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URBAN CONSTRUCTED WETLANDS IN ARID AND SEMIARID ZONES

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Abstract

The development of societies and the increasing growth of recent constructions, especially in cities, have caused environmental issues, destruction, and reduction of natural resources and the environment, especially green and green-blue spaces. According to studies, in the past years, many parts of natural and even pristine surfaces and spaces in big cities have been turned into artificial, and impermeable spaces, which has aggravated environmental and ecological problems and also it has aggravated the aesthetic characteristics of the urban landscape, particularly in arid and semiarid areas. In this case, the studies show that identifying and applying natural ecosystems such as wetlands and their artificial types due to their multifunctional aspects and benefits, especially in urban areas, can be the basis for reducing many issues mentioned. Therefore, it is necessary to pay attention to this critical issue and do more research to know different types of constructed wetland ecosystems along with their services and values. The primary aim of this research is to identify the values and services of this ecosystem and to examine the diverse patterns of constructed wetlands in order to extract and design simple patterns of construcred wetlands. We want to know their role and position in landscape architecture and urban planning and design process. Also, this study aims to examine the potencial and possibillity of building constructed wetlands in urban areas particularly in arid areas and Mediterranean regions, according to Koppen climate classiffication. In this regard, the theoretical framework is provided based on the study of specialized texts and the study of similar foreign case studies and diverse patterns of urban wetlands with their different functions. These reviews have been done in a specific format consisting of some main aspects, such as the function and supply sources of wetlands. The final result and extractted simplified patterns, according to case studies, can be considered as a framework for designing and planning urban constructed wetlands and a guide for planning and designing a landscape consisting of this element, especially in areas with arid, semiarid, and Mediterranean climates with hot and dry summers.

Keywords:

Constructed wetland;
Services and values;
Water reuse;
Patterns;
Arid and semiarid zones.

1 Introduction

The growing population has caused many environmental issues associated with the water sector, such as increasing demand for freshwater and resources, production of wastewater, and degradation of green spaces because of construction and city development [1]. Demographic growth and urban development have diminished the quality of groundwater, surface water, and groundwater level. Furthermore, the lack of vegetation cover in arid and urban areas leads to the generation of extensive overland flows [2]. In arid and semiarid areas, water supplies are limited due to population expansion. Floods are infrequent but very damaging, putting lives and infrastructure in danger [3]. The problem of water scarcity and pollution needs to be dealt with immediately, as the effects on the

environment become increasingly serious and irreversible [4]. Water shortage is one of the most serious problems in drylands, especially in developing countries. In this case, the reuse of unconventional water such as wastewater for consumption and agricultural irrigation can prove beneficial [5]. Studies suggest that recognizing natural infrastructures and ecosystems such as wetlands and their artificial kinds because of their multiple functions and benefits, particularly in urban areas, can provide a context to reduce mentioned difficulties [6]. In arid and semiarid areas where water resources are scarce, some infrastructure, like wetlands that treat polluted water, can be beneficial for improving water resources [7]. Artificial wetlands have the potential to play an important role in water quality, contributing to the development of the ecosystem and human health [8]. Green infrastructure, such as treatment wetlands, is aimed at integrating anthropomorphic values, ecological models and functions, and promoting ecosystem health [9]. Constructed wetland is one of the natural treatment technologies that act as green, environmental, and ecological technologies, so the future of the investigation and uses of constructed wetlands is a significant need. Further development requires more understanding of these systems [4]. Since there has been no comprehensive water management in communities, particularly in developing countries, during the last few years, and this issue has provided difficulties in the context of the environment, it is vital to study and provide suitable and adaptable natural solutions for water management, especially in arid zones. Students, engineers, and officials are interested in gaining more information about wetlands. However, unfortunately, many studies just have discussed technical and chemical aspects. Attention must be paid to aesthetic values, landscape features, wildlife habitat, and other multiple-use aspects, as well. This paper intends to emphasize the valuable potential of constructed wetlands in integrating water renovation processes and other multifunctional aspects. Also, this paper aims to introduce urban constructed wetlands and their different patterns as one of the green infrastructures and to study successful case studies in arid, semiarid, and Mediterranean climates with hot and dry summers to recognize constructed wetlands as a natural multifunctional structure that can act as a practical component in surface water management network and groundwater restoration as it provides social, economic, environmental, and recreational benefits.

2 Methodology

Given that we have encountered many environmental and water issues resulted from the growing population, urbanization, and industrial developments the aim of this paper is to understand the potential and the possibility of developing constructed wetlands in urban areas to alleviate and address many mentioned problems, especially in arid and Mediterranean regions with hot and dry summers. In this regard, literature and related sources were studied and reviewed to explain man-made wetlands and their services and values and their position in urban areas. Moreover, we studied a great number of case studies around the world to become familiar with different types of wetlands. According to the Koppen climate classification, we selected case studies from arid and Mediterranean areas with hot and dry summers. We analyzed them according to their supply sources and functions, which are presented in Table 1. Finally, according to the case studies and reviews, we extracted and designed simple patterns, which are presented in Table 2, both to classify constructed wetlands and making specialists such as urban planners, designers, landscape architects, and the public familiar with these advantageous artificial ecosystems.

3 Wetlands

The Ramsar Convention defines *wetlands* as õall areas of marsh, fen, peatland, or water, whether natural or artificial, permanent or temporary, with static or flowing water, fresh, brackish, or salt.ò The convention set a depth of (20 feet) 6 m as the limit for any water body to be included in the term wetland. Wetlands are transitional environments between terrestrial and aquatic ecosystems and are considered one of the most biologically diverse ecosystems. Worldwide, wetlands are vital to human survival. They are one of the most productive environments in the world, and many species of plants and animals depend on wetlands for survival [4].

4 Constructed wetland as a multifunctional and coast-effective structure

Natural wetlands contribute significantly to enhancing biodiversity, reducing the danger of flood, preserving wildlife habitat and shorelines, and air purification. However, constructed wetlands are artificial systems mimicking natural wetlands in a controlled atmosphere [10]. In any aquatic system,

many processes may occur because of the physical, chemical, biological or ecological nature. Consequently, aquifers will perform several functions. For example, a wetland that performs the function of flood reduction may enhance water storage.

