# CONSERVATION INNOVATION GRANTS
## Final Report – Revised for Web Site, December 2007

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| **Grantee Name: Cape Cod Cranberry Growers' Association** | |
| **Project Title: Irrigation Automation for the Cranberry Industry** | |
| **Project Director: Jeffrey LaFleur** | |
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| **Period Covered by Report: September 2005 – July 2007** | |
| **Project End Date: July 30, 2007** | |


## SUMMARY
This conservation innovation grant gave Massachusetts cranberry growers the opportunity to purchase, install and evaluate irrigation automation technology on their farms. The participants were able to evaluate the systems over a variety of conditions and across more than one growing season. The systems were used on frost nights in both the spring and fall, as well as for conventional irrigation events during the entire growing season.

Overall, the grower participants are very pleased with the systems and see irrigation automation as a critical component of their operation. Water usage was the biggest savings with automated systems but growers were also able to save on fuel, labor, safety, mileage and pump longevity. On average, growers were able to save at least two hours of water use on a frost night. For a conventional cranberry irrigation system, 2 hours of water savings equates to approximately 9,300 gallons of water per acre. Carrying the frost night savings across a typical growing season, more than 280,000 gallons of water could be conserved.

Further water savings can be expected as some growers started their pumps closer to the actual frost tolerance temperature as they gained more confidence in the auto-start system and cycled their pumps on/off during the night as the temperatures fluctuated. Growers also saved on fuel, labor, mileage, safety and pump life. Most grower participants expect to invest in more systems to further automate their operations.

Of further significance and a testament to the success of this Conservation Innovation Grant, irrigation automation systems were recently approved as a cost-share practice of the USDA/NRCS Environmental Quality Incentives Program for Massachusetts' growers. Growers are now eligible to receive payment for installing these water-saving systems as part of their bog operations.

## SYSTEMS

Two different types of systems were installed. Ten growers utilized Internet-based (cellular) auto-start systems and one grower installed a radio-based system. The functionality of the systems was similar. These systems were designed to allow for automatic start/stop of irrigation pumps based on either pre-set temperature thresholds or scheduled irrigation events.

### Internet (Cellular) Based

A local company, KC Enterprises LTD. of Buzzards Bay, Massachusetts, manufactured the Internet-based system. This system was comprised of a control panel mounted in the grower's pump house. This control interfaced with a Ryeso engine controller and a FW Murphy throttle control and pressure regulator gauge. The control panel accessed the Internet via a wireless modem, utilizing cellular signals. The system was battery powered with impact resistant solar panels used to recharge the battery. A thermistor type temperature probe (hard-wired) was used to measure bog canopy temperature (see Appendix A for photo details of the installed system). In some instances a pusher fan control and/or a pump primer control was also connected to the automated system. The pusher fan is used to cool the pump house and the pump primer is sometimes necessary for those setups with a long time delay to fill the inlet pipe from the water source.

A password-protected web site allows the grower to remotely start/stop the pumps, schedule an irrigation event and input settings for desired pump speed (RPM), pump start-up/cool-down time, water discharge pressure and temperature high/low tolerances. Additionally, when the system is running, the grower can monitor RPM, coolant temperature, battery voltage, oil pressure, water discharge pressure, and run hours. The grower can also receive notification of pump start via a text message or email.

The pump will automatically shut-down if any of the following parameters fall out of the pre-set range: low oil pressure, high or low water discharge pressure, high engine RPM, and coolant temperature. The grower also receives a text message or email notification of the system shutdown.

Initially, there were numerous issues with the auto-start systems. Most of the issues have been resolved. Table 1 identifies the problem, status, and result.

**Table 1**

| Problem | Status | Result |
|---|---|---|
| Pump House Over Heat | Solved | Keep Doors/Windows Open; Install Metal Screens; Install Pusher Fans |
| Temperature Probes Not Calibrated | Solved | Training/Experience Required |
| Pumps Start/Stop By Themselves | Solved | Software Glitch |
| Modem Outages | Solved | Different Modem Manufacturer Used |
| User Issues Primarily With Web Interface | Solved (mostly) | Training/Experience/Communication Between Farm Employees |
| Wired Temperature Probes Don't Always Reach Bog's Cold Spot | Unresolved | Wireless Temperature Probes Are Being Tested/Evaluated |
| Server Outages (sporadic) | Unresolved | Server Needs Re-start |
| Temperature Probes Slow To React To Temperature Changes | Unresolved | Only Occurs in Certain Climatic Conditions; More Research Needed |

