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A scenario of blockage of water tunnel that protects Batna city from flooding, Algeria

Tout F., Gachi A. **Scenariusz zablokowania tunelu wodnego chroniącego miasto Batna przed powodziami (Algieria).** Niniejsze opracowanie ma na celu modelowanie scenariusza powodzi miejskiej wynikającej z zablokowania tunelu wodnego (WT) chroniącego miasto Batna, w północno-wschodniej Algierii. Wykorzystano systemy informacji geograficznej (ARC GIS i Hec-Ras2D) oraz zmodyfikowano DEM (cyfrowy model wysokości), aby uwzględnić najnowsze zmiany w sieci hydrograficznej. Najwyższa wartość przepływu – 370 m³/s, który WT może przyjąć, została wykorzystana do stworzenia hydrogramu powodziowego zgodnie z powszechnie stosowanymi metodami matematycznymi i empirycznymi (czas koncentracji metodą Giandottiego i hydrogram przepływu metodą Sokołowskiego), mimo że stworzenie modelu symulującego rzeczywistość w obszarze miejskim wymaga dużej liczby danych ilościowych i jakościowych. Opracowanie ma na celu przypomnienie znaczenia WT dla miasta i poparcie dla podjęcia przez władze decyzji o dalszej ochronie jego funkcji, ponieważ około 7,4 km² miasta zostanie dotknięte powodzią w takim scenariuszu blokady. Ponieważ WT jest uważany za ujście zlewni o powierzchni 163 km², a także jego wejście znajduje się w niebezpiecznym miejscu, to tunel ten jest jedynym środkiem ochrony wielofunkcyjnego centrum miasta przed dużymi przepływami. Dlatego wymaga on okresowej konserwacji i czyszczenia, uświadamiania mieszkańcom jego znaczenia oraz pełnej kontroli jego wszystkich funkcji.

Тоут Ф., Гахи А. **Сценарий блокировки водного туннеля, защищающего город Батна от наводнений (Алжир)**. Данное исследование направлено на моделирование сценария городского наводнения в результате блокировки водного туннеля (ВТ), который защищает город Батна на северо-востоке Алжира. Были использованы географические информационные системы (ARCGIS и Hec-Ras2D), а также была модифицирована цифровая модель рельефа (DEM), чтобы принять во внимание новейшие изменения гидрографической сети. Наибольшее значение потока (370 м³/с), который ВТ может поглотить, было использовано для создания гидрограммы наводнения в соответствии с общими математическими и эмпирическими методами (время концентрации по методу Джандотти и гидрограмма стока по методу Соколовского), хотя достижение моделирования, которое имитирует реальность в городской зоне, требует большого количества количественных и качественных данных. исследование призвано напомнить о важности ВТ для города и поддержать принятие решения властями для дальнейшей защиты его функции, потому что приблизительно 7.4 км² города будут затронуты наводнениями при таком сценарии блокирования. Поскольку ВТ считается устьем дренажного бассейна площадью 163 км², а также его вход расположен в опасном месте, этот ВТ является единственным средством защиты многофункционального центра города от больших потоков. Поэтому он требует периодического обслуживания и очистки, повышения осведомленности граждан о его важности, а также полного контроля над его функцией и водока-налов, в которые он поступает.

Tout F., Gachi A**. synariw insidad nafaq miah yahmi madinat Batna min alfayadanat – Aljazayir**. hadhih aldirasat tahdif ila namdhajat zahirat alfayadan fi almintaqa alhadariat natijat sinariw insidad nafaq miyah yahmi madinat batna alwaqiea shamal sharq aljazayir, ayn tama istighlal nuzm almaelumat aljughrafia (ARC GIS w Hec-Ras 2D) w namudhaj irtifaat raqmiat DEM tama tadiluh liahtawi shabakat qanawat almayiyat alati tama ainshaouha, kama tama istighlal aala qimat liltadafuq yumkin an yastaweibha nafaq almiyah wahia 370 m^3/s l'iinsha haydrughraf alfayadan hasab turuq riadia w tajribia shayiea (zman altarkiz hasb tariqat Giandotti w haydrughraf alfayadan hasb tariqat Sokolovsky), waraghm an alhusol aala namdhaja tuhaki alwaqia fi almintaqat alhadariat yatatalab alhusul alaa kamiyat kabira min albayanat alkamiya w alnaweia, aldirasat ja'at min ajil altadhkir bi'ahamiyat alqanaat bialnisbat lilmadina kama tahdif ila daem aitikhadh qarar min taraf asulutat lihimaya akbar liwazifat alqanaat liana ma yuqarib 7.4 KM^{2}min almadina sawf tataathar bialfayadanat fi halat huduth hadha alsiynariw hayth tutabar alqanaat masban lihawd sarf bimisahat 163KM^2 wayaqa madkhaluha fi mawqie khatir w tumathil alwasila alwahidat lihimayat markaz almadinat mutaadid alwazayif min tadafuqat kabira w min dhalik fa'iinaha tastawjib alsiyana w altanzif aldawriayyn w taweiat almuatinin bi'ahamiyatiha w alraqaba alkamila aala wazifatiha w alqanawat alwasilat ilyha.

