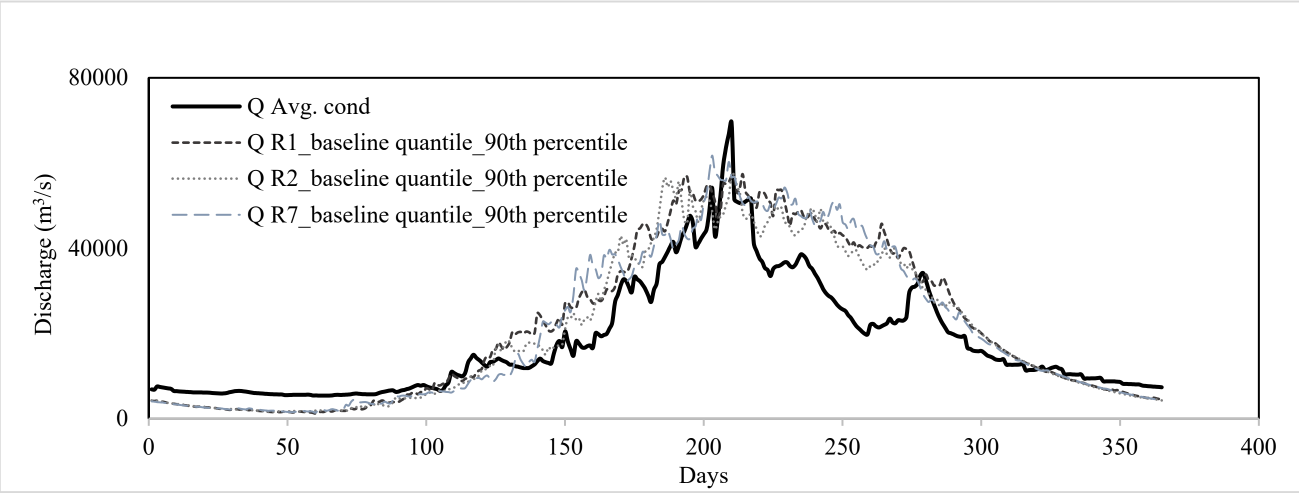


Figure S1. 90th percentile annual Daily flow hydrographs for baseline condition of Moderate (R1i1p1), Driest (R2i1p1) and Wettest (R7i1p1) ensemble of RCP 8.5 scenario and avg. flow at 2.33 – year return period.

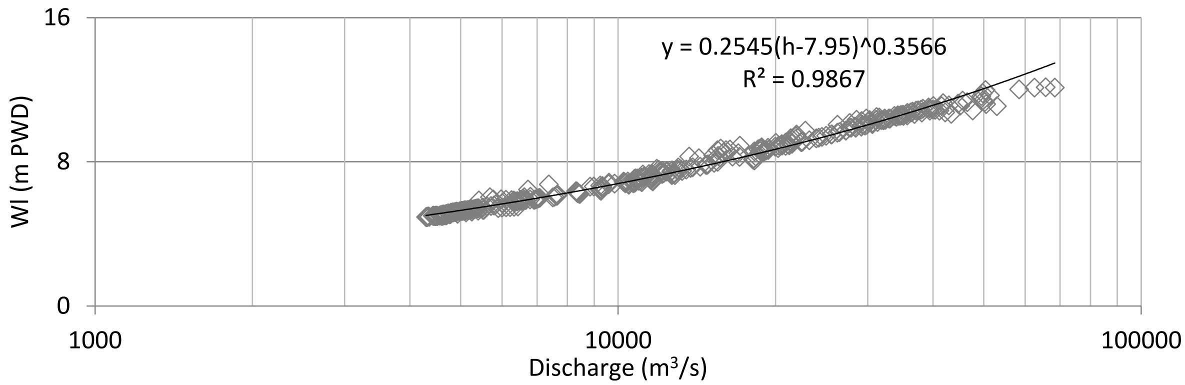


Figure S2. Example of the rating curve at Bahadurabad used to generate the water level boundaries.