**Radio Based**

One grower utilized an irrigation automation system using radio frequencies to interface with his computer, rather than a cellular based system. This system was built by a graduate student in the electric and computer engineering department at the University of Massachusetts Dartmouth. His Masters Project was entitled "Automation and Remote Monitoring of Cranberry Farms". This system has a weather station installed that measures temperature, humidity, rainfall and wind speed. The control board (mounted in the growers pump house) measures pump pressure and battery voltage. Based on a pre-set temperature threshold, the control board will automatically turn on/off the irrigation pump. Radio frequencies are used to relay information from the weather station to the control board and then to a master computer at the grower's house. The grower installed "PCAnywhere" software to be able to access this master computer from a laptop or web-enabled cell phone. From the computer, the grower can also start/stop the pumps (see Appendix B for photo details of the installed system).

Unfortunately, several problems have occurred with this system. The primary hurdle is that the graduate student has completed his project and has left the university. One of the two professors overseeing the project has also left and the remaining professor has moved on to other projects. This has left the grower with an unsupported system that needs upgrades/changes in order to be fully operational. A list of the issues can be found in Table 2 below.

**Table 2**

| Problem | Status | Result |
|---|---|---|
| System Settings Don't Save After Computer Shut Down | Resolved | Software re-written |
| Some Temperature Probes Give False Readings | Unresolved | Controller Board Needs Upgrade |
| No Ability To Schedule Irrigation | Unresolved | Controller Board Needs Upgrade |
| Rain Gauge Not Working (sporadic) | Unresolved | Controller Board Needs Upgrade |

## PARTICIPANTS

Eleven growers participated in the grant program, installing 133 systems in total. These systems represented 1,835 acres of cranberry bog and were installed on all of the different styles of irrigation pumps utilized by cranberry growers (diesel/propane/electric). The names of the growers have been removed from the table below for privacy concerns.

**Table 3**

| Grower | Funds Granted | Systems Granted | Systems Installed | Acres Automated |
|---|---|---|---|---|
| Grower A | $70,000 | 20 | 61 | 825 |
| Grower B | $15,000 | 3 | 13 | 161 |
| Grower C | $20,000 | 5 | 17 | 195 |
| Grower D | $20,000 | 5 | 9 | 161 |
| Grower E | $3,000 | 1 | 2 | 41 |
| Grower F | $5,000 | 1 | 4 | 107 |
| Grower G | $20,000 | 5 | 9 | 144 |
| Grower H | $5,000 | 2 | 4 | 55 |
| Grower I | $4,000 | 1 | 1 | 24 |
| Grower J | $10,000 | 2 | 5 | 50 |
| Grower K | $5,000 | 1 | 8 | 72 |
| **Total** | **$177,000** | **46** | **133** | **1,874** |

## RESULT SUMMARY

There are numerous savings for growers utilizing an irrigation automation system. The savings vary tremendously depending on how the grower is using the system and the climatic conditions. Water use is the most obvious and sought after savings for these systems but there other savings to be enjoyed as well. These additional savings have a direct financial or production impact to a grower's operation.

**Water – Frost Night**

*Start/Stop*

Since all growers participating in this grant program had multiple pumps at various locations, there was universal acceptance that 2-3 hours of water use was saved on each frost night. This savings was a result of a 1 hour buffer that growers needed to insure that they could reach all of their pumps in time prior to the critical frost-kill temperature threshold being met. The pumps also tended to stay on longer after the frost event was over as the grower drove around shutting off their systems. This resulted in additional hour of water use shutting down the systems.

From this information, a simple base line of water savings can be calculated, assuming a 2-hour pump start/stop savings. Typically, there are 30 frost events in a typical year, divided among the spring and fall frost seasons. Industry data show that a common irrigation system with a 50x60 spacing (50 psi) and 15 impact heads (Rainbird) per acre, pumps out 5.2 gallons of water per minute per head. This equates to 78 gallons per acre. Growers can save over 9,000 gallons of water per acre on each frost night and over 280,000 gallons of water per acre over the course of the growing season (spring and fall frosts).

