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Key Biodiversity Survey of Kurdistan, Northern Iraq

DRAFT Water Quality 2009 Review

Prepared for Nature Iraq and the Iraqi Ministry of Environment by

Zana Jamal Kareem, Omed M. Mustafa, Ghasak Sabah Al-Obaidi, & Mohammed A.T. Al-Saffar

Edited by

Anna Bachmann with Amanda Bullock, Daniel Burnham & Christina Dela Cruz

March 2010

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KBA Team

The Key Biodiversity Areas (KBA) team mainly consisted of staff from Nature Iraq (NI), the Twin Rivers Institute for Scientific Research (TRI), the Iraqi Ministry of Environment (MoE) and the Kurdistan Ministry of Environment (KMoE):

Water Quality & Sediments - Adel Omran Salman (MoE), Abbas Abd Safeeh (MoE), Haider A. Falih (NI), Ali Khair Alah, Anwar Hama (KMoE), & Karwan Musa Hameed (KMoE)

Plankton - Aseel Ghazi Radhi (NI/TRI), Ghasak Sabah Al-Obaidi (NI/TRI) & Suad K. Salman (NI/TRI)

Benthic Macroinvertebrates - Ali Sadiq Al-Zubaidi (NI/TRI), Ghazwan Bashir (MoE), & Mohammed A.T. Al-Saffar (NI/TRI)

Lab Work– Zana Jameel (TRI), Tamara Yasin (TRI), Ali M. Maher (TRI), , Hussam Jabar (TRI), Omed Mustafa (TRI), Raid Abdulmehdi (TRI), Ala'a Hamed Mahmood (NI), & Salman Khair Alah (NI).

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Additional local partners have assisted the project logistically and with information about the survey sites. These have included the many drivers, guides, herders, fisherman and hunters who have helped the team and we include them in our thanks.

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Introduction

This document presents field observations from the Key Biodiversity Areas (KBA) Survey conducted in winter (Jan/Feb) & summer (Jun) 2009 in Sulaimani, one of the three northern governorates of Iraq, known collectively as Iraqi Kurdistan. This survey is a joint effort of Nature Iraq (NI,) the Iraqi Ministry of Environment (MoE) and the Kurdish Ministry of Environment (KMoE). The 2009 surveys represent the fifth and sixth seasonal survey conducted in Kurdistan, Northern Iraq since the start of the project in February 2007. It should be noted that a severe drought was affecting the whole Kurdish region of Northern Iraq during the previous summer survey season and very little rain or snow had fallen by the time of the winter 2009 survey. All survey sites appeared to have reduced water. Spring rains occurred in 2009 but the overall drought continued into summer. The field effort focused on the following surveys: birds, water quality physical and chemical parameters, bacteria and coliform, heavy metals in sediment and water, phytoplankton, zooplankton and benthic macroinvertebrates. This report reviews the basic water quality and biota findings (benthic macroinvertebrates and phytoplankton only, zooplankton assessment was not completed) that provide information about water quality and health of each site. Previous surveys included sites in Erbil and Dohuk but for logistical and financial reasons, the survey was restricted to Sulaimani Governorate sites within the Diyala (Darbandikhan) Basin and the Little Lab (Dukan) basin. In summer the survey was restricted further to the Diyala (Darbandikhan) Basin only with additional sites being added within the basin. Additional information on birds for these and other sites can be found in the KBA Kurdistan Site Review 2009. The bird and botany surveys represented by this report visited sites throughout Iraqi Kurdistan.

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Survey Area

The following table includes the site names and site codes with original GPS coordinates of the KBA Kurdistan Survey sites. During the winter 2009 survey additional sites were added to provide more information on conditions throughout the upper watersheds of the Diyala and Little Zab Rivers. During the summer 2009 survey, when the survey was restricted further to just the Diyala watershed, a few additional sites were added there as well.

Table 1: KBA Kurdistan Survey Areas for Winter 2009 (WS09) and Summer 2009 (SS09) Water Quality sites

Site Name	Site Code	Coordinates					
		Latitude (North)			Longitude (East)		
		°	′	″	°	′	″
Diyala River Watershed (Darbandikhan Basin)							
Kela Spi (Sediment only)	**QA_EIA_WQ1-SS09 (Dry)**	**35**	**34**	**0.2**	**45**	**16**	**22.6**
Kela Spi (Water Quality)	**QA_EIA_WQ1-SS09 (Revised)**	**35**	**33**	**8.5**	**45**	**17**	**58.2**
Sarchinar (winter)	**QA_EIA_WQ2-WS (Dry)**	**35**	**35**	**58**	**45**	**22**	**52**
Sarchinar (revised for summer)	**QA_EIA_WQ2-SS**	**35**	**35**	**24.3**	**45**	**22**	**40.5**
Below Qara Dagh Bridge	**QA_EIA_WQ3-SS**	**35**	**28**	**48.2**	**45**	**26**	**6**
Qara Ali	**QA_EIA_WQ4-SS**	**35**	**22**	**0.4**	**45**	**34**	**11.7**
Cha Khan	**S15 – WS (Dry)**	**35**	**27**	**32**	**45**	**52**	**4.5**
Said Sadiq	**S29-SS**	**35**	**18**	**37.1**	**45**	**51**	**6.4**
Ahmed Awa	**S4A-WS & SS**	**35**	**19**	**1.8**	**46**	**5**	**25.2**
Zalm	**S12-WS & SS**	**35**	**18**	**26.8**	**45**	**58**	**19.9**
New Halabja	**QA_EIA_WQ5-WS & SS**	**35**	**20**	**25**	**45**	**43**	**53**
Darbandikhan Lake/ Tanjero Input	**S1A-WS & SS**	**35**	**12**	**7.5**	**45**	**49**	**7.9**
Darbandikhan Lake/ Sirwan Input	**S1B-WS & SS**	**35**	**8**	**25.2**	**45**	**49**	**49.1**
Darbandikhan Lake/ Center North	**S1C-WS & SS**	**35**	**8**	**53.6**	**45**	**46**	**45.9**
Darbandikhan Lake/ Center South	**S1D-WS & SS**	**35**	**8**	**33.6**	**45**	**45**	**18.1**
Darbandikhan Lake/Near Dam	**S1E-WS & SS**	**35**	**7**	**10**	**45**	**42**	**56.7**
Diyala (Sirwan River) – After Darbandikhan Dam	**S1F-WS & SS**	**35**	**6**	**11.9**	**45**	**42**	**3.3**
Qara Dagh	**S11-WS**	**35**	**19**	**52.5**	**45**	**17**	**25.4**
Bani Khelan (Garmk)	**S3A-WS09 & SS**	**35**	**3**	**27.5**	**45**	**40**	**1.3**
Bani Khan	**S3B-WS**	**34**	**54**	**32.3**	**45**	**36**	**4.5**
Kalar	**S3-WS**	**34**	**35**	**1.5**	**45**	**18**	**25**
Little Zab Watershed (Dukan Basin)							
Penjween	**S5-WS**	**35**	**45**	**19.2**	**45**	**56**	**37.7**
Kani Sard (Chami Gawra)	**S21-WS (formerly S5A)**	**35**	**33**	**55.7**	**45**	**56**	**0**
Zamok	**S16-WS**	**35**	**46**	**26.7**	**45**	**26**	**1.1**
Sargalu	**S7-WS**	**35**	**52**	**30.5**	**45**	**9**	**55.1**
Du Choman (Mawat area)	**S8-WS**	**35**	**57**	**34.9**	**45**	**23**	**13.6**
Little Zab above Du Choman junction	**S17-WS**	**35**	**58**	**12.5**	**45**	**24**	**16**
Mertka	**S18 - WS**	**36**	**15**	**27.3**	**45**	**6**	**43.7**
Darua Kotr	**S19 - WS**	**36**	**18**	**39.2**	**45**	**0**	**22**
Dukan Lake /Little Zab Input	**S2A-WS**	**36**	**8**	**51.9**	**44**	**56**	**46.4**
Dukan Lake - Little Zab Input	**S2B-WS**	**36**	**7**	**35.3**	**44**	**51**	**41**
Dukan Lake / Center of Lake	**S2C-WS**	**36**	**5**	**28.4**	**44**	**56**	**5.6**
Dukan Lake / Before Dam	**S2D-WS**	**35**	**57**	**47.3**	**44**	**57**	**52**
Dukan Lake/After Dam	**S2E-WS**	**35**	**56**	**30**	**44**	**57**	**34.9**
Chami Razan	**S10-WS**	**35**	**48**	**20.2**	**44**	**58**	**36.4**
Little Zab below Tabban Junction	**S20-WS**	**35**	**52**	**31**	**44**	**56**	**11.1**

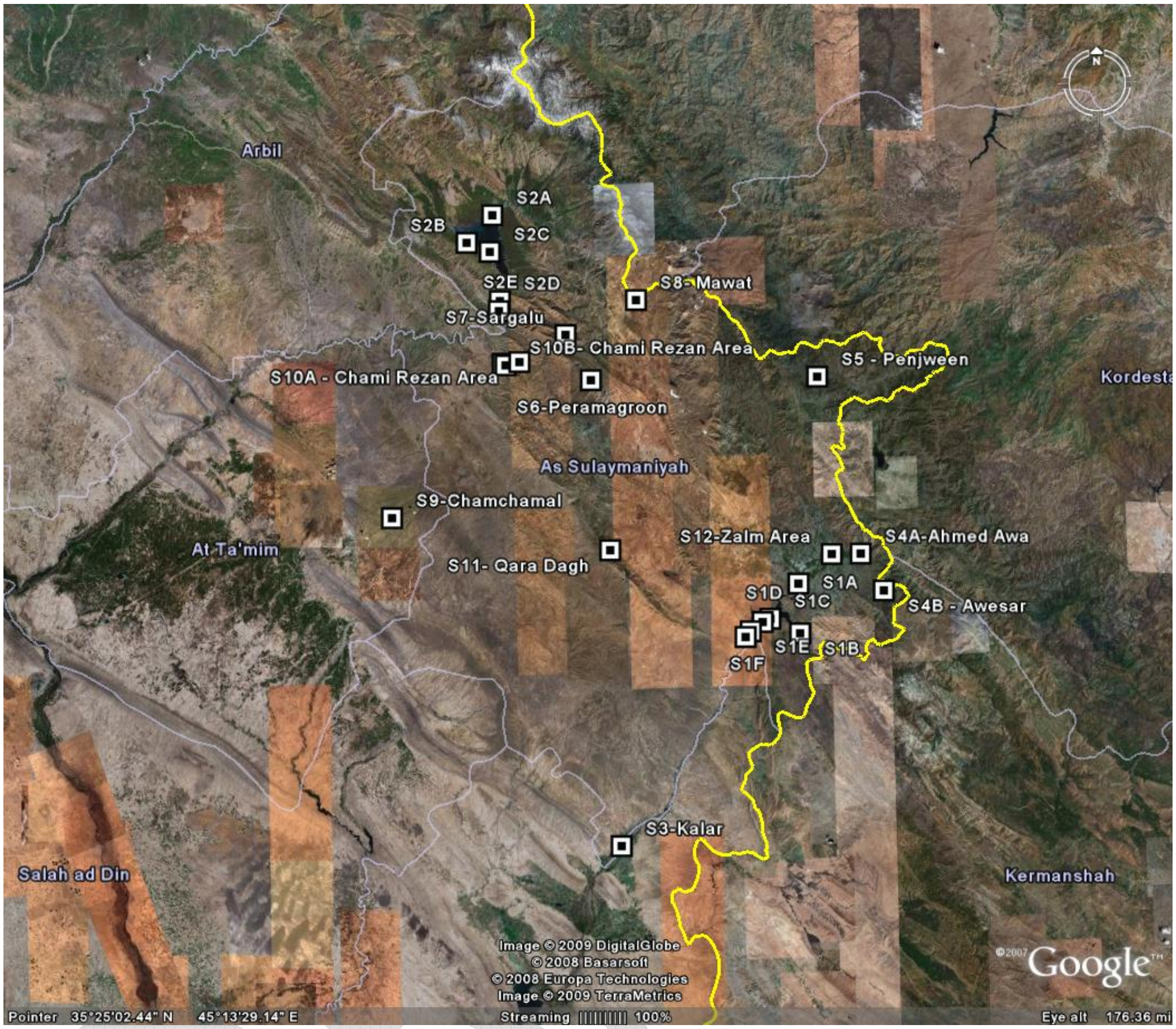

Plate 1: Sulaimani Survey Sites in Winter 2009 (Google Earth, 2009)

Plate 2: Sulaimani Survey Sites in Summer 2009 (Google Earth, 2009)

Materials & Methods

Water Quality

During the winter and summer, physical water quality parameters were measured using multi-meters. These meters consisted of the following:

1. pH, conductivity and salinity meter manufactured by WTW (made in Germany) — model 330i
2. Oxygen meter manufactured by WTW, model 315i
3. Turbidity meter manufactured by WTW, model Turb 430

The sample collection procedure was: if the water body was less than 2 meters deep, samples were collected just from the surface; but if the water depth was more than 2 meters in depth, samples were collected from the surface and "bottom" (which, depending on overall depth, was either approximately 2 meters from the bottom or up to approximately 25 meters in depth).

Different chemical parameters were determined for the water samples, including: major cations (Ca, Mg, Na and K), anions (SO4, Cl, HCO3, PO4, NO3 and NO2) and nutrients (TP and TN). Total dissolved solids (TDS), total suspended solids, alkalinity, total hardness (TH) and five-day biochemical oxygen demand (BOD5) of the samples were also determined. The procedures for all parameters determined in the lab are listed in the table below.

Table 2: Procedure and References for Lab Analysis

Parameter	Methodology	Method No. and Reference
Anions (SO4, Cl, HCO3, PO4, NO3 and NO2)	Ion Chromatography (HPLC)	4110 B; APHA 2005
Cations (Ca, Mg, Na and K)	Ion Chromatography (HPLC)	4110 B; APHA 2005
(TN)	Ion Chromatography (HPLC)	4110 B; APHA 2005
BOD5	5-Day BOD Test (Winkler)	5210 B; APHA 2005
TDS	TDS Dried at 180 °C	2540 C; APHA 2005
TSS	TSS Dried at 103-105 °C	2540 D; APHA 2005
TH	EDTA Titrimetric Method	2340 C; APHA 2005
TP	Ascorbic Acid Method	4500 E; APHA 2005
Total Alkalinity	Titration	Modified from Lind, 1979

In the text and tables below, physical and chemical water quality parameters were compared to one of several different reference standards: natural surface water quality (Kabata-Pendias and Mukherjee, 2007 and Agardy and Sullivan, 2005), surface water standards (Seminole Tribe of Florida (STF), 2000), river water standards (Allan and Castillo, 2007 and Kabata-Pendias and Mukherjee, 2007), natural groundwater quality (Kabata-Pendias and Mukherjee, 2007; Agardy and Sullivan, 2005; Mazor, 2004 and WHO, 2006), groundwater standards (GWQS, 2008) and lake water quality data from Walker Lake in the United States of America[1] (Kabata-Pendias and Mukherjee, 2007 and NDEP, 1999). Please note that when sample results exceed all reference standard maximum levels, the value will be listed in bold, red text.

Bacteria & Coliform

Coliform bacteria (of which *Escherichia coli* is a member) are often associated with enteric pathogenic organisms and are useful indicators of fecal contamination. The MPN (most probably number) test for coliforms consists of three steps: a presumptive test, a confirmation test, and a completed test.

The first step is the presumptive test. A set of tubes of lauryl sulfate tryptose (LST) lactose broth is inoculated with samples of water and then incubated. Lauryl sulfate is a surface-active detergent which inhibits the growth of gram-positive organisms while encouraging the growth of coliforms. Coliforms use oxygen present in the broth and then ferment the lactose, producing acid and gas under anaerobic conditions. Gas formation in 24 or 48 hours is a positive test. The formation of gas is observed by its presence in the inverted Durham tube (Prescott, 2002)

The next step is to inoculate media such as Levine's eosin methylene blue (EMB) agar, Endo agar, MacConky agar or brilliant green lactose bile (BGLB) broth from positive presumptive tubes in what is called the confirmed test. In addition to these media, there are several other

[1] Though not completely appropriate as a reference standard for lakes in Iraqi Kurdistan (i.e. Dukan and Darbandikhan), Walker Lake, which is a natural, terminal lake in an arid to semi-arid region of Nevada in the USA, was one of few lakes that Nature Iraq was able to obtain comprehensive parameter reference levels for.

media that can be used for the confirmed test. Brilliant green lactose bile broth (BGLB), Eijkman's medium, and EC medium are a few others that can be used.

If gas is now formed in 24 or 48 hours, a Gram stain is made from the growth on the slant. If the cells are gram-negative after examination under oil and there is no indication of spores, the completed test is considered to be positive (Josephine, 2003).

Further biochemical studies (IMViC) may be performed on isolated cultures. In practice a complete test is seldom performed. All three tests are necessary to prove that an organism in a water sample is actually a coliform. In actual practice, when it has been shown that the presumptive and confirmed tests give essentially the same results, then the completed step is generally not done because of the time it takes.

Sample collection for fecal coliform bacteria and *E. coli* test was carried out using a 100 ml standard dark bottle and the sample was taken approximately 5 cm under the water surface.

Five test tubes containing Durham tubes and double strength LST lactose broth 10 test tubes containing Durham tubes and single strength LST lactose broth

Presumptive Test

1. Set up five DSLB and ten SSLB tubes. Label each tube according to the amount of water that is to be dispensed to it: 10 ml, 1.0 ml, and 0.1 ml, respectively.
2. Mix the bottle of water to be tested.
3. With a 10 ml pipette, transfer 10 ml of water to the DSLB tubes.
4. With a 1.0 ml pipette, transfer 1 ml of water to each of the middle set of SSLB tubes and 0.1 ml to each of the last three SSLB tubes.
5. Incubate the tubes at 37°C for 24 h.

Confirmed Test

1. Select one positive lactose broth tube from the presumptive test and streak one plate of MacConky agar. Use a streak method which will produce good isolation of colonies.
2. Incubate the plate for 24 h at 37°C.

Calculations

Consider the following: If you had gas in the first five tubes and gas only in one tube of the second series, but none in the last five tubes, your test would be read as 5-1-0. And according to the Most Probable Number (MPN) Index (Prescott, 2002) you can determine what the MPN for the individual reading for this sample would be 43. This means that this particular sample of water would have approximately 43 organisms per 100 ml.

Fecal coliform bacteria parameters were compared the following reference standards: the World Health Organization Guidelines for Drinking Water Quality (2006) and the Connecticut Department of Environmental Protection Water Quality Standards (2008). In the tables below concerning fecal coliform and bacteria, please note that when sample results exceeds any reference standard maximum levels, the value will be listed in bold red text. E. coli, when present is noted by a red (**+**) sign.

Phytoplankton

For the quantitative sampling of phytoplankton, water samples were collected at the surface of each study site using a 1000 ml polyethylene bottle. The bottle was rinsed with the water from the site several times before being used to collect a 1000 ml water sample. Samples were preserved by adding 1 ml Lugol solution per 100 ml of water.

The diversity, richness and distribution of local photoplankton populations were calculated using the canonical correspondence analysis (CCA) method (Ter Braak and Prentice, 1988; Ter Braak & Verdonschot, 1995). The CCA calculations were performed with the assistance of the computer program CANOCO, version 4.5 (Ter Braak and Šmilauer, 2002) and these phytoplankton results were in turn used to estimate the sites' overall water quality according to Kassim (2005).

Zooplankton

For zooplankton, please note that data results are available but no analysis is included in this report. The methodology for zooplankton collection and identification included the following: water samples were taken from the selected station using a Van Dorn water sampler and a bucket (the latter was used only for surface samples). Forty (40) liters of water were collected and then concentrated down to 250 ml using a Hydro-Bios plankton net of 80 micron mesh size. The 250 ml samples were fixed with 5 ml of formaldehyde. The individual

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zooplankton species were identified and counted using a counting cell slide (cell size: 1 ml in capacity) and the unit measurements for zooplankton density are listed as individuals per liter (ind./l) using a binocular compound microscope (4, 10 and 40X). The classification of the zooplankton into groups such as Rotifera, Cladocera, and Copepoda was done according to, Edmondson (1959), Thorp & Covich (1991, 2001), Smith (2001) and Fernando (2002).

Zooplankton diversity index was calculated and water quality was determined according to the diversity index to three grades (Boyed, 1981; Ali, Salam, Jamshaisd, and Zahra, 2003).

1. Diversity index more than 3 indicates clean water quality.
2. Diversity index rank 1- 3 indicates moderate polluted water quality.
3. Less than 1 indicates heavy polluted water quality.

Benthic Macroinvertebrates

For benthic macroinvertebrates, samples were collected from the study sites by mean of different tools depending on the study area: Surber Sampler (0.0929 m² sampling area) and a Hess Stream Sampler (0.086 m² sampling area). In each site, 4 - 6 replicates were collected in order to get a representative sample for the area. The samples were washed immediately in the field and sieved using a 0.5 mm mesh size, and were washed in the lab later using the same sieve. Benthic macroinvertebrates were collected by mean of a dissecting microscope (BioVision 103B) and preserved in specific glass containers using 70% ethanol (Wetzel and Likens, 2000; Chairman, Ehlke, Irwin, Lium and Slack, 1977).

Benthic macroinvertebrates specimens were identified using BioVision 103B dissecting microscopes, Fisher S90009A compound biological microscopes, and Swift Optics M-9 Digital Microscopes, with the aid of many references (Ahmed, 1975; Oliver and Roussel, 1983; Peckarsky, Fraissinet, Penton and Conklin, 1990; Merritt and Cummins, 1996; Westfall and May, 1996; Wiggins, 1996; Needham, Westfall and May, 2000; Thorp and Covich, 2001; Bouchard, 2004; Thompson, 2004; Plaziat and Younis, 2005). Results for each site were defined by the density in m².

To evaluate the biological conditions in each site, we used several community indices recommended by Miller (2008):

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- Taxa Richness– A reduction in taxa richness typically indicates pollution.
- Taxa Evenness – How balanced is the community? A healthy community is characterized by a diverse number of taxa that have abundances somewhat proportional to each other.
- EPT% – How abundant are the mayflies (Ephemeroptera), stoneflies (Plecoptera), and caddisflies (Trichoptera)?

Biological conditions described in Miller (2008) were determined as follows:

Non-impaired site: A non-impaired site has a benthic community comparable to other undisturbed streams within the region.

- High Richness (high number of species/taxa).
- High Evenness (individuals are evenly distributed among the taxa).
- Sensitive species are well represented.

Moderately Impaired site: Moderately impaired sites are characterized by reduced taxa richness, in particular the EPT taxa.

- Less EPT% (less sensitive species are more dominant)

Severely Impaired site: A severely impaired site is one in which the benthic community has undergone a dramatic change.

- Low Richness (low number of species/taxa)
- Low Evenness (numbers can be high "dominance" or low "paucity of organisms")
- Low EPT% (community is dominated by pollution tolerant species)

Diversity, richness, and evenness were calculated by using CANOCO 4.5 Package. (Ter Braak and Šmilauer, 2002)

An additional water quality tool is the Pollution Tolerance Index (PTI) (Mitchell and Stapp, 2000) and Pollution Index (PI) (Waterwatch South Australia, 2004). These indices were modified for the species observed in Kurdistan-Iraq waters. Tolerance values of benthic macroinvertebrates which are obtained by determining the tolerance values of organisms to various types of stressors and calculating an average value (range from 0 which is very sensitive to 10 which is very tolerant) were extracted from many literatures such as Stribling, Jessup, White, Boward, and Hurd (1998), Barbour Gerrisen, Snyder, and Stribling (1999), Davis, Minshall, Robinson, and Landres (2001), Bode, Novak, Abele, Heitzman, and Smith

(2002), Klemm, Blacksom, Thoeny, Fulk, Herlihy, Kaufman and Cormier (2002), Mandaville (2002), Chessman (2003), Ode (2003), and Wilton (2004). Then, individuals were classified according to their tolerance values into four main categories (NSW Water Bug Survey, 2003):

- Very sensitive; sensitivity values ≈ 10 & 9; tolerance values ≈ 1 & 2
- Sensitive; sensitivity values ≈ 8, 7, & 6; tolerance values ≈ 3, 4 & 5
- Tolerant; sensitivity values ≈ 5, 4, & 3; tolerance values ≈ 6, 7 & 8
- Very tolerant; sensitivity values ≈ 2 & 1; tolerance values ≈ 9 & 10

In the original PTI and PI, there are certain orders or families in each tolerance group. These indices were developed in the U.S. and Australia respectively. For Kurdistan, Iraq, similar Iraqi genera were evaluated and those with similar tolerance were used to replace the American and Australian genera. Replacement was order-oriented i.e. two or more species with the same tolerance number and same order were put in the same cell in Microsoft Excel. For calculation, refer to Mitchell and Stapp (2000) and Waterwatch South Australia (2004). Finally, water quality was determined according to the following five grades:

- Modified Pollution Tolerance Index (Modified PTI) grades:
  - Excellent water quality (29+)
  - Very good water quality (23 – 28)
  - Good water quality (17 – 22)
  - Fair water quality (11 – 16)
  - Poor water quality (0 – 10)
- Modified Pollution Index (Modified PI) grades:
  - Excellent water quality (111+)
  - Very good water quality (74 – 110)
  - Good water quality (56 – 73)
  - Fair water quality (45 – 55)
  - Poor water quality (0 – 44)

Heavy Metals in Water

Heavy metals in water were analyzed (after stabilizing the pH with HNO3) with an atomic absorption spectrophotometer (Phoenix-986), using the procedures for heavy metal analysis outlined in the American Public Health Association's *Standard Method for Examination Water & Wastewater* (APHA, 2005). Results were compared to the same reference standards and levels listed for water quality materials and methods. In the tables for heavy metals in water below, please note that when sample results exceeds all reference standard maximum levels, the values will be listed in bold, red text.

Tests for Sediments

The summer 2008 survey was the first time the work included analysis of heavy metals in sediments from the stream beds where water sampling occurred. Samples were collected from the study sites using either a small trawl or, in deeper water, a Poner Grab (Petite Ponar grab 1728-C30). The samples were placed in a plastic container and returned to the lab, where they were dried in an oven at 40° C. Each sample was passed through a 63 micron mesh using a sieve shaker (model RX-29) then digested with HNO3+HCL using a hot plate, based on United State Environmental Protection Agency Method 3050B (USEPA, 1996). The resulting liquid sample was analyzed with an atomic absorption spectrophotometer (Phoenix-986), using procedures for heavy metal analysis outlined in by the APHA (2005).

The results of sediment heavy metals anyalsis were presented in tables and charts and were compared to aquatic sediment quality (Guidelines for the Protection and Management of Aquatic Sediment Quality in Ontario, 1993) and Canadian contamination levels (CSQG, 2002). In the tables below heavy metals in sediments, please note that when sample results exceeds all reference standard maximum levels, the value will be listed in bold, red text.

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Heavy Metals in Soil

The summer 2009 survey was the first time the work included analysis of heavy metals in soils. Samples were collected from the study sites using either a small trawl or, in deeper water, a Poner Grab (Petite ponar grab 1728-C30). The samples were placed in a plastic container and when returned to the lab where they were dried in an oven at 40°C. Each sample was passed through a 63 micron mesh using a sieve shaker (model RX-29) and then digested with HNO3+HCL by using a hot plate, based on united state environmental protection agency method no.3050B (USEPA, 1996). The resulting liquid sample was analyzed with an Atomic Absorption spectrophotometer (Phoenix-986), using procedures for heavy metal analysis outlined from (APHA, 2005).

Results of soil heavy metals are presented in tables and occasionally charts and were compared to world soil background (Kabata-Pendias and Mukherjee, 2007; Essington; Kabata-Pendias, 2001) and Maximum Allowable Concentration in Agricultural soils of Poland (Kabata-Pendias, 2001). In the tables below heavy metals in water, please note that when sample results exceeds all reference standard maximum levels, the value will be listed in bold, red text.

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Field & Lab Review

Diyala River Watershed (Darbandikhan Basin)

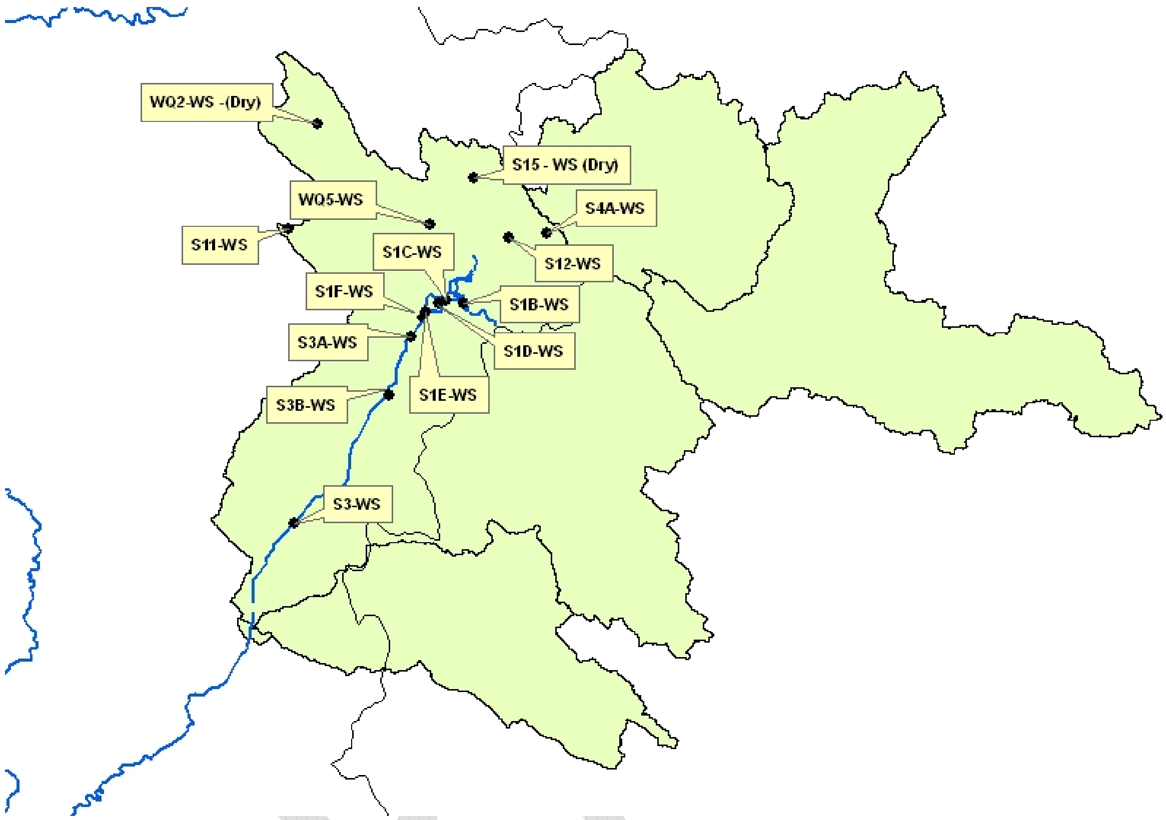

Plate 3: Upper Diyala River Watershed (Darbandikhan Basin) and KBA Sample Sites in Iraqi Kurdistan (shows the winter survey sites)

1. *Kela Spi (QA_EIA_WQ1 – Dry & Adjusted site) – Elev. 720 m*

Site Description: This site is revised from the located on the Kela Spi (QA_EIA_WQ_1) that was visited in past projects. An upland soil sample was taken at the original QA_EIA_WQ1 site but this area only contained stagnant water in summer, so the water quality sample point was relocated 2.8 km downstream (east) of the original site. This site is primarily a wetland/stream habitat and covered in vegetation but surrounded by a more grassland environment that is primarily used for agriculture and grazing. The site is fed primarily by groundwater and water draining from the surrounding land. It was visited only during the summer survey.

Plate

Observations (Summer- 11 Jun 2009, this site was not visited in summer):

Water Quality: QA_EIA_WQ_1 for summer: Sampling Time 12:55 PM, Water Depth 0.3m, Air temperature 33°C, Water temperature 21°C.

The water in this site was contaminated with NO2, NO3, HCO3, Ca, Mg, Cl, SO4 and Na compared to the river and surface water standards (see the table below). Sewage from the Raparin district and surrounding villages and agriculture runoff are the main sources of contamination.

Table 3: Physical & Chemical Water quality parameters at Kela Spi (QA_EIA_WQ1 (Adjusted))

Parameters	Summer	River Standards[1 & 2]	Surface Water Standards[2,3&4]
Field Analysis			
Water Temperature °C	21	N/A	N/A
Conductivity µS/cm	553	N/A	<1275
pH	7.3	N/A	6-8.5
Turbidity NTU	1.6	N/A	10
TDS mg/L	ND	N/A	500
Salinity ppt	0	N/A	N/A
DO mg/L	9.3	N/A	>5
DO%	114	N/A	N/A
Secchi disc m	0.3	N/A	N/A
Lab Analysis			
TSS mg/L	6	N/A	N/A
TDS mg/L	329	N/A	500
BOD mg/L	6.2	N/A	N/A
Orthophosphate (PO4) mg/L	ND	10	N/A
Nitrite-Nitrogen (NO2) mg/L	**0.049**	0.001	N/A
Nitrate-Nitrogen (NO3) mg/L	**16.1**	1	10
Total Alkalinity as CaCO3 mg/L	125	N/A	>20
Bicarbonate (HCO3) mg/L	**147**	58.4	58
Total Hardness (TH) mg/L	317	N/A	N/A
Calcium (Ca) mg/L	**62.8**	15	15
Magnesium (Mg) mg/L	**10.6**	4.1	4.1
Chloride (Cl) mg/L	**20.1**	7.8	7.8
Total Nitrogen (TN) mg/L	ND	N/A	N/A
Sulfate (SO4) mg/L	**13.6**	11.2	3.7
Total Phosphorous (TP) mg/L	0.0036	0.025	N/A
Potassium (K) mg/L	0.68	2.3	2.3
Sodium (Na) mg/L	**6.55**	6.3	6.3
1= Allan and Castillo, 2007; 2=Kabata-Pendias and Mukherjee, 2007; 3=Agardy and Sullivan, 2005; 4=STF, 2000; ND=not detected; N/A=not available			

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Bacteria & Coliform: QA_EIA_WQ_1 for summer- Sampling Time- 12:55 pm, Water Depth- 0.3m, Air temperature- 33°C, Water temperature-21°C.

The results from this site indicate a high level of contamination due to the presence of *E. coli* bacteria and fecal coliform bacteria, which was ≥ 2400 colonies per 100 ml and, based on the international standards, this water is not proper for any type of use. The contamination source seems to come from the agriculture activity in the area but potentially from sewage runoff as well and the proximity of the airport may have some additional impact.

Table 4: Fecal Coliform bacteria count and E. coli at site (QA_EIA_WQ1 (Adjusted))

	Winter	Summer	Drinking Standards[1 & 2]	Surface Water Standards [2]		
Fecal Coli form Bacteria Colony/100 ml	---	**≥ 2400**	0 in 100ml	Body-contact	Fishing and boating	Domestic water supply
				100 Colonies/100 mL	> 1000 Colonies/100 mL	> 2000 Colonies/100 mL
Escherichia coli	---	+				
1= WHO, 2006; 2= CDWQ, 2006						

<u>*Phytoplankton*</u>: The total phytoplankton count during the summer survey was 1508.9 x 10^3 cell/L and a total of 43 individual species were recorded. The dominant species in this site were pennate diatoms; of the 36 pennate diatoms identified in the sample area, *Cymbella affinis, Achnanthes minutissima* and *Denticula* sp. (400.8 x 10^3 cell/L, 267.2 x 10^3 cell/L and 233.8 x 10^3 cell/L respectively), were the most common species. This site is considered to have good diversity, very good richness and good evenness values (See Annex 2: Table 160, Table 162 & Table 164).

Table 5: Number of species, total count and percentage for phytoplankton groups in Kela Spi (QA_EIA_WQ1 Adjusted)

Phytoplankton Groups (WQ1)	Sp. #	Total Count (cell x 103/L)	%
Cyanophyta	2	10.1	0.67
Euglenophyta	0	0	0.00
Pyrrophyta	1	1	0.07
Chlorophyta	2	2	0.13
Bacillariophyceae/Centrales	2	2	0.13
Bacillariophyceae/Pennales	36	1493.8	99.00
Total	43	1508.9	100

<u>*Benthic Macroinvertebrates:*</u> In summer the total density found was 486 indv. /m² and comparing with the other studied sites, this density was relatively moderate (Annex 4: **Error! Reference source not found.**). Although, the site has a good diversity and very good richness and evenness (Annex 4: Table 168, respectively), The dominant species was the larva of the red-blood midge Chironomus riparius which is known as very tolerant organism (pollution tolerance number ≈ 10) and the EPT% was relatively very low (Table 174).

However, water quality was still good depending on the modified pollution tolerance and pollution indices (See Annex 1, Table 157 & Table 158). The good water quality could be confirmed by the presence of the sensitive bio-indicators such as the Small minnow mayfly Procloeon spp.

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Heavy Metals in Water (Summer): Mainly heavy metals (Ni, Pb, Cu, Cd and Zn) in the water at this site exceed the river standards and Cd and Ni exceed the surface water standards (see table below). The water at this site is stagnant in the summer season, which contributes to an increasing concentration of heavy metal because there is thus no input and output of water. Contaminants released from the Sulaimani airport, sewage from the Raparin district and surrounding villages and agriculture runoff are the main sources of contamination.

Table 6: Heavy metals in water of Kela Spi (QA_EIA_WQ1 Adjusted)

Heavy Metal	Summer	River Standards[1 & 2]	Surface Water Standards[2,3&4]
Nickel (Ni) mg/L	**0.019**	0.0008	0.0005-0.006
Lead (Pb) mg/L	0.0092	0.0015	0.09
Iron (Fe) mg/L	0.00007	0.67	0.22-0.35
Copper (Cu) mg/L	0.0253	0.002	0.27
Manganese (Mn)mg/L	ND	0.00002	0.07-0.5
Cadmium (Cd) mg/L	**0.0023**	0.00008	0.000005
Zinc (Zn) mg/L	**0.0213**	0.0006	N/A
1= Allan and Castillo, 2007; 2=Kabata-Pendias and Mukherjee, 2007; 3=Agardy and Sullivan, 2005; 4=STF, 2000; ND=not detected; N/A=not available			

Heavy Metals in Soil: Heavy metals in the soil of Kelaspi site show concentrations higher than the world soil background, but not exceeding the maximum allowable concentration in agricultural soils of Poland, except for Ni (see table below). Soil of the adjusted Kela Spi site had some differences in concentrations (higher lead levels than the original sight but lower nickel, iron, copper, cadmum and zinc). This difference may be related to the wetness of the adjusted Kela Spi site. Both areas have been affected by anthropogenic activities (the adjusted site is also closer to the Sulaimani airport), so soil contamination with heavy metals for such activities is possible.

Table 7: Heavy Metals in Soil of Kela Spi (QA_EIA_WQ1 Adjusted)

Heavy Metal	Summer		Soil Background[1 & 2]	*Agricultural Soils[3]
	Kelaspi	Kelaspi (adjusted)		
Nickel (Ni) mg/kg	**165.6**	**114.075**	19-22	30-75
Lead (Pb) mg/kg	33.8	62.725	25	70-150
Iron (Fe) mg/kg	33252.5	25700	2000	N/A
Copper (Cu) mg/kg	49.3	47.875	20	30-70
Manganese (Mn)mg/kg	**692.8**	**665**	437	N/A
Cadmium (Cd) mg/kg	2.6	2.2	0.5	10
Zinc (Zn) mg/kg	86.0	84.1	64	100-300
1=Kabata-Pendias and Mukherjee, 2007; 2=Essington; 3=Kabata-Pendias, 2001; *=Maximum Allowable Concentration in Agricultural soils of Poland.; ND=not detected; N/A=not available				

Heavy Metals in Sediments: Sediments of the adjusted Kela Spi site from summer were contaminated with Pb, Cu and Cd (see table below) and Ni, Cu, Cd, Mn, Zn and Pb exceed the background in soils (see table below). The probable source of the contamination may be related to contaminants released from airplanes at Sulaimani airport, sewage and agriculture runoff.

Table 8: Heavy metals in sediment of Kela Spi (QA_EIA_WQ1 Adjusted)

Heavy Metal	Summer	Background[1]	CSQG[2]

	Kelaspi (adjusted)		
Nickel (Ni) mg/kg	**212.25**	31	N/A
Lead (Pb) mg/kg	**37.2**	23	35
Iron (Fe) mg/kg	34265	N/A	N/A
Copper (Cu) mg/kg	**49.5**	25	35.7
Manganese (Mn) mg/kg	**933.25**	400	N/A
Cadmium (Cd) mg/kg	**1.35**	1.1	0.6
Zinc (Zn) mg/kg	85	65	123
1= ASQ, 1993; 2= CSQG, 2002; N/A=not available			

Conservation Issues & Recommendations: Fecal colifrom Bacteria and E. coli result for the adjusted Kela Spi site during summer 2009 showes a high level of bacterial contamination, the reason may come from the surrounded grassland environment that is primarily used for agriculture and grazing but further investigation is recommended.

Benthic Macroinvertebrates results for this site during summer 2009 indicated moderately impaired habitat and good water quality. Evualation of the effect of various sources of contamination is required to understand and mitigate pollution sources, such as construction and building operations, the airport, garbage, agricultural practices and tourist activity. The site includes the upstream portion and a main tributaries of the Tanjero River, so remediation and cleanup of the site and surrounding area is of great concern.

Phytoplankton total count indicate that Kela Spi during summer 2009, had mesotrophic water quality. This may have being a good reason for the good diversity and very good richness values recorded in this site compared to the other surveyed sites.

2. Quilisan (QA_EIA_WQ2) – Elev. 759 m

Site Description: This site is located on the Quilisan Stream in northwestern Sulaimani City in an area known as Sarchinar. Upstream from the site to the north there is a broken dam (Chaq Chaq Dam). Additionally, there is a closed cement factory to the southeast of this dam. Downstream of the winter sample site and upstream of the first bridge in Sarchinar that crosses the Quilisan there is a large building that has been built on fill that extends well into the floodplain of the Quilisan Stream. Some debris is present near this site and there is also no plant cover. There is extensive dumping of fill in the area along the stream and a brick and cement wall lines portions of the western side of the stream. The area is impacted by a high level of anthropogenic activities (tourism, industrial, fuel station, gravel mining, sewage disposal, car washing, and agricultural activities). No water was present at the site in winter.

In summer, the survey point was moved southward in order to sample in an area of flowing water below the Sarchinar Bridge and a weir downstream of the bridge. Here the Quilisan is a small (less than a meter wide in many areas) stream but is still actively flowing. Further downstream of this area are a series of earthen dams for water extraction as well as numerous pumps in the stream pulling water to irrigate local gardens and small farms. Many areas along the stream are impacted by dumping, garbage and debris and one of the main sewage inputs in Sarchinar enters the stream just above the second bridge. Below this second bridge there is a parks development project creating walkways and fountains along both embankments, though in summer the Quilisan is carrying mostly untreated sewage water.

Plate

Observations (Winter: 8 Jan 2009; Summer (adjusted downstream): 11 Jun 2009):

Water Quality: This site was dry during the winter survey, so no field or lab parameters were available.

QA_EIA_WQ_2 (adjusted) for summer: Sampling Time 09:48 AM, Water Depth 0.12m, Air temperature 32°C, Water temperature 21.4°C.

Water at this site was contaminated with NO2, NO3, HCO3, Ca, Mg, Cl, SO4 and Na in comparison to river and surface water standards (See Table 9). Dumping, garbage, construction and agricultural runoff entering the stream seem to be the main sources of this contamination.

Table 9: Physical & Chemical Water Quality Parameters at Quilisan (QA_EIA_WQ2)

Parameters	Summer	River Standards[1 & 2]	Surface Water Standards[2,3&4]
Field Analysis			
Water Temperature °C	21.4	N/A	N/A
Conductivity µS/cm	477	N/A	<1275
pH	7.3	N/A	6-8.5
Turbidity NTU	6.9	N/A	10
TDS mg/L	ND	N/A	500
Salinity ppt	0	N/A	N/A
DO mg/L	5.7	N/A	>5
DO%	73	N/A	N/A
Secchi disc m	0.12	N/A	N/A
Lab Analysis			
TSS mg/L	2	N/A	N/A
TDS mg/L	301	N/A	500
BOD mg/L	2.5	N/A	N/A
Orthophosphate (PO4) mg/L	ND	10	N/A
Nitrite-Nitrogen (NO2) mg/L	**0.049**	0.001	N/A
Nitrate-Nitrogen (NO3) mg/L	3.3	1	10
Total Alkalinity as CaCO3 mg/L	95.5	N/A	>20
Bicarbonate (HCO3) mg/L	**114.1**	58.4	58
Total Hardness (TH) mg/L	270	N/A	N/A
Calcium (Ca) mg/L	**65.26**	15	15
Magnesium (Mg) mg/L	**5.68**	4.1	4.1
Chloride (Cl) mg/L	**9.96**	7.8	7.8
Total Nitrogen (TN) mg/L	ND	N/A	N/A
Sulfate (SO4) mg/L	**39.12**	11.2	3.7
Total Phosphorous (TP) mg/L	ND	0.025	N/A
Potassium (K) mg/L	1.43	2.3	2.3
Sodium (Na) mg/L	**8.55**	6.3	6.3
1= Allan and Castillo, 2007; 2=Kabata-Pendias and Mukherjee, 2007; 3=Agardy and Sullivan, 2005; 4=STF, 2000; ND=not detected; N/A=not available			

Bacteria & Coliform, Plankton, Benthic Macroinvertebrates, Heavy Metals: No samples in winter.

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Bacteria & Coliform: This site was dry during the winter survey, so no field or lab parameters were available. QA_EIA_WQ_2 for summer- Sampling Time- 09:48 am, Water Depth- 0.12m, Air temperature- 32°C, Water temperature-21.4°C.

According to the results from this site there is a high level of contamination by fecal coliform bacteria. This contamination may come from the construction projects and human activity upstream and in this area. Furthermore, the scarcity of water after a dry summer may contribute to the conditions of the stream.

Table 10: Fecal Coliform bacteria count and E. coli at site Quilisan (QA_EIA_WQ2)

	Winter	Summer	Drinking Standards[1 &2]	Surface Water Standards[2]		
				Body-contact	Fishing and boating	Domestic water supply
Fecal Coli form Bacteria Colony/100 ml	---	≥ 2400	0 in 100ml	100 Colonies/100 mL	> 1000 Colonies/100 mL	> 2000 Colonies/100 mL
Escherichia coli	---	+				
1= WHO, 2006; 2= CDWQ, 2006;						

Phytoplankton: The total phytoplankton count during the summer survey was 214.2 x 10^3 cell/L and a total of 22 individual species were recorded. The dominant species in this site were pennate diatoms (92.02%) (see table below). Among these, *Achnanthes minutissima, Cocconeis pediculus, Gomphonema angustatum, Navicula cryptocephala, Nitzschia hungarica* and *Nitzschia palea* were the most common species. This site is considered to have moderate diversity as well as good richness and evenness values (See Annex 2: Table 176, Table 178 & Table 180).

Table 11: Number of species, total count and percentage for phytoplankton groups in Quilisan (QA_EIA_WQ2)

Phytoplankton Groups (WQ2)	Sp. #	Total Count (cell x 10^3/L)	%
Cyanophyta	1	1	0.47
Euglenophyta	1	1	0.47
Pyrrophyta	0	0	0
Chlorophyta	3	3	1.40
Bacillariophyceae/Centrales	2	12.1	5.65
Bacillariophyceae/Pennales	15	197.1	92.02
Total	22	214.2	100

Benthic Macroinvertebrates: **Total density found was 879 indv. /m² and comparing with the other studied sites, this density was relatively very good (Annex 4: Table 183). The site also characterized by a good by a good diversity, very good richness and evenness, and a moderate EPT% (Annex 4: Table 168, Table 170,** Table 172 & Table 174, respectively). However, it was dominated by the Small minnow mayfly *Fallceon* sp.3 which is known as tolerant organism (pollution tolerance number ≈ 6).

Water quality was good depending on the modified pollution tolerance and pollution indices (See Annex 1, Table 174). The good water quality could be confirmed by the presence of the sensitive bio-indicators such as the Small minnow mayfly *Procloeon* sp.2.

Heavy Metals in Water (Summer): Mainly heavy metals (Ni, Pb, Cu, Mn, Cd and Zn) in water of this site exceed the river standards and Cd and Ni exceed the surface water standards (see Table 12

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below). Dumping, garbage and agricultural runoff entering the stream seem to be the main sources of heavy metal contamination.

Table 12: Heavy Metals in Water of Quilisan (QA_EIA_WQ2)

Heavy Metal	Summer	River Standards[1 & 2]	Surface Water Standards[2,3&4]
Nickel (Ni) mg/L	**0.018**	0.0008	0.0005-0.006
Lead (Pb) mg/L	0.0089	0.0015	0.09
Iron (Fe) mg/L	0.00002	0.67	0.22-0.35
Copper (Cu) mg/L	0.0237	0.002	0.27
Manganese (Mn)mg/L	0.0098	0.00002	0.07-0.5
Cadmium (Cd) mg/L	**0.0023**	0.00008	0.000005
Zinc (Zn) mg/L	**0.021**	0.0006	N/A
1= Allan and Castillo, 2007; 2=Kabata-Pendias and Mukherjee, 2007; 3=Agardy and Sullivan, 2005; 4=STF, 2000; ND=not detected; N/A=not available			

Heavy Metals in Soil: Soil sample from this site contained heavy metals of a concentration higher than the world soil background, but not exceeding the maximum allowable concentration in reference standard for agricultural soils of Poland, except for Ni (see Table 13 below). Soil sampling was done in an area mainly comprised of agricultural area and farmland; because of this composition the comparsion with agricultural soil of another area like Poland was useful to assess the heavy metal impression. The area is impacted by anthropogenic activities, so soil contamination with heavy metals is possible.

Table 13: Heavy Metals in Soil of Quilisan (QA_EIA_WQ2)

Heavy Metal	Summer	Soil Background[1 & 2]	*Agricultural Soils[3]
Nickel (Ni) mg/kg	**127.7**	19-22	30-75
Lead (Pb) mg/kg	40.2	25	70-150
Iron (Fe) mg/kg	37567.5	2000	N/A
Copper (Cu) mg/kg	52.1	20	30-70
Manganese (Mn)mg/kg	**757.5**	437	N/A
Cadmium (Cd) mg/kg	2.2	0.5	10
Zinc (Zn) mg/kg	116.5	64	100-300
1=Kabata-Pendias and Mukherjee, 2007; 2=Essington; 3=Kabata-Pendias, 2001; *=Maximum Allowable Concentration in Agricultural soils of Poland.; ND=not detected; N/A=not available			

Heavy Metals in Sediments: Sediments of the upstream Qiliasan site in winter represented sediments contaminated with Ni, Cu, Mn and Zn in winter sampling and contaminated with Ni, Cu, Cd, Mn and Pb in summer sampling at the downstream revised site (

Table 14). Some of the heavy metals are at high levels such as nickel, which exceeds background and contamination levels (

Table 14). One of the sources of this contamination in the sediment of the area is sewage from Kani Bardina and surrounding district. Generally, concentration of heavy metals in sediment of this site shows variation between two seasons of sampling (concentration was higher in winter than summer, except Pb and Cd). Heavy metals in soil of the area affects the heavy metals in sediments (see the section of heavy metals in soil), because soils and rocks are the parent material of sediments; but because the levels of heavy metals in sediment of this site are higher than the levels in the soil, the sediments were contaminated.

Table 14 : Heavy metals in sediment of Quilisan (QA_EIA_WQ2)

Heavy Metal	Winter	Summer	Background[1]	CSQG[2]

Nickel (Ni) mg/kg	**469.8**	**115.0**	31	N/A
Lead (Pb) mg/kg	29.85	**41.9**	23	35
Iron (Fe) mg/kg	33886	30907.5	N/A	N/A
Copper (Cu) mg/kg	**97.5**	**59.3**	25	35.7
Manganese (Mn) mg/kg	1753.6	901.8	400	N/A
Cadmium (Cd) mg/kg	0.4	**3.0**	1.1	0.6
Zinc (Zn) mg/kg	**270.5**	92.8	65	123
1= ASQ, 1993; 2= CSQG, 2002; N/A=not available				

Conservation Issues & Recommendations: Fecal colifrom Bacteria and Ecoli result for Sarchinar (QA-EIA-WQ2) during summer 2009 indicates a high level of bacterial contaminations; the resion may come from the surrounded grassland environment that is primarily used for agriculture.the building prosiss, human activity and sewage discharge is the maine resion behind this contaminations, so the building activity and sewage discharge should be controlled and organized.

Benthic Macroinvertebrates results for Sarchinar (QA-EIA-WQ2) during summer 2009 indicated moderately impaired habitat and good water quality. It is recommended to study heavy metals in the sediment and soil of the upper Qiliasan stream before sewage enters the watershed in order to determine their background levels. Evaulation of the effect of various sources of contamination is required, such as construction and building operations, garbage, agricultural practices and tourist activity. The site includes the upstream portion and source of the main tributaries of the Tanjero River, so remediation and cleanup of the site and surrounding area is of great concern.

Phytoplankton results for Sarchinar during summer 2009 indicate that this site had oligotrophic water, which may have not supported the diversity of the phytoplankton community.

3. Below Qara Dagh Bridge (QA_EIA_WQ3) – Elev 654

Site Description: This site is along Tanjero River. It's mixed sewage water. The water runs in high speed. The bed stream consists of gravel. There are green algae on the rocks. In west there are many abandoned gravel mines and many industrial foundations located in the north-west. Dumping site of Sulaimani City is on the north. Farmlands in the north and around were found. Habitat type: permanent wetlands and sparse woodlands.

Plate

Observations (Summer- 12 Jun 2009, not visited in winter):

Water Quality: QA_EIA_WQ3-SS Summer: Sampling Time 08:41 AM, Water Depth 0.2 m, Air temperature 35°C, Water temperature 22.5°C.

The water at this site was found to be turbid, contaminated and in excess of the level of natural rivers and surface waters for the following: nitrate (NO3), nitrite (NO2), bicarbonate (HCO3), calcium (Ca), magnesium (Mg), chloride (Cl), sulfate (SO4), total phosphorous (TP), potassium (K) and sodium (Na) (see Table 15). The source of contamination that affects the Tanjero as defined by Mustafa (2006) is mainly: sewage disposal of Sulaimani City and towns below, industrial waste from the surrounding foundations as well as waste disposal dumping to the north of the site (the city dump) where municipal and industrial waste is dumped and partially burned.

Table 15: Physical & Chemical Water Quality Parameters at Below Qara Dagh Bridge (QA_EIA_WQ3)

Parameters	Summer	River Standards [1 & 2]	Surface Water Standards [2,3&4]

Parameters	Summer	River Standards [1 & 2]	Surface Water Standards [2,3&4]
Field Analysis			
Water Temperature °C	22.5	N/A	N/A
Conductivity µS/cm	886	N/A	<1275
pH	7.6	N/A	6-8.5
Turbidity NTU	**159**	N/A	10
TDS mg/L	ND	N/A	500
Salinity ppt	0.2	N/A	N/A
DO mg/L	4.9	N/A	>5
DO%	60.8	N/A	N/A
Secchi disc m	0.1	N/A	N/A
Lab Analysis			
TSS mg/L	120	N/A	N/A
TDS mg/L	496	N/A	500
BOD mg/L	ND	N/A	N/A
Orthophosphate (PO4) mg/L	1.35	10	N/A
Nitrite-Nitrogen (NO2) mg/L	**0.13**	0.001	N/A
Nitrate-Nitrogen (NO3) mg/L	2.95	1	10
Total Alkalinity as CaCO3 mg/L	99.5	N/A	>20
Bicarbonate (HCO3) mg/L	**212.6**	58.4	58
Total Hardness (TH) mg/L	345	N/A	N/A
Calcium (Ca) mg/L	**105.1**	15	15
Magnesium (Mg) mg/L	**17.17**	4.1	4.1
Chloride (Cl) mg/L	**50.4**	7.8	7.8
Total Nitrogen (TN) mg/L	ND	N/A	N/A
Sulfate (SO4) mg/L	**83**	11.2	3.7
Total Phosphorous (TP) mg/L	**2.23**	0.025	N/A
Potassium (K) mg/L	**10**	2.3	2.3
Sodium (Na) mg/L	**59.6**	6.3	6.3
1= Allan and Castillo, 2007; 2=Kabata-Pendias and Mukherjee, 2007; 3=Agardy and Sullivan, 2005; 4=STF, 2000; ND=not detected; N/A=not available			

Bacteria & Coliform: From the results of summer we conclude that this site is contaminated with fecal coliform bacteria and *E. coli* bacteria.

Table 16: Fecal Coliform bacteria count and E. coli at site (QA_EIA_WQ3)

	Winter	Summer	Drinking Standards [1 & 2]	Surface Water Standards [2]		
				Body-contact	Fishing and boating	Domestic water supply
Fecal Coli form Bacteria Colony/100 ml	---	**≥ 2400**	0 in 100ml	100 Colonies/100 mL	> 1000 Colonies/100 mL	> 2000 Colonies/100 mL
Escherichia coli	---	+				
1= WHO, 2006; 2= CDWQ, 2006;						

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Phytoplankton: The total phytoplankton count during the summer survey was 1101.6 x 10^3 cell/L and a total of 27 individual species were recorded. The dominant species in this site were pennate diatoms; *Nitzschia hungarica, Nitzschia palea* and *Nitzschia dissipata* (400.8 x 10^3 cell/L, 189.3 x 10^3 cell/L and 111.3 x 10^3 cell/L respectively) were the most common species. Additionally, *Euglena* sp. and *Phacus* sp. were the most prevalent Euglenophyta species while the blue-green algae *Oscillatoria limnetica* and *Anabaena* sp. were also recorded along with the green algae *Coelastrum astroideum* and *Ankistrodesmus falcatus*. This site is considered to have moderate diversity, very good richness and good evenness values (See Annex 2: Table 176, Table 178 & Table 180).

Table 17: Number of species, total count and percentage for phytoplankton groups in Below Qara Dagh Bridge (QA_EIA_WQ3)

Phytoplankton Groups (WQ3)	Sp. #	Total Count (cell x 10^3/L)	%
Cyanophyta	3	73.4	6.66
Euglenophyta	2	90.6	8.22
Pyrrophyta	0	0	0
Chlorophyta	2	72.5	6.58
Bacillariophyceae/Centrales	5	36.4	3.3
Bacillariophyceae/Pennales	15	828.7	75.23
Total	27	1101.6	100

Zooplankton: During summer 2009, in the surface water layer below the Qara Dagh Bridge (WQ-3), zooplankton density of 469 ind/l was recorded (Rotifera formed 58%, Copepoda 25.6% and Cladocera 16.4%). The dominant zooplankton species was *Lepadella ovalis* (63.4 ind/l) from Rotifera.

