# HEAVY METAL POLLUTANT LOAD FROM A MAJOR HIGHWAY RUNOFF - SULAIMANI CITY

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doi:10.23918/iec2018.08

## ABSTRACT

First flush is the first rainfall after a dry season, which washes out several months of contaminant buildup. Surface runoff from highways can be considered as a critical nonpoint source of water resources heavy metals pollution. In this study, samples of rainfall runoff were collected after the first and second rainfall from a major highway in Sulaimani City and tested for expected Zinc(Zn), Copper (Cu) and Lead (Pb) heavy metals pollutants. Results revealed levels of heavy metals pollution in the highway runoff from the first and second rainfalls which can be considered as heavy metal pollution source for receiving water bodies. After first flush, average test results of heavy metals pollutants were 0.062 part per million (ppm), 0.075 ppm and 0.051 ppm for Zn, Cu and Pb respectively. Low Impact Development (LID) practices found to be a new sustainable stormwater management. Though, the removal of heavy metals from water is costly, consequently, a set of LID techniques are recommended for stormwater treatment as cost effective stormwater treatment for streets and highway runoff treatment. Furthermore, as Sulaimani city uses combined (sanitary and stormwater) sewer system, LID systems can reduce flooding, which makes the treatment of combined wastewater more feasible, improving the quality of receiving water bodies.

**Keywords:** Sulaimani, Runoff, LID Systems, Heavy Metals, Bioretention Basins.

## 1. INTRODUCTION

Roadways and streets as the non-point source of pollution are considered as one of the largest sources of environmental heavy metals pollution. Zinc (Zn), Copper (Cu), and Lead (Pb) are most common heavy metals released from on road automobiles parts wearing and tearing [1]. However, Lead concentrations have been reduced due to prohibiting leaded gasoline worldwide, but it is still might be used as an octane booster additive to gasoline in some developing countries [2].

While rainfall runoff moves on ground, it carries away natural and manmade pollutants, in conclusion depositing them into downstream water bodies such as lakes, rivers and ground water [3]. Cu, Pb and Zn were found in almost all urban street and highway stormwater runoff in concentrations that would violate the U.S. Environmental Protection Agency (EPA) for water quality criteria, seldom cadmium and mercury were also present above those standards [4]. Car brake pads release Cu, while tire wear releases Zn, also motor oil and fuel burn or leakage can become another pollution sources to the environment [1,5]. Chronic exposure to heavy metals can result in many human disorders and increases cancer risks [6, 7, 8].

Since the 1970s, the non-point sources of pollutions are controlled using Best Management Practices (BMPs) that are designed to limit the quantity of pollutants released into a waterbody. BMPs, are structures, tools, or processes for removing or reducing stormwater runoff pollutants from reaching downstream receiving water bodies [5]. From the 1990s, EPA agencies have started to assess and adopt the local stormwater management plans through the adoption of local BMPs replicating the natural filtering and pollutants removals from storm runoffs which are known as Low Impact Development (LID) [5,9]. LID is an on-site interrupting and delaying of the runoff flow on pervious areas, LID utilizes the possible biological, chemical and physical processes that are found in the natural environment to maintain or restore the watershed's hydrologic and ecological functions [2,10].

The first half inch rainfall after the dry season (first flush) is considered the more hazardous and contaminated runoff, which washes away about 80% of the total mass of pollutants built-up on roads and streets [11]. Sediment particles are more critical for pollutants adsorption and transporting with storm runoff [2,12]. Furthermore, sediments deposited in lakes and rivers impair the water quality and degrade the ecosystem of the water bodies, stormwater runoff contributes about 70 % of the pollution in rivers and lakes [10].

Urbanization and elevated number of automobiles in the Kurdistan Region of Iraq are contributed to the deterioration of the environment and water resources quality [13]. The objective of this study is to measure and estimate the heavy metal pollution involvement of streets to water resources in Sulaimani City which impair the quality of water in the area. Finally, from literature, the author suggested some effective methods to reduce and eliminate the impacts of highways and roads pollutants on water resources downstream of Sulaimani City by selecting sustainable LID practices for the stormwater runoff management.

