The model and simulation of low impact development of the sponge airport, China

Jing Peng, Jiayi Ouyang, Lei Yu and Xinchen Wu

ABSTRACT

Recently urban waterlogging problems have become more and more serious, and the construction of an airport runway makes the impervious area of the airport high, which leads to the deterioration of the water environment and frequent waterlogging disasters. It is of great significance to design and construct the sponge airport with low impact development (LID) facilities. In this paper, we take catchment N1 of Beijing Daxing International Airport as a case study. The LID facilities are designed and the runoff process of a heavy rainfall in catchment N1 is simulated before and after the implementation of LID facilities. The results show that the total amount of surface runoff, the number of overflow junctions and full-flow conduits of the rainwater drainage system in catchment N1 of Beijing Daxing International Airport are significantly reduced after the implementation of the LID facilities. Therefore, the application of LID facilities has greatly improved the ability of the airport to remove rainwater and effectively alleviated the risk of waterlogging in the airport flight area. This study provides theoretical support for airport designers and managers to solve flood control and rainwater drainage problems and has vital practical significance.

Key words | low impact development facilities, runoff process simulation, sponge airport, urban waterlogging

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INTRODUCTION

Under the influence of urbanization and climate change, urban waterlogging problems have become more and more serious, which has led to flood disasters in some cities of China, and the shortage of water resources is becoming more and more serious, which has attracted more attention (Jiang *et al.* 2016; Sang & Yang 2017; Zhou *et al.* 2018). In China, many cities were flooded every year, and the number of waterlogged cities was increasing from 2013 to 2016. In order to alleviate the waterlogging and reduce the pollution load of runoff in most cities, the concept of the sponge city has been put forward (Hu *et al.* 2018). The content of sponge city is to advocate the construction of a 'rainwater system' with low impact, so that cities can absorb, save, store and filter and purify rainwater when it rains, like a sponge. When there is demand, they can reasonably release and make full use of the stored rainwater resources (Zhang *et al.* 2018).

With the increase of airport scale and passenger flow, the contradiction between supply and demand of airport water resources has become increasingly obvious. The water consumption data of Brussels (BRU), Orly (ORY), Zurich (ZRH), Manhattan (MAN), Atlanta (ATL) and Amsterdam (AMS) airports are sorted out by Carvalho *et al.* (2013). It can be seen that the average water consumption is about 20 L/passenger, with about 800 thousand m^3 of water consumption per year. In addition to the life water of the passengers, the airport also needs a large amount of water for the terminal air-conditioning system, toilet

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sanitation system, and so on (Carvalho *et al.* 2013). Overall, the annual water consumption of a large airport is almost the same as that of a small city. Airport water supply in China and other countries still depends mainly on urban water supply. A variety of models has been established to calculate the cost of rainwater utilization, taking Belo Horizonte Airport in Brazil as an example (Moreira Neto *et al.* 2012). Because the main purpose of rainwater utilization in the airport is to flush toilet water and for irrigation, rainwater treatment cost is relatively low. The cost is nearly 60% lower than the tap water price.

Because the infiltration capacity of the impervious area in an airport flight area is weak, the pressure of the water supply and drainage facilities will increase when there is heavy rain; the rainwater cannot be discharged quickly, increasing the frequency of waterlogging in the airport. Therefore, many airports have taken a series of measures to collect and utilize rainwater. In the overall reporting data, a great part of the harvested rainwater in airports is used in landscape irrigation, air conditioning, washing of paved areas and aircraft, fire control and so on, and toilet flushing occupies more than 50% of these activities. The rainwater composition collected by the roof of São Paulo Airport has been researched. The results show that an index such as physicochemical microorganisms is not up to standard in the early rain. The rainwater can meet the requirements of non-potable water after runoff in 25 minutes (Ribeiro *et al.* 2012).

Singapore Changi Airport can collect a lot of rainwater every month for flushing toilets and terminal air-conditioning systems, saving about $390,000 per year (Peng *et al.* 2018). Brussels Airport uses rainwater storage tanks installed on the roof to flush toilets. The roof of Atlanta Airport terminal also uses rainwater tanks to collect rainwater to irrigate plants. The new airport in Munich, Germany, covers an area of about 20 square kilometres. In order not to destroy the natural balance of water quality and quantity, a detailed rainwater collection and utilization design is planned. Considering that the pipes from upstream cannot be cut off, drainage pipes are built under the airport buildings to ensure the upstream. Underground water flows smoothly through the airport buildings to the designated locations. At the same time, the construction of an underground water seepage system between the runway and taxiway makes rainfall infiltration occur quickly (Suppan & Graf 2000). Atlanta Airport has installed three 11.37 m^3 water cisterns, which capture water runoff from the roof. The water collected from the cisterns is used to irrigate plants and 36.37 m^3 of harvested rainwater per month is used.

Some airports in China have also carried out rainwater recycling. Nanjing Lukou Airport has also set up a rainwater recovery system. The building area of T2 terminal is 263,000 m^2. The whole roof is siphoned to recover rainwater. One floor underground is equipped with a storage tank, which can meet the three-day toilet flushing capacity of the main building (Peng *et al.* 2016). The rainwater utilization project of the new airport building of Changzhou Airport embodies the concept of the green building. The rainwater is collected by a landscaped lake and used for greening water of the square green space after treatment (Ji *et al.* 2013).

