Tracking the Chemical Footprint of Surface-Runoff Infiltration on Groundwater Recharge in an Arid Region - 10454

Omar M. Al-Qudah[*], John C. Walton[*], and Arturo Woocay[*]
[*] Environmental Science and Engineering, University of Texas at El Paso (UTEP), 500 W. University Ave., El Paso, TX, 79968,

ABSTRACT

This research, as part of the Nye County Nuclear Waste Repository Project Office (NWRPO) attempts to provide new insight into the chemical evolution of southern Nevada's groundwater, its potential flow paths, infiltration rates, and surface-runoff processes, through initiating a surface-runoff sampling network. The sampling network tracks the chemical footprint of the surface-runoff water and groundwater recharging infiltration chemistry, by collecting baseline data through a long term study on a comprehensive suite of chemical parameters. These parameters include major ion chemistry, nutrients, trace elements, and stable isotope ratios. Multiple analytical methods are employed to analyze this data to develop a defensible groundwater chemistry monitoring network, down-gradient of Yucca Mountain, suitable for long-term performance confirmation monitoring. This study includes precipitation water chemistry, surface water runoff chemistry, soil chemistry, and groundwater chemistry in the study area. The field sampling and analyses provide the required chemical data for precipitation water, surface water runoff, and sediment analysis. The groundwater chemistry and isotopic data administered by the NWRPO contain data from more than 200 wells that encompass the entire region. New methods were developed to control the construction and emplacement of the surface-runoff samplers. In addition, improved methods for the collection, field testing, and handling of precipitation water samples, surface-runoff water samples, and sediment samples were employed between the time the samples were gathered and chemical analyses obtained. The design and emplacement of sixty surface-runoff samplers at thirty separate locations is explained and a look at initial data is provided. It is our belief that long term data collection of this type will help us to better understand processes controlling groundwater recharge, and thus the sustainable yield of groundwater in Nye County.

INTRODUCTION

Natural tributaries in arid regions are generally ephemeral and the flow occurs intermittently during short, isolated periods separated by longer periods of low or zero flow; sustained flow is rare and baseflow is essentially absent [1]. Peak flow rates occur within a few hours of the start of a rise [1]. Normally, large volumes of surface-runoff water move into the ephemeral channel in a short period causing the flash flood characteristic of arid zone drainage basins, flash floods are usual hydrologic features of desert drainage [2]. Drainage basins with high relief, a large percentage of land bedrock, sparse vegetation and shallow soils are particularly susceptible to flash flooding [2]. Regularly, peak flow rates are reached almost immediately because the ephemeral flood wave forms a steep wave front, or the wall of water of legends, in its travel downstream [3, 4]. Two mechanisms contribute to the formation of the wall of water of legends. First, rate of infiltration into the permeable dry streambed is highest at the wave front and decreases in the upstream direction, with the effect that the leading edge of the wave steepens as it moves downstream [2]. Second, the deeper portion of the flood wave near the peak travels faster than the leading edge of the wave, with the result that the wave peak approaches the front until the peak and front almost coincide and a shock front is formed [1].

Studies of the Amargosa Desert regional groundwater indicate that the groundwater recharge is occurring from streamflow in Fortymile Wash. Water quality studies have studied precipitation, surface water, and groundwater isotopic and common ion concentrations and concluded recharge water is entering the groundwater system north of Yucca Mountain from streamflow. Computer simulation of the groundwater system has determined that recharge from Fortymile Wash is a significant component of the water budget. Groundwater levels rise after streamflow events in Fortymile Canyon. Channel geomorphic studies indicate water is being lost from streamflow in the Yucca Mountain area. Several water chemistry studies have determined that streamflow in Fortymile Wash is a source of groundwater recharge. Claassen [5] investigated common ion and isotope ages and concluded groundwater in the west central Amargosa Desert was recharged primarily from overland flow of snowmelt near the present day Fortymile Wash stream channel. White and Chuma [6], investigated carbon and isotopic mass balances of the Oasis Valley-Fortymile Canyon groundwater basin and concluded groundwater in Fortymile Canyon may be from local origin. Benson and Klieforth [7], investigated stable isotopes in precipitation and groundwater in the Yucca Mountain area and concluded groundwater recharge occurred by infiltration of cold-season precipitation, probably along the bottom of Fortymile Canyon.

Estimates of net infiltration from both the mean glacial transition and mean modern climates indicate that the largest infiltration rates occur along northwest-trending fault-controlled washes on the north end of Yucca Mountain [8, 9]. Water from the Eastern Yucca Mountain facies appears to be a mixture of water from the Timber Mountain area to the north and local recharge from the northwest-trending washes on the north end of Yucca Mountain [8, 9]. Water from the Timber Mountain area does not appear to flow beneath the crest of Yucca Mountain and mix with water from the Western Yucca Mountain facies [8, 9].

This study explores the relationship between rainfall-runoff and groundwater chemistry, during a flash flood event in the Amargosa Desert Region, Nevada, and presents evidence of runoff chemical signature on the infiltration and groundwater recharge.

STUDY AREA

Description of the Study Area

The Amargosa Desert (Figure 1) is located in the southern portion of Nye County in south central Nevada, within the Great Basin, and is part of the Death Valley groundwater basin. The Funeral Mountains separate the Amargosa Desert from Death Valley to the southwest, and a series of mountain ranges bound the north and east extents of the desert. The Amargosa River is a major drainage component (over 8,047 km^2) of the unique closed-basin, hydrologic regime known as the Great Basin.

