Automation of Surface Irrigation Systems

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UC Cooperative Extension-Imperial County
UC Desert Research and Extension Center
Holtville, CA

Phase 1: Cooperating Partners- Imperial Valley (2011-Date)

- UCCE/UC Desert Research and Extension Center (DREC)
- US Bureau of Reclamation Yuma Area Office Water Conservation Field Services Program
- US Bureau of Reclamation Science & Technology Program
- US Bureau of Reclamation Hydraulic Investigations and Laboratory Services Group
- Control Design Inc. (DREC), Rubicon Water (DREC & commercial field)
- Alfalfa Grower

Phase 2: Cooperating Partners (2014-2017)

- UCCE (Imperial, Kern, Fresno, and Yolo) and UCD (Daniele and Dan Putnam)- four locations
- California Department of Water Resources
- US Bureau of Reclamation Science & Technology Program
- US Bureau of Reclamation Hydraulic Investigations and Laboratory Services Group
- Control Design Inc., Rubicon Water, Observant, (tule ET sensors?)
- Alfalfa Growers

California

- Alfalfa is California's largest agricultural water user

  - About 1 million acre of alfalfa

  - About 4.0 - 5.5 million ac-ft of water per year

- Surface (flood) irrigation is the primary method of irrigation for alfalfa and other field crops in California

- Imperial Valley (2015):
  - 128,623 acres (140,134 acres same month last year)
  - Water use 6.5-7 ac-ft/ac

Irrigation Methods in California:

1- Surface irrigation (flood):
- Border strip (flat) irrigation (slope 0.1-0.2%)
- Furrow irrigation (slope)
- Basin irrigation (zero slope)

2- Sprinkler Irrigation (various types)

3- Drip Irrigation (various types)
- Surface drip
- Subsurface drip

Surface irrigation:

- Water application methods where water is applied over the soil surface by gravity (no energy is needed).

- Most common irrigation system throughout the world

- Has been used for thousands of years

- Land leveling practices over the past century made it more efficient

- High efficiency possible on medium and heavy soils

Surface irrigation methods:

- Border (flat) irrigation

  Runoff rate: 5-20% (vary)

- Furrow (bed) irrigation

  Runoff rate: 15-30% (vary)

Surface runoff:

Water losses: lower efficiency

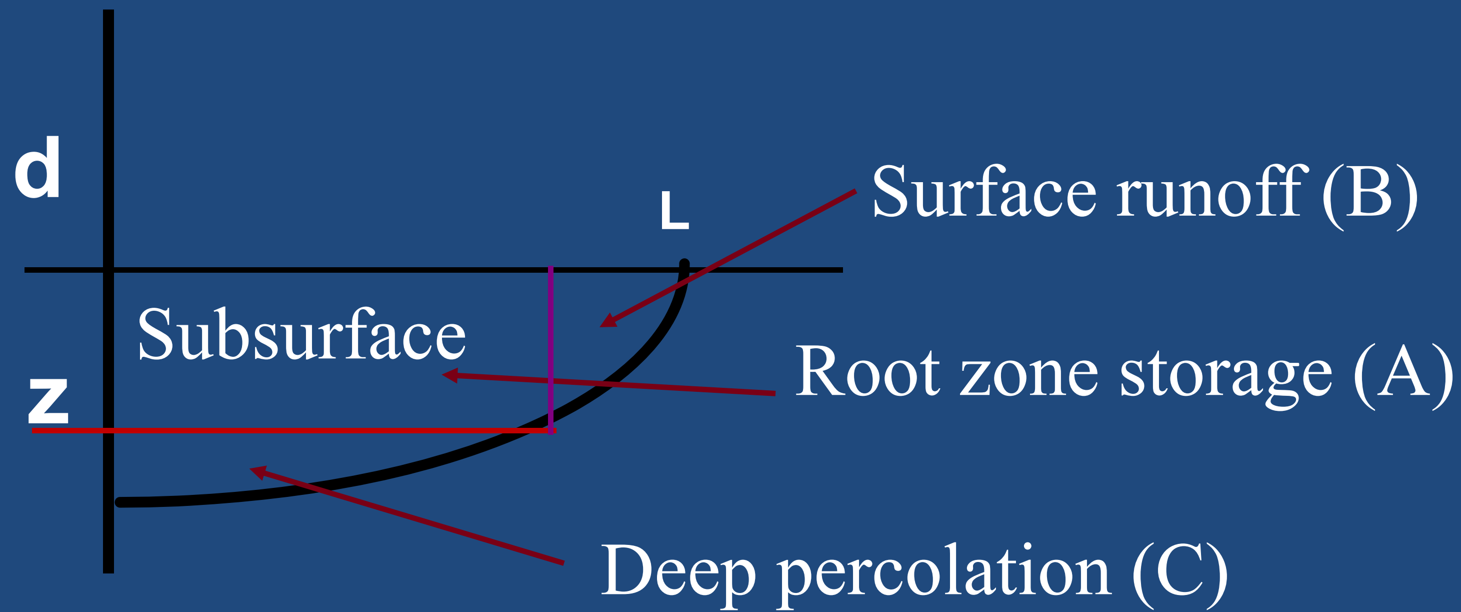
Nutrient losses: surface runoff & deep percolation

Pesticides losses: mostly surface runoff & some with deep percolation

*** Usually no runoff with basin irrigation**

Surface Irrigation

Applied water = Root zone storage + runoff + deep percolation



On-Farm Water Conservation =Higher Application Efficiency (AE)

IRRIGATION = Evapotranspiration (ET)+ DEEP PERCOLATION + Runoff

A + B + C

Application Efficiency (AE)= A/(A+B+C)

