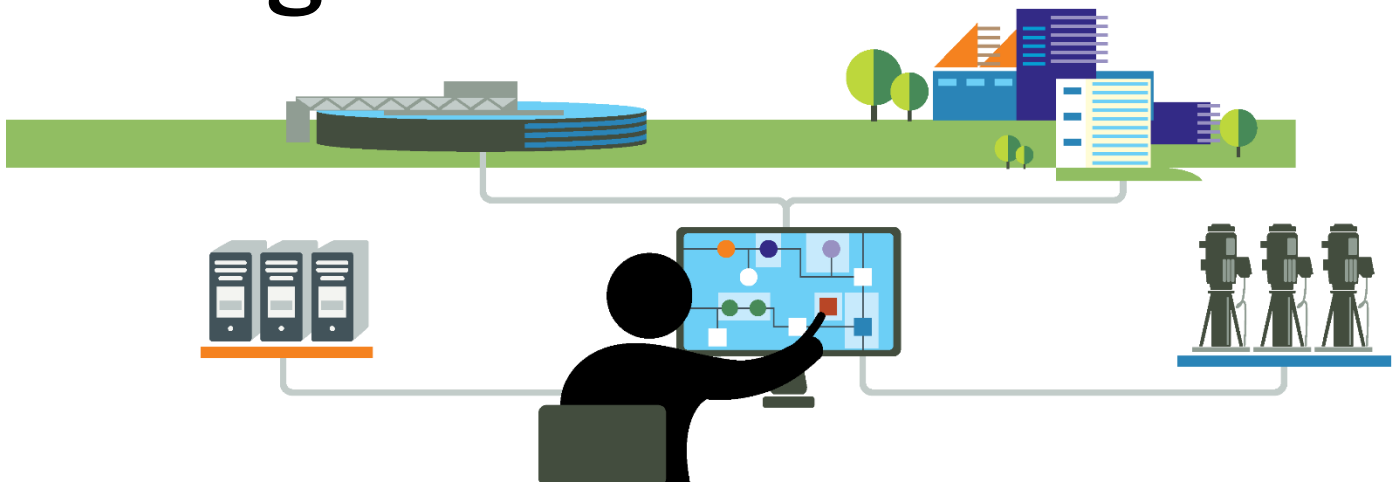
Forecasting Combined Sewer Overflows (CSOs) for Advanced Public Notification Using Data-Driven Modeling



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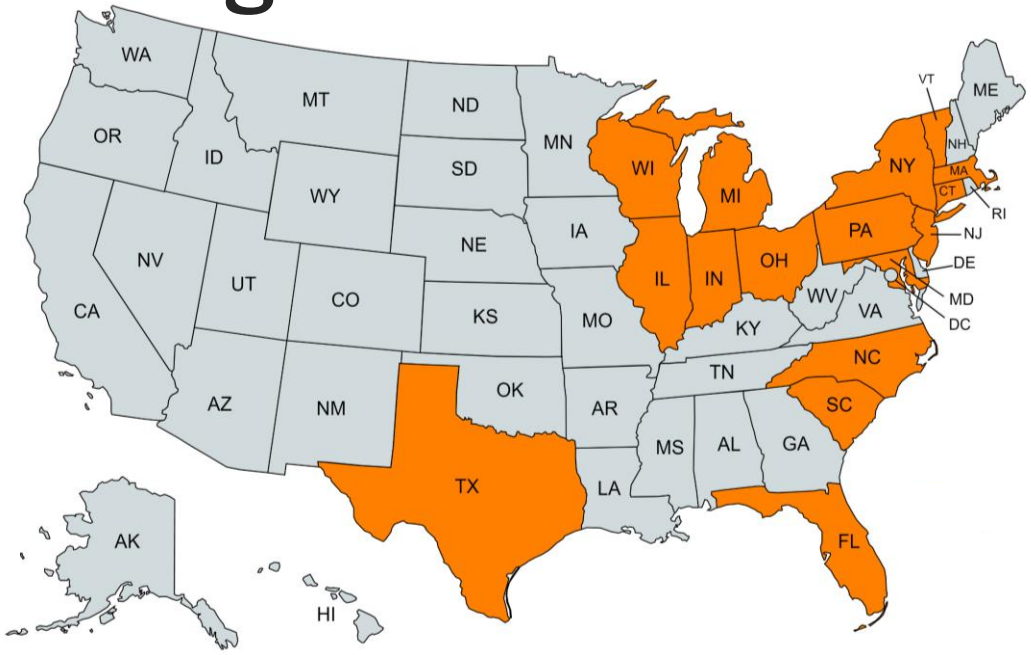
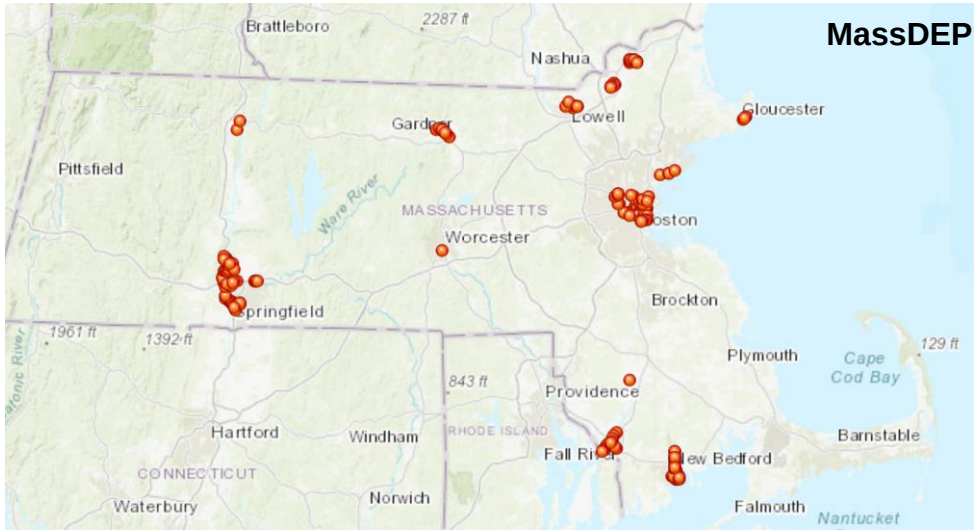
Public Notification of CSO/SSO Discharges

- Several states have passed laws or guidance on public notification of CSO/SSO discharges.
- Massachusetts passed a law (314 CMR 16.00) requiring more immediate public notifications, no more than 2 hours following the discovery of the event.
- Utilities can stay one step ahead by investing in data solutions such as predictive analytics to provide real-time insights

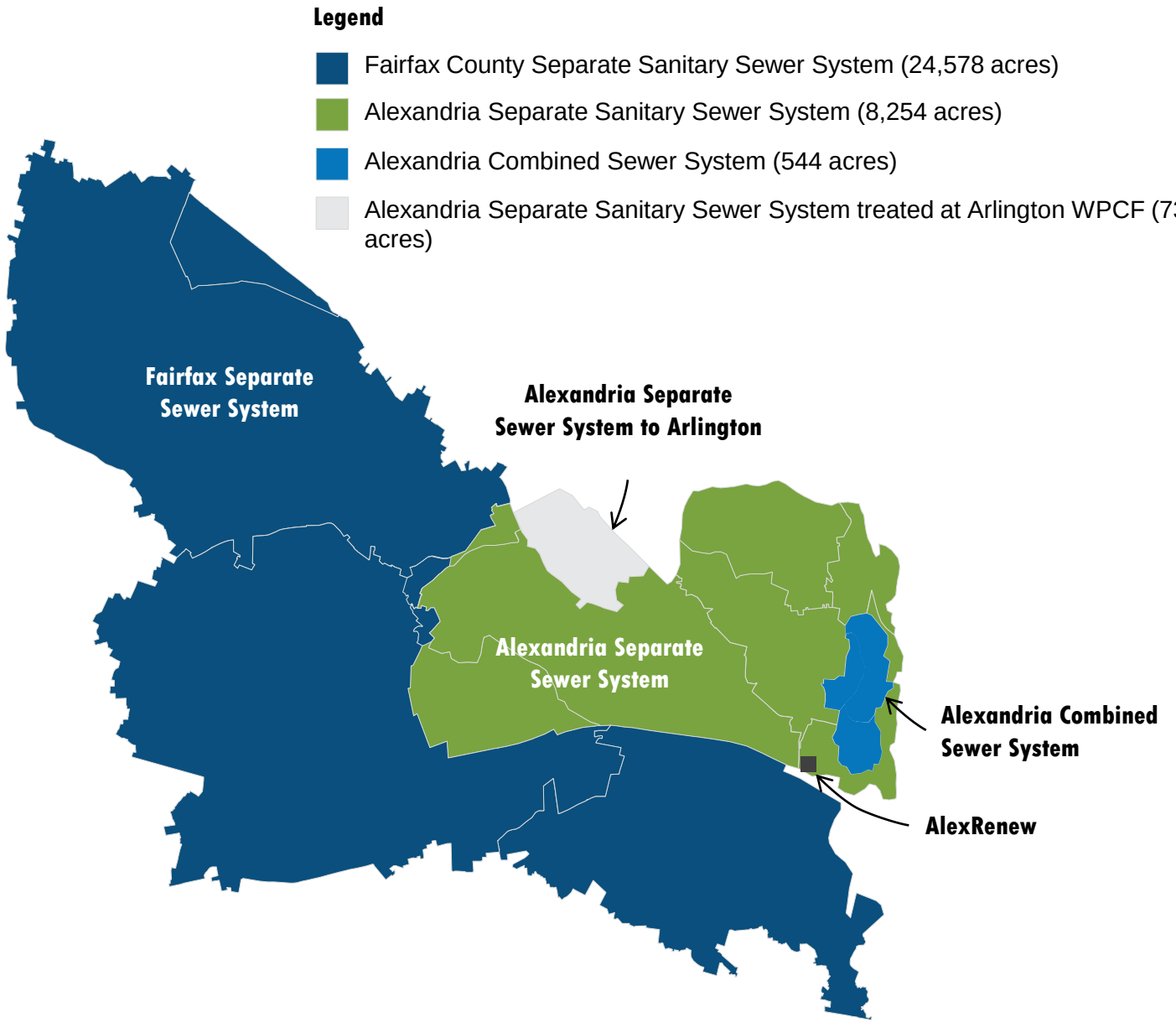




AlexRenew

- Purifies 13 billion gallons of wastewater at its Water Resource Recovery Facility each year
- Serves over 300,000 customers in Alexandria and Fairfax County
- Independent political subdivision
- Invests over $50M annually to protect waterways and the Chesapeake Bay
- Governed by a 5-member citizen Board