## 2. LOW IMPACT DEVELOPMENT (LID)

LID is the on-site interrupting and delaying the runoff flow on pervious areas such as grassed or graveled swales and bioretention basins. LID gives the water a chance to infiltrate and also the removal of pollutants (settled, filtered and up-taken by plants), consequently reduce amount of runoff at the outlet and improve water quality as well [3,9]. LID is the stormwater management at the site or at the pollution source, using treatment and volume control practices for storm events at lower costs of construction [14]. The LID practices execution recharges groundwater, and decreases soil erosion which consequently reduces pollutant transport due to their attachments to the sediment particles. There are different types of LID systems such as bioretention (rain garden), lawn swales (vegetated channel), vegetated rooftops, rain harvesting (rain barrels), cisterns, vegetated filter strips and permeable pavements. Perhaps, the most practical and popular types are the following:

## 2.1. SWALES

Swales or Bioswales are small trenches usually constructed in the road medians or beside streets which convey and infiltrate the collected rainwater from roads and sidewalks (Figure 1). There are two types of swales rock surface infiltration swales and grass surface swales, which the bed and sides of bioswales channel covered with native grasses. Swales have underneath perforated pipe to convey the filtered water to the stormwater sewer pipe network. Also they usually have inlet risers to drain the excess stormwater overflow beyond the infiltration capacity of the swales. Continuous street curbstone should be interrupted, to let flowing runoff entrance from street to the swale management structure. Continuity of swales interrupted by building entrances and road branches can be achieved by underground pipes connecting between discontinuous swales [9,14].

## 2.2. BIORETENTION BASINS

Bioretention basins are depressed area designed to capture and retain the stormwater for a specific time before entering the stormwater management facilities (Figure 2). This depressed small pond usually contains plants such as native grasses and trees which help retard the flow rate and up-taking of the pollutants. Bioretention can be used to improve the treatment as secondary treatment units for streets runoff overflow from bioswales. Bioretention basins fundamental element is the filter media which consist of 60- 120 cm material composed from 65% sand, 20% sandy loam and 15% vegetation based feedstock. A shallow depth of water (about 30 cm) is hold inside the bioretention basin. Overflow inlets are provided to safeguard surface flooding from retention area to the surrounding lands during storm events [9,14].

## 2.3. PERMEABLE PAVEMENT

Local roads, parking lots and sidewalk surface can be constructed from permeable and perforated materials such as permeable pavements and porous tiles to allow water to infiltrate down to the ground. Also, parking lots and impervious pavements can be interrupted by pervious soil strips as much as possible in areas which are not obstacle the movement of cars and parking activity. The technique of reducing impervious area and increasing pervious areas is known as green parking method. Implementing green parking practice reduces pollutants washout volume from parking areas, decreases the urban heat island effect, recharges groundwater and improves aesthetics of the site [15].

## 3. METHODOLOGY

### 3.1 STUDY AREA

For this study, Tasluja major highway was selected as the research area. The highway connects Sulaimani City with Kirkuk City and considered as one of the city's roadways with high volume of traffic load, Figure 3. The City of Sulaimani as one of largest cities of Kurdistan Regional Government in Iraq, is located at north east of Iraq on the Iran border with geographic coordinates of Latitude = 35°33′40″ N and Longitude =45°26′14″. The weather of the city is dry and warm in summer with average temperature of 31.5°C, while the city is cold and wet during winter season with average.