One process, such as denitrification and plant nutrient uptake processes, may enhance the water quality level while it causes other functions, such as supporting the food web [11]. The primary purpose of a small investment in the constructed wetland is water purification; secondary functions offer many other ecological, environmental, social, and recreational results [12]. Economic, recreational, and social factors are significant assets that could be achieved through the performance of constructed wetlands. It is environmentally friendly technology because it lacks hard materials and dependence on natural resources [10]. Constructed wetlands are not only multifunctional but also rational and cost-effective [11]. This is critical in regions where financial and technological resources are not available. Therefore, constructed wetlands represent a viable, economical, technically simple, and efficient option for the purification of water at the local level [4].

4.1 Reducing the danger of flood

Human actions seriously have changed the patterns of water movement. It is evident when we compare how water acts in a ónaturalô area, such as a forest or a meadow, with how water behaves in a built-up area, such as a town or city centre. The water cycle is short-circuited because of built development, which causes flooding problems [13]. Coincident with the loss of wetland habitats, runoff growth resulting from urbanization, and polluted surface water, there is a growing pressure for low-cost answers to enhance water quality and flood control [14]. Wetlands, streams, and rivers are part of the hydrological cycle and play a role in flood management and sediment distribution [9].

4.2 Water purification

Constructed wetlands are not functional in supplying potable water; however, they play a significant role in water reuse for non-potable uses, mainly in arid areas where water resources are limited [8]. Constructed wetlands are effective and low-cost natural methods to treat wastewater and stormwater, and their operation is cost-effective [15]. Wastewater should be considered a valuable resource; therefore, treating them is vital [4]. Constructed wetlands slow down the water; as a result, suspended solids become trapped, contaminants are transformed into less soluble forms through plants and microorganisms [6].

4.3 Increasing the level and quality of the groundwater

Groundwater sources of drinking water are priceless, so they should be protected from contamination. So significant is it to infiltrate the water into the soil to charge the groundwater resources or to use surface and treated water instead of potable water for reuse. Again, constructed wetlands can be applied to reduce pollutants before the water infiltrates into the groundwater [8].

4.4 Improving wildlife

Although the lack of water availability degrades aquatic habitats, treated water discharge can revitalize and create aquatic habitats, particularly in arid areas where water resources are limited [11]. Although macrophyte species seriously contribute to the installation of the wetland ecosystem, wetland biodiversity contains many different kinds of wildlife species, and these species contribute to the mass of biodiversity [4]. For example, a series of shallow ponds built in Gilbert first aim to recharge the groundwater. However, then the area was converted into an urban habitat for birds, bats, and other fauna [12]. The design phase is a crucial stage for habitat restoration and biodiversity. Profiles and infrastructural details should be managed in the land-forming step to create ecotones by creating shallow, low-high, and deep areas [16].

4.5 Climate change adaptation

Alleviation of global warming is an action that demands modifications at every scale. Of course, constructed wetlands cannot mitigate climate change effects, but they can assist us in adapting to our changing circumstances. However, each project that grows plant biomass contributes. The water in the constructed wetland is shaded by trees and returns to the river at a lower temperature. In a period of growing global temperature, this is a paramount consideration for the habitat of aquatic organisms

[8]. While heat island is an adverse result of developments, observation shows that wetlands influence microclimate by their role in temperature reduction and humidity increase. The water bodies' size and distribution contributed significantly to microclimate results [17].

4.6 Enhancing environmental aesthetic characteristics and educational benefits

Constructed wetlands are appealing structures due to the combination of water, vegetation, and wildlife [16]. The appearance of the treatment wetlands is important, especially where it is located in a public space. The planting design is as important as treatment efficiency, and landscape architects play a substantial role in this regard. Houtan Park on Shanghaiôs Huangpu riverfront in China is an excellent example of the combination of art and science, see Table 3, pattern 1. While the project has reached technological features such as water purification and flood control, it creates a picturesque area [8]. Since wetlands are high-priority landscape features, much effort is made to conserve, restore or create them. Signage and pamphlets install, and graphic transmission is significant actions to engage and familiarize the public with wetlands' ecological and economic advantages [18].

5 Advantages and limitation of constructed wetlands

There are some benefits and limitations as to constructed wetland construction. When it comes to benefits, constructed wetlands are easily operated, low cost and maintenance green technology systems which cause habitat improvement, flood control, and wastewater treatment. Constructed wetlands are self-adaptive treatment units with less sludge production. As far as limitations are concerned, it should be noted that the function of plants in different seasons can restrict wetland performance. Moreover, wetland construction needs more area. Less phosphorus is removed because of the low phosphorus adsorption capacity of the substrate media. Furthermore, long hydraulic retention time is required and treatment efficiency for a single unit is low [19].

6 Constructed wetlands within urban context

With the social growth and improvement of life quality, contemporary people have attached more priority to the urban landscape environment, and they are inclined to live by the water, so constructed wetland is vital for solving water environment issues, and building a waterscape [20]. Moreover, since urban development and urbanization are growing, urban wetland restoration and creation is a pressing need and an important part of urban master planning [17]. Constructed wetlands are becoming beneficial assets of landscapes around the buildings, and it is possible within a few years that landscape architecture will deal with wastewater treatment, not only sanitary engineers [12]. Constructed wetlands contribute to urban design goals such as creating recreational and landscape values, wildlife habitat, and flood control and are becoming a part of the urban landscape [15].

6.1 Ecological landscape

Since ecological ideas were introduced to artificial landscapes, the constructed wetland has become an essential ecological landscape type in the city, in addition to its roles in clarifying water. The sewage treatment system established based on constructed wetlands can clarify water and the structural characteristics of wetland ecosystems and waterscapes has peculiar structure, function, and landscape effect. The constructed wetland has its natural ecological features, so it is a kind of eco-environment landscape resource combining functions and landscape, and the combination with the park system further enhances the vitality of wetlands. Planning and creation of constructed wetlands should pursue ecological ideas based on fostering the sustainable evolution of the wetland ecosystem, using modern engineering techniques and landscape design means to fulfill applicable, aesthetic, and ecological requirements, merging human activities with the natural environment, and creating a place for citizens enjoying the nature [20].