The water savings for growers using a conventional system with pop-up sprinkler heads are less than for impact heads. If a grower has a 40x50 spacing with 22 Hunter pop-up rotors per acre, 2.9 gallons of water per minute are being delivered per head or 64 gallons per minute per acre. With a 2-hour water use savings on a frost night, growers with this common system would save in excess of 7,600 gallons of water per acre on each frost night and over 230,000 gallons of water per acre over the course of the growing season (spring and fall frosts).

*Tolerance*

Growers also have the opportunity to start their pumps closer to the actual tolerance on a frost night. Most growers start their pumps 3-4° above tolerance to insure enough time to start all of the pumps, especially on a night where the temperature is dropping quickly. Automation allows growers to start 1-2° above tolerance. Not all of the growers participating in the grant program were comfortable starting their systems so close to tolerance. However, those that were not yet comfortable admitted that given more time and experience with the system, they most assuredly would be starting their pumps closer to the tolerance. Of the 11 growers participating, 7 have either consistently or at least experimented with starting their pumps 1-2° above tolerance. This saves them 30 minutes to one hour on a typical frost night. That equates to approximately 2,000 – 4,000 gallons of water saved per acre.

*Cycling*

Further water savings can be achieved through the use of cycling on frost nights. Cycling is a method of having the pumps automatically turn on/off based on temperature fluctuations during the night, which can be effected directly by the water being applied to the bog through the sprinkler system. The length of time and frequency that the pumps turn off is dependent on the ambient air temperature (on a hard frost night, the pumps will not cycle due to the extreme cold) and the grower's high/low temperature settings. If the grower sets the stop temperature too far from the start, there may never be enough temperature differential to initiate cycling. Of the 11 grower participants, 2 are now consistently attempting to cycle their systems during frost events, 6 are experimenting with cycling but are not yet comfortable enough with the technology to rely exclusively on it and 3 have not yet tried to cycle.

Growers that have used cycling report an average savings of 25-35% water use on a given frost night. The savings vary tremendously, dependent upon the grower's temperature high/low differential setting and the temperature. The data show a range of savings of 0 –67% compared to non-cycling. A typical frost event is 6-8 hours in duration and can last up to 12 hours in extreme cases. In the latter instance, cycling would be minimal to non-existent as most likely the temperature is quite low for the duration of the night. However, if the growers are obtaining a 25% savings in water on an average frost night (7 hours) that is an additional savings of 8,000 gallons of water per acre for a conventional irrigation system using impact heads and 6,700 gallons per acre for pop-up heads.

*Frost Night Summary*

In summation, if a grower were to employ all of the cultural practices noted above for water savings opportunities with an auto-start system for frost control, significant water savings could be attained. The savings would depend largely on the crops stage of development and climatic conditions but assuming a typical growing season for southeastern Massachusetts, a cumulative water savings could be in excess of 530,000 gallons per acre per year. This would be for a conventional system with a 50x60 spacing (50 psi) and 15 impact heads (Rainbird) per acre, pumping out 5.2 gallons of water per minute per head.

**Water – Irrigation Event**

The Internet-based automation system allows growers to schedule up to three irrigation events for any given day. Irrigation is generally conducted in the early morning hours and the timing is not nearly as critical as a frost event. However, there can still be numerous pumps at multiple locations that need to be turned on/off. Scheduling an irrigation event or starting/stopping pumps remotely at the same time, does save water. Invariably, if a grower is targeting an irrigation event for a 3-hour duration on some locations and 4 hours on other bogs, some pumps will be left on for longer than the desired 3 hours, as the grower travels to multiple locations. Automation does allow for water savings in this situation. Some of the participants reported savings of about 30 minutes on a typical irrigation event where they are irrigating most of their bogs at once. This represents about 2,000 gallons of water saved per acre for each irrigation event.

**Fuel**
Since the pumps are running for less time, growers can save on fuel expenditures or electricity.

**Labor**
Less labor is required on a frost night or to start a series of irrigation events. The labor savings could be fewer workers required at a given time or less time spent.

**Safety**
Auto-starts alleviate the need to rush to different pumps/locations to start the systems. On frost nights, driving on narrow bog roads in the dark is a safety concern.

**Mileage**
Avoiding the need to drive to different locations, which often involves different towns saves on mileage, plus wear and tear. Several grant participants reported driving in excess of 100 miles on a frost night. This would equate to an approximate 150 gallons of fuel savings per vehicle per season (based on an assumed 20 mpg rating).

