

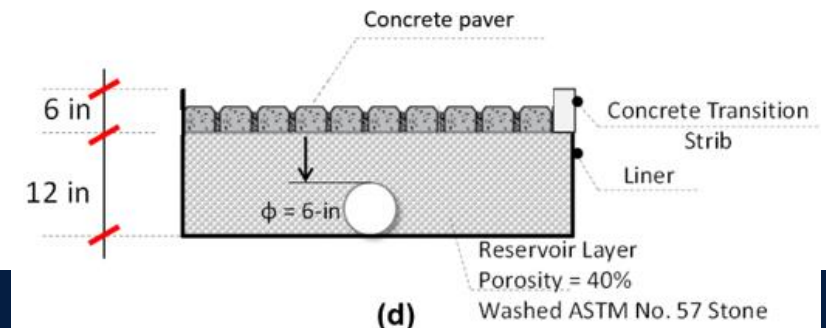
Demonstrating the Benefits of Permeable Pavements over the Edwards Aquifer

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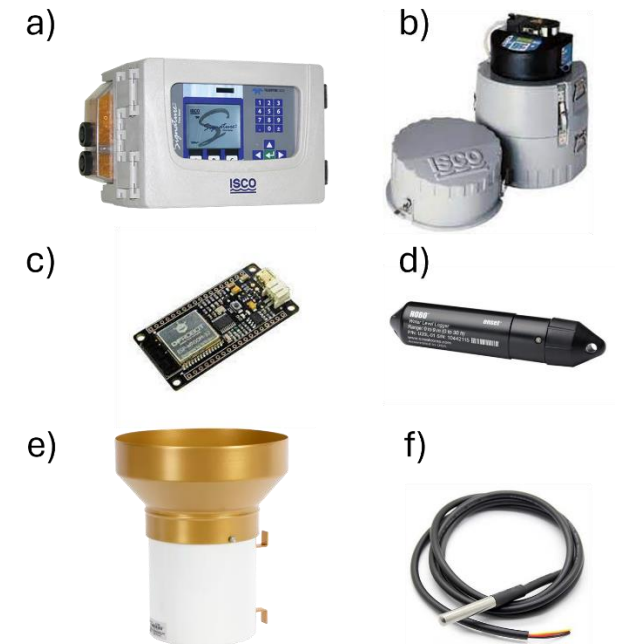
Overview and Goal of the Project

- Evaluate the performance of four types of permeable pavers:
 - Water Quantity
 - Water Quality
 - Temperature
- How? Build and monitor four (4) permeable pavement (PP) parking lots:
 - 36 ft by 57 ft (area 2050 ft²)
 - 8 parking stalls per lot
 - Paved surfaces:
 - (a) Plastic Grid Paver (PGr)
 - (b) Pervious Concrete (PC)
 - (c) Porous Asphalt (PA)
 - (d) Permeable Interlocking Concrete Paver (PICP)
 - PP base layers identical. Equipped with impermeable bottom liner (TCEQ requirement) and perforated side drains.
- One conventional (impermeable asphalt concrete) parking lot to serve as Control (CP)