Qingdao's new airport has launched an attempt to pilot the first green sponge airport in China. According to the municipal drainage design and the functional zoning of construction land, Qingdao's new airport is divided into six water catchment zones: transportation service area, terminal area, south working area, north working area, east movement area and west movement area. Corresponding low impact development (LID) facilities are designed, such as concave-down greenbelt, permeable pavements, biological detention, grass planted ditches and rainwater storage tanks (Pan 2018). Beijing's new airport has also carried out the design planning of the sponge airport, and through the construction of a digital rainwater management system, the rainwater pipeline system of the new airport has been simulated and checked, and the waterlogging risk caused by excessive rainfall has been evaluated. Through the study and construction of the sponge airport, the ability of the existing rainwater system to deal with the waterlogging risk is optimized, and the establishment of the rainwater system is scientifically and reasonably guided (Ren *et al.* 2017; Xie *et al.* 2017).

In summary, current rainwater utilization at airports mainly focuses on the collection of rainwater for flushing toilets, greening, fire control and so on. Few scholars have conducted research on the sponge airport, so that the airport can respond to heavy rain disasters, like sponge city with good elasticity. When it rains, it absorbs water, stores water, and seeps water. When it is needed, it releases stored water and uses it. Therefore, this paper puts forward the construction concept of the sponge airport, realizes the construction of the sponge airport by implementing LID facilities, and establishes models to simulate the runoff of rainstorms. The research can be applied both to sponge cities and airports. It will help to achieve the construction goal of a 'safe airport, green airport, smart airport, humane airport' and contribute to the construction of a green, environmentally friendly and harmonious sponge city.

The purpose of this paper is to study how LID facilities affect the total amount of surface runoff, the number of overflow junctions, water depth of junctions, inflow of junctions, and full-flow conduits of the study area. In this study, we are taking a catchment of Beijing Daxing International Airport as a case study. According to the characteristics of different regions in the airport, appropriate LID facilities are designed and the runoff process of a heavy rainfall in catchment N1 is simulated before and after the implementation of LID facilities. The simulation results show that the application of LID facilities greatly improves the ability of the airport to remove rainwater and effectively alleviates the risk of waterlogging in the airport flight area. Models are built in a one-hour rainfall scenario with a five-year return period and a one-hour rainfall scenario with a 100-year return period in this paper. In future research works, we can further simulate the actual operation of the airport rainwater drainage system using a five-minute rainfall scenario with short-duration rainfall pattern.

MATERIALS AND METHODS

LID facilities of sponge airports

The essence of building a sponge airport is to build a 'rainwater utilization and drainage system with LID in airport flight area'. LID facilities for the airport are designed to realize the functions of rainwater storage, infiltration and reuse in certain places, such as the flying area, terminal area, freight area and so on by means of seepage, stagnant water storage, purified water, drainage and other emerging technologies. That can make sponge airports, like sponges, have good 'elasticity' in adaptation to environmental changes and response to rainstorm disasters. When it rains, the airport will absorb, store, infiltrate, discharge and purify water, and if necessary, the storage water will be released and utilized (Ministry of Housing and Urban-Rural Development 2014). An effective green sustainable development of a rainwater recycling system can be established by designing and implementing LID facilities. The LID facilities of the sponge airport mainly include: biological retention, grass planted ditch, rainwater bucket, permeable pavement, concave green space and so on (Table 1).

Table 1 | Application location and role of LID facilities at sponge airport

Measures	Location	Function
Biological detention	Soil area in the flying area; green space around parking lots; the construction area of the work area	Infiltration and purification of rainwater; reduce peak and total rainfall runoff
Grass planted ditch	Drainage ditch in the flying area	Rainwater conveyance and purification of water quality; reduce flood peak and reduce runoff
Rainwater bucket	Specific location in flying area; near the rainwater pipe of the terminal building	Save and reduce the total discharge; staggering drainage
Permeable paving	Maintenance area; freight area road	Extending the time of runoff and achieving in situ infiltration; reducing total discharge volume
Concave green space	The soil area in the flight area; around the square and parking lot; the building area of the work area	Purifying rainwater; in situ infiltration; accumulation of stagnant surrounding rainwater
Impounding reservoir	The way along each catchment area; terminal reservoir	Storage; purifying rainwater; reduce the total discharge volume; staggering drainage

Software

Storm Water Management Model (SWMM) is a dynamic rainfall–runoff simulation model, which can simulate a single precipitation event or long-term water quality and quantity in urban areas. The model has been used in Tianjin, Shanghai and other areas in China. SWMM integrates the functions of modeling area data input, urban hydrology, and hydraulic and water quality simulation calculation. It can simulate the process of water flow and rainwater storage in surface runoff and the drainage system. The simulation results can be represented by time-series charts, profiles, animation demonstrations and statistical analysis. It can also show the total rainfall, total infiltration, surface runoff of each sub-catchment area and the depth, head, volume, inflow and overflow of each node. It can be judged whether the node produces overflow by whether the inflow depth at any time exceeds the maximum capacity of the node (Qin *et al.* 2013; Rabori & Ghazavi 2018).

