USAID | LEBANON
FROM THE AMERICAN PEOPLE

LITANI RIVER BASIN MANAGEMENT SUPPORT PROGRAM

WATER QUALITY SURVEY – WET SEASON (WINTER 2010-2011)

SEPTEMBER 2011
This report was produced for review by the United States Agency for International Development (USAID). It was prepared by International Resources Group (IRG) for the Wet Season Water Quality Survey of the Litani River Basin Project.

LITANI RIVER BASIN MANAGEMENT SUPPORT PROGRAM

WATER QUALITY SURVEY – WET SEASON (WINTER 2010-2011)

Contract No.: EPP-I-00-04-00024-00 order no 7.

September 2011

TABLE OF CONTENTS

1. INTRODUCTION 1
 1.1. Authorization 1
 1.2. Purpose of this Report 1
 1.3. Program Objectives 1
 1.4. Program Components 2
2. BACKGROUND INFORMATION 3
3. STUDY OBJECTIVES AND WORK PLAN 4
4. STUDY METHODOLOGY 5
 4.1. Field and Reconnaissance Surveys 5
 4.2. Sampling Framework 5
 4.3. ULB Sampling Locations 12
  4.3.1. Sampling the Upper Litani Basin 12
  4.3.2. Sampling the Qaraoun Lake 12
  4.3.3. Sampling of Irrigation Canal 900 21
  4.3.4. Sample Collection Procedural Guidelines and Log Forms 21
  4.3.5. Sampling and Analytical Quality Determination 21
5. RESULTS AND DISCUSSION 25
 5.1. Results of the Field Study of the ULB 25
  5.1.1. The Yellow Zone (Upper Zone of the ULB) 25
  5.1.2. The Orange Zone (Middle Zone of ULB) 26
  5.1.3. The Green Zone (lower Zone of the URB) 28
 5.2. Litani River Water Quality Assessment 30
  5.2.1. Domestic Water Use 36
  5.2.2. Irrigation Water Use 42
  5.2.3. Water for Livestock Use 48
 5.3. Ground Water Quality Assessment 51
  5.3.1. Water Springs Quality Assessment 51
  5.3.2. Well Water Quality Assessment 56
 5.4. Qaraoun Lake Water Quality Assessment 63
 5.5. Irrigation Canal 900 Water Quality Assessment 69
  5.5.1. Water for Irrigation Use 71
  5.5.2. Water for Livestock Use 75
 5.6. Wastewater Quality Assessment 75
  5.6.1. Domestic Wastewater (Sewage) 75
  5.6.2. Industrial Wastewater Quality Assessment 81
 5.7. Soil Quality Assessment 81
 5.8. Sediments Quality Assessment 92
6. CONCLUSION AND RECOMMENDATIONS 100
 6.1. Conclusion 100
  6.1.1. Upper Litani River Basin Characteristics 100
  6.1.2. Litani River Water Quality Profile Assessment 101
  6.1.3. Ground Water Sources 105
  6.1.4. Qaraoun Lake Water Assessment 109
  6.1.5. Irrigation Canal 900 Water Quality Assessment 111
  6.1.6. Wastewater Quality Assessment 112
  6.1.7. Quality Assessment 113

6.1.8. Sediments Quality Assessment 115
6.2. Recommendations 116
6.2.1. Restore Litani River Health and Wellbeing 116
6.2.2. Protect and Sustain the Quality of Ground Water Resources 117
6.2.3. Regulate the Use of Wastewater for Irrigation 118
6.2.4. Enhance the Water Quality of the Qaraoun Lake 119
6.2.5. Enhance the Quality of Irrigation Canal 900 119
6.2.6. Develop an Sustain Water Quality Monitoring Programs 119
6.2.7. Complete the Risk Analysis Process to 120
7. REFERENCE LIST 121
8. APPENDIX I: DETAILED RESULTS 123
8.1. Surface Results 124
8.2. Spring Results 135
8.3. Well Results 139
8.4. Lake Results 144
8.5. Canal 900 Results 149
8.6. Wastewater Results ..... **Error! Bookmark not defined.**
8.7. Industrial Results ..... **Error! Bookmark not defined.**
9. APPENDIX II: SAMPLED SITES ..... ERROR! BOOKMARK NOT DEFINED.
9.1. Yellow Zone ..... **Error! Bookmark not defined.**
9.2. Orange Zone ..... **Error! Bookmark not defined.**
9.3. Green Zone ..... **Error! Bookmark not defined.**
9.4. GPS Data ..... **Error! Bookmark not defined.**

LIST OF TABLES

Table 1. Standard Analytical Method for the Determination of the Physical, Chemical and Microbiological Quality Parameters.......... 24
Table 2. Major Solid Waste Dump Sites Scattered along the ULB.......... 30
Table 3. Percentage of Surface water Sampling Sites Exceeding Recommended National and International standard Levels for Drinking Water.......... 35
Table 4. The Percentage of Surface Water Sampling Sites Exceeding Recommended National and International Standard Levels for Drinking Water.......... 37
Table 5. Comparison of the Surface Water Quality Profile Reported by the BAMAS 2005 Study and the Current 2010-11 Study.......... 39
Table 6. Guidelines for Evaluating Water Quality for Irrigation.......... 43
Table 7. Recommended Maximum Concentrations of Trace Metals in Irrigation Water.......... 49
Table 8. Water Quality Guide for Livestock and Poultry.......... 50
Table 9. Restrictive levels of Magnesium in Drinking Water for Livestock.......... 50
Table 10. Guideline Levels for Trace Metals in Drinking Water for Livestock.......... 51
Table 11. Percentage of Well Water Sampling Sites Exceeding the Recommended National and International Standard Levels for Drinking Water.......... 57
Table 12. Comparison of Ground Water Quality Profile Reported by the BAMAS 2005 Study and the Current 2010-11 Study.......... 58
Table 13. Comparison of the Quaaoun Lake water Quality Profile: BAMAS 2005 and Current 2010-11 Study (level in mg/l unless indicated).......... 68
Table 14. Comparison of the Quality of Irrigation Canal 900; BAMAS 2005 and Current 2010-11 Study (levels in mg/l unless indicated).......... 71
Table 15. Survival Times of Excreted Pathogens in Freshwater and Sewage at 20-30°C.......... 79
Table 16. Survival Times of Selected Excreted Pathogens in Soil and on Crop Surfaces at 20-30°C.......... 80
Table 17. Sources of Metals and Related Health Risks.......... 83
Table 18. Canadian Environmental Quality Guidelines for Soils.......... 84
Table 19. Metal Content in Soil (Dry and the Wet Seasons of the Year).......... 85
Table 20. Metal Content in Canal Soil (Dry and Wet Seasons of the Year).......... 86
Table 21. Sediment Quality Criteria and Guidelines.......... 93
Table 22. Metal Content in Sediments: Dry and Wet Seasons.......... 95

LIST OF FIGURES

Figure 1. Upper Litani Basin Urbanization Profile 7
Figure 2. Upper Litani Basin Urbanization Profile 8
Figure 3. Upper Litani Basin Point and Nonpoint sources of Pollution 9
Figure 4. Upper Litani Basin Types and Location of Samples 10
Figure 5. Upper Litani Basin Types and Location of Samples 11
Figure 6. Wastewater Treatment Plant by the Lake in Bab Merae (Under Construction) 12
Figure 7. Location of Surface Water Sampling Points along the Litani River and its Tributaries 14
Figure 8. Location of Sediment Samples along the Litani River, its Tributaries and Qaraoun Lake 14
Figure 9. Location of Groundwater Samples along the Litani River and its Tributaries 15
Figure 10. Location of Spring Water Samples along the Litani River and its Tributaries 16
Figure 11. Location of Well Water Samples along the Litani River and its Tributaries 17
Figure 12. Location of Wastewater and industrial Waste Samples along the Litani River and its Tributaries 18
Figure 13. Location of Soil Samples along the Litani River and its Tributaries 19
Figure 14. Location of Water and Sediment Samples along the Qaraoun Lake 20
Figure 15. Irrigation Canal 900 21
Figure 16. Location of Water and Soil samples along Irrigation Canal 900 23
Figure 17. Sewage Discharge in Ablah 25
Figure 18. Litani River in Fersol 25
Figure 19. Litani River in Taraya 26
Figure 20. Dead Animals Discharge in River Flow in Temnine Al Tahta 26
Figure 21. Bedawni Tributary Originating from Qaa El Reem Springs 27
Figure 22. Solid waste Dumping in Delhameyieh 27
Figure 23. Ghzayel Tributary Originating from Anjar & Chamsine Water Springs 27
Figure 24. Solid Waste Dumping in Housh Al Harrimi 27
Figure 25. River Flow in Soghbeine 28
Figure 26. Ras Al Ain Spring in Kobb Elias 28
Figure 27. Litani River In Jeb Jenine 29
Figure 28. Spring Water in Aitaneit 29

Figure 29. Dissolved Oxygen (DO) Levels along the Litani River & Its Tributaries for both Wet & Dry Seasons ... 32
Figure 30. Biochemical Oxygen Demand (BOD) Levels along the Litani and its Tributaries ... 33
Figure 31. Major Point and Nonpoint Sources of Pollution along the Upper Litani Basin (Wet and Dry Seasons) ... 34
Figure 32. Degree of Restriction on Surface Water Use for Irrigation Based on the Total Dissolved Solids (TDS) Content ... 44
Figure 33. Degree of Restriction on Surface Water Use for Irrigation Based on EC and SAR Levels ... 45
Figure 34. Degree of Restriction on Surface Water Use for Irrigation Based on Sodium Levels ... 46
Figure 35. Degree of Restriction on Surface Water Use for Irrigation Based on Chloride Levels ... 47
Figure 36. Degree of Restrictive Surface Water Use for Irrigation Based on Bicarbonate Levels ... 47
Figure 37. Degree of Restriction on Spring Water Use for Irrigation Based on TDS Content ... 53
Figure 38. Degree of Restriction on Spring Water Use for Irrigation Based on EC and SAR Levels ... 54
Figure 39. Degree of Restriction on Spring Water Use for Irrigation Based on Sodium Levels ... 54
Figure 40. Degree of Restrictive Spring Water Use for Irrigation Based on Chloride Levels ... 55
Figure 41. Degree of Restrictive Water Use for Irrigation Based on Bicarbonate Alkalinity Levels ... 56
Figure 42. Degree of Restriction on Well Water Use for Irrigation Based on the Total Dissolved Solids 60
Figure 43. Degree of Restriction on Well Water Use for Irrigation Based on EC and SAR Levels ... 60
Figure 44. Degree of Restriction on Well Water Use for Irrigation Based on Sodium Levels ... 61
Figure 45. Degree of Restriction on well Water Use for Irrigation Based on Chloride Levels ... 61
Figure 46. Degree of Restriction on Well Water Use for Irrigation Based on Bicarbonate Alkalinity Levels ... 62
Figure 47. BOD (mg/l) Variability along the Qaraoun Lake ... 64
Figure 48. Ammonia (mg/l ammonia N) Variability along the Qaraoun Lake ... 65
Figure 49. Iron (mg/l) Variability along the Qaraoun Lake ... 65
Figure 50. Cadmium (ug/l) Variability along the Qaraoun Lake ... 65
Figure 51. Molybdenum (ug/l) Variability along the Qaraoun Lake ... 66
Figure 52. Nickel (ug/l) Variability along the Qaraoun Lake ... 66
Figure 53. Copper (ug/l) Variability along the Qaraoun Lake ... 66
Figure 54. Zinc (ug/l) Variability along the Qaraoun Lake ... 67
Figure 55. Aluminium (ug/l) Variability along the Qaraoun Lake ... 67
Figure 56. Barium (ug/l) Variability along the Qaraoun Lake ... 67
Figure 57. Manganese (mg/l) Variability along the Qaraoun Lake ... 68

Figure 58. Degree of Restriction on Canal 900 Water Use for Irrigation Based on the Total Mineral Content (TDS) ... 72
Figure 59. Degree of Restriction on Canal 900 Water Use for Irrigation Based on EC and SAR Levels. 72
Figure 60. Degree of Restrictive on Canal 900 Water Use for Irrigation Based on Sodium Levels... 73
Figure 61. Degree of Restriction on Canal 900 Water Use for Irrigation Based on Chloride Levels... 74
Figure 62. Degree of Restriction on Canal 900 Water Use for Irrigation Based on Bicarbonate Levels .. 74
Figure 63. Degree of Restriction on Sewage Use for Irrigation Based on the TDS Of Wastewater Samples ... 76
Figure 64. Degree of Restriction on Domestic Wastewater Use for Irrigation Based on Sodium Levels 77
Figure 65. Degree of Restriction on Domestic Wastewater Use for Irrigation Based on Chloride Levels77
Figure 66. Degree of Restriction on Domestic Wastewater Use for Irrigation Based on Bicarbonate Hardness Levels ... 78
Figure 67. Barium Analytical Profile in Soil (mg/kg) of the Wet Season ... 84
Figure 68. Percentages of Analyzed Soil Samples (wet and dry season) higher than the Canadian Guideline levels for Agricultural Use ... 85
Figure 69. Lead Analytical Profile in Soil (mg/k): Wet season... 86
Figure 70. Zinc Analytical Profile in Soil (mg/k)-wet season... 87
Figure 71. Percentages of Analyzed Canal Soil Samples (wet and dry season) Higher than the Canadian Guideline Levels for Agricultural Use... 88
Figure 72. Copper Analytical Profile in Soil (mg/k)-wet season... 88
Figure 73. Nickel Analytical Profile in Soil (mg/k)-Wet season ... 89
Figure 74. Chromium Analytical Profile in Soil (mg/k)-Wet season... 89
Figure 75. Arsenic Analytical Profile in Soil (mg/k)-Wet Season... 90
Figure 76. Mercury Analytical Profile in Soil (mg/k)-Wet Season... 91
Figure 77. Cadmium Analytical Profile in Soil (mg/k)-Wet Season... 91
Figure 78. Manganese Analytical Profile in Soil (mg/k)-wet season ... 92
Figure 79. Barium Analytical Profile in Sediments (mg/k): Wet Season ... 94
Figure 80. Manganese Analytical Profile in Sediment (mg/k): Wet Season ... 94
Figure 81. Lead Analytical Profile in Sediment (mg/k): Wet Season ... 95
Figure 82. Zinc Analytical Profile in Sediment (mg/k): Wet Season... 96
Figure 83. Copper Analytical Profile in Sediment (mg/k): Wet Season ... 96
Figure 84. Cadmium Analytical Profile in Sediment (mg/k): Wet Season ... 97
Figure 85. Nickel Analytical Profile in Sediment (mg/k): Wet Season ... 97

Figure 86. Arsenic Analytical Profile in Sediment (mg/k): Wet Season 98
Figure 87. Mercury Analytical Profile in Sediment (mg/k): Wet Season 99
Figure 88. Chromium Analytical Profile in Sediment (mg/k): Wet Season 99

ACRONYMS

AUB	American University of Beirut (LRBMS subcontractor)
BAMAS	Basin Management Advisory Services (similar survey funded by USAID and conducted in 2005)
BOD	Biochemical Oxygen Demand
EPA	Environmental Protection Agency (USA)
ES	Electrical Conductivity
GIS	Geographic Information System
GOL	Government of Lebanon
IQC	Indefinite Quantity Contract (contracting mechanism for USAID)
IRBM	Integrated River Basin Management
IRG	International Resources Group (US consulting firm, prime LRBMS contractor)
IWRM	Integrated Water Resources Management
LRA	Litani River Authority (also called Office National du Litani)
LRBMS	Litani River Basin Management Support Program
M&E	Monitoring & Evaluation
MEW	Ministry of Energy and Water
ONL	Office National du Litani (also called Litani River Authority)
TDS	Total Dissolved Solids
ULB	Upper Litani Basin
USAID	United States Agency for International Development
WHO	World Health Organization

FOREWORD

This water quality survey was carried out by a team led by Dr Mey Jurdi from the American University of Beirut (AUB) under subcontract with IRG, the main contractor under the Litani River Basin Management Support (LRBMS) Program, a USAID-funded program in Lebanon (Contract EPP-I-00-04-00024-00 Task Order No. 7 under the Integrated Water and Coastal Resources Management Indefinite Quantity Contract (IQC) II.

Apart from the main text which details both methodology and results, an Executive Summary presents the main findings, conclusions, and recommendations, while detailed results are provided as appendices.

This survey is the second of its kind, and follows directly the similar survey carried out summer 2010.

EXECUTIVE SUMMARY

INTRODUCTION-CONTEXT OF STUDY

This study is conducted as part of the efforts of the International Resource Group (IRG) under the USAID/Lebanon funded Litani River Basin Management Support Program (LRBMS) to assist the Litani River Authority (LRA) in upgrading and improving the management of Upper Litani Basin (ULB). Phase one of the study (Dry season, July- August 2010), focused on:

(a) Evaluating the Upper Litani Basin water quality profile

(b) Comparing results to previous quality assessment studies (BAMAS 20005)

(c) Exposing environmental health risks associated with multipurpose water usage

(d) Proposing appropriate mitigation measures.

Phase two of the study (wet season, March-April 2011) aims to assess seasonable water quality variability and impacts on multipurpose water uses and also propose appropriate mitigation measures.

FIELD SURVEY

First a field survey was conducted between March 15 and March 30, 2011to update the previous list of 149 sampling sites (some being point and nonpoint sources of pollution). A few sites were added and a few were modified, resulting in a new list of 155 sampling sites. These are on

- The Litani river and its tributaries (43);
- The Qaraoun Lake (10);
- The Irrigation Canal 900 (7);
- Groundwater springs and wells located within the ULB (41);
- Sewage effluents from residential areas located along the river water flow (5);
- Major industrial wastewater effluents disposing directly into the river (7):
- Soils of agricultural areas bordering the river and irrigation canal (35); and
- River sediments (7).

METHODOLOGY

Sampling types and locations are presented in figure 1. Sample collection and transportation, analytical water testing and quality control were performed following standard methods and procedures. Complete physical, chemical and microbiological (total dissolved solid, total suspended solids, electric conductivity, dissolved oxygen, biochemical oxygen demand, pH, alkalinity, ammonia, nitrates, phosphates, sulfates , chlorides, potassium, calcium, magnesium, sodium, lead mercury, cadmium, chromium, nickel, copper, zinc, iron, aluminum, arsenic, barium, cobalt, boron, manganese, molybdenum, organochlorines, organophosphorous, total coliforms, fecal coliforms and fecal streptococci) water quality assessment was conducted. Additionally, season variability and changes over time (with BAMAS 2005) were assessed.

KEY FINDINGS – SURFACE WATER

Progressive exposure to pollution is impacting the ability of the river to dilute and handle organic and inorganic contaminants reflecting on reduced self-purification capacity with time. The overall BOD load has increased tenfold since 2005 while dissolved oxygen levels decreased by 33%.

Major pollution hot spots are distributed throughout the basin (Saidi, Housh barada, hezzine, Temnine al Tahta, Ferzol, Rayyak, Ablah, Jdeita, Taanayel, Deir Zannoun, Housh Al Harrimi, Delhameiyeh, Al Marj, Kobb Elias, Ammique, mansoura, and Jeb Jannine) and no longer restricted to the mid-upper basin.

Seasonal water quality variability (comparison with last summer study) shows somewhat better quality due to the dilution from rain-provided winter flows:

- Reduced TDS mean level to 255 mg/l (against 503 mg/l); only 5% sampling sites (against 23%) exceed the recommended Lebanese and EPA standards;
- pH mean level 7.7 (only Saidi site exceeds acceptable limit of 8.5) against 7.9 for dry season,
- Relatively lower mean levels of ammonia, nitrate, phosphates, sulfates and chloride;
- Decrease of barium by 37%; cadmium by 10%; chromium 30%; nickel by 65%; iron by 50%; and zinc by 59%; 20% increase in Molybdenum and 20% increase of copper;
- Fecal contamination of sampled sites for both the wet season (65% of sampled sites) and the dry season (50% of the sampled sites).

Definition of indicators:

1.TDS: measures mineral content; reflects on the type of water source and exposure to pollution. Increased levels in surface water represent mostly increased exposure to sewage, industrial wastewater effluents, leachate of municipal solid waste dump sites and agriculture run off.

2. pH: measures alkalinity or acidity; agricultural runoff and sewage shift the pH towards alkalinity.

3. BOD: measures oxygen needed by aerobic microorganisms to treat organic pollution; high BOD reveals pollution from sewage and inefficient wastewater treatment, agribusiness effluents and excessive application of organic fertilizers.

4. Nitrates: measures presence of nitrates which causes algae growth and impacts aquatic life. Sources of nitrates are mostly nonpoint-source runoff from heavily fertilized croplands. High nitrate presence is improper for domestic use.

5. Fecal Coliform: measures sewage discharge. Decreasing levels found by the survey (as compared to BAMAS) are due to reducing conditions no supporting development of fecal organisms, not decreased discharge of sewage.

Table 1. Comparison of Surface Water Quality Profiles Reported by BAMAS 2005 and Current Study 2010-11

Indicator	Survey season	BAMAS 2005 Calculated from surface water results			Current 2010-11 Study			Drinking Water Standards	
								MoE Lebanon	USA-EPA
		Min.	*Mean*	*Max.*	*Min.*	*Mean*	*Max.*	*GV (25 oC)*	*GV/MAL*
Temperature (°C)	*W*	4.1	12.39	17.7	10.00	17.36	25.00	NA	NA
	D	12	20.07	25	15.50	23.73	32.10		
TDS (mg/l)	*W*	114	202.2	415	118.00	254.96	533	500	500
	D	88	290.96	706	187.00	502.08	1979		
pH (pH units)	*W*	6.8	7.09	8.18	4.53	7.66	8.54	6.5-8.5	6.5-8.5
	D	6.57	7.59	7.68	7.27	7.93	8.66		
DO(mg/l O_2)	*W*	3.95	7.94	9.73	0.90	4.83	9.10	NA	NA
	D	0	5.93	8	0.38	4.65	9.40		
BOD (mg/l)	*W*	0	6.57	45	2.00	19.28	70.00	NA	NA
	D	2	48.46	624	2.50	547.65	2530		
NO_3^- (mg/l)	*W*	<1	13.57	49.7	0.20	1.41	9.60	10 (as N)	10 (as N)
	D	3	13.46	62	0.10	1.23	4.90		
FC (CFU/100ml)	*W*	0	20122	$12x\ 10^4$	0	190.04	400	0	0
	D	0	2,234,87	$15x\ 10^5$	1	71.61	400		
Manganse (mg/l)	W	NA	NA	NA	0.010	0.080	0.380	0.05	0.005
	D	NA	NA	NA	0.010	0.070	0.270		
Cadmium (mg/l)	W	NA	NA	NA	0.000	0.001	0.003	0.005	0.003
	D	NA	NA	NA	0.000	0.010	0.070		

*NA: Not Available

Comparing to previous studies (BAMAS 2005) for the same winter period shows the following:

- 50% increase in the overall mean TDS
- Shift in the overall pH value from 7.3 (BAMAS 2005) to 7.7 attributed to sewage discharge and solid waste dumping along the river and its tributaries,
- Reduction in the mean level of total dissolved oxygen by 33%, despite algae growth, indicative of progressive exposure to pollution; in parallel the BOD overall mean level increased tenfold from 27.5mg/l to 283.50 mg/l;
- Fivefold increase in the overall mean levels of ammonia and decrease in nitrates by 83% mg/l reflective of prevailing reducing conditions.

The potential domestic water use is limited by:

(a) The decreased water flow;

(b) The exposure to high organic loads;

(c) The trace metals profiles for both wet and dry seasons; and

(d) Fecal contamination.

Water use for irrigation is relatively restricted by:

(a) Increased soil salinity relating to increased TDS;

(b) Reduction in water infiltration rate due to increased sodium and magnesium level;

(c) Projected crop toxicity (cadmium being the main element of concern as its mean level approaches the maximum recommended level of 0.01 mg/l in summer);

(d) Deposits on leaves and fruits associated with increased bicarbonate levels; and

(e) Microbiological safety based on the total and fecal coliform counts.

The river water and its tributaries fall within the maximum limits of class 1B (wet season) in comparison to class 2-3 limits (dry season). So although the microbial load is higher than in the summer, the BOD levels are diluted by the increased water quantities due to winter precipitations.

Surface water use by livestock is also restricted by the levels of trace metals.

Key Findings – Lake Water

The main findings for winter 2011 are the following:

- A pH level of 8.1 that is relatively less than the mean of 8.3 for the dry season. This is mostly due to replenishment by rainfall. Still, the alkaline pH shows exposure to pollution sources;
- Relatively higher BOD; This impacts the oxidation, leading to reducing conditions reflected by higher ammonia, and phosphates levels. Also, relatively higher levels of iron and cadmium from the dissolution of the precipitates of these metals under reducing conditions;
- Cadmium levels (exceeding in summer the recommended National Standard level of 0.005 mg/l reduced by replenishment by rains;
- Manganese levels slightly decreased with none of the sites exceeding the standard level of 0.05mg/l; in comparison 30% of the sampled sited exceeded the recommended level in summer;
- All other trace metals were measured below the recommended Lebanese standards; and
- Microbiological fecal contamination still detected in 90% of sites (50% in summer).

Furthermore, monitoring changes over time shows a degradation of the quality of Qaraoun Lake (comparing with Jurdi et.al, 2002, and BAMAS 2005):

- 23% increase in the levels of TDS;

- 64% increase in the overall total dissolved oxygen, mostly due to suspended algae growth that masks the increase in biochemical oxygen demand;
- Change in pH towards alkalinity (from 7.3 to 8.2) due exposure to domestic wastewater discharge and industrial wastewater discharge;
- Detected trace metals; but at levels below the permissible upper limit value (Lebanese standards), with the exception of high levels cadmium and manganese in summer;
- High levels of cadmium and manganese in summer; and
- Increased fecal loads in almost all sampled sites.

The deterioration in water quality and accumulation of metals in sediments is mainly attributed to direct wastewater discharge, and agriculture runoff. Sanitary sewer systems coverage has increased, replacing the point source cesspools. Yet, the sanitary sewers still discharge into the lake, awaiting the completion of the treatment plants (Bab Merae and Sagbine).

Table 2. Comparison of Lake Water Quality Profiles Reported by BAMAS 2005 and Current 2010-11

Indicator	Survey Season	BAMAS 2005 Calculated from lake water results			Current 2010-11 Study Lake water results			Drinking water standard	
								MoE-Lebanon	USEPA
		Min.	Mean	Max.	Min.	Mean	Max.	GV[1] (25 ^{o}C)	GV/MAL[2]
Temperature (^{o}C)	*W*	11.3	12.52	16	22.80	23.08	23.30	NA[6]	NA
	D	16.5	20.7	24.8	32.20	33.68	34.70		
TDS (mg/l)	*W*	211	226.8	239	234.5	241.55	248.00	500[7]	500[7]
	D	120	160	196	221	235.10	256.00		
pH (pH units)	*W*	6.82	7.58	7.78	7.85	8.10	8.32	6.5-8.5	6.5-8.5
	D	6.50	7.59	7.5	8.20	8.27	8.32		
DO (mg/l O_2)	*W*	6.82	7.00	8.68	8.10	9.81	11.20	NA	NA
	D	1.3	3.3	7.7	7.22	8.39	9.41		
BOD (mg/l)	*W*	<2	2.1	3	2.00	2.67	4.00	NA	NA
	D	<2	2.57	4	2.00	2.65	3.30		
NH_4 (mg/l)	*W*	0.52	0.62	0.7	0.25	0.30	0.46	NA	NA
	D	<0.02	0.3	1	0.00	0.20	0.35		
NO_3^- (mg/l)	*W*	16.2	27.9	34.1	1.70	2.00	2.40	10 (as N)	10 (as N)
	D	16.1	21.7	31.2	0.80	0.93	1.20		
SO_4^{2-} (mg/l)	*W*	34	39	43	34.00	35.50	37.00	250	250
	D	25	29.3	33	36.00	37.10	39.00		
P_2O_5 (mg/l)	*W*	0.19	0.22	0.33	0.21	0.40	0.90	NA	NA
	D	0.01	0.13	0.35	0.00	0.09	0.245		
FC (CFU/100ml)	*W*	6	39	196	0	181.42	400	0	0
	D	0	17	450	0	160.60	400		
Manganese (mg/l)	*W*	NA	NA	NA	0.0200	0.0300	0.0300	0.05	
	D	NA	NA	NA	0.0020	0.0040	0.0060		
Cadmium (mg/l)	*W*	NA	NA	NA	0.0005	0.0007	0.0010	0.005	
	D	NA	NA	NA	0.0007	0.0100	0.0210		

*NA: Not Available

KEY FINDINGS – GROUND WATER

The main findings for the winter 2011 are:

- Overall mean mineral content around 277 mg/l (against 385 mg/l in summer); these levels are acceptable when compared to Lebanese standards, EPA standards and WHO guidelines;
- pH level of 7.5 (7.8 in summer), due to replenishment of aquifers by infiltrating precipitations;
- The levels of all tested macro-elements and microelements (with the exception of nitrates) are within the recommendations of the National Standards, EPA Standards and WHO Guidelines;
- High nitrate levels exceeding the recommended 10 mg/l (nitrate nitrogen limit) detected only in 1 well (Hezzine) in comparison to 20% of wells in summer (sampled wells in Housh Barada, Hezzine, Sariene, Helanieyeh and Ablah);

- High manganese levels the sampling sites of Mansoura (0.064mg/l, over the 0.05mg/l limit), and to a lesser extend in Ablah (0.038 mg/l), Helannieyeh (0.033 mg/l), and Sariene (0.040 mg/l);
- All other trace metals were diluted with the exception of zinc levels increased by 59%.

Table 3. Comparison of Ground Water Quality Profile Reported by the BAMAS 2005 Study and the Current 2010-11 Study

Indicator	Survey round	BAMAS 2005 Calculated from Ground water results			Current 2010-11 Study Ground water results			Drinking water standard		Reclaimed WW for irrigation
								MoE-Lebanon	USEPA	
		Min.	Mean	Max.	Min.	Mean	Max.	GV[1] (25 °C)	GV/MAL[2]	MoE guidelines
Temperature (°C)	W	11.6	17.26	20.1	10.20	18.23	22.50	NA[6]	NA	
	S	18.4	22	33.3	15.15	20.59	27.6			
TDS (mg/l)	W				120.00	276.89	637.00	500[7]	500[7]	
	S				171.00	335.27	629.50			
pH (pH units)	W	6.41	6.85	7.5	7.04	7.50	8.08	6.5-8.5	6.5-8.5	
	S	6.54	6.9	7.22	7.16	7.77	8.6			
DO (mg/l O_2)	W				0.10	5.10	7.80	NA	NA	
	S				4.1	6.04	7.77			
BOD (mg/l)	W							NA	NA	10-45
	S									
NH_4 [8](mg/l)	W				0.1	0.18	0.44	NA	NA	
	S				0.00	0.36	42.09			
NO_3^- (mg/l)	W	1	60.32	318	0.0	2.67	12.40	10 (as N)	10 (as N)	
	S	3	48.31	171	0.2	4.27	29.00			
SO_4^{2-} (mg/l)	W	7	39.08	250	0	13.55	63.00	250	250	
	S	7	31.42	205	1.5	15.92	60.00			
P_2O_5[9] (mg/l)	W	<0.01	0.12	2.3	0.15	0.56	1.21	NA	NA	
	S	0	0.31	12	0.05	0.61	3.46			
FC (CFU[10]/100,ml)	W	0	18	255	0	1.22	21	0	0	5-2,000
	S	0	42.85	400	0	65.37	400			

*NA: Not Available

Moreover, comparing the overall surface water quality profile to the BAMAS study in 2005 shows the following:

- A shift of the pH from 6.5 to 7.5,
- The reduction in nitrate levels by 86% and sulfates by 65% due to increased sewerage collection;
- Fecal organism loads reduced from 78% to 15% of samples of the dry season; and from 23% to 13% of samples of the wet season.

The increase of coverage by sanitary sewer systems has definitely reduced the exposure of ground water aquifers to contamination. Yet, in some areas the systems are still deficient. Additionally, leachates from scattered municipal dumps sites add to the pollution.

KEY FINDINGS – SOILS AND SEDIMENTS

Generally, the detection of pollutant sources in soils is easier in the dry season. In the wet season, the precipitations, surface flows, seepage/leaching tend to wash the soils of contaminants. As such, comparing the soil and canal soil quality for the wet and dry seasons show the following:

- Minimal variability in molybdenum, cobalt, zinc, nickel, chromium, arsenic, mercury, cadmium, and manganese;
- Decrease in barium and lead levels; and
- Increase in copper levels; this may be attributed to a number of factors such as increased waste dumping dissolution of copper cables due to wet season acidic conditions, leaching of copper from fertilizers and addition of copper sulphate to control algae growth.

Comparing to the 2005 BAMAS study, the levels of trace metals are building up in soil due to direct and secondary (irrigation from sewage) exposure to domestic and industrial wastewater.

CONCLUSION

The continuous exposure to various sources of pollution (domestic wastewater, industrial sewage, haphazard garbage dumping, and overuse of chemicals in agriculture) is disrupting the ecologic balance of the Upper Litani Basin. Subsequently, this is limiting the ability of the river to restore its oxygen levels that are needed for self purification and for the regeneration of acceptable water quality and sufficient quantity for multipurpose usage. Recommended steps include:

- Stopping the "complete" tapping of springs feeding the river tributaries for irrigation as it is limiting the water flow and destroying the ability of the river to handle the increasingly high pollution loads;
- Complete the coverage of sewerage networks, properly operate wastewater treatment plants;
- Enforce release standards with industries and urban areas;
- Build adequate solid waste disposal facilities, close and neutralize ad-hoc dumping sites;
- Prevent the haphazard dumping of solid wastes, including dead animals, especially during the wet season; and
- Provide extension services to farmers to optimize and reduce use of fertilizers and pesticides.

RECOMMENDATIONS

Restoring the Litani River and its tributaries ecologic viability cannot be achieved by a single type of environmental intervention and should be part of an Integrated River Basin Management (IRBM) approach, which should include the following short and mid-term measures:

Restore Litani River ecological wellbeing and sustainable water flow by addressing all types of environmental stresses, mobilizing involved communities and empowering municipalities to:

(a) Stop the "complete" tapping of springs and tributaries water flow for irrigation;

(b) Control the drilling of new wells and the overexploitation of ground water aquifers;

(c) Enforce onsite treatment of major industrial wastewater effluents discharging into the Litani River and its tributaries, or into the domestic sewage networks which in turn flow directly into the river;

(d) Prevent the discharge of untreated domestic sewage directly into the river and its tributaries;

(e) Regulate the discharge of municipal and industrial solid wastes along the river water flow;

(f) Raise awareness to reduce the over-application of pesticides.

Protect and sustain the quality of ground water resources; the above recommended interventions will regulate the overexploitation of these resources and reduce the water body exposure to pollution sources. Additionally, the following is recommended:

(a) Enforce existing regulations to replace leaching cesspools with waterproof and properly designed septic tanks;

(b) Regulate the use of fertilizers (types and quantities applied); and

(c) Identify and improve the monitoring of all water sources used by communities, as main and complementary domestic water sources, to determine water safety.

Regulate wastewater use for irrigation; the suitability of raw untreated wastewater for irrigation is depends on wastewater salinity, infiltration rate, plant toxicity and other health factors. If such use is needed due to the scarcity of alternative water supplies, it should be regulated and restricted to crops presenting low risks to consumers.

Enhance the water quality of the Qaraoun Lake; implementing the above interventions will upgrade the water quality of the Qaraoun Lake for various uses; especially irrigation and fisheries. Moreover, treating wastewater effluents along the lake is critical to control the levels of enriching nutrients (mainly phosphates and nitrates) and prevent eutrophication.

Enhance the quality of Irrigation Canal 900; implementing the above interventions will also improve the quality of Canal 900 water since it originates from the lake. Additionally, the levels of added copper sulfate (used to control algae growth) should be monitored to prevent the progressive accumulation of copper in soils irrigated with canal water.

Develop and sustain water quality monitoring programs by:

(a) Initiating ecological studies to identify aquatic biological indicators, monitor the state of aquatic species, and evaluate the need to promote fisheries;

(b) Conducting studies to evaluate the level of the risk associated with the translocation of trace metals into the aerial edible portions of crops grown in soil progressively exposed to wastewater irrigation, and surface and spring water contaminated by sewage and industrial wastewater; and

(c) Conducting studies to evaluate the level of the risk associated with excreta pathogens in fresh water, sewage and on crop surfaces (e.g. *Enteroviruses, Ascaris lambriocoides eggs and Entamoeba histolytica*).

