THESIS

TOWARD UNDERSTANDING CHANGES IN LARGE-SCALE FLOODPLAIN CONNECTIVITY CAUSED BY LEVEES

Submitted by

Kara Scheel

Department of Civil Engineering

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Master's Committee:

Advisor: Ryan Morrison

Jeffrey Niemann
Sara Rathburn

ABSTRACT

TOWARD UNDERSTANDING CHANGES IN LARGE-SCALE FLOODPLAIN CONNECTIVITY CAUSED BY LEVEES

The widespread construction of levees has reduced river-floodplain connectivity and harmed associated fluvial processes in many river systems. Despite the recognition that levees can alter floodplain connectivity, few studies have examined the role of levees in reducing floodplain areas at large watershed scales. In this paper we explore the application of a hydrogeomorphic floodplain mapping approach in the Wabash basin, U.S. to assess floodplain loss in levee-protected areas. We evaluate 10-m and 30-m topographic resolutions and spatially examine the influence of levees on floodplain area in relation to river network attributes within discrete HUC-10 sub-basins. Generally, we found that the floodplains mapped in levee-protected areas were influenced by topographic resolution, stream order, and elevation details of levees found in topography datasets. We show that, when compared to Federal Emergency Management Agency maps, our approach under predicts floodplain area when using 10-m resolution topography data but only slightly over predicts when using 30-m resolution topography. After removing details of levees from topography datasets, we found that basin-aggregate results changed little compared to topography datasets that contain levees, though larger floodplain areas were produced in some regions where levees were removed. This work contributes to a growing research emphasis on linking water resource management to river-floodplain connectivity.

ACKNOWLEDGEMENTS

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INTRODUCTION

Floodplains are important landscape features that provide numerous environmental and human services, including riparian habitat, pollutant removal, energy recycling, flood attenuation, and groundwater recharge (Amoros and Bornette, 2002; Horner *et al.*, 2010; Junk *et al.*, 1989; Tockner and Stanford, 2002). River-Floodplain connectivity, is a key component to these processes as it allows for the water mediated exchange of sediment, organisms, and energy between the river channels and floodplains (Covino, 2017; Harvey and Gooseff, 2015; Pringle, 2003). As development within floodplains has increased, flood management activities have significantly transformed river-floodplain connectivity dynamics by disrupting the timing and extent of floodplain inundation, likely leading to floodplain habitat loss and decline of natural functions of the riparian system (e.g., Tockner *et al.*, 1999). It remains a challenge to maintain ecosystem functions while simultaneously protecting human development. An important step in addressing this challenge is identifying the extent of floodplain connectivity loss caused by various water management activities or infrastructures. Determining the extent and degree of floodplain connectivity loss caused by levees can have important implications for riverine management and restoration. Therefore, in this study we aim to better understand the relationship between levees and hydrogeomorphic floodplain delineations.

Loss of floodplain connectivity refers to the interruption of the transfer of water between the fluvial ecosystem and surface or subsurface waters of the river channel (Tockner et al., 1999). This interruption is mainly due to human-driven hydrology, landscape, and river geometry modifications (e.g. levees, weirs, storage areas, split channels). Hydrologic connectivity can occur on four dimensions: longitudinal, lateral, vertical, and temporal (Pringle, 2003; Ward, 1989). Longitudinal connectivity describes changes along the rivers primary axis of flow. Vertical connectivity includes the exchanges between the surface and groundwater via infiltration into the alluvial floodplain while temporal refers to changes occurring on both annual (hydrological phases, unpredictable fluctuation) and historical scales (such as wet and dry periods). Lateral connectivity, the major focus of this paper, refers to the permanent and episodic link between the main course of the river and various features lying in the alluvial floodplain. The degree to which this connection exists is a time-dependent phenomenon (Tockner et al., 1999) that has a strong correlation to seasonal precipitation patterns. The extent of the connection depends on the hydrologic condition within the river and the river stage exceeding bankfull elevations.

Common floodplain mapping approaches use one- or two-dimensional hydraulic computer models to estimate water elevations, which are then compared to the elevations of surrounding topography to estimate flood inundation areas. Flood Insurance Rate Maps (FIRMs), developed by the Federal Emergency Management Agency (FEMA) under the National Flood Insurance Program, are the most widely used flood inundation maps in the United States (U.S.). FIRMs show the inundation area produced by a 100-year discharge and are the foremost hydraulic resource used for developmental policy in the U.S. (Burby, 2001). Because the primary intent of FIRMs is to inform policy makers and developmental planners of flooding risk, they are limited in their usefulness in identifying management impacts to floodplain connectivity. Loss of floodplain connectivity occurs when the transfer of water between the fluvial ecosystem and surface or subsurface waters of the river channel is interrupted (Tockner *et al.*, 1999). This interruption is mainly due to human-driven hydrology, landscape, and river geometry modifications (e.g., levees, weirs, storage areas, split channels).

Two particular attributes of FIRMs—and hydraulic models in general—create challenges for assessing floodplain connectivity, especially at larger scales. First, hydraulic modeling can be data and computationally intensive (Jafarzadegan and Merwade, 2017). Using hydraulic modeling to characterize floodplain connectivity at large watershed scales, which is important for many hydrologic and ecological processes (Opperman *et al.*, 2010), becomes infeasible. Second, inundation areas identified in FIRMs are the hydraulic products of human development of the floodplain, and therefore depict the *altered* floodplain area rather than the floodplain landscapes created by hydrogeomorphic processes within a watershed. In levee-protected areas hydraulic models do not estimate floodplain areas unless overtopping of the levees occur. Therefore, it is difficult to assess changes in fluvial connectivity using national flood datasets, such as FEMA FIRMs, and evaluate the implications for floodplain ecological resources.

Numerous hydrogeomorphic methods have been developed to circumvent the limitations of hydraulic floodplain delineation techniques. Hydrogeomorphic mapping is based on the assumption that Digital Elevation Models (DEMs) contain information about landform morphology (such as slope and elevation changes) that define fluvial corridors. Mapping methods have been developed by Gallant and Dowling (2003), McGlynn and Seibert (2003), Dodov and Foufoula-Georgiou (2006), Nardi *et al.* (2006), and Fullom *et al.*¸(2016). More recently, studies have incorporated geomorphic classifications (Manfreda *et al.*, 2008, 2014; Samela *et al.*, 2017) and soil classifications (Sangwan and Merwade, 2015) to perform large-scale floodplain mapping. A benefit of these approaches is that floodplain delineation results are based on topographic or soil characteristics (Jafarzadegan and Merwade, 2017; Nardi *et al.*, 2013; Sangwan and Merwade, 2015) rather than hydraulic computations. Additionally, hydrogeomorphic mapping is time and cost effective in comparison to hydraulic mapping. This provides an opportunity to use hydrogeomorphic modeling to delineate floodplain landscapes across large regions and identify areas where hydraulically-derived inundation boundaries and hydrogeomorphic boundaries may differ due to floodplain modifications.

The construction of levees is a topographic modification that can control the extent of flooding by eliminating areas that were historically connected to rivers during overbank discharges. The elimination of floodplain area resulting from levee construction can have ecological implications, such as the disruption of lateral fluxes of sediment, nutrients, and organisms to sustain aquatic habitat and biotic productivity along rivers (Junk *et al.*, 1989). Levee construction in the U.S. has been widespread, yet it is difficult to quantify the overall extent of levee construction because a comprehensive database does not exist (Wohl *et al.*, 2017). The U.S. Army Corps of Engineers (USACE) National Levee Database (NLD) is the single best source of geospatial levee data in the U.S. (http://nld.usace.army.mil), although it primarily includes levees recognized by the USACE as providing protection against low-frequency, high risk flood events, such as the 100-year event. Despite the recognition that levees can eliminate floodplain areas that would otherwise be hydrologically connected to an adjacent river (for instance, FEMA removes areas protected by USACE levees from flood-hazard FIRMs), few studies have explored the role of levees in reducing floodplain areas, especially the cumulative impacts at large watershed scales. Examining the hydrologic effects of levees at a reach scale, Remo *et al.* (2009) demonstrated that levees reduced flooding inundation by 72-84% in select sections of the Mississippi River, U.S. Conversely, Guida *et al.* (2015) showed that the hypothetical removal of levees along the Lower Tisza River in Hungary would reconnect nearly 95% of historical floodplain wetlands.

The detailed hydraulic models used in the aforementioned studies become impractical as the size of modeling domains increase (Jafarzadegan and Merwade, 2017), but hydrogeomorphic floodplain mapping techniques may help us understand the spatial distribution and variability of floodplain changes caused by levees at larger watershed scales.

Thus, our research objectives were to 1) assess the performance of a hydrogeomorphic floodplain mapping technique in levee-protected areas, and 2) determine the ability of the hydrogeomorphic technique to assess changes in river-floodplain connectivity caused by levees. Our approach builds off the hydrogeomorphic floodplain model developed by Nardi *et al.* (2006, 2013), which uses a hydrologic scaling principle (Leopold and Maddock Jr, 1953) to quickly estimate flooding depths across a range of Strahler stream orders (Strahler, 1952) in ungaged river networks. To evaluate our approach, we focused on a 103,000 km^2 portion of the Wabash Basin, U.S. We used the 100-year hydrologic return period to delineate floodplain boundaries because it allowed us to compare model outputs to FEMA flood-hazard maps that use the same recurrence interval. In addition, levees identified in the USACE NLD were constructed to protect against similar low-frequency, high-risk floods.

METHODOLOGY

Study Site Description

The Wabash basin of the mid-western U.S. is a large river basin mostly located in Indiana with regions extending west into Ohio and east into Illinois (Figure 1). It covers approximately 103,000 km^2 and is the second largest tributary to the Ohio River. The majority of the watershed consists of glacial tills in two physiographic provinces: Central Lowlands and Interior Low Plateaus. About 65% of the basin is row-crop agriculture, producing mostly corn and soybeans, and 2.3% urban areas (Pyron and Neumann, 2008). Average annual precipitation ranges from 94 and 125 cm (U.S. Army Corps of Engineers, 2011).

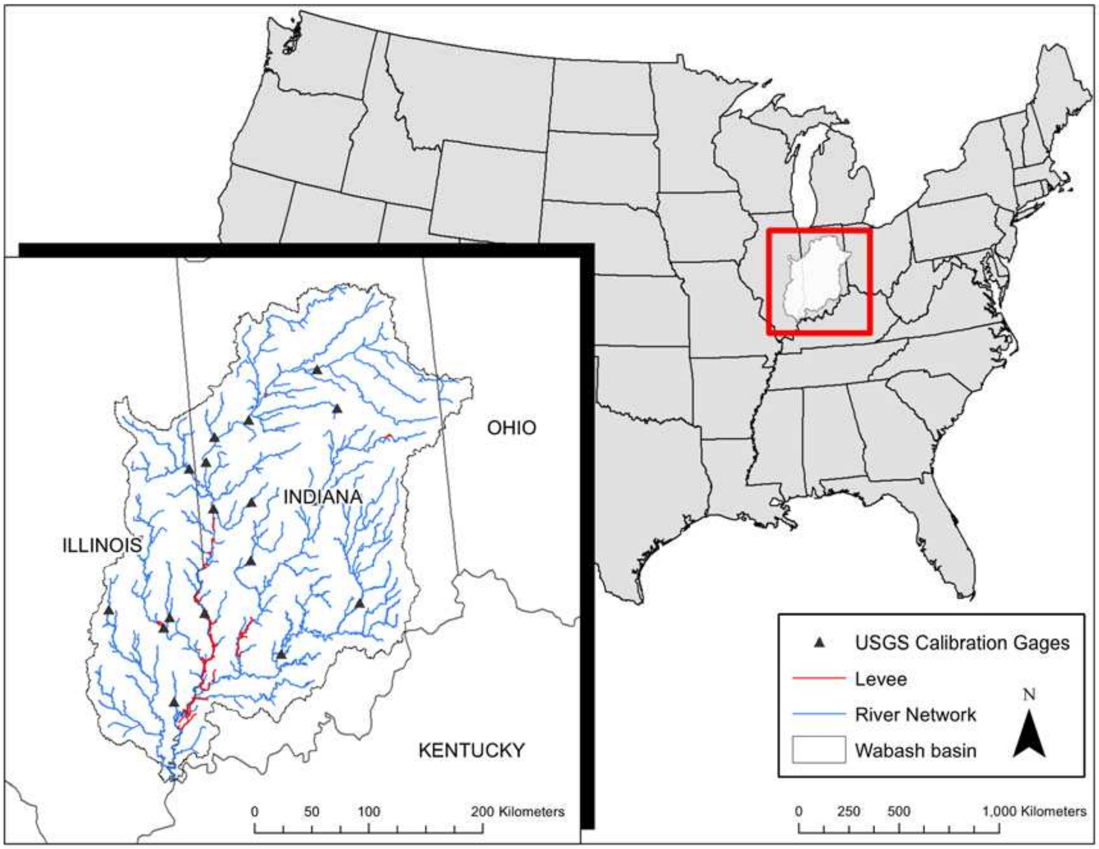


Figure 1. Location map of the Wabash Basin. The map also shows the locations of levees in the basin that are identified in the USACE NLD and the location of USGS gages that we used for determining model scaling parameters

A series of federally constructed levees and floodwalls span approximately 385 km of the river, implemented for urban and agricultural flood control purposes. The Nature Conservancy identified that a loss of connectivity due to dams on tributaries, levees, and agriculture as threatening to the ecological processes of the basin (U.S. Army Corps of Engineers, 2011).

Data Collection and Processing

We accessed and compiled numerous public datasets (Table 1). The data included digital elevation models (DEMs) at various resolutions, levee geospatial information, FEMA flood-hazard maps, hydrography information, and U.S. Geological Survey (USGS) river discharge and stage data. These data sources were processed according to the descriptions below and used within the general study framework shown in Figure 2.

Expanding on the hydrogeomorphic floodplain delineation approach developed by Nardi *et al.* (2006), our mapping methodology contains the following components (Figure 2). We chose to use this methodology because it creates a scalable relationship that can be widely applied to most basin in the United States due to the wide availability of USGS gage data. Previous studies have demonstrated the ability of this method to be applied to a range of stream orders, flood magnitudes and floodplain properties for different climatic, hydrologic, and geomorphic conditions (Nardi, 2006).

Determine Scaling Relationship. A scaling regression based on Leopold and Maddock (1953) is used to relate discharge stage to upstream contributing area along a river network. The scaling relationship is expressed in Equation (1):

$$F_i = aC^b \tag{1}$$

Where F_i is the maximum flow depth (m) for the flood recurrence interval i, a and b are dimensionless scaling parameters, and C is the upstream contributing area (m^2).

The scaling parameters *a* and *b* were determined by a series of regression analyses using peak annual discharge and stage data from USGS stream gages distributed throughout the basin. Although scaling parameters can be determined for any hydrologic recurrence interval, we focused exclusively on the 100-year return period since it allowed us to compare our results to FEMA FIRMs within the basin.

Table 1. Sources and descriptions of datasets used in this study.

Data	**Description**	**Reference**
National Aeronautics and Space Administration (NASA) Shuttle Radar Topography Mission (SRTM) elevation data	30m-resolution digital elevation model data	NASA SRTM, Accessed 03/2015, https://www2.jpl.nasa.gov/srtm/
USGS 3D Elevation Program (3DEP) data	10m-resolution digital elevation model data	USGS 3DEP, Accessed 12/2016, https://nationalmap.gov/3DEP/index.html
USGS National Water Information System (NWI)	Peak annual discharge and stage data from USGS gages distributed throughout the basin	USGS NWI. Accessed 12/2016, http://waterdata.usgs.gov/nwis.
USGS National Hydrography Dataset Plus Version 2 (NHD)	River network attributes (e.g., river order)	USGS NHD, Accessed 12/2016, http://www.horizon-systems.com/NHDPlus/NHDPlusV2_home.php
U.S. Army Corps of Engineers (USACE) National Levee Database (NLD)	Geospatial levee attributes	USACE NLD, Accessed 12/2016, http://nld.usace.army.mil
U.S. Department of Agriculture (USDA) National Resources Conservation Service (NRCS) Watershed Boundary Dataset (WBD)	HUC-10 boundaries and attributes	USDA WBD, Accessed 12/2016, https://datagateway.nrcs.usda.gov
U.S. Federal Emergency Management Agency (FEMA) Flood Insurance Rate Maps (FIRMs)	Flood-hazards maps indicating zones "A" and "AE" associated with the 100-year flood recurrence interval	Indiana Floodplain Information Portal, Accessed 12/2016, http://dnrmaps.dnr.in.gov/appsphp/fdms/; FEMA National Flood Hazard Layer, Accessed 03/2015, https://hazards.fema.gov/femaportal/wps/portal/NFHLWMS

We selected USGS gages that were geographically distributed throughout the basin and located on rivers that encompass a range of Strahler stream orders. Peak annual data for some gages contain inaccuracies that are noted by the USGS using qualification codes, and any observation with a qualification code indicating inaccuracies was removed. We used a log Pearson III distribution to perform a flood frequency regression analysis (Interagency Advisory Committee on Water Data, 1982) and estimated the 100-year flood discharge for each gage. To estimate the flood stage for the 100-year flood discharge, we applied a LOESS regression (Cleveland, 1979) to fit the discharge-flood stage data at each gage. Finally, the scaling parameters were estimated through a log-log scaling regression of 100-year flood stages and upstream contributing drainage area.

DEM Processing. Our hydrogeomorphic floodplain mapping model requires topographic data that can be compared to estimated flood depths. We used two topographic resolutions in this study: NASA SRTM elevation 30m resolution global data and the USGS 3D Elevation Program (3DEP) 10m resolution data (Table 1). These two resolutions were chosen to assess the effects of DEM resolution on our hydrogeomorphic floodplain delineation methodology.

Each DEM was processed using Python scripts (Python version 3.6), including pit filling, flow direction estimation, and cell accumulation calculations for each DEM cell within the watershed (Jenson and Domingue, 1988; Nardi *et al.*, 2008). Pit filling is a necessary procedure to ensure hydrologic connectivity in the DEM. The procedure generally modifies the elevation of any cells that internally depressed to avoid interruption in the flow. The flow direction is calculated using the standard method, an Eight Direction (D8) algorithm (Jenson and Domingue, 1988) for which there are eight directions that can be assigned to a cell based on the steepest flow path. Cell accumulation estimates the number of cells flowing toward the target cell. A river network is then defined by setting a user-defined threshold for minimum cell accumulation values (Grimaldi *et al.*, 2005, 2004; Nardi *et al.*, 2008; Tarboton *et al.*, 1991; Tarboton and Ames, 2001). We determined the minimum appropriate thresholds according to the constant-drop analysis method (Tarboton and Ames, 2001), a method that uses a t-test to evaluate a range of threshold for the stream network to determine the smallest statistically acceptable threshold. The watershed boundary was defined by filtering cells that contribute to the user-defined outlet point.

Floodplain Delineation. Using Equation (1) we estimated the flow depth (*F*) at each river network cell in the basin based on the contributing area (*C*) to that cell. We compared the flood elevation at each river network cell to the elevation of its hydrologically connected cells (defined by the cell accumulation grid produced during DEM processing) to determine the spatial extent of flood inundation. In other words, the contributing area is defined for each stream network cell, and the elevation of each of the sub-basin cells is evaluated to determine if the cell falls below the absolute value of the flow depth of the stream network cell. All spatially contiguous cells with an absolute elevation below the flooding elevation were mapped as floodplain.

Fit-indices Analyses. We evaluated our hydrogeomorphic floodplain results by comparing them to FEMA’s digital Flood Insurance Rating Maps (FIRMs). We selected FIRM layers identified as “Zone AE” and “Zone A”, which represent hydraulically modeled and approximated flood hazard boundaries, respectively, for the 100-year recurrence interval. These digital map layers were obtained through FEMA’s Map Service Center and the Indiana State Department of Natural Resources (Table 1).

To evaluate the differences between our model results and FEMA flood-hazard maps, conformity and bias fit-indices were calculated as:

$$Conformity = A/(A + B + C) \tag{2}$$

$$Bias = (A + C)/(A + B) \tag{3}$$

where A, B, and C are defined by the overlapping differences in flooding area shown in Table 2. The conformity index ranges from 0 to 1 and measures how well our modeled floodplain areas match the FEMA flood-hazard maps. The bias index measures the tendency of our results to over predict or under predict floodplain area compared to FEMA flood-hazard maps, with $bias < 1$ indicating over prediction and $bias > 1$ indicating under prediction (Hunter, 2005). Other studies (e.g., Lane *et al.*, 2017; Sangwan and Merwade, 2015) have used similar fit-indices to compare model outputs.

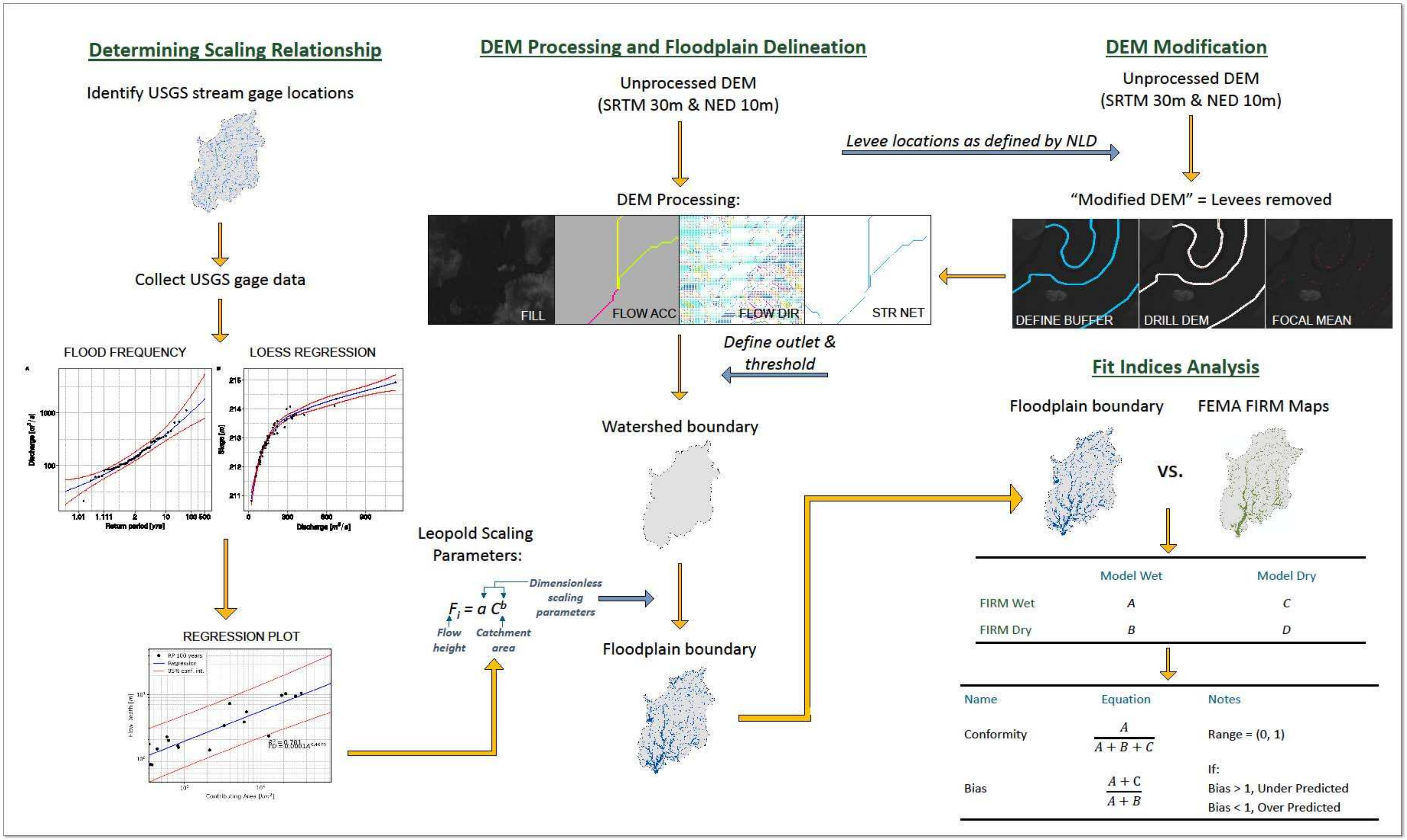
Table 2. Matrix of variables used in conformity and bias calculations

	Model Wet	Model Dry
FIRM Wet	*A* (Model and FIRM flood maps overlap)	*B* (Model shows no flood area where FIRM shows flood)
FIRM Dry	*C* (Model shows flood area where FIRM shows no flood)	*D* (Model and FIRM flood maps show no flooding)

We examined the spatial distribution of model results by computing fit-indices within boundaries defined by 10-digit Hydrologic Unit Codes (HUC-10). Because levees tend to be clustered within watersheds, we assumed that the spatial scales of HUC-10 sub-basins would be appropriate for capturing floodplain differences within HUC-10s that included or did not include levees. We used ArcGIS (version 10.x, ESRI, Redlands, California) and R (version 3.x, R Core Team, Vienna, Austria) to compute and map model results within the basin.

DEM Modification. During the study we found that topographic representations of levees within the DEMs influenced the hydrologic connectivity of upstream cells to the river network. Thus, to further evaluate the influence of levees on floodplain delineations, we removed the levees from the topographic rasters to create modified levee-free DEMs.

We removed levees from the 10m and 30m DEMs using a custom Python script. The script included the following steps to remove the levees: 1) identify the centerline of levees located within the basin based on NLD records; 2) create a buffer around the centerline of the levee; 3) "drill" or delete the raster values within the defined buffer; 4) redefine the drilled raster values by using "focal mean" ArcGIS function. The focal mean tool reassign the raster cells an elevation based on the mean value of its neighboring cells. To minimize modification to the original DEMs we used a 90m buffer radius, which was the smallest radius that would completely surround each levee in the basin. After the DEMs were modified to eliminate levees we followed the same floodplain delineation steps to map the floodplain within the modified DEMs, and we compared results from the new DEMs to FEMA flood-hazard maps using the fit-indices.



	Model Wet	Model Dry
FIRM Wet	A	C
FIRM Dry	B	D

Name	Equation	Notes
Conformity	$\frac{A}{A+B+C}$	Range = (0, 1)
Bias	$\frac{A+C}{A+B}$	If: Bias > 1, Under Predicted Bias < 1, Over Predicted

Figure 2. Methodology Flowchart. The three components – DEM processing and floodplain delineation, determining scaling relationship, and DEM modification - capture our hydrogeomorphic modeling method. The yellow arrows represent model processes while the blue arrows represent user inputs. We then compare the results to FEMA maps based on two fit indices. The A, B, and C parameters represent a match, model over prediction, and model under prediction, respectively.

RESULTS

The 100-year floodplain was delineated for the 10m and 30m DEMs for a total of 233 HUC-10 sub-basins within a 103,000 km^2 study area of the Wabash Basin. The calibrated scaling parameters for the 10m DEM were determined to be a = 0.0001 and b = 0.4679, and the scaling parameters for the 30m DEM were determined to be a = 0.0035 and b = 0.3172. The variation in scaling parameter values are due to differences in DEM resolution and subsequent details affecting the DEM processing outputs. The contributing area thresholds for each DEM resolution were 100 and 50 km^2 for the 10m and 30m DEM, respectively. Using these scaling parameters, we delineated the floodplain for each DEM (Figure 3).

Detailed illustrations of our model results are shown in the insets of Figure 3. In some locations it is clear that our model estimates floodplain areas that surround an existing levee (e.g., inset 3), while in other locations the floodplain delineations are bounded by a levee, particularly with the 10m DEM (e.g., inset 2). These results show that our hydrogeomorphic model can be sensitive to topographic representations of levees, especially with DEMs of finer resolutions.

Comparisons of our model results to FEMA 100-year flood hazard maps are shown in Figure 4. Unfortunately, geospatial digital data of FEMA FIRMs were not available for the entire Wabash Basin, but we were able to obtain data from 74 of 84 counties in the basin. Figure 4 highlights three areas where differences between our results and FEMA FIRMs are spatially variable. In general, it appears that flood inundation results from the 10m DEM tend to be smaller than FEMA flood-hazard areas, while results from the 30m DEM often extend beyond the flood-hazard boundaries. In addition, FEMA flood-hazard areas extend further upstream within a stream network compared to our model predictions.

Conformity and bias calculations for each DEM resolution are shown in Table 3. Flood inundation results from the 10m DEM are a better overall match to the FEMA boundaries than the 30m floodplain (conformity values of 0.45 and 0.40, respectively). And, as illustrated in Figure 4, 10m DEM results tend to under predict and the 30m DEM results tend to over predict compared to FEMA flood-hazard maps (bias values of 1.70 and 0.90, respectively). Inset 1 of Figure 4 indicates an over prediction, especially in the 30m DEM, over predict in low order streams within headwater regions.

Table 3. Mean conformity and bias calculations for Wabash basin

DEM Type	Conformity	Bias
10m resolution with Levees	0.45	1.70
10m resolution without Levees	0.47	1.66
30m resolution with Levees	0.40	0.90
30m resolution without Levees	0.40	0.90

Figure 5 shows the spatial variability of conformity and bias fit-indices. Although the basin-aggregate conformity values for both DEM resolutions are similar (Table 3), Figure 5 illustrates differences in spatial heterogeneity between the two DEMs. Compared to the 10m DEM, conformity values of 30m DEM results are generally lower in the headwater sub-basins but consistently higher near the bottom of the basin. A gradient from low to high conformity values is discernable with 30m DEM results, while the conformity values for 10m results appear more disparate.

A comparison of bias values between the two DEM resolutions show even more contrast (Figure 5). Bias values for the 30m DEM results are almost equally split with 90 HUC-10s showing over prediction and 98 HUC-10s showing under prediction. So, although the basin-aggregate bias value is 0.90 (indicating only slight over prediction), the spatial distribution shows a near-equal split in sub-basins showing opposite bias values. A spatial distribution of bias values for the 10m DEM results almost uniformly show under predictions, however (Figure 5).

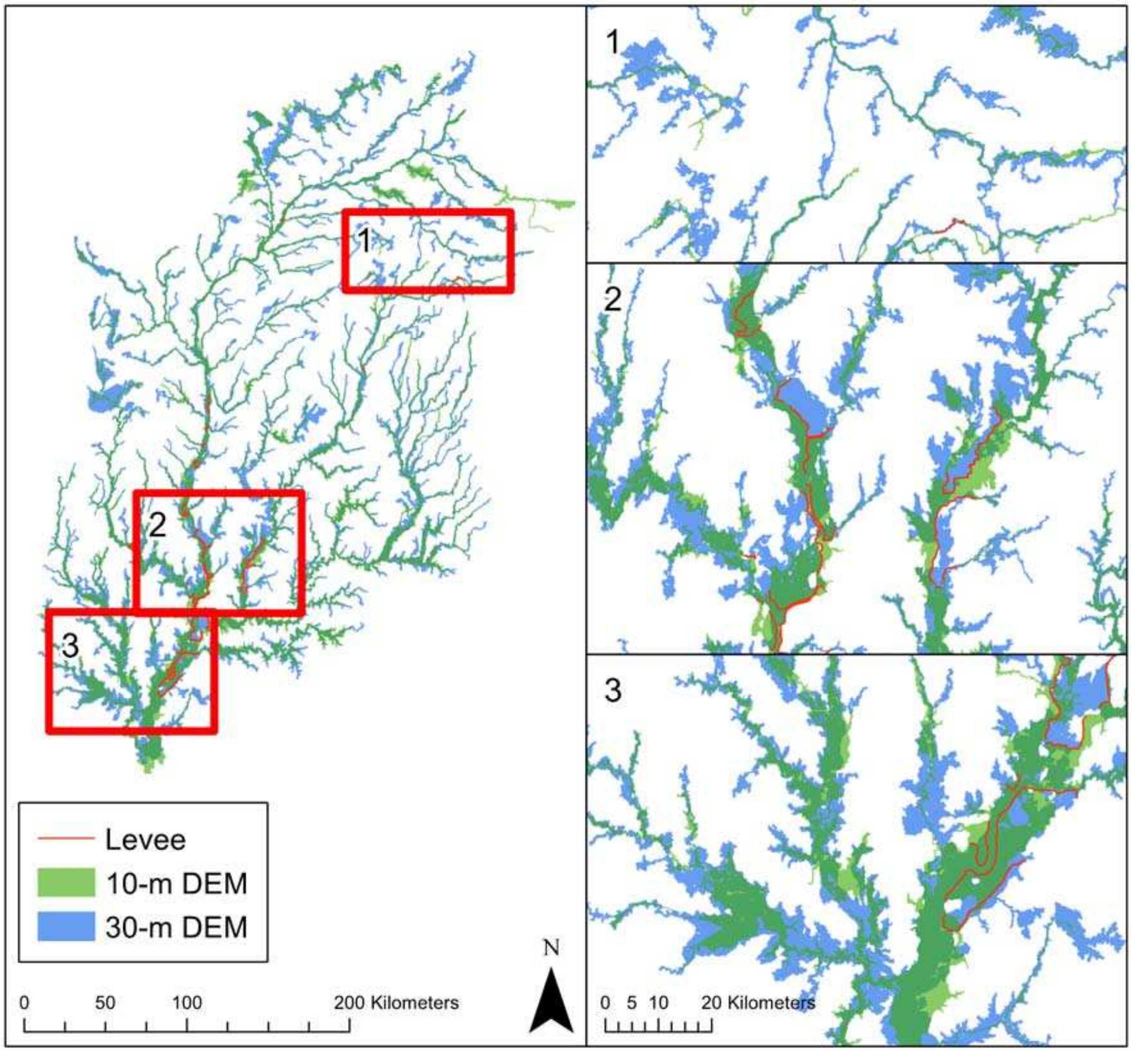


Figure 3. Comparison of 30m and 10m DEM delineated floodplains for the Wabash Basin.

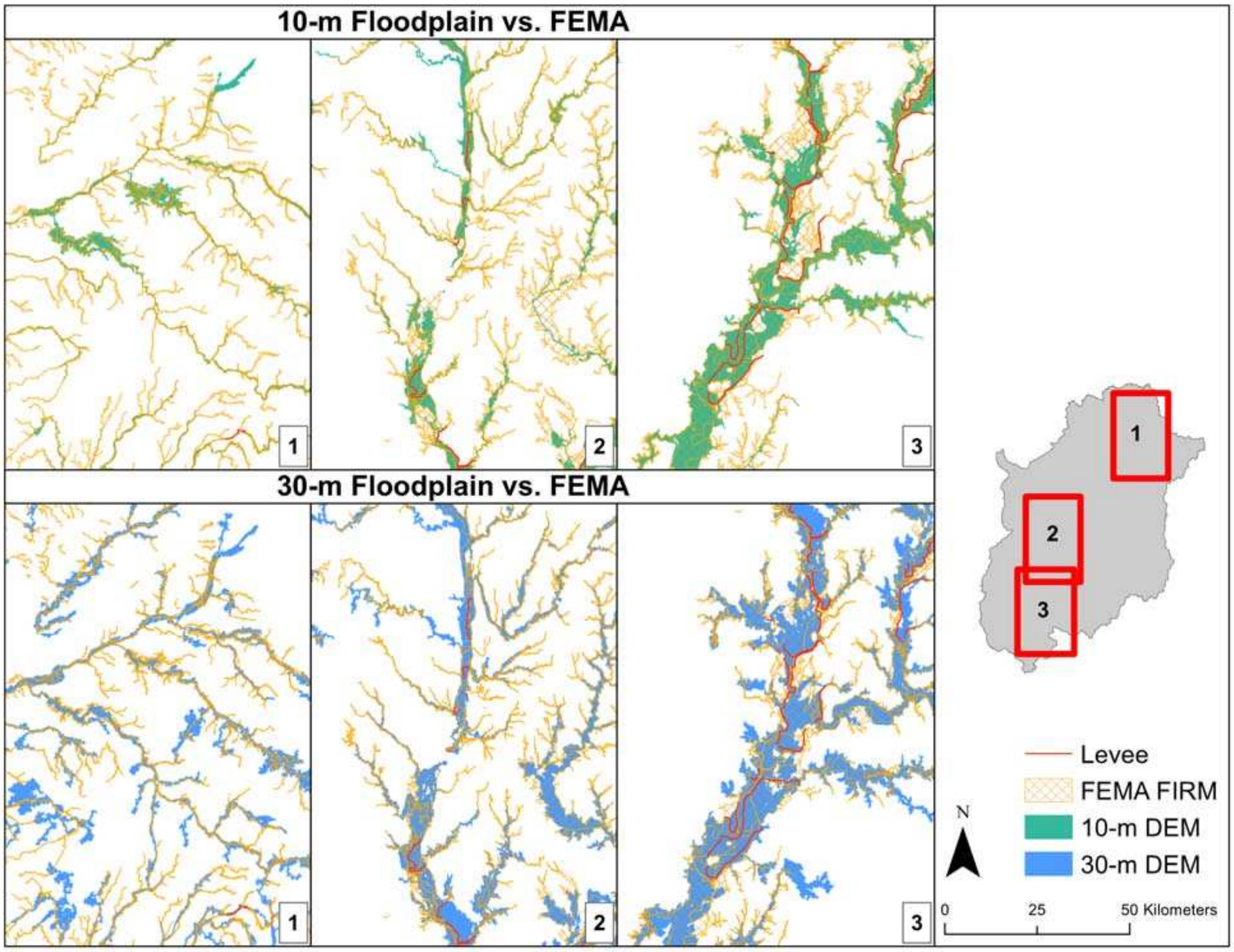


Figure 4. Comparison of 10m DEM and 30m DEM floodplain results to FEMA 100-yr flood-hazard boundaries.

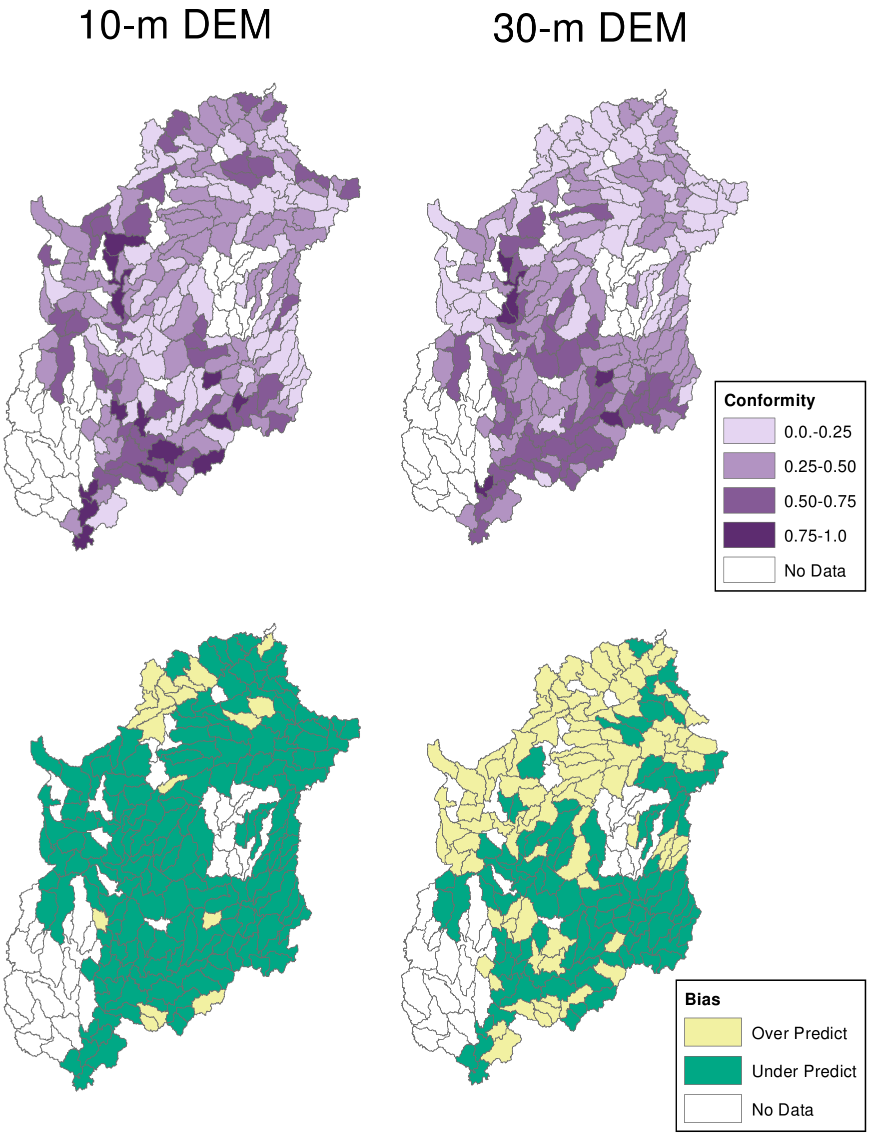


Figure 5. Conformity and bias values for HUC-10 sub-basins within the Wabash basin.

Because DEM resolution and user-defined contributing area thresholds can influence the results of our hydrogeomorphic mapping approach (e.g., Tarboton *et al.*, 1991; Wolock and Price, 1994), we assessed the variability of conformity and bias values in relation to maximum Strahler stream order of each HUC-10 sub-basin (Figure 6). We also partitioned HUC-10s sub-basins according to whether they contained levees, and we evaluated differences in conformity and bias values between sub-basins with and without levees (Figure 7).

Figure 6 illustrates how median conformity values increase with maximum stream order for both the 10m and 30m DEMs and range from 0.25 to 0.75. The 10m DEM results, however, show greater variability in conformity indices, especially at stream orders larger than four. Thus, the agreement between our model results and FEMA flood-hazard maps is highest in sub-basins with larger stream orders. This trend agrees with the spatial distribution of conformity values (especially the 30m DEM results in Figure 5), in which the furthest downstream sub-basins with large stream orders have the highest conformity values.

We found that results from the 10m DEM consistently under predict floodplain area (median bias values > 1) compared to FEMA FIRMs regardless of stream order, with under prediction magnitudes generally increasing inversely relative to stream order size (Figure 6). Variability in bias values for the 10m DEM are also largest at stream orders less than four. Median bias values from the 30m DEM results show slight over predictions (values < 1) in HUC-10 sub-basins with maximum streams orders of one to three (Figure 6). In stream orders greater than three, results from the 30m DEM slightly under predict flood areas.

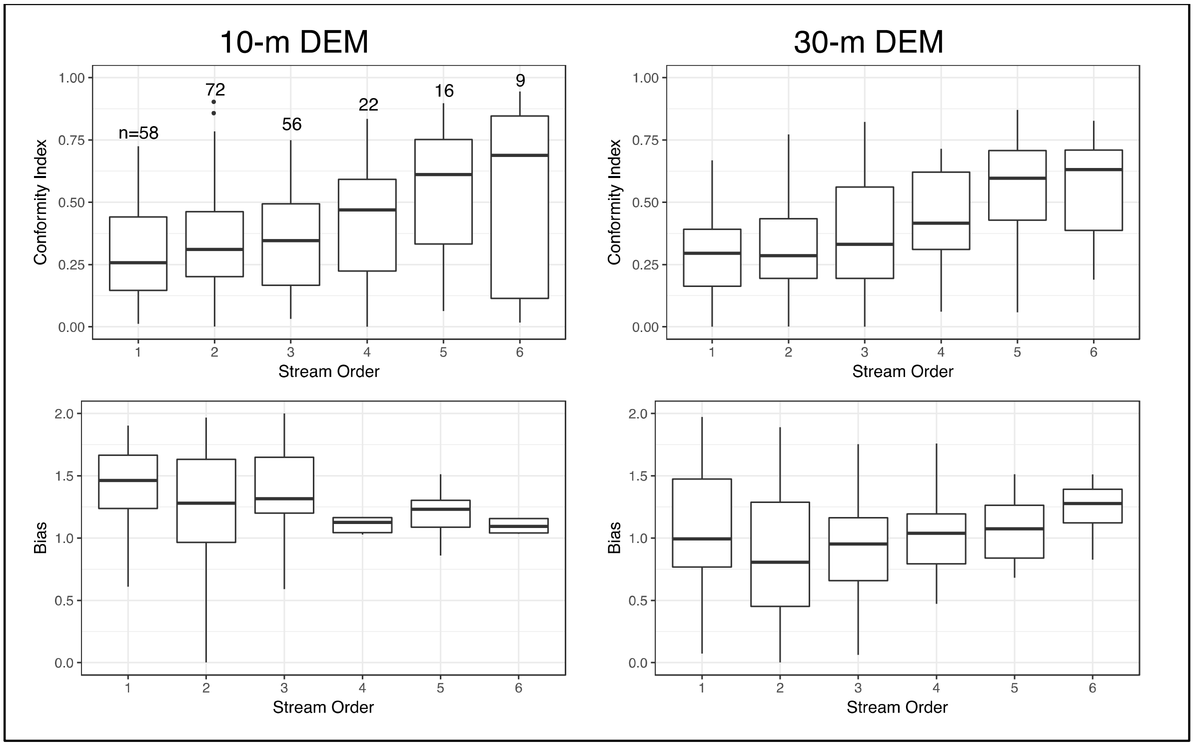


Figure 6. Conformity and bias values according to maximum stream order in each HUC-10 sub-basin. The number of sub-basins for each maximum stream orders is shown in the top-left plot.

We attempted to further identify the impacts of levees on our model results by partitioning HUC-10 sub-basins according to levee presence. We found that this resulted in fewer HUC-10 sub-basins with levees than we anticipated (Figure 7), yet we found these results useful for examining general model behavior.

As shown in Figure 7, results in sub-basins that contain levees generally have higher median conformity values compared to results in sub-basins without levees across all stream order sizes. However, the relative difference in conformity values between sub-basins with and without levees varied substantially across stream orders and DEM resolution. When compared to the 30m DEM results, we found that median conformity values for the 10m DEM were up to 50% greater at stream orders larger than three (Figure 6).

Median bias values in sub-basins that contain levees were generally equal to or greater than bias values in sub-basins without levees, indicating a tendency for the model to under predict when levees are present (Figure 7). This is most pronounced in results for the 10m DEM, which also shows larger differences in bias values between sub-basins with and without levees (e.g., the model more strongly under predicts when levees are present in fifth order streams compared to fourth order streams). The results for the 30m DEM show that median bias values for sub-basins with levees are higher or near-equal to values in sub-basins without levees (Figure 7).

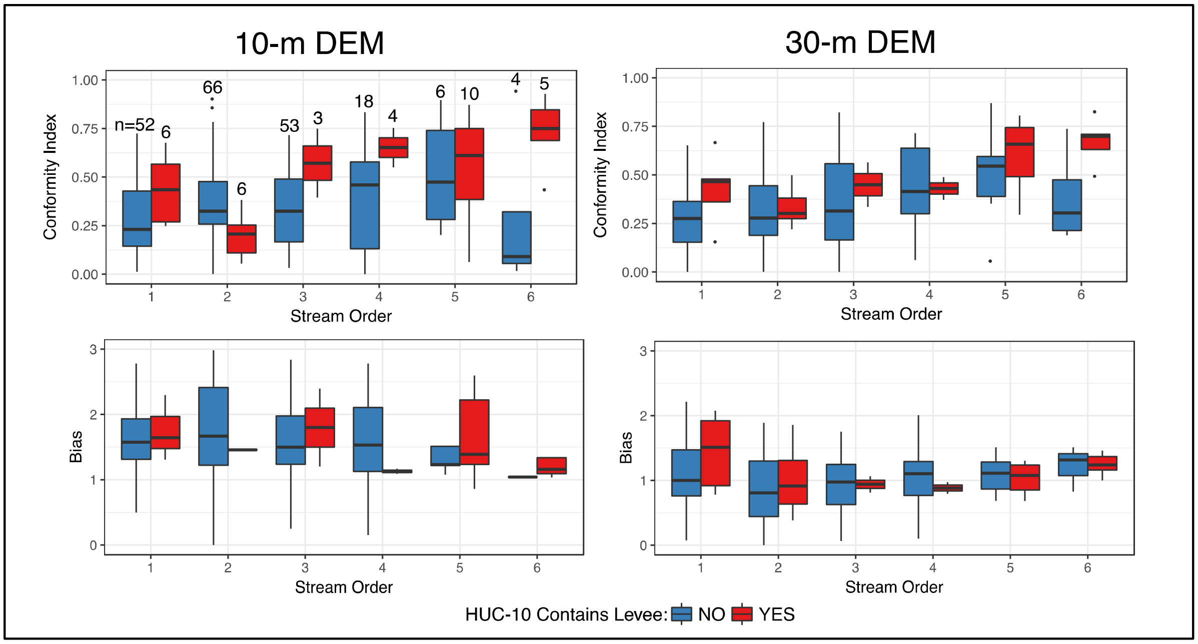


Figure 7. Conformity and bias values for HUC-10 sub-basins that contain (red) or do not contain levees (blue). The number of sub-basins for each maximum stream orders is shown in the top-left plot. Outlier values have been removed from the bias boxplots for clarity.

Because of the pronounced differences in conformity values between sub-basins partitioned by levee presence (Figure 7), we further investigated the impacts of levees on our floodplain mapping approach by removing topographic details of levees from the DEMs (see Methodology). Flood delineation results using the modified 10m and 30m DEMs are compared to those from the unmodified DEMs in Figure 8. In general, Figure 8 shows that when levees were removed from the DEMs, flooding boundaries extended beyond the original levee locations to create larger floodplain areas. For instance, inset 3 shows new areas of flooding near levees with both the modified 10m and 30m DEMs. However, regions of reduced flooding also were created with the modified DEMs (Figure 8), likely caused by changes in hydrologic connectivity that are determined during DEM processing. As expected, the floodplain delineations did not noticeably change in areas where levees were not present, as illustrated in inset 1. The percentage of floodplain loss was found by comparing the modified DEM to the unmodified DEM and calculating the percentage of total area increase. The total floodplain loss calculated was 1.7% and 2.2% for the 10m and 30m, respectively.

Basin-aggregated values of conformity and bias slightly improved or remained the same depending on the DEM resolution (Table 3). Results for the 10m DEM show a small improvement in conformity (value increased from 0.45 to 0.47) and less bias toward under prediction (value decreased from 1.70 to 1.66). However, removing topographic details of levees in the 30m DEM did not change conformity or bias values.

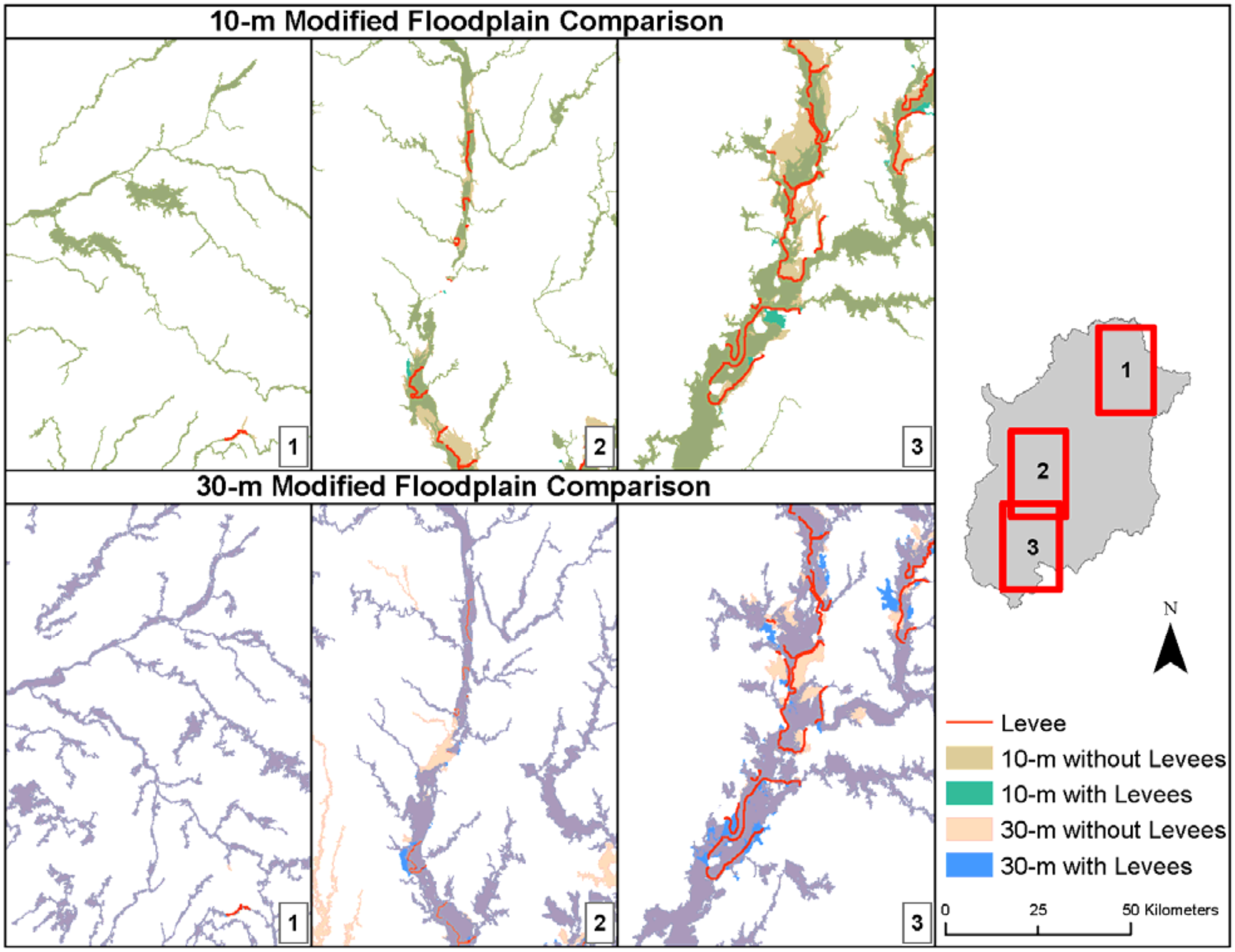


Figure 8. Floodplain results for the original and modified DEMs.

