

Phase-out of Distribution Transformers Suspected to Contain PCBs at Three Utilities in the Minnesota Portion of the Lake Superior Basin

Minnesota Pollution Control Agency
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Photo credit: Scott Bohling, MPCA - a suspect transformer in the Lake Country Power service area

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Executive Summary

Manufacture of polychlorinated biphenyls (PCBs) has been discontinued but use of PCB bearing equipment continues. PCBs are one of nine toxic chemicals targeted by the Lake Superior Zero Discharge Demonstration. This project's objective was to assist owners of small quantities of PCBs to remove contaminated distribution transformers in the Lake Superior watershed.

- Four utilities shared their transformers' serial numbers with the Minnesota Pollution Control Agency. The agency compared their serial numbers to manufacturing serial numbers. 638 transformers (3 to 4% of all transformers in the four utilities) were on the manufacturers' list of transformers that may contain PCBs.
- The MPCA visited each of the suspect transformers in the Lake Country Power and Cooperative Light and Power service areas within the Lake Superior watershed. The coordinates were entered in a GPS unit and the closest body of water was also entered. This allowed the MPCA to prioritize transformers using the distance to water.
- Lake Country Power volunteered to remove all of their 292 suspect transformers, although the contract could cover only a portion of the cost.
- Similarly, Cooperative Light and Power contracted to purchase 145 transformers to replace the suspect transformers manufactured by General Electric (GE) that were closest to Lake Superior. (Suspect GE transformers are highly likely to contain PCBs and are therefore a priority.)
- The City of Grand Marais contracted to replace 14 suspect transformers and test others.
- This project and voluntary actions by participants will result in the replacement of 82% of the suspect transformers owned by the three facilities that participated and 71% of the suspect transformers originally identified at all four utilities. (Arrowhead Electric Power did not participate in the final stage.)

Introduction

Polychlorinated biphenyls (PCBs) were once commonly used as dielectric fluids in electrical equipment. Manufacture of PCBs was discontinued in 1977, two years before a federal ban on manufacturing. The Toxic Substances Control Act (TSCA) allows the continuing use of certain PCB bearing equipment, but the disposal of the oils from this equipment is strictly regulated.

When transformer manufacturers switched from PCB to non-PCB fluids, the new transformers were filled using the same equipment that had been used for PCBs. The result was that some older transformers contained high concentrations of PCBs while newer transformers were contaminated with various levels of PCBs, depending on how long the filling equipment had been flushed with non-PCB fluids.

Because of the highly persistent, bioaccumulative and toxic nature of PCBs, this group of chemicals has been included on a variety of lists of toxic chemicals targeted for source reduction, including the Great Lakes Water Quality Agreement (GLWQA), the Great Lakes Water Quality Initiative (GLI), the Canada Ontario Agreement Respecting the Great Lakes (COA), the Binational Toxics Strategy (BTS) and the Lake Superior Binational Program to Restore and Protect the Lake Superior Basin (LSBP). The LSBP includes a Zero Discharge Demonstration for nine toxic chemicals, including chlordane, DDT, dieldrin, dioxin, hexachlorobenzene, mercury, octachlorostyrene, PCBs and toxaphene.

As a participant in the LSBP, the Minnesota Pollution Control Agency proposed a project to find and remove as many PCB contaminated transformers as possible. The tentative goal was to remove half of the suspect transformers. The project was funded through a combination of sources, including the Great Lakes National Program Office (GLNPO), the Legislative Commission on Minnesota Resources (LCMR) and the Minnesota Pollution Control Agency (MPCA). The project focused on the smaller utilities in the Lake Superior basin since Minnesota Power, the largest utility in the region, already has a PCB phase-out plan.

Project Description

Identifying the Suspect Transformers

Manufacturers have supplied lists of transformer serial numbers which contain PCBs or are likely to contain PCBs. The MPCA obtained this list of “suspect” transformers from Elizabethton Electric System, an electric utility in Tennessee. A hard copy of Elizabethton Electric’s list (i.e., Distribution Transformer Manufacturers and Available Polychlorinated (PCB) Information) is available from the MPCA. They had prepared a list for quick identification of transformers suspected of containing PCBs for their line workers.

They also identified the likelihood that particular manufacturers’ transformers on the lists actually were contaminated. They found the transformers most likely to contain PCBs were made by GE, Westinghouse and Wagner. With further refinements with using information from the manufacturers, Elizabethton Electric was able to narrow down the range of serial numbers and increase “hits” (i.e., PCBs greater >50 ppm) by using specific sections of serial numbers.

The confidence levels for each manufacturer increased dramatically. Based on the further development of the query by Elizabethton Electric, 70% of all GE transformers, 72% of all Wagner transformers, and nearly 100 % of all Westinghouse transformers on the lists are contaminated with >50 ppm PCBs. The MPCA used this specific serial number data to come up with queries for the Minnesota database.

The MPCA also contacted nine facilities that had responded to a voluntary 1997 survey indicating that they owned PCB transformers. Each contact included a certified letter that gave participants a guarantee that the PCBs removed as part of the project would not be subject to Minnesota hazardous waste fees. The agency discovered that some of the facilities had since removed all their PCB transformers (i.e., the City of Virginia and Bend Tech, Inc.). We also found that the City of Biwabik had its own utility, but the City was unable to take advantage of the project because they were in the process of trying to sell the utility.

Ultimately, we worked with four utilities, who shared their transformer inventories with the agency. An MPCA student worker developed a database and compared the inventories to the manufacturers' list of suspects. The first three utilities analyzed included the City of Grand Marais, Arrowhead Electric Cooperative and Cooperative Light and Power. 6,852 transformers were run through database queries to separate non-PCB transformers from those that might contain PCBs. Of the 6,852 transformers evaluated, 346 tripped the queries. This is a rate of 5.0% transformers identified as suspect, although rates at individual utilities ranged from 3.6 to 9.2%. Table 1 summarizes how many transformers were found in each of the three inventories.

Table 1. Number of transformers in each category.

Utility	Highly Likely	Mod. Likely	Test First	Suspects	Total Transformers
Grand Marais	11	0	4	15	162
Arrowhead	18	39	33	90	2,506
Cooperative	179	62	0	241	4,184
Total	207	101	37	346	6,852

To elaborate on the results of this table:

- 207 of the 346 (60%) were classified as *Highly Likely* to contain >50 ppm PCBs. These are General Electric (GE), Wagner, and Westinghouse transformers.
- 101 of the 346 (29%) were classified as *Moderately Likely* to contain >50 ppm PCBs. These transformers are made by various other manufacturers. Elizabethton Electric found these other manufacturers had much less contamination.
- 37 of the 346 (11%) were classified as *Test First*. These transformers are Allis Chalmers. Other possibilities include Duncan, Pittsburgh, Packard, and American Corp., although none of these have been found in the Lake Superior transformer inventory, yet.