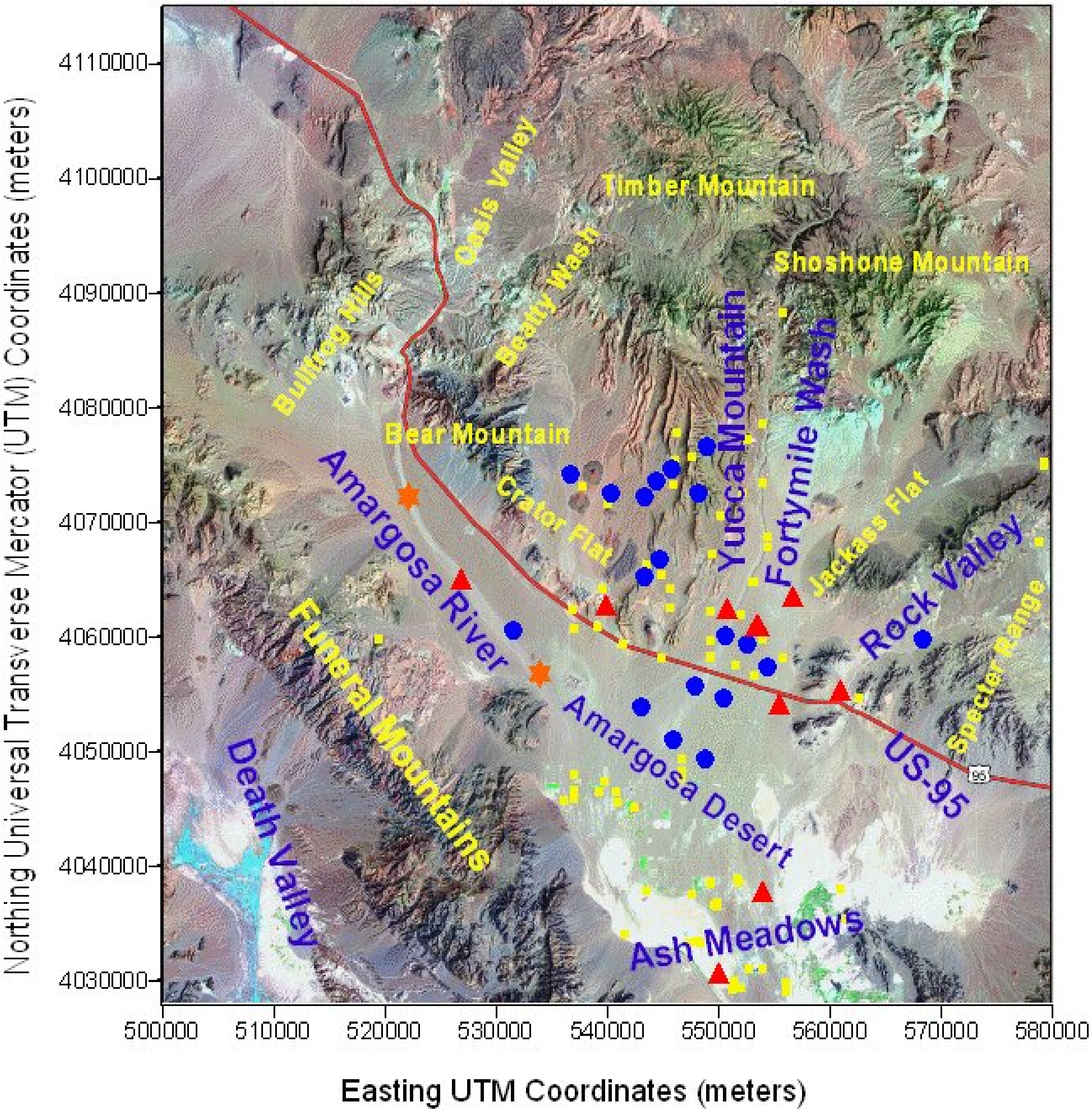

Fig. 1. DEM map for the study area shows Locations of Amargosa Desert Region, Amargosa River, Yucca Mountain, and Fortymile Wash, Nye County, Nevada. Phase 1 site locations are shown in blue circles, phase 2 site locations are shown in red triangles, phase 3 site locations are shown in orange stars, and groundwater wells are shown in yellow squares.

This river system begins in the Oasis Valley, turns southeast to run through the Amargosa Desert, continues until it turns northwest, and terminates in Death Valley from its southeast extension. As a result of a dry, semi-arid, continental climate, the Amargosa River and its tributaries are ephemeral streams that are dry most of the time except in a few relatively short reaches where discharging springs maintain small, perennial base flows. Fortymile Wash and Beatty Wash (in addition to the Washes in Crater Flat and Rock Valley) are the major tributaries of the upper Amargosa River, which drains through several small, populated areas downstream (Figure 1). Fortymile Wash originates between Timber Mountain and Shoshone Mountain. Fortymile Wash is an ephemeral drainage, flows southward along the east side of Yucca Mountain, and fans out in the northern part of the Amargosa Desert just north of Highway 95. Near U.S. Highway 95, the Fortymile Wash channel changes from being moderately confined to several distributary channels that are poorly confined. This poorly-defined, distributary drainage pattern persists downstream to its confluence with the Amargosa River. Yucca Mountain is located on federal land in southern Nevada, north of the Amargosa Desert, approximately 160 km northwest of Las Vegas, in the Basin and Range province of the western United States, within a zone between the Mojave Desert and the southern boundary of the Great Basin Desert, and it's part of the Amargosa River drainage basin which is the major tributary drainage area to the Death Valley. Yucca Mountain has been chosen by the U.S Department of Energy as a potential site of a geologic repository for long term storage of the Nation's high-level nuclear waste, and it is expected to hold approximately 70,000 metric tons of radioactive waste, and will remain the proposed site to hold this waste until time as congress change the nuclear waste policy act. The present climate in the Amargosa Desert region is considered arid to semiarid, with average annual precipitation ranging from less than 130 millimeters (mm) at lower elevations to more than 280 mm at higher elevations [10].