**Productivity**
Staying out on a frost night results in tired workers the next day, which is further magnified when consecutive frost nights are encountered. Automation diminishes the amount of time spent out on a frost night or may allow some companies to schedule shifts, as noted in the decreased labor needs noted above.

**Economic**
One participant shared his opinion that starting pumps more accurately on a frost night can save him 1% of the crop per year. This economic observation could reasonably be applied to most growers. 1% savings in crop to this particular grower would represent over $15,000 per year in savings.

**Pump Life**
The life or required maintenance of an irrigation pump may be extended by proper start-up/shut-down times set within the system. This applies to gas or diesel pumps. In order to save time, growers often skip proper pump warm-up or cool-down. The warm-up/cool-down settings in the Internet-based auto-start system insure that the pump is always run at the optimal performance standards.

**Chemigation**
Cranberry growers apply the majority of their pesticide applications through the sprinkler system, called chemigation. As the chemicals are applied to different zones of an irrigation system, valves are open/shut accordingly. In order to maintain consistent pressure and not potentially blow out irrigation pipes, the grower needs to run into the pump house and cycle the pump up or down

depending on how many valves remain open. This is a difficult task and can diminish the effect of the application as too much or too little water may be applied at any given time until the pump is running at the needed RPM. Because the Internet-based auto-start system has the optimal RPM pre-set into the system, the pump automatically adjusts its speed as valves are opened or closed. This provides ease of use to the grower and increased efficacy of the application.

## COMMUNICATION/EDUCATION OUTREACH

Several different communication methods were employed during the duration of the grant. Three grant participant user sessions were held in order to obtain feedback, answer questions, allow group learning, share ideas, etc. In one of the user sessions, KC Enterprises was present to personally interact with the group, answer questions, hear how the growers were using the systems and better understand user issues/concerns. Individual grower interviews were also conducted at the conclusion of the grant, allowing an opportunity for a frank discussion on how each grower is using the system, comfort level, experiences, etc.

Furthermore, a panel presentation was conducted on irrigation automation at the Cape Cod Cranberry Growers' Association (CCCGA) winter meeting in March 2006, attended by over 300 cranberry growers. Grant participants and KC Irrigation comprised the panel, which included PowerPoint presentations and a questions and answers component. The University of Massachusetts Cranberry Station also had a panel discussion on irrigation automation at their winter meeting, held in January 2007 and attended by over 200 cranberry growers. This panel was similarly constructed.

During the course of this grant, growers have also been exposed to irrigation automation technology through KC Enterprises, Ltd. They have been a vendor at the CCCGA winter meeting (2006 & 2007), the CCCGA Annual Meeting (2006 & 2007), as well as an advertiser in the CCCGA Bogside newsletter, sent to over 400 members of the CCCGA.

## DATA

Obtaining specific and consistent data points over the course of the grant proved to be problematic. Much of the data were obtained through group user sessions and individual interviews. This information is considered to be largely reliable and directionally useful but certainly anecdotal. Five data loggers were installed to track pump start/stop events, collecting total run time. Four different locations were used, 3 automated systems and one conventional non-automated system to be used as a control. The systems were in place in the fall of 2006 but were not apparently calibrated correctly and yielded inconsistent information. The systems were further investigated and utilized during the spring frost season of 2007. All but one of the locations yielded results that were viewed as reliable and corroborated by the participating grower. There was a maximum of 11 data points that were useful to compare automated vs. non-automated systems. Due to the different geographic locations, different varieties of cranberry and different managers, not every bog required frost prevention. However, from the limited data points, it can be seen that in most cases water savings can be obtained through cycling (see Table 4).

