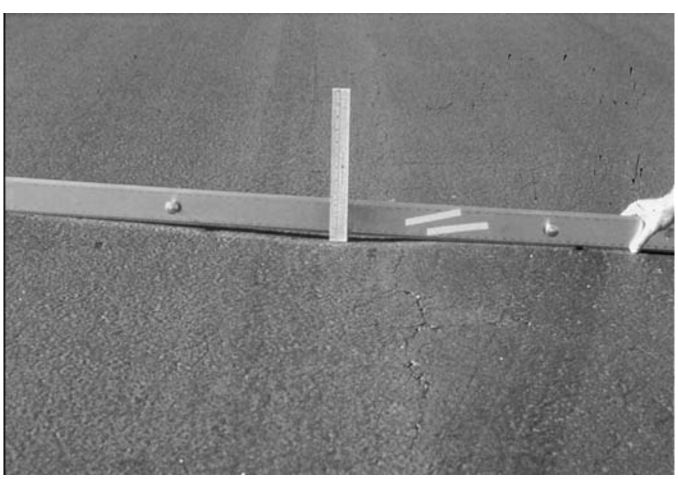


FIG. X1.41 Low-Severity Rutting

FIG. X1.43 High-Severity Rutting

normally occurs only in unstable liquid asphalt mix (cutback or emulsion) pavements.

X1.20.2 Shoves also occur where asphalt pavements abut PCC pavements. The PCC pavements increase in length and push the asphalt pavement, causing the shoving.

X1.20.3 *Severity Levels*:

X1.20.3.1 **L**—Shove causes low-severity ride quality (Fig. X1.44).

X1.20.3.2 **M**—Shove causes medium-severity ride quality (Fig. X1.45).

X1.20.3.3 **H**—Shove causes high-severity ride quality (Fig. X1.46).

X1.20.4 *How to Measure*—Shoves are measured in square meters (feet) of surface area. Shoves occurring in patches are considered in rating the patch, not as a separate distress.

SLIPPAGE CRACKING

X1.21 *Description*—Slippage cracks are crescent or half-moon shaped cracks, usually transverse to the direction of travel. They are produced when braking or turning wheels cause the pavement surface to slide or deform. This distress usually occurs in overlaps when there is a poor bond between the surface and the next layer of the pavement structure.

FIG. X1.44 Low-Severity Shoving

FIG. X1.45 Medium-Severity Shoving

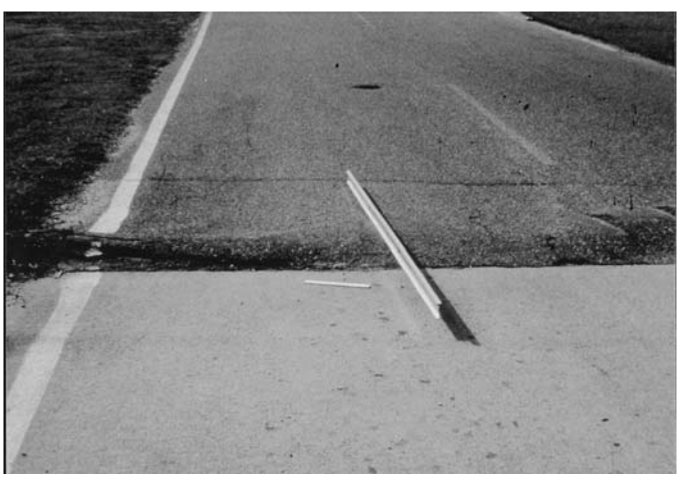


FIG. X1.46 High-Severity Shoving

X1.21.1 *Severity Level*:

X1.21.1.1 **L**—Average crack width is < 10 mm (⅜ in.) (Fig. X1.47).

X1.21.1.2 **M**—One of the following conditions exists (Fig. X1.48): average crack width is ≥ 10 and < 40 mm (≥ ⅜ and< 1-½ in.); or the area around the crack is moderately spalled, or surrounded with secondary cracks.

X1.21.1.3 **H**—One of the following conditions exists (Fig. X1.49): the average crack width is > 40 mm (1-½ in.) or the area around the crack is broken into easily removed pieces.

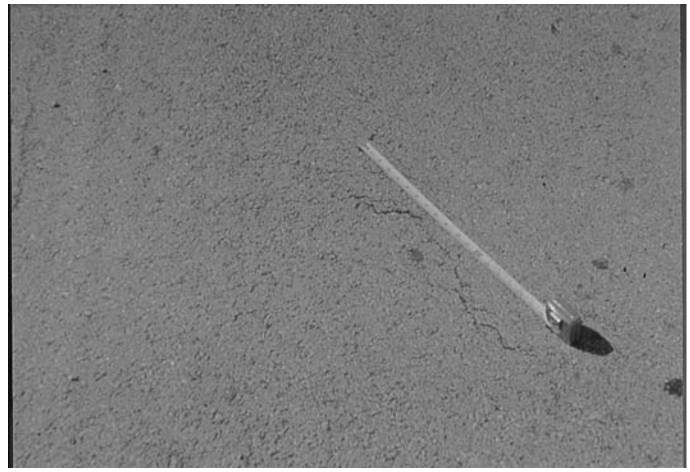


FIG. X1.47 Low-Severity Slippage Cracking

FIG. X1.48 Medium-Severity Slippage Cracking

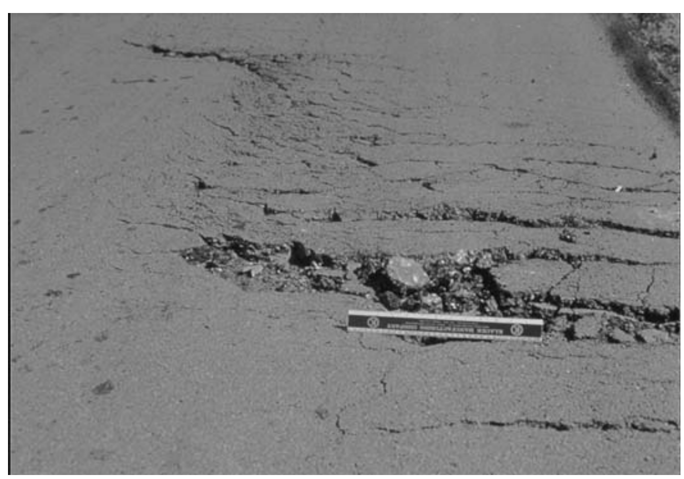


FIG. X1.49 High-Severity Slippage Cracking

X1.21.2 *How to Measure*—The area associated with a given slippage crack is measured in square meters (square feet) and rated according to the highest level of severity in the area.

SWELL

X1.22 *Description*—Swell is characterized by an upward bulge in the pavement's surface, a long, gradual wave more than 3 m (10 ft) long (Fig. X1.50). Swelling can be accompanied by surface cracking. This distress usually is caused by frost action in the subgrade or by swelling soil.

X1.22.1 *Severity Level*:

X1.22.1.1 **L**—Swell causes low-severity ride quality. Low-severity swells are not always easy to see but can be detected by driving at the speed limit over the pavement section. An upward motion will occur at the swell if it is present.

X1.22.1.2 **M**—Swell causes medium-severity ride quality.

X1.22.1.3 **H**—Swell causes high-severity ride quality.

X1.22.2 *How to Measure*—The surface area of the swell is measured in square meters (square feet).

WEATHERING AND RAVELING

X1.23 *Description*—Weathering and raveling are the wearing away of the pavement surface due to a loss of asphalt or tar binder and dislodged aggregate particles. These distresses indicate that either the asphalt binder has hardened appreciably or that a poor-quality mixture is present. In addition, raveling may be caused by certain types of traffic, for example, tracked vehicles. Softening of the surface and dislodging of the aggregates due to oil spillage also are included under raveling.

X1.23.1 *Severity Levels*:

X1.23.1.1 **L**—Aggregate or binder has started to wear away. In some areas, the surface is starting to pit (Fig. X1.51). In the case of oil spillage, the oil stain can be seen, but the surface is hard and cannot be penetrated with a coin.

X1.23.1.2 **M**—Aggregate or binder has worn away. The surface texture is moderately rough and pitted (Fig. X1.52). In the case of oil spillage, the surface is soft and can be penetrated with a coin.

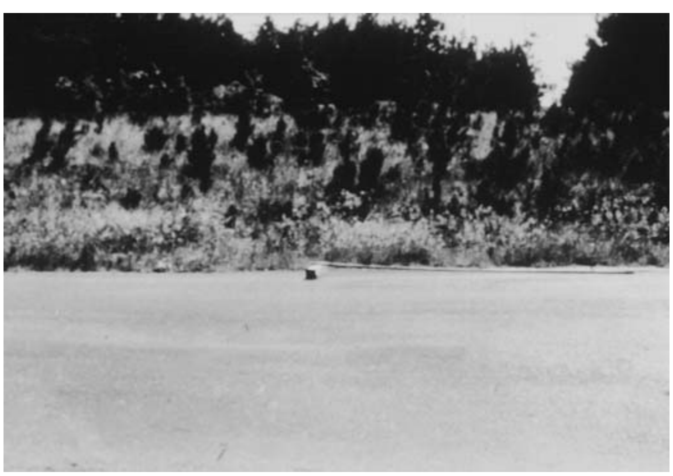


FIG. X1.50 Example Swell. Severity level is based on ride quality criteria.

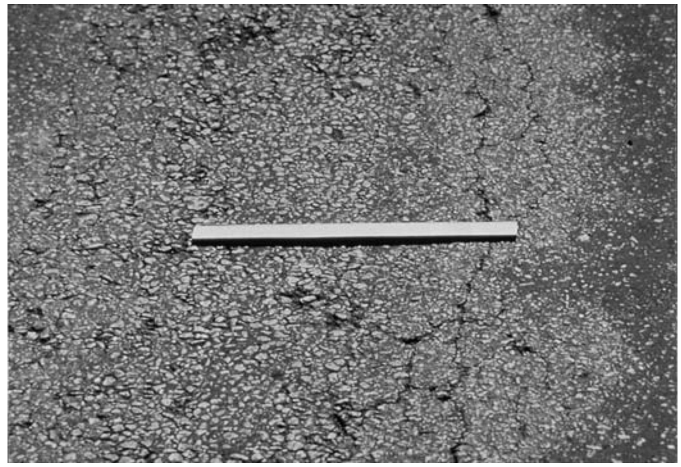


FIG. X1.51 Low-Severity Weathering and Raveling

FIG. X1.52 Medium-Severity Weathering and Raveling

X1.23.1.3 **H**—Aggregate or binder has been worn away considerably. The surface texture is very rough and severely pitted. The pitted areas are less than 10 mm (4 in.) in diameter and less than 13 mm (½ in.) deep (Fig. X1.53); pitted areas larger than this are counted as potholes. In the case of oil

FIG. X1.53 High-Severity Weathering and Raveling

spillage, the asphalt binder has lost its binding effect and the aggregate has become loose.

X1.23.2 *How to Measure*—Weathering and raveling are measured in square meters (square feet) of surface area.

X2. DISTRESS IN JOINTED CONCRETE PAVEMENTS

X2.1 This Appendix lists alphabetically 19 distress types for jointed concrete pavements. Distress definitions apply to both plain and reinforced jointed concrete pavements, with the exception of linear cracking distress, which is defined separately for plain and reinforced jointed concrete.

X2.1.1 During the field condition surveys and validation of the PCI, several questions often are asked about the identification and counted method of some of the distresses. Answers to these questions are included under the heading "How to Count." For convenience, however, the most frequently raised issues are addressed below.

X2.1.1.1 Faulting is counted only at joints. Faulting associated with cracks is not counted separately since it is incorporated into the severity-level definitions of cracks. Crack definitions are also used in defining corner breaks and divided slabs.

X2.1.1.2 Joint seal damage is not counted on a slab-by-slab basis. Instead, a severity level is assigned based on the overall condition of the joint seal in the area.

X2.1.1.3 Cracks in reinforced concrete slabs that are less than ⅛ in. wide are counted as shrinkage cracks. Shrinkage cracks should not be counted to determine if the slab is broken into four or more pieces.

X2.1.1.4 Low-severity scaling, that is, crazing, should only be counted if there is evidence that future scaling is likely to occur.

X2.1.2 The user should note that the items above are general issues and do not stand alone as inspection criteria. To measure each distress type properly, the inspector must be familiar with the individual distress criteria.

X2.2 *Ride Quality*:

X2.2.1 Ride quality must be evaluated in order to establish a severity level for the following distress types:

X2.2.1.1 Blowup/buckling.

X2.2.1.2 Railroad crossings.

X2.2.2 To determine the effect these distresses have on ride quality, the inspector should drive at the normal operating speed and use the following severity-level definitions of ride quality:

X2.2.2.1 **L**—Low. Vehicle vibrations, for example, from corrugation, are noticeable, but no reduction in speed is necessary for comfort or safety, or individual bumps or settlements, or both, cause the vehicle to bounce slightly but create little discomfort.

X2.2.2.2 **M**—Medium. Vehicle vibrations are significant and some reduction in speed is necessary for safety and comfort, or individual bumps or settlements cause the vehicle to bounce significantly, or both, creating some discomfort.

X2.2.2.3 **H**—High. Vehicle vibrations are so excessive that speed must be reduced considerably for safety and comfort, or individual bumps or settlements, or both, cause the vehicle to bounce excessively, creating substantial discomfort, a safety hazard, or high potential vehicle damage, or a combination thereof.

X2.2.3 The inspector should drive at the posted speed in a sedan that is representative of cars typically seen in local traffic. Pavement sections near stop signs should be rated at a deceleration speed appropriate for the intersection.

BLOWUP/BUCKLING

X2.3 *Description*—Blowups or buckles occur in hot weather, usually at a transverse crack or joint that is not wide enough to permit slab expansion. The insufficient width usually is caused by infiltration of incompressible materials into the joint space. When expansion cannot relieve enough pressure, a localized upward movement of the slab edges (buckling) or shattering will occur in the vicinity of the joint. Blowups also can occur at utility cuts and drainage inlets.

X2.3.1 *Severity Levels*:

X2.3.1.1 **L**—Buckling or shattering causes low-severity ride quality (Fig. X2.1).

X2.3.1.2 **M**—Buckling or shattering causes medium-severity ride quality (Fig. X2.2).

X2.3.1.3 **H**—Buckling or shattering causes high-severity ride quality (Fig. X2.3).

X2.3.2 *How to Count*—At a crack, a blowup is counted as being in one slab; however, if the blowup occurs at a joint and affects two slabs, the distress should be recorded as occurring in two slabs. When a blowup renders the pavement impassable, it should be repaired immediately.

CORNER BREAK

X2.4 *Description*—A corner break is a crack that intersects the joints at a distance less than or equal to one-half the slab length on both sides, measured from the corner of the slab. For

FIG. X2.1 Low Severity Blowup/Buckling

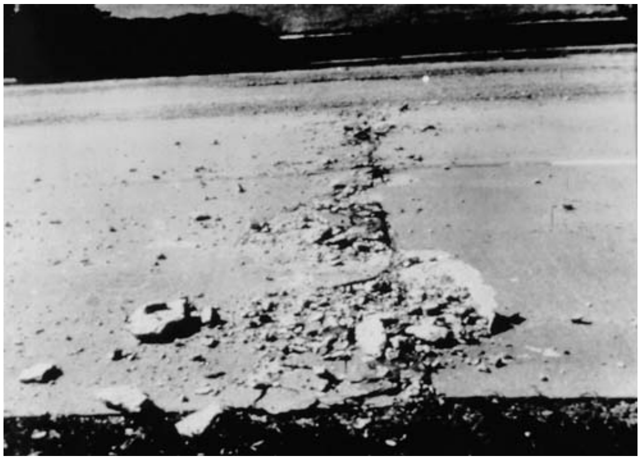


FIG. X2.2 Medium Severity Blowup/Buckling

FIG. X2.3 High-Severity Blowup/Buckling

example, a slab measuring 3.5 by 6.0 m (11.5 by 20.0 ft) that has a crack 1.5 m (5 ft) on one side and 3.5 m (11.5 ft) on the other side is not considered a corner break; it is a diagonal crack. However, a crack that intersects 0.5 m (4 ft) on one side and 2.5 m (8 ft) on the other is considered a corner break. A corner break differs from a corner spall in that the crack extends vertically through the entire slab thickness, whereas a corner spall intersects the joint at an angle. Load repetition combined with loss of support and curling stresses usually cause corner breaks.

X2.4.1 *Severity Levels*—

X2.4.1.1 **L**—Break is defined by a low-severity[4] crack. A low severity crack is < 13 mm (½ in.), cracks of any width with satisfactory filler; no faulting. The area between the break and the joints is not cracked or may be lightly cracked (Fig. X2.4).