S1.1 Hydrological simulation

S1.1.1 Climate model selection

Climate modelling studies are highly dependent on the climatic projections simulated by different Global Climate Models (GCMs) and Regional Climate Models (RCMs). The low spatial resolution of GCMs causes restrictions in regional-scale simulations. On the other hand, high-resolution RCMs are expensive and introduce uncertainties from parameterizations and bias corrections [69]. Atmosphere Global Climate Model (AGCM) is a subset of GCMs enforced with different SSTs (Sea Surface Temperature) and SICs (Sea Ice Forcing) which can address all these limitations [69–72]. EC-Earth-HR [19,72,73] is such an AGCM simulated by Swedish Meteorological and Hydrological Institute (SMHI) under HELIX (End cLimate Impact and eXtremes) project. The high resolution (0.5° (~50 km)) and bias-corrected EC-Earth3-HR climate data are used in this study. It has already shown satisfactory performance in climate-induced flood studies [19,69,73]. This EC-EARTH3-HR GCM has seven different realizations/ variants enforced with different SSTs and SICs, as tabulated in Table 2.There are 7 ensembles in this study. The Ensemble member is defined as 'rNiMpL' where N is the number of realizations; M is the number of different initialization states, and L is the number of used physical parameterizations. For example, R5i1p1 means the number of realization members = 5, number of different initialization states = 1 and number of used physical parameterizations =1 for this ensemble. For details kindly see Taylor [48].

S1.1.2 The schematization of Hydrologic Model

A hydrologic model of the Brahmaputra basin developed by ref. [28] in SWAT has been used to estimate the future flow at Bahadurabad Transit of Brahmaputra River (Figure 1 a). The model topography has been set up using HydroSHEDS 90m DEM [49]. The GlobCover land use map prepared by the European Space Agency [50] and the soil map prepared by the Food and Agricultural Organization [50,51] have been used as land-use and soil information of the model, respectively. Daily precipitation and temperature data from the Princeton Global Forcing (version 2) dataset [52] of the period 2001 to 2012 are used during the development of the SWAT model.

S1.1.3 Hydrologic model Validation

Before calibrating the model, sensitivity analyses are performed on all hydrology parameters of SWAT using SWAT-CUP. For more details, see Ref. [28]. EC-Earth-HR [74] is an AGCM simulated by Swedish Meteorological and Hydrological Institute (SMHI) for the RCP 8.5 Scenario under the HELIX (End cLimate Impact and eXtremes) project. It is a high resolution (0.5° (~50 km)) data. The outputs from the EC-Earth3-HR models were bias corrected against the Princeton Global Forcings (version 2) data set using the Inter-Sectoral Impact Model Intercomparison Project (ISIMIP) [75] trend preserving bias correction method. Mohammed et al. [28] used the dataset in the SWAT model for simulating future discharge for Brahmaputra basin and found satisfactory results for the basin. It is the same SWAT model outputs that we have used in this study. So, further validation of the climate model is not done in the current study. This EC-EARTH3-HR GCM has seven different realizations/ variants enforced with different SSTs and SICs, as tabulated in Table 2. The hydrologic model has been calibrated for 2001–2006 and validated for 2007–2012, comparing against the observed discharge data of Bangladesh Water Development Board (BWDB) (Figure S3).

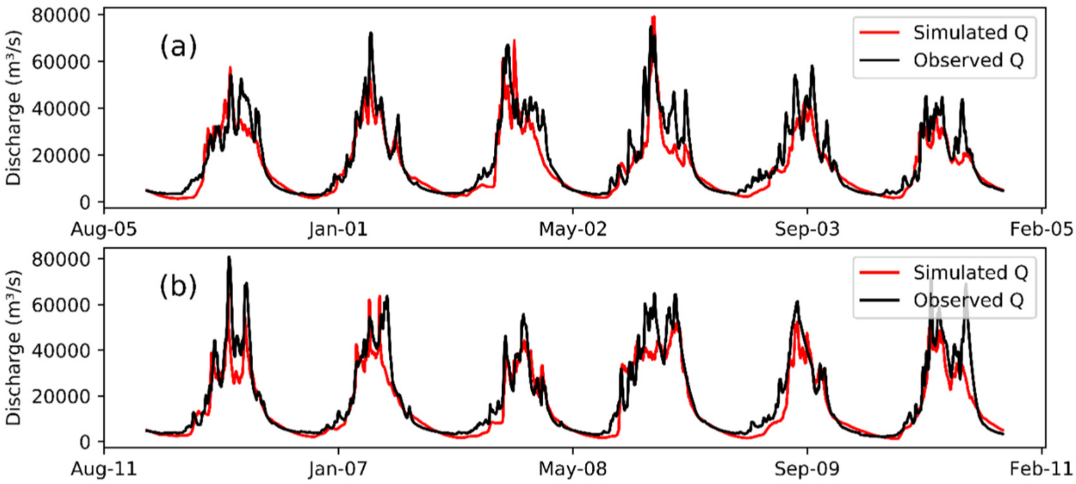


Figure S3. Validation of SWAT model for Brahmaputra River basin (a) calibration and (b) validation.