**Table 4**

| | **Location 1 (non-automated)** | **Location 2 Automated** | **% Diff. from non-automated** | **Location 3 Automated** | **% Diff. from non-automated** | **Location 4 Automated** | **% Diff. from non-automated** |
|---|---|---|---|---|---|---|---|
| 5/2/2007 | 3:41:38 | 1:13:00 | -67% | | | 0:42:20 | -81% |
| 5/3/2007 | 3:28:49 | 1:42:00 | -51% | | | 0:52:28 | -75% |
| 5/4/2007 | 7:55:11 | 8:07:00 | 2% | | | 1:40:16 | -79% |
| 5/6/2007 | 10:23:49 | 8:42:00 | -16% | | | 11:29:55 | 11% |
| 5/13/2007 | 7:00:16 | 6:54:00 | -1% | | | 8:21:20 | 19% |
| 5/21/2007 | 7:29:13 | 1:57:00 | -74% | | | 5:39:10 | -24% |
| 5/22/2007 | 6:54:08 | 2:25:25 | -65% | 9:02:31 | 31% | 3:42:17 | -46% |
| 5/24/2007 | 0:50:13 | 0:56:07 | 12% | 0:52:43 | 5% | 0:43:16 | -14% |
| 5/28/2007 | 3:35:37 | 0:19:24 | -91% | 0:15:25 | -93% | | |
| 5/29/2007 | 1:49:21 | | | | | 0:25:54 | -76% |
| 5/31/2007 | 2:11:28 | | | 2:00:56 | -8% | | |
| | | **Average** | **-39%** | **Average** | **-16%** | **Average** | **-41%** |
| | | **Median** | **-51%** | **Median** | **-2%** | **Median** | **-46%** |

Note: Table 4 represents data loggers installed on different pumps to determine total run-time for that particular pump. “Location 1” was a conventional, non-automated pump that served as a control. The first column in Table 4 above is the date of a frost event. The time stamps represent the total hours/minutes/seconds that the pump ran during the frost event. In some instances a particular pump system did not frost protect on nights where other systems did, making comparisons difficult.

Additional data was obtained from grower participants but was anecdotal. Table 5 represents information obtained from a participant during the spring of 2006 growing season. It captures 2 frost nights where a conventional, non-automated system was compared to their auto-start systems. The percentage savings shown in the last column represent pump run-time that was saved due to the cycling on/off of the automated pumps.

**Table 5**

Grower participant pump run-time savings, conventional system versus automated – 2 nights, spring 2006

| Pump Location | Frost Duration | % Savings |
|---|---|---|
| 1 | 9 hours | 38% |
| 2 | 9 hours | 52% |
| 3 | 9 hours | 24% |
| 4 | 9 hours | 24% |
| 1 | 10 hours | 38% |
| 2 | 10 hours | 67% |
| 3 | 10 hours | 9% |
| 4 | 10 hours | 36% |

Table 6 below is a compilation of information gathered from the grower participants. The table displays the total number of acres automated by grower, the types of heads they employed, the degrees above frost tolerance that they set their automated system to start, whether they employed cycling on frost nights, and if they did cycle, what percentage of total run-time did they save versus a non-automated system on their farm.

**Table 6**

| Company | Total Acres Automated | Total Acres Sprinkler Impact Heads | Total Acres Sprinkler Pop-Up Heads | Start ° Above Tolerance | Cycling | Est. Cycle Savings* |
|---|---|---|---|---|---|---|
| Grower A | 825 | | | 2° | Yes | 30% |
| Grower B | 161 | 151 | 10 | 2° | Some | 40% |
| Grower C | 195 | | | 2° | Some | 25% |
| Grower D | 161 | 70 | 91 | 2° | Some | 60% |
| Grower D | 41 | | | 4° | No | NA |
| Grower E | 107 | | | 3° | Some | 50% |
| Grower F | 144 | 144 | | 1° | Yes | 32%** |
| Grower G | 55 | 45 | 10 | 2° | Some | 40% |
| Grower H | 24 | | 24 | NA | No | NA |
| Grower I | 50 | | | 5° | Some | 25% |
| Grower J | 72 | | 72 | NA | No | NA |
| **Total** | **1,835** | **410** | **207** | | | |

* Estimate provided by grower for spring '07 frost nights; % of total pump run-time savings as compared to a conventional, non-automated system

** Obtained from data loggers for spring '07 frost nights

## CONCLUSIONS

Overall, the cranberry growers who participated in the CIG process have been satisfied with the irrigation automation technology. Based on feedback from the participants, all have concluded that irrigation automation technology is a vital component of their operation and is necessary to reduce water usage and its resultant savings in fuel and labor. Although some fine-tuning of existing systems is needed, the systems are meeting the grower's needs.

