**NASA DEVELOP National Program**



Wise County Clerk of Court's Office

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Peru Disasters II

Identifying and Mapping Flood Prone Regions in the La Libertad Region of Peru Using NASA's Earth Observations

 **Technical Report**

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# I. Abstract

In recent years, natural disasters have devastated the rural regions of Peru. Large flooding events in 2008, 2013, and 2014 disrupted central highlands districts, including the Cascas district of the Gran Chimu province about 110 km inland from the coastal city of Trujillo. The primary study area for this project was the Ochape river sub-basin near the city of Cascas, the capital of the Gran Chimu province. In partnership with Water for People and the Instituto Nacional de Defensa Civil Del Peru (INDECI), this project aimed to create resources and tools necessary for flood risk assessment projects in the Cascas district of Peru. NASA Earth observations were used in this project to provide input datasets for the Coupled Routing and Excess Storage (CREST) distributed hydrological model, which was developed by the University of Oklahoma in collaboration with NASA SERVIR. These inputs included Digital Elevation Models (DEMs) and related data from the HydroSHEDS portfolio of NASA’s Shuttle Radar Topography Mission (SRTM), rainfall data collected by Tropical Rainfall Measuring Mission (TRMM), and Landsat 8 imagery. All final maps, models, datasets, and tutorials developed in this project will enable Water For People and local authorities to better prepare for flooding based on historical examples.

**Keywords**

Flood Mitigation, Earth Observations (EO), Landsat 8, TRMM, CREST, Digital Elevation Model (DEM), Flow Accumulation (FAC), Inundation Model

# II. Introduction

**Background Information**

Rivers of the Andean highlands are often dry during the summer months and when the rainy season arrives during the months between November and April their tributaries swell in volume, in number and in velocity. Although seasonal flooding is common in the Peruvian highlands, flooding events in 2008, 2013, and 2014 have been excessive. In addition to that, this year’s El Nino event has heightened concerns of protracted flooding that accompanied El Nino events in1984 and 1992 within the District of Cascas, Peru. This is a political jurisdiction of 465 square kilometers located about 110 kilometers inland from the regional coastal city of Trujillo. Sixty-eight percent of the district’s population lives in rural areas and the remainder resides in or near the town of Cascas, the capitol of the district and of the larger Gran Chimu Province (Water for People, 2015).

Often dry during the summer months, during the rainy season from November to April highland rivers and their tributaries in the Andes Mountains swell in volume, in number, and in velocity. The Chepate and Cascas rivers flow through this mountainous geomorphology within the District of Cascas, forming separately within and traveling through the Ochape sub-basin before their confluence at its outlet. Here, at the lower extent of the District of Cascas, they form the Ochape River which leaves the highlands behind as it makes its way toward the coast and joins even larger systems. Agriculture of the sub-basin’s river valleys includes rice, alfalfa, tomatoes, fruits, and well-renowned viticulture around the town. This basin was selected as the study area due to its involvement in projects done by Water for People, a non-profit organization that has been working in the district since 2008.

Hydrologic models theoretically portray the hydrologic cycle using specific inputs and forced parameters. With the rise of Geographic Information Systems (GIS), the methodologies used to organize input parameters and other geospatial data within hydrologic models have been improved, thus facilitating the diversity of modeling strategies and multiplicity of hydrologic models. At the most basic level, these models can be assessed as either deterministic or stochastic (Vieux, 2003). Here, we are interested in deterministic modeling, which puts forward representations of real-world processes that often include surface runoff, channel flow, and inundation to name a few.

‘Distribution’ within the concept of a distributed hydrologic model refers to the real world spatial variability of the land surface and atmosphere, which exerts control over local hydrological patterning. The bounty of data from Earth observations has made this distributed concept possible.

As described by Vieux & Associates in 2003 (see references), distributed hydrologic modeling is best characterized by:

* Division of the watershed into grid cells
* Connection of the cells to form a drainage network
* Use of physics to predict runoff rates and volume
* Use of GIS data to describe terrestrial features
* Inputs from radar, satellite, and rain gauges etc.