Lake Country Power is the fourth utility whose inventory was analyzed. This was the largest utility in the project, with approximately 35,000 distribution transformers. Unlike the other utilities, which are mostly within the Lake Superior basin, about 70% of Lake Country's transformers are outside the Lake Superior basin. This utility had 292 transformers within the

basin that tripped the database query. This works out to a rate of suspect transformers in the basin of roughly 2.8%. Adding these transformers to the ones in Table 1 gives an overall rate of 3.7%. Of the 292 suspect transformers, 63% were classified as *Highly Likely*, 36% were classified as *Moderately Likely* and only 1 transformer was in the *Test First* category.

Pre-Testing versus Not Pre-Testing

Originally it was believed that it would be most effective to test suspect transformers before replacing them since replacement and disposal is expensive. In some cases (e.g., the City of Virginia) this has already been done. A bucket truck is brought to the transformer, power is cut briefly while a lineman cuts a hole through the transformer with a Hilty gun or a special drill, pipettes out a sample and reseals the transformer.

As we progressed in negotiations with the utilities, it became clear that this may not be as effective as first thought. The main concern expressed by the utilities was going to the same transformer twice if it turned out to contain PCBs. The cost of a crew and tying up a bucket truck is also expensive. Inconvenience to the customer also has to be figured in as well as the arrangements a utility makes to prepare customers for a brief loss of power. Plus, the transformers that are on the suspect list are quite old by now and some are due for replacement by more efficient units. Also, some utilities are concerned about using a sampled transformer although others have used them and have not had any problems due to the sampling holes.

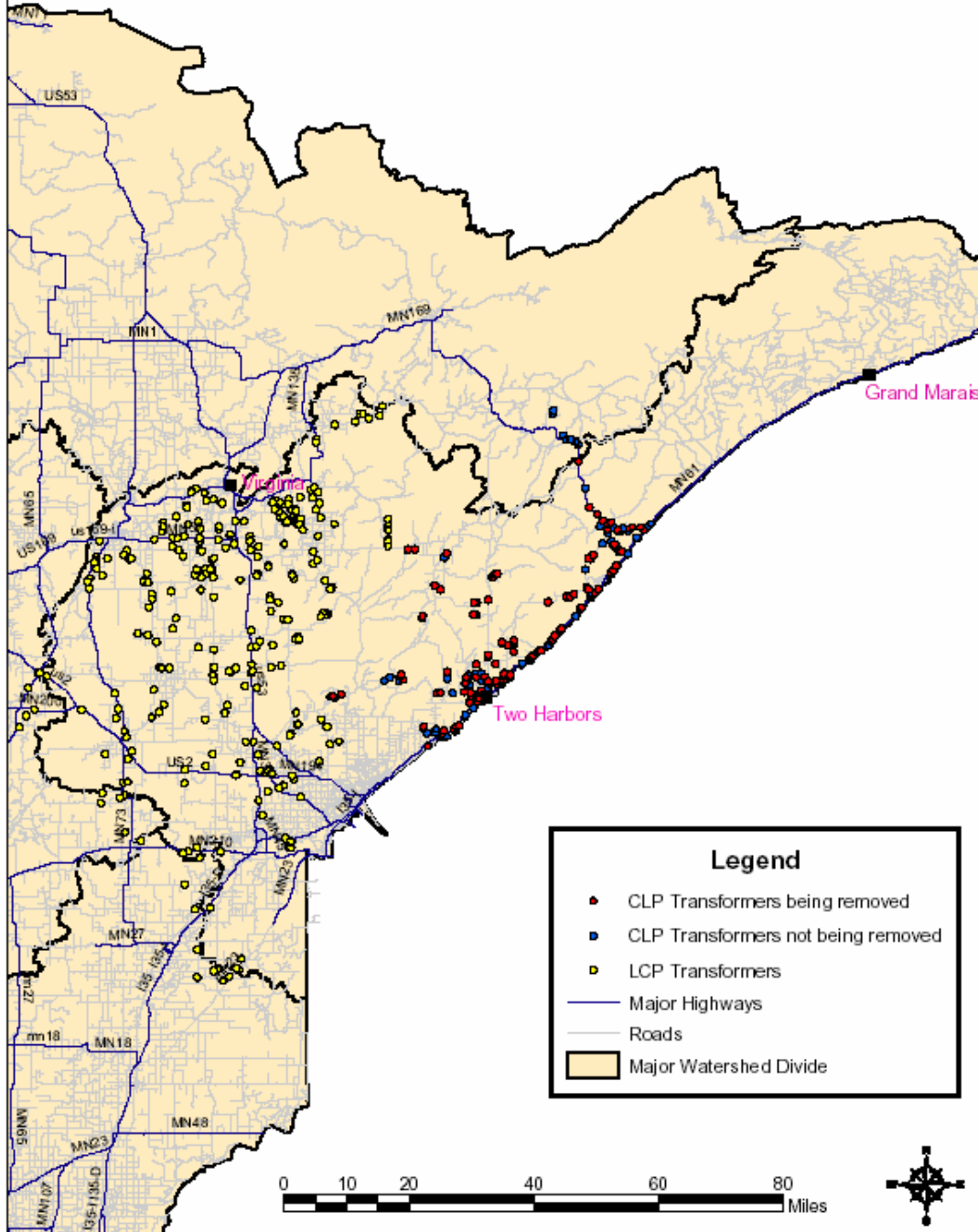
The end result was that neither of the contracts with Lake Country Power or Cooperative Light and Power called for pre-testing transformers. However, the City of Grand Marais wanted to do additional testing. The City had replaced some transformers already as part of a road realignment project. In checking the oil analyzes, the director of Public Works found a transformer that was not on the suspect list that did test positive for PCBs. Under these circumstances and given the small size of the Grand Marais inventory, it seemed reasonable to test more transformers, even those not on the suspect list.

There may be other good reasons to pre-test. For example, the City of Biwabik's records did not include the serial numbers of their transformers, making it impossible to compare to the manufacturers' list. If this utility were to participate in a similar project in the future, the first step needed would be testing all the transformers in this small town (population 954).

Tagging the Transformers

It was clear at the onset of this project that there was insufficient funding to replace all the suspect transformers in the basin. The MPCA student worker tagged the transformers with a Global Positioning System (GPS) unit and also tagged the closest waterbody. Suspect transformers closest to water became the highest priority. Figure 1 shows a map of all the Lake Country Power and Cooperative Light and Power transformers that were tagged for this project. Note that 28 of the tagged Lake Country Power transformers turned out to be outside the Lake Superior basin and 16 of the Cooperative Light and Power basin transformers were outside the basin, which demonstrates the usefulness of GPS tagging for watershed-specific projects such as this. Also, because the transformers are so close together, some points on the map are overlaid.

