RATES, Inc.

Rio Grande Valley Flood Management

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Andrew Ernest N.S. Ernest, Ph.D., P.E., BCEE

William Kirkey, Ph.D.

Christopher Fuller, Ph.D.

Skyler LeVrier, M.S.   Linda Navarro, M.S.

Ivan Santos-Chavez, M.S.

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Approval Page

Technical Review By:

William Kirkey, Ph.D.
Chief Research and Technology Development Officer

Final Approval For Submission:

Andrew N.S. Ernest, Ph.D., P.E., BCEE, D.WRE
President and CEO

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CONTENTS

RGVFlood is a cloud-based Regional Water Resource Decision Support System focused on the Lower Rio Grande Valley. It is built on the *GeoNode* geospatial content management system with extensions from *REON*. REON Extensions include integration of geolocated real-time data streams and application hooks to execute decision support tools based on the geospatial data.

ONE

INTRODUCTION

RGVFlood is a cloud-based Regional Water Resource Decision Support System focused on the Lower Rio Grande Valley. It is built on the GeoNode[1] geospatial content management system with extensions from REON[2]. *REON* Extensions include integration of geolocated real-time data streams and application hooks to execute decision support tools based on the geospatial data.

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[1] https://geonode.org/

[2] https://reon.cc

RGVFLOOD END-USER INTERFACE DEVELOPMENT

This constitutes Deliverable 1.2.1.4.3.2.3 "End-User Interface Development Report".

2.1 Background

A beta version *RGVFlood.com* was released in the Fall of 2021 to demonstrate the proposed functionality of the system. This version of *RGVFlood.com* was based on *GeoNode* v3.3.2, with additional enhancements, including integration of an *API* for ingestion of timeseries *RTHS* data, a 'Flood Wizard' app for visualizing data and a *H&H* model availability. After operating for 6 months, it was determined that installation on a single bare-metal server was insufficient for the anticipated demand, and the base software suite upon which *RGVFlood.com* was constructed, limited the implementation of Continuous Integration/Continuous Delivery pathways for the already integrated extension and planned extensions - specifically those associated with *H&H* model execution.

In the Spring of 2022, the beta site was decommissioned to allow for spin-up of a re-incarnation of *RGVFlood.com* addressing the key issues identified during beta deployment:

1. Migration from a single-stack *Docker* container deployment, to a scalable *Kubernetes* cluster.

2. Reliance on an inter-pod shared, cloud-based *NFS* volume service to ensure expansion and accomodation of the large volumes of geospatial data to be stored, and that produces by the integrated *H&H* and visualization tools.

3. Reliance on a managed cloud-served database service, to ensure minimal data access bottlenecks.

4. Integration of *GeoNode* v4.0 to promote future growth and seamless conntinuous deployment.

2.2 Development Infrastructure

The *RGVFlood.com CI/CD* process relies on the following *RATES* projects:

`spyce`	*Spyce* is a suite of tools designed to facilitate development and deployment of the *Water Wizard* ecosystem of services.
`waterwizard`	*Water Wizard* is the host platform for *Wizards* and project documentation deployment.
`geonodegcp`	*GeoNodeGCP* is a migration pathway for converting new releases of *GeoNode* for deployment on *GCP*.
`reonode`	*REONode* serves as the development platform for *REON* apps and extensions prior to release on REONcc.
`reoncc`	REONcc is the reference implementation of tools and application developed to a stable status on *REONode*.

2.2.1 spyce

Spyce is a suite of tools designed to facilitate development and deployment of the *Water Wizard* ecosystem of services. Most operations related to development, deployment, maintenance, backup/restore, etc of the *REON.cc* cyberinfrastructure are handled via the *RATES Spyce* application. The *Spyce Python* codebase provides functionality through a series of *spells* delivered via *CLI* using the python `fabric` package. *Spyce* provides a wide assortment of tools (*spells*), to simplify development, deployment and maintenance operations, ranging from generating project documentation and ingestion into the *Water Wizard* platform, creation and deletion of clusters, instantiation of specific apps on clusters, backup and restore, etc. Key to *Spyce* operation is the reliance on environment variables to provide consistency between vendor/service provider toolchains.

2.2.2 waterwizard

Water Wizard is the host platform for *Wizards* and project documentation deployment. It also serves as a loose template for deploying *Django* apps as a *Docker* stack, or as a *k8s* app. *Wizards*, such as *Spyce Wizard* are incorporated into the *Water Wizard* platform. Each *Wizard* is comprised of *Spells* that provide the desired functionality. *Flood Wizard* is a set tools designed to interact with flood forecasting tools to provide decision support and visualization functionality for the end user.

