

A Drop in the Digital Ocean

The Development of a Smartphone-based System for Water
Quality Monitoring in
South Africa using Machine Learning Techniques

Water Research Commission

in collaboration with

University of the Witwatersrand



The Current State of Things

Deadly cholera outbreak was just a matter of time

Drinking water has been dirty for at least three years, the Department of Water and Sanitation's own tests show

24 May 2023 | By [Steve Kretzmann](#) and [Chris Gilili](#)

[News](#) | [Pretoria](#)



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Conflict of interest

He does not work for, consult, receive funding from any organization that would benefit from this article. He has disclosed no relevant financial interests that could potentially bias their academic work.

ISA |  University of South Africa



From **Challenge** to Opportunity

- Failing infrastructure at national level
- Neglect of rural and low-resource areas
- Focus on maintaining existing systems, instead of innovating
- Little to no real-time and accessible water quality data
- Devices are costly, clunky and require expert knowledge

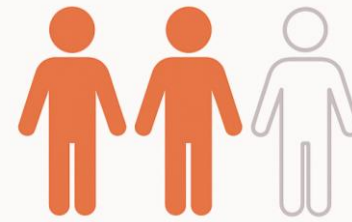
Viljoen, G & van der Walt, K. (2018). South Africa's water crisis - An interdisciplinary approach. Tydskrif vir Geesteswetenskappe. 58. 483-500.
10.17159/2224-7912/2018/v58n3a3.



From Challenge to Opportunity

- Paper-based testing tools offer lower manufacturing costs
- Computer vision + CNNs offer scalable solutions
- Increasing internet access in SA
- Citizen science gaining ground in environmental monitoring

3 out of 4 have internet access¹



2 out of 3 have reliable, clean water access²

¹ Tshililo, F.P., Mutanga, S., Sikhwivhilu, K., Siame, J., Hongoro, C., Managa, L.R., Mbohwa, C., & Madyira, D.M. (2022). Analysis of the determinants of household's water access and payments among the urban poor: A case study of Diepsloot Township. Physics and Chemistry of the Earth, Parts A/B/C, 127, 103183.

² International Trade Administration. (2023). South Africa - Digital Economy. Country Commercial Guides. Retrieved from <https://www.trade.gov/country-commercial-guides/south-africa-digital-economy>





At the Core

Research Questions

To what extent can a water monitoring application, leveraging **machine learning** techniques and convolutional neural networks, accurately **evaluate and categorise real-time water quality parameters**, including pH, chlorine, and hardness?

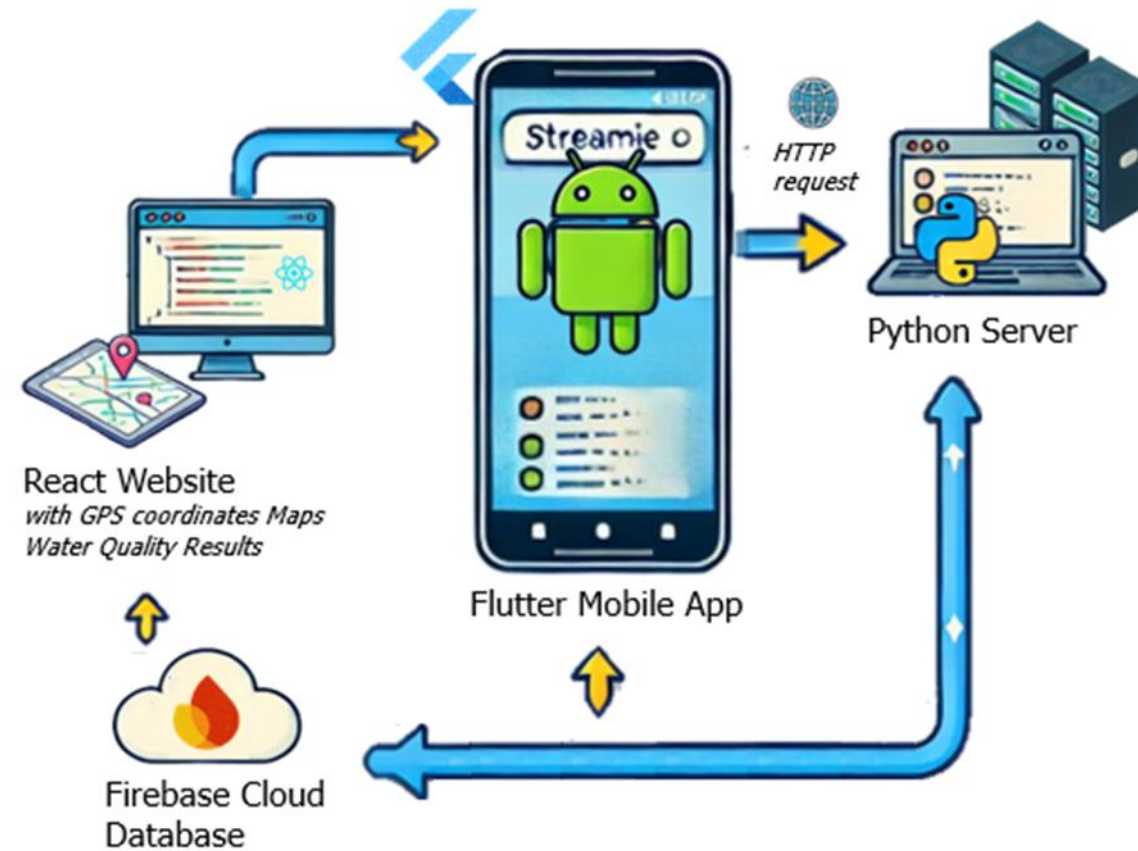
- What minimum averaged performance metrics should be obtained by the trained model in classifying water quality parameters to ensure 90% accuracy in ideal conditions and 80% accuracy in non-ideal conditions?