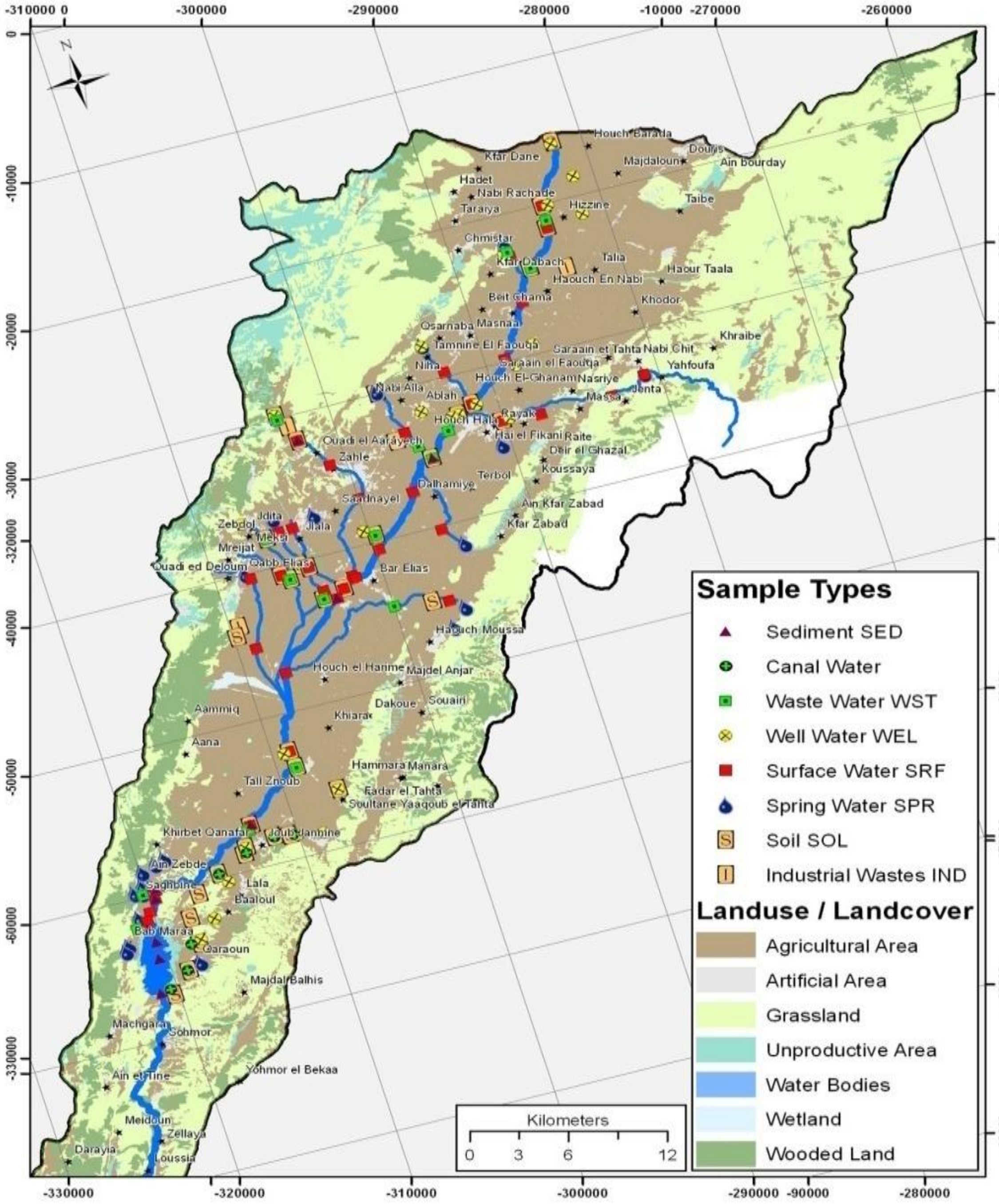


Figure 1. Upper Litani Basin Types and Location of Samples

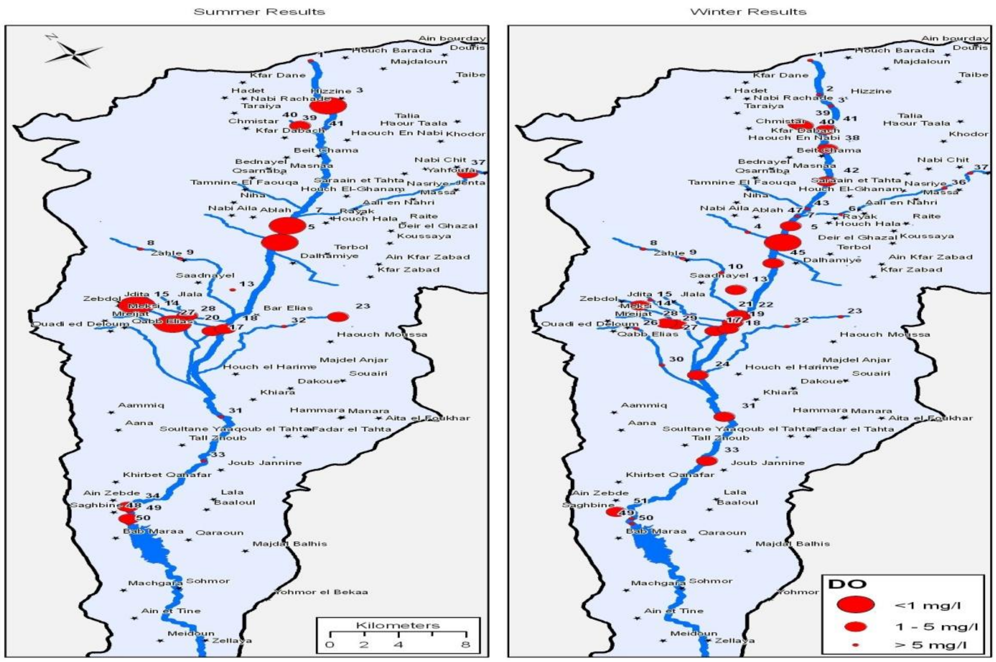


Figure 2. Dissolved Oxygen (DO) Levels along the Litani River and its Tributaries for both Wet & Dry Seasons

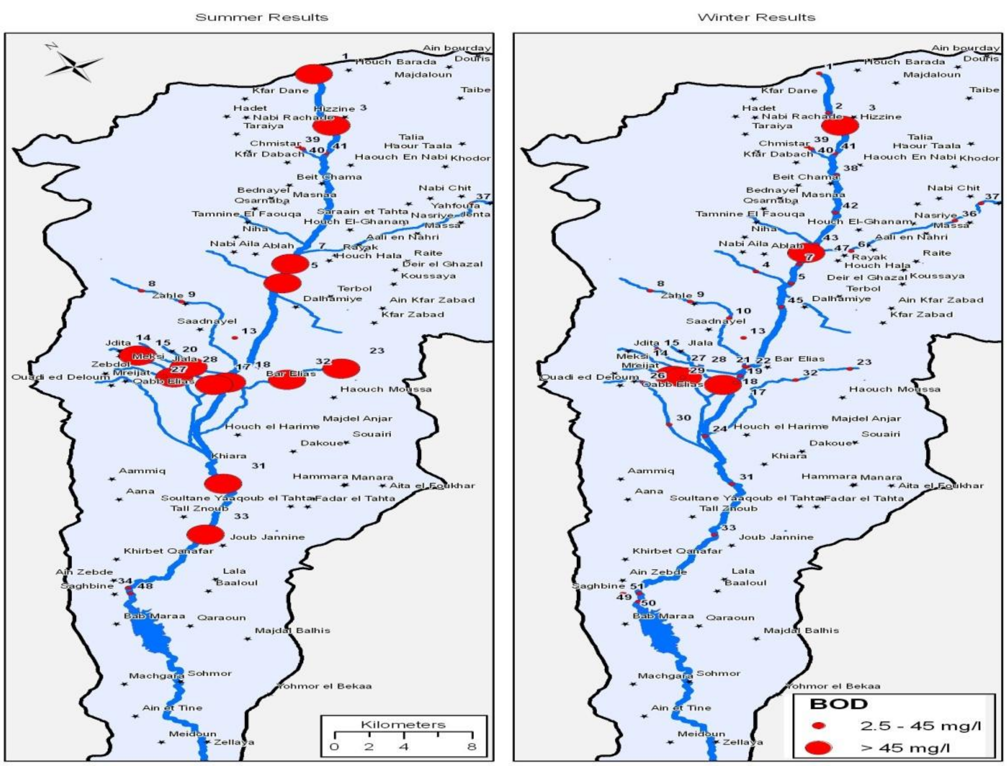


Figure 3. Biochemical Oxygen Demand (BOD) Levels along the Litani River and its Tributaries for both Wet & Dry Seasons

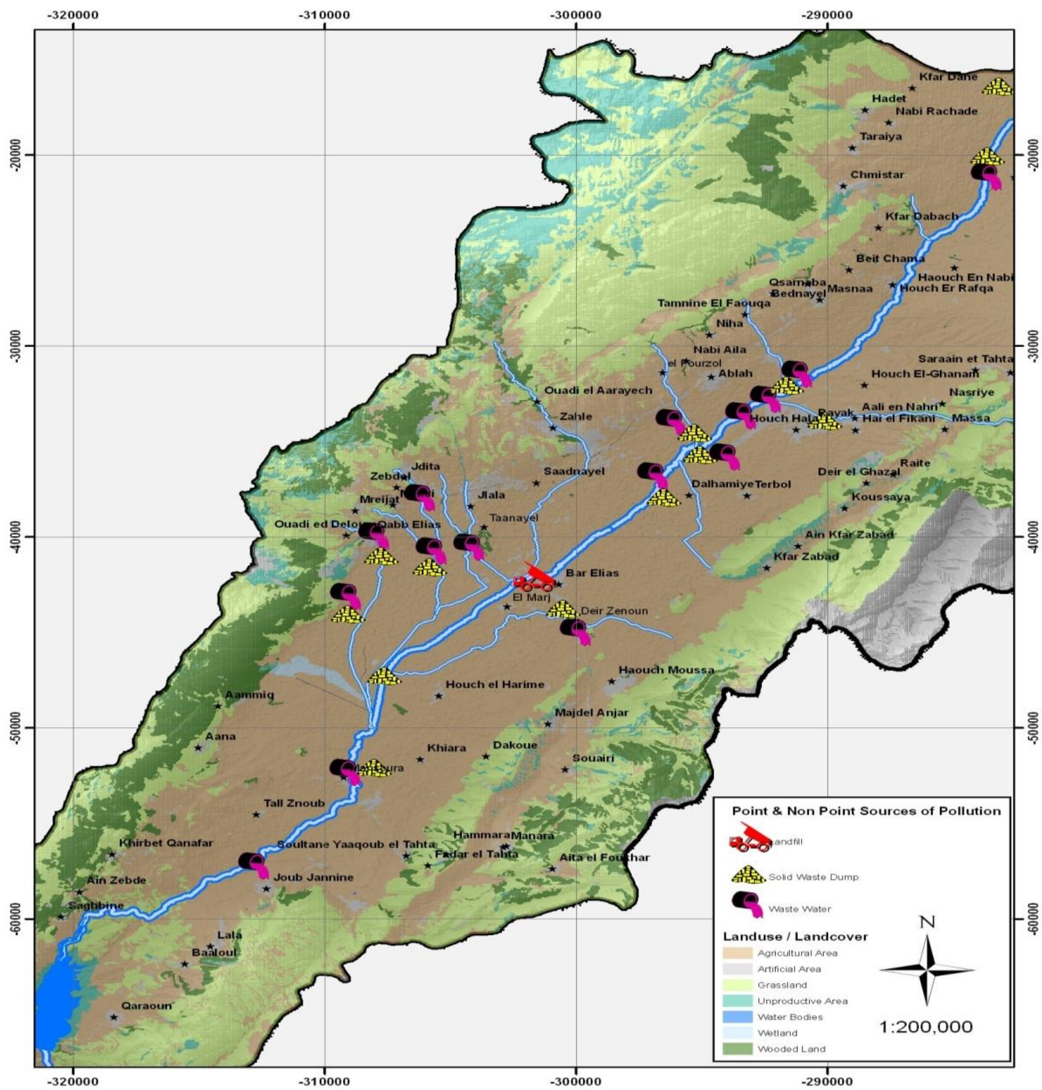


Figure 4. Major Point and Nonpoint Sources of Pollution along the Upper Litani Basin

ملخص تنفيذي

المقدمة- سياق الدراسة:

أجريت هذه الدراسة كجزء من نشاط المجموعة العالمية للموارد تحت المشروع المحمول من الوكالة الأميركية للتنمية الدولية أي مشروع برنامج دعم إدارة حوض الليطاني و ذلك من أجل مساعدة المصلحة الوطنية لنهر الليطاني لتطوير و تحسين إدارة الحوض الأعلى لليطاني المرحلة الأولى من هذه الدراسة (فصل جاف من تموز الى اب 2010) ركزت على:

أ-تقييم واقع نوعية المياه في الحوض الأعلى لليطاني

ب- مقارنة النتائج مع الدراسات النوعية السابقة ("باماس" 2005)

ج- عرض مخاطر الصحة البيئية بالنسبة إلى إستخدامات المياه المتعددة

د- إقتراح قياسات نوعية مناسبة

المرحلة الثانية للدراسة (الموسم الرطب اذار و نيسان 2011 / مساعدت على معرفة واقع نوعية المياه حسب الفصل و تأثيرها على استخدامات المياه المتعددة كذلك إقتراح قياسات نوعية مناسبة.

المسح الكلي:

أولا إن المسح الكلي أجري بين 15 اذار و 30 اذار 2011 و ذلك من أجل تطوير القائمة القديمة و التي تحوي 149 مكان ثم أخذ العينات منه (البعض كان مصدر محدد و غير محدد للتلوث) بعض المواقع تم إضافتها و أخرى تعديلها و بالنتيجة أصبحت القائمة من 155 موقع تفصيل هذه المواقع و عدد العينات على الشكل التالي:

. في نهر الليطاني و روافده (43)

. بحيرة القرعون (10)

. قناة الري 900 (7)

. الينابيع و ابار المياه الجوفية الواقعة في حوض الليطاني الأعلى (41)

. مياه الصرف الصحي الناتجة عن المناطق السكنية الواقعة على ضفاف النهر (5)

. المياه الملوثة الناتجة عن المصانع الكبيرة والتي تصرف ملوثاتها مباشرة في النهر (7)

. من التربة المستخدمة للزراعة و التي تحاذي النهر و قناة الري (35) و

. حول النهر (7)

الطريقة

إن نوعية العينات و مواقعها تتمثل في الصورة (1) إن جمع العينات و نقلها و تحليل المياه و فحصها تم إتباعها بحسب الطرق و المقاييس المعتمدة. تم إتمام الفحوصات الفيزيائية الكيميائية و الميكروبيولوجية ل (مجموع المعادن الذائبة–مجموع المعادن العالقة–الموصولية–الأوكسيجين المذاب– الحاجة البيولوجية للأوكسيجين– الحموضة– القلوية– أمونيا–الأوزون– الفوسفات– السولفات– الكلورايد– البوتاسيم– الكالسيم– ماغنيزيوم– صوديوم– زئبق– الرصاص– كادميوم– كروميوم– نيكل– النحاس– زنك– الحديد– المينيوم– أرسينبك– باريوم– كوبالت– بورون– مانغانيز– الكلورين العضوي– الفوسفوريس العضوي– مجموع الكوليفورم) قد أجري مع نوعية المياه هذا بالإضافة أهم النتائج – المياه السطحية.

النتائج الرئيسية – المياه السطحية

إن التعرض التدريجي للتلوث يؤثرعلى قدرة النهر في التخفيف ومعالجة الملوثات العضوية وغير العضوية بحيث يعكس انخفاض القدرة على التطهيرالذاتي مع مرور الوقت. زاد ال BOD العام عشرة أضعاف منذ العام 2005 في حين أن مستويات الأوكسجين المذاب انخفضت بنسبة 33 ٪.

تم توزيع النقاط الساخنة الرئيسية للتلوث في جميع أنحاء الحوض (السعيدي، حوش بردى ، حزين ، سرعين التحتا ، الفرزل ، رياق ، ابلح ، جديتا ، تعنايل ، دير زنون، حوش الحريمي ، الدلهمية ، المرج ، قب الياس ، عميق ، المنصورة و جب جنين) والتي لم تعد تقتصر على منتصف الحوض الاعلى.

التباين الموسمي لنوعية المياه (دراسة مقارنة مع الصيف الماضي) يوضح او يظهر تحسن في نوعية المياه بسبب زيادة التدفقات في الشتاء ما يزيد كمية المياه بالنسبة إلى الملوثات:

- انخفاض مستوى TDS إلى 255 ملغ / لتر (بدلاً من 503 ملغ / لتر) ؛ فقط 5مواقع أخذت العينات منها (مقابل 23 ٪) تتجاوزت المعايير اللبنانية ومعايير وكالة حماية البيئة الموصى بها؛
- درجة الحموضة 7.7 (فقط موقع السعيدي يتجاوز الحد المقبول 8.5) بالمقابل 7.9 في موسم الجفاف،
- مستويات متوسطة أقل نسبيا للأمونيا والنترات والفوسفات و الكبريتات و الكلوريد؛
- النقص في الباريوم بنسبة 37 ٪ ؛ الكادميوم بنسبة 10 ٪، الكروم 30٪، النيكل بنسبة 65 ٪، الحديد بنسبة 50 ٪، و الزنك بنسبة 59 ٪ ، وزيادة 20 ٪ في المولبيدينوم و زيادة بنسبة 20 ٪ من النحاس ؛

- تلوث برازي من مواقع أخذ العينات للموسم الرطب (65 ٪ من مواقع عينات) ولموسم الجفاف (50 ٪ من مواقع عينات).

تعريف المؤشرات :

1. TDS مجموع المعادن الذائبة؛ يعكس نوع مصدر المياه و التعرض للتلوث. زيادة المستويات في المياه السطحية في الغالب تمثل زيادة التعرض لمياه الصرف الصحي والنفايات السائلة ومياه الصرف الصناعي، الراشح من مكبات النفايات الصلبة للبلديات والزراعة.
2. الحموضة: قياس الحموضة أو القلوية؛ الصرف الزراعي ومياه الصرف الصحي تحول درجة الحموضة نحو القلوية.
3. BOD الحاجة البيولوجية للأوكسجين حيث ان الكائنات الحية الدقيقة الهوائية لعلاج التلوث العضوي؛BOD نسبة تركيزعالية بسبب مياه الصرف الصحي ومعالجة مياه الصرف الصحي غير فعالة والنفايات السائلة الناتجة عن الأعمال الزراعية والاستخدام المفرط للأسمدة العضوية.
4. النترات : وجود النترات الذي يسبب نمو الطحالب والتأثيرعلى الحياة المائية. مصادر النترات هي في معظمها الجريان السطحي غير المحدد المصدر من الأراضي الزراعية المخصبة بالاسمدة بشكل كبير. إن ارتفاع تركيز النترات غير لائق للاستخدام المنزلي.
5. القولونية البرازية : تدل على تصريف مياه الصرف الصحي . هناك انخفاض في المستويات التي وجدت من قبل المسح (بالمقارنة مع BAMAS) ومن الواضح أن هذا التراجع في التركيز يعود إلى انخفاض الظروف التي تدعم تطور ونموالكائنات البرازية ، ولم يكن ذلك بسبب خفض كميات تصريف مياه الصرف الصحي.

الجدول 1. مقارنة لنوعية المياه السطحية المنشورة في تقرير BAMAS 2005 والدراسة الحالية 2010-2011

Indicator المؤشر	**Survey Season** فصل المسح	**BAMAS 2005 Calculated from surface water results** دراسة 2005 محسوبة على اساس مسح المياه السطحية			**Current 2010-11 Study** الدراسة الحالية 2010-2011			**Drinking Water Standards** مقاييس مياه الشرب	
								MoE Lebanon وزارة البيئة اللبنانية	**USA-EPA** وكالة حماية البيئة الامريكية
		Min. *النسبة الادنى*	*Mean* *الوسطية*	*Max.* *القصوى*	*Min.* *الادنى*	*Mean* *الوسطية*	*Max.* *القصوى*	*GV (25 oC)*	*GV/MAL*
Temperature (°C) الحرارة	*W*	4.1	12.39	17.7	10.00	17.36	25.00	NA	NA
	D	12	20.07	25	15.50	23.73	32.10		
TDS (mg/l) مجموع المعادن الصلبة	*W*	114	202.2	415	118.00	254.96	533	500	500
	D	88	290.96	706	187.00	502.08	1979		
pH (pH units) الحموضة	*W*	6.8	7.09	8.18	4.53	7.66	8.54	6.5-8.5	6.5-8.5
	D	6.57	7.59	7.68	7.27	7.93	8.66		
DO(mg/l O_2) الاوكسيجين الذائب	*W*	3.95	7.94	9.73	0.90	4.83	9.10	NA	NA
	D	0	5.93	8	0.38	4.65	9.40		
BOD (mg/l) الحاجة البيولوجة للاوكسيجين	*W*	0	6.57	45	2.00	19.28	70.00	NA	NA
	D	2	48.46	624	2.50	547.65	2530		
NO_3^- (mg/l) النيترات	*W*	<1	13.57	49.7	0.20	1.41	9.60	10 (as N)	10 (as N)
	D	3	13.46	62	0.10	1.23	4.90		
FC (CFU/100ml) الكائنات البرازية	*W*	0	20122	12×10^4	0	190.04	400	0	0
	D	0	2,234,87	15×10^5	1	71.61	400		
Manganse (mg/l) المانغانيز	W	NA	NA	NA	0.010	0.080	0.380	0.05	0.005
	D	NA	NA	NA	0.010	0.070	0.270		
Cadmium (mg/l) الكادميوم	W	NA	NA	NA	0.000	0.001	0.003	0.005	0.003
	D	NA	NA	NA	0.000	0.010	0.070		

NA*: غير متوفر

المقارنة مع الدراسات السابقة (BAMAS 2005) لفترة الشتاء نفسه تظهر ما يلي:

- زيادة بنسبة 50٪ في المتوسط العام ل TDS
- التحول في قيمة الرقم الهيدروجيني العام من 7.3 (BAMAS 2005) إلى 7.7 نسبة إلى تصريف مياه الصرف الصحي ورمي النفايات الصلبة على طول النهر وروافده،

- إنخفاض في المستوى المتوسط من إجمالي الأوكسجين المذاب بنسبة 33٪، على الرغم من نمو الطحالب، مما يدل على التعرض التدريجي للتلوث؛ بالتوازي الحاجة البيولوجية للاوكسيجين ارتفعت عشرة أضعاف من مستوى mg27.5 / لتر إلى 283.50 ملغ / لتر؛
- زيادة قدرها خمسة أضعاف في مستويات المتوسط العام للأمونيا وانخفاض بنسبة 83٪ النترات ملجم / لتر تعكس الظروف السائدة.

إن استخدام المياه للأغراض المنزلية المحتملة محدودة بسبب:

(أ) إنخفاض في تدفق المياه؛

(ب) التعرض لتلوثات عضوية عالية؛

(ج) قياس تغيير نسب المعادن النذرة في المواسم الرطبة والجافة على حد سواء، و

(د) التلوث برازي.

استخدام المياه يقتصر على أغراض الري بسبب :

(أ) زيادة ملوحة التربة المتعلقة بزيادةTDS ؛

(ب) انخفاض في معدل تسرب المياه بسبب زيادة مستوى الصوديوم والمغنيسيوم؛

(ج) توقع سمية المحاصيل (الكادميوم كونها العنصر الرئيسي للقلق مع اقتراب مستواه المتوسط الحد من الحد الأقصى الموصى به من 0.01 ملغ / لتر في الصيف)؛

(د) البقايا على أوراق الشجر والفواكه مرتبط بزيادة مستويات البيكربونات؛ و

(ه) السلامة الميكروبيولوجية تعتمد على أساس إجمالي القولونات البرازية المتبقية.

إن مياه النهر وروافده تقع ضمن الحدود القصوى من الدرجة B1 (في موسم الأمطار) بالمقارنة مع فئة 2-3 من الحدود (موسم الجفاف). حتى اوعلى الرغم من أن الحمل الميكروبي هو أعلى مما كانت عليه في الصيف، تقل مستويات ال BOD بسبب زيادة كميات المياه الناتجة عن الأمطار في فصل الشتاء.

استخدام المياه السطحية للماشية يقتصر أيضا على مستويات المعادن النذرة.

النتائج الرئيسة – مياه البحيرة

النتائج الرئيسية لشتاء 2011 على الشكل التالي:

- مستوى الرقم الهيدروجيني من 8.1 والذي هو أقل نسبيا من المتوسط 8.3 لموسم الجفاف. ويرجع ذلك بشكل عام إلى تجديد المياه الناتج عن هطول الأمطار. ولكنه لا يزال واضحاً ان درجة الحموضة القلوية هي بسبب التعرض لمصادر التلوث؛
- BOD أعلى نسبيا، وهذا يؤثر على الأكسدة، مما يؤدي إلى الحد من الظروف التي تعكسها على الأمونيا العالية، ومستويات الفوسفات. أيضا، ومستويات أعلى نسبيا من الحديد والكادميوم وبسبب ذوبان الرواسب من هذه المعادن تحت ظروف الحد الاقصى؛
- مستويات الكادميوم (تتجاوز في الصيف المستوى القياسي الوطني الموصى به 0.005 ملغم / لتر بنسبة التجديد من الامطار؛
- انخفضت مستويات المنغنيز قليلا في بعض المواقع وفي البعض الآخر تجاوز المستوى القياسي للMG0.05 / لتر؛ مقارنة مع التجاوزت السابقة 30٪ من عينات مذكورة في أكثر من المستوى الموصى به وذلك في فصل الصيف؛
- تم قياس جميع المعادن النذرة الأخرى وهي دون المعايير اللبنانية الموصى بها؛ و
- تلوث برازي ميكروبيولوجي لا يزال يسجل مستويات عالية 90٪ من المواقع (50٪ في الصيف).

بالاضافة إلى ذلك، فان رصد التغيرات على مر الزمن يظهر تدهوراً في نوعية مياه بحيرة القرعون (مقارنة مع دراسة د. مي الجردي et.al 2002، وBAMAS 2005):

- زيادة بنسبة 23٪ في مستويات TDS؛
- زيادة 64٪ في مجموع الأوكسجين المذاب، يرجع ذلك في معظمه إلى نمو الطحالب التي ادت إلى الزيادة في الطلب على الأكسجين البيوكيميائي؛
- التغير في درجة الحموضة القلوية نحو (7.3–8.2) بسبب التعرض لتصريف مياه الصرف الصحي المنزلي وتصريف المياه العادمة الصناعية؛
- اكتشاف المعادن النذرة، ولكن على مستويات أقل من قيمة الحد الأعلى المسموح به (المعايير اللبنانية)، باستثناء ارتفاع مستويات الكادميوم والمنجنيز في الصيف؛
- مستويات عالية من الكادميوم والمنجنيز في الصيف، و
- زيادة كثافة البراز في مواقع أخذ العينات كلها تقريبا.

يعزى التدهور في نوعية المياه وتراكم المعادن في الرواسب بشكل أساسي إلى تصريف مياه الصرف الصحي مباشرة، والجريان السطحي وما يحمله من الملوثات الزراعية. وزادت أنظمة وشبكات الصرف الصحي، لتحل محل الجور الصحية. ومع ذلك، فإن تصريف المجاري الصحية لا تزال تصب في البحيرة، في انتظار الانتهاء من محطات المعالجة (باب مارع

وصغبين).

الجدول 2. مقارنة لنوعية مياه البحيرة وتقرير 2005BAMAS والدراسة الحالية 2010 – 2011

Indicator المؤشر	Survey Season الفصل الممسوح	BAMAS 2005 Calculated from lake water results الاحتساب من مياه البحيرة 2005			Current 2010-11 Study Lake water results نتائج الدراسة الحالية 2010-2011			Drinking water standard مواصفات مياه الشرب	
								MoE-Lebanon وزارة البيئة اللبنانية	USEPA الوكالة الامريكية لحماية البيئة
		Min. الحد الادنى	Mean الوسطي	Max. الاقصى	Min. الحد الادنى	Mean الوسطي	Max. الاقصى	GV[1] (25 °C)	GV/MAL[2]
Temperature (°C) الحرارة	W	11.3	12.52	16	22.80	23.08	23.30	NA[6]	NA
	D	16.5	20.7	24.8	32.20	33.68	34.70		
TDS (mg/l) مجموع المعادن الذائبة	W	211	226.8	239	234.5	241.55	248.00	500[7]	500[7]
	D	120	160	196	221	235.10	256.00		
pH (pH units) الحموضة	W	6.82	7.58	7.78	7.85	8.10	8.32	6.5-8.5	6.5-8.5
	D	6.50	7.59	7.5	8.20	8.27	8.32		
DO (mg/l O_2) الاكسيجين المذاب	W	6.82	7.00	8.68	8.10	9.81	11.20	NA	NA
	D	1.3	3.3	7.7	7.22	8.39	9.41		
BOD (mg/l) الحاجة البيولوجية للاوكسيجين	W	<2	2.1	3	2.00	2.67	4.00	NA	NA
	D	<2	2.57	4	2.00	2.65	3.30		
NH_4 (mg/l) الامونيا	W	0.52	0.62	0.7	0.25	0.30	0.46	NA	NA
	D	<0.02	0.3	1	0.00	0.20	0.35		
NO_3^- (mg/l) النيترات	W	16.2	27.9	34.1	1.70	2.00	2.40	10 (as N)	10 (as N)
	D	16.1	21.7	31.2	0.80	0.93	1.20		
SO_4^{2-} (mg/l) السولفات	W	34	39	43	34.00	35.50	37.00	250	250
	D	25	29.3	33	36.00	37.10	39.00		
P_2O_5 (mg/l) الفوسفوريوس	W	0.19	0.22	0.33	0.21	0.40	0.90	NA	NA
	D	0.01	0.13	0.35	0.00	0.09	0.245		
FC (CFU/100ml) القولونيات البرازية	W	6	39	196	0	181.42	400	0	0
	D	0	17	450	0	160.60	400		
Manganese (mg/l) المانغانيز	W	NA	NA	NA	0.0200	0.0300	0.0300	0.05	
	D	NA	NA	NA	0.0020	0.0040	0.0060		
Cadmium (mg/l) الكادميوم	W	NA	NA	NA	0.0005	0.0007	0.0010	0.005	
	D	NA	NA	NA	0.0007	0.0100	0.0210		

*NA: Not Available غير متوفر

النتائج الرئيسية – المياه الجوفية

النتائج الرئيسية لشتاء 2011 هي:

- الناتج العمومي للمحتوى المعدني حوالي 277 ملغ / لتر (بمقابل 385 ملغ / لتر في الصيف)، وهذه المستويات هي مقبولة بالمقارنة مع المعايير اللبنانية والمعايير والمبادئ التوجيهية لمنظمة الصحة العالمية ووكالة حماية البيئة؛

- مستوى الرقم الهيدروجيني 7.5 (7.8 في الصيف)، وذلك بسبب تجديد موارد المياه الجوفية عن طريق تغذية الأمطار لها؛
- مستويات جميع العناصر الصغرى التي تم اختبارها (مع استثناء النترات) ضمن توصيات المعايير الوطنية، ومعايير وكالة حماية البيئة والمبادئ التوجيهية لمنظمة الصحة العالمية؛
- مستويات عالية من النترات تتجاوز الموصى بها اي 10 ملغ / لتر (حد نترات النيتروجين) هناك فقط عينة واحدة جيدة في(حزين) بالمقارنة مع 20٪ من الآبار في الصيف (الآبار التي اخذت منها العينات في حوش بردى، حزين، سارعين، الحلانية ووابلح)؛
- ارتفاع مستويات المنغنيز في مواقع أخذ العينات في المنصورة (mg0.064 / لتر، اعلى من الحد MG0.05 / لتر)، وإلى أقل في ابلح (0.038 ملغم / لتر)، حلانية (0.033 ملغم / لتر)، وسرعين(0.040 ملغم / لتر)؛
- كانت مخففة كل المعادن النذرة الأخرى باستثناء مستويات الزنك ارتفعت بنسبة 59٪.

الجدول 3. مقارنة نوعية المياه الجوفية في تقرير BAMAS 2005 ونتائج الدراسة الحالية 2010-11

Indicator المؤشر	Survey Round المنطقة الممسوحة	BAMAS 2005 Calculated from Ground water results الاحتساب في نتائج المياه الجوفية 2005			Current 2010-11 Study Ground water results نتائج الدراسة الحالية 2010-11			Drinking water standard مواصفات مياه الشرب: MoE-Lebanon وزارة البيئة اللبنانية	Drinking water standard مواصفات مياه الشرب: USEPA وكالة حماية البيئة الامريكية	Reclaimed WW for irrigation مياه الصرف الصحي للري
		Min. الحد الادنى	**Mean** الوسطي	**Max.** الاقصى	**Min.** الحد الادنى	**Mean** الوسطي	**Max.** الاقصى	**GV[1] (25 °C)**	**GV/MAL[2]**	**MoE guidelines** مواصفات وزارة البيئة
Temperature (°C) الحرارة	W	11.6	17.26	20.1	10.20	18.23	22.50	NA[6]	NA	
	S	18.4	22	33.3	15.15	20.59	27.6			
TDS (mg/l) مجموع المعادن الذائبة	W				120.00	276.89	637.00	500[7]	500[7]	
	S				171.00	335.27	629.50			
pH (pH units) الحموضة	W	6.41	6.85	7.5	7.04	7.50	8.08	6.5-8.5	6.5-8.5	
	S	6.54	6.9	7.22	7.16	7.77	8.6			
DO (mg/l O_2) الاوكسيجين المذاب	W				0.10	5.10	7.80	NA	NA	
	S				4.1	6.04	7.77			
BOD (mg/l) الحاجة البولوجية للاوكسيجين	W							NA	NA	10-45
	S									
NH_4[8] (mg/l) الامونيا	W				0.1	0.18	0.44	NA	NA	
	S				0.00	0.36	42.09			
NO_3^- (mg/l) النيترات	W	1	60.32	318	0.0	2.67	12.40	10 (as N)	10 (as N)	
	S	3	48.31	171	0.2	4.27	29.00			
SO_4^{2-} (mg/l) السولفات	W	7	39.08	250	0	13.55	63.00	250	250	
	S	7	31.42	205	1.5	15.92	60.00			
P_2O_5[9] (mg/l) الفوسفات	W	<0.01	0.12	2.3	0.15	0.56	1.21	NA	NA	
	S	0	0.31	12	0.05	0.61	3.46			
FC (CFU[10]/100,ml) القولونات البرازية	W	0	18	255	0	1.22	21	0	0	5-2,000
	S	0	42.85	400	0	65.37	400			

*NA: Not Available غير متوفرة

علاوة على ذلك، فان المقارنة الشاملة للمياه السطحية لدراسة BAMAS في عام 2005 تشير إلى التالي:

- التحول في درجة الحموضة من 6.5 إلى 7.5
- الانخفاض في مستويات النترات بنسبة 86٪ وبنسبة 65٪ الكبريتات بسبب الزيادة الناتجة عن جمع مياه الصرف الصحي؛
- كثافة البراز العضوي انخفضت من 78٪ إلى 15٪ في عينات موسم الجفاف، ومن 23٪ إلى 13٪ في عينات الموسم الرطب.

إن زيادة التغطية لشبكات المجاري الصحية قد قلل بالتأكيد من تعرض المياه الجوفية إلى التلوث. ولكن في بعض المناطق لا تزال النظم اي شبكات الصرف الصحي ناقصة وغير مكتملة. بالإضافة إلى ذلك، مياه الرشح من مواقع الطمر للنفايات المنزلية البلدية لا تزال تسبب التلوث للمياه الجوفية.

النتائج الرئيسية – التربة والوحول

بشكل عام، يمكن اكتشاف مصادر تلوث التربة في فصل الجفاف بسهولة اكبر. في فصل الامطار او الرطوبة، المتساقطات، الجيران السطحي، التسرب/ الرشح يقوم بشكل ما بتنظيف التربة او بعبارة اخرى غسلها من الملوثات. وكذلك، فان المقارنة بين نوعية التربة ونوعية تربة القناة لفصلي الجفاف والمطر–الرطوبة تبين التالي:

- التباين في الحد الأدنى بين الموليبدينوم والكوبالت، والزنك، والنيكل، والكروم والزرنيخ والزئبق والكادميوم والمنجنيز و؛
- النقص في مستويات الرصاص والباريوم، و
- زيادة في مستويات النحاس، وهذا يمكن أن يعزى إلى عدد من العوامل مثل زيادة النفايات إلقاء وتحلل الكابلات النحاسية بسبب الظروف الحمضية في الموسم الرطب، الرشح من النحاس ومن الأسمدة وإضافة كبريتات النحاس للسيطرة على نمو الطحالب.

إن مقارنة دراسة BAMAS عام 2005، تظهر ان مستويات المعادن النذرة بدأت ببناء نفسها في التربة لاسباب مباشرة وثانوية (الري من مياه الصرف الصحي) التعرض لمياه الصرف الصحي المنزلية والصناعية.

الخلاصة

إن التعرض المستمر لمختلف مصادر التلوث (مياه الصرف الصحي المنزلي، المجاري الصناعية، ورمي النفايات المنزلية العشوائي، والإفراط في استخدام المواد الكيميائية في الزراعة) ينتج عنه الإخلال بالتوازن البيئي في حوض الليطاني الاعلى. وهذا ما يؤدي إلى الحد من قدرة النهر لاستعادة مستويات الأوكسجين حيث أنه هناك حاجة لتنقية والتنفس وتجديد نوعية المياه من اجل اعادة ستخدامها لعدد من الأغراض. وتشمل الخطوات الموصى بها التالي:

- وقف "بشكل كامل" الضخ من الينابيع التي تغذي روافد النهر للري لن ذلك من شأنه الحد من تدفق المياه وتدمير قدرة النهر لمعالجة كثافة التلوث العالية والتي هي على نحو متزايد؛
- أكمال شبكات الصرف الصحي، وجعلها تعمل بشكل صحيح بعد وصلها بمحطات معالجة مياه الصرف الصحي؛
- فرض معايير الصرف على المصانع والمناطق السكنية؛
- بناء مرافق التخلص من النفايات الصلبة كافة او بشكل كافٍ، اقفال وتحييد مكبات النفايات؛
- منع إلقاء النفايات الصلبة بشكل عشوائي، بما في ذلك الحيوانات الميتة، وخصوصا خلال موسم الأمطار، و
- توفير خدمات الإرشاد للمزارعين لتحسين وتقليل استخدام الأسمدة والمبيدات الحشرية.

التوصيات

إن استعادة نهر الليطاني وروافده قدرتها على البقاء سليمة بيئياً، لا يمكن أن يتحقق عن طريق نوع واحد من التدخل البيئي انما ينبغي أن تكون جزءا من (IRBM) نهج الإدارة المتكاملة لحوض النهر ، التي ينبغي أن تشمل تدابير قصيرة ومتوسطة الأجل وهي على الشكل التالي:

استعادة نهر الليطاني الرفاهية البيئية وتدفق المياه المستدامة والسليمة من خلال معالجة جميع أنواع الضغوط البيئية (التلوث)، وتعبئة المجتمعات المحلية وتمكين البلديات المعنية من:

(أ) وقف "بشكل كامل" الضخ الجائر من الينابيع وتدفق الروافد من اجل الري؛

(ب) السيطرة ومراقبة حفرالآبار الجديدة، كذلك مراقبة الإفراط في استغلال المياه الجوفية؛

(ج) فرض العلاج في الموقع للنفايات السائلة، المياه العادمة الصناعية من المصانع الكبرى التي تصب في نهر الليطاني وروافده، أو في شبكات الصرف الصحي المنزلي والتي بدورها تتدفق مباشرة في النهر؛

(د) منع تصريف مياه الصرف الصحي غير المعالجة المحلية مباشرة في النهر وروافده؛

(ه) تنظيم تصريف النفايات الصلبة البلدية والصناعية على طول تدفق مياه النهر؛

(و) رفع مستوى الوعي للحد من الإفراط في استخدام المبيدات.

إن الحماية والحفاظ على نوعية موارد المياه الجوفية، والتدخلات الموصى بها أعلاه سوف تنظيم الإفراط في استغلال واستخراج هذه الموارد وتقليل تعرض المياه لمصادر التلوث. بالإضافة إلى ذلك، يوصى بما يلي:

(أ) فرض الأنظمة القائمة لتحل محل الجور الصحية ومنع رشح الصرف الصحي منها للمياه الجوفية وذلك عبر تصميمها بشكل صحيح؛

(ب) تنظيم استخدام الأسمدة (الأنواع والكميات التطبيقية)، و

(ج) تحديد وتحسين رصد جميع مصادر المياه التي تستخدمها المجتمعات، ومصادر المياه المحلية الرئيسية والتكميلية، لتحديد سلامة المياه.

تنظيم استخدام المياه العادمة لأغراض الري، ومدى ملائمة هذه المياه العادمة غير المعالجة للري بحيث تحوي هذه المياه على ملوحة مياه الصرف الصحي، ومعدل تسرب السمية إلى المنتوجات النباتية والعوامل الصحية الأخرى. إذا كان هناك حاجة لمثل هذا الاستخدام نظرا لندرة مصادر المياه البديلة، ينبغي تنظيم ذلك وتقديم المحاصيل مع اقل مخاطر للمستهلكين.

تحسين نوعية المياه في بحيرة القرعون، تنفيذ التدخلات أعلاه سوف تحسن نوعية المياه في بحيرة القرعون للاستخدامات المختلفة، خصوصا الري والثروة السمكية. وعلاوة على ذلك، فان علاج النفايات السائلة ومياه الصرف الصحي على طول البحيرة أمر بالغ الأهمية للسيطرة على مستويات المغذيات المخصبة (بشكل رئيسي الفوسفات والنترات) ومنع زيادة المغذيات.

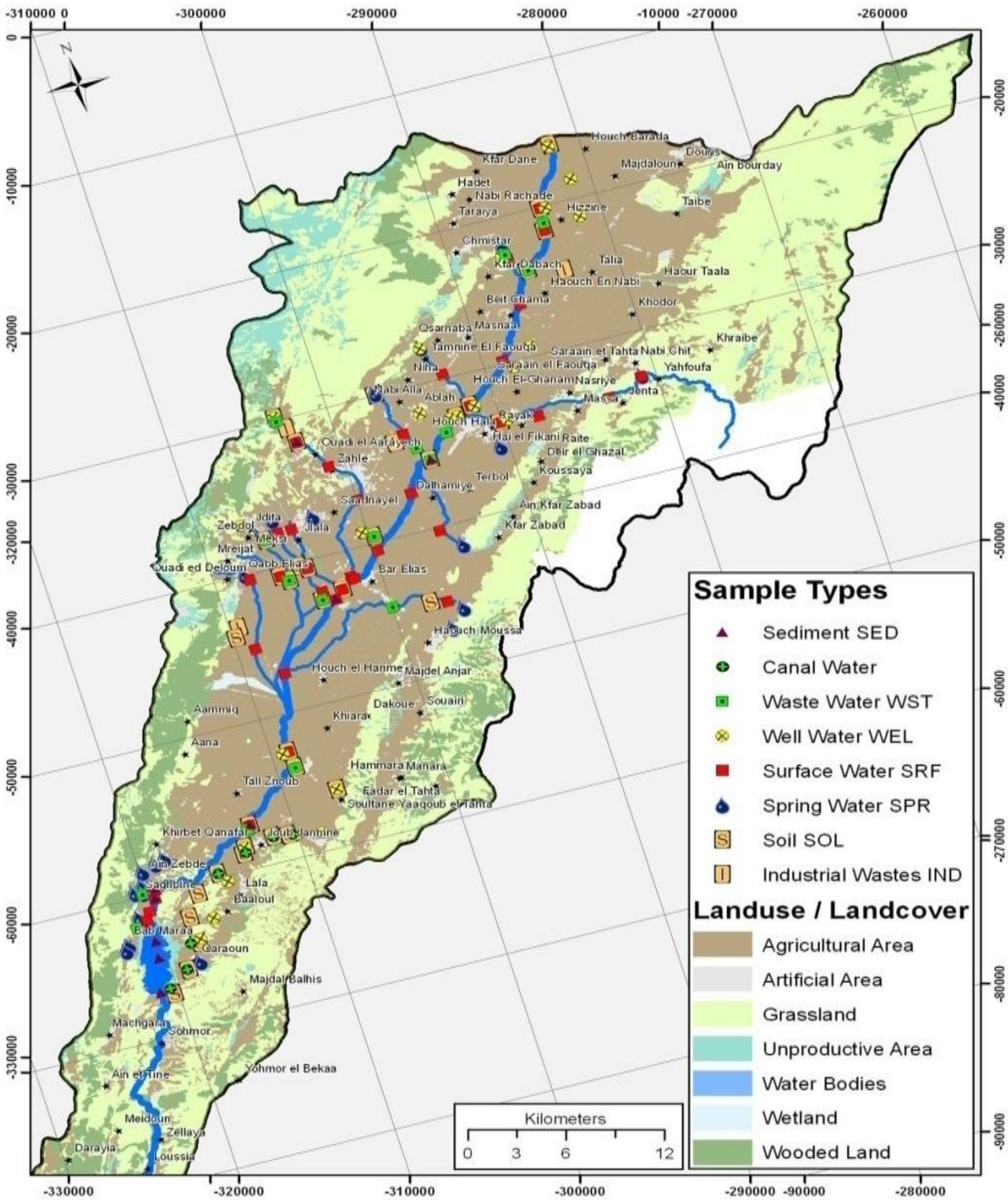
تحسين نوعية المياه في قناة الري 900؛ إن تنفيذ التدخلات أعلاه أيضا سوف يحسين نوعية المياه في القناة 900 ولأن مصدرها من البحيرة. بالإضافة إلى ذلك، ينبغي رصد مستويات كبريتات النحاس واضافاته (تستخدم للسيطرة على نمو الطحالب) لمنع تراكمه التدريجي في التربة المروية بمياه القناة.