2.2.3 geonodegcp

GeoNodeGCP is a migration pathway for converting new releases of *GeoNode* for deployment on *GCP*. It includes adaptations to *GCP* such as reliance on CloudSQL and FileStore rather than generic, image-buit container services. Although *GeoNodeGCP* is specific for *GCP* applications, it can be readily modified to work with any *kubernetes* cyber-infrastructure.

2.2.4 reonode

REONode serves as the development platform for *REON* apps and extensions prior to release on REONcc. Because of the *CI/CD* nature of the end-user products such as REONcc, *RGVFlood.com* and *SustainRGV*, a seperate development platform is used to ensure full seperation from operational databases and filesystems, prior to integration.

2.2.5 reoncc

REONcc is the reference implementation of tools and application developed to a stable status on *REONode*. It includes all data and tools relevant to water resources management, including hydro-logic extremes and ecological resilience. :term"*REONcc* serves as the host platform for *REON*.

2.3 Cloud Infrastructure

RGVFlood.com cloud deployment relies of conversion of it's component services to be converted to be delivered via a *Microservices Architecture*. Several options are available for deploying the microservices version of *RGVFlood.com*, including an on-premise hardware cluster, Google Cloud Platform, Amazon Web Services and Microsoft's Azure.

2.3.1 Google Cloud Platform

Google Cloud Platfrom (*GCP*) was selected as the initial platform for *RGVFlood.com*, based on Cost of Service, and integration with existing *RATES* operations.

2.3.2 Google App Engine

Google App Engine (*GAE*) allows users to deploy containerized apps on *GCP*, whithout have to worry about underlying server management. Other than providing a cloud testing environment for individual microservices, *GAE* currently has limited utility for use in the *RGVFlood.com* ecosystem.

2.3.3 Google Compute Engine

Google Compute Engine (*GCE*) provides access to virtual machines (*VM*), and serves as the infrastructure basis for the *GAE* environment. A *GCE VM* was used to support the transition from a self-contained docker-stack to deploy a fully cloud-leverage *RGVFlood.com* deployment.

2.3.4 Google Kubernetes Engine

Google Kubernetes Engine (*GKE*) provides the user access to the container orchestration facilities of *GCP*. Google's Autopilot custer configuration was selected for cluster creation, allowing for ease of horizontal (node/cpu) and vertical (memory) scaling. As a result, cluster size is reported in terms of the number of *vCPU* and memory rather than the traditional node count. Running the following applications to support continuous development:

- geonodegcp-app
- reonode-app
- waterwizard-app
- rgvflood-app

with nominal use, the cluster scaled to 9.75 *vCPU* and 38.2 GB of memory. With one *vCPU* being roughly equivalent to one hardware core, this is similar in capacity to a single standard bare-metal server. With the integration of user-applications (e.g. RTHS Data API and Flood Wizard), along with anticipated end-user access and demand, horizontal scaling needs are expected to quadruple at a minimum.+

2.3.5 CloudSQL

Rather than rely on containerized database services, the decision was made to switch to Google CloudSQL managed database services. Similar services are available though *AWS* and *Azure*. Unlike a single-stack *Docker* deployment, switching to a *K8s* with potentialy multiple replicas needing to access the database services, reliance on managed database services eliminates the need to construct and manage a separate workload specially for database services.

The first step in transtioning to *k8s* involved deploying the `docker-compose.yml` stack on a *GCE VM*. The database service was then replaced with a CloudQSL-Proxy service, allowing the con-

tainers to access the databases managed by CloudDQL and permitting the number of replicas to be scale with no collisions or impacts in performance.

2.3.6 Filestore

Persistent file storage is handled differently between standard *Docker* desktop deployments and scalable *K8s* clusters. Implelementing persistent storage between reboots and between containers for the *K8s* deplyoment involved changing from volume mounts to and *NFS* share. This *NFS* share is also mounted by as *GCE VM* used during the development process for debugging. It is anticipated that the volume of filestorage needed will eventually be in excess of 1TB, more once real-time forecast data is produced.

2.4 Component Integrations

RGVFlood serves as the core platform into which value-added component services are plugged-in and provided for use by the end-user.