To achieve higher efficiency, reduce B and/or C

BUT

Need to have a balance,

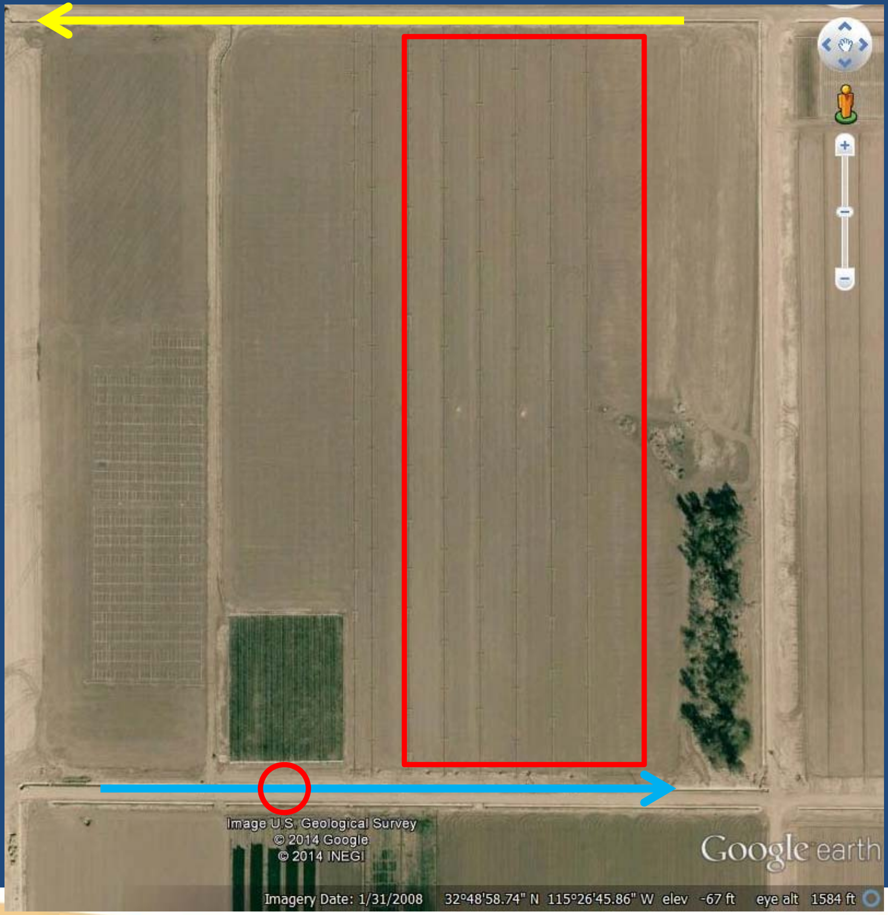
Deep Percolation sometimes is needed for salinity control

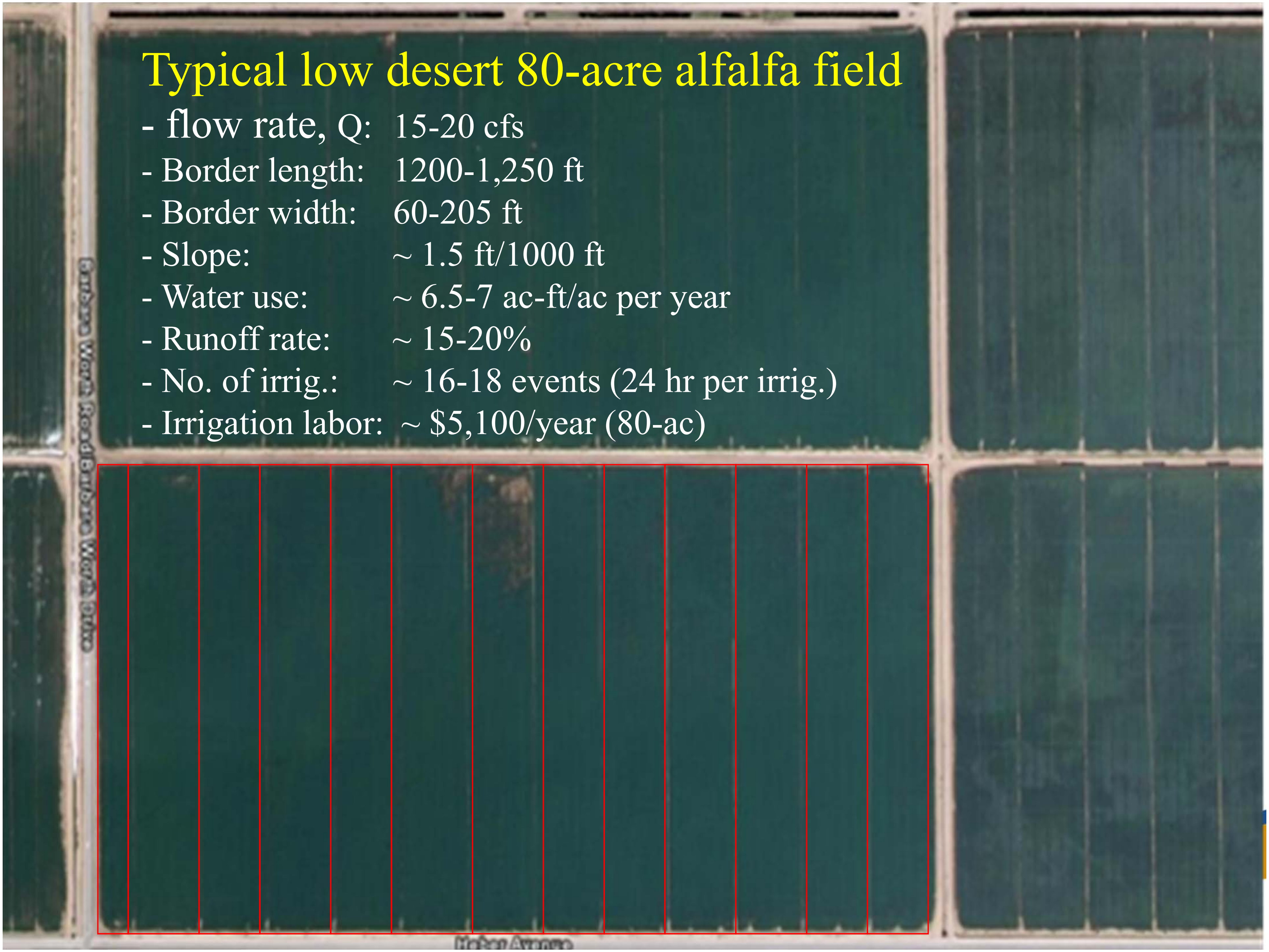
(650 ppm ~ 0.9 tons of salt/ac-ft)

Runoff is needed for Uniformity (100% AE means under irrigation)

Automated Surface Irrigation Field Test Site

- Border irrigated field
- 60' wide borders
- 1200' run length
  - Supply Canal
  - Runoff Canal
  - Flow Measurement