Methods & Materials



What Have We Done?



Overview of Water Quality System



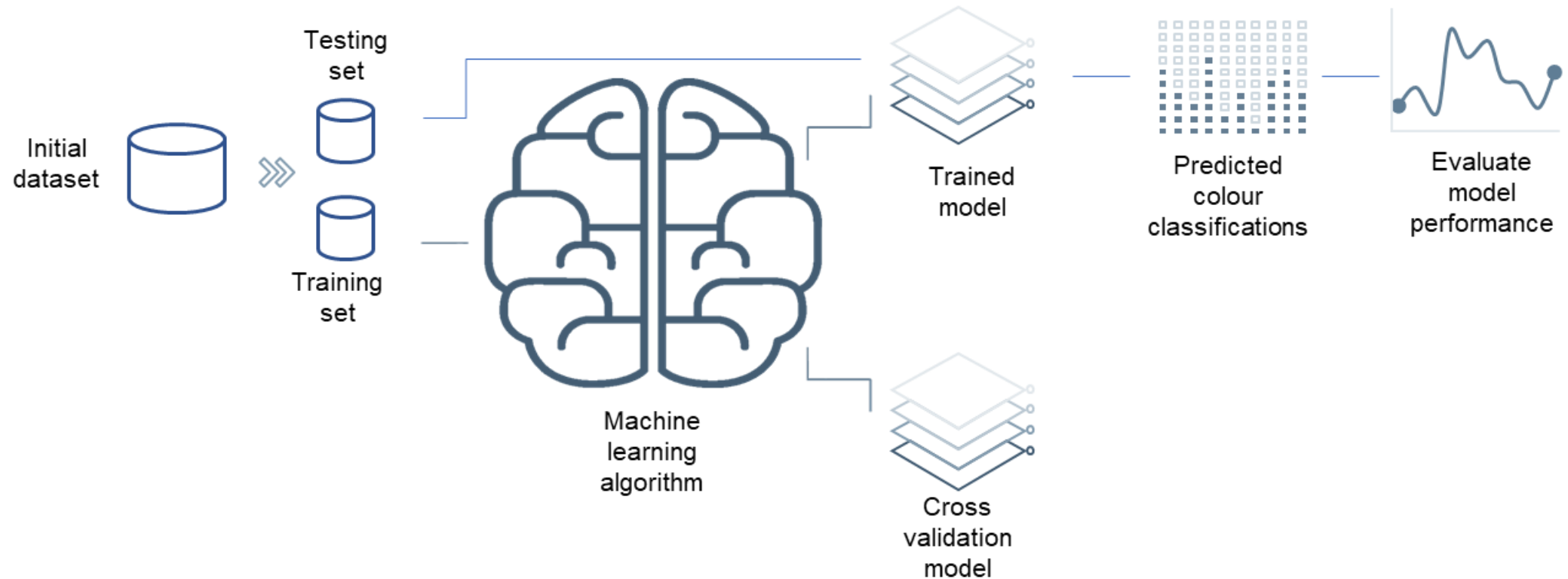
From Test Strip to Touchscreen

Three main processes of development:

1. The backend algorithm for colorimetric analysis
 - Supervised CNN model trained on test strip images using SANS241:2015 guidelines
 - Data collected under diverse conditions - for both development and testing
 - Colour classification logic
2. Developing the user interface (UI)
3. Connect the app to other elements of the system



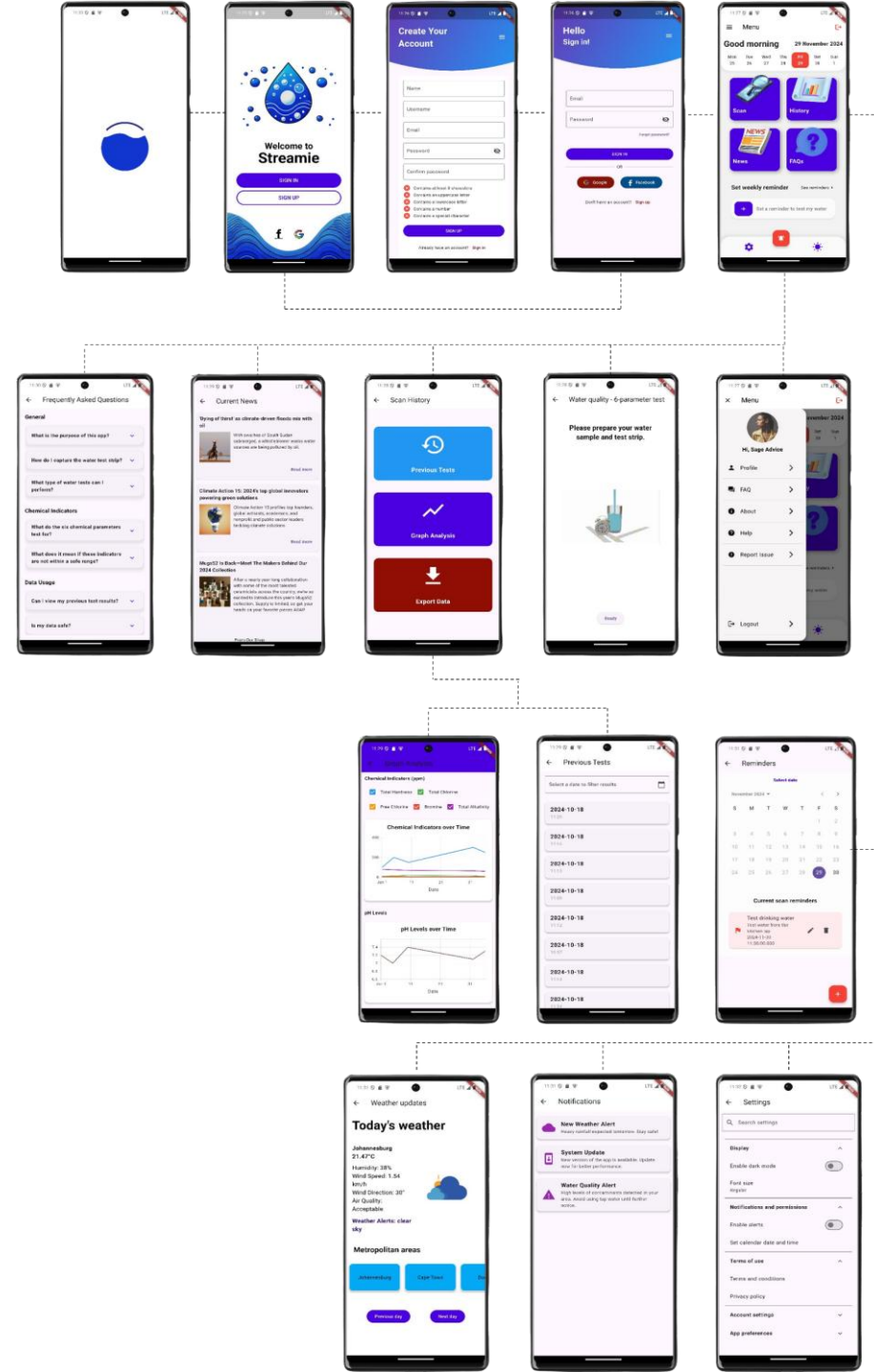
Backend Development Summary



Overview of the UI

Some fun features:

- Graphing data over time
- Real-time weather and news feeds
- Notifications sent to app users from the datahub with potential warnings
- AI-generated podcast from historic results
- Reminder feature





Results

What the Data Tells Us

Accuracy of object detection outcomes

- Model achieved a 0.91 F1 score after 50 epochs
- 97% classification accuracy of regions of interest (ROI) achieved under ideal conditions
- Detection accuracy for misoriented strips: 85.0%

Precision of colour classification

- Colour classification accuracy: 88.37%
- Misclassifications: 9%

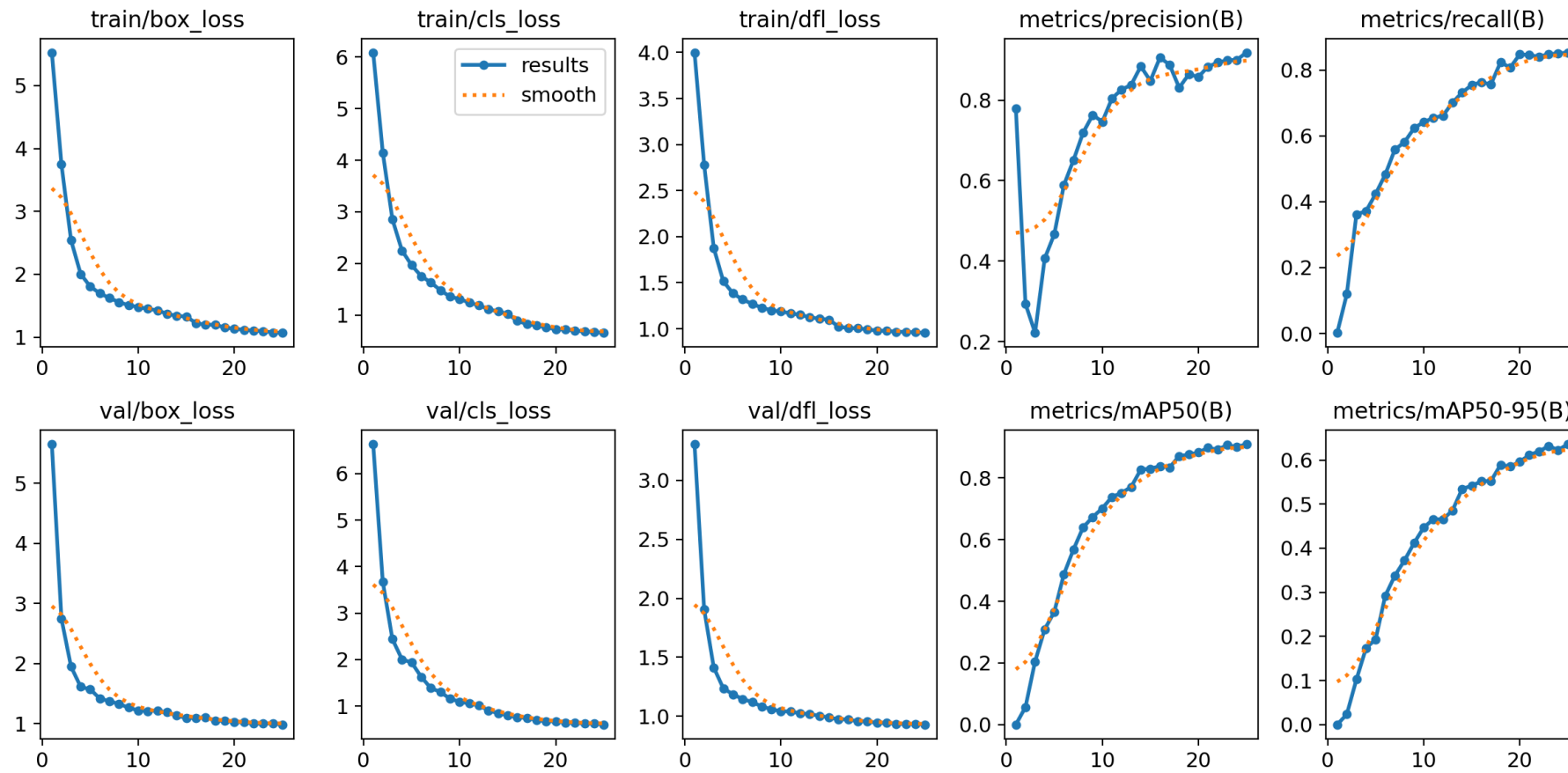
Accuracy of overall safety prediction

- 86 % of samples accurately classified as safe or unsafe
- False negatives (unsafe classified as safe): 2%
- False positives (safe classified as unsafe): 4%

*For a sample of 100 images



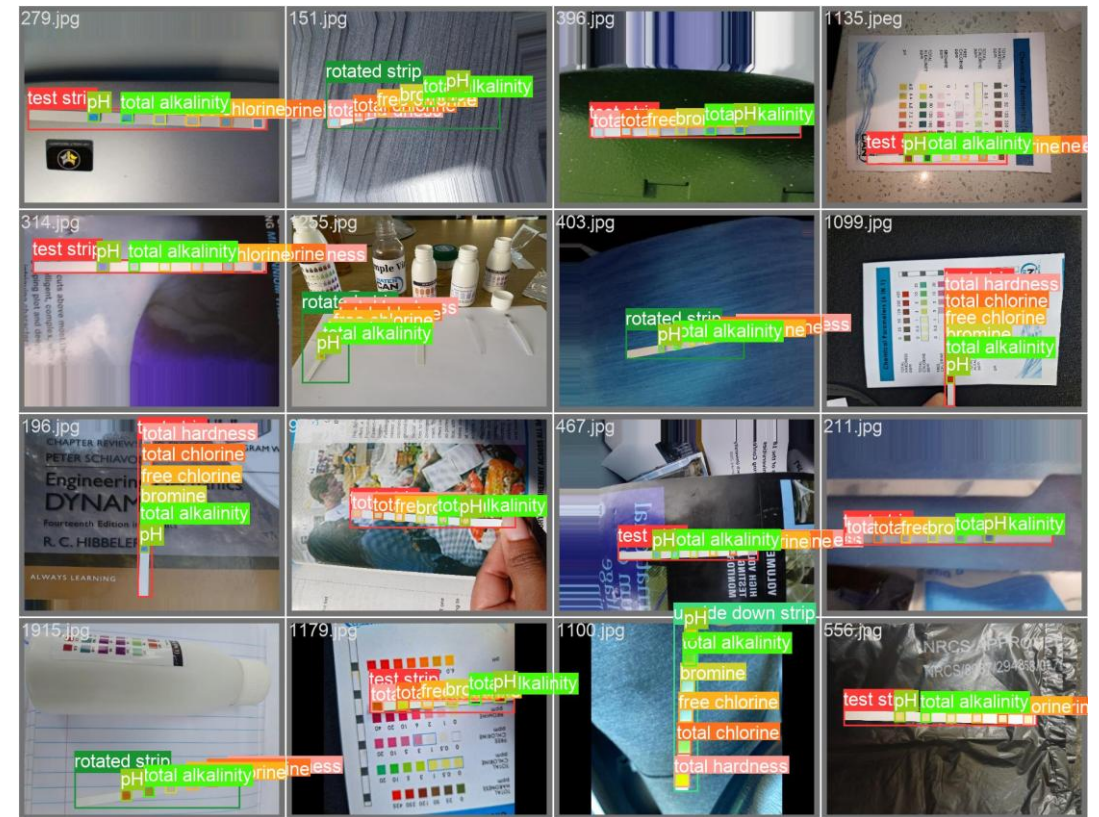
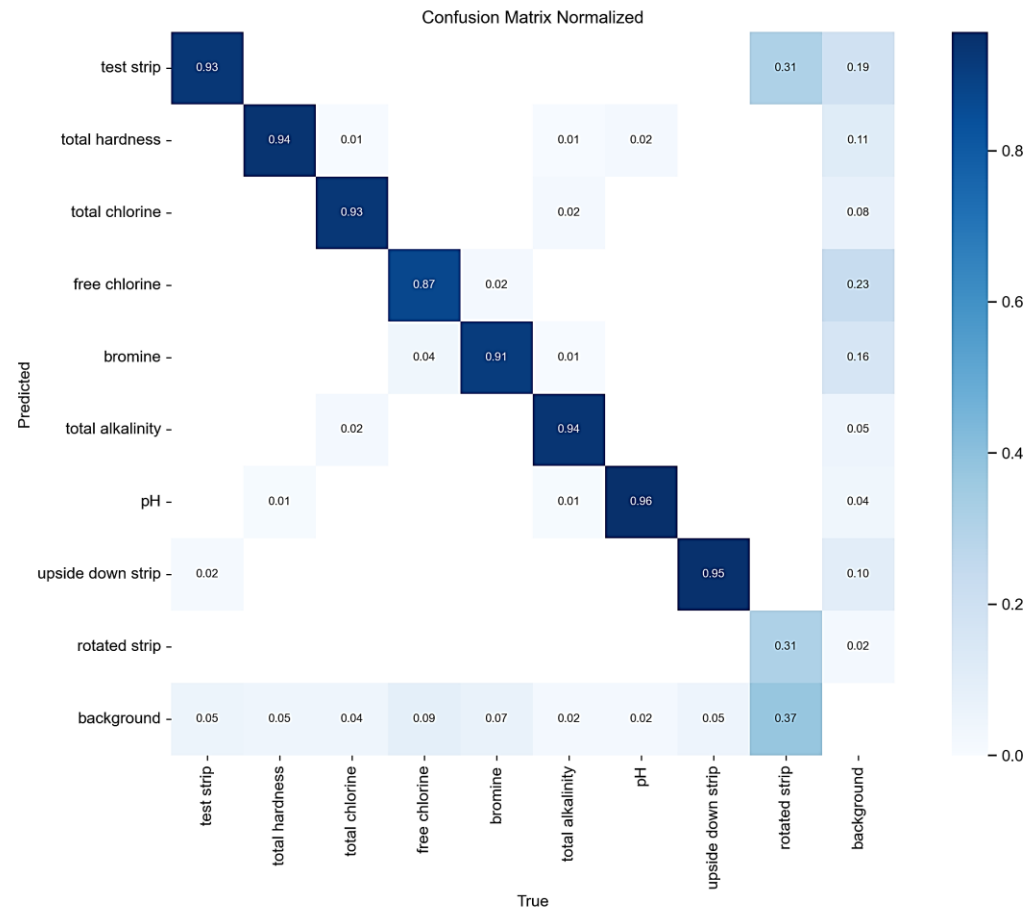
Results: Continued