S1.2 Hydromorphic simulation

A physics-based 2D morpho-dynamic model of the Brahmaputra-Jamuna that is well-calibrated and validated [53,54] has been used to assess the impacts of several climatic scenarios over the char. The numerical model was used on the open-source platform of Delft3D (flow version 4.00.01.000000)([55]). Here the fundamentals of the morphology model are described briefly. The detail of the model can be seen in Shampa (2019).

The model solves two-dimensional depth-averaged shallow water equations (derived from Navier-Stokes' equations) for incompressible free surface flow using Boussinesq approximations in the hydrodynamic section.

The continuity equation was used to determine mass conservation. (S1)

$$\frac{\partial \mathrm{h}}{\partial \mathrm{t}}+\frac{\partial(\mathrm{hu})}{\partial \mathrm{x}}+\frac{\partial(\mathrm{hv})}{\partial \mathrm{y}}=0 \tag{S1}$$

In the x-direction, conservation of momentum is shown by Equation (S2)

$$\frac{\partial u}{\partial t}+u\frac{\partial u}{\partial x}+v\frac{\partial u}{\partial y}+g\frac{\partial \zeta}{\partial x}+\frac{gn^2}{\sqrt[3]{h}}\left(\frac{u(u^2+v^2)}{h}\right)-v_h\left(\frac{\partial^2 u}{\partial x^2}+\frac{\partial^2 u}{\partial y^2}\right)=0 \tag{S2}$$

In the y-direction, conservation of momentum is shown by Equation (S3)

$$\frac{\partial v}{\partial t}+u\frac{\partial v}{\partial x}+v\frac{\partial v}{\partial x}+g\frac{\partial \zeta}{\partial x}+\frac{gn^2}{\sqrt[3]{h}}\left(\frac{v\,(u^2+v^2)}{h}\right)-v_h\left(\frac{\partial^2 v}{\partial x^2}+\frac{\partial^2 v}{\partial y^2}\right)=0 \tag{S3}$$

Where ζ is the elevation of the water level in relation to a datum (here in meters); h represents water depth (m); g is the acceleration due to gravity (m/s^2); u, v is depth average velocity in the x and y directions, respectively (m/s); $v_h$denotes kinetic eddy viscosity (m^2/s); n represents the Manning's coefficient (sm$^{-1/3}$).

The sediment transport (advection-diffusion equation) is calculated by Equation (S4)

$$\frac{\partial(hc)}{\partial t}+\frac{\partial(huc)}{\partial x}+\frac{\partial(hvc)}{\partial y}=h\left[\frac{\partial}{\partial x}\left(D_H\frac{\partial c}{\partial x}\right)+\frac{\partial}{\partial y}\left(D_H\frac{\partial c}{\partial y}\right)\right]+hS \tag{S4}$$

Here, c represents the mass sediment concentration (kg/m^3), and D_H denotes the horizontal diffusivity. S is sediment the source terms per unit area. The turbulent kinetic energy is denoted by k and the dissipation is presented by ε. $k-\varepsilon$ turbulence model was used for turbulence closure.

Reference [76] estimated the sediment load of the Brahmaputra-Jamuna using several sediment formulas and concluded that [77] predicts the sediment load well. Therefore, for the numerical model [77] was used to calculate the bedload transport.

The bedload transport rate $|\bar{S}_{bed}|$ was computed by Equation S5.

$$|\bar{S}_{bed}|=\begin{cases}0.053\sqrt{(s-1)gd_{50}^3}D_*^{-0.3}\left(\frac{\mu_c\tau-\tau_c}{\tau_c}\right)^{2.1} & if\ \left(\frac{\mu_c\tau-\tau_c}{\tau_c}\right)<3.0\\ 0.1\sqrt{(s-1)gd_{50}^3}D_*^{-0.3}\left(\frac{\mu_c\tau-\tau_c}{\tau_c}\right)^{1.5} & if\ \left(\frac{\mu_c\tau-\tau_c}{\tau_c}\right)\geq 3.0\end{cases} \tag{S5}$$

