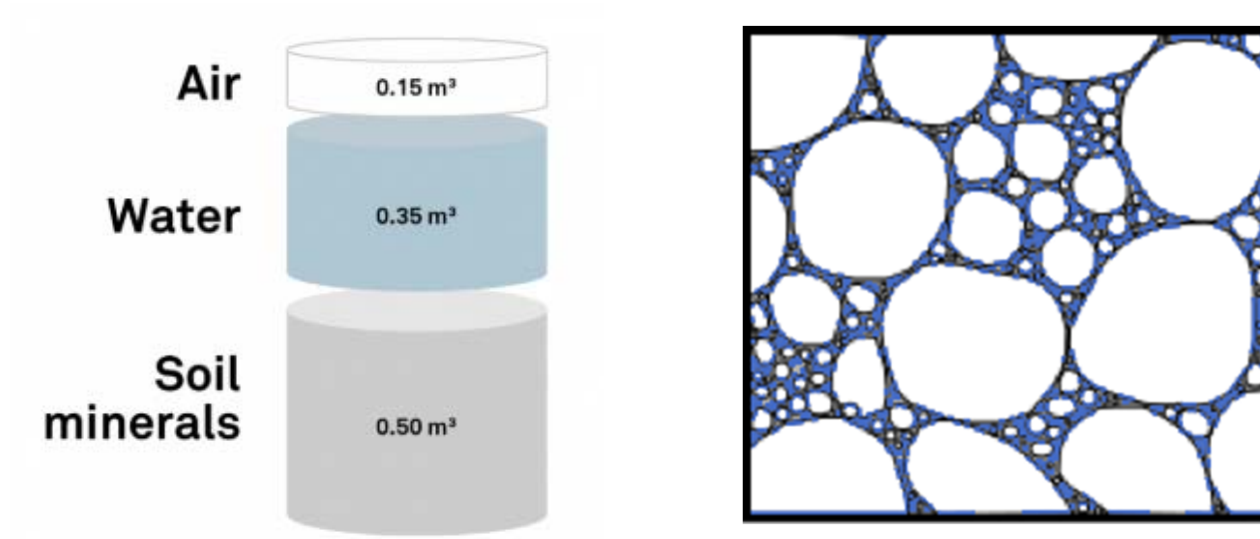
