

A COMPARISON OF FULL AND PARTIAL
LIGHTING ON TWO SECTIONS OF ROADWAY

by

M. H. Hilton
Senior Research Scientist

(The opinions, findings, and conclusions expressed in this report are those of the author and not necessarily those of the sponsoring agencies.)

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SUMMARY

The average illumination levels and uniformity of the lighting were determined on two sections of roadway when all of the lighting was in operation and when the lighting was partially turned off. The illumination on both sections was found to be within the recommended quality and quantity standards when all of the luminaires were in operation. By turning out every third light during the early service life of one study section, a 22% reduction in the average levels of illumination occurred, but the uniformity and minimum average levels of illumination remained within the suggested standards. This finding was probably related to the customary over design of lighting systems (with respect to the initial illumination output) to compensate for lamp lumen and dirt depreciation that results from normal continued use.

After the lighting had been in service for slightly less than two years, the average levels of illumination had depreciated by 32% with all the lighting in operation. Had one-third of the lighting been turned off at that time, the uniformity of the illumination would not have been acceptable under the standards. Therefore, from the standpoint of quality standards, some reduction in the number of luminaires in operation on new or relamped systems might be acceptable until such time as the depreciation factors compensate for the initial over design. This approach could possibly be used in some instances to reduce energy consumption in the operation of lighting systems similar to that evaluated in this study. The effects of reducing the lighting on interchange ramps by turning out some of the lights would be much more difficult to predict because of the varying geometric conditions that are encountered.

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INTRODUCTION

In the interest of conserving energy in the operation of highways, one of the first items considered for reduction is roadway lighting. There are several factors that contribute to this tendency. First, it is relatively simple to turn the lighting off and the consequent savings in energy and money are immediate. Secondly, in the case of freeway lighting, it is often questioned whether the lighting of a particular section of roadway is effective enough to justify its costs. While several recent studies have indicated that freeway lighting is effective in reducing accidents, (1,2,3,4) the effectiveness of particular sections of lighting can always be questioned in the absence of substantiating data. Therefore, the desire to cut back on roadway lighting is particularly strong during periods of energy shortage or when there is a need to reduce operating costs.

This report concerns a case study in which a portion of the lighting was turned off on two sections of roadway in an effort to conserve energy and reduce operating costs. Illumination measurements were taken over the two roadway sections when all of the lighting was on and when it was partially turned off.

GENERAL DESCRIPTION OF TEST SECTIONS

The first of the two study sections is located on Route I-64 and begins just east of the east end of the Hampton Roads Bridge Tunnel as shown in Figure 1. It included both the eastbound and westbound lanes of the roadway over the edge of Willoughby Bay. The luminaires on this section are mounted at a height of 40 ft. and have 400-watt mercury lamps. The mounting poles are spaced approximately 130 ft. apart on the outside shoulders of the roadway.

The second study section consists mainly of a loop ramp on International Terminal Boulevard, which passes over Route 564 as shown in Figure 2. This loop ramp is illuminated by 250-watt mercury luminaires mounted on 30 ft. poles spaced approximately 75 to 80 ft. apart. The luminaires are mounted on the outside of curvature of the loop ramp.

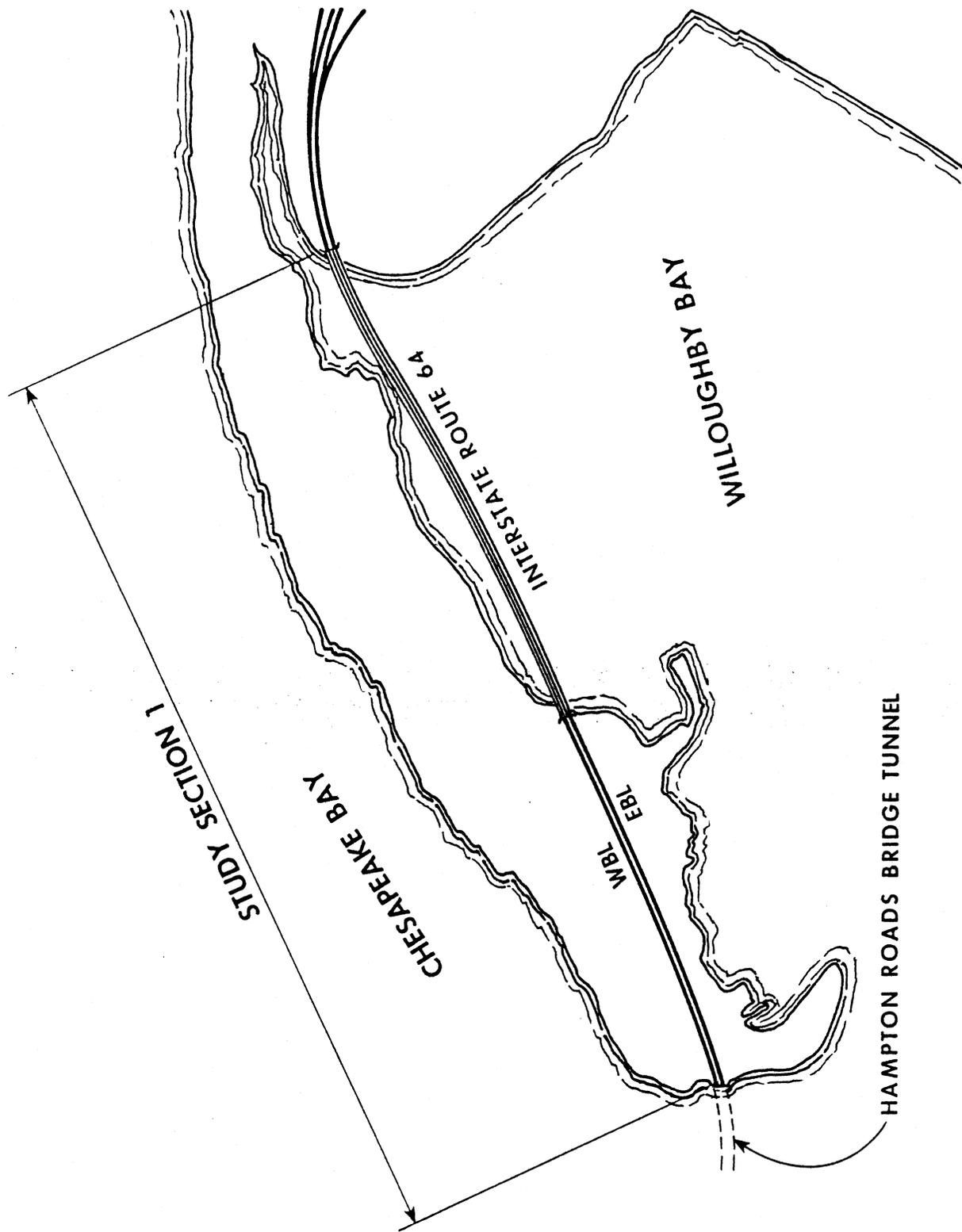


Figure 1: Study section 1 on Rte. I-64.