DISCUSSION

The importance of floodplains is difficult to overstate. Floodplains are unique interfaces between aquatic and terrestrial environments, which support high levels of biodiversity (e.g., Tockner and Stanford, 2002), modulate surface and sub-surface hydrologic processes (e.g., McAllister *et al.*, 2000), and facilitate biogeochemical processes (e.g., Tockner *et al.*, 1999). Yet, human development within river corridors has either eliminated floodplains or fundamentally altered the connectivity between rivers and their floodplains (Ignacio *et al.*, 2015; Nardi *et al.*, 2015; Wohl *et al.*, 2017). Levees are perhaps the most obvious obstruction to river-floodplain connectivity – not only as topographic features within floodplain landscapes but also because their purpose is to prevent water from inundating large areas that once were hydrologically connected to a river. Yet, it is surprising that few studies exist that help us understand the relative impacts of levees on floodplain loss, especially at large watershed scales. Impacts of floodplain connectivity loss can have important implications for riverine management and restoration. .

Our first objective was to assess the performance of our hydrogeomorphic floodplain mapping technique in levee-protected areas. Our results show that floodplain areas delineated using our model are sensitive to topographic details of levees. We presumed that the influence of levees on our modelling results would be limited because of the relatively small topographic details of the levees in comparison to the hydrogeomorphic boundaries such that large differences between FEMA flood-hazard areas, which preclude flooding behind many levees, and our hydrogeomorphic floodplain areas would highlight the relative impact of levees. However, we found that levees were often identifiable in raster elevation datasets, which influenced our hydrologic processing of the DEMs. As illustrated in Figure 10, rather than being directed downslope toward a stream network, the high-elevation raster cells created by a levee forced flow lines to be parallel to the levee, thereby reducing connectivity to the adjacent river network. This caused the subsequent floodplain area near levees to have similar boundaries as FEMA FIRMs (Figure 3 and 4), leading to higher conformity values in levee-protected sub-basins (Figure 7). The effect of levees on flow direction and floodplain mapping results become more pronounced as the raster resolution decreases from 30 m to 10 m. (Figure 7).

The higher conformity values in sub-basins with levees (Figure 7) and the strong influence of topographic details of levees on flow direction (Figure 9) led us to explore differences in floodplain delineations when levees were removed from the DEMs. This analysis was intended to help us evaluate the ability of our hydrogeomorphic technique to assess changes in river-floodplain connectivity caused by levees, our second research objective. We found only minor differences in conformity and bias values when comparing our original results to those with levees removed (Table 3). We assume the similar results are due to the relative small increase in floodplain area mapped in levee-protected regions compared to the overwhelming cumulative floodplain area located in sub-basins not influenced by levees. Noticeable increases in floodplain area in many levee-protected areas (e.g., Figure 8) are encouraging, however, and we plan to refine our analyses to further partition the effects of levees in these small regions.

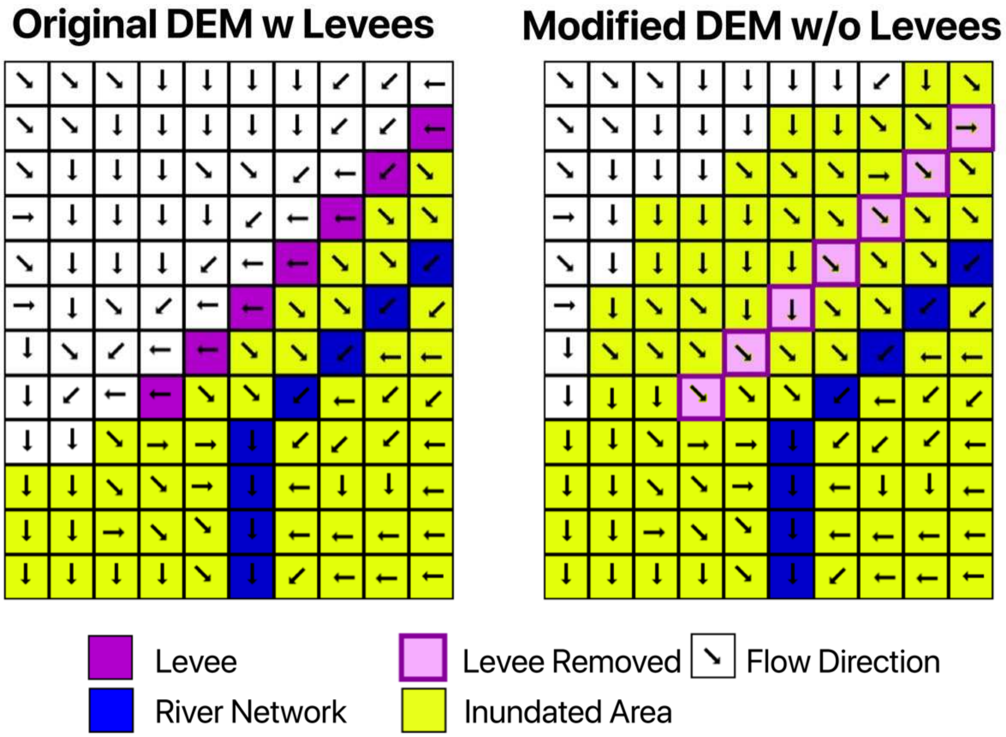


Figure 9. Illustration of the influences of levees on hydrologic connectivity and floodplain mapping.

Overall, we found that our results had higher conformity values in larger stream orders (e.g., 4-6) (Figure 6 and 7), which typically have more defined fluvial corridors that are identifiable in topographic datasets. Spatially, this corresponds to the gradient of increasing conformity values and distinct break in bias values shown in Figure 5, particularly with the 30m DEM results. Stream orders tend to increase along the same gradient of conformity values shown for the 30m DEM results in Figure 5. In addition, at lower stream orders located in the upper-portion of the basin, we expect floodplain widths to decrease such that the resolution size of the topographic rasters becomes a larger proportion of the overall floodplain widths. This leads to the general over prediction of floodplain area in the upper basin when using the 30m DEM (Figure 5). We suspect that underestimation of the scaling parameters for the 10m DEM may have contributed to the overall under prediction of floodplain area (Figure 5 and 6) because the scaling parameters are notably less than values reported in other studies (Nardi *et al.*, 2006, 2013).

This study tests the behavior of the hydrogeomorphic floodplain mapping technique using different DEM resolutions. Given the results presented in this study, particularly the tendency of the model to consistently under predict floodplain areas throughout our study basin when using 10m DEMs, we recommend using 30m resolution topographic datasets or similar for future hydrogeomorphic floodplain delineations. The topographic detail within 30m resolution datasets is sufficient for capturing floodplain landscapes formed by low-frequency flood events, such as the 100-year flood. Our approach assumes that floodplain landscapes are primarily created by large-scale hydrologic forces over large time periods rather than localized hydraulic interactions and small topographic details (e.g. Nardi *et al.,* 2006), which are more evident in 10m resolution datasets. This fundamental aspect needs be considered when evaluating our model performance relative to FEMA flood-hazard maps.

We anticipate our work will contribute to a growing research emphasis on linking levee impacts on river-floodplain connectivity to watershed management and riverine restoration. For instance, numerous recent studies have examined the ecological benefits of removing levees in riverine restoration efforts (e.g., Choi and Harvey, 2017; Nichols and Viers, 2017), though these studies focus on short segments of rivers rather than evaluating watershed-scale restoration potential. Recent work by Remo *et al.* (2017) highlights a tool for assessing the economic and ecological tradeoffs of removing levees to reconnect portions of a floodplain. Still, as watershed-scale improvements to rivers are increasingly being promoted (Bernhardt and Palmer, 2011;

Wohl *et al.*, 2015), more work is needed to assess geomorphic, ecological, and hydrologic alterations caused by levees beyond the reach scale.

SUMMARY

In this study we investigated how a hydrogeomorphic floodplain model can be applied to evaluate changes in floodplain connectivity due to human development. Our research objectives were to 1) assess the performance of a hydrogeomorphic floodplain mapping technique in levee-protected areas and 2) determine the ability of the hydrogeomorphic technique to assess changes in river-floodplain connectivity caused by levees. We focused our study on a portion of the Wabash Basin, USA, which contains numerous levees systems. Using multiple indices to compare our floodplain mapping results to FEMA 100-yr floodplain boundaries, we found that DEM resolution can strongly influence the delineations of floodplains in leveee-protected areas. Generally, results from the 30m DEM resolution over predicted and results from the 10m DEM resolution under predicted floodplain areas compared to FEMA flood-hazard maps. In addition, we found that results from our hydrogeomorphic floodplain mapping approach was influenced by topographic details of levees within the DEMs, as model results were affected by flow direction and cell accumulation disruptions caused by levees. The evidence of disruption in the delineation of flood regions led us to artificially remove levees from the original DEM and re-map floodplain areas. Regions of increased floodplain area were noticeable in the new floodplain results, but overall comparisons to FEMA flood-hazard layers were similar to results that included levees. Though we expected our model to produce greater differences in floodplain extent in levee-protected regions, we demonstrate the applicability of hydrogeomorphic floodplain modeling to assess human alterations to floodplain connectivity. Future work is still needed to understand the implications of floodplain disconnectivity on aquatic habitat and ecological function loss, and to inform management and restoration activities that seek to improve river-floodplain dynamics.

LITERATURE CITED

Amoros, C. and G. Bornette, 2002. Connectivity and Biocomplexity in Waterbodies of Riverine Floodplains. Freshwater Biology 47:761–776.

Bernhardt, E.S. and M.A. Palmer, 2011. River Restoration: The Fuzzy Logic of Repairing Reaches to Reverse Catchment Scale Degradation. Ecological Applications 21:1926–1931.

Burby, R.J., 2001. Flood Insurance and Floodplain Management: The US Experience. Global Environmental Change Part B: Environmental Hazards 3:111–122.

Choi, J. and J.W. Harvey, 2017. Predicting Outcomes of Restored Everglades High Flow: A Model System for Scientifically Managed Floodplains. Restoration Ecology 25:S39–S47.

Cleveland, W.S., 1979. Robust Locally Weighted Regression and Smoothing Scatterplots. Journal of the American Statistical Association 74:829–836.

Covino, T., 2017. Hydrologic Connectivity as a Framework for Understanding Biogeochemical Flux through Watersheds and Along Fluvial Networks. Geomorphology 277:133–144. https://doi.org/10.1016/j.geomorph.2016.09.030

Dodov, B.A. and E. Foufoula-Georgiou, 2006. Floodplain Morphometry Extraction from a High-Resolution Digital Elevation Model: A Simple Algorithm for Regional Analysis Studies. IEEE Geoscience and Remote Sensing Letters 3:410–413.

Follum, M. L., Tavakoly, A. A., Niemann, J. D., & Snow, A. D. (2016). AutoRAPID: A Model for Prompt Streamflow Estimation and Flood Inundation Mapping over Regional to Continental Extents. Journal of the American Water Resources Association, 53(2), 1–20. https://doi.org/10.1111/1752-1688.12476.

Gallant, J.C. and T.I. Dowling, 2003. A Multiresolution Index of Valley Bottom Flatness for Mapping Depositional Areas. Water Resources Research 39:1347.

Grimaldi, S., V. Teles, and R.L. Bras, 2004. Sensitivity of a Physically Based Method for Terrain Interpolation to Initial Conditions and Its Conditioning on Stream Location. Earth Surface Processes and Landforms 29:587–597.

Grimaldi, S., V. Teles, and R.L. Bras, 2005. Preserving First and Second Moments of the Slope Area Relationship during the Interpolation of Digital Elevation Models. Advances in Water Resources 28:583–588.

Guida, R.J., T.L. Swanson, J.W.F. Remo, and T. Kiss, 2015. Strategic Floodplain Reconnection for the Lower Tisza River, Hungary: Opportunities for Flood-Height Reduction and Floodplain-Wetland Reconnection. Journal of Hydrology 521:274–285.

Horner, G.J., P.J. Baker, R.M. Nally, S.C. Cunningham, J.R. Thomson, and F. Hamilton, 2010. Forest Structure, Habitat and Carbon Benefits from Thinning Floodplain Forests:

Managing Early Stand Density Makes a Difference. Forest Ecology and Management 259:286–293.

Hunter, N.M., 2005. Development and Assessment of Dynamic Storage Cell Codes for Flood Inundation Modelling. University of Bristol.

Ignacio, J.A.F., G.T. Cruz, F. Nardi, and S. Henry, 2015. Assessing the Effectiveness of a Social Vulnerability Index in Predicting Heterogeneity in the Impacts of Natural Hazards: Case Study of the Tropical Storm Washi Flood in the Philippines. Vienna Yearbook of Population Research 13:91–129.

Interagency Advisory Committee on Water Data, 1982. Guidelines for Determining Flood Flow Frequency: Bulletin 17-B of the Hydrology Subcommittee. U.S. Department of Interior Geological Survey, Office of Water Data Coordination, Reston, Virginia.

Jafarzadegan, K. and V. Merwade, 2017. A DEM-Based Approach for Large-Scale Floodplain Mapping in Ungauged Watersheds. Journal of Hydrology 550:650–662.

Jenson, S.K. and J.O. Domingue, 1988. Extracting Topographic Structure from Digital Elevation Data for Geographic Information System Analysis. Photogrammetric Engineering and Remote Sensing 54:1593–1600.

Junk, W., P. Bayley, and R. Sparks, 1989. The Flood Pulse Concept in River-Floodplain Systems. Proceedings of the International Large River Symposium (LARS). Canadian Special Publication of Fisheries and Aquatic Sciences, pp. 110–127.

Harvey, J. and M. Gooseff, 2015. River Corridor Science: Hydrologic Exchange and Ecological Consequences from Bedforms to Basins. Water Resources Research 51:6893–6922. https://doi.org/10.1002/2015WR017617.

Lane, C.R., A. Hall, E. D'Amico, N. Sangwan, and V. Merwade, 2017. Characterizing the Extent of Spatially Integrated Floodplain and Wetland Systems in the White River, Indiana, USA. JAWRA Journal of the American Water Resources Association 53:774–790.

Leopold, L.B. and T. Maddock Jr, 1953. The Hydraulic Geometry of Stream Channels and Some Physiographic Implications. U.S. Geological Survey.

Manfreda, S., F. Nardi, C. Samela, S. Grimaldi, A.C. Taramasso, G. Roth, and A. Sole, 2014. Investigation on the Use of Geomorphic Approaches for the Delineation of Flood Prone Areas. Journal of Hydrology 517:863–876.

Manfreda, S., A. Sole, and M. Fiorentino, 2008. Can the Basin Morphology Alone Provide an Insight into Floodplain Delineation? WIT Press, pp. 47–56.

McAllister, L.S., B.E. Peniston, S.G. Leibowitz, B. Abbruzzese, and J.B. Hyman, 2000. A Synoptic Assessment for Prioritizing Wetland Restoration Efforts to Optimize Flood Attenuation. Wetlands 20:70–83.

McGlynn, B.L. and J. Seibert, 2003. Distributed Assessment of Contributing Area and Riparian Buffering along Stream Networks. Water Resources Research 39:1082.

Nardi, F., A. Annis, and C. Biscarini, 2015. On the Impact of Urbanization on Flood Hydrology of Small Ungauged Basins: The Case Study of the Tiber River Tributary Network within the City of Rome. Journal of Flood Risk Management. doi:10.1111/jfr3.12186.

Nardi, F., C. Biscarini, S. Di Francesco, P. Manciola, and L. Ubertini, 2013. Comparing a Large-Scale DEM-Based Floodplain Delineation Algorithm with Standard Flood Maps: The Tiber River Basin Case Study. Irrigation and Drainage 62:11–19.

Nardi, F., S. Grimaldi, M. Santini, A. Petroselli, and L. Ubertini, 2008. Hydrogeomorphic Properties of Simulated Drainage Patterns Using Digital Elevation Models: The Flat Area Issue. Hydrological Sciences Journal 53:1176–1193.

Nardi, F., E.R. Vivoni, and S. Grimaldi, 2006. Investigating a Floodplain Scaling Relation Using a Hydrogeomorphic Delineation Method. Water Resources Research 42:W09409.

Nichols, A.L. and J.H. Viers, 2017. Not All Breaks Are Equal: Variable Hydrologic and Geomorphic Responses to Intentional Levee Breaches along the Lower Cosumnes River, California. River Research and Applications 33:1143–1155.

Opperman, J.J., R. Luster, B.A. McKenney, M. Roberts, and A.W. Meadows, 2010. Ecologically Functional Floodplains: Connectivity, Flow Regime, and Scale. JAWRA Journal of the American Water Resources Association 46:211–226.

Pringle, C., 2003. What Is Hydrologic Connectivity and Why Is It Ecologically Important? Hydrological Processes 17:2685–2689. https://doi.org/10.1002/hyp.5145.

Pyron, M. and K. Neumann, 2008. Hydrologic Alterations in the Wabash River Watershed, USA. River Research and Applications 24:1175–1184.

Remo, J.W.F., R.J. Guida, and S. Secchi, 2017. Screening the Suitability of Levee Protected Areas for Strategic Floodplain Reconnection Along the LaGrange Segment of the Illinois River, USA. River Research and Applications 33:863–878.

Remo, J.W.F., N. Pinter, and R. Heine, 2009. The Use of Retro- and Scenario-Modeling to Assess Effects of 100+ Years River of Engineering and Land-Cover Change on Middle and Lower Mississippi River Flood Stages. Journal of Hydrology 376:403–416.

Samela, C., T.J. Troy, and S. Manfreda, 2017. Geomorphic Classifiers for Flood-Prone Areas Delineation for Data-Scarce Environments. Advances in Water Resources 102:13–28.

Sangwan, N. and V. Merwade, 2015. A Faster and Economical Approach to Floodplain Mapping Using Soil Information. JAWRA Journal of the American Water Resources Association 51:1286–1304.

Strahler, A.N., 1952. Hypsometric (Area-Altitude) Analysis of Erosional Topology. Geological Society of America Bulletin 63:1117–1142.

Tarboton, D.G. and D.P. Ames, 2001. Advances in the Mapping of Flow Networks from Digital Elevation Data. American Society of Civil Engineers, pp. 1–10.

Tarboton, D.G., R.L. Bras, and I. Rodriguez-Iturbe, 1991. On the Extraction of Channel Networks from Digital Elevation Data. Hydrological Processes 5:81–100.

Tockner, K., D. Pennetzdorfer, N. Reiner, F. Schiemer, and J.V. Ward, 1999. Hydrological Connectivity, and the Exchange of Organic Matter and Nutrients in a Dynamic River–floodplain System (Danube, Austria). Freshwater Biology 41:521–535.

Tockner, K. and J.A. Stanford, 2002. Riverine Flood Plains: Present State and Future Trends. Environmental Conservation 29:308–330.

U.S. Army Corps of Engineers, 2011. Wabash River Watershed Section 729 Initial Watershed Assessment. U.S. Army Corps of Engineers Louisville District. http://www.lrl.usace.army.mil/Portals/64/docs/CWProjects/WabashStudy.pdf.

Ward, J. V. (1989). The Four-Dimensional Nature of Lotic Ecosystems. Journal of the North American Benthological Society, 8(1), 2–8.

Wohl, E., S.N. Lane, and A.C. Wilcox, 2015. The Science and Practice of River Restoration. Water Resources Research 51:5974–5997.

Wohl, E., K.B. Lininger, and J. Baron, 2017. Land before Water: The Relative Temporal Sequence of Human Alteration of Freshwater Ecosystems in the Conterminous United States. Anthropocene 18:27–46.

Wolock, D.M. and C.V. Price, 1994. Effects of Digital Elevation Model Map Scale and Data Resolution on a Topography-Based Watershed Model. Water Resources Research 30:3041–3052.

APPENDIX A
Extended Literature Review

APPENDIX CONTENTS

Appendix provides a detailed literature review covering existing research of floodplain significance, floodplain mapping techniques, floodplain modifications from levees, and equations used in this methodology.

EXTENDED LITERATURE REVIEW

Floodplain Significance

A floodplain is an “area that are periodically inundated by the lateral overflow of rivers or lakes, and/or by direct precipitation or groundwater” (Junk, 1989). The floodplain receives water periodically from an adjacent source and then stores, redistributes and eventually releases the water to the river under base flow conditions (Mertes, 1997; Ward, Tockner, Arscott, & Claret, 2002; Woessner, 2000). The extent of the floodplain depends on the flood magnitude and terrain (Cushing, 2001).

Floodplains are important landscape features that provide numerous environmental and human services, including riparian habitat, pollutant removal, energy recycling, flood attenuation, and groundwater recharge (Amoros & Bornette, 2002; Horner et al., 2010; Junk, Bayley, & Sparks, 1989; Tockner & Stanford, 2002). Although they are widely regarded for their importance, they are frequently recognized as in danger of elimination. As development within floodplains has increased, flood management activities have significantly transformed river-floodplain connectivity dynamics by disrupting the timing and extent of floodplain inundation, likely leading to floodplain habitat loss and decline of natural functions of the riparian system (e.g. Ward, Tockner, Pennetzdorfer, Reiner, & Schiemer, 1999).

Loss of floodplain connectivity refers to the interruption of the transfer of water between the fluvial ecosystem and surface or subsurface waters of the river channel (Ward et al., 1999). This interruption is mainly due to human-driven hydrology, landscape, and river geometry modifications (e.g. levees, weirs, storage areas, split channels). Hydrologic connectivity can occur on four dimensions: longitudinal, lateral, vertical, and temporal (Pringle, 2001; Ward, 1989). Longitudinal connectivity describes changes along the rivers primary axis of flow.

Vertical connectivity includes the exchanges between the surface and groundwater via infiltration into the alluvial floodplain while temporal refers to changes occurring on both annual (hydrological phases, unpredictable fluctuation) and historical scales (such as wet and dry periods). Lateral connectivity, the major focus of this paper, refers to the permanent and episodic link between the main course of the river and various features lying in the alluvial floodplain. The degree to which this connection exists is a time-dependent phenomenon (Ward et al., 1999) that has a strong correlation to seasonal precipitation patterns. The extent of the connection depends on the hydrologic condition within the river and the river stage exceeding bankfull elevations.

There are two prevailing theories on the connection between rivers and its surrounding environment: the river continuum concept (RCC) (Vanote, Minshall, Cummins, Sedell, & Cushing, 1980) and the flood pulse concept (Junk, 1989). The RCC (Vanote et al., 1980) is based on the hypothesis that aquatic communities and ecological predictably change from the headwaters to the mouth of the river, resulting in a longitudinally oriented continuum of features. The flood pulse concept (Junk, 1989) builds off the RCC to extend the theory laterally, stating that the most important hydrologic feature of large rivers in the annual flood pulse (the pulsing of river discharge).

Hydrologic changes often remove the flood pulse from floodplains and in the long term, sedimentation and the modified flood pulse produce a man-made river-floodplain (Junk, 1989). Levees support flood control and agricultural development on floodplains by increasing the effective elevation of the floodplain. This isolates a sizeable portion of the floodplain system, making them functionally extinct (Tockner & Stanford, 2002) while permanently inundating other portions of the former floodplain. Isolated floodplains occur when the natural floodplain is severed from lateral connectivity because of a levee. Often these areas are converted into urban and agricultural use. Permanently inundated areas are continuously connected to the main channel. The dynamic interaction between water and land is the principal process that produces and maintains river floodplains (Bayley, 1995) and these developments interfere with the natural lateral connectivity.

It remains a challenge to maintain ecosystem functions while simultaneously protecting human development. An important step in addressing this challenge is identifying the extent of floodplain loss caused by various water management activities or infrastructures.

Floodplain Mapping Approaches

Several methods exist for mapping the extent of floodplains. In the past, flood inundation maps had to be generated manually from topographic surveys. The advancement of digitally derived topographic data, called Digital Elevation Models (DEMs) and geographic information systems (GIS) have enabled the acquisition of data and analysis of the river basin to be widely available to flood managers. The use of DEMs to automatically define watershed attributes is faster and less subjective. DEM quality and resolution can affect application results and must be chosen to be consistent with the scale of application and the processes that are modeled, the size of land surface features to be resolved, and study objectives (Garbrecht & Martz, 2006). Remote sensing data, such as light detection and ranging (LiDAR) and synthetic aperture radar (SAR) are used to generated digital elevation models (DEMs). LIDAR data allows for the creation of less than 1 m resolution DEMs, however, LIDAR is only available for small portions of river basins. DEMs generated from these technologies are high resolution. The resolution of the data influences the extraction of the channel network to a point where the same method produces different results for the same area. Garbrect and Martz (1994) applied several DEM resolutions to extract drainage properties and concluded that a DEM should have a grid cell area of less than 5% of the network reference area in order to reproduce important drainage features with about 10% accuracy.

Commonly today, floodplain mapping approaches use one- or two-dimensional hydraulic computer models to estimate water elevations. One-dimensional or two-dimensional numerical models are based on discharge observation at upstream and downstream locations of the floodplain reach. These models account for time-varying boundary conditions, floodplain roughness and hydraulic infrastructure such as bridges and levees. Flood Insurance Rate Maps (FIRMs), developed by the Federal Emergency Management Agency (FEMA) under the National Flood Insurance Program, are the most widely used flood inundation maps in the United States (U.S.). FIRMs show the inundation area produced by a 100-year discharge and are the foremost hydraulic resource used for developmental policy in the U.S. (Burby, 2001). Because the primary intent of FIRMs is to inform policy makers and developmental planners of flooding risk, they are limited in their usefulness in identifying management impacts to floodplain connectivity.

Two particular attributes of FIRMs—and hydraulic models in general—create challenges for assessing floodplain connectivity, especially at larger scales. First, hydraulic modeling can be data and computationally intensive (Jafarzadegan & Merwade, 2017). Using hydraulic modeling to characterize floodplain connectivity at large watershed scales, which is important for many hydrologic and ecological processes (Opperman et al., 2010) becomes infeasible. Second, inundation areas identified in FIRMs are the hydraulic products of human development of the floodplain, and therefore depict the *altered* floodplain area rather than the floodplain landscapes created by hydrogeomorphic processes within a watershed. In levee-protected areas hydraulic models do not estimate floodplain areas unless overtopping of the levees occur. Therefore, it is difficult to assess changes in fluvial connectivity using national flood datasets, such as FEMA FIRMs, and evaluate the implications for floodplain ecological resources.

Numerous hydrogeomorphic methods have been developed to circumvent the limitations of hydraulic floodplain delineation techniques. Hydrogeomorphic mapping is based on the assumption that Digital Terrain Models (DTMs) contain information about landform morphology (such as slope and elevation changes) that define the fluvial corridors. Mapping methods have been developed by Gallant and Dowling (2003), McGlynn and Seibert (2003), Dodov and Foufoula-Georgiou (2006), and Nardi *et al.* (2006). More recently, studies have incorporated geomorphic classifications (Manfreda et al., 2014; Manfreda, Sole, & Fiorentino, 2008; Samela, Troy, & Manfreda, 2017) and soil classifications (Sangwan & Merwade, 2015) to perform large-scale floodplain mapping. A benefit of these approaches is that floodplain delineation results are based on topographic or soils characteristics (Jafarzadegan & Merwade, 2017; Nardi *et al.*, 2013; Sangwan & Merwade, 2015) rather than hydraulic computations. This provides on opportunity to use hydrogeomorphic modeling to delineate floodplain landscapes across large regions and identify areas where hydraulically-derived inundation boundaries and hydrogeomorphic boundaries may differ due to floodplain modifications.

Floodplain Modifications from Levees

The construction of levees is a topographic modification that can control the extent of flooding by eliminating areas that were historically connected to rivers during overbank discharges. The elimination of floodplain area resulting from levee construction can have ecological implications, such as the disruption of lateral fluxes of sediment, nutrients, and organisms to sustain aquatic habitat and biotic productivity along rivers (Junk et al., 1989).

Human development within river corridors has either eliminated floodplains or fundamentally altered the connectivity between rivers and their floodplains (Ignacio *et al.*, 2015; Nardi *et al.*, 2015; Wohl, 2017). Determining the extent and degree of floodplain loss caused by levees can have important implications for riverine management and restoration.

Numerous recent studies have examined the ecological benefits of removing levees in riverine restoration efforts (e.g. Choi & Harvey, 2017; Nichols & Viers, 2017), though these studies focus on short segments of rivers rather than evaluating watershed-scale restoration potential. Recent work by Remo *et al.* (2017) highlights a tool for assessing the economic and ecological tradeoffs of removing levees to reconnect portions of a floodplain. Still, as watershed-scale improvements to rivers are increasingly being promoted (Bernhardt & Palmer, 2011; Wohl, 2015), more work is needed to assess geomorphic, ecological, and hydrologic alterations caused by levees beyond the reach scale.

Levee construction in the U.S. has been widespread, yet it is difficult to quantify the overall extent of levee construction because a comprehensive database does not exist (Wohl et al., 2017). The U.S. Army Corps of Engineers (USACE) National Levee Database (NLD) is the single best source of geospatial levee data in the U.S. (http://nld.usace.army.mil), though it primarily includes levees recognized by the USACE as providing protection against low-frequency, high risk flood events, such as the 100-year event. Despite the recognition that levees can eliminate floodplain areas that would otherwise be hydrologically connected to an adjacent river (for instance, FEMA removes areas protected by USACE levees from flood-hazard FIRMs), few studies have explored the role of levees in reducing floodplain areas, especially the cumulative impacts at large watershed scales. Examining the hydrologic effects of levees at a reach scale, Remo *et al.* (2009) demonstrated that levees reduced flooding inundation by 72-84%

in select sections of the Mississippi River, U.S. Similarly, Guida *et al.* (2015) showed that the hypothetical removal of levees along the Lower Tisza River in Hungary would reconnect nearly 95% of historical floodplain wetlands.

The detailed hydraulic models used in the aforementioned studies become impractical as the size of modeling domains increase (Jafarzadegan & Merwade, 2017), but hydrogeomorphic floodplain mapping techniques may help us understand the spatial distribution and variability of floodplain changes caused by levees at larger watershed scales.

LITERATURE CITED

Amoros, C. and G4. Bornette, 2002. Connectivity and Biocomplexity in Waterbodies of Riverine Floodplains. Freshwater Biology 47:761–776.

Bernhardt, E.S. and M.A. Palmer, 2011. River Restoration: The Fuzzy Logic of Repairing Reaches to Reverse Catchment Scale Degradation. Ecological Applications 21:1926–1931.

Burby, R.J., 2001. Flood Insurance and Floodplain Management: The US Experience. Global Environmental Change Part B: Environmental Hazards 3:111–122.

Choi, J. and J.W. Harvey, 2017. Predicting Outcomes of Restored Everglades High Flow: A Model System for Scientifically Managed Floodplains. Restoration Ecology 25:S39–S47.

Cleveland, W.S., 1979. Robust Locally Weighted Regression and Smoothing Scatterplots. Journal of the American Statistical Association 74:829–836.

Dodov, B.A. and E. Foufoula-Georgiou, 2006. Floodplain Morphometry Extraction From a High-Resolution Digital Elevation Model: A Simple Algorithm for Regional Analysis Studies. IEEE Geoscience and Remote Sensing Letters 3:410–413.

Gallant, J.C. and T.I. Dowling, 2003. A Multiresolution Index of Valley Bottom Flatness for Mapping Depositional Areas. Water Resources Research 39:1347.

Grimaldi, S., V. Teles, and R.L. Bras, 2004. Sensitivity of a Physically Based Method for Terrain Interpolation to Initial Conditions and Its Conditioning on Stream Location. Earth Surface Processes and Landforms 29:587–597.

Grimaldi, S., V. Teles, and R.L. Bras, 2005. Preserving First and Second Moments of the Slope Area Relationship during the Interpolation of Digital Elevation Models. Advances in Water Resources 28:583–588.

Guida, R.J., T.L. Swanson, J.W.F. Remo, and T. Kiss, 2015. Strategic Floodplain Reconnection for the Lower Tisza River, Hungary: Opportunities for Flood-Height Reduction and Floodplain-Wetland Reconnection. Journal of Hydrology 521:274–285.

Horner, G.J., P.J. Baker, R.M. Nally, S.C. Cunningham, J.R. Thomson, and F. Hamilton, 2010. Forest Structure, Habitat and Carbon Benefits from Thinning Floodplain Forests: Managing Early Stand Density Makes a Difference. Forest Ecology and Management 259:286–293.

Hunter, N.M., 2005. Development and Assessment of Dynamic Storage Cell Codes for Flood Inundation Modelling. University of Bristol.

Ignacio, J.A.F., G.T. Cruz, F. Nardi, and S. Henry, 2015. Assessing the Effectiveness of a Social Vulnerability Index in Predicting Heterogeneity in the Impacts of Natural Hazards: Case

Study of the Tropical Storm Washi Flood in the Philippines. Vienna Yearbook of Population Research 13:91–129.

Interagency Advisory Committee on Water Data, 1982. Guidelines for Determining Flood Flow Frequency: Bulletin 17-B of the Hydrology Subcommittee. U.S. Department of Interior Geological Survey, Office of Water Data Coordination, Reston, Virginia.

Jafarzadegan, K. and V. Merwade, 2017. A DEM-Based Approach for Large-Scale Floodplain Mapping in Ungauged Watersheds. Journal of Hydrology 550:650–662.

Jenson, S.K. and J.O. Domingue, 1988. Extracting Topographic Structure from Digital Elevation Data for Geographic Information System Analysis. Photogrammetric Engineering and Remote Sensing 54:1593–1600.

Junk, W., P. Bayley, and R. Sparks, 1989. The Flood Pulse Concept in River-Floodplain Systems. Proceedings of the International Large River Symposium (LARS). Canadian Special Publication of Fisheries and Aquatic Sciences, pp. 110–127.

Lane, C.R., A. Hall, E. D’Amico, N. Sangwan, and V. Merwade, 2017. Characterizing the Extent of Spatially Integrated Floodplain and Wetland Systems in the White River, Indiana, USA. JAWRA Journal of the American Water Resources Association 53:774–790.

Leopold, L.B. and T. Maddock Jr, 1953. The Hydraulic Geometry of Stream Channels and Some Physiographic Implications. U.S. Geological Survey.

Manfreda, S., F. Nardi, C. Samela, S. Grimaldi, A.C. Taramasso, G. Roth, and A. Sole, 2014. Investigation on the Use of Geomorphic Approaches for the Delineation of Flood Prone Areas. Journal of Hydrology 517:863–876.

Manfreda, S., A. Sole, and M. Fiorentino, 2008. Can the Basin Morphology Alone Provide an Insight into Floodplain Delineation? WIT Press, pp. 47–56.

McAllister, L.S., B.E. Peniston, S.G. Leibowitz, B. Abbruzzese, and J.B. Hyman, 2000. A Synoptic Assessment for Prioritizing Wetland Restoration Efforts to Optimize Flood Attenuation. Wetlands 20:70–83.

McGlynn, B.L. and J. Seibert, 2003. Distributed Assessment of Contributing Area and Riparian Buffering along Stream Networks. Water Resources Research 39:1082.

Nardi, F., A. Annis, and C. Biscarini, 2015. On the Impact of Urbanization on Flood Hydrology of Small Ungauged Basins: The Case Study of the Tiber River Tributary Network within the City of Rome. Journal of Flood Risk Management. doi:10.1111/jfr3.12186.

Nardi, F., C. Biscarini, S. Di Francesco, P. Manciola, and L. Ubertini, 2013. Comparing a Large-Scale DEM-Based Floodplain Delineation Algorithm with Standard Flood Maps: The Tiber River Basin Case Study. Irrigation and Drainage 62:11–19.

Nardi, F., S. Grimaldi, M. Santini, A. Petroselli, and L. Ubertini, 2008. Hydrogeomorphic Properties of Simulated Drainage Patterns Using Digital Elevation Models: The Flat Area Issue. Hydrological Sciences Journal 53:1176–1193.

Nardi, F., E.R. Vivoni, and S. Grimaldi, 2006. Investigating a Floodplain Scaling Relation Using a Hydrogeomorphic Delineation Method. Water Resources Research 42:W09409.

Nichols, A.L. and J.H. Viers, 2017. Not All Breaks Are Equal: Variable Hydrologic and Geomorphic Responses to Intentional Levee Breaches along the Lower Cosumnes River, California. River Research and Applications 33:1143–1155.

Opperman, J.J., R. Luster, B.A. McKenney, M. Roberts, and A.W. Meadows, 2010. Ecologically Functional Floodplains: Connectivity, Flow Regime, and Scale. JAWRA Journal of the American Water Resources Association 46:211–226.

Pyron, M. and K. Neumann, 2008. Hydrologic Alterations in the Wabash River Watershed, USA. River Research and Applications 24:1175–1184.

Remo, J.W.F., R.J. Guida, and S. Secchi, 2017. Screening the Suitability of Levee Protected Areas for Strategic Floodplain Reconnection Along the LaGrange Segment of the Illinois River, USA. River Research and Applications 33:863–878.

Remo, J.W.F., N. Pinter, and R. Heine, 2009. The Use of Retro- and Scenario-Modeling to Assess Effects of 100+ Years River of Engineering and Land-Cover Change on Middle and Lower Mississippi River Flood Stages. Journal of Hydrology 376:403–416.

Samela, C., T.J. Troy, and S. Manfreda, 2017. Geomorphic Classifiers for Flood-Prone Areas Delineation for Data-Scarce Environments. Advances in Water Resources 102:13–28.

Sangwan, N. and V. Merwade, 2015. A Faster and Economical Approach to Floodplain Mapping Using Soil Information. JAWRA Journal of the American Water Resources Association 51:1286–1304.

Strahler, A.N., 1952. Hypsometric (Area-Altitude) Analysis of Erosional Topology. Geological Society of America Bulletin 63:1117–1142.

Tarboton, D.G. and D.P. Ames, 2001. Advances in the Mapping of Flow Networks from Digital Elevation Data. American Society of Civil Engineers, pp. 1–10.

Tarboton, D.G., R.L. Bras, and I. Rodriguez-Iturbe, 1991. On the Extraction of Channel Networks from Digital Elevation Data. Hydrological Processes 5:81–100.

Tockner, K., D. Pennetzdorfer, N. Reiner, F. Schiemer, and J.V. Ward, 1999. Hydrological Connectivity, and the Exchange of Organic Matter and Nutrients in a Dynamic River–floodplain System (Danube, Austria). Freshwater Biology 41:521–535.

Tockner, K. and J.A. Stanford, 2002. Riverine Flood Plains: Present State and Future Trends. Environmental Conservation 29:308–330.

U.S. Army Corps of Engineers, 2011. Wabash River Watershed Section 729 Initial Watershed Assessment. U.S. Army Corps of Engineers Louisville District. http://www.lrl.usace.army.mil/Portals/64/docs/CWProjects/WabashStudy.pdf.

Wohl, E., S.N. Lane, and A.C. Wilcox, 2015. The Science and Practice of River Restoration. Water Resources Research 51:5974–5997.

Wohl, E., K.B. Lininger, and J. Baron, 2017. Land before Water: The Relative Temporal Sequence of Human Alteration of Freshwater Ecosystems in the Conterminous United States. Anthropocene 18:27–46.

Wolock, D.M. and C.V. Price, 1994. Effects of Digital Elevation Model Map Scale and Data Resolution on a Topography-Based Watershed Model. Water Resources Research 30:3041–3052.

