



Crown Agriculture Solutions
Farming made simple

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July 18, 2019

Dr. Andrew Rawicz
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V5A 1S6

Re: Design Specification for Crown Agriculture Solutions

Dear Dr. Andrew Rawicz:

The attached document is the Design Specification for Crown Agriculture Solutions. CAS' goal is to significantly enhance crop yield at a fraction of the cost to the farmer further making farming effortless. CAS' first product is CNN. CNN is a network of sensors spread throughout the farm providing the farmer necessary data thereby significantly improving crop yield.

The Design Specification is to provide an exhaustive list entailing the implementation of CNN. Included are hardware, software, and firmware design choices and justifications thereof. Further included are a Test Plan in conjunction with a User Interface Appendices. Test Plan entails Tests conducted on parts separately further on integration thereby ensuring a robust CNN and reducing needless engineering hours past production. User Interface (UI) is a powerful feature of CNN and is expected to complement an intuitive UI with a unique guidance making the farmer duty effortless. The attached UI Appendix entails an exhaustive list of UI features.

Crown Agriculture Solutions is operated by an innovative marketing personnel with a broad skill set to design and produce customer focused products. This capstone project proposal is prepared in partial completion of the graduation requirements at the Simon Fraser University in the Engineering Science program.

If you have any questions or concerns regarding my proposal, please feel free to contact me by my direct line at (778) 840.8462 or via email at mike_saad@sfu.ca

Sincerely

Maikel Saad



Crown Agriculture Solutions

Farming made simple

Design Specifications for

Crown Agriculture Solutions

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Submitted To

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Prepared On July 18, 2019

ABSTRACT

Farmers abroad know very little about the various needs of different areas in the farm. Consequently, annual yield is poor. Further the average farmer needlessly spends folds annually on irrigation as well as every aspect of the farming process from seed to harvest.

CAS has formulated a comprehensive solution to solve all the aforementioned problems encountered by farmers. CNN helps farmers generate quality crop from almost every seed planted by empowering the farmer with the tools necessary to do so. Further CNN will cut all costs to only a small fraction. This means superior quality crops, higher percentage yield, at a negligible fraction of the costs!

The Design Specification is to provide an exhaustive list entailing the implementation of CNN. Included are hardware, software, and firmware design choices and justifications thereof for all three stages of CNN development. Further included are a Test Plan in conjunction with a User Interface Appendix.

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Introduction & Background

Project goal is to engineer a way to extract information from a farm with an effortless and productive manner. Collected data is intuitively presented to the farmer to enhance their crops. The type of data, volume of data, speed of access, will be the deliverables for this project. Project background stems from the laborious task of farmers to manually and visually judge and collect data and this leads to inefficiency, poor and limited access to data, as the size of the property increases. My goal is to minimize physical efforts to collect data with initial capital cost and maximize productivity for the farmers.

This product is a comprehensive solution to all the challenges faced by farmers across the globe. Farmers suffer from low yielding and increasing costs to the point that most barely breakeven. CNN's primary goals is to reverse this experience by providing high resolution data and take control of the crops and expect healthy yield year after year. Using CNN means deploying a method which leads to a very healthy crop yield at a very low costs. Furthermore, CNN means a significant reduction in tedious labour.

Scope

The Design Specification is to provide an exhaustive list entailing the implementation of CNN. Included are hardware, software, and firmware design choices and justifications thereof for all three stages of CNN development. Further included are a Test Plan in conjunction with a User Interface Appendices. Test Plan entails Tests conducted on parts separately further on integration thereby ensuring a robust CNN and reducing needless engineering hours past production. User Interface (UI) is a powerful feature of CNN and is expected to complement an

intuitive UI with a unique guidance making the farmer duty effortless. The attached UI Appendix entails an exhaustive list of UI features.

Intended Audience:

Intended audience of this Design Specification should only include the proprietor, financing institution, legal representative body, and examining professors.