سيناريو انسداد نفقمياه يحمي مدينة باتنة من الفيضانات –الجزائر

هذه الدراسة تهدف الى نمذجة ظاهرة الفيضان في المنطقة الحضرية ناتجة عن سيناريو انسداد نفق مائي يحمي مدينة باتنة الواقعة شمال شرق الجزائر، اين تم استغلال نظم المعلومات الجغرافية (ARCGIS و Hec-Ras 2D) و نموذج ارتفاعات رقمية DEM تم تعديله ليحتوي شبكة القنوات المائية التي تم انشائها، كما تم استغلال اعلى قيمة للتدفق يمكن ان يستوعبها النفق المائي وهي 370متر مكعب /ثانية لإنشاء هيدروغراف الفيضان حسب طرق رياضية و تجريبية شائعة(زمن التركيز حسب طريقة Giandottiو هيدروغراف الفيضان حسب طريقة Sokolovsky)، ورغم ان الوصول الى نمذجة تحاكي الواقع في المنطقة الحضرية يتطلب الحصول على كمية كبيرة من البيانات الكمية و النوعية، الدراسة جاءت من اجل التذكير بأهمية القناة بالنسبة للمدينة كما تهدف الى دعم اتخاذ قرار من طرف السلطات لحماية أكبر لوظيفة القناة لأن ما يقارب 7.4 كم^2 من المدينة سوف تتأثر بالفيضانات في حالة حدوث هذا السيناريو حيث تعتبر القناة مصبا لحوض صرف بمساحة 163كم^{2}ويقع مدخلها في موقع خطير و تمثل الوسيلة الوحيدة لحماية مركز المدينة متعدد الوظائف من تدفقات كبيرة و من ذلك فإنها تستوجب الصيانة و التنظيف الدوريين و توعية المواطنين بأهميتها و الرقابة الكاملة على و وظيفتها و القنوات الواصلة اليها.

Key words: urban vulnerability, flood, water channel, hydrographic network, Geographic Information Systems (GIS), Hec-Ras 2D, city, DEM, watershed, hydraulic modelling

Słowa kluczowe: podatność miast na zagrożenia, powódź, kanał wodny, sieć hydrograficzna, Systemy Informacji Geograficznej (GIS), Hec-Ras 2D, miasto, DEM, dział wodny, modelowanie hydrauliczne

Ключевые слова: уязвимость городов, наводнение, водный канал, гидрографическая сеть, Географические информационные системы (ГИС), Hec-Ras 2D, город, DEM, водораздел, гидравлическое моделирование

alkalimat almiftahia: hashasha hadaria, Fayadan, qnat miah, shabakat haydrughrafia, haydrughraf fayadan, nuzm malumat jughrafia, Hec-Ras2D, mdina, DEM, hud sarf, nmdhajat haydrulikia, ARC GIS

الكلمات المفتاحية:هشاشة حضرية.فيضان. قناةمياه. شبكةهيدروغرافية. هيدروغراف فيضان. نظم معلومات جغرافية. Hec-Ras.2D. مدينة.DEM. حوضصرف.نمذجة هيدروليكية. ARC GIS

Abstract

This study aims to model a scenario of an urban flood resulting from a water tunnel (WT) blockage, a tunnel which protects the city of Batna, in northeastern Algeria, where geographic information systems have been used (ARCGIS and Hec-Ras2D) and a DEM (digital elevation model) was modified to contain the new changes in the hydrographic network, the highest flow value that the (WT) could absorb 370 m^3/s was used to create the flood hydrograph according to common mathematical and empirical methods (concentration-time by Giandotti method and flow hydrograph by Sokolovsky method), even though reaching modelling that simulates the reality in the urban area requires a large amount of quantitative and qualitative data, the study is intended to remind of the importance of the (WT) for the city and to support making a decision by the authorities to further protect its function, because approximately 7.4 km^2 of the city will be affected

by the floods in such a blockage scenario as the (WT) is considered to be an estuary of a drainage basin with an area of 163 km^2 and also its entrance is located in a dangerous place, this (WT) is the only means to protect the multi-functional city centre from large flows. Therefore, it requires periodic maintenance and cleaning, awareness-raising among citizens of its importance, and full control of its function and the water channels to which it comes.

Introduction

In recent decades, in the context of climate change, much attention has been paid to protecting cities from flood hazards, since the last is directly linked to the effects of climate on the hydrological cycle, especially in terms of rainfall intensity and frequency (ONGDAS et al., 2020). As a result, the phenomenon of flooding has become frequent in many cities (DEVI, SRIDHARAN, KUIRY, 2019) and many countries in the world suffer from its social, economic and environmental consequences. For example, in Algeria, the phenomenon of catastrophic floods has become more frequent every year (HARKAT, CHAOUCHE, BENCHERIF, 2020), especially since the infrastructure of most cities does not support good rainwater drainage, because the drainage system is not prepared to absorb big water flows, and urbanization at the expense of agricultural lands increases the values of expected flows (ZAFAR, ZAIDI, 2016). For example, the city of Batna experienced remarcable urbanization, especially with the end of the 1980s, and this urbanization, which many factors can be said to have contributed to it, has brought many problems to the city managers (DRIDI, BENDIB, KALLA, 2015). The authorities were unable to keep up with the high demand for housing (DJAFRI et al., 2019) in addition to the delay in the legal framing of the construction process, which contributed significantly to the proliferation of chaotic buildings that were not subject to any technical conditions for construction, or to the general rules for construction or the organizational plans for reconstruction. Large occupied areas of the city's perimeter were agricultural land, and there were entire neighbourhoods located near the natural paths of rivers, this form of unplanned construction can make them exceptionally vulnerable in future for flash floods (ERTAN, ÇELIK, 2021) and to remedy the situation and protect the new neighbourhoods local authorities have built channels to protect the city's periphery, the most important of which is the water channel (1G). On the eastern side of the city, which drains the water coming from the subwatersheds of Tazoult and Ali Ben Tennon, which became the meeting point of their discharge near the entrance of the water tunnel (Phot. 1), which has thus become the most important part of the hydrographic network, taking the highest stream order value in the watershed according to STRAHLER (1957) classification for the total watershed, Al Madher river, whose area is estimated at 310.72 km^2.