6.2 Urban wetland planning

For urban wetland planning in advance, different functions such as water purification, flood management, groundwater recharge, biodiversity enhancement, microclimate creation, and cultural and aesthetic values should be considered. Then according to city master planning, urban landscape planning, ecological and flood control planning, wetlands are classified as water purification wetlands, flood control wetlands, local microclimate adjustment wetlands, and cultural and scenic wetlands.

Three main factors should be considered for urban wetland planning: determining the primary function of proposed wetlands, their area and distribution, and the required ecological water [21].

7 Wetlands in arid areas

There is a need for more examination of the best combination of plants, soil, and water for constructed wetlands in arid areas [12]. In arid and semiarid zones, precipitation is less than evaporation, runoff coefficients, and groundwater recharge is rare. Therefore, few wetlands are supported by water supplies generated locally [11]. Many experts and policymakers believe that restored and treatment wetlands which their supply sources are urban runoff or wastewater provide tangible ecological benefits and water quality in arid areas where aquatic habitats are in danger [14].

7.1 Advantages

Constructed wetlands are cost-effective, and it is because of the use of local materials such as soil, gravel, and plants and lower overall costs, particularly for the operation phase of these treatment facilities. It is known that the climatic condition of arid regions has a positive direct effect on wetlands efficiency. Moreover, higher temperatures benefit plant metabolism and development. For instance, reed species remain green throughout the year [22].

7.2 Challenges

Irrespective of the benefits of building constructed wetlands in arid regions, there are many concerns, such as higher water losses via evapotranspiration, which could influence their potential ecosystem services. Before constructing wetlands, it is vital to identify regional plant species, and their water needs to have the optimum combination in arid areas [22]. In arid and semiarid climates, long periods with little rain stress the wetland plants, while in rainy climates, the large volume of rainwater shows the designer other challenges [8]. Moreover, the annual plant cycle should be considered. However, it may be changed because of the arid climatic condition. Furthermore, plants are more productive in a warm climate, so higher biomass production should be considered. Another challenge in building constructed wetlands, in addition to climatic conditions and water resources, is considering local, cultural, social, and religious characteristics and taboos, in addition to the climate, water resources, and onsite conditions [22]. Another issue concerning constructed wetlands is the mosquito production caused by low water quality and the coverage by inundated vegetation [11]. The best way to deal with this difficulty is to manage it through design, construction, and management phases by paying attention to slopes, hydrological patterns, and vegetation management [22]. For example, wide plant variety increases the diversity of predatory insects hunting mosquito larvae in marsh wetlands compared to open water with no vegetation cover. The flying range of adult mosquitoes is (100-300 feet) 30-90 m (although wind can extend this distance, and some species have a longer flight range), so placement of the wetland in the watershed or buffers of recreation areas or upland habitat can control the impact of mosquitoes on people in residential areas [9].

8 Constructed wetlands and landscape architecture

8.1 Water in landscape

While landscape architects are keen on identifying people's needs and interests, environmental psychology studies indicate that the natural environment appeals to people and is their preference. Kaplan's studies show that water and projects including wetlands are appealing landscapes influencing people's environmental perception [18].

8.2 Constructed wetlands in landscape architecture

Unfortunately, the majority of studies regarding constructed wetlands are about treatment function. However, a few studies have been done on landscape functions and features. These valuable constructions should be considered in any integrated planning and landscape design [23]. Purifying and treating processes, avoiding floods, and retaining and managing rainwater should not be concealed but, wherever possible, be presented openly and creatively. Also, they can be integrated into open spaces within the planning process and become part of the urban development [11]. Treating wastewater facilities are generally unattractive industrial structures. However, now there is a

recognition of wastewater treatment facilities' artistic and architectural quality significance [7]. Although the initial aim of constructed wetland is wastewater treatment, it is ógreen technologyô or ó environmentally friendly technologyô which offers recreational opportunities. Moreover, water and environmental engineers typically design constructed wetlands. However, it is landscape architecture that should contribute to the design phase [23]. The park should coordinate with its neighbouring environment in constructing an urban wetland park landscape. In integrated design, influence factors should be considered comprehensively to achieve harmony. The influence factors include internal structure, design form, and so on [24]. In terms of landscape construction, natural ecological roles and social space functions should be synthesized. For example, original biological resources and regional natural and cultural factors should be fully employed to design spaces with ecological aesthetics for social and particular activities, combine the spaces with a natural ecological environment, and reflect natural and ecological beauty. Wetland resources are used to create a water environment in the living spaces, planning green space systems and communion spaces combined to form an ecological axis and core in urban residential areas, improve the landscape environment and ecological quality of the living environment [20].

8.3 The role of landscape architecture in wetland projects

Since wetland construction is a multidisciplinary field, many experts, such as chemical engineers, aquatic biologists, ecologists, wildlife experts, landscape architects, and civil engineers, should collaborate to operate it [20]. The design fields, urban and architectural forms, should be included in the technological, analytical, and modelling processes to produce optimized and multi-functional results. Urban development directly affects surface water and groundwater by influencing water infiltration, runoff, evapotranspiration, and water quality. Landscape architects use hydrological models as a principal part of infrastructural design and development. So important is it to comprehend the scientific, technical, and aesthetical aspects of wetlands, particularly in populated urban and suburban areas, and landscape architectures by diverse educational backgrounds and experience play a significant role in this regard. Constructed wetlands should appeal to the public to be understood. Developing the functional aspects of constructed wetlands, landscape architects conduct an aesthetic appeal of them. Kaplan mentioned that effective communication is significant for a successful project. A successful wetland project, particularly in a public area, is understood by the public [7].

9 Case studies

We investigated and found many constructed wetlands built worldwide, particularly in countries with arid, semiarid, and Mediterranean with hot summer climates such as Australia and some parts of North America. The climatic classification applied is according to Koppen climate classification. We looked for wetland projects built worldwide. Although many of them were small-scale projects to treat wastewater or to investigate the efficiency of constructed wetlands to treat wastewater or stormwater and they had nothing to do with urban spaces and landscapes, some of them were located in urban spaces and nearby. We selected the second group (wetlands built in and around urban areas). Although constructed wetlands are frequently used in spaces where rainfall is frequent, we tried to find case studies located in arid zones such as Arizona, or zones with dry and hot summers such as Australia, see Fig. 1. We listed case studies located in urban spaces in the Table 1. We reviewed them to find out their supply source, function, the aim of their construction and benefits and to learn from them to take advantage of constructed wetlands to address many problems associated with water in arid, semiarid and Mediterranean regions with hot and dry summers.

