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Highlighting the Potentials of Gene C. Reid Park, Tucson, AZ, as a Tool for Flash Flooding Control

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Abstract

This study investigates the effectiveness of Gene C. Reid Park in Tucson, AZ, for managing flash flooding, comparing it with Ormsby and Santa Rosa Parks also in Tucson, AZ. Flash flooding poses a significant environmental risk in Tucson, AZ, leading to extensive damage and fatalities. The study employed purposive sampling and a mixed-method approach, which included case studies of the parks, the quadrant method, and the rational model used to calculate the proportions of vegetation and impervious surfaces and estimate runoff for each location. Data analysis was conducted using regression analysis. Gene C. Reid Park showed a notably lower runoff rate of 310.65 ft^3/s, in contrast to Santa Rosa Park's 1963.5 ft^3/s and Ormsby Park's 1859.07 ft^3/s. The lower runoff rate observed in Gene C. Reid Park is due to its abundant vegetation and sufficient park facilities, demonstrating its effectiveness as a "sponge" during flash flooding. Results indicate that urban parks designed for flood mitigation should prioritize increasing green spaces and incorporating features that effectively absorb floodwaters. This study contributes to a better understanding of the roles of urban parks in flood management and offers valuable insights for sustainable urban planning in Tucson and other cities facing similar challenges.

Keywords

Flash Flooding, Flood Adaptation, Impervious Surfaces, Quadrant Method

1. Introduction

1.1. The Challenge of Flash Flooding in Tucson, AZ

Flash flooding, defined as a rapid increase in water discharge at a specific location [1], is a common environmental hazard in Tucson, AZ, particularly during the monsoon season. Such floods contribute to environmental damage and account for over 5,000 annual deaths in the United States [1]. The Federal Emergency Management Agency (FEMA) reported that 44 of the 2016 major disaster declarations were related to flash floods [2]. Despite Tucson implementing flood control measures such as urban parks after the devastating 1983 flash flood, which resulted in an estimated $105.7 million in damages and 12 lives lost, flooding remains a significant social issue [3], accounting for 49% of extreme storm events in the Tucson area over the past 21 years [4].

1.2. The Role of Urban Parks in Flood Control

Urban parks are valuable tools for flood control [5]. Their effectiveness in managing flooding within cities has been widely recognized. By designing and managing them as interconnected green spaces, cities can significantly reduce flooding and lower stormwater management costs [6]. Research shows that parks can substantially decrease potential runoff by 2,494 cubic meters per hectare, with economic benefits amounting to three-quarters of a city's green space maintenance costs. [6] especially when they are designed to function like sponges.

A sponge park is a green area designed to replicate natural processes for managing stormwater and alleviating flooding [7]. They play a crucial role in the larger "sponge city" initiative, which seeks to create more durable and sustainable urban settings, and resilience against climate change [8]. These parks meet water management objectives through features like absorbent materials, diverse vegetation, swales, constructed wetlands and ponds, drainage tree pits, and underground infrastructure. [9] Their advantages include flood prevention, enhanced water quality, replenishment of groundwater, and reduction of the impacts of heat islands [10] in a desert climate like Tucson's, where rainfall events can be intense and soils infiltrate slowly; such features are essential for effective flood mitigation.

1.3. The Effect of Vegetation and Impervious Surfaces on Runoff

Vegetation significantly impacts surface water runoff by increasing the water retention capacity of hydrological systems and lowering peak flows that can lead to flooding [11]. Enhanced vegetation results in improved rainwater absorption and reduced surface runoff [12]. Areas rich in vegetation are effective at capturing more rainfall, leading to lower runoff levels. Different types and sizes of trees play a significant role in absorbing excess rainwater, which aids in minimizing runoff and mitigating flood risks [13]. Taller, sturdier, and denser tree trunks offer greater resistance to the flow of water. Expanding green areas is essential for enhancing resilience against climate change [13]. On the other hand, surfaces that do not allow water to pass through, like rooftops, asphalt, concrete roads, and parking lots, block water from infiltrating the soil [14]. As urban areas expand, these impermeable surfaces frequently take the place of absorbent soil, greatly decreasing the amount of water that can be absorbed into the ground compared to natural, plant-covered landscapes [14].

