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Outfall Inventory Using Airphoto Interpretation

The technique is reasonably economical, requires no expensive or unusual equipment, and is sufficiently simple so that it can be put into operation with minimal operator training.

Introduction

Outfall delineation along our nation's waterways has recently become a topic of considerable interest. An operational program to detect outfalls along long stretches of waterways must be economical, efficient and accurate. To determine the effectiveness of conventional stereo color airphoto interpretation for outfall detection, a test program was conducted along stretches of the Cuyahoga and Ashtabula Rivers in Ohio. The program results indicate that conventional air photo interpretation will provide an efficient and accurate tool for outfall delineation and study over vast stretches of waterways.

Abstract: *Outfall delineation along stretches of the Cuyahoga and Ashtabula Rivers in Ohio was successfully accomplished using airphoto interpretation of 70 mm stereo color and color-infrared imagery. Twenty-six major outfalls were detected along a 10-mile stretch of the Cuyahoga River between Cuyahoga Falls and Lake Rockwell; 18 were discovered over an equivalent stretch of the Ashtabula River and its tributaries. A subsequent field survey on the Cuyahoga River yielded 27 major outfalls—the 26 detected by the aerial imagery and one covered by dense foliage. Three detection mechanisms were most common in the airphoto interpretation: gross stream discoloration, identification of discharge structures, and evaluation of drainage patterns. The color imagery proved most useful for outfall detection with little additional information supplied by the color-infrared imagery. The program results indicate that conventional color airphoto interpretation provides an efficient and accurate outfall inventory procedure.*

Two regions were studied: (1) a 10-mile stretch of the Cuyahoga River between Cuyahoga Falls and Lake Rockwell; and (2) a 12-mile waterway segment near Ashtabula, Ohio consisting of 4 miles of Lake Erie shoreline, 5 miles of the Ashtabula River, and 3 miles of Fields Brook. These regions are depicted in Figures 1–3.

Overflights were made on May 12, 1971, between 1300 and 1630 hours. Imagery was taken at an altitude of about 2,500 feet, except over Fields Brook, where a 1,000-foot altitude was flown due to the narrowness of the brook. Flight speed was 100 knots. Ektachrome MS2448 color film and Ektachrome CD2443 color-infrared film were utilized in Hasselblad 500 EL cameras with 80 mm lenses. Imagery was taken at 1/250 sec, $f/11$ MS and $f/8$ CD. Exposure intervals were 3 seconds at 2,500 feet, and 2 seconds at 1,000 feet—thus providing stereo coverage. Approximately 45 feet of each film type was expended. The scale of the imagery was 1:3,800 and 1:9,500.