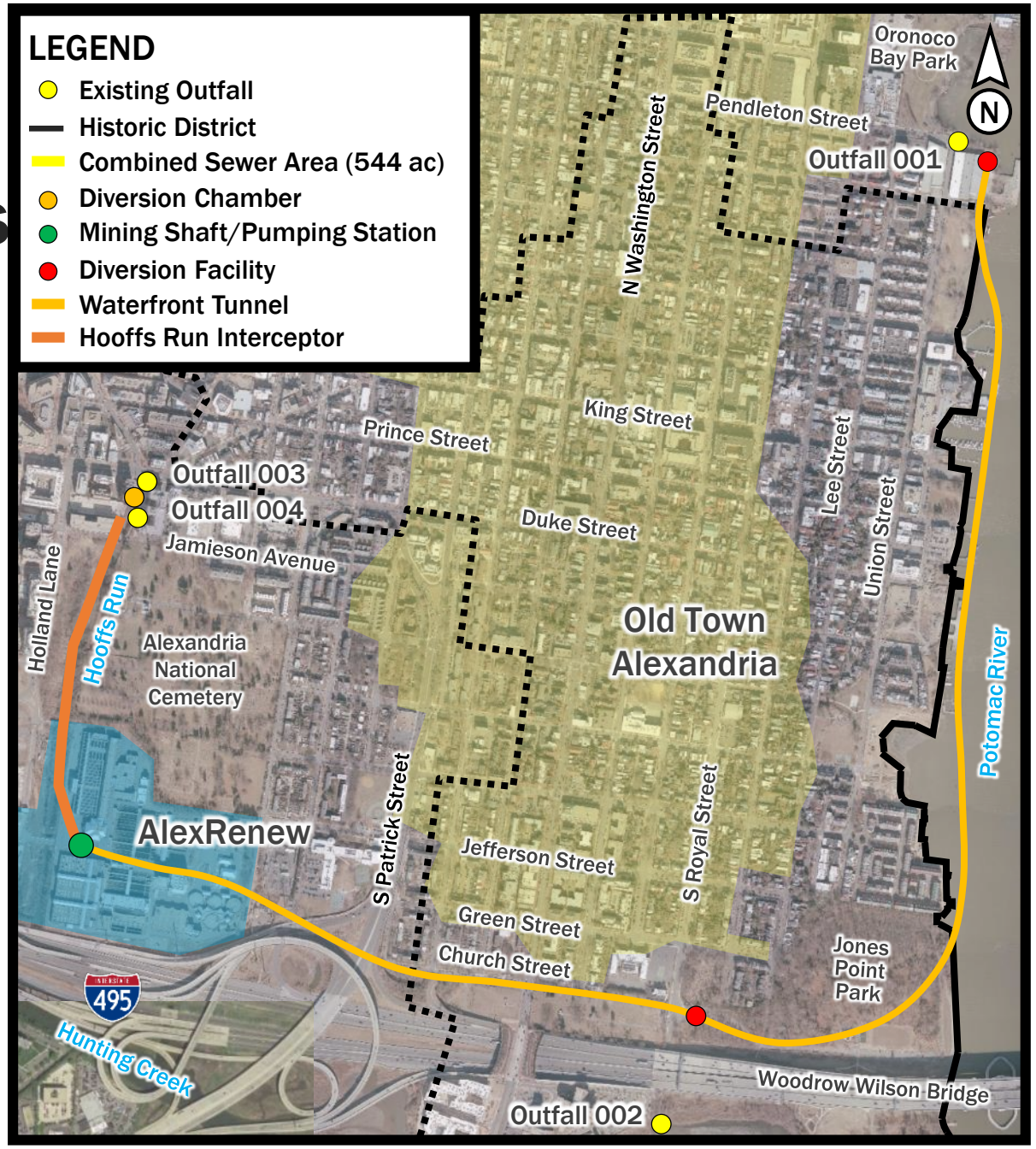
AlexRenew Serves both Separate Sanitary and Combined Sewer Systems



A 2017 Virginia Law Requires Remediation of Alexandria's Four Combined Sewer Outfalls by July 2025

Outfall	Current Overflow Volume (million gallons)*	Current Overflow Events*	2017 Law Requirement
001	63	37	4-6 overflows per year
002	38	46	80% bacteria reduction
003	31	70	99% bacteria reduction
004	8	45	99% bacteria reduction

*Yearly average based on 2000-2016 climate period



RiverRenew Tunnel System Project details.

Components:

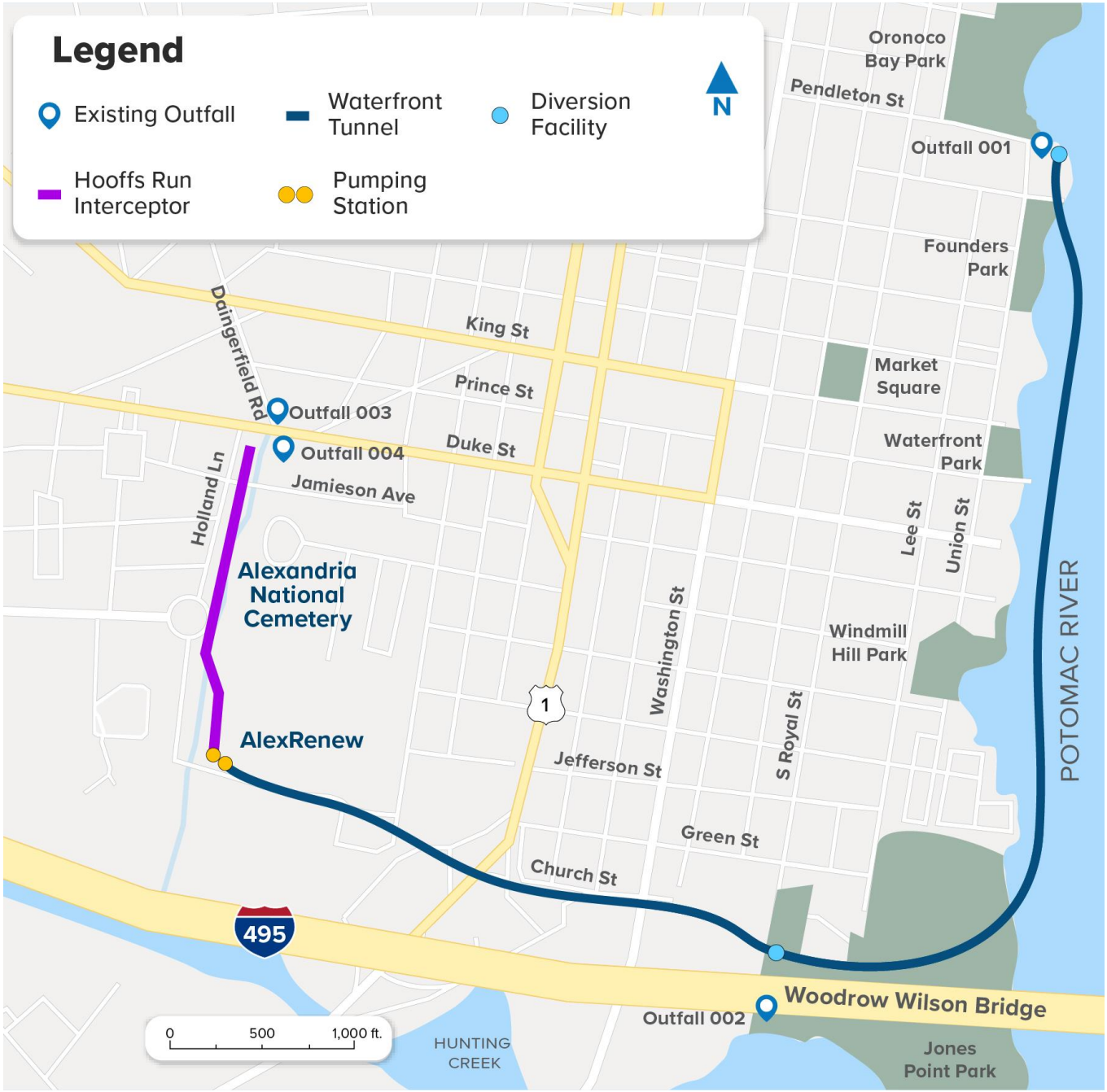
- Two-mile-long, 12-foot-wide **Waterfront Tunnel** approximately 100 feet below ground
- **Diversion facilities** to direct combined sewage into the tunnel system
- Half-mile-long, six-foot-wide **Hooffs Run Interceptor**
- **Pumping stations** housed in two large shafts
- Superstructure to house pumping station equipment