Where s is the relative density of sediment particle $\left(\frac{\rho_s}{\rho_f}\right)$, ρ_s and ρ_f denotes the density of sediment and fluid respectively, d_{50} identifies the particle size; τ and τ_c are the terms for bed shear stress and critical bed shear stress, respectively. μ_c is the proportion of overall bed roughness to grain-related bed roughness. Dimensionless particle parameter is denoted by D_*. The mass-balance equation [78] can be used to compute the bed elevation using Equation (S6) considering a size fraction of k in a mixed sediment transport

$$(1-\lambda)\frac{\partial \eta_{bk}}{\partial t}+m_f\left(\frac{\partial q_{uk}}{\partial x}+\frac{\partial q_{vk}}{\partial y}\right)+m_f(E_k-D_k) \tag{S6}$$

Here, λ is porosity,q_{uk}, q_{vk} is bedload transport vector considering the size fraction k, η_{bk} is the bed change due to size fraction k; for the size fraction k; E_k, D_k are upward and downward suspended sediment transport flux near the bed; To adapt the morphology the morphological acceleration factor m_f is used. The morphological developments occur over a time scale several times longer than usual flow variations. Utilizing a m_f is one method of solving this issue, in which the morphology is changing is scaled up until it starts to significantly affect the hydrodynamic flows [79]. At each computational time step, the morphological time scale factor is implemented by merely multiplying the fluxes of erosion and deposition from the bed to the flow and vice versa by the m_f. This enables the hydrodynamic flow calculations to dynamically account for faster bed-level variations.The summation of the bed variations, $\delta\eta_b$ in one-time step is calculated by using Equation S7.

$$\delta\eta_b = \sum_{k=1}^{M} \delta\eta_{bk} \tag{S7}$$

Here M is the total size fractions here considered as 1.

Roelvink et al. [80] method has been implemented for calculating the erosion of adjacent dry cells near the bank or bar. If the maximum fraction of erosion to reallocate the edge from the wet cells to surrounding dry cell(s) is $\theta_{dc,thr}$ and h_{dcmax} is the water depth in the wet cell at which the full $\theta_{dc,thr}$ will be reallocated, the actual fraction of erosion in an edge, θ_{dc} can be expressed as

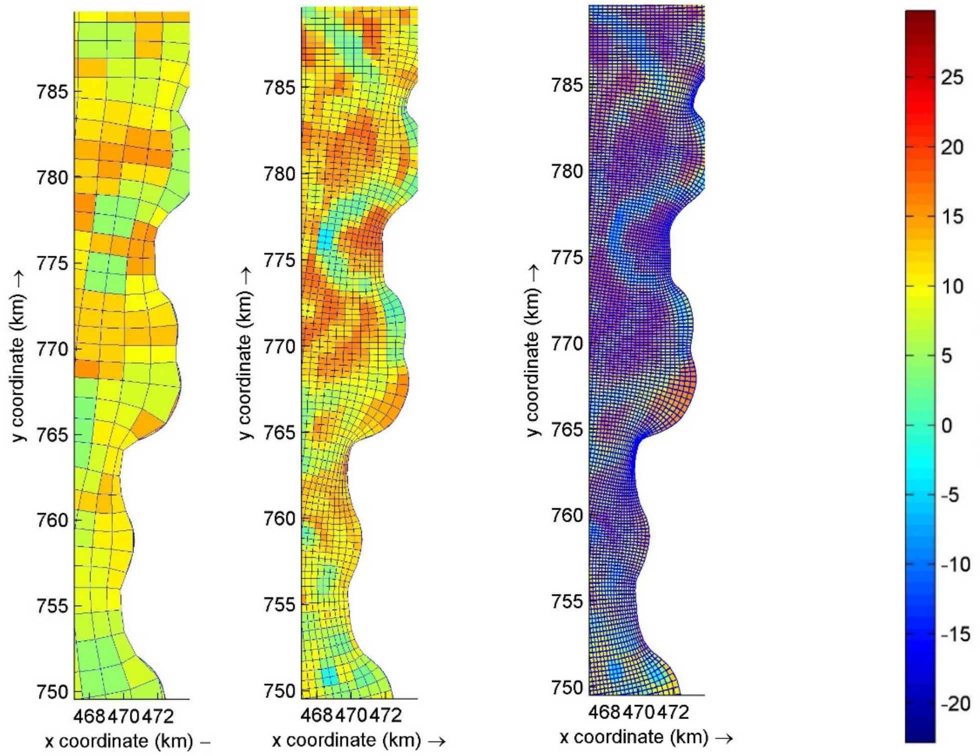
$$\theta_{dc} = min\left(\frac{h - h_{dc,thr}}{h_{dcmax} - h_{dc,thr}}, 1\right)\theta_{dc,thr} \tag{S8}$$

Where, $h_{dc,thr}$ is the minimum threshold flow depth for reallocating the erosion in a dry cell.