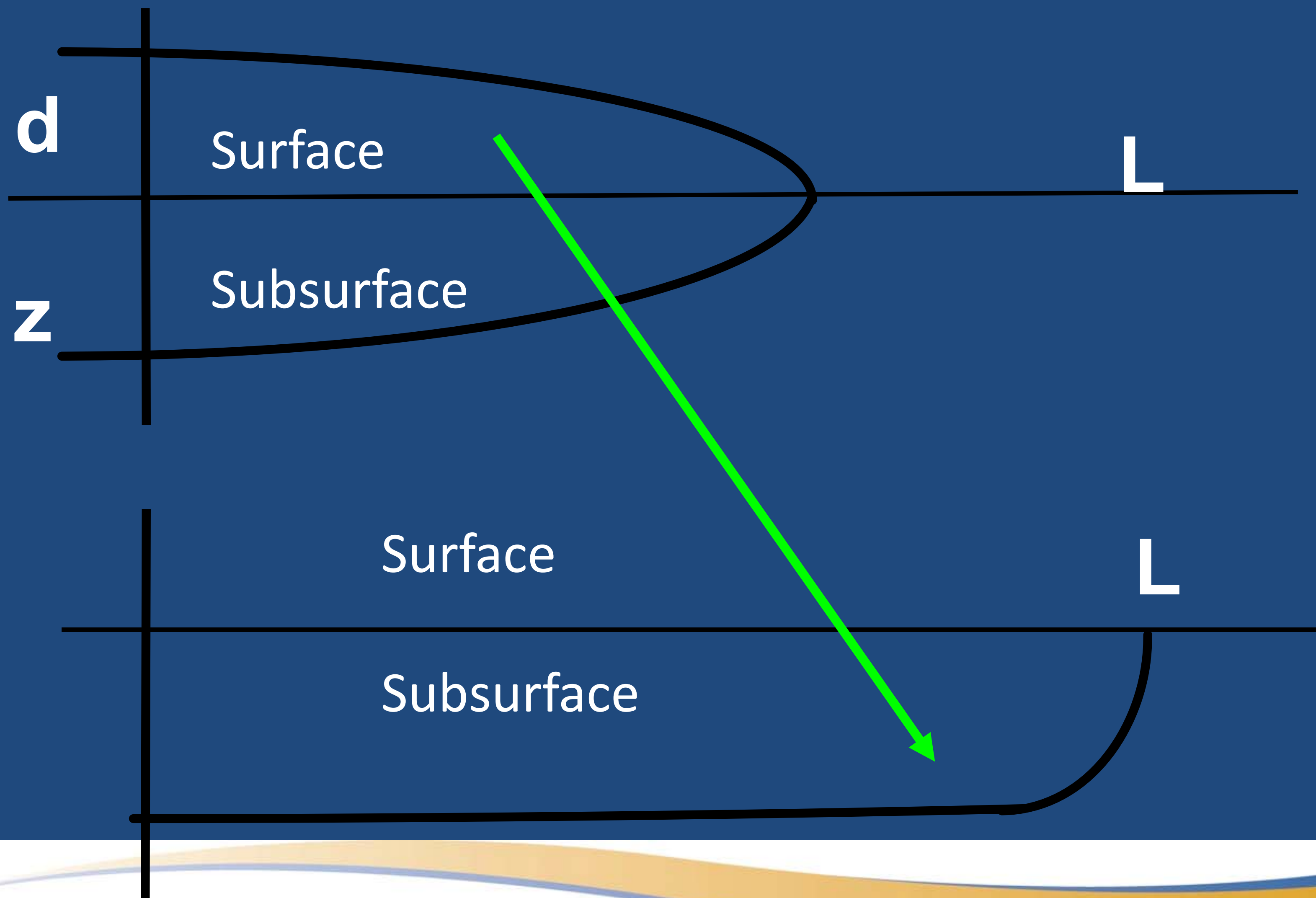




Typical low desert 80-acre alfalfa field
- flow rate, Q: 15-20 cfs
- Border length: 1200-1,250 ft
- Border width: 60-205 ft
- Slope: ~ 1.5 ft/1000 ft
- Water use: ~ 6.5-7 ac-ft/ac per year
- Runoff rate: ~ 15-20%
- No. of irrig.: ~ 16-18 events (24 hr per irrig.)
- Irrigation labor: ~ $5,100/year (80-ac)

Volume applied= Surface storage +Subsurface storage

flow rate*time= d*L + z*L



Automation of Surface Irrigation Systems

- Irrigators typically work in 24-hr shifts

- Make decisions on when to turn the water off based on a number of variables (flow rate, advance rate, crop height, etc)

- Automation: smart decisions based on accurate and real-time data (flow rate, advance rate, automated gates, ETc , and other variables)

Optimization (Automation of surface irrigation systems)

- The process of considering all flood irrigation variables to improve on-farm irrigation efficiency

- Adjust irrigation time to allow for changing crop roughness (height and density of the crop)

- Adjusting border/set length to allow for variable soil type across the field

- Adjusting flow rate to an irrigation set (one or more border/land) to improve efficiency

- Computer simulation models are needed

- Accurate measurements during irrigation events (flow rate and advance rate)

Optimization

- Soil type 114 & 115 (heavy soils)- lower flow rate or high flow rate will work depending on the time of the year (considerations: erosion rate & scalding)
- Soil type 106 or 110 (lighter soil)- higher flow rate to increase efficiency
- Soil type 115 & 106 (change flow rate during the irrigation event)

Soil Web via Gmaps!

Zoom to location: Holtville, CA Go!

Map Unit Legend

Area (Ac)	Map Symbol	Map Unit
75.8	115	IMPERIAL-GLENBAR SILTY CLAY LOAMS, WET, 0 TO 2 PERCENT SLOPES
24.8	110	HOLTVILLE SILTY CLAY, WET
13.1	106	GLENBAR CLAY LOAM, WET
5.4	114	IMPERIAL SILTY CLAY, WET

Automated Surface Irrigation:

Previous UCCE-USBR efforts (unsuccessful)

Now 80-ac field (has state of the art system)

Motorization of Existing Gates:

Existing Port Gates

Gates Motorized w/Linear Actuators

Automated Surface Irrigation:

Current Project: Turnout Flow Control

Prototypes

Automated Surface Irrigation:

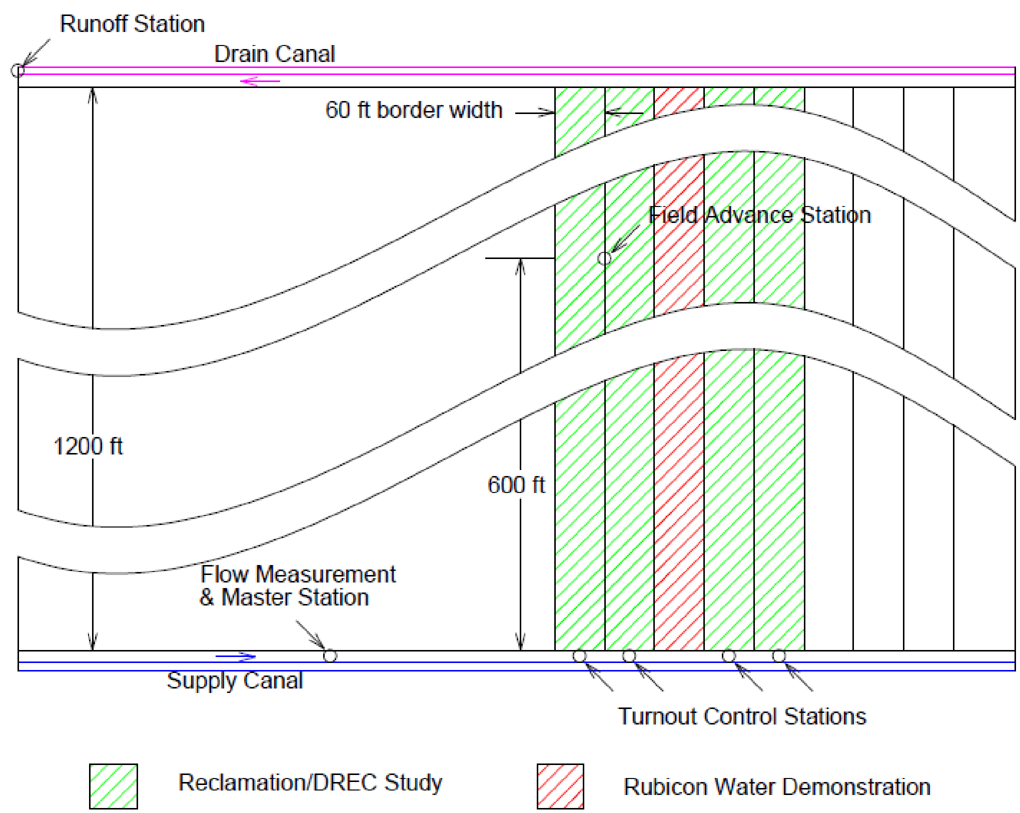
Current Project: Turnout Flow Control

Prototypes

Automation of Surface Irrigation Systems

Automated Surface Irrigation

Automation Demonstration Layout



Turnout System Compatible with Automated Operation:

Tarp Gate Turnout

- **Linear Actuator Operator**
- **2 Rectangular Frames,**
  - **Vertical Stationary Frame**
  - **Hinged Frame**
- **Fitted Tarp**

Turnout System Compatible with Automated Operation:

Tarp Gate Turnout

"Drop-In" Installation & "Self Contained System"

Turnout System Compatible with Automated Operation:

Tarp Gate Turnout

Canal Bank or Culvert Outlet Installation

Automated Surface Irrigation Field Test :

Automation System Stations

Flow Measurement – Main Control Station

Automated Surface Irrigation Field Test :

Flow Measurement

- Two-level “venturi solution” flow measurement @ long-throated flume.

- Third level measured to monitor canal fill below flume

Automated Surface Irrigation Field Test :

Automation System Stations

Turnout Stations

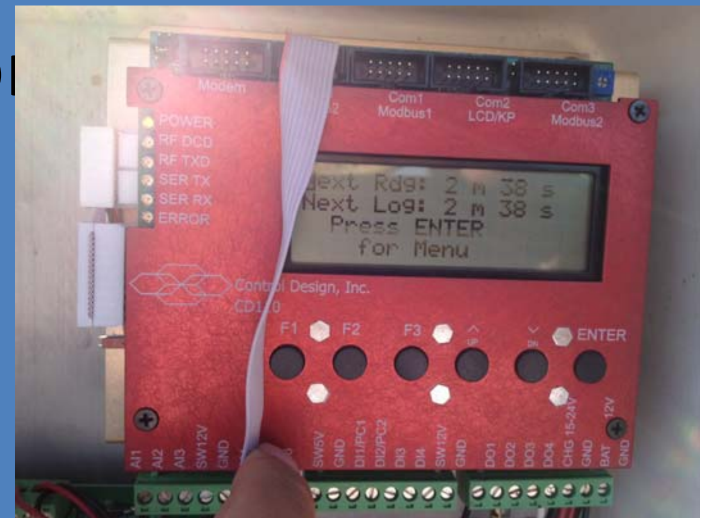
Automated Surface Irrigation Field Test :

Automation System Stations

Field Advance Sensing Station

Automated Surface Irrigatio

Automation System Stations



Field Runoff Measurement Station

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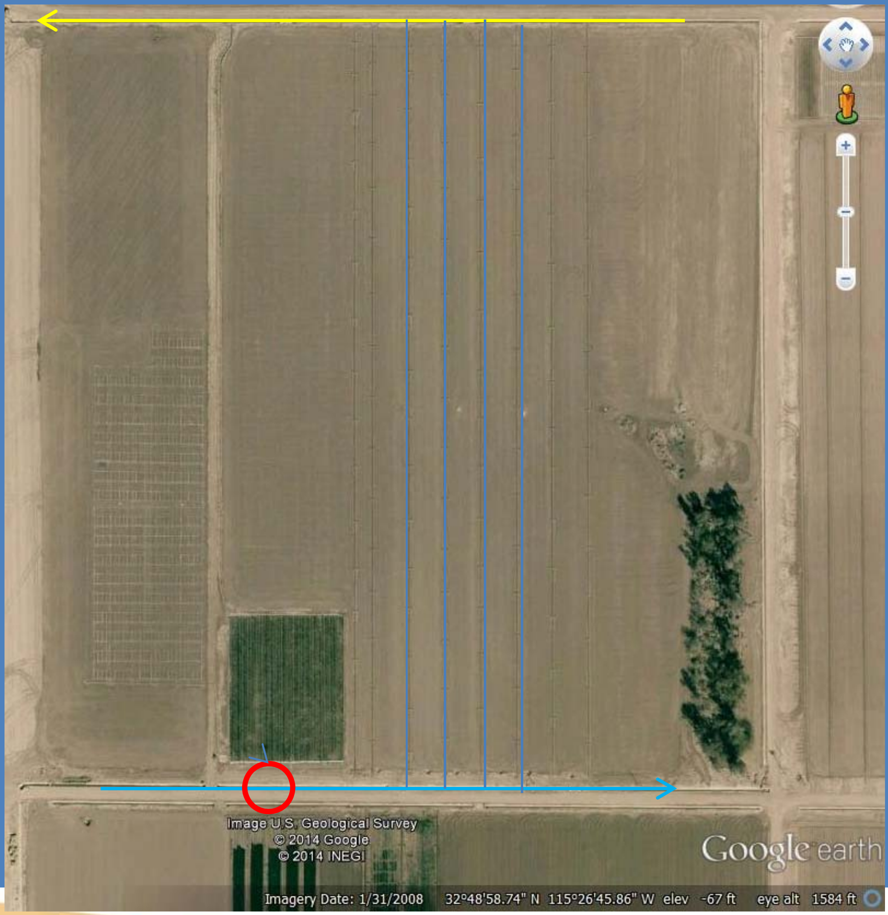
Automation Operating Cycle: Startup

