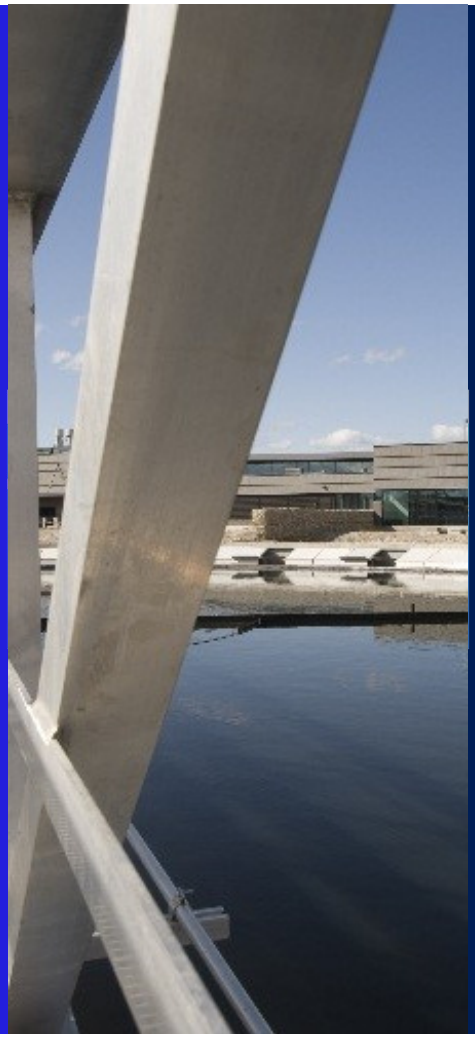
Jacobs Challenging today. Reinventing tomorrow.

Wastewater Epidemiology: Lessons Learned from the COVID-19 Pandemic

In the kNOW Webinar Series

Sept. 21, 2020



Agenda

- Moderator: **Peter Nicol**, Jacobs Global Market Director for Water
- **Tim Constantine**, Jacobs Global Technology Leader for Wastewater Treatment will discuss treatment plant testing for COVID-19 in the United States
- **Scott Harding**, Account Manager for COVID-19 Testing and **James Herrin**, Project Manager for Source Molecular will discuss COVID-19 testing protocols
- **Mel Makdessi**, Jacobs Middle East Business Development Director will share the wastewater-based epidemiology implementation programs in the Middle East
- **Susan Moisio**, Jacobs Global Solutions Director for Conveyance and Storage will discuss the benefits of collection system sampling and a focus on how you need to understand your system
- **Q&A**

Monitoring COVID-19 Spread in Wastewater Streams

- Our Water, Digital Solutions and OMFS teams launched pilot program to monitor wastewater streams to understand the impacts and spread of COVID-19
- Genetic testing techniques, sampling raw wastewater allows for tracking virus in raw wastewater, which can be correlated with public health and epidemiological data
- In addition to sampling at the treatment plant, sampling has expanded to the collection system, providing more specific locations of potential disease hotspots

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Wastewater Treatment Plant Testing for COVID-19

September 21st, 2020

Background – Wastewater Based Epidemiology (WBE)

Science News *from research organizations*

Wastewater test could provide early warning of COVID-19

Date: March 31, 2020

Source: Cranfield University

Summary: Researchers are working on a new test to detect SARS-CoV-2 in the wastewater of communities infected with the virus. The wastewater-based epidemiology (WBE) approach could provide an effective and rapid way to predict the potential spread of novel coronavirus pneumonia (COVID-19) by picking up on biomarkers in feces and urine from disease carriers that enter the sewer system.

abc NEWS | CORONAVIRUS HEALTH & SCIENCE

Sewage analysis suggests a New England metro area with fewer than 500 COVID-19 cases may have exponentially more

Epidemiologists are studying wastewater to gauge rates of COVID-19 infection.

NEWS · 03 APRIL 2020 · CORRECTION 03 APRIL 2020 **nature**

How sewage could reveal true scale of coronavirus outbreak

Wastewater testing could also be used as an early-warning sign if the viru returns.

Scientists say they found the virus, that causes COVID-19, in a Dutch city's wastewater before the first confirmed case in the city

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THE STRAITS TIMES SINGAPORE

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Testing wastewater for early alarm on disease outbreaks

PUBLISHED MAY 23, 2020, 5:00 AM SGT

PUB working with researchers to study possibility of such sampling for pathogens

Audrey Tan Science and Environment Correspondent

The authorities are looking into the possibility of sampling used water for pathogens as an early warning system for outbreaks like Covid-19, The Straits Times has learnt.

Background – Wastewater Based Epidemiology (WBE)

- WBE studies provide a data driven picture of the virus in communities:
  - Environmental surveillance
  - Long-term trends
  - Early warning system
- Non-invasive method for SARS-CoV-2 detection
  - Detected in waste of asymptomatic people
- WBE has been used in the past to assess the impact of poliovirus vaccination campaigns in Israel

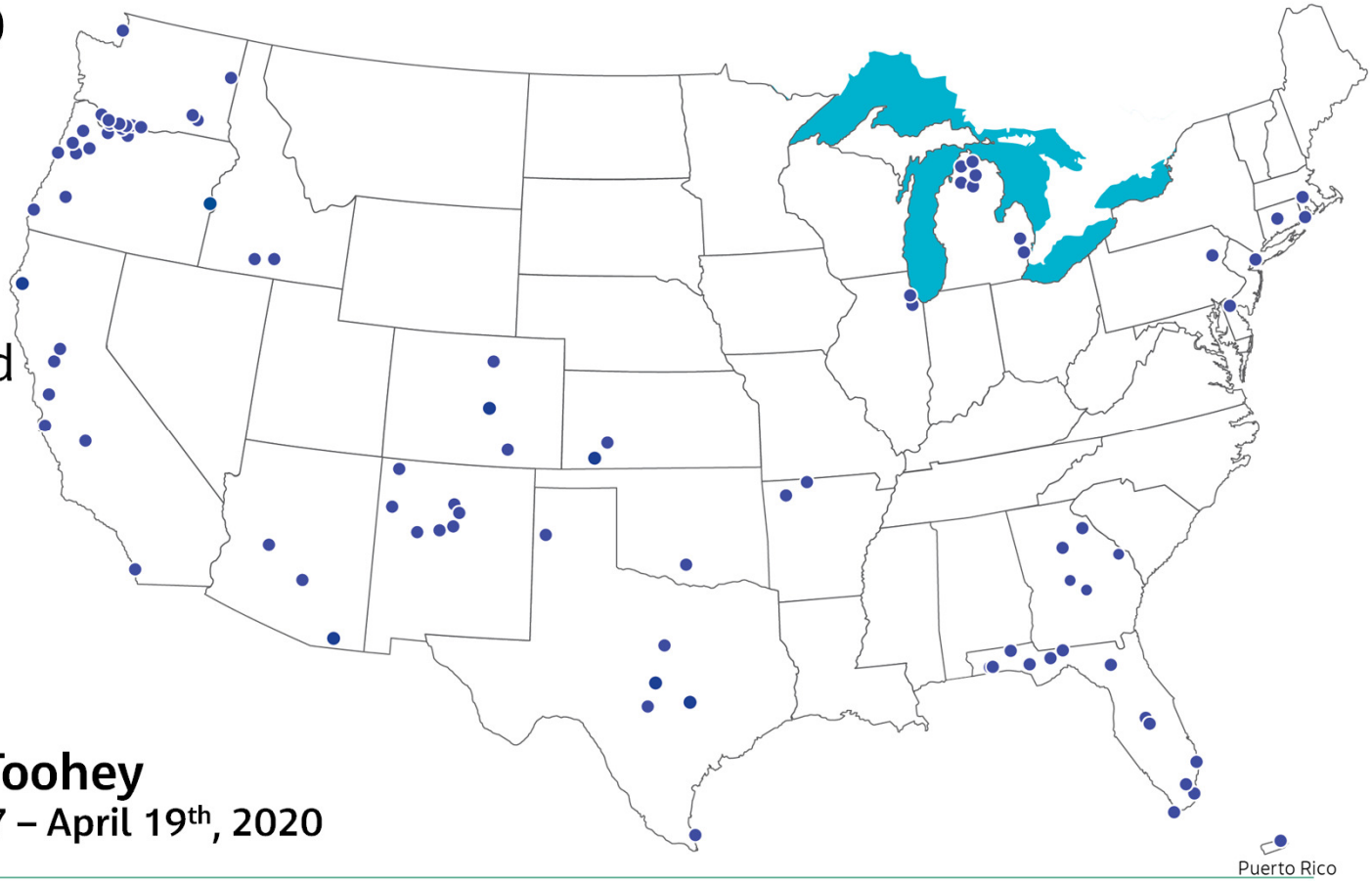
Courtesy AAAS ScienceMag: Israel's Silent Polio Epidemic Breaks All the Rules, 11/8/2013

Jacobs COVID-19 Initiative Details

- Jacobs operates over 100 Wastewater Treatment facilities worldwide
- 70+ facilities in USA
- Early April 2020 Jacobs-funded initiative launched to test these facilities for virus in raw sewage

My personal motivation:

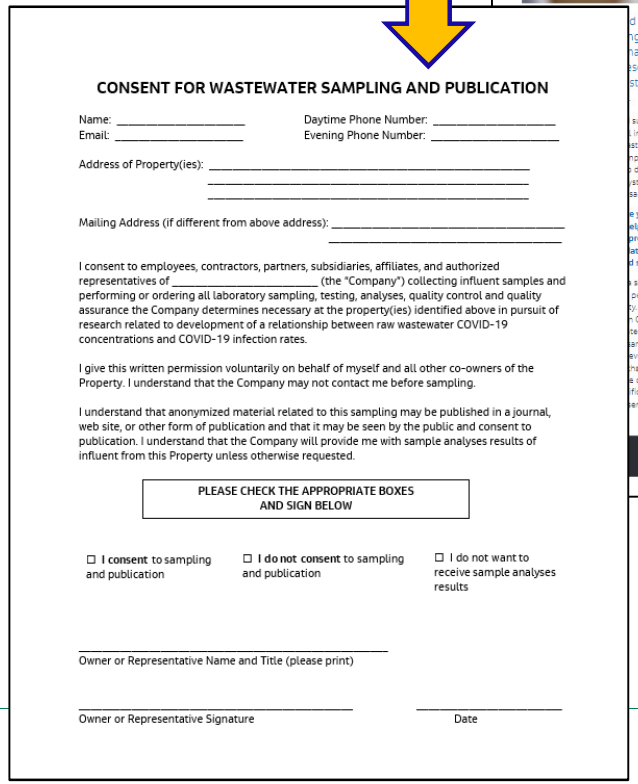
John Gerald Toohey
January 21st, 1927 – April 19th, 2020



Mobilizing Jacobs COVID-19 Initiative

- Found academic partner in Arizona State University (ASU) Biodesign Institute
- Jacobs O&M group facilitated client communication
  - COVID sampling info flyer
  - Consent form for sampling
- Developed sampling plan in coordination with ASU
- Original plan was to sample all 70 plants that we operate in the US over several weeks

Consent Form



CONSENT FOR WASTEWATER SAMPLING AND PUBLICATION

Name: _____ Daytime Phone Number: _____
Email: _____ Evening Phone Number: _____

Address of Property(ies): _____

Mailing Address (if different from above address): _____

I consent to employees, contractors, partners, subsidiaries, affiliates, and authorized representatives of _____ (the "Company") collecting influent samples and performing or ordering all laboratory sampling, testing, analyses, quality control and quality assurance the Company determines necessary at the property(ies) identified above in pursuit of research related to development of a relationship between raw wastewater COVID-19 concentrations and COVID-19 infection rates.

