Prepared for

FirstEnergy Corp
Akron, Ohio

Toledo Edison Company Bay Shore Station

THERMAL MIXING ZONE STUDY

January 2003

Prepared by

#925-002

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EXECUTIVE SUMMARY

This report presents the methods and results of a Thermal Mixing Zone Study (the Study) at the Toledo Edison Company Bay Shore Station in Oregon, Ohio. Lawler, Matusky & Skelly Engineers LLP (LMS), Pearl River, New York, performed the Study for FirstEnergy Service Company (FirstEnergy), Akron, Ohio, in accordance with a detailed Plan of Study. LMS prepared the Plan of Study for FirstEnergy, in response to a requirement contained in the Bay Shore Station's NPDES permit. The Ohio Environmental Protection Agency (OEPA) approved the Plan of Study, with some additional requirements, on 10 May 2002 and requested that field studies begin no later than 15 June 2002. That target was achieved and the Study was completed as described in this document.

The purpose of the Study was to carry out the investigations detailed in the Plan of Study. In addition to those investigations, at the request of OEPA, FirstEnergy agreed to measure dissolved oxygen (DO) concentrations in the region of the Mobile Surveys, when the work schedule permitted and using a DO meter provided by OEPA. The Plan of Study details two broad areas of investigation: an investigation of the thermal plume resulting from the Station's cooling water discharge and an investigation of the transfer of e. coli and fecal coliform bacteria from the Bay Shore Station intake to Maumee Bay, via the Station's cooling water system discharge.

LMS conducted the thermal plume portion of the Study, which is reported in the main body of this document. FirstEnergy did the sampling for bacteriological portion of the Study directly, with the laboratory analyses done by Jones & Henry Laboratories, Inc.. The methods and results of the bacteriological study may be found in Appendix D. As agreed, LMS also measured DO whenever conditions permitted during the field surveys; the methods and results of the DO measurements are presented in Appendix E.

The plan for the thermal plume portion of the Study included two major elements: a Field Survey Program and a Modeling Study.

The Field Survey Program, in turn, included a Mobile Survey element and a Fixed Station element, as well as acquisition of auxiliary data. LMS performed the five Mobile Survey events called for in the Plan of Study, plus a sixth Mobile Survey event made necessary by the delayed deployment of the fixed stations. In addition, LMS measured DO concentrations during each of the five planned Mobile Surveys, as agreed. The Fixed Station element of the Field Survey Program included deployment of 21 fixed water temperature monitoring stations and two fixed water current monitoring stations during the period from late June through mid-September 2002. Eighteen of the water temperature stations collected data for the entire period, as did the two current monitoring stations. Initial problems with the Station 1 tether system, rectified during the first servicing event, led to questionable data immediately following deployment. The other two water temperature stations collected data for all but the last three weeks of the Field Survey Program, during which time they were lost due to unknown causes. The Field Survey Program was intended both to satisfy the specific requirement in the Station's NPDES permit for delineation of the cooling water discharge plume and to support the Modeling Study.

The Modeling Study called for use of the U.S. Environmental Protection Agency-approved CORMIX model to:

- Produce preliminary estimates of the discharge plume to aid in locating the fixed sampling stations and establishing the Mobile Survey track lines.

- Produce estimates of the discharge plume under a range of natural conditions, not all of which may have been observed during the Field Study Program.

Thus, the modeling was to be conducted in two stages, a preliminary stage used to guide the detailed design of the Field Survey Program and a final stage, in which the model was validated for the Bay Shore discharge and used to produce the forecasts of worst case conditions.

CORMIX is unique among water quality models in that it does not require field data for calibration of model parameters. Nonetheless, regulatory agencies frequently require comparison of CORMIX results with field data to establish a degree of confidence in the model results. This process is often called model "validation", in contrast to the "calibration and verification" process typically used with other models. The Field Survey Program fulfilled the requirement for field data in the validation process.

The results of the validation process showed that CORMIX cannot be used to represent the Bay Shore Station discharge. Those limitations relate to its inability to represent:

- surface discharges that are wide relative to their depth
- discharges in a low ambient flow situation
- discharges to the head of a cove or other enclosed water body

As a result, it was necessary to abandon the CORMIX model and expand the planned data analysis into a detailed evaluation of the observed Station discharge conditions.

The Data Analysis makes extensive use of both thermodynamic and statistical methods to understand the important relationships between the extent of the thermal plume and the anticipated driving factors, such as discharge flow and cooling water temperature. It includes use of a process called Response Temperature Modeling to produce estimates of natural temperatures in the vicinity of the Station, so that estimates of the extent of the thermal plume can be generated for a range of conditions.

The Data Analysis produced a model of the Bay Shore Station thermal discharge that can be used to estimate the likelihood of a given thermal plume area, given a set of inputs representative of the limnology, meteorology, and plant operating conditions. The model is restricted to use during summer conditions, because it is a statistical model based solely on data acquired during the summer of 2002. Using a statistical analysis of the range of these inputs, the Report concludes that the largest plume expected under worst case conditions at the Bay Shore Generating Station will not exceed 184 ha more than 5 percent of the time and that the typical (50% exceedance) plume during the summer period will not be larger than 34 ha.

1 INTRODUCTION

This report presents the methods and results of a Thermal Mixing Zone Study (the Study) at the Toledo Edison Company Bay Shore Station in Oregon, Ohio. Lawler, Matusky & Skelly Engineers LLP (LMS), Pearl River, New York, performed the Study for FirstEnergy Corp (FirstEnergy), Akron, Ohio, in accordance with a detailed Plan of Study (Appendix A). LMS prepared the Plan of Study for FirstEnergy, in response to a requirement contained in the Bay Shore Station's discharge permit. The Ohio Environmental Protection Agency (OEPA) approved the Plan of Study, with some additional requirements, on 10 May 2002 and requested that field studies begin no later than 15 June 2002. That target was achieved and the Study completed as described in this document.

1.1 BACKGROUND

1.1.1 Bay Shore Station

The Toledo Edison Company-Bay Shore Station (the Station) is located in Oregon, Ohio, on a peninsula between the southeastern bank of the Maumee River and the southeastern shore of Maumee Bay (Figure 1-1). The Station consists of four generating units, with the generating and cooling water system (CWS) pump capacities shown in table 1-1. Each unit is cooled with once-through cooling water drawn from a navigable side channel of the Maumee River. The once-through cooling water is discharged from Outfall 001 to a channel directly tributary to Maumee Bay.

1.1.2 Maumee Bay

As shown in Figure 1-2, Maumee Bay is on the southwestern shore of Lake Erie. The boundary between Maumee Bay and the main body of Lake Erie is usually arbitrarily defined as a line between North Cape and Cedar Point. The Bay is relatively shallow, with depths ranging from about 1 ft Low Water Datum (LWD) to about 8 ft LWD outside the dredged navigation channel. The navigation channel project dimensions are a width of 500 ft and a depth of 28 ft LWD from the Maumee Bay Entrance Light to the mouth of the Maumee River.[1]

The Station discharges its cooling water to an unnamed region of the Bay to the southeast of the Confined Disposal Facility (CDF). For purposes of this report, the unnamed region is "the Cove", which is bounded by a line extending from and continuing parallel to the northeastern wall of the CDF to the shoreline between the Station and Maumee Bay State Park. The CDF was constructed in 1975 to contain contaminated dredge materials produced by maintenance dredging of the navigation channel.

Lake levels, water temperatures and circulation within Maumee Bay are influenced by wind-driven seiches in Lake Erie. In addition, local wind effects and discharge from the Maumee River may influence water currents in the Bay.

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[1] National Ocean Survey Chart 14847, 30th Edition, 30 October 1999.

Maumee Bay was the subject of a two-year environmental quality study to determine any impacts resulting from construction of the CDF. The first year of the study was conducted in 1974 to determine conditions before construction and the second year of study took place in 1976, following construction. The study was undertaken by a consortium of environmental organizations and documented in two comprehensive reports.[2,3]

According to the 1977 Report, Maumee Bay has a surface area of about 40 km^2, a mean depth of 1.5 m, and a volume of 0.06 km^3. The 1977 Report estimates the typical "turnover time" (bay volume divided by mean Maumee River discharge) to be approximately 5 days. It indicates this is a very short turnover time relative to other comparably sized Great Lakes bays, so that conditions in Maumee Bay will typically strongly reflect conditions in the Maumee River discharge.

1.1.3 Maumee River

The Maumee River is the principal tributary to Maumee Bay, with the Ottawa River and smaller creeks and ditches providing additional inflows. The Maumee River drains approximately 16,400 km^2 in western Ohio and eastern Indiana. The 1977 Report indicates the mean river discharge over the period of record at that time was 136 m^3/s. It also indicates the soil conditions in the Maumee drainage basin contribute to a heavy sediment load in the river, which gives rise to the on-going need to dredge the Maumee Bay navigation channel and to operate the CDF.

1.1.4 Other Discharges

In addition to the Station thermal discharge, the Cove receives treated wastewater from the City of Oregon Wastewater Treatment Plant. The Plant has a capacity to treat up to 8 MGD of dry-weather flows, with a wet-weather capacity of 36 MGD. The wastewater discharge is within about 400 m northeast of the mouth of the Station discharge canal, in approximately 1 m of water (LWD). Under its discharge permit, the Plant must achieve better than 90% removal for BOD and suspended solids, and must meet permit criteria for phosphorus, coliform bacteria, chlorine, and heavy metals.[4]

1.1.5 Recent Water Quality Concerns

As has been widely reported in regional news media, the nearby Maumee Bay State Park beach has been subject to frequent closures in recent years, due to high bacteria levels in the lake water. Reportedly, one reason for the inclusion of bacteria sampling in the Permit was concern for the effect that the Station's discharge of Maumee River water to the Cove might have on those bacteria levels.

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[2] P.C. Fraleigh, J.C. Burham, G.H. Gronau, T.L. Kovacik, and T.J. Tramer. The Maumee Bay Environmental Quality Study 1974. Report to the Toledo-Lucas County Port Authority Environmental Advisory Committee (1975).

[3] P.C. Fraleigh, J.C. Burnham, G.H. Gronau, and T.L. Kovacik. Maumee Bay Environmental Quality Study 1977 Final Report. Report to the Toledo-Lucas County Port Authority Environmental Advisory Committee (January 1979).

[4] See the web site at http://ci.oregon.oh.us.

However, the media have recently reported that the elevated bacteria levels are now attributed primarily to "bacteria harboring in sediments…in creeks and ditches such as Wolf Creek and Berger Ditch and possibly the Maumee River"[5] that are transported into Maumee Bay during wet weather. Other published reports indicate that the Maumee River is not complicit in the elevated bacteria levels.[6]

1.2 PURPOSE OF STUDY

The purpose of the Study was to carry out the investigations detailed in the Plan of Study (Appendix A). In addition to those investigations, at the request of OEPA, FirstEnergy agreed to measure dissolved oxygen (DO) concentrations in the region of the Mobile Surveys, when the work schedule permitted and using a DO meter provided by OEPA.

1.3 OVERVIEW OF STUDY PLAN

The Plan of Study (Appendix A) details two broad areas of investigation: an investigation of the thermal plume resulting from the Station's cooling water discharge and an investigation of the transfer of bacteria from the Station intake to Maumee Bay, via the Station's CWS.

LMS conducted the thermal plume portion of the study, which is reported in the main body of this document (Sections 2 through 6, plus Appendices A, B and C). FirstEnergy did the sampling for the pathogen portion of the Study directly, with the laboratory analyses done by Jones & Henry Laboratories, Inc., Northwood, OH. The methods and results of the pathogen study may be found in Appendix D. As agreed, LMS measured DO whenever conditions permitted during the field surveys; the methods and results of the DO measurements are presented in Appendix E.

1.3.1 Delta T Concepts

The term "delta T" refers to a difference between a temperature of interest and some reference temperature. Because the reference temperature can be selected in any number of ways, the delta T associated with a measurement or forecast of temperature at any given point can vary due solely to the value of the reference temperature. The Plan of Study and the letter from FirstEnergy to OEPA dated 18 April 2002 (Appendix A) discuss the concept of delta T in detail.

In the present case, the basic reference temperature selected is the maximum water temperature allowed in Maumee Bay under the OEPA water quality criteria (Table 1-2). The boundary of the Station's thermal plume is defined as the locus of points where the delta T (relative to the criterion temperature) is zero, enclosing water with a delta T greater than zero.

However, it is important to note that, as described in Appendix A, a number of factors can contribute to the delta T associated with the Station, in addition to the heat added by the Station itself. For example, there can be a difference (positive or negative) between the water

[5] Toledo Metropolitan Area Council of Governments, Volume 5, Issue 9, October 2001.
[6] The Blade, Toledo, Ohio, 09 October 2001.

temperature at the Station intake from the Maumee River and the criterion temperature in Maumee Bay. This could lead to a thermal plume (either cooler or warmer), any time the Station's pumps are running, even if it were not generating any electricity.

It is also important to note that there are discrete steps in the criterion temperatures. As a result, even under identical conditions, the size of the thermal plume can change dramatically from day to day on those days when the criterion changes.

1.3.2 Field Survey Program

As presented in the Plan of Study (Appendix A), the Field Survey Program consisted of a mobile survey element and a fixed station element, as well as acquisition of auxiliary data. The mobile survey events included the five thermal plume mapping surveys called for in the Plan of Study, plus a sixth mobile survey event made necessary by the delayed deployment of the fixed stations. In addition, LMS measured DO concentrations during each of the five planned mobile surveys, as agreed. The Field Survey Program was intended both to satisfy the specific requirement in the Station's NPDES permit for delineation of the cooling water discharge plume and to support the modeling effort.

1.3.3 Modeling

The Plan of Study (Appendix A) calls for use of the CORMIX model to:

- Produce preliminary estimates of the discharge plume to aid in locating the fixed sampling stations and establishing the mobile survey track lines.
- Produce estimates of the discharge plume under a range of natural conditions, not all of which may have been observed during the Field Study Program.

Thus, the modeling was to be conducted in two stages, a preliminary stage used to guide the detailed design of the Field Survey Program and a final stage, in which the model was validated for the Bay Shore discharge and used to produce the forecasts of worst case conditions.

The model selected in the Plan of Study is CORMIX-GI version 4.1GT, which was provided by Dr. Robert Doneker at Oregon Graduate Institute. Detailed information on CORMIX-GI can be found at: http://www.cormix.info.[7] Section 4 in the Plan of Study details the basis for selection of the model. In summary, CORMIX was selected because:

- It meets the OEPA requirement for a U.S. Environmental Protection Agency (U.S. EPA) approved model.
- It is widely used to model generating station discharge plumes.

[7] Note, Oregon Graduate Institute is no longer supporting CORMIX-GI version 4.1GT. The model was transferred to MixZon Inc. in October 2002. MixZon, Inc. now offers an updated version, CORMIX-GI version 4.2GT. The fundamental computational methodology of the two versions is the same; the principal change is improved graphic visualization of the model results.

- It is the only U.S. EPA-approved model capable of handling a surface discharge canal.

In addition, LMS has extensive experience in applying CORMIX to a wide variety of generating station and wastewater discharges, so there was no "learning curve" in using the model.

CORMIX is unique among water quality models in that it does not require field data for calibration of model parameters. Nonetheless, regulatory agencies frequently require comparison of CORMIX results with field data to establish a degree of confidence in the model results. This process is often called model "validation", in contrast to the "calibration and verification" process typically used with other models. The Field Survey Program fulfilled the requirement for field data in the validation process.

While CORMIX is the best available U.S. EPA-approved model to represent the Station discharge, it has certain limitations. Those limitations relate to its ability to represent:

- surface discharges that are wide relative to their depth
- discharges in a low ambient flow situation
- discharges to the head of a cove or other enclosed water body

As a result, the Field Survey data and the validation process were expected to be particularly important to this application of CORMIX. The Field Survey Program was specifically designed so that the data could be used independently of the CORMIX model, to develop an understanding of the Station discharge if CORMIX proved unsuitable.

1.3.4 Data Analysis

As it turned out, the limitations of the CORMIX model for application to the Station discharge could not be overcome. It was necessary to abandon the CORMIX model and expand the planned data analysis into a detailed evaluation of the observed Station discharge conditions. The analysis makes extensive use of statistical methods to understand the important relationships between the extent of the thermal plume and the anticipated driving factors, such as discharge flow and cooling water temperature. It includes use of a process called Response Temperature Modeling to produce estimates of natural temperatures in the vicinity of the Station, so that estimates of the extent of the thermal plume can be generated for a range of conditions.

1.4 OVERVIEW OF REPORT

The main body of the Report is organized into three broad topics. Section 2 describes the methods and results of the Field Survey Program, including the preliminary application of CORMIX to lay out the fixed and mobile survey elements. The actual field data are included on the accompanying CD-ROM as Appendix D. Section 3 details the methods and results of the CORMIX model validation effort, and the reasons for abandoning use of the model in favor of a statistical analysis. The results of the CORMIX model validation runs are included on the same CD-ROM, as Appendix E. Section 4 presents the methods and results of the statistical analysis, focusing on the extent of the thermal plume under varying meteorological, limnological and plant operating conditions. Figures and tables for these sections may be found at the end of each section.

The remainder of the Report includes Section 5, which summarizes the results of the Study and presents our conclusions regarding the thermal plume, based on the Study. The appendices follow the Section 5. As previously noted, Appendix A is the Plan of Study and related documents. Appendix B contains the instrument specification sheets and Appendix C presents the QA/QC data for the instrumentation. Appendix F provides the results of the bacteriological studies that were conducted by FirstEnergy and Jones & Henry Laboratories, Inc. in conjunction with the Thermal Study.[8] Finally, the results of the voluntary DO measurements performed during the Mobile Surveys can be found in Appendix G.

[8] While LMS did not perform the bacteriological studies, we include the bacteriological study results in this report for the convenience of the reader, so that all aspects of the Study may be found in one document.

Table 1-1. Bay Shore Station Operating Capacity

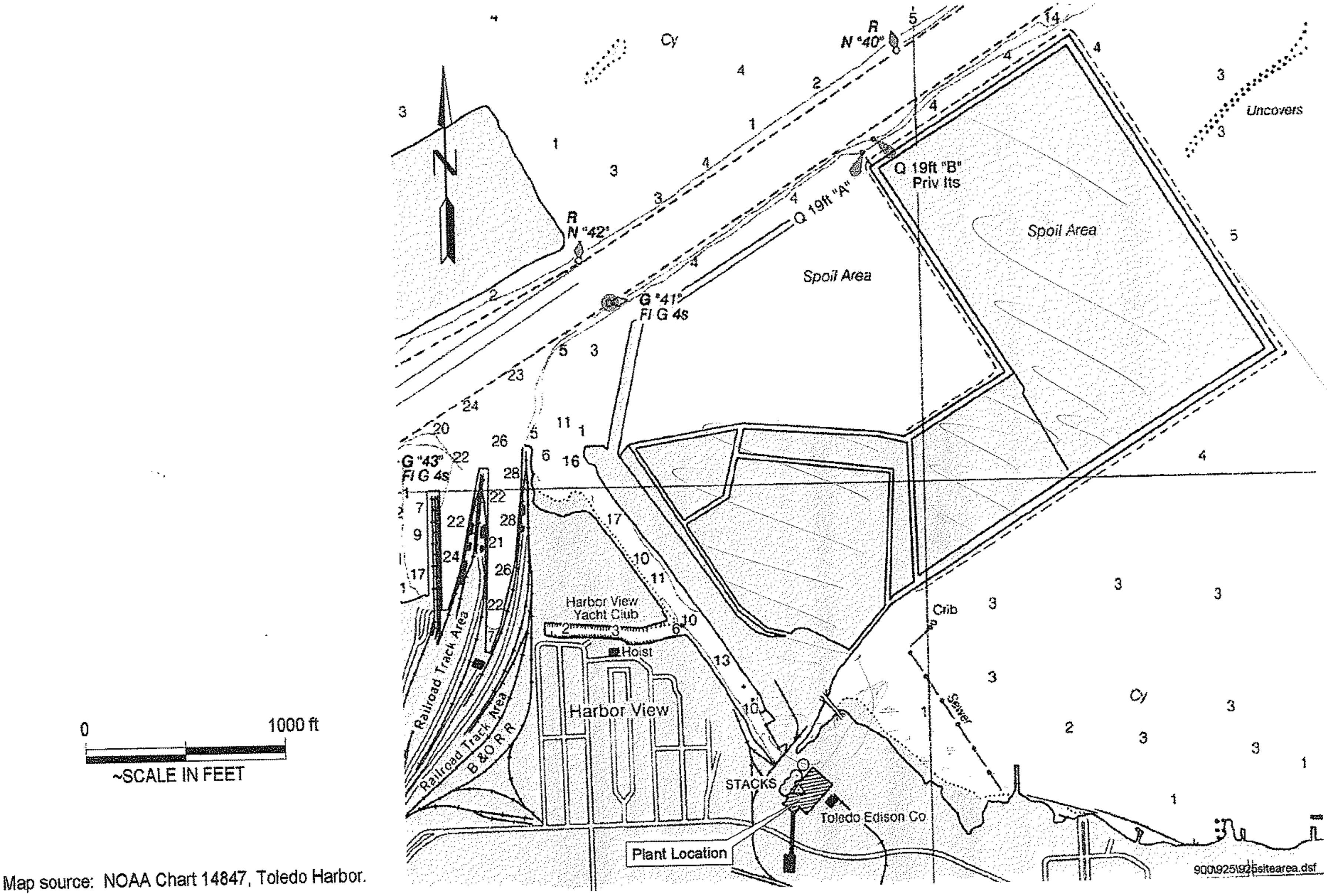
Unit	Rating (MWe)	Circulating Water Pumps	Pumping Capacity (total, MGD)
1	136	2	184.3
2	138	2	184.3
3	142	2	184.3
4	215	2	192.0
Total Plant	631	8	744.9

Table 1-2. OEPA Temperature Criteria for Maumee Bay

(J) Maumee bay - includes all waters of the state known as Maumee bay including the Maumee river estuary and the estuary portions of all tributaries entering Maumee bay to the lake Erie mean high water level. Shown as degrees fahrenheit and (celsius).

	Jan. 1-31	Feb. 1-29	Mar. 1-15	Mar. 16-31	Apr. 1-15	Apr. 16-30	May 1-15	May 16-31	June 1-15
Average:	47 (8.3)	47 (8.3)	48 (8.9)	50 (10.0)	52 (11.1)	57 (13.9)	61 (16.1)	65 (18.3)	71 (21.7)
Daily Maximum:	52 (11.1)	52 (11.1)	53 (11.7)	54 (12.2)	59 (15.0)	63 (17.2)	63 (18.9)	76 (24.4)	77 (25.0)

	June 16-30	July 1-31	Aug. 1-31	Sept. 1-15	Sept. 16-30	Oct. 1-15	Oct. 16-31	Nov. 1-30	Dec. 1-31
Average:	83 (28.3)	83 (28.3)	83 (28.3)	83 (28.3)	75 (23.9)	69 (20.6)	64 (17.8)	59 (15.0)	47 (8.3)
Daily Maximum	87 (30.6)	87 (30.6)	87 (30.6)	87 (30.6)	80 (26.7)	74 (23.3)	69 (20.6)	64 (17.8)	52 (11.1)



Map source: NOAA Chart 14847, Toledo Harbor.

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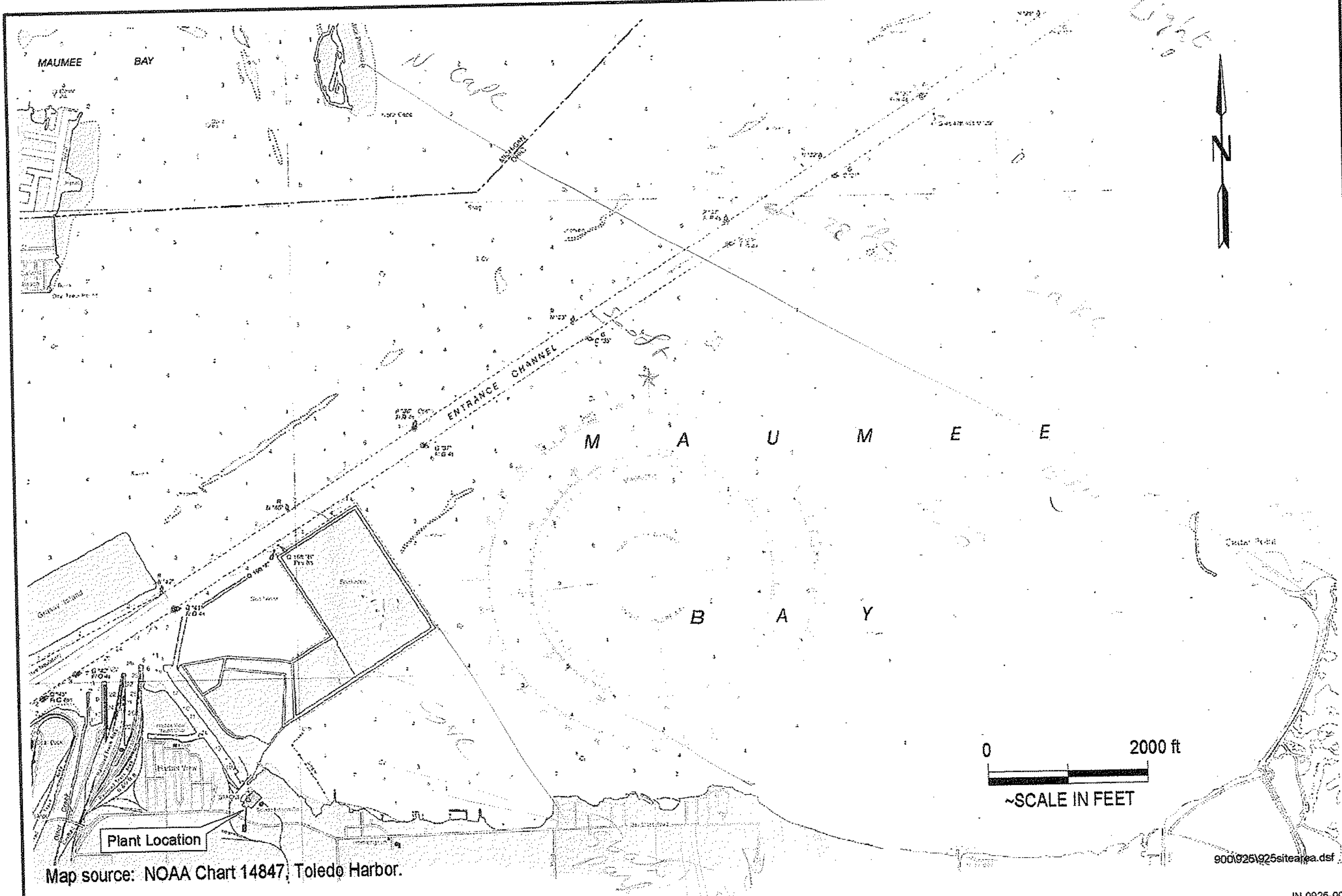
LMS Lawler, Matusky & Skelly Engineers LLP One Blue Hill Plaza, Pearl River, New York 10965, (845)735-8300	FirstEnergy Corp, Toledo Edison Bay Shore Station **Facility Location**	**FIGURE** **1 - 1**



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FirstEnergy Corp, Toledo Edison Bay Shore Station

Maumee Bay and Vicinity

FIGURE 1 - 2

2 FIELD SURVEY PROGRAM

Section 2 describes the Field Survey Program ("the Program") LMS conducted at the Bay Shore Generating Station during 2002 in accordance with the Plan of Study. The Program consisted of two major elements, a Mobile Survey element and a Fixed Station element. Table 2-1 summarizes the Program and the remainder of this section provides details of the Program.

2.1 PURPOSE OF FIELD SURVEY PROGRAM

The purpose of the Program was to sufficiently understand the physical processes in Maumee Bay to characterize the behavior of the thermal plume associated with the Bay Shore Station discharge. The Program was intended to:

1. Provide field observations that define the Station thermal plume under a range of actual conditions.
2. Provide field observations that can be used to perform and evaluate the CORMIX modeling.

In conjunction with plant operating data, meteorological data, and other external data sets, the findings of the Program would be used to model the thermal plume, with the ultimate goal of generalizing the observed conditions to a wider range of potential conditions and projecting the spatial extent of a reasonable worst-case plume based on relevant historical data.

2.2 OVERVIEW OF FIELD STUDIES

To provide both the spatial and temporal resolution necessary, the Plan of Study called for five Mobile Surveys to be performed during the summer of 2002. These surveys would occur periodically throughout the summer in an attempt to include as wide a range of meteorological and limnological conditions as possible. The Plan noted that constraints of mobilization, the unpredictable nature of environmental conditions, and the occurrence of all surveys in the same summer would limit the range of conditions observed. However, these surveys would be treated as a stochastic subset of potential conditions, i.e., each survey would be placed in the historical context based on meteorological and limnological observations.

Concurrent with the Mobile Surveys, the Plan called for the deployment of fixed monitoring stations within that portion of Maumee Bay influenced by the thermal discharge as determined during the Reconnaissance Survey. The Fixed Stations included: twenty surface-only temperature stations within the influence of the discharge; one surface and bottom temperature station located outside of the influence of the plume; and two fixed velocity monitoring stations. The locations of the Fixed Stations were determined based on both preliminary CORMIX modeling of the Bay Shore 001 discharge, and the Reconnaissance Survey.

OEPA requested that the Program begin no later than 15 June 2002; FirstEnergy authorized LMS to begin the Study on 24 May 2002. The initial field event began on 10 June 2002 and was completed on 14 June 2002, in accordance with the OEPA request. The Fixed Stations were deployed on 26 June 2002, following a prolonged approval process for deployment of the buoys in Lake Erie. Formal approval was received from the Ninth Coast Guard District Aids to Navigation and Waterways Management Branch in the form of a Letter of No Objection dated 12 June 2002. The Division of Watercraft of the Ohio Department of Natural Resources (ODNR) was initially contacted at the suggestion of the U.S. Coast Guard on 03 June 2002, at which time ODNR indicated that they had authority over the deployment of buoys in Lake Erie. This determination was reversed on 19 June 2002, at which time LMS scheduled the deployment for the following week. Because the Fixed Station deployment was intended to take place concurrent with a Mobile Survey to provide supporting data, LMS added a Mobile Survey to the Program to provide comparable data, calling the combined deployment and Mobile Survey Event 1A.

2.3 METHODOLOGY

2.3.1 Fixed Stations

LMS deployed 21 fixed water temperature monitoring stations (Stations 1 through 21) and two fixed current monitoring stations (Stations 22 and 23) on 26 June 2002 and recovered all instrumentation on 17 September 2002. The locations (Figure 2-1) were based on both preliminary CORMIX modeling of the Station's Outfall 001 discharge and the Reconnaissance Survey. The CORMIX modeling suggested that the thermal plume centerline would tend to hug the shoreline and be shorter than the southeastern face of the Confined Disposal Facility (CDF). The Reconnaissance Survey confirmed the expectation that the centerline would hug the CDF wall, but it also revealed the plume extending beyond the eastern corner of the CDF in a southeasterly direction, generally describing a clockwise circulation pattern. Accordingly, 19 of the 21 fixed temperature monitoring stations were distributed within the region where LMS anticipated the plume boundary would occur most of the time, as shown in Figure 2-1. The remaining two stations monitored the discharge temperature at the mouth of the discharge canal (Station 1) and lake background temperature (the lake water temperature expected not to be influenced directly by the thermal plume) at a point well beyond the anticipated region of the thermal plume (Station 21, Figure 2-2). The two fixed water current stations (Stations 22 and 23) were deployed at locations selected to assist in understanding any water movements that would tend to deflect or distribute the thermal plume within the Cove.

2.3.1.1 Temperature Stations

The 21 fixed temperature monitoring stations consisted of dual temperature sensors mounted to a moored buoy assembly (Figure 2-3). Mr. Jeff Herr of Curtice, Ohio, a local commercial fisherman experienced with anchoring tackle commonly used in Lake Erie, fabricated the mooring assemblies and provided suitable, lake-design ground tackle for use with the fixed stations. Each moored buoy assembly included a 13-pound Polyform Model A0 heavy-duty inflatable white buoy tethered to a standard fish trap hook anchor using 3/8" 3-strand sinking line. Fish trap hook anchors are widely used in the Lake Erie fishery and well adapted to local bottom conditions. A plastic ring was knotted into the line approximately 1 foot below the buoy, on which a pair of temperature sensors were mounted using heavy duty tie-wraps. The instruments were paired to provide redundant protection against instrument failure and data loss. An additional pair of instruments was mounted near the bottom at Station 21 (the lake background monitoring station). Station 1 was tethered to the bridge near the mouth of the discharge channel via a loop of floating line connected to the bridge at two points approximately 50 feet apart, rather than being anchored to the bottom, allowing landside access to the temperature sensors.

LMS used Onset Computer Corporation Optic StowAway® Temp Loggers to measure water temperatures. Each instrument has an operating range of -4°C to +37°C, an accuracy of +/-0.2°C, a resolution of 0.16°C, and a response time in water of 4 minutes. All Loggers were tested for calibration in accordance with manufacturer's recommendations prior to deployment (see Appendix C). Only instruments that passed the calibration verification procedure were placed in service. Following recovery, instruments were tested again. Instruments used for multiple deployments were checked before and after each deployment. A total of 100 sensors were rotated through the Program, with 44 instruments in service at any given time. The entire set of instruments was replaced during each survey so that no instrument remained in service longer than the duration between servicings. Each set of Loggers deployed were time-synchronized using GPS time and identical delayed deployment start times. Loggers recorded data in 6-minute intervals (i.e., 0.1 hours).

Deployment of the temperature sensors just below the marker buoys differs from the Plan of Study. The Plan called for the temperature instruments to be deployed near the bottom at each station, to minimize the possibility of loss due to vandalism. The bottom deployment was believed justified under the assumption that the plume would be vertically well-mixed. The preliminary CORMIX modeling suggested that the plume would be stratified over significant areas of the plume away from the discharge, so LMS investigated the desirability of deploying the sensors nearer the surface. Conversations with commercial boatmen in the region convinced LMS personnel that vandalism would not be an issue, so the temperature sensors were deployed at the preferred near-surface location, where they would monitor the highest temperature water. The success of the Fixed Station element supports this decision.

2.3.1.2 Water Current Stations

Each of the two fixed current velocity monitoring stations consisted of an acoustic Doppler current meter rigidly mounted to a weighted assembly (Figure 2-4). The weighted assembly was designed to rest on the bottom and provide an immobile platform for current measurements. Each assembly was constructed of pressure treated lumber and concrete blocks connected with stainless steel hardware. The instrument was mounted to the assembly using stainless steel hose clamps. A 13-pound Polyform Model A0 heavy-duty inflatable white buoy was tied to the top of the assembly using a short length of floating line to avoid interference with the sensors and simplify instrument recovery and redeployment.

LMS used Nortek Aquadopp® Current Meters to measure current velocity. The Aquadopp is an acoustical current meter that measures average water velocity within a single fixed volume of water located a specified distance from the transducers. A built-in compass with programmable magnetic declination and automatic tilt detection sensor allow velocities to be reported relative to earth coordinates (rather than instrument coordinates), eliminating the need for precision alignment during deployment. Both meters were recovered and redeployed during each servicing event. Prior to redeployment, recovered data was scanned for obvious anomalies that could indicate instrument problems and to determine battery status. Each instrument was resynchronized prior to redeployment using GPS time and identical delayed deployment start times. Current meters recorded data in 10-minute intervals.

The two current monitoring stations were located to observe (1) the anticipated currents near the plume centerline (as forecast by the preliminary CORMIX modeling) and (2) ambient currents in the region of the Cove assumed to provide dilution water to the plume. See Section 3 for additional information on the importance of ambient current information to the CORMIX modeling.

2.3.2 Mobile Surveys

The purpose of the Mobile Surveys was to determine the detailed distribution of water temperatures and currents in the Station plume and surrounding area at the time of each survey. The five planned Mobile Survey events were undertaken during the summer of 2002, beginning with a Reconnaissance Survey on 11 June 2002, and ending with a surface temperature and current velocity survey on 17 September 2002. The surveys were scheduled in approximately three-week intervals during the four-month summer period called for in the Schedule of Compliance (June through September). Table 2-1 presents the schedule of field activities during the Program.

LMS subcontracted Meinke Marine (Curtice, Ohio) to provide a work vessel and crew with local knowledge of the work area. The work platform used throughout the Program was the **M/V Lady K**, a 45 ft, aluminum-hulled, U.S. Coast Guard documented, uninspected lake workboat. The vessel's relatively deep draft (4.5 feet) limited access to shallower portions of the work area, but provided a very stable work platform and minimized the potential of weather-related delays. The vessel was operated by a U.S. Coast Guard licensed boat captain, who was responsible for the safety of all passengers and crew members. The LMS chief scientist directed the work; the boat captain had the authority to override the chief scientist's direction, if he believed it jeopardized the safety of the vessel or personnel aboard. There was always at least one crew member in addition to the LMS chief scientist, but occasionally a second crew member was added to assist in recovering and redeploying moored instrumentation.

Horizontal boat position was determined using a Trimble Ag132 real-time Differential Global Positioning System (DGPS) with L-band satellite differential correction. Differential corrections from ground-based stations were acquired in real-time by the OmniStar satellite linkage system, improving the overall positional resolution to better than 1 meter and eliminating AM frequency interference often associated with ground-based beacons. All on-board instrumentation was synchronized to the DGPS system time (local DST). Precise time synchronization was necessary to integrate the positioning data with output from the survey instruments.

All mobile instrumentation was mounted to the portside gunwale just aft of the vessel's forward superstructure, except for the DGPS antenna, which was mounted directly above the instrumentation array on the portside bulkhead of the superstructure. Simultaneous observations of temperature, current velocity, and position were made at one-second intervals during each of the mobile surveys. Data streams from all instruments were fed to a notebook PC running Hypack® Max (v00.5B) hydrographic survey software and WinRiver, which synchronized the data streams and provided time and positional information from the DGPS.

Prior to the first Mobile Survey, a Reconnaissance Survey was performed 11 June 2002. The purpose of this survey was to 1) determine the probable extent of the plume to finalize fixed station locations and Mobile Survey track lines established by preliminary CORMIX modeling; 2) determine the navigational limitations of the work area and develop alternative approaches as required; and 3) test all equipment prior to executing a formal Mobile Survey. The Reconnaissance Survey was performed in a manner similar to the anticipated approach of the surface temperature and current velocity surveys. Track lines were spaced densely in the Cove initially. Once the plume shape and extent was roughly identified, the course was varied to attempt to remain within the thermal plume. Additional investigations focused on the eastern corner of the CDF and along an extended line paralleling the southern shoreline of the CDF in an attempt to determine the maximum possible spatial extent of the thermal plume prior to performing the first Mobile Survey.

Water temperature and current velocities were recorded simultaneously at one-second intervals along planned track lines, as shown in Figure 2-1. Actual track lines achieved for each Mobile Survey are shown on the temperature contour plots (Figures 2-6 through 2-12). The track lines were preliminarily based on modeling and the Reconnaissance Survey, and modified based on field observations as the Program progressed. The target track line was finalized along with the locations of the fixed temperature monitoring stations, so that the final four surveys followed the same target track line. Sections of the track line were aligned with the array of fixed temperature stations to provide overlapping coverage during survey days. The berm of material or shoal area (labeled "uncovers" on the NOAA chart[1]) that extends from the northeast face of the CDF roughly parallel to the Maumee River navigation channel limited the survey area to southwest of this barrier. The final target track line as shown in Figure 2-1 is 13.25 statute miles in length. The boat speed was maintained below 1.5 m/sec (under 5 ft/sec) based on limitations associated with acquiring current velocity (instrument drag, turbulence, and instrument range). The Mobile Surveys took an average of 4.5 hours to complete.

As each Mobile Survey progressed, the boat was periodically stopped to profile vertical temperature variations. The profiles were taken in areas believed to be within the thermal plume, but occasionally uninfluenced regions were measured to determine if stratification in the shallow waters of Maumee Bay occurs naturally. Vertical profiling was performed as few as three times in a survey, but at least seven times during each of the last three surveys following the calibration of the profiling instrumentation.

[1] National Oceanographic and Atmospheric Administration (NOAA). 1999. Chart 14847: Toledo Harbor.

2.3.2.1 Temperature Measurements

Surface water temperatures were measured using a Falmouth Scientific Inc. (FSI, Cataumet, MA) Ocean Temperature Module (OTM). The OTM uses a platinum resistance thermometer with a range of -2 to +32 C, an accuracy of +/- 0.003 C, and a response time of 150 milliseconds. Because the temperature variability was never this extreme, the response time during the surveys was probably much shorter. The OTM was factory calibrated 12 August 2002, so that all data collected after that date are directly presented. The electronic calibration results were used to post-process field data collected prior to the factory calibration. Consequently, all surface temperature results reflect measurements from calibrated equipment. The OTM was programmed to send measurements to the notebook PC at a rate greater than the sampling rate programmed in Hypack MAX (1 Hz), but only the most recent data in any 1-second interval was recorded. At a typical boat speed of 5 ft/second and a sampling rate of 1 Hz, each measurement of surface temperature represents an average temperature along approximately 5 feet of trackline.

Vertical temperature profiles were measured using an FSI Model A800-011 Micro-CTD. The CTD measures conductivity, temperature, and pressure simultaneously to output salinity and temperature as functions of depth. Because Lake Erie is a freshwater system, the conductivity meter was not necessary for this Program. The temperature sensor uses an electronic thermistor with an accuracy of +/- 0.01 C, and a response time of approximately 1 second. Like the OTM, the CTD was factory calibrated mid-Program (16 August 2002), and all data collected after that date were directly used without adjustment. However, the CTD malfunctioned prior to commencing the 30 July 2002 survey, and was damaged in transit to the manufacturer for repair. Therefore, the electronic calibration results could not be used to post-process field data collected prior to the factory calibration. Consequently, vertical profiling data prior to the 30 July 2002 survey were not collected with calibrated instruments. In addition, the CTD failure required the use of a backup vertical profiling system during the 30 July 2002 survey. A YSI Model 58 Dissolved Oxygen Meter probe was lowered through the water column, and readings were manually recorded in 1-foot intervals based on gradations marked on the probe cable prior to the survey. Manually recorded data were key entered into the database during post-processing. The data stream from the CTD was fed to the laptop PC and date and time stamped by the Hypack MAX software.

2.3.2.2 Current Velocity Measurements

Water velocity data were acquired using an RD Instruments (San Diego, CA) Workhorse 1200 kHz Acoustic Doppler Current Profiler (ADCP) with bottom tracking (firmware v16.21). The ADCP is capable of measuring water velocities at multiple depths simultaneously. The bottom tracking feature allows the user to acquire data while in motion by measuring the bottom velocity with respect to the mobile work platform. The instrument emits a four-beam acoustic signal in user-defined sets of pulses (called pings). The sound waves bounce off particles floating in the water column. By precisely measuring the change in frequency and the arrival time of return signals, the ADCP can determine the current velocity and distance from the sensor from which the signal was derived. The use of simultaneous data from each of the four sensors (oriented in a convex array) in conjunction with a factory-calibrated internal compass allows the direction of each velocity reading to be determined. Statistical formulations reduce the number of signals into single values within each user-specified bin (depth range).

ADCPs can be configured for different applications, and are available in a range of frequencies. Selection of the appropriate frequency is based primarily on depth, and in shallow depths (less than about 60 feet) the 1200 kHz ADCP yields the highest resolution data. The ADCP configuration is shown in Table 2-2.

As a consequence of using acoustic energy, there is a physical limit to how close to its sensors an ADCP can measure current velocity. In the configuration shown in Table 2-2, the blind distance from the sensors is 2.66 feet. In addition, a minimum submerged sensor depth is necessary to ensure acoustical continuity between the sensors and the water column during rough sea conditions. The sensors were submerged 1.5 feet below the surface which, including the blind distance, results in a first bin depth of 4.16 feet.

The ADCP fed its data stream directly to the notebook PC onboard. Data were processed and displayed in real-time using WinRiver (v1.03.000). The data were not fed through Hypack MAX, but were precisely synchronized to GPS time for adding positional information during the post-processing phase of the Program.

2.3.3 Additional Investigations

2.3.3.1 Bathymetric Measurements

Bathymetric data were extracted from the ADCP measurements performed during each Mobile Survey. The distance from each ADCP sensor to the bottom must be determined for every set of measurements when the bottom tracking routine is used to adjust relative velocities to absolute velocities. Therefore, four depth measurements were taken every second during each mobile survey, which were averaged to yield a single depth every 1 second. The 20-degree convex orientation of the four ADCP sensors covers a bottom area with a radius of approximately 36.4% of the measured depth. A source of error is that pitch and roll compensation used for correcting ADCP velocities are not used for the depth measurements, resulting in a maximum error associated with boat motion of about 6.4% of the measured depth. Because the depth of Maumee Bay does not exceed 10 feet anywhere within the study area, each measurement represents an area less than 5.5 ft x 5.5 ft with a maximum error of -0.64 feet (the depth cannot be underestimated, only overestimated, due to pitch and roll errors). The final bottom depth with respect to the Low Water Datum (LWD) was determined by adding the depth of the instrument (1.5 feet), and subtracting the water surface elevation from the LWD elevation.[2]

2.3.3.2 Discharge Channel Measurements

A current velocity and bathymetry transect was performed across the discharge channel in order to provide detailed information on the geometry and discharge velocity. Because of shallow

[2] LWD = 569.2 ft Mean Sea Level (MSL). Source: National Ocean Survey (NOS) Station Station # 9063085, U.S. Coast Guard (USCG) Station Toledo.

depths in the surrounding area of Lake Erie, strong currents in the canal, and other navigational hazards, the transect could not be performed from a boat. Therefore, the ADCP was pulled across the width of the discharge channel from land. The ADCP was rigged with flotation and lines to maintain a relatively stable vertical position, and was pulled across the discharge channel along the northeastern side of the bridge at the mouth of the discharge channel. A single pass was made and the data collected was immediately reviewed for validity. The resulting data were used to determine the cross-sectional area of the discharge as a function of water surface elevation and to estimate the velocity of the discharge for modeling purposes.

2.3.3.3 Stationary Velocity Tests

During preliminary processing of Mobile Survey data from the initial surveys, current velocity vector maps generated from the mobile ADCP data showed very low velocities with no discernable pattern. Portions of the data appeared to violate laws of continuity and conservation of mass. To eliminate the possibility that the boat wake was contaminating the measured velocities, stationary velocity tests were performed during subsequent Mobile Surveys. The boat was stopped periodically and held roughly in position. Once the boat was approximately stationary and the engines were put into neutral, current velocities were measured for several minutes. Although the boat was allowed to drift, its size tended to keep it relatively stationary for the duration of the test, and any significant boat speed was removed from the ADCP data using the bottom tracking function. The data collected during these tests were used to validate the presumption that the Mobile Survey represented an instantaneous snapshot of current velocity conditions in Maumee Bay by comparing temporal variability with spatial variability of current velocity measurements.

2.3.4 Auxiliary Data

Auxiliary data were acquired from a number of outside data sources to supplement the data collected during the Field Survey Program. These data sets were used to identify environmental and operational conditions that were expected to affect plume size, and to statistically describe the summer during which the field studies were performed in comparison with historical conditions. Table 2-3 summarizes these data sets.

2.4 RESULTS

Presentation of all data collected during the Field Survey Program is provided at the end of Section 2.0. Table 2-4 summarizes the data sets collected during the Program.

Overall, the Program recovered 96.2% of the planned Fixed Station data and more than 100% of the planned Mobile Survey data, as follows:

- 100% of the planned data from the five planned Mobile Survey events
- additional Mobile Survey data from the un-scheduled Event 1A
- 100% data recovery from 18 of the Fixed Stations
- 85.5% of the planned data from Station 1 in the highly dynamic discharge canal

- 67.5% of the planned data from Stations 9 and 21, due to physical loss during the final deployment period

The following paragraphs discuss the results of the Field Survey Program by event.

2.4.1 Reconnaissance Survey

LMS performed the Reconnaissance Survey on 11 June 2002. The purpose of the Reconnaissance Survey was to confirm the feasibility of installing the Fixed Stations, and the feasibility of conducting the Bathymetric Survey and the Mobile Surveys in the Study Area. The available navigational information on the Cove prior to the Reconnaissance and Bathymetric surveys was severely limited, and it was not clear if the intended boat operations could be carried out as planned. The Reconnaissance Survey disclosed that boat operations could be carried out throughout the Study Area, except in the area immediately in front of the discharge canal, where a shoal area prevented the **M/V Lady K** from approaching the mouth of the canal. As a result, it was necessary to deploy, service, and retrieve Station 1 from a bridge across the discharge canal near the mouth, with the surface buoy tethered to the bridge, rather than anchored. The bathymetric chart presented in the next section does not show the shoal area, because **M/V Lady K** could not carry the bathymetric instruments into that region of the Cove.

2.4.2 Bathymetry

Bathymetry data are shown on Figure 2-5. Because the ADCP was used to determine water depth and the instrument was onboard for every Mobile Survey, it was possible to enhance the Bathymetric Survey results by collecting and processing sounding data from a total of five survey events. Bathymetry in the Cove is shallow (less than 5 feet below LWD) and generally very smooth, sloping gently from about -3 feet LWD near the discharge to about -5 feet LWD at the mouth. Water depths increase to the extent of the study area where the bottom is approximately -7 feet LWD. The region northeast of the CDF includes a prominent berm or shoal that parallels the Maumee River navigational channel and precludes navigation across it. This berm may also have an influence on flow patterns in this vicinity.

2.4.3 Temperature

All Mobile Survey surface temperature contour maps are shown in Figures 2-6 through 2-12. Vertical temperature profiling locations are shown in Figures 2-13 through 2-19, and profile results are shown in Figures 2-20 through 2-26. The surface temperature contour maps indicate adequate coverage to define the regulatory plume (i.e., the 21.7°C isotherm prior to 16 June, the 30.6°C isotherm from 16 June through 15 September, and the 26.7°C isotherm from 16 September onward), except for the Reconnaissance Survey (11 June) and the first Mobile Survey (12 June). The large variability of temperature contours throughout the summer is evident when the temperature contour maps are considered collectively.

Vertical temperature profiles generally validate the presumption that the plume is vertically well mixed in the vicinity of the discharge. However, stratification occurred in at least one of the vertical profile measurements taken during four of the seven surveys. This condition is probably the result of meteorological conditions. For example, the 11 June Reconnaissance Survey was performed during strong northeasterly winds and rough seas, which is evident in the generally well-mixed state of the plume. However, stratification is evident the following day (12 June), a day of calm winds and low wave energy.

The temporal variability of surface temperature throughout the summer is shown in the Fixed Station temperature monitoring data (Figures 2-27 through 2-47), and compared with the OEPA temperature criteria (dashed lines). The stations are numbered from 01 (the discharge) to 21 (the remote, background station) in a sequence roughly related to distance from the discharge. A clear diurnal temperature cycle can be seen in Figures 2-27 through 2-47 for the Fixed Stations farthest from the discharge (particularly Stations 11 through 21), by comparing the instantaneous water temperature observations with the 24-hour running average water temperatures. This diurnal temperature cycle corresponds with what one would expect of near surface waters due to the daily solar cycle; the minimum water temperatures occur just before dawn, with temperatures increasing as the incoming solar radiation increases over the day to a peak around mid-afternoon, and subsequent cooling through the evening and night hours to a minimum the next morning. Longer period trends are also evident, and are probably due to a combination of seasonal meteorology and plant operating conditions.

The temperature fluctuations at the Fixed Stations closest to the discharge are more closely a function of the variations in discharge temperature than they are to the solar cycle, so that, for example, the water temperature at Station 2 on 05 August 2002 (Figure 2-28) displays a nearly constant value, corresponding to the nearly constant temperature of the discharge on that date (Figure 2-74). On other days, the temperature at Station 2 displays a nearly square shape, similar to that of the discharge temperature and clearly different from the more sinusoidal shape of the stations more strongly influenced by the solar cycle.

It is important to note that both the daily average and instantaneous maximum water quality criteria are exceeded at least once at every station except station 21 (the remote location), and are exceeded the majority of the time at Station 2 (near the mouth of the discharge channel), indicating the presence of a regulatory plume most days of the summer. Station 21 appears to be uninfluenced by the heat from the discharge, and no data collected at this station exceeded either the daily average or instantaneous temperature criteria during the Program.

2.4.4 Velocity

The velocity measurements taken during the Mobile Survey were intended to reveal any circulation patterns that may exist within the study area. However, preliminary data analysis indicated that the velocity measurements showed no predominant directionality and often appeared to violate laws of continuity and conservation of mass. In addition, the magnitude of the Mobile Survey velocity data was generally different from the magnitude of the Fixed Station velocity data (order 1 ft/sec versus order 0.1 ft/sec). In response to these preliminary findings, stationary velocity tests were performed as described above. The results of these tests are shown as "radar" scatter plots in Figures 2-48 through 2-68.

The magnitude of the velocity (speed) is indicated by the rings on the plot, with greater speeds farther from the center. The direction of motion is indicated by the relative angle of the data point from north. A minimum of two minutes of one-second interval data were collected, resulting in at least 120 measurements, except in near-bottom bins which sporadically yield invalid measurements with slight changes in water depth. Rayleigh's test of significance was applied to the mean angle. This test of significance determines how large a sample must be to confidently indicate a nonrandom population distribution. The mean angle and angular dispersion of each set of measurements was determined for this test (alpha = 0.05). In addition, the magnitude of the mean velocity was compared to its standard deviation to characterize the scatter of measurements over the relatively short interval of each of these tests.

A total of 76 unique depth locations were tested within 21 discrete sampling events. In all cases, the magnitude of the mean velocity was less than the magnitude of the standard deviation, indicating that the magnitude was within one standard deviation of zero. In over half the depth locations, direction was not statistically significant, indicating that there was no mean direction (i.e., the distribution was uniform). Because it would not be possible to distinguish between directionally significant data and insignificant data from the Mobile Survey, the Mobile Survey velocity data were rejected as unreliable. In other words, the presumption that the Mobile Surveys represented instantaneous snapshots of current velocity conditions in Maumee Bay was not valid, because temporal and spatial variability of current velocities are on the same scale.

Both Fixed Station velocity data sets appeared to have a more directional tendency as well as a consistent velocity. Rayleigh's test of significance was not applied to the northern station (Station 22), because a bimodal directional distribution is evident in Figure 2-69. The directional oscillation between 225 degrees and about 75 degrees clockwise from true north is roughly parallel to the southeastern shoreline of the CDF. Station 23 (Figure 2-70), along the southern shore of the Cove, does not appear to be bimodal. The Rayleigh's test indicates a significant mean direction of 33 degrees clockwise from true north. Both data sets reveal consistently low velocities (on the order of 0.1 ft/sec), further supporting the likelihood that current velocities in the Cove are generally very low and difficult to predict.

2.4.5 Discharge Data

The cross-section of the discharge channel is shown in Figure 2-71. Because both the water level and discharge flow vary, the cross-sectional area and average discharge velocity also vary. Figure 2-72 shows a calculated discharge cross-sectional area as a function of water level in Lake Erie at the Toledo NOS gage. This graph was used in conjunction with reported discharge flow to estimate average discharge velocity. Figure 2-73 presents a set of velocity curves as a function of lake level and percent maximum plant flow, and indicates the relative importance of water level to average discharge velocity.

The plant operating data is presented in Figures 2-74 and 2-75. Each date tick corresponds to midnight of the date indicated, with the remainder of that day to the right of the tick. Figure 2-74 shows the variation of Station intake temperatures, discharge temperature, and flow as routinely monitored and recorded by the Station, from 01 June 2002 through 30 September 2002. Intake temperatures are representative of water temperatures in the side channel of the Maumee River that feeds the Station intake pumps. As discussed in Section 4, the intake water temperature may be more closely related to water temperatures in Toledo Harbor and the Maumee Bay shipping channel than to the Maumee River. The intake temperature ranges from about 20°C at the beginning of the record through a maximum of about 29°C in mid-August to about 20°C again at the end of the record. The daily average intake temperature, and presumably the source water ambient temperature, never exceeded the OEPA criterion for daily average or maximum water temperature in Maumee Bay during the summer of 2002 (see Table 1-2). The discharge temperatures in Figure 2-74 display a diurnal variation that reflects closely the variation in load. They also reflect the seasonal and short-term variations in intake temperatures. In fact, many of the distinct peaks in discharge temperature (see, for example, 21 September 2002) are more strongly related to changes in intake temperature than to Station load.

Unlike intake and discharge temperature, the cooling water flows during the summer exhibit long periods of constant, near-peak pump capacity, reflecting the fact that the Station cooling water pumps are constant speed pumps. As is routinely done throughout the power industry, Station personnel allow the pumps to run even when the Station is operating at reduced load, because of the difficulties inherent in restarting such large pumps. Periods of reduced flow are typically associated with cooling system or generating unit maintenance, when a reasonable period of reduced cooling water need can be forecast. The discharge temperature typically does not increase during these periods. Brief periods of reduced flow are more representative of an unscheduled pump outage or similar event, and typically result in a corresponding spike in the discharge water temperature.

Figure 2-75 shows the total electrical load (MWe) carried by the Station during the period 01 June 2002 through 30 September 2002, corresponding to the period of the field surveys. While there are a number of exceptions, it is clear that the most common daily pattern is for reduced load during the pre-dawn hours, with a rapid increase to a daily plateau approaching the maximum plant capacity of 631 MWe. It is also clear from Figure 2-75 that the Station operated very near 100% capacity factor during most of that time. In particular, the Station operated at nearly 100% capacity factor on the day before and the day of Mobile Surveys 1, 2 and 3. Mobile Survey 4 was conducted on the last of five days during which the Station was at about 50% capacity factor. The Station was at nearly 100% capacity factor on the day Mobile Survey 5 was performed, but had been at about 80% the two previous days. Thus, as anticipated in the Plan of Study, the five Mobile Surveys spanned a range of Station operating conditions and constitute a reasonable sample of those conditions.

2.4.6 Meteorological Data

Tables 2-5 through 2-8 compare the climate during the Study period with the long-term meteorological conditions at Toledo Express Airport (TOL). In summary, average conditions during the summer of 2002 and during the seven Mobile Survey dates were representative of the long-term historical average conditions in the vicinity of the Station.

Summers in Toledo are characterized by much warmer air temperatures, generally lower wind speeds, relatively high solar radiation, and a higher evaporation rate than the remainder of the year. The median air temperature in summer is 19 Fahrenheit degrees higher than the annual median (70°F versus 51°F), and the median air temperature during the 2002 summer months was even higher (74°F). Air temperatures during the Mobile Surveys spanned the 25th through 95th percentile of historical summer temperatures, indicating a slightly warmer set of summer days than the historical average, but representative of the middle 80% of summer 2002 observations.

Relative humidity during the 2002 summer months was somewhat lower than during the historical summer months, consistent with the relatively low precipitation experienced throughout a large portion of the country. The rate of evaporation is strongly related to relative humidity, and lower than average relative humidity suggests greater surface cooling of the Station thermal plume during the Study period than would be typical. However, solar radiation during summer 2002 was higher than historical summers, and wind speeds were slightly lower than average, both suggesting additional heating of surface waters. The higher solar radiation may also be the result of relatively low precipitation due to the corresponding reduction in cloud cover during the summer of 2002.

2.4.7 Lake Levels

Lake levels at Toledo, OH and Buffalo, NY during the period 01 June 2002 through 30 September 2002 are shown in Figure 2-76. These two stations represent the western and eastern ends of Lake Erie, respectively. The importance of lake levels was anticipated to be primarily to identify seiches, or periods of water level oscillation driven by wind. In a thermally stratified lake, the wind tends to push warmer epilimnion water toward the downwind end of the lake, leaving cooler hypolimnion water to surface at the upwind end of the lake. Because cold water is denser than warm water, a shorter column of cold water will yield the same hydrostatic pressure as a taller column of warm water. Therefore, the water level differences evident in the two time series can indicate periods of surface temperature variation, which could impact the dynamics of the thermal plume.

An example of a prominent seiche is evident beginning 10 July, when the water level at Toledo reached an unusually high elevation resulting in a corresponding low water level at Buffalo. The temporary instability causes water to flow from Toledo to Buffalo, leveling the water at the two ends of the lake. The flow does not reverse until an instability sets up in the opposite direction, causing the water to rebound. This phenomenon continues as a dampened oscillation, which dies out over about a five-day period. The surface and bottom temperatures at Station 21 clearly reflect the seiche: during the oscillations, the surface and bottom temperatures are nearly equal and tend to be decreasing. The pattern occurs again beginning on 23 July and again beginning on 05 August.

In addition to seiches, water levels in Lake Erie fluctuate seasonally and over periods of years. During the period from 1970 through 2001, the annual average water level at Toledo has decreased an average of approximately 1 inch every three years. The lowest annual average water level record has been exceeded in each of the last three years of complete data (1999-

2001). Although the three preceding summers had lower average water levels, the summer of 2002 ranks fourth overall in the historical record behind 2001, 1999, and 2000. As noted earlier, decreased water levels correspond to larger average discharge velocities, which may impact the thermal plume.

2.4.8 River Flows

The Bay Shore Station intake draws cooling water from the Maumee River near its mouth. Based on 50 years of data (1953-2002) from the Waterville, OH gaging station[3] and adjusting flows on a drainage area weighting basis, the average flow at the mouth of the Maumee River is 5,400 cfs. Flow exhibits a high degree of seasonal variability, with monthly averages peaking in March (11,600 cfs) and reaching a minimum in September (1,364 cfs). The Bay Shore Station, which has a maximum withdrawal of 1,154 cfs (745.9 MGD), regularly exceeds the monthly average flow rates during summer months. Monthly average flows in August, September, and October are lower than Station discharge during more than half of the 50-year historical record. Of the 99 days of the Field Survey Program (11 June 2002 through 17 September 2002), Station discharge exceeded Maumee River flow for 74 days. The large discharge flow relative to Maumee River flow suggests that the Bay Shore Station intake was drawing water from Lake Erie, and that intake temperatures may be reflective of ambient conditions in Lake Erie. (See Section 4.3.2 for additional discussion of the relative river and Station flows.)

2.5 SUMMARY OF FIELD SURVEY PROGRAM

The Field Survey Program provided adequate data to sufficiently understand the physical processes in Maumee Bay influencing the behavior of the thermal plume associated with the Bay Shore Station discharge. There were no data gaps in the plant operation data, the fixed station velocity data, and in 18 of the 21 fixed station temperature data sets. Based on meteorological and other external data sets, the Mobile Surveys were performed under a representative range of summer conditions and provide sufficient coverage to perform and evaluate the thermal plume modeling.

[3] U.S. Geological Survey (USGS-NWIS). 2002. Daily Discharge Flow Data, 1953-2002, Station 04193500, Maumee River at Waterville, OH. http://waterdata.usgs.gov/nwis/discharge/.

Table 2-1. Schedule of Field Activities

Event	Date	Activity
1	11 June 2002	Reconnaissance Survey
	12 June 2002	Mobile Survey
	13 June 2002	Discharge Channel Study
1A	26 June 2002	Additional Mobile Survey Fixed Station Deployment
2	09 July 2002	Mobile Survey Fixed Station Servicing
3	30 July 2002	Mobile Survey Fixed Station Servicing
4	20 August 2002	Mobile Survey Fixed Station Servicing
5	17 September 2002	Mobile Survey Fixed Station Retrieval

where are F.S.S. data on 7-9-2002

Table 2-2. ADCP Configuration

Variable	Value
Frequency	1200 kHz
Bin size	0.82 ft
Ensemble interval	1 second
Pings per ensemble	10 water column, 10 bottom track
Transducer depth below water surface	1.5 ft
First bin depth below water surface	4.16 ft
Salinity (used for speed of sound calculation)	0 ppt
Temperature (used for speed of sound calculation)	Measured
Magnetic variation (magnetic north to true north)	-6.5°[4]

[4] National Oceanographic and Atmospheric Administration (NOAA). 1999. Chart 14847: Toledo Harbor.

Table 2-3. Auxiliary Data

Data Set	Duration	Timescale	Description	Ref.
Meteorology	1955-2002	Daily	Air temperature (dry bulb, wet bulb, dew point); relative humidity; wind speed and direction; barometric pressure; solar radiation	5
Lake Level	1970-2002	6-minute	Water surface elevation	6 7
Maumee River Flow	1953-2002	Daily	Discharge flow	8
Plant Operations	2002	6-minute	Pump operation status; discharge flow; intake temperature; discharge temperature; electrical power generated	9

[5] National Weather Service (NOAA-NWS). 2002. Daily Meteorology Data, 1955-2002, Station 338357, Toledo Express Airport (TOL). Provided by the Midwest Regional Climate Center, Champaign, IL.
[6] National Ocean Service (NOAA-NOS). 2002. Preliminary (Great Lakes) Water Level Data, 1970-2002, Station 9063085, Toledo, OH. http://co-ops.nos.noaa.gov.
[7] National Ocean Service (NOAA-NOS). 2002. Preliminary (Great Lakes) Water Level Data, 1970-2002, Station 9063020, Buffalo, NY. http://co-ops.nos.noaa.gov.
[8] U.S. Geological Survey (USGS-NWIS). 2002. Daily Discharge Flow Data, 1953-2002, Station 04193500, Maumee River at Waterville, OH. http://waterdata.usgs.gov/nwis/discharge/.
[9] FirstEnergy Corp (2002). Bay Shore Station Discharge Data, May-September 2002.

Table 2-4. Field Survey Program Data

Item	Program Section	Date(s)	Figure(s)
Bathymetry	Additional Investigation	12 Jun, 9 Jul, 30 Jul, 20 Aug, 17 Sep (combined)	2-5
Surface Temperature Contours	Mobile Survey	11 Jun, 12 Jun, 26 Jun, 9 Jul, 30 Jul, 20 Aug, 17 Sep	2-6 to 2-12
Vertical Temperature Profiles	Mobile Survey	11 Jun, 12 Jun, 26 Jun, 9 Jul, 30 Jul, 20 Aug, 17 Sep	2-13 to 2-26
Temporal Temperatures	Fixed Station	27 Jun - 17 Sep (continuous)	2-27 to 2-47
Stationary Velocity Tests	Mobile Survey	30 Jul, 20 Aug, 17 Sep	2-48 to 2-68
Temporal Velocities	Fixed Station	27 Jun - 17 Sep (continuous)	2-69 to 2-70
Discharge Canal Geometry	Additional Investigation	12 Jun	2-71 to 2-73

Table 2-5. Statistical Summary of Historical Meteorological Data (All Months)[10]

Statistic	Air Temp (F)	Dewpoint Temp (F)	Wet-Bulb Temp (F)	Relative Humidity (%)	Wind Speed (mi/hr)	Sea Level Pressure (mb)	Solar Radiation (MJ/m^2)
Max	90	76	79	100	31.1	1046	32.77
99%	81	71	74	96	19.6	1035	29.79
95%	76	67	70	91	16.0	1029	28.13
90%	73	64	67	87	14.1	1026	26.28
75%	66	56	60	80	11.5	1021	20.97
50%	51	40	46	72	9.1	1017	13.03
25%	34	26	31	65	6.8	1013	7.49
10%	24	15	22	58	5.1	1009	4.23
5%	17	9	15	53	4.4	1006	3.19
1%	6	-3	5	45	2.8	1000	2.42
Min	-12	-24	-12	27	0.0	977	0.12

[10] National Weather Service (NOAA-NWS). 2002. Daily Meteorology Data, 1955-2002, Station 338357, Toledo Express Airport (TOL). Provided by the Midwest Regional Climate Center, Champaign, IL.

Table 2-6. Statistical Summary of Historical Meteorological Data (June - September)[11]

Statistic	Air Temp (F)	Dewpoint Temp (F)	Wet-Bulb Temp (F)	Relative Humidity (%)	Wind Speed (mi/hr)	Sea Level Pressure (mb)	Solar Radiation (MJ/sq m)
Max	90	76	79	100	20.5	1036	30.99
99%	83	73	75	94	14.5	1028	30.27
95%	80	70	73	88	12.4	1024	29.34
90%	78	68	71	85	11.3	1022	28.40
75%	74	65	68	79	9.2	1020	25.68
50%	70	59	63	72	7.2	1016	21.13
25%	64	53	58	66	5.8	1013	15.82
10%	59	47	53	60	4.5	1011	11.17
5%	55	44	50	57	3.5	1009	9.30
1%	49	38	44	49	2.3	1005	6.69
Min	39	26	36	35	0.0	995	2.28

[11] National Weather Service (NOAA-NWS). 2002. Daily Meteorology Data, 1955-2002, Station 338357, Toledo Express Airport (TOL). Provided by the Midwest Regional Climate Center, Champaign, IL.

Table 2-7. Statistical Summary of 2002 Meteorological Data (June – September)[12]

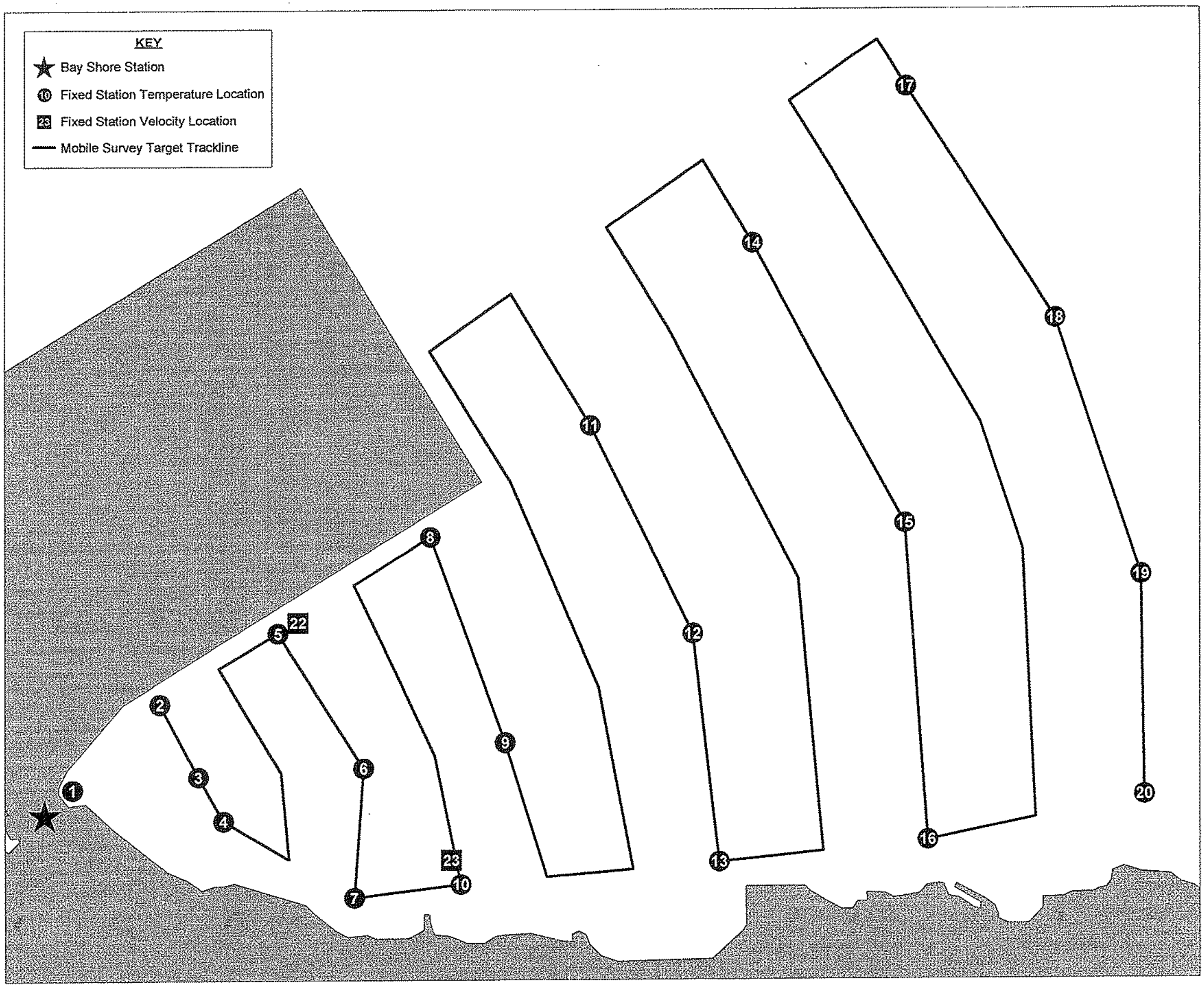
Statistic	Air Temp (F)	Dewpoint Temp (F)	Wet-Bulb Temp (F)	Relative Humidity (%)	Wind Speed (mi/hr)	Sea Level Pressure (mb)	Solar Radiation (MJ/sq m)
Max	85	75	77	89	15.0	1027	30.70
99%	85	72	75	86	12.7	1025	30.60
95%	82	71	73	81	11.5	1024	30.31
90%	81	69	73	76	10.3	1023	29.55
75%	79	67	71	72	9.2	1021	28.54
50%	74	61	66	65	5.8	1017	24.56
25%	69	54	60	60	4.6	1015	20.86
10%	65	50	57	55	3.5	1010	13.64
5%	60	49	55	53	2.3	1009	11.44
1%	56	42	50	47	1.4	1005	8.47
Min	55	42	48	40	1.2	1003	7.60

[12] National Weather Service (NOAA-NWS). 2002. Daily Meteorology Data, June-September 2002, Station 338357, Toledo Express Airport (TOL). Provided by the Midwest Regional Climate Center, Champaign, IL.

Table 2-8. Meteorological Data During Mobile Surveys[13]

Date	Air Temp (F)	Dewpoint Temp (F)	Wet-Bulb Temp (F)	Relative Humidity (%)	Wind Speed (mi/hr)	Sea Level Pressure (mb)	Solar Radiation (MJ/sq m)
11 Jun	80	65	70	61	12.7	1014	25.20
12 Jun	77	67	70	68	9.2	1010	16.44
26 Jun	65	49	56	61	7.7	1018	28.11
09 Jul	80	72	74	77	10.3	1013	17.73
30 Jul	81	72	75	77	6.6	1018	25.09
20 Aug	81	68	72	67	10.5	1013	24.39
17 Sep	77	59	65	60	4.1	1022	19.92

[13] National Weather Service (NOAA-NWS). 2002. Daily Meteorology Data, June-September 2002, Station 338357, Toledo Express Airport (TOL). Provided by the Midwest Regional Climate Center, Champaign, IL.