Runoff History in the Study Area

Precipitation associated with a weather disturbance moving eastward from California has caused the most extensive regional runoff in Fortymile Wash and Amargosa River since February 1969 [11]. The 1969 flood was the largest known in the Amargosa River system during the previous 25 years. Flow in Fortymile Wash was first documented during site-characterization studies in March 1983. The Wash had flow again three times during July and August 1984 as the result of severe but localized convective storms. The first runoff documented case during site-characterization studies was the runoff of March 9-11, 1995 [11], where Fortymile Wash and Amargosa River flowed, simultaneously throughout their entire Nevada reaches. Preliminary data reported for selected U.S. Geological Survey's (USGS) rain gages around nuclear tests site boundaries and within Amargosa Desert area showed that cumulative precipitation ranged from about 51 to 152 mm during March 9-11, 1995 with the larger amounts falling at the higher-altitude sites [11].

PREVIOUS STUDIES

Fisher and Minckley [2] described the change in selected chemical parameters during a single flash flooding event on Sycamore Creek, Arizona. Although floods are often viewed as dilution phenomena in terms of dissolved substances, in which low conductivity rainwater dilutes groundwater or spring water that are rich in dissolved salts, they observed that the dilution effects are partially offset by increased leaching and dissolution of solutes from newly exposed rock and soil minerals accumulated salt crusts, and from suspended particles. They noted that the major anions, bicarbonate, and conductivity followed a dilution pattern. Nitrate, phosphate and iron varied widely through the cycle, and generally increased over levels recorded at base flow. They attributed the increased concentrations of nitrate as discharge increased to leaching from the ephemeral stream beds and surrounding lands, and suggested that surface-runoff contributed few nitrates to streams but yielded significant amounts of phosphate from high concentrations of particles in the water.

Savard [12,13] presented the first hydrologic time series evidence for groundwater recharging in Fortymile Wash watershed, which had been hypothesized by previous water quality and regional groundwater studies, after five separate streamflow event periods happened in the Pah and Fortymile Canyons of Fortymile Wash approximately 10 km from Yucca Mountain during 1992-1993. Savard explained the source of groundwater recharge as a streamflow infiltrating through the streambed sediments and the under-laying alluvial material. In 1997 Savard [14] estimated the volumes of streamflow, streamflow infiltration loss, and groundwater recharge rate for four reaches of Fortymile Wash near Yucca Mountain (Fortymile Canyon, upper Jackass Flats, lower Jackass Flats, and Amargosa Desert) based on streamflow data from continuous streamflow gauging stations, crest-stage gages, and miscellaneous sites during 1969-1995 and depth-to-water data in boreholes from 1983-1995. He concluded that the Amargosa Desert reach had the highest groundwater recharge rate, 64,300 m^3 per year. The Fortymile Canyon reach had a lower rate, 27,000 m^3 per year, even though it had more frequent steamflow. The lower Jackass Flats reach had the third highest groundwater recharge rate, 16,400 m^3 per year. The upper Jackass Flats reach had the lowest groundwater recharge rate, 1,100 m^3 per year. The greatest depth to the water table, 100 to 350 m, of all the reaches was probably the biggest reason for very little recharge in the upper Jackass Flats reach.

In 2001 USGS [15] developed conceptual and numerical models of net infiltration for Yucca Mountain and the surrounding Death Valley region. The conceptual model describes the effects of precipitation, surface-runoff and runon, evapotranspiration, and redistribution of water in the shallow unsaturated zone on estimated rates of net infiltration [15], The numerical model simulated net infiltration ranging from zero, for a soil thickness greater than 6 meters, to over 350 mm per year for thin soils at high elevations in the Spring Mountains. Estimated average net infiltration over the entire model domain is 7.8 mm per year [15].

Lemoine and others [16] discussed a proposed methodology for the implementation of a monitoring tool for surface water run-off in (semi-) arid areas, by using integrated remote sensing and GIS techniques in order to develop alternative sources of drinking water and industrial water supplies.

Flint et al. [17] presented a summary of methods used to estimate the quantity of water percolating below the root zone on Yucca Mountain. Estimates of annual average percolation range from 0 to 6.5 mm per year. It is generally agreed that the greatest amounts of net recharge occur where shallow soils overlie fractured bedrock and that little or no deep percolation occurs in deep colluviums and alluvium [18].