X2.4.1.2 **M**—Break is defined by a medium-severity[4] crack, or the area between the break and the joints, or both, has a medium crack. A medium severity crack is a nonfilled crack > 13 mm and < 50 mm (>½ in. and < 2 in.), a nonfilled crack < 50 mm (2 in.) with faulting < 10 mm (⅜ in.), or a any filled crack with faulting < 10 mm (⅜ in.) (Fig. X2.5).

X2.4.1.3 **H**—Break is defined by a high-severity[4] crack, or the area between the break and the joints, or both, is highly cracked. A high severity crack is a nonfilled crack >50 mm (2 in.) wide, or any filled or nonfilled crack with faulting >10 mm (⅜ in.) (Fig. X2.6).

X2.4.2 *How to Count*—Distressed slab is recorded as one slab if it:

X2.4.2.1 A single corner break.

X2.4.2.2 More than one break of a particular severity.

X2.4.2.3 Two or more breaks of different severities. For two or more breaks, the highest level of severity should be recorded. For example, a slab containing both low- and medium-severity corner breaks should be counted as one slab with a medium corner break.

FIG. X2.4 Low-Severity Corner Break

FIG. X2.5 Medium-Severity Corner Break

[4] The above crack severity definitions are for nonreinforced slabs. For reinforced slabs, see *linear cracking*.

FIG. X2.6 High-Severity Corner Break

FIG. X2.7 Low-Severity Divided Slab

DIVIDED SLAB

X2.5 *Description*—Slab is divided by cracks into four or more pieces due to overloading, or inadequate support, or both. If all pieces or cracks are contained within a corner break, the distress is categorized as a severe corner break.

X2.5.1 *Severity Levels*—Table X2.1 lists severity levels for divided slabs. Examples are shown in Figs. X2.7-X2.9.

X2.5.2 *How to Count*—If the divided slab is medium- or high-severity, no other distress is counted for that slab.

DURABILITY ("D") CRACKING

X2.6 *Description*—"D" cracking is caused by freeze-thaw expansion of the large aggregate, which, over time, gradually breaks down the concrete. This distress usually appears as a pattern of cracks running parallel and close to a joint or linear crack. Since the concrete becomes saturated near joints and cracks, a dark-colored deposit can usually be found around fine" D" cracks. This type of distress may eventually lead to disintegration of the entire slab.

X2.6.1 *Severity Levels*:

X2.6.1.1 *L*—"D" cracks cover less than 15 % of slab area. Most of the cracks are tight, but a few pieces may be loose and or missing (Fig. X2.10).

X2.6.1.2 **M**—One of the following conditions exists (Fig. X2.11): "D" cracks cover less than 15 % of the area and most of the pieces are loose and or missing, or "D" cracks cover more than 15 % of the area. Most of the cracks are tight, but a few pieces may be loose and or missing.

X2.6.1.3 *H*—"D" cracks cover more than 15 % of the area and most of the pieces have come out or could be removed easily (Fig. X2.12).

TABLE X2.1 Levels of Severity for Faulting

Severity Level	Difference of Elevation
L	>3 and <10 mm (>⅛ and <⅜ in.)
M	>10 and <20 mm (>⅜ and <¾ in.)
H	>20 mm (>¾ in.)

FIG. X2.8 Medium-Severity Divided Slab

FIG. X2.9 High-Severity Divided Slab

X2.6.2 *How to Count*—When the distress is located and rated at one severity, it is counted as one slab. If more than one severity level exists, the slab is counted as having the higher severity distress. For example, if low and medium "D" cracking are on the same slab, the slab is counted as medium-severity cracking only.

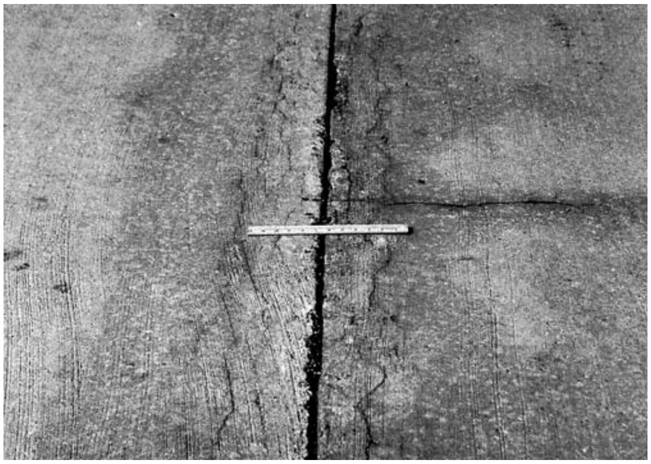


FIG. X2.10 Low-Severity Durability Cracking

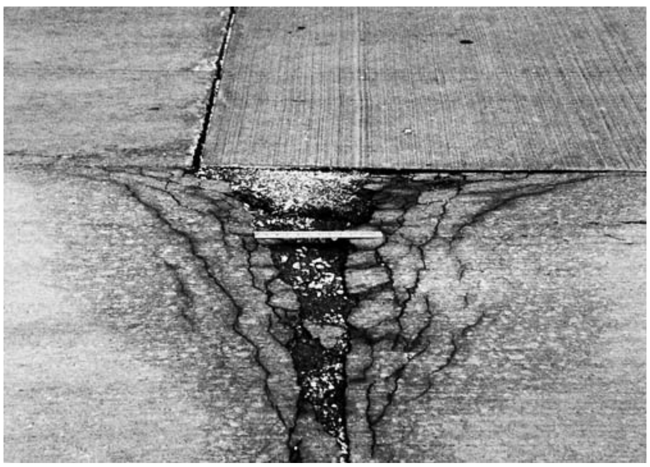


FIG. X2.11 Medium-Severity Durability Cracking

FIG. X2.12 High-Severity Durability Cracking

FAULTING

X2.7 *Description*:

X2.7.1 Faulting is the difference in elevation across a joint. Some common causes of faulting are as follows:

X2.7.1.1 Settlement because of soft foundation.

X2.7.1.2 Pumping or eroding of material from under the slab.

X2.7.1.3 Curling of the slab edges due to temperature and moisture changes.

X2.7.2 *Severity Levels*—Severity levels are defined by the difference in elevation across the joint as indicated in Table X2.2. Figs. X2.13-X2.15 show examples of the different severity levels.

X2.7.3 *How to Count*—Faulting across a joint is counted as one slab. Only affected slabs are counted. Faults across a crack are not counted as distress but are considered when defining crack severity.

JOINT SEAL DAMAGE

X2.8 *Description*:

X2.8.1 Joint seal damage is any condition that enables soil or rocks to accumulate in the joints or allows significant water infiltration. Accumulation of incompressible materials prevents the slab from expanding and may result in buckling, shattering, or spalling. A pliable joint filler bonded to the edges of the slabs protects the joints from material accumulation and prevents water from seeping down and softening the foundation supporting the slab. Typical types of joint seal damage are as follows:

X2.8.1.1 Stripping of joint sealant.

X2.8.1.2 Extrusion of joint sealant.

X2.8.1.3 Weed growth.

X2.8.1.4 Hardening of the filler (oxidation).

X2.8.1.5 Loss of bond to the slab edges.

X2.8.1.6 Lack or absence of sealant in the joint.

X2.8.2 *Severity Levels*:

X2.8.2.1 **L**—Joint sealant is in generally good condition throughout section (Fig. X2.16). Sealant is performing well, with only minor damage (see X2.8.1.1-X2.8.1.6). Joint seal damage is at low severity if a few of the joints have sealer, which has debonded from, but is still in contact with, the joint edge. This condition exists if a knife blade can be inserted between sealer and joint face without resistance.

X2.8.2.2 **M**—Joint sealant is in generally fair condition over the entire section, with one or more of the above types of damage occurring to a moderate degree. Sealant needs replacement within two years (Fig. X2.17). Joint seal damage is at medium severity if a few of the joints have any of the following conditions: joint sealer is in place, but water access is possible through visible openings no more than 3 mm (⅛ in.) wide. If a knife blade cannot be inserted easily between sealer and joint face, this condition does not exist; pumping debris are evident at the joint; joint sealer is oxidized and "lifeless" but pliable (like a rope), and generally fills the joint opening; or, vegetation in the joint is obvious but does not obscure the joint opening.

TABLE X2.2 Levels of Severity for Punchouts

Severity of the Majority of Cracks	Number of Pieces 2 to 3	4 to 5	>5
L	L	L	M
M	L	M	H
H	M	H	H

FIG. X2.13 Low-Severity Faulting

FIG. X2.14 Medium-Severity Faulting

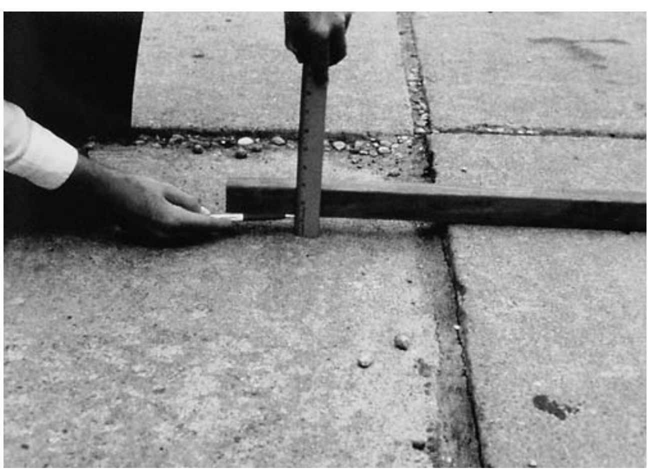


FIG. X2.15 High-Severity Faulting

FIG. X2.16 Low-Severity Joint Seal Damage

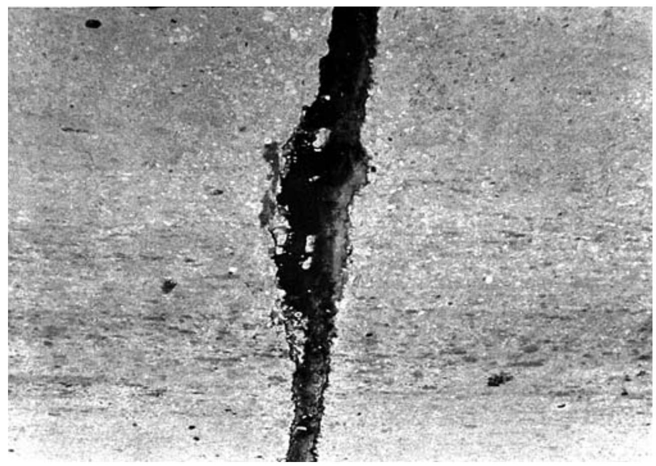


FIG. X2.17 Medium-Severity Joint Seal Damage

FIG. X2.18 High-Severity Joint Seal Damage

X2.8.2.3 **H**—Joint sealant is in generally poor condition over the entire section, with one or more of the above types of damage occurring to a severe degree. Sealant needs immediate replacement (Fig. X2.18). Joint seal damage is at high severity if 10 % or more of the joint sealer exceeds limiting criteria listed above or if 10 % or more of sealer is missing.

X2.8.3 *How to Count*—Joint seal damage is not counted on a slab-by-slab basis but is rated based on the overall condition of the sealant over the entire area.

LANE/SHOULDER DROP-OFF

X2.9 *Description*—Lane/shoulder drop-off is the difference between the settlement or erosion of the shoulder and the pavement travel-lane edge. The elevation difference can be a safety hazard, and it also can cause increased water infiltration.

X2.9.1 *Severity Levels*:

X2.9.1.1 **L**—The difference between the pavement edge and shoulder is >25 and ≤50 mm (>1 and ≤2 in.) (Fig. X2.19).

X2.9.1.2 **M**—The difference in elevation is >50 and ≤100 mm (>2 and ≤4 in.) (Fig. X2.20).

X2.9.1.3 **H**—The difference in elevation is >100 mm (>4 in.) (Fig. X2.21).

X2.9.2 *How to Count*—The mean lane/shoulder drop-off is computed by averaging the maximum and minimum drop along the slab. Each slab exhibiting distress is measured separately and counted as one slab with the appropriate severity level.

LINEAR CRACKING
(Longitudinal, Transverse, and Diagonal Cracks)

X2.10 *Description*—These cracks, which divide the slab into two or three pieces, usually are caused by a combination of repeated traffic loading, thermal gradient curling, and repeated moisture loading. (Slabs divided into four or more pieces are counted as divided slabs.) Hairline cracks that are only a few feet long and do not extend across the entire slab, are counted as shrinkage cracks.

X2.10.1 *Severity Levels (Nonreinforced Slabs)*:

X2.10.1.1 **L**—Nonfilled[4] cracks ≤ 13 mm (≤ ½ in.) or filled cracks of any width with the filler in satisfactory condition. No faulting exists (Fig. X2.22).

X2.10.1.2 **M**—One of the following conditions exists: nonfilled crack with a width >13 and ≤50 mm (>½ and ≤ 2 in.); nonfilled crack of any width ≤ 50 mm (2 in.) with faulting of <10 mm (⅜ in.), or filled crack of any width with faulting <10 mm (⅜ in.) (Fig. X2.23).

X2.10.1.3 **H**—One of the following conditions exists: nonfilled crack with a width >50 mm (2 in.), or filled or nonfilled crack of any width with faulting >10 mm (⅜ in.) (Fig. X2.24).

X2.10.2 *Reinforced Slabs*:

X2.10.2.1 **L**—Nonfilled cracks ≥ 3 and < 25 mm (≥ ⅛ to < 1 in.) wide; filled crack of any width with the filler in satisfactory condition. No faulting exists.

FIG. X2.19 Low-Severity Lane/Shoulder Drop-Off

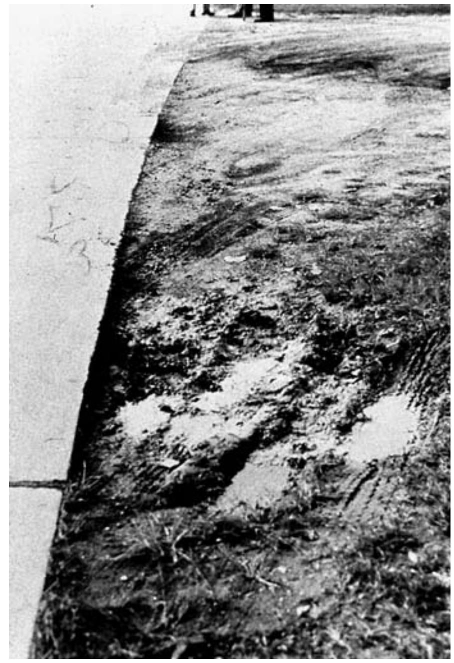


FIG. X2.20 Medium-Severity Lane/Shoulder Drop-Off

FIG. X2.21 High-Severity Lane/Shoulder Drop-Off

X2.10.2.2 **M**—One of the following conditions exists: nonfilled cracks with a width ≥ 25 and < 75 mm (≥ 1 and < 3 in.) and no faulting; nonfilled crack of any width ≤ 75 mm (3 in.) with ≤ 10 mm (⅜ in.) of faulting, or filled crack of any width with ≤ 10 mm (⅜ in.) faulting.

X2.10.2.3 **H**—Once of the following conditions exists: nonfilled crack >75 mm (3 in.) wide, or filled or nonfilled crack of any width with faulting >10 mm (⅜ in.).

X2.10.3 *How to Count*—One the severity has been identified, the distress is recorded as one slab. If two medium severity cracks are within one slab, the slab is counted as

FIG. X2.22 Low-Severity Linear Cracking

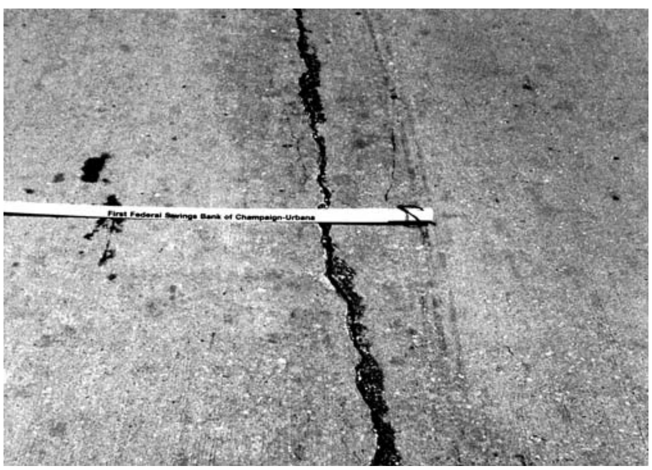


FIG. X2.23 Medium-Severity Linear Cracking

having one high-severity crack. Slabs divided into four or more pieces are counted as divided slabs. In reinforced slabs, cracks <3 mm (1⁄8 in.) wide are counted as shrinkage cracks. Slabs longer than 9 m (29.5 ft) are divided into approximately equal length" slabs" having imaginary joints assumed to be in perfect condition.