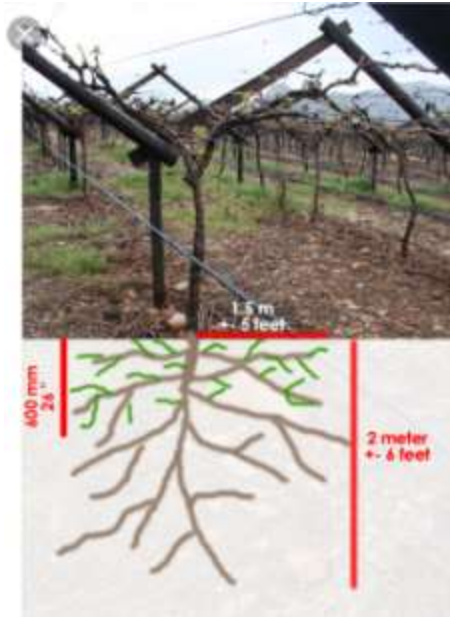
System Specifications:

Use Case

Initially, the farmer will have three options. Periodic notification, possibly daily, Interrupt notification of issues as they arise, or a combination of both. Upon opening the application farmer immediately understands areas in farm needing hydration. Farmer then addresses such issues thereby cutting hydration costs and reducing dehydration.

High Level Design

CNN is comprised of a network of nodes, central nodes, and a base station. Each node is in communication with its corresponding central node. Only central nodes communicate with base stations. Nodes report soil moisture data collected by sensor to central nodes. Base station collects and interprets data from central nodes and sends action to App. The farmer receives instructions via App. Each node is positioned at the center of each 4 vines. Effective soil moisture readings for vines require sensor to be 0.7 meters deep in the soil. Spacing between vines in a vineyard 3 meters. A vine's roots are 2 meters deep and 1.5 meters wide. Hence node density to be 3m x 3m or approximately 10m².



Functional Justification:

Every aspect of CNN has been wisely chosen to enhance performance and cut costs. SPI is chosen for low bandwidth combined with long range antenna to accommodate 1000 hectare farms. The choice for base station hardware is Raspberry Pi zero W for many reasons. Due to the need for many base stations accommodating large node volume there is a need for cutting costs as well as power. The chosen hardware also comes with dual SPI port. Moving forward with such hardware paired with python delivers a plethora of readily available source code online making such a decision the wiser choice. Further python is intuitive and requires minimal engineering hours. App is programmed via C++ thereby cutting engineering hours.

Safety and Sustainability

Safety is ensured in CNN via consistent firmware and software updates paired with hardware redundancies. CNN boasts a robust system in every aspect. Thereby guaranteeing data accuracy and precise farmer action.

Environment safety is a priority at CAS. CNN is sold with an optional upgrade which is 100% safe for the environment.

Mechanical Design

Enclosure

Plastic Node enclosure will not have any sharp edges that could potentially harm an animal and thereby leaving a rotting carcass in the field. Enclosure will also be heat and moisture safe. At bottom of enclosure is the soil moisture sensor. Batteries shall be directly above sensors. Batteries are strategically placed for minimum center of gravity. At uppermost will be microcontroller. Enclosure shall be pole-shaped and inserted deep into soil for stability.



Node Enclosure

Hardware Design

Node

sensor

Each node includes a soil moisture sensor that should not rust. sensor should be capable of measuring a threshold of 20% in soil moisture reduction. The sensor of choice utilizes capacitive sensing. Capacitive sensors do not rust thereby delivering reliability and no maintenance nor replacement during product lifetime. Sensor is by DFRobot with part number SEN0193. Sensor soil moisture voltage reading is between 0 and 3

volts. 0 volts corresponding to very moist soil and 3 volts corresponds to very dry soil. Threshold is 0.6 Volts. Upon threshold soil must be hydrated.



Antenna

Antenna choice is very difficult in such an application. Farm size is approximately 3km x 3km. To appreciate the antenna choice, a comparison of alternative options is a must. BLE and WIFI both have a limit of 100m in open space. BLE has a mesh networking option which can accommodate a large number of nodes. However, as the number of nodes increases a bottleneck situation arises thereby crashing the network. WIFI also has its faults. As the number of repeaters increase the number of IOT devices increase at the cost of bandwidth thereby creating, again, a bottleneck situation. Further repeaters consume a large amount of power. Due to the limited range there is a need for more nodes thereby increasing system cost significantly.

Antenna of choice communicates with microcontroller via SPI and is accompanied with an RF module thereby cutting engine hours significantly. Antenna of choice is by NORDIC semiconductor. Antenna part number is nRF24L01+. Antenna range is 1km thereby eliminating the need for mesh networking as well as repeaters. However, there is a need for 4 central nodes acting as repeaters.