Woocay and Walton [19] calculated the infiltration dates before present and pore velocities for four boreholes in the unsaturated zone near Yucca Mountain by applying a chloride mass-balance method. They observed, from pore velocities, two distinct slopes corresponding to different infiltration regimes. The first one, near the surface, presents the slowest infiltration rate indicating that, over the recent past, infiltration has been negligible at these locations. The second pore velocity corresponds to a past wetter period (late Pleistocene to early Holocene) with much higher pore velocities. The borehole nearest Fortymile Wash exhibits the highest pore velocities, whereas boreholes farther from the wash demonstrate lower velocities. They considered that the most dilute groundwater is present beneath Fortymile Wash, not beneath the mountains, suggesting that runoff infiltration is the dominant form of recharge in the region. They concluded that the younger and fresher groundwater beneath Fortymile Wash is the result of significant lowland infiltration due to accumulated surface-runoff occurring in localized areas such as the wash.

The present research as part of the Independent Scientific Investigation Program (ISIP) attempts to provide new insight into the chemical evolution of southern Nevada's groundwater and its potential flow paths and rates during the infiltration and surface-runoff processes, through initiating a surface-runoff sampling network to track the chemical footprint of the surface-runoff water on the groundwater recharging and infiltration chemistry, by collecting a baseline data through a long term study on a comprehensive suite of chemical parameters. Multiple analytical methods are created to analyze these data to develop a defensible groundwater chemistry monitoring network, down-gradient of YM, suitable for long-term performance confirmation monitoring.

METHODS

Site Locations Selection

The site locations were selected to include the major ephemeral streams that are tributaries the Amargosa River, and are surrounded by Nye County wells and boreholes (the yellow squares in Figure 1). The study plan is divided into three phases, Phase 1 was in January 2009 and includes 19 site locations (the blue circles in Figure 1), Phase 2 was in Feb. 2009 and includes nine site locations (the red triangles in Figure 1), where Phase 3 includes two site locations (the orange stars in Figure 1) and was in September 2009. In total, 60 surface-runoff samplers were installed in 30 different site locations in the vicinity of the Amargosa Desert Region.

Surface-Runoff Samplers (SRSs) Design and Construction

SRSs were designed to collect the soil water to measure the chemical characteristics of runoff water that has leached (infiltrated) through the soil profile. The construction started by threading flexible polyethylene tubing through a hole made about 25 mm below the top edge of the 9.5-liter bucket as shown in Figure 2a, to provide an access to the inside of the SRS once it is buried. The inner edge of the tubing was fixed to the bucket bottom with an epoxy adhesive, and the outer end blocked with a plug to prevent clogging the tubing. The completed devices were soaked in tap water for 24 hours before rinsing with distilled water to leach potential contaminants from the materials. In order to wash the silica sand to prevent the sand from chemically influencing the collected water, an array of holes was drilled in the bottom of one of the 19-liter buckets with a 1.6-mm bit (Figure 2b). A volume of 9.5 liter of sand filled in the meshed bucket and 19 liter of deionized water were poured on top of sand. After about 5 minutes, 3.8 liter of distilled was water poured into the sand-filled buckets.

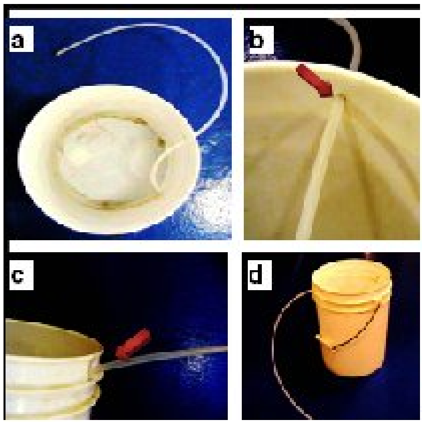

Fig. 2a.

Fig. 2b.

Fig. 2a. Photographic sequence of SRS construction: a. shows the 6.35-mm outer diameter polyethylene tubing glued to the bottom of the bucket, b. and c. show the tube exiting the device, and d. shows the finished device. Fig. 2b. Photographic sequence of the washing sand protocol: a. Two 19-liter buckets were needed; bucket #2 is graduated to 19 liter; b. mesh of holes drilled 25.4-mm by 25.4-mm With a 1.6–mm bit; c. The meshed bucket filled with 9.5 liter of the sand; d. bucket #2 Filled with 19 liter of deionized water to rinse bucket #1; e. 3.8 liter of deionized water poured; f. 10 ml collected of the residual rinsed water and the conductivity measured (the conductivity of the last rinse outflow should be <0.1 μS/cm).

Field Emplacement of SRSs

Each arroyo that was selected as a sampling location has two samplers a) one filled with washed sand and b) a second sampler filled with alluvial material (sand and silt) from the arroyo. The devices were placed at locations in surface-runoff channels where water is likely to pool and where sufficient depth of sediment facilitates digging a hole for emplacement. The samplers were placed in a low gradient (depositional) portion of the arroyo to the extent possible to prevent washing out during storms. The emplacement procedure for both washed sand filled samplers and alluvial material filled samplers was the same with a few exceptions detailed in the following:

1. Upon selection of a site for each SRS, approximately 3 liter of alluvial materials was collected in a test bucket after recording the observed sediment moisture. These materials were passed through a No. 4 (4.75 mm) sieve, according to ASTM D422-63-98 [20], and 2 liter of the sieved material was collected in 2-liter sized wide-mouth HDPE bottles. The initial water content of the sediment was determined in the lab according to ASTM D-2216-98 [21]. The collected sediment was extracted in the lab according to ASTM D-4542-95 [22], by mixing 2 kg of sediment with 3 liter of distilled water and the mixture left over night to settle, after that the leachate was separated, filtered, poured in to 2-liter wide mouth HDPE, and stored in a refrigerator for shipping later to the laboratory for analysis. Latex gloves must be worn during the emplacement process to avoid contaminating the sampler with sweat.

2. A hole was dug at the selected locations within the arroyos, and the excavated dirt placed downstream of each hole.

3. The depth of the hole was tested by using an additional bucket called the test bucket that has the same size as the sampler bucket. The test bucket was placed in the hole and the depth was tested by moving a straight edge laid on the surrounding undisturbed surface over the top of the sampler. For an ideal fit, the top of the sampler was 25-50 mm below the undisturbed surface of the arroyo.

4. When an adequate depth was reached, the test bucket was removed and the earth was leveled beneath it to provide a stable base.

5. 5a below followed for the washed sand samplers and 5b for the alluvial material samplers.

   5a. half of the SRSs were filled with the 8/12 washed sand. The lid was placed on the top of each sampler to check the depth and the level again. The previously removed alluvial material from the hole was used to backfill around the sampler within 25-50 mm of the top, and after removing the lid of the sampler the remaining space to the surface was backfilled with washed sand, and the area brought back up to grade with the undisturbed arroyo surface.

   5b. the second half of the SRSs (alluvial material samplers) were placed about 1.5-2.0 m down gradient of the washed sand samplers. If the arroyo width was 5 m or wider, the washed sand sampler and alluvial sampler was placed cross gradient. Over the sampler tubing intake washed silica sand was layered (filter pack) to further prevent entry and clogging of the hole. After that, the sampler was filled with the alluvial material. The bucket and bucket sides were backfilled with alluvial material and the area was brought back up to grade with the undisturbed arroyo surface.

6. The upper end of the sampling tube was sealed with a cap (ear plug), and the sampling tube was buried underneath the ground level to prevent sun (UV) damage.

7. T-post (fence post) was painted at the top and was pounded on a flank of the wash to prevent it from being washed away during a storm. The T-post will identify the site and serve as the mount for the rain gauge.

8. The rain gauge was mounted about 25 mm above the top of the T-post.

9. The coordinates of the SRS location were recorded by using a Trimble® GeoXH unit that has high accuracy In addition the distance and direction were recorded between the two samplers and from the T-post to the washed sand sampler and the alluvial sampler.

Precipitation Monitoring in the Study Area

Mathematica[7] software is used to monitor the weather data from the Amargosa Desert Region, in order to decide if a storm is strong enough to create surface-runoff in the area or not. Using Mathematica[7], two weather stations (KDRA and KBJN) in the Amargosa Desert Region are monitored daily. These stations provide data for temperature, pressure, humidity, wind speed, and the precipitation rate.

RESULTS

Surface-Runoff Sampling and Samples Chemical Analysis Results

Two storm events occurred in the study area after the installation of the samplers, the first one was in the period of February 10-12, 2009, and the second one was during February 17-18, 2009. The accumulated water level in the rain gauges was registered as shown in Table I.

In order to decide if the amount of water stored in the samplers after the storm events is enough to analyze all the chemical parameters (the major anions and cations, dissolved metals, nutrients, alkalinity, stable isotope ratio analysis of water, tritium, pH, EC, TDS, temperature, and stable isotope ratio analysis of carbon in total dissolved inorganic carbon) sample volume is compared to ACZ laboratory requirements (Table II). The total amount of water required to analyze all parameters is 2030 ml. A simple model was developed to predict sample volume based on the hydrological properties of the silica sands and the alluvial sands (i.e. sand porosity, specific yield, and specific retention), sampler dimensions, rainfall rate, and the thickness of the layer that lies above the tubing hole's entrance into the sampler.

Assuming the sediment around samplers is saturated and there is no evapotranspiration, for both types of samplers Eq. 1 is designed to calculate the water level in the sampler, and Eq.2 is designed to calculate the water volume in the sampler:

$$H = (R-(Sr*C))/n, \qquad \text{(Eq.1)}$$

Where:
H: water level in sampler, mm
R: rain gauge reading, mm
Sr: Specific retention, dimensionless
C: layer covers thickness, mm
n: porosity, dimensionless

$$V = \pi*(D/2)^2*H*(n-Sr)*0.001, \qquad \text{(Eq.2)}$$

Where:
V: water volume in sampler, liter
D: sampler average diameter, mm
H: water level in sampler, mm
n: porosity, dimensionless
Sr: Specific retention, dimensionless

The estimated amount of water accumulated in the washed sand filled buckets is obtained by the substituting values of porosity, specific retention, rainfall amount, sampler average diameter, sampler depth, and the thickness of the layer that cover the sampler, in the equations 1 and 2. Measured and estimated amounts of water obtained from the sampling process are shown in Table I below.

Table I. The Estimated and the Measured Amount of water accumulated in the Washed sand Filled Buckets and the Rainfall Observations during the Period of 2/10-18/2009

Bucket filler hydrological properties			Estimated amount of water in the washed sand filled bucket			Measured amount of water in the washed sand filled bucket (Liter)
Specific Retention (Sr)			0.075			
Depth of bucket (mm)			210			
Average diameter of bucket (mm)			216			
Porosity (n)			0.38			
Thickness of the cover layer(mm)			50.4			
SRS Location	Elevation (m)	Cumulative rain gauges precipitation (mm) during the period 02/10-18/2009	Volume (Liter)	% Full	Depth (mm)	Volume (Liter)
SRS-6A	820.68	33	0.86	37%	77	1.45 ± 0.05
SRS-6B	818.81	30	0.77	33%	68	2.00 ± 0.05
SRS-7A	805.35	27	0.68	29%	60	1.55 ± 0.05
SRS-7B	799.05	29	0.75	32%	67	1.82 ± 0.05
SRS-8A1	761.29	27	0.68	29%	60	0.70 ± 0.05
SRS-8A2	763.45	27	0.69	29%	61	0.97 ± 0.05
SRS-8B	765.06	30	0.79	33%	70	1.30 ± 0.05
SRS-9	904.14	37	0.98	41%	87	0.80 ± 0.05
SRS-10	899.23	48	1.31	56%	117	1.01 ± 0.05
SRS-11	1212.12	52	1.43	61%	127	2.24 ± 0.05
SRS-14A	1095.85	46	1.24	53%	110	1.99 ± 0.05
SRS-14B	1115.96	48	1.31	56%	117	1.82 ± 0.05
SRS-14C	1149.69	50	1.35	57%	120	1.50 ± 0.05
SRS-15	815.08	32	0.83	35%	74	2.10 ± 0.05
SRS-17	967.32	41	1.09	46%	97	0.70 ± 0.05
SRS-18	960.61	42	1.13	48%	100	1.35 ± 0.05
SRS-19	1154.89	53	1.46	62%	130	2.10 ± 0.05
SRS-20	782.77	32	0.83	35%	74	1.25 ± 0.05
SRS-21	912.74	23	0.56	24%	50	0.80 ± 0.05

In Figure 3, cumulative precipitation was plotted versus the elevation of SRS locations (Table I). It is clear in the figure that precipitation increased with elevation. This agrees with previous literature results that indicate that the rainfall rate in the Yucca Mountain is higher than that in the Amargosa Desert. This will increase the chances of surface- runoff on the mountain sides.

Prior to the sampling process the chemical parameters were ordered based on their importance in this study (Table II). Table II includes all the required information to deal with the samples during sampling, storage, and shipping. When limited amounts of water are available, samples are allocated according to the priority list.

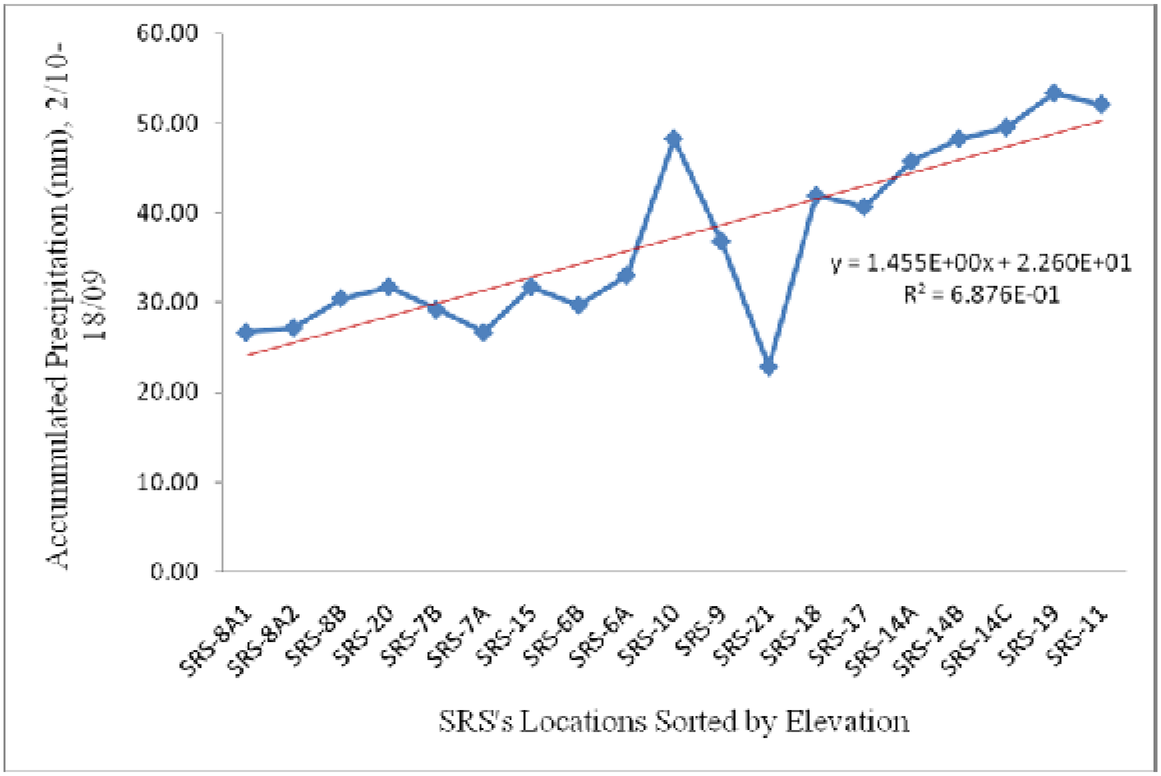

Fig. 3. The relationship between the cumulated rain gauges precipitation and SRS's elevation.

According to the calculated results (Table I) that were obtained after the February 10-18, 2009 storm events, the estimated water volume in the washed sand samplers was sufficient to analyze the first six priorities in Table II, and very little water could be pumped from the alluvial sand samplers insufficient to do any analysis. We decided to collect the samples during the period of February 24-28, 2009, after sufficient precipitation had occurred to provide adequate sample size for chemical analysis.

The sampling session included all the SRSs that were installed. Samples were collected from each of the devices for the laboratory analyses listed in Table II, in order listed under the priority column. Subsequent to arrival at each location the cap was removed from the tube, and the peristaltic pump was attached where the direction of flow was from bottom to top. The first 25 ml of sample was purged. After purging was complete, the requested water samples were collected in the specified order. Prior to collecting samples requiring filtering from each sampling location, a clean piece of silicone tubing was installed on the peristaltic pump along with a new large-capacity 0.45 micron filter on the discharge end of the tubing. After sampling was completed, the remaining water (if any) from the SRS was purged to provide space for collection during the next runoff event.

Table III summarizes the first priority results that were obtained after the end of the sampling process. All the natural alluvial samplers failed to produce water, all the water in the alluvial samplers is bound by the alluvium and failed to gravity drain.

Table II. Sample Collection in Order of Priority, Storage, and Shipping Information

Priority	Sample Type	Filters (Yes/ No)	Sample Size (ml)	Bottle Size (ml)	Bottle Type	Bottles Per Sample	Type of Storage	Special Shipping Instruction
1	pH, EC,TDS, Temp.	No	30	50	HDPE	1	Field test	None
2	Alkalinity, Anions	Yes	250	250	HDPE	1	Refrigerate	Ship with Cold Packs
3	Metals, Cations[1]	Yes	250	250	HDPE	1	Cool, Dry, and Unexposed to Sunlight	None
4	Nutrients [2]	Yes	250	250	HDPE	1	Refrigerate	Ship with Cold Packs
5	Stable Isotope Ratio Analysis of Oxygen and Hydrogen in Water	No	125	125	HDPE	1	Cool, Dry, and Unexposed to Sunlight	None
6	Tritium	No	125	125	Amber Glass	1	Cool, Dry, and Unexposed to Sunlight	Wrap in Bubble Wrap
7	Stable Isotope Ratio Analysis of Carbon in Total Dissolved Inorganic Carbon; Radiocarbon (C-14) [3]	No	1,000	1,000	HDPE	1	Cool, Dry, and Unexposed to Sunlight	Ship with Cold Packs, Tape Seal Around Cap

[1] HNO_3 preservation required.
[2] H_2SO_4 preservation required.
[3] NaOH preservation required.

In contrast, all the washed sand samplers had stored water in different amounts, where the maximum amount was in the sampler that installed in site SRS-11, 2.24 liter, and the minimum amount was in the samplers at sites SRS-8A1 and SRS-17, 0.70 liter (Table I). The first priority for all collected samples was done in the field (Table III). During the sampling process we noted that the water in all the rain gauges in site locations had evaporated.

Surface-runoff samples were analyzed for the major anions and cations by ACZ Laboratories, Inc. Figure 4 shows an interesting match between the average major anions and cations for groundwater in green line (triangle symbol) and surface-runoff in blue line (circle symbol), where the average precipitation major anions and cations in red line (square symbol) has a different trend. Groundwater chemistry data used herein were obtained from the NWRPO website as of March 2003 [23] and a Los Alamos National Laboratory report [24], where as the precipitation chemistry data were taken from Stetzenbach [25] and Meijer [26].

Long-term monitoring of these parameters in addition to the multiple analytical methods and infiltration modeling that will be applied may clarify the infiltration and groundwater recharge chemistry in the Amargosa Desert Region.

Table III. First Priority Results of Surface-Runoff Sampling

	Washed Sand Filled Bucket						
Location	**Date**	**Time 24H**	**Water Amount (Liter)**	**pH**	**Temp. °C**	**EC (µS/cm)**	**TDS (ppm)**
SRS-6A[1]	2/25/09	1625	1.45 ± 0.05	6.57	19.20	148.9	75.2
SRS-6B[1]	2/25/09	1535	2.00 ± 0.05	6.88	24.40	86.4	43.4
SRS-7A[1]	2/26/09	1010	1.55 ± 0.05	6.54	20.40	136.6	68.8
SRS-7B[1]	2/26/09	1102	1.82 ± 0.05	7.30	20.80	422.0	213.0
SRS-8A1[2]	2/26/09	1209	0.70 ± 0.05	6.54	23.20	141.3	71.10
SRS-8A2[1]	2/26/09	1240	0.97 ± 0.05	6.60	23.20	158.5	79.8
SRS-8B[1]	2/26/09	1136	1.30 ± 0.05	6.77	23.00	178.5	90.5
SRS-9[1]	2/26/09	1520	0.80 ± 0.05	6.70	14.40	173.1	86.3
SRS-10[1]	2/26/09	1459	1.01 ± 0.05	6.62	21.80	146.6	74.1
SRS-11[1]	2/25/09	1425	2.24 ± 0.05	6.55	23.60	68.7	34.7
SRS-14A[1]	2/27/09	1106	1.99 ± 0.05	6.65	14.10	114.4	58.9
SRS-14B[1]	2/27/09	1136	1.82 ± 0.05	6.88	14.60	131.2	65.9
SRS-14C[1]	2/25/09	1320	1.50 ± 0.05	6.77	32.40	77.0	38.9
SRS-15[1]	2/25/09	1012	2.10 ± 0.05	6.47	21.20	75.2	74.1
SRS-17[1]	2/27/09	1002	0.70 ± 0.05	6.71	17.90	118.4	59.3
SRS-18[1]	2/27/09	1035	1.35 ± 0.05	6.86	16.70	131.3	65.6
SRS-19[1]	2/27/09	1207	2.10 ± 0.05	6.63	19.70	113.7	57.8
SRS-20[1]	2/26/09	1353	1.25 ± 0.05	6.65	20.00	174.5	87.9
SRS-21[1]	2/26/09	1640	0.80 ± 0.05	6.36	12.40	172.8	84.7

[1] Silica sand saturated.
[2] Silica sand saturated but there was no enough water for tritium analysis.

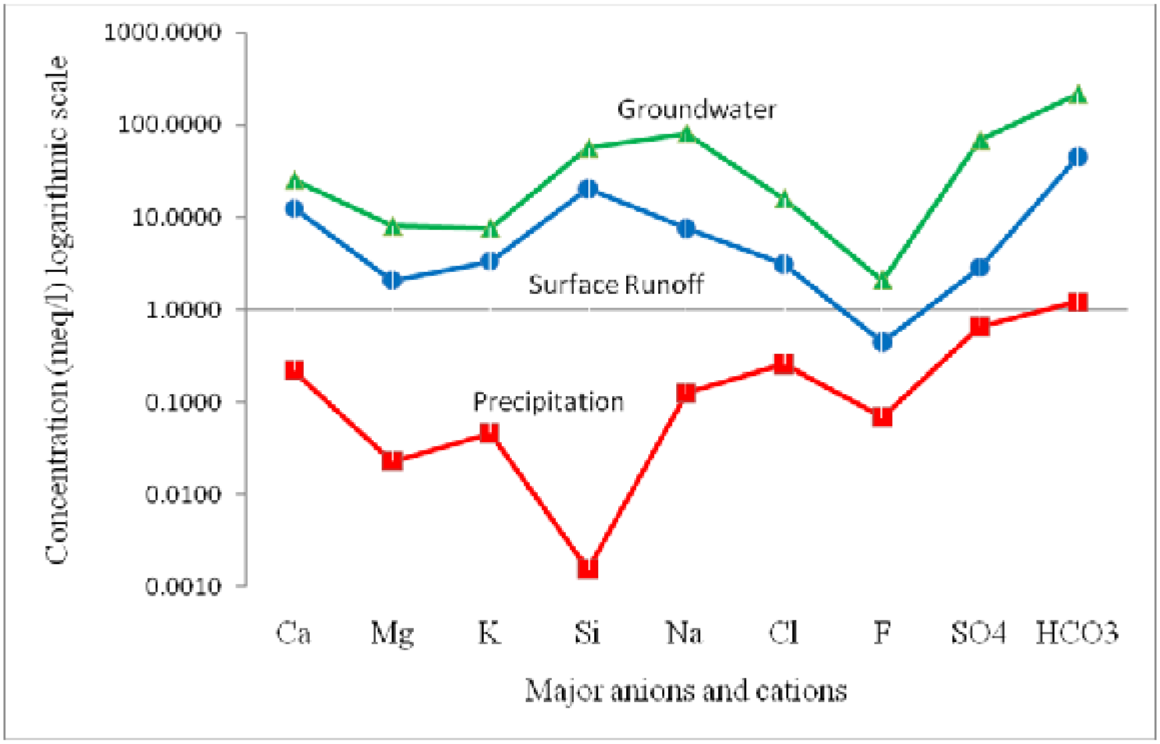

Fig.4. Average concentration of major anions and cations of groundwater, surface-runoff, and rainfall.

CONCLUSIONS

Studies of Amargosa Desert regional groundwater indicate that infiltration of surface-runoff occurs in the valleys subsequent to runoff-producing storms and this infiltration represents a large portion of the groundwater recharge. Sampling of surface-runoff in a desert environment from ephemeral arroyos is complicated by a number of practical concerns. Surface-runoff events are uncommon, sometimes separated by gaps of more than a year, and difficult to forecast in advance.

This study presents a modification to the lysimeter called "Surface-Runoff Sampler (SRS)" designed to provide a stronger collection surface, more efficient connections for sample collection, and to measure particularly the first flush of runoff. In the absent of runoff a SRS acts as lysimeter. SRS design has the advantages of low cost, low maintenance, and being long lived. Disadvantages are that it captures both precipitation and runoff and requires manual pumping. The SRS design proved its ability to resist the arid weather conditions and capture surface-runoff.

The sampling processes included surface-runoff, precipitation, and sediment samples. The sampling results indicate that there is a high similarity between groundwater and surface- runoff chemistry, and this suggests that surface-runoff is a main source of groundwater recharge especially in the ephemeral arroyos. Moreover, the hydrological model that was built and the forecasting program proved their ability in providing an initial estimate of the precipitation rate in the study area and the amount of water accumulated in the SRSs.

Further sample collection, statistical analysis, and infiltration modeling are required to achieve the main goal of this study which is to better understand processes controlling groundwater recharge, and thus the sustainable yield of groundwater in Nye County.

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