Modeling Storm Water at Ambos Nogales

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April 28, 2016
Ambos Nogales

- The Ambos Nogales watershed covers 235 square kilometers with just under half its area in Mexico.

- The Nogales Wash is a nested tributary within the Santa Cruz Watershed drainage basin.

- The watershed as a whole is considered a potential source of contamination to the Nogales Wash and Santa Cruz River.
Issues

Lack of appropriate (i.) urban planning, (ii.) communication, & (iii.) stormwater control threatens quality of life, livelihoods, and lives!

Photos of Ambos Nogales, 2008 (top), and 1908 (bottom) illustrating urban development (Alberto Suarez Barnett private collection, http://www.municipiodenogales.org/)
Issues

Normal rainfall has the potential of realizing abnormal runoff that augments:

I. loss of life and property through flooding
II. soil loss and watershed-capacity for revegetation
III. nonpoint-source pollution of shared drainages, (sediment, solid waste)
IV. inflow and infiltration (I&I) into shared sewers
   a. scour of sewer lines, shortening design life and return on investment
   b. lost sewer-conveyance capacity
   c. sanitary sewer "overflows" (SSOs) containing microbial/industrial contaminants
   d. operational challenges for wastewater treatment plants
V. wear and tear on upstream infrastructure:
   a. roads and sewer lines flooded, clogged, destroyed, washed downstream
VI. wear-and-tear on downstream infrastructure:
   a. concrete debris threatens sewer lines crossing the wash
   b. erosion of concrete lining and natural banks of the Nogales Wash
   c. ... and by association, the International Outfall Interceptor (IOI)

This puts public health and the environment at risk.
Sources of Sediment

Annual Soil Loss Map for the Ambos Nogales watershed (t/a/y).

The estimated potential soil lose due to erosion is 64,149 tons per year

Legend

Annual Soil Loss

- 0 - 1.2936
- 1.2937 - 3.5573
- 3.5574 - 5.9827
- 5.9828 - 9.7018
- 9.7019 - 14.7143
- 14.7144 - 20.5354
- 20.5355 - 27.4883
- 27.4884 - 41.3942

Sources of Sediment

- High-risk or “Hot-Spot” Areas
- The soil losses from east-central Nogales, Sonora, are more critical than other areas

Sinks of Sediment

- SEDMOD calculates an SDR to be used in determining the amount of eroded material that would be available for transport and deposition along hillslopes and streams (Fraser 1999).

- This is multiplied by the results of the USLE to derive:
  - Annual sediment delivery to streams was estimated at 2,955 tons.
  - The annual proportion of pollutants expected to actually reach the watershed outlet is estimated at 609 tons.

Urban Growth

Urban Growth

- A cellular automaton model
- Urban growth can be predicted on the basis of a variety of growth rules, the pattern of urban cells, and the interaction of urban cells and their surroundings (Clarke and Gaydos, 1998; USGS, 2003)
- Urban area classifications for this watershed were used as input to the SLEUTH (Slope, Landuse, Excluded, Urban, Transportation, Hillshade) urban growth model to predict land use changes to the year 2030.

SLEUTH Urban Growth Model

Predicted 27-Years Growth to 2030

<table>
<thead>
<tr>
<th>Probability Range</th>
<th>Color</th>
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<tr>
<td>0-50%</td>
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<tr>
<td>50-60%</td>
<td>Yellow</td>
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<tr>
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<td>90-95%</td>
<td>Red</td>
</tr>
<tr>
<td>95-100%</td>
<td>Red</td>
</tr>
</tbody>
</table>

Erosion Model + Urban Growth

• Predicted urban development will increase erosion potential.

Urban Growth + Erosion = More Sediment Yield

Predicted surface erosion and sediment yield change in the Ambos Nogales Watershed

<table>
<thead>
<tr>
<th>Total Potential Erosion</th>
<th>Net Sediment Delivery</th>
<th>Delivery to Streams</th>
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</thead>
<tbody>
<tr>
<td>2030</td>
<td>74,871</td>
<td>18,898</td>
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<tr>
<td>2002</td>
<td>64,149</td>
<td>16,290</td>
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</table>

Alternative Futures...

- Despite the negative environmental impacts due to urban growth predictions, the population in this watershed is expected to continue to grow.
- Sustainable development is an option we can consider to accommodate the influx of humans while preserving natural resources and quality of life.
- Scenarios were developed to embrace this and identify areas of land suitable for development as well as simulate erosion-control measures...

If Urban development occurs in sustainable development zone areas.

→ **And** “Hot-spot” areas get excluded from growth and are planted with native grasses to reach at least an 80% cover of the surface.