PATCHING, LARGE (MORE THAN 0.5 M^2 [5.5 FT^2]) AND UTILITY CUTS

X2.11 *Description*—A patch is an area where the original pavement has been removed and replaced by filler material. A utility cut is a patch that has replaced the original pavement to allow the installation or maintenance of underground utilities. The severity levels of a utility cut are assessed according to the same criteria as large patching.

X2.11.1 *Severity Levels*:

FIG. X2.24 High-Severity Linear Cracking

X2.11.1.1 **L**—Patch is functioning well, with little or no deterioration (Fig. X2.25).

X2.11.1.2 **M**—Patch is moderately deteriorated, or moderate spalling can be seen around the edges, or both. Patch material can be dislodged with considerable effort (Fig. X2.26).

X2.11.1.3 **H**—Patch is badly deteriorated. The extent of the deterioration warrants replacement (Fig. X2.27).

X2.11.2 *How to Count*—If a single slab has one or more patches with the same severity level, it is counted as one slab containing that distress. If a single slab has more than one severity level, it is counted as one slab with the higher severity level.

PATCHING, SMALL (LESS THAN 0.5 M^2 [5.5 FT^2])

X2.12 *Description*—A patch is an area where the original pavement has been removed and replaced by a filler material.

X2.12.1 *Severity Levels*:

X2.12.1.1 **L**—Patch is functioning well with little or no deterioration (Fig. X2.28).

X2.12.1.2 **M**—Patch is moderately deteriorated. Patch material can be dislodged with considerable effort (Fig. X2.29).

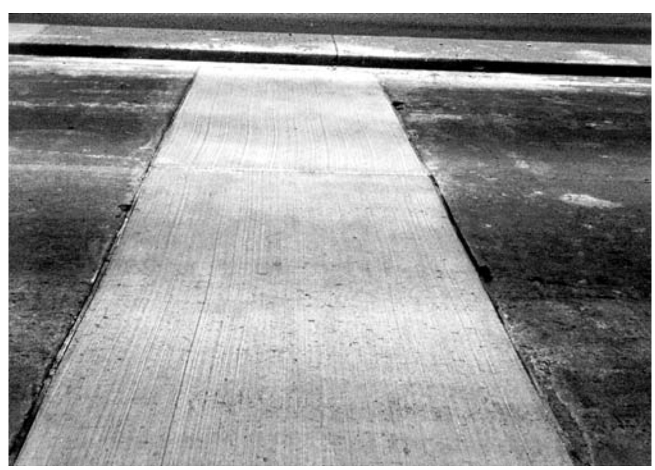


FIG. X2.25 Low-Severity Patching, Large and Utility Cuts

FIG. X2.26 Medium-Severity Patching, Large and Utility Cuts

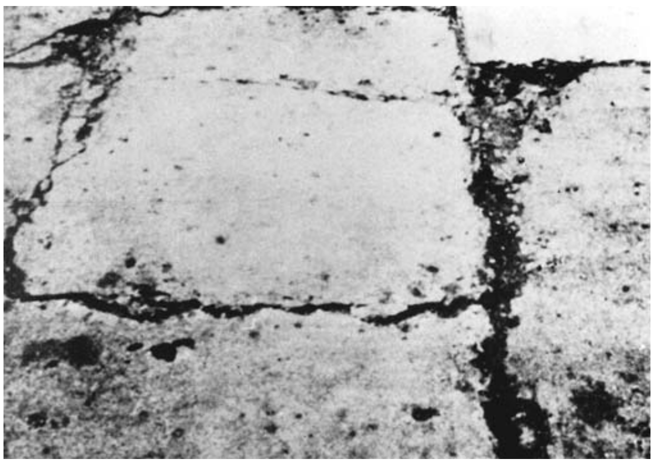


FIG. X2.27 High-Severity Patching, Large and Utility Cuts

FIG. X2.28 Low-Severity Patching, Small

X2.12.1.3 **H**—Patch is badly deteriorated. The extent of deterioration warrants replacement (Fig. X2.30).

X2.12.2 *How to Count*—If a single slab has one or more patches with the same severity level, it is counted as one slab containing that distress. If a single slab has more than one severity level, it is counted as one slab with the higher severity level.

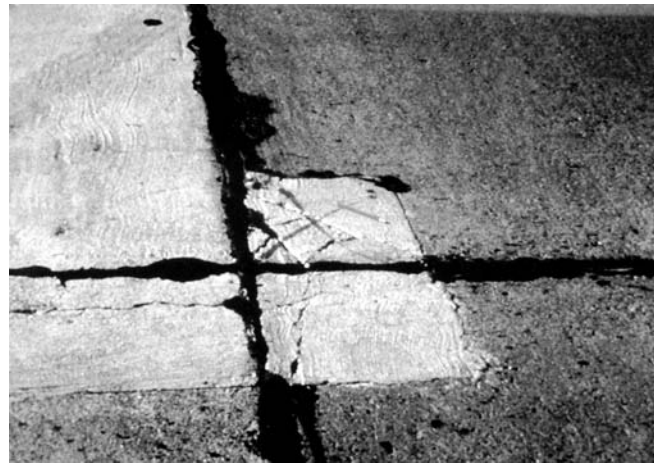


FIG. X2.29 Medium-Severity Patching, Small

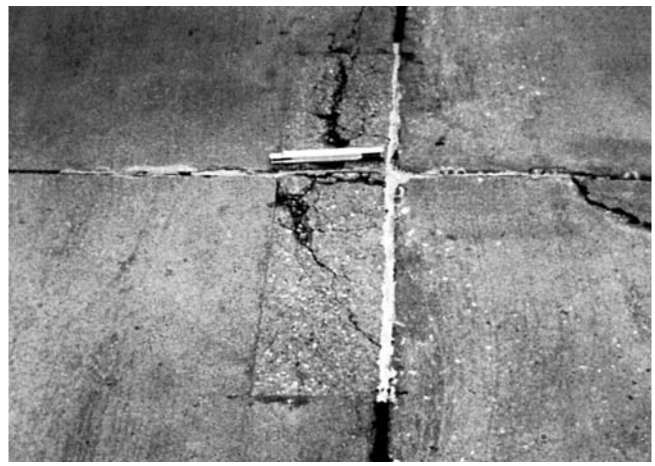


FIG. X2.30 High-Severity Patching, Small

POLISHED AGGREGATE

X2.13 *Description*—This distress is caused by repeated traffic applications. Polished aggregate is present when close examination of a pavement reveals that the portion of aggregate extending above the asphalt is either very small, or there are no rough or angular aggregate particles to provide good skid resistance.

X2.13.1 *Severity Levels*—No degrees of severity are defined; however, the degree of polishing should be significant before it is included in the condition survey and rated as a defect (Fig. X2.31).

X2.13.2 *How to Count*—A slab with polished aggregate is counted as one slab.

POPOUTS

X2.14 *Description*—A popout is a small piece of pavement that breaks loose from the surface due to freeze-thaw action, combined with expansive aggregates. Popouts usually range in diameter from approximately 25 to 100 mm (1 to 4 in.) and in depth from 13 to 50 mm (½ to 2 in.).

X2.14.1 *Severity Levels*—No degrees of severity are defined for popouts; however, popouts must be extensive before

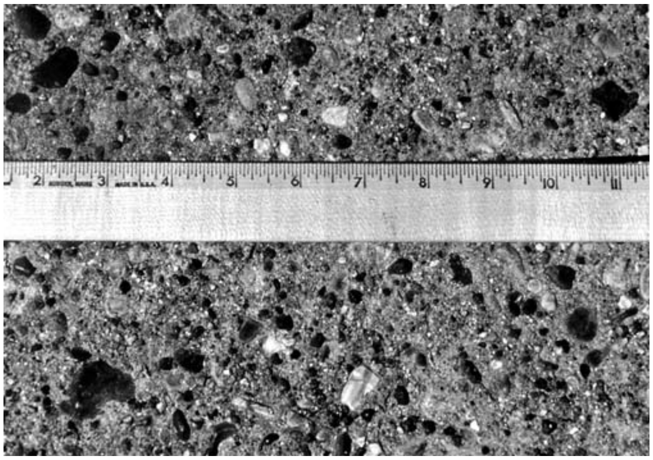


FIG. X2.31 Polished Aggregate

they are counted as a distress. Average popout density must exceed approximately three popouts/m^2 over the entire slab area (Fig. X2.32).

X2.14.2 *How to Count*—The density of the distress must be measured. If there is any doubt that the average is greater than three popouts per square yard, at least three random 1 m^2 (11 ft^2) areas should be checked. When the average is greater than this density, the slab should be counted.

PUMPING

X2.15 *Description*—Pumping is the ejection of material from the slab foundation through joints or cracks. This is caused by deflection of the slab with passing loads. As a load moves across the joint between the slabs, water is first forced under the leading slab, and then forced back under the trailing slab. This action erodes and eventually removes soil particles resulting in progressive loss of pavement support. Pumping can be identified by surface stains and evidence of base or subgrade material on the pavement close to joints or cracks. Pumping near joints is caused by poor joint sealer and indicates loss of support; repeated loading eventually will produce cracks. Pumping also can occur along the slab edge causing loss of support.

FIG. X2.32 Popouts

X2.15.1 *Severity Levels*—No degrees of severity are defined. It is enough to indicate that pumping exists (Fig. X2.33 and Fig. X2.34).

X2.15.2 *How to Count*—One pumping joint between two slabs is counted as two slabs; however, if the remaining joints around the slab are also pumping, one slab is added per additional pumping joint.

PUNCHOUT

X2.16 *Description*—This distress is a localized area of the slab that is broken into pieces. The punchout can take many different shapes and forms, but it is usually defined by a crack and a joint. The distance between the join and the crack or two closely spaced cracks is ≤ 1.5 m (5 ft) wide. This distress is caused by heavy repeated loads, inadequate slab thickness, loss of foundation support, or a localized concrete construction deficiency, for example, honeycombing.

X2.16.1 *Severity Levels*—Table X2.2 lists the severity levels for punchouts, and Figs. X2.35-X2.37 show examples.

X2.16.2 *How to Count*—If a slab contains more than one punchout or a punchout and a crack, it is counted as shattered.

RAILROAD CROSSING

X2.17 *Description*—Railroad crossing distress is characterized by depressions or bumps around the tracks.

X2.17.1 *Severity Levels*:

X2.17.1.1 **L**—Railroad crossing causes low-severity ride quality (Fig. X2.38).

X2.17.1.2 **M**—Railroad crossing causes medium-severity ride quality (Fig. X2.39).

X2.17.1.3 **H**—Railroad crossing causes high-severity ride quality (Fig. X2.40).

FIG. X2.33 Pumping

FIG. X2.34 Pumping

FIG. X2.35 Low-Severity Punchout

X2.17.2 *How to Count*—The number of slabs crossed by the railroad tracks is counted. Any large bump created by the tracks should be counted as part of the crossing.

SCALING, MAP CRACKING, AND CRAZING

X2.18 *Description*—Map cracking or crazing refers to a network of shallow, fine, or hairline cracks that extend only through the upper surface of the concrete. The cracks tend to intersect at angles of 120°. Map cracking or crazing usually is caused by concrete over-finishing and may lead to surface scaling, which is the breakdown of the slab surface to a depth of approximately 6 to 13 mm (¼ to ½ in.). Scaling also may be caused by deicing salts, improper construction, freeze-thaw cycles and poor aggregate. The type of scaling defined here is not caused by "D" cracking. If scaling is caused by "D" cracking, it should be counted under that distress only.

X2.18.1 *Severity Levels*:

FIG. X2.36 Medium-Severity Punchout

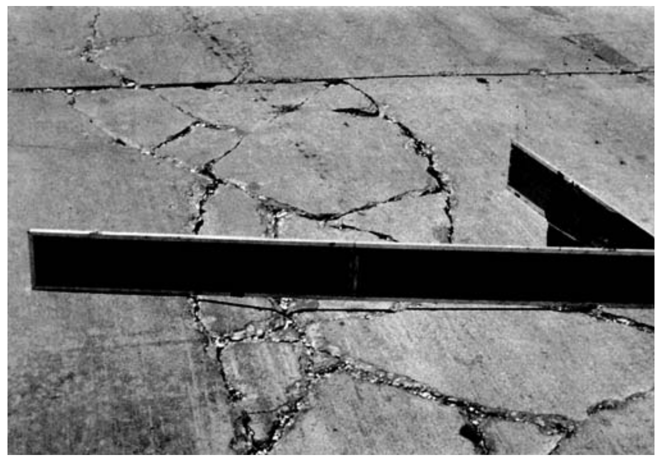


FIG. X2.37 High-Severity Punchout

FIG. X2.38 Low-Severity Railroad Crossing

X2.18.1.1 **L**—Crazing or map cracking exists over most of the slab area; the surface is in good condition, with only minor scaling present (Fig. X2.41).

X2.18.1.2 **M**—Slab is scaled but less than 15 % of the slab is affected (Fig. X2.42).

X2.18.1.3 **H**—Slab is scaled over more than 15 % of its area (Fig. X2.43).

FIG. X2.39 Medium-Severity Railroad Crossing

FIG. X2.40 High-Severity Railroad Crossing

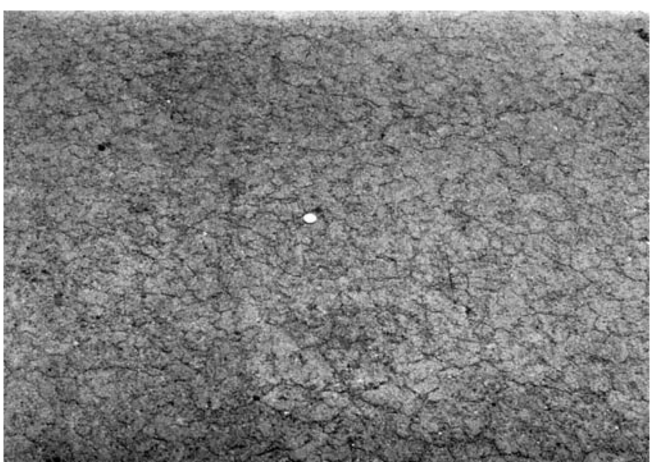


FIG. X2.41 Low-Severity Scaling, Map Cracking, and Crazing

X2.18.2 *How to Count*—A scaled slab is counted as one slab. Low-severity crazing only should be counted if the potential for scaling appears to be imminent or a few small pieces come out.

SHRINKAGE CRACKS

X2.19 *Description*—Shrinkage cracks are hairline cracks

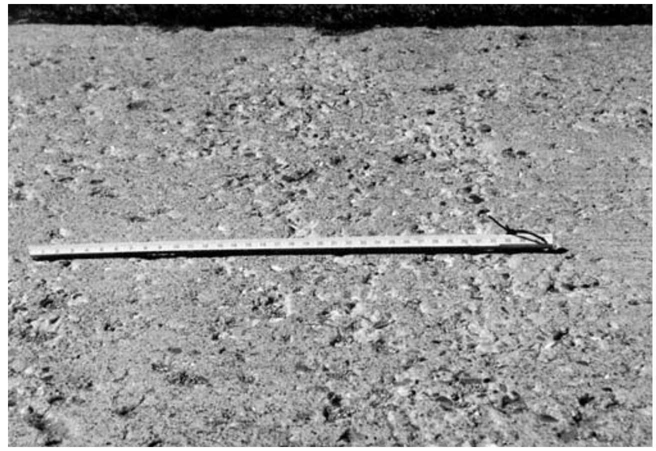


FIG. X2.42 Medium-Severity Scaling, Map Cracking, and Crazing

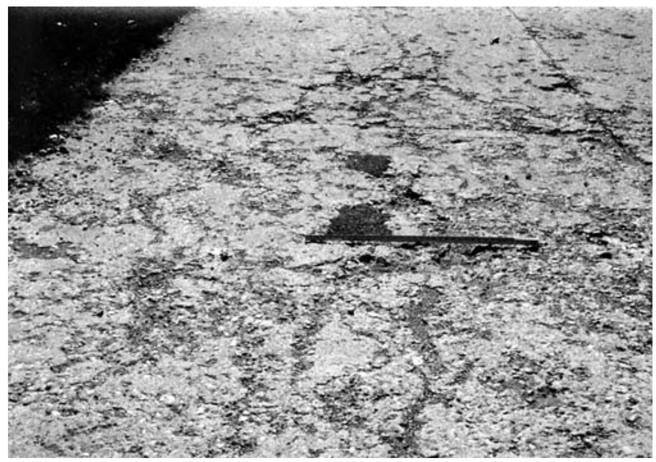


FIG. X2.43 High-Severity Scaling, Map Cracking, and Crazing

that usually are less than 2-m long and do not extend across the entire slab. They are formed during the setting and curing of the concrete and usually do not extend through the depth of the slab.