Photo 1. Water tunnel entrance (phot. by F. Tout, 2021)
Fot. 1. Wejście do tunelu wodnego (fot. F. Tout, 2021)
Фот. 1. Вход в водный туннель (фот. F. Tout, 2021)

This new classification of the hydrographic network in the Al Madher river watershed is a result of the imposition of the network of channels that are made for the protection of the city on the digital elevation model. The low 30 m accuracy cannot capture the actual rivers and waterways that make up the network (FAROOQ, SHAFIQUE, SHAHZAD, 2019). This highlighted the importance of this water tunnel (WT) Compare with the al Gourzi river (GZ), which has been the focus of several previous studies on the subject.

The development of flood simulator scenarios on Batna is a potentially supportive means of decision-making (GUELLOUH, DRIDI, KALLA, 2016). And this tunnel's blockage scenario might come true as the pollution by solid waste increases at the channel level (1G). In the absence of the necessary periodic maintenance, cleaning and control of the operation of this channel, the potential failure of this tunnel will put a lot to the test because of its location, the elevation of its entry point regarding the city and, in particular to its centre, which can be considered an administrative and economic and a residential location, and the headquarters of many other urban facilities, including health and security, the ideal combination of such an event may not be expected because many factors interfere and history has shown that hydrological accidents cannot be accurately predicted and that human prevention arrangements are designed to give them a greater sense of security than to protect cities.

In this research, we are more interested in identifying areas at risk of flooding if the tunnel is blocked through hydrological and hydraulic modelling, which is central to prevention and protection (ANNIS et al., 2020), referring to some of the actions that must be taken to avoid blockage as it represents the only factor preventing a social, economic and environmental disaster in the city, since the action taken to protect part of the city may turn the problem from one part to another, but doubly, with the construction of this channel, a new basin has been created, consisting of two important basins, relatively close morphometric properties and big slopes and a geology that supports the formation of surface runoff in a significant area of the two basins and a lack of vegetation cover (SLIMANI, KALLA, 2017) and its absence in the low basin levels adjacent to large drainage density areas, in addition, the length of the longest water paths is similar for the two basins that make up the new basin, and therefore the hypothesis that they have a convergent concentration-time is likely.

The concentration-time is the time it takes for water to reach from the farthest point in the drainage basin to the point under investigation (SALIMI et al., 2016), and it can also be described as the difference in time between the onset of effective precipitation and the greatest value of the resulting flow (GERICKE, SMITHERS, 2014). It is one of the most important elements for creating modelling of flood forecast in the Hec-Ras environment (GUELLOUH, DRIDI, KALLA, 2020) as it is included in the formation of the flood hydrograph curve.

Study area

The city of Batna is located in eastern Algeria (Fig. 1), with a population of more than 400 thousand people. According to the Agency of the Hydrographic watersheds, the city belongs to the subwatershed 07-03, which represents part of the watershed of the Constantine highlands. It has a semi-arid climate and it is located within a special topographic area, because it is surroundded by many mountains like Ich Ali, Boumerzoug, Kessrou and Azzab (HARKAT, CHAOUCHE, BENCHERIF, 2020), and it is considered a natural estuary for many dry rivers, and it is threatened by flooding at increasing levels with the change in the climatic situation. The city does not have any Low Impact Development LID measures, the Water Tunnel (WT) is with a length of 2621 meters and a diameter of 8 meters and it is designed to fit for a period of return of 100 years, the (WT) was proposed in 1984 by the Swedish study office Scandia consult. The tunnel is designed to accommodate water that comes from the subwatersheds Tazoult and Ali Ben Tennon which represent a new watershed with 163.34 km^2. Its main flow path is with 18.16 km south-north, and the most important drainage point that our study is concerned with is located the end of this stream, which is the entrance to the water tunnel, which flows into al Gourzi river, which in turn flows into Al Madher river.