Microcontroller

As there is a plethora of microcontrollers available in the market, the best choice is the least costly choice in this application due to the high number of nodes. However, one must consider many design restrictions

before a choice is decided. Design restrictions include programming memory, future peripherals, on-chip-memory for sensor readings, number of ADCs and DACs, number of I/O pins. If a wise choice is initially made, costs will be cut significantly. Initially one must choose the least costly microcontroller which has all necessary attributes for application. Further if one considers future endeavors and chooses a microcontroller capable of such endeavors, costs will be cut significantly due to the high volume of a single microcontroller and vendor and a significant cut in engineering hours. Alternatively, changing microcontrollers every release will increase costs due to more engineering hours and less bulk purchasing power. After careful consideration the PIC16F18875 is the chip of choice.

This microcontroller is the least costly solution for CNN needs. Although it has capability of many peripherals, it suffers from programable memory; hence its inexpensive nature. A deciding factor for the microcontroller only contains the minimum programmable memory necessary due to the expensive nature of memory. Further a need for the microcontroller to be programmable by C extensively cuts engineering hours.



Base Station:

Base station will collect high volume of data and interprets such data in order to generate a readily available report for the farmer. there are two conflicting criteria for choosing a board to accomplish required tasks. Board of choice must be inexpensive without sacrificing capability. Device of choice must be capable of WIFI for farmer Application. The board of choice is the most capable Raspberry Pi available. This Raspberry Pi 3 model B+ delivers a 1.4GHz quad core paired with BLE 4.2, WIFI and 2 SPI ports



Battery:

Each node must endure up to 3 years of service. To accomplish this, a node must be equipped with 4 AA batteries. Each battery must have 2600mAh. The battery company of choice is ACDelco. Battery model number is AC255.



Software Design

Application:

The only method of communication between the farmer and CNN is the App. This App interprets base station report thereby updating the UI. Base station report is delivered to the App only upon farmer opening the App. Nodes report to base station only when threshold reached. The App will be programmed using Python language in order to minimize engineering hours; since python has a plethora of open source code available online paired with simplicity in software development

Initially Node microcontroller boots and reads sensor soil moisture level. If sensor reading differential from previous reading is beyond

threshold then node reports to base station. However, if threshold is not achieved, previous differential is update until differential reaches threshold in a sensor reading. Once a threshold reading is achieved, and node updates base station, microcontroller will be in "stand-by" mode to conserve power. Sensor reads soil moisture level once every preset time period. Microcontroller is awakened when the timer completes the time period.

Communication:

Due to High volume of nodes, CNN needs a communication standard that is capable of long range and low bandwidth. Long range is required due to the size of commercial farms being 1000 hectares. Low bandwidth is necessary for base station to communicate effectively with all nodes. Therefore, the best communication standard of choice is 2.4 GHz ISM band since it does not require licensing. Such a decision is optimal for CNN because there is no outside interference in a farm.

Firmware:

Firmware checks for each node will be done by comparing node firmware with a bug-free firmware version in base station. This can also be accomplished by dual firmware on node. Firmware acquires an analog signal from soil moisture sensor and converts to digital format using an ADC. Digital reading is compared with threshold. microcontroller sends report to base station upon threshold via ISM. However, if threshold is not reached microcontroller returns to sleep mode and timer is reset. Due to complexity in programming, firmware checks and update will be conducted in the production stage.

Conclusion:

Design specifications document for CNN clearly defines in detail hardware, firmware, and software decisions taken in designing CNN. Decisions and

justifications thereof have been clearly defined. CAS boasts a powerful delivery of CNN's first version to market including an intuitive one-click user interface paired with a network structure which is virtually error-free due to its' simplicity. Hardware components have been carefully chosen after rigorous research to meet design criteria delivered at the most cost-effective solution. Software and firmware choices have been carefully considered as to minimize engineering hours and memory utilized thereby cutting costs to a minimum.

TEST PLAN APPENDIX

Unit Testing

COMPONENT	TESTING SCENARIO	ACCEPTANCE CRITERIA
AA batteries	Insert 4 AA batteries in parallel in holster.	VCC reads 1.5 Volts
Microcontroller	Write to register, read from same register, and compare.	Values should match
Raspberry Pi	Insert 5V into USB power input of RPi	RPi starts as required. RPi behaves as required.
Sensor	Apply incremental soil moisture levels and read sensor data	Sensor readings accurate to within 2%
ADC	Acquire different Analog data and observe Digital data output	Accurate to within 2%