APPENDIX B
Code

APPENDIX CONTENTS

1. R Code – code used to perform fit indices analysis
2. Hydrotools (python) –
    a. Hydrobase – DEM Preprocessing script
    b. Basin – Generates watershed
    c. Map Comparison – Determines A, B, and C parameters used in Fit Analyses
    d. Map Comparison by HUC10 – Determines A, B, and C parameters in each HUC10
    e. Floodplain Preprocessing – produces supplementary rasters needed in floodplain delineation
    f. Floodplain – Produces floodplain polygon and floodplain depth raster
    g. Levee Remover – smooths out elevation changes from levees

```
############################
####Initialize##############
############################
# Load packages
library(dataRetrieval)
library(ggplot2)
library(scales)

#set working directory
setwd("~/Documents/Research/R")

#import data
MaxStreamorder<-read.csv('HUCmaxStreamOrder.csv')
Findex.30<-read.csv('30m_result.csv')
Findex.10<-read.csv('10m_results_result.csv')
properties <- read.csv('30HUC_properties.txt')


#join data based on HUC
F_maxstreamorder_30 <- merge(x=MaxStreamorder,y=Findex.
30,by="HUC10",all=TRUE)
F_maxstreamorder_10 <- merge(x=MaxStreamorder,y=Findex.
10,by="HUC10",all=TRUE)
F_levee_30 <-merge(x=F_maxstreamorder_30,y=levee,by="HUC10",all=TRUE)
F_levee_10 <-merge(x=F_maxstreamorder_10,y=levee,by="HUC10",all=TRUE)

#boxplot of F index vs streamorder

F_maxstreamorder_30$StreamOrder<-factor(F_maxstreamorder_30$StreamOrder)
F1.box30 <-ggplot(F_maxstreamorder_30, aes(StreamOrder, F1)) + geom_boxplot()+
  scale_y_continuous(limits = c(0,1)) + theme(text = element_text(size=16)) +
xlab("Stream Order") + ylab("Conformity Index") + theme_bw()
F1.box30
ggsave("F1.box30.pdf", dpi = 300, width = 5, height = 3)

F_maxstreamorder_10$StreamOrder<-factor(F_maxstreamorder_10$StreamOrder)
F1.box10 <-ggplot(F_maxstreamorder_10, aes(StreamOrder, F1)) + geom_boxplot()+
  scale_y_continuous(limits = c(0,1)) + theme(text = element_text(size=16)) +
xlab("Stream Order") + ylab("Conformity Index") + theme_bw()
F1.box10
ggsave("F1.box10.pdf", dpi = 300, width = 5, height = 3)

F_maxstreamorder_30$StreamOrder<-factor(F_maxstreamorder_30$StreamOrder)
F2.box30 <-ggplot(F_maxstreamorder_30, aes(StreamOrder, F2)) + geom_boxplot()+
  scale_y_continuous(limits = c(-1,1)) + theme(text = element_text(size=16)) +
xlab("Stream Order") + ylab("F2 Index") + theme_bw()
F2.box30
```

```
#ggsave("F2.box30.pdf", width = 5, height = 3)

F_maxstreamorder_10$StreamOrder<-factor(F_maxstreamorder_10$StreamOrder)
F2.box10 <-ggplot(F_maxstreamorder_10, aes(StreamOrder, F2)) + geom_boxplot()+
  scale_y_continuous(limits = c(-1,1)) + theme(text = element_text(size=16)) +
xlab("Stream Order") + ylab("F2 Index") + theme_bw()
F2.box10
#ggsave("F2.box10.png", width = 5, height = 3)

F_maxstreamorder_30$StreamOrder<-factor(F_maxstreamorder_30$StreamOrder)
F3.box30 <-ggplot(F_maxstreamorder_30, aes(StreamOrder, F3)) + geom_boxplot()+
  scale_y_continuous(limits = c(-1,1)) + theme(text = element_text(size=16))+
xlab("Stream Order") + ylab("F3 Index")+ theme_bw()
F3.box30
#ggsave("F3.box30.png", width = 5, height = 3)

F_maxstreamorder_10$StreamOrder<-factor(F_maxstreamorder_10$StreamOrder)
F3.box10 <-ggplot(F_maxstreamorder_10, aes(StreamOrder, F3)) + geom_boxplot()+
  scale_y_continuous(limits = c(-1,1)) + theme(text = element_text(size=16))+
xlab("Stream Order") + ylab("F3 Index")+ theme_bw()
F3.box10
#ggsave("F3.box10.png", width = 5, height = 3)

F_maxstreamorder_30$StreamOrder<-factor(F_maxstreamorder_30$StreamOrder)
F_maxstreamorder_30$bias <- as.numeric(as.character(F_maxstreamorder_30$bias))
bias30<- ggplot(F_maxstreamorder_30, aes(StreamOrder, bias))+
geom_boxplot(outlier.shape = NA)+
  theme(text = element_text(size=16))+ xlab("Stream Order") + ylab("Bias") +
#scale_y_log10(breaks = trans_breaks("log10", function(x) 10^x), labels =
trans_format("log10", math_format(10^.x))) +
  theme_bw() +scale_y_continuous(limits = c(0,2))
bias30
ggsave("bias30.pdf", dpi = 300, width = 5, height = 3)

F_maxstreamorder_10$StreamOrder<-factor(F_maxstreamorder_10$StreamOrder)
F_maxstreamorder_10$bias <- as.numeric(as.character(F_maxstreamorder_10$bias))
bias10<- ggplot(F_maxstreamorder_10, aes(StreamOrder, bias))+
geom_boxplot(outlier.shape = NA)+
  theme(text = element_text(size=16))+ xlab("Stream Order") + ylab("Bias") +
#scale_y_log10(breaks = trans_breaks("log10", function(x) 10^x), labels =
trans_format("log10", math_format(10^.x))) +
  theme_bw() +scale_y_continuous(limits = c(0,2))
bias10
ggsave("bias10.pdf", dpi = 300, width = 5, height = 3)

#create boxplots of streamorder, F indices seperated by leveed and non-leveed HUC
```

```
levF330 <- ggplot(F_maxstreamorder_30, aes(StreamOrder, F3)) +
  geom_boxplot(aes(fill = Levee_Presence)) + labs(fill = "HUC10 Contains Levee:") +
  theme(legend.position="bottom", legend.text = element_text(size = 14), legend.title =
element_text(size = 14)) +
  theme(axis.text=element_text(size=16),
        axis.title=element_text(size=16)) +
  scale_fill_brewer(palette = "Set1", direction = -1) +
  scale_y_continuous(limits = c(-1,1)) +
  xlab("Stream Order") +
  ylab(expression(paste("F3 Index")))
levF330
#ggsave("levF330.png", width = 5, height = 3)

levF310 <- ggplot(F_maxstreamorder_10, aes(StreamOrder, F3)) +
  geom_boxplot(aes(fill = Levee_Presence)) + labs(fill = "HUC10 Contains Levee:") +
  theme(legend.position="bottom", legend.text = element_text(size = 14), legend.title =
element_text(size = 14)) +
  theme(axis.text=element_text(size=16),
        axis.title=element_text(size=16)) +
  scale_fill_brewer(palette = "Set1", direction = -1) +
  scale_y_continuous(limits = c(-1,1)) +
  xlab("Stream Order") +
  ylab(expression(paste("F3 Index")))
levF330
#ggsave("levF310.png", width = 5, height = 3)


levF230 <- ggplot(F_maxstreamorder_30, aes(StreamOrder, F2)) +
  geom_boxplot(aes(fill = Levee_Presence)) + labs(fill = "HUC10 Contains Levee:") +
  theme(legend.position="bottom", legend.text = element_text(size = 14), legend.title =
element_text(size = 14)) +
  theme(axis.text=element_text(size=16),
        axis.title=element_text(size=16)) +
  scale_fill_brewer(palette = "Set1", direction = -1) +
  scale_y_continuous(limits = c(-1,1)) +
  xlab("Stream Order") +
  ylab(expression(paste("F2 Index")))
levF230
#ggsave("levF230.png", width = 5, height = 3)

levF210 <- ggplot(F_maxstreamorder_10, aes(StreamOrder, F2)) +
  geom_boxplot(aes(fill = Levee_Presence)) + labs(fill = "HUC10 Contains Levee:") +
  theme(legend.position="bottom", legend.text = element_text(size = 14), legend.title =
element_text(size = 14)) +
  theme(axis.text=element_text(size=16),
        axis.title=element_text(size=16)) +
  scale_fill_brewer(palette = "Set1", direction = -1) +
```

```
  scale_y_continuous(limits = c(-1,1)) +
  xlab("Stream Order") +
  ylab(expression(paste("F2 Index")))
levF210
#ggsave("levF210.png", width = 5, height = 3)

levF130 <- ggplot(F_maxstreamorder_30, aes(StreamOrder, F1)) +
  geom_boxplot(aes(fill = Levee_Presence)) + labs(fill = "HUC10 Contains Levee:") +
  theme(axis.text=element_text(size=16),
        axis.title=element_text(size=16)) +
  theme_bw() +
  theme(legend.position="bottom", legend.text = element_text(size = 12), legend.title =
element_text(size = 12)) +
  scale_fill_brewer(palette = "Set1", direction = -1) +
  scale_y_continuous(limits = c(0,1)) +
  xlab("Stream Order") +
  ylab(expression(paste("Conformity Index")))
levF130
ggsave("levF130.pdf", dpi = 300, width = 5, height = 3)

levF110 <- ggplot(F_maxstreamorder_10, aes(StreamOrder, F1)) +
  geom_boxplot(aes(fill = Levee_Presence)) + labs(fill = "HUC10 Contains Levee:") +
  theme(axis.text=element_text(size=16),
        axis.title=element_text(size=16)) +
  theme_bw() +
  theme(legend.position="bottom", legend.text = element_text(size = 12), legend.title =
element_text(size = 12)) +
  scale_fill_brewer(palette = "Set1", direction = -1) +
  scale_y_continuous(limits = c(0,1)) +
  xlab("Stream Order") +
  ylab(expression(paste("Conformity Index")))
levF110
ggsave("levF110.pdf", dpi = 300, width = 5, height = 3)


levbias30 <- ggplot(F_maxstreamorder_30, aes(StreamOrder, bias)) +
  geom_boxplot(outlier.shape = NA, aes(fill = Levee_Presence)) + labs(fill = "HUC10
Contains Levee:") +
  theme(axis.text=element_text(size=16),
        axis.title=element_text(size=16)) +
  theme_bw()+
  theme(legend.position="bottom", legend.text = element_text(size = 12), legend.title =
element_text(size = 12)) +
  scale_fill_brewer(palette = "Set1", direction = -1) +
  scale_y_continuous(limits = c(0,3)) +
  #scale_y_log10(breaks = trans_breaks("log10", function(x) 10^x), labels =
trans_format("log10", math_format(10^.x))) +
```

```
  xlab("Stream Order") +
  ylab("Bias")
levbias30
ggsave("levbias30.pdf", dpi = 300, width = 5, height = 3)

levbias10 <- ggplot(F_maxstreamorder_10, aes(StreamOrder, bias)) +
  geom_boxplot(outlier.shape = NA, aes(fill = Levee_Presence)) + labs(fill = "HUC10
Contains Levee:") +
  theme(axis.text=element_text(size=16),
        axis.title=element_text(size=16)) +
  theme_bw()+
  theme(legend.position="bottom", legend.text = element_text(size = 12), legend.title =
element_text(size = 12)) +
  scale_fill_brewer(palette = "Set1", direction = -1) +
  scale_y_continuous(limits = c(0,3)) +
  #scale_y_log10(breaks = trans_breaks("log10", function(x) 10^x), labels =
trans_format("log10", math_format(10^.x))) +
  xlab("Stream Order") +
  ylab("Bias")
levbias10
ggsave("levbias10.pdf", dpi = 300, width = 5, height = 3)
```

```
#------------------------------------------
# HYDROBASE.py
# Description:
# From a given DEM, it:
# -Fills the DEM for hydrologic processing
# -Calculates sinks              - dem_sink
# -Calculates flow direction     - dem_dir
# -Calculates flow accumulartion - dem_acc
# -Extracts stream network and stream orders both in grid and
shapefile formats dem_ord
#------------------------------------------

#Import system modules
import sys, string, os, arcpy, math, traceback
from arcpy.sa import *

# Allow output to overwrite...
arcpy.env.overwriteOutput = True

# Check out the ArcGIS Spatial Analyst extension license
arcpy.CheckOutExtension("Spatial")


try:


#INPUTS-------------------------------------------------------------
-------------------

    DEM = arcpy.GetParameterAsText(0)       # DEM [meters] input grid
--> required
    bl_tresh = arcpy.GetParameterAsText(1)  # threshold area [Square
kilometers] for stream network
    FlagS=     arcpy.GetParameterAsText(2)  # Flag for calculating
sinks

    #Suffix for stream order layer
    sfx =  bl_tresh
    if "." in bl_tresh:
        sfx = sfx.replace(".","")


    # CREATING THE FOLDER FOR THE
OUTPUTS-----------------------------------------------------------
    DEM_name = os.path.basename(DEM).split('.')[0] #Name of DEM
    DEM_path = os.path.dirname(DEM)                #Path of DEM
    OutPath =DEM_path+"\\HYDROBASE"
    if not os.path.exists(OutPath):
        os.makedirs(OutPath)
```

```
    #OUTPUT FILES
NAME------------------------------------------------------------------
---
    #Permanent files
    SINK = OutPath + "\\"+ DEM_name + '_sink'             #SINKS GRID
    FILL = OutPath + "\\"+ DEM_name + '_fill'             #DEM FILLED
GRID
    FDIR = OutPath + "\\"+ DEM_name + '_dir'              #FLOW
DIRECTION GRID
    FACC = OutPath + "\\"+ DEM_name + '_acc'              #FLOW
ACCUMULATION
    CONA = OutPath + "\\"+ DEM_name + '_ca'
#CONTRIBUTING AREA GRID
    SORD = OutPath + "\\"+ DEM_name + '_ord' +sfx         #STREAM
ORDER GRID
    SLIN = OutPath + "\\"+ DEM_name + '_bl' +sfx + '.shp' #STREAM LINE
SHP
    #temporary file names
    FDIR1 = OutPath + "\\" +DEM_name  + '_dir1'           #first FLOW
DIRECTION computation, before FILLING,
    STREAM = OutPath+ "\\" + DEM_name + '_stream'         #stream
network without order


    #-------------------------START
--------------------------------------------------------------

    arcpy.AddMessage('-----------------------------------------')
    arcpy.AddMessage('HYDROBASE CALCULATION')

    arcpy.env.extent = DEM
    arcpy.env.mask = DEM

    #get the cellsize of DEM grid
    pixelsize = float( arcpy.GetRasterProperties_management (DEM,
"CELLSIZEX").getOutput(0) )
    cellarea = pixelsize ** 2
    # define cell size and extension for raster calculator
    arcpy.env.cellSize = pixelsize
    arcpy.AddMessage(FlagS)
    if FlagS =="true" :
        arcpy.AddMessage(' ')
        arcpy.AddMessage(' - Computing Flow direction...')
        outFD= FlowDirection(DEM)
        outFD.save(FDIR1)
        arcpy.AddMessage(' - Computing Sinks...')
        outSK= Sink(FDIR1)
        outSK.save(SINK)
        arcpy.Delete_management(FDIR1)
```

```
    #fill the raw DEM
    if not arcpy.Exists(FILL):
        arcpy.AddMessage(' - Computing DEM Filling...')
        outFill = Fill (DEM)
        outFill.save(FILL)
        arcpy.AddMessage(' - Computing Flow Direction...')
        #calculate the new FLOW DIRECTION
        outFD = FlowDirection(FILL)
        outFD.save(FDIR)
        arcpy.AddMessage(' - Computing Flow Accumulation...')
        outFac = FlowAccumulation(FDIR)
        outFac.save(FACC)

    #calculate the CONTRIBUTING AREA
    outTimes = Raster(FACC) * cellarea
    outTimes.save(CONA)
    # treshold area in m^2
    bl_tresh = float(bl_tresh) * 1000000

    # Extracting stream network
    arcpy.AddMessage(' - Computing Stream Network...')
    outSN = SetNull (CONA, 1,  "VALUE < %f" % bl_tresh )
    outSN.save(STREAM)
    # Calculating stream order grid
    arcpy.AddMessage(' - Computing Stream Order...')
    outSO = StreamOrder(STREAM, FDIR)
    outSO.save(SORD)
    # calculation of stream network shape file
    arcpy.AddMessage(' - Converting Stream to Feature...')
    StreamToFeature(SORD, FDIR, SLIN)

    arcpy.Delete_management(STREAM)
    arcpy.Delete_management(CONA)
    arcpy.AddMessage(' ')
    arcpy.AddMessage('HYDROBASE COMPLETED!')


#----------------------------------------------------------------------
------------------------------


except:
    arcpy.AddError(arcpy.GetMessages())
    arcpy.AddMessage(traceback.format_exc())
    #print arcpy.GetMessages()
```

```
#--------------------------------------------
#  Sub_Basins.py
#
#
#--------------------------------------------

#Import system modules
import sys, string, os, arcpy, math, traceback
from arcpy.sa import *

# Allow output to overwrite...
arcpy.env.overwriteOutput = True

# Check out the ArcGIS Spatial Analyst extension license
arcpy.CheckOutExtension("Spatial")

try:


    #INPUT ARGIMENTS
    DEM =        arcpy.GetParameterAsText(0)     # DEM Name
    Nodes =      arcpy.GetParameterAsText(1)     # Node of the Outlet
    Folder =     arcpy.GetParameterAsText(2)     # Folder Name for the 
results
    Basin_name = arcpy.GetParameterAsText(3)     # Short Name of the 
Basin
    SuffixOrd =  arcpy.GetParameterAsText(4)     # suffix for the 
stream order network



    if "." in SuffixOrd:
        SuffixOrd = SuffixOrd.replace(".","")

    #GETTING THE NAME OF THE DEM
    DEM_name = os.path.basename(DEM).split('.')[0]
    DEM_path = os.path.dirname(DEM)


    #GETTING FILES
    hydrobase_path = DEM_path +"\\HYDROBASE"
#HYDROBASE PATH
    FILL= hydrobase_path + "\\"+ DEM_name + "_fill"
#FLOW DIRECTION
    FD= hydrobase_path + "\\"+ DEM_name + "_dir"
#FLOW DIRECTION
    FA= hydrobase_path + "\\"+ DEM_name + "_acc"
#FLOW ACCUMULATION
    SORD  = hydrobase_path + "\\" + DEM_name + "_ord" + SuffixOrd
#STREAM ORDER
```

```
    SL = hydrobase_path + "\\" + DEM_name + "_bl" + SuffixOrd +".shp"
#STREAM LINE

    #OUTPUTFOLDER
    SB_path= DEM_path + "\\" + Folder + "\\BASIN"
    #Creating the new folder
    if not os.path.exists(SB_path):
        os.makedirs(SB_path)

    #OUTPUT FILES
    WAT_GRD = SB_path + "\\"+ Basin_name + "_sb"
    WAT_SB = SB_path + "\\"+ Basin_name + "_sb.shp"
    FD_SB = SB_path + "\\" +Basin_name + "_dir"
    DEM_SB = SB_path + "\\" +Basin_name
    FILL_SB = SB_path + "\\" +Basin_name+ "_fill"
    ACC_SB = SB_path + "\\" +Basin_name + "_acc"
    SORD_SBG = SB_path + "\\"+ Basin_name + "_ord"+ SuffixOrd
    SORD_SB = SB_path + "\\" +Basin_name + "_bl" + SuffixOrd +".shp"
    Nodes_SB1 = SB_path + "\\"+ Basin_name + "_node.shp"

    arcpy.Copy_management(Nodes, Nodes_SB1)

    pixelsize = float(arcpy.GetRasterProperties_management(DEM,
"CELLSIZEX").getOutput(0) )
    #Calculating the area of the cell
    arcpy.env.cellSize = pixelsize


    #Extension enviroment
    arcpy.env.extent = DEM

    arcpy.AddMessage('')
    arcpy.AddMessage('-----------------------------------------')
    arcpy.AddMessage('BASIN MODULE STARTED')
    arcpy.AddMessage(' ')

    arcpy.AddMessage(' - Delineating Watersheds...')
    outWat = Watershed(FD, Nodes_SB1,  "Id")
    outWat.save(WAT_GRD)
    # Convert raster watershed to polygon
    arcpy.AddMessage(' - Converting Watershed Grid to Polygon...')
    arcpy.RasterToPolygon_conversion(WAT_GRD, WAT_SB)

    #GIVING THE NAMES TO THE SUBBASINS SHAPE
    arcpy.DeleteField_management(WAT_SB,"GRIDCODE")
    arcpy.AddField_management(WAT_SB, "Name", "TEXT")
    arcpy.CalculateField_management(WAT_SB, "Name", "'%s'" %Folder,
"PYTHON")
    arcpy.AddField_management(WAT_SB, "Code", "TEXT")
    arcpy.CalculateField_management(WAT_SB, "Code", "'%s'"
```

```
%Basin_name, "PYTHON")


    #CALCULATING AREAS OF THE SUBBASINS
    #Add the field AREA to the basin shape file
    arcpy.AddField_management(WAT_SB, "AREA", "float")
    #calculate area [square kilometers] to the basin shape file
    arcpy.CalculateField_management(WAT_SB, "AREA", "!
shape.area@squarekilometers!", "PYTHON")


    #CHECK THE NUMBER OF WATERSHED
    n_Wat= int(arcpy.GetCount_management(WAT_SB).getOutput(0) )

    if n_Wat > 1:
        arcpy.AddMessage(' - Deleting errors of watersheds')
        # Create a table view and select records to be deleted
        arcpy.MakeTableView_management(WAT_SB, "tv")
        query = 'AREA < 0.01'
        arcpy.SelectLayerByAttribute_management("tv", "NEW_SELECTION",
query)
        # Delete selected records
        arcpy.DeleteRows_management("tv")


    cursor = arcpy.da.SearchCursor(WAT_SB, ["AREA", "ID"])
    for row in cursor:
        Area=row[0]
    del cursor, row

    #Extension enviroment
    arcpy.env.extent = WAT_GRD
    #Mask for the calculation
    arcpy.env.mask = WAT_GRD


    if not arcpy.Exists(DEM_SB):

        arcpy.AddMessage(' - Clipping DEM grid...')
        outEBM = ExtractByMask(DEM, WAT_GRD)
        outEBM.save(DEM_SB)

    if not arcpy.Exists(FILL_SB):
        outEBM = ExtractByMask(FILL, WAT_GRD)
        outEBM.save(FILL_SB)

    if not arcpy.Exists(FD_SB):
        arcpy.AddMessage(' - Clipping Flow Drection Grid...')
        outEBM = ExtractByMask(FD, WAT_GRD)
        outEBM.save(FD_SB)
```

```
        arcpy.AddMessage(' - Clipping Flow Accumulation Grid...')
        outEBM = ExtractByMask(FA, WAT_GRD)
        outEBM.save(ACC_SB)


    arcpy.AddMessage(' - Clipping Stream order Grid...')
    outEBM = ExtractByMask(SORD, WAT_GRD)
    outEBM.save(SORD_SBG)

    #Clipping stream network on watershed
    arcpy.AddMessage(' - Clipping stream network...')
    arcpy.Clip_analysis(SL, WAT_SB, SORD_SB )



    #GIVING THE RESULTS FOR Nodes Shape
    arcpy.AddField_management (Nodes_SB1, "Name", "TEXT")
    arcpy.CalculateField_management(Nodes_SB1, "Name", "'%s'" %Folder,
"PYTHON")
    arcpy.AddField_management (Nodes_SB1, "Code", "TEXT")
    arcpy.CalculateField_management(Nodes_SB1, "Code", "'%s'"
%Basin_name, "PYTHON")
    arcpy.AddField_management (Nodes_SB1, "AREA", "float")
    cursor = arcpy.da.UpdateCursor(Nodes_SB1,["AREA"])
    # loop for the rows
    for row in cursor:
        row[0]=  Area
        cursor.updateRow(row)
    # Delete cursor and row objects to remove locks on the data
    del cursor, row


    arcpy.Delete_management(WAT_GRD)


    arcpy.AddMessage(' ')
    arcpy.AddMessage('BASIN MODULE COMPLETED!')
except:

    arcpy.AddError(arcpy.GetMessages())
    arcpy.AddMessage(traceback.format_exc())
    #print arcpy.GetMessages()
```

```
#-------------------------------------------
#  Numerical Comparison of  maps using an objective function F
#
#
#-------------------------------------------

#Import system modules
from __future__ import division
import sys, string, os, arcpy, math, traceback, glob
from arcpy.sa import *

# Allow output to overwrite...
arcpy.env.overwriteOutput = True

# Check out the ArcGIS Spatial Analyst extension license
arcpy.CheckOutExtension("Spatial")

try:


    #INPUT ARGIMENTS
    path  =   arcpy.GetParameterAsText(0)       # Workpath
    Name  =   arcpy.GetParameterAsText(1)       # Map Name
    F_ref =   arcpy.GetParameterAsText(2)       # Flooded area
reference
    F_com_string = arcpy.GetParameterAsText(3)  # List of the Flooded
area to be compared
    DEM=  arcpy.GetParameterAsText(4)           # Reference raster for
rasterizing the maps



    #OUTPUT FILES
    DFRM= path +"\\dfrm"                        #Rasterized compared
map
    FPL = path +"\\FPL"                         #Rasterized FLoodplain
map
    A_map=  path +"\\A"                         #Intersection of
reference and comparing maps
    B_map=  path +"\\B"                         #Flooded area only in
reference  map
    C_map=  path +"\\C"                         #Flooded area only in
comparing map
    STAT_A= path +"\\"+ Name + '_StatA.dbf'     #Statistics with the
sum of the feature areas in A_map
    STAT_B= path +"\\"+ Name + '_StatB.dbf'     #Statistics with the
sum of the feature areas in B_map
    STAT_C= path +"\\"+ Name + '_StatC.dbf'     #Statistics with the
sum of the feature areas in C_map
    RES   = path +"\\"+ Name + '_result.csv'    #Results
```

```
    #VARIABLES
    F_com_name = []                             #Name of Flooded area
to be compared
    A_list= []                                  #List of the sum of the
areas of the A_map
    B_list= []                                  #List of the sum of the
areas of the B_map
    C_list= []                                  #List of the sum of the
areas of the C_map
    F1_list= []                                 #List of the F1
Objective Functions
    F2_list= []                                 #List of the F2
Objective Functions
    F3_list= []                                 #List of the F3
Objective Functions
    TP_list= []                                 #List of the True
positives rates


    F_com_list = F_com_string.split(";")          #Vector list of
Flooded areas to be compared
    n_F=len(F_com_list)                           #Number of flooded
areas to be compared
    arcpy.env.extent=DEM
    pixelsize = float(arcpy.GetRasterProperties_management (DEM,
"CELLSIZEX").getOutput(0) )
    arcpy.PolygonToRaster_conversion(F_ref, "Id", DFRM,
"MAXIMUM_AREA", "NONE", pixelsize)

    R = open(RES, 'w')
    R.write('%s;%s;%s;%s;%s;%s;%s;%s\n' %
('Name','A','B','C','F1','F2','F3','TP rate') )
    R.close()

    #CICLE FOR EACH FLOODED MAP TO BE COMPARED
    for k in range(n_F):
        arcpy.AddMessage(' ')
        arcpy.AddMessage('Comparing map %s of %s' % (k+1,n_F))
        A= 0                                        #Sum of the areas
of the A_map
        B= 0                                        #Sum of the areas
of the B_map
        C= 0                                        #Sum of the areas
of the C_map
        #READING EACH FLOOD MAP TO BE COMPARED
        F_com_name.append(os.path.basename(F_com_list[k][:-4]))
        F_com=F_com_list[k]
        arcpy.PolygonToRaster_conversion(F_com, "Id", FPL,
"MAXIMUM_AREA", "NONE", pixelsize)
```

```
#CREATING FLOOD AREAS COMPARISON
#Intersection of reference and comparing flood map
arcpy.env.extent=DEM
outEBM = ExtractByMask(DFRM, F_com)
outEBM.save(A_map)
#Flooded area only in reference flood map
arcpy.env.extent=DFRM
arcpy.env.mask = DFRM
outCon = Con(IsNull(FPL),DFRM)
outCon.save(C_map)
#Flooded area only in comparing flood map
arcpy.env.extent=FPL
arcpy.env.mask = FPL
outCon = Con(IsNull(DFRM),FPL)
outCon.save(B_map)
#CALCULATING RESPECTIVE AREAS
#adding area field
ca=pixelsize**2
rows = arcpy.SearchCursor( A_map )
for row in rows:
    A = row.getValue( "COUNT" )*ca
del row
del rows
rows = arcpy.SearchCursor( B_map )
for row in rows:
    B = row.getValue( "COUNT" )*ca
del row
del rows
rows = arcpy.SearchCursor( C_map )
for row in rows:
    C = row.getValue( "COUNT" )*ca
del row
del rows



#CALCULATIONG MEASUREMENT INDEXES
F1 = A / (A + B + C )
F2 = (A - B) / (A + B + C )
F3 = (A - C) / (A + B + C )
TP= A / (A+C)

A_list.append(A)
B_list.append(B)
C_list.append(C)
F1_list.append(F1)
F2_list.append(F2)
F3_list.append(F3)
TP_list.append(TP)
```

```
        #DELETING FILES
        #arcpy.Delete_management(A_map)
        #arcpy.Delete_management(B_map)
        #arcpy.Delete_management(C_map)
        arcpy.Delete_management(FPL)

#----------------------------------------------------------------
        arcpy.AddMessage('Comparison of map %s of %s COMPLETED!' %
(k+1,n_F))
        #WRITING THE RESULTS
        R = open(RES, 'a')
        R.write('%s;%.0f;%.0f;%.0f;%6.3f;%.3f;%.3f;%.3f\n' %
(F_com_name[k],A_list[k],B_list[k],C_list[k],F1_list[k],F2_list[k],F3_
list[k],TP_list[k]))
        R.close()

    arcpy.Delete_management(DFRM)

except:

    arcpy.AddError(arcpy.GetMessages())
    arcpy.AddMessage(traceback.format_exc())
```

```
#-------------------------------------------
#  Numerical Comparison of  maps using an objective function F
#
#
#-------------------------------------------

#Import system modules
from __future__ import division
import sys, string, os, arcpy, math, traceback, glob,numpy
from arcpy.sa import *

# Allow output to overwrite...
arcpy.env.overwriteOutput = True

# Check out the ArcGIS Spatial Analyst extension license
arcpy.CheckOutExtension("Spatial")

try:


    #INPUT ARGIMENTS
    path  =   arcpy.GetParameterAsText(0)       # Workpath
    Name  =   arcpy.GetParameterAsText(1)       # Map Name
    F_ref =   arcpy.GetParameterAsText(2)       # Flooded area
reference
    F_com_string = arcpy.GetParameterAsText(3)  # List of the Flooded
area to be compared
    DEM=  arcpy.GetParameterAsText(4)           # Reference raster for
rasterizing the maps
    HUC= arcpy.GetParameterAsText(5)            # HUC10 for the
analysis



    #OUTPUT FILES
    DFRM= path +"\\dfrm"                        #whole Rasterized
compared map
    FPL = path +"\\FPL"                         #wole Rasterized
FLoodplain map
    DFRMi= path +"\\dfrmi"                      # Rasterized  compared
map for the i-HUC10
    FPLi = path +"\\FPLi"                       # Rasterized
FLoodplain map for the i-HUC10
    A_map=  path +"\\A"                         #Intersection of
reference and comparing maps
    B_map=  path +"\\B"                         #Flooded area only in
reference  map
    C_map=  path +"\\C"                         #Flooded area only in
comparing map
    STAT_A= path +"\\"+ Name + '_StatA.dbf'     #Statistics with the
```

```
sum of the feature areas in A_map
    STAT_B= path +"\\"+ Name + '_StatB.dbf'     #Statistics with the
sum of the feature areas in B_map
    STAT_C= path +"\\"+ Name + '_StatC.dbf'     #Statistics with the
sum of the feature areas in C_map
    RES   = path +"\\"+ Name + '_result.csv'    #Results

    #VARIABLES
    F_com_name = []                            #Name of Flooded area
to be compared

    #GETTING THE CODES OF THE HUC10
    nB  = int(arcpy.GetCount_management(HUC).getOutput(0)) #Number of
basins
    rows = arcpy.da.SearchCursor(HUC, "HUC10")
    Codes=[]
    HUC10s=[]

    for row in rows:
        Codes.append(str(row[0]))
    del row
    del rows

    arcpy.MakeFeatureLayer_management(HUC,"lyr")

    for i in range(nB):

        HUC10s.append(path+"\\"+Codes[i]+".shp")
        sel_con = "HUC10 = '%s'" % (Codes[i])
        arcpy.SelectLayerByAttribute_management("lyr",
"NEW_SELECTION", sel_con)
        arcpy.CopyFeatures_management("lyr", HUC10s[i])



    F_com_list = F_com_string.split(";")         #Vector list of
Flooded areas to be compared
    n_F=len(F_com_list)                          #Number of flooded
areas to be compared
    arcpy.env.extent=DEM
    pixelsize = float(arcpy.GetRasterProperties_management (DEM,
"CELLSIZEX").getOutput(0) )
    arcpy.PolygonToRaster_conversion(F_ref, "Id", DFRM,
"MAXIMUM_AREA", "NONE", pixelsize)

    A_list= numpy.zeros((nB,n_F))                  #List of the sum of
the areas of the A_map
    B_list= numpy.zeros((nB,n_F))                  #List of the sum of
the areas of the B_map
    C_list= numpy.zeros((nB,n_F))                  #List of the sum of
```

```
the areas of the C_map
    F1_list=numpy.zeros((nB,n_F))                  #List of the F1
Objective Functions
    F2_list=numpy.zeros((nB,n_F))                  #List of the F2
Objective Functions
    F3_list=numpy.zeros((nB,n_F))                  #List of the F3
Objective Functions
    TP_list=numpy.zeros((nB,n_F))                  #List of the True
positives rates

    R = open(RES, 'w')
    R.write('%s;%s;%s;%s;%s;%s;%s;%s;%s\n' %
('HUC10','Name','A','B','C','F1','F2','F3','TP rate') )
    R.close()

    #CICLE FOR EACH FLOODED MAP AND HC10 TO BE COMPARED
    for i in range (nB):
        arcpy.env.extent=HUC10s[i]
        arcpy.env.mask = HUC10s[i]
        outEBM = ExtractByMask(DFRM, HUC10s[i])
        outEBM.save(DFRMi)

        for k in range(n_F):
            arcpy.AddMessage(' ')
            arcpy.AddMessage('HUC10:%s, Comparing map %s of %s' %
(Codes[i],k+1,n_F))
            A= 0                                    #Sum of the
areas of the A_map
            B= 0                                    #Sum of the
areas of the B_map
            C= 0                                    #Sum of the
areas of the C_map
            #READING EACH FLOOD MAP TO BE COMPARED
            F_com_name.append(os.path.basename(F_com_list[k][:-4]))
            F_com=F_com_list[k]
            arcpy.env.extent=HUC10s[i]
            arcpy.env.mask = HUC10s[i]
            arcpy.PolygonToRaster_conversion(F_com, "Id", FPL,
"MAXIMUM_AREA", "NONE", pixelsize)

            outEBM = ExtractByMask(FPL, HUC10s[i])
            outEBM.save(FPLi)

            try:
                #CREATING FLOOD AREAS COMPARISON
                #Intersection of reference and comparing flood map
                arcpy.env.extent=HUC10s[i]
                outEBM = ExtractByMask(DFRMi, F_com)
                outEBM.save(A_map)
                #Flooded area only in reference flood map
```

```
arcpy.env.extent=DFRMi
arcpy.env.mask = DFRMi
outCon = Con(IsNull(FPLi),DFRMi)
outCon.save(C_map)
#Flooded area only in comparing flood map
arcpy.env.extent=FPLi
arcpy.env.mask = FPLi
outCon = Con(IsNull(DFRMi),FPLi)
outCon.save(B_map)
#CALCULATING RESPECTIVE AREAS
#adding area field
ca=pixelsize**2
rows = arcpy.SearchCursor( A_map )
for row in rows:
    A = row.getValue( "COUNT" )*ca
del row
del rows
rows = arcpy.SearchCursor( B_map )
for row in rows:
    B = row.getValue( "COUNT" )*ca
del row
del rows
rows = arcpy.SearchCursor( C_map )
for row in rows:
    C = row.getValue( "COUNT" )*ca
del row
del rows



#CALCULATIONG MEASUREMENT INDEXES
F1 = A / (A + B + C )
F2 = (A - B) / (A + B + C )
F3 = (A - C) / (A + B + C )
TP= A / (A+C)

A_list[i,k]=A
B_list[i,k]=B
C_list[i,k]=C
F1_list[i,k]=F1
F2_list[i,k]=F2
F3_list[i,k]=F3
TP_list[i,k]=TP

#DELETING FILES
arcpy.Delete_management(A_map)
arcpy.Delete_management(B_map)
arcpy.Delete_management(C_map)
arcpy.Delete_management(FPL)
arcpy.Delete_management(FPLi)
```

```
            except:
                A_list[i,k]=0
                B_list[i,k]=0
                C_list[i,k]=0
                F1_list[i,k]=0
                F2_list[i,k]=0
                F3_list[i,k]=0
                TP_list[i,k]=0


#----------------------------------------------------------------
            #WRITING THE RESULTS
            R = open(RES, 'a')
            R.write('%s;%s;%.0f;%.0f;%.0f;%6.3f;%.3f;%.3f;%.3f\n' %
(Codes[i],F_com_name[k],A_list[i,k],B_list[i,k],C_list[i,k],F1_list[i,
k],F2_list[i,k],F3_list[i,k],TP_list[i,k]))
            R.close()

        arcpy.Delete_management(DFRMi)
        arcpy.Delete_management(HUC10s[i])

    arcpy.Delete_management(DFRM)

except:

    arcpy.AddError(arcpy.GetMessages())
    arcpy.AddMessage(traceback.format_exc())
```

```
#-------------------------------------------
#  Floodplain Pre-processing Tool:
#  2 Inputs:
#   - The Path oming from the Basin Analysis (i.e. C:\Documents\Wabash
where inside you have the BASIN folder)
#   - The threshold area used for the stream network
#  4 Outputs in the folder FLOODPLAIN\PRE+Threshold Suffix:
#   - The flow accumulation only in the stream network (Suffix: -
accblc)
#   - The DEM raster (in centimeters) in which each cell elevation is
subtracted by the elevation of the hydrologically connected stream
elevation (Suffix: -diff)
#   - The stream newtowk raster with the values of the hortonian
stream order (Suffix: -word)
#   - The polygon to whic the stream order is assigned (Suffix: -
wsord.shp)
#-------------------------------------------

#Import system modules
import sys, string, os, arcpy, math, traceback, glob, numpy
from arcpy.sa import *

# Allow output to overwrite...
arcpy.env.overwriteOutput = True

# Check out the ArcGIS Spatial Analyst extension license
arcpy.CheckOutExtension("Spatial")

try:


    #INPUT ARGIMENTS
    FolderPath = arcpy.GetParameterAsText(0)
    bl_tresh =  arcpy.GetParameterAsText(1)     # treshold area in km2
for stream network

    B_path = FolderPath +"\\BASIN"
    os.chdir(B_path)

    #Getting basin code
    os.chdir(B_path)
    Code = glob.glob("*acc")[0][:-4]


    suff_ord =  bl_tresh
    if "." in bl_tresh:
        suff_ord = suff_ord.replace(".","")

    #GETTING FILES
    DEM= B_path + "\\"+ Code                                #DEM
```

```
    FILL= B_path + "\\"+ Code  + "_fill"                        #FILLED
DEM
    FACC= B_path + "\\"+ Code + "_acc"                          #FLOW
ACCUMULATION
    FD= B_path + "\\"+ Code + "_dir"                            #FLOW
DIRECTION
    SORD  = B_path + "\\" + Code + "_ord" + suff_ord        #STREAM
ORDER
    SL_SB = B_path + "\\" + Code + "_bl" + suff_ord +".shp" #STREAM
LINE

    #Get the pixelsize
    pixelsize = float(arcpy.GetRasterProperties_management (DEM,
"CELLSIZEX").getOutput(0) )
    cellarea = pixelsize ** 2                              #calculate
the cell area

    #OUTPUTFOLDER
    FPP_path= FolderPath +"\\FLOODPLAIN\\PRE"+ suff_ord
    #Creating the new folder
    if not os.path.exists(FPP_path):
        os.makedirs(FPP_path)

    #OUTPUT FILES
    DEM_BL = FPP_path + "\\"+ Code + "_bldem"
    DEM_BLcm = FPP_path + "\\"+ Code + "_bldemc"
    DEM_BLWAT = FPP_path + "\\"+ Code + "_blwat"
    DEM_DIFF = FPP_path + "\\"+ Code + "_diff"
    ACC_BL = FPP_path + "\\"+ Code + "_accbl"
    ACC_BLC = FPP_path + "\\"+ Code + "_accblc"
    WAT_ORD = FPP_path + "\\"+ Code + "_word"
    WAT_SORD = FPP_path + "\\"+ Code + "_wsord.shp"


    #Calculating the area of the cell
    arcpy.env.cellSize = pixelsize

    #Extension enviroment
    arcpy.env.extent = DEM

    arcpy.AddMessage('')
    arcpy.AddMessage('--------------------------------------------')
    arcpy.AddMessage('FLOODPLAIN PREPROCESSING')
    arcpy.AddMessage(' ')


    #Mask for the calculation
    arcpy.env.mask = DEM

    bl_tresh = float(bl_tresh) * 1000000
```

```
    outA = SetNull (FACC, FACC,  "VALUE < %f" % (bl_tresh/cellarea) )
    outA.save(ACC_BL)

    outAC = Raster(ACC_BL)∗cellarea
    outAC.save(ACC_BLC)

    outBD = SetNull (FACC, FILL,  "VALUE < %f" % (bl_tresh/cellarea) )
    outBD.save(DEM_BL)

    outBDc = Raster(DEM_BL) ∗ 100
    outBDc.save(DEM_BLcm)

    outW = Watershed(FD, DEM_BLcm,  "VALUE")
    outW.save(DEM_BLWAT)

    outD = Raster(FILL)∗100 − Raster(DEM_BLWAT)
    outD.save(DEM_DIFF)

    outW = Watershed(FD, SORD,  "VALUE")
    outW.save(WAT_ORD)

    arcpy.RasterToPolygon_conversion(WAT_ORD, WAT_SORD,"NO_SIMPLIFY")

    arcpy.Delete_management(ACC_BL)
    arcpy.Delete_management(DEM_BL)
    arcpy.Delete_management(DEM_BLcm)
    arcpy.Delete_management(DEM_BLWAT)

    arcpy.AddMessage(' ')
    arcpy.AddMessage('FLOODPLAIN PREPROCESSING  COMPLETED!')
except:

    arcpy.AddError(arcpy.GetMessages())
    arcpy.AddMessage(traceback.format_exc())
```

```
#-------------------------------------------
#  Floodplain Tool
#  5 Inputs:
#    - The Basin Path (the same of the one assigned for the pre-
processing
#    - The Leopold "a" parameter"
#    - The Leopold "b" parameter"
#    - The suffix of the simulation
#    - The threshold area for delineating the stream network
#  3 Outputs:
#    - The dissolved floodplain polygon
#    - The floodplain polygon splitted by the stream orders
#    - The raster of the floodplain polygon (with the depths (cm))
#-------------------------------------------

#Import system modules
from __future__ import division
import sys, string, os, arcpy, math, traceback, glob
from arcpy.sa import *

# Allow output to overwrite...
arcpy.env.overwriteOutput = True

# Check out the ArcGIS Spatial Analyst extension license
arcpy.CheckOutExtension("Spatial")

try:


    #INPUT ARGIMENTS
    path =   arcpy.GetParameterAsText(0)             # Basin path
    a     =  float(arcpy.GetParameterAsText(1))      # Leopold a
parameter
    b     =  float(arcpy.GetParameterAsText(2))      # Leopold b
parameter
    suff  =  arcpy.GetParameterAsText(3)             # suffix ogf the
simulation
    bl_tresh =  arcpy.GetParameterAsText(4)     # treshold area in km2
for stream network

    suff_ord =  bl_tresh
    if "." in bl_tresh:
        suff_ord = suff_ord.replace(".","")

    FPP_path= path + "\\FLOODPLAIN\\PRE"+ suff_ord
    B_path=path + "\\BASIN"
    #GETTING FILES
    os.chdir(B_path)
    Code = glob.glob("*acc")[0][:-4]
    FACC = B_path + "\\"+ Code + "_acc"
```

```
    FD = B_path + "\\"+ Code + "_dir"
    DEM = B_path + "\\"+ Code + "_fill"
    ACC_BLC = FPP_path + "\\"+ Code + "_accblc"
    DEM_DIFF = FPP_path + "\\"+ Code + "_diff"
    WAT_SORD = FPP_path + "\\"+ Code + "_wsord.shp"


    #Getting DEM pixelsize
    pixelsize_ob = arcpy.GetRasterProperties_management (DEM,
"CELLSIZEX")#get the cellsize of SINK grid
    pixelsize = float( pixelsize_ob.getOutput(0) )
    cellarea = pixelsize ** 2                            #calculate
the cell area

    #OUTPUT FILES

    FP_path = path + "\\FLOODPLAIN\\FPL"+ suff_ord
    if not os.path.exists(FP_path):
        os.makedirs(FP_path)

    WAT_FL = FP_path + "\\"+ Code + "_watfl"
    WAT_HGD = FP_path + "\\"+ Code + "_wathgd"
    FPL_GRD = FP_path + "\\"+ Code + "_fpl" + suff
    FPL1 = FP_path + "\\"+ Code + "_fpl1" + suff + ".shp"
    FPL2 = FP_path + "\\"+ Code + "_fp2" + suff + ".shp"
    FPL = FP_path + "\\"+ Code + "_fpl" + suff + ".shp"
    FPL_ORD = FP_path + "\\"+ Code + "_fpl" + suff + "_ord.shp"

    arcpy.AddMessage('')
    arcpy.AddMessage('-----------------------------------------')
    arcpy.AddMessage('FLOODPLAIN MODULE')
    arcpy.AddMessage(' ')

    arcpy.AddMessage('- Computing Leopold water head...')
    outF = a* (Raster(ACC_BLC)**b)*100
    outF.save(WAT_FL)

    outW = Watershed(FD, WAT_FL,  "VALUE")
    outW.save(WAT_HGD)

    #outCon = SetNull (DEM_DIFF, 1,  "VALUE < %f" % bl_tresh )
    arcpy.AddMessage('- Delineating floodplain polygon...')
    outCon = Con(Raster(DEM_DIFF)<= Raster(WAT_HGD) ,Raster(WAT_HGD))
    outCon.save(FPL_GRD)

    arcpy.RasterToPolygon_conversion(FPL_GRD, FPL1,"SIMPLIFY")
    arcpy.EliminatePolygonPart_management(FPL1, FPL2, "AREA",
cellarea*10000, "", "CONTAINED_ONLY")
    arcpy.Dissolve_management(FPL2, FPL)
```

```
    arcpy.AddField_management(FPL, "AREA", "float")
    arcpy.CalculateField_management(FPL, "AREA", "!
shape.area@squaremeters!", "PYTHON")
    arcpy.AddField_management(FPL, "a", "float")
    arcpy.CalculateField_management(FPL, "a", "%f" %a, "PYTHON")
    arcpy.AddField_management(FPL, "b", "float")
    arcpy.CalculateField_management(FPL, "b", "%f" %b, "PYTHON")

    arcpy.Clip_analysis(WAT_SORD, FPL, FPL_ORD)
    arcpy.AddField_management(FPL_ORD, "AREA", "float")
    arcpy.CalculateField_management(FPL_ORD, "AREA", "!
shape.area@squaremeters!", "PYTHON")

    arcpy.Delete_management(WAT_FL)
    arcpy.Delete_management(WAT_HGD)
    #arcpy.Delete_management(FPL_GRD)
    arcpy.Delete_management(FPL1)
    arcpy.Delete_management(FPL2)

    arcpy.AddMessage(' ')
    arcpy.AddMessage('FLOODPLAIN  COMPLETED!')

except:

    arcpy.AddError(arcpy.GetMessages())
    arcpy.AddMessage(traceback.format_exc())
```

```
#-------------------------------------------
#  Levee remover tool
# 4 Inputs:
#   - DEM to be modified
#   - Levee shapefile (same Corrdinate system of the DEM)
#   - Buffer: Meters of buffer for the levee removing
#   - Output path
# Output:
#   -DEM with the levee removal
#-------------------------------------------

#Import system modules
import sys, string, os, arcpy, math, traceback
from arcpy.sa import *

# Allow output to overwrite...
arcpy.env.overwriteOutput = True

# Check out the ArcGIS Spatial Analyst extension license
arcpy.CheckOutExtension("Spatial")

try:


    #INPUT ARGIMENTS
    DEM =        arcpy.GetParameterAsText(0)           # DEM Name
    Levees     = arcpy.GetParameterAsText(1)           # Shapefile fo
the Levees
    Buffer     = float(arcpy.GetParameterAsText(2))    # Buffer for
the levee removal
    OUT        = arcpy.GetParameterAsText(3)           # Output path

    #OUTPUTS
    BUFF= OUT+"\\LeveeBuffer.shp"
    MASK= OUT+"\\LeveeMASK.shp"
    DEML= OUT+"\\dem_lev"  #DEM of the levee
    DEMdr= OUT+"\\dem_dr"  #DEM "drilled" by the levee occupancy
    DEMo1= OUT+"\\dem1"   #DEM filled around the mask
    DEMo= OUT+"\\dem"     #DEM output without levees

    #Preliminary operations
    pixelsize = float(arcpy.GetRasterProperties_management(DEM,
"CELLSIZEX").getOutput(0) )
    arcpy.env.cellSize = pixelsize

    #ANALYSIS---------------------------------------------------

    arcpy.env.extent = DEM
    arcpy.env.mask = DEM
    #buffer
```

```
    arcpy.Buffer_analysis(Levees,BUFF,  Buffer, "FULL")
    arcpy.Buffer_analysis(BUFF,  MASK, 2*pixelsize,"FULL")
    #DEM of the levees
    outEBM = ExtractByMask(DEM, BUFF)
    outEBM.save(DEML)

    #Drilling the DEM
    OutRC = Con(IsNull(Raster(DEML)),DEM,SetNull(DEM, DEM,  "VALUE >
-1000"))
    OutRC.save(DEMdr)

    #Filling the drilled DEM around the MASK
    arcpy.env.extent = MASK
    arcpy.env.mask = MASK
    Ncell=3*(math.ceil(Buffer/pixelsize)+1)
    neighborhood = NbrRectangle(Ncell, Ncell, "CELL")
    outFS = FocalStatistics(DEMdr, neighborhood)
    outFS.save(DEMo1)

    arcpy.env.extent = DEM
    arcpy.env.mask = DEM

    OutRC = Con(IsNull(Raster(DEMo1)),DEM,DEMo1)
    OutRC.save(DEMo)


    #arcpy.Delete_management(BUFF)
    #arcpy.Delete_management(DEML)
    #arcpy.Delete_management(DEMdr)
    #arcpy.Delete_management(DEMo1)

except:

    arcpy.AddError(arcpy.GetMessages())
    arcpy.AddMessage(traceback.format_exc())
    #print arcpy.GetMessages()
```

APPENDIX C
Raw Data

APPENDIX CONTENTS

HUC10	Name	A	B	C	F1	F2	F3	TP rate	bias
512010810	FPL_county	3055511	736161	4160993	0.384	0.292	-0.139	0.423	1.903251125
512010901	FPL_county	365649	79502	734077	0.31	0.243	-0.312	0.332	2.470456092
512010902	FPL_county	6218314	1990821	3411036	0.535	0.364	0.242	0.646	1.17300422
512010904	FPL_county	880972	544999	879880	0.382	0.146	0	0.5	1.234844187
512010905	FPL_county	16407353	1715592	17356413	0.462	0.414	-0.027	0.486	1.863039699
512010906	FPL_county	8151370	35235	8219656	0.497	0.495	-0.004	0.498	1.999733223
512010908	FPL_county	16570625	3168163	6335334	0.636	0.514	0.393	0.723	1.160454178
512011102	FPL_county	5373669	1138435	12731113	0.279	0.22	-0.382	0.297	2.780173965
512011108	FPL_county	1039181	138756	8899541	0.103	0.089	-0.78	0.105	8.437396907
512011110	FPL_county	7641407	1006329	16228003	0.307	0.267	-0.345	0.32	2.7601918
512011113	FPL_county	34761062	9795004	3513167	0.723	0.519	0.65	0.908	0.859012755
512011114	FPL_county	1817724	74936	24947796	0.068	0.065	-0.862	0.068	14.14174759
512011201	FPL_county	8284568	169128	36618388	0.184	0.18	-0.629	0.184	5.311635999
512011202	FPL_county	4820233	3277540	11106337	0.251	0.08	-0.327	0.303	1.966783954
512011203	FPL_county	7055813	1509145	16251823	0.284	0.224	-0.371	0.303	2.721278493
512011205	FPL_county	12234946	411305	8813091	0.57	0.551	0.159	0.581	1.664369701
512011206	FPL_county	2964893	175579	8379950	0.257	0.242	-0.47	0.261	3.612464305
512011207	FPL_county	6191020	253989	16808634	0.266	0.255	-0.457	0.269	3.568599206
512011208	FPL_county	42539439	1224686	20486562	0.662	0.643	0.343	0.675	1.440129353
512011213	FPL_county	7702845	542320	17145599	0.303	0.282	-0.372	0.31	3.013698816
512011214	FPL_county	7027228	128434	13778234	0.336	0.33	-0.322	0.338	2.907552369
512011215	FPL_county	74131742	22431	118258141	0.385	0.385	-0.229	0.385	2.594457941
512011301	FPL_county	2823457	4766934	6418607	0.202	-0.139	-0.257	0.306	1.217600516
512011410	FPL_county	47771573	1754003	68492173	0.405	0.39	-0.176	0.411	2.347549597
512010811	FPL_county	1196498	89328	1386568	0.448	0.414	-0.071	0.463	2.008876784
512010907	FPL_county	3912860	564354	3131737	0.514	0.44	0.103	0.555	1.573433166
512011103	FPL_county	1595297	1069553	2795964	0.292	0.096	-0.22	0.363	1.64784547
512011105	FPL_county	3450836	170021	16944512	0.168	0.16	-0.656	0.169	5.632740536
512011111	FPL_county	41346315	4260941	69937698	0.358	0.321	-0.247	0.372	2.440050614
512011302	FPL_county	83991757	2450066	106221701	0.436	0.423	-0.115	0.442	2.200479483
512011303	FPL_county	100047455	5009410	40311501	0.688	0.654	0.411	0.713	1.336028407
512011306	FPL_county	131532168	2861868	7395160	0.928	0.907	0.876	0.947	1.033731348
512011308	FPL_county	167205268	7056210	23335626	0.846	0.81	0.728	0.878	1.093419476
512011309	FPL_county	160257245	1495349	8027899	0.944	0.935	0.897	0.952	1.04038606
512010104	FPL_county	6650066	1360464	7461362	0.43	0.342	-0.052	0.471	1.761609781
512010106	FPL_county	16060959	596313	8774184	0.632	0.608	0.287	0.647	1.490948998
512010107	FPL_county	2469321	113546	14264178	0.147	0.14	-0.7	0.148	6.478652985
512010108	FPL_county	8399999	21339	15007585	0.359	0.358	-0.282	0.359	2.779556408
512010109	FPL_county	213196	2481	4930206	0.041	0.041	-0.917	0.041	23.84770745
512010110	FPL_county	2428627	30272	9818427	0.198	0.195	-0.602	0.198	4.980706406
512010111	FPL_county	1112629	45756	17052102	0.061	0.059	-0.875	0.061	15.68108271
512010112	FPL_county	1021018	56574	5036704	0.167	0.158	-0.657	0.169	5.621535795
512010113	FPL_county	8702424	851196	17860917	0.317	0.286	-0.334	0.328	2.780447726
512010114	FPL_county	23678049	5888694	9581014	0.605	0.454	0.36	0.712	1.12488085
512010115	FPL_county	6160251	399991	24053127	0.201	0.188	-0.584	0.204	4.605527967
512010116	FPL_county	8164372	3112879	5520266	0.486	0.301	0.157	0.597	1.213472858
512010201	FPL_county	2547036	308876	22242351	0.101	0.089	-0.785	0.103	8.680024805
512010202	FPL_county	4554830	25012	14870318	0.234	0.233	-0.53	0.234	4.241445011
512010203	FPL_county	3107023	314236	15142966	0.167	0.15	-0.648	0.17	5.334290388

512010204	FPL_county	40508519	25128635	4229379	0.58	0.22	0.519	0.905	0.681594117
512010302	FPL_county	8207250	622219	9344692	0.452	0.417	-0.063	0.468	1.987881944
512010303	FPL_county	852585	58857	5942986	0.124	0.116	-0.743	0.125	7.455845792
512010304	FPL_county	6107746	57964	13360477	0.313	0.31	-0.371	0.314	3.157498974
512010305	FPL_county	3926160	285155	17353336	0.182	0.169	-0.623	0.185	5.052933822
512010306	FPL_county	52985940	17367330	3644777	0.716	0.481	0.667	0.936	0.804947901
512010401	FPL_county	4401682	8438807	3170744	0.275	-0.252	0.077	0.581	0.589730344
512010402	FPL_county	5887900	1352623	2029332	0.635	0.489	0.416	0.744	1.093461343
512010403	FPL_county	4216079	984493	5541010	0.393	0.301	-0.123	0.432	1.876156892
512010404	FPL_county	4198610	441975	8283675	0.325	0.291	-0.316	0.336	2.689808505
512010405	FPL_county	3142655	156225	13458837	0.188	0.178	-0.616	0.189	5.032463139
512010407	FPL_county	4977153	381728	4748175	0.492	0.455	0.023	0.512	1.81480574
512010501	FPL_county	6168588	2916159	4074444	0.469	0.247	0.159	0.602	1.127497772
512010502	FPL_county	4041492	574875	14879052	0.207	0.178	-0.556	0.214	4.098578817
512010504	FPL_county	953923	19057	9709050	0.089	0.088	-0.82	0.089	10.95908755
512010505	FPL_county	9778329	4623017	11202514	0.382	0.201	-0.056	0.466	1.45686681
512010601	FPL_county	16649233	4147693	9524936	0.549	0.412	0.235	0.636	1.25855951
512010602	FPL_county	13152046	5821996	14019916	0.399	0.222	-0.026	0.484	1.432059758
512010603	FPL_county	9245438	8144919	12343529	0.311	0.037	-0.104	0.428	1.241433226
512010604	FPL_county	13685036	5331884	11332337	0.451	0.275	0.078	0.547	1.315532326
512010605	FPL_county	12331916	13506181	3405875	0.422	-0.04	0.305	0.784	0.609092496
512010606	FPL_county	20735985	4478901	10488486	0.581	0.455	0.287	0.664	1.238334807
512010607	FPL_county	126250	805043	105109	0.122	-0.655	0.02	0.546	0.248427724
512010608	FPL_county	808318	2542372	853677	0.192	-0.412	-0.011	0.486	0.496015746
512010609	FPL_county	2952188	890500	516911	0.677	0.473	0.559	0.851	0.902779252
512010610	FPL_county	94291	75949863	1191	0.001	-0.998	0.001	0.988	0.001255613
512010611	FPL_county	3992362	32836840	480485	0.107	-0.773	0.094	0.893	0.121448382
512010612	FPL_county	7205884	48157072	1110147	0.128	-0.725	0.108	0.867	0.150209302
512010613	FPL_county	16715435	9544191	2665247	0.578	0.248	0.486	0.862	0.738041052
512010701	FPL_county	6563418	540136	11540868	0.352	0.323	-0.267	0.363	2.548623689
512010702	FPL_county	3136799	494678	4936359	0.366	0.308	-0.21	0.389	2.223105915
512010703	FPL_county	12549678	4607136	10076287	0.461	0.292	0.091	0.555	1.318774278
512010704	FPL_county	20283688	4977748	18197584	0.467	0.352	0.048	0.527	1.523320844
512010803	FPL_county	1998861	150865	6601729	0.228	0.211	-0.526	0.232	4.000784286
512010804	FPL_county	9144101	2912586	6690859	0.488	0.332	0.131	0.577	1.313375723
512010805	FPL_county	32895101	621623	17754517	0.642	0.629	0.295	0.649	1.511174481
512010806	FPL_county	27652347	760081	7356153	0.773	0.752	0.567	0.79	1.232154464
512010807	FPL_county	1398776	2527484	10157576	0.099	-0.08	-0.622	0.121	2.943348632
512010809	FPL_county	5492078	140642	14417723	0.274	0.267	-0.445	0.276	3.534669041
512010812	FPL_county	18036099	2555076	30845721	0.351	0.301	-0.249	0.369	2.373920867
512010813	FPL_county	1526812	70569	30807409	0.047	0.045	-0.904	0.047	20.24202178
512010815	FPL_county	6276477	53895	11701956	0.348	0.345	-0.301	0.349	2.840027885
512010816	FPL_county	48560338	1373168	5738127	0.872	0.848	0.769	0.894	1.087415432
512011001	FPL_county	5901002	760578	11645679	0.322	0.281	-0.314	0.336	2.634011901
512011002	FPL_county	1050198	1463092	174686	0.391	-0.154	0.326	0.857	0.487362779
512011003	FPL_county	2414732	480286	8169037	0.218	0.175	-0.52	0.228	3.655856026
512011004	FPL_county	7274666	539441	19786727	0.264	0.244	-0.453	0.269	3.463145949
512011005	FPL_county	780031	116226	8224619	0.086	0.073	-0.816	0.087	10.04695082
512011006	FPL_county	8062538	111362	16649432	0.325	0.32	-0.346	0.326	3.02327775
512011104	FPL_county	1373367	138160	23991690	0.054	0.048	-0.887	0.054	16.78108099