In this study, we aim to simulate the drainage and rainwater accumulation in catchment N1 of the airport during specific rainfall scenarios. The runoff and overflow junctions of the drainage network in each sub-catchment area will be studied in specific rainfall scenarios. The change of runoff flow and peak of runoff in each sub-catchment is studied before and after the implementation of the LID facilities. SWMM has good versatility, relatively low demand for research data, no time-step limit, and no scale limit. Therefore, this study chose SWMM for the simulation among all the hydrological models.

CASE STUDY

Site description

In this study, we are taking Beijing Daxing International Airport as an example. Beijing Daxing International Airport is located in the south of Daxing District of Beijing. It is about 50 km from the center of Beijing. It faces Yongding River in the south. The location is shown in Figure 1. The airport has been constructed and operated in stages. The planned land area for this period (2020) is about 27 km^2, and the annual passenger throughput is about 45 million. Before the development of the airport, the impervious area was mainly a small number of self-built residential roofs and roads near residential buildings, and cultivated land was the main pervious area. In the first phase of airport construction, the areas of the flight area, maintenance area and freight area are large and impervious pavement accounts for 69% of the total area. It consists of pavement, apron and runway in the flight area. The pervious area is green space and greening in the flight area. According to the implementation of the traditional rainwater collection system, there will be a high proportion of impervious pavement, which will naturally change the original characteristics (Ge *et al.* 2015).

Figure 1 | The location of Beijing Daxing International Airport.

Application and data analysis

The analysis is done for the preliminary design of the rainwater drainage system in Beijing Daxing International Airport. The simulation models are used to check and verify whether the rainwater drainage system in the initial design phase can meet the drainage requirements during specific rainfall scenarios. Combining with SWMM model application, the developed movement area is generalized. According to the topography of Beijing Daxing International

Airport, it can be divided into seven drainage zones, namely, N1, N2, N3, N4, N5, N6 and S1. Because the rainwater drainage of the airport is very complex, we take N1 (Figure 2) as an example for simulation. N1 is the maintenance area, part of the flight area and the western part of the terminal area. According to the preliminary design manual of the rainwater drainage system, the area of catchment N1 is 593.83 ha. The runoff factor of N1 is 0.7. There are three main rainwater drainage networks. Storage is located at the northern end of N1. Storm water is conveyed to the storage of N1 through the nearest channel or pipes in the form of catchment surface runoff. The storage of N1 has an area of 100,000 m^2 and a capacity of 270,000 m^3. For the simulation of this site, three main rainwater drainage networks were considered according to the flow of rainwater, respectively J1 to J10, J11 to J18 and J21 to Outfall 55. Storm water was conveyed to the storage of N1 through the nearest junctions and conduits in the established models. The layout of rainwater junctions, conduits, and storage of catchment N1 in the models is shown in Figure 2.

The parameters of SWMM include hydrologic parameters and hydraulic parameters. The hydraulic parameters of the drainage networks are set according to design data. The catchment N1 can be divided into sub-catchments according to the terrain. The hydrologic parameters include area of the sub-catchment, width, percentage of slope, percentage of impervious, Manning's n of impervious (N-imperv), depth of depression storage of pervious (Dstore-imperv) and so on. The area of the sub-catchment and percentage of land area which is impervious are set according to the airport design plan. Width is calculated by Equation (1):

$$\text{Width} = \text{Area}/\text{Flow Length} \tag{1}$$

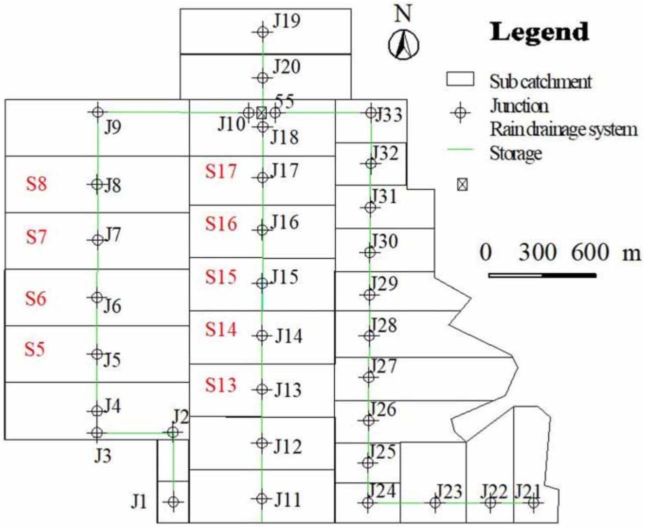

Figure 2 | The distribution of sub-catchment and rain drainage system in N1.

The slope of the sub-catchment is obtained by analyzing the slope of regional digital elevation model (DEM) data. Dstore-imperv and Dstore-perv are obtained by analyzing subsurface properties of the airport. Manning's n can be selected from Table 2. In this study, the N-perv of overland flow is set as 0.15, the N-imperv of channels is set as 0.03, and the N-imperv of closed conduits is set as 0.013. The Horton model is used in the permeability model.

In the design process of rainwater drainage systems in the airport, the water conservancy department customarily uses a columnar process in which the rainfall varies with time during the unit time (1 h, 1 d, or a standard calendar). Therefore, the time distribution of heavy rain can be divided into daily rain type, hourly rain type, and stage rain type (Huo 2011). The purpose of this study is to verify whether the flood control and drainage facilities of Beijing Daxing Airport at the initial design stage meet the flood control requirements. It is suitable for the use of hourly rain type for longer hours.