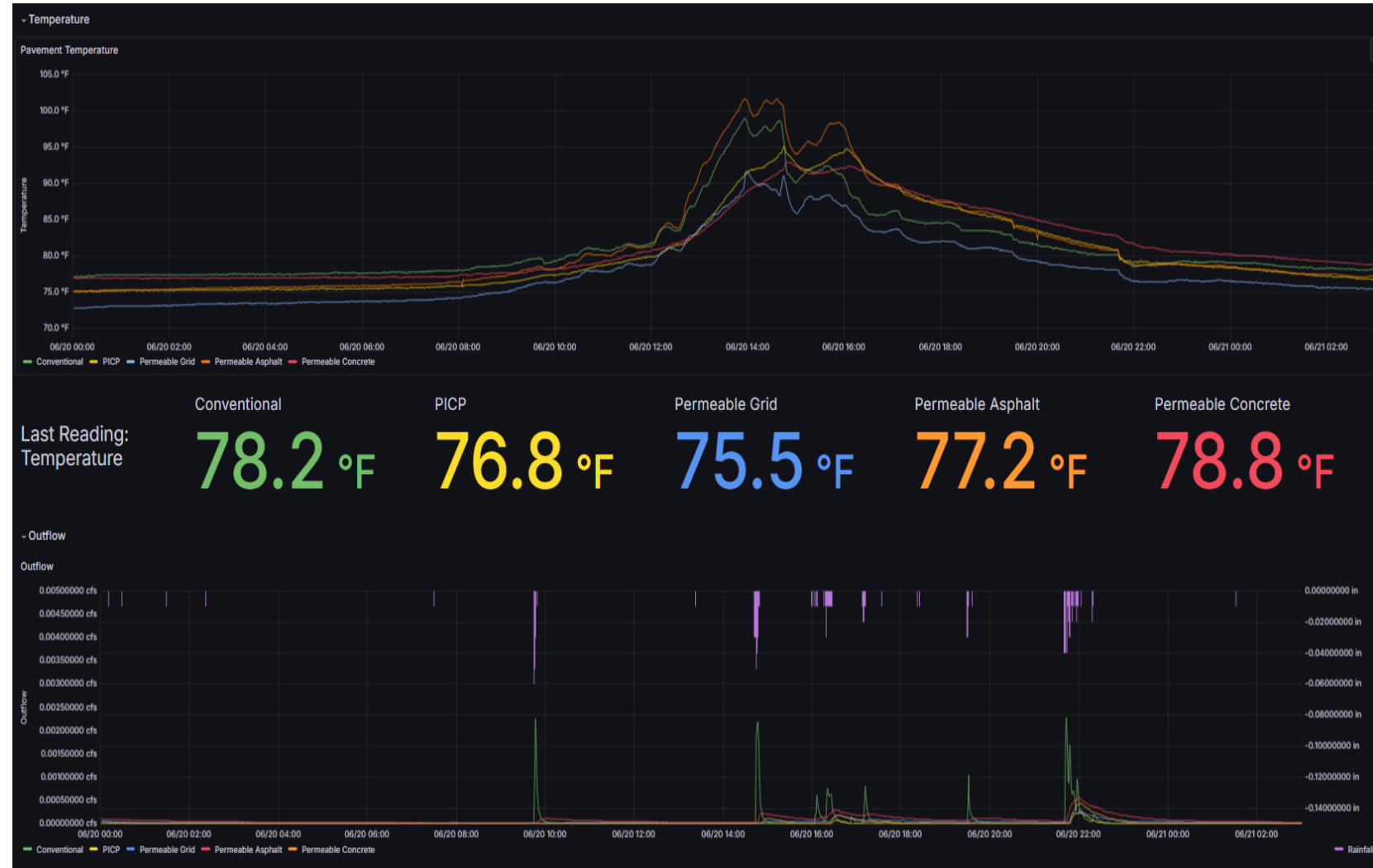
Monitoring Setup

- For each Parking Lot:
 - Monitoring Box:
 - 1) One Automatic Water Sampler
 - 2) Flow Meter
 - 3) Power/Communication devices
 - Water Quantity:
 - Rainfall, Flow rates, and Runoff Volumes
 - Water Quality:
 - TSS, VSS, Bacteria, pH, Conductivity, Metals, Hardness, and Hydrocarbons
 - Pavement and Water Temperature
 - Lot Occupancy:
 - Cameras and AI algorithm



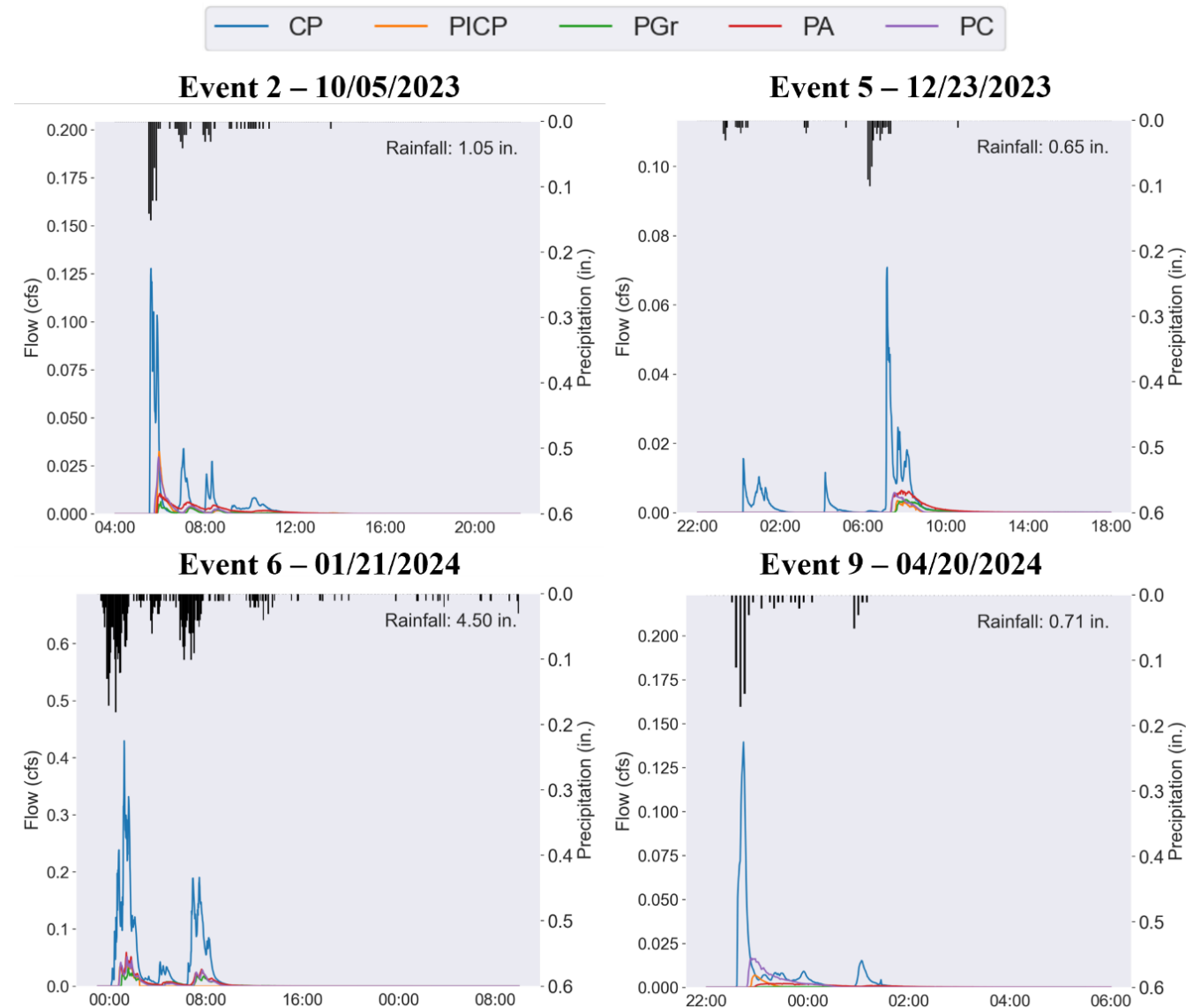
Real-Time Monitoring (RTM)