Figure 1.
Lake Country Power and Cooperative Light and Power Suspect Transformers



Replacing the Transformers

To their great credit, Lake Country Power decided to use the contract money for purchasing the new transformers and they would take on the remaining costs, including taking down the old transformer, hanging the new one, testing the oil and disposing of the old transformer. In this way, they covered all their distribution transformers in the Lake Superior basin (see Appendix A). As of November 2004 they had replaced over half of the transformers.

Also to their credit, Cooperative Light and Power (CLP) made a similar decision but chose to replace 145 GE transformers, which are in the *Highly Likely* category. (CLP has 241 suspect transformers.) As mentioned above, the CLP transformers were tagged with GPS so the 145 GEs closest to water became the highest priority for replacement (see Appendix B). The MPCA provided this list of high priority transformers to CLP. Figure 2 shows one of these high priority transformers near the shore of Lake Superior.

Figure 2. Example of a high priority suspect transformer in the CLP service area.



Photo credit: Michael Taylor, MPCA

Although the contracts with the MPCA only covered the cost of the replacement transformers, the utilities have agreed that they will share the test results with the agency. We anticipate the results will be available sometime in late spring or early summer since the utilities will use the non-construction season to hang the new transformers and get the old ones tested and disposed. The MPCA will prepare an addendum to this report when the results are available.

Note that timing is important with this type of project. The utilities are extremely busy during the construction season and are not able to put much physical effort into a phase-out project, although they can negotiate contracts, order equipment and so on. After the construction season, they can do the work of actually replacing the transformers. This work comes to an end with the spring thaw when weight restrictions are put on the county roads and the bucket trucks can not travel on them.

Grand Marais removed 13 suspect transformers and tested others. While Grand Marais originally had 15 suspects, some transformers were removed as part of highway work before the contract started. Figure 3 shows the Grand Marais crew who worked on the project.

While we are still waiting for the Lake Country Power and Cooperative Light and Power testing results, some data are available from Grand Marais and are summarized in Appendix C. Of the 11 suspect transformers tested in Appendix C, 6 had concentrations >50 ppm PCBs but did not exceed 500 ppm. The other suspects were <50 ppm. Six other transformers also tested out between 50 and 500 ppm but were NOT on the suspect list. Since none of the serial numbers of these last 6 corresponds to the inventory that was originally supplied to the MPCA, this confirms the importance of 1) having a complete inventory and 2) the value of pre-testing in small utilities or ones with incomplete records. Surprisingly, of these 6, one is NOT on GE's list of suspect transformers. GE does note in its materials supplied to Elizabethton Electric that their list is "approximate and subject to many exceptions." Of the 12 that contained >50 ppm PCBs, 9 were made by GE and other 3 were Westinghouse. Half of the >50 ppm transformers were 25 KVA although sizes of the contaminated transformers ranged from 7.5 to 150 KVA.

Figure 3. Grand Marais Public Works Director and linemen.



Photo Credit: Mike Taylor, Grand Marais

Although the MPCA and Arrowhead Electric Cooperative negotiated and the company was cooperative, we were not able to produce a contract in a satisfactory time period due to funding deadlines. This utility would be a good candidate for a future project.

Costs

Costs include several categories. Besides the cost of administering the project, the actual cost of phasing-out transformers includes replacement, disposal, labor and testing. Table 2 shows some typical costs for replacement, disposal and testing at Grand Marais. The cost of labor will vary depending on the utility and the transformer situation. \$21 per hour for labor was acceptable.

Table 2. Costs associated with transformer change-out

Size	Replacement Transformer*	Disposal of Old Transformer	Testing Oil for PCBs
10 KVA	\$267	\$212	\$12
15 KVA	\$320	\$245	\$12
25 KVA	\$423	\$349	\$12
50 KVA	\$620	\$545	\$12

* equipment such as AMP cutouts, lightening arrestors, compression connectors and new wire should be replaced at the same time, adding about \$70 per transformer to the overall cost.

Using this information, a typical 15 KVA transformer change-out would cost about \$650 dollars, not including labor, taxes or hazardous waste fees.

Funding

Table 3 summarizes how the three sources of funding were used for contracts for the phase-out project. In the future, we would like to pursue funding to assist Cooperative Light and Power, Arrowhead Electric Cooperative, the City of Biwabik and any remaining contaminated transformers in the City of Grand Marais system.

Table 3. Funding sources for the project.

Utility	Contract #	LCMR	State TSCA Match	GLNPO	Total
Allotment number		200-K21Z- WP6	330-K22Y- H01	300-K21Z- WP3	
Grand Marais	A-60982	-	\$25,098 ¹	-	\$36,300 ¹
Cooperative	A-59805	\$51,568	\$6,182	-	\$57,750
Lake Country	A-57519	\$35,432	-	\$22,666	\$58,098
Total	NA	\$87,000	\$31,280	\$22,666 ²	\$152,148

¹ Grand Marais was able to spend \$25,098 of the \$36,300 allotted in the contract. We are evaluating a second contract for \$11,200 to finish the work.

² The total GLNPO grant was \$50,000. The remainder was for staff, fringe, indirect, supplies and printing.

Results

Due to the funding made available by GLNPO and the LCMR, the MPCA was able to make a total of \$152,148 available to utilities for phasing-out distribution transformers that had the potential to be contaminated with PCBs. The three utilities that contracted with the MPCA to do the work each took a slightly different route. Lake Country Power completely eliminated the potential liability. Cooperative Light and Power eliminated the risk in over half of its suspect transformers and is taking out those closest to water. Grand Marais tested as well as removed transformers in their system.

Table 4 describes the final numbers from this PCB phase-out project. Note that the tentative goal of removing half of the suspect transformers was easily met, although this was only possible due to the actions taken by the utilities. The grant funding would have been insufficient by itself. More specifically, 82% of the transformers at the three participating utilities will be phased-out. However, once the Arrowhead Electric Cooperative inventory is added, the percent reduction falls to 71%, which still exceeds the original goal.

As mentioned previously, when Lake Country Power and Cooperative Light and Power test results are available, the MPCA will prepare an addendum to this report. We expect to have a clearer understanding of what the actual rate of PCB contaminated transformers is compared to the suspect list. For example, 3-4% of the transformers in the inventories were on the suspect list, but how many actually were contaminated at a level of 50 ppm or more? We will also have a better understanding of which types (i.e., manufacturers and sizes) of transformers in the basin are most likely to be contaminated.

Table 4. Number of transformers being removed as part of the project.