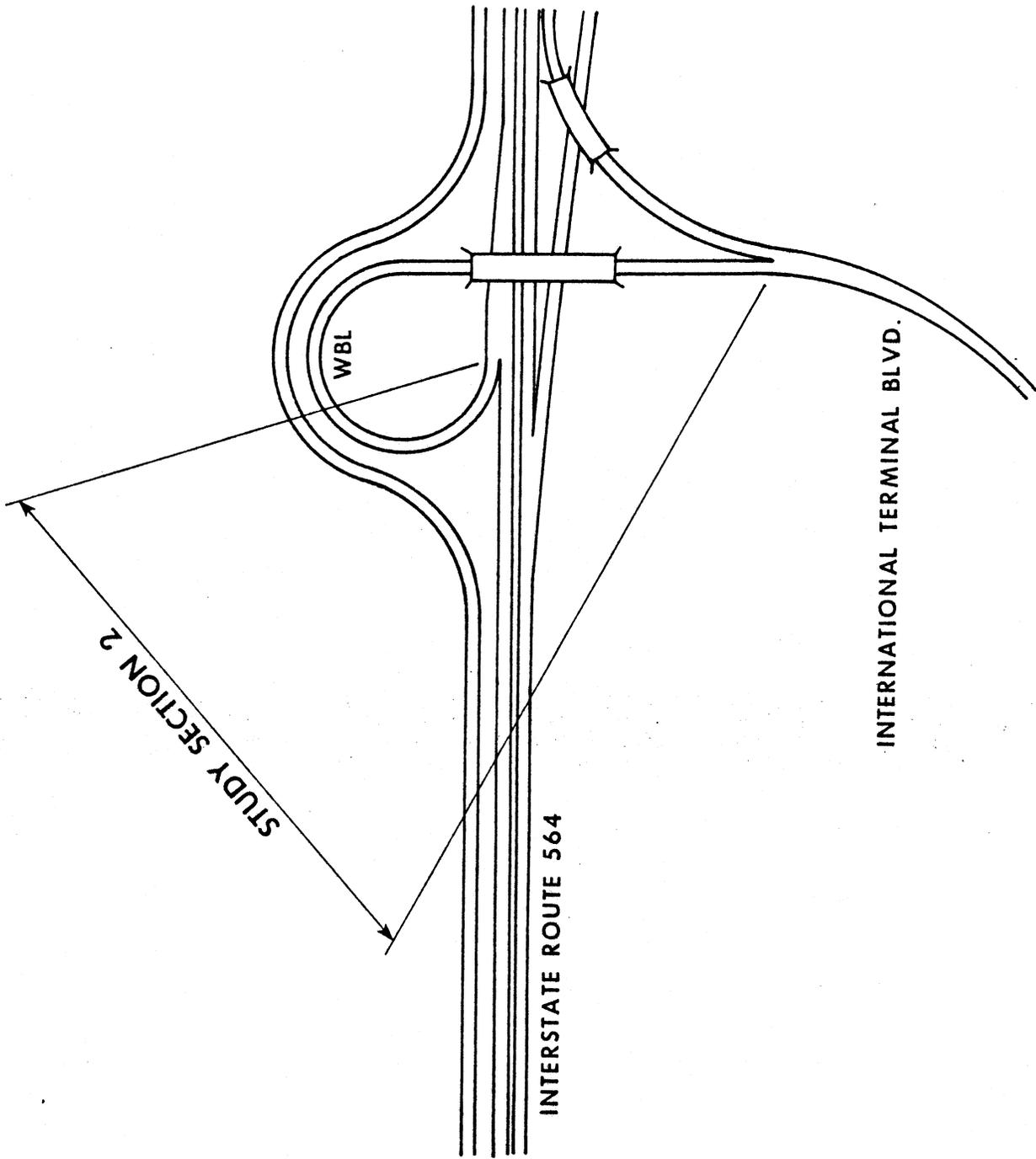


Figure 2: Study section 2 on International Terminal Blvd.

PURPOSE AND SCOPE

The purpose of this study was to review the illumination levels and uniformity of the lighting on two sections of roadway when all of the lighting was in operation and when the lighting was partially reduced to conserve energy. The scope was limited to comparing these two physical conditions to determine whether, or to what extent, the uniformity and minimum levels of illumination conformed to the AASHTO Guide⁽⁵⁾ and the American National Standard Practice For Roadway Lighting.⁽⁶⁾

ILLUMINATION MEASUREMENTS

The illumination data were collected on the two test sections using the mobile photometric equipment developed for the general lighting studies and described in an earlier report.⁽⁷⁾ This equipment is mounted in a vehicle and is designed to record variations in illumination levels on a continuous strip chart as the vehicle is driven down the roadway. The components of the equipment are portable and can be mounted in the vehicle in a short period of time and removed easily after data collection is complete. Typical examples of the data charts are shown later in Figures 3 and 4.

For this study the data were collected on both the EBL and WBL of study section 1. For each lane, data runs were completed for both the right-hand and left-hand driving lanes and for the right and left shoulder areas. Therefore, four data runs were made to cover the total roadway width in each traffic direction. For study section 2, data runs were made down the center of the loop ramp and on the right-hand and left-hand sides of the paved roadway.