Growers utilizing irrigation automation technology are saving water, the amount saved depends on the climatic conditions, willingness to start pumps closer to tolerance on a frost night and/or cycle the pumps, and the size of the operation (number of pumps to start). Of the eleven grower participants, all had numerous pumps and locations. Automating pump start/stop is saving these growers 2-3 hours of run time on a frost night. On a marginal frost night, these growers are able to hold off starting their pumps later as they don't need to visit the multiple locations, just in case the temperature drops below threshold. Assuming a 2-hour pump start/stop savings, 30 frost events in a typical year, and an irrigation system pumping out 78 gallons of water per minute per acre, growers can save over 280,000 gallons of water per acre over the course of the growing season. This figure does not represent any potential savings from cycling on frost nights or irrigation water savings.

Automation systems have the greatest impact for growers who need to travel in order to reach their pumping station (i.e. growers who do not live next to their bog) or for those growers with multiple pumps and/or multiple locations. By automating their pumping systems, they conserve time, which ultimately is conserving water. This savings in time enables growers to not have to start their systems too soon in order to protect their crop from a frost event. A grower can receive frost damage in as little as 20 minutes, especially during the spring growing season. Each grower in this grant program had multiple pumps to start and various locations. The benefits of an auto-start system to a grower not facing these physical limitations is primarily convenience, pump longevity (through proper pump start-up/shut-down for gas and diesel systems) but also water savings through confidence, as the grower could set their system to start just above frost tolerance, proving more timely (and likely accurate) than manually temperature monitoring.

## NEXT STEPS

Many of the grower participants are interested in refining the current automation systems and furthering their capabilities.

- Cycling: More research and experience in cycling systems on frost nights is needed to insure that potential cold damage is minimized or avoided in a variety of climatic conditions. Some growers experimenting with cycling noted that plant growth seemed slowed compared to conventionally protected bogs.
- Wireless Temperature Probes: Would allow growers to precisely place the probes in the coldest location in the bog, especially as the cold spot moves as weather conditions dictate.
- Reporting: Online reporting capabilities are needed to allow growers to quickly ascertain how long their pumps ran, which locations, etc. This is especially relevant for large growers with multiple locations.
- Inline Pressure Sensors: Enable a grower to determine where there was a problem with a water line and potentially to open/shut zones for irrigation.
- Soil Moisture Probes: Although the data are not yet understood, the use of soil moisture probes would enable growers to irrigate automatically based on soil conditions.
- Gate Control Valves: Automating gate control valves would allow growers to manage water either remotely or automatically based on water pressure (height).