Construction Cost:

- $454.4 million

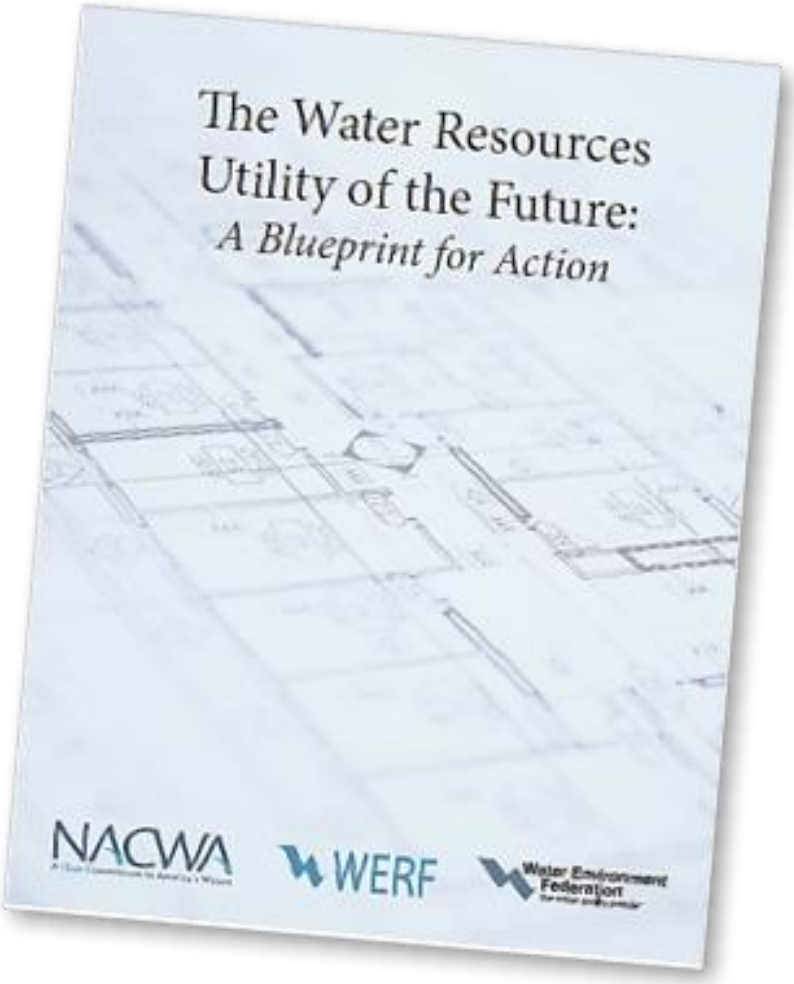
Tunnel Project Schedule:

- December 2020 – July 2025



NACWA: The Utility of the Future will be…

- Focused on innovation
- Highly automated
- Predictive infrastructure
- Enabled with full real-time monitoring and control
- Highly leveraging analytics and intelligence systems
- Highly integrated digital and physical systems



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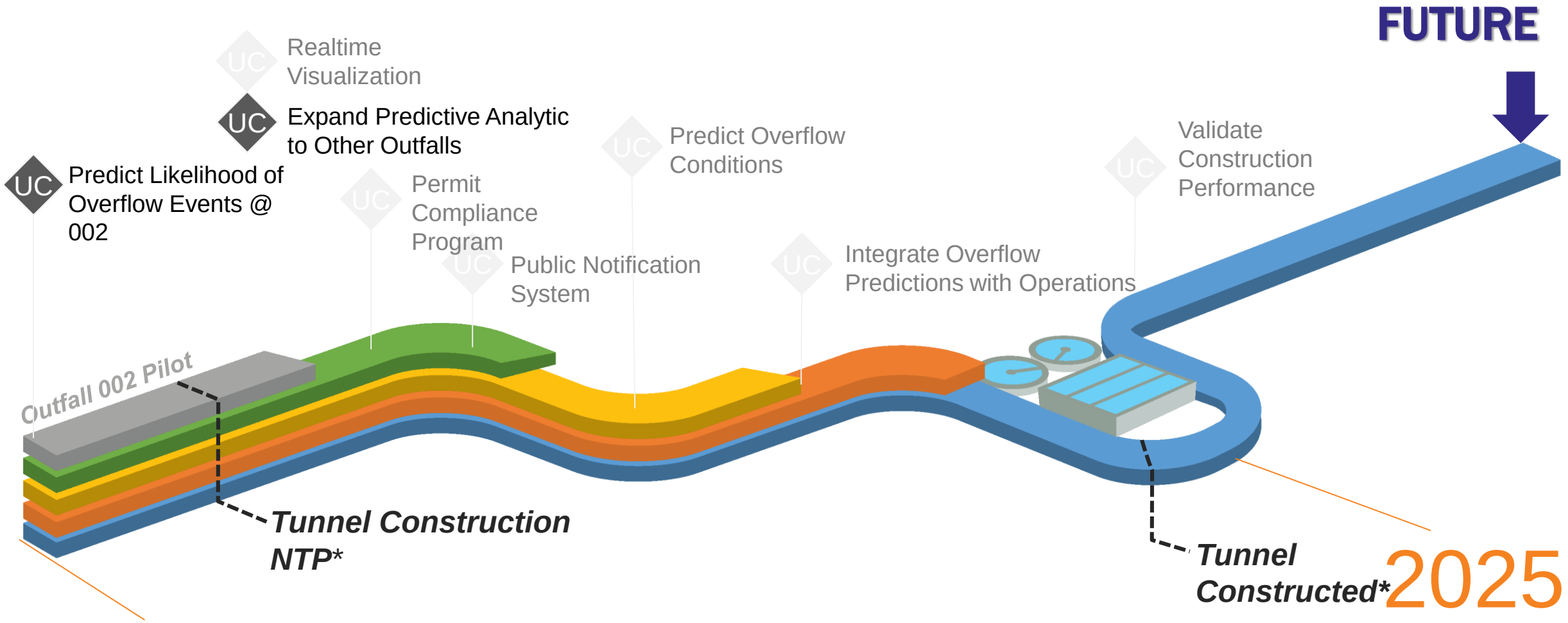
Smart Utility Roadmap



Leveraging Models for AlexRenew's Future Smart Utility Program

Public Reporting

Report performance benefits of tunnel system

Event Forecasting

Model forecasted precipitation data to understand how tunnel system will perform during an event

Operational Preparedness

Utilize predictive models to enhance the operational efficiency of the tunnel system and wastewater plant