2.4.1 RTHS Data API

Originally packaged with the beta release of *RGVFlood*, the RTHS Data *API* ingests RTHS time-series data on-demand for use by the end-user. *RGVFlood* is also able to serve the data to other component services such as Flood Wizard, WRF-Hydro and the RAS Data Provider. The RTHS Data API wil be included in the next release of *RGVFlood.com*.

2.4.2 Flood Wizard

Flood Wizard is a Javascript Progressive Web Application developed using the Ionic framework. It was packaged with the last beta release of *RGVFlood*, with the foliiwing features:

- Ability to view and inspect the *RGVFlood* delineated sub-basins and RTHS stations

- Ability to view and download the input data and modeling results from the Tier II modeling effots

- Overlay and compare stage height data from multiple RTHS stations

Flood Wizard was deployed to seed end-user discussion on the type of applications deemed most useful by end-users. Flood Wizard will be included in the next release of *RGVFlood.com*, incorporating user-recommended modifications and additions.

2.4.3 RAS Data Provider

The goal of this component is to generate HEC RAS input data for selected domains from *RGVFlood.com* availalble data on demand. At the very minimum, this will include discharge data extracted from hydrologic model outputs, along with pertinent RTHS data. Other data, such as topographic and hydraulic asset surveys will also be provided. The development of this component is currently on-going.

2.4.4 WRF-Hydro

Although not a direct integration, the outputs of the Tier I modeling effort will be ingested into *RGVFlood.com* for visualization and decision support application. Development of this component is pending prototype deployment of the Tier I model.

2.5 Conclusions

RGVFlood.com has been successfully taken out of beta and deployed in production mode.

1. The single-stack *Docker* container deployment used in the beta deployment has been coverted to a scalable *Kubernetes* cluster.

2. The production system now relies on a shared inter-pod, cloud-based *NFS* volume service, ensuring expansion and accomodation of the large volumes of geospatial data being stored, and produced by the *H&H* and visualization tools to be integrated.

3. Database services are now provided by a Google's CloudSQL, a managed cloud-served database service, resulting in minimal data access bottle-necks.

4. The core *GeoNode* application has been upgraded to v4.0 maximizing the potential for future growth and seamless conntinuous deployment.

5. A step-wise development process has been implemented, allowing both for the continuous integration of changes in third-party applications (e.g. *GeoNode*), incorporation of new *RGVFlood* apps, rigorous testing and continuous deployment.

GLOSSARY

API
    Application Programming Interface

API.RGVFlood.com
    RGVFlood.com data assimilation service.

AU
    Assessment Unit

AWS
    Amazon Web Services

Azure
    Microsoft's Cloud Computing Platform

Bernoulli
    The Bernoulli equation is a simplification of the Navier-Stokes equations assuming inviscid fluid and steady (non-time-variant) flow.

BLE
    Base Level Engineering

Celery
    A task scheduling and messaging application used to maximize parallel task processing.

CentOS
    A *Linux* distribution

CI
    Cyberinfrastructure

CI/CD
    Continuous Integration and Continuous Delivery/Continuous Deployment

CLI
    Command-Line Interface

Cloud
    Servers, software and databases that are accessed over the Internet

Clover

Cloud Virtual Water Model Executor

COP

Common Operating Picture

CPU

Centralized Processing Unit

Crowdsource

Data collection from open, relatively un-controlled, sources.

CUAHSI

Consortium of Universities for the Advancement of Hydrologic Science

Cyberinfrastructure

computing systems, data storage systems, advanced instruments and data repositories, visualization environments, and people, all linked by high speed networks

DEM

Digital Elevation Model

Deterministic

Approaches to describing processes that do not rely on randomness.

DFIRM

Digital Flood Insurance Rate Map

DHS

Department of Homeland Security

DIKW

Data, Information, Knowledge, Wisdom

Django

<https://www.djangoproject.com/>

DO

Dissolved Oxygen

Docker

Docker is a container deployment platform that allows for the rapid deployment of a applications in the cloud, independent of the physical infrastructure.

DRF

Django ReST Framework

DSS

Decision Support System

EC2

AWS Elastic Cloud Compute

Eeyore

URL: Eeyore.ratesresearch.org CPU: Dual Intel(R) Xeon(R) E-2124 CPU @ 3.30GHz Memory: 16GB HD: 4TB OS: Ubuntu Linux 20.04

FEMA

Federal Emergency Management Agency

FIF

Flood Infrastructure Fund

FOSS

Free and Open Source Software

GAE

Google App Engine

GCE

Google Compute Engine

GCP

Google Cloud Platform

GCS

Google Cloud storage

GeoNode

A web-based application and platform for developing geospatial information systems (GIS) and for deploying spatial data infrastructures (SDI).