512011107	FPL_county	1616835	292003	23926381	0.063	0.051	-0.864	0.063	13.38155255
512011112	FPL_county	6756862	508673	8853289	0.419	0.388	-0.13	0.433	2.148520515
512011115	FPL_county	16490527	447037	47724229	0.255	0.248	-0.483	0.257	3.791262781
512011118	FPL_county	9811976	57468	29706790	0.248	0.246	-0.503	0.248	4.004153223
512011305	FPL_county	25594629	15583	33178370	0.435	0.435	-0.129	0.435	2.294904822
512011307	FPL_county	2505946	15086	64720253	0.037	0.037	-0.925	0.037	26.66614267
512020101	FPL_county	8637413	247141	23240938	0.269	0.261	-0.455	0.271	3.588064297
512020102	FPL_county	2771150	240888	12762874	0.176	0.16	-0.633	0.178	5.15731342
512020103	FPL_county	17984288	757898	26899313	0.394	0.377	-0.195	0.401	2.394790074
512020104	FPL_county	8561286	576661	11870488	0.408	0.38	-0.158	0.419	2.235926078
512020105	FPL_county	1855936	77120	8047551	0.186	0.178	-0.62	0.187	5.123228194
512020106	FPL_county	12506800	2754376	20842782	0.346	0.27	-0.231	0.375	2.185256366
512020113	FPL_county	8118617	170319	49756538	0.14	0.137	-0.717	0.14	6.982217621
512020115	FPL_county	16593354	311854	14840045	0.523	0.513	0.055	0.528	1.859391437
512020116	FPL_county	1209401	82976	18479463	0.061	0.057	-0.873	0.061	15.23461343
512020117	FPL_county	35717566	2427238	13135669	0.697	0.649	0.44	0.731	1.280731053
512020201	FPL_county	30613567	1518872	28018691	0.509	0.484	0.043	0.522	1.824706117
512020202	FPL_county	40715760	1098436	41341948	0.49	0.476	-0.008	0.496	1.962436585
512020203	FPL_county	1602344	154934	24205481	0.062	0.056	-0.871	0.062	14.68625055
512020205	FPL_county	73587537	22109848	38099643	0.55	0.385	0.265	0.659	1.167087063
512020206	FPL_county	22251383	72356	68558177	0.245	0.244	-0.51	0.245	4.067847237
512020207	FPL_county	1373665	304906	13564244	0.09	0.07	-0.8	0.092	8.899182102
512020208	FPL_county	48592893	5566518	10371963	0.753	0.667	0.592	0.824	1.088727793
512020209	FPL_county	45151287	1862685	26686415	0.613	0.587	0.251	0.629	1.528007504
512020210	FPL_county	173384179	14101006	43568000	0.75	0.689	0.562	0.799	1.15716972
512020301	FPL_county	1804126	95779	13885130	0.114	0.108	-0.765	0.115	8.257916054
512020302	FPL_county	245354	4268	14445712	0.017	0.016	-0.966	0.017	58.85325011
512020303	FPL_county	1045732	46053	14348444	0.068	0.065	-0.862	0.068	14.10000687
512020304	FPL_county	6258313	59453	35144775	0.151	0.15	-0.697	0.151	6.553438035
512020305	FPL_county	22401653	8842967	24408454	0.403	0.244	-0.036	0.479	1.498181351
512020306	FPL_county	758791	17171	23233097	0.032	0.031	-0.936	0.032	30.91889551
512020307	FPL_county	9615653	16972	48206103	0.166	0.166	-0.667	0.166	6.002699783
512020308	FPL_county	6996658	215677	169564022	0.04	0.038	-0.92	0.04	24.48037702
512020401	FPL_county	13092494	3605274	27782667	0.294	0.213	-0.33	0.32	2.447941605
512020402	FPL_county	5311338	1696635	5143898	0.437	0.297	0.014	0.508	1.491905862
512020403	FPL_county	11076958	353143	29803760	0.269	0.26	-0.454	0.271	3.576584144
512020404	FPL_county	11622454	328230	21830847	0.344	0.334	-0.302	0.347	2.799279188
512020405	FPL_county	742017	52406	12753742	0.055	0.051	-0.887	0.055	16.98812723
512020409	FPL_county	12901828	122975	21005755	0.379	0.376	-0.238	0.38	2.603308703
512020501	FPL_county	6636369	4332701	8498558	0.341	0.118	-0.096	0.438	1.379782151
512020502	FPL_county	721869	154438	4106503	0.145	0.114	-0.679	0.15	5.509909198
512020503	FPL_county	1781000	3032782	3566268	0.213	-0.149	-0.213	0.333	1.110824711
512020504	FPL_county	13175966	621722	9498534	0.566	0.539	0.158	0.581	1.643355032
512020505	FPL_county	2404310	1782191	12499654	0.144	0.037	-0.605	0.161	3.560004882
512020506	FPL_county	12001304	220541	67418551	0.151	0.148	-0.696	0.151	6.498188694
512020601	FPL_county	3883183	1012780	33399903	0.101	0.075	-0.771	0.104	7.615066944
512020602	FPL_county	24125086	556811	27839936	0.459	0.449	-0.071	0.464	2.105390116
512020603	FPL_county	3428901	67591	51299032	0.063	0.061	-0.874	0.063	15.6522403
512020604	FPL_county	4157420	6758252	39741589	0.082	-0.051	-0.702	0.095	4.021649698
512020605	FPL_county	52019809	1760157	63669757	0.443	0.428	-0.099	0.45	2.151164729

512020606	FPL_county	57956741	4871150	6683812	0.834	0.764	0.738	0.897	1.028851231
512020701	FPL_county	0	0	0	0	0	0	0	#DIV/0!
512020702	FPL_county	2002037	12307	13836992	0.126	0.126	-0.747	0.126	7.863120202
512020703	FPL_county	1009505	15384	6654334	0.131	0.129	-0.735	0.132	7.477725881
512020704	FPL_county	1502892	7841	11819968	0.113	0.112	-0.774	0.113	8.818805176
512020705	FPL_county	13383901	393638	11876939	0.522	0.506	0.059	0.53	1.83347984
512020706	FPL_county	21358104	112950	26401955	0.446	0.444	-0.105	0.447	2.22439285
512020707	FPL_county	55084551	1198681	38769702	0.58	0.567	0.172	0.587	1.667534889
512020708	FPL_county	7889639	52505	21908265	0.264	0.263	-0.47	0.265	3.751871535
512020709	FPL_county	47789637	328727	29337866	0.617	0.613	0.238	0.62	1.602870434
512020801	FPL_county	23110916	836407	13527124	0.617	0.594	0.256	0.631	1.529943034
512020802	FPL_county	3772814	2779	10247698	0.269	0.269	-0.462	0.269	3.713459581
512020803	FPL_county	22781991	403167	6142981	0.777	0.763	0.567	0.788	1.247564153
512020804	FPL_county	6990008	686336	16999299	0.283	0.255	-0.406	0.291	3.125095358
512020805	FPL_county	6006706	653483	8718305	0.391	0.348	-0.176	0.408	2.210899871
512020806	FPL_county	10541388	1169600	24357140	0.292	0.26	-0.383	0.302	2.979981535
512020807	FPL_county	55734262	4002784	1911617	0.904	0.839	0.873	0.967	0.9649938
512020808	FPL_county	10067255	546588	39490776	0.201	0.19	-0.587	0.203	4.669188248
512020809	FPL_county	2763408	41984	30583692	0.083	0.082	-0.833	0.083	11.88678801
512020810	FPL_county	28578281	92901	21539440	0.569	0.567	0.14	0.57	1.74801726
512020811	FPL_county	3507609	415871	16635437	0.171	0.15	-0.639	0.174	5.133974431
512020812	FPL_county	2012856	184611	10945448	0.153	0.139	-0.68	0.155	5.89692769
512020813	FPL_county	19809555	320985	27043528	0.42	0.413	-0.153	0.423	2.3274628
512020814	FPL_county	23975114	381529	26378531	0.473	0.465	-0.047	0.476	2.067347499
512020901	FPL_county	37163685	5160672	925040	0.859	0.74	0.838	0.976	0.899924481
512020902	FPL_county	3773409	77815	18088604	0.172	0.168	-0.652	0.173	5.676640206
512020903	FPL_county	11357150	501527	32196259	0.258	0.246	-0.473	0.261	3.672703878
512020904	FPL_county	47159776	5968692	18084236	0.662	0.578	0.408	0.723	1.228042412
512020905	FPL_county	7651630	198209	4380442	0.626	0.609	0.267	0.636	1.532779462
512020906	FPL_county	37529632	5873409	4460539	0.784	0.661	0.691	0.894	0.967447673
512020907	FPL_county	3913753	5027970	1096351	0.39	-0.111	0.281	0.781	0.56030633
512010808	FPL_county	15118649	277016	1456243	0.897	0.881	0.811	0.912	1.076594743
512011106	FPL_county	34691982	775465	10812250	0.75	0.733	0.516	0.762	1.282985832
512011116	FPL_county	26895244	1791025	15349711	0.611	0.57	0.262	0.637	1.472654217
512011117	FPL_county	76118692	753332	24080620	0.754	0.747	0.515	0.76	1.303456144
512011119	FPL_county	38243759	2817898	15395069	0.677	0.627	0.405	0.713	1.306299646
512010101	FPL_county	1939805	5856	16232568	0.107	0.106	-0.786	0.107	9.339948223
512010105	FPL_county	14225569	302425	5104991	0.725	0.709	0.465	0.736	1.330573237
512010301	FPL_county	297263	2184	25410614	0.012	0.011	-0.977	0.012	85.85117567
512011204	FPL_county	4230768	136969	3343047	0.549	0.531	0.115	0.559	1.734036413
512010814	FPL_county	4941620	1289895	11893217	0.273	0.201	-0.384	0.294	2.701564066
512020815	FPL_county	78663843	4330915	17094781	0.786	0.743	0.615	0.821	1.153791231
512020908	FPL_county	79388392	4875418	21758095	0.749	0.703	0.544	0.785	1.200355016
512010102	FPL_county	30260226	3082508	22139227	0.545	0.49	0.146	0.577	1.571540384
512010103	FPL_county	7857978	2094442	9335858	0.407	0.299	-0.077	0.457	1.727603538

HUC10	Name	A	B	C	F1	F2	F3	TP rate	bias
512010610	FPL_county	80395	113630490	19652	0.001	-0.998	0.001	0.804	0.000879837
512010609	FPL_county	2067048	53805787	1396196	0.036	-0.903	0.012	0.597	0.061984397
512011002	FPL_county	302822	16596237	920971	0.017	-0.914	-0.035	0.247	0.072417819
512010608	FPL_county	569019	22166726	1104093	0.024	-0.906	-0.022	0.34	0.073589495
512010612	FPL_county	5734853	75282008	2566391	0.069	-0.832	0.038	0.691	0.102463165
512010611	FPL_county	2305554	24082811	2171562	0.081	-0.763	0.005	0.515	0.169662501
512011205	FPL_county	17705689	105165775	3356050	0.14	-0.693	0.114	0.841	0.171412778
512010605	FPL_county	8567442	72847822	7161420	0.097	-0.726	0.016	0.545	0.193193036
512010901	FPL_county	430561	4878198	670853	0.072	-0.744	-0.04	0.391	0.207471087
512010804	FPL_county	10480846	57430714	5338237	0.143	-0.641	0.07	0.663	0.232936528
512011203	FPL_county	13509063	85094682	9816246	0.125	-0.66	0.034	0.579	0.236556015
512010701	FPL_county	4854973	67489039	13221427	0.057	-0.732	-0.098	0.269	0.249867259
512010904	FPL_county	789659	6269034	986180	0.098	-0.681	-0.024	0.445	0.251581844
512011202	FPL_county	9440176	53586933	6470915	0.136	-0.635	0.043	0.593	0.252448371
512020907	FPL_county	4218065	14804318	789659	0.213	-0.534	0.173	0.842	0.263254294
512010810	FPL_county	4960380	21448530	2229625	0.173	-0.576	0.095	0.69	0.272256788
512010606	FPL_county	8732699	88407855	22465082	0.073	-0.666	-0.115	0.28	0.321161242
512010902	FPL_county	5382008	22492773	4194840	0.168	-0.534	0.037	0.562	0.343566753
512010407	FPL_county	6022489	21881770	3683884	0.191	-0.502	0.074	0.62	0.347845574
512020305	FPL_county	23052860	105355150	23721926	0.152	-0.541	-0.004	0.493	0.364266886
512011204	FPL_county	5286427	15376017	2279649	0.23	-0.44	0.131	0.699	0.366175269
512010303	FPL_county	4506594	13404550	2266250	0.223	-0.441	0.111	0.665	0.378135757
512020207	FPL_county	9770689	29413902	5142609	0.22	-0.443	0.104	0.655	0.380590881
512010604	FPL_county	6754085	57122533	18312226	0.082	-0.613	-0.141	0.269	0.392417629
512010405	FPL_county	6009983	34293887	10602332	0.118	-0.556	-0.09	0.362	0.412176672
512010402	FPL_county	6001050	12742630	1916084	0.29	-0.326	0.198	0.758	0.42238952
512010116	FPL_county	8311071	23162733	5287320	0.226	-0.404	0.082	0.611	0.432054257
512010907	FPL_county	4462824	11926172	2804897	0.233	-0.389	0.086	0.614	0.443451264
512010203	FPL_county	8551363	32218799	9693867	0.169	-0.469	-0.023	0.469	0.447514288
512010305	FPL_county	14000367	32866426	7208764	0.259	-0.349	0.126	0.66	0.452540693
512011201	FPL_county	26793020	68451101	18088906	0.236	-0.368	0.077	0.597	0.471230408
512010613	FPL_county	14641741	26416949	4729914	0.32	-0.257	0.216	0.756	0.47180402
512010202	FPL_county	15650254	24731331	3768745	0.354	-0.206	0.269	0.806	0.480887489
512010504	FPL_county	1878566	20033575	8799695	0.061	-0.591	-0.225	0.176	0.487321663
512010501	FPL_county	7097998	12387998	3138984	0.314	-0.234	0.175	0.693	0.525350719
512010201	FPL_county	13552834	33255896	11188324	0.234	-0.34	0.041	0.548	0.528558626
512010401	FPL_county	3079134	11086490	4460144	0.165	-0.43	-0.074	0.408	0.532223501
512010603	FPL_county	9044453	30832429	12523776	0.173	-0.416	-0.066	0.419	0.540870497
512010807	FPL_county	3811623	17335872	7725080	0.132	-0.468	-0.136	0.33	0.545535204
512010403	FPL_county	4522673	13320581	5226577	0.196	-0.381	-0.031	0.464	0.546382964
512010404	FPL_county	5261415	16309494	7153381	0.183	-0.385	-0.066	0.424	0.575534207
512020502	FPL_county	2105459	6014450	2728075	0.194	-0.36	-0.057	0.436	0.595269479
512011115	FPL_county	38058166	66581468	26066784	0.291	-0.218	0.092	0.594	0.612817033
512020905	FPL_county	8905995	10684514	3099679	0.393	-0.078	0.256	0.742	0.612831142
512020105	FPL_county	3016604	12208449	6852346	0.137	-0.416	-0.174	0.306	0.64820464
512010302	FPL_county	6107351	20578476	11456307	0.16	-0.379	-0.14	0.348	0.658164276
512020402	FPL_county	4964846	10889075	5504387	0.232	-0.277	-0.025	0.474	0.660356072
512020812	FPL_county	6503073	12886448	6440544	0.252	-0.247	0.002	0.502	0.667557337
512011116	FPL_county	34499341	27858702	7942146	0.491	0.094	0.378	0.813	0.680609669

512011301	FPL_county	1242552	12308496	8021648	0.058	-0.513	-0.314	0.134	0.683651921
512010702	FPL_county	3719615	7852819	4359203	0.233	-0.259	-0.04	0.46	0.698108799
512010505	FPL_county	10774735	19084913	10192317	0.269	-0.207	0.015	0.514	0.702186844
512010111	FPL_county	11114181	14426461	7016709	0.341	-0.102	0.126	0.613	0.709883878
512011001	FPL_county	7457096	16577478	10080657	0.219	-0.267	-0.077	0.425	0.729688531
512010703	FPL_county	12124480	18812463	10474593	0.293	-0.162	0.04	0.537	0.730488239
512010906	FPL_county	11916346	10172665	4441385	0.449	0.066	0.282	0.728	0.740537048
512020106	FPL_county	6640638	37689241	26669747	0.094	-0.437	-0.282	0.199	0.751420616
512011006	FPL_county	17589563	15144658	7075666	0.442	0.061	0.264	0.713	0.753499801
512010304	FPL_county	10782775	14864168	8664809	0.314	-0.119	0.062	0.554	0.758280782
512020503	FPL_county	711050	6322631	4631653	0.061	-0.481	-0.336	0.133	0.759588472
512010602	FPL_county	14175450	21088538	12971309	0.294	-0.143	0.025	0.522	0.769815342
512010814	FPL_county	10019914	11560821	6775524	0.353	-0.054	0.114	0.597	0.778260703
512011305	FPL_county	53702166	21674530	5067574	0.668	0.398	0.605	0.914	0.7796805
512020208	FPL_county	43698331	30618042	15287582	0.488	0.146	0.317	0.741	0.79371356
512010905	FPL_county	17768219	24096210	15970048	0.307	-0.109	0.031	0.527	0.805893399
512020906	FPL_county	33160315	18877672	8799695	0.545	0.235	0.4	0.79	0.806334227
512011307	FPL_county	40194890	43059637	26962743	0.365	-0.026	0.12	0.599	0.80665443
512011213	FPL_county	13276811	17476117	11622457	0.313	-0.099	0.039	0.533	0.809655198
512020908	FPL_county	81378640	43064103	19749513	0.564	0.266	0.427	0.805	0.812648055
512010806	FPL_county	29135198	13911932	5850086	0.596	0.311	0.476	0.833	0.812720476
512010908	FPL_county	14455046	13982501	8907781	0.387	0.013	0.149	0.619	0.821548603
512020904	FPL_county	51947766	27201249	13242866	0.562	0.268	0.419	0.797	0.823644261
512020301	FPL_county	5524933	13501917	10216436	0.189	-0.273	-0.16	0.351	0.827323966
512011112	FPL_county	9214176	9616152	6387840	0.365	-0.016	0.112	0.591	0.828557846
512010114	FPL_county	23700487	15492143	9542010	0.486	0.168	0.291	0.713	0.84818235
512011113	FPL_county	33338971	11572434	4880878	0.67	0.437	0.572	0.872	0.851005418
512020117	FPL_county	38616465	17752140	10242341	0.58	0.313	0.426	0.79	0.866773375
512020405	FPL_county	6625453	8388786	6846986	0.303	-0.081	-0.01	0.492	0.897310813
512010108	FPL_county	14779306	11091849	8581734	0.429	0.107	0.18	0.633	0.902976307
512010811	FPL_county	1682045	1159477	899532	0.45	0.14	0.209	0.652	0.908519096
512010704	FPL_county	27248592	15067836	11254426	0.509	0.227	0.299	0.708	0.909883462
512020504	FPL_county	12557721	12125374	10116388	0.361	0.012	0.07	0.554	0.918608829
512020802	FPL_county	9090010	6087699	4896064	0.453	0.15	0.209	0.65	0.921487821
512011005	FPL_county	4266302	5197992	4753139	0.3	-0.066	-0.034	0.473	0.952996705
512010803	FPL_county	4033156	4986285	4563764	0.297	-0.07	-0.039	0.469	0.953154414
512010502	FPL_county	7862645	11668015	11014134	0.257	-0.125	-0.103	0.417	0.966520281
512020205	FPL_county	61512108	53523511	50432764	0.372	0.048	0.067	0.549	0.973132261
512010106	FPL_county	9159686	16064735	15698491	0.224	-0.169	-0.16	0.368	0.985480579
512010816	FPL_county	48706948	6126110	5562450	0.806	0.705	0.714	0.898	0.989720435
512011004	FPL_county	11856496	15248278	15193788	0.28	-0.08	-0.079	0.438	0.997989653
512011303	FPL_county	116453252	23861277	23912194	0.709	0.564	0.563	0.83	1.000362878
512020104	FPL_county	9282065	11104355	11119541	0.295	-0.058	-0.058	0.455	1.000744908
512010113	FPL_county	9641164	16727549	16891019	0.223	-0.164	-0.168	0.363	1.006199392
512020601	FPL_county	15356365	21268981	21811201	0.263	-0.101	-0.11	0.413	1.014804502
512010601	FPL_county	12624717	13119593	13565340	0.321	-0.013	-0.024	0.482	1.017314389
512010115	FPL_county	9717092	19816509	20474855	0.194	-0.202	-0.215	0.322	1.022291423
512010808	FPL_county	15187535	870054	1392622	0.87	0.82	0.791	0.916	1.032543366
512020814	FPL_county	40859490	7576795	9433923	0.706	0.575	0.543	0.812	1.038341669
512020709	FPL_county	53946032	19728967	23077871	0.558	0.354	0.319	0.7	1.045455094

512020901	FPL_county	30397402	5728600	7714360	0.693	0.563	0.517	0.798	1.05496761
512020103	FPL_county	21788869	20254215	23020701	0.335	0.024	-0.019	0.486	1.065801215
512020209	FPL_county	54947398	12377278	16863327	0.653	0.506	0.452	0.765	1.066633057
512011106	FPL_county	37354261	4838001	8014502	0.744	0.648	0.584	0.823	1.07528634
512011410	FPL_county	70695912	37413218	45825229	0.459	0.216	0.162	0.607	1.077810366
512010815	FPL_county	13158004	3478430	4812096	0.613	0.451	0.389	0.732	1.080165377
512010112	FPL_county	2208186	3317639	3834848	0.236	-0.119	-0.174	0.365	1.093598512
512011102	FPL_county	5456150	10994482	12655088	0.187	-0.19	-0.247	0.301	1.100944815
512011206	FPL_county	5622300	4647732	5730387	0.351	0.061	-0.007	0.495	1.105418854
512020206	FPL_county	57179703	23601333	33744520	0.499	0.293	0.205	0.629	1.125563963
512020606	FPL_county	50557823	6671903	14034311	0.709	0.616	0.513	0.783	1.128646571
512020707	FPL_county	62157948	19647679	31640847	0.548	0.375	0.269	0.663	1.146605661
512020811	FPL_county	14359465	3105039	5783984	0.618	0.484	0.369	0.713	1.153393706
512020409	FPL_county	18886605	10534443	15059796	0.425	0.188	0.086	0.556	1.153813454
512020202	FPL_county	59656766	11186537	22371287	0.64	0.52	0.4	0.727	1.157880132
512020813	FPL_county	34841467	5416846	11935105	0.668	0.564	0.439	0.745	1.161910883
512011306	FPL_county	116846295	2555672	21921075	0.827	0.809	0.672	0.842	1.162186633
512011103	FPL_county	3707109	92008	708371	0.822	0.802	0.665	0.84	1.162238489
512020810	FPL_county	38827279	4218958	11249960	0.715	0.637	0.508	0.775	1.163336043
512011111	FPL_county	81957485	13401870	29170930	0.658	0.551	0.424	0.738	1.165364583
512010805	FPL_county	34593135	7916241	16100467	0.59	0.455	0.316	0.682	1.19252755
512020815	FPL_county	69418523	10789028	26371392	0.651	0.55	0.404	0.725	1.194275524
512020803	FPL_county	22850978	676212	6058220	0.772	0.75	0.568	0.79	1.22875694
512011108	FPL_county	3339078	4681677	6556670	0.229	-0.092	-0.221	0.337	1.233767644
512011117	FPL_county	77602748	3540959	22675896	0.747	0.713	0.529	0.774	1.235815416
512011308	FPL_county	141792014	12128053	48828434	0.699	0.64	0.459	0.744	1.238437922
512020308	FPL_county	127986382	14189742	48449684	0.671	0.597	0.417	0.725	1.240968322
512020801	FPL_county	25541536	3710682	11109715	0.633	0.541	0.358	0.697	1.252939213
512011207	FPL_county	12503231	5792023	10505858	0.434	0.233	0.069	0.543	1.257653433
512020102	FPL_county	5209605	7108717	10345068	0.23	-0.084	-0.227	0.335	1.262726612
512011208	FPL_county	44871207	5041669	18181807	0.659	0.585	0.392	0.712	1.263261488
512020203	FPL_county	11637643	8529031	14177236	0.339	0.091	-0.074	0.451	1.280076179
512020501	FPL_county	4386895	7375807	10754190	0.195	-0.133	-0.283	0.29	1.287211476
512011107	FPL_county	10304870	9456255	15202721	0.295	0.024	-0.14	0.404	1.290796501
512010306	FPL_county	32476063	11342861	24183751	0.478	0.311	0.122	0.573	1.293044393
512020704	FPL_county	5749146	4512847	7581262	0.322	0.069	-0.103	0.431	1.299007707
512011215	FPL_county	128092682	19886184	64432238	0.603	0.509	0.3	0.665	1.301029838
512020115	FPL_county	20478428	3515054	10956964	0.586	0.485	0.272	0.651	1.310163819
512011110	FPL_county	10959644	7241815	12965056	0.352	0.119	-0.064	0.458	1.314438584
512020807	FPL_county	43681359	129526	13939624	0.756	0.754	0.515	0.758	1.315220704
512011309	FPL_county	125679041	2266250	42646048	0.737	0.723	0.487	0.747	1.315602065
512020808	FPL_county	32324206	4821029	17197414	0.595	0.506	0.278	0.653	1.333189035
512020304	FPL_county	25813986	4712942	15616309	0.559	0.457	0.221	0.623	1.357172101
512011104	FPL_county	10476380	8029688	14836476	0.314	0.073	-0.131	0.414	1.367813844
512020210	FPL_county	145191835	13191056	71547207	0.631	0.574	0.32	0.67	1.368449841
512020809	FPL_county	19136723	5171194	14216540	0.497	0.363	0.128	0.574	1.372115225
512020605	FPL_county	72816557	9282065	42855076	0.583	0.508	0.24	0.63	1.408935134
512020708	FPL_county	17398401	3515947	12320108	0.524	0.418	0.153	0.585	1.420962729
512020706	FPL_county	31551519	1923230	16229992	0.635	0.596	0.308	0.66	1.427389672
512020705	FPL_county	10899794	6550417	14365718	0.343	0.137	-0.109	0.431	1.447862837

512011302	FPL_county	106098358	24265933	83983442	0.495	0.382	0.103	0.558	1.458081799
512011214	FPL_county	9297251	4885345	11577793	0.361	0.171	-0.089	0.445	1.471877504
512010301	FPL_county	6666544	10686301	19046502	0.183	-0.11	-0.34	0.259	1.481776965
512010812	FPL_county	19301980	13443854	29595237	0.31	0.094	-0.165	0.395	1.493234742
512020303	FPL_county	7149808	3052335	8258367	0.387	0.222	-0.06	0.464	1.510288084
512010809	FPL_county	11045399	2124218	8858651	0.501	0.405	0.099	0.555	1.51136134
512020101	FPL_county	7172140	13890493	24664335	0.157	-0.147	-0.383	0.225	1.511514491
512020604	FPL_county	16152277	12554148	27772054	0.286	0.064	-0.206	0.368	1.53012195
512020201	FPL_county	31982080	6313698	26638483	0.493	0.395	0.082	0.546	1.530731743
512011114	FPL_county	15684198	1845515	11150806	0.547	0.483	0.158	0.584	1.530829626
512020702	FPL_county	6168987	4071567	9650990	0.31	0.105	-0.175	0.39	1.544836051
512020903	FPL_county	24532130	3594556	19002731	0.521	0.444	0.117	0.564	1.547813383
512020506	FPL_county	32444798	18674004	46973987	0.331	0.14	-0.148	0.409	1.553612015
512020307	FPL_county	32918236	4251116	24865323	0.531	0.462	0.13	0.57	1.55460227
512020805	FPL_county	7616100	1841942	7122116	0.459	0.348	0.03	0.517	1.558273478
512020806	FPL_county	18569491	3153276	16309494	0.488	0.405	0.059	0.532	1.605641906
512010813	FPL_county	16475644	3647259	15841416	0.458	0.357	0.018	0.51	1.605983987
512010204	FPL_county	21000104	6155588	23739791	0.413	0.292	-0.054	0.469	1.647532863
512010109	FPL_county	1063002	2046503	4088539	0.148	-0.137	-0.42	0.206	1.65670774
512020505	FPL_county	2772739	6202932	12140559	0.131	-0.162	-0.444	0.186	1.661524581
512020804	FPL_county	10922126	3238138	13065103	0.401	0.282	-0.079	0.455	1.693981765
512020603	FPL_county	20202405	11318742	34462716	0.306	0.135	-0.216	0.37	1.734236416
512020116	FPL_county	7156954	4058168	12509484	0.302	0.131	-0.226	0.364	1.753564339
512020703	FPL_county	2578004	1789238	5105985	0.272	0.083	-0.267	0.336	1.759460318
512010107	FPL_county	6116284	2942462	10632704	0.311	0.161	-0.229	0.365	1.848930084
512011105	FPL_county	9023014	1983080	11395564	0.403	0.314	-0.106	0.442	1.855206579
512020401	FPL_county	13677893	8261940	27178023	0.278	0.11	-0.275	0.335	1.862179899
512020113	FPL_county	24662549	5919762	33106718	0.387	0.294	-0.133	0.427	1.888976507
512011118	FPL_county	19134043	1474804	20452523	0.466	0.43	-0.032	0.483	1.92085302
512020902	FPL_county	9349955	1786559	12445168	0.396	0.321	-0.131	0.429	1.957086661
512011003	FPL_county	1932163	3426619	8636225	0.138	-0.107	-0.479	0.183	1.972162331
512020602	FPL_county	21050127	4846040	30940516	0.37	0.285	-0.174	0.405	2.007657851
512011119	FPL_county	25779148	78609	27942671	0.479	0.478	-0.04	0.48	2.077590063
512010110	FPL_county	5197992	311754	7004203	0.415	0.39	-0.144	0.426	2.214656538
512020306	FPL_county	7713467	3076454	16368450	0.284	0.171	-0.319	0.32	2.23189002
512020403	FPL_county	10734538	3172035	30064209	0.244	0.172	-0.44	0.263	2.933774338
512020404	FPL_county	4584309	5348957	28828804	0.118	-0.02	-0.625	0.137	3.363759009
512020302	FPL_county	3261363	104514	11424149	0.221	0.213	-0.552	0.222	4.363056642

HUC10	Name	A	B	C	F1	F2	F3	TP rate	bias
512010810	wab_fplnolev	3055511	736161	4160993	0.384	0.292	-0.139	0.423	1.9
512010901	wab_fplnolev	367038	13279983	732588	0.026	-0.898	-0.025	0.334	0.08
512010902	wab_fplnolev	6219207	1989928	3411731	0.535	0.364	0.242	0.646	1.17
512010904	wab_fplnolev	880972	544999	879880	0.382	0.146	0	0.5	1.23
512010905	wab_fplnolev	16407353	1715592	17358100	0.462	0.414	-0.027	0.486	1.86
512010906	wab_fplnolev	8151469	35136	8219954	0.497	0.495	-0.004	0.498	2
512010908	wab_fplnolev	16571915	4129530	6335334	0.613	0.46	0.379	0.723	1.11
512011102	wab_fplnolev	5373669	1138435	12731113	0.279	0.22	-0.382	0.297	2.78
512011108	wab_fplnolev	1039181	138756	8899541	0.103	0.089	-0.78	0.105	8.44
512011110	wab_fplnolev	8353549	1045732	15517548	0.335	0.293	-0.288	0.35	2.54
512011113	wab_fplnolev	35045026	9689597	3236052	0.731	0.529	0.663	0.915	0.86
512011114	wab_fplnolev	16599607	3707604	10166905	0.545	0.423	0.211	0.62	1.32
512011201	wab_fplnolev	8284568	169128	36618388	0.184	0.18	-0.629	0.184	5.31
512011202	wab_fplnolev	4820233	3277540	11106337	0.251	0.08	-0.327	0.303	1.97
512011203	wab_fplnolev	7055813	1509145	16251823	0.284	0.224	-0.371	0.303	2.72
512011205	wab_fplnolev	12234946	411305	8813091	0.57	0.551	0.159	0.581	1.66
512011206	wab_fplnolev	2964893	175579	8379950	0.257	0.242	-0.47	0.261	3.61
512011207	wab_fplnolev	6191020	253989	16808634	0.266	0.255	-0.457	0.269	3.57
512011208	wab_fplnolev	42539935	37059866	20486065	0.425	0.055	0.22	0.675	0.79
512011213	wab_fplnolev	7704334	540831	17161281	0.303	0.282	-0.372	0.31	3.02
512011214	wab_fplnolev	7027228	128434	13778234	0.336	0.33	-0.322	0.338	2.91
512011215	wab_fplnolev	170195768	11100680	22207315	0.836	0.782	0.727	0.885	1.06
512011301	wab_fplnolev	3045685	4766934	6196875	0.217	-0.123	-0.225	0.33	1.18
512011410	wab_fplnolev	47832316	3425328	68439867	0.4	0.371	-0.172	0.411	2.27
512010811	wab_fplnolev	1196498	4888222	1386568	0.16	-0.494	-0.025	0.463	0.42
512010907	wab_fplnolev	3912860	564354	3131737	0.514	0.44	0.103	0.555	1.57
512011103	wab_fplnolev	3947897	6642522	441875	0.358	-0.244	0.318	0.899	0.41
512011105	wab_fplnolev	9091298	1550534	11303057	0.414	0.344	-0.101	0.446	1.92
512011111	wab_fplnolev	49279626	4349971	62005479	0.426	0.389	-0.11	0.443	2.08
512011302	wab_fplnolev	122464691	18628839	67746583	0.586	0.497	0.262	0.644	1.35
512011303	wab_fplnolev	86672983	10389828	53707511	0.575	0.506	0.219	0.617	1.45
512011306	wab_fplnolev	129526757	2996654	9429454	0.912	0.891	0.846	0.932	1.05
512011308	wab_fplnolev	168277898	7054423	22260217	0.852	0.816	0.739	0.883	1.09
512011309	wab_fplnolev	150190883	5129010	18100911	0.866	0.836	0.762	0.892	1.08
512010104	wab_fplnolev	6650066	1360464	7461362	0.43	0.342	-0.052	0.471	1.76
512010106	wab_fplnolev	16060959	596313	8774184	0.632	0.608	0.287	0.647	1.49
512010107	wab_fplnolev	2469321	113546	14264178	0.147	0.14	-0.7	0.148	6.48
512010108	wab_fplnolev	8399999	21339	15007585	0.359	0.358	-0.282	0.359	2.78
512010109	wab_fplnolev	213196	97963	4930106	0.041	0.022	-0.9	0.041	16.53
512010110	wab_fplnolev	2429124	13459731	9817534	0.094	-0.429	-0.287	0.198	0.77
512010111	wab_fplnolev	1112629	45756	17052102	0.061	0.059	-0.875	0.061	15.68
512010112	wab_fplnolev	1021018	56574	5036704	0.167	0.158	-0.657	0.169	5.62
512010113	wab_fplnolev	8702424	851196	17860917	0.317	0.286	-0.334	0.328	2.78
512010114	wab_fplnolev	23678049	5888694	9581014	0.605	0.454	0.36	0.712	1.12
512010115	wab_fplnolev	6160251	399991	24053127	0.201	0.188	-0.584	0.204	4.61
512010116	wab_fplnolev	8164372	3112879	5520266	0.486	0.301	0.157	0.597	1.21
512010201	wab_fplnolev	2547036	308876	22242351	0.101	0.089	-0.785	0.103	8.68
512010202	wab_fplnolev	4554830	25012	14870318	0.234	0.233	-0.53	0.234	4.24
512010203	wab_fplnolev	3107023	314236	15142966	0.167	0.15	-0.648	0.17	5.33

512010204	wab_fplnolev	40508519	25128635	4229379	0.58	0.22	0.519	0.905	0.68
512010302	wab_fplnolev	8207250	622219	9344692	0.452	0.417	-0.063	0.468	1.99
512010303	wab_fplnolev	852585	58857	5942986	0.124	0.116	-0.743	0.125	7.46
512010304	wab_fplnolev	6107746	57964	13360477	0.313	0.31	-0.371	0.314	3.16
512010305	wab_fplnolev	3926160	285155	17353336	0.182	0.169	-0.623	0.185	5.05
512010306	wab_fplnolev	52985940	17367330	3644777	0.716	0.481	0.667	0.936	0.8
512010401	wab_fplnolev	4401682	8462132	3170744	0.275	-0.253	0.077	0.581	0.59
512010402	wab_fplnolev	5893756	4663512	2023476	0.468	0.098	0.308	0.744	0.75
512010403	wab_fplnolev	4216079	984493	5541010	0.393	0.301	-0.123	0.432	1.88
512010404	wab_fplnolev	4198610	441975	8283675	0.325	0.291	-0.316	0.336	2.69
512010405	wab_fplnolev	3143251	155629	13460723	0.188	0.178	-0.616	0.189	5.03
512010407	wab_fplnolev	4977153	381728	4748175	0.492	0.455	0.023	0.512	1.81
512010501	wab_fplnolev	6168588	2916159	4074444	0.469	0.247	0.159	0.602	1.13
512010502	wab_fplnolev	4041889	574478	14879052	0.207	0.178	-0.556	0.214	4.1
512010504	wab_fplnolev	953923	19057	9709050	0.089	0.088	-0.82	0.089	10.96
512010505	wab_fplnolev	9778131	4708077	11202712	0.381	0.197	-0.055	0.466	1.45
512010601	wab_fplnolev	16649233	4353147	9524936	0.545	0.403	0.233	0.636	1.25
512010602	wab_fplnolev	13152046	5821996	14019916	0.399	0.222	-0.026	0.484	1.43
512010603	wab_fplnolev	9245438	8144919	12343529	0.311	0.037	-0.104	0.428	1.24
512010604	wab_fplnolev	13685036	5331884	11332337	0.451	0.275	0.078	0.547	1.32
512010605	wab_fplnolev	12331916	13506181	3405875	0.422	-0.04	0.305	0.784	0.61
512010606	wab_fplnolev	20739062	5942390	10485409	0.558	0.398	0.276	0.664	1.17
512010607	wab_fplnolev	126250	805043	105109	0.122	-0.655	0.02	0.546	0.25
512010608	wab_fplnolev	808318	2542372	853677	0.192	-0.412	-0.011	0.486	0.5
512010609	wab_fplnolev	2952188	890500	516911	0.677	0.473	0.559	0.851	0.9
512010610	wab_fplnolev	94291	75949863	1191	0.001	-0.998	0.001	0.988	0
512010611	wab_fplnolev	3992362	32981055	480485	0.107	-0.774	0.094	0.893	0.12
512010612	wab_fplnolev	7205884	48157072	1110147	0.128	-0.725	0.108	0.867	0.15
512010613	wab_fplnolev	16718512	9541114	2665247	0.578	0.248	0.486	0.863	0.74
512010701	wab_fplnolev	6563418	540136	11540868	0.352	0.323	-0.267	0.363	2.55
512010702	wab_fplnolev	3136799	494678	4936359	0.366	0.308	-0.21	0.389	2.22
512010703	wab_fplnolev	12549678	4607136	10076287	0.461	0.292	0.091	0.555	1.32
512010704	wab_fplnolev	20285276	4976160	18197584	0.467	0.352	0.048	0.527	1.52
512010803	wab_fplnolev	1998861	150865	6601729	0.228	0.211	-0.526	0.232	4
512010804	wab_fplnolev	9144101	2912586	6690859	0.488	0.332	0.131	0.577	1.31
512010805	wab_fplnolev	32900163	616561	17754616	0.642	0.63	0.295	0.649	1.51
512010806	wab_fplnolev	27652347	760081	7356153	0.773	0.752	0.567	0.79	1.23
512010807	wab_fplnolev	1398776	2527484	10157576	0.099	-0.08	-0.622	0.121	2.94
512010809	wab_fplnolev	5492178	140642	14417524	0.274	0.267	-0.445	0.276	3.53
512010812	wab_fplnolev	18036099	2555076	30845721	0.351	0.301	-0.249	0.369	2.37
512010813	wab_fplnolev	1526812	70569	30807409	0.047	0.045	-0.904	0.047	20.24
512010815	wab_fplnolev	8025716	1715294	9949938	0.408	0.32	-0.098	0.446	1.85
512010816	wab_fplnolev	51470741	37647842	2828519	0.56	0.15	0.529	0.948	0.61
512011001	wab_fplnolev	5901002	760578	11645679	0.322	0.281	-0.314	0.336	2.63
512011002	wab_fplnolev	1050198	1463092	174686	0.391	-0.154	0.326	0.857	0.49
512011003	wab_fplnolev	2414732	480286	8169037	0.218	0.175	-0.52	0.228	3.66
512011004	wab_fplnolev	7274666	539441	19786727	0.264	0.244	-0.453	0.269	3.46
512011005	wab_fplnolev	780031	116226	8224619	0.086	0.073	-0.816	0.087	10.05
512011006	wab_fplnolev	8212113	118310	16498865	0.331	0.326	-0.334	0.332	2.97
512011104	wab_fplnolev	3718423	222129	21644549	0.145	0.137	-0.701	0.147	6.44

512011107	wab_fplnolev	3041715	749064	22505075	0.116	0.087	-0.74	0.119	6.74
512011112	wab_fplnolev	7711877	607529	7899565	0.475	0.438	-0.012	0.494	1.88
512011115	wab_fplnolev	21465000	26558180	42746084	0.236	-0.056	-0.234	0.334	1.34
512011118	wab_fplnolev	10383476	401182	29134595	0.26	0.25	-0.47	0.263	3.66
512011305	wab_fplnolev	41450134	641871	17317902	0.698	0.687	0.406	0.705	1.4
512011307	wab_fplnolev	2506144	46550	64720054	0.037	0.037	-0.925	0.037	26.34
512020101	wab_fplnolev	10711111	1384186	21167538	0.322	0.28	-0.314	0.336	2.64
512020102	wab_fplnolev	2771150	240888	12762874	0.176	0.16	-0.633	0.178	5.16
512020103	wab_fplnolev	18452367	3314959	26433815	0.383	0.314	-0.166	0.411	2.06
512020104	wab_fplnolev	8561286	576661	11870488	0.408	0.38	-0.158	0.419	2.24
512020105	wab_fplnolev	1855936	77120	8047551	0.186	0.178	-0.62	0.187	5.12
512020106	wab_fplnolev	12507396	2753781	20844171	0.346	0.27	-0.231	0.375	2.19
512020113	wab_fplnolev	8118617	170319	49756538	0.14	0.137	-0.717	0.14	6.98
512020115	wab_fplnolev	16593552	311655	14840045	0.523	0.513	0.055	0.528	1.86
512020116	wab_fplnolev	1209401	82976	18479463	0.061	0.057	-0.873	0.061	15.23
512020117	wab_fplnolev	35717566	2427238	13135669	0.697	0.649	0.44	0.731	1.28
512020201	wab_fplnolev	30613567	1518872	28018691	0.509	0.484	0.043	0.522	1.82
512020202	wab_fplnolev	40719531	1094664	41342544	0.49	0.477	-0.007	0.496	1.96
512020203	wab_fplnolev	1602344	154835	24205481	0.062	0.056	-0.871	0.062	14.69
512020205	wab_fplnolev	86248378	56197279	25439993	0.514	0.179	0.362	0.772	0.78
512020206	wab_fplnolev	26473616	77318	64336143	0.291	0.29	-0.417	0.292	3.42
512020207	wab_fplnolev	11033783	17586581	3898369	0.339	-0.202	0.219	0.739	0.52
512020208	wab_fplnolev	54510768	30357395	4451607	0.61	0.27	0.56	0.925	0.69
512020209	wab_fplnolev	45151883	1863876	26685819	0.613	0.587	0.251	0.629	1.53
512020210	wab_fplnolev	202951320	16371721	14005127	0.87	0.8	0.81	0.935	0.99
512020301	wab_fplnolev	1804126	95779	13885130	0.114	0.108	-0.765	0.115	8.26
512020302	wab_fplnolev	245354	4268	14445712	0.017	0.016	-0.966	0.017	58.85
512020303	wab_fplnolev	1045732	46053	14348444	0.068	0.065	-0.862	0.068	14.1
512020304	wab_fplnolev	6258313	59453	35144775	0.151	0.15	-0.697	0.151	6.55
512020305	wab_fplnolev	22401653	8842967	24408454	0.403	0.244	-0.036	0.479	1.5
512020306	wab_fplnolev	758791	17171	23233097	0.032	0.031	-0.936	0.032	30.92
512020307	wab_fplnolev	9615653	16972	48206103	0.166	0.166	-0.667	0.166	6
512020308	wab_fplnolev	6996658	215677	169564022	0.04	0.038	-0.92	0.04	24.48
512020401	wab_fplnolev	13092494	3605274	27782667	0.294	0.213	-0.33	0.32	2.45
512020402	wab_fplnolev	5311338	1696635	5143898	0.437	0.297	0.014	0.508	1.49
512020403	wab_fplnolev	11076958	353143	29804157	0.269	0.26	-0.454	0.271	3.58
512020404	wab_fplnolev	11622454	328230	21833031	0.344	0.334	-0.302	0.347	2.8
512020405	wab_fplnolev	743109	2366892	12754040	0.047	-0.102	-0.757	0.055	4.34
512020409	wab_fplnolev	12906195	582021	21001388	0.374	0.357	-0.235	0.381	2.51
512020501	wab_fplnolev	6636369	4332701	8498558	0.341	0.118	-0.096	0.438	1.38
512020502	wab_fplnolev	721869	154438	4106503	0.145	0.114	-0.679	0.15	5.51
512020503	wab_fplnolev	1781000	3032782	3566268	0.213	-0.149	-0.213	0.333	1.11
512020504	wab_fplnolev	13389856	711646	9286033	0.573	0.542	0.175	0.59	1.61
512020505	wab_fplnolev	2404310	1782191	12499654	0.144	0.037	-0.605	0.161	3.56
512020506	wab_fplnolev	12001304	220541	67418551	0.151	0.148	-0.696	0.151	6.5
512020601	wab_fplnolev	3883183	1012780	33399903	0.101	0.075	-0.771	0.104	7.62
512020602	wab_fplnolev	24125086	556811	27839936	0.459	0.449	-0.071	0.464	2.11
512020603	wab_fplnolev	3428901	67591	51299032	0.063	0.061	-0.874	0.063	15.65
512020604	wab_fplnolev	4157420	6758252	39741589	0.082	-0.051	-0.702	0.095	4.02
512020605	wab_fplnolev	52019809	1760157	63669757	0.443	0.428	-0.099	0.45	2.15

512020606	wab_fplnolev	57956741	4871150	6683812	0.834	0.764	0.738	0.897	1.03
512020701	wab_fplnolev	0	0	0	0	0	0	0	#DIV/0!
512020702	wab_fplnolev	2002037	71165	13836992	0.126	0.121	-0.744	0.126	7.64
512020703	wab_fplnolev	1009505	15384	6654334	0.131	0.129	-0.735	0.132	7.48
512020704	wab_fplnolev	1502892	7841	11819968	0.113	0.112	-0.774	0.113	8.82
512020705	wab_fplnolev	13383901	393638	11876939	0.522	0.506	0.059	0.53	1.83
512020706	wab_fplnolev	21358104	1032333	26401955	0.438	0.417	-0.103	0.447	2.13
512020707	wab_fplnolev	55084551	1198681	38769702	0.58	0.567	0.172	0.587	1.67
512020708	wab_fplnolev	7889639	52505	21908265	0.264	0.263	-0.47	0.265	3.75
512020709	wab_fplnolev	47789637	328727	29337866	0.617	0.613	0.238	0.62	1.6
512020801	wab_fplnolev	23110916	836407	13527124	0.617	0.594	0.256	0.631	1.53
512020802	wab_fplnolev	3772814	2779	10247698	0.269	0.269	-0.462	0.269	3.71
512020803	wab_fplnolev	22781991	403167	6142981	0.777	0.763	0.567	0.788	1.25
512020804	wab_fplnolev	6990008	686336	16999299	0.283	0.255	-0.406	0.291	3.13
512020805	wab_fplnolev	6006706	653483	8718305	0.391	0.348	-0.176	0.408	2.21
512020806	wab_fplnolev	10541388	1169600	24357140	0.292	0.26	-0.383	0.302	2.98
512020807	wab_fplnolev	55734262	4002784	1911617	0.904	0.839	0.873	0.967	0.96
512020808	wab_fplnolev	10067255	546588	39490776	0.201	0.19	-0.587	0.203	4.67
512020809	wab_fplnolev	2763408	41984	30583692	0.083	0.082	-0.833	0.083	11.89
512020810	wab_fplnolev	28578281	92901	21539440	0.569	0.567	0.14	0.57	1.75
512020811	wab_fplnolev	3507609	415871	16635437	0.171	0.15	-0.639	0.174	5.13
512020812	wab_fplnolev	2012856	184611	10945448	0.153	0.139	-0.68	0.155	5.9
512020813	wab_fplnolev	19809555	320985	27043528	0.42	0.413	-0.153	0.423	2.33
512020814	wab_fplnolev	23975114	381529	26378531	0.473	0.465	-0.047	0.476	2.07
512020901	wab_fplnolev	37164181	13262018	924544	0.724	0.465	0.706	0.976	0.76
512020902	wab_fplnolev	3773409	77815	18088604	0.172	0.168	-0.652	0.173	5.68
512020903	wab_fplnolev	11357150	501527	32196259	0.258	0.246	-0.473	0.261	3.67
512020904	wab_fplnolev	47159776	5968692	18084236	0.662	0.578	0.408	0.723	1.23
512020905	wab_fplnolev	7651630	198209	4380442	0.626	0.609	0.267	0.636	1.53
512020906	wab_fplnolev	37529632	5873409	4460539	0.784	0.661	0.691	0.894	0.97
512020907	wab_fplnolev	3913753	5027970	1096351	0.39	-0.111	0.281	0.781	0.56
512010808	wab_fplnolev	15166489	11850340	1408403	0.534	0.117	0.484	0.915	0.61
512011106	wab_fplnolev	37344524	1865365	8167846	0.788	0.749	0.616	0.821	1.16
512011116	wab_fplnolev	40309417	20178579	1935339	0.646	0.322	0.615	0.954	0.7
512011117	wab_fplnolev	99837237	17232942	368924	0.85	0.703	0.847	0.996	0.86
512011119	wab_fplnolev	47887798	5799069	5758275	0.806	0.708	0.709	0.893	1
512010101	wab_fplnolev	1939805	5856	16232568	0.107	0.106	-0.786	0.107	9.34
512010105	wab_fplnolev	14225569	302425	5104991	0.725	0.709	0.465	0.736	1.33
512010301	wab_fplnolev	297263	2184	25410614	0.012	0.011	-0.977	0.012	85.85
512011204	wab_fplnolev	4230768	136969	3343047	0.549	0.531	0.115	0.559	1.73
512010814	wab_fplnolev	4941620	1289895	11893217	0.273	0.201	-0.384	0.294	2.7
512020815	wab_fplnolev	78663843	4330915	17094781	0.786	0.743	0.615	0.821	1.15
512020908	wab_fplnolev	88241383	4921174	12907287	0.832	0.786	0.71	0.872	1.09
512010102	wab_fplnolev	30260424	7595850	22139029	0.504	0.378	0.135	0.577	1.38
512010103	wab_fplnolev	7857978	2094442	9335858	0.407	0.299	-0.077	0.457	1.73