→ **Then**, the erosion will **decrease** in 2030 11,123 t/y from 2002!!

Sustainable Development
• Using models USLE, SEDMOD, and SLEUTH developed approach for sustainable urban development **increases air & water quality** in the future:

  – plant native grasses in areas identified as high-risk “hot spots”
  – promote development in low-risk zones

City of Green Creeks

USGS contracted by Arizona State University (Dr. Francisco Lara-Valencia) to help with EPA Border 2012 grant to assist City of Nogales, Sonora with first “City Plan”...

City of Green Creeks

Proposes the creation of a network of 35 potential locations for a city-wide green network. **Green infrastructure** strategies provide the city with environmentally responsible planning and design alternatives that can

i. reduce runoff volume,

ii. protect water resources,

iii. preserve riparian habitats, and

iv. offer the additional community benefit of creating more interesting places to live, work, and play!

Example:
Colosio Green Corridor

The hillside has been occupied by low-income, self-produced housing lacking the most basic services, like water, sewers, and open space.

City of Green Creeks

“Ambos Nogales Special Flood Damage Reduction Study - Nogales, Sonora Mexico” (January, 2005)

IBWC & ACE hired Tetra Tech to develop recommendations:

- Flood proofing structures
- Relocation of structures and infrastructure
- Flood warning
- Floodplain management
- Channel modification/enlargement
- Stormwater inlet improvements
- Stormwater detention

Rainfall-runoff Model

- USGS, USDA-ARS, & UA used the Kinematic Runoff and Erosion Model (KINEROS2) to identify flood-prone areas in 2009.

“AGWA is designed to evaluate relative change and can only provide qualitative estimates of runoff and erosion. It cannot provide reliable quantitative estimates of runoff and erosion without careful calibration. It is also subject to the assumptions and limitations of its component models, and should always be applied with these in mind.”

A “Perfect Storm”

- Variations of homogeneous design storms were dictated by the NOAA Atlas 14 for Arizona.
- Precipitation depth (inches) was extracted at site: Nogales, Arizona (02-5921): Latitude 31.35N and Longitude 110.9167W (3907 ft) and fit into the model.
- Rainfall events include:
  - a 10-year 1-h (1.82 in.)
  - a 25-year 6-h (2.93 in.)
  - a 100-year 6-h (3.76 in.)
**Generate scenarios of varying climatic events**

- Extreme hydrologic events are described as having an ‘X’-year recurrence interval.

- In order to simulate potential precipitation events, values from the NOAA 14 Atlas for Nogales, Arizona were modeled.

- Caveat: When rainfall data are collected at a point within a stream basin, it is unlikely that this same amount of rainfall occurred uniformly throughout the entire basin.
Rainfall-runoff Model

- Locations for potential human intervention can be located by using quantiles to classify runoff into 3 classes of risk.

Ambos Nogales watershed runoff (mm) classified into three categories of runoff to identify areas of high, medium, and low risk.

IBWC-funded Research

- Model impacts of Detention Features:
  - including those identified as new construction by the City of Nogales, Sonora (8 shown)
  - and those to be rehabilitated by CONAGUA (4 shown)
Embankment dams identified for modeling

- Rock Gabion Dams constructed by City:
  - Capulines
  - Cuesta Blanca
  - Bellotas Fraccionamiento
  - Bellotas Maquiladoras
  - Chimeneas
  - Villa Sonora
- Earthen dams rehabilitated by CONAGUA:
  - Represo Chimeneas
  - Represo Villa Sonora
  - Represo Pirinola
  - Represo Unison II
- Earthen dams constructed by the City:
  - San Carlos Dique 1
  - San Carlos Dique 2
Chimeneas
**SECCIONES TRANSVERSALES**

![Graph showing cross-sections with elevation and volume data](image)

### Compactación

<table>
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<tr>
<th>ORDENADAS DE LA CURVA</th>
<th>CURVA</th>
<th>MASA</th>
<th>VOLÚMEN</th>
<th>CORTE</th>
<th>TERRAPLEN</th>
<th>CORTE</th>
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<tr>
<td>ESCALA VERTICAL</td>
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**PERFIL**

![Profile diagram](image)
LOCALIZACION
2D Area = 8851 m²
Volume = 24756 m³
Describe basins in 3-D terminology, using total volume, the total basin depth, top and bottom surface areas, and discharge structures.
Describe basins in 3-D terminology, using total volume, the total basin depth, top and bottom surface areas, and discharge structures.
Purpose: Diminish impacts of flooding and sedimentation on wastewater infrastructure with the goal of reducing the incidence of sanitary sewer overflows.