Integration Testing

component	Testing Scenario	Acceptance Criteria
Two Raspberry Pi BLE communication	A statement input through keyboard to 1 RPi and sent via BLE to second RPi. And reverse	Keyboard input is sent successfully to

	situation.	other RPi
Base Station communication with multiple nodes	Base Station reads reports from 6 nodes simultaneously via ISM	Information communicated is confirmed
Sensor acquisition	Voltage output is read for a reference soil moisture level. A second voltage reading for higher moisture level. A third voltage reading for lower moisture level.	Voltage reading from sensor is inversely proportional to soil moisture
Analog to Digital Converter	Three analog readings will be conducted and digital output will be observed	Output is proportional to input
microcontroller sensor data acquisition	microcontroller acquires data from ADC. ADC input to microcontroller is displayed on screen. ADC output readings are manually read.	ADC output is compared with RPi screen output. Matching data is a success
Node sends correct sensor data to base station via BLE	Base Station data is compared with node data.	Successful if data is matching
Base station can pair each node with its report	Two node reports acquired by Base Station are compared with report acquisition from nodes directly.	both reports match corresponding nodes
Base Station can incorporate two data acquisitions into a report	Report is compared with data acquired from nodes	Report format is correct
Base Station can continuously incorporate data into	Report is continuously displayed on a screen. Data from report is compared with	Format and data are correct

report	node data	
App can display simple data on android mobile screen sent via WIFI from a computer	App output is compared with data sent from computer via WIFI.	Matching data is a success
App can read simple data from Base Station via WIFI and display on mobile screen	Base Station output is displayed on a screen and compared with App acquired data on mobile screen	Matching screens are a success
App can display a farm Map based upon simple zones.	Base Station zone boundaries are compared with App map zone boundaries	A correct map is a large milestone
App can display different zone boundaries on map.	Different reports from base station containing different zone boundaries are sent to App.	All maps are as defined by report
App can acquire report from base station and present map to farmer within 3-5 seconds	Different report sizes are to be sent to App. Once farmer opens App, a timer is started and largest report time is recorded	Largest report time should be approx. 5 seconds
App asserts farmer within 5-10 seconds upon area irrigation requirement completion.	Assertion is tested by determining if irrigation is complete. Two situations will be tested. Firstly if irrigation requirements are complete and second if irrigation requirements are incomplete	Asserts complete and does not assert incomplete

User Acceptance Testing

Upon completion of gamma phase, several vineyards will be equipped with nodes for 1 acre each for farmer evaluation purposes. this will be a gift for many reasons. Justifications include customer adoption of system for complete farm, customer referrals, requests for upgrades.

Feedback acquired will be focused on how to improve the User Interface as this is the only method of communication between farmer and system.

Upgrades include an environmentally friendly version with rechargeable batteries and biodegradable casing material. Further a farmer may commit to an ongoing contract with a complete upgrade every three years or as desired.

User Interface Appendix

Introduction

Following is an appendix detailing CNN's powerful user interface. Included is a detailed description of the User Interface, steps taken by farmer to navigate through the Application. In addition, included is the basic requirements for operating CNN, feedback from farmers, and continuous refinement towards CAS's goal of perfect simplicity.

Analysis

User Analysis

CNN delivers a User Interface with powerful simplicity such that there are no cognitive requirements to operate CNN.

- Farmer accesses his smartphone or Tablet.
- Farmer sees CNN button on first screen
- Farmer selects CNN button
- User Interface, as described below, is launched.

Technical Analysis

CNN's powerfully intuitive User Interface is described in extensive detail in the following 7 elements of UI interaction.

Discoverability

CNN UI is very simple to even the novice user. Upon farmer opening app the screen displays a map of zones. Each zone corresponds to one water

pump. Each node representing a vine area requiring irrigation will be represented by a black dot on the map. Farmer will activate zone pumps according to farmer's discretion.

Feedback

Once zone is fully irrigated app will assert completion to farmer. pump will shut down either automatically or via farmer decision. Shutdown will be asserted to farmer.

Conceptual

Upon viewing map farmer will activate associated pump by clicking on zone in touchscreen. A pop-up will ask for pump shutdown, or manual shutdown, once irrigation is completed

Affordances

CNN boasts a simple UI to a novice user commanding a powerful system paired with a robust network of nodes. Further a node network is tailored for CNN

Signifiers/Mappings

Upon farmer selection of zone to irrigate pump will start irrigating selected zone. During this process, a node adequately irrigated will disappear from the map. Once a zone is irrigated zone color will become blue thereby asserting farmer zone is irrigated.