S1.2.1 The schematization of the Hydromorphic model

For the numerical model, a 225-km long curvilinear grid was constructed with an average width of 13 km, starting from almost 10 km downstream of the water level measuring station at Noonkhawa and ending near the water level measuring station at Aricha, as shown in Figure 4. Grid cells of 1117 × 73 were used to discretize the reach. Because the bar sizes varied from 549 × 205 m^2 to 28,635 × 10,475 m^2 within reach of the Brahmaputra-Jamuna River, this grid resolution was chosen to cover every bar by at least two grid cells Orthogonal curvilinear grid was generated in Cartesian coordinates systems where the average grid cell size was 201 × 178 m^2. As the 'existing state,' we used interpolated river bathymetry (using the triangular interpolation method on the measured cross-section data of BWDB) from the year 2020 and SRTM topography data (where necessary). The boundary discharge and water level can be seen in Sec 4.

Grid convergency was tested considering the one coarse grid for which the average grid size was 603 × 534 m^2 and one finer grid of 100 × 89 m^2 resolution (shown in Figure S4). The convergency was tested against two measured parameters discharge and water level for the measured discharge and water level of the year 2011. For the discharge (at Bahadurabad) correlation, all the grid shows good correlation (coefficient of determination, r^2 values was 0.99) whereas for the water level correlation (at Mathura) the model grid shows better r^2 (0.99) whereas the other grid shows 0.98 (0.9805 for the course grid and 0.9857 for the finer one) slightly lower value of that.



603 × 534 m² | 201 × 178 m² | 100 × 89 m² | Initial bed level in mPWD

Figure S4. The grids used for the convergency test. The average grid size of the curvilinear grid is shown below the grids.

S1.2.2 Hydromorphic Model Validation

The hydromorphic model was validated for the year 2011. Water level calibration was carried out at four locations: Chilmari, Kazipur, Sirajganj, and Mathura, while discharge and sediment calibration were carried out solely at the Bahadurabad station. (Locations are shown in Figure 1). Figure S5 a and b show the model-simulated and observed discharge and water levels at Bahadurabad and Mathura, respectively. Due to a lack of current data, the sediment calibration was done using a data set of sediment measured by the Bangladesh Water Development Board (BWDB) (at Bahadurabad Figure 1) and the Flood Action Plan-24 (FAP-24) research from 1968 to 2001 as shown in Figure S 5c. Here, the coefficient of determination, r^2 values vary between 0.99 to 0.94, which is quite satisfactory for the hydrodynamic model [81]. A comparison of inundation derived from simulation and Synthetic Aperture Radar (SAR) images of the recent flood (of the year 2020) is shown in Figure S6. This figure indicates that during mid-July 2020 76.7% char area was inundated, whereas the simulation result shows 77.7% area was inundated. The percentage of error was 1.3%.

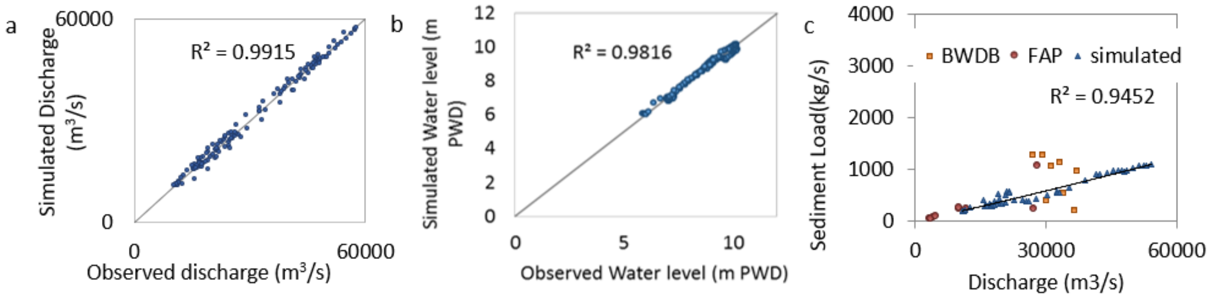


Figure S5. Validation of the model for the hydraulic condition of the year 2011 a) Comparison between simulated and observed discharge at Bahadurabad b) Comparison between simulated and observed water level at Mathura (c) Comparison between simulated and observed (Bangladesh Water Development Board (BWDB) and Flood Action Plan (FAP)) sediment load at Bahadurabad (adopted from Shampa.