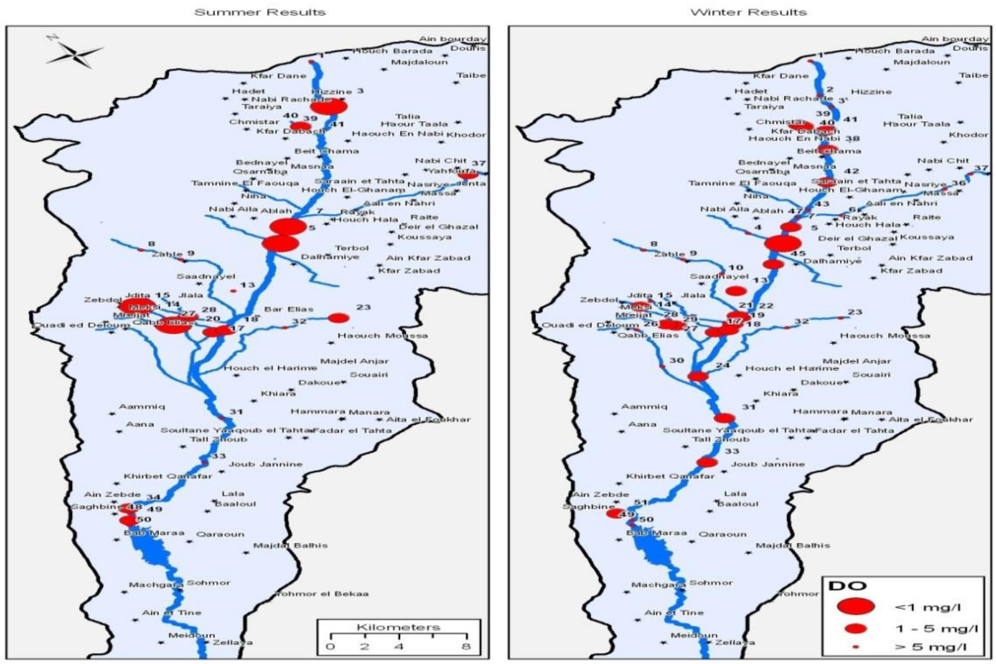
تطوير ودعم برامج مراقبة نوعية المياه عن طريق:

(أ) الشروع في الدراسات البيئية لتحديد المؤشرات البيولوجية المائية، ورصد حالة الأنواع المائية، وتقييم الحاجة إلى تعزيز صيد الأسماك؛

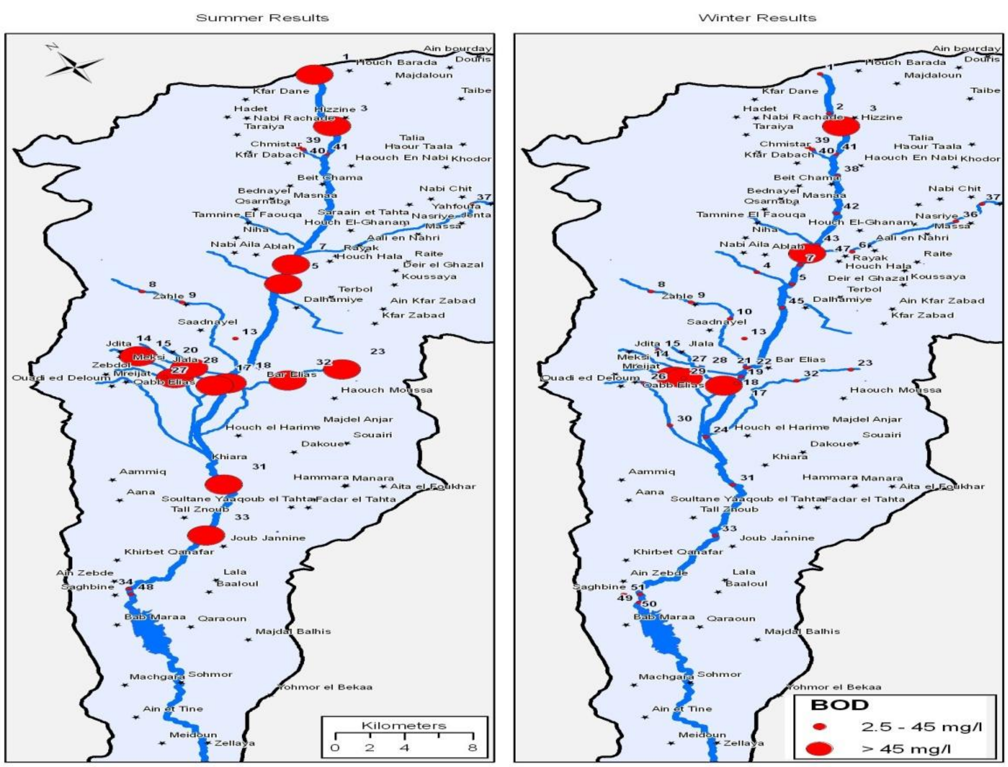
(ب) إجراء دراسات لتقييم مستوى المخاطر المرتبطة بانتقال المعادن النذرة في الأجزاء الصالحة للأكل من المحاصيل الزراعية والمزروعة في التربة التي تتعرض تدريجيا إلى الري من مياه الصرف الصحي، والمياه السطحية ومياه الينابيع الملوثة بمياه الصرف الصحي ومياه الصرف الصناعي، و

(ج) إجراء دراسات لتقييم مستوى المخاطر المرتبطة بمسببات الأمراض والفضلات في المياه العذبة والصرف الصحي وعلى القشرة الخارجية للمحاصيل (مثل الفيروسات المعوية، الإسكارس بيوض الامبريوسيدوس المتحولة).

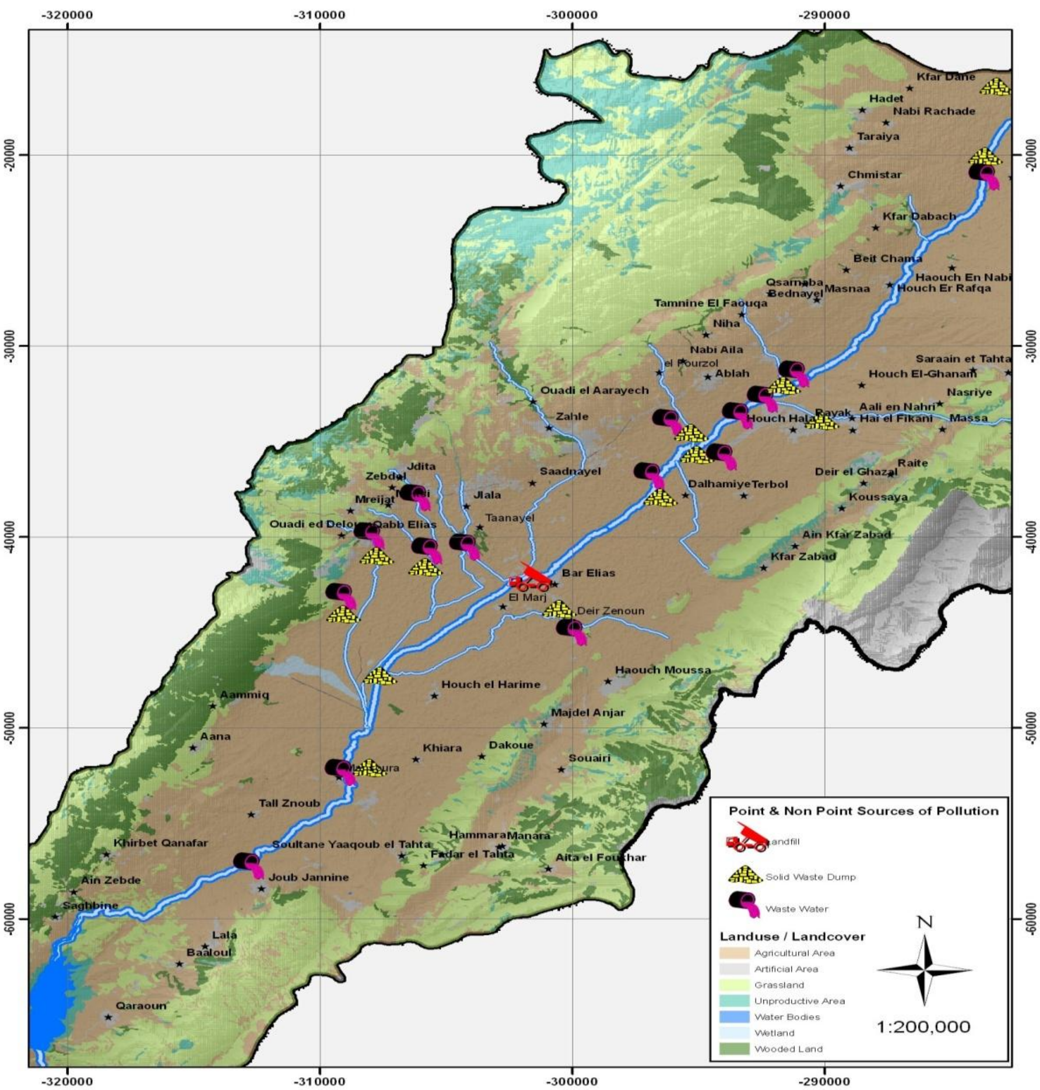




الشكل 2. مستوى الاكسيجين المذاب على طول نهر الليطاني وروافده لموسمي الجفاف والامطار



الشكل 3. مستويات الحاجة البيولوجية للاكسيجين على طول نهر الليطاني وروافده لموسمي الجفاف والامطار



الشكل 4. النقاط المحددة والغير محددة لمصادر التلوث على طول الحوض الاعلى لليطاني

1. INTRODUCTION

1.1.AUTHORIZATION

International Resources Group (IRG) was contracted by USAID/Lebanon (Contract EPP-I-00-04-00024-00 Task Order No. 7) under the Integrated Water and Coastal Resources Management Indefinite Quantity Contract (IQC) II to implement the Litani River Basin Management Support (LRBMS) Program. The period of performance of the contract is September 29, 2009 to September 30, 2012.

1.2.PURPOSE OF THIS REPORT

The purpose of this report is to present the results of a Litani River Basin-wide survey that was carried out in Spring 2011 to investigate the quality of surface, spring, canal and ground-waters. This survey was conducted by a team from the American University of Beirut (AUB) led by Dr. Mey Jurdi (Professor and Chair, Environmental Health Department) and including:

- Dr. Samira Korfali (Project Consultant, Lebanese American University)
- Ms. Mona El Rez (Field Work Coordinator)
- Ms. Nora Karahagopian (Technical Lab Supervisor, AUB)
- Mr. Khalil Kreidieh (Research Assistant, AUB)

1.3.PROGRAM OBJECTIVES

The purpose of the LRBMS Program is to set the ground for improved, more efficient and sustainable basin management at the Litani river basin through provision of technical support to the Litani River Authority and implementation of limited small scale infrastructure activities.

The LRBMS program is part of USAID's increasing support to the water sector in Lebanon. The Litani River Basin suffers the fate of many river basins around the world: increasing demands compete for limited natural resources. Groundwater over-exploitation, deforestation and overgrazing, unplanned urban sprawl, untreated wastewater effluents, and unsustainable agricultural practices contribute to environmental degradation in the form of declining water and soil quality.

Solutions do exist to reverse these trends and establish sustainable management practices. The key to successfully implementing such solutions requires applying the principles of Integrated Water Resources Management (IWRM) through a single river basin authority rather than multiple agencies responsible for different aspects of water management as is the case in many countries. Fortunately, the existence of the Litani River Authority (LRA) provides a unique platform to become such an IWRM river basin authority that will mobilize stakeholders in the river basin and address these challenges in an integrated manner. Successful implementation of LRBMS will prepare the LRA to assume the role of an integrated river basin authority when legal constraints are removed.

1.4.PROGRAM COMPONENTS

Under the LRBMS program, LRBMS will work with national and regional institutions and stakeholders to set the ground for improved, more efficient and sustainable basin management at the Litani River basin. The LRBMS technical assistance team will provide technical services and related resources to LRA in order to improve their planning and operational performance and equip them with the necessary resources for improved river basin management.

To achieve the LRBMS program objectives, the Contractor shall undertake tasks grouped under the following four components:

1) Building Capacity of LRA towards Integrated River Basin Management
2) Long Term Water Monitoring of the Litani River
3) Integrated Irrigation Management which will be implemented under two sub-components:
    a. Participatory Agriculture Extension Program: implemented under a Pilot Area: West Bekaa Irrigation Management Project
    b. Machghara Plain Irrigation Plan
4) Risk Management which will be implemented under two sub-components:
    a. Qaraoun Dam Monitoring System
    b. Litani River Flood Management Model

2. BACKGROUND INFORMATION

The Litani River is the largest and most important water resource in Lebanon. The river is 170 km in length with 60 km of tributaries, draining over 2170 km2 (20% of the countries area) and totally contained within its boundaries. The river arises from Nabeh Al Oleik near Baalbek and flows into the Mediterranean 70 km south of Beirut (7 km north of Tyre).

Still, the implementation of the watershed management plans and the water supply schemes (irrigation and domestic) continue to be challenged by prolonged social and economical instability in the country. And despite all invested efforts, the water quality and quantity continue to be impacted by excessive exposure to various sources of pollution (BAMAS, 2005a and b, Dry Season 2010 Report).

All this necessitates immediate intervention through the development and implementation of integrated river basin management (IRBM). Instating and sustaining IRBM will ensure the coordination, conservation, management and development of water, land and related resources across all sectors of the river basin. This is crucial to “maximize the economic and social benefits derived from water resources in an equitable manner while preserving and, where necessary, restoring freshwater ecosystems" (Global Water Partnership, 2000).

Currently, the International Resource Group (IRG) under the USAID/Lebanon funded Litani River Basin Management Support Program is assisting the Litani River Authority (LRA) to improve the management of this vital water resource through the following activities (a) building the capacity of LRA towards integrated River Basin Management (IRBM), (b) developing integrated irrigation management schemes, (c) upgrading the Litani River and the Qaraoun Dam monitoring systems, and (d) developing flood management models.

3. STUDY OBJECTIVES AND WORK PLAN

Based on the above presented goals, the objective of this work is to update the water quality inventories that were conducted in 2005 under the USAID-funded activity of the Litani Basin Management Advisory Services (BAMAS).

Phase one of the field study, that was conducted in the mid of the dry season (August 2010), focused on (a) evaluating the Upper Litani Basin water quality profile, (b) comparing to results of previous basin quality assessment (BAMAS 2005), (c) exposing environmental health risks associated with multipurpose water usage, and (e) proposing appropriate mitigation measures.

Phase two of the field study, conducted at the end of the wet season (March-April 2011), aims to determine seasonable water variability and accordingly, develop proper river basin management strategies. As such, the direct objectives are to:

Evaluate the quality of the Litani River Basin in the wet season (under maximal water flow conditions) and reflect on water quality variability and its impacts on water use, and

Project on environmental and health impacts associated with water use for domestic, agricultural (crops and livestock), and various other uses.

To achieve the indicated study objectives the following tasks were conducted:

Collecting samples at the end of the wet season from river water, lake water, canal water, sewage, Industrial wastewater, river and lake sediments and soils from agricultural lands of the Upper litani Basin (ULB),

Conducting water quality analysis (physical, chemical and microbiological),

Evaluating the quality of collected samples based on National and International Standards and relative to the type of water usage,

Presenting results in a scientific comprehensive manner (figures, tables and maps),

Analysing water quality variability (Wet and Dry Seasons 2010 -2011 and BAMAS 2005),

Assessing possible environmental risks associated with water usage for agricultural activities (crops, livestock), and on human health (public health impacts), and

Recommending priority environmental interventions to manage contamination loads and upgrade water quality.

This field assessment is an essential step towards instating a comprehensive effective and sustainable river basin management as clearly indicated in the "Terms of Reference for Consulting Services in the LRBMS Project Water Quality Survey".

4. STUDY METHODOLOGY

4.1.FIELD AND RECONNAISSANCE SURVEYS

Over a period of 8 days (between March 15 and March 30, 2011) an updated inventory of of all possible point and nonpoint sources of pollution within the Upper Litani Basin (divided logistically into the following indicated three geographic zones) was conducted:

Yellow Zone (Upper Zone) between Saidi and Rayak (Saidi, Housh Barada, Taraya, Housh Sneid, Chemistar, Hezeine, Bednayel, Housh Rafka, Sifri, Temnine Al Fawka, Temnine Al Tahta, Ablah, Ferzol, Rayak, Yahfoufa, Janta, Masa, Seraine and Helaniyeh),

Orange Zone (Middle Zone) between Rayak and Ammiq (Qaa El Reem, Hazerta, Zahle, Amrousieh, Jdeita, Chtoura, Tannayel, Jalala, Anjar, Majdel Anjar, Saadnayel, Bar Elias, Dier Zanoun, Housh Al Harimi, Faour, Dalhamyieh and Al Marj), and

Green Zone (Lower Zone) between Ammiq and Qaraoun (Kobb Elias, Tal Al Akhdar, Ammiq, Housh Ammiq, Al Marj, Mansoura, Ghazza, Luci/Sultan Yaakoub, Kherbeit Kanafar, Ain Zebdeh, Jeb Janine, Kamed Al Louze, Saghbeine, Lala, Dier Ain Al Jawzeh, Bab Merea, Baaloul, Aitaneit and Qaroun)

The updated inventory of point and non-point sources of pollution are presented in Appendix 8.1; Tables 8.1.1.b, 8.1.2.b, & 8.1.3.b. Additionally, maps reflecting on urbanization pressures, type of land cover, and the location of sampling points along the Upper Litani Basin (ULB) are presented in Figures 1-3.

4.2.SAMPLING FRAMEWORK

The sampling campaign framework developed for the dry season was used to collect samples from:

The Litani River and its Tributaries (50 Sampling Sites), The Qaraoun Lake (10 Sampling Sites),

Irrigation Canal 900 (7 Sampling Sites),

Groundwater springs and wells located within the ULB (48 Sampling Sites),

Domestic wastewater (sewage) effluents (from residential communities) disposed directly through sewer outlets along the water flow (12 Sites),

Major industrial wastewater effluents (resulting from major industries) disposed directly into the river (7 Sites),

Soils of agricultural areas bordering the river and irrigated by Canal 900 (35 Sampling Sites), and

River and Lake Sediments (11 sampling Sites).

The numbers, types and GPS coordinates of samples collected for both the wet and dry seasons, are presented in Appendix 8; Tables 8.1.1.c, 8.1.2.c, 8.1.3.c. 8.1.4 & 8.1.5. And, maps reflecting on sample types and location along the ULB are presented in Figures 4 & 5.

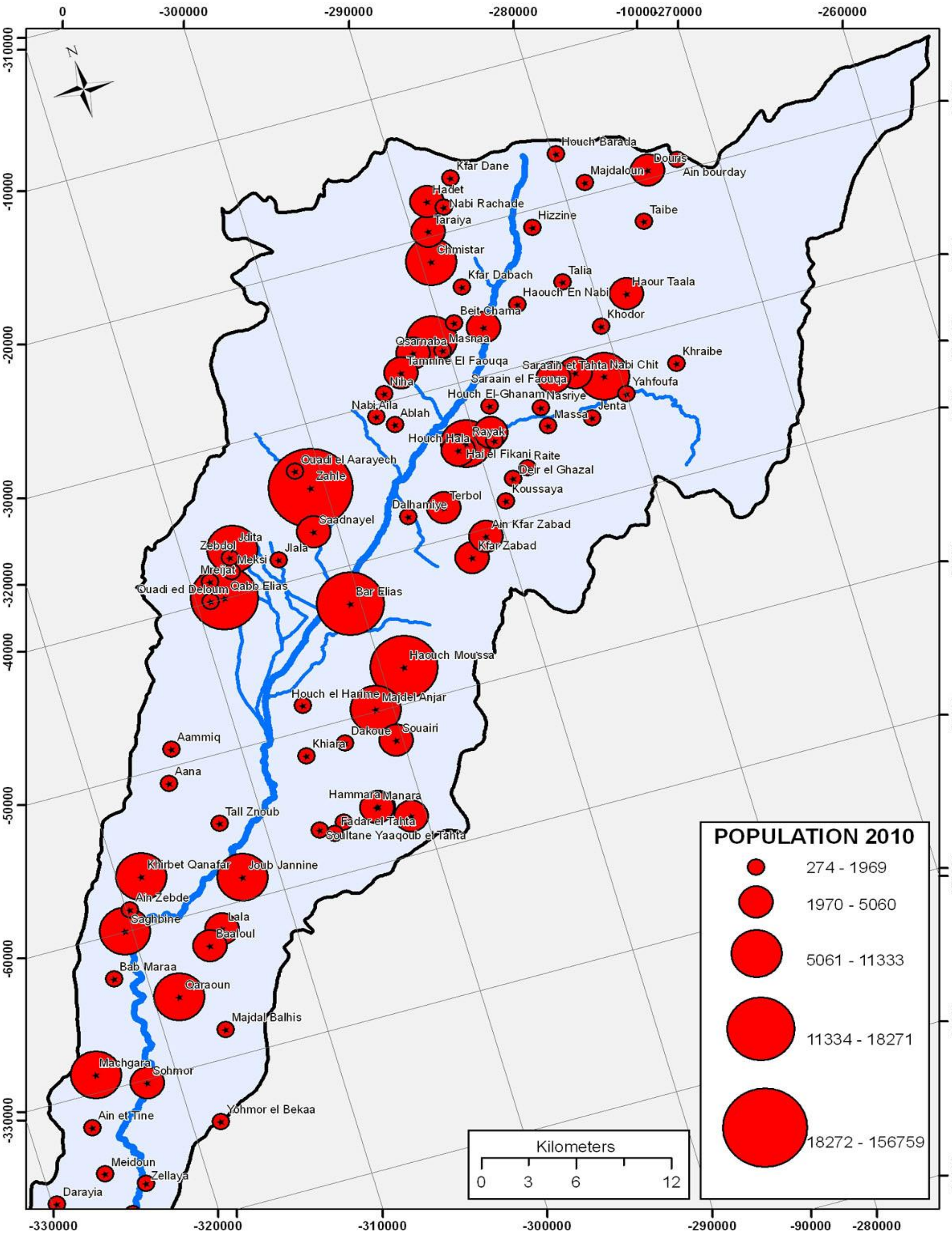


Figure 1. Upper Litani Basin Urbanization Profile

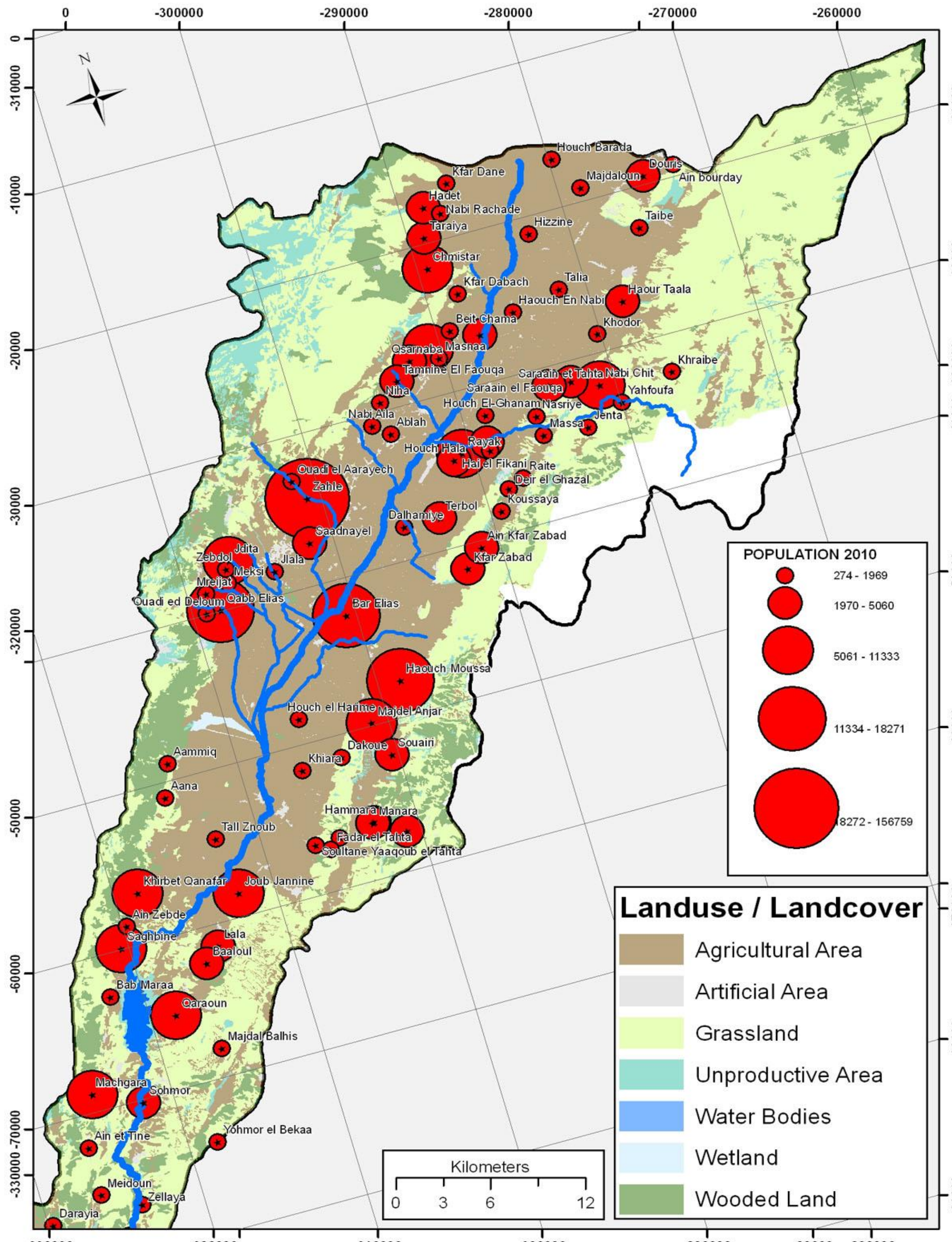


Figure 2. Upper Litani Basin Urbanization Profile

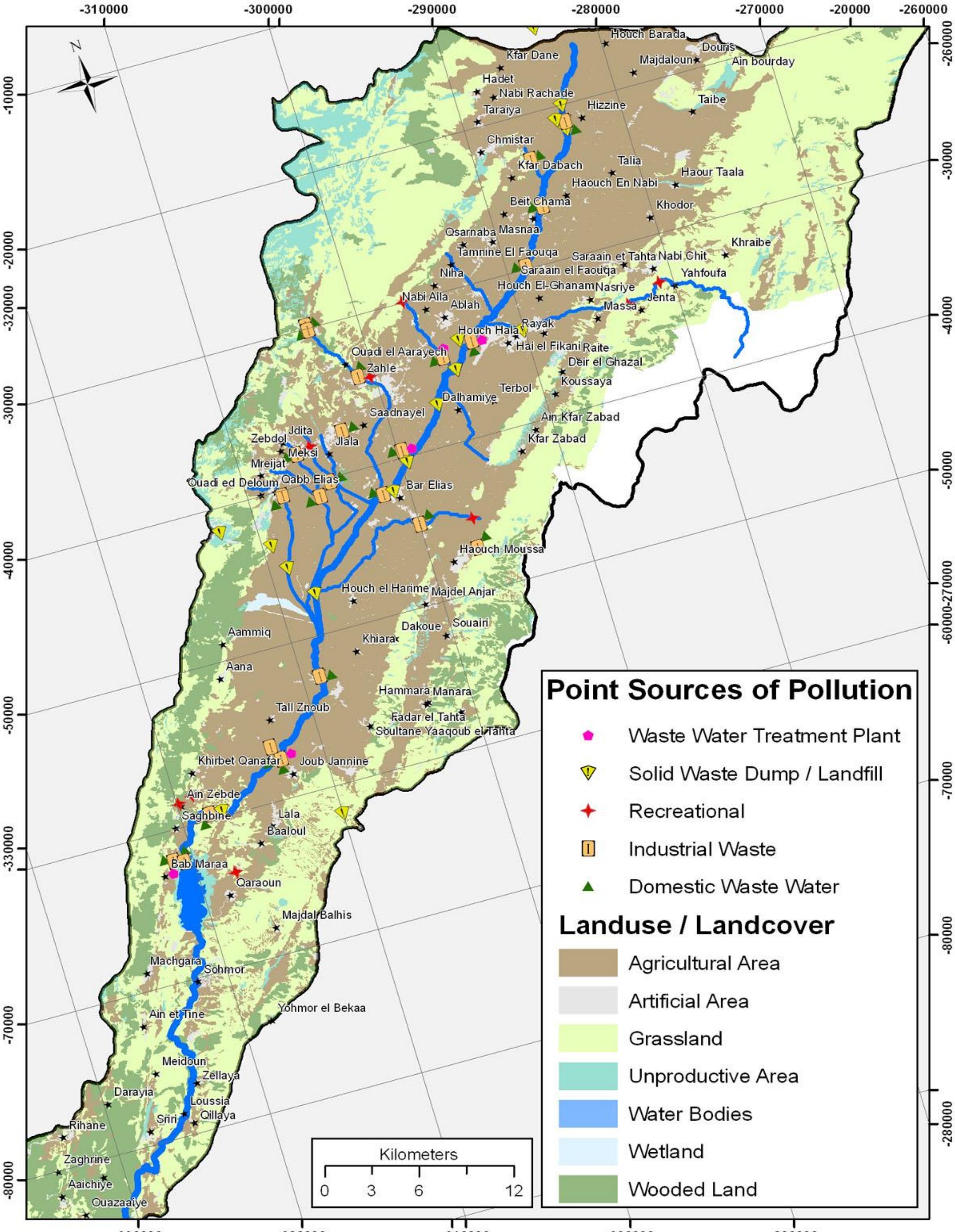


Figure 3. Upper Litani Basin Point and Nonpoint sources of Pollution

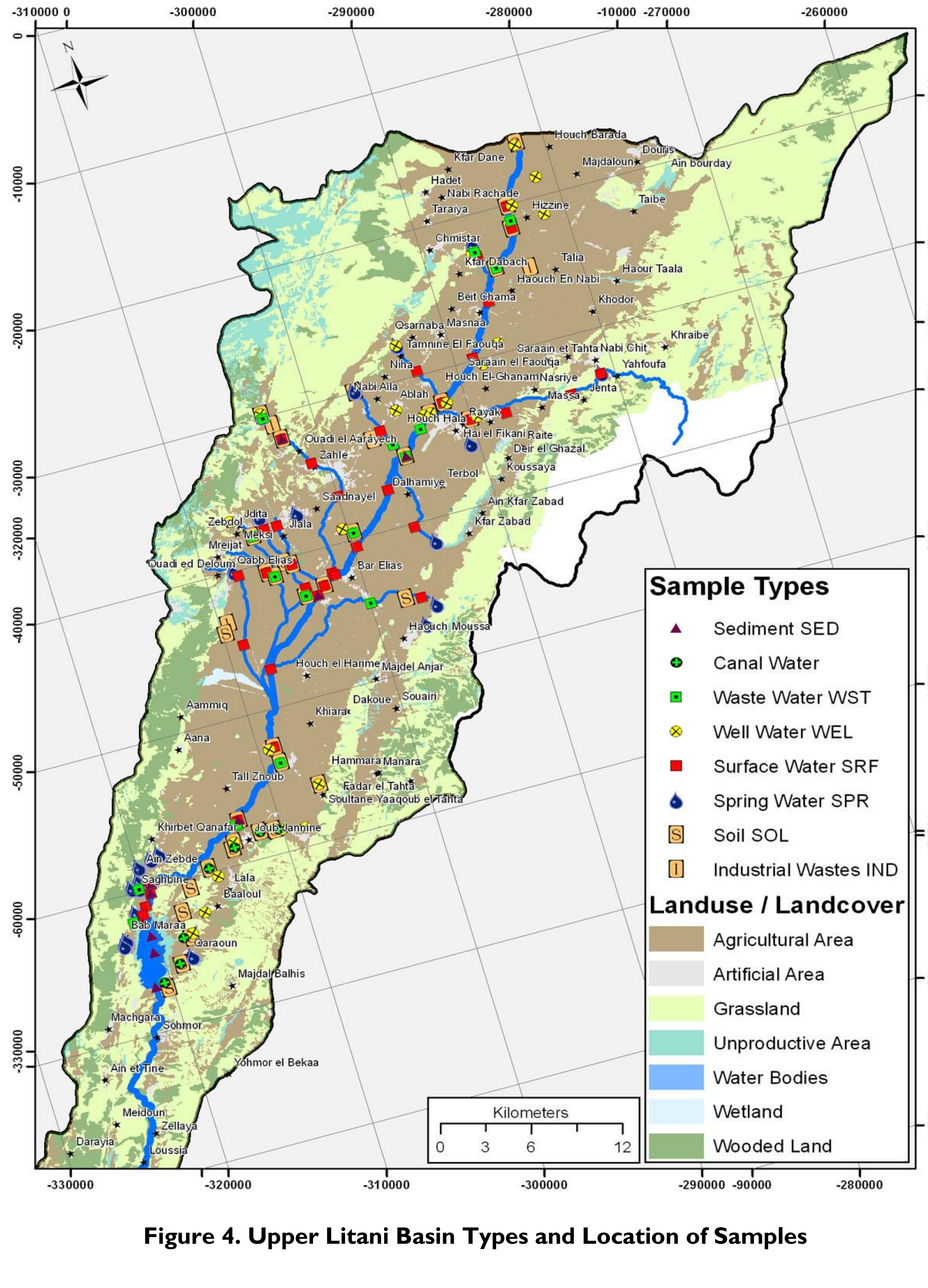


Figure 4. Upper Litani Basin Types and Location of Samples

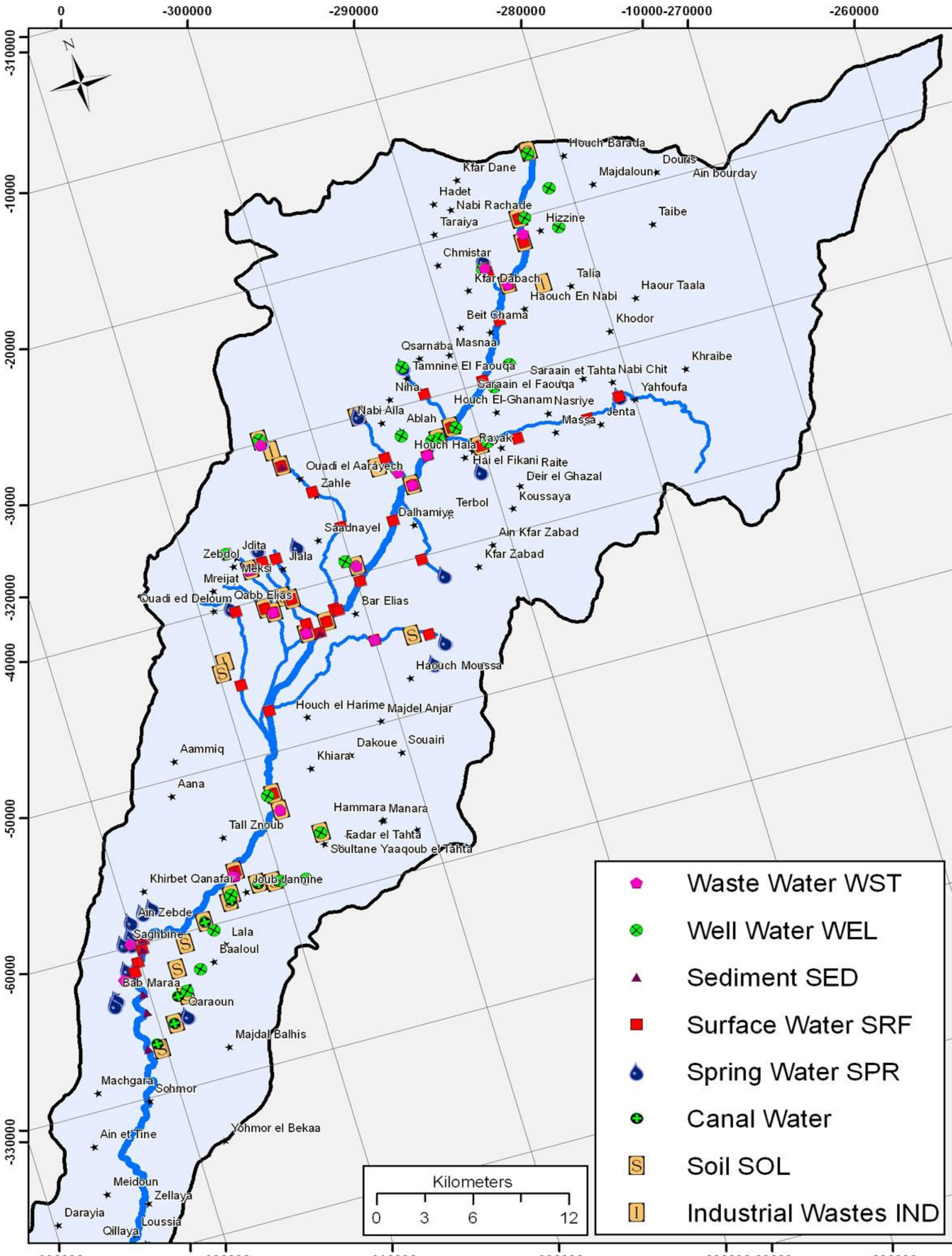


Figure 5. Upper Litani Basin Types and Location of Samples

4.3.ULB SAMPLING LOCATIONS

4.3.1. SAMPLING THE UPPER LITANI BASIN

Based on the findings of the updated field and reconnaissance surveys, and in line with the developed sampling framework for the dry season, samples were collected. The location of the sampling sites along the river (all river samples were collected directly at subsurface points), river sediments, ground water (springs and wells), domestic wastewater (sewage), industrial wastewater, soil and sediments as presented in figures 7-13.

4.3.2. SAMPLING THE QARAOUN LAKE

As indicted in the dry season report, the thirteen sampling sites were located to reflect on the three previously studied and defined water zones:

Receiving Zone (S4-S6)

Central Zone (S6-S11)

Dam Zone (S11-S13)

In addition, lake sediment samples were collected to reflect on conditions within the previously identified three lake water zones, as presented in figure 6.

