Quality Assurance Results UMRR-EMP LTRMP Fish Component: Mapping of the Electrical Fields on the New Fleet of Electrofishing Rigs

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Preface

U.S. Army Corps of Engineers' Upper Mississippi River Restoration – Environmental Management Program (UMRR–EMP) Long Term Resource Monitoring Program (LTRMP) element is implemented by the United States Geological Survey Upper Midwest Environment Sciences Center (UMESC), in cooperation with the five Upper Mississippi River System (UMRS) states of Illinois, Iowa, Minnesota, Missouri, and Wisconsin. The US Army Corps of Engineers (Corps) provides guidance and has overall program responsibility.

Executive Summary

This letter details the results of a quality assurance audit performed to evaluate the effective fishing fields of the UMRR–EMP LTRMP (LTRMP) Fish Component electrofishing fleet. In a highly standardized field sampling program like the LTRMP, it is necessary to ensure, through quality assurance audits, that field equipment is performing as originally designed and specified. Now that the LTRMP has entirely replaced its aging electrofishing fleet, we report the results of a quality assurance audit on the new electrofishing rigs. Our evaluation sought to achieve two key objectives: (1) complete a continuity test on all major components of the electrical circuitry of each electrofishing rig in the LTRMP fleet; and (2) map the electrical field, *in situ*, with the rig operating under LTRMP standard procedures (Gutreuter et al. 1995). Our over–arching goal is to demonstrate that the replacement fleet exhibits sampling specifications analogous to the original fleet, developed in 1989.

Results from the quality assurance audit demonstrate all LTRMP electrofishing rigs were operable and in good repair. While nominal and minor resistance was observed in a few rigs, the continuity of the circuitry of each rig in the fleet was found to be acceptable or exemplary. Instances of observed, yet nominal, resistance in the circuitry were rectified to zero resistance on each rig prior to field testing and mapping of the aqueous electrical field. Finally, the electrical field of each LTRMP electrofishing rig was found to be within operational specifications for sampling under LTRMP Fish Component protocols.

Introduction

Quality assurance on the LTRMP electrofishing fleet was formerly conducted annually between 1989 and 1997. The purpose of these audits was to ensure that the entire LTRMP electrofishing fleet maintained standardized methods and standardized fishing power (measured in watts, or the area of the effective fishing field) over time and among LTRMP field stations. The original electrofishing rig fleet was designed, procured, and built by LTRMP fisheries biologists, and thus, the entire fleet was initially identical in every possible way.

Audits were discontinued on an annual basis after 1997. The reason they were abandoned is (a) in 1991, the fisheries component standardized their effort on a power goal, described in the Fish Component Procedures Manual (Gutreuter et al. 1995); (b) once a power goal was established and fishing arrays were identically set across the entire electrofishing rig fleet, electrical fields were found not to vary among rigs or over time between 1991 and 1997. Consequently, such audits were only recommended when major system components were replaced or when rigs were replaced (Gutreuter et al. 1995).

Beginning in 2005, 16 years after program inception, LTRMP began to replace an aging fleet. This replacement was achieved piecemeal as budgets would permit. By May 2012, the entire fleet was replaced.

As the fleet was replaced, each state partner had both new administrative and procurement demands (e.g., purchasing limitations, state safety regulations), as well as changing needs given changing field conditions (e.g., leaping silver carp) and data collection methods (e.g., onboard computer data entry requirements) that influenced some design features of each rig as it was procured. It proved impossible to maintain a strictly identical fleet of rigs.

Thus, direction was given within the fish component to maintain strict standardization in critical electrofishing rig characteristics that may affect its fishing properties, while also allowing minor variances in non–critical rig components. Critical components include: (1) the control box; (2) boom dimensions; (3) boom arrangements; and (4) the electrical array (dropper) dimensions and arrangements. These critical components and their configurations and arrangement on an LTRMP electrofishing rig can be found in Gutrueter et al. (1995). Thus, as we have progressed on replacing the fleet over time, we have aimed to maintain strict standards in the key components of the rigs, permitting modifications of non–critical aspects of the rig to improve safety and operating efficiency. It's important to note that these small changes were assessed to be inconsequential to the fishing power of the rig by all component staff.

The most crucial change in the new fleet was upon the hulls themselves. Some of the rigs in the new fleet now have slightly larger hulls (length and/or beam) to accommodate safety and sea–worthiness concerns. Correspondingly, the new fleet varies slightly in its hull dimensions (Table 1). On an electrofishing rig, the hull serves as the cathode in the circuit. Based on electromechanical theoretical principles, it would take substantial physical changes in the hull to appreciably influence the fishing electrical field (Reynolds 1983). The changes in the hull dimensions were permitted to accommodate safety, workflow, and efficiency in each replacement rig and are minor by any measure (Table 1). Still, it is prudent and necessary, in a standardized sampling program, to empirically confirm theoretical predictions that may affect sampling characteristics of these rigs. Thus, our goal with this audit is to empirically confirm these theoretical predictions, thus demonstrating a considered and responsible transition from the old LTRMP electrofishing fleet to the new replacement fleet.

Between May 30, 2012 and June 11, 2012, the entire LTRMP electrofishing fleet was assessed. Two key assessments were made: (1) a continuity test was made on each and every rig to ensure no–to–low resistance at every critical electrical junction in the rig’s circuitry; and (2) the electrical field emanating from each rig was mapped, *in situ*, while fishing under LTRMP procedures (uniform base power of 3000 watts; see Gutreuter et al. 1995; Burkhardt and Gutreuter 1995).

Methods

Continuity tests

Continuity tests were conducted at each major electrical junction on each LTRMP electrofishing rig. Tests were performed using a standard two–lead electrical multimeter, set to read resistance (Ohms). Electrical resistance was measured between each major electrical junction in the circuit: (1) dropper wires to boom input; (2) boom input to output on the electrical control box (Wisconsin box); (3) input on the electrical control box (Wisconsin box) to output on the electrical control box (Wisconsin box); and

(4) generator to input on the electrical control box (Wisconsin box). Readings were taken in the order presented above.

