SURFACE WATER CHARACTERIZATION & UTILIZATION IN THE MIDDLE EAST, RESPECTIVELY EXEMPLIFIED BY NAHAL ESHTEMOA (WADI SAMOA) & THE SHIQMA-BESOR (WADI GAZA) RESERVOIRS, ISRAEL

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ABSTRACT

The nature of surface water in the Middle East has benefited from limited research. Automatic, modern instrumentation has been deployed (Nahal Eshtemoa), demonstrating that hydrographs are steep and recessions fast, hence discrete events cannot be pumped unless floodwater is diverted to valley/side valley reservoirs. Use of floodwater in modern water supply systems requires backup due to large variation in annual flood volumes. Water quality in natural channels systems unaffected by pollution has low salinity and is very high with the exception of elevated sediment concentrations, often 3-5%. Bedload discharges are among the highest recorded worldwide. Both can be predicted with relatively small errors. Surface water reservoirs may be utilized for local water supply, the most serious efficiency parameter being reservoir lifespan. It may be increased by constructing reservoirs to span part of a river section (Wadi Bsor-Gaza), or by identifying industrial uses for the deposited sediment (Shiqma Reservoir).

Cooperation between Palestinians and Israelis on surface water issues is needed, particularly in Wadi Besor (Gaza), the largest local catchment draining to the Mediterranean and the only drainage basin common to the Palestinians in the headwaters (Hebron) and the outlet (Gaza and Mediterranean Sea) as well as to the Israelis midbasin (Northern Negev).

KEYWORDS: Surface water, basin cooperation, sediment, reservoir

INTRODUCTION

Unlike the situation with groundwater, considerably less research has been undertaken on surface water in semiarid and arid regions, among others in the Middle East. There are several reasons why this situation has occurred:

1. *Flow events are rare*. They occur a few times a year, often less frequently with increase in drainage area due to local rainfall (e.g., Sharon, 1972) and large transmission losses (e.g., Shentsis et al., 1999); at times a channel remains dry during an entire or even several years (Reid et al., 1998a).
2. *Flow events are short-lived*, typically lasting one day or only a few hours (Reid et al., 1998a). There is insufficient time to organize instrumentation and undertake measurements.
3. *Hydrograph rise is quick, at times bore-like* (Reid et al., 1994; 1998a). Hence, it is not only dangerous to wade these ephemeral rivers, but gauging parties rarely arrive on time to gauge the rising stage, often not even the substantial part of the recession.
4. *Water is turbid* due to high concentrations of sediment (Alexandrov et al., 2003a). This adds another dimension of difficulty to wade and gauge these rivers.
5. The lack of continuous vegetative cover implies muddy *river sites that are logistically difficult* to approach.
6. All but few ephemeral channels are distant from settlements. *Equipment is, therefore, prone to damage*.

Given that water needs in this part of the world are severe and even though there are difficulties in the acquisition of data as outlined above, it is surprising that so little attention has been directed to the hydrologic regimen of ephemeral channels and relevant aspects related to trans-boundary cooperation, among others between the Palestinians and Israelis. Though only few and scattered data have been available until lately on the hydrology and on the dynamics of dryland rivers, exceptions are the long-lasting effort of hydrologic and sediment data collection at the hyper-arid Nahal Yael (e.g., Schick, 1988) near Elat (Akaba) and the world renown hydrologic investigations at Walnut Gulch, Arizona and other southwestern sites (e.g., Renard and Keppel, 1966).

This contribution centers on surface water quantity and quality in dryland Middle East channels exemplified by the surface water regimen of Nahal Eshtemoa (Wadi Samoa), a confluent of the Besor, and on related surface water issues, illustrated by the Besor Macha Reservoir located downstream of Wadi Eshtemoa, as well as by the Shiqma Reservoir (Fig. 1).