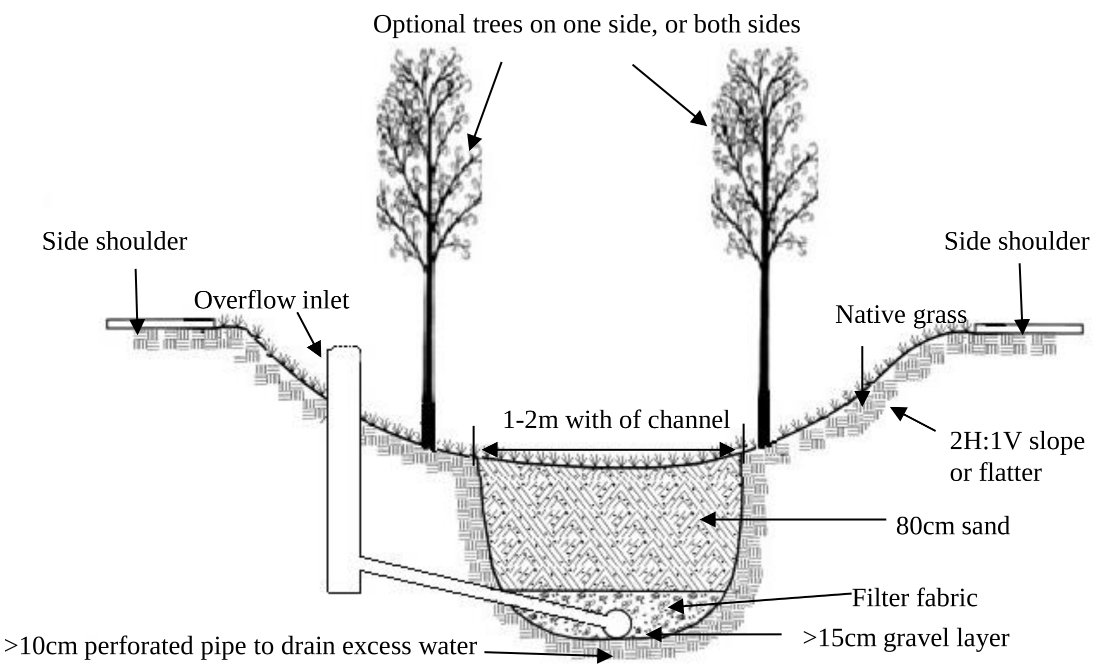

FIGURE 1. Bioswales for streets, [14]

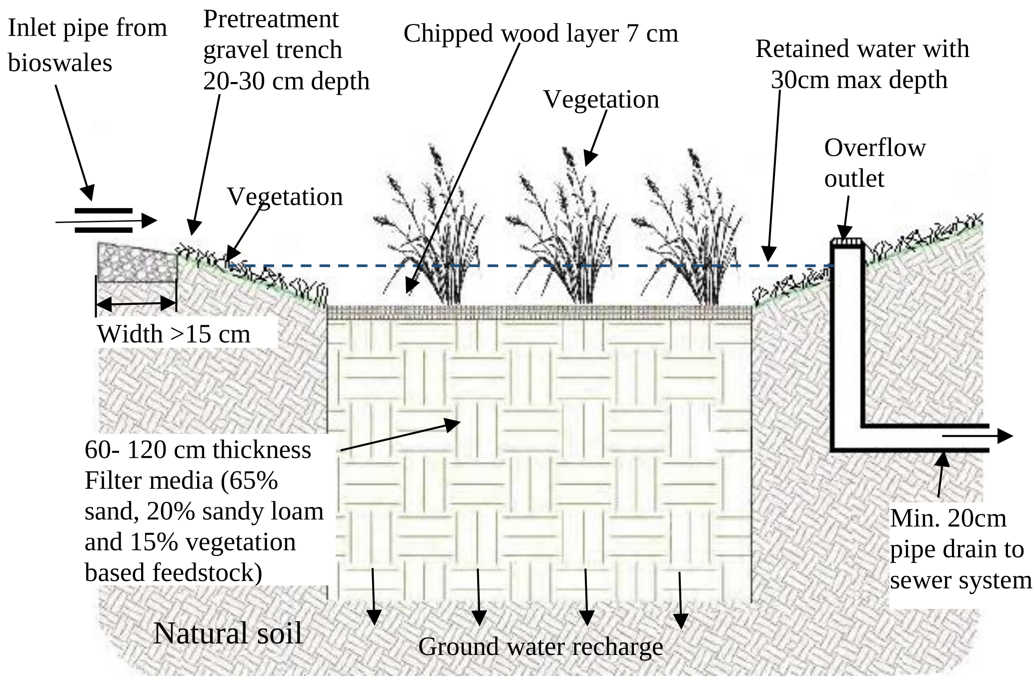


FIGURE 2. Typical bioretention basin, [14]

Temperature of 7.6$^{o}$C. The evaporation during summer and winter are 329.5 (mm) and 53 (mm) respectively. Precipitation starts with light rainfall in October and strengthens during November and mostly continues to May. The average annual precipitation varies between 328mm for dry years and 848mm for wet years [13,16]. Sulaimani as a developing city is observing a rapid growth and development, current population more than 735000 with massive traffic volume with high number of cars. Sulaimani city has a combined sewer system which collects the stormwater and sanitary sewage together in a single pipe system that drains the sewage downstream of the city without any treatment plants [17].