○ **Main Control (MC)**

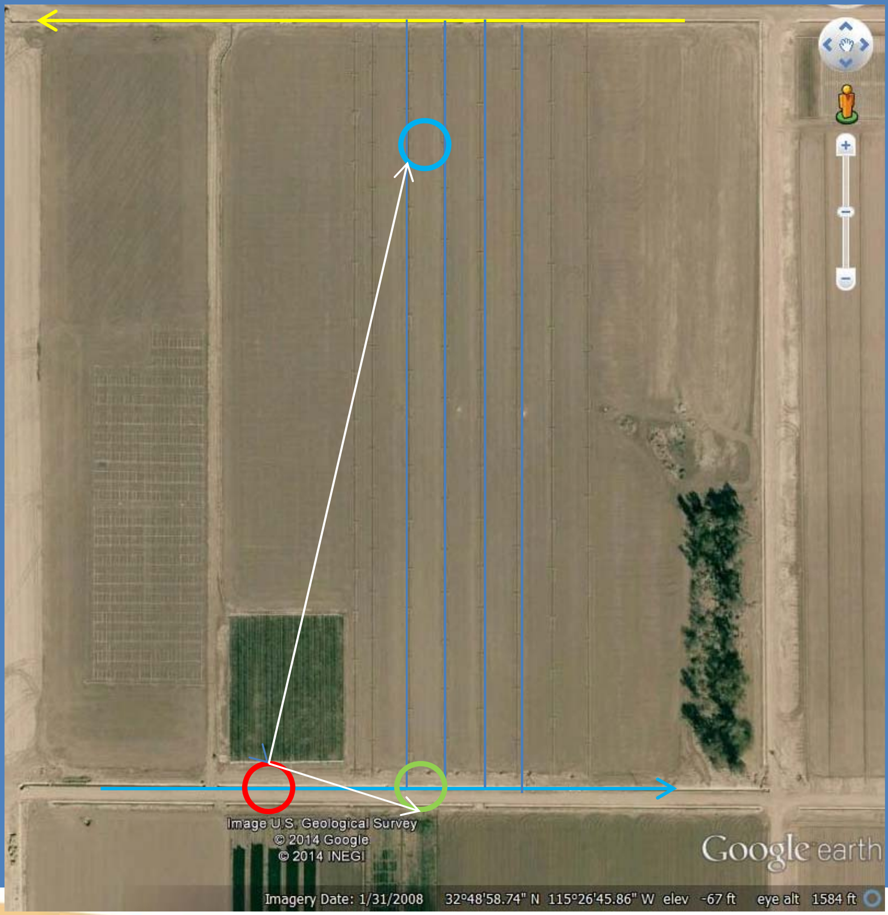
- **MC placed in "Auto" Mode**
- **MC monitors canal fill**
- **MC keeps "running average" flow rate**



Automation Operating Cycle: Once Canal has Filled → Start Irrigation

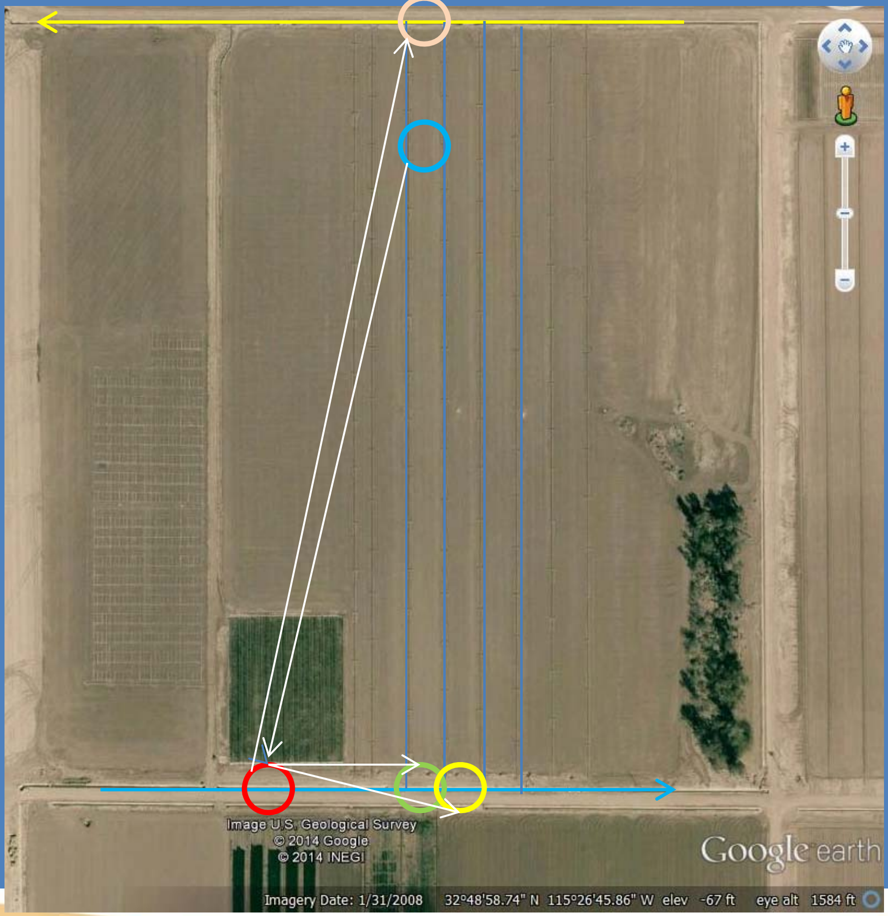
- Main Control (MC)
- Field Advance (FA)
- Section 1 Gate (G1)

- MC activates FA
- MC opens G1
- MC computes inc vol
- MC keeps sect vol total
- MC keeps field vol total