I give this written permission voluntarily on behalf of myself and all other co-owners of the Property. I understand that the Company may not contact me before sampling.

I understand that anonymized material related to this sampling may be published in a journal, web site, or other form of publication and that it may be seen by the public and consent to publication. I understand that the Company will provide me with sample analyses results of influent from this Property unless otherwise requested.

PLEASE CHECK THE APPROPRIATE BOXES AND SIGN BELOW

☐ **I consent** to sampling and publication

☐ **I do not consent** to sampling and publication

☐ I do not want to receive sample analyses results

_____
Owner or Representative Name and Title (please print)

_____ _____
Owner or Representative Signature Date

Jacobs

d the world are struggling to understand the true spread of the COVID-19 virus.
ng place at an increased rate, it is difficult to test enough of the population to
haking process for reopening businesses and/or relaxing social distancing
search has shown that monitoring for the presence of the COVID-19 virus in
stream at wastewater treatment plants can measure the degree of outbreak

subsequent analysis for the COVID-19
in public health efforts to track disease
stewater data can help quantify the
pacted by the virus and provide decision
drive conclusions. Eventually, this could
stem for disease outbreak using non-
sampling and analysis methods.

e you to participate in this sampling
elp our communities understand the
pread. Our goal is to assist in the
ata to mitigate the public health
d spread of the disease.

sample is collected at the wastewater
personnel who are experts in this type
y. The samples are then sent to the
Center for Environmental Health
te University. At the Arizona State
ample will be analyzed using Centers
evention-approved detection methods
hain reaction, or qPCR). The data
e collection will then be correlated to
fic to your facility's area which can help
ence/absence of the virus as well as

It's important to note that studies show there is no increased risk of COVID-19 transmission from wastewater and the virus detected in the qPCR analysis is thought to be non-viable. All appropriate health and safety precautions will be taken by Jacobs personnel when collecting samples. In most cases, the sample will be drawn from samples already being collected to meet regulatory requirements, resulting in no additional exposure to operations personnel.

We will provide you with the data from the samples that are collected at your facilities to be used in your community's public health efforts. The data will be kept confidential throughout the collection and analysis process and any data that is published in scientific studies will be kept strictly anonymous.

There will be no additional cost to our clients for the first round of this research study. Jacobs is available to assist with any public announcements or community relations initiatives to help educate the community about this method of tracking disease.

Your participation will help not only your community, but the world at large, as we seek to better understand the spread of the disease. If you would like to participate, please sign the attached release form. Jacobs will begin collecting samples at your facility as soon as we have your consent.

COVID Testing Info Flyer

Mobilizing Jacobs COVID-19 Initiative

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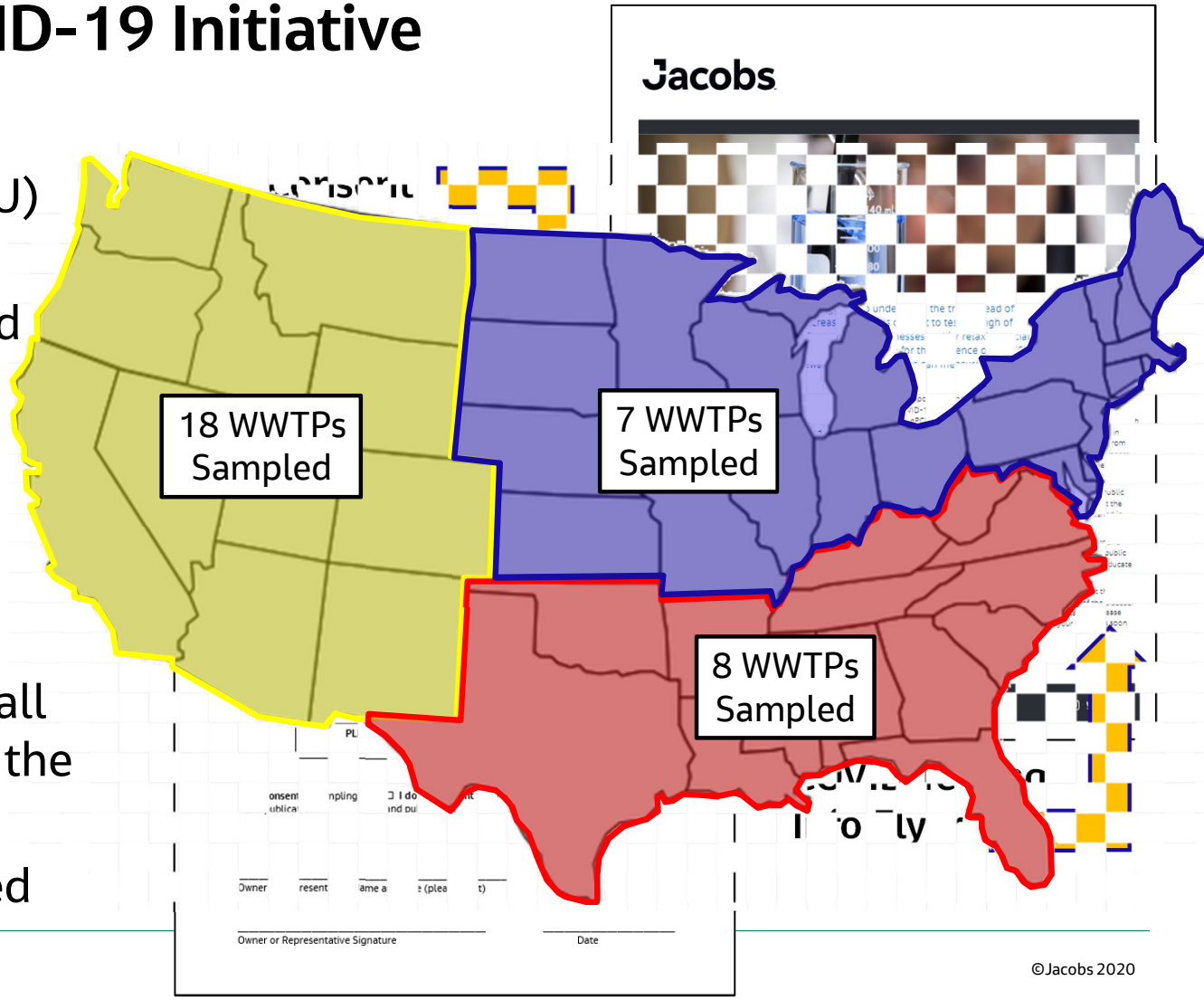
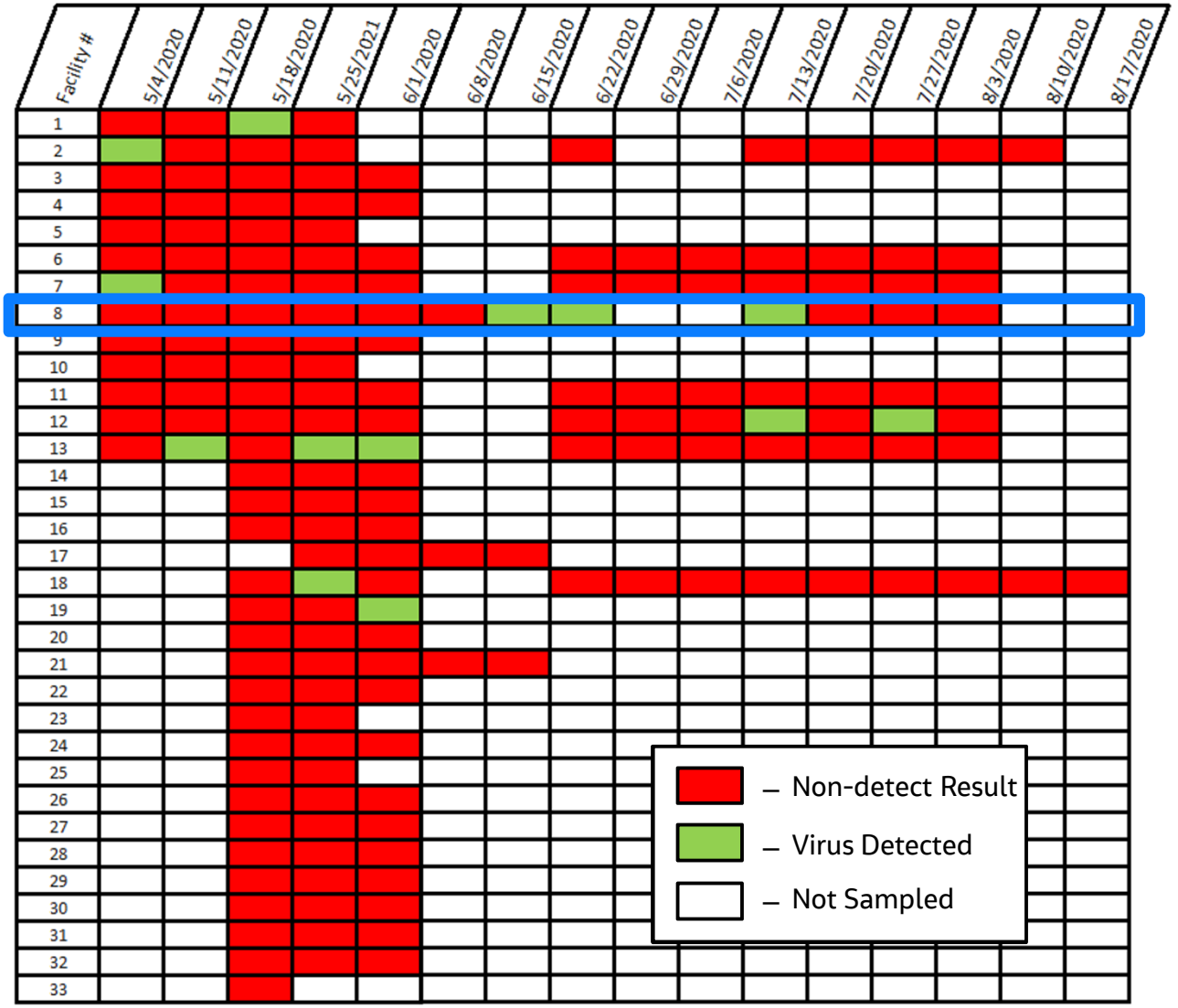
- Original plan was to sample all 70 plants that we operate in the US over several weeks
- 30+ plants ultimately sampled