Based on the historical rainfall data collected by the observation station of the Beijing Meteorological Bureau, a frequency analysis approach was used to derive the design of torrential rain in Beijing. The torrential rain process in a five-year return period was used for one-hour rainfall within 24 hours. The rainstorm process line in a 100-year return period was expressed as one-hour rainfall within 48 hours. The rainfall was zero after 30 hours, so only

Table 2 | Manning's n of different type areas

Type	Manning's n
Concrete channels	0.011–0.020
Vegetal channels	0.030–0.40
Closed conduits – concrete pipe	0.011–0.015
Overland flow – smooth asphalt	0.011
Overland flow – smooth concrete	0.012
Overland flow – short grass	0.15
Overland flow – dense grass	0.24

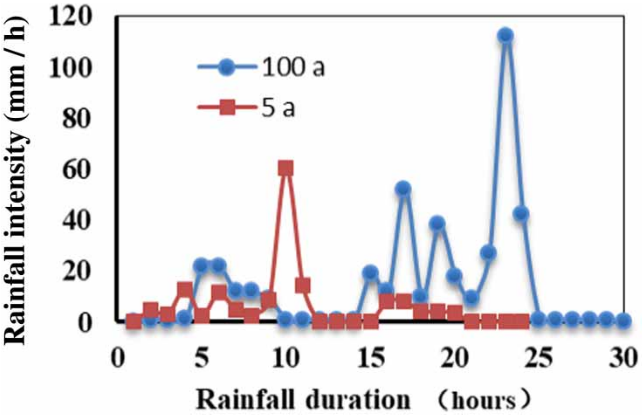

Figure 3 | One-hour rainfall hydrograph with different return periods.

rainwater runoff within 30 hours was simulated in the model (Figure 3).

In this study, the runoff process of catchment N1 in Beijing Daxing Airport is simulated and the model is checked in a one-hour rainfall scenario with a five-year return period (Figure 3). At this rainfall intensity, only J7 and J8 junctions have overflow for a short period of time. Junction 7 just appears to overflow at 10:30. Junction 8 begins to overflow at 10:30, but the situation of accumulating water lasts less than 10 minutes. Other junctions and conduits in N1 are not in full flow, which can meet the requirements of design (the design time of rainwater accumulation in the airside of the airport is 10 minutes). The total runoff of N1 in the simulation is about 6.4×10^5 m^3. The theoretical and calculated total runoff of N1 is about 6.7×10^5 m^3. The simulation result of storm runoff in this model is close to the theoretical and calculated value and the relative error is only 4.7%.

On this basis, the model is simulated in a one-hour rainfall scenario with a 100-year return period (Figure 3). The rainfall series used in this simulation is assumed to be an independent rainfall event. There is no rainfall before it. So it is assumed that the junctions and conduits do not have water accumulation before simulation. The water depth of storage is located at the flood control level. The permeability coefficient of the impervious area can be set according to the hydrological conditions in the research area.

In this study, two models are considered:

1. Model 1: This is a traditional hydrological model, which does not adopt LID facilities in any sub-catchment.
2. Model 2: In order to verify the effect of LID facility implementation, Model 2 is built, in which the LID facilities are adopted in some sub-catchments, such as: S5–S8, S13–S17.

RESULTS AND DISCUSSION

This study focuses on the analysis of the rainwater runoff process within 30 hours in the N1 catchment under a one-hour rainfall scenario with a 100-year return period. The lead time for these small catchments in N1 is much less than one hour, so the time-step of the simulation in the model is set as 15 minutes. The time-series plots and water elevation profile maps are created using simulation results. The time-series plot describes the objects and variables to be graphed in a time-series plot. Time series for certain system-wide variables, such as total runoff, total inflow, depth, etc., can also be plotted. A profile plot displays the variation in simulated water depth with distance over a connected path of drainage system links and nodes at a particular point in time. The full flow and overflow situation of each junction and conduit are analyzed in detail. The appropriate LID facilities are added to the sub-catchments where the overflow junction appears. The results of before LID and after LID are compared.

Simulation analysis without LID facilities

The first scenario (Model 1) is a simulation without LID facilities. The water elevation profiles of conducts and junctions are shown (Figures 4 and 5). No junctions and conduits overflow before 17:00. The rainfall reaches the higher peak at 17:00. Junction 7 (J7) and J8 begin full flow at 17:45, and one conduit is at full flow (Figure 4(a)). It lasts less than an hour, and the junctions do not accumulate water. J7 and J8 appear at full flow for a second time at 19:45, and one conduit is at full flow (Figure 4(b)). It lasts for a very short time. However, after 21:00, with the further increase of rainfall intensity, the number of overflow junctions and full-flow conduits continues to increase. J7 begins to overflow at 23:30, and there is one full-flow junction and one full-flow conduit (Figure 4(c)). There are