Ideally, resistance should be zero at each junction. Readings above zero indicate resistance in the circuitry which may result in a diminished electrical field in the water under standardized sampling situations. Resistance readings less than 1 Ohm have no measurable effect on the emanating aqueous electrical field, but should still be rectified if found because readings with resistance indicate potential compromises to the circuitry (Burke O'Neal, personal communication). Resistance readings above 1 Ohm require due attention as this may impair and affect the effective aqueous fishing field and fishing power of the electrofishing rig. Field crews should measure the continuity of the entire circuitry of the electrofishing rig at the beginning of the sampling year, and at the beginning of each sampling period within an annual effort. Within a sampling period, crews should evaluate continuity within the circuitry any time a problem is suspected, evidenced by unusual fish behavior within the active electrical field.

Sources of resistance in the circuitry may include (a) loose connections; (b) worn connections; (c) corroded connections; (d) compromised wiring within the circuit; (e) bad components in the control box or generator; and (f) improper grounding of the circuitry (all rigs should possess a "floated" ground). Testing each major leg of the circuit permits operators to focus in on which part of the circuit possesses observed resistance so that repairs and maintenance may be achieved.

Prior to mapping the *in situ* electrical fields on each rig, continuity tests were performed on each rig in their storage garages (bench tested) and any observed resistance above 1 Ohm was rectified before mapping proceeded. Prior to mapping the electrical field for each rig, resistance was rectified to zero Ohms at each junction in the rig's circuitry to ensure a common basis for the tests among rigs.

Electrical field mapping

Each rig was launched at a nearby landing to map the aqueous electrical field emanating from the rig while operating under LTRMP standard protocols. Each rig took position in an area of low to no flow, possessing a minimum depth of 3 meters for the mapping exercise. Prior to mapping the field, each operator was instructed to ready the rig for sampling according to LTRMP standard protocols. Foremost, these protocols require standardizing effort on a uniform base power of 3000 watts. This is achieved by making *in situ* temperature and conductivity readings of the water and adjusting electrical power output settings to achieve a uniform base power of 3000 watts. These methods are detailed in Gutreuter et al. (1995).

While electroshocking under LTRMP standardized protocols, the electrical field emanating from the rig was mapped using an oscilloscope and probe from the bow deck of the rig. The probe was constructed from a surplus electrofishing boom measuring 5.2 meters in length fitted with a 0.6 meter articulating arm at one end. Two metal multimeter probe pins were attached to the end of the articulating arm and spaced exactly 1 cm apart at the tip of the articulating arm. The pins were electrically wired, internally, through the entire constructed probe and fitted with a plug that matched the input on the oscilloscope (Tektronix Model 222 digital storage oscilloscope). The probe was graduated in 0.3 meter increments so that measurements of voltage in the water relative to the hull of the rig could be made.

Six measurements were made on each side of the rig (port and starboard), resulting in twelve total observations per rig. On each side of the rig, we made the following measurements. First, a measurement of voltage was made at the dropper, where it should be highest and between 1–2 volts. The next four readings were then taken at the distance from the bow or gunwale of the rig where voltage read 0.1 volts, representing the furthest edge of the effective fishing field. These four readings were taken (1) directly fore of the dropper, measured relative to the fore bow; (2) perpendicular to the bow, measured relative to the [port/starboard side] bow; (3) perpendicular to the gunwale midship, measured relative to the gunwale; and (4) perpendicular to the gunwale stern, measured relative to the gunwale. The final measurement measured the vertical depth to which the 0.1 volts field emanated, and was measured immediately adjacent to the fore bow, and directly aft of the dropper array. All measurements were noted and mapped on graduated graph paper. Distances recorded for each standard measure were compared across the fleet (Table 2).

Results

Continuity tests

Several instances of nominal resistance (< 2 Ohms) were discovered and rectified prior to testing. Most instances were associated with the dropper array due to either corrosion in the dropper wires or weak/loose connections with the stainless steel ring. Recommendations for routine maintenance (wire brushing or replacing connections; tightening connections) were verbally expressed to field crews.

Finally, recommendations for field operators to perform regular continuity tests were made: continuity tests should be made at the beginning of each LTRMP Fish sampling period or when a problem is suspected in the fishing capacity of the rig.

Prior to mapping the electrical fields, *in situ*, minor maintenance was applied and resistance was resolved at each circuit junction to zero Ohms on each rig. This provided a common basis for electrical field measurements throughout the fleet of electrofishing rigs.

Environmental conditions

For a given voltage and amperage, fishing power on an electrofishing rig will vary as a function of water temperature and water conductivity Reynolds (1983). Therefore, LTRMP standardizes its electrofishing effort on a power goal of 3000 watts by adjusting amperage and voltage to achieve a uniform and standard fishing power across the fleet (1200 river miles) and throughout a sampling year (June 15 – Oct 31) [see Gutreuter et al. 1995].

During our electrical field mapping efforts, water temperature varied from 19.3^{o}C in Lake City, Minnesota on 4 June 2012 to 26.7^{o}C in Havana, Illinois on 11 June 2012 (Appendix A). Conductivity also varied notably among field stations during this assessment, ranging from 325μS/cm in Lake City on 4 June 2012 to 816 μS/cm in Havana on 11 June 2012. Correspondingly, power goals ranged from 3353 watts in Lake City to 5400 watts in Havana.

Electrical field mapping

Voltage at each dropper array on each LTRMP electrofishing rig was found to range between 1–2 volts, which is fully within operating specifications (Gutreuter et al. 1995). LTRMP electrofishing protocols try to achieve a uniform fishing power under varying river conditions (temperature and water conductivity), resulting in an attempt to standardize the overall dimensions and surface area of the effective fishing field (defined as the area encapsulating a voltage gradient of 1 – 2 V/cm at the dropper array to 0.1 V/cm at a 2 – 3 m fore bow distance away from dropper array). Thus, mapping efforts sought to define the distance of the 0.1 V/cm contour about the electrofishing rig. LTRMP protocols state a general aim of a 2 – 3 m effective fishing field halo about the dropper arrays and boat hull, fore to mid–ship, which represents the effective area able to be dipnetted by sampling crews.