1.4. Gap in Literature

While current studies address the overall impact of urban parks on controlling flash floods and examine how park characteristics affect surface runoff, there is a significant absence of detailed information regarding the influence of urban parks in Tucson on managing flash floods. This deficiency is particularly important considering Tucson's distinct desert climate, regular monsoon seasons, and hydrologic soil types, which heighten the potential for runoff. This research aims to address this deficiency by performing case studies on Gene C. Reid, Ormsby, and Santa Rosa Parks, evaluating their percentages of vegetation and impervious surfaces, and utilizing the rational model to determine their runoff rates.

2. Materials and Methods

2.1. Study Area

Tucson, Arizona's second-largest city, spans 226.71 square miles and has a metropolitan population of 980,26335 [3]. It sits on an alluvial plain at an elevation of approximately 2,400 feet and is surrounded by five mountain ranges [3]. The soil mainly consists of Group C and D hydrologic types, characterized by slow infiltration rates and a high potential for runoff [15]. The vegetation is typical of the Sonoran Desert, with the saguaro cactus as the dominant plant [16]. Tucson features a desert climate (Köppen classification BWh), characterized by hot summers and a monsoon season from June to September [17].

2.2. Procedure

A mixed-methods approach was employed in this study, combining case studies of the selected parks with measurements of vegetation and impervious surfaces using the quadrant method. Purposive sampling was used. The selection of four quadrants per park was a decision, balancing the need for a representative sample with the logistical constraints of a manual, time-intensive procedure. While a larger sample size would ideally reduce sampling error, a sample of four quadrants was deemed sufficient to capture the general trends in vegetation coverage and impervious surfaces.

2.2.1. The Quadrant Method

This technique involved dividing a map of each park into eight equal-sized quadrats, each measuring 1.53 in. by 1.53 in. (approximately 2.334 in^2) (**Figure 1**).

The sizes of the quadrants were determined by the overall size of the park and the number of quadrants needed to cover the entire area. Four quadrats were randomly chosen for measurement. To find the proportion of green space in each sampled quadrant, vertical and horizontal measurements were taken along both axes of the quadrant with a ruler. The following formula was used to calculate the green area of the park.

$$\text{PGS} = \text{GSA}\ (\text{in}^2)/\text{TQA}(2.334\text{in}^2) \times 100$$

$$\text{PIS TQA-PGS} \times 100$$

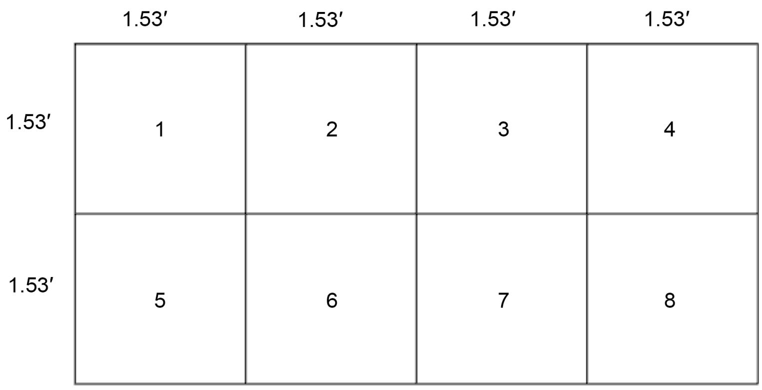

Figure 1. Quadrants source: Fieldwork.

where:

PGS = Proportion of Green Spaces 54

TQA = Total Quadrant Area

PIS = Proportion of Impervious Surfaces

The proportion of Green Spaces for the entire park was calculated by averaging the PGS for the four sampled quadrats [(Q1 + Q2 + Q3 + Q4)/4].