X2.19.1 *Severity Levels*—No degrees of severity are defined. It is enough to indicate that shrinkage cracks are present (Fig. X2.44).

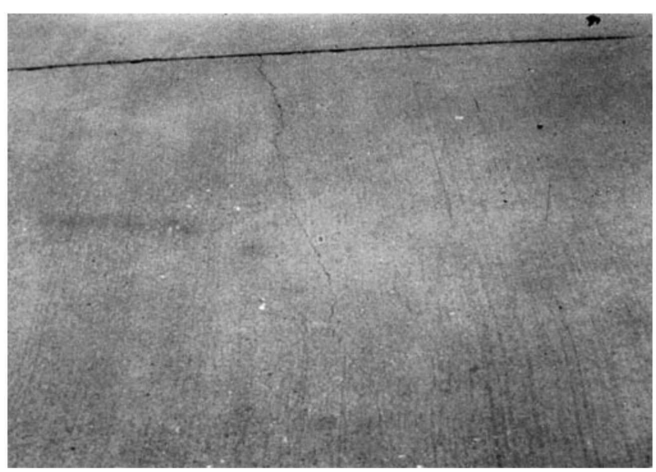


FIG. X2.44 Shrinkage Cracks

X2.19.2 *How to Count*—If any shrinkage cracks exist on a particular slab, the slab is counted as one slab with shrinkage cracks.

SPALLING, CORNER

X2.20 *Description*—Corner spalling is the breakdown of the slab within approximately 0.5 m (1.5 ft) of the corner. A corner spall differs from a corner break in that the spall usually angles downward to intersect the joint, whereas a break extends vertically through the slab corner. Spalls less than 130 mm (5 in.) from the crack to the corner on both sides should not be counted.

X2.20.1 *Severity Levels*—Table X2.3 lists the levels of severity for corner spalling. Figs. X2.45-X2.47 show examples. Corner spalling with an area of less than 650 cm (10 in.^{2}) from the crack to the corner on both sides should not be counted.

X2.20.2 *How to Count*—If one or more corner spalls with the same severity level are in a slab, the slab is counted as one slab with corner spalling. If more than one severity level occurs, it is counted as one slab with the higher severity level.

SPALLING, JOINT

X2.21 *Description*:

X2.21.1 Joint spalling is the breakdown of the slab edges within 0.5 m (1.5 ft) of the joint. A joint spall usually does not extend vertically through the slab, but intersects the joint at an angle. Spalling results from:

X2.21.1.1 Excessive stresses at the joint caused by traffic loading or by infiltration of incompressible materials.

X2.21.1.2 Weak concrete at the joint caused by overworking.

X2.21.1.3 Water accumulation in the joint and freeze-thaw action.

X2.21.2 *Severity Levels*—Table X2.4 and Figs. X2.48-X2.50 show the severity levels of joint spalling. A frayed joint where the concrete has been worn away along the entire joint is rated as low severity.

X2.21.3 *How to Count*—If spall is along the edge of one slab, it is counted as one slab with joint spalling. If spalling is on more than one edge of the same slab, the edge having the highest severity is counted and recorded as one slab. Joint spalling also can occur along the edges of two adjacent slabs. If this is the case, each slab is counted as having joint spalling.

TABLE X2.3 Levels of Severity for Corner Spalling

Depth of Spall	Dimensions of Sides of Spall 130 × 130 mm to 300 × 300 mm (5 × 5 in.) to (12 × 12 in.)	300 × 300 mm (>12 × 12 in.)
<25 mm (1 in.)	L	L
>25 to 50 mm (1 to 2 in.)	L	M
>50 mm (2 in.)	M	H

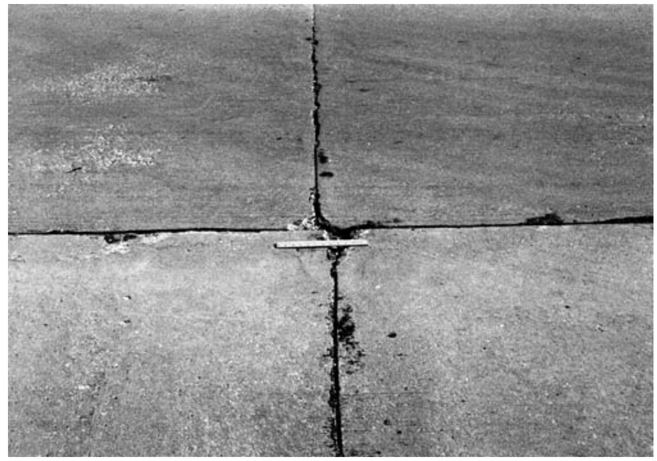


FIG. X2.45 Low-Severity Spalling, Corner

FIG. X2.46 Medium-Severity Spalling, Corner

FIG. X2.47 High-Severity Spalling, Corner

TABLE X2.4 Levels of Severity for Joint Spalling

Spall Pieces	Width of Spall	Length of Spall <0.5 m (1.5 ft)	Length of Spall >0.5 m (1.5 ft)
Tight—cannot be removed easily (maybe a few pieces missing.	<100 mm (4 in.)	**L**	**L**
	>100 mm	**L**	**L**
Loose—can be removed and some pieces are missing; if most or all pieces are missing, spall is shallow, less than 25 mm (1 in.).	<100 mm	**L**	**M**
	>100 mm	**L**	**M**
Missing—most or all pieces have been removed.	<100 mm	**L**	**M**
	>100 mm	**M**	**H**

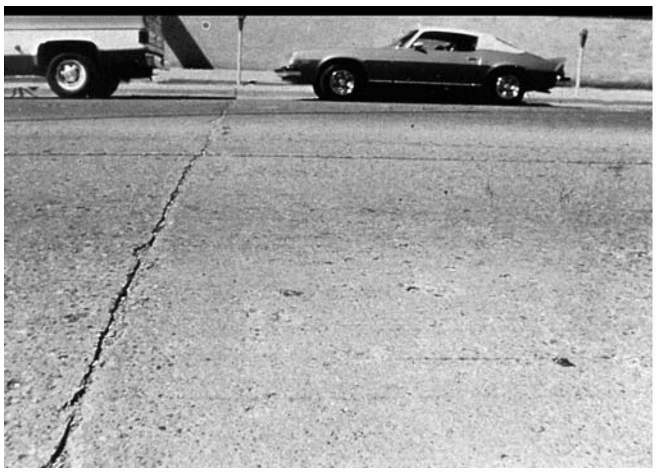


FIG. X2.48 Low-Severity Spalling, Joint

FIG. X2.49 Medium-Severity Spalling, Joint

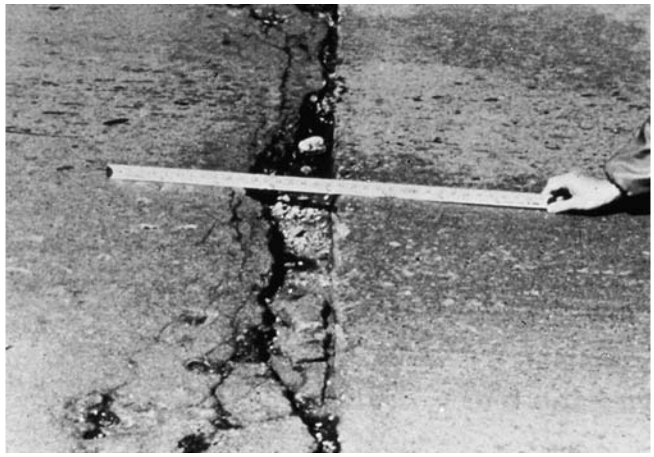


FIG. X2.50 High-Severity Spalling, Joint

X3. DEDUCT VALUE CURVES FOR ASPHALT

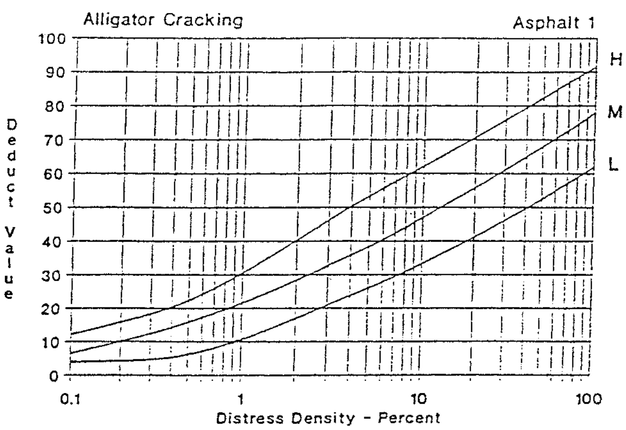


FIG. X3.1 Alligator Cracking

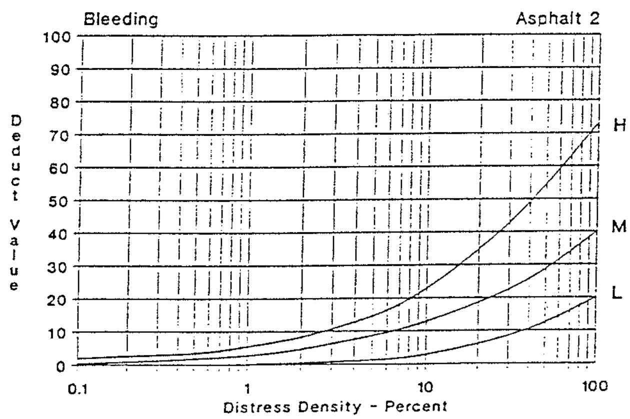


FIG. X3.2 Bleeding

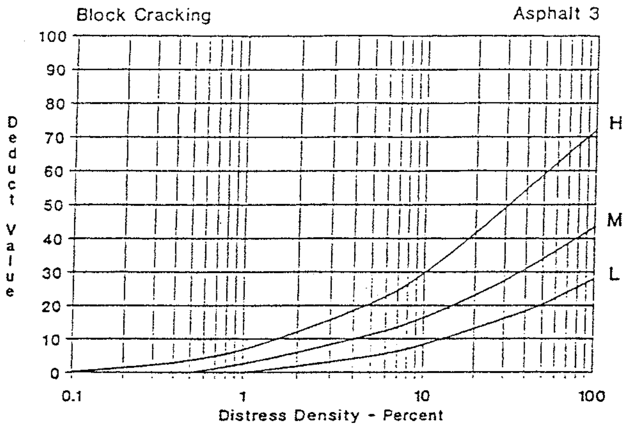


FIG. X3.3 Block Cracking

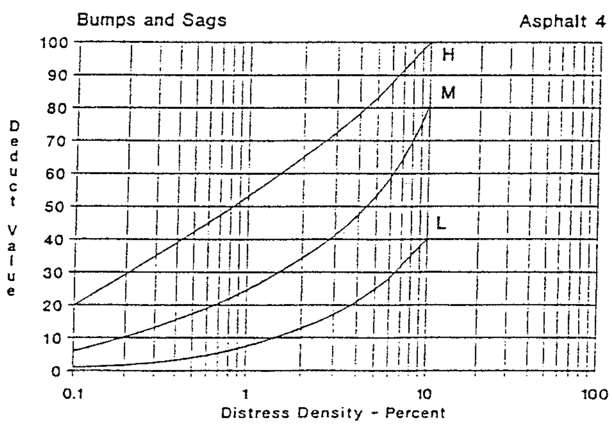


FIG. X3.4 Bumps and Sags

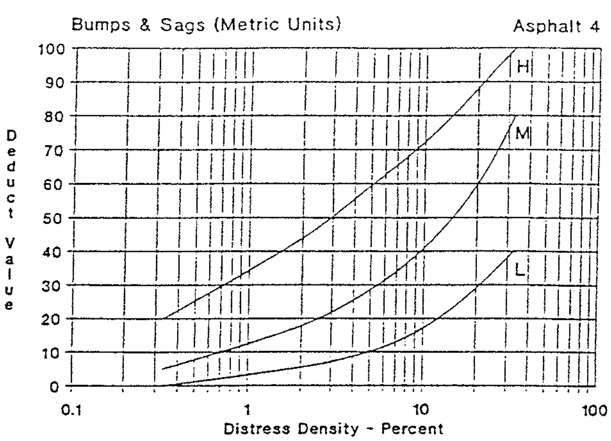


FIG. X3.5 Bumps and Sags (Metric units)

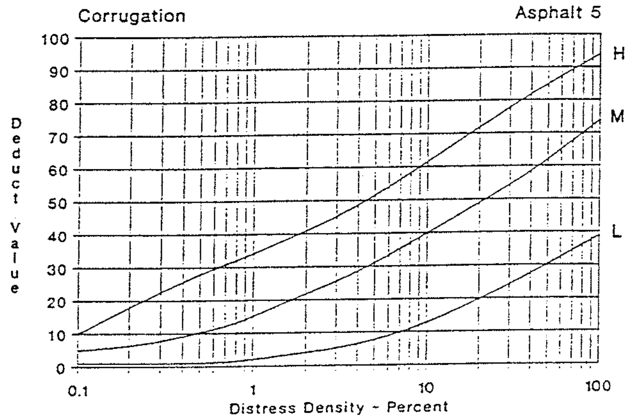


FIG. X3.6 Corrugation

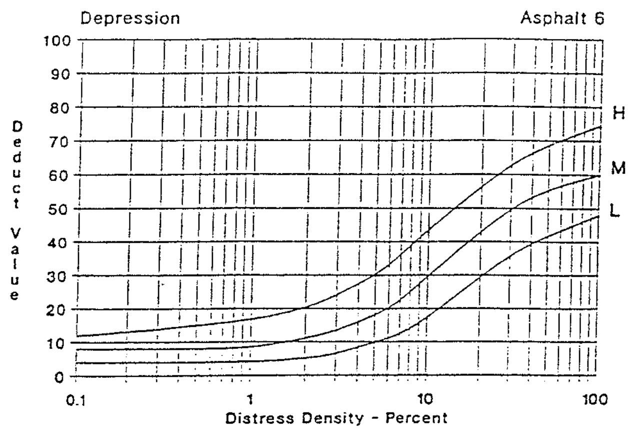


FIG. X3.7 Depression

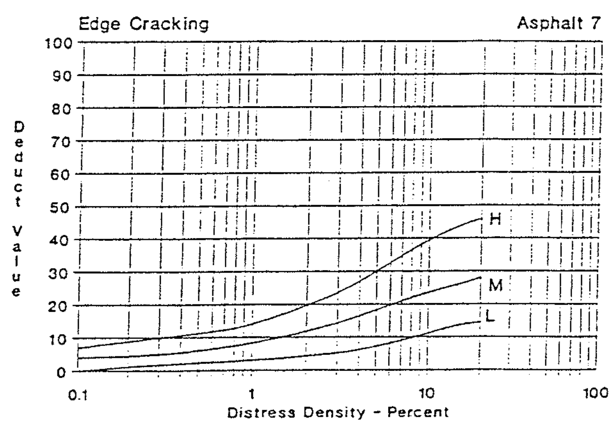


FIG. X3.8 Edge Cracking

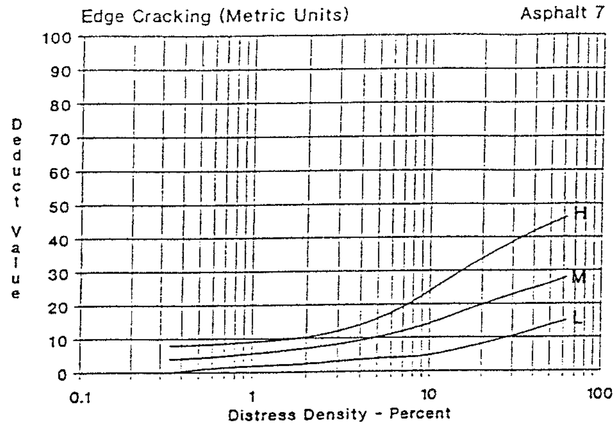


FIG. X3.9 Edge Cracking (metric units)