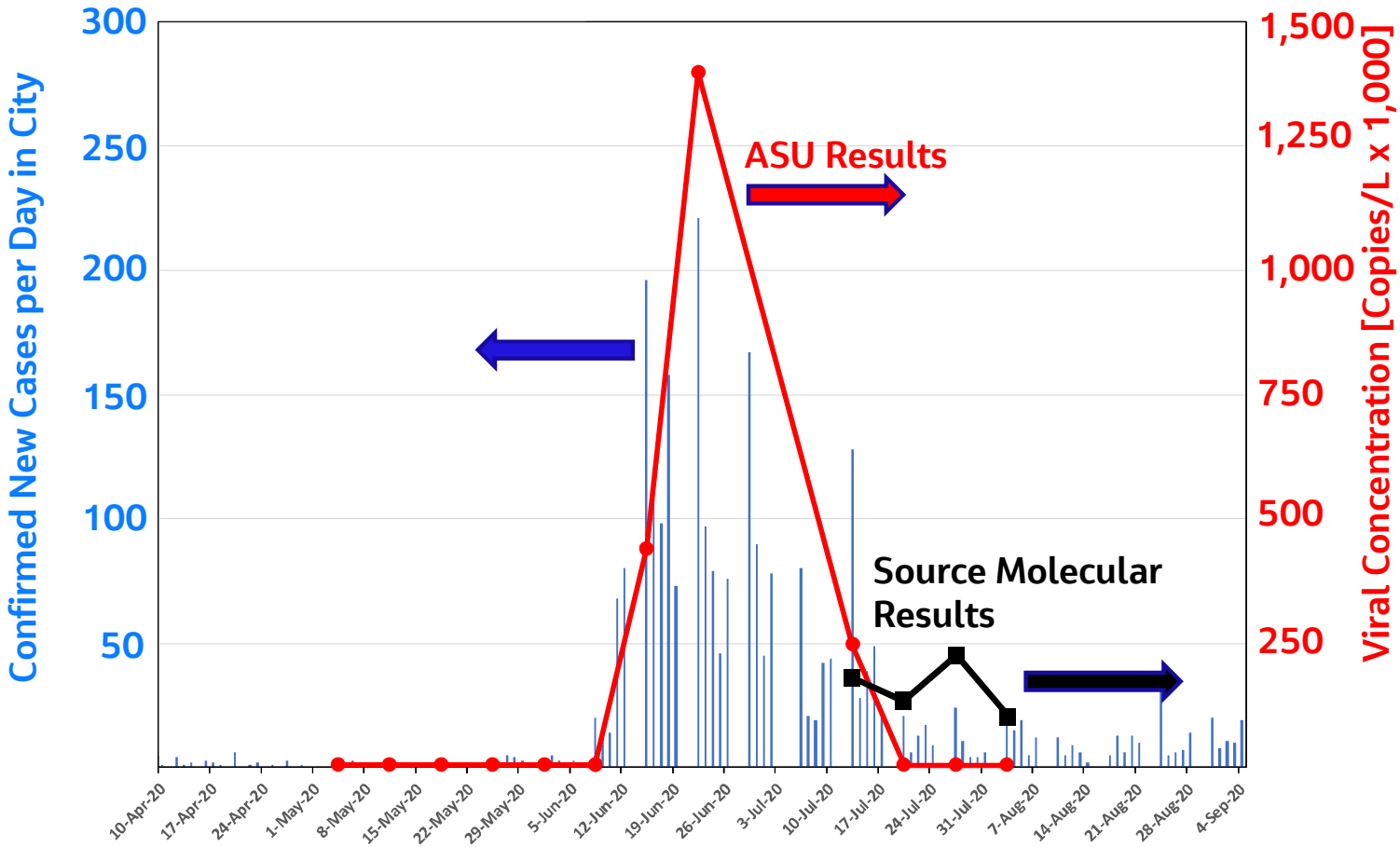


Test Results (ASU): Non-detects Prevalent

- Sampling/shipping issues?
- Issues at lab with viral extraction, detection, quantification?
- Is the sewage “matrix” inhibiting testing and by how much?
- Degradation of RNA in sewers? Temp effects?
- Did we miss the infection “wave” in the community?



SARS CoV-2 Testing Results – “Facility 8”



Summary to Date of Jacobs COVID-19 Testing Program

Lessons Learned

- Logistics of sample collection, shipping & receiving not trivial
- Virus can be detected, but many non-detects early on
- Many different lab methods for viral extraction, detection and quantification
- Improved success later on in trial

Next Steps

- Continue with ASU, re-analyze samples with new lab methods
- Continue successes with Source Molecular at targeted sites
- Collection system sampling
- Execute programmatic approach with utilities

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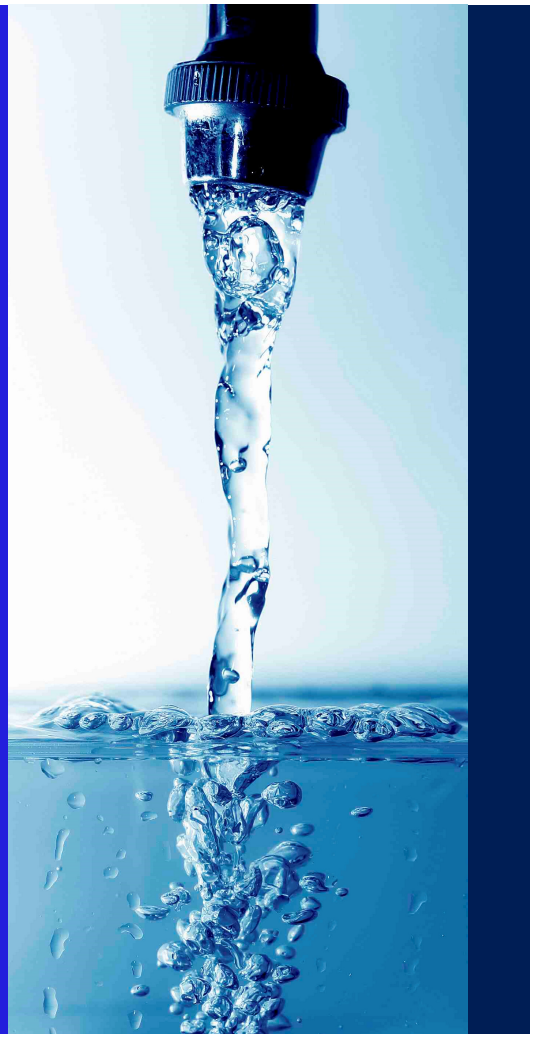
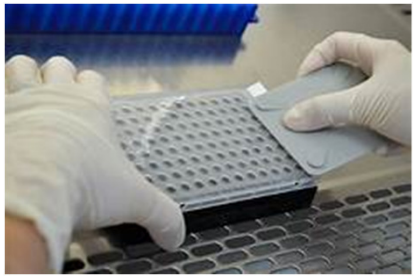
COVID-19 Testing Protocols

James Herrin, Source Molecular
Scott Harding, Source Molecular



Who is Source Molecular?

- Environmental Biological Testing Laboratory (Est. 2002)
- Accredited by A2LA to ISO 17025:2017
- Background in Microbial Source Tracking (MST) and pathogen detection in environmental samples
- Experienced in extracting RNA and DNA from wastewater samples & analyzing for the concentration of genetic markers
- Understand the unique nature of wastewater and have developed QA/QC procedures which respect the variability of wastewater
- Began offering COVID-19 wastewater testing in March 2020
- Participating in Water Research Foundation (WRF) interlaboratory study