Outfall detection on waterways of this type

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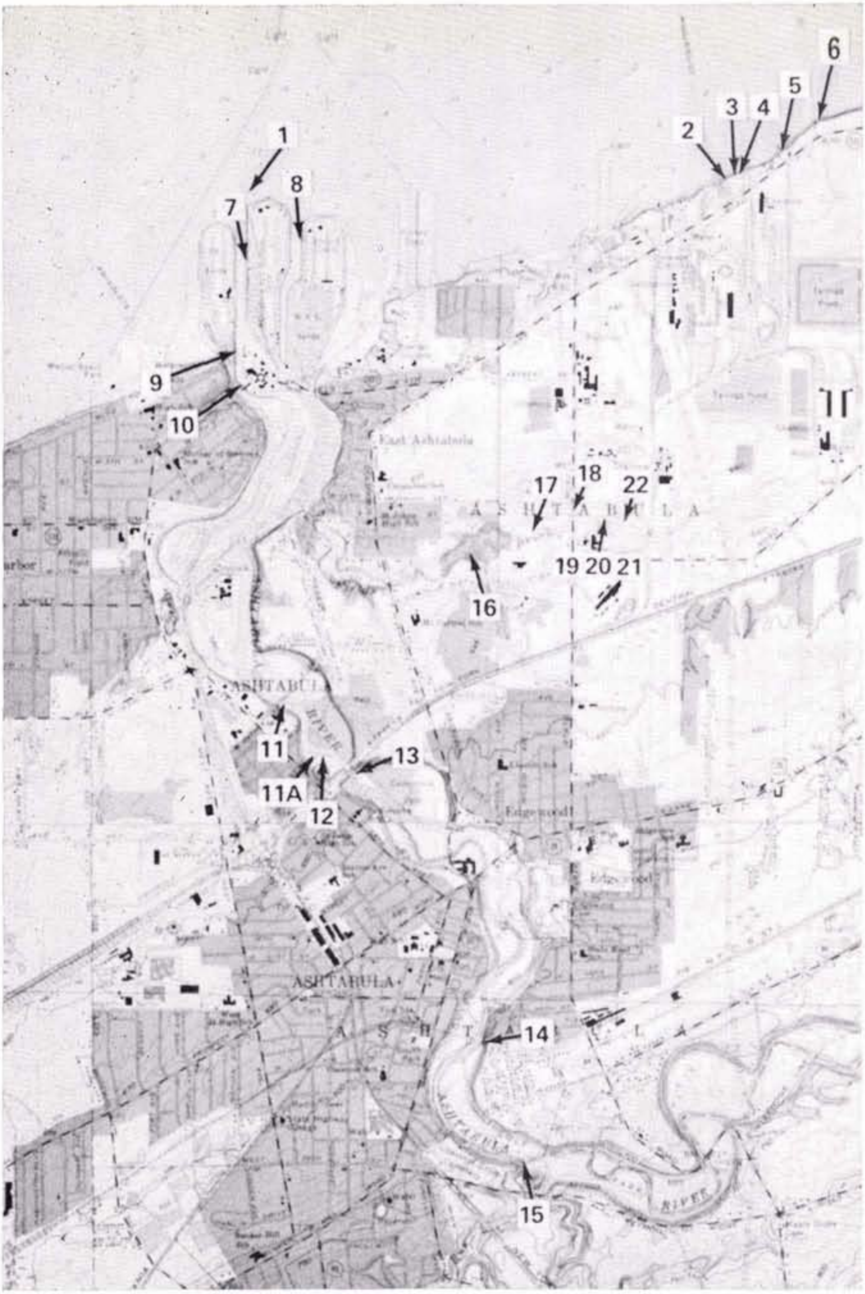

FIG. 1. Ashtabula and Fields Brook outfalls.

is quite difficult. The streams are highly turbid, making detection due to turbidity variation between effluent and ambient stream difficult. The streams are also narrow and winding. The narrow stream width makes high-altitude imagery useless; the winding nature of the streams makes low-altitude imagery somewhat difficult to fly. In addition, dense vegetation exists on the stream banks providing cover for many outfall sources.

It was considered that the scheme most suitable for overcoming such difficulties was interpretation of conventional color photography. In addition to economy of operation and ease of data collection, the system