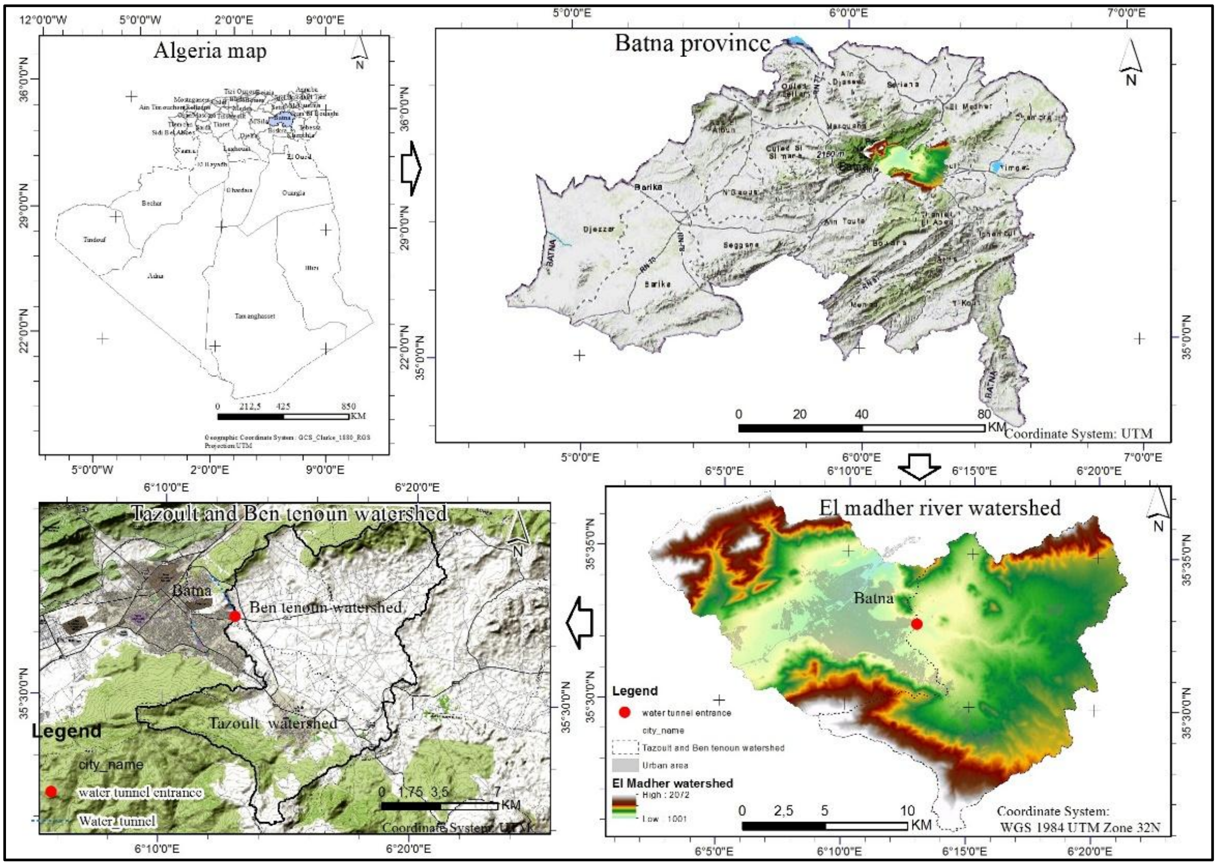

Fig 1. The location of the drainage basin of Ali Ben Tennon and Tazoult
Rys. 1. Położenie zlewni Ali Ben Tennon i Tazoult
Рис. 1. Расположение водосборного бассейна Али Бен Теннон и Тазулт

Methodology

Using geographic information systems (GIS) in Arcmap for graphic processing of a 4.77-meter precision digital elevation model in preparation for a relatively acceptable hydraulic modelling environment, using the Hec-Ras tool that is commonly used for flood modelling (COHEN et al., 2018) by using the tunnel's maximum flow value of 370 m^3/s, which could be considered a basis for hydraulic modelling (MOKHTAR et al., 2018) issued by the Batna Directorate of Water Resources (Algeria), and a concentration-time using the Experimental method of Giandotti commonly used (MANFREDA et al., 2020). As well as some of the results of the topographic study needed to run the model, we wanted to provide an idea of the consequences of the blockage of this water tunnel on Batna City and its centre in particular. This comes at a time when the status of the means of protection is deteriorating, is mainly represented in an iron fence placed directly at the entrance, which cannot be completely relied upon to protect the tunnel from being blocked by waste and inactive rubble, which is a normal sight at the level of the channel (1G) (Phot. 2) that flows into the tunnel (WT). The research did not address the geological situation, soil characteristics, temperature data, evaporation or wind, since the entire area concerned with inundation is located within the urban area with little permeability and almost zero green spaces. The effect of the old, low-flowing sewers placed on the edges of the roads most of which clogged are also ignored.

Photo 2. (1G) water channel (phot. by F. Tout, 2021)
Fot. 2. (1G) kanał wodny (fot. F. Tout, 2021)
Фот. 2. (1G) водный канал (фот. F. Tout, 2021)

Obtaining an acceptable flood simulation depends largely on the accuracy of the topographic data (OGANIA et al., 2019). The extent of the flood is related to the accuracy of the DEM (AZIZIAN, BROCCA, 2019). Accordingly, the digital elevation model for our study was prepared from small models that were downloaded. From the link, LAND VIEWER to reach an accuracy of 4.77 meters, and it was confirmed that it could give acceptable results through field check and ARC GIS IMAGERY images, as using the resulting digital elevation model and using the Arc hydro tools tool pack, in a high percentage the actual basin was determined as stated in the study of BELLA, DRIDI, KALLA (2020). In contrast to the use of digital elevation models with an accuracy of 30 meters, where parts are ignored and parts with large areas are added in a way that can affect the hydrological study significantly.

The graphical treatment of the resulting DEM was carried out using DEM Reconditioning and Level DEM after changing the DEM accuracy to 1 meter to allow us to impose the hydrographic network that includes the new water channels and the water tunnel as an open channel, the Park Aforage (PA) water divider basin (Phot. 3) with a capacity of 80000 m^3 and the covered channels of the Belt Channel (BC) (Phot. 4) and the thalweg channel (TC) as open water channels that drain 60% and 40% of the water of the (PA) respectively (BELLA, 2006) in order for us to obtain results with higher accuracy, and this was done after ensuring the direction of water flow and the acceptable slope. Fig. 2 illustrates the hydrographic network after imposing the network on the DEM, although access to the ideal accuracy for built channels on the DEM is not currently available at the technical level, as it requires high-efficiency computers, and it is also linked to the original accuracy of the DEM but the use of the two tools can contribute to giving better results.