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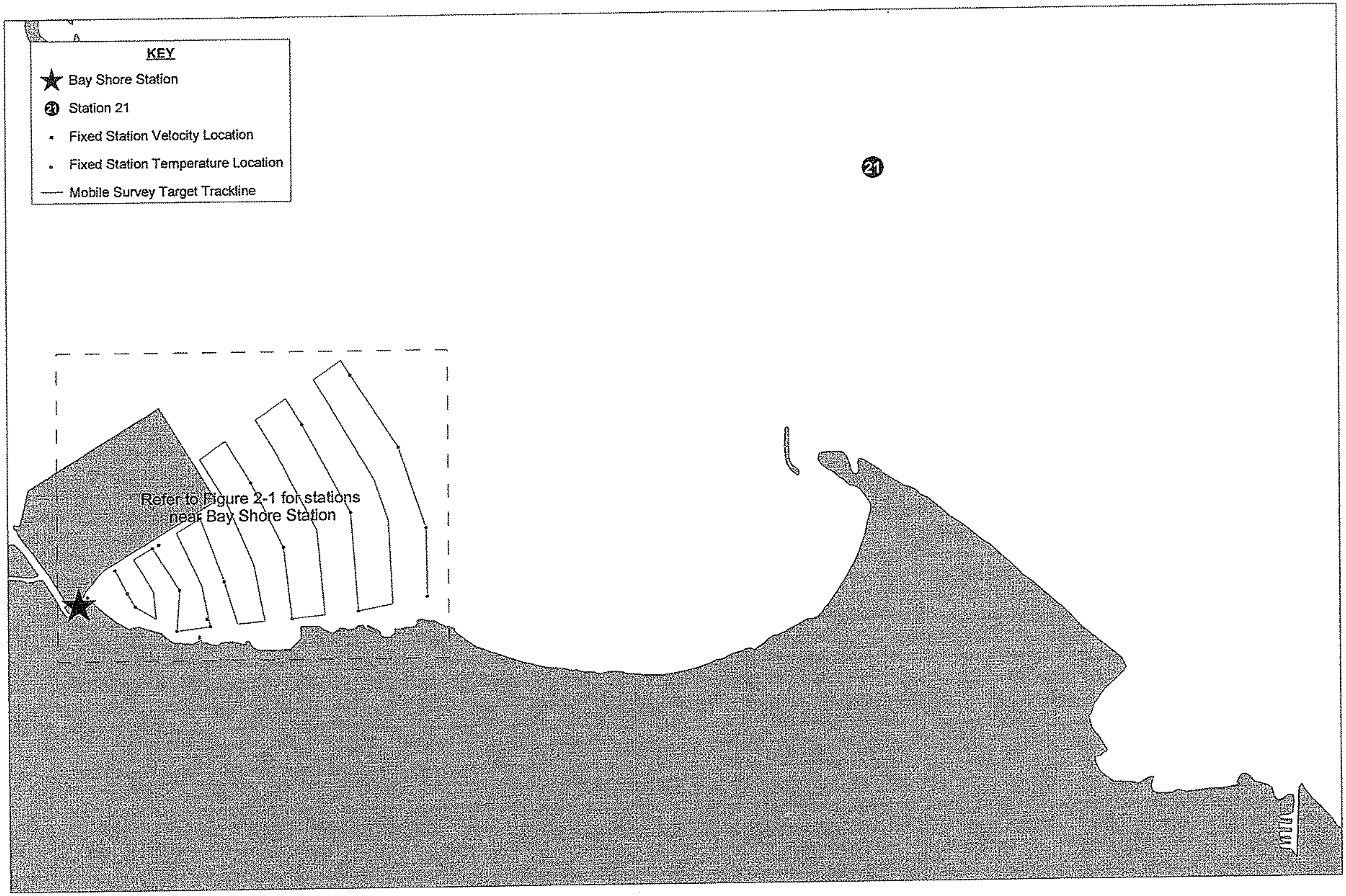
0 500 1000 1500
Scale: 1 inch = 1500 feet

FirstEnergy Corp, Toledo Edison Bay Shore Station

Sampling Locations Near Bay Shore Station

FIGURE 2 - 1



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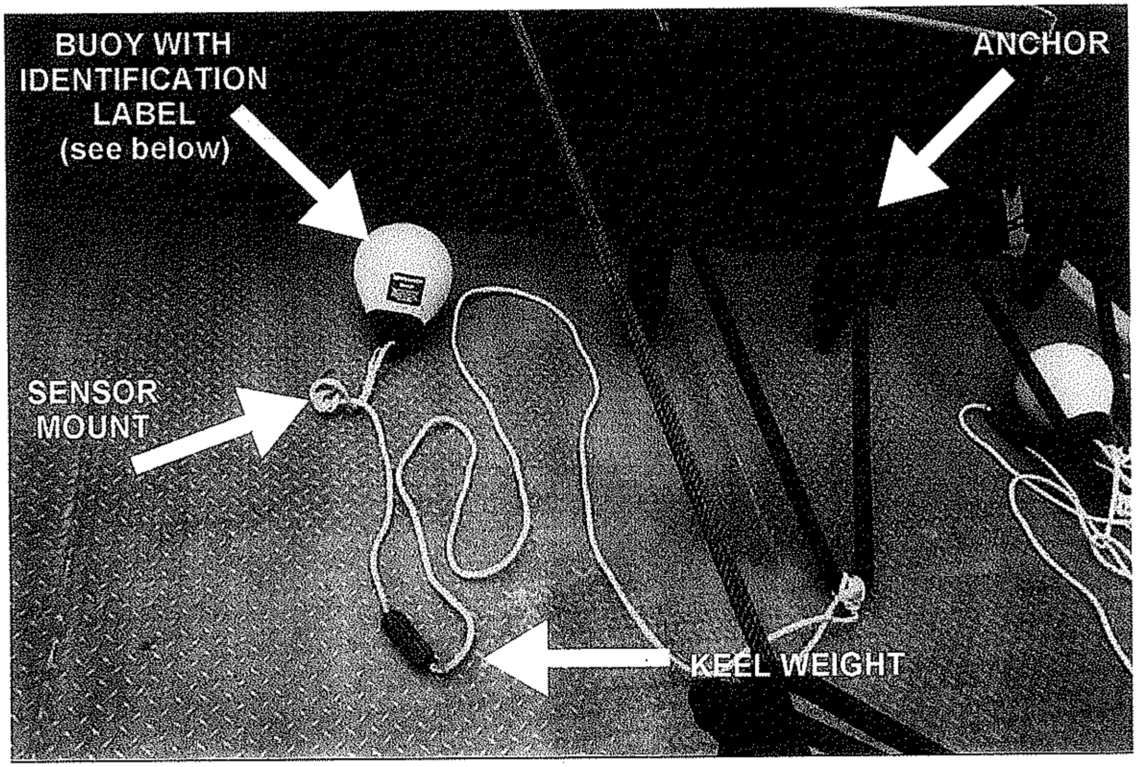
Sampling Location Remote From Bay Shore Station (Station 21)

FIGURE 2 - 2



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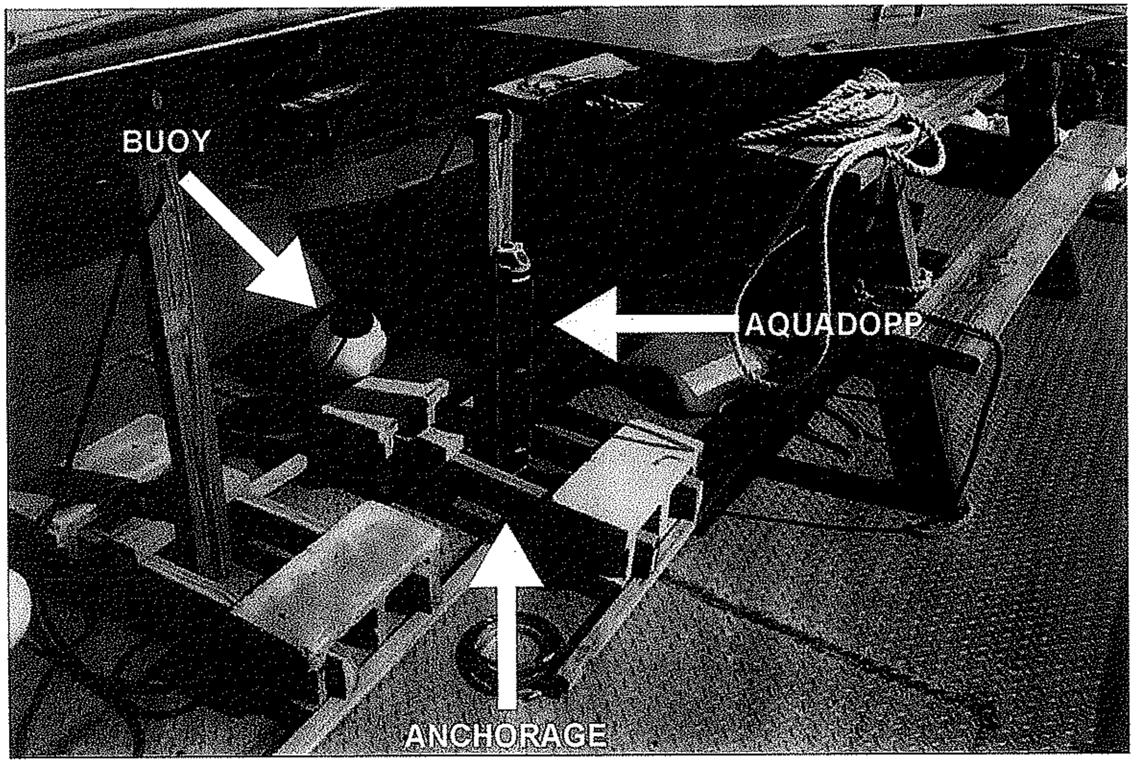
FirstEnergy Corp, Toledo Edison Bay Shore Station

Fixed Station Temperature Monitoring Assembly

FIGURE 2 - 3



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Matusky
& Skelly
Engineers LLP
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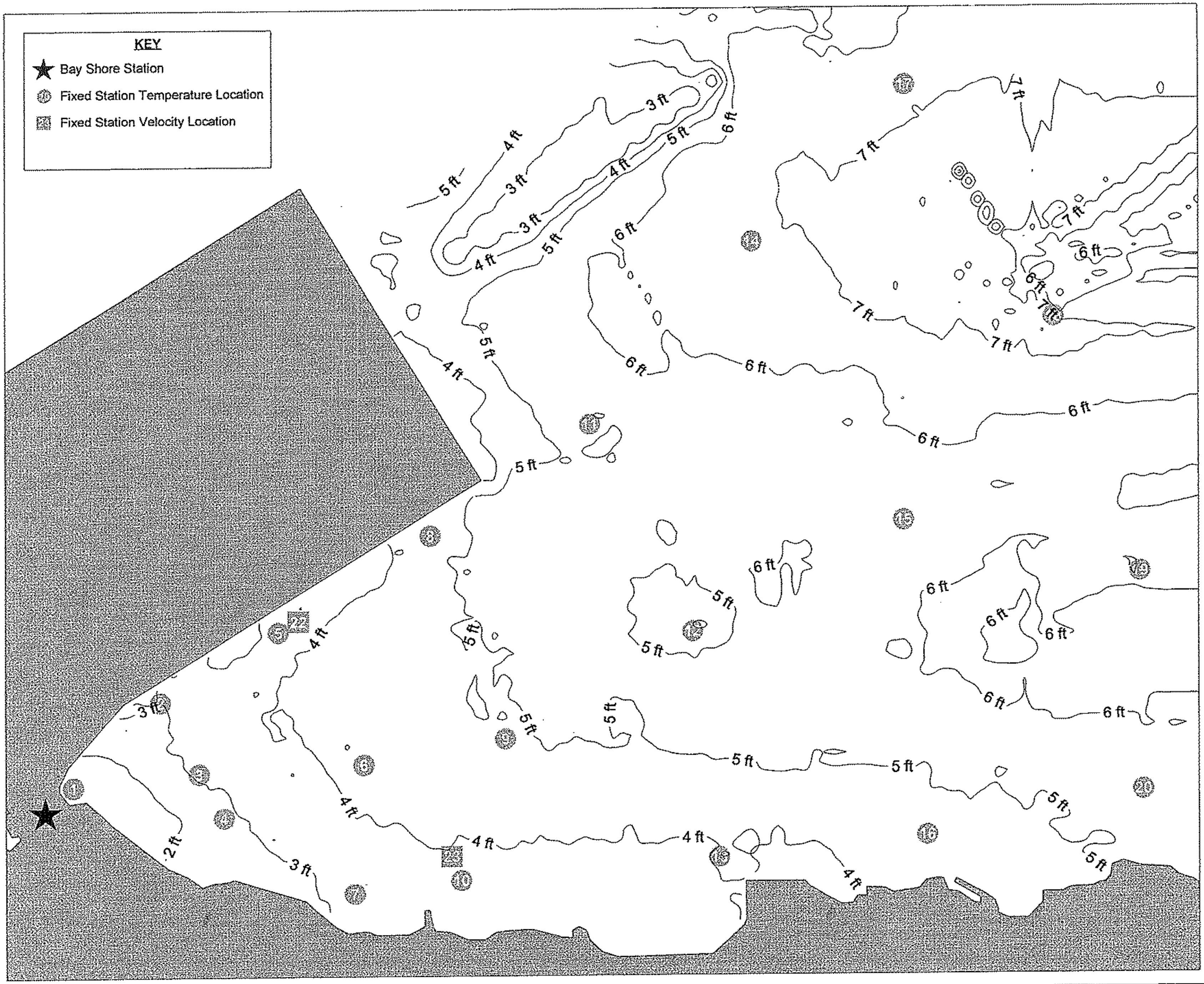
FirstEnergy Corp, Toledo Edison Bay Shore Station

Fixed Station Current Velocity Monitoring Assemblies (2)

FIGURE
2 - 4



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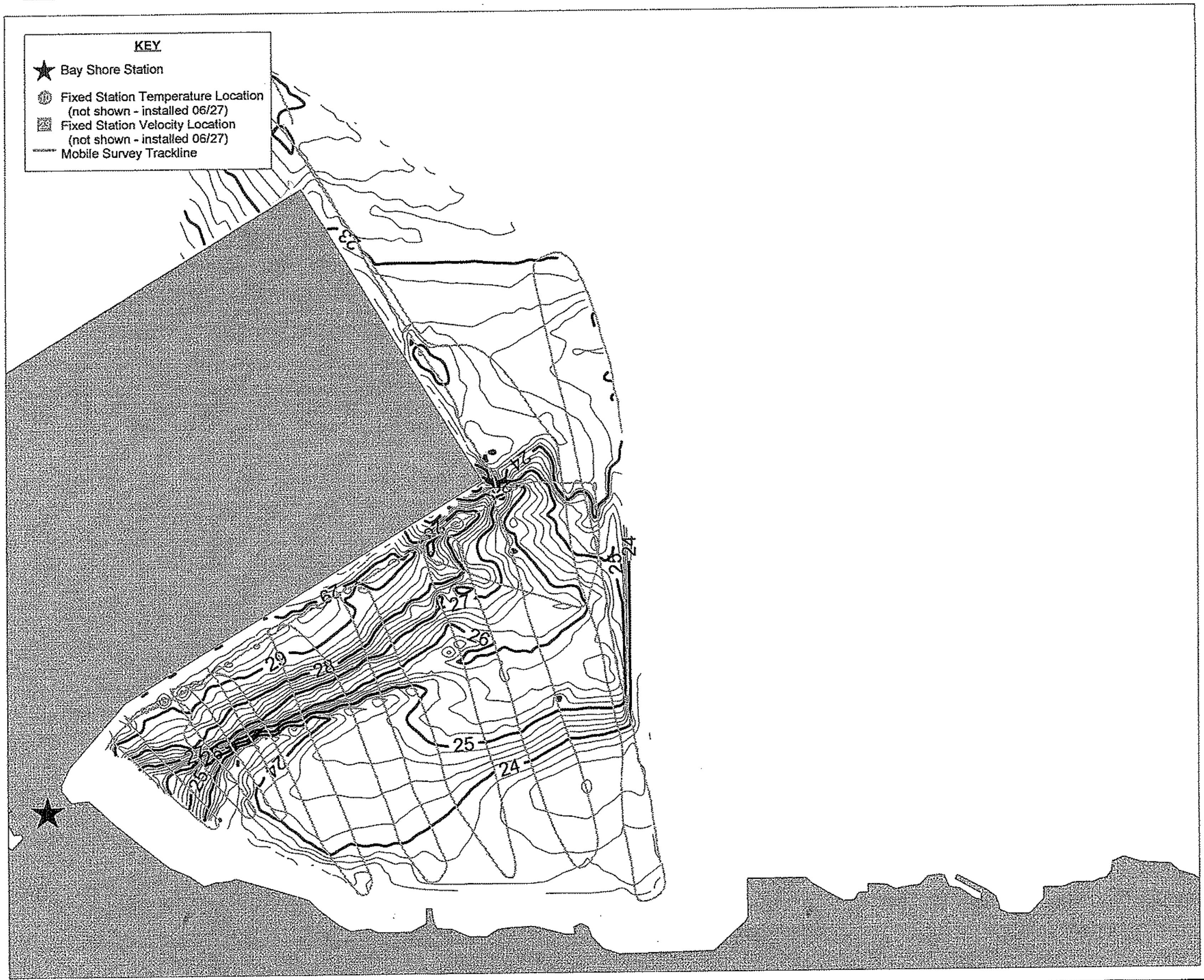
0 500 1000 1500
Scale: 1 inch = 1500 feet

FirstEnergy Corp, Toledo Edison Bay Shore Station

Bathymetry Near Bay Shore Station

FIGURE 2 - 5



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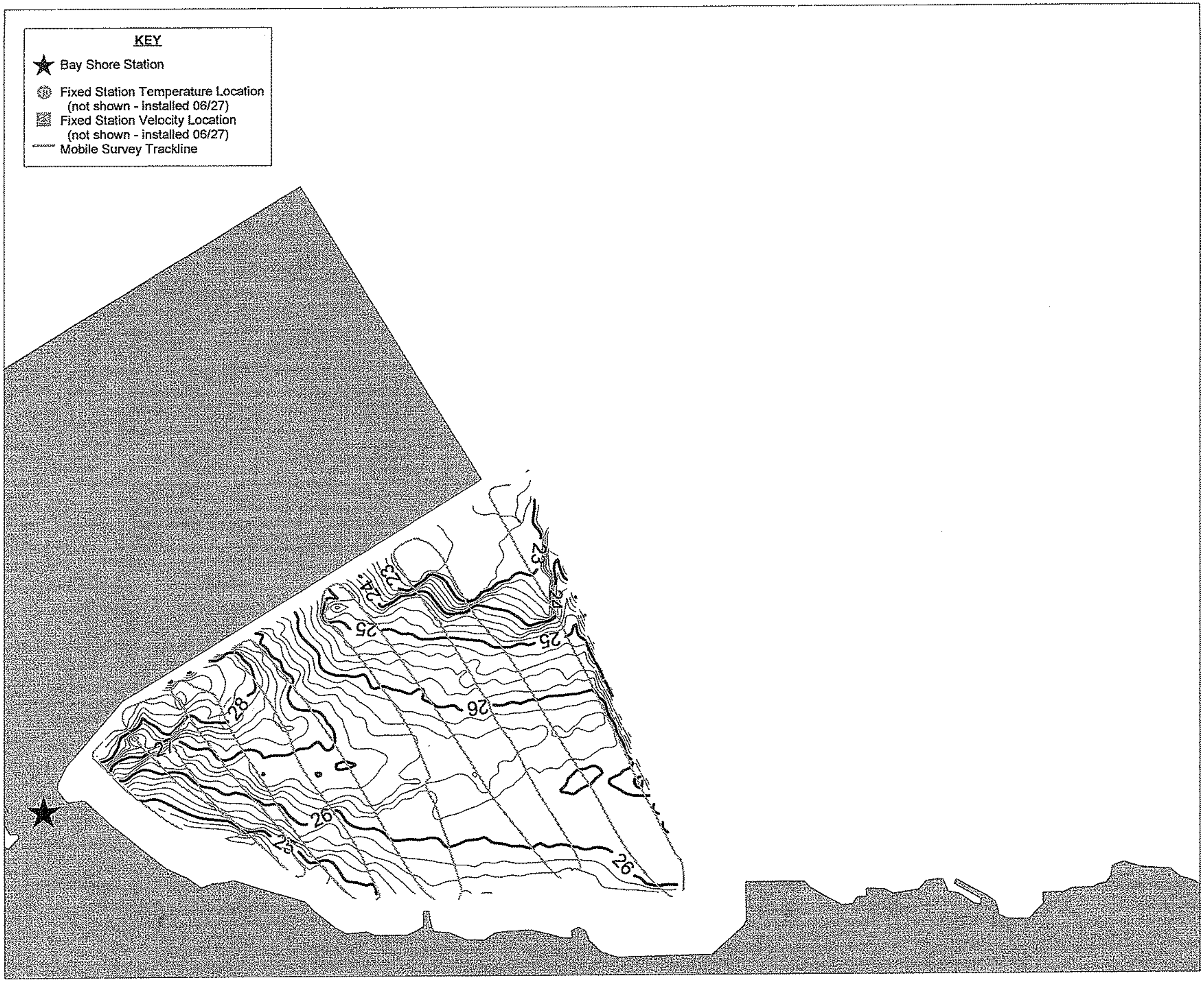
0 500 1000 1500
Scale: 1 inch = 1500 feet

FirstEnergy Corp, Toledo Edison Bay Shore Station

Surface Temperature Contours - 11 June 2002

FIGURE 2 - 6



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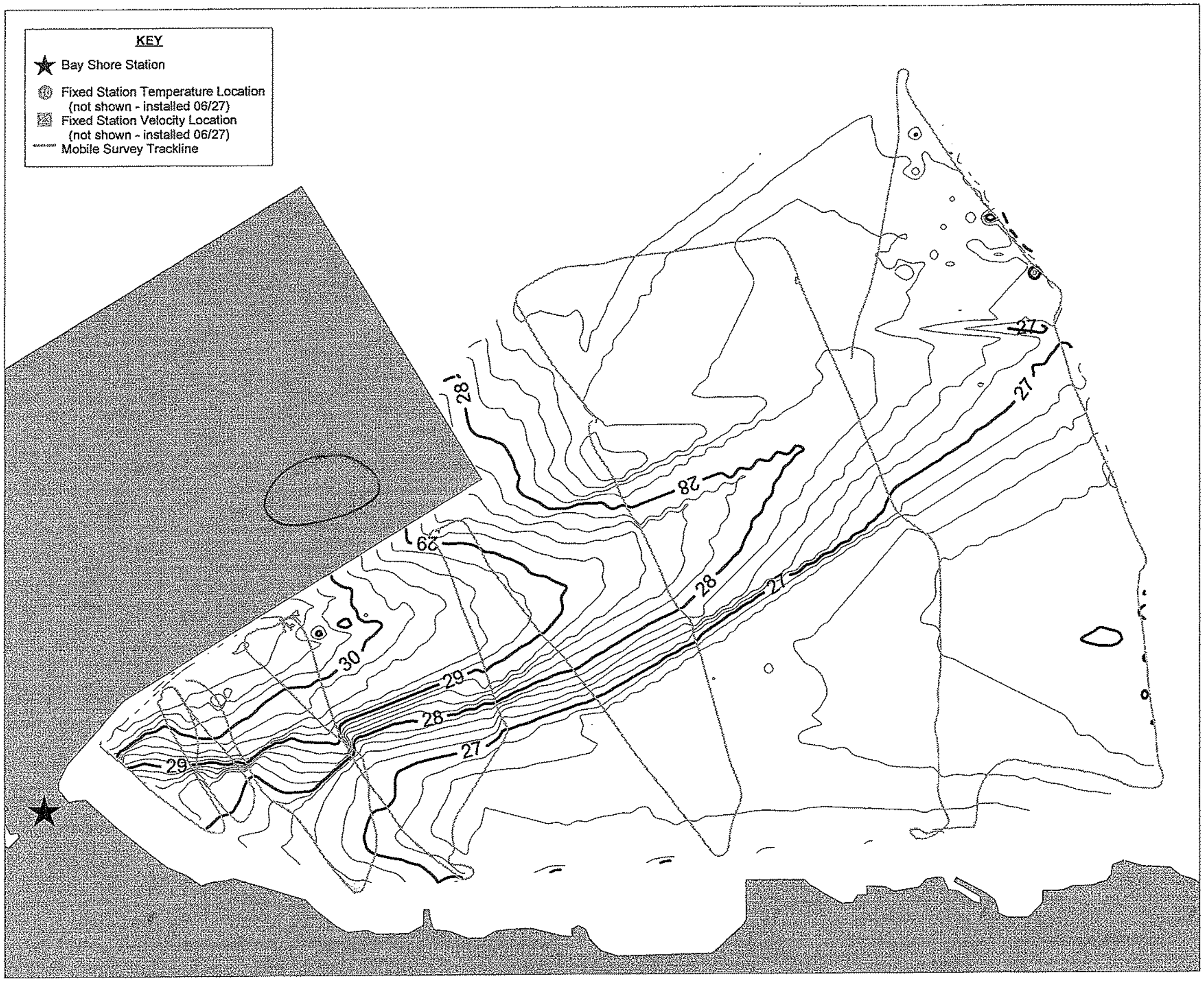
LMS Lawler, Matusky & Skelly Engineers LLP One Blue Hill Plaza, Pearl River, New York 10965, (845)735-8300	0 500 1000 1500 Scale: 1 inch = 1500 feet	FirstEnergy Corp, Toledo Edison Bay Shore Station **Surface Temperature Contours - 12 June 2002**	FIGURE 2 - 7



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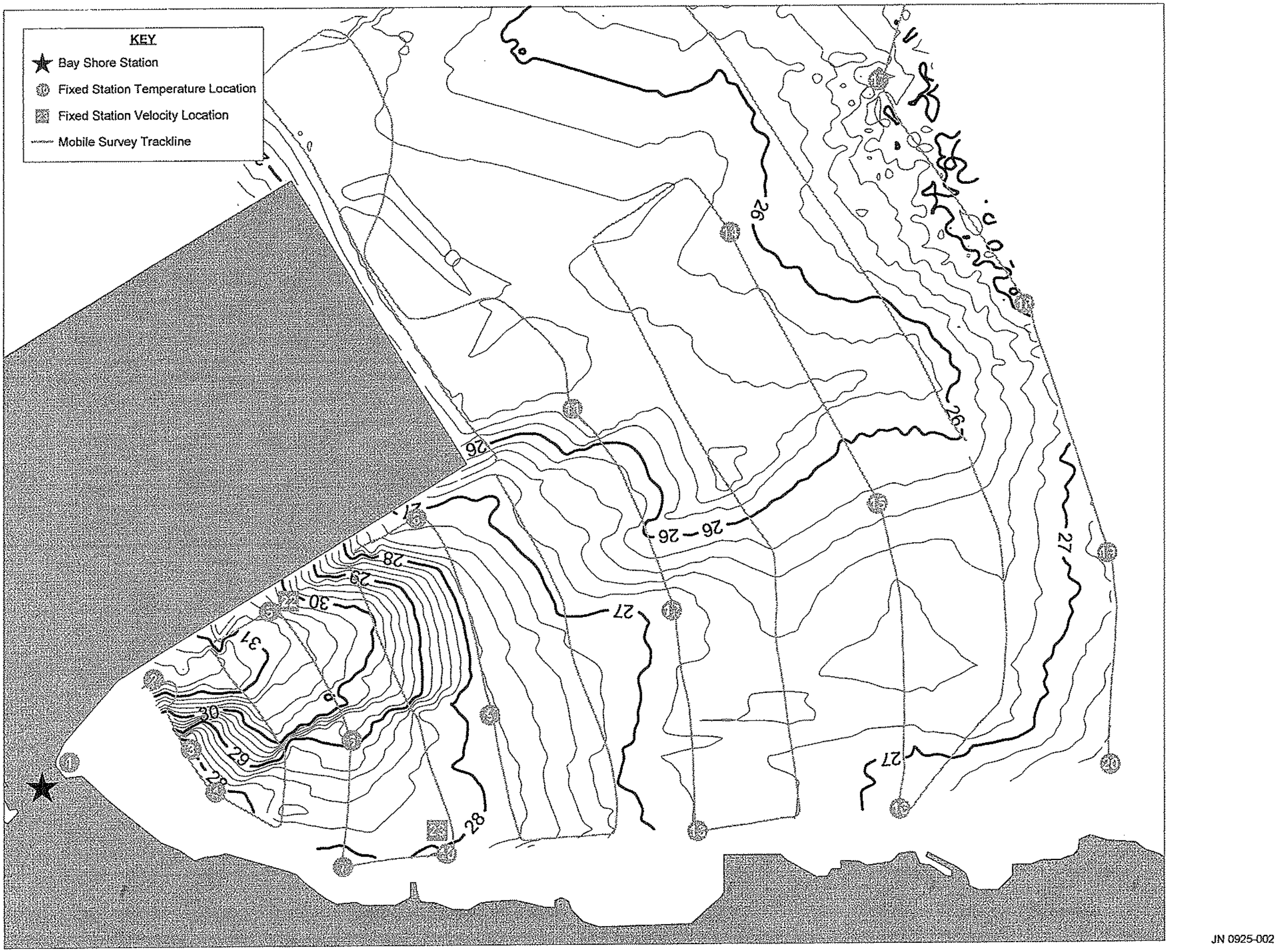
Scale: 1 inch = 1500 feet

FirstEnergy Corp, Toledo Edison Bay Shore Station

Surface Temperature Contours - 26 June 2002

FIGURE 2 - 8



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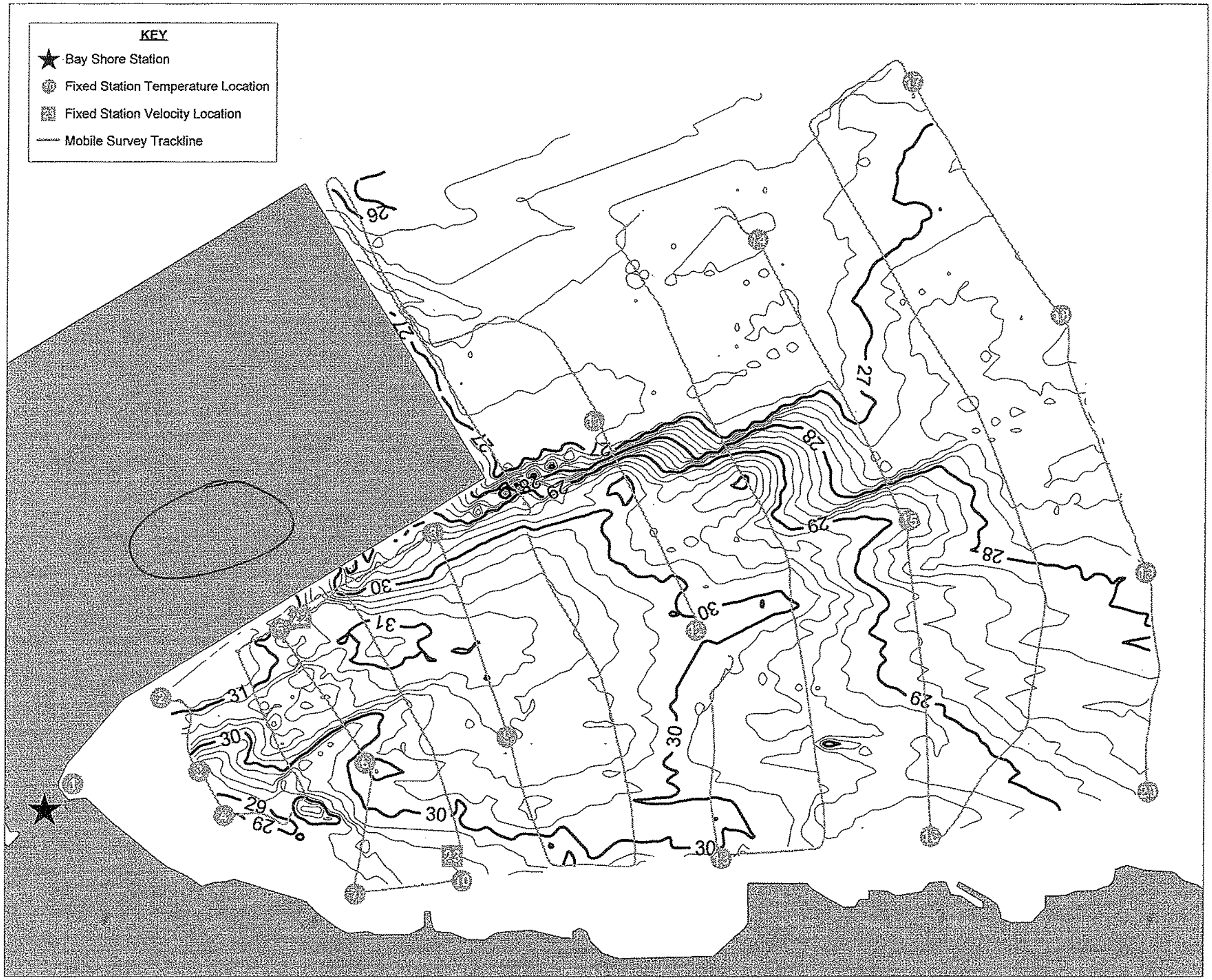
0 500 1000 1500
Scale: 1 inch = 1500 feet

FirstEnergy Corp, Toledo Edison Bay Shore Station

Surface Temperature Contours - 09 July 2002

FIGURE 2 - 9



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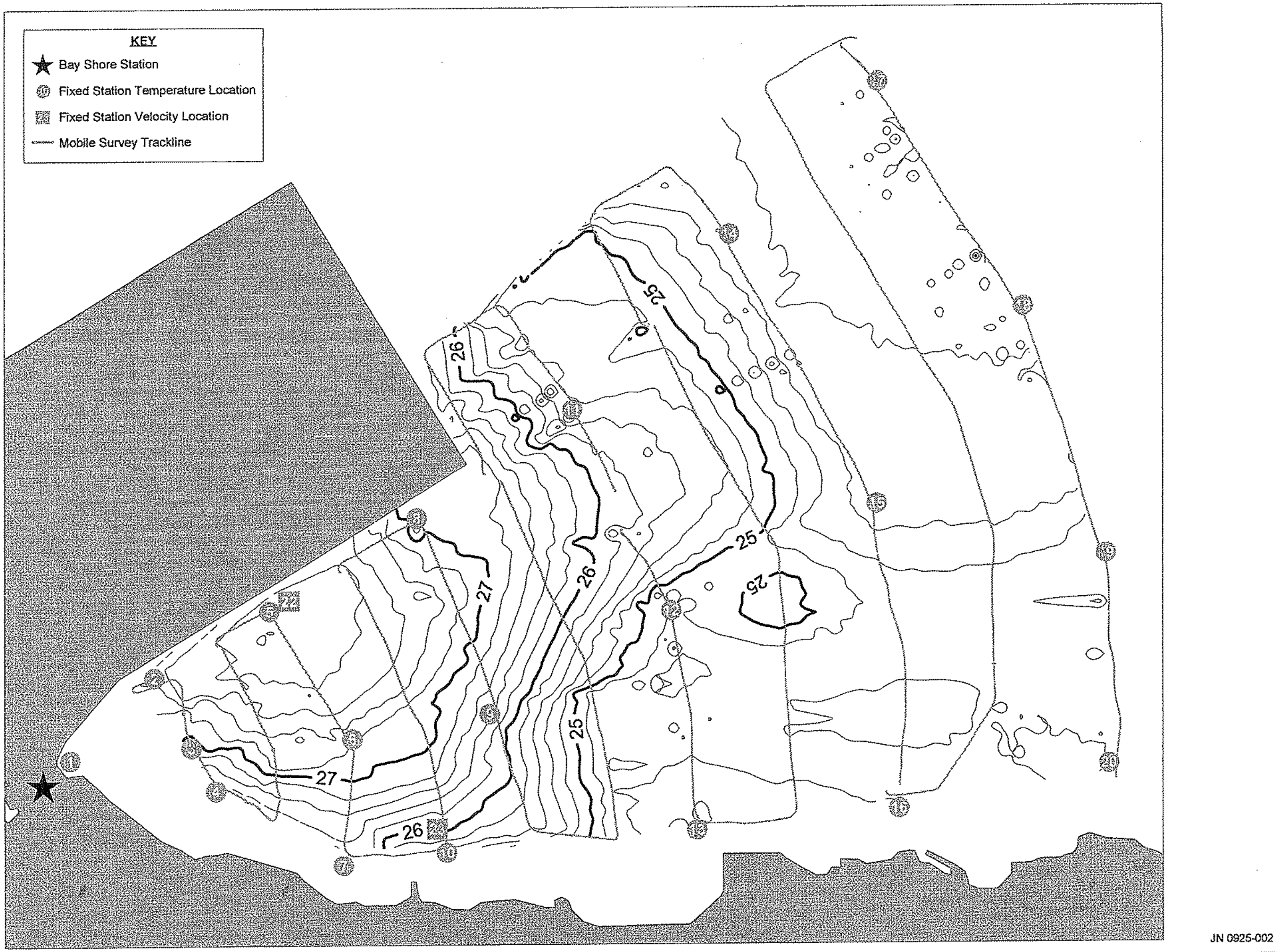
0 500 1000 1500
Scale: 1 inch = 1500 feet

FirstEnergy Corp, Toledo Edison Bay Shore Station

Surface Temperature Contours - 30 July 2002

FIGURE 2 - 10



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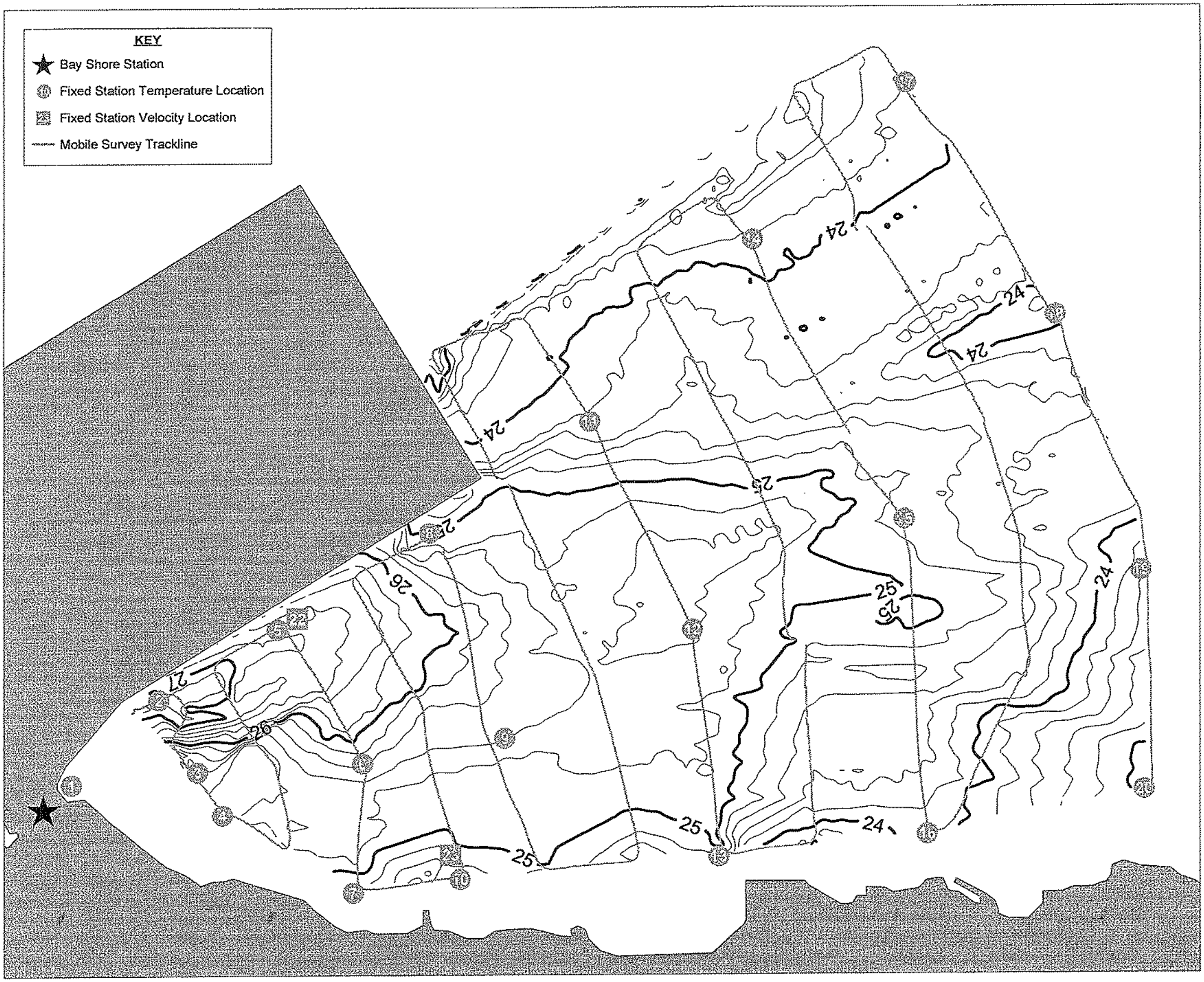
0 500 1000 1500
Scale: 1 inch = 1500 feet

FirstEnergy Corp, Toledo Edison Bay Shore Station

Surface Temperature Contours - 20 August 2002

FIGURE 2 - 11



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0 500 1000 1500
Scale: 1 inch = 1500 feet

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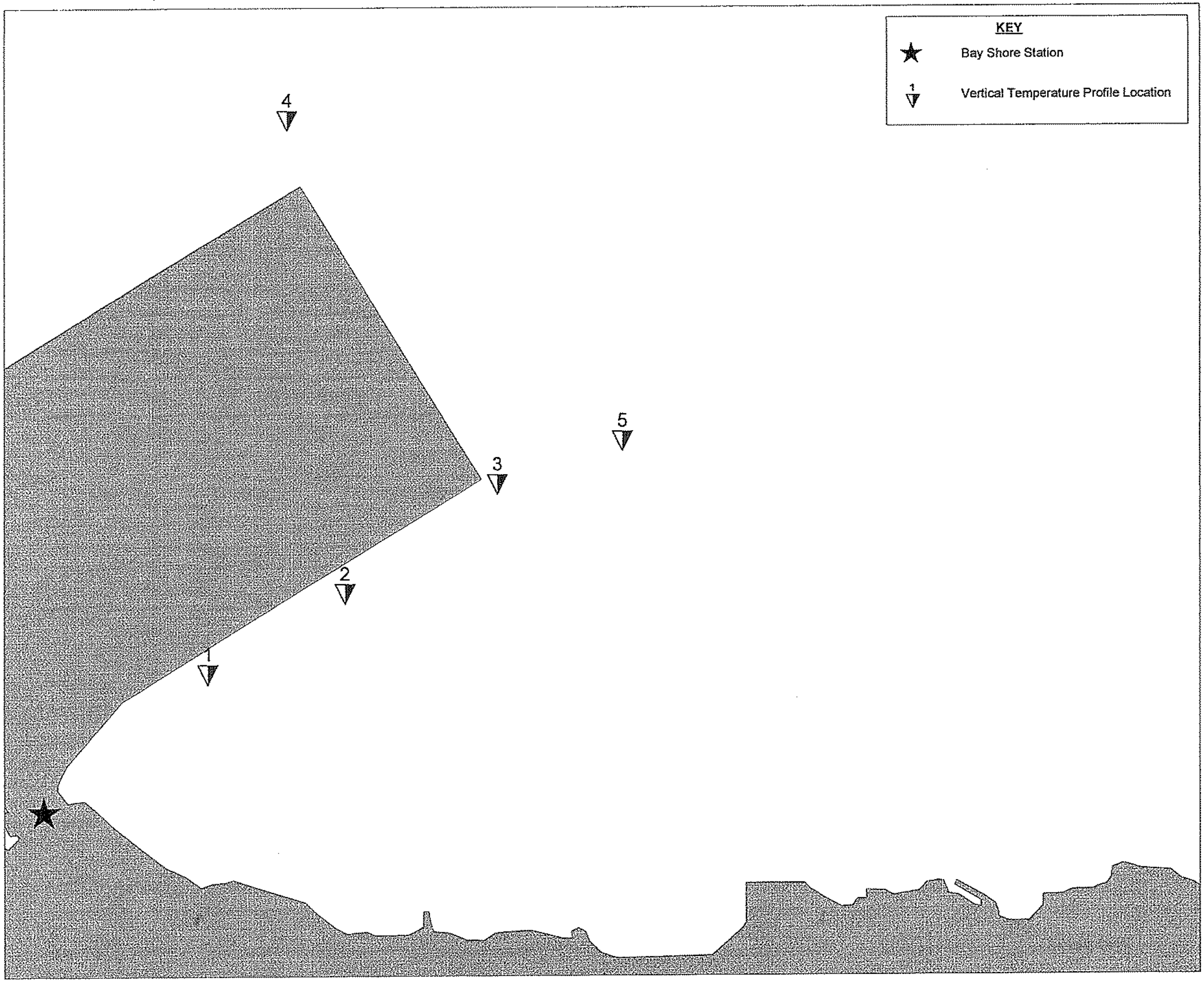
Surface Temperature Contours - 17 September 2002

FIGURE 2 - 12



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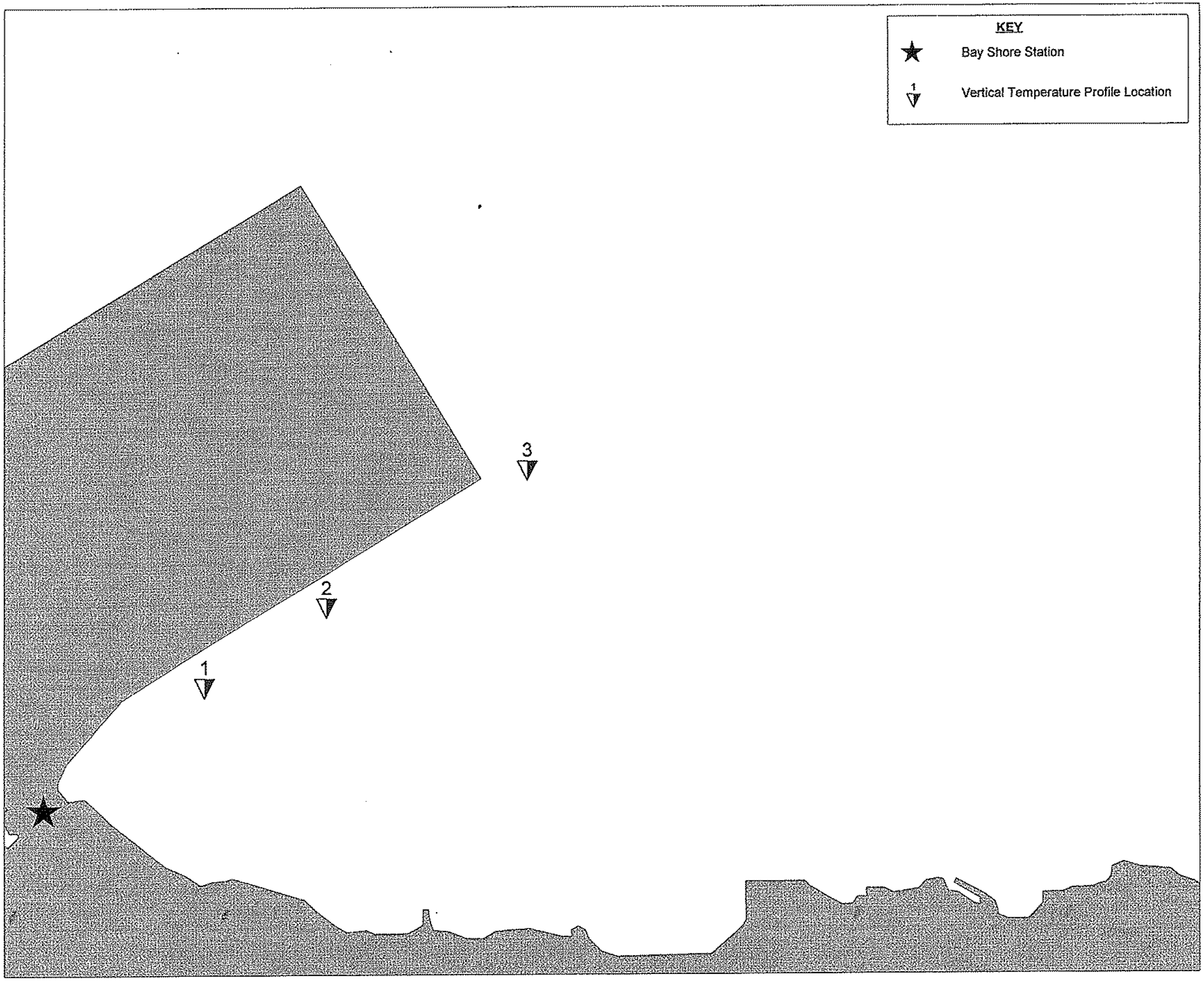
FirstEnergy Corp, Toledo Edison Bay Shore Station

Vertical Temperature Profile Locations - 11 June 2002

FIGURE 2 - 13



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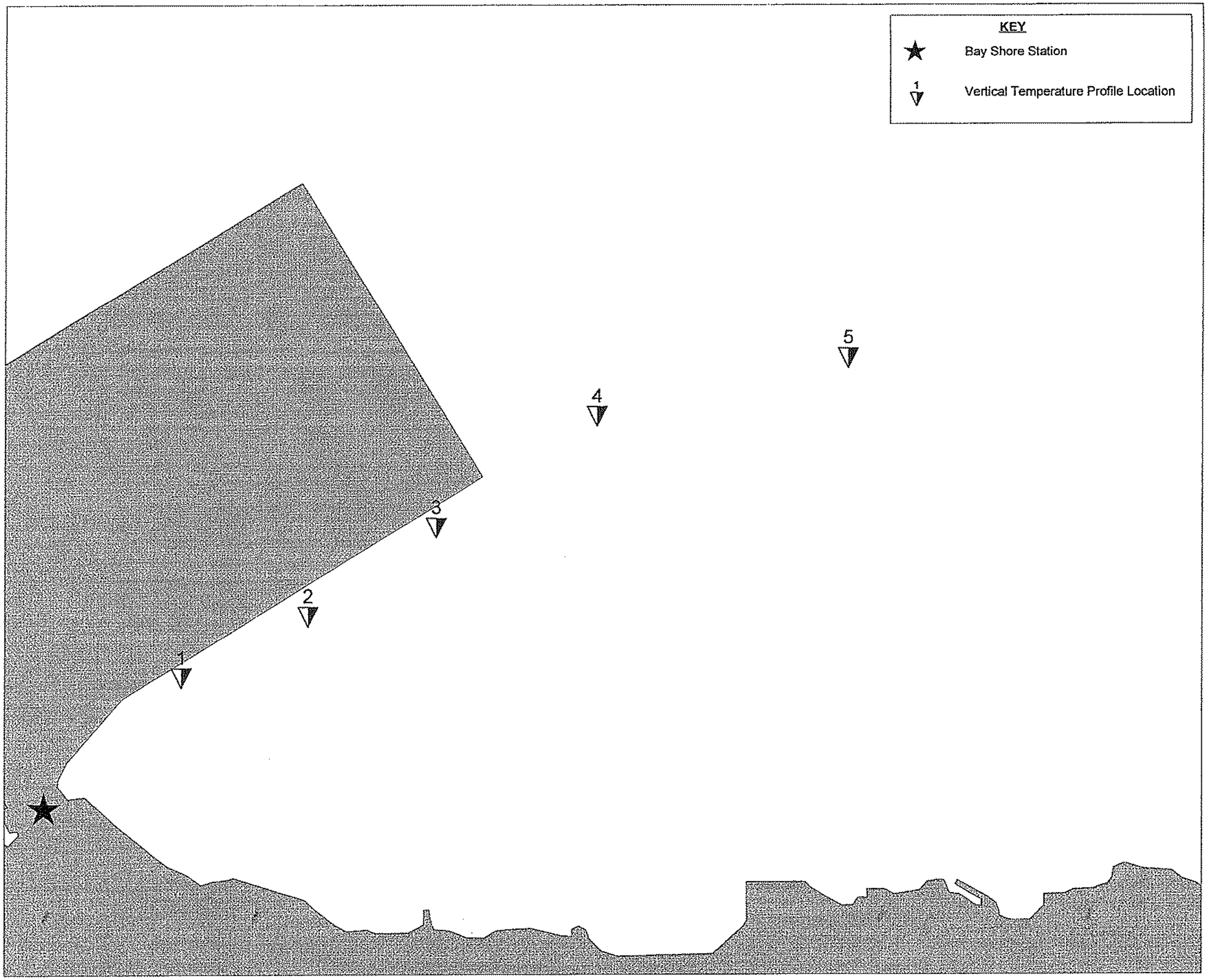
Vertical Temperature Profile Locations - 12 June 2002

FIGURE 2 - 14



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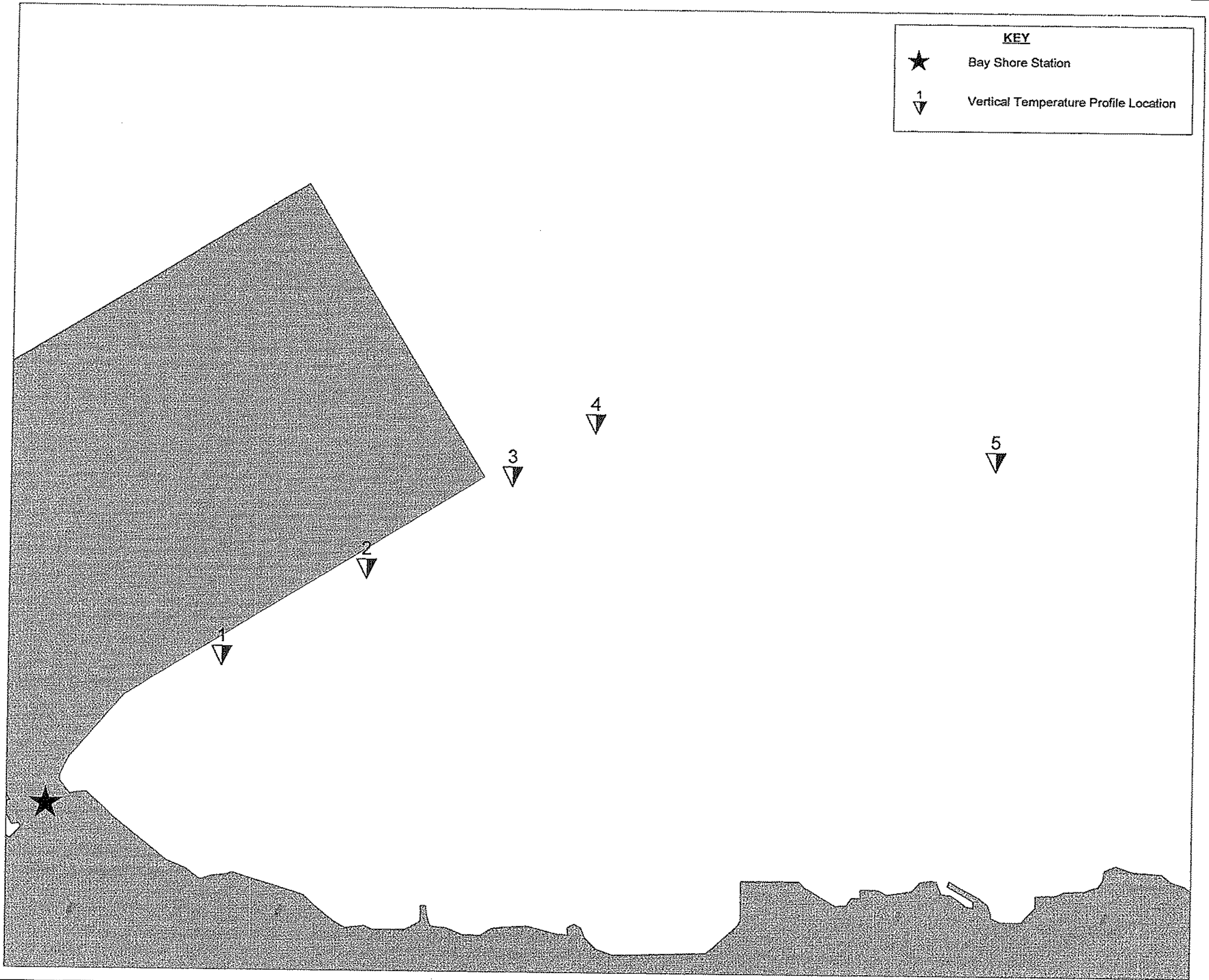
0 500 1000 1500

Scale: 1 inch = 1500 feet

FirstEnergy Corp, Toledo Edison Bay Shore Station

Vertical Temperature Profile Locations - 26 June 2002

FIGURE 2 - 15



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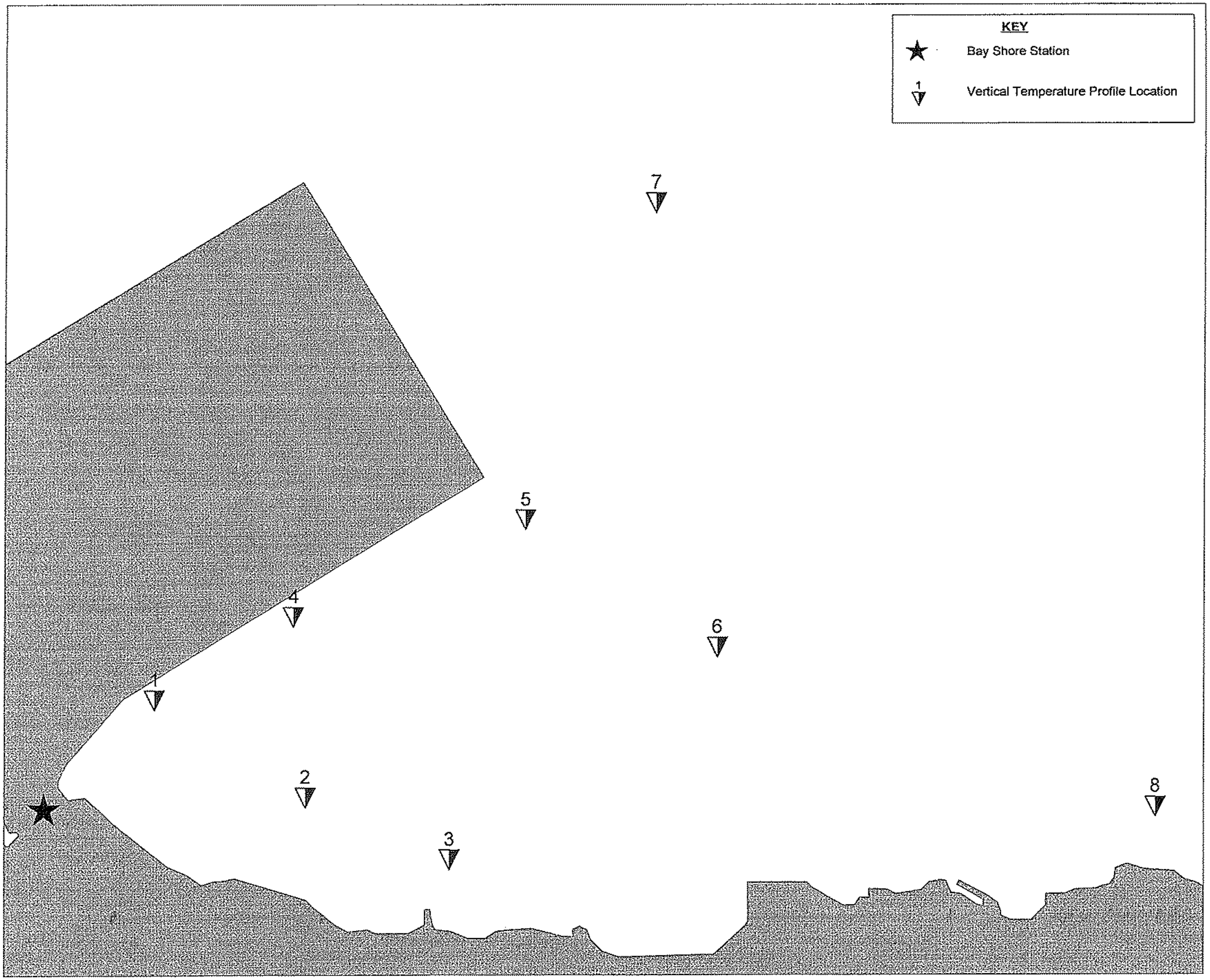
Vertical Temperature Profile Locations - 09 July 2002

FIGURE 2 - 16



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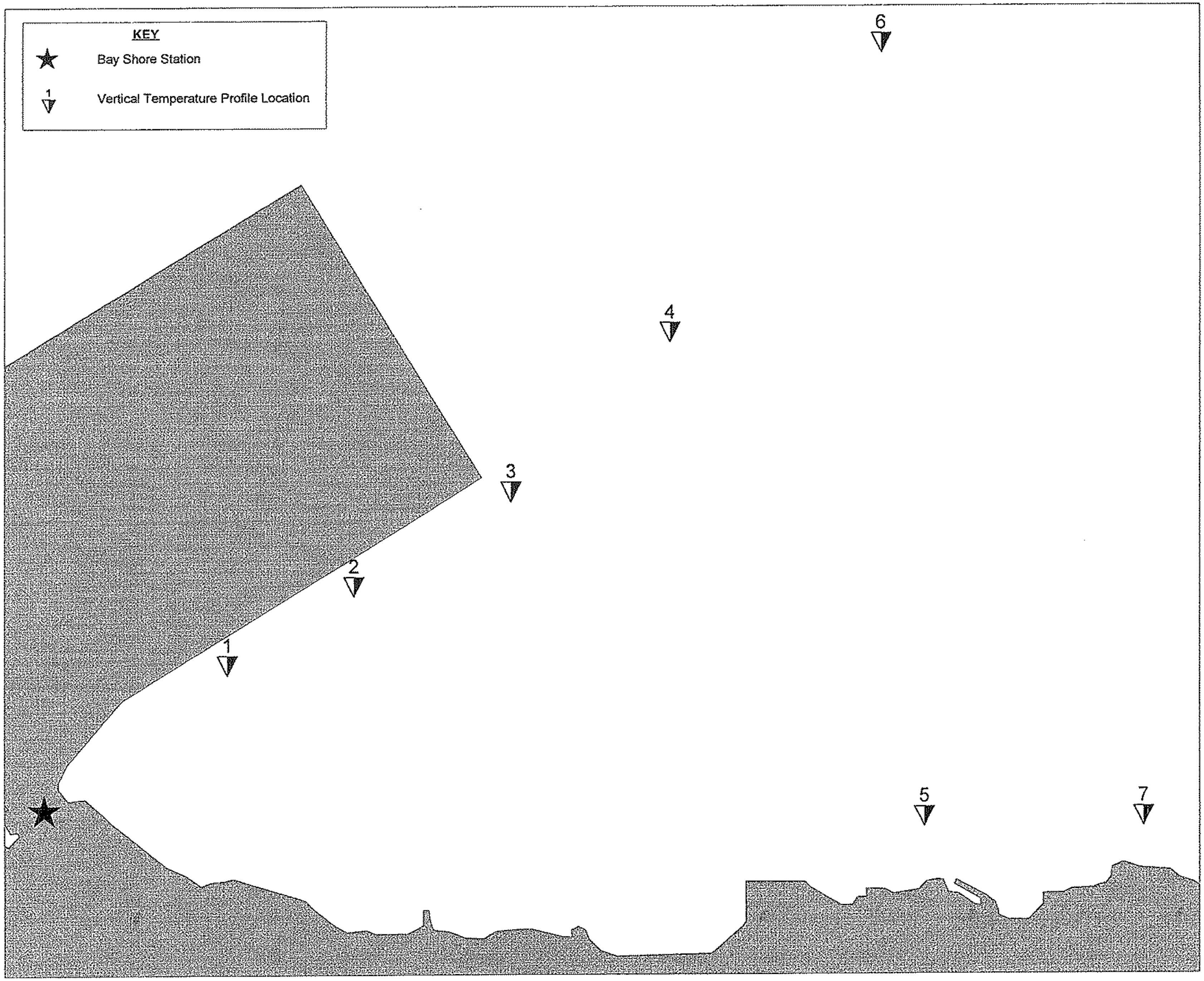
0 500 1000 1500
Scale: 1 inch = 1500 feet

FirstEnergy Corp, Toledo Edison Bay Shore Station

Vertical Temperature Profile Locations - 30 July 2002

FIGURE 2 - 17



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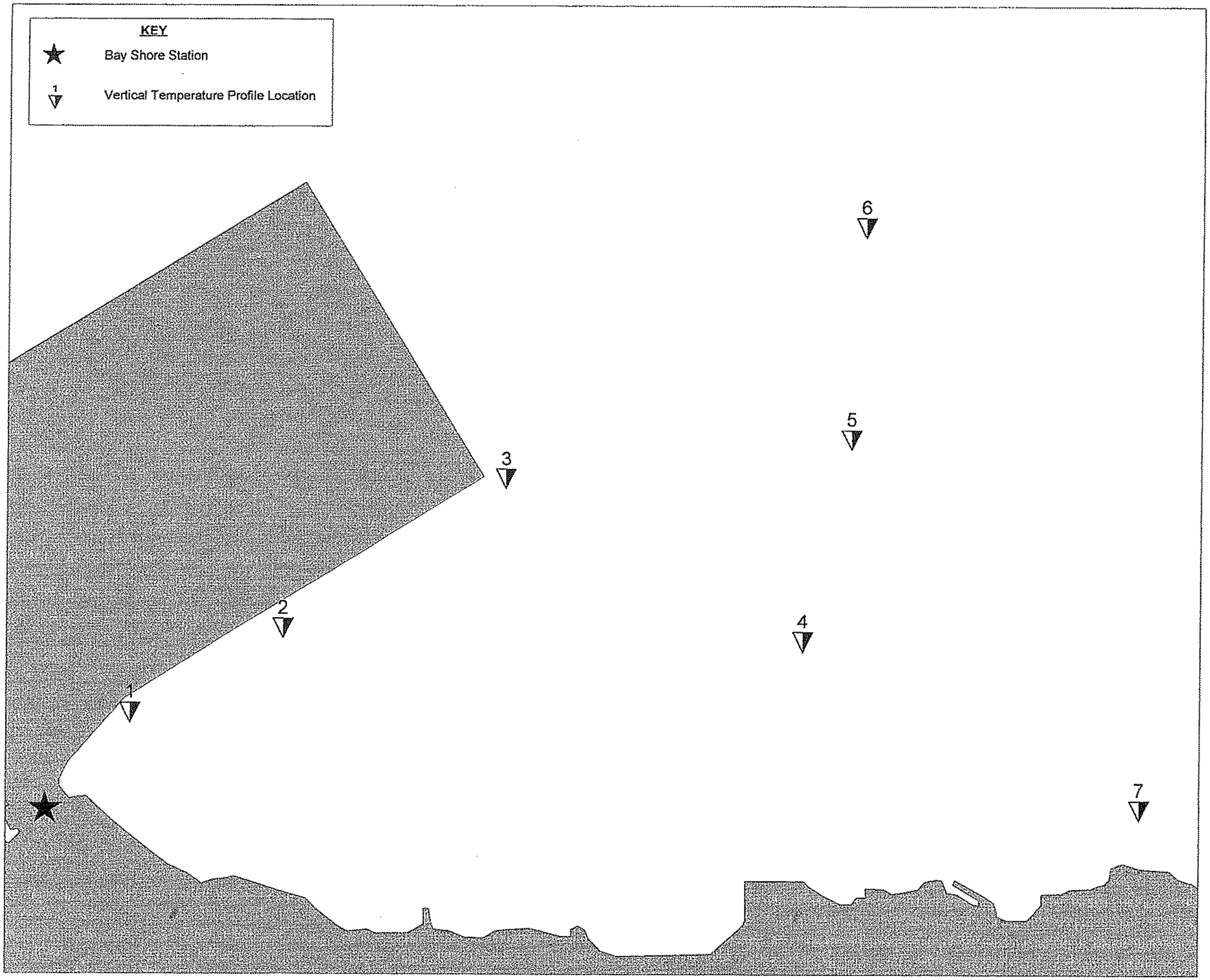
0 500 1000 1500
Scale: 1 inch = 1500 feet

FirstEnergy Corp, Toledo Edison Bay Shore Station

Vertical Temperature Profile Locations - 20 August 2002

FIGURE 2 - 18



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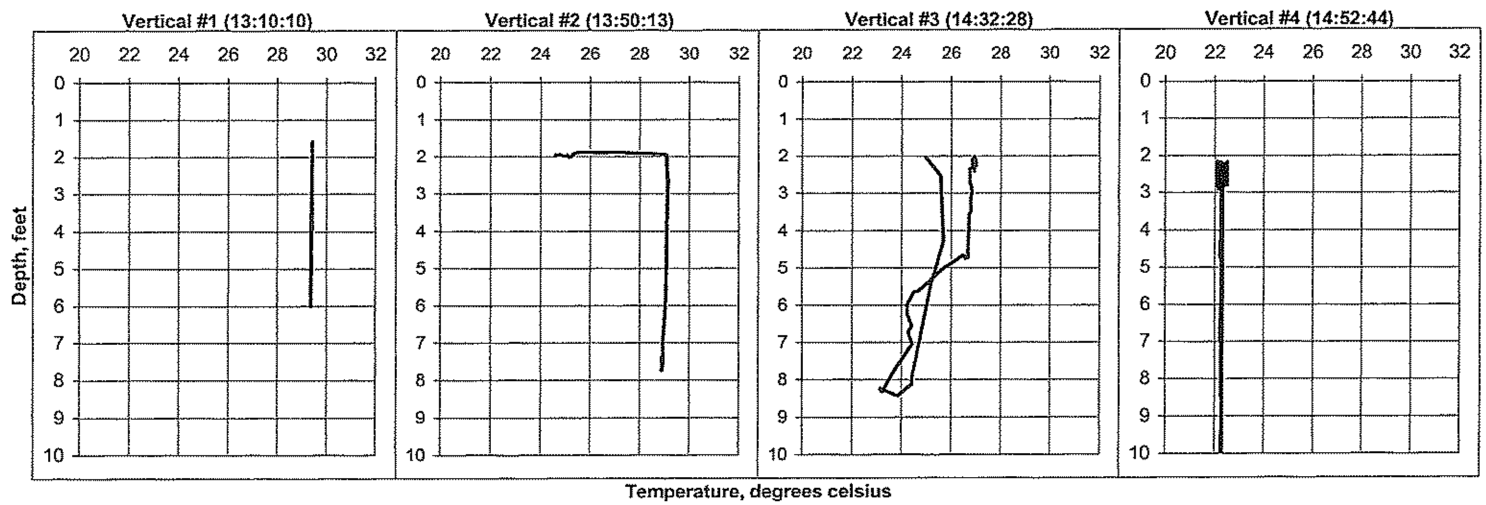
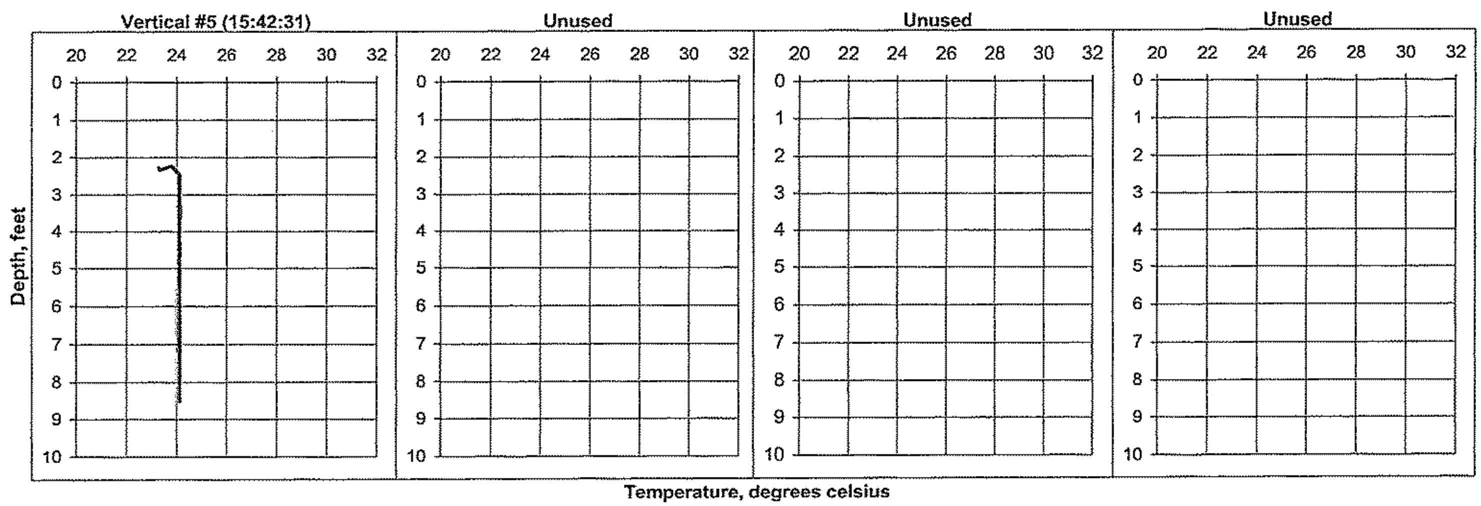
0 500 1000 1500
Scale: 1 inch = 1500 feet

FirstEnergy Corp, Toledo Edison Bay Shore Station

Vertical Temperature Profile Locations - 17 September 2002

FIGURE 2 - 19





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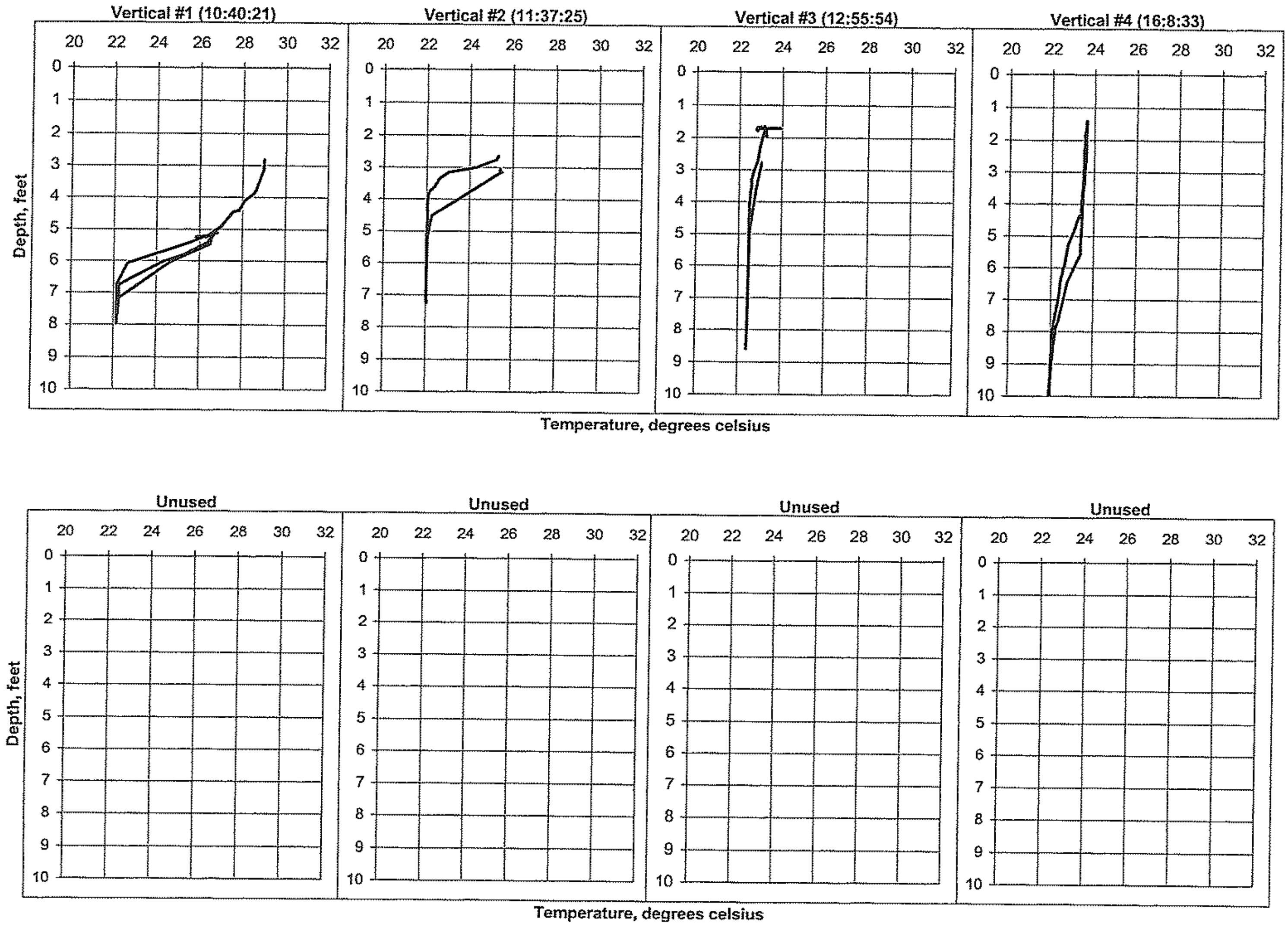
Vertical Temperature Profiles - 11 June 2002

FIGURE 2 - 20



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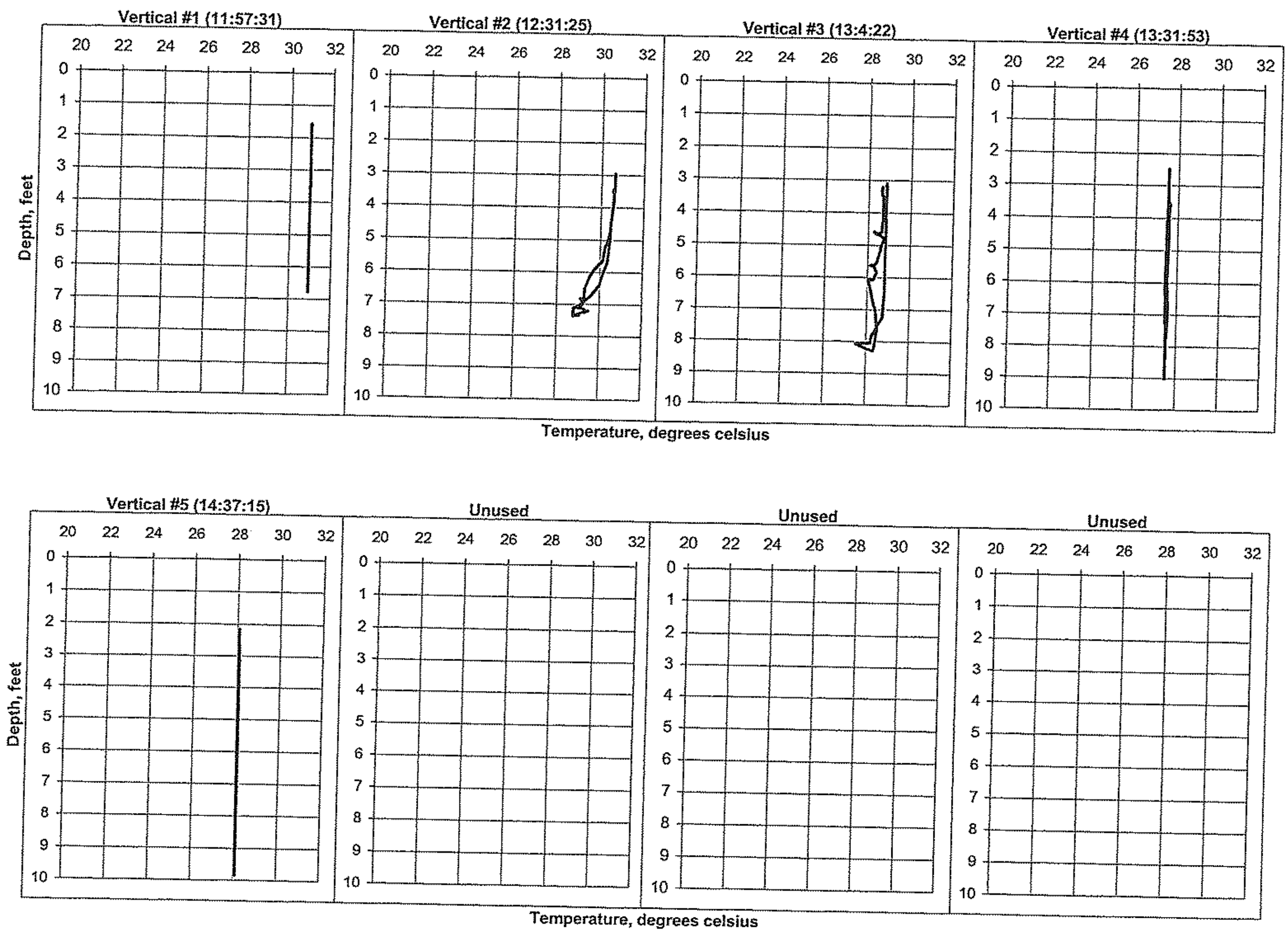
Vertical Temperature Profiles - 12 June 2002

FIGURE 2 - 21



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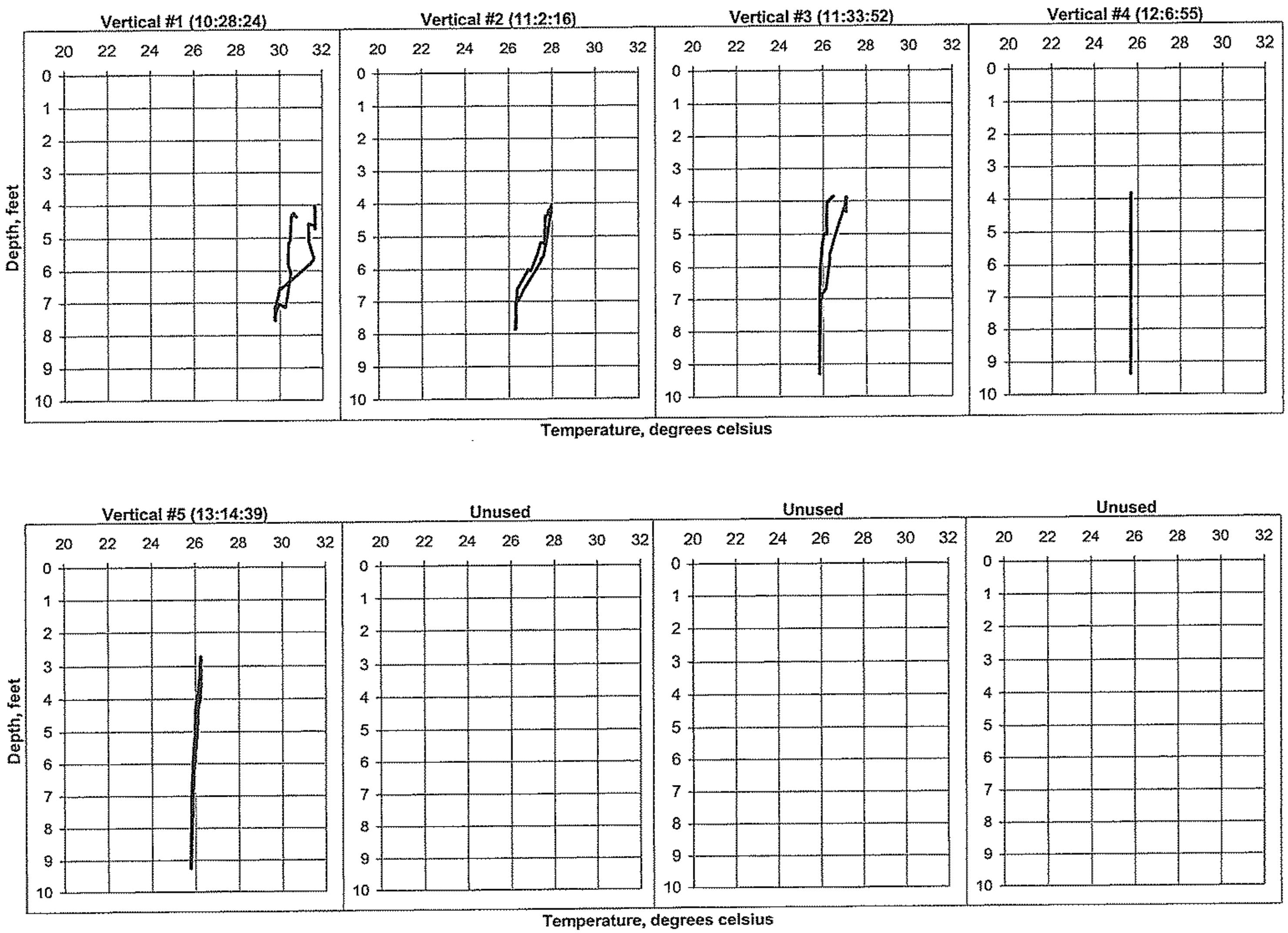
Vertical Temperature Profiles - 26 June 2002

FIGURE 2 - 22



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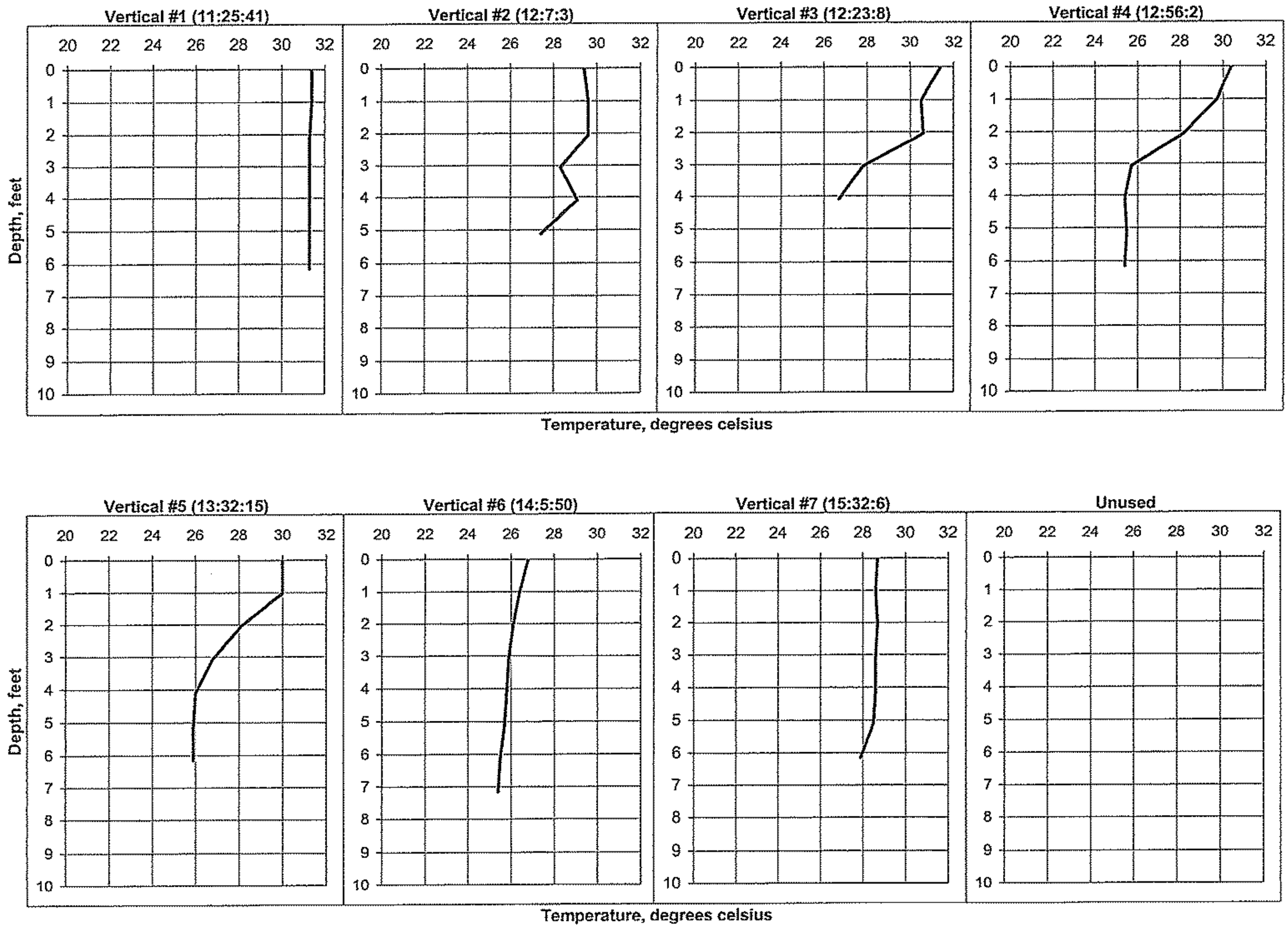
Vertical Temperature Profiles - 09 July 2002

FIGURE 2 - 23



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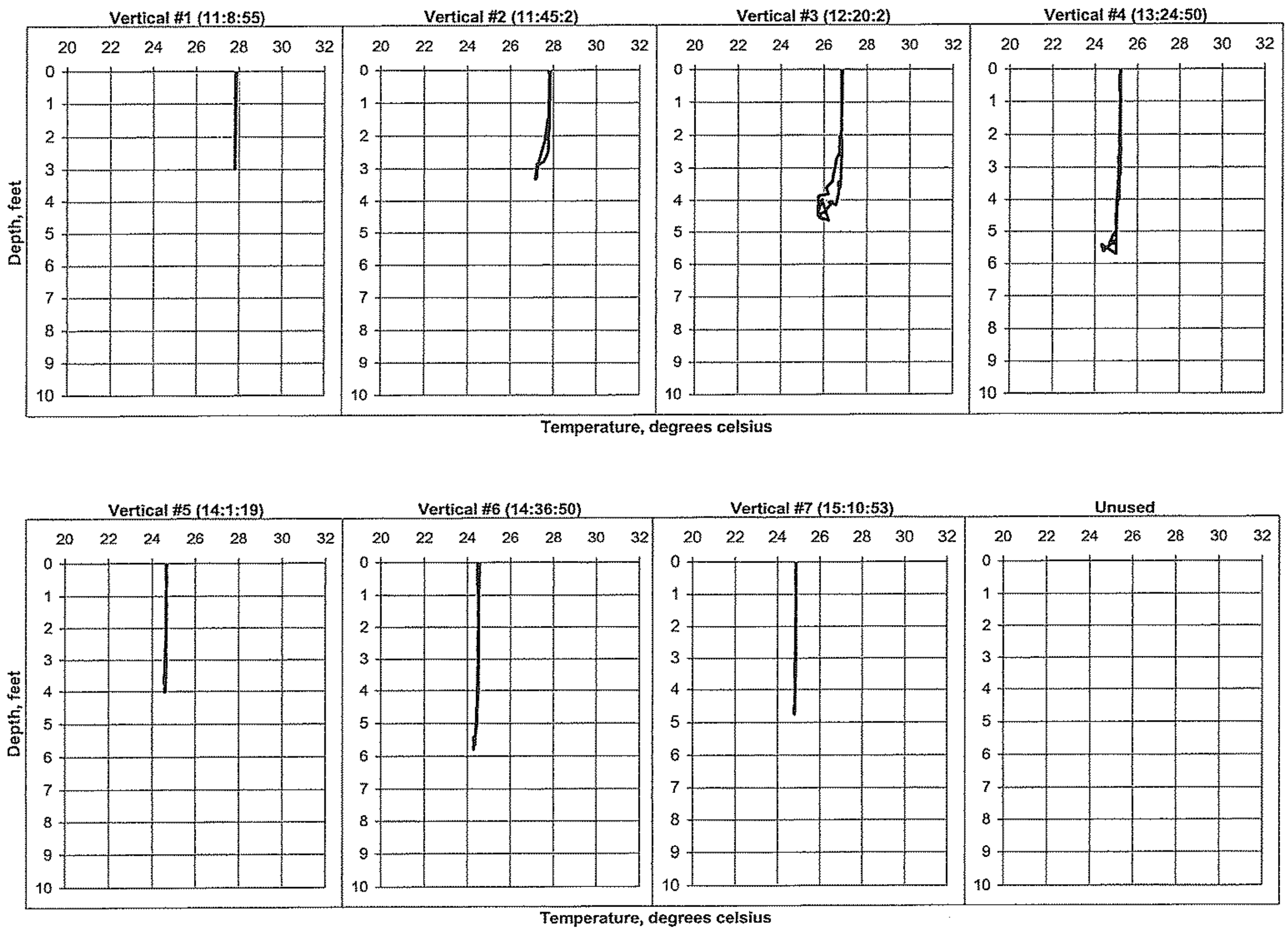
Vertical Temperature Profiles - 30 July 2002

FIGURE 2 - 24



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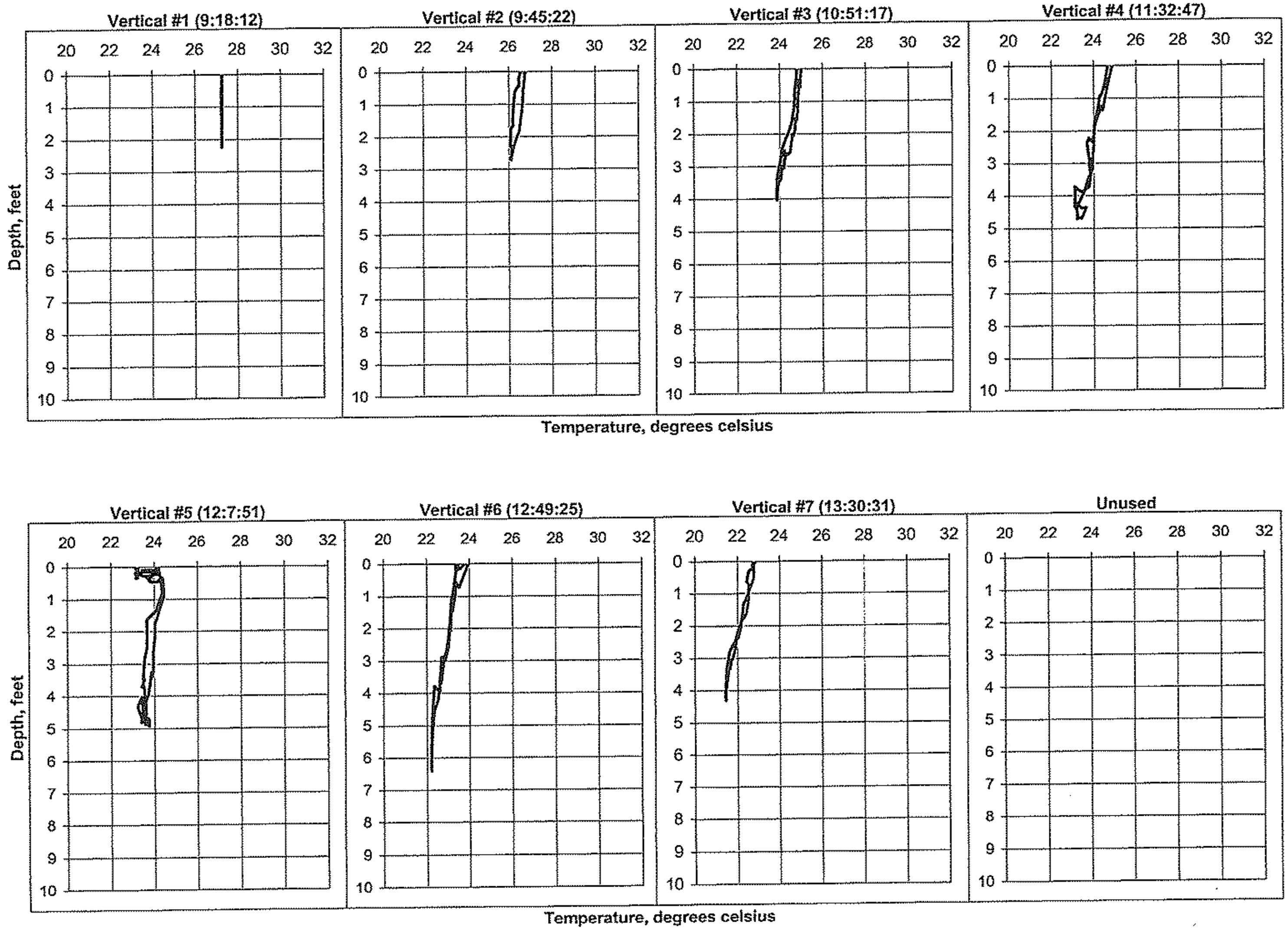
Vertical Temperature Profiles - 20 August 2002