All measurements to the 0.1 V/cm isopleth were found to be within operating specs and general guidance provided Gutreuter et al. (1995) [see Table 2]. The rigs operated by Bellevue, Iowa, Lake City, Minnesota, Jackson, Missouri, and Alton, Illinois were remarkably similar in the area and shape of their effective fishing fields (Appendix A). Slight variations were found in the La Crosse, Wisconsin and Havana, Illinois rigs (Appendix A; Table 2); however and importantly, both rigs remain within general and acceptable specifications.

Discussion

During the quality assurance audit of the LTRMP electrofishing fleet, all electrofishing rigs were found to be operable and good condition. Nominal and minimal resistance (< 2 Ohms) was observed in just a few rigs, mostly associated with the stainless steel dropper wires and their attachment points on the stainless steel ring on the dropper array, which is to be expected since these are the portions of the circuitry coming into regular contact with rocks, logs, vegetation, and water. Additionally, measurements were made after an extended period of storage, during which corrosion can establish. Measurements were gained in late–May and early–June after the rigs has set all winter in their storage, and before field crews would normally achieve their continuity tests and apply maintenance prior to the new sampling season, which began June 15, 2012. Field crews were encouraged to regularly inspect these connections for loose connections, wear, and corrosion; test continuity on the full circuitry of the rig per sampling period or when problems is suspected; and apply maintenance regimens when necessary.

The electrical field of each and every LTRMP electrofishing rig was found to be within operational specifications for sampling under LTRMP Fish Component protocols, which attempt to create a 2–3 m “halo” of voltage gradient around the dropper array assembly (anode) and boat (cathode). This halo coincides with the effective distance field operators require to dip net stunned fish (Gutreuter et al. (1995). The effective voltage gradient for the capture of fish ranges from 0.1 to 1–2 V/cm (Reynolds 1983). Such a gradient is generally sufficient to produce a voltage drop of 2 to 20 V over the length of a 20 cm fish, enough to capture but not harm the fish.

While all rigs were found to have effective fishing fields within general operating specifications, two rigs did demonstrate some minor deviations from the wider fleet, which may provide instructive lessons (Appendix A). Again, we stress that these are non–critical deviations. Rigs that deviated slightly from the wider fleet include the La Crosse and Havana rigs. Reasons why La Crosse and Havana varied slightly from the rest of the fleet in the shape of their effective fishing fields may include the following:

La Crosse was the first rig tested and the test was conducted with an anchor deployed, a situation not replicated on the rest of the fleet. The metal anchor may have had the effect of warping the effective field by changing conductivity within the testing zone. Future tests should ensure there are no metal objects proximate to the testing site.

The La Crosse rig is brand new and may have an idiosyncrasy of which operators are not fully aware yet, or deviations may have been due to the La Crosse rig being the first tested and due to the need to refine the mapping method (e.g., based on the La Crosse effort, all subsequent efforts were mapped without an anchor deployed). It is recommended that the electrical field be mapped on the La Crosse rig again, preferably at the end of the season, once any such idiosyncrasies have had an opportunity to be identified and fully remedied. Regardless, the deviations on the La Crosse rig's field, whether due to the mapping method or the rig itself, were non–critical and within general guidance and specifications outlined in Gutreuter et al. (1995).

The Havana rig, given high water temperatures and water conductivity (the highest observed in this audit), had to test under a high voltage output setting on the Wisconsin control box, which is an unusual situation for the entire fleet [LTRMP Fish component field leads DeLain, Bartels, Bowler, Ratcliff, Ridings, Solomon, personal communications]. Havana uses a Honda generator for its power source and the Honda model they use possesses "inverter technology" (not all Honda generators possess inverter technology). Recently, Burke O'Neal of ETS Electrofishing (ETS), the designer of our standard [Wisconsin] control box, submitted the following observation during a consult and bench test of one of our newest electrofishing rigs which also possess a Honda inverter technology generator:

"Both ETS boxes and the boat wiring were tested under load by attaching resistor banks to both the starboard and aft booms. There was voltage instability on both boxes particularly in the HIGH voltage range position due to the generator's being "inverter technology". Although they are quiet, the Honda inverter generators are known to be somewhat incompatible with electrofishing pulser boxes because the boxes present a variable pulsing capacitive load to the generator and the inverter has difficulty compensating for this type of load. Fortunately where these boxes will be used, LOW voltage range can almost always be used which is considerably more stable than HIGH voltage range. Operators must be made aware of this characteristic."

Thus, when fishing on the “high power” setting (necessary when environmental conditions dictate), and when using an inverter technology generator, field operators should expect unstable capacitive loads to be delivered to the water. We suspect this is what happened on the Havana rig during our tests. One could audibly hear the generator surging, trying to balance the load at high power settings. Several times during our field mapping exercise, internal control box breakers were set off, requiring a re–start of the test.

The Honda type inverter technology generators have been favored on the newer rigs in the fleet because they are significantly quieter (and perhaps cleaner) than other generators. Not all new generators possess, however, inverter technology (e.g., La Crosse rig). Generally and usually, these new generators are beneficial to our field operations (operator safety, health). However, field operators need to be aware that at high voltage control box settings (infrequent in our operations, but sometimes dictated by field conditions and the need to achieve a standardized power goal), may be affecting their effective fishing field, though results from the Havana trial suggest these are comparatively minor and within general operating specs (2–2.5 m halo standard). Burke O’Neal (ETS Electrofishing) also reported that the Wisconsin (ETS) control boxes can be fitted with a new and additional resistor to deal with this issue.

This quality assurance audit demonstrates the new UMRR–EMP LTRMP electrofishing fleet possesses electrical qualities fully analogous to the initial fleet of rigs manufactured at program inception (1989–1990). Minor, non–critical deviations in the physical dimensions of the hulls and operating decks of the new rigs, permitted to improve safety and operation in dynamic and changing field conditions, are demonstrated here to be inconsequential to the electromechanical characteristics of the emanating electrical field each new rig generates. While non–critical elements of the rigs now vary to address local safety and operating concerns, critical electrical components remain entirely standardized across the fleet. Maintaining strict standardization in these aspects of the rigs is essential to ensure data deriving from the program are comparable through time (decades) and over space (1200 river km). These critical elements include: the control box (Wisconsin box); boom dimensions, composition, and spacing; dropper array composition and configuration; and dropper lead composition and configuration (see Gutreuteret al, 1995).

