Evaluation of historic Columbia River floods with HEC-RAS

Haley Dillon and Charles Cannon

GEOG 593 – Digital Terrain Analysis

Fall 2010

Historic floods

Flood of 1894

Looking north from 1st Ave. to Stark

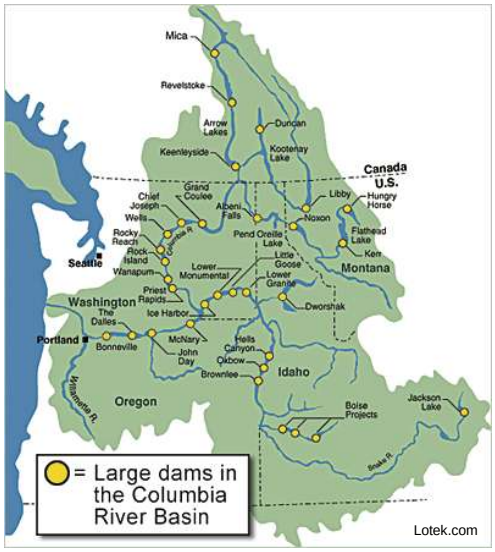
Flood of 1948

Aerial view of the city of Vanport

North Park Blocks looking north to Ankeny

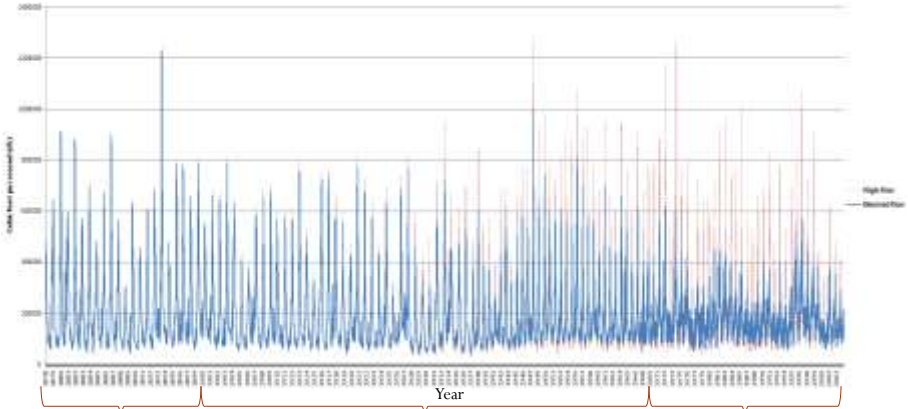
Railroad dike breach

Altered Hydrology



Altered hydrology

Flood profile from The Dalles gauge (Naik and Jay), 1878-



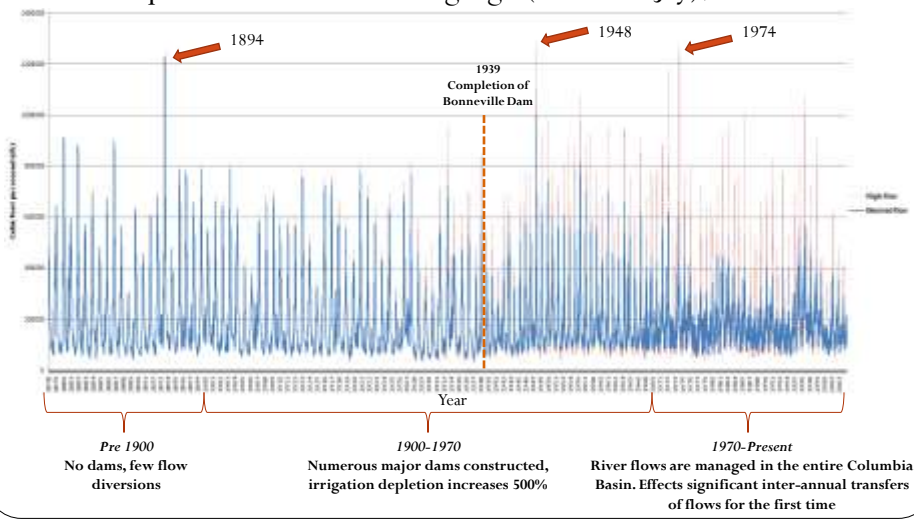
Pre 1900
No dams, few flow diversions

1900-1970
Numerous major dams constructed, irrigation depletion increases 500%

1970-Present
River flows are managed in the entire Columbia Basin. Effects significant inter-annual transfers of flows for the first time.