Utility	Number of Transformers in the Lake Superior basin ¹	Number of Suspect Transformers	Number of Transformers Being Phased-out	Percent Reduction
Lake Country Power	10,500	292	292	100%
Cooperative Light and Power	4,184	241	145	60%
City of Grand Marais	162	15	15	100%
subtotal	14,846	548	452	82%
Arrowhead Electric Cooperative	2,506	90	0	0%
Grand Total	17,352	638	452	71%

¹ approximate

Lessons Learned and Recommendations:

- Contract directly with the utilities rather than a disposal company: Utilities that own their distribution systems will probably prefer to either do the work themselves or use subcontractors of their own choosing.
- Allot more time for the seasonal nature of the project: While some small utilities might be able to spend time on a project such as this at any time of the year, there is typically a busy season (i.e., construction season) and a slower winter season. Start negotiations in winter, go on hiatus during construction season and allow another winter (or even two, depending on the quantity of transformers) for the work.
- Be prepared to track multiple funding sources: This project had multiple funding sources, which was difficult to track under the current MPCA system. The MPCA should consider linking such allotments and treating them as one unit with several subsets.
- Don't separate known versus suspect transformer phase-out efforts: Unnecessary time was spent investigating the possibilities of a disposal contractor. In the end, the contracts went directly to the utilities who then focused on the transformers identified as suspects.
- Biwabik needs help: Since they were in the midst of negotiations on selling their utility, the City was not able to participate in this project. In addition, the Biwabik inventory is unsuitable for comparing to manufacturing information since they do not have a list of serial numbers for their in-service transformers. The City would benefit from a two-part project to test all the transformers (similar to what the City of Virginia did) and then remove those that contain PCBs.
- There are still suspect transformers left standing: Although it was known at the onset that there was insufficient funding to handle all the suspect transformers and the utilities were generous in their participation, there are still suspect transformers at Cooperative Light and Power and Arrowhead Electric Cooperative in the Lake Superior watershed that were not be tested or removed as part of this project.

- Look for opportunities to change-out other types of PCB bearing equipment: While it is reasonable to target distribution transformers since leaking transformers can contaminate nearby waters, capacitors, substation transformers, bushings and some other types of electrical equipment also contain PCBs.
- Electric cooperatives are mostly willing to meet us partway: The participating utilities are taking on some of the financial burden of change-outs, which means that the state and federal funding dollars stretched further than originally anticipated. The tradeoff is that the negotiation time took longer than anticipated and results will consequently take longer.
- Environmental stewardship awards would be appropriate: The MPCA will be seeking opportunities to nominate the utilities for their efforts.

Acknowledgements

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Jon Cress at Arrowhead Electric Cooperative; and
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Thank you!

Appendix A. List of Lake Country suspect transformers (sorted by distance to water).

Manufacturer and Serial Number AB=AB Chance D=Dowzer GE=General Electric LM=Line Material M=Moloney MG=McGraw Edison W=Wagner	Distance to Water (feet)	Position
M 1312881	45	N47.46003 W92.37107
M 1223B54	53	N46.92459 W92.49356
GE B629601	54	N47.14927 W92.39999
W 5M32404	63	N46.92318 W92.17675
GE H350482P73	68	N47.20806 W92.34654
GE L465935P73	82	N47.30454 W92.32342
M 1212867	85	N47.09658 W92.52573
LM 3C102006	90	N46.86119 W92.41220
GE H37265P73A	91	N47.21075 W92.34941
M 1105266D	96	N46.85437 W92.41486
GE 9814026	97	N47.22029 W92.21231
GE B171832	97	N47.22129 W92.21109
GE B136393	108	N47.37820 W92.26153
GE B182947	110	N47.22365 W92.22719
GE H399012P74	127	N47.38876 W92.25166
LM 4G54222	127	N46.37518 W92.66098
M 1194429	127	N47.09005 W92.54406
GE H373241P73	128	N47.08864 W92.54199
LM 6K70219W	129	N46.89500 W92.45250
GE B117750	132	N47.21829 W92.21784
LM 4F54115	134	N46.39346 W92.52190
GE H374753P73	136	N47.35288 W92.59793
GE H398295P74	138	N47.41496 W92.77553
GE B106890	140	N47.31536 W92.44969
GE B122519	140	N47.22741 W92.40441
LM 839647	140	N46.95668 W92.21664
GE B107534	143	N47.46234 W92.31424
GE B144888	143	N47.46405 W92.31546
GE H391353P74	143	N47.45947 W92.37683
M 1199946	144	N47.09832 W92.40478
GE B181762	148	N47.31334 W92.98002
GE H398250P74	148	N47.41688 W92.29198
GE H398962P74	149	N47.37244 W92.64627
GE B177963	150	N47.16785 W92.31289
GE B179915	150	N47.20986 W92.36129
GE B897030	150	N47.35490 W92.88162
GE H372697P73	154	N47.31893 W92.82924
GE B133662	155	N46.39599 W92.58788

GE B171377	157	N47.31103 W92.33041
GE B123838	160	N47.16354 W92.30846
GE B158925	160	N47.44080 W92.24799
GE B107084	165	N47.44536 W92.32977
GE B117517	166	N47.31126 W92.45150
LM 354415	169	N46.82220 W92.36597
LM 407291	169	N47.01178 W92.77038
LM 7L50663A	169	N46.39032 W92.60435
GE B123841	177	N47.48926 W92.34150
GE B833421	180	N47.14572 W92.45575
GE H398233P74	180	N47.37166 W92.71788
LM 6J750184W	180	N46.99218 W92.32023
GE B289960	182	N47.21896 W92.21546
LM 4K54361	185	N46.39552 W92.58940
M 1190307	187	N47.30169 W92.50854
LM 326670	190	N46.84932 W92.40473
GE H398246P74	193	N47.48547 W92.39010
M 121643	195	N46.39032 W92.60544
GE F55241165P	198	N47.21544 W92.23343
LM 354531	199	N46.95106 W92.90509
GE H394458P74	200	N47.40231 W92.23956
GE B621576	201	N46.39431 W92.59380
LM 300404	201	N47.03832 W92.93719
LM 70D50238A	201	N46.96475 W92.31612
LM 7122005016	201	N46.98219 W92.81215
LM 780289	201	N46.96421 W92.31592
LM 978438	203	N47.27956 W92.20053
M 1192024	203	N47.33431 W92.41065
GE H450421P73	205	N47.40581 W92.54248
GE H398986P74	208	N47.47241 W92.69102
M 1192000	211	N47.16362 W92.32035
LM 4F752543	214	N46.79466 W92.92174
M 102211402	215	N47.42663 W92.77054
GE H398313P74	222	N47.33164 W92.41095
LM 268626	224	N46.53740 W92.61749
GE H394472P74	237	N47.43498 W92.35082
GE H339168P73	238	N47.68238 W92.02495
GE H398132P74	238	N47.26290 W92.60131
GE B-121-367	241	N46.78683 W92.44998
GE H398125P74	242	N47.43799 W92.34658
GE B179991	248	N47.40923 W92.54096
GE H399143P74	275	N47.49323 W92.25764
GE B118865	281	N46.41803 W92.51218
GE L465934P74	284	N47.47734 W92.69031
GE H398258P74	286	N47.40147 W92.73826
GE H398124P74	296	N47.44032 W92.25112
LM 644444	296	N46.80106 W92.90492
GE B106769	304	N47.31432 W92.66551