RESULTS

Presently, the quantity and quality of roadway lighting is measured most often in terms of the average horizontal footcandles of illumination on the roadway. The uniformity ratio, which can be defined as the ratio of the average level to the minimum level of illumination for a given area, is another factor used to define the quality of lighting and has significance in this particular study. It is commonly accepted that the uniformity ratios of the illumination should not exceed 3:1 on most types of roadways. High uniformity ratios indicate substantial variations in the levels of illumination. Therefore, uniformity data help to define the effects of turning off some of the lights on a given system.

Uniformity can be determined from the data charts by first finding the area bounded by the continuous curve and the baseline. The area can be determined by use of a planimeter and converted to units of footcandle-feet by using the appropriate scale factor. By obtaining the product of the scale factor and the area, and by dividing this by the length of the section being considered, the average level of illumination for each test run can be obtained. If a number of lanes are involved, an overall average can be determined from the lane averages. The average footcandle values are then divided by the minimum value for a given area to determine the uniformity ratio. These procedures were used to determine the average levels of illumination and uniformity values presented in this report.

Study Section 1

First Data Run

When the first illumination data were collected on study section 1, every third light on the EBL was turned out. On the WBL all the lights were on. The effects of turning every third light out are clearly seen by comparing the illumination data charts shown in Figures 3 and 4 with those in Figures 5 and 6. These data are given for the total roadway width, showing the left shoulder and left-hand lane in Figure 3 and the right-hand lane and right shoulder in Figure 4, and so on. Figures 3 and 4 show a typical section of the WBL where all the lights were on at the time of the tests. It can be noted that the peaks on the continuous curve are spaced uniformly and represent the higher levels of illumination located under each luminaire. By comparing these data with those shown in Figures 5 and 6 for the EBL, the location of every light that was turned out is clearly indicated by the low level of illumination shown as the deepest trough in the continuous curve. Therefore, it can be seen that the average levels of illumination, as would be expected, are lower on the EBL and the uniformity of the lighting is not as good because of the low levels in the areas under the lights that were turned out. It can also be noted, in either case, that the highest general levels of illumination are in the right-hand lane and they are lower on each side of this lane as the distance from the luminaire increases.

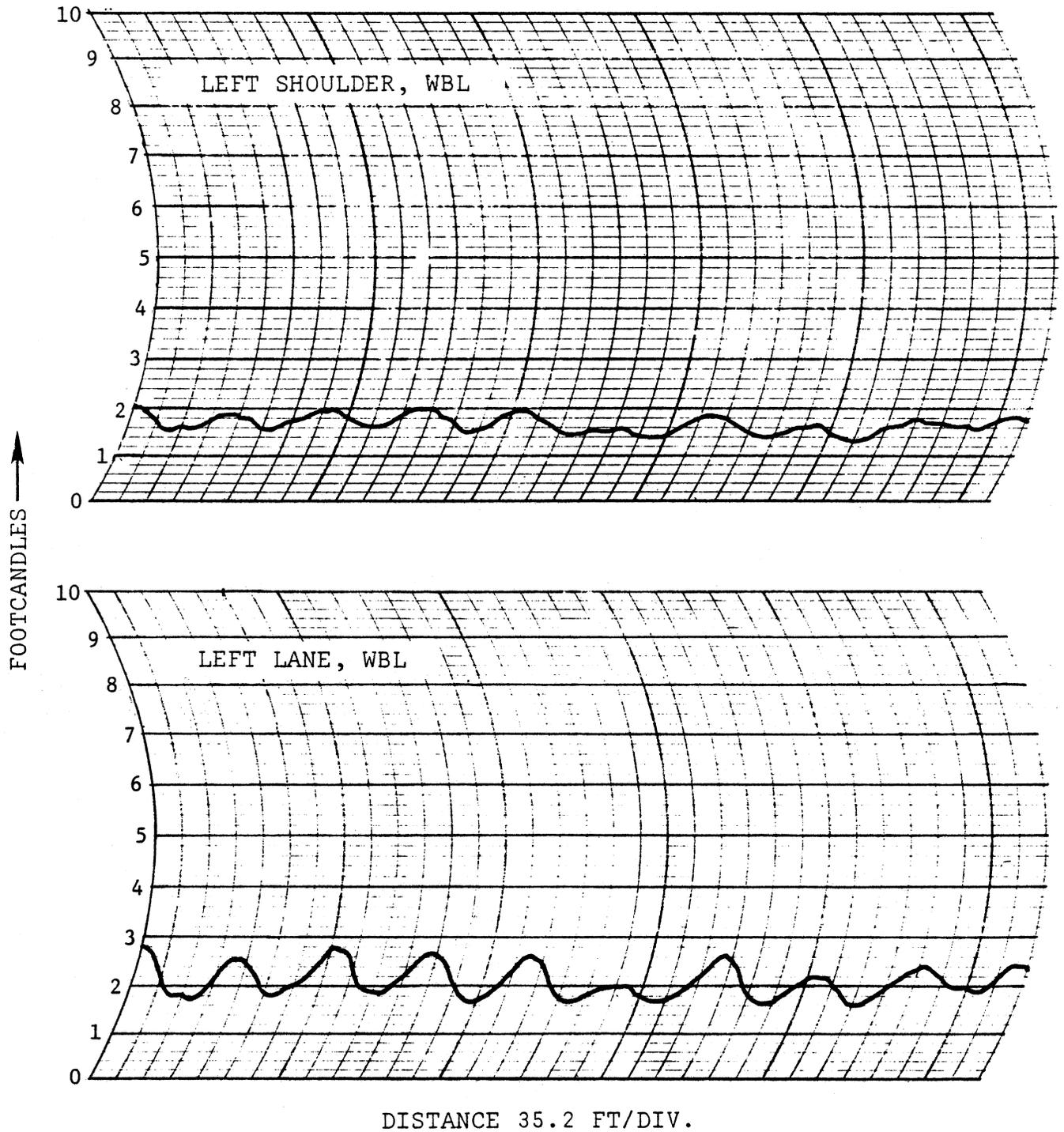


Figure 3. Typical illumination levels on the left lane and left shoulder of the WBL of Rte. I-64. (Study section 1, 1st data run.)