Quadrant measurements on the map were not converted to real-world areas; instead, the calculations were purely proportional, providing a relative measure of vegetation and impervious surfaces within the sampled quadrants. This clarifies that the study's conclusions are based on proportional relationships observed within the sampled quadrats. Authors' calculations reflect the ratio of vegetation in relative to each other, allowing for a comparative analysis across different parks. The use of a 15-meter pixel size from Google Earth further reinforces that the study is based on a pixel-by-pixel, proportional assessment, rather than a conversion to real-world area measurements.

A statistically significant negative correlation was observed between the percentage of green space and stormwater runoff (R2 = 0.99, $p < 0.01$), indicating that parks with greater vegetation coverage, such as Gene C. Reid Park (62.49% green space), consistently exhibited lower runoff rates (310.65 ft^2/s) compared to parks with limited green spaces, such as Santa Rosa (8.24% green space, 1963.5 ft^2/s) and Ormsby (5.69% green space, 1859.07 ft^2/s)

2.2.2. Determination of Runoff

The rational model was used to estimate the direct runoff from the sampled parks after a precipitation event. The rational model is expressed as:

$Qp = 0.002778CiA$

where:

Qp = peak discharge in ft^3/s

C = a dimensionless runoff coefficient representing a ratio of runoff to rainfall (0.20) (Arizona Department of Transportation, 2014)

i = the average rainfall intensity in inches per hour (2.5 mm/hr.) (National Weather Service, 2025)

A = the drainage area of the catchment or watershed of interest in acres

While this study employs the Rational Model to estimate runoff, it is crucial to acknowledge the inherent limitations and simplifications of this approach. The model assumes a uniform rainfall distribution and a simplified representation of infiltration dynamics, using a single runoff coefficient (C). This is particularly relevant for the complex, low-permeability Group C/D desert soils found in Tucson, where infiltration is highly variable. Rather than a deficit, this choice of model is a deliberate methodological decision that highlights a key aspect of our study. By employing a straightforward, well-established model, our research provides a foundational assessment of runoff potential based on measurable land cover data (vegetation and impervious surfaces) that other, more complex models often require. Our findings offer a baseline for future, more intricate hydrological modeling in arid urban environments. This work establishes a valuable first-pass characterization of runoff dynamics in this specific region, providing a critical starting point for understanding how vegetation and impervious surfaces interact to influence hydrological processes in this unique urban desert ecosystem.

3. Findings

3.1. Case Studies

3.1.1. Gene C. Reid

Description: The park spans 131 acres [18] and is L-shaped, as illustrated in Figure 2 below.

Figure 2. Site Plan, Gene. C. Reid Park. Source: City of Tucson, 2017.

Amenities at the park include a lake (Figure 3) and a baseball court (Figure 4). Others include picnic centers, outdoor pools, and a golf course.

3.1.2. Santa Rosa Park

Description: The park covers 4.84 acres [19] and is square-shaped, as shown in Figure 5 below.

Amenities at the park include picnic areas (Figure 6), a volleyball court, soccer fields, and playgrounds.

Figure 3. Lake. Source: Kathryn Vercil.

Figure 4. Baseball Court. Source: Kathryn Vercil.

Figure 5. Site Plan. Source: Santa Rosa Park.

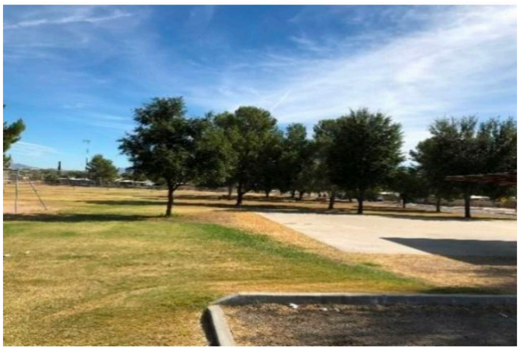

Figure 6. Picnic area. Source: Fieldwork.

3.1.3. Ormsby Park

Description: The park has a size of 4.84 acres [20] is rectangular shaped as shown in Figure 7 below

Figure 7. Ormsby Park. **Source**: Rean, 2016.

Amenities at the park include picnic areas, a basketball court (Figure 8), a volleyball court (Figure 9), and a picnic area. Other amenities include a softball court, picnic center, and ramadas.