- Custom software was developed to allow RTM of precipitation events and remote data collection and transmission.



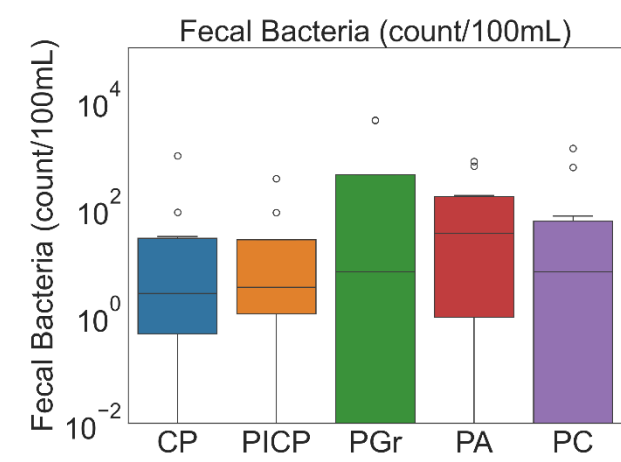
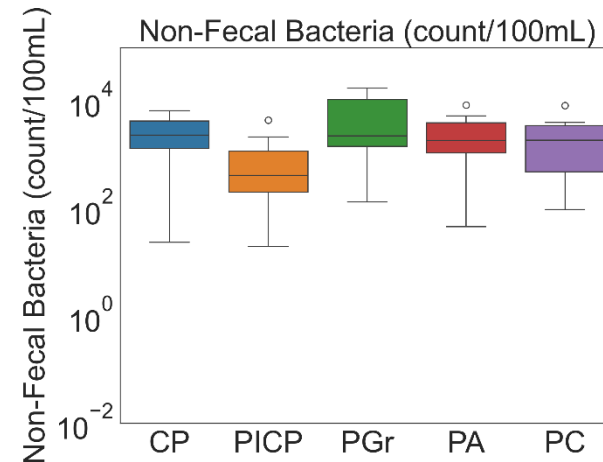
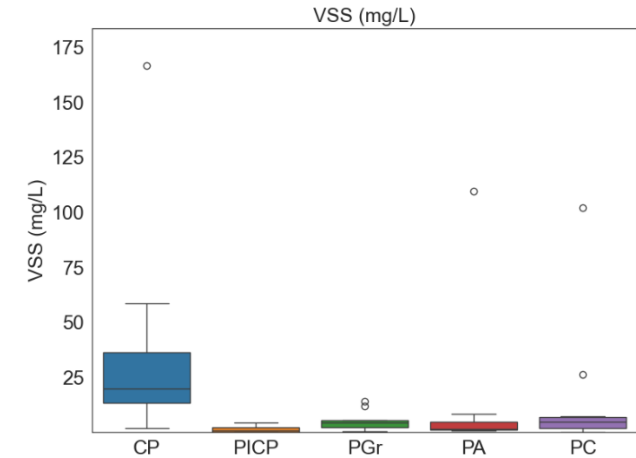
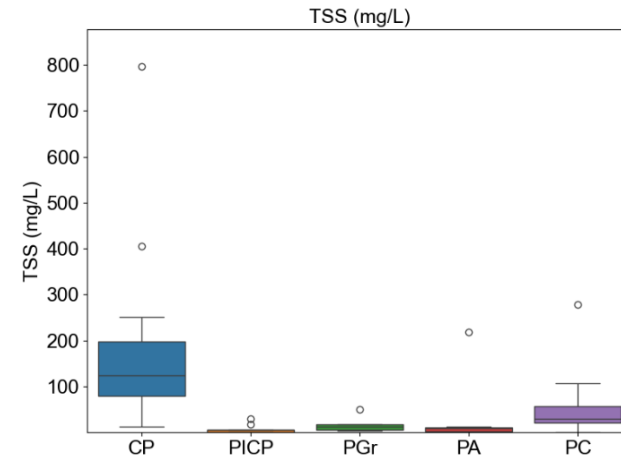
Water Quantity Results