Figure 6. Wastewater Treatment Plant by the Lake in Bab Merae (Under Construction)

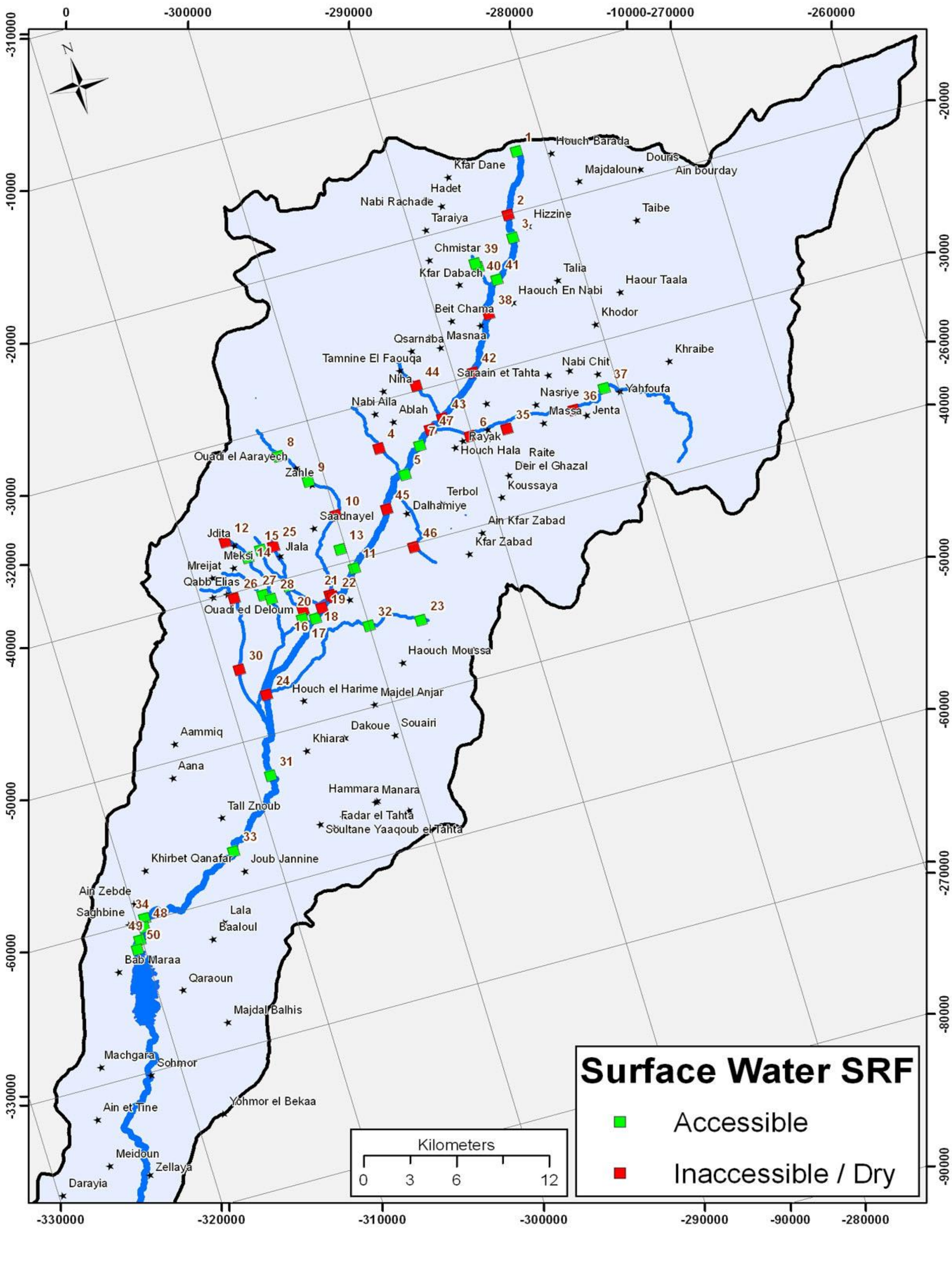

Surface Water SRF
Accessible
Inaccessible / Dry
Kilometers
0 3 6 12
Houch Barada
Douris
Ain bourday
Majdaloun
Kfar Dane
Hadet
Nabi Rachade
Taraiya
Hizzine
Taibe
Chmistar
Kfar Dabach
Talia
Haour Taala
Haouch En Nabi
Beit Chama
Khodor
Qsarnaba
Masnaa
Tamnine El Faouqa
Khraibe
Nabi Chit
Niha
Saraain et Tahta
Yahfoufa
Nasriye
Nabi Aila
Ablah
Massa
Jenta
Rayak
Houch Hala
Raite
Ouadi el Aarayech
Deir el Ghazal
Zahle
Koussaya
Terbol
Saadnayel
Dalhamiye
Ain Kfar Zabad
Kfar Zabad
Jdita
Jlala
Meksi
Mreijat
Qabb Elias
Ouadi ed Deloum
Haouch Moussa
Houch el Harime
Majdel Anjar
Dakoue
Souairi
Aammiq
Khiara
Aana
Hammara
Manara
Tall Znoub
Kadar el Tahta
Soultane Yaaqoub el Tahta
Khirbet Qanafar
Joub Jannine
Ain Zebde
Saghbine
Lala
Baaloul
Bab Maraa
Qaraoun
Majdal Balhis
Machgara
Sohmor
Ain et Tine
Yohmor el Bekaa
Meidoun
Zellaya
Darayia

Figure 7. Location of Surface Water Sampling Points along the Litani River and its Tributaries

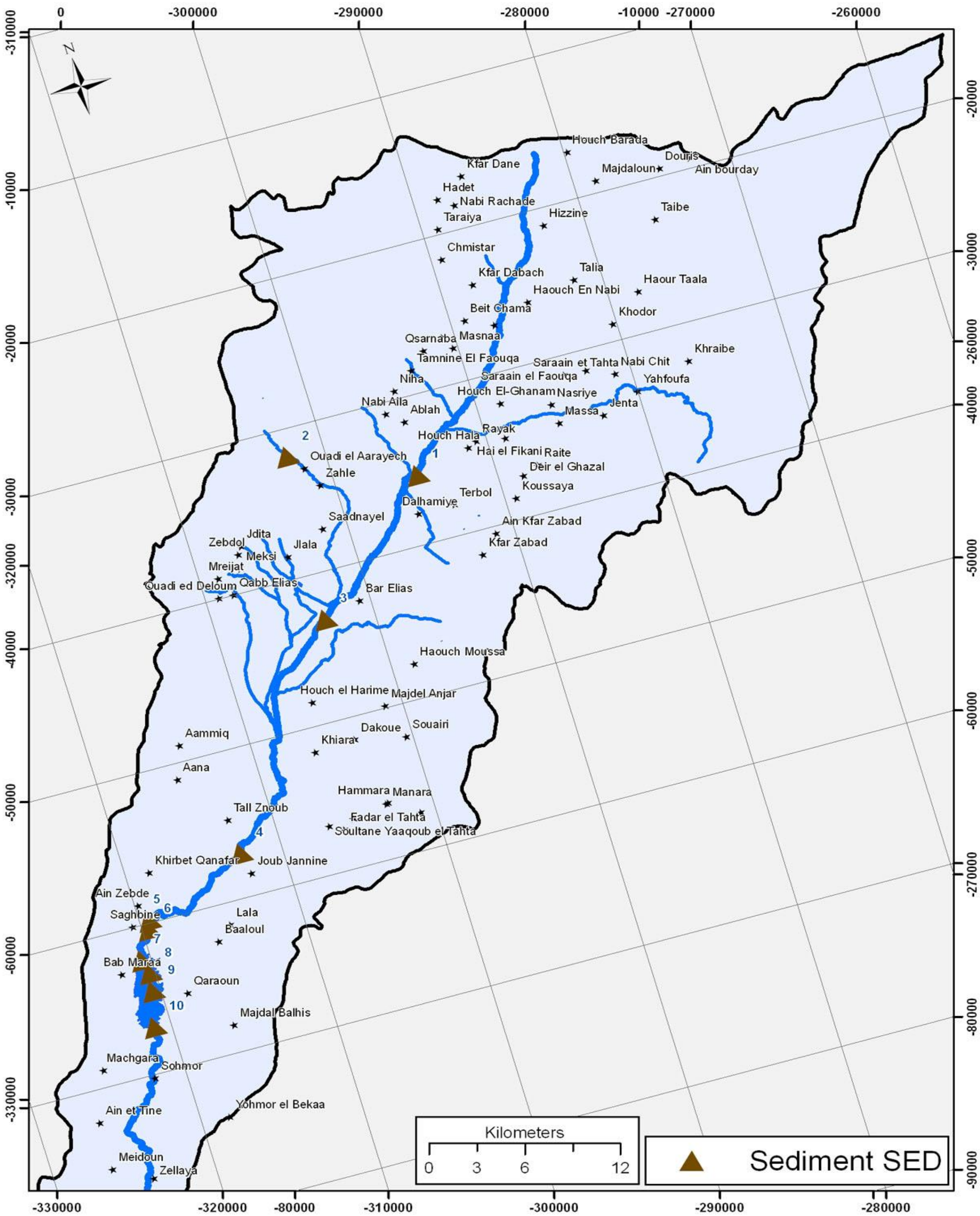


Figure 8. Location of Sediment Samples along the Litani River, its Tributaries and Qaraoun Lake

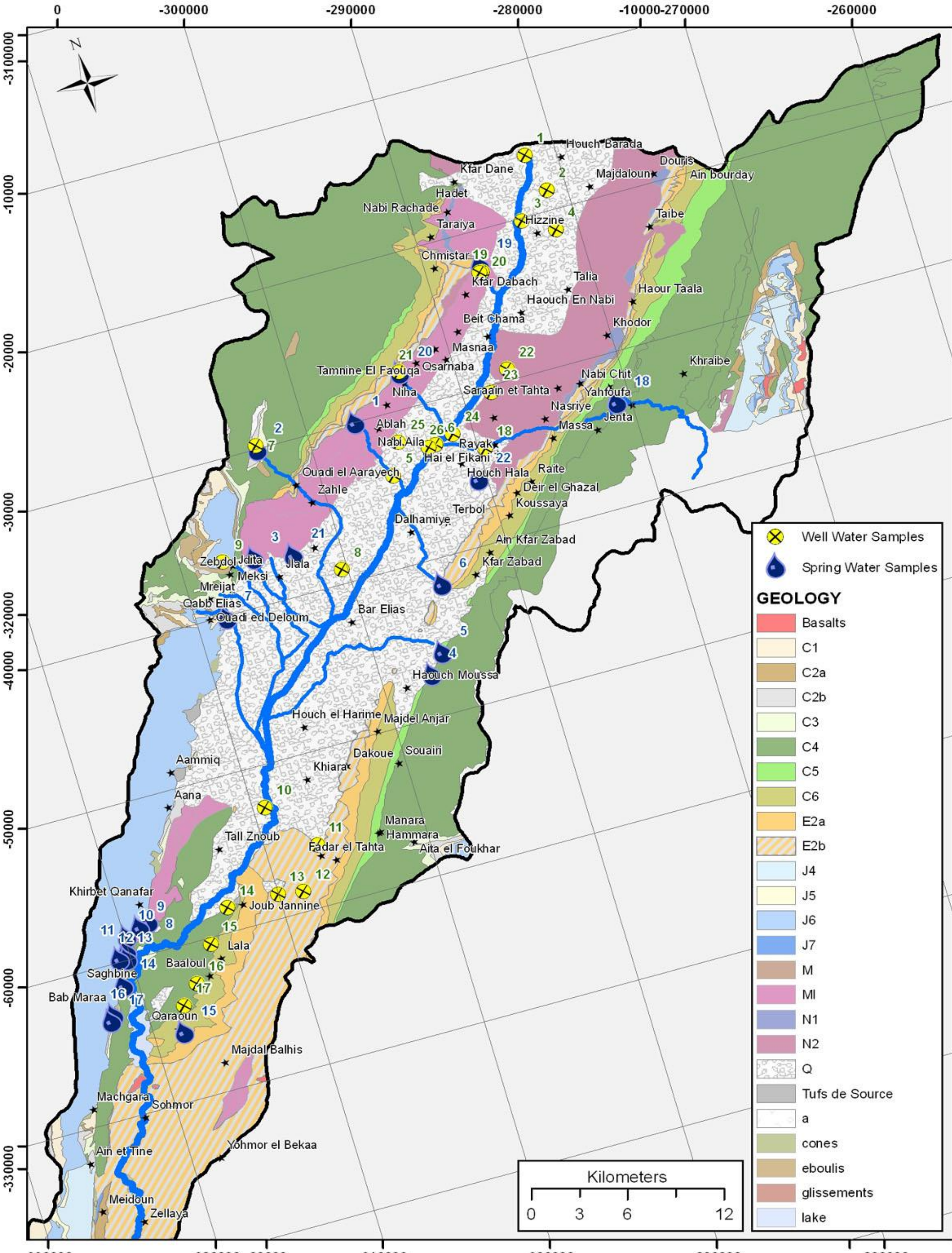


Figure 9. Location of Groundwater Samples along the Litani River and its Tributaries

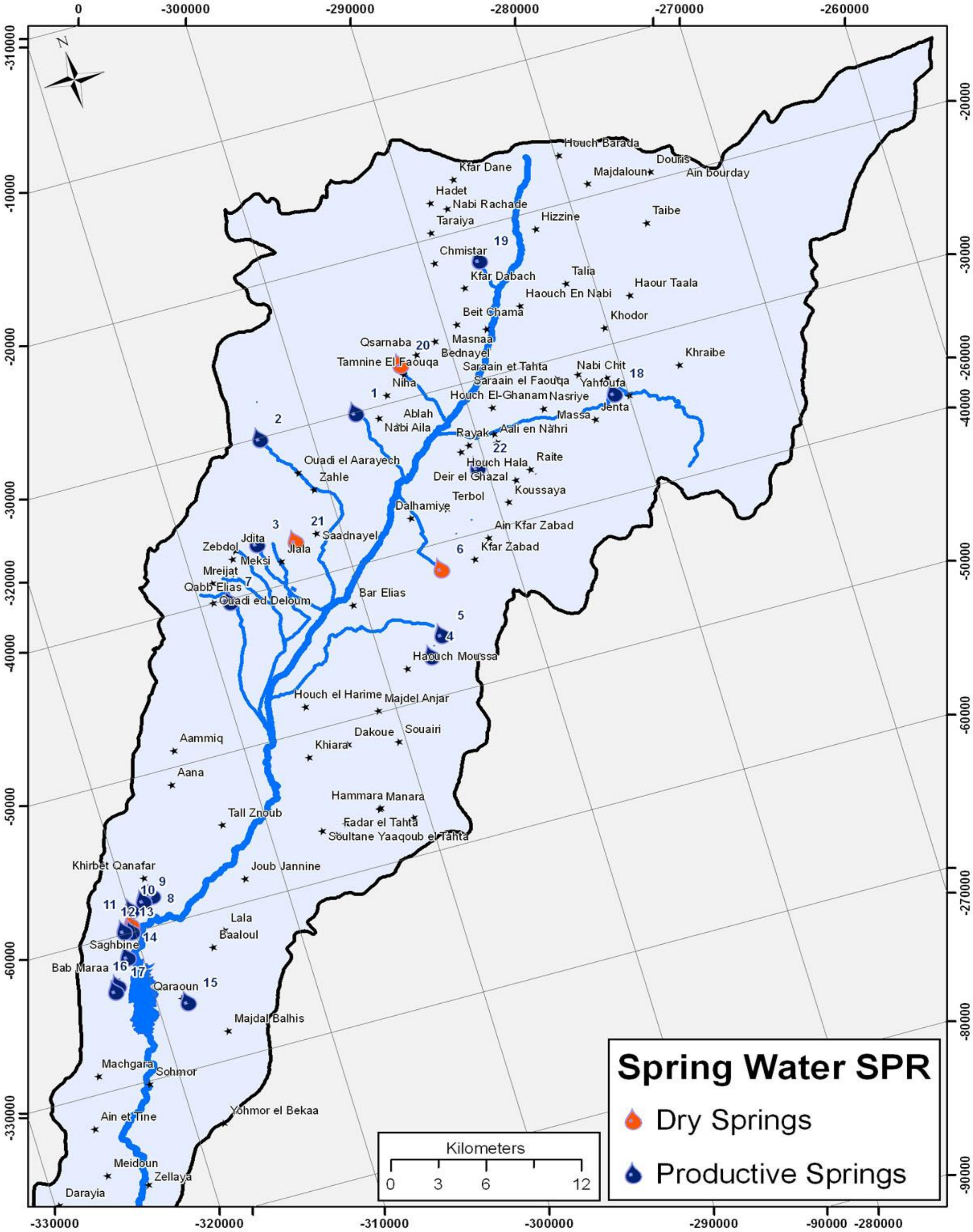


Figure 10. Location of Spring Water Samples along the Litani River and its Tributaries

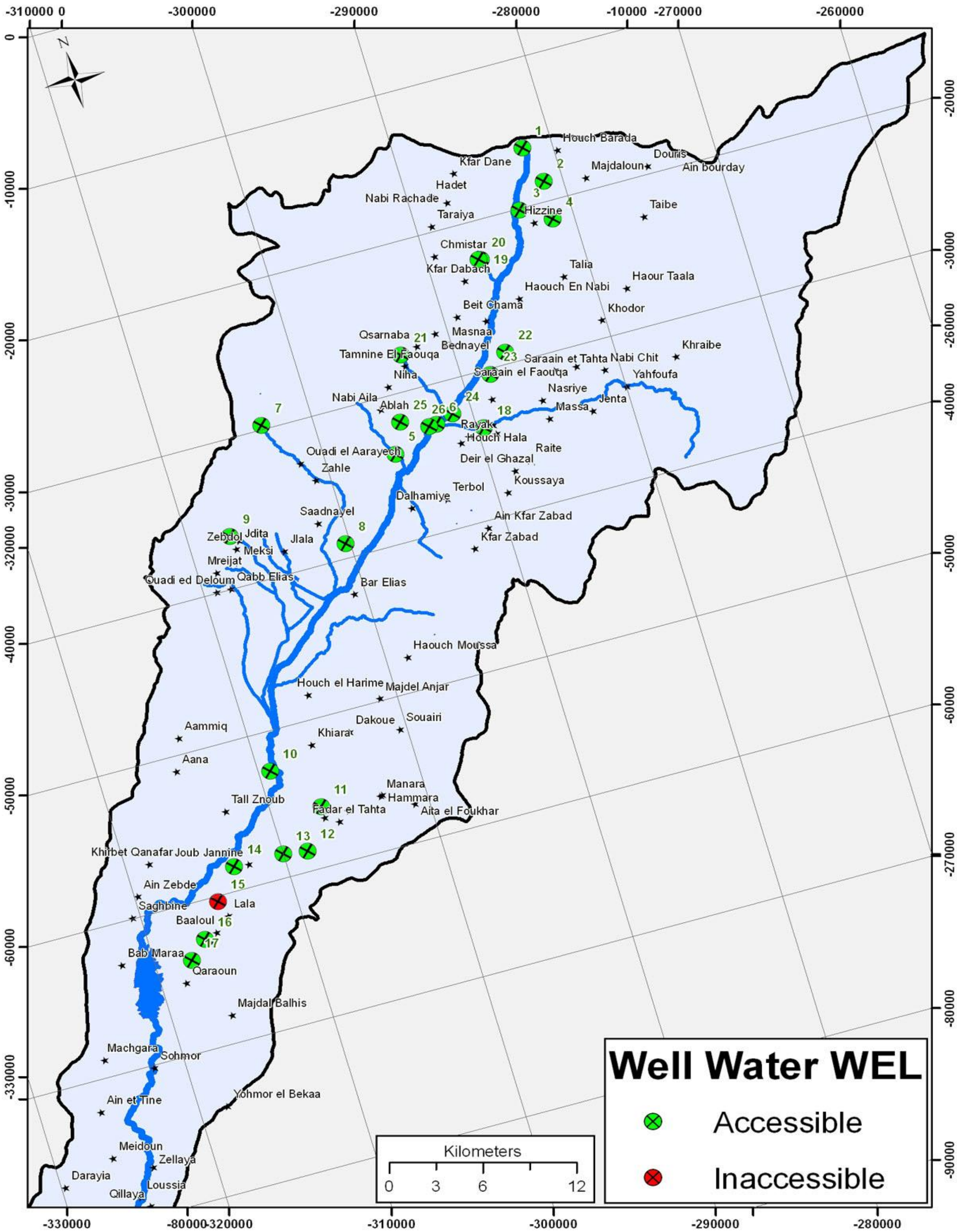


Figure 11. Location of Well Water Samples along the Litani River and its Tributaries

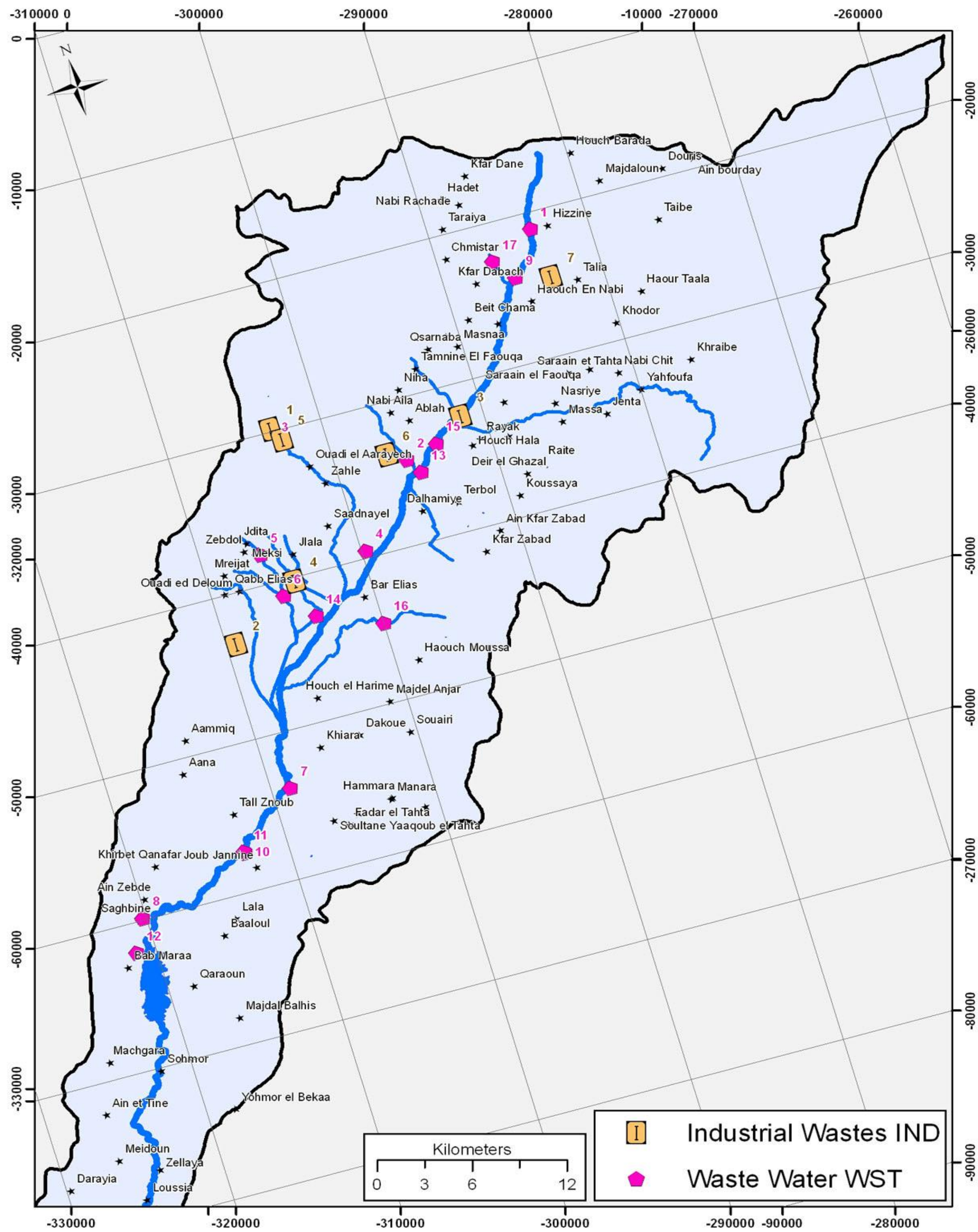


Figure 12. Location of Wastewater and industrial Waste Samples along the Litani River and its Tributaries

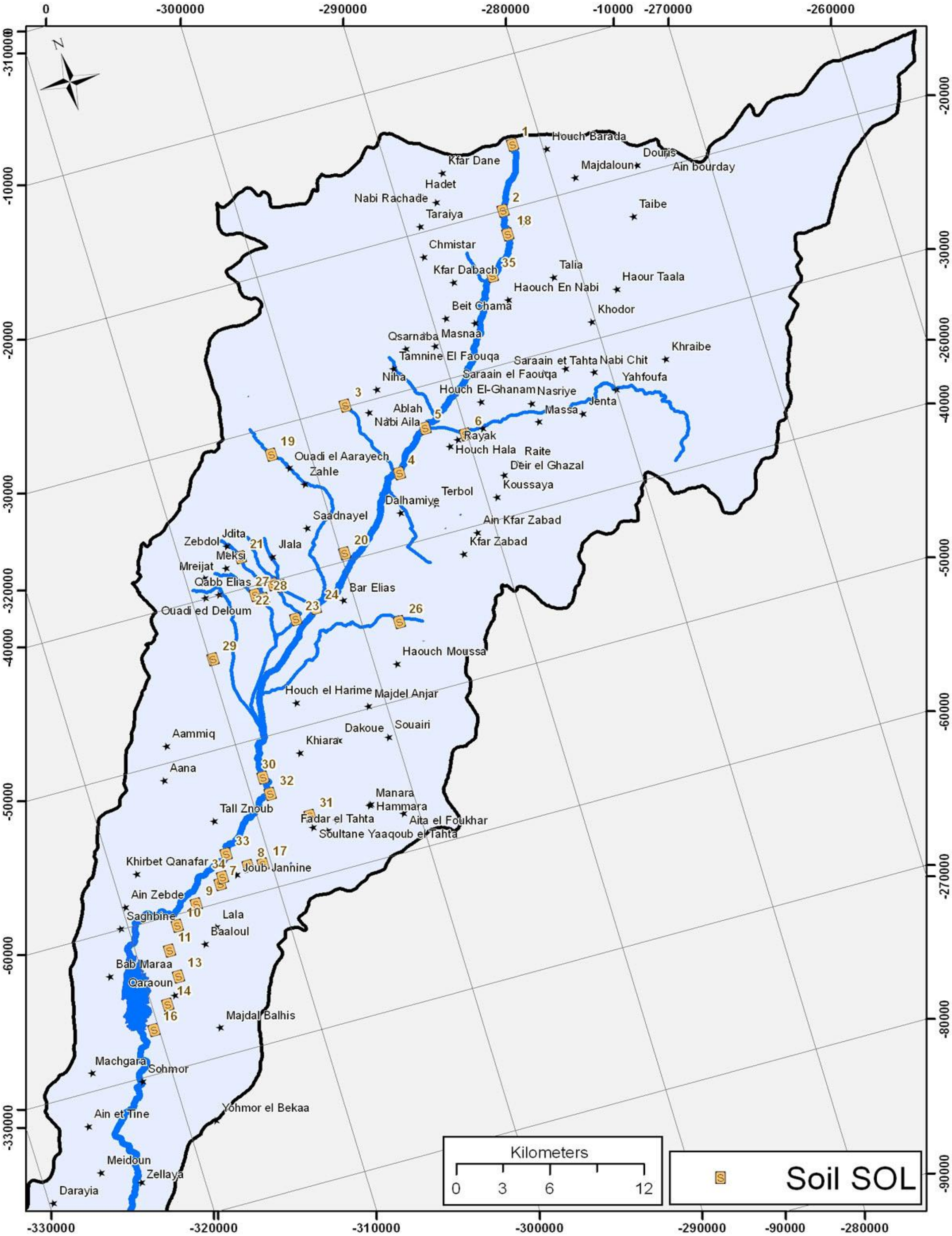


Figure 13. Location of Soil Samples along the Litani River and its Tributaries

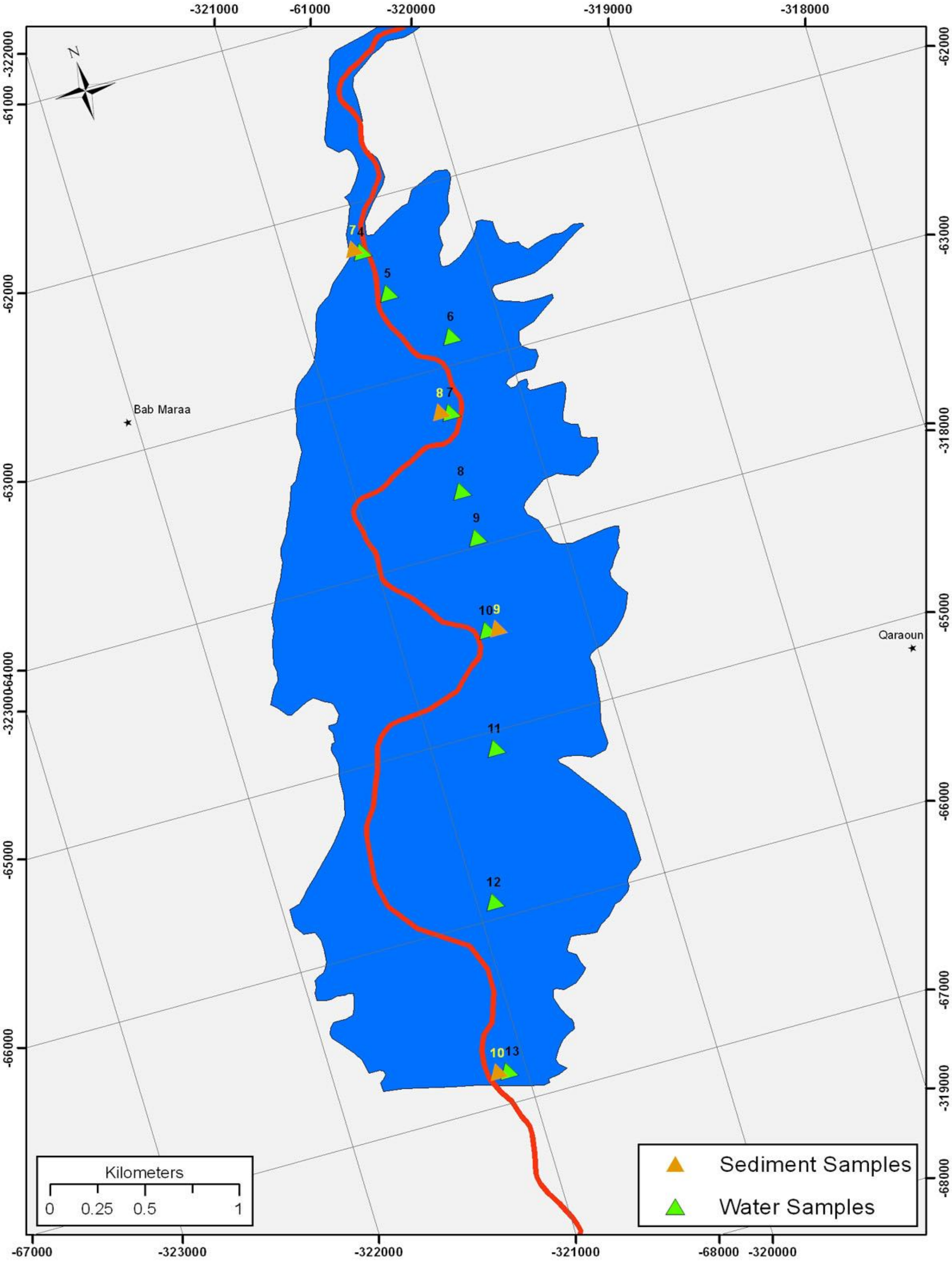


Figure 14. Location of Water and Sediment Samples along the Qaraoun Lake

4.3.3. SAMPLING OF IRRIGATION CANAL 900

A total of 7 samples were collected, based on the sampling framework of the dry season to reflect on the quality of the irrigation canal, as presented in Figures 15- 16. Additionally, soil was sampled from agricultural lands, east and west of water sampling points.

Figure 15. Irrigation Canal 900

4.3.4. SAMPLE COLLECTION PROCEDURAL GUIDELINES AND LOG FORMS

The procedural guidelines developed for the dry season sampling (following recommendations specified by the Standard Methods for the Examination of Water and Wastewater, 21st Edition, 2005), were implemented. Additionally, the developed sample log forms were used for the accurate recording of sample characteristics.

4.3.5. SAMPLING AND ANALYTICAL QUALITY DETERMINATION

The collected samples were analysed at the Water Quality Assessment and Management Research Unit (Associate Research Unit funded by the Lebanese National Council for Scientific Research and in collaboration with the Lebanese American University). All analytical work in this research unit is governed by standard procedures and methods (Standard Methods for the Examination of Water and Wastewater, 21st Edition, 2005). Analytical testing of the temperature, dissolved oxygen, pH, electrical conductivity (EC), and total dissolved solids.

(TDS) were conducted onsite. Water samples for physical and chemical analysis were collected in polyethylene bottles that were presoaked overnight in 10% (v/v) nitric acid and then rinsed with distilled water.

Sampling was done in accordance with standard methods recommended by the American Public Health Association, the American Water Works Association, and the Water Pollution Control Federation (Standard Methods for the Examination of Water and Wastewater, 21st Edition, 2005). On the other hand, water samples for microbiological testing were collected in sterile borosilicate 300 ml bottles. All samples were transported in ice boxes to the laboratory. Upon delivery to the laboratory, water samples were filtered (when needed) and divided into two parts: one for physical and chemical macro-elements testing and the other (acidified with nitric acid to pH <2 and stored at 40C) for trace metals testing. Water samples for pesticide residues testing were collected in amber bottles, transported to the laboratory in cold storage and stored at 40C till extraction. Extracted sample were restored at 40C for a maximum of 40 days prior to analytical testing.

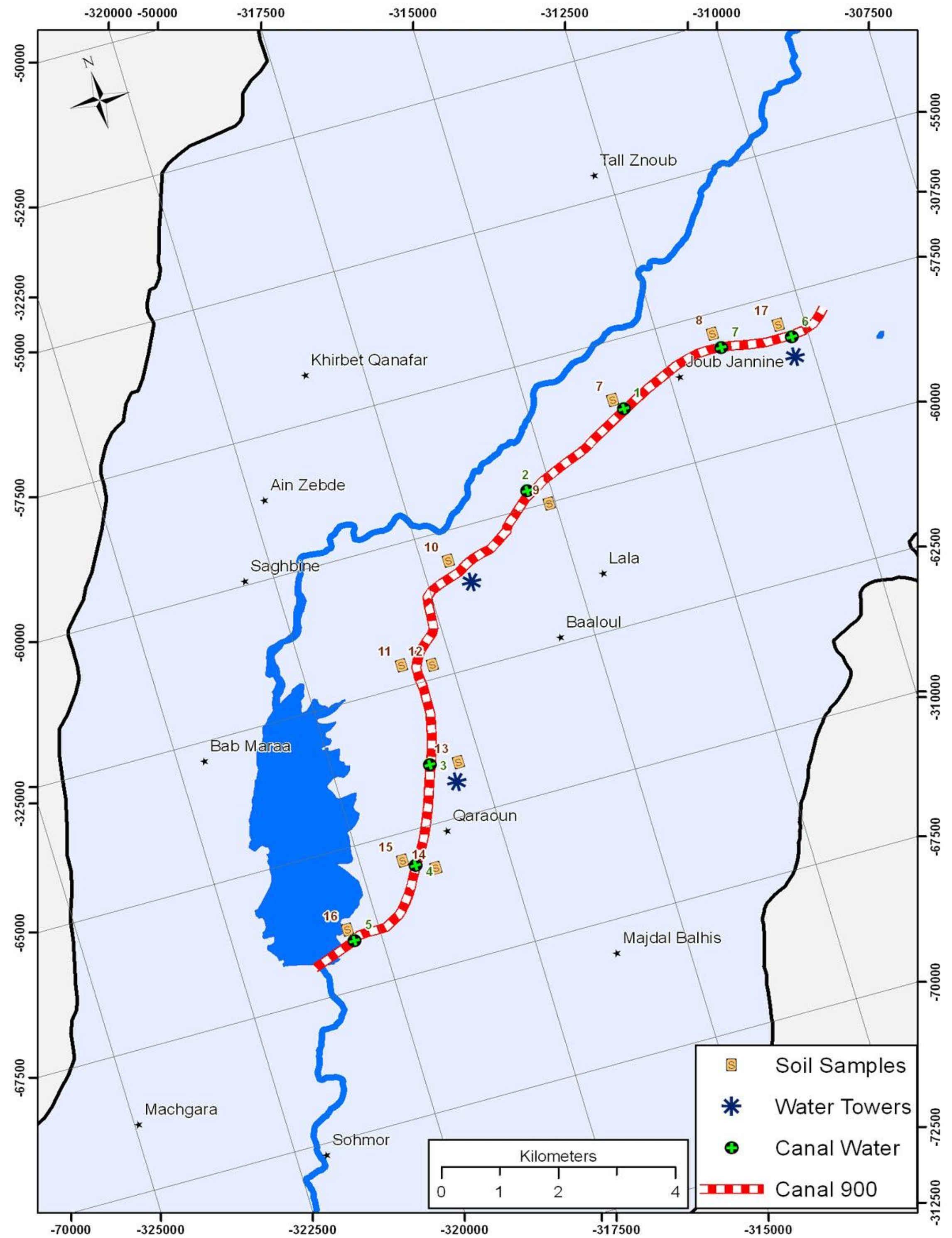


Figure 16. Location of Water and Soil samples along Irrigation Canal 900

The various physical, chemical and microbiological parameters were determined by standard methods and procedures (APHA, AWWA, WPCF, 2005) as presented in table 1. Furthermore certified prepared reagents (EPA Standards) of the HACH Chemical Company (USA) were used, and recommended quality control measures were implemented.

Table 1. Standard Analytical Method for the Determination of the Physical, Chemical and Microbiological Quality Parameters

Type of Sample	Analytical Parameter	Standard Analytical Method	Type of Analytical Equipment
Water	pH	Electrometric Method	SensIon 7 HACH, pH Meter
	Electric Conductivity	Electrical Conductivity Method	SensIon 7 HACH, Conductivity Meter
	Alkalinity	Titration Method using Sulfuric Acid Standard Solution (0.02N)	Burret Titration
	Nitrates	Cadmium Reduction Method	DR 2800 HACH Spectrophotometer
	Phosphates	PhosVer 3 (Ascorbic Acid) Method	DR 2800 HACH Spectrophotometer
	Sulfates	SulfaVer 4 Turbidimetric Method	DR 2800 HACH Spectrophotometer
	Ammonia	Nessler Method	DR 2800 HACH Spectrophotometer
	Sodium & Potassium	Flame Photometry	JENWAY Flame Photometer
	Calcium & Magnesium	EDTA Titration Methods	Buret Titration
	Chlorides	Mercuric Nitrate Titration Method	Buret Titration
	DO & BOD5	Electrode Methods	SensIon 6 HACH, DO Meter
	Organochlorines & Orgnophosphates	Liquid- Liquid Extraction, GC/MS	Liquid- Liquid Extraction GC/MS
	T. Coliform, E. coli & Strep. feacalis	Membrane Filter Technique	Millipore Filtration
Soil	PH, Electric Conductivity (EC)	Extraction and electrode Method	XRF-NITON XL3t Thermo Scientific
	Nitrates	X Ray Fluorescence	XRF-NITON XL3t Thermo Scientific
	Phosphates	X Ray Fluorescence	XRF-NITON XL3t Thermo Scientific
	Sulfates	X Ray Fluorescence	XRF-NITON XL3t Thermo Scientific
	Ammonia	X Ray Fluorescence	XRF-NITON XL3t Thermo Scientific
	Chlorides	X Ray Fluorescence	XRF-NITON XL3t Thermo Scientific
	Soluble Sodium & Potassium	X Ray Fluorescence	XRF-NITON XL3t Thermo Scientific
	Soluble Calcium & Magnesium	X Ray Fluorescence	XRF-NITON XL3t Thermo Scientific
	Trace Metals: Mg Pb. Cd, Cr, Zn, Fe, Al, As, Ba, Co, Bo, Mn &Mo	X Ray Fluorescence	XRF-NITON XL3t Thermo Scientific

5. RESULTS AND DISCUSSION

5.1.RESULTS OF THE FIELD STUDY OF THE ULB

5.1.1. THE YELLOW ZONE (UPPER ZONE OF THE ULB)

This zone of the Upper Litani Basin (between Saidi and Rayyak), as presented before (refer to the Dry Season 2010 Report), is mainly characterized by mixed residential, agricultural and industrial activities. The major source of the Litani are dry (Al Oleik Spring) and the water flow in winter is mostly the discharge from Al Yamouneh (channelled to the river basin at Saidi), Rain Water, and the tributaries of Housh Bay; Temnine (minimal water flow to sustain tributary); Habbis/Ferzsol; and Yahfoufa/ Hala (minimal water flow to sustain tributary). The river flow, even in winter, is relatively of minimal to moderate flow, turbid greenish to black in color with moderate bamboo growth.