Number of Epochs



Results: Continued



Example of Object Detection Results





Implications

Why This Matters

- Stresses importance of misclassifications caused by variable lighting, inconsistent user input, and hardware limitations
- Generates structured data for long-term water quality trend analysis
- Insight into infrastructure failures and water stress in underserved regions
- Supports local governance with actionable, hyper-local water data
- Potential for a scalable early-warning contamination system
- Citizen science empowers communities and democratizes water testing and data





Challenges

In Murky Waters

- Limitations of the test strip quality and chemical indicators
- Test strip variability by manufacturer
- Data collected and quality – including manual readings recorded
- Experimental model accuracy and computational constraints
- Lighting conditions and camera quality affect accuracy
- Limited dataset for edge cases – extreme highs and lows seldomly recorded





Future Work

The Bigger Picture

- Future improvements include:
 - More dynamic model for environmental variability
 - Expanding the dataset and parameter range – perhaps to include biological indicators
 - Allowing for more than one input type – beyond images
- Ongoing collaboration with end-users ensures relevance and usability in the field
- Use cases
 - Agriculture applications
 - Travel and tourism safety





Conclusions

Key Takeaways

- Achieved above 90% ROI detection accuracy – Strong F1 score shows reliable algorithm performance
- Challenges under real-world conditions – Lighting, rotation, and user error affect results
- Mobile-based and scalable – Provides low-cost, decentralised water testing
- Empowers communities – Encourages citizen science and shared water stewardship
- Aligns with SANS 241, supporting safe drinking water and policy adoption potential



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(OUTA)



The WRC Team



Those who graciously tolerated
me





THANK YOU

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 <https://www.wits.ac.za/wits-water/>

Q&A Session