According to case studies, Australia is a pioneer country in using constructed wetlands. Mainly they are used to manage and treat stormwater. In arid zones, rainfall is infrequent so constructed wetlands are mainly applied to treat wastewater or as secondary treatment facilities or as basins to infiltrate treated wastewater or stormwater into the soil to recharge the groundwater.

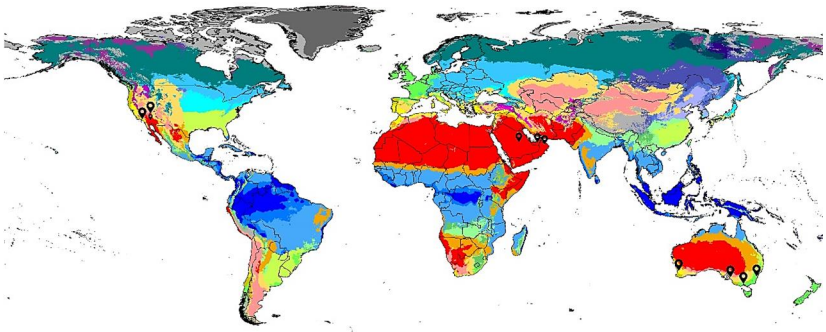


Fig. 1: Red color is the indicator of arid regions and yellow shows Mediterranean regions with hot summers such as Perth and Adelaide [11].

Table 1: Selected case studies [11].

No.	Case study	Source	Function	Location	Climate
1	Sweetwater Wetlands Park	Reclaimed water	Water treatment	Arizona	Arid Climate
2	The Riparian Preserve at Water Ranch	Reclaimed water	Groundwater Recharge	Arizona	Arid Climate
3	Tres Rios Wetlands	Treated water	Water conservation	Arizona	Arid Climate
4	Neely Ranch Riparian Preserve	Treated water	Water conservation - Groundwater recharge	Arizona	Arid Climate
5	Freestone Park	Reclaimed water	Recreational acclivities	Arizona	Arid Climate
6	Clark County Wetlands Park	Waste water- Stormwater	Waste water and stormwater management	Nevada - Las Vegas	Arid Climate
7	The Chino Creek Wetlands and Educational Park	Recycled water	Water conservation	California - Los Angeles	Mediterranean hot summer climates
8	South Los Angeles Wetlands Park	Stormwater	Water conservation	California- Los Angeles	Mediterranean hot summer climates
9	Al Ansab Wetland	Treated water	Water source- Habitat	Masghat - Oman	Arid Climate
10	Al Wathba Wetland Reserve	Water- Treated wastewater	Conservation	Abu Dhabi	Arid Climate
11	Wadi Hanifah Project	Treated wastewater	Water treatment	Riyadh, Saudi Arabia	Arid Climate
12	Oaklands Wetland and Reserve	Stormwater	Water conservation	Adelaide	Mediterranean hot summer climates
13	Greenfields Wetlands	Stormwater	Flood protection and retention - Water conservation	Adelaide	Mediterranean hot summer climates
14	Kaurna Park Wetlands	Stormwater	Water conservation	Adelaide	Mediterranean hot summer climates
15	Edinburgh Wetland	Stormwater	Water conservation	Adelaide	Mediterranean hot summer climates
16	Glade Crescent Wetland	Stormwater	Water treatment	Adelaide	Mediterranean hot summer climates
17	Warriparinga Wetlands	Stormwater	Stormwater management and treatment	Adelaide	Mediterranean hot summer climates
18	Banksia St, O'Connor Wetland	Stormwater	Stormwater management and treatment	Adelaide	Mediterranean hot summer climates
19	The Valley Ponds, Gungahlin	Stormwater	Stormwater management and treatment	Canberra	Mediterranean hot summer climates
20	Norgrove Park	Stormwater	Stormwater management and treatment	Canberra	Mediterranean hot summer climates
21	Tirhatuan Wetlands, East link project	Stormwater	Stormwater management and treatment	Melbourne	Oceanic climate
22	Tom Beteman Wetlands	Stormwater	Stormwater management and treatment	Perth	Mediterranean hot summer climates
23	Wharf Street Wetland	Stormwater	Stormwater management and treatment	Perth	Mediterranean hot summer climates
24	Liege Street Wetland	Stormwater	Stormwater management and treatment	Perth	Mediterranean hot summer climates
25	Tom Bateman constructed wetland	Stormwater	Stormwater management and treatment	Perth	Mediterranean hot summer climates

Some mentioned projects have similar functions so we described some of the listed Constructed wetlands to explain this artificial ecosystem more and to become more familiar with different types of constructed wetlands and their services.

8.1 The Sweetwater Wetlands Park, City of Tucson, Arizona, USA

It consists of a series of basins which functions as a water treatment structure and restores the local aquifer. In times of high water use, the reclaimed water is recovered to irrigate public areas. The Sweetwater Wetlands also act as a public park, where visitors can experience wildlife in an urban environment and become better familiar with ecosystems and water resources [11].

Fig. 2: The Sweetwater Wetlands Park [11].

8.2 The South Los Angeles Wetland Park, USA

This project contains two main parts: The first part is a pre-treatment stormwater system and constructed wetlands, and the second part is a recreation space functioning as educational and community facilities. While this system enhances stormwater quality, offering many recreational and social services [11].

Fig. 3: Los Angeles wetland park [11].

8.3 The Riparian Preserve at Water Ranch in Gilbert Arizona, USA

The main function of this project is to infiltrate treated wastewater into the soil to increase the groundwater level. Moreover, the project has attracted many strange and native birds and now is a suitable place for birdwatching and recreational activities.

Fig. 4: Riparian Preserve at Water Ranch in Gilbert Arizona [11].

8.4 Oaklands Wetland, Marion, Australia

One of the immediate goals of the wetland is to supply clean water to more than 30 local reserves and other open areas. It is dwelling to a variety of wildlife, providing a place for education, examination, and studies into wetlands and showcasing the site's stormwater reuse plan [11].

Fig. 5: Oaklands Wetland, Marion, Australia [11].