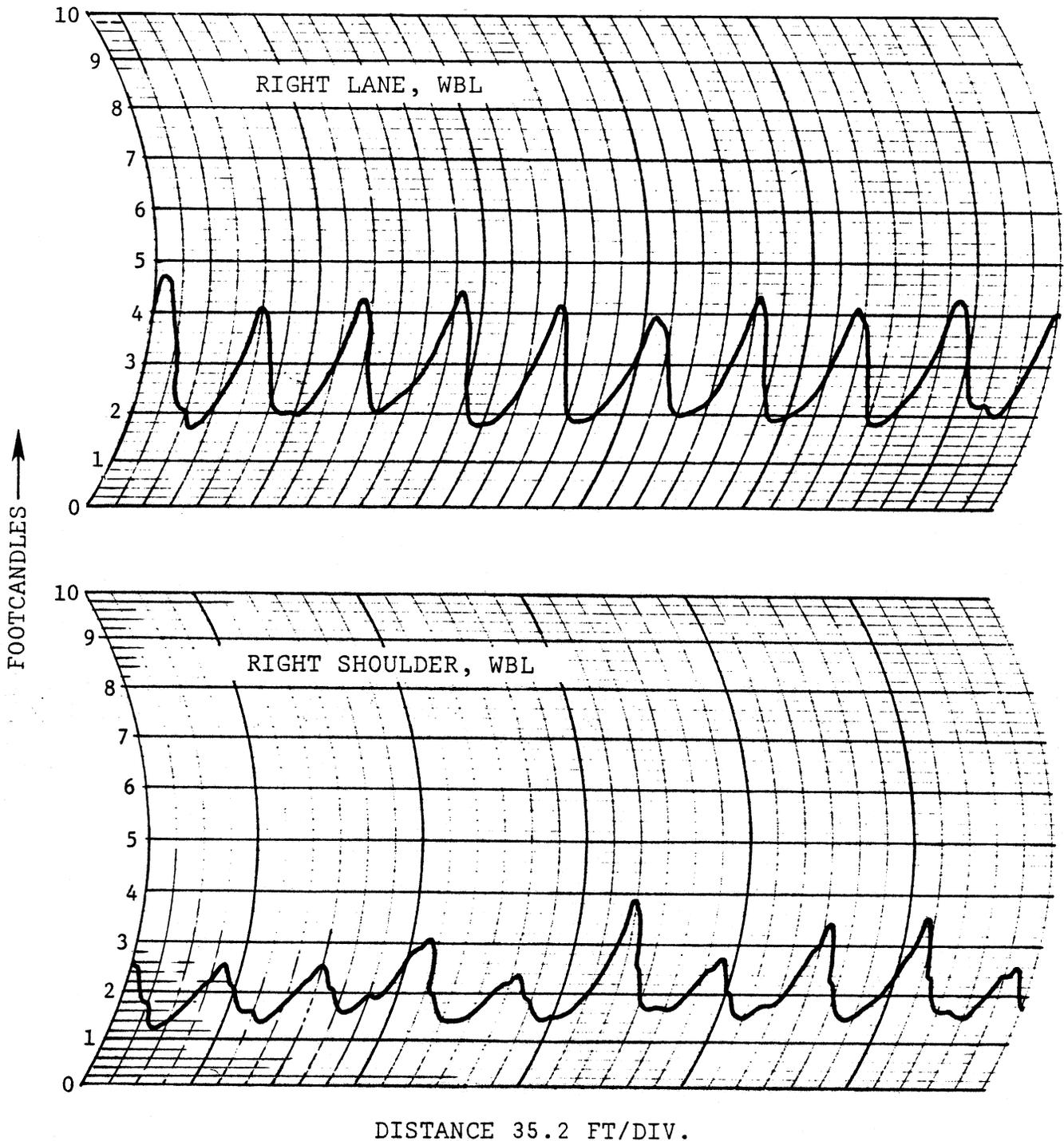


Figure 4. Typical illumination levels on the right lane and right shoulder of the WBL of Rte. I-64. (Study section 1, 1st data run.)