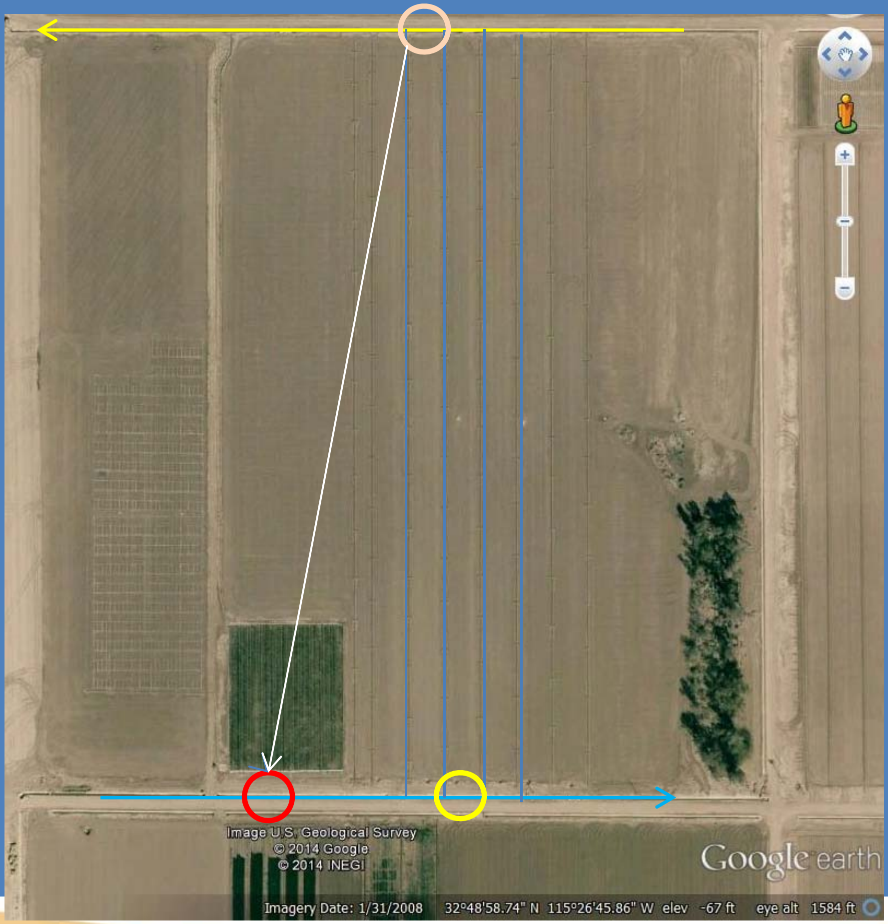
Automation Operating Cycle: Water Sensed @ Field Advance

- Main Control (MC)
- Field Advance (FA)
- Section 1 Gate (G1)
- Section 2 Gate (G2)
- Runoff Station (RO)
  - FA alerts MC
  - MC identifies Tgt Vol
  - MC opens G2
  - MC closes G1
  - MC Activates RO
  - MC estimates ending time



Automation Operating Cycle: Section 1 Runoff Measurement Complete

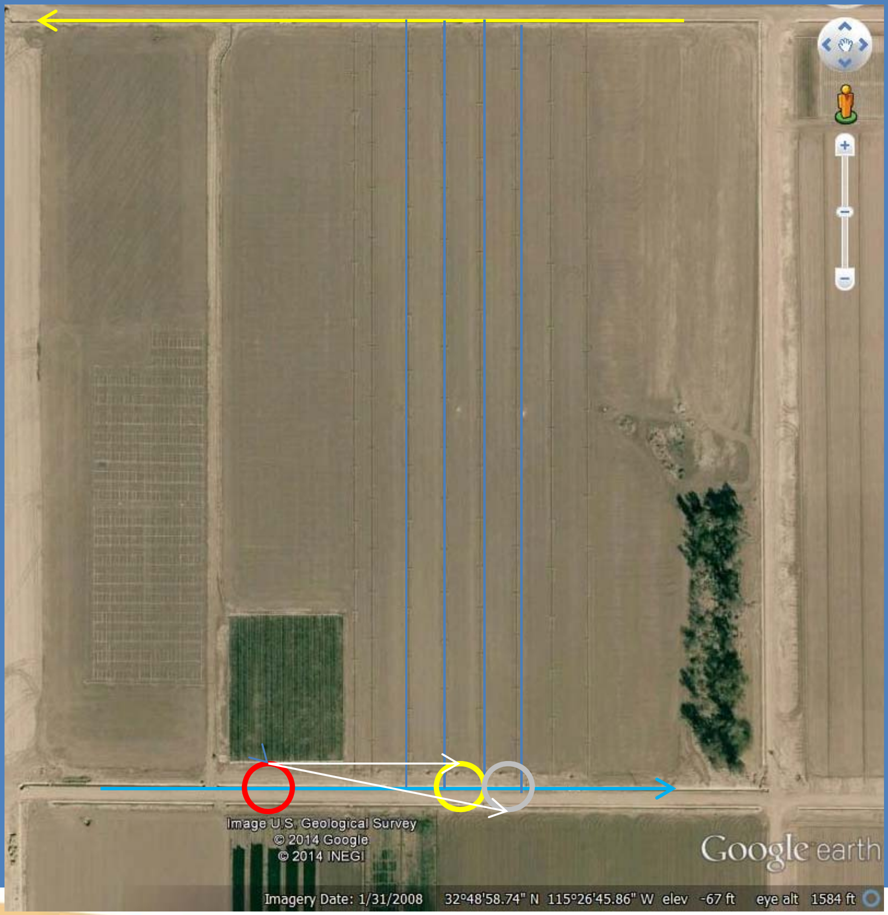
- Main Control (MC)
- Section 2 Gate (G2)
- Runoff Station (RO)



- RO reports RO Vol to MC
- MC compares RO Vol & Tgt Vol
- MC adjusts Tgt Vol if needed
- MC estimates ending time

Automation Operating Cycle: Target Volume reached for Section 2 (& subsequent sections)

- Main Control (MC)
- Section 2 Gate (G2)
- Section 3 Gate (G3)