LM 7122050162	311	N47.00163 W93.21095
GE H374053P73	314	N47.39388 W92.25776
M 1191998	329	N47.08085 W92.60415
LM 3J752436	336	N46.87737 W92.24411
LM 902487	347	N47.36243 W92.90623
GE H398326P74	349	N47.13995 W92.59903
GE B116426	355	N47.28209 W92.19351
LM 538106	360	N46.44023 W92.66267
GE H349474P73	364	N47.43838 W92.64960
M 1312889	365	N47.08933 W92.54752
GE B603582	370	N46.65656 W92.64822
GE H372605P73	372	N47.48246 W92.38929
GE L465926P74	379	N47.37248 W92.89521
GE B117691	383	N47.50592 W92.62840
GE H393741P74	383	N47.31487 W92.62820
GE B603145	389	N46.83226 W92.89471
M 1192006	389	N47.05002 W92.45284
W 5L34440	393	N46.79516 W92.30728
GE B123816	396	N47.47843 W92.36153
GE H397472P74	396	N47.30684 W93.02185
GE H398262P74	397	N47.68653 W92.08232
GE H394475P74	400	N47.35559 W92.97056
GE H373345P73	421	N47.66938 W92.10665
LM 70BJ260016	441	N47.08715 W93.19334
GE B156624	444	N47.18440 W92.47333
GE H398125P74	450	N47.39375 W92.47333
GE H383844P74	460	N47.43013 W92.68676
GE B592199	464	N46.65361 W92.65039
GE H37409P73A	465	N47.10432 W92.47096
LM 511548	471	N46.67671 W92.34223
M 1200131	471	N47.14425 W92.47139
GE B103894	475	N47.46544 W92.33190
GE H398291P74	476	N47.32711 W92.62851
GE B106795	483	N47.35798 W92.70436
M 1053995	487	N47.00069 W93.05147
GE H383795P74	491	N47.44488 W92.35383
LM 7022005008	491	N47.23926 W92.82076
LM 472911	494	N46.83591 W92.33129
M 1223B517	496	N47.25836 W92.80878
GE H398102P74	498	N47.08495 W92.47462
GE B116342	504	N47.25640 W92.40663
GE B118590	505	N46.65603 W92.64761
LM 328316	507	N46.94328 W92.33896
GE H383826P74	510	N47.41596 W92.25515
GE H394477P74	512	N47.32911 W92.99911
GE H399032P74	515	N47.44873 W92.35629
LM 823228	515	N47.51032 W92.67150
LM 839477	519	N46.82753 W92.70326

GE H348419P73	523	N47.50656 W92.67372
GE H391369P74	524	N47.09751 W92.59736
LM 587087	542	N46.92382 W92.46591
GE L465965P74	571	N47.34348 W93.00850
GE H398317P74	585	N47.30816 W92.60037
WG 5L34442	595	N47.04991 W93.23286
LM 918316	603	N47.04700 W92.80420
M 1099	603	N46.99317 W92.56457
LM 7022010160	605	N47.15758 W92.79547
GE H398243P74	615	N47.39184 W92.24023
GE H399185P74	623	N47.46563 W92.24748
GE H373200P73	624	N47.40509 W92.70084
M 143010	624	N46.93873 W92.34374
GE H398290P74	634	N47.41386 W92.20509
GE H383783P74	650	N47.29624 W92.82340
GE B136353	660	N47.42675 W92.57930
LM 2J53243	667	N47.09928 W92.78557
M 1113464	667	N46.85155 W92.42901
LM 5J753864D	671	N47.17369 W92.82513
GE B181766	672	N47.39709 W92.80179
GE H393711P74	682	N47.40289 W92.47305
LM 436706	686	N46.69467 W92.84954
LM 7122005015	686	N46.91670 W92.20790
M 106267	686	N46.80545 W92.97946
M 1128909	687	N46.67713 W92.34815
GE L465942P74	688	N47.43056 W92.18480
LM 892864	691	N46.69917 W92.36187
LM 823184	692	N47.40064 W92.64777
M 1192933	698	N47.15910 W92.44451
GE B603766	702	N46.80767 W92.42024
GE H372595P73	712	N47.66267 W92.17856
GE B171444	718	N47.32718 W92.60410
M 149940	727	N46.75161 W92.43798
GE B171424	729	N47.06881 W92.60007
M 120927	741	N46.53485 W92.66873
GE H383807P74	742	N47.68813 W92.09288
GE B110875	746	N46.65586 W92.64686
GE B566040	752	N47.00292 W92.92722
LM 903218	758	N46.36648 W92.57406
GE L466015P74	766	N47.48115 W92.57165
W 5L38445	771	N47.30713 W92.64086
GE B156717	772	N47.08857 W92.46940
W 5M61117	785	N47.28373 W93.02503
GE H348427P73	818	N47.38077 W92.21017
LM 8L102120A	824	N47.27081 W92.81031
GE B171478	845	N47.39411 W92.29663
GE H373310P73	878	N47.43945 W92.52424
GE B122172	917	N46.87755 W92.51259

GE H399104P74	930	N47.44600 W92.35781
GE H372039P73	941	N47.31362 W92.32979
LM 450822	949	N46.66491 W92.70723
GE B183434	950	N47.10187 W92.37069
GE H394490P74	951	N47.29905 W93.03092
GE H383817P74	952	N47.42431 W92.25878
GE H398287P74	961	N47.35176 W92.88847
LM 524832	963	N46.66834 W92.57836
GE H383790P74	964	N47.46604 W92.38851
LM 354410	972	N46.81587 W92.38065
GE F55826965P	999	N47.39632 W92.58123
GE B177716	1014	N47.37231 W92.47303
GE L465944P74	1019	N47.34891 W92.60490
GE H372061P73	1029	N47.44346 W92.29947
GE H393690P74	1040	N47.62211 W92.24458
GE H348386P73	1061	N47.41441 W92.24729
GE B171302	1072	N47.62827 W92.24431
GE B121451	1082	N46.86956 W92.62818
LM 4F54112	1088	N47.17795 W92.85842
GE B898667	1119	N47.37062 W92.63982
GE H394494P74	1119	N47.32649 W92.65895
GE L466018P74	1124	N47.48122 W92.56851
GE B621662	1130	N46.85683 W92.44553
GE H398980P74	1151	N47.67689 W92.06363
LM 8L50518A	1162	N47.08620 W93.19968
LM 7122007015	1167	N46.98183 W92.81599
GE H350446P73	1172	N47.43726 W92.77047
GE H384540P74	1172	N47.47977 W92.23608
GE H350516P73	1177	N47.44033 W92.33828
M 1191913	1188	N47.24805 W92.37912
GE H374826P73	1193	N47.44540 W92.36751
GE H391345P74	1224	N47.35414 W92.96299
GE B171489	1225	N47.14512 W92.65357
GE H398155P74	1225	N47.43094 W92.30291
GE H383778P74	1246	N47.48219 W92.36852
M 123473	1246	N46.99488 W92.78642
GE H374788P73	1251	N47.27952 W92.64243
LM 70A750023A	1262	N47.09732 W92.77626
LM 729180	1262	N46.82995 W92.91094
GE B171336	1267	N47.39949 W92.72155
M 1191926	1283	N47.48877 W92.62372
LM 407104	1299	N46.89658 W92.60579
LM 5B752613D	1325	N46.69075 W92.34187
GE H383761P74	1335	N47.29939 W92.83812
GE B133669	1351	N46.91411 W92.38723
LM 7022001064	1373	N46.95140 W92.53483
GE H391333P74	1378	N47.34841 W92.99579
M 1192040	1394	N47.09922 W92.60057