Field operators should remain aware of discovered issues during these audits. These include (1) unbalanced capacitive loads associated with inverter–enabled generator technology when operating at “high” voltage control box settings, dictated by high conductivity and high water temperature field situations; and (b) the need to periodically and routinely assess resistance in the rig’s electrofishing circuitry. The former may be remedied by procuring and using generators that do not possess inverter technology or by modifying existing control boxes with an additional resistor designed to mitigate such capacitive loads when inverter–type generators are used (Burke O’Neal, ETS Electrofishing personal communication). The latter can be assessed and remedied by routinely checking electrical resistance of major electrofishing circuitry junctions using a standard multimeter as part of a regular and responsible maintenance regime.

Table 1. Critical hull dimensions and manufacturers of the new UMRR–EMP LTRMP fish component electrofishing fleet.

Field station	Length (ft)	Beam (in)	Manufacturer
Lake City, Minnesota	19	96	Kann
La Crosse, Wisconsin	19	96	Kann
Bellevue, Iowa	21	84	Kann
East Alton, Illinois	20	97	Oquakwa
Jackson, Missouri	18	102	Kann
Havana, Illinois	20	93	Hamm

Table 2. Measurements (in meters) from the anode (dropper array) and/or cathode (boat hull) to the edge of the effective fishing field (0.1 V/cm) for each electrofishing rig in the UMRR–EMP LTRMP fish component fleet. Schematics of these measurements can be found in Appendix A.

Measurement	**Lake City**	**La Crosse**	**Bellevue**	**East Alton**	**Jackson**	**Havana**
Port fore	2.5	2.5	2.0	2.3	2.5	2.5
Port bow	3.5	3.0	3.5	3.5	3.5	3.3
Port midship	2.5	2.5	2.5	2.5	2.5	2.3
Port stern	0.3	0.3	0.3	0.3	0.3	0.3
Starboard fore	2.5	2.5	2.0	2.3	2.5	2.5
Starboard bow	3.5	3.0	3.5	3.5	3.5	2.6
Starboard midship	2.5	2.5	2.5	2.5	2.5	2.3
Starboard stern	0.3	0.3	0.3	0.3	0.3	0.3

References

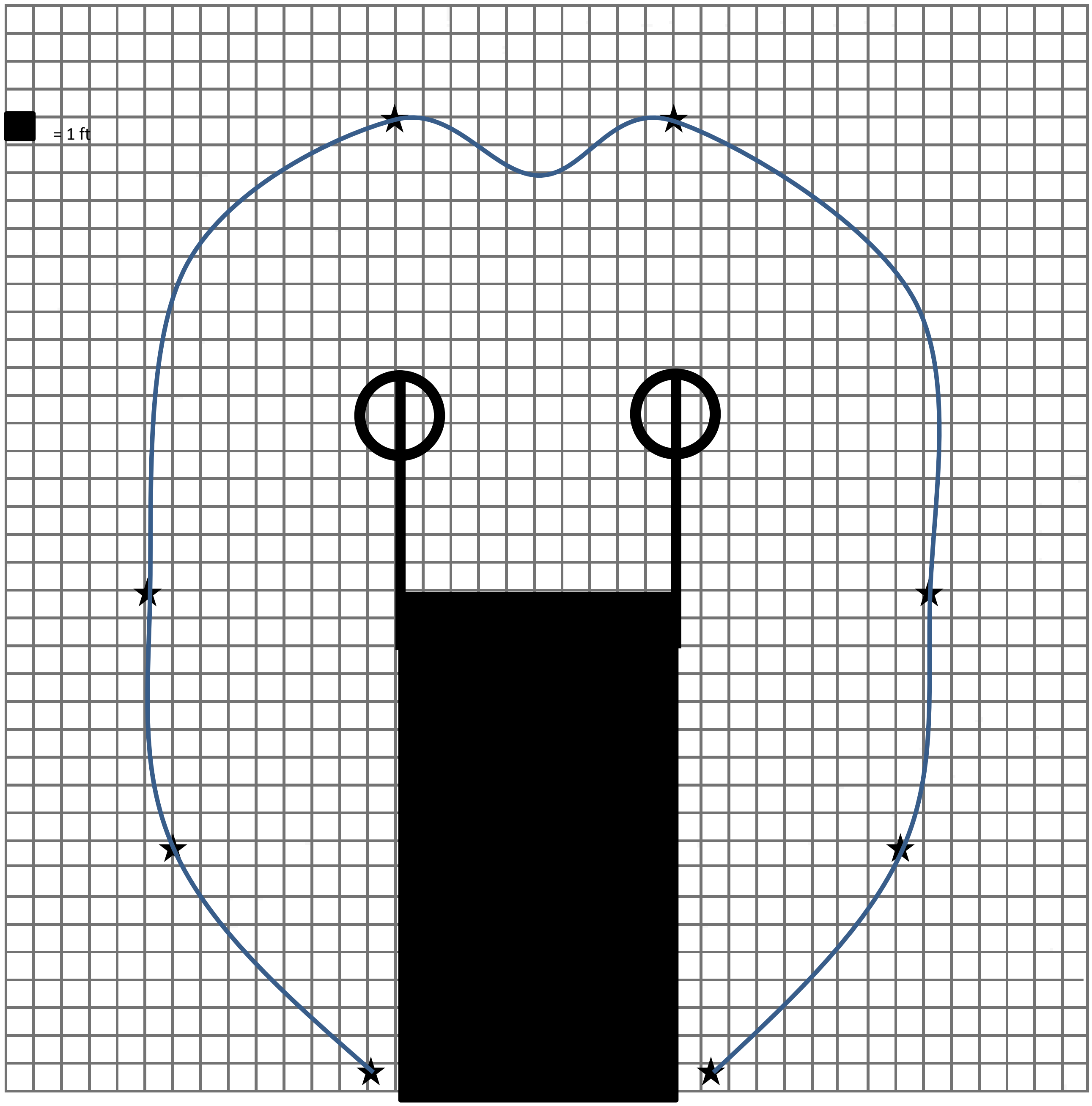
Burkhardt, R. W., and S. Gutreuter. 1995. Improving electrofishing catch consistency by standardizing power. North American Journal of Fisheries Management 15:375–381.