Figure 17. Sewage Discharge in Ablah

Figure 18. Litani River in Fersol

Additionally, the river is exposed to wastewater discharge (sewage and industrial wastewater effluents, and leachates from dump sites scattered along the river basin and carried over along the water flow.

Figure 19. Litani River in Taraya

Figure 20. Dead Animals Discharge in River Flow in Temnine Al Tahta

5.1.2. THE ORANGE ZONE (MIDDLE ZONE OF ULB)

This middle region of the Upper Litani Basin, as indicated before (refer to the Dry Season 2010 Report), is mainly characterized by mixed residential, agricultural, industrial (active sector) and recreational (active sector) activities.

The river flow is minimal, to moderate, to high and is heavily exposed to sewage and industrial wastewater discharge. Moreover, the water is relatively turbid with algae growth on river bed, and the presence of tadpoles, water snakes, fish and turtles is indicated (Figures 21-24). Additionally, the water flow is sustained in winter by the tributaries of:

Al Berdawni Tributary (tributary becomes dry in summer before the joining point with the Chtoura Tributary in the Marj Area, as the water is “completely” tapped for irrigation),

Chtoura Tributary (the Jdeita spring, one of the two spring outflows that form this tributary becomes is dry in summer),

Al Ghzayel Tributary (becomes stagnating sewage in summer),

Al Faour Tributary (dry in winter and summer and no longer contributing to water flow), and

Jalala Storm Water Runoff (dry even in winter when it is not raining).

Figure 21. BeRdawni Tributary Originating from Qaa El Reem Springs

Figure 22. Solid waste Dumping in Delhameyieh

Figure 23. Ghzayel Tributary Originating from Anjar & Chamsine Water Springs

Figure 24. Solid Waste Dumping in Housh Al Harrimi

5.1.3. THE GREEN ZONE (LOWER ZONE OF THE URB)

This lower region of the Upper Litani Basin, as indicated before (refer to the Dry Season 2010 Report), is mainly characterized by mixed residential, agricultural, and to a lesser extent industrial, recreational (Qaraoun Lake area) activities, and aquaculture farming of trout fish.

The river flow is moderate to high. The water is clear to blue green due to algae growth on river bed, and the presence of fish, frogs, water snakes, turtles, and ducks is evident (figures 25-28). Water springs and the tributaries of Habasiyeh, Hafir and Jair contribute to the water flow, only, in winter (become dry with stagnating wastewater in summer). Moreover, the major dependence is on the abundant number of water springs (Dry season Reports, 2010) that are almost dry in summer, or completely tapped for irrigation, is problematic and challenges sustainability of water flow.

Figure 25. River Flow in Soghbine

Figure 26. Ras Al Ain Spring in Kobb Elias

Figure 27. Litani River In Jeb Jenine **Figure 28. Spring Water in Aitaneit**

The detailed description of the profiles of cities/villages of the Upper Litani basin is presented in the Dry Season 2010 Report). Moreover, the updated inventory of the Upper Litani Basin confirmed the exposure to pollution resulting from:

The deficient management of municipal solid waste and domestic wastewater (sewage),

The lack of compliance in implementing onsite measures to insure the proper management of the various sources and types of industrial wastes (solid and liquid),

The excessive dependence on groundwater and raw untreated sewage as a source of irrigation water, mostly for the dry season,

The excessive application of pesticides, fertilizers and animal manure,

The flourishing "query business" and the prevalence of stone cutting open sites, and

The dumping of solid waste and the discharge of sewage by recreational sites along the river bank and its tributaries.

Additionally, it to be noted that the problem of solid wastes scattering (dump sites) along the ULB becomes more evident during the wet season. Moreover dead animals are discharged along the river flow. Accordingly, the major problematic sites associated with all such practices are presented in table 2:

Table 2. Major Solid Waste Dump Sites Scattered along the ULB

City / Village	GPS Code	Elevation	North	East
Saidi	20	1021	34°01.787	36°04.563
Housh Barada	25	997	33°58.831	36°04.831
Hezzine	28	983	33°57.966	36°04.775
	29	987	33°58.249	36°04.810
Temnine Al Tahta	136	926	33°35.760	35°48.575
Ferzol	36	906	33°50.418	35°57.817
Rayyak	41	946	33°51.230	36°00.902
Dier Zanoun	84	879	33°45.307	35°54.711
Housh Al Harimi	85	875	33°43.710	35°49.819
Dalhamieyeh	139	865	33°49.335	35°56.694
Al Marj	78	880	33°46.649	35°46.642
Kobb Elias	88	912	33°47.446	35°49.544
Tal Al Akhdar	93	871	33°44.843	35°48.987
Ammiq	90	884	33°47.114	35°51.031
	91	890	33°45.760	35°48.575
Mansoura	95	868	33°40.786	35°49.098

5.2. LITANI RIVER WATER QUALITY ASSESSMENT

Among the 50 sampling sites (along the Litani river and its tributaries), identified by the reconnaissance survey, 6 sites (12%) were found dry even in the wet season, and one site was inaccessible (Figure 6). Additionally, as indicated before the water flow was mostly minimal to moderate. Moreover, sewage and industrial wastewater outlets and solid waste dump sites are scattered throughout the river basin. However, some discharge points of industries are diffused which makes it difficult to locate them along the river and its tributaries.

Reflecting on the levels of dissolved oxygen (a major factor that determines ecological viability and self purification capacity of a water body) the contamination profile becomes evident. The mean levels of oxygen in water samples even in winter (higher levels of saturation due to prevailing lower temperatures) is 4.83 (ranging between 0.90 and 9.10 with a standard deviation of 2.08) comparable to the 4.65 mg/l level (ranging 0.38 and 9.4 with a standard deviation of 2.7) of the dry season, as presented in appendix 8.2.1: table 8.2.1.b.

Additionally, Levels of oxygen dropped to less than 5 mg/l (needed to support aquatic life) in about 44% of sampled sites comparable to conditions of the dry season (46% of the sampled with oxygen levels <5 mg/l), despite the extensive growth of algae on the river bed. In comparison, the dissolved oxygen reported by the BAMAS 2005 Study was higher for both the wet (7.94mg/l; 1.64 folds) and the dry (5.93

mg/l; 1.28 folds) seasons. These findings reflect on the continuous progressive exposure to sources of pollution throughout the year, and with time, despite river replenishment of river basin by rain. Moreover, the drop in oxygen levels along the river and its tributaries is concurrent with a mean BOD level of 19.20 mg/l (ranging between 2 and 70 mg/l and with a standard deviation of 16.57). This load is considered minimal in comparison to the levels of the dry season (mean level is 548 mg/l ranging between 2.5 and 2530 mg/l with a standard deviation of 768 mg/l) as presented in appendix 8.2.1: table 8.2.1.b. It is to be noted that the levels of BOD in winter are much less (due to dilution). And, the decomposition of organic matter takes a longer period of time at lower temperatures (mean temperature of the wet season is 17.36^{0}C in comparison to the 26.30^{0}C of the dry season). Yet, the BOD load is 3 folds that reported by BAMAS 2005 Study for the wet season and 11 folds the load reported for the dry season. Overall, the increase in BOD is 10.30 folds between 2005 and 2010-11.

Although there is no set guideline level for BOD, (Lebanese Standards, Environmental protection Agency [EPA] Standards, and the World Health Organization [WHO] Guidelines) still, surface waters with minimal exposure to organic contaminants are expected to have low BODs of less than 30mg/l. Evaluating BOD levels based on this recommended level, about 14 % of the sampled sites (wet season) in comparison 62% of sampled sites (dry season) have higher biochemical oxygen demands. Still, increased BOD levels even in the wet season are, as indicated before, is a direct reflection of continuous exposure to organic sources of pollution such as domestic wastewater (sewage) discharge, leachate of municipal solid waste dump sites (increased dump sites during winter with solid waste carry over all along the water flow as presented in table 2), food processing plants wastewater effluents, other types of industrial wastewater effluents (e.g. paper mills) and agricultural runoff.

As such, comparing the wet and dry seasons mostly all previously identified hot spots (Hezzine, Ferzol, Ablah, Jdeita, Al Marj, Taanayel, Ammiq, Dier Zanoun, and Jeb Janine) are still problematic in addition to the sites of Saidi, Housh Barda, Temnine Al Tahta, Rayyak, Jdeita, Hosh Al Harimi, Dalhameiyeh, Kobb Elias, and Mansoura. These sites are mostly exposed to dumping of solid wastes as presented in figure 31 and table 3. And, this further confirms the exposure to the indicated sources of pollution; whether sewage, industrial wastewater discharge, or leachates of solid waste dump sites and agriculture run off.

Per se, the ecological viability and the self purification capacity of this vital resource are continuously and challenged by increased contamination loads associated, mostly, with the direct disposal of wastewater and dumping of solid waste along the river and its tributaries.

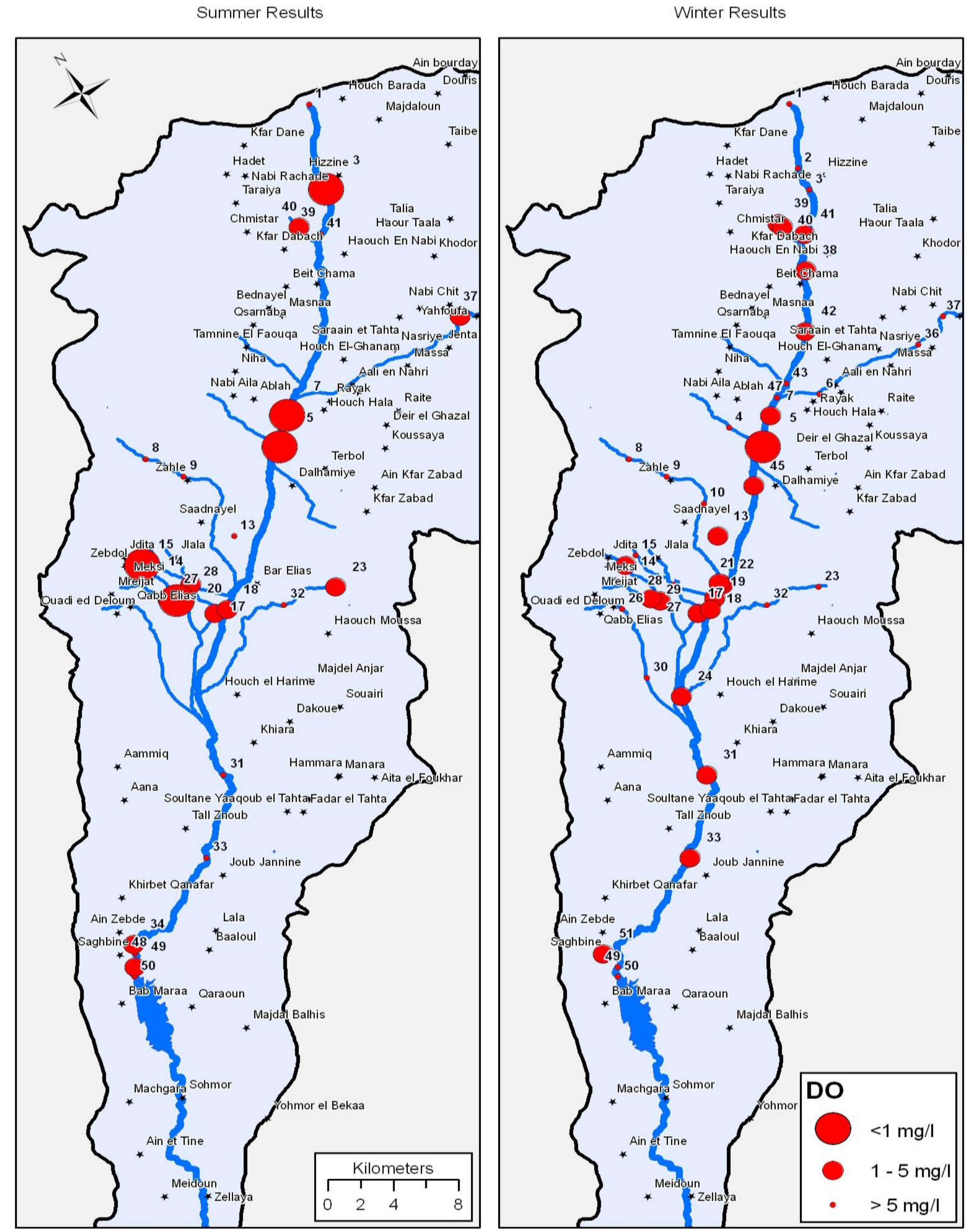


Figure 29. Dissolved Oxygen (DO) Levels along the Litani River & Its Tributaries for both Wet & Dry Seasons

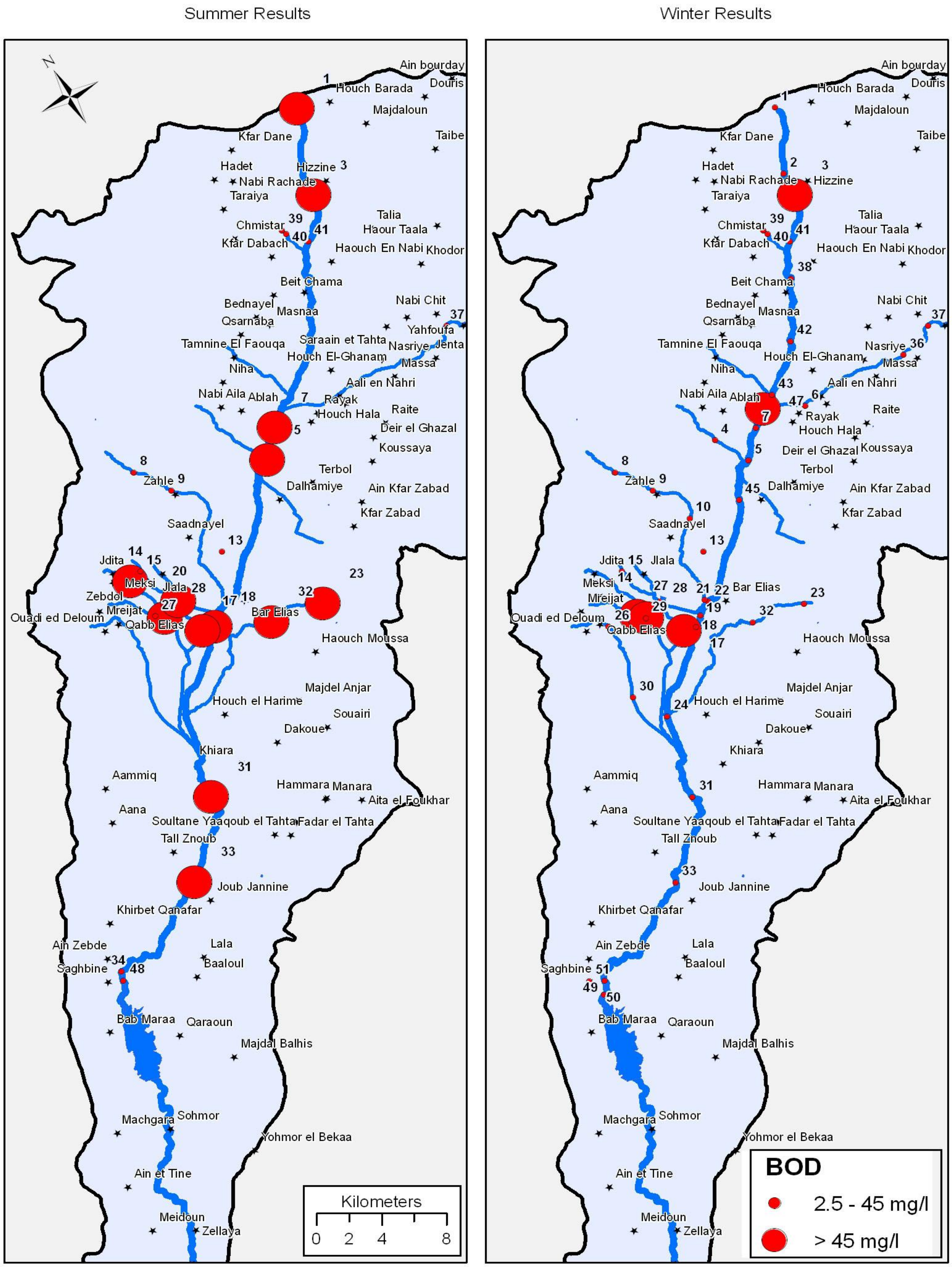


Figure 30. Biochemical Oxygen Demand (BOD) Levels along the Litani and its Tributaries

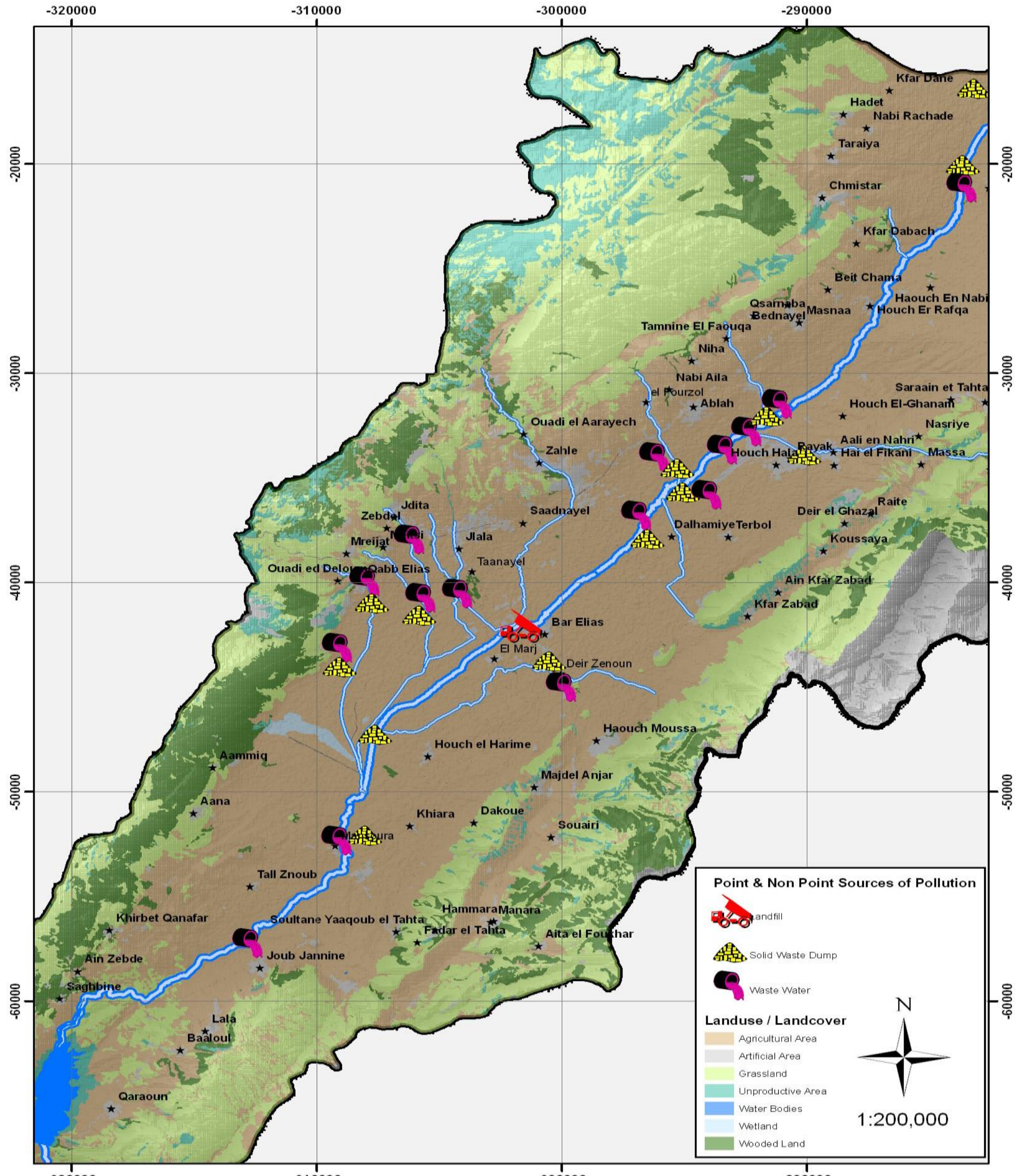


Figure 31. Major Point and Nonpoint Sources of Pollution along the Upper Litani Basin (Wet and Dry Seasons)

Table 3. Percentage of Surface water Sampling Sites Exceeding Recommended National and International standard Levels for Drinking Water

City / Village	Point Sources of Pollution	Non-Point Sources of Pollution
Saidi	Leachates of Solid Waste Dumping by the River Canal near Bedouin Settlement.	Agricultural Runoff
Housh Barada	Leachates of Solid Waste Dumping and Carryover of Solid Waste along Water Flow.	Agricultural Runoff
Hezzine	Domestic Wastewater (Sewage) Discharge Leachates of Solid Waste Dump Sites.	Agricultural Runoff
Temnine Al Tahta	Industrial Wastewater Discharge. Leachates of Solid Waste Dump by the River.	
Ferzol	Industrial Wastewater (e.g. Master potato Chips) discharge. Discharge of Secondary Treated Wastewater Effluent. Leachates of Solid Waste Dumps by the River. Leachates of Solid Waste Dumping (Fruits and Vegetables Market Place).	Agricultural Runoff
Rayyak	Sewage infiltration from and Cesspools. Leachates of Solid Waste Dumps.	Agricultural Runoff
Ablah	Industrial Wastewater Discharge (Poultry Processing Plant {e.g. Tanmeiyah}). Discharge of Secondary Treated Wastewater. Effluent (Wastewater Treatment Plant under construction). Leachates of Solid Waste Dumps by the River.	Agricultural Runoff
Jdeita	Industrial Wastewater Effluents (Dairy Plants {e.g. Jarjoura} , Serum Industry and Paper Mills) Discharge	Agricultural Runoff
Taanayel	Industrial Wastewater Effluent Discharge (e.g. Taanayel Dairy Plant).	Agricultural Runoff
Dier Zanoun	Domestic Wastewater (Anjar & Majd Al Anjar) Discharge. Leachates of Solid Waste Dumps by the River.	Agricultural Runoff
Housh Al Harimi	Leachates of Solid Wastes Dumps by the River	
Delhameyieh	Wastewater Discharge from Zahle. Cesspools Sewage Infiltration. Leachates of Solid Waste Dumps by the River. Animal Wastes.	Agricultural Runoff
Al Marj	Leachate of Solid Waste "landfill".	Agricultural Runoff
Kobb Elias	Domestic Wastewater Discharge. Leachates of Solid Wastes Dumps by the River.	Agricultural Runoff
Ammiq	Industrial Wastewater (e.g. SICOMO Industry) Discharge. Wastewater Discharge (Main Sewer from Kobb Elias & Maksi. Leachates of Solid Wastes Dumps by the River.	Agricultural Runoff
Mansoura	Wastewater Discharge. Leachates of Solid Wastes Dumps by the River.	Agricultural Runoff
Jeb Janine	Domestic Wastewater Discharge (Jeb Janine & Kamed Al Louze) as the Wastewater Treatment Plant is still under Construction.	Agricultural Runoff

Moreover, when evaluating the physical, chemical and microbiological water quality profile of the River and its tributaries (URB) for multipurpose usage, the following can be concluded:

5.2.1. DOMESTIC WATER USE

Evaluating the quality of surface water for domestic water use, reflects on an overall mean mineral content of 255 (ranging between 118 and 533 with a standard deviation of 97.39) in comparison to the level of 503 mg/l (ranging between 187 and 1979 mg/l with a maximum level of 1979 mg/l) as presented in table 4 and appendix 8.2.1: table 8.2.1.a. This mean level of TDS is acceptable when compared to the Lebanese Standards, EPA Standards and WHO Guidelines, and is about 50% of the level reported for the dry season. Additionally, only 5% of sampling sites (wet season) in comparison to about 23% of the sampled sites (dry season) exceeded the recommended Lebanese and EPA standard levels as presented in Tables 4 and 5. This is expected for the wet season due to the recharge of the river basin by rain.

High TDS levels reflecting on the presence of inorganic salts such as calcium, magnesium, potassium, sodium, bicarbonates, chlorides and sulfates in addition to small amounts of organic matter, may be objectionable to consumers (WHO, 2008). TDS levels in water usually originate from natural sources such as rocks, bedrocks, soil, plankton, and silt, seawater intrusion, sewage, urban runoff and industrial wastewater (UNESCO/WHO/UNEP, 1996; WHO, 2008). At TDS levels lower than 600 mg/l, the taste of water is acceptable; however, it may become significantly unpalatable for consumers at levels exceeding 1000 mg/l (WHO, 2008). On the other hand, TDS levels greater than 1200 mg/l are associated with excessive scaling in water pipes, heaters, boilers and household appliances (WHO, 2006), Still, No direct health hazards are associated with the ingestion of water containing high levels of TDS (WHO, 2008). However, their presence may be associated with irritation of the gastrointestinal tract (WHO, 2006).

Table 4. The Percentage of Surface Water Sampling Sites Exceeding Recommended National and International Standard Levels for Drinking Water

Water Quality Parameter	BAMAS Study 2005		Current Study 2010-11	
	Dry Season %	Wet Season %	Dry Season %	Wet Season %
Total Dissolved Solids	17	None	23	5
Nitrates	8	17	None	None
Phosphate	68	28	69	54
Sulfates	None	None	None	None
Manganese	*NA	*NA	42	48
Cadmium	*NA	*NA	45	None
Fecal Coliform Count	100	98	50	65%

*Not Availble

Comparing to the mean TDS (255 mg/l for the wet season) to results reported by the BAMAS 2005 study (mean TDS level of 202 mg/l) shows an increase in the overall mineral content from 202 mg/l to 250 mg/l (1.26 folds increase in comparison to 1.72 folds increase for the dry season). This is mostly reflective of increased exposure to contamination loads, despite efforts to increase sewerage coverage, yet sewer outflows continue to discharge along the River and its tributaries, mostly due lack in wastewater treatment.

As for the pH of the water samples for the wet season is 7.66 (maximum level: 8.66 and a minimum level 7.27, with a standard deviation of 0.37) in comparison to the mean value is 7.93 (maximum level: 8.54; minimum level 7.28 with a standard deviation of 0.56) for the dry season, as presented in appendix 8.2: table 8.2.1.b. And, all pH values of sampled sites were within the acceptable range of 6.5-8.5 except for on site in Saidi (pH level of 8.54). This drop is mainly due to replenishment by rain water. Elevated pH levels have no direct health impact, but it is considered an important water quality parameter that should be accounted for when treating the water source, especially when disinfecting by chlorination. The water pH should be less than 8 for optimal disinfection (UNESCO/WHO/UNEP, 1996; WHO, 2008). Still, the increase of the pH towards alkalinity is a major reflection of exposure to sources of pollution such as sewage discharge, leachate of solid waste dumps and food processing plants' effluents. Comparing to the pH levels reported by BAMAS 2005 study for the wet season, the increase in the pH mean level from 7.09 to 7.66, is a clear indication of progressive exposure to such sources of pollution.

Moreover, the mean relatively low levels of ammonia (3.46 mg/l as NH_4) of the wet season in comparison to the higher level of 15.26 mg/l as NH4 for the dry season (Table 4 & Appendix 8.2.1; table 8.2.1.b) is still reflective of sewage pollution and condition conditions of relatively lower oxygen levels, as discussed before. No Health specific standard/guideline level is recommended by EPA or

WHO. In comparison the BAMAS 2005 Study, results reflect on an overall increase in the mean level from 1.625 mg/l as NH4 for the wet season to 9.86 mg/l as NH4 for the dry season reflecting on an increase in ammonia levels by 5.76 folds (Table 5). And, an overall decrease in the nitrate levels by 97% due to the prevailing reducing conditions as presented before.

The mean levels of nitrate is 1.41 mg/l as nitrate N (maximum level: 9.60 mg/l; minimum level 0.20mg/l with a standard deviation of 1.2 mg/l), in comparison to the comparable levels of the dry season, as presented in table 5. This reflects on relative reducing conditions, even in winter, as justified by the lower available oxygen levels. Yet, all samples have acceptable nitrate levels of less than 10mg/l as nitrate N (Lebanese Standards, EPA Standards and WHO Guidelines). In comparison, the BAMAS 2005 study results reflect on higher nitrate levels with 8% of the samples for the wet season exceeding the standard level (Tables 4 and 5). High nitrate concentrations are mostly associated with the occurrence of methemoglobinemia (Cyanosis or blue – baby syndrome) in infants and young children. Methemoglobinemia develops when immature infant gut converts nitrates to nitrites which react with haemoglobin to form methemoglobin, so blocking oxygen transport (Afzal, 2006; Rizk, 2009; WHO, 2008).

As for the presence of phosphates in sampled sites, the mean level was 2.92 mg/l as P_2O_5 (maximum level; 44.95 mg/l as P_2O_5 as; minimum level 0.05 mg/l as P2O5) with a standard deviation of 26.58 mg/l as PO4 (Tables 4 and 5). This is also reflective of exposure to sewage point sources of pollution. Comparing to the recommended national standard level, about 69% of sampled sites exceed the acceptable limits. This finding is comparable to the 68% non-conformity reported by the BAMAS 2005 study and the overall mean level is only 1.07 folds (Current study: 5.91 mg/l as P2O5; BAMAS 2005 Study: 5.53 mg/l as P2O5) that reported by BAMAS 2005 Study.

Orthophosphates, originate from the weathering of phosphorus–bearing rocks and the decomposition of organic matter (UNESCO/WHO/UNEP, 1996). In addition, the presence of high concentrations of phosphates reflects on sources of contaminants such as domestic wastewater (detergents), industrial effluents, and fertilizers and existing conditions reflect on continued exposure to these sources of pollution (UNESCO/WHO/UNEP, 1996).

As for the levels of sulfates in water, mostly these levels are not as high when associated with sewage discharge. The mean level is 22.26 mg/l with a standard deviation of 11.56 mg/l as SO4 (maximum level: 42 mg/l as SO4; minimum level 0.00 mg/l as SO4), as presented in table 5 and appendix 8.2.1; table 8.2.1.b. This may be attributed, similar to nitrates, to reduced levels of the oxygen in surface water. Concurrently, under minimal levels of oxygen, high levels of H_2S prevail, and are associated with a foul smell of some parts of the River and its tributaries. Still, the mean levels were all below the acceptable limit of 250 mg/l. Sulfate is naturally present in water originating from sedimentary rocks (pyrite or gypsum) and is also contributed anthropogenically from industrial effluents, cesspools infiltrates' and agricultural activities (WHO 2006).

Comparing to the BAMAS 2005 study results, for the dry and wet seasons (mean overall value of 20.45 mg/l), the overall increase in sulfates is only 1.09 folds. This confirms the reduction in oxygen levels and the prevailing reduced chemical forms. Still, all levels of both studies were below the recommended Lebanese standard of 250 mg/l as presented in tables 4 and 5.

Table 5. Comparison of the Surface Water Quality Profile Reported by the BAMAS 2005 Study and the Current 2010-11 Study

Indicator	Survey Season	BAMAS 2005 Calculated from surface water results			Current 2010-11 Study			Drinking Water Standards: LIBNOR	Drinking Water Standards: US EPA	Reclaimed WW for irrigation
		Min.	Mean	Max.	Min.	Mean	Max.	GV[1] (25 °C)	GV/MAL[2]	MoE guideline
Temperature (°C)	*W*	4.1	12.39	17.7	10.00	17.36	25.00	NA[6]	NA	
	D	12	20.07	25	15.50	23.73	32.10			
TDS (mg/l)	*W*	114	202.2	415	118.00	254.96	533	500[7]	500[7]	
	D	88	291	706	187.00	502.08	1979			
pH (pH units)	*W*	6.8	7.09	8.18	4.53	7.66	8.54	6.5-8.5	6.5-8.5	
	D	6.57	7.59	7.68	7.27	7.93	8.66			
DO(mg/l O_2)	*W*	3.95	7.94	9.73	0.90	4.83	9.10	NA	NA	
	D	0	5.93	8	0.38	4.65	9.40			
BOD (mg/l)	*W*	0	6.57	45	2.00	19.28	70.00	NA	NA	10-45
	D	2	48.46	624	2.50	547.65	2530			
NH_4 [8] (mg/l)	*W*	<0.01	1.12	11.01	0.09	3.46	31.23	NA	NA	
	D	0	12.31	120	0.10	15.26	88.22			
NO_3^- (mg/l)	*W*	<1	13.57	49.7	0.20	1.41	9.60	10 (as N)	10 (as N)	
	D	3	13.46	62	0.10	1.23	4.90			
SO_4^{2-} (mg/l)	*W*	<7	19.65	115	0.00	22.26	42.00	250	250	
	D	4	21.26	225	0.00	22.58	90.00			
P_2O_5[9] (mg/l)	*W*	0.01	0.31	2.01	0.05	2.92	44.95	NA	NA	
	D	0	10.75	197	0.00	8.58	72.44			
FC (CFU[10]/100,ml)	*W*	0	20122	$12x10^4$	0	190.04	400	0	0	5-2,000
	D	0	2,234, 877	$15x10^5$	1	71.61	400			

[1]GV: Guideline value

[2]MAL: Maximum admissible level ; USEPA: US Environmental

[6]NA: Not Available

[7]reference temperature at 25oC

Protection Agency

[3]All values reported < a certain value are set equal to that value when calculating the average

[4]W: Winter sampling round, based on 94 river samples including springs and sources

[5]S: Summer sampling round, based on 76 river samples including springs and sources

[87]Initial value reported is NH_3 , for comparison a conversion factor of 1.0588 was used ($NH_4 = NH_3*1.0588$)

[8]Initial value reported is o-PO43-, for comparison a conversion factor of 0.743 was used (P2O5 = o-PO43-*0.743)

[10]CFU: colony forming unit

As for the chloride levels of sampled water sites, these ranged between 10 and 250 mg/l with a mean level of 64.88 mg/l and a standard deviation of 47.83 mg/l, as presented in table 4 and appendix 8.2; table 8.2.1.b. And, all sampled sites did not exceed the recommended national standards, EPA standards and WHO guidelines. This element was not determined in the BAMAS study, as such there is no basis for comparison.

As for the presence of trace metals in the sampled sites, comparing the levels (Appendix 8.2; table 8.2.1.d) to the set National and International Standards, the main problems during the wet season related to:

Increase in the levels of copper (3 folds levels of the dry season) and Molybdenum (1.2 folds level of the dry season). Yet levels are still much less than the set limits, for both the dry and wet seasons,

Decrease in the levels aluminium to 45% of the dry season level (0.04316 mg/l); nickel to 65% of the dry season level (0.00118 mg/l); zinc to 59% of the dry season level (0.0131 mg/l); and Iron to 50% of the dry season level (0.00016 mg/l); still these levels are much less than the set limits for both the dry and wet seasons,

Cadmium; decrease of cadmium levels to less than 10% of levels reported for the dry season (higher levels exceeding in 45% of the sampled sites the recommended standard levels were detected for the dry season),

Manganese; levels still exceed the National and EPA standard levels of 0.05 mg/l in 49% of the sampled sites for the wet season, and in 48% of the sampled sites for the dry season, and

Barium; lower detected levels of 0.102 mg/l (37% of level that detected for the dry season) in comparison to the national standard level of 0.500 mg/l.

The major sources of cadmium are waste streams, leaching landfills, industrial wastes (batteries, plastics, paints, electroplating), fertilizers and pesticides. And, it is associated in man with bone and cardiovascular diseases, liver and nerve damage and cancer (Perfect Life Institute, 2002). Manganese on the other hand, is present in steel and alloys, fertilizers ($MnSO_4$), ceramics, fungicides (MnO_2), dry-cell batteries, fireworks and disinfectants ($KMnO_4$). Exposure to high concentrations over the course of years is associated with toxicity to the nervous system, producing a syndrome that resembles Parkinsonism. This type of effect is more likely to occur in the elderly (Perfect Life Institute, 2002).

As for Barium, the main sources are cement, ceramics, glazes, glass, paper making, pharmaceutical and cosmetic products. The health effects of barium depend upon the water-solubility of the compounds. Barium compounds that dissolve in water can be harmful to human health. The uptake of very large amounts of barium that are water-soluble may cause paralyses and in some cases even death. On the other hand, small amounts of water-soluble barium may cause breathing difficulties, increased blood pressure, heart rhythm changes, stomach irritation and muscle weakness, changes in nerve reflexes, swelling of brain, and liver, kidney and heart damage (Perfect Life Institute, 2002).

Additionally, molybdenum is mostly associated with steel and alloys, fertilizers and ceramics. It is highly toxic leading to liver dysfunction, joints pain, articular deformities, erytheria, and edema of the joints. As for copper, it's mainly from metal plating, fertilizers, animal feed, pesticides and fungicides and is associated with gastrointestinal diseases, anemia, liver and kidney damage.

Moreover, the microbiological water quality profile is of major concern due to health risks posed by fecal contamination. Contamination by fecal bacteria can cause infection for those who use this water for drinking, preparation of food and personal hygiene (UNESCO/WHO/UNEP, 1996). E. coli, particularly, can cause diseases such as urinary tract infection, bacteraemia, meningitis and diarrhoea that can be mild and non bloody, highly bloody and even fatal, especially in infants and young children. Other symptoms of infection include abdominal cramps, nausea, vomiting and fever (WHO, 2008). Results of the study (Table 4 and 5 and Appendix 8.2.1: table 8.2.1.e) show fecal contamination in 65% of sampled sites (wet season) in comparison to 50% of the sampled sites (dry season). In comparison, fecal coliforms were reported in 92% of the tested samples (dry season) and in 98% of sampled sites (wet season) in 2005 (BAMAS 2005).

Still, it is important to reflect on specific environmental conditions that may have impacted the presence of fecal organisms in water samples such as the decreased oxygen levels in surface water (does not support the residence of pathogenic microorganisms) and shallow water films (enhances destruction of fecal organisms by near UVB radiation) prevailing in the dry season. These factors can explain the discrepancy for the dry season between the BOD profile reflecting on high organic loads, and the detection of fecal coliforms in surface water (river and its tributaries) sampled sites.

To conclude, sites for possible water extraction for domestic purposes are not limited as is the case for the dry season with minimal water flow, high organic loads, detected levels of trace metals (cadmium and manganese) and microbiological contamination. As such, maintaining a sustainable water flow, and reducing exposure to pollution (direct sewage discharge, scattered solid waste dump sites, industrial wastewater effluents and excessive applications of fertilizers and pesticides) will recover the ecologic wellbeing of the river.

5.2.2. IRRIGATION WATER USE

The suitability of a water source for irrigation does not only depend on the level of the dissolved solids (salt content) in water but also on the kind of chemical elements constituting this mineral content. Various soil and cropping problems may develop if the total salt content increases. As such, special management practices may be needed to maintain good crop yields. Additionally, acceptable water quality for irrigation should also be judged on the potential severity of the problems that may result during long-term use (Ayers and Westcot, 1994; Westcot, 1997). The guidelines for evaluating the quality of irrigation water is presented in table 6.

Hence, resulting problems vary both in kind and degree, and are modified by the type and condition of soil, climate and type of crops, as well as by proper skilled management. As a result, there is no set limit on water quality; rather, its suitability for use is determined by the conditions of use that may affect the accumulation of the water constituents and possibly restrict crop yield. The soil problems most commonly encountered and used as a basis to evaluate water quality are those related to salinity, water infiltration rate, toxicity and other miscellaneous problems (Ayers and Westcot, 1994; Westcot, 1997). As such, assessing the suitability of the quality of the sampled surface water (ULB) for irrigation purposes is evaluated based on international guidelines and standards as presented in table 6, and will relate mostly to water salinity, water infiltration rate, and crop toxicity.

5.2.2.1. WATER SALINITY

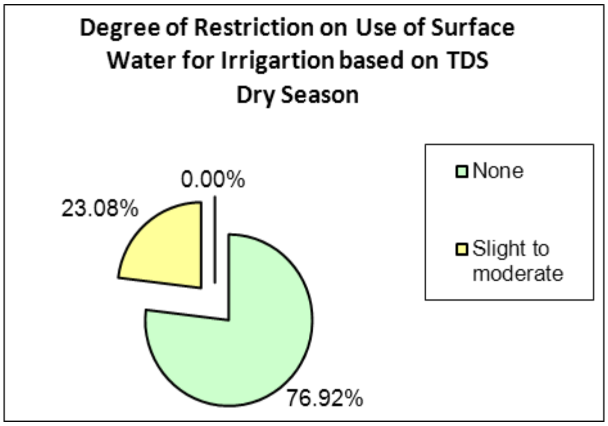
This is caused by salt accumulation in the crop root zone to a concentration that causes a loss in yield due to the inability of the crop to extract sufficient water from the salty soil. This results in water stress, slowed plant growth and reduced plant yield with time. The plant will wilt; become darker bluish-green in color, and with thicker and waxier leaves. As such, proper soil leaching is the key to controlling water the quality-related salinity problem. Over time, salt removal by leaching must equal or exceed the salt additions from the applied water. This is critical to prevent the level of the salt building up to damaging concentrations.