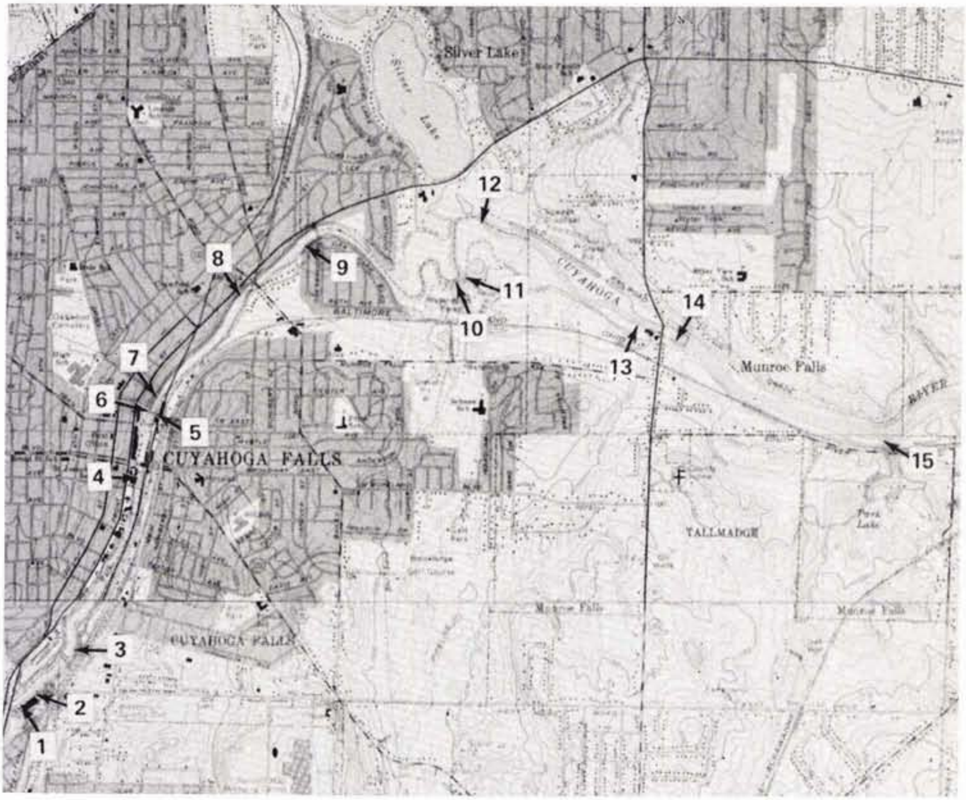

FIG. 2. Cuyahoga River outfalls.

possesses sufficient spatial resolution for the interpreter to distinguish between outfalls and objects such as rocks and dead tree limbs. Further, it is possible to detect outfalls masked by ambient turbidity and vegetation through interpretation of structures and topography near the stream bank. In point of fact, the latter technique proved an extremely important method for outfall location.

Subsequent to processing, the imagery was analyzed for outfall presence by a photointerpreter. Interpretation technique consisted of visual analyses using a stereomicroscope viewer. Figures 1–3 contain the results of this analysis. Outfalls are indicated in numbered sequence on maps corresponding to USGS topographic maps of the Ashtabula and Cuyahoga regions. Tables describing outfall types and positions are attached as Appendices I and II.

Upon completion of the analysis of the aerial imagery, a field survey was conducted by personnel of the Corps of Engineers to ascertain the accuracy of the aerial map. The ground survey was restricted to the Cuyahoga region, consisting of a boat cruise of the area. The ground survey indicated the aerial photointerpretation was unusually accurate in outfall mapping. The survey verified the presence of all 26 outfalls extracted from the airphotos; furthermore, only one major outfall was found which had not been extracted from the imagery. The undetected outfall was one covered by dense foliage. The detection accuracy obtained is quite remarkable in view of the difficulties described above.

Discussion of Detection Techniques

Three detection mechanisms were found to be most important for the present outfall interpretation problem. They were: (1) gross discoloration or turbidity variation due to discharge, (2) identification of discharge structures, and (3) identification of drainage patterns and interpretation of building complexes and land patterns removed from the stream shore.

Figure 4 contains an example of detection by gross discoloration. The two discharges to the left of the roadway were bright orange and black. This figure, as all photographic

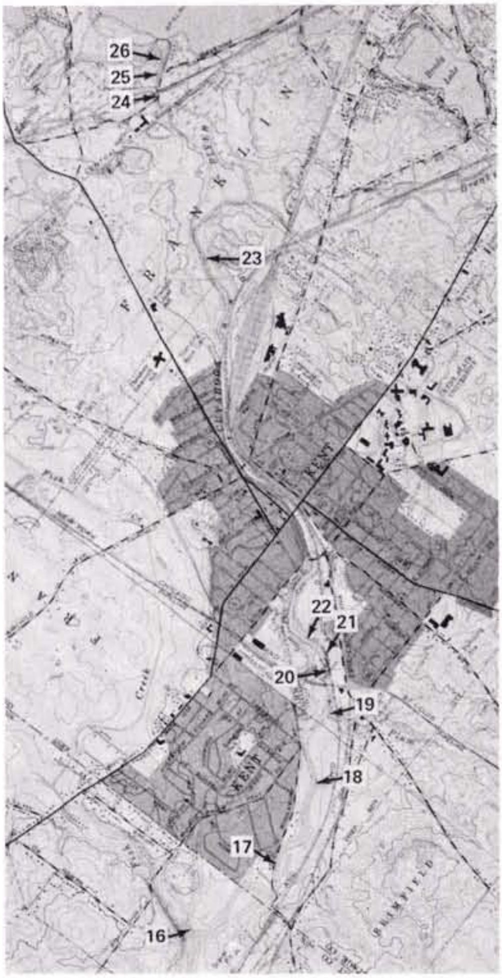

FIG. 3. Cuyahoga River outfalls.

