



Remote Monitoring of Environmental Sites using Solar Powered Wi-Fi Enabled Systems

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Wi-Fi Enabled Monitoring

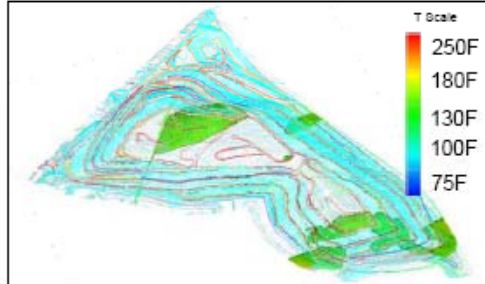
- Overview
- Goals and Monitoring Targets
- Idealized and Proof-of-Concept Layout
- Test Area and Radio Layout
- Components & Sensors
- Data Analysis
- Results Summary

Overview

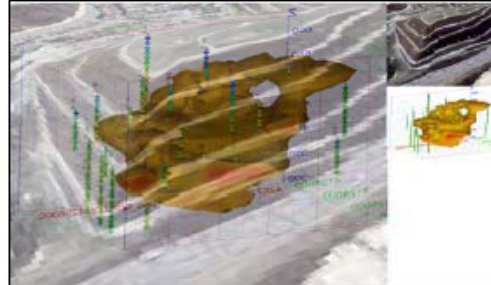
- **Use of Wi-Fi Enabled Sensors for Environmental Monitoring**
- Developed as part of an ongoing long-term O&M program for landfill monitoring.
- Way to reduce cost per data point for routine data collection:
 - System had to use off-the-shelf components
 - Use readily available software and systems
 - Must be internet capable and secure
 - Must run on limited power
 - Must be low voltage and intrinsically safe
 - Must be transportable
 - Must have broad capability and capacity
 - ◆ i.e., wireless cameras, motion sensors, wireless computer etc.
- Outgrowth of smart oilfield monitoring systems
- Applicable to any sensor with 4-20 mA outputs

Project Goals

Enhanced Oxidation Zones: Their Locations to Date



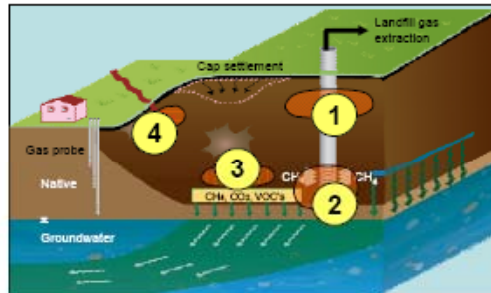
Northeast Temperature Profiles in Refuse, Wells at T > 130 °F



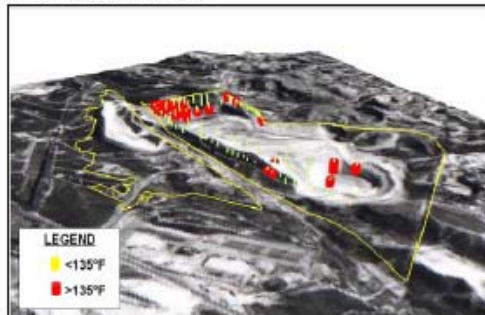
Well Head Vacuum Distribution Vs. Temperature