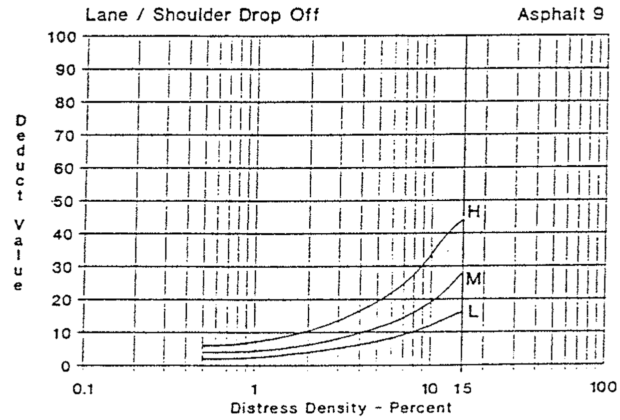


FIG. X3.12 Lane/Shoulder Drop-Off

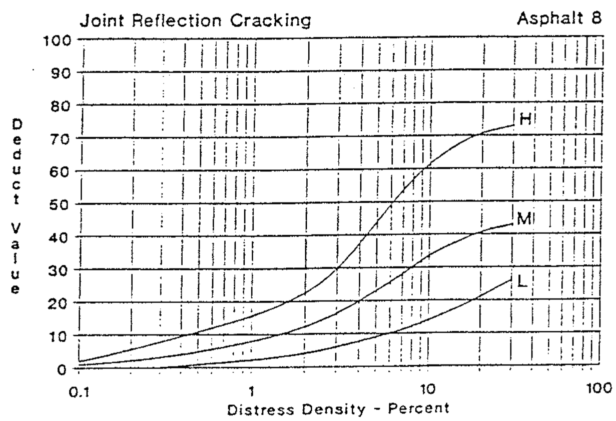


FIG. X3.10 Joint Reflection Cracking

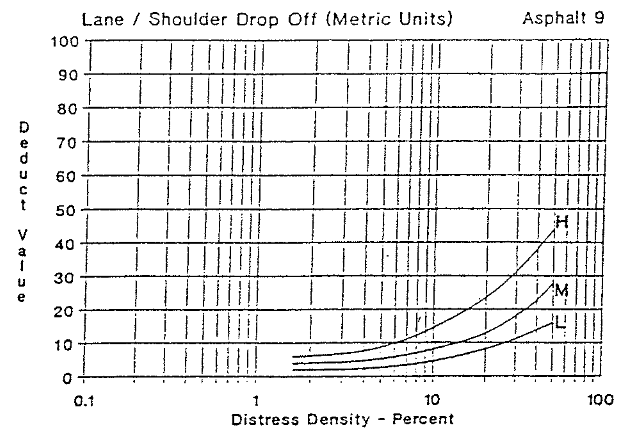


FIG. X3.13 Lane/Shoulder Drop-Off (metric units)

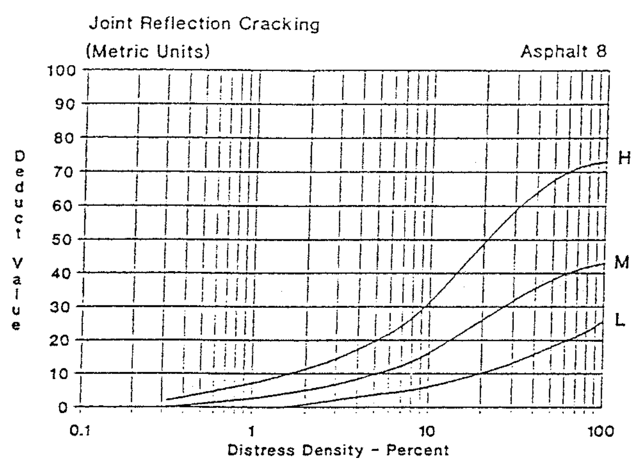


FIG. X3.11 Joint Reflection Cracking (metric units)

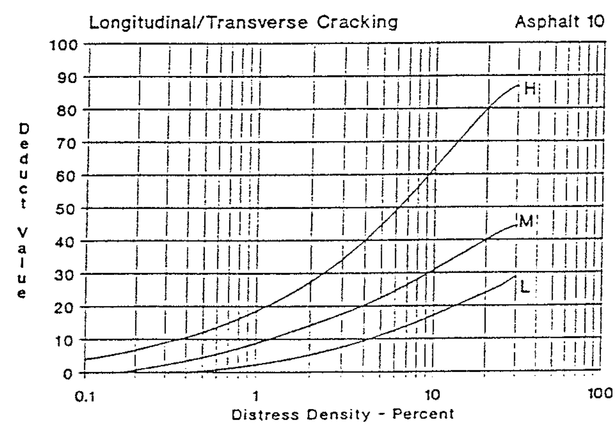


FIG. X3.14 Longitudinal/Transverse Cracking

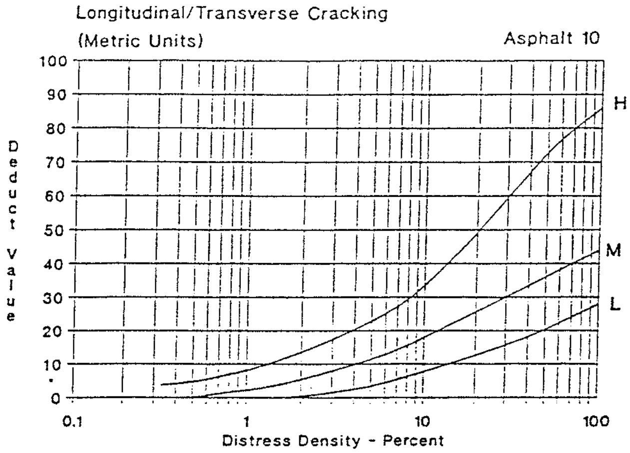


FIG. X3.15 Longitudinal/Transverse Cracking (metric units)

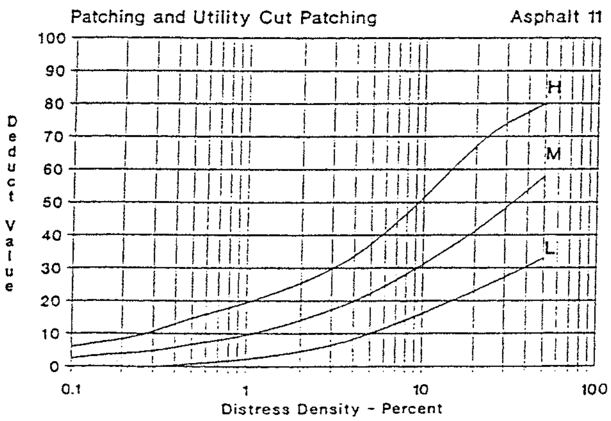


FIG. X3.16 Patching and Utility Cut Patching

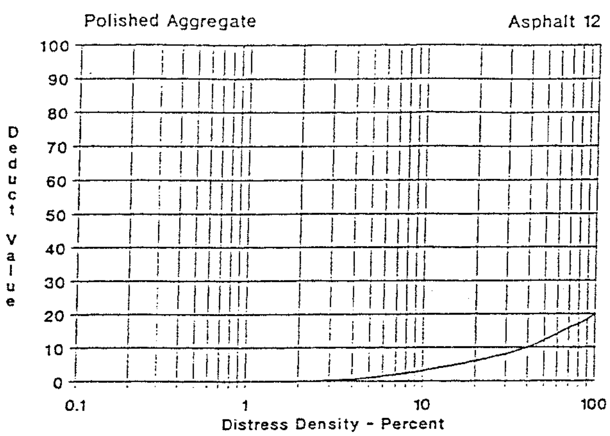


FIG. X3.17 Polished Aggregate

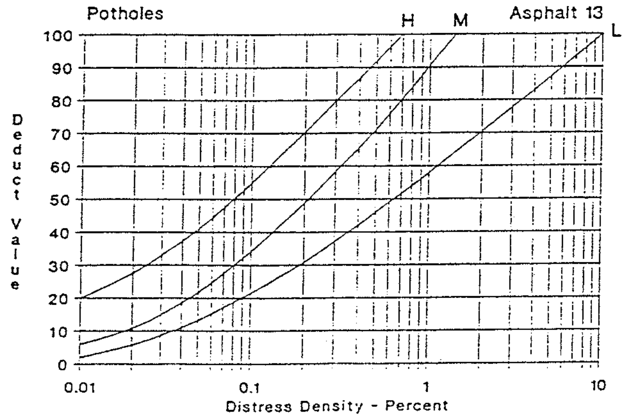


FIG. X3.18 Potholes

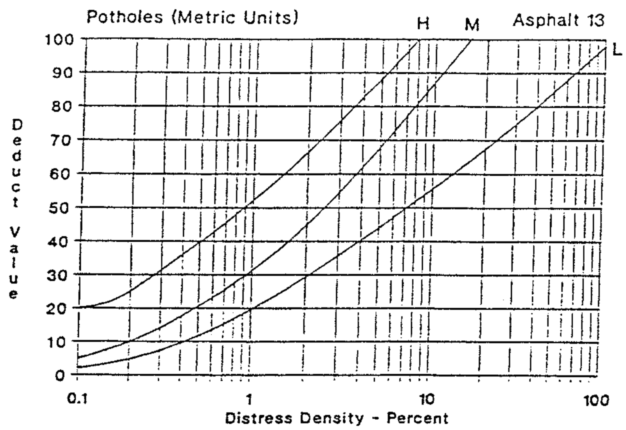


FIG. X3.19 Potholes (metric units)

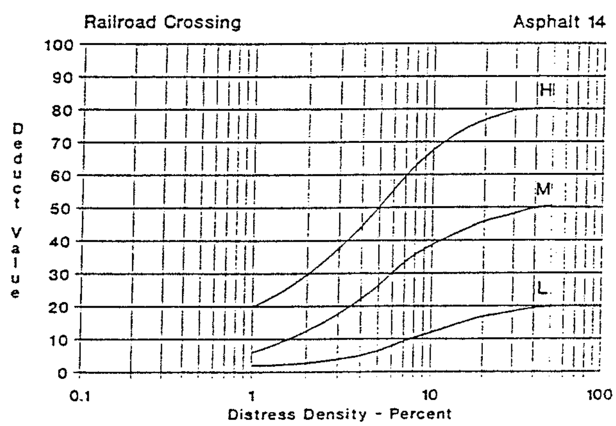


FIG. X3.20 Railroad Crossing

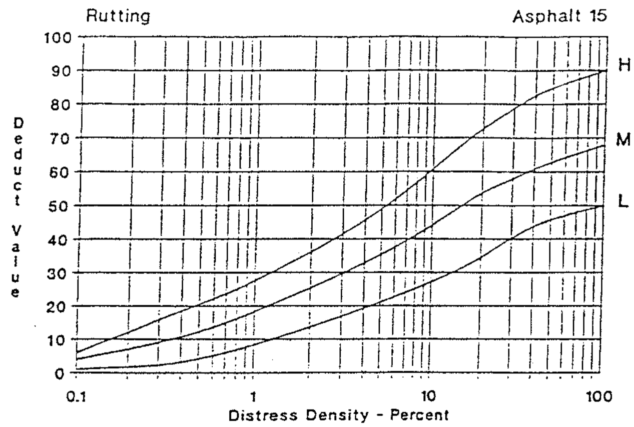


FIG. X3.21 Rutting

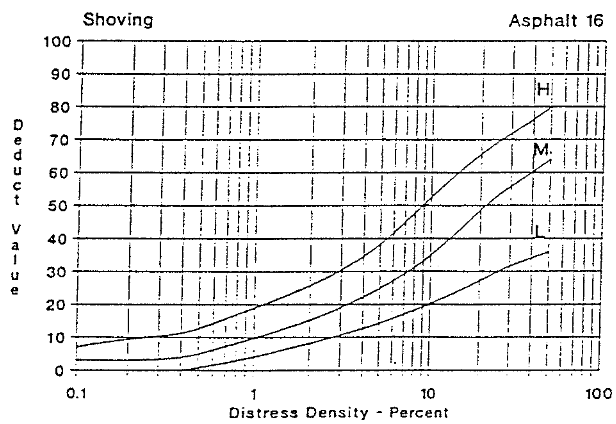


FIG. X3.22 Shoving

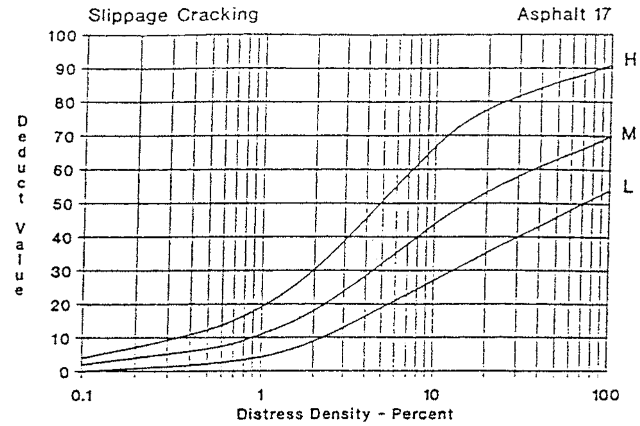


FIG. X3.23 Slippage Cracking

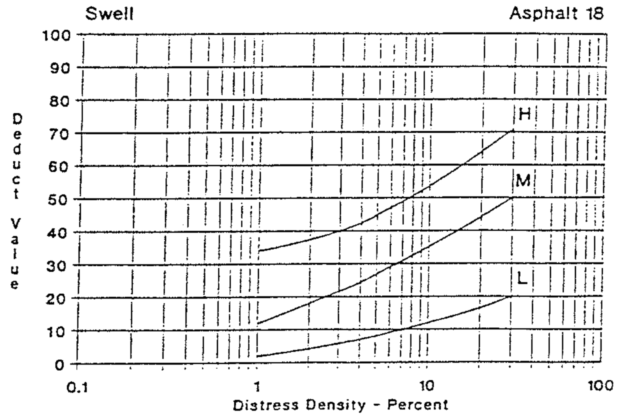


FIG. X3.24 Swell

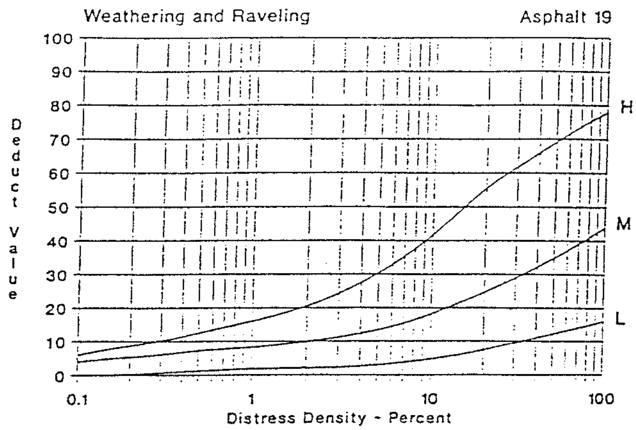


FIG. X3.25 Weathering and Raveling

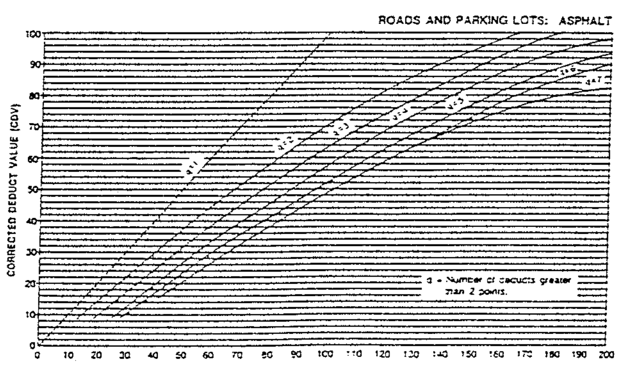


FIG. X3.26 Total Deduct Value

X4. DEDUCT VALUE CURVES FOR CONCRETE

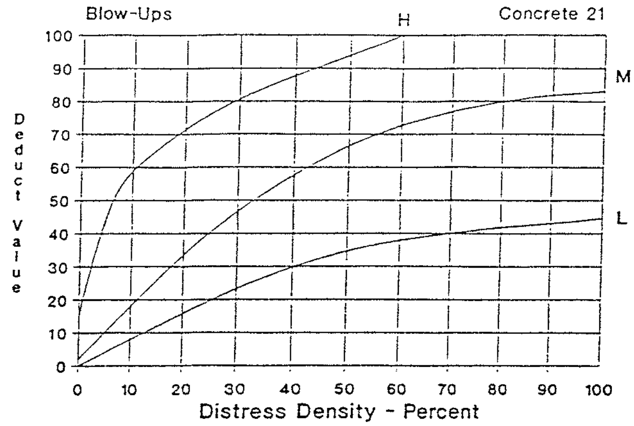


FIG. X4.1 Blowups

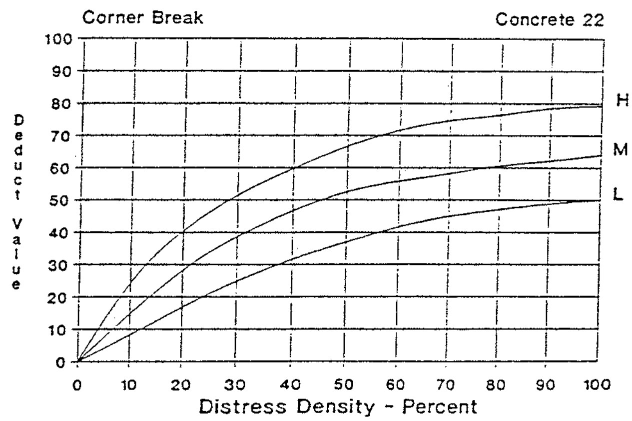


FIG. X4.2 Corner Break

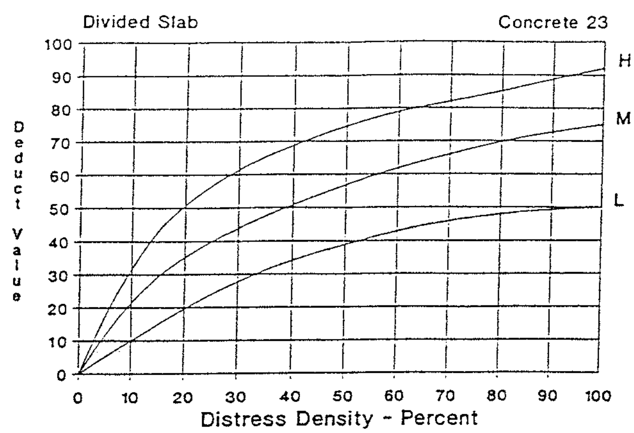


FIG. X4.3 Divided Slab

REFERENCES

(**1**) *PAVER Asphalt Distress Manual*, US Army Construction Engineering Laboratories, TR 97/104, June 1997.