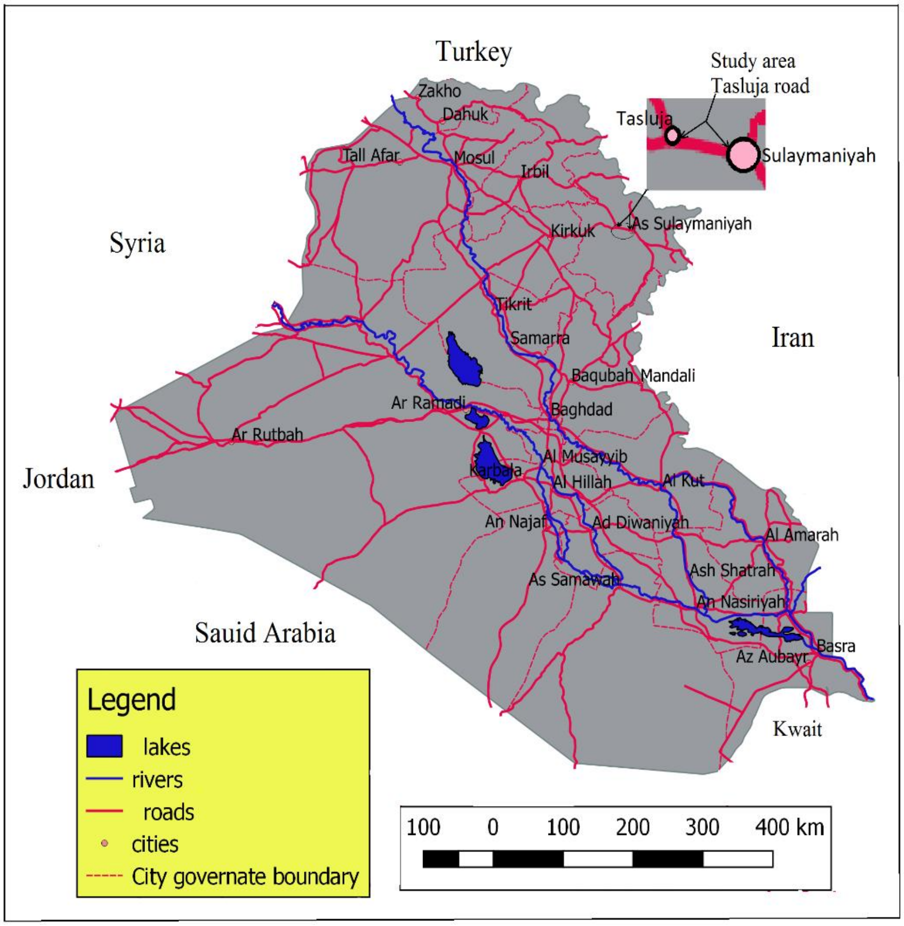


FIGURE 3. Study area: Tasluja Highway

## 3.2 RUNOFF SAMPLING

Rainfall runoff were collected from Tasluja highway. Four sampling points were assigned on the highway, two points at each side, to collect samples of runoff depending on the highest amount of drainage area from the highway surface. Two sets of samples were collected after the first and the second rainfall events. The first rainfall (first flush) occurred on November 2, 2016, and the second rainfall was happened on November 29, 2016. Four samples of runoff from the street were collected after each rainfall at the same specified sites along Tasluja highway. Water samples were collected, transferred in sealed plastic bottles and tested during the next 24 hours for heavy metals contents (Zn, Cu and Pb) using Perkin Elmer ICP-OES Optema 2100 Optical Emission Spectrometer.