8.5 Glade Crescent Wetland, Marion, Australia

The primary aim of this project is to improve the water quality. However, it enhances wildlife habitat, recreational and educational opportunities at the same time [11].

Fig. 6: Glade Crescent Wetland, Marion, Australia [11].

8.6 Warriparinga Wetlands, Marion, Australia

The project is a series of ponds slowing the water and infiltrating it into the soil. It is a place suitable to sit, relax, and enjoy natural environment and sounds.

Fig. 7: Warriparinga Wetlands, Marion, Australia [11].

8.7 Sydney Park wetlands, Sydney, Australia

It is a large-scale project in order to treat stormwater and runoff from surrounding area. This project makes a great contribution to water reuse by capturing and treating 850 *million litters* of stormwater yearly. At the same time, it acts as a recreational space in a high-density inner-city area, improving wildlife habitat and native plants [11].

Fig. 8: Sydney Park wetlands, Sydney, Australia [11].

8.8 Banksia St, OôConnor Wetland, Australia

The main goal of this project is to improve water quality by trapping nitrogen, phosphorous, and sediments. At the same time, it increases urban biodiversity by planting native plants.

Fig. 9: Banksia St, O'Connor Wetland [11].

8.9 The Valley Ponds, Gungahlin, Australia

This project plays a role in enhancing the quality of stormwater before it joins Ginninderra Creek. In addition to recreational and educational opportunities, it improves urban biodiversity, and irrigation system by stormwater reuse.

Fig. 10: The Valley Ponds, Gungahlin, Australia [11].

8.10 Norgrove Park, Canberra, Australia

It seems that it is planned to have the double objective of treating flows from the outer stormwater catchment and treating recirculated discharges from the open water pond between the wetland and Eyre Street. It is also clear that the wetland has landscape purposes ï it contains boardwalks, a viewing area, and formal landscaped edges. The wetland provides habitat value, but it is unclear whether this was a vital intent that drove its design [11].

Fig. 11: Norgrove Park [11].

8.11 Tirhatuan Wetlands, East link project, Melbourne, Australia

It is a transport infrastructure located in Melbourne, Australia. It is a combination of green and manufactured infrastructure. It is worth mentioning that roughly 60 wetlands are constructed to treat and preserve wastewater streaming from roads and surrounding areas. Moreover, they act as a habitat for wildlife and recreational places for cyclists and pedestrians [24].

Fig. 12: Tirhatuan Wetlands, East link project [11].

8.12 Wadi Hanifah Project, Riyadh, Saudi Arabia.

This project is a bioremediation structure, which is a combination of automatic and biological procedures. Urban wastewater is diverted to a bioremediation facility, which also serves as a public park. Provincial water cycling programs are typically legislated and employed by water authorities and related engineering services. However, this project indicates that the transformation toward multi-objective optimization at the regional and urban scales offers designers and planners the option to reconsider emergent infrastructural landscapes as a socio-cultural, economic, and ecological extension of the city. This project is also an example of a team of multinational professionals specializing in ecology, river hydrology, hydrogeology, hydraulics, infrastructure, transportation, landscape architecture, architecture, land use planning, urban management, economics, communications, and data management. Moreover, this project provides environmental improvement and improves people's quality of life and economy by enhancing tourism and employment possibilities [7].

Fig. 13: Wadi Hanifah [11].

9 Extracted patterns

One of the main aims of this study was to extract simplified patterns of constructed wetlands. According to examining theories and different types of constructed wetlands and studying case studies around the world we extract simple patterns. They can play a substantial role in classifying constructed wetlands and introducing them to specialists and the public. The first one is suitable for sites near the water bodies, such as rivers. This pattern is applicable in all kinds of climates. Unfortunately, many factories or industrial developments release their effluent into the river without treatment. Administrators can apply this pattern of constructed wetlands to treat polluted water. And then treated water can be released into the nature.

The second one, is especially advantageous for arid and semi-arid regions where the water resources are limited. Urban wastewater, treated wastewater, and stormwater resulted from rainfalls can be released into the series of ponds to infiltrate into the soil and increase the groundwater level.

The third one is suitable for urban spaces. These ponds can be filled with urban wastewater or stormwater received from urban infrastructures. The water can be treated along the way and then released to the urban wastewater infrastructures.

The last one is suitable for populated urban areas. These wetlands can act like rain gardens. Runoff resulted from rainfalls can be collected, treated and infiltrated into the grounds. All of these patterns create wildlife habitat, recreational and educational opportunities, as well.

Table 2: Extracted patterns [11].