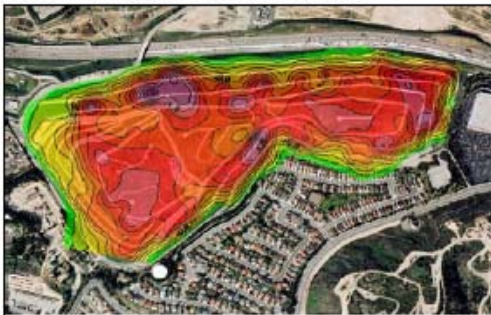
Defining 4 Different Types of EOZ



1964 Aerial Photograph and Surface Elevations With Current Extraction Wells

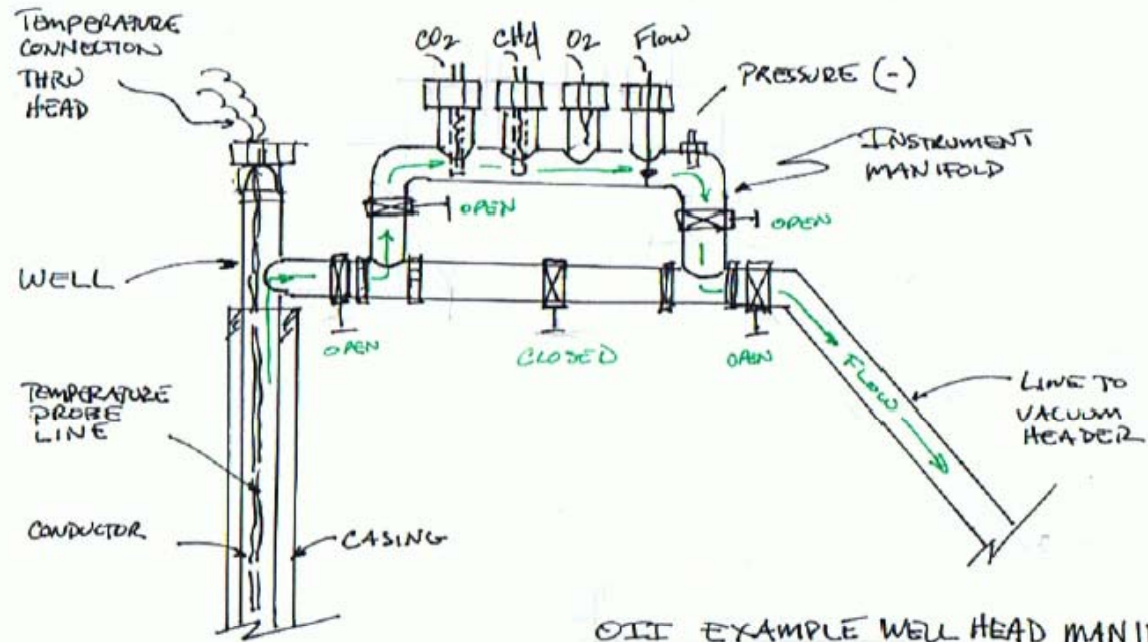


Cap Settlement and EOZ Locations Correlate



- Downhole-LFG well temps were measured at 10 ft intervals, using thermocouples, at East and NSSP.
- Subsequently, digital thermal probes were installed at highest T locations at the North East. (WiFi System)
- EOZ location graphics have been generated (at a confidence level commensurate with data).
- **Preliminary Results:**
 - With 25 % of the SP LF volume characterized (25% X 30MM cu. yd. = 7.5 MM cu. yd.) 2.3 MM cu. yd. are EOZ-influenced.
 - EOZ is an oxidative condition which is exacerbated by excessive well vacuum, which causes unwanted air intrusion through the cap.
 - Decision-logic is being generated to define how to manage EOZ conditions both in the short and long-term.
 - We have created 4 different classifications of EOZ:
 - 1 In close proximity to cover (e.g. NSSP-NC) (of concern: thermal breakthrough, settlement and H&S).
 - 2 Deep w/gas collection, to manage GW impacts (e.g. NE deep) (EOZ governs well operability and lifetime).
 - 3 Deep within LF prism (leave alone, for local conditions cannot be dramatically affected).
 - 4 Close to LF boundary compliance probes (e.g. SE) (condition needs careful management, via reduced well vacuum and cap maintenance to reduce air infiltration).
- Investigation of EOZ management practices should be coupled with the assessment of the appropriate LFG collection "array" for the long-term at OII.
 - i.e. collect gas with minimal vacuum (migrate to passive?)
 - operate with more of a "balance" of gas generation Vs collection"

Monitoring Targets



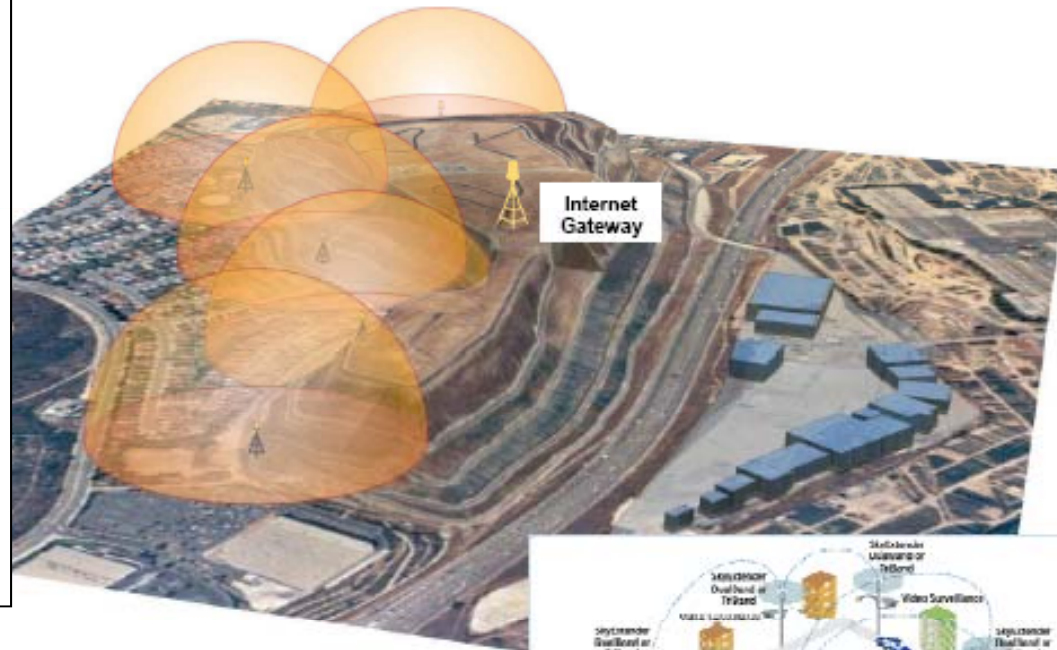
OIL EXAMPLE WELL HEAD MANIFOLD
SENSOR LAYOUT + VALVE CONNECT

MRL 42-07

MANIFOLD LAYOUT ALLOWS
MULTIPLE SENSORS TO BE
DEPLOYED. CAN BE TAKEN
OFF LINE WITHOUT INTERRUPTING
WELL. QUICK-CONNECTS +
THREADED FLANGES SIMPLIFY HOOKUP.

System Vision

- Create a Wi-Fi mesh over the area of interest
- Use primarily for remote monitoring
- Possible use for municipal Wi-Fi for nearby residences
- Additional use for public service, emergency or security