Altered hydrology

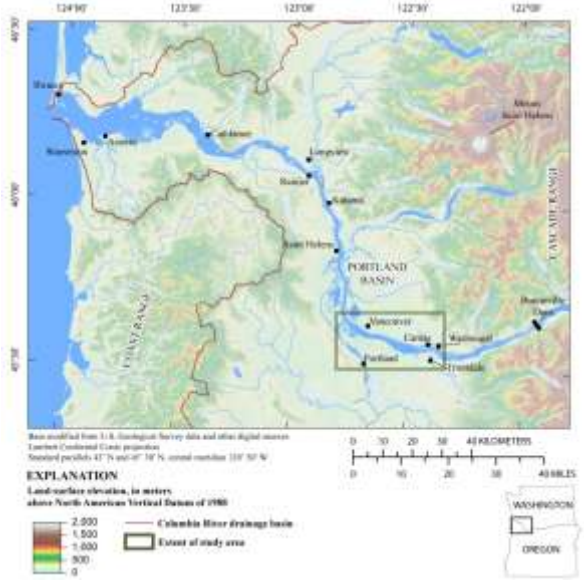
Flood profile from The Dalles gauge (Naik and Jay), 1878-2004



Introduction

- Explanation of floodplain evolution
  - Natural floodplains are dynamic systems
  - The Columbia River flow regime has been severely altered by flow regulation, water withdrawals and probably climate change
- Habitat
  - The dynamic nature of floodplains enhances habitat through reworking of landforms during seasonal floods
  - Isolation from seasonal flows impedes landform evolution and thus decreases ecosystem function
- Safety/Economics
  - Thousands of people live and work within the Columbia River floodplain
- In this project we investigate the effects of flow regime and flood control on the area of inundated land for historic flood scenarios

Study Area



Methods

HEC-RAS and HEC GeoRAS

(Hydraulic Engineering Centers River Analysis system)

- One dimensional hydraulic modeling
- HEC-RAS – developed by the US Army Corps of Engineers
- HEC-GeoRAS – allows for preparation of data for input into HEC-RAS
- Basics HEC-RAS
  - Required data – only required data is terrain data.

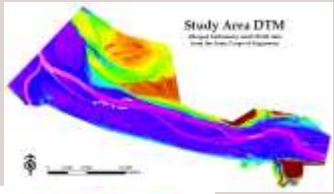
    Land use data is optional.

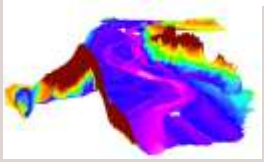
Required Inputs	Optional Inputs
•**Stream centerline** •**Flow path centerline** •**3D Cross sections**	•**Banks** •Bridges & culverts •Ineffective flow areas •Block obstructions •Land use •**Levee Alignment** •Levee points •Inline structures •Lateral structures •Storage areas •Storage area connections

Data and Preprocessing

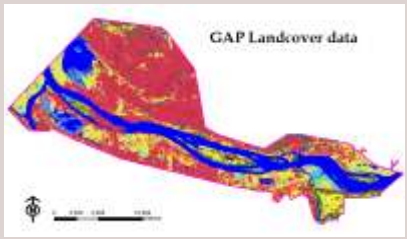
Source dataset

DTM	GAP Landcover
•Data Source: Army Corps of Engineers •Merge of 2010 LiDAR and Bathymetry data delivered as a raster DTM. 1 meter resolution. •Disclaimer: data is preliminary and still in post-processing stages, scheduled to be released at a later date	•Data Source: National Landcover Gap Analysis Project, 2010 •Classified from remote sensing (LandSat) and elevation data