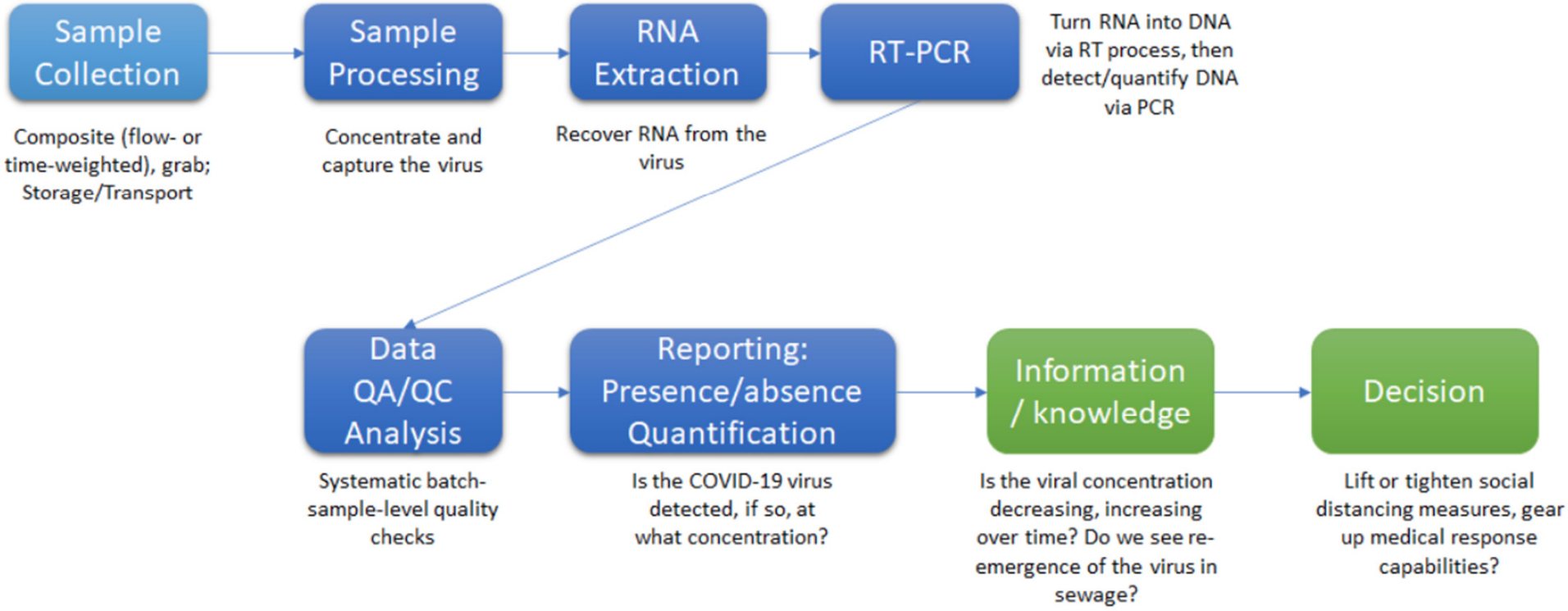
ilac-MRA

A2LA ACCREDITED
Certificate 4126.01

ISO 17025 Accredited Testing Laboratory

THE Water Research FOUNDATION

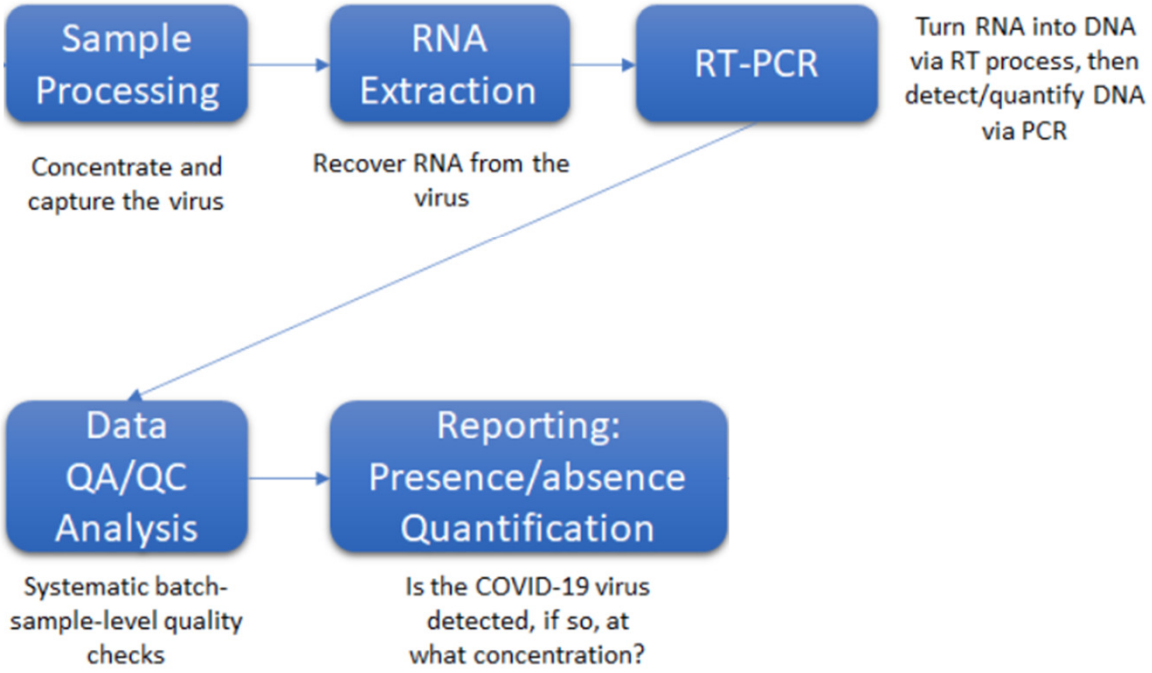
WBE Workflow, From Sample to Decision



Source Molecular

WBE Workflow, From Sample to Decision

Analytical Processes



Source Molecular

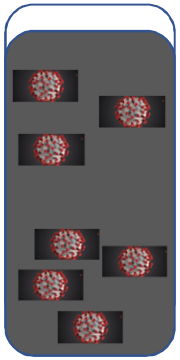
WBE Workflow, From Sample to Decision

Analytical Processes

Sample Processing

Concentrate and capture the virus

Within-lab Unit Process	Quality Control	Purpose	At Source Molecular
Sample Processing	Matrix Spike	To ensure the matrix is not preventing detection/quantification of the COVID-19 virus if present	√
	Processing Blank	To ensure cleanliness during sample processing	√



Biosafety Level

BSL 1 → No Concentration, lower volume

BSL 2 → Concentration Method, higher volume

Source Molecular

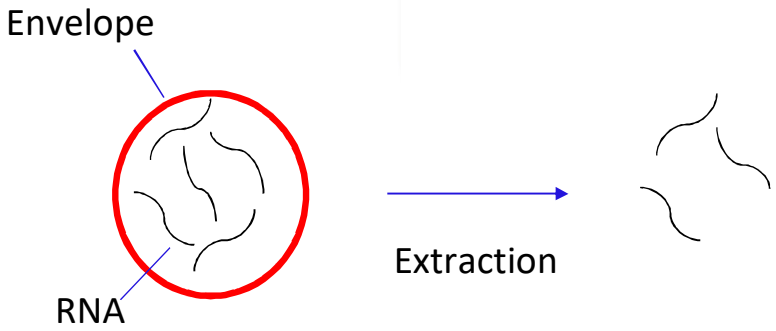
WBE Workflow, From Sample to Decision

Analytical Processes

RNA Extraction

Recover RNA from the virus

Within-lab Unit Process	Quality Control	Purpose	At Source Molecular
RNA Extraction	Positive Extraction Control	To check success of viral RNA extraction	√
	Negative Extraction Control	To ensure cleanliness during extraction	√
	Extraction Process Control	To check recovery of RNA extraction for each individual sample	√



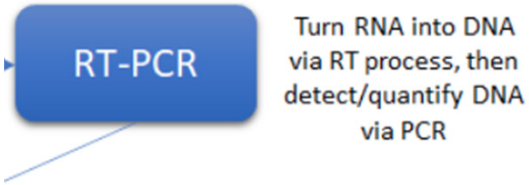
QAQC should be adequate to address potential for false positives, false negatives, and contamination

Source Molecular

WBE Workflow, From Sample to Decision

Analytical Processes

Within-lab Unit Process	Quality Control	Purpose	At Source Molecular
RT-PCR (real time or digital RT-PCR)	RNA positive control	Positive control for both RT and PCR	√
	DNA positive control	Positive control for PCR	√
	No template control	To ensure cleanliness during RT-PCR	√
	Inhibition control	To check if any compounds interfered with RT-PCR for each individual sample	√



Source Molecular

SARS-COV-2 Results Report

Analysis Requested	RT-qPCR Result	Copies Per Liter	Result Qualifier	Limit of Detection (copies per Liter)	Limint of Quantification (copies per liter)	Equivalent Vol Water analyzed (ml)	Reaction 1 (Ct)	Reaction 2 (Ct)
2019 nCoV_N1	Detected	1.37E+03	DNQ	1.19E+03	2.97E+03	3.36	35.85	35.98
2019 nCoV_N2	Not Detected	ND	ND	1.19E+03	2.97E+03	3.36	ND	ND

Sample ID	Analysis Requested	RT-qPCR Result	Reaction 1 (Ct)	Reaction 2 (Ct)	Plate ID	Inhibition Check
INF 0920-1478	Mouse Lung ACTB SPC	Detected	28.59	28.41	20200910_q06	Pass

Sample ID	Analysis Requested	RT-qPCR Result	Reaction 1 (Ct)	Reaction 2 (Ct)	Plate ID	Matrix Spike Recovery
INF 0920-1478	HCoV OC43_N	Detected	21.95	21.94	20200910_q06	4.56%

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Wastewater Epidemiology Implementation Programs in the Middle East

Mel Makdessi, Jacobs

WBE Concept

THE CONCEPT

- Use rRT – PCR on wastewater
- Positive or negative for genetic fragments
- Quantify the magnitude of RNA concentration
- Map to hydraulic modelling, urban planning data, transportation modelling

ADVANTAGES

- Mapping of spatial trends
- Mapping of temporal trends
- Full population coverage
- Anonymous data (individual privacy)
- Lead indicator

ALTERNATIVES

- Clinical surveillance -> lagging indicator
- Mass testing -> significant time and cost
- Search engine trends -> obscure correlation to cases
- Hospitalization records -> lagging indicator
- Morbidity rates -> lagging indicator, criteria for classification

CHALLENGES

- Selection of biomarkers
- Stability in wastewater
- Uncertainties in population & flow
- Time-lag between collection & analysis

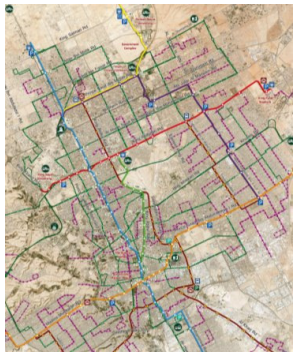
Examples:

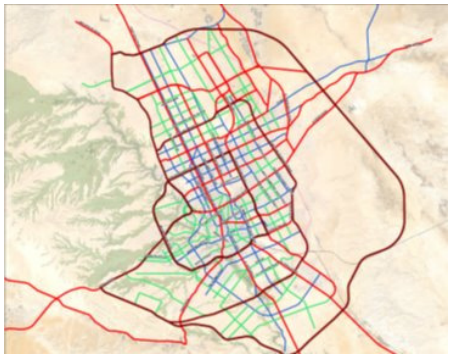
- *Khalifa University, Abu Dhabi successfully detected SARS-CoV-2 in Wastewater.*
- *Roslin Institute in Edinburgh, Scotland, running a pilot study.*
- *Studies in the U.S. and the Netherlands, pick up a signal ~1 week before the first clinical case.*
- *Extensive scientific Literature.*

Sims et Kasprzyk-Hordern, 2020; Been et al., 2017; Choi et al., 2019; Lopardo et al., 2018; Rousis et al., 2017

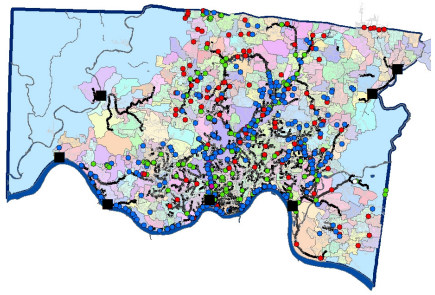
WBE Concept

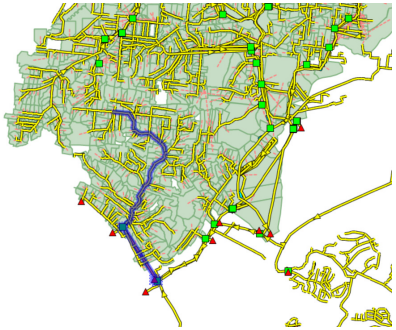
Transportation Modelling





Hydraulic Modelling





$Rel = f(Con, Pop, Cnx)$

$Where$:

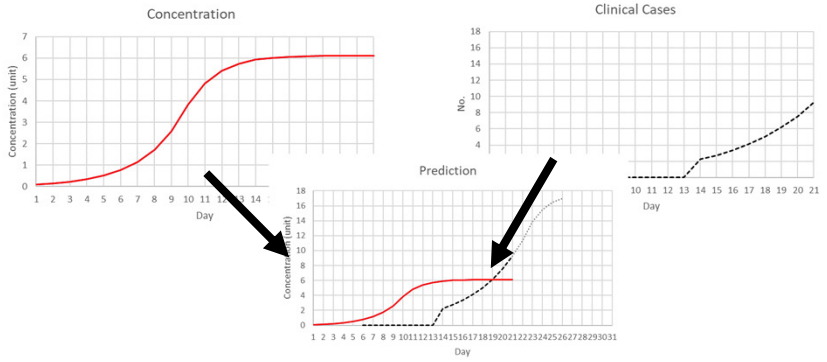
$Rel = Relevance\ of\ Positive\ Signal$

$Con = Concentration, corrected\ for\ dilution, travel\ time, mixing.$

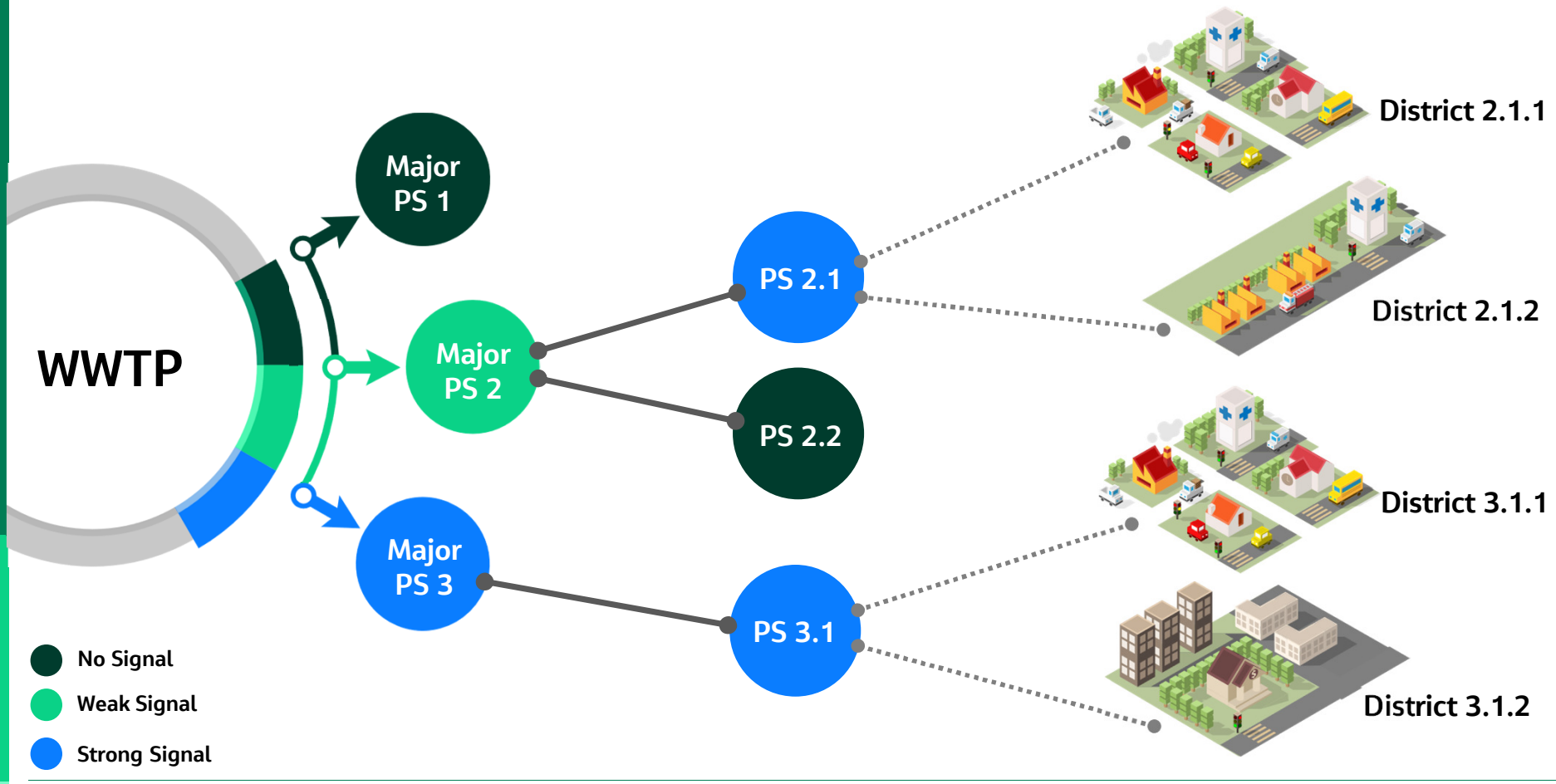
$Pop = Population\ Density, Landuse$

$Cnx = Connectivity$

Data-Processing



Scalable and Adaptable to Needs



WBE Opportunities & Risks

OPPORTUNITIES

- **HIGH COVERAGE** of population
- Significantly **REDUCED COST** and resources
- **FREQUENT** testing, quick reporting
- Dynamic – **FOCUS-IN** on affected areas, scale back to monitor unaffected areas at high level
- **LEAD INDICATOR** – time to allocate resources and take actions before clinical cases
- Pathway to **CORRELATE** sample concentrations to cases with better accuracy over time
- Build a **DATABASE** for future references and research.
- **ADAPT/EXPAND** to monitor other diseases, substances

RISKS

- Thousands of samples, **DATA INTEGRITY** in hands of multiple Civil Contractors, laboratories
- To be **REPRESENTATIVE,** sample locations and timings need to be studied
- Hydraulic phenomenon (mixing, dilution, travel time) need to be accounted for **ACCURATE** interpretation
- Data changing hands creates **DATA SECURITY** challenges
- Mobilization during pandemic, **HEALTH & SAFETY** challenges to manage
- Compliance with Authority Processes & Procedures, quick **APPROVALS** are important
- Value depends on good **TIME MANAGEMENT**, otherwise is diminished

Jacobs' Solution

QUICK-START PLAN
- Mobilization
- Approvals
- Procurement

01 PLANNING
- Updating Sampling Plan
- Send Work Orders to Contractors, Laboratories

02 FIELD SAMPLING
- Supervise Contractors, Laboratories
- Compliance with specifications, HSE requirements

03 DATABASE DEVELOPMENT
- Build Geo-Database
- Hosted in MOH servers
- Digital security

04 DATA ANALYSIS & SCENARIO MODELLING
- Correct for Mixing, Dilution, Travel Time
- Map to density, land use, etc.
- Analyze connectivity
- Run "What if" scenarios

05 PUBLISH TO LIVE DASHBOARD
- Live updates to mobile devices
- Geospatial representation of data
- Permission level access

STAKEHOLDER FEEDBACK
- Map to Health Sector data
- Requests for information
- Drill-down to affected areas
- Scenarios modeling

Summary

WBE is not a new concept.

Full potential not yet realized.

Not limited to COVID-19 detection.

Scalable, long term potential.

Lead Indicator for Health Authorities, Proactive vs Reactive.

Addresses the gaps in other current detection methods.

Complexity in implementation.