## 4. RESULTS AND DISCUSSIONS

Tearing and wearing of operative vehicle parts on roads is the major source of heavy metal pollution in runoff from highways and roads. Results of the heavy metal tests for both first and second flush runoff samples are shown in Tables 1 and 2 respectively. Test results show that the samples of runoff from roads of the city are polluted with heavy Zn, Cu and Pb heavy metals which can deteriorate the quality of water in the downstream area. As the first flush washes out long dry season collected pollutants, for this reason, in general higher heavy metal concentration can be observed from the first flush sample results compared to the second rainfall results. However, Pb heavy metal could not be detected for all sample points for the second rainfall sample results. According to USEPA [18], maximum allowable concentration of Zn, Cu and Pb heavy metals in water are 5 mg/L (ppm), 1.3 mg/L and 0.015 mg/L. Tables 1 and 2 show that the average Zn concentration for first and second rainfalls of 0.062 mg/L and 0.022 mg/L respectively are below the maximum allowable limit in surface water. Also Cu average concentration of 0.075 mg/L for both rainfalls are below the maximum allowable limit of USEPA. Comparing to the standards, Pb contents of 0.051 mg/L is higher than the allowable limit of 0.015 mg/L. However, Lead was not detected in the second rainfall, this may be because of inexistence of the pollutant spill during the period between the two rainfalls. Nevertheless, the shown accumulated amount of pollution is out of only two rainfall events, therefore continuous receiving of heavy metals at the downstream water bodies results in the buildup of heavy metal which exceeds the maximum allowable limits resulting in pollution in the downstream environment.

TABLE 1.

First rainfall runoff water samples result of heavy metals tests

| Sample Number | Zn (mg/L) | Cu (mg/L) | Pb (mg/L) |
|---|---|---|---|
| 1 | 0.118 | 0.085 | 0.01 |
| 2 | 0.030 | 0.084 | 0.099 |
| 3 | 0.024 | 0.064 | 0.009 |
| 4 | 0.076 | 0.067 | 0.085 |
| Average | 0.062 | 0.075 | 0.051 |

TABLE 2.

Second rainfall runoff water samples result of heavy metals tests

| Sample Number | Zn (mg/L) | Cu (mg/L) | Pb (mg/L) |
|---|---|---|---|
| 1 | 0.01 | 0.078 | Not detected |
| 2 | 0.001 | 0.077 | Not detected |
| 3 | 0.002 | 0.076 | Not detected |
| 4 | 0.076 | 0.067 | Not detected |
| Average | 0.022 | 0.075 | Not detected |

Figure 4 shows Zn, Cu and Pb heavy metals concentration for first and second rainfalls at each of the sample locations of 1,2,3 and 4. Zn concentrations are reduced in the second rainfall compared to the first rainfall, this may due to spilling less amounts of Zn during the one-month period between the two rainfalls. Cu concentration stayed almost same for the two rainfalls, means existence of same amount of Cu during the period between the two rainfalls. As a final point, concentration of Pb was not detected in the second rainfall, which may be due to not existence of reasonable amount of Pb spill in the period between the two rainfall events. While LID practices can reduce the environmental impacts of roads and highways on receiving water, the city can use a set of LID systems to enhance quality of water.