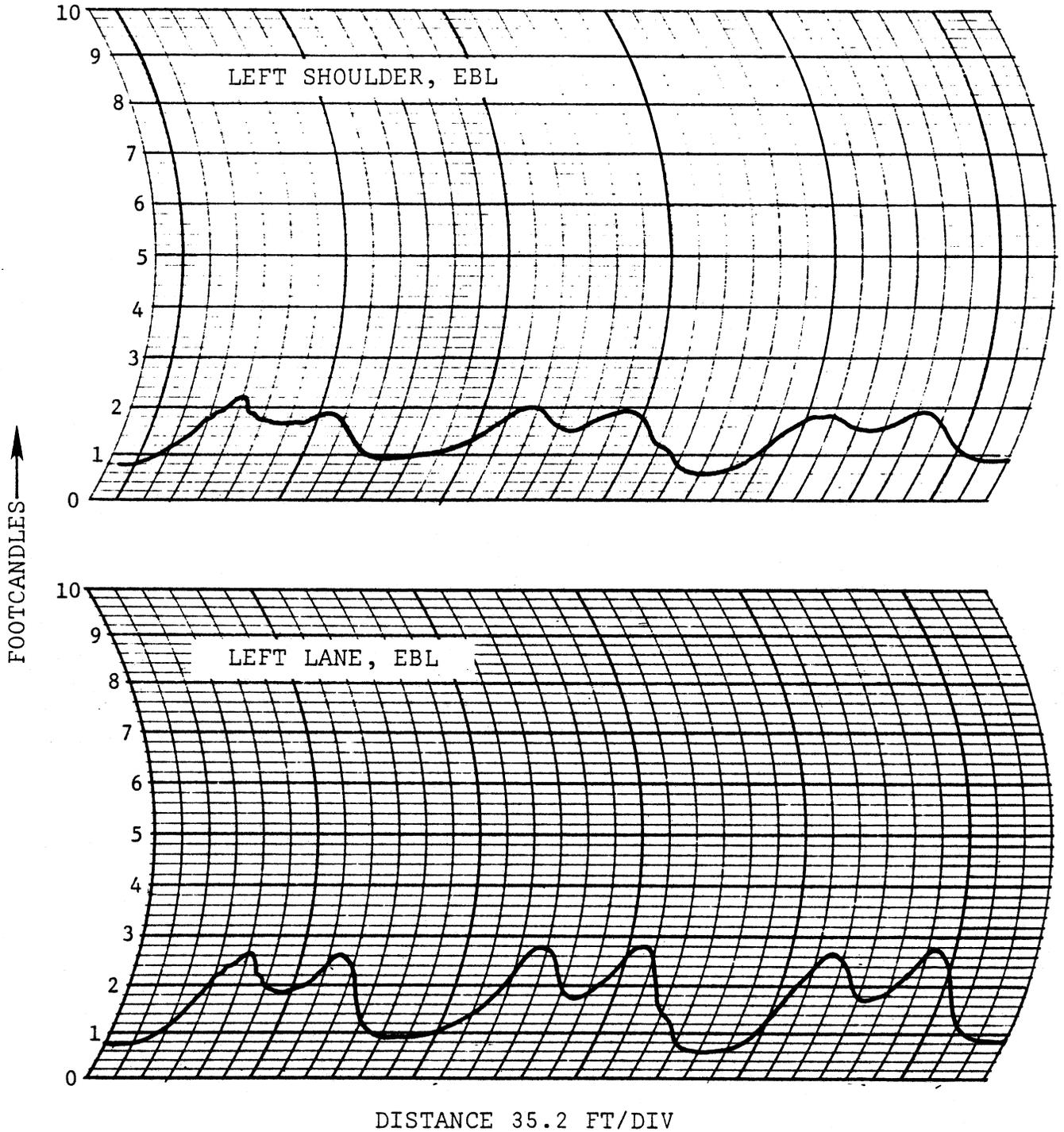


Figure 5. Illumination levels with every third light turned out on the EBL. (Study section 1, 1st data run.)

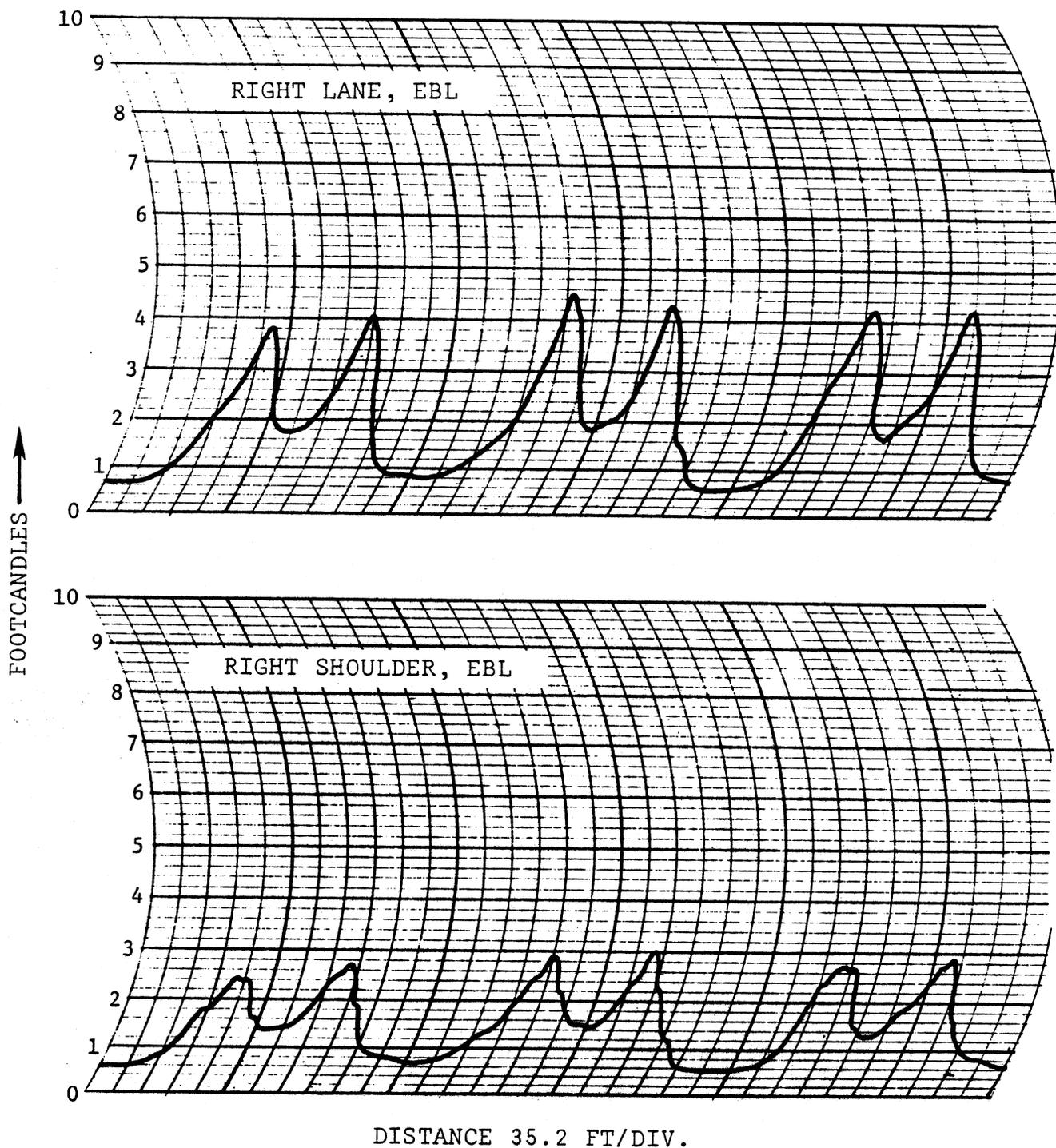


Figure 6. Illumination levels with every third light turned out on the EBL. (Study section 1, 1st data run.)

Using the procedure described earlier, the average footcandles (fc) level for each lane and shoulder and for the total roadway width for both the WBL and EBL were calculated and are given in Table 1. In the WBL, the initial average levels of illumination ranged from 1.48 fc for the left shoulder to 2.66 fc for the right-hand lane. The total roadway average was 2.01 fc. On the EBL, with every third light turned out the initial average levels of illumination ranged from 1.32 fc for the left shoulder to 1.91 fc for the right-hand lane. The total roadway average was 1.57 fc. Comparatively, the average illumination level on the EBL was 22% lower than that on the WBL. While the average illumination with every third light turned out was much lower than with all the lights on, it was still within the 0.6 fc average maintained horizontal illumination recommended by the standards.^(5,6) It should be stressed, however, that these initial lighting levels were higher than those that would be expected at the time of the lowest effective output as will be discussed later.