FIGURE 2 - 25



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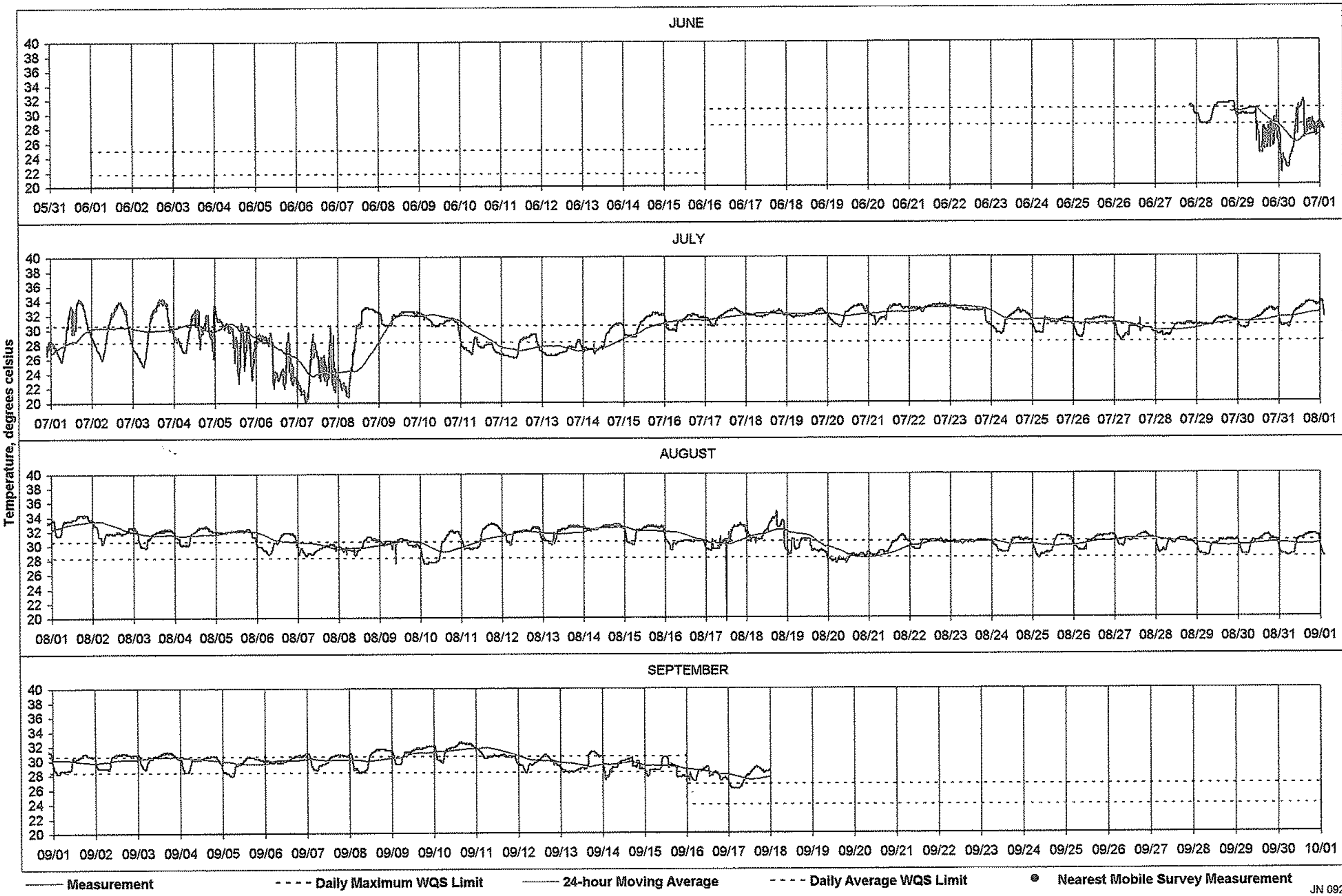
Vertical Temperature Profiles - 17 September 2002

FIGURE 2 - 26



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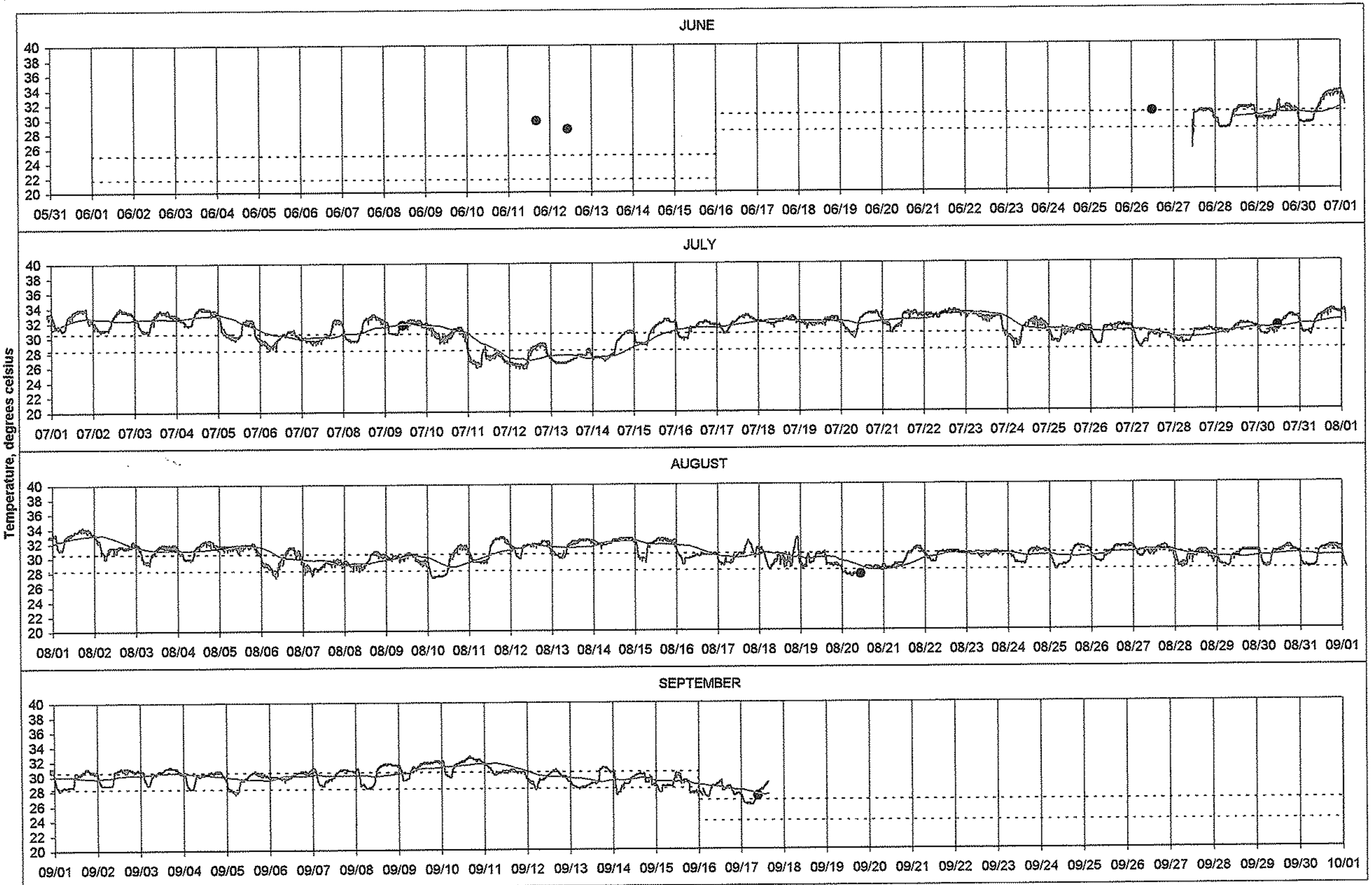
Fixed Station Temperatures, Station 1

FIGURE 2 - 27



—— Measurement - - - - Daily Maximum WQS Limit —— 24-hour Moving Average - - - - Daily Average WQS Limit ● Nearest Mobile Survey Measurement

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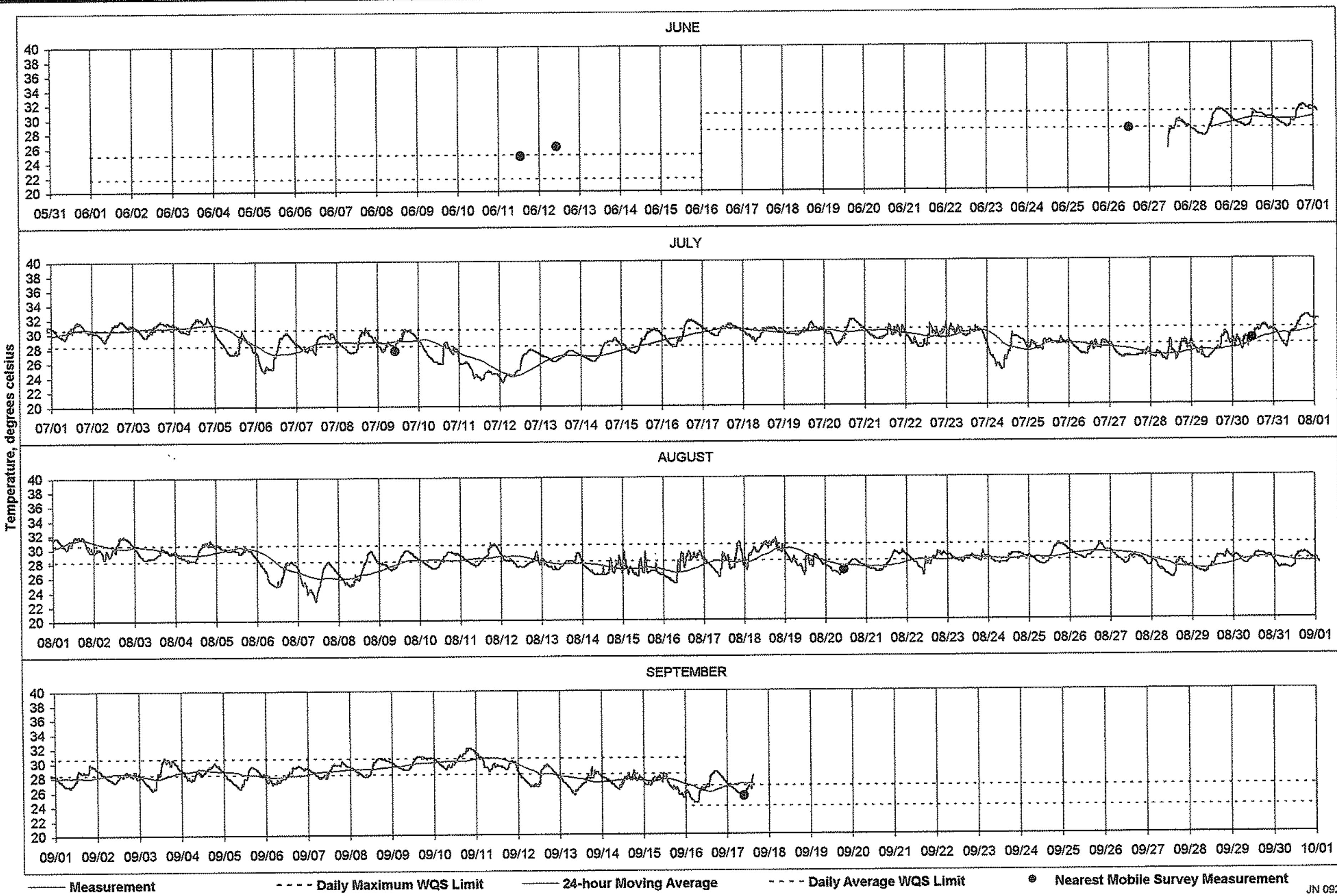

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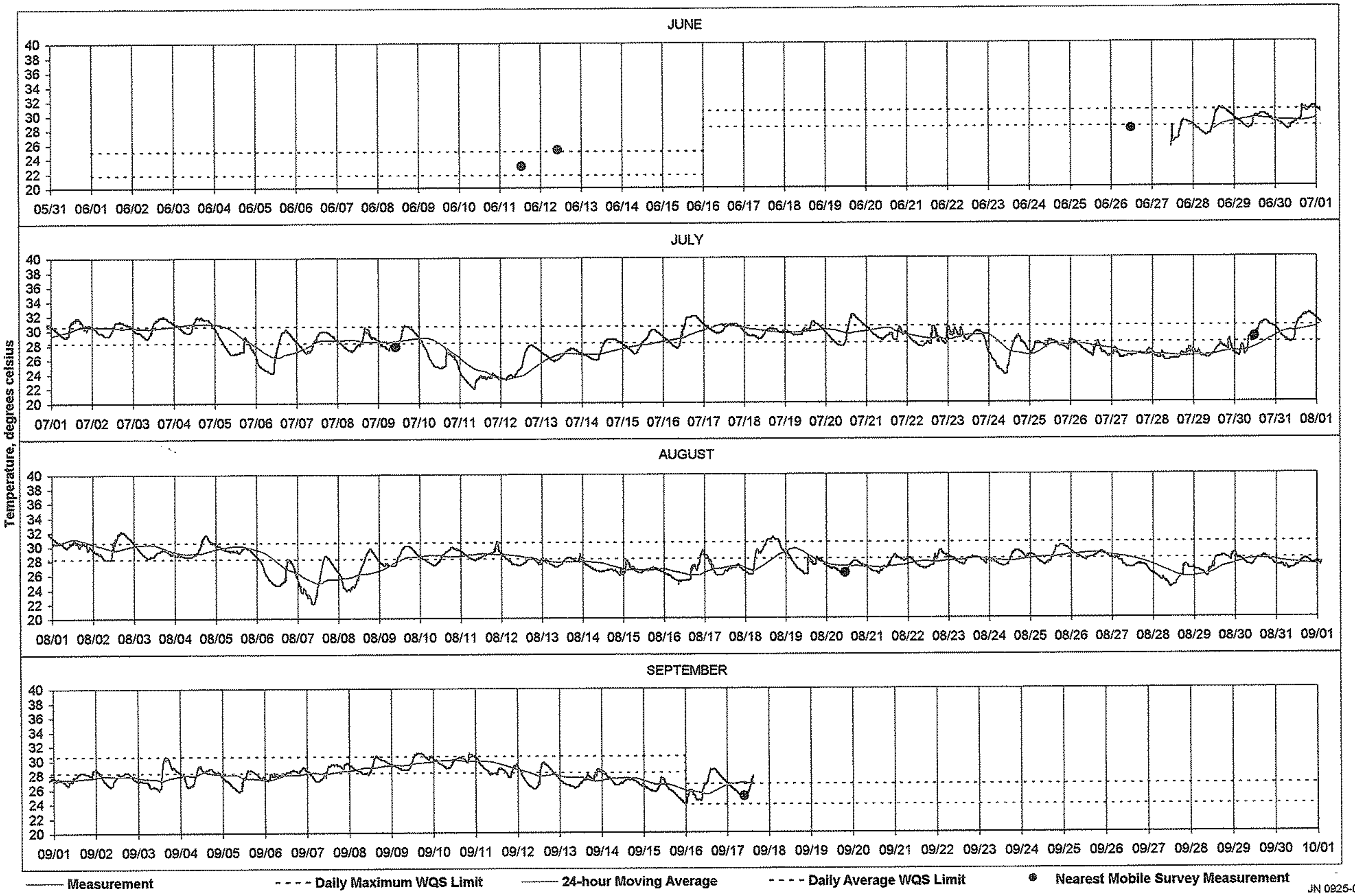
Fixed Station Temperatures, Station 3

FIGURE 2 - 29



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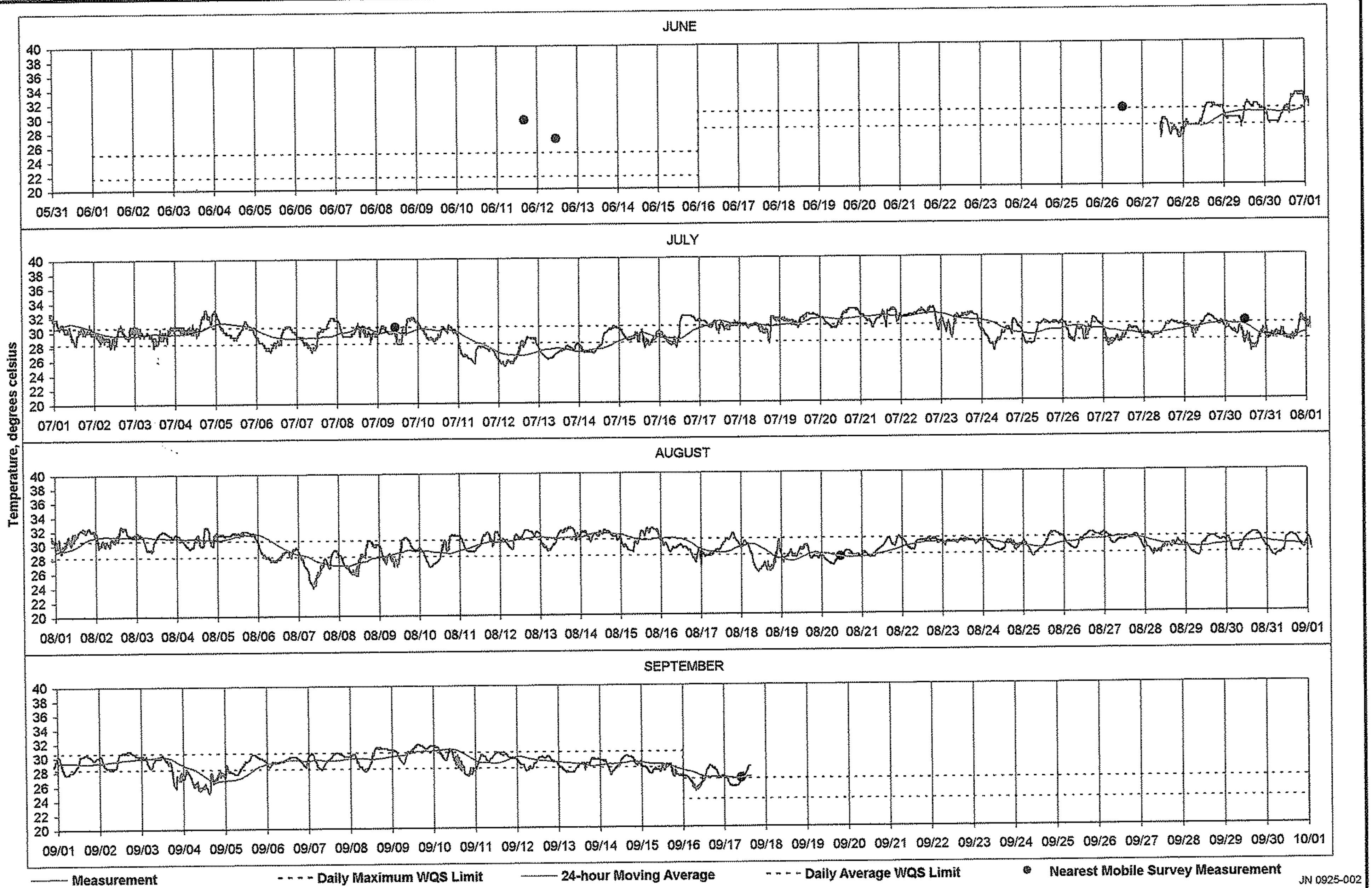
Fixed Station Temperatures, Station 4

FIGURE 2 - 30



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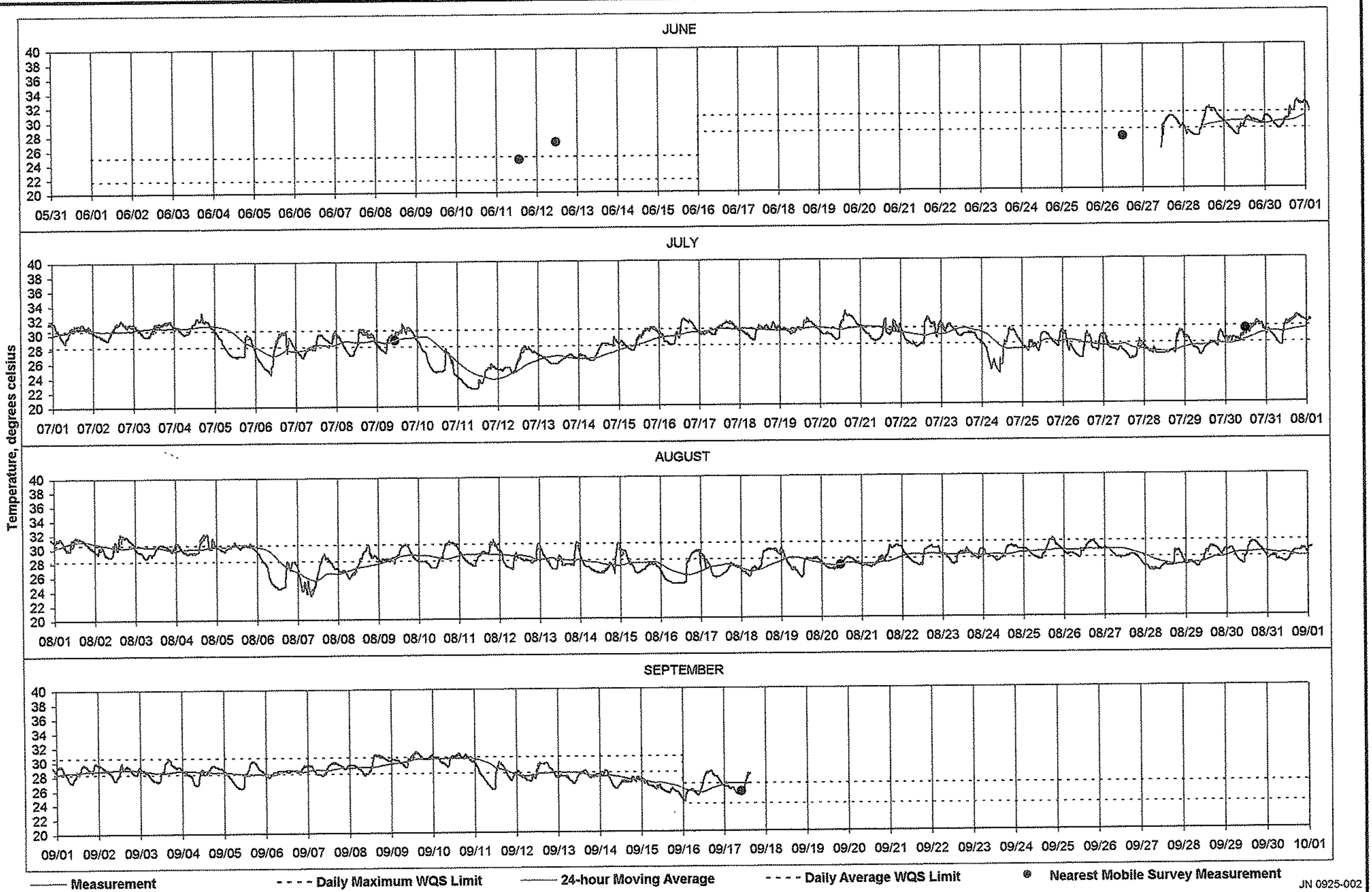
Fixed Station Temperatures, Station 5

FIGURE 2 - 31



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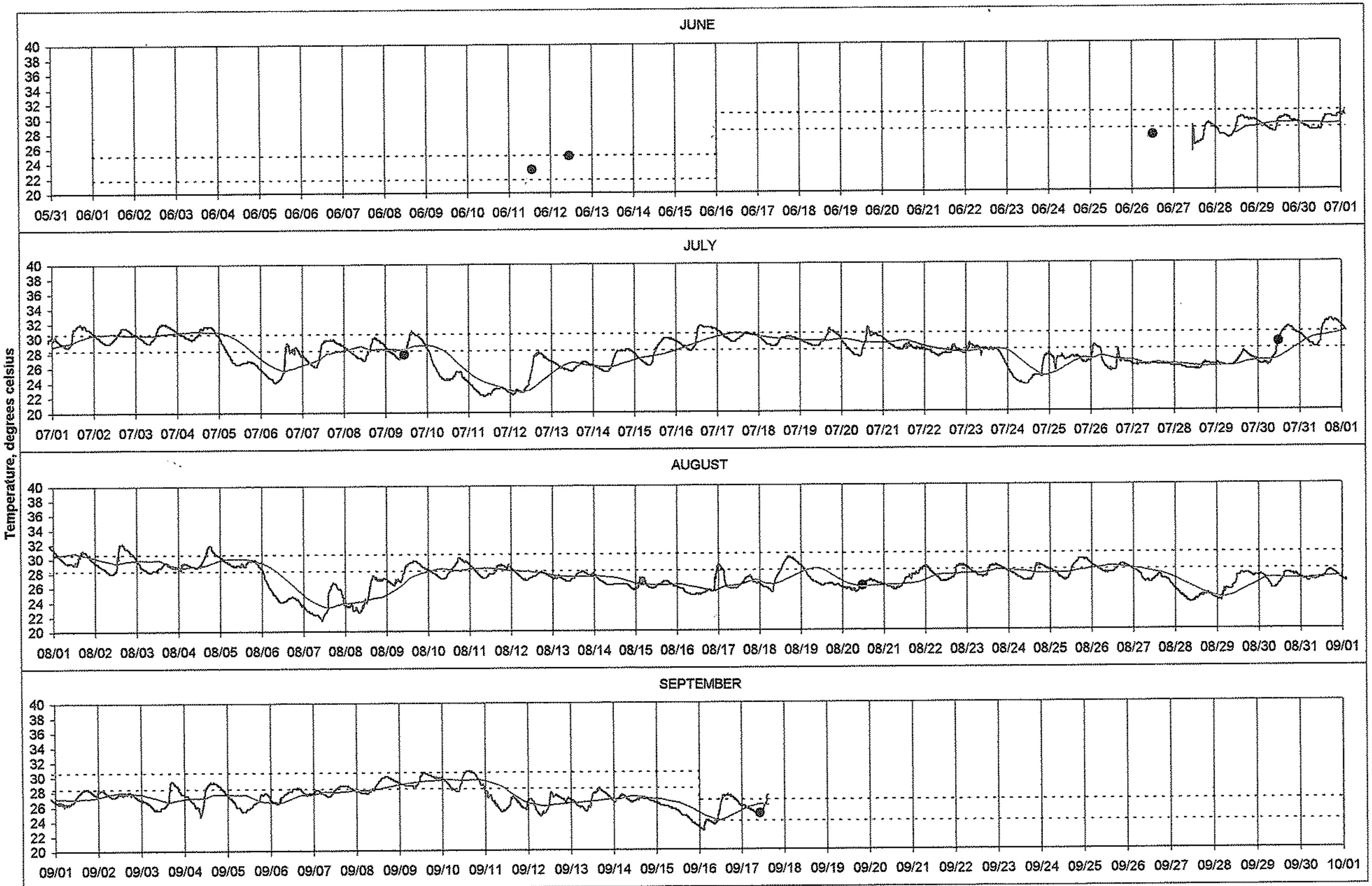
Fixed Station Temperatures, Station 6

FIGURE 2 - 32



—— Measurement - - - - Daily Maximum WQS Limit —— 24-hour Moving Average - - - - Daily Average WQS Limit ● Nearest Mobile Survey Measurement

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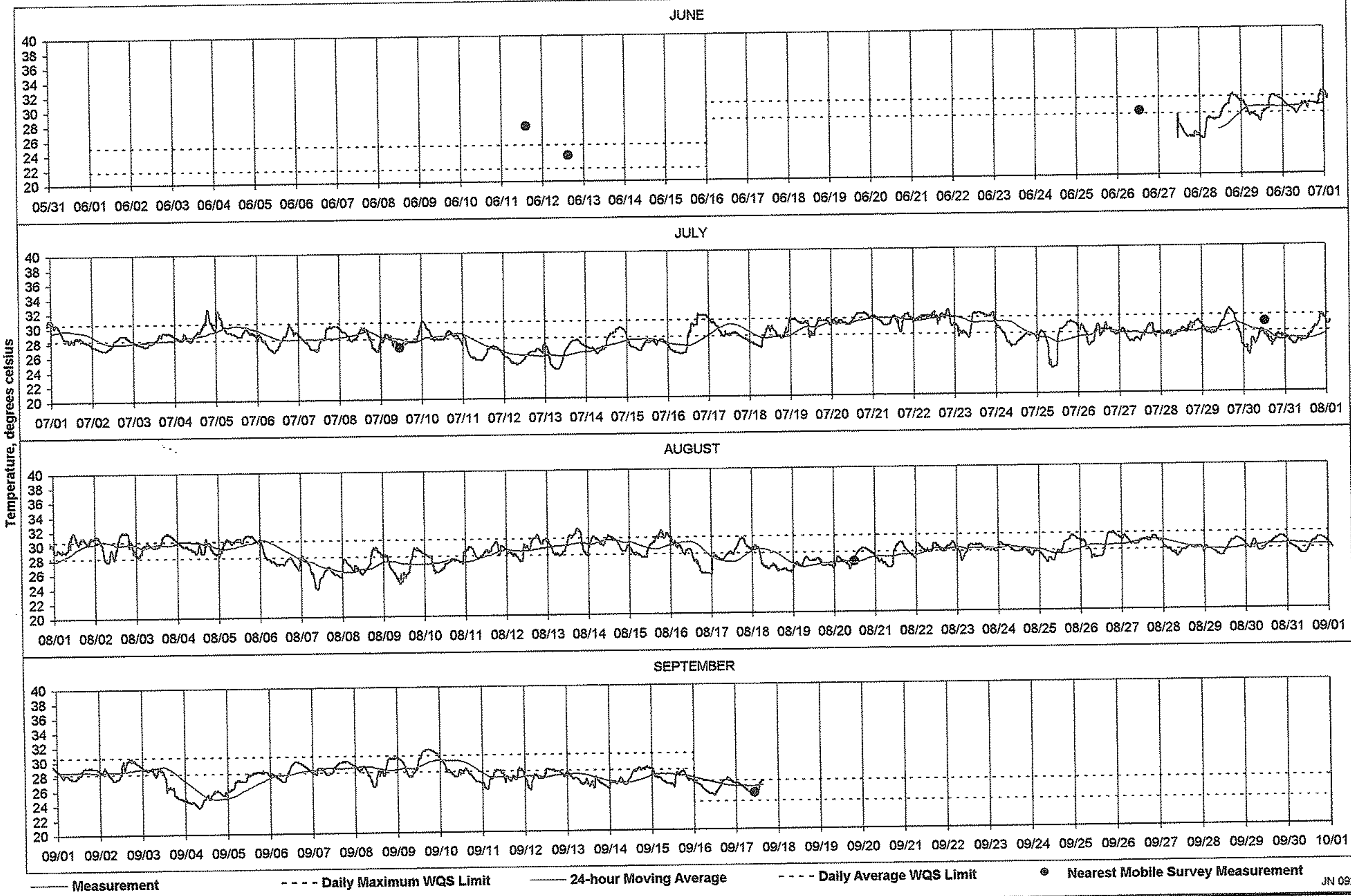
FirstEnergy Corp, Toledo Edison Bay Shore Station

Fixed Station Temperatures, Station 7

FIGURE 2 - 33



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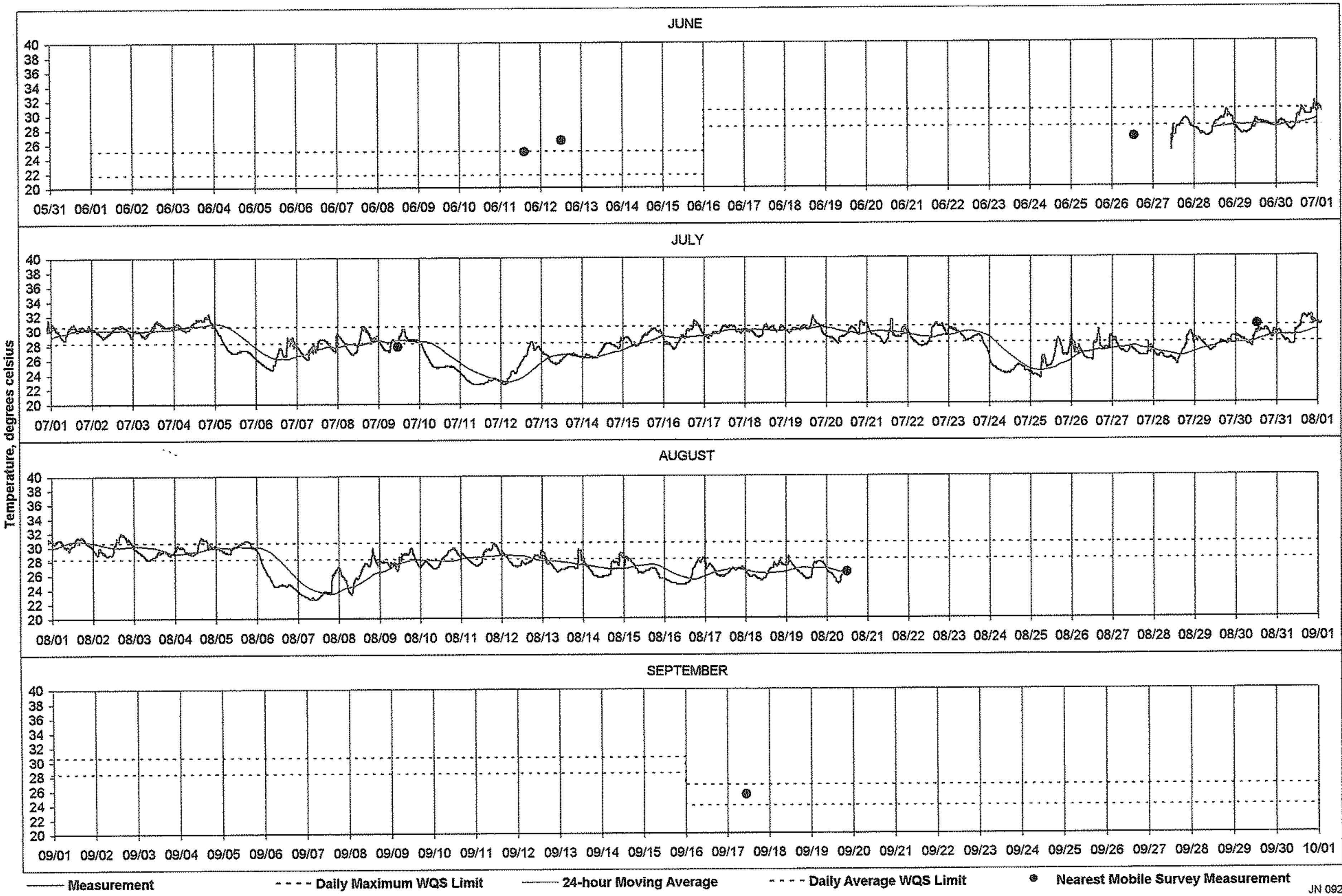
Fixed Station Temperatures, Station 8

FIGURE 2 - 34



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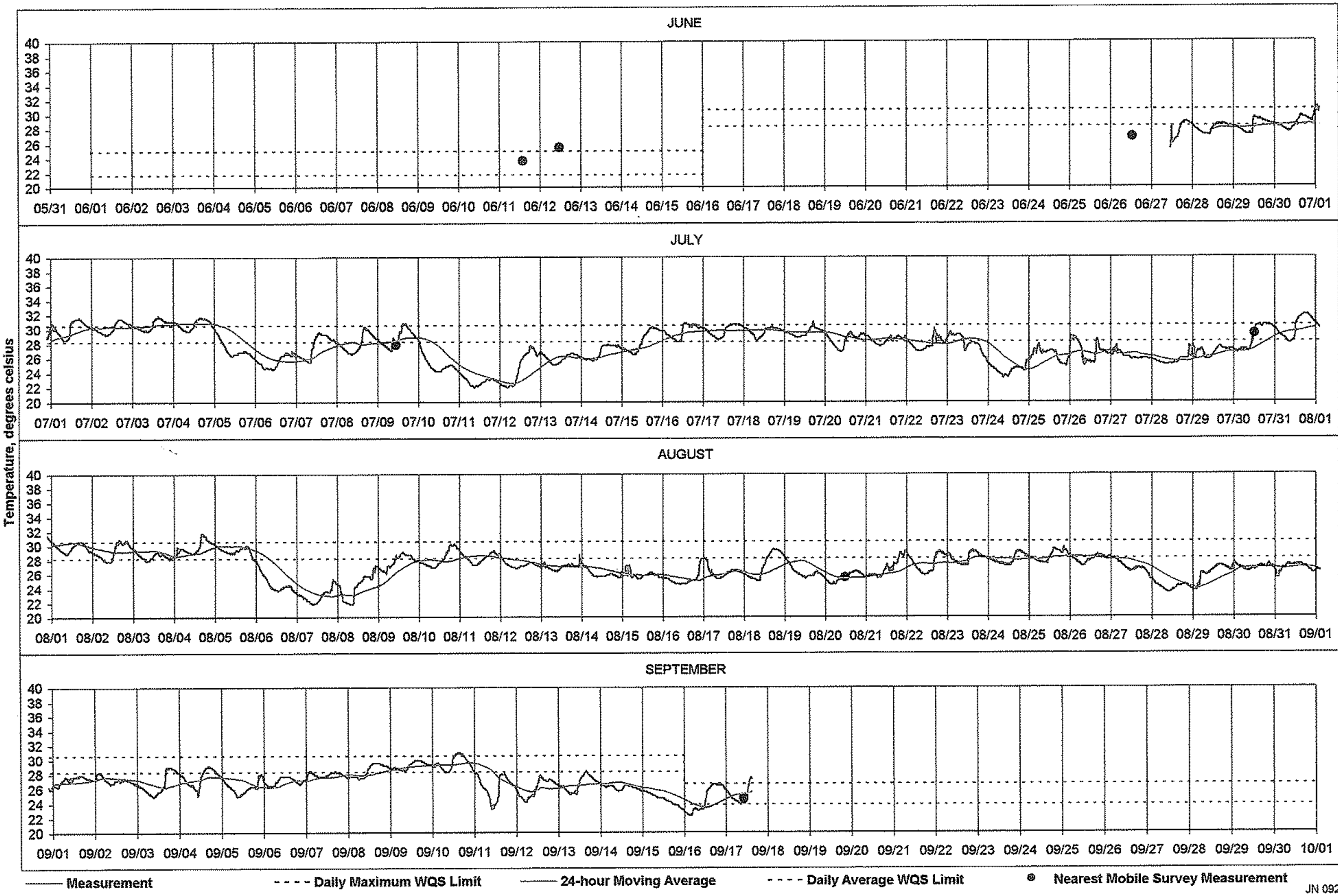
Fixed Station Temperatures, Station 9

FIGURE 2 - 35



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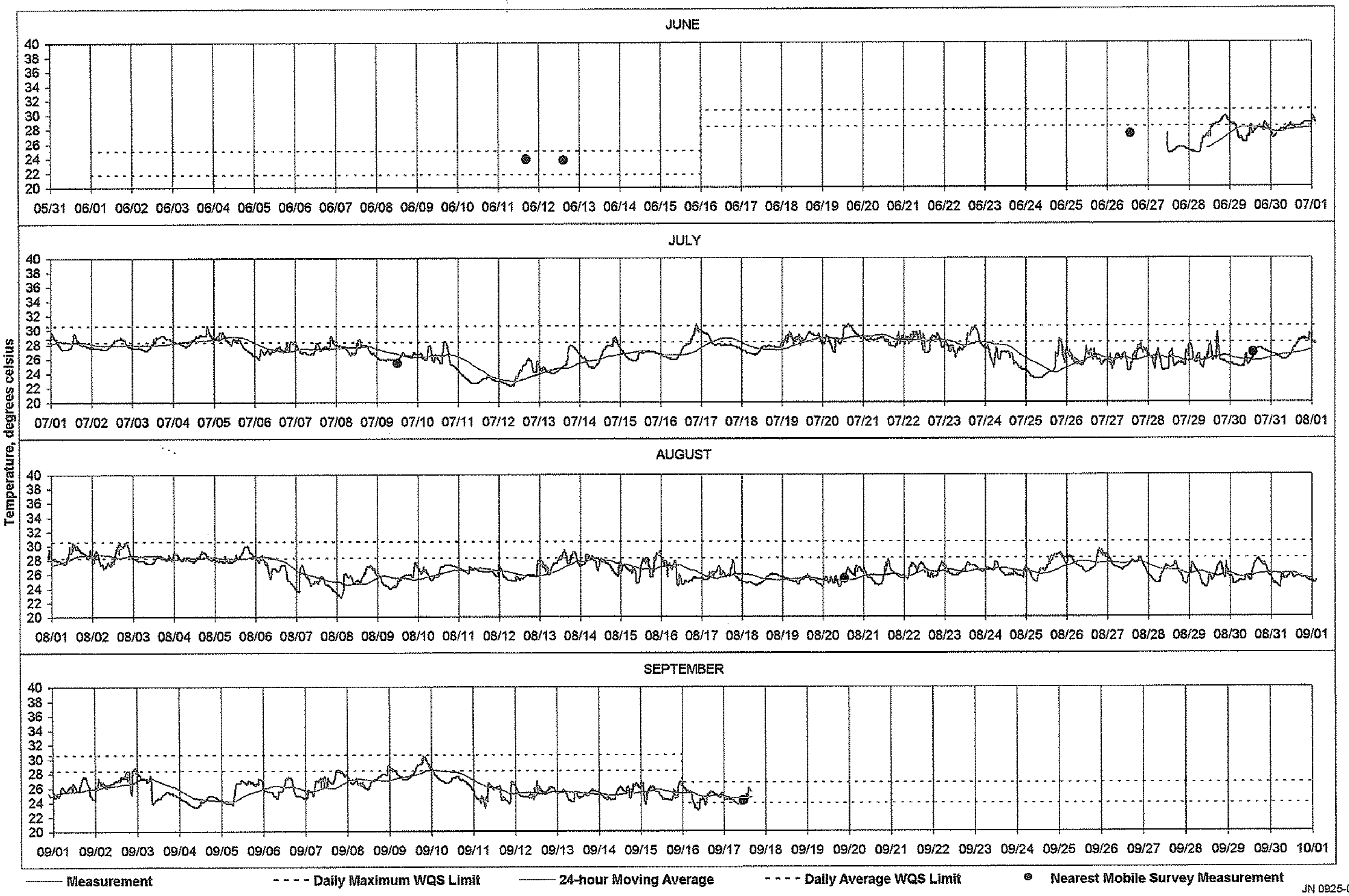
Fixed Station Temperatures, Station 10

FIGURE 2 - 36



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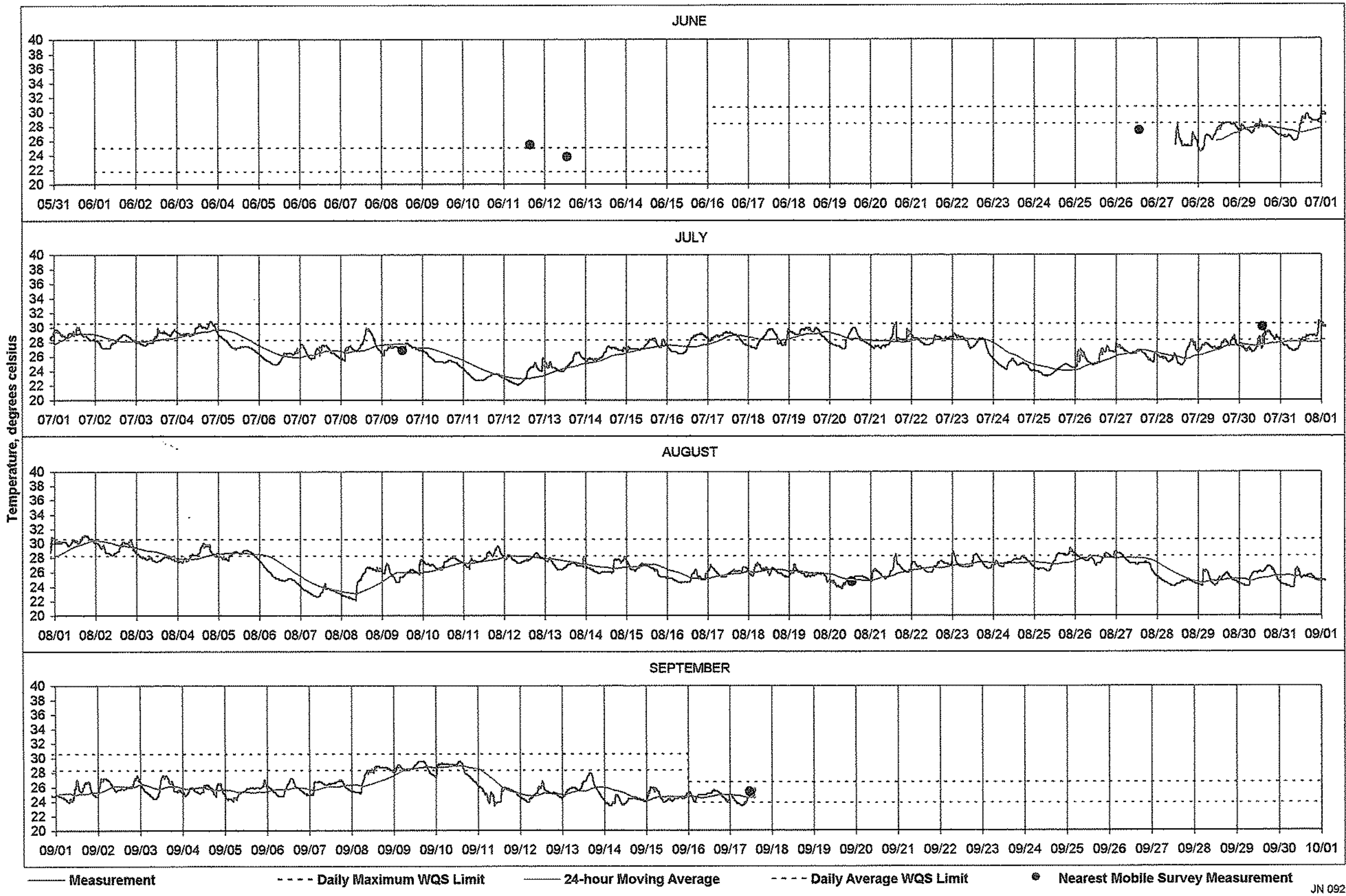
Fixed Station Temperatures, Station 11

FIGURE 2 - 37



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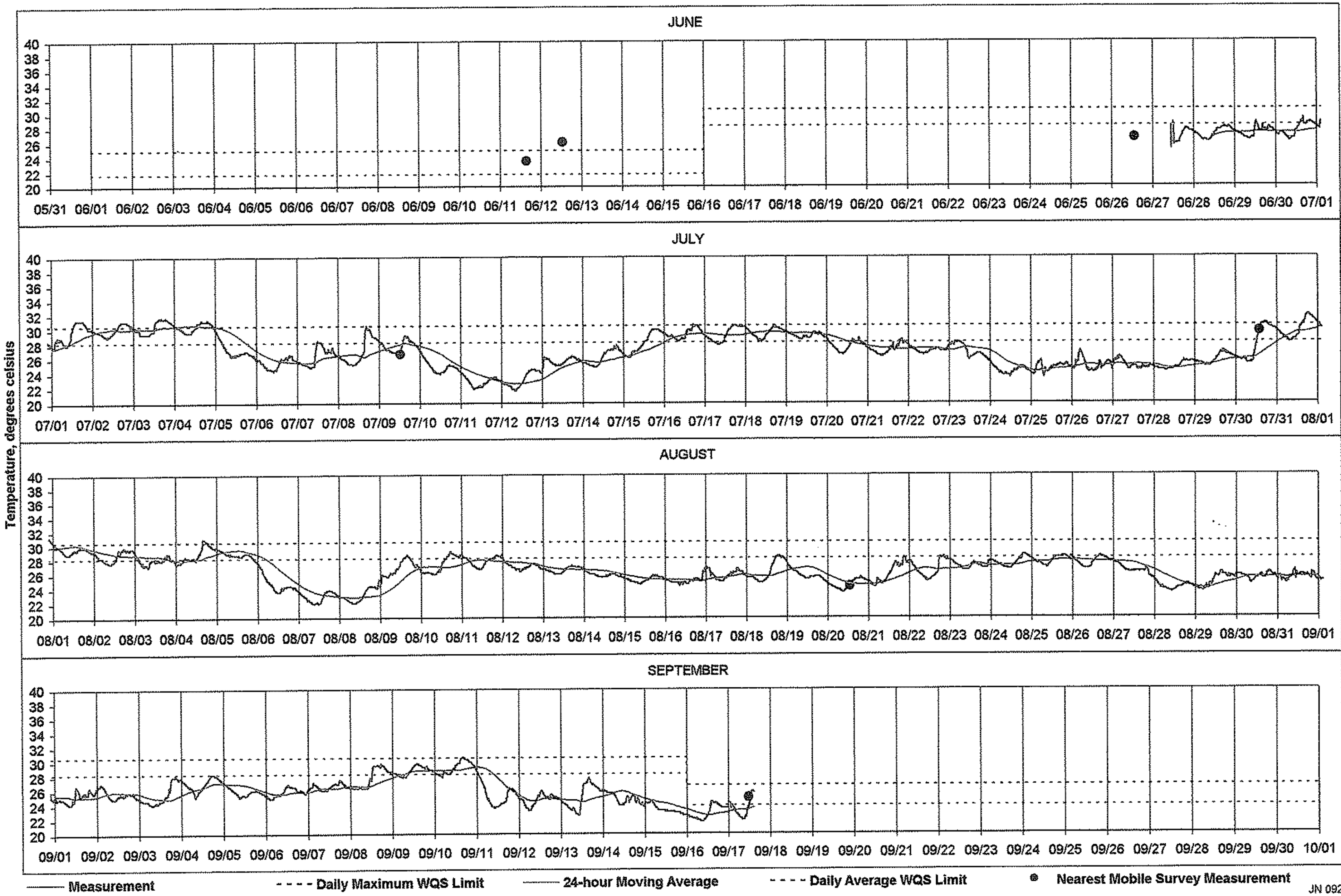
Fixed Station Temperatures, Station 12

FIGURE 2 - 38



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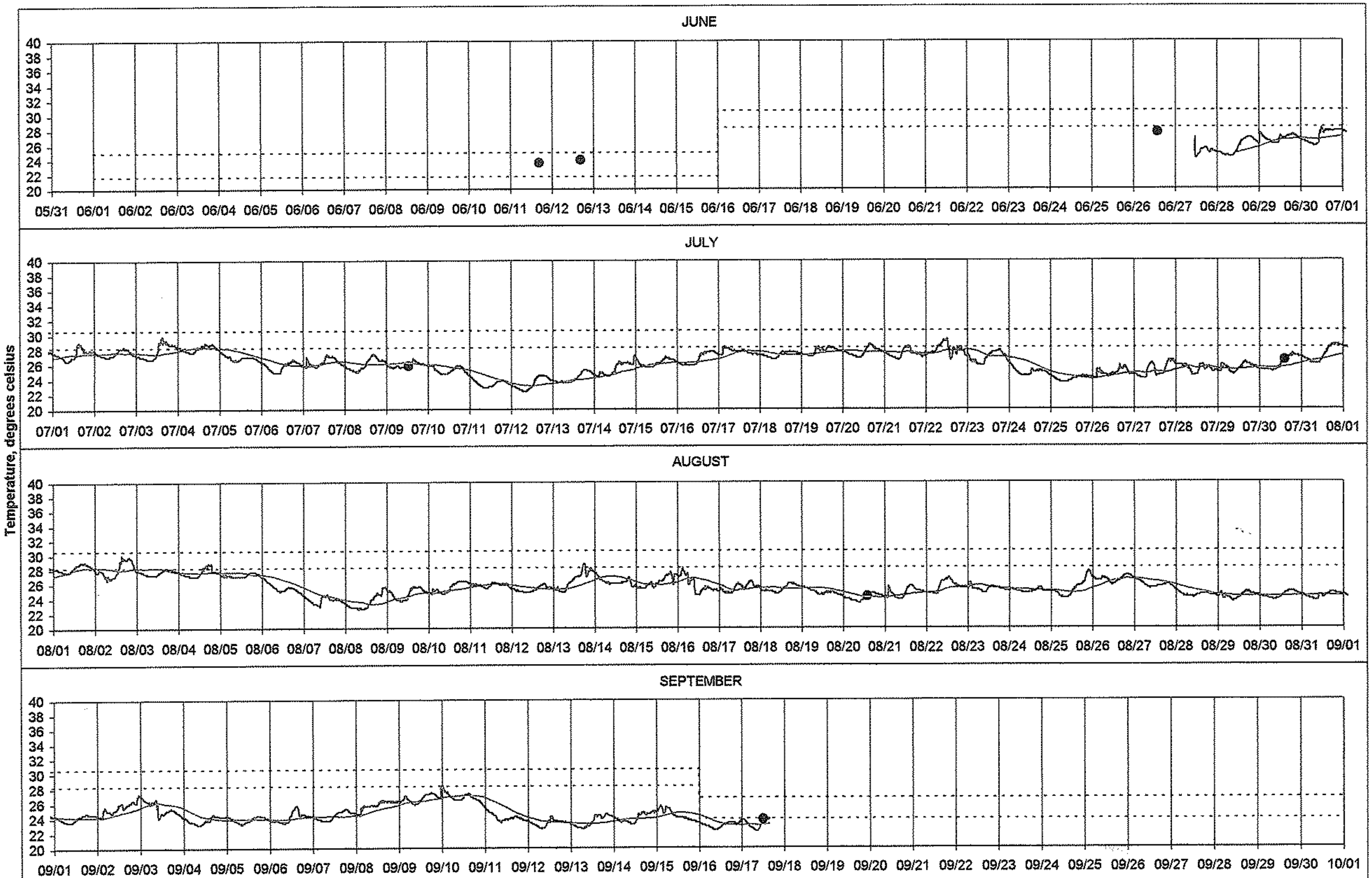
FirstEnergy Corp, Toledo Edison Bay Shore Station

Fixed Station Temperatures, Station 13

FIGURE 2 - 39



Measurement ---- Daily Maximum WQS Limit 24-hour Moving Average ---- Daily Average WQS Limit ● Nearest Mobile Survey Measurement

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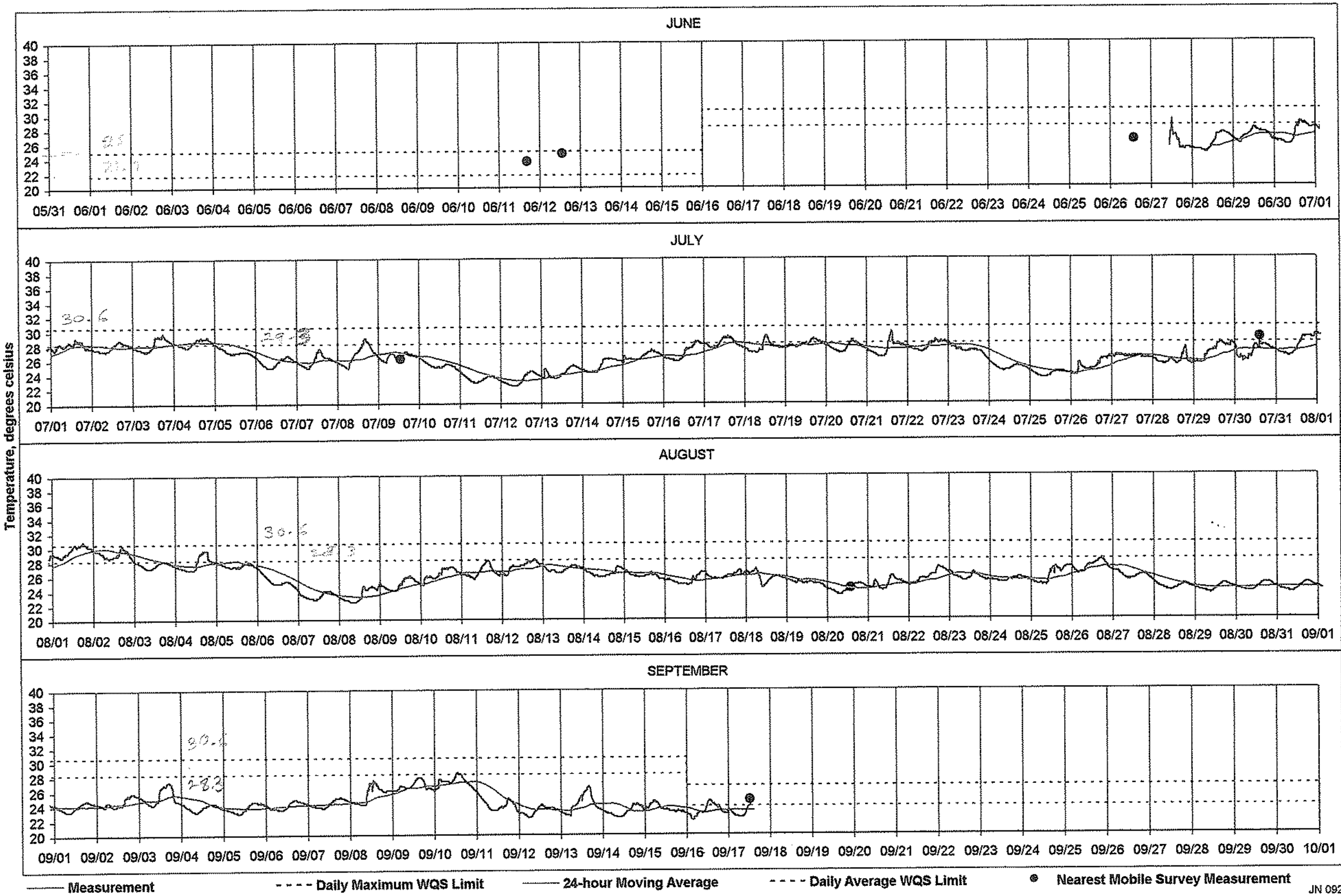
Fixed Station Temperatures, Station 14

FIGURE 2 - 40



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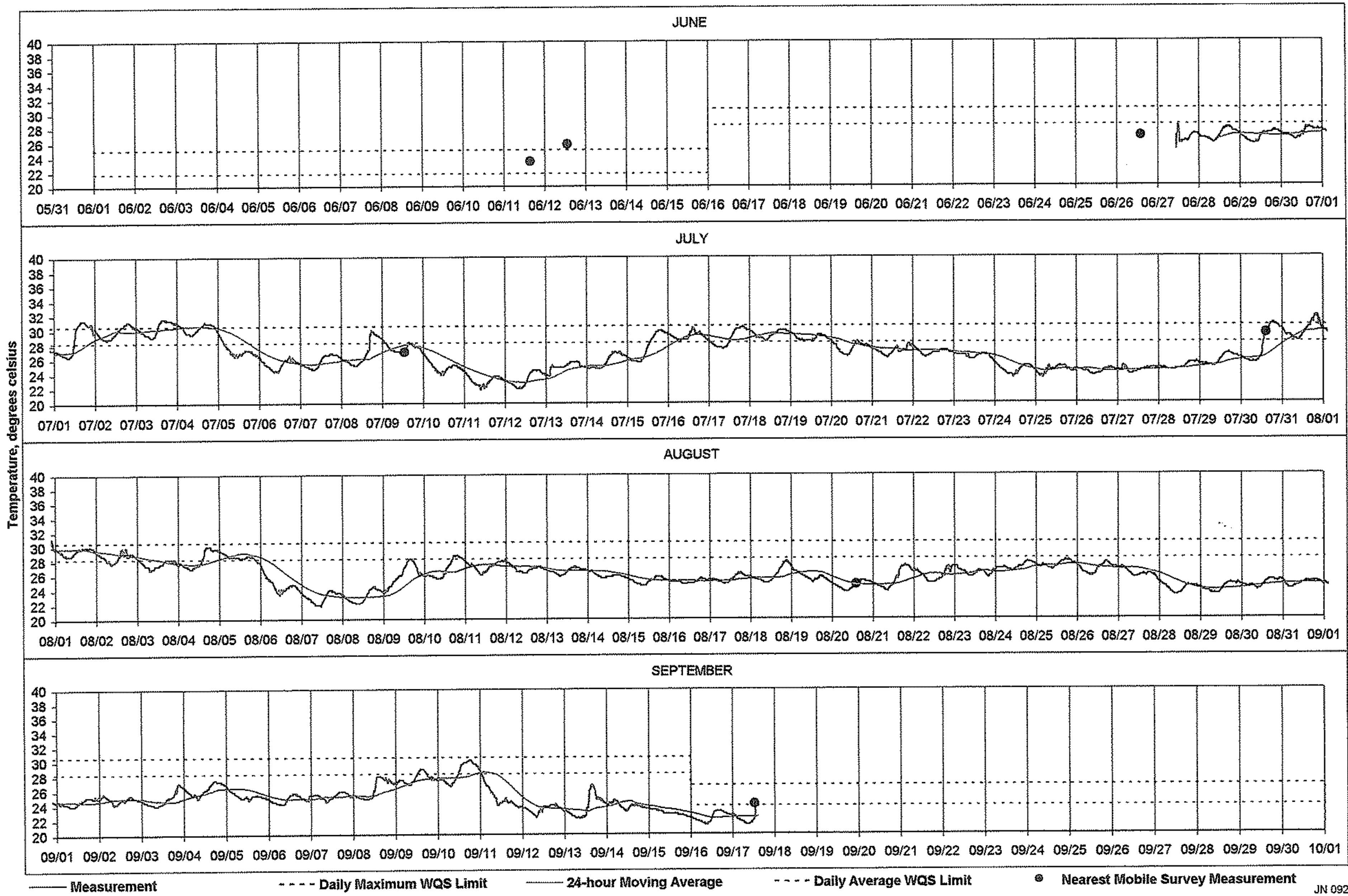
Fixed Station Temperatures, Station 15

FIGURE 2 - 41



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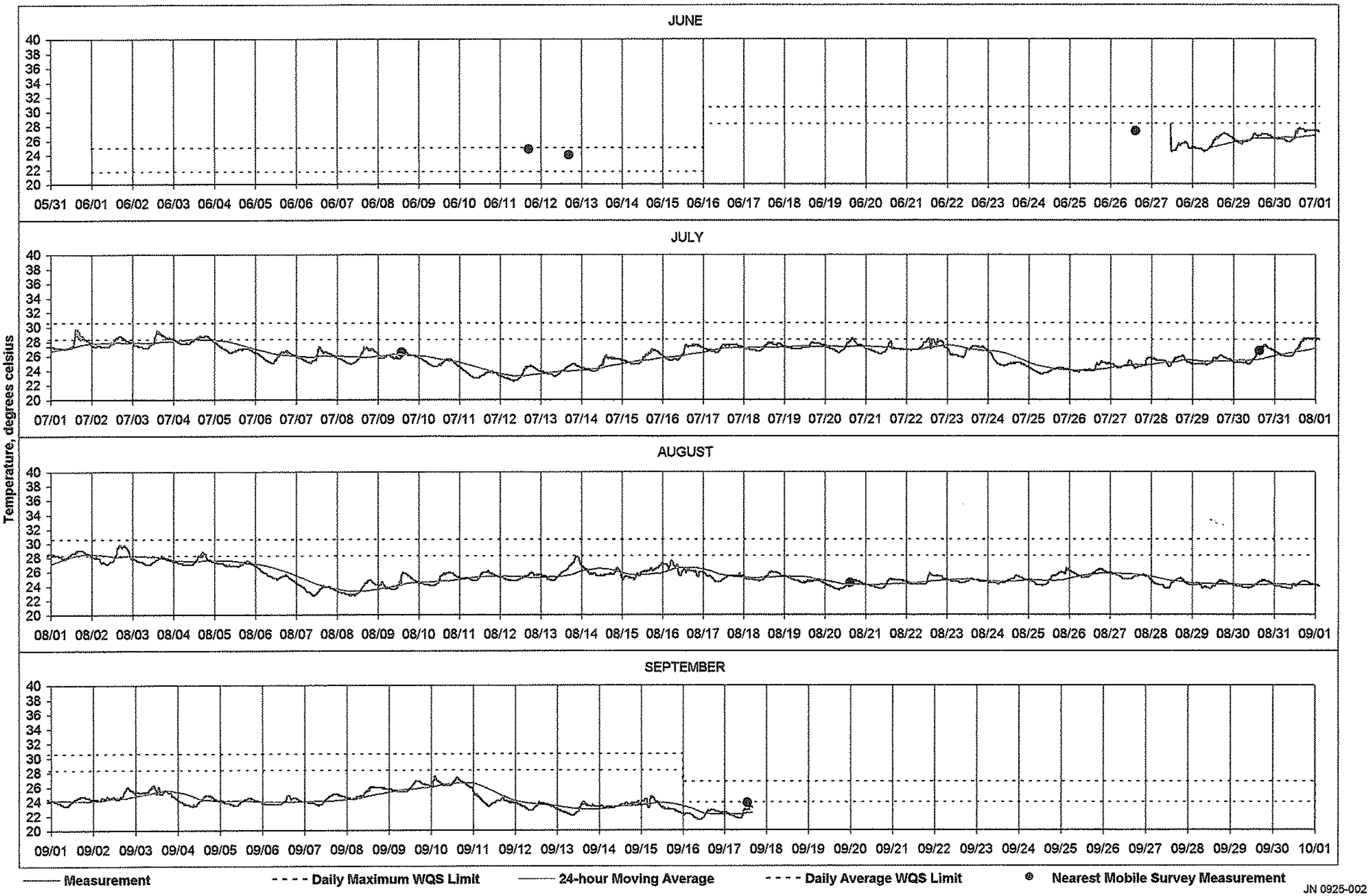
Fixed Station Temperatures, Station 16

FIGURE 2 - 42



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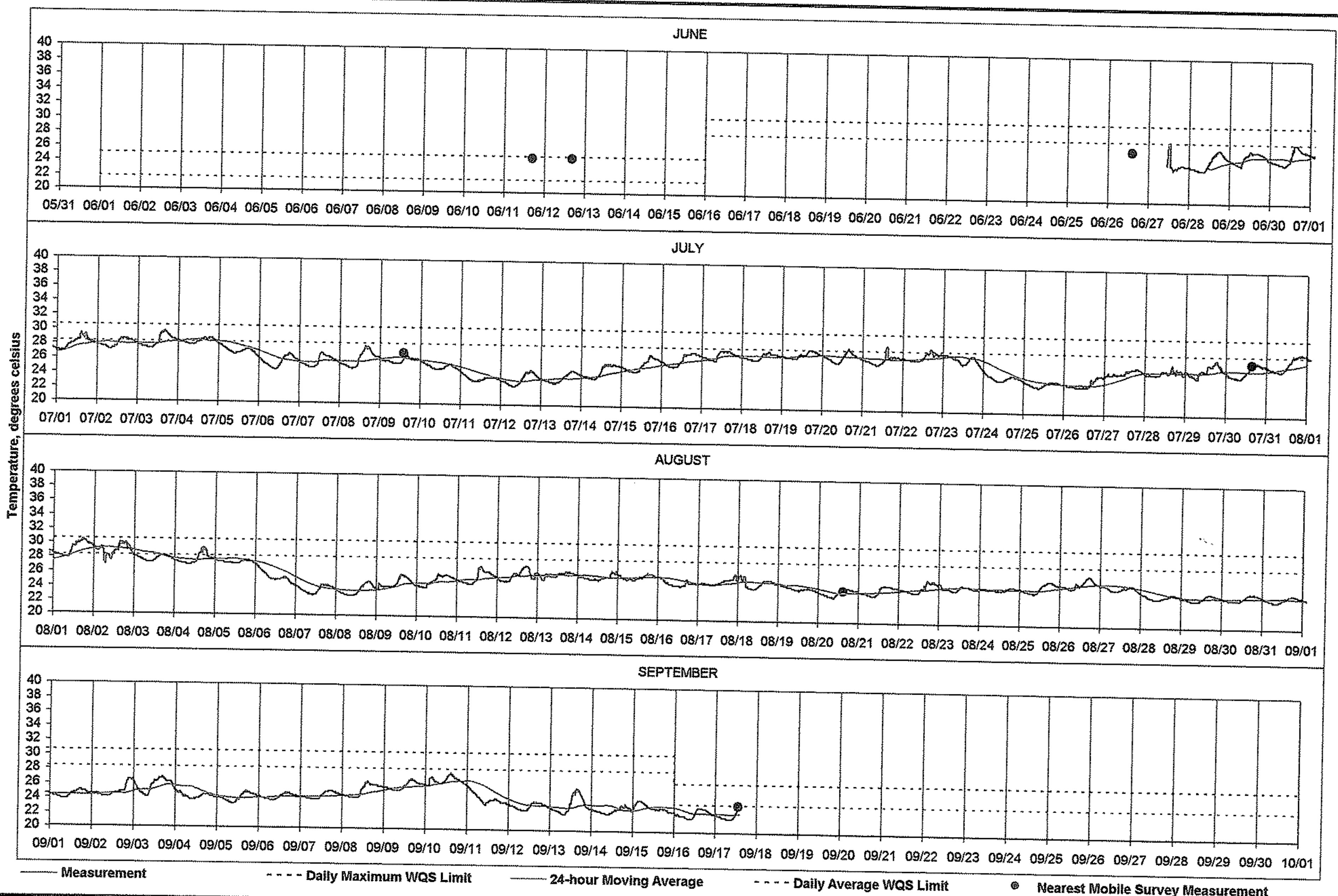
Fixed Station Temperatures, Station 17

FIGURE 2 - 43



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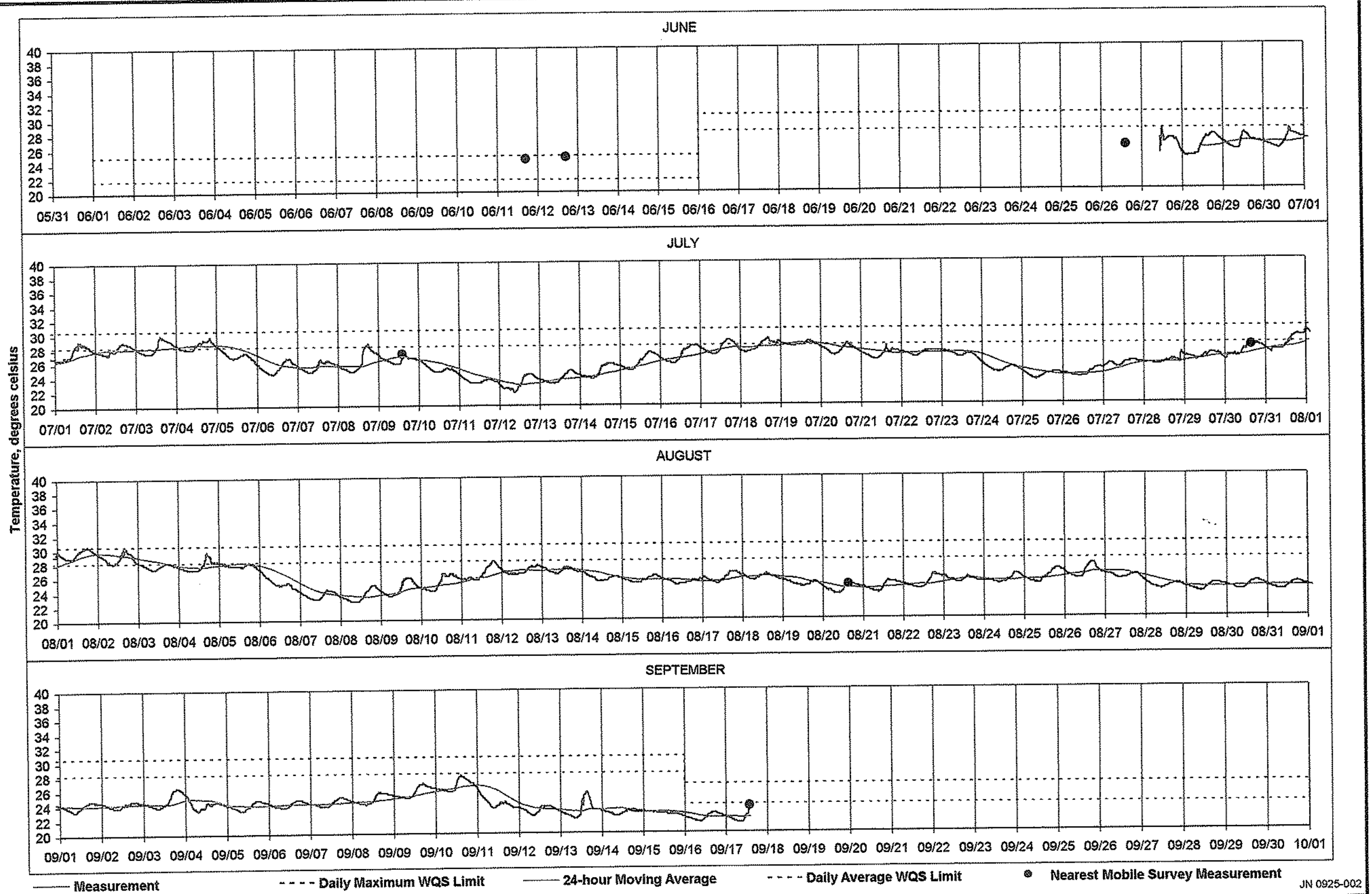
Fixed Station Temperatures, Station 18

FIGURE 2 - 44



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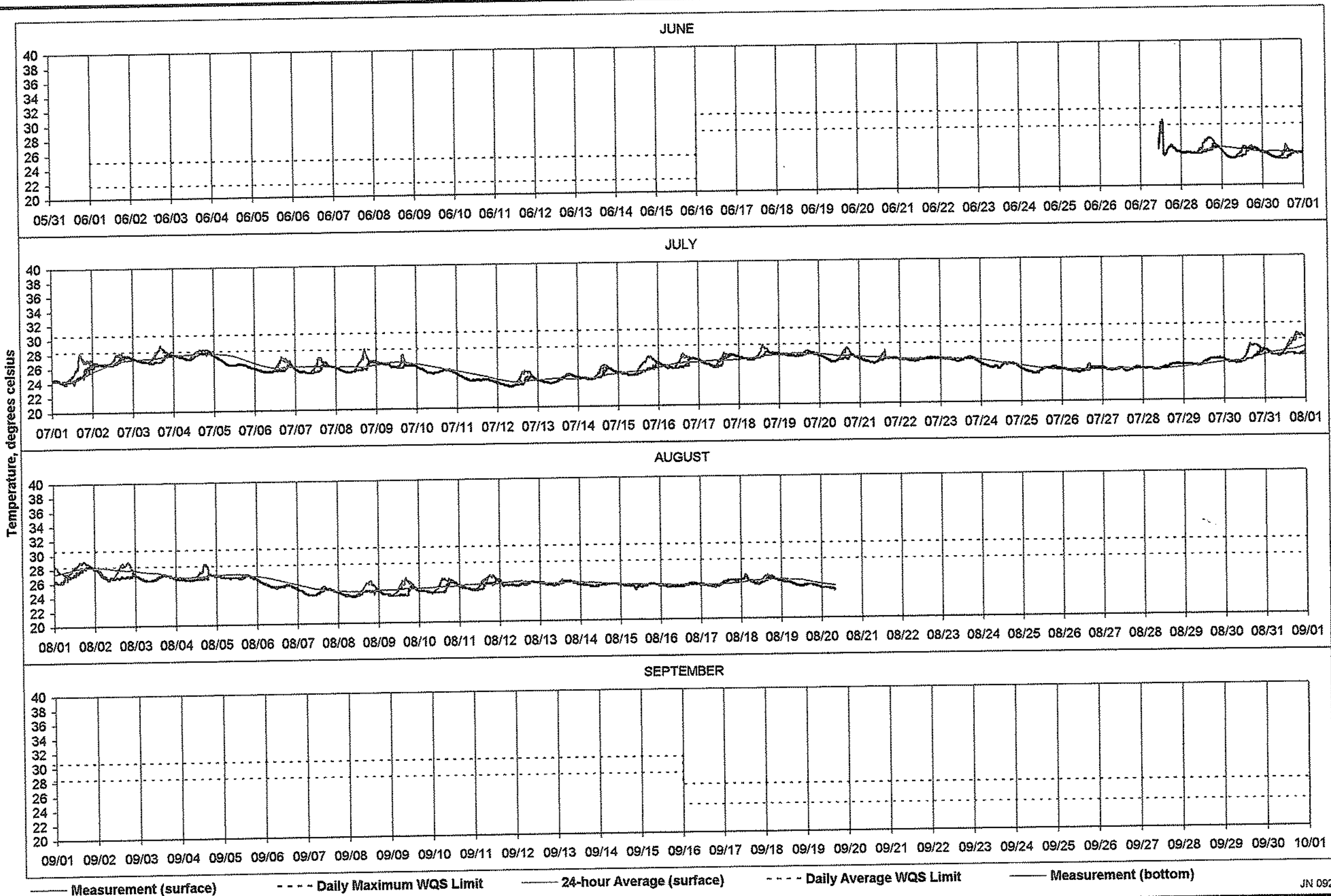
Fixed Station Temperatures, Station 19

FIGURE 2 - 45



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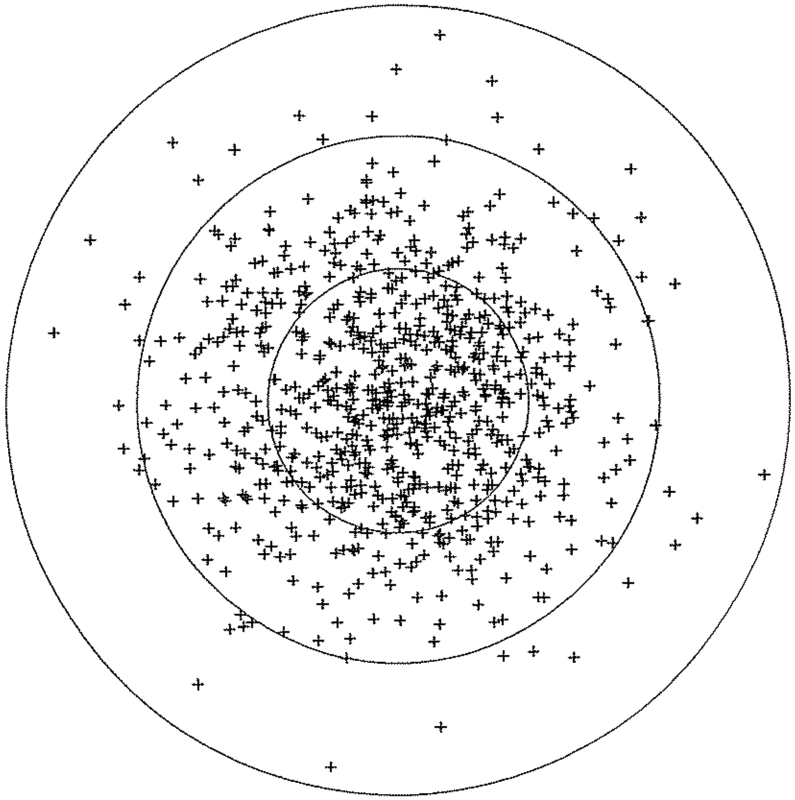
Fixed Station Temperatures, Station 21

FIGURE 2 - 47



The scatter plot shows all data collected during the test. Each point is plotted radially according to its magnitude (0-3 ft/sec), and located on the radar plot according to its direction (0-360 azimuth degrees). For example, a magnitude of 3 ft/sec at 0 degrees north would be plotted on the outermost radial gridline at the top of the plot.

Bin No	Depth (ft)	Seconds	Magnitude (ft/sec)		Direction (az deg)		
			Mean	SD	Mean	Disp	Sig?
1	4.16	258	0.52	1.05	41	76	Y
2	4.98	259	0.58	1.01	48	71	Y
3	5.80	214	0.43	1.03	45	83	Y
4	6.62	36	0.42	1.82	71	89	Y
5	7.44	0					
6	8.26	0					

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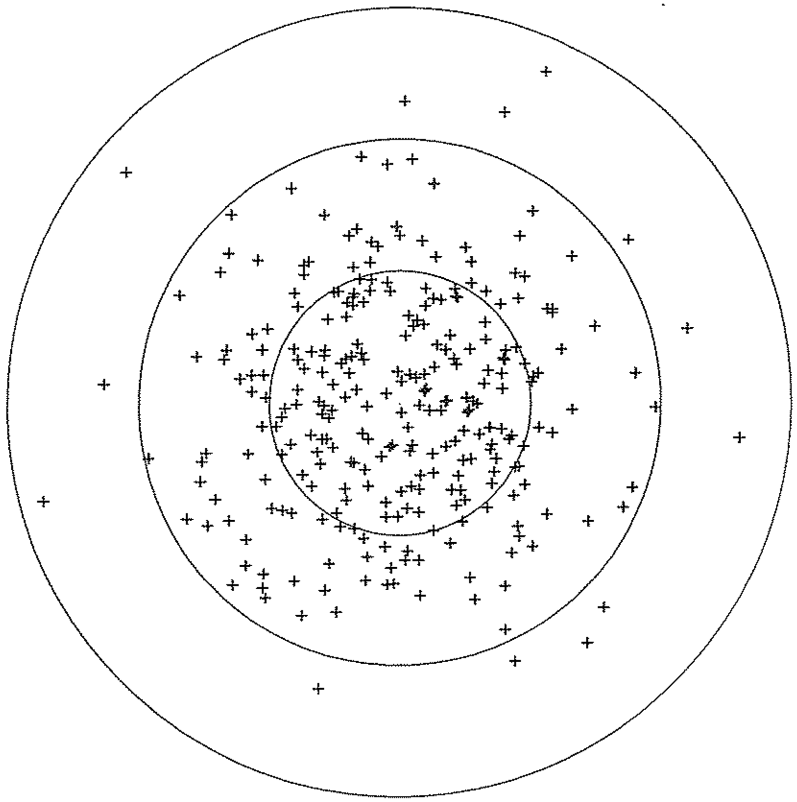
Stationary Velocity Test - 30 July 2002 (11:24)

FIGURE 2 - 48



The scatter plot shows all data collected during the test. Each point is plotted radially according to its magnitude (0-3 ft/sec), and located on the radar plot according to its direction (0-360 azimuth degrees). For example, a magnitude of 3 ft/sec at 0 degrees north would be plotted on the outermost radial gridline at the top of the plot.

Bin No	Depth (ft)	Seconds	Magnitude (ft/sec)		Direction (az deg)		
			Mean	SD	Mean	Disp	Sig?
1	4.16	158	0.03	1.09	231	139	N
2	4.98	118	0.17	1.28	336	114	N
3	5.80	6	0.52	0.76	66	70	N
4	6.62	0					
5	7.44	0					
6	8.26	0					

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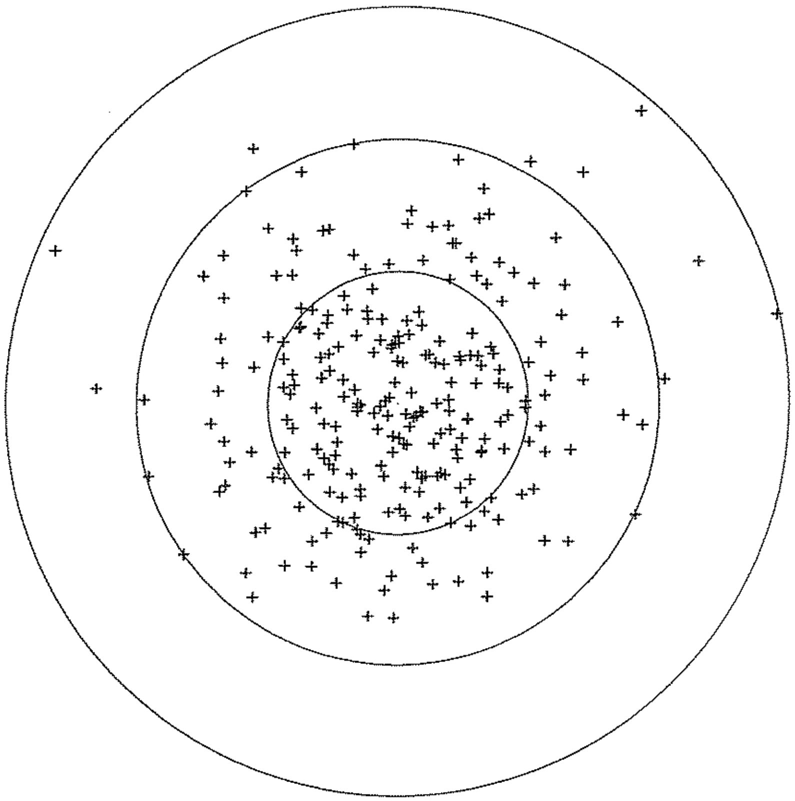
Stationary Velocity Test - 30 July 2002 (12:05)

FIGURE 2 - 49



The scatter plot shows all data collected during the test. Each point is plotted radially according to its magnitude (0-3 ft/sec), and located on the radar plot according to its direction (0-360 azimuth degrees). For example, a magnitude of 3 ft/sec at 0 degrees north would be plotted on the outermost radial gridline at the top of the plot.

Bin No	Depth (ft)	Seconds	Magnitude (ft/sec)		Direction (az deg)		
			Mean	SD	Mean	Disp	Sig?
1	4.16	183	0.05	1.12	343	144	N
2	4.98	69	0.24	1.15	277	113	N
3	5.80	0					
4	6.62	0					
5	7.44	0					
6	8.26	0					

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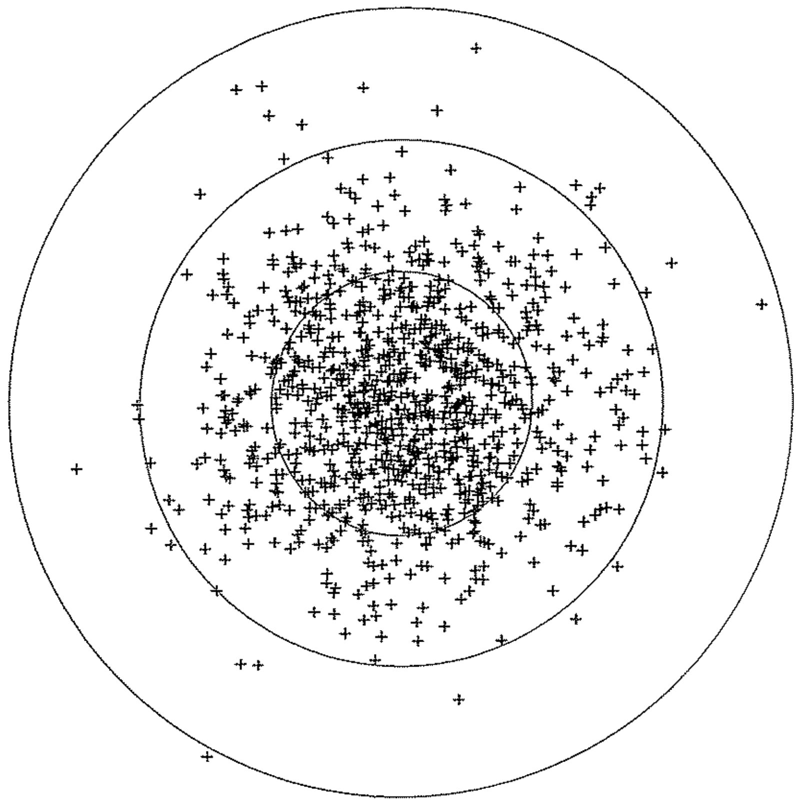
Stationary Velocity Test - 30 July 2002 (12:21)

FIGURE 2 - 50



The scatter plot shows all data collected during the test. Each point is plotted radially according to its magnitude (0-3 ft/sec), and located on the radar plot according to its direction (0-360 azimuth degrees). For example, a magnitude of 3 ft/sec at 0 degrees north would be plotted on the outermost radial gridline at the top of the plot.