Photo 3. Water divider basin (phot. by F. Tout, 2021)
Fot. 3. Zlewnia z rozdzielaczem wody (fot. F. Tout, 2021)
Фот. 3. Водораздельный бассейн (фот.: F. Tout, 2021)

Photo 4. (BC) Water channel entrance (phot. by F. Tout, 2021)
Fot. 4. (BC) Wejście do kanału wodnego (fot. F. Tout, 2021)
Фот. 4. (BC) Вход в водный канал (фот.: F. Tout, 2021)

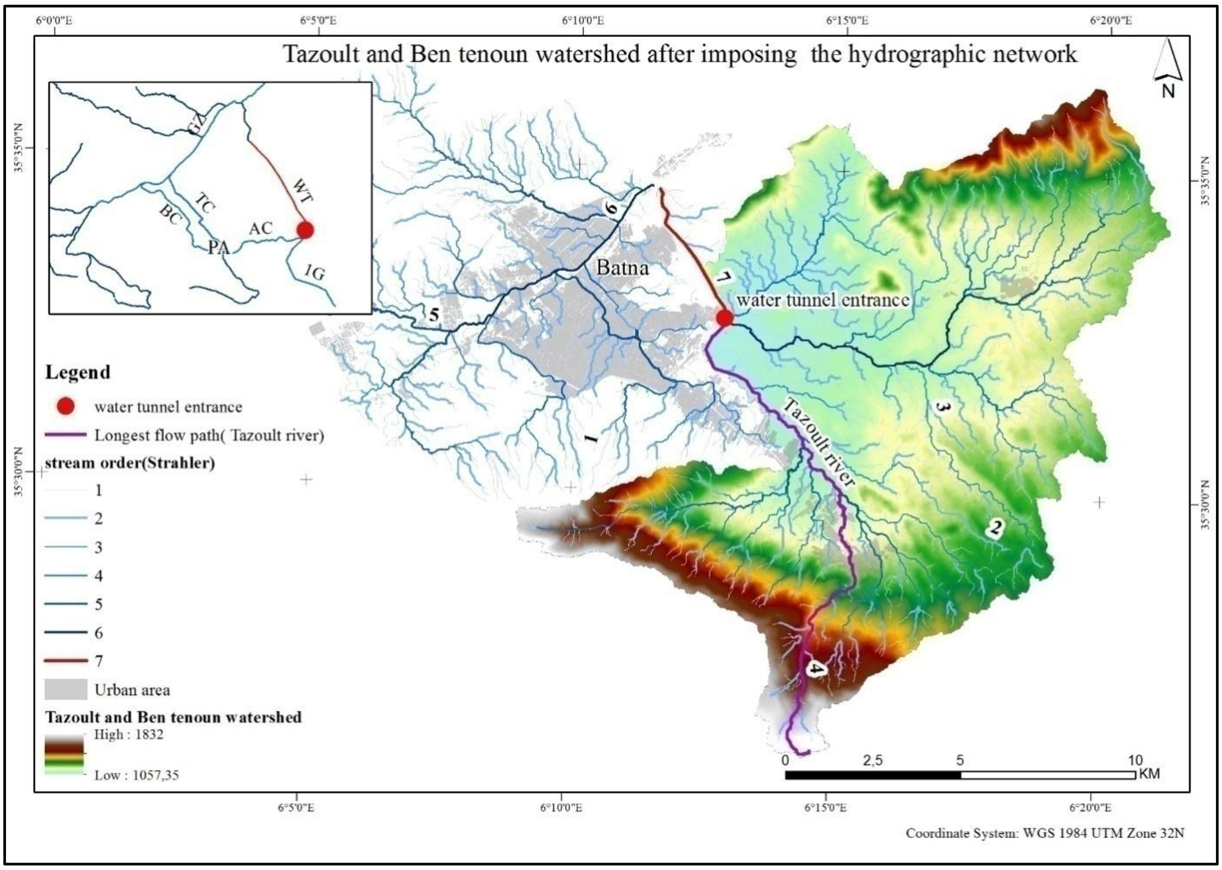

Fig. 2. Tazoult and Ali Ben Tennon watershed
Rys. 2. Dział wodny między Tazoulti i Ali Ben Tennon
Рис. 2. Водораздел Тазульти и Али Бен Теннон

The concentration-time according to GIANDOTTI (1934) is given by the following formula:

$$t_c = \frac{4\sqrt{A}+1.5L}{0.8\sqrt{H_{mean}-H_{\min}}}$$

where: (t_c) is the concentration-time in hours and (A) in (km^2) is the area of the basin and L in (km) is the length of the mainstream of the basin, (H_{mean}) and (H_{min}) in(m) are, respectively, the average altitude of the basin and the smallest altitude of basin. This formula has been calibrated in 12 drainage basins of different sizes (GRIMALDI et al., 2012).

Below is the data that was used to obtain the concentration-time:

(A)km^2	L(km)	H_{mean}(m)	H_{min} (m)	t_c (h)
163.34	18.16	1241.89	1060	7.26

Flood Hydrograph

Based on the maximum flow value that the tunnel can absorb and the computed concentration-time, we calculated the flood hydrograph by the SOKOLOVSKY (1959) method. The flood hydrograph curve can be found by employing two equations, one to climb to the maximum flow value and another for the descend as follows (VOSKRESENSKY, 1969):

$$Q_x = Q_M \left(\frac{x}{t_1} \right)^2 m^3 / \sec$$

$$Q_z = Q_M \left(\frac{t_3 - z}{t_2} \right)^2 m^3 / \sec$$

Where's:

Qx: Instant flow during ascent from the beginning of the flood (m^3/s)

Qz: Instant flow during descent from peak flood (m^3/s)

QM: Maximum flow value of flood 370 (m^3/s)

t1: rise time (h) where $t1 = t_c = 7.26$ h.