examples in this paper, is a black-and-white copy of the original color imagery. Even though the streams studied were relatively turbid, there were still numerous examples of stream discoloration. No particular colors could be ascribed to detection by gross discoloration. For example, bright yellow, red, and orange discharges were observed, as well as discharges which appeared in brighter and darker tones of the ambient stream color.

Detection by discoloration is keyed to the interpreter identifying an outfall pattern by tonal change or variation. As the tonal variation becomes less pronounced, greater detection difficulty is encountered. In instances where the interpreter only suspects existence of a pattern due to small tonal difference, various contrast enhancement techniques may prove useful. For example, copying the image to a high gamma and density slicing the image on an electronic density analyzer may enable the interpreter to detect the outfall spatial pattern.

Figures 5 and 6 are stereo pairs which are examples of detection by identification of discharge structures. Figure 5 is of a drainage pipe under construction beneath a railway. Figure 6 depicts a sluice from a treatment pond. Figure 5 is a good example of how

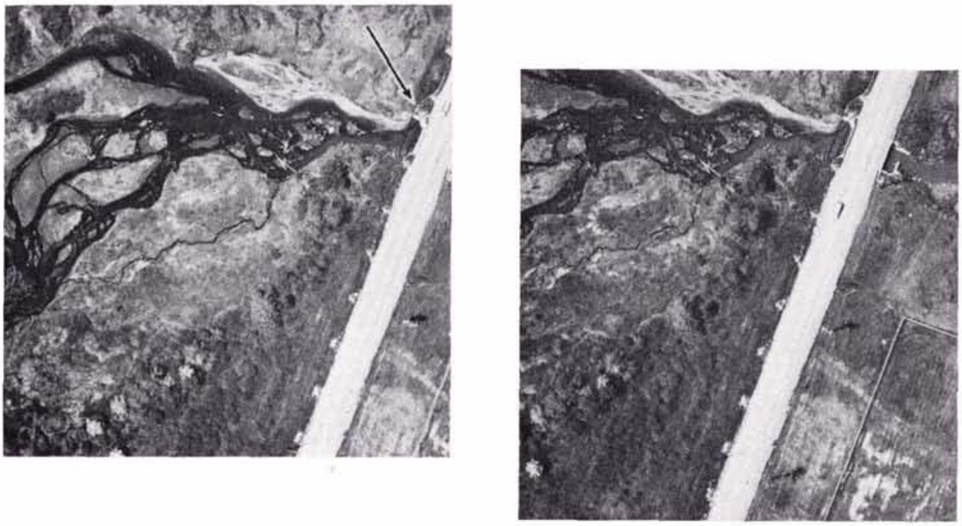

FIG. 4. Stereo pair of outfalls detectable by gross discoloration. The two outfalls (arrow) are bright orange and black in the original color imagery, black and white in this illustration.