Bin No	Depth (ft)	Seconds	Magnitude (ft/sec)		Direction (az deg)		
			Mean	SD	Mean	Disp	Sig?
1	4.16	288	0.07	1.00	344	131	N
2	4.98	289	0.16	0.99	324	114	Y
3	5.80	286	0.22	1.01	290	106	Y
4	6.62	103	0.14	1.40	308	137	N
5	7.44	0					
6	8.26	0					

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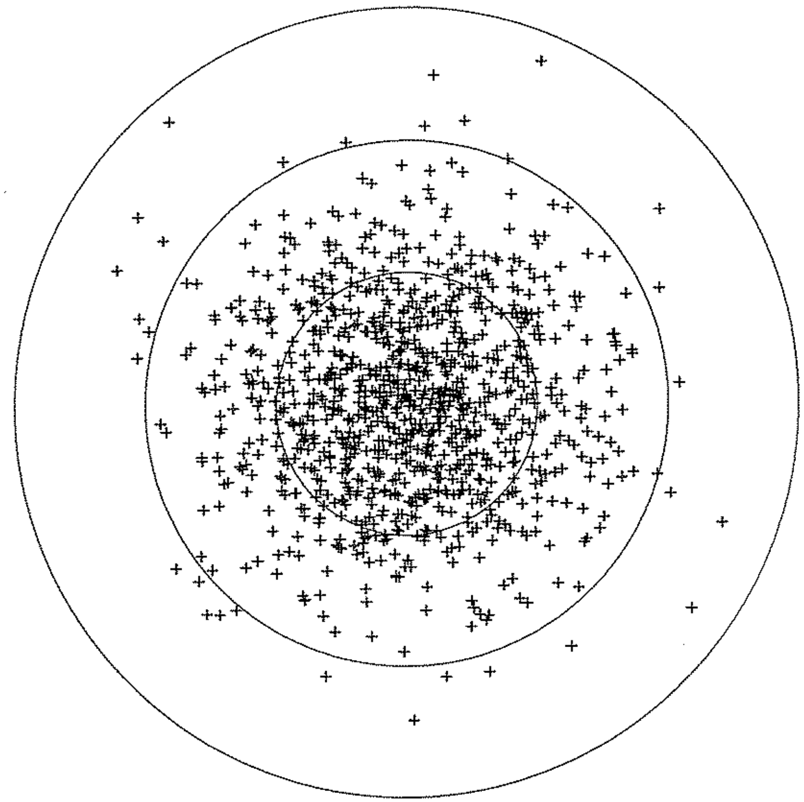
Stationary Velocity Test - 30 July 2002 (12:53)

FIGURE 2 - 51



The scatter plot shows all data collected during the test. Each point is plotted radially according to its magnitude (0-3 ft/sec), and located on the radar plot according to its direction (0-360 azimuth degrees). For example, a magnitude of 3 ft/sec at 0 degrees north would be plotted on the outermost radial gridline at the top of the plot.

Bin No	Depth (ft)	Seconds	Magnitude (ft/sec)		Direction (az deg)		
			Mean	SD	Mean	Disp	Sig?
1	4.16	333	0.15	1.03	316	112	Y
2	4.98	334	0.04	1.03	353	150	N
3	5.80	335	0.03	1.04	308	165	N
4	6.62	13	0.47	1.98	2	84	N
5	7.44	0					
6	8.26	0					

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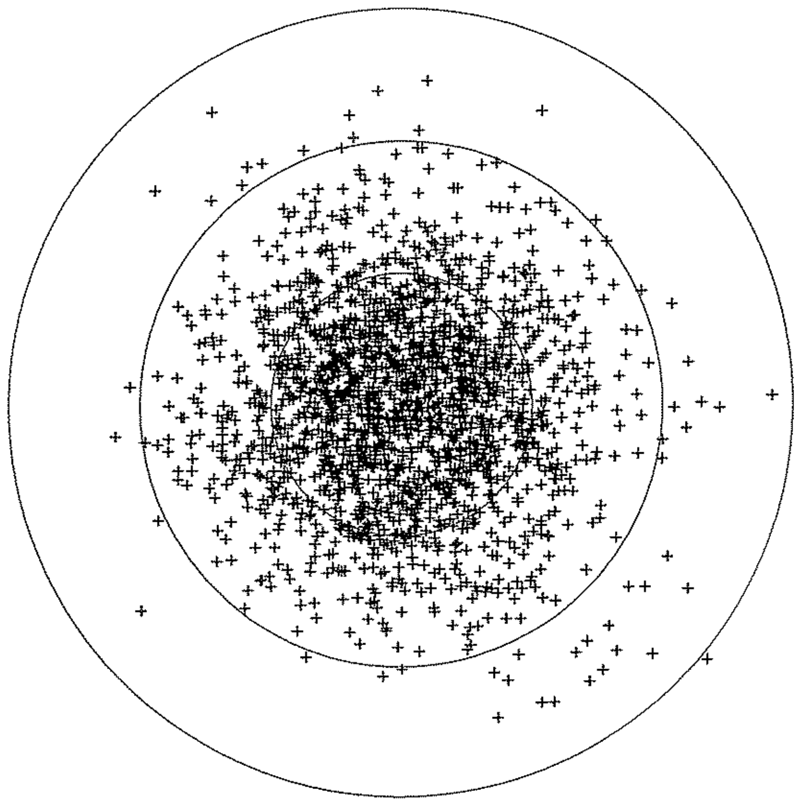
Stationary Velocity Test - 30 July 2002 (13:29)

FIGURE 2 - 52



The scatter plot shows all data collected during the test. Each point is plotted radially according to its magnitude (0-3 ft/sec), and located on the radar plot according to its direction (0-360 azimuth degrees). For example, a magnitude of 3 ft/sec at 0 degrees north would be plotted on the outermost radial gridline at the top of the plot.

Bin No	Depth (ft)	Seconds	Magnitude (ft/sec)		Direction (az deg)		
			Mean	SD	Mean	Disp	Sig?
1	4.16	466	0.11	1.03	179	122	Y
2	4.98	456	0.12	1.00	159	119	Y
3	5.80	466	0.11	0.98	177	126	Y
4	6.62	459	0.08	1.06	292	135	N
5	7.44	37	0.46	1.63	260	98	N
6	8.26	0					

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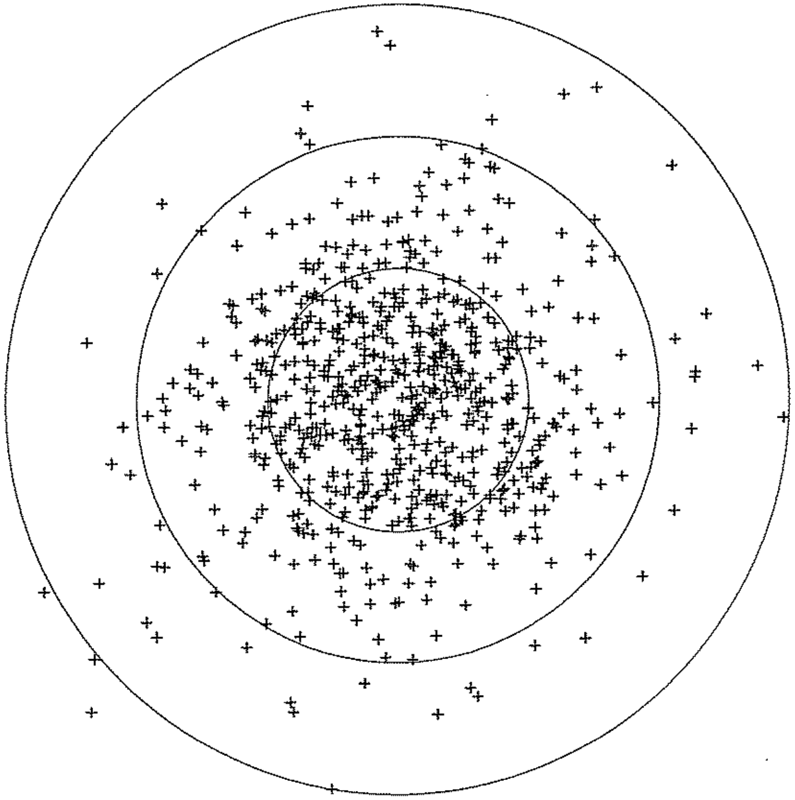
Stationary Velocity Test - 30 July 2002 (14:04)

FIGURE 2 - 53



The scatter plot shows all data collected during the test. Each point is plotted radially according to its magnitude (0-3 ft/sec), and located on the radar plot according to its direction (0-360 azimuth degrees). For example, a magnitude of 3 ft/sec at 0 degrees north would be plotted on the outermost radial gridline at the top of the plot.

Bin No	Depth (ft)	Seconds	Magnitude (ft/sec) Mean	Magnitude (ft/sec) SD	Direction (az deg) Mean	Direction (az deg) Disp	Direction (az deg) Sig?
1	4.16	215	0.19	1.24	155	117	Y
2	4.98	212	0.09	1.09	33	140	N
3	5.80	232	0.03	1.14	25	141	N
4	6.62	21	0.03	1.51	114	135	N
5	7.44	0					
6	8.26	0					

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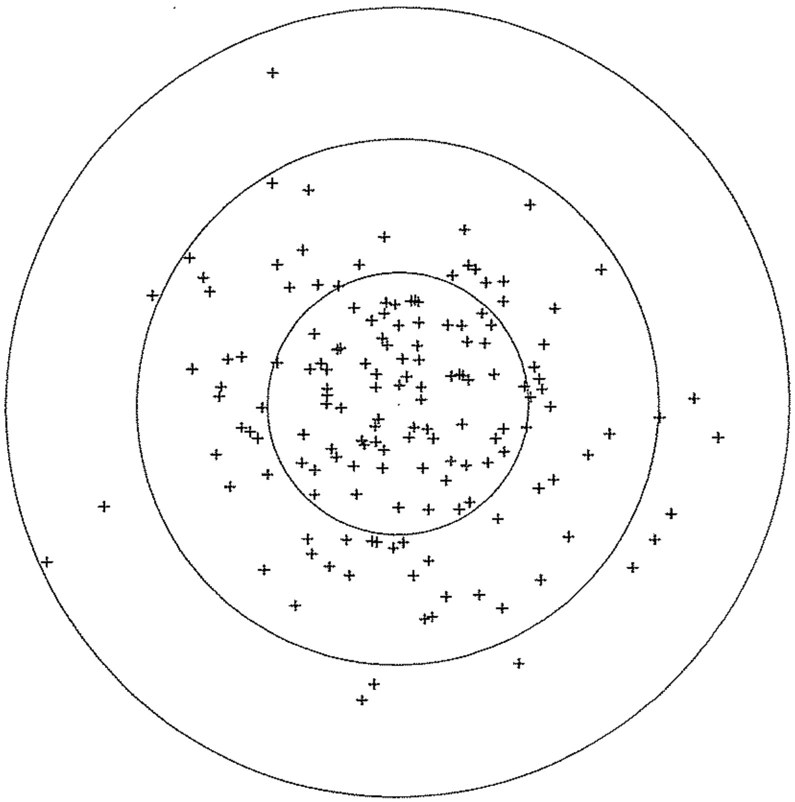
Stationary Velocity Test - 30 July 2002 (15:30)

FIGURE 2 - 54



The scatter plot shows all data collected during the test. Each point is plotted radially according to its magnitude (0-3 ft/sec), and located on the radar plot according to its direction (0-360 azimuth degrees). For example, a magnitude of 3 ft/sec at 0 degrees north would be plotted on the outermost radial gridline at the top of the plot.

Bin No	Depth (ft)	Seconds	Magnitude (ft/sec)		Direction (az deg)		
			Mean	SD	Mean	Disp	Sig?
1	4.16	159	0.26	1.24	53	108	Y
2	4.98	0					
3	5.80	0					
4	6.62	0					
5	7.44	0					
6	8.26	0					

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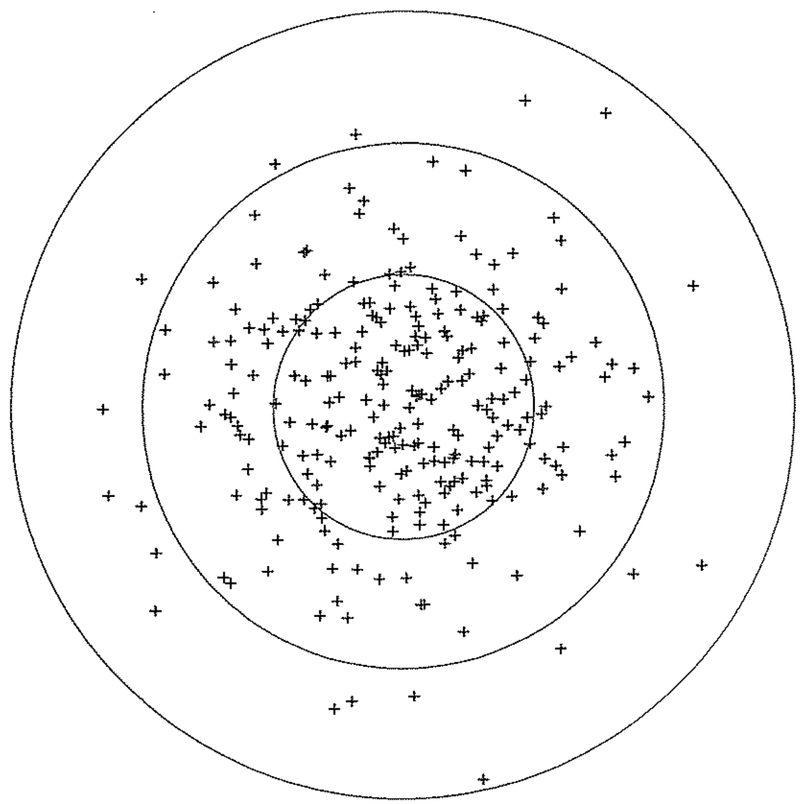
Stationary Velocity Test - 20 August 2002 (11:08)

FIGURE 2 - 55



The scatter plot shows all data collected during the test. Each point is plotted radially according to its magnitude (0-3 ft/sec), and located on the radar plot according to its direction (0-360 azimuth degrees). For example, a magnitude of 3 ft/sec at 0 degrees north would be plotted on the outermost radial gridline at the top of the plot.

Bin No	Depth (ft)	Seconds	Magnitude (ft/sec)		Direction (az deg)		
			Mean	SD	Mean	Disp	Sig?
1	4.16	184	0.18	1.07	104	107	Y
2	4.98	76	0.22	1.53	63	114	N
3	5.80	0					
4	6.62	0					
5	7.44	0					
6	8.26	0					

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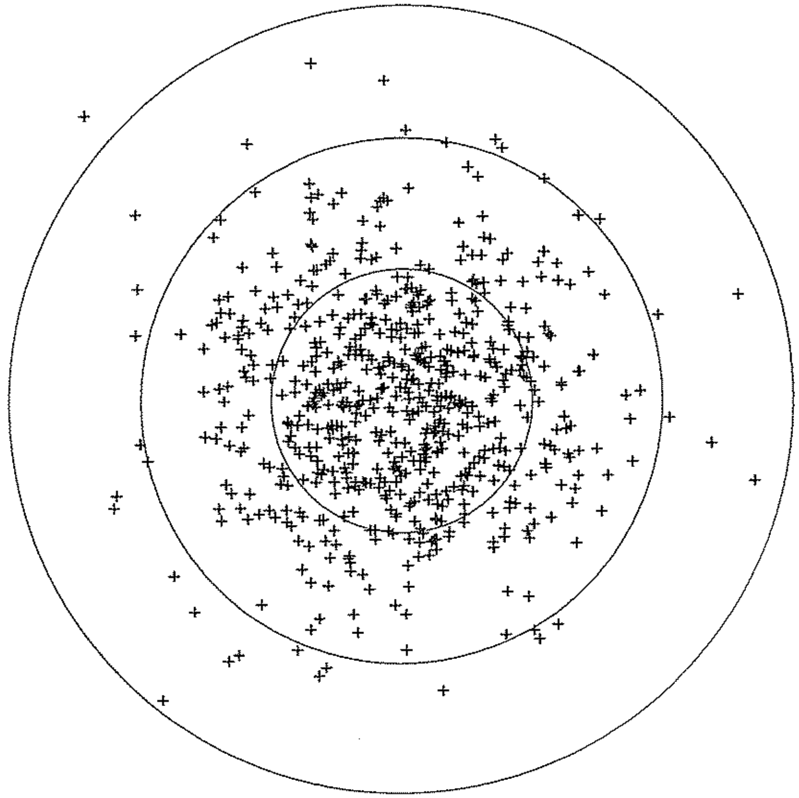
Stationary Velocity Test - 20 August 2002 (11:43)

FIGURE 2 - 56



The scatter plot shows all data collected during the test. Each point is plotted radially according to its magnitude (0-3 ft/sec), and located on the radar plot according to its direction (0-360 azimuth degrees). For example, a magnitude of 3 ft/sec at 0 degrees north would be plotted on the outermost radial gridline at the top of the plot.

Bin No	Depth (ft)	Seconds	Magnitude (ft/sec)		Direction (az deg)		
			Mean	SD	Mean	Disp	Sig?
1	4.16	209	0.15	1.08	335	128	N
2	4.98	204	0.25	1.04	48	102	Y
3	5.80	201	0.21	1.09	20	104	Y
4	6.62	29	0.14	1.68	0	139	N
5	7.44	0					
6	8.26	0					

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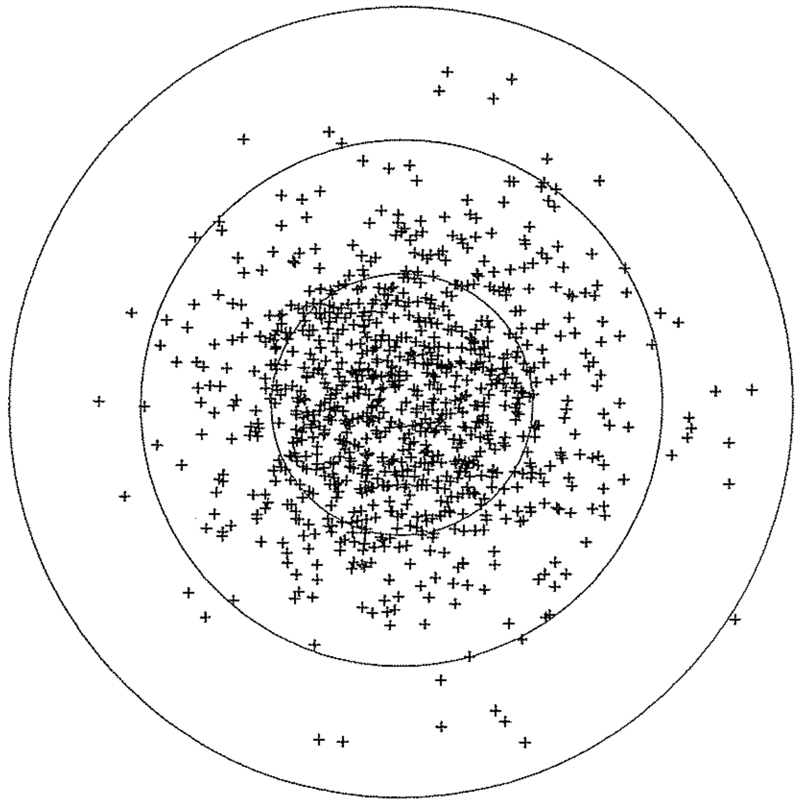
Stationary Velocity Test - 20 August 2002 (12:19)

FIGURE 2 - 57



The scatter plot shows all data collected during the test. Each point is plotted radially according to its magnitude (0-3 ft/sec), and located on the radar plot according to its direction (0-360 azimuth degrees). For example, a magnitude of 3 ft/sec at 0 degrees north would be plotted on the outermost radial gridline at the top of the plot.

Bin No	Depth (ft)	Seconds	Magnitude (ft/sec)		Direction (az deg)		
			Mean	SD	Mean	Disp	Sig?
1	4.16	224	0.17	1.07	352	107	Y
2	4.98	224	0.23	1.05	26	101	Y
3	5.80	234	0.16	0.97	45	110	Y
4	6.62	237	0.24	1.06	74	101	Y
5	7.44	49	0.42	1.36	85	84	Y
6	8.26	1	1.92	#DIV/0!	179	0	#N/A

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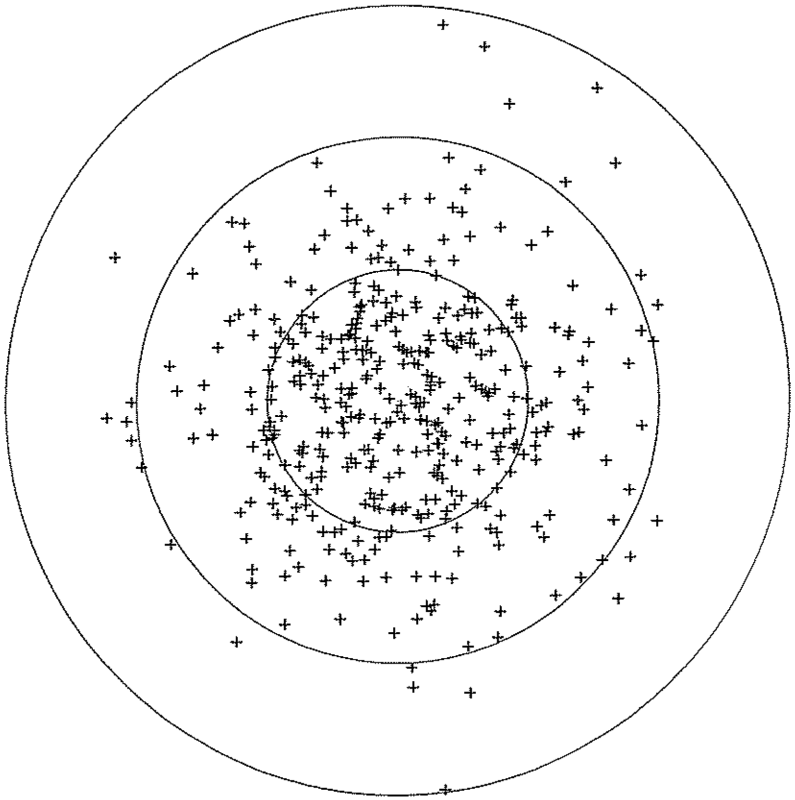
Stationary Velocity Test - 20 August 2002 (13:23)

FIGURE 2 - 58



The scatter plot shows all data collected during the test. Each point is plotted radially according to its magnitude (0-3 ft/sec), and located on the radar plot according to its direction (0-360 azimuth degrees). For example, a magnitude of 3 ft/sec at 0 degrees north would be plotted on the outermost radial gridline at the top of the plot.

Bin No	Depth (ft)	Seconds	Magnitude (ft/sec)		Direction (az deg)		
			Mean	SD	Mean	Disp	Sig?
1	4.16	176	0.06	1.19	314	130	N
2	4.98	188	0.22	1.11	89	112	Y
3	5.80	52	0.24	1.52	8	124	N
4	6.62	1	0.38	#DIV/0!	228	0	#N/A
5	7.44	0					
6	8.26	0					

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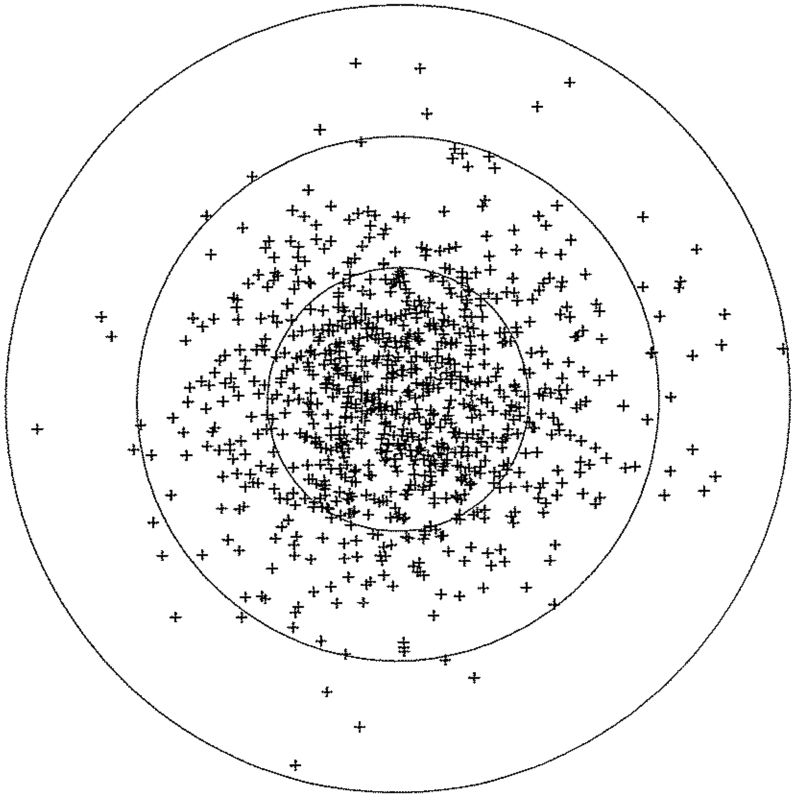
Stationary Velocity Test - 20 August 2002 (14:00)

FIGURE 2 - 59



The scatter plot shows all data collected during the test. Each point is plotted radially according to its magnitude (0-3 ft/sec), and located on the radar plot according to its direction (0-360 azimuth degrees). For example, a magnitude of 3 ft/sec at 0 degrees north would be plotted on the outermost radial gridline at the top of the plot.

Bin No	Depth (ft)	Seconds	Magnitude (ft/sec)		Direction (az deg)		
			Mean	SD	Mean	Disp	Sig?
1	4.16	212	0.14	1.12	231	124	N
2	4.98	203	0.06	1.03	175	131	N
3	5.80	228	0.04	1.03	29	138	N
4	6.62	249	0.16	1.06	227	112	Y
5	7.44	16	0.42	1.74	70	94	N
6	8.26	0					

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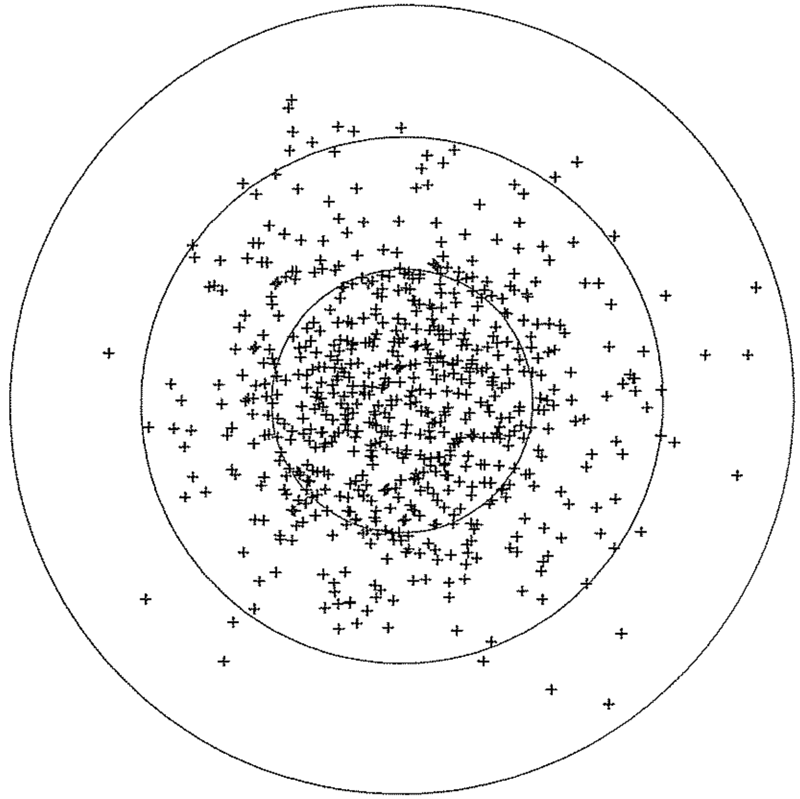
Stationary Velocity Test - 20 August 2002 (14:35)

FIGURE 2 - 60



The scatter plot shows all data collected during the test. Each point is plotted radially according to its magnitude (0-3 ft/sec), and located on the radar plot according to its direction (0-360 azimuth degrees). For example, a magnitude of 3 ft/sec at 0 degrees north would be plotted on the outermost radial gridline at the top of the plot.

Bin No	Depth (ft)	Seconds	Magnitude (ft/sec)		Direction (az deg)		
			Mean	SD	Mean	Disp	Sig?
1	4.16	188	0.21	1.14	297	107	Y
2	4.98	228	0.10	1.06	268	129	N
3	5.80	219	0.02	1.12	63	162	N
4	6.62	40	0.32	1.17	244	95	N
5	7.44	0					
6	8.26	0					

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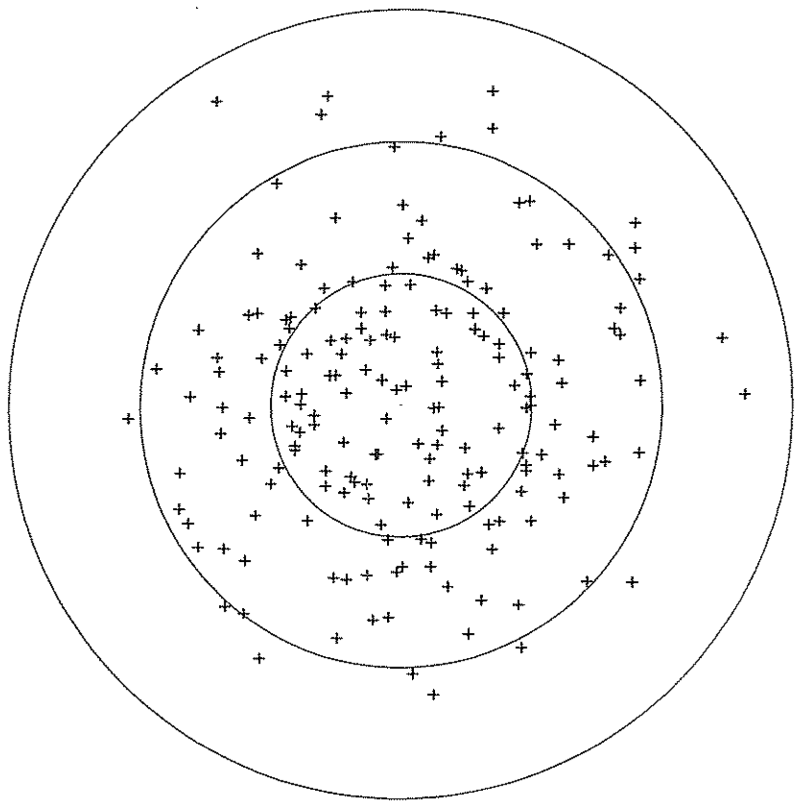
Stationary Velocity Test - 20 August 2002 (15:09)

FIGURE 2 - 61



The scatter plot shows all data collected during the test. Each point is plotted radially according to its magnitude (0-3 ft/sec), and located on the radar plot according to its direction (0-360 azimuth degrees). For example, a magnitude of 3 ft/sec at 0 degrees north would be plotted on the outermost radial gridline at the top of the plot.

Bin No	Depth (ft)	Seconds	Magnitude (ft/sec)		Direction (az deg)		
			Mean	SD	Mean	Disp	Sig?
1	4.16	182	0.22	1.34	114	111	Y
2	4.98	0					
3	5.80	0					
4	6.62	0					
5	7.44	0					
6	8.26	0					

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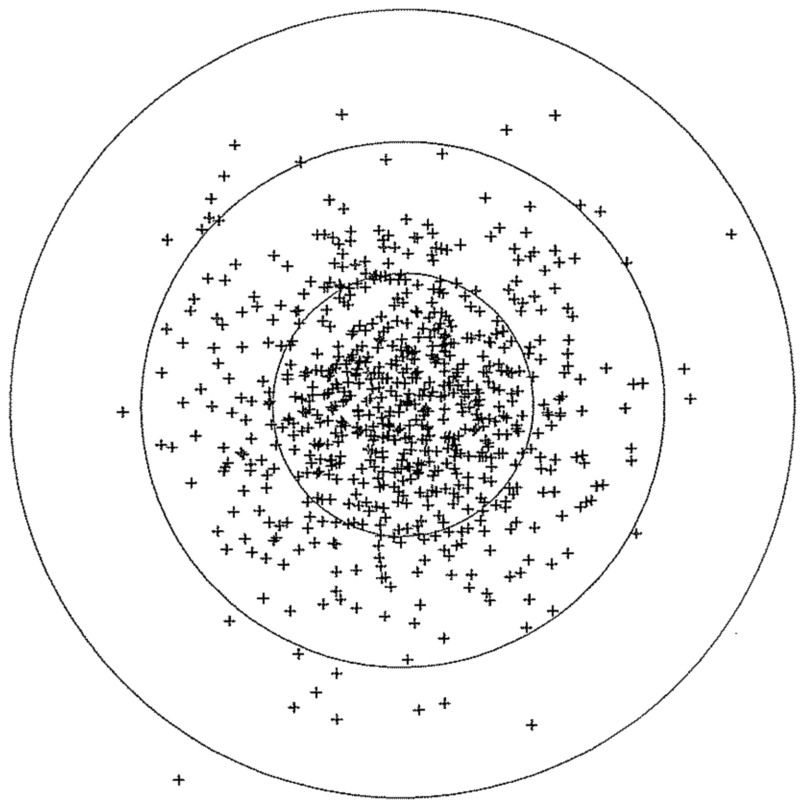
Stationary Velocity Test - 17 September 2002 (09:43)

FIGURE 2 - 62



The scatter plot shows all data collected during the test. Each point is plotted radially according to its magnitude (0-3 ft/sec), and located on the radar plot according to its direction (0-360 azimuth degrees). For example, a magnitude of 3 ft/sec at 0 degrees north would be plotted on the outermost radial gridline at the top of the plot.

Bin No	Depth (ft)	Seconds	Magnitude (ft/sec)		Direction (az deg)		
			Mean	SD	Mean	Disp	Sig?
1	4.16	344	0.05	1.00	261	140	N
2	4.98	346	0.03	1.02	4	142	N
3	5.80	32	0.10	1.95	190	123	N
4	6.62	0					
5	7.44	0					
6	8.26	0					

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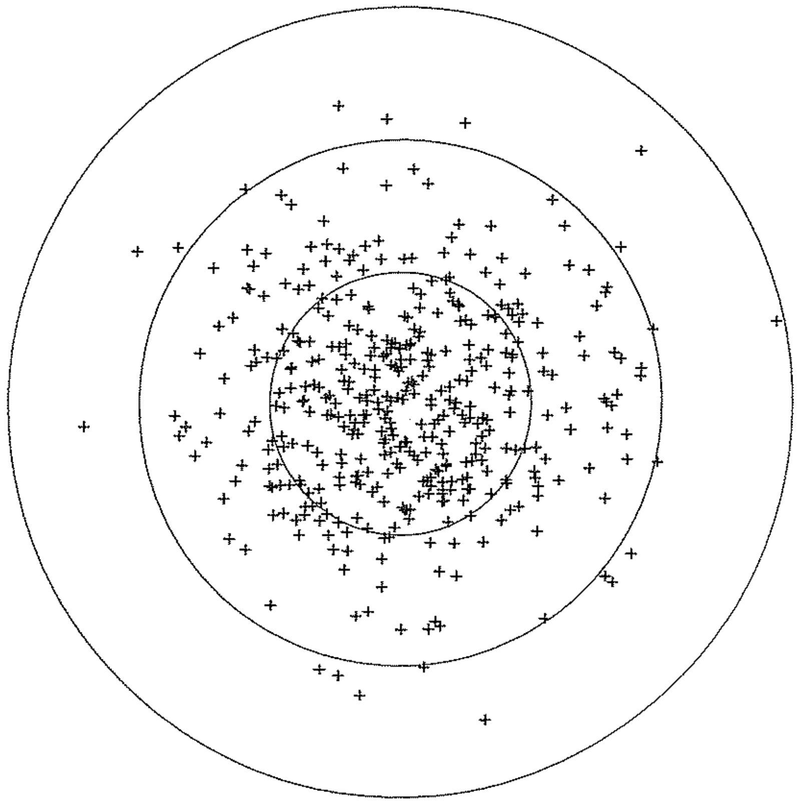
FirstEnergy Corp, Toledo Edison Bay Shore Station

Stationary Velocity Test - 17 September 2002 (10:15)

FIGURE 2 - 63



The scatter plot shows all data collected during the test. Each point is plotted radially according to its magnitude (0-3 ft/sec), and located on the radar plot according to its direction (0-360 azimuth degrees). For example, a magnitude of 3 ft/sec at 0 degrees north would be plotted on the outermost radial gridline at the top of the plot.

Bin No	Depth (ft)	Seconds	Magnitude (ft/sec)		Direction (az deg)		
			Mean	SD	Mean	Disp	Sig?
1	4.16	200	0.10	1.02	190	132	N
2	4.98	199	0.27	1.05	161	103	Y
3	5.80	25	0.34	1.50	187	103	N
4	6.62	0					
5	7.44	0					
6	8.26	0					

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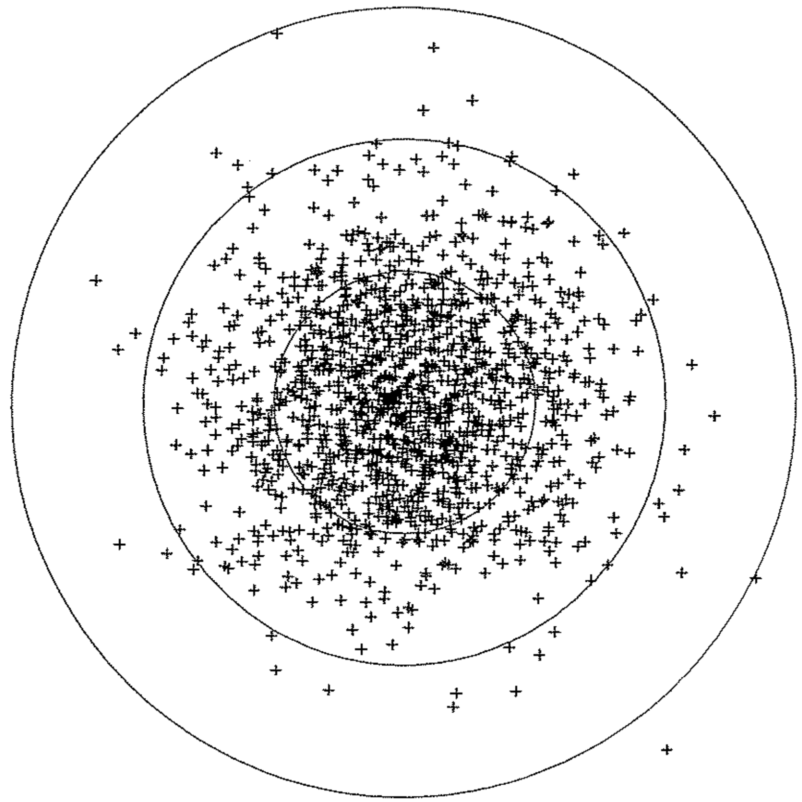
Stationary Velocity Test - 17 September 2002 (10:49)

FIGURE 2 - 64



The scatter plot shows all data collected during the test. Each point is plotted radially according to its magnitude (0-3 ft/sec), and located on the radar plot according to its direction (0-360 azimuth degrees). For example, a magnitude of 3 ft/sec at 0 degrees north would be plotted on the outermost radial gridline at the top of the plot.

Bin No	Depth (ft)	Seconds	Magnitude (ft/sec)		Direction (az deg)		
			Mean	SD	Mean	Disp	Sig?
1	4.16	405	0.08	1.03	358	125	Y
2	4.98	419	0.13	1.03	312	114	Y
3	5.80	421	0.11	1.05	311	131	N
4	6.62	60	0.29	1.42	358	103	N
5	7.44	0					
6	8.26	0					

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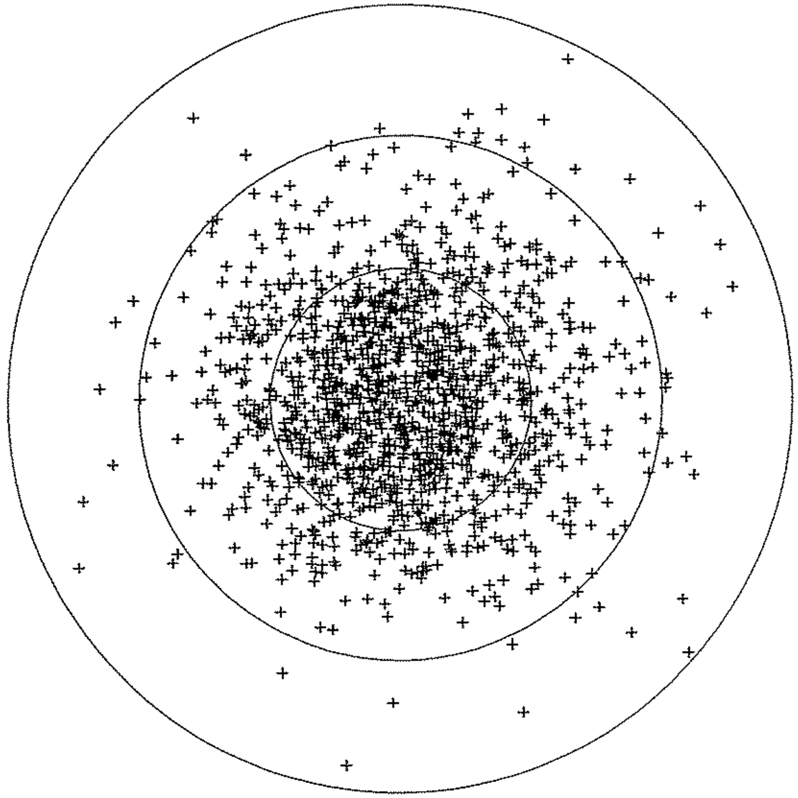
Stationary Velocity Test - 17 September 2002 (11:29)

FIGURE 2 - 65



The scatter plot shows all data collected during the test. Each point is plotted radially according to its magnitude (0-3 ft/sec), and located on the radar plot according to its direction (0-360 azimuth degrees). For example, a magnitude of 3 ft/sec at 0 degrees north would be plotted on the outermost radial gridline at the top of the plot.

Bin No	Depth (ft)	Seconds	Magnitude (ft/sec)		Direction (az deg)		
			Mean	SD	Mean	Disp	Sig?
1	4.16	384	0.16	1.08	135	111	Y
2	4.98	395	0.16	1.01	109	117	Y
3	5.80	403	0.02	1.02	214	161	N
4	6.62	67	0.03	1.53	145	135	N
5	7.44	0					
6	8.26	0					

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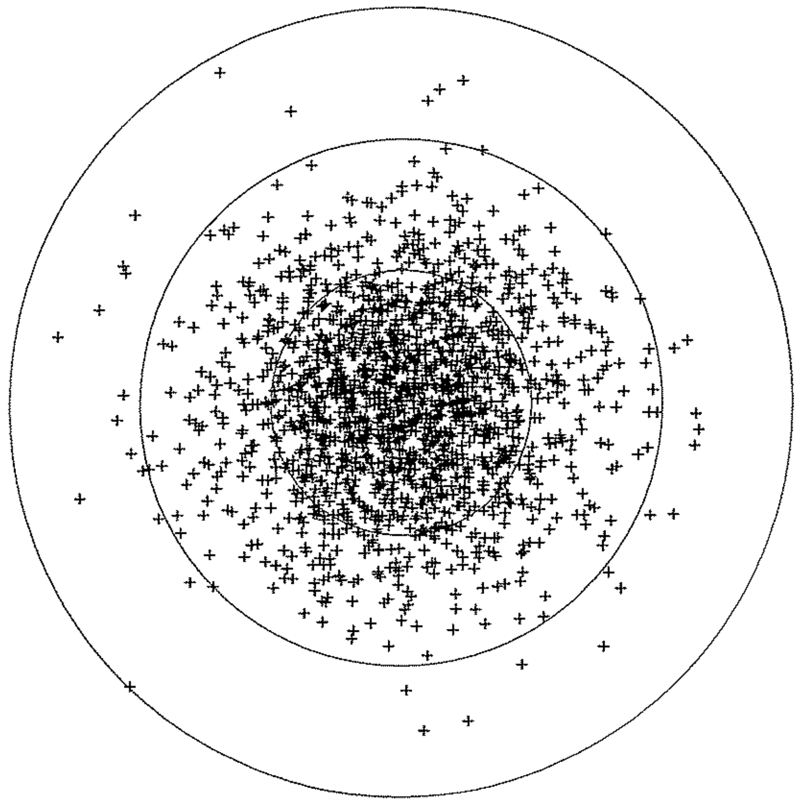
Stationary Velocity Test - 17 September 2002 (12:04)

FIGURE 2 - 66



The scatter plot shows all data collected during the test. Each point is plotted radially according to its magnitude (0-3 ft/sec), and located on the radar plot according to its direction (0-360 azimuth degrees). For example, a magnitude of 3 ft/sec at 0 degrees north would be plotted on the outermost radial gridline at the top of the plot.

Bin No	Depth (ft)	Seconds	Magnitude (ft/sec)		Direction (az deg)		
			Mean	SD	Mean	Disp	Sig?
1	4.16	319	0.10	0.98	164	123	Y
2	4.98	323	0.06	1.01	54	132	N
3	5.80	325	0.08	0.99	57	135	N
4	6.62	323	0.12	1.04	316	125	N
5	7.44	324	0.05	0.97	309	142	N
6	8.26	7	0.78	1.77	282	64	N

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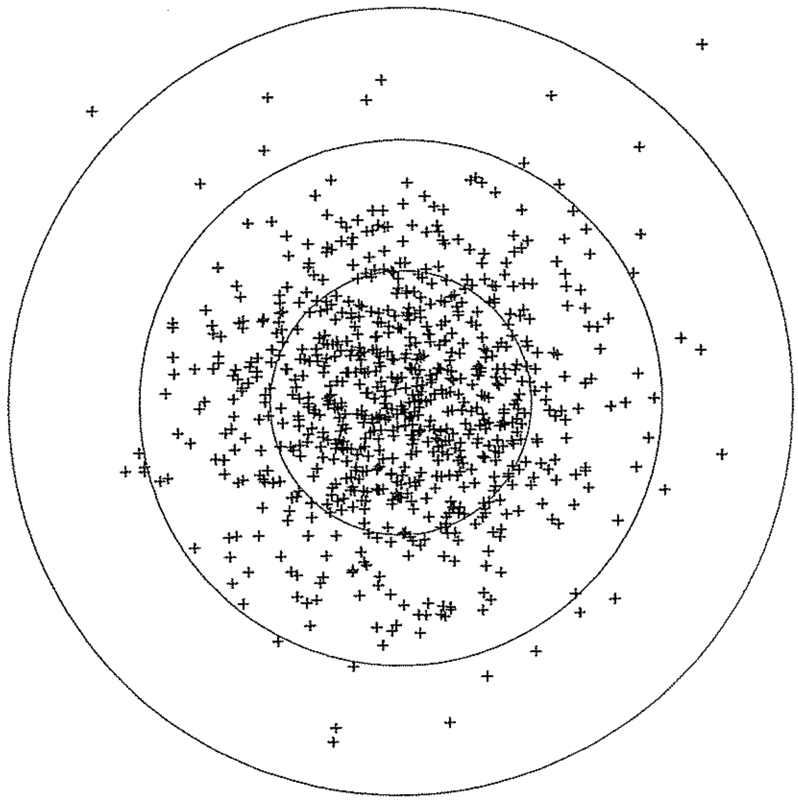
Stationary Velocity Test - 17 September 2002 (12:46)

FIGURE 2 - 67



The scatter plot shows all data collected during the test. Each point is plotted radially according to its magnitude (0-3 ft/sec), and located on the radar plot according to its direction (0-360 azimuth degrees). For example, a magnitude of 3 ft/sec at 0 degrees north would be plotted on the outermost radial gridline at the top of the plot.

Bin No	Depth (ft)	Seconds	Magnitude (ft/sec)		Direction (az deg)		
			Mean	SD	Mean	Disp	Sig?
1	4.16	376	0.06	1.06	287	143	N
2	4.98	397	0.07	1.08	256	136	N
3	5.80	32	0.57	1.87	10	87	Y
4	6.62	0					
5	7.44	0					
6	8.26	0					

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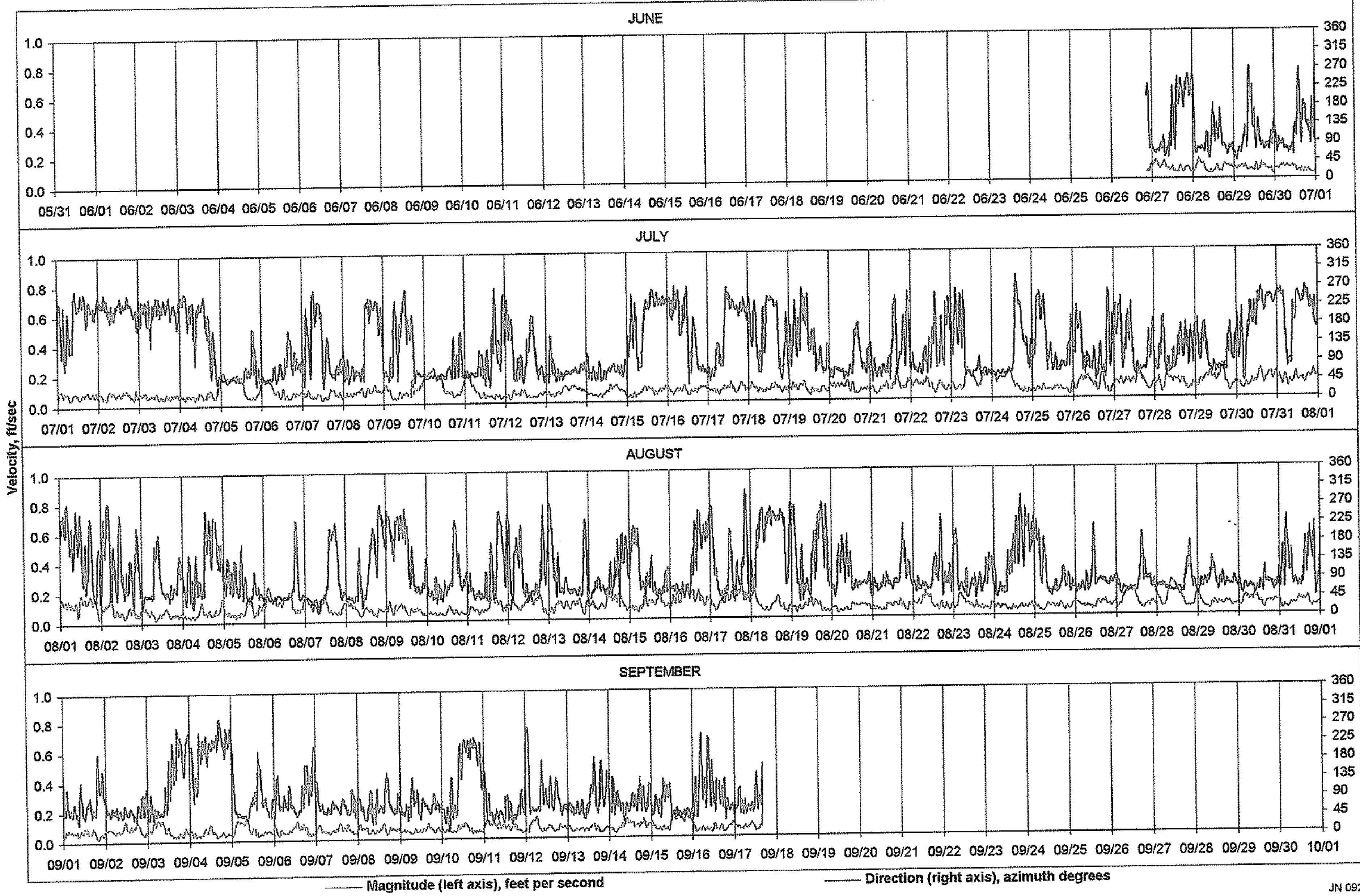
Stationary Velocity Test - 17 September 2002 (13:26)

FIGURE 2 - 68



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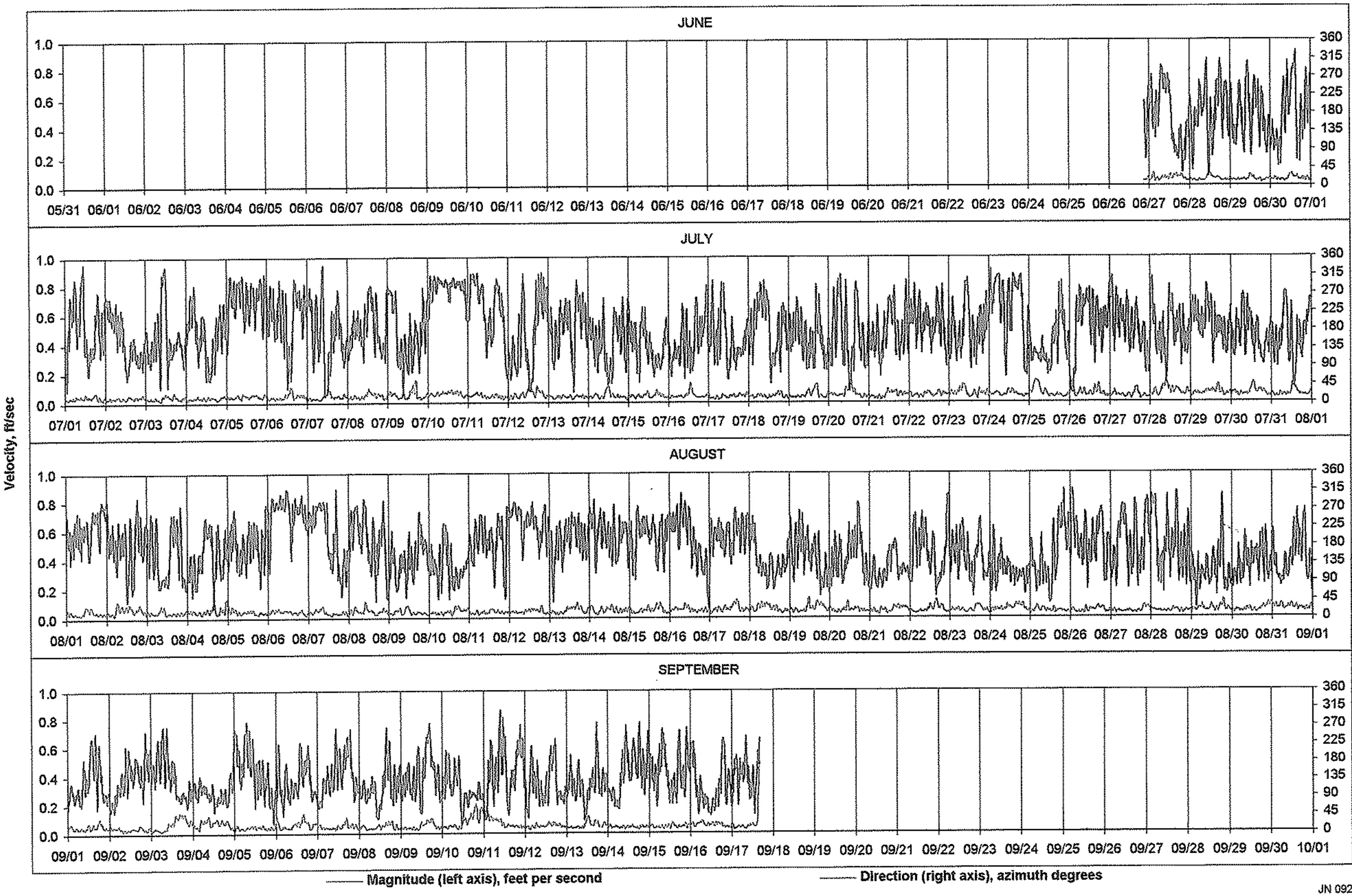
FirstEnergy Corp, Toledo Edison Bay Shore Station

Fixed Station Velocity, Station 22 (northern shore)

FIGURE 2 - 69



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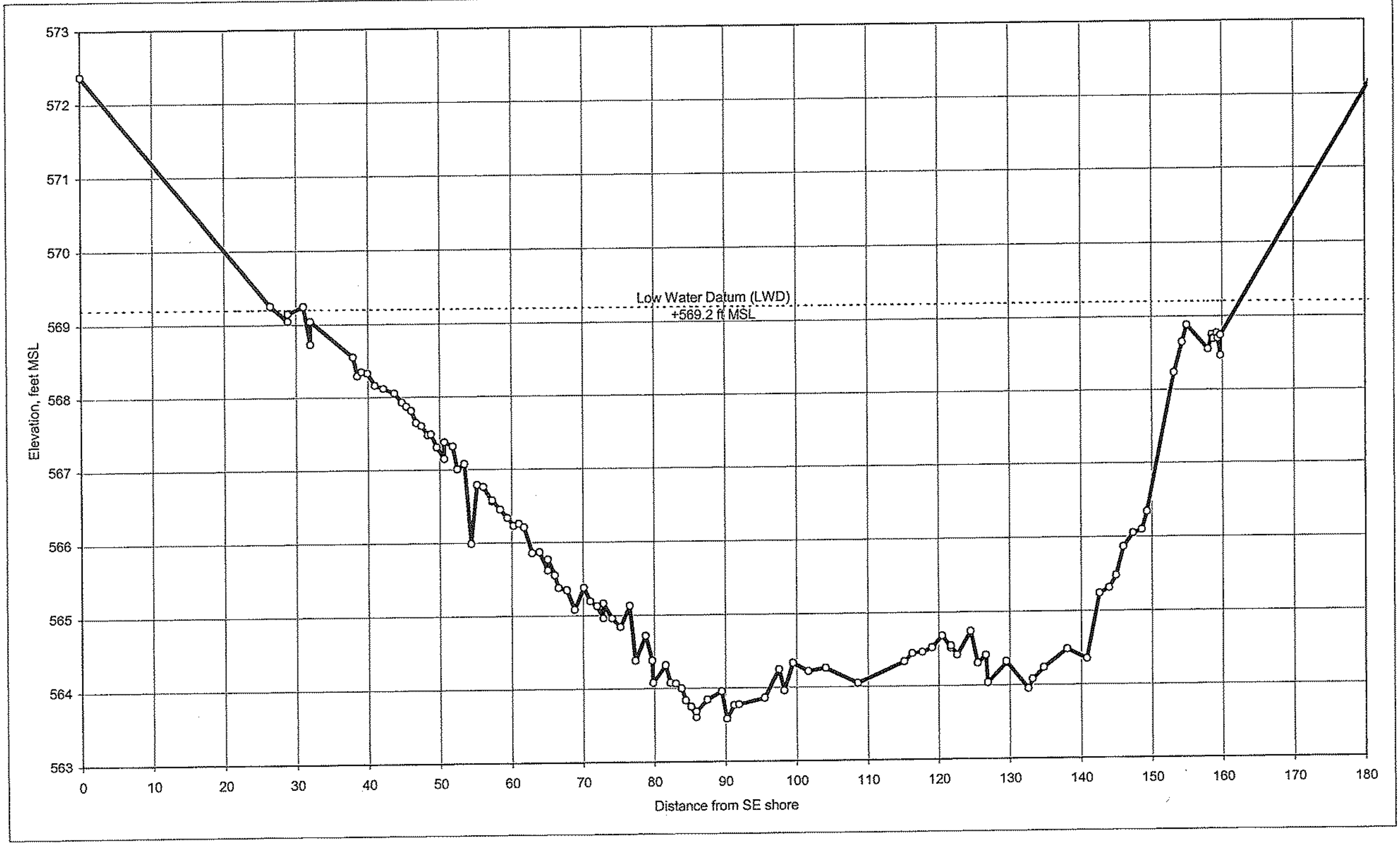
Fixed Station Velocity, Station 23 (southern shore)

FIGURE 2 - 70



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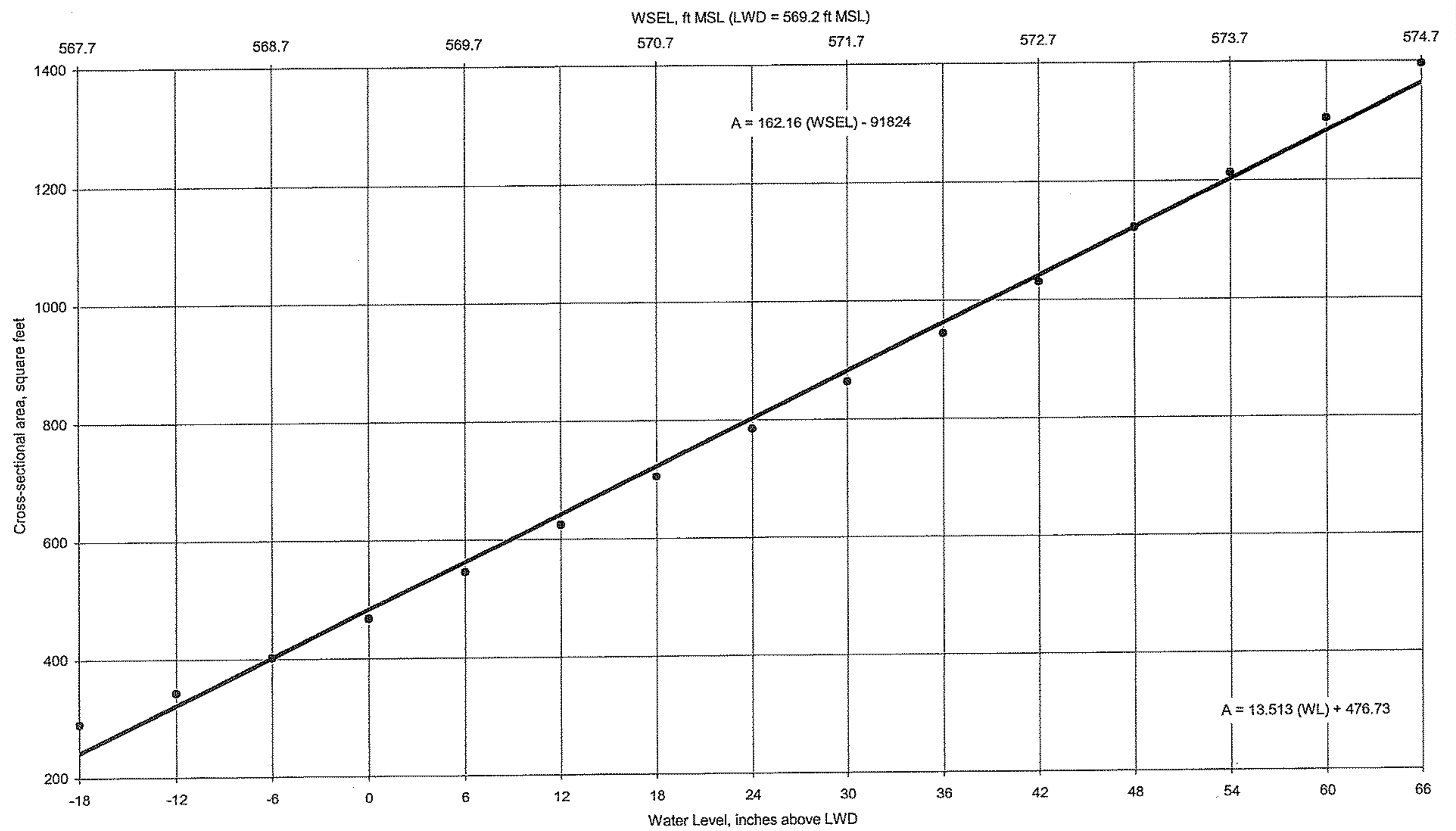
Discharge Canal Cross-Section (View Up-Current)

FIGURE 2 - 71



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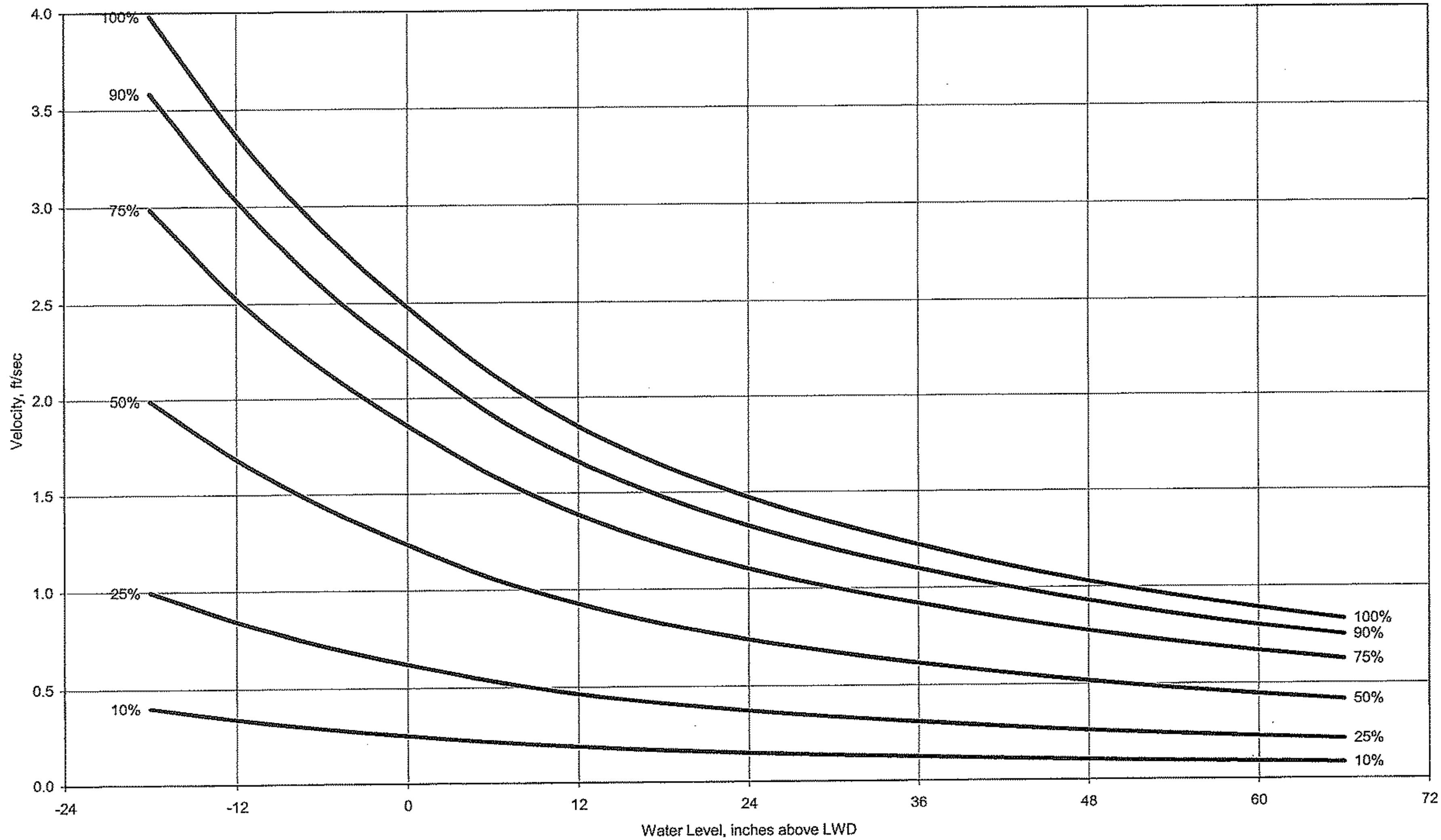
Discharge Canal Cross-Sectional Area vs Water Level

FIGURE 2 - 72



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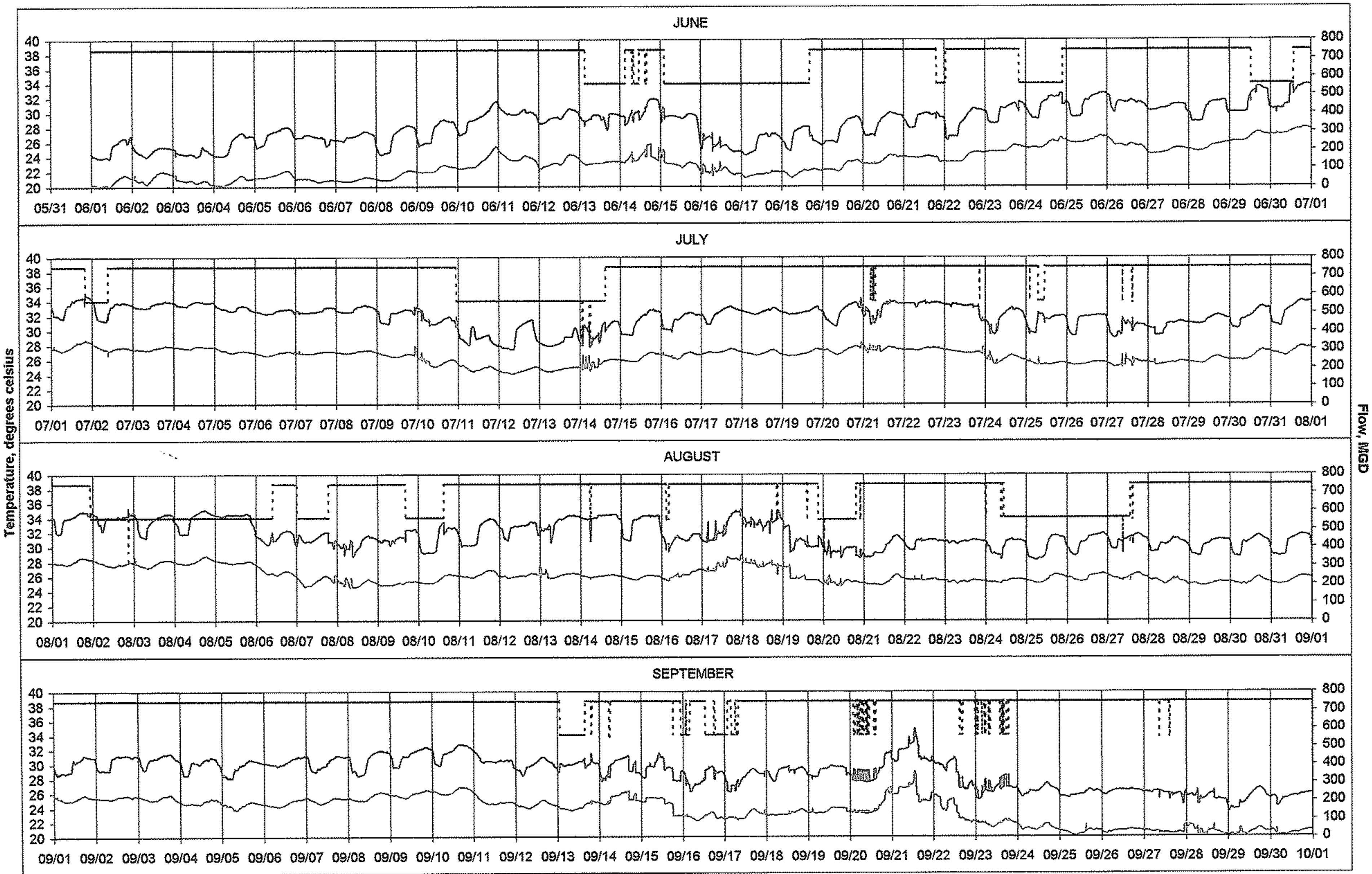
Mean Discharge Velocity for Percent Maximum Plant Flow

FIGURE 2 - 73



——— Intake Temperature ——— Discharge Temperature - - - - Plant Flow

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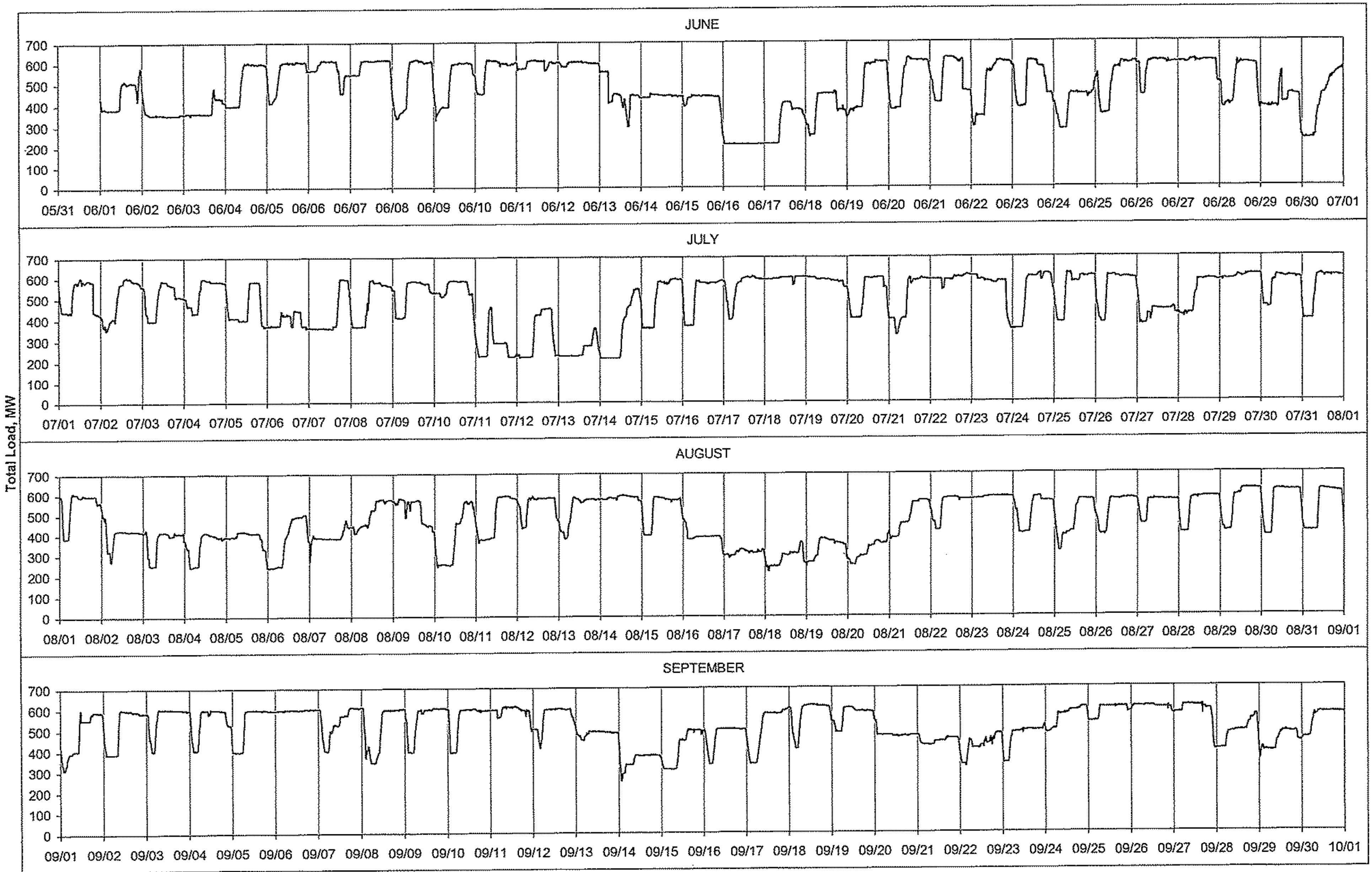
Station Intake Temperature, Discharge Temperature, and Flow

FIGURE 2 - 74



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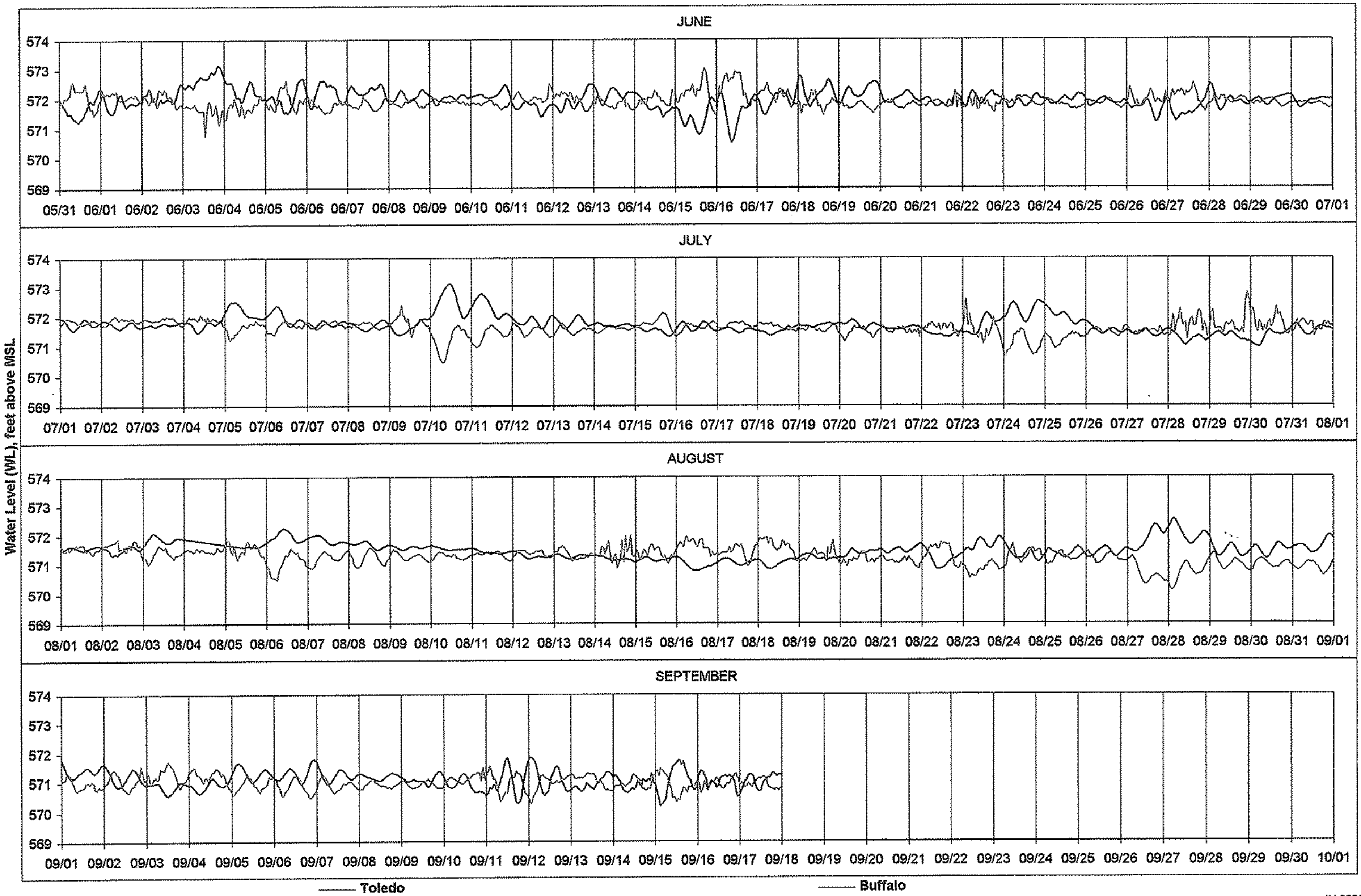
Station Total Load

FIGURE 2 - 75



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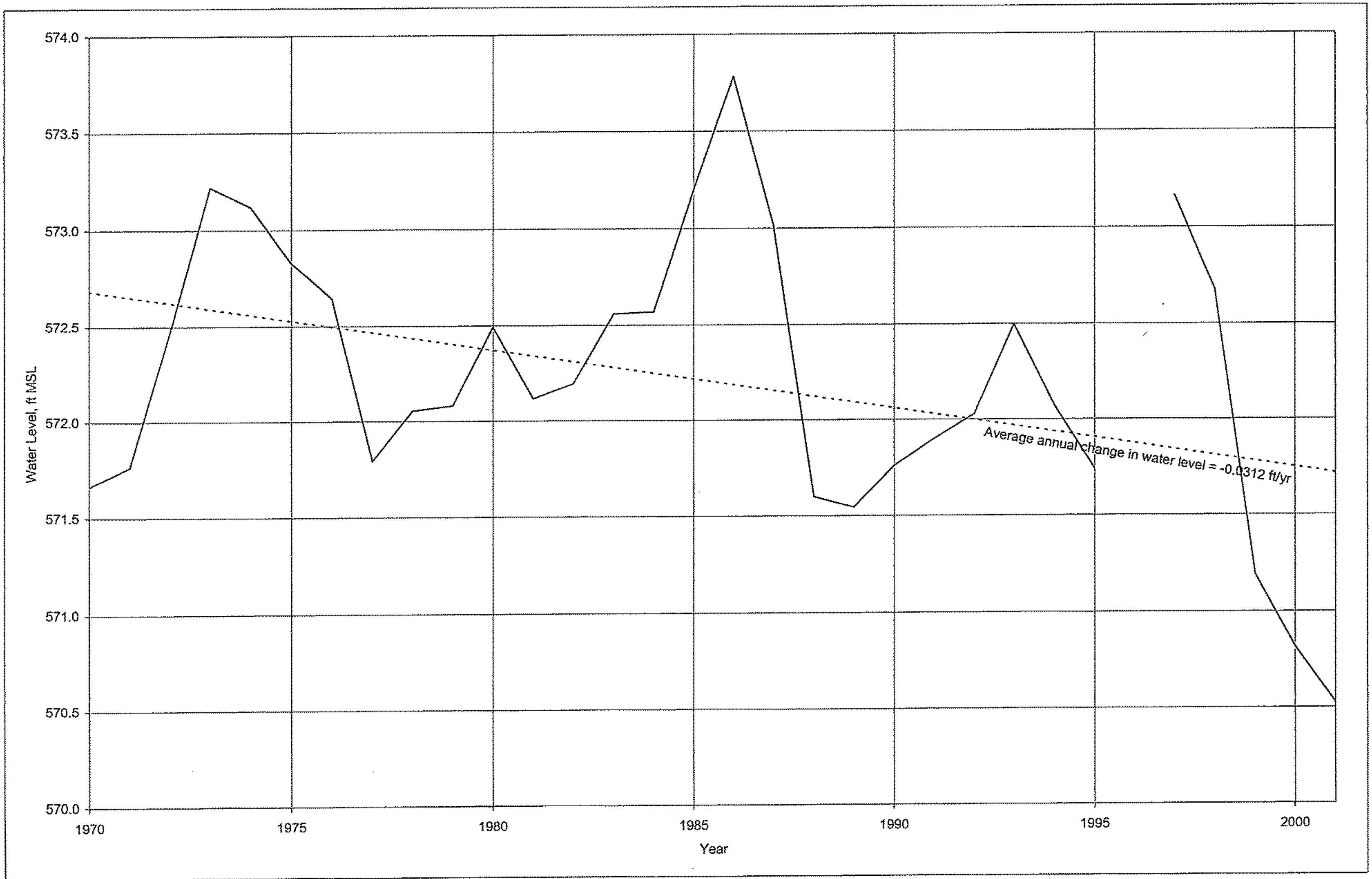
FirstEnergy Corp, Toledo Edison Bay Shore Station

Lake Erie Water Levels, Summer 2002

FIGURE 2 - 76



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Annual Average Water Levels - Toledo, Ohio (1970 - 2001)

FIGURE 2 - 77

3 PLUME MODELING

This section of the report presents the methods and results of CORMIX modeling of the Bay Shore Station cooling water discharge. Based on the results of the validation step described in this section, LMS concludes that the CORMIX model cannot be used to forecast the thermal plume associated with the Station discharge. As a consequence, the CORMIX modeling is abandoned in favor of the methods described in Section 4 of the report. The potential for this outcome was considered in the Plan of Study, but it could not be determined in advance with any certainty whether the model could be adapted to the Station or not.

3.1 PURPOSE OF MODELING

As noted in Section 1, the CORMIX model was used for two purposes in this Study:

- To produce preliminary estimates of the discharge plume as an aid in locating fixed sampling stations and establishing mobile survey track lines. (See Section 2 for a discussion of the CORMIX modeling performed to guide design of the Field Survey Program.)

- To produce estimates of the discharge plume under a range of natural conditions, not all of which may have been observed during the Field Studies.

The CORMIX modeling described in this section addressed the second purpose and was expected to provide estimates of the thermal plume for limnological, meteorological, and Station operating scenarios that could reasonable be expected to produce worst case plumes, but might not be observed during the Field Survey Program. This would allow evaluation of the maximum, worst case extent of the Station's influence on water temperatures in Maumee Bay.

3.2 CHOICE OF CORMIX MODEL

The version of the CORMIX model used in the Study is CORMIX-GI version 4.1GT, provided by Dr. Robert L. Doneker, Oregon Graduate Institute, Portland, Oregon. Section 1.3.3 of this Report and Section 4 in the Plan of Study (Appendix A) discuss the basis for selection of the CORMIX model and sources of information on the model.

While CORMIX is the best available U.S. EPA-approved model to represent the Station discharge, it has certain limitations with respect to the Station discharge configuration. Those limitations relate to:

- The shallow depth of the discharge canal, relative to its width

- The lack of an ambient passing flow or circulation in the Cove

- The location of the discharge adjacent to the Confined Disposal Facility (CDF) and at the head of the Cove

As a result, the validation step in the application of CORMIX is particularly important in this Study. If the model cannot be shown to be valid for this specific discharge, then any forecasts produced may be questionable.

3.3 MODELING METHODOLOGY

CORMIX is unique among water quality models in that it does not require field data for calibration of model parameters. Nonetheless, regulatory agencies frequently require comparison of CORMIX results with field data to establish a degree of confidence in the model results. LMS calls this initial stage in the application of CORMIX the validation step. In the validation step, CORMIX is run for observed conditions and the model results compared with the plume observed during those conditions. The Mobile Surveys were designed, in part, to satisfy the need for such a set of observed conditions. If the model results are sufficiently similar to the observed plume, CORMIX is considered valid for that particular discharge and receiving water.