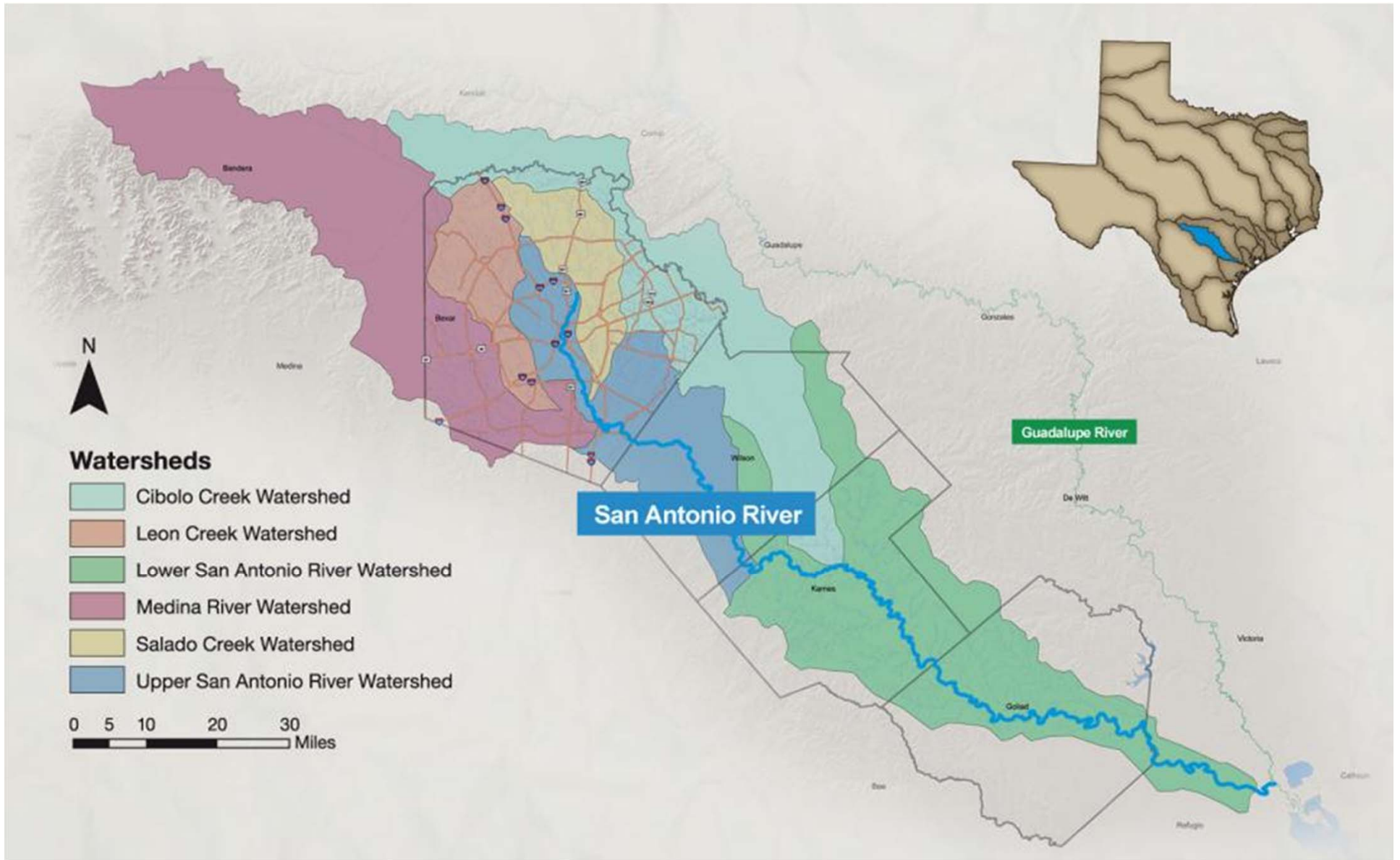