Outfall 002 Pilot Study

Existing data sources were used to develop a model to predict overflows

1 DATA SOURCES

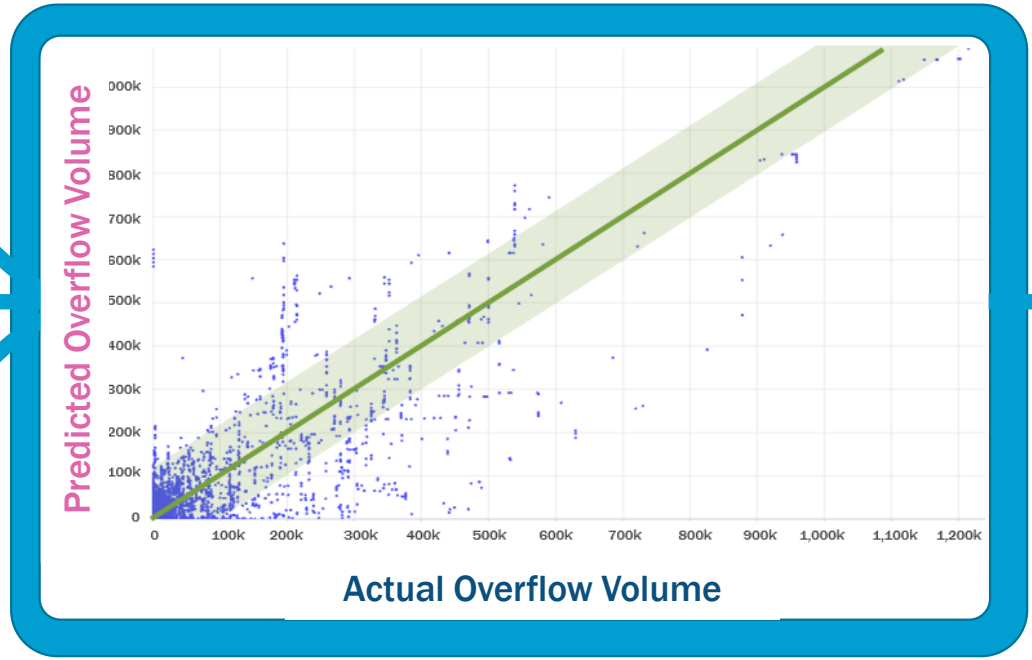
2 PREDICTIVE MODEL

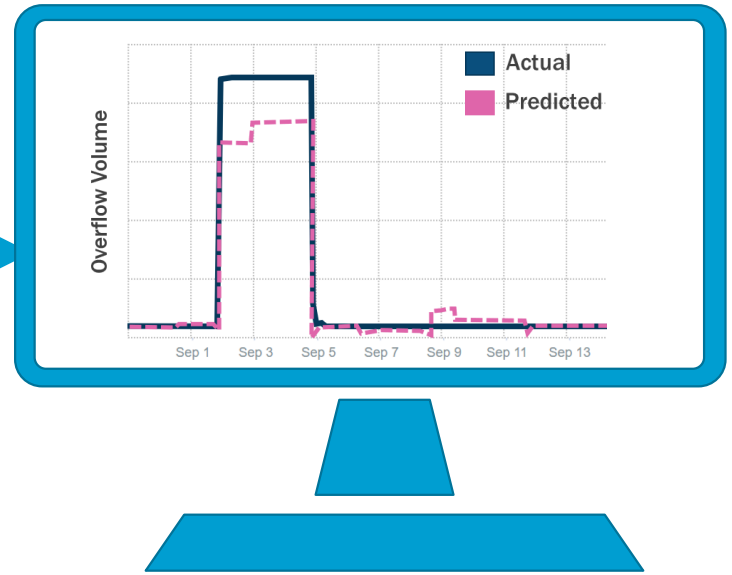
3 OVERFLOW PREDICTIONS

XPSWMM Model

Overflow Events

Rainfall Data

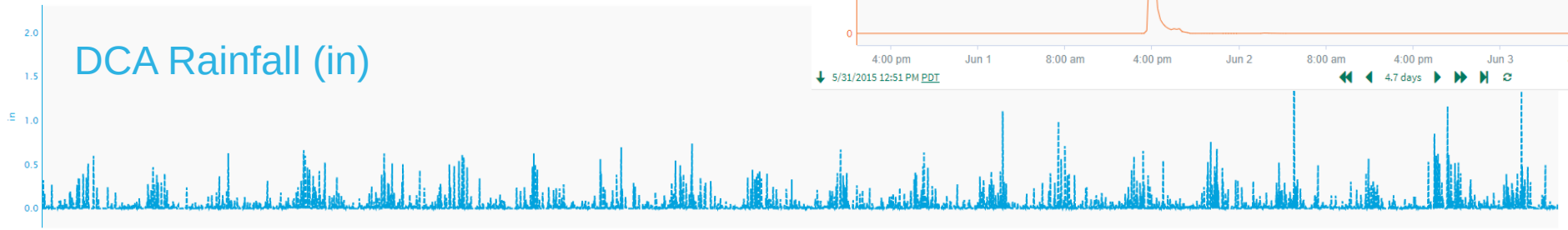


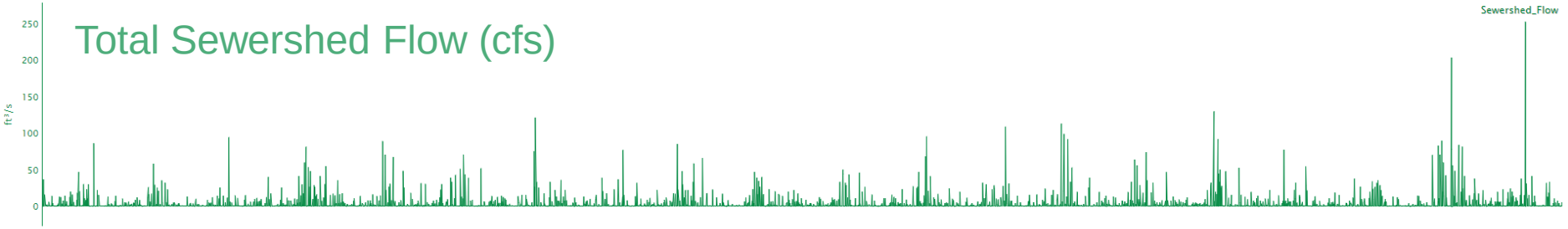


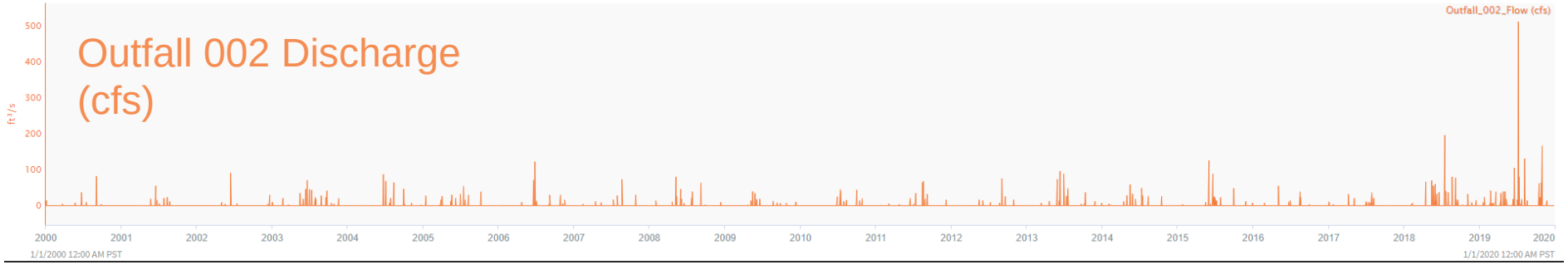
CSO Prediction Analytics Summary

- Objective: Use rainfall forecast to predict occurrence and volume of overflow at CSO Outfall 002
- Available data:
  - 20 years, 2000-2019, 15-minute intervals
    - Modeled sewer flows
    - Modeled overflow discharge
    - DCA rainfall
- Assumption: Calibrated model is representative of combined sewer conditions