Flood control dams built using gabions in Nogales, Sonora.
Map courtesy of City of Nogales, Sonora.
Mapa cortesía de la Municipalidad de Nogales, Sonora.
Flood control dams built using gabions
Nogales, Sonora
Flood control dams built using gabions

Nogales, Sonora
<table>
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<tr>
<th>Channel Impacts</th>
<th>Cuesta Blanca</th>
<th>Capulines</th>
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<td>w/out feature</td>
<td>8,518,604</td>
<td>9,268,617</td>
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<tr>
<td>w/ feature</td>
<td>2,964,995</td>
<td>3,869,279</td>
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<tr>
<td>Difference</td>
<td>5,553,609</td>
<td>5,399,338</td>
</tr>
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Flood control dams built using gabions in Nogales, Sonora.
Emergency Response

• 2009—working with Chuck McHugh, AZ Dept of Emergency & Military Affairs (ADEMA) to help establish trigger points for flood reaction in the Nogales Wash with USACE, ADEQ, and the NWS... to reduce the impact of disaster on person and property.

• Floyd Gray (USGS) funded on DHS proposal with NOAA and UofA to develop an Early Warning Hazard System and needs help to identify best locations for gauges (precip. & water).

Norman, Laura M. (2010). Flash-Flood Forecasting at Ambos Nogales, In the Border Climate Summary, Climate Assessment for the Southwest (CLIMAS) program, University of Arizona, Tucson, Ariz., http://www.climas.arizona.edu/files/climas/pdfs/periodicals/BorderClimateSummary_Jun10.pdf (NEWSLETTER)
Nogales, Sonora

Nogales, Arizona
Current Flood Warning System
The NWS, UA, and USDA had developed and implemented a version of KINEROS2, adapted to flash flood prediction using radar precipitation product (K2/NWS) that displays graphs of both radar-derived rainfall and predicted runoff.

- 20 cooperative rainfall gauges to be purchased and installed in Nogales, Sonora and attached to Internet monitoring network for Arizona (Rainlog.org).
- This could be used to calibrate the K2 model for advanced flood warning
- Could help planning for future scenarios
- And also act as a demonstration to locate most advantageous sites for larger more extensive equipment (radar) that will provide emergency managers with the most reliable alert system...
**Community-based flood warning system**

- One effective way to mitigate flood risk is to provide a tool that allows the forecaster to effectively predict the timing and magnitude of peak flows in small watersheds.

- Incorporate real-time rainfall data input and compute volumes of runoff, peak flow, and watershed discharge rate.

- A runoff graph will show stage of flows and equivalent discharge rate in streams, and indicates the peak stage (discharge) and time of peak
Nogales, Sonora

• 20 cooperative rainfall gauges purchased and installed in Nogales, Sonora and attached to Internet monitoring network for Arizona (Rainlog.org).

• Needed help from colleagues in Nogales, Sonora
  – Input on storm distributions and site selection... Multiple gages are desirable since precipitation is highly variable during the monsoon season, when thunderstorms can produce heavy and localized rainfall.
  – Operations and maintenance:
    • installation, operation and maintenance of the gages
    • Tie to the internet, and possibility of setting thresholds for ER communication
Potential candidate locations recognized with the help of Commander Eduardo Canizales and Ing. Francisco Gastelum...
Rain Gages
Rain Gages

- The system in place and 100% operational
- Real-time data connections via satellite and via connection to the Arizona Statewide Flood Warning System through one of its existing repeaters located along the border.
- Additionally, the base station, located in Nogales, Sonora, provides local emergency operations personnel with complete off-grid, real-time data access.
- Plans to coordinate installation of high-visibility staff gauges at frequently flooded transportation corridors and crossings...
Workshops and Trainings

- On October 12, 2012, a training was held at the C4 Center ALERT Training, Nogales, Sonora.
- On April 17-18, 2013, a software demonstration and training workshop for an Emergency Flood Warning System being created for the city of Nogales, Sonora, Mexico at the Santa Cruz County Flood Control District office in Nogales, AZ.
- April 15, 2016 a training was held in Nogales, Ariz. on three aspects of the Nogales, Sonora ALERT System: (i.) ALERT System Overview, (ii.) Davis Web Data Setup, and (iii.) Equipment Training
Rain Gages

- Base Station
- 3 Weather Stations
- 1 Precip/Stream Station
- 1 Precipitation Station
Nogales Wash Stream gage

Installed by USGS/ADWR with a grant from Border 2012
Maintained by U.S. IBWC
The system began recording data on April 23, 2010
Arroyo Nogales

Baseflow = 2.5 – 3.5 cfs
(71 – 99 lps)
A State Emergency

Nogales braces for another night of flooding

By JB Miller and Manuel Coppel
Published Friday, July 30, 2010 5:06 PM CDT

Nogales, Arizona | Wednesday, August 11, 2010

Heavy rain runoff causes flooding in Nogales, AZ

By Jamar Younger | Arizona Daily Star | Posted: Friday, July 30, 2010 8:12 pm | Community

Heavy water flow in a Nogales, Ariz., wash destroyed three concrete panels and threatened to force the evacuations of some city residents.