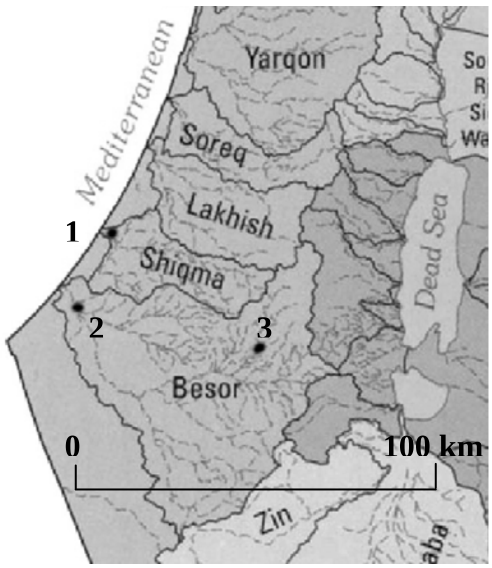

Figure 1. Map of the Northern Negev, Southern West Bank and Gaza Strip showing the Shiqma Basin and its reservoir (1) at the outlet, and the location of Wadi Eshtemoa (Samoa) at the upstream (2) and the Macha Reservoir (3) at the downstream Besor (Wadi Gaza) Basin.

CHARACTERIZATION OF RUNOFF IN DRYLAND MIDDLE EAST EPHEMERAL WADIS

Herewith no distinction is made between arid and semiarid regions for simplicity and because many of the surface water problems afflicting semiarid regions also typify the more arid regions and their channels. For these, description is given of their hydrologic properties, first directing attention at water quantity, thereafter at water quality of natural, unpolluted channels.

Water quantity

Soils are typically uncovered by vegetation or merely sparsely so in the Besor Basin, thereby developing a crust, which, in combination with high intensity storms produces a direct and fast runoff response to rainfall. This is translated to a fast and short-lived hydrograph rise in floods occurring in spring and particularly so in autumn, when the ground is totally devoid of vegetative cover. Such a response in the Eshtemoa is demonstrated by the 31 October, 2002 event (Fig. 2). Not only is the rate of rise fast and short lived, often arriving as a flood bore (Reid et al., 1994), but the recession is also relatively steep, in this instance with merely 3 hours of water usefully in the channels. As flood duration is so short, the use of a side-valley reservoir into which flood water may be pumped is not useful in this dryland setting. This is so because the size of the required pumps would be prohibitive, given the short duration and small flood volume. It epitomizes the need for the deployment of other types of surface reservoirs – see hereafter. The flood (Fig. 2) had a maximum depth exceeding bankfull discharge, a discharge with a recurrence interval of ca. 2 years in these incised channels.

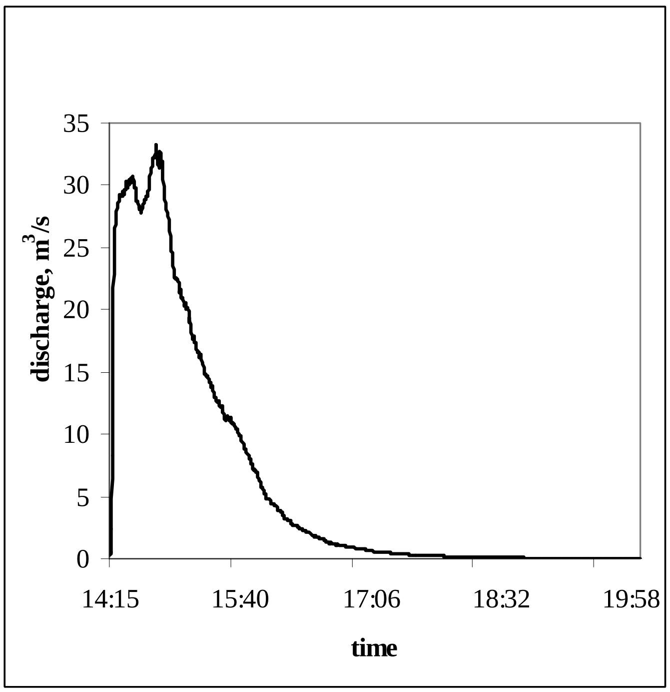

Figure 2. Discharge hydrograph of Wadi Eshtemoa on 31 October, 2002. This is a typical flood generated by a Dead Sea local, convective rainstorm. Peak flow depth of 1.43 m with flow velocity exceeding 4 m/s, this flood was dangerous due to its drowning potential. Water use is restricted by the short-lived event.