- 11 rainfall events from August 2023 to May 2024.
- Rainfall:
 - Depths: 0.48 to 4.5 inches.
 - Duration: 85 min to 34.8 hours
- Peak flows and outflow volume are significantly reduced:
 - On average 90% to 76%
- Water is retained in base layer and drains from the perforated underdrain pipes.



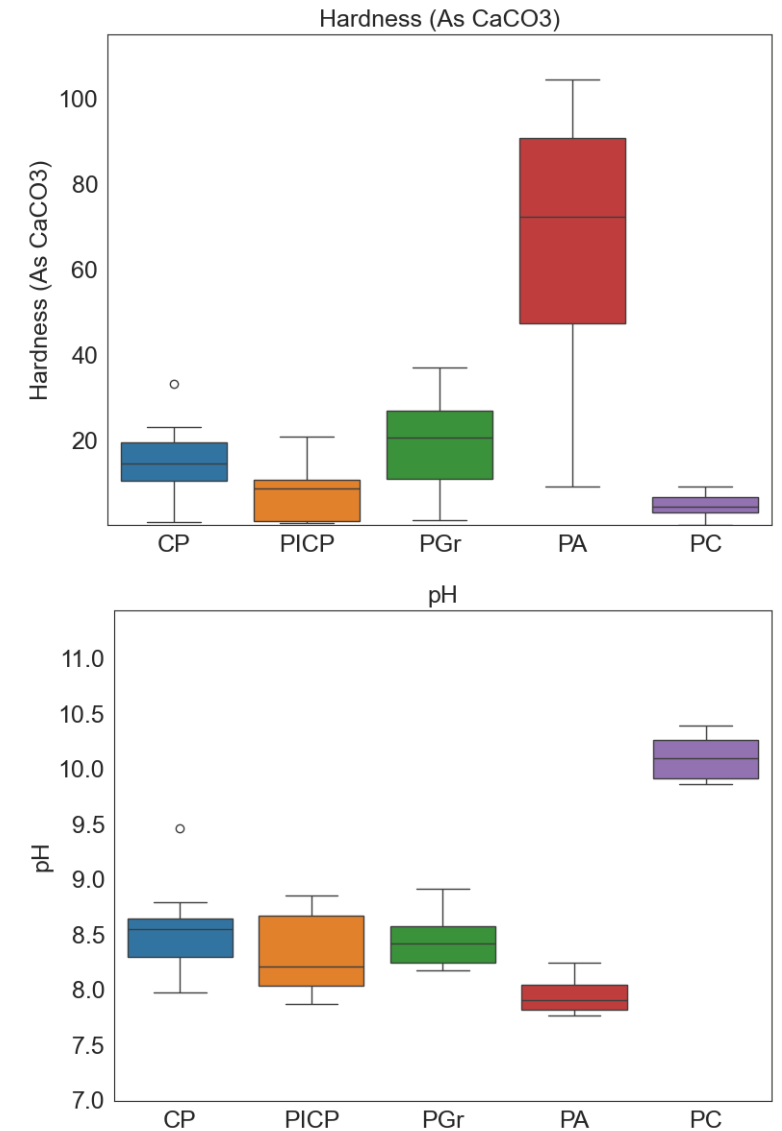
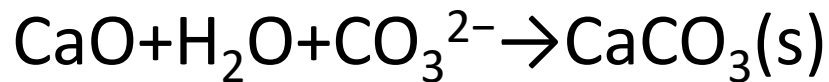
Water Quality Results

- Suspended Solids:
 - Significant reduction in concentration and loads of TSS and VSS from PPs to Control (CP)
- Fecal and Non-Fecal Bacteria:
 - No significant statistical differences between Control and PPs
 - Visible sources of contamination from Wildlife
- Metals:
 - Very low concentrations of Zn, Cu
 - No Pb detection
 - No detection in the tests for most of the samples