# APPENDIX A
## Internet (cellular) System Photographs

**Control Box and Pump**

**Solar Panel at Pump House**


**Antenna Mounted on Pump House Roof**

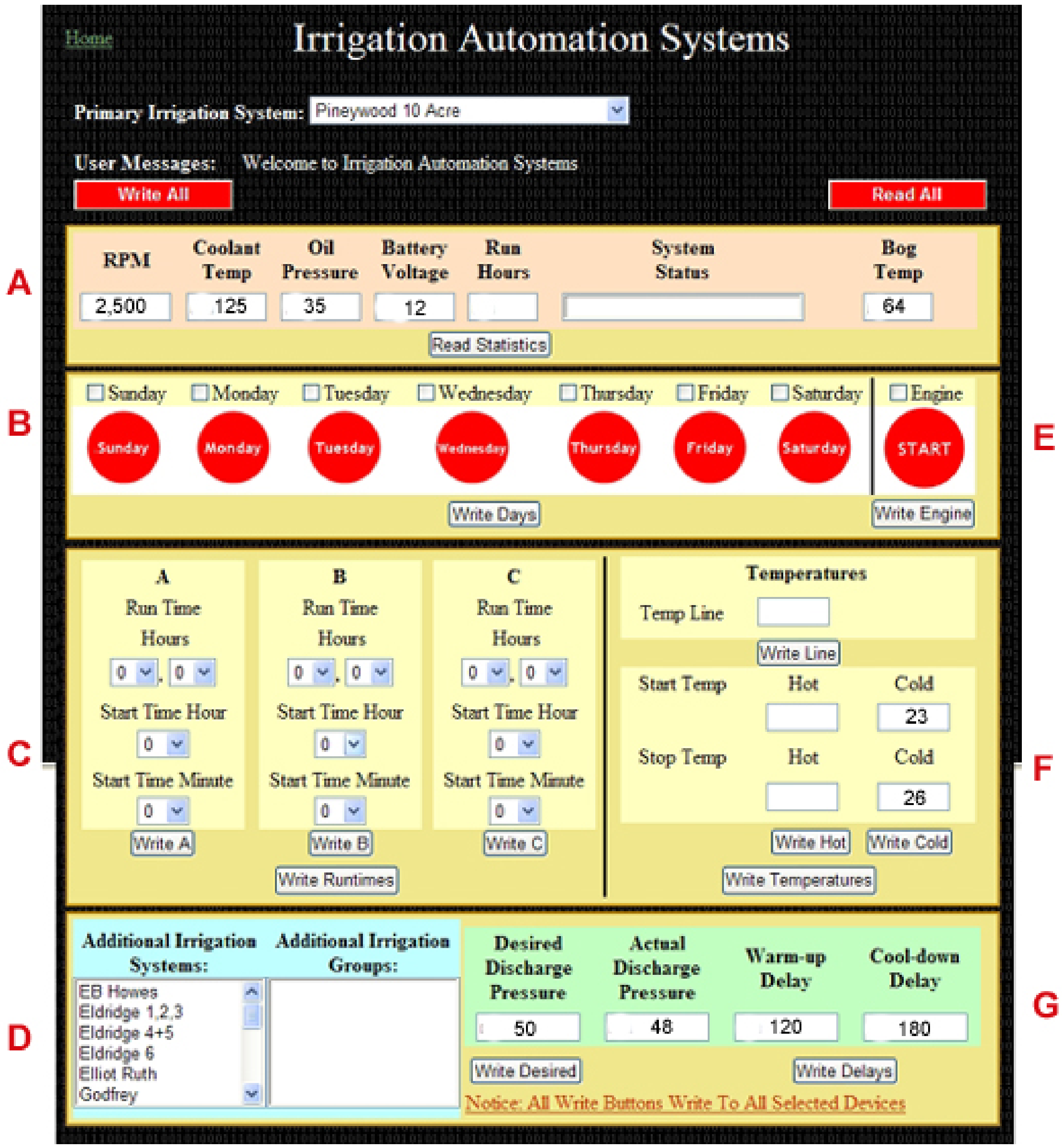

**Controller in Pump House**


**Metal Screen Door for Airflow/Vandals**


**Metal Screen for Window Airflow/Vandals**


**Temperature Probe (thermistor type)**


**Laptop Connecting to Remote Server**




**Screen Shot of Web Interface (system refreshes manually, takes approximately 8-seconds to re-load data)**

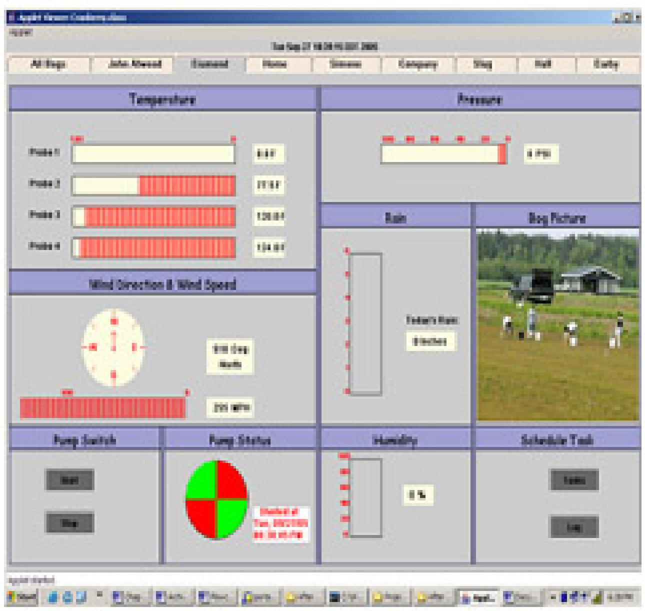
**A: Pump gauge readings, current bog temperature**
**B: Select days of the week to turn on pump (irrigation event)**
**C: Select duration of irrigation event, schedule up to 3 events**
**D: Create groups of irrigation systems, allows for duplicating settings across different auto-start systems**
**E: Start/Stop pump immediately from remote web interface**
**F: Set desired temperature start/stop settings (for frost control; set desired start/stop based on high temperatures (used to cool bogs during excessive heat, most growers don't employ this practice)**
**G: Set desired water discharge pressure and warm-up/cool-down times**

## Appendix B
**Radio System Photographs**

**Pump House**

**Weather Station**

**Temperature Probe (thermistor type)**




**User Interface Screen**

**Irrigation of a Cranberry Bog**