The number of flood events varies considerably between years (Table 1). Indeed, the standard deviation is as large as the mean, such that prediction of annual yields is manifested with a high degree of uncertainty. The extent of uncertainty concerning the availability of this surface water resource is even more conspicuous when considering the volumes of individual floods, for which the standard deviation exceeds the mean by a factor of more than 2. Considering that the mean duration of flow is about 4 days/yr, and that most of the water is discharged within 5 hr/yr, it is obvious that for water supply there is a necessity to detain an entire flood, a task obtainable only within a valley reservoir. That merely 2.5% of the rainfall may be utilized by the collection of runoff (Table 1) is typical of dryland channels. This ratio may be significantly increased to about 97% on roof top harvesting, as shown for the Gaza area (Ben Asher et al., 1995). Observe that one dry year may considerably affect prediction of average hydrologic response, unless the record is long. Unfortunately, most of the rivers in the Middle East, and specifically so the medium and smaller ones, have short records; more commonly, no hydrologic records are available. The Besor Basin has several longer records on its larger tributaries.

Table 1. Characteristics of flood volumes in the Upper Besor Eshtemoa Basin (Laronne and Alexandrov, 2000). The mean number of flow events per year (5) varies considerably (0-10; std=3).

	until 1997/98	**including 1998/99**
mean annual volume, 10^6 m^3	0.90	0.79
std - mean annual volume, 10^6 m^3	1.02	1.00
mean flood volume, 10^6 m^3	0.19	0.19
std - mean flood volume, 10^6 m^3	0.43	0.43
mean duration of flow event, hr	34.5	34.5
mean duration of flow, hr/yr	100	88
std -mean duration of flow, hr/yr	70	74
runoff/rainfall excl dry years, %	2.56	1.83
std - runoff/rainfall excl dry years, %	2.57	2.44

Not all floods are of the, sudden, short lived-type. Most of the winter floods are generated by Mediterranean cyclones. These are more prolonged and therefore supply most of the water. Because the generative process of floods depends on two alternative synoptic conditions, the relationship between flood volume and rainfall is unclear. However, the relationship between flood volume and flood peak is relatively well defined, enabling the prediction of flood volumes also for engaged basins where peak flood stage has been documented (Shentsis, 2002).

Water quality

Solutes

Unlike the typically high concentrations of sediment in dryland channels, the chemical quality is rather high. It is a typical calcium-bicarbonate system slightly enriched with sodium. Total dissolved solids (TDS) are low, as demonstrated by the low electrical conductance (EC) of flood water. Typically floods carry about 150 mg\l TDS, considerably less than most drinking water available in the area! TDS increases in the first flush of the first flood of a year, but even in these instances it is relatively low, often below 400 mg\l. Self evidently, in semiarid area where salts are deposited on the surface due to their higher content, such as in marine shales, runoff is more saline (Laronne and Schumm, 1982). In these areas TDS is increased also by the continuous dissolution of soluble minerals in transported sediment (Laronne and Shen, 1982).

Sediment

Unquestionably the major water quality problem of unpolluted flood waters in the semiarid Middle East are high sediment loads. This is true of high suspended sediment concentrations (Alexandrov et al., 2003b) as well as exceptionally high discharges of bedload (Laronne and Reid, 1993), the coarse fractions of the sediment mobilized as traction load by streams on their beds.

Suspended sediment concentrations are not only high, but they are particularly so at the onset of the hydrologic season during autumn (Fig 3). Similar to the runoff response being quicker in autumn than in winter or spring, so suspended sediment concentrations are particularly high in the first event of a hydrologic year. Typically suspended sediment concentrations are in the 3-5% range, implying that reservoir capacity is decreased by 2-4% of entering flood volumes (Laronne and Wilhelm, 2001). Because the interconnectedness between hillslopes and channels is high, sediment load can be predicted with reasonable accuracy based on flood volume (Laronne and Alexandrov, 2000).