(**2**) *PAVER Asphalt Distress Manual*, US Army Construction Engineering Laboratories, TR 97/105, June 1997.

(**3**) Carey, W.N., Jr. and Irick, P.E., "The Pavement Serviceability-Performance Concept," *HRB Bulletin 250*, 1960.

(**4**) Sayers, M. W., Gillespie, T. D., and Queiroz, C. A. V., "The International Road Roughness Experiment: Establishing Correlation and a Calibration Standard for Measurements," World Bank Technical Paper No. 45, the International Bank for Reconstruction and Development/the World Bank, Washington, DC, 1986.

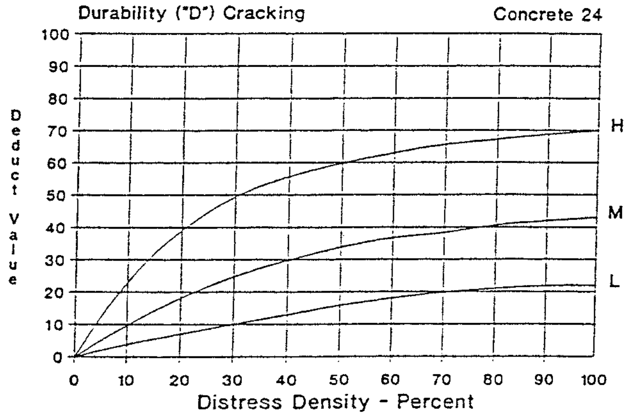


FIG. X4.4 Durability ("D") Cracking

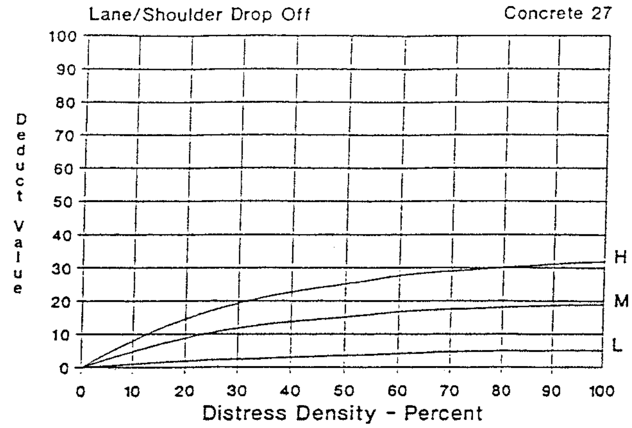


FIG. X4.7 Lane/Shoulder Drop-Off

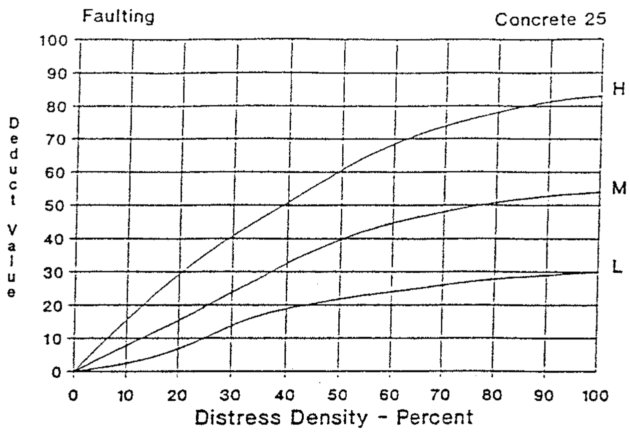


FIG. X4.5 Faulting

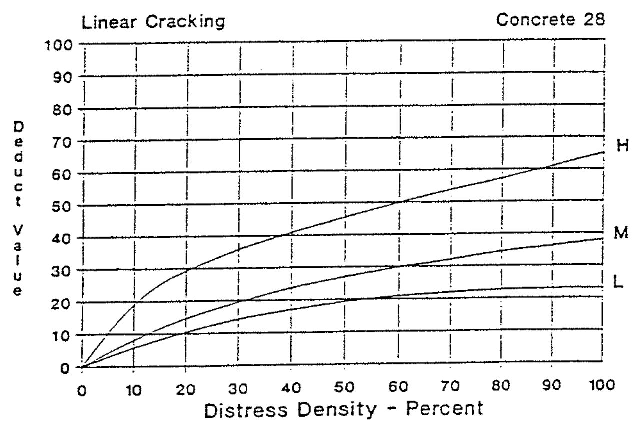


FIG. X4.8 Linear Cracking

Joint Seal Damage Concrete 26

Joint seal damage is not rated by density. The severity of the distress is determined by the sealant's overall condition for a particular sample unit.

The deduct values for the three levels of severity are:

LOW	2 points
MEDIUM	4 points
HIGH	8 points

FIG. X4.6 Rigid Pavement Deduct Values, Distress 26, joint seal damage

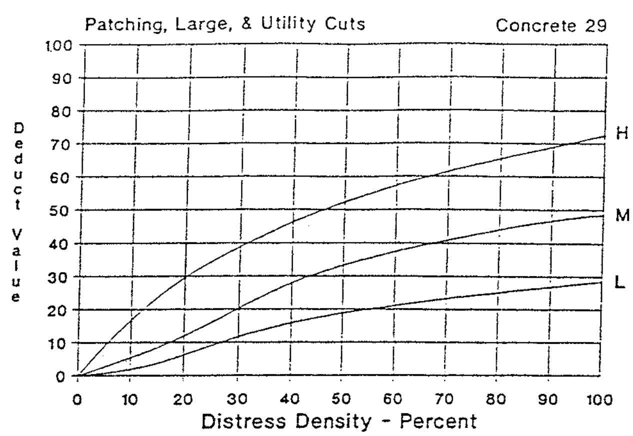


FIG. X4.9 Patching, Large, and Utility Cuts

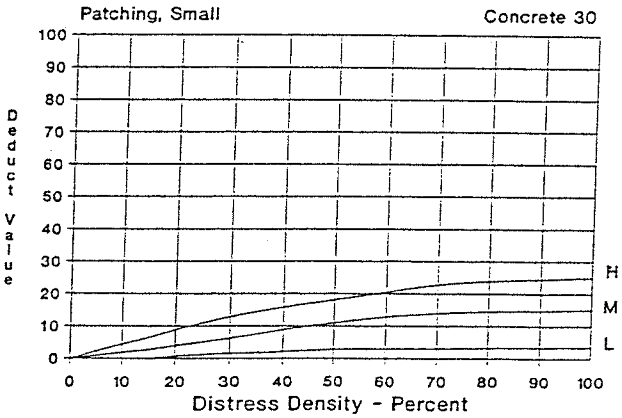


FIG. X4.10 Patching, Small

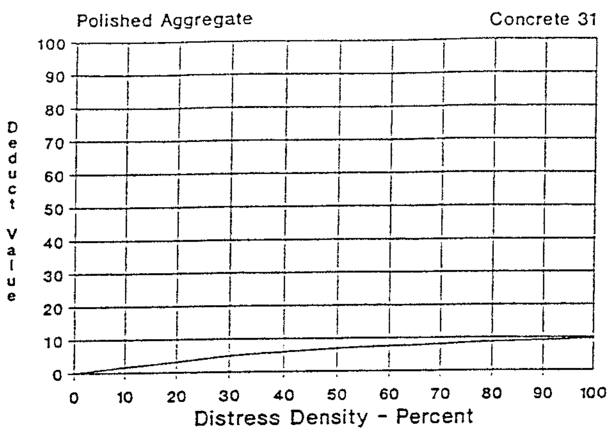


FIG. X4.11 Polished Aggregate

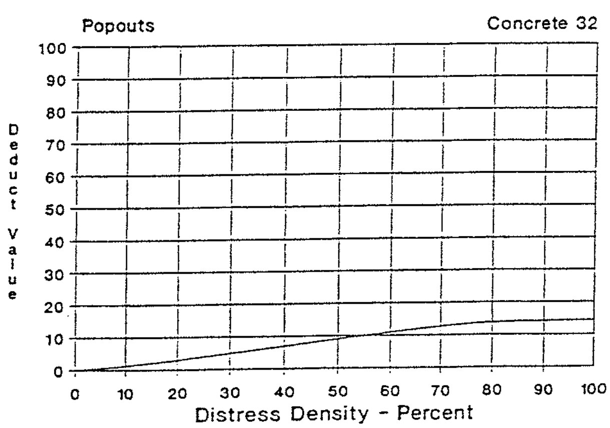


FIG. X4.12 Popouts

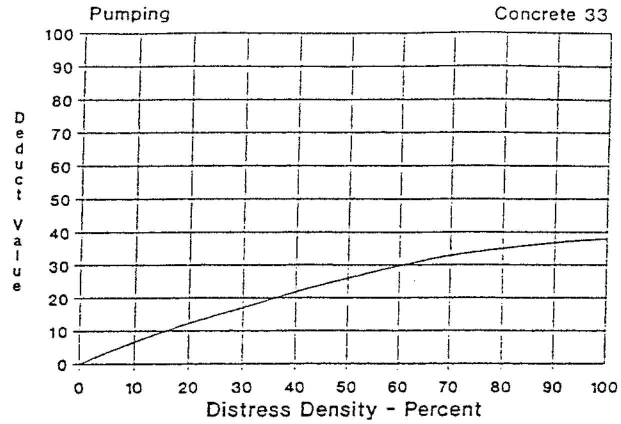


FIG. X4.13 Pumping

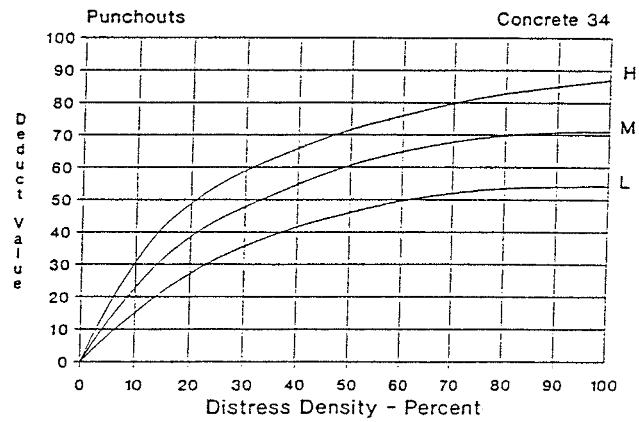


FIG. X4.14 Punchouts

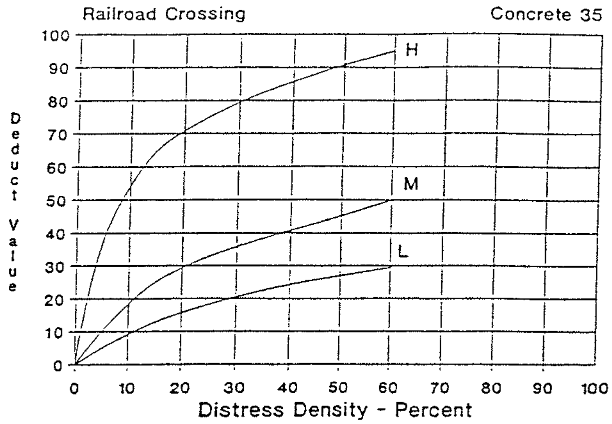


FIG. X4.15 Railroad Crossing

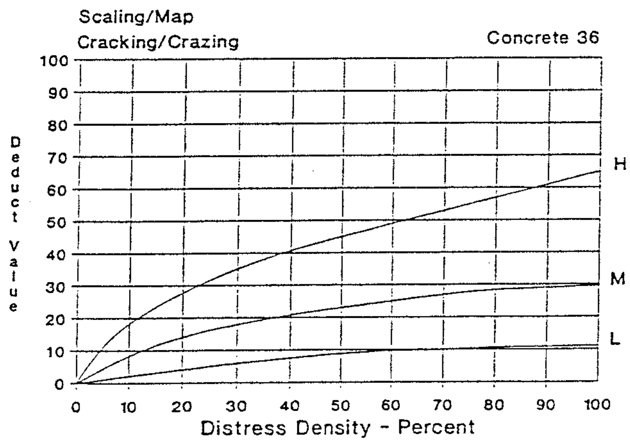


FIG. X4.16 Scaling/Map Cracking/Crazing

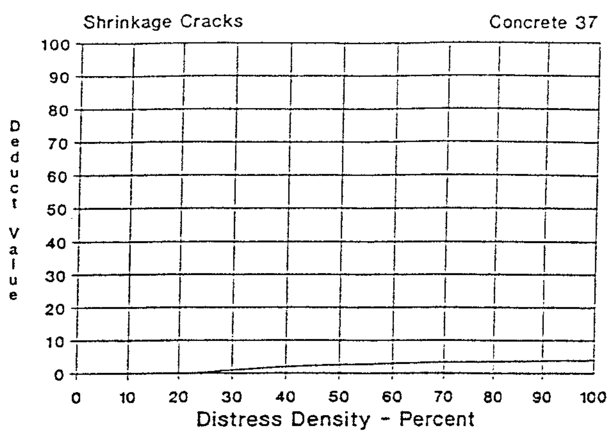


FIG. X4.17 Shrinkage Cracks

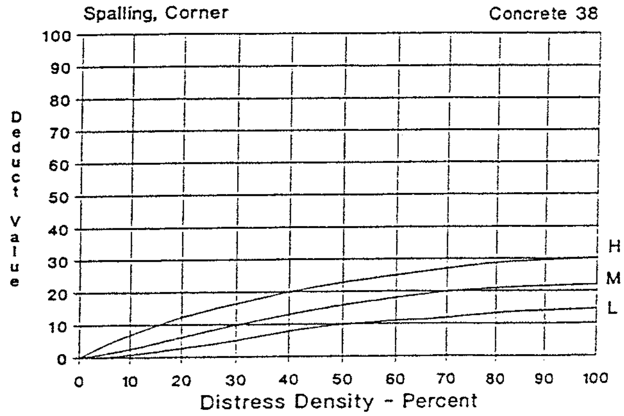


FIG. X4.18 Spalling, Corner

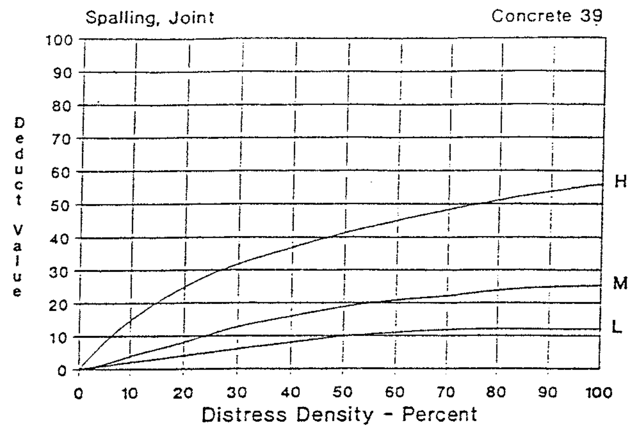
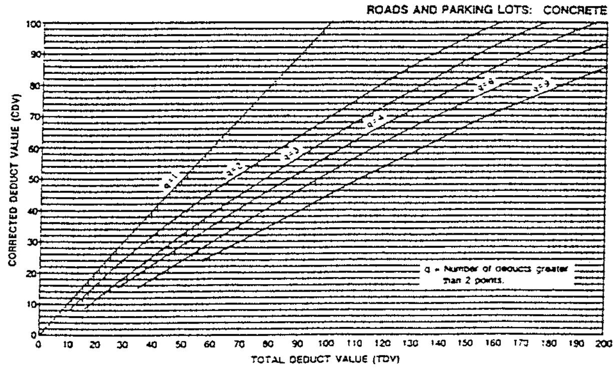


FIG. X4.19 Spalling, Joint



Corrected deduct values for jointed concrete pavement.