HUC10	Name	A	B	C	F1	F2	F3	TP rate	bias
512010810	wab_fplwab	5034522	21360095	2264463	0.176	-0.57	0.097	0.69	0.277
512010901	wab_fplwab	422521	81501019	713730	0.005	-0.981	-0.004	0.372	0.014
512010902	wab_fplwab	5424885	22542797	4373496	0.168	-0.529	0.033	0.554	0.35
512010904	wab_fplwab	788766	6300299	1051390	0.097	-0.677	-0.032	0.429	0.26
512010905	wab_fplwab	17744994	25231568	16472071	0.298	-0.126	0.021	0.519	0.796
512010906	wab_fplwab	11911880	10643423	4772791	0.436	0.046	0.261	0.714	0.74
512010908	wab_fplwab	14439860	15847668	9111449	0.367	-0.036	0.135	0.613	0.778
512011102	wab_fplwab	5458830	11193683	13050811	0.184	-0.193	-0.256	0.295	1.112
512011108	wab_fplwab	3366770	4827281	6606694	0.227	-0.099	-0.219	0.338	1.217
512011110	wab_fplwab	11530450	9266880	12540748	0.346	0.068	-0.03	0.479	1.157
512011113	wab_fplwab	20881297	10768482	17655666	0.424	0.205	0.065	0.542	1.218
512011114	wab_fplwab	14606010	2084021	12126267	0.507	0.435	0.086	0.546	1.602
512011201	wab_fplwab	26764435	68522564	19011664	0.234	-0.365	0.068	0.585	0.48
512011202	wab_fplwab	9446429	53610159	6966685	0.135	-0.631	0.035	0.576	0.26
512011203	wab_fplwab	13476905	85354626	10109242	0.124	-0.66	0.031	0.571	0.239
512011205	wab_fplwab	17573484	105603482	4032263	0.138	-0.692	0.106	0.813	0.175
512011206	wab_fplwab	5527612	4811202	5908149	0.34	0.044	-0.023	0.483	1.106
512011207	wab_fplwab	12605065	6741579	10655929	0.42	0.195	0.065	0.542	1.202
512011208	wab_fplwab	44891752	43999366	18318479	0.419	0.008	0.248	0.71	0.711
512011213	wab_fplwab	13216068	17994219	12026220	0.306	-0.111	0.028	0.524	0.809
512011214	wab_fplwab	9292785	5201566	11596552	0.356	0.157	-0.088	0.445	1.441
512011215	wab_fplwab	121773624	22155114	70981762	0.567	0.464	0.236	0.632	1.339
512011301	wab_fplwab	1206820	12337974	8162786	0.056	-0.513	-0.32	0.129	0.692
512011410	wab_fplwab	70474379	41277544	46001205	0.447	0.185	0.155	0.605	1.042
512010811	wab_fplwab	1583784	16698964	1024591	0.082	-0.783	0.029	0.607	0.143
512010907	wab_fplwab	4418160	12071777	2898691	0.228	-0.395	0.078	0.604	0.444
512011103	wab_fplwab	4041196	16643580	386790	0.192	-0.598	0.173	0.913	0.214
512011105	wab_fplwab	8577268	2860280	11984235	0.366	0.244	-0.145	0.417	1.798
512011111	wab_fplwab	71210441	6472702	40326202	0.603	0.549	0.262	0.638	1.436
512011302	wab_fplwab	139831265	65492560	51079498	0.545	0.29	0.346	0.732	0.93
512011303	wab_fplwab	116152217	24734904	24835845	0.701	0.552	0.551	0.824	1.001
512011306	wab_fplwab	76142236	2862067	63124477	0.536	0.516	0.092	0.547	1.763
512011308	wab_fplwab	142170764	12898953	48829328	0.697	0.634	0.458	0.744	1.232
512011309	wab_fplwab	125586140	29665806	42985494	0.634	0.484	0.417	0.745	1.086
512010106	wab_fplwab	9150753	16252324	15777993	0.222	-0.172	-0.161	0.367	0.981
512010107	wab_fplwab	6127896	3221165	10854237	0.303	0.144	-0.234	0.361	1.816
512010108	wab_fplwab	14767694	11389311	8898849	0.421	0.096	0.167	0.624	0.905
512010109	wab_fplwab	1030844	2977300	4183227	0.126	-0.238	-0.385	0.198	1.301
512010110	wab_fplwab	5162261	17351951	7122116	0.174	-0.411	-0.066	0.42	0.546
512010111	wab_fplwab	11130260	14761441	7227523	0.336	-0.11	0.118	0.606	0.709
512010112	wab_fplwab	2330566	3266722	3813409	0.248	-0.099	-0.158	0.379	1.098
512010113	wab_fplwab	9686721	16999106	17142030	0.221	-0.167	-0.17	0.361	1.005
512010114	wab_fplwab	23727285	15627028	10044926	0.48	0.164	0.277	0.703	0.858
512010115	wab_fplwab	9659029	20273868	20656191	0.191	-0.21	-0.217	0.319	1.013
512010116	wab_fplwab	8385213	23256527	5687509	0.225	-0.398	0.072	0.596	0.445
512010201	wab_fplwab	13509063	33463137	11625137	0.231	-0.341	0.032	0.537	0.535
512010202	wab_fplwab	15679732	24892122	4139456	0.351	-0.206	0.258	0.791	0.488
512010203	wab_fplwab	8538857	32268822	9927013	0.168	-0.468	-0.027	0.462	0.453
512010204	wab_fplwab	20992957	6655824	24011348	0.406	0.278	-0.058	0.466	1.628

512010302	wab_fplwab	6061793	20594555	11652829	0.158	-0.379	-0.146	0.342	0.665
512010303	wab_fplwab	4529819	13490304	2537807	0.22	-0.436	0.097	0.641	0.392
512010304	wab_fplwab	10747937	15089274	8792548	0.31	-0.125	0.056	0.55	0.756
512010305	wab_fplwab	14115600	33032576	7458882	0.258	-0.346	0.122	0.654	0.458
512010306	wab_fplwab	32487676	11698386	24310597	0.474	0.304	0.119	0.572	1.285
512010401	wab_fplwab	3121118	11118648	4551258	0.166	-0.426	-0.076	0.407	0.539
512010402	wab_fplwab	5956387	59410221	2075981	0.088	-0.793	0.058	0.742	0.123
512010403	wab_fplwab	4503914	13488518	5399874	0.193	-0.384	-0.038	0.455	0.55
512010404	wab_fplwab	5256949	16463138	7376701	0.181	-0.385	-0.073	0.416	0.582
512010405	wab_fplwab	5987651	34544005	10814039	0.117	-0.556	-0.094	0.356	0.415
512010407	wab_fplwab	6019809	22113130	3934002	0.188	-0.502	0.065	0.605	0.354
512010501	wab_fplwab	7009563	12727444	3541853	0.301	-0.246	0.149	0.664	0.535
512010502	wab_fplwab	7858178	11923492	11247280	0.253	-0.131	-0.109	0.411	0.966
512010504	wab_fplwab	1869634	20108611	8934580	0.06	-0.59	-0.229	0.173	0.492
512010505	wab_fplwab	10429036	19622667	10718459	0.256	-0.225	-0.007	0.493	0.704
512010601	wab_fplwab	12669381	13375965	13964636	0.317	-0.018	-0.032	0.476	1.023
512010602	wab_fplwab	14116493	21293993	13153538	0.291	-0.148	0.02	0.518	0.77
512010603	wab_fplwab	9083757	30944089	12612211	0.173	-0.415	-0.067	0.419	0.542
512010604	wab_fplwab	6497714	57557560	18642739	0.079	-0.617	-0.147	0.258	0.392
512010605	wab_fplwab	8554936	72828170	7466922	0.096	-0.723	0.012	0.534	0.197
512010606	wab_fplwab	8688928	94469648	22978717	0.069	-0.68	-0.113	0.274	0.307
512010608	wab_fplwab	567232	22172086	1128212	0.024	-0.905	-0.024	0.335	0.075
512010609	wab_fplwab	2081341	53742364	1493563	0.036	-0.901	0.01	0.582	0.064
512010610	wab_fplwab	85755	113698379	25012	0.001	-0.998	0.001	0.774	0.001
512010611	wab_fplwab	2263570	24476747	2243918	0.078	-0.766	0.001	0.502	0.169
512010612	wab_fplwab	5801849	75290048	2650360	0.069	-0.83	0.038	0.686	0.104
512010613	wab_fplwab	14676579	26736743	4946088	0.317	-0.26	0.21	0.748	0.474
512010701	wab_fplwab	4693290	67640897	13599284	0.055	-0.733	-0.104	0.257	0.253
512010702	wab_fplwab	3665125	8068099	4503914	0.226	-0.271	-0.052	0.449	0.696
512010703	wab_fplwab	11901160	19522620	10899794	0.281	-0.18	0.024	0.522	0.726
512010704	wab_fplwab	27216434	16077241	11760022	0.494	0.202	0.281	0.698	0.9
512010803	wab_fplwab	3958121	5219431	4743313	0.284	-0.091	-0.056	0.455	0.948
512010804	wab_fplwab	10658609	57491457	5578529	0.145	-0.635	0.069	0.656	0.238
512010805	wab_fplwab	34422519	8308391	16423834	0.582	0.441	0.304	0.677	1.19
512010806	wab_fplwab	29153957	13899426	6062687	0.594	0.311	0.47	0.828	0.818
512010807	wab_fplwab	3964374	17411801	7810834	0.136	-0.461	-0.132	0.337	0.551
512010809	wab_fplwab	11001628	2546739	9123955	0.485	0.373	0.083	0.547	1.485
512010812	wab_fplwab	19093846	14090588	30164256	0.301	0.079	-0.175	0.388	1.484
512010813	wab_fplwab	16740948	4061741	15799431	0.457	0.346	0.026	0.514	1.564
512010815	wab_fplwab	13022226	3852714	5185486	0.59	0.416	0.355	0.715	1.079
512010816	wab_fplwab	48911509	43766220	6160054	0.495	0.052	0.433	0.888	0.594
512011001	wab_fplwab	7395460	16963374	10414744	0.213	-0.275	-0.087	0.415	0.731
512011002	wab_fplwab	309075	16576584	945090	0.017	-0.912	-0.036	0.246	0.074
512011003	wab_fplwab	2038463	3448951	8662130	0.144	-0.1	-0.468	0.191	1.95
512011004	wab_fplwab	11768062	15540380	15727969	0.273	-0.088	-0.092	0.428	1.007
512011005	wab_fplwab	4283274	5252482	4822815	0.298	-0.068	-0.038	0.47	0.955
512011006	wab_fplwab	17526140	15755661	7491040	0.43	0.043	0.246	0.701	0.752
512011104	wab_fplwab	10697020	8694288	14901686	0.312	0.058	-0.123	0.418	1.32
512011107	wab_fplwab	10223582	9649203	15494823	0.289	0.016	-0.149	0.398	1.294
512011112	wab_fplwab	9324943	9454468	6569176	0.368	-0.005	0.109	0.587	0.846

512011115	wab_fplwab	37436443	64640372	27242340	0.289	-0.21	0.079	0.579	0.634
512011118	wab_fplwab	18407807	1951815	21375281	0.441	0.394	-0.071	0.463	1.954
512011305	wab_fplwab	49579682	25642476	9336555	0.586	0.283	0.476	0.842	0.783
512011307	wab_fplwab	40311016	73427560	27534442	0.285	-0.234	0.09	0.594	0.597
512020101	wab_fplwab	8039514	14791812	24024747	0.172	-0.144	-0.341	0.251	1.404
512020102	wab_fplwab	5231044	7199831	10429036	0.229	-0.086	-0.227	0.334	1.26
512020103	wab_fplwab	22210497	22824180	23112709	0.326	-0.009	-0.013	0.49	1.006
512020104	wab_fplwab	9339235	11396458	11293730	0.292	-0.064	-0.061	0.453	0.995
512020105	wab_fplwab	3046082	12288844	6836267	0.137	-0.417	-0.171	0.308	0.644
512020106	wab_fplwab	6576322	37998316	26771581	0.092	-0.44	-0.283	0.197	0.748
512020113	wab_fplwab	24810833	8011822	33491722	0.374	0.253	-0.131	0.426	1.776
512020115	wab_fplwab	20310492	3820556	11222268	0.575	0.466	0.257	0.644	1.307
512020116	wab_fplwab	7153381	5507067	12595238	0.283	0.065	-0.215	0.362	1.56
512020117	wab_fplwab	38357414	18426566	10883715	0.567	0.295	0.406	0.779	0.867
512020201	wab_fplwab	32079447	7069413	26577740	0.488	0.381	0.084	0.547	1.498
512020202	wab_fplwab	59496869	12313855	22821500	0.629	0.499	0.388	0.723	1.146
512020203	wab_fplwab	11748410	8734485	14312121	0.338	0.087	-0.074	0.451	1.272
512020205	wab_fplwab	65430924	55980922	46507695	0.39	0.056	0.113	0.585	0.922
512020206	wab_fplwab	53377906	11378592	37832166	0.52	0.409	0.152	0.585	1.409
512020207	wab_fplwab	10662182	32132151	4474436	0.226	-0.454	0.131	0.704	0.354
512020208	wab_fplwab	50616780	27121747	8672849	0.586	0.272	0.485	0.854	0.763
512020209	wab_fplwab	54950971	15818190	17254583	0.624	0.445	0.428	0.761	1.02
512020210	wab_fplwab	174958582	20565077	42483471	0.735	0.649	0.557	0.805	1.112
512020301	wab_fplwab	5495454	13497451	10355787	0.187	-0.273	-0.166	0.347	0.835
512020302	wab_fplwab	3267616	182229	11442015	0.219	0.207	-0.549	0.222	4.264
512020303	wab_fplwab	7108717	3226525	8390573	0.38	0.207	-0.068	0.459	1.5
512020304	wab_fplwab	25794334	4735274	15806578	0.557	0.454	0.216	0.62	1.363
512020305	wab_fplwab	23002836	105726754	24881402	0.15	-0.539	-0.012	0.48	0.372
512020306	wab_fplwab	7674163	3255110	16397035	0.281	0.162	-0.319	0.319	2.202
512020307	wab_fplwab	32826229	4927329	25328935	0.52	0.442	0.119	0.564	1.54
512020308	wab_fplwab	127922959	14420208	48669431	0.67	0.594	0.415	0.724	1.241
512020401	wab_fplwab	13693972	8819347	27496924	0.274	0.097	-0.276	0.332	1.83
512020402	wab_fplwab	4941621	11057905	5688403	0.228	-0.282	-0.034	0.465	0.664
512020403	wab_fplwab	10808680	3692817	30141924	0.242	0.159	-0.433	0.264	2.824
512020404	wab_fplwab	4595922	5588355	28919918	0.118	-0.025	-0.622	0.137	3.291
512020405	wab_fplwab	6763911	15597550	6858599	0.231	-0.302	-0.003	0.497	0.609
512020409	wab_fplwab	18932162	12019967	15226839	0.41	0.15	0.08	0.554	1.104
512020501	wab_fplwab	4465503	7626819	10728285	0.196	-0.139	-0.274	0.294	1.256
512020502	wab_fplwab	2087594	6120750	2882612	0.188	-0.364	-0.072	0.42	0.606
512020503	wab_fplwab	731596	6397667	4695969	0.062	-0.479	-0.335	0.135	0.761
512020504	wab_fplwab	12688140	12711365	10313803	0.355	-0.001	0.066	0.552	0.906
512020505	wab_fplwab	2770952	6367295	12120014	0.13	-0.169	-0.44	0.186	1.63
512020506	wab_fplwab	32463557	19461877	47253583	0.327	0.131	-0.149	0.407	1.535
512020601	wab_fplwab	15529661	21415479	22483841	0.261	-0.099	-0.117	0.409	1.029
512020602	wab_fplwab	21086752	5449897	31205820	0.365	0.271	-0.175	0.403	1.971
512020603	wab_fplwab	20483788	11633177	34951340	0.305	0.132	-0.216	0.37	1.726
512020604	wab_fplwab	16230885	13086542	28021279	0.283	0.055	-0.206	0.367	1.509
512020605	wab_fplwab	72734376	10819399	43013186	0.575	0.489	0.235	0.628	1.385
512020606	wab_fplwab	50548890	7347222	14347852	0.7	0.598	0.501	0.779	1.121
512020701	wab_fplwab	16972	7340076	540434	0.002	-0.927	-0.066	0.03	0.076

512020702	wab_fplwab	5955493	5373075	10139614	0.277	0.027	-0.195	0.37	1.421
512020703	wab_fplwab	2517261	2143870	5365929	0.251	0.037	-0.284	0.319	1.691
512020704	wab_fplwab	5650885	4827281	8118122	0.304	0.044	-0.133	0.41	1.314
512020705	wab_fplwab	10837265	6793389	14585465	0.336	0.126	-0.116	0.426	1.442
512020706	wab_fplwab	31508642	8219956	16212126	0.563	0.416	0.273	0.66	1.201
512020707	wab_fplwab	62055221	20242603	32438545	0.541	0.364	0.258	0.657	1.148
512020708	wab_fplwab	17331405	3803583	12464820	0.516	0.403	0.145	0.582	1.41
512020709	wab_fplwab	54120221	20222951	23386053	0.554	0.347	0.314	0.698	1.043
512020801	wab_fplwab	25480793	4043875	11525983	0.621	0.522	0.34	0.689	1.253
512020802	wab_fplwab	9174872	6023382	4960380	0.455	0.156	0.209	0.649	0.93
512020803	wab_fplwab	22845619	990647	6306552	0.758	0.725	0.549	0.784	1.223
512020804	wab_fplwab	10905154	3732121	13217854	0.391	0.258	-0.083	0.452	1.648
512020805	wab_fplwab	7591981	2128685	7254321	0.447	0.322	0.02	0.511	1.527
512020806	wab_fplwab	18661498	3517734	16394355	0.484	0.393	0.059	0.532	1.581
512020807	wab_fplwab	43607217	1087121	14111133	0.742	0.723	0.502	0.756	1.291
512020808	wab_fplwab	32127684	5440964	17887025	0.579	0.481	0.257	0.642	1.331
512020809	wab_fplwab	18824968	5781304	14880247	0.477	0.33	0.1	0.559	1.37
512020810	wab_fplwab	38781722	5044348	11582260	0.7	0.609	0.491	0.77	1.149
512020811	wab_fplwab	14375544	3445378	5843833	0.607	0.462	0.361	0.711	1.135
512020812	wab_fplwab	6532552	13151751	6857705	0.246	-0.249	-0.012	0.488	0.68
512020813	wab_fplwab	35134462	5673217	12569333	0.658	0.552	0.423	0.737	1.169
512020814	wab_fplwab	40920233	8336976	10056539	0.69	0.549	0.52	0.803	1.035
512020901	wab_fplwab	30305394	11471493	8072565	0.608	0.378	0.446	0.79	0.919
512020902	wab_fplwab	9349955	1963428	12485365	0.393	0.31	-0.132	0.428	1.93
512020903	wab_fplwab	24640217	4272555	19116178	0.513	0.424	0.115	0.563	1.513
512020904	wab_fplwab	51737845	28401816	14015553	0.549	0.248	0.401	0.787	0.82
512020905	wab_fplwab	8867584	10822079	3289054	0.386	-0.085	0.243	0.729	0.617
512020906	wab_fplwab	33110291	19172454	9332982	0.537	0.226	0.386	0.78	0.812
512020907	wab_fplwab	4212705	14826650	862908	0.212	-0.533	0.168	0.83	0.267
512010808	wab_fplwab	15250065	15292049	1491776	0.476	-0.001	0.429	0.911	0.548
512011106	wab_fplwab	36004516	12274551	9775156	0.62	0.409	0.452	0.786	0.948
512011116	wab_fplwab	33260362	28933317	9380326	0.465	0.06	0.334	0.78	0.686
512011117	wab_fplwab	64439384	4338658	36067046	0.615	0.573	0.271	0.641	1.461
512011119	wab_fplwab	32422466	12042299	21051914	0.495	0.311	0.174	0.606	1.203
512010301	wab_fplwab	7017602	11046292	18793704	0.19	-0.109	-0.32	0.272	1.429
512011204	wab_fplwab	5365036	15478744	2473490	0.23	-0.434	0.124	0.684	0.376
512010814	wab_fplwab	9882349	12061951	7257895	0.338	-0.075	0.09	0.577	0.781
512020815	wab_fplwab	69431922	11023960	26450001	0.649	0.546	0.402	0.724	1.192
512020908	wab_fplwab	85874514	44359358	16297881	0.586	0.283	0.475	0.84	0.785

APPENDIX D
Other Result

APPENDIX D1
SSURGO Analysis Results

APPENDIX CONTENTS

Merwade (2015) developed floodplain maps derived using SSURGO soil data, publically available at: https://mapsweb.lib.purdue.edu/floodplain/. This floodplain delineation approach is based off of presence of alluvial soils. We performed the fit index analysis with these SSURGO maps to compare our results to a non-hydraulically based floodplain. We believe that these results are more representative of the natural fluvial floodplain than those derived by FEMA. The following Appendix contains the results from that analysis. Results were lower than expected. This is due to the more inclusive area of the SSURGO maps. Results were similar in high order HUC10s, but the model greatly underpredicted the floodplain area in the high order HUC10s when compared to the SSURGO results.

HUC10	Name	A	B	C	F1	F2	F3	TP rate	Bias
512020703	wab_fplwab	1390	1021713	10591809	0	-0.088	-0.912	0	10.35
512020702	wab_fplwab	42381	2037173	13621613	0.003	-0.127	-0.865	0.003	6.57
512020704	wab_fplwab	49627	1469146	15437947	0.003	-0.084	-0.908	0.003	10.2
512010610	wab_fplwab	586884	75485655	186398	0.008	-0.982	0.005	0.759	0.01
512010608	wab_fplwab	32257	3319127	395226	0.009	-0.877	-0.097	0.075	0.13
512020302	wab_fplwab	251508	43671	25592049	0.01	0.008	-0.979	0.01	87.55
512011307	wab_fplwab	2523811	244262	227685423	0.011	0.01	-0.977	0.011	83.17
512020207	wab_fplwab	1216348	588175	65006400	0.018	0.009	-0.955	0.018	36.7
512010301	wab_fplwab	268083	93794	13727317	0.019	0.012	-0.955	0.019	38.67
512020306	wab_fplwab	737253	97169	33144128	0.022	0.019	-0.954	0.022	40.6
512010813	wab_fplwab	1574355	87144	58774290	0.026	0.025	-0.946	0.026	36.32
512020116	wab_fplwab	1237787	165951	44830997	0.027	0.023	-0.943	0.027	32.82
512020203	wab_fplwab	1703781	217861	58455687	0.028	0.025	-0.94	0.028	31.31
512011114	wab_fplwab	1887201	121387	61642807	0.03	0.028	-0.939	0.03	31.63
512020603	wab_fplwab	2013054	1630830	63536063	0.03	0.006	-0.916	0.031	17.99
512020303	wab_fplwab	1013078	143520	30858425	0.032	0.027	-0.932	0.032	27.56
512020308	wab_fplwab	6924104	597604	211576525	0.032	0.029	-0.934	0.032	29.05
512011108	wab_fplwab	1158087	84167	31372160	0.036	0.033	-0.926	0.036	26.19
512010109	wab_fplwab	301829	64415	7877729	0.037	0.029	-0.919	0.037	22.33
512011104	wab_fplwab	1429743	196124	35627047	0.038	0.033	-0.918	0.039	22.79
512011403	wab_fplwab	541526	49726	11639029	0.044	0.04	-0.907	0.044	20.6
512020701	wab_fplwab	668669	279100	12494692	0.05	0.029	-0.88	0.051	13.89
512010611	wab_fplwab	1930376	35036490	444654	0.052	-0.885	0.04	0.813	0.06
512011107	wab_fplwab	1361159	682862	24149601	0.052	0.026	-0.87	0.053	12.48
512020812	wab_fplwab	1259027	1025087	21524949	0.053	0.01	-0.851	0.055	9.97
512020502	wab_fplwab	793430	128533	12356829	0.06	0.05	-0.871	0.06	14.26
512020809	wab_fplwab	2577507	626089	38741117	0.061	0.047	-0.862	0.062	12.9
512011005	wab_fplwab	820923	168333	12235442	0.062	0.049	-0.863	0.063	13.2
512010303	wab_fplwab	858640	99055	12265615	0.065	0.057	-0.863	0.065	13.7
512010111	wab_fplwab	658644	558597	8098071	0.071	0.011	-0.799	0.075	7.19
512010504	wab_fplwab	729313	271755	8456078	0.077	0.048	-0.817	0.079	9.18
512010201	wab_fplwab	2142282	836208	23000150	0.082	0.05	-0.803	0.085	8.44
512020304	wab_fplwab	6078566	348081	66749485	0.083	0.078	-0.829	0.083	11.33
512010607	wab_fplwab	395921	552543	3622445	0.087	-0.034	-0.706	0.099	4.24
512020601	wab_fplwab	4585499	505298	46555621	0.089	0.079	-0.813	0.09	10.05
512010405	wab_fplwab	2564902	851791	24851223	0.091	0.061	-0.788	0.094	8.02
512010807	wab_fplwab	1455052	2514680	11902150	0.092	-0.067	-0.658	0.109	3.36
512011118	wab_fplwab	3287664	6602920	25646638	0.093	-0.093	-0.629	0.114	2.93
512020113	wab_fplwab	7472677	1252973	71001494	0.094	0.078	-0.797	0.095	8.99
512011103	wab_fplwab	3014023	2116277	25427189	0.099	0.029	-0.733	0.106	5.54
512010110	wab_fplwab	3388902	12608039	18048902	0.1	-0.271	-0.431	0.158	1.34
512020307	wab_fplwab	9580815	421628	84381325	0.102	0.097	-0.793	0.102	9.39
512011305	wab_fplwab	7357543	18320459	44965684	0.104	-0.155	-0.532	0.141	2.04
512020802	wab_fplwab	3494409	373291	27441335	0.112	0.1	-0.765	0.113	8
512011105	wab_fplwab	3336894	314633	25772292	0.113	0.103	-0.762	0.115	7.97
512010612	wab_fplwab	6483817	48905739	1606612	0.114	-0.744	0.086	0.801	0.15
512011501	wab_fplwab	5119978	193742	39088701	0.115	0.111	-0.765	0.116	8.32
512020708	wab_fplwab	7845075	243071	57607667	0.119	0.116	-0.757	0.12	8.09
512020206	wab_fplwab	9389356	13048425	54499850	0.122	-0.048	-0.586	0.147	2.85

512020604	wab_fplwab	9842347	1313716	68519667	0.124	0.107	-0.736	0.126	7.02
512010702	wab_fplwab	3099182	667379	20778366	0.126	0.099	-0.72	0.13	6.34
512011207	wab_fplwab	6274392	323466	42824295	0.127	0.12	-0.74	0.128	7.44
512011213	wab_fplwab	5360369	2929261	33847833	0.127	0.058	-0.676	0.137	4.73
512020301	wab_fplwab	1791223	120196	11855104	0.13	0.121	-0.731	0.131	7.14
512020902	wab_fplwab	3770233	121684	25179651	0.13	0.126	-0.736	0.13	7.44
512020808	wab_fplwab	9333575	1301805	58252714	0.135	0.117	-0.71	0.138	6.35
512011304	wab_fplwab	24946307	4716216	152918461	0.137	0.111	-0.701	0.14	6
512011115	wab_fplwab	13845230	3469694	82444994	0.139	0.104	-0.688	0.144	5.56
512020505	wab_fplwab	2164614	2107841	10533944	0.146	0.004	-0.565	0.17	2.97
512020811	wab_fplwab	2614330	1382101	13927511	0.146	0.069	-0.631	0.158	4.14
512010403	wab_fplwab	3660062	1572568	19581372	0.147	0.084	-0.642	0.157	4.44
512011006	wab_fplwab	7659273	817251	43580009	0.147	0.131	-0.69	0.149	6.04
512010112	wab_fplwab	963451	161584	5317095	0.15	0.124	-0.676	0.153	5.58
512010404	wab_fplwab	3651626	992235	19741765	0.15	0.109	-0.66	0.156	5.04
512020408	wab_fplwab	9205936	1110544	50504312	0.151	0.133	-0.679	0.154	5.79
512010305	wab_fplwab	3859660	450014	20745116	0.154	0.136	-0.674	0.157	5.71
512011502	wab_fplwab	18966399	492395	100208345	0.158	0.154	-0.679	0.159	6.12
512011002	wab_fplwab	1777526	762265	8404664	0.162	0.093	-0.606	0.175	4.01
512011301	wab_fplwab	4497859	3179875	19641917	0.165	0.048	-0.554	0.186	3.14
512011110	wab_fplwab	8528334	175083	42820027	0.166	0.162	-0.666	0.166	5.9
512010901	wab_fplwab	3244191	10514490	5722147	0.167	-0.373	-0.127	0.362	0.65
512010814	wab_fplwab	5959164	544801	29132114	0.167	0.152	-0.65	0.17	5.4
512011214	wab_fplwab	6221193	1049007	28465430	0.174	0.145	-0.622	0.179	4.77
512011112	wab_fplwab	5744876	1618026	25449620	0.175	0.126	-0.601	0.184	4.24
512020804	wab_fplwab	7271292	472743	33175194	0.178	0.166	-0.633	0.18	5.22
512020101	wab_fplwab	7205983	1842636	30685526	0.181	0.135	-0.591	0.19	4.19
512020806	wab_fplwab	10765105	1086823	46826781	0.183	0.165	-0.615	0.187	4.86
512020305	wab_fplwab	20193864	11411045	78282413	0.184	0.08	-0.529	0.205	3.12
512020907	wab_fplwab	8505605	542617	36118946	0.188	0.176	-0.611	0.191	4.93
512020506	wab_fplwab	11615209	991143	48931545	0.189	0.173	-0.606	0.192	4.8
512011209	wab_fplwab	3352278	80693	14163932	0.191	0.186	-0.614	0.191	5.1
512020401	wab_fplwab	7925470	8862222	24552570	0.192	-0.023	-0.402	0.244	1.93
512010815	wab_fplwab	5255856	1196101	20553657	0.195	0.15	-0.566	0.204	4
512020109	wab_fplwab	4119803	613782	16398619	0.195	0.166	-0.581	0.201	4.33
512020903	wab_fplwab	11659972	306494	47478180	0.196	0.191	-0.603	0.197	4.94
512010803	wab_fplwab	1845812	376865	7102660	0.198	0.158	-0.564	0.206	4.03
512010406	wab_fplwab	3212232	486639	12341643	0.2	0.17	-0.569	0.207	4.21
512011402	wab_fplwab	4138760	118211	16183041	0.202	0.197	-0.589	0.204	4.77
512011505	wab_fplwab	49085090	675319	193565239	0.202	0.199	-0.594	0.202	4.88
512020501	wab_fplwab	3429497	7566471	5803932	0.204	-0.246	-0.141	0.371	0.84
512011210	wab_fplwab	22676584	877895	86845684	0.205	0.197	-0.581	0.207	4.65
512020102	wab_fplwab	2296918	758096	8147003	0.205	0.137	-0.522	0.22	3.42
512020110	wab_fplwab	7576892	1240467	27559148	0.208	0.174	-0.549	0.216	3.98
512020406	wab_fplwab	4176675	322672	15563403	0.208	0.192	-0.568	0.212	4.39
512011003	wab_fplwab	2704452	272252	9925919	0.21	0.189	-0.56	0.214	4.24
512010107	wab_fplwab	1842835	790552	6114595	0.211	0.12	-0.488	0.232	3.02
512010809	wab_fplwab	4634233	1246720	16111876	0.211	0.154	-0.522	0.223	3.53
512010401	wab_fplwab	5576543	7334715	13111749	0.214	-0.068	-0.29	0.298	1.45
512010115	wab_fplwab	5517884	1129899	18730871	0.217	0.173	-0.521	0.228	3.65

512010603	wab_fplwab	4868172	12546700	4620635	0.221	-0.348	0.011	0.513	0.54
512020112	wab_fplwab	12523177	1397883	42610603	0.222	0.197	-0.532	0.227	3.96
512011504	wab_fplwab	33037331	1122157	113014096	0.224	0.217	-0.543	0.226	4.28
512020805	wab_fplwab	6088392	638397	20434950	0.224	0.201	-0.528	0.23	3.94
512020403	wab_fplwab	4837305	6676963	9951923	0.225	-0.086	-0.238	0.327	1.28
512020111	wab_fplwab	7547513	922162	24909286	0.226	0.198	-0.52	0.233	3.83
512011206	wab_fplwab	3075560	120791	10155988	0.23	0.221	-0.53	0.232	4.14
512011211	wab_fplwab	6720734	286643	21957495	0.232	0.222	-0.526	0.234	4.09
512010812	wab_fplwab	15211749	5543988	44779882	0.232	0.148	-0.451	0.254	2.89
512010203	wab_fplwab	3082210	391058	9654263	0.235	0.205	-0.501	0.242	3.67
512010811	wab_fplwab	5611083	442769	17556706	0.238	0.219	-0.506	0.242	3.83
512020405	wab_fplwab	2858989	273740	8812794	0.239	0.216	-0.498	0.245	3.73
512010502	wab_fplwab	3980055	705591	11806271	0.241	0.199	-0.475	0.252	3.37
512020905	wab_fplwab	7649844	227687	23918242	0.241	0.233	-0.512	0.242	4.01
512010909	wab_fplwab	7396549	1003549	22076102	0.243	0.21	-0.482	0.251	3.51
512020407	wab_fplwab	7160624	887026	21029080	0.246	0.216	-0.477	0.254	3.5
512010407	wab_fplwab	3696587	1768296	9090901	0.254	0.132	-0.371	0.289	2.34
512011401	wab_fplwab	11964183	750156	33866989	0.257	0.241	-0.47	0.261	3.6
512010505	wab_fplwab	9041175	5704976	20154262	0.259	0.096	-0.318	0.31	1.98
512010202	wab_fplwab	3744924	1014070	9383897	0.265	0.193	-0.399	0.285	2.76
512011111	wab_fplwab	35341991	10404121	86836156	0.267	0.188	-0.388	0.289	2.67
512010402	wab_fplwab	4458058	6162435	5958866	0.269	-0.103	-0.091	0.428	0.98
512010605	wab_fplwab	10041152	15901062	10165218	0.278	-0.162	-0.003	0.497	0.78
512011202	wab_fplwab	2824548	5278088	2011863	0.279	-0.243	0.08	0.584	0.6
512020705	wab_fplwab	13060137	866282	32101870	0.284	0.265	-0.414	0.289	3.24
512020503	wab_fplwab	4295283	589465	9995098	0.289	0.249	-0.383	0.301	2.93
512011503	wab_fplwab	68526416	914222	164745079	0.293	0.289	-0.411	0.294	3.36
512011404	wab_fplwab	28719419	1092381	67576662	0.295	0.284	-0.399	0.298	3.23
512020813	wab_fplwab	18209693	2169179	40299690	0.3	0.264	-0.364	0.311	2.87
512010204	wab_fplwab	22101412	43631224	7608852	0.301	-0.294	0.198	0.744	0.45
512020409	wab_fplwab	12678906	970101	28415902	0.301	0.278	-0.374	0.309	3.01
512010904	wab_fplwab	836308	613286	1305478	0.304	0.081	-0.17	0.39	1.48
512020105	wab_fplwab	1757080	259051	3663735	0.309	0.264	-0.336	0.324	2.69
512010306	wab_fplwab	25750159	44679537	12687739	0.31	-0.228	0.157	0.67	0.55
512011407	wab_fplwab	34788158	501427	76578731	0.311	0.306	-0.374	0.312	3.16
512020706	wab_fplwab	20823725	1783382	44403017	0.311	0.284	-0.352	0.319	2.89
512010304	wab_fplwab	5470540	752935	11291643	0.312	0.269	-0.332	0.326	2.69
512011101	wab_fplwab	3852514	902510	7552079	0.313	0.24	-0.301	0.338	2.4
512020114	wab_fplwab	24974793	2731151	51812767	0.314	0.28	-0.338	0.325	2.77
512010116	wab_fplwab	9343600	1992012	17988457	0.319	0.251	-0.295	0.342	2.41
512011410	wab_fplwab	42915608	8570417	82417600	0.32	0.256	-0.295	0.342	2.43
512010302	wab_fplwab	6777606	2076477	12209636	0.322	0.223	-0.258	0.357	2.14
512020115	wab_fplwab	15490452	1553512	30311341	0.327	0.294	-0.313	0.338	2.69
512010704	wab_fplwab	20972406	4799489	37663326	0.331	0.255	-0.263	0.358	2.28
512020402	wab_fplwab	6601928	541923	12627592	0.334	0.307	-0.305	0.343	2.69
512010602	wab_fplwab	8951252	10043931	7748203	0.335	-0.041	0.045	0.536	0.88
512010801	wab_fplwab	7462255	1579317	13038202	0.338	0.266	-0.253	0.364	2.27
512020202	wab_fplwab	40395271	1717577	77383675	0.338	0.324	-0.31	0.343	2.8
512010604	wab_fplwab	10585059	8493794	12125072	0.339	0.067	-0.049	0.466	1.19
512011004	wab_fplwab	7372927	688023	13524245	0.342	0.31	-0.285	0.353	2.59

512010501	wab_fplwab	5228958	3876533	6049584	0.345	0.089	-0.054	0.464	1.24
512010113	wab_fplwab	7900756	1760554	13184501	0.346	0.269	-0.231	0.375	2.18
512010703	wab_fplwab	14865057	2700879	25307390	0.347	0.284	-0.244	0.37	2.29
512010701	wab_fplwab	6167497	1013971	10556871	0.348	0.291	-0.247	0.369	2.33
512010804	wab_fplwab	9601460	2647481	15290953	0.349	0.253	-0.207	0.386	2.03
512011406	wab_fplwab	28611233	829559	52103083	0.351	0.341	-0.288	0.354	2.74
512010810	wab_fplwab	2908616	982309	4329426	0.354	0.234	-0.173	0.402	1.86
512011102	wab_fplwab	5183798	1434606	7967156	0.355	0.257	-0.191	0.394	1.99
512011409	wab_fplwab	91030002	12231968	148842230	0.361	0.313	-0.229	0.379	2.32
512010114	wab_fplwab	23837946	5900605	36170557	0.362	0.272	-0.187	0.397	2.02
512020106	wab_fplwab	11653520	3825319	16366759	0.366	0.246	-0.148	0.416	1.81
512010606	wab_fplwab	13835305	12870663	10977606	0.367	0.026	0.076	0.558	0.93
512011405	wab_fplwab	41754346	5351833	66402397	0.368	0.321	-0.217	0.386	2.3
512020814	wab_fplwab	21099748	3530140	32536698	0.369	0.307	-0.2	0.393	2.18
512020201	wab_fplwab	29948471	2411059	48623463	0.37	0.34	-0.231	0.381	2.43
512020108	wab_fplwab	12659452	4055586	17236415	0.373	0.253	-0.135	0.423	1.79
512011302	wab_fplwab	66906802	19774221	88175677	0.383	0.27	-0.122	0.431	1.79
512010902	wab_fplwab	3933902	4399499	1912511	0.384	-0.045	0.197	0.673	0.7
512010108	wab_fplwab	5438482	3050747	5583391	0.386	0.17	-0.01	0.493	1.3
512011204	wab_fplwab	4136974	311159	6167596	0.39	0.36	-0.191	0.401	2.32
512010903	wab_fplwab	5582994	3031491	5482351	0.396	0.181	0.007	0.505	1.28
512010906	wab_fplwab	6648875	1629837	8420743	0.398	0.301	-0.106	0.441	1.82
512020404	wab_fplwab	9861007	2269624	12662429	0.398	0.306	-0.113	0.438	1.86
512010905	wab_fplwab	15305146	2908417	19954961	0.401	0.325	-0.122	0.434	1.94
512020504	wab_fplwab	11615506	2335627	14641241	0.406	0.325	-0.106	0.442	1.88
512011116	wab_fplwab	25862117	2896904	34810689	0.407	0.361	-0.141	0.426	2.11
512020104	wab_fplwab	6027152	3179577	5550241	0.408	0.193	0.032	0.521	1.26
512010106	wab_fplwab	8434043	8313947	3850132	0.409	0.006	0.223	0.687	0.73
512020209	wab_fplwab	39480653	7733018	45402398	0.426	0.343	-0.064	0.465	1.8
512010907	wab_fplwab	3819860	717899	4416769	0.427	0.346	-0.067	0.464	1.82
512011203	wab_fplwab	4350269	4247741	1574057	0.428	0.01	0.273	0.734	0.69
512020605	wab_fplwab	47789240	6212458	56698011	0.432	0.376	-0.08	0.457	1.93
512020801	wab_fplwab	22140617	1915984	27091765	0.433	0.395	-0.097	0.45	2.05
512020208	wab_fplwab	44502270	9833415	48319252	0.434	0.338	-0.037	0.479	1.71
512010613	wab_fplwab	16379860	10015346	11195268	0.436	0.169	0.138	0.594	1.04
512020103	wab_fplwab	15152395	3860752	15681614	0.437	0.325	-0.015	0.491	1.62
512011215	wab_fplwab	54400696	19968361	49375902	0.44	0.278	0.041	0.524	1.4
512020709	wab_fplwab	46064913	2358555	55906665	0.442	0.419	-0.094	0.452	2.11
512011119	wab_fplwab	29089931	12134303	24343741	0.444	0.259	0.072	0.544	1.3
512020204	wab_fplwab	18740300	686535	22662490	0.445	0.429	-0.093	0.453	2.13
512011303	wab_fplwab	74241417	31048694	59324053	0.451	0.262	0.091	0.556	1.27
512020205	wab_fplwab	73060403	23010968	64534054	0.455	0.312	0.053	0.531	1.43
512011001	wab_fplwab	6126207	619638	6574236	0.46	0.413	-0.034	0.482	1.88
512010503	wab_fplwab	13653671	7712572	7675649	0.47	0.205	0.206	0.64	1
512010601	wab_fplwab	14316286	6769070	9362557	0.47	0.248	0.163	0.605	1.12
512020602	wab_fplwab	22896629	1880849	23842214	0.471	0.432	-0.019	0.49	1.89
512020117	wab_fplwab	35482633	2744749	36644491	0.474	0.437	-0.016	0.492	1.89
512011201	wab_fplwab	6181590	2375825	4239403	0.483	0.297	0.152	0.593	1.22
512011117	wab_fplwab	46419545	30586074	19065156	0.483	0.165	0.285	0.709	0.85
512020107	wab_fplwab	11787810	1548450	10681633	0.491	0.426	0.046	0.525	1.68

512011109	wab_fplwab	29128739	4612000	25348084	0.493	0.415	0.064	0.535	1.61
512010802	wab_fplwab	13790542	8777857	5128017	0.498	0.181	0.313	0.729	0.84
512010908	wab_fplwab	14704664	6161244	8510171	0.501	0.291	0.211	0.633	1.11
512020707	wab_fplwab	54293602	2254736	50940232	0.505	0.484	0.031	0.516	1.86
512010609	wab_fplwab	2195878	1653360	480882	0.507	0.125	0.396	0.82	0.7
512020810	wab_fplwab	23531651	5407217	17403161	0.508	0.391	0.132	0.575	1.41
512011205	wab_fplwab	11547518	1166920	9933760	0.51	0.458	0.071	0.538	1.69
512020904	wab_fplwab	49287269	4150274	42940819	0.511	0.468	0.066	0.534	1.73
512020815	wab_fplwab	76437395	6814330	66014019	0.512	0.466	0.07	0.537	1.71
512020908	wab_fplwab	73385159	11257301	54409927	0.528	0.447	0.136	0.574	1.51
512010806	wab_fplwab	24942833	3491431	18694247	0.529	0.455	0.133	0.572	1.53
512010805	wab_fplwab	31012168	2576515	23835167	0.54	0.495	0.125	0.565	1.63
512011208	wab_fplwab	77460398	2363319	62361202	0.545	0.528	0.106	0.554	1.75
512011212	wab_fplwab	89126821	4256177	64759756	0.564	0.537	0.154	0.579	1.65
512011408	wab_fplwab	115317962	2280641	86916154	0.564	0.553	0.139	0.57	1.72
512020906	wab_fplwab	41281106	2210369	29275138	0.567	0.537	0.165	0.585	1.62
512011113	wab_fplwab	41762087	2860577	28923980	0.568	0.529	0.175	0.591	1.58
512020901	wab_fplwab	41219172	9244347	21225006	0.575	0.446	0.279	0.66	1.24
512011309	wab_fplwab	121220155	58789178	26945366	0.586	0.302	0.456	0.818	0.82
512011106	wab_fplwab	32997233	2629814	18757372	0.607	0.558	0.262	0.638	1.45
512010506	wab_fplwab	22205528	7483594	5378433	0.633	0.42	0.48	0.805	0.93
512020210	wab_fplwab	156423588	31373152	57146239	0.639	0.511	0.405	0.732	1.14
512020606	wab_fplwab	57877437	5049012	26817628	0.645	0.589	0.346	0.683	1.35
512010816	wab_fplwab	69640732	10817907	24830975	0.661	0.559	0.426	0.737	1.17
512020803	wab_fplwab	22054564	1203842	9014178	0.683	0.646	0.404	0.71	1.34
514020206	wab_fplwab	6417317	1728594	582418	0.735	0.537	0.669	0.917	0.86
512011306	wab_fplwab	115960527	18675686	18734246	0.756	0.634	0.634	0.861	1
512020807	wab_fplwab	50678700	9114623	7011149	0.759	0.622	0.654	0.878	0.96
512010808	wab_fplwab	25956407	1099627	5692868	0.793	0.759	0.619	0.82	1.17
512011308	wab_fplwab	168244648	6174345	37222344	0.795	0.766	0.619	0.819	1.18

HUC10	Name	A	B	C	F1	F2	F3	TP rate	bias
512010608	wab_fplwab	36624	22615153	386790	0.002	-0.98	-0.015	0.086	0.019
512010610	wab_fplwab	534181	113391984	221533	0.005	-0.989	0.003	0.707	0.007
512010609	wab_fplwab	1580211	54331928	1171982	0.028	-0.924	0.007	0.574	0.049
512010606	wab_fplwab	4135883	99041452	20907203	0.033	-0.765	-0.135	0.165	0.243
512010604	wab_fplwab	4129630	59964054	18407807	0.05	-0.677	-0.173	0.183	0.352
512010611	wab_fplwab	1402449	25316429	978141	0.051	-0.863	0.015	0.589	0.089
512011203	wab_fplwab	5222111	93433444	912038	0.052	-0.886	0.043	0.851	0.062
512010701	wab_fplwab	4536966	67754343	12287057	0.054	-0.747	-0.092	0.27	0.233
512011202	wab_fplwab	3645473	59439699	1297042	0.057	-0.867	0.036	0.738	0.078
512020702	wab_fplwab	1313121	9603646	12302243	0.057	-0.357	-0.473	0.096	1.247
512010111	wab_fplwab	1882140	23791602	6947927	0.058	-0.672	-0.155	0.213	0.344
512010607	wab_fplwab	698544	7705427	3356050	0.059	-0.596	-0.226	0.172	0.482
512010504	wab_fplwab	1823183	20137196	7438337	0.062	-0.623	-0.191	0.197	0.422
512010612	wab_fplwab	5280174	76025217	3022857	0.063	-0.839	0.027	0.636	0.102
512020704	wab_fplwab	1522148	8751458	13942304	0.063	-0.299	-0.513	0.098	1.505
512020703	wab_fplwab	990647	3414114	9705480	0.07	-0.172	-0.618	0.093	2.428
512020501	wab_fplwab	1434607	10416530	7793862	0.073	-0.457	-0.324	0.155	0.779
512011201	wab_fplwab	7296306	87845089	3369450	0.074	-0.818	0.04	0.684	0.112
512010402	wab_fplwab	5476696	59914924	5309652	0.077	-0.77	0.002	0.508	0.165
512010901	wab_fplwab	7106037	74957748	2353791	0.084	-0.804	0.056	0.751	0.115
512011301	wab_fplwab	2955861	10670222	21341336	0.085	-0.221	-0.526	0.122	1.783
512020404	wab_fplwab	2552992	7443697	19950500	0.085	-0.163	-0.581	0.113	2.251
512010109	wab_fplwab	972781	3055909	7344543	0.086	-0.183	-0.56	0.117	2.065
512010405	wab_fplwab	5447217	35174660	22377540	0.086	-0.472	-0.269	0.196	0.685
512010903	wab_fplwab	7397246	71608844	4048342	0.089	-0.773	0.04	0.646	0.145
512020106	wab_fplwab	5914402	38665596	22019335	0.089	-0.492	-0.242	0.212	0.627
512010603	wab_fplwab	4082287	35941094	5415059	0.09	-0.701	-0.029	0.43	0.237
512020105	wab_fplwab	1734748	13591245	3731228	0.091	-0.622	-0.105	0.317	0.357
512020701	wab_fplwab	1809784	5515107	11340181	0.097	-0.199	-0.511	0.138	1.795
512010302	wab_fplwab	4131417	22524931	14952603	0.099	-0.442	-0.26	0.216	0.716
512010902	wab_fplwab	3112185	24934106	2937102	0.1	-0.704	0.006	0.514	0.216
512010605	wab_fplwab	9781409	71766954	10634490	0.106	-0.672	-0.009	0.479	0.25
512020403	wab_fplwab	2914770	11147233	11949398	0.112	-0.316	-0.347	0.196	1.057
512010404	wab_fplwab	4604855	17038410	18880352	0.114	-0.307	-0.352	0.196	1.085
512020812	wab_fplwab	4350270	15106247	18524827	0.115	-0.283	-0.373	0.19	1.176
512010407	wab_fplwab	4310073	23780882	8398612	0.118	-0.534	-0.112	0.339	0.452
512010904	wab_fplwab	996900	6151121	1233619	0.119	-0.615	-0.028	0.447	0.312
512010203	wab_fplwab	5933161	34908463	7362408	0.123	-0.601	-0.03	0.446	0.326
512010201	wab_fplwab	7967158	38920180	17601176	0.124	-0.48	-0.149	0.312	0.545
512010110	wab_fplwab	4944301	17754820	16512268	0.126	-0.327	-0.295	0.23	0.945
512020302	wab_fplwab	3294414	249225	22476694	0.127	0.117	-0.737	0.128	7.272
512010108	wab_fplwab	4340444	21581628	6807682	0.133	-0.527	-0.075	0.389	0.43
512011205	wab_fplwab	17389469	105694596	5002364	0.136	-0.689	0.097	0.777	0.182
512011002	wab_fplwab	3342651	13685039	6988124	0.139	-0.431	-0.152	0.324	0.607
512020301	wab_fplwab	4018864	15057116	9853764	0.139	-0.382	-0.202	0.29	0.727
512020503	wab_fplwab	2665546	4541432	11795753	0.14	-0.099	-0.48	0.184	2.007
512020603	wab_fplwab	12078030	19913876	54285478	0.14	-0.091	-0.489	0.182	2.074
512010401	wab_fplwab	4082287	10116388	14748042	0.141	-0.208	-0.368	0.217	1.326
512010403	wab_fplwab	5167621	12790867	18182701	0.143	-0.211	-0.36	0.221	1.3

512010804	wab_fplwab	11775208	56531182	13423308	0.144	-0.548	-0.02	0.467	0.369
512011118	wab_fplwab	6318165	14432714	23097523	0.144	-0.185	-0.383	0.215	1.418
512010301	wab_fplwab	4108192	13897640	10109242	0.146	-0.348	-0.213	0.289	0.79
512010807	wab_fplwab	4473543	16900845	8954232	0.148	-0.41	-0.148	0.333	0.628
512020405	wab_fplwab	4475329	17800377	7450843	0.151	-0.448	-0.1	0.375	0.535
512010810	wab_fplwab	4639693	21981818	2682518	0.158	-0.592	0.067	0.634	0.275
512020505	wab_fplwab	2982660	6057327	9811780	0.158	-0.163	-0.362	0.233	1.415
512020104	wab_fplwab	4440492	16157636	7283800	0.159	-0.42	-0.102	0.379	0.569
512011107	wab_fplwab	6315485	13632336	19256422	0.161	-0.187	-0.33	0.247	1.282
512010406	wab_fplwab	4904103	12507697	10929273	0.173	-0.268	-0.213	0.31	0.909
512010502	wab_fplwab	5318585	14390730	10698806	0.175	-0.298	-0.177	0.332	0.813
512010702	wab_fplwab	5389154	6617413	18707949	0.175	-0.04	-0.434	0.224	2.007
512020101	wab_fplwab	8832746	12476432	29266510	0.175	-0.072	-0.404	0.232	1.788
512020206	wab_fplwab	21743312	59337866	42955123	0.175	-0.303	-0.171	0.336	0.798
512020116	wab_fplwab	8922967	3867006	37188112	0.179	0.101	-0.566	0.194	3.605
512020408	wab_fplwab	14893646	23176132	45011452	0.179	-0.1	-0.363	0.249	1.574
512011213	wab_fplwab	10866743	20316745	29085175	0.18	-0.157	-0.302	0.272	1.281
512011214	wab_fplwab	7548210	6982764	27353999	0.18	0.013	-0.473	0.216	2.402
512010112	wab_fplwab	1855341	3794651	4547685	0.182	-0.19	-0.264	0.29	1.133
512010202	wab_fplwab	8339656	32152696	4874625	0.184	-0.525	0.076	0.631	0.326
512010505	wab_fplwab	9352635	21012610	20148808	0.185	-0.231	-0.214	0.317	0.972
512011211	wab_fplwab	7802795	12695286	21358309	0.186	-0.117	-0.324	0.268	1.423
512010113	wab_fplwab	7727759	18727601	13587672	0.193	-0.275	-0.146	0.363	0.806
512010115	wab_fplwab	8776469	20861645	15618096	0.194	-0.267	-0.151	0.36	0.823
512011115	wab_fplwab	33113865	72595917	63958800	0.195	-0.233	-0.182	0.341	0.918
512020401	wab_fplwab	9077504	13089222	23725499	0.198	-0.087	-0.319	0.277	1.48
512011104	wab_fplwab	9408911	9802847	27720244	0.2	-0.008	-0.39	0.253	1.933
512010304	wab_fplwab	7210551	18531973	10069938	0.201	-0.316	-0.08	0.417	0.671
512020407	wab_fplwab	11230308	27622877	16953548	0.201	-0.294	-0.103	0.398	0.725
512020604	wab_fplwab	18279175	10945352	60598283	0.204	0.082	-0.471	0.232	2.699
512020705	wab_fplwab	10730965	7290053	34540432	0.204	0.065	-0.453	0.237	2.512
512020303	wab_fplwab	7249855	3006778	24878722	0.206	0.121	-0.502	0.226	3.132
512010813	wab_fplwab	14049497	6056434	46371023	0.211	0.12	-0.486	0.233	3.005
512010303	wab_fplwab	5503494	12492511	7917135	0.212	-0.27	-0.093	0.41	0.746
512010305	wab_fplwab	12745309	34514527	12647942	0.213	-0.363	0.002	0.502	0.537
512010501	wab_fplwab	5470443	14237086	5744679	0.215	-0.344	-0.011	0.488	0.569
512020306	wab_fplwab	7996637	3046082	26033733	0.216	0.134	-0.486	0.235	3.082
512020305	wab_fplwab	40868422	88314954	59098467	0.217	-0.252	-0.097	0.409	0.774
512011003	wab_fplwab	3277442	2348431	9419630	0.218	0.062	-0.408	0.258	2.257
512020108	wab_fplwab	13125846	29648834	16768639	0.22	-0.277	-0.061	0.439	0.699
512020207	wab_fplwab	19147442	20577582	47200879	0.22	-0.016	-0.323	0.289	1.67
512011108	wab_fplwab	7493720	941516	25127054	0.223	0.195	-0.525	0.23	3.867
512020504	wab_fplwab	9469654	15610056	17170615	0.224	-0.145	-0.182	0.355	1.062
512010907	wab_fplwab	4566444	11902947	3862540	0.225	-0.361	0.035	0.542	0.512
512020102	wab_fplwab	4193946	8169933	6244022	0.225	-0.214	-0.11	0.402	0.844
512020406	wab_fplwab	6888077	10353107	13066890	0.227	-0.114	-0.204	0.345	1.157
512010602	wab_fplwab	9674215	25669275	7102464	0.228	-0.377	0.061	0.577	0.475
512010106	wab_fplwab	7087278	18234511	5293573	0.231	-0.364	0.059	0.572	0.489
512010801	wab_fplwab	7657190	12111974	12975775	0.234	-0.136	-0.162	0.371	1.044
512011204	wab_fplwab	6022489	14729283	4572697	0.238	-0.344	0.057	0.568	0.511