Raw Model Data

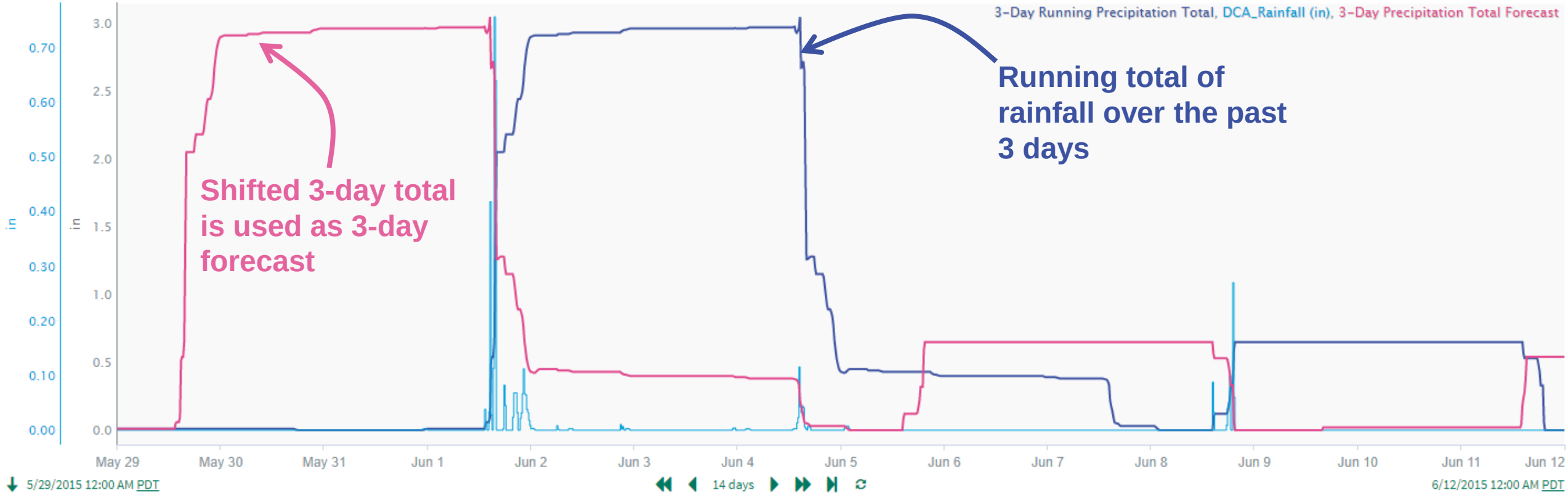






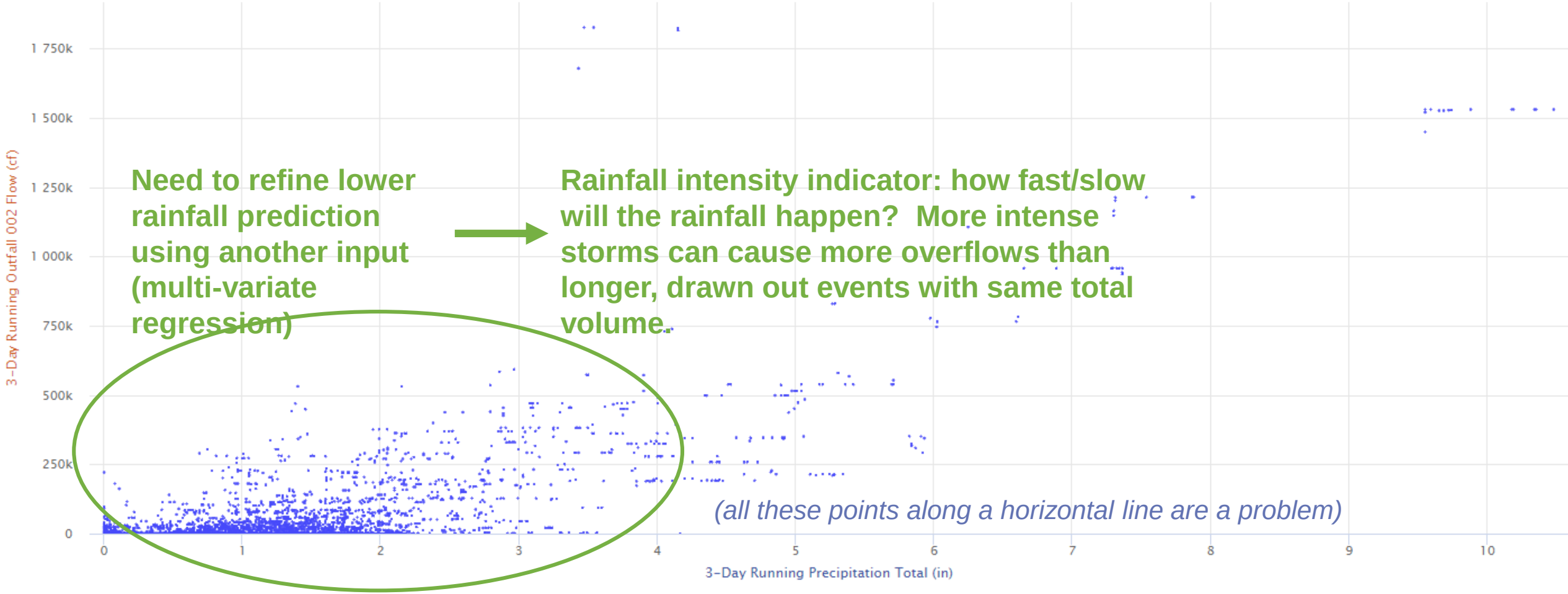
Rainfall Data to Forecast Transformation

- Rainfall forecasts are not available in 15-minute increments
- Need to transform data to be representative of forecast data



3-day Discharge vs. 3-day Rainfall

Does rainfall directly correlate to CSO events?



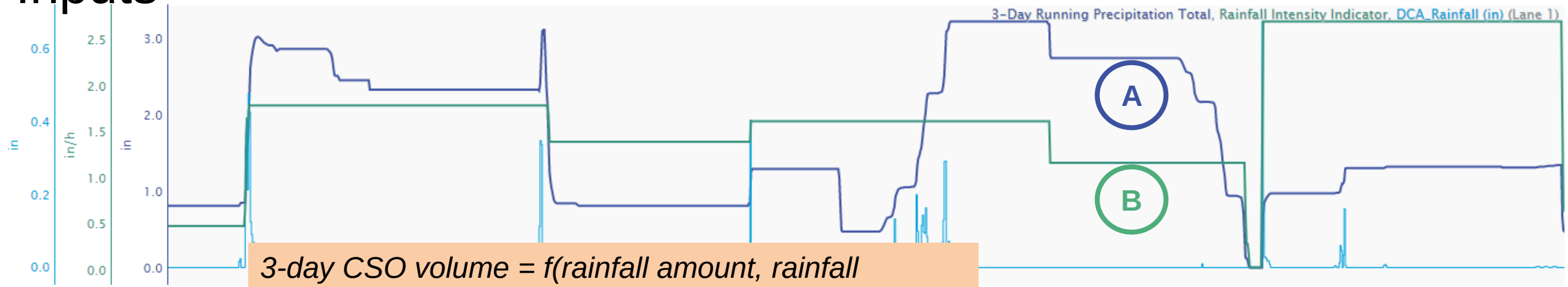
Need to refine lower rainfall prediction using another input (multi-variate regression)

Rainfall intensity indicator: how fast/slow will the rainfall happen? More intense storms can cause more overflows than longer, drawn out events with same total volume.

(all these points along a horizontal line are a problem)

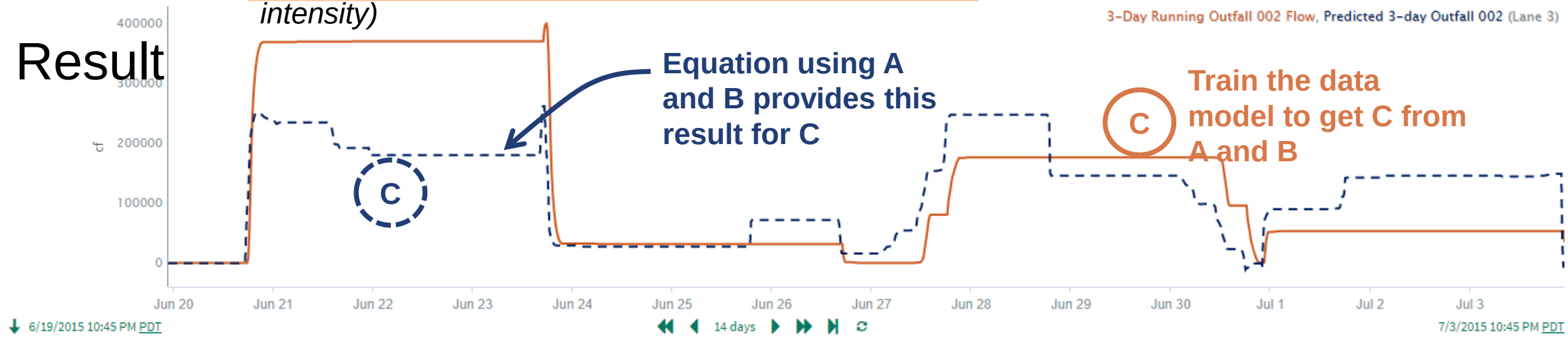
Prediction: Inputs and Result

Inputs



3-day CSO volume = f(rainfall amount, rainfall intensity)

Result



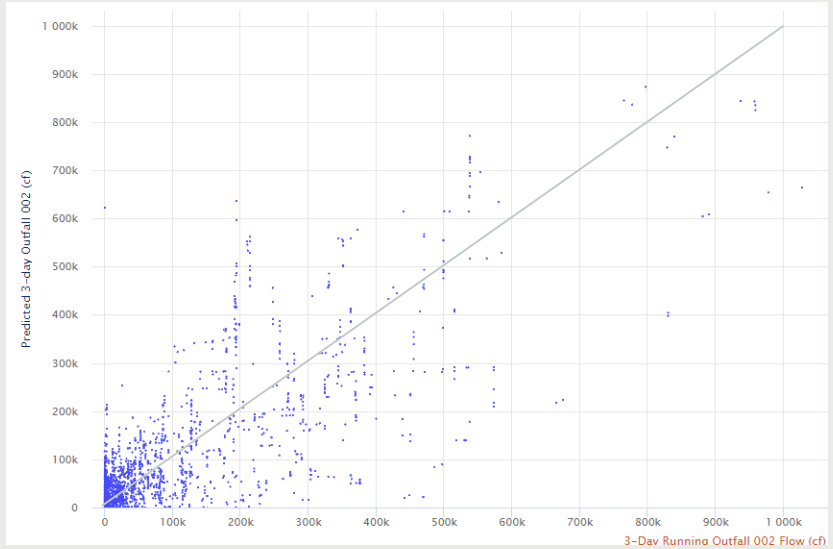
How good is the prediction?

Can it predict IF a CSO will happen?

20-Year Period		
Actual CSO Events		258
Predicted CSO Events	258	
Valid Predictions	215	
	83% of events could be predicted	

With a perfect rainfall forecast, the analytic can predict 83% of CSO events.

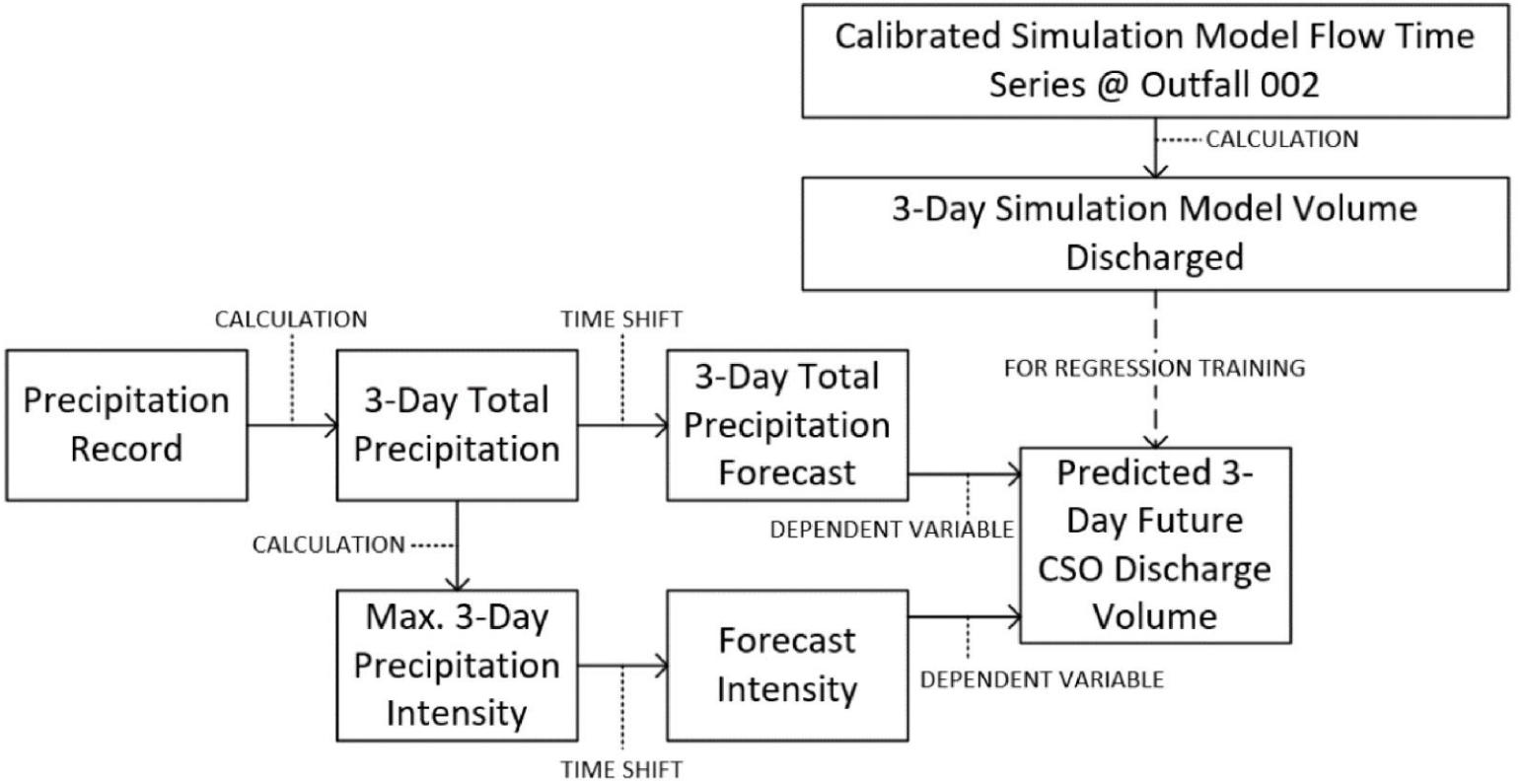
Can it predict how large the CSO will be?