Constraints

Once nodes are placed in soil, farmer cannot access nodes simply because nodes must be inserted 0.7 meters deep in soil to reflect soil moisture level correctly. A node is a one-piece enclosure for robustness also. Customer also cannot access or modify base station. This is in part due to the fact that farmers are novice computer users. Further collaboration with other companies may damage CNN thereby sacrificing vines, needless costs in irrigation and complete system malfunction. Farmer only has access to app provided by CAS.

Engineering Standards

- For communication purposes, we will use 2.4 GHz frequencies in the ISM band which do not require licensing.
- ETSI EN 300 328: Covers wideband transmission systems; Data transmission equipment operating in the 2,4 GHz ISM band and using wide band modulation techniques
- IEC60730: Covers equipment, such as controls for household electronics.
- ISO 9241-303: Requirements for electronic visual displays
- IEC/TR2 61438:1996 - Possible safety and health hazards in the use of alkaline secondary cells and batteries - Guide to equipment manufacturers and users

Usability testing:

Analytical

- A side bar constantly present, providing the farmer the option of a **map** or a **list**.
- CNN app boasts a one-click UI. Meaning only one path per screen

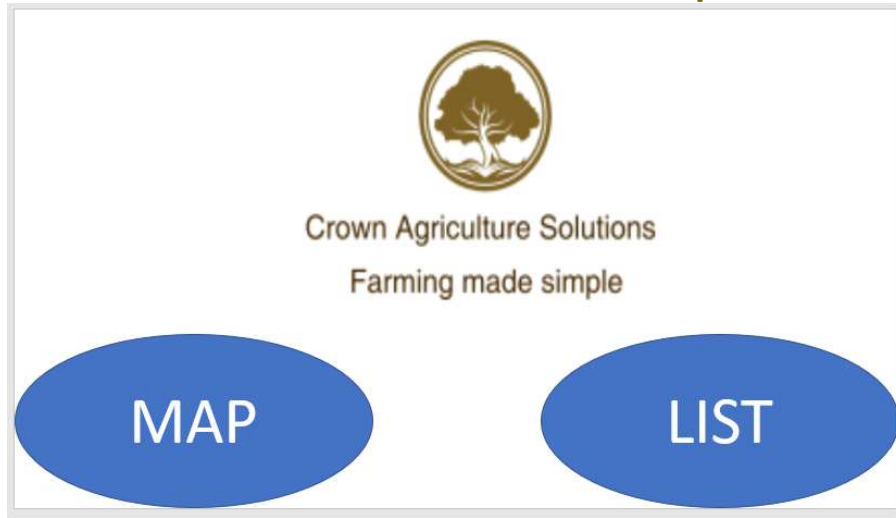
thereby providing a powerfully intuitive User Interface (UI).

- Once app is opened, a map will be displayed with a zone for each pump.
- Each zone will have a checkbox for irrigating more than one zone simultaneously.
- All nodes within close proximity will need irrigation at same time interval and thereby **conserving water usage** per zone.
- Clicking anywhere in the zone other than the checkbox the zone will be displayed on full screen thereby viewing all nodes in zone requiring irrigation as **black dots**.
- Dots indicate that sensors are communicating with the base station and identifying areas in need of irrigation. Noting that sensors provide data regarding the soil moisture content.
- Total number of nodes requiring irrigation is also displayed and only one button on screen displaying "irrigate".
- A pop-up will ask "**shutdown pump manually**" upon decision map will only have "**stop**" button.

Empirical

- Nodes have no sharp edges.
- Nodes are inserted 0.7 meters into soil. Only a short antenna is above ground. Such a structure is robust from storms, animals, and farm vehicles.
- Reliability is easily achieved due to the structure of CNN. Communication is initiated Only when threshold is achieved terminated only if 'ack' packet is received.
- Batteries are enclosed such that any leaks are not harmful to soil and vines.
- A capacitive sensor is chosen rather than a resistive sensor because a resistive sensor rusts and produce less accurate readings.