LEGEND



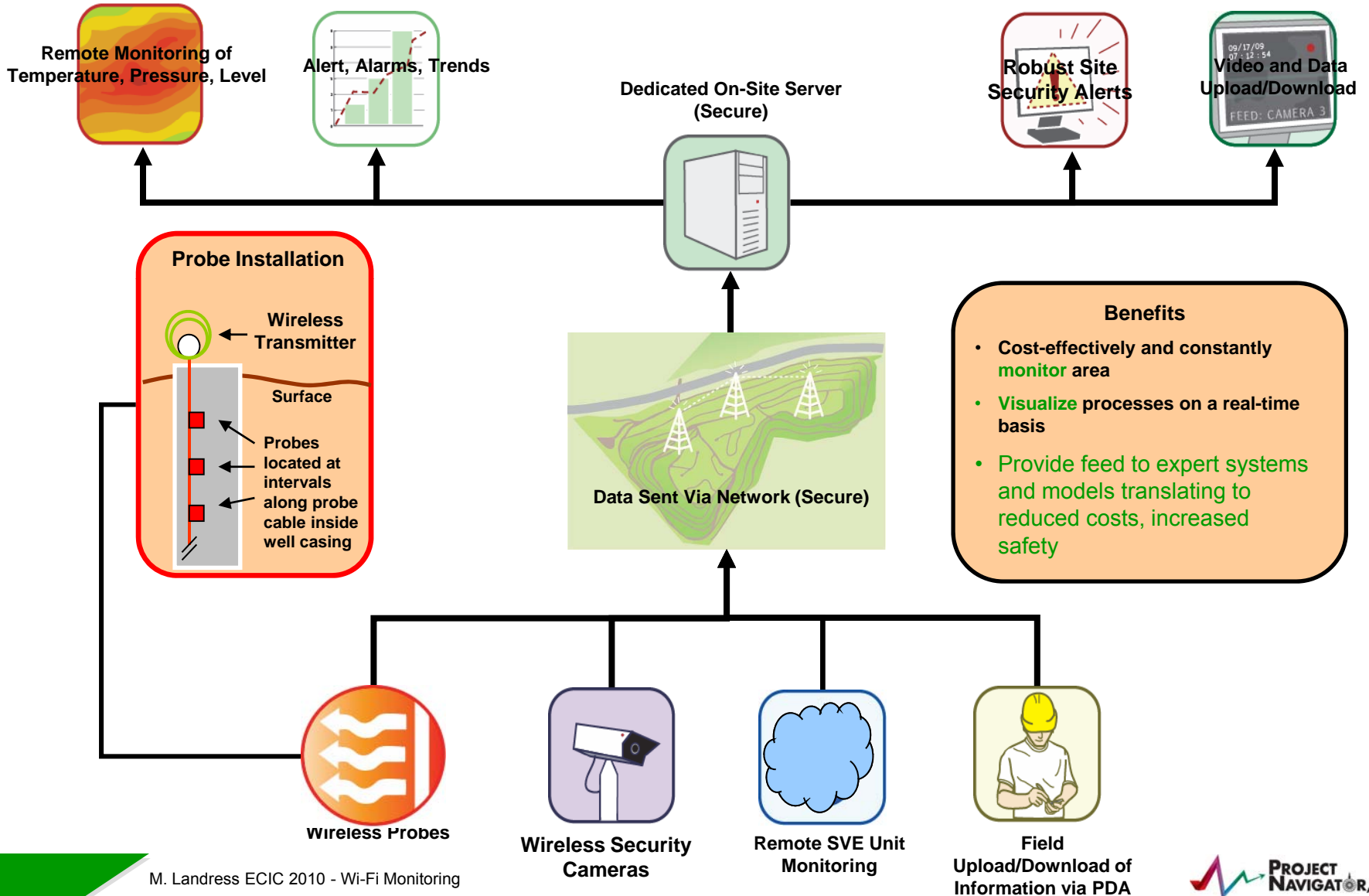
Extender (repeater)



Wi-Fi Broadcast Region



Idealized System Layout



Proof of Concept Layout

Initial conceptual site layout for monitoring.



Gateway (Base Station)

- Power grid connection
- Mounted at NCI office
- Connected to T-1 line
- Receives sensor network data carried over Wi-Fi network



Wi-Fi Extender (Repeater)

- Solar-powered
- 6'-9" mobile platform
- Receives data from wireless sensors



Wireless* Sensors

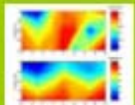
- Rapidly deployed
- Transmit to Wi-Fi network



Pipe and Drain Integrity Monitoring (wireless strain gauges)