Table 6. Guidelines for Evaluating Water Quality for Irrigation

Potential Irrigation Problem			Units	Degree of Restriction on Use		
				None	Slight to Moderate	Severe
Salinity(affects crop water availability)						
	EC_w (or)		dS/m	< 0.7	0.7 – 3.0	> 3.0
	TDS		mg/l	< 450	450 – 2000	> 2000
Infiltration (affects infiltration rate of water into the soil. Evaluate using EC_w and SAR together)						
SAR	= 0 – 3	and EC_w	=	> 0.7	0.7 – 0.2	< 0.2
	= 3 – 6		=	> 1.2	1.2 – 0.3	< 0.3
	= 6 – 12		=	> 1.9	1.9 – 0.5	< 0.5
	= 12 – 20		=	> 2.9	2.9 – 1.3	< 1.3
	= 20 – 40		=	> 5.0	5.0 – 2.9	< 2.9
Specific Ion Toxicity (affects sensitive crops						
	Sodium (Na)					
	surface irrigation		SAR	< 3	3 – 9	> 9
	sprinkler irrigation		mg/l	< 70	>70	
	Chloride (Cl)					
	surface irrigation		mg/l	< 140	140 – 350	> 350
	sprinkler irrigation		mg/l	< 100	> 100	
	Boron (B)		mg/l	< 0.7	0.7 – 3.0	> 3.0
	Trace Elements (see Table 21)					
Miscellaneous Effects (affects susceptible crops)						
	Nitrogen (NO_3 - N)		mg/l	< 5	5 – 30	> 30
	Bicarbonate (HCO_3)					
	(overhead sprinkling only)		mg/l	< 90	90-500	> 500
	pH			Normal Range 6.5 – 8.4		
	Residual Chlorine		mg/l	<1.0	1.0-5.	>5.0

Source: Adapted from Ayers and Westcot 1994

The amount of leaching required is dependent upon the quality of the irrigation water and the salinity tolerance of the crop grown (Westcot, 1997). As such, the total dissolved solid content and the water electrical conductivity are two major indicators used to determine the suitability of irrigation water. Comparing the water suitability for both the wet and the dry seasons it is evident that the degree of restriction on water use in the wet season is minimal 5% of sample sites in comparison to 23% of sampled sites that fall within the slight to moderate category of restriction on use for irrigation during the dry season (Figures 32).



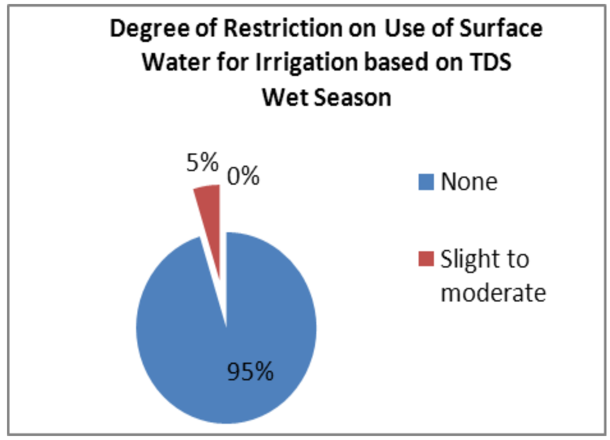


Figure 32. Degree of Restriction on Surface Water Use for Irrigation Based on the Total Dissolved Solids (TDS) Content

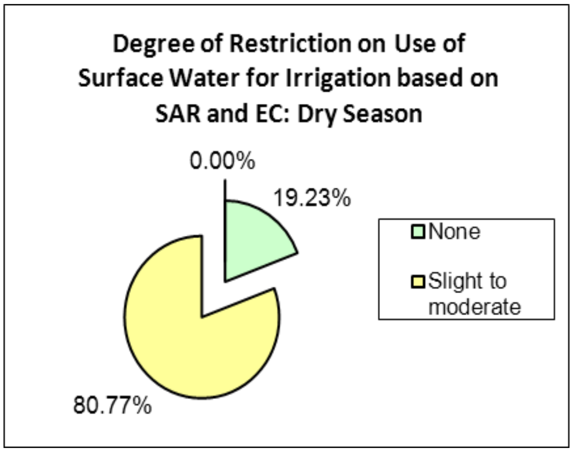
5.2.2.2. WATER INFILTRATION RATE

Water infiltration problems occur when irrigation water remains at the soil surface too long, or infiltrates too slowly to provide the crop with sufficient amounts of water to maintain acceptable yields. The infiltration rate depends on the quality of the irrigation water, organic load and inorganic content (sodium relative to the calcium and magnesium), and is also impacted by soil characteristics (e.g. structure, degree of compaction (WHO 2006). The most important quality indicators used to evaluate the water infiltration rate are the water salinity and the sodium content relative to the calcium and magnesium levels (sodium adsorption ratio). The Sodium adsorption ratio (SAR) is computed in the following manner:

$SAR = [Na^{+}] / \{([Ca^{2+}] + [Mg^{2+}]) / 2\}^{1/2}$

Hence, low salinity water or water with high sodium to calcium ratio will decrease infiltration. Additionally, when both factors operate at the same time added problems, especially if irrigation time is prolonged to achieve adequate infiltration, can result. Such problems lead to crusting of seedbeds, excessive weeds, nutritional disorders and drowning of the crop, rotting of seeds, lack of aeration, and plant and root diseases. Furthermore, among the serious side effects of infiltration is the potential to develop disease and vector (mosquito) problems (Ayers and Westcot, 1994; Westcot, 1997).

Evaluating the quality of surface water based of these two restrictive factors (water salinity and sodium adsorption ratio), results show comparable levels of restriction for both the wet and dry seasons of the year; about 81- 86% of the sampled sites fall within the slight to moderate category of restriction on surface water use for irrigation (Figure 33).



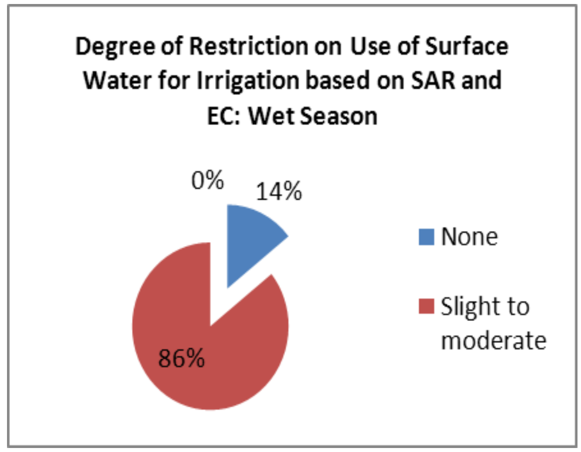


Figure 33. Degree of Restriction on Surface Water Use for Irrigation Based on EC and SAR Levels

5.2.2.3. PLANT TOXICITY

Toxicity problems occur if certain ions in the soil or water are taken up by the plant and accumulate to concentrations high enough to cause crop damage or reduced yields. The degree of damage depends on the uptake and the crop sensitivity. The permanent perennial-type crops (tree crops) are the more sensitive. Damage often occurs at relatively low ion concentrations for crops. It is usually first spotted by marginal leaf burn and interveinal chlorosis. Additionally, if the level of accumulation is high enough, reduced yields result. The more tolerant annual crops are not sensitive at low concentrations but almost all crops will be damaged or killed if concentrations are sufficiently high (Ayers and Westcot, 1994; Westcot, 1997).

The ions of major concern are chloride, sodium, boron and selective trace metals (Table 6). The degree of damage depends upon the duration of exposure, concentration of the toxic ion, crop sensitivity, and the volume of water transpired by the crop. In a hot climate or hot part of the year, accumulation is more rapid than if the same crop was grown in a cooler climate or cooler season when it might show little or no damage.

In reference to the levels of sodium in water associated with restriction on water use (<70 mg/l minimal; >70 mg/l slight to moderate), results show no degree of restriction during the wet season and less than

4% of sampled surface water fall within the slight to moderate category of restriction on surface water use for irrigation in the dry season (Figure 34).

As for the level of chlorides, and in reference to levels associated with restriction on water use (<100 mg/l none; >100 mg/l slight to moderate), results are comparable show that less than 20% of sampled sites fall within the slight to moderate category of restriction on water use for irrigation, for both the dry and wet seasons of the year, as presented in figure 35.

As for Boron, concentrations were below detectable levels to be associated with restrictive surface water use for irrigation. Additionally, based on restrictive water use associated with levels of bicarbonates in water (<90mg/l none; 90-500 mg/l slight to moderate; >500 mg/l severe), results show that the high bicarbonate levels of all samples fall within the slight to moderate restrictive water use category for both the wet and dry seasons, mostly due to the geological nature of the river bed and the constant exposure to sewage (Figure 36).

Finally, in reference to the presence of toxic trace metals (table 7) results of the study (Appendix 8.2.1; Table 8.2.1.d) show that the main element of concern, among tested metals, in the dry season is cadmium. The mean level of cadmium (0.00994 mg/l) approaches the maximum recommended level of 0.01 mg/l in nutrient solutions, whereas in winter the levels are reduced by 90% due to dilution by rain.

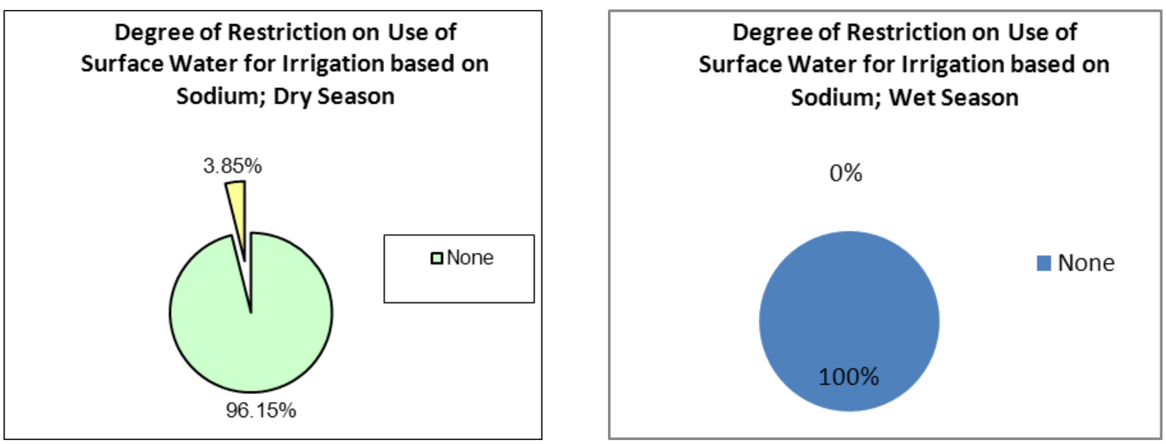
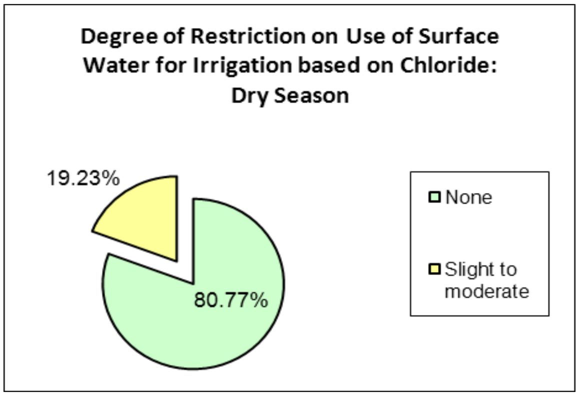


Figure 34. Degree of Restriction on Surface Water Use for Irrigation Based on Sodium Levels



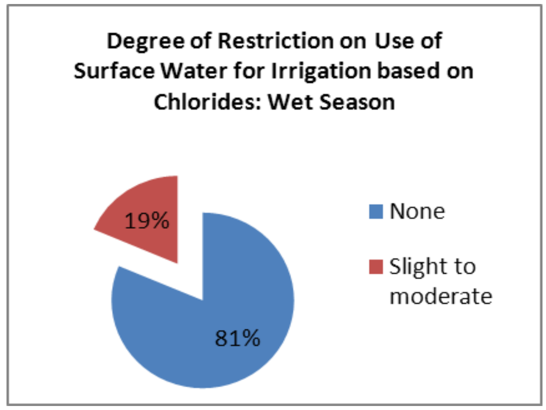
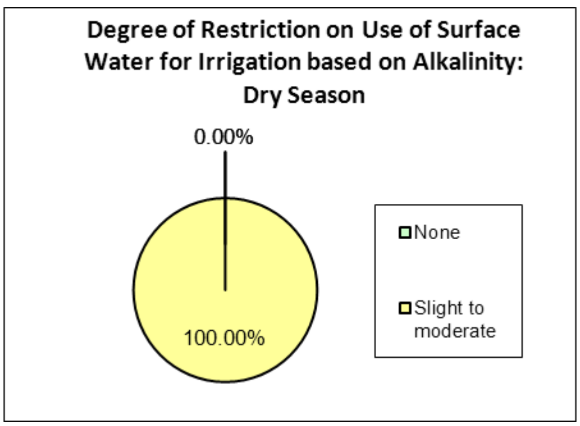


Figure 35. Degree of Restriction on Surface Water Use for Irrigation Based on Chloride Levels



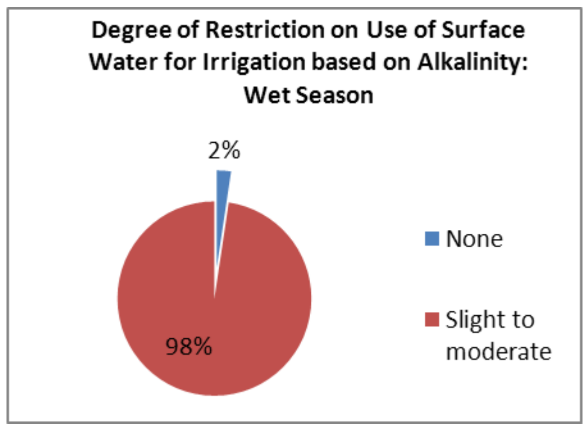


Figure 36. Degree of Restrictive Surface Water Use for Irrigation Based on Bicarbonate Levels

Cadmium is toxic to beans, beets and turnips at concentrations as low as 0.1 mg/l in nutrient solutions. Conservative limits are recommended due to its potential to accumulate in plants and soils to concentrations that may be harmful to humans. The major sources of cadmium are waste streams, leaching of landfills, industrial wastes (batteries, plastics, paints, electroplating), fertilizers and pesticides (WHO 2006).

Moreover, the divisions in "Restriction on Use" entity (none, slight to moderate and high), as presented in table 6, are somewhat arbitrary since change occurs gradually and there is no clear-cut breaking point. "A change of 10 to 20 percent above or below a guideline value has little significance if considered in proper perspective with other factors affecting yield. And values presented are applicable under normal field conditions prevailing in most irrigated areas in the arid and semi-arid regions of the world" (FAO 1997). As such, when evaluating the suitability of water for irrigation based on the recommended chemical profile, mostly restrictions on water use relate to (a) the levels of carbonate and bicarbonate hardness that are relatively high due to soil composition, geological formation and exposure to pollution and (b) the increasing levels of trace metals, mostly for the dry season.

Moreover, evaluating water quality based on the microbiological profile of the sampled sites, for the wet season, 60% exceed the recommended limit of 1000/100ml for the total coliform count and 43% exceed the recommended level of 100/100ml for fecal coliforms. As such, even during the cold weather, the continuous exposure to sewage discharge sustains high microbiological contamination loads in the river water. Still, as will be discussed later, the residence time of microorganisms in soil and on crops is impacted by factors such as climate conditions, types of soil, availability of irrigation water, proper pest control and implementation of proper management strategies.

Furthermore, evaluating the quality of the sampled sites in reference to the proposed National standards, based on BOD levels and fecal coliform counts, results show that sampled sites fall within the maximum limits of class 1B in comparison to class 2-3 limits indicated for the dry season. So although the microbial loads are higher, the BOD levels are diluted by the increased water volume. As such, if the water flow is sustained, and measures are taken to prevent the complete tapping of water springs feeding tributaries, then water use for irrigation with minimal restrictions can be achieved.

In conclusion, tapping water spring feeding tributaries and water tributaries “completely” for irrigation is destroying the ability of the river and its tributaries to handle the increasingly higher loads of contaminants (dry season) introduced by the various sources of pollution. Controlling such practices is essential to enhance the self purification capacity of this vital water resource and improve water quality for multipurpose usage.

5.2.3. WATER FOR LIVESTOCK USE

Water with a high salt may cause physiological upset or even death in livestock. The main reported outcome is depression of appetite, which is usually caused by a water imbalance related to any specific ion (Table 7). The most common exception is water containing a high level of magnesium which is known to cause scouring and diarrhea (Tables 8 and 9). As such, and based on the conductivity levels, the quality of “almost” all sampled sites (92% of sites), is suitable for use by livestock. Additionally, results of the study show that the levels of magnesium in water samples, for both the dry and wet seasons, do not exceed 68 and 84 mg/l, respectively. Hence, this confirms that the quality of the sampled water along the river and its tributaries is suitable for drinking by all types of Livestock, based on the magnesium water content (Table 9).

Table 7. Recommended Maximum Concentrations of Trace Metals in Irrigation Water

Element	Maximum Concentration (mg/l)	Remarks
Al (aluminium)	5.00	Can cause non-productivity in acid soils (pH < 5.5), but more alkaline soils at pH > 7.0 will precipitate the ion and eliminate any toxicity
As (arsenic)	0.10	Toxicity to plants varies widely, ranging from 12 mg/l for Sudan grass to less than 0.05 mg/l for rice.
Be (beryllium)	0.10	Toxicity to plants varies widely, ranging from 5 mg/l for kale to 0.5 mg/l for bush beans.
Cd (cadmium)	0.01	Toxic to beans, beets and turnips at concentrations as low as 0.1 mg/l in nutrient solutions. Conservative limits recommended due to its potential for accumulation in plants and soils to concentrations that may be harmful to humans.
Co (cobalt)	0.05	Toxic to tomato plants at 0.1 mg/l in nutrient solution. Tends to be inactivated by neutral and alkaline soils.
Cr (chromium)	0.10	Not generally recognized as an essential growth element. Conservative limits recommended due to lack of knowledge on its toxicity to plants.
Cu (copper)	0.20	Toxic to a number of plants at 0.1 to 1.0 mg/l in nutrient solutions.
F (fluoride)	1.00	Inactivated by neutral and alkaline soils.
Fe (iron)	5.00	Not toxic to plants in aerated soils, but can contribute to soil acidification and loss of availability of essential phosphorus and molybdenum. Overhead sprinkling may result in unsightly deposits on plants, equipment and buildings.
Li (lithium)	2.50	Tolerated by most crops up to 5 mg/l; mobile in soil. Toxic to citrus at low concentrations (<0.075 mg/l). Acts similarly to boron.
Mn (manganese)	0.20	Toxic to a number of crops at few-tenths to a few mg/l, but usually only in acid soils.
Mo (molybdenum)	0.01	Not toxic to plants at normal concentrations in soil and water. Can be toxic to livestock if forage is grown in soils with high concentrations of available molybdenum.
Ni (nickel)	0.20	Toxic to a number of plants at 0.5 mg/l to 1.0 mg/l; reduced toxicity at neutral or alkaline pH
Pb (lead)	5.00	Can inhibit plant cell growth at very high concentrations.
Se (selenium)	0.02	Toxic to plants at concentrations as low as 0.025 mg/l and toxic to livestock if forage is grown in soils with relatively high levels of added selenium. An essential element to animals but in very low concentrations.
Ti (titanium)	----	Effectively excluded by plants; specific tolerance unknown.
V (vanadium)	0.10	Toxic to many plants at relatively low concentrations.
Zn (zinc)	2.00	Toxic to many plants at widely varying concentrations; reduced toxicity at pH > 6.0 and in fine textured or organic soils.

Source: Adapted from FAO, 1997

Table 8. Water Quality Guide for Livestock and Poultry

EC (dS/m)	Rating	Remarks
<1.5	Excellent	Usable for all classes of livestock and poultry.
1.5 – 5.0	Very Satisfactory	Usable for all classes of livestock and poultry. May cause temporary diarrhea in livestock not accustomed to such water; watery droppings in poultry.
5.0 – 8.0	Satisfactory for Livestock	May cause temporary diarrhea or be refused at first by animals not accustomed to such water
	Unfit for Poultry	Often causes watery faces, increased mortality and decreased growth, especially in turkeys.
8.0 – 11.0	Limited Use for Livestock	Usable with reasonable safety for dairy and beef cattle, sheep, swine and horses. Avoid use for pregnant or lactating animals.
	Unfit for Poultry	Not acceptable for poultry
11.0 – 16.0	Very Limited Use	Unfit for poultry and probably unfit for swine. Considerable risk in using for pregnant or lactating cows, horses or sheep, or for the young of these species. In general, use should be avoided although older ruminants, horses, poultry and swine may subsist on waters such as these under certain conditions.
>16.0	Not Recommended	Risks with such highly saline water are so great that it cannot be recommended for use under any conditions.

Source: FAO 1997

As for trace metals, results show that the levels of the tested elements (Appendix 8.2.1; Table 8.2.1.d) do not exceed the recommended levels except for cadmium levels (dry season only) and manganese (wet and dry seasons). This renders the water unsuitable for use.

Hence, the main limiting factor for water use is neither the high TDS, nor high levels of magnesium, but the trace metals water quality profile.

Table 9. Restrictive levels of Magnesium in Drinking Water for Livestock

Type of Livestock	Magnesium Concentration (mg/l)
Poultry	<250
Swine	<250
Horses	250
Cows lactating	250
Ewes with lambs	250
Beef cattle	400
Adult sheep	500

Source: Adapted from FAO 1997

Table 10. Guideline Levels for Trace Metals in Drinking Water for Livestock

Element	Upper Limit (mg/l)
Aluminium (Al)	5.0
Arsenic (As)	0.2
Beryllium (Be)	0.1
Boron (B)	5.0
Cadmium (Cd)	0.05
Chromium (Cr)	1.0
Cobalt (Co)	1.0
Copper (Cu)	0.5
Fluoride (F)	2.0
Lead (Pb)	0.1
Manganese (Mn)	0.05
Mercury (Hg)	0.01
Nitrate + Nitrite (N03-N +NO2-N)	100.00
Nitrite (NO2-N)	10.0
Selenium (Se)	0.05
Vanadium (V)	0.10
Zinc (Zn)	24.0

Source: Adapted from FAO, 1997

5.3.GROUND WATER QUALITY ASSESSMENT

5.3.1. WATER SPRINGS QUALITY ASSESSMENT

All water springs identified through the field survey of the Upper Litani Basin (Dry Season 2010 Report), were sampled; still, 3 out of the identified 22 springs (14%) are dry even in winter, and 4 (18%) are dry in summer. The location and GPS coordinates of the sampled water springs are presented in figures 8-9 and appendix 8.1.4.

Mostly water springs are located in combined domestic, agricultural and to a lesser extent industrial and recreational settings. Additionally, during the dry season, these sources are mostly tapped for irrigation. Evaluating the physical, chemical and microbiological water quality profile of spring water sources for multipurpose usage, the following can be concluded:

5.3.1.1. DOMESTIC WATER USE

Evaluating the quality of spring water sources for possible domestic water use, results show a mean mineral content for the wet season of 199 mg/l (between 125 and 294 with a standard deviation of 39.85) in comparison to a mean content of 284 mg/l (ranging between 396 mg/l; and 172 mg/l with a standard deviation of 67 mg/l) for the dry season (Appendix 8.2.2.1: table 8.2.2.1.a. This decrease in levels is due to replenishment by rain. Moreover, all TDS levels are acceptable when compared to the National Standards, EPA Standards and WHO Guidelines set limit.

All tested macro-elements and microelements for both wet and dry seasons of the year fall within the sets limit values recommended by the National Standards, EPA Standards and WHO Guidelines. Still, the following is to be noted:

Nitrates; acceptable levels (wet and dry seasons) with the exception of one spring (17 mg/l as nitrate N) in Rayyak exceeding the standard level of 10 mg/l as nitrate N (dry season). This should be further investigated to identify the direct source of pollution,

Cadmium; the mean level of cadmium (0.00736 mg/l) exceeds the recommended national standards of 0.005 mg/l b by 1.5 folds for the dry season but is within the acceptable limit (0.00194 mg/l) for the wet season,

Manganese; the mean level of 0.07 mg/l exceeds the recommended guideline level of 0.05 mg/l by 1.4 folds, for the dry season, but is below the recommended limit (mean of 0.02 mg/l) for the wet season, and

Barium; levels are detectable both in the wet and dry seasons; but still levels are below recommended limit,

Other trace metals; all other trace metals with the exception of molybdenum and chromium showed a decrease in levels for the wet season. The mean molybdenum concentration (0.00482 mg/l) doubled, but is still much less than the acceptable limit of 0.07 mg/l; and the mean chromium concentration (0.0025 mg/l) increased by 12 folds but still is much less than the acceptable limit of 0.05 mg/l, and

Fecal microbiological water quality also limits its potential domestic use. Fecal coliforms were detected in both the dry (67% of sampled springs) and wet (53% of sampled springs) seasons of the year, thus limiting for domestic water use.

As such, the quality of spring water sources should be continuously monitored as the impacts of pollution is becoming more evident. It is crucial to screen all springs used by communities, as complementary sources of domestic water, in order to determine water safety based on the set Lebanese standards for drinking water. Additionally, water sources used to feed domestic networks should also be continuously monitored. Determination of the levels of trace metals should be an integral component of routine water quality assessment. Sources exceeding the acceptable levels for trace metals should not be used and alternative sources should be immediately identified as such sources will require advanced treatment, beyond disinfection, to insure water safety.

5.3.1.2. IRRIGATION WATER USE

As discussed before, the suitability of a water source for irrigation does not depend only on the TDS but is also dependent on the kind of chemical elements constituting this mineral content. Besides, acceptable quality is judged on the potential severity of the problems that may result with long-term use as presented in table 6 (Ayers and Westcot, 1994; Westcot, 1997).

5.3.1.2.1. WATER SALINITY

In reference to the levels of total dissolved solids (TDS) associated with restriction on spring water use for irrigation (<450 mg/l none; 450-2000 mg/l slight to moderate, and >2000 umhos/cm severe), results show that all spring water sources can be used for irrigation without any restrictions, for both the wet and dry seasons (Figure 37).

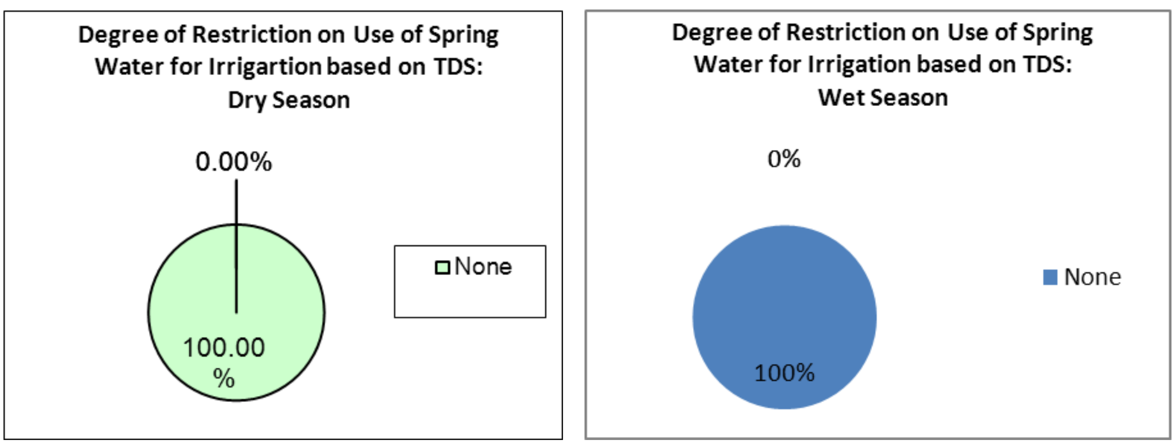
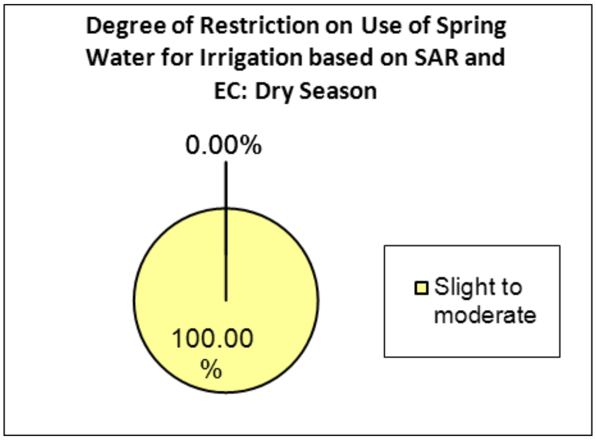


Figure 37. Degree of Restriction on Spring Water Use for Irrigation Based on TDS Content

5.3.1.2.2. WATER INFILTRATION RATE

Evaluating the quality of spring water sources based on EC and SAR, results show that all spring water sources can be used for irrigation under the slight to moderate restriction category, as presented in Figure 38.



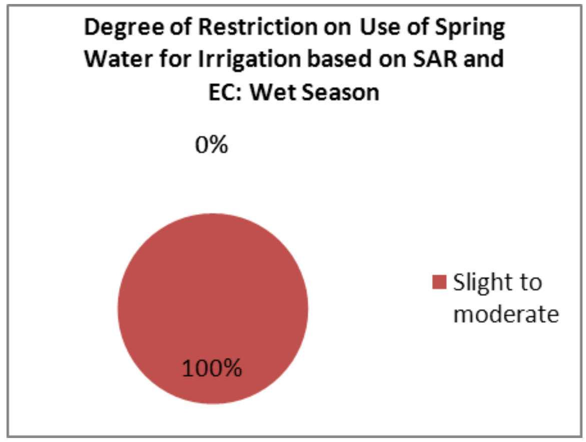
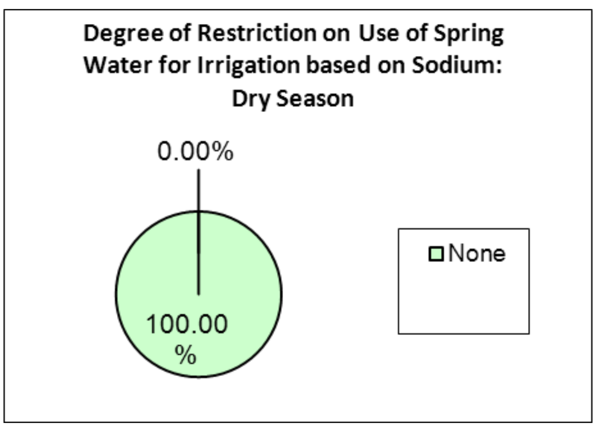


Figure 38. Degree of Restriction on Spring Water Use for Irrigation Based on EC and SAR Levels

5.3.1.2.3. PLANT TOXICITY

As indicated before, the ions of major concern are chloride, sodium and boron and selective trace metals (Table 6). In reference to the levels of sodium in water associated with restrictive water use for irrigation (<70 mg/l minimal; >70 mg/l slight to moderate), results show that all sources can be used for irrigation for the wet and dry seasons without any restriction (Figure 39).



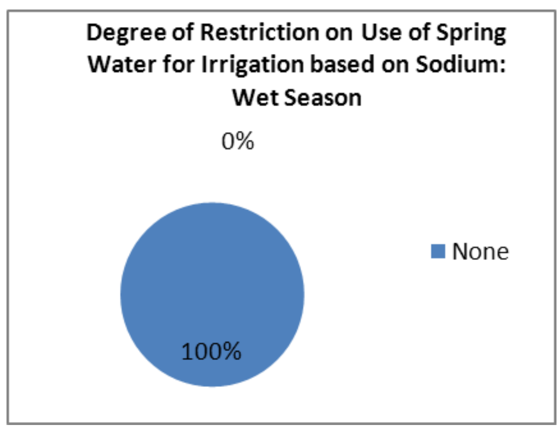
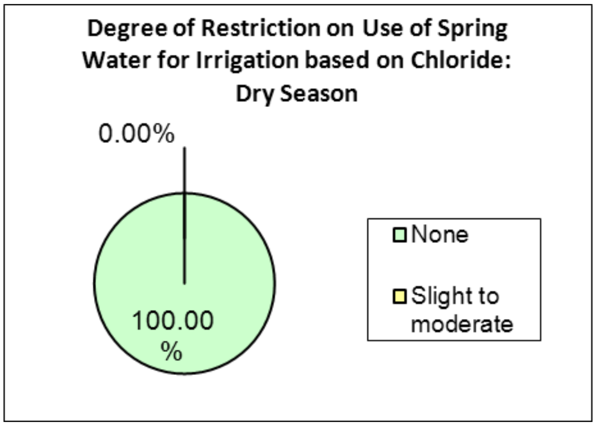


Figure 39. Degree of Restriction on Spring Water Use for Irrigation Based on Sodium Levels

As for the levels of chloride, and in reference to restriction on water use for irrigation (<100 mg/l none; >100 mg/l slight to moderate), results show that all spring water sources can be used for irrigation without any restriction, as presented in figure 40.



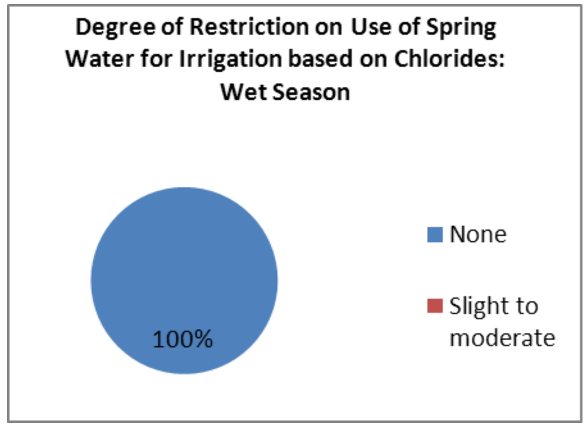
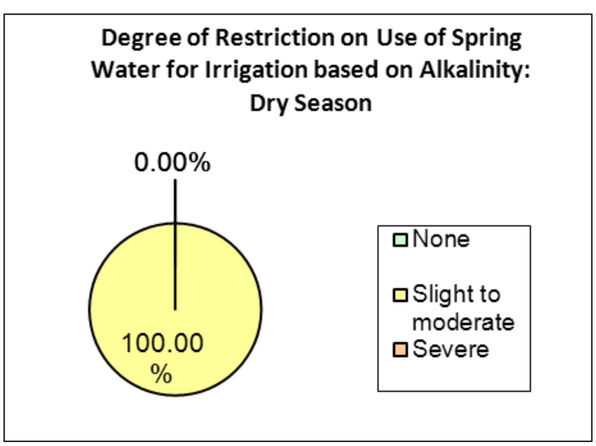


Figure 40. Degree of Restrictive Spring Water Use for Irrigation Based on Chloride Levels

As for Boron, the concentrations are below detectable levels to be associated with any restriction on water use for irrigation. Additionally, based on restriction due to bicarbonates in water (<90mg/l none; 90-500 mg/l slight to moderate; >500 mg/l severe), results show that the levels of all samples, dry and wet seasons, fall within the slight to moderate restrictive water use category reflective of carbonate and bicarbonate water hardness (figure 41).

Finally, in reference to the presence of toxic trace metals (table 7), results of the study (Appendix 8.2.2.1; Table 8.2.2.1.d) show that the levels of trace metals are not associated with restriction on spring water use during the wet and dry seasons.

Evaluating the microbiological profile of spring water samples for irrigation use, 5% of sampled springs (wet season) and 61% of sampled springs exceeded the recommended limit of 1000/100ml for total coliform count. And, 14% of spring water sources (wet season) in comparison to 16% (dry season) exceeded the recommended level of 100/100ml for fecal coliforms (Appendix 8.2.2.2 Table 8.2.2.2.e).



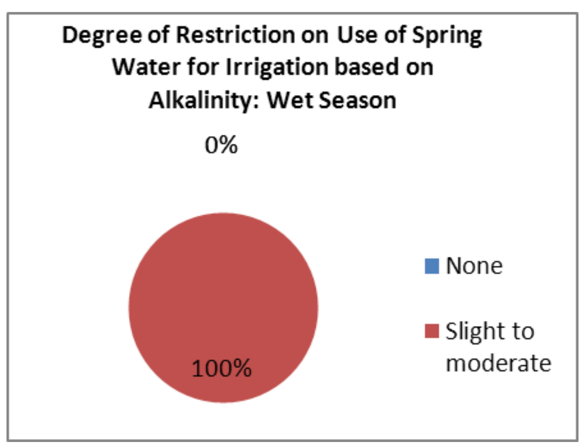


Figure 41. Degree of Restrictive Water Use for Irrigation Based on Bicarbonate Alkalinity Levels

Still, as will be discussed later, the residence time of microorganisms in soil and on crops is impacted by climate conditions, types of soil, availability of irrigation water, the type of crops to be grown, proper pest control, and proper management strategies (Ayers and Westcot, 1994; Westcot, 1997).

5.3.1.3. WATER FOR LIVESTOCK USE

As presented in tables 7-9, and based on the conductivity levels of all sampled sites, the quality of spring water sources is suitable for use by livestock. Additionally, results of the study show that the levels of magnesium in water samples do not exceed 8 mg/l with a mean level of 5.10 mg/l and a standard deviation of 1.5 mg/l. As such, the quality of the sampled spring is safe for drinking by all types of Livestock.

As for the presence of trace metals in livestock drinking water, results show that the levels of tested trace metals (appendix 8.2.2.1; table 8.2.2.1.d) do exceed the recommended levels for cadmium and manganese for the dry season in comparison to the wet seasons with diluted levels This renders the water unsafe for use only in summer and early fall. As such, the main limiting factor is not the high TDS, nor the high magnesium levels, but the level of trace metals in spring water sources.

5.3.2. WELL WATER QUALITY ASSESSMENT

A total of 26 accessible wells were identified through the field survey of the Upper litany Basin; 3 (11%) were inaccessible during the wet season (cut off electricity or well pump being out of order). The location and GPS coordinates of the sampled wells are presented in figures 8 and 10 and appendix 8.1.4. Mostly all ground water sources are located in combined domestic and agricultural settings and are "mostly" used for domestic and agricultural activities. Evaluating the physical, chemical and microbiological quality profile for multipurpose usage, the following can be concluded:

5.3.2.1. DOMESTIC WATER USE

Evaluating the quality of well water sources for possible domestic water use, shows an overall mean mineral content ranging between 277 and 385 mg/l for the wet and dry seasons, respectively (Appendix 8.2: Table 8.2.2.2.a). These mean levels are acceptable when compared to the Lebanese standards, EPA standards and the WHO guidelines recommended levels; still 12% exceed the standard 500mg/l level for the dry season and 5% for the wet season.

No direct health hazards are associated with the ingestion of water containing high levels of TDS (WHO, 2008). However, their presence may be associated with irritation of the gastrointestinal tract and levels >1200 mg/l are associated with excessive scaling in water pipes, heaters, boilers and household appliances (WHO Guidelines for Drinking Water Quality, First Addendum to Third Edition, Volume 1, 2006).

Additionally, the pH level is 7.50 in comparison to 7.77 for the dry season. Comparing to BAMAS 2005 reported overall value (wet and dry seasons); the shift of the pH from 6.47 to 7.63 reflects overexploitation of ground water aquifers beyond recharge.

Excluding the levels of nitrates in sampled well water sources, results show that the levels of all tested macro-elements and microelements (appendix 8.2; Tables 8.2.2.2.b,c&d) are within the sets limit values recommended by the National Standards, EPA Standards and WHO Guidelines (Table 12). Yet, high nitrate levels exceeding the recommended 10 mg/l as nitrate nitrogen limit was detected only in 5% of the sampled wells (Hezzine) in comparison to 20% of wells in the dry season (sampled wells in Housh Barada, Hezzine, Sariene, Helanieyeh and Ablah). Comparing to levels reported by BAMAS 2005 Study (wet and dry seasons), reduction in nitrate levels by 93% is evident due to increase in sewerage coverage; but, in some areas coverage is still limited (Tables 11-12).