3D view of the floodplain looking downstream from the Columbia Gorge

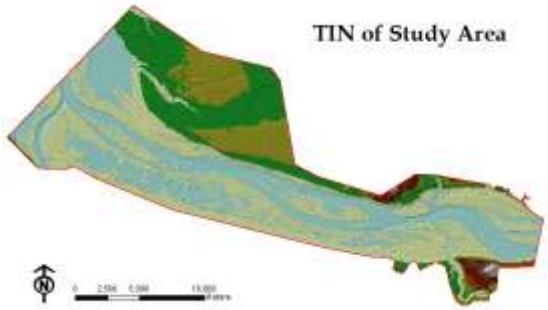


Pre-processing

- TIN (using ARC GIS)
- Geometry data (using HEC-GeoRAS)
  - Flow paths
  - Banks
  - 3D cross sections
  - Levee alignment table
  - Manning's N table

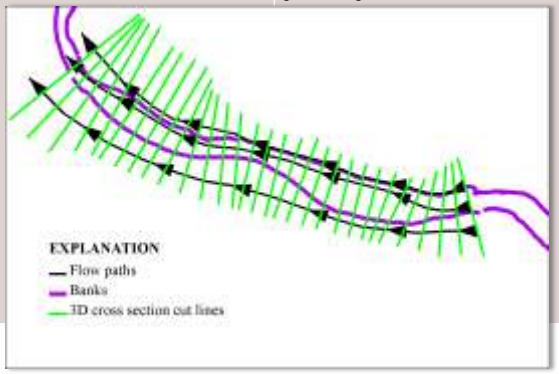
TIN

- Creation:
  - Using DTM dataset
    - Tolerance of 2 m
  - Holes in original DTM were filled



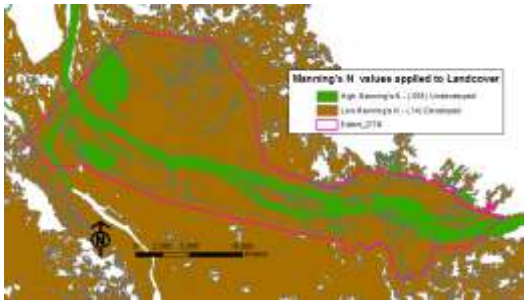
Creating Geometry Data

Flow Paths	Banks	3D Cross Sections
•Center line •Left and right of channel	•Edge of channel •Transition from channelized to overbank flow •Generally drawn as inflection point in profile curvature	•Perpendicular to centerline •Direction is from left to right •Adjustment of centerline to avoid overlap •Must span entire floodplain •Attributes are ✓River/reach ✓Stationing (distance to downstream end of centerline) ✓Bank stations () ✓Downstream reach lengths •2D to 3D



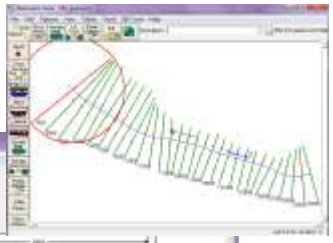
Manning's-n

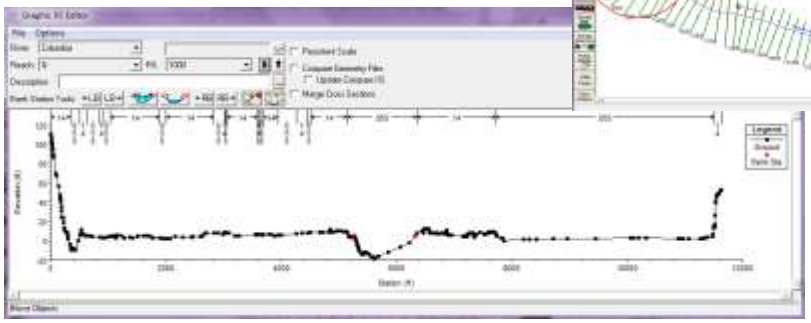
- Roughness coefficient
- Applied to land-cover dataset
- Limit of 20 per cross section in HEC-RAS
- Level 1 still too many at most cross sections
- Split into 2 groups split at 0.07
- Average assigned each group
- For three remaining cross sections with excess n-values, values were removed from right bank (Washington side)