Remote Data Access and Upload for Field Personnel



Subsurface Temperature Monitoring



Wireless Security Cameras



Gas Monitoring



Settlement Monitoring



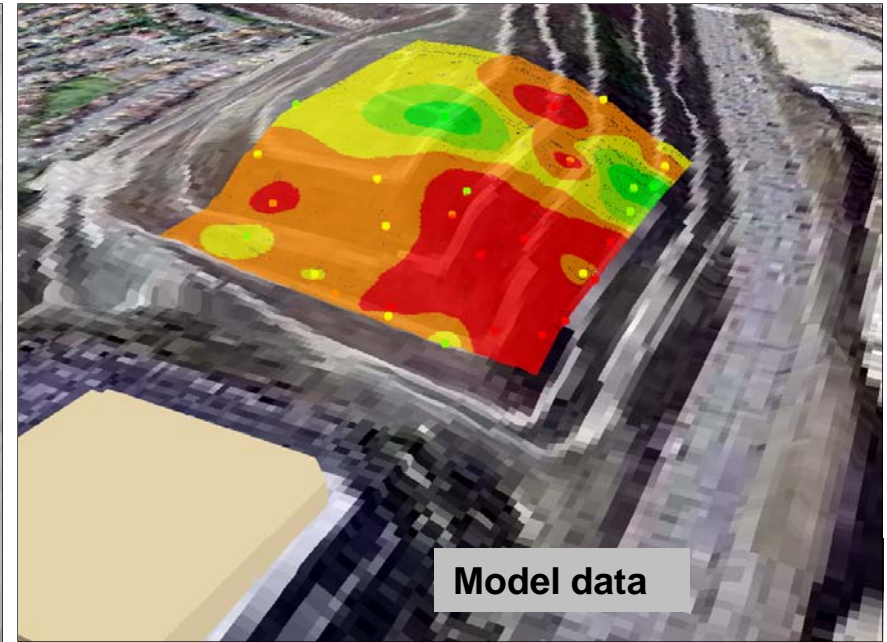
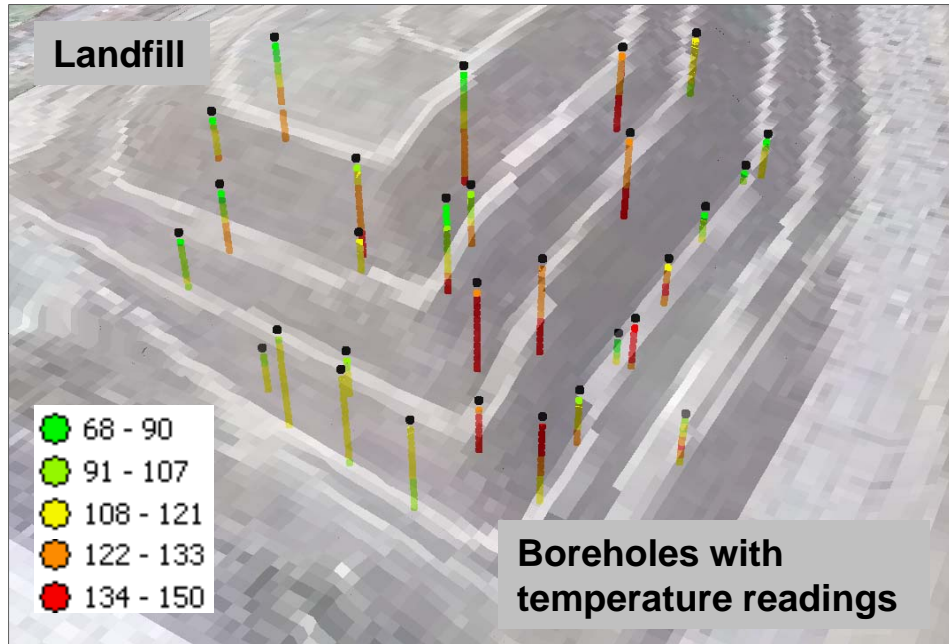
Moisture Detection



Wi-Fi Radio Communications



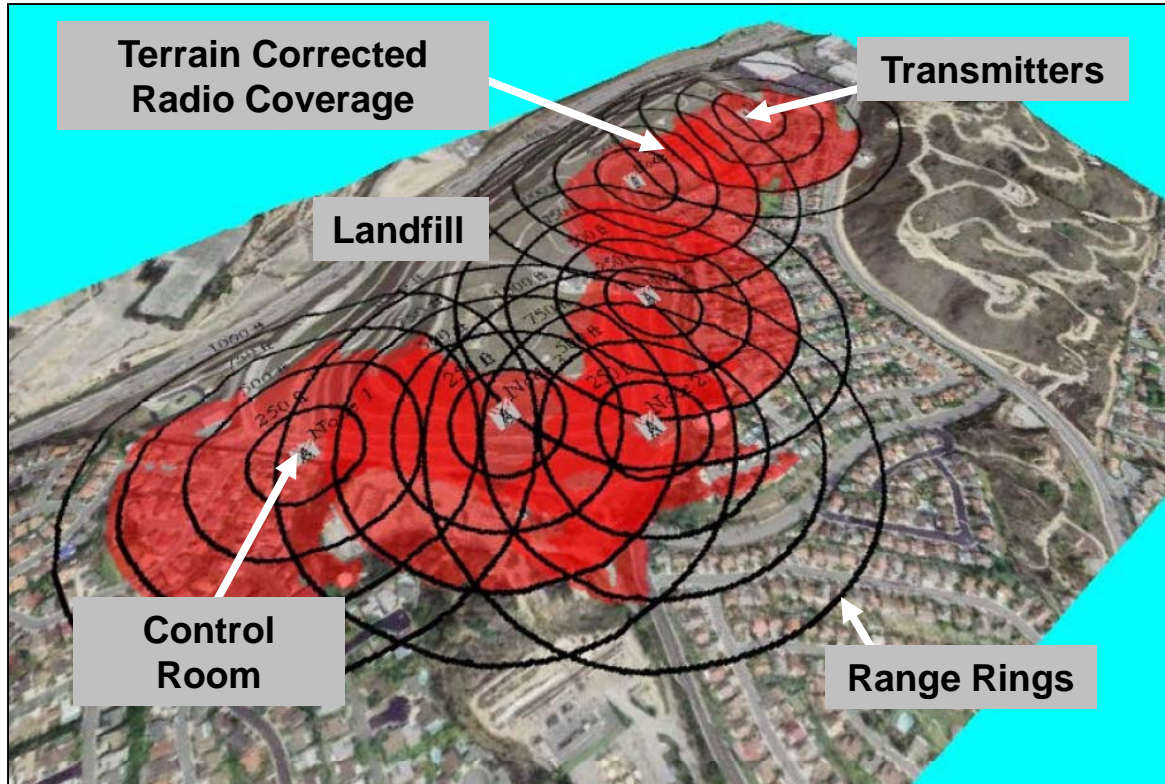
Area Selected for Proof of Concept



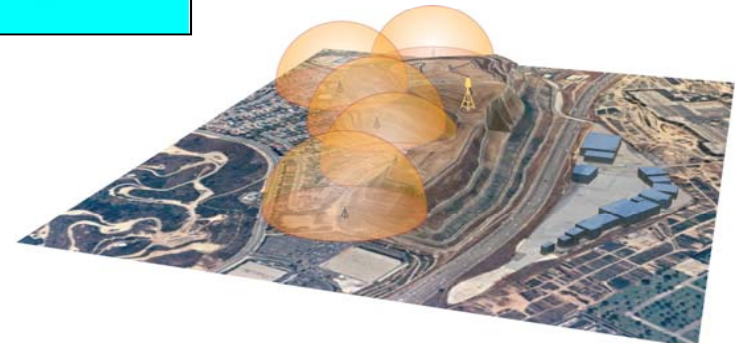
- Areas selected for subsurface temperature monitoring of enhanced oxidation
- Temperature readings taken manually at 10 foot intervals
- Model created of subsurface temperature
- Interval range for sensors selected in selected wells