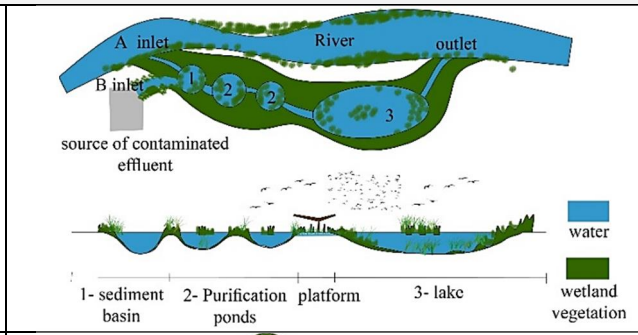
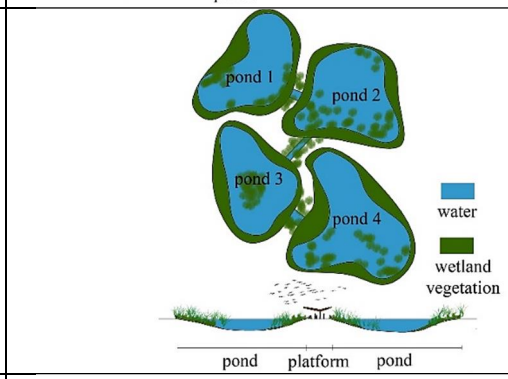
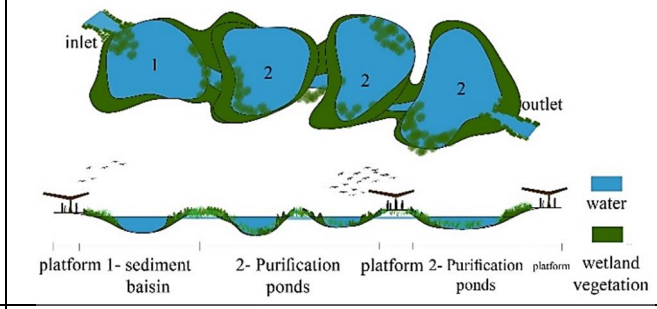
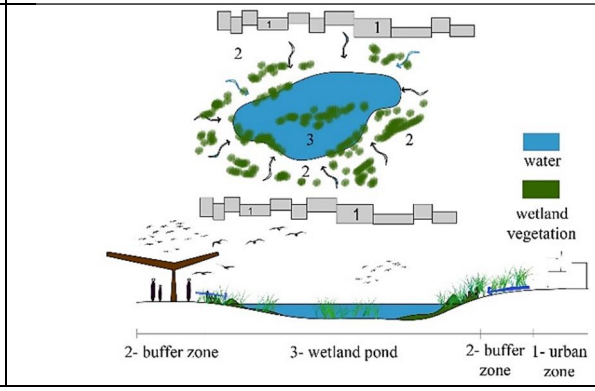
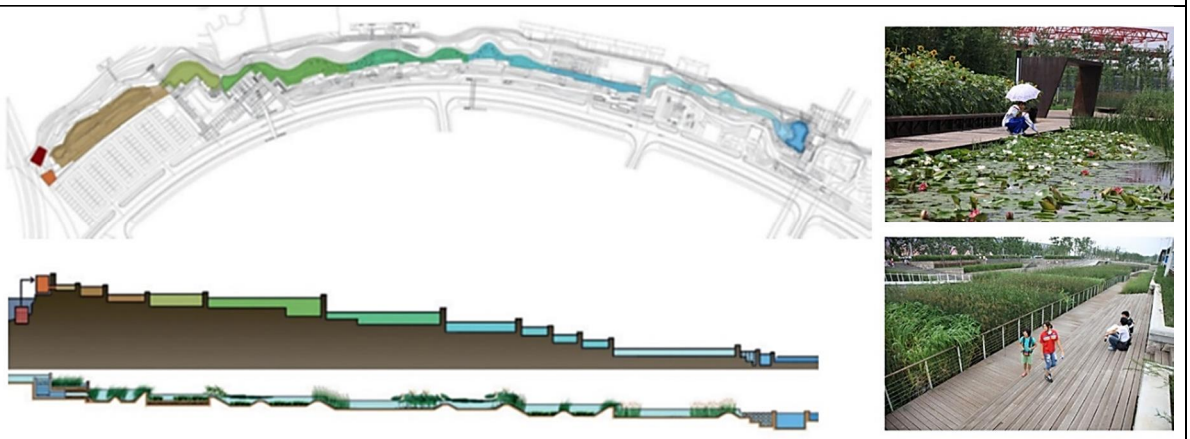
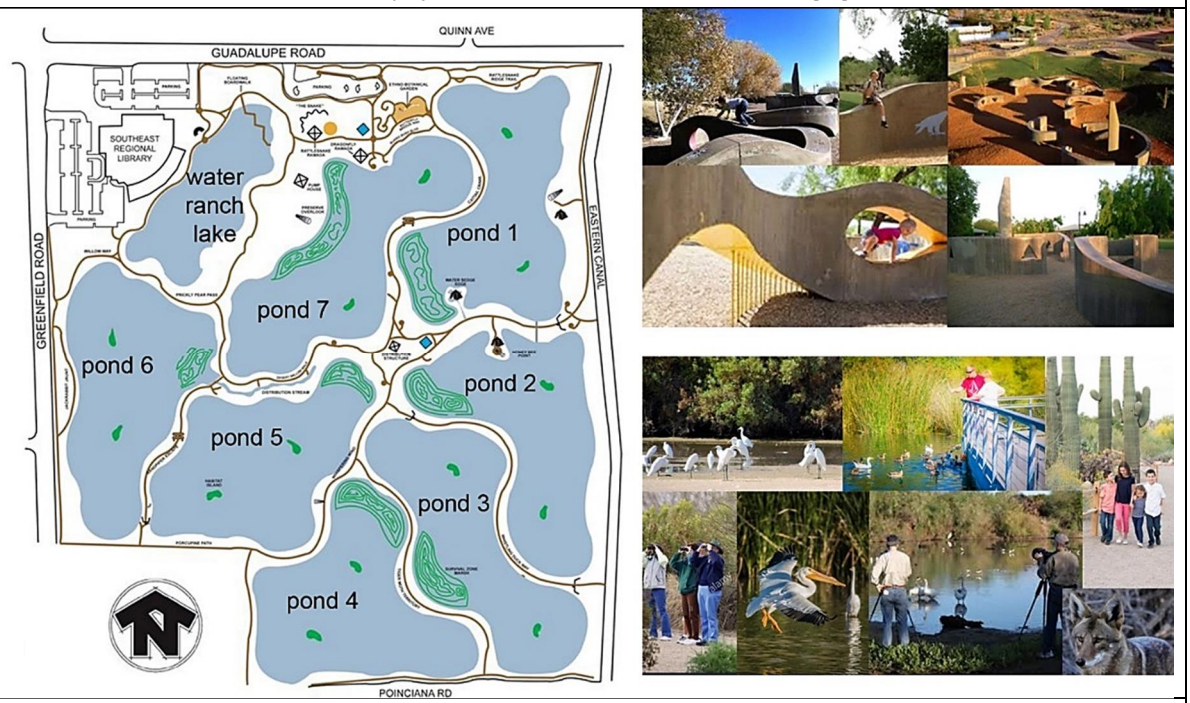
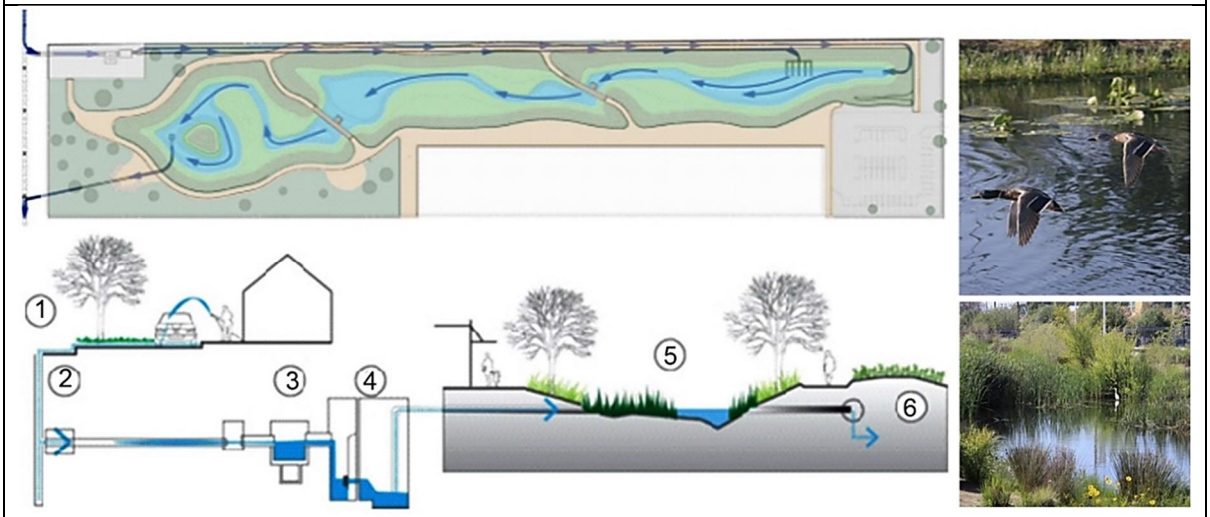
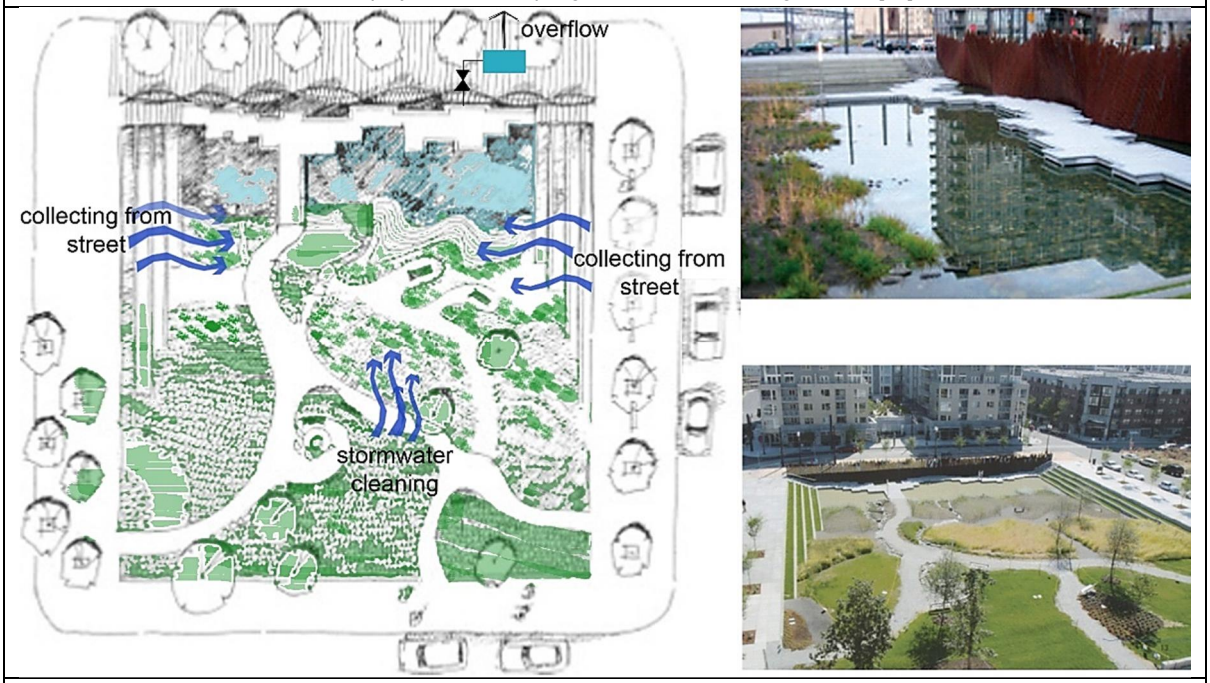
	Pattern	Function
1		• Purifying the wastewater or polluted water resulted from industrial activities and discharging it into water resources. • Reducing the possibility of flooding. • Creating wildlife habitat, educational and recreational opportunity.
2		• Treating wastewater, and stormwater and using it for irrigation and charging groundwater resources. • Creating wildlife habitat, educational, and recreation opportunities.
3		• Purifying effluent and stormwater to infiltrate it into the ground or urban system. • Creating wildlife habitat, educational, and recreation opportunities.
4		• Collecting and treating runoff and wastewater and infiltrating it into water resources. • Redusing the danger of flooding in urban developments. • Creating wildlife habitat, educational, and recreation opportunities.