As noted in the opening paragraph of this section, CORMIX did not pass the validation test in this case, so LMS did not proceed to the forecasting stage. Had CORMIX passed, the forecasting stage would have involved a statistical evaluation of limnological, meteorological, climatological, and plant operating data to identify conditions that might reasonably be expected to produce worst case thermal plume conditions. Because the OEPA temperature regulations for Maumee Bay incorporate discrete jumps in the threshold criteria, the statistical evaluation would have required consideration of conditions during discrete time periods, corresponding to the criteria schedule. Conditions that might lead to a small or nonexistent thermal plume during one such period might produce a very different plume during another regulatory period. Once the worst case scenarios were identified, LMS would then have run CORMIX for those scenarios to forecast the plumes that would have occurred. As a result of failure to pass the validation test, the statistical evaluations became part of the analyses reported in Section 4.

3.4 VALIDATION SCENARIOS

The Field Survey Program produced seven Mobile Surveys for which validation scenarios can be developed:

- 11 June 2002
- 12 June 2002
- 26 June 2002
- 09 July 2002
- 30 July 2002
- 20 August 2002
- 17 September 2002

See Section 2 for additional details on each of these Mobile Surveys.

Table 3-1 lists the CORMIX input data for each of the validation scenarios. The input data were developed from the data sets detailed in Section 2. As indicated in the first column, there are three broad categories of inputs, each corresponding to a tabbed input sheet in the CORMIX input window. As shown, some characteristics are essentially constant throughout the set of runs. For example, zero wind speed is assumed throughout, to minimize surface heat exchange and produce conservatively larger plumes. Other characteristics are highly dependent on the actual conditions on the specific date modeled. For example, the discharge excess temperature is a function of intake cooling water temperature, plant load and discharge flow on a given date.

In Table 3-1, the individual scenarios modeled are identified by the corresponding CORMIX computer filenames. The first three digits of the filename are the month and day represented by the scenario. The next two digits (indicated in Table 3-1 as "nn") identify the ambient current speed used in the scenario. See the discussion of "Current Speed" below for more information on the reasons for multiple current speed scenarios. Because all other scenario characteristics are the same for a given date, the table uses a single column to represent all the scenarios for that date. The next character is an "o" for the runs shown in Table 3-1, indicating that a co-flowing discharge configuration was modeled. In addition to the co-flowing runs, LMS did a number of model runs assuming a cross-flowing configuration, in an attempt to overcome the limitations of CORMIX for this discharge. They were named with an "x" in this position. The computer runs can be found in Appendix C, but they are not discussed in this section, because they did not provide the hoped-for improvements. Finally, if more than one variation of the same scenario was run, the last two characters of the filename indicate the sequence number.

The following sections describe the development of each model input for each scenario. Note that the units are a mixture of SI (metric) and U.S. Customary. CORMIX does its calculations in SI units, but allows input of U.S. Customary units for the convenience of the user. CORMIX performs the necessary conversions to get all inputs into a consistent system of units. For convenience, LMS elected to specify the inputs in the observed or reported units, resulting in the mix shown.

3.4.1 Ambient Characteristics

Ambient characteristics are descriptive of the water body receiving the discharge. The ambient inputs were developed as follows:

Average Depth – The average depth is a depth that is characteristic of the water body receiving the discharge in the area expected to be occupied by the plume. A constant value of 6 ft was used in all scenarios, representative of typical water depths in the Cove.

Discharge Depth – The discharge depth is a depth characteristic of the water body immediately in front of (or above, in the case of submerged discharges) the discharge. A value must be entered, but, for surface discharges, it is overridden by another value entered on the Discharge tab sheet (see below). A nominal value of 7 ft was entered for all scenarios, because there is a scoured region immediately in front of the Station discharge canal that is slightly deeper than the typical water depths in the Cove.

Water Body Characteristic – CORMIX adjusts its calculations, depending on whether it is likely that the plume may contact the far shore of the receiving water body. If the receiving waters are sufficiently wide, there is no need to do these extra calculations, so the user is offered the option of specifying the water body as "unbounded", which is a reasonable description of the Cove.

Flow Classification – CORMIX can be used to model a wide variety of receiving waters, including tidal waters. It is fundamentally a steady-state model, so the unsteady tidal calculations are done piecewise, for periods of time short enough to be considered steady state. All other waters are considered to have a constant ("steady") ambient water speed, so the flow in the Cove is described as "Steady".

Current Speed – As discussed in Section 2 of this Report, ambient water movements in the Cove have very low speeds and appear somewhat random. CORMIX has difficulty calculating plume characteristics for near-zero ambient current speeds. It was necessary to do a sensitivity analysis on current speed for each day simulated, to find the lowest velocity for which CORMIX would produce reasonable results. The "nn" in the CORMIX file names indicate the corresponding current speeds, as shown here:

"nn"	Water Speed (ft/sec)
00	0.0
01	0.1
02	0.2
03	0.3
04	0.4
07	0.7
10	1.0

Manning Coefficient – Also known as "Manning's n", this coefficient describes the "roughness" of the Cove bottom in the hydraulic calculations. A value of 0.02 is used throughout, typical of a relatively smooth, clay bottom with little submerged aquatic vegetation.

Wind Speed – In CORMIX, wind is used to compute the loss of heat at the water surface; it does not participate directly in the calculation of the plume shape. That is, the model does not consider surface wind shear in its calculations. To forecast a worst case plume, LMS assumes that there is no loss of heat to the atmosphere; all changes to water temperature are exclusively the result of mixing the discharge with ambient water. To enforce this assumption, LMS sets wind speed to zero.

Receiving Water Type – This input controls whether CORMIX computes the density of the ambient water, or uses an input value for that variable. The choices are "fresh" or "non-fresh". LMS elected to allow CORMIX to compute the density of the ambient Cove water and specified "fresh" throughout.

Stratification – Based on the vertical temperature profiles presented in Section 2 for areas of the Cove not affected by the discharge plume, LMS assumed that the ambient water temperature and, therefore, density was uniform over water depth, as is borne out by the data in Section 2.

Water Temperature – For ambient freshwater conditions, CORMIX computes ambient water density based on the input ambient water temperature. In a free-flowing stream or river, this would be the upstream water temperature, but the configuration of the Station discharge and the Cove does not provide a natural circulation. Based on the orientation of the discharge along the CDF shoreline, LMS assumes that the discharge itself must induce a clockwise circulatory flow in the Cove, to provide dilution water for the plume. The analysis of Station's cooling water intake temperatures, now incorporated into the analyses presented in Section 4, leads LMS to conclude that Station intake temperatures provide a reasonable estimate of ambient temperatures for purposes of the ambient density calculation. The temperature associated with each scenario in Table 3-1 is the daily average observed intake temperature on the date being simulated.

3.4.2 Effluent Characteristics

In CORMIX, effluent characteristics refer to the properties of the waste stream being discharged. The following paragraphs describe the development of each input effluent characteristic:

Flow Rate – As described in Section 2, the Station routinely records and reports the daily average cooling water discharge flow. The value shown for each scenario modeled is the value reported by the Station for that date.

Type – Like the Receiving Water Type described above, the effluent type specified determines how CORMIX computes the density of the effluent. Because the Station discharges only cooling water drawn from the Maumee River, the effluent is specified as "fresh".

Temperature – When the effluent is specified as "fresh", CORMIX will calculate the effluent density based on the effluent temperature. The value input for each scenario is the daily average observed discharge temperature for the date being simulated.

Concentration – CORMIX can model a variety of pollutants in addition to heat, so the pollutant concentration is specified separately from the effluent temperature, even if heat is the modeled pollutant. In this case, only that portion of the discharge temperature that exceeds the OEPA criterion temperature for the date being modeled is considered a pollutant. The concentration specified for each scenario is the difference between the daily average observed discharge temperature on that date and the OEPA average temperature criterion value for that date. The average temperature criterion is used, not the daily maximum temperature criterion, because all the other model inputs are specified as daily average values.

Pollutant Type – CORMIX can model a number of different types of pollutants: conservative, non-conservative, heated, sediment and brine. In this case, the most appropriate type specification is "heated".

Heat Loss Coefficient – When the Pollutant Type is "heated", CORMIX can compute the loss of heat to the atmosphere at the water surface. As noted in the paragraph on "Wind Speed" (above), LMS assumed no heat loss to the atmosphere, as a conservative assumption expected to produce larger plumes. In addition to setting the Wind Speed to zero, LMS set the Heat Loss Coefficient to zero to assure no heat loss to the atmosphere.

3.4.3 Discharge Conditions

Discharge conditions refer to the physical configuration of the discharge and its position and orientation relative to the receiving waters. The next paragraphs detail the choice of Discharge Conditions inputs.

Class – CORMIX classifies discharges into three broad categories:

- Submerged, single port (CORMIX1)
- Submerged, multi-port (CORMIX2)
- Surface (CORMIX3)

The terms in parentheses above refer to the specific sub-model within CORMIX that is used to evaluate each type of discharge. In this case, the Station discharge is clearly a surface discharge.

Bank – Because CORMIX assumes there is always some nominal flow in the receiving waters, it uses up- and down-stream directions to establish its basic coordinate axes. The positive x-axis is downstream and the positive y-axis is across the stream from the bank nearest the discharge. To associate this coordinate system with the real world, it is necessary to specify which bank is nearest the discharge, using the standard nomenclature looking downstream. In this case, there is no clear directionality to the flow, but LMS anticipates an induced clockwise circulation in the Cove (see "Ambient Water Temperature", above). Under these circumstances, the Station discharge is on the left bank.

Discharge Depth – As noted above, when modeling a surface discharge, CORMIX allows the ambient water depth to be over-ridden on the Discharge input tab-sheet, because the bottom of a discharge canal may enter the receiving waters above the natural bottom. The CORMIX3 module has limits on the relative magnitudes of the water depth and canal depth, so it screens the values entered in the Discharge tab-sheet for acceptability. In this case, the canal depth and the receiving water depth are essentially the same, so the model constraints are met.

Outlet Type – The CORMIX3 model is capable of representing either a surface channel (canal) discharge or a surface pipe discharge. The Station's discharge is clearly a channel.

Width and Depth – While the width and depth of the canal are separate inputs, they must be considered together, because CORMIX3 will only model canals with an aspect (depth/width) ratio between 5 and 0.05. As illustrated in Figures 2-71 and 2-72, the actual physical width and depth of the Station discharge canal are a function of the Lake level. At Low Water Datum (LWD) the canal is approximately 130 ft wide at the surface, but slopes to a roughly flat bottom about 50 ft wide. The flat bottom is about 5 ft below LWD, but the average depth across the surface width is closer to 3.7 ft, giving an aspect ratio of about 0.028, which is too low for CORMIX3. It was necessary to adopt an artificial canal cross-section that met the aspect ratio criterion, while preserving the essential physical characteristics of the discharge. One of the key parameters computed by CORMIX3 for a discharge is the average discharge velocity, which is a component of the discharge momentum. Discharge velocity is a function of discharge flow and cross-sectional area. The approach used was to maintain the average discharge velocity while achieving an acceptable aspect ratio, by maintaining the cross-sectional area while adjusting the relative width of the canal. Based on its survey of the canal cross-section, LMS developed the relationship between Lake level and cross-sectional area shown in Figure 2-72. The Lake levels ranged between 571.05 ft MSL and 571.94 ft MSL for the seven scenarios, or between 7 and 8 ft above the deepest part of the canal. Assuming a canal depth of 7 ft, we were able to compute a surrogate canal width for each scenario that preserved the cross-sectional area on that date, while achieving an acceptable aspect ratio. The resulting widths are shown in Table 3-1, along with the constant 7 ft assumed depth.

3.5 VALIDATION RESULTS

Appendix C (on the CD-ROM) presents the detailed CORMIX output for each of the model runs performed as part of the validation process.

In summary, the model runs for the lowest ambient current speeds evaluated terminate well before the plume is fully developed and the higher ambient current speed runs all produce plume sizes much larger than those observed. For the lowest current speed runs (0.0 ft/sec to 0.2 ft/sec; nn = 00, 01 and 02), the delta T (concentration) is still well above zero at the point of termination, between 100 m and 200 m from the discharge. All the higher current speed runs produce thermal plumes well in excess of 15 000 m (50,000 ft or 9.5 statute miles), which are much greater than the plumes described in Section 2.

3.6 DISCUSSION OF VALIDATION RESULTS

Figure 3-1 is a representative plot of the centerline delta T for one of the lowest ambient current runs that extends beyond the first several hundred meters from the discharge. As can be seen, the delta T approaches an asymptote, but is still some 0.2 Celsius degrees above zero delta T when the run ends at about 15 000 m. This suggests that the model would forecast a plume extending tens of miles from the discharge, if it were allowed to run to a delta T closer to zero. The field data presented in Section 2 clearly indicate that the observed thermal plume is much smaller than is forecast by these CORMIX runs.

The behavior of the CORMIX runs for higher ambient currents suggests that the plume is being pushed out to these very large distances by the artificially high ambient currents needed to get the model to run. If the model were capable of running at ambient currents more representative of the Cove, the forecast extent of the thermal plume would likely be closer to those observed.

LMS consulted with Dr. Robert L. Doneker, who provided CORMIX-GI version 4.1 GT, regarding the performance of CORMIX for the Station discharge. Dr. Doneker noted that CORMIX-GI version 4.2 GT from ModZon, Inc. had been released in October 2002, but that the changes were primarily in graphic visualization of results. He indicated that version 4.2 was likely to experience the same limitations as the version LMS used. Under those circumstances, LMS saw no reason to upgrade to the newer version.

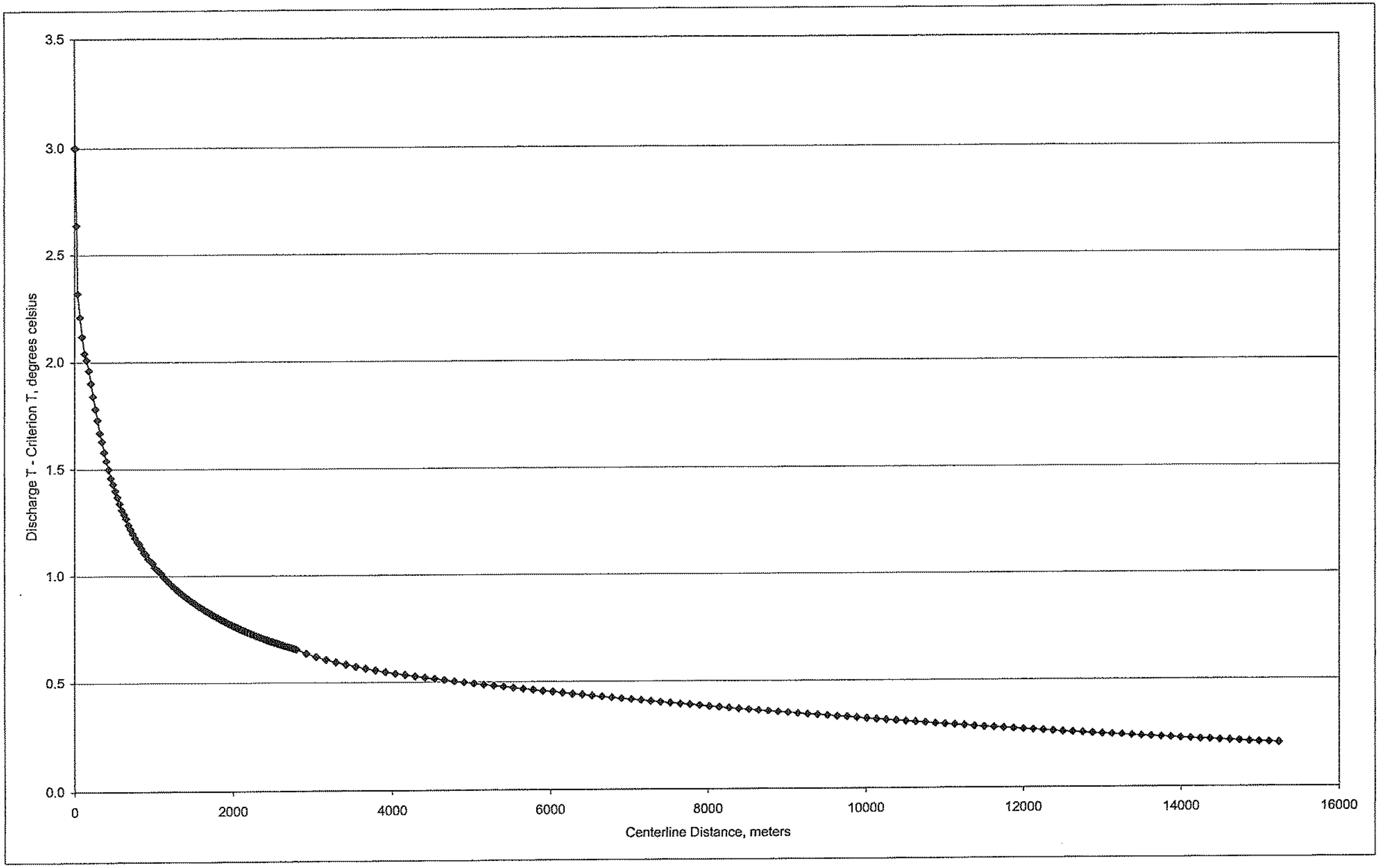
Thus, while CORMIX can be made to produce results, those results can only be achieved by setting an artificially high ambient current speed of 0.3 ft/sec or greater, which is well above the nearly zero ambient currents observed in the Cove (see Section 2). When those ambient currents are used, the forecast plume is pushed outward to distances much greater than those observed during the Field Survey Program.

3.7 CONCLUSIONS

Therefore, LMS concludes that CORMIX is not an appropriate standalone modeling tool to represent the Station discharge. The CORMIX modeling is abandoned and a detailed analysis of the plume using thermodynamic and statistical methods is presented in Section 4 of the Report.

Table 3-1. CORMIX Validation Inputs.
(See text for explanation of each parameter.)

	Parameter	Units	Scenario (CORMIX File Name)						
			611nno	612nno	626nno	709nno	730nno	820nno	917nno
	Scenario Date (2002)	n/a	11 June	12 June	26 June	09 July	30 July	20 August	17 September
Ambient	Average Depth	[ft]	← 6 →						
	Discharge Depth	[ft]	← 7 →						
	Water Body Characteristic	n/a	← unbounded →						
	Flow Classification	n/a	← Steady →						
	Current Speed	[ft/sec]	← See Text →						
	Manning Coefficient	n/a	← 0.02 →						
	Wind Speed	m/s	← 0 →						
	Receiving Water Type	n/a	← Fresh →						
	Stratification	n/a	← Uniform →						
	Water Temperature	[degrees Celsius]	23.9	23.3	25.56	26.75	26.49	25.18	22.99
Effluent	Flow Rate	[MGD]	745.9	745.9	745.9	745.9	745.9	586.7	707.5
	Type	n/a	← Fresh →						
	Temperature	[deg Celsius]	30.07	29.54	31.3	32.29	31.97	29.44	28.11
	Concentration	[Celsius degrees]	8.37	7.84	3.00	3.99	3.67	1.14	4.21
	Pollutant Type	n/a	← Heated →						
	Heat Loss Coefficient	W/m^2/degrees Celsius	← 0 →						
Discharge	Class	n/a	← Surface (CORMIX3) →						
	Bank	n/a	← Left →						
	Discharge Depth	[ft]	7	7	7	7	7	7	7
	Outlet Type	n/a	← Channel →						
	Width	[ft]	127	132	126	125	117	119	132
	Depth	[ft]	7	7	7	7	7	7	7



JN 0925-002

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FirstEnergy Corp, Toledo Edison Bay Shore Station

Example: Discharge Temperature Minus Criterion Temperature Along Centerline (CORMIX Run 62603o01)

FIGURE 3-1

4 DATA ANALYSIS

While Section 3 concludes that the CORMIX model is not a satisfactory tool for forecasting the Bay Shore Station thermal discharge plume, it is still desirable to develop a means for estimating the area encompassed by the plume under a range of conditions. This section of the report presents one such tool, based on a combination of thermodynamic modeling and statistical analysis of the data. It is limited to use during the "summer" months, i.e., the mid-June through mid-September period for which we have field survey data, but it makes use of annual limnological, meteorological, and plant operating data in the computations. It also has limited statistical reliability, as detailed in this section. Nonetheless, it represents a reasonable initial tool.

4.1 PURPOSE OF THE ANALYSIS

The goal of the analysis is an estimate of the probability distribution of thermal plume areas associated with the Station discharge during summer months. The thermal plume is defined as the region bounded by the Station discharge and the locus of points having water temperature equal to the daily average criterion temperature established in the OEPA regulations for Maumee Bay. Because discrete, large jumps in plume area can occur on the days when the criterion changes, the estimates are restricted to the period 16 June through 15 September, when the daily average temperature criterion is 83°F (28.3°C). This corresponds to the period during which the majority of the field data were collected in the Field Survey Program (Section 2).

4.2 CONCEPTUAL OVERVIEW

As noted in Section 1.3.1, the difference (delta T) between the temperature of the Station cooling water discharge and the OEPA criterion temperature can be expected to be a function of a number of factors. For example, if the Station were to cease generating but continue pumping cooling water, there could be a delta T (positive or negative) due to the difference between the temperature of the water withdrawn at the intake and the regulatory criterion. A positive difference would result in a thermal plume associated with the discharge, even though the Station was not heating the water.

There are a number of such potential influencing factors, in addition to the intake temperature and the criterion temperature. The Station adds heat to the cooling water, changing the delta T and the relative buoyancy of the discharge, and it adds momentum to the discharge, promoting mixing with the ambient receiving water. Both seasonal and shorter-term changes in the thermal structure of Lake Erie, such as seiches, may influence both the intake temperature and the temperature of the ambient water diluting the plume. Local meteorological conditions, such as onshore winds, might tend to minimize the size of the plume, while offshore winds might have the opposite effect. Based on the information presented in Section 2 of this Report, we can begin our analysis by listing the factors that can reasonably be included in an evaluation of contributing factors (Table 4-1). Also listed in Table 4-1 are some simple statistics descriptive of the daily average values of these factors. The R^2 values shown are for a linear model in which the corresponding factor is the only variable. They are presented to give a rough idea of the relative importance of each factor in the overall model. As each factor is added to the linear model, the R^2 values for the remaining factors change due to communality among the factors. For example, intake temperature is strongly related to dewpoint temperature, wet bulb temperature, relative humidity, and incident solar radiation, so the relative importance of those factors is reduced when intake temperature is included in the model.

It should be noted that wind direction presents some difficulties in a linear regression model. Wind is a vector quantity that can be described either as a speed and direction (polar coordinates) or as vector components (north and east in a Cartesian coordinate system).[1] If wind direction is used, there is a problematic discontinuity at north, where the value changes from 355° to 000°. A linear model cannot accommodate this discontinuity correctly, giving inappropriate weight to values just west of north, relative to values just east of north. Wind speed is often the more important variable, not wind direction. For example, CORMIX considers only wind speed in estimating surface heat loss in the plume. Converting wind speed and direction to Cartesian coordinates has the advantage of allowing a linear model to incorporate wind direction, but with wind speed as a "hidden" component. In developing the linear regression model described later in this section, LMS considered both ways of representing wind: wind speed alone and the vector representation that includes both speed and direction.

As described in Section 2, the Field Survey Program focused on collecting or acquiring data on as many of the potential influences as possible both during the immediate field activities and over the historical record. This section identifies those factors that have the greatest influence and merges them into a unified model of the process.

4.3 METHODOLOGY

The analyses presented in this section rely on two different branches of science, thermodynamics and statistics. The thermodynamic component is the Response Temperature Model (RTM), which provides a means for estimating the temperature that a body of water would achieve solely as a result of meteorological and climatological effects. It does not incorporate the influence of such physical processes as advection, so it does not account for the potential effects of currents, for example. Because it relies solely on the meteorological record, the RTM can be used to generate a long-term hindcast of natural water temperatures at a specific location in a body of water. The statistical component of the analysis relies on commonly used statistical tools, such as regression analysis and principal components analysis. Information on these statistical tools can be found in a number of standard statistical texts or on the Internet (see, for example, http://www.statsoftinc.com/textbook/stfacan.html for information on principal components analysis).

[1] Remember also, that wind direction is reported as the direction FROM which the wind is blowing. This must be accounted for in any vector conversion.

4.3.1 Response Temperature Model

We could reasonably use the observed intake temperatures as part of our model, if only the period of the Field Survey Program were being modeled. The Station provided the intake temperatures for that period of time as part of the Study.

However, development of a reliable statistical distribution of plume areas requires a larger data set than the plumes observed during the Field Survey Program. One way to generate the larger data set would be to retrieve the Station intake temperatures going back to the beginning of operations at the Station in the late 1960s, but those data are not retrievable.

Because the intake temperatures are reflective of a relatively natural thermal regime, even though the water comes from a highly developed river-mouth harbor, response temperature modeling can be used to estimate the intake temperatures based solely on the longer and more accessible meteorological record.

The use of the Response Temperature Model (RTM) described here differs from the one considered in the Plan of Study (Appendix A). The Plan of Study discounts the use of Response Temperature for direct use in modeling the Station thermal plume, because it does not include advective processes and other factors expected to be important in the plume. The purpose considered here is to estimate the water temperature at a single point (the Station intake), not throughout the dynamic thermal discharge plume. Thus the RTM is expect to prove a valuable tool for the analyses discussed in this section.

The Response Temperature Model (RTM) is based on the fundamental work of Dr. John E. Edinger and others in the mid-1960's and early 1970's.[2,3,4,5] This body of work remains today the core knowledge regarding anthropogenic heat in the aquatic environment.

The response temperature (T_r) is the daily average temperature that a fully mixed column of water would reach in response to meteorological and solar conditions. T_r is computed by solving the following equation that relates the change in the temperature of a fully mixed column of water of depth, D, to meteorological and solar inputs:

$$dT_r/dt = H_n/(\rho C_p D)$$

[2] Edinger, John E., and John C. Geyer. Heat Exchange in the Environment. Cooling Water Studies for Edison Electric Institute, Research Project RP-49. The Johns Hopkins University, Baltimore, Maryland. 01 June 1965.

[3] Geyer, John C., John E. Edinger, Willard L. Graves and Derek K. Brady. Field Sites and Survey Methods. Cooling Water Studies for Edison Electric Institute, Research project RP-49. The Johns Hopkins University, Baltimore, Maryland. June 1968.

[4] Wunderlich, Walter O. Heat and Mass Transfer between a Water Surface and the Atmosphere. Water Resources Research Laboratory Report No. 14. Tennessee Valley Authority, Office of Natural Resources and Economic Development, Division of Air and Water Resources, Water Systems Development Branch, Norris, Tennessee. Report No. 0-6803, April 1972.

[5] Edinger, John E., Derek K. Brady and John C. Geyer. Heat Exchange and Transport in the Environment. Electric Power Research Institute Cooling Water Discharge Research Project RP-49. The Johns Hopkins University, Baltimore, Maryland. Report No. 14, November 1974. (EPRI Publication No. 74-049-00-3).

where:

T_r = response temperature
ρ = density of water
C_p = specific heat of water
D = depth of water column
dT_r/dt = change in response temperature with time
H_n = net rate of surface heat exchange = $(H_s + H_a - H_{sr} - H_{ar}) - (H_b + H_e + H_c)$

with: H_s = short-wave solar radiation
H_a = long-wave atmospheric radiation
H_{sr} = reflected short-wave radiation
H_{ar} = reflected long-wave atmospheric radiation
H_b = back-radiation from the water column
H_e = evaporative heat loss from the water column
H_c = conductive heat exchange with the water column

Each of the terms in the equation can be evaluated from basic principles of heat exchange and readily available meteorological and astronomical data. Details of these calculations may be found in Dr. Edinger's report.[1] In developing the RTM for the Station, meteorological data from the National Weather Service station at Toledo Express Airport (TOL) were used. An initial guess is made for the water temperature on the first day and the change in temperature is added to that guess to estimate the temperature for the second day. The estimate for the third day is computed by adding the second day's change in temperature to the second day's estimated water temperature, and so on for the period of available meteorological data. Any inaccuracy in the initial water temperature guess disappears rapidly as the response temperature rapidly converges to observed temperatures.

Typically, in applying the RTM, the depth of the water column (D) is used as a calibration parameter, because the mixed depth of water in the region is not always known. In this case, the water column depth was adjusted until the root mean square (RMS) difference between the observed intake temperatures and the RTM temperatures for the period 27 June 2002 through 17 September 2002 was minimized. The calibrated value of D is 19 ft, with a RMS difference of 1.08 F°. Figure 4-1 compares the observed and modeled intake water temperatures for the calibration period.

The resulting model was then applied to the 48-year record of meteorological observations for the National Weather Service station at Toledo Express Airport (TOL) to create a 48-year record of estimated natural temperatures at the Station intake, if the Station had been in operation during the entire period. The data actually used in the final analysis of plume area are restricted to the summer months corresponding to the period of the Field Survey Program. The D coefficient was recalibrated for the summer 2002 period to reflect the fact that the initial value was no longer an initial guess, but was calculated from the prior historical data. The revised D was 23 ft, giving the same RMS difference of 1.08 F° as the shorter record analysis. Figure 4-2 illustrates the results of the historical analysis.

4.3.2 Discussion of RTM Results

The relatively large calibrated value for D suggests that the principal source of water for the Station intakes is not the Maumee River, but the Toledo Harbor shipping channel, Maumee Bay, and, ultimately, Lake Erie during summer months. To confirm this interpretation, LMS compared the Station cooling water flow with the available freshwater supply from the Maumee River, as observed by the U.S. Geological Survey gaging station at Waterville, Ohio (Gaging Station No. 04193500). Because this gaging station is some distance upstream from the Station intake canal, LMS adjusted the observed flow upwards by area proportioning, assuming that all drainage from the relatively urban tributary area downstream of the gage reaches the Maumee River. The comparison is between adjusted average daily river flow and the maximum intake capacity of the cooling water pumps (745.9 MGD or 1157 cfs).

Table 4-2 summarizes the results of the comparison for the 50-year period 01 October 1953 through 30 September 2002. The columns represent months and the rows are the years. The shaded cells are the months in which the Station's water withdrawal would have exceeded the available average daily river flows. As illustrated in Figure 4-3, those events occur mostly during the summer and fall seasons.

Specifically, during the period for which the RTM was calibrated (27 June 2002 through 17 September 2002), the actual daily average Station intake flow exceeded the area-adjusted Maumee River flow on 74 of the 99 days. Averaged over the period, the actual daily average Station intake flow was about 3.44 times greater than the area-adjusted River flow.

This clearly suggests that, during the summer and fall months, the source of cooling water for the Bay Shore Station is predominantly the Toledo Harbor shipping channel and Maumee Bay, with the possibility that some water is coming from the larger region of Lake Erie.

It is, however, unlikely that there is much, if any, recirculation of discharged cooling water into the Station intakes. The distance around the CDF from the discharge to the intakes is approximately 7 miles, with a shoal area extending approximately another 4 miles from the CDF toward Lake Erie, parallel to the shipping channel.

This analysis also provides support for use of the Station intake temperature as the assumed temperature in regions of Maumee Bay at the boundary of the gridding area used to estimate plume areas (see next section).

4.3.3 Plume Area Estimates

Because the goal of the analysis is a model that will estimate the likelihood of occurrence of thermal plumes of a given area, it is necessary to develop a data set of plume areas for the observation period. This was done using the fixed station data, as supported by the mobile survey data.

It is not possible to generate a real plume area based on the maximum daily temperature criteria found in the OEPA regulations for Maumee Bay. The daily maximum temperatures at points in the Cove may not occur simultaneously, so any such analysis would not represent a real situation that occurred in the Cove.

The plume area was estimated by computing the daily average temperature observed at each of the fixed stations for the period of deployment. The daily average temperatures were then gridded and contoured using the well-know Surfer computer software package.[6] To provide closure for the contours, water temperatures at the boundary of the gridding area were assumed equal to the corresponding daily average intake temperature. This is consistent with the conclusions reached in the RTM modeling. One of the contours was specified as the OEPA criterion daily average water temperature. Surfer was then used to compute the area within the OEPA criterion water temperature contour for each day in the data set. Because the fixed station network was developed using preliminary CORMIX modeling results, which were biased toward shorter plumes, some plumes extended beyond the monitoring network. Days on which this occurred were eliminated from the data set, so there is some bias toward smaller plumes in the final set of daily plume areas. Figure 4-4 is an illustration of the results of Surfer daily average temperature contouring. The heavy contour line corresponds to the OEPA criterion temperature and defines the boundary of the thermal plume.

4.3.4 Statistical Methods

The NCSS statistical analysis computer package[7] was used to perform multiple regression analyses on the available data set to identify those variables that contribute to the variability of the plume area during the period of the Field Survey Program.

Because wind is a vector quantity described by two variables (speed and direction), principal components analysis (PCA) was used to determine if wind could be reduced to a single factor. As discussed above, one of the problems with describing wind in terms of speed and direction is the discontinuity that occurs in the direction component at north (the 000°/360° discontinuity). LMS evaluated all the ways in which wind could be correctly incorporated into the linear model and found that the most appropriate approach was to consider only wind speed. This is consistent with the heat loss formulation used, for example, in CORMIX.

4.4 RESULTS

4.4.1 Preliminary Statistical Model

A preliminary analysis using actual observed and acquired data from the Field Survey Program was done to identify the principal sources of plume area variability. The resulting statistical model for the period of the Field Survey Program is:

[6] Golden Software Inc., Golden Colorado (www.goldensoftware.com)

[7] Hintze, J. (2001). NCSS. Number Cruncher Statistical Systems, Kaysville, Utah. (www.ncss.com)

$$\log A = (-8.083249 - 0.00110152Q_d + 0.3545905T_i - 0.05516206W + 0.003802833P)$$

where:

A	= Plume area based on daily average water temperature and criterion temperature (hectares)
Q_d	= Daily average Station discharge flow (MGD)
T_i	= Daily average Station intake water temperature (°C)
W	= Daily average Wind speed reported by NWS for TOL (mph)
P	= Daily average Station load (MW)

and:

log	= the common (base-10) logarithm

The model has an R^2 of 0.740094, a respectable value given the nature of the phenomenon we are trying to describe and the daily average data employed. All the factors included in the model are significant at the 5% level. Applying the model to the data on which it is based produces the sequence of daily thermal plume areas shown in Figure 4-5, along with the actual observed areas during the period. The RMS difference between the forecast and observed series is 90.15 ha.

4.4.2 Generalized Statistical Model

Because intake water temperature is not available for the duration of the meteorological data, the final statistical model substitutes RTM forecast water temperature (T_r) for the intake water temperature. The resulting statistical model for summer months is:

$$\log A = (-4.384648 - 0.00121666Q_d + 0.2282059T_r - 0.04509878W + 0.002904766P)$$

where the T_r employed is based on a D of 23 ft. It has an R^2 of 0.483684. The reduction in the R^2 due to replacing T_i with T_r suggests that the Response Temperature Model does not include some important factor affecting intake temperature. LMS explored this possibility by including other variables in alternate regression models, but was unable to improve on the overall R^2 when T_r is substituted for T_i.

Applying the model to the data from the period of the Field Survey Program and comparing it with the observed plume areas produces the results shown in Figure 4-6. The RMS difference between the forecast and observed series is 134 ha, reflecting the reduced R^2.

4.4.3 Distribution of Plume Areas

Finally, the generalized statistical model was applied to the entire 48-year period of available meteorological data. Because the Station was not in existence for the early years and because our goal is an estimate of maximum or worst case plume area, the Station load and cooling water flow were set to maximum values (631 MW and 744.9 MGD, respectively). Figure 4-7 shows the cumulative probability distribution of the resulting plume areas during summer months (16

June through and including 15 September). The typical or average plume area during summer months is approximately 34.0 hectares. Fewer than 5% of the plume areas are expected to exceed 184 hectares and fewer than 1% will exceed 340 ha.

4.5 DISCUSSION OF RESULTS

The generalized statistical model presented in Section 4.4.2, incorporating the RTM, represents a reasonable tool for estimating the statistical variability of the Station thermal plume during summer months.

While the R^2 is relatively low, the linear model incorporates the principal factors expected to be important in determining plume size. To improve on this aspect of the model would require additional evaluation of the factors influencing intake temperature, since it is the introduction of RTM as a surrogate for intake temperature that causes the R^2 to decrease. One area of investigation might be the influence of lake tilt (seiching). Lake tilt is eliminated from the linear model when intake temperature is introduced, so there is clearly some relationship (communality) between the two factors.

To illustrate the influence of this unknown factor in the calculations, consider the results presented in Figures 4-1, 4-2, 4-5 and 4-6 for 17 and 18 August 2002. Note that there is an excursion in intake temperature on those dates, relative to the trend in temperature on the preceding and following days. As can be seen in Figures 4-1 and 4-2, the RTM model under-predicts that excursion, implying that the meteorological conditions on those dates does not account for the change in intake temperature. The excursion was apparently the result of some other cause, not included in the RTM methodology.

One might suspect a measurement error on those dates, if it were not for the results presented in Figures 4-5 and 4-6. Figure 4-6 compares the RTM-based plume area hindcasts with the observed plume areas. The RTM-based hindcasts underestimate the plume areas on those days. In contrast, the intake temperature-based plume area hindcasts shown in Figure 4-5 match the observed areas closely. Clearly, the intake temperature excursion shown on 17 and 18 August 2002 was real, because it produced a corresponding change in plume area that is not represented by the RTM-based model, absent some unknown factor.

The generalized statistical model allows us to place the plumes observed during the 2002 Field Survey Program in the overall context of historical plumes at the Station. The average plume observed during the period of the Field Survey Program was about 87.5 ha, which falls in the 81st percentile (Figure 4-7). In general, the plumes observed during 2002 tend to fall in the range of historically larger area plumes hindcast by the model. This may be reflective of the shift toward higher air temperatures seen in the meteorological data (Section 2.4.6), or it may be an artifact of the differences between RTM and intake temperature as a factor in the linear model.

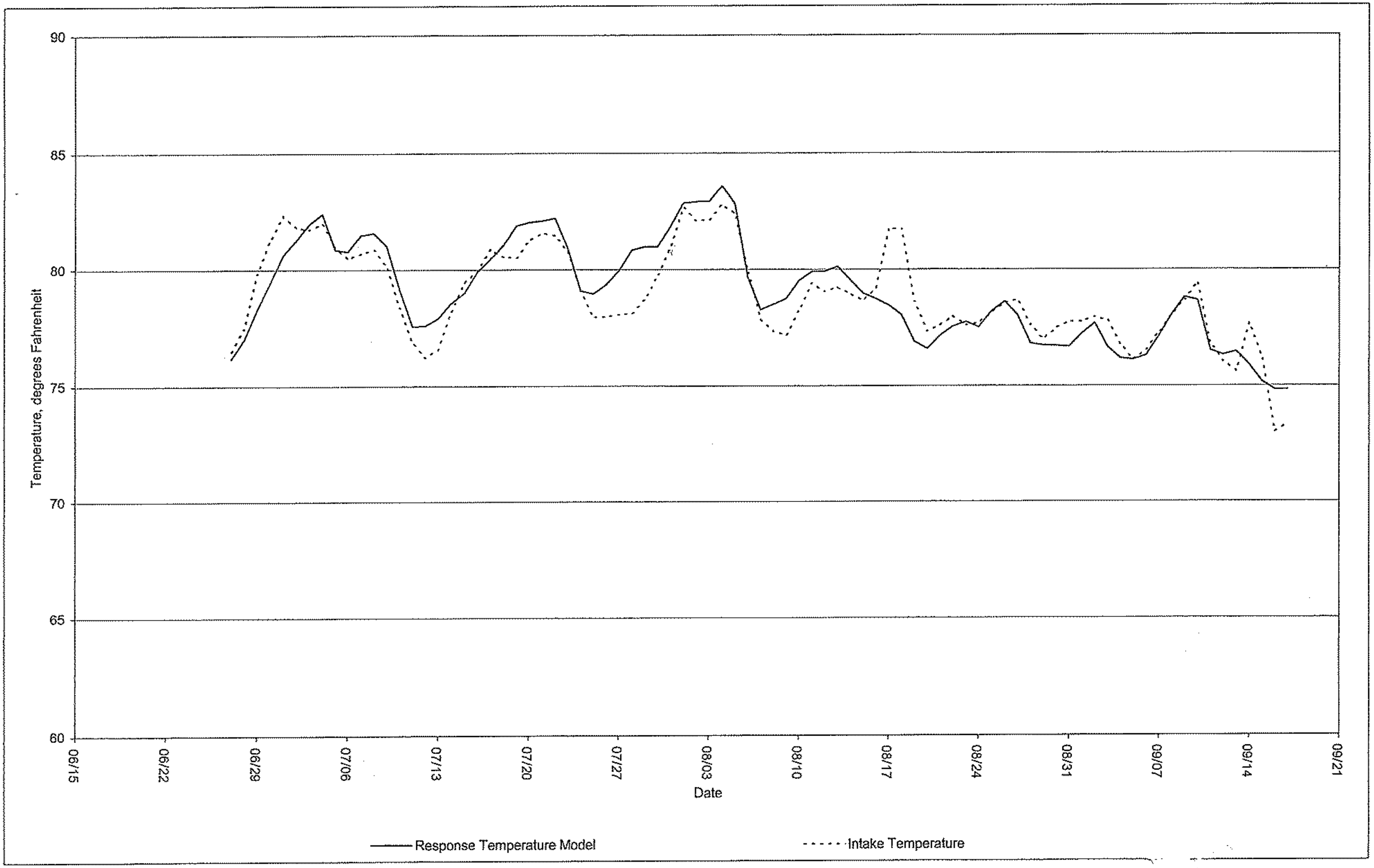
Table 4-1. Potential factors affecting plume area.

Factor (daily average)	Units	Mean	Standard Deviation	Incremental R^2 (w.r.t. log area)
Discharge Flow	MGD	713.97	57.56	0.015802
Discharge Temperature	°C	31.57	1.44	0.250580
Intake Temperature	°C	26.10	1.15	0.262063
Dewpoint Temperature	°C	16.68	3.88	0.168557
Wet Bulb Temperature	°C	19.31	2.99	0.231946
Relative Humidity	%	65	8.7	0.000433
Wind Speed	mph	6.38	2.70	0.022771
Wind Direction (Note 1)	azimuthal degrees	180.25	96.41	0.127632
Sea Level Air Pressure	millibars	1018.17	3.79	0.013773
Incident Solar Radiation	Joules/m^2	23.996	5.550	0.093990
Water Level Difference (Note 2)	feet	0.127	0.410	0.023857
"Discharge Heat Rate" (Note 3)	MGD-°C	3910	580	0.007936
River Flow (Note 4)	cfs	665.5	863.4	0.035485
Plant Electrical Load	MW	496.72	76.22	0.078855
Log Plume Area	log(ft^2)	7.0148	0.4605	n/a

Note 1: See the text in the Conceptual Overview section regarding interpretation of azimuthal wind direction.
Note 2: Lake level at Buffalo, NY minus lake level at Toledo, OH.
Note 3: This is a measure of actual heat load, which would require use of water density and specific heat (both essentially constants) in the calculation.
Note 4: Adjusted for drainage area below the Waterville USGS gage.

Table 4-2. Comparison of River Flow to Plant Intake Flow. (area-adjusted, monthly average daily river flow in cfs; shaded cells indicate flows less than maximum Station intake flow of 1157 cfs)

Year	1	2	3	4	5	6	7	8	9	10	11	12	Annual
1953										144	223	310	225
1954	605	1900	6981	9509	2346	2408	943	2710	412	9438	2524	4315	3688
1955	9807	6296	18405	5996	1164	908	1437	695	150	971	7903	1360	4586
1956	532	12215	16541	5767	14853	3544	1028	1205	340	202	308	707	4754
1957	3101	4892	3687	27025	5961	4606	5863	376	692	2234	3648	14344	6352
1958	3150	2914	6056	4680	2186	9184	8962	6456	2164	546	5279	1818	4452
1959	9231	27419	13562	11313	9962	1774	932	363	364	1486	4813	8266	7325
1960	13879	13051	4190	7668	2777	6909	1364	391	278	216	445	238	4241
1961	301	1471	13296	21400	6931	1489	1023	1561	859	613	2176	986	4342
1962	7629	6483	18344	2616	1830	1011	484	216	310	293	358	234	3316
1963	328	515	14181	4292	1006	1953	970	544	133	100	261	185	2056
1964	609	443	9588	17067	2940	2397	396	206	165	118	205	359	2865
1965	3193	7742	13804	13900	3691	793	448	356	823	2577	1281	5954	4524
1966	5426	3765	5070	3527	8923	1220	2801	577	289	249	5711	24872	5242
1967	2647	9601	16721	9106	8179	1172	694	561	232	786	2504	19520	5977
1968	5631	14243	7322	6564	9718	6913	2913	2263	690	420	1947	6651	5407
1969	19269	12319	3836	11292	8155	4593	3932	584	767	1358	7259	2202	6251
1970	1552	9373	9721	15250	9046	2240	2478	869	535	913	1775	4157	4787
1971	1258	14568	9236	1993	6671	3524	1044	357	658	731	379	5375	3752
1972	5514	1198	10185	19050	4816	2652	3712	1129	8755	5839	19576	12760	7919
1973	8032	5388	21223	9184	5259	11112	5195	2150	372	441	1483	7358	6451
1974	20531	11234	15137	10170	7619	2186	578	481	506	278	791	4978	6197
1975	9813	14084	8304	6435	7422	7642	2220	2371	3150	1544	1598	8652	6053
1976	5125	31314	13369	3159	2928	1871	1116	565	301	534	373	526	4995
1977	333	1658	14490	12424	4988	684	2019	1444	3249	1219	1437	19698	5343
1978	1889	892	30274	19889	4115	2243	3119	574	366	271	512	1600	5514
1979	2786	2397	16050	13394	5307	2353	3213	5104	1627	488	5285	10438	5731
1980	4239	3385	18408	12576	4283	10332	3877	3613	1544	523	572	2177	5463
1981	1294	15963	3399	8390	9696	25087	2814	1414	5182	4303	2957	4541	6977
1982	8702	13289	39884	11483	5241	4855	3711	430	333	319	5471	13437	8931
1983	3092	4446	4631	15215	13198	2982	2993	516	247	1162	8770	13931	5934
1984	1046	11618	15646	18613	7455	2347	760	811	463	1101	2609	4225	5520
1985	7767	15092	14140	11213	1297	2230	764	707	945	2278	10656	9902	6346
1986	3381	14017	14468	4161	3492	7048	9018	1856	2773	9165	4394	6677	6667
1987	2483	4472	3990	4272	3844	3203	3617	686	667	439	1296	9000	3162
1988	2689	6949	6848	6881	1192	242	369	577	587	2034	6089	2951	3093
1989	9058	2737	3685	9807	7974	11657	1780	906	2180	658	1945	589	4407
1990	7681	22438	7926	7012	11201	4956	8096	2951	1807	6193	3268	17448	8345
1991	17540	7724	4104	11062	3028	5272	618	624	372	3630	3966	3118	5066
1992	3835	6747	7859	11350	2970	3937	11690	2744	10777	3318	19847	4927	7461
1993	22599	2759	19734	14359	2699	7614	7823	440	982	832	3655	3402	7285
1994	3613	8760	7589	15155	2472	1868	1887	569	199	189	463	2036	3685
1995	5095	2086	7987	12626	4498	4425	2712	1666	298	939	3741	882	3913
1996	11146	3782	8969	8423	17655	10819	2850	1849	453	593	3531	12917	6945
1997	5410	13795	18107	3350	10749	13532	6857	3715	4346	783	2851	8788	7658
1998	13543	11451	15011	13346	5099	5239	4480	10090	1033	751	830	825	6789
1999	12978	6012	10259	16467	3987	3924	814	409	164	459	424	1031	4728
2000	745	4289	3877	8256	7459	13794	2932	1757	2176	2054	1288	4194	4381
2001	1302	15820	3939	8398	8887	5515	949	749	842	14543	2047	12298	6218
2002	2170	12881	8870	16798	10335	2605	648	592	261				6050
Monthly	5991	8736	11610	10651	6072	4916	2876	1506	1364	1842	3484	6269	5422



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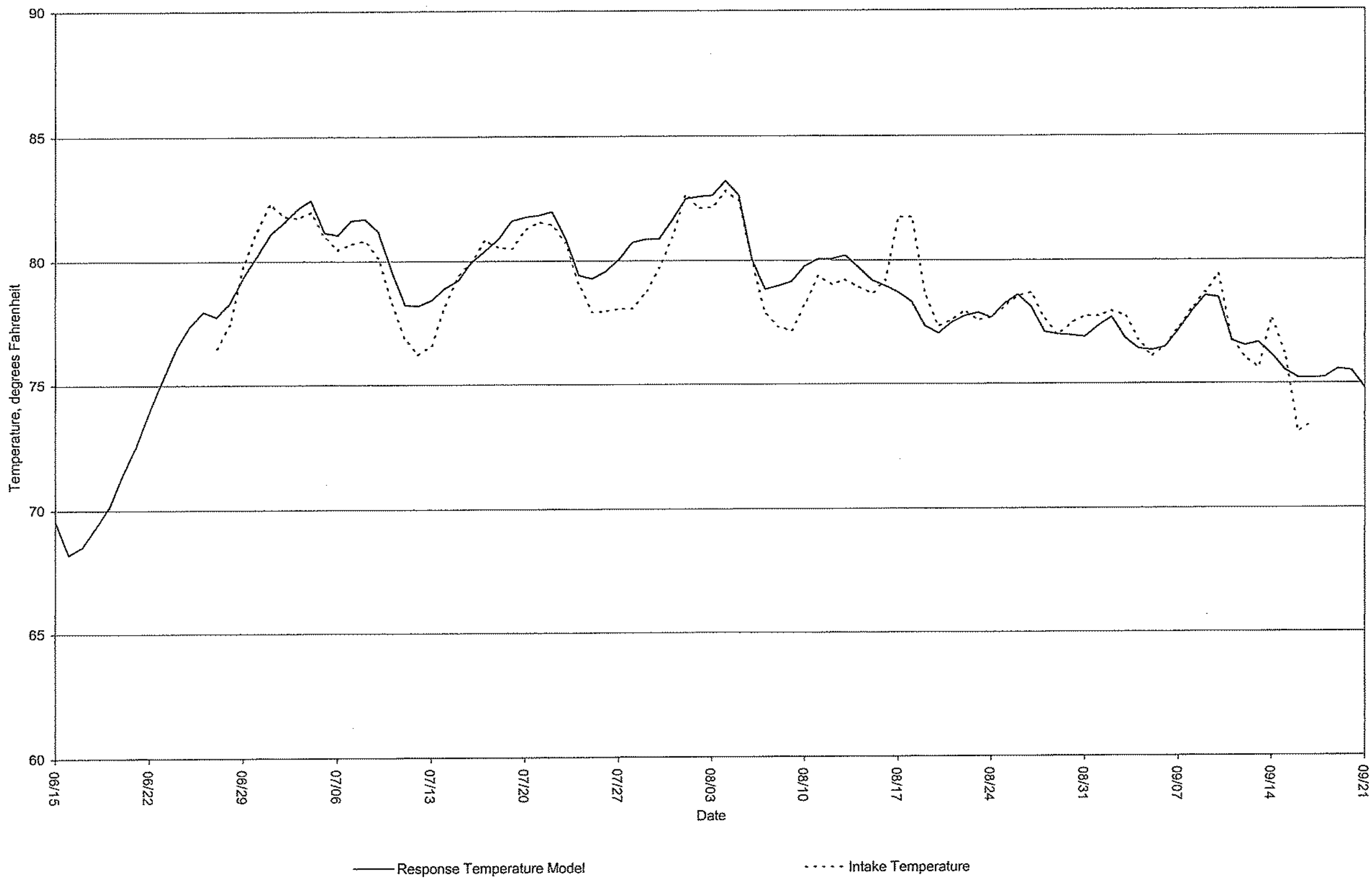
FirstEnergy Corp, Toledo Edison Bay Shore Station

Comparison of RTM Calibration with Intake Temperature Summer 2002

FIGURE 4 - 1



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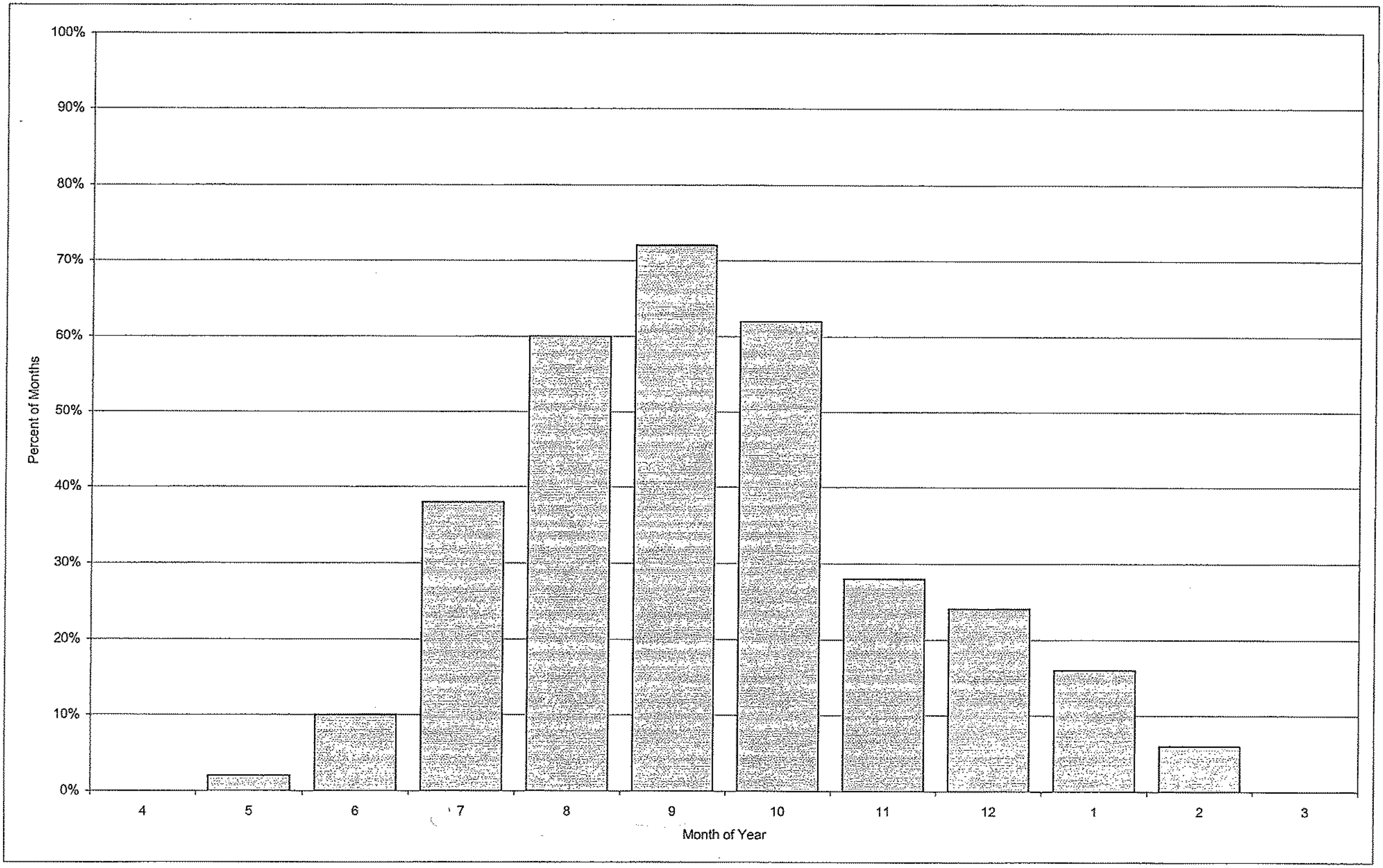
FirstEnergy Corp, Toledo Edison Bay Shore Station

Comparison of Historical RTM Results with Intake Temperature
Summer 2002

FIGURE 4 - 2



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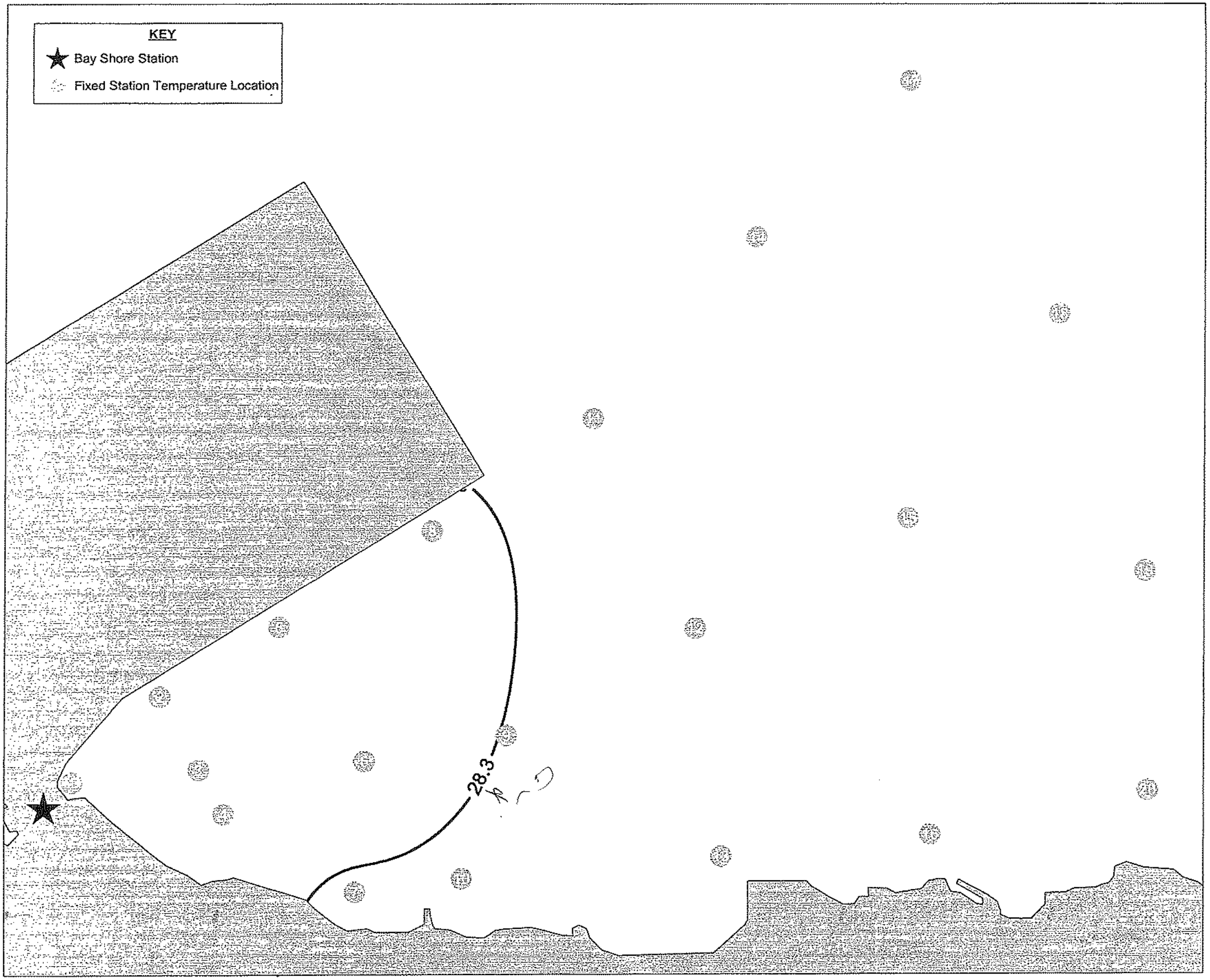
Percentage of Months in 50-Year Record for which Maumee River Flow < Maximum Station Discharge Flow

FIGURE 4 - 3



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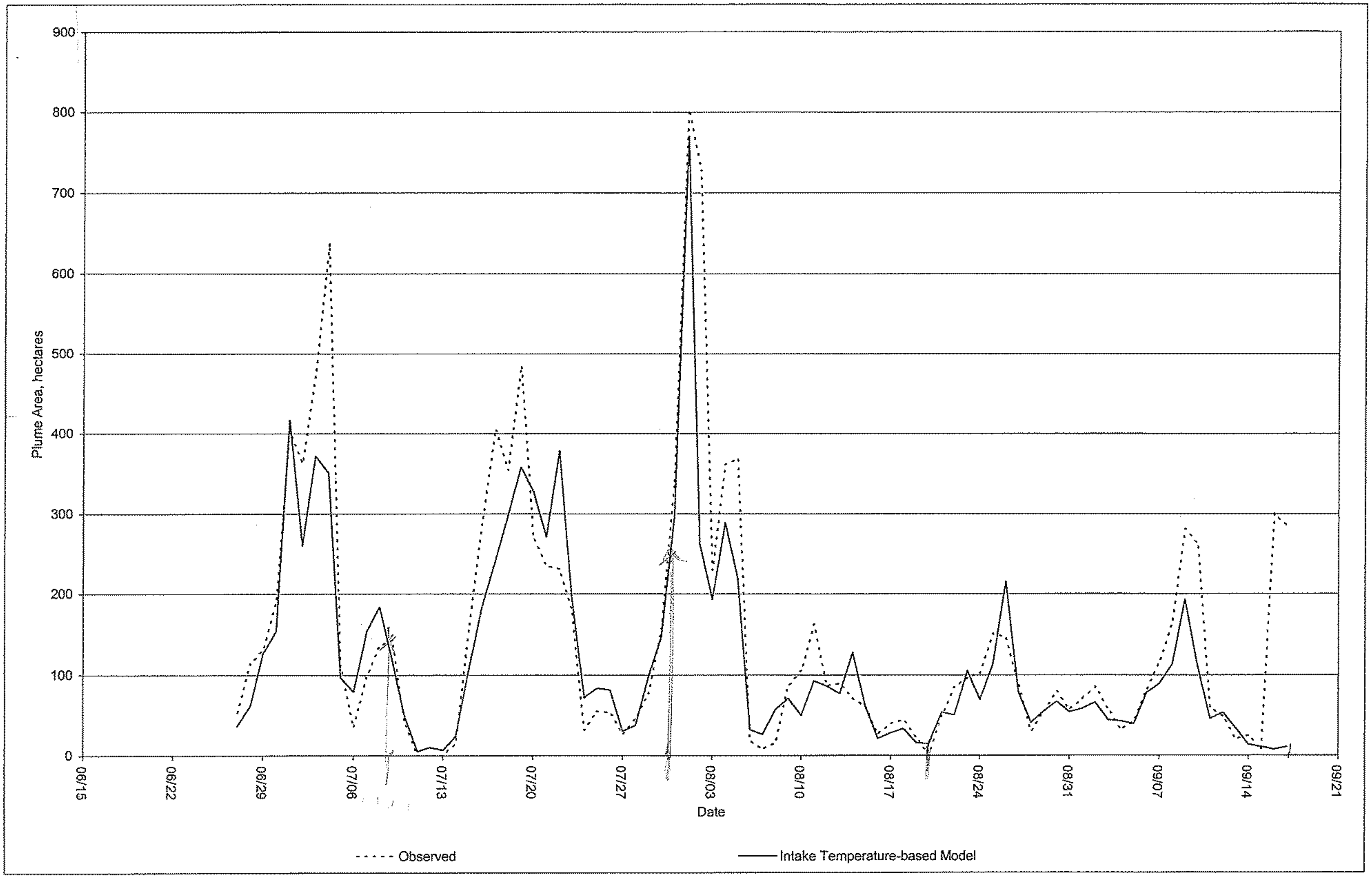
Typical Surface Temperature Contour Based on Fixed Station Daily Average Data (07 September 2002)

FIGURE 4 - 4



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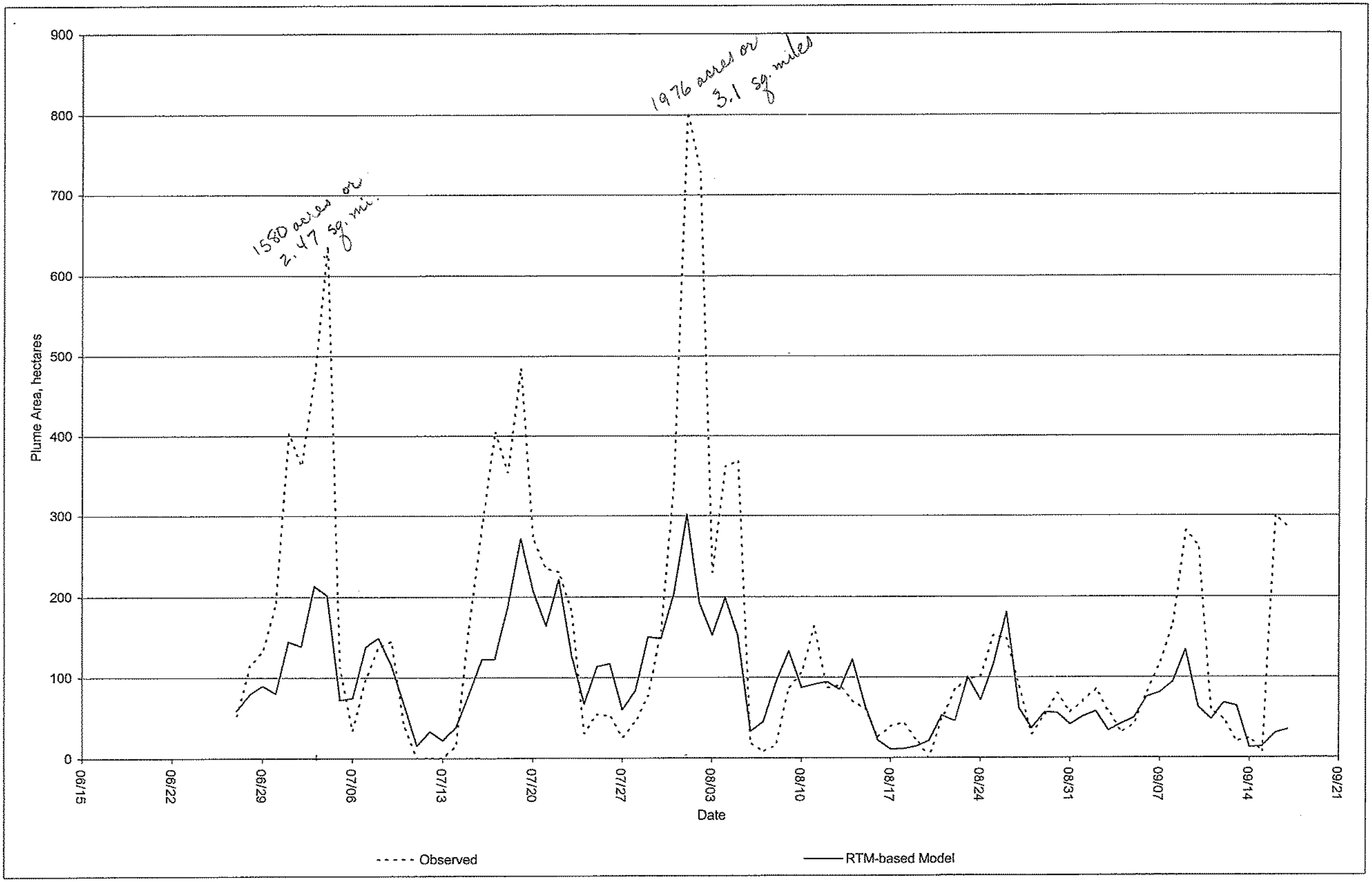
Comparison of Intake Temperature-Based Model Plume with Observed Plume

FIGURE 4 - 5



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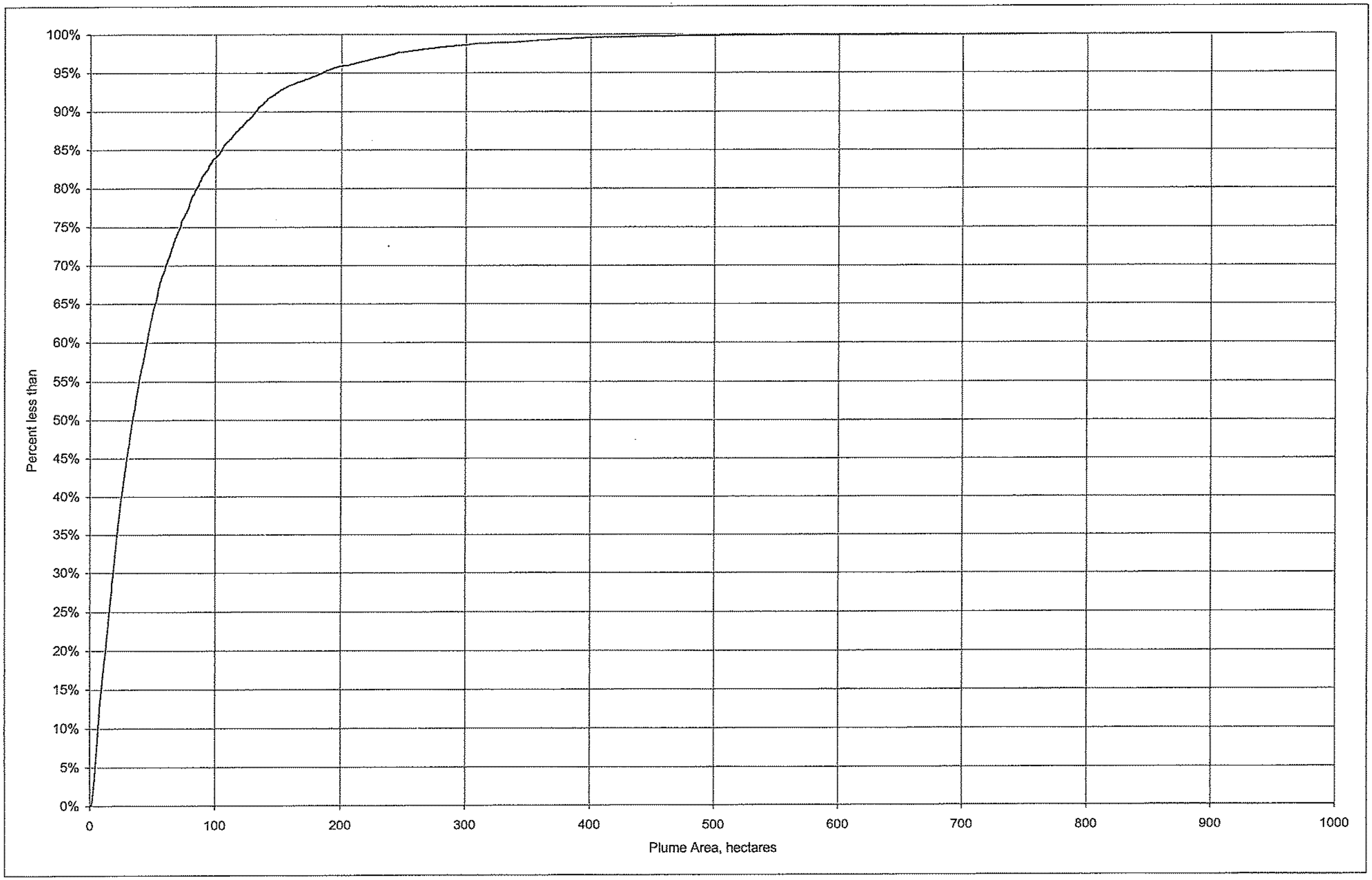
Comparison of RTM-Based Model Plume with Observed Plume

FIGURE 4 - 6



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FirstEnergy Corp, Toledo Edison Bay Shore Station

Forecast Cumulative Probability Distribution of Station Thermal Plumes

FIGURE 4 - 7

5 SUMMARY AND CONCLUSIONS

In summary, LMS successfully concluded the planned Field Survey Program within the time limits requested by OEPA, evaluated use of the CORMIX model to represent the Station thermal plume, and developed an alternative statistical model of the thermal plume.

Based on the results presented in this report, we conclude that:

- CORMIX-GI version 4.1 GT is not adequate to represent the characteristics of the Station discharge, because of the location and physical characteristics of the discharge relative to the receiving waters and the low ambient water current speeds.
- Based on this Study, the most useful linear model of the Station thermal plume is:

$$\log A = (-4.384648 - 0.00121666Q_d + 0.2282059T_r - 0.04509878W + 0.002904766P)$$

where:

A	= Plume area based on daily average water temperature and criterion temperature (hectares)
Q_d	= Daily average Station discharge flow (MGD)
T_r	= Daily average Station Response Temperature (°C)
W	= Daily average Wind speed reported by NWS for TOL (mph)
P	= Daily average Station load (MW)

and:

log	= the common (base-10) logarithm

- During the Field Survey Period, the Station thermal plume area ranged from 0 to about 800 ha. or 1976 acres (3.1 sq. miles)
- Based on historical meteorological data and worst case Station operating conditions, the average thermal plume would have an area of about 34 ha and the 95th percentile plume would be about 184 ha. 84 acres (0.13 sq. miles)
- The plumes observed during the 2002 Field Survey Program tend to fall in the higher percentiles of the historical plume distribution, but this may be consistent with the warmer meteorological conditions experienced during 2002.
- Frequently during summer months the plant intake flow comes primarily from Toledo Harbor and Maumee Bay, rather than Maumee River.
- The linear regression model developed is limited to the summer period and has marginal statistical reliability.

APPENDIX A

PLAN OF STUDY and ASSOCIATED DOCUMENTS

Prepared for

FirstEnergy Corporation, Akron, Ohio

on behalf of

Toledo Edison

Toledo Edison Company Bayshore Station
THERMAL MIXING ZONE STUDY
Plan of Study

January 2002

Prepared by

#925-001

LMS **LAWLER, MATUSKY & SKELLY ENGINEERS LLP**
One Blue Hill Plaza • Pearl River, New York 10965
ENVIRONMENTAL SCIENCE & ENGINEERING CONSULTANTS

Toledo Edison Company – Bayshore Station
Thermal Mixing Zone Study
Plan of Study

1.0 Introduction

This document presents a Plan of Study for the Toledo Edison Company-Bayshore Station thermal discharge (the Plan). The Plan responds to requirements contained in Ohio Environmental Protection Agency Permit No. 2IB00000*PD, issued 29 June 2001 and effective 01 August 2001 (the Permit). Lawler, Matusky & Skelly Engineers LLP (LMS), Pearl River, New York prepared the Plan for FirstEnergy Corporation (FirstEnergy), Akron, Ohio, on behalf of Toledo Edison.

2.0 Background

2.1 Bayshore Station

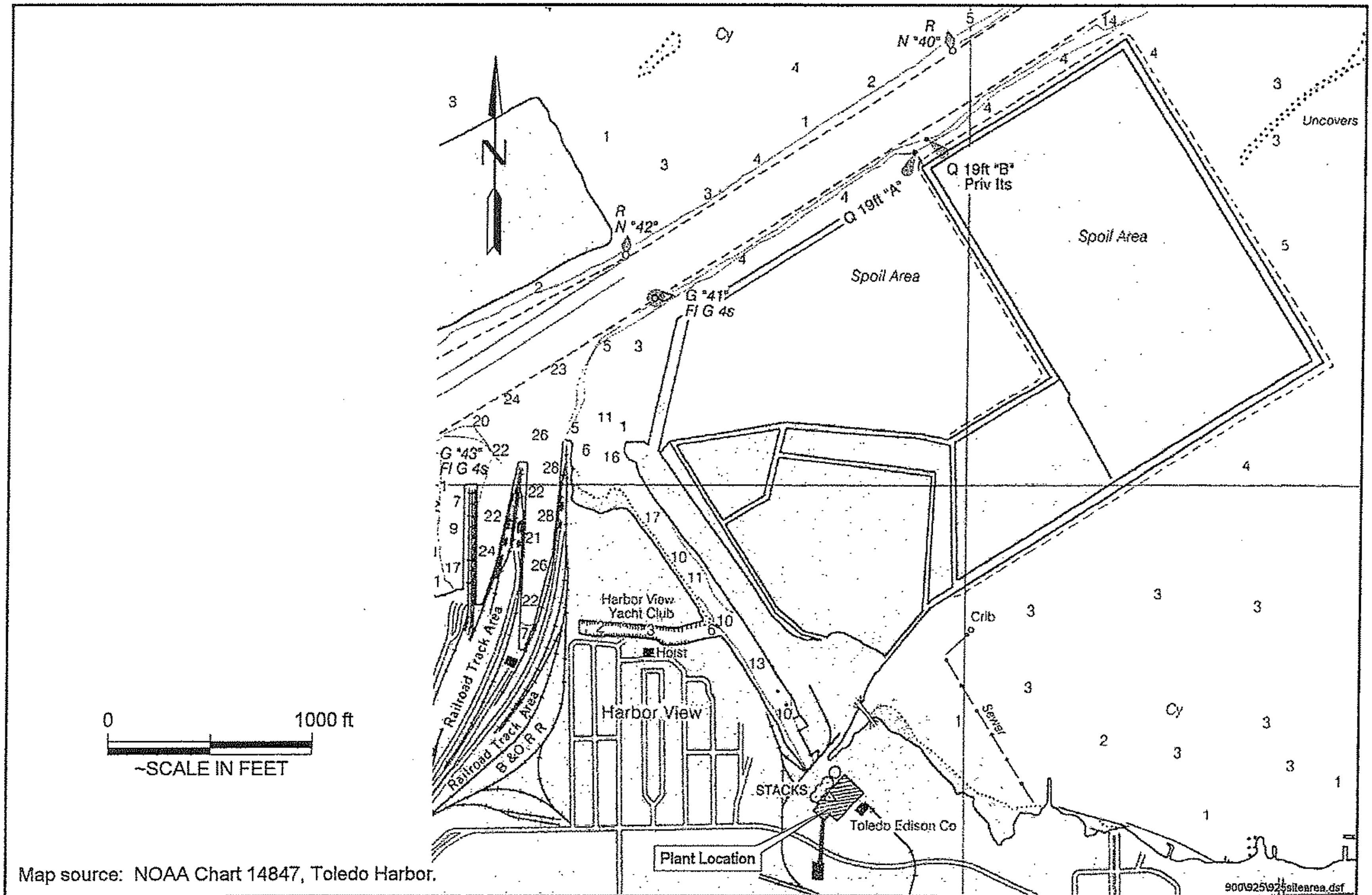
The Toledo Edison Company-Bayshore Station (the Station) is located in Oregon, Ohio, on a peninsula between the southeastern shore at the mouth of the Maumee River and the southeastern shore of Maumee Bay (Figure 2-1). The Station consists of four generating units, with the following generating and pump capacities:

Unit	Rating (MWe)	Circulating Water Pumps	Pumping Capacity (total, MGD)
1	136	2	184.3
2	138	2	184.3
3	142	2	184.3
4	215	2	192.0
Total Plant	631	8	744.9

Each unit is cooled with once-through cooling water drawn from a navigable side channel of the Maumee River. The once-through cooling water is discharged from Outfall 001 to a canal directly tributary to Maumee Bay. In addition to the once-through cooling water discharge, the Station is permitted to discharge low volume wastewater to Driftmeyer Ditch and to Maumee Bay from Outfalls 002 and 003, respectively.

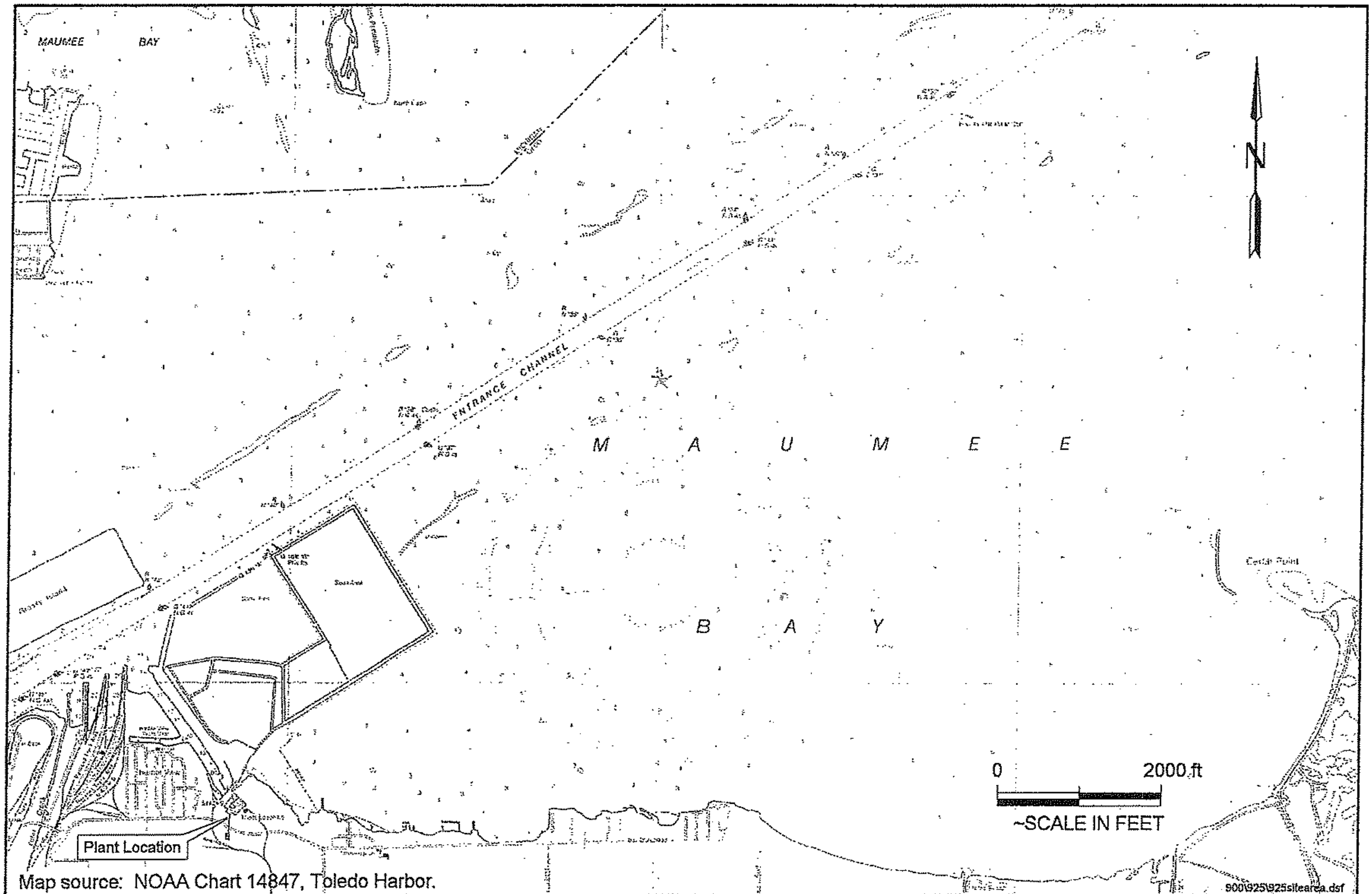
2.2 Maumee Bay

As shown in Figure 2-2, Maumee Bay is on the southwestern shore of Lake Erie. The boundary between Maumee Bay and the main body of Lake Erie is usually arbitrarily defined as a line



Map source: NOAA Chart 14847, Toledo Harbor.

LMS Lawler, Matusky & Skelly Engineers LLP One Blue Hill Plaza • Pearl River, New York 10965 ENVIRONMENTAL SCIENCE & ENGINEERING CONSULTANTS	**Facility Location** TOLEDO EDISON COMPANY	**Figure 2-1**



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Maumee Bay and Vicinity

TOLEDO EDISON COMPANY

Figure 2-2

between North Cape and Cedar Point. The Bay is relatively shallow, with depths ranging from about 1 ft Low Water Datum (LWD) to about 8 ft LWD outside the dredged navigation channel. The navigation channel project dimensions are a width of 500 ft and a depth of 28 ft LWD from the Maumee Bay Entrance Light to the mouth of the Maumee River.[1]

The Station discharges its cooling water to an unnamed region of the Bay to the southeast of the Confined Disposal Facility (CDF). For purposes of this Plan of Study, the unnamed region will be called "the Cove", bounded by a line extending from and continuing parallel to the northeastern wall of the CDF to the shoreline between the Station and Maumee Bay State Park. The CDF was constructed in 1975 to contain contaminated dredge materials produced by maintenance dredging of the navigation channel.

Lake levels, water temperatures and circulation within Maumee Bay are influenced by wind-driven seiches in Lake Erie. In addition, local wind effects and discharge from the Maumee River may influence water currents in the Bay.

Maumee Bay was the subject of a two-year environmental quality study to determine any impacts resulting from construction of the CDF. The first year of the study was conducted in 1974 to determine conditions before construction and the second year of study took place in 1976, following construction. The study was undertaken by a consortium of environmental organizations and documented in two comprehensive reports.[2,3]

According to the 1977 Report, Maumee Bay has a surface area of about 40 km^2, a mean depth of 1.5 m, and a volume of 0.06 km^3. The Report estimates the typical "turnover time" (bay volume divided by mean Maumee River discharge) to be approximately 5 days. It indicates this is a very short turnover time relative to other comparably sized Great Lakes bays, so that conditions in Maumee Bay will typically strongly reflect conditions in the Maumee River discharge.

2.3 Maumee River

The Maumee River is the principal tributary to Maumee Bay, with the Ottawa River and smaller creeks and ditches providing additional inflows. The Maumee River drains approximately 16,400 km^2 in western Ohio and eastern Indiana. The 1977 Report indicates the mean river discharge over the period of record at that time was 136 m^3/s. It also indicates the soil conditions in the Maumee drainage basin contribute to a heavy sediment load in the river, which gives rise to the on-going need to dredge the Maumee Bay navigation channel and to operate the CDF.

[1] National Ocean Survey Chart 14847, 30th Edition, 30 October 1999.
[2] P.C. Fraleigh, J.C. Burham, G.H. Gronau, T.L. Kovacik, and T.J. Tramer. The Maumee Bay Environmental Quality Study 1974. Report to the Toledo-Lucas County Port Authority Environmental Advisory Committee (1975).
[3] P.C. Fraleigh, J.C. Burnham, G.H. Gronau, and T.L. Kovacik. Maumee Bay Environmental Quality Study 1977 Final Report. Report to the Toledo-Lucas County Port Authority Environmental Advisory Committee (January 1979).

2.4 Other Discharges

In addition to the Station thermal discharge, the Cove receives treated wastewater from the City of Oregon Wastewater Treatment Plant. The Plant has a capacity to treat up to 8 MGD of dry-weather flows, with a wet-weather capacity of 36 MGD. The wastewater discharge is within about 400 m northeast of the mouth of the Station discharge canal, in approximately 1 m of water (LWD). Under its discharge permit, the Plant must achieve better than 90% removal for BOD and suspended solids, and must meet permit criteria for phosphorus, coliform bacteria, chlorine, and heavy metals.[4]

2.5 Recent Water Quality Concerns

As has been widely reported in regional news media, the nearby Maumee Bay State Park beach has been subject to frequent closures in recent years, due to high bacteria levels in the lake water. Reportedly, one reason for the inclusion of bacteria sampling in the Permit was concern for the effect that the Station's discharge of Maumee River water to the Cove might have on those bacteria levels.