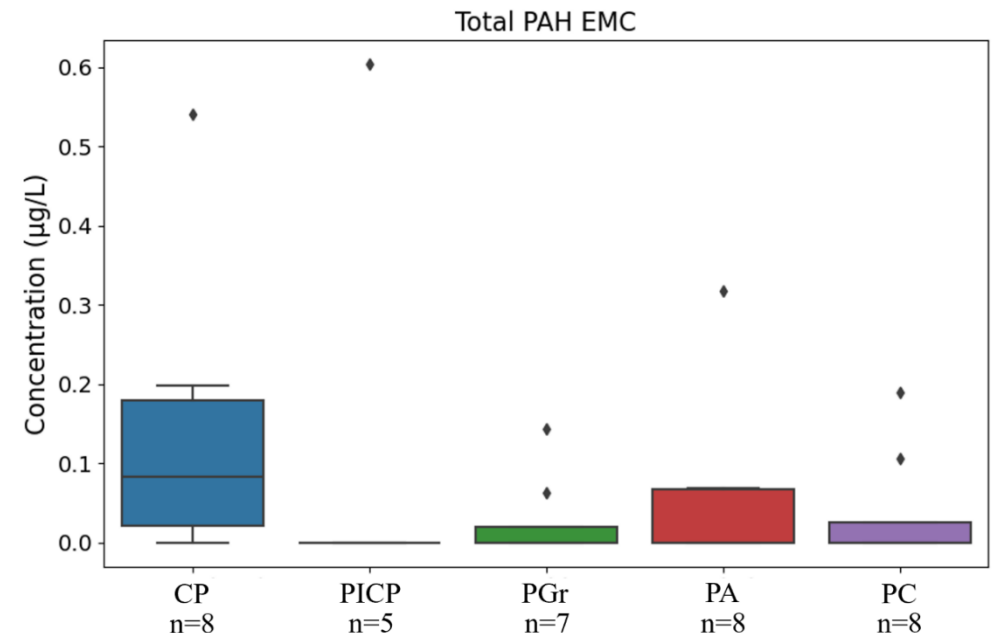
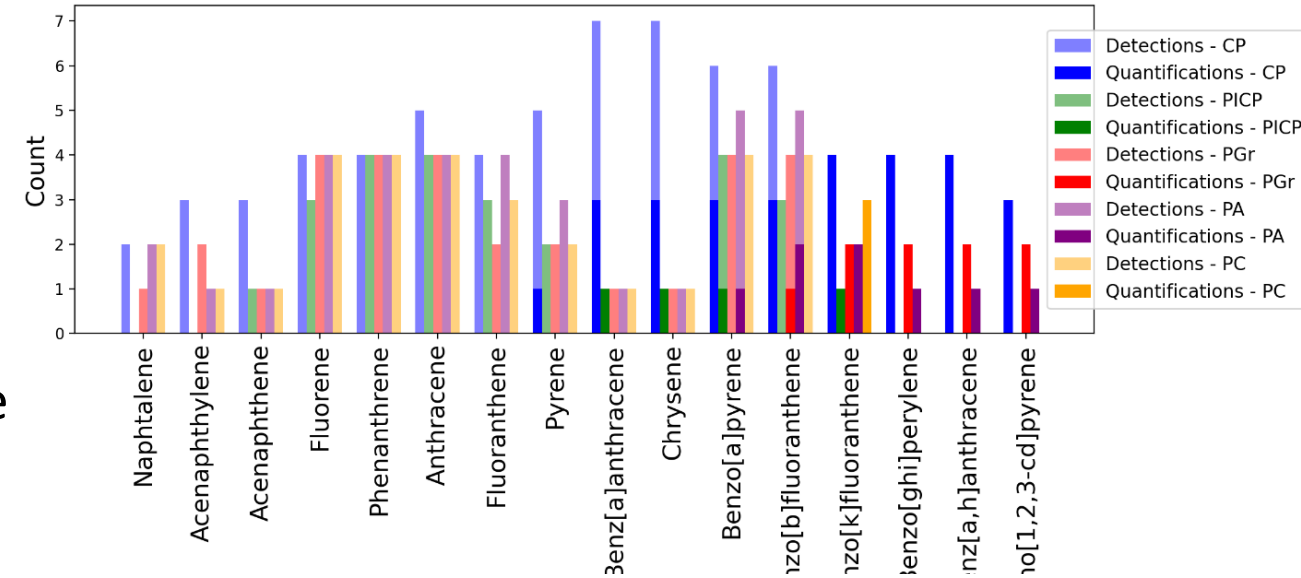
Water Quality Results

- Hardness:
 - PC reduces hardness
 - PA increases hardness
 - Leaching minerals (Mg^{+} and Ca^{+})
- pH:
 - PC increases pH significantly
 - Source: Cementitious materials
 - PA reduces pH significantly
- High pH mobilizes $CaCO_3$ in solid form, which reduces minerals:



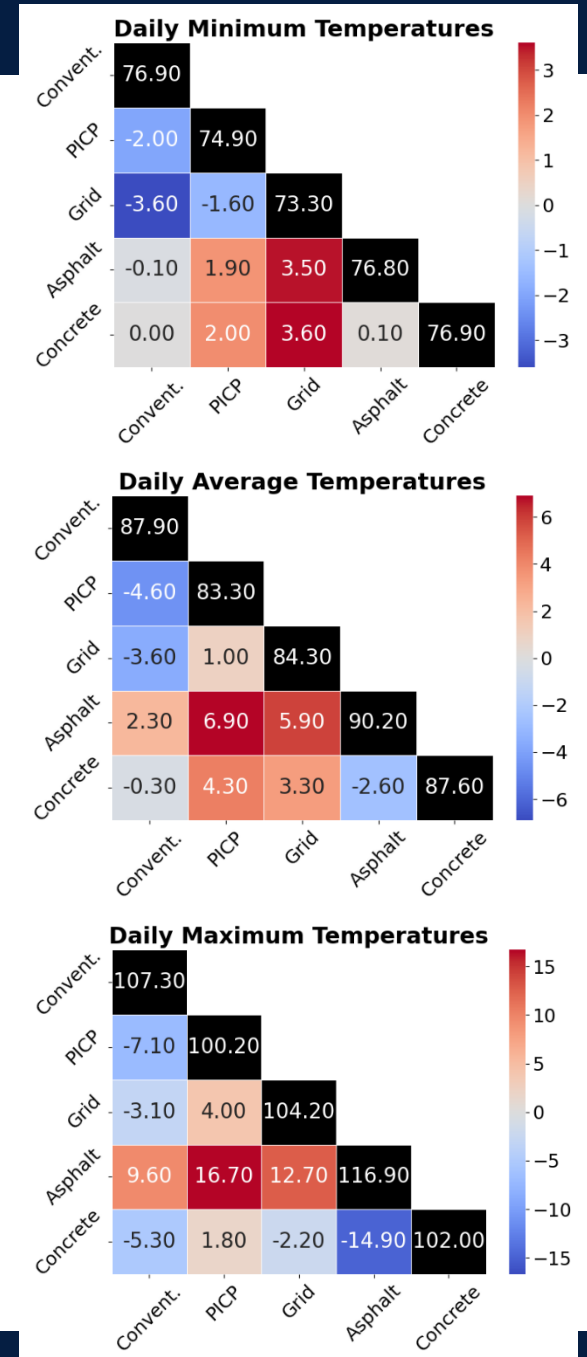
Water Quality Results

- Total Petroleum Hydrocarbons (TPH):
 - No detection above the PQL
 - Literature suggests TPH gets trapped in the drainage layer (porous and liner)
- Polycyclic Aromatic Hydrocarbon (PAH):
 - A total of 16 compounds
 - Some samples identified heavy compounds
 - We can't affirm statistically that PPs reduced PAH in comparison to the Control
 - Average concentration of PAH in the Control is higher than the PPs



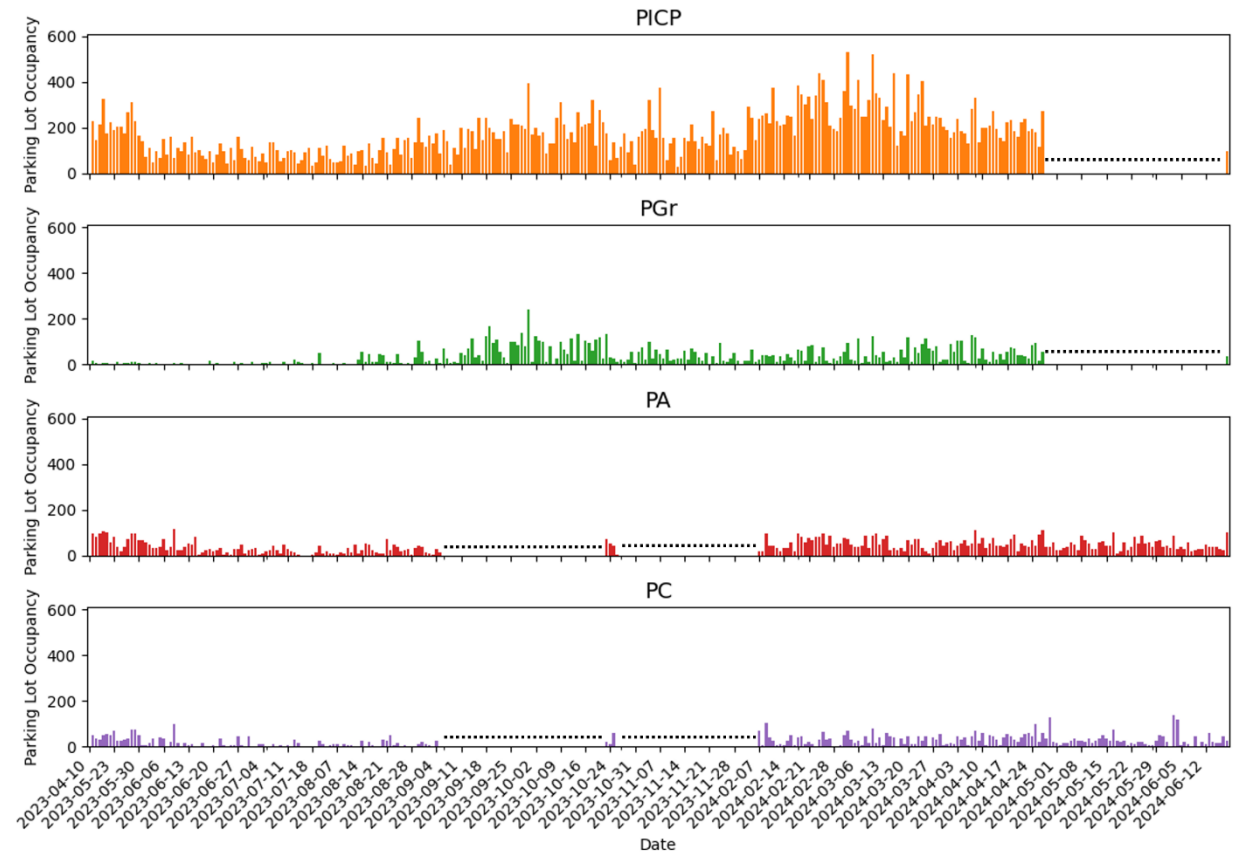
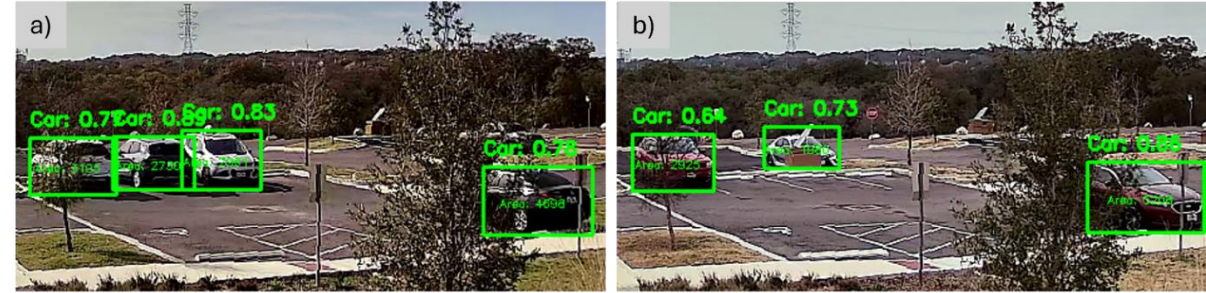
Pavement Temperature