The Coupled Routing Excess Storage (CREST) distributed hydrological model is a strategy that was jointly conceived by the University of Oklahoma and NASA SERVIR. Using inputs of rainfall, digital elevation models (DEM), flow direction and accumulation maps, and potential evapotranspiration (PET) data, the model generates a water extent map and calculates flow through cell-to-cell routing of surface water. The runoff generation component and routing scheme are coupled, providing realistic interactions between atmospheric, land surface, and subsurface water (Wang, et al., 2011).

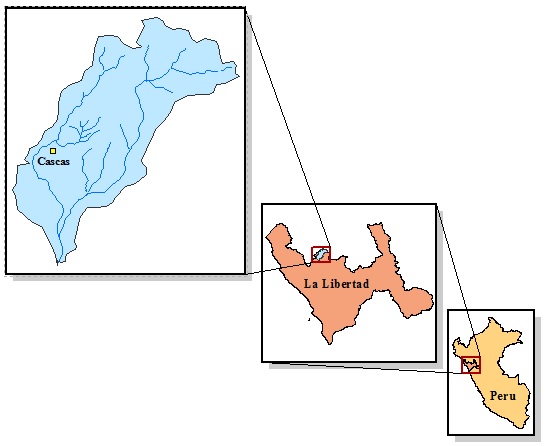
**Project Objectives**

The Wise County DEVELOP team reviewed the performance of CREST 2.0 hydrological model using the Ochape sub-basin as a subject area. The analysis has been conducted using remotely sensed input data from NASA Earth observations (EO). Our study period spanned 2007 to 2014 with 3 major floods identified during 2008, 2013 and 2014. The objectives of the Wise DEVELOP team were to produce outputs in order to understand the predictive capability of the CREST 2.0 model for this region of Peru.

The national application areas covered were Disasters, Water Resources, and Ecological Forecasting. This project addressed the disaster application area by using hydrologic modelling to simulate flood risks. This ties into the water resources application area through the use of modelling in this project, which contributed to an enhanced understanding of the factors controlling surface water inundation. Lastly, the results of this project will provide support for our partner organization to be able to forecast and model discharge based on historical rainfall episodes that should provide insight into future scenarios.

**Study Area**

Our study area was the Ochape Sub-Basin located in the District of Cascas, Gran [Chimú](https://en.wikipedia.org/wiki/Gran_Chim%C3%BA_Province) Province. This lies within the region of La Libertad, Peru, represented by *Figure 1*.



**Figure 1.** This image relates the study area to the region and country in which it is located. The Ochape Sub-Basin (top left) is found in the northern area of La Libertad, Peru.

**Project Partners**

Water for People is a non-profit organization currently working with local Peruvian governments to enhance water resource management systems in the Cascas and Asuncion districts. DEVELOP teams from the fall of 2014 and spring of 2015 helped develop tools and methodologies for these water management efforts. End-products from this term will help Water for People mitigate the risks associated with flooding within their region of operation. The term’s deliverables, along with those of the previous terms, will help Water for People provide complete water security to people within Peru.

Instituto Nacional de Defensa Civil Peru (INDECI) is directly responsible for disaster management in Peru. Partners from Water for People are currently in contact with INDECI and Consejo de Cuenca. End results can be used to produce flood inundation maps, as well as aid project partners in future decision making and flood prediction.