# Monitoring Real-Time Soil Moisture



August 8, 2019

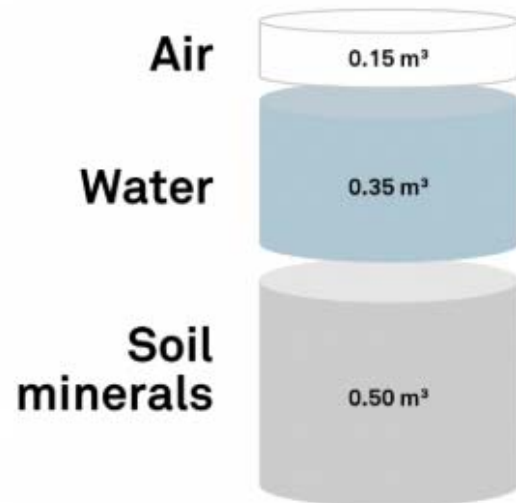
# San Antonio River Authority



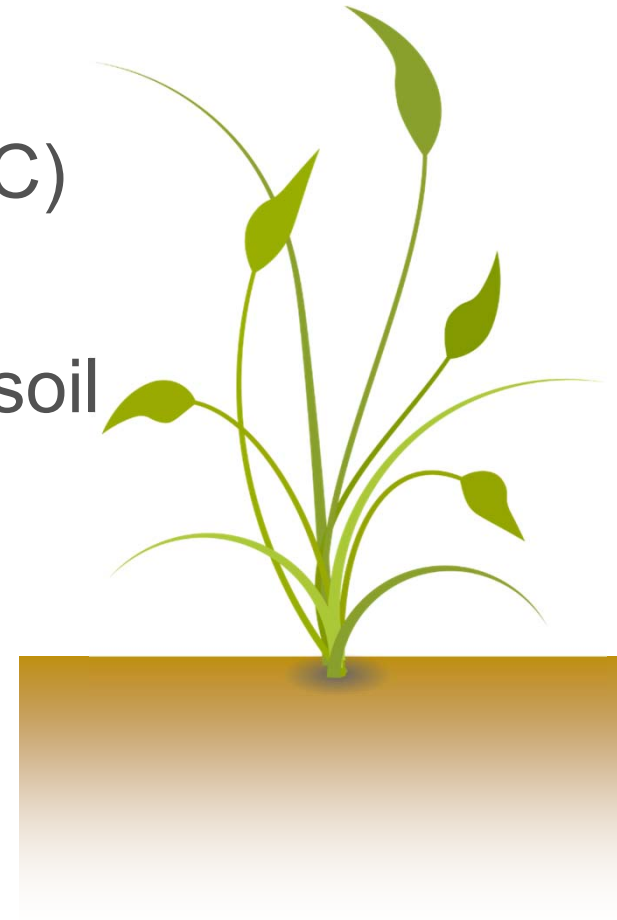
# Soil Moisture

Volumetric Water Content (VWC)

= Volume of water / Volume of soil

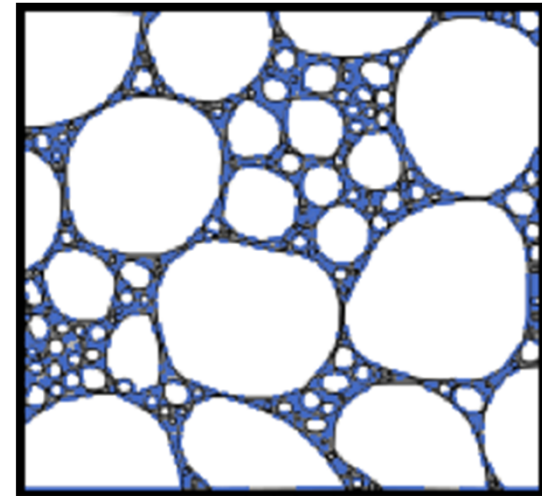


$$\text{VWC} = 35\%$$



# Gravimetric Method

- Sample  
Weigh  
Heat to evaporate water  
Weigh  
Calculate



$$w = \frac{M_{moist} - M_{dry}}{M_{dry}}$$

$$\theta = w \times \rho_b$$

# Capacitive Sensor

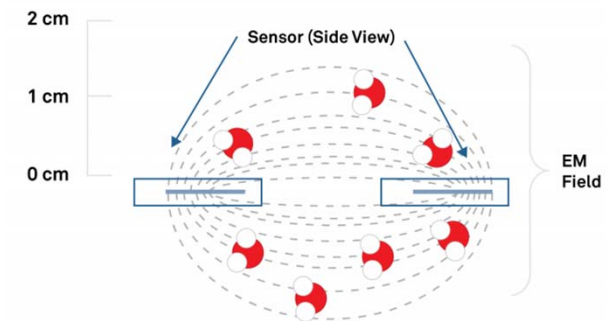
- Quantify Changes in Electro-Magnetic Field
- Capacitance  $\propto$  Permittivity