FIG. X4.20 Corrected Deduct Values for Jointed Concrete Pavement

Hardin Solar Energy II LLC
Case No. 18-1360-EL-BGN
Supplement to Application
November 14, 2018

Attachment 2

Decommissioning Plan

by Santec Consulting Services, Inc.
November 12, 2018

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Hardin County, Ohio

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Prepared by:
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1165 Scheuring Road
De Pere, Wisconsin 54115

Project No: 193705143
November 12, 2018

This document entitled Decommissioning Plan Hardin Solar II Energy Center, Hardin County, Ohio, was prepared by Stantec Consulting Services Inc. ("Stantec") for the use of Hardin Solar Energy II LLC (the "Client"), and the applicable regulatory agencies. Any reliance on this document by any other third party is strictly prohibited. The material in this document reflects Stantec's professional judgment in light of the scope, schedule and other limitations stated in the document and in the contract between Stantec and the Client. The opinions in this document are based on conditions and information existing at the time this document was published and do not take into account any subsequent changes.

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REGISTERED
PROFESSIONAL ENGINEER

Table of Contents

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LIST OF FIGURES

1.0 INTRODUCTION

Hardin Solar Energy II LLC (Hardin Solar II), an affiliate of Invenergy Solar Development North America LLC (Invenergy), is proposing to construct the Hardin Solar II Energy Center in Hardin County, Ohio. The proposed Hardin Solar II Energy Center (the Project) is to be located within the townships of Marion, McDonald, and Roundhead, Ohio (Figure 1). Major components of the Project include solar modules, racking, tracking system, inverters, transformers and a Project substation. Solar modules being considered include models from Jinko, Longi, Trina, and Hanwha. The Project will occupy approximately 3,297 acres of leased land and will have a maximum nameplate generating capacity of up to 170 megawatts ($MW_{[AC]}$, hereinafter referred to as MW).

This Decommissioning Plan (Plan) provides a description of the decommissioning and restoration of the Project. A start-of-construction is planned as early as mid-2019, with a projected Commercial Operation Date in mid to late 2020. The Project will consist of the installation of the perimeter fencing; solar arrays and associated racking, trackers, foundations, and steel piles; transformers; inverters; access and internal roads; and electrical collection system (Figure 2).

This Plan includes an overview of the primary decommissioning Project activities; dismantling and removal of facilities, and restoration of land. A summary of estimated costs associated with decommissioning the Project is also included in Section 4.0. Summary statistics and estimated costs are provided for a 170-MW Project array design.

1.1 SOLAR FARM COMPONENTS

The main components of the Project include:

- Solar panels
- Racking and Tracking system
- Foundations and steel piles
- Transformers and inverters
- Electrical cabling and conduits
- Perimeter fencing, site access and internal roads
- Project substation

1.2 TRIGGERING EVENTS AND EXPECTED LIFETIME OF PROJECT

Project decommissioning may be triggered by events, such as: abandonment during Project construction or when the Project reaches the end of its operational life.

If properly maintained, the expected lifetime of a utility-scale solar panel is approximately 25 to 30 years with an opportunity for a project lifetime of 50 years or more with equipment replacement and repowering. Depending on market conditions and project viability, the solar arrays may be retrofitted with updated components (e.g., panels, frame, tracking system, etc.) to extend the life of the project. In the event that the modules are not retrofitted, or at the end of the Project's useful life, the panels and associated components will be decommissioned and removed from the Project site.

Components of the solar facility that have resale value may be sold in the wholesale market. Components with no wholesale value will be salvaged and sold as scrap for recycling or disposed of at an approved offsite licensed solid waste disposal facility (landfill). Decommissioning activities will include removal of the arrays and associated components as listed in Section 1.1 and described in Section 2.

1.3 DECOMMISSIONING SEQUENCE

Decommissioning activities will begin shortly after the Project ceases operation and are anticipated to be completed in twelve months. Monitoring and site restoration may extend beyond this period to ensure successful revegetation and rehabilitation. The anticipated sequence of decommissioning and removal is described below; however, overlap of activities is expected.

- Prepare access roads for component removal
- Install temporary fencing and best management practices (BMPs) to protect sensitive resources
- De-energize solar arrays
- Dismantle panels and racking
- Remove frame and internal components
- Remove portions of structural foundations less than three feet (36 inches) below the surface and backfill sites
- Remove inverters and transformers
- Remove above ground electrical cables and cables and conduits less than three feet (36 inches) below the surface
- Remove access and internal roads and grade site
- De-compact subsoils (if required), restore and revegetate disturbed land to pre-construction conditions to the extent practicable

2.0 PROJECT COMPONENTS AND DECOMMISSIONING ACTIVITIES

The solar facility components and decommissioning activities necessary to restore the Project area, as near as practicable, to pre-construction conditions are described within this section.

2.1 OVERVIEW OF SOLAR FACILITY SYSTEM

Hardin Solar anticipates utilizing panels manufactured by Longi Solar, or a comparable mono or multi-crystalline module. Approximately 592,000 solar modules will be utilized, with a total nameplate generating capacity of up to 170 $MW_{[AC]}$ (approximately 207.2 $MW_{[DC]}$) on the 3,297-acre site. Statistics and cost estimates provided in this Plan are based on a 350-watt module.

Foundations, steel piles, and electric cabling and conduit less than three feet (36 inches) below the soil surface will be removed. Components and cabling deeper than 36 inches below the surface will be abandoned in place. Access roads may be left in place if requested and/or agreed to by the landowner. Public roads damaged or modified during the decommissioning and reclamation process will be repaired upon completion of the decommissioning phase.

Estimated quantities of materials to be removed and salvaged or disposed of are included in this section. Most of the materials described have salvage value; although, there are some components that will likely have none at the time of decommissioning. All recyclable materials, salvaged and non-salvage, will be recycled to the furthest extent possible. All other non-recyclable waste materials will be disposed of in accordance with state and federal law in an approved licensed solid waste facility. For purposes of this report, no estimated recovery or salvage values were considered, as directed by the Ohio Power Siting Board (OPSB) for the Project.

Table 1 presents a summary of the primary components of the Project included in this decommissioning plan.

Table 1 Primary Components of Solar Farm to be Decommissioned

Component	Quantity	Unit of Measure
Solar Modules (350-watt$_{[dc]}$)(approximate)	592,000	Each
Tracking System (based on 80 panels per tracker)	7,400	Tracker
Steel Piles (above 36-inch depth; based on approximately 392 piles per $MW_{[DC]}$)	81,400	Each
Inverters and Transformers	72	Each
Concrete Foundations (Inverters/Transformers)	72	Each
Electrical Cables and Conduits (approximate, left in place below 36-inch depth)	20,000	Lineal Foot (estimated)
Perimeter Fencing	160,660	Lineal Foot (estimated)
Internal Access Roads (approximate)	120,260	Lineal Foot (estimated)

2.2 SOLAR MODULES

Hardin Solar is considering the Longi Solar module or similar model for the Project. Each module assembly (with frame) has a total weight of approximately 58 pounds. The modules are approximately 77 inches (6.42 feet) by 39 inches (3.25 feet) in size and are mainly comprised of non-metallic materials such as silicon, mono- or poly-crystalline glass, composite film, plastic, and epoxies, with an anodized aluminum frame.

At the time of decommissioning, module components in working condition may be refurbished and sold in a secondary market yielding greater revenue than selling as salvage material.

2.3 TRACKING SYSTEM AND SUPPORT

The solar modules will be mounted on a NEXTracker (or similar design) horizontal tracking system. Each tracker is approximately 85 meters (283 feet) in length. Smaller trackers may be employed at the edges of the layout, to efficiently utilize available space. The NEXTracker systems are mainly comprised of galvanized and stainless steel; steel piles that support the system are comprised of structural steel.

The solar arrays will be deactivated from the surrounding electrical system and made safe for disassembly. Liquid wastes, including oils and hydraulic fluids will be removed and properly disposed of or recycled according to regulations current at the time of decommissioning. Electronic components, and internal electrical wiring will be removed and salvaged. The steel piles will be cut and removed to a depth of three feet (36 inches) below the ground surface.

The supports, tracking system, and posts contain salvageable materials which can be sold to provide revenue to offset the decommissioning costs. As stated earlier, the revenue generated from salvageable equipment has not been included in the decommissioning estimate.

2.4 INVERTERS AND TRANSFORMERS

Inverters and transformers generally sit on small concrete footings within the array. The inverters and transformers will be deactivated, disassembled and removed. Depending on condition, the equipment may be sold for refurbishment and re-use. If not re-used, they will be salvaged or disposed of at an approved solid waste management facility. All oils, lubricants, and hazardous materials will be collected and disposed of at a licensed facility.

2.5 ELECTRICAL CABLING AND CONDUITS

The Project's electrical collection system will consist of both above and below ground collection cables. The underground cables will be placed at a depth of approximately three to four feet (36-48 inches) or greater. Cabling that is above a depth of three feet will be removed and salvaged, while cable greater than three feet in depth will be abandoned in place. The system will not interfere with future farming activities because of the depth. If, at the time of decommissioning, the salvage value of the underground cable exceeds the cost of extraction and restoration, the cables may be removed and salvaged. All above-ground cabling will be removed during decommissioning activities.

2.6 PROJECT SUBSTATION

Hardin Solar will include a Project substation as shown on the attached figures. The substation footprint will be approximately 285 feet by 230 feet and will contain within its perimeter, a gravel pad, power transformer and footings, electrical control house and concrete foundations, as needed. The substation decommissioning is included in this Plan.

2.7 PERIMETER FENCING, SITE ACCESS AND INTERNAL ROADS

The Hardin Solar site will include a chain-link security fence around the perimeter of the site. An access road will allow access to the substation and solar facility. Internal roads will be located within the array to allow access to the equipment. The internal roads will be approximately 16 feet wide and total approximately 120,260 linear feet (22.8 miles). The internal access road lengths may change with final Project design. To be conservative, the decommissioning estimate assumes that all internal roads will be completely removed.

During construction of the Project site access roads will be installed with a four-inch subgrade (2-inch stone), capped with two-inches of granular fill. The estimated quantity of these materials is provided in Table 2. A typical access road cross-section is shown in Figure 3.

Table 2 Typical Access Road Construction Materials

Item	Quantity	Unit
Geogrid or Geofabric	213,795	Square Yards
No. 2 stone, 4" thick	23,755	Cubic Yards
Compacted granular backfill, 2" thick	11,877	Cubic Yards

Decommissioning activities include the removal and stockpiling of aggregate materials onsite for salvage preparation. It is conservatively assumed that all Geogrid or Geofabric and aggregate materials will be removed from the Project site and hauled up to five miles from the Project area. Following removal of aggregate and Geogrid or Geofabric, the access road areas will be graded, de-compacted with deep ripper or chisel plow (ripped to 18 inches), back-filled with native subsoil and topsoil, as needed, and land contours restored as near as practicable to preconstruction conditions.

3.0 LAND USE AND ENVIRONMENT

3.1 SOILS AND PRIME FARMLAND

The proposed solar facility is predominantly located on land currently utilized for agricultural purposes. The site lays within the Eastern Corn Belt Plain Ecoregion, and is characterized by loamy and well drained soils. Natural and man-made drainage waterways are located in low-lying areas of the Project site.

Project area soils include: Blount silt loams (Ble/Blg); Colwood Loam (Co); Carlisle Muck (Ca); Linwood Muck (Ln); Glynwood clay and silt loams (Gwd/Gwe/Gwg); McGuffey muck (Mc); Milford silty clay loam (Mf); Olentangy silt loam (Ot); Pewamo silty clay loam (PkA); Pewamo varian muck (Po); Roundhead muck (Ro); and Sloan silt loam (So). The majority of soils (approximately 93%) within the proposed Project area are classified as prime farmland, if drained. In general, the Project area and the land surrounding it are drained by a system of natural and man-made drainage features; therefore, the majority of the land to be utilized for the solar facility can be considered prime farmland.

Areas of the Project that were previously utilized for agricultural purposes will be restored to their preconstruction condition and land use. Topsoil reserved during construction and stored in long-term berms will be used if available, and supplemented with comparable soils. Restored areas will be revegetated in consultation with the current landowner and in compliance with regulations in place at the time of decommissioning.

3.2 RESTORATION AND REVEGETATION

Project sites that have been excavated and back-filled will be graded as previously described to restore land contours as near as practicable to preconstruction conditions. Topsoil will be placed on disturbed areas and seeded with appropriate vegetation to reintegrate it with the surrounding environment. Soils compacted during de-construction activities will be de-compacted, as necessary, to restore the land to pre-construction land use. Drainage will be restored to pre-construction conditions via natural and man-made drainage features. Work will be completed to comply with the conditions agreed upon by Hardin Solar II and the OPSB or as directed by regulations in affect at the time of decommissioning.

3.3 SURFACE WATER DRAINAGE AND CONTROL

As previously described, the proposed Project area is predominantly located in actively drained agricultural land. The terrain is relatively flat with several ditches protected by grassy buffers and berms along the edges. The Project facilities are being sited to avoid wetlands, waterways, and drainage ditches (Figure 4) to the extent practicable. The existing Project site conditions and proposed BMPs to protect surface water features are described in a Stormwater Pollution Prevention Plan (SWP3) currently being prepared for the Project construction activities.

Surface water conditions at the Project site will be reassessed prior to the decommissioning phase. Hardin Solar will obtain the required water quality permits from the Ohio Environmental Protection Agency (OEPA) and the U.S. Army Corp of Engineers (USACE), if needed, before decommissioning of the Project. Construction storm water permits will also be obtained and a SWP3 prepared describing the protection needed to reflect conditions present at the time of decommissioning. BMPs may include: construction entrances, temporary seeding, permanent seeding, mulching (in non-agricultural areas), erosion control matting, silt fence, filter berms, and filter socks.

3.4 MAJOR EQUIPMENT REQUIRED FOR DECOMMISSIONING

The activities involved in decommissioning the Project include removal of the above ground components of the Project: solar modules, racking, tracking system, foundations and piles (to a depth of three feet below the surface), inverters, transformers, access roads, and electrical cabling and conduits (to a depth of three feet below the surface). Restoration activities include back-filling of pile and foundation sites; de-compaction of subsoils; grading of surfaces to pre-construction land contours and revegetation of the disturbed areas.

Equipment required for the decommissioning activities is similar to what is needed to construct the solar facility and may include, but is not limited to: small cranes, low ground pressure (LGP) track mounted excavators, backhoes, LGP track bulldozers, LGP off-road end-dump trucks, front-end loaders, deep rippers, water trucks, disc plows and tractors to restore subgrade conditions, and ancillary equipment. Over-the-road dump trucks will be required to transport material removed from the site to disposal facilities.

4.0 DECOMMISSIONING COST ESTIMATE SUMMARY

Expenses associated with decommissioning the Project will be dependent on labor costs at the time of decommissioning. For the purposes of this report approximate 2017 to early-2018 average market values were used to estimate labor expenses. Fluctuation and inflation of the labor costs were not factored into the estimates.

4.1 DECOMMISSIONING EXPENSES

Project decommissioning will incur costs associated with the backfilling, grading and restoration of the proposed Project site as described in Section 2. Table 3 summarizes the estimates for activities associated with the major components of the Project.

Table 3 Estimated Decommissioning Expenses – 170 MW Solar Array

Activity	Unit	Number	Cost per Unit	Total
Overhead and management (includes estimated permitting required)	Lump Sum		$210,000	$210,000
Solar modules and Tracking Systems; disassembly and removal (592,000 modules and 7,400 trackers)	Lump Sum		$4,329,000	$4,329,000
Steel pile/post removal	Each	81,400	$4.00	$325,600
Transformers and inverters	Each	72/ea	$950/set	$68,400
Concrete foundation removal	Each	72	$400	$28,800
Access road excavation and removal	Lump Sum		$391,959	$391,959
Above-ground electric collection removal	Linear Mile	1	$32,000	$32,000
Perimeter fence removal	Linear Feet	160,660	$2.25	$361,485
Topsoil replacement and rehabilitation of site	Lump Sum		$178,163	$178,163
Substation removal and site grading	Lump Sum		$300,000	$300,000
Total estimated decommissioning cost				**$6,225,407**

4.2 DECOMMISSIONING REVENUES

Revenue from decommissioning the Project will be realized through the sale of the solar facility components and construction materials. Modules and other components may be sold within a secondary market or as salvage. For purposes of this report, no estimated recovery or salvage values were considered, as directed by the OPSB.