TABLE 1
ILLUMINATION AND UNIFORMITY
(1st Data Run, Study Section 1)

Lane	Illumination in fc					Uniformity Ratio	
	Right Shoulder	Right-Hand Lane	Left-Hand Lane	Left Shoulder	Total Roadway Average	Overall	Driving Lanes
WBL	2.02	2.66	1.87	1.48	2.01	1.67:1	1.42:1
EBL*	1.40	1.91	1.63	1.32	1.57	2.85:1	2.95:1

*Every 3rd light turned out.

1fc = 10.76lx

The uniformity ratios reported in Table 1 are also within the recommended standard of 3:1 for freeways. While the initial ratios for the WBL were quite low at 1.67:1 overall and 1.42:1 for the driving lanes only, those on the EBL were respectively 2.85:1 and 2.95:1. The uniformity ratio on the EBL was 71% higher than that on the WBL. Thus, although the lighting was reduced on the EBL, the initial data (taken shortly after the lighting was first activated) indicated that the average lighting levels and uniformity were still acceptable at that time.

Second Data Run

Approximately two years after the first data were collected on study section 1 a second set were collected. All of the lighting had been reactivated long before the second data were collected so all lighting was on in both the EBL and WBL of the study section. Since the same illumination patterns existed on each lane, the data for only a section of the EBL are given in Figures 7 and 8 as an example of the levels of illumination found. These data, like those shown earlier, are given for the total roadway width, with the left shoulder and left-hand lane being shown in Figure 7 and the right-hand lane and right shoulder in Figure 8. The vertical footcandle scale factor is only half that of the previous data shown, however, so the peaks and troughs of the continuous curve appear more pronounced. The illumination and uniformity values determined from the second data run are presented in Table 2. The average illumination and uniformity were virtually the same for both the EBL and WBL in this second test run. The total roadway average illumination level was the same for each lane (1.36 fc), which was 32% lower than that for the comparable situation on the WBL recorded during the first tests. This reduction resulted from the normally expected depreciation due to aging of the mercury lamping and to soiling of the luminaires. Since the 1.36 fc average for the second tests was 13% lower than the 1.57 fc average on the EBL for the first tests, it is apparent that depreciation in the illumination levels with time had the net effect of reducing the average levels below those existing initially with one-third of the lights turned off. Were one third of the lights off during the second tests and the average levels of illumination 22% lower as they were initially, one would expect an average of 1.06 fc of illumination, which would be acceptable since it is greater than the 0.6 fc minimum recommended by the standards.

TABLE 2

ILLUMINATION AND UNIFORMITY
(2nd Data Run, Study Section 1)

Lane	Illumination in fc					Uniformity Ratio	
	Right Shoulder	Right-Hand Lane	Left-Hand Lane	Left Shoulder	Total Roadway Average	Overall	Driving Lanes
WBL*	1.16	1.97	1.34	0.96	1.36	2.78:1	2.07:1
EBL*	1.19	1.89	1.39	0.95	1.36	2.72:1	2.05:1