Next Step: Compute radio line-of-sight and Wi-Fi range

Radio Line-of-Sight Analysis

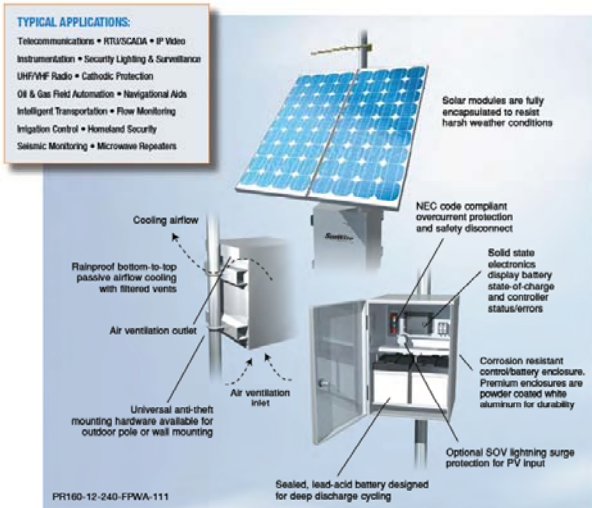


- Using radio modeling software, a range of locations were identified to optimize coverage between transmitter and receiver nodes.
- Ultimately 3 Wi-Fi extenders were needed to cover the location to the base. A distance of over 4000 feet