The flooding affected the community of Chula Vista in the northern part of the city by with sandbags in case more damage occurred, said Flavio Gonzalez, utilities director.

The sandbags also will be used during repairs to the panels, which lime the sides, he said.

"During repairs, we will have to divert the flow of water," he said.

The flooding, which destroyed the panels on the west side of the wash, was a result of heavy rains in Sonora, Mexico, he said.

The wash flows from a storm-water tunnel that spans two sides of the international border, bringing storm water from Mexico.

The waters started to recede Friday evening, but officials were concerned about forecasts for more rain late Friday night and Saturday, he said.
July 31, 2010
A Real Storm: *Downstream*

“John Hays, Floodplain Coordinator for Santa Cruz County... said Tuesday’s deluge was a 10-year event, meaning it had a 10-percent chance of occurring in any given year. He said the last time a 10-year event occurred in Nogales was in 2008”...
USGS 09481000 NOGALES WASH AT NOGALES, AZ

Discharge, cubic feet per second

--- Provisional Data Subject to Revision ---

△ Median daily statistic (2 years) ★ Measured discharge

Discharge

http://waterdata.usgs.gov/az/nwis/uv?site_no=09481000
### Rain Gages

<table>
<thead>
<tr>
<th>Precip On</th>
<th>Milimeters (mm)</th>
<th>Inches (in.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>7/31/2010</td>
<td>1.524</td>
<td>0.06</td>
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<td>7/30/2010</td>
<td>52.07</td>
<td><strong>2.05</strong></td>
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<td>7/29/2010</td>
<td>17.78</td>
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<td>7/28/2010</td>
<td>7.62</td>
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<td>7/27/2010</td>
<td>13.208</td>
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<tr>
<td>7/22/2010</td>
<td>7.112</td>
<td>0.28</td>
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<td>7/20/2010</td>
<td>1.27</td>
<td>0.05</td>
</tr>
<tr>
<td>7/19/2010</td>
<td>24.384</td>
<td>0.96</td>
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</table>
The NWS, UA, and USDA have developed and implemented a version of KINEROS2, adapted to flash flood prediction using radar precipitation product (K2/NWS) that displays graphs of both radar-derived rainfall and predicted runoff.
Nogales Wash at Nogales Arizona

KINEROS2 Modeling Results

Michael Schaffner, NWS WRH
A collaborative partnership with NWS Tucson, USDA
Southwest Watershed Research Center, and the United States Geological Survey (USGS)

Image source: https://twitter.com/johnpatrickkvoa/status/641381356904148992
Calibrated with Stream Gage

2014 Monsoon Events | 2015 Monsoon Events

2014 Monsoon Peak Flow Events
- Observed (USGS)
- Operational Simulation (KINEROS2)

2015 Monsoon Peak Flow Events
- Observed (USGS)
- Operational Simulation (KINEROS2)

Working now to calibrate with Real-time Rainfall...

**Hopes to employ this summer monsoon season!**
Recommendations

1. Urban planning
   → Revegetation of Hot-Spots
   → City of Green Creeks
   → Consider stormwater regulations

2. Communication
   → Meetings, trainings, publications
   → Emergency Flood Warning System

3. Stormwater control
   → Detention Basins...

→ Effective Binational Stormwater Program
Recommendations

- Flood proofing structures
- Relocation of structures and infrastructure
- Flood warning
- Floodplain management
- Channel modification/enlargement
- Stormwater inlet improvements
- Stormwater detention

(from Tetra Tech, IBWC, ACE 2005)

→ Effective Binational Stormwater Program
Presentations


5. Norman, Laura, 2009-Apr-02, presentation at the National Technical Meeting, Arizona Department of Water Resources, Nogales, AZ, invited by Steven Lyell, Civil Engineer, International Boundary and Water Commission United States and Mexico, U.S. Section. (PRESENTED)

6. Norman, Laura, 2009-Feb-20, presentation at the *Southeast Arizona Health Education Center*, Nogales, AZ, invited by ose Rodriguez, Arizona Department of Environmental Quality. (PRESENTED)


Publications