*All lights on

1fc = 10.76lx

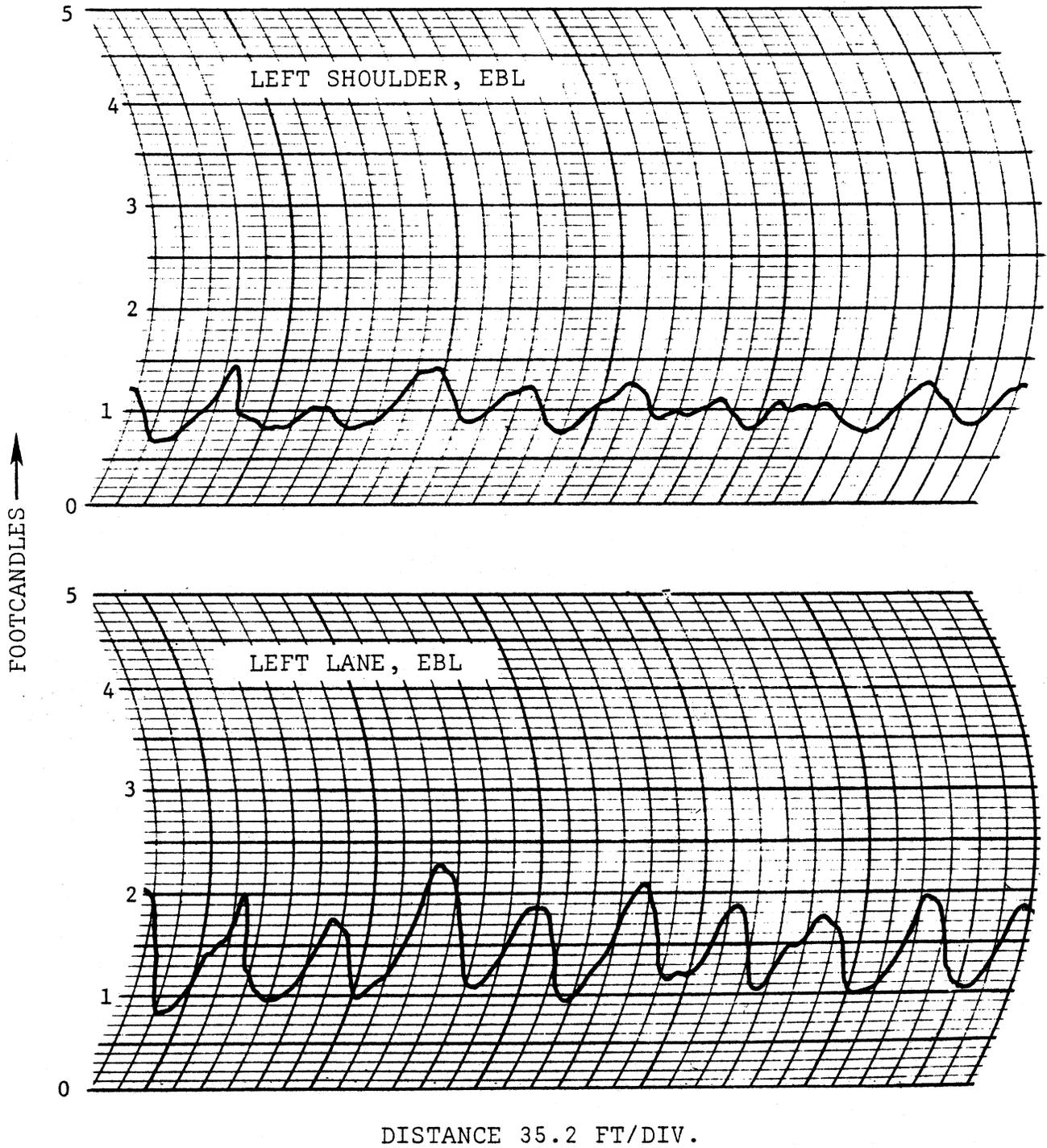


Figure 7. Typical illumination levels on the left shoulder and left lane of the EBL of Rte. I-64. (Study section 1, 2nd data run.)

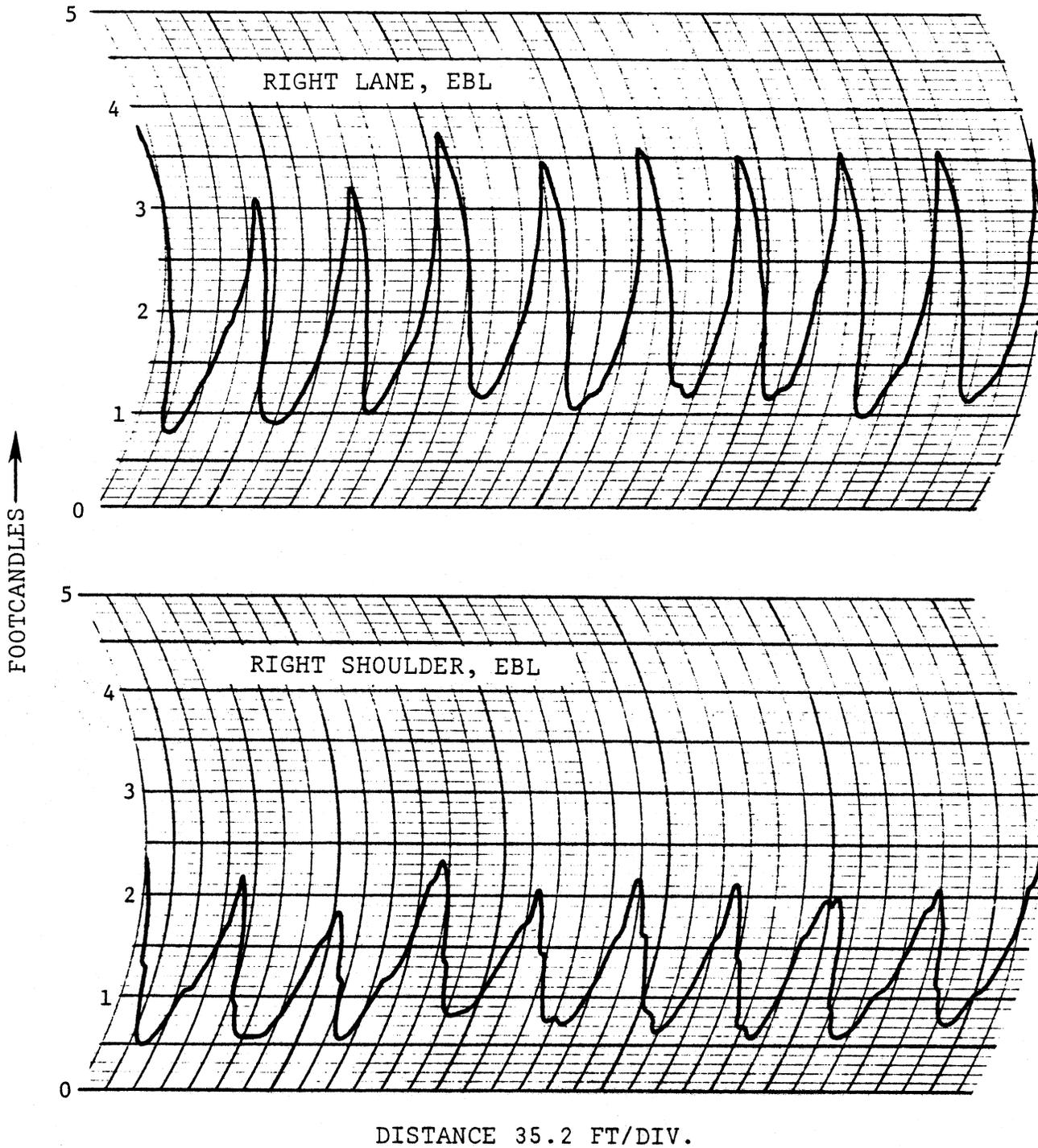


Figure 8. Typical illumination levels on the right lane and right shoulder of the EBL of Rte. I-64. (Study section 1, 2nd data run.)

The uniformity of the illumination would not be acceptable, however, if the increased ratio of 71% were experienced as it was in the first tests when one-third of the lighting was turned off. If the overall uniformity ratio of 2.72:1 (Table 2) were increased by 71%, a ratio of 4.65:1 would result, which would exceed the 3.0:1 maximum recommended. Considering only the driving lanes, the uniformity would be increased to 3.51:1 if the same assumption were applied.

In summary, the average maintained levels of illumination would be adequate were one-third of the lights turned off after a 32% depreciation in illumination occurred; but the uniformity of the illumination would be poor.