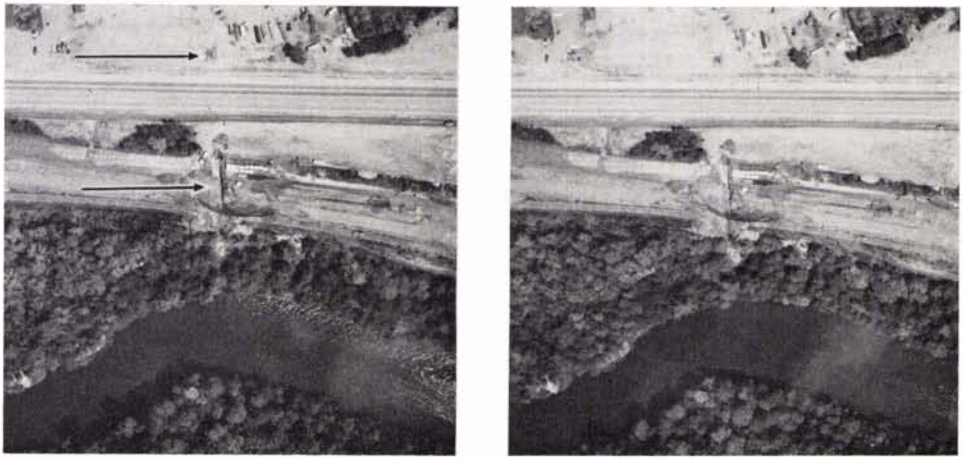

FIG. 5. Stereo pair of drainage pipe under railway. Point of discharge is not visible due to vegetation along river bank. Interpretation of objects removed from the bank, however, enables detection. Rows of white rectangles are aluminum conduits to be placed in cut and subsequently backfilled.

interpretation of objects removed from the stream bank can yield outfall detection, even when the outfall itself is obscured by vegetation. Figure 6 shows an outfall not discharging at time of flight, but detectable by interpretation of discharge structure. Not all outfalls of interest discharge continuously, and it is important to be able to detect outfalls even if dormant. An apparent outfall appears across from the sluice. Inspection of the orginal color imagery indicates this is river bottom.

Many different types of discharge structures were encountered. Frequently, open pipes were observed. In other instances, breaks in the shoreline pattern, either in vegetation or topography were clues for discharge structure presence. Sharp changes in tone caused by concrete or metal parts can indicate a discharge structure, even when much of the structure is hidden by vegetation, or is underground. All on-shore buildings should be inspected closely, both commercial buildings and residential units or complexes. Near-shore ponds and enclosed bodies of water also warrant close inspection.

Figure 7 contains an outfall obtained from consideration of drainage patterns. Actual point of discharge occurs well away from the stream bank, and the point of entry into the stream is hidden by vegetation. Without stereo interpretation the presence of this

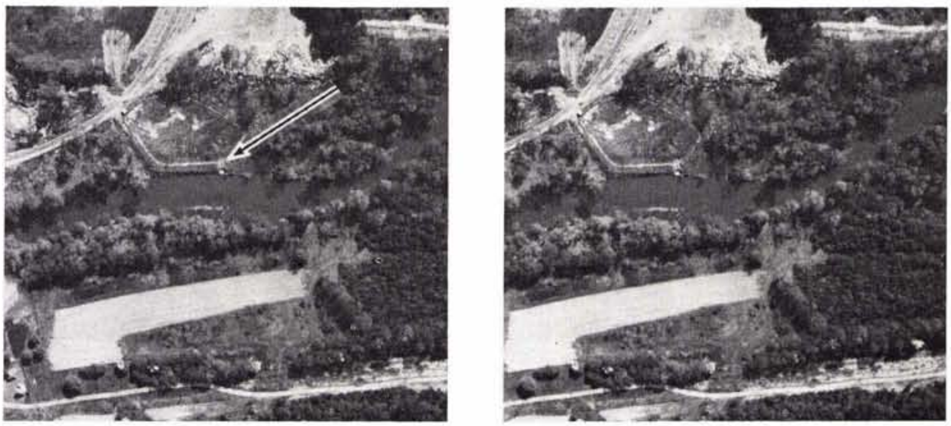

FIG. 6. Stereo pair of treatment pond with observable discharge structure (sluice). Outfall probably not discharging at time of flight. Discoloration across from sluice is not a discharge, but river bottom in shallow area of the river.