Figure 8. Basketball Court. Source: **Rean.**

Figure 9. Volleyball Court **Source:** Rean.

3.1.4. Results of Land Cover and Runoff Rates

The study revealed significant differences in runoff rates among the parks. Gene C. Reid Park exhibited a runoff rate of 310.65 ft^3/s as shown in Table 1.

Table 1. Park land cover and calculated runoff rates.

Park Name	Proportion of Green Spaces (%)	Proportion of Impervious Surfaces (%)	Calculated Runoff Rate (ft^3/s)
Gene C. Reid	62.49	37.51	310.65
Ormsby	8.24	91.76	1859.07
Santa Rosa	5.69	94.31	1963.5

The reduced runoff is linked to the abundant vegetation present in the park, which consists of 62.49% green space, along with park facilities such as lakes, outdoor swimming pools, and a golf course that act as stormwater storage areas. Santa Rosa Park has a runoff rate of 1963.5 ft^3/s and comprises 5.69% vegetation alongside 94.31% impervious surfaces. While it has an 8,000-square-foot skate park that could theoretically be utilized for stormwater management, it is not currently being used in that way. Ormsby Park, on the other hand, records a runoff rate of 1859.07 ft^3/s, with 8.24% vegetation and 91.76% impervious surfaces. This park lacks dedicated facilities for flood control.

4. Discussion

The study's findings show that flood mitigation in parks heavily depends on factors like the percentage of vegetation and park facilities that can be designed to act as a sponge. More vegetation directly relates to a park's ability to manage flooding. For instance, Gene C. Reid Park, which features 62.49% vegetation and 37.51% impervious areas, experiences a runoff rate of 310.65 ft^3/s. In contrast, Ormsby Park has much lower vegetation at 8.24% and a greater share of impervious surfaces at 91.76%, leading to a runoff rate of 1,859.07 ft^3/s. Likewise, Santa Rosa Park, characterized by 5.69% vegetation and 94.31% impervious surfaces, has a runoff rate of 1963.5 ft^3/s. These figures indicate that Gene C. Reid Park has a greater capacity to manage floodwater compared to Santa Rosa and Ormsby Parks.

The study also found a positive correlation between runoff rates and impervious surfaces, as well as a weak negative correlation with green spaces. This suggests that the percentage of impervious surfaces has a significant impact on a park's ability to mitigate flash floods. Specifically, higher proportions of impervious surfaces are associated with increased runoff rates, while more green spaces tend to reduce runoff rates.

Beyond vegetation, having specific amenities is crucial for flood control. Gene C. Reid Park features a lake, outdoor pools, and a golf course, all of which serve as stormwater reservoirs. Santa Rosa Park has an 8,000-square-foot skate park that could potentially hold stormwater, but it is not used for that purpose at present. Conversely, Ormsby Park lacks facilities designed to manage flooding. This demonstrates that parks need proper infrastructure to control floods effectively.

5. Conclusion

The study finds that Gene C. Reid Park effectively controls flooding due to its abundant vegetation and water-absorbing features, which work together to reduce storm runoff. The Park can evolve into a “sponge park” with minimal financial input, effectively soaking up stormwater and consequently decreasing flood hazards. This study enhances comprehension of how urban parks contribute to flood management and offers essential insights for sustainable city planning in Tucson and other municipalities facing comparable issues.

6. Recommendations

To enhance flood mitigation efforts, the author recommends that urban parks prioritize landscape designs that focus on expanding park size, increasing the proportion of green spaces, and incorporating amenities capable of absorbing water during flooding. Consistent efforts should be made to maintain and maximize the proportion of green spaces within parks. Furthermore, the overall percentage of impervious cover on park sites should ideally be kept below 10%. Green spaces play a crucial role in enhancing essential ecosystem services through nature-based solutions, thereby increasing soil storage and infiltration, and reducing stormwater runoff. By planning and managing urban parks as part of an interconnected green space network, cities can effectively reduce flooding and lower stormwater management costs.

Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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