Gutreuter, S., R. Burkhardt, and K. Lubinski. 1995. Long Term Resource Monitoring Program procedures: Fish monitoring. National Biological Service, Environmental Management Technical Center, Onalaska, Wisconsin, July 1995. LTRMPP 95–P002–1. 42 pp. + Appendixes A–J.

Reynolds, J.B. 1983. Electrofishing. Pages 147–163 *in* L. A. Nielsen and D. L. Johnson, editors. Fisheries Techniques. American Fisheries Society, Bethesda, Maryland.

Appendices

Appendix A: Field data and maps of the effective electrofishing fields observed on UMRR–EMP LTRMP fish component electrofishing rigs as part of a quality assurance audit of the new fleet of rigs. Stars denote field measurement locations and the position of the 0.1 V/cm field boundaries. The line connecting the stars outlines the 0.1 V/cm contour. The area within the connected line represents the empirically observed effective fishing field of the electrofishing rig. The black rectangle denotes a generalized electrofishing rig hull (cathode in the circuit). The two black lines and circles attached to the rig represent the electrofishing booms (lines) and arrays (circles), which represent the anode in the circuit. The field is mapped on graduated graph paper to scale, with each graduated unit representing 1 foot, using an oscilloscope and probe as described in the Methods section.



Field station: La Crosse, WI (Pool 8)

Date: 30 May 2012

Boat operator: Andy Bartels, Wisconsin DNR

Time: 10:00 am

Conductivity: 430

Boat specs: Length: 19 ft Beam: 96 in

Water Temperature: 20.5 ^{o} C

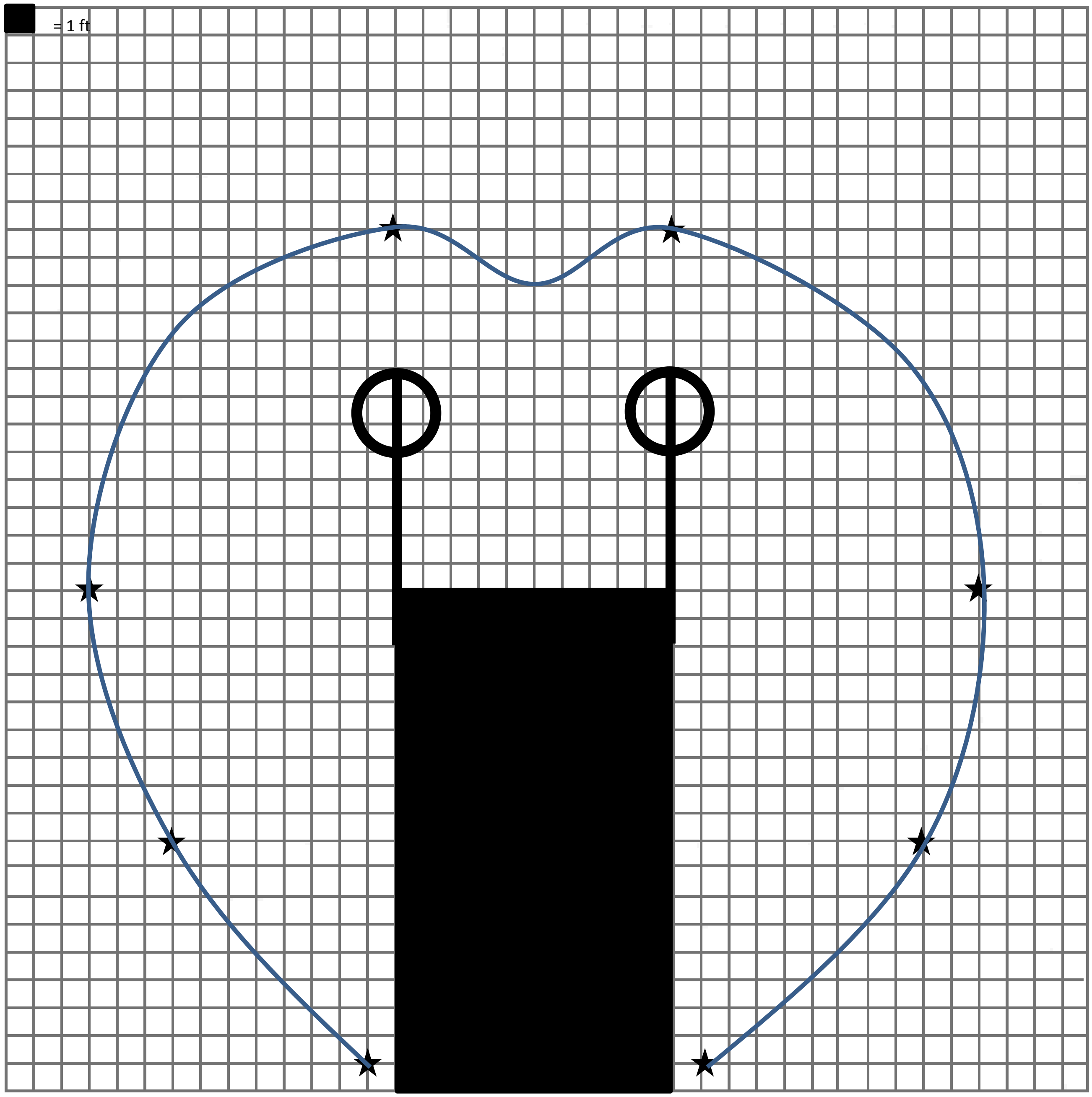
Continuity test OK?: Full pass

E–field mapper: Randy Burkhardt (contract)

Power goal: 3753 watts

Supporting crew: Brian S. Ickes (LTRMP Fish PI)