However, the media have recently reported that the elevated bacteria levels are now attributed primarily to "bacteria harboring in sediments...in creeks and ditches such as Wolf Creek and Berger Ditch and possibly the Maumee River"[5] that are transported into Maumee Bay during wet weather. Other published reports indicate that the Maumee River is not complicit in the elevated bacteria levels.[6]

3.0 Purpose of the Plan

The purpose of the Plan is to provide the information required by the Permit Schedule of Compliance regarding a "Bacteria and Temperature Study". The following paragraphs present the Schedule of Compliance text and commentary on those requirements:

> *1. Within six months after the effective date of the permit, the permittee shall submit two copies of a Plan of Study to determine the extent of the impact of the thermal discharge from outfall 2IB00000001 and to determine the bacteria levels at the Toledo Edison Bayshore Station. The Plan, at a minimum, shall define the requirements of the study necessary to characterize the size, areal extent, and depth of the discharge plume from outfall 2IB00000001 for temperature during the summer and winter seasons, and compare the bacteria levels in the water withdrawn at intake station 2IB00000800 to bacteria levels at outfall 2IB00000001. Additionally, the Plan of Study shall include the following components (Event Code 34099):*
>
> *a. A proposed sampling schedule for temperature at the intake station 2IB00000800, the outfall 2IB00000001, and within and along the discharge plume and mixing zone for outfall 2IB00000001, and a proposed sampling schedule for E. coli and fecal coliform*

---

[4] See the web site at http://ci.oregon.oh.us.
[5] Toledo Metropolitan Area Council of Governments, Volume 5, Issue 9, October 2001.
[6] The Blade, Toledo, Ohio, 09 October 2001.

at the intake station 2IB00000800 and the outfall 2IB00000001. Sampling within and along the discharge plume and mixing zone shall occur after sampling at outfall 2IB00000001 based upon the time required for the effluent to flow to the various sampling locations in Maumee Bay.

Water temperature is currently monitored on a continuous basis at both the intake and discharge stations; the Plan incorporates the existing monitoring to satisfy the temperature sampling requirement at these points.

Between June and September 2001, FirstEnergy performed E. coli sampling at the intake and discharge stations; the Plan calls for extension of this program to the same months in 2002, and expansion to include sampling for fecal coliforms.

Use of travel time as the criterion for timing of temperature sampling in the discharge plume does not seem appropriate for a generating station discharge. Changes in Station operations, and therefore discharge temperatures and flows, may be expected to occur over much longer intervals than the anticipated travel time in the plume. Thus, we anticipate that, under relatively constant meteorological and limnological conditions, the thermal plume will remain relatively stable for long periods, and sampling can be done at times convenient to the work schedule.

b. Sampling shall occur during summer months defined as June through September under a range of conditions, including wet and dry rainfall conditions, high and low background water temperatures, and variable wind patterns. Historical data may also be used as appropriate in developing a model of the mixing zone;

While an attempt will be made to include as wide a range of meteorological and limnological conditions as possible, the constraints of mobilizing any field sampling program are such that infrequently occurring events may be missed. In addition, the sampling program will be limited to one summer, so the range of conditions available will be those that occur during that summer. As detailed below, the purpose of the modeling is to generalize the observed conditions to a wider range of potential conditions.

c. A description of the process that will be used to determine and justify the sampling locations and the number of sampling locations within and along the discharge plume and mixing zone for outfall 2IB00000001. The mixing zone is defined as the area and depth within which the effluent discharge and the receiving waters mix, and the outside edge of the mixing zone is the area in which the effluent is sufficiently diluted to meet maximum aquatic water quality standards;

As detailed below, the sampling locations will be determined using a preliminary application of the model. It is our understanding that the "maximum aquatic water quality standards" that determine the mixing zone are the water temperature standards for Western Lake Erie. See Section 5.1.1 for a discussion of the mixing zone concept.

d. A description of procedures which will be used to evaluate the impact of weather conditions on the size and areal extent of the discharge plume, the mixing zone, and the area in which temperature returns to background levels; and

The approach to evaluating the impact of weather conditions is discussed later in the Plan. See Sections 5.1.1 and 5.1.2 for a discussion of the mixing zone concept and its relationship to background temperature.

e. A description of a U.S. EPA-approved (or equivalent) model which will be used to characterize the mixing zone.

See Section 4 for a description of the model selected to represent the Station discharge plume.

As demonstrated in the following sections, the Plan presented in this document satisfies each of the foregoing requirements.

4.0 Selection of Model

Because the data required for modeling will necessarily affect the design of the field program called for in the Permit, it is necessary to select a model before describing the Field Studies.

The U.S. EPA-approved model selected for use in the Bayshore Thermal Mixing Zone Study (the Study) is CORMIX. CORMIX is widely used to model generating station discharge plumes and it is the only U.S. EPA-approved plume model capable of handling a surface discharge canal. Visual Plume, the other U.S. EPA-approved thermal plume model, is intended for application to discharges submerged in deep water. The DOS version of CORMIX is available from U.S. EPA's Center for Exposure Assessment Modeling (CEAM, Athens, Georgia). Detailed information on CORMIX can be found at the CEAM web site: http://www.epa.gov/ceampubl/cormix.htm.

The specific version of CORMIX to be applied during the Study is CORMIX-GI version 4.1GT. CORMIX-GI is Windows-based, so it is more readily used on modern computers than the DOS version and it has graphic visualization capabilities not found in the DOS version. Detailed information on CORMIX-GI can be found at the Oregon Graduate Institute web site: http://www.cormix.info.[7]

CORMIX is unique among water quality models in that it does not require field data for calibration of model parameters. Nonetheless, regulatory agencies frequently require comparison of CORMIX results with field data to establish a degree of confidence in the model results. The Field Studies described below will fulfill that requirement.

[7] Note that this web site uses a new four-letter web site category—.info—instead of one of the older, three-letter .edu, .gov, .org or .com categories.

While CORMIX is the best available U.S. EPA-approved model to represent the Station discharge, it has certain limitations. As a result, field survey data will be particularly important to this application of CORMIX over any available model.

5.0 Study Plan

The Study consists of three phases:

1. Preliminary modeling to define specific locations for both fixed and mobile sampling stations
2. Conduct of Field Studies based on the results of the preliminary modeling
3. Final modeling and analysis based on the results of the Field Studies

5.1 Plume Size and the Concept of "Delta T"

5.1.1 Mixing Zone Concept

Paragraph 1.c. of the Permit Schedule of Compliance defines the mixing zone as:

> ***the area and depth within which the effluent discharge and the receiving waters mix, and the outside edge of the mixing zone is the area in which the effluent is sufficiently diluted to meet maximum aquatic water quality standards***

Under this definition, the edge of the mixing zone is determined relative to the water quality standards applicable to the receiving waters. The Ohio Water Quality Standards establish the following criteria for water temperatures in the western basin of Lake Erie (the region west of a line from Pelee Point, Canada to Scott Point, Catawba Island, Ohio):

Period	Average [°F (°C)]	Daily Maximum [°F (°C)]
January 1 – 31	--	35 (1.7)
February 1 – 29	--	38 (3.3)
March 1 – 15	--	39 (3.9)
March 16 – 31	--	45 (7.2)
April 1 – 15	--	51 (10.6)
April 16 – 30	53 (11.7)	56 (13.3)
May 1 – 15	59 (15.0	64 (17.8)
May 16 – 31	65 (18.3)	72 (22.2)
June 1 – 15	75 (23.9) 21.7	78 (25.6) 25
June 16 – 30	80 (26.7) 27.3	83 (28.3) 30.6
July 1 –31	83 (28.3) 28.3	85 (29.4) 30.6
August 1 – 31	83 (28.3) 28.3	85 (29.4) 30.6
September 1 – 15	78 (25.6) 28.3	83 (28.3) 30.6
September 16 – 30	76 (24.4) 23.9	81 (27.2) 26.7
October 1 – 15	66 (18.9) 20.6	71 (21.7) 23.3
October 16 – 31	60 (15.6)	65 (18.3)
November 1 –30	53 (11.7)	58 (14.4)
December 1 – 31	--	46 (7.8)

Thus, under the definition of mixing zone adopted by the Permit Schedule of Compliance, the outside edge of the mixing zone is the locus of points at which the water temperature is equal to the Daily Maximum given in the foregoing table. It should be noted that there will be discrete, potentially large, changes in mixing zone size on the days when the criterion changes. The magnitude of the change will depend on the temperature gradient in the plume where the criterion temperature occurs.

Because the change in temperature across a typical once-through cooling system (Station delta T) is relatively (but not totally) independent of the intake temperature, the discharge temperature will be primarily a function of Maumee River water temperature and Station capacity factor.

It should be noted that the Daily Maximum temperature typically differs from the so-called "background" temperature, as discussed in the next section. It is possible for the background temperature to be higher or lower than the criterion Daily Maximum temperature. The background temperature could be higher than the Daily Maximum if, for example, Maumee River discharge temperatures exceeded the Daily Maximum, causing water temperatures in Maumee Bay to be higher than the criterion. In such a case, the Mixing Zone would be independent of the Station discharge and strongly dependent on Maumee River temperatures.

5.1.2 Background Temperature Concept

The Permit Schedule of Compliance also requires that the discharge temperatures be compared with "background temperature":

b. Sampling shall occur during summer months defined as June through September under a range of conditions, including wet and dry rainfall conditions, __high and low background water temperatures__ **[emphasis added]***, and variable wind patterns. Historical data may also be used as appropriate in developing a model of the mixing zone;*

...

d. A description of procedures which will be used to evaluate the impact of weather conditions on the size and areal extent of the discharge plume, the mixing zone, and __the area in which temperature returns to background levels__ **[emphasis added]***; and*

There does not appear to be any formal definition or use of "background temperature" in the Ohio Water Quality Standards, so it is necessary to adopt a working definition for this Plan.

Background temperature is often defined as the temperature that exists where the discharge under study no longer has a measurable effect. It is virtually impossible to measure, because it is not possible to separate the thermal component due to the discharge from that due to other causes, for example, the Maumee River. The spatial variability of temperatures in the receiving waters due to other causes may be larger than any changes resulting from the Station discharge at the edges or perimeter of the thermal plume.

Another definition of background temperature is the temperature that would occur in the absence of the discharge under study. Again, this version of background temperature cannot be measured directly, because it is impossible to separate the changes due to the Station from changes due to other causes, including such phenomena as internal seiches. It is possible to estimate background temperature defined this way, but we believe this is beyond the intended scope of the study.

In addition, the background temperature is not necessarily the temperature of the dilution water used in CORMIX modeling. If there is significant re-entrainment of cooling water, the dilution water will typically be warmer than the background temperature. The CORMIX model does not incorporate a mechanism to estimate the farfield re-entrainment.[8] When this factor comes into play, it can be addressed either through a farfield model or detailed field data. Such a model would necessarily encompass a larger scope than we believe was intended in the Permit Schedule of Compliance. As a result, this Plan incorporates the use of extensive field data to address this issue.

In some studies of thermal discharges, background temperature has been estimated by computation of what is known as the Response Temperature (RT). RT is an estimate of the daily average temperature that a mass of water of a given depth would achieve in a continuously stirred tank reactor (CSTR) under the prevailing weather conditions over a span of time. That

---

[8] CORMIX does incorporate the effects of nearfield re-entrainment resulting, for example, from re-circulation in the lee of a plume that becomes attached to the shoreline after discharge.

span can be 40 or 50 years of daily estimates or more, if the necessary meteorological data are available.

However, RT does not account for advective processes, such as internal seiches or the contributions of the Maumee River, that may be expected to affect temperatures in the Cove and Maumee Bay. Because we anticipate that such factors may play a significant role in determining the size of the Station thermal plume, RT is not expected to be a useful tool in this Study.

As a result, this Plan adopts a pragmatic definition of background temperature, based on what can be achieved within the intended scope of the Study. As detailed below, preliminary CORMIX modeling will be used to approximate the discharge plume. Based on that estimate, a fixed station will be established in waters that are expected to be outside the dominant influence of the plume. The observed temperatures at the fixed site will be used in the analysis as an estimate of background temperature, and used with an appreciation of the limitations on those measurements discussed here.

5.1.3 Delta T

The term "delta T" is used to designate a temperature difference. Several different delta Ts will be required in evaluating the Station discharge:

- Station delta T – the temperature increase that occurs as a result of the cooling water passing through the Station cooling system, as measured by the difference between the intake water temperature and the discharge water temperature
- River delta T – the difference between the Maumee River water temperature and the receiving water temperature
- Discharge delta T – the difference between the discharge water temperature and the receiving water temperature; the Discharge delta T is the sum of the Station delta T and the River delta T
- Background delta T – the difference between the water temperature at any point in the plume and the background temperature
- Mixing Zone delta T – the difference between the water temperature at any point in the plume and the criterion Daily Maximum temperature

Note that the receiving water temperature is not necessarily the same as the background temperature. As noted in the discussion of background temperature, if re-entrainment occurs in the Cove, the receiving water temperature may be elevated relative to the background temperature. When computing the temperature at any point in the plume, the calculation is done by diluting the actual discharge temperature (river temperature plus Station delta T) with the receiving water temperature. In the absence of a calibrated farfield model, it may be possible to estimate the receiving water temperature (i.e., the background temperature plus the local build-up of previously discharged heat) from fixed water temperature recording station(s) located near the discharge but outside the direct influence of the thermal plume. If these station(s) can be determined, they may provide an estimate of the dilution water temperature prior to being drawn into the recently discharged plume. The calculations for Background delta T and Mixing Zone delta T are then done using the resulting plume temperature.

5.2 Modeling

5.2.1 Purpose of Modeling

The CORMIX model will be used for two purposes:

- To produce preliminary estimates of the discharge plume to aid in locating fixed sampling stations and establishing mobile survey track lines.
- To produce estimates of the discharge plume under a range of natural conditions, not all of which may have been observed during the Field Studies.

5.2.2 Preliminary Modeling

5.2.2.1 Purpose

The purpose of the preliminary CORMIX modeling is to estimate the 3-dimensional extent of the Station's discharge plume for use in establishing the locations of:

1. The Fixed Stations
2. The Background Current and Temperature Station
3. The Mobile Survey track lines

5.2.2.2 Data Requirements

The CORMIX model will require estimates of the inputs shown in Table 5-1. The necessary estimates will be made based on available information on historical Station operations, discharge design, and ambient water conditions. If the available data are insufficient, appropriate estimates will be made based on the experience of the modelers with inputs from knowledgeable FirstEnergy personnel.

5.2.2.3 Methodology

Due to the dimensions of the discharge canal, it will be necessary to approximate the discharge canal to produce results from CORMIX. For the preliminary modeling, the approach will be to determine through trial-and-error, the largest overall discharge width and smallest depth that will result in stable operation of CORMIX. The fundamental limitation on the discharge characteristics is the aspect ratio, the ratio of the depth to the width, which is extraordinarily low in this case. The ratio can be increased by reducing the width or increasing the depth. The objective will be to find the combination that reflects the minimum deviation from the prototype, but allows CORMIX to function.

TABLE 5-1. Required Inputs for the CORMIX Model (assuming a buoyant surface plume)

SUMMARY OF INPUT PARAMETERS
Ambient (Receiving water conditions)
Cross Section of the simulated receiving water
Manning's n (details the estimated frictional characteristics of the receiving water bottom)
General depth of the receiving water
Ambient Velocity
Ambient Density
Stratification Type (either uniform density over depth [i.e., well-mixed] or stratified)
Discharge
Outfall Bank (details which side of the simulated receiving water channel the outfall is located)
Outfall Configuration (the three options in the model are flush, protruding or co-flow outfall designs)
Outfall angle (details the orientation of discharge centerline and receiving water channel flow)
Outfall Channel Width
Outfall Channel Depth
Depth at Discharge
Discharge Density
Discharge Flowrate
Discharge Delta T
Surface heat exchange coefficient

5.2.2.4 Anticipated Results

We will use the standard graphical outputs available from CORMIX to evaluate the extent of the thermal plume and to establish the parameters for the Field Studies. The standard graphical outputs include plan and profile views of the plume, as well as three-dimensional views. CORMIX defines the plume boundary in terms of plume dynamics, not comparison with an imposed standard such as the Daily Maximum, so judgement will be exercised in interpreting these graphical outputs.

5.2.3 Post-Field Study Modeling

5.2.3.1 Purpose

The purpose of the Post-Field Study Modeling is to satisfy the following requirements of Paragraph 5.e in the Permit Schedule of Compliance:

> ***An evaluation of the impact of weather conditions on the size, depth, and areal extent of the discharge plume and the mixing zone, and results of modeling efforts for both summer and winter seasons.***

5.2.3.2 Approach

The evaluation of weather effects will be accomplished by analyzing both the results of the Field Studies and the results of the CORMIX modeling. As previously noted, the limitations of CORMIX in this case necessarily require a greater reliance on the Field Studies. CORMIX can incorporate weather in two direct ways: through the effects of receiving water temperature on water density and through the specification of surface wind speed, which affects the rate of surface cooling. In addition, to the extent that water levels and therefore depths are seasonal, seasonality can be incorporated through specification of receiving water depths.

5.2.3.3 Data Requirements

The data requirements for the Post-Survey modeling are identical to those for the Preliminary modeling; the difference is in the source of the data to fill that need. In the Post-Survey modeling we will rely primarily on data obtained during the Field Studies, both as model inputs and as the prototype against which model results will be compared.

5.2.3.4 Methodology

As each Mobile Survey is completed (see below), we will use CORMIX to represent the discharge and receiving water conditions that occurred during that survey. Model results will be compared with the observed distribution of water temperatures in the Cove and Maumee Bay. Through the succession of five Mobile Surveys, we expect to be able to iterate to find a combination of model inputs that produce a reasonable representation the Station discharge, given the limitations of the CORMIX model.

Once the basic model inputs are established, we will then use the model to evaluate a range of representative summer and winter conditions. Those conditions are presented in Table 5-2. The intent of the design conditions is to define a set of model input parameters that provide for a reasonable approximation of "worst" or "best" receiving water conditions for the dilution and dissipation of the thermal plume. Thus, the extreme values are not proposed for selection (i.e., the maximum or minimum value on record) as the probability that the extreme ambient water temperature, water surface elevation and wind speed values would occur simultaneously is minute, and thus the resultant model simulation would not be realistic.

Available data will be evaluated to identify the typical ranges of river and background water temperatures, and wind conditions that are representative of summer and winter conditions. The CORMIX model will then be run for these representative conditions, to develop estimates of the Station thermal plume under typical conditions.

5.2.3.5 Anticipated Results

The model results will be presented graphically as plots of the horizontal extent of the mixing zone and the locus of points where the plume returns to background under the various modeling scenarios specified in Table 5-2. We do not anticipate that it will be necessary to show the vertical dimension, since the shallow depths are expected to assure that the plume extends to the bottom.

5.3 Field Studies

5.3.1 Purpose of Field Studies

The purposes of the Field Studies are:

1. To provide field observations that define the Station thermal plume under a range of actual conditions.
2. To provide field observations representative of the variability in the bacterial conditions in the Station intake and discharge.
3. To provide field observations that can be used to perform and evaluate the CORMIX modeling.

5.3.2 Constraints on the Field Studies

We foresee three potentially significant practical constraints on the Field Studies. First, the depths and conditions in the Cove, as indicated on the available charts and documentation, may restrict the access to some areas of the Cove. This will be especially true if the lake levels are lower than usual during the summer months.

Secondly, those same depths and conditions, as well as the presence of the Station discharge suggest that there may be significance presence of submerged aquatic vegetation (SAV). SAV can present difficulties for operation of survey vessels, interfering with both the propulsion and steering systems, and fouling any over-the-side equipment while underway. Growth of SAV can

TABLE 5-2. General Description of Seasonal Conditions to be Evaluated Using the CORMIX model

Season	Specific Months Reviewed for Model Input Data and Simulated	Design Condition[9]	Seasonal Model Input Parameters, as determined from the Historical Record		
			Ambient Water Temperature[10]	Water Surface Elevation[11]	Wind Speed[12]
Winter	January, February, and March	Reasonable "Worst" Case	90^{th} Percentile	10^{th} Percentile	10^{th} Percentile
		Reasonable "Best" Case	10^{th} Percentile	90^{th} Percentile	90^{th} Percentile
Summer	June, July, and August	Reasonable "Worst" Case	90^{th} Percentile	10^{th} Percentile	10^{th} Percentile
		Reasonable "Best" Case	10^{th} Percentile	90^{th} Percentile	90^{th} Percentile

[9] These "Design Conditions" represent extreme events, because it would be highly unlikely that all three seasonal extremes would occur simultaneously.
[10] The selected ambient water temperature will affect the size of the predicted mixing zone, when compared to the fixed regulatory standard. The higher ambient temperatures will likely define a larger mixing zone for the thermal plume (where the discharge delta T is relatively constant).
[11] Seasonally influenced by the level of freshwater inflow to the lake, this parameter defines the average depth of the simulated receiving water. The lower average depth reduces the volume of receiving water available for the dilution of the thermal plume.
[12] Defines the surface heat exchange coefficient, where lower wind speed reduces the amount of heat lost to the atmosphere. Please note that the CORMIX model cannot simulate wind-induced plume advection.

also inhibit the function of fixed station instrumentation by creating a barrier between the instrument and the water, attenuating temperature changes and water flows. The effects of SAV will be minimized to the extent feasible through use of appropriate operating procedures and protective coatings. Nonetheless, we anticipate some limitations on the conduct of the field studies may result.

The third constraint is weather and lake conditions. Due to the shallow depths in the Cove, it will be necessary to use relatively small vessels with low freeboard. The same shallow depths can be expected to give rise to choppy lake conditions under adverse weather, which may threaten the small vessels. As discussed below, the boat crew chief will have full authority to determine when to begin, postpone, discontinue and resume any field activity based on available information, experience and judgment.

5.3.3 Design of Field Studies

The Field Studies will consist of Fixed Stations operated during the summer period, a Reconnaissance Survey, a Bathymetric Survey, and five intensive Mobile Surveys conducted at intervals over the summer period.

5.3.3.1 Fixed Stations

The main purpose of the Fixed Stations is to monitor the conditions in the receiving waters during the periods between the Mobile Surveys, so that we can "interpolate" the behavior of the discharge plume for times between the Mobile Surveys. In addition, the Fixed Station sampling will satisfy the requirement to monitor the Station intake and discharge for water temperature and bacteriological condition.

5.3.3.1.1 Bacteriological Stations

The purpose of the Bacteriological Stations is to satisfy the requirement for bacteriological sampling in the Permit Schedule of Compliance. The Station is not expected to be a source of bacterial contamination. Bacteria discharged from the Station are drawn into the Station with the cooling water and discharged after the water passes through the heat exchangers (condensers). Sampling for E. coli was done from June 2001 through September 2001 and the E. coli sampling program will be performed during the summer months of the Field Studies. Analysis for fecal coliforms will begin with the summer period and will continue through the end of the Field Studies.

5.3.3.1.1.1 Methodology

The fecal coliform analyses will conform to Standard Methods 18th Edition Method 9222d. The E. coli analyses will conform to EPA Method 1103.1. The laboratory performing the analyses will be responsible for providing all sample bottles, sample transportation, and chain of custody materials.

5.3.3.1.1.2 Location and Depth

The intake bacteriological sample will be taken at the screen house intakes and will consist of a once daily grab sample from between 2 and 6 feet below the surface.

The discharge bacteriological sample will be taken at the road bridge over the discharge canal and will consist of a once daily grab sample from between 2 and 6 feet below the surface.

5.3.3.1.1.3 Sampling Schedule

The bacteriological samples will be taken on Tuesday and Thursday each week during the summer period at approximately the same time of day (typically between 1000 hours ET and 1200 hours ET). The samples will be scheduled to be taken about 2 hours after condenser circulating water chlorine/bromine treatment is completed, to assure they are not affected by the chlorination/bromination process. The bacteriological sample at the discharge point will be timed relative to the intake to match approximately the estimated travel time through the Station cooling system.

5.3.3.1.2 Temperature Stations

The purpose of the fixed water temperature recording stations is to provide a continuous record of water temperatures during the periods between the intensive Mobile Surveys. Water temperatures will be recorded at 20 moored stations in the Cove and Maumee Bay on a continuous basis during the summer period. In addition, water temperature will be recorded on a continuous basis at one offshore station to establish background water temperature. The background temperature station will be co-located with one of the Water Current Stations.

5.3.3.1.2.1 Instrumentation

At all but the intake and discharge, the water temperature will be recorded using instruments capable of ±0.2°C accuracy over a range of 0°C to 50°C, with 12-bit resolution. The water temperature recorders will have a temperature response time of 5 minutes or better. Water temperatures at the intake and discharge will be observed using the existing continuous recording sensors at the Station.

5.3.3.1.2.2 Location and Depth

The exact location of each temperature recording station will be determined based on the results of the preliminary CORMIX modeling. The temperature recorders will be deployed just above the Bay bottom, to minimize the likelihood of attracting vandals or interfering with boating traffic. We anticipate that the shallow water column will be well mixed, so the bottom mounted instruments will record a temperature representative of the entire water column, including the surface (where we would ordinarily expect to find the highest temperatures). Two temperature units will be deployed at each location for redundancy. Actual location of each fixed station will be determined using the Differential Global Positioning System (DGPS).

In addition to the existing intake and discharge sensors, we anticipate that 10 of the instruments will be deployed along the approximate plume centerline, with the other 10 deployed along lines perpendicular to the centerline at each centerline station. Based on the location of the discharge relative to the CDF bulkhead, we expect the plume will tend to hug the CDF bulkhead, so the lines nearest the discharge point will have only one off-centerline instruments per line. Once the centerline separates from the CDF, instruments will be deployed on both sides of the modeled centerline. The expected plume centerline will be estimated during the preliminary CORMIX modeling and the sensors allocated accordingly.

The background temperature station will be co-located with one of the water current recording stations, at a site to be determined based on the preliminary CORMIX modeling. It is anticipated that the water current stations will be located in water of sufficient depth to require separate surface and bottom temperature recording instruments. The intention is to place the background station out of the immediate influence of the plume, but within the Cove region, so the data will be representative of that part of Maumee Bay.

5.3.3.1.2.3 Sampling Schedule

The temperature recorders will be deployed in early June and remain on station until late September. The exact dates of deployment and retrieval will be determined by operational considerations, such as weather conditions for working on the lake. Each temperature recorder will be set to record water temperature once every 6 minutes (0.1 hour), with the temperature measurements synchronized to occur at approximately the same time at all stations.

5.3.3.1.2.4 Servicing Cycle

To minimize data loss due to malfunction or vandalism, one of the two temperature recorders at each location will be retrieved and replaced on a monthly basis, coordinated with the monthly Mobile Surveys. The remaining temperature recorder at each station will be retrieved and replaced during the following monthly servicing so that no recorder will be deployed for longer than two months. The staggered recovery cycle allows for overlapping deployment periods that will reveal instrument calibration differentials, if present.

5.3.3.1.3 Water Current Stations

The purpose of the Water Current Stations will be to assist in an understanding of the relationship between water currents in the Cove and Maumee Bay, and anticipated driving factors, such as wind conditions, waves and seiches. Two instruments are required to define the circulation in the Cove. The discharge entrainment is expected to generate a clockwise current that enters the eastern side of the Cove and flows toward the CDF, where the water is entrained into the plume and carried out of the Cove along the CDF shoreline. Other, larger scale effects, such as winds and seiches, have the potential to create other current effects that may either reinforce or oppose the discharge-generated circulation.

5.3.3.1.3.1 Instrumentation

The water currents will be measured using two bottom-mounted recording acoustic doppler current meters. The bottom-mounted meters are capable of measuring water currents in a user-specified depth region ("cell") within the water column above it. The instruments are capable of measuring water speeds of 5 m/s to an accuracy of ±1% of relative speed ±0.5 cm/s, with current direction accuracy of ±2° and repeatability of ±0.1°. The instrument will also be capable of measuring and recording water temperatures to a repeatability of ±0.1°C. In addition to the temperature measurement built-in to the current meters, temperature recording devices identical to those used at the Temperature Stations will be co-located at the surface and bottom of one of the current meter locations.

5.3.3.1.3.2 Location and Depth

The locations of the current meters will be determined based on the CORMIX modeling and on preliminary field observations during the Reconnaissance Survey (see below). They will be located out of the region dominated by the plume momentum, at points intended to characterize currents in the Cove and Maumee Bay. The instruments will be positioned on the bottom and will be mounted to minimize the elevation of the sensor heads above the bottom, thereby maximizing the portion of the water column sampled. It is assumed that the water depth at the station will be at least 2 m LWD. If minimum water depth at a representative location cannot be assured due to existing lake level, the current meters will not be deployed (or will be retrieved, if previously deployed).

5.3.3.1.3.3 Sampling Schedule

The current meters will be set to record water currents and temperatures at the instrument once every 6 minutes, with the observations synchronized to occur approximately at the same time as the water temperature measurements at the other Fixed Stations.

5.3.3.1.3.4 Servicing Cycle

To minimize data loss due to malfunction or vandalism, the water current recorders will be retrieved, data downloaded, serviced and redeployed on a monthly basis, coordinated with the monthly Mobile Surveys.

5.3.3.2 Reconnaissance Survey

Prior to installation of the Fixed Stations and conduct of the Bathymetric Survey and first Mobile Survey, we will perform a Reconnaissance Survey. The purpose of the Reconnaissance Survey is to confirm the feasibility of installing the Fixed Stations at the specified locations, and the feasibility of conducting the Bathymetric Survey and Mobile Surveys along the defined track lines. The available navigational information on the Cove is severely limited, so the feasibility of these activities cannot be confirmed without conducting a Reconnaissance Survey. Final adjustments to the proposed Fixed Station locations and survey track lines will be made following the Reconnaissance Survey.

5.3.3.3 Bathymetric Survey

Due to the relative lack of detailed information on the bathymetry of the discharge canal and the Cove, a survey of water depths will be conducted. The survey will use both standard acoustic depth sounding equipment and mechanical staffs, in conjunction with the DGPS positioning system. Reference lake elevation will be acquired from the National Ocean Survey (NOS) lake level gage located near U.S. Coast Guard (USCG) Station Toledo. Water surface elevation within the discharge canal itself will be determined by staff gage tied in to a local benchmark, because it may differ from lake level due to hydrodynamic conditions. The Bathymetric Survey will be coordinated with the first Mobile Survey, but will not coincide with that survey, because the Bathymetric Survey will require closer track line spacing in some areas than the Mobile Surveys. In addition to acquiring data needed for the modeling, the Bathymetric Survey will aid in making final adjustments to locations of the Fixed Stations.

5.3.3.4 Mobile Surveys

Five Mobile Surveys will be undertaken, one at the beginning of the summer period, then approximately monthly thereafter for the remainder of the four-month summer period called for in the Schedule of Compliance (June through September). The purpose of the Mobile Surveys will be to determine the detailed distribution of water temperatures and currents in the Station plume and surrounding area at the time of each survey.

5.3.3.4.1 Instrumentation

All instrumentation will be mounted on a small boat capable of navigating in shallow water (depths greater than 1 ft). The instrumentation will operate continuously while the boat is moving along each track line.

Horizontal boat position will be determined using a real-time Differential Global Positioning System (DGPS) aboard the boat and will be automatically logged every second to a digital computer. Differential corrections required by the DGPS will be acquired in real time from the nearest receivable U.S. Coast Guard beacon broadcasting this information.

Surface water temperatures will be determined using a fast response electronic temperature sensor and logged with the position data. The fast response sensor will have a response time of better than 1 second, with an accuracy of ±0.003°C and a resolution of ±0.0001°C.

Water currents will be determined using a direct-reading acoustic doppler current profiler (ADCP), with the capability of sensing currents in water depths ranging from 30 cm to 21 m, and logged every second to a digital computer. Velocity accuracy will be ±0.25% of relative speed with a resolution of 1 mm/s; direction accuracy will be ±2°. Vertical cell dimension will be approximately 10 cm.

5.3.3.4.2 Track Lines

In the Cove, water temperature will be recorded continuously along track lines running from shore to shore perpendicular to the CDF bulkhead. Beyond the CDF, the track lines will extend approximately 1 statute mile on both sides of a line extending parallel to the CDF bulkhead, so that the track lines running to the northwest will end in the navigation channel. Surface water temperatures will be measured during the same time of day for each of the five mobile surveys. The acceptable boat speed for acquiring temperature data is greater than for acquiring current velocity (due to the relative size and drag of the two instruments), so the two parameters will be measured on separate passes along the track lines, at different times during the same day. The number of lines will be determined by the ability of the boat to complete both elements of the survey during daylight hours in one day. At least one track line will be in close proximity to the Fixed Station Current Meters. The spacing of the temperature track lines will be determined by the longitudinal extent of the plume mixing zone, as forecast by the preliminary modeling and the Reconnaissance Survey, plus at least two track lines beyond the end of the plume mixing zone. Current velocity track lines will be determined based on field observations of spatial variability in local currents during the Reconnaissance Survey. At a nominal boat operating speed of 2 m/s (about 4 statute miles per hour) for temperature and 1 m/s (about 2 statute miles per hour) for current velocity, we anticipate covering approximately 18 statute miles of temperature track line in 4 hours and 15 statute miles of current track lines in 6 hours during a nominal 10-hour survey day.

5.3.3.4.3 Station Location and Vertical Profiling

The boat will periodically stop to verify our assumption that the relatively shallow water column is vertically well mixed. The verification will be accomplished by lowering the fast-response temperature sensor into the water. At the depths typical of Maumee Bay and the navigation channel, sensor depth will be assumed equal to the length of line paid out. The bottom and corresponding surface temperature will be manually recorded on a field data sheet. The vertical temperature verification will be performed as frequently as necessary to characterize the degree of stratification in the Cove and Maumee Bay.

5.3.3.4.4 Timing of Surveys

Because it is not possible to forecast weather sufficiently in advance to assure the surveys will cover a range of weather conditions, they will be scheduled for fixed dates occurring once a month during the summer. The stochastic nature of weather will determine the actual range of conditions observed. Surveying will only be conducted on days when the responsible boat chief determines that it is safe to operate the small boat being used. Surveys may be postponed at the boat chief's discretion for any safety reason and commenced when the boat chief considers conditions safe. If unsafe boating conditions occur, surveying on any given day may be abandoned and resumed when conditions permit.

5.3.4 Auxiliary Data

5.3.4.1 Meteorology

Meteorological data will be obtained from the National Weather Service (NWS) cooperative station operated by USCG Station Toledo.

5.3.4.2 Climatology

Climatological data will be obtained from National Oceanic and Atmospheric Administration's Midwestern Regional Climate Center located at Illinois State University. We anticipate acquiring data for the NWS stations located at Metcalf Field, Toledo Express Airport, and USCG Station Toledo.

5.3.4.3 Lake Level

As noted above, lake level information will be obtained from the National Ocean Survey lake level gage located adjacent to USCG Station Toledo.

5.3.4.4 River Flow

River flow data will be obtained from the United States Geological Survey (USGS) gaging station 04193500 at Waterville, Ohio.

5.3.5 Data Analysis

Paragraph 1.d in the Permit Schedule of Compliance requires:

> ***d. A description of the procedures which will be used to evaluate of the impact of weather conditions on the size and areal extent of the discharge plume, the mixing zone, and the area in which temperature returns to background levels;***

In addition, paragraph 5.e requires that the Final Report include:

> ***e. An evaluation of the impact of weather conditions on the size, depth, and areal extent of the discharge plume and the mixing zone, and the results of modelling efforts for both summer and winter seasons.***

These two paragraphs clearly indicate the focus of the analysis on the relationship between weather conditions and the Station's thermal plume.

We can anticipate three basic mechanisms in which weather may affect the physical dimensions of the Stations thermal plume:

- Regional weather will affect the capacity factor of the Station. Seasonal changes in the duration of the day will change the pattern and magnitude of the load carried by the

Station. Shorter-term weather events will create load changes within the overall seasonal pattern. This, in turn, will affect the Station delta T, as well as the duration of operation at a given Station delta T. For a given River delta T, any change in the Station delta T will result in a change in the size of the region occupied by the plume, both relative to the criterion Daily Maximum temperature and relative to the background temperature.

- Regional weather will affect the temperature of the Maumee River and the background temperature in Maumee Bay. In the absence of internal seiches, Bay water temperature can be expected to track River water temperature closely.[13] In addition, the shallow waters of the Bay may be expected to respond rapidly to changes in solar radiation, relative humidity and other factors associated with direct heating and cooling of the water column.

- The effect of periods of strong winds can be to setup the Lake surface, with corresponding displacement of the thermocline. When a period of strong winds ends, the response of the Lake can be a periodic standing wave at the surface density discontinuity, as well as the corresponding displacements of the thermocline. The effect on the plume would be to produce changes in the background temperatures experienced by the plume. For a given Station delta T, the effect of decreasing background temperature may be to increase the region required for the plume to return to background, but may decrease the mixing zone, due to entrainment of cooler water.

Given these three broad categories of potential impacts of weather on the plume, the focus of the data analysis will be on identifying the degree of correlation between plume size and the weather factors expected to affect the size. We will combine the Mobile Survey data with the Fixed Station temperature data to develop a daily estimate of plume size during the summer period of study. The Mobile Survey temperature data will be contoured to develop a representation of water temperature in the survey area. We will then compare the contours with the criterion Daily Maximum and observed background temperature for the date of the Mobile Survey to establish the locus of the mixing zone boundary and the region required for the plume to return to background. The resulting plume sizes will then be compared with the Fixed Station data to establish the relationship between the daily pattern of temperature at the 20 stations and the size of the plume. Once a relationship is developed, the Fixed Station data will be used to estimate the daily size of the plume.

We will then use standard statistical methods to evaluate the influence of the anticipated driving factors, including wind speed, wind direction, cloud cover, relative humidity, river water temperature, lake level variations (as a measure of seiche activity). We will also use statistical techniques to evaluate the influence of wind, cloud cover, air temperature and relative humidity on Station load factor and corresponding Station delta T.

The specific statistical tools will be selected based on the quality and quantity of weather data available to the Study. We anticipate that the statistical analysis will be similar to those successfully applied by Fraleigh in the 1977 Report sections on Water Mass Mixing Patterns and

[13] See the 1977 Report.

Water Temperature. Typical methods would include regression and analysis of covariance. Because of the influence of the periodic changes in the criterion Daily Maximum, it may also be desirable to apply a CART-type analysis.

6.0 Reporting

6.1 Status Report

Paragraph 4 of the Permit Schedule of Compliance requires that a Status Report on the progress of the study be submitted within 12 months after the effective date of the Permit, i.e., by 31 July 2002. The Status Report will be submitted as required.

6.1.1 Contents

The Status Report will be a brief letter report that will incorporate:

1. A brief presentation of the preliminary CORMIX modeling results
2. The final Mobile Survey tracklines
3. The final schedule for the Mobile Surveys and an indication of the actual dates on which they were completed
4. An assessment of the data retrieval achieved by the Mobile Surveys
5. The date on which the Bathymetric Survey was performed and an assessment of the data retrieval associated with that survey
6. The locations of the Fixed Stations
7. The dates of deployment and servicing of the Fixed Stations
8. An assessment of the percent data retrieval to date from the Fixed Stations

6.1.2 Audience

The intended audience for the Status Report will be the professional staff of the Ohio EPA.

6.2 Final Report

Paragraph 5 of the Permit Schedule of Compliance requires that a Final Report on the Study be submitted within 18 months of the effective date of the Permit, i.e., by 31 January 2003.

6.2.1 Contents

As required by Paragraph 5 of the Permit Schedule of Compliance, the Final Report will include the following information:

- A summary and conclusions of the findings of the Study.
- All sampling data for all locations.
- Sampling data for the intake station compared to sampling data for outfall 2IB00000001 and the discharge plume and mixing zone.

- A graphical representation of the discharge plume and the mixing zone for outfall 2IB00000001 under wet and dry weather, as well as high and low background water temperatures, and variable wind patterns, and the area in which temperature returns to background levels.
- An evaluation of the impact of weather conditions on the size, depth, and areal extent of the discharge plume and the mixing zone, and results of modeling efforts for both summer and winter seasons.

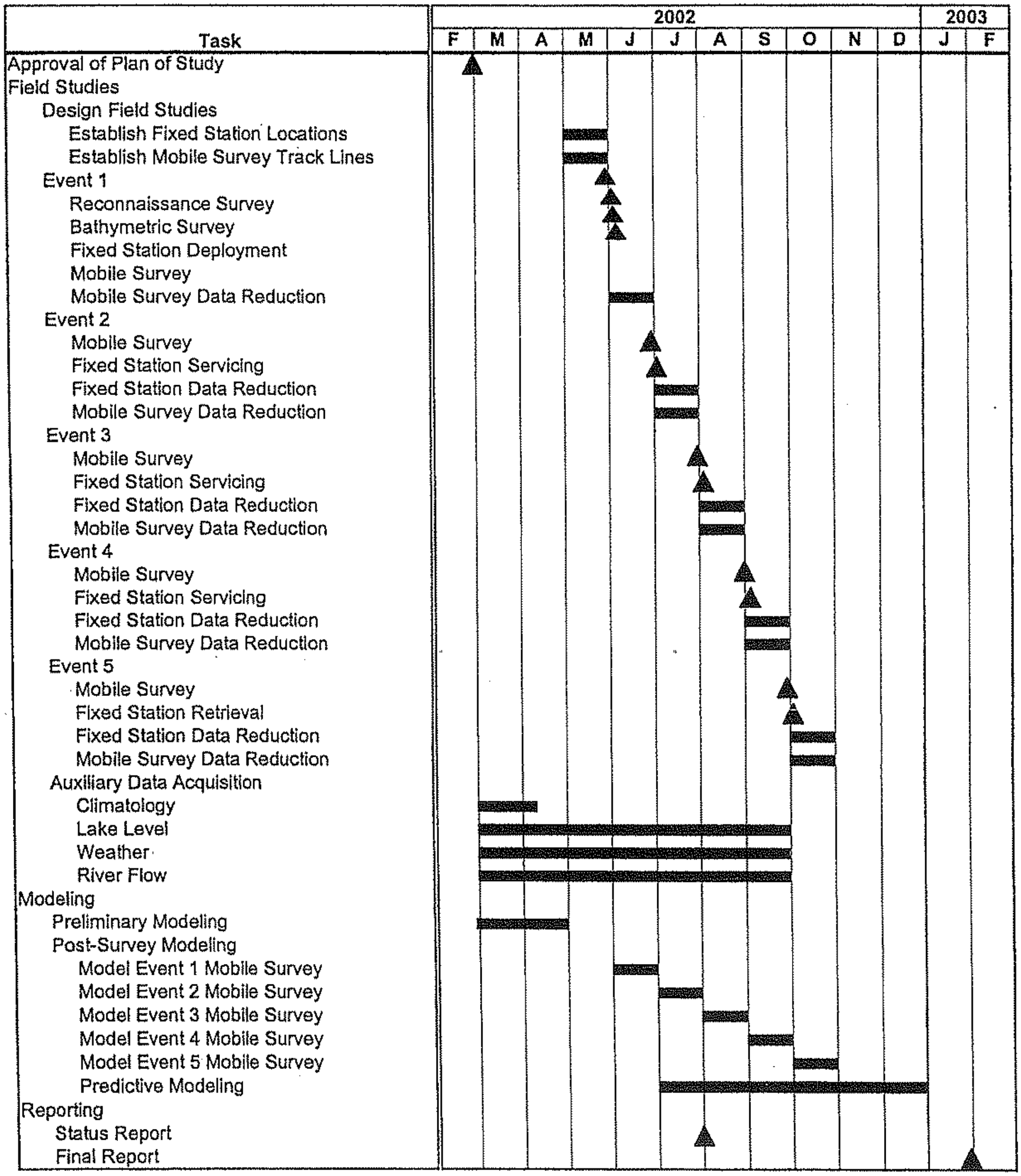
6.2.2 Audience

The Final Report will be written for an audience of water quality professionals, including the Ohio EPA professional staff, but the summary and conclusions section will be appropriate for a general audience.

7.0 Schedule

Figure 7-1 shows the anticipated schedule for the Study. All Field Study elements will be completed during the summer of 2002. The Status Report will be delivered to Ohio EPA on or before 31 July 2002. The Final Report will be delivered to Ohio EPA on or before 31 January 2003.

Figure 7-1. Anticipated Study Schedule.



ToledoEdison
A FirstEnergy Company

76 South Main Street
Akron, Ohio 44308

April 18, 2002

Sent via UPS overnight mail

Mr. Alex Smaili
Unit Supervisor
Division of Surface Water
347 North Dunbridge Road
Bowling Green, Ohio 43202-9398

Re: Toledo Edison Company Bay Shore Station Plan of Study

Dear Mr. Smaili:

Please find attached the Toledo Edison (a FirstEnergy Corp. Company) response to the OEPA comments on the Bay Shore Plant Thermal Mixing Zone Plan of Study. We would appreciate the opportunity to either meet with the OEPA or hold a conference call to discuss these issues in more detail prior to any final determination on the Plan of Study.

If you have any questions please contact me at 330 384-4657.

Sincerely,

Scott F. Brown

Scott F. Brown
Environmental Engineer

SFB/paf
Enclosure

cc: Michael McCullough
Division of Surface Water – Central Office
File: WTN PE Bay Shore

bcc: ERHarrison
DCSchramm
FJStarheim
DJWeber
JAZavrl
CVBeckers-LMS Eng.
DMolzahn-NRG

Response to Ohio Environmental Protection Agency Comments
on
Toledo Edison Company – Bayshore Station – Thermal Mixing Zone Study
Plan of Study
April 17, 2002

In a letter to Mr. Scott F. Brown, P.E., (FirstEnergy), dated 03 April 2002, the Ohio Environmental Protection Agency (OEPA) provided nine comments on the Plan of Study (POS) for a Thermal Mixing Zone Study at the Bayshore Station. Both the POS and the Study itself are required under the terms of the existing OEPA permit for the Station cooling water discharge. This document responds to each of OEPA's comments. The text of the comment is quoted first, followed by FirstEnergy's response.

Comment # 1

On page 6, the POS states that, "Changes in Station operation, and therefore discharge temperatures and flows may be expected to occur over much longer intervals than anticipated travel time in the plume. Thus, we anticipate that under relatively constant meteorological and limnological conditions, the thermal plume will remain relatively stable for long periods, and sampling can be done at times convenient to the work schedule."

We agree that the thermal plume may remain stable for long periods under constant weather conditions. However, one of the characteristics of Maumee Bay is the potentially rapid changes which can occur in the weather. We believe that these changes are likely to be important influences on the behavior of the thermal plume, and we want to emphasize the importance of capturing this variability in model development and actual sampling events.

> FirstEnergy recognizes the potential influence of weather conditions and agrees with OEPA's assessment of the need to understand these effects. Two short-term meteorological effects are expected to influence the plume: (1) the effects of internal seiches (driven by lake-wide wind stress and, to a lesser degree, barometric pressure gradients) on background water temperatures and (2) the effect of local wind stresses on local currents.
>
> While CORMIX cannot model these effects directly, it can account for them through appropriate model inputs. The POS includes continuous temperature monitoring at 20 moored stations and acquisition of NWS meteorological data as part of our evaluation of the relationship between short-term meteorology and seiche-driven temperature changes. The POS also includes two continuous current meter stations as part of our evaluation of the relationship between short-term meteorology and local currents.
>
> In general, the purpose of modeling is to assist in the evaluation of conditions and events that have not been or are unlikely to be observed. The difficulties of forecasting and mobilizing a field survey in response to such meteorological events make effective use of CORMIX central to the POS. We expect to be able to use the continuous monitoring data, in combination with the five mobile surveys and the CORMIX modeling to understand these phenomena.

Comment #2 ✓

On Pages 7 and 8, the POS references western Lake Erie with regard to applicable water quality standards for this study. This is incorrect; the reference should be to Maumee Bay.

In addition, the temperature standards listed on page 9 are incorrect. Instead, this table should list temperature standards for Maumee Bay which are found in Table 7-15(J), Rule 3745-1-07 of the Ohio Administrative Code.

> The POS erroneously reflects the temperature standards that were in place when the POS was submitted (31 January 2002), instead of the standards that became effective on 22 February 2002. There appear to have been no separate temperature standards for Maumee Bay in the old standards. We were aware of the pending change in the standards, but failed to include the appropriate information in the POS. We understand that the new standards will govern our analysis of the thermal plume.

Comment #3 ✓

On Page 11, the POS discusses the various delta T's. However, the definitions of the delta T's is not clear to us. For example, what is the "receiving water"? Is this the point at which the Maumee River discharges to the Bay? Do these definitions presume that there will be differences in the temperature between the beginning of the intake channel and the point of withdrawal for the plant, or between Maumee Bay and the point of withdrawal? Please provide clarification for the terminology and the delta T's used in this section.

> The purpose of the section on delta T in the POS is to acquaint the reader with the fact that there is more than one delta T that must be considered in understanding the Station's thermal plume. The CORMIX modeling does not use all the various delta Ts directly, but the modeler (and those charged with reviewing the modeling) must be aware of the relationships among them to assure that the correct values are observed and used.
>
> The term "receiving water" has the same meaning that it is generally given in referring to wastewater discharges; it means the body of water into which the Station discharges its cooling water. In this case, that body of water is the region of Maumee Bay called "the Cove" in the POS.
>
> The definitions do not address any difference between the temperature at the beginning of the intake channel and the point of withdrawal for the plant. The flow withdrawn from the intake channel is typically about 745 MGD. We expect that flow is sufficient to assure the withdrawal temperature is identical to the river temperature, in the absence of other anthropogenic heat sources in the channel. The surface area of the channel is insufficient to produce a significant change in temperature due to surface exchange with the atmosphere.
>
> As a result, the term "River delta T" refers to the difference that would be observed between the water temperature at the withdrawal point and the receiving water temperature. It would be expected to exist even if the Station were totally shut down, but still pumping water. That is, we expect that there would be a thermal plume if the Station's cooling water pumps were running, even if it were not discharging waste heat.

In this case, the discharge water temperature would be equal to the temperature of the water withdrawn from the intake channel. Depending on season and other conditions, that plume might be either a cool plume or a warm plume, relative to the receiving water temperature.

However, if the Station is discharging waste heat, there will be a temperature difference between the temperature of the water withdrawn from the intake channel and the temperature of the water discharged from the discharge canal. That temperature difference is referred to as the Station delta T.

The Discharge delta T is the difference between the temperature of the water discharged from the discharge canal and the receiving water temperature with which it mixes. That receiving water temperature would be expected to differ from background temperature if there is any re-entrainment of previously discharged cooling water into the plume. The jet momentum of a discharge, even a surface canal discharge, creates turbulent mixing that draws surrounding water into the plume. That water must be replaced by water from further way from the discharge point. In a river, the natural flow of the stream would replace that water with water having background temperature, but, in a water body with no dominant circulation such as Maumee Bay, the jet itself will typically generate a circulation pattern. The circulation pattern may bring previously warmed water back into the immediate vicinity of the discharge, warming the receiving waters at that point and reducing the temperature difference (the discharge delta T). This affects the relative buoyancy of the plume and the way it mixes with the surrounding waters.

Note that the Discharge Delta T is not the algebraic sum of the Station Delta T and the River Delta T, because they have different reference temperatures.

The Mixing Zone Delta T is simply the difference between the local water temperature, (the result of mixing of cooling water with receiving water) and the criterion maximum water temperature in Maumee Bay. The locus of points enclosing the region of positive Mixing Zone Delta Ts is the boundary of the plume with respect to the water quality standards and defines the mixing zone at that point in time.

The Background Delta T is similar to the Mixing Zone Delta T, except that the reference temperature is the hypothetical background temperature, not the criterion maximum temperature. As may be inferred from the discussion of background temperature presented in the POS, the Background Delta T is a somewhat tenuous concept, because of the difficulty in observing or estimating background temperature. For example, if we were to position the background temperature station many miles out into Lake Erie, the observed background water temperature would be substantially lower than one would ordinarily expect in the shallow waters of the Cove (in the absence of the cooling water discharge). Computation of a Background Delta T based on the background temperature observed out in Lake Erie would result in a much larger apparent plume than if it were computed based on the higher temperature more typical of the Cove shallows.

Finally, we recognize that the concepts surrounding the estimation of the various delta Ts are challenging, and we hope that this lengthy additional explanation will clarify those concepts. There may well be additional questions left unanswered by the foregoing; we will be happy to discuss them in a conference call or other appropriate forum.

Comment #4

On pages 10 and 11, the term "re-entrainment" is used. It appears that this term is used to describe recirculation of the **cooling** water discharge such that it would be withdrawn into the plant a second time at the intake structure. Given the existence of the Confined Disposal Facility (CDF), is it reasonable to assume that cooling water discharged from the Bayshore Station would travel around this structure and re-enter the intake channel for the plant? Please provide clarification regarding the definition of re-entrainment in this context.

The term re-entrainment as used in the POS refers to direct recirculation of previously discharged cooling water back into the plume in the vicinity of the discharge. It does not refer to recirculation of previously discharged cooling water into the intake pumps.

The jet momentum of a discharge, even a surface canal discharge, creates turbulent mixing that draws surrounding water into the plume. That water must be replaced by water from further way from the discharge point. In a river, the natural flow of the stream would replace that water with water having background temperature and carry the mixed water away from the discharge site. In a water body with no dominant circulation, such as Maumee Bay, the jet itself will typically generate a circulation pattern. That circulation pattern may bring previously warmed water back into the immediate vicinity of the discharge, warming the receiving waters at that point and reducing the temperature difference (the discharge delta T). This, in turn, affects the relative buoyancy of the plume and the way it mixes with the surrounding waters.

While recirculation of cooling water from the discharge into the intake pumps can, and often does, occur in once-through cooling systems, it is not expected to be a significant factor at Bayshore Station, because the CDF forms a significant barrier between the intake and discharge points. The lowest mean daily flow over 80 years of data recorded at the USGS gage in Waterville is about 489 MGD (September 1) compared with the maximum plant flow of 745 MGD. These relative flows mean that, on a day when the Maumee experiences a flow of 489 MGD, about 256 MGD of the intake water would have to come from Lake Erie through reverse flow at the mouth of the Maumee. For the discharged cooling water to complete the circuit around the CDF, it would have to travel approximately 2 miles by the shortest route, mixing with and losing heat to the surrounding water over the entire path. Hence, we expect little impact from recirculation of cooling water to the intake pumps.

Comment #5

Footnote #12 on page 16 states that "...the CORMIX model cannot simulate wind-induced plume advection." As a result, we would like to emphasize once again the importance of gathering actual samples under varying wind conditions (e.g., speed and direction) to test the validity of the model.

As noted in our response to Comment #1, FirstEnergy agrees with OEPA regarding the importance of meteorological effects in understanding the Station thermal plume. Given the logistical issues involved in attempting to mount a field survey of the magnitude necessary to map the Station's thermal plume in response to forecast short-term weather conditions, the POS incorporates a long-term continuous monitoring network. The data from that network will be combined with the information gathered during the five field surveys to create a portrait of conditions in the region of the discharge. Given the stochastic nature of short-term meteorology, we expect that periodic scheduled field surveys will have a high likelihood of observing a range of weather conditions.

Comment #6

On page 19, the POS states that "...we expect the plume will tend to hug the CDF bulkhead..." While this statement may generally be true, residents of the Maumee Bay area and those who spend considerable time on the waters of the Bay have suggested that the plume frequently extends to the south shoreline of the Bay. Please consider this information in determining sampling locations.

The phrase cited in this question refers to the plume centerline, as defined in the CORMIX model. We recognize that the plume will have a surface width that may encompass significant portions of the Bay, especially if the circulation patterns discussed in our response to Comment #4 develop. The preliminary CORMIX modeling described in the POS will be used to gain an understanding of the dimensions of the plume expected under a range of conditions and to design an array of fixed stations that may be expected to cover that region appropriately. Anecdotal information from people with extensive experience in the Maumee Bay area will supplement the information that can be derived from the modeling.

Comment #7

After reviewing the POS, we believe that it would be very useful to have dissolved oxygen readings collected at the same time temperature sampling is being conducted.

While we recognize that collecting this data goes beyond the scope of the permit requirements, we hope you will consider this request. We believe that collecting this information could be done easily. In addition, Ohio EPA's Northwest District Office could provide a dissolved oxygen meter in order to obtain the readings.

FirstEnergy is willing to consider incorporating dissolved oxygen (DO) measurements in the field surveys with the following understandings. The measurements would be at a single point in the water column, when the survey boat is stopped for vertical profiling. The measurements would be manually recorded and made on a "not to interfere" basis, so that, if conditions required suspension of the DO measurements to improve chances of completing thermal surveying, the DO observations would be restricted or discontinued on a given survey. The DO observations would be reported by location, depth, and date/time, and provided to OEPA as a separate deliverable. They would not constitute a formal part of the report required by the permit and would not be included in that report.

We would be happy to use a DO meter provided by OEPA. We would expect a briefing for field personnel on correct use of the meter provided, and we would rely on OEPA for calibration and quality control on the instrument.

Comment #8

The permit requires the thermal plume to be determined based upon the edge of the mixing zone, which is defined as the location where the thermal discharge is sufficiently cooled to meet daily maximum aquatic life water quality standards for temperature. After reviewing the POS, we believe that it would also be useful to have the size of the mixing zone determined based upon the location where the thermal plume cools enough to reach the background or ambient temperature. Would it be possible to model this additional scenario without expending excessive resources? Again, we recognize that this request goes beyond the scope of the permit requirements; as such, we would appreciate your consideration for its inclusion.

The mechanics of modeling the mixing zone relative to background temperature are straightforward and present a relatively small additional effort, compared with the overall field and modeling program described in the POS.

However, given the (at best) ambiguous nature of the background temperature concept, FirstEnergy believes it is inappropriate to define a mixing zone in these terms. As discussed in the POS and in our response to Comment #3, determination of the background temperature is strongly influenced by choice of measurement location, and the size of the corresponding mixing zone can be expanded or diminished accordingly.

In addition, it is unclear how information on the size of a plume based on background temperature would be used in the permitting process. The concept of background or ambient temperature is not defined in the Ohio water quality standards.

Given these considerations, we respectfully decline to include estimation of a mixing zone based on background temperature. We would be happy to discuss our decision with OEPA further, in a conference call or other appropriate forum.

Comment #9

We would like to review the map showing sampling locations and probe placements prior to implementation of sampling. We may be able to provide some helpful suggestions regarding sampling locations, and would provide review and comments within 14 days of receiving the map.

We will provide a map of the planned sampling locations as soon as it is available, and we expect to be able to be able to accommodate the 14-day review period proposed. However, the overall period for performance of the field elements of the Study is established in the Permit and delays in either availability of the sampling locations or completion of the review cannot be allowed to impact the overall schedule. Last minute changes to the location of fixed stations, track lines and vertical profiling can be accommodated, as long as neither the number of fixed stations and instrumentation nor the overall level of effort to complete a field survey is increased.

Ohio EPA

State of Ohio Environmental Protection Agency

STREET ADDRESS: MAILING ADDRESS:

Lazarus Government Center
122 S. Front Street
Columbus, OH 43215-1099

TELE: (614) 644-3020 FAX: (614) 644-2329

P.O. Box 1049
Columbus, OH 43216-1049

May 10, 2002

RE: Toledo Edison Bayshore Station
Plan of Study Required by NPDES
Permit - 2IB00000*PD

Scott F. Brown, P.E.
Environmental Department
First Energy
76 South Main Street
Akron, Ohio 44308

Dear Mr. Brown:

I am writing to you with regard to the Plan of Study which has been developed for evaluating the Toledo Edison Bayshore Station's thermal discharge into Maumee Bay. We reviewed the Plan of Study which was submitted in January 2002, and provided comments regarding the document to First Energy in early April 2002. First Energy subsequently responded to our comments in a letter dated April 18, 2002. After our review of the Plan of Study and the April 18th letter, we believe that the proposed activities described in the Plan of Study will meet the requirements of the NPDES permit (permit # 2IB00000*PD). Furthermore, we believe that the April 18th letter from First Energy has satisfactorily addressed any questions and/or concerns that we expressed in our comment letter of early April 2002.

We think that this study will provide useful information towards better understanding the impact of the Bayshore Station's thermal discharge, and we look forward to having the results of the study available. If you have any questions, please feel free to contact me at (614) 644-4824.

Sincerely,

Mike McCullough

Mike McCullough
Division of Surface Water

APPENDIX B

INSTRUMENT DATA SHEETS

APPENDIX B - INSTRUMENT DATA SHEETS

Data Sheet List
(included in alphabetical order)

Falmouth Scientific, Inc. Ocean Temperature Module (Mobile Survey Surface Temperature)

Falmouth Scientific, Inc. 3-Inch Micro CTD (Mobile Survey Temperature Profile)

Nortek Aquadopp Open Water Current Meter (Fixed Station Velocity Monitoring)

Onset Optic StowAway Temp Logger (Fixed Station Temperature Monitoring)

RD Instruments Workhorse Sentinel ADCP (Mobile Survey Current Velocity and Bathymetry)

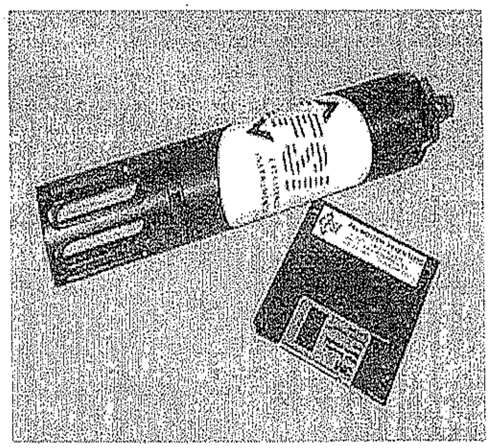
Trimble AgGPS 132 Differential GPS (Mobile Survey Positioning)

YSI Model 58 Dissolved Oxygen Meter (Mobile Survey Temperature Profile, 30 July 2002)

OCEAN SENSOR MODULES

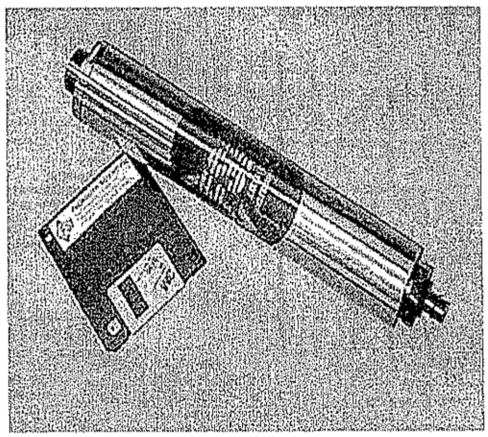
Direct Digital Output with Standards Accuracy

FSI's individual sensor modules provide a powerful tool to obtain high-accuracy physical oceanographic data. Three individual units are available: Ocean Conductivity Module (OCM), Ocean Temperature Module (OTM), and Ocean Pressure Module (OPM). All modules use a low-power microcontroller to collect, scale, and transmit real-time data via RS-232 or RS-485.



The OCM uses proven inductively coupled conductivity sensors. The large inside diameter of these sensors more accurately reproduces the salinity structure of the water without requiring a pump.

The OTM uses a standards-grade Platinum Resistance Thermometer (PRT) for superior stability without sudden calibration "jumps" typical of thermistor-based sensors.



The OPM, which incorporates a platinum strain gauge for maximum reliability, is available in a variety of full-scale ranges to meet the accuracy requirement of specific projects.

FEATURES

- **High-Accuracy**
  - **OCM ± 0.0003 S/m (.003 mmho/cm)**
  - **OTM ± 0.003 C**
  - **OPM ± 0.03% Full Scale**
- **High-Quality Sensors**
  - **OCM-Inductive Conductivity Sensor**
  - **OPM-Titanium Pressure Transducer**
  - **OTM-Platinum Resistance Thermometer**
- **Internal Reference Electronics**
- **Self-Calibrating Electronics**
- **High-Speed Sampling, 32 Hz**
- **Direct-Digital Output**
- **Sensors with Predictable Spatial Response**
- **Titanium Pressure Housing Rated to 7000M**

Excellence In Instrumentation

FSI Falmouth Scientific, Inc.

1140 Route 28A, P.O. Box 315 • Cataumet, MA 02534-0315 • email: fsi@falmouth.com
Telephone: 508/564-7640 • Facsimile: 508/564-7643 • Website: www.falmouth.com

Ocean Sensor Module Specifications

Modules

Parameter	OCM Conductivity	OTM Temperature	OPM Pressure
Range	0 - 7.0 S/m (0 - 70 mS/cm)	-2 to 32 C	User Specified: 0-200 dBar 0-1000 dBar 0-2000 dBar 0-3000 dBar 0-7000 dBar
Accuracy	–0.0003* S/m (–0.003 mS/cm)	–0.003 C*	–0.03% full scale*
Stability / month	–0.00005 S/m (–0.0005 mS/cm)	–0.0005 C	–0.002% full scale
Resolution	0.00001 S/m (–0.0001 mS/cm)	0.0001 C	0.0004% full scale
Response@ 1 m/sec flow	50 msec	150 msec	25 msec
Sensor Type	Inductive Cell	Platinum Thermometer	Strain Gauge

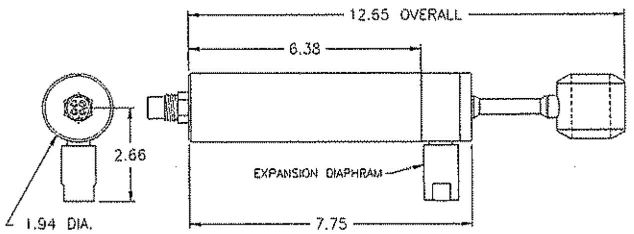
**Higher accuracy calibration available, contact factory*

System

Power	12 VDC –20% @ 72 mA (OTM), 95 mAOPM,OCM)
Warmup Time	2.0 seconds from power on
Physical	7,000m operating depth (1.25 full scale for OPM) see outline drawings below for dimensions
Material	Titanium 6AL-4V
Connector	SUBCONN MICRO 4 MCBH4F mates with MCIL4M
Data Format	Conductivity in mS/cm Temperature in " C per ITS-90 Pressure in dBars (SNNNNN.NN) Baud Rate: 4800, 9600, or 19,200 user selectable Data Bits: 8 data, 1 stop, no parity Format: ASCII
Data Options	RS-232 or RS-485 specified at time of order

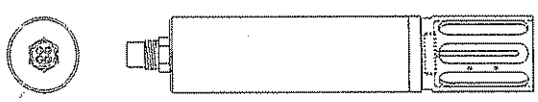
Specifications Subject to Change without Notice

OCM



OPM

OTM



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Rev. IV(7/20/00)

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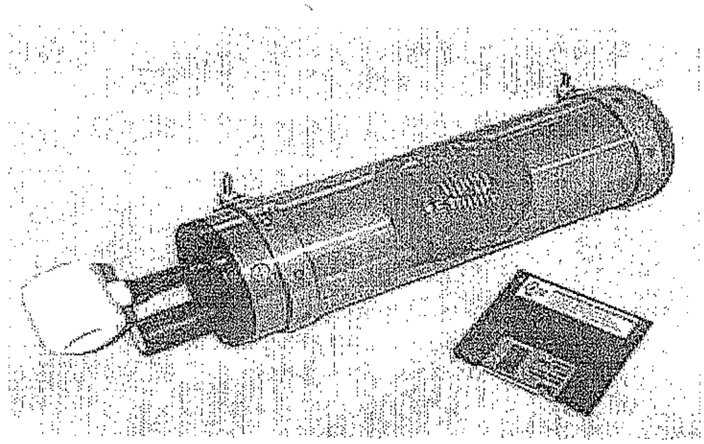
Telephone: 508/564-7640 • Facsimile: 508/564-7643 • Website: www.falmouth.com

3" MICRO CTD

High-Accuracy CTD with External Input, Direct Digital Output, and Datalogging Capability



The FSI 3" Micro CTD incorporates proven inductively coupled conductivity sensor technology with a platinum resistance thermometer and micro-machined silicon pressure sensor to provide highly accurate and stable readings. Data is stored in internal memory or output continuously via RS-232 or RS-485. All 3" Micro CTD sensors are mounted in the flow, with no pumps or other devices required. Precise internal fixed references provide continuous calibration for increased long-term reliability. The 3" Micro CTD 12-bit digitizer supports up to eight optional external sensors (e.g. pH, DO, Turbidity). The 3" Micro CTD can also be used in conjunction with the FSI Sure-Fire Sampler for profiling applications.

FEATURES

- High-Accuracy*
  - ± 0.0002 S/m Conductivity
  - ± 0.002 º C Temperature
  - ± 0.02% Full Scale Pressure
- Salinity Calculation using PSS-78
- Sound Velocity Calculation using UNESCO 44
- Inductive Conductivity Sensor with no Electrodes to Foul, No Pump Required
- Highly Stable Platinum Thermometer
- Precision-Machined Silicon Pressure Sensor
- Internal Fixed References for continuous Self-Calibration
- Built-in Real-Time Clock
- 2 MB Internal Datalogging or Direct Digital Output via RS-232 or RS- 485
- High-Performance 8-channel, 12-bit Digitizer for Optional External Sensors (pH, DO, Turbidity, etc.)
- Windows 98/ NT® Software for System Configuration, Data Acquisition, Real-Time Graphing, and Data Analysis

*Calibrated accuracy

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Micro CTD 3" Specifications

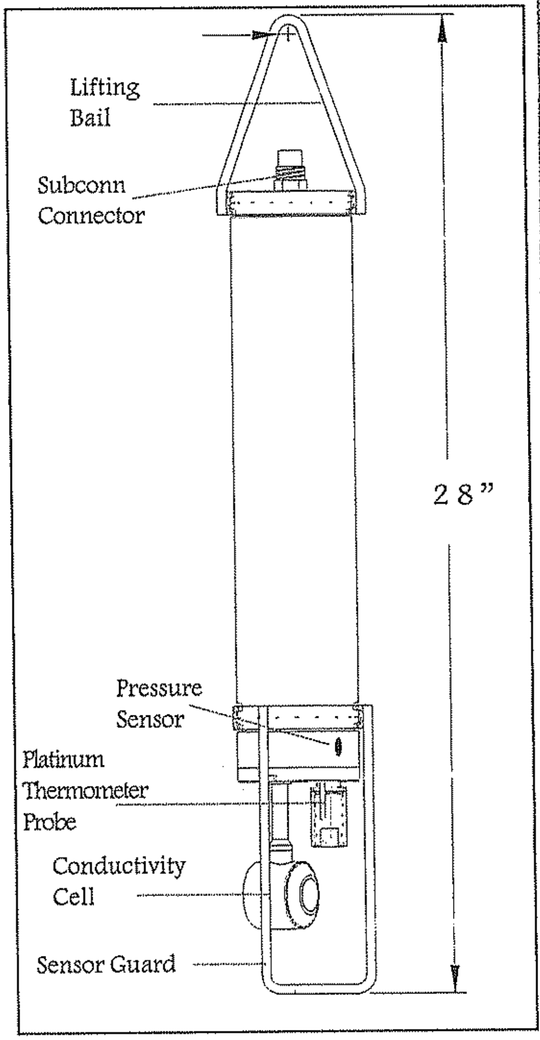
SENSORS

PARAMETER UNITS	CONDUCTIVITY	TEMPERATURE	PRESSURE
SENSOR	Inductive Cell	Platinum Thermometer	Precision-machined Silicon
RANGE	0 - 7.0 S/m (0 -70 m S/cm)	-2° to 32°C	Customer specified
ACCURACY	± 0.0002 S/m (± 0.002 m S/cm)*	± 0.002°C*	+/- 0.02% full scale*
STABILITY	± 0.00005 S/m/month (±0.0005 mS/cm/month)	± 0.0005°C/month	+/- 0.05% FS/month.
RESOLUTION	0.00001 S/m (0.0001 mS/cm)	0.0001°C	0.001% full scale
RESPONSE	5.0 cm at 1 m/sec flow	150 msec	25 msec

**Calibrated accuracy*

SYSTEM:

Power:	UWU +7 to 30 VDC @ 85 mA @ 590 mW
Physical:	500 meter, Delrin Housing Standard 7,000 meter, 64-AVL Titanium Houisng Optional
Sample Rate:	User Programmable from 1.83 t o 4.5 Frames per Second
Resolution:	16 bits @ 5 Hertz, 18 bits @ 2 Hertz
DC Channels:	Type: 8 Unipolar, Range: 0 -> 5.0 VDC Resolution: 1.22 mV Rate: Same as CTD Sampling Rate Programmed
Connector:	SUBCONN MCBH4F, mates with MCIL4M
Data Format:	Baud Rates: 9.6, 19.2, 38.4 kbps Data Bits: 8 Stop bits : 1 Format : ASCII Protocol: RS-232 or RS-485
Real Time Clock:	Programmable Alarm / Sleep Functions +/- 5 ppm Initial Accuracy; +/- 12 ppm/year,
Warm-Up:	3.0 Seconds after power up
Battery Options:	8 each 1.5 vdc Alkaline "C" Cell Welded Pack 6 each 1.5 vdc Alkaline Replaceable "C" Cell



Specifications Subject to Change without Notice

FSI *Excellence In Instrumentation*

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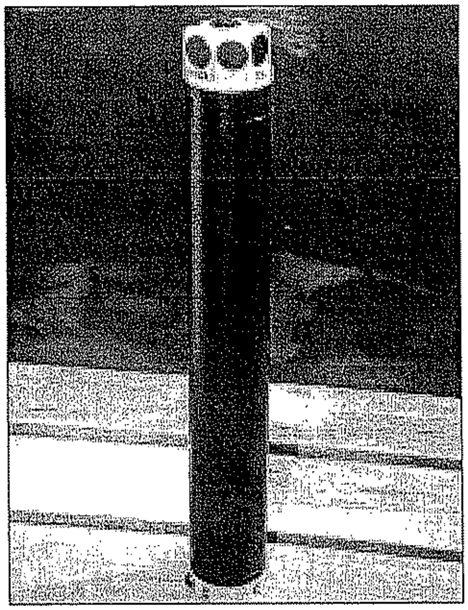
Nortek Aquadopp™

Open water Current Meter (3D)



Features

The Aquadopp has several significant advantages when compared to other open water current meters:

- ✓ All plastic and titanium parts stops corrosion
- ✓ Small and light weight (less than 3kg!)
- ✓ No moving parts that can be blocked or sensitive parts that are easily damaged
- ✓ Biological fouling does not affect accuracy
- ✓ Low power consumption for long deployments
- ✓ A variety of sensor heads and the ability to move the sampling volume away from the mounting structure assure undisturbed measurements in all situations

The Aquadopp

The Aquadopp is designed both for real time data collection and self-contained deployments. The instrument uses Doppler technology to achieve accurate and non-intrusive measurements and it comes standard with compass, tilt, pressure, and temperature sensors.

Leading oceanographers and engineers all over the world uses the Aquadopp. Typical applications are:

- ✓ Self-contained deployments on mooring lines, bottom frames or fixed structures
- ✓ Permanent monitoring stations in coastal areas or rivers.
- ✓ Real time data collection on buoys, ROVs, offshore platforms, etc.

The Aquadopp is usually configured and controlled from a PC but it can be operated from any third-party controller using the RS-232 or RS-422 interface.

Software

The Aquadopp comes standard with Windows software both for real time data collection and for controlling autonomous deployments. Different views and menus guide you through the process from configuration to data conversion. The software has an on-line help section and requires no special skills.
New firmware versions from Nortek can be loaded into the Aquadopp using the standard software, removing the need for opening the canister and replacing components.

In the final analyses, the Aquadopp offers great value through the combined use of advanced Doppler technology and a flexible system design. The warranty is two years on material defects and workmanship.

Wave directional spectra

The Aquadopp can be configured to collect wave directional data at the same time as it measures the mean current. At this time Nortek does not provide software for wave directional analyses but the procedure is documented in the Technical note: "Aquadopp and Vector wave measurement near Scripps Pier".

Diagnostic mode

The diagnostic mode is unique for the Aquadopp. It allows the user to intersperse the average data with periods of rapid sampling (1Hz). Diagnostic data are typically used to analyze the mooring motion or to gather information about surface waves or internal waves.

NORTEK AS

www.NortekUSA.com

Water Velocity Measurement

Range	± 5 m/s (inquire for higher ranges)
Accuracy	1% of measured value ± 0.5 cm/s
Maximum sampling rate (output)	1 s
Internal sampling rate	23 Hz

Measurement area

Measurement cell size (user selectable)	0.75 m
Measurement cell position (user selectable)	0.3 - 5.0 m
Default position (along beam)	0.3 - 1.8 m

Doppler uncertainty (noise)

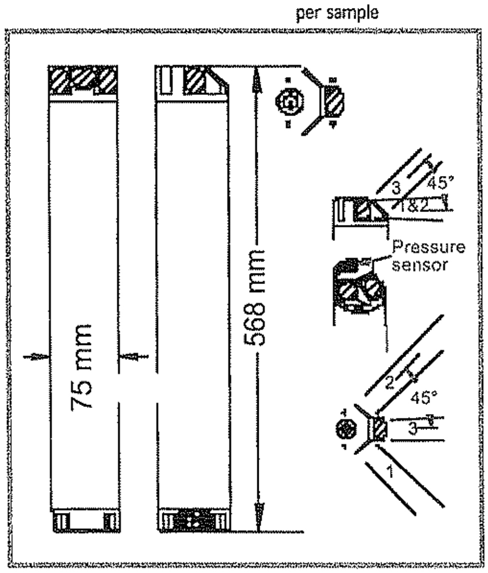
Typical uncertainty for default configurations	0.5 - 1.0 cm/s
Uncertainty in U,V at 1 Hz sampling rate	1.5 cm/s

Echo Intensity

Acoustic frequency	2 MHz
Resolution	0.45 dB
Dynamic range	90 dB

Sensors

Temperature	***Thermistor embedded in head***	
	- Range	-4°C to 40°C
	- Accuracy/Resolution -	0.1°C/0.01°C
	- Time response	10 min
Compass	***Flux-gate with liquid tilt***	
	- Maximum tilt	30°
	- Accuracy/Resolution	2°/0.1°
Tilt	***Liquid level***	
	- Accuracy/Resolution	0.2°/0.1°
	- Up or down	Automatic detect
Pressure	***Piezoresistive***	
	- Range	0-200 m (standard)
	- Accuracy/Resolution	0.25% / Better than 0.005% of full scale per sample



Data Communication

I/O	RS-232 or RS-422
Baud rate	300 - 115200
User control	Handled via WIN32 software, ActiveX function calls, or direct commands

Software ("Aquadopp")

Operating system	WIN95, WIN98, NT 4.0
Functions	Deployment planning, start with alarm, data retrieval, ASCII conversion. Online data collection and graphical display. Test modes.

Data Recording

Capacity (standard)	2 MB, expandable to 21MB or 78MB
Data record	40 bytes
Diagnostic record	40 bytes

Power

DC input	9-16 VDC
Peak current	2 amp at 12VDC (user adjustable)
Max consumption at 1 Hz	0.2-1.0 W
Avg. consumption at 0.02 Hz	0.1 W
Avg. consumption at 0.002Hz	0.01 W
Sleep consumption	0.0013 W
Battery capacity	50 Wh
New battery voltage	13.5 VDC
Data collection (alkaline)	6 months at 10-min, ± 1.0 cm/s noise
Data collection (lithium)	12 months at 10-min, ± 1.0 cm/s noise

Connectors

Bulkhead (Impulse)	LPMBH-5-FS (bronze, titanium optional)
Cable	LPMIL-5-MP on 5-m neoprene cable

Materials

Standard model	Delrin and polyurethane plastics with titanium screws

Environmental

Operating temperature	-5°C to 45°C
Storage temperature	-15°C to 60°C
Shock and vibration	IEC 721 - 3 - 2
Pressure rating	300 m (pressure sensor OK to 1.5*range)

Antifouling paint

May be applied to all surfaces

Dimensions

Cylinder	Diameter: 75mm Length: 550 mm or 450 mm
Weight in air	3.5 kg
Weight in water	Neutral

Options

Acoustic beams	Several different sensor heads available. See separate specification sheet.
Battery	Rechargeable Ni-Mn and Lithium available
Connectors	LPMBH-8-FS with PLPMIL-8-MP on 10-m polyurethane cable for optional RS422 systems.

nortekusa.com

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Product Information

Optic StowAway Temp logger

Completely Sealed Underwater Temperature Logger with Optic Communication

Order Now!

Features and Specifications

- Waterproof to 100 feet
- 6-year, factory replaceable battery (typical use**)
- Dark translucent case keeps logger camouflaged
- Capacity: 7943 or 32,520 measurements
- Streamlined design: 5.2" long x 0.8" tall x 1.0" thick (132 x 20 x 25 mm) and 1.9 oz.
- Two measurement ranges†: +24°:F to +99°F (-4°C to +37°C), -32°F to +167°F (-35°C to +75°C)
- User-selectable sampling interval: 0.5 seconds to 9 hours, recording times up to several years
- Blinking LED light shows if temperature goes out of user-determined limits
- Uses optic communications through Optic Base Station for launch and readout
- Readout and relaunched in the field with optional Optic Shuttle
- Precision components eliminate the need for user calibration
- Programmable start time/date
- Triggered start with Optic coupler or magnet
- Memory modes: stop when full, wrap-around when full
- Nonvolatile EEPROM memory retains data even if battery fails
- Multiple sampling with minimum, maximum or averaging
- Blinking LED light confirms operation
- Time accuracy: ±1 minute per week at +68°F (+20°C)
- Mounting tab
- Compliance certificate available
- NIST-traceable temperature accuracy certification available

**20 three-month deployments in water (+35° F to +80°F) with 4 minute or longer intervals (no multiple sampling), one offload per deployment.

Notice: To guarantee specified accuracy, the TidbiT and Optic StowAway units should not be used in condensing environments and water temperatures higher than +30°C (+86°F) for more than 8 weeks cumulatively. Prolonged exposure will lead to measurement drift and eventual failure. If your application temperatures and environment are questionable based on the above statement, please contact Onset for more information.

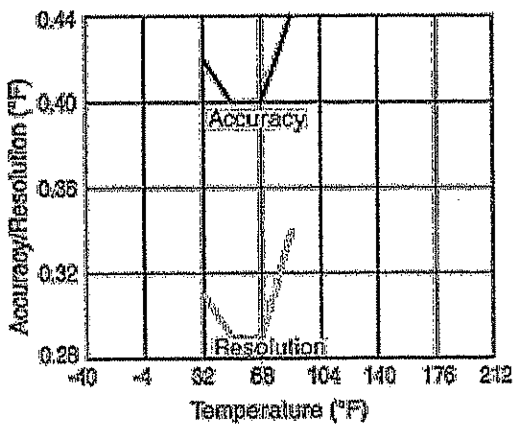
View our Temperature Logger Comparison Chart

Measurement specifications

-5°C to +37°C Models

- Range†: +24°F to +99°F (-4°C to +37°C)
- Accuracy: ±0.4°F (±0.2°C) at +70°F, see plot at right
- Resolution: 0.29°F (0.16°C) at +70°F, see plot at right
- Response time in water: 4 min. typical to 90%
- Response time in still air: 24 min. typical to 90%

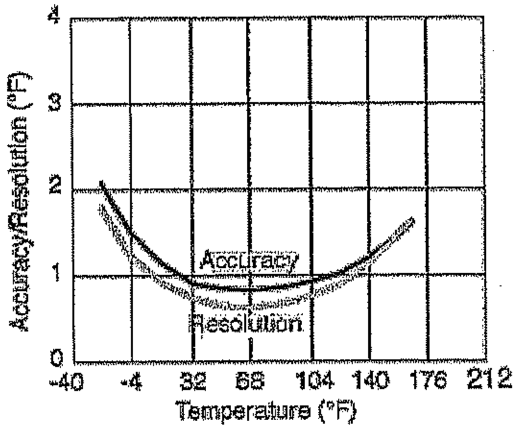
Temperature Accuracy and Resolution
-5°C to +37°C Models



-39°C to +75°C Models

- Range†: -32°F to +167°F (-35°C to +75°C)
- Accuracy: ±0.9°F (±0.5°C) at +70°F, see plot at right
- Resolution: 0.7°F (0.4°C) at +70°F, see plot at right
- Response time in water: 4 min. typical to 90%
- Response time in still air: 24 min. typical to 90%

Temperature Accuracy and Resolution
-39°C to +75°C Models



† Specified range is narrower than nominal range due to precision calibration process. Using Optic StowAway Temp loggers in wet environments (over 90% RH) for extended periods may lead to premature failure.

A software starter kit and an Optic Base Station are required for operation
BoxCar Pro or BoxCar starter kits are available. Each starter kit includes software, computer interface cable and software manual. If you already have logger software, you can refer to the Logger Software Compatibility Chart. The Optic Base Station includes an Optic Coupler and TidbiT Coupler. Upgrades for BoxCar Pro and BoxCar are available on this website.

*USB Serial Adapter requires BoxCar Pro 4.3 or later software for Windows®.

Order Now!

D-3931-M

Quick Accuracy Check

We receive many calls requesting information on how to calibrate our loggers. While our loggers cannot be calibrated, you can certainly check to see if the loggers are recording within their specifications. Ideally, testing should be done in a controlled environment. Unfortunately, not everyone has access to this type of environment.

Following is a simple test that you can run to check the temperature accuracy of your logger. Please keep in mind that you will need to place loggers that are not waterproof into a waterproof container prior to testing. Please allow time for the inside temperature of the container to acclimate to the external temperature.

Place crushed ice (preferable made from distilled water), in an insulated container that is large enough to hold the loggers that you are testing. It is important to crush the ice to maintain as consistent and uniformed a temperature as possible. Fill the container with distilled water to just below the level of the ice and stir the mixture around. Submerge the loggers, or thermistor probes that you are testing. Place the entire container in a refrigerator to minimize temperature gradients. Allow enough time for the logger to acclimate. The ice will melt slowly, so the actual temperature should settle around 0°C if the ice bath was prepared correctly.

Listed below are the temperatures that you would expect to see from the loggers, if everything was performed correctly.