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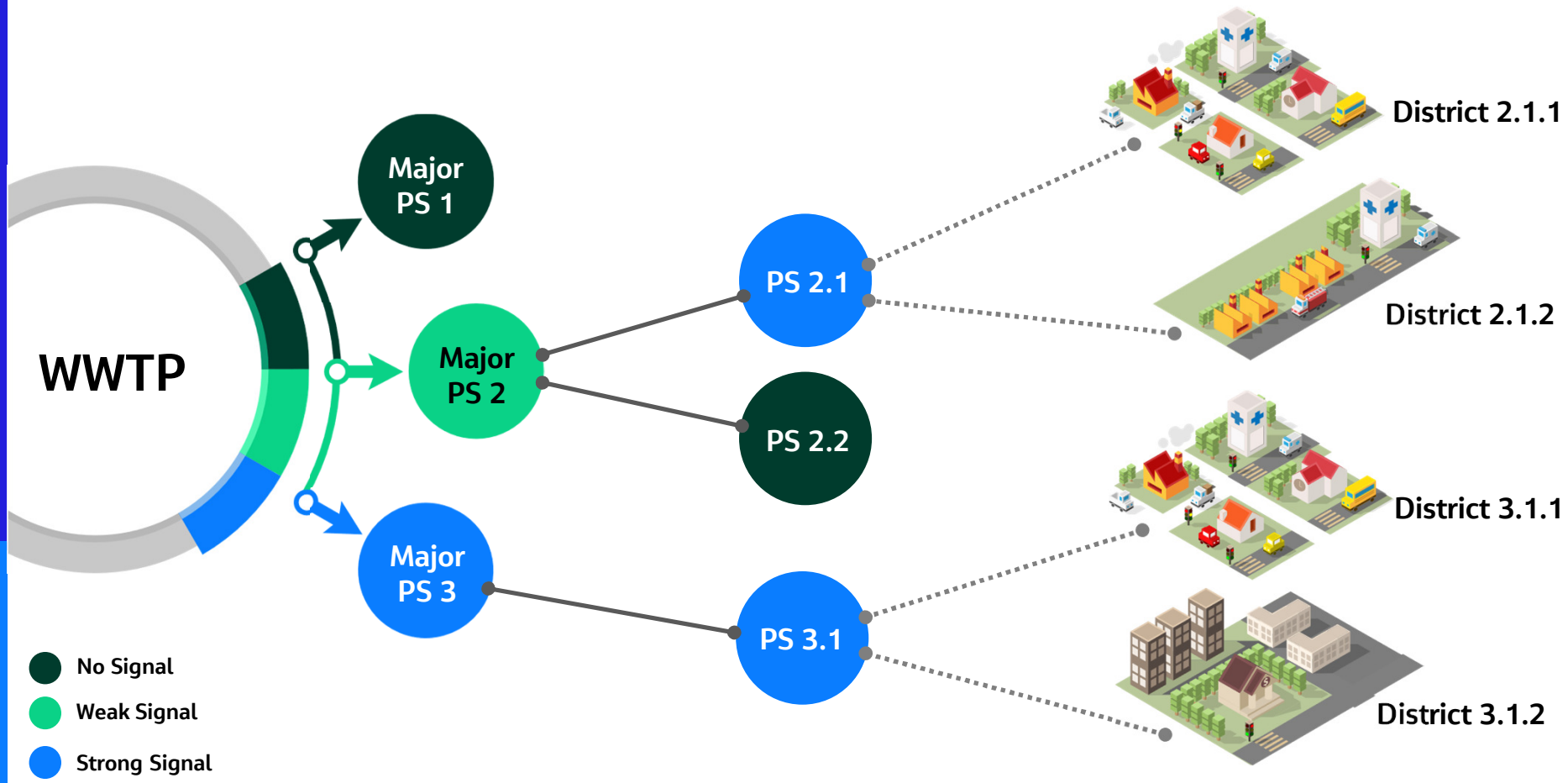
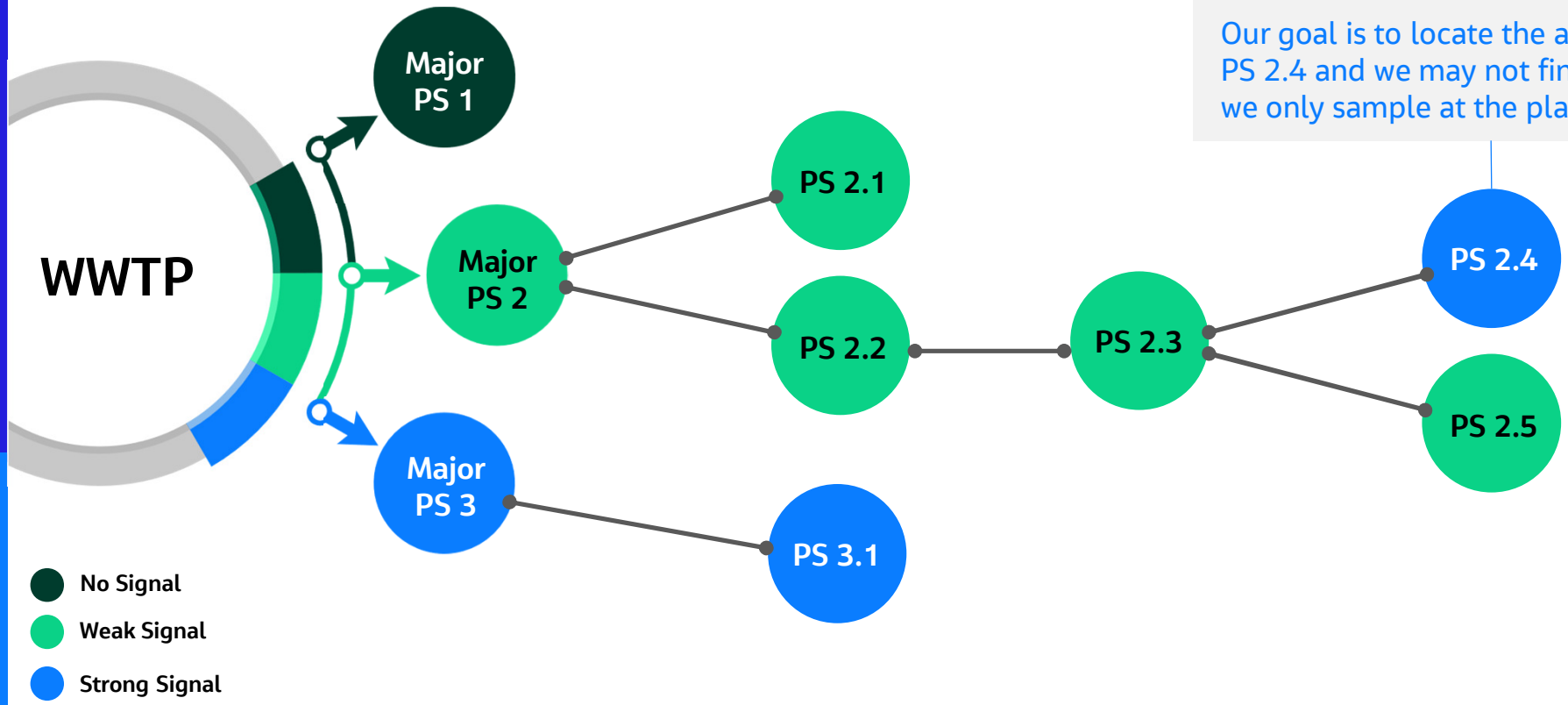
Collection System Sampling

Susan Moisio, Jacobs

Collection System Overview

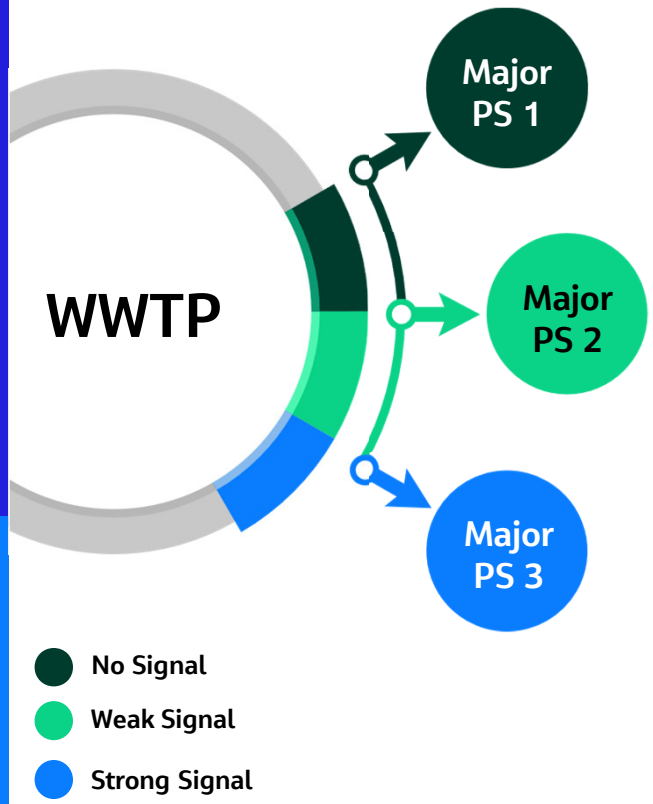


Why move into the collection system and sample?



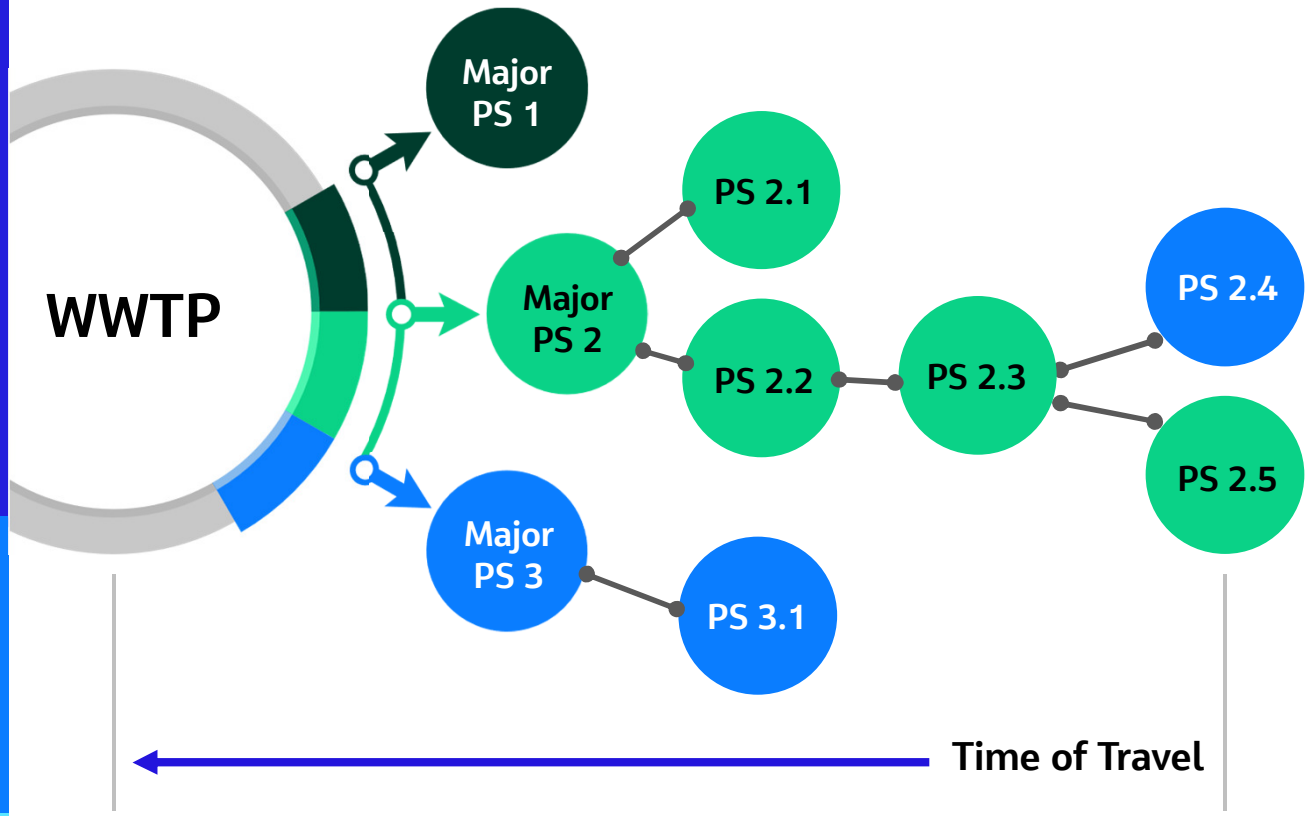
Our goal is to locate the area served by PS 2.4 and we may not find this area if we only sample at the plant