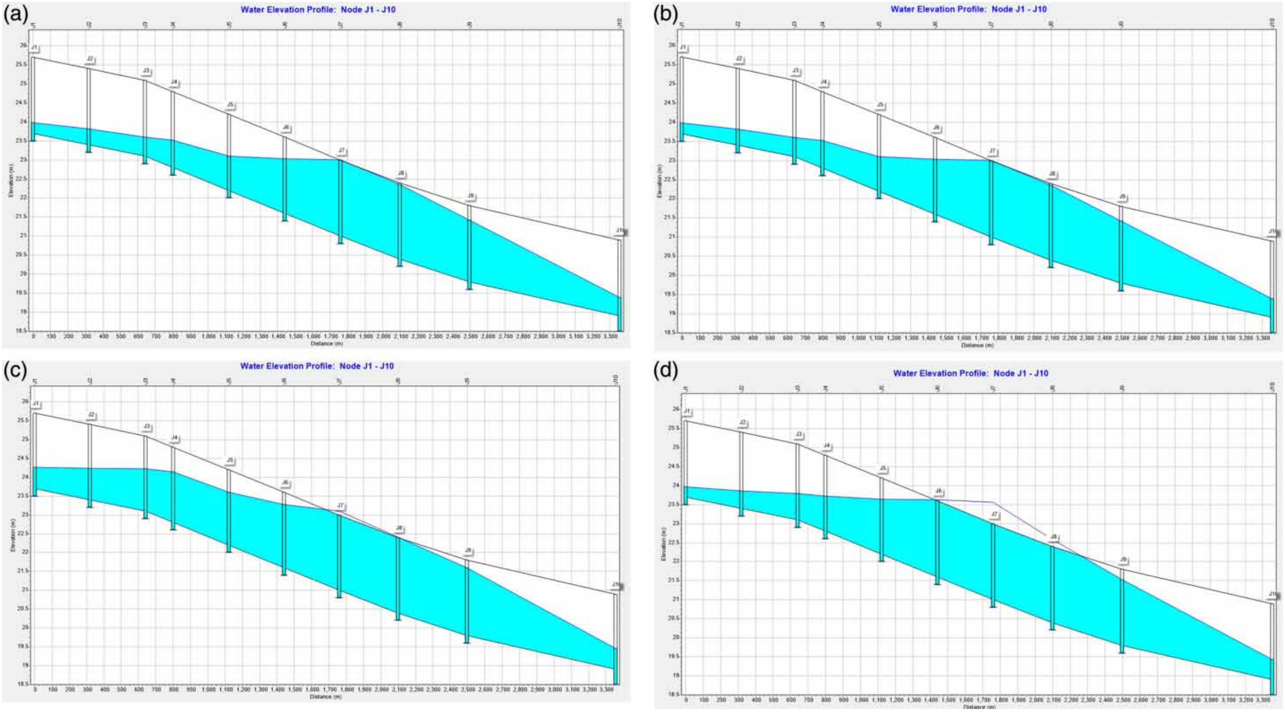

Figure 4 | The water elevation profile at (a) 17:45, (b) 19:45, (c) 23:30, (d) 25:15.

three overflow junctions and four full-flow conduits at 25:15 (Figure 4(b)). It lasts for five hours and the maximum depth of water accumulation is 0.6 m (the maximum allowable water depth of the junction is 2.2 m), which will seriously affect the operation of the airport.

Meanwhile, J17 and J16 begin to overflow at 23:30, and there is a full-flow junction and two full-flow conduits (Figure 5(a)). There is one full-flow junction, three overflow junctions and three full-flow conduits at 24:00 (Figure 5(b)). It lasts for 1.5 hours and the maximum depth of water accumulation is 0.5 m (the maximum allowable water depth of the junction is 2.2 m) (Figure 5(d)).

The results of simulation show that part of the rainwater pipe network is key to restricting the rainwater drainage system, and there is a bottleneck area. The main reason is that the impermeable pavement rate of the study area is high, and the water storage capacity of the ground is not good. Most of the rainwater has to pass through the surface runoff into the rainwater pipe network, which greatly increases the drainage pressure of the pipe network. It can be seen that the rainwater control ability of the study area is poor and the drainage system cannot operate effectively without effective LID facilities.

Simulation analysis with LID facilities

From the simulation of Model 1, it can be seen that many junctions and conduits appear to overflow in a one-hour rainfall scenario with a 100-year return period, and the water depth accumulation in junctions is deeper, so we need to take appropriate LID facilities to reduce the impact of rainstorms. Therefore, the corresponding LID facilities are added in Model 2. In the SWMM model, there is a special LID module, in which different LID facilities such as Green Roof, Infiltration Trench, Rain Barrel, Vegetative Swale and Permeable Pavement are set up. Because there is a large area of maintenance room in the sub-catchment S5–S8 and considering the features and suitability of LID facilities, the Rain Barrel and Green Roof are set up. Because there is mainly runway, taxiway and surface area in the sub-catchment S13–S17 and considering the features and suitability of LID facilities, the Rain Barrel and