Importing Geometry Data into HEC-RAS

- Export to HEC-RAS format
- HEC-RAS - Edit geometry: Cross sections are limited to 500 points – 3 cross sections were filtered to remove excess points.
- Can use editor to edit bank stations, Manning's N, etc…





Flow data and boundary conditions

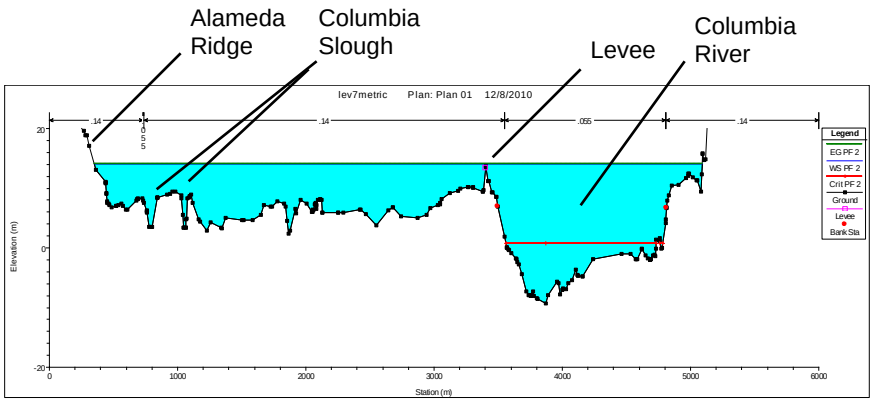
- Steady flow
- Flow conditions
  - We used discharge at The Dalles gage for observed and virgin flows (estimated by Naik and Jay, 2005)
  - We developed a stage-discharge relationship for model boundary conditions which are the stage at Washougal and the Willamette River.
- Profiles used in analysis:

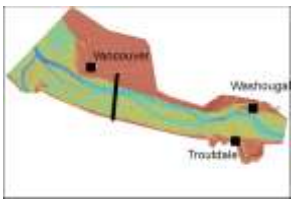
Flood Scenario	Mean Daily Discharge at The Dalles ($m^3 s^{-1}$)	Stage at Washougal (m, NAVD 88)	Stage at Willamette River Confluence (m, NAVD 88)
June 6, 1894 - Observed	34,830	14.0	11.6
May 30, 1948 - Observed	26,732	12.2	10.1
May 30, 1948 - Virgin	36,002	14.2	11.8
June 19, 1974 - Observed	16,084	10.0	8.0
June 19, 1974 - Virgin	35,710	14.2	11.8