GE H398113P74	1399	N47.48684 W92.38392
LM 756016	1404	N46.67010 W92.68917
GE B121431	1415	N47.00943 W92.55563
GE H399106P74	1415	N47.42101 W92.58102
GE B6030144	1447	N46.95931 W93.26187
GE B621661	1467	N46.84774 W92.52468
LM 5A54417	1525	N47.09742 W92.75256
GE H344616P73	1536	N47.38607 W92.52775
GE H349454P73	1536	N47.42128 W92.64546
M 1010914	1547	N47.09879 W92.75215
GE H383832P74	1552	N47.47768 W92.34166
M 1101B627	1552	N47.09732 W92.77746
M 123469	1589	N46.39603 W92.53079
M 14621K8	1658	N46.37823 W92.55190
GE H349432P73	1674	N47.49106 W92.59725
LM 328317	1684	N47.00891 W92.55394
GE H339202P73	1695	N47.43877 W92.49230
GE H372689P73	1747	N47.39411 W92.99037
GE H38319P74A	1758	N47.34617 W92.24446
GE B171268	1790	N47.42990 W92.30970
LM 324721	1795	N46.84639 W92.52969
LM 70BN037006	1822	N47.07839 W93.16790
GE H398144P74	1837	N47.70337 W92.01307
LM 5L754226D	1837	N46.93538 W92.89786
GE B117743	1853	N47.37990 W92.73993
GE H374069P74	1969	N47.49360 W92.30102
M 1093	1969	N46.90328 W92.88206
LM 500827	1980	N46.98587 W93.24058
GE B171436	2038	N47.26399 W92.40602
GE B427818	2038	N47.29909 W92.21886
GE H372661P73	2091	N47.48129 W92.39555
GE H384541P74	2122	N47.45020 W92.72563
GE B171835	2281	N47.37786 W92.55704
GE H383763P74	2317	N47.44531 W92.22992
GE B122277	2328	N47.18953 W92.73946
LM 928153	2371	N47.36772 W92.25784
GE H394582P74	2386	N47.32769 W92.61134
GE H398153P74	2386	N47.43889 W92.33049
LM 250852	2402	N46.67884 W92.66094
AC 2742408	2423	N47.51565 W92.65671
GE H392426P74	2529	N47.37949 W92.44447
LM 407101	2529	N47.21223 W92.72824
GE B117694	2544	N47.51588 W92.25169
GE H398154P74	2592	N47.38567 W92.35554
M 1192881	2598	N47.05417 W92.49339
GE H372615P74	2635	N47.50565 W92.23823
GE H398143P74	2767	N47.33817 W92.26003
GE L465933P74	2793	N47.27623 W92.74525

LM 345816	2946	N46.97709 W92.62987
GE B566396	3057	N46.59261 W92.70091
LM 4G54212	3073	N46.71463 W92.90211
WG 5K72018	3157	N46.97937 W92.93381
LM 281917	3348	N46.78231 W92.98386
GE H347528P73	3353	N47.39394 W92.64818
GE H374769P73	3358	N47.51035 W92.26308
GE B130814	3527	N46.71337 W92.90356
LM 3L752459	3759	N46.89695 W92.97184
LM 354325	3769	N46.86070 W92.69975
M 1191919	4018	N46.84404 W92.33612
GE H350465P73	4308	N47.35628 W92.44874
LM 780063	4440	N46.97560 W92.23578
LM 839525	6124	N46.88538 W92.89243

Appendix B. List of Cooperative Light and Power suspect transformers
(sorted by distance to water).

Manufacturer and Serial Number AB=AB Chance D=Dowzer GE=General Electric LM=Line Material M=Moloney MG=McGraw Edison W=Wagner	Distance to Water (feet)	Position
GE B491128*	0	N/A
GE B535905*	0	N/A
GE B665094*	0	N/A
GE B667454*	0	N/A
GE B667563*	0	N/A
GE B810250*	0	N/A
GE B810265*	0	N/A
GE B810272*	0	N/A
GE B603672	4	N47 06.887 W91 39.913
M 1191954	4	N47 12.502 W91 53.263
GE B810283	11	N47 15.171 W91 23.546
GE D46254360P	14	N47 15.278 W91 18.304
LM 929774	16	N47 01.972 W91 43.661
GE B621549	17	N47 04.179 W91 42.437
GE B667446	19	N47 09.019 W91 27.015
GE B878024	22	N47 15.454 W91 18.265
GE B569804	24	N46 58.722 W91 44.733
AB 70D46337	25	N47 07.397 W91 29.882
GE B800663	25	N47 07.636 W91 29.083
GE B599667	28	N47 23.072 W91 08.887
GE B605449	29	N47 07.634 W91 29.414
GE B491453	30	N47 15.191 W91 22.877
GE E45831862P	31	N47 15.496 W91 22.094
GE B800665	34	N47 10.403 W91 25.071
GE D251322	38	N47 16.162 W91 19.093
GE B603693	39	N47 02.551 W91 40.066
AB 70L51698	43	N47 25.191 W91 14.759
LM 65234101	47	N47 02.269 W91 41.404
GE B810242	49	N47 08.437 W91 27.491
GE B535906	55	N47 03.780 W91 36.583
GE B491438	59	N47 16.082 W91 17.098
GE B587865	62	N47 04.076 W91 48.305
GE B629534	62	N46.95695 W91.76852
LM 62149	62	N47.03304 W92.16650
GE B806897	65	N47 10.471 W91 24.981