Table 11. Percentage of Well Water Sampling Sites Exceeding the Recommended National and International Standard Levels for Drinking Water

Water Quality Parameter	BAMAS Study 2005		Current Study 2010	
	Dry Season %	Wet Season	Dry Season %	Wet Season%
Phosphates	3	7	None	None
Nitrates	70	77	20	5
Sulfates	35	7	None	None
Fecal Coliforms	78	23	15	14

As for trace metals, high manganese levels were detected in the wet season at the sampling sites of Mansoura (0.064mg/l exceeding the 0.05mg/l limit), and to a lesser extend in Ablah (0.038 mg/l), Helannieyeh (0.033 mg/l), and Sariene (0.040 mg/l) in comparison to higher levels detected during the dry season. The levels of all other trace metals were diluted with the exception of zinc levels that increased 1.59 folds but still the mean level of 0.0323mg/l is much less than the acceptable level of 5 mg/l (Appendix 8.2.2.2; Table: 8.2.2.2.c).

Additionally, the presence of total coliform organism was detected in 14% of samples in comparison to the 16% detected for the dry season samples). Fecal coliforms was also detected in 13% of samples in comparison to 15% of samples of the dry season. Comparing to BAMAS 2005 results, detection of fecal organisms has been reduced from 78% to 15% of samples of the dry season; and from 23% to 13% of samples of the wet season.

To conclude, findings reflect on efforts to increase the coverage of the sanitary sewer systems in some areas are still highly deficient. As such, the high level of nitrates and manganese is of major concern and needs to be addressed.

Table 12. Comparison of Ground Water Quality Profile Reported by the BAMAS 2005 Study and the Current 2010-11 Study

Indicator	Survey round	BAMAS 2005 Calculated from Ground water results			Current 2010-11 Study Ground water results			Drinking water standard		Reclaimed WW for irrigation
								MoE-Lebanon	USEPA	
		Min.	Mean	Max.	Min.	Mean	Max.	GV[1] (25 °C)	GV/MAL[2]	MoE guidelines
Temperature (°C)	W	11.6	17.26	20.1	10.20	18.23	22.50	NA[6]	NA	
	S	18.4	22	33.3	15.15	20.59	27.6			
TDS (mg/l)	W				120.00	276.89	637.00	500[7]	500[7]	
	S				171.00	335.27	629.50			
pH (pH units)	W	6.41	6.85	7.5	7.04	7.50	8.08	6.5-8.5	6.5-8.5	
	S	6.54	6.9	7.22	7.16	7.77	8.6			
DO (mg/l O_2)	W				0.10	5.10	7.80	NA	NA	
	S				4.1	6.04	7.77			
BOD (mg/l)	W							NA	NA	10-45
	S									
NH_4 [8](mg/l)	W				0.1	0.18	0.44	NA	NA	
	S				0.00	0.36	42.09			
NO_3^- (mg/l)	W	1	60.32	318	0.0	2.67	12.40	10 (as N)	10 (as N)	
	S	3	48.31	171	0.2	4.27	29.00			
SO_4^{2-} (mg/l)	W	7	39.08	250	0	13.55	63.00	250	250	
	S	7	31.42	205	1.5	15.92	60.00			
P_2O_5[9] (mg/l)	W	<0.01	0.12	2.3	0.15	0.56	1.21	NA	NA	
	S	0	0.31	12	0.05	0.61	3.46			
FC (CFU[10]/100,ml)	W	0	18	255	0	1.22	21	0	0	5-2,000
	S	0	42.85	400	0	65.37	400			

[1] GV: Guideline value

[2] MAL: Maximum admissible level ; USEPA: US Environmental Protection Agency

[7] reference temperature at 25°C

[8] Initial value reported is NH_3 , for comparison a conversion factor of 1.0588 was used ($NH_4 = NH_3*1.0588$)

[3] All values reported < a certain value are set equal to that value when calculating the average

[4] W: Winter sampling round, based on 94 river samples including springs and sources

[5] S: Summer sampling round, based on 76 river samples including springs and sources

[6] NA: Not applicable

[9] Initial value reported is o-PO_4^{3-}, for comparison a conversion factor of 0.743 was used (P_2O_5 = o-PO_4^{3-} *0.743)

[10] CFU: colony forming unit

As such, the quality of well water sources should be continuously monitored as the impacts of pollution sources are evident (e.g. sewage, agriculture run off). It is crucial to screen all private wells used by communities in order to determine the water safety based on the Lebanese Standards for Drinking Water. Additionally, sources used to feed domestic networks should also be continuously monitored. And sources exceeding the acceptable levels of nitrates and trace metals should not be used; alternative sources should be immediately identified.

5.3.2.2. IRRIGATION WATER USE

Assessing the suitability of the quality of well water sources of the Upper Litani Basin for irrigation based on international guidelines and standards, as presented in table 6, reflects on the following issues and concerns:

5.3.2.2.1. WATER SALINITY

In reference to the levels of total dissolved solids (TDS) associated with restriction on water use for irrigation (<450 mg/l none; 450-2000 mg/l slight to moderate, and >2000 umhos/cm severe), results show that only 9% of sampled wells (wet season) in comparison to 76% (dry season) fall within the slight to moderate restrictive category use for irrigation (Figure 41). This is mostly due to aquifer recharge that dilutes the mineral content of wells.

5.3.2.2.2. WATER INFILTRATION RATE

Evaluating the quality of well water sources based on EC and SAR, results show that 80 % of sampled wells (wet and dry seasons) fall in the category of slight to moderate restrictive well water use for irrigation (Figure 42).

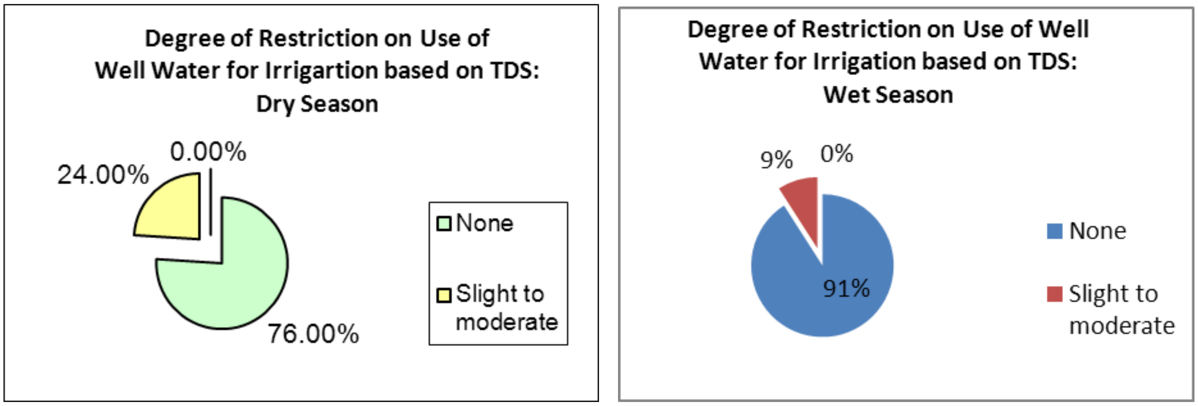


Figure 42. Degree of Restriction on Well Water Use for Irrigation Based on the Total Dissolved Solids

5.3.2.2.3. PLANT TOXICITY

As indicated before, the ions of major concern are chloride, sodium and boron and selective trace metals (Table 7). In reference to the levels of sodium in water associated with restrictive water use for irrigation (<70 mg/l minimal; >70 mg/l slight to moderate), results show that all wells can be used for irrigation, during both seasons without any restrictions (Figure 43).

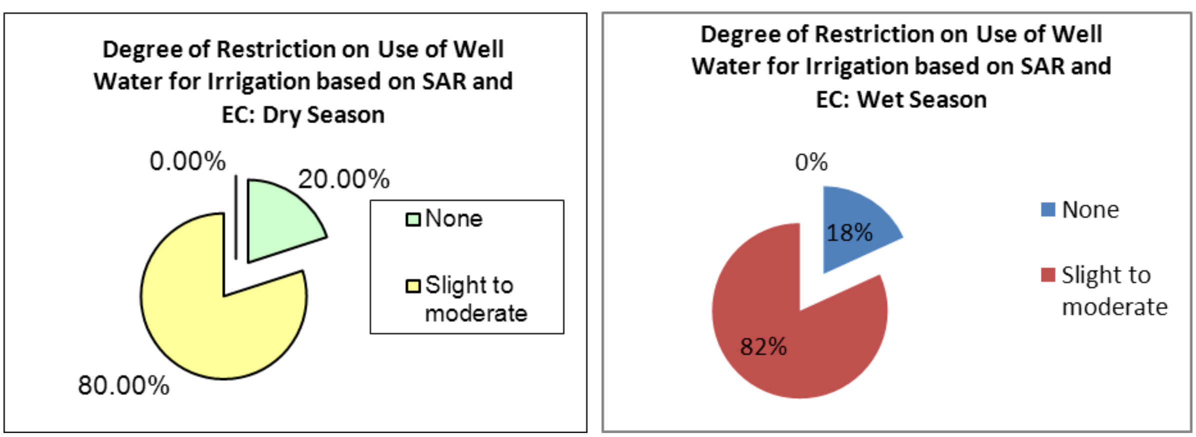


Figure 43. Degree of Restriction on Well Water Use for Irrigation Based on EC and SAR Levels

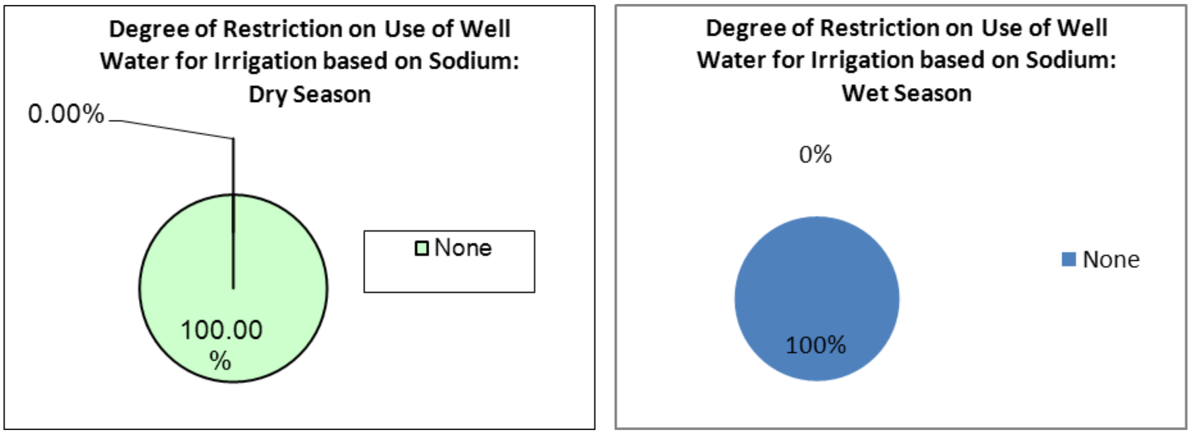


Figure 44. Degree of Restriction on Well Water Use for Irrigation Based on Sodium Levels

As for the levels of chlorides, and in reference to the levels associated with the restriction on water use for irrigation (<100 mg/l none; >100 mg/l slight to moderate), results show that only 4-5% of sampled wells (one site in Ablah) fall within the slight to moderate restrictive category for irrigation water (wet and dry season) as presented in figure 45.

Additionally, based on restriction on water use associated with levels of bicarbonates in water (<90mg/l none; 90-500 mg/l slight to moderate; >500 mg/l severe), results show that the high bicarbonate levels of all samples (wet and dry season) full within the slight to moderate restrictive water category for irrigation (figure 46). As for Boron, the concentrations were below detectable levels to be associated with restrictive water use.

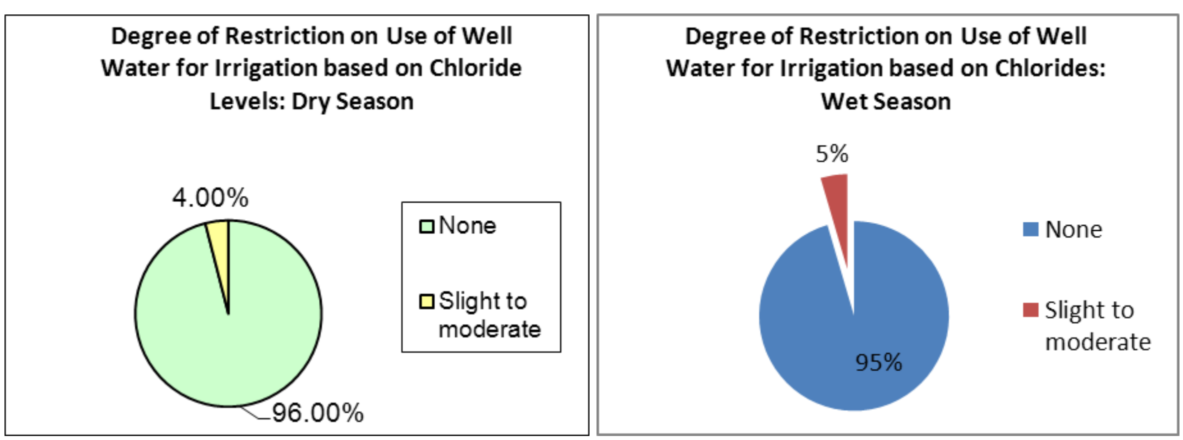
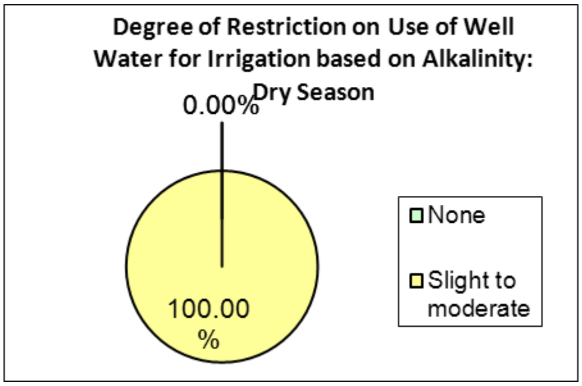


Figure 45. Degree of Restriction on well Water Use for Irrigation Based on Chloride Levels



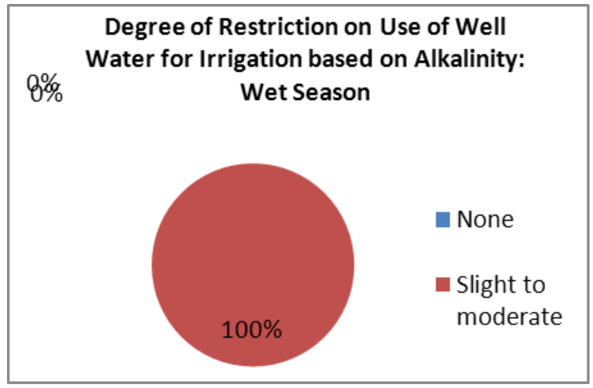


Figure 46. Degree of Restriction on Well Water Use for Irrigation Based on Bicarbonate Alkalinity Levels

Moreover, in reference to the presence of toxic trace metals, results (Appendix 8.2.2.2: Table 8.2.2.2.e), show that the levels of trace metals (with the exception of one site in Mansoura with high levels of manganese in the wet season) are not associated with any restriction on well water use for irrigation. In comparison higher restriction is indicated for the dry season for the wells of Hezzine, Ferzol, Rayyak, and Temnine Al Fawka. Still, the impact of manganese is mostly in acidic soils.

Finally, evaluating the microbiological profile for irrigation use, only 9% of samples (wet season) in comparison to 16% of samples (dry season) exceeded the recommended limit of 1000/100ml for the total coliform count. And none of the samples (wet season) compared to 8% of samples (dry season) exceeded the recommended level of 100/100ml for fecal coliforms (Appendix 8.2: Table 8.2.2.2.e). Still, as will be presented later on, the residence time of microorganisms in soil and on crops is impacted by climate conditions, types of soil, availability of irrigation water, the type of crops to be grown, proper pest control and proper management strategies, and should as such be evaluated (Ayers and Westcot, 1994; Westcot, 1997).

5.3.2.3. WATER FOR LIVESTOCK USE

Based on the conductivity levels of all sampled sites, the quality of water sources is suitable for livestock (Tables 7-10). Additionally, results of the study show that the levels of magnesium (both for wet and dry seasons) do not exceed the recommended levels (Appendix 8.2: Table 8.2.2.2.a). As such, the quality of the sampled wells, based on the indicated water quality parameters, is suitable for drinking by all types of Livestock. As for the presence of trace metals in livestock drinking water, results show that mostly the levels of tested trace metals (appendix 8.2: table 8.2.2.2.e) with the exception of manganese levels, do not exceed the recommended limits presented in table 10, as mentioned before.

5.4.QARAOUN LAKE WATER QUALITY ASSESSMENT

The overall physico-chemical water quality showed relatively more variability when compared to the results of previous conducted studies (Jurdi et.al, 2001; Korfali et.al, 2006). The total dissolved solids and electrical conductivity also show variability with time and among the lake zones as presented in table 13. Additionally, the levels of natural macro-elements (e.g. bicarbonate alkalinity and chlorides) minimal variability is detected in comparison to previously reported findings and among the sampled sites

The overall pH level (wet and dry seasons), on the other hand, shifted towards alkalinity from a mean pH of 6.50 (BAMAS 2005) for the wet season to a mean of pH of 8.10 (Current 2010-11 Study); and from a mean pH level of 6.82 (BAMAS 2005 for the dry season) to 8.27 (Current Study 2010-11). This reflects on progressive exposure to sewage, dump sites leachate and alkaline industrial wastewater effluents such as, dairy plants, paper mills, etc.

As for the biological oxygen demand of water, increased levels also reflect on increased exposure to organic contamination loads indicated by the presented sources of pollution. Results show relatively higher BOD in the receiving zone in contrast to the middle lake zone (dry season) as presented in figure 47.

Concurrently, this impacts the oxidation receiving zone in winter leading to reducing conditions. These reducing conditions are reflected by relatively higher ammonia levels and higher levels of iron and cadmium from the dissolution of the precipitates of these metals under reducing conditions (Table 13 and figures 47-50).

Stil, the levels of cadmium that exceeded the recommended National Standard level of 0.005 mg/l by 2.1 folds (higher levels reported in the mid lake water zone) for the dry season were reduced by replenishment by rain.

As for manganese, the levels slightly decreased in the wet season (from 0.0377 mg/l to 0.0300 mg/l and none of the sites exceeded the standard level of 0.05. In comparison 30% of the sampled sited exceeded the recommended level for the dry season.

All other trace metal, were detected at levels below the recommended Lebanese standards. Mostly, boron, cadmium, aluminium, manganese, iron, and copper were concentrated in the receiving zone (river inflow into the lake); nickel at the receiving zone and the damp zone; molybdenum and chromium in the central zone; and zinc throughout the lake as presented in figures 49 -57.

Moreover, comparing the existing physicochemical water profile with that reported by Jurdi et.al (2001) shows that the mid zone (2.5- 3.6 km from receiving zone) that was considered as the "better water extraction zone" for multi-purpose usage (lower organic loads, and higher scavenging of metals in the sediments) is at present a relatively reducing medium (higher organic loads and more solubility of metal sediments).

This variability in the water quality makes it difficult to define a better "quality" water zone for possible water extraction. The most probable explanation to this major finding relates to the disposal of sewage directly by the lake. A wastewater treatment plant located directly by the lake is under construction in Bab Merea.

Additionally, another wastewater treatment plant, located directly by the lake, in Saghbine, is also under construction. Furthermore the sanitary sewer systems coverage has increased, replacing the point source cesspools. Yet, at present the sanitary sewer systems are discharging into the lake, awaiting the completion of the treatment plant under construction.

Hence, the delay in "closing the loop"; completing the wastewater treatment plants, and ensuring proper wastewater treatment, is boasting the levels and diffusion of organic contaminants throughout the lake.

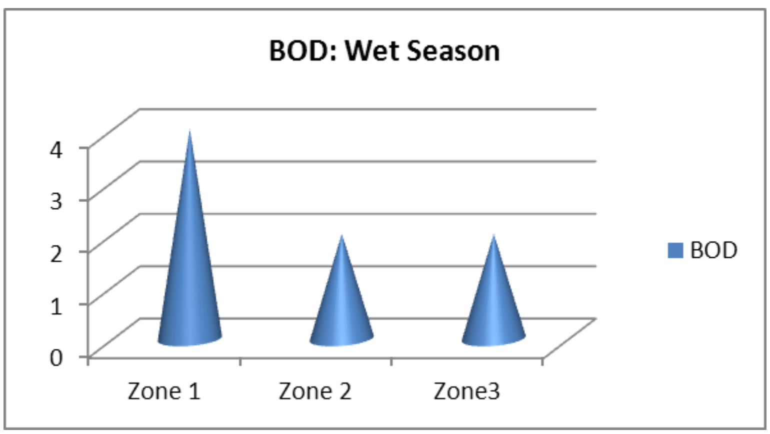


Figure 47. BOD (mg/l) Variability along the Qaraoun Lake

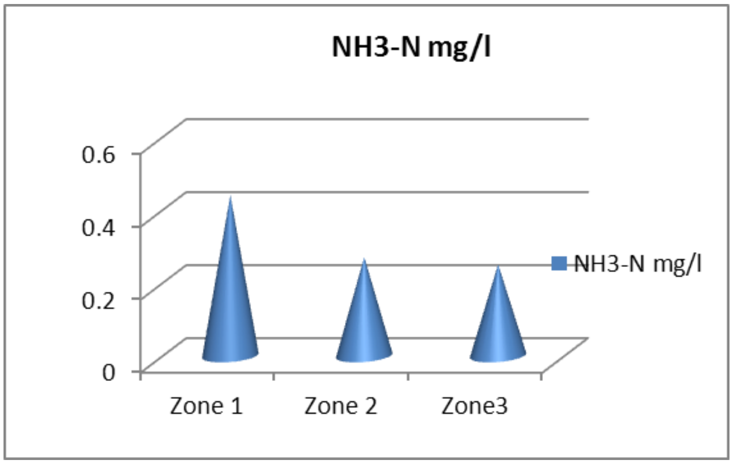


Figure 48. Ammonia (mg/l ammonia N) Variability along the Qaraoun Lake

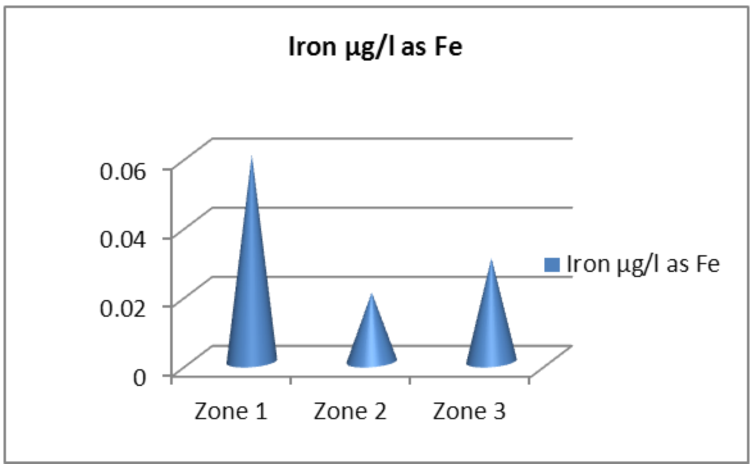


Figure 49. Iron (mg/l) Variability along the Qaraoun Lake

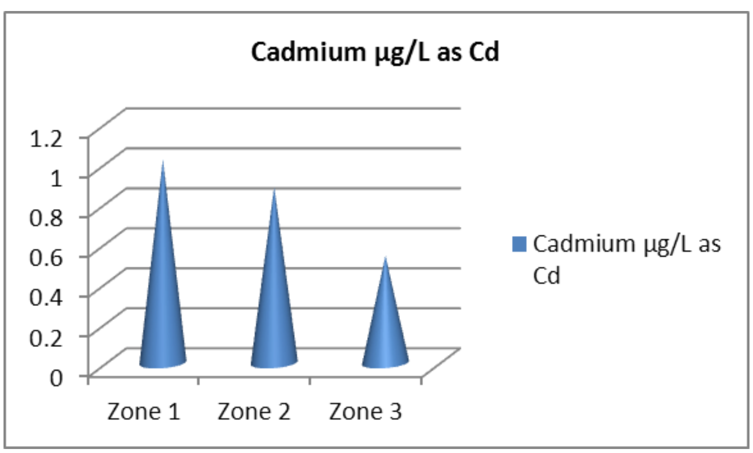


Figure 50. Cadmium (ug/l) Variability along the Qaraoun Lake

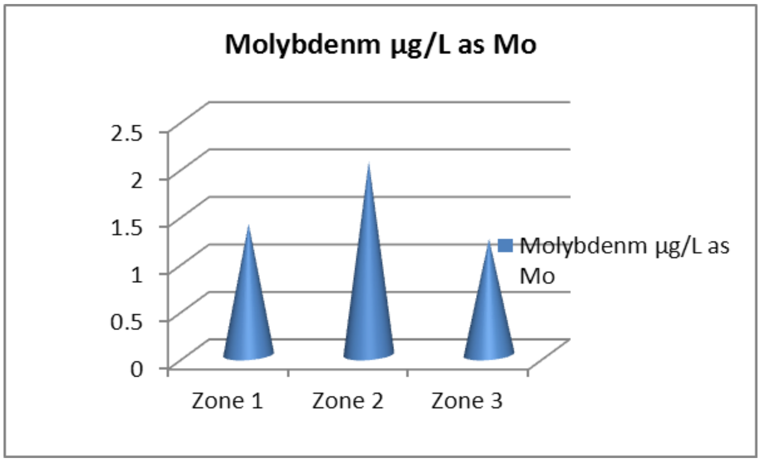


Figure 51. Molybdenum (ug/l) Variability along the Qaraoun Lake

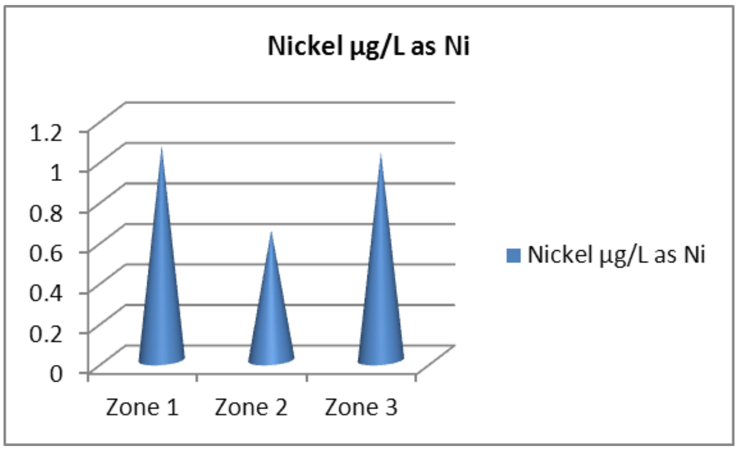


Figure 52. Nickel (ug/l) Variability along the Qaraoun Lake

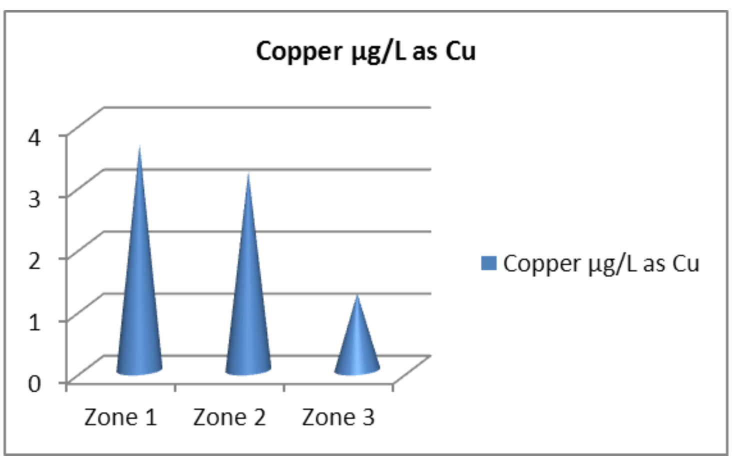


Figure 53. Copper (ug/l) Variability along the Qaraoun Lake

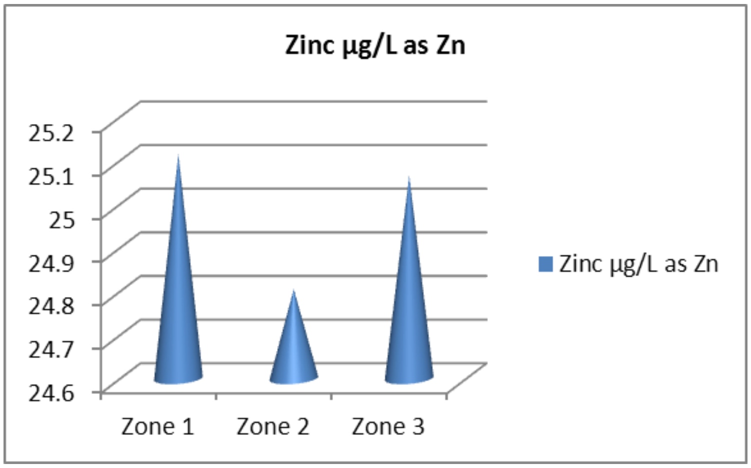


Figure 54. Zinc (ug/l) Variability along the Qaraoun Lake

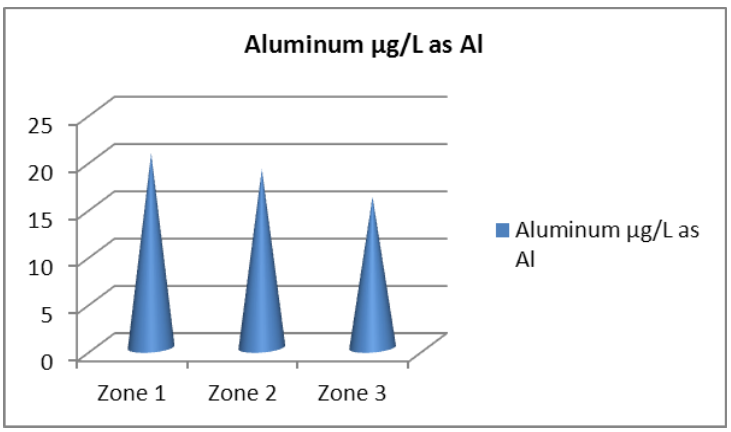


Figure 55. Aluminium (ug/l) Variability along the Qaraoun Lake

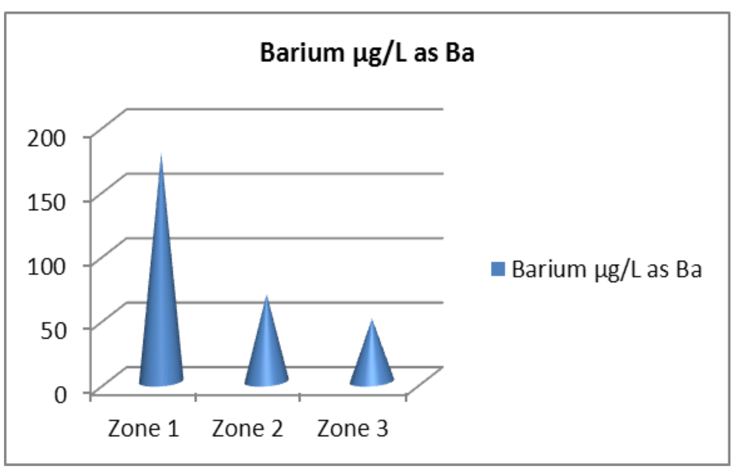


Figure 56. Barium (ug/l) Variability along the Qaraoun Lake

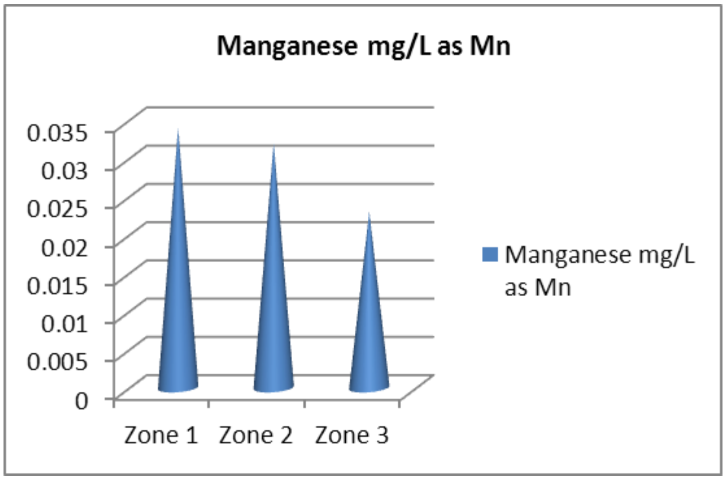


Figure 57. Manganese (mg/l) Variability along the Qaraoun Lake

Table 13. Comparison of the Quaaoun Lake water Quality Profile: BAMAS 2005 and Current 2010-11 Study (level in mg/l unless indicated)

Indicator	Survey Season	BAMAS 2005 Calculated from lake water results			Current Study 2010-11 Lake water results			Drinking water standard MoE-Lebanon	Drinking water standard USEPA	Reclaimed WW for irrigation
		Min.	Mean	Max.	Min.	Mean	Max.	GV[1] (25 °C)	GV/MAL[2]	MoE guidelines
Temperature (°C)	W	11.3	12.52	16	22.80	23.08	23.30	NA[6]	NA	
	D	16.5	20.7	24.8	32.20	33.68	34.70			
TDS (mg/l)	W	211	226.8	239	234.5	241.55	248.00	500[7]	500[7]	
	D	120	160	196	221	235.10	256.00			
pH (pH units)	W	6.82	7.58	7.78	7.85	8.10	8.32	6.5-8.5	6.5-8.5	
	D	6.50	7.59	7.5	8.20	8.27	8.32			
DO (mg/l O_2)	W	6.82	7.00	8.68	8.10	9.81	11.20	NA	NA	
	D	1.3	3.3	7.7	7.22	8.39	9.41			
BOD (mg/l)	W	<2	2.1	3	2.00	2.67	4.00	NA	NA	10-45
	D	<2	2.57	4	2.00	2.65	3.30			
NH_4 [8] (mg/l)	W	0.52	0.62	0.7	0.25	0.30	0.46	NA	NA	
	D	<0.02	0.3	1	0.00	0.20	0.35			
NO_3^- (mg/l)	W	16.2	27.9	34.1	1.70	2.00	2.40	10 (as N)	10 (as N)	
	D	16.1	21.7	31.2	0.80	0.93	1.20			
SO_4^{2-} (mg/l)	W	34	39	43	34.00	35.50	37.00	250	250	
	D	25	29.3	33	36.00	37.10	39.00			
P_2O_5[9] (mg/l)	W	0.19	0.22	0.33	0.21	0.40	0.90	NA	NA	
	D	0.01	0.13	0.35	0.00	0.09	0.245			
FC (CFU[10]/100,ml)	W	6	39	196	0	181.42	400	0	0	5-2,000
	D	0	17	450	0	160.60	400			

[1] GV: Guideline value

[6]NA: Not Applicable

[2] MAL: Maximum admissible level ; USEPA: US Environmental Protection Agency

[3] All values reported < a certain value are set equal to that value when calculating the average

[4] W: Winter sampling round, based on 94 river samples including springs and sources

[5] S: Summer sampling round, based on 76 river samples including springs and sources

[7] Reference temperature at 25°C

[9]8Initial value reported is NH_3 , for comparison a conversion factor of 1.0588 was used ($NH_4 = NH_3*1.0588$)

[9] Initial value reported is o-PO_4^{3-}, for comparison a conversion factor of 0.743 was used (P_2O_5 = o-PO_4^{3-} *0.743)

[10]CFU: colony forming unit

Comparing the Qaraoun Lake water quality profile with results reported by BAMAS 2005 Study the following can be concluded:

Increase in the levels of total dissolved solids (from 193 to 238; 1.23 folds) reflective on progressive exposure to the various indicated sources of pollution, Increase in the overall total dissolved oxygen (from 5.54 to 9.1; 1.64 folds), masking the increase in biochemical oxygen demand boasted by organic contaminants. This increase in the levels of dissolved oxygen is mostly reflective of suspended algae growth,

Change in pH towards alkalinity (from 7.29 to 8.18) reflective of exposure to domestic wastewater discharge and industrial wastewater discharge as specified before,

The presence of trace metals but at levels below the permissible upper limits values (Lebanese standards), and mostly concentrated in the receiving zone (river inflow into the lake), with the exception of cadmium and manganese (Figures 47-55), and

High levels of cadmium for the dry season exceeding the recommended National Standard level of 0.005 mg/l by 2.1 folds (higher levels reported in the mid lake water zone),

High manganese level to 0.04 mg/l for the dry season, compared to the maximum standard limit of 0.05mg/l, with 30% of the sampled sites exceeding this limit level (higher levels reported in the receiving water zone),

Increased microbiologic fecal contamination loads in mostly all sampled sites.

This change in the quality of the water profile is concurrent with the progressive exposure to pollution from the various point and nonpoint sources identified in the ULB. As for the suitability of the water for irrigation, a detailed presentation of irrigation Canal 900 water quality will follow.

5.5.IRRIGATION CANAL 900 WATER QUALITY ASSESSMENT

Comparing to the results of the BAMAS study of 2005 (wet and dry seasons) to the results of the current study 2010, as presented in table 14, the main findings reflect on:

Increase in the levels of total dissolved solids (from 215 to 303; 1.4 folds) reflective of progressive exposure of the Qaraoun Lake to point and nonpoint sources of pollution as presented before,
Decrease in the levels of dissolved oxygen from 6.99 to 5.43 mg/l (22% reduction) despite the progressive growth of algae. This is mostly due to the increase in the BOD from <2 to 6.5 mg/l (4.5 folds),
Change in pH towards alkalinity (from 7.29 to 7.52) reflective of exposure to domestic wastewater discharge, industrial wastewater discharge, etc. as specified before,
Increase in cadmium levels mostly of the dry season (0.0419. The mean level of 0.0103 of the wet season exceeds minimally the permissible levels in irrigation water (0.01mg/l), and
Decrease in fecal loads.
This change in the quality profile of Canal 900 is concurrent with the progressive exposure of the Qaraoun Lake water to contamination loads from the various point and nonpoint sources of pollution identified in the Upper Litani Basin. As such, change in the water quality of the irrigation canal reflects on similar variability in water quality. And, as discussed before, the acceptable water quality for irrigation is evaluated based on the water mineral content and mineral and projected long term impacts on the quality.

Table 14. Comparison of the Quality of Irrigation Canal 900; BAMAS 2005 and Current 2010-11 Study (levels in mg/l unless indicated)

Indicator	Survey round	BAMAS 2005 Calculated from canal water results			Study 2010 Canal water results			Drinking water standard MoE-Lebanon	Drinking water standard USEPA	Reclaimed WW for irrigation
		Min.	Mean	Max.	Min.	Mean	Max.	GV[1] (25 °C)	GV/MAL[2]	MoE guidelines
Temperature (°C)	W	12.9	16.75	21.2	15.30	18.76	23.20	NA[6]	NA	
	D	15.8	20.63	25.7	20.90	24.41	29.50			
TDS (mg/l)	W	222	191	257	233.00	267.71	300.00	500[7]	500[7]	
	D	148	238.4	208	319.00	339.86	363.00			
pH (pH units)	W	7.07	7.50	7.99	5.5	7.34	7.8	6.5-8.5	6.5-8.5	
	D	6.7	7.09	7.46	7.51	7.71	7.90			
DO (mg/l O_2)	W	3.2	9.15	15.44	3	5.92	8.5	NA	NA	
	D	2	4.84	7.76	1.59	4.94	6.86			
BOD (mg/l)	W	<2	3.7	2.1				NA	NA	10-45
	D	<2	<2	<2	6.00	9.00	14.00			
NH_4 [8] (mg/l)	W	0.11	0.30	0.47	0.27	0.32	0.42	NA	NA	
	D	<0.01	0.49	1.1	0.32	0.58	0.83			
NO_3^- (mg/l)	W	16.8	20.7	25.1	1.3	2.26	3	10 (as N)	10 (as N)	
	D	11.2	19.75	24.4	0.80	1.39	1.90			
SO_4^{2-} (mg/l)	W	32	36.8	44	42	43.00	44	250	250	
	D	27	38.45	33	34.00	35.29	37.00			
P_2O_5[9] (mg/l)	W	0.01	0.21	0.4	0.20	0.39	0.69	NA	NA	
	D	0.01	0.18	0.4	0.17	0.35	0.51			
FC (CFU[10]/100,ml)	W	0	27	216	0	5.28	15	0	0	5-2,000
	D	0	241	1200	0	0	0			

1 GV: Guideline value

2 MAL: Maximum admissible level ; USEPA: US Environmental Protection Agency

3 All values reported < a certain value are set equal to that value when calculating the average

4 W: Winter sampling round, based on 94 river samples including springs and sources

5 S: Summer sampling round, based on 76 river samples including springs and sources

6 NA: Not applicable

7 reference temperature at 25oC

8 Initial value reported is NH3 , for comparison a conversion factor of 1.0588 was used (NH4 = NH3*1.0588)

9 Initial value reported is o-PO43-, for comparison a conversion factor of 0.743 was used (P2O5 = o-PO43- *0.743)

10 CFU: colony forming unit

5.5.1. WATER FOR IRRIGATION USE

5.5.1.1. WATER SALINITY

In reference to the levels of total dissolved solids (TDS) associated with restrictive water use for irrigation (<450 mg/l none; 450-2000 mg/l slight to moderate, and >2000 umhos/cm severe), results show that Canal 900 water is acceptable for irrigation for both the dry and wet seasons of the year (Figure 58).