512011001	wab_fplwab	7137302	16970521	5649992	0.24	-0.33	0.05	0.558	0.53
512011102	wab_fplwab	5842047	10803320	7526772	0.242	-0.205	-0.07	0.437	0.803
512011114	wab_fplwab	16785612	1610583	46811410	0.257	0.233	-0.46	0.264	3.457
512010601	wab_fplwab	10273606	15726182	13556407	0.26	-0.138	-0.083	0.431	0.917
512011209	wab_fplwab	6818401	8449529	10807787	0.261	-0.063	-0.153	0.387	1.154
512011112	wab_fplwab	10734538	8300351	20780357	0.27	0.061	-0.252	0.341	1.656
512020601	wab_fplwab	18904470	18473016	32540379	0.27	0.006	-0.195	0.367	1.376
512020811	wab_fplwab	7369554	10384372	9509852	0.27	-0.111	-0.079	0.437	0.951
512011304	wab_fplwab	64543898	59129732	114210228	0.271	0.023	-0.209	0.361	1.445
512020409	wab_fplwab	15414428	15357258	25722871	0.273	0.001	-0.182	0.375	1.337
512010812	wab_fplwab	20181860	12768535	40311016	0.275	0.101	-0.275	0.334	1.836
512020402	wab_fplwab	7714360	8523671	11776101	0.275	-0.029	-0.145	0.396	1.2
512020113	wab_fplwab	24366873	8925647	54707106	0.277	0.175	-0.345	0.308	2.375
512020203	wab_fplwab	17540433	3037150	42842570	0.277	0.229	-0.399	0.29	2.934
512011119	wab_fplwab	17618148	8824706	35924121	0.282	0.141	-0.294	0.329	2.025
512010703	wab_fplwab	15804791	15471598	24361514	0.284	0.006	-0.154	0.393	1.284
512020804	wab_fplwab	12254006	2424360	28266931	0.285	0.229	-0.373	0.302	2.761
512010613	wab_fplwab	15471598	26020333	12390677	0.287	-0.196	0.057	0.555	0.672
512011006	wab_fplwab	18925909	14216540	32702956	0.287	0.072	-0.209	0.367	1.558
512020502	wab_fplwab	4838894	3504335	8401292	0.289	0.08	-0.213	0.365	1.587
512010803	wab_fplwab	4111765	4947874	5079186	0.291	-0.059	-0.068	0.447	1.014
512010116	wab_fplwab	13498344	18247017	14354105	0.293	-0.103	-0.019	0.485	0.877
512011005	wab_fplwab	5204245	4401187	8144028	0.293	0.045	-0.166	0.39	1.39
512011501	wab_fplwab	13646628	2295728	30625188	0.293	0.244	-0.365	0.308	2.777
512011110	wab_fplwab	16069202	2194787	35787450	0.297	0.257	-0.365	0.31	2.839
512020103	wab_fplwab	16926750	25611211	14197782	0.298	-0.153	0.048	0.544	0.732
512020708	wab_fplwab	19852240	1550733	45291942	0.298	0.274	-0.381	0.305	3.044
512011105	wab_fplwab	9376753	1905365	19780777	0.302	0.241	-0.335	0.322	2.584
512011307	wab_fplwab	80073559	34997791	150421092	0.302	0.17	-0.265	0.347	2.003
512010905	wab_fplwab	18120171	24148020	17280489	0.304	-0.101	0.014	0.512	0.838
512020110	wab_fplwab	15935210	16916031	19414533	0.305	-0.019	-0.067	0.451	1.076
512011302	wab_fplwab	67386312	64179440	88062156	0.307	0.015	-0.094	0.433	1.182
512010107	wab_fplwab	4050128	5047028	3907204	0.311	-0.077	0.011	0.509	0.875
512020204	wab_fplwab	23598653	33734694	18046922	0.313	-0.134	0.074	0.567	0.726
512020111	wab_fplwab	13952130	11765382	18674898	0.314	0.049	-0.106	0.428	1.269
512010906	wab_fplwab	9144500	13279490	6378014	0.317	-0.144	0.096	0.589	0.692
512020806	wab_fplwab	19281434	2953181	38462821	0.318	0.269	-0.316	0.334	2.597
512020809	wab_fplwab	16271083	9066785	25792547	0.318	0.141	-0.186	0.387	1.66
512020805	wab_fplwab	8870264	1059429	17715516	0.321	0.283	-0.32	0.334	2.677
512011207	wab_fplwab	16754347	2795964	32448371	0.322	0.268	-0.302	0.341	2.517
512020304	wab_fplwab	25680887	5755399	47740420	0.324	0.252	-0.279	0.35	2.336
512020114	wab_fplwab	28071303	9806420	48615834	0.325	0.211	-0.238	0.366	2.025
512020602	wab_fplwab	18054068	8391466	28821657	0.327	0.175	-0.195	0.385	1.773
512020107	wab_fplwab	13930691	19514580	9013188	0.328	-0.132	0.116	0.607	0.686
512020506	wab_fplwab	27811358	23763017	32879825	0.329	0.048	-0.06	0.458	1.177
512020902	wab_fplwab	10041353	1322947	19075087	0.33	0.286	-0.297	0.345	2.562
512010815	wab_fplwab	10694340	6139509	15385843	0.332	0.141	-0.146	0.41	1.549
512020109	wab_fplwab	8451316	4844254	12177184	0.332	0.142	-0.146	0.41	1.552
512011004	wab_fplwab	12198622	15095527	9198990	0.334	-0.079	0.082	0.57	0.784
512011206	wab_fplwab	6135936	4488729	7298985	0.342	0.092	-0.065	0.457	1.265

512011406	wab_fplwab	34528819	19259995	46972200	0.343	0.152	-0.123	0.424	1.515
512011403	wab_fplwab	4951447	1853555	7514266	0.346	0.216	-0.179	0.397	1.832
512020907	wab_fplwab	16521201	2903158	28353579	0.346	0.285	-0.248	0.368	2.31
512010908	wab_fplwab	13861909	16091534	9492879	0.351	-0.057	0.111	0.594	0.78
512020205	wab_fplwab	66992376	49503754	70922805	0.357	0.093	-0.021	0.486	1.184
512020905	wab_fplwab	13733276	6191319	18326519	0.359	0.197	-0.12	0.428	1.609
512011305	wab_fplwab	34277807	41708105	19209079	0.36	-0.078	0.158	0.641	0.704
512010306	wab_fplwab	22114916	21807628	17033050	0.363	0.005	0.083	0.565	0.891
512020307	wab_fplwab	35149648	2905838	58783139	0.363	0.333	-0.244	0.374	2.468
512011502	wab_fplwab	48255842	8738058	71626709	0.375	0.307	-0.182	0.403	2.103
512011101	wab_fplwab	5218538	2238558	6427145	0.376	0.215	-0.087	0.448	1.562
512011407	wab_fplwab	53042926	26689400	58945716	0.382	0.19	-0.043	0.474	1.405
512011210	wab_fplwab	50503333	20447164	59575478	0.387	0.23	-0.07	0.459	1.551
512011402	wab_fplwab	8718406	1951815	11772528	0.388	0.302	-0.136	0.425	1.92
512020201	wab_fplwab	33045975	5909043	45787712	0.39	0.32	-0.15	0.419	2.024
512010204	wab_fplwab	16058482	11266932	13712731	0.391	0.117	0.057	0.539	1.09
512011410	wab_fplwab	67173712	45028424	59037724	0.392	0.129	0.048	0.532	1.125
512010114	wab_fplwab	28147231	11375912	32007091	0.394	0.234	-0.054	0.468	1.522
512010814	wab_fplwab	16281802	5713415	18738320	0.4	0.259	-0.06	0.465	1.592
512011215	wab_fplwab	73022012	76292307	32725288	0.401	-0.018	0.221	0.691	0.708
512010809	wab_fplwab	9933266	3610635	11173138	0.402	0.256	-0.05	0.471	1.558
512020112	wab_fplwab	27797066	13434028	27969469	0.402	0.208	-0.002	0.498	1.353
512020808	wab_fplwab	30400975	7636645	37206870	0.404	0.303	-0.09	0.45	1.777
512020706	wab_fplwab	30520675	9021228	35051387	0.409	0.288	-0.061	0.465	1.658
512011401	wab_fplwab	20934894	4761179	25399504	0.41	0.317	-0.087	0.452	1.803
512011405	wab_fplwab	64573376	47355417	44756867	0.412	0.11	0.126	0.591	0.977
512020115	wab_fplwab	20587409	3837528	25430769	0.413	0.336	-0.097	0.447	1.884
512020903	wab_fplwab	25854183	2986233	33551571	0.414	0.367	-0.123	0.435	2.06
512010704	wab_fplwab	30083861	13099048	28944930	0.417	0.235	0.016	0.51	1.367
512020802	wab_fplwab	13718091	1763333	17331405	0.418	0.364	-0.11	0.442	2.006
512010503	wab_fplwab	12206662	7246282	9285639	0.425	0.173	0.102	0.568	1.105
512010806	wab_fplwab	26029266	17370710	17774472	0.425	0.142	0.135	0.594	1.009
512011504	wab_fplwab	65292466	5892964	81301818	0.428	0.39	-0.105	0.445	2.059
512010909	wab_fplwab	18802636	13821711	11100782	0.43	0.114	0.176	0.629	0.917
512020208	wab_fplwab	50556930	24188218	42801479	0.43	0.224	0.066	0.542	1.249
512020209	wab_fplwab	46319213	21811201	38715619	0.434	0.229	0.071	0.545	1.248
512011117	wab_fplwab	44759547	37089851	21150175	0.435	0.074	0.229	0.679	0.805
512011103	wab_fplwab	15444800	6503967	13491198	0.436	0.252	0.055	0.534	1.318
512020813	wab_fplwab	30807417	10323629	28884187	0.44	0.293	0.027	0.516	1.451
512020709	wab_fplwab	54264039	20488255	48198672	0.441	0.275	0.049	0.53	1.371
512020210	wab_fplwab	114940930	44333453	99198669	0.445	0.273	0.061	0.537	1.344
512020801	wab_fplwab	24473174	5206032	25052912	0.447	0.352	-0.011	0.494	1.669
512020202	wab_fplwab	59707683	12336187	58889439	0.456	0.362	0.006	0.503	1.646
512020906	wab_fplwab	39064891	13316115	31746254	0.464	0.306	0.087	0.552	1.352
512010802	wab_fplwab	12571120	7726866	6679050	0.466	0.18	0.218	0.653	0.948
512020117	wab_fplwab	41377592	15539487	31246017	0.469	0.293	0.115	0.57	1.276
512011404	wab_fplwab	52226469	14410382	44579998	0.47	0.34	0.069	0.539	1.453
512020815	wab_fplwab	72067989	8957805	70453834	0.476	0.417	0.011	0.506	1.759
512011109	wab_fplwab	31957068	11128474	22878670	0.484	0.316	0.138	0.583	1.273
512020707	wab_fplwab	61750613	20885764	44135145	0.487	0.322	0.139	0.583	1.281

512020908	wab_fplwab	83867316	41978769	44981080	0.491	0.245	0.228	0.651	1.024
512010805	wab_fplwab	32259889	10562135	22736639	0.492	0.331	0.145	0.587	1.284
512011503	wab_fplwab	121771837	8179759	111886808	0.504	0.47	0.041	0.521	1.798
512011408	wab_fplwab	124016648	41348113	78617513	0.508	0.339	0.186	0.612	1.225
512011409	wab_fplwab	144612096	42802372	96305337	0.51	0.359	0.17	0.6	1.285
512011113	wab_fplwab	39527610	5955493	31605116	0.513	0.436	0.103	0.556	1.564
512011303	wab_fplwab	93875617	47411693	41057798	0.515	0.255	0.29	0.696	0.955
512011116	wab_fplwab	42387890	20761598	18691870	0.518	0.264	0.29	0.694	0.967
512020605	wab_fplwab	64049021	18659712	40548628	0.52	0.368	0.191	0.612	1.265
512020814	wab_fplwab	35620406	13432241	19185853	0.522	0.325	0.241	0.65	1.117
512020308	wab_fplwab	124656236	19260889	94612573	0.523	0.442	0.126	0.569	1.524
512020904	wab_fplwab	60056062	19527086	33237137	0.532	0.359	0.238	0.644	1.172
512011212	wab_fplwab	108219897	46764066	46086960	0.538	0.306	0.309	0.701	0.996
512010811	wab_fplwab	14966002	3582943	8485260	0.554	0.421	0.24	0.638	1.264
512020901	wab_fplwab	37203297	4702222	25162785	0.555	0.485	0.18	0.597	1.488
512020810	wab_fplwab	30668959	12678313	11015921	0.564	0.331	0.362	0.736	0.962
512020606	wab_fplwab	51752138	6199359	33364876	0.567	0.499	0.201	0.608	1.469
512011208	wab_fplwab	84115648	5423099	55937151	0.578	0.541	0.194	0.601	1.564
512011505	wab_fplwab	150553297	15384950	92733113	0.582	0.523	0.224	0.619	1.466
512010816	wab_fplwab	69969676	24305237	25056485	0.586	0.383	0.376	0.736	1.008
512010506	wab_fplwab	20610634	7631285	6851452	0.587	0.37	0.392	0.751	0.972
512011106	wab_fplwab	35098731	7261468	16785612	0.593	0.471	0.31	0.676	1.225
512011111	wab_fplwab	83206289	13184803	39490092	0.612	0.515	0.322	0.678	1.273
512011308	wab_fplwab	140486933	14753401	65416631	0.637	0.57	0.34	0.682	1.326
512020803	wab_fplwab	21580735	2332352	9471441	0.646	0.577	0.363	0.695	1.299
512010808	wab_fplwab	25486152	5107771	6374441	0.689	0.551	0.517	0.8	1.041
512020807	wab_fplwab	42169930	2285902	15543954	0.703	0.665	0.444	0.731	1.298
512011306	wab_fplwab	107266768	13328621	28264251	0.721	0.631	0.531	0.791	1.124
512011309	wab_fplwab	141601745	13925331	7685775	0.868	0.782	0.82	0.949	0.96
514020206	wab_fplwab	6843413	597604	249225	0.89	0.812	0.857	0.965	0.953

APPENDIX D2
Landcover Analysis Results

DESCRIPTION OF APPENDIX

A comparison was performed to determine the relationship of the fit index parameters to landcover type. Landcover data was obtained from the National Landcover Database (NLD). The results are presented in this appendix. The two landcover types that seem to change significantly across the parameters was cultivated crops and deciduous forest. majority of the floodplain area was cultivated crops.

Table D1. Description of Landcover Type:

Landcover type	
11	Open Water - All areas of open water, generally with less than 25% cover or vegetation or soil
21	Developed, Open Space - Includes areas with a mixture of some constructed materials, but mostly vegetation in the form of lawn grasses. Impervious surfaces account for less than 20 percent of total cover. These areas most commonly include large-lot single-family housing units, parks, golf courses, and vegetation planted in developed settings for recreation, erosion control, or aesthetic purposes.
22	Developed, Low Intensity -Includes areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 20-49 percent of total cover. These areas most commonly include single-family housing units.
23	Developed, Medium Intensity - Includes areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 50-79 percent of the total cover. These areas most commonly include single-family housing units.
24	Developed, High Intensity - Includes highly developed areas where people reside or work in high numbers. Examples include apartment complexes, row houses and commercial/industrial. Impervious surfaces account for 80 to 100 percent of the total cover.
31	Barren Land (Rock/Sand/Clay) - Barren areas of bedrock, desert pavement, scarps, talus, slides, volcanic material, glacial debris, sand dunes, strip mines, gravel pits and other accumulations of earthen material. Generally, vegetation accounts for less than 15% of total cover.
41	Deciduous Forest - Areas dominated by trees generally greater than 5 meters tall, and greater than 20% of total vegetation cover. More than 75 percent of the tree species shed foliage simultaneously in response to seasonal change.
42	Evergreen Forest - Areas dominated by trees generally greater than 5 meters tall, and greater than 20% of total vegetation cover. More than 75 percent of the tree species maintain their leaves all year. Canopy is never without green foliage.
43	Mixed Forest - Areas dominated by trees generally greater than 5 meters tall, and greater than 20% of total vegetation cover. Neither deciduous nor evergreen species are greater than 75 percent of total tree cover.
52	Shrub/Scrub - Areas dominated by shrubs; less than 5 meters tall with shrub canopy typically greater than 20% of total vegetation. This class includes true shrubs, young trees in an early successional stage or trees stunted from environmental conditions.
71	Grassland/Herbaceous - Areas dominated by grammanoid or herbaceous vegetation, generally greater than 80% of total vegetation. These areas are not subject to intensive management such as tilling, but can be utilized for grazing.
81	Pasture/Hay - Areas of grasses, legumes, or grass-legume mixtures planted for livestock grazing or the production of seed or hay crops, typically on a perennial cycle. Pasture/hay vegetation accounts for greater than 20 percent of total vegetation.
82	Cultivated Crops - Areas used for the production of annual crops, such as corn, soybeans, vegetables, tobacco, and cotton, and also perennial woody crops such as

	orchards and vineyards. Crop vegetation accounts for greater than 20 percent of total vegetation. This class also includes all land being actively tilled.
90	Woody Wetlands - Areas where forest or shrub land vegetation accounts for greater than 20 percent of vegetative cover and the soil or substrate is periodically saturated with or covered with water.
95	Emergent Herbaceous Wetlands - Areas where perennial herbaceous vegetation accounts for greater than 80 percent of vegetative cover and the soil or substrate is periodically saturated with or covered with water.

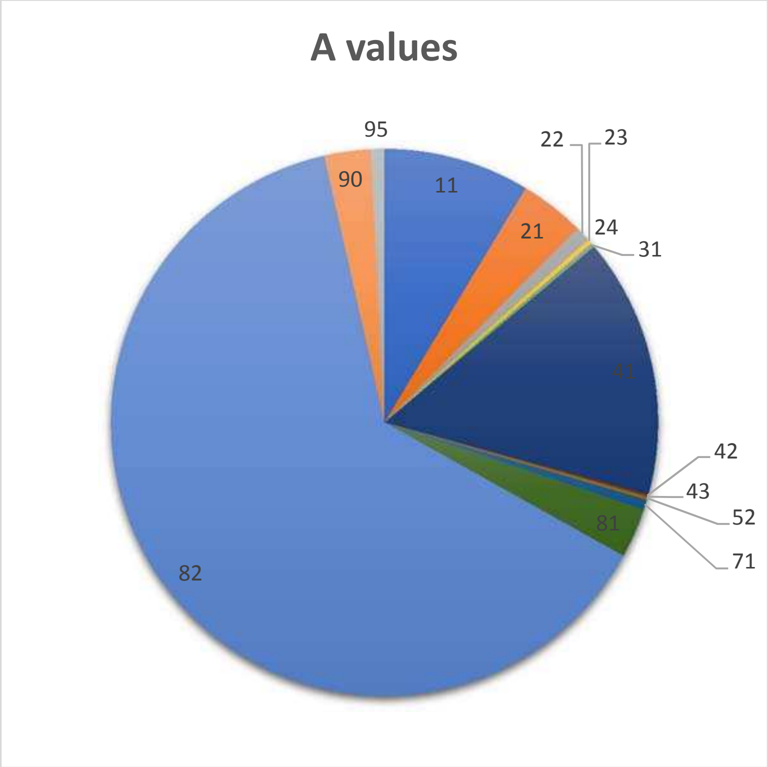


Figure D1. Distribution of A values

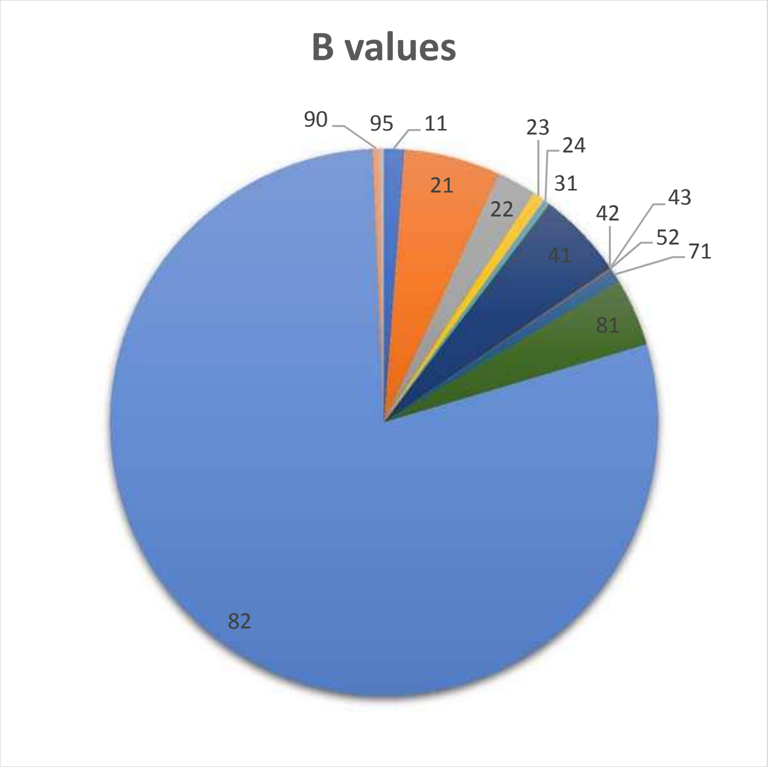


Figure D2. Distribution of B values

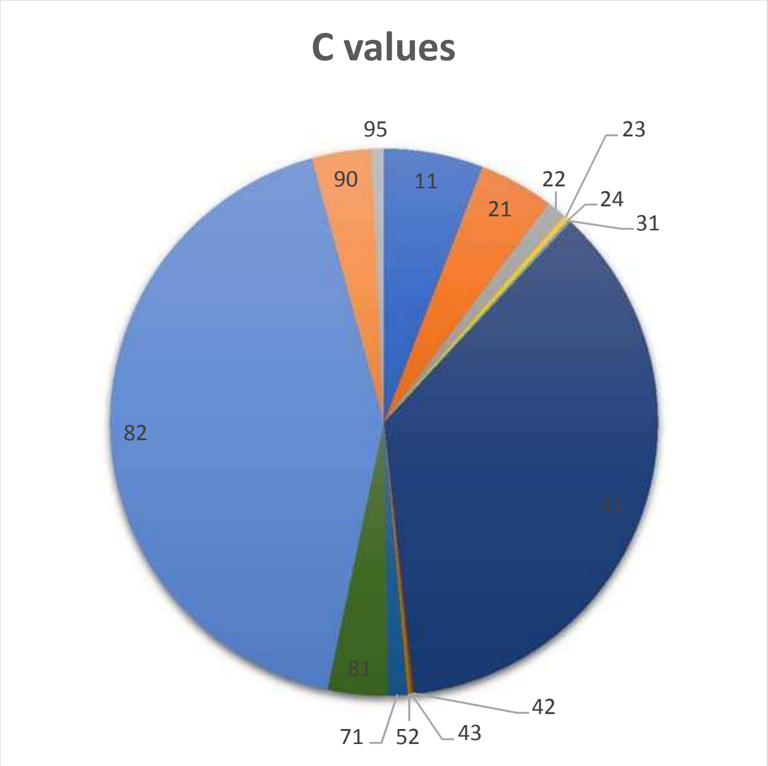


Figure D3. Distribution of C values

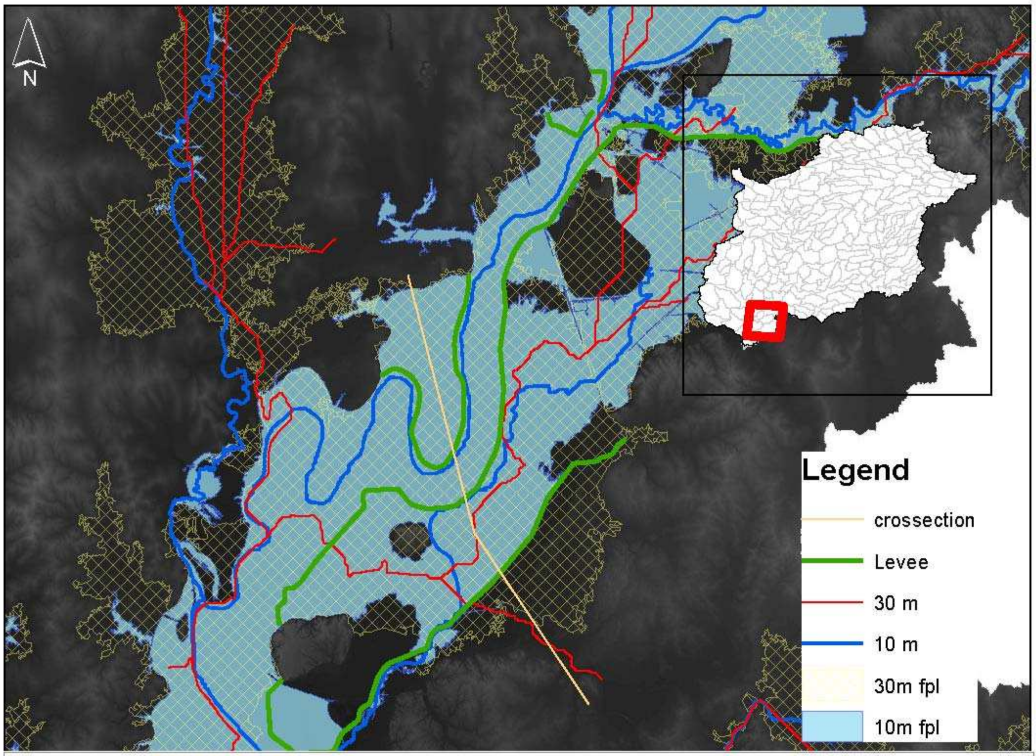
Table D2. Count of cells associated with each fit index analysis parameter

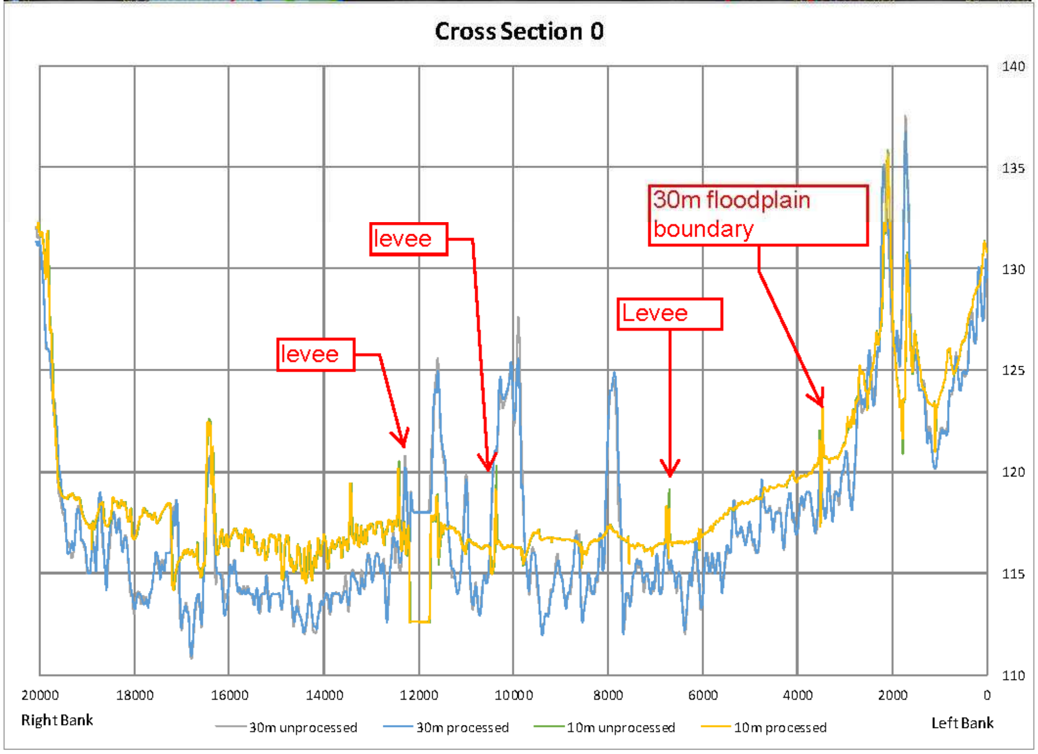
Landcover Code	COUNT A	COUNT B	COUNT C
11	405000	46814	181909
21	180377	226710	137712
22	41936	91471	35515
23	13167	28471	10205
24	5399	11162	3305
31	5878	4070	2200
41	722995	204068	1130907
42	6067	2272	4305
43	336	134	124
52	6887	1997	6442
71	28520	31395	35670
81	137713	159956	110348
82	2973811	3128863	1319901
90	127982	16160	109273
95	38378	9702	23209

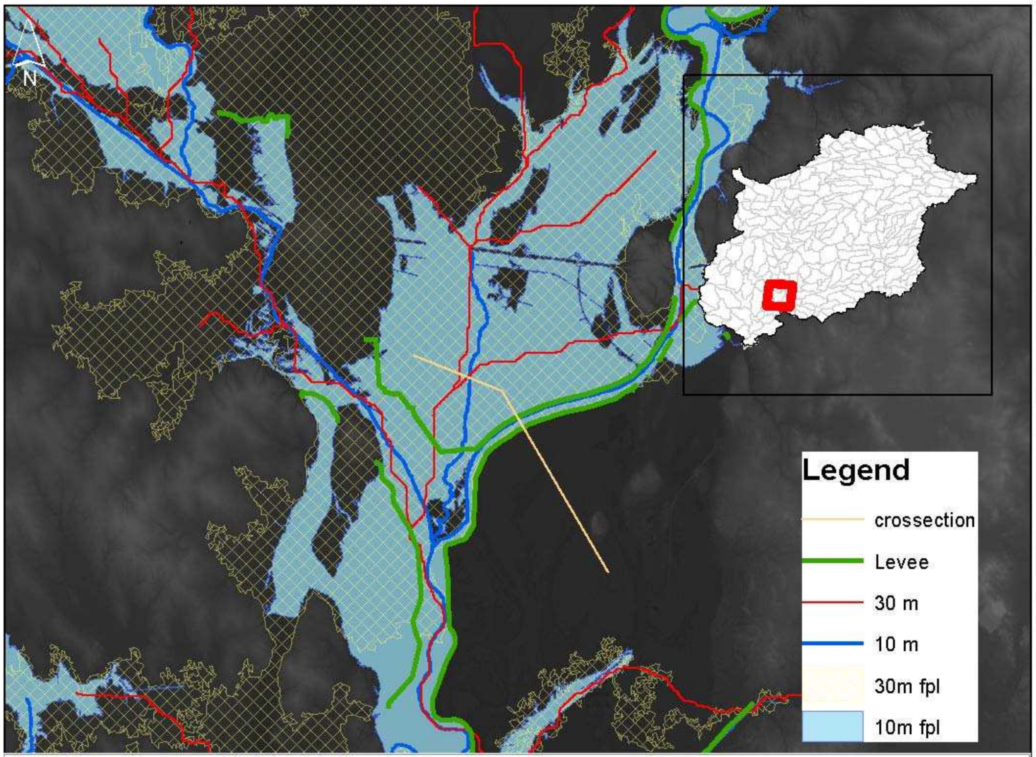
APPENDIX D3
Cross Section Analysis

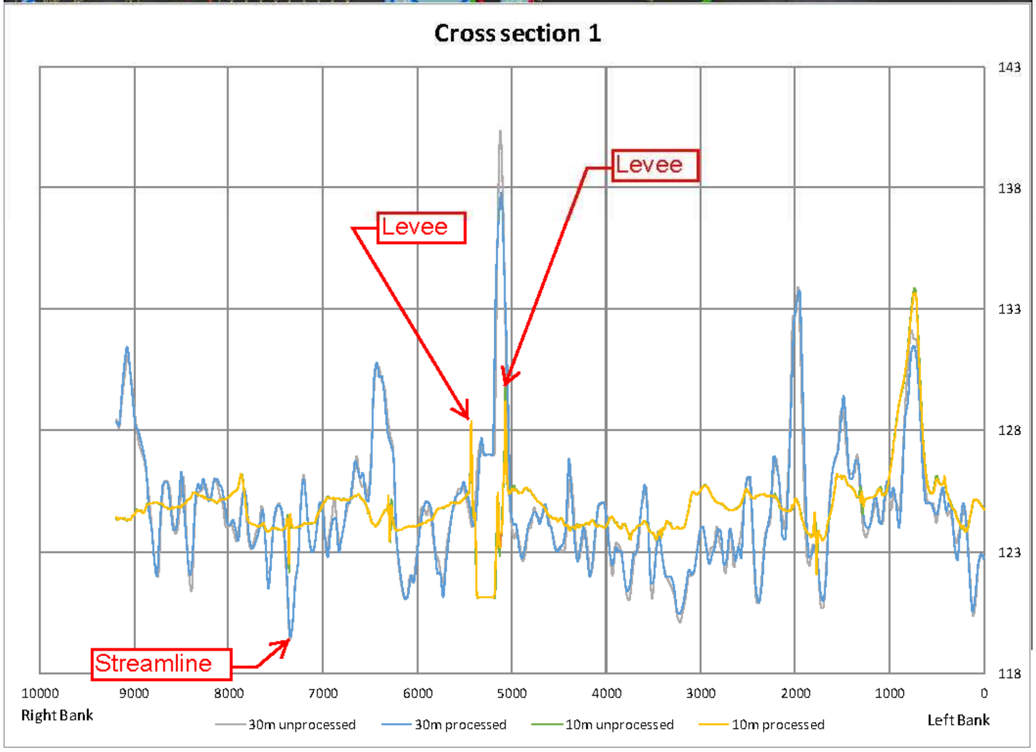
DESCRIPTION OF APPENDIX

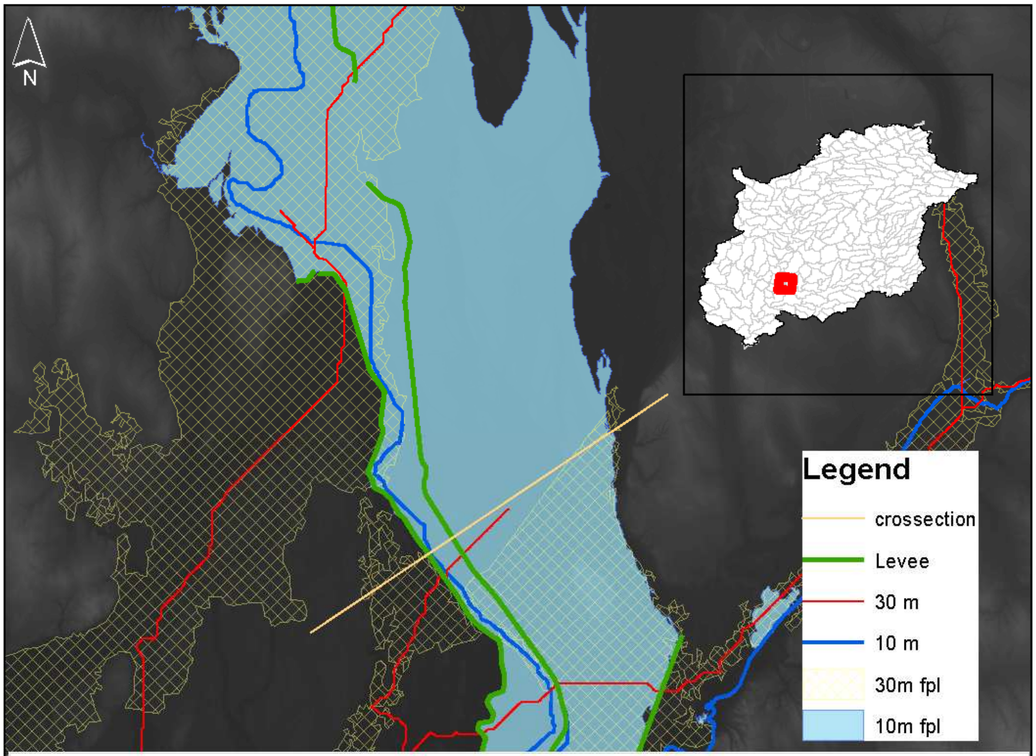
Several cross sections were cut in the 10m and 30m DEMs at levee locations to determine differences in elevations changes across the two resolutions of DEMs. Location and cross section data are presented in this appendix. As shown in the cross sections, the 10m DEM is more detailed and therefore is more able to pick up elevations changes caused by levees. This analysis was key to determining the need to remove levees from the DEMs. The results are presented below.

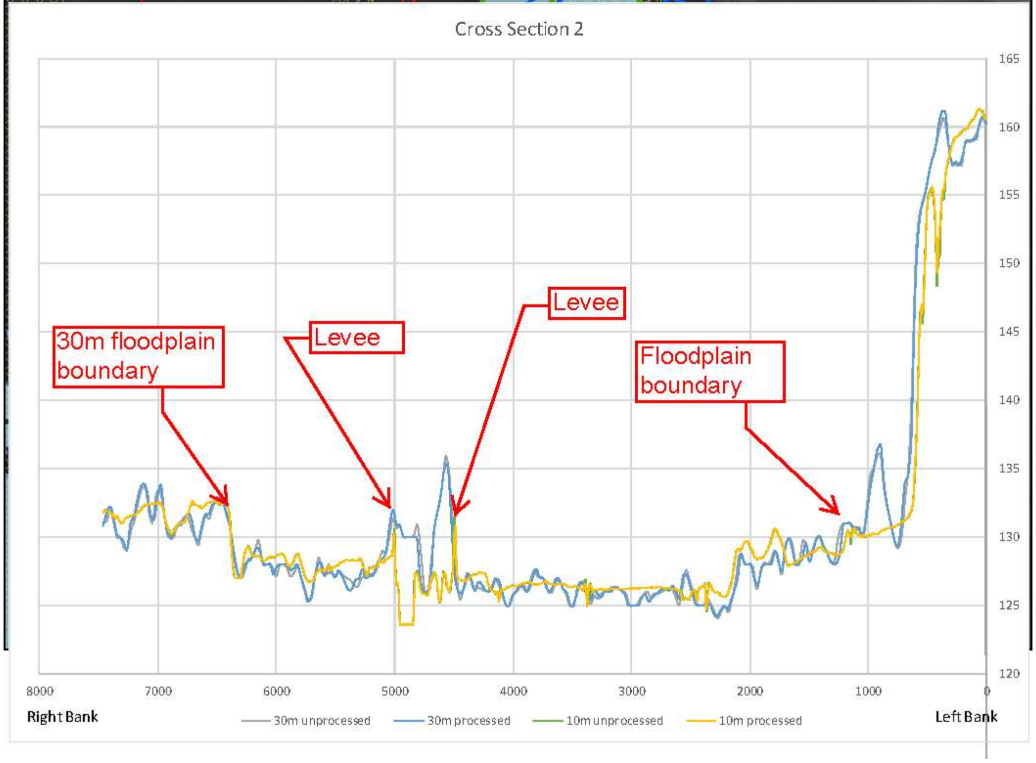

N
Legend
crossection
Levee
30 m
10 m
30m fpl
10m fpl

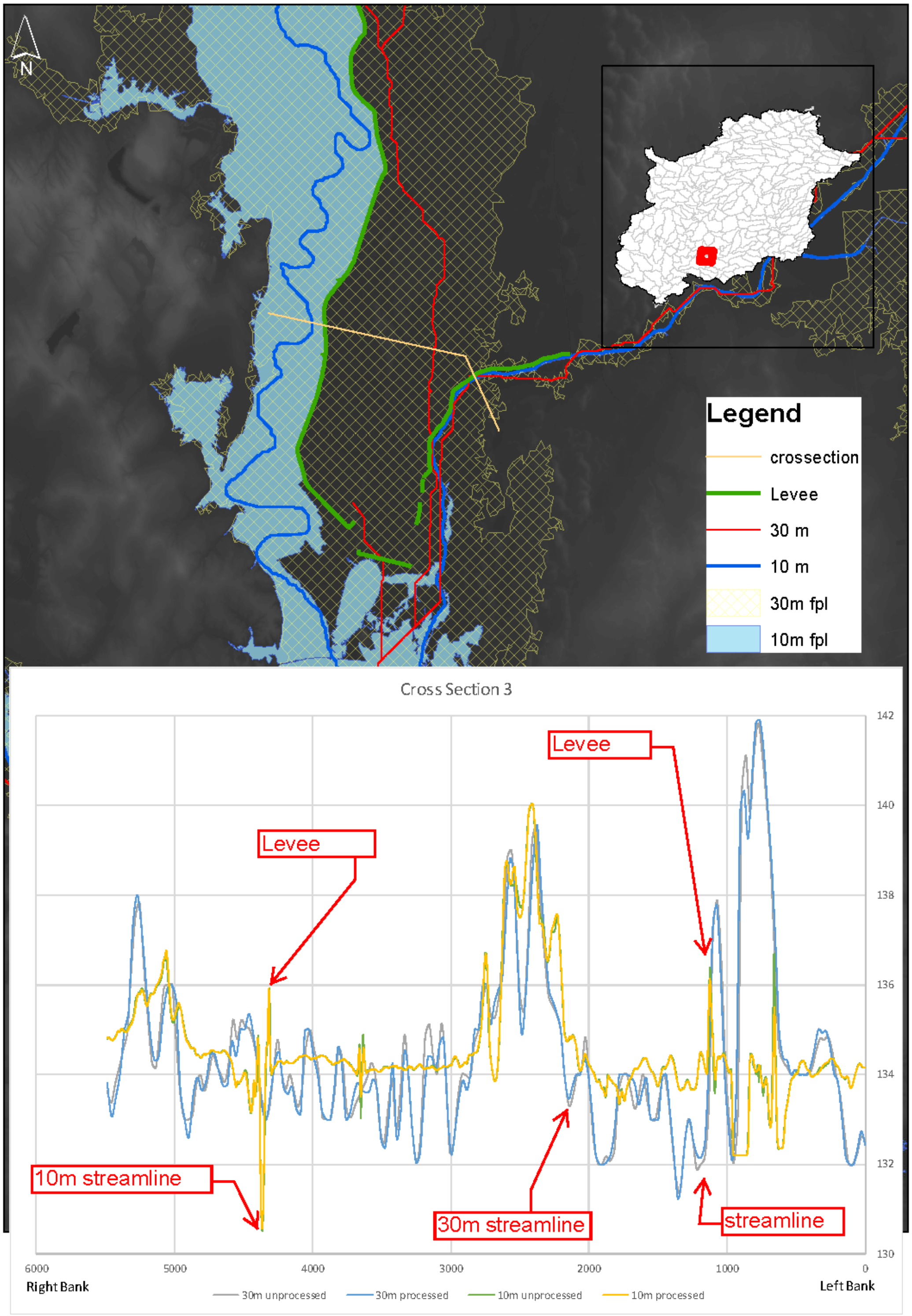

Cross Section 0
140
135
130
125
120
115
110
20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
Right Bank
Left Bank
30m unprocessed
30m processed
10m unprocessed
10m processed
levee
levee
Levee
30m floodplain boundary

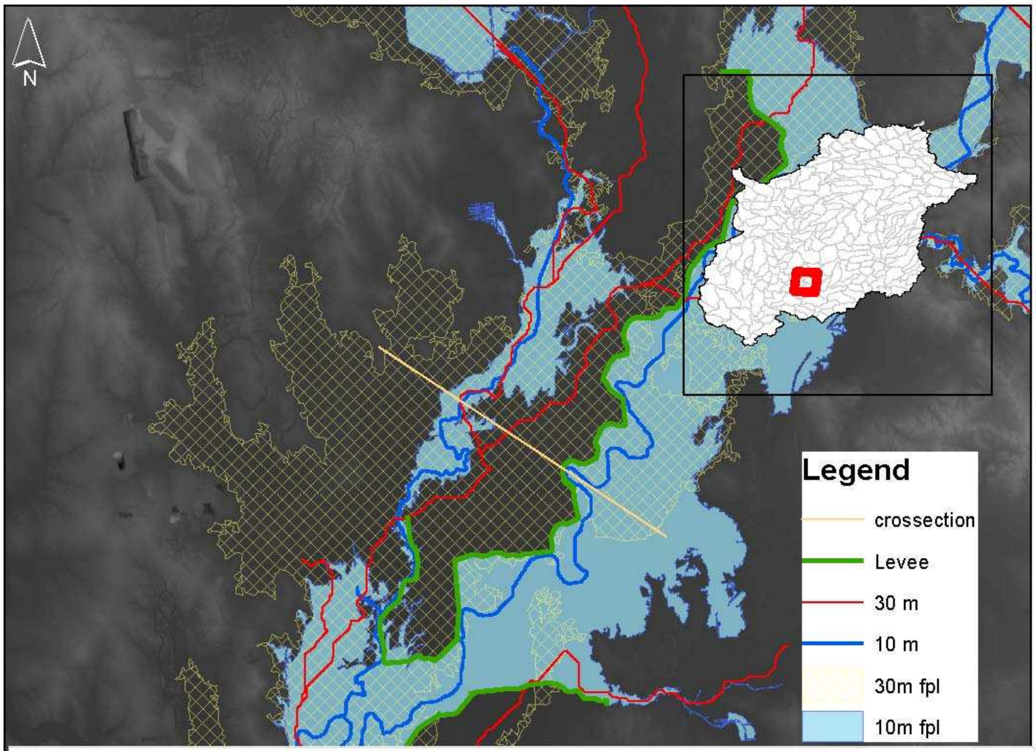

N
Legend
crossection
Levee
30 m
10 m
30m fpl
10m fpl

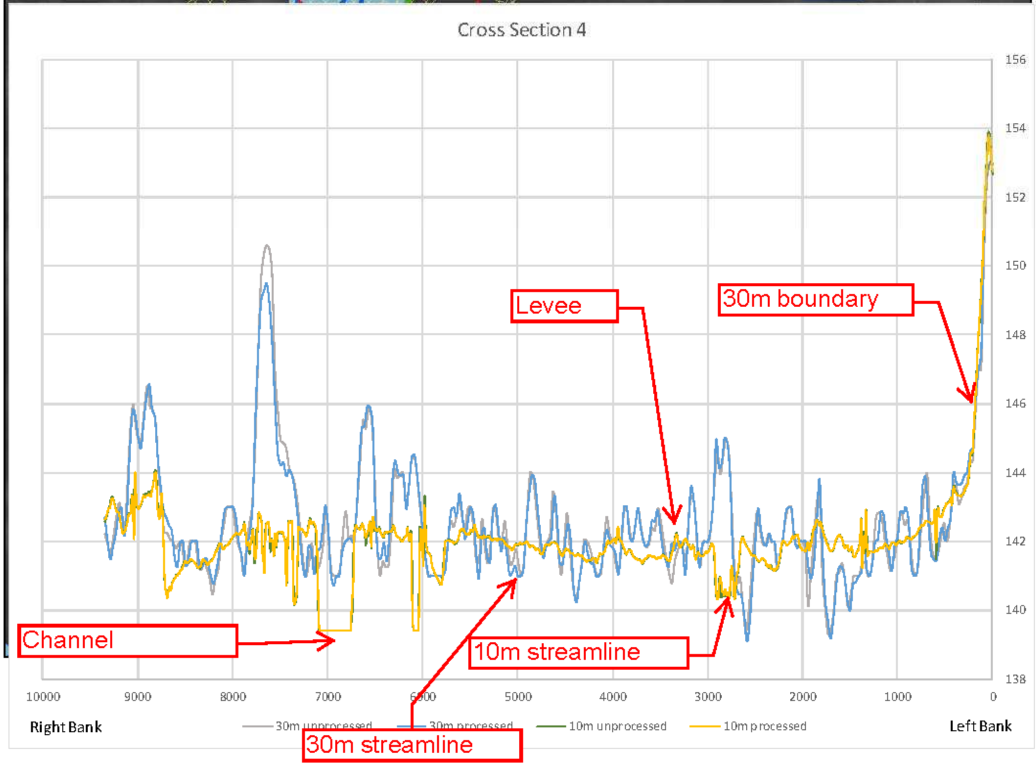

Cross section 1
143
138
133
128
123
118
Levee
Levee
Streamline
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
Right Bank
Left Bank
30m unprocessed
30m processed
10m unprocessed
10m processed


N
Legend
crossection
Levee
30 m
10 m
30m fpl
10m fpl


Cross Section 2
30m floodplain boundary
Levee
Levee
Floodplain boundary
165
160
155
150
145
140
135
130
125
120
8000
7000
6000
5000
4000
3000
2000
1000
0
Right Bank
Left Bank
30m unprocessed
30m processed
10m unprocessed
10m processed


N
Legend
crossection
Levee
30 m
10 m
30m fpl
10m fpl
Cross Section 3
Levee
Levee
10m streamline
30m streamline
streamline
142
140
138
136
134
132
130
6000
5000
4000
3000
2000
1000
0
Right Bank
Left Bank
30m unprocessed
30m processed
10m unprocessed
10m processed


N
Legend
crossection
Levee
30 m
10 m
30m fpl
10m fpl

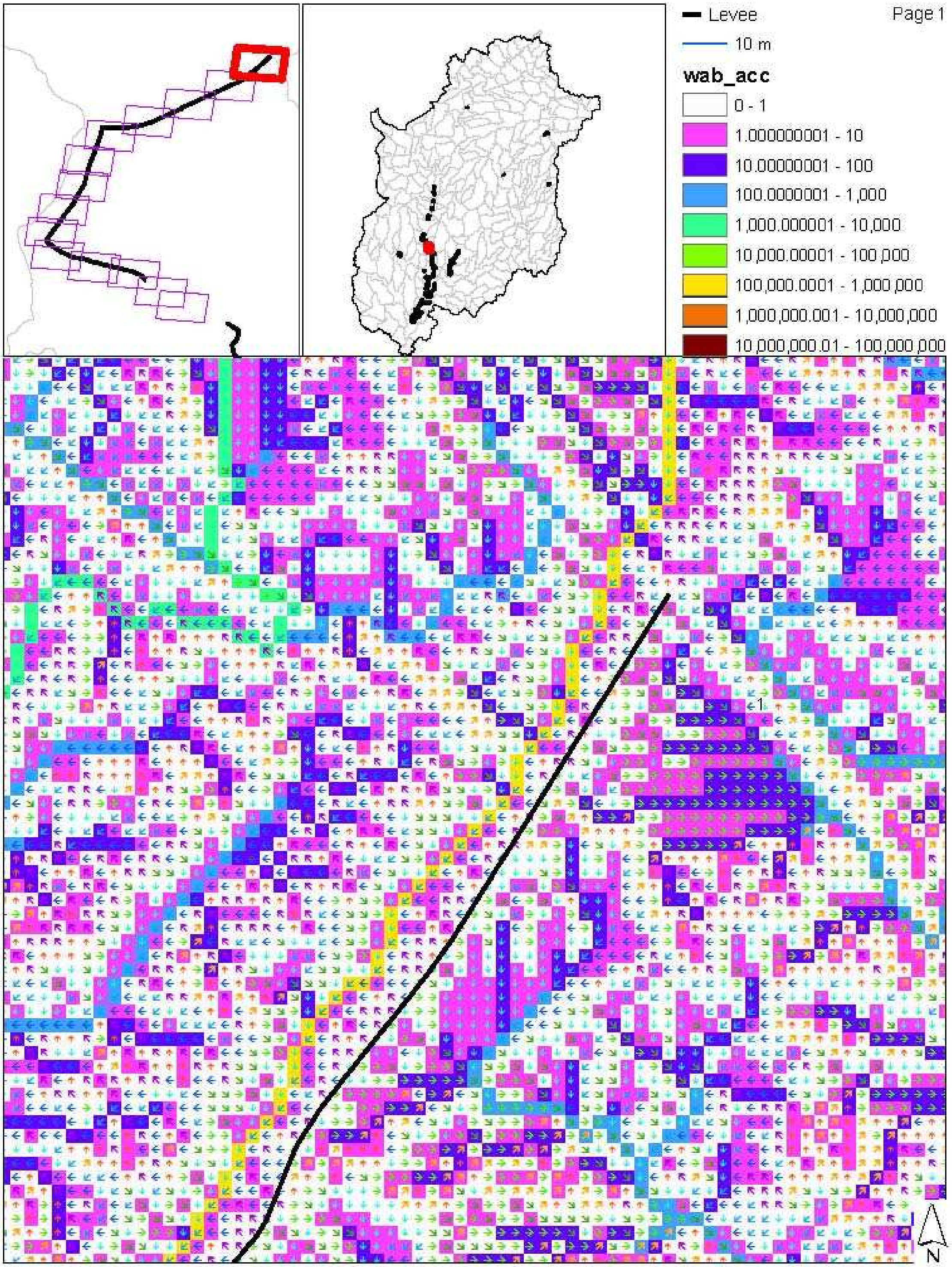

Cross Section 4
156
154
152
150
148
146
144
142
140
138
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
Right Bank
Left Bank
30m unprocessed
30m processed
10m unprocessed
10m processed
Levee
30m boundary
Channel
10m streamline
30m streamline

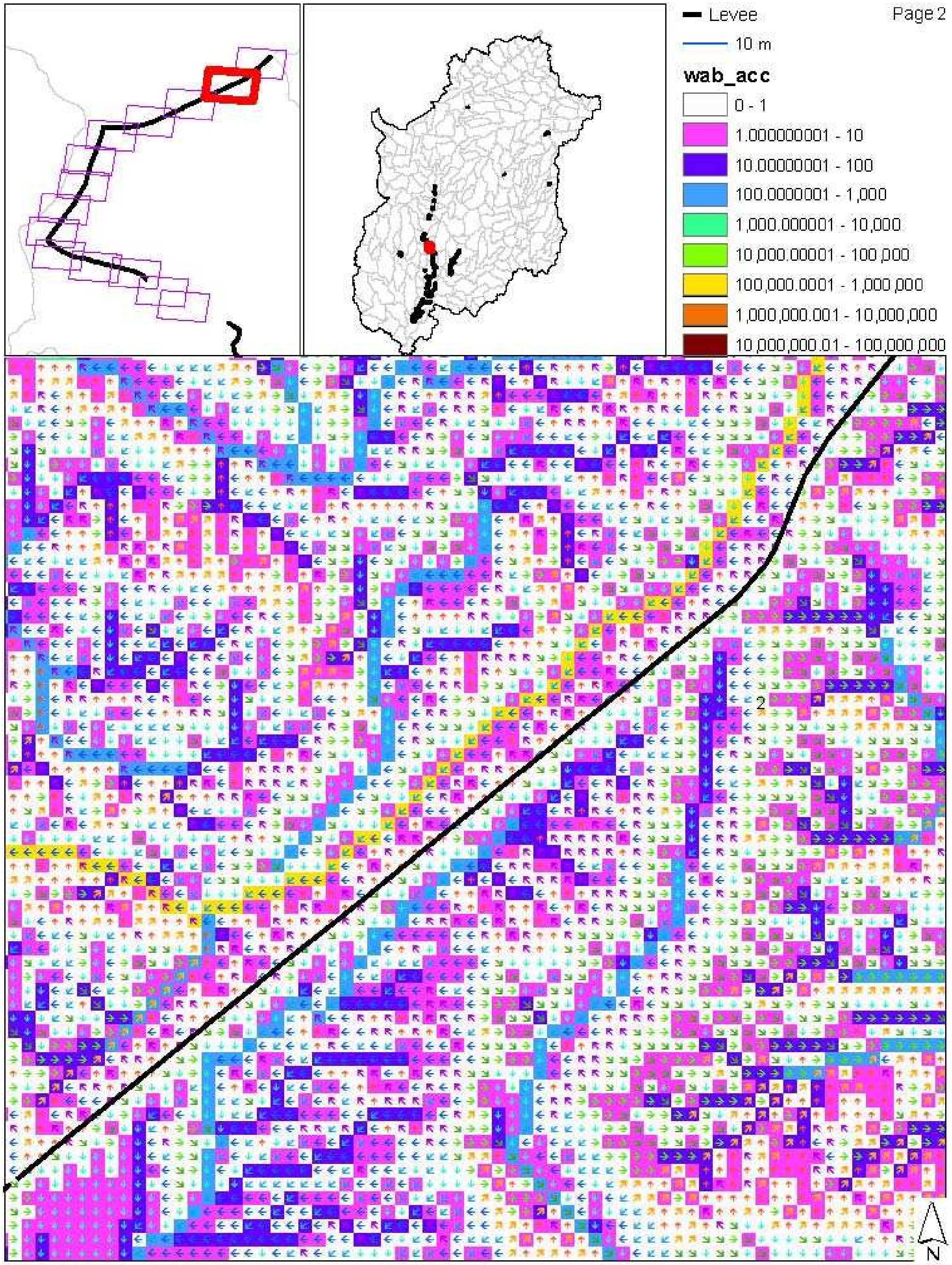
APPENDIX D4
Levee Flow Direction and Accumulations Analysis

DESCRIPTION OF APPENDIX

The flow direction and accumulation for the 10m and 30m resolution DEMs was developed for an area where we observed the levee disrupting floodplain delineation. The results are presented in this appendix. This analysis helped determine the effects levees had on the floodplain delineation.