- PGr, PICP, and PC reduce average and maximum temperatures significantly in comparison to the Control
 - Maximum temperature of PICP is 7.1F cooler than Conventional Asphalt
- PA and Control presented similar temperatures in minimum and average
- PA increased the maximum temperature
 - Darker color



Parking Lot Occupancy

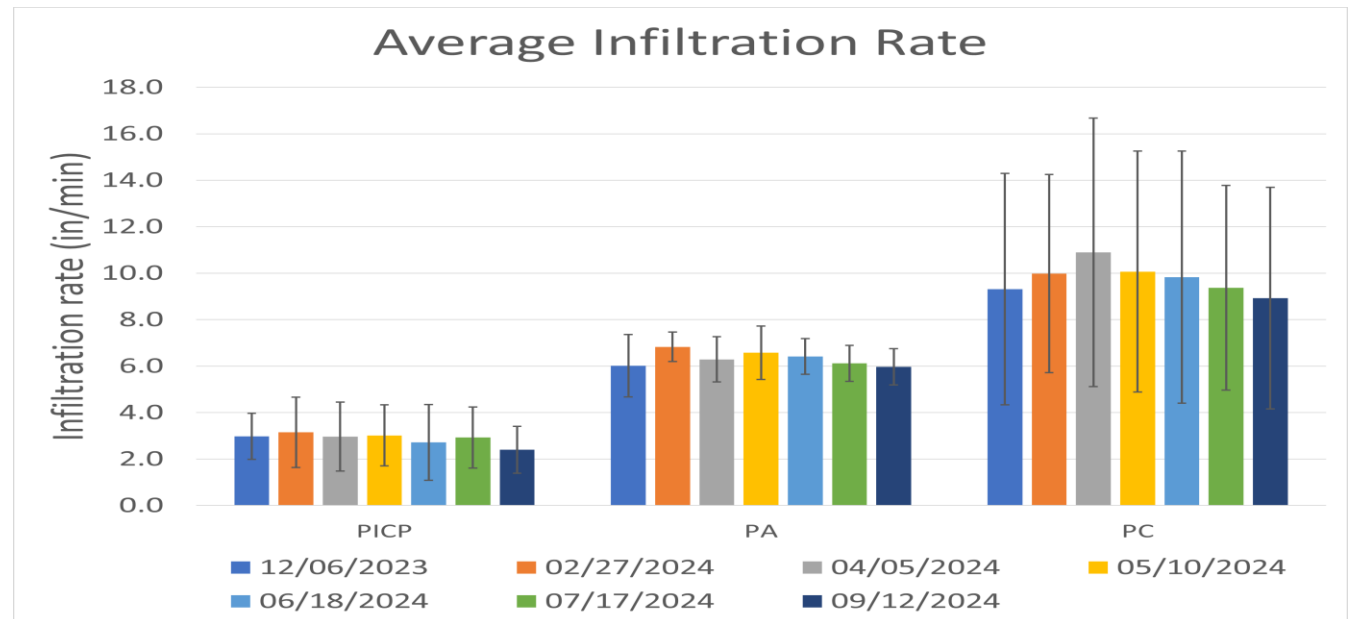
- Developed an AI algorithm to identify and count # of cars in each parking lot
 - Using video images 5 minutes apart
 - Cameras located in the pavilion
- The accuracy of the model was highly dependent on the position of cameras and line of sight obstructions (trees)
- PICP was the most used lot
- For the Control, we found a statistically significant correlation between TSS/VSS and occupancy