Perfect predictions fall on diagonal line

R^2 = 0.77
(perfect would be 1.0)

Can the developed analytic be applied to the other outfalls?



How well does the 002 model predict CSO events for all locations?

Outfall	Actual Overflows	Overflows Predicted	Model Efficiency
001	460	383	83%
002	231	238	103%
003	1394	744	53%
004	749	405	54%

Model Efficiency

Updates to the 002 Pilot Study model show improvements to CSO detection for 002 and positive predictions for 001

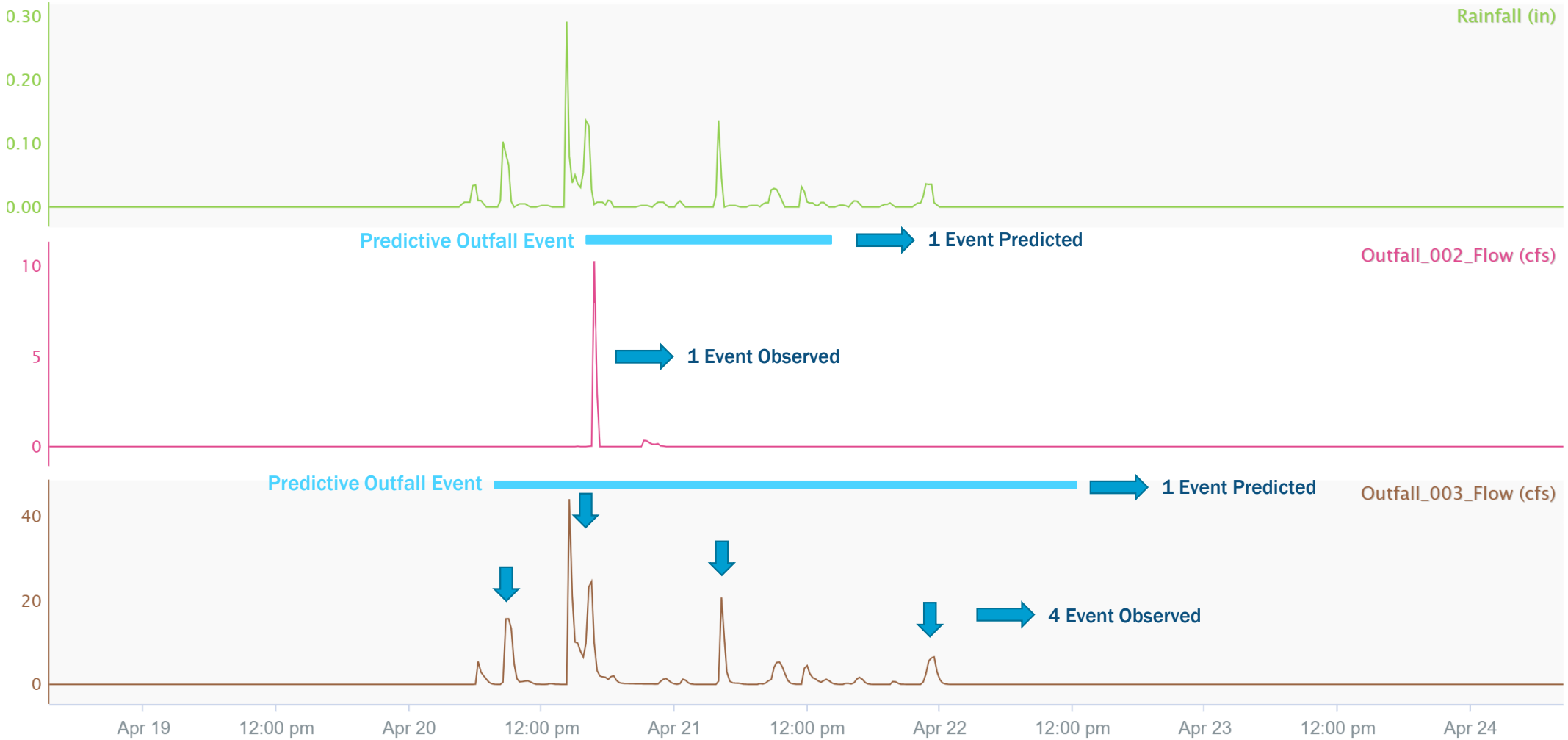
Model Shortfalls

There is a lower predictive success rate when the model is run on the hydraulic configurations found in 003 and 004

Model Optimization

Provide agility within the model to successfully predict events across differing site and hydraulic conditions

How do different outfalls respond to rainfall events?



How well does the optimized model perform?

Outfall	Actual Overflows	Overflows Predicted (Old)	Model Efficiency
001	460	440 (383)	96%
002	231	224 (238)	97%
003	1394	1250 (744)	90%

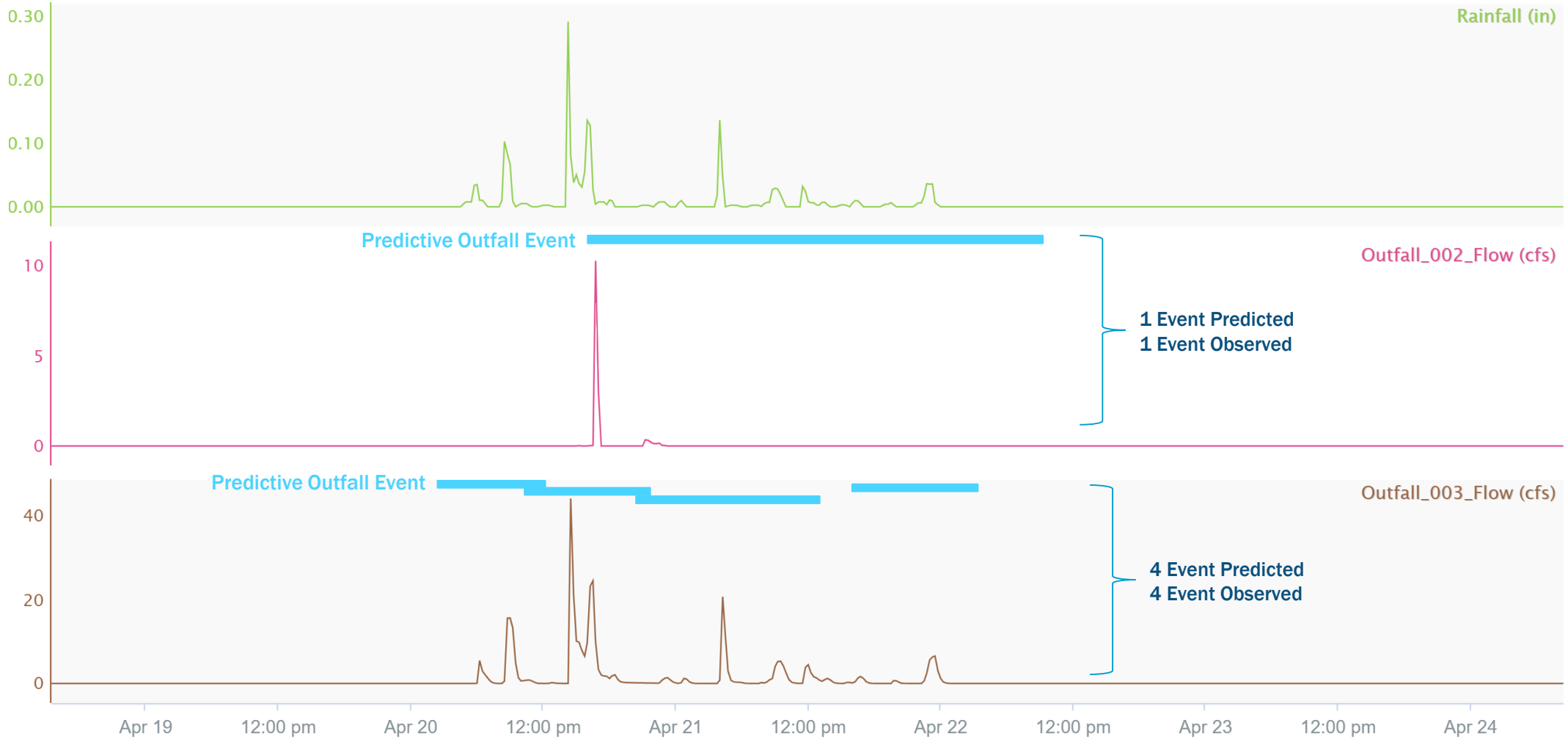
Pilot Study Approach

3-day Forecast Data → 3-day Aggregate Predictor; Rainfall Intensity Coefficient → 3-day Aggregate Outfall Prediction