GE B491387	69	N47 03.164 W91 37.342
GE B556525	72	N47 03.277 W91 44.670
LM 8F101412A	73	N47 01.956 W91 47.193
AB 70L51697	75	N47 09.723 W91 26.125
AB 70L51696	79	N47 13.618 W91 20.476
GE B569823	80	N47 07.218 W91 39.912
GE B577694	80	N47 14.912 W91 39.677
GE B139484	83	N47 14.480 W91 42.025
LM 8B100252A	88	N47.00920 W92.15449
LM 8F101436A	91	N47 14.577 W91 42.611
GE D52076460P	98	N47 06.618 W91 31.240
GE B535908	103	N47 09.985 W91 25.627
GE B806852	104	N47 15.564 W91 17.800
W 5P65301	104	N47 01.956 W91 47.204
LM 652085	107	N46.94366 W91.78049
AB 1219961	112	N47 18.414 W91 14.167
GE B665160	123	N47 09.868 W91 25.819
GE B636756	125	N46.95741 W91.76788
GE B636754	128	N46.93224 W91.82919
GE B810263	128	N47 41.116 W91 25.560
GE B810278	128	N47 25.083 W91 05.896
GE D48975360P	128	N47 23.191 W91 08.912
GE D48975060P	131	N47 09.784 W91 25.873
GE B629487	138	N47 12.644 W91 53.201
GE B599886	147	N47 09.171 W91 26.598
LM 8J108888A	151	N47 01.859 W91 43.270
GE B556527	152	N47.06406 W91.59558
GE B636767	154	N47.36949 W91.90991
GE B491429	155	N47.34065 W91.31584
AB 69G35132	156	N47 40.836 W91 25.702
GE B667411	160	N47 24.204 W91 07.384
GE B578654	165	N47.36997 W91.90930
M 127935	165	N47.01238 W91.70346
GE B636591	175	N47 03.683 W91 41.314
GE D233319	176	N47 21.146 W91 48.471
MG 637803120	176	N47 10.552 W91 24.773
W 5R29882	177	N47 05.962 W91 32.872
GE B578653	179	N46.94383 W91.78124
GE B156441A	182	N47 00.748 W91 42.309
GE B665161	183	N47 40.810 W91 25.715
GE B810267	185	N47.06383 W91.60471
GE B810288	190	N47.35033 W91.18136
GE B810285	192	N47.34428 W91.30827
MG 637803121	193	N47.32201 W91.22065
GE B535895	194	N47 15.309 W91 18.303
GE B882345	196	N47 16.138 W91 17.048
GE B491433	206	N47 18.212 W91 14.429
M 1217202	207	N47 16.442 W91 49.485

GE B810286	209	N47 10.668 W91 24.671
AB 70D46342	212	N47 15.524 W91 18.360
GE B556822	214	N47 12.438 W91 21.787
GE B621617	215	N47.01917 W91.69881
LM 8B100258A	215	N47.30743 W91.63983
GE B599673	221	N47 40.888 W91 25.676
AB 70L51702	222	N47 25.440 W91 14.118
GE D28934858P	222	N47 22.361 W91 13.777
GE B667441	225	N47.31102 W91.23047
GE B810276	225	N47.34872 W91.29737
GE B815846	226	N47.02643 W92.18907
LM 8F101627A	232	N47.06539 W92.01855
W 5R29880	232	N47 40.915 W91 25.634
GE B644796	233	N47.37223 W91.22721
LM 8B100298A	237	N47.01113 W91.70473
GE B810253	240	N47 07.687 W91 29.429
GE B636563	253	N47.02938 W92.19515
GE B878020	257	N47 41.205 W91 25.520
GE B810262	261	N47 26.646 W91 16.890
MG 637803128	264	N47 18.446 W91 14.381
D 77D1441702	267	N47 04.142 W91 44.429
M 1272935	272	N47 00.767 W91 42.122
GE B824942	281	N47.30962 W91.62864
GE B491435	285	N47.06101 W91.61135
GE B800664	296	N47 06.745 W91 30.930
GE E38464561	297	N47 01.913 W91 43.580
GE B876226	300	N46.93165 W91.81143
GE B810261	307	N47 16.500 W91 19.481
GE B665118	314	N47 25.105 W91 14.771
M 1193048	316	N47 05.883 W91 42.308
GE D48974960P	317	N47 25.491 W91 15.388
GE B636760	321	N47.07230 W92.00088
GE 98313G7	325	N47 08.651 W91 34.485
GE B636576	327	N47 17.089 W91 50.591
GE B196968	328	N47.07743 W91.96302
GE B665883	335	N47 06.346 W91 31.450
GE B603637	345	N46.90913 W91.87363
GE D51958060P	347	N47 13.417 W91 20.761
LM 8G101722A	351	N46.94905 W91.78537
D 77D1441703	353	N47 01.952 W91 50.507
GE B621676	359	N47.07298 W91.96543
W 5R29881	364	N47.05120 W91.63252
D 77D1441720	368	N47.05433 W91.66333
GE B897020	368	N47.02715 W92.20418
GE B491372	379	N47.35453 W91.20165
GE B878027	381	N47 37.049 W91 22.798
D 77D1441705	387	N46.99725 W91.71796
D 77D1441710	387	N46.94489 W91.81874

GE B599161	387	N47 15.301 W91 18.390
GE B535903	393	N47.33942 W91.30878
LM 916845	393	N47.30216 W91.64598
D 77D1441730	401	N47.06655 W91.95605
GE B810248	405	N47.06732 W91.59417
GE D212928	409	N47 14.585 W91 41.946
GE B806889	420	N47.06913 W91.59257
GE B667448	422	N47 06.331 W91 31.251
GE D233295	428	N47.30873 W91.63106
GE B535893	436	N47 06.514 W91 31.525
GE B806892	436	N47.05854 W91.61627
GE B603742	458	N47.06279 W91.96859
GE B599669	471	N47.05731 W91.61787
GE B629491	475	N47 01.532 W91 43.425
GE B800662	477	N47 24.888 W91 15.021
GE B636745	504	N46.94832 W91.78487
GE B665148	518	N47 14.992 W91 18.725
D 77D1441712	540	N47 03.284 W91 39.565
AB 70L51701	546	N47.06529 W91.60271
MG 637803131	561	N47.05524 W91.62036
GE B556666	567	N47.32304 W91.22014
GE B823814	570	N47.34852 W91.30010
GE B636577	573	N47.30319 W91.64235
GE B599683	580	N47.05216 W91.62520
GE B599176	583	N47 27.649 W91 18.592
M 1192036	597	N47 09.153 W91 34.491
D 77D144712	619	N47.05552 W91.66014
GE B535889	629	N47 06.989 W91 30.675
GE B629157	630	N47 03.116 W91 43.867
GE B810270	639	N47 25.643 W91 15.906
GE B599690	646	N47 06.420 W91 31.246
LM 8F101588A	661	N47.07711 W91.61191
GE B810275	663	N47.35638 W91.21023
LM 8F101409A	672	N47.05819 W91.66566
GE B810287	673	N47 24.145 W91 10.750
LM 916921	688	N46.95436 W91.77709
GE D248681	713	N47 02.089 W91 44.860
GE 800669	731	N47.34246 W91.19320
MG 637803124	756	N47 14.512 W91 27.358
GE D212765	785	N47 12.793 W91 53.161
GE B665146	791	N47.31574 W91.22683
GE B667457	792	N47.06550 W91.60491
GE D212860	804	N47.37007 W91.93251
GE D46254060P	805	N47.07300 W91.59019
GE B629512	855	N47 04.497 W91 43.864
GE B621673	970	N47 04.159 W91 40.745
GE B810281	980	N47.31116 W91.23299
GE B815509	1003	N47 24.353 W91 12.951