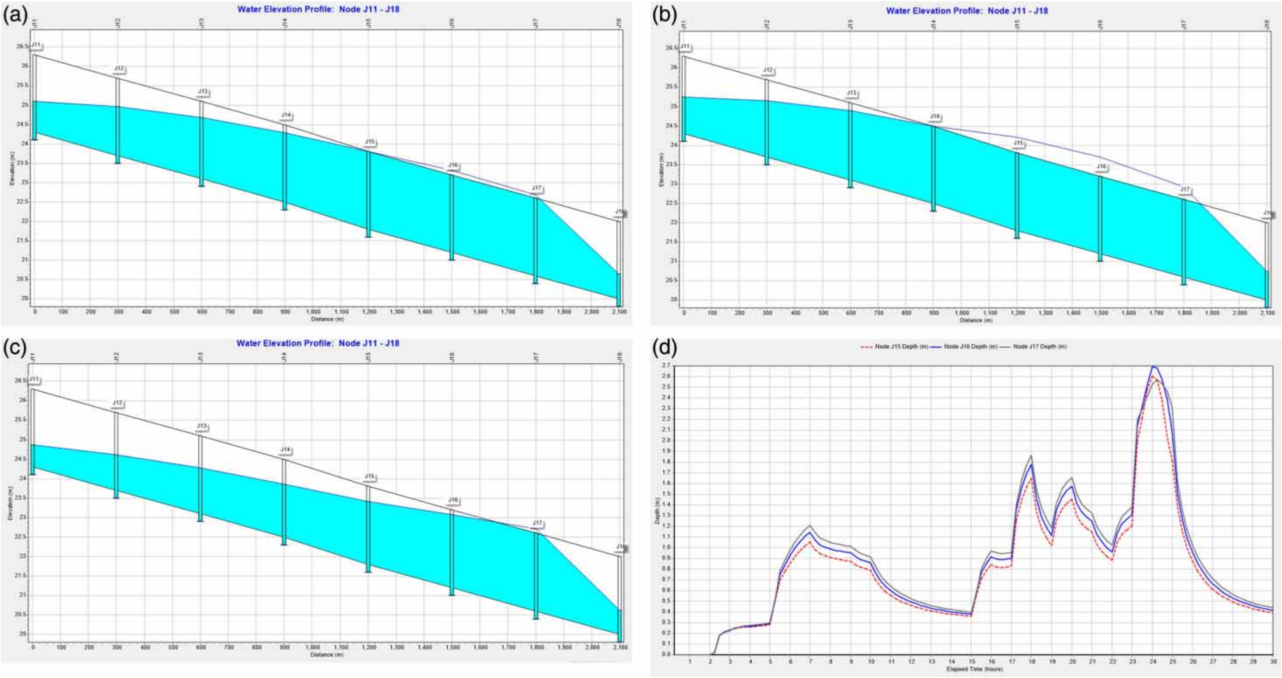

Figure 5 | The water level profile at (a) 23:30, (b) 24:00, (c) 25:00 and (d) water depth at J15–J17.

Vegetative Swale are installed. Two storage tanks along the way are set up between J16 and J18. They are located at S16 and S17, and the total volume of the storage tanks is about 4.0×10^4 m^3 (Table 3). The parameters of all designed LID facilities can be seen from Table 3. The effect of LID facilities is significant (Figures 6–8).

Model 2 is simulated to obtain the water elevation profiles for junctions and conduits (Figure 6). It can be seen that the most disadvantageous situation of drainage networks in N1 occurs at 24:00, with only J7 overflow, J17 full flow and one conduit overflow. Comparing Figures 4 and 5 with Figure 6, it is obvious that the number of overflow junctions and conduits is greatly reduced.

Figure 7(a) and 7(c) are the water depth of J6–J8 and J15-J17 before the implementation of LID in Model 1. Figure 7(b) and 7(d) are the water depth of J6–J8 and J15–J17 in Model 2 after the implementation of LID facilities. It can be seen that J6–J8 overflow occurred many times and lasted nearly five hours in Model 1. The maximum depth of water accumulation in J7 is 0.6 m (the allowable water depth of the junction is 2.2 m) (Figure 7(a)). In Model 2, junctions J6–J8 do not appear with full flow, beginning overflow at 23:30, the duration is shortened to two hours, and the maximum depth of water accumulation in J7 is only 0.2 m (Figure 7(b)). In Model 1, junctions J15–J17 begin to overflow at 23:30 and this lasts

Table 3 | The parameters of LID in Model 2

Sub-catchment	LID type	Design guidelines	% of Area	% From imperv
S5–S8	Rain Barrel	Based on land-use characteristics of sub-catchment areas and features and suitability of low-impact development facilities	54	40
	Green Roof		36	20
S15–S17	Vegetative Swale		65	50
	Rain Barrel		16	50
S16–S17	storage tanks along the way		30	70