$$C = \epsilon l \frac{K(\sqrt{1 - k^2})}{K(k)}$$

$\epsilon$  : permittivity

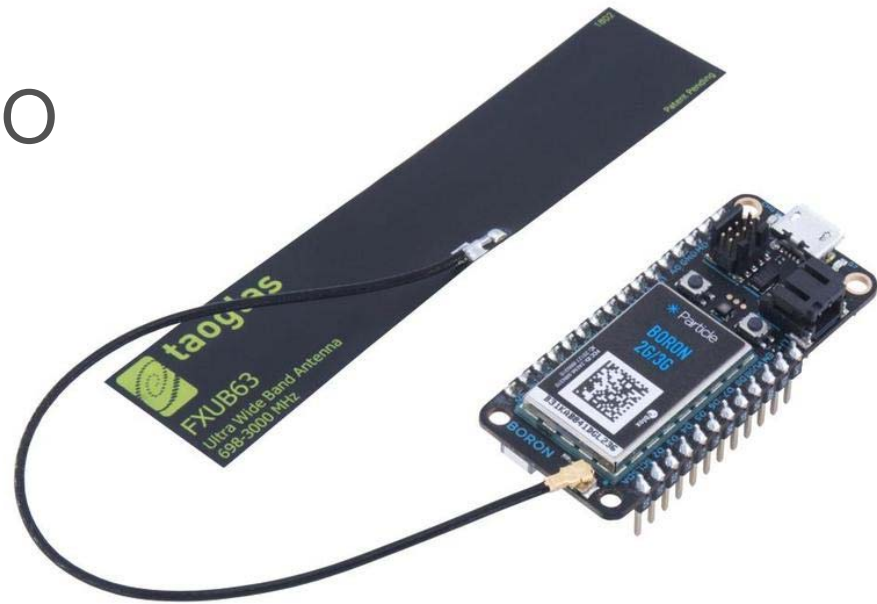
$\epsilon$  :  $\epsilon_0 \epsilon_r$

<u>Material</u>	<u>Relative Dielectric Permittivity <math>\epsilon_r</math></u>
Air	1
Soil Minerals	3 -16
Organic Matter	2 - 5
Ice	5
Water	80



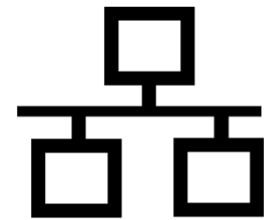
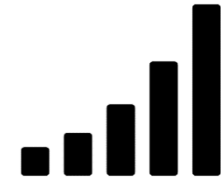
# Microcontroller ( $\mu\text{C}$ )

- Processor
- Memory
- General Purpose I/O
- Connectivity



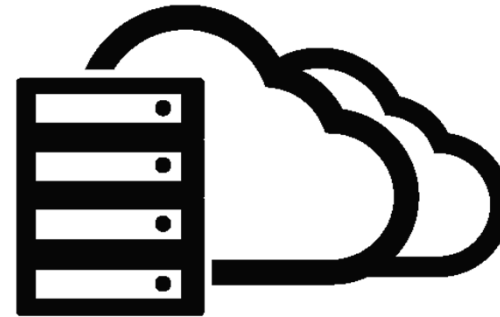
# Connectivity

- Send / Receive Data
- Updates
- Mesh Networks
- Events



# Web Server

- Manage Devices
- Manage Events



The screenshot displays the Particle web interface for a device named 'sara\_boron\_01'. The interface includes a sidebar with navigation icons, a top header with user information, and a main content area. The device details section shows the following information:

- ID: e00fc683e324aab09d81aid
- Name: sara\_boron\_01
- Device OS: 1.21-rc1.0
- Firmware: none
- Owner: unowned
- Groups: + Add groups
- ICCID: 89014103271226476560
- IMEI: 352753091084523
- Serial Number: B40KAB84IHG7UDR
- Last Handshake: Jul 15th 2019, 4:50 pm

Below the device details is an 'EVENTS' section with a search bar and a table of events:

NAME	DATA	DEVICE	PUBLISHED AT
ADCC_Value	447	e00fc683e324aab09d81aid	7/15/19 at 4:51:47 pm
ADCC_Value	445	e00fc683e324aab09d81aid	7/15/19 at 4:51:32 pm
ADCC_Value	448	e00fc683e324aab09d81aid	7/15/19 at 4:51:17 pm