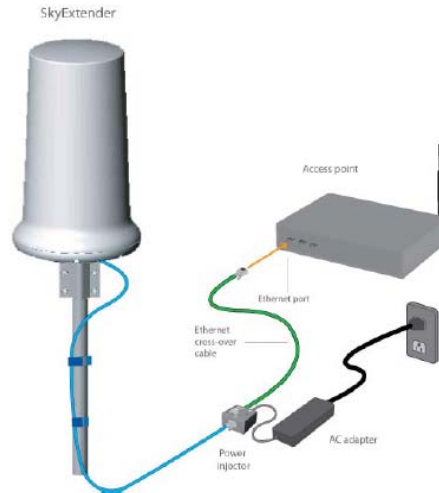


Off-the Shelf System Components

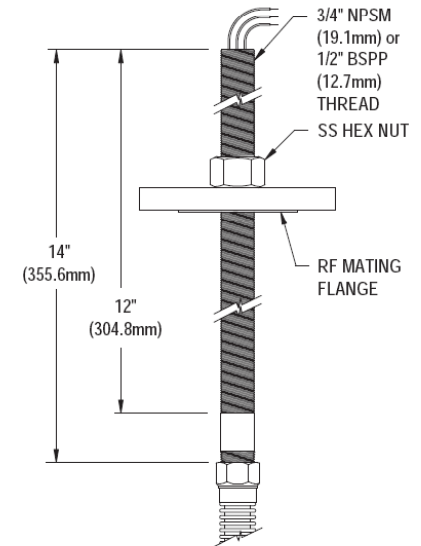
Sunwise PV System



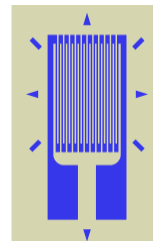
Sky Pilot Gateway



Weed Instrument Temperature Probe



ArchRock
Data
Transmitters



Strain
Gauge

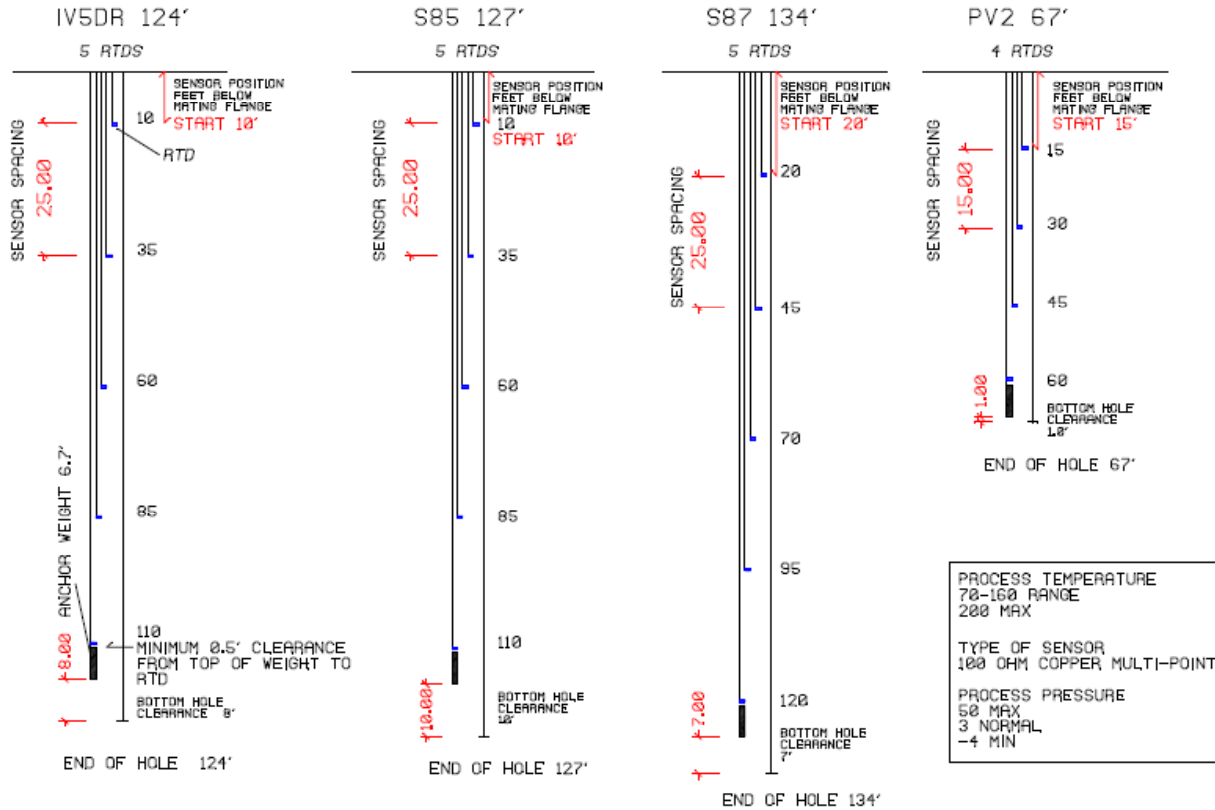


Water
Level
Alarm



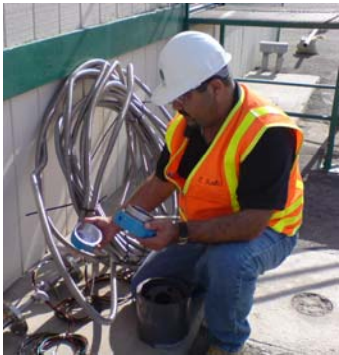
GDS
Gas
Sensor

Subsurface Temperature Probes



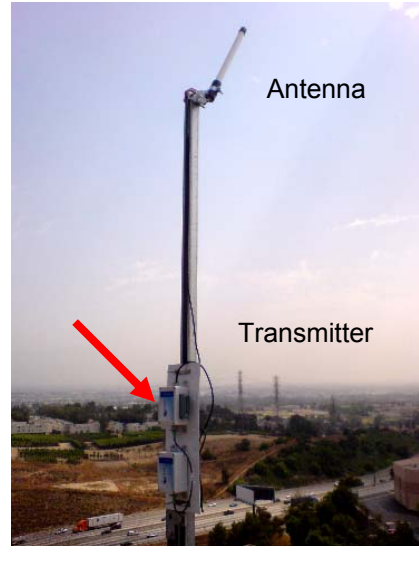
Probes custom made in stainless housing.
3-wire RTD sensors, 5 per well. 0.75 inch diameter.

Sensor Installation



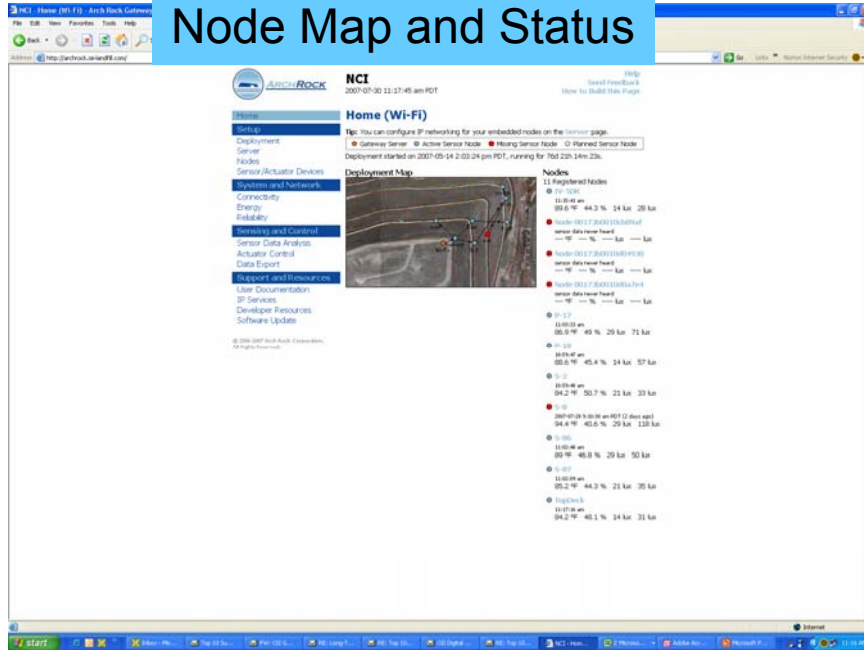
- Modified storage tank temperature sensor
- Flexible stainless steel jacket
- Probe weighted to hang straight in hole.