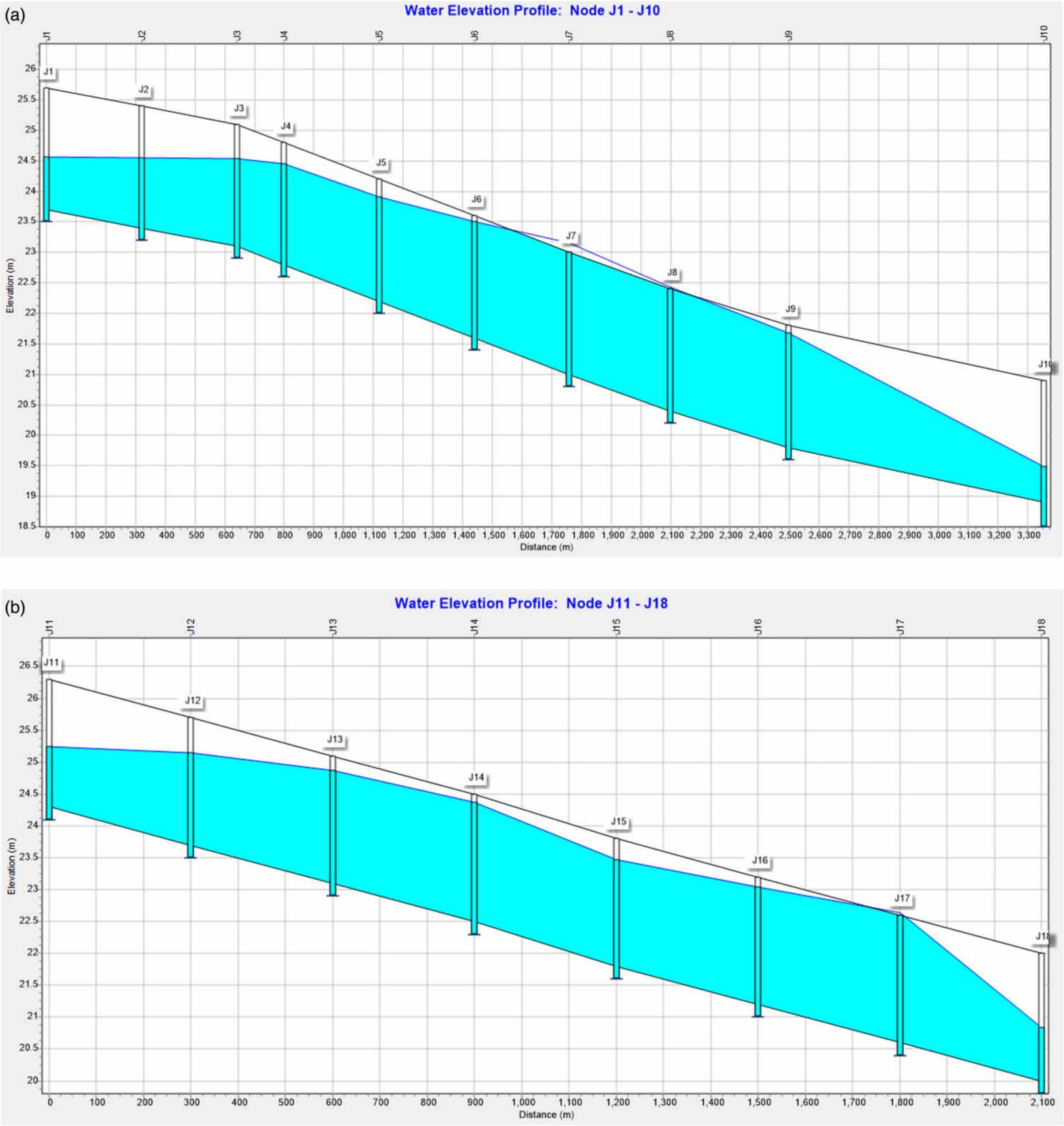

Figure 6 | The water elevation profiles after LID at 24:00: (a) J1–J10, (b) J11–J18.

nearly two hours. The maximum depth of water accumulation in J17 reaches 0.5 m (the allowable water depth of J15–J17 is 2.2 m) (Figure 7(c)). In Model 2, the overflow time of J17 is very short, lasting only 15 minutes, and the maximum depth of water accumulation is only 0.1 m (Figure 7(d)).

Figure 8 is a total inflow comparison chart of junctions before and after LID facilities. Because the total inflow