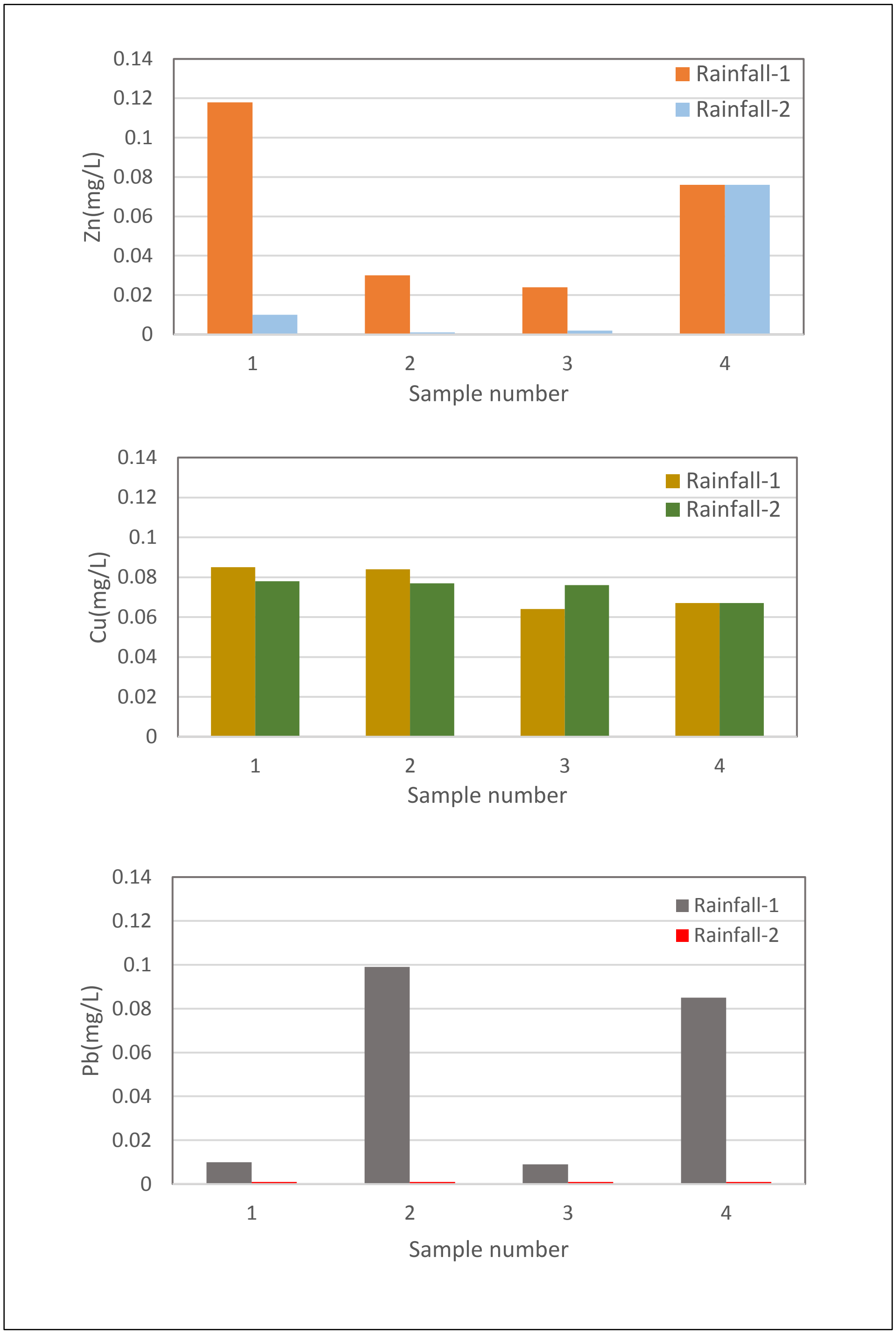


FIGURE 4. Comparison of Zn, Cu and Pb concentrations for 1st and 2nd rainfalls

## 5. CONCLUSIONS

Pollutants from tearing and wearing of cars parts and tires considered as a hazardous nonpoint source of heavy metal contaminations. Heavy metals namely Zn, Cu and Lead were detected in samples of stormwater from Sulaimani City main roads. First flush ($1^{st}$ rainfall) runoff has more contamination load compared to $2^{nd}$ rainfall. After first flush, average test results of heavy metals pollutants were 0.062 ppm, 0.075 ppm and 0.051 ppm for Zn, Cu and Pb respectively. After second rainfall average test results were 0.022 ppm, 0.075 ppm for Zn, Cu respectively, while Pb heavy metal was not detected. Results of this study showed that the Pb concentration in highway runoffs are higher than the allowable Pb concentration in surface water, while the Zn and Cu concentrations are lower than the maximum allowable concentration. However, the concentration of heavy metals pollutants is relatively low, but continues receiving even small doses will be buildup and collected in water bodies to cause severe heavy metal pollution hereafter. Using LID systems to treat runoff from highways and impervious areas can reduce heavy metal pollutant and protect Sulaimani City environment.

## 6. RECOMMENDATION

This study suggests the following LID systems to manage the stormwater for streets and roads of Sulaimani City:

- Grass swales (with vegetation) and rock swales (without vegetation) in the medians and shoulder of the streets to treat rainfall flow from both sides of the street.
- Bioretention basins are recommended in the appropriate areas to improve the treatment as secondary treatment units for streets runoff overflow from bioswales.
- Parking lots and impervious pavements can be interrupted by pervious soil strips as much as possible (green parking), or using pervious pavements may be used.

- Implementing green parking practice reduces pollutants washout volume from parking areas, decreases the urban heat island effect, recharges groundwater and improves aesthetics of the site.
- Whereas the city has combined sewer network which collect sanitary wastewater and stormwater in one sewer pipe network, application of LID systems can reduce the amount of accumulated water during storms which make treatment of the combined sewer systems for the city feasible during storm events.

## ACKNOWLEDGEMENTS

The author would like to express his deep gratitude to Kurdistan Region Strategic Research Center for their contribution to conduct this study.

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