Permeable Pavement Cost and Maintenance

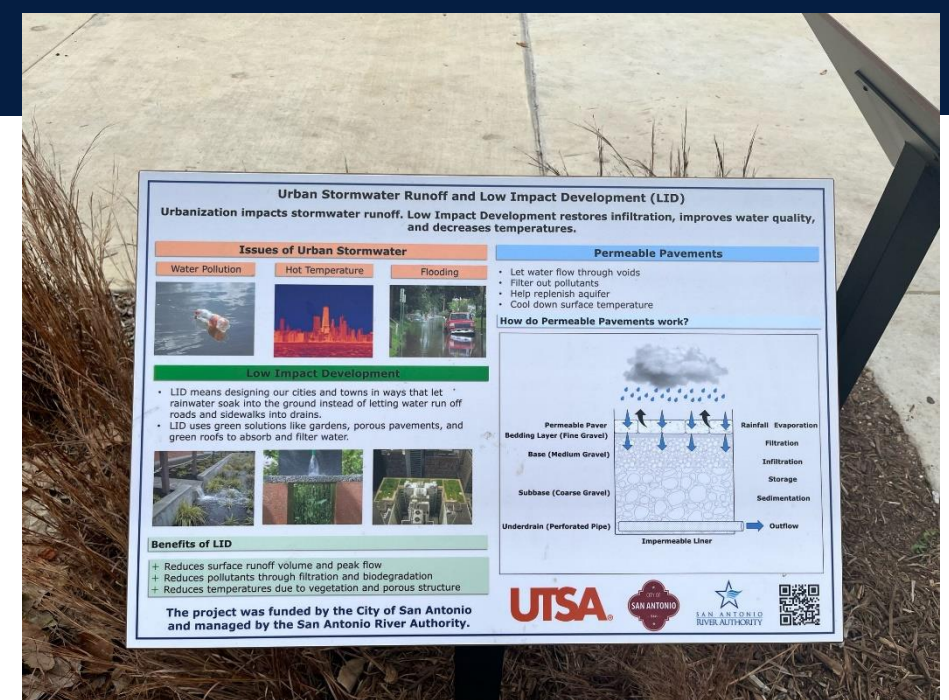
- PP unit construction costs ranged from \$13.05/ft² to \$21.59/ft².
- The PGr and the PICP were the easiest to construct, requiring no specialized paving equipment.
- None of the PPs required any structural repairs during the observation period.
- No statistically significant clogging:
 - Seven infiltration tests were performed from December 2023 to September 2024

Permeable Pavement Type	Total Cost \$	Unit Cost \$/ft ²
PGr	\$34,100	16.63
PC	\$44,250	21.59
PA	\$26,756	13.05
PICP	\$34,100	16.63



Public Outreach

- Two outdoor panels were installed to educate the public about:
 - Urban stormwater runoff
 - Low Impact Development (LID)
 - Benefits of permeable pavements.
- Provide information on the environmental impact and performance of the permeable pavements used in the study.



Environmental Benefits of Permeable Pavements

- Water Quantity Management:
 - All permeable pavements reduce the volume and runoff peak compared to conventional pavement through effective water storage.
- Water Quality Improvement:
 - All four permeable pavement types yielded substantially lower TSS and VSS concentrations in water outflow compared to conventional pavement.
 - In general, PPs maintain pH levels, lower PAH averages, and remove metal effectively
- Thermal Performance:
 - All permeable pavements, except the PA, demonstrated better thermal performance, maintaining lower average and maximum temperatures.

Conclusions and Recommendations

Conclusions:

- Permeable pavements effectively manage stormwater, improve water quality, and improve thermal performance.
- Permeable pavements demonstrated better pollutant mitigation and thermal performance than conventional pavement.

Recommendations:

- Permeable pavements should be considered as a Low Impact Development (LID) strategy, especially over sensitive aquifers.
- Regular monitoring and maintenance, such as vacuum sweeping or pressure washing, are essential to prevent clogging and maintain permeability.

Final Report

Submitted 2/1/2025

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Permeable Pavements over
the Edwards Aquifer



Final Report to the:
San Antonio River
Authority

February 1st, 2025

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Questions?

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