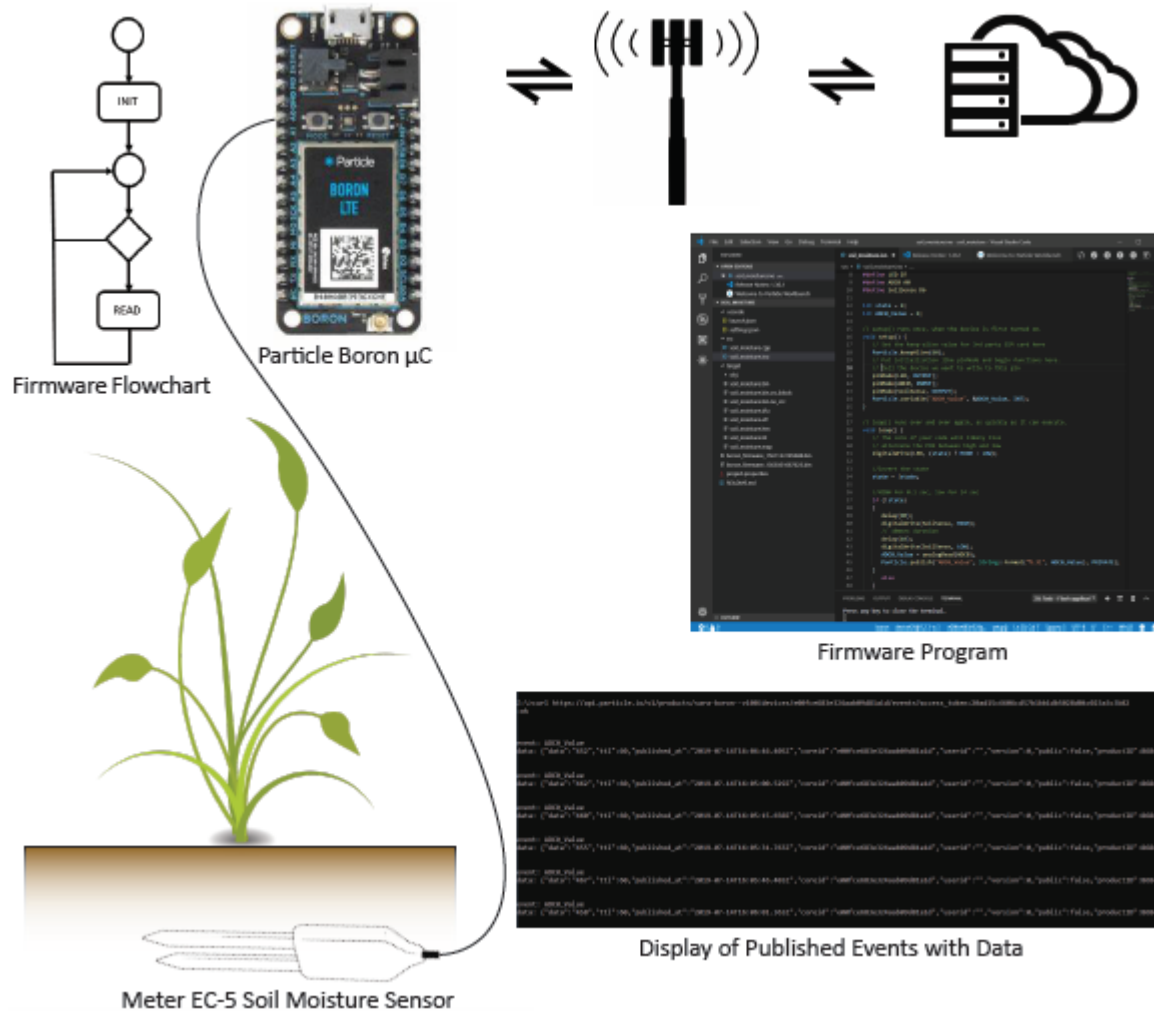
To the right of the events table is a 'LAST VITALS' section showing: Jul 15th, 2019, 04:50PM, Good cellular signal, 87ms round-trip time, 96KB of 164KB RAM used, and 0 disconnect events. Below this is a 'FIRMWARE' section with a toggle for 'Force Enable OTA'.