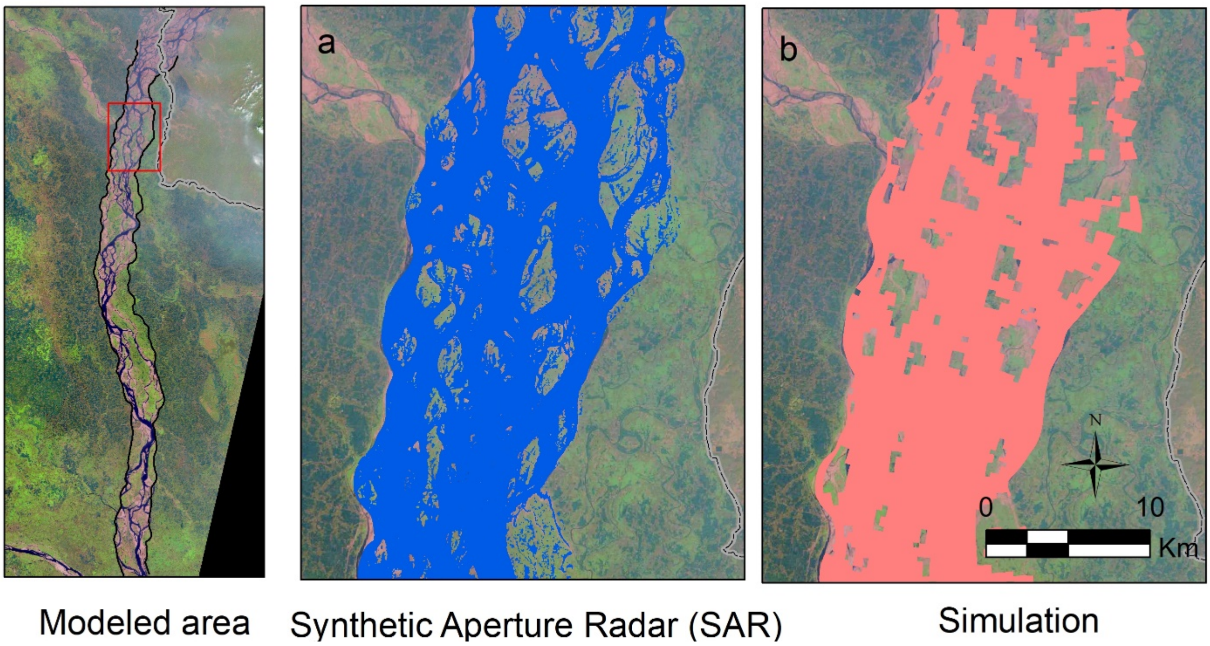


Figure S6. Comparison of char inundation derived from simulated and Synthetic Aperture Radar (SAR) images: black lines show the considered area and the red box indicate the zoomed area shown in sub-figure a and b. sub-figure a) Inundation derived from SAR image July 13, 2020 shown by blue lines sub-figure b) Inundation derived from simulation July 13, 2020 shown by red lines.

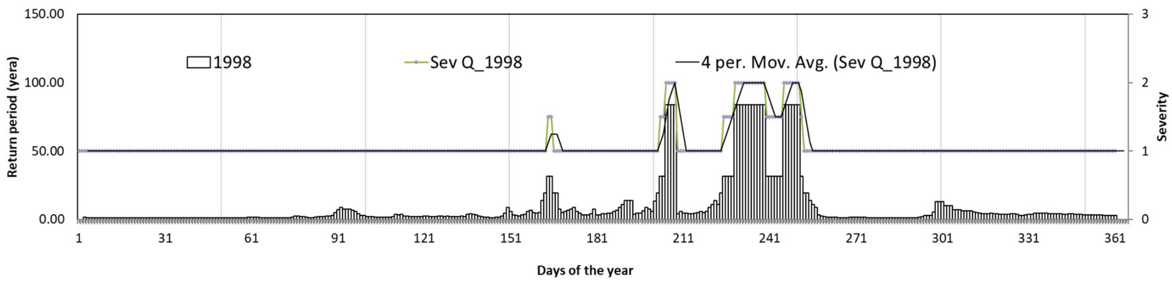


Figure S7. Return period and severity of observed extreme event-1998 hydrograph.