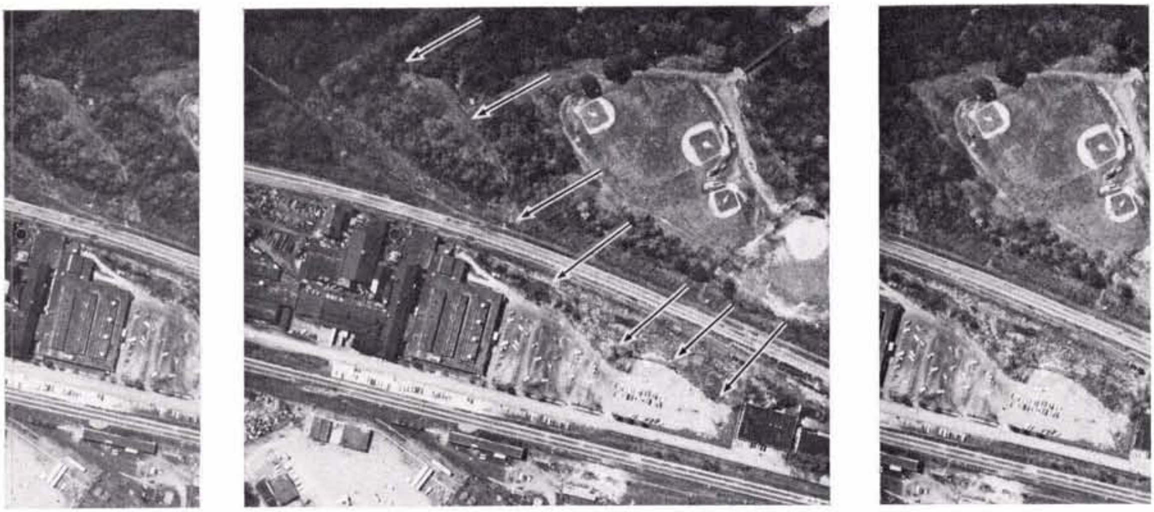

FIG. 7. Outfall detectable from drainage pattern. Arrows follow drainage pattern from river bank, under railway tracks, to approximate source.

outfall would be difficult to establish.

All potential drainage patterns, detectable either by topography or breaks in vegetation continuity (variations in vegetation vigor are included here), should be traced away from the shoreline to a possible source. Frequently, the patterns lead to a building complex or a treatment pond several hundred yards away from the shoreline. The treatment ponds themselves often have secondary drainage patterns, in addition to a main outlet.

Figure 8 contains one final example of two outfalls. These outfalls occur just downstream (to the left) of the outfall of Figure 7. The upper outfall denoted *A* is from a sewage plant. Detection of this outfall occurred from both turbidity change and close analysis of the shoreline structures. Discharge *B* was detected by turbidity change and analysis of the discharge channel leading back to the treatment ponds denoted by *C*. Both effluents show as a slight whitish tone on the original color imagery.

Two other detection mechanisms were of minor importance in the study; both involved visual detection of the effluent at discharge point into the stream. In the one instance, discharge was made visible due to the reflectance increase caused by bubbles and foam generated by a high-velocity discharge. In the other instance, detection occurred by damping of capillary waves in the discharge area due to effluent characteristics. Wave damping resulted in a reflectance anomaly and enabled outfall detection to occur.

CONCLUSIONS

Airphoto interpretation of 70 mm stereo color and color-infrared imagery has been used to delineate outfalls into typical inland waterways. The waterways studied presented a difficult problem due to stream width, meandering, turbidity and vegetation cover. Nevertheless, subsequent field surveys indicated interpretation of aerial imagery was unusually accurate in the detection process.

It was found that: color imagery provided

FIG. 8. Outfall pair just downstream of the outfall of Figure 7. Outfall *A* is from a sewage treatment plant, and is detectable by turbidity change and analysis of shoreline structures. Outfall *B* is detectable from turbidity change and analysis of the discharge channel back to treatment ponds *C*.

sufficient information for detection in almost all instances, with relatively little additional information provided by color-infrared imagery; stereo display was invaluable for interpretation; and three detection mechanisms were dominant—(1) gross discoloration, (2) identification of discharge structures, and (3) evaluation of drainage patterns and complexes displaced from the shoreline.

The fact that conventional airphoto interpretation can be successfully used for outfall delineation means that it is practical to monitor long expanses of waterways. The technique is reasonably economical, requires no expensive or unusual equipment, and is sufficiently simple to be put into large-scale operational usage with minimal operator training. Given the conventional interpretation approach as a basis for a monitoring system, it then becomes practical to develop and apply more sophisticated photographic enhancement techniques for special problems which will arise for the interpreter.

ACKNOWLEDGMENT

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APPENDIX I

OUTFALLS AND OUTFALL CLUES—LAKE ERIE SHORELINE, ASHTABULA RIVER & FIELDS BROOK

Eighteen outfalls and four outfall clues. The numbers refer to the maps of Figure 1. The method of outfall detection is indicated by the key: *A*, discoloration; *B*, discharge structures; and *C*, drainage patterns and interpretation of complexes away from the shore.