GE B599887	1109	N47 24.661 W91 09.734
GE B664949	1109	N47 24.653 W91 06.637
LM 7L102956A	1114	N47.00990 W91.73250
LM 794799	1135	N47 08.915 W91 37.104
GE B634804	1146	N47 22.509 W91 16.103
GE B139482	1151	N46.98138 W91.74443
GE B878030	1156	N47.31507 W91.32654
GE B587931	1204	N47 04.981 W91 48.312
GE B175952	1251	N47 02.038 W91 49.679
LM 8E101547A	1299	N47 07.620 W91 34.773
D 77D1441724	1309	N46.94071 W91.84797
GE D51958460P	1320	N47 24.517 W91 07.247
GE B491451	1330	N47 25.111 W91 14.892
GE B810244	1373	N47.36231 W91.21622
MG 637803130	1394	N47 24.305 W91 12.816
LM 916777	1399	N47.36863 W91.93464
LM 8F101564A	1415	N47.06003 W91.63983
GE B636782	1441	N47 08.966 W91 37.109
GE B810255	1462	N47.36300 W91.21420
GE D215138	1463	N47 36.939 W91 21.119
GE B665881	1473	N47 24.603 W91 14.764
M 1192764	1473	N47.35807 W91.80195
LM 8B100251A	1478	N47.01017 W91.73039
AB 70D46336	1558	N47.36765 W91.22449
GE B810279	1616	N47 24.449 W91 10.289
GE B578651	1674	N47 08.484 W91 35.913
AB 70D46340	1695	N47.37025 W91.22015
GE B810273	1721	N47 37.036 W91 21.861
LM 4185801	1753	N47 36.816 W91 21.180
LM 771201	1784	N47.09948 W91.64142
GE D23319	1790	N47.34939 W91.81053
GE B535886	1827	N47 24.656 W91 13.681
GE B569761	1854	N47 12.800 W91 42.055
GE B156440A	1921	N46.95583 W91.88674
GE B190584	1921	N47.05621 W91.65251
GE B882344	1996	N47 25.234 W91 14.754
GE B806840	2001	N47 24.890 W91 16.422
GE B800667	2049	N47 24.505 W91 14.763
GE B599178	2064	N47 30.279 W91 19.277
GE B815511	2064	N47 24.506 W91 14.761
GE B810280	2070	N47 24.891 W91 16.439
GE B631727	2080	N47 07.218 W91 39.912
GE B810251	2100	N47 24.166 W91 12.857
GE B636562	2107	N47 04.616 W91 42.600
D 77D1441713	2270	N46.95131 W91.88854
GE B629763	2365	N46.94885 W91.84597
MG 637803127	2402	N47 37.099 W91 22.020
GE B810260	2482	N47 24.525 W91 11.654

LM 661984	2503	N46.93921 W91.82555
GE D46254160P	2571	N47 34.035 W91 20.529
GE B107086	2618	N47 04.695 W91 41.324
W 5R29883	2851	N47 22.743 W91 14.170
GE B190583	2952	N47 12.836 W91 42.789
D 77D1441717	2999	N46.94003 W91.87772
AB 164410	3199	N47 24.161 W91 12.326
GE B491441	3205	N47 25.360 W91 15.172
GE B810256	3384	N47 23.996 W91 14.811
GE B605438	4488	N47 24.687 W91 08.113
GE B587918	4789	N47 36.501 W91 20.598
GE B810243	4968	N47 37.054 W91 22.958
GE D51958660P	5387	N47 36.381 W91 20.575
GE B806891	6547	N47 37.756 W91 23.758
GE B535897	8448	N47 37.796 W91 25.312

* These transformers are next to Lake Superior but were not accessible for tagging at the time of the field work.

BOLDED transformers are the first 145 GE's closest to water

Appendix C. Grand Marais Test Results.

Sample ID	Size (KVA)	Manufacturer	Suspect?	Araclor 1242	Araclor 1254	Araclor 1260	Total PCBs (if >50 ppm)
911	25	GE				<2	
912	37.5	GE	Y	13		105	118
913		Eastern				<2	
914		Eastern				<2	
915		Eastern				<2	
916	25	Eastern				<2	
917	3	Allis Chalmers			9		
918	15	Westinghouse				6	
919	25	GE				<2	
920	15	Allis Chalmers	Y			27	
921	15	Westinghouse	Y	35	210		245
922	25	GE	Y			181	181
923	25	Westinghouse	Y	59			59
924	15	Allis Chalmers	Y			<2	
925	5	GE				<2	
926	50	Allis Chalmers	Y			30	
927	5	GE	Y			3	
8602	50	Westinghouse				<2	
8603	50	Westinghouse				<2	
8604	50	Westinghouse				<2	
8605	50	Westinghouse				<2	
8606	50	Westinghouse				<2	
8607	50	Westinghouse				<2	
8608	50	Westinghouse				<2	
8609	50	Westinghouse				<2	
8610	50	Westinghouse				<2	
8611	50	Westinghouse				<2	
8612	75	Westinghouse				<2	
8613	300	Westinghouse				<2	
8614	150	GE	Y			114	114
8615	25	GE	Y			347	347
8616	25	GE	Y			59	59
8617	25	GE	Y			394	394
8618	25	GE				<2	
8619	50	Kuhlman				<2	

Sample ID	Size (KVA)	Manufacturer	Suspect?	Araclor 1242	Araclor 1254	Araclor 1260	Total PCBs (if >50 ppm)
8620	25	RTE				<2	
8621	15	ML				<2	
691	7.5	GE	Y			219	219
692	5	Allis Chalmers	Y			<2	
693	10	GE	Y			120	120
694	25	GE	Y			195	195
695	10	GE				<2	
696	10	Westinghouse				12	
697	25	Kuhlman				<2	
698	25	Westinghouse	Y		134		134
699	15	Allis Chalmers				<2	