The screenshot shows a Visual Studio Code editor with a file named 'iot\_modules.pio'. The code is a C++ program that implements a simple web server. Key parts of the code include:

- Includes: `<Arduino.h>`, `<HTTP.h>`, `<WiFi.h>`, `<Particle.h>`, `<WebServer.h>`, `<String.h>`, and `<SPI.h>`.
- Global variables: `WiFiServer server(80);`, `WebServer webServer(80);`, and `uint8_t state = 0;`.
- Setup function: `void setup() { Serial.begin(115200); server.begin(); webServer.begin(); }`
- Loop function: `void loop() { if (server.hasClient()) { HTTPRequest req(server.client()); Particle.publish("ADCC_Value", 8000, PRIVATE); }`
- HTTP request handling: `if (req.method() == HTTP_GET) { Particle.publish("ADCC_Value", 8000, PRIVATE); }`

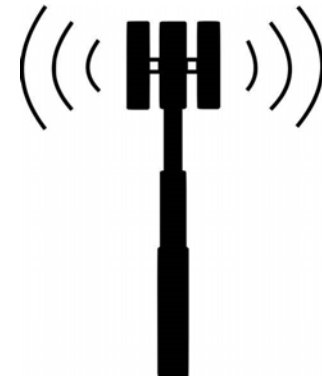


# Internet of Things (IoT)



# Internet of Things (IoT)

- Bi-Directional Communication
- Send
  - Firmware Program Update
  - Control Signals
- Receive
  - Sensor Data
  - Status



# Internet of Things (IoT)

- Cost
- Size
- Scalable



Philadelphia Water District and Drexel University – 2017  
Project: Monitor soil moisture to determine when  
to irrigate green stormwater infrastructure

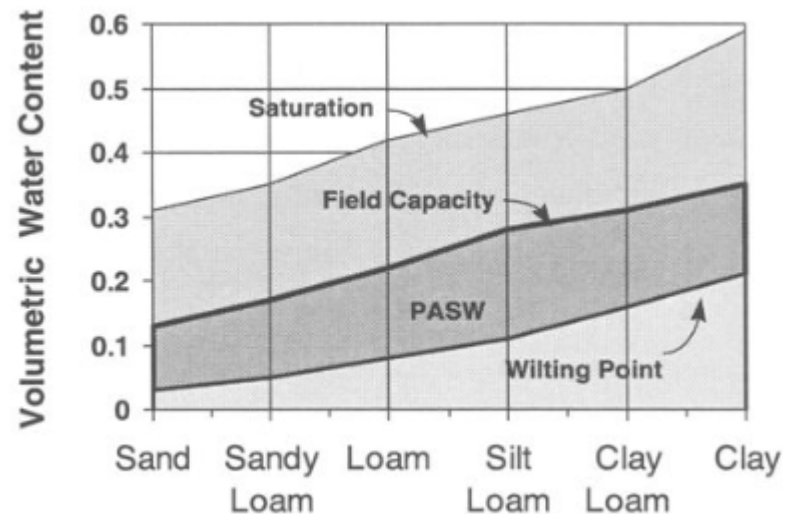
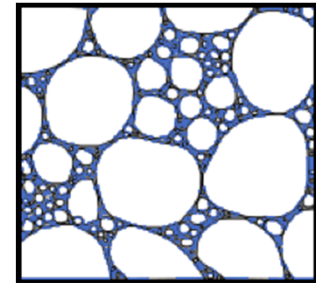
# Internet of Things (IoT)