Table 3: Similar projects.

Pattern 1
Similar project: Houtan Park, Shanghai, China [11]

Functions
• The river water enters on the left and travels through a series of cells that target particular contaminants. There are 15 wetland compartments in the treatment sequence. • The landscape architect has achieved the technical outcome (water purification and flood control) while simultaneously providing scenic diversity. • Education is a cultural ecosystem service.
Pattern 2
Similar project: Water Ranch, Gilbert, Arizona, USA [11]

Functions
• Recharging groundwater • Creating urban habitats for birds, bats, and other fauna • Functionning as an educational as well as a recreational center • At nearly seventy acres, the recharge ponds restore significant lost habitat. • Xeriscape design and botanic-garden exhibits of rare Sonoran plant communities make this an educational and recreational center. • Reclaimed water undergoes final purification by the working of marsh plants, microorganisms, and solar energy.

Pattern 3
Similar project: South Los Angeles Wetland Park, USA [11]

Functions
• Water is collected from the watershed and is entered the subsurface stormwater system. • Collected wastewater travell through basins. • Oil, grease, and trash are drived from the fllow. • Extra water is discharged back into the stormwater system after treatment.
Pattern 4
Simillar project: Tanner Springs Park, Portland, Oregon, USA [11]

Functions
• Rainwater is gathered and filtered through a wetland system. • An orthogonal path floats over the wetlands, bringing urban residents an intimate connection with these natural hydrological cycles. • Stormwater runoff is absorbed and cleansed before finally collecting in the open water pool.