Notes: Depth of field 10 ft



Field station: Bellevue, Iowa (Pool 13)

Date: 1 June 2012

Boat operator: Mel Bowler, Iowa DNR

Time: 9:30 am

Conductivity: 394

Boat specs: Length: 21 ft Beam: 84 in

Water Temperature: 19.3 ^{o} C

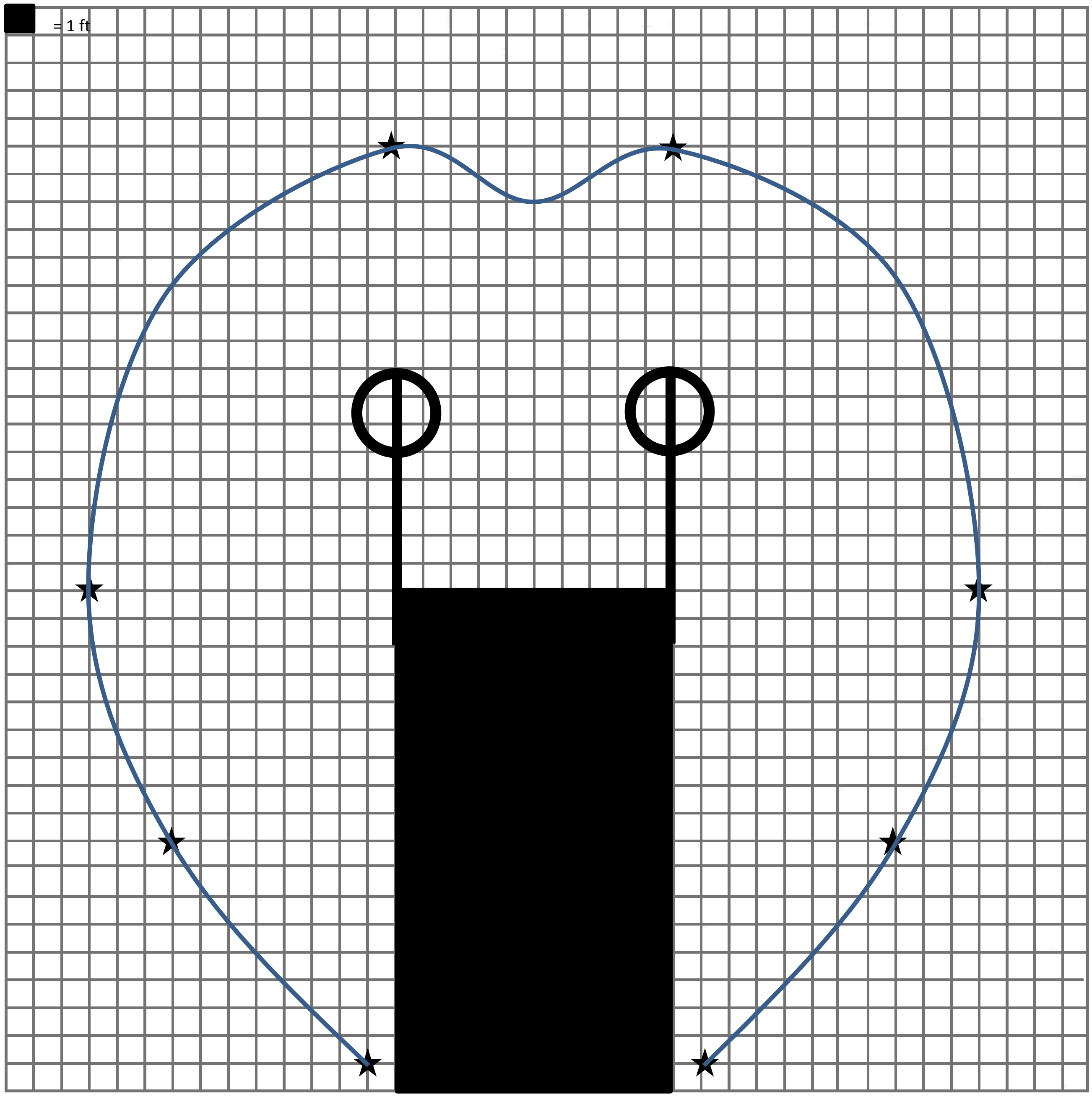
Continuity test OK?: Full pass

E–field mapper: Randy Burkhardt (contract)

Power goal: 3942 watts (est), 3740 (run)

Supporting crew: Brian S. Ickes (LTRMP Fish PI)

Notes: Depth of field 10 ft



Field station: Lake City, Minnesota (Pool 4)

Boat operator: Steve DeLain, MN DNR

Conductivity: 325

Water Temperature: 21.0 ° C

E–field mapper: Randy Burkhardt (contract)

Supporting crew: Brian S. Ickes (LTRMP Fish PI)