User Interface Example

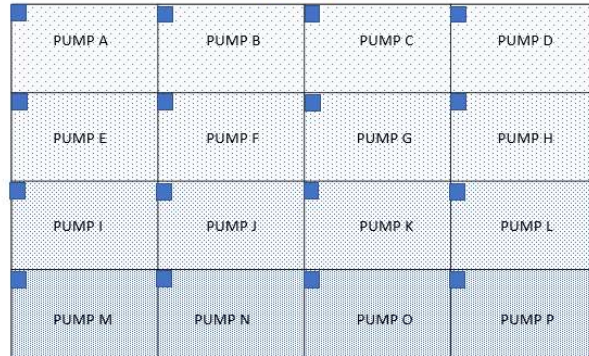


LIST

PUMP ID	NODES AT THRESHOLD	PUMP ID	NODES AT THRESHOLD	PUMP ID	NODES AT THRESHOLD
PUMP A	100	PUMP F	75	PUMP K	155
PUMP B	50	PUMP G	200	PUMP L	30
PUMP C	25	PUMP H	20	PUMP M	90
PUMP D	125	PUMP I	60	PUMP N	10
PUMP E	150	PUMP J	175	PUMP O	50

MAP

MAP



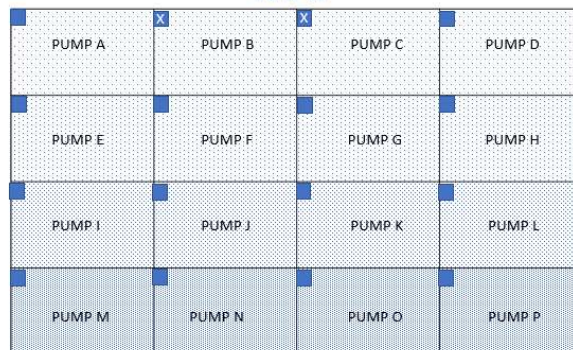
LIST

LIST

PUMP ID	NODES AT THRESHOLD	PUMP ID	NODES AT THRESHOLD	PUMP ID	NODES AT THRESHOLD
PUMP A	100	PUMP F	75	PUMP K	155
PUMP B	50	SHUTDOWN PUMPS MANUALLY? YES NO		PUMP L	30
PUMP C	25			PUMP M	90
PUMP D	125	PUMP I	60	PUMP N	10
PUMP E	150	PUMP J	175	PUMP O	50

MAP

MAP



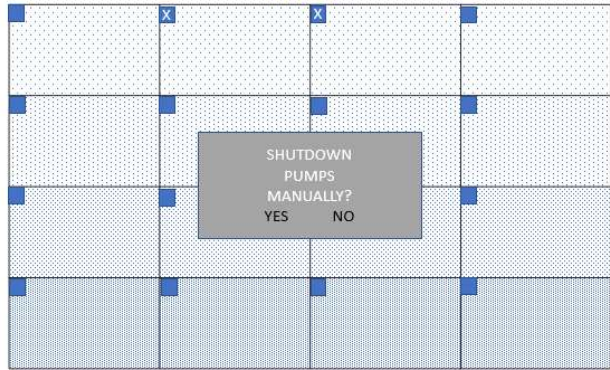
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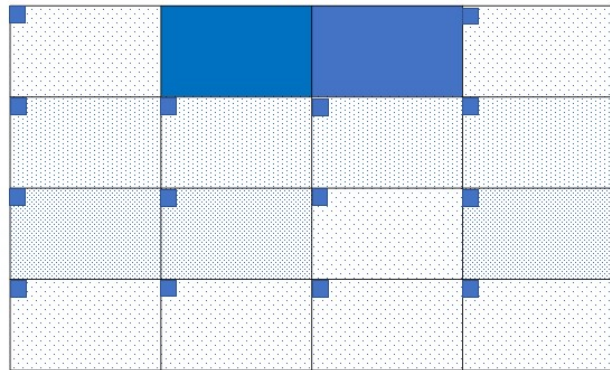
MAP

MAP



LIST

MAP



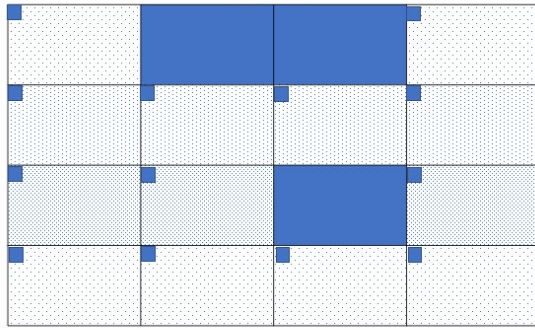
LIST

PUMP K



55 VINES

MAP



LIST