10 Conclusion

Although there are a significant number of constructed wetlands in arid, semiarid, and Mediterranean regions, such as Australia and America, which proves the feasibility of constructing wetlands in these areas, they need to be recognized and implemented, particularly in developing

countries. Constructed wetlands are practical solutions to water management and maintenance, particularly in regions dealing with maintenance and shortage of water resources. Furthermore, many studies have explained and surveyed technological aspects of constructed wetlands, and a few have considered aesthetic features. This paper introduces constructed wetlands as a multifunctional construction in urban areas. Moreover, identified case studies are specific evidence to confirm that it is feasible and beneficial to construct different types of artificial wetlands with different purposes in arid, semiarid, and Mediterranean climates. According to the case studies, we found out that in arid and semiarid regions, constructed wetlands are mainly constructed to treat wastewater and in some cases their supply sorces are treated wastewater. They can function as a secondary treatment facility in arban areas while providing other pssibilities such as wildlife habitat and recreational areas. Moreover, treated wastewater can be infiltrated into the soil to recharge groundwater gradually. Also, the number of case studies show that Australia is one of the pioneer countries in using constructed wetlands. Given that building constructed wetland in regions such as Perth and Adeline is applicable, using this artificial ecosystem is feasible in regions with simillar climate. It is worth mentioning that the supply source for these wetlands mainly is stormwater. Finally, extracted patterns according to case studies pave the way for designers, other specialists, and the public to become more familiar with these valuable systems and apply them in urban areas for different purposes.

References

[1] ZAPATER PEREYRA, M.: Design and development of two novel constructed wetlands: the duplex-constructed wetland and the constructed wetroof. The Netherlands, CRC Press/Balkema, 2015.
[2] SIMMERS, I.: Understanding water in a dry environment: hydrological processes in arid and semi-arid zones. Lisse, Exton, Pa: A. A. Balkema, 2003.
[3] WHEATER, H. - SOROOSHIAN, S. - SHARMA, K.: Hydrological modelling in arid and semi-arid areas. Cambridge, New York, Cambridge University Press, 2008.
[4] DE BAZÚA, D. - DEL CARMEN, M.: Artificial or constructed wetlands: a suitable technology for sustainable water management. Boca Raton, CRC Press, Taylor & Francis Group, CRC Press is an imprint of the Taylor & Francis Group, an informa business, 2018.
[5] AL-SAMRRAIE, L. - ALRAWASHDEH, K. - AL-ISSA, H. - SHAKHATREH, S. - HUSSIEN, A. - QASEM, I.: Improve Heavy Metals and Pollutants Removal from the Pharmaceuticals Wastewater Using Washingtonia Robusta: New Extraction Process. Civil and Environmental Engineering, Vol. 18, Iss. 1, 2022, pp. 340-349, doi: https://doi.org/10.2478/cee-2022-0032.
[6] BREARS, R.: Blue and green cities: the role of blue-green infrastructure in managing urban water resources. London, Palgrave Macmillan, 2018.
[7] MARGOLIS, L. - CHAOUNI, A. - DREISEITL, H.: Out of Water: design solutions for arid regions. Basel, Birkhäuser, 2015.
[8] AUSTIN, G. - Kongjian, Y.: Constructed wetlands and sustainable development. London, New York, Routledge, Taylor & Francis Group, 2016.
[9] AUSTIN, G.: Green infrastructure for landscape planning: integrating human and natural systems. Abingdon, Oxon, Routledge, 2014.
[10] MAHMOUD GABER, R.: Implementation of Constructed Wetlands Landscape Design. Urban Research, 2020, pp. 80-101.
[11] LACHINANI, M.: Urban Constructed Wetlands in Arid and Semi-arid Zones. Master Thesis. Architecture and Urban Planning Department. Shahid Beheshti University, 2019.
[12] SORVING, K. - THOMPSON, J.: Susainable landscape construction a guide to green building outdoors. Island press, 2018.
[13] DUNNETT, N. - CLAYDEN, A.: Rain gardens: managing water sustainably in the garden and designed landscape. Portland, or: Timber Press, 2007.
[14] SUTULA, M. - STEIN, E.: Habitat Value of Natural and Constructed Wetlands Used to Treat Urban Runoff: A Literature Review. California, 2003.
[15] CAMPBELL, C. - Ogden, M.: Constructed wetlands in the sustainable landscape. New York, Wiley, 1999.
[16] HARRINGTON, R. - CARROL, P. - CARTY, A. - KEOHANE, J. - RYDER, C.: Integrated Constructed Wetlands: concept, design, site evaluation and performance. Int. J. Water, 2007, pp. 243-256.
[17] JIA, H. - MAA, H. ï WEI, M.: Urban wetland planning: A case study in the Beijing central region. Ecological Complexity, 2011, pp. 213-221.
[18] LEPAGE, B.: Wetlands: integrating multidisciplinary concepts. Dordrecht, New York, Springer, 2011.

[19] WISHWAKARMA, S. - DHARMENDRA, A.: Critical Review on Economical and Sustainable Solutions for Wastewater Treatment Using Constructed Wetland. Civil and Environmental Engineering Reports, 2022, pp. 260-284.
[20] LIN, B.: Planning and ecological landscape design of urban constructed wetland. Landscape research, 2014, pp. 41-49.
[21] HAIFENG, J. - HONGTAO, M. - MINGJIE, W.: Urban wetland planning: A case study in the Beijing central region. Ecological Complexity, 2011, pp. 213-221.
[22] STEFANAKIS, A.: Constructed Wetlands for Sustainable Wastewater Treatment in Hot and Arid Climates: Opportunities, Challenges and Case Studies in the Middle East. Water, 2020, 1665.
[23] ZHAO, X. - ZHAO, Y. - WANG, J. - MENG, X. - ZHANG, B. - ZHANG, R. - WANG, W.: Design of a novel constructed treatment wetland system with consideration of ambient landscape. International Journal of Environmental Studies, 2015, pp. 146-153.
[24] WENJING, l. - QI, l.: Ecological landscape design of urban wetland park: a case study of the aixi lake wetland park in Nanchang city. landscape research, 2015, pp. 57-60.
[25] KHAN SEFID, M.: Infrastructure as landscape architecture. Manzar, 2016, pp. 78-89.