Date: 4 June 2012

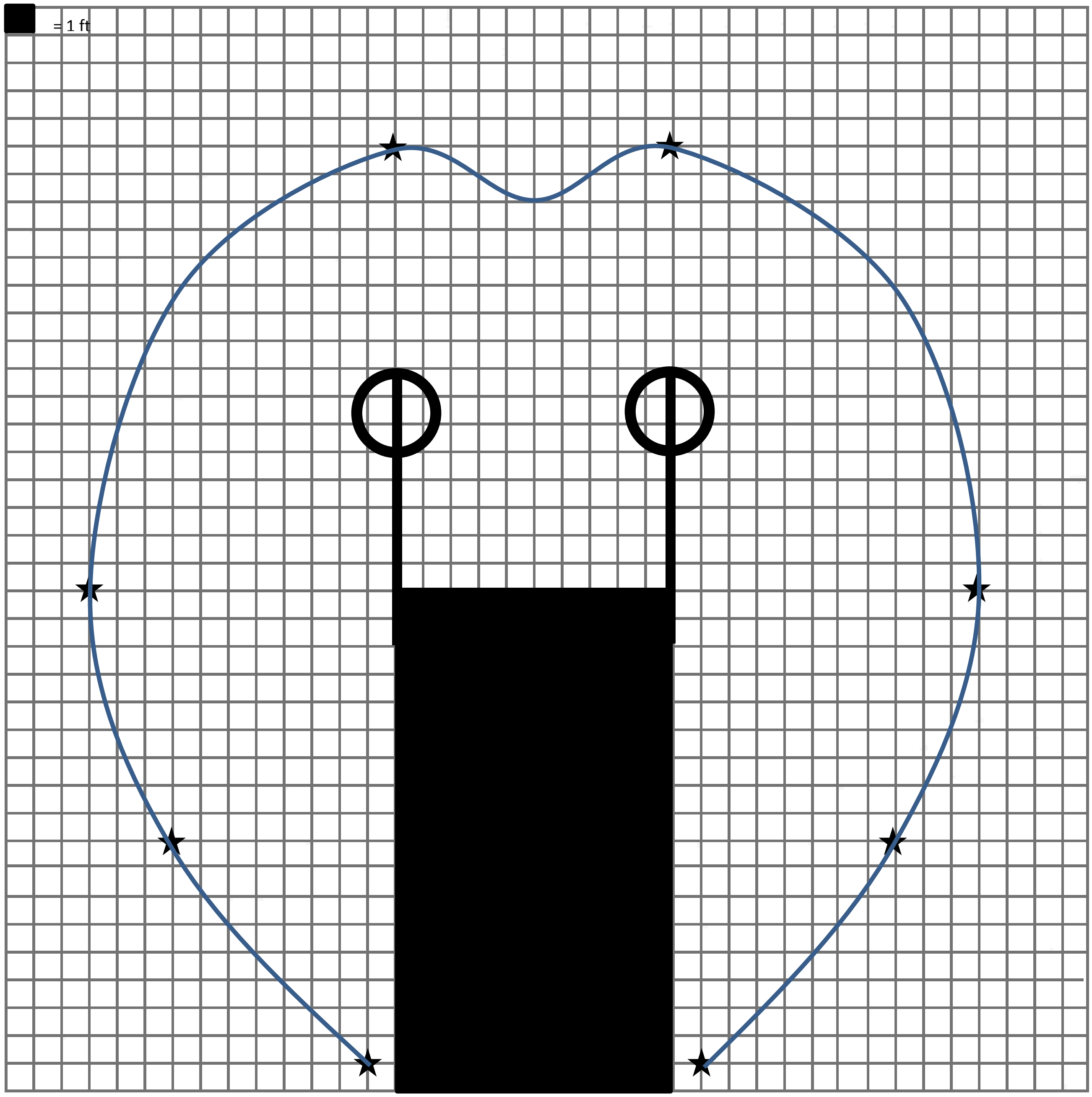
Time: 10:20 am

Boat specs: Length: 19 ft Beam: 96 in

Continuity test OK?: Full pass

Power goal: 3353 watts

Notes: Depth 12 ft



Field station: Jackson, Missouri (Open River)

Boat operator: Joe Ridings, MO DOC

Conductivity: 561

Water Temperature: 24.3 ^{o} C

E–field mapper: Randy Burkhardt (contract)

Supporting crew: Brian S. Ickes (LTRMP Fish PI)