Part # Accuracy
WTAxx-05+37 @ 0°C ± .23°C
WTAxx-39+75 @ 0°C ± .51°C

D-5317-A

Workhorse Sentinel ADCP

Self-Contained 1200, 600 or 300 kHz

Our most popular instrument. Over 1000 Workhorse Sentinel ADCPs are profiling currents in 50 countries. Our customers choose it for its unbeatable precision in shallow waters, for its 175-meter profiling range and for an unmatched low power consumption that makes it ideal for year-long deployments.

Customers tell us they like it because it's light and easy to deploy on buoys, boats or on the bottom. Links to shore are by cable or modem and Sentinel is easily upgraded to measure pressure, to undertake bottom-tracking tasks or to be used as a directional wave gauge.

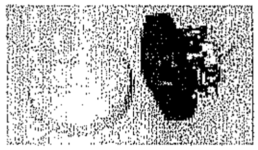
			Long Range Mode	
Frequency	Range	Cell Size	Range	Cell Size
1200 kHz	14m	1m	19m	2m
600 kHz	47m	2m	67m	4m
300 kHz	126m	8m	165m	8m

RD Instruments
Tel: (858) 693-1178
sales@rdinstruments.com

RD Instruments

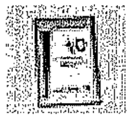
www.rdinstruments.com

Included in a complete system:



Transducer and electronics: molded composite plastic transducer head with four beams at 20° from vertical in a convex configuration, temperature sensor, electronics assemblies, fluxgate compass, pitch and roll sensors.

Batteries: one 28-D cell alkaline battery pack (factory degaussed).

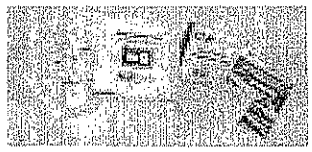


Memory: 10 MB PC card internal memory (upgradeable to 440Mb).

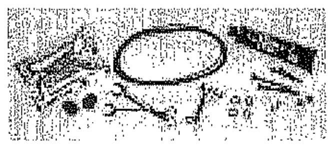
Pressure case: composite plastic, 200m rated. End cap with wet-mateable connector and dummy plug.

Power supply for laboratory testing: 110-220V AC/24V DC power converter.

Input/output cable: 5 meter cable for communications and power.



Manuals and software: users guide; operation manual and easy-to-use Windows software package.



Spares parts and tool kit for maintenance.

Ship case: ruggedized compact case.

Workhorse Sentinel ADCP 1200, 600 or 300 kHz

Water Profiling

Depth Cell Size[a]	Typical range 12m[b] 1200kHz		Typical range 50m[b] 600kHz		Typical range 110m[b] 300kHz	
Vertical Resolution	Range (m)	Std. Dev.[c] (mm/s)	Range (m)	Std. Dev.[c] (mm/s)	Range (m)	Std. Dev.[c] (mm/s)
0.25m	11	182				
0.50m	12	66	36	182	see (a)	
1.0m	14	30	41	66	86	182
2.0m	15[b]	18	47	30	99	66
4.0m	see (a)		52[b]	18	112	30
8.0m					126[b]	18

Notes: a) user's choice of depth cell size is not limited to the typical values specified, b) longer ranges available, c) BroadBand mode single-ping standard deviation (Std.Dev.)

Long Range Mode

	Range (m)	Depth Cell Size (m)	Std. Dev. (mm/s)
1200kHz	19	2	35
600kHz	67	4	38
300kHz	165	8	38

Profile Parameters

Velocity accuracy:
- 1200, 600: ±0.25% of the water velocity relative to the ADCP ±2.5mm/s
- 300: ±0.5% of the water velocity relative to the ADCP ±5 mm/s

Velocity resolution: 1mm/s
Velocity range: ±5m/s (default): ±20m/s (maximum)
Number of depth cells: 1-128
Ping rate: 2 Hz (typical)

Echo Intensity Profile

Vertical resolution: depth cell size
Dynamic range: 80 dB
Precision: ±1.5dB (relative measure)

Transducer and Hardware

Beam angle: 20°
Configuration: 4 beam, convex
Internal memory: Unit comes with 10Mb card, standard. Two PCMCIA card slots available (10-220Mb each).
Communications: Serial port selectable by switch for RS-232 or RS-422. ASCII or binary output at 1200-115,400 baud.

Standard Sensors

Temperature (mounted on transducer)
- Range: -5° to 45°C
- Precision: ±0.4°C
- Resolution: 0.01°

Tilt
- Range: ±15°
- Accuracy : ±0.5°
- Precision: ±0.5°
- Resolution: 0.01°

Compass (fluxgate type, includes built-in field calibration feature)
- Accuracy: ±2° [e]
- Precision: ±0.5° [e]
- Resolution: 0.01°
- Maximum tilt: ±15°

Note: e) @ 60° magnetic dip angle, 0.5G total field

Power

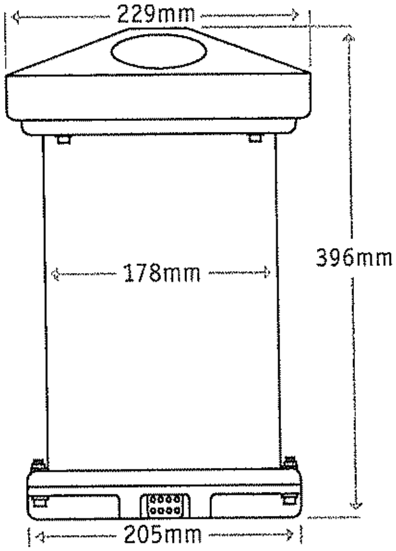
DC input: 20-60V DC. Internal battery pack, external battery pack or external power supply.
Voltage: 42V DC (new)
28V DC (depleted)
Capacity: @ 0°C: 400 watt hours

Transmit
- 16W @ 35V (1200kHz)
- 37W @ 35V (600kHz)
- 115W @ 35V (300kHz)

Environmental

Standard depth rating: 200m. Optional to 6000m.
Operating temperature: -5° to 45°C
Storage temperature: -30° to 75°C
Weight in air: 13.0kg
Weight in water: 4.5kg

Dimensions



Software

Use RDI's Windows™-based software for the best results:
- WinSC — Data Acquisition
- WinADCP — Data Display and Export

Upgrades Available

- Memory - 10-220Mb PCMCIA cards
- Pressure sensor
- External battery case
- High resolution water profiling modes
- Bottom tracking
- AC/DC power converter, 48V DC output
- Pressure cases for depths up to 6000m

For More Information

Call, e-mail or visit our web page. Ask for our Primer about ADCPs.

Internet: www.rdinstruments.com

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E-mail: sales@rdinstruments.com

Trimble

*Ag*GPS 132

Combination DGPS receiver with The Choice technology

Sub-meter differential GPS accuracy for precision farming

The data collected in precision farming such as soil types, fertility, insect infestations, and crop yields are dependent upon accurate position information. The differential GPS receiver is the heart of your precision farming system, providing a way to measure and compare performance from year to year.

The Trimble AgGPS™ 132 differential GPS receiver utilizes The Choice™ technology. This technology combines a GPS receiver, a beacon differential receiver and a satellite differential receiver in the same housing. These receivers use a combined antenna with a single antenna cable. This configuration greatly improves the accuracy, reliability and availability of differential GPS corrections.

The medium frequency (MF) beacon receiver uses the broadcasts from government-established navigation beacon reference stations around the world. The L-band satellite differential correction receiver requires a subscription to a differential correction service and provides multiple vendor support. A built-in virtual reference station (VRS) permits the satellite corrections to be uniformly accurate over the entire satellite coverage area, without the degradation in accuracy associated with increasing distance from fixed reference stations.

The AgGPS 132 is designed for easy set up and installation with a built-in display and keyboard. The source and status of DGPS corrections can easily be determined for either of the two built-in differential correction receivers or from an external differential correction source.

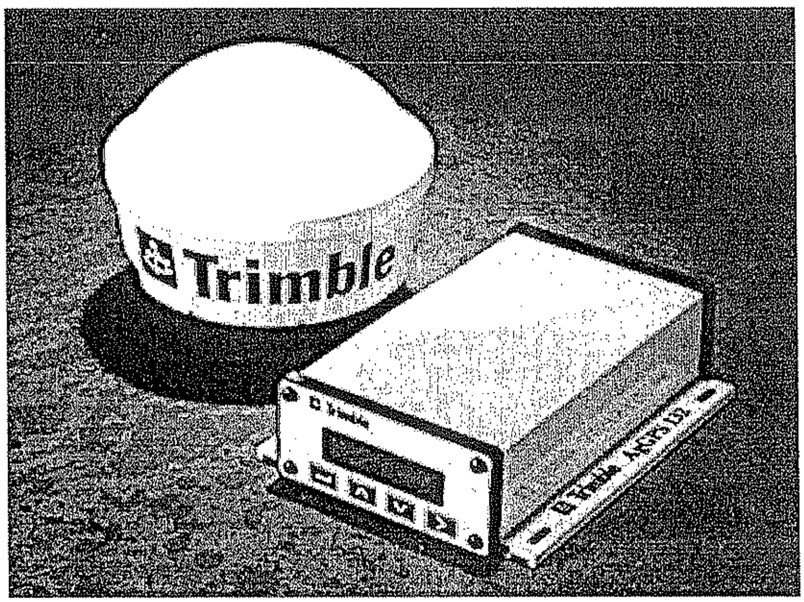
To ensure that the AgGPS 132 can be powered from the machine's power system, it operates over an input voltage range of 10 to 32 volts. The AgGPS 132 is easy to install and connects to a wide range of precision agriculture equipment, including yield monitors, variable rate planters, application controllers and portable field computers. It can be easily transported with an optional AgField Pack.

The receiver can output industry-standard NMEA 0183 messages. The user-selectable outputs include position, velocity, navigation, and status information. The standard configuration outputs positions once per second with very low latency. For applications on faster moving vehicles, the AgGPS 132 can optionally output 10 positions per second, with latency of less than 100 ms.

The L-band satellite receiver uses a Trimble developed, sensitive design to provide coverage across the entire satellite footprint.

The MF beacon differential correction receiver built into the AgGPS 132 is a dual-channel, all-digital, low noise design allowing it to receive corrections at distances of hundreds of miles from the reference stations.

The AgGPS 132 includes a high accuracy 12-channel GPS engine with improved ionosphere and troposphere models. It provides sub-meter differential position accuracy and offers differential speed accuracy of better than 0.1 mile per hour (0.16 kph), thus eliminating the need for an external speed sensor. The positions are computed using robust differential processing techniques, allowing you to begin operation a few seconds after you switch on your machine.



*Ag*GPS 132

Combination DGPS receiver with The Choice technology

Standard Features

- 12-channel GPS receiver
- L-band satellite differential correction receiver
- Dual-channel digital medium frequency beacon receiver
- Sub-meter differential accuracy
- 2 line, 16 character liquid crystal display
- 4 button keyboard
- Combined L1 GPS, Satellite differential and beacon antenna
- Two programmable RS-232 serial ports:
  - NMEA-0183 output/RTCM SC-104 input
  - TSIP I/O
- Operation manual
- 5 meter ruggedized antenna cable
- GPS receiver to PC cable
- Magnetic mount for antenna

Physical Characteristics

• AgGPS 132 Housing

Size:	14.5cm W x 5.1cm H x 19.5cm D (5.7"W x 2.0"H x 7.7" D)
Weight:	0.76kg (1.68 lb.)
Power:	7W (max.), 10 to 32 VDC
Operating temp:	-20°C to +65°C
Storage temp:	-30°C to +85°C
Humidity:	100% condensing, unit fully sealed
Casing:	Dust proof, waterproof, shock resistant

• Combined Antenna

Size:	15.5cm D x 14cm H (6.1" D X 5.5" H)
Weight:	.55kg (1.2 lb)
Operating temp:	-30°C to +65°C
Storage temp:	-40°C to +85°C
Humidity:	100% condensing, unit fully sealed
Casing:	Dust proof, waterproof, shock resistant

Ordering Information

AgGPS 132	Part Number 33300-00
Add 10 Hz capability[1]	Part Number 33176-10
Add Scorpio capability[2]	Part Number 33176-20
Add DGPS Base Station	Part Number 33176-30
Add Everest™ Multi-Path Reduction	Part Number 33176-40
AgField Pack 120 Volt	Part Number 32294-00
AgField Pack 240 Volt	Part Number 32294-10
Ag Leader yield monitor cable	Part Number 30660

[1] Available with beacon differential and some satellite differential vendors

[2] Scorpio Marine Electronics, Ltd. provides the Differential GPS Service which is transmitted from marine radiobeacons throughout the United Kingdom and the Republic of Ireland.

Performance Characteristics

• GPS Receiver

General:	12-channel, parallel tracking, L1 C/A code with carrier phase filtered measurements and multi-bit digitizer
Update rate:	1 Hz standard; 10 Hz optional[1]
Differential speed accuracy:	0.1 MPH (0.16 KPH)[3]
Differential position accuracy:	Less than 1 meter horizontal RMS[3] At least 5 satellites, PDOP <4 and RTCM SC-104 standard format broad cast from a Trimble 4000RSi or equivalent reference station.
Time to first fix:	<30 seconds, typical
NMEA messages:	ALM, GGA*, GLL, GSA*, GSV, VTG*, MSS, RMC*, ZDA *Default messages

• Differential Correction Dual-channel MF Receiver

Frequency range:	283.5 KHz to 325.0 KHz
Channel spacing:	500 Hz
MSK modulation:	50, 100 & 200 bits/second
Signal strength:	10 µV/meter minimum @ 100BPS
Dynamic range:	100 dB
Channel selectivity:	70 dB >500 Hz offset
Frequency offset:	17 ppm maximum
3rd order intercept:	+15 dBm @ RF input (min. AGC setting)
Beacon acquisition time:	<5 seconds, typical
Operating Modes:	Auto power, Auto distance, and Manual modes

• L-band Satellite Differential Correction Receiver with Multiple Vendor Support

Bit Error Rate:	10^{-5} for Eb/N of >5.5 dB
Acquisition and re-acquisition Time:	<2 seconds, typical
Frequency band:	1525-1560 Mhz
Channel spacing:	5 kHz

[3] All non-differential GPS receivers are subject to degradation of position and velocity accuracy under U.S. Department of Defense-imposed Selective Availability (S/A). Positions may be degraded up to 100 meters 2D 2σRMS.

Trimble follows a policy of continuous product improvement. Specifications are thus subject to change without notice.

Trimble

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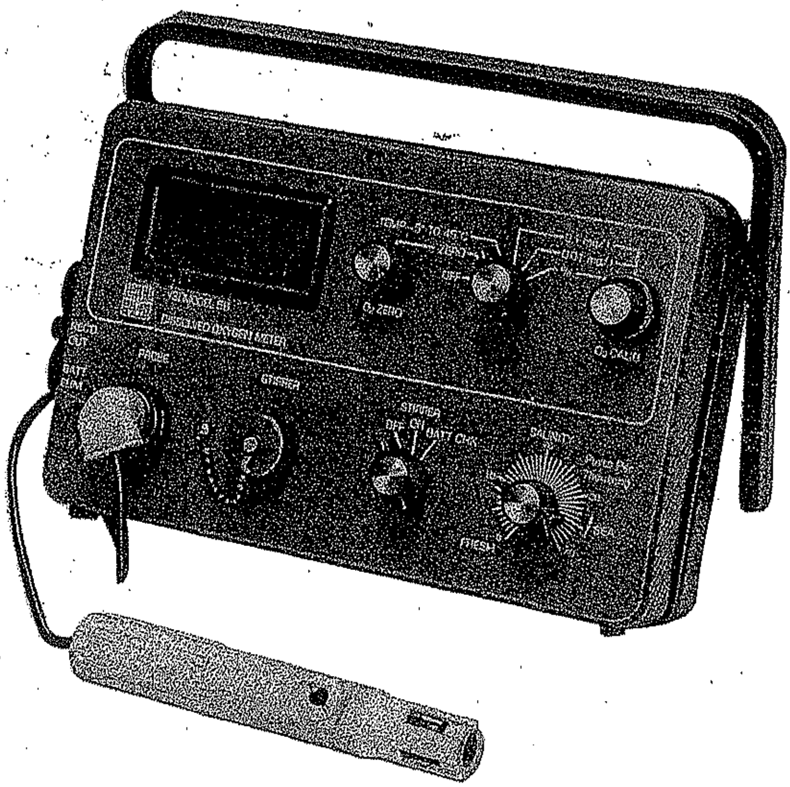
INSTRUCTION MANUAL
YSI MODEL 58
DISSOLVED OXYGEN METER



Scientific Division
Yellow Springs Instrument Co., Inc.
Yellow Springs, Ohio 45387 • Phone 513-767-7241 • Telex 20-5437

PRICE INCLUDING HANDLING $5.00

GENERAL DESCRIPTION

The YSI Model 58 Dissolved Oxygen Meter is intended for field or laboratory use for dissolved oxygen and temperature measurement in water and wastewater applications, but is also suitable for use in certain other fluids. (See "Measuring Oxygen in Fluids Other Than Water," page 21.) The meter may be used with any of the YSI 5700 Series probes. Dissolved oxygen is indicated in mg/l (1 mg/l ≈ 1 part per million) or in % air saturation; the % air saturation feature is discussed below in detail. Display sensitivity in the mg/l mode may be selected to read in tenths or in hundredths of a mg/l. Temperature is indicated in °C from -5°C to +45°C with 0.1°C resolution. The mg/l mode is automatically temperature compensated for changes in solubility of oxygen in water and for permeability of the probe membrane; the % air saturation mode is compensated for permeability of the membrane. A salinity compensation control allows direct determination of mg/l of dissolved oxygen in oceanic or estuarine waters. Batteries provide complete portability; a battery eliminator feature bypasses the instrument batteries for extended line powered use (not including stirrer). Instrument batteries are carried internally in one holder while a second holder allows internal installation of batteries for powering a submersible stirrer for use in the field.

The probes use Clark-type membrane covered polarographic sensors with built-in thermistors for temperature measurement and compensation. A thin, permeable membrane stretched over the sensor isolates the sensor elements from the environment, but allows oxygen and certain other gases to enter. When a polarizing voltage is applied across the sensor, oxygen that has passed through the membrane reacts at the cathode, causing a current to flow.

The membrane passes oxygen at a rate proportional to the pressure difference across it. Since oxygen is rapidly consumed at the cathode, it can be assumed that the oxygen pressure inside the membrane is effectively zero. Hence, the force causing the oxygen to diffuse through the membrane is proportional to the absolute pressure of oxygen outside the membrane. If the oxygen pressure increases, more oxygen diffuses through the membrane and more current flows through the sensor. A lower pressure results in less current.

% AIR SATURATION

The % air saturation feature of this instrument allows quick determination of the degree of air saturation occurring in fresh or saline water. This feature also allows measurement in fluids of unknown oxygen solubility (see "Measuring Oxygen in Fluids Other than Water").

The % air saturation displayed in this mode is the saturation which would occur if the sample were saturated with air under a normal barometric pressure of 1013 millibars (760 mm Hg, or 29.92 inches Hg). Results reported from such measurements should be noted as % air saturation corrected to "standard pressure."

This feature also makes possible a simple and quick calibration procedure which eliminates the need to determine exact probe temperature or to calculate the barometric pressure effect on the calibration value. To calibrate the Model

58, the function switch is set to the % air saturation mode with the probe in moist air; then the **O_2 CALIB** control is adjusted to obtain a meter reading corresponding to the calibration value for the local altitude. Charts for quickly determining calibration values are conveniently located on the instrument's back cover.

This simple procedure accurately calibrates the meter for readings in both the mg/l and the % air saturation modes. The instrument may be switched from one mode to the other without losing its calibration. (Other methods of calibration are also possible and are discussed in detail in this manual.)

SPECIFICATIONS

INSTRUMENT

Oxygen Measurement

MODES:
- 0 to 20.0 mg/l dissolved oxygen
- 0 to 20.00 mg/l dissolved oxygen
- 0 to 200.0% air saturation

ACCURACY:
- ± .03 mg/l in 0 to 20.00 mg/l mode
- ± 0.3% air saturation

TEMPERATURE COMPENSATION:
- The mg/l modes are automatically temperature compensated to an accuracy of ± 1% of the dissolved oxygen reading between 5° and 45°C; and to an accuracy of ± 2% between 0° and 5°C. *Note:* See "Temperature Sensitivity" in probe specifications.
- The % air saturation mode is automatically temperature compensated to an accuracy of ± 1% of the oxygen reading between 5° and 45°C; and to an accuracy of ± 1.5% between 0° and 5°C. *Note:* See "Temperature Sensitivity" in probe specifications.

SALINITY COMPENSATION:
- Salinity range: 0 to 40 parts per thousand
- Accuracy: ± 0.3% of reading ± 1 digit

MODE TO MODE ACCURACY (mg/l to % air saturation)
- ± 0.5% of reading, ± 2 least significant digits (in the 0.01 mg/l mode)

Temperature Measurement

RANGE: -5° to +45°C

ACCURACY: ± 0.3°C, plus probe interchangeability

Recorder Output

VOLTAGE: 0 to 1 volt, full scale

ACCURACY: ± 0.4% of full scale, ± 1 least significant digit (in the 0.01 mg/l mode)

MINIMUM LOAD IMPEDANCE: 50KΩ

Instrument Environment

AMBIENT TEMPERATURE RANGE FOR SPECIFICATION PERFORMANCE:
0° to 45°C.

WATER RESISTANCE: With REC'D OUT and BATT ELIM (and STIRRER) receptacles capped, every case opening is gasketed to resist the entry of water.

Power Supplies

INSTRUMENT:

- 4 D size carbon-zinc batteries, or YSI 5401 battery eliminator (115 VAC), or YSI 5402 battery eliminator (230 VAC)
- ~1000 hours battery life
- Low battery indicator signal (LOBAT) appears automatically when approximately 50 hours of battery life remain.

STIRRER (OPTIONAL):

- A holder is provided for 4 additional D size batteries to power the optional field stirrer (YSI 5795A or 5791A).
- Battery life for the stirrer is typically 100 hours.
- The stirrer battery status can be checked by front panel control. LOBAT signal appears while STIRRER switch is held on BATT CHK position when approximately 5 hours of stirrer battery life remain.

PROBE (YSI Models 5739, 5720A or 5750)

CATHODE: Gold
ANODE: Silver
MEMBRANE: .001" FEP Teflon, YSI 5775, standard
.0005" FEP Teflon available, YSI 5776
ELECTROLYTE: Half-saturated KCl with Kodak Photo-Flo

TEMPERATURE SENSITIVITY:
When measuring oxygen, the probe output current increases approximately 3.5% per 1°C of increase in temperature. The circuitry automatically compensates for this effect in a typical probe. However, the exact temperature sensitivity of an individual probe may vary slightly according to its condition. Therefore, a probe should be calibrated at a temperature as close as possible to the measurement temperature in order to minimize the possible effect of such variation.

TEMPERATURE SENSOR ACCURACY: ±0.2°C

PRESSURE COMPENSATION:
Effective 0.5% of reading with pressures to 100 psi (230 feet sea water)

POLARIZING VOLTAGE: 0.8 volts nominal

PROBE CURRENT: Air at 30°C, 19 microamps nominal
Nitrogen at 30°C, .15 microamps or less

PROBE RESPONSE TIME:
Typical response for temperature and dissolved oxygen readings is 90% in 10 seconds at a constant temperature of 30°C with YSI 5775 Membrane. D.O. response at low temperature and low D.O. is typically 90% in 30 seconds. YSI 5776 High Sensitivity Membranes may be used to improve response at low temperature and D.O. concentrations.

APPENDIX C

FIELD SURVEY QA/QC

APPENDIX C - FIELD SURVEY QA/QC

Table List

Figure List

Table C-1. Temperature Sensor Assignments

Station	06/27 - 07/09		07/09 - 07/30		07/30 - 08/20		08/20 - 0917	
	Sensor 1	Sensor 2	Sensor 1	Sensor 2	Sensor 1	Sensor 2	Sensor 1	Sensor 2
1	185977	188877	149258	188880	124348	186068	188860	149200
2	124381	188846	188854	188878	149176	149256	124337	123746
3	188838	188840	109806	188882	109799	188840	186193	188842
4	103462	188842	188817	188828	188851	188866	188862	188891
5	123746	188894	124330	188871	124353	188863	124351	149258
6	124337	188853	188848	188862	186067	188857	188882	188815
7	149175	188872	124325	188875	124381	149171	188879	188849
8	124332	186193	69736	188887	186192	188884	188847	188828
9	109805	188818	188830	188860	188846	188937	149178	124330
10	188857	188893	149200	188814	103462	186191	188877	188867
11	149171	188855	188847	188856	124328	188886	124339	149203
12	188895	188937	149178	149227	188844	188853	188890	124331
13	124348	149201	109824	188833	109805	188894	69736	124439
14	186191	188831	124439	188873	188835	219	188852	188830
15	124351	186068	188879	188891	188818	188855	149169	188848
16	188885	188888	93511	188852	188831	188895	93511	188889
17	124339	188866	149203	188867	188850	188893	185977	188880
18	188851	188896	124331	188890	188841	188872	188833	188854
19	188839	188844	149169	188815	149175	188888	188887	188878
20	124349	188841	149202	188816	124349	188839	188814	188875
21B	186067	188886	188858	188889	124347	188874	109824	149227
21S	188881	188884	188845	188849	188881	188838	149202	188873

Table C-2. Sensor Calibration Verification Schedule

S/N	06/20	07/02	07/16	08/12	09/10	09/24	Count	
219		✓			✓		2	
69736		✓		✓		✓	3	
93511		✓		✓		✓	3	
103462	✓		✓		✓		3	
109799					✓		1	
109805	✓		✓		✓		3	
109806				✓			1	
109824				✓			1	a
123746	✓		✓			✓	3	
124325				✓		✓	2	
124328					✓		1	
124330		✓		✓			2	a
124331		✓		✓		✓	3	
124332	✓						1	b
124337	✓		✓			✓	3	
124339	✓		✓			✓	3	
124347		✓			✓		2	
124348	✓		✓		✓		3	
124349	✓		✓		✓		3	
124351	✓		✓			✓	3	
124353		✓			✓		2	
124381	✓		✓		✓		3	
124439		✓		✓		✓	3	
149169		✓		✓		✓	3	
149171	✓		✓		✓		3	
149175	✓		✓		✓		3	
149176		✓					1	
149178		✓		✓			2	a
149200		✓		✓		✓	3	
149201	✓						1	b
149202		✓		✓			2	a
149203		✓		✓		✓	3	
149227		✓		✓			2	a
149256		✓			✓		2	
149258	✓			✓		✓	3	
185977	✓			✓		✓	3	

Notes: a. Instrument lost (6); b. Data unrecoverable (11)

Table C-2. Sensor Calibration Verification Schedule (continued)

S/N	06/20	07/02	07/16	08/12	09/10	09/24	Count	
186067	✓		✓		✓		3	
186068	✓		✓		✓		3	
186191	✓		✓		✓		3	
186192		✓			✓		2	
186193	✓		✓			✓	3	
188814		✓		✓		✓	3	
188815		✓		✓		✓	3	
188816		✓		✓		✓	3	
188817		✓					1	b
188818	✓		✓		✓		3	
188828	✓			✓		✓	3	
188830		✓		✓	✓	✓	4	
188831	✓		✓				2	
188833		✓		✓		✓	3	
188835		✓			✓		2	
188838	✓		✓		✓		3	
188839	✓		✓		✓		3	
188840	✓		✓		✓		3	
188841	✓		✓		✓		3	
188842	✓		✓			✓	3	
188844	✓		✓		✓		3	
188845	✓						1	b
188846	✓		✓		✓		3	
188847	✓			✓		✓	3	
188848		✓		✓		✓	3	
188849	✓			✓		✓	3	
188850		✓			✓		2	
188851	✓		✓		✓		3	
188852		✓		✓		✓	3	
188853	✓		✓		✓		3	
188854		✓	✓	✓		✓	4	
188855	✓				✓		2	
188856		✓					1	b
188857	✓		✓		✓		3	
188858	✓						1	b
188860		✓		✓		✓	3	

Notes: a. Instrument lost (6); b. Data unrecoverable (11)

Table C-2. Sensor Calibration Verification Schedule (continued)

S/N	06/20	07/02	07/16	08/12	09/10	09/24	Count	
188862		✓		✓		✓	3	
188863		✓			✓		2	
188866	✓		✓		✓		3	
188867		✓		✓		✓	3	
188871		✓					1	b
188872	✓		✓		✓		3	
188873		✓		✓			2	a
188874	✓				✓		2	
188875		✓		✓		✓	3	
188877	✓			✓		✓	3	
188878	✓			✓			2	b
188879		✓		✓		✓	3	
188880	✓			✓		✓	3	
188881	✓		✓		✓		3	
188882		✓		✓		✓	3	
188884	✓		✓		✓		3	
188885	✓						1	b
188886	✓		✓		✓		3	
188887	✓			✓		✓	3	
188888	✓		✓		✓		3	
188889	✓			✓		✓	3	
188890		✓		✓			2	b
188891		✓		✓		✓	3	
188893	✓		✓		✓		3	
188894	✓		✓		✓		3	
188895	✓		✓		✓		3	
188896	✓						1	b
188937	✓		✓		✓		3	

Notes: a. Instrument lost (6); b. Data unrecoverable (11)

Table C-3. Calibration Verification Results, 20 June 2002

No	S/N	Mean Value	Lower 95% Confidence Limit	Upper 95% Confidence Limit	Status
1	103462	(0.02)	(0.02)	(0.02)	PASS
2	109805	0.09	0.08	0.09	PASS
3	123746	(0.03)	(0.03)	(0.03)	PASS
4	124332	0.00	0.00	0.00	PASS
5	124337	0.06	0.06	0.06	PASS
6	124338	0.21	0.21	0.22	PASS
7	124339	0.00	0.00	0.00	PASS
8	124348	0.09	0.09	0.09	PASS
9	124349	0.03	0.03	0.04	PASS
10	124351	0.08	0.08	0.08	PASS
11	124381	0.14	0.13	0.14	PASS
12	149171	0.11	0.11	0.11	PASS
13	149175	(0.01)	(0.01)	(0.01)	PASS
14	149201	(0.04)	(0.04)	(0.04)	PASS
15	149258	0.09	0.09	0.10	PASS
16	185977	0.00	0.00	0.00	PASS
17	186067	0.06	0.06	0.06	PASS
18	186068	0.00	0.00	0.00	PASS
19	186191	0.01	0.01	0.01	PASS
20	186193	0.11	0.11	0.12	PASS
21	188818	0.12	0.12	0.12	PASS
22	188828	0.20	0.19	0.20	PASS
23	188831	0.06	0.06	0.06	PASS
24	188838	0.14	0.14	0.15	PASS
25	188839	0.09	0.09	0.10	PASS
26	188840	0.09	0.08	0.09	PASS
27	188841	0.00	0.00	0.00	PASS
28	188842	0.05	0.05	0.05	PASS
29	188844	0.03	0.03	0.03	PASS
30	188845	0.06	0.06	0.06	PASS

Note: Refer to Instrument Data Sheet (Appendix B) for manufacturer's Quick Accuracy Check protocol. Instrument passed if mean ± 95% confidence limit falls within 0 ± 0.23°C.

Table C-3. Calibration Verification Results, 20 June 2002 (continued)

No	S/N	Mean Value	Lower 95% Confidence Limit	Upper 95% Confidence Limit	Status
31	188846	0.15	0.14	0.15	PASS
32	188847	0.04	0.04	0.04	PASS
33	188849	(0.07)	(0.07)	(0.07)	PASS
34	188851	0.09	0.08	0.09	PASS
35	188853	0.10	0.10	0.11	PASS
36	188855	0.09	0.08	0.09	PASS
37	188857	0.01	0.01	0.01	PASS
38	188858	0.02	0.02	0.02	PASS
39	188861	0.00	0.00	0.00	PASS
40	188866	0.18	0.18	0.18	PASS
41	188872	0.01	0.01	0.01	PASS
42	188874	0.04	0.04	0.04	PASS
43	188877	0.07	0.07	0.07	PASS
44	188878	0.07	0.06	0.07	PASS
45	188880	0.03	0.03	0.03	PASS
46	188881	0.09	0.09	0.09	PASS
47	188884	0.24	0.23	0.25	FAIL(a)
48	188885	(0.18)	(0.18)	(0.18)	PASS
49	188886	0.03	0.03	0.03	PASS
50	188887	0.04	0.03	0.04	PASS
51	188888	0.00	0.00	0.00	PASS
52	188889	0.03	0.03	0.03	PASS
53	188893	0.17	0.16	0.17	PASS
54	188894	(0.07)	(0.08)	(0.07)	PASS
55	188895	0.08	0.07	0.08	PASS
56	188896	0.10	0.09	0.10	PASS
57	188937	0.09	0.09	0.10	PASS
58	433252	(0.24)	(0.26)	(0.23)	FAIL

Notes: Refer to Instrument Data Sheet (Appendix B) for manufacturer's Quick Accuracy Check protocol. Instrument passed if mean ± 95% confidence limit falls within 0 ± 0.23°C.
(a) Instrument passed retest initiated due to suspected procedural error.

Table C-4. Calibration Verification Results, 02 July 2002

No	S/N	Mean Value	Lower 95% Confidence Limit	Upper 95% Confidence Limit	Status
1	219	(0.04)	(0.04)	(0.04)	PASS
2	69736	0.13	0.13	0.13	PASS
3	93511	0.00	0.00	0.00	PASS
4	124330	(0.04)	(0.04)	(0.04)	PASS
5	124331	0.09	0.09	0.09	PASS
6	124347	0.11	0.11	0.11	PASS
7	124353	(0.09)	(0.09)	(0.09)	PASS
8	124439	0.09	0.08	0.09	PASS
9	149167	(0.20)	(0.20)	(0.20)	PASS
10	149169	(0.10)	(0.10)	(0.10)	PASS
11	149176	(0.06)	(0.06)	(0.06)	PASS
12	149178	(0.04)	(0.04)	(0.04)	PASS
13	149200	0.07	0.07	0.07	PASS
14	149202	0.00	(0.00)	0.00	PASS
15	149203	0.07	0.07	0.07	PASS
16	149227	0.03	0.03	0.03	PASS
17	149256	(0.06)	(0.06)	(0.06)	PASS
18	186192	0.10	0.10	0.10	PASS
19	188814	(0.06)	(0.06)	(0.06)	PASS
20	188815	(0.07)	(0.08)	(0.07)	PASS
21	188816	(0.09)	(0.09)	(0.09)	PASS
22	188817	0.08	0.08	0.08	PASS
23	188830	0.05	0.04	0.05	PASS
24	188833	0.09	0.09	0.09	PASS
25	188834	0.07	0.07	0.08	PASS
26	188835	(0.00)	(0.01)	(0.00)	PASS
27	188837	0.06	0.06	0.07	PASS
28	188848	0.05	0.05	0.05	PASS
29	188850	(0.16)	(0.16)	(0.16)	PASS
30	188852	0.09	0.09	0.09	PASS

Note: Refer to Instrument Data Sheet (Appendix B) for manufacturer's Quick Accuracy Check protocol. Instrument passed if mean ± 95% confidence limit falls within 0 ± 0.23°C.

Table C-4. Calibration Verification Results, 02 July 2002 (continued)

No	S/N	Mean Value	Lower 95% Confidence Limit	Upper 95% Confidence Limit	Status
31	188854	0.05	0.05	0.06	PASS
32	188856	0.01	0.01	0.01	PASS
33	188860	0.11	0.11	0.11	PASS
34	188862	0.02	0.02	0.02	PASS
35	188863	0.05	0.05	0.05	PASS
36	188864	0.07	0.07	0.07	PASS
37	188867	0.17	0.17	0.17	PASS
38	188871	(0.06)	(0.07)	(0.06)	PASS
39	188873	(0.03)	(0.04)	(0.03)	PASS
40	188875	0.09	0.09	0.09	PASS
41	188879	0.02	0.02	0.02	PASS
42	188882	(0.01)	(0.01)	(0.00)	PASS
43	188890	(0.05)	(0.05)	(0.05)	PASS
44	188891	0.06	0.06	0.06	PASS

Note: Refer to Instrument Data Sheet (Appendix B) for manufacturer's Quick Accuracy Check protocol. Instrument passed if mean ± 95% confidence limit falls within 0 ± 0.23°C.

Table C-5. Calibration Verification Results, 16 July 2002

No	S/N	Mean Value	Lower 95% Confidence Limit	Upper 95% Confidence Limit	Status
1	103462	(0.02)	(0.02)	(0.02)	PASS
2	109805	0.00	0.00	0.00	PASS
3	123746	(0.03)	(0.03)	(0.03)	PASS
4	124337	0.06	0.06	0.06	PASS
5	124339	0.00	0.00	0.00	PASS
6	124348	0.09	0.09	0.09	PASS
7	124349	(0.02)	(0.02)	(0.02)	PASS
8	124351	(0.06)	(0.06)	(0.06)	PASS
9	124381	0.03	0.02	0.03	PASS
10	149171	0.11	0.11	0.11	PASS
11	149175	(0.02)	(0.02)	(0.02)	PASS
12	186067	0.06	0.06	0.06	PASS
13	186068	0.00	0.00	0.00	PASS
14	186191	(0.00)	(0.01)	(0.00)	PASS
15	186193	0.06	0.06	0.06	PASS
16	188818	0.12	0.12	0.12	PASS
17	188831	0.06	0.06	0.06	PASS
18	188838	0.06	0.06	0.06	PASS
19	188839	0.00	0.00	0.00	PASS
20	188840	0.02	0.02	0.02	PASS
21	188841	0.00	0.00	0.00	PASS
22	188842	0.05	0.05	0.05	PASS
23	188844	0.03	0.03	0.03	PASS
24	188846	0.01	0.01	0.01	PASS
25	188851	0.03	0.03	0.03	PASS
26	188853	0.02	0.02	0.02	PASS
27	188854	(0.10)	(0.10)	(0.09)	PASS
28	188857	0.01	0.01	0.01	PASS
29	188866	0.18	0.18	0.18	PASS
30	188872	0.01	0.01	0.01	PASS

Note: Refer to Instrument Data Sheet (Appendix B) for manufacturer's Quick Accuracy Check protocol. Instrument passed if mean ± 95% confidence limit falls within 0 ± 0.23°C.

Table C-5. Calibration Verification Results, 16 July 2002 (continued)

No	S/N	Mean Value	Lower 95% Confidence Limit	Upper 95% Confidence Limit	Status
31	**188881**	0.09	0.09	0.09	**PASS**
32	**188884**	0.03	0.03	0.03	**PASS**
33	**188886**	0.03	0.03	0.03	**PASS**
34	**188888**	0.00	0.00	0.00	**PASS**
35	**188893**	0.06	0.06	0.06	**PASS**
36	**188894**	(0.12)	(0.13)	(0.12)	**PASS**
37	**188895**	(0.11)	(0.11)	(0.11)	**PASS**
38	**188937**	(0.06)	(0.06)	(0.06)	**PASS**

Note: Refer to Instrument Data Sheet (Appendix B) for manufacturer's Quick Accuracy Check protocol. Instrument passed if mean ± 95% confidence limit falls within 0 ± 0.23°C.

Table C-6. Calibration Verification Results, 12 August 2002

No	S/N	Mean Value	Lower 95% Confidence Limit	Upper 95% Confidence Limit	Status
1	69736	0.13	0.13	0.13	PASS
2	93511	0.00	0.00	0.00	PASS
3	109806	(0.02)	(0.02)	(0.01)	PASS
4	109824	(0.03)	(0.03)	(0.03)	PASS
5	124325	(0.01)	(0.01)	(0.01)	PASS
6	124330	(0.04)	(0.04)	(0.04)	PASS
7	124331	0.09	0.09	0.09	PASS
8	124439	0.00	0.00	0.00	PASS
9	149169	(0.10)	(0.10)	(0.10)	PASS
10	149178	(0.04)	(0.04)	(0.04)	PASS
11	149200	0.07	0.07	0.07	PASS
12	149202	0.06	0.06	0.07	PASS
13	149203	0.07	0.07	0.07	PASS
14	149227	0.03	0.03	0.03	PASS
15	149258	0.00	0.00	0.00	PASS
16	185977	0.00	0.00	0.00	PASS
17	188814	(0.06)	(0.06)	(0.06)	PASS
18	188815	(0.10)	(0.10)	(0.10)	PASS
19	188816	(0.10)	(0.10)	(0.10)	PASS
20	188828	0.07	0.07	0.07	PASS
21	188830	0.02	0.02	0.02	PASS
22	188833	0.09	0.09	0.09	PASS
23	188847	0.04	0.04	0.04	PASS
24	188848	0.05	0.05	0.05	PASS
25	188849	(0.07)	(0.07)	(0.07)	PASS
26	188852	0.09	0.09	0.09	PASS
27	188854	0.02	0.02	0.03	PASS
28	188860	0.11	0.11	0.11	PASS
29	188862	0.02	0.02	0.02	PASS
30	188867	0.17	0.17	0.17	PASS

Note: Refer to Instrument Data Sheet (Appendix B) for manufacturer's Quick Accuracy Check protocol. Instrument passed if mean ± 95% confidence limit falls within 0 ± 0.23°C.

Table C-6. Calibration Verification Results, 12 August 2002 (continued)

No	S/N	Mean Value	Lower 95% Confidence Limit	Upper 95% Confidence Limit	Status
31	188873	(0.06)	(0.07)	(0.06)	PASS
32	188875	0.09	0.09	0.09	PASS
33	188877	(0.07)	(0.07)	(0.06)	PASS
34	188878	0.03	0.03	0.03	PASS
35	188879	0.00	(0.00)	0.00	PASS
36	188880	0.03	0.03	0.03	PASS
37	188882	(0.09)	(0.09)	(0.09)	PASS
38	188887	0.00	0.00	0.00	PASS
39	188889	0.03	0.03	0.03	PASS
40	188890	(0.05)	(0.05)	(0.05)	PASS
41	188891	0.06	0.06	0.06	PASS

Note: Refer to Instrument Data Sheet (Appendix B) for manufacturer's Quick Accuracy Check protocol. Instrument passed if mean ± 95% confidence limit falls within 0 ± 0.23°C.

Table C-7. Calibration Verification Results, 10 September 2002

No	S/N	Mean Value	Lower 95% Confidence Limit	Upper 95% Confidence Limit	Status
1	219	(0.04)	(0.04)	(0.04)	PASS
2	103462	(0.02)	(0.02)	(0.02)	PASS
3	109799	(0.17)	(0.17)	(0.17)	PASS
4	109805	0.00	0.00	0.00	PASS
5	124328	(0.05)	(0.06)	(0.05)	PASS
6	124347	0.02	0.01	0.02	PASS
7	124348	0.09	0.09	0.09	PASS
8	124349	(0.02)	(0.02)	(0.02)	PASS
9	124353	(0.09)	(0.09)	(0.09)	PASS
10	124381	(0.02)	(0.03)	(0.02)	PASS
11	149171	0.11	0.11	0.11	PASS
12	149174	(0.06)	(0.06)	(0.06)	PASS
13	149175	(0.02)	(0.02)	(0.02)	PASS
14	149256	(0.06)	(0.06)	(0.06)	PASS
15	186067	0.06	0.06	0.06	PASS
16	186068	0.00	0.00	0.00	PASS
17	186191	(0.02)	(0.02)	(0.01)	PASS
18	186192	0.10	0.10	0.10	PASS
19	188818	0.12	0.12	0.12	PASS
20	188830	0.06	0.06	0.06	PASS
21	188835	(0.01)	(0.01)	(0.01)	PASS
22	188838	0.06	0.06	0.06	PASS
23	188839	0.00	0.00	0.00	PASS
24	188840	0.02	0.02	0.02	PASS
25	188841	0.00	0.00	0.00	PASS
26	188844	0.03	0.03	0.03	PASS
27	188846	0.01	0.01	0.01	PASS
28	188850	(0.16)	(0.16)	(0.16)	PASS
29	188851	0.03	0.03	0.03	PASS
30	188853	0.02	0.02	0.02	PASS

Note: Refer to Instrument Data Sheet (Appendix B) for manufacturer's Quick Accuracy Check protocol. Instrument passed if mean ± 95% confidence limit falls within 0 ± 0.23°C.

Table C-7. Calibration Verification Results, 10 September 2002 (continued)

No	S/N	Mean Value	Lower 95% Confidence Limit	Upper 95% Confidence Limit	Status
31	188855	(0.12)	(0.12)	(0.12)	PASS
32	188857	0.01	0.01	0.01	PASS
33	188863	0.05	0.05	0.05	PASS
34	188866	0.17	0.17	0.17	PASS
35	188872	0.01	0.01	0.01	PASS
36	188874	0.04	0.04	0.04	PASS
37	188881	0.09	0.09	0.09	PASS
38	188884	0.03	0.03	0.03	PASS
39	188886	0.03	0.03	0.03	PASS
40	188888	0.00	0.00	0.00	PASS
41	188893	0.06	0.06	0.06	PASS
42	188894	(0.13)	(0.13)	(0.13)	PASS
43	188895	(0.11)	(0.11)	(0.11)	PASS
44	188937	(0.06)	(0.06)	(0.06)	PASS

Note: Refer to Instrument Data Sheet (Appendix B) for manufacturer's Quick Accuracy Check protocol. Instrument passed if mean ± 95% confidence limit falls within 0 ± 0.23°C.

Table C-8. Calibration Verification Results, 24 September 2002

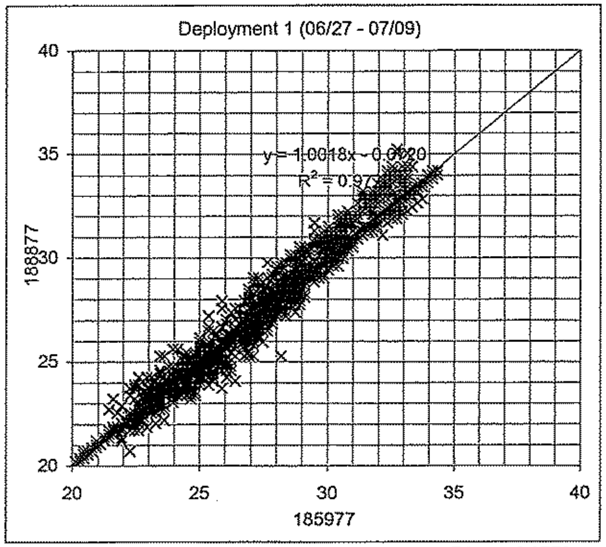
No	S/N	Mean Value	Lower 95% Confidence Limit	Upper 95% Confidence Limit	Status
1	69736	0.13	0.13	0.13	PASS
2	93511	0.00	0.00	0.00	PASS
3	123746	(0.03)	(0.03)	(0.03)	PASS
4	124325	(0.01)	(0.01)	(0.01)	PASS
5	124331	0.09	0.09	0.09	PASS
6	124337	0.06	0.06	0.06	PASS
7	124339	0.00	0.00	0.00	PASS
8	124351	(0.06)	(0.06)	(0.06)	PASS
9	124439	0.00	0.00	0.00	PASS
10	149169	(0.10)	(0.10)	(0.10)	PASS
11	149200	0.02	0.01	0.02	PASS
12	149203	0.07	0.07	0.07	PASS
13	149258	0.02	0.02	0.02	PASS
14	185977	0.00	0.00	0.00	PASS
15	186193	0.06	0.06	0.06	PASS
16	188814	(0.06)	(0.06)	(0.06)	PASS
17	188815	(0.10)	(0.10)	(0.10)	PASS
18	188816	(0.10)	(0.10)	(0.10)	PASS
19	188828	0.07	0.07	0.07	PASS
20	188830	0.02	0.02	0.02	PASS
21	188833	0.09	0.09	0.09	PASS
22	188842	0.05	0.05	0.05	PASS
23	188847	0.04	0.04	0.04	PASS
24	188848	0.05	0.05	0.05	PASS
25	188849	(0.07)	(0.07)	(0.07)	PASS
26	188852	0.09	0.09	0.09	PASS
27	188854	(0.04)	(0.04)	(0.04)	PASS
28	188860	0.11	0.11	0.11	PASS
29	188862	0.02	0.02	0.02	PASS
30	188867	0.17	0.17	0.17	PASS

Note: Refer to Instrument Data Sheet (Appendix B) for manufacturer's Quick Accuracy Check protocol. Instrument passed if mean ± 95% confidence limit falls within 0 ± 0.23°C.

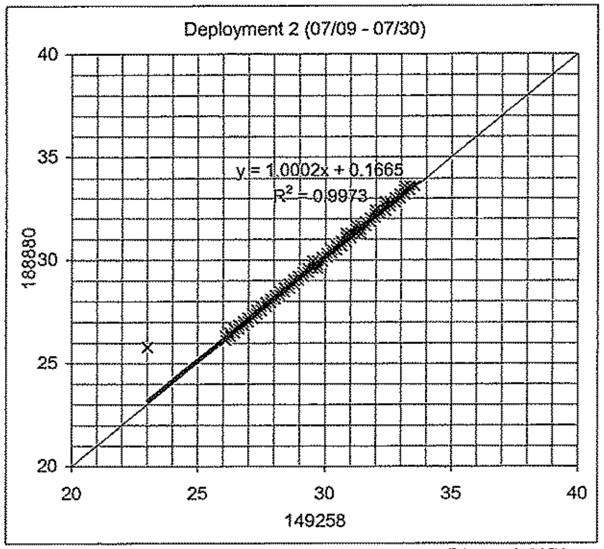
Table C-8. Calibration Verification Results, 24 September 2002 (continued)

No	S/N	Mean Value	Lower 95% Confidence Limit	Upper 95% Confidence Limit	Status
31	**188875**	0.09	0.09	0.09	**PASS**
32	**188877**	(0.08)	(0.08)	(0.08)	**PASS**
33	**188879**	0.00	0.00	0.00	**PASS**
34	**188880**	0.03	0.03	0.03	**PASS**
35	**188882**	(0.09)	(0.09)	(0.09)	**PASS**
36	**188887**	(0.04)	(0.05)	(0.04)	**PASS**
37	**188889**	0.01	0.01	0.01	**PASS**
38	**188891**	0.06	0.06	0.06	**PASS**

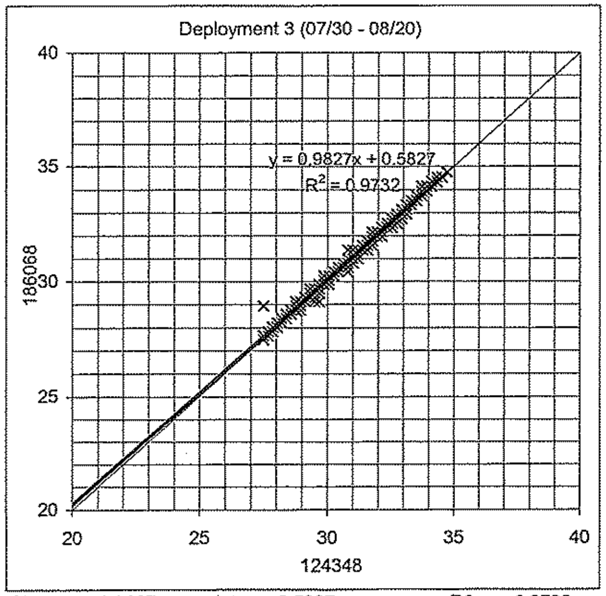
Note: Refer to Instrument Data Sheet (Appendix B) for manufacturer's Quick Accuracy Check protocol. Instrument passed if mean ± 95% confidence limit falls within 0 ± 0.23°C.



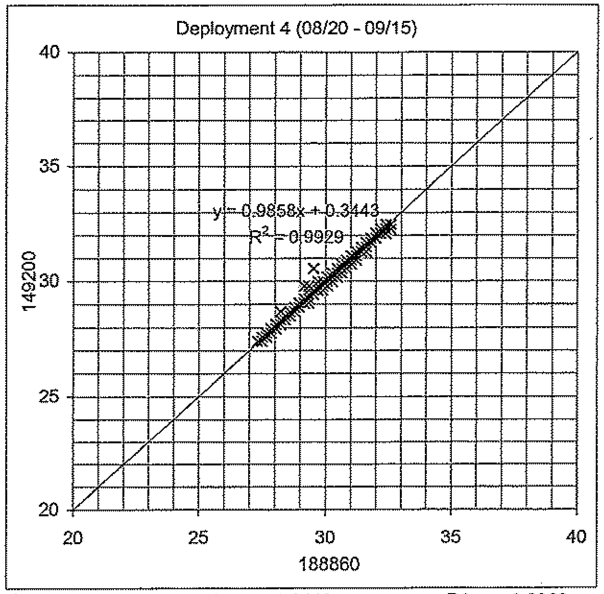
Slope: 1.0018 Int: -0.0720 R2: 0.9776



Slope: 1.0002 Int: 0.1665 R2: 0.9973



Slope: 0.9827 Int: 0.5827 R2: 0.9732



Slope: 0.9858 Int: 0.3443 R2: 0.9929

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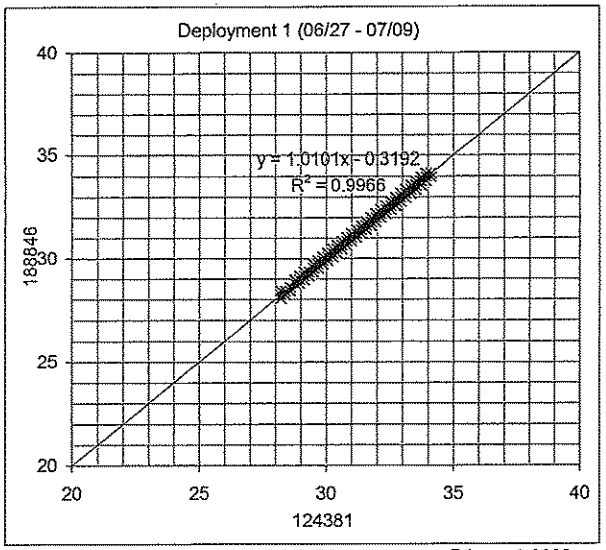
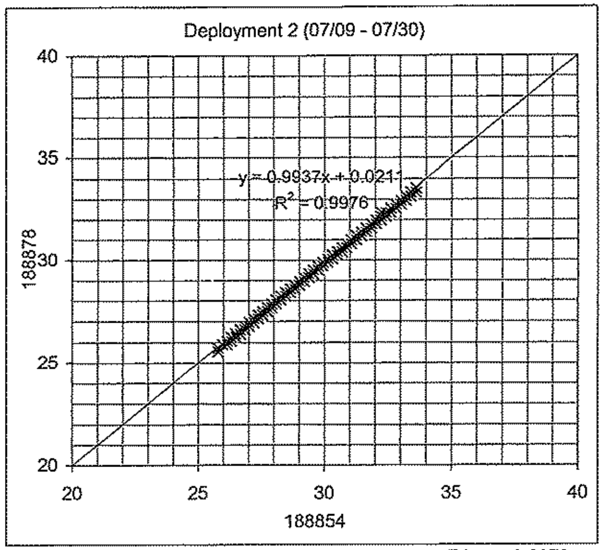
Duplicate sensor comparison, Station 1

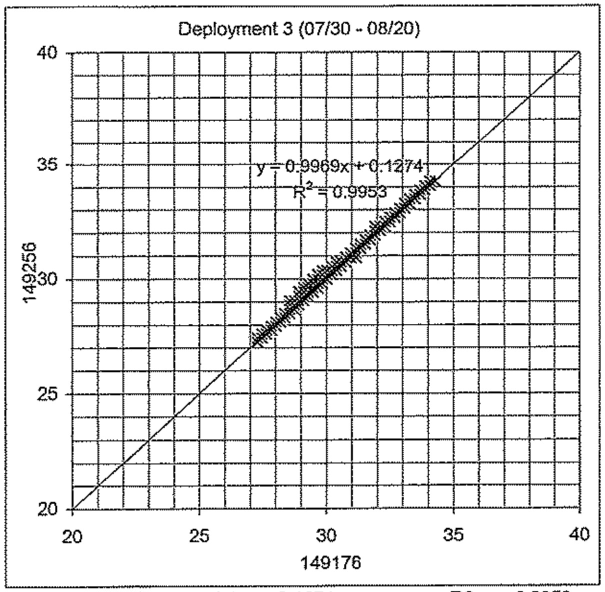
FIGURE C - 1



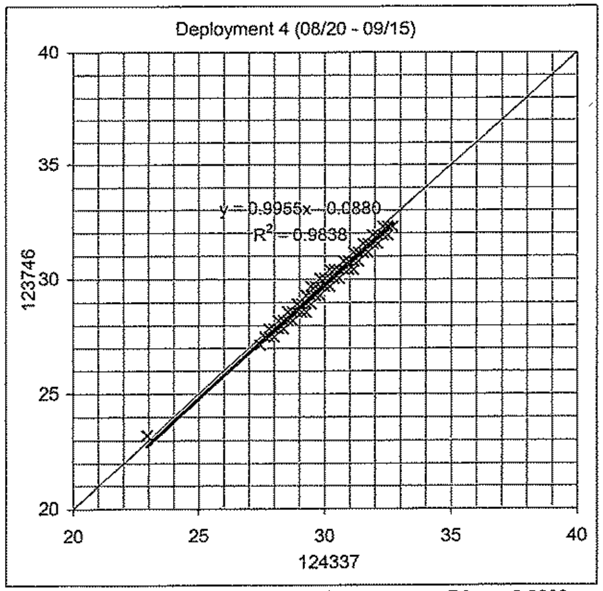
Slope: 1.0101 Int: -0.3192 R2: 0.9966



Slope: 0.9937 Int: 0.0211 R2: 0.9976



Slope: 0.9969 Int: 0.1274 R2: 0.9953



Slope: 0.9955 Int: -0.0880 R2: 0.9838

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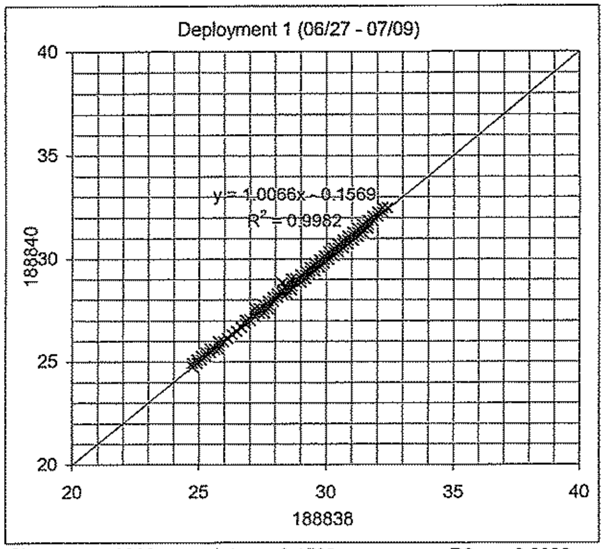
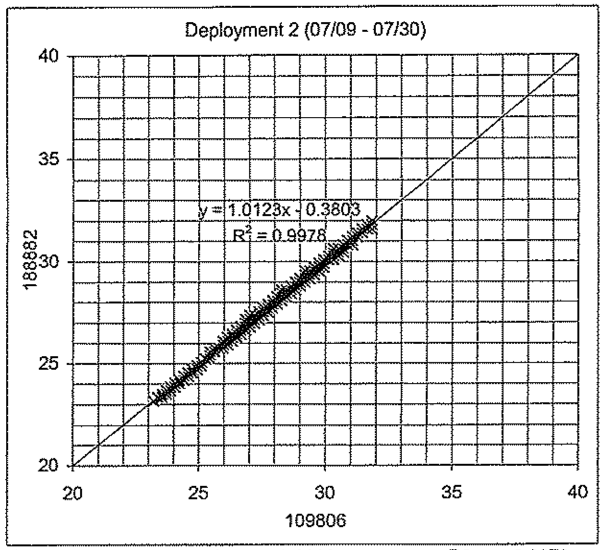
Duplicate sensor comparison, Station 2

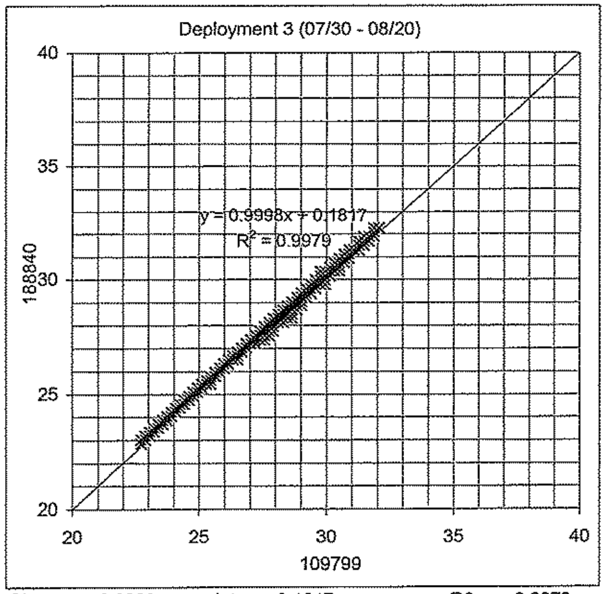
FIGURE C - 2



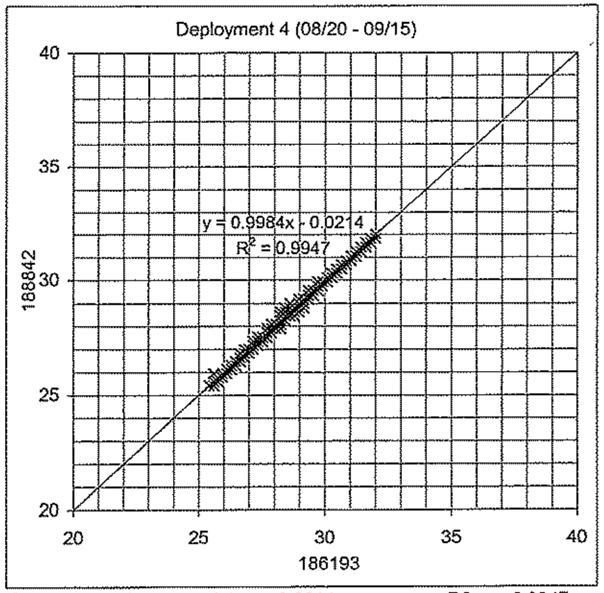
Slope: 1.0066 Int: -0.1569 R2: 0.9982



Slope: 1.0123 Int: -0.3803 R2: 0.9978



Slope: 0.9998 Int: 0.1817 R2: 0.9979



Slope: 0.9984 Int: -0.0214 R2: 0.9947

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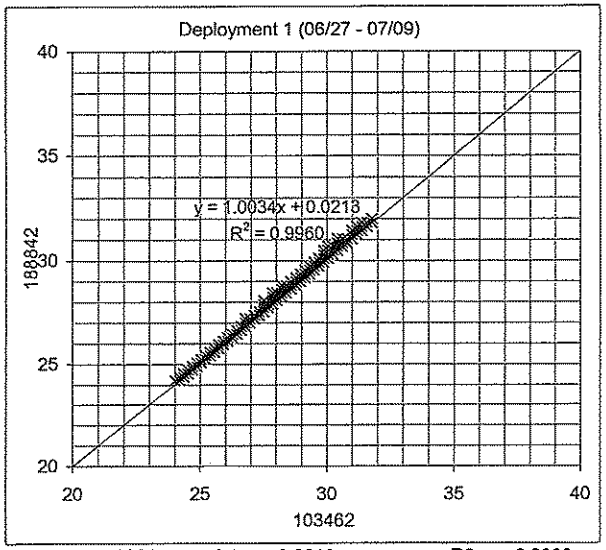
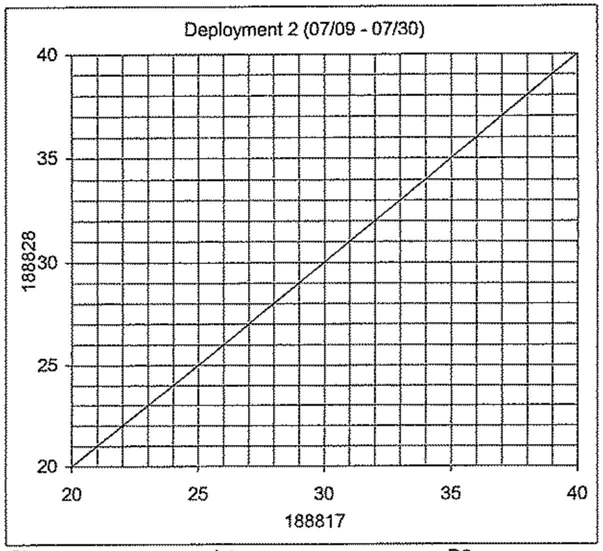
Duplicate sensor comparison, Station 3

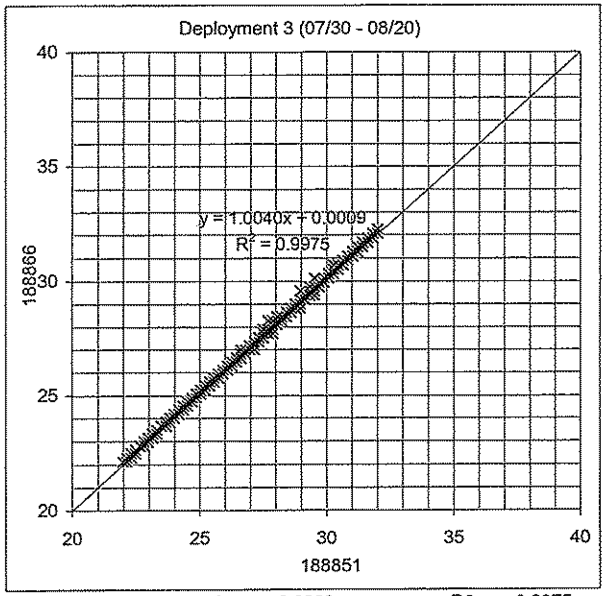
FIGURE C - 3



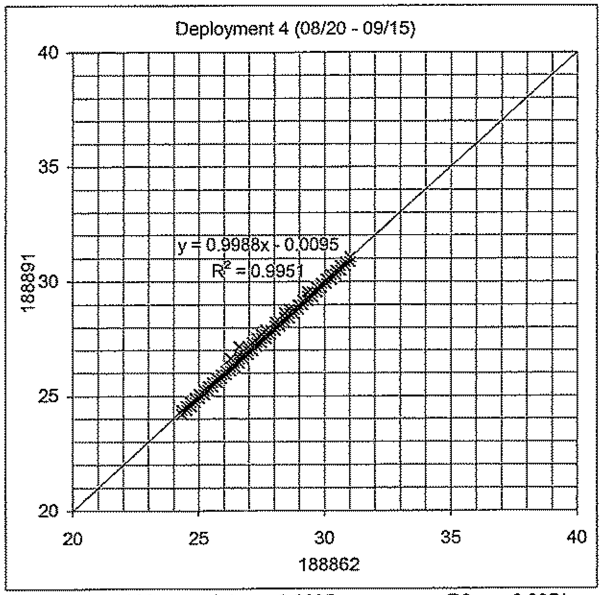
Slope: 1.0034 Int: 0.0213 R2: 0.9960



Slope: Int: R2:



Slope: 1.0040 Int: 0.0009 R2: 0.9975



Slope: 0.9988 Int: -0.0095 R2: 0.9951

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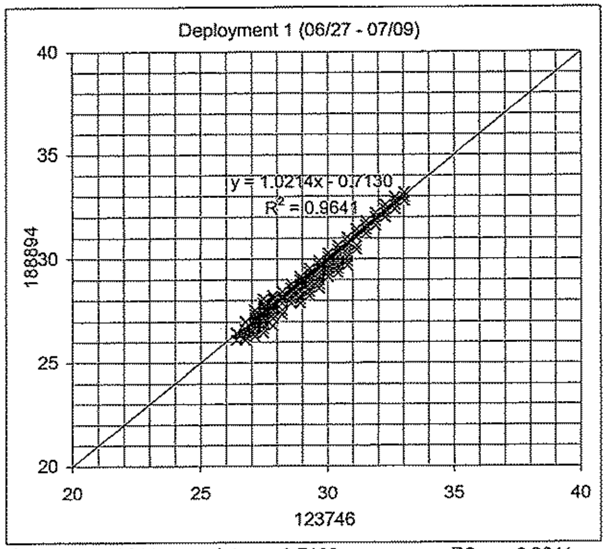
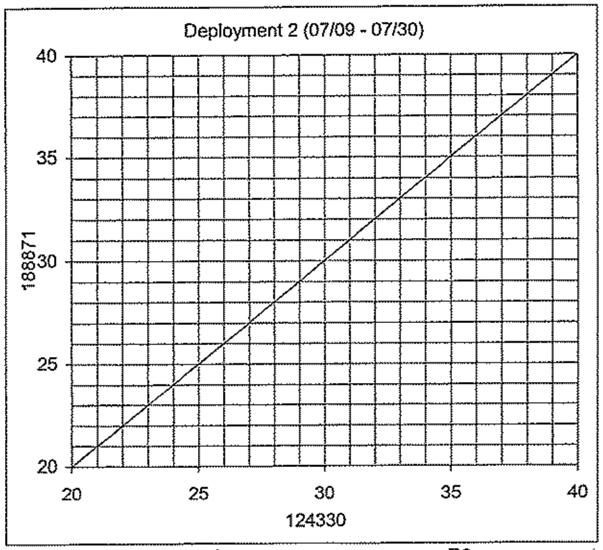
Duplicate sensor comparison, Station 4

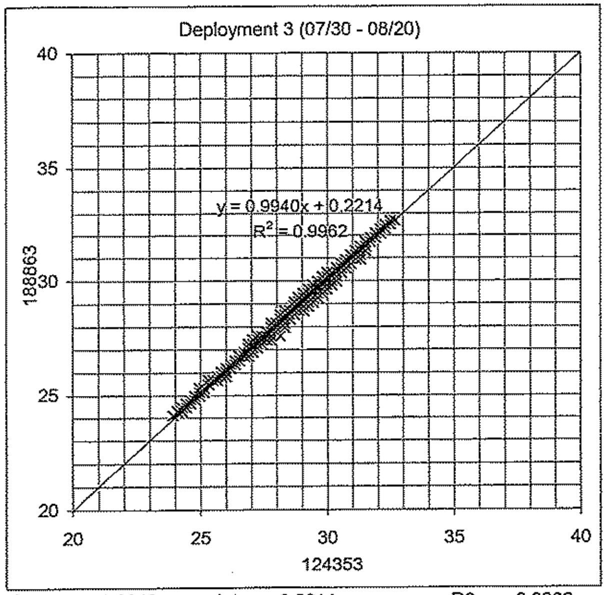
FIGURE C - 4



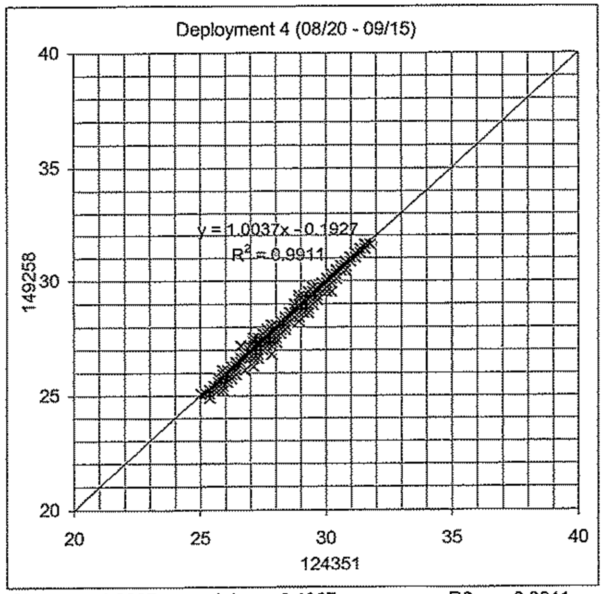
Slope: 1.0214 Int: -0.7130 R2: 0.9641



Slope: Int: R2:



Slope: 0.9940 Int: 0.2214 R2: 0.9962



Slope: 1.0037 Int: -0.1927 R2: 0.9911

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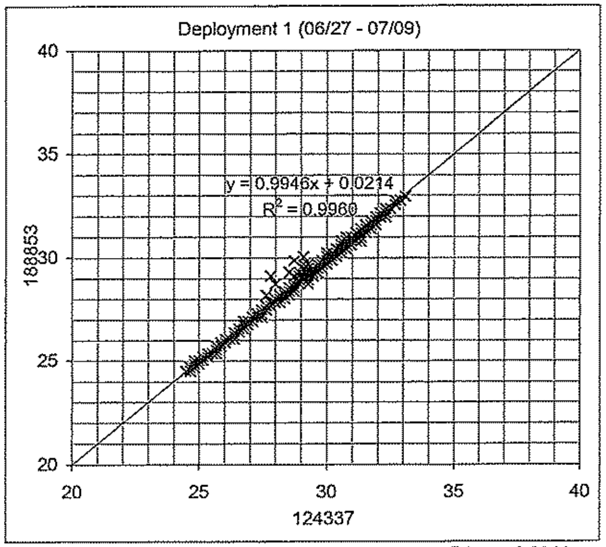
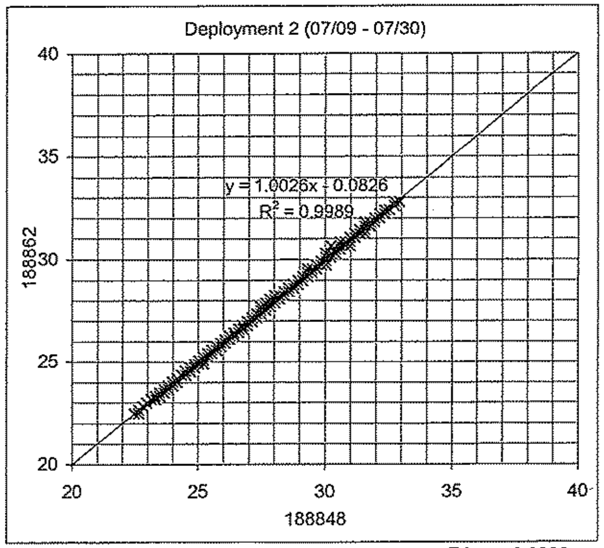
Duplicate sensor comparison, Station 5

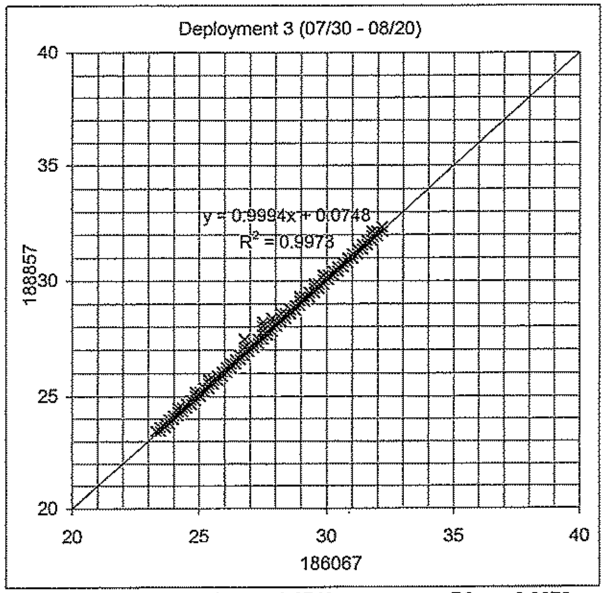
FIGURE C - 5



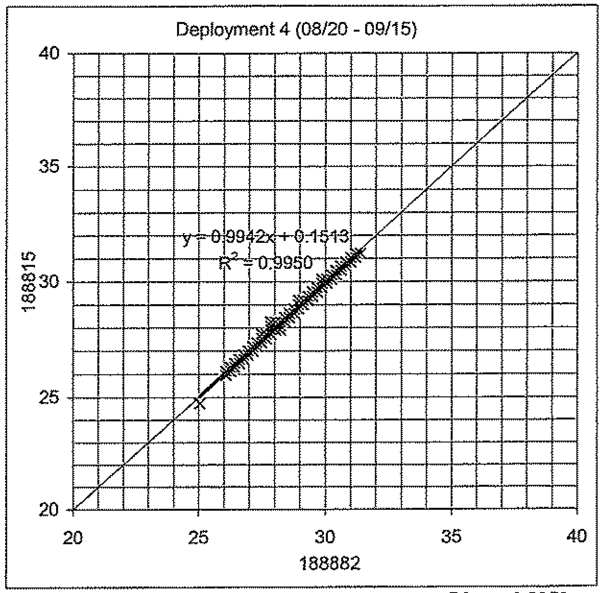
Slope: 0.9946 Int: 0.0214 R2: 0.9960



Slope: 1.0026 Int: -0.0826 R2: 0.9989



Slope: 0.9994 Int: 0.0748 R2: 0.9973



Slope: 0.9942 Int: 0.1513 R2: 0.9950

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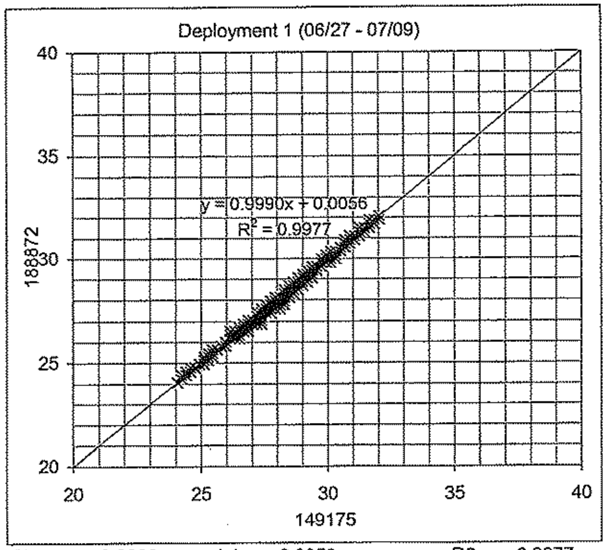
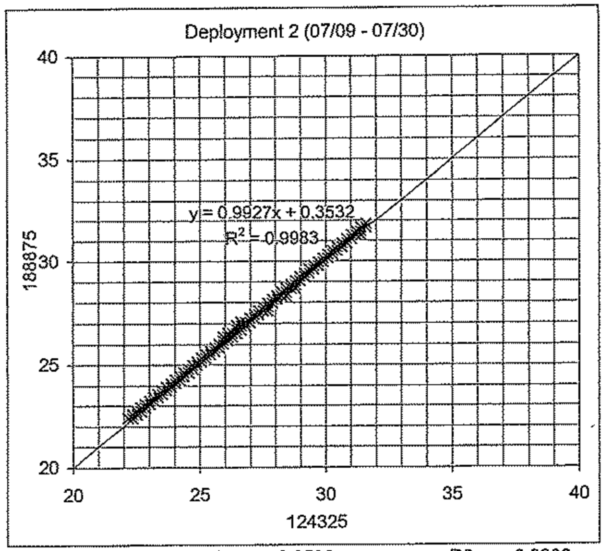
Duplicate sensor comparison, Station 6

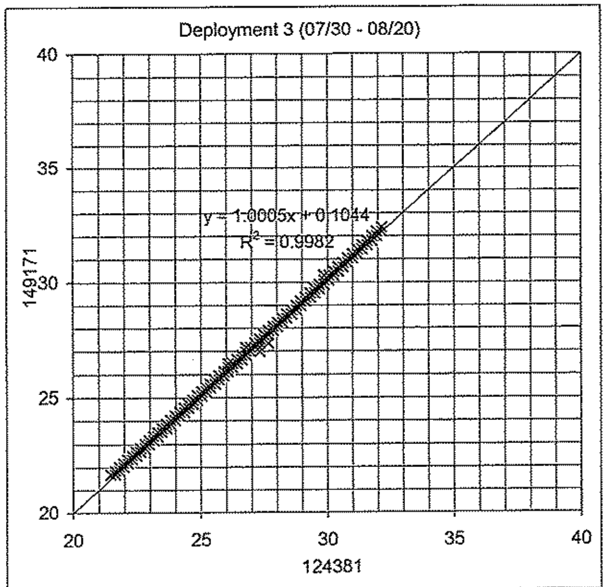
FIGURE C - 6



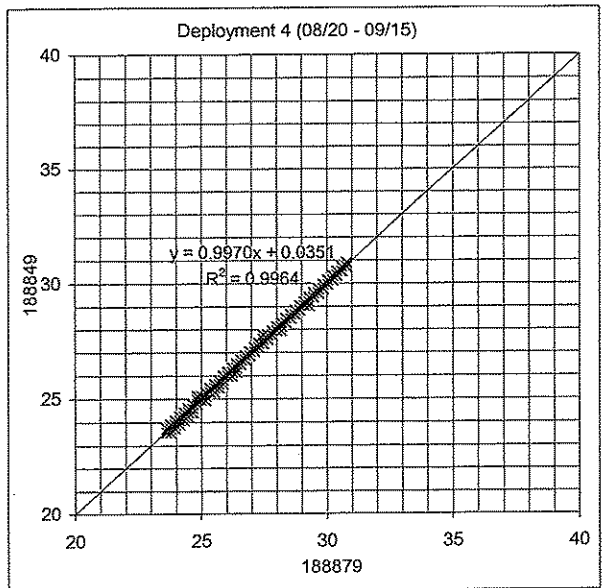
Slope: 0.9990 Int: 0.0056 R2: 0.9977



Slope: 0.9927 Int: 0.3532 R2: 0.9983



Slope: 1.0005 Int: 0.1044 R2: 0.9982



Slope: 0.9970 Int: 0.0351 R2: 0.9964

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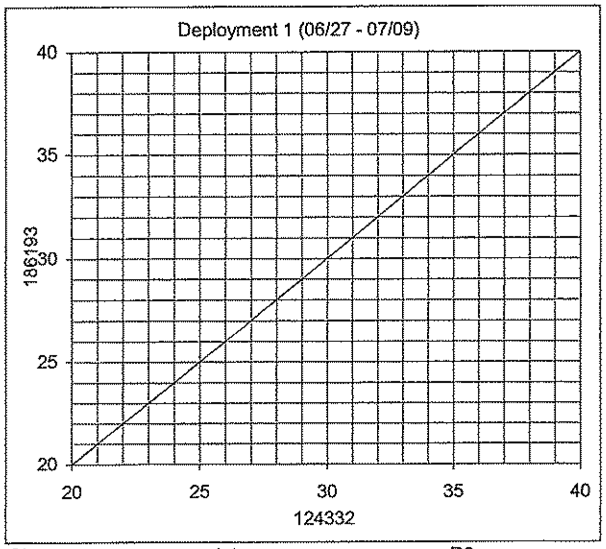
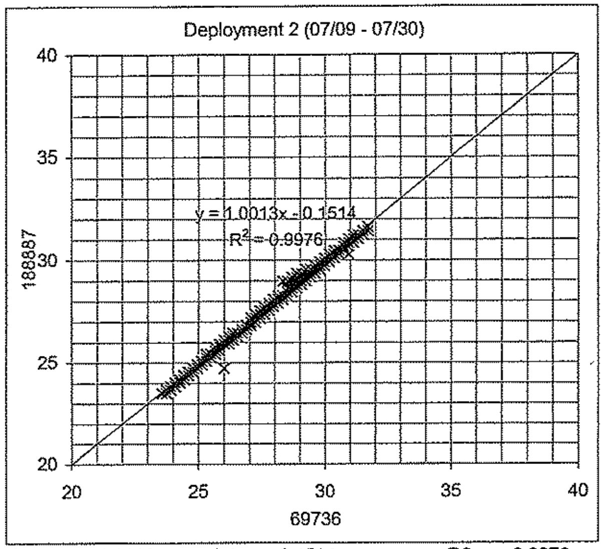
Duplicate sensor comparison, Station 7

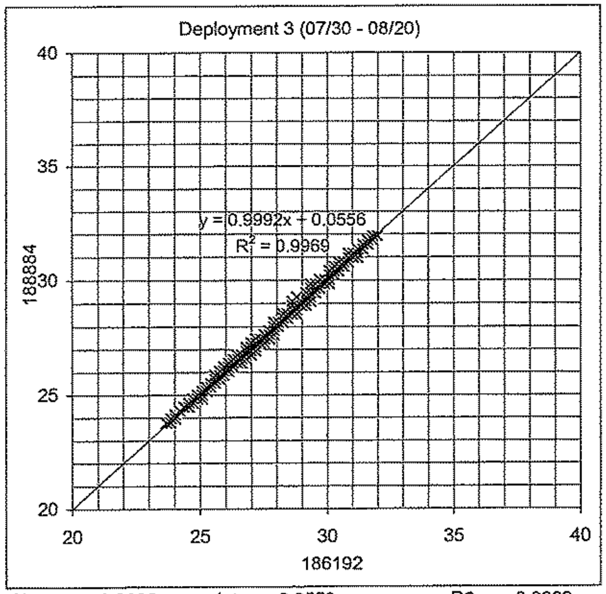
FIGURE C - 7



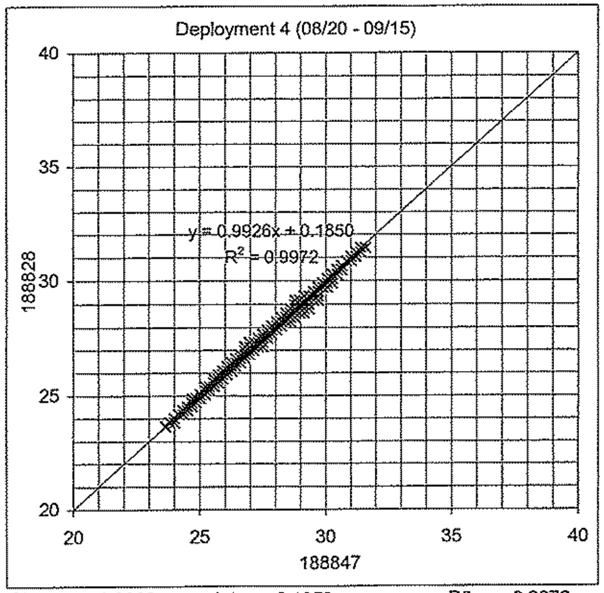
Slope: Int: R2:



Slope: 1.0013 Int: -0.1514 R2: 0.9976



Slope: 0.9992 Int: 0.0556 R2: 0.9969



Slope: 0.9926 Int: 0.1850 R2: 0.9972

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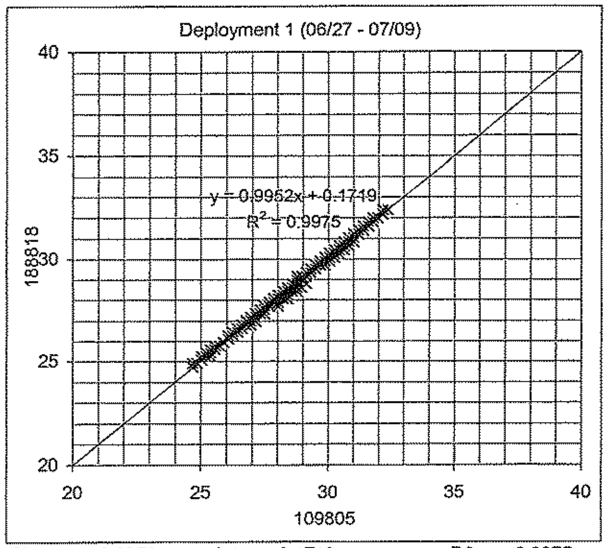
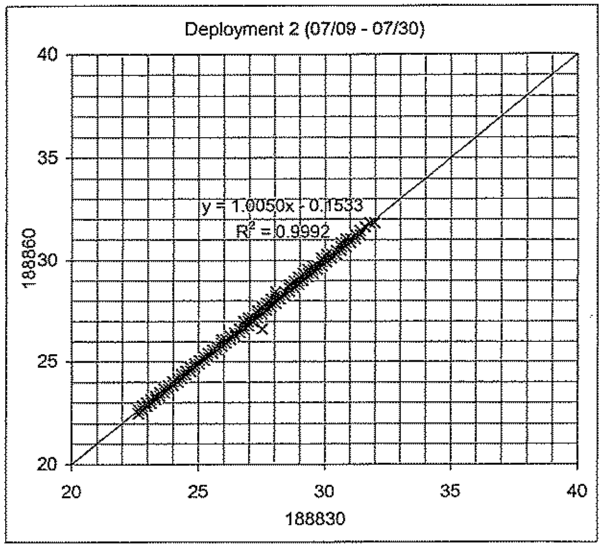
Duplicate sensor comparison, Station 8

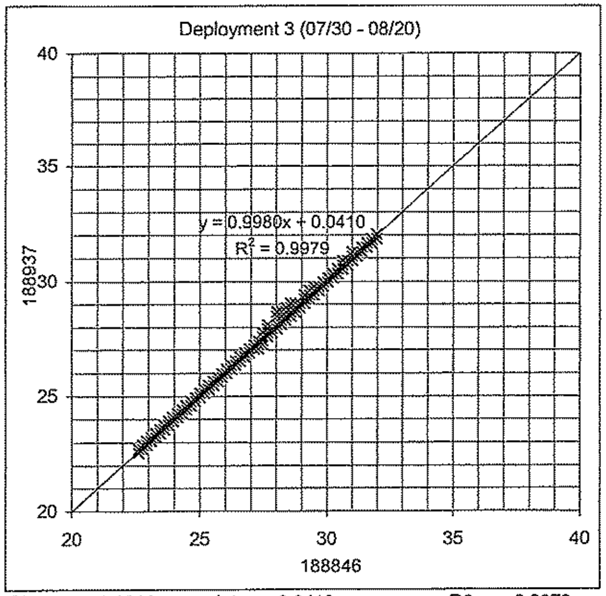
FIGURE C - 8



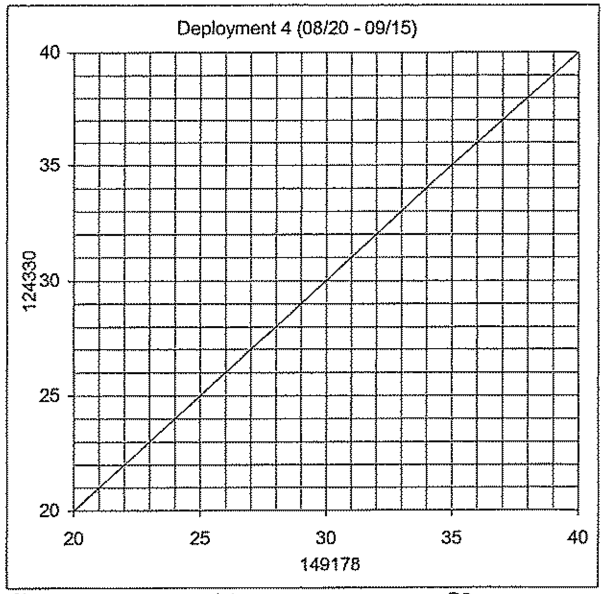
Slope: 0.9952 Int: 0.1719 R2: 0.9975



Slope: 1.0050 Int: -0.1533 R2: 0.9992



Slope: 0.9980 Int: 0.0410 R2: 0.9979



Slope: Int: R2:

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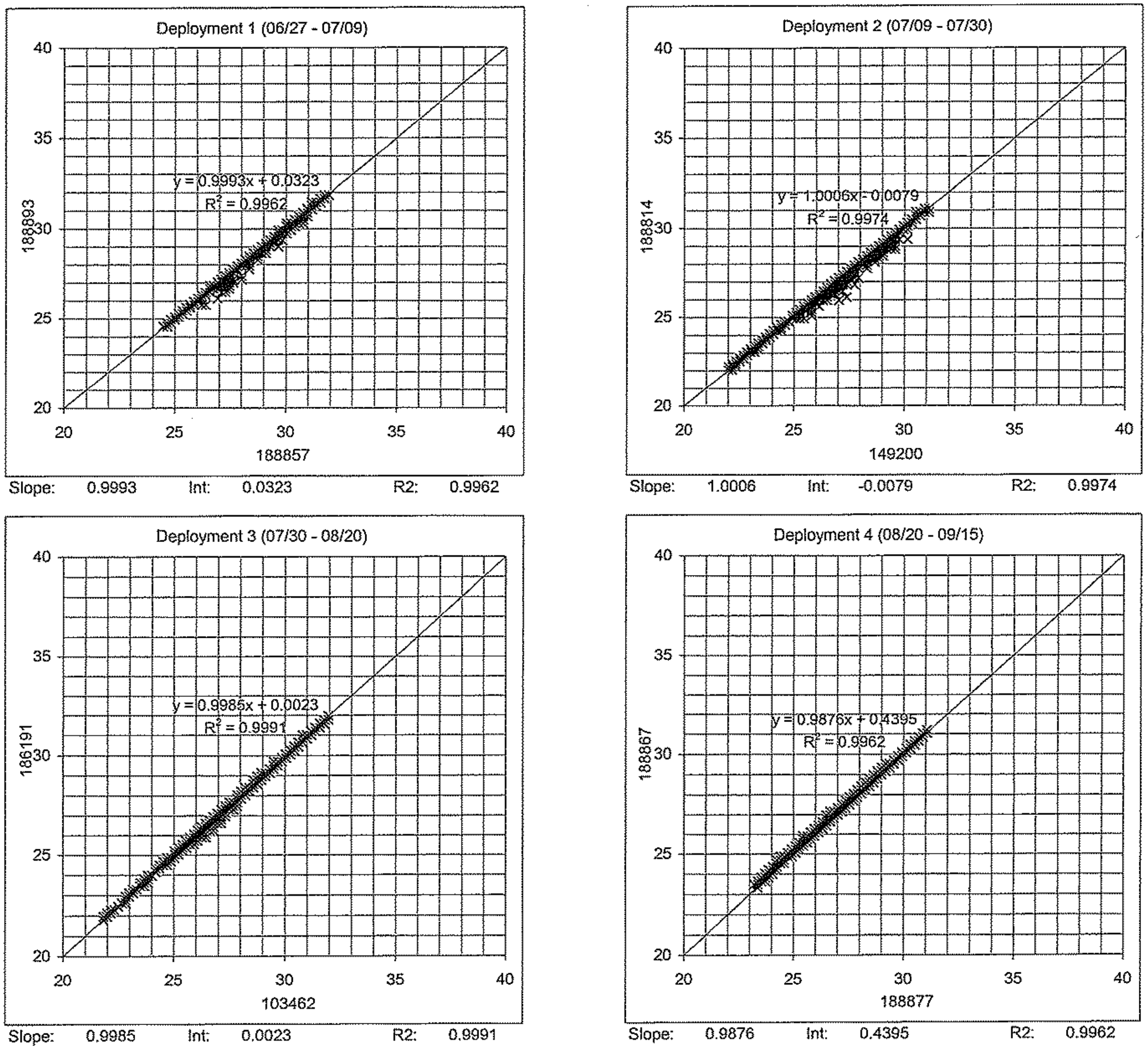
Duplicate sensor comparison, Station 9

FIGURE C - 9



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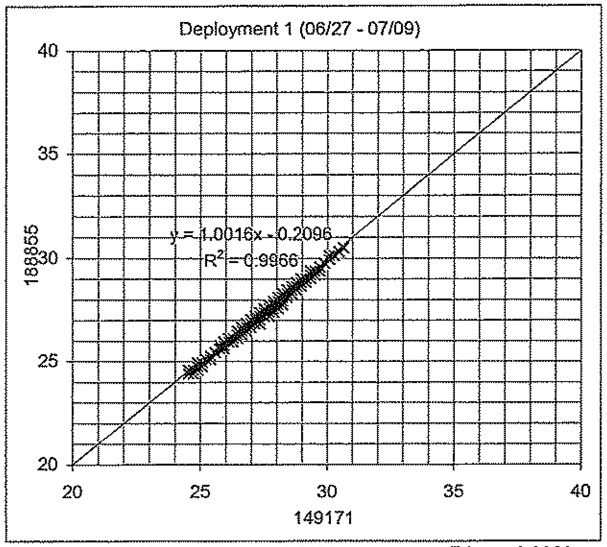
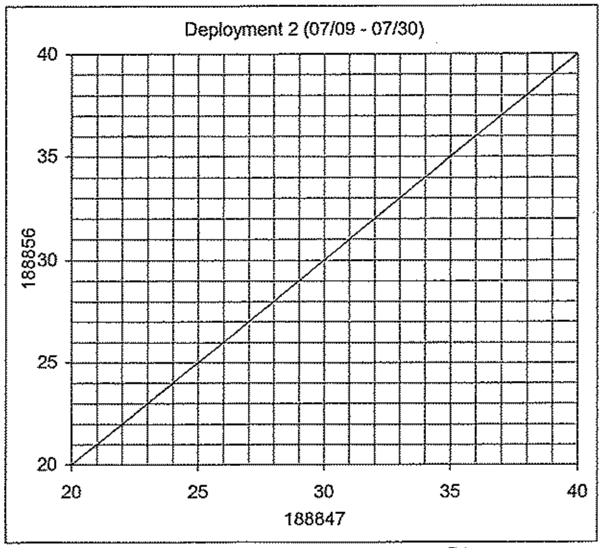
Duplicate sensor comparison, Station 10

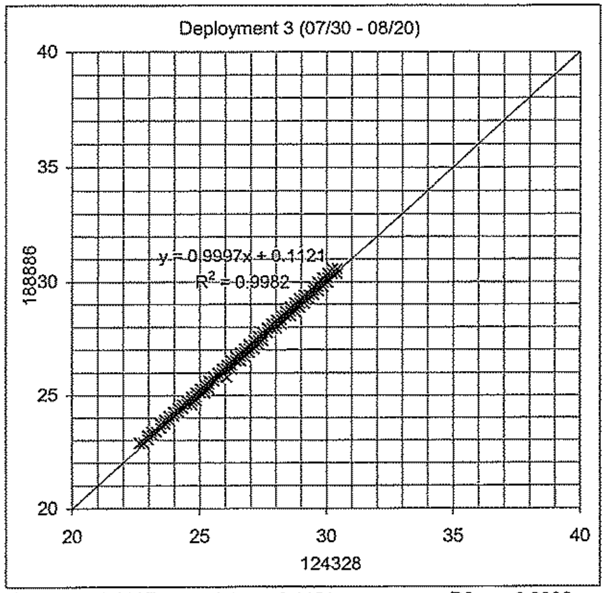
FIGURE C - 10



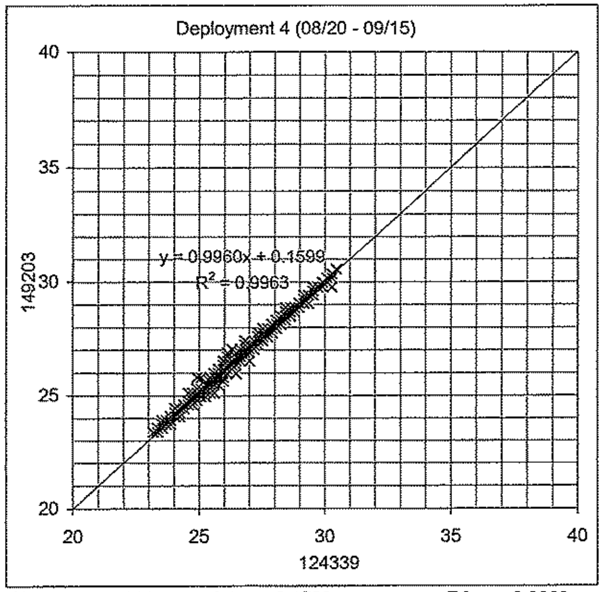
Slope: 1.0016 Int: -0.2096 R2: 0.9966



Slope: Int: R2:



Slope: 0.9997 Int: 0.1121 R2: 0.9982



Slope: 0.9960 Int: 0.1599 R2: 0.9963

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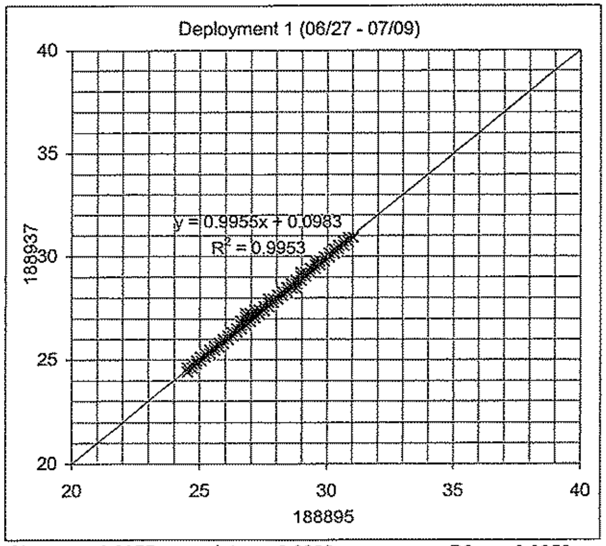
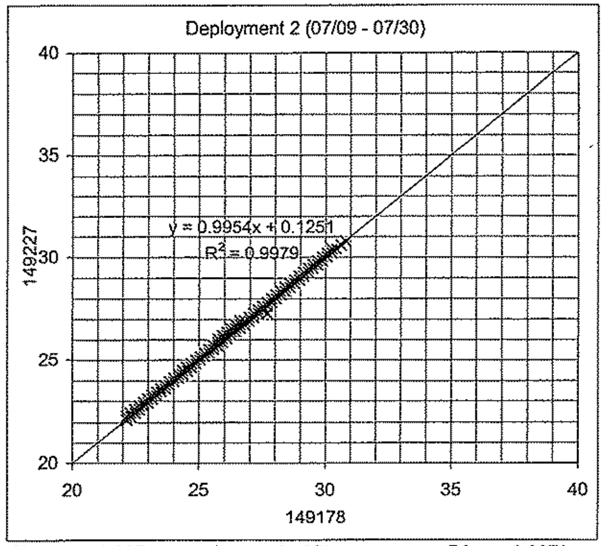
Duplicate sensor comparison, Station 11

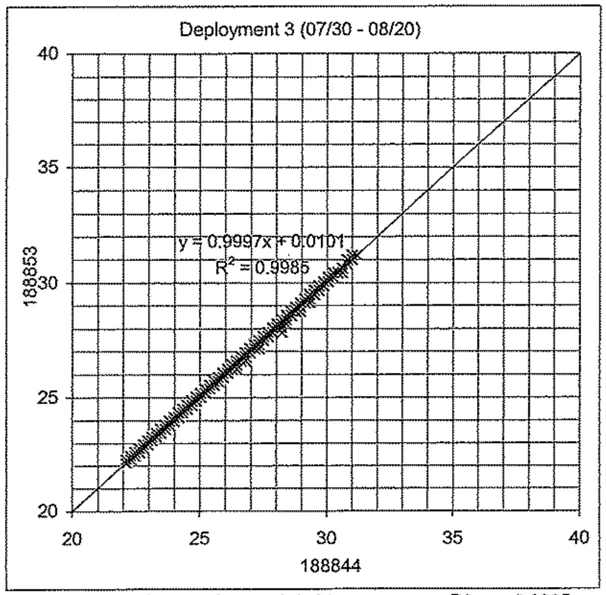
FIGURE C - 11



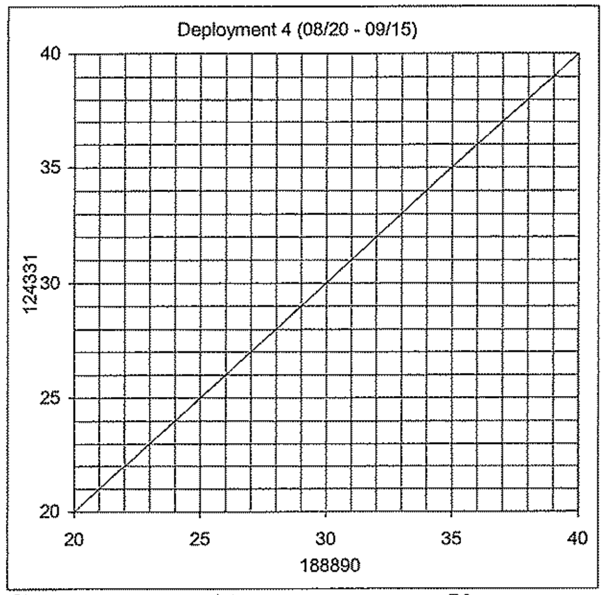
Slope: 0.9955 Int: 0.0983 R2: 0.9953



Slope: 0.9954 Int: 0.1251 R2: 0.9979



Slope: 0.9997 Int: 0.0101 R2: 0.9985



Slope: Int: R2:

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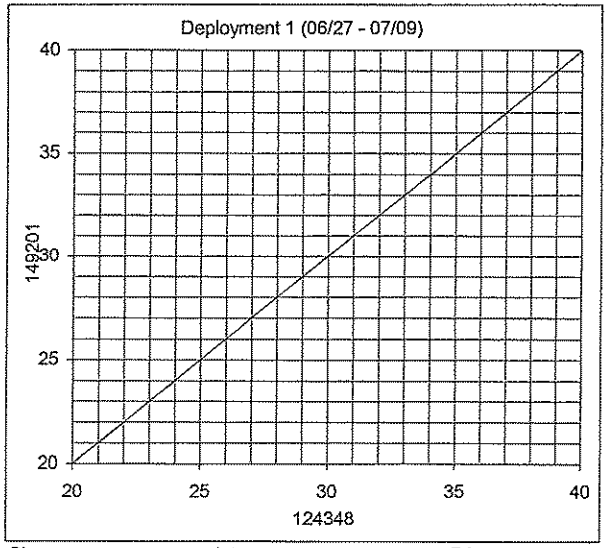
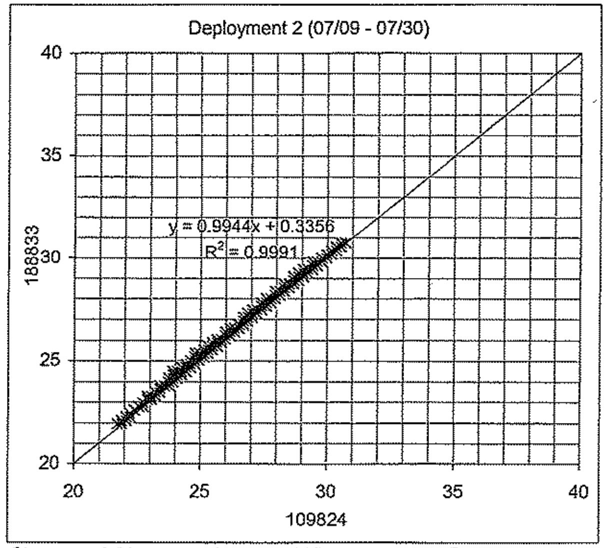
Duplicate sensor comparison, Station 12

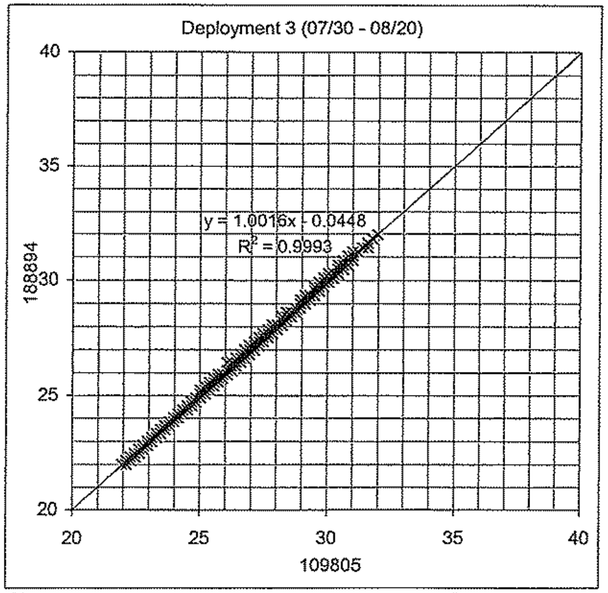
FIGURE C - 12



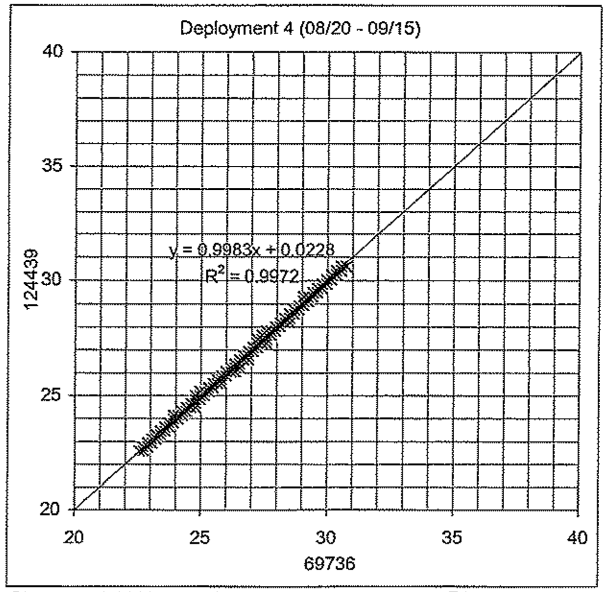
Slope: Int: R2:



Slope: 0.9944 Int: 0.3356 R2: 0.9991



Slope: 1.0016 Int: -0.0448 R2: 0.9993



Slope: 0.9983 Int: 0.0228 R2: 0.9972

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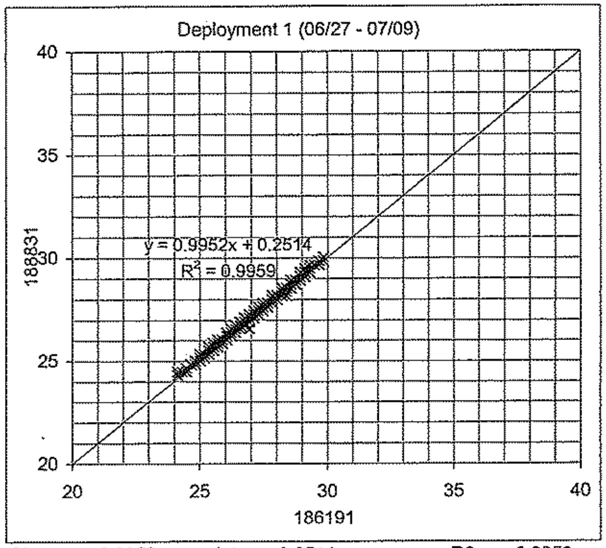
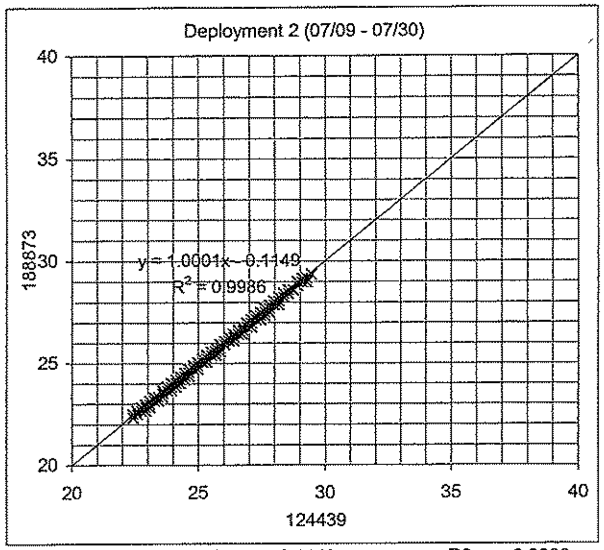
Duplicate sensor comparison, Station 13

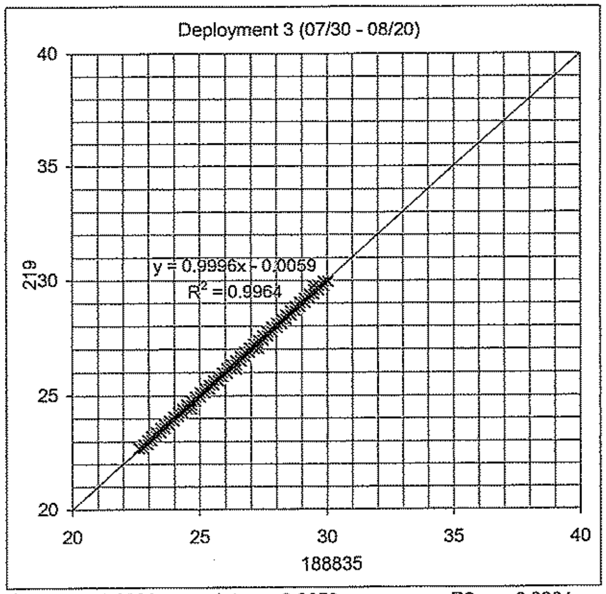
FIGURE C - 13



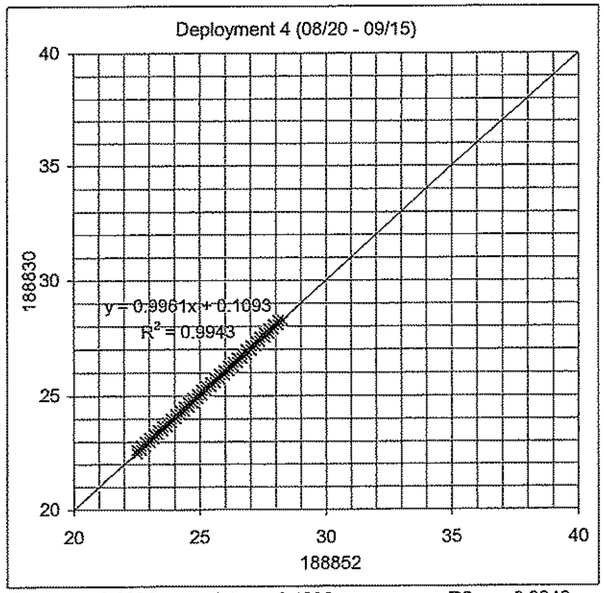
Slope: 0.9952 Int: 0.2514 R2: 0.9959



Slope: 1.0001 Int: -0.1149 R2: 0.9986



Slope: 0.9996 Int: -0.0059 R2: 0.9964



Slope: 0.9961 Int: 0.1093 R2: 0.9943

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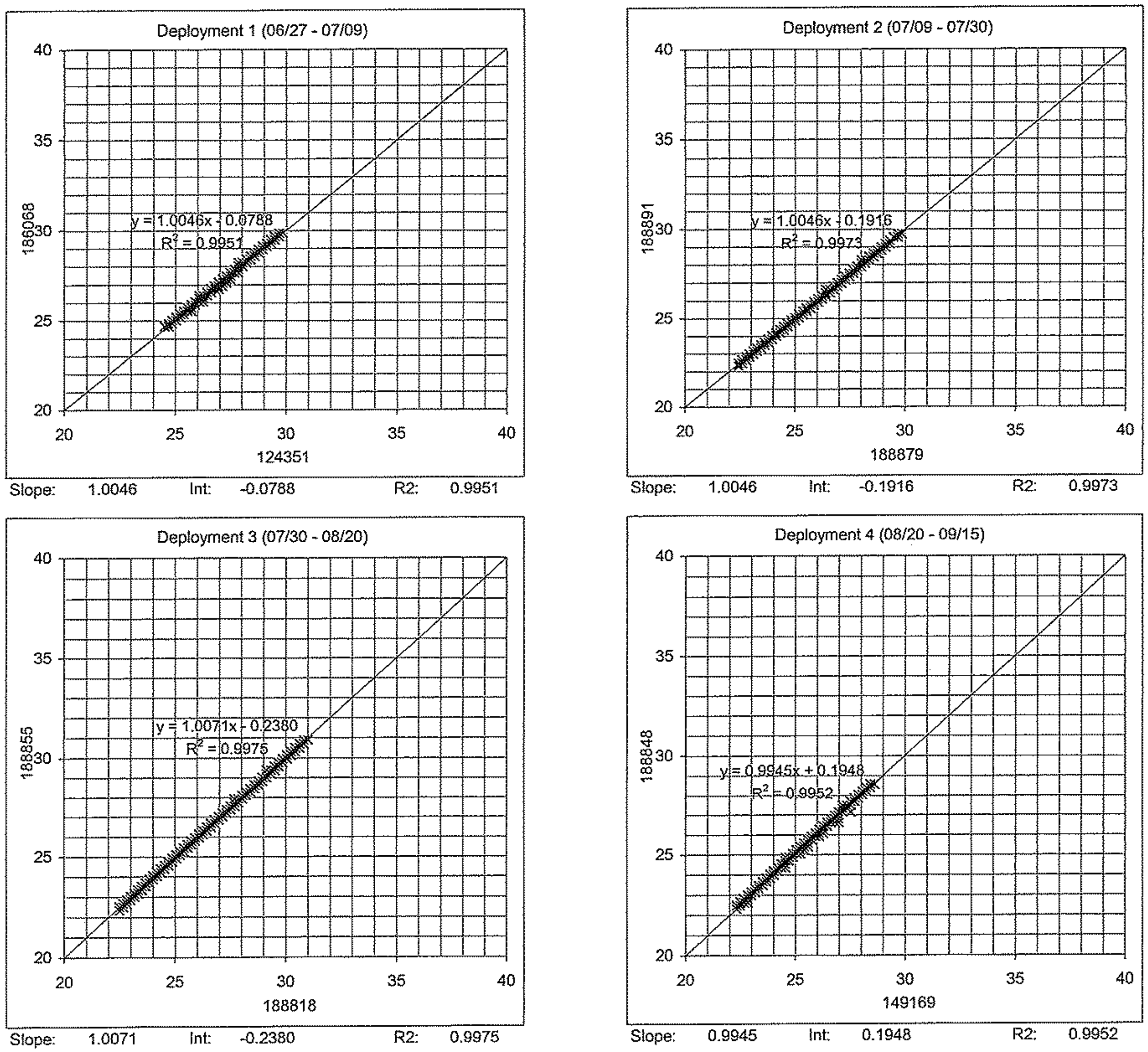
Duplicate sensor comparison, Station 14

FIGURE C - 14



JN 0925-002

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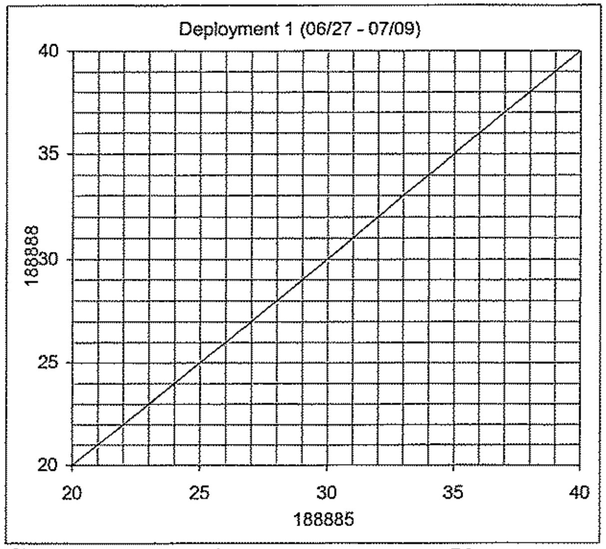
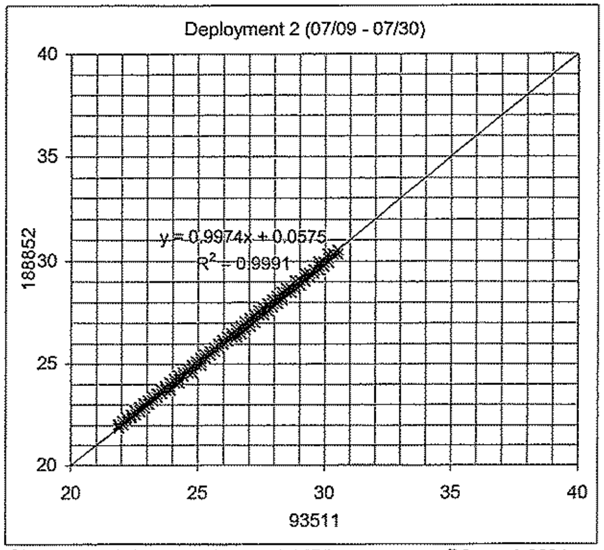
Duplicate sensor comparison, Station 15

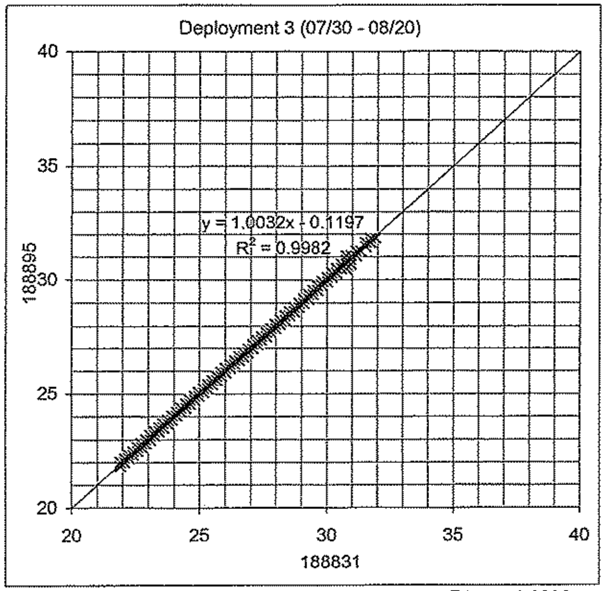
FIGURE C - 15



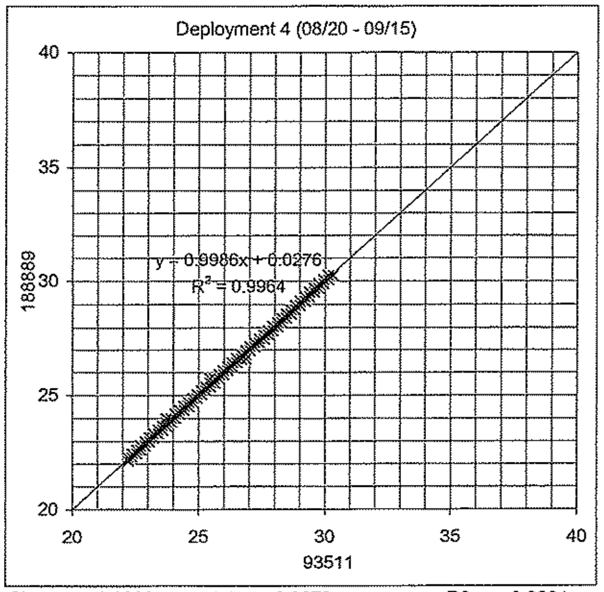
Slope: Int: R2:



Slope: 0.9974 Int: 0.0575 R2: 0.9991



Slope: 1.0032 Int: -0.1197 R2: 0.9982



Slope: 0.9986 Int: 0.0276 R2: 0.9964

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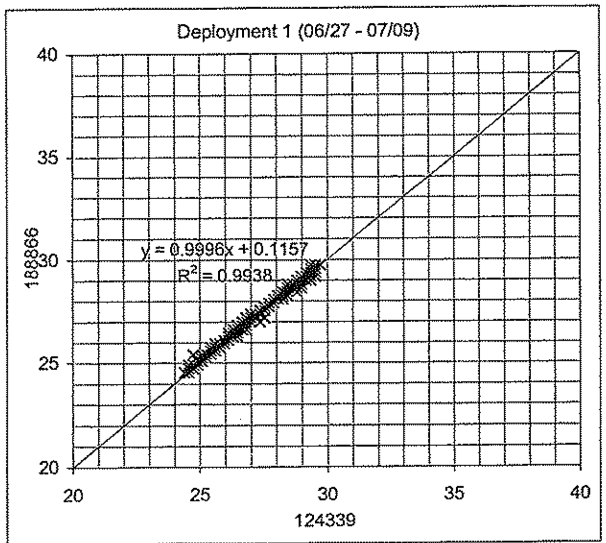
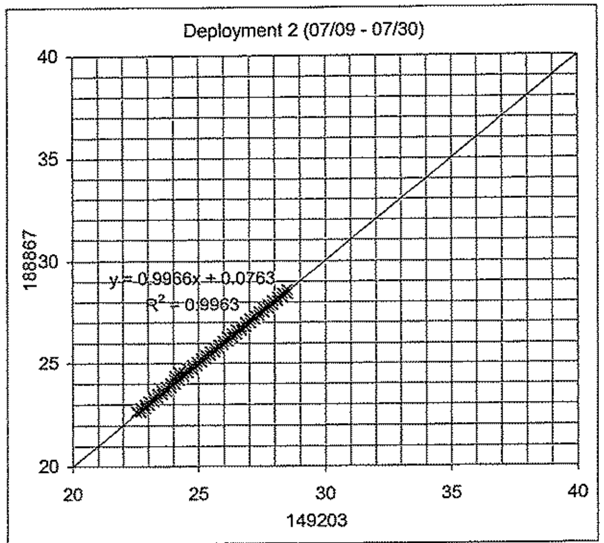
Duplicate sensor comparison, Station 16

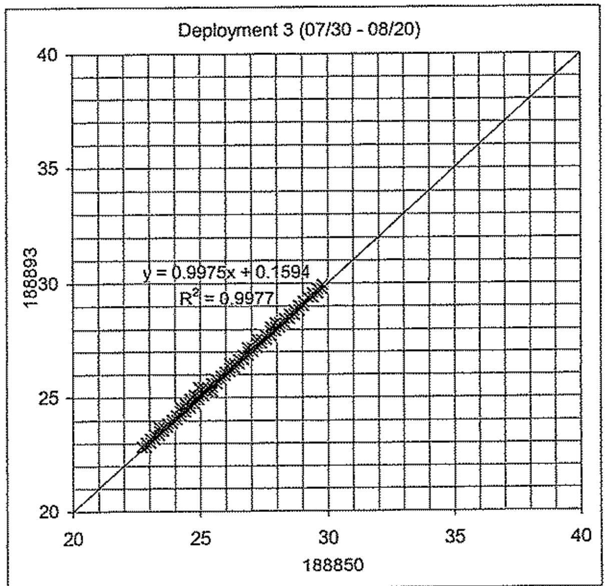
FIGURE C - 16



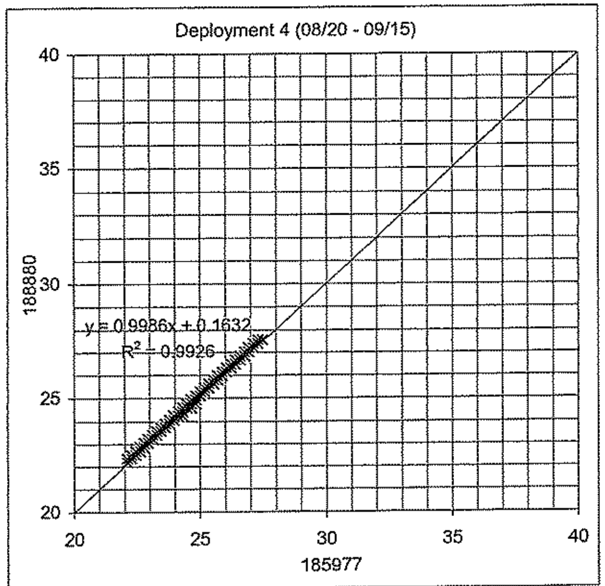
Slope: 0.9996 Int: 0.1157 R2: 0.9938



Slope: 0.9966 Int: 0.0763 R2: 0.9963



Slope: 0.9975 Int: 0.1594 R2: 0.9977



Slope: 0.9986 Int: 0.1632 R2: 0.9926

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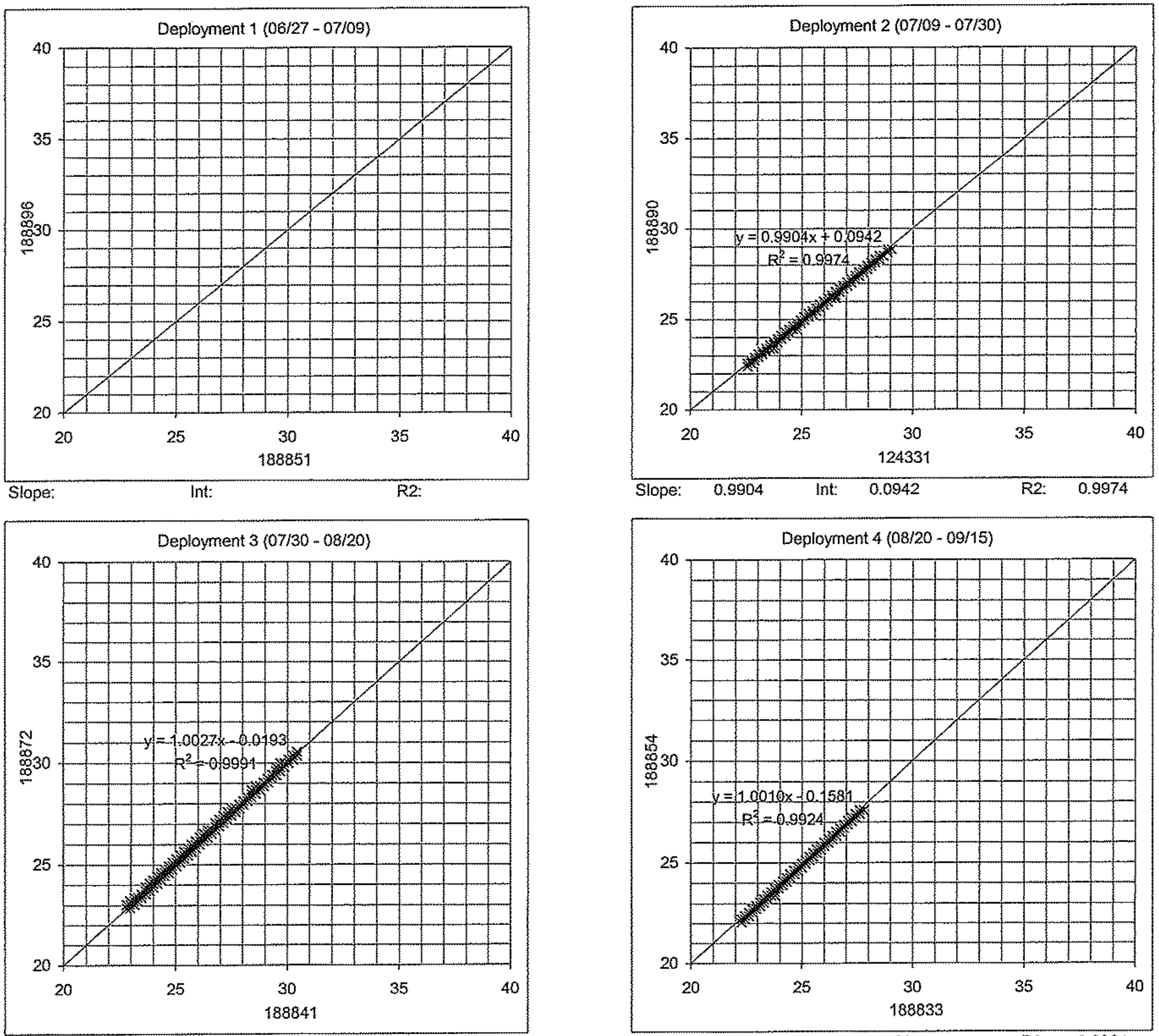
Duplicate sensor comparison, Station 17

FIGURE C - 17



Slope: Int: R2:

Slope: 0.9904 Int: 0.0942 R2: 0.9974

Slope: 1.0027 Int: -0.0193 R2: 0.9991

Slope: 1.0010 Int: -0.1581 R2: 0.9924

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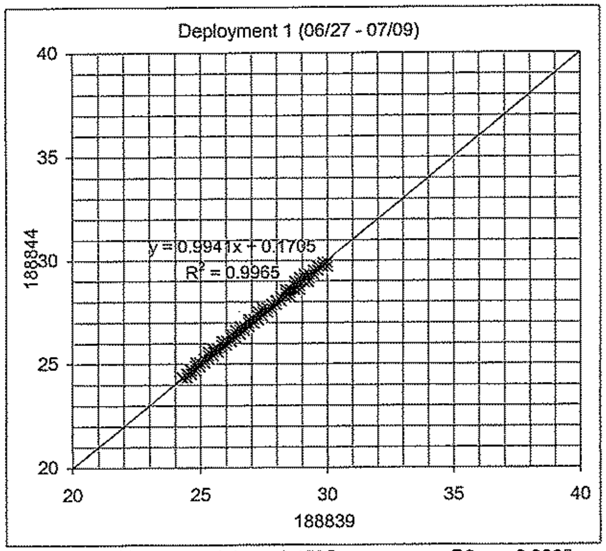
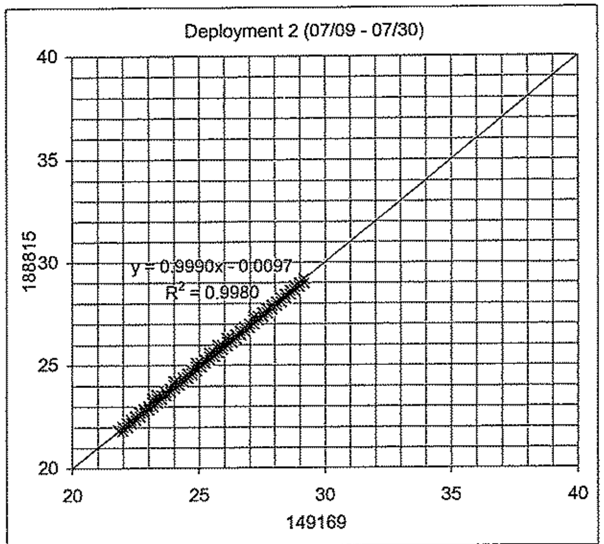
Duplicate sensor comparison, Station 18

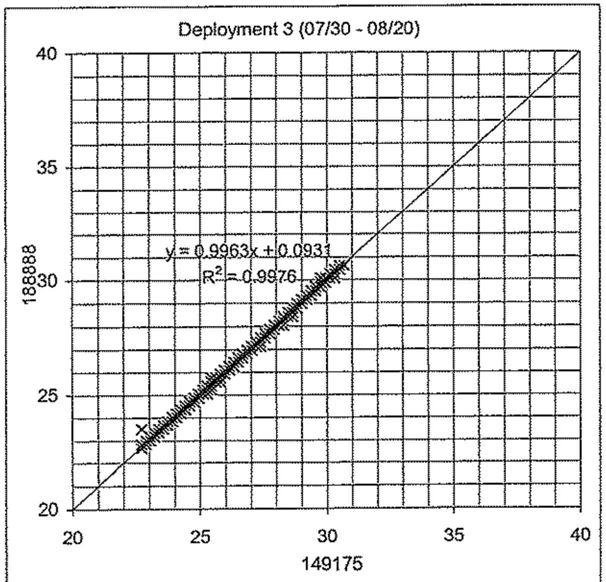
FIGURE C - 18



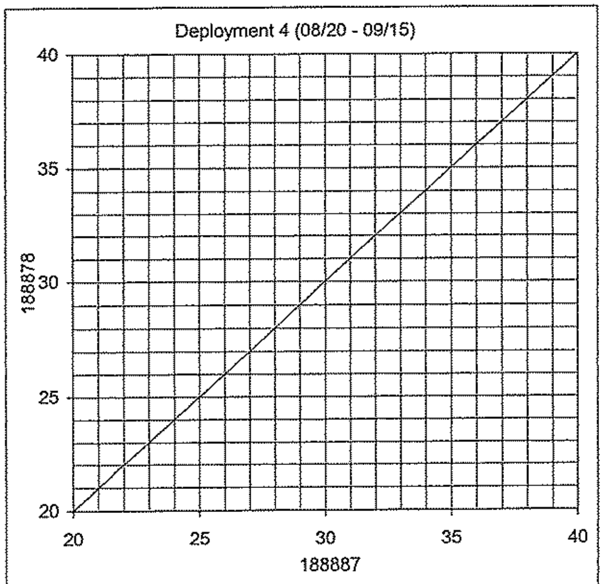
Slope: 0.9941 Int: 0.1705 R2: 0.9965



Slope: 0.9990 Int: -0.0097 R2: 0.9980



Slope: 0.9963 Int: 0.0931 R2: 0.9976



Slope: Int: R2:

JN 0925-002

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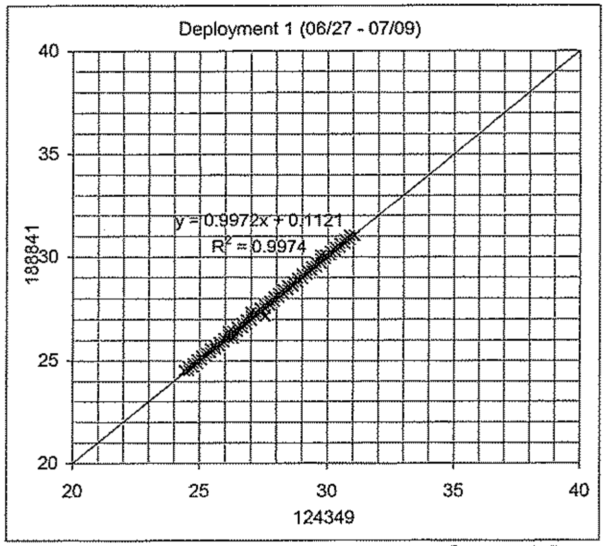
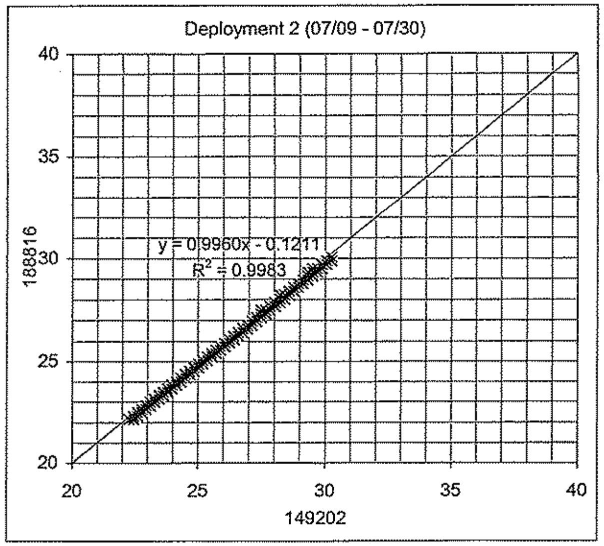
Duplicate sensor comparison, Station 19

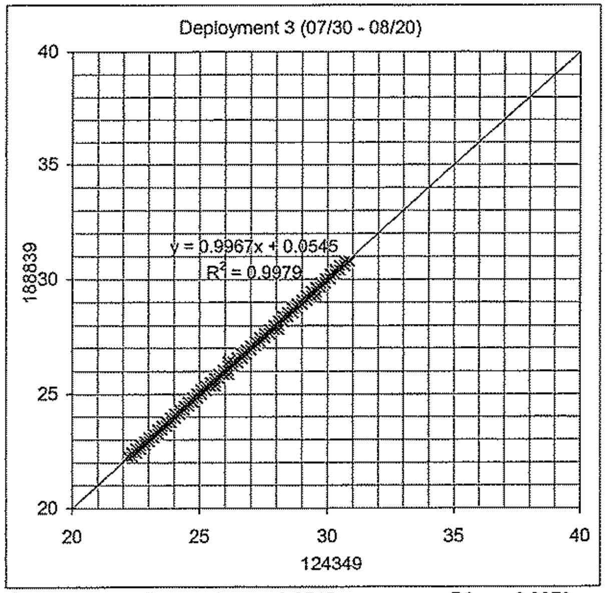
FIGURE C - 19



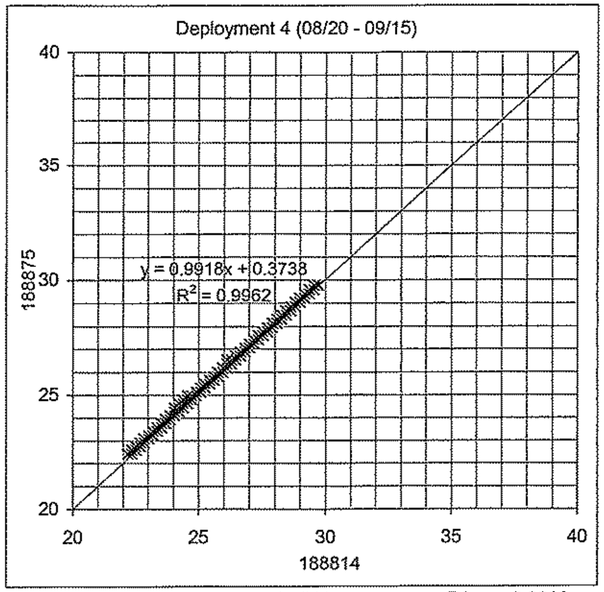
Slope: 0.9972 Int: 0.1121 R2: 0.9974



Slope: 0.9960 Int: -0.1211 R2: 0.9983



Slope: 0.9967 Int: 0.0545 R2: 0.9979



Slope: 0.9918 Int: 0.3738 R2: 0.9962

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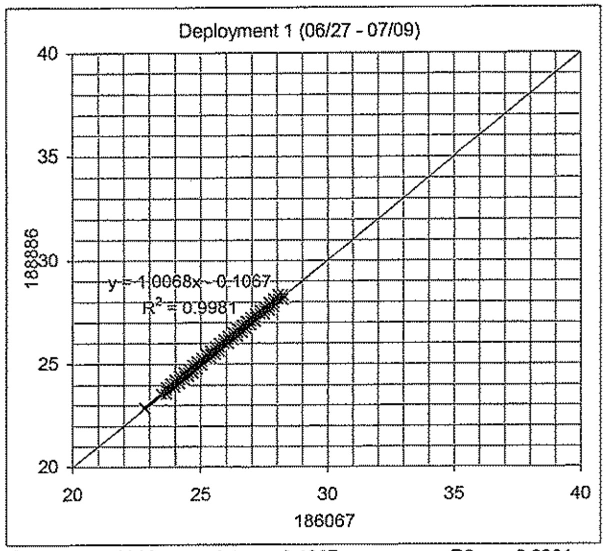
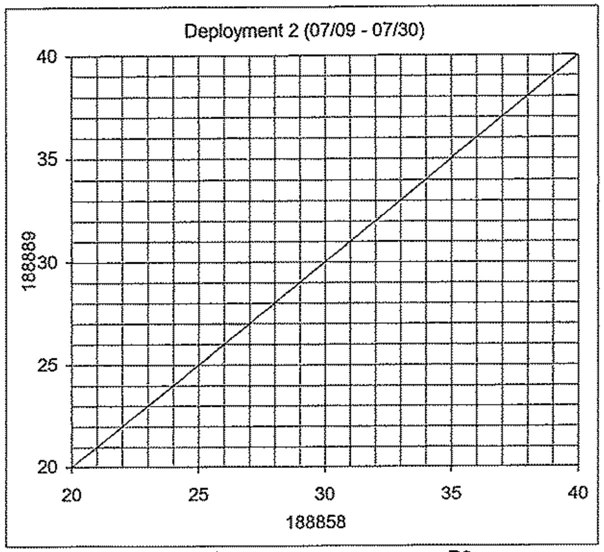
Duplicate sensor comparison, Station 20

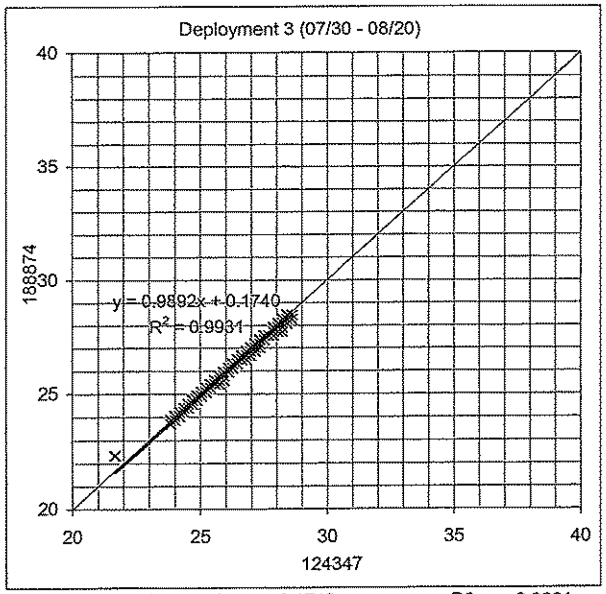
FIGURE C - 20



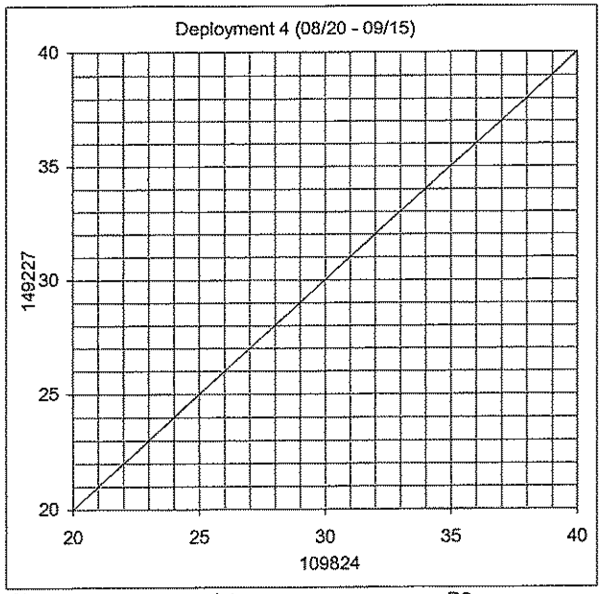
Slope: 1.0068 Int: -0.1067 R2: 0.9981



Slope: Int: R2:



Slope: 0.9892 Int: 0.1740 R2: 0.9931



Slope: Int: R2:

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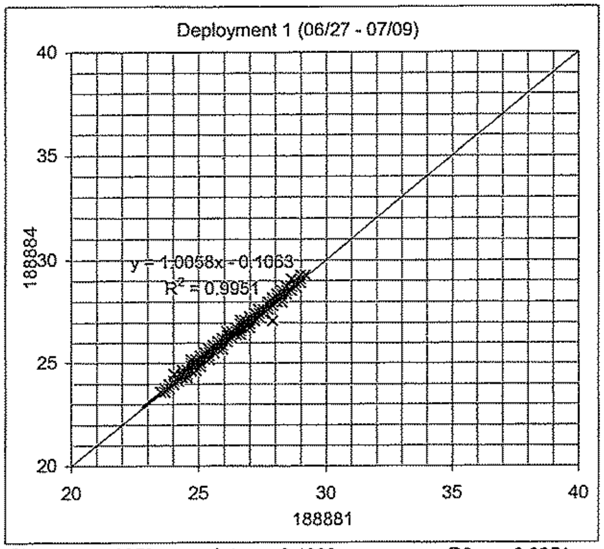
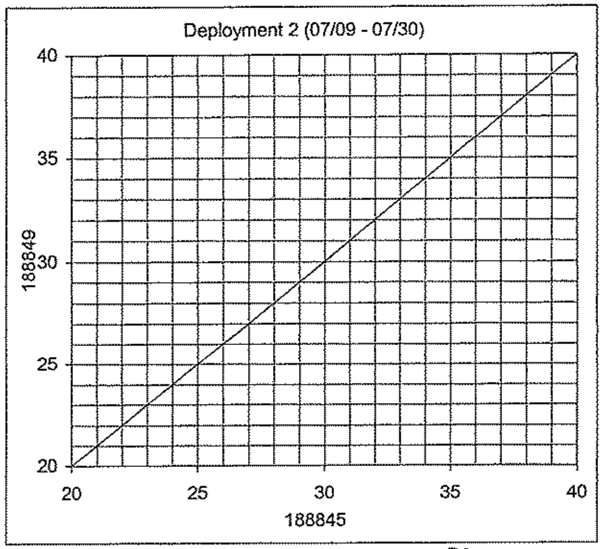
Duplicate sensor comparison, Station 21 (bottom).

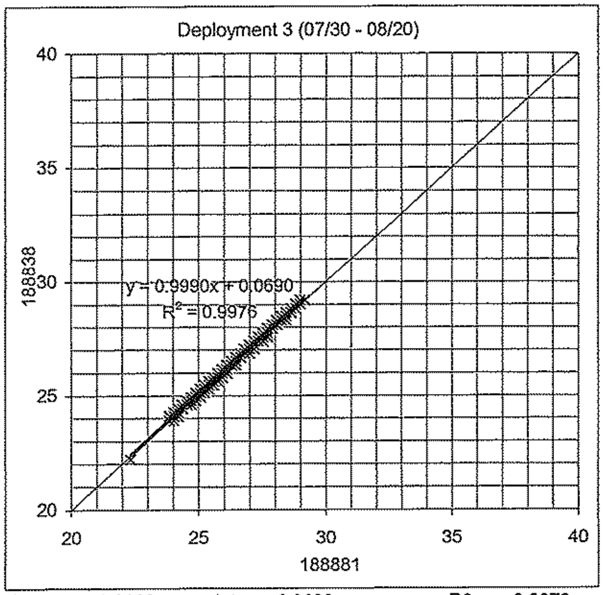
FIGURE C - 21



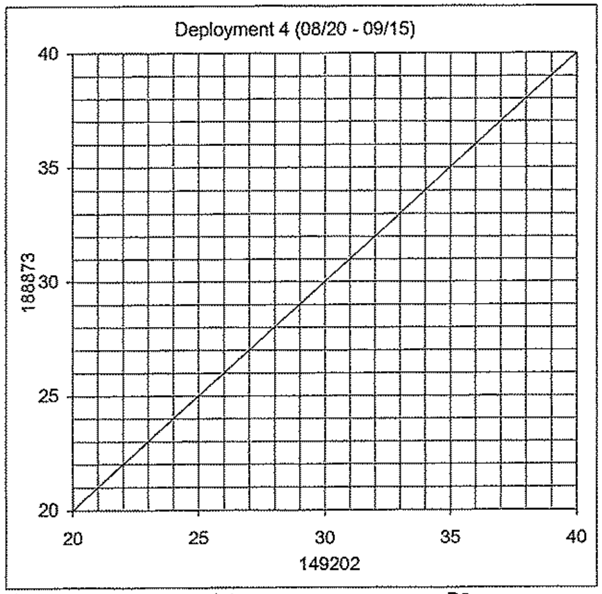
Slope: 1.0058 Int: -0.1063 R2: 0.9951



Slope: Int: R2:



Slope: 0.9990 Int: 0.0690 R2: 0.9976



Slope: Int: R2:

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FirstEnergy Corp, Toledo Edison Bay Shore Station

Duplicate sensor comparison, Station 21 (surface).

FIGURE C - 22

APPENDIX D

FIELD SURVEY PROGRAM DATA

The Field Survey Program data may be found on the CD-ROM accompanying the Report.

APPENDIX E

CORMIX MODELING RESULTS

The CORMIX modeling results may be found on the CD-ROM accompanying the Report.

APPENDIX F

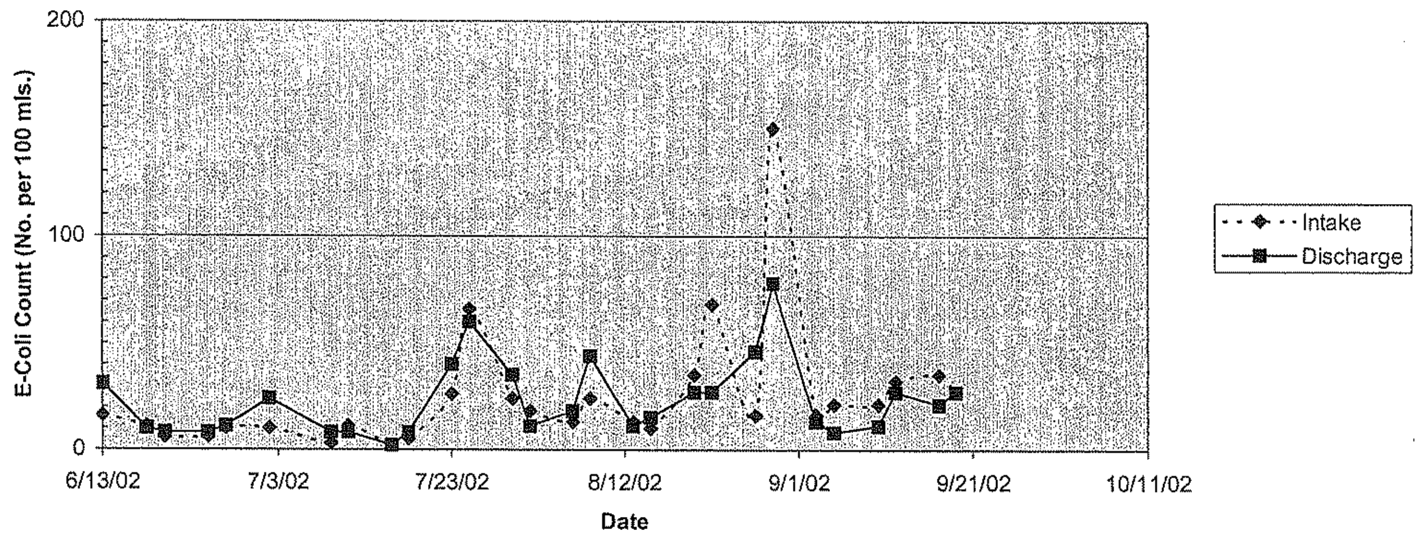
BACTERIOLOGICAL STUDY RESULTS

Sampling, data tabulation, and graphics provided by Bay Shore Station.
Laboratory analyses performed by Jones & Henry Laboratories, Inc., Northwood, OH

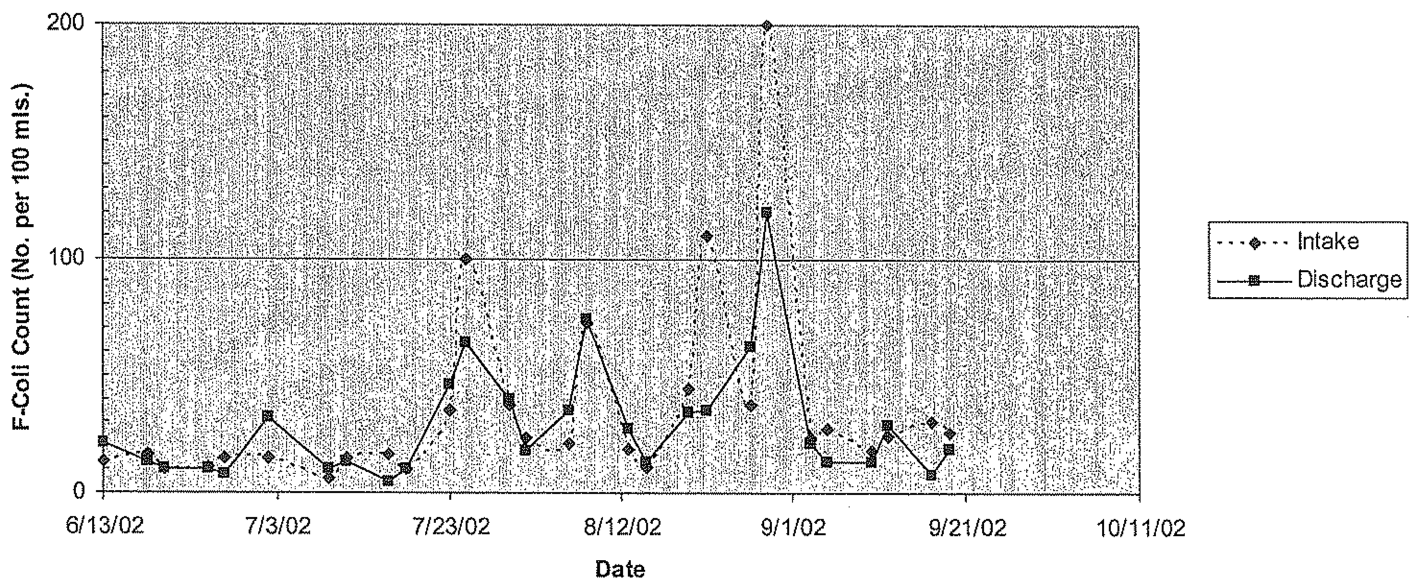
City of Oregon Maumee Bay Water Quality Monitoring Project
Bay Shore Plant Intake and Discharge

Date	Time	Sample Point	Jones&H E-coli Intake	Jones&H E-coli Discharge	Jones&H F-coli Intake	Jones&H F-coli Discharge	Weather Conditions	Wind Direction	Sample Depth (ft)	Other Comments
6/13/02	0906	Intake	16		13		Cool, cloudy	NNW 10-15	6	
6/13/02	0911	Discharge		31		21			3	
6/18/02	0933	Intake	11		16		Mostly Sunny	ENE 15-20	6	
6/18/02	0937	Discharge		10		13			3	
6/20/02	0904	Intake	6		10		Sunny		4	
6/20/02	0909	Discharge		8		10			4	
6/25/02	0900	Intake	6		11		Sunny	None	2	
6/25/02	0907	Discharge		8		10			2	
6/27/02	0930	Intake	10		15		Cloudy	SW 5-10	5	
6/27/02	0936	Discharge		11		8			5	
7/2/02	0954	Intake	10		15		Hazy	NW 5-10	3	
7/2/02	1000	Discharge		24		32			3	
7/9/02	0952	Intake	3		6		Cloudy	Calm	6	
7/9/02	0959	Discharge		8		10			3	
7/11/02	0930	Intake	11		15		Partly Sunny	N 5	5	
7/11/02	0937	Discharge		8		13			5	
7/16/02	0856	Intake	2		16		Sunny	Calm	3	
7/16/02	0910	Discharge		2		5				
7/18/02	1000	Intake	5		10		Sunny	Calm	4	
7/18/02	1010	Discharge		8		10			4	
7/23/02	1040	Intake	26		35		Sunny	NE 5-10	4	
7/23/02	1045	Discharge		40		46			4	
7/25/02	0845	Intake	66		100		Sunny	N 15-20	6	
7/25/02	0855	Discharge		60		64			3	
7/30/02	0900	Intake	24		37		Sunny	SW 5	5	
7/30/02	0910	Discharge		35		40			5	
8/1/02	0900	Intake	18		23		Sunny	Calm	5	
8/1/02	0910	Discharge		11		18			5	
8/6/02	0953	Intake	13		21		Cloudy	N 5	3	
8/6/02	0958	Discharge		18		35			3	
8/8/02	0945	Intake	24		72		Sunny	N 5	4	
8/8/02	0951	Discharge		44		74			4	
8/13/02	1000	Intake	13		19		Hazy	SSW 5	4	
8/13/02	1005	Discharge		11		27			4	
8/15/02	1000	Intake	10		11		Partly Cloudy	NNW 5-10	6	
8/15/02	1009	Discharge		15		13			3	
8/20/02	1025	Intake	35		44		Sunny	NE 15	6	Cleaning Intake Screens
8/20/02	1029	Discharge		27		34			3	
8/22/02	1015	Intake	68		110		Overcast	SSW 20-25	6	
8/22/02	1019	Discharge		27		35			3	
8/27/02	0933	Intake	16		37		Sunny	N	5	
8/27/02	0943	Discharge		46		62			5	
8/29/02	1010	Intake	150		200		Cloudy	NE 5	5	
8/29/02	1015	Discharge		78		120			5	
9/3/02	1015	Intake	16		23		Partly Sunny	SSW 5	5	
9/3/02	1020	Discharge		13		21			5	
9/5/02	0931	Intake	21		27		Cloudy	SW 5-10	4	
9/5/02	0935	Discharge		8		13			4	
9/10/02	0918	Intake	21		18		Sunny	Calm	4	
9/10/02	0925	Discharge		11		13			4	
9/12/02	0920	Intake	32		24		Partly Sunny	N 5	5	
9/12/02	0930	Discharge		27		29			5	
9/17/02	0918	Intake	35		30		Cloudy	N	5	
9/17/02	0925	Discharge		21		8			5	
9/19/02	0945	Intake	27		26		Partly Sunny	SW 5-10	5	
9/19/02	0950	Discharge		27		19			5	

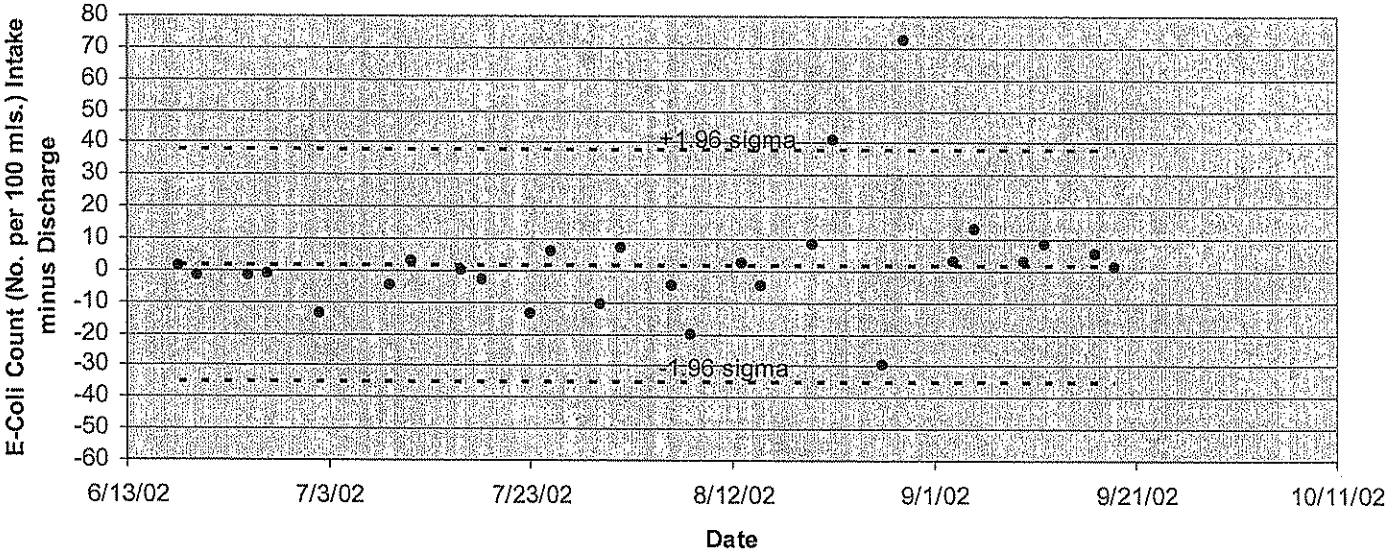
Bay Shore Plant E-Coli Study



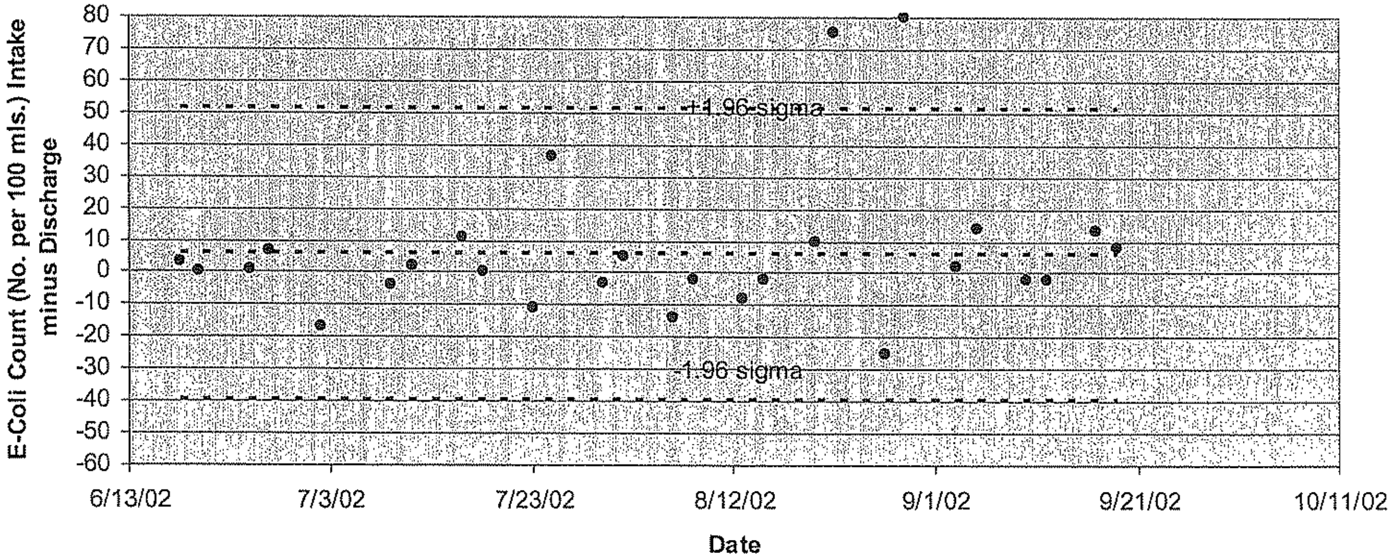
Bay Shore Plant F-Coli Study



Bay Shore Plant E-Coli Study
Statistical Data (Intake Minus Discharge)



Bay Shore Plant F-Coli Study
Statistical Data (Intake Minus Discharge)



APPENDIX G

DISSOLVED OXYGEN MEASUREMENTS

APPENDIX G - DISSOLVED OXYGEN MEASUREMENTS

In addition to the investigations detailed in the Plan of Study (Appendix A), OEPA requested that FirstEnergy measure dissolved oxygen (DO) concentrations in the region of the Mobile Surveys, when the work schedule permitted. OEPA agreed to provide a DO meter for these measurements. LMS measured DO during the five scheduled Mobile Surveys in accordance with OEPA's request. However, the instrument provided by OEPA malfunctioned during the 09 July 2002 Mobile Survey, and subsequent DO measurements were made using a YSI Model 58 DO meter provided by LMS.

DO measurements were taken near the surface at all sampling locations. In addition, DO measurements were made at multiple depths during the 30 July 2002 survey because the LMS DO meter also served as the backup vertical temperature profiling instrument and was used during 30 July 2002 survey following the CTD malfunction.

Table G-1. Dissolved Oxygen Measurements, 12 June 2002

Time	Depth (S,M,B)	DO (mg/L)	Temperature (Deg C)
10:13	S	6.6	
10:26	S	7.3	
10:37	S	6.8	
10:50	S	7.6	
11:18	S	7.7	
11:26	S	6.9	
11:36	S	7.5	
11:54	S	7.8	
12:31	S	7.5	
12:53	S	9.0	
16:10	S	9.9	

Note: Measurements performed using the DO meter provided by OEPA.

Table G-2. Dissolved Oxygen Measurements, 09 July 2002

Time	Depth (S,M,B)	DO (mg/L)	Temperature (Deg C)
10:28	S	6.0	
11:16	S	7.0	

Note: Measurements performed using the DO meter provided by OEPA.

Table G-3. Dissolved Oxygen Measurements, 30 July 2002

Time	Depth (S,M,B)	DO (mg/L)	Temperature (Deg C)
11:24	S	6.6	31.4
11:26	M	6.2	31.3
11:28	B (6ft)	6.2	31.3
11:37	S	6.5	29.0
11:38	M	6.6	28.8
11:40	B (5ft)	6.6	26.5
12:05	S	6.6	29.4
12:06	M	7.3	28.3
12:08	B (5ft)	7.4	27.4
12:21	S	6.0	31.4
12:22	M	6.1	60.6
12:24	B (4ft)	6.6	26.7
12:53	S	6.3	30.4
12:55	M	7.4	25.7
12:58	B (6ft)	7.3	25.4
13:29	S	6.2	30.0
13:31	M	7.3	26.8
13:34	B (6ft)	7.5	25.9
14:04	S	7.9	26.8
14:08	M	7.8	25.8
14:11	B (7ft)	8.0	25.4
15:30	S	7.7	28.7
15:32	M	7.4	28.6
15:34	B (6ft)	8.2	27.9

Note: Measurements performed using the DO meter provided by LMS.

Table G-4. Dissolved Oxygen Measurements, 20 August 2002

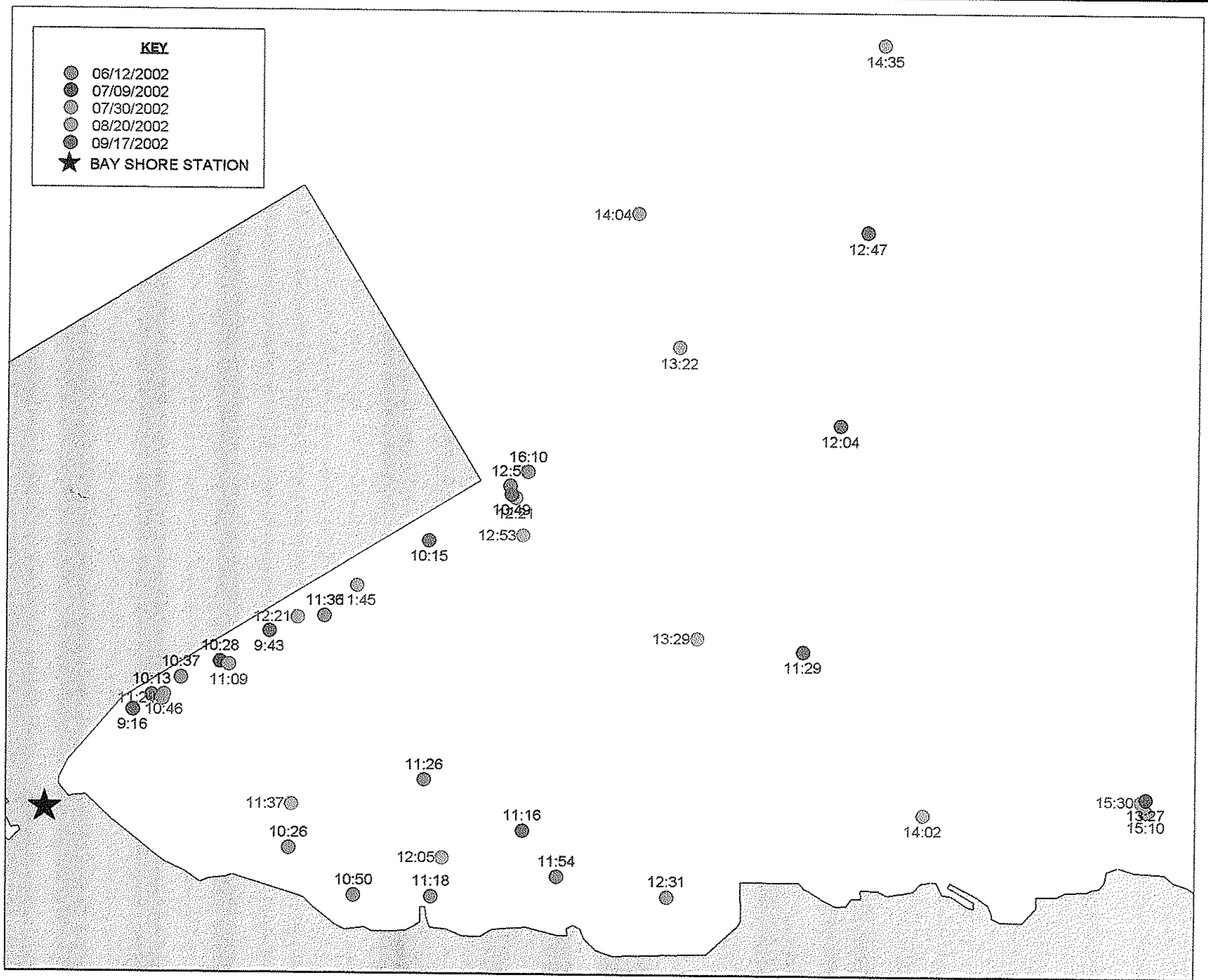
Time	Depth (S,M,B)	DO (mg/L)	Temperature (Deg C)
10:46	S	6.9	27.5
11:09	S	6.7	27.6
11:45	S	6.5	27.6
12:21	S	6.7	26.7
13:22	S	7.8	25.1
14:02	S	8.8	24.5
14:35	S	9.8	24.4
15:10	S	9.5	24.7

Note: Measurements performed using the DO meter provided by LMS.

Table G-5. Dissolved Oxygen Measurements, 17 September 2002

Time	Depth (S,M,B)	DO (mg/L)	Temperature (Deg C)
9:16	S	6.1	27.2
9:43	S	6.7	26.7
10:15	S	5.4	25.0
10:49	S	6.1	24.8
11:29	S	6.3	25.0
12:04	S	5.4	24.4
12:47	S	6.4	24.1
13:27	S	6.8	22.8

Note: Measurements performed using the DO meter provided by LMS.



JN 0925-002

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Scale: 1 inch = 1500 feet

FirstEnergy Corp, Toledo Edison Bay Shore Station

Dissolved Oxygen Sampling Locations - Summer 2002

FIGURE G - 1