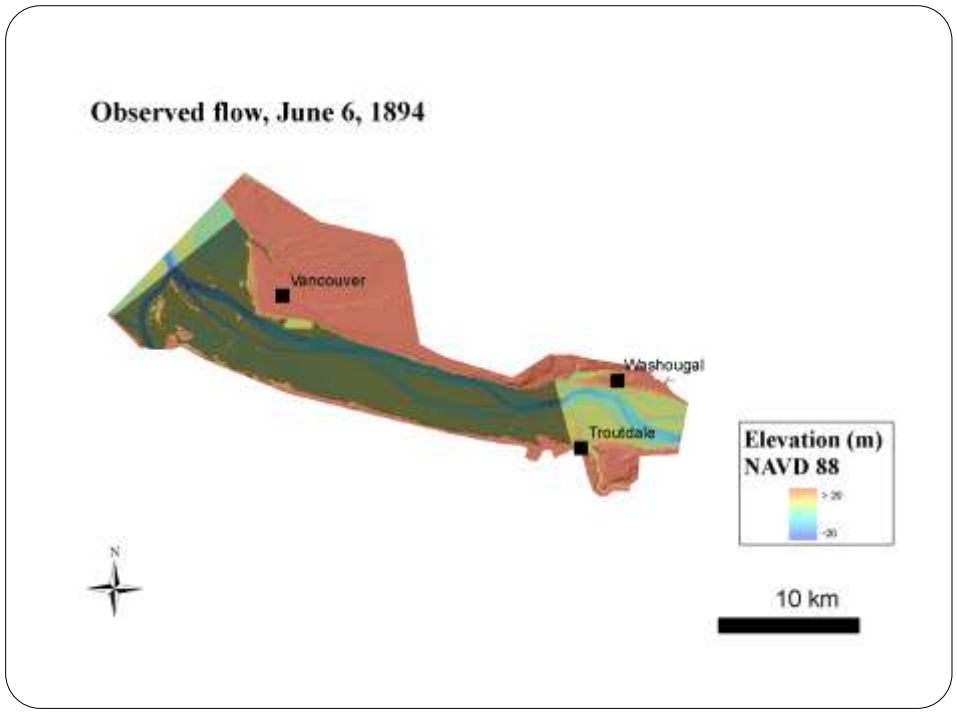
Post-Processing

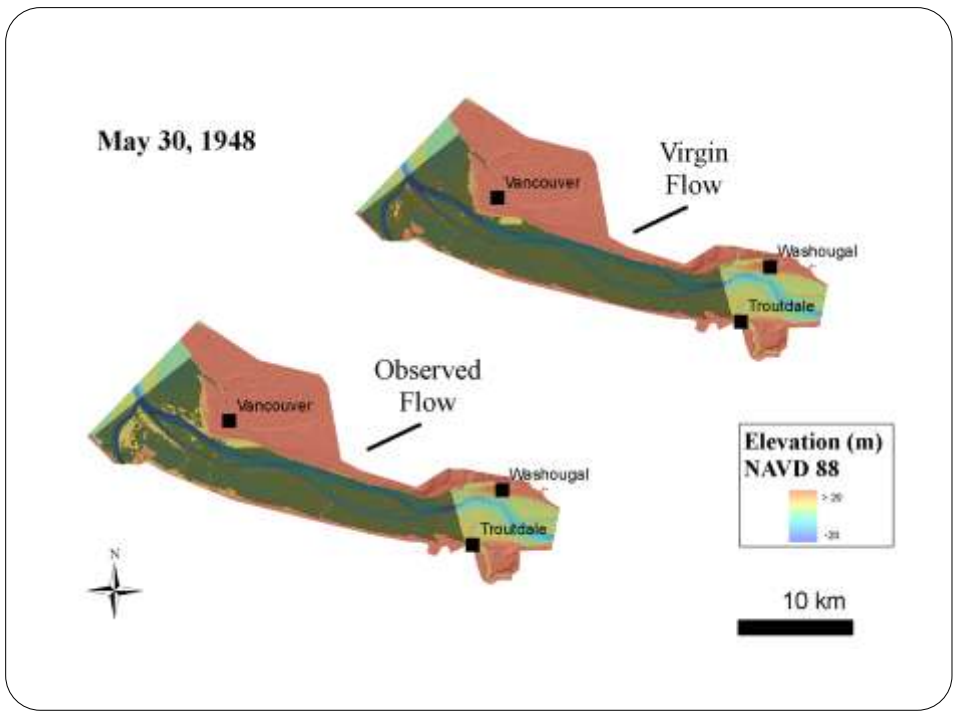
- Export the water surface profile from HEC-RAS to HEC-GeoRAS
- Convert the surface profile to a raster
- Subtract the DTM from the water surface to get inundation water depth
- The extent of the depth is the inundation area which is converted to a polygon