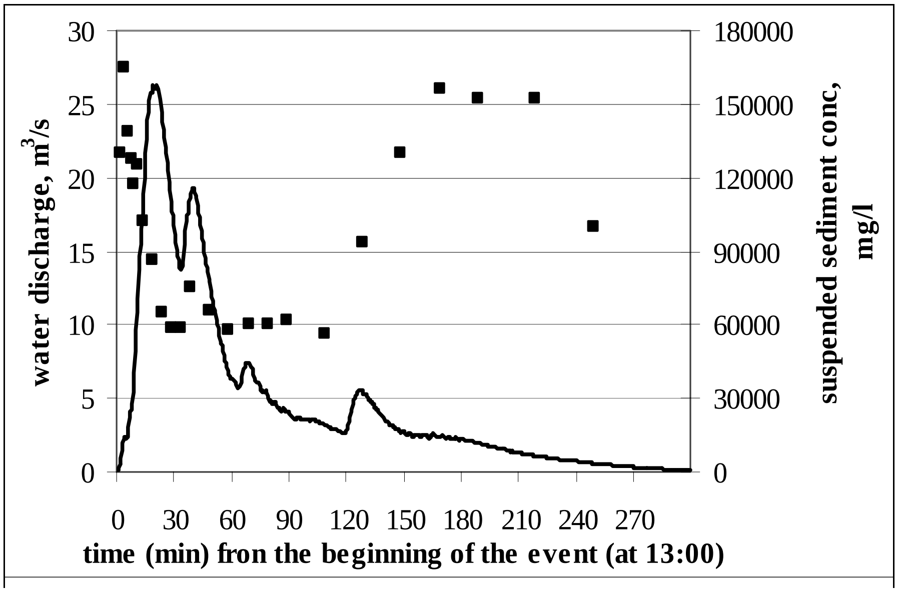

Figure 3. Discharge hydrograph and suspended sediment concentration, Wadi Eshtemoa on 18 October, 1997. Note the very elevated concentrations.

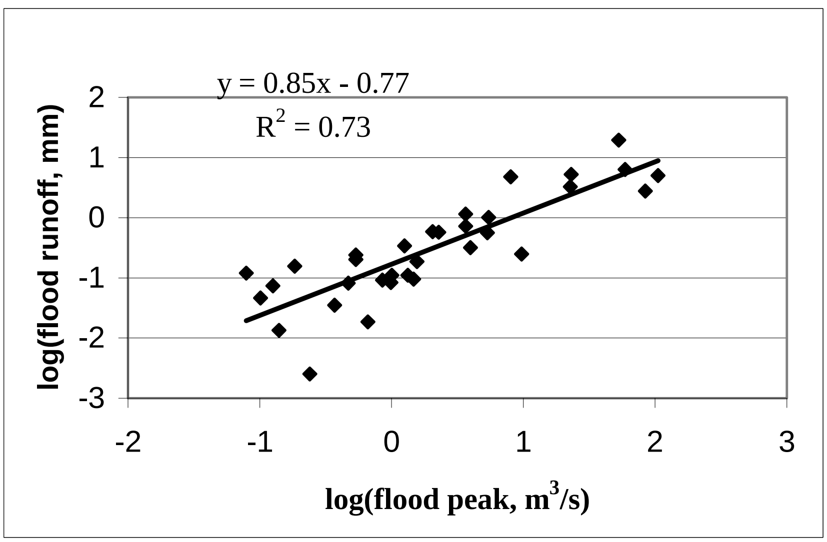

Figure 4. Scatter graph of flood runoff *vs* flood peak for Wadi Eshtemoa (Laronne and Alexandrov, 2000).

Bedload discharge is exceptionally high in these dryland channels in comparison with humid counterparts (Reid and Laronne, 1995). The reasons are manifold, but primary among these is the lack of an amour layer and a high supply of coarse sediment from hillslopes and banks (Laronne et al., 1994). Bedload fluxes are typically as high as 0.7 kg/sm at very low discharges barely capable to transport bedload, but have been recorded as much as an order of magnitude higher. Because wadi beds are unarmored, it is unsurprising that in this transport-limited system where supply is endless, the prediction of bedload discharge is rather accurate (Reid et al., 1996). Although bedload discharge is very high, it comprises merely 6 % of the sediment load (Powell et al., 1996). Hence, the overwhelming contributor to reservoir siltation is not sand and gravel incoming as bedload, but fine sand, silt and clay - the suspended load.

SURFACE WATER RESERVOIRS

Surface water reservoirs are commonly used in drylands, primarily so for irrigation rather than flood mitigation or power supply. This is also the case of Wadi Besor, draining an area surpassing 2,200 km2 to the Mediterranean with more than 100 ponds (capacity < 10,000 m3) locally termed Limans that serve to increase local forage of seasonals as forage for livestock, as well as the of trees, whether for soil conservation or for tourism. These have all but filled with sediment (Laronne, 1989). A handful of reservoirs with a larger capacity (< 100,000 m3) have also been constructed in the past 5 decades, but these have either silted (e.g., Yeruham), or else their earth dam has failed (e.g., Revivim). Although it is maintained that the combined storage of these reservoirs has considerably decreased flood volumes reaching the lower Besor, the extent of this decrease and the effect of soil conservation-afforestation measures in the Lahav-Yatir uplands have not been determined.