Study Section 2

First Data Run

On study section 2, the first data were collected when all of the lighting was on. A typical data chart for the center of the loop ramp on International Terminal Boulevard is shown in Figure 9. The beginning of the ramp is at the right-hand side of the data chart where the irregularity of the first few peaks in the curve resulted from the lighting approaching the gore of the ramp. The regularly spaced intervals between the peaks represent the lighting around the ramp loop. The data for all three tests, i.e., the right side, center, and left side of the loop ramp, are shown in Table 3. The maximum average level of illumination of 2.33 fc was in the center of the ramp roadway with that for the left side, which is nearest to the luminaires, being nearly the same at 2.27 fc. The total roadway average was 1.88 fc and the uniformity was 2.29:1 — both well within the accepted standards.

Second Data Run

The second set of data were collected on study section 2 at the same time as those for section 1. In this case, however, the lighting was reduced on study section 2 during the second data run. The data chart shown in Figure 10 reveals that six of the fourteen lights that were on in the first tests were off during the second tests. As can be seen from Figure 10, considerable depreciation had occurred as indicated by the lower peak values. Also, the levels of illumination in the areas where the lights were out were, for the most part, nil. The total average level of illumination was less than one-third of the initial levels at 0.60 fc, and the uniformity ratio was extremely high, since the lowest level of illumination in the area was for all practical purposes zero.

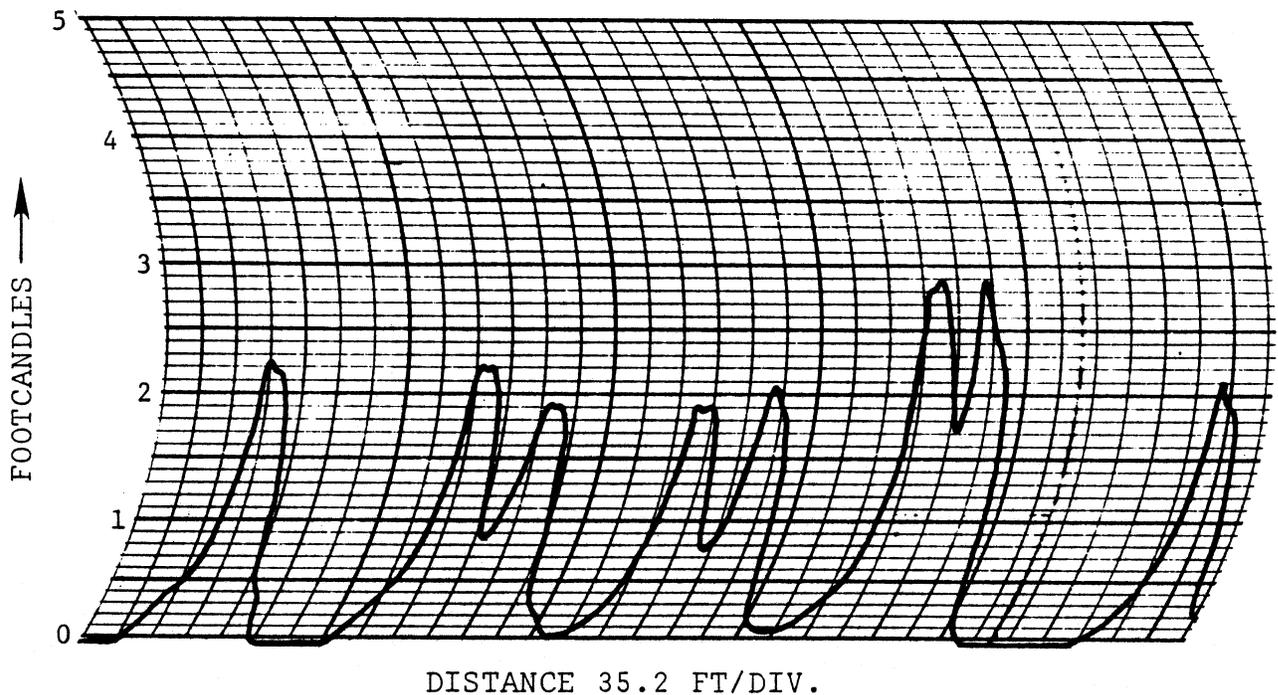


Figure 10. Illumination levels down the center of the International Terminal Blvd. ramp with approximately 40% of the lights out. (Study section 2, 2nd data run.)

CONCLUSIONS

The determination of the average levels and uniformity of the illumination on two study sections of roadway were made when all of the lighting was in operation and when it was partially turned off. A comparison of the full lighting with the reduced lighting for the same sections of roadway led to the conclusions summarized below.

1. The lighting on both study sections was well within the quality and quantity standards recommended for average maintained and uniformity of illumination when all of the luminaires were in operation.
2. Reducing the lighting by turning out every third light on study section 1 did not violate the standards for minimum average levels of illumination and uniformity during the early service life of the system. This result was probably due to the fact that lighting is over designed with respect to initial output to compensate for lamp lumen and dirt depreciation that result from continued use. Therefore, the 22% lower average levels of illumination that resulted from turning out every third light, in effect, cancelled out some of the initial over design in the system.

3. After the system had been in service for slightly less than two years, the average levels of illumination had depreciated by approximately 32% under the full lighting condition. The uniformity ratios had also increased to a point only slightly below the 3:1 maximum suggested by the standards for freeways. Therefore, had every third light been turned out under the prevailing conditions at that time, the average maintained level of illumination would have been acceptable, but the uniformity of the lighting would not have been acceptable when judged by the 3:1 maximum ratio.
4. Reducing the lighting levels on the loop ramp (study section 2) by turning out 43% of the lights resulted in a borderline condition for the average maintained levels of illumination. The minimum standard of 0.6 fc would likely be violated as the lamp lumen and dirt depreciation factors further affect the output of the luminaires. The uniformity ratio under this reduced lighting condition was also extremely high and would not meet the quality standard.

RECOMMENDATIONS

Reducing the illumination levels on new lighting systems (or on systems that have been relamped and the lamp housing cleaned) by turning out approximately one-third of the lighting might be acceptable for a short period of time — probably not more than 6 months after activation. The standards for quality and quantity of illumination might not be violated in many situations until such time as the initial over design for lamp lumen and dirt depreciation ceases to compensate for the initial reduction. This approach could be used to reduce energy consumption in the operation of roadway lighting systems similar to that evaluated in the tests conducted in this study. The effects of reducing the lighting on loop ramps by turning out some of the lights will be harder to predict because of the geometric conditions involved.

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