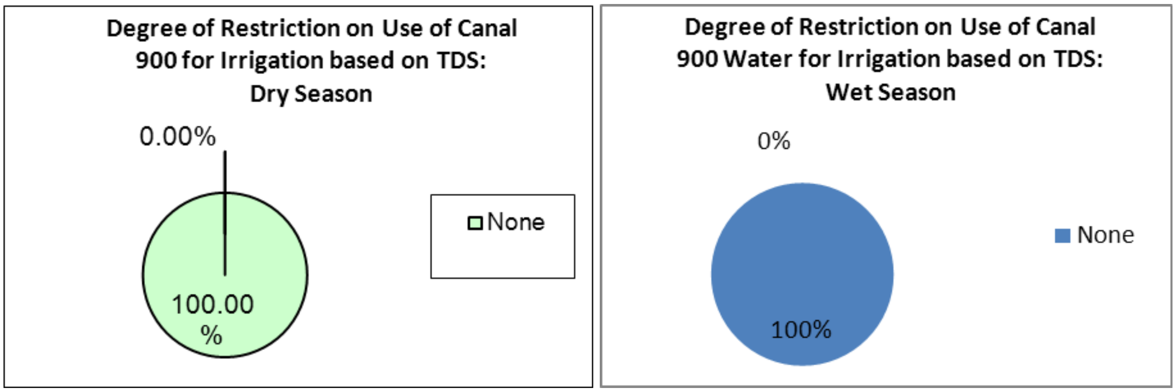


Figure 58. Degree of Restriction on Canal 900 Water Use for Irrigation Based on the Total Mineral Content (TDS)

5.5.1.2. WATER INFILTRATION RATE

Evaluating the quality of Canal 900 irrigation water based of these two restrictive factors (water salinity and sodium adsorption ratio), results show that the canal water falls under the category of slight to moderate restrictive use for both the wet and dry seasons of the year, as presented in Figure 59.

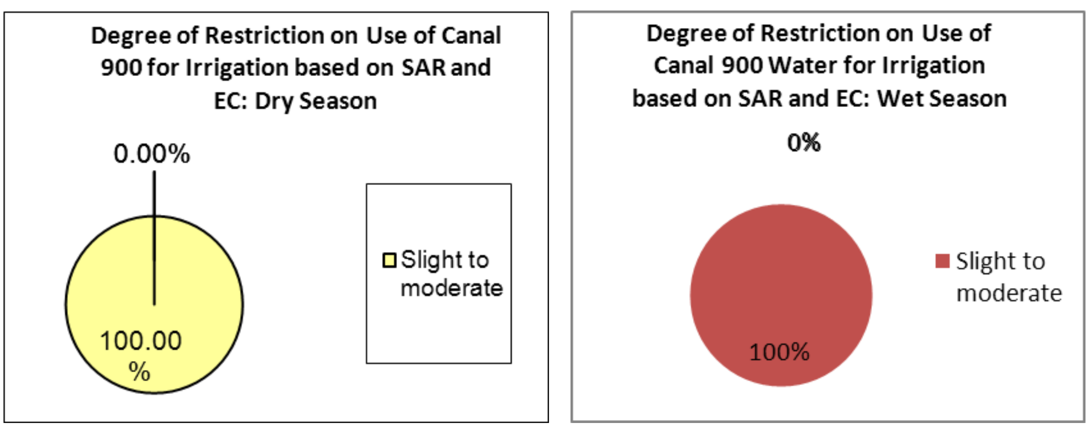


Figure 59. Degree of Restriction on Canal 900 Water Use for Irrigation Based on EC and SAR Levels

5.5.1.3. PLANT TOXICITY

As indicated before, the ions of major concern are chloride, sodium and boron and selective trace metals (Table 5). The degree of damage depends upon the duration of exposure, concentration of the toxic ion, crop sensitivity, and the volume of water transpired by the crop. In a hot climate or hot part of the year, accumulation is more rapid than if the same crop were grown in a cooler climate or cooler season when it might show little or no damage.

In reference to the levels of sodium in water associated with restrictive water use for irrigation (<70 mg/l minimal; >70 mg/l slight to moderate), results show that Canal 900 water is acceptable for irrigation for both the dry and wet seasons of the year (Figure 60).

As for the levels of chloride and in reference to limits associated with restrictive water use for irrigation (<100 mg/l none; >100 mg/l slight to moderate), results show that Canal 900 water is acceptable for irrigation as presented in figure 61.

As for Boron, the concentrations were below detectable levels to be associated with restrictive water use.

Additionally, based on restrictive water use associated with levels of bicarbonates in water (<90mg/l none; 90-500 mg/l slight to moderate; >500 mg/l severe), results show that the high bicarbonate levels of Canal 900 puts slight to moderate restrictions on water use for irrigation for both the wet and dry seasons of the year, as presented in figure 62.

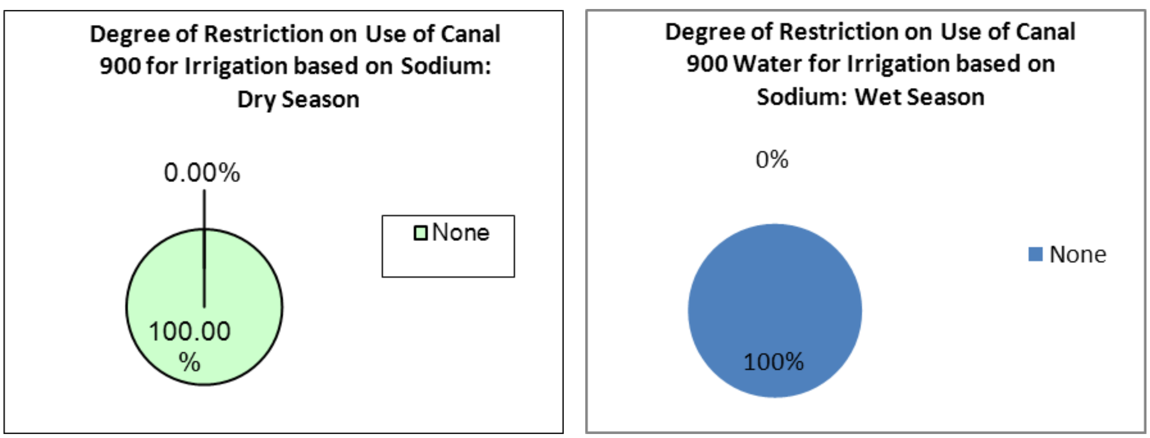


Figure 60. Degree of Restrictive on Canal 900 Water Use for Irrigation Based on Sodium Levels

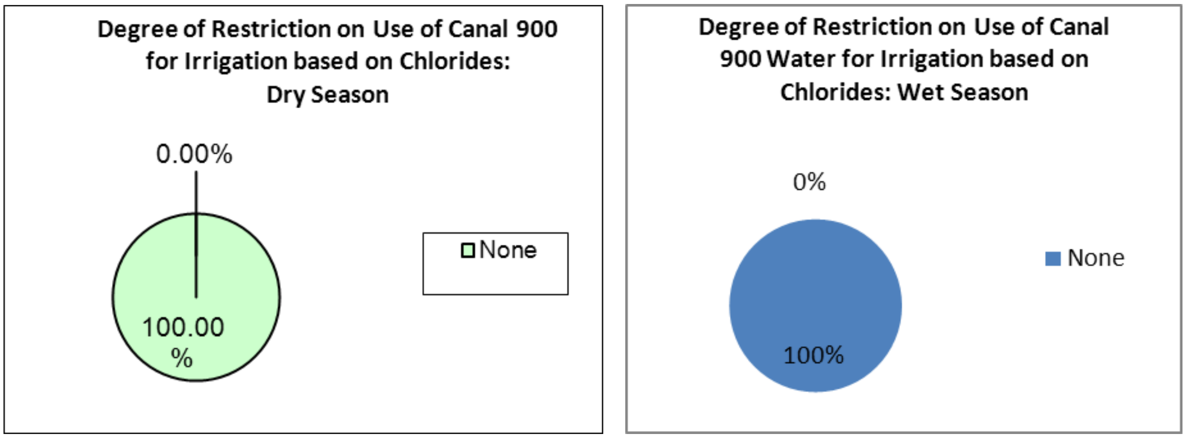


Figure 61. Degree of Restriction on Canal 900 Water Use for Irrigation Based on Chloride Levels

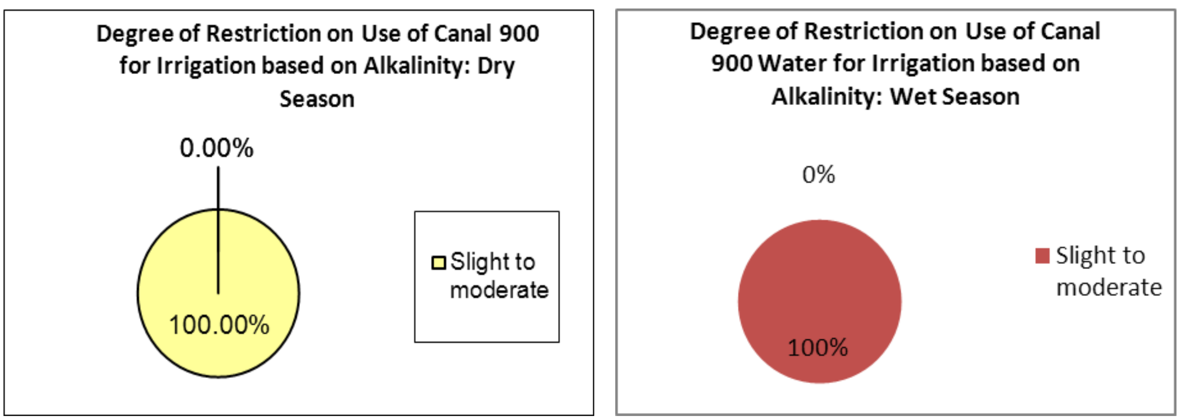


Figure 62. Degree of Restriction on Canal 900 Water Use for Irrigation Based on Bicarbonate Levels

Finally, in reference to the presence of toxic trace metals (table 7), and despite the addition of copper sulfate to control algae growth, results of the study (Appendix 8.2.4; Table: 8.2.4.e) show that the levels of trace metals are mostly below acceptable limits with the exception of cadmium and manganese for the dry season of the year. Still, only 20% of the canal water samples were tested for trace metals. As such, it is important to monitor water quality to verify levels of cadmium in irrigation water.

Additionally, evaluating the microbiological profile of canal 900 irrigation water sources for irrigation use all the sampled sites exceeded the total coliform count limit of 1000/100ml for the for the dry season and 72% of sampled sited for the wet season. But none exceeded the recommended level of 100/100ml for fecal coliforms for both the wet and dry seasons (Appendix 8.2.5; Table: 8.2.5.e). Yet, as will be discussed later, the residence time of microorganisms in soil and on crops is impacted by climate conditions, types of soil, availability of irrigation water, the type of crops to be grown, proper pest control and proper management strategies. On the other hand evaluating the water quality for irrigation in reference to the proposed National Standards (based on the biochemical oxygen demand levels and fecal coliform counts), results show that sampled sites fall within 1A category of irrigation water for the wet season and 1B category of irrigation water for the dry season.

5.5.2. WATER FOR LIVESTOCK USE

Based on the conductivity levels of all sampled water sites, the quality of spring water sources is suitable for use by livestock (reference to tables 7-10). Additionally, results of the study show that the levels of magnesium are also within the limits for both the dry and wet seasons. As such, the quality of the sampled irrigation water sites along canal 900 is suitable for drinking by all types of Livestock. Still, when evaluating the presence of trace metals in livestock drinking water results show that the main concern is the level of cadmium and for the end of peak of the dry season.

5.6.WASTEWATER QUALITY ASSESSMENT

5.6.1. DOMESTIC WASTEWATER (SEWAGE)

Agronomic and economic benefits can result from wastewater use in agriculture such as increasing the available water supply, safeguarding better quality supplies for other types of utilization, natural ecological water conservation, and reducing on the application of fertilizers (provision of nitrogen and phosphorous; required for agricultural crop production). Additionally, micronutrients and organic matter also provide additional benefits.

Yet, the suitability of raw, untreated wastewater for irrigation is governed by wastewater salinity, infiltration rate plant toxicity in addition to major issues associated with health risks (WHO 2006). As such, special management practices are essential to manage use, maintain good crop yields, and as important, reduce exposure to health risks.

5.6.1.1. SEWAGE SALINITY

Evaluating water quality based on the risk of increased soil salinity, results show that in reference to the levels of total dissolved solids (TDS) associated with restrictive water use, 75% of samples fall within the slight to moderate degree of restrictive use (dry season) in comparison to only 14 % of samples for the wet season as presented in Figure 63.

This is mostly due to the dilution of the total dissolved solids by the storm water drained through combined sewerage systems. Comparing to restriction associated with the use of river water for irrigation, 23% of sampled river sites fall within the slight to moderate category in comparison to restrictive use indicted for 5% of samples in the wet season.

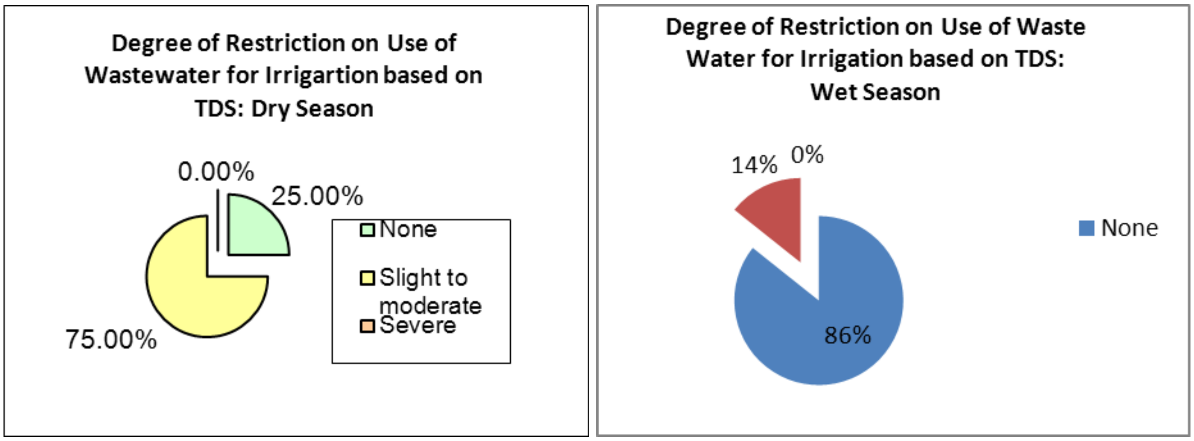


Figure 63. Degree of Restriction on Sewage Use for Irrigation Based on the TDS Of Wastewater Samples

5.6.1.2. WASTEWATER INFILTRATION RATE

As presented before, low salinity water or water with high sodium to calcium ratio will decrease infiltration. And, these factors can have an additive impact, especially if irrigation periods are prolonged to achieve adequate infiltration. Based of these two restrictive factors (EC and SAR Ratio), results of the study show that wastewater samples fall, mostly, for the dry season within the slight to moderate restriction for the wet and dry seasons.

5.6.1.3. PLANT TOXICITY

As indicated before, toxicity problems occur if certain constituents (ions) in the soil or water are taken up by the plant and accumulate to concentrations high enough to cause crop damage or reduced yields. As such, relating to the levels of sodium in sewage associated with restrictive sewage use (<70 mg/l minimal; >70 mg/l slight to moderate), results show that 34% the wastewater samples fall within the slight to moderate restriction category for the dry season in comparison to the wet season with no indicted restriction on use (Figure 64). This is mostly due to sewage dilution by storm water in combined collection systems.

As for chloride and in reference to levels associated with restrictive sewage use for irrigation results show that 75% of samples (dry season) in comparison to 29% of samples (wet season) fall within the slight to moderate restriction on use as presented in Figure 65. This is due to the dilution of the total dissolved solids by storm water in the combined sewerage systems.

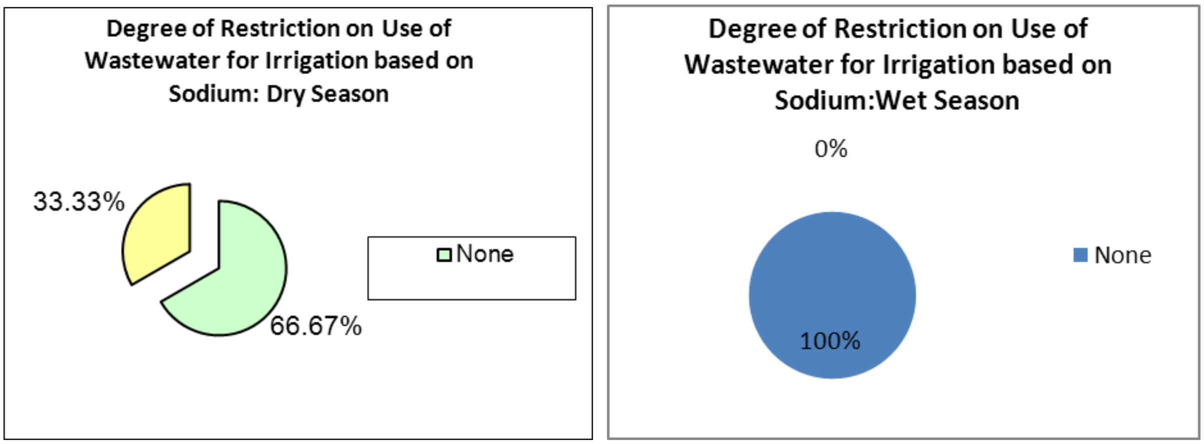


Figure 64. Degree of Restriction on Domestic Wastewater Use for Irrigation Based on Sodium Levels

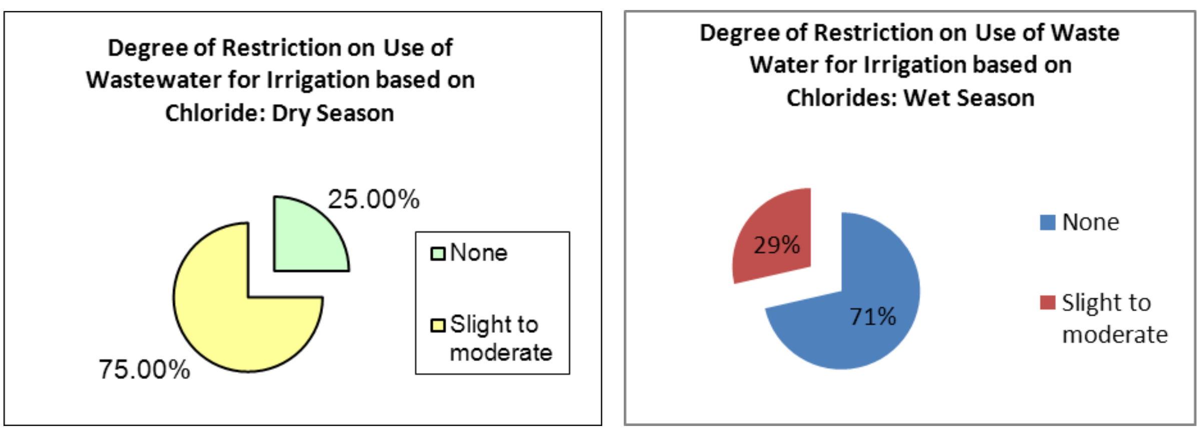


Figure 65. Degree of Restriction on Domestic Wastewater Use for Irrigation Based on Chloride Levels

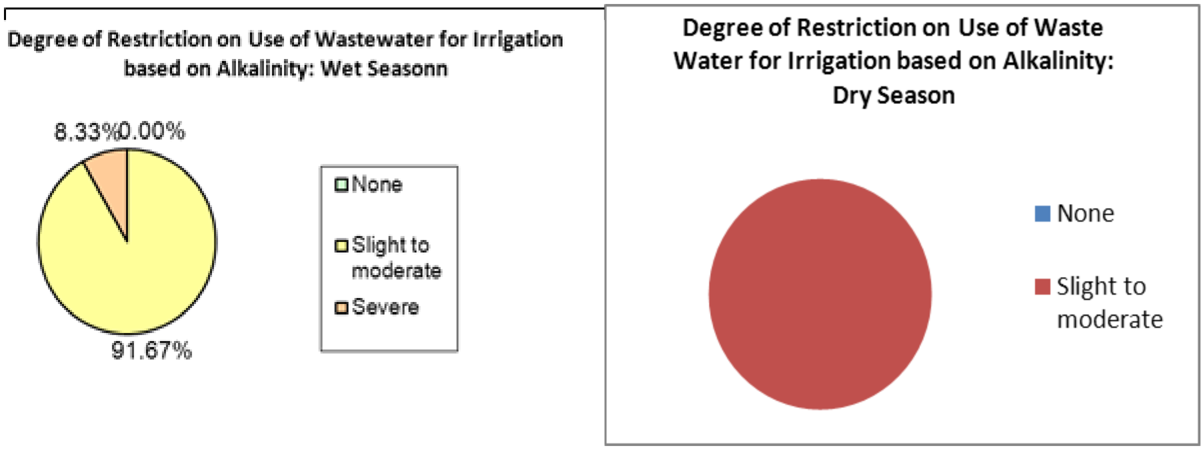


Figure 66. Degree of Restriction on Domestic Wastewater Use for Irrigation Based on Bicarbonate Hardness Levels

Additionally, in reference to boron in water, levels were below detectable limits to be associated with restrictive water use. As for bicarbonate hardness results show that wastewater samples (wet and dry seasons) fall mostly within the slight to moderate to strict category of restriction on use, as presented in Figure 66.

Moreover, in reference to the presence of toxic trace metals and the corresponding categories of restrictive water use, results (Appendix 8.2.5.1; Table: 8.2.5.1.e) show that the levels (wet and dry seasons) are not coupled with restrictive water use for irrigation.

On the other hand evaluating the wastewater quality for irrigation use in reference to the proposed national standards for reclaimed wastewater use in agriculture, results show that relatively high BOD levels and fecal coliform load, even in winter, restrict domestic wastewater use for direct crop irrigation.

5.6.1.4. HEALTH RISKS ASSOCIATED WITH WASTEWATER USE

Wastewater or natural water supplies exposed to wastewater discharge are likely to contain pathogenic organisms similar to those in the original human excreta (WHO 2006):

Bacteria**;** associated mostly with diarrhea (the most prevalent type of infection), cholera, typhoid, paratyphoid and other *Salmonella* type diseases.

Viruses; of particular importance the adenoviruses, enteroviruses (including polioviruses), hepatitis A virus, reoviruses and diarrhoea-causing viruses (especially rotavirus).

Protozoa; of particular importance *Giardia lamblia, Balantidium coli* and *Entamoeba histolytica*.

Helminths; mostly do not multiply within the human host, however, soil, water or plant life can act as intermediate hosts for the propagation of the disease agent

The survival time of pathogens in fresh water and sewage is presented in table 15. The survival times may however, may be altered by the type or degree of sewage treatment prior to use or discharge into the water body. As most sewage treatment is designed to reduce organic pollution some pathogenic organisms will reach the agricultural fields when the water is used. As such, whether sewage is treated, partially treated, or untreated water, pathogenic organisms will be present and as such, site management to minimize or eliminate the potential risks is essential.

Table 15. Survival Times of Excreted Pathogens in Freshwater and Sewage at 20-30°C

Pathogen	Survival time (days)
Viruses[a]	
Enteroviruses[b]	<120 but usually <50
Bacteria	
Faecal coliform[a]	<60 but usually <30
Salmonella spp.[a]	<60 but usually <30
Shigella spp.[a]	<30 but usually <10
Vibrio cholera[c]	<30 but usually <10
Protozoa	
Entamoeba histolytica cysts	<30 but usually <15
Helminths	
Ascaris lumbriocoides eggs	Many months

Source: FAO, 1997

Mostly all excreted pathogens can survive in soil for periods of time exceeding the survival on crops that are directly exposed to sunlight and desiccation. Nevertheless, survival times can be long enough in some cases to pose potential risks to crop handlers and consumers (the survival times of selected excreted pathogens in soil and on crop surfaces are presented in table 16).

Table 16. Survival Times of Selected Excreted Pathogens in Soil and on Crop Surfaces at 20-30°C

Pathogen	Survival time (days)
Viruses[a]	
Enteroviruses[b]	<120 but usually <50
Bacteria	
Faecal coliform[a]	<60 but usually <30
Salmonella spp.[a]	<60 but usually <30
Shigella spp.[a]	<30 but usually <10
Vibrio cholera[c]	<30 but usually <10
Protozoa	
Entamoeba histolytica cysts	<30 but usually <15
Helminths	
Ascaris lumbriocoides eggs	Many months

Source FAO, 1997

As such, the determining factors for sewage use include climate conditions, types of soil, availability of irrigation water, the quality of the wastewater to be used, the type of crops to be grown, proper pest control and proper management strategies. Focusing on exposure to public health risks, the level of the risk can be classified in the following manner (Christofer *et al.* 2010):

"Lowest risk to consumer (field worker protection needed):

Crops not for human consumption (for example cotton, sisal).

Crops normally processed by heat or drying before human consumption (grains, oilseeds, sugar beet).

Vegetables and fruit grown exclusively for canning or other processing that effectively destroys pathogens.

Fodder crops and other animal feed crops that are sun-dried and harvested before consumption by animals.

Landscape irrigation in fenced areas without public access (nurseries, forests, green belts)".

"Increased risk to consumer and handler";

Pasture, green fodder crops.

Crops for human consumption that do not come into direct contact with wastewater, on condition that none must be picked off the ground and that spray irrigation must not be used (tree crops, vineyards, etc.).

Crops for human consumption normally eaten only after cooking (potatoes, eggplant, beetroot).

Crops for human consumption, the peel of which is not eaten (melons, citrus fruits, bananas, nuts, groundnuts).

Any crop not identified as high-risk if sprinkler irrigation is used".

“Highest risk to consumer, field worker and handler “
Any crops eaten uncooked and grown in close contact with wastewater effluent (fresh vegetables such as lettuce or carrots, or spray-irrigated fruit).
Landscape irrigation with public access (parks, lawns, golf courses).

5.6.2. INDUSTRIAL WASTEWATER QUALITY ASSESSMENT

Industrial wastewater effluents these should not be used for irrigation mostly due to problems associated with soil salinity and crop toxicity mostly due to the high levels of total dissolved solids, high BOD levels bicarbonate alkalinity and fecal microbial loads as presented in appendix 8.2.5.2; table 8.2.5.3.a,b.c,d)
Moreover, relatively high overall mean levels (0.8490 mg/l) of Barium were detected in industrial wastewater samples in comparison to domestic wastewater (0.3860mg/l) (Appendix 8.2.5.2; Table 8.2.5.2.b). This reflects on the major source of pollution leading to the increase in barium levels in surface water.
As such, the industrial sector is mostly contributing to the increase in the levels of barium in the water and soil sediments, whereas increased levels of cadmium and manganese may be attributed to agricultural (fertilizers and pesticides) and industrial activities along the river and its tributaries and solid waste dumping.

5.7. SOIL QUALITY ASSESSMENT

Soil is the product of weathering of rocks and mineral deposits and represents the interaction between the atmosphere, the biosphere and hydrosphere. The presence of heavy metals in large amounts in soils can be harmful to plants, animals, and people. Heavy metal content of soils is of major significance in relation to

their fertility and nutrient status. Metals such as Zn and Cu are essential elements for normal growth of plants and living organism. However, high concentration of these elements becomes toxic. Other metals like Cd, As, Pb, Hg in low concentration, may be tolerated by the ecosystem, but they may become harmful in higher concentration. Recently a great deal of concern has been expressed over problem of soil contamination with heavy metals due to rapid industrialization and urbanization (Skordas & Kelepertsis, 2005; Govil et al., 2008).
Metals can bioaccumulate in plants and animals eventually reach humans through food chain (Skordas & Kelepertsis, 2005; Govil et al.., 2008). Soil samples represent an excellent media to monitor heavy metal

pollution as they deposit in topsoil. Furthermore, soils do not only serve as sources for certain metals but also function as sinks for metal contaminants. Generally, the detection of pollutant sources of metals in soil is more explicit in the dry season. The variables are limited and existing state can be considered as a steady state and/or closed system. Whereas, in the wet season, the dynamic flow due to running water, leaching and/or erosion of soil and weathering of rocks and deposition in soil constrains the justification of the point pollutant source. Yet, the amounts of metals in soil in the wet season would reflect on metal contamination. Additionally, the metal content in wet season could become of lower than the content of the dry, due to dilution from upper clean soil and eroded material, and/or dissolution due to wet acidic conditions. Thus, metals arising from anthropogenic sources generally prevail less in soils in wet season. The upper Litani Basin remain to be exposed during wet season (as previously indicated for the dry season) to various sources of point and non point sources of pollution as presented in appendix 8.1. Nevertheless, heavy industries are minimal, and the main activities relate mostly relate to food processing plants, textiles and paper industries. Hence, it is important to determine the content of heavy metals (As, Ba, Cr, Co, Cu, Mn, Mo, Ni, Pb &Zn) in soils of the dry and wet seasons.

The sources of metals and the associated health risks are presented in Table 17. The collected soil samples from the Upper Litani Basin are referred to soil samples and the soil samples irrigated with Irrigation Canal 900 are referred to as canal soil samples. The discussion will focus primarily on the metal content detected in the wet season soils. The analytical results of wet season are presented in appendix 8.26. The soil chemical profile is compared to the Canadian Soil Quality Guidelines for the Protection of Environmental and Human Health as presented in Table 18 (CCME, 1999).

Table 17. Sources of Metals and Related Health Risks

Metal	Source	Projected Health Risk
As	Pesticides, Wood Preservatives, and Glass Products.	Liver and Nervous system damage, Cancer.
Ba	Cement, Ceramic glazes, Glass and Paper making, Pharmaceutical and Cosmetics products.	Little is known about possible health effects. The degree of absorption depends on solubility of compound. High amounts > 2 mg/L- cardiovascular diseases.
Cd	Batteries, Plastics, Fertilizers, Pesticides, Paints & Electroplating.	Bone and Cardiovascular diseases, Cancer, liver and nerve cell damage.
Co	Alloys, Ceramics and Paints	Respiratory Irritation, Heart damage and failure and Thyroid Problems
Cr	Stainless steel, Alloy, Cast Iron, Pigments and Wood treatment, and Tanneries.	Cr (III) has bioavailability and toxicity than Cr (VI). However high doses of both cause gastrointestinal irritation, Stomach ulcer, kidney and liver damage, Cr (IV) is Carcinogenic.
Cu	Smelting and Metal plating operations, Fertilizers and Animal Feeds, Electrical works, Pesticides and Fungicides.	Gastrointestinal diseases, Anemia, Liver and Kidney damage.
Hg	Electrical Industry, Paints, Pesticides and Fungicides.	Adrenal disfunction, Brain and Central Nervous System Damage, Haring loss. Research suggests that it may contribute to autism and multiple sclerosis.
Mn	Steel and Alloys; $MnSO_4$ used as Fertilizer, Ceramics, and Fungicide, MnO_2 dry-cell batteries, fireworks, and $KMnO_4$ used as disinfectant	Little is provided for its toxicity or health and it is related to water hardness.
Mo	Steel and Alloys, fertilizers, ceramics and plastics.	Highly toxic and associated with Liver disfunction , joint pains articular deformities, erythema, and edema of the joint areas.
Ni	Alloys, Electroplating, Ceramics, Pigments, Alkaline Batteries, Catalyst in Plastic and Rubber Industry.	Gastrointestinal Distress and Intestinal Cancer, Kidney and Heart Damage, dysfunction.
Pb	Smelting operation, Automobile Emission, Urban runoffs, Pesticides, Plastics, Paints and Ceramic Glaze.	Central Nervous system and Kidney damage. Fecal Development, Delay growth and Learning Disabilities.
Zn	Galvanization works, motor oil, Tire wear, Pigments, and Pesticides.	Little is known about long term effects of ingesting Zn from food or water. It might cause anemia and pancreas damage.

(Source: Perfect Life Institute, 2002)

Table 18. Canadian Environmental Quality Guidelines for Soils

Parameter	Agricultural use(mg/kg)
Arsenic (As)	12
Barium (Ba)	750
Cadmium (Cd)	1.4
Chromium (Cr)	64
Cobalt (Co)	40
Copper (Cu)	63
Lead (Pb)	70
Manganese (Mn)	470*
Molybdenum	5
Mercury (Hg)	6.6
Nickel (Ni)	50
Zinc (Zn)	200

Source: Adapted from Alloway, 2005

Results show that Molybdenum (Mo) and Cobalt levels (Co), whether in soil or canal-soil samples, were below detection limits; this is concurrent with results of the dry season. While barium (Ba) was detected in 58 % of soil samples and 25 % of canal soil samples, (Figure 67); but the levels were below Canadian guidelines for agricultural use. Additional, the levels of Ba detected in the wet season for both soil and canal soils were far below those detected in the dry season.

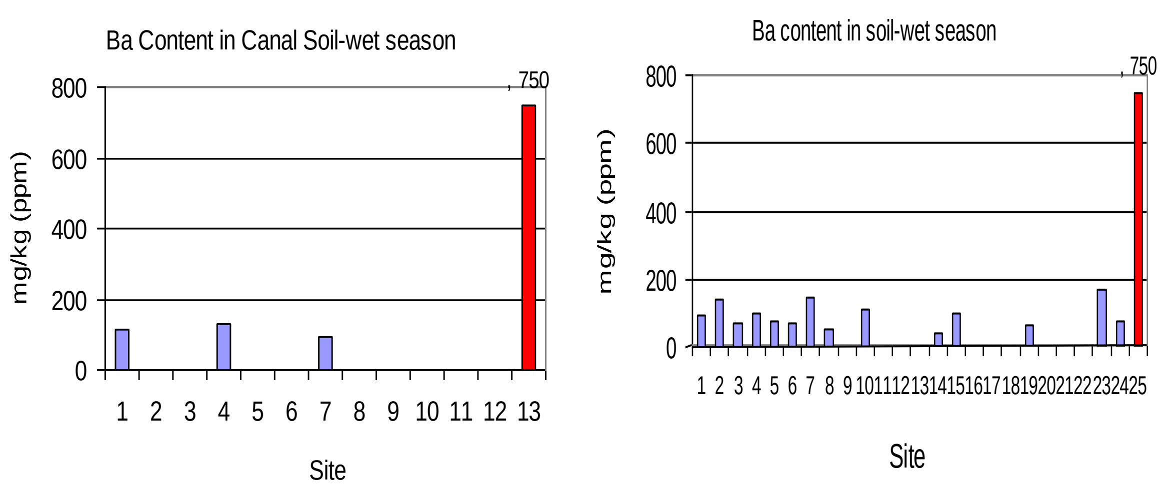


Figure 67. Barium Analytical Profile in Soil (mg/kg) of the Wet Season

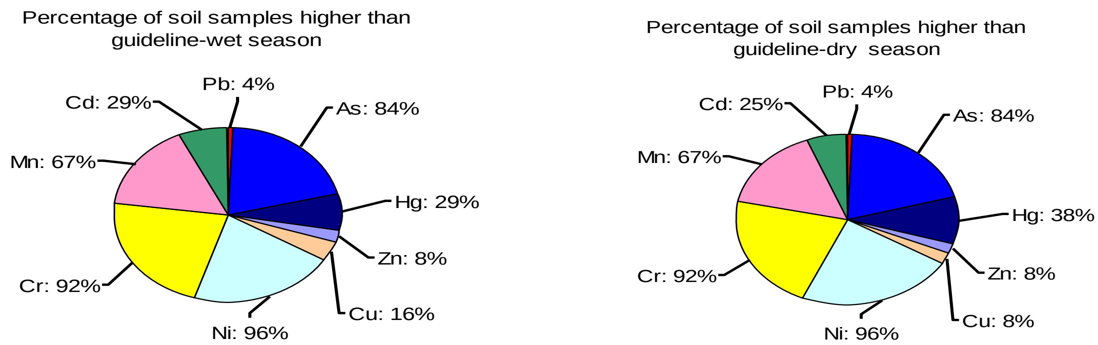


Figure 68. Percentages of Analyzed Soil Samples (wet and dry season) higher than the Canadian Guideline levels for Agricultural Use

Table 19. Metal Content in Soil (Dry and the Wet Seasons of the Year)

Parameter	Metal in Soil – Dry season				Metal in Soil – Wet season			
	SD	Min	Max	Mean	SD	Min	Max	Mean
As (mg/kg)	5.6	6	28	17.6	5.8	7.9	28.4	17.5
Ba (mg/g)	100	0.01	358	202	55	0.01	171	54
Cd(mg/kg)	5.1	0.01	15	2.8	3.2	0.01	7.8	2.02
Cr(mg/kg)	57	35	272	143	44	35	210	135
Cu(mg/kg)	24	23	147	47	30	33	162	62
Hg(mg/kg)	3.5	0.01	8	3.8	4.2	0.01	11.7	3.6
Mn(mg/kg)	271	123	1226	593	342	200	1495	715
Ni(mg/kg)	23	48	140	98	32	40	187	90
Pb(mg/kg)	35	0.01	164	14	26	0.01	127	11
Zn(mg/kg)	66	33	299	95	57	42	355	109

As for lead similar pattern for the levels of the wet and the dry season soil samples were exhibited; this is also indicated by the Paired Sample T-test that showed no statistical significant differences (P= 0.257). Only 4% (one site) of wet season soil samples (Figure 68) exceeded the Canadian guideline by more than 1.79 fold (Figure 69). The source of this metal is most probably due to solid waste dump of asphalt industry of Al-Marj village. However, all soil canal samples were far below the Canadian guideline level and 75 % of samples were below detection limits.

Moreover, the mean Pb levels in soils were reduced during wet season (Table 19). This reduction in Pb levels of wet soil samples is most probably due to a wash process and dissolving resulting from the wet season higher acidic conditions.

Also, only 8% (2 sites) of wet season soil samples (Figure 70) had Zn levels higher than the Canadian guideline level (Zn: 200 mg/kg); which is same percentage of the dry season (Figure 68). But, all soil canal samples had zinc at lower levels than the Canadian guideline. Moreover, mean seasonal variation in Zn levels was insignificant for both soil samples and soil canal samples (dry-soil: 109 mg/kg and wet soil: 95 mg/g; dry canal soil: 138 mg/kg; wet canal soil: 136 mg/kg).

Table 20. Metal Content in Canal Soil (Dry and Wet Seasons of the Year)

Parameter	Metal in Canal Soil – Dry season				Metal in Canal Soil – Wet season			
	SD	Min	Max	Mean	SD	Min	Max	Mean
As (mg/kg)	6	9	26	19	7	7	28	18
Ba (mg/g)	94	43	315	209	152	0.01	132	29
Cd(mg/kg)	5.9	0.01	14	3.6	3.5	0.01	10	1.8
Cr(mg/kg)	83	100	350	202	89	10	236	129
Cu(mg/kg)	11	36	73	56	26	30	119	64
Hg(mg/kg)	3.9	0.01	9	3	3.3	0.01	7.5	3.5
Mn(mg/kg)	288	307	1133	603	298	343	1175	736
Ni(mg/kg)	54	98	247	156	36	61	240	128
Pb(mg/kg)	4	0.01	13	1.6	6.5	0.01	21	1.8
Zn(mg/kg)	43	60	197	136	41	60	198	138