Data Collection and Transmission

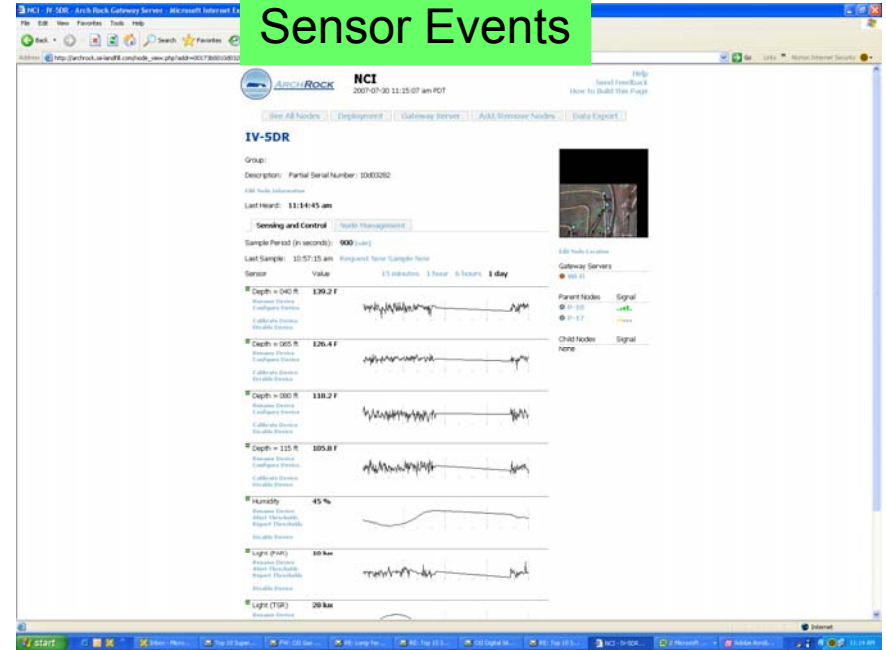


Internet Data Interface

Node Map and Status



Sensor Events

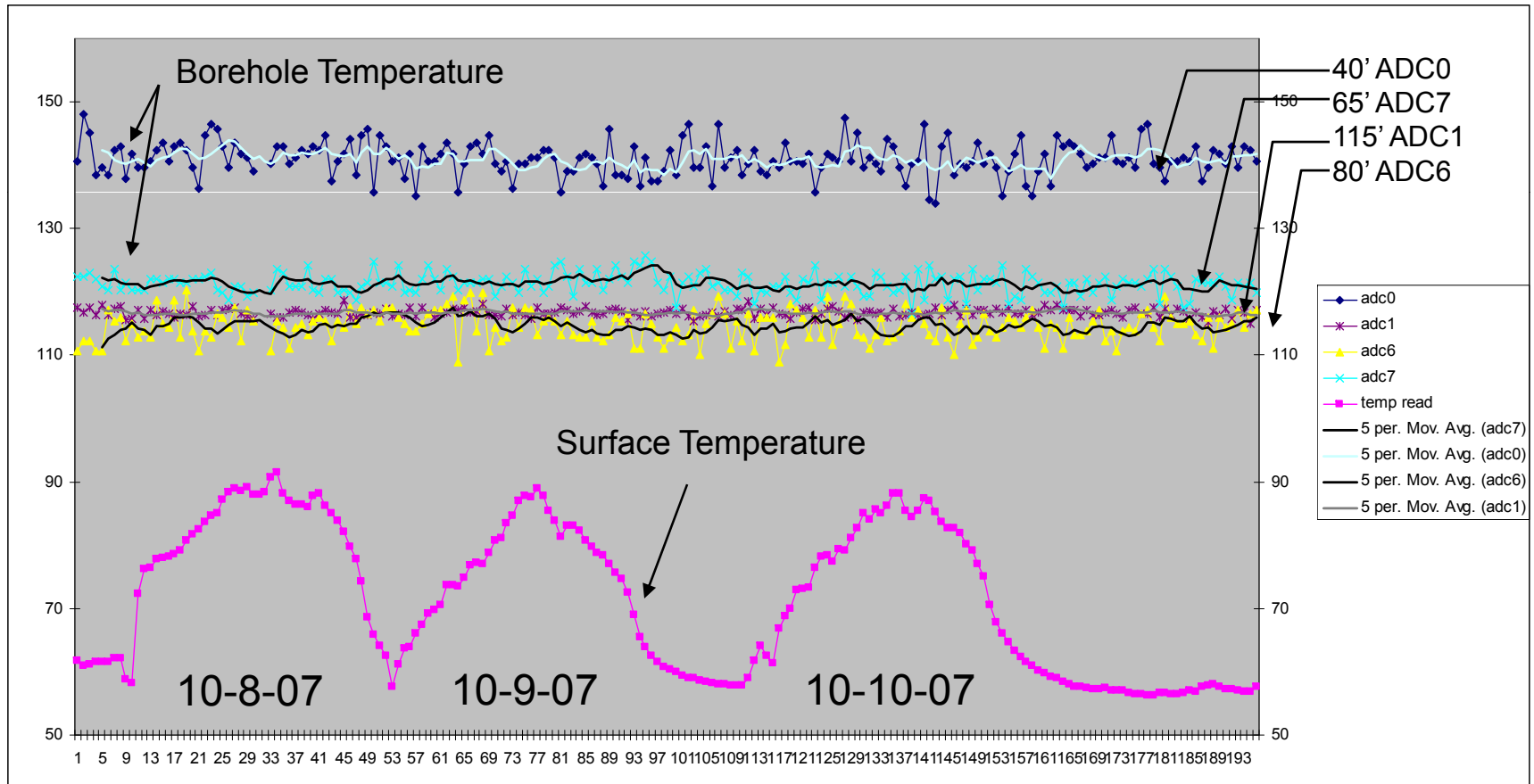


CSV Output

<eventname>	<timestamp>	<time>	<segno>	<nodeid>	<nodename>	<value>
ADC0ReadEvent	1225829738	11/4/08 12:15 PM	236	00173b00116de628	IV-5DR e628	144.1
ADC0ReadEvent	1225830571	11/4/08 12:29 PM	38	00173b00116de628	IV-5DR e628	144.1
ADC0ReadEvent	1225832371	11/4/08 12:59 PM	66	00173b00116de628	IV-5DR e628	143
ADC0ReadEvent	1225833272	11/4/08 1:14 PM	76	00173b00116de628	IV-5DR e628	143.5
ADC0ReadEvent	1225835971	11/4/08 1:59 PM	103	00173b00116de628	IV-5DR e628	141.8
ADC0ReadEvent	1225836873	11/4/08 2:14 PM	115	00173b00116de628	IV-5DR e628	144.7
ADC0ReadEvent	1225839571	11/4/08 2:59 PM	142	00173b00116de628	IV-5DR e628	143.5
ADC0ReadEvent	1225843171	11/4/08 3:59 PM	206	00173b00116de628	IV-5DR e628	143
ADC0ReadEvent	1225845875	11/4/08 4:44 PM	233	00173b00116de628	IV-5DR e628	143
ADC0ReadEvent	1225853071	11/4/08 6:44 PM	59	00173b00116de628	IV-5DR e628	144.1
ADC0ReadEvent	1225874670	11/5/08 12:44 AM	67	00173b00116de628	IV-5DR e628	144.7
ADC0ReadEvent	1225875571	11/5/08 12:59 AM	76	00173b00116de628	IV-5DR e628	143.5
ADC0ReadEvent	1225878271	11/5/2008 1:44	103	00173b00116de628	IV-5DR e628	143
ADC0ReadEvent	1225881871	11/5/2008 2:44	140	00173b00116de628	IV-5DR e628	144.1
ADC0ReadEvent	1225883670	11/5/2008 3:14	158	00173b00116de628	IV-5DR e628	144.7
ADC0ReadEvent	1225884572	11/5/2008 3:29	167	00173b00116de628	IV-5DR e628	142.4
ADC0ReadEvent	1225887270	11/5/2008 4:14	194	00173b00116de628	IV-5DR e628	143.5
ADC0ReadEvent	1225888171	11/5/2008 4:29	204	00173b00116de628	IV-5DR e628	144.1

Sensor Analysis – Short Span Variation