The prediction of reservoir siltation rate, or its life expectancy, is more accurate in dryland settings due to the nature of runoff response. The prediction is reasonably accurate based on monitored and calculated suspended and bedload yields (Reid et al., 1998b) or on rates of reservoir accumulation (Laronne and Wilhelm, 2001). Nevertheless, because sediment is the most serious water quality parameter in natural wadi systems affecting their suitability and feasibility for reservoir construction, it must be carefully taken into consideration when optimally planning their location (Puschmann and Lohr, 1996).

Because the Wadi Besor system does delivers at times large volumes of flood water (5-10 million m3), and because sedimentation rate is very high, a reservoir plan must be utilized to enable detaining large flood volumes and contemporaneously decreasing the volume of accumulated sediment. One such system exists on the lower Besor, the Macha Reservoir, delivering irrigation water to selected agricultural settlements. Designed by Lavi Natif Inc., though a valley reservoir it does not dam the entire valley. Instead, it utilizes a sill spread across the wadi bed to elevate it, thereby diverting some of the surface water into a reservoir located within the valley, but occupying merely half of the width (Laronne, 2000). This enables water to move mostly into the reservoir unless it is full, in which case the rest of the flood water and its sediment are transported downstream without entry into the reservoir. This not only decreases siltation rate, but allows the downstream reach to continue acting as a flooded reach with respect to fauna and flora. This approach and plan are welcome also because the location is on a river quarry site, thereby decreasing the ill effects of wadi quarrying (Laronne, 1995a). Though ingenious, a scientific-engineering aspect that requires solution is the continuous and considerable deposition of sediment at the sill and inlet to the reservoir, requiring periodic large-scale cleaning.

Unquestionably, if we are to continue constructing surface water reservoirs in semiarid and arid areas, as solution must be found to their short life span and thus, their low feasibility. Flushing of sediment is unrealistic where water is so expensive and where sedimentation is so massive. An alternative approach is the implementation of soil conservation measures on uplands and agricultural fields. If these fail, a worthy alternative is the use of reservoir sediment as an aggregate (Laronne, 2000). Located between Ashqelon and Gaza, the Shiqma Reservoir is a good example of such re-use. It was constructed in the mid-50's and has been very useful as a detention reservoir, from which water has been added to the Coastal Aquifer. By mid-70's the reservoir had silted, and was reactivated by quarrying the silt and elevating the banks and the dam/spillway. This allowed continuous reservoir operation for an additional span of 2 decades, at which time it was not possible to increase the elevation of the spillway due to its location on the flat-lying coastal plain.

Mineralogical, chemical and soil mechanical aggregate analyses of the reservoir sediments were undertaken. These showed the upstream deposits are coarse sand and gravel and may be used as substrate aggregate. Mid and lower-reservoir sediments were found to be useful as a cover for the bed of sewage ponds. The bulk - the clayey fractions - are excellent for pottery and for bricks, with an industry in a nearby town devoted solely to the use of commonly available clay mixed with Shiqma clay. They are particularly appropriate for the voluminous cement industry.

CONCLUSION

The Wadi Besor Basin is not only the largest basin draining into the Israeli-Palestinian Mediterranean, but it is also the only basin in this politically charged and contested area that drains in its uplands the Palestinian territories (Hebron-Samoa area), in its midst the Israeli Northern Negev and it its outlet yet again a Palestinian area (Gaza and the associated Mediterranean Coast). The basin generates runoff that is only in part used for irrigation, with future plans as yet undecided. The planned use of this water necessitates collaboration between the upstream, mid and downstream users not only for water quantity, but more so with respect to its quality. This is obvious among others because water salinity has increased and groundwater levels have receded in the Gaza Strip (Horvitz-Mizrahi et al., 1999). Within the basin sewage is dumped into the channels (e.g., Hebron, Ofakim), industries are point pollutants (e.g., Hovav Industrial Complex), with interaction between polluted groundwater and surface water (Adar and Laronne, 2000) while pesticides and herbicides are utilized on agricultural fields throughout the basin. Collaboration is desirable not only with respect to water use, but as much so for the master planning of the basin in its entirety with respect to tourism, river habitats and more, a process which has begun only on the Israeli side and is direly desirable as a Palestinian-Israeli initiative.

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