Collection System Changes the Dynamics and Introduces More Complexity

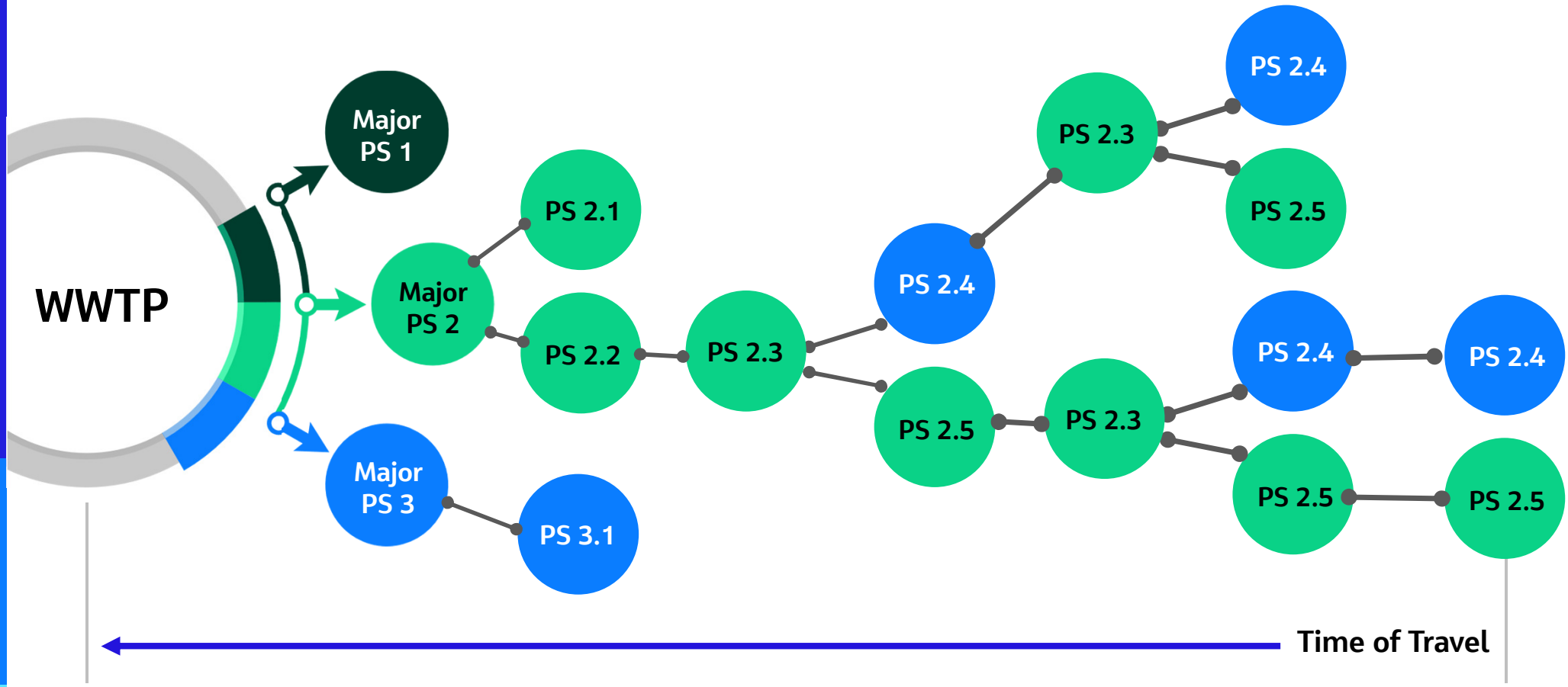


- Size of the Collection System
- Type of Collection System
- Configuration of the Collection System

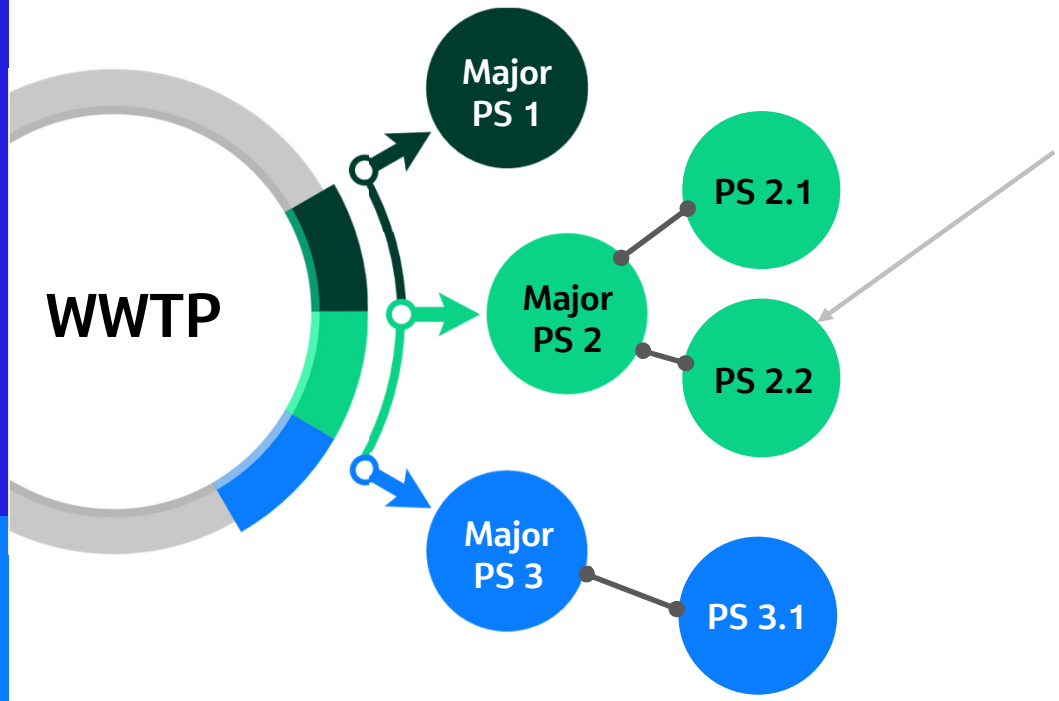
Collection System Size Impacts Sampling – Time of Travel



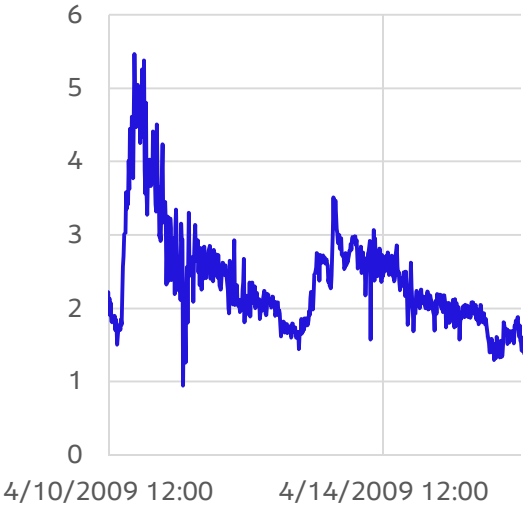
Collection System Size Impacts Sampling – Time of Travel



Sanitary Sewer Overflows or Inflow and Infiltration Can Impact the Sample

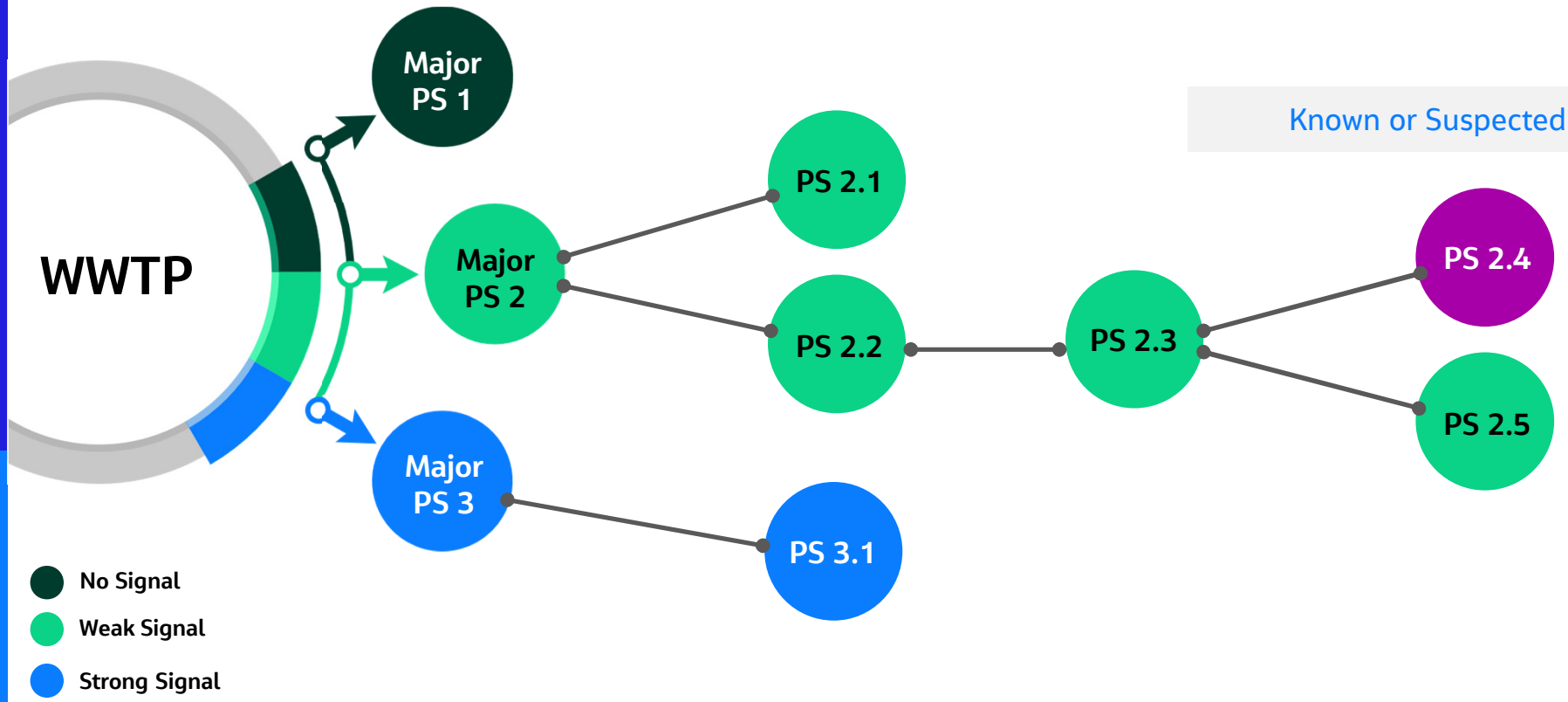


Sanitary Sewer Overflow - SSO



Sanitary Sewer Wet Weather Hydrograph

Sampling at Known or Suspected Hotspots



Structures, Collection System Configuration Impact Sample

- Pretreatment Facilities
- Equalization Facilities for Wet Weather either tanks or tunnels
- Flow Equalization for Treatment Plant Processes
- Pump Station Wet Wells

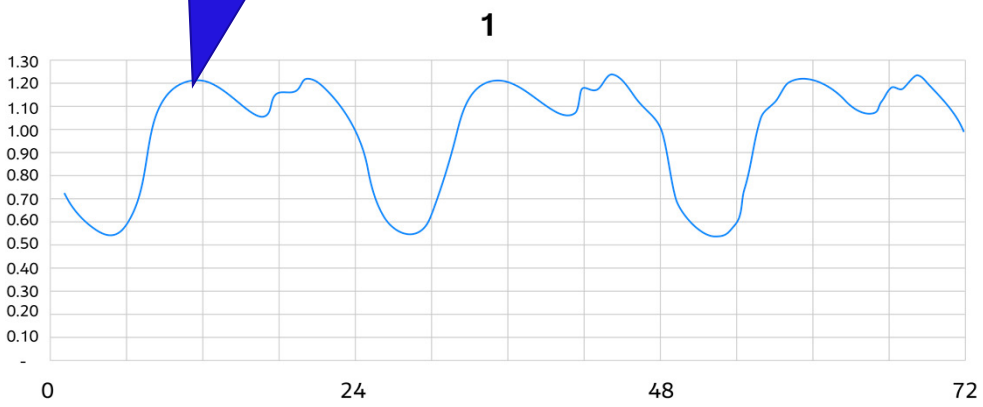
Advantages & Disadvantages of Composite or Grab Samples

Composite Sampler pulls individual samples over time

Grab samples can be scheduled

Exploring Technology for COVID-19 Tracking that Capitalizes on Sensors in the Collection System

Morning Peak of the Diurnal Pattern



Using flow data enables us to develop a sampling plan to sample when the virus is most prevalent in the sewer.