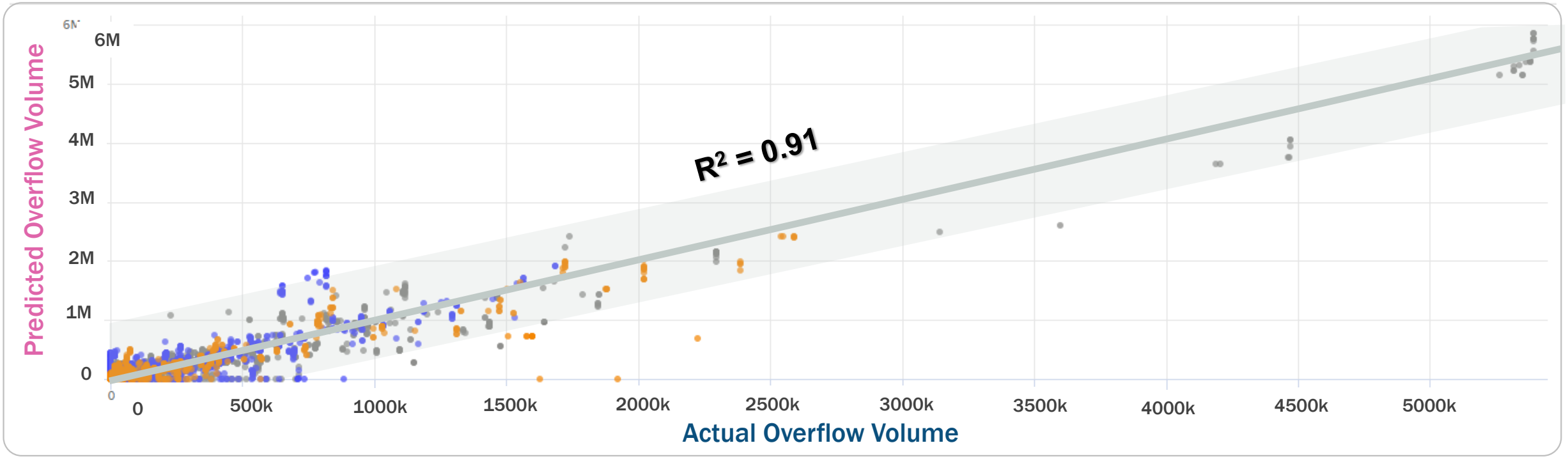
Updated Approach

3-day Forecast Data → 3-day Aggregate Predictor; Rainfall Intensity Coefficient → 3-day Aggregate Outfall Prediction → 3-day Outfall Event Prediction

How does the optimized model perform on differing hydraulic conditions?



How well does the analytic perform for Outfall 001?



Legend

Perfect Prediction

Data Pair (Actual vs Predicted)

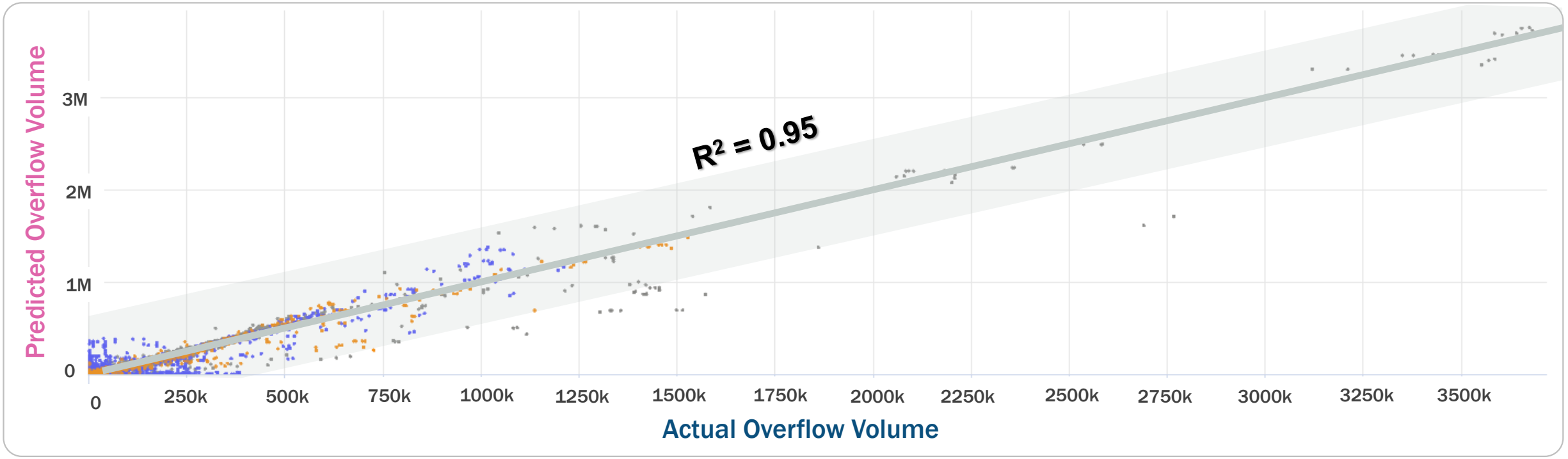
Data Record: 20-year (2000-2019)

Model Accuracy

Event Prediction

- Predicted: 383
- Actual: 460

How well does the analytic perform for Outfall 003?



Legend

Perfect Prediction

Data Pair (Actual vs Predicted)

Data Record: 20-year (2000-2019)

Model Accuracy

Event Prediction

- Predicted: 1250
- Actual: 1394

Model Validation

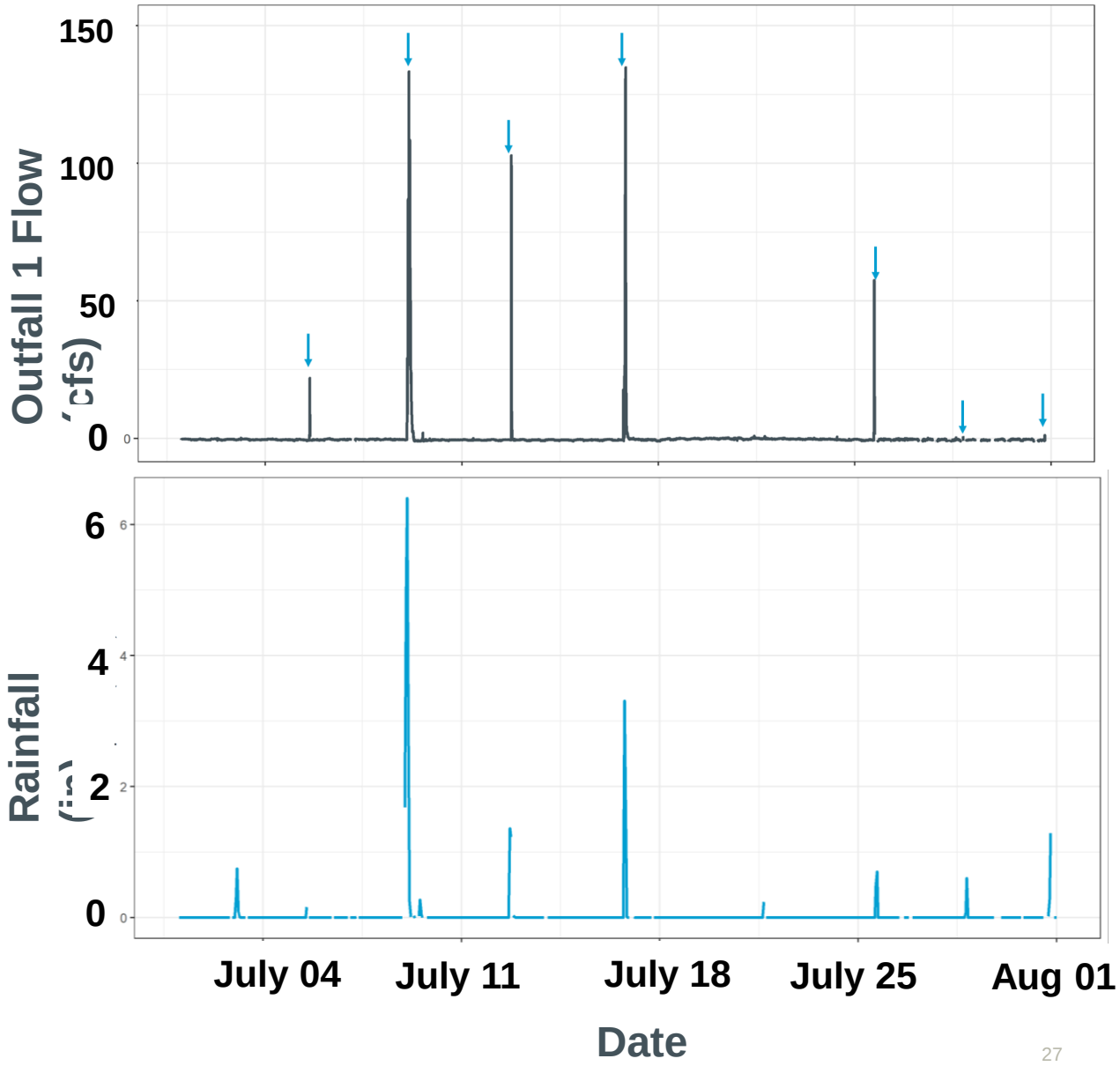
Field Data Collection and Model Validation