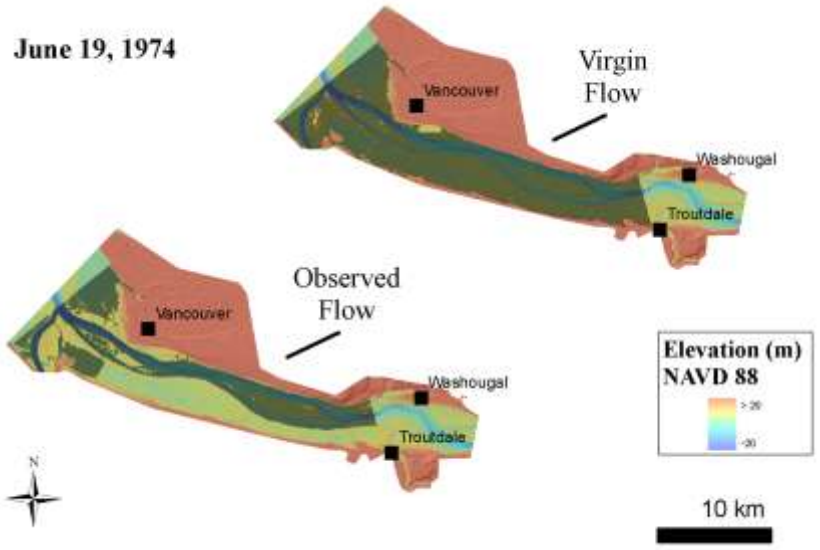
Results


Alameda Ridge
Columbia Slough
Levee
Columbia River
lev7metric Plan: Plan 01 12/8/2010
Legend
EG PF 2
WS PF 2
Crit PF 2
Ground
Levee
Bank Sta
Elevation (m)
Station (m)


Vancouver
Washougal
Troutdale


Observed flow, June 6, 1894
Vancouver
Washougal
Troutdale
Elevation (m)
NAVD 88
N
10 km


May 30, 1948
Virgin
Flow
Vancouver
Washougal
Troutdale
Observed
Flow
Vancouver
Washougal
Troutdale
Elevation (m)
NAVD 88
N
10 km



Results Summary

Flood Scenario	Mean Daily Discharge at The Dalles ($m^3 s^{-1}$)	Stage at Washougal (m, NAVD 88)	Stage at Willamette River Confluence (m, NAVD 88)	Area (km^2)
June 6, 1894 - Observed	34,830	14.0	11.6	155.1849
May 30, 1948 - Observed	26,732	12.2	10.1	144.9921
May 30, 1948 - Virgin	36,002	14.2	11.8	156.1186
June 19, 1974 - Observed	16,084	10.0	8.0	81.7423
June 19, 1974 - Virgin	35,710	14.2	11.8	156.1081

Conclusions

- Virgin flows for each modeled year were very similar (within 1 square kilometer)
- By the 1948 flood, large dams were being constructed system wide and irrigation depletion was increasing rapidly. A slight decrease in area (11 square kilometers) is observed and may be attributable to these factors.
- The virgin 1974 flow was discovered while processing data from The Dalles. Our HEC-GeoRAS analysis shows that if there were no alterations of the hydrology at this point in time, there could have been a flood as devastating as the largest flood on record.
- Our modeling supports the hypothesis that the modified flow regime has significantly reduced the potential for the historic Columbia River floodplain to be inundated.

Limitations / future improvements

- Create a better Manning's N coverage
- Use a published dataset with a more complete coverage
- Add effect of tributaries
- Extend to other reaches
- Spatial resolution of modeling results
- Ground truthing

References

- Ayres Associates, 2007, Summary of Work Performed by Ayres Associates in Support of URS Storm Surge Modeling for FEMA Region 4: retrieved online November 26, 2010 from http://www.fema.gov/library/file?type=publishedFile&file=summary_of_work_performed_in_support_of_storm_surge_modeling.pdf&fileid=7198e050-e9aa-11de-ae85-001cc456982e
- Naik, P.K., and D.A. Jay, 2005, Estimation of Columbia River virgin flow: 1879 to 1928: Hydrological Processes, v. 19, pp. 1807-1824. DOI: 10.1002/hyp.5636.
- U.S. Army Corps of Engineers, 1968, Flood Profiles, Columbia River and tributaries, Washington and Oregon, below Bonneville Dam (revised): U.S. Army Engineers District, Portland, drawing CL-03-116.
- U.S. Army Corps of Engineers, 2009, HEC–GeoRAS GIS Tools for support of HEC-RAS using ArcGIS®l, version 4.2: Davis, California, U.S. Army Corps of Engineers, Institute for Water Resources, Hydrologic Engineering Center.
- U.S. Army Corps of Engineers, 2010, HEC–RAS River Analysis System, user's manual, version 4.1: Davis, California, U.S. Army Corps of Engineers, Institute for Water Resources, Hydrologic Engineering Center.
- Lotek.com. Retrieved online December 7, 2010 from: http://www.lotek.com/sustaining-the-pacific-northwest-fishery.htm