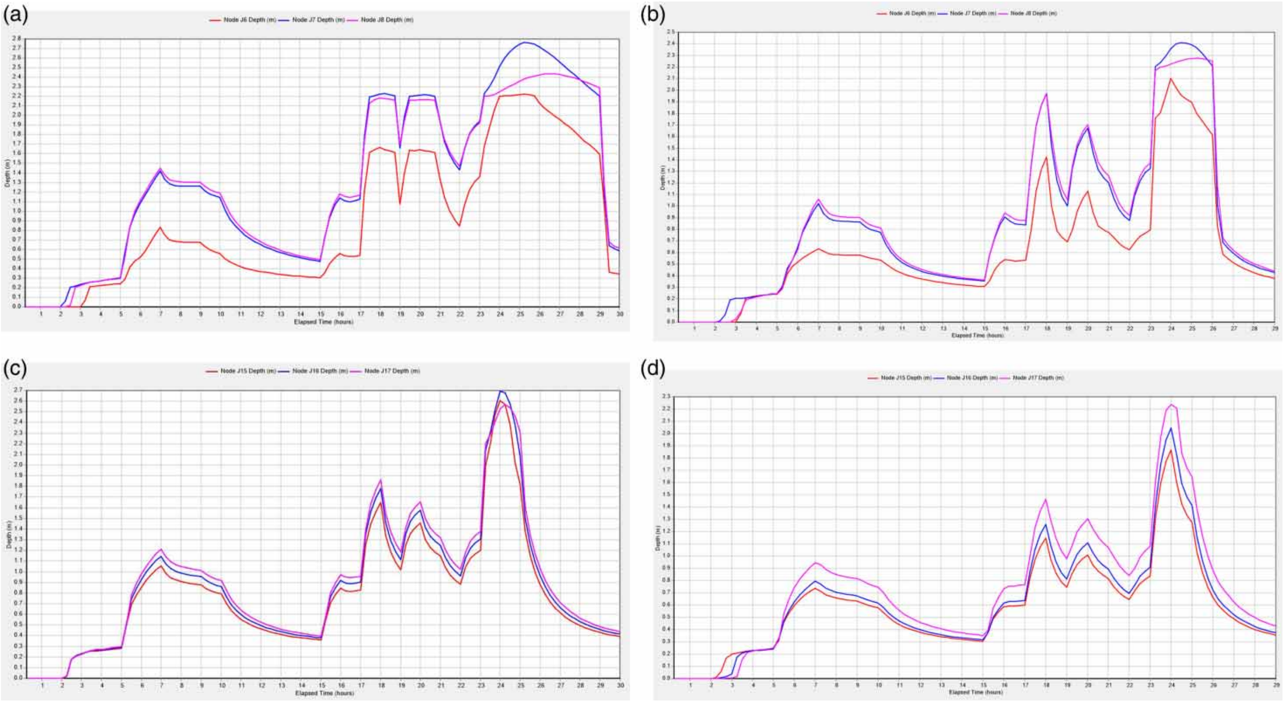

Figure 7 | The water depth of junctions, before LID (a) and (c) and after LID (b) and (d).

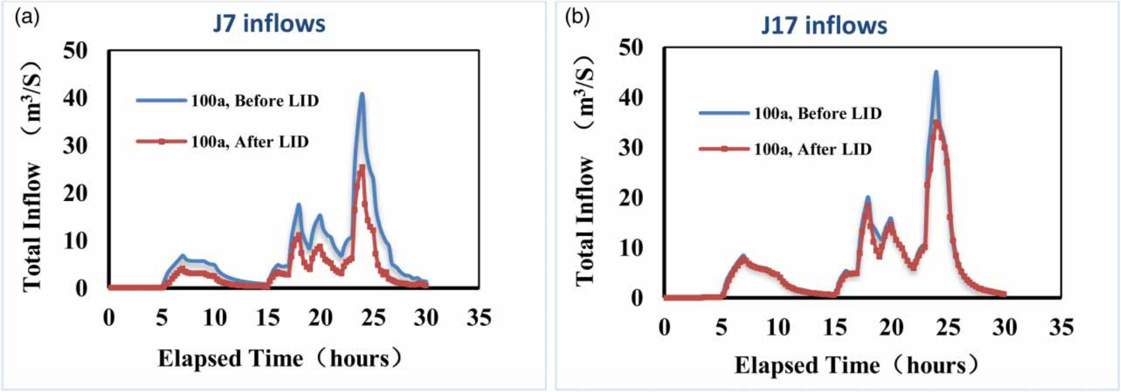

Figure 8 | The comparison of total inflow at junctions before and after LID.

variation of other junctions is the same as that of J7 and J17, these two junctions are chosen as the research objects for analysis. The maximum total inflow of J7 decreases from 45 m^3/s to 35 m^3/s, and the maximum total inflow of J17 decreases from 44 m^3/s to 39 m^3/s. It can be seen that the implementation of LID facilities effectively reduces the total runoff and peak flow of the junctions.

Through the analysis before and after implementation of LID facilities, it can be seen that the rainwater depth of junctions has changed significantly and the overflow situation of junctions and conduits has improved significantly after LID. The LID facilities greatly increase the reduction rate of surface runoff of rainwater, and also increase the reduction rate of a number of overflow junctions and full-flow conduits to a certain extent. The simulation results show that most of the overflow junctions and full-flow conduits in Model 1 still have flow space in Model 2, because the establishment of LID facilities increases the storage and infiltration of rainwater and reduces the total discharge inflow. A series of LID facilities has been adopted to greatly improve the rainwater removal capacity and effectively alleviate the risk of waterlogging in the N1 catchment in Model 2.

CONCLUSIONS

The construction of an airport runway and other facilities, making the airport impervious area account for a high proportion of the area, and airport waterlogging risk is greatly increased in the event of heavy rain. Therefore, the construction of the sponge airport is carried out based on LID facilities in this paper, and models are built to simulate the rainwater runoff process within 30 hours in the N1 catchment of Beijing Daxing Airport under a one-hour rainfall scenario with a 100-year return period. The full flow and overflow situation of each junction and conduit are analyzed in detail. LID facilities are not applied in Model 1, there are many overflow junctions and full-flow conduits, and the water depth accumulation in the junctions is deeper. In Model 2, the appropriate LID facilities are added to some sub-catchments of N1 where the overflow junctions appear. The simulation results before and after LID facilities are compared. The results show that the water depth of junctions has changed significantly and the overflow situation of junctions and conduits has improved significantly after LID. The LID facilities greatly increase the reduction rate of surface runoff of rainwater, and also increase the reduction rate of the number of overflow junctions and full-flow conduits to a certain extent. Most overflow junctions and conduits in Model 1 still have flow space after LID facilities in Model 2. Therefore, the application of LID facilities has greatly improved the rainwater removal ability of the N1 catchment and effectively alleviated the risk of waterlogging. This study provides a theoretical basis for the design of the rainwater drainage system of Beijing Daxing Airport. It also has important theoretical and guiding significance for the construction of the LID sponge airport.

For future research, we can further simulate the operation of a whole rainwater drainage system in the airport airside area using a five-minute rainfall scenario with short-duration rainfall pattern. The practical measurement data could then be used to verify the developed simulation model. Selecting the optimal LID and control strategy and realizing the real-time control of airport floods could be the main extension of the model developed in this paper.

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