Date: 8 June 2012

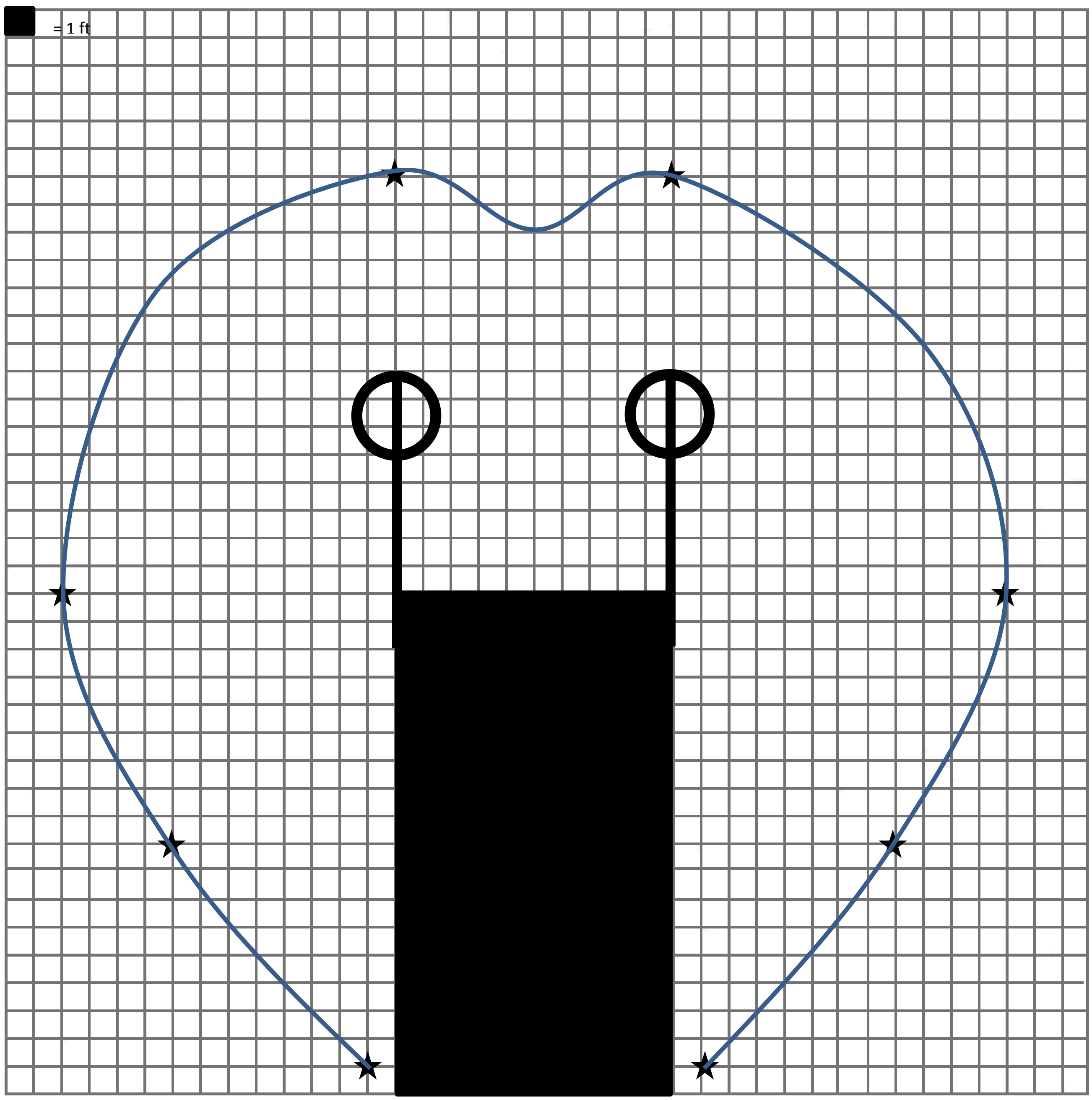
Time: 10:00 am

Boat specs: Length: 18 ft Beam: 102 in

Continuity test OK?: Full pass

Power goal: 4500 watts

Notes: Some corrosion on anodes; depth 12ft



Field station: Alton, Illinois (Pool 26)

Date: 11 June 2012

Boat operator: Eric Ratcliff, INHS

Time: 8:30 am

Conductivity: 500

Boat specs: Length: 20 ft Beam: 97 in

Water Temperature: 24.5 ^{o} C

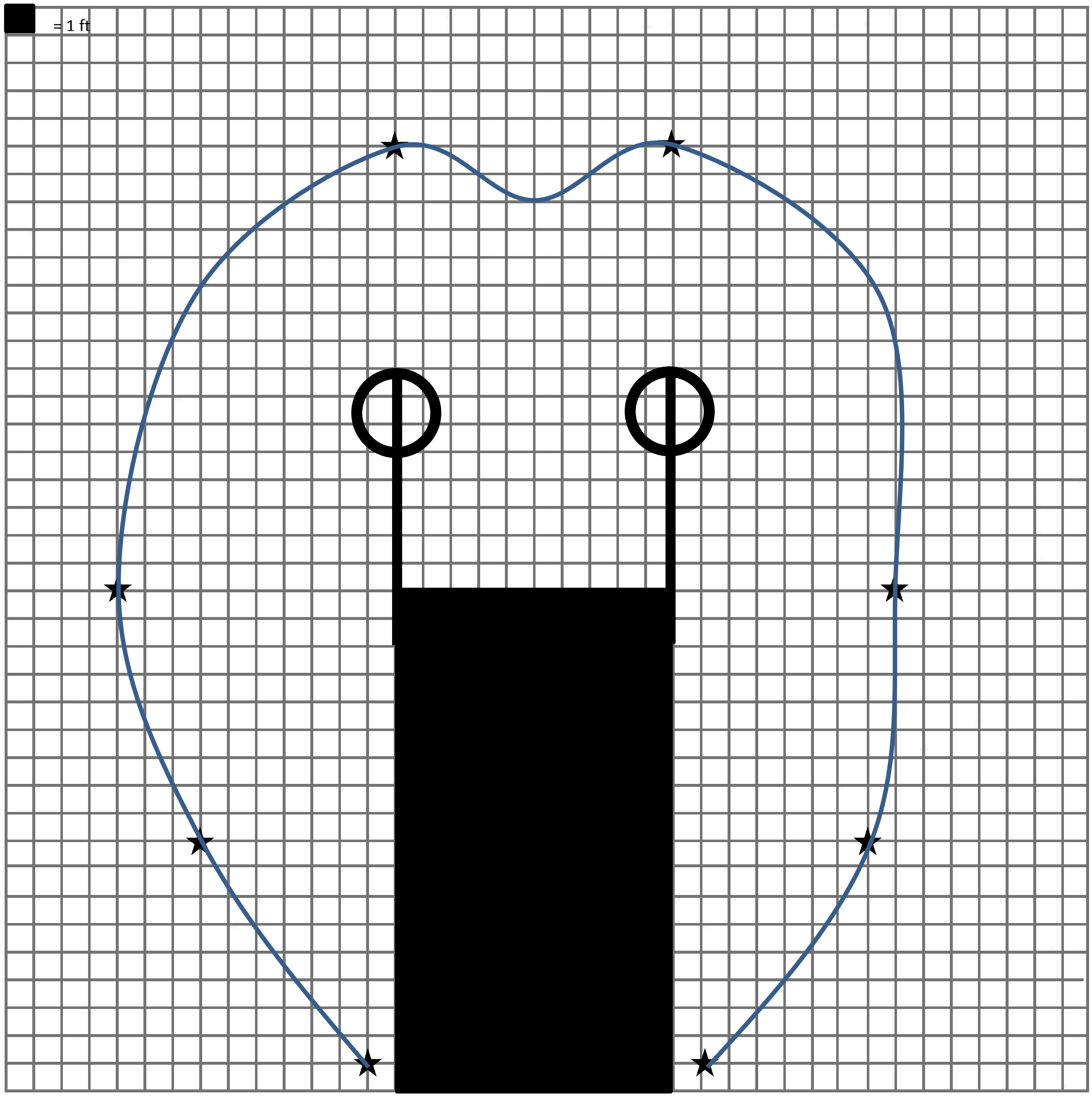
Continuity test OK?: Full pass

E–field mapper: Randy Burkhardt (contract)

Power goal: 4220 watts

Supporting crew: Brian S. Ickes (LTRMP Fish PI)

Notes: Min resist in several droppers; depth 7 ft



Field station: Havana, Illinois (La Grange)

Boat operator: Levi Solomon, INHS

Conductivity: 816

Water Temperature: 26.7 ^{o} C

E–field mapper: Randy Burkhardt (contract)

Supporting crew: B. Ickes; N. Michaels (INHS)

Date: 11 June 2012

Time: 3:00 pm

Boat specs: Length: 20 ft Beam: 93 in

Continuity test OK?: Full pass

Power goal: 5400 watts

Notes: Depth 7.5 ft

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