Is the Vaccine Effective?

- In 2013, researchers in Israel detected an outbreak of polio through their wastewater epidemiology program before any local clinics reported symptoms. Armed with this information, the government targeted vaccination efforts that effectively contained the outbreak.
- Sampling in the collection system can be used to test if the COVID-19 virus is still present after the vaccine has been deployed

In early August, Israel launched a mass campaign to vaccinate children against polio, including this little girl at a clinic in Rahat.

David Buimovitch/AFP/Getty Images

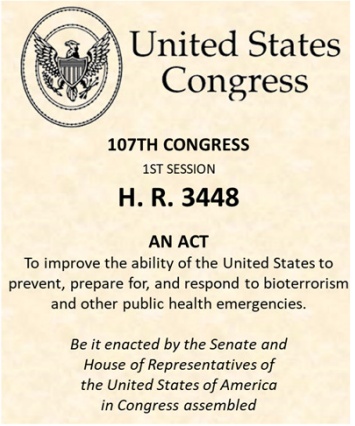
We need to take these lessons forward to the next pandemic

We see an Early Warning System needed such as we did for Drinking Water for the US EPA

US EPA Water Security Initiative (WSi)

- Post 9/11, Development of WSi Program
  - HR 3448 Public Health Security and Bio-terrorism Response Act
  - HSPD-9

    Directed EPA to *..."develop robust, comprehensive, and fully coordinated **surveillance and monitoring** systems for water quality that provides **early detection** and awareness of disease, pest, or poisonous agents"…*



United States Congress

107TH CONGRESS

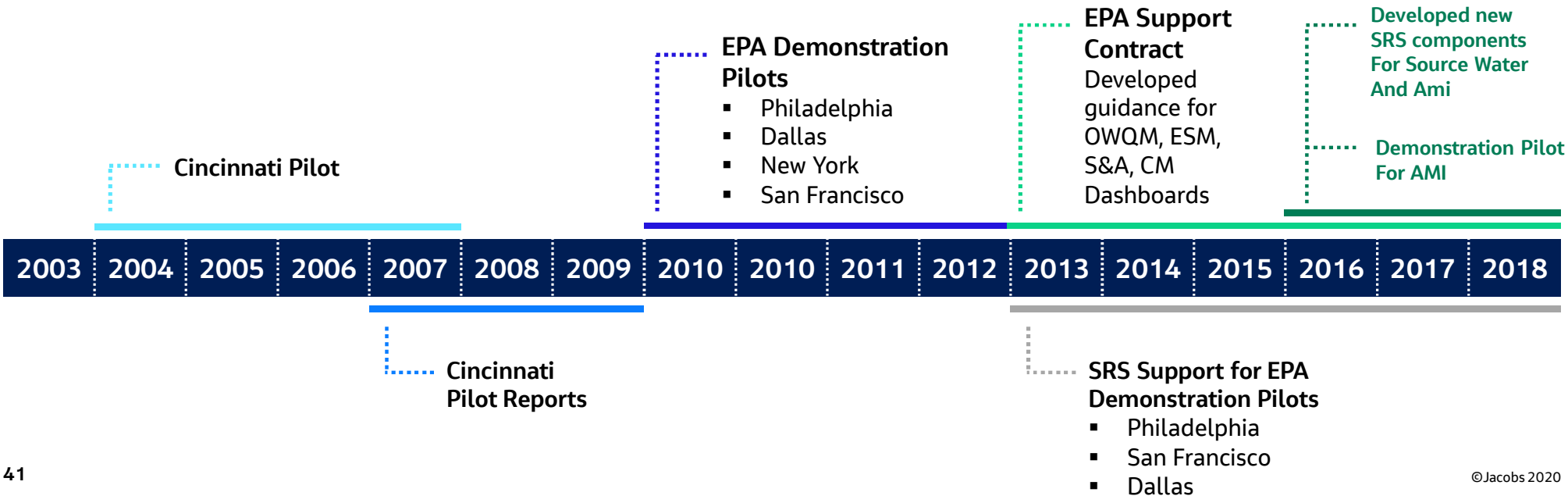
1ST SESSION

H. R. 3448

AN ACT

To improve the ability of the United States to prevent, prepare for, and respond to bioterrorism and other public health emergencies.

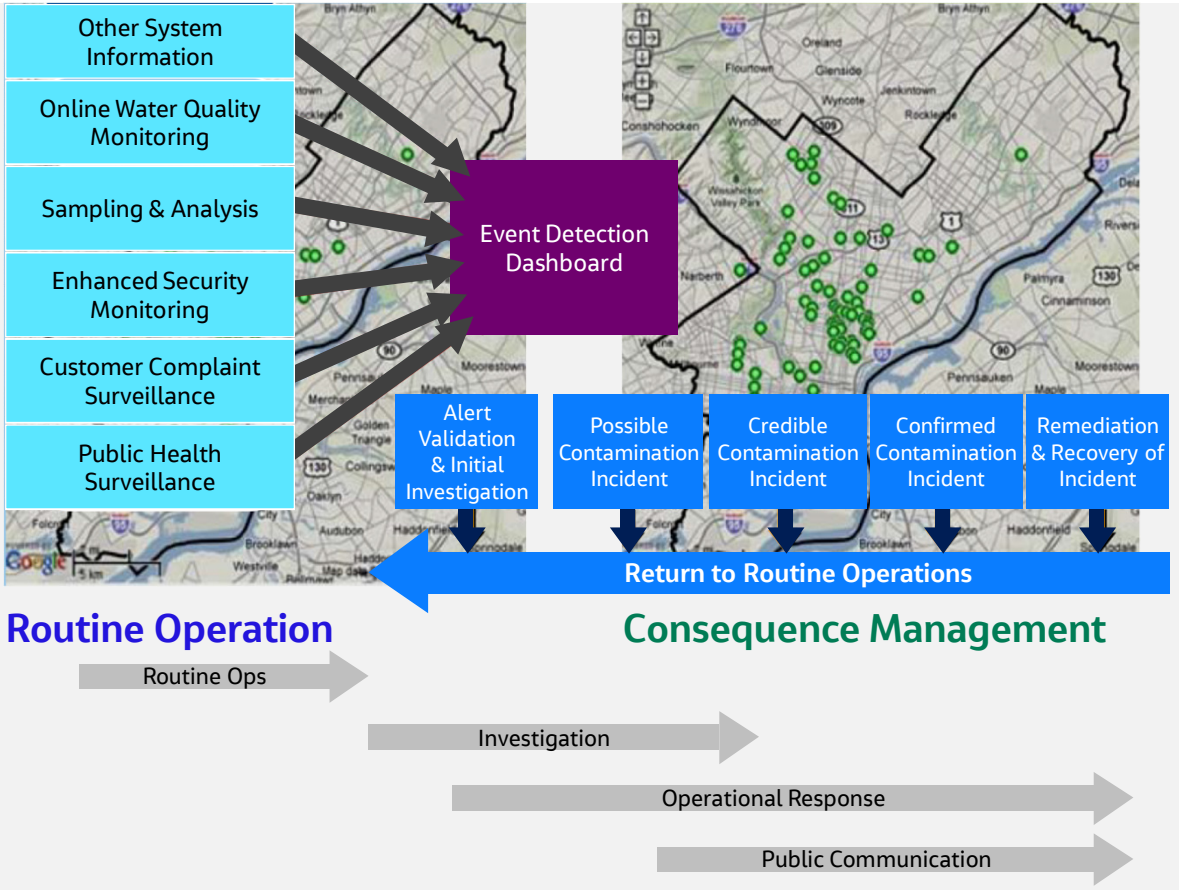
Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled



Insight Through Realtime Data Fusion

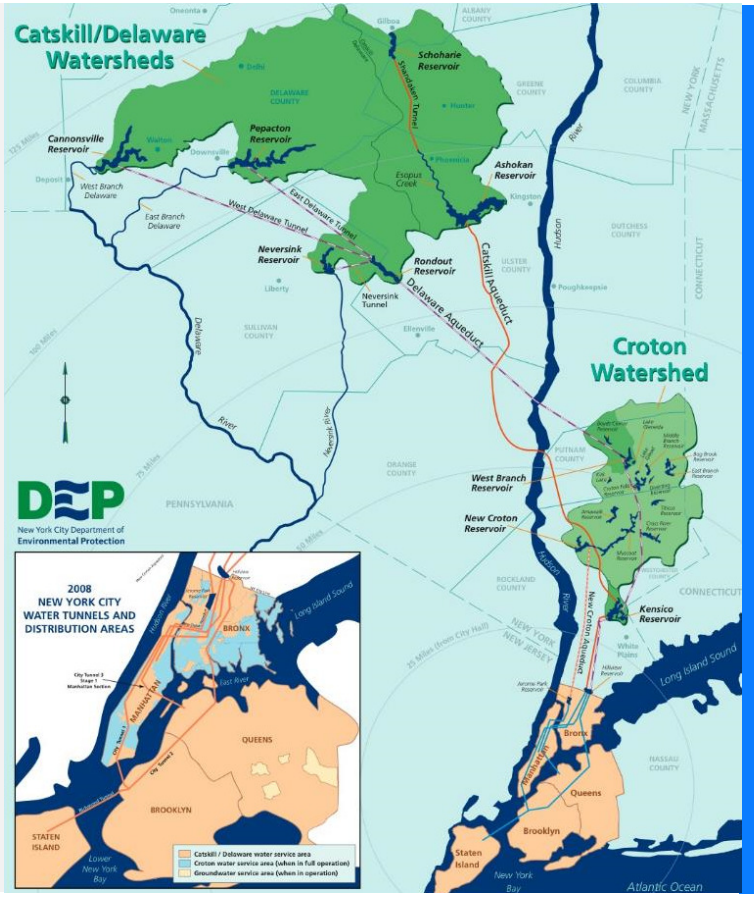
Developed SRS Architecture

- Multiple streaming data feeds
- Realtime analytics
- Geospatial dashboard
- Included health/epidemiology data feeds



NYC Water Supply

- Deliver > 1 billion gallons of water daily
- To > 9 million customers
- 19 reservoirs, 3 controlled lakes
- > 6,000 miles of pipes, aqueducts, and tunnels
- Gravity feed
- 98% of water from Cat/Del watershed
  - Not filtered



Real-time Dashboard

Thank you!

Questions & Answers