t2: time of fall (h). t2 = t1 * where (= 2.5)

t3: base time (h). Where t3 = t1 + t2

In this research, we used HEC-RAS2D developed by the U.S. Army Corps of Engineers Center, which is a widely used model (VOJTEK et al., 2019), and the use of 2D is better than 1D to estimate flood wave dynamics and represent channel capacity overruns (MORSY et al., 2018; ONGDAS et al., 2020) for modelling we used the resulting flood hydrograph data (Fig. 3) and the 2D Flow area Data (Fig. 4) which is related to the DEM prepared, and those are simple model production requirements (ASHOK, UMAMAHESH, 2019). And starting with HEC-RAS 6.1 it has become possible to dispense with HEC-geoRAS, the tool that comes as an attachment to the program ARCGIS, where the new 6.1 version within the RAS MAPER window allows for the preparation of the engineering elements needed to run both the1D and 2D models. Although flood modelling in urban areas can be highly complex, as there are many elements to be taken into account, such as buildings (BERETTA et al., 2018), which can affect the flood profile, which depends on the type and quantity of input used to run the model, but this does not prevent getting a map of the flood extension in the area as the use of HEC-RAS2D can produce reasonable results (PAPAIOANNOU et al., 2018) because it has a great ability to determine boundaries, depths and flood velocity (ABDEL-KARIM et al., 2019).

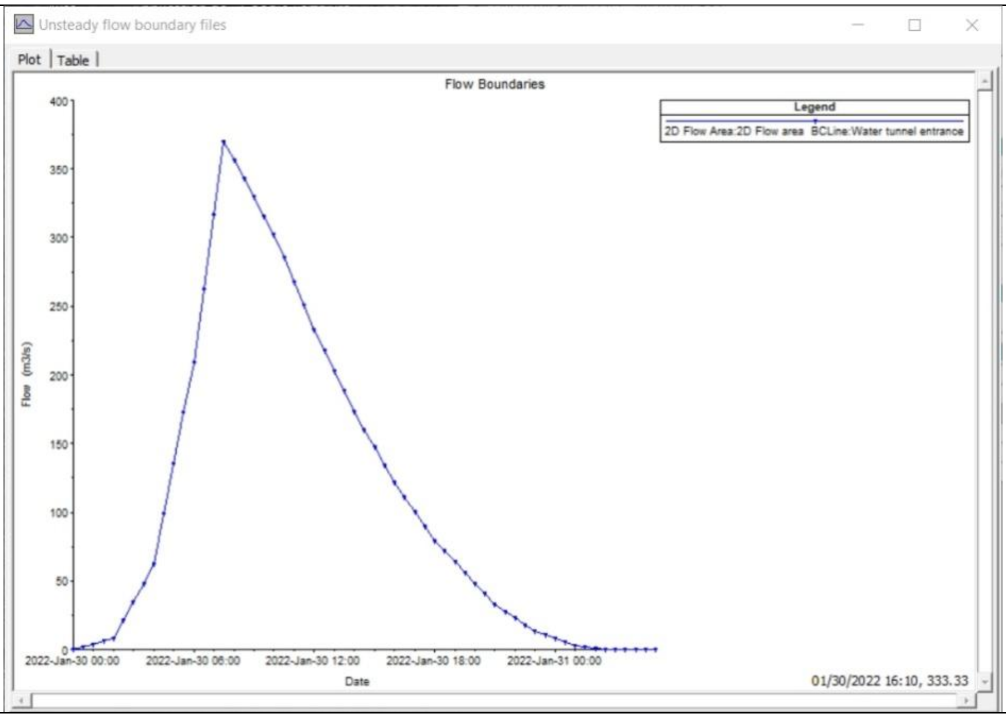

Fig. 3. Flow hydrograph

Rys. 3. Hydrogram przepływu

Рис. 3. Гидрограмма потока

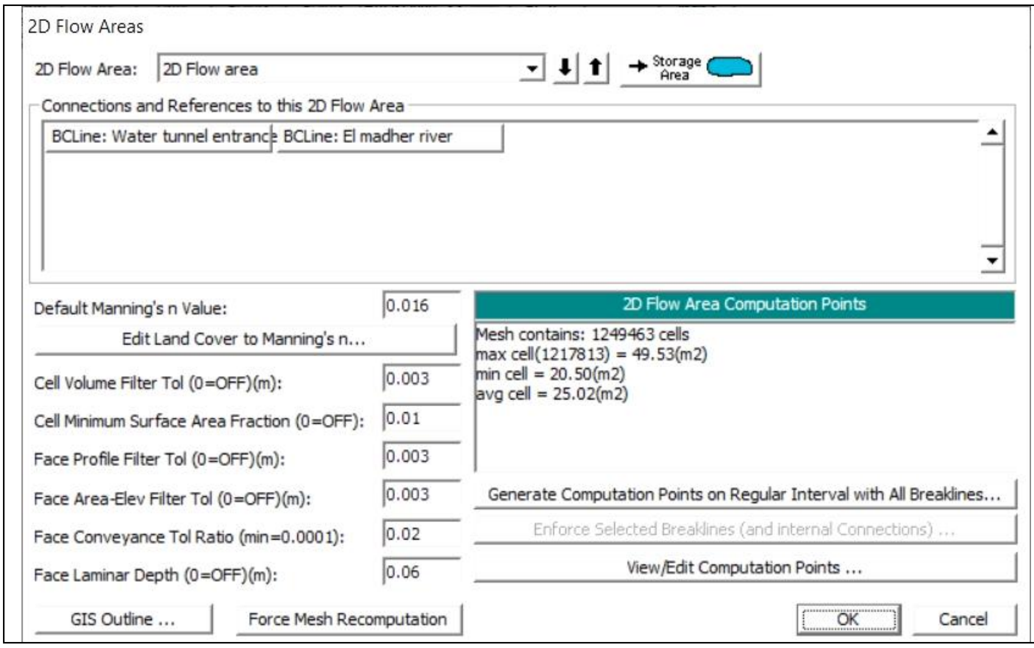

Fig.4. 2D Flow area data
Rys. 4. Dane obszaru przepływu 2D
Рис. 4. 2D Данные по площади потока