GeoNode

<https://geonode.org/>

GeoNode/db

PostgreSQL with *PostGIS* extensions database server storing *GeoNode Django* and *GeoServer* data.

GeoNodeGCP

An implementation of *GeoNode* on *GCP*

GeoServer

Open source server for sharing geospatial data.

GeoTIFF

A public domain metadata standard which has the georeferencing information embedded within the *TIFF* file.

GIS

Geospatial Information System

GitHub

An online software development platform used for storing, tracking, and collaborating on software projects.

GKE

Google *Kubernetes* Engine. https://cloud.google.com/kubernetes-engine/

H&H

Hydrologic and Hydraulic

HAND

Height Above Nearest Drainage <http://handmodel.ccst.inpe.br/>

HEC

Hydrologic Engineering Center

HEC-DSS

HEC Data Storage System

HEC-HMS

Hydrologic Engineering Center Hydrologic Modeling System. <https://www.hec.usace.army.mil/software/hec-hms/>

HEC-RAS

Hydrologic Engineering Center River Analysis System. <https://www.hec.usace.army.mil/software/hec-ras/>

HEC-RTS

Hydrologic Engineering Center Real Time Simulation

Hogwarts

RATES Kubernetes on-premise multi-node bare-metal cluster.

HPC

High Performace Computing

HPCC

HPC cluster

HTML

Hypertext Markup Language

HUC

Hydrologic Unit Code

HWMD

Hidalgo/Willacy Main Drain

IBWCNF

USIBWC North Floodway

IDV

Integrated Data Viewer from *UniData*

InfoWorks ICM

<https://www.innovyze.com/en-us/products/infoworks-icm>

IT

Information Technology

K8s

Kubernetes

KIND

Kubernetes IN *Docker*. https://github.com/kubernetes-sigs/kind

Kubernetes

An orchestration system facilites the deployment and management of containerized applications, with a specific focus on scaling to increase demand for the provided services. https://kubernetes.io/

LaTeX

A high-quality typesetting system including features designed for the production of technical and scientific documentation

LiDAR

Light Detection and Ranging

Linux

An open source operating system that is made up of the kernel, the base component of the OS, and the tools, apps, and services bundled along with it.

LLM

Lower Laguna Madre

LLM/BSC

Lower Laguna Madre/Brownsville Ship Channel watershed.

LRGV

Lower Rio Grande Valley

LRGVDC

Lower Rio Grande Valley Development Council

LSM

Land Surface Models focus on describing the processes driving the exchange of terrestrial water with atmospheric.

Mechanistic

Formulations describing physical, biological or chemical processes based on a theoretical understanding.

Metadata

Data that provides information about other data

Microservices Architecture

A modular approach to developing applications. allowing large applications to be separated into smaller independent parts.

MIKE Urban+

<https://www.mikepoweredbydhi.com/download/mike-2019/mike-urban-plus?ref=
[%7B5399F5D6-40C6-4BB2-8311-37B615A652C6%7D](%7B5399F5D6-40C6-4BB2-8311-37B615A652C6%7D)>

MPI

Message Passing Interface

NAT

Network Address Translation

Navier-Stokes

The Navier-Stokes equations are mathematically representations of conservation of mass and momentum for simple fluids such as water.

NCAR

National Center for Atmospheric Research

NetCDF

NetCDF (Network Common Data Form) is a set of software libraries and machine-independent data formats that support the creation, access, and sharing of array-oriented scientific data. It is also a community standard for sharing scientific data. The Unidata Program Center supports and maintains netCDF programming interfaces for C, C++, Java, and Fortran. Programming interfaces are also available for Python, IDL, MATLAB, R, Ruby, and Perl. Reproduced from NetCDF[3].

NFS

Network File Systemn a protocol that lets users on client computers access files on a network, making it a distributed file system.

NGINX

High performance web server.

NIC

Network interface controller

NLDAS

North American Land Data Assimilation System

NOAA

National Oceanic and Atmospheric Agency

NWC

National Water Center

NWM

National Water Model

NWS

National Weather Service

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[3] https://www.unidata.ucar.edu/software/netcdf/

ODM

Observations Data Model

PDF

Portable Document Format

PostGIS

Spatial database extender for *PostgreSQL*

PostgreSQL

Open source object-relational database system, available with *PostGIS* extensions

Primo

Parallel raster inundation model

PWA

Progressive Web Application, an application format that allows installation as native applications onto mobile devices and desktop PCs directly from the web.