- Applications
  - Flood
  - Water Quality
  - Security
  - Control

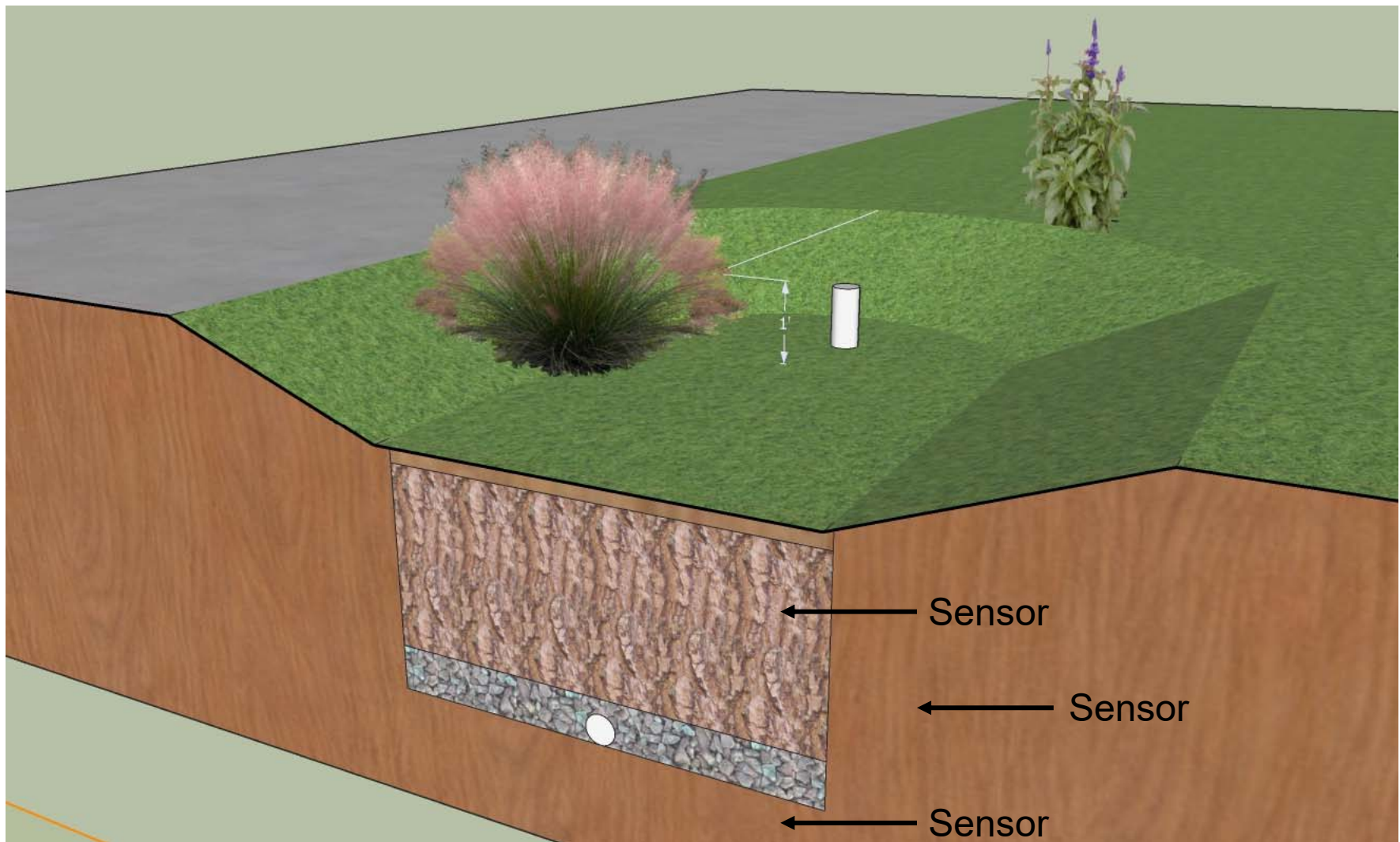


# Soil Moisture Data

- Estimate Stormwater Retention
  - Bioretention
  - Green Roof
- Calculate Plant Available Water



# Bioretention Example



# Bioretention Example



# Lessons

- Sensor Interface
- Calibration





# What's Next

- Calibration
- Temperature Sensor
- Solar Power
- Integration



# Resources

Particle - All-in-One IoT Platform

<https://www.particle.io/>

Meter EC-5 Soil Moisture Sensor

<https://www.metergroup.com/environment/products/ec-5-soil-moisture-sensor/>

Equation for capacitance of two parallel coplanar strips

Binns; Lawrenson (1973). Analysis and computation of electric and magnetic field problems. Pergamon Press. ISBN 978-0-08-016638-4.

# Contact

Jake Aalfs, PLA  
San Antonio River Authority  
[jaalfs@sara-tx.org](mailto:jaalfs@sara-tx.org)  
210.302.3248