Results and discussion

Using geographic information systems (GIS) to describe flood and flow characteristics has become necessary (GUELLOUH, DRIDI, KALLA, 2016). In our study the employment of GIS showed the potential vulnerability of the city to the risk of water tunnel blockages (WT). As approximately 7.4 km^2 of the city centre is at risk from torrential rain, the most fragile areas at high speeds of flows are those adjacent to the covered channels the belt channel (BC) and thalweg channel (TC) as well as areas adjacent to the Park Afforage water divider basin (PA).

The results of the study do not fully support the findings of BELLA (2006), GUELLOUH, DRIDI, KALLA (2016), HARKAT, CHAOUCHE, BENCHERIF (2020). These studies took al Gourzi river as the most important flow path in the Al Madher watershed. In this study, the water tunnel (WT) was found to be of greater importance than the al Gourzi river (GZ) being in the seventh order (STRAHLER, 1957) which is the highest value in the basin. After the channel was created, it became a drainage path for both the Tazoult watershed and the Ali Ben Tennon and the imposition of the new channels network on DEM allowed these findings to be reached in our study.

The wide extension of the wetted area of the city (Fig. 5 and 6) is due to the flatness of the downtown area, and in the case a similar scenario, the topography will not be a helpful factor in reducing the extent of the damage, as the area is considered as an estuary and a passage for several other rivers (GUELLOUH, DRIDI, KALLA, 2016) that may further complicate the problem, especially if this was coupled with large flows in al Gourzi river resulting from the western subwatersheds which they are the Hamla and Saqn.

Azzeb channel (AC) (Phot. 5), The (BC) channel (29 m^3/s), the (TC) channel (35 m^3/s) and the water divider basin Park Afforage (PA) will not have a significant impact on the protection of the city in floods of this kind, especially with the bad condition in which they are being as a result of the mud and the poor condition of the channels due to the accumulation of household waste and rubble waste that will not allow the channels even to pass the normal flows.

The fundamentals of protecting the city from flooding must start from the drainage basins of Tazoult and Ben Tannoun, including launching well-studied afforestation operations (HARKAT, CHAOUCHE, BENCHERIF, 2020) that increase the interception values for rainwater and evaporation or rebuilding earthen dams (BELLA, 2006),

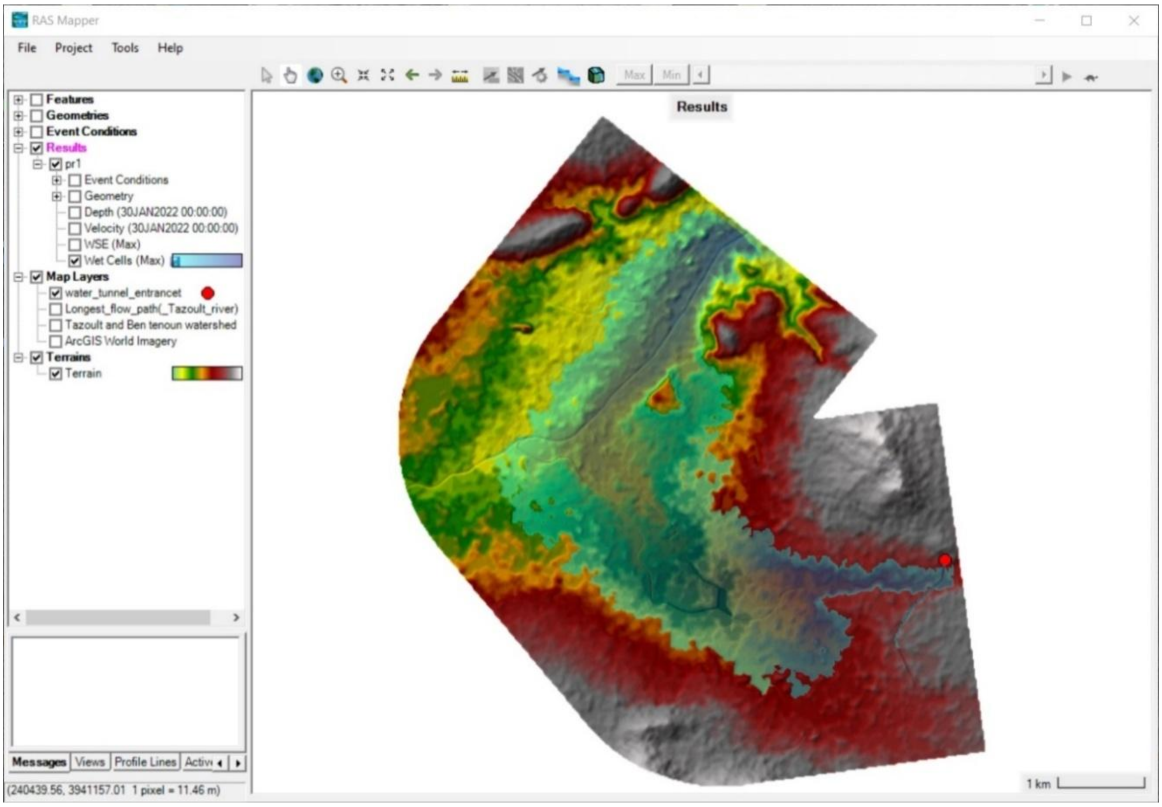

Fig. 5. Wet Cells on RAS Terrain
Rys. 5. Komórki wilgotne na terenie RAS
Рис. 5. Влажные клетки на местности RAS