10m Levee Flow Direction and Accumulation Analysis


Levee
10 m
wab_acc
0 - 1
1.000000001 - 10
10.00000001 - 100
100.0000001 - 1,000
1,000.000001 - 10,000
10,000.00001 - 100,000
100,000.0001 - 1,000,000
1,000,000.001 - 10,000,000
10,000,000.01 - 100,000,000
Page 1
1
N


Levee
Page 2
10 m
wab_acc
0 - 1
1.000000001 - 10
10.00000001 - 100
100.0000001 - 1,000
1,000.000001 - 10,000
10,000.00001 - 100,000
100,000.0001 - 1,000,000
1,000,000.001 - 10,000,000
10,000,000.01 - 100,000,000
2
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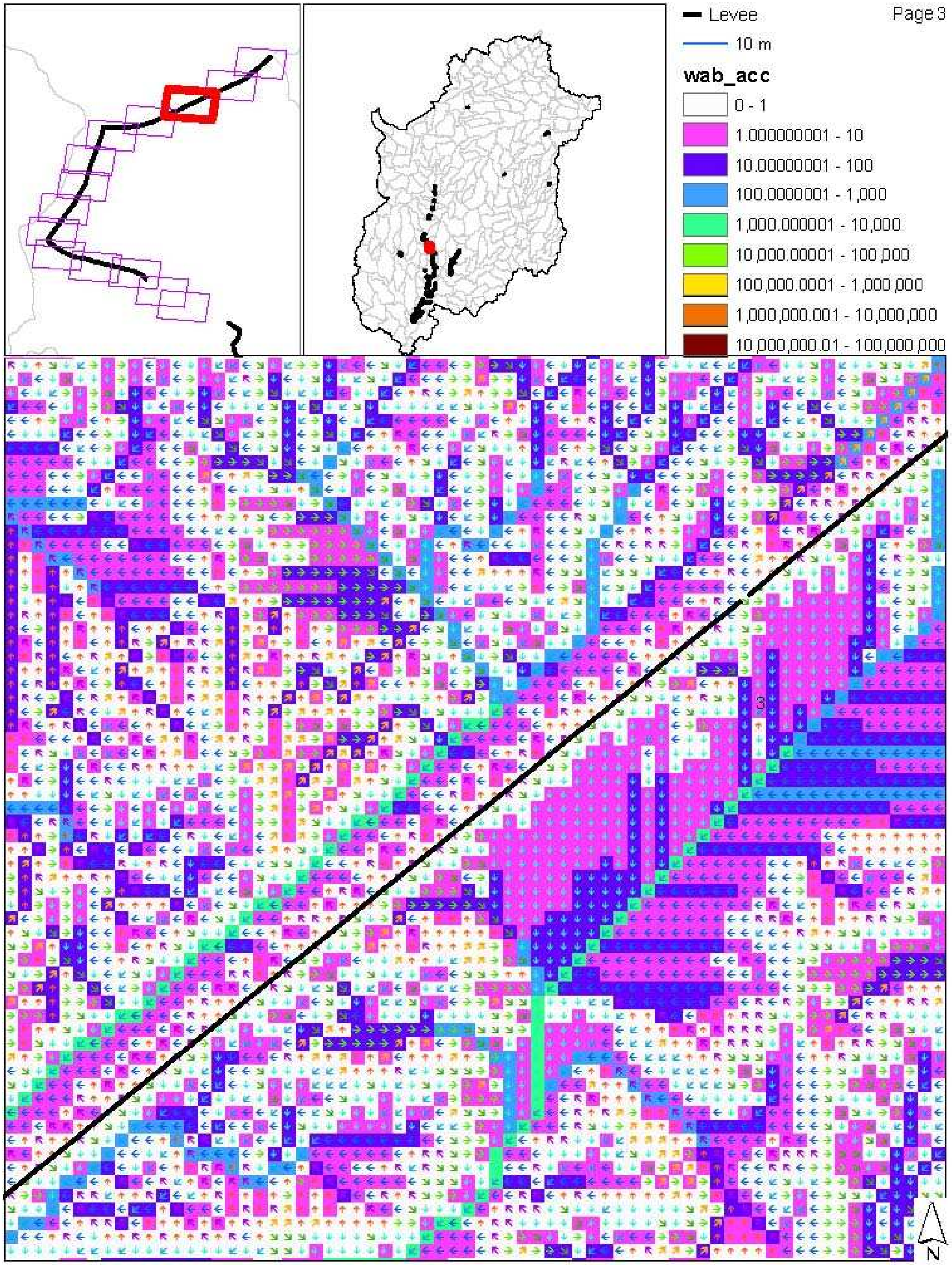
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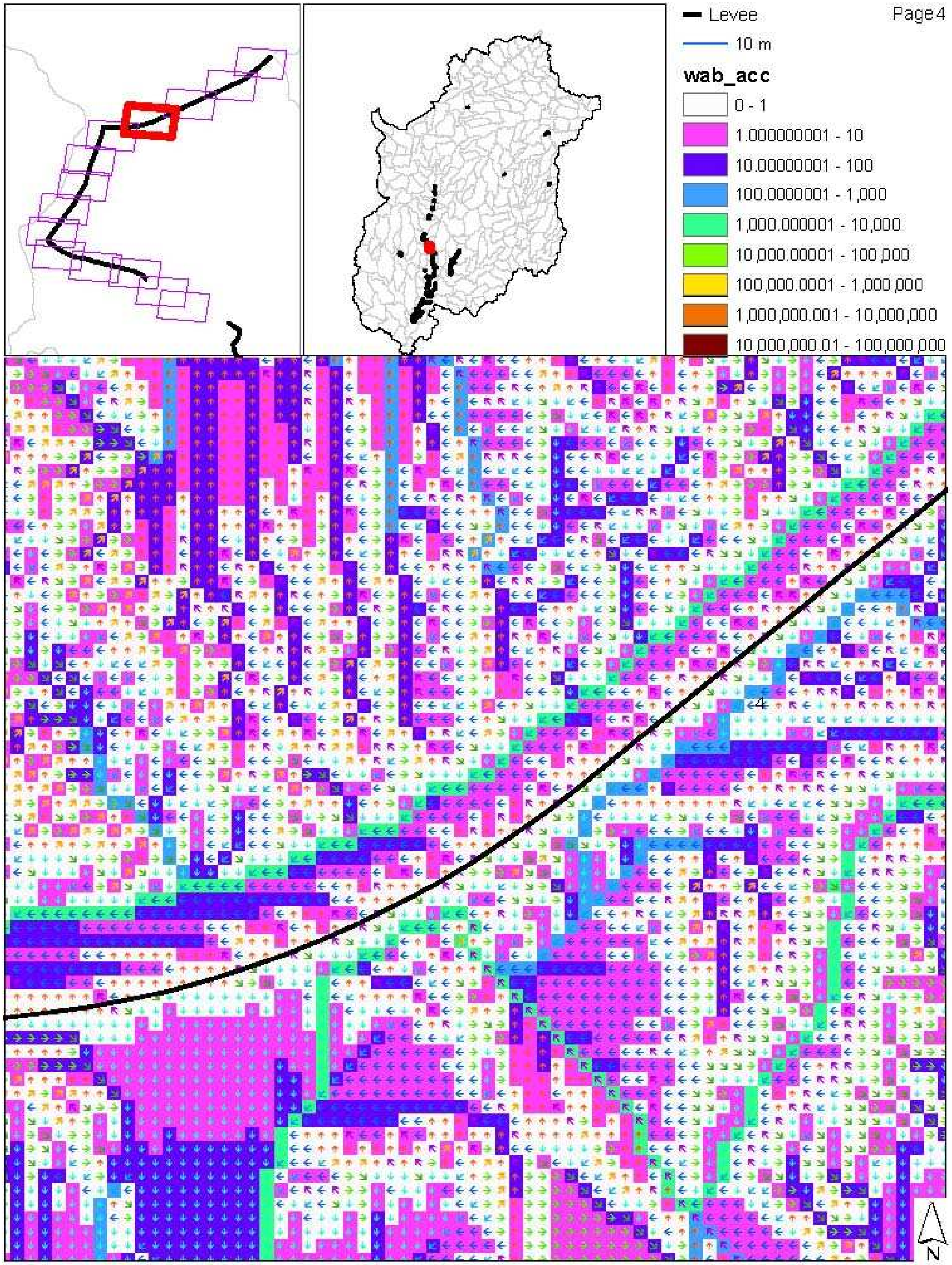
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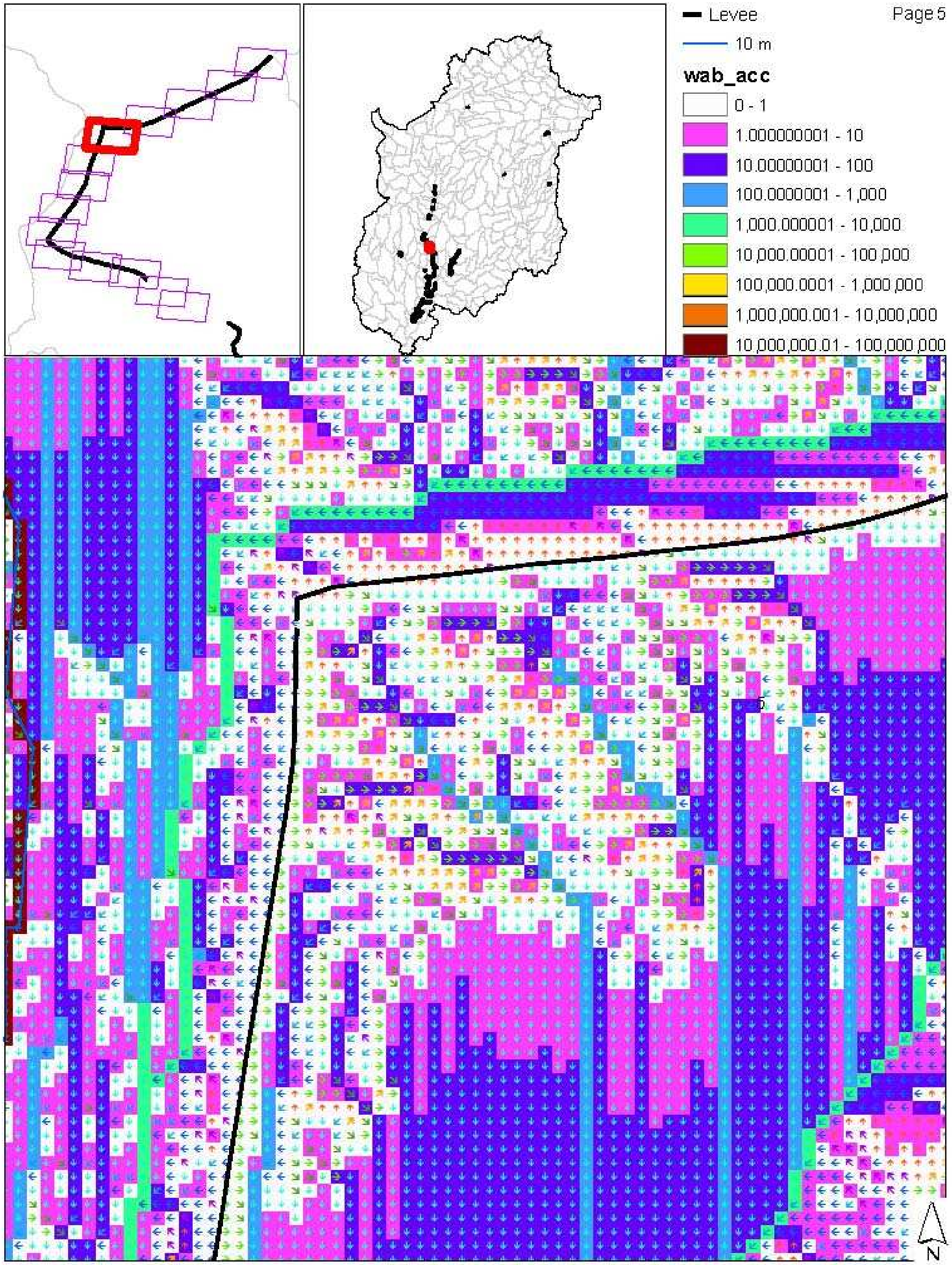
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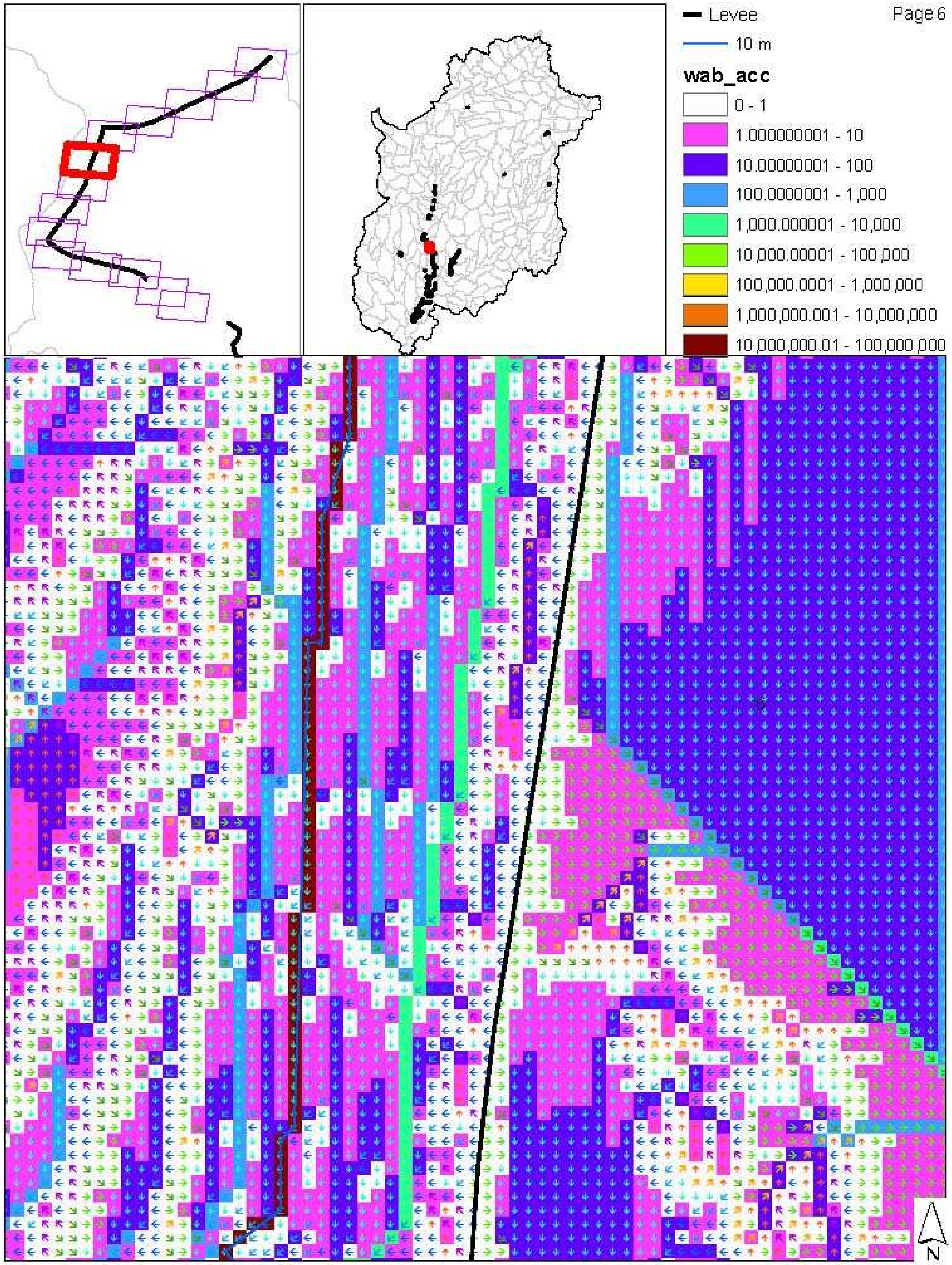
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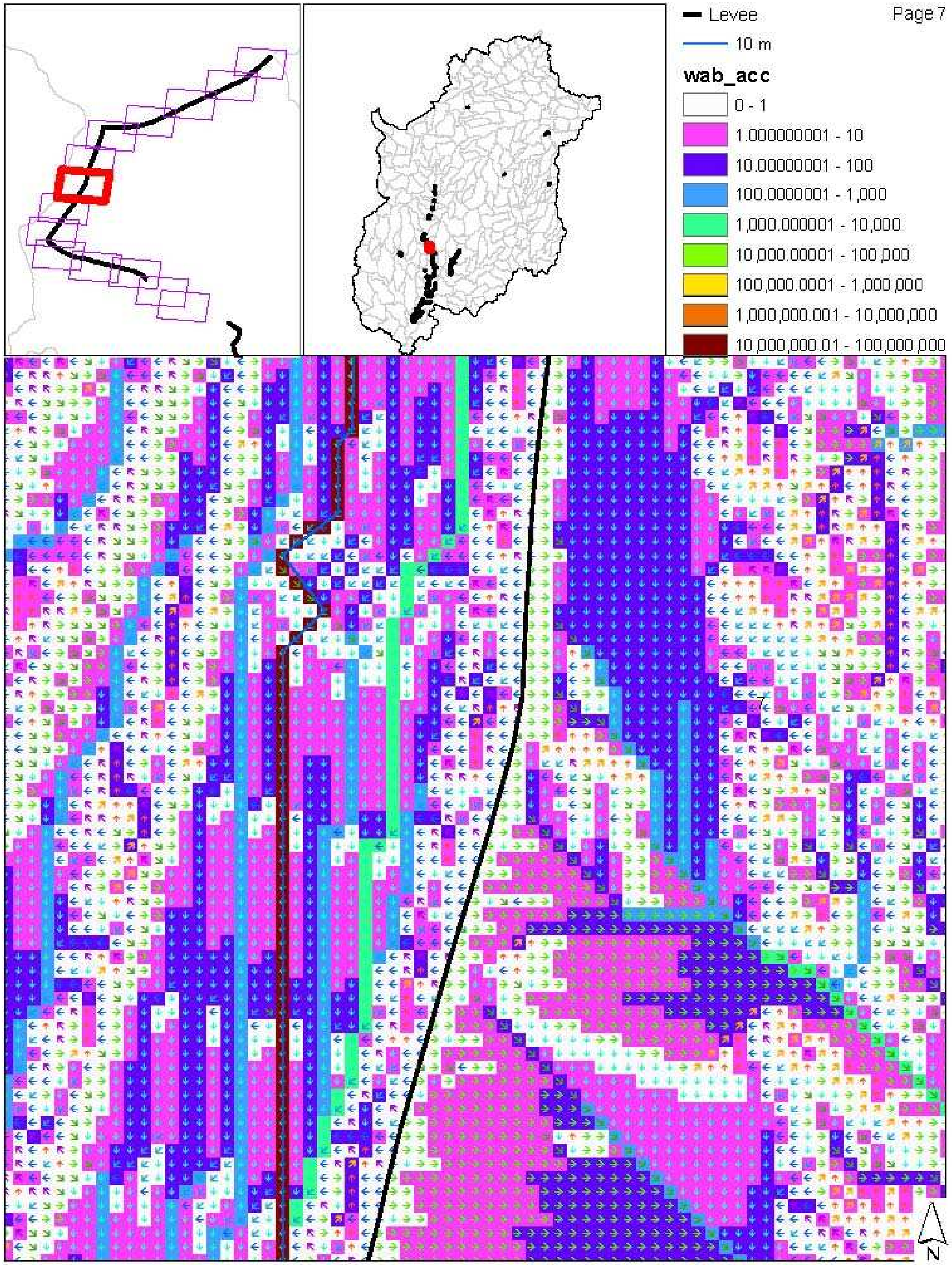
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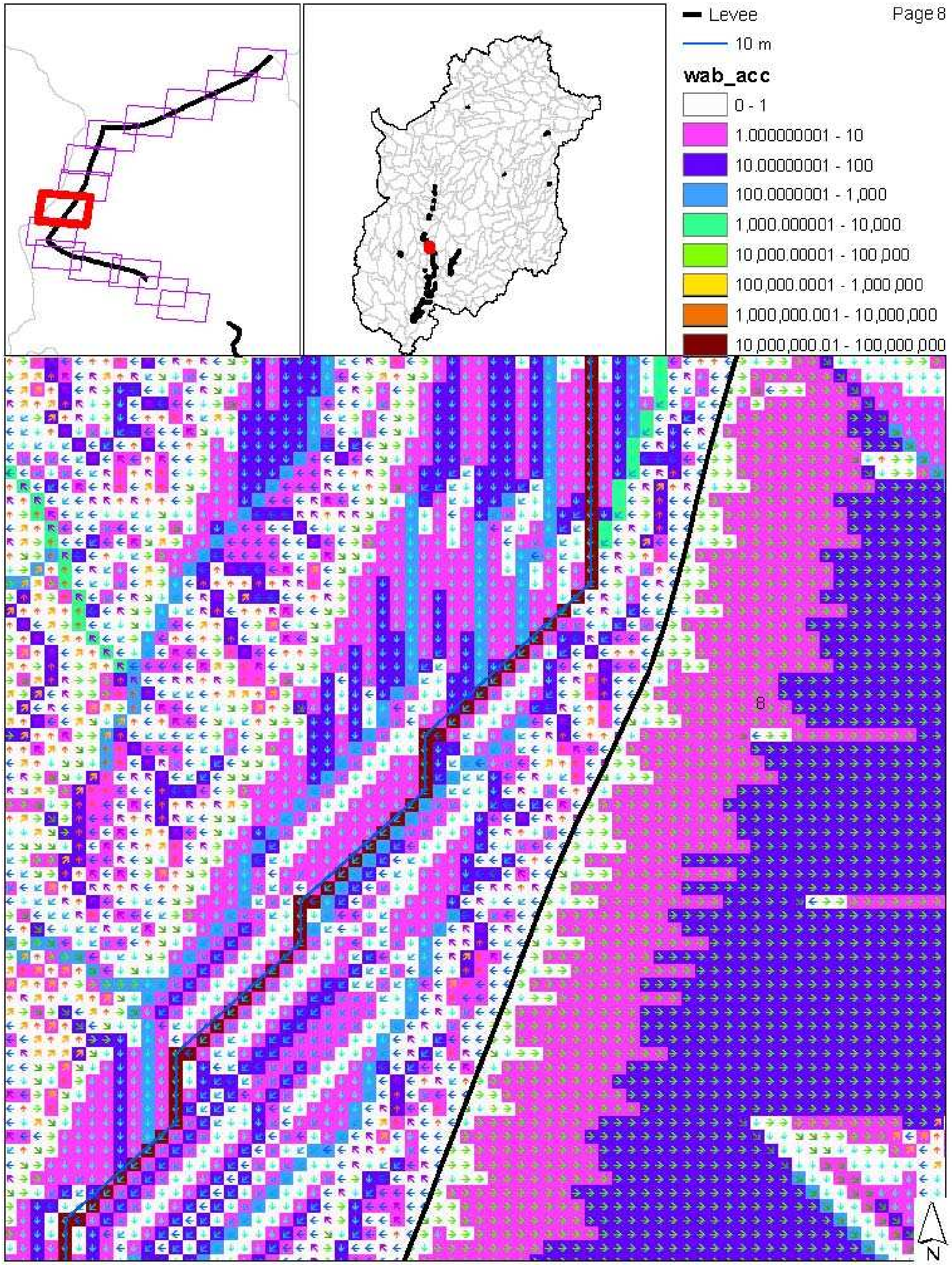
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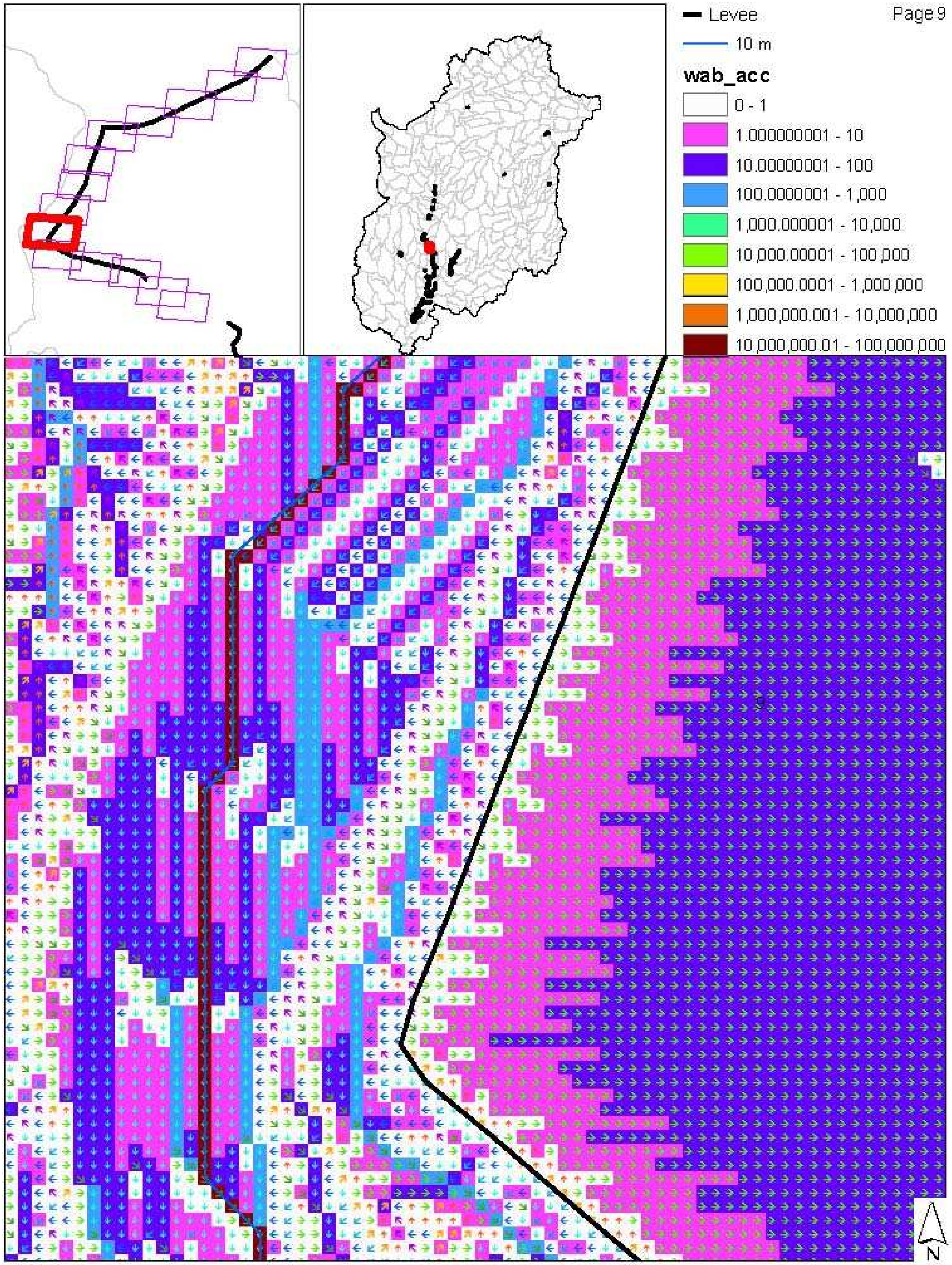
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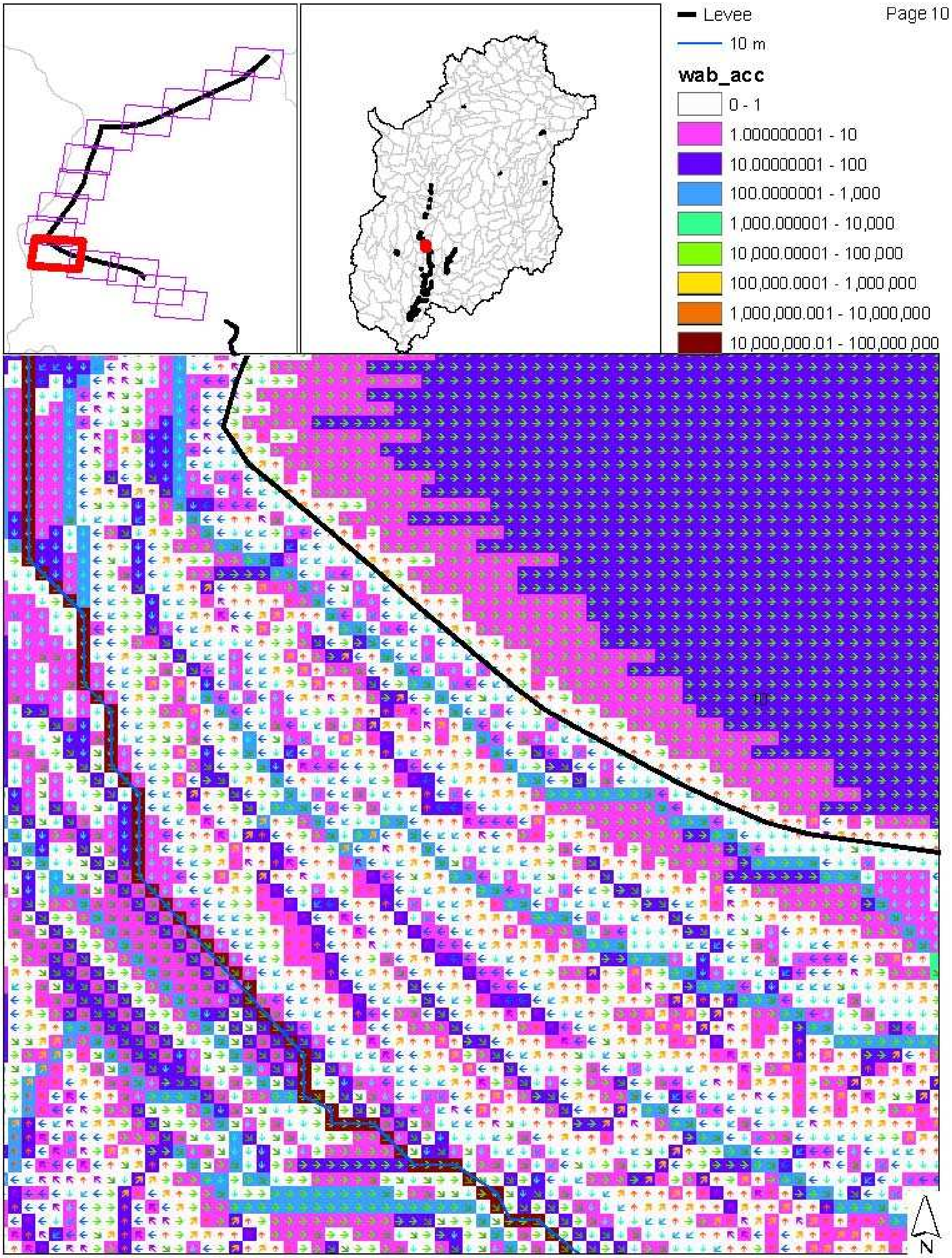
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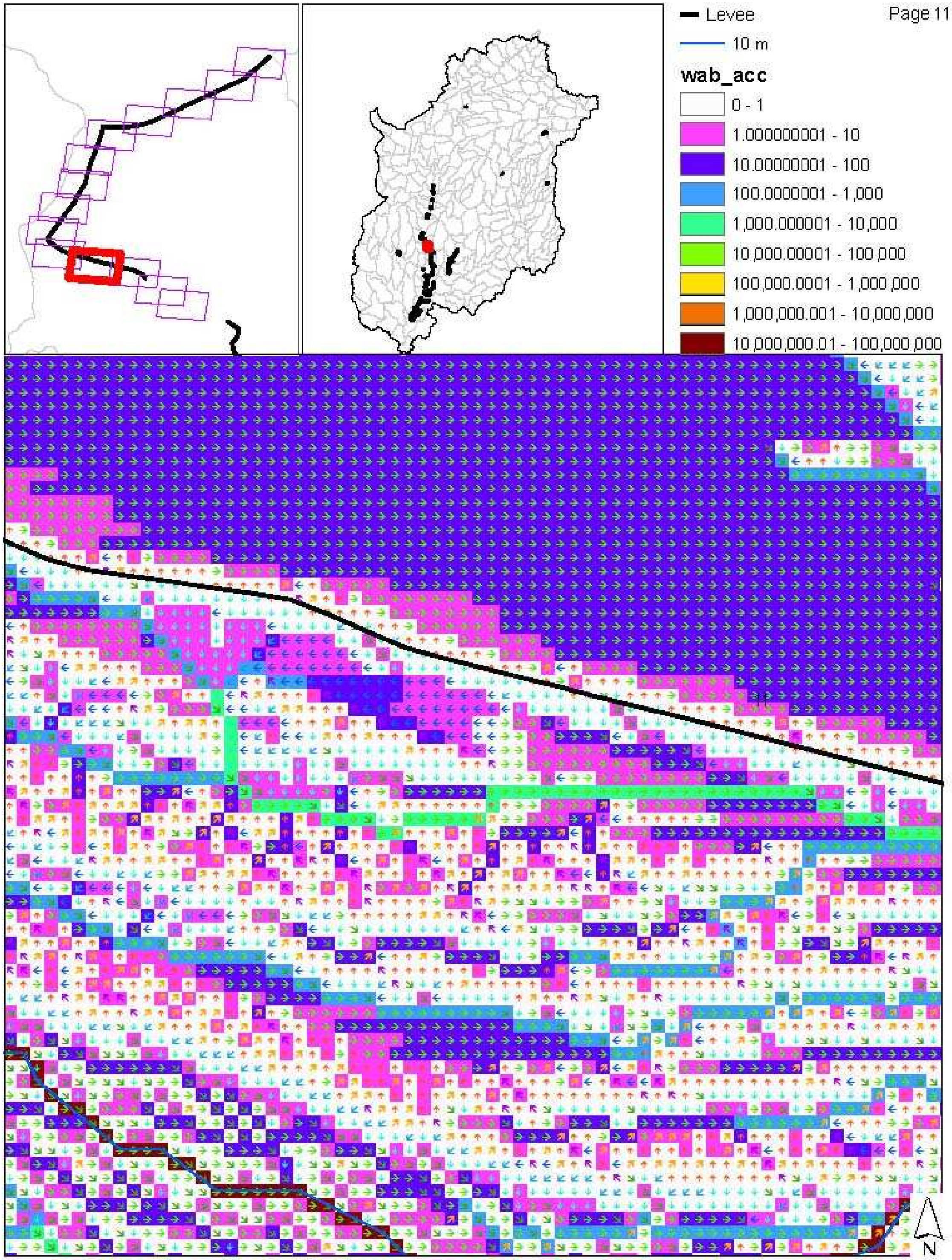
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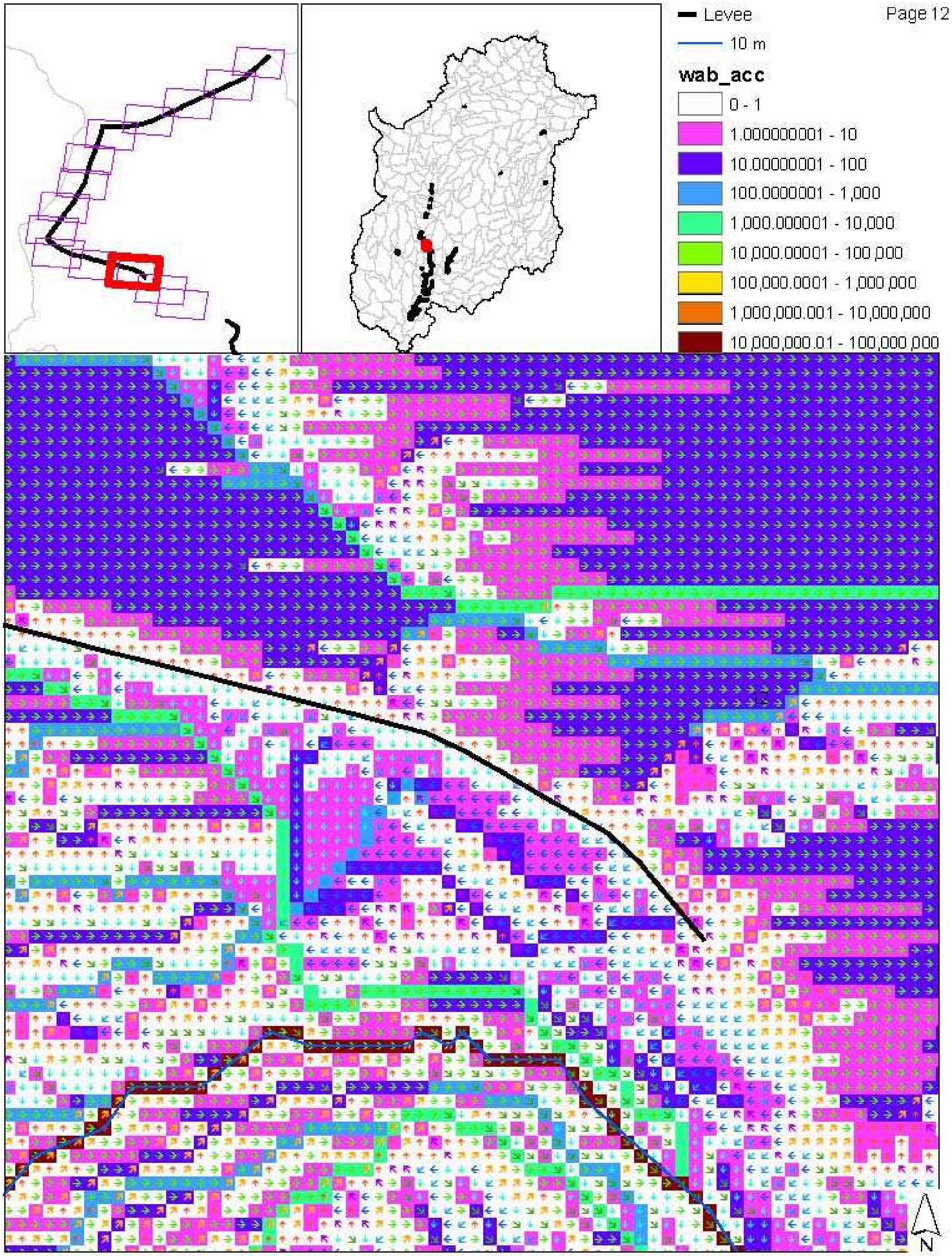
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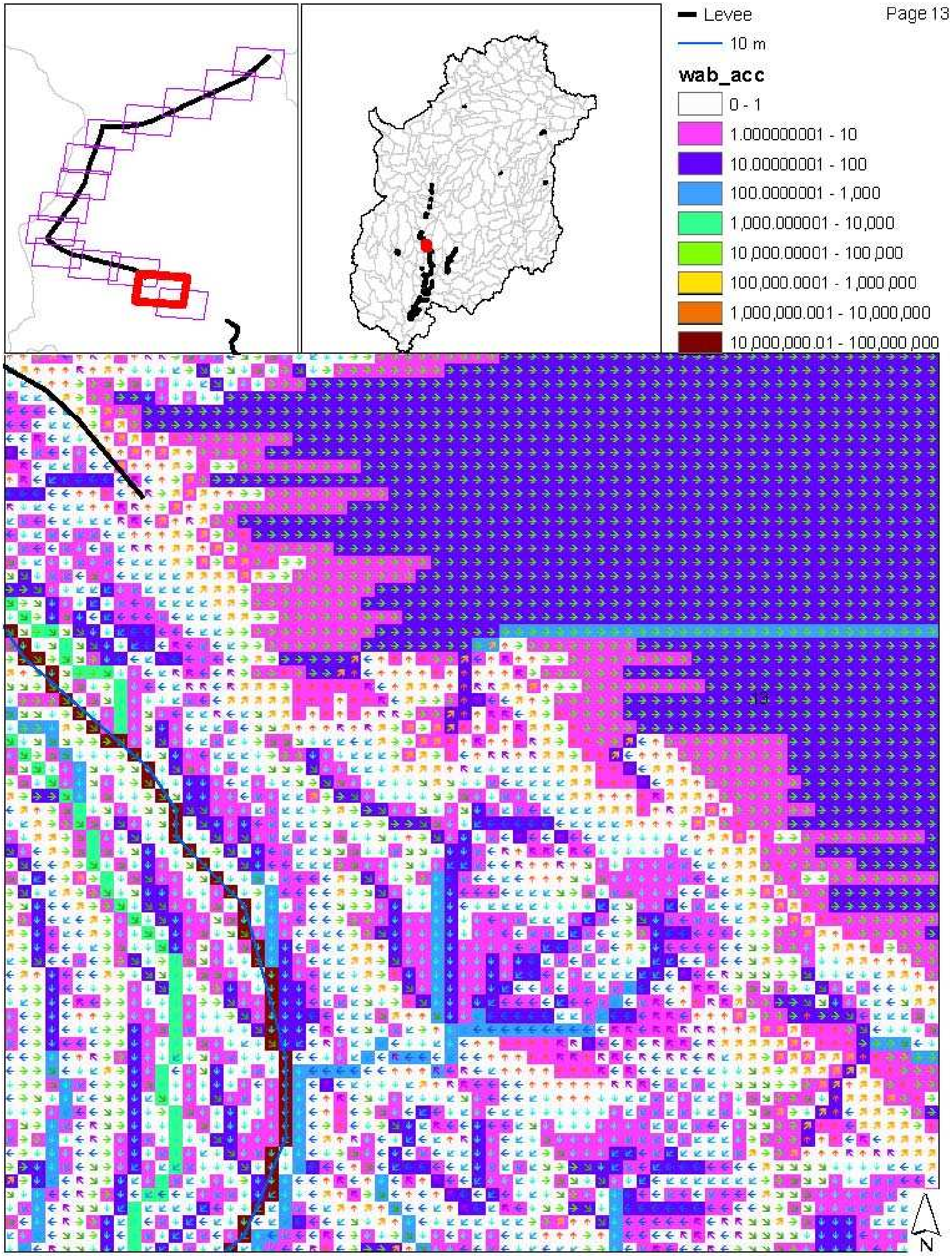