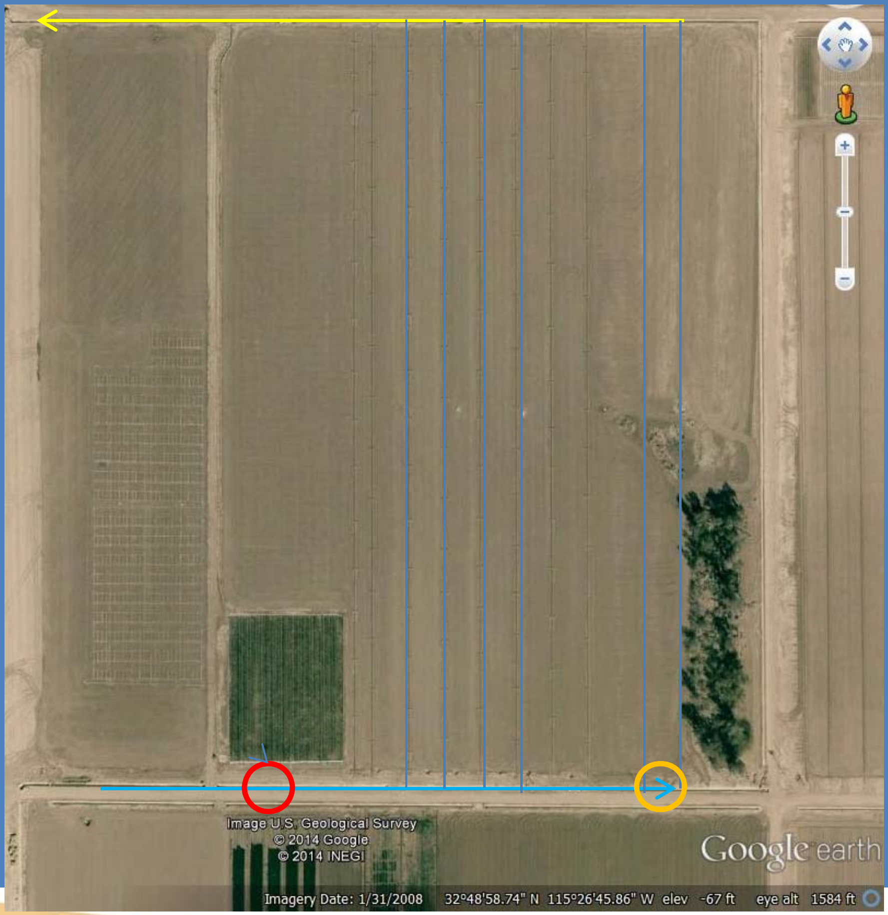
- MC opens G3
- MC closes G2
- MC updates estimated ending time

Automation Operating Cycle: End of Irrigation

○ **Main Control (MC)**

○ **Section n Gate (Gn)**

- **MC in alert mode**
- **Activities for end of irrigation expected to be "site specific"**



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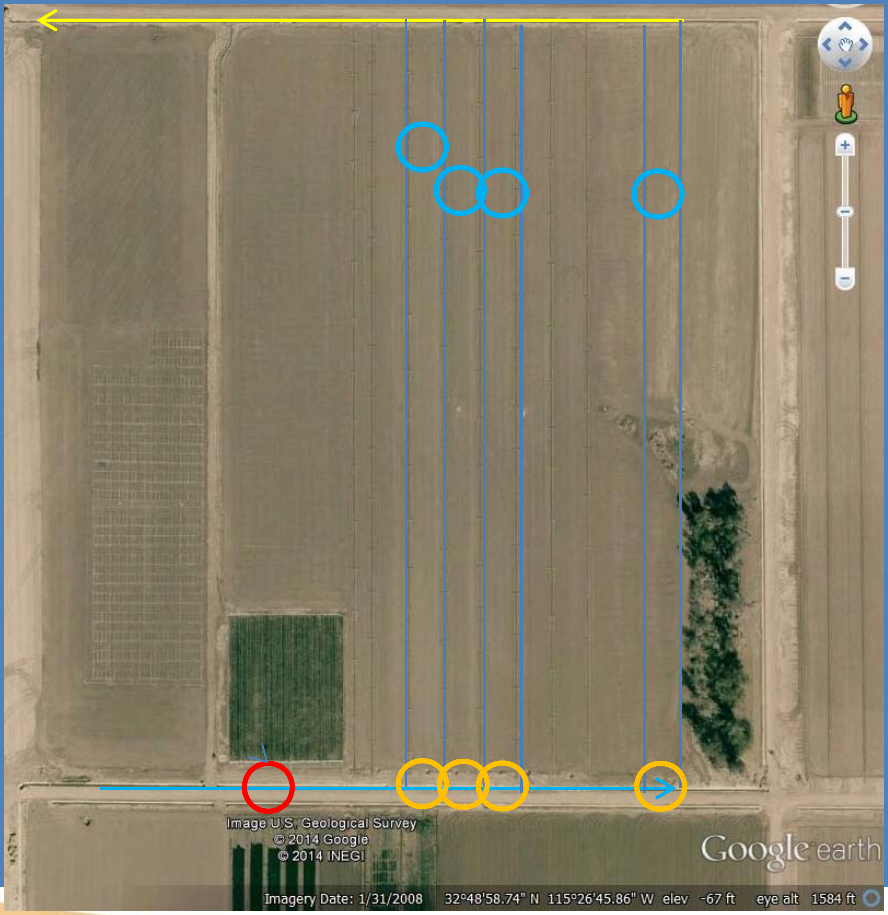
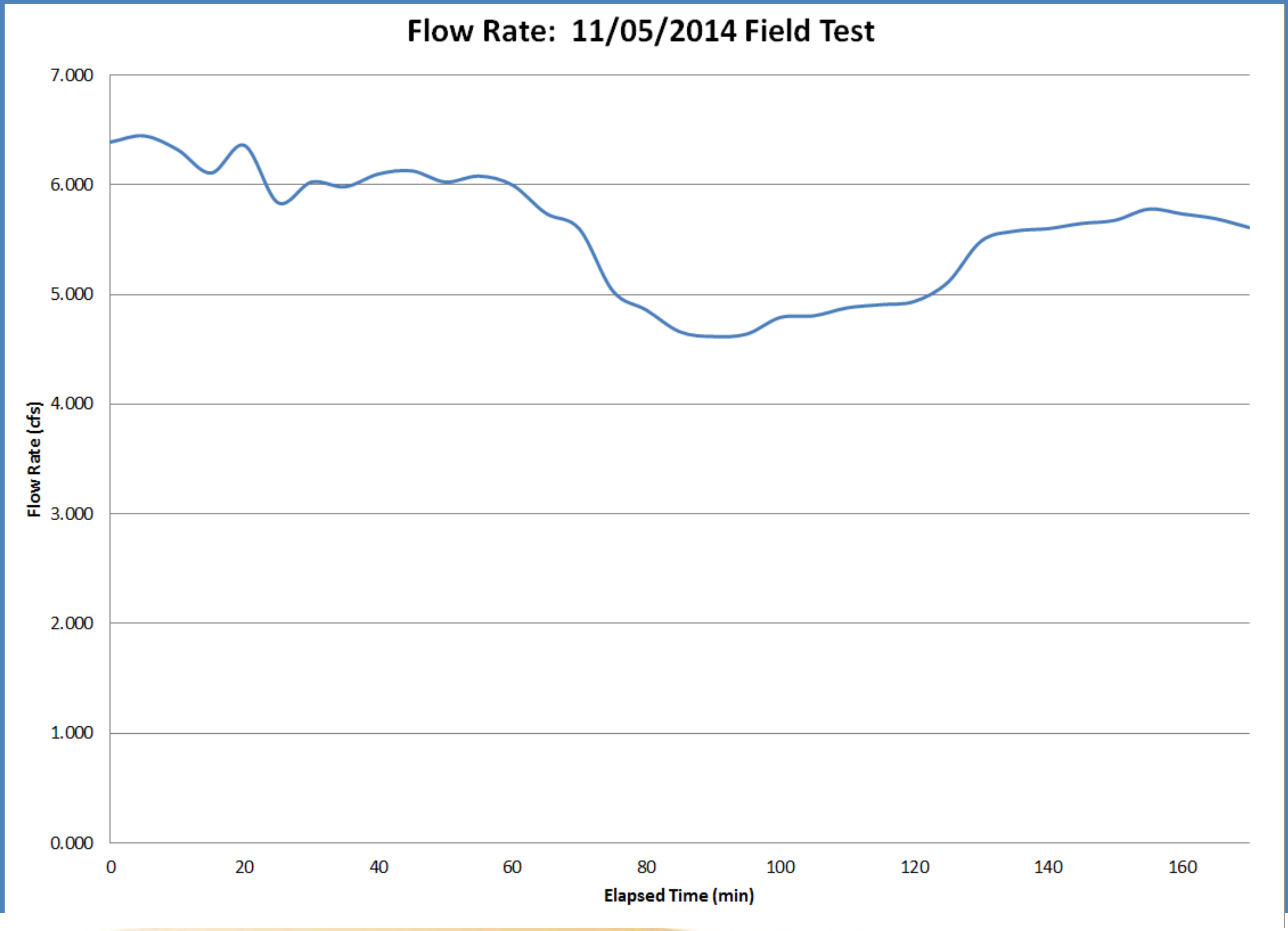
Automation Operating Cycle: Operation w/Field Advance Sensor in Each Section