Python

<https://www.python.org/>

R

A language and environment for statistical computing and graphics

RabbitMQ

An open-source inter-process message broker

RATES

Research, Applied Technology, Education and Service, Inc., a non-profit technology-based company.

RBAC

Role Based Access Control

REON

River and Estuary Observation Network. A partnership of organizations, supported by cloud software, committed to furthering the Democratization of Water Intelligence by sharing water data, analytics and models for local and regional decision making.

REON.cc

Cloud-based cyber-infrastructure that supports *REON*'s goals.

REON/db

PostgreSQL with *PostGIS* extensions database server storing *REON* specific data for *RTHS*, *REON/WM* & *REON.cc* data.

REON/RGV

Instantiation of *REON* with specific application to the Lower Rio Grande Valley - this includes the collection of *RTHS* stations, the *REON* partners with a stake in the LRGV, and the application of the *REON/WM* to the *LRGV*.

REON/WM
>   *REON* Water Model

REONode
>   *REON* Development Environment. A live implementation of *REON.cc* extensions and applications under active development.

ReST
>   REpresentational State Transfer

RGVFlood
>   Instantiation of the *REON* Cyberinfrastructure specific to the *LRGV*.

RGVFlood.com
>   The domain name and *URL* for *RGVFlood*.

RTHS
>   Real Time Hydrologic System

RTHS.us
>   Cloud server of *RTHS* network data

RVD
>   Raymondville Drain

RWRAC
>   Regional Water Resources Advisory Committee

SA
>   Situational Awareness

SaaS
>   Software as a Service

SMT
>   Simultaneous Multi-Threading

SONAR
>   Sound Navigation Ranging, a technique for detecting and determining the distance and direction of underwater objects by acoustic means.

Sphinx
>   Documentation generator supporting multiple output formats

SPRNT
>   Simulation Program for River Networks

Spyce
>   Smartphone Python Computing Environment

Stochastic
>   Approaches to describing processes in statistical terms.

SustainRGV

Instantiation of the *REON* Cyberinfrastructure specific to the *LRGV* sustainability.

SustainRGV.org

The domain name and *URL* for *SustainRGV*.

SWMM

Stormwater Management Model

SWTF

Stormwater Taskforce

Tastypie

a webservice *API* framework for *Django*

TGLO

Texas General Land Office

Tier I

Tier I Real-Time Regional Hydrologic Modeling Framework

Tier II

Tier II On-Demand Sub-Regional Hydraulic Modeling Framework

Tier III

Tier III Off-Line Urban Stormwater Modeling Framework

TIFF

Tag Image File Format, a computer file used to store raster graphics and image information.

Tigger

URL: Tigger.water-wizard.org CPU: Dual Intel(R) Xeon(R) CPU E3-1245 v3 @ 3.40GHz Memory: 16GB HD: 4TB OS: Ubuntu Linux 20.04

TIN

Triangular Irregular Networks are a form of vector-based digital geographic data and are constructed by triangulating a set of vertices.

TOML

Tom's Obvious Minimal Language

TWDB

Texas Water Development Board

TWDB/FIF

The Texas Water Development Board Flood Infrastructure Fund.

Ubuntu

A *Linux* distribution

UCAR

University Corporation for Atmospheric Research

UI

> User Interface

UniData

> A *UCAR* community program focused on sharing geoscience data and the tools to access and visualize that data.

URL

> Uniform Resource Locator

USACE

> United States Army Corps of Engineers

USGS

> United States Geological Survey

USIBWC

> United States International Boundary Water Commission

UTRGV

> University of Texas Rio Grande Valley

vCPU

> Virtual *CPU*

VCS

> Version Control System

VIC

> Variable Infiltration Capacity (VIC) Macroscale Hydrologic Model. <https://vic.readthedocs.io/en/master/>

VM

> Virtual Machine

Water Wizard

> A suite of decision support tools designed for regional decision makers.

Wizard.RGVFlood.com

> A web, mobile and desktop client-side application that, working with the server-side components at *RGVFlood.com*, provides the end-user with the up-to-date analytics, visualization and decision support services from the core *REON.cc CI*.

WPP

> Watershed Protection Plan

WPS

> WRF Preprocessing System

WRDA

> Water Resources Development Act

WRF

Weather Research and Forecasting Model

WRF-Hydro

WRF Hydrological modeling system. <https://ral. .edu/projects/wrf_hydro/overview>

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