4.3 DECOMMISSIONING COST SUMMARY

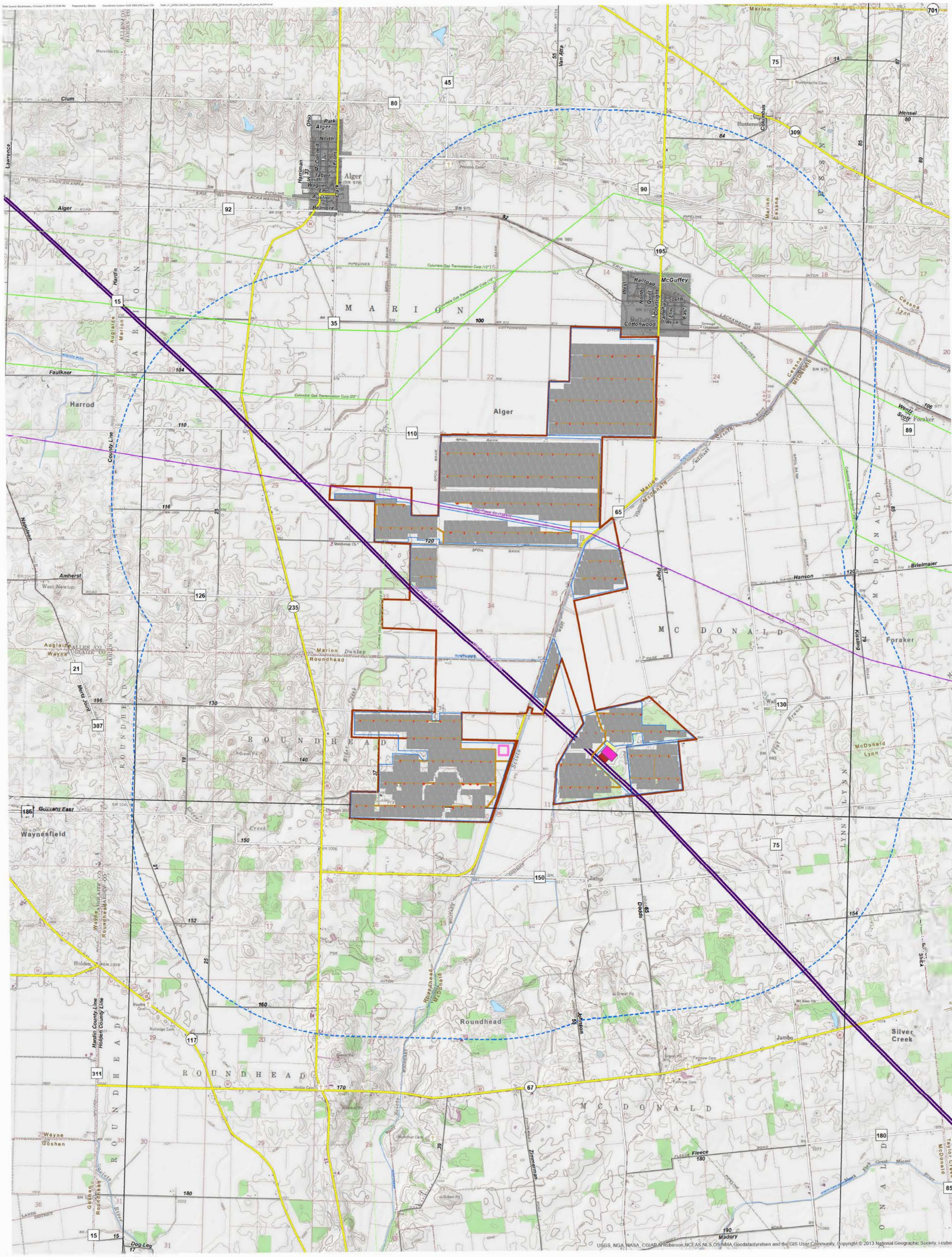
The estimated cost to decommission the Project, using the information detailed in this Plan are based on 2017 to early 2018 prices, with no market fluctuations or inflation considered. The total cost to decommission the Project facilities as described in this Plan is $6,225,407. This cost does not include the expected revenue from the recovery or salvage of facilities, which would offset a portion of the decommissioning cost.

4.4 FINANCIAL ASSURANCE

Hardin Solar II will post decommissioning funds in the form of a performance bond prior to the preconstruction conference to cover the removal cost of the arrays to be constructed.

FIGURES

Figure 1 Project Location



Legend

School
Church
Cemetery
River
Waterbody
Preliminary Project Fence
Preliminary Access Roads
Preliminary Racking
Preliminary Inverter
Preliminary O&M Building
Project Substation Area
Preliminary Storage Facility
Interconnection Substation
Natural Gas Pipeline
1" - 12"
13" - 24"
Estimated Natural Gas Line
1" - 12"
Transmission Line
100 - 161 kV
345 - 500 kV
Proposed Project Boundary
2mi Buffer
Township

1,600 0 1,600
Feet
1:25,000

Project Area Map

Hardin Solar Energy Center, Hardin County, Ohio

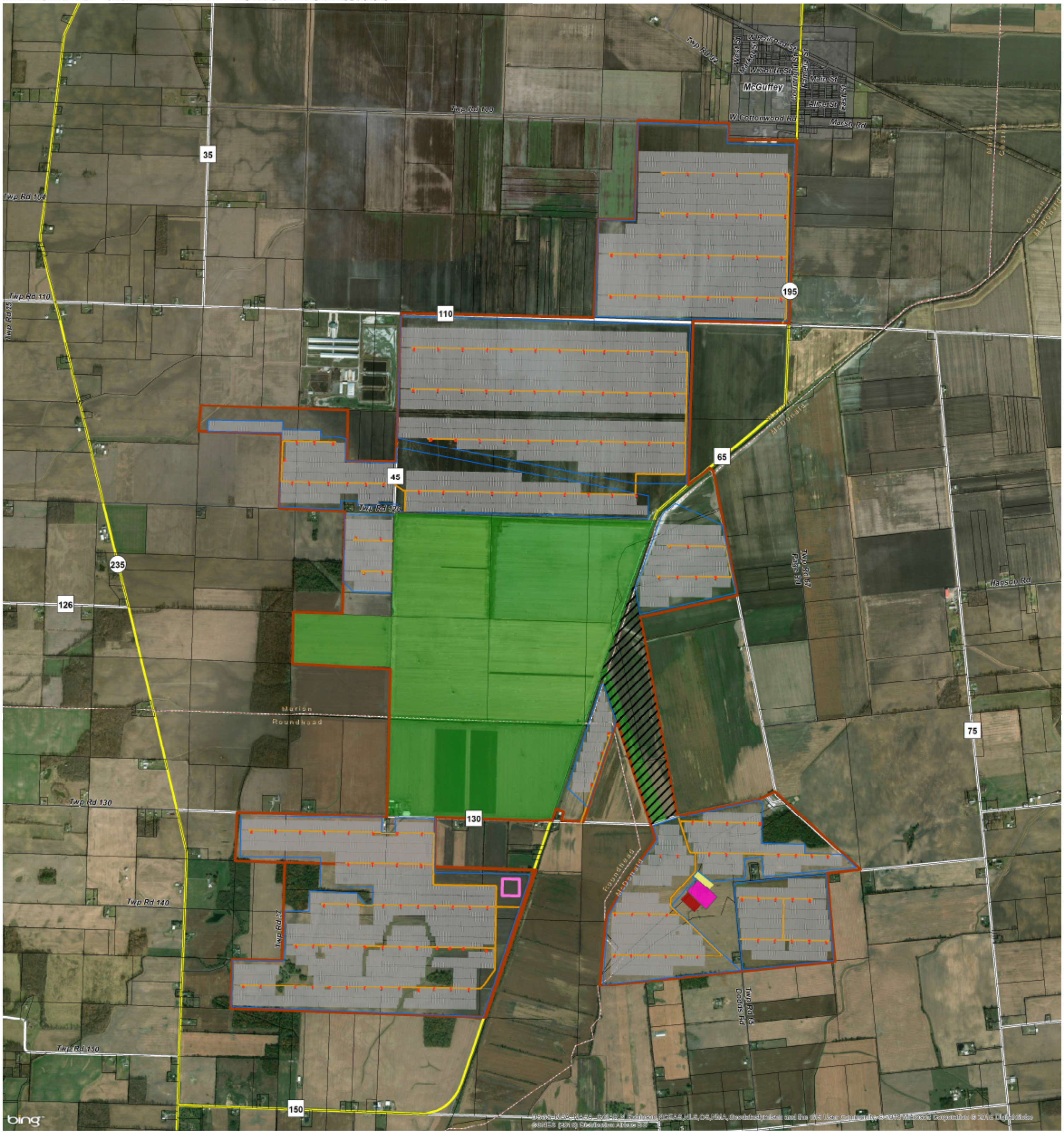
Rev. 00

October 3, 2018

Invenergy

Figure 2 Proposed Project Layout

Figure 2



Legend

- Preliminary Project Fenceline
- Preliminary Access Roads
- Preliminary Racking
- Preliminary Inverter
- Preliminary O&M Building
- Project Substation Area
- Preliminary Storage Facility
- Interconnection Substation
- Underground Collection Cable Route
- Permitted Phase 1
- Proposed Project Boundary
- Township
- Parcel
- Municipal Boundary

Road Classification

- US/State Route
- County Road
- Local Road
- Dirt/Unpaved Road

1,500 0 1,500
Feet
1:20,000

Project Area Map

Hardin Solar II Energy Center | Hardin County, Ohio

Rev. 00
October 03, 2018

Invenergy

Figure 3 Access Road Detail

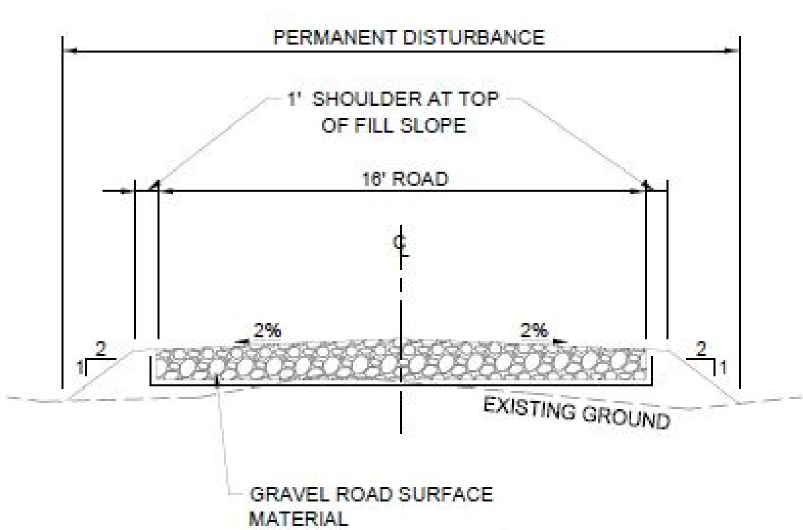
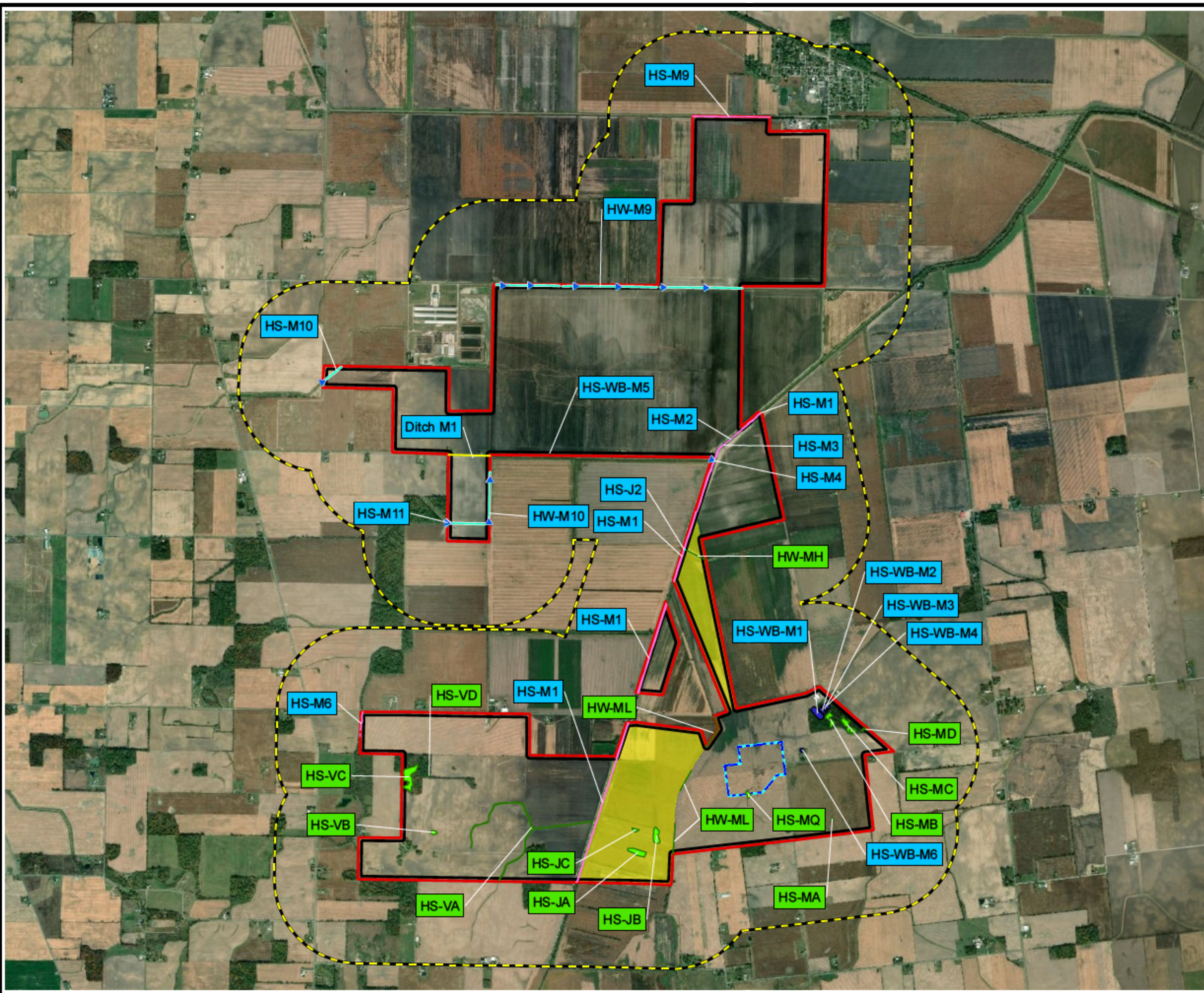


Figure 4 Potential Wetlands and Waterways with Project Boundary

Figure 08-4



Legend

- Study Area (September 2018)
- Project Area (September 2018)
- Proposed Underground Collection Corridor
- Half Mile Buffer
- Point of Interconnection Facility Studied 2017

Delineated Streams

- Ditch
- Ephemeral
- Intermittent
- Perennial

Delineated Area Type

- Stream Polygon
- Water/Pond Boundary
- Wetland Boundary

0 1,500 3,000 Feet

1 " = 3,000 '

1:36,000

N

PROJECT:	HARDIN SOLAR ENERGY II, LLC HARDIN SOLAR II ENERGY CENTER CONFIDENTIAL BUSINESS INFORMATION		
TITLE:	DELINEATED RESOURCES		
DRAWN BY:	D. KENWORTHY	PROJ NO.:	302899.0000.0000
CHECKED BY:	M. MOLNAR		FIGURE 08-4
APPROVED BY:	J. PITTS		
DATE:	OCTOBER 2018		

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FILE NO.: HSII_Fig8-4_Delin_Resources_11x17.mxd

TRC - GIS

Coordinate System: NAD 1983 2011 StatePlane Ohio South FIPS 3402 Ft US (Foot US)
Map Rotation: 0

Plot Date: 10/10/2018, 06:57:10 AM by DKENWORTHY -- LAYOUT: ANSI B(11"x17")
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