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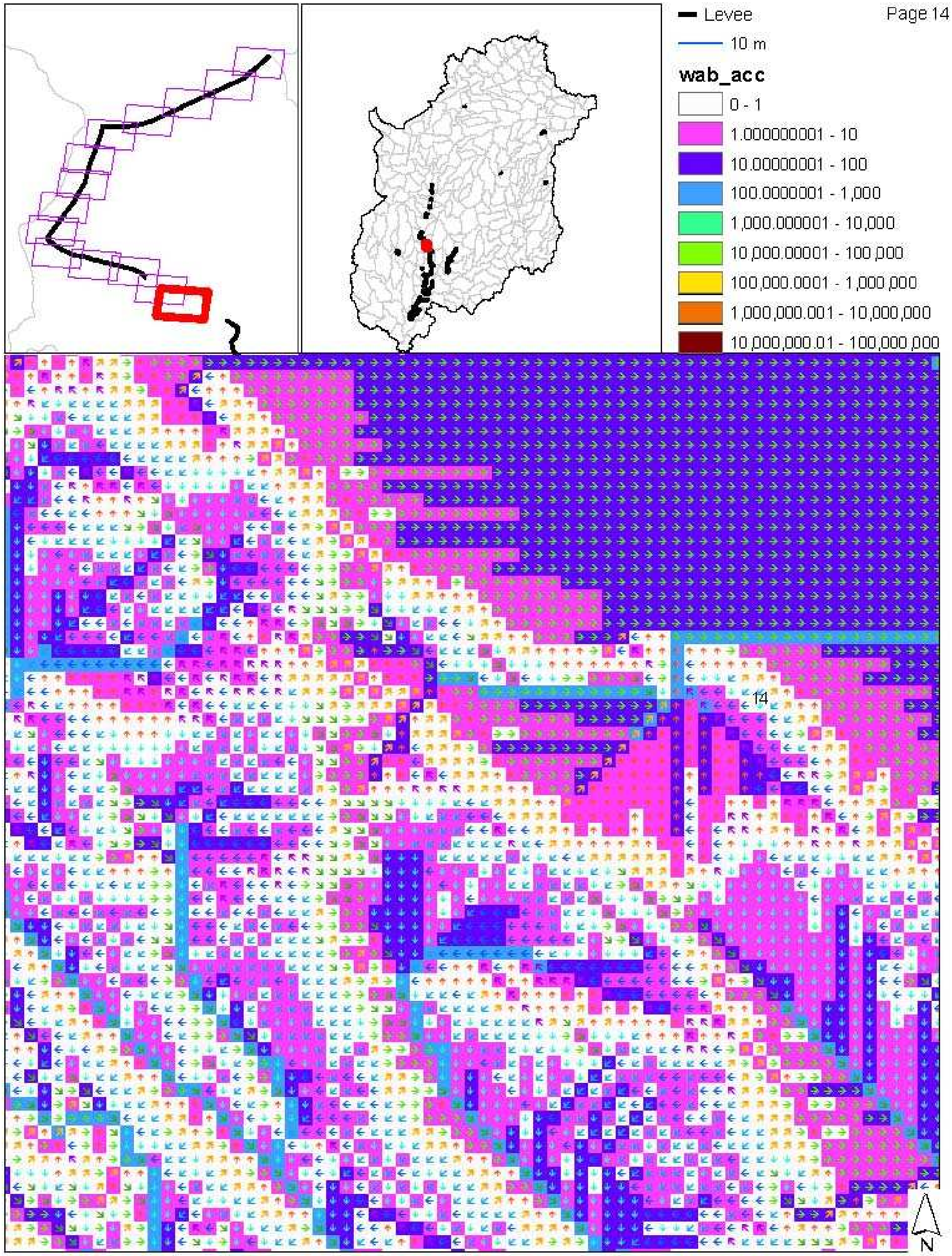
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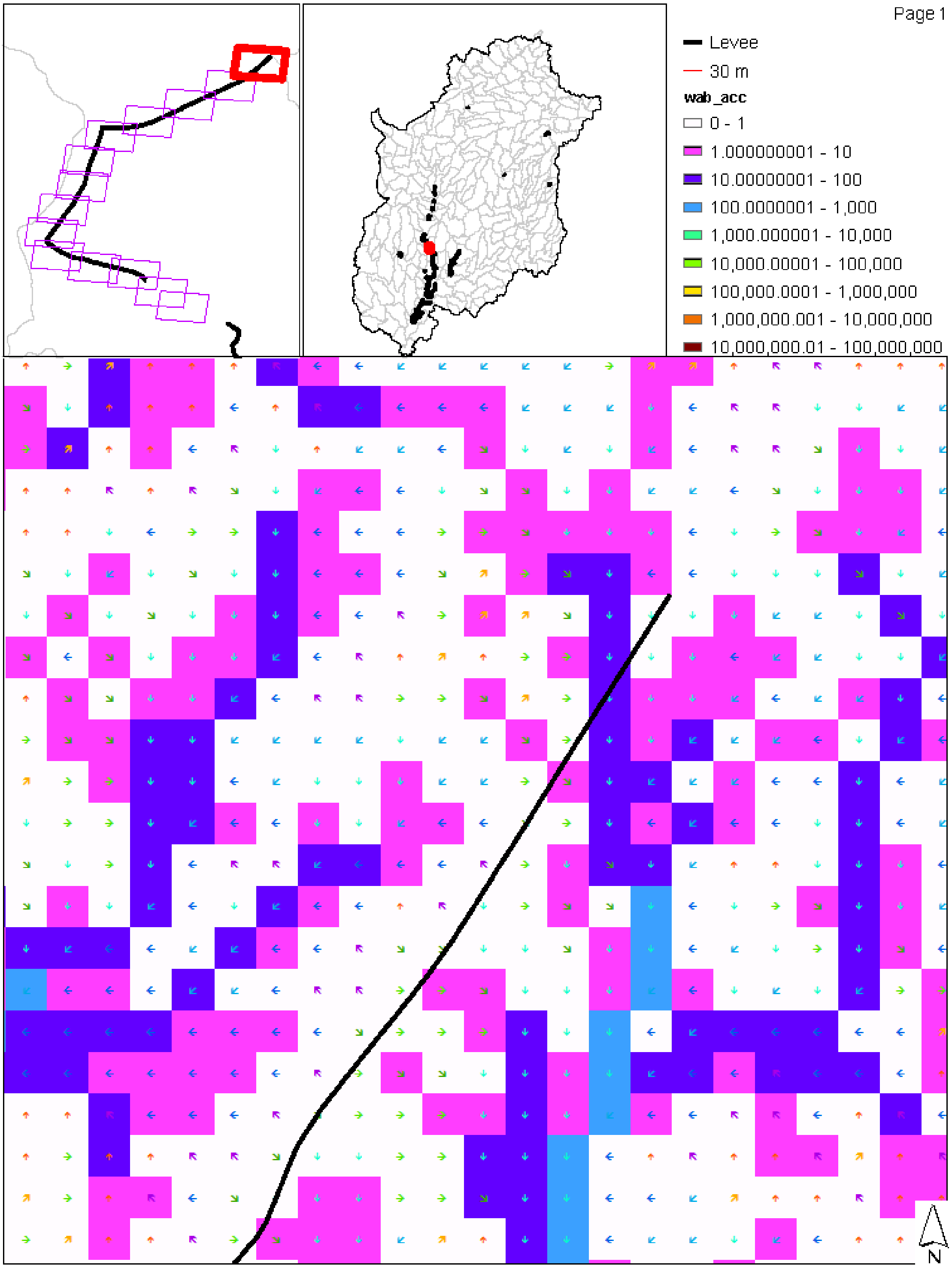
10m Levee Flow Direction and Accumulation Analysis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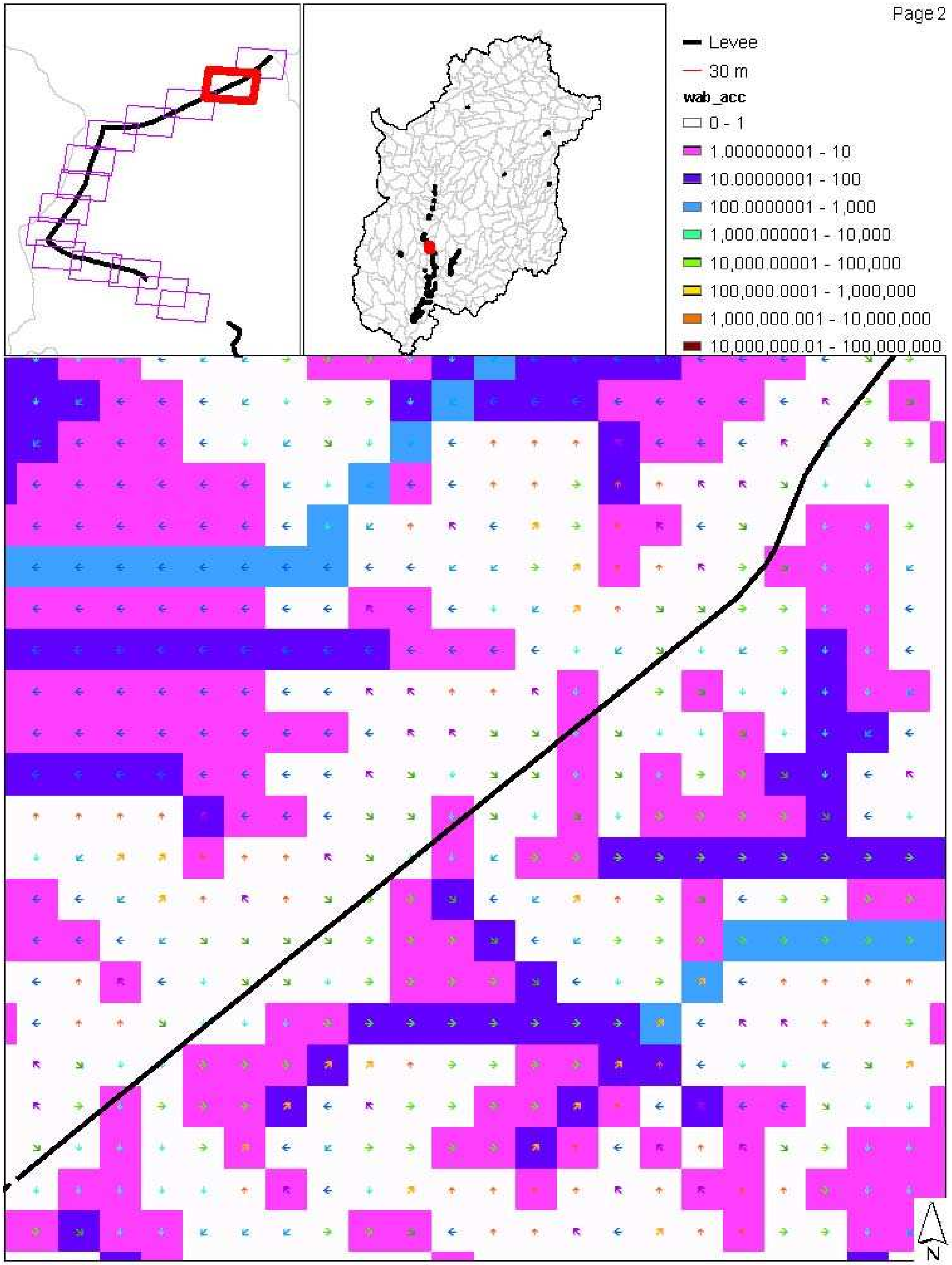
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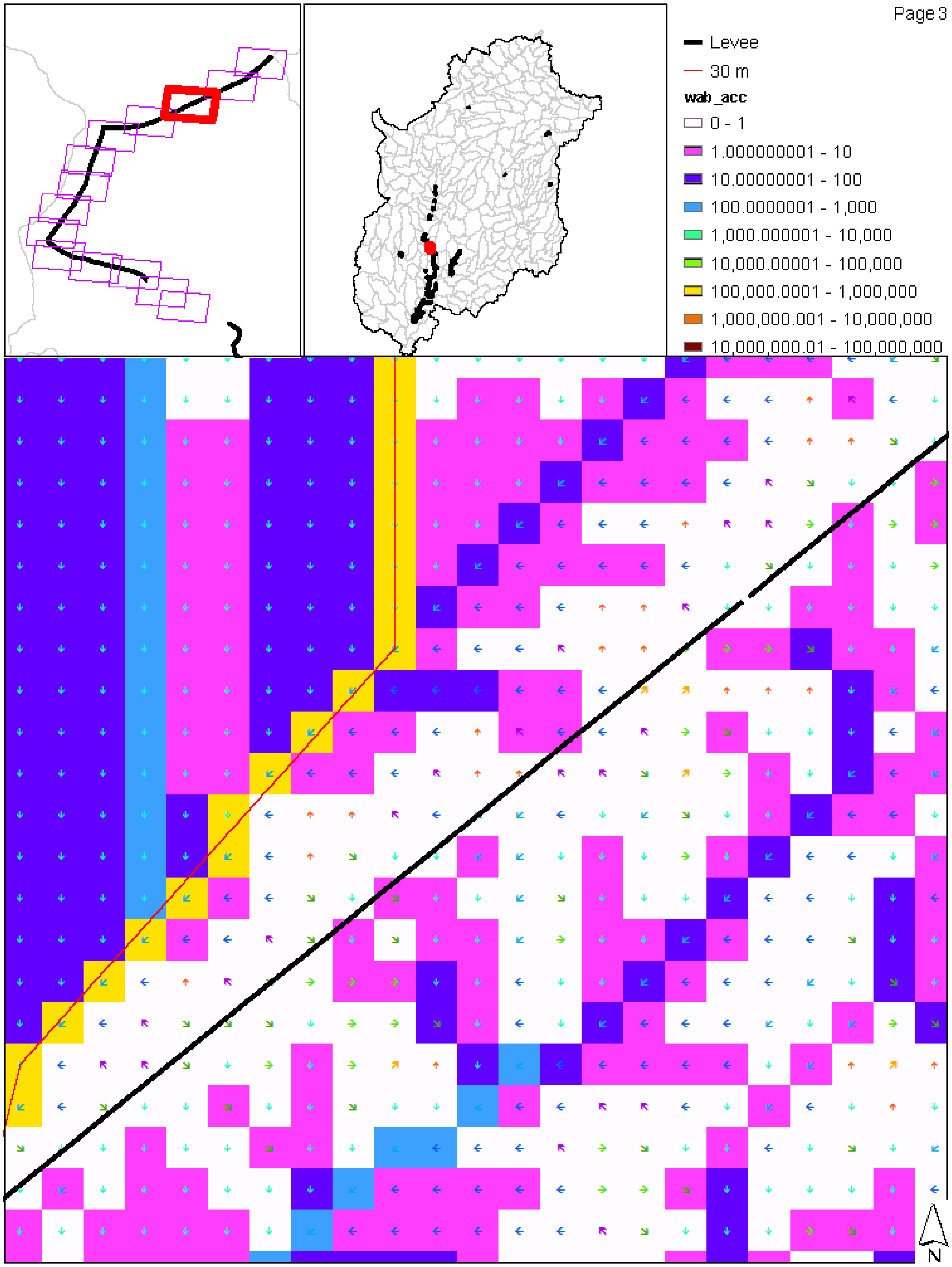
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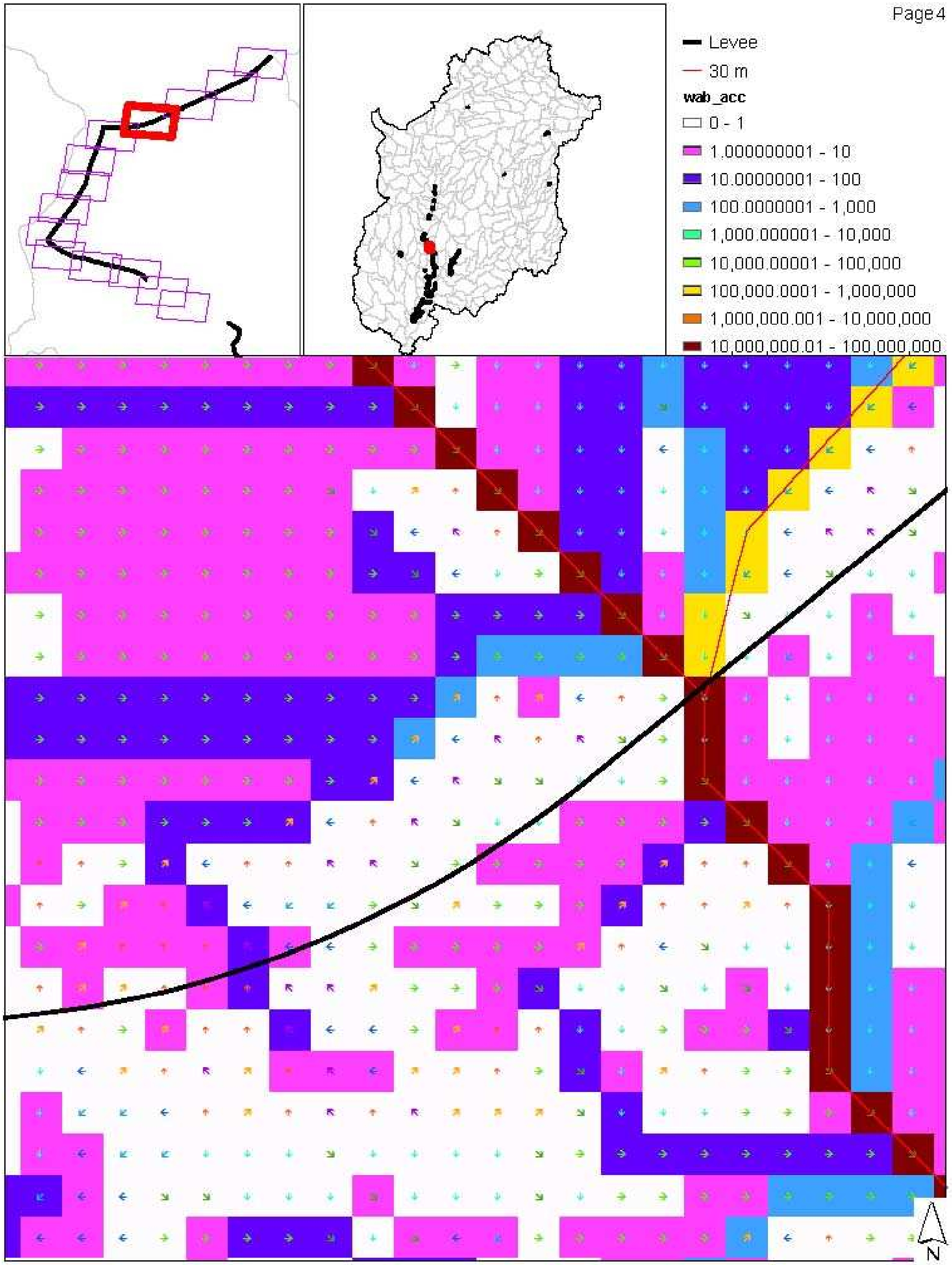
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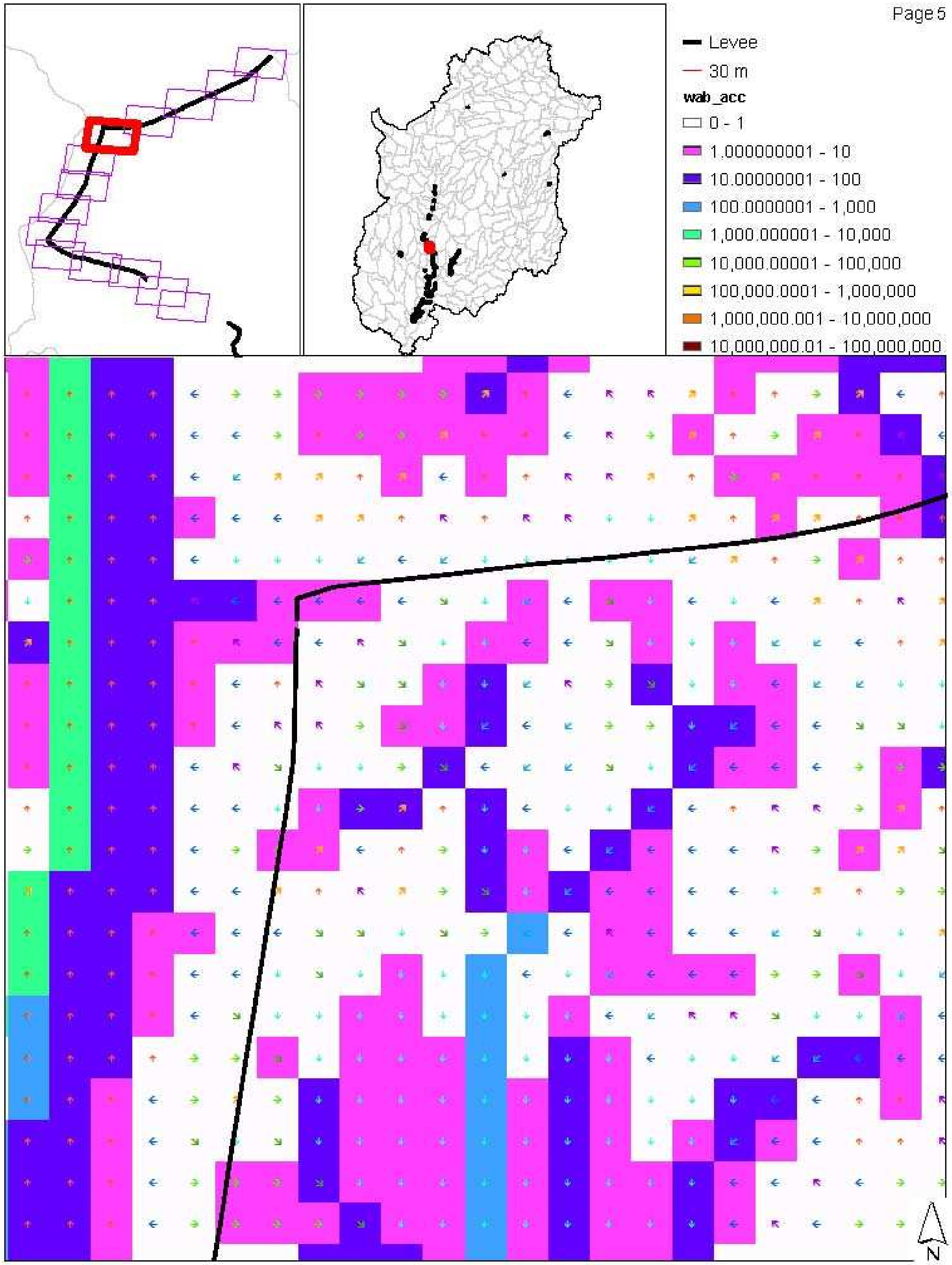
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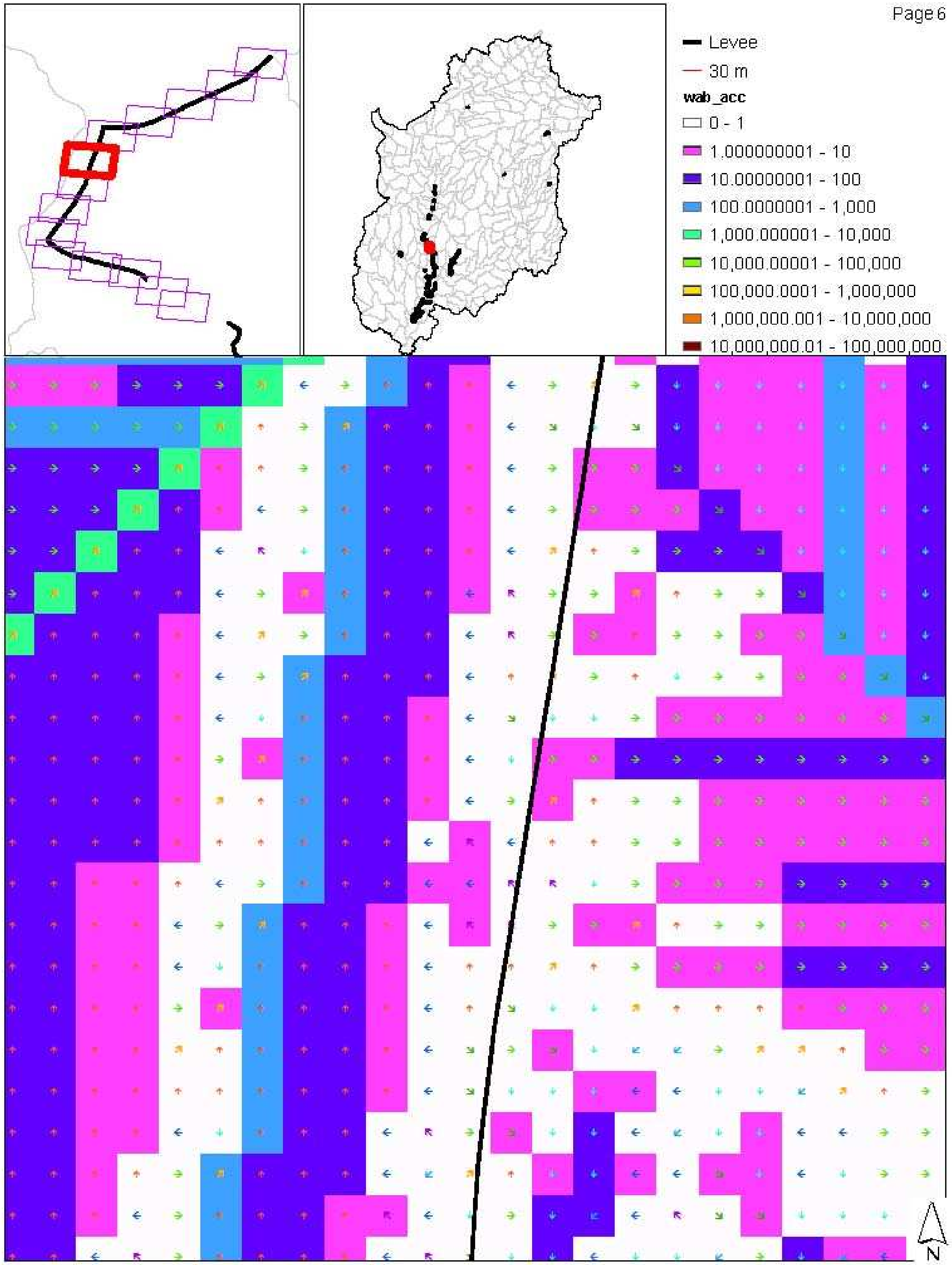
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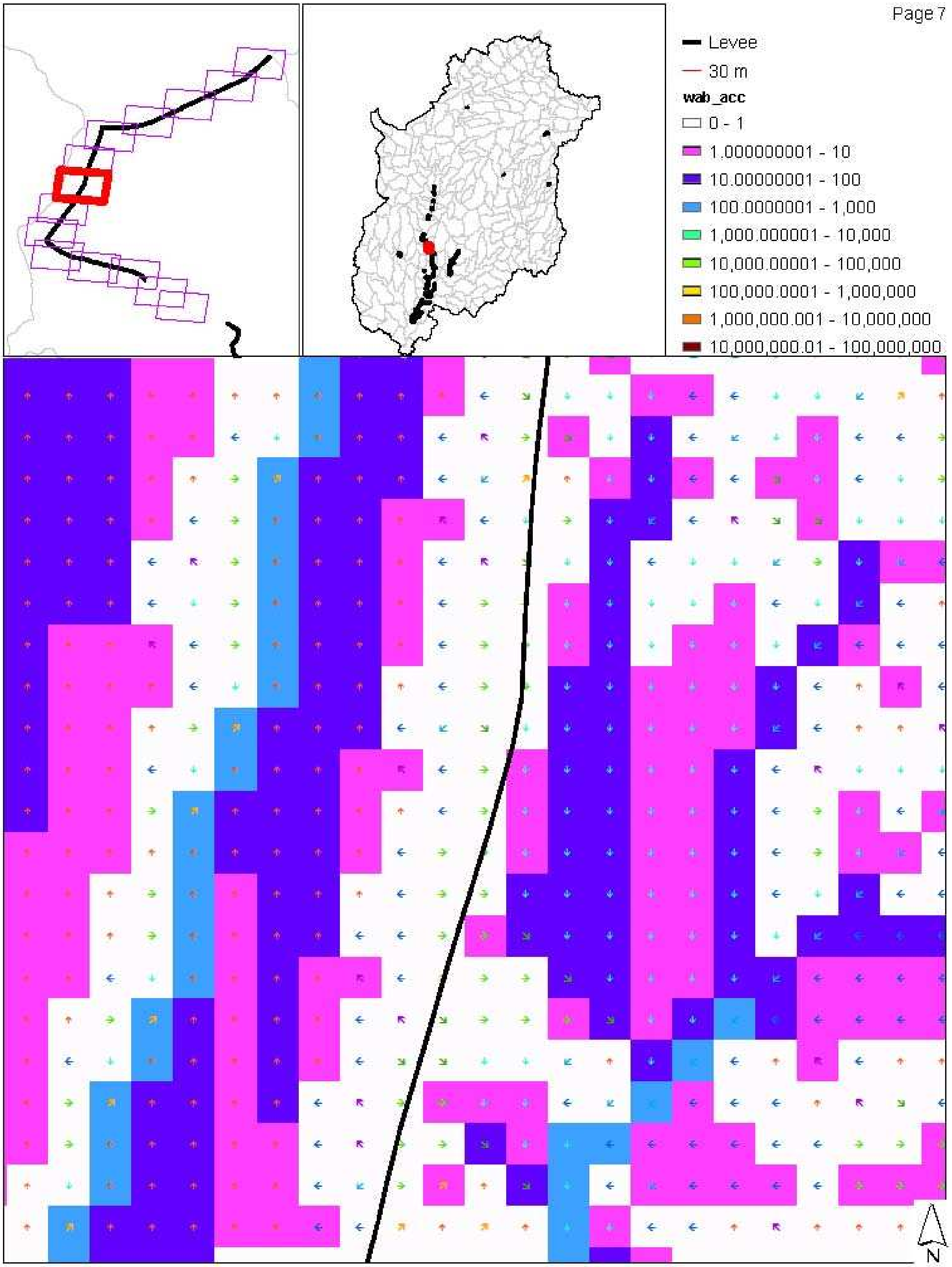
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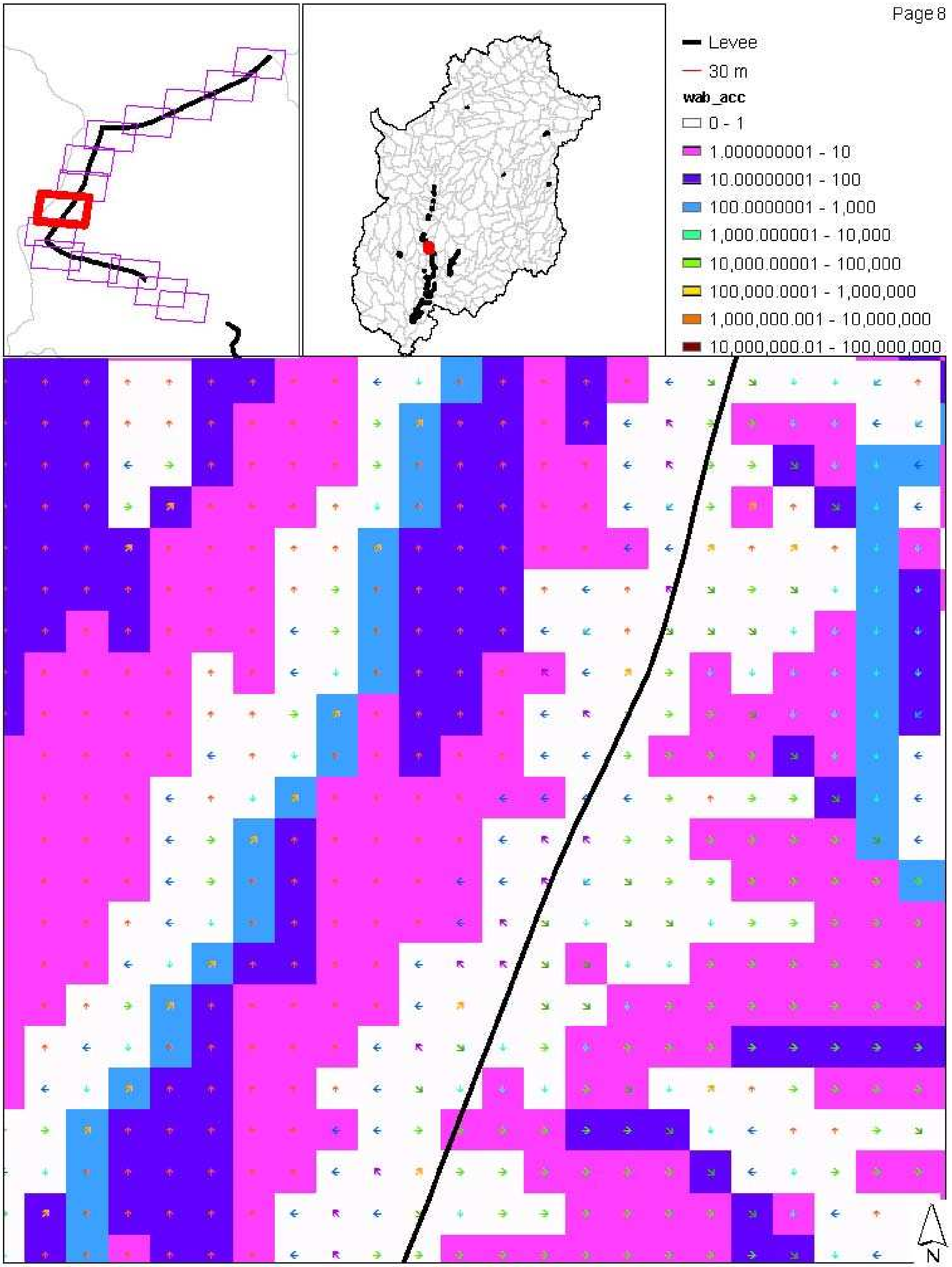
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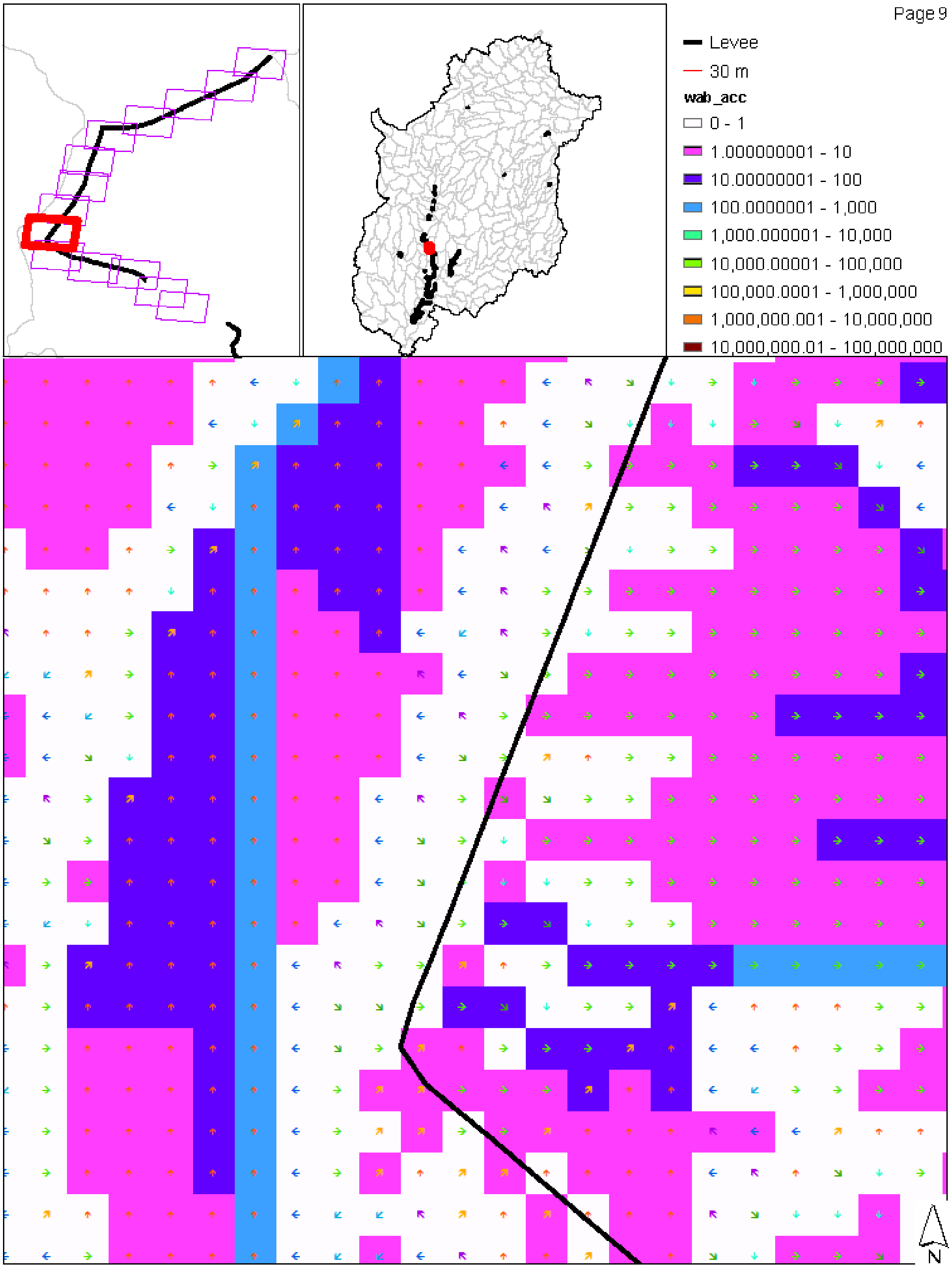
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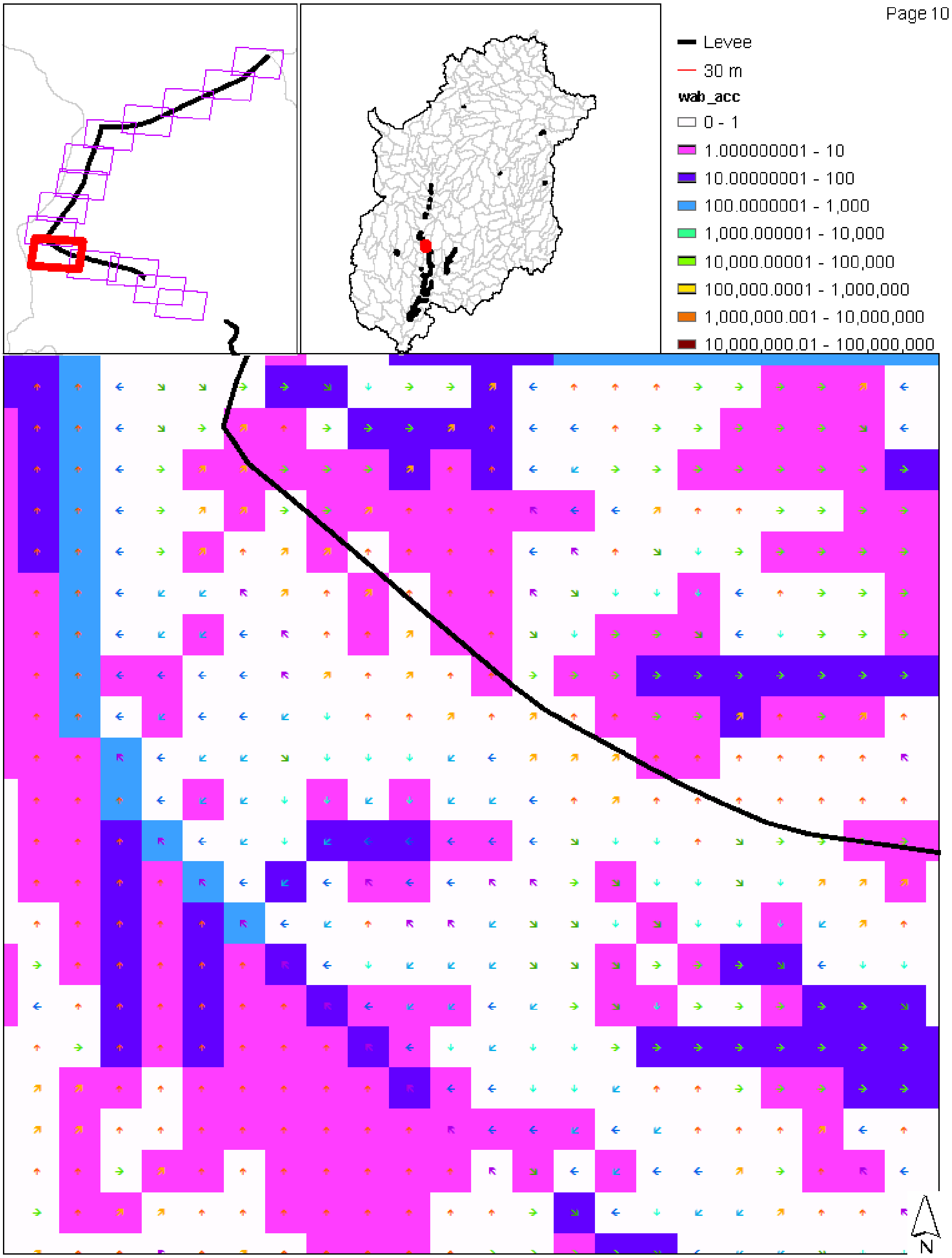
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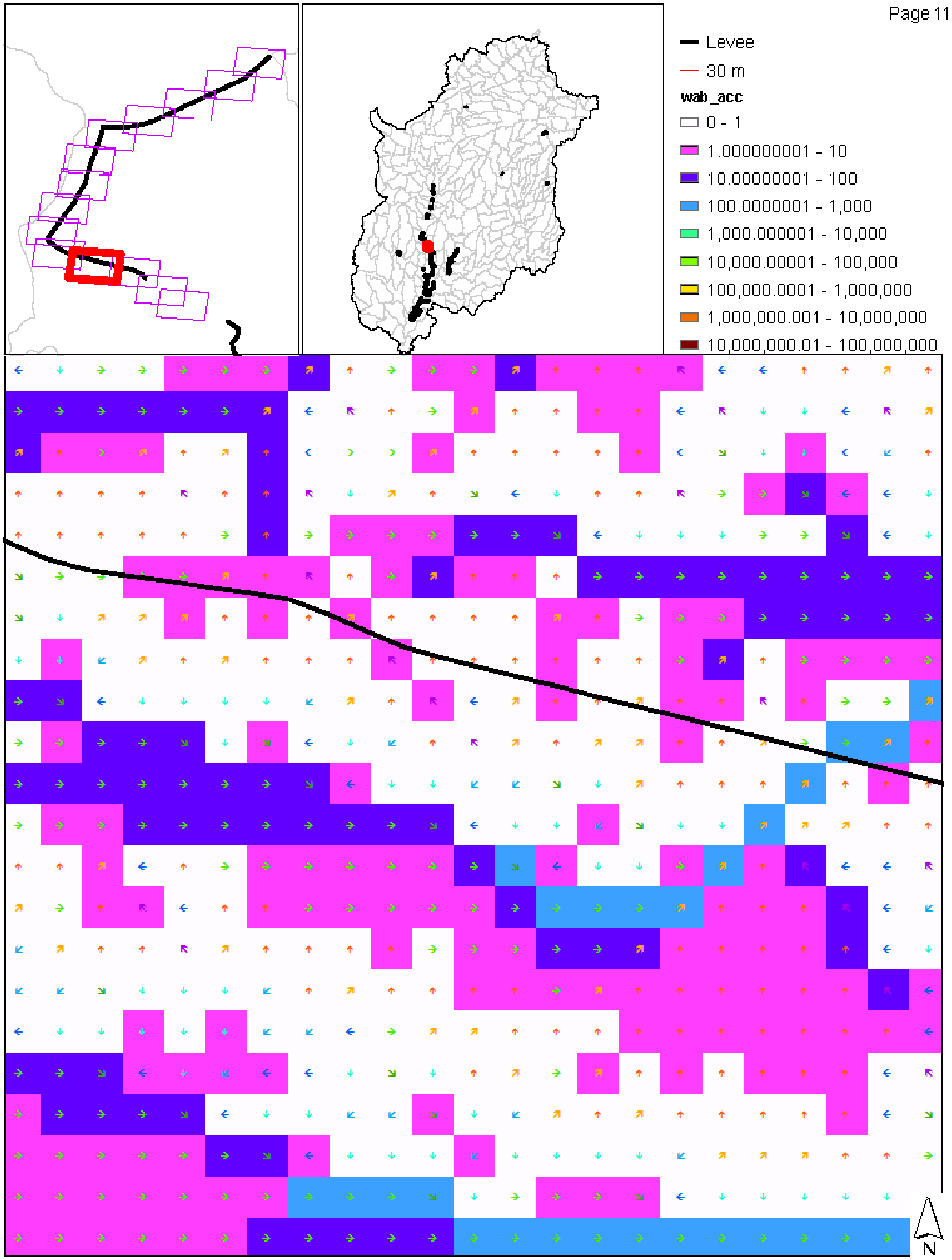
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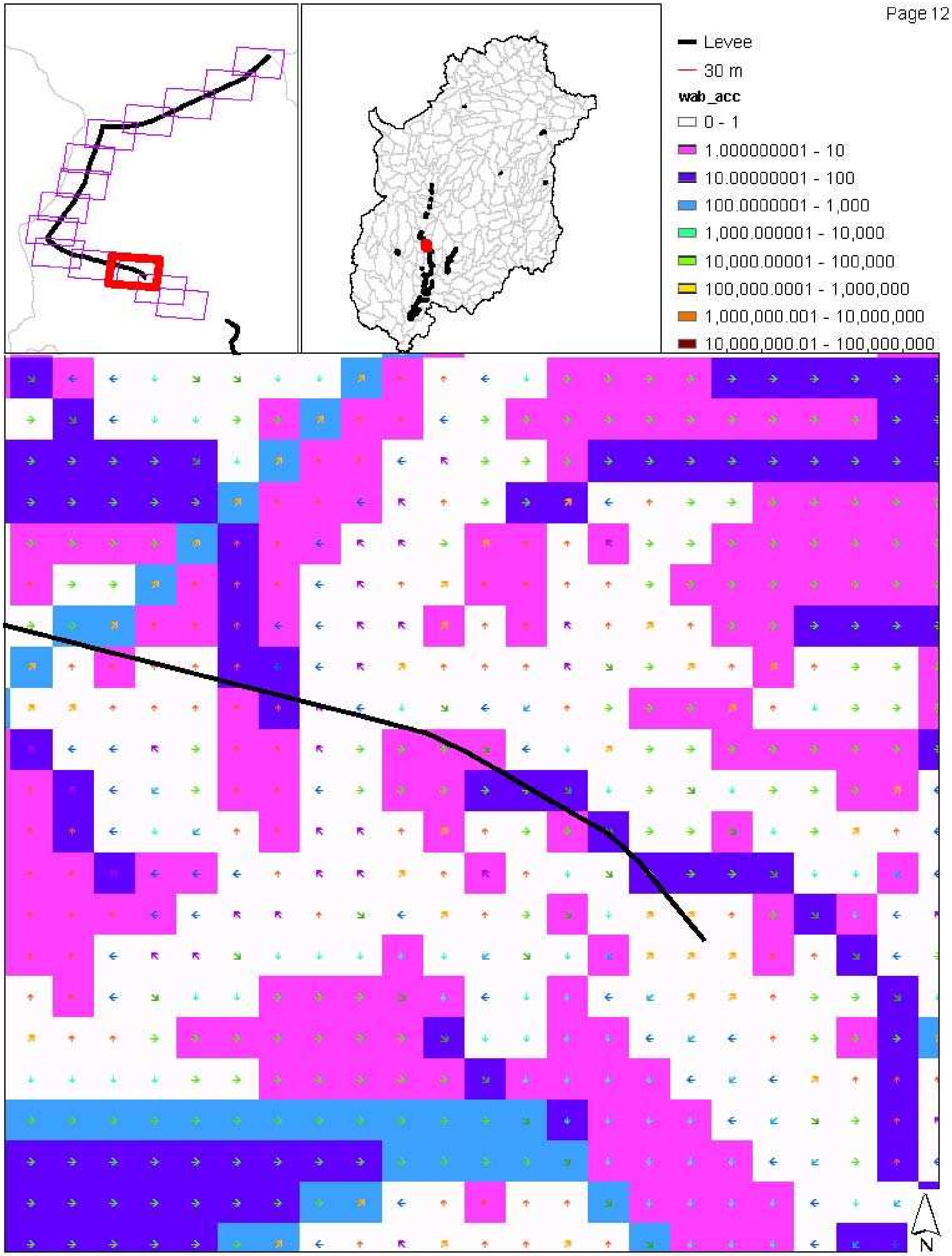
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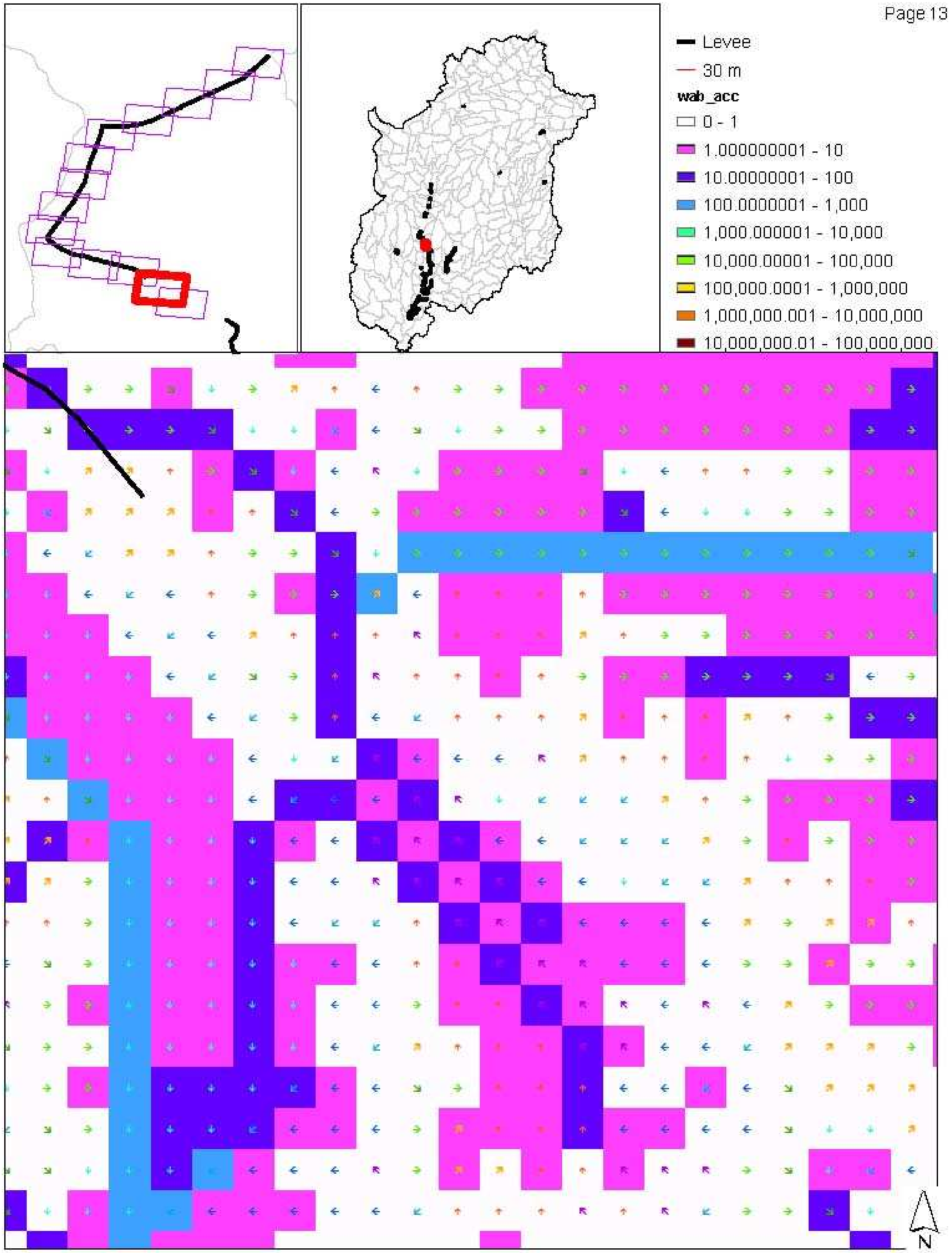
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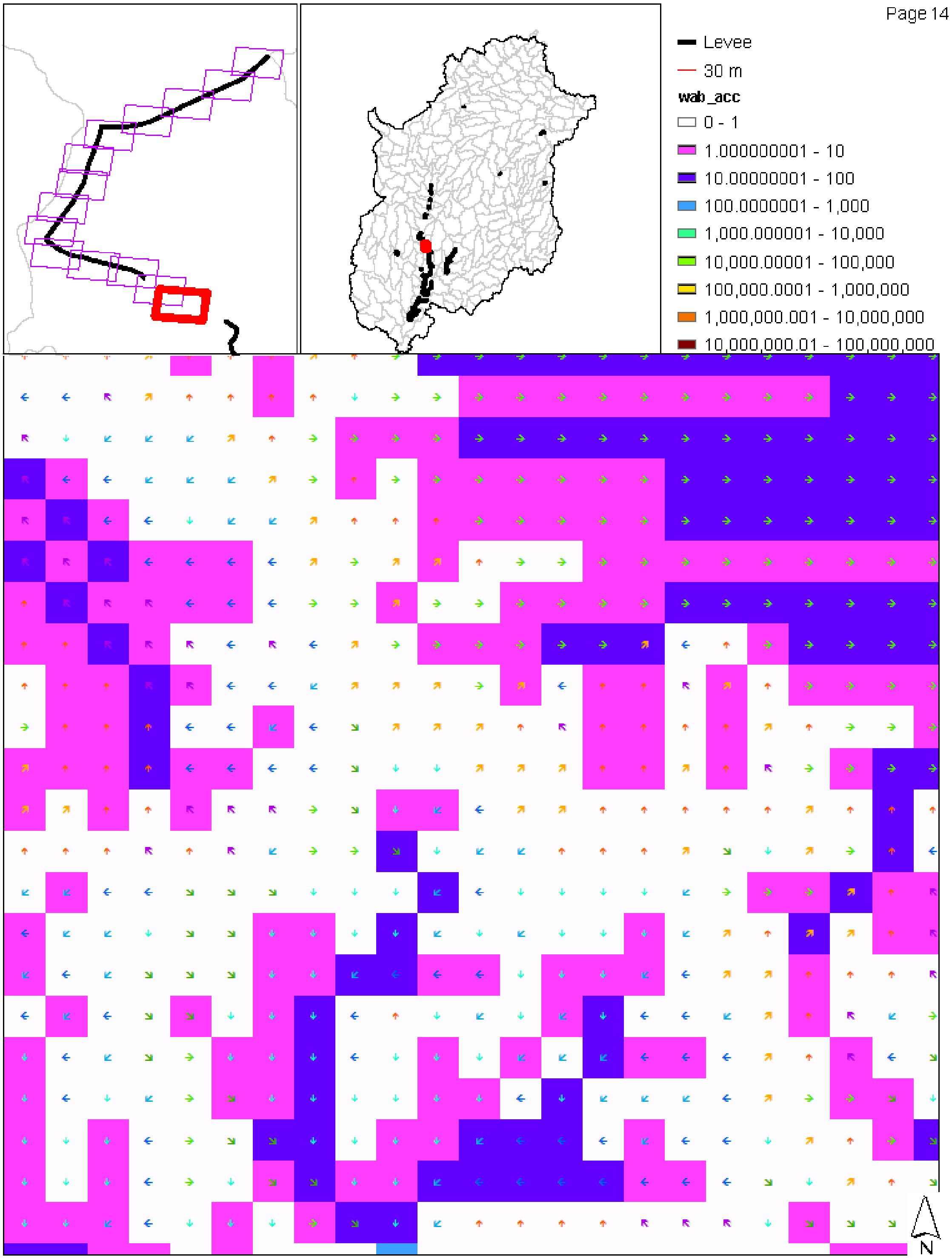
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