Borehole temperature not influenced by surface temperature



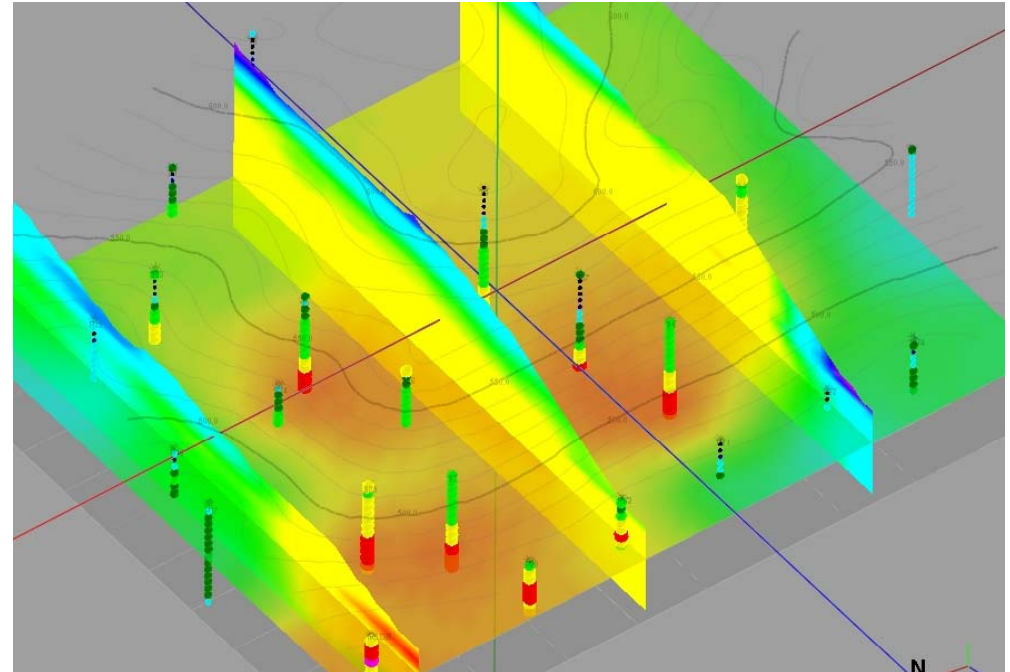
Where We Ended Up

Subject: SOUNDINGS ON GAS WELLS (NE AREA) Page 1 of 2
 Date: APRIL 3, 2007 AMBIENT TEMPS.
 Tech.: 0800 = 59°
 1200 = 67°
 1400 = 71°

COMMENTS:

WELL ID	VAC.	SAMPLE KEY		
		TEMP.	LIQUID	BOTTOM
PV-4	-13.0	118°	DRY	69.30
* P-22	-4.0	69°	DRY	21.50
* V-3D	-2.0	64°	DRY	85.20
* V-3S	-15.0	110°	DRY	25.30
* P-21	-11.0	86°	DRY	47.80
PV-2	-26.0	129°	DRY	66.90
P-20	-5.0	124°	DRY	69.80
* V-1D	-55.0	109°	DRY	37.70
P-19	-27.0	127°	DRY	73.00
IV-5DR	-2.0	134°	DRY	124.30
* P-18	-10.0	130°	DRY	69.20
P-17	-16.0	129°	DRY	59.00
P-18A	-23.0	98°	126.67	130.50
P-17A	-15.0	108°	141.00	141.50
P-16A	-15.0	115°	DRY	144.60
P-16	-46.0	108°	DRY	62.60
P-15	-45.0	100°	DRY	79.30
F-6	-72.0	84°	3550 (GIL)	54.00
* F-6	-72.0	90°	167.10 (GIL)	185.20

* = BROKEN/SHEARED WELL



Change from manual monitoring to automated data collection and modeling.

Assessing the Results

- Initial system performance good. Wi-Fi system performed as designed.
- Water and moisture issues in the electronics at the surface were greater than expected even in southern California
- Sensors had shorter battery life than expected (3 mo vs. ~9 mo. Due to load resistance and interval.
- Solar chargers very sensitive to sun angle and clouds
- Data recorded at ranges from 1 second to 1 hour and large data sets were generated which allowed for time-series processing, smoothing and refinement of timing events.
- Data channeled to neural network processing for modeling of temperature variations, surface subsidence and their relation to gas extraction rates at the landfill.
- After initial capital cost of ~30K, data acquired at low cost.