- **Main Control (MC)**
- **Section n Gate (Gn)**
- **Field Advance n (FA_n)**



- **FA_n(s) placed at "cut-off" locations**
- **One or multiple FA units may be used**
- **FA placement may be adjusted from section to section**

Inflow Variation, 11/05/2014 Field Test



Automated Surface Irrigation Field Test

Additional system components:

Office Base Station

Automated Surface Irrigation Field Test

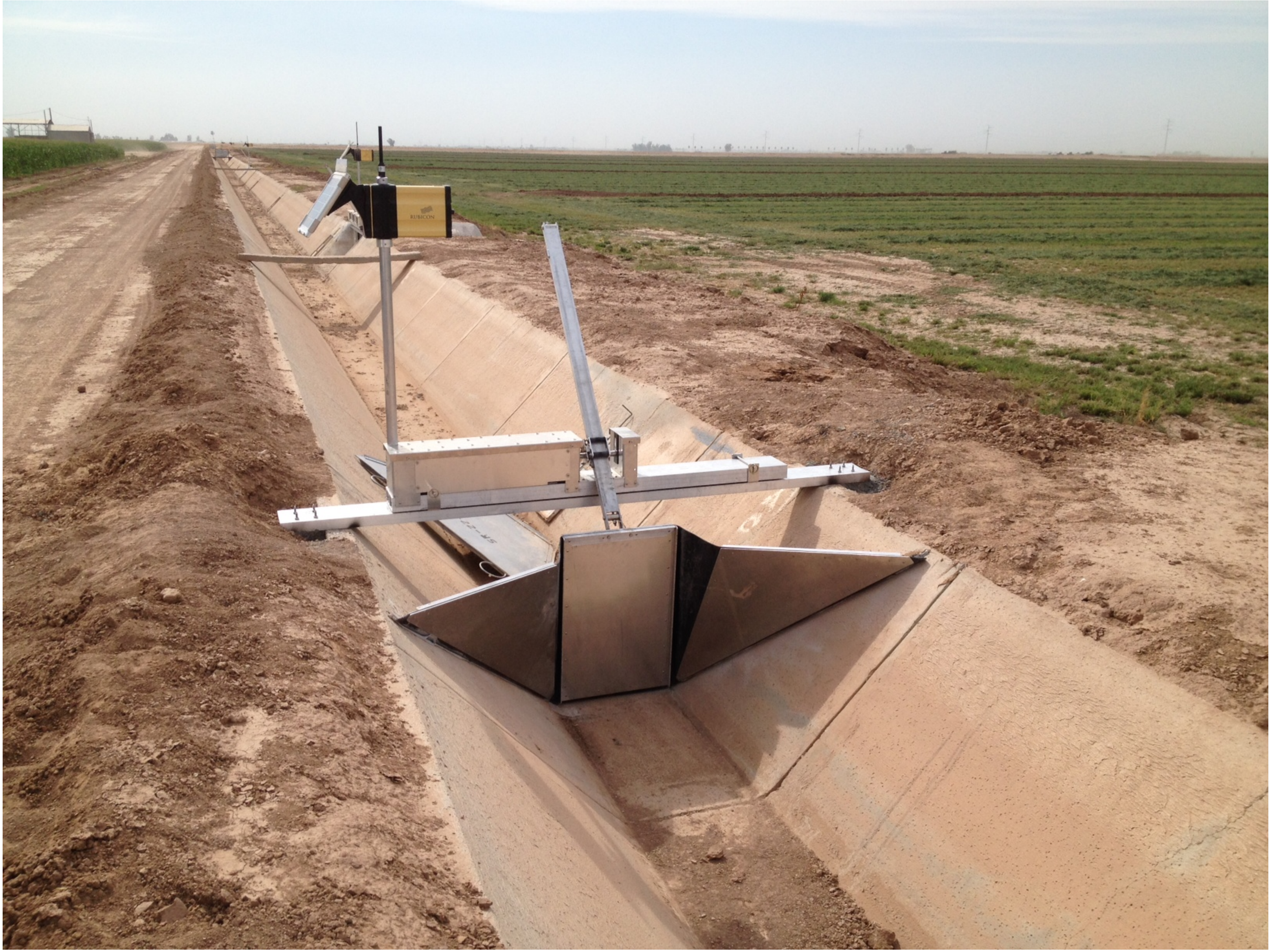
Additional system components:

Portable Station

Automated Surface Irrigation Field Test :

Current Project Status:

- Programming for basic functions has been developed and tested for each station type
- User menu functions of Main Control program are currently being refined
- Main Control programming for multiple field sensor option is being developed.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Summary and Desired Outcomes

- Water conservation (reducing runoff to less than 5% of applied water)
- Labor savings (one irrigator per 4 fields vs 1 irrigator per field)
- Value of conserved water (currently $285 per ac-ft in IID service area)
- Drought and limited water supplies (deficit irrigate the lower end of the field)

Thank you