# III. Methodology

**Data Acquisition**

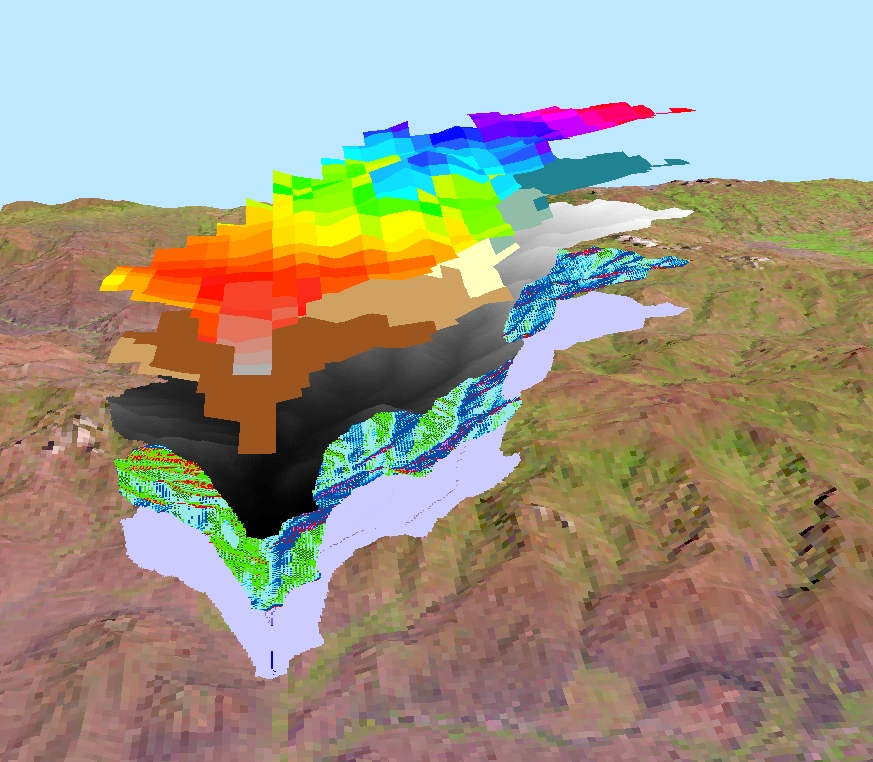
A Digital Elevation Model (DEM) was required in order to have a precise representation of surface terrain. All DEM data used for the study area were downloaded via the USGS HydroSHEDS site at a resolution of 90 meters. Due to the large scale of the study area, the DEM was resampled to 30 meters using the Resampling Tool in ArcGIS. CREST required alterations of the DEM by manipulation of the data to represent flow direction and flow accumulation. The flow direction (FDR) and flow accumulation (FAC) maps are discussed more below.

Precipitation data is another necessary input for calibrating the CREST model. The model utilized average rainfall data for the study area during flood prone months of the year. Rainfall data were acquired by NASA’s Tropical Rainfall Measuring Mission (TRMM), which ceased data collection in the spring of 2015 and has been replaced by Global Precipitation Measurement (GPM).

Potential Evapotranspiration (PET) data was required for the CREST model. These data simulate evaporation rates given a specific amount of water. The interpretation of PET data is important for CREST model simulation, as it dictates how much water is available for the cell-to-cell routing scheme.

**Data Processing**

The DEM resolution was upgraded to 30 meter resolution in order to better gauge the large-scale study area. This was done using the Resampling tool in ArcMap. The Fill function in ArcMap was then used on this resampled DEM to correct any missing data with a built-in algorithm. Following this, creation of the Flow Direction Map (FDR) and Flow Accumulation Map (FAC) were produced as outlined in the 2012 Upper Missouri Rivers Technical Paper Appendix A (Skym, et al., 2012). The FDR is a raster dataset showing the direction of flow from each cell to its steepest counterpart. The FDR is required as an input for determining water routing patterns. This sets the stage for the creation of the FAC, which tracks the accumulation of flow to each cell.

***Figure 2:*** *Data layer inputs for the study area displayed in ArcScene.**From top to bottom: Rainfall, PET, DEM, Flow Direction, Flow Accumulation*

The CREST model required datasets for the study area encompassing precipitation data, DEM, FDR, FAC and potential evapotranspiration (PET) data. All data were set to World Geodetic System 1984 reference system while the map units were set to decimal degrees as required by the CREST model. The inputs, parameters, run style, and various other model attributes are specified in the control file. The model will output discharge data based off of the initial conditions that have been set. This model was not calibrated due to lack of in-situ gauge data.

# IV. Results & Discussion

The generation of results is ongoing. CREST v2.1.3 (MATLAB), which fixed some problems of outputting the grid variables amongst other issues, was only released in mid-July of 2015. CREST v2.1.3 is actually code under development for CREST v3.0 (MATLAB) which is to be released toward the end of 2015.

However, the decision was made in consultation with NASA SERVIR to switch to the FORTRAN processing platform rather than continuing to use the MATLAB platform. This was done for two reasons. First, the MATLAB platform is not accessible to our partner organization at this time. Second, we were provided with more direct help in setting up the project folder in FORTRAN rather than with the MATLAB version.

# V. Conclusions

The predictive ability of CREST v2.1.3 is undetermined. Dialogue between our node, NASA SERVIR, and Water for People will continue to the point of substantial completion.

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