Field Data Collection During Construction

1. Install flow meters at Outfall 001 (shown to the left) outside areas impacted by construction
2. Verify the quality of data
3. Use field data to validate the model's approach and for continued training of the predicative accuracy

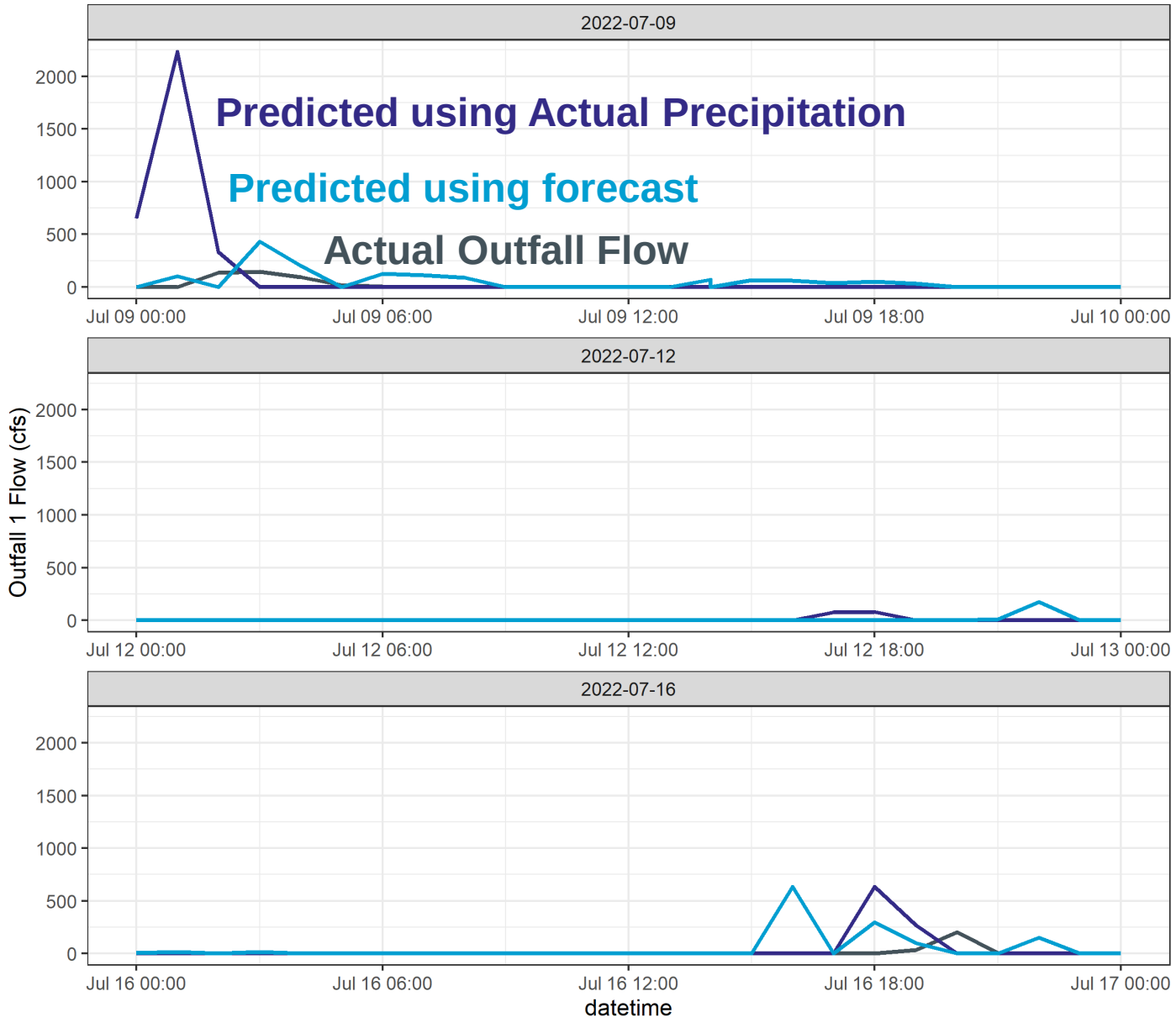
Results

- Outfall 001 Flow was measured and data from July 1st through July 31st was used for the validation.
- A total of 7 outfall events were observed.

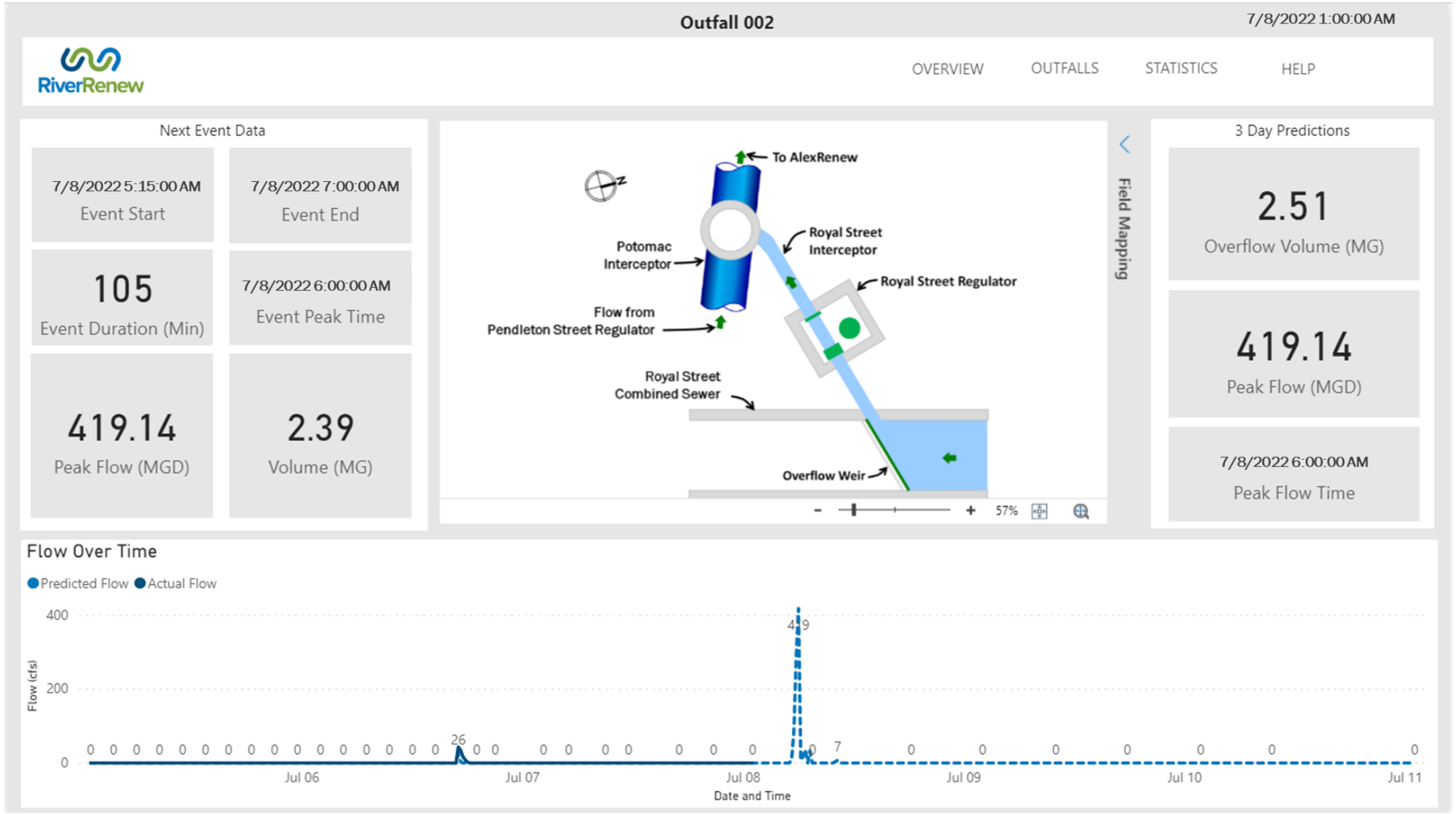


Results

- Outfall 001 Flow was measured and data from July 1st through July 31st was used for the validation.
- A total of 7 outfall events were observed.
- 3 of the 7 outfall events were chosen for validation based on availability of forecast data.
- The analytic was able to predict the occurrence of the event within a 6-hour time window.



Example Public Notification Dashboard



Summary and Next Steps

- A predictive analytic was developed based on a simple multi-variate linear regression model.
- The model was refined to predict outfall flow events at multiple outfalls.
- Model validation showed that the predictive analytic was able to predict the occurrence of an event within a 6-hour time window.
- **Next Steps**
  - Implement a data pipeline to automatically import forecast data and make predictions
  - Implement a real-time public notification dashboard.
  - Evaluate ability to use ML/AI models to predict outfall flow based on forecast data.

Thank you.

Questions?

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