1. "Oil slick" traced back to Ashtabula River mouth.
2, 3, 4. Three outfalls from plant extending 250 feet east from breakwater. (*C*)
5. Runoff from "dump" and road drainage ditch about 1,300 feet from breakwall above. (*C*)
6. Runoff. (*C*)
7. Possible source of oil slick (1) in lake, ship appears to be discharging oil while tied up and loading. (*B*)
8. Slick between Union Dock and Ashtabula and Buffalo Dock.
9. Outfall about 800 feet north of 6th Street bridge. (*B*)
10. 6th Street bridge—slick along shore, no visible source.
11–11a. Seems to be oil on surface between 11 and 11a.
12. Outflow from small stream about 1,000 feet north of New York Bridge. (*C*)
13. Drainage ditch or small stream 120 feet south of New York Central Bridge. (*C*)
14. Drainage ditch either side of NYC and St. Louis tracks. (*C*)
15. Discoloration from Hubbard Run creek. (*A*)
16. Stream into Fields Brook on the east side of 4 lane highway. (*C*)
17. Stream into Fields Brook halfway between 4 lane highway and State Road (about 1,400 feet west of State Road). (*C*)
18. Drainage pipe that runs north along west side of State Road (appears to be major source of water color). Pipe has two discharge points. Minor outfall visible just to east of State Road. (*A*)
19. "Chemical plant" at corner of Middle and State Roads—drainage from piles 800 feet from State Road. (*C*)
20, 21. Secondary drainage patterns leading from "chemical plant" listed in 19 above. (*C*)
22. Drainage ditch running north about 350 to 400 feet west of railroad tracks. (*C*)

APPENDIX II

OUTFALLS—CUYAHOGA RIVER BETWEEN CUYAHOGA FALLS AND LAKE ROCKWELL

The numbers refer to the map of Figures 2 and 3. The method of detection is indicated by the key: *A*, discoloration; *B*, discharge structures; and *C*, drainage patterns and interpretation of complexes away from the shore.

1, 2. Two outfalls from plant just east of the Gorge Expressway Bridges. One at each end of the building. (*B*)
3. Drainage ditch under construction 1,000 feet upriver of plant in 1 and 2 above. (*B*)
4. Plant immediately downstream from Broad Blvd. Plant in heavy shadow. (*B*)
5. Drainage pipe upstream from Portage Trail Bridge about 60 feet downstream from dam. (*B*)
6. Outfall from building on opposite shore from outfall 5. (*B*)
7. Drainage or output pipe at end of Oakwood Drive 390 feet upstream from dam. (*A*)
8. Drainage pipe 300 feet downstream from Bailey Bridge. (*B*)
9. Outfall 200 feet downstream from Oak Park Blvd. Bridge. (*B*)
10, 11, 12. Tributaries from Water Works Park. (*C*)
13. Pond with sluice at factory 1,000 feet downstream from North Avenue. (*B*)
14. Outfall below dam from reservoir south of dam (same plant as above). (*B*)
15. Outflow from park sanitary system. (*C*)
16. Fish Creek, *definite* discoloration. (*A*)
17. Outfall 600 feet upstream from N. East Avenue, Middlebury Bridge. (*B*)
18. Drainage ditch under highways from residential community about 2,800 feet upsteam from 17. (*B*), (*C*)
19. Heavy discoloration from filtration plant 800 feet below railroad bridge. (*A*)
20. Kent Sewage Plant outfall. (*A*), (*B*)
21. Discharge from factory across from sewage plant (heavy discoloration). (*A*), (*C*)
22. Outfall from drainage pattern from plant just to east of factory listed in 21 (180 feet). (*C*)
23. Visible discoloration from drainage ditch flow about 800 feet below large bend in river ahead. (*A*)
24. Outfall just below railroad bridge from building and construction. (*B*)
25. Pond sluice outfall 450 feet upstream from railroad bridge. (*B*)
26. Stream alongside pond about 120 feet from outfall 25. (*B*), (*C*)

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