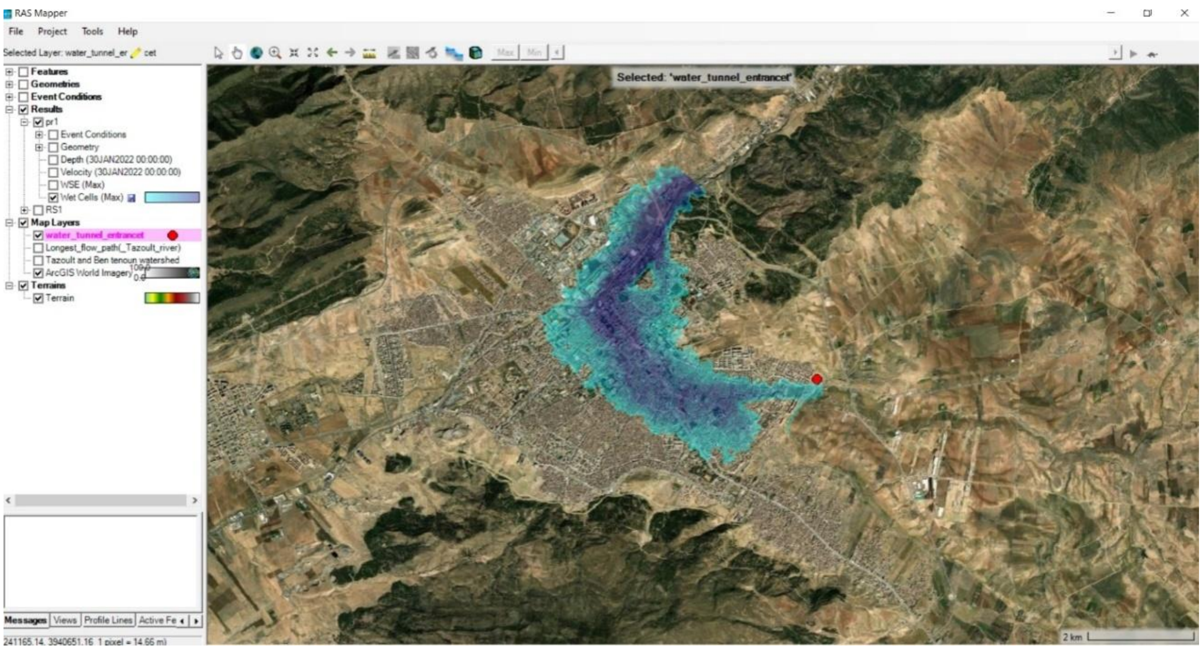

Fig. 6. Wet area of Batna city in case of the water tunnel blockage
Rys. 6. Mokry obszar miasta Batna w przypadku zablokowania tunelu wodnego
Рис. 6. Влажная зона города Батна в случае перекрытия водного туннеля

Photo 5. (AC) Water channel (phot. by F. Tout, 2021)
Fot. 5. (AC) kanał wodny (fot. F. Tout, 2021)
Фот. 5. (AC) водный канал (фот. Ф. Tout, 2021)

which may create A time difference that prevents the occurrence of large simultaneous flows. Also, trash traps (Phot. 6) and sequestration areas for solid waste and inactive rubble must be set and preserved and well maintained in a way that prevents its access to the water channels and the entrance to the water tunnel.

Photo 6. Trash trap before reaching the entrance to the water tunnel (phot. by F. Tout, 2020)
Fot. 6. Pułapka na śmieci przed wejściem do tunelu wodnego (fot. F. Tout, 2020)
Фот. 6. Мусорная ловушка перед входом в водный туннель (фот. F. Tout, 2020)

The area adjacent to the al Madhar River, which passes through many municipalities, may be heavily affected. This may result in loss of life, demolition of buildings or severe pollution of agricultural areas and the environment. The construction works near the valley should be stopped and the inhabitants invited to take auxiliary measures to better protect their property thus it is preferable to strengthen the sewage treatment plant located outside the city to better control the quality of water that is discharged into the natural environment, as the current plant, which is out of service, allows only little treatment of these flows.

Although the value of the flow that was used dates back to a study that went back nearly 4 decades, based on which the 1G protection channel was established, it represents a sufficient reason to think seriously about the dire consequences that may result if a defect of any kind occurs that prevents the passage of water through the water tunnel because. It reflects a realistic value, as an example a catastrophic floods in the city resulted from flows ranging from 400 to 500 m^3/s in September 1969, and with the climatic changes, this value is likely to rise, and it is worthwhile for the authorities to think of new solutions related to the sites of new housing programs directed to the city.

Conclusion

This study indicates the great change that occurred in the shape of the hydrographic network and the limits of the subwatersheds after establishing the water tunnel in the eastern of the city of Batna, to protect it from floods, now according to the Strahler classification of stream order this water tunnel is more important than the al Gourzi river which has been the focus of interest in several previous studies, And due to this importance, its failure to move large volumes of water may create a disaster, as its entrance is located at a higher altitude for the city centre, especially with the poor procedures for drainage within the city, these procedures, which cannot deal with large flows, and which are not well cleaned and maintained. To prevent the risk, it is important to protect the function of this tunnel, fencing all the channels connected to it, and raising civil society's awareness of its importance, and it shouldn't just be relied upon, but other backup solutions must be developed to better protect the city if a similar scenario happens.

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