Benthic Macroinvertebrates: **Total density found was 276 indv. /m² and comparing with the other studied sites, sites, this density was relatively low (Annex 4: Table 183). Although, the site has relatively a moderate richness richness and evenness (Annex 4: Table 170 &**

Table 172, respectively), the diversity was relatively low (Annex 4: Table 168) and the EPT% was zero. In addition, the dominant species was the larva of the red-blood midge Chironomus riparius which is known as very tolerant organism (pollution tolerance number ≈ 10).

Water quality depending on the modified pollution tolerance and pollution indices was poor (See Annex 1, Table 174) and this could be confirmed by the presence of the very tolerant bio-indicators such as the rat-tailed maggot Eristalis sp.

Heavy Metals in Water (Summer): Mainly heavy metals (Ni, Pb, Cu, Mn, Cd and Zn) in the water of this site exceed the river reference standards but Ni, Cd, and Zn exceeded the surface water standards (see Table below). The source of contamination, as was explained above, is likely: sewage disposal from Sulaimani City, industrial waste from the surrounding foundations and waste disposal dumping in the north of the site (city dump).

Table 18: Heavy Metals in Water of Below Qara Dagh Bridge (QA_EIA_WQ3)

Heavy Metal	Summer	River Standards[1 & 2]	Surface Water Standards[2,3&4]
Nickel (Ni) mg/L	**0.02**	0.0008	0.0005-0.006
Lead (Pb) mg/L	0.009	0.0015	0.09
Iron (Fe) mg/L	0.0001	0.67	0.22-0.35
Copper (Cu) mg/L	0.025	0.002	0.27
Manganese (Mn)mg/L	0.05	0.00002	0.07-0.5
Cadmium (Cd) mg/L	**0.002**	0.00008	0.000005

Heavy Metal	Summer	River Standards[1 & 2]	Surface Water Standards[2,3&4]
Zinc (Zn) mg/L	**0.044**	0.0006	N/A
1= Allan and Castillo, 2007; 2=Kabata-Pendias and Mukherjee, 2007; 3=Agardy and Sullivan, 2005; 4=STF, 2000; ND=not detected; N/A=not available			

Heavy Metals in Soil: Soil sample of this site contained heavy metals with a higher concentration than the world soil background, but not exceedimg the maximum allowable concentration in agricultural soils of Poland, except for Ni (see table below). The area was overloaded by anthropogenic and industrial activities, so soil contamination with heavy metals is possible.

Table 19: Heavy Metals in Soil of Below Qara Dagh Bridge (QA_EIA_WQ3)

Heavy Metal	Summer	Soil Background[1 & 2]	*Agricultural Soils[3]
Nickel (Ni) mg/kg	**146.2**	19-22	30-75
Lead (Pb) mg/kg	42.1	25	70-150
Iron (Fe) mg/kg	**31897.5**	2000	N/A
Copper (Cu) mg/kg	51	20	30-70
Manganese (Mn)mg/kg	**688.8**	437	N/A
Cadmium (Cd) mg/kg	1.4	0.5	10
Zinc (Zn) mg/kg	82.5	64	100-300
1=Kabata-Pendias and Mukherjee, 2007; 2=Essington; 3=Kabata-Pendias, 2001; *=Maximum Allowable Concentration in Agricultural soils of Poland.; ND=not detected; N/A=not available			

Heavy Metals in Sediments: Sediments of the site is contaminated with Ni, Pb, Cu, Mn, Cd and Zn (see Table below). The source of contamination is likely: sewage disposal from Sulaimani City, industrial waste from the surrounding foundations and waste disposal dumping in the north of the site (city dump).

Table 20: Heavy metals in sediment of Below Qara Dagh Bridge (QA_EIA_WQ3)

Heavy Metal	Summer	Background[1]	CSQG[2]
Nickel (Ni) mg/kg	**103.03**	31	N/A
Lead (Pb) mg/kg	**46.8**	23	35
Iron (Fe) mg/kg	25657.5	N/A	N/A
Copper (Cu) mg/kg	**48.4**	25	35.7
Manganese (Mn) mg/kg	**662.7**	400	N/A
Cadmium (Cd) mg/kg	**2.3**	1.1	0.6
Zinc (Zn) mg/kg	90	65	123
1= ASQ, 1993; 2= CSQG, 2002; N/A=not available			

Conservation Issues & Recommendations: The water and sediments at this site are contaminated with nutrients (in water) and heavy metals (in water and sediments). Fecal coliform Bacteria and *E. coli* result for Below Qara Dagh Bridge (QA-EIA-WQ3) during summer 2009 indicates that the river is highly contaminated with fecal coliform and this is likely coming mostly from the sewage and nutrient discharges from the city and industrial zones of the city, so remediation and further monitoring is recommended.

Phytoplankton results for Qara Dagh Bridge during summer 2009 indicate meso-oligotrophic water conditions.

Benthic Macroinvertebrates results for Below Qara Dagh Bridge (QA-EIA-WQ3) during summer 2009 indicated severely impaired habitat and poor water quality.

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Farmers used this water in the surrounding areas along Tanjero River and the runoff irrigation water returns to the Darbandikhan Lake, which has an active fisheries and recreational use, as well as use further downstream for human consumption. The water of the river (especially at this site) is not suitable for the above uses and the farmers must be warned to be careful when using the water of the site.

4. *Qara Ali Site (QA_EIA_WQ4) – Elev 569*

Site Description: This sample point is along the Tanjero River at the proposed site of the Qara Ali Irrigation Dam. The site was visited during summer and the water was runs with a high speed. The stream bed was gravel and algae was noted on the rocks. Many gravel mines are located near the sampling site. The general habitat was river/riparian and shrublands.

Plate

Observations (Not visited in winter; Summer: 12 June 2009):

Water Quality: QA_EIA_WQ_4 For summer: Sampling Time 11:26 AM, Water Depth 0.3m, Air temperature 37°C, Water temperature 25.3°C.

During the summer survey, this site was contaminated with NO2, HCO3, Ca, Mg, Cl, TP, Na and SO4 compared to reference concentrations for natural rivers and surface water standards (see Table 21).

Table 21: Physical & Chemical Water Quality Parameters at Site Qara Ali (QA_EIA_WQ4)

Parameters	Summer	River Standards [1 & 2]	Surface Water Standards [2,3&4]
Field Analysis			
Water Temperature °C	25.6	N/A	N/A
Conductivity µS/cm	904	N/A	<1275
pH	7.9	N/A	6-8.5
Turbidity NTU	147	N/A	10
TDS mg/L	ND	N/A	500
Salinity ppt	0.2	N/A	N/A
DO mg/L	7.8	N/A	>5
DO%	111.7	N/A	N/A
Secchi disc m	0.1	N/A	N/A
Lab Analysis			
TSS mg/L	157	N/A	N/A
TDS mg/L	545	N/A	500
BOD mg/L	ND	N/A	N/A
Orthophosphate (PO4) mg/L	0.68	10	N/A
Nitrite-Nitrogen (NO2) mg/L	**1.6**	0.001	N/A
Nitrate-Nitrogen (NO3) mg/L	9	1	10
Total Alkalinity as CaCO3 mg/L	194	N/A	>20
Bicarbonate (HCO3) mg/L	218	58.4	58
Total Hardness (TH) mg/L	390	N/A	N/A

Parameters	Summer	River Standards [1 & 2]	Surface Water Standards [2,3&4]
Calcium (Ca) mg/L	**119.05**	15	15
Magnesium (Mg) mg/L	**19.16**	4.1	4.1
Chloride (Cl) mg/L	**46.76**	7.8	7.8
Total Nitrogen (TN) mg/L	ND	N/A	N/A
Sulfate (SO4) mg/L	**94.71**	11.2	3.7
Total Phosphorous (TP) mg/L	**5.1**	0.025	N/A
Potassium (K) mg/L	7.8	2.3	2.3
Sodium (Na) mg/L	**58.08**	6.3	6.3
1= Allan and Castillo, 2007; 2=Kabata-Pendias and Mukherjee, 2007; 3=Agardy and Sullivan, 2005; 4=STF, 2000; ND=not detected; N/A=not available			

Bacteria & Coliform: As expected from the site description and other chemical analysis (BOD, NO3, NO2, etc.) there was high fecal coliform contamination and the existence of *E. coli* at the Qara Ali site (QA_EIA_WQ4) during summer sampling.

Table 22: Fecal Coliform bacteria count and E. coli at site (QA_EIA_WQ4)

	Winter	Summer	Drinking Standards [1 & 2]	Surface Water Standards [2]		
				Body-contact	Fishing and boating	Domestic water supply
Fecal Coli form Bacteria Colony/100 ml	---	**≥ 2,400**	0 in 100ml	100 Colonies/100 mL	> 1000 Colonies/100 mL	> 2000 Colonies/100 mL
Escherichia coli	---	**+**				
1= WHO, 2006; 2= CDWQ, 2006						

Phytoplankton: The total phytoplankton count during the summer survey was 2534.2 x 10^3 cell/L and a total of 24 species were recorded. The dominant species in ths site was *Euglena* sp. (1059.7 x 10^3 cell/L). Additionally, *Nitzschia palea, Nitzschia dissipata, Nitzschia hungarica* and *Gomphonema angustatum* (456.5 x 10^3 cell/L, 311.7 x 10^3 cell/L, 167 x 10^3 cell/L respectively) were the most common pennate diatom species. This site is considered to have moderate diversity, very good richness and good evenness values (See Annex 2: Table 176, Table 178 & Table 180).

Table 23: Number of species, total count and percentage for phytoplankton groups in Qara Ali (QA_EIA_WQ4)

Phytoplankton Groups (WQ4)	Sp. #	Total Count (cell x 10^3/L)	%
Cyanophyta	1	1	0.04
Euglenophyta	2	1068.8	42.18
Pyrrophyta	1	9.1	0.36
Chlorophyta	0	0	0
Bacillariophyceae/Centrales	3	3	0.12
Bacillariophyceae/Pennales	17	1452.3	57.31
Total	24	2534.2	100

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<u>*Benthic Macroinvertebrates*</u>: Total density found was 581 indv. /m² and comparing with the other studied sites, this density was relatively moderate (Annex 4: Table 166). Although, the site has relatively a moderate diversity and good richness and evenness (Annex 4: Table 185, Table 187 & Table 189 respectively), the EPT% was very low (Annex 4: Table 174) and the dominant species was the larva of the red-blood midge Chironomus riparius which is known as very tolerant organism (pollution tolerance number ≈ 10).

Water quality depending on the modified pollution tolerance and pollution indices was poor to fair (See Annex 1, Table 174) and this could be confirmed by the presence of the tolerant and very tolerant bio-indicators such as the shore fly *Ephydra* sp., the gastropod *Valvata* sp., and the aquatic worm *Limnodrilus hoffmeisteri*.

<u>*Heavy Metals in Water:*</u> This site was contaminated with Ni, Cu, Cd, Zn and Mn (see Table below). The source(s) of this contamination are likely come from contamination sources from the upstream (sewages of Sulaimani city and waste disposal site of Sulaimani).

Table 24: Heavy metals in water of site Qara Ali (QA_EIA_WQ4)

Heavy Metal	Summer	River Standards[1 & 2]	Surface Water Standards[2,3&4]
Nickel (Ni) mg/L	**0.017**	0.0008	0.0005-0.006
Lead (Pb) mg/L	0.0094	0.0015	0.09
Iron (Fe) mg/L	0.00004	0.67	0.22-0.35
Copper (Cu) mg/L	0.024	0.002	0.27
Manganese (Mn)mg/L	0.047	0.00002	0.07-0.5
Cadmium (Cd) mg/L	**0.0023**	0.00008	0.000005
Zinc (Zn) mg/L	**0.025**	0.0006	N/A
1= Allan and Castillo, 2007; 2=Kabata-Pendias and Mukherjee, 2007; 3=Agardy and Sullivan, 2005; 4=STF, 2000; ND=not detected; N/A=not available			

<u>*Heavy Metals in Soil*</u>: Heavy metals Ni, Pb, Fe, Cu, Mn, Cd and Zn in the soil of this site show higher concentrations than the world soil background, but not exceeding the maximum allowable concentration in agricultural soils of Poland, except Ni (see Table below).

Table 25: Heavy Metals in Soil of Qara Ali (QA_EIA_WQ4)

Heavy Metal	Summer	Soil Background [1 & 2]	*Agricultural Soils [3]
Nickel (Ni) mg/kg	**168.55**	19-22	30-75
Lead (Pb) mg/kg	43.85	25	70-150
Iron (Fe) mg/kg	**46377.5**	2000	N/A
Copper (Cu) mg/kg	66.3	20	30-70
Manganese (Mn)mg/kg	972.25	437	N/A
Cadmium (Cd) mg/kg	2.5	0.5	10
Zinc (Zn) mg/kg	106.3	64	100-300
1=Kabata-Pendias and Mukherjee, 2007; 2=Essington; 3=Kabata-Pendias, 2001; *=Maximum Allowable Concentration in Agricultural soils of Poland.; ND=not detected; N/A=not available			

<u>*Heavy Metals in Sediments:*</u> Sediments of the site were contaminated with Pb, Cd and Cu (see Table below). Same sources as water quality section are the most probable source of contamination of sediments.

Table 26: Heavy metals in sediment of Qara Ali (QA_EIA_WQ4)

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Heavy Metal	Summer	Background[1]	CSQG[2]
Nickel (Ni) mg/kg	**112.4**	31	N/A
Lead (Pb) mg/kg	**48**	23	35
Iron (Fe) mg/kg	28852.5	N/A	N/A
Copper (Cu) mg/kg	**58.4**	25	35.7
Manganese (Mn) mg/kg	**601.2**	400	N/A
Cadmium (Cd) mg/kg	**0.97**	N/A	0.6
Zinc (Zn) mg/kg	120.5	65	123
1= ASQ, 1993; 2= CSQG, 2002; N/A=not available			

Conservation Issues & Recommendations: Water and sediments of the site might be contaminated with heavy metals and water was contaminated with other contaminant. Bacteriological results for Qara Ali (QA_EIA_WQ4) during summer 2009 indicated a high level of contamination by fecal coliform. Remediation and more monitoring is needed.

Phytoplankton results for Qara Ali during summer 2009 indicate mesotrophic water conditions.

Benthic Macroinvertebrates results for Qara Ali (QA_EIA_WQ4) during summer 2009 indicated severely impaired habitat and poor to fair water quality.

5. Cha Khan Site (S15) – Elev 645

Site Description: This site is located approximately 40 km southeast of Sulaimani City and 12 km north of Said Sadiq. This site was a rocky riverbed known as Cha Khan that was dry in winter when the site was visited. As such, only a sediment sample was taken at that time. The riverbed runs from northwestern to southeastern, with a width was approximately 50 meters. The surrounding land is agricultural and pasture lands with little to no plant cover and high mountains to the west of the area.

Plate

Observations (Winter: 9 Jan 2009, not visited in summer):

Water Quality: This site was dry during the winter survey, thus no field or lab parameters were available.

Bacteria & Coliform: There is no field or lab parameter available because the site was dry during the survey.

Phytoplankton: Dry Site, sample was not taken.

Zooplankton: Dry Site, sample was not taken.

Benthic Macroinvertebrates: We didn't sample here.

Heavy Metals in Water: This site was dry during winter survey.

Heavy Metals in Sediments: Sediments of Cha Khan site were contaminated with Cu and Zn; Ni and Pb exceeding the background level in sediments (see table below). Agrochemicals used in the surrounding farmland may be the source of the contamination.

Table 27: Heavy metals in sediment of Cha Khan Site (S15)

Heavy Metal	Winter	Background[1]	CSQG[2]
Nickel (Ni) mg/kg	**251.7**	31	N/A
Lead (Pb) mg/kg	24.6	23	35
Iron (Fe) mg/kg	32576.5	N/A	N/A

Copper (Cu) mg/kg	**90.2**	25	35.7
Manganese (Mn) mg/kg	**1812.6**	400	N/A
Cadmium (Cd) mg/kg	0.4	N/A	0.6
Zinc (Zn) mg/kg	**254.3**	65	123
1= ASQ, 1993; 2= CSQG, 2002; N/A=not available			

Conservation Issues & Recommendations: An investigation was recommended to indicate the reasons for drying the river in winter, which may be caused by intensive use for irrigation in surrounding agricultural areas or it may be natural (rainfall deficiency). Excess heavy metal concentration and contamination is a point of interest. Additional work to identify the source of these contaminants is needed (i.e. checking with farmers and the agricultural department in the area to determine what agrochemicals in use may contain heavy metals). Phyto-remediation may represent a recommended solution for this problem.

6. Said Sadiq (S29) – Elev 491

Site Description: This sample point was along a stream south of the town of Said Sadiq. The water runs with a slow speed through an area of high agricultural activity. The water source comes from ground water. There were submerge plants and green algae observed at and the general habitat was permanent wetlands and shrublands.

Plate

Observations (Summer: 13 Jun 2009, not visited in winter):

Water Quality: S29 for summer: Sampling Time 01:30 PM, Water Depth 0.1m, Air temperature 42°C, Water temperature 30°C.

During the summer, the site was contaminated by NO2, HCO3, Ca, Mg, SO4 and Na according to the natural river and surface water standards (see Table 28). The source of contamination is may be come from anthropogenic activities in Said Sadiq town such as sewage disposal and agricultural activity.

Table 28: Physical & Chemical Water Quality Parameters at Said Sadiq S29

Parameters	Summer	River Standards [1 & 2]	Surface Water Standards [2,3&4]
Field Analysis			
Water Temperature °C	30	N/A	N/A
Conductivity µS/cm	554	N/A	<1275
pH	7.5	N/A	6-8.5
Turbidity NTU	8.1	N/A	10
TDS mg/L	ND	N/A	500
Salinity ppt	ND	N/A	N/A
DO mg/L	5.5	N/A	>5
DO%	156.7	N/A	N/A
Secchi disc m	0.1	N/A	N/A
Lab Analysis			
TSS mg/L	10	N/A	N/A
TDS mg/L	345	N/A	500
BOD mg/L	2.4	N/A	N/A
Orthophosphate (PO4) mg/L	0.058	10	N/A

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Parameters	Summer	River Standards [1 & 2]	Surface Water Standards [2,3&4]
Nitrite-Nitrogen (NO2) mg/L	**0.135**	0.001	N/A
Nitrate-Nitrogen (NO3) mg/L	ND	1	10
Total Alkalinity as CaCO3 mg/L	136	N/A	>20
Bicarbonate (HCO3) mg/L	**158.6**	58.4	58
Total Hardness (TH) mg/L	331	N/A	N/A
Calcium (Ca) mg/L	**48.5**	15	15
Magnesium (Mg) mg/L	**16.4**	4.1	4.1
Chloride (Cl) mg/L	15.4	7.8	7.8
Total Nitrogen (TN) mg/L		N/A	N/A
Sulfate (SO4) mg/L	**64.6**	11.2	3.7
Total Phosphorous (TP) mg/L	ND	0.025	N/A
Potassium (K) mg/L	1.6	2.3	2.3
Sodium (Na) mg/L	**13.3**	6.3	6.3
1= Allan and Castillo, 2007; 2=Kabata-Pendias and Mukherjee, 2007; 3=Agardy and Sullivan, 2005; 4=STF, 2000; ND=not detected; N/A=not available			

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Bacteria & Coliform: According to the results from the summer survey this site is considered a contaminated area with fecal coliform bacteria and the present of *E. coli* bacteria.

Table 29: Fecal Coliform bacteria count and E. coli at site (S29)

	Winter	Summer	Drinking Standards [1 & 2]	Surface Water Standards [2]		
				Body-contact	Fishing and boating	Domestic water supply
Fecal Coli form Bacteria Colony/100 ml	---	**920**	0 in 100ml	100 Colonies/100 mL	> 1000 Colonies/100 mL	> 2000 Colonies/100 mL
Escherichia coli	---	**+**				
1= WHO, 2006; 2= CDWQ, 2006						

Phytoplankton: In summer 2009, the total phytoplankton count in Said Sadiq was 8847 x 10^3 cell/L and a total of 26 species were recorded. Chlorophyta was the dominant group 84.39%, the dominant species was *Scenedesmus bijuga* (7427.5 x 10^3 cell/L). The centric diatoms were dominated by *Cyclotella meneghiniana* (968.6 x 10^3 cell/L), the pennate diatoms dominated by 17 species all of which were recoreded in low numbers. Said Sadiq demonstrated low diversity, very good richness and low evenness values (See Annex 2: Table 176, Table 178 & Table 180).

Table 30: Number of species, total count and percentage for phytoplankton groups in Said Sadiq (S29)

Said Sadiq (S29)	Sp. #-SS	Total Count (cell x 103/L)	%-SS
Cyanophyta	0	0	0.00
Euglenophyta	2	2	0.02
Pyrrophyta	0	0	0.00
Chlorophyta	4	7465.7	84.39
Bacillariophyceae/Centrales	3	970.6	10.97
Bacillariophyceae/Pennales	17	408.7	4.62
Total	26	8847	100.00

Benthic Macroinvertebrates: **Total density found in summer was 508 indv. /m^2 and comparing with the other other studied sites, this density was moderate (Annex 4: Table 183). The site also has relatively moderate diversity moderate diversity and good richness and evenness (Annex 4: Table 168, Table 170 &**

Table 172, respectively). However, the dominant species was the red-blood midge larva *Chironomus riparius* which is known as very tolerant organism (pollution tolerance number ≈ 10) and the EPT% was very low (Table 174

Water quality depending on the modified pollution tolerance and pollution indices was fair (See Annex 1, Table 174) and this could be confirmed by the presence of tolerant bio-indicators such as the Small minnow mayflies *Fallceon* spp. and very tolerant bio-indicators such as the Pond Damselfly larva *Enallagma* sp.1.

Heavy Metals in Water: Depending on measurements for heavy metals in water samples, this site was contaminated with Ni, Cd and Zn, compared with optimum levels in river water (see *Heavy Metals in Water*: Depending on measurements for heavy metals in water samples, this site was contaminated with Cu, Ni, Pb, Mn and Zn in the winter sample and with Ni, Cu, Cd, Pb, Mn and Zn in the summer sample, compared with optimum levels in river water (see **Error! Not a valid bookmark self-reference.** below). Variation in heavy metal concentration between winter and summer samples was obvious, and this may be because in summer some of the contamination sources like sewages may evaporate and thus disappear before reaching the stream.

Table 55 below).

Table 31: Heavy metals in water of Said Sadiq S29

Heavy Metal	Summer	River Standards[1 & 2]	Surface Water Standards[2,3&4]
Nickel (Ni) mg/L	**0.016**	0.0008	0.0005-0.006
Lead (Pb) mg/L	0.0124	0.0015	0.09
Iron (Fe) mg/L	0.0001	0.67	0.22-0.35
Copper (Cu) mg/L	0.0236	0.002	0.27
Manganese (Mn)mg/L	0.03	0.00002	0.07-0.5
Cadmium (Cd) mg/L	**0.0024**	0.00008	0.000005
Zinc (Zn) mg/L	**0.032**	0.0006	N/A
1= Allan and Castillo, 2007; 2=Kabata-Pendias and Mukherjee, 2007; 3=Agardy and Sullivan, 2005; 4=STF, 2000; ND=not detected; N/A=not available			

Heavy Metals in Soil: Heavy metals Ni, Pb, Fe, Cu, and Mn in the soil of this site show higher concentrations than the world soil background except Zn, and Ni exceeds the maximum allowable concentration in agricultural soils of Poland (see Table below).

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Table 32: Heavy Metals in Soil of Said Sadiq S29

Heavy Metal	Summer	Soil Background [1 & 2]	*Agricultural Soils [3]
Nickel (Ni) mg/kg	**84.4**	19-22	30-75
Lead (Pb) mg/kg	34.5	25	70-150
Iron (Fe) mg/kg	**30590**	2000	N/A
Copper (Cu) mg/kg	52.4	20	30-70
Manganese (Mn)mg/kg	**949.7**	437	N/A
Cadmium (Cd) mg/kg	0.4	0.5	10
Zinc (Zn) mg/kg	91.1	64	100-300
1=Kabata-Pendias and Mukherjee, 2007; 2=Essington; 3=Kabata-Pendias, 2001; *=Maximum Allowable Concentration in Agricultural soils of Poland.; ND=not detected; N/A=not available			

Heavy Metals in Sediments: Sediments of the Said Sadiq site were contaminated with Pb, Cu, Mn and Zn (see Table below). Sewages of Said Sadiq town and agricultural activities of the surrounding farms may be the main sources of sediment contamination by heavy metals.

Table 33: Heavy metals in sediment of Said Sadiq S29

Heavy Metal	Summer	Background[1]	CSQG[2]
Nickel (Ni) mg/kg	**88.4**	31	N/A
Lead (Pb) mg/kg	**42.2**	23	35
Iron (Fe) mg/kg	324.80	N/A	N/A
Copper (Cu) mg/kg	**62.6**	25	35.7
Manganese (Mn) mg/kg	**735.7**	400	N/A
Cadmium (Cd) mg/kg	ND	N/A	0.6
Zinc (Zn) mg/kg	**143.7**	65	123
1= ASQ, 1993; 2= CSQG, 2002; N/A=not available			

Conservation Issues & Recommendations: Heavy metal contamination in water and sediment, exceeding of background of heavy metals soils in Said Sadiq area, was obvious. Water of the site was contaminated with some ions. Source of these contaminations may be related to anthropogenic activities in Said Sadiq area.

The result shows that Said Sadiq (S29) site is contaminated with fecal coliform bacteria and *E. coli* and it may be due to the agriculture and grazing activities around the stream as well as from sewage coming from the town of Said Sadiq.

Phytoplankton results for Said Sadiq during summer 2009 indicate eutrophic water conditions.

Benthic Macroinvertebrates results for Said Sadiq (S29) during summer 2009 indicated moderately to somewhat severely impaired habitat and fair water quality.

7. Ahmed Awa (S4A) – Elev 817

Site Description: This site is located southeast of Sulaimani City near the Iran/Iraq border in a narrow valley surrounded by high mountains. This sampling station was near the base of a large waterfall that issues from the nearby Zalm Springs. There are many villages below the Ahmed Awa waterfall and the area is used for agriculture including orchards, some grazing and tourism to the falls and along the stream. There is a lot of trash generated by local tourist activity at the site and the banks of the stream immediately below the falls before the first village are lined with makeshift cafes and shops. The spring issues from the mountain side and a fence has been erected in front of it.

There has also been some cement work near the spring and along one side is a cement channel that takes a portion of the water to a now-defunct pump room of some kind. Some of the water is diverted through pipes and water channels to the towns and villages below.

Plate

Observations (Winter: 10 Jan 2009; Summer: 14 June 2009):

Water Quality: For winter: Sampling Time 10:44 AM, Water Depth 0.6m, Air temperature 10°C, Water temperature 13.5°C.

For summer: Sampling Time 10:52 AM, Water Depth 0.38m, Air temperature 24°C, Water temperature 13.7°C.

Though the sample was taken at the base of the waterfall, not directly at the spring mouth itself (this is now blocked from access by a fence), sample results were compared to groundwater reference standards and were generally within normal ranges for this type of water (see Table 34), except Ca and NO3 in the winter sample and just NO3 in the summer sample. A source of excess Ca may be the weathering of limestone and dolomite rocks by the Qamchuqa Formation and Avroman Group (Ali and Ameen, 2005). NO3 contamination of the spring is possibly from tourist activity and from some orchards upstream from the site.

Table 34: Physical & Chemical Water Quality Parameters at Site Ahmed Awa (S4A)

Parameters	Winter	Summer	Groundwater Standards[1,2,3,4&5]
Field Analysis			
Water Temperature °C	13.5	13.7	N/A
Conductivity µS/cm	303	300	N/A
pH	8.12	7.4	6.5-8.5
Turbidity NTU	0.47	1.13	N/A
TDS mg/L	183	ND	500
Salinity ppt	ND	ND	N/A
DO mg/L	10.63	11.3	N/A
DO%	109.5	116	N/A
Secchi disc m	0.6	0.38	N/A
Lab Analysis			
TSS mg/L	0.001	ND	N/A
TDS mg/L	159.5	178	500
BOD mg/L	ND	6.1	N/A
Orthophosphate (PO4) mg/L	ND	0.0036	0.1
Nitrite-Nitrogen (NO2) mg/L	0.01	0.0023	0.231
Nitrate-Nitrogen (NO3) mg/L	**11.33**	**3.84**	1.943
Total Alkalinity as CaCO3 mg/L	76	98.8	N/A
Bicarbonate (HCO3) mg/L	19.52	110.1	200
Total Hardness (TH) mg/L	180.6	209	250
Calcium (Ca) mg/L	**53.5**	43.99	50
Magnesium (Mg) mg/L	4.94	1.75	7
Chloride (Cl) mg/L	16.84	4.77	20
Total Nitrogen (TN) mg/L	65.12	ND	N/A
Sulfate (SO4) mg/L	14.44	6.38	30
Total Phosphorous (TP) mg/L	ND	0.0162	100
Potassium (K) mg/L	1.3	0.28	3
Sodium (Na) mg/L	1.08	0.3	30
1=Kabata-Pendias and Mukherjee, 2007; 2=Agardy and Sullivan, 2005; 3=Mazor, 2004; 4=WHO,			

Parameters	Winter	Summer	Groundwater Standards[1,2,3,4&5]
2006; 5= GWQS, 2008; ND=not detected; N/A=not available			

Bacteria & Coliform: Generally the water from this site was considered to be clean water and remains in the normal range of reference standards for coliform; this result was nearly the same during both the winter and summer survey. Due to the proximity of the source of the water and the nature of the site where the samples were taken (near the base of a large waterfall with water issuing from the mountainside), the temperature is nearly stable and cold. Furthermore, the tourist activities and fertilizer used by locals has not yet made any serious contamination at this site (see table below) though is likely a problem further downstream.

Table 35: Fecal Coliform bacteria count and E. coli at site Ahmed Awa (S4A)

	Winter	Summer	Drinking Standards [1 & 2]	Surface Water Standards [2]		
Fecal Coli form Bacteria Colony/100 ml	8	5	0 in 100ml	Body-contact	Fishing and boating	Domestic water supply
				100 Colonies/100 mL	> 1000 Colonies/100 mL	> 2000 Colonies/100 mL
Escherichia coli	+	+				
1= WHO, 2006; 2= CDWQ, 2006						

Phytoplankton: The total phytoplankton count during the winter 2009 survey was 176 x 10^3 cell/L and a total of 19 species were recorded. The dominant species in this site were 16 species of pennate diatoms, all of which were recorded in low numbers. The only centric diatom recorded was *Cyclotella ocellata,* while *Peridinium cinctum* and *Leptolyngbya perelegans* were the only Pyrrhophyta and blue-green algae respectively (See Table 36). This site is considered to have moderate diversity, good richness and very good evenness values (See Annex 2: Table 159, Table 161 & Table 163).

In summer 2009, the total phytoplankton count during the summer 2009 survey was 141.3 x 10^3 cell/L and a total of 21 species were recorded. Similar to the winter survey, the dominant species in this site were 17 species of pennate diatoms, all of which were recorded in low numbers. Most prevalent among these were *Rhoicosphenia curvata* and *Diatoma hiemale* (33.4 x 10^3 cell/L and 22.3 x 10^3 cell/L respectively). *Cyclotella ocellata* and *Stephanodiscus astrea* were the only two centric diatoms recorded, while *Chlorella vulgaris* and *Coelastrum astroideum* were the only two green algae recorded in the site. During the summer Ahmed Awa demonstrated moderate diversity, good richness and very good evenness values (See Annex 2: Table 176, Table 178 & Table 180).

Table 36: Number of species, total count and percentage for phytoplankton groups in Ahmed Awa S4A

Phytoplankton Groups (S4A)	Sp. #-WS	Sp. #-SS	Total Count (cell x 103/L)-WS	Total Count (cell x 103/L)-SS	%-WS	%-SS
Cyanophyta	1	0	1	0	0.57	0
Euglenophyta	0	0	0	0	0.00	0
Pyrrhophyta	1	0	9.1	0	5.17	0
Cryptophyta	0	0	0	0	0.00	0
Chlorophyta	0	2	0	36.2	0.00	25.62

Phytoplankton Groups (S4A)	Sp. #-WS	Sp. #-SS	Total Count (cell x 103/L)-WS	Total Count (cell x 103/L)-SS	%-WS	%-SS
Bacillariophyceae/Centrales	1	2	33.4	34.4	18.98	24.35
Bacillariophyceae/Pennales	16	17	132.5	70.7	75.28	50.04
Total	19	21	176	141.3	100	100

Benthic Macroinvertebrates: Total density found in winter was 503 indv. /m² and comparing with the other studied sites, this density was relatively good (Annex 4: Table 165). The dominant species was the larva of the blackfly *Simulium* sp. which is known as a tolerant organism (pollution tolerance number ≈ 6). Although EPT% was relatively low (Annex 4:

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), the site characterized by a relatively good diversity, very good richness, and excellent evenness (See Annex 4: **Error! Reference source not found.**, **Error! Reference source not found.**, & **Error! Reference source not found.**). Depending on the modified pollution tolerance and pollution indices, water quality was excellent (See Annex 1, Table 173 & Table 174) and this could be confirmed by the presence of the sensitive and very sensitive aquatic organisms such as the Small Eastern Caddisfly *Beraea* sp. and the Rolled-wing Stonefly *Perlomyia* sp.

In summer, total density found was 1167 indv. /m^2 and comparing with the other studied sites, this density was density was the highest (Annex 4: Table 166). The site also has relatively the highest EPT% (Table 174), very good richness, good evenness, and moderate diversity (Table 170,

Table 172 & Table 168, respectively). However, the dominant species was the Small minnow mayfly Baetis sp. which is known as tolerant organism (pollution tolerance number ≈ 6). Water quality depending on the modified pollution tolerance and pollution indices was very good to excellent (See Annex 1, Table 173 & Table 174) and this could be confirmed by the well presence of very sensitive bio-indicators such as the Stream Mayfly *Leucrocuta* sp., the Primitive Caddisfly *Rhyacophila* sp., and the Spiny Crawler Mayflies *Ephemerella* spp.

Briefly, overall we suggested considering the habitat here as non-impaired to moderately impaired and the water quality as excellent (refer to Methods & Procedures).

Heavy Metals in Water: This site shows contamination with Pb and Zn in winter sample, and contamination with Pb and Ni in summer samples if compared to reference levels in natural groundwater. In addition, other heavy metals were in the optimum range (see Table 37). A metal fence around the site and upstream orchards may be the source of heavy metal contamination in the water.

Table 37: Heavy metals in water of site Ahmed Awa (S4A)

Heavy Metal	Winter	Summer	Groundwater Standards[1,2,3,4&5]
Nickel (Ni) mg/L	0.01	**0.027**	0.015
Lead (Pb) mg/L	**0.01**	**0.01**	0.005
Iron (Fe) mg/L	ND	0.0001	0.75
Copper (Cu) mg/L	ND	0.02	0.746
Manganese (Mn)mg/L	0.02	0.01	0.05
Cadmium (Cd) mg/L	ND	0.0025	0.004
Zinc (Zn) mg/L	**0.06**	ND	0.05
1=Kabata-Pendias and Mukherjee, 2007; 2=Agardy and Sullivan, 2005; 3=Mazor, 2004; 4=WHO, 2006; 5= GWQS, 2008; ND=not detected			

Heavy Metals in Soil: Heavy metals in the soil of this site show concentrations higher than the world soil background, but not exceeding the maximum allowable concentration in agricultural soils of Poland, except for Ni (see Table 38 below).

Table 38: Heavy Metals in Soil of Ahmed Awa (S4A)

Heavy Metal	Summer	Soil Background[1 & 2]	*Agricultural Soils[3]
Nickel (Ni) mg/kg	**147.6**	19-22	30-75
Lead (Pb) mg/kg	39.8	25	70-150
Iron (Fe) mg/kg	**48315**	2000	N/A
Copper (Cu) mg/kg	58.2	20	30-70
Manganese (Mn)mg/kg	**1027.3**	437	N/A
Cadmium (Cd) mg/kg	ND	0.5	10
Zinc (Zn) mg/ Kg	113.3	64	100-300

1=Kabata-Pendias and Mukherjee, 2007; 2=Essington; 3=Kabata-Pendias, 2001; *=Maximum Allowable Concentration in Agricultural soils of Poland.; ND=not detected; N/A=not available

Heavy Metals in Sediments: Sediments of the Ahmed Awa site in the winter sample show contaminated sediments with Pb, Cd, Cu and Zn and Ni exceeding the background; same for the summer sample except Zn (see Table below). A metal fence around the site, tourist activity and fertilizer used in the upstream orchards may be the source of this contamination.

Table 39: Heavy metals in sediment of Ahmed Awa (S4A)

Heavy Metal	Winter	Summer	Background[1]	CSQG[2]
Nickel (Ni) mg/kg	**245.3**	**73.8**	31	N/A
Lead (Pb) mg/kg	**40**	**40.7**	23	35
Iron (Fe) mg/kg	29523	25300	N/A	N/A
Copper (Cu) mg/kg	**64.5**	**40.5**	25	35.7
Manganese (Mn) mg/kg	**840.45**	379.8	400	N/A
Cadmium (Cd) mg/kg	**6.2**	**2.1**	N/A	0.6
Zinc (Zn) mg/kg	**331.9**	**73.1**	65	123
1= ASQ, 1993; 2= CSQG, 2002; N/A=not available				

Conservation Issues & Recommendations: The spring contained within this site should be protected as a national heritage site to avoid the contamination of its pure natural waters, which may be adversely affected by the high tourist activities in the area at certain times of the year. According to the results from Ahmed Awa (S4A) during winter and summer 2009 the water is not contaminated with fecal coliform bacteria but *E. coli* is present at the site and may come from tourism activities or other upstream sources.

The phytoplankton diversity in this site was moderate and the recorded species that may favor contamination were found in low abundances. Generally, according to phytoplankton results mesotrophic water conditions were indicated.

Benthic Macroinvertebrates results for Ahmed Awa (S4A) during winter and summer 2009 indicated non-impaired to moderately impaired habitat and excellent water quality.

8. Zalm Area (S12) - Elev 507

Site Description: This site is located along a stream called the Zalm which has its main source at Ahmed Awa. It was visited by the KBA team for the first time in summer 2008 due to security concerns in the Ahmed Awa region. Its waters are an important source for Darbandikhan Lake and both of its banks are lined with agricultural fields. The water also flows from Khormal spring and appears to contain a high concentration of sulfur as well as sewage from Khormal town. The sample point is located approximately 300 meters upstream (east) of a bridge, where many people drive their vehicles into the stream bed to wash them. In summer, tire marks could be seen in the stream bed at the sampling point. The stream is narrow at the sampling point and the area adjacent to the stream is partially wooded with agricultural fields beyond. In addition, a new farm has been built with greenhouses along the northern bank close to the sample point.

Plate

Observations (Winter -10 Jan 2009; Summer – 14 June 2009):

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Water Quality: For winter: Sampling Time 07:49 AM, Water Depth 0.25m, Air temperature 5°C,Water temperature 15.7°C.

For summer: Sampling Time 08:15 AM, Water Depth 0.23m, Air temperature 29°C, Water temperature 20.2°C.

During the winter survey, this site was considered a contaminated site with respect to NO3, NO2, HCO3, Ca, Mg, Cl, and SO4 compared to reference concentrations for natural rivers and surface water standards (see Table 40).

During the summer survey, this site was contaminated with NO3, NO2, HCO3, Ca, Mg, Cl, TP and SO4 compared to reference concentrations for natural rivers and surface water standards (see Table 40).

Washing vehicles in the stream, sewage from Khormal town, nearby farmland activities and pollution from picnickers at the site are the most likely sources of the contamination.

Table 40: Physical & Chemical Water Quality Parameters at site Zalm (S12)

Parameters	**Winter**	**Summer**	**River Standards [1 & 2]**	**Surface Water Standards [2,3&4]**
Field Analysis				
Water Temperature °C	15.7	20.2	N/A	N/A
Conductivity µS/cm	477	454	N/A	<1275
pH	7.85	7.6	N/A	6-8.5
Turbidity NTU	1.85	8.46	N/A	10
TDS mg/L	288	ND	N/A	500
Salinity ppt	ND	ND	N/A	N/A
DO mg/L	13.31	8.71	N/A	>5
DO%	144.3	104	N/A	N/A
Secchi disc m	0.25	0.23	N/A	N/A
Lab Analysis				
TSS mg/L	0.001	76	N/A	N/A
TDS mg/L	275	299	N/A	500
BOD mg/L	ND	ND	N/A	N/A
Orthophosphate (PO4) mg/L	ND	0.01	10	N/A
Nitrite-Nitrogen (NO2) mg/L	**0.01**	**0.0075**	0.001	N/A
Nitrate-Nitrogen (NO3) mg/L	**17.03**	8.38	1	10
Total Alkalinity as CaCO3 mg/L	103	132.5	N/A	>20
Bicarbonate (HCO3) mg/L	**76.86**	**153.7**	58.4	58
Total Hardness (TH) mg/L	260.2	276	N/A	N/A
Calcium (Ca) mg/L	**59.04**	**51**	15	15
Magnesium (Mg) mg/L	**8.43**	**4.32**	4.1	4.1
Chloride (Cl) mg/L	22.93	8.7	7.8	7.8
Total Nitrogen (TN) mg/L	61.24	ND	N/A	N/A
Sulfate (SO4) mg/L	**39.21**	**23.56**	11.2	3.7
Total Phosphorous (TP)	ND	0.037	0.025	N/A

Parameters	Winter	Summer	River Standards [1 & 2]	Surface Water Standards [2,3&4]
mg/L				
Potassium (K) mg/L	1.61	0.9	2.3	2.3
Sodium (Na) mg/L	5.77	5.51	6.3	6.3
1= Allan and Castillo, 2007; 2=Kabata-Pendias and Mukherjee, 2007; 3=Agardy and Sullivan, 2005; 4=STF, 2000; ND=not detected; N/A=not available				

Bacteria & Coliform: The fecal coliform bacteria count and the present of *E. coli* (see table below) at the site, as indicated from the levels of NO3 and NO2, mean this area was already considered somewhat contaminated in the winter survey but during the summer sampling the level of fecal coliform bacteria rose much higher. During the summer the source of the contamination is obviously increasing and may come from sewage from Khormal town, other human activities upstream, and from animals grazing along the stream.

Table 41: Fecal Coliform bacteria count and E. coli at site (Zalm S12)

	Winter	Summer	Drinking Standards [1 & 2]	Surface Water Standards [2]		
Fecal Coli form Bacteria Colony/100 ml	**140**	**540**	0 in 100ml	Body-contact	Fishing and boating	Domestic water supply
				100 Colonies/100 mL	> 1000 Colonies/100 mL	> 2000 Colonies/100 mL
Escherichia coli	+	+				
1= WHO, 2006; 2= CDWQ, 2006						

Phytoplankton: The total phytoplankton count during the winter survey was 340.8 x 10^3 cell/L and a total of 30 species were recorded. This dominant species in this site were pennate diatoms (99.12%) almost to the exclusion of all other species (see table below). *Achnanthes minutissima* was the most common pennate diatom (122.5 x 10^3 cell/L). This species is known to be more physiologically active than larger diatom cells, partly due to their large surface to volume ratio (Allen, 1977, as cited in Wehr & Sheath 2003). The prevalence of *Achnanthes minutissima* may also result from the relatively high calcium ion concentrations at the site (according to the water quality data above), as it has been indicated that the presence of lime causes the proliferation of *Achnanthes minutissima*. (Cleve & Grun., as cited in Stoermer and Smol, 2004). This diatom also appears to prefer a nitrogen and/or phosphorus-enriched environment (Pringle and Bowers, 1984; Fairchild et al., 1985; McCormick and Stevenson, 1989; Stevenson et al., 1991; Peterson and Grimm, 1992 as cited in Stevenson, Bothwell and Lowe 1996). This site is considered to have moderate diversity, very good richness and evenness values (See Annex 2: Table 175, Table 177 & Table 179).

The total phytoplankton count during the summer survey was 679.3 x 10^3 cell/L and a total of 49 species were recorded. This dominant species in this site were pennate diatoms (92.14%) as in the winter survey (see table below). The most common pennate diatoms were *Amphora veneta* and *Achnanthes minutissima* (144.7x 10^3 cell/L and 133.6 x 10^3 cell/L respectively). This site is considered to have relatively good diversity, very good richness and evenness values. (See Annex 2: Table 176, Table 178 & Table 180)

Table 42: Number of species, total count and percentage for phytoplankton groups in Zalm S12

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Phytoplankton Groups (S12)	Sp. #-WS	Sp. #-SS	Total Count (cell x 103/L)-WS	Total Count (cell x 103/L)-SS	%-WS	%-SS
Cyanophyta	0	3	0	11.1	0.00	1.63
Euglenophyta	0	0	0	0	0.00	0
Pyrrhophyta	1	1	1	9.1	0.29	1.34
Cryptophyta	0	0	0	0	0.00	0
Chlorophyta	0	2	0	19.1	0.00	2.81
Bacillariophyceae/Centrales	2	4	2	14.1	0.59	2.08
Bacillariophyceae/Pennales	27	39	337.8	625.9	99.12	92.14
Total	30	49	340.8	679.3	100	100

<u>*Benthic Macroinvertebrates:*</u> Total density found in winter was 782 indv. /m^2 and comparing with the other studied sites, this density was relatively high (Annex 4: Table 165). No EPT species were found in this site (Annex 4: **Error! Reference source not found.**) and the dominant species was related to the Amphipods, which are known as tolerant organisms (pollution tolerance number ≈ 6). Although the relative richness was good (Annex 4: **Error! Reference source not found.**), the relative evenness and diversity was moderate and low respectively (See Annex 4: **Error! Reference source not found.** & **Error! Reference source not found.**). Depending on the modified pollution tolerance and pollution indices, water quality was fair (See See Annex 1, Table 173 & Table 174) and this could be confirmed by the presence of the tolerant aquatic organisms such as the Bluet damselfly larva *Enallagma* sp. and the Corporal dragonfly larva *Ladona* sp.

Total density found in summer was 795 indv. /m^2 and comparing with the other studied sites, this density was density was very good (Annex 4: Table 166). The site also has relatively moderate diversity and good richness and evenness (Annex 4: Table 168, Table 170 &

Table 172 respectively). However, the dominant species was the Gammarid Amphipod *Gammarus* sp.1, which is known as a tolerant organism (pollution tolerance number ≈ 6) and the EPT% was very low (Table 174). Water quality depending on the modified pollution tolerance and pollution indices was good to very good (See Annex 1, Table 173 & Table 174) and this could be confirmed by the well presence of sensitive bio-indicators such as the Ringtail Dragonfly larva *Erpetogomphus* sp.2 and the Stream Mayflies *Heptagenia* spp.

Overall, we suggested considering the habitat here as moderately impaired and the water quality as fair to good (See Methods & Procedures).

<u>*Heavy Metals in Water:*</u> This site was contaminated with Ni, Cu, Cd and Zn in the winter sample and with Ni, Cu, Cd and Mn in the summer sample (see Table below). The source(s) of this contamination are likely the same as were discussed previously in the water quality section.

Table 43: Heavy metals in water of site Zalm (S12)

Heavy Metal	Winter	Summer	River Standards[1 & 2]	Surface Water Standards[2,3&4]
Nickel (Ni) mg/L	**0.07**	**0.021**	0.0008	0.0005-0.006
Lead (Pb) mg/L	ND	0.008	0.0015	0.09
Iron (Fe) mg/L	0.00	0.00007	0.67	0.22-0.35
Copper (Cu) mg/L	0.18	0.02	0.002	0.27
Manganese (Mn)mg/L	ND	0.029	0.00002	0.07-0.5
Cadmium (Cd) mg/L	**0.03**	**0.0027**	0.00008	0.000005
Zinc (Zn) mg/L	**0.34**	ND	0.0006	N/A

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1= Allan and Castillo, 2007; 2=Kabata-Pendias and Mukherjee, 2007; 3=Agardy and Sullivan, 2005; 4=STF, 2000; ND=not detected; N/A=not available

Heavy Metals in Soil: Heavy metals Ni, Pb, Fe, Cu, Mn, Cd and Zn in the soil of this site show higher concentrations than the world soil background, but not exceeding the maximum allowable concentration in agricultural soils of Poland (see Table below).

Table 44: Heavy Metals in Soil of Zalm (S12)

Heavy Metal	Summer	Soil Background [1 & 2]	*Agricultural Soils [3]
Nickel (Ni) mg/kg	69.8	19-22	30-75
Lead (Pb) mg/kg	35.9	25	70-150
Iron (Fe) mg/kg	**30600**	2000	N/A
Copper (Cu) mg/kg	43.3	20	30-70
Manganese (Mn)mg/kg	754.5	437	N/A
Cadmium (Cd) mg/kg	0.7	0.5	10
Zinc (Zn) mg/kg	81.6	64	100-300
1=Kabata-Pendias and Mukherjee, 2007; 2=Essington; 3=Kabata-Pendias, 2001; *=Maximum Allowable Concentration in Agricultural soils of Poland.; ND=not detected; N/A=not available			

Heavy Metals in Sediments: Sediments of the Zalm site were contaminated with Ni, Pb, Cd, Cu and Zn in the winter sample and with Pb and Cu in the summer sample (see Table below). Washing vehicles in the stream and sewage from Khormal town are the most probable source of contamination.

Table 45: Heavy metals in sediment of Zalm (S12)

Heavy Metal	Winter	Summer	Background[1]	CSQG[2]
Nickel (Ni) mg/kg	**237.6**	**52.8**	31	N/A
Lead (Pb) mg/kg	**38.9**	**37.1**	23	35
Iron (Fe) mg/kg	25374	23937.5	N/A	N/A
Copper (Cu) mg/kg	**59.4**	**36.9**	25	35.7
Manganese (Mn) mg/kg	**1231.3**	**487.3**	400	N/A
Cadmium (Cd) mg/kg	**2**	**0.6**	N/A	0.6
Zinc (Zn) mg/kg	**240.8**	71.8	65	123
1= ASQ, 1993; 2= CSQG, 2002; N/A=not available				

Conservation Issues & Recommendations: The results from Zalm Area (S12) during winter and summer 2009 indicates that this is a contaminated area from a bacterialogical point of view and this may be primarily due to sewage from Khormal town.

Phytoplankton results indicate moderate to slightly eutrophic water conditions. Benthic Macroinvertebrate results for the Zalm Area (S12) during winter and summer 2009 indicate a moderately impaired habitat and fair to very good water quality.

Study and conservation of the mineralized spring at Khormal is recommended for two reasons. To begin with, the spring represents a natural mineralized spring that may be important for creating a tourist destination. Secondly, it is important to determine the effects of the high level of sulfates coming from the spring on the surrounding area.

As discussed above, sewage discharge from Khormal town upstream from the site, litter and other pollution from recreational activities, agricultural chemical runoff from farms, and extensive car washing and cars driving in the streambed are all potential sources of heavy metals, nutrients and other pollution at the site. Efforts should be made to stop the car washing and driving of cars through the site. Also, an anti-littering program and proper facilities for picnickers are needed. A study of agricultural chemical use in the area is also an important step toward addressing these impacts.

9. New Halabja Site (QA_EIA_WQ_5) – Elev 513

Site Description: This site is located along the Tanjero River, southeast of Sulaimani City and downstream from New Halabja just upstream from a bridge crossing the river, while northeast of the area is the town of Said Sadiq. The streambed consists of gravel and green algae, and is lined on both sides by agricultural fields. The main access road is located along the southwest boundary of the site. This site was previously sampled during spring 2008 for the Qara Ali Irrigation Dam Environmental Impact Assessment.

Plate

Observations (Winter- 8 Jan 2009; Summer- 13 Jun 2009):

Water Quality: QA_EIA_WQ_5 for winter: Sampling Time 08:33 AM, Water Depth 0.05m, Air temperature 2°C, Water temperature 4.3°C.

QA_EIA_WQ_5 for summer: Sampling Time 09:19 AM, Water Depth 0.23m, Air temperature 36°C, Water temperature 22.5°C.

During the winter survey, the water at this site was found to be contaminated in excess of the level of natural rivers and surface waters (see Table 46) for the following: nitrate (NO3), nitrite (NO2), bicarbonate (HCO3), calcium (Ca), magnesium (Mg), chloride (Cl), sulfate (SO4), total phosphorous (TP), potassium (K) and sodium (Na) (see Table). Total dissolved solids (TDS), turbidity and pH in this site exceeded levels in surface waters for a potable water supply (see table below). The source of contamination is twofold: anthropogenic activities in Said Sadiq town such as sewage disposal, sewage from Sulaimani and New Halabja, and agricultural activity. According to Hynes (1974), the site has fair water quality depending on the biological oxygen demand. Total Phosphorus is graphed below with other sites from the basin, showing that this site as well as Bani Khan (S3B), three Darbandikahn Lake Sites (S1A, S1E, S1D), Diyala (Sirwan) River below the dam (S1F) and Kalar (S3) all exceed river standards.

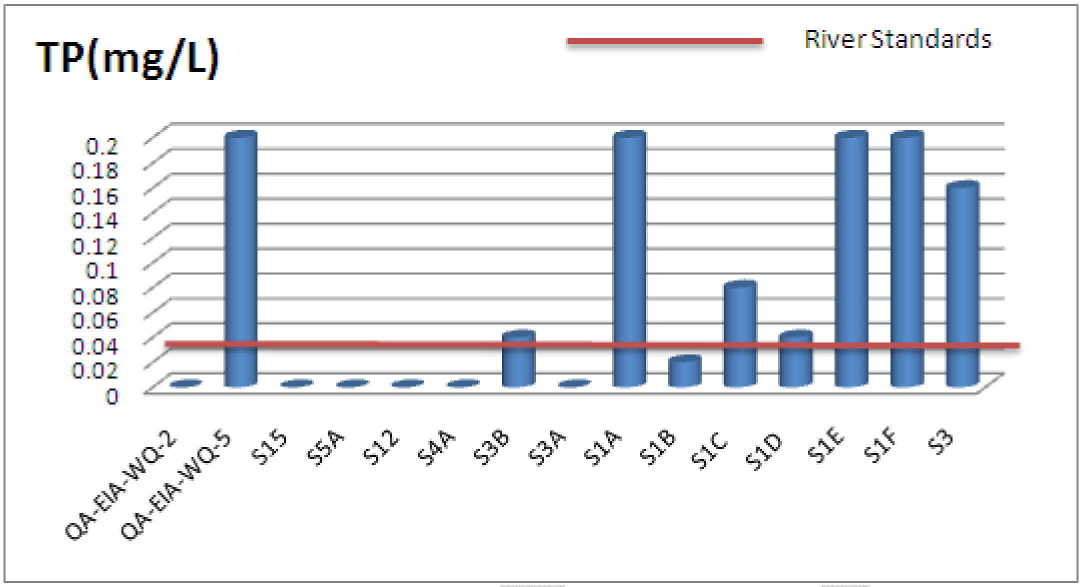

Figure 1: Concentration of total phosphorous in winter water samples of Darbandikhan basin (Diyala River watershed)

During the summer survey, the site had a high level of turbidity and TDS and was contaminated by NO3, NO2, HCO3, Ca, Mg, SO4, TP, K and Na according to the natural river and surface water standards (see Table 46).

Table 46: Physical & Chemical Water Quality Parameters at New Halabja Site 5

Parameters	Winter	Summer	River Standards [1 & 2]	Surface Water Standards [2,3&4]
Field Analysis				
Water Temperature °C	4.3	22.5	N/A	N/A
Conductivity µS/cm	886	799	N/A	<1275
pH	**8.66**	8.2	N/A	6-8.5
Turbidity NTU	**60.9**	**138**	N/A	10
TDS mg/L	**526**	ND	N/A	500
Salinity ppt	0.2	0.2	N/A	N/A
DO mg/L	12.85	10.2	N/A	>5
DO%	103.5	124.1	N/A	N/A
Secchi disc m	0.05	0.23	N/A	N/A
Lab Analysis				
TSS mg/L	0.05	132	N/A	N/A
TDS mg/L	**516.5**	**519**	N/A	500
BOD mg/L	4.33	ND	N/A	N/A
Orthophosphate (PO4) mg/L	2.28	0.29	10	N/A
Nitrite-Nitrogen (NO2) mg/L	**0.73**	**1.6**	0.001	N/A
Nitrate-Nitrogen (NO3) mg/L	2.15	**16.6**	1	10
Total Alkalinity as CaCO3 mg/L	152	160.5	N/A	>20
Bicarbonate (HCO3)	**136.64**	**172.6**	58.4	58

Parameters	Winter	Summer	River Standards [1 & 2]	Surface Water Standards [2,3&4]
mg/L				
Total Hardness (TH) mg/L	332.05	368.5	N/A	N/A
Calcium (Ca) mg/L	**108.31**	**108.9**	15	15
Magnesium (Mg) mg/L	**15.83**	**18.44**	4.1	4.1
Chloride (Cl) mg/L	**51.47**	ND	7.8	7.8
Total Nitrogen (TN) mg/L	30.32	ND	N/A	N/A
Sulfate (SO4) mg/L	**71.59**	**88.7**	11.2	3.7
Total Phosphorous (TP) mg/L	**7.3**	**0.43**	0.025	N/A
Potassium (K) mg/L	**8.53**	**6.47**	2.3	2.3
Sodium (Na) mg/L	**50.43**	**50.44**	6.3	6.3
1= Allan and Castillo, 2007; 2=Kabata-Pendias and Mukherjee, 2007; 3=Agardy and Sullivan, 2005; 4=STF, 2000; ND=not detected; N/A=not available				

Bacteria & Coliform: As expected from the site description and other chemical analysis (BOD, NO3, NO2, etc.) there were fecal coliform concentrations and the existence of *E. coli* at the New Halabja site (QA_EIA_WQ5) during the winter sampling, while during the summer sampling the number of fecal coliform was lower, though still above the normal standards to be considered safe. The reason may be the agricultural and domestic activities (the stream site is surrounded by farmlands and downstream from the town of New Halabja). The decrease in the fecal coliform in the summer samples may be due to low water depth and quantity due to drought conditions.

Table 47: Fecal Coliform bacteria count and E. coli at site (QA_EIA_WQ5)

	Winter	**Summer**	**Drinking Standards** [1 & 2]	**Surface Water Standards** [2]		
				Body-contact	Fishing and boating	Domestic water supply
Fecal Coli form Bacteria Colony/100 ml	---	**1600**	0 in 100ml	100 Colonies/100 mL	> 1000 Colonies/100 mL	> 2000 Colonies/100 mL
Escherichia coli	---	**+**				
1= WHO, 2006; 2= CDWQ, 2006						

Phytoplankton: The total phytoplankton count during winter 2009 was 1537.5 x 10^3 cell/L and a total number of 27 species were recorded. This dominant species in this site were pennate diatoms, chiefly *Nitzschia palea* and *Nitzschia hungarica* (890.75 x 103cell/L and 178.15 x 103cell/L, respectively). Only two centric diatoms were identified in this site: *Cyclotella ocellata* and *Stephanodiscus astrea* (44.5 x 10^3 cell/L and 1 x 10^3 cell/L, respectively). *Peridinium cinctum* (36.25 x 103cell/L), *Euglena* sp. (27.25 x 10^3 cell/L) as well as *Oscillatoria proteus* (9.15 x 10^3 cell/L), *Lyngbya* sp. (15 x 10^3 cell/L) and *Anabaena* sp. (27.25 x 10^3 cell/L) represented Pyrrhophyta, Euglenophyta and Cyanophyta, respectively (See Table 48).

According to Palmer (1969 as mentioned in Wehr and Sheath, 2003 p. 672), *Nitzschia palea* is one of the most common and pollution-dependent species.

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With increased nutrient concentrations such as those observed at this site, blue-green algae may also increase in number. These species may become dangerous, as they have the ability to produce toxins such as microcystins and anatoxins that are harmful to animals and humans if present in high numbers (Huisman, Matthijs and Visser 2005).

In summer, the dominant species in this site were pennate diatoms, represented by *Nitzschia palea* (4052.6 x 10^3 cell/L) as was the case in winter 2009. In winter this site had low diversity, but good to moderate richness and evenness values (See Annex 2: Table 175, Table 177 & Table 179). In summer, this site is considered to have very low diversity, good richness and very low evenness values. (See Annex 2: Table 176, Table 178 & Table 180)

Table 48: Number of species, total count and percentage for phytoplankton groups in New Halabja (QA_EIA_WQ5)

Phytoplankton Group WQ-5	Sp. #-WS	Sp. #-SS	Total Count (cell x 103/L)-WS	Total Count (cell x 103/L)-WS	%-WS	%-WS
Cyanophyta	3	1	37.3	9.1	2.43	0.21
Euglenophyta	1	2	27.2	27.2	1.77	0.63
Pyrrhophyta	1	0	36.2	0	2.35	0
Cryptophyta	0	0	0	0	0.00	0
Chlorophyta	0	1	0	1	0.00	0
Bacillariophyceae/Centrales	2	1	45.5	22.3	2.96	0.02
Bacillariophyceae/Pennales	20	16	1391.3	4271	90.49	98.62
Total	27	21	1537.5	4330.6	100	100

Benthic Macroinvertebrates: Total density found in the winter survey was 218 indv. /m² and comparing with the other studied sites, this density was relatively low (See Annex 4: Table 165). No EPT species were found in this site (Annex 4:

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). The dominant species was the white midge larva *Cricotopus sylvestris*, which is known as a tolerant organism (pollution tolerance number ≈ 7). Although the site has been characterized with relatively low diversity and richness, it has very good balance (See Annex 1, **Error! Reference source not found.**, **Error! Reference source not found.**, and **Error! Reference source not found.**).

Based on the modified pollution tolerance and pollution indices, water quality was poor (see See Annex 1, Table 173 & Table 174) and this could be confirmed by the presence of the tolerant and very tolerant aquatic organisms such as the Lunged snail *Physella* sp. and the larvae of the Blood midge *Paratendipes albimanus*.

Total density found in the summer survey was 1135 indv. /m² and comparing with the other studied sites, this sites, this density was relatively high (Annex 4: Table 183). Although, the site has relatively a good diversity and diversity and richness and a very good evenness (Annex 4: Table 168, Table 170 &

Table 172, respectively), the EPT% was low (Table 174) and the dominant species was the larva of the red-blood midge Chironomus riparius which is known as very tolerant organism (pollution tolerance number ≈ 10).

Water quality depending on the modified pollution tolerance and pollution indices was poor to fair (See Annex 1, Table 173 & Table 174) and this could be confirmed by the presence of the tolerant and very tolerant bio-indicators such as the Forktail damselfly Ischnura sp.2, and the red-blood midge larva *Paratendipes albimanus*.

Briefly, we suggested considering the habitat here as severely impaired and the water quality as poor (See Methods & Procedures).

Heavy Metals in Water: Depending on measurements for heavy metals in water samples, this site was contaminated with Cu, Ni, Pb, Mn and Zn in the winter sample and with Ni, Cu, Cd, Pb, Mn and Zn in the summer sample, compared with optimum levels in river water (see **Error! Not a valid bookmark self-reference.** below). Variation in heavy metal concentration between winter and summer samples was obvious, and this may be because in summer some of the contamination sources like sewages may evaporate and thus disappear before reaching the stream.

Table 49: Heavy metals in water of New Halabja QA_EIA_WQ5

Heavy Metal	Winter	Summer	River Standards[1 & 2]	Surface Water Standards[2,3&4]
Nickel (Ni) mg/L	**0.04**	**0.024**	0.0008	0.0005-0.006
Lead (Pb) mg/L	0.01	0.0092	0.0015	0.09
Iron (Fe) mg/L	0.2	0.0001	0.67	0.22-0.35
Copper (Cu) mg/L	0.02	0.0253	0.002	0.27
Manganese (Mn)mg/L	0.02	0.0101	0.00002	0.07-0.5
Cadmium (Cd) mg/L	ND	0.0024	0.00008	0.000005
Zinc (Zn) mg/L	**0.11**	**0.0163**	0.0006	N/A
1= Allan and Castillo, 2007; 2=Kabata-Pendias and Mukherjee, 2007; 3=Agardy and Sullivan, 2005; 4=STF, 2000; ND=not detected; N/A=not available				

Heavy Metals in Soil: Heavy metals Ni, Pb, Fe, Cu, and Mn in the soil of this site show higher concentrations than the world soil background except Zn, and Ni exceeds the maximum allowable concentration in agricultural soils of Poland (see Table below).

Table 50: Heavy Metals in Soil of New Halabja QA_EIA_WQ5

Heavy Metal	Summer	Soil Background [1 & 2]	*Agricultural Soils [3]
Nickel (Ni) mg/kg	**116.5**	19-22	30-75
Lead (Pb) mg/kg	35.3	25	70-150
Iron (Fe) mg/kg	**27492.5**	2000	N/A
Copper (Cu) mg/kg	47.7	20	30-70

Manganese (Mn)mg/kg	**709.8**	437	N/A
Cadmium (Cd) mg/kg	ND	0.5	10
Zinc (Zn) mg/kg	57.6	64	100-300
1=Kabata-Pendias and Mukherjee, 2007; 2=Essington; 3=Kabata-Pendias, 2001; *=Maximum Allowable Concentration in Agricultural soils of Poland.; ND=not detected; N/A=not available			

Heavy Metals in Sediments: Sediments of the New Halabja site were contaminated with Pb, Cu, Cd and Zn in winter and contaminated with Pb, Cu, Mn and Cd in the summer sample (see Table below). Sewages from the nearest town and others upstream and agricultural activities of the surrounding farms may be the main sources of sediment contamination by heavy metals.

Table 51: Heavy metals in sediment of New Halabja QA_EIA_WQ5

Heavy Metal	Winter	Summer	Background[1]	CSQG[2]
Nickel (Ni) mg/kg	**551.1**	**129.7**	31	N/A
Lead (Pb) mg/kg	**37.05**	**40.6**	23	35
Iron (Fe) mg/kg	34585	36977.5	N/A	N/A
Copper (Cu) mg/kg	**105.05**	**54.8**	25	35.7
Manganese (Mn) mg/kg	**2195.1**	**864.8**	400	N/A
Cadmium (Cd) mg/kg	**0.85**	**1.1**	N/A	0.6
Zinc (Zn) mg/kg	**254**	91.4	65	123
1= ASQ, 1993; 2= CSQG, 2002; N/A=not available				

Conservation Issues & Recommendations: Further studies are needed to identify the specific sources of contamination and guide the stream restoration process at the New Halabja site. Nutrient contamination was obvious in this site, which may adversely affect the downstream habitat and cause algal blooms at Darbandikhan Lake. Before entering Darbandikhan Lake the water quality issue must be solved by improving small dams and lakes across the stream before the main lake in addition to other remediation projects.

The New Halabja site's phytoplankton results recorded during winter 2009 indicated mesotrophic-eutrophic water conditions.

Benthic Macroinvertebrates results for New Halabja Site (QA_EIA_WQ5) during winter and summer 2009 indicate severely impaired habitat and poor water quality.

Overall, this site along the Tanjero River is adversely affected by municipal and industrial sewage, waste and agricultural input upstream, which has degraded the water quality of the site. Proper remediation of the site will require wastewater treatment, containment and proper treatment of solid wastes and assessment of the agricultural impact on the water and river sediment.

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10. Darbandikhan (S1)– Winter Elev. 349 & Summer Elev. 458 m

Site Description: Darbandikhan is a large, deep, fresh water lake of approximately 7500 ha, located 60 km southeast of Sulaimani City. It is fed by two rivers, the Tanjero in the northeast and the Sirwan in the southeast, and surrounded by mountains (Bashari, Zmnako, and Zawaly) that are covered in oak forests and/or grassland habitats. The lake and surrounding mountains support a large number of birds and other wildlife. Water levels have declined since the previous summer due to extensive drought conditions and the lack of significant winter rainfall before the winter sampling occurred. Water levels did increase somewhat in spring and early summer and there were some brief showers even during the summer survey, but drought conditions continue in the area during 2009.

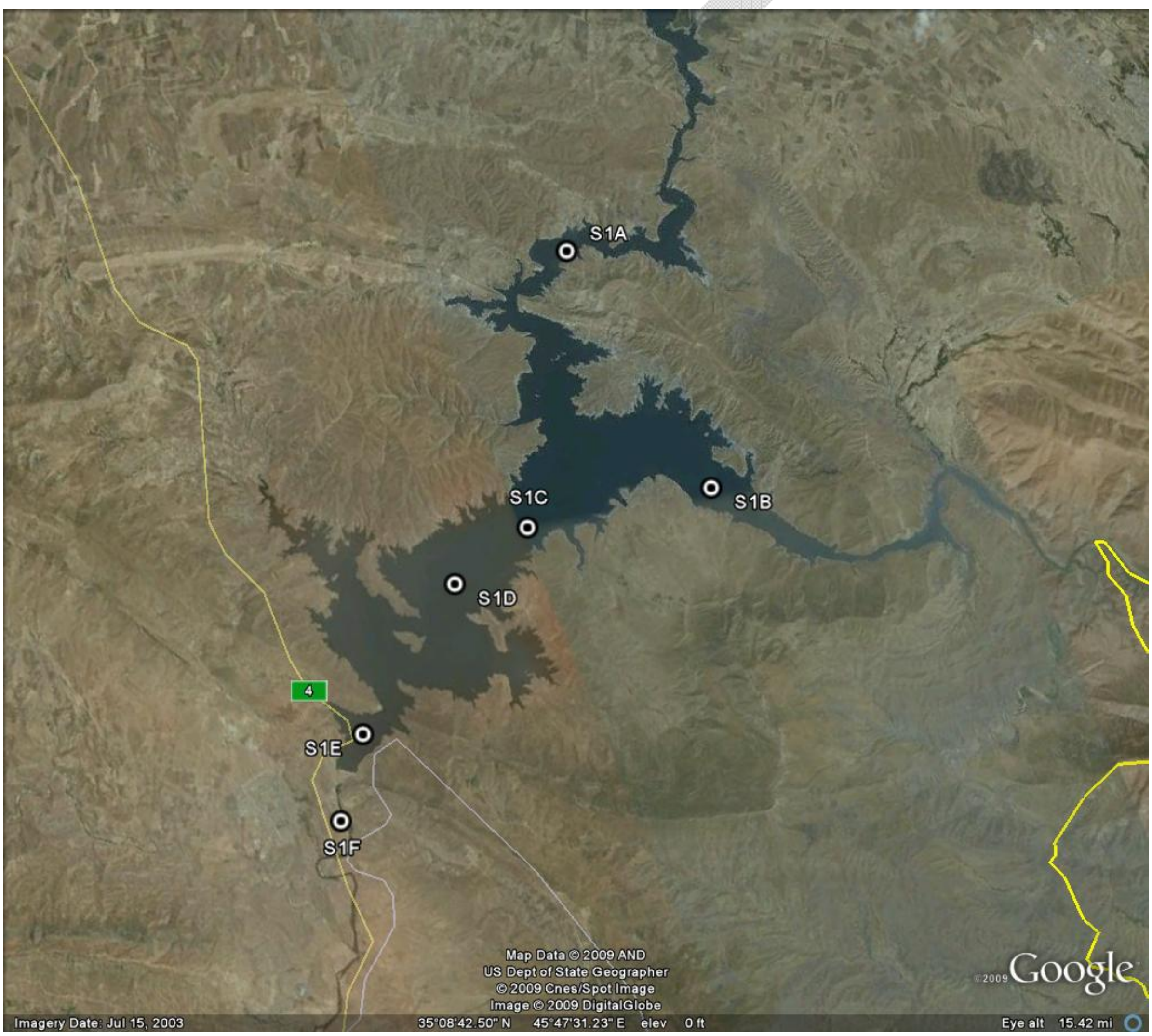

Plate 4: Survey points at Darbandikhan Lake (Google Earth, 2009)

Observations (Winter: 14-16 Jan 2009; Summer: 16-18 Jun 2009)

<u>*Water Quality: Darbandikhan Lake – Tanjero Input (S1A) Sample Site*</u> For winter: Sample Date 15/1/09, Sample Time 09:11 AM, Water Depth 0.5m, Air temperature 3°C, Water temperature 7°C.

For summer, *S1A-Surface*: Sampling Date 18/6/09, Sample Time 09:11 AM, Water Depth 20m, Air temperature 31°C, Water temperature 27.2°C. *S1A-Bottom*: Sampling Date 18/6/09, Sample Time 09:11 AM, Water Depth 20m, Water temperature 20°C.

During the winter survey, this site was considered a contaminated site due to high levels of NO3, NO2, SO4, TP, HCO3, Ca, Mg and Na when compared to reference standards for natural rivers (see Table 52).

During the summer survey, both surface and bottom samples were contaminated with NO3, NO2, SO4, TP, Ca, Mg and Na compared to reference standards for natural rivers, except HCO3, which showed normal levels in the surface sample (see Table 52).

The source of the NO3, NO2, SO4 and TP contamination was sewage from Sulaimani City and other towns that disposed of their waste into the Tanjero River upstream of the site (Mustafa, 2006) as well as in other tributaries leading to the river. The sodium contamination may be the result of poor agricultural practices around the river on the land upstream from the lake. The Tanjero River at this site is very turbid during the winter, exceeding the reference limit of 10 NTU used for natural surface waters (STF, 2000).

Plate 5: Darbandikhan Lake - Tanjero Input (S1A)

Table 52: Physical & Chemical Water Qquality Parameters at site Tanjero Input (S1A)

Parameters	Winter	Summer		River Standards[1 & 2]	Surface Water Standards[2,3&4]
		Surface	Bottom		
Field Analysis					
Water Temperature °C	9.7	27.7	20	N/A	N/A
Conductivity µS/cm	559	277	420	N/A	<1275
pH	8.28	**8.9**	7.6	N/A	6-8.5
Turbidity NTU	**201**	7.9	4.05	N/A	10
TDS mg/L	336	ND	ND	N/A	500
Salinity ppt	ND	ND	ND	N/A	N/A
DO mg/L	10	15.7	**1.9**	N/A	>5
DO%	89.1	210	22.6	N/A	N/A
Secchi disc m	0.15	1.4	ND	N/A	N/A
Lab Analysis					
TSS mg/L	0.064	5	9	N/A	N/A
TDS mg/L	331.5	ND	ND	N/A	500
BOD mg/L	0.84	4.2	ND	N/A	N/A
Orthophosphate (PO4) mg/L	0.02	0.14	0.14	10	N/A
Nitrite-Nitrogen (NO2) mg/L	**0.13**	**0.037**	**0.09**	0.001	N/A
Nitrate-Nitrogen (NO3) mg/L	9.2	1.14	**17.3**	1	10
Total Alkalinity as CaCO3 mg/L	118	40	101.5	N/A	>20
Bicarbonate (HCO3) mg/L	**136.64**	14.6	**123.8**	58.4	58
Total Hardness (TH) mg/L	294.18	158.5	273	N/A	N/A
Calcium (Ca) mg/L	**96.35**	**28.44**	**46.37**	15	15
Magnesium (Mg) mg/L	**14.4**	**10.96**	**7.78**	4.1	4.1
Chloride (Cl) mg/L	**7.82**	**8.62**	**11.27**	7.8	7.8

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Parameters	Winter	Summer		River Standards[1 & 2]	Surface Water Standards[2,3&4]
		Surface	Bottom		
Total Nitrogen (TN) mg/L	36.26	ND	ND	N/A	N/A
Sulfate (SO4) mg/L	**39.93**	**52.6**	**43.95**	11.2	3.7
Total Phosphorous (TP) mg/L	**0.57**	**0.32**	**0.32**	0.025	N/A
Potassium (K) mg/L	1.74	**2.3**	2.13	2.3	2.3
Sodium (Na) mg/L	**23.55**	**11.23**	**10.62**	6.3	6.3
1= Allan and Castillo, 2007; 2=Kabata-Pendias and Mukherjee, 2007; 3=Agardy and Sullivan, 2005; 4=STF, 2000; ND=not detected; N/A=not available					

Bacteria & Coliform at S1A: For winter, Sample Date–15/1/09, Sample Time- 09:11 am, Water Depth- 0.5m, Air temperature- 3°C, Water temperature-7°C.

For summer, *S1A-Surface*: Sampling Date–18/06/09, Sample Time- 09:11 am, Water Depth- 20m, Air temperature- 31°C, Water temperature-27.2°C.

At the winter survey the results from this site indicate a fecal coliform bacteria contamination, which may came from sewage discharge from the towns and villages along the streams. During the summer survey there was a decrease in the fecal coliform bacteria contamination, but the water is still considered contaminated by fecal coliform. This contamination may be due to the increase in the water levels and flow in summer.

Table 53: Fecal Coliform bacteria count and E. coli at site Darbandikhan (S1A)

	Winter	Summer	Drinking Standards [1 & 2]	Surface Water Standards [2]		
				Body-contact	Fishing and boating	Domestic water supply
Fecal Coli form Bacteria Colony/100 ml	**≥ 2400**	**130**	0 in 100ml	100 Colonies/100 mL	> 1000 Colonies/100 mL	> 2000 Colonies/100 mL
Escherichia coli	+	+				
1= WHO, 2006; 2= CDWQ, 2006						

Phytoplankton at S1A: The total phytoplankton count during the winter survey was 1089.9 x 10^3 cell/L and a total of 65 species were recorded. The dominant species in this site were pennate diatoms (77.55%) (See the table below). *Nitzschia dissipata, Nitzschia frustulum* and *Fragilaria acus* var. *radians* were the most common pennate diatoms. Some benthic and epiphytic diatoms, mostly belonging to the genera *Navicula* and *Nitzschia*, have demonstrated the ability to decompose various solid organic compounds and organic phosphates (Tanaka and Ohwada, 1988 as cited in Stevenson, Bothwell and Lowe 1996). In addition to these three species, other pennate diatoms were also recorded including *Navicula gracilis, Navicula cryptocephala, Nitzschia palea, Gomphonema angustatum, Fragilaria ulna*, and *Achnanthes minutissima*. This site is considered to have good diversity, very good richness and evenness values (See Annex 2: Table 175, Table 177 & Table 179).

The total phytoplankton count during the summer survey at S1A was 3177.5 x 10^3 cell/L and a total of 15 species were recorded. This dominant species in this site were green algae (94.99%) (See the table below). Of these, *Chlorella vulgaris* was the most common green algae in this site (2826.1 x 10^3 cell/L) while the Phyrrophyta were represented by *Peridinium cinctum* (108.6 x 10^3 cell/L). This site is considered to have relatively very low diversity, good richness and low evenness values. (See Annex 2: Table 176, Table 178 & Table 180)

Table 54: Number of species, total count and percentage for phytoplankton groups in Tanjero Input (S1A)

Phytoplankton Groups (S1A)	Sp. #-WS	Sp. #-SS	Total Count (cell x 103/L)-WS	Total Count (cell x 103/L)-SS	%-WS	%-SS
Cyanophyta	1	0	9.1	0.00	0.83	0.00
Euglenophyta	0	0	0.00	0.00	0.00	0.00
Pyrrhophyta	1	2	18.1	109.6	1.66	3.45
Cryptophyta	0	0	0.00	0.00	0.00	0.00
Chlorophyta	5	6	13.1	3018.3	1.20	94.99
Bacillariophyceae/Centrales	6	1	204.4	22.3	18.75	0.7
Bacillariophyceae/Pennales	52	6	845.2	27.3	77.55	0.86
Total	65	15	1089.9	3177.5	100.00	100.00

Benthic Macroinvertebrates at Tanjero Input (S1A): **Total density found in summer was 140 indv. /m^2 and comparing with the other studied sites, this density was the lowest (Annex 4: Table 166). Although, the site has relatively a moderate diversity and richness and an excellent evenness (Annex 4: Table 168, Table 170 &** Table 172, respectively), the EPT% was zero (Annex 4: Table 174) and the dominant species was the red-blood worm Tubifex tubifex which is known as very tolerant organism (pollution tolerance number ≈ 10).

Water quality depending on the modified pollution tolerance and pollution indices was poor (See Annex 1, Table 173) and this could be confirmed by the presence of the tolerant and very tolerant bio-indicators such as the midge larva *Dicrotendipes* sp.2 and the lunged snail *Physella acuta*.

Water Quality at S1B: Darbandikhan Lake – Sirwan Input (S1B) Sample Site: - For winter, Sample Time- 10:15 am, Date- 15/1/2009, Water Depth- 0.7m, Air temperature- 8°C, Water temperature- 12°C.

For summer, *S1B-Surface:* Sampling Time- 12:34 am, Date- 18/6/2009, Water Depth- 25m, Air temperature- 31°C, Water temperature-26.8°C. *S1B-Bottom:* Sampling Time- 12:34 am, Date- 18/6/2009, Water Depth- 25m, Water temperature-22.3°C.

For winter sampling, the water at this site had high turbidity in winter compared to natural surface water standards and the Sirwan River at this site was contaminated compared to river and surface water quality standards (see Table 55). Results showed high levels of NO2, NO3, SO4, Cl and Na levels, which may be from fertilizers used in agricultural activities (Yuce et al., 2006; Mustafa, 2006; Güllbahar and Elhatip, 2005; WHO, 1996); the high Ca, Mg and HCO3 levels may be from the dissolution of limestone (through rock-water interactions).

For summer sampling, the water in the surface sample was contaminated with NO2, Ca, Mg, SO4, TP and Na, but the bottom sample was turbid and contaminated with NO2, HCO3, Cl, Ca, Mg, SO4, TP and Na. The sources of this contamination are the same as in winter sampling. These inputs are likely coming mostly from Iranian sources.

Table 55: Physical & Chemical Water quality parameters at site Sirwan Input (S1B)

Parameters	Winter	Summer		River Standards[1 & 2]	Surface Water Standards[2,3&4]
		Surface	Bottom		
Field Analysis					
Water Temperature °C	12	26.8	22.3	N/A	N/A
Conductivity µS/cm	441	277	415	N/A	<1275

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Parameters	Winter	Summer		River Standards[1 & 2]	Surface Water Standards[2,3&4]
		Surface	Bottom		
pH	8.24	**8.7**	7.8	N/A	6-8.5
Turbidity NTU	**209**	6.2	**13.7**	N/A	10
TDS mg/L	266	ND	ND	N/A	500
Salinity ppt	ND	ND	ND	N/A	N/A
DO mg/L	9.9	14.1	5.5	N/A	>5
DO%	94.7	184	64.9	N/A	N/A
Secchi disc m	0.7	2.5	ND	N/A	N/A
Lab Analysis					
TSS mg/L	0.007	5	8	N/A	N/A
TDS mg/L	220.5	132	181	N/A	500
BOD mg/L	0.62	3.85	ND	N/A	N/A
Orthophosphate (PO4) mg/L	0.02	0.14	0.13	10	N/A
Nitrite-Nitrogen (NO2) mg/L	**0.04**	**0.029**	**0.046**	0.001	N/A
Nitrate-Nitrogen (NO3) mg/L	**10.78**	1.66	3.18	1	10
Total Alkalinity as CaCO3 mg/L	70	35.5	94.5	N/A	>20
Bicarbonate (HCO3) mg/L	**63.44**	4.3	**115.3**	58.4	58
Total Hardness (TH) mg/L	215.54	158	240	N/A	N/A
Calcium (Ca) mg/L	**79.3**	**32.13**	**46.43**	15	15
Magnesium (Mg) mg/L	**9.55**	**9.28**	**6.26**	4.1	4.1
Chloride (Cl) mg/L	**8.66**	**6.69**	**9.36**	7.8	7.8
Total Nitrogen (TN) mg/L	57.3	ND	ND	N/A	N/A
Sulfate (SO4) mg/L	**81.57**	**56.5**	**63.84**	11.2	3.7
Total Phosphorous (TP) mg/L	0.02	**0.33**	**0.34**	0.025	N/A
Potassium (K) mg/L	**2.63**	1.79	1.63	2.3	2.3
Sodium (Na) mg/L	**26.53**	**9.69**	**8.53**	6.3	6.3
1= Allan and Castillo, 2007; 2=Kabata-Pendias and Mukherjee, 2007; 3=Agardy and Sullivan, 2005; 4=STF, 2000; ND=not detected; N/A=not available					

<u>Bacteria & Coliform at S1B:</u> The results of the winter survey indicate that the water is within the limits of the normal range according to the international standards for surface water; but during the summer survey the number of fecal coliform bacteria increased and rose slightly above the normal range. The area's agricultural activities and fertilizers, the distance from sewage discharge points, and the speed of the river's current may result in a decline in the number of fecal coliform bacteria by the time the water reaches this area (See Table 56).

Table 56: Fecal Coliform bacteria count and E. coli at site (Sirwan Input (S1B))

	Winter	Summer	Drinking Standards [1 & 2]	Surface Water Standards[2]		
Fecal Coli form Bacteria	8	**170**	0 in 100ml	Body-contact	Fishing and boating	Domestic water supply

Colony/100 ml				100 Colonies/100 mL	> 1000 Colonies/100 mL	> 2000 Colonies/100 mL
Escherichia coli	+	+				
1= WHO, 2006; 2= CDWQ, 2006						

<u>*Phytoplankton at S1B*</u>: The total phytoplankton count during the winter survey was 714.7 x 10^3 cell/L and a total of 23 species were recorded. The dominant species in this site were centric diatoms (79.46%) (see Table 57). *Aulacoseira granulate* was the most common centric diatom (512.2 x 10^3 cell/L). The presence of diatoms associated with turbulent environments has been useful for making inferences with regard to changing water levels. The genus *Aulacoseira* is a particularly good example: a heavily silicified diatom with high sinking rates, its ecology requires turbulence to maintain a significant presence in the water column (Bradbury 1975 as cited in Stoermer and Smol, 2004). Increased turbulence and the corresponding nutrient increase during low water stages in a lake can favor this genus over other planktonic species (Stoermer and Smol, 2004). *Cyclotella ocellata* and *Stephanodiscus astrea* were also recorded in the survey site (33.4 x 103cell/L and 22.3 x 10^3 cell/L respectively). Although the presence of *Cyclotella ocellata* reflects oligotrophic conditions, the prevalence of *Aulacoseira granulate* indicates relatively eutrophic water conditions. In addition, the pennate diatoms were represented by 16 individual species although each was found in low densities, including *Nitzschia palea, Nitzschia dissipata, Navicula gracilis, Navicula cryptocephala, Hantzschia amphioxys, Gyrosigma spencerii, Gomphonema olivaceum, Fragilaria ulna, Diatoma vulgare* and *Cymbella ventricosa*. This site is considered to have low diversity, good richness and moderate evenness values (See Annex 2: Table 175, Table 177 & Table 179).

The total phytoplankton count during the summer survey at S1B was 2508.7 x 10^3 cell/L and a total of 30 species were recorded. The dominant species in this site were green algae (64.71%) (see Table 57). *Chlorella vulgaris* was the dominant green algae (1322.5 x 10^3 cell/L). *Chlorella spp.* is widely distributed in freshwater all over the world, and are often a major component of phytoplankton populations in nutrient-poor waters. *Chlorella spp.* have evolved a variety of efficient nutrient intake mechanisms and are able to rapidly increase in population and out-compete larger species of phytoplankton in lakes of low to moderate nutrient status. The order Pyrrophyta was represented by *Peridinium cinctum* (579.7 x 10^3 cell/L). The blue-green algae were represented by both *Anabaena* sp. and *Chroococcus minutes* (163 x 10^3 cell/L and 9.1 x 10^3cell/L respectively). *Aulacoseira granulate, Cyclotella meneghiniana* and *Cyclotella ocellata* were the only three centric diatoms recoreded in low densities (11.1 x 10^3 cell/L, 22.3 x 10^3 cell/L and 11.1 x 10^3 cell/L respectively). The pennate diatoms were represented by 14 species also found in low densities, including *Achnanthes hungarica, Achnanthes minutissima, Cocconeis pediculus, Cymbella affinis, Cymbella microcephala, Fragilaria fasciculate, Navicula cryptocephala, Nitzschia dissipata* and *Nitzschia palea*. This site is considered to have relatively low diversity, very good richness and moderate evenness values. (See Annex 2: Table 176, Table 178 & Table 180)

Table 57: Number of species, total count and percentage for phytoplankton groups in Sirwan Input (S1B)

Phytoplankton Groups (S1B)	Sp. #-WS	Sp. #-SS	Total Count (cell x 103/L)-WS	Total Count (cell x 103/L)-SS	%-WS	%-SS
Cyanophyta	1	2	1	172.1	0.14	6.86
Euglenophyta	0	0	0	0	0.00	0
Pyrrhophyta	1	1	90.5	579.7	12.66	23.11
Cryptophyta	0	0	0	0	0.00	0
Chlorophyta	2	10	19.1	1623.5	2.67	64.71

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Phytoplankton Groups (S1B)	Sp. #-WS	Sp. #-SS	Total Count (cell x 103/L)-WS	Total Count (cell x 103/L)-SS	%-WS	%-SS
Bacillariophyceae/Centrales	3	3	567.9	44.5	79.46	1.77
Bacillariophyceae/Pennales	16	14	36.2	88.9	5.07	3.54
Total	23	30	714.7	2508.7	100.00	100

Benthic Macroinvertebrates at Sirwan Input (S1B): Total density found in summer was 333 indv. /m² and comparing with the other studied sites, this density was low (Annex 4: Table 166). Although, the site has relatively an excellent evenness, it has a low diversity, lowest richness (

Table 172: Table 168 & Table 170, respectively), zero EPT% (Table 174), and the dominant species was the red-blood worm *Tubifex tubifex* which is known as very tolerant organism (pollution tolerance number ≈ 10).

Water quality depending on the modified pollution tolerance and pollution indices was poor (See Annex 1, Table 173 & Table 174) and this could be confirmed by the presence of the tolerant and very tolerant bio-indicators such as the midge larva *Paratrichocladius* sp. and the aquatic worm *Limnodrilus hoffmeisteri*.

Water Quality at S1C: Darbandikhan Lake (S1C) Sample Site- For winter: SIC-Surface, Sampling Time- 09:15 am, Date- 16/1/2009, Water Depth- 30m, Air temperature- 8°C, Water temperature-12.4°C. *S1C-Bottom:* Sampling Time- 09:15 am, Date- 16/1/2009, Water temperature-12.6°C.

For summer: SIC-Surface- Sampling Time- 10:00 am, Date- 16/6/2009, Water Depth- 35m, Air temperature- 29°C, Water temperature-27.4°C. *S1C-Bottom:* Sampling Time- 10:00 am, Date- 16/6/2009, Water Depth- 25 m Water temperature-15.3°C.

During the winter survey, Darbandikhan Lake showed excess concentrations of SO4, HCO3, Ca, Mg, Cl and Na (see Table 58). There was no major difference between the water quality parameters in the surface and bottom samples.

For summer sampling, the lake showed contamination with SO4, Ca, Mg, Cl, Na and HCO3 in the surface water alone (see Table 58).

Table 58: Physical & Chemical Water quality parameters at site Darbandikhan Lake (S1C)

Parameters	Surface		Bottom		Surface Water Standards [1,2&3]
	Winter	Summer	Winter	Summer	
Field Analysis					
Water Temperature °C	12.4	27.4	12.6	15.3	N/A
Conductivity µS/cm	444	283	442	426	<1275
pH	8.14	**8.5**	8.00	7.5	6-8.5
Turbidity NTU	4.24	**10.4**	4.4	2.07	10
TDS mg/L	268	ND	267	ND	500
Salinity ppt	ND	ND	ND	ND	N/A
DO mg/L	7.8	12.5	6.87	6.3	>5
DO%	76.9	166.6	66.2	66.1	N/A
Secchi disc m	2.5	2.75	ND	ND	N/A
Lab Analysis					
TSS mg/L	0.003	9	0.002	4	N/A
TDS mg/L	336.5	160	342.5	234	500
BOD mg/L	ND		ND		N/A
Orthophosphate (PO4)	ND	0.0036	0.03	0.0018	N/A

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Parameters	Surface		Bottom		Surface Water Standards [1,2&3]
	Winter	Summer	Winter	Summer	
mg/L					
Nitrite-Nitrogen (NO2) mg/L	0.05	0.027	0.05	0.006	N/A
Nitrate-Nitrogen (NO3) mg/L	3.49	1.76	3.88	7.16	10
Total Alkalinity as CaCO3 mg/L	66.5	51.5	68	50.5	>20
Bicarbonate (HCO3) mg/L	**81.13**	43.9	**82.96**	44.7	58
Total Hardness (TH) mg/L	221.37	181.33	217.48	256.5	N/A
Calcium (Ca) mg/L	**78.4**	**27.2**	**68.3**	**46.4**	15
Magnesium (Mg) mg/L	**9.45**	**9.16**	**9.88**	**7.85**	4.1
Chloride (Cl) mg/L	**8.53**	7.51	**8.53**	**10.47**	7.8
Total Nitrogen (TN) mg/L	38.33	ND	42.99	ND	N/A
Sulfate (SO4) mg/L	**76**	**55.8**	**74.78**	**61.2**	3.7
Total Phosphorous (TP) mg/L	0.08	0.017	0.08	0.037	N/A
Potassium (K) mg/L	**2.65**	1.82	**2.53**	2.08	2.3
Sodium (Na) mg/L	**24.55**	**9.71**	**25.73**	**10.81**	6.3
1=Kabata-Pendias and Mukherjee, 2007; 2=Agardy and Sullivan, 2005; 3=STF, 2000; ND=not detected; N/A=not available					

<u>Bacteria & Coliform at S1C:</u> The results of the winter survey showed that the area is not greatly affected by sewage; the fecal coliform bacteria count was only 2 colonies/100 ml, which is lower than the standard for surface water (See Table 59). During the summer survey the results from this site were still under the reference standard for surface water. Water currents and the fact that this site is in the center of Darbandikhan Lake and is therefore relatively far from any civilian area may lower the potential for contamination here.

Table 59: Fecal Coliform bacteria count and E. coli at site (Sirwan Input (S1C))

	Winter	Summer	Drinking Standards [1 & 2]	Surface Water Standards [2]		
Fecal Coli form Bacteria Colony/100 ml	2	17	0 in 100ml	Body-contact	Fishing and boating	Domestic water supply
				100 Colonies/100 mL	> 1000 Colonies/100 mL	> 2000 Colonies/100 mL
Escherichia coli	+	+				
1= WHO, 2006; 2= CDWQ, 2006						

<u>Phytoplankton at S1C:</u> The total phytoplankton count during the winter survey was 1488.2 x 10^3 cell/L and a total of 19 species were recorded. The dominant species in this site were centric diatoms (92.01%) (see Table 60). This group was represented by three species: *Aulacoseira granulate, Cyclotella ocellata* and *Stephanodiscus astrea* (1246.9 x 10^3 cell/L, 111.3 x 10^3 cell/L and 11.1 x 10^3 cell/L

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respectively). This site is considered to have very low diversity, good richness and low evenness values (See Annex 2: Table 175, Table 177 & Table 179).

The total phytoplankton count during the summer survey at S1C was 4391.3 x 10^3 cell/L and a total of 18 species were recorded. The dominant species in this site were green algae (99.13%) (see Table 60). *Chlorella vulgaris* was the most common green algae throught this site (4112.3 x 10^3 cell/L), with the presence of other species such as *Scenedesmus bijuga, Coelastrum astroideum, Oocystis* sp. and *Tetraedron minimum*. Compared to the other surveyed sites this site is considered to have relatively very low diversity, good richness and very low evenness values. (See Annex 2: Table 176, Table 178 & Table 180)

Table 60: Number of species, total count and percentage for phytoplankton groups in Center North of Darbandikhan Lake (S1C)

Phytoplankton Groups (S1C)	Sp. #-WS	Sp. #-SS	Total Count (cell x 103/L)-WS	Total Count (cell x 103/L)-SS	%-WS	%-SS
Cyanophyta	0	1	0	1	0.00	0.02
Euglenophyta	0	0	0	0	0.00	0.00
Pyrrhophyta	1	1	45.3	1	3.04	0.02
Cryptophyta	1	0	1	0	0.07	0.00
Chlorophyta	6	11	23.1	4352.9	1.55	99.13
Bacillariophyceae/Centrales	3	2	1369.3	23.3	92.01	0.53
Bacillariophyceae/Pennales	8	3	49.5	13.1	3.33	0.30
Total	19	18	1488.2	4391.3	100	100

<u>Water Quality at S1D:</u> Darbandikhan Lake (S1D) Sample Site-For winter: SID-Surface, Sampling Time- 11:00 am, Date- 16/1/2009, Water Depth- 30m, Air temperature- 9°C, Water temperature-12.7°C. *<u>SID-Bottom:</u>* Sampling Time- 11:00 am, Date- 16/1/2009, Water temperature-13.4°C.

For summer: SID-Surface, Sampling Time- 11:45 am, Date- 16/6/2009, Water Depth- 35m, Air temperature- 35°C, Water temperature-27.7°C. *<u>SID-Bottom:</u>* Sampling Time- 11:45 am, Date-16/6/2009, Water Depth- 35 m, Water temperature-15.5°C.

For both the winter and summer samples, there are differences between the water quality parameters at the surface and bottom, especially DO, HCO3, total hardness, Ca and Na. Indications of water contamination at this site are also present (see Table below).

Table 61: Physical & Chemical Water quality parameters at site Darbandikhan Lake (S1D)

Parameters	Surface		Bottom		Surface Water Standards [1,2&3]
	Winter	Summer	Winter	Summer	
Field Analysis					
Water Temperature °C	12.7	27.7	13.4	15.5	N/A
Conductivity µS/cm	442	289	441	436	<1275
pH	8.07	**8.5**	7.99	7.7	6-8.5
Turbidity NTU	3.75	5.11	3.5	1.08	10
TDS mg/L	266	ND	266	ND	500
Salinity ppt	ND	ND	ND	ND	N/A
DO mg/L	11.01	11.9	9.6	6.4	>5
DO%	108.1	158.3	93.9	66.1	N/A

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Parameters	Surface		Bottom		Surface Water Standards [1,2&3]
	Winter	Summer	Winter	Summer	
Secchi disc m	2.5	2.5	ND	ND	N/A
Lab Analysis					
TSS mg/L	0.002	3	0.002	3	N/A
TDS mg/L	277.5	ND	338	ND	500
BOD mg/L	ND	ND	ND	ND	N/A
Orthophosphate (PO4) mg/L	ND	0.01	ND	0.002	N/A
Nitrite-Nitrogen (NO2) mg/L	0.05	0.008	0.06	0.025	N/A
Nitrate-Nitrogen (NO3) mg/L	3.48	4.83	3.44	6.8	10
Total Alkalinity as CaCO3 mg/L	67	50.5	68	99.5	>20
Bicarbonate (HCO3) mg/L	**81.74**	42.7	**58.56**	**115.9**	58
Total Hardness (TH) mg/L	218.45	185	266.2	264.67	N/A
Calcium (Ca) mg/L	**92.6**	**33.67**	**76.5**	**46.55**	15
Magnesium (Mg) mg/L	**10.95**	**9.24**	**10.55**	**8.43**	4.1
Chloride (Cl) mg/L	8.65	8.94	8.63	10.93	7.8
Total Nitrogen (TN) mg/L	24.92	ND	28.25	ND	N/A
Sulfate (SO4) mg/L	**76.54**	**53.9**	**76.65**	**61.36**	3.7
Total Phosphorous (TP) mg/L	0.04	0.016	0.06	0.014	N/A
Potassium (K) mg/L	**2.41**	2.05	**2.66**	2.23	2.3
Sodium (Na) mg/L	**25.55**	**10.04**	**28.1**	**11.35**	6.3
1=Kabata-Pendias and Mukherjee, 2007; 2=Agardy and Sullivan, 2005; 3=STF, 2000; ND=not detected; N/A=not available					

Bacteria & Coliform at S1D: The water in this site was not considered contaminated based on the results from the winter survey, in which only 5 colonies/100 ml of fecal coliform bacteria were found, while during the summer survey the number of fecal coliform bacteria increased to 350 colonies/100 ml, which is above the standard normal range (see table below).

Table 62: Fecal Coliform bacteria count and E. coli at site S1D

	Winter	Summer	Drinking Standards [1 & 2]	Surface Water Standards [2]		
				Body-contact	Fishing and boating	Domestic water supply
Fecal Coli form Bacteria Colony/100 ml	5	**350**	0 in 100ml	100 Colonies/100 mL	> 1000 Colonies/100 mL	> 2000 Colonies/100 mL
Escherichia coli	+	+				
1= WHO, 2006; 2= CDWQ, 2006						

Phytoplankton at S1D: The total phytoplankton count during the winter survey was 692 x 10^3 cell/L and a total of 17 species were recorded (see Table 63). As with the previous two sites, the dominant species in S1D were the centric diatoms, particularly *Aulacoseira granulate, Cyclotella ocellata* and *Stephanodiscus astrea*. Diatoms are clearly the most diverse and abundant group, with *Cyclotella* and smaller species of *Stephanodiscus* especially common in larger rivers worldwide (Wehr and Sheath, 2003). This site is considered to have low diversity, good richness and moderate evenness values (See Annex 2: Table 175, Table 177 & Table 179).

The total phytoplankton count during the summer survey at S1D was 4158.4 x 10^3 cell/L and a total of 19 species were recorded (see Table 63). Thie dominent species in this site were comprised of green algae: *Chlorella vulgaris* (3614.1 x 10^3 cell/L) in addition to the presence of *Scenedesmus bijuga, Coelastrum astroideum, Ankistrodesmus falcatus, Oocystis* sp. and *Tetraedron minimum* in much lower densities. The centric diatoms that had been dominant during the winter were represented by both *Aulacoseira granulate* and *Cyclotella ocellata* (77.9 10^3 cell/L and 22.3$10^3$ cell/L respectively). This site is considered to have relatively very low diversity, good richness and low evenness values. (See Annex 2: Table 176, Table 178 & Table 180)

Table 63: Number of species, total count and percentage for phytoplankton groups in Center South of Darbandikhan Lake (S1D)

Phytoplankton Groups (S1D)	Sp. #-WS	Sp. #-SS	Total Count (cell x 103/L)-WS	Total Count (cell x 103/L)-SS	%-WS	%-SS
Cyanophyta	0	0	0	0	0.00	0.00
Euglenophyta	0	0	0	0	0.00	0.00
Pyrrhophyta	1	1	9.1	9.1	1.32	0.22
Cryptophyta	1	0	9.1	0	1.32	0.00
Chlorophyta	7	7	56.5	3986.5	8.16	95.87
Bacillariophyceae/Centrales	3	2	612.3	100.2	88.48	2.41
Bacillariophyceae/Pennales	5	9	5	62.6	0.72	1.51
Total	17	19	692	4158.4	100	100

Water Quality at S1E: Darbandikhan Lake-Near dam (S1E) Sample Site-For winter: SIE-Surface, Sampling Time- 09:38 am, Date- 14/1/2009, Water Depth- 20m, Air temperature- 8°C, Water temperature-12.6°C. *SIE-Bottom*: Sampling Time- 09:38 am, Date- 14/1/2009, Water temperature-12.4°C.

For summer: SIE-Surface, Sampling Time 08:30 AM, Date 17/6/2009, Water Depth 55m, Air temperature 33°C, Water temperature 27°C. *SIE-Bottom*: Sampling Time 08:30 AM, Date 17/6/2009, Water Depth 55 m, Water temperature 16.1°C.

During the winter survey, the site only differences between the surface and bottom water quality parameters were total nitrogen (TN) and total phosphorous (TP). The site showed elevated levels of the nutrients NO2, TN and TP when compared to a reference lake in the United States (Walker Lake, see Table 64 below). Concentrations of sulfate and sodium were considered high compared to surface water quality standards (see Table 39 below).

During the summer survey, the site show contamination with HCO3 (just in bottom), Ca, Mg, Cl, SO4 and Na if compared to surface water quality standards (See Table 64).

Differences in temperature between the winter and summer seasons was obvious in both surface and bottom samples compared to the changes in temperature at Walker Lake (See Table 64).

Table 64: Physical & Chemical Water quality parameters at site Darbandikhan Lake (S1E)

Parameters	Surface		Bottom		Walker Lake[1]	Surface Water Standards[1,2&3]
	Winter	Summer	Winter	Summer		
Field Analysis						
Water Temperature °C	**12.6**	**27**	**12.4**	**16.1**	ΔT≤2 °C	N/A
Conductivity µS/cm	446	296	446	418	N/A	<1275
pH	8.11	8.5	8.10	7.8	6.5-9.7	6-8.5
Turbidity NTU	4.2	7.7	6.1	1.26	N/A	10
TDS mg/L	269	ND	269	ND	≤12,000	500
Salinity ppt	ND	ND	ND	ND	N/A	N/A
DO mg/L	9.15	11.2	7.81	6.1	> 5	>5
DO%	83.9	148.1	75.6	64.4	N/A	N/A
Secchi disc m	2.6	3	ND	ND	N/A	N/A
Lab Analysis						
TSS mg/L	0.003	2	0.002	2	≤ 25	N/A
TDS mg/L	352.5	ND	316.5	ND	≤12,000	500
BOD mg/L	ND	ND	ND	ND	N/A	N/A
Orthophosphate (PO4) mg/L	ND	ND	ND	ND	N/A	N/A
Nitrite-Nitrogen (NO2) mg/L	0.07	0.025	**0.07**	0.0093	≤0.06	N/A
Nitrate-Nitrogen (NO3) mg/L	2.76	2.44	4.27	5.58	≤90	10
Total Alkalinity as CaCO3 mg/L	72	52.5	72	96.5	N/A	>20
Bicarbonate (HCO3) mg/L	29.28	51.9	31.72	**110.4**	N/A	58
Total Hardness (TH) mg/L	221.37	185	223.1	260	N/A	N/A
Calcium (Ca) mg/L	**68.4**	**34.47**	**71.95**	**36.15**	N/A	15
Magnesium (Mg) mg/L	**9.7**	**9.51**	**10.13**	**8.72**	N/A	4.1
Chloride (Cl) mg/L	8.29	7.48	8.07	11.24	≤3,200	7.8
Total Nitrogen (TN) mg/L	**39.05**	ND	**43.8**	ND	≤0.18	N/A
Sulfate (SO4) mg/L	**81.94**	**56.36**	**77.31**	**65.2**	N/A	3.7
Total Phosphorous (TP) mg/L	0.69	ND	0.35	ND	≤0.82	N/A
Potassium (K) mg/L	**2.54**	**2.35**	**2.64**	2.13	N/A	2.3
Sodium (Na) mg/L	**24**	**11.15**	**24.7**	**11.66**	N/A	6.3
1= NDEP, 1999; 2=Kabata-Pendias and Mukherjee, 2007; 3=Agardy and Sullivan, 2005; 4=STF, 2000; ND=not detected; N/A=not available						

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Bacteria & Coliform at S1E: According to the results this site was not contaminated with fecal coliform nor *E. coli* during both surveys (see Table 65).

Table 65: Fecal Coliform bacteria count and E. coli at site S1E

	Winter	Summer	Drinking Standards[1 & 2]	Surface Water Standards[2]		
Fecal Coli	0	0	0 in 100ml	Body-contact	Fishing and	Domestic

	Winter	Summer	Drinking Standards[1 & 2]	Surface Water Standards[2]		
form Bacteria Colony/100 ml					boating	water supply
				100 Colonies/100 mL	> 1000 Colonies/100 mL	> 2000 Colonies/100 mL
Escherichia coli	-	-				
1= WHO, 2006; 2= CDWQ, 2006						

<u>*Phytoplankton at S1E:*</u> The total phytoplankton count during the winter survey was 954.3 x 10^3 cell/L and a total of 11 species were recorded (See Table 66). The dominant species in this site were centric diatoms (99.16%). This group was represented by three species: *Aulacoseira granulate, Cyclotella ocellata* and *Stephanodiscus astrea* (912.9 x 10^3 cell/L, 22.3 x 10^3 cell /L and 11.1 x 10^3 cell/L respectively). This site is considered to have very low diversity, moderate richness and very low evenness values (See Annex 2: Table 175, Table 177 & Table 179).

The total phytoplankton count during the summer survey at S1E was 954.3 x 10^3 cell/L and a total of 11 species were recorded (See Table 66). The dominant species in this site were centric diatoms (71.92%). The centric diatoms were represented by three species: *Cyclotella ocellata, Cyclotella meneghiniana* and *Stephanodiscus astrea* (44.5 x 10^3 cell/L, 11.1 x 10^3 cell /L and 1 x 10^3 cell /L respectively). This site is considered to have relatively low diversity, good richness and good evenness values. (See Annex 2: Table 176, Table 178 & Table 180)

Table 66: Number of species, total count and percentage for phytoplankton groups in Near Dam (S1E)

Phytoplankton Group (S1E)	Sp. #-WS	Sp. #-SS	Total Count (cell x 103/L)-WS	Total Count (cell x 103/L)-SS	%-WS	%-SS
Cyanophyta	1	0	1	0	0.10	0
Euglenophyta	0	0	0	0	0.00	0
Pyrrhophyta	0	0	0	0	0.00	0
Cryptophyta	0	0	0	0	0.00	0
Chlorophyta	5	0	5	0	0.52	0
Bacillariophyceae/Centrales	3	3	946.3	56.6	99.16	71.92
Bacillariophyceae/Pennales	2	12	2	21.1	0.21	28.08
Total	11	15	954.3	78.7	100	100

<u>*Water Quality at the Diyala (Sirwan) River/After Darbandikhan Dam (S1F):*</u> Diyala (Sirwan) River/After Darbandikhan Dam (S1F) Sample Site-For winter: Sampling Time- 11:40 am, Date- 14/1/2009, Water Depth- 0.6m, Air temperature- 11°C, Water temperature-13.1°C. Sampling was conducted on the western bank.

For summer: Sampling Time- 10:22 am, Date- 17/6/2009, Water Depth- 0.53m, Air temperature- 35°C, Water temperature-17.5°C. Sampling was conducted on the western bank.

During the winter survey, high nutrient levels were found at the site for NO2, NO3, SO4 and TP (see Table 67 below). This last site, which is in the river approximately 860 meters downstream (south) of the dam shows increased concentrations over other sites in Darbandikhan Lake itself and alkaline minerals (Ca and Mg), Cl, Na and K are dominant and exceed the standard value. The water was somewhat turbid compared to natural surface water standards (see the table below).

During the summer survey, high nutrient levels were found at the site for NO3, SO4 and TP, and alkaline minerals (Ca and Mg), HCO3, Cl, Na and K are dominant and exceed the river and surface water standards (see Table 67 below).

Table 67: Physical & Chemical Water Quality Parameters at Diyala (Sirwan) River/After Darbandikhan Dam (S1F)

Parameters	Winter	Summer	River Standards[1 & 2]	Surface Water Standards[2,3&4]
Field Analysis				
Water Temperature °C	13.1	17.5	N/A	N/A
Conductivity µS/cm	455	583	N/A	<1275
pH	8.21	7.4	N/A	6-8.5
Turbidity NTU	**11.7**	5.29	N/A	10
TDS mg/L	275	ND	N/A	500
Salinity ppt	ND	ND	N/A	N/A
DO mg/L	11.59	9.7	N/A	>5
DO%	111.7	103.2	N/A	N/A
Secchi disc m	0.6	0.53	N/A	N/A
Lab Analysis				
TSS mg/L	0.005	5	N/A	N/A
TDS mg/L	307.5	259	N/A	500
BOD mg/L	0.31	2.45	N/A	N/A
Orthophosphate (PO4) mg/L	0.01	ND	10	N/A
Nitrite-Nitrogen (NO2) mg/L	**0.08**	**0.18**	0.001	N/A
Nitrate-Nitrogen (NO3) mg/L	2.88	5.64	1	10
Total Alkalinity as CaCO3 mg/L	72	102	N/A	>20
Bicarbonate (HCO3) mg/L	48.8	**117.1**	58.4	58
Total Hardness (TH) mg/L	225.25	270.67	N/A	N/A
Calcium (Ca) mg/L	**66.2**	**86.07**	15	15
Magnesium (Mg) mg/L	**13.52**	**9.3**	4.1	4.1
Chloride (Cl) mg/L	**8.87**	**13.89**	7.8	7.8
Total Nitrogen (TN) mg/L	ND	ND	N/A	N/A
Sulfate (SO4) mg/L	**70.28**	**80.68**	11.2	3.7
Total Phosphorous (TP) mg/L	**1.4**	**0.122**	0.025	N/A
Potassium (K) mg/L	**2.66**	**2.49**	2.3	2.3
Sodium (Na) mg/L	**15.95**	**15.91**	6.3	6.3
1= Allan and Castillo, 2007; 2=Kabata-Pendias and Mukherjee, 2007; 3=Agardy and Sullivan, 2005; 4=STF, 2000; ND=not detected; N/A=not available				

<u>*Bacteria & Coliform at Diyala (Sirwan) River/After Darbandikhan Dam (S1F):*</u> In the winter the water at this site contains *E. coli* and a high fecal coliform colony count of ≥ 2400 colonies/100 ml, which is an indicator of sewage contamination. During the summer sampling the water in this area was found to be contaminated with fecal coliform bacteria, though the number decreased at the summer survey (see table below). This finding is supported by the water quality data.

Table 68: Fecal Coliform bacteria count and E. coli at site Diyala (Sirwan) River – After Dam (S1F)

	Winter	Summer	Drinking Standards 1 & 2	Surface Water Standards [2]		
Fecal Coli form Bacteria Colony/100 ml	≥ 2400	1600	0 in 100ml	Body-contact	Fishing and boating	Domestic water supply
				100 Colonies/100 mL	> 1000 Colonies/100 mL	> 2000 Colonies/100 mL
Escherichia coli	+	+				
1= WHO, 2006; 2= CDWQ, 2006						

<u>*Phytoplankton at Diyala (Sirwan) River / After Darbandikhan Dam (S1F):*</u> The total phytoplankton count during the winter survey was 1991.9 x 10^3 cell/L and a total of 35 species were recorded. The dominant species in this site were centric diatoms (90.03%) (see Table 69). This group was represented by three species: *Aulacoseira granulate, Cyclotella ocellata* and *Stephanodiscus astrea* (1496.6 x 10^3 cell/L, 322.8 x 10^3 cell/L and 1 x 10^3 cell/L respectively). This site is considered to have low diversity, very good richness and low evenness values (See Annex 2: Table 175, Table 177 & Table 179).

The total phytoplankton count during the summer survey at S1F was 340.3 x 10^3 cell/L and a total of 34 species were recorded. The dominant species in this site were pennate diatoms (79.87%) (see Table 69). The pennate diatoms were primarily represented by 26 individual species; among these were *Nitzschia dissipata, Fragilaria fasciculate, Diatoma vulgare, Cymbella affinis, Achnanthes minutissima, Gomphonema angustatum, Navicula gracilis, Navicula parva* and *Nitzschia palea*. The blue-green algae were represented by both *Oscillatoria limnetica* and *Lyngbya limnetica* (45.3 x 10^3 cell/L and 1 x 10^3 cell/L). This site is considered to have relatively good diversity, very good richness and evenness values. (See Annex 2: Table 176, Table 178 & Table 180)

Table 69: Number of species, total count and percentage for phytoplankton groups in Diyala (Sirwan) River - After Dam (S1F)

Phytoplankton Group (S1F)	Sp. #-WS	Sp. #-SS	Total Count (cell x 103/L)-WS	Total Count (cell x 103/L)-SS	%-WS	%-SS
Cyanophyta	2	2	54.3	46.3	2.73	13.61
Euglenophyta	0	0	0	0	0.00	0
Pyrrhophyta	1	1	18.1	9.1	0.91	2.67
Cryptophyta	0	0	0	0	0.00	0
Chlorophyta	9	2	9	10.1	0.45	2.97
Bacillariophyceae/Centrales	3	3	1793.4	3	90.03	0.88
Bacillariophyceae/Pennales	20	26	117.1	271.8	5.88	79.87
Total	35	34	1991.9	340.3	100	100

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Benthic Macroinvertebrates at Diyala (Sirwan) River/After Darbandikhan Dam (S1F): This was the only site in which benthic macroinvertebrates were sampled in winter 2009. Total density found in winter was 485 indv. /m² and comparing with the other studied sites, this density was relatively good (Annex 4: Table 165). No EPT species were found in this site (Annex 4: **Error! Reference source not found.**) and the dominant species was the lunged snail *Physella* sp., which are known as tolerant organisms (pollution tolerance number ≈ 8). Although the relative evenness was very good (See Annex 4: **Error! Reference source not found.**), the relative diversity and richness was good and moderate respectively (See Annex 4: **Error! Reference source not found.** & **Error! Reference source not found.**). Based on the modified pollution tolerance and pollution indices, water quality was fair (See Annex 1) and this could be confirmed by the presence of the tolerant aquatic organisms such as the lunged snails *Gyraulus* spp. and *Lymnaea* spp.

Total density found in summer was 705 indv. /m² and comparing with the other studied sites, this density was good (Annex 4: Table 166). Although, the site has relatively an excellent evenness and good diversity and richness (

Table 172: Table 168 & Table 170, respectively), EPT% was zero (Table 174) and the dominant species was the midge larva *Paratrichocladius* sp. which is known as tolerant organism (pollution tolerance number ≈ 6). Water quality depending on the modified pollution tolerance and pollution indices was poor (See Annex 1, Table 173 & Table 174) and this could be confirmed by the presence of the tolerant and very tolerant bio-indicators such as the leeches *Nephelopsis* sp.1 and *Mooreobdella* sp.2, and the gastropods *Bithynia* sp. and *Gyraulus* sp.

Briefly, we suggested considering the habitat here as moderately to somewhat severely impaired and the water quality as fair in winter but poor in summer (See Methods & Procedures).

Heavy Metals in Waters: Generally, sample sites throughout Darbandikhan Lake were contaminated by heavy metals (in both winter and summer samples, with some exceptions). The two inputs to the lake were compared to river water quality standards. The Tanjero River input (S1A) site was found to be the most contaminated and the source is likely municipal and industrial sewage disposal into the river from the city of Sulaimani city (Mustafa, 2006) and towns along the river, as well as waste disposal (landfill) from the city of Sulaimani and from agricultural practices. For the Sirwan input (S1B), contamination came from fertilizer and agricultural practices from the surrounding farms. For the deeper lake sample sites contamination was restricted to Ni and in some samples Zn also exceeds the levels for surface water quality standards (see Table 70). Below the same, the water shows elevated levels for Ni, Pb, Mn, Cd and Zn.

Table 70: Heavy Metals in water of Darbandikhan Lake Watershed

	Heavy Metals	Ni mg/L	Pb mg/L	Fe mg/L	Cu mg/L	Mn mg/L	Cd mg/L	Zn mg/L
S1A-S	Winter	**0.10**	0.07	0.02	0.05	ND	**0.02**	**0.10**
	Summer	**0.014**	0.012	0.0002	0.02	ND	**0.002**	ND
S1A-B	Summer	**0.016**	0.01	0.0002	0.02	ND	**0.002**	**0.016**
S1B-S	Winter	**0.09**	0.07	ND	0.05	0.02	ND	**0.10**
	Summer	**0.018**	0.0096	0.0002	0.02	ND	**0.002**	**0.015**
S1B-B	Summer	**0.018**	0.01	0.0002	0.02	0.009	**0.002**	**0.017**
S1C-S	Winter	**0.09**	0.06	ND	ND	0.02	ND	**0.03**
	Summer	**0.013**	0.01	0.0001	0.02	ND	**0.002**	**0.017**
S1C-B	Winter	**0.02**	ND	ND	0.05	ND	ND	**0.05**
	Summer	**0.017**	0.01	0.0001	0.02	ND	**0.002**	**0.008**
S1D-S	Winter	**0.06**	ND	ND	0.12	ND	ND	**0.06**
	Summer	**0.013**	0.012	0.0003	0.02	ND	**0.002**	ND

	Heavy Metals	Ni mg/L	Pb mg/L	Fe mg/L	Cu mg/L	Mn mg/L	Cd mg/L	Zn mg/L
S1D-B	Winter	**0.05**	0.03	0.01	0.06	0.01	ND	**0.10**
	Summer	**0.014**	0.01	0.0003	0.02	ND	**0.002**	**0.007**
S1E-S	Winter	**0.09**	0.06	0.01	ND	0.02	ND	**0.06**
	Summer	**0.016**	0.01	0.0001	0.02	ND	**0.0019**	**0.01**
S1E-B	Winter	**0.08**	0.04	0.02	0.01	0.01	ND	**0.13**
	Summer	**0.017**	0.0097	0.0001	0.02	ND	**0.0022**	ND
S1F	Winter	**0.07**	0.03	0.02	ND	0.01	ND	**0.06**
	Summer	**0.012**	0.0097	0.0002	0.02	0.018	**0.00193**	**0.025**
River [1&2]		0.0008	0.0015	0.67	0.002	0.00002	0.00008	0.0006
Surface Water[2,3&4]		0.0005-0.006	0.09	0.22-0.35	0.27	0.05-0.7	0.000005	N/A
1= Allan and Castillo, 2007; 2=Kabata-Pendias and Mukherjee, 2007; 3=Agardy and Sullivan, 2005; 4=STF, 2000; S=Surface;B=Bottom; ND=not detected; N/A=not available								

Heavy Metals in Soil: Generally, heavy metals in soil samples of Darbandikhan Lake show high concentration and exceed the world soil background (see Table 71 below) with exceptions for S1E sample (Zn and Mn does not exceed the background).

Table 71: Heavy Metals in soils of Darbandikhan Lake Watershed

Heavy Metals	Cd mg/kg	Cu mg/kg	Zn mg/kg	Pb mg/kg	Mn mg/kg	Fe mg/kg	Ni mg/kg
S1A	N/A	55.6	90.5	35.25	**782.25**	**37172.5**	**127.6**
S1B	N/A	54.5	114	32.4	**820.7**	**37867.5**	**112.1**
S1C	N/A	51.07	85.9	38.5	**1325**	**36090**	71.8
S1D	0.87	42.15	78.3	39.7	**605.2**	**28825**	**94.1**
S1E	1.3	39.4	59.6	33.02	265.5	**22245**	**218.8**
S1F	N/A	**75.9**	99.95	36.1	**789**	**33825**	48.4
Soil Background [1 & 2]	0.5	20	64	25	437	2000	19-22
*Agricultural Soils [3]	10	30-70	100-300	70-150	N/A	N/A	30-75
1=Kabata-Pendias and Mukherjee, 2007; 2=Essington; 3=Kabata-Pendias, 2001; *=Maximum Allowable Concentration in Agricultural soils of Poland.; ND=not detected; N/A=not available							

Heavy Metals in Sediments: Sediments of the Darbandikhan Lake watershed show contaminated sediments with Pb, Cd, Cu and Zn with exceptions for Cd, Zn and Pb in some samples (see Table 72 and the figures below). Variation in heavy metal concentration was obvious between two seasons (winter and summer). The source of this contamination is likely coming from municipal and industrial sewage disposal, as well as waste disposal (landfill) and agricultural practices.

Table 72: Heavy Metals in sediments of Darbandikhan Lake Watershed

	Heavy Metals	Cd mg/kg	Cu mg/kg	Zn mg/kg	Pb mg/kg	Mn mg/kg	Fe mg/kg	Ni mg/kg
S1A	Winter	**4.4**	**96.1**	**310.4**	33.6	**1600.8**	31154	**503.4**
	Summer	N/A	**48.4**	82.3	**39.6**	**465**	28847.5	**108.2**
S1B	Winter	**5.3**	**77.3**	**259.6**	33.85	**1282.2**	35526	**565.7**
	Summer	N/A	**54.1**	94.0	**40.7**	**524.5**	34430	**140.5**
S1C	Winter	**5.3**	**89.45**	**348.5**	34.5	**1378.8**	36048.5	**622**
	Summer	**0.6**	**49.35**	90.6	**41.3**	**567.3**	34920	**157.7**
S1D	Winter	**4.6**	**102**	**330.7**	**36.85**	**1497.65**	35443.5	**592.4**
	Summer	**1.15**	**55.2**	102.8	**40.6**	**663.8**	34625	**158.6**

	Heavy Metals	Cd mg/kg	Cu mg/kg	Zn mg/kg	Pb mg/kg	Mn mg/kg	Fe mg/kg	Ni mg/kg
S1E	Winter	**4.4**	**88.15**	**270.75**	**36.95**	**1379.4**	31379	**469.8**
	Summer	**1.4**	**42.9**	79.9	**39.1**	**549.5**	22705	**112.3**
S1F	Winter	**9.8**	**119.35**	**417.95**	**52.05**	**1454.25**	32073	**262.2**
	Summer	N/A	**51.6**	**149.4**	**49.7**	**640.5**	27957.5	**56.6**
Background[1]		N/A	25	65	23	400	N/A	31
CSQG[2]		0.6	35.7	123	35	N/A	N/A	N/A
1= ASQ, 1993; 2= CSQG, 2002; N/A=not available								

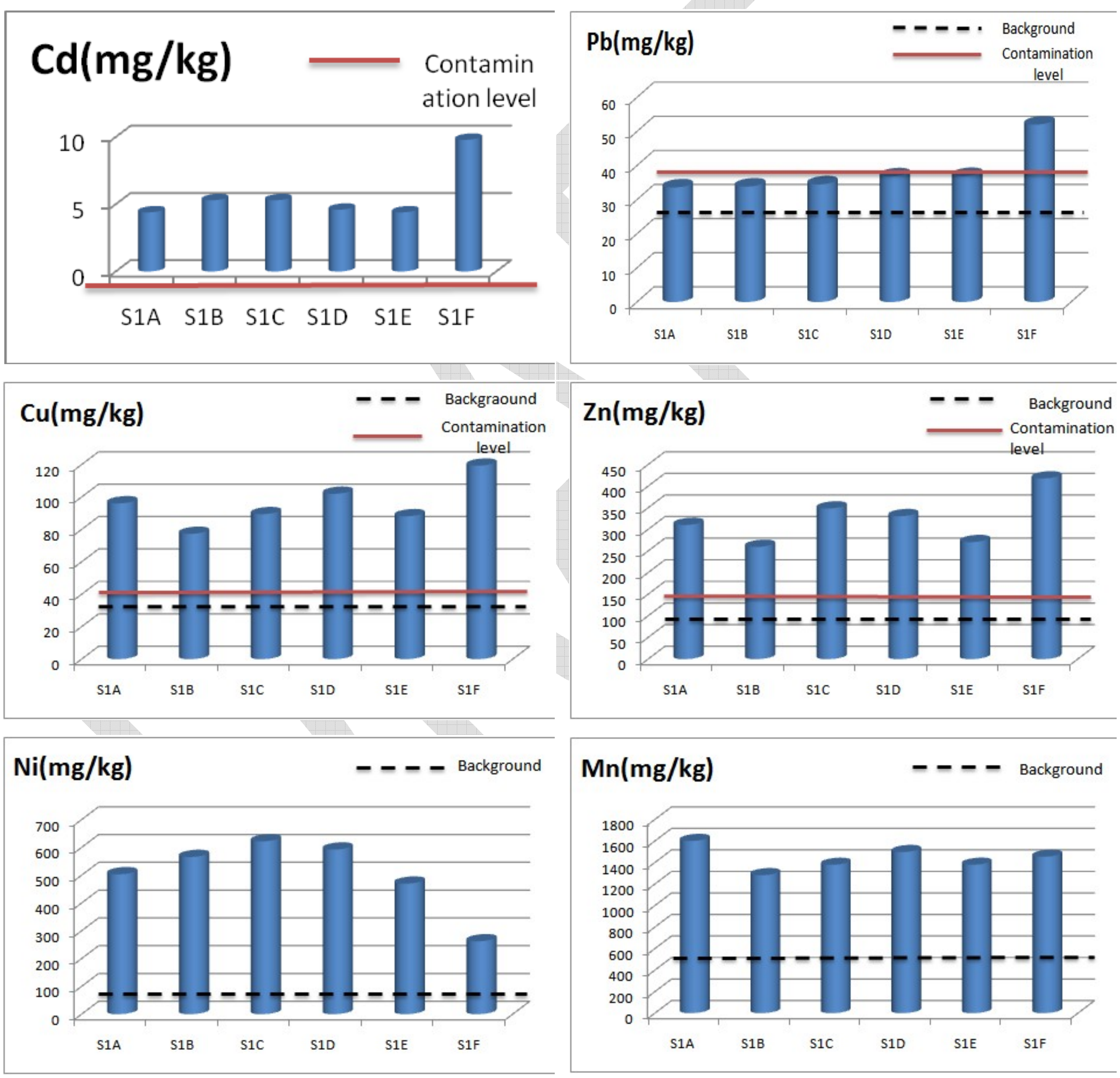

Figure 2: Heavy metal contamination in sediment samples of Darbandikhan Lake (winter survey)

Conservation Issues & Recommendations: The water and sediment quality within Darbandikhan Lake sites shows contamination resulting from the lake's two main sources: the Tanjero and Sirwan rivers, as demonstrated by the vector maps (see the following figures for Zn and Cu). The arrows point towards areas of higher concentrations and away from the areas of lower concentrations. The Zn and Cu found in the lake sediment may come from the northwest and northeast part of the lake near the Tanjero and Sirwan inputs, concentrated near the lake's output on the southwest side. Nutrient contamination was observed during both the winter and summer surveys at the surface and bottom of the lake, which may make eutrophication and the formation of algal blooms more likely at these sites (fish kills have occurred at the lake in these areas in 2004 and 2008 and this is one possible cause of these problems). Investigating and mitigating the contaminant sources to the Tanjero and Sirwan rivers is necessary to restore lake water quality.

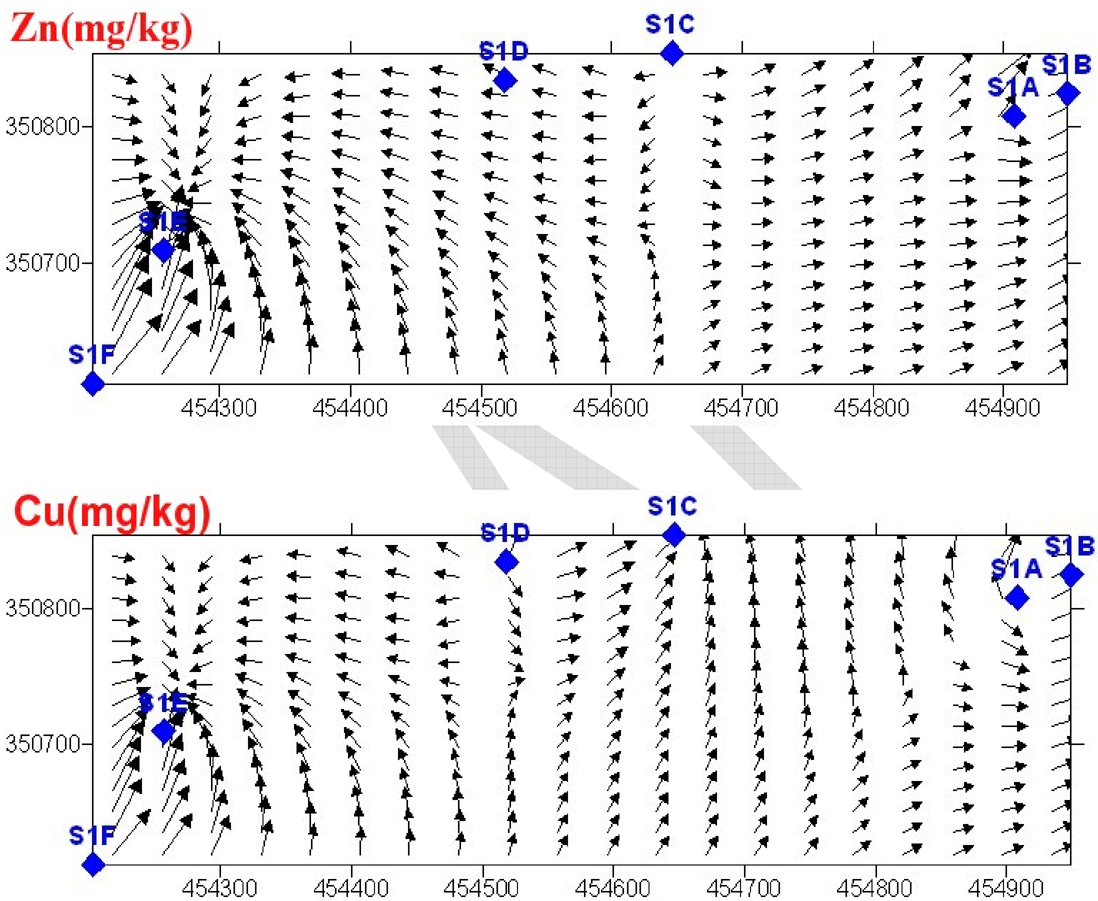

Figure 3: Vector maps of Zn & Cu in sediments of Darbandikhan Lake showing input (winter survey)

Fecal coliform bacteria and *E. coli* results for Darbandikhan Lake/ at Tanjero Input (S1A) and after the dam for winter sampling indicate a high level of contamination this contamination remains during the summer survey but was slightly lower. While the results from Sirwan Input (S1B) and Lake Center (S1D) during winter and summer show these sites as not contaminated with fecal coliform bacteria, they appear to become moderately contaminated in summer.

Generally, phytoplankton results for Darbandikhan Lake during both winter and summer 2009 indicated a range from oligo-mesotrophic water conditions in the surveyed sites. Specifically, during winter 2009 diatoms and especially the centric diatoms were the dominant group, whereas, during summer 2009 the Chlorophyta was the main dominant group.

Benthic Macroinvertebrates results for Darbandikhan Lake/ at both the Tanjero Input (S1A) and the Sirwan Input during summer 2009 indicated severely impaired habitat and poor water quality at both sites. However, sampling was not sufficient and these results will considered as preliminary results and more sampling will be required to determine the habitat and water quality conditions.

Benthic macroinvertebrates results for Darbandikhan Lake/After the Dam (S1F) in the Diyala River during summer 2009 indicated moderately to somewhat severely impaired habitat and poor water quality. In the previous winter, water quality was somewhat better.

More monitoring in different seasons is necessary to fully characterize the situation in the lake.

11. Qara Dagh Area (S11) - Elev 1048

Site Description: The site is located southwest of Sulaimani City. This location is near a high mountain ridge with the water quality sample point in the valley below. The water comes from Kani Bajga, which is fed by spring water. Past samplings at the site have shown the water flow to be very slow or stagnant, but the site was found to be dry in winter during the sole visit to this site. The stream is surrounded by plants but the area is rocky. Plant decomposition and trash were observed and the area attracts many picnickers, particularly in spring.

Plate

Observations (Winter: 28 Jan 2009):

Water Quality: This site was dry during the winter survey, so no field or lab parameters were available.

Bacteria & Coliform, Phytoplankton, Zooplankton, Benthic Invertebrates: Dry site, samples not taken.

Heavy Metals in Water: This site was dry during winter survey, so no heavy metals were measured during that time.

Heavy Metals in Sediments: The sediments at the Qara Dagh site are highly contaminated with Ni, Cd, Cu and Zn (see Table 73 below). This contamination may arise from tourist activity, trash and possible agricultural practices upstream from the site.

Table 73: Heavy metals in sediment of Qara Dagh Area (S11)

Heavy Metal	Winter	Background[1]	CSQG[2]
Nickel (Ni) mg/kg	**918.2**	31	N/A
Lead (Pb) mg/kg	18.95	23	35
Iron (Fe) mg/kg	34169	N/A	N/A
Copper (Cu) mg/kg	**63**	25	35.7
Manganese (Mn) mg/kg	**1631.3**	400	N/A
Cadmium (Cd) mg/kg	**9.9**	1.1	0.6
Zinc (Zn) mg/kg	**200.6**	65	123
1= ASQ, 1993; 2= CSQG, 2002; N/A=not available			

Conservation Issues & Recommendations: Intense tourist activity (includeing car washing in local streams) may be the source of heavy metal contamination, particularly during the spring season. Pollution from nearby villages upstream should also be examined.

12. Bani Khelan (Garmk) (Diyala River) - (S3A)

Site Description: The site is located approximately 7.8 km southwest of the town of Darbandikhan along the Dilaya River. Sampling was conducted on the western bank of the river and accessed from Route 4 in Sulaimani Governorate. The water runs very quickly and is approximately 70-100 meters in width, while mountains and high hills surround the area. The main access road runs along the river on the west side There is extensive gravel mining in many areas along the river and one is located below the sampling point. In addition, the Bani Khelan bottled water factory is upstream of the site.

Plate

Observations (Winter – 13 Jan 2009, Summer-15 Jul 2009):

Water Quality: Bani Khelan (Diyala River): (S3A) Sample Site. For winter: Sampling Time 08:00 AM, Water Depth 0.5m, Air temperature 5°C, Water temperature 12.5°C.

For summer: Sampling Time 08:39 AM, Date 15/6/2009, Water Depth 0.36m, Air temperature 30°C, Water temperature 13.9°C.

For winter sampling, in this site turbidity, DO, NO2, NO3, Ca, Mg, Cl, K, Na and SO4 exceed the river and surface water quality standards (see Table 74 below). For summer sampling, NO2, NO3, HCO3, Ca, Mg, Cl, Na and SO4 exceed the river and surface water quality standards (see Table 74 below).

Table 74: Physical & Chemical Water quality parameters at site Bani Khelan (Diyala River) - (S3A)

Parameters	Winter	Summer	River Standards[1 & 2]	Surface Water Standards[2,3&4]
Field Analysis				
Water Temperature °C	12.5	13.9	N/A	N/A
Conductivity µS/cm	446	423	N/A	<1275
pH	8.05	7.4	N/A	6-8.5
Turbidity NTU	6.27	7.47	N/A	10
TDS mg/L	269	ND	N/A	500
Salinity ppt	ND	ND	N/A	N/A
DO mg/L	12.1	10.3	N/A	>5
DO%	113.8	103.4	N/A	N/A
Secchi disc m	0.5	0.36	N/A	N/A
Lab Analysis				
TSS mg/L	0.004	12	N/A	N/A
TDS mg/L	329	293	N/A	500
BOD mg/L	ND	3.4	N/A	N/A
Orthophosphate (PO4) mg/L	ND	ND	10	N/A
Nitrite-Nitrogen (NO2) mg/L	**0.07**	**0.056**	0.001	N/A
Nitrate-Nitrogen (NO3) mg/L	9	4.27	1	10
Total Alkalinity as CaCO3 mg/L	71	103.5	N/A	>20
Bicarbonate (HCO3) mg/L	**37.82**	**119**	58.4	58
Total Hardness (TH) mg/L	227.19	255.33	N/A	N/A
Calcium (Ca) mg/L	**65.92**	**46.67**	15	15
Magnesium (Mg) mg/L	**13.07**	**9.28**	4.1	4.1
Chloride (Cl) mg/L	**11.9**	**11.28**	7.8	7.8

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Parameters	Winter	Summer	River Standards[1 & 2]	Surface Water Standards[2,3&4]
Total Nitrogen (TN) mg/L	33.63	ND	N/A	N/A
Sulfate (SO4) mg/L	**68.67**	**69.93**	11.2	3.7
Total Phosphorous (TP) mg/L	ND	0.0072	0.025	N/A
Potassium (K) mg/L	**2.49**	2.15	2.3	2.3
Sodium (Na) mg/L	**15.16**	**12.25**	6.3	6.3
1= Allan and Castillo, 2007; 2=Kabata-Pendias and Mukherjee, 2007; 3=Agardy and Sullivan, 2005; 4=STF, 2000; ND=not detected; N/A=not available				

<u>*Bacteria & Coliform*</u>: At the winter sampling the water in this site was contaminated with fecal coliform bacteria and *E. coli*, and during the summer survey, even with the decrease of the fecal coliform bacteria number from 1600 to 540 Colony/100ml, according to the reference standards the water was still considered contaminated with fecal coliform bacteria (see Table 75).

Table 75: Fecal Coliform bacteria count and E. coli at site Bani Khelan (S3A)

	Winter	Summer	Drinking Standards 1 & 2	Surface Water Standards [2]		
Fecal Coli form Bacteria Colony/100 ml	**1600**	**540**	0 in 100ml	Body-contact	Fishing and boating	Domestic water supply
				100 Colonies/100 mL	> 1000 Colonies/100 mL	> 2000 Colonies/100 mL
Escherichia coli	+	+				
1= WHO, 2006; 2= CDWQ, 2006						

<u>*Phytoplankton*</u>: The total phytoplankton count: during the winter survey was 2022.8 x 10^3 cell/L and a total of 36 species were recorded. The dominant species in this site were centric diatoms (90.86%) (see Table 76) which were represented by four species: *Aulacoseira granulate, Cyclotella ocellata, Stephanodiscus astrea* and *Cyclotella meneghiniana* (1592.1 x 10^3 cell/L, 233.8 x 10^3 cell/L, 11.1 x 10^3 cell/L and 1 x 10^3 cell/L respectively). Although found in small densities, the pennate diatoms in this site were represented by twenty five genera. Each genus was represented by several species such as *Nitzschia* (4 sp.), *Navicula* (3 sp.), *Gomphonema* (3 sp.), *Cymbella* (5 sp.) and *Cocconeis* (4 sp.). In addition the presence of the pennate diatoms *Achnanthes minutissima, Diatoma vulgare* and others indicate relatively deep waters; generally, the pennate diatoms are common across the full spectrum of lake tropic status, from oligotrophic to eutrophic conditions (Stoermer and Smol, 2004). This is supported by the presence of *Euglena* sp. and the blue-green algae *Anabaena* sp., *Leptolyngbya perelegans* and *Oscillatoria limnetica*. Euglenoids are particularly abundant in lakes and reservoirs surrounded by agricultural land having high levels of organic matter, although species diversity may be low in some nutrient-enriched situations (Lackey, 1968; Palmer, 1980 as cited in Wehr and Sheath, 2003). The blue-green algae *Anabaena* and *Oscillatoria* are common in freshwater ecosystems and can produce blooms that form pond scum, produce toxins that can spoil the water's taste, and can be lethal to fish, cattle and birds that drink the water if found in higher quantities (Kolbe and Luedke, 2005). This site is considered to have low diversity, very good richness and low evenness values (See Annex 2: Table 175, Table 177 & Table 179).

The total phytoplankton count during the summer survey at S3A was 232.4 x 10^3 cell/L and a total of 29 species were recorded. The dominant species in this site were pennate diatoms (81.80%) (see Table 76 below). The pennate diatoms were mainly represented by *Cocconeis placentula, Achnanthes minutissima, Cymbella turgida*, and *Rhoicosphenia curvata. Oscillatoria limnetica* and *Lyngbya aestuarii* were the two blue-green algae recorded, while the green algae by *Chlorella vulgaris*, *Closterium* sp., *Coelastrum astroideum* and *Scenedesmus quadricauda* were also present. This site is considered to have relatively good diversity, very good richness and evenness values. (See Annex 2: Table 176, Table 178 & Table 180)

Table 76: Number of species, total count and percentage for phytoplankton groups in Bani Khelan (S3A)

Phytoplankton Groups (S3A)	Sp. #-WS	Sp. #-SS	Total Count (cell x 103/L)-WS	Total Count (cell x 103/L)-SS	%-WS	%-SS
Cyanophyta	3	2	3	19.1	0.15	8.22
Euglenophyta	1	0	9.1	0	0.45	0
Pyrrhophyta	1	1	1	9.1	0.05	3.92
Cryptophyta	0	0	0	0	0.00	0
Chlorophyta	2	4	10.1	12.1	0.50	5.21
Bacillariophyceae/Centrales	4	2	1838	2	90.86	0.86
Bacillariophyceae/Pennales	25	20	161.6	190.1	7.99	81.80
Total	36	29	2022.8	232.4	100	100

Benthic Macroinvertebrates: Total density found was 314 indv. /m² and comparing with the other studied sites, this density was relatively moderate (Annex 4: Table 165). EPT % was very low (Annex 4: **Error! Reference source not found.**) and the dominant species was the lunged snail *Physella* sp., which are known as tolerant organisms (pollution tolerance number ≈ 8). Although the relative evenness was very good (Annex 4: **Error! Reference source not found.**), the relative richness and diversity were moderate and low respectively (Annex 4: **Error! Reference source not found.** & **Error! Reference source not found.** respectively). Based on the modified pollution tolerance and pollution indices, water quality was poor to fair (see Annex 1, Table 173 & Table 174) and this is indicated by the presence of the tolerant and very tolerant aquatic organisms such as the white midge *Orthocladius clarkei* and the aquatic worm *Limnodrilus hoffmeisteri*.

In summer, the total density found was 905 indv. /m² and comparing with the other studied sites, this density this density was very good (Annex 4: Table 166). The site also has relatively a good diversity and very good richness and evenness (Annex 4: Table 168, Table 170 &

Table 172, respectively). However, EPT% was very low (Table 174), and the dominant species was the lunged snail *Physella* sp.1 which is known as tolerant organism (pollution tolerance number ≈ 8). Water quality depending on the modified pollution tolerance and pollution indices was fair (See Annex 1, Table 173) and this could be confirmed by the presence of a wide array of bio-indicators from the sensitive beetle *Dryops* sp. to the tolerant leeches *Dina* sp. and *Helobdella* sp.

Briefly, we suggested considering the habitat here as moderately to somewhat severely impaired and the water quality as poor to fair (See Methods & Procedures).

Heavy Metals in Water: This site was contaminated with Ni, Pb, Cu, Mn and Zn in the winter sample and with Ni, Pb, Cu, Mn and Cd in the summer sample (see Table 77). Anthropogenic activities (mining and agricultural practices) are the main sources of heavy metal contamination in addition to the effect of the Banikhelan Bottled Water Foundation.

Table 77: Heavy metals in water of Bani Khelan - (S3A)

Heavy Metal	Winter	Summer	River Standards [1 & 2]	Surface Water Standards [2,3&4]

Heavy Metal	Winter	Summer	River Standards [1 & 2]	Surface Water Standards [2,3&4]
Nickel (Ni) mg/L	**0.07**	**0.016**	0.0008	0.0005-0.006
Lead (Pb) mg/L	0.04	0.0097	0.0015	0.09
Iron (Fe) mg/L	ND	0.0001	0.67	0.22-0.35
Copper (Cu) mg/L	0.14	0.0224	0.002	0.27
Manganese (Mn)mg/L	0.01	0.0083	0.00002	0.07-0.5
Cadmium (Cd) mg/L	ND	**0.0024**	0.00008	0.000005
Zinc (Zn) mg/L	**0.02**	ND	0.0006	N/A
1= Allan and Castillo, 2007; 2=Kabata-Pendias and Mukherjee, 2007; 3=Agardy and Sullivan, 2005; 4=STF, 2000; ND=not detected; N/A=not available				

Heavy Metals in Soil: Heavy metals Ni, Pb, Fe, Cu and Mn in the soil of this site show higher concentrations than the world soil background, but not exceeding the maximum allowable concentration in agricultural soils of Poland (see Table 78).

Table 78: Heavy Metals in Soil of Bani Khelan - (S3A)

Heavy Metal	Summer	Soil Background [1 & 2]	*Agricultural Soils [3]
Nickel (Ni) mg/kg	63.4	19-22	30-75
Lead (Pb) mg/kg	31.4	25	70-150
Iron (Fe) mg/kg	31182.5	2000	N/A
Copper (Cu) mg/kg	38.8	20	30-70
Manganese (Mn)mg/kg	711	437	N/A
Cadmium (Cd) mg/kg	ND	0.5	10
Zinc (Zn) mg/kg	45.4	64	100-300
1=Kabata-Pendias and Mukherjee, 2007; 2=Essington; 3=Kabata-Pendias, 2001; *=Maximum Allowable Concentration in Agricultural soils of Poland.; ND=not detected; N/A=not available			

Heavy Metals in Sediments: Sediments of the Bani Khelan (Diyala River) site show contaminated sediments with Ni, Pb, Cd, Cu and Zn in winter and with Pb and Cu in summer (see Table 79). Probable source of sediment contamination with heavy metals may be from the Bani Khelan bottled water industrial foundation.

Table 79: Heavy metals in sediment of Bani Khelan (S3A)

Heavy Metal	Winter	Summer	Background[1]	CSQG[2]
Nickel (Ni) mg/kg	**279.3**	**64.8**	31	N/A
Lead (Pb) mg/kg	**48.5**	**36.9**	23	35
Iron (Fe) mg/kg	31919	34137.5	N/A	N/A
Copper (Cu) mg/kg	**55.3**	**41.3**	25	35.7
Manganese (Mn) mg/kg	**1765.3**	**766.3**	400	N/A
Cadmium (Cd) mg/kg	**3.4**	ND	1.1	0.6
Zinc (Zn) mg/kg	**312.55**	43.3	65	123
1= ASQ, 1993; 2= CSQG, 2002; N/A=not available				

Conservation Issues & Recommendations: The sampling site is located downstream from the Bani Khelan bottled water factory; it is possible that contamination of the site may be coming from this plant. It is also very likely that untreated sewage is entering the water from the towns and villages upstream. Fecal coliform bacteria results indicate from Bani Khelan (S3A) should be considered as contaminated water with higher contamination in winter than in summer.

Phytoplankton results during both winter and summer 2009 indicate mesotrophic to oligotrophic water conditions in site Bani Khelan.

The benthic macroinvertebrate results for Bani Khelan during the winter 2009 indicated moderately to somewhat severely impaired habitat and poor to fair water quality. In summer, conditions improved slighly for results indicted moderately impared habitat and fair water quality.

Further investigation regarding the source of the contamination is recommended. Monitoring of water resources in this area is also required because of their importance and effects on other downstream ecosystems such as Diyala River.

13. Bani Khan (Diyala River) - (S3B)

Site Description: The site is located approximately 46 km southwest of the town of Darbandikhan along the Diyala River. The sampling point was along the western bank of the river. The water runs with a high speed. The bed stream consists of cobblestones and gravel. There were green algae on the rocks. To the northwest there are many abandoned gravel mines and a small village is located to the south.

Plate

Observations (Winter: 11 Jan 2009):

Water Quality: Bani Khan (Diyala River) (S3B) Sample Site. For winter: Sampling Time 12:52 AM, Water Depth 0.3m, Air temperature 9°C, Water temperature 12.7°C.

Contamination of this site with total phosphorous and total nitrogen, along with elevated levels of SO_4, NO_2, NO_3, HCO_3, Ca and Na compared to river water quality standards (see Table 80) were detected. Excess of some parameters (HCO_3) may be caused by gravel and sand quarries upstream of the site, others by contaminants from Darbandikhan Lake, Darbandikhan town, upstream villages and surrounding farmland through the use of agrochemicals.

Table 80: Physical & Chemical Water quality parameters at site Bani Khan (Diyala River) - (S3B)

Parameters	Winter	River Standards [1 & 2]	Surface Water Standards [2,3&4]
Field Analysis			
Water Temperature °C	12.7	N/A	N/A
Conductivity µS/cm	717	N/A	<1275
pH	8.48	N/A	6-8.5
Turbidity NTU	8.8	N/A	10
TDS mg/L	432	N/A	500
Salinity ppt	ND	N/A	N/A
DO mg/L	12.15	N/A	>5
DO%	114.4	N/A	N/A
Secchi disc m	0.3	N/A	N/A
Lab Analysis			
TSS mg/L	0.004	N/A	N/A
TDS mg/L	423	N/A	500
BOD mg/L	ND	N/A	N/A
Orthophosphate (PO_4) mg/L	ND	10	N/A
Nitrite-Nitrogen (NO_2) mg/L	0.08	0.001	N/A
Nitrate-Nitrogen (NO_3)	3.69	1	10

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Parameters	Winter	River Standards [1 & 2]	Surface Water Standards [2,3&4]
mg/L			
Total Alkalinity as CaCO3 mg/L	112	N/A	>20
Bicarbonate (HCO3) mg/L	**136.64**	**58.4**	58
Total Hardness (TH) mg/L	316.51	N/A	N/A
Calcium (Ca) mg/L	**39.12**	**15**	15
Magnesium (Mg) mg/L	**24.87**	4.1	4.1
Chloride (Cl) mg/L	**15.558**	**7.8**	7.8
Total Nitrogen (TN) mg/L	61.7	N/A	N/A
Sulfate (SO4) mg/L	**108.46**	**11.2**	3.7
Total Phosphorous (TP) mg/L	0.04	0.025	N/A
Potassium (K) mg/L	**2.92**	**2.3**	2.3
Sodium (Na) mg/L	**59.68**	**6.3**	6.3
1= Allan and Castillo, 2007; 2=Kabata-Pendias and Mukherjee, 2007; 3=Agardy and Sullivan, 2005; 4=STF, 2000; ND=not detected; N/A=not available			

Bacteria & Coliform: The result obtained from this site during winter indicate contamination by fecal coliform bacteria of 170 Colonies/100 ml. Contaminants may come from Darbandikhan Lake, Darbandikhan town, and the surrounding farmlands through their use of agrochemicals, while during summer this site was dry and thus no samples were collected (see table below).

Table 81: Fecal Coliform bacteria count and E. coli at site Bani Khan (S3B)

	Winter	Summer	Drinking Standards [1 & 2]	Surface Water Standards [2]		
				Body-contact	Fishing and boating	Domestic water supply
Fecal Coli form Bacteria Colony/100 ml	**170**	---	0 in 100ml	100 Colonies/100 ml	> 1000 Colonies/100 ml	> 2000 Colonies/100 ml
Escherichia coli	**+**	---				
1= WHO, 2006; 2= CDWQ, 2006						

Phytoplankton: The total phytoplankton count: during the survey was 514.1 x 10^3 cell/L and a total of 39 species were recorded. The dominant species in this site were pennate diatoms (82.37%) (see Table 82).

Achnanthes minutissima was the most common pennate diatom. Although found in small quantities, other pennate diatoms in this site were also recorded. Each genus was represented by just a few species such as *Cymbella* (9 sp.), *Navicula* (5 sp.), *Gomphonema* (4 sp.), *Cocconeis* (3 sp.) and *Nitzschia* (2 sp.) in addition to the presence of *Rhoicosphenia curvata, Diatoma vulgare* and others. Members of the Cymbellaceae are widely distributed in freshwater ecosystems, including both lakes and rivers. This group is found across a broad temperature spectrum, but some species seem restricted to cool-water environments (Wehr and Sheath, 2003).

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This site is considered to have moderate diversity, very good richness and good evenness values (See Annex 2: Table 175, Table 177 & Table 179).

Table 82: Number of species, total count and percentage for phytoplankton groups in Bani Khan/Diyala River (S3B)

Phytoplankton Groups (S3B)	Sp. #	Total Count (cell x 103/L)	%
Cyanophyta	2	10.1	1.96
Euglenophyta	0	0	0.00
Pyrrhophyta	1	1	0.19
Cryptophyta	0	0	0.00
Chlorophyta	2	55.3	10.75
Bacillariophyceae/Centrales	3	24.3	4.72
Bacillariophyceae/Pennales	31	423.9	82.37
Total	39	514.6	100

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Benthic Macroinvertebrates: Total density found in winter was 366 indv. /m^2 and comparing with the other studied sites, this density was relatively moderate (Annex 4: Table 165). EPT % was very good (See Annex 4: **Error! Reference source not found.**) and the dominant species was the Common net-spinning caddisfly Ceratopsyche sp., which is known as a sensitive organism (pollution tolerance number ≈ 5). Although the relative diversity was low (See Annex 4: Table 167), the relative richness and evenness were good (See Annex 4: **Error! Reference source not found.** & Table 171, respectively). Depending on the modified pollution tolerance and pollution indices, water quality was good (See Annex 1, Table 173) and this could be confirmed by the presence of the sensitive and very sensitive aquatic organisms such as the Humpless-case caddisfly Amiocentrus sp. and the Flat-headed mayfly *Rhithrogena* sp.

Heavy Metals in Water: This site was contaminated with Ni, Pb, Cu, Mn, Cd and Zn (see Table 83 below).

Table 83: Heavy metals in water of site Bani Khan (Diyala River) - (S3B)

Heavy Metal	Winter	River Standards [1 & 2]	Surface Water Standards [2,3&4]
Nickel (Ni) mg/L	**0.03**	0.0008	0.0005-0.006
Lead (Pb) mg/L	0.02	0.0015	0.09
Iron (Fe) mg/L	0.05	0.67	0.22-0.35
Copper (Cu) mg/L	0.03	0.002	0.27
Manganese (Mn)mg/L	0.01	0.00002	0.07-0.5
Cadmium (Cd) mg/L	**0.03**	0.00008	0.000005
Zinc (Zn) mg/L	**0.14**	0.0006	N/A
1= Allan and Castillo, 2007; 2=Kabata-Pendias and Mukherjee, 2007; 3=Agardy and Sullivan, 2005; 4=STF, 2000; ND=not detected; N/A=not available			

Heavy Metals in Sediments: Sediments of the Bani Khan (Diyala River) site represented contaminated sediments with Ni, Pb, Cd, Cu and Zn (see Table 84 below). The source of the heavy metal contamination may come from upstream (Darbandikhan Lake and/or town) and the surrounding farmland (through the use of agrochemicals).

Table 84: Heavy metals in sediment of Bani Khan (Diyala River) - (S3B)

Heavy Metal	Winter	Background [1]	CSQG [2]

Nickel (Ni) mg/kg	**426.4**	31	N/A
Lead (Pb) mg/kg	**39.05**	23	35
Iron (Fe) mg/kg	30018.5	N/A	N/A
Copper (Cu) mg/kg	**65.25**	25	35.7
Manganese (Mn) mg/kg	**1619.95**	400	N/A
Cadmium (Cd) mg/kg	**4.7**	1.1	0.6
Zinc (Zn) mg/kg	**288.1**	65	123
1= ASQ, 1993; 2= CSQG, 2002; N/A=not available			

Conservation Issues & Recommendations: Nutrient and heavy metal contamination in this site may be coming from agrochemical use or possibly from sewage dumping upstream. The area around the site is primarily rural. This confusion surrounding the contamination source affecting this site would be better outlined by more accurate information from the field team about specific threats in the surrounding areas. Also, the upstream habitat surrounding Darbandikhan Lake may also influence this site, because the water that comes from the lake is contaminated by excess nutrients and heavy metals. Mining processes may also have a negative effect on the water quality in this site.

Bacteria results recorded from this site indicate moderate contamination with fecal coliform bacteria and it may come from the villages along the river, more work is needed to determin the sources of such pollution.

Phytoplankton results indicate relatively oligotrophic water conditions in the Bani Khan site.

Benthic macroinvertebrate results for Kani Bani (Diyala River) - (S3B) during winter 2009 indicated non-impaired to moderately impaired habitat and good water quality.

As with other sites showing elevated nutrients, bacteria and heavy metals, more work is needed to identify and mitigate the sources of such pollution.

14. Kalar (Diyala River) - (S3) - Elev. 202

Site Description: This site, like S3A and S3B, is located between two important bird areas: Darbandikhan to the north and Baquba Wetlands to the south. There are surrounding hills, some cultivated areas, and extensive riparian zones along the entire Diyala River. The Diyala River flows south-southwest from the outlet of Darbandikhan Lake and eventually enters the Tigris River south of Baghdad. Kalar (S3) represents the lowest site in the Diyala Watershed where sampling was conducted as part of the winter 2009 survey. In the winter 2008 survey this site (formerly labeled S3A) and a site approximately 24 km upstream (labeled S3B) were sampled; in the summer of 2008, only this site was surveyed. For the winter survey, the site codes were reassigned, with S3A being assigned to Bani Khelan, S3B being assigned to Bani Khan and S3 being assigned to Kalar. The Kalar sample site is just located downstream (south) of a bridge (Grda Gozina) near the town of Kalar on the east bank of the Diyala River. The western bank, also near the bridge is more affected by the sewage from the town of Kalar. The river here is well braided with large sand and gravel bars throughout and the flood plain is roughly 800 to 1000 meters wide.

Plate

Observations (Winter – 11 Jan 2009):

Water Quality: Kalar (Diyala River) (S3) Sample Site. For winter: Sampling Time 09:03 AM, Water Depth 0.7m, Air temperature 5°C, Water temperature 11.1°C.

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The water at this site was characterized by high turbidity, NO2, NO3, TP, SO4, Ca and Mg compared to river water quality standards (see Table 85 below). Agricultural practice in the surrounding farmland, gravel mining operations and sewage-contaminated water coming from upstream (Darbandikhan Lake and/or town and other villages upstream) are likely the source of these contaminants.

Table 85: Physical & Chemical Water quality parameters at site Kalar (Diyala River) (S3)

Parameters	Winter	River Standards[1&2]	Surface Water Standards[2,3&4]
Field Analysis			
Water Temperature °C	11.1	N/A	N/A
Conductivity µS/cm	455	N/A	<1275
pH	8.34	N/A	6-8.5
Turbidity NTU	**50.4**	N/A	10
TDS mg/L	274	N/A	500
Salinity ppt	ND	N/A	N/A
DO mg/L	12.5	N/A	>5
DO%	111.4	N/A	N/A
Secchi disc m	0.5	N/A	N/A
Lab Analysis			
TSS mg/L	0.1	N/A	N/A
TDS mg/L	353.5	N/A	500
BOD mg/L	ND	N/A	N/A
Orthophosphate (PO4) mg/L	0.002	10	N/A
Nitrite-Nitrogen (NO2) mg/L	0.03	0.001	N/A
Nitrate-Nitrogen (NO3) mg/L	2.43	1	10
Total Alkalinity as CaCO3 mg/L	72	N/A	>20
Bicarbonate (HCO3) mg/L	15.62	58.4	58
Total Hardness (TH) mg/L	233.99	N/A	N/A
Calcium (Ca) mg/L	**70.98**	15	15
Magnesium (Mg) mg/L	14.54	4.1	4.1
Chloride (Cl) mg/L	3.763	7.8	7.8
Total Nitrogen (TN) mg/L	55.14	N/A	N/A
Sulfate (SO4) mg/L	**65.8**	11.2	3.7
Total Phosphorous (TP) mg/L	0.16	0.025	N/A
Potassium (K) mg/L	**2.19**	2.3	2.3
Sodium (Na) mg/L	**11.56**	6.3	6.3
1= Allan and Castillo, 2007; 2=Kabata-Pendias and Mukherjee, 2007; 3=Agardy and Sullivan, 2005; 4=STF, 2000; ND=not detected; N/A=not available			

Bacteria & Coliform: The water in this site is considered contaminated by fecal coliform bacteria and *E. coli* according to WHO and CDWQ standards (see Table 86 below). Fecal deposits are capable of providing a long-term source of potential pollution to surface water (Thelin and Gifford, 1983), thus

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even if the town of Kalar and surrounding villages were not affecting this area, the cause may be sewage contamination from even farther upstream.

Table 86: Fecal Coliform bacteria count and E. coli at site (Garmk (S3))

	Winter	Summer	Drinking Standards[1 & 2]	Surface Water Standards[2]		
Fecal Coli form Bacteria Colony/100 ml	350	---	0 in 100ml	Body-contact	Fishing and boating	Domestic water supply
				100 Colonies/100 mL	> 1000 Colonies/100 mL	> 2000 Colonies/100 mL
Escherichia coli	+	---				
1= WHO, 2006; 2= CDWQ, 2006						

<u>*Phytoplankton:*</u> Total phytoplankton count: 2179.6 x 103cell/L. Species number: 41. This site was dominated by the pennate & centric diatoms (52.6% and 45.04%, respectively) (see Table 87 below).

The pennate diatoms were dominated by *Diatoma vulgare, Nitzschia dissipata* and *Rhoicosphenia curvata* (423.1 x 103cell/L, 189.3 x 103cell/L and 167 x 103cell/L), respectively. The centric diatoms were dominated by *Aulacoseira granulate* and *Cyclotella ocellata* (812.7 x 103cell/L and 167 x 103cell/L), respectively. This site had moderate diversity, very good richness and good evenness values (See Annex 2: Table 175, Table 177 & Table 179).

Table 87: Number of species, total count and percentage for phytoplankton groups in Kalar/Diyala River (S3)

Phytoplankton Groups (S3)	Sp. #	Total Count (cell x 103/L)	%
Cyanophyta	2	2	0.09
Euglenophyta	0	0	0.00
Pyrrhophyta	1	1	0.05
Cryptophyta	0	0	0.00
Chlorophyta	6	48.5	2.23
Bacillariophyceae/Centrales	4	981.7	45.04
Bacillariophyceae/Pennales	28	1146.4	52.60
Total	41	2179.6	100

<u>*Benthic Macroinvertebrates*</u>: Total density found was 340 indv. /m² and comparing with the other studied sites, this density was relatively moderate (Annex 4: Table 165). EPT % was moderate (Annex 4: Table 173) and the dominant species was the Flat-headed mayfly *Macdunnoa* sp.1, which is known as a sensitive organism (pollution tolerance number ≈ 4). The relative diversity, richness, and evenness were good, very good, and excellent respectively (See Annex 4: **Error! Reference source not found.**, **Error! Reference source not found.** & **Error! Reference source not found.** respectively). Based on the modified pollution tolerance and pollution indices, water quality was very good (See Annex 1, Table 173) and this could be confirmed by the presence of the sensitive and very sensitive aquatic organisms such as the Saddle-case caddisfly *Anagapetus* sp. and the Flat-headed mayfly *Rhithrogena* sp.

Briefly, we suggested considering the habitat here as non-impaired to moderately impaired and the water quality as very good (See Methods & Procedures).

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Heavy Metals in Water: This site was contaminated with Ni, Pb, Cu, Mn and Zn (see Table 88 below). The source of contamination was discussed previously in the water quality section.

Table 88: Heavy metals in water of site Kalar (Diyala River) - (S3)

Heavy Metal	Winter	River Standards[1 & 2]	Surface Water Standards[2,3&4]
Nickel (Ni) mg/L	**0.05**	0.0008	0.0005-0.006
Lead (Pb) mg/L	0.03	0.0015	0.09
Iron (Fe) mg/L	ND	0.67	0.22-0.35
Copper (Cu) mg/L	0.01	0.002	0.27
Manganese (Mn)mg/L	0.01	0.00002	0.07-0.5
Cadmium (Cd) mg/L	ND	0.00008	0.000005
Zinc (Zn) mg/L	**0.05**	0.0006	N/A
1= Allan and Castillo, 2007; 2=Kabata-Pendias and Mukherjee, 2007; 3=Agardy and Sullivan, 2005; 4=STF, 2000; ND=not detected; N/A=not available			

Heavy Metals in Sediments: Sediments of the Kalar (Diyala River) site represented sediments contaminated with Ni, Pb, Cd, Cu and Zn (see Table 89 below). Agricultural practice in the surrounding farmland, and sewage and other wastewater entering the river upstream are the likely source of these contaminants.

Table 89: Heavy metals in sediment of Kalar (Diyala River) - (S3)

Heavy Metal	Winter	Background[1]	CSQG[2]
Nickel (Ni) mg/kg	**345**	31	N/A
Lead (Pb) mg/kg	**42.2**	23	35
Iron (Fe) mg/kg	30226.5	N/A	N/A
Copper (Cu) mg/kg	**67.5**	25	35.7
Manganese (Mn) mg/kg	**1567.3**	400	N/A
Cadmium (Cd) mg/kg	**4.9**	N/A	0.6
Zinc (Zn) mg/kg	**246.6**	65	123
1= ASQ, 1993; 2= CSQG, 2002; N/A=not available			

Conservation Issues & Recommendations: Heavy metal and nutrient contamination was very obvious in the water at this site. Contaminated water from farther upstream, sewage from Kalar town, agricultural chemicals and mining processes are the possible sources of water contamination in this site. This site's sediments are contaminated with heavy metals, most likely from the same sources that contaminate the water. This site requires remediation and contamination prevention because this river is representative of the Diyala River which later empties into the Tigris River. Along the course of the river there are agricultural areas and urbanized towns that use this water, at which time these contaminants enter the human food chain. Sewage treatment plants for Kalar town, management of agrochemicals used in the surrounding farmlands and better mining procedures are recommended for minimizing and reducing the contamination in the river.

Results from the site indicate fecal coliform bacteria contamination and it is likely that this is sewage from Kalar town or upstream towns and agricultural chemicals are also possible sources of water contamination in this site. More monitoring and control of sewage discharge is recommended

Phytoplankton results indicate relatively mesotrophic water conditions in site Kalar/Diyala River.

Benthic Macroinvertebrates results for Kalar (Diyala River) - (S3) during winter 2009 indicate non-impaired to moderately impaired habitat and very good water quality.

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Little Zab River Watershed (Dukan Basin)

<u>Please Note: For logistical reasons, the Little Zab River Watershed sites in the Dukan Basin were only visited in the winter of 2009.</u>

1. Penjween (S5) - Elev 1202

Site Description: This area is near the Iranian Border and was previously visited in the summer of 2008. Security has sometimes been a problem in the area, but this has not been the case since 2007. The sampling location was under the Tatan bridge. The site is surrounded by many trees as well as submerged and emerging plants (*Ceratophyllum* sp. and reeds). To the south is Bastan Mountain and to the north is Barawa Mountain. To the west is Tatan hill and some agricultural cultivation and to the east is Qoqzhan Mountain. Local people use the river water for drinking, despite the fact that trash was found in the river, including discarded tires. In 2008, there was also an adjacent sampling area approximately 200 meters downstream from the bridge because the benthic and fish team wanted to do additional sampling. In winter 2009, only the upstream area was surveyed.

Plate

Observations (Winter – 17 Jan 2009):

<u>Water Quality:</u> Penjween (S5) Sample Site. For winter: Sampling Time 09:35 AM, Water Depth 0.6m, Air temperature 1°C, Water temperature 7.2°C.

Water quality parameters of this site were in the optimum range for natural river water (see Table 90 below), except NO2, NO3, SO4, HCO3, Ca and Mg. The nutrients may be coming from trash found near the river or from agricultural runoff, and source alkaline elements (Ca and Mg) may come from water rock interactions.

Table 90: Physical & Chemical Water quality parameters at site Penjween (S5)

Parameters	Winter	River Standards [1&2]	Surface Water Standards [2,3&4]
Field Analysis			
Water Temperature °C	7.2	N/A	N/A
Conductivity µS/cm	304	N/A	<1275
pH	8.17	N/A	6-8.5
Turbidity NTU	ND	N/A	10
TDS mg/L	182	N/A	500
Salinity ppt	ND	N/A	N/A
DO mg/L	8.2	N/A	>5
DO%	75.6	N/A	N/A
Secchi disc m	0.6	N/A	N/A
Lab Analysis			
TSS mg/L	0.002	N/A	N/A
TDS mg/L	169	N/A	500
BOD mg/L	ND	N/A	N/A
Orthophosphate (PO4) mg/L	0.01	10	N/A
Nitrite-Nitrogen (NO2) mg/L	**0.02**	0.001	N/A
Nitrate-Nitrogen (NO3) mg/L	3.77	1	10
Total Alkalinity as CaCO3	64	N/A	>20

Parameters	Winter	River Standards 1&2	Surface Water Standards 2,3&4
mg/L			
Bicarbonate (HCO3) mg/L	**78.08**	58.4	58
Total Hardness (TH) mg/L	162.14	N/A	N/A
Calcium (Ca) mg/L	**50.14**	15	15
Magnesium (Mg) mg/L	8.16	4.1	4.1
Chloride (Cl) mg/L	3.32	7.8	7.8
Total Nitrogen (TN) mg/L	31.12	N/A	N/A
Sulfate (SO4) mg/L	**15.68**	11.2	3.7
Total Phosphorous (TP) mg/L	0.01	0.025	N/A
Potassium (K) mg/L	1.38	2.3	2.3
Sodium (Na) mg/L	5.38	6.3	6.3
1= Allan and Castillo, 2007; 2=Kabata-Pendias and Mukherjee, 2007; 3=Agardy and Sullivan, 2005; 4=STF, 2000; ND=not detected; N/A=not available			

Bacteria & Coliform: The water at this site is contaminated by fecal coliform bacteria, according to surface water quality standards (see Table 91 below), caused by either the trash found near the river or from agricultural areas around the river (the improper management of livestock waste (manure) can cause surface and groundwater pollution). Water pollution from animal production systems can result from direct discharge, runoff, and/or seepage of pollutants to surface or groundwater (Schumacher, 2002).

Table 91: Fecal Coliform bacteria count and E. coli at site (Penjween (S5))

	Winter	Summer	Drinking Standards1 & 2	Surface Water Standards2		
				Body-contact	Fishing and boating	Domestic water supply
Fecal Coli form Bacteria Colony/100 ml	**350**	---	0 in 100ml	100 Colonies/100 mL	> 1000 Colonies/100 mL	> 2000 Colonies/100 mL
Escherichia coli	+	---				
1= WHO, 2006; 2= CDWQ, 2006						

Phytoplankton: The total phytoplankton count during the survey was 472.1 x 10^3 cell/L and a total of 31 species were recorded. The dominant species in this site were pennate (93.18%) (see Table 92 below).

The pennate diatoms were primarily represented by *Achnanthes minutissima, Diatoma vulgare, Nitzschia dissipata, Navicula cryptocephala* and *Nitzschia palea* (133.6 x 10^3 cell/L, 77.9 x 10^3 cell/L, 77.9 x 10^3 cell/L, 66.8 x 10^3 cell/L and 44.5x10^3 cell/L respectively).

This site is considered to have moderate diversity, very good richness and good evenness values (See Annex 2: Table 175, Table 177 & Table 179).

Table 92: Number of species, total count and percentage for phytoplankton groups in Penjween S5

Phytoplankton Groups (S5)	Sp. #	Total Count (cell x 103/L)	%
Cyanophyta	1	18.1	3.83
Euglenophyta	0	0	0.00
Pyrrhophyta	1	1	0.21
Cryptophyta	0	0	0.00
Chlorophyta	2	10.1	2.14
Bacillariophyceae/Centrales	3	3	0.64
Bacillariophyceae/Pennales	24	439.9	93.18
Total	31	472.1	100

Benthic Macroinvertebrates: Total density found was 212 indv. /m^2 and comparing it with the other studied sites, this density was relatively low (Table 165). EPT % was also low (Annex 4: Table 173) and the dominant species was lunged snails *Gyraulus* sp.1, which is known as a tolerant organism (pollution tolerance number ≈ 8). The relative diversity, richness, and evenness were very good, very good, and excellent respectively (See Annex 4: Table 167, Table 169 & Table 171, respectively).

Depending on the modified pollution tolerance and pollution indices, water quality was very good to excellent (See Annex 1, Table 173) and this could be confirmed by the presence of the sensitive and very sensitive aquatic organisms such as the Whitetail dragonfly *Plathemis* sp. and the Spiny crawler mayflies *Ephemerella* spp.

Briefly, we suggested considering the habitat here as non-impaired to moderately impaired and the water quality as very good to excellent (See Methods & Procedures).

Heavy Metals in Water: This site was contaminated with Ni, Pb, Cu, and Zn (see Table 93 below). The contamination level of Zn was high, possibly a result of the trash near the river, manure sewage and agrochemicals (Krishna and Govil, 2005).

Table 93: Heavy metals in water of site Penjween (S5)

Heavy Metal	Winter	River Standards [1&2]	Surface Water Standards [2,3&4]
Nickel (Ni) mg/L	**0.05**	0.0008	0.0005-0.006
Lead (Pb) mg/L	0.03	0.0015	0.09
Iron (Fe) mg/L	ND	0.67	0.22-0.35
Copper (Cu) mg/L	**0.14**	0.002	0.27
Manganese (Mn)mg/L	ND	0.00002	0.07-0.5
Cadmium (Cd) mg/L	ND	0.00008	0.000005
Zinc (Zn) mg/L	**0.2**	0.0006	N/A
1= Allan and Castillo, 2007; 2=Kabata-Pendias and Mukherjee, 2007; 3=Agardy and Sullivan, 2005; 4=STF, 2000; ND=not detected; N/A=not available			

Heavy Metals in Sediments: Sediments of the Penjween site show contaminated sediments with Pb, Cd, Cu and Zn (see Table 94 below) compared to background and Canadian sediment quality guidelines. Geogenic sources (from igneous or metamorphic rock bodies) may be the source of this contamination with heavy metals if the river passes over these types of rocks upstream. Zinc levels for sediments were found to be highest at this site of all sites in the Basin (See Figure 4).

Table 94: Heavy metals in sediment of Penjween (S5)

Heavy Metal	Winter	Background [1]	CSQG [2]

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Nickel (Ni) mg/kg	**297.7**	31	N/A
Lead (Pb) mg/kg	**40.4**	23	35
Iron (Fe) mg/kg	38697	N/A	N/A
Copper (Cu) mg/kg	**100.1**	25	35.7
Manganese (Mn) mg/kg	**1261.25**	400	N/A
Cadmium (Cd) mg/kg	**6.7**	N/A	0.6
Zinc (Zn) mg/kg	**409.9**	65	123
1= ASQ, 1993; 2= CSQG, 2002; N/A=not available			

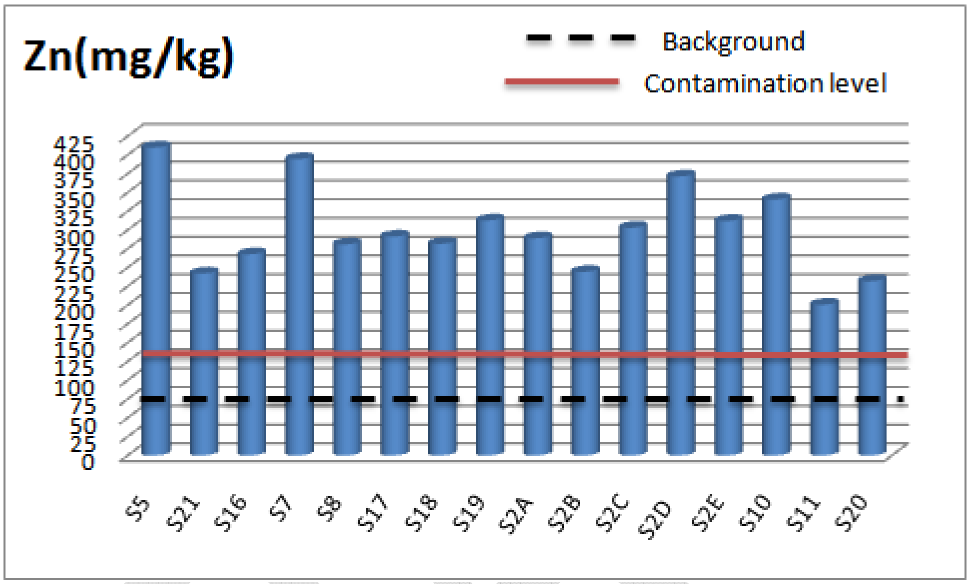

Figure 4: Concentration of zinc in sediment samples of Little Zab River Watershed (Dukan Basin)

Conservation Issues & Recommendations: Investigating the river upstream from the sampling site was recommended to determine the effect of geogenic sources (igneous and metamorphic rock bodies) on the water and sedimentary contamination at the site.

The site results indicate the presence of fecal coliform bacteria, which may be coming from local activity, and according to the results this water should not be used for drinking or body contact (swimming) and needs to be monitored and treated.

Phytoplankton results indicate mesotrophic water conditions in Penjween during winter 2009.

Benthic Macroinvertebrates results for Penjween (S5) during winter 2009 indicate non-impaired to moderately impaired habitat and very good to excellent water quality.

More work should be done to monitor and, if possible, mitigate both nutrient and anthropomorphic heavy metal contamination if that proves to be present.

2. Kani Sard (Chami Gawra) (S21) – Elev 1192

Site Description: This site is located high in the Little Zab watershed near the Iranian border. It is located south of Penjween town on a stream called Kani Sard or Chami Gawra. The site was only visited in winter, when the stream was shallow and approximately 7 to 8 meters wide. There was some snow on the ground on the north-facing hills. During winter the current was running high and the streambed consisted of gravel and cobblestones. There were many algae (brown and green algae) on the rocks at this site. Approximately 400 to 500 meters upstream (east) of the site was a bridge. To the northwest there were high mountains. A small village called Kani Sard lies on the north. There is evidence of fuel smuggling here with a large area of the upland, northern embankment covered by hundreds of empty 20L fuel jerry can, with evidence of fuel dumping and spills on the soil and fumes in the air.

Plate

Observations (Winter- 9 Jan 2009):

Water Quality: Kani Sard (Chami Gawra) (S21) Sample Site. For winter: Sampling Time 09:54 AM, Water Depth 0.1m, Air temperature 8°C, Water temperature 5.8°C.

NO3 and NO2 concentrations at this site exceed the river and surface water quality reference standards (see Table 95 below). High HCO3, Ca and Mg concentrations (see Figure 5 below) show the distribution of Mg in the watershed; for example, concentration of Mg in the water samples in the center of the watershed was greater than in other parts, and the lower concentration of Mg located in the northeast toward southwest of the watershed in this site may have resulted from chemical weathering of the rocks (Davis and Dewiest, 1966).

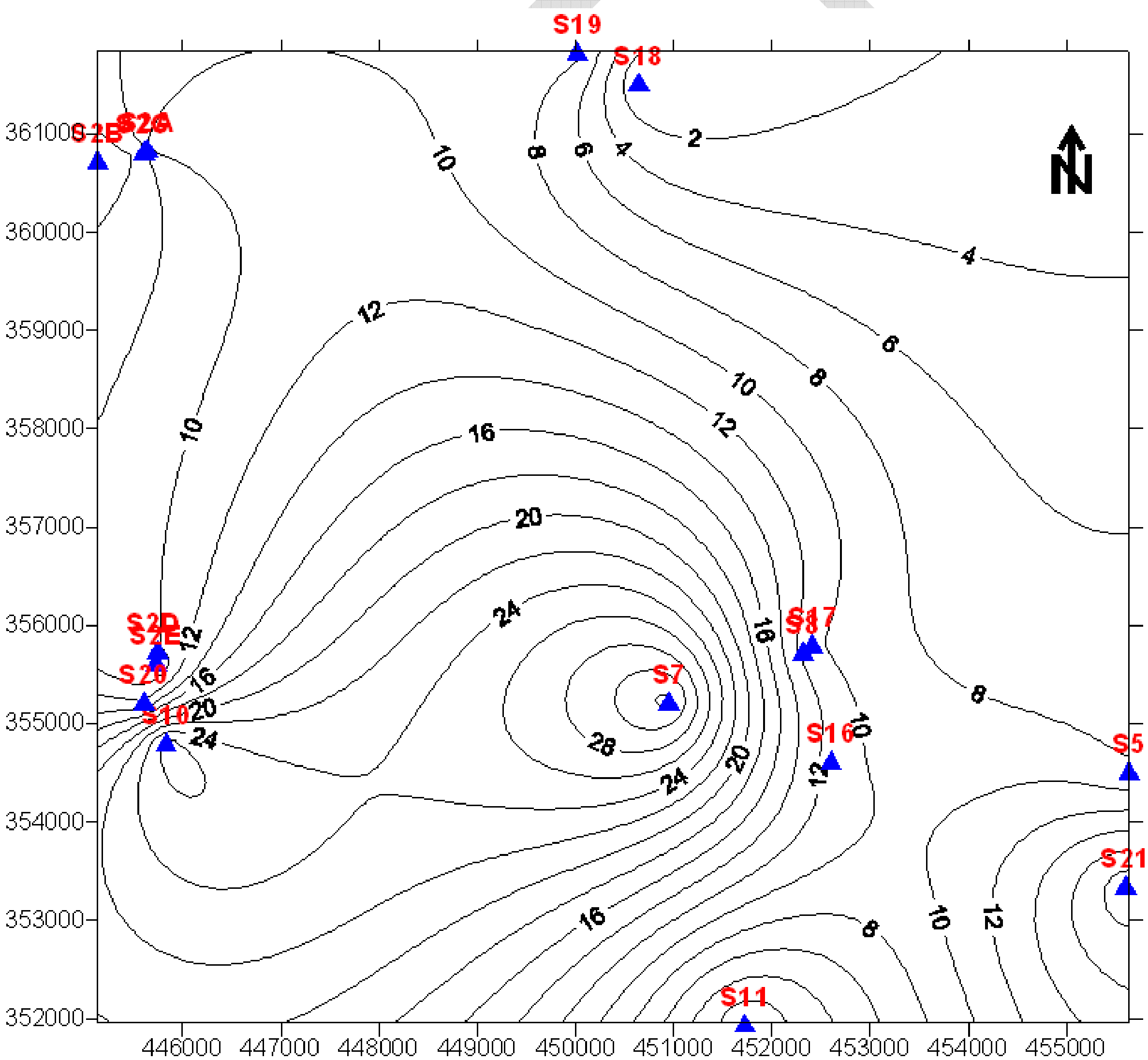

Figure 5: Concentration distribution map of magnesium in water samples of Little Zab River Watershed (Dukan

Basin)

Table 95: Physical & Chemical Water quality parameters at site Kani Sard (Chami Gawra) (S21)

Parameters	Winter	RiverStandards[1&2]	Surface Water Standards [2,3&4]
Field Analysis			
Water Temperature °C	5.8	N/A	N/A
Conductivity µS/cm	436	N/A	<1275
pH	8.47	N/A	6-8.5
Turbidity NTU	<0.01	N/A	10
TDS mg/L	258	N/A	500
Salinity ppt	ND	N/A	N/A
DO mg/L	15.7	N/A	>5
DO%	135.1	N/A	N/A
Secchi disc m	0.1	N/A	N/A
Lab Analysis			
TSS mg/L	0.02	N/A	N/A
TDS mg/L	**198.5**	N/A	500
BOD mg/L	ND	N/A	N/A
Orthophosphate (PO4) mg/L	ND	10	N/A
Nitrite-Nitrogen (NO2) mg/L	0.004	0.001	N/A
Nitrate-Nitrogen (NO3) mg/L	**11.07**	1	10
Total Alkalinity as CaCO3 mg/L	147	N/A	>20
Bicarbonate (HCO3) mg/L	**178.12**	58.4	58
Total Hardness (TH) mg/L	240.78	N/A	N/A
Calcium (Ca) mg/L	**48.7**	15	15
Magnesium (Mg) mg/L	**19.49**	4.1	4.1
Chloride (Cl) mg/L	**29.43**	7.8	7.8
Total Nitrogen (TN) mg/L	22.3	N/A	N/A
Sulfate (SO4) mg/L	**25.15**	11.2	3.7
Total Phosphorous (TP) mg/L	ND	0.025	N/A
Potassium (K) mg/L	1.62	2.3	2.3
Sodium (Na) mg/L	**9.63**	6.3	6.3
1= Allan and Castillo, 2007; 2=Kabata-Pendias and Mukherjee, 2007; 3=Agardy and Sullivan, 2005; 4=STF, 2000; ND=not detected; N/A=not available			

Bacteria & Coliform: In the water of this site fecal coli form bacteria concentrations were 33 colony/100 ml, which is considered as non contaminated water with fecal coliform bacteria and this may be due to the nature of this site— cold mountains—and this colony may come from the human activity and Kani Sard village (See Table 96).

Table 96: Fecal Coliform bacteria count and E. coli at site Kani Sard (Chami Gawra) S21

	Winter	Summer	Drinking Standards 1 & 2	Surface Water Standards 2		
				Body-contact	Fishing and boating	Domestic water supply
Fecal Coli form Bacteria Colony/100 ml	33	---	0 in 100ml	100 Colonies/100 mL	> 1000 Colonies/100 mL	> 2000 Colonies/100 mL
Escherichia coli	+	---				
1= WHO, 2006; 2= CDWQ, 2006						

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__Phytoplankton:__ The total phytoplankton count during the survey was 307.3 x 10^3 cell/L and a total of 35 species were recorded.

The dominant species in this site were pennates (90.17%) (See Table 97 below). The genus *Cymbella* was represented by 6 species, particularly by *Cymbella cistula* (89.1 x 10^3 cell/L). *Fragilaria* was also represented by 6 species, particularly by *Fragilaria vaucheriae* (11.1 x 10^3 cell/L). *Nitzschia* was presented by 8 species, particularly by *Nitzschia acicularis*, *Nitzschia sigmoidea* and *Nitzschia dissipata* (33.4 x 10^3 cell/L, 33.4 x 10^3 cell/L and 22.3 x 10^3 cell/L respectively).

Cymbella sp and *Fragilaria vaucheriae* were prominent most likely due to the fact that they are capable of rapid colonization and replacement compared to other diatoms (Stevenson, Bothwell and Lowe, 1996).

This site is considered to have moderate diversity, very good richness and very good evenness values (See Annex 2: Table 175, Table 177 & Table 179).

Table 97: Number of species, total count and percentage for phytoplankton groups in Kani Sard (Chami Gawra) S21

Phytoplankton Groups (S5A)	Sp. #	Total Count (cell x 10^3/L)	%
Cyanophyta	0	0	0.00
Euglenophyta	1	1	0.33
Pyrrhophyta	1	18.1	5.89
Cryptophyta	0	0	0.00
Chlorophyta	1	9.1	2.96
Bacillariophyceae/Centrales	2	2	0.65
Bacillariophyceae/Pennales	30	277.1	90.17
Total	35	307.3	100

__Benthic Macroinvertebrates:__ Total density found was 285 indv. /m^2 and comparing with the other studied sites, this density was relatively low (Annex 4: Table 165). No EPT species was found in this site (Annex 4: Table 173) and the dominant species was the blackfly larva *Simulium* sp., which is known as tolerant organism (pollution tolerance number ≈ 6). Although the relative evenness was excellent (Annex 4: **Error! Reference source not found.Error! Reference source not found.**), the relative diversity and richness were moderate (Annex 4: Table 167 & Table 169, respectively).

Depending on the modified pollution tolerance and pollution indices, water quality was poor to fair (See Annex 1, Table 173) and this could be confirmed by the absence of sensitive and very sensitive species and the well presence of the tolerant and very tolerant aquatic organisms such as the white midge *Pentaneura* sp. and the blood midge *Paratendipes albimanus*.

Briefly, we suggested considering the habitat here as moderately to somewhat severely impaired and the water quality as poor to fair (refer to Methods & Procedures).

Heavy Metals in Water: This site was contaminated with Ni, Pb, Cu and Zn compared to standards for natural river and surface water (see Table 98 below). Fuel smuggling, wastes from the Iran-Iraq War (the area represented by a hot war line in the eighteenth) and water-rock interactions (some rock formations in the area contain sulfide ores which are a source of some heavy metals) may be the source of heavy metal contamination in the area.

Table 98: Heavy metals in water of site Kani Sard (Chami Gawra) S21

Heavy Metal	Winter	River Standards[1&2]	Surface Water Standards[2,3&4]
Nickel (Ni) mg/L	**0.11**	0.0008	0.0005-0.006
Lead (Pb) mg/L	0.07	0.0015	0.09
Iron (Fe) mg/L	0.01	0.67	0.22-0.35
Copper (Cu) mg/L	0.12	0.002	0.27
Manganese (Mn)mg/L	ND	0.00002	0.07-0.5
Cadmium (Cd) mg/L	ND	0.00008	0.000005
Zinc (Zn) mg/L	**0.06**	0.0006	N/A
1= Allan and Castillo, 2007; 2=Kabata-Pendias and Mukherjee, 2007; 3=Agardy and Sullivan, 2005; 4=STF, 2000; ND=not detected; N/A=not available			

Heavy Metals in Sediments: Sediments of the Kani Sard (Chami Gawra) site show contaminated sediments with Ni, Pb, Cu and Zn (see Table 99 below). The probable source of sediment contamination is geogenic sources, wastes of Iran-Iraq war (the area represented by a hot war line in the eighteenth) and fuel smuggling.

Table 99: Heavy metals in sediment of Kani Sard (Chami Gawra) S21

Heavy Metal	Winter	Background[1]	CSQG[2]
Nickel (Ni) mg/kg	**681.2**	31	N/A
Lead (Pb) mg/kg	29.8	23	35
Iron (Fe) mg/kg	34387	N/A	N/A
Copper (Cu) mg/kg	**104.65**	25	35.7
Manganese (Mn) mg/kg	**1790.3**	400	N/A
Cadmium (Cd) mg/kg	0.3	N/A	0.6
Zinc (Zn) mg/kg	**242**	65	123
1= ASQ, 1993; 2= CSQG, 2002; N/A=not available			

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Conservation Issues & Recommendations: It is possible that the nitrate in the water of this site could be coming from upstream in Iran, though this cannot be confirmed (Iran is approximately 8 km upstream from the sample point); thus more study is required. In addition, sources of heavy metals (especially Ni) may be geogenic as the area is composed of igneous and metamorphic rocks, so further investigation is needed. Fuel smuggling may also represent a possible source for heavy metal contamination in the water and sediments of the area. Fuel smuggling represents a major local issue beyond heavy metal contamination, and is also a source for hydrocarbon contamination. This problem must be fixed by the local authorities responsible for the region in order to prevent any further environmental contamination in the soil, sediment and water. Water and sediment quality in the area may badly affected by waste from the Iran-Iraq War, which saw heavy combat in the 1980's).

Military operations and bombardment in Zamok/Near Chwarta may have added an additional dose of heavy metals and other chemical poisons to the local environment.

The water from this site has less contamination by fecal coliform bacteria than other sites but is still not suitable for drinking according to the surface water standards. The levels of fecal coliform bacteria may be coming from upstream or from the small village called Kani Sard lying to the north, and human activities in this area, which include fuel smuggling/trading. The water should be treated before use as drinking water and requires more monitoring.

According to the phytoplankton results, Kani Sard (Chami Gawra) had relatively oligotrophic-mesotrophic water conditions during winter 2009. More sampling is needed.

The benthic macroinvertebrate results for Kani Sard (Chami Gawra) during winter 2009 indicate moderately to somewhat severely impaired habitat and poor to fair water quality.

3. Zamok / Near Chwarta (S16) – Elev 819

Site Description: The site is located north of Sulaimani city and is accessible from a gravel mine along the road to Sargalu from Chwarta along the Kareza River. There are extensive gravel mines above and below the site, where the river is approximately 150 m wide. There are also destroyed buildings on west side of river and some agricultural fields.

Plate

Observations (Winter- 24 Jan 2009):

Water Quality: Zamok/Near Chwarta (S16) Sample Site. For winter: Sampling Time 10:06 AM, Water Depth 0.3m, Air temperature 6°C, Water temperature 12.1°C.

The site was turbid compared to surface water quality standards (see Table 100 below). Turbidity of this site originates from the gravel quarry on the river. Also, HCO3, NO2, TP, Ca, Na and SO4 exceed river and surface water quality standards; nutrients may come from agricultural practices.

Table 100: Physical & Chemical Water quality parameters at site Zamok/ Near Chwarta (S16)

Parameters	Winter	River Standards [1&2]	Surface Water Standards[2,3&4]
Field Analysis			
Water Temperature °C	12.1	N/A	N/A
Conductivity µS/cm	374	N/A	<1275
pH	8.25	N/A	6-8.5
Turbidity NTU	20.8	N/A	10
TDS mg/L	224	N/A	500
Salinity ppt	ND	N/A	N/A
DO mg/L	13.4	N/A	>5
DO%	114.9	N/A	N/A
Secchi disc m	0.3	N/A	N/A
Lab Analysis			
TSS mg/L	0.015	N/A	N/A
TDS mg/L	227.5	N/A	500
BOD mg/L	ND	N/A	N/A
Orthophosphate (PO4) mg/L	0.02	10	N/A
Nitrite-Nitrogen (NO2) mg/L	0.01	0.001	N/A
Nitrate-Nitrogen (NO3)	0.84	1	10

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Parameters	Winter	River Standards [1&2]	Surface Water Standards [2,3&4]
mg/L			
Total Alkalinity as CaCO3 mg/L	88	N/A	>20
Bicarbonate (HCO3) mg/L	**107.36**	58.4	58
Total Hardness (TH) mg/L	193.21	N/A	N/A
Calcium (Ca) mg/L	**36.67**	15	15
Magnesium (Mg) mg/L	**11.1**	4.1	4.1
Chloride (Cl) mg/L	7.11	7.8	7.8
Total Nitrogen (TN) mg/L	40.98	N/A	N/A
Sulfate (SO4) mg/L	**37.02**	11.2	3.7
Total Phosphorous (TP) mg/L	**0.07**	0.025	N/A
Potassium (K) mg/L	1.6	2.3	2.3
Sodium (Na) mg/L	**8.01**	6.3	6.3
1= Allan and Castillo, 2007; 2=Kabata-Pendias and Mukherjee, 2007; 3=Agardy and Sullivan, 2005; 4=STF, 2000; ND=not detected; N/A=not available			

Bacteria & Coliform: According to the surface water standards the water quality at this site is not considered contaminated with fecal coliform bacteria as it contains only 5 colonies/100 ml (see Table 101 below).

Table 101: Fecal Coliform bacteria count and E. coli at site (Chwarta (S16))

	Winter	Summer	Drinking Standards[1 & 2]	Surface Water Standards[2]		
				Body-contact	Fishing and boating	Domestic water supply
Fecal Coli form Bacteria Colony/100 ml	**5**	---	0 in 100ml	100 Colonies/100 mL	> 1000 Colonies/100 mL	> 2000 Colonies/100 mL
Escherichia coli	**+**	---				
1= WHO, 2006; 2= CDWQ, 2006						

Phytoplankton: The total phytoplankton count during the survey was 599.7 x 10^3cell/L and a total of 48 species were recorded. The dominant species in this site were pennates (99.01%) (See Table 102 below).

Both *Diatoma vulgare* and *Achnanthes minutissima* (233.8 x 10^3 cell/L and 189.3 x 10^3 cell/L respectively) were the most common diatoms recorded. This site is considered to have moderate diversity, very good richness and moderate evenness values (See Annex 2: Table 175, Table 177 & Table 179).

Table 102: Number of species, total count and percentage for phytoplankton groups in Zamok/Near Chwarta S16

Phytoplankton Groups (S16)	Sp. #	Total Count (cell x 103/L)	%
Cyanophyta	1	1	0.17
Euglenophyta	1	1	0.17

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Phytoplankton Groups (S16)	Sp. #	Total Count (cell x 103/L)	%
Pyrrhophyta	1	1	0.17
Cryptophyta	1	1	0.17
Chlorophyta	1	1	0.17
Bacillariophyceae/Centrales	1	1	0.17
Bacillariophyceae/Pennales	42	599.7	99.01
Total	48	605.7	100

Benthic Macroinvertebrates: Total density found was 506 indv. /m² and comparing it with the other studied sites, this density was relatively good (

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). EPT % was low (

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) and the dominant species was the Forktail damselfly *Ischnura* sp.3, which is known as very tolerant organism (pollution tolerance number ≈ 9). The relative diversity, richness, and evenness were good, very good, and excellent respectively (**Error! Reference source not found.**, **Error! Reference source not found.** and **Error! Reference source not found.** respectively).

Depending on the modified pollution tolerance and pollution indices, water quality was good to very good (See Annex 1, Table 173) and this could be confirmed by the presence of the sensitive and very sensitive aquatic organisms such as the moth larva *Petrophila* sp. and the Humpless-case caddisfly *Amiocentrus* sp.

Briefly, we suggested considering the habitat here as moderately impaired and the water quality as good to very good (Refer to Methods & Procedures).

Heavy Metals in Water: This site was contaminated with Ni, Pb, Mn, Cu and Zn compared to natural river levels (see Table 103 below), but had lower levels of contamination than the upstream sites like Kani Sard (Chami Gawra) (S21) because of dilution effect.

Table 103: Heavy metals in water of site Zamok/ Near Chwarta (S16)

Heavy Metal	Winter	River Standards[1&2]	Surface Water Standards [2,3&4]
Nickel (Ni) mg/L	**0.05**	0.0008	0.0005-0.006
Lead (Pb) mg/L	0.03	0.0015	0.09
Iron (Fe) mg/L	ND	0.67	0.22-0.35
Copper (Cu) mg/L	0.1	0.002	0.27
Manganese (Mn)mg/L	0.01	0.00002	0.07-0.5
Cadmium (Cd) mg/L	ND	0.00008	0.000005
Zinc (Zn) mg/L	**0.11**	0.0006	N/A
1= Allan and Castillo, 2007; 2=Kabata-Pendias and Mukherjee, 2007; 3=Agardy and Sullivan, 2005; 4=STF, 2000; ND=not detected; N/A=not available			

Heavy Metals in Sediments: Sediments of the Zamok site show sediments contaminated with Pb, Cd, Cu and Zn (see Table 104 below). Anthropogenic activity, agricultural practices and wastes of the Iran-Iraq War (the area represented by a hot war line in the eighteenth) in the area may cause sediment contamination.

Table 104: Heavy metals in sediment of Zamok/ Near Chwarta (S16)

Heavy Metal	Winter	Background[1]	CSQG[2]
Nickel (Ni) mg/kg	**568.6**	31	N/A
Lead (Pb) mg/kg	**40.6**	23	35
Iron (Fe) mg/kg	32594	N/A	N/A
Copper (Cu) mg/kg	**108.6**	25	35.7
Manganese (Mn) mg/kg	**1517**	400	N/A
Cadmium (Cd) mg/kg	8.75	N/A	0.6
Zinc (Zn) mg/kg	**267.8**	65	123
1= ASQ, 1993; 2= CSQG, 2002; N/A=not available			

Conservation Issues & Recommendations: Results recorded in the Zamok/Near Chwarta site in winter 2009 indicates that this site is much less contaminated with fecal coliform bacteria according to the surface water quality standards than other sites but would require treatment before use as drinking water.

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The phytoplankton for Zamok/Near Chwarta in winter 2009 indicate oligotrophic water conditions during winter 2009. The benthic macroinvertebrate results for the site indicate a moderately impaired habitat but in contrast good to very good water quality.

Water and sediment quality in the area may be affected by waste from the Iran-Iraq War, which saw heavy combat in the 1980's. Military operations and bombardment in Zamok/Near Chwarta may have added an additional dose of heavy metals and other chemical poisons to the local environment. A specific program for investigating and evaluating the consequences of war in that area is recommended.

4. *Sargalu (S7)- Elev 972*

Site Description: This site is a small stream in the town of Sargalu-Bargalu located northwest of Sulaimani city. The water current runs at a fast pace and passes through tourist picnic area. The main roadway is on the northwest side of the stream and crosses it below the sampling point when the stream flows into a narrow gorge. The source of the stream is several springs within and around the town of Sargalu. There is a large amount of trash in and around the stream.

Plate

Observations (Winter – 22 Jan 2009):

Water Quality: Sargalu (S7) Sample Site. For winter: Sampling Time 11:15 AM, Water Depth 0.3m, Air temperature 7°C, Water temperature15°C.

Water at this site was hard and contaminated with NO2, SO4 and TP (see Table 105). The hardness of the water (see Figure 6) comes from the dissolution of Jurassic-period rocks (containing Ca and Mg) in the area. Contamination of the stream with other nutrients originates from Sargalu town sewage mixing with the local spring water of the stream.

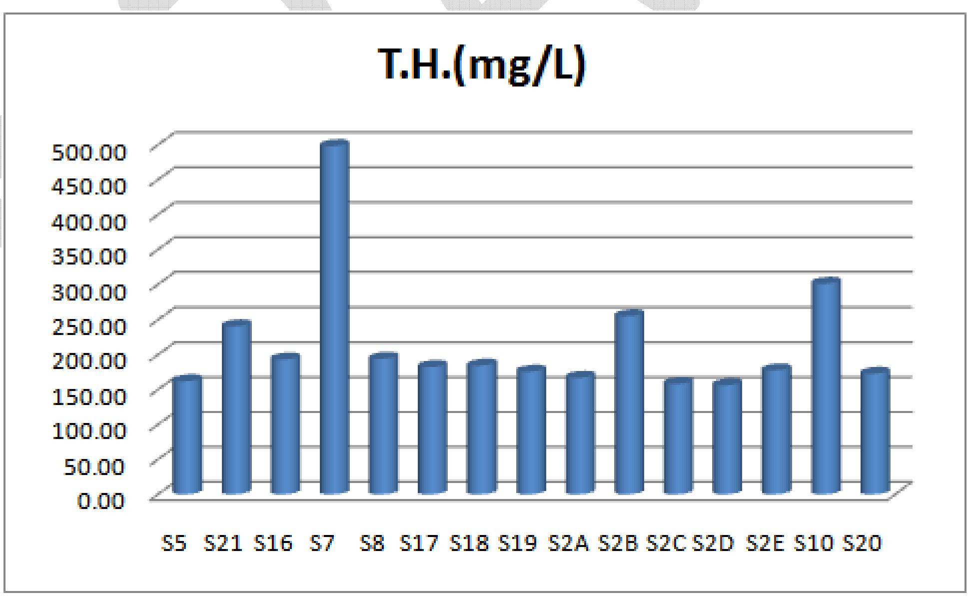

Figure 6: Hardness in winter water samples of Little Zab River Watershed (Dukan Basin)

Table 105: Physical & Chemical Water quality parameters at site Sargalu (S7)

Parameters	Winter	River Standards[1&2]	Surface Water Standards [2,3&4]

Parameters	Winter	River Standards[1&2]	Surface Water Standards [2,3&4]
Field Analysis			
Water Temperature °C	15	N/A	N/A
Conductivity µS/cm	862	N/A	<1275
pH	8.45	N/A	6-8.5
Turbidity NTU	4.51	N/A	10
TDS mg/L	521	N/A	500
Salinity ppt	0.2	N/A	N/A
DO mg/L	12.7	N/A	>5
DO%	137.4	N/A	N/A
Secchi disc m	0.3	N/A	N/A
Lab Analysis			
TSS mg/L	0.003	N/A	N/A
TDS mg/L	480.5	N/A	500
BOD mg/L	ND	N/A	N/A
Orthophosphate (PO4) mg/L	0.1	10	N/A
Nitrite-Nitrogen (NO2) mg/L	**0.15**	0.001	N/A
Nitrate-Nitrogen (NO3) mg/L	2.98	1	10
Total Alkalinity as CaCO3 mg/L	135	N/A	>20
Bicarbonate (HCO3) mg/L	**164.7**	58.4	58
Total Hardness (TH) mg/L	498.07	N/A	N/A
Calcium (Ca) mg/L	**90.94**	15	15
Magnesium (Mg) mg/L	**32.77**	4.1	4.1
Chloride (Cl) mg/L	**46.79**	7.8	7.8
Total Nitrogen (TN) mg/L	30.27	N/A	N/A
Sulfate (SO4) mg/L	**234.3**	11.2	3.7
Total Phosphorous (TP) mg/L	**0.27**	0.025	N/A
Potassium (K) mg/L	1.37	2.3	2.3
Sodium (Na) mg/L	**6.91**	6.3	6.3

1= Allan and Castillo, 2007; 2=Kabata-Pendias and Mukherjee, 2007; 3=Agardy and Sullivan, 2005; 4=STF, 2000; ND=not detected; N/A=not available

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<u>Bacteria & Coliform:</u> The water at this site is contaminated with fecal coliform bacteria according to the water quality standards (see table below). The water is most likely affected by tourism and from sewage from the town of Sargalu.

Table 106: Fecal Coliform bacteria count and E. coli at site (Sargalu (S7))

	Winter	Summer	Drinking Standards[1 & 2]	Surface Water Standards[2]		
Fecal Coli form Bacteria	**≥ 2400**	---	0 in 100ml	Body-contact	Fishing and boating	Domestic water supply

Colony/100 ml				100 Colonies/100 mL	> 1000 Colonies/100 mL	> 2000 Colonies/100 mL
Escherichia coli	+	---				
1= WHO, 2006; 2= CDWQ, 2006						

<u>Phytoplankton:</u> The total phytoplankton count during the survey was 233.3 x 10^3 cell/L and a total of 35 species were recorded. The dominant species in this site were pennates (94.38%) (see Table 107).

Thirty pennate diatoms were recorded in this site, all in small abundances. The main diatoms recorded were: Achnanthes minutissima, Amphora perpusilla, Cymbella microcephala, Gomphonema angustatum, Navicula gracilis, Navicula radiosa, Nitzschia dissipata, Nitzschia hungarica, and Surirella linearis.

This site is considered to have good diversity, very good richness and evenness values (See Annex 2: Table 175, Table 177 & Table 179).

Table 107: Number of species, total count and percentage for phytoplankton groups in Sargalu S7

Phytoplankton Groups (S7)	Sp. #	Total Count (cell x 103/L)	%
Cyanophyta	2	2	0.86
Euglenophyta	0	0	0.00
Pyrrhophyta	1	9.1	3.90
Cryptophyta	0	0	0.00
Chlorophyta	0	0	0.00
Bacillariophyceae/Centrales	2	2	0.86
Bacillariophyceae/Pennales	30	220.2	94.38
Total	35	233.3	100

<u>Benthic Macroinvertebrates:</u> Total density found was 1009 indv. /m² and comparing with the other studied sites, this density was relatively high (Table 165). EPT % was good (Table 173) and the dominant species was the Small minnow mayfly *Fallceon* sp. which is known as a tolerant organism (pollution tolerance number ≈ 6). The relative diversity, richness, and evenness were moderate, good, and good respectively (See Annex 4: Table 167, Table 169, & Table 171 respectively).

Depending on the modified pollution tolerance and pollution indices, water quality was good to very good (See Annex 1, Table 173) and this could be confirmed by the presence of the sensitive and very sensitive aquatic organisms such as the water Snipe fly larva *Atherix* sp. and the Humpless-case caddisfly *Amiocentrus* sp.

Briefly, we suggested considering the habitat here as non-impaired to moderately impaired and the water quality as good to very good (Refer to Methods & Procedures).

<u>Heavy Metals in Water:</u> This site was contaminated with Ni, Pb, Mn, Cu and Zn compared to natural river levels (see Table 108 below). The potential sources of contamination were discussed previously in the water quality section.

Table 108: Heavy metals in water of site Sargalu (S7)

Heavy Metal	Winter	River Standards[1&2]	Surface Water Standards[2,3&4]

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Nickel (Ni) mg/L	**0.1**	0.0008	0.0005-0.006
Lead (Pb) mg/L	0.06	0.0015	0.09
Iron (Fe) mg/L	0.01	0.67	0.22-0.35
Copper (Cu) mg/L	0.05	0.002	0.27
Manganese (Mn)mg/L	0.02	0.00002	0.07-0.5
Cadmium (Cd) mg/L	ND	0.00008	0.000005
Zinc (Zn) mg/L	**0.07**	0.0006	N/A
1= Allan and Castillo, 2007; 2=Kabata-Pendias and Mukherjee, 2007; 3=Agardy and Sullivan, 2005; 4=STF, 2000; ND=not detected; N/A=not available			

Heavy Metals in Sediments: Sediments of Sargalu site show contamination by Pb, Cd, Cu and Zn (see Table 109 below). Disposing of the untreated sewages of Sargalu town may cause the accumulation of heavy metals in sediments. Sediments of the Sagalu stream show a higher concentration of cadmium among sediments testing in the Little Zab watershed (see Figure 7 below). In addition to the direct mixing of the water with Sargalu town sewage, in the past the area was heavily bombarded by conventional and chemical weapons which may be a source of the sediment contamination.

Table 109: Heavy metals in sediment of Sargalu (S7)

Heavy Metal	Winter	Background[1]	CSQG[2]
Nickel (Ni) mg/kg	**231.4**	31	N/A
Lead (Pb) mg/kg	**44.2**	23	35
Iron (Fe) mg/kg	19898	N/A	N/A
Copper (Cu) mg/kg	**50.15**	25	35.7
Manganese (Mn) mg/kg	371.6	400	N/A
Cadmium (Cd) mg/kg	**14.5**	N/A	0.6
Zinc (Zn) mg/kg	**394.5**	65	123
1= ASQ, 1993; 2= CSQG, 2002; N/A=not available			

Conservation Issues & Recommendations: As stated above, sediments from the Sagalu River show higher concentrations of cadmium than all the sediments of the Little Zab watershed (see Figure 7 below showing the highest concentration of Cadmium in sediments of the watershed: rising areas represent higher concentrations and falling areas represent lower ones). The sources of this contamination should be investigated further and mitigated if possible. Studying and determining the effect of chemical weapons on the Sargalu area is also recommended.

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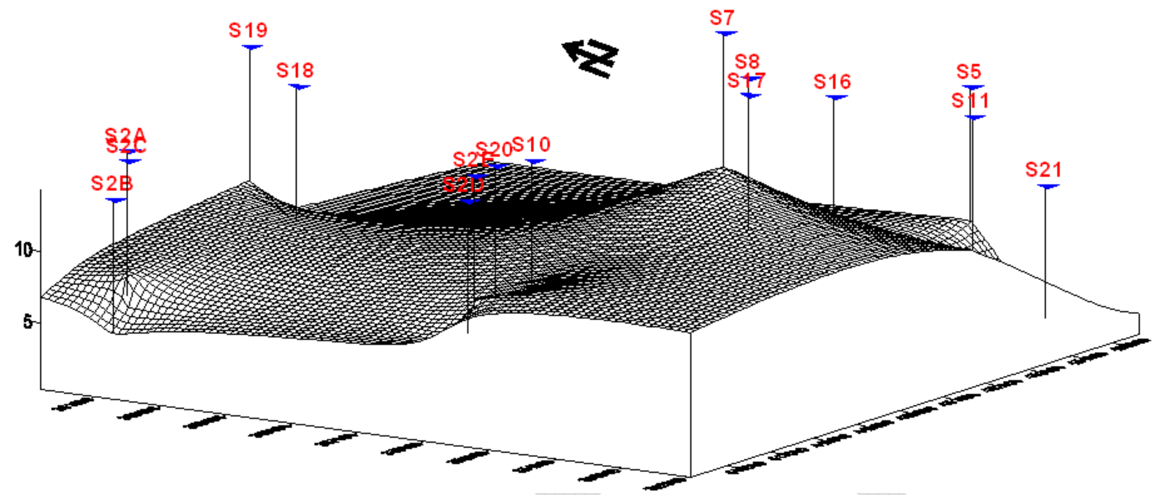

Figure 7: 3D concentration distribution map of cadmium in sediment samples of Little Zab River Watershed (Dukan Basin)

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Results from the Sargalu (S7) site show a high level of fecal coliform contamination likely coming from the town of Sargalu and the trash around the stream. Mitigation and further investigation and monitoring are recommended.

Phytoplankton results during winter 2009 indicate oligotrophic water conditions in Sargalu. The benthic macroinvertebrates results for Sargalu (S7) during winter 2009 indicate non-impaired to moderately impaired habitat and good to very good water quality.

5. Du Choman (Mawat) (S8) – Elev. 655

Site Description: The site is located northwest of Sulaimani city and north of the town of Mawat near the Iranian border. The sampling station is located along a stream called Du Choman or Chami Qashan. There are high hills bordering the river here and upstream the river flows through a deep gorge. The water had a fast current during winter. There is a village nearby called Isawa but few houses are near the site. Grazing animals do frequent the site, and fishermen were seen at the site with a small catch of fish.

Plate

Observations (Winter – 25 Jan 2009):

Water Quality: Mawat (S8) Sample Site. For winter: Sampling Time 08:52 AM, Water Depth 0.4m, Air temperature 9°C, Water temperature 15.4°C.

The water of Du Choman/Chami Qashan shows high turbidity, related to the rainy weather of the season. NO2, NO3, TP, SO4, Ca, Mg, HCO3 and Na appear at high levels compared to natural river and surface water standards (see Table 110 below) but the source of this contamination was unknown and may be upstream.

Table 110: Physical & Chemical Water quality parameters at site Du Choman (Mawat) (S8)

Parameters	Winter	River Standards[1&2]	Surface Water Standards[2,3&4]
Field Analysis			
Water Temperature °C	15.4	N/A	N/A

Parameters	Winter	River Standards[1&2]	Surface Water Standards[2,3&4]
Conductivity µS/cm	374	N/A	<1275
pH	8.2	N/A	6-8.5
Turbidity NTU	**13.2**	N/A	10
TDS mg/L	223	N/A	500
Salinity ppt	ND	N/A	N/A
DO mg/L	12.71	N/A	>5
DO%	108.4	N/A	N/A
Secchi disc m	0.4	N/A	N/A
Lab Analysis			
TSS mg/L	0.005	N/A	N/A
TDS mg/L	200	N/A	500
BOD mg/L	ND	N/A	N/A
Orthophosphate (PO4) mg/L	0.07	10	N/A
Nitrite-Nitrogen (NO2) mg/L	0.06	0.001	N/A
Nitrate-Nitrogen (NO3) mg/L	1.32	1	10
Total Alkalinity as CaCO3 mg/L	82	N/A	>20
Bicarbonate (HCO3) mg/L	**100.04**	58.4	58
Total Hardness (TH) mg/L	194.18	N/A	N/A
Calcium (Ca) mg/L	**50.66**	15	15
Magnesium (Mg) mg/L	**11.37**	4.1	4.1
Chloride (Cl) mg/L	7.52	7.8	7.8
Total Nitrogen (TN) mg/L	31.27	N/A	N/A
Sulfate (SO4) mg/L	**25.71**	11.2	3.7
Total Phosphorous (TP) mg/L	0.22	0.025	N/A
Potassium (K) mg/L	1.59	2.3	2.3
Sodium (Na) mg/L	**7.46**	6.3	6.3
1= Allan and Castillo, 2007; 2=Kabata-Pendias and Mukherjee, 2007; 3=Agardy and Sullivan, 2005; 4=STF, 2000; ND=not detected; N/A=not available			

<u>Bacteria & Coliform:</u> At this area of the river the water is not considered contaminated with fecal coliform bacteria according to the surface water quality standards (see Table 111 below). This may be due to the high speed of the stream and/or its distance from most major human activities. The gorge upstream limits direct activity on the river itself.

Table 111: Fecal Coliform bacteria count and E. coli at site Du Choman (Mawat) S8

	Winter	Summer	Drinking Standards[1 & 2]	Surface Water Standards[2]		
Fecal Coli form Bacteria Colony/100 ml	7	---	0 in 100ml	Body-contact	Fishing and boating	Domestic water supply
				100 Colonies/100 mL	> 1000 Colonies/100 mL	> 2000 Colonies/100 mL

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Escherichia coli	+	---		
1= WHO, 2006; 2= CDWQ, 2006;				

Phytoplankton: The total phytoplankton count during this survey was 816.3 x 10^3 cell/L and a total of 35 species were recorded. The dominant species in this site were pennates (96.03%) (See Thirty-two pennate diatoms were recorded in this site, all found in low abundances. The main diatoms recorded were: *Diatoma vulgare, Achnanthes minutissima*, and *Cymbella microcephala* (334 x 10^3 cell/L, 155.8 x 10^3 cell/L and 77.9 x 10^3 cell/L respectively). In addition, the following species were also present; *Achnanthes microcephala, Cymbella ventricosa, Gomphonema angustatum, Navicula cryptocephala, Navicula parva, Nitzschia acicularis, Nitzschia amphibian, Nitzschia dissipata, Nitzschia frustulum* and *Nitzschia longissima*. This site is considered to have moderate diversity, very good richness and good evenness values (See Annex 2: Table 175, Table 177 & Table 179).

Table 112 below**Error! Reference source not found.**).

Thirty-two pennate diatoms were recorded in this site, all found in low abundances. The main diatoms recorded were: *Diatoma vulgare, Achnanthes minutissima*, and *Cymbella microcephala* (334 x 10^3 cell/L, 155.8 x 10^3 cell/L and 77.9 x 10^3 cell/L respectively). In addition, the following species were also present; *Achnanthes microcephala, Cymbella ventricosa, Gomphonema angustatum, Navicula cryptocephala, Navicula parva, Nitzschia acicularis, Nitzschia amphibian, Nitzschia dissipata, Nitzschia frustulum* and *Nitzschia longissima*. This site is considered to have moderate diversity, very good richness and good evenness values (See Annex 2: Table 175, Table 177 & Table 179).

Table 112: Number of species, total count and percentage for phytoplankton groups in Du Choman (Mawat) S8

Phytoplankton Groups (S8)	Sp. #	Total Count (cell x 103/L)	%
Cyanophyta	0	0	0.00
Euglenophyta	0	0	0.00
Pyrrhophyta	1	1	0.12
Cryptophyta	0	0	0.00
Chlorophyta	1	9.1	1.11
Bacillariophyceae/Centrales	1	22.3	2.73
Bacillariophyceae/Pennales	32	783.9	96.03
Total	35	816.3	100

Benthic Macroinvertebrates: Total density found was 317 indv. /m² and comparing with the other studied sites, this density was relatively moderate (

). EPT % was also moderate (

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) and the dominant species was the Small minnow mayfly *Fallceon* sp. which is known as a tolerant organism (pollution tolerance number ≈ 6). The relative diversity, richness, and evenness were moderate, good, and very good respectively (See Annex 4: Table 167, Table 169, & Table 171 respectively).

Based on the modified pollution tolerance and pollution indices, water quality was very good (see Annex 4**Error! Reference source not found.**) and this could be confirmed by the presence of the sensitive and very sensitive aquatic organisms such as the Common skimmer dragonfly larva *Erythrodiplax* sp. and Saddle-case caddisfly larva *Anagapetus* sp.

Briefly, we suggested considering the habitat here as non-impaired to moderately impaired and the water quality as very good (Refer to Methods & Procedures).

Heavy Metals in Water: This site was contaminated with Ni, Pb and Zn compared to natural river levels (see Table 113 below). The source of this contamination may be related to the rocks (geogenic). In addition to the geogenic source, past heavy bombardment of the area by conventional weapons may be a source of heavy metal contamination.

Table 113: Heavy metals in water of site Du Choman (Mawat) S8

Heavy Metal	Winter	River Standards [1&2]	Surface Water Standards [2,3&4]
Nickel (Ni) mg/L	**0.03**	0.0008	0.0005-0.006
Lead (Pb) mg/L	0.02	0.0015	0.09
Iron (Fe) mg/L	ND	0.67	0.22-0.35
Copper (Cu) mg/L	ND	0.002	0.27
Manganese (Mn)mg/L	ND	0.00002	0.07-0.5
Cadmium (Cd) mg/L	ND	0.00008	0.000005
Zinc (Zn) mg/L	**0.03**	0.0006	N/A
1= Allan and Castillo, 2007; 2=Kabata-Pendias and Mukherjee, 2007; 3=Agardy and Sullivan, 2005; 4=STF, 2000; ND=not detected; N/A=not available			

Heavy Metals in Sediments: Sediments of the Mawat site show contaminated sediments with Ni, Cd, Cu and Zn (see Table 114 below). Parent materials of the sediment upstream of the site (igneous and metamorphic rocks) may represent the source of excess concentration of heavy metals. In the past the area underwent heavily bombardment by conventional weapons that may represent a source of the sediment contamination.

Table 114: Heavy metals in sediment of Du Choman (Mawat) S8

Heavy Metal	Winter	Background [1]	CSQG [2]
Nickel (Ni) mg/kg	**458.6**	31	N/A
Lead (Pb) mg/kg	22.6	23	35
Iron (Fe) mg/kg	32606	N/A	N/A
Copper (Cu) mg/kg	**113**	25	35.7
Manganese (Mn) mg/kg	**1645.9**	400	N/A
Cadmium (Cd) mg/kg	**10.3**	N/A	0.6
Zinc (Zn) mg/kg	**280.8**	65	123
1= ASQ, 1993; 2= CSQG, 2002; N/A=not available			

Conservation Issues & Recommendations: It is necessary to identify the main source of the phosphorous in this area. The area was heavily bombarded by conventional weapons in the past, which may be a possible source of the water and sediment heavy metal contamination. Determining the level of heavy metals in soils and rocks upstream from this site to identify the baseline of heavy metals in local sediments is recommended.

The results from Du Choman (Mawat) (S8) site shows that though the water is not suitable for drinking without treatment its level of contaminated with fecal coliform bacteria is low in comparison to the surface water quality standards.

Phytoplankton results indicated oligotrophic water conditions during winter 2009. The benthic macroinvertebrate results for the Du Choman (Mawat) site during winter 2009 indicate a non-impaired to moderately impaired habitat and very good water quality.

6. Little Zab River/Above Du Choman Junction (S17) – Elev 651

Site Description: This site is located north of Sulaimani city and the town of Mawat. The station is along the sizeable Little Zab River which is approximately 20 meters in diameter and serves as the natural border between Iraqi Kurdistan and Iran. The water current runs at a high speed and the streambed is gravel and cobblestones. There were many algae on the rocks during the winter. There are mine fields in the area and the area was the scene of heavy fighting during the Iran/Iraq war in the 1980s.

Fuel spills as a result of smuggling activities were noted in winter, including broken plastic jerry cans which were seen on the banks and the gravel bars in addition to the faint smell of benzene in the air. In summer, Nature Iraq did not sample at this site but staff revisited the area and found extensive contamination of the site such as fuel spills due to smuggling activities (jerry cans were floating down the river at intervals, hundreds of cans were noted on the rock, and there was a film of fuel on the water in the side eddies in addition to a strong odor of fuel). Twenty liter jerry cans of fuel are being smuggled from Iran into Iraqi Kurdistan. Iranian border forces attempt to stop the trade and have blocked roads and even attacked smugglers they have found on the river but this has not stopped the trade. To avoid capture, smugglers throw the cans in the water and attempt to retrieve them downstream on the Kurdistan, Iraq side, but often enough cans slip through to break on the rocks and release their fuel into the water.

Plate

Observations (winter- 25 Jan 2009):

<u>*Water Quality:*</u> Little Zab River/Above Du Choman Junction (S17) Sample Site. For winter: Sampling Time 10:50 AM, Water Depth 0.3m, Air temperature 12°C, Water temperature18.2°C.

The water in this site was turbid and showed high dissolved oxygen (see Table 115 below). Contamination with NO2, NO3, HCO3, Ca, Mg, Cl, SO4, TP and Na was obvious in this site compared to the recommended levels in natural river and surface waters (see Table 98 below).

Table 115: Physical & Chemical Water quality parameters at Little Zab River/ Above Du Choman Junction (S17)

Parameters	Winter	River Standards[1&2]	Surface Water Standards [2,3&4]
Field Analysis			
Water Temperature °C	18.2	N/A	N/A
Conductivity µS/cm	389	N/A	<1275
pH	8.48	N/A	6-8.5
Turbidity NTU	**13.9**	N/A	10
TDS mg/L	232	N/A	500
Salinity ppt	ND	N/A	N/A
DO mg/L	14.47	N/A	>5
DO%	125.4	N/A	N/A
Secchi disc m	0.3	N/A	N/A

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Parameters	Winter	River Standards[1&2]	Surface Water Standards [2,3&4]
Lab Analysis			
TSS mg/L	0.008	N/A	N/A
TDS mg/L	251.5	N/A	500
BOD mg/L	ND	N/A	N/A
Orthophosphate (PO4) mg/L	0.02	10	N/A
Nitrite-Nitrogen (NO2) mg/L	**0.01**	0.001	N/A
Nitrate-Nitrogen (NO3) mg/L	2	1	10
Total Alkalinity as CaCO3 mg/L	134	N/A	>20
Bicarbonate (HCO3) mg/L	**163.48**	58.4	58
Total Hardness (TH) mg/L	182.53	N/A	N/A
Calcium (Ca) mg/L	**52.92**	15	15
Magnesium (Mg) mg/L	**10.42**	4.1	4.1
Chloride (Cl) mg/L	**8.96**	7.8	7.8
Total Nitrogen (TN) mg/L	36.86	N/A	N/A
Sulfate (SO4) mg/L	**35.05**	11.2	3.7
Total Phosphorous (TP) mg/L	**0.1**	0.025	N/A
Potassium (K) mg/L	**2.41**	2.3	2.3
Sodium (Na) mg/L	**17.85**	6.3	6.3
1= Allan and Castillo, 2007; 2=Kabata-Pendias and Mukherjee, 2007; 3=Agardy and Sullivan, 2005; 4=STF, 2000; ND=not detected; N/A=not available			

Bacteria & Coliform: In winter the water quality of the river was contaminated according to fecal coliform bacteria standards. This area showed a level of 920 colonies/100 ml (see Table 116 below).

Table 116: Fecal Coliform bacteria count and E. coli at site Little Zab River / Above Du Choman Junction (S17)

	Winter	Summer	Drinking Standards[1 & 2]	Surface Water Standards[2]		
				Body-contact	Fishing and boating	Domestic water supply
Fecal Coli form Bacteria Colony/100 ml	**920**	---	0 in 100ml	100 Colonies/100 mL	> 1000 Colonies/100 mL	> 2000 Colonies/100 mL
Escherichia coli	**+**	---				
1= WHO, 2006; 2= CDWQ, 2006						

Phytoplankton: The total phytoplankton count during this survey was 3032 x 10^3 cell/L and a total of 43 species were recorded. The dominant species in this site were pennates (98.27%) (see Table 117 below).

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The main diatoms recorded were: *Diatoma vulgare, Nitzschia dissipata, Cymbella tumida* and *Gomphoneis olivacea* (979.8 x 10^3 cell/L, 857.3 x 10^3 cell/L, 434.2 x 10^3 cell/L and 356.3 x 10^3 cell/L respectively). In addition the following pennate species were also recorded: *Cymbella microcephala, Cymbella ventricosa, Fragilaria vaucheriae, Navicula cryptocephala, Navicula gracilis* and *Surirella ovata.* This site is considered to have moderate diversity, very good richness and good evenness values (See Annex 2: Table 175, Table 177 & Table 179).

Table 117: Number of species, total count and percentage for phytoplankton groups at Little Zab River / Above Du Choman Junction (S17)

Phytoplankton Groups (S17)	Sp. #	Total Count (cell x 10^3/L)	%
Cyanophyta	3	29.2	0.96
Euglenophyta	0	0	0.00
Pyrrhophyta	1	1	0.03
Cryptophyta	0	0	0.00
Chlorophyta	3	11.1	0.37
Bacillariophyceae/Centrales	1	11.1	0.37
Bacillariophyceae/Pennales	35	2979.6	98.27
Total	43	3032	100

<u>*Benthic Macroinvertebrates:*</u> Total density found was 337 indv. /m² and comparing with the other studied sites, this density was relatively moderate (

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). EPT % was very low (

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) and the dominant species was the aquatic worm *Limnodrilus hoffmeisteri*, which is known as a very tolerant organism (pollution tolerance number ≈ 10). The relative diversity, richness, and evenness were moderate, good, and good respectively (See Annex 4: Table 167, Table 169, & Table 171 respectively).

Depending on the modified pollution tolerance and pollution indices, water quality was good (See Annex 1, Table 173) and this could be confirmed by the presence of the sensitive and tolerant aquatic organisms such as the Spinyleg dragonfly (*Dromogomphus* sp.), the Riffle beetle (*Neocylloepus* sp.), the Square-gilled mayfly (*Caenis* sp.1), and the White midge (*Paratrichocladius* sp.).

Briefly, we suggested considering the habitat here as moderately impaired and the water quality as good (See Methods & Procedures).

Heavy Metals in Water: The site was high in Ni, Pb, Mn, Cu, Mn and Zn when compared to natural river reference levels (see Table 118 below). The diversity of rock types (Volcanic, sedimentary and metamorphic rocks) found upstream of the site as well as fuel spills due to smuggling activities may be sources of the contamination with these heavy metals.

Table 118: Heavy metals in water of the Little Zab River/ Above Du Choman Junction (S17)

Heavy Metal	Winter	River Standards [1&2]	Surface Water Standards [2,3&4]
Nickel (Ni) mg/L	**0.03**	0.0008	0.0005-0.006
Lead (Pb) mg/L	0.02	0.0015	0.09
Iron (Fe) mg/L	0.03	0.67	0.22-0.35
Copper (Cu) mg/L	0.18	0.002	0.27
Manganese (Mn) mg/L	0.02	0.00002	0.07-0.5
Cadmium (Cd) mg/L	ND	0.00008	0.000005
Zinc (Zn) mg/L	**0.08**	0.0006	N/A
1= Allan and Castillo, 2007; 2=Kabata-Pendias and Mukherjee, 2007; 3=Agardy and Sullivan, 2005; 4=STF, 2000; ND=not detected; N/A=not available			

Heavy Metals in Sediments: Sediments of Little Zab River/Above Du Choman Junction site show sediments contaminated with Cd and Zn (see Table 119). Rock bodies that contain ore minerals rich in some heavy metals like Metabasalt and Gabbro found upstream of the site and fuel spills due to smuggling activities may be the source of the contamination with these heavy metals.

Table 119: Heavy metals in sediment of Little Zab River/ Above Du Choman Junction (S17)

Heavy Metal	Winter	Background[1]	CSQG[2]
Nickel (Ni) mg/kg	**296.8**	31	N/A
Lead (Pb) mg/kg	23.15	23	35
Iron (Fe) mg/kg	34045	N/A	N/A
Copper (Cu) mg/kg	N/A	25	35.7
Manganese (Mn) mg/kg	**1944.8**	400	N/A
Cadmium (Cd) mg/kg	**7.7**	N/A	0.6
Zinc (Zn) mg/kg	**291.3**	65	123
1= ASQ, 1993; 2= CSQG, 2002; N/A=not available			

Conservation Issues & Recommendations: The results recorded from Little Zab River/Above Du Choman Junction (S17) indicated significant fecal coliform bacteria contamination. Sewage, agriculture and grazing animals may all be sources. Mitigation of contamination and further monitoring is highly recommended

Phytoplankton results indicate mesotrophic waters conditions in the Little Zab above Du Choman Junction site during winter 2009. Benthic Macroinvertebrate results for the Little Zab River/Above Du Choman Junction site during winter 2009 indicate a moderately impaired habitat and good water quality.

Further study of the rocks and soil in the area around the Du Choman site is recommended to discover the effect of rocks on the heavy metal geochemistry in the water and sediments.

Fuel spills caused by fuel smuggling from Iran to Iraqi Kurdistan is a severe and chronic problem in the Little Zab River area because the river serves as the natural boundary between Iran and Iraq at this point. Local officials (Forestry, Border and Defense Force officials) indicated that the fuel smuggling is a regular and frequent occurrence and spills are common since the smugglers often simply throw the fuel cans in the water from the Iranian side and then try and catch them downstream on the Kurdistan-Iraq side. Many fuel cans are lost in the process (in summer, apparently one smuggler attempted to bring 1,000 fuel cans across but was only able to recover 300 from the river).

It is recommended that KRG and Iraqi security forces become more active in the area. The opening of an official border crossing at the site may have a positive effect in order to decrease the amount of smuggling. Ultimately, new development needs to come to the area to provide local people involved in the smuggling trade with alternative sources of income.

7. Mertka (S18) – Elev 579

Site Description: This site is located north of Qaladze town. The station is along the eastern bank of a small river called the Zharawa that runs with a fast current over a rocky riverbed. There is a village called Rishwan to the southeast, and Qandil Mountain is to the north. This site is a grazing area near agricultural fields. The water is primarily fed from snowfall.

Plate

Observations (Winter - 26 Jan 2009):

Water Quality: Mertka (S18) Sample Site. For winter: Sampling Time 11:52 AM, Water Depth 0.3m, Air temperature 13°C, Water temperature 9°C.

Some parameters at this site did exceed or came close to the standard levels (such as NO_2, HCO_3, SO_4 and TP), others are in the permissible levels for example chloride (see Table 120 below).

Table 120: Physical & Chemical Water quality parameters at site Mertka (S18)

Parameters	**Winter**	**River Standards[1&2]**	**Surface Water Standards[2,3&4]**
Field Analysis			
Water Temperature °C	9	N/A	N/A
Conductivity µS/cm	330	N/A	<1275
pH	8.11	N/A	6-8.5
Turbidity NTU	5.02	N/A	10
TDS mg/L	198	N/A	500
Salinity ppt	ND	N/A	N/A
DO mg/L	14.68	N/A	>5
DO%	135.4	N/A	N/A
Secchi disc m	0.3	N/A	N/A
Lab Analysis			
TSS mg/L	0.003	N/A	N/A

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Parameters	Winter	River Standards[1&2]	Surface Water Standards[2,3&4]
TDS mg/L	ND	N/A	500
BOD mg/L	ND	N/A	N/A
Orthophosphate (PO4) mg/L	0.01	10	N/A
Nitrite-Nitrogen (NO2) mg/L	**0.02**	0.001	N/A
Nitrate-Nitrogen (NO3) mg/L	1.1	1	10
Total Alkalinity as CaCO3 mg/L	76	N/A	>20
Bicarbonate (HCO3) mg/L	**92.72**	58.4	58
Total Hardness (TH) mg/L	184.47	N/A	N/A
Calcium (Ca) mg/L	ND	15	15
Magnesium (Mg) mg/L	ND	4.1	4.1
Chloride (Cl) mg/L	4.22	7.8	7.8
Total Nitrogen (TN) mg/L	37.82	N/A	N/A
Sulfate (SO4) mg/L	10.41	11.2	3.7
Total Phosphorous (TP) mg/L	**0.13**	0.025	N/A
Potassium (K) mg/L	ND	2.3	2.3
Sodium (Na) mg/L	ND	6.3	6.3
1= Allan and Castillo, 2007; 2=Kabata-Pendias and Mukherjee, 2007; 3=Agardy and Sullivan, 2005; 4=STF, 2000; ND=not detected; N/A=not available			

Bacteria & Coliform: The water in this site is not considered contaminated with fecal coliform bacteria (sewage contamination), although it does slightly exceed the normal range of surface standard for body contact (100 Colonies/100 ml); but this is negligible with respect to other water quality parameters (see Table 121).

Table 121: Fecal Coliform bacteria count and E. coli at site (Mertka (S18))

	Winter	Summer	Drinking Standards[1 & 2]	Surface Water Standards[2]		
				Body-contact	Fishing and boating	Domestic water supply
Fecal Coli form Bacteria Colony/100 ml	**130**	---	0 in 100ml	100 Colonies/100 mL	> 1000 Colonies/100 mL	> 2000 Colonies/100 mL
Escherichia coli	**+**	---				
1= WHO, 2006; 2= CDWQ, 2006						

Phytoplankton: The total phytoplankton count during this survey was 3751.7 x 10^3 cell/L and a total of 39 species were recorded. The dominant species in this site were pennates (100%) (see Table 122 below).

The most common diatoms recorded were: *Diatoma vulgare, Nitzschia dissipata, Gomphoneis olivacea, Cymbella turgid, Cymbella affinis* and *Cymbella tumida* (2293.6 x 10^3 cell/L, 456.5 x 10^3 cell/L, 289.5 x 10^3 cell/L, 155.8 x 10^3 cell/L, 122.5 x 10^3 cell/L and 122.5 x 10^3 cell/L respectively). In addition the following pennate species were also recorded: *Fragilaria ulna, Navicula cryptocephala, Navicula placentula,* and *Nitzschia acicularis*. This site is considered to have low diversity, very good richness and moderate evenness values (See Annex 2: Table 175, Table 177 & Table 179).

Table 122: Number of species, total count and percentage for phytoplankton groups in Mertka (S18)

Phytoplankton Groups (S18)	Sp. #	Total Count (cell x 10^3/L)	%
Cyanophyta	3	19.2	0.52
Euglenophyta	0	0	0.00
Pyrrhophyta	1	18.1	0.49
Cryptophyta	0	0	0.00
Chlorophyta	1	1	0.03
Bacillariophyceae/Centrales	1	11.1	0.30
Bacillariophyceae/Pennales	33	3702.3	100.00
Total	39	3751.7	101.33

<u>*Benthic Macroinvertebrates:*</u> Total density found was 172 indv. /m² and comparing with the other studied sites, this density was relatively low (

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). EPT % was moderate (

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) and the dominant species was the Small minnow mayfly *Fallceon* sp. which is known as a tolerant organism (pollution tolerance number ≈ 6). The relative diversity, richness, and evenness were moderate, good, and excellent respectively (See Annex 4: Table 167, Table 169, & Table 171 respectively).

Depending on the modified pollution tolerance and pollution indices, water quality was good to very good (see Annex 1, Table 173) and this could be confirmed by the presence of the sensitive and very sensitive aquatic organisms such as the riffle beetle *Neocylloepus* sp. and the Crane fly *Hexatoma* sp.

Briefly, we suggested considering the habitat here as moderately impaired and the water quality as good to very good (Refer to Methods & Procedures).

Heavy Metals in Water: This site shows high levels of Ni, Pb, Mn, Cu and Zn when compared to natural river levels (see Table 123 below). The rock units upstream (Qandil Ophiolites) may cause the excess level of heavy metals in the water of the site.

Table 123: Heavy metals in water of site Mertka (S18)

Heavy Metal	Winter	River Standards1&2	Surface Water Standards 2,3&4
Nickel (Ni) mg/L	**0.06**	0.0008	0.0005-0.006
Lead (Pb) mg/L	0.05	0.0015	0.09
Iron (Fe) mg/L	0.01	0.67	0.22-0.35
Copper (Cu) mg/L	0.05	0.002	0.27
Manganese (Mn)mg/L	0.01	0.00002	0.07-0.5
Cadmium (Cd) mg/L	ND	0.00008	0.000005
Zinc (Zn) mg/L	**0.02**	0.0006	N/A
1= Allan and Castillo, 2007; 2=Kabata-Pendias and Mukherjee, 2007; 3=Agardy and Sullivan, 2005; 4=STF, 2000; ND=not detected; N/A=not available			

Heavy Metals in Sediments: Sediments of the Mertka site show contaminated sediments with Ni, Cd and Zn (see Table 124 below). The parent material of sediments in the upstream (Qandil Ophiolites) may cause the excess level of heavy metals in sediments of the site. Some of the heavy metals show lower concentrations here than among the sediment of other samples from the Dukan watershed, such as copper.

Table 124: Heavy metals in sediment of Mertka (S18)

Heavy Metal	Winter	Background [1]	CSQG [2]
Nickel (Ni) mg/kg	**294.8**	31	N/A
Lead (Pb) mg/kg	27.7	23	35
Iron (Fe) mg/kg	35128	N/A	N/A
Copper (Cu) mg/kg	3.85	25	35.7
Manganese (Mn) mg/kg	1729.1	400	N/A
Cadmium (Cd) mg/kg	**7.05**	N/A	0.6
Zinc (Zn) mg/kg	**281.8**	65	123
1= ASQ, 1993; 2= CSQG, 2002; N/A=not available			

Conservation Issues & Recommendations: The water at this site is arguably one of the most potable for various uses among those sites surveyed during the winter-KBA. With regard to heavy metal levels, except for nickel, cadmium and zinc, sediment levels are relatively low at the site and the heavy metals in the water indicate that these minerals have an active source somewhere in the river. Consequently, more study is needed to understand this data.

Excess nutrient concentration may be related to the surrounding farmland. Communication with local farmers and related authorities is necessary to understand the type of the fertilizer that is commonly used in the surrounding agricultural fields.

The fecal coliform bacteria results from this site shows a moderate contamination with fecal coliform bacteria and this may comes from the villages near the site, and the grazing area near agricultural fields, further more monitoring are recommended.

The phytoplankton results indicated mesotrophic water conditions in Mertka during winter 2009. The benthic macroinvertebrate results for Mertka (S18) during winter 2009 indicate a moderately impaired habitat and good to very good water quality. This was the only sampling trip to this site conducted by Nature Iraq and more study is necessary to characterize the site.

8. *Darua Kotr (S19) – Elev 612*

Site Description: This site is located northwest of Qaladze town along a river with a fast running current. Due to drought conditions, what is typically a wide river is only a narrow, snow-fed stream. There is a village called Darua Kotr to the east, while the main access road is along the northeast side of the river. There is active grazing in the area along with high hills and mountains. A weir is located about 1-2 km upstream from the sampling site.

Plate

Observations (Winter – 26 Jan 2009):

Water Quality: Darua Kotr (S19) Sample Site. For winter: Sampling Time 09:50 AM, Water Depth 0.2m, Air temperature 11°C, Water temperature 7°C.

Water at this site was turbid and shows contamination with NO2, NO3, SO4, TP, HCO3, Ca, Mg and Na (see Table 125 below).

Table 125: Physical & Chemical Water quality parameters at site Darua Kotr (S19)

Parameters	**Winter**	**River Standards[1&2]**	**Surface Water Standards[2,3&4]**
Field Analysis			
Water Temperature °C	7	N/A	N/A
Conductivity µS/cm	299	N/A	<1275
pH	8.16	N/A	6-8.5
Turbidity NTU	24.8	N/A	10
TDS mg/L	180	N/A	500
Salinity ppt	ND	N/A	N/A
DO mg/L	11.72	N/A	>5
DO%	104.9	N/A	N/A
Secchi disc m	0.2	N/A	N/A
Lab Analysis			
TSS mg/L	0.007	N/A	N/A
TDS mg/L	188.5	N/A	500
BOD mg/L	ND	N/A	N/A
Orthophosphate (PO4) mg/L	0.01	10	N/A
Nitrite-Nitrogen (NO2) mg/L	**0.01**	0.001	N/A
Nitrate-Nitrogen (NO3) mg/L	3.51	1	10

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Parameters	Winter	River Standards[1&2]	Surface Water Standards[2,3&4]
Total Alkalinity as $CaCO_3$ mg/L	73	N/A	>20
Bicarbonate (HCO_3) mg/L	**89.06**	58.4	58
Total Hardness (TH) mg/L	175.73	N/A	N/A
Calcium (Ca) mg/L	**35.68**	15	15
Magnesium (Mg) mg/L	**8.65**	4.1	4.1
Chloride (Cl) mg/L	3.29	7.8	7.8
Total Nitrogen (TN) mg/L	31.73	N/A	N/A
Sulfate (SO_4) mg/L	**17.59**	11.2	3.7
Total Phosphorous (TP) mg/L	**0.11**	0.025	N/A
Potassium (K) mg/L	1.54	2.3	2.3
Sodium (Na) mg/L	7.24	6.3	6.3
1= Allan and Castillo, 2007; 2=Kabata-Pendias and Mukherjee, 2007; 3=Agardy and Sullivan, 2005; 4=STF, 2000; ND=not detected; N/A=not available			

Bacteria & Coliform: The water in this site is not considered contaminated, as the number of fecal coliform bacteria colonies was below all reference standards (33 colonies /100 ml) (see Table 126 below).

Table 126: Fecal Coliform bacteria count and E. coli at site (Darua Kotr (S19))

	Winter	Summer	Drinking Standards[1 & 2]	Surface Water Standards[2]		
				Body-contact	Fishing and boating	Domestic water supply
Fecal Coli form Bacteria Colony/100 ml	33	---	0 in 100ml	100 Colonies/100 mL	> 1000 Colonies/100 mL	> 2000 Colonies/100 mL
Escherichia coli	+	---				
1= WHO, 2006; 2= CDWQ, 2006;						

Phytoplankton: The total phytoplankton count during this survey was 388.3 x 10^3 cell/L and a total of 30 species were recorded. The dominant species in this site were pennates (98.45%) (see Table 127 below).

The most prevalent diatoms recorded were: *Diatoma vulgare, Achnanthes minutissima* and *Gomphoneis olivacea* (144.7 x 10^3 cell/L, 66.8 x 10^3 cell/L and 44.5 x 10^3 cell/L respectively. The following species were also recored: *Amphora veneta, Cocconeis placentula* var. *euglypta*, and *Cymbella microcephala*. This site is considered to have moderate diversity, very good richness and good evenness values (See Annex 2: Table 175, Table 177 & Table 179).

Table 127: Number of species, total count and percentage for phytoplankton groups in Darua Kotr S19

Phytoplankton Groups (S19)	Sp. #	Total Count (cell x 10^3/L)	%
Cyanophyta	1	1	0.26

Euglenophyta	0	0	0.00
Pyrrhophyta	1	1	0.26
Cryptophyta	0	0	0.00
Chlorophyta	1	1	0.26
Bacillariophyceae/Centrales	3	3	0.77
Bacillariophyceae/Pennales	24	382.3	98.45
Total	30	388.3	100.00

Benthic Macroinvertebrates: Total density found was 128 indv. /m² and comparing with the other studied sites, this density was relatively very low (

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). EPT % was also very low (

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) and the dominant species was the white midge *Pentaneura* sp., which is known as a tolerant organism (pollution tolerance number ≈ 6). The relative diversity, richness, and evenness were moderate, good, and very good respectively (See Annex 4: Table 167, Table 169, & Table 171 respectively).

Depending on the modified pollution tolerance and pollution indices, water quality was good (See Annex 1, Table 173) and this could be confirmed by the well presence of the tolerant species such as the white midges *Orthocladius clarkei, Paratrichocladius* sp., and *Pentaneura* sp. In addition, there was some sensitive species such as the Common net-spinning caddisfly *Ceratopsyche* sp.

Briefly, we suggested considering the habitat here as moderately impaired to somewhat severely impaired and the water quality as good (Refer to Methods & Procedures).

Heavy Metals in Water: This site had high levels of Ni, Pb, Mn, Cu and Zn compared to natural river levels (see Table 128Table 129 below). Geogenic source upstream of the river may be the source of heavy metal contamination.

Table 128: Heavy metals in water of site Darua Kotr (S19)

Heavy Metal	Winter	River Standards [1&2]	Surface Water Standards [2,3&4]
Nickel (Ni) mg/L	0.08	0.0008	0.0005-0.006
Lead (Pb) mg/L	0.05	0.0015	0.09
Iron (Fe) mg/L	ND	0.67	0.22-0.35
Copper (Cu) mg/L	0.07	0.002	0.27
Manganese (Mn)mg/L	0.01	0.00002	0.07-0.5
Cadmium (Cd) mg/L	ND	0.00008	0.000005
Zinc (Zn) mg/L	**0.03**	0.0006	N/A
1= Allan and Castillo, 2007; 2=Kabata-Pendias and Mukherjee, 2007; 3=Agardy and Sullivan, 2005; 4=STF, 2000; ND=not detected; N/A=not available			

Heavy Metals in Sediments: Sediments of Darua Kotr site show contamination with Ni, Cu, Cd and Zn (see Table 129 below). A geogenic source upstream of the river may be the source of heavy metal contamination.

Table 129: Heavy metals in sediment of Darua Kotr (S19)

Heavy Metal	Winter	Background[1]	CSQG[2]
Nickel (Ni) mg/kg	535.4	31	N/A
Lead (Pb) mg/kg	27.4	23	35
Iron (Fe) mg/kg	32259	N/A	N/A
Copper (Cu) mg/kg	**92.6**	25	35.7
Manganese (Mn) mg/kg	**1607.85**	400	N/A
Cadmium (Cd) mg/kg	**10.3**	1.1	0.6
Zinc (Zn) mg/kg	**312.8**	65	123
1= ASQ, 1993; 2= CSQG, 2002; N/A=not available			

Conservation Issues & Recommendations: The water in this site (Darua Kotr (S19)) is considerd as low levels of fecal coliform bacteria contamination and the low level for fecal coliform maybe coming from the grazing activity in the area, further monitorining is recommended.

The phytoplankton results for winter 2009 indicate oligotrophic water conditions in Darua Kotr. The benthic macroinvertebrate results for Darua Kotr during winter 2009 indicate a moderately impaired to somewhat severely impaired habitat and good water quality.

Water in the site shows nutrient and heavy metal contamination. The source of nutrient contamination was unknown (though could be attributed to sewage discharge from the surrounding village), while the heavy metals mayu result from geogenic sources upstream. Source of heavy metal contamination in sediments may also be geogenic in origin.

This river is a tributary of the Little Zab River and a keen interest should be taken in its well-being since it is used for domestic irrigation until it flows into the main Little Zab River.

9. Dukan (S2) – Pool Elev. 478.9 - Surveyed in winter only

Site Description: This site is a large lake and reservoir of about 25,000 ha that is fed by the Little Zab River from the northeast and the Hizop stream from the northwest. It is surrounded by mountains (Mt. Kosrat, Qarasrd, and Sara), hills, and lowland areas characterized by steppe grasslands and some oak forests. About 65 km northwest of Sulaimani City, there is a gorge that extends from the Turba Village to Bemusha Village. This gorge separates the larger, northern part of the lake from the small southern part of the lake. Dukan town is located on the south side of the smaller lake, below the dam. Villages and towns with agricultural land, such as Rania, Chwar Qurna, and Qala Dza, surround the lake with the most dense populations and agricultural development located to the northwest of the large lake. During winter sampling, the water level was low due to drought conditions and the low winter rainfall that had occurred by the time of sampling. The snow pack did not appear to be substantial in the winter of 2008 or 2009 and little snowmelt was evident from the mountains in Iran as well as those closer to the lake.

Plate 6: Survey Points at Dukan Lake (Google Earth, 2009)

Observations (Winter 19 Jan 2009):

Water Quality at S2A: Little Zab Input (S2A) Sample Site-For winter: Sampling Time- 10:49 am, Water Depth- 0.75m, Air temperature- 10°C, Water temperature-9.4°C.

The water at this site was turbid (see Figure 8 below) and shows high levels for some parameters such as NO2, NO3, SO4 and TP (see Table 130). The source of this contamination may be anthropogenic activities of the surrounding towns (i.e. untreated sewage).

Table 130: Physical & Chemical Water quality parameters at site Little Zab Input (S2A)

Parameters	Winter	River Standards [1&2]	Surface Water Standards [2,3&4]
Field Analysis			
Water Temperature °C	9.4	N/A	N/A
Conductivity µS/cm	320	N/A	<1275
pH	8.44	N/A	6-8.5
Turbidity NTU	**37.2**	N/A	10
TDS mg/L	192	N/A	500
Salinity ppt	ND	N/A	N/A
DO mg/L	12.07	N/A	>5
DO%	108.2	N/A	N/A
Secchi disc m	0.2	N/A	N/A
Lab Analysis			
TSS mg/L	0.034	N/A	N/A
TDS mg/L	210.5	N/A	500
BOD mg/L	ND	N/A	N/A
Orthophosphate (PO4) mg/L	0.02	10	N/A

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Parameters	Winter	River Standards [1&2]	Surface Water Standards [2,3&4]
Nitrate-Nitrogen (NO2) mg/L	0.03	0.001	N/A
Nitrate-Nitrogen (NO3) mg/L	1.34	1	10
Total Alkalinity as CaCO3 mg/L	66	N/A	>20
Bicarbonate (HCO3) mg/L	**80.52**	58.4	58
Total Hardness (TH) mg/L	166.99	N/A	N/A
Calcium (Ca) mg/L	**55.98**	15	15
Magnesium (Mg) mg/L	**10.78**	4.1	4.1
Chloride (Cl) mg/L	3.56	7.8	7.8
Total Nitrogen (TN) mg/L	32.68	N/A	N/A
Sulfate (SO4) mg/L	**21.94**	11.2	3.7
Total Phosphorous (TP) mg/L	**0.42**	0.025	N/A
Potassium (K) mg/L	2.28	2.3	2.3
Sodium (Na) mg/L	**6.61**	6.3	6.3
1= Allan and Castillo, 2007; 2=Kabata-Pendias and Mukherjee, 2007; 3=Agardy and Sullivan, 2005; 4=STF, 2000; ND=not detected; N/A=not available			

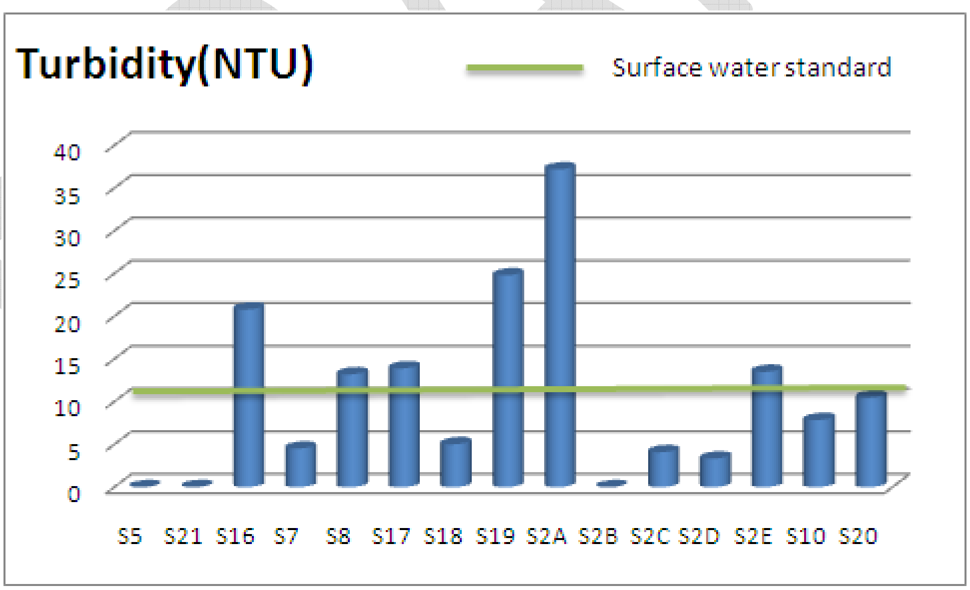

Figure 8: Turbidity in water samples of Little Zab River Watershed (Dukan Basin)

Bacteria & Coliform at S2A: The water in this site showed low contamination by fecal coliform bacteria but was above the standard for body contact; this was confirmed by the other water quality parameters.

Table 131: Fecal Coliform bacteria count and E. coli at site Dukan (S2A)

	Winter	Summer	Drinking	Surface Water Standards[2]

			Standards[1 & 2]			
Fecal Coli form Bacteria Colony/100 ml	220	---	0 in 100ml	Body-contact	Fishing and boating	Domestic water supply
				100 Colonies/100 mL	> 1000 Colonies/100 mL	> 2000 Colonies/100 mL
Escherichia coli	+	---				
1= WHO, 2006; 2= CDWQ, 2006						

Phytoplankton at S2A: The total phytoplankton count during this survey was 1714.5 x 10^3 cell/L and a total of 58 species were recorded. The dominant species in this site were Pyrrhophyta (Dinoflagellates) and centric diatoms (45.44% and 39.08%, respectively) (see Table 132 below).

The Pyrrhophyta was represented by both *Peridinium cinctum* and *Ceratium hirundinella* (751.8 x 10^3 cell/L and 27.2 x 10^3 cell/L, respectively). The dinoflagellate *Ceratium hirundinella* is a large planktonic alga common in mesotrophic and eutrophic lakes with stable stratification; it regulates its position in the water column by active migration and perhaps by changes in the shape and size of its horn-like projections (Heaney and Furnass, 1980, as cited in Wehr and Sheath, 2003).

Generally, Dinoflagellates are found in greatest abundance during the summer months, and may also be found in autumn, spring, and winter samples. Some species seem more prevalent in cooler months while some are exclusively cold-weather species.

Cyclotella ocellata was the most prevalent centric diatom (645.7 x 10^3 cell/L). Thirty-nine pennate diatoms were recorded, although these were found in low abundances, including *Achnanthes minutissima, Diatoma vulgare, Navicula cryptocephala, Nitzschia dissipata,* and *Surirella angustata*.

This site is considered to have low diversity, very good richness and moderate evenness values (See Annex 2: Table 175, Table 177 & Table 179).

Table 132: Number of species, total count and percentage for phytoplankton groups in Dokan Lake/Little Zab Input S2A

Phytoplankton Groups (S2A)	Sp. #	Total Count (cell x 10^3/L)	%
Cyanophyta	3	3	0.17
Euglenophyta	2	2	0.12
Pyrrhophyta	2	779	45.44
Cryptophyta	1	1	0.06
Chlorophyta	7	7	0.41
Bacillariophyceae/Centrales	4	670	39.08
Bacillariophyceae/Pennales	39	252.5	14.73
Total	58	1714.5	100

Water Quality at S2B: Sample Site-For winter: S2B-Surface, Sampling Time- 12:19 am, Date- 19/01/2009, Water Depth- 1m, Air temperature- 11°C, Water temperature-12.1°C.

S2B-Bottom, Sampling Time- 09:38 am, Date- 19/01/2009.

This site was contaminated with NO2, NO3, SO4 and TP (see Table 133 below). The bottom sample shows wide variations from the surface sample in some parameters like Ca and Mg.

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Table 133: Physical & Chemical Water quality parameters at site (S2B)

Parameters	**Surface**	**Bottom**	**River Standards[1&2]**	**Surface Water Standards[2,3&4]**
Field Analysis				
Water Temperature °C	12.1	ND	ΔT≤2 °C	N/A
Conductivity µS/cm	482	ND	N/A	<1275
pH	8.15	ND	6.5-9.7	6-8.5
Turbidity NTU	ND	ND	N/A	10
TDS mg/L	291	ND	≤12,000	500
Salinity ppt	ND	ND	N/A	N/A
DO mg/L	12.09	ND	> 5	>5
DO%	114.5	ND	N/A	N/A
Secchi disc m	0.3	ND	N/A	N/A
Lab Analysis				
TSS mg/L	0.027	ND	N/A	N/A
TDS mg/L	240	ND	N/A	500
BOD mg/L	ND	ND	N/A	N/A
Orthophosphate (PO4) mg/L	0.03	ND	10	N/A
Nitrite-Nitrogen (NO2) mg/L	**0.04**	**0.03**	0.001	N/A
Nitrate-Nitrogen (NO3) mg/L	10.32	ND	1	10
Total Alkalinity as CaCO3 mg/L	100	ND	N/A	>20
Bicarbonate (HCO3) mg/L	**75.64**	ND	58.4	58
Total Hardness (TH) mg/L	255.35	ND	N/A	N/A
Calcium (Ca) mg/L	48	34.85	15	15
Magnesium (Mg) mg/L	**5**	**19.39**	4.1	4.1
Chloride (Cl) mg/L	3.73	ND	7.8	7.8
Total Nitrogen (TN) mg/L	29.22	ND	N/A	N/A
Sulfate (SO4) mg/L	**40.06**	ND	11.2	3.7
Total Phosphorous (TP) mg/L	**0.21**	ND	0.025	N/A
Potassium (K) mg/L	2.01	1.76	2.3	2.3
Sodium (Na) mg/L	4.32	6.17	6.3	6.3

1= Allan and Castillo, 2007; 2=Kabata-Pendias and Mukherjee, 2007; 3=Agardy and Sullivan, 2005; 4=STF, 2000; ND=not detected; N/A=not available

Bacteria & Coliform at S2B: This site was considered contaminated with fecal coliform bacteria, with results of 1600 colonies/100 ml exceeding the normal fishing and boating standard (see Table 134 below). This may be because of sewage and other nutrient discharges from villages and towns such as Rania, Chwar Qurna, and Qaladza, as well as from agricultural lands in and around the lake.

Table 134: Fecal Coliform bacteria count and E. coli at site (Dukan (S2B))

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	Winter	Summer	Drinking Standards[1 & 2]	Surface Water Standards[2]		
Fecal Coli form Bacteria Colony/100 ml	**1600**	---	0 in 100ml	Body-contact	Fishing and boating	Domestic water supply
				100 Colonies/100 mL	> 1000 Colonies/100 mL	> 2000 Colonies/100 mL
Escherichia coli	+	---				
1= WHO, 2006; 2= CDWQ, 2006						

<u>*Phytoplankton at S2B:*</u> The total phytoplankton count during this survey was 1814.7 x 10^3 cell/L and a total of 64 species were recorded. The dominant species in this site were centric and pennate diatoms (44.79% and 36.85% respectively) (see Table 135 below).

The most common centric diatoms were *Cyclotella ocellata* and *Aulacoseira granulate* (545.6 x 10^3 cell/L and 244.9 x 10^3 cell/L, respectively. Both *Diatoma vulgare* and *Nitzschia dissipata* were the most dominant pennate diatoms. *Ceratium hirundinella* and *Peridinium cinctum*, were the only two dinoflagellates recorded (9.1 x 10^3 cell/L and 298.9 x 10^3 cell/L respectively).

This site had good diversity, very good richness and good evenness values (See Annex 2: Table 175, Table 177 & Table 179).

Table 135: Number of species, total count and percentage for phytoplankton groups in Dokan Lake/Near Rania S2B

Phytoplankton Groups (S2B)	Sp. #	Total Count (cell x 10^3/L)	%
Cyanophyta	3	29.2	1.59
Euglenophyta	0	0	0.00
Pyrrophyta	2	308	16.72
Cryptophyta	0	0	0.00
Chlorophyta	1	1	0.05
Bacillariophyceae/Centrales	5	824.9	44.79
Bacillariophyceae/Pennales	53	678.6	36.85
Total	64	1841.7	100

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<u>*Water Quality at S2C:*</u> Sample Site-For winter: S2C-Surface, Sampling Time- 10:16 am, Date- 20/01/2009, Water Depth- 13m, Air temperature- 8°C, Water temperature-10.3°C. <u>*S2C-Bottom*</u>, Sampling Time- 10:16 am, Date- 20/01/2009, Water temperature-10.3°C.

Water of this site was contaminated with TN, TP, HCO3, Ca, Mg and Na (see Table 136 below). Source of the nutrients may be from sewages and agricultural practices from the surrounding towns and farmlands. Variation between surface and bottom sample parameters was obvious in this site. Reason of this variation was unknown.

Table 136: Physical & Chemical Water quality parameters at site S2C

Parameters	Surface	Bottom	Walker Lake[1]	Surface Water Standards[2,3&4]
Field Analysis				
Water Temperature °C	**10.3**	**10.3**	ΔT≤2 °C	N/A

Parameters	Surface	Bottom	Walker Lake[1]	Surface Water Standards[2,3&4]
Conductivity µS/cm	298	298	N/A	<1275
pH	8.2	8.3	6.5-9.7	6-8.5
Turbidity NTU	4.09	4.29	N/A	10
TDS mg/L	179	180	≤12,000	500
Salinity ppt	ND	ND	N/A	N/A
DO mg/L	10.83	9.64	> 5	>5
DO%	104.5	89.9	N/A	N/A
Secchi disc m	2	ND	N/A	N/A
Lab Analysis				
TSS mg/L	0.001	ND	≤ 25	N/A
TDS mg/L	162	223	≤12,000	500
BOD mg/L	ND	ND	N/A	N/A
Orthophosphate (PO4) mg/L	0.02	0.01	N/A	N/A
Nitrite-Nitrogen (NO2) mg/L	0.03	0.02	≤0.06	N/A
Nitrate-Nitrogen (NO3) mg/L	1.51	1.68	≤90	10
Total Alkalinity as CaCO3 mg/L	64	61	N/A	>20
Bicarbonate (HCO3) mg/L	**65.88**	**74.42**	N/A	58
Total Hardness (TH) mg/L	158.26	155.34	N/A	N/A
Calcium (Ca) mg/L	**49.55**	**64.8**	N/A	15
Magnesium (Mg) mg/L	**6.35**	**6.15**	N/A	4.1
Chloride (Cl) mg/L	3.24	3.41	≤3,200	7.8
Total Nitrogen (TN) mg/L	**26.46**	**35.87**	≤0.18	N/A
Sulfate (SO4) mg/L	**26.11**	**27.31**	N/A	3.7
Total Phosphorous (TP) mg/L	**1.63**	0.81	≤0.82	N/A
Potassium (K) mg/L	2.17	2.14	N/A	2.3
Sodium (Na) mg/L	**22.05**	**21.5**	N/A	6.3
1= NDEP, 1999; 2=Kabata-Pendias and Mukherjee, 2007; 3=Agardy and Sullivan, 2005; 4=STF, 2000; ND=not detected; N/A=not available				

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<u>Bacteria & Coliform at S2C:</u> Though *E. coli* and fecal coliform was not present, this site was not contaminated with fecal coliform bacteria (see Table 137 below).

Table 137: Fecal Coliform bacteria count and E. coli at site Dukan (S2C)

	Winter	Summer	Drinking Standards[1 & 2]	Surface Water Standards[2]		
				Body-contact	Fishing and boating	Domestic water supply
Fecal Coli form Bacteria Colony/100 ml	0	---	0 in 100ml	100 Colonies/100 mL	> 1000 Colonies/100 mL	> 2000 Colonies/100 mL

	Winter	Summer	Drinking Standards[1 & 2]	Surface Water Standards[2]
Escherichia coli	-	---		
1= WHO, 2006; 2= CDWQ, 2006				

Phytoplankton at S2C: The total phytoplankton count during this survey was 587.6 x 10^3 cell/L and a total of 17 species were recorded. The dominant species in this site were centric diatoms (83.36%) (see Table 138 below).

Aulacoseira granulate (378.5 x 10^3 cell/L) was the most common diatom. Both, *Diatoma vulgare* and *Nitzschia dissipata* were the dominant pennate diatoms. *Ceratium hirundinella* and *Peridinium cinctum* were the only two dinoflagellates recorded (9.1 x 10^3 cell/L and 45.3 x 10^3 cell/L, respectively).

This site had low diversity, good richness and moderate evenness values (See Annex 2: Table 175, Table 177 & Table 179).

Table 138: Number of species, total count and percentage for phytoplankton groups in Dokan Lake/Centre of Lake S2C

Phytoplankton Groups (S2C)	Sp. #	Total Count (cell x 10^3/L)	%
Cyanophyta	0	0	0.00
Euglenophyta	0	0	0.00
Pyrrophyta	2	54.4	9.26
Cryptophyta	1	1	0.17
Chlorophyta	6	6	1.02
Bacillariophyceae/Centrales	3	489.8	83.36
Bacillariophyceae/Pennales	5	36.4	6.19
Total	17	587.6	100

Water Quality at S2D: Sample Site-For winter: S2D-Surface, Sampling Time- 12:09 am, Date- 20/01/2009, Water Depth- 45m, Air temperature- 12°C, Water temperature-11.6°C. *S2D-Bottom*: Sampling Time- 11.6am, Date- 20/01/2009, Water temperature-11.3°C.

Contamination of this site with TP, TN, SO4 and Na (see Figure 9 below, west part of the watershed shows higher concentration of Na) was obvious and there was little variations recorded between surface and bottom samples (see Table 139 below). Source of this contamination may be from sewages and agricultural practices from the surrounding towns and farmlands.

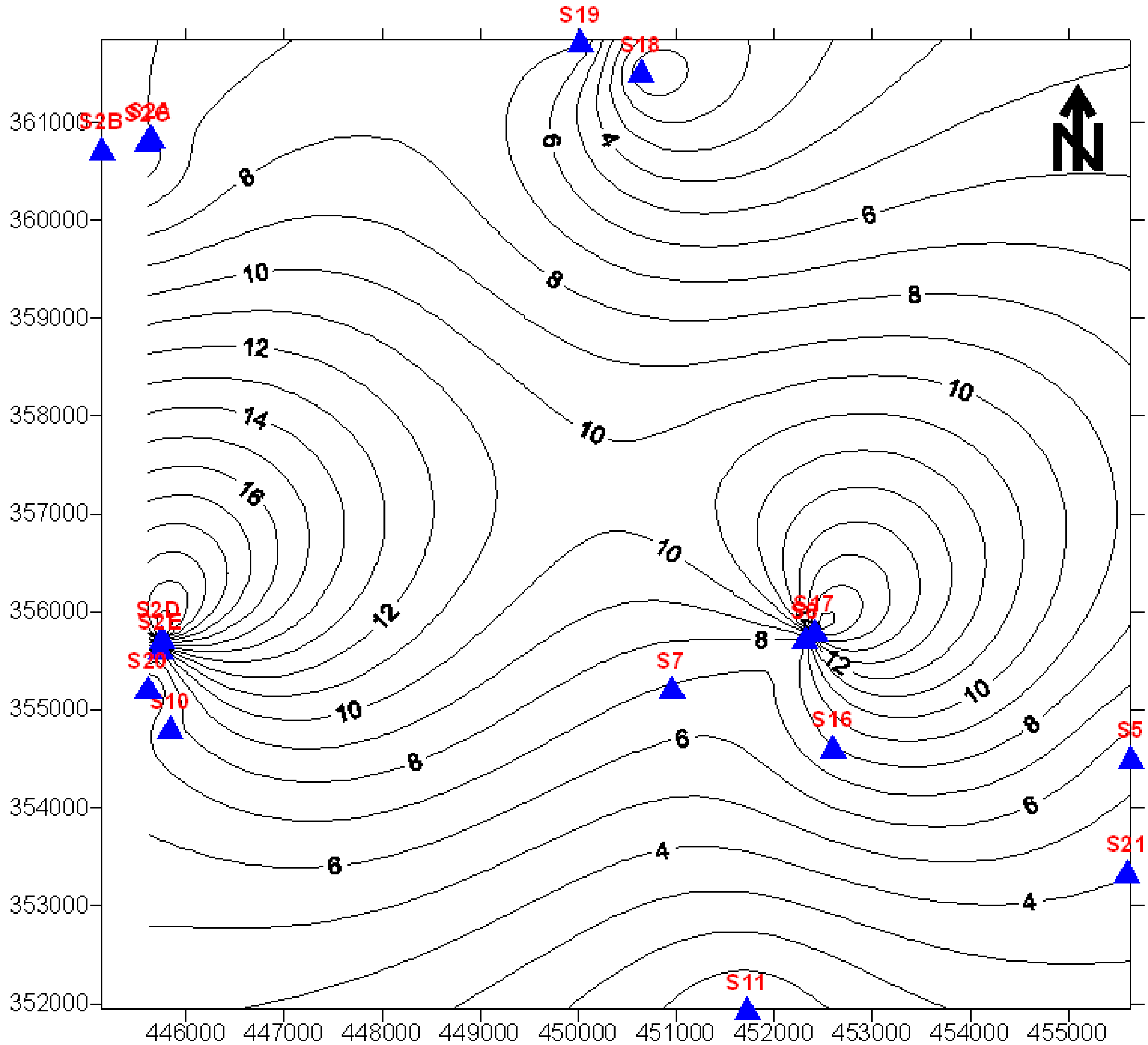

Figure 9: Concentration distribution map of sodium in water samples of Little Zab River Watershed (Dukan Basin)

Table 139: Physical & Chemical Water quality parameters at site (S2D)

Parameters	**Surface**	**Bottom**	**Walker Lake[1]**	**Surface Water Standards[2,3&4]**
Field Analysis				
Water Temperature °C	11.6	11.3	ΔT≤2 °C	N/A
Conductivity µS/cm	292	292	N/A	<1275
pH	8.2	8.2	6.5-9.7	6-8.5
Turbidity NTU	3.34	4.07	N/A	10
TDS mg/L	176	176	≤12,000	500
Salinity ppt	ND	ND	N/A	N/A
DO mg/L	10.3	8.45	> 5	>5
DO%	98.2	79.7	N/A	N/A
Secchi disc m	3	ND	N/A	N/A

Parameters	Surface	Bottom	Walker Lake[1]	Surface Water Standards[2,3&4]
Lab Analysis				
TSS mg/L	0.06	0.035	≤ 25	N/A
TDS mg/L	207	181	≤12,000	500
BOD mg/L	ND	ND	N/A	N/A
Orthophosphate (PO4) mg/L	0.01	0.01	N/A	N/A
Nitrite-Nitrogen (NO2) mg/L	0.02	0.03	≤0.06	N/A
Nitrate-Nitrogen (NO3) mg/L	1.36	1.37	≤90	10
Total Alkalinity as CaCO3 mg/L	59	58	N/A	>20
Bicarbonate (HCO3) mg/L	**71.98**	**7076**	N/A	58
Total Hardness (TH) mg/L	156.31	152.43	N/A	N/A
Calcium (Ca) mg/L	**40.99**	**39.44**	N/A	15
Magnesium (Mg) mg/L	**9.88**	**9.58**	N/A	4.1
Chloride (Cl) mg/L	3.2	3.15	≤3,200	7.8
Total Nitrogen (TN) mg/L	**30.23**	**32.43**	≤0.18	N/A
Sulfate (SO4) mg/L	**20.26**	**19.83**	N/A	3.7
Total Phosphorous (TP) mg/L	**0.95**	**1.01**	≤0.82	N/A
Potassium (K) mg/L	2.17	**2.36**	N/A	2.3
Sodium (Na) mg/L	**8.81**	**9.03**	N/A	6.3
1= NDEP, 1999; 2=Kabata-Pendias and Mukherjee, 2007; 3=Agardy and Sullivan, 2005; 4=STF, 2000; ND=not detected; N/A=not available				

Bacteria & Coliform at S2D: Though *E. coli* was not present, the fecal coliform count was zero and thus the site is not considered contaminated by sewage (See table below).

Table 140: Fecal Coliform bacteria count and E. coli at site Dukan (S2D)

	Winter	Summer	Drinking Standards[1 & 2]	Surface Water Standards[2]		
				Body-contact	Fishing and boating	Domestic water supply
Fecal Coli form Bacteria Colony/100 ml	0	---	0 in 100ml	100 Colonies/100 mL	> 1000 Colonies/100 mL	> 2000 Colonies/100 mL
Escherichia coli	-	---				
1= WHO, 2006; 2= CDWQ, 2006						

Phytoplankton at S2D: Total phytoplankton count: 562 x 103cell/L. species number: 25. This site was dominated by the centric diatoms (69.32%) (see Table 141 below).

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Aulacoseira granulate and *Cyclotella ocellata* (378.5 x 103cell/L and 111.3 x 103cell/L, respectively) were the dominant centric diatoms. *Stephanodiscus astrea* was also recorded (33.4 x 103cell/L). *Peridinium cinctum* was the only dinoflagellate recorded (90.6 x 103cell/L). The pennate diatoms were mainly represented by *Achnanthes minutissima*, *Fragilaria acus* and *Fragilaria acus* var. *radians*.

This site had moderate diversity, good richness and good evenness values (See Annex 2: Table 175, Table 177 & Table 179).

Table 141: Number of species, total count and percentage for phytoplankton groups in Dokan Lake/Before Dam S2D

Phytoplankton Groups (S2D)	Sp. #	Total Count (cell x 103/L)	%
Cyanophyta	0	0	0.00
Euglenophyta	0	0	0.00
Pyrrophyta	1	90.6	16.12
Cryptophyta	0	0	0.00
Chlorophyta	7	15.1	2.69
Bacillariophyceae/Centrales	3	389.6	69.32
Bacillariophyceae/Pennales	14	66.7	11.87
Total	25	562	100

<u>*Water Quality at Little Zab River after Dukan Dam (S2E):*</u> Sample Site-For winter: S2E Sampling Time- 10:37 am, Date- 21/01/2009, Water Depth- 0.5m, Air temperature- 9°C, Water temperature- 11.4°C.

Water of this site was turbid and shows contamination with NO3 and SO4 with excess levels of alkaline elements HCO3, Ca and Mg (see Table 142 below) compared to river and surface water standards.

Table 142: Physical & Chemical Water quality parameters at site Little Zab River after Dukan Dam (S2E)

Parameters	Winter	River Standards [1&2]	Surface Water Standards [2,3&4]
Field Analysis			
Water Temperature °C	11.4	N/A	N/A
Conductivity µS/cm	310	N/A	<1275
pH	8	N/A	6-8.5
Turbidity NTU	**13.5**	N/A	10
TDS mg/L	187	N/A	500
Salinity ppt	ND	N/A	N/A
DO mg/L	11.4	N/A	>5
DO%	107.3	N/A	N/A
Secchi disc m	0.4	N/A	N/A
Lab Analysis			
TSS mg/L	0.012	N/A	N/A
TDS mg/L	177	N/A	500
BOD mg/L	ND	N/A	N/A
Orthophosphate (PO4) mg/L	ND	10	N/A
Nitrite-Nitrogen (NO2) mg/L	ND	0.001	N/A
Nitrate-Nitrogen (NO3) mg/L	1.74	1	10

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Parameters	Winter	River Standards [1&2]	Surface Water Standards [2,3&4]
Total Alkalinity as $CaCO_3$ mg/L	62	N/A	>20
Bicarbonate (HCO_3) mg/L	**75.64**	58.4	58
Total Hardness (TH) mg/L	177.67	N/A	N/A
Calcium (Ca) mg/L	**76**	15	15
Magnesium (Mg) mg/L	**7.55**	4.1	4.1
Chloride (Cl) mg/L	3.14	7.8	7.8
Total Nitrogen (TN) mg/L	ND	N/A	N/A
Sulfate (SO_4) mg/L	**21.58**	11.2	3.7
Total Phosphorous (TP) mg/L	0.06	0.025	N/A
Potassium (K) mg/L	2.26	2.3	2.3
Sodium (Na) mg/L	**20.88**	6.3	6.3
1= Allan and Castillo, 2007; 2=Kabata-Pendias and Mukherjee, 2007; 3=Agardy and Sullivan, 2005; 4=STF, 2000; ND=not detected; N/A=not available			

Bacteria & Coliform at Little Zab River after Dukan Dam (S2E): The water in this site is not contaminated with fecal coliform bacteria; 5 colonies/100 ml were found which is in the normal range according to the water quality standards (see Table 143 below).

Table 143: Fecal Coliform bacteria count and E. coli at site Little Zab River after Dukan Dam (S2E)

	Winter	Summer	Drinking Standards[1 & 2]	Surface Water Standards[2]		
Fecal Coli form Bacteria Colony/100 ml	5	---	0 in 100ml	Body-contact	Fishing and boating	Domestic water supply
				100 Colonies/100 mL	> 1000 Colonies/100 mL	> 2000 Colonies/100 mL
Escherichia coli	+	---				
1= WHO, 2006; 2= CDWQ, 2006						

Phytoplankton at Little Zab River after Dukan Dam (S2E): The total phytoplankton count during this survey was 999.5 x 10^3 cell/L and a total of 35 species were recorded. The dominant species in this site were centric diatoms (77.97%) (see Table 144 below).

Cyclotella ocellata and *Aulacoseira granulate* (601.2 x 10^3 cell/L and 155.8 x 10^3 cell/L, respectively) were the dominant centric diatoms. Both *Diatoma vulgare* and *Nitzschia dissipata* were the dominant pennate diatoms. *Stephanodiscus astrea* was also recorded (22.3 x 10^3 cell/L).

The pennate diatoms were represented by twenty-seven species found in low abundances mainly represented by: Achnanthes minutissima, Cymbella microcephala, Cymbella turgid, Cymbella ventricosa, Fragilaria construens, Navicula gracilis, Nitzschia dissipata and Nitzschia palea. This site had low diversity, very good richness and moderate evenness values (See Annex 2: Table 175, Table 177 & Table 179).

Table 144: Number of species, total count and percentage for phytoplankton groups in Little Zab River after Dukan Dam (S2E)

Phytoplankton Groups (S2E)	Sp. #	Total Count (cell x 10^3/L)	%
Cyanophyta	1	1	0.10
Euglenophyta	0	0	0.00
Pyrrophyta	1	9.1	0.91
Cryptophyta	0	0	0.00
Chlorophyta	3	3	0.30
Bacillariophyceae/Centrales	3	779.3	77.97
Bacillariophyceae/Pennales	27	207.1	20.72
Total	35	999.5	100

<u>Benthic Macroinvertebrates at Little Zab River after Dukan Dam (S2E):</u> Total density found was 235 indv. /m² and comparing with the other studied sites, this density was relatively low (

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). EPT % was very low (

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) and the dominant organisms were the aquatic earthworms, which are known as very tolerant organisms (pollution tolerance number ≈ 10). Although the relative evenness was excellent (Annex 4: **Error! Reference source not found.**), the relative diversity and richness were good (Annex 4: **Error! Reference source not found.** & **Error! Reference source not found.** respectively).

Based on the modified pollution tolerance and pollution indices, water quality was fair to good (See Annex 1**Error! Reference source not found.**) and this could be confirmed by the presence of the tolerant aquatic organisms such as the air-breathing freshwater snail *Lymnaea auricularia* and the Minute moss beetle *Limnebius* sp. 2, and the presence of some sensitive organisms such as the Long-toed beetle *Dryops* sp.

Briefly, we suggested considering the habitat here as moderately impaired and the water quality as fair to good (Refer to Methods & Procedures).

Heavy Metals in Water: Generally sampling sites at Dukan Lake show water with heavy metal contamination based on the surface water quality standards used as references (see Table 145 below). The main source of heavy metal contamination in water samples from Dukan Lake may be geogenic (the majority of the Little Zab River tributaries are coming from Iran, passing above igneous and metamorphic rocks territories containing heavy metals). Other sources are the sewage of surrounding towns and agricultural practices. For site S2E, tourist activity may be an added source of contamination.

Table 145: Heavy Metals in water of Dukan Lake Watershed

	Heavy Metals	**Ni mg/L**	**Pb mg/L**	**Fe mg/L**	**Cu mg/L**	**Mn mg/L**	**Cd mg/L**	**Zn mg/L**
S2A	Winter	ND	ND	0.03	ND	0.01	ND	**0.05**
S2B	Winter	**0.04**	0.03	0.03	ND	ND	ND	**0.08**
S2C-S	Winter	**0.05**	0.02	ND	0.02	ND	ND	**0.01**
S2C-B	Winter	**0.02**	ND	0.00	0.05	0.01	ND	**0.07**
S2D-S	Winter	**0.05**	0.03	ND	0.08	0.01	0.00	**0.06**
S2D-B	Winter	ND	ND	ND	0.02	0.01	ND	**0.05**
S2E	Winter	0.09	0.05	0.01	ND	0.01	ND	**0.04**
River[1&2]		0.0005-0.006	0.0015	0.67	0.002	0.00002	0.00008	0.0006
Surface Water[2,3&4]		0.0005-0.006	0.09	0.22-0.35	0.27	0.07-0.5	0.000005	N/A
1= Allan and Castillo, 2007; 2=Kabata-Pendias and Mukherjee, 2007; 3=Agardy and Sullivan, 2005; 4=STF, 2000; ND=not detected; N/A=not available								

Heavy Metals in Sediments: Sediments of Dukan Lake Watershed site also show sediments contaminated with Cd, Pb, Cu, Zn and Ni (see Table 146 below). Contamination of S2E sediments with Pb is higher than among all sites, just as was found in the sediments of the site in KBA 2008 survey. Geogenic source, sewage disposal and agrochemical use may be the main sources of contamination in samples of the Dukan Lake sediments.

Table 146: Heavy Metals in sediments of Dukan Lake Watershed

	Heavy Metals	**Cd mg/kg**	**Cu mg/kg**	**Zn mg/kg**	**Pb mg/kg**	**Mn mg/kg**	**Fe mg/kg**	**Ni mg/kg**
S2A	Winter	**8.3**	**111.9**	**289.05**	**38.9**	**1497.825**	38109	**469.8**
S2B	Winter	**4.85**	**87.8**	**244.3**	**38.95**	**1642.8**	31988	**1292.5**
S2C	Winter	**6.5**	**103.9**	**303.1**	34.4	**1919.9**	37806	**469.8**
S2D	Winter	**6.6**	**118.4**	**371.4**	**37.4**	**1578**	38960	**741.5**
S2E	Winter	**10.1**	**94.9**	**312.175**	**62.1**	**1597.25**	30878	**611.4**

Background [1]	N/A	25	65	23	400	N/A	31
CSQG [2]	0.6	35.7	123	35	N/A	N/A	N/A
1= ASQ, 1993; 2= CSQG, 2002; N/A=not available							

Conservation Issues & Recommendations: Generally, the Dukan Lake site water samples show nutrient contamination (thought nitrites tended to be lower in some sites) and heavy metals likely related to sewage, agricultural runoff, tourist activities and other anthropogenic activities. Additionally, geogenic sources and sewage disposal are likely the main sources of heavy metal contamination. Site S2C shows obvious variation between water quality parameters in the surface and bottom samples, and the reason of this variation must be determined.

Retaining ponds and small dams within the contaminated tributaries of the Little Zab River are recommended to remediate and minimizing the contaminant load in the Dukan Lake.

The bacteria results from the Dukan sites varied between contaminated and non-contaminated water. The results from Little Zap Input (S2A) and Near Rania (S2B) are contaminated with fecal coliform bacteria and this is related to sewage, agricultural runoff, grazing animals and tourist activities. On the other hand the waters from Center of Lake (S2C), Before Dam (S2D) and Little Zab/After Dam (S2E) are considerd as non-contaminated water with fecal coliform bacteria. More investigations and monitoring trips are recommended.

The phytoplankton results for Dukan Lake during winter 2009 indicate oligotrophic-mesotrophic water conditions. Dukan Lake is primarily inhabited by the centric diatoms compared with the other phytoplankton groups that were found in low abundances during the survey period.

During winter 2009, the benthic macroinvertebrate results for Little Zab River/After Dukan Dam (S2E) indicate a moderately impaired habitat and fair to good water quality.

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10. Chami Rezan (S10) - Elev 530

Site Description: In 2007, this area was sampled at two locations along a small stream called Chemi Rezan. At this time, the sample points were upstream along the main channel and on a secondary channel feeding into Chemi Rezan. These sites, particularly the second point, were found to have significant human impact due to agriculture and tourism. Though not sampled in winter 2008 for logistical reasons, in summer 2008 a single, new sample point was chosen downstream from the original points along the main Chemi Rezan channel where the stream enters a narrow, winding wadi which is primarily affected by cattle grazing. The site is surrounded by mountains and rocky ridges, while the stream itself is surrounded by trees and some reeds at this location. Algae were found on the rocks and the water was turbid. Trash from the popular picnicking area upstream was found, and many frogs were seen. There are three villages upstream of the point called Zarzy, Zulkan and Awalan.

Plate

Observations (27 Jan 2009):

Water Quality: Chemi Rezan (S10) Sample Site-For winter: S10, Sampling Time- 10:18 am, Water Depth- 0.3m, Air temperature- 11°C, Water temperature-9.2°C.

This site was contaminated with NO_2, NO_3, Cl, SO_3, TP, HCO_3, Na, Ca and Mg compared to river and surface water standards (see Table 147 below). The source of this contamination may be the tourism activity and agricultural practices.

Table 147: Physical & Chemical Water quality parameters at Chemi Rezan (S10)

Parameters	Winter	River Standards [1&2]	Surface Water Standards [2,3&4]
Field Analysis			
Water Temperature °C	9.2	N/A	N/A
Conductivity µS/cm	549	N/A	<1275
pH	8.44	N/A	6-8.5
Turbidity NTU	7.85	N/A	10
TDS mg/L	330	N/A	500
Salinity ppt	ND	N/A	N/A
DO mg/L	11.10	N/A	>5
DO%	102.3	N/A	N/A
Secchi disc m	0.3	N/A	N/A
Lab Analysis			
TSS mg/L	0.004	N/A	N/A
TDS mg/L	286.5	N/A	500
BOD mg/L	ND	N/A	N/A
Orthophosphate (PO4) mg/L	0.01	10	N/A
Nitrite-Nitrogen (NO2) mg/L	**0.01**	0.001	N/A
Nitrate-Nitrogen (NO3) mg/L	2.63	1	10
Total Alkalinity as CaCO3 mg/L	134.5	N/A	>20
Bicarbonate (HCO3) mg/L	**200.11**	58.4	58
Total Hardness (TH) mg/L	300.98	N/A	N/A
Calcium (Ca) mg/L	**40.95**	15	15
Magnesium (Mg) mg/L	**26.9**	4.1	4.1
Chloride (Cl) mg/L	**19.96**	7.8	7.8
Total Nitrogen (TN) mg/L	34.11	N/A	N/A
Sulfate (SO4) mg/L	**53.8**	11.2	3.7
Total Phosphorous (TP) mg/L	**0.11**	0.025	N/A
Potassium (K) mg/L	1.7	2.3	2.3
Sodium (Na) mg/L	**7.79**	6.3	6.3
1= Allan and Castillo, 2007; 2=Kabata-Pendias and Mukherjee, 2007; 3=Agardy and Sullivan, 2005; 4=STF, 2000; ND=not detected; N/A=not available			

Bacteria & Coliform: The water at this site considered is not contaminated with fecal coliform bacteria as the results indicate a presence of 17 colony/100 ml, which is lower than the normal range of surface water quality (see Table 148). This low quantity of bacteria may result from tourism activity and agricultural practices.

Table 148: Fecal Coliform bacteria count and E. coli at site Chemi Rezan (S10)

	Winter	Summer	Drinking Standards [1 & 2]	Surface Water Standards [2]		
Fecal Coli form Bacteria	**17**	---	0 in 100ml	Body-contact	Fishing and boating	Domestic water supply

	Winter	Summer	Drinking Standards[1 & 2]	Surface Water Standards[2]		
Colony/100 ml				100 Colonies/100 mL	> 1000 Colonies/100 mL	> 2000 Colonies/100 mL
Escherichia coli	+	---				
1= WHO, 2006; 2= CDWQ, 2006						

<u>*Phytoplankton:*</u> The total phytoplankton count during this survey was 999.5 x 10^3 cell/L and a total of 35 species were recorded. The dominant species in this site were pennate diatoms (94.53%) (see Table 149 below).

Achnanthes affinis was the main dominant diatom (111.3 x 10^3 cell/L), in addition to the presence of *Achnanthes minutissima, Cymbella affinis, Diatoma vulgar, Fragilaria brevistriata*, and *Navicula cryptocephala*. This site had moderate diversity, very good richness and very good evenness values (See Annex 2: Table 175, Table 177 & Table 179).

Table 149: Number of species, total count and percentage for phytoplankton groups in Chami Razan S10

Phytoplankton Groups (S10)	Sp. #	Total Count (cell x 10^3/L)	%
Cyanophyta	1	1	0.26
Euglenophyta	0	0	0.00
Pyrrophyta	1	9.1	2.35
Cryptophyta	0	0	0.00
Chlorophyta	1	9.1	2.35
Bacillariophyceae/Centrales	2	2	0.52
Bacillariophyceae/Pennales	31	366.1	94.53
Total	36	387.3	100

<u>*Benthic Macroinvertebrates*</u>: Total density found was 410 indv. $/m^2$ and comparing with the other studied sites, this density was relatively moderate (

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). EPT % was also moderate (

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) and the dominant species was the aquatic worm Limnodrilus hoffmeisteri, which is known as very tolerant organism (pollution tolerance number ≈ 10). The relative diversity, richness, and evenness were good, very good, and very good respectively (See Annex 4: Table 167, Table 169, & Table 171 respectively).

Depending on the modified pollution tolerance and pollution indices, water quality was very good to excellent (See Annex 1, Table 173) and this could be confirmed by the well presence of the sensitive and very sensitive aquatic organisms such as the Flat-headed mayfly Macdunnoa sp.1, the Humpless-case caddisfly Amiocentrus sp., the Snaketail dragonfly Ophiogomphus sp., and the Crane fly Hexatoma sp.

Briefly, we suggested considering the habitat here as non-impaired to moderately impaired and the water quality as very good to excellent (Refer to Important Notes on Methods & Procedures).

Heavy Metals in Water: This site was contaminated with Ni and Zn compared to natural river levels and surface water standards (see Table 150 below), and the levels of Pb, Mn, & Cu was also quite high; this may be from agricultural pesticide (Hem, 1985).

Table 150: Heavy metals in water of site Chemi Rezan (S10)

Heavy Metal	Winter	River Standards [1&2]	Surface Water Standards [2,3&4]
Nickel (Ni) mg/L	**0.08**	0.0008	0.0005-0.006
Lead (Pb) mg/L	0.04	0.0015	0.09
Iron (Fe) mg/L	0.02	0.67	0.22-0.35
Copper (Cu) mg/L	0.13	0.002	0.27
Manganese (Mn)mg/L	0.01	0.00002	0.07-0.5
Cadmium (Cd) mg/L	ND	0.00008	0.000005
Zinc (Zn) mg/L	**0.08**	0.0006	N/A
1= Allan and Castillo, 2007; 2=Kabata-Pendias and Mukherjee, 2007; 3=Agardy and Sullivan, 2005; 4=STF, 2000; ND=not detected; N/A=not available			

Heavy Metals in Sediments: Sediments of Chemi Rezan site show contaminated sediments with Ni, Cd, Cu and Zn (see Table 151) and Pb was also quite high. Agrochemicals and tourist activity may be the source of this heavy metal contamination in sediment samples.

Table 151: Heavy metals in sediment of Chemi Rezan (S10)

Heavy Metal	Winter	Background [1]	CSQG [2]
Nickel (Ni) mg/kg	**987.2**	31	N/A
Lead (Pb) mg/kg	33.9	23	35
Iron (Fe) mg/kg	28651	N/A	N/A
Copper (Cu) mg/kg	**87.1**	25	35.7
Manganese (Mn) mg/kg	**1135.6**	400	N/A
Cadmium (Cd) mg/kg	**10.7**	N/A	0.6
Zinc (Zn) mg/kg	**340.55**	65	123
1= ASQ, 1993; 2= CSQG, 2002; N/A=not available			

Conservation Issues & Recommendations: The benthic macroinvertebrate results for Chemi Rezan (S10) during winter 2009 indicate a non-impaired to moderately impaired habitat and very good to excellent water quality.

The bacteria results from Chami Rezan (S10) indicate that the stream is not highly contaminated with fecal coliform bacteria according to the international standards for surface water.

The phytoplankton results for Chemi Rezan during winter 2009 indicated oligotrophic-mesotrophic water conditions.

Tourism in the Chami Rezan area seriously degrades the water quality and this must be taken into consideration in order to prevent the area from further environmental depletion by increasing the local population's knowledge of their surrounding environment.

11. Little Zab River/ Below Tabban Junction (S20) – Elev. 397

Site Description: This station is located inside a gorge along the Little Zab River downstream from where the Chemi Rezan (Tabban) stream enters the Little Zab. The water runs fast current over a river bed with rocks of various sizes covered in brown algae. The site is accessed from a gravel road west of the main checkpoint into Dukan. The site is located several kilometers downstream from the town of Dukan and is affected by sewage discharges from the town which enters the river untreated.

Plate

Observations (Winter 29 Jan 2009):

Water Quality: Little Zab River/ Below Tabban Junction Sample Site-For winter: S20, Sampling Time- 11:05 am, Water Depth- 0.3m, Air temperature- 14°C, Water temperature-9.6°C.

Water at this site shows contamination with NO2, NO3, HCO3, SO4, Ca and Mg (see Table 152 below).

Table 152: Physical & Chemical Water quality parameters at the Little Zab River/ Below Tabban Junction (S20)

Parameters	Winter	River Standards [1&2]	Surface Water Standards [2,3&4]
Field Analysis			
Water Temperature °C	9.6	N/A	N/A
Conductivity µS/cm	323	N/A	<1275
pH	8.01	N/A	6-8.5
Turbidity NTU	**10.5**	N/A	10
TDS mg/L	94	N/A	500
Salinity ppt	ND	N/A	N/A
DO mg/L	14.3	N/A	>5
DO%	132.1	N/A	N/A
Secchi disc m	0.3	N/A	N/A
Lab Analysis			
TSS mg/L	0.008	N/A	N/A
TDS mg/L	207.5	N/A	500
BOD mg/L	1.75	N/A	N/A
Orthophosphate (PO4) mg/L	ND	10	N/A
Nitrite-Nitrogen (NO2) mg/L	**0.03**	0.001	N/A
Nitrate-Nitrogen (NO3) mg/L	1.17	1	10
Total Alkalinity as CaCO3 mg/L	73	N/A	>20
Bicarbonate (HCO3) mg/L	**89.06**	58.4	58
Total Hardness (TH)	172.82	N/A	N/A

Parameters	Winter	River Standards [1&2]	Surface Water Standards [2,3&4]
mg/L			
Calcium (Ca) mg/L	**54.66**	15	15
Magnesium (Mg) mg/L	**11.85**	4.1	4.1
Chloride (Cl) mg/L	7.32	7.8	7.8
Total Nitrogen (TN) mg/L	36.57	N/A	N/A
Sulfate (SO4) mg/L	**22.21**	11.2	3.7
Total Phosphorous (TP) mg/L	0.01	0.025	N/A
Potassium (K) mg/L	2.17	2.3	2.3
Sodium (Na) mg/L	6	6.3	6.3
1= Allan and Castillo, 2007; 2=Kabata-Pendias and Mukherjee, 2007; 3=Agardy and Sullivan, 2005; 4=STF, 2000; ND=not detected; N/A=not available			

Bacteria & Coliform: The water at this site is considered contaminated with fecal coliform bacteria as the results indicate 1600 colony/100 ml of coliform bacteria, which is higher than the normal range of surface water quality standards (See Table 153).

Table 153: Fecal Coliform bacteria count and E. coli at site (Little Zab River/ Below Tabban Junction (S20))

	Winter	Summer	Drinking Standards[1 & 2]	Surface Water Standards[2]		
				Body-contact	Fishing and boating	Domestic water supply
Fecal Coli form Bacteria Colony/100 ml	**1600**	---	0 in 100ml	100 Colonies/100 mL	> 1000 Colonies/100 mL	> 2000 Colonies/100 mL
Escherichia coli	**+**	---				
1= WHO, 2006; 2= CDWQ, 2006						

Phytoplankton: The total phytoplankton count during this survey was 1753.6 x 10^3 cell/L and a total of 40 species were recorded. The dominant species in this site were centric and pennate diatoms (74.29% and 23.87%, respectively) (see Table 154 below).

The centric diatoms were represented by Cyclotella ocellata and Aulacoseira granulate (757.1 x 10^3 cell/L and 489.9 x 10^3 cell/L, respectively). Diatoma vulgare, Gomphoneis olivacea, Achnanthes minutissima, Cocconeis pediculus and Cymbella affinis was the primary diatom (111.3 x 10^3 cell/L, 77.9 x 10^3 cell/L, 44.5 x 10^3 cell/L, 44.5 x 10^3 cell/L and 33.4 x 10^3 cell/L), respectively. This site had moderate diversity, very good richness and moderate evenness values (See Annex 2: Table 175, Table 177 & Table 179).

Table 154: Number of species, total count and percentage for phytoplankton groups in Little Zab River/ below Tabban Junction (S20)

Phytoplankton Groups	Sp. #	Total Count (cell x 10^3/L)	%
Cyanophyta	3	11.1	0.63
Euglenophyta	0	0	0.00
Pyrrophyta	1	9.1	0.52

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Cryptophyta	0	0	0.00
Chlorophyta	4	12.1	0.69
Bacillariophyceae/Centrales	3	1302.7	74.29
Bacillariophyceae/Pennales	29	418.6	23.87
Total	40	1753.6	100.00

Benthic Macroinvertebrates: Total density found was 378 indv. /m² and comparing with the other studied sites, this density was relatively moderate (Annex 4: Table 165). EPT % was very low (Annex 4:

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) and the dominant species was related to the amphipods, which are known as tolerant organisms (pollution tolerance number ≈ 6). The relative diversity, richness, and evenness were moderate, good, and very good respectively (See Annex 4: Table 167, Table 169, & Table 171, respectively).

Depending on the modified pollution tolerance and pollution indices, water quality was fair (See Annex 1, Table 173) and this could be confirmed by the well presence of the tolerant aquatic organisms such as the white midges *Cricotopus trifascia, Orthocladius clarkei,* and *Paratrichocladius* sp., the lunged snails *Physella* sp. and *Lymnaea auricularia*, and the Ring Horn Microcaddisfly *Leucotrichia* sp.

Briefly, we suggested considering the habitat here as moderately impaired to somewhat severely impaired and the water quality as fair (refer to Methods & Procedures).

Heavy Metals in Water: This site was contaminated with Ni, Pb, Mn, Cu and Zn compared to natural river levels (see Table 155).

Table 155: Heavy metals in water of the Little Zab River/ Below Tabban Junction (S20)

Heavy Metal	Winter	River Standards[1&2]	Surface Water Standards[2,3&4]
Nickel (Ni) mg/L	**0.07**	0.0008	0.0005-0.006
Lead (Pb) mg/L	0.04	0.0015	0.09
Iron (Fe) mg/L	ND	0.67	0.22-0.35
Copper (Cu) mg/L	0.04	0.002	0.27
Manganese (Mn)mg/L	0.01	0.00002	0.07-0.5
Cadmium (Cd) mg/L	ND	0.00008	0.000005
Zinc (Zn) mg/L	**0.04**	0.0006	N/A
1= Allan and Castillo, 2007; 2=Kabata-Pendias and Mukherjee, 2007; 3=Agardy and Sullivan, 2005; 4=STF, 2000; ND=not detected; N/A=not available			

Heavy Metals in Sediments: Sediments of Little Zab River/Below Tabban Junction site show contaminated sediments with Cd, Mn, Cu and Zn (see Table 156 below).

Table 156: Heavy metals in sediment of Little Zab River/ Below Tabban Junction (S20)

Heavy Metal	Winter	Background[1]	CSQG[2]
Nickel (Ni) mg/kg	**966.1**	31	N/A
Lead (Pb) mg/kg	21.25	23	35
Iron (Fe) mg/kg	33650.5	N/A	N/A
Copper (Cu) mg/kg	**83.4**	25	35.7
Manganese (Mn) mg/kg	3365.8	400	N/A
Cadmium (Cd) mg/kg	**10.3**	1.1	0.6
Zinc (Zn) mg/kg	**231.9**	65	123
1= ASQ, 1993; 2= CSQG, 2002; N/A=not available			

Conservation Issues & Recommendations: The bacteria results for the Little Zab River/Below Tabban Junction site during winter 2009 showed a site with high contaminated of fecal coliform bacteria likely caused by the sewage inputs upstream from the town of dukan as well as the extensive tourist sites lining the river upstream. Agricultural run-off and grazing may be additional sources. Mitigation of these levels is needed and regular monitoring should be started.

The phytoplankton results for the Little Zab River/Below Tabban Junction site during winter 2009 indicated mesotrophic-eutrophic water conditions.

The benthic macroinvertebrate survey results from the Little Zab River/Below Tabban Junction (S20) during winter 2009 indicated a moderately to somewhat severely impaired habitat and fair water quality.

Water contamination in this site may be caused by sewage, agricultural runoff and various tourist activities upstream. Tourism plays a negative role and serves to degrade the overall water quality. In order to solve this problem, restricted area for picnickers must be established to avoid littering, trash and other sources of contamination being put into the water courses.

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Summary Conclusions

Water Quality Findings

Diyala Watershed (Darbandikhan Basin) Water Quality

Results from the surveyed sites during the winter KBA survey indicated overall poor water quality, although some of the samples from the Darbandikhan Basin watershed, such as Ahmad Awa (S4A) and other upstream sites in the Dukan Basin, showed higher-quality results.

Nutrient contamination was obvious in many samples from the Diyala watershed. Concentrations typically exceeded the river and surface water standards used as a baseline for this study. For example, sulfate levels exceeded these standards in all water samples from the Diyala watershed (see Figure 10).

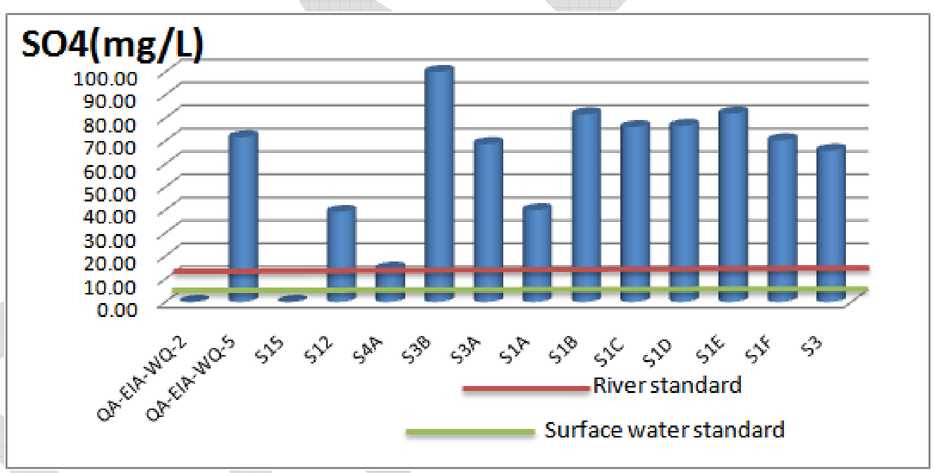
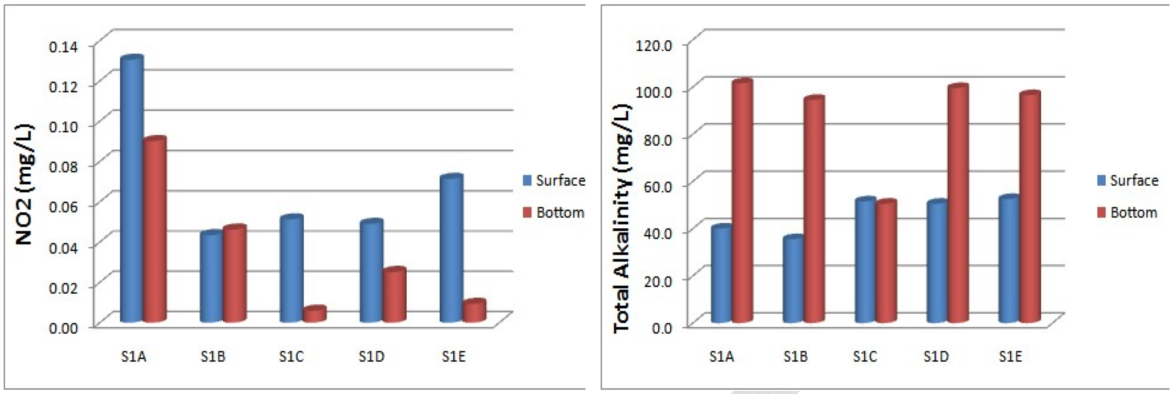


Figure 10: Concentration of SO4 in water samples (winter) of Darbandikhan Basin (Diyala River Watershed)

The most common sources of contamination are: lack of municipal sewage disposal, industrial waste, agricultural chemical runoff, prior use of chemical and conventional weapons, tourism and other geogenic sources such as inputs from naturally occurring igneous and metamorphic rocks.

The chemical content often differs between the samples taken at the surface and bottom of various bodies of water such as Darbandikhan Lake, which fluctuates as shown in Figure 11.

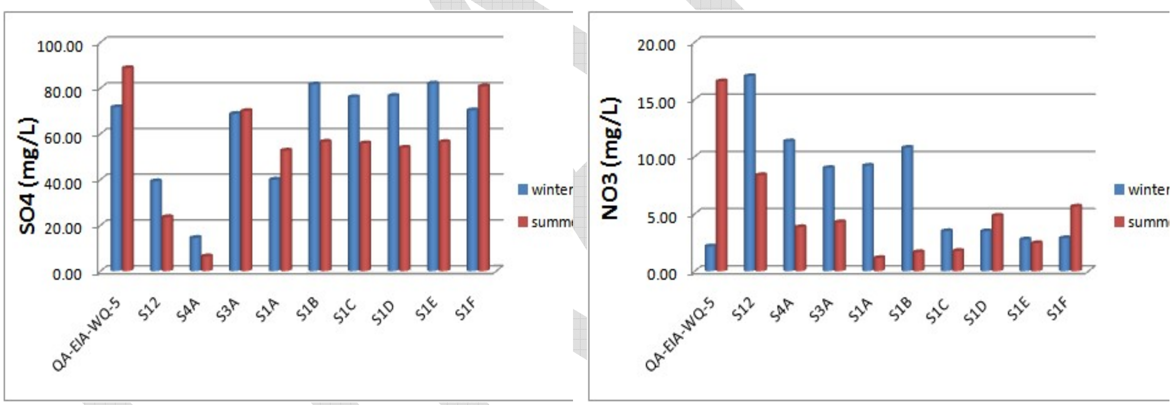


NO2 in Drabandikhan Lake samples (surface-bottom comparison)

Total alkalinity in Drabandikhan Lake samples (surface-bottom comparison)

Figure 11: Comparison between surface and bottom samples in Darbandikhan Lake (summer survey)

For sites surveyed in both winter and summer, the fluctuation of certain parameters such as excess nutrients was obvious (see Figure 12).



SO4 in Diyala watershed samples (winter-summer comparison)

NO3 in Diyala watershed samples (winter-summer comparison)

Figure 12: Comparison between winter and summer samples in Diyala River watershed

In general, the concentration of contaminants in Darbandikhan Lake is greater on the northeast side than on the south and west, which indicates that the Tanjero and Sirwan inputs entering the lake from the northeast are the main sources of contamination. This was evident in the case of nitrate contamination in the lake samples, as shown in the figure (Figure 13) below the concentration of nitrates is highest in the northeast in samples S1A and S1B and decreases toward the southwest, as shown by samples S1E and S1F.

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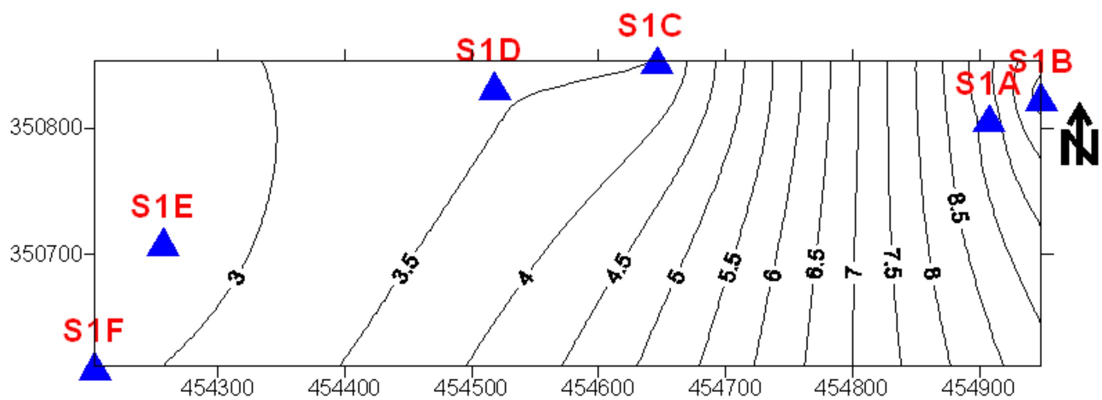

Figure 13: Concentration distribution map of nitrate in water samples (winter) of Darbandikhan Lake

Little Zab Watershed (Dukan Basin) Water Quality

The majority of the survey sites in the Little Zab watershed contain contaminated water, although the type and source of the pollution varies considerably from upstream to downstream. Geogenic sources account for most of the contamination in the upstream sites, while agriculture and sewage are the main sources of contamination downstream and around the lake. Tourism below the Dukan Dam is an additional source of contamination in the Little Zab watershed.

Nutrient contamination is obvious in samples from the Little Zab watershed, and generally concentrations exceeded those specified by the river and surface water standards. For example, nitrites (NO2) exceed the standard parameters in a majority of the water samples from the Little Zab watershed (see below).

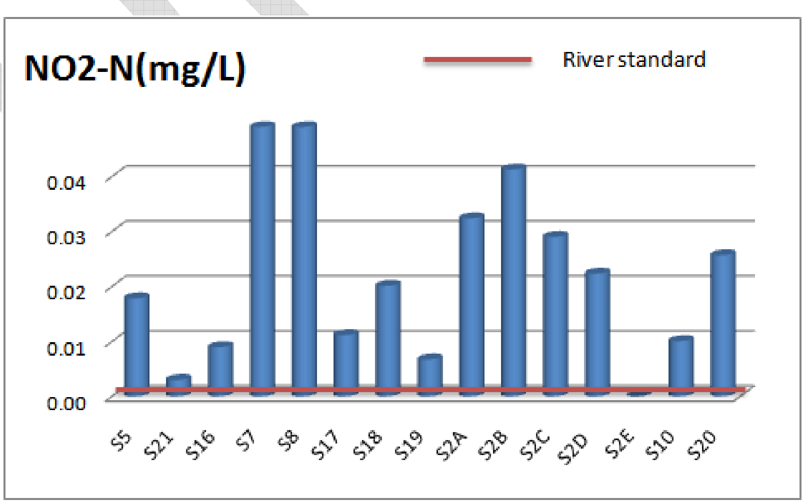

Figure 14: Concentration of nitrite-nitrogen in water samples of Little Zab River Watershed (Dukan Basin)

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Certain elements are well within acceptable limits, however. For example, chloride (Cl) is typically found at safe levels, though exceptions do exist (see Figure 15 below).

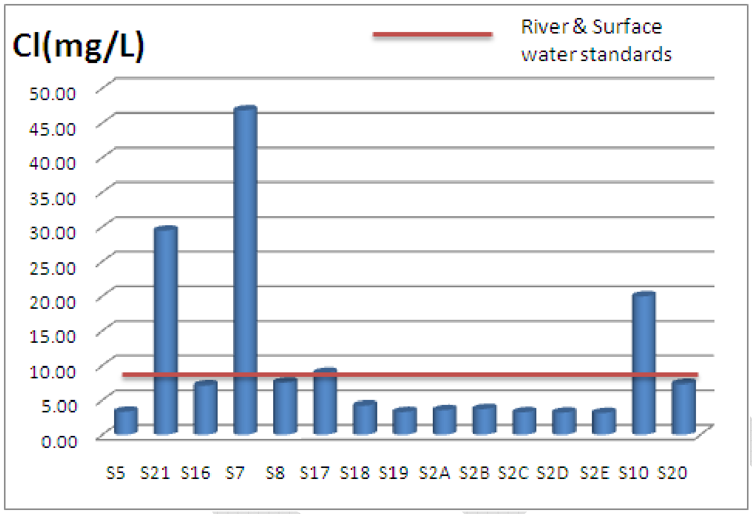
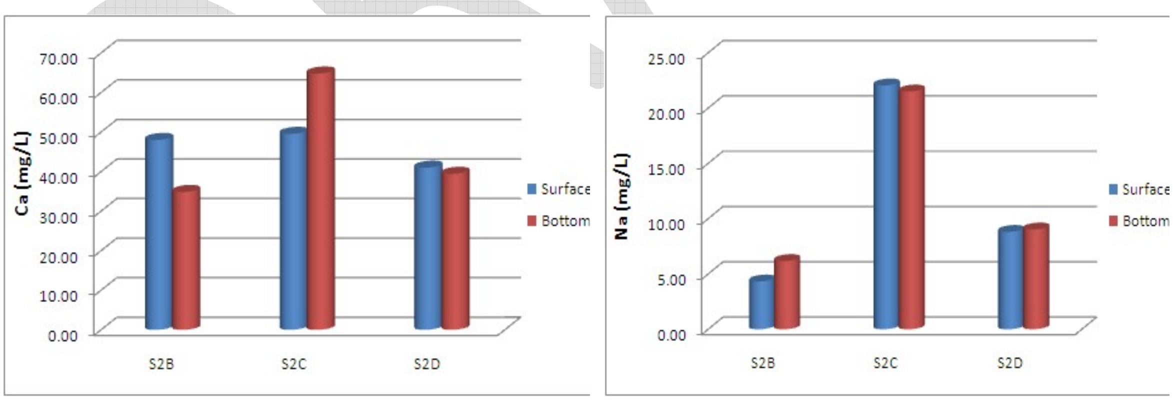


Figure 15: Concentration of chloride in water samples of Little Zab River Watershed (Dukan Basin)

It is also noteworthy that there are no major differences between the chemical content of samples taken from the surface and bottom of Dukan Lake, though small fluctuations do occur (See figures below).



Ca in Dukan Lake samples (surface-bottom comparison) **Na in Dukan Lake samples (surface-bottom comparison)**

Figure 16: Comparison between surface and bottom samples in Dukan Lake (winter survey)

Comparing the Two Basins

The degree of contamination between Dukan and Darbandikhan basins varied among the different parameters. For example, the total phosphorus levels (TP) show a higher degree of contamination in the New Halabja site-WQ-5 (Darbandikhan Basin), while the Dukan Basin samples typically show higher contamination with TP (See Figure 17).

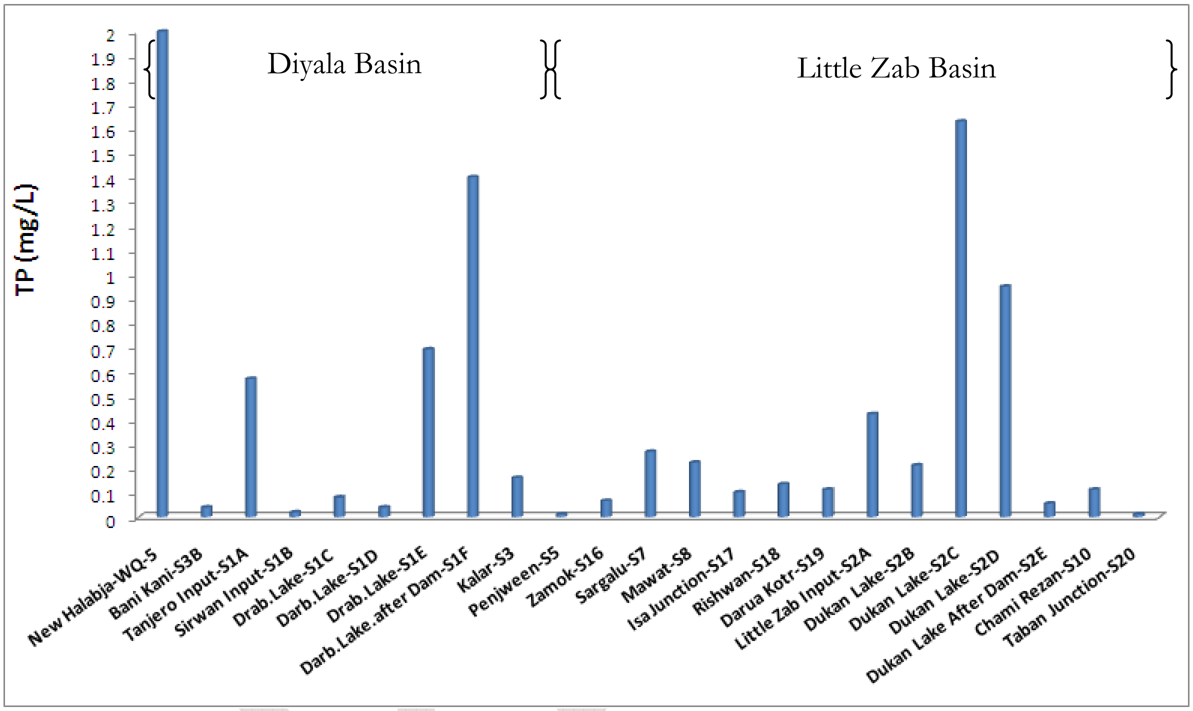


Figure 17: Comparing TP between Diyala and Little Zab watershed samples (winter survey)

Heavy Metals in Water, Soil & Sediment Findings

Determining the natural amount of heavy metal in rocks, soils and sediments is important to indicate the background levels in the sediments in each of the studied areas. Most of the survey sites show some amount of heavy metal contamination in both their water and sediment samples. Source of heavy metal contamination in the water are similar to those that cause overall water quality reduction and contamination, such as: municipal sewage disposal, industrial wastes, agricultural chemicals; prior use of chemical and conventional weapons, tourism and geogenic sources. The primary source of heavy metal contamination in sediments is likely geogenic in origin (parent materials) while secondary sources such of sewage, industrial waste, agrochemicals and other human activities are strong contributors. Further investigation is needed to discover for certain the source of such contamination.

Diyala Watershed (Darbandikhan Basin) Heavy Metals

Soil samples collected in Diyala (Darbandikhan) Basin during summer show heavy metal concentration, higher than the world background. This excess concentration of heavy metals in the soil contributes to high concentrations in the sediments of the surrounding water bodies. Some soil samples may be contaminated with heavy metals, especially those agricultural soils that are irrigated by sewage and other contaminated waters. Agrochemicals might be the secondary source of contamination in soils. Figure 18 and Figure 19 show concentration distribution maps for two heavy metals that were often found to exceed reference standards. Their distribution is mapped for Darbandikhan Lake.

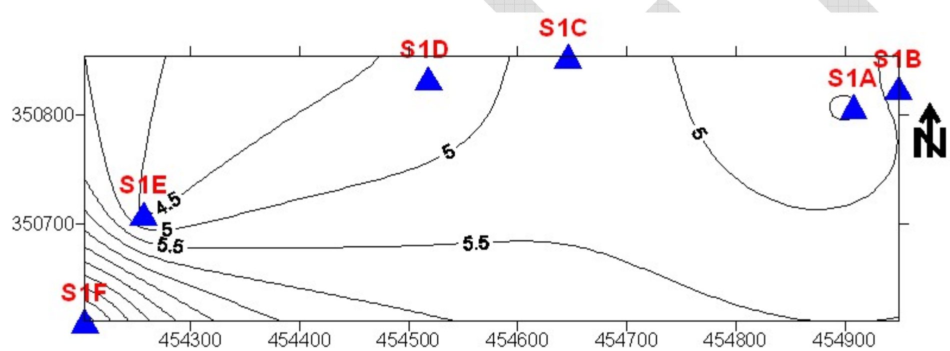


Figure 18: Concentration distribution map of cadmium in sediment samples of Darbandikhan Lake

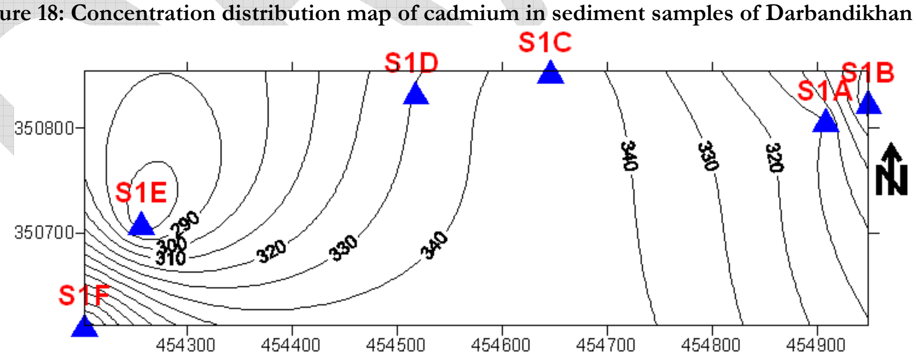


Figure 19: Concentration distribution map of zinc in sediment samples of Darbandikhan Lake

Little Zab Watershed (Dukan Basin) Heavy Metals

The water quality in the Little Zab watershed is quite poor when the concentrations of heavy metals are taken into consideration. Most of the samples in the watershed were contaminated with Ni, Pb, Mn, Cd and Zn and exceed the standard levels in river or surface water (see figure below).

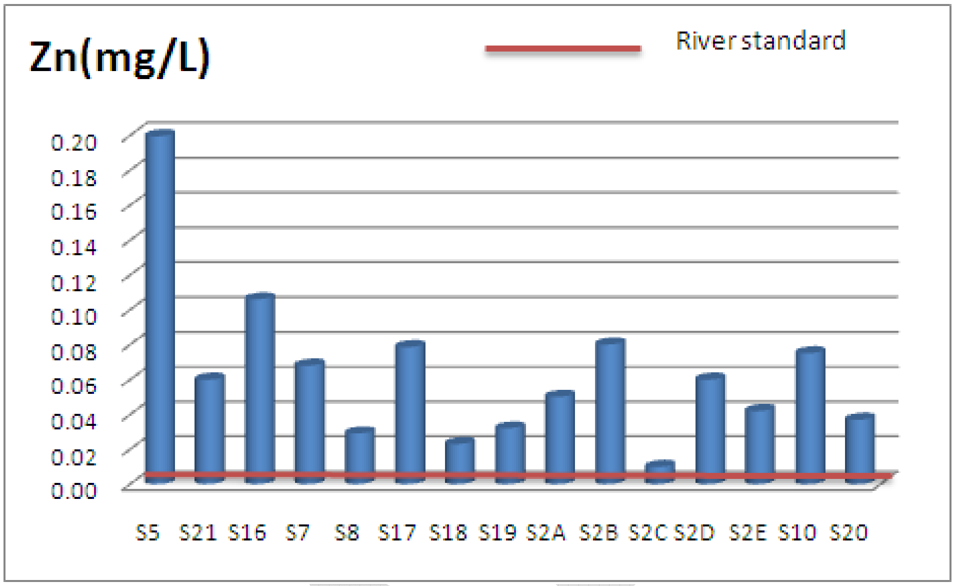


Figure 20: Concentration of zinc in water samples of Little Zab River Watershed (Dukan Basin)

Sediment quality in the Little Zab watershed samples was poor as well and was contaminated with heavy metals (mainly with Cd, Cu, Pb, Zn and Mn) with levels often exceeded the one or more reference standards for river and/or surface water (See the example for copper below).

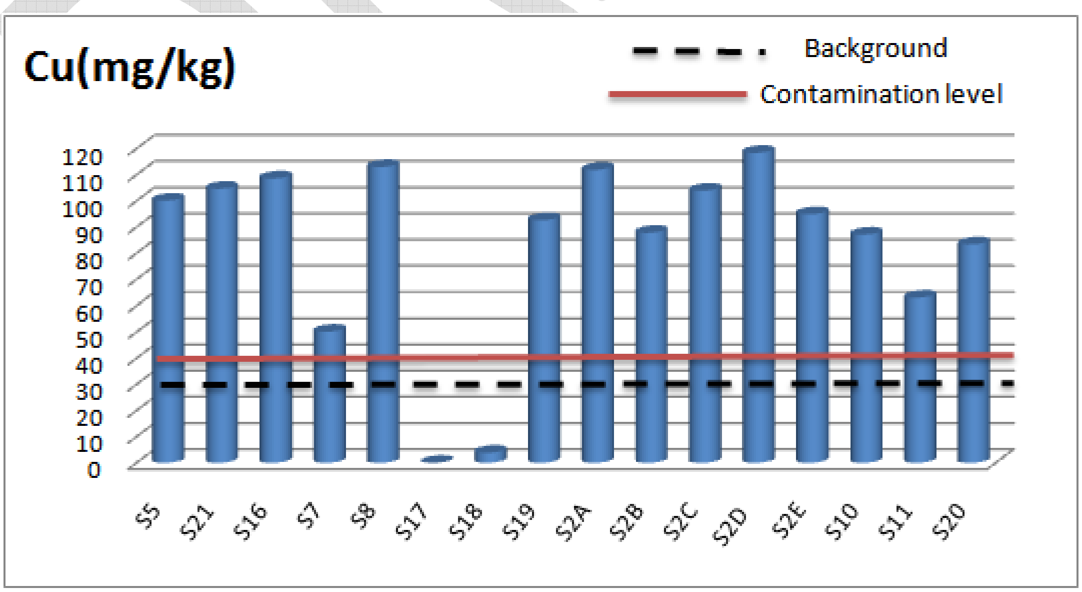


Figure 21: Concentration of copper in sediment samples of Little Zab River Watershed (Dukan Basin)

Bacteria & Coliform Findings

Fecal coliform bacteria have long been used as an indicator organism of the sanitary quality of water for drinking or body-contact recreation. The presence of fecal coliform bacteria in water indicates the possible presence of pathogens such as entero-, rota-, and reoviruses, found in the feces of warm-blooded animals. These bacteria and pathogens may cause human diseases ranging from mild diarrhea to respiratory disease, septicemia, meningitis, and polio (Pepper, Gerba, & Brusseau, 1996). The fecal coliform bacteria group can include any combination of *Escherichia coli* (*E. coli*) and species of the *Klebsiella*, *Enterobacter*, and *Citrobacter* genera (Gleeson and Gray, 1997).

Fecal coliform bacteria are found in the feces of all warm-blooded animals, but some examples can also originate in soil and water (Holt et al., 1993, p. 787). One of the main concerns with the land application of animal manure is that bacterial pathogens will reach groundwater and surface water via runoff during or after a storm event (Stoddard et al., 1998). Infectious diseases of microbiological etiology, originating in man and other animals, can be transmitted through waters that receive animal wastes. Thus, human and livestock exposure to surface or groundwater contaminated with fecal bacteria is an important water quality concern (Stoddard et al., 1998). The existance and the absence of *E. coli* in all the sites and their effects on the contaminations can be based on the number of fecal coliform bacteria in which thire are no numerical count for *E. coli*.

Diyala Watershed (Darbandikhan Basin) – Bacteria & Coliform

Irrigation of agricultural fields with sewage waters is an active practice along the Tanjero River, which carries most of the sewage of the city of Sulaimani. This indicates that there is likely exposure of human and livestock to fecal bacteria within the Darbandikhan Basin. For winter 2009 all sites in the survey indicate varying but often high levels of fecal coliform bacteria and *E. coli* and these issues demand urgent attention and more examination.

The winter 2009 results for the Diyala River Watershed (Darbandikhan Basin) show that high contaminations with fecal coliform bacteria were found at the New Halabja Site (QA_EIA_WQ_5), the Tanjero input into Darbandikhan Lake (S1A), in the Diyala (Sirwan)

River below Darbandikhan Dam (S1F) and at Bani Khelan (Garmk) on the Diyala River (S3A).

But Kalar, further south (S3), as well as Bani Khan just upstream - (S3B), as well as at Zalm Area (S12), a tributary to the lake, showed low levels of fecal coliform contamination.

Other sites Ahmed Awa (S4A), Darbandikhan Lake – Sirwan Input (S1B), Kani Sard (Chami Gawra) (S21), Darbandikhan Lake (S1D) and Darbandikhan Lake (S1C) did not reach contaminated levels and Darbandikhan Lake-Near the dam (S1E) appeared to be compliantly clear of fecal coliform bacteria in the winter of 2009.

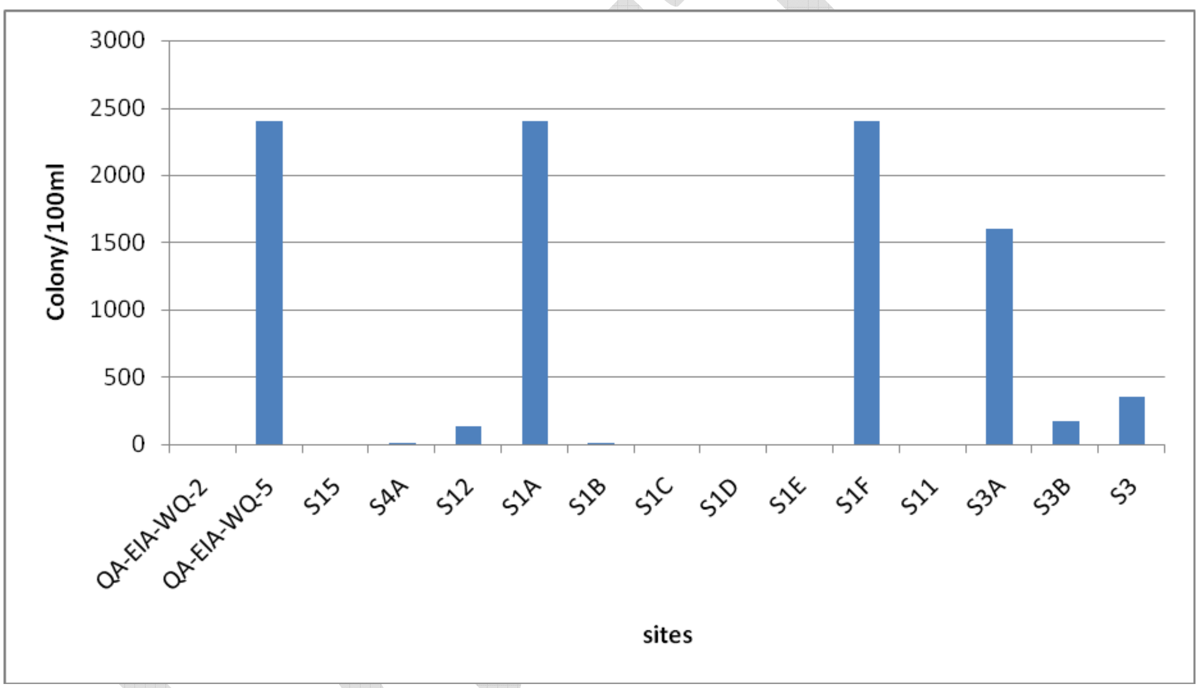


Figure 22: Diyala River Basin (Darbandikhan Basin) – Water quality ranks in Sulaimani sites during Kurdistan KBA - winter survey 2009, based on fecal coliform bacteria' results.

For the summer 2009 the Diyala River Watershed (Darbandikhan Basin) show that high contaminations with fecal coliform bacteria were found at the New Halabja Site (QA_EIA_WQ_5), Kela Spi (QA-EIA-WQ-1), Sarchinar (QA-EIA-WQ-2), Below Qara Dagh Bridge(QA-EIA-WQ-3), Qara Ali (QA-EIA-WQ-4) and Said Sadiq (S29), Diyala (Sirwan) River below Darbandikhan Dam (S1F), Zalm Area (S12), and Garmk on the Diyala River (S3A).

Darbandikhan Lake (S1D) and Darbandikhan Lake – Sirwan Input (S1B), Tanjero input into Darbandikhan Lake (S1A) showed low levels of fecal coliform contamination.

Other sites Ahmed Awa (S4A), Darbandikhan Lake-Near the dam (S1E), and Lake (S1C) appeared to be not contaminated with and clear of fecal coliform bacteria.

Little Zab Watershed (Dukan Basin) – Bacteria & Coliform

The winter 2009 results for the Little Zab River Watershed (Dukan Basin) indicated excessive levels of contamination at Sargalu (S7), Dukan Lake at the Little Zab Input (S2B), Little Zap below Tabban Junction (S20) and the Little Zab above Du Choman Junction (S17).

But in winter there were low levels of contaminations at Penjween (S5), Little Zap Input (S2A) and Mertka (Rishwan) (S18).

Zamok (S16), Mawat (S8), Darua Kotr (S19), Chami Razan Area (S10) and Dukan Lake Below the dam (S2E) were considered to be not contaminated with fecal coliform bacteria. But only the Dukan Lake center and above the dam (S2C and S2D) were completely free from fecal coliform bacteria.

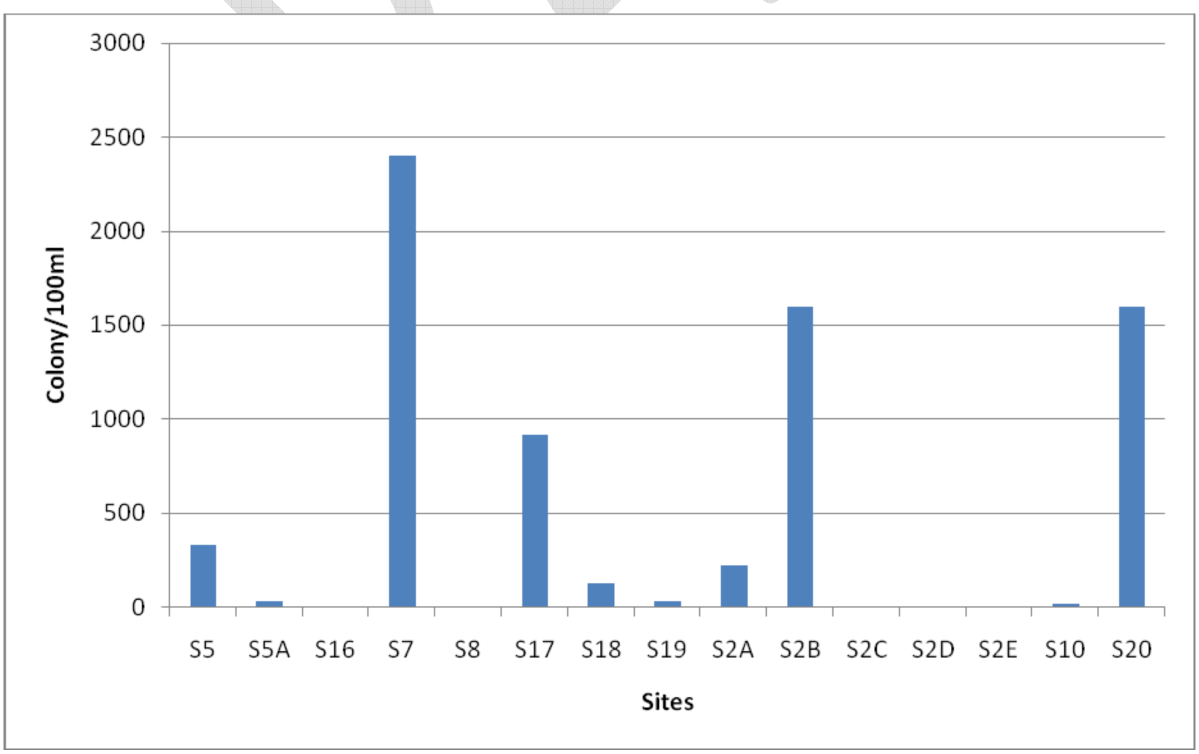


Figure 23: Little Zab River Watershed (Dukan Basin) - Water quality ranks in Sulaimani sites during Kurdistan KBA - winter survey 2009, based on fecal coliform bacteria' results.

Comparing the two Basins

Sewage disposal, agricultural and domestic activities as well as the improper management of livestock waste (manure) varies from site to site according to the frequency of these activities throughout the respective basins, which may have caused instances of surface water bacteria and coliform pollution. Those sites that were not contaminated were areas with either high currents, pure water sources or were located some distance from human settlements.

Phytoplankton Findings

During the winter and summer 2009 surveys, various properties of the local phytoplankton communities were assessed via the level of species richness, Shannon-Weaver Index of Diversity and the presence of indicator species.

Diyala Watershed (Darbandikhan Basin) Phytoplankton

In terms of water quality, the phytoplankton results in the surveyed Diyala River Watershed (Darbandikhan Basin) sites indicate relatively oligotrophic-eutrophic water conditions in all six sites along Darbandikhan Lake. Bani Kani/Diyala River (S3B) had oligotrophic water conditions. Whereas, Ahmed Awa (S4A), Garmak/Diyala River (S3A) and Kalar/Diyala River (S3) had mesotrophic water conditions and Zalm Area (S12) had relatively eutrophic water conditions. During winter the diatoms mainly the centric diatoms, in Diyala Watershed (Darbandikhan Basin) where the most dominated phytoplankton group (See Figure 24).

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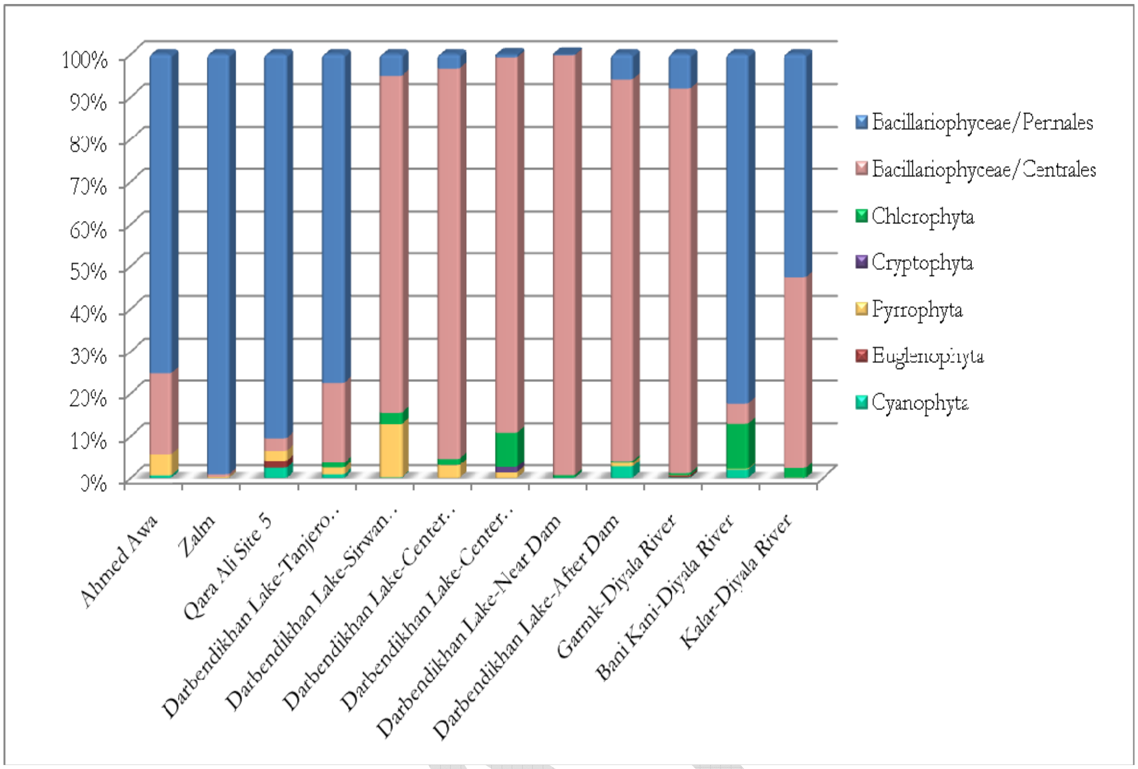

Figure 24: Percentage for Phytoplankton Groups in Diyala River Watershed (Darbendhikan Basin) sites during Kurdistan KBA - winter surveys 2009

Compared with the winter survey, the phytoplankton groups were more diverse during the summer survey (Figure 25). This may reflect effects of higher water flows during winter that homogenize conditions among sites. While, during low flow periods (typically warm seasons), local factors may be more important determinants of water quality and increase variability among sites. As a result this will be reflected in the diversity of the phytoplankton groups as noticed. Many planktonic diatoms have regular annual fluctuations in growth that can be attributed to environmental conditions. Additionally, there are other factors, such as grazing by zooplankton, invertebrates and fungal parasitism that may affect the distribution and abundance of the phytoplankton groups during different seasons.

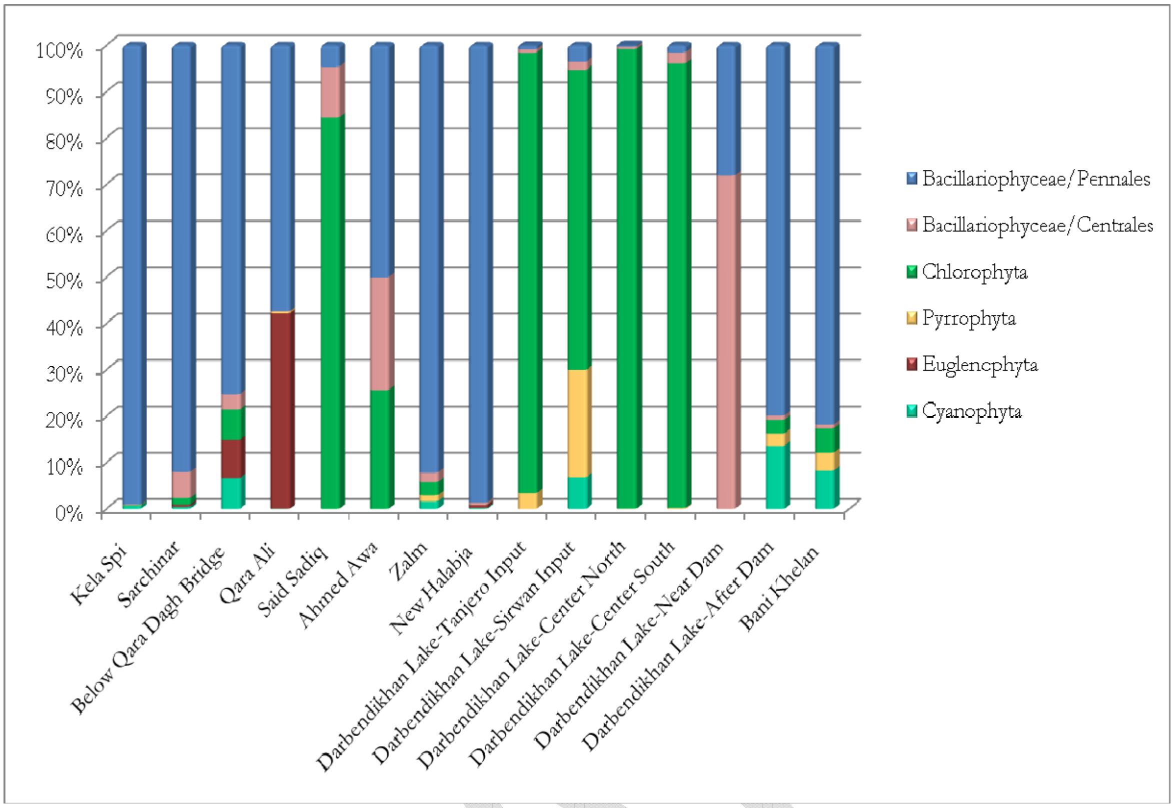

Figure 25: Percentage for Phytoplankton Groups in Diyala River Watershed (Darbendhikan Basin) sites during Kurdistan KBA - summer survey2009

Little Zab Watershed (Dukan Basin) Phytoplankton

As for the sites in Little Zab River Watershed (Dukan Basin) phytoplankton results indicate the following: oligotrophic water conditions in site Zamok/Near Chwarta (S16), Sargula (S7), Mawat (S8), Darua Kotr (S19). Oligotrophic-mesotrophic water conditions were recorded in site Kani Sard (Chami Gawra) (S5A), Chami Razan (S10) and all five sites surveyed in Dukan Lake. While, mesotrophic water conditions were recorded in Penjween (S5), Little Zab River/Above Du Choman (S17) and Mertka (S18). On the other hand, the Little Zab River/Below Tabban Junction (S20) had relatively mesotrophic-eutrophic water. During winter the diatoms mainly the pennate diatoms, in the Little Zab (Dukan Basin) the diatoms where the most dominated phytoplankton. See Figure 26.

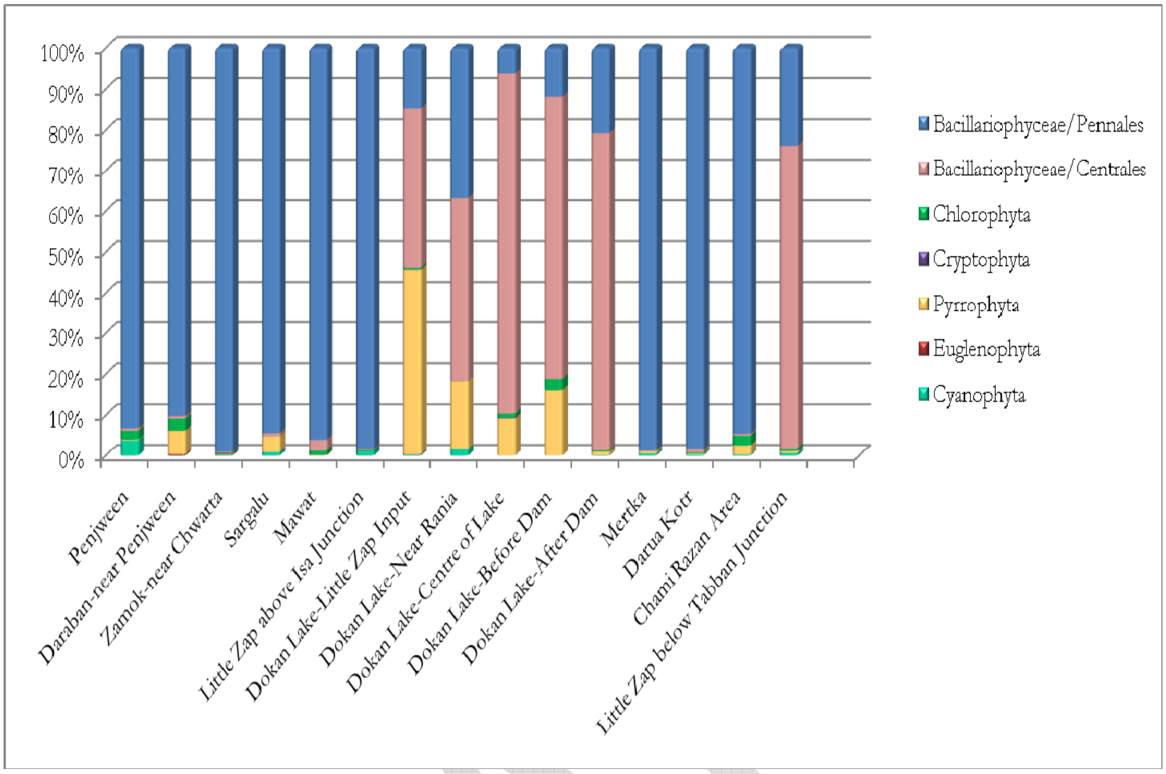

Figure 26: Percentage of Phytoplankton groups in Little Zab Watershed (Dukan Basin) sites during Kurdistan KBA - winter survey 2009

Comparing the two Basins

The diatoms, centric and pennate, were the dominant phytoplankton group during the winter survey, where the centric diatoms were more common at Darbandikhan Lake and Little Zab River/Below Tabban Junction (S20). On the other hand, the pennate diatoms were dominant in the Little Zab Watershed (Dukan Basin). Diatoms are widely recognized and used as indicators of river and stream water quality because diatom species composition responds directly to nutrients and can be a more stable indicator of tropic state than measurements of nutrient concentrations or algal biomass. These results are in agreement with previous studies (Shabban, 1980 and Kassim et al., 2005 as cited in Kassim 2005). Generally, the dominancy of the centric diatoms in Darbandikhan Basin and the pennate diatoms in and Dukan Basin indicate that the Darbandikhan Basin is more disturbed then Dukan Basin.

In terms of diversity, Tangero Input & Sargalu had the highest diversity values while the Darbandikhan Lake-Center North site and Darbandikhan Lake-Near Dam site had the lowest diversity values respectively.

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In general, the distribution of phytoplankton in a particular body of water is the result of a complex series of interactions between hydrological, water quality and biotic factors. Short-term differences in community composition are driven by immigration of cells, differences in growth rate between populations and loss processes such as death, emigration, sloughing and grazing.

Similar to the winter survey, during summer 2009 survey, various properties of the local phytoplankton communities were assessed via the level of species richness, Shannon-Weaver Index for Diversity and the presence of indicator species. As shown is Figure 25, the most dominated groups were the pennate diatoms and the Chlorophyta.

In further surveys specific issues need to be covered and studied in more detail in order to have further clarification on the phytoplankton community and species such as: How do diatom assemblages vary among study sites in these basins? Which water chemistry characteristics have the greatest influence on diatom assemblage composition overall and how does their importance vary with spatial scale and geographic region? What is the relative importance of natural vs. "pollution related" factors?

Benthic Macroinvertebrates Findings

Diyala Watershed (Darbandikhan Basin):

Winter 2009 results for the Diyala River Basin (Darbandikhan Basin) indicated non-impaired to moderately impaired habitat at Ahmed Awa (S4A), Kalar (Diyala River) - (S3), and Bani Khan (Diyala River) - (S3B), moderately impaired habitat at Zalm Area (S12) and Diyala (Sirwan) River/After Darbandikhan Dam (S1F), moderately to somewhat severely impaired habitat at Bani Khelan (Garmk) (Diyala River) - (S3A), and severely impaired habitat at New Halabja (QA_EIA_WQ_5).

In terms of water quality, winter 2009 results for the Diyala River Basin (Darbandikhan Basin) indicate excellent water quality at Ahmed Awa (S4A), very good water quality at Kalar (Diyala River) - (S3), good at Bani Khan (Diyala River) - (S3B), fair at Diyala (Sirwan) River/After Darbandikhan Dam (S1F) and Zalm Area (S12), poor to fair at Bani Khelna

(Garmk) (Diyala River) - (S3A), and poor at New Halabja (QA_EIA_WQ_5) (See Figure 27).

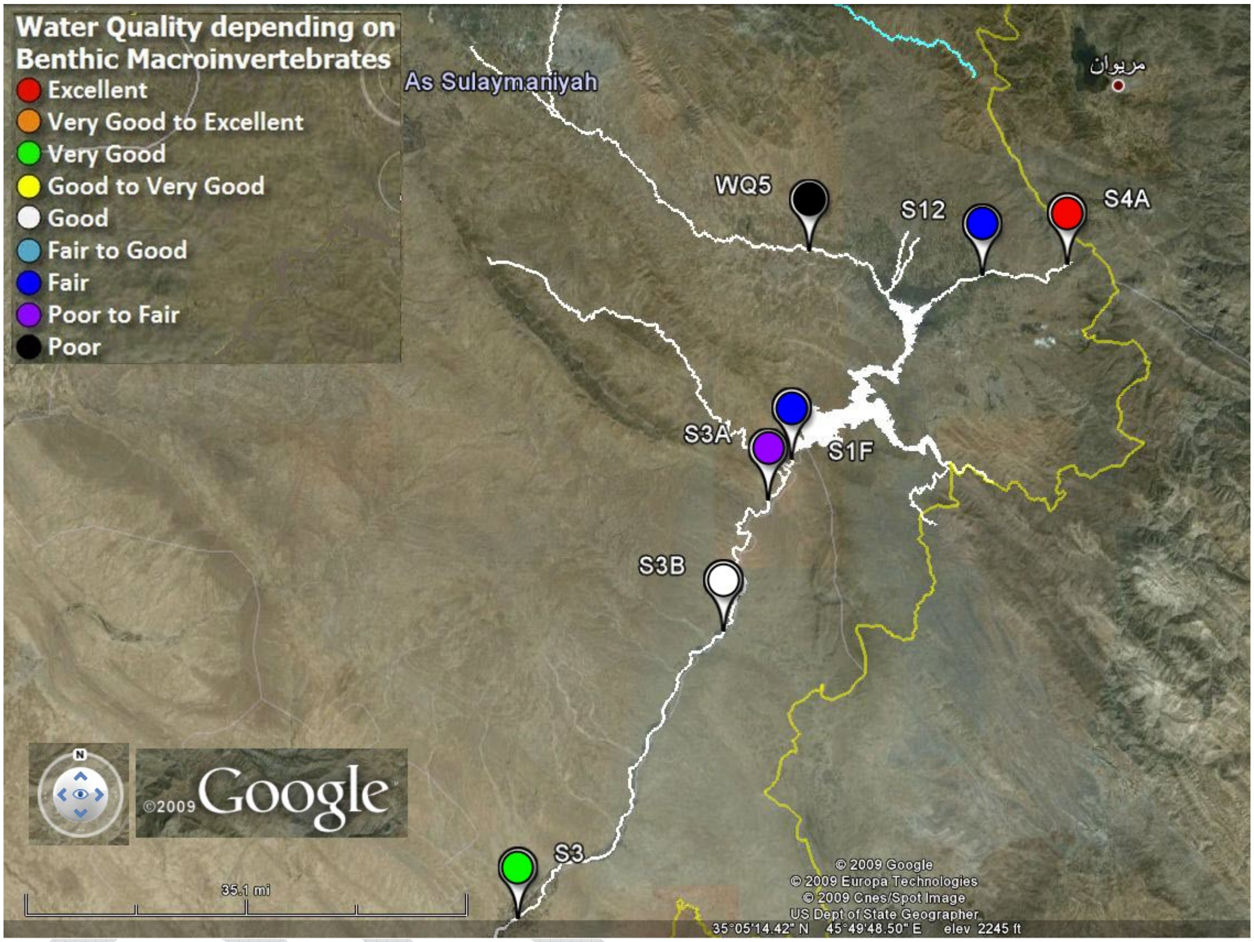

Figure 27: Water quality ranks in Diyala River Watershed (Darbandikhan Basin) sites during Kurdistan KBA - winter surveys 2009, depending on benthic macroinvertebrates' results.

Summer 2009 results for the Diyala River Basin (Darbandikhan Basin) indicated non-impaired to moderately impaired habitat at Ahmed Awa (S4A), moderately impaired habitats at Kela Spi (QA-EIA-WQ1), Sarchinar (QA-EIA-WQ2), Bani Khelan (S3B), and Zalm (S12), moderately to somewhat severely impaired habitats at Diyala (Sirwan) River/After the Dam (S1F) and Said Sadiq (S29), and severely impaired habitats at Qara Dagh Bridge (QA-EIA-WQ3), Qara Ali (QA-EIA-WQ4), and New Halabja (QA-EIA-WQ5).

In terms of water quality, summer 2009 results for the Diyala River Basin (Darbandikhan Basin) indicate very good to excellent water quality at Ahmed Awa (S4A), good to very good at Zalm Area (S12), good at Kela Spi (QA_EIA_WQ1) and Sarchinar (QA_EIA_WQ2), fair at Bani Khelan (S3A) and Said Sadiq (S29), poor to fair at Qara Ali (QA_EIA_WQ4) and New Halabja (QA_EIA_WQ5), and poor at Below Qara Dagh Bridge (QA_EIA_WQ3) and Diyala (Sirwan) River/After the Dam (S1F) (See Figure 28).

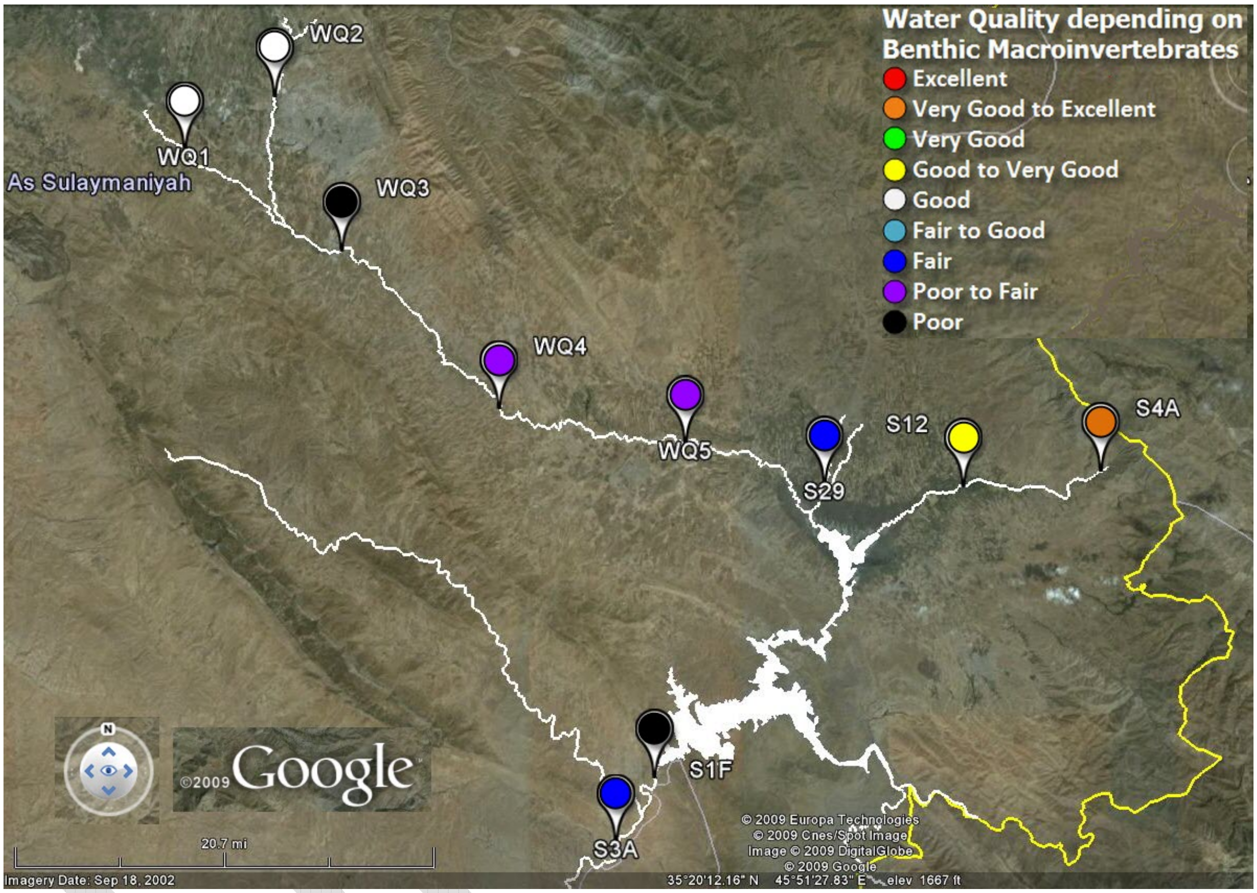

Figure 28: Water quality ranks in Diyala River Watershed (Darbandikhan Basin) sites during Kurdistan KBA - summer surveys 2009, depending on benthic macroinvertebrates' results.

Little Zab Watershed (Dukan Basin):

Winter 2009 results for the Little Zab River Watershed (Dukan Basin) indicated non-impaired to moderately impaired habitat at Chemi Rezan (S10), Du Choman (Mawat Area) (S8), Penjween (S5), and Sargalu (S7), moderately impaired habitat at Little Zab River/ Above Du Choman (S17), Little Zab River/After Dukan Dam (S2E), Mertka (S18), and Zamok/Near Chwarta (S16), moderately to somewhat severely impaired habitat at Kani Sard (Chami Gawra) (S21), Darua Kotr (S19), and Little Zab River/ Below Tabban Junction (S20).

In terms of water quality, winter 2009 results for the Little Zab River Watershed (Dukan Basin) indicate very good to excellent water quality at Chemi Rezan (S10) and Penjween (S5), very good at Du Choman (Mawat Area) (S8), good to very good at Mertka (S18), Sargalu (S7), and Zamok/Near Chwarta (S16), good at Darua Kotr (S19) and Little Zab River/Above Du Choman (S17), fair to good at Little Zab River/After Dukan Dam (S2E), fair at Little Zab River/Below Tabban Junction (S20), and poor to fair at Kani Sard (Chami Gawra) (S21) (See figure below).

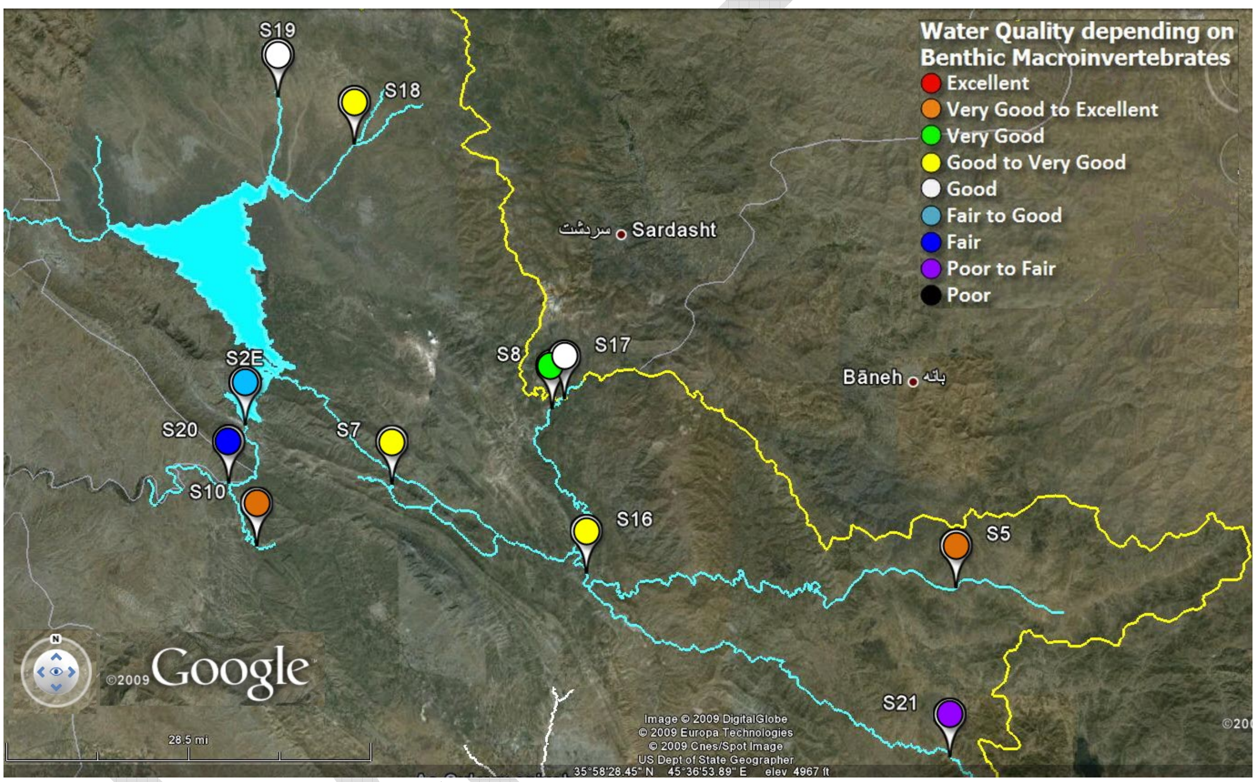

Figure 29: Water quality ranks in Little Zab Watershed (Dukan Basin) sites during Kurdistan KBA - winter surveys 2009, depending on benthic macroinvertebrates' results.

Comparing the two Basins

The figures below demonstrate the ranks in terms of water quality in the sites studied by the benthic macroinvertebrates team in winter (the only time when both basins were surveyed). All sites within both basins (Little Zab/Dukan and Diyala/Darbandikhan) are considered together in the graph below, which represents the difference between all the sites in winter survey in 2009. Overall, winter results appear to illustrate that the Little Zab Watershed (Dukan Basin) has generally better water quality than the Diyala Watershed (Darbandikhan Basin).

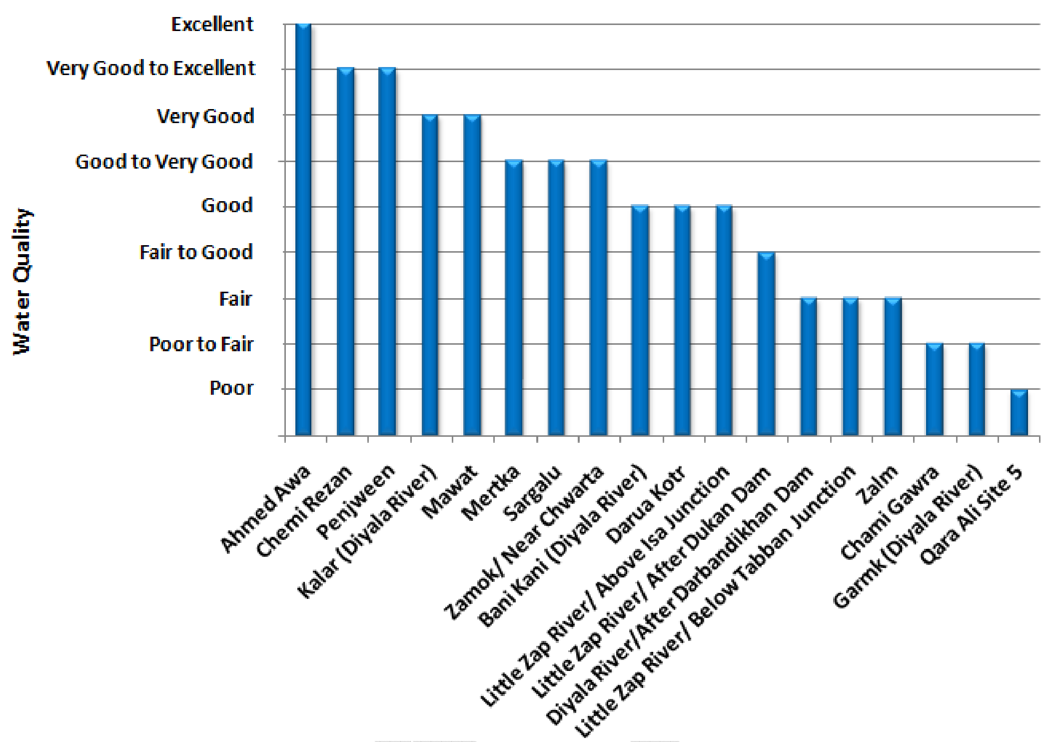

Figure 30: Water quality ranks in Sulaimani sites during Kurdistan KBA - winter survey 2009, depending on benthic macroinvertebrates' results.

Threats seen at Watersheds

Quality of water in Dukan and Darbandikhan basins was threatened by action of contaminants from four main sources: anthropogenic (sewages and related impacts), agricultural (agrochemicals), industrial (industrial wastes) and geogenic sources (natural; rock bodies contain high amounts of heavy metals). The images below provide typical examples of theats seen on both watersheds.

Sewage from Darbandikhan City entering Sirwan/Diyala River (S1F)

Broken Chaq Chaq Dam and dumping of materials along Quilisan Stream. (QA_EIA_WQ2)

Broken jerry cans of fuel from smuggling activities on the Little Zab River border with Iran (Mawat Area/S8)

Dumped fuel jerry cans left from smuggling activity near Penjween (S5)

Gravel mining near

Burning municipal garbage near (WQ_EIA_WQ3)

Car washing near Zamok (S16)

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Recommendations for the Watersheds & Next Steps

Further inquiry into the sampling sites as well as more detailed field observations and notes are required, alongside a detailed examination of the geological composition of the survey areas in order to resolve some important points regarding water contamination. Specific classification of the samples according to local geology and rock formations (such as whether or not the water generates or is running through regions containing sedimentary, metamorphic or igneous rock) is essential. Additional research concerning background levels of heavy metal contamination in Iraqi soil and sediment is recommended to determine their effect on water contamination.

Also, defining which agrochemicals are commonly used to increase fertility of local agricultural soils is recommended to specify their composition and actual effects on water contamination. Investigation into the industrial sources of water contamination in each area is also required. Remediation of the contaminated bodies of water (either chemical or phyto remediation depending on the detailed study of the selected area) is recommended to prevent further contamination in the studied areas. Building small dams and ponds along the streams and tributaries may prove to be a good first step towards remediation. Also, communicating knowledge of environmental issues and ethics to local peoples through media and educational campaigns is highly recommended.

Currently the identification of benthic macroinvertebrates collected during the KBA surveys are being rechecked in cooperation with various experts in the U.S., Canada, and Turkey with a special focus is on the genera important for monitoring water quality. Several papers are currently being developed on some of the genera and more are planned. In addition, Nature Iraq and the Twin Rivers Institute for Scientific Research (TRI, a part of the American University of Iraq-Sulaimani) are now DNA barcoding aquatic insects' specimens (the benthic larvae) in order to prepare a database for future surveys concerning adults (flying terrestrial phase). In terms of benthic macroinvertebrates, it is recommended (and is a goal of Nature Iraq/TRI) that:

- A list of benthic macroinvertebrates in Iraq be published providing information about the beneficial and harmful species;
- A guide for benthic macroinvertebrates in Iraq should be published;

- The exact tolerance value for benthic macroinvertebrates inhabiting Iraq should be found and an Iraqi Tolerance Index should be implemented instead of modifying the American and Australian indexes, and

- The collecting of adult (flying terrestrial) phase organisms also be initiated as a tool for estimating water quality.

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References

Agardy, F.J., Sullivan, P. and Clark, J. J. (2005). *The environmental science of drinking water.* Elsevier Science & Technology books.

Ahmed, M.M. (1975). *Systematic Study on Mollusca from Arabian Gulf and Shatt al Arab, Iraq.* Basrah, Iraq: Centre for Arab Gulf Studies, University of Basrah.

Ali, M.; Salam, A.; Jamshaisd, S. and Zahra, T. (2003): *Studies on biodiversity relation to seasonal variation in water of river Indus at Ghatt, Punjab, Pakistan.* Pakistan Journal of Biological Sciences 6(21):1840-1844.

Ali, S.S. and Ameen, D.A.M. (2005). *Geological and hydrochemical study of the Zalm spring, Sharazoor, Sulaimani, Iraq.* Iraqi Journal of Earth Science, 5(1): 45-57.

Allan, J.D. and Castillo M.M. (2007). *Stream Ecology* (2nd Ed.). Springer.

APHA. (2005). *Standard methods for the examination of water, sewage, and wastewater.* 21th Ed., Washington D.C., American Public Health Association

Barbour, M.T., Gerritsen, J., Snyder, B.D., and Stribling, J.B. (1999). *Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates and Fish.* Second Edition. EPA 841-B-99-002. Washington, D.C: U.S. Environmental Protection Agency; Office of Water.

Barros, P., Fidalgo, M.L., and Soares, A.M.V.M. (2001): *Resistance of cladoceran species to taxic microcystis.* Lirnnetica 20(1):173-177.

Bode, R.W., Novak, M.A., Abele, L.E., Heitzman, D.L., Smith, A.J. (2002). *Quality assurance work plan for biological stream monitoring in New York* State. Albany, NY: Stream Biomonitoring Unit, Bureau of Water Assessment and Management, Division of Water, NYS Department of Environmental Conservation.

Bouchard, R.W., Jr. (2004). *Guide to aquatic macroinvertebrates of the Upper Midwest.* St. Paul, MN: Water Resources Center, University of Minnesota. 208pp.

Boyed, C.E. (1981): *Water quality in warmwater fish ponds.* Alabama: Craftmaster printers.

British Colombia Ground Water Association (BCGWA). http://www.bcgwa.org/

Buttermilk Bay, Massachusetts, USA, and management implications. Environmental

Canadian Council of Ministers of the Environment. (1999, updated 2002). *Canadian Sediment Quality Guidelines for the Protection of Aquatic Life (CSQG).* Retrieved from http://www.ccme.ca /assets/pdf/sedqg_summary_table.pdf on 10 January 2009.

Chairman, P.E.G., Ehlke, T.A., Irwin, G.A., Lium, B.W., Slack, K.V. (Eds.). (1977). *Techniques of water-resources investigations of the United States Geological Survey, Chapter A4: Method for collection and analysis of aquatic biological and microbiological samples*. United States Department of the Interior.

Chessman, B.C. (2003). *New sensitivity grades for Australian river macroinvertebrates*. Marine and Freshwater Research. 54: 95–103.

Davis, J.C., Minshall, G.W., Robinson, C.T., Landres, P. (2001). *Monitoring wilderness stream ecosystems*. Gen. Tech. Rep. RMRS-GTR-70. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 137pp.

Davis, S.N. and DeWiest, R.J.M. (1966). *Hydrogeology*. New York: John Wiley & Sons.

Smith, D.G. (2001). *Pennaks Freshwater Invertebrates of the United States*. New York: John Wiley & Sons.

Edmondson, W. T. (1959). *Freshwater biology*. 2nd Edition. New York: John Wiley & Sons. 124 pp.

Einarsson, A. & E. B. Ornolfsdottir (2004). *Long-term changes in benthic cladocera populations in Lake Myvatn, Iceland*. Aquatic Ecology 38: 253-262.

Fernando, C.H. (2002). *A guide to tropical freshwater zooplankton, identification, ecology impact on fisheries*. Leiden, the Netherlands: Backhuys Publishers. 291pp.

Gleeson, C., and Gray, N.F. (1997). *The coliform index and waterborne disease—problems of microbial drinking water assessment*. London: E. and F.N. Spon, LTD., 210 p.

Groundwater Quality Standard (GWQS). (2008) *New Jersey Administrative Code*. Fact sheet. Retreived from http://www.nj.gov/dep/wms/bwqsa/njac79C.pdf on 5 January 2010.

Ontario MoE (1993). *Guidelines for the Protection and Managements of Aquatic Sediment Quality in Ontario (ASQ).* Queen's Printer for Ontario. http://www.ene.gov.on.ca/envision/gp/B1-3.pdf. Retrieved 10 January 2009.

Gülbahar, N. and Elhatip, H. (2005). *Estimation of environmental impacts on the water quality of the Tahtali Dam Watershed in Izmir, Turkey*. Environmental Geology, 47: 725-728.

Hem, J.D. (1985). *Study and Interpretation of the Chemical Characteristics of Natural Water.* USGS Water Supply Paper 2254.

Holt, J.G., Krieg, N.R., Sneath, P.H.A. and others, eds. (1993). *Bergey's manual of determinative bacteriology* (9th Ed.). Baltimore, MD: Williams and Wilkens.

Schumacher, J. (2002). *Richmond Lake Water Quality Project: Surface Water Pollution from Livestock Production.* College of Agriculture and Biological Sciences, South Dakota State University, USSA. Retreived from http://agbiopubs.sdstate.edu/articles/ExEx1010.pdf on 5 January 2010.

Huisman, J., Matthijs, H.C. P., & Visser, P. (2005). *Harmful Cyanobacteria.* Vol 3. Netherlands: Springer.

Hynes, H.B.N. (1974). *The Biology of Polluted Water.* UK: Liverpool Uni. Press.

Kabata-Pendias, A. and Mukherjee, A.B. (2007). *Trace elements from soil to human.* Berlin: Springer.

Kassim, T.I. (2005).*The Phytoplankton in Iraqi Aquatic Habitats.* MoSRT, Directorate of Water Treatment Technology, Water Research Centre. (In Arabic)

Klemm, D.J., Blocksom, K.A., Thoeny, W.T., Fulk, F.A., Herlihy, A.T., Kaufmann, P.R., and Cormier, S.M. (2002). *Methods development and use of macroinvertebrates as indicators of ecological conditions for streams in the mid-Atlantic highlands region.* Environmental Monitoring and Assessment 78: 169–212

Kolbe, C.M., Luedke, M. (2005). *A Guide to Freshwater Ecology.* Texas Commission on Environmental Quality. PO Box 13087. Austin TX 78711-3087

Koste, W. (1978). *Rotatoria.* Die Rädertiere Mitteleuropas Ein Bestimmungswerk, begründet von Max Voigt Überordnung Monogononta. Gebrüder Borntraeger, Stuttgart, 673p.

Krishna, A.K. and Govil, P.K. (2005). *Heavy metal distribution and contamination in soils of Thane-Belapur industrial development area, Mumbai, Western India.* Environmental Geology, 47: 1054-1061.

Mandaville, S.M. (2002). *Benthic Macroinvertebrates in Freshwaters-Taxa Tolerance Values, Metrics, and Protocols.* Project H-1, Soil & Water Conservation Society of Metro Halifax. xviii, Chapters I-VI, Appendices A-B. 128pp.

Mazor, E. (2004). *Chemical and isotopic groundwater hydrology* (3rd ed.). Marcel Dekker, Inc.

McCulloch G. P; Irvine, K,Eckardt, F.D. & Bryant, R. (2008). *Hydrochemical fluctuation and crustacean community composition in an ephemeral saline lake (Sua Pan, Makgadikgadi Botswana).* Hydrobiologia, 596(1).

Merritt, R.W. and Cummins, K.W. (Eds.). (1996). *An Introduction to the Aquatic Insects of North America.* 3rd ed. Kendall-Hunt. ISBN# 0-7872-3241-6. 862pp.

Miller, T. (2008). *Water Monitoring Report. Ambient Biomonitoring Network, Northeast Water Region, Passaic River Drainages, Watershed Management Areas 3, 4, 5, and 6, Round 3 Benthic Macroinvertebrate Data.* Volume 1 of 2. Bureau of Freshwater and Biological Monitoring, NJ Department of Environmental Protection.

Mitchell, M.K., and Stapp, W.B. (2000). *Field Manual for Water Quality Monitoring.* 12th ed. Dubuque, Iowa: Kendall/Hunt Publishing Company. ISBN 0-7872-6801-1

Mustafa, O.M. (2006). *Impact of Sewage Wastewater on the Environment of Tanjero River and its Basin within Sulaimani City/NE-Iraq.* Unpublished M.Sc. Thesis, University of Baghdad: College of Science.

Needham, J.G., Westfall, M.J., and May, M.L. (2000). *Dragonflies of North America.* Scientific Publishers, USA.

Nevada Division of Environmental Protection (NDEP). (1999). *Proposed New Walker Lake Water Quality Standards.* Fact Sheet. (http://ndep.nv.gov/bwqp/newstand.pdf)

NSW Water Bug Survey (2003). *Bug Detective Guide.* NSW Department of Infrastructure, Planning and Natural Resources. www.bugsurvey.nsw.gov.au

Ode, P. (2003). *List of Californian Macroinvertebrate Taxa and Standard Taxonomic Effort.* California Department of Fish and Game, Aquatic Bioassessment Laboratory.

Oliver, D.R., Roussel, M.E. (1983). *The insects and arachnids of Canada, part 11, the genera of larval midges of Canada (Diptera: Chironomidae).* Ontario, Canada: NRC Research Press.

Peckarsky, B.L., Fraissinet, P.R., Penton, M.A., and Conklin, D.J. (1990). *Freshwater Macroinvertebrates of Northeastern North America.* Cornell Univ. Press. ISBN: 0-8014-9688-8. XII, 442pp.

Pepper, I.L., Gerba, C.P., and Brusseau, M.L., eds. (1996). *Pollution science.* New York, Academic Press, 397 p.

Plaziat J.C., Younis, W.R. (2005). *The modern environments of Molluscs in southern Mesopotamia, Iraq: A guide to paleogeographical reconstructions of Quaternary fluvial, palustrine and marine deposits.* Carnets de Géologie / Notebooks on Geology, Brest, Article 2005/01 (CG2005_A01).

Ryding, S. O. & W. Rast (1989): *The control of eutrophication of lakes and reservoirs.* Man and Biospher Series, voi. 1.

Schumacher, J. (2002). *Surface Water Pollution from Livestock Production.* Agricultural Engineering Department. South Dakota State University / USDA.

Seminole Tribe of Florida (STF). (2000). *Water Quality Protection and Restoration: Surface Water Quality Standards.* Fact Sheet. (http://www.seminoletrib.com/services/water.shtml)

Stevenson, R.J., Bothwell, M.L. and Lowe, R.L. (1996). *Algal Ecology: Freshwater Benthic Ecosystems.* Academic Press. www.academicpress.com.

Stoddard, C.S., M.S. Coyne, and J.H. Grove. (1998). *Fecal bacteria survival and infiltration.* American Society of Agronomy. J. Environ. Qual. 27:1515-1523.

Stoddard, C.S., M.S. Coyne, and J.H. Grove. 1998. *Fecal bacteria survival and infiltration through a shallow agricultural soil: timing and tillage effects*. J. Environ. Qual. 27:1516-1523.

Stoermer, E.F. and J.P. Smol. (2004). *The Diatoms Applications for the Environmental and Earth Sciences*. Cambridge University Press. (e-book: netLibrary).

Stribling, J.B., Jessup, B.K., White, J.S., Boward, D., and Hurd, M. (1998). *Development of a Benthic Index of Biotic Integrity for Maryland Streams.* Maryland Department of Natural Resources. Report no. CBWP-EA-98-3

Ter Braak, C.J.F. and Šmilauer, P. (2002). *CANOCO Reference Manual and CanoDraw for Windows User's Guide: Software for Canonical Community Ordination (version 4.5).* Ithaca, NY: Microcomputer Power. 500 pp.

Thelin R. and G.F. Gifford. (1983). *Fecal coliform release patterns from fecal material of cattle.* J. Environ. Qual. 12(1):57-63.

Thompson, F.G. (2004). *An Identification Manual for the Freshwater Snails of Florida.* Florida Museum of Natural History, University of Florida, Gainesville, Florida 32611– 7800.

Thorp, J. H. and Covich, A.P. (1991): *Ecology and classification of North American freshwater invertebrates.* New York: Academic press. 991pp.

Thorp, J.H. and Covich, A.P., eds. (2001). *Ecology and Classification of North American Freshwater Invertebrates.* Second Edition. San Diego: Academic Press. An Imprint of Elsevier. ISBN-10: 0126906475. 950 pp.

Stoddard, C.S., Coyne, M.S., and Grove, J.H. (1998). *Fecal bacteria survival and infiltration through a shallow agricultural soil: timing and tillage effects.* American Society of Agronomy. J. Environ. Qual. Volume: 27, Issue: 6, pp: 1516-1523.

U.S. Environmental Protection Agency. (1996). *Acid digestion of sediments, sludges and soils.* USEPA, Method No.3050B.

Waterwatch South Australia (2004). *Aquatic Macroinvertebrate Record Sheet.* Australian Water Quality Centre. http://www.onkaparinga.net/downloads/own/macro_id.pdf

Wehr, J. D. and Sheath, R. G. (2003). *Freshwater Algae of North America*. Elsivier, San Diego, California 92101-4495, USA.

Westfall, M.J., May, M.L. (1996). *Damselflies of North America*. Scientific Publishers, USA.

Wetzel, R.G., Likens, G.E. (2000). *Limnological Analyses*. 3rd ed. Springer-Verlag New York, Inc. USA. ISBN 0-387-98928-5.

Wiggins, G.B., ed. (1996). *Larvae of the North America Caddisfly Genera (Trichoptera*). 2nd ed. University of Toronto Press, Canada.

Wilton, T.F. (2004). *Biological Assessment of Iowa's Wadeable Streams*. Des Moines, Iowa: Iowa Department of Natural Resources.

World Health Organization (WHO). (2006). *Guidelines for Drinking-Water Quality* (3rd ed.), Vol.1. (http://www.who.int/water_sanitation_health/dwq/gdwq0506.pdf)

Yuce, G.; Pinarbasi, A.; Ozcelik, S. and Ugurlnoglu, D. (2006). *Soil and water pollution derived from anthropogenic activities in the Porsuk River Basin, Turkey*. Environmental Geology, 49: 359-375.

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Annex 1: Water Quality based on Modified Pollution Index and Pollution Tolerance Index

Table 157: Water quality in Sulaimani sites during Kurdistan KBA - winter **survey 2009 based on Modified PI and PTI**

Site Name	**Modified PI**	**Modified PTI**	**Water Quality depending on the Modified PI**	**Water Quality depending on the Modified PTI**	**Final Water Quality Rank**
Ahmed Awa	145	45	Excellent	Excellent	Excellent
Chemi Rezan	110	40	Very Good	Excellent	Very Good to Excellent
Penjween	108	37	Very Good	Excellent	Very Good to Excellent
Kalar (Diyala River)	72	29	Good	Excellent	Very Good
Mawat (Du Choman)	76	28	Very Good	Very Good	Very Good
Mertka	64	25	Good	Very Good	Good to Very Good
Sargalu	82	22	Very Good	Good	Good to Very Good
Zamok/ Near Chwarta	96	22	Very Good	Good	Good to Very Good
Bani Khan (Diyala River)	60	22	Good	Good	Good
Darua Kotr	57	19	Good	Good	Good
Little Zab River/ Above Du Choman	59	22	Good	Good	Good
Little Zab River/ After Dukan Dam	46	19	Fair	Good	Fair to good
Diyala River/After Darbandikhan Dam	46	11	Fair	Fair	Fair
Little Zab River/ Below Tabban Junction	51	15	Fair	Fair	Fair
Zalm	44	22	Poor	Good	Fair
Kani Sard (Chami Gawra)	27	12	Poor	Fair	Poor to Fair
Garmk (Diyala River)	27	14	Poor	Fair	Poor to Fair
New Halaja (Qara Ali Site 5)	13	7	Poor	Poor	Poor

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Table 158: Water quality in Sulaimani sites during Kurdistan KBA - summer survey 2009

Site Name	Modified PI	Modified PTI	Water Quality depending on the Modified PI	Water Quality depending on the Modified PTI	Final Water Quality Rank
Ahmed Awa	109	30	Very Good	Excellent	Very Good to Excellent
Zalm	70	27	Good	Very Good	Good to Very Good
Kela Spi	62	22	Good	Good	Good
Sarchinar	70	20	Good	Good	Good
Bani Khelan	47	14	Fair	Fair	Fair
Said Sadiq	38	20	Poor	Good	Fair
New Halabja	37	12	Poor	Fair	Poor to Fair
Qara Ali	28	15	Poor	Fair	Poor to Fair
Below Qara Dagh Bridge	6	6	Poor	Poor	Poor
Darbandikhan Lake/After Dam	22	10	Poor	Poor	Poor
Darbandikhan Lake/ Sirwan Input	10	3	Poor	Poor	Poor
Darbandikhan Lake/ Tanjero Input	12	7	Poor	Poor	Poor

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Annex 2: Tables of Biotic Indicators - Phytoplankton

Table 159: Phytoplankton diversity in Sulaimani sites during Kurdistan KBA - winter survey 2009

Site Name	Site Code	Shannon' diversity (H)	Relative Diversity Rank
Darbandikhan Lake-Tanjero Input	S1A	2.85	2.55 - 3.38 Good
Sargalu	S7	2.64	
Dokan Lake-Near Rania	S2B	2.55	
Kani Sard	S22	2.49	1.7 - 2.54 Moderate
Chami Razan Area	S10	2.48	
Bani Khan-Diyala River	S3B	2.36	
Zalm	S12	2.34	
Ahmed Awa	S4A	2.24	
Kalar-Diyala River	S3	2.17	
Mawat	S8	2.15	
Penjween	S5	2.12	
Darua Kotr	S19	2.09	
Zamok-near Chwarta	S16	1.94	
Little Zab above Du Choman Junction	S17	1.90	
Little Zab below Tabban Junction	S20	1.82	
Dokan Lake-Before Dam	S2D	1.74	
Qara Ali Site 5	QA-5	1.60	0.86 - 1.69 Low
Dokan Lake-After Dam	S2E	1.57	
Dokan Lake-Little Zab Input	S2A	1.56	
Mertka	S18	1.54	
Dokan Lake-Centre of Lake	S2C	1.30	
Darbandikhan Lake-Sirwan Input	S1B	1.12	
Darbandikhan Lake-Center South	S1D	1.10	
Diyala (Sirwan) River/After the Dam - After Dam	S1F	0.98	
Garmk-Diyala River	S3A	0.93	
Darbandikhan Lake-Center North	S1C	0.73	0 - 0.85 Very Low
Darbandikhan Lake-Near Dam	S1E	0.24	

Relative Diversity Rank	4.24 - 5.07 Excellent	1.7 - 2.54 Moderate
Number of Species in the whole survey = 159	3.39 - 4.23 Very good	0.86 - 1.69 Low
Max. Diversity in perfect evenness = 5.07	2.55 - 3.38 Good	0 - 0.85 Very Low

Table 160: Phytoplankton diversity in Sulaimani sites during Kurdistan KBA - summer survey 2009

Site Name	Site Code	Shannon' diversity (H)	Relative Diversity Rank
Zalm	S12	2.68	Good
Diyala (Sirwan) River/After the Dam-After Dam	S1F	2.56	
Bani khelan	S3A	2.55	

Site Name	Site Code	Shannon' diversity (H)	Relative Diversity Rank
Kela Spi	WQ 1	2.49	
Below Qara Dagh Bridge	WQ 3	2.20	Moderate
Ahmed Awa	S4A	2.06	
Chaq Chaq	WQ 2	2.00	
Qara Ali	WQ 4	1.79	
Darbandikhan Lake-Sirwan Input	S1B	1.56	Low
Darbandikhan Lake-Near Dam	S1E	1.54	
Said Sadiq	S29	0.65	Very Low
Darbandikhan Lake-Center South	S1D	0.60	
Darbandikhan Lake-Tangero Input	S1A	0.52	
New Halabja	WQ 5	0.39	
Darbandikhan Lake-Center North	S1C	0.33	

Relative Diversity Rank	3.95 - 4.73 Excellent	1.59 - 2.37 Moderate
Number of Species in the whole survey = 113	3.16 - 3.94 Very good	0.8 - 1.58 Low
Max. Diversity in perfect evenness = 4.73	2.38 - 3.15 Good	0 - 0.79 Very Low

Table 161: Phytoplankton richness in Sulaimani sites during Kurdistan KBA - winter survey 2009

Site Name	Site Code	Number of species	Richness	Relative Richness Rank
Darbandikhan Lake-Tanjero Input	S1A	65	4.17	3.39 - 4.23 Very good
Dokan Lake-Near Rania	S2B	64	4.16	
Dokan Lake-Little Zab Input	S2A	58	4.06	
Zamok-near Chwarta	S16	48	3.87	
Little Zab above Isa Junction	S17	43	3.76	
Kalar-Diyala River	S3	41	3.71	
Little Zab below Tabban Junction	S20	40	3.69	
Bani Khan-Diyala River	S3B	39	3.66	
Mertka	S18	39	3.66	
Garmk-Diyala River	S3A	36	3.58	
Chami Razan Area	S10	36	3.58	
Diyala (Sirwan) River/After the Dam - After Dam	S1F	35	3.56	

Site Name	Site Code	Number of species	Richness	Relative Richness Rank
Dokan Lake-After Dam	S2E	35	3.56	
Kani Sarda	S22	35	3.56	
Sargalu	S7	35	3.56	
Mawat	S8	35	3.56	
Penjween	S5	31	3.43	
Zalm	S12	30	3.40	
Darua Kotr	S19	30	3.40	
Qara Ali Site 5	QA-5	27	3.30	2.55 - 3.38 Good
Dokan Lake-Before Dam	S2D	25	3.22	
Darbandikhan Lake-Sirwan Input	S1B	23	3.14	
Darbandikhan Lake-Center North	S1C	19	2.94	
Ahmed Awa	S4A	19	2.94	
Darbandikhan Lake-Center South	S1D	17	2.83	
Dokan Lake-Centre of Lake	S2C	17	2.83	
Darbandikhan Lake-Near Dam	S1E	11	2.40	1.7 - 2.54 Moderate

Relative Richness Rank	4.24 - 5.07 Excellent	1.7 - 2.54 Moderate
Number of Species in the whole survey = 159	3.39 - 4.23 Very good	0.86 - 1.69 Low
Max. Richness = 5.07	2.55 - 3.38 Good	0 - 0.85 Very Low

Table 162: Phytoplankton richness in Sulaimani sites during Kurdistan KBA - summer survey 2009

Site Name	Site Code	Number of species	Richness	Relative Richness Rank
Zalm	S12	49	3.89	Very good
Kela Spi	WQ 1	43	3.76	
Diyala (Sirwan) River/After the Dam-After Dam	S1F	34	3.53	
Darbandikhan Lake-Sirwan Input	S1B	30	3.40	
Bani khelan	S3A	29	3.37	
Below Qara Dagh Bridge	WQ 3	27	3.30	
Said Sadiq	S29	26	3.26	
Qara Ali	WQ 4	24	3.18	
Chaq Chaq	WQ 2	22	3.09	Good
Ahmed Awa	S4A	21	3.04	

Site Name	Site Code	Number of species	Richness	Relative Richness Rank
New Halabja	WQ 5	21	3.04	
Darbandikhan Lake-Center South	S1D	19	2.94	
Darbandikhan Lake-Center North	S1C	18	2.89	
Darbandikhan Lake-Tangero Input	S1A	15	2.71	
Darbandikhan Lake-Near Dam	S1E	15	2.71	
Relative Richness Rank		3.95 - 4.73 Excellent	1.59 - 2.37 Moderate	
Number of Species in the whole survey = 113		3.16 - 3.94 Very good	0.8 - 1.58 Low	
Max. Richness = 4.73		2.38 - 3.15 Good	0 - 0.79 Very Low	

Table 163: Phytoplankton evenness in Sulaimani sites during Kurdistan KBA - winter survey 2009

Site Name	Site Code	Evenness	Relative Evenness Rank
Ahmed Awa	S4A	0.76	0.68 - 0.83 Very good
Sargalu	S7	0.74	
Kani Sarda	S22	0.70	
Chami Rezan Area	S10	0.69	
Zalm	S12	0.69	
Darbandikhan Lake-Tanjero Input	S1A	0.68	
Bani Khan-Diyala River	S3B	0.64	0.51 - 0.67 Good
Penjween	S5	0.62	
Darua Kotr	S19	0.61	
Dokan Lake-Near Rania	S2B	0.61	
Mawat	S8	0.60	
Kalar-Diyala River	S3	0.58	
Dokan Lake-Before Dam	S2D	0.54	
Little Zab above Isa Junction	S17	0.51	
Zamok-near Chwarta	S16	0.50	0.34 - 0.5 Moderate
Little Zab below Tabban Junction	S20	0.49	
Qara Ali Site 5	QA-5	0.48	
Dokan Lake-Centre of Lake	S2C	0.46	
Dokan Lake-After Dam	S2E	0.44	
Mertka	S18	0.42	
Darbandikhan Lake-Center South	S1D	0.39	
Dokan Lake-Little Zab Input	S2A	0.39	
Darbandikhan Lake-Sirwan Input	S1B	0.36	
Diyala (Sirwan) River/After the Dam-After Dam	S1F	0.28	0.18 - 0.33 Low
Garmk-Diyala River	S3A	0.26	
Darbandikhan Lake-Center North	S1C	0.25	
Darbandikhan Lake-Near Dam	S1E	0.10	0 - 0.17 Very Low

Relative Evenness Rank	0.84 - 1 Excellent	0.34 - 0.5 Moderate
	0.68 - 0.83 Very good	0.18 - 0.33 Low

Site Name	Site Code	Evenness	Relative Evenness Rank
		0.51 - 0.67 Good	0 - 0.17 Very Low

Table 164: Phytoplankton evenness in Sulaimani sites during Kurdistan KBA - summer survey 2009

Site Name	Site Code	Evenness	Relative Evenness Rank
Bani khelan	S3A	0.76	Very good
Diyala (Sirwan) River/After the Dam-After Dam	S1F	0.73	
Zalm	S12	0.69	
Ahmed Awa	S4A	0.68	
Below Qara Dagh Bridge	WQ 3	0.67	Good
Kela Spi	WQ 1	0.66	
Chaq Chaq	WQ 2	0.65	
Darbandikhan Lake-Near Dam	S1E	0.57	
Qara Ali	WQ 4	0.56	
Darbandikhan Lake-Sirwan Input	S1B	0.46	Moderate
Darbandikhan Lake-Center South	S1D	0.20	Low
Said Sadiq	S29	0.20	
Darbandikhan Lake-Tangero Input	S1A	0.19	
New Halabja	WQ 5	0.13	Very Low
Darbandikhan Lake-Center North	S1C	0.11	
Relative Evenness Rank		0.84 - 1 Excellent	0.34 - 0.5 Moderate
		0.68 - 0.83 Very good	0.18 - 0.33 Low
		0.51 - 0.67 Good	0 - 0.17 Very Low

Annex 3: Tables of Biotic Indicators – Benthic Macroinvertebrates

Table 165: Benthic Macroinvertebrates' density (indv./m²) in Sulaimani sites during Kurdistan KBA - winter survey 2009

Site Name	Density (indv./m²)	Relative Density Rank
Sargalu	1009	735 - 881+ High
Zalm	782	
Zamok/ Near Chwarta	506	441 - 587 Good
Ahmed Awa	503	
Diyala River/After Darbandikhan Dam	485	
Chemi Rezan	410	295 - 440 Moderate
Little Zab River/ Below Tabban Junction	378	
Bani Khan (Diyala River)	366	
Kalar (Diyala River)	340	
Little Zab River/ Above Isa Junction	337	
Mawat	317	
Garmk (Diyala River)	314	
Kani Sard (Chami Gawra)	285	148 - 294 Low
Little Zab River/ After Dukan Dam	235	
Qara Ali Site 5	218	
Penjween	212	
Mertka	172	
Darua Kotr	128	0 - 147 Very Low

Relative Density Rank	735 - 881+ High 588 - 734 Very good 441 - 587 Good	295 - 440 Moderate 148 - 294 Low 0 - 147 Very Low

Table 166: Benthic Macroinvertebrates' density (indv./m²) in Sulaimani sites during Kurdistan KBA - summer survey 2009

Site Name	Density (indv./m²)	Relative Density Rank
Ahmed Awa	1167	High
New Halabja	1135	
Bani Khelan	905	Very good
Sarchinar	879	
Zalm	795	
Darbandikhan Lake/After Dam	705	Good
Qara Ali	581	Moderate
Said Sadiq	508	
Kela Spi	486	

Site Name	Density (indv./m²)	Relative Density Rank
Darbandikhan Lake/ Sirwan Input	333	Low
Below Qara Dagh Bridge	276	
Darbandikhan Lake/ Tanjero Input	140	Very Low

Relative Density Rank	976+ High 781 - 975 Very good 586 - 780 Good	391 - 585 Moderate 196 - 390 Low 0 - 195 Very Low

Table 167: Benthic Macroinvertebrates' diversity in Sulaimani sites during Kurdistan KBA - winter survey 2009

Site Name	Shannon' Diversity (H)	Relative Diversity Rank
Penjween	2.96	2.96 - 3.68 Very good
Zamok/ Near Chwarta	2.82	2.22 - 2.95 Good
Ahmed Awa	2.78	
Chemi Rezan	2.66	
Kalar (Diyala River)	2.65	
Little Zab River/ After Dukan Dam	2.44	
Mertka	2.18	1.48 - 2.21 Moderate
Mawat	2.12	
Diyala River/After Darbandikhan Dam	1.90	
Sargalu	1.80	
Kani Sard (Chami Gawra)	1.74	
Little Zab River/ Below Tabban Junction	1.72	
Little Zab River/ Above Isa Junction	1.62	
Darua Kotr	1.61	
Garmk (Diyala River)	1.32	0.75 - 1.47 Low
Bani Khan (Diyala River)	1.29	
Qara Ali Site 5	1.14	
Zalm	1.04	

Relative Diversity Rank Number of Species in the whole survey = 83 Max. Diversity in perfect evenness = 4.42	3.69 - 4.42 Excellent 2.96 - 3.68 Very good 2.22 - 2.95 Good	1.48 - 2.21 Moderate 0.75 - 1.47 Low 0 - 0.74 Very Low

Table 168: Benthic Macroinvertebrates' diversity in Sulaimani sites during Kurdistan KBA - summer survey 2009

Site Name	Shannon' Diversity (H)	Relative Diversity Rank
Sarchinar	2.71	Good
Kela Spi	2.69	
Bani Khelan	2.29	
Darbandikhan Lake/After Dam	2.28	

Site Name	**Shannon' Diversity (H)**	**Relative Diversity Rank**
New Halabja	2.23	
Ahmed Awa	1.83	Moderate
Said Sadiq	1.74	
Qara Ali	1.63	
Darbandikhan Lake/ Tanjero Input	1.52	
Zalm	1.51	
Darbandikhan Lake/ Sirwan Input	1.22	Low
Below Qara Dagh Bridge	0.75	

Relative Diversity Rank	3.69 + Excellent	1.48 - 2.21 Moderate
Number of Species in the whole survey = 86	2.96 - 3.68 Very good	0.75 - 1.47 Low
Max. Diversity in perfect evenness = 4.45	2.22 - 2.95 Good	0 - 0.74 Very Low

Table 169: Benthic Macroinvertebrates' richness in Sulaimani sites during Kurdistan KBA - winter survey 2009

Site Name	Number of species	Richness	Relative Richness Rank
Chemi Rezan	28	3.33	2.96 - 3.68 Very good
Ahmed Awa	27	3.30	
Penjween	24	3.18	
Zamok/ Near Chwarta	24	3.18	
Kalar (Diyala River)	20	3.00	
Little Zab River/ After Dukan Dam	17	2.83	2.22 - 2.95 Good
Sargalu	17	2.83	
Diyala River/After Darbandikhan Dam	14	2.64	
Mawat	14	2.64	
Mertka	13	2.56	
Bani Khan (Diyala River)	12	2.48	
Little Zab River/ Above Isa Junction	12	2.48	
Zalm	11	2.40	
Little Zab River/ Below Tabban Junction	11	2.40	
Darua Kotr	10	2.30	
Garmk (Diyala River)	7	1.95	1.48 - 2.21 Moderate
Kani Sard (Chami Gawra)	7	1.95	
Qara Ali Site 5	4	1.39	0.75 - 1.47 Low

Relative Richness Rank	3.69 - 4.42 Excellent	1.48 - 2.21 Moderate
Number of Species in the whole survey = 83	2.96 - 3.68 Very good	0.75 - 1.47 Low
Max. Richness = 4.42	2.22 - 2.95 Good	0 - 0.74 Very Low

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Table 170: Benthic Macroinvertebrates' richness in Sulaimani sites during Kurdistan KBA - summer survey 2009

Site Name	Number of species	Richness	Relative Richness Rank
Kela Spi	29	3.37	Very good
Sarchinar	28	3.33	
Bani Khelan	21	3.04	
Ahmed Awa	20	3	
Said Sadiq	17	2.83	Good
New Halabja	15	2.71	
Zalm	15	2.71	
Qara Ali	14	2.64	
Darbandikhan Lake/After Dam	14	2.64	
Darbandikhan Lake/ Tanjero Input	6	1.79	Moderate
Below Qara Dagh Bridge	5	1.61	
Darbandikhan Lake/ Sirwan Input	4	1.39	Low

Relative Richness Rank	3.69 + Excellent	1.48 - 2.21 Moderate
Number of Species in the whole survey = 86	2.96 - 3.68 Very good	0.75 - 1.47 Low
Max. Richness = 4.45	2.22 - 2.95 Good	0 - 0.74 Very Low

Table 171: Benthic Macroinvertebrates' evenness in Sulaimani sites during Kurdistan KBA - winter survey 2009

Site Name	Evenness	Relative Evenness Rank
Penjween	0.93	0.84 - 1 Excellent
Kani Sard (Chami Gawra)	0.89	
Zamok/ Near Chwarta	0.89	
Kalar (Diyala River)	0.88	
Little Zab River/ After Dukan Dam	0.86	
Mertka	0.85	
Ahmed Awa	0.84	
Qara Ali Site 5	0.83	0.68 - 0.83 Very good
Mawat	0.80	
Chemi Rezan	0.80	
Diyala River/After Darbandikhan Dam	0.72	
Little Zab River/ Below Tabban Junction	0.72	
Darua Kotr	0.70	
Garmk (Diyala River)	0.68	
Little Zab River/ Above Isa Junction	0.65	0.51 - 0.67 Good
Sargalu	0.64	

Site Name	Evenness	Relative Evenness Rank
Bani Khan (Diyala River)	0.52	
Zalm	0.43	0.34 - 0.5 Moderate

Relative Evenness Rank	0.84 - 1 Excellent	0.34 - 0.5 Moderate
	0.68 - 0.83 Very good	0.18 - 0.33 Low
	0.51 - 0.67 Good	0 - 0.17 Very Low

Table 172: Benthic Macroinvertebrates' evenness in Sulaimani sites during Kurdistan KBA - summer survey 2009

Site Name	Evenness	Relative Evenness Rank
Darbandikhan Lake/ Sirwan Input	0.88	Excellent
Darbandikhan Lake/After Dam	0.87	
Darbandikhan Lake/ Tanjero Input	0.85	
New Halabja	0.83	Very good
Sarchinar	0.81	
Kela Spi	0.8	
Bani Khelan	0.75	
Qara Ali	0.62	Good
Said Sadiq	0.62	
Ahmed Awa	0.61	
Zalm	0.56	
Below Qara Dagh Bridge	0.47	Moderate

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Table 173: Percentage of Ephemeroptera, Plecoptera, & Trichoptera (EPT %) in Sulaimani sites during Kurdistan KBA - winter survey 2009

Site Name	EPT %	EPT % Rank
Bani Khan (Diyala River)	82	Very good
Sargalu	63	Good
Kalar (Diyala River)	44	Moderate
Mawat	43	
Mertka	37	
Chemi Rezan	35	
Penjween	27	Low
Ahmed Awa	26	
Zamok/ Near Chwarta	20	
Darua Kotr	9	Very Low
Little Zab River/ Above Isa Junction	6	
Little Zab River/ Below Tabban Junction	3	
Little Zab River/ After Dukan Dam	2	
Garmk (Diyala River)	1	
Diyala River/After Darbandikhan Dam	0	
Kani Sard (Chami Gawra)	0	
Zalm	0	
Qara Ali Site 5	0	

EPT % Rank	84 - 100 Excellent 68 - 83 Very good 51 - 67 Good	34 - 50 Moderate 18 - 33 Low 0 - 17 Very Low

Table 174: Percentage of Ephemeroptera, Plecoptera, & Trichoptera (EPT%) in Sulaimani sites during Kurdistan KBA - summer survey 2009

Site Name	EPT %	EPT % Rank
Ahmed Awa	78	Very good
Sarchinar	40	Moderate
New Halabja	24	Low
Said Sadiq	9	Very Low
Zalm	8	
Kela Spi	4	
Qara Ali	2	
Bani Khelan	2	
Below Qara Dagh Bridge	0	
Darbandikhan Lake/ Tanjero Input	0	
Darbandikhan Lake/ Sirwan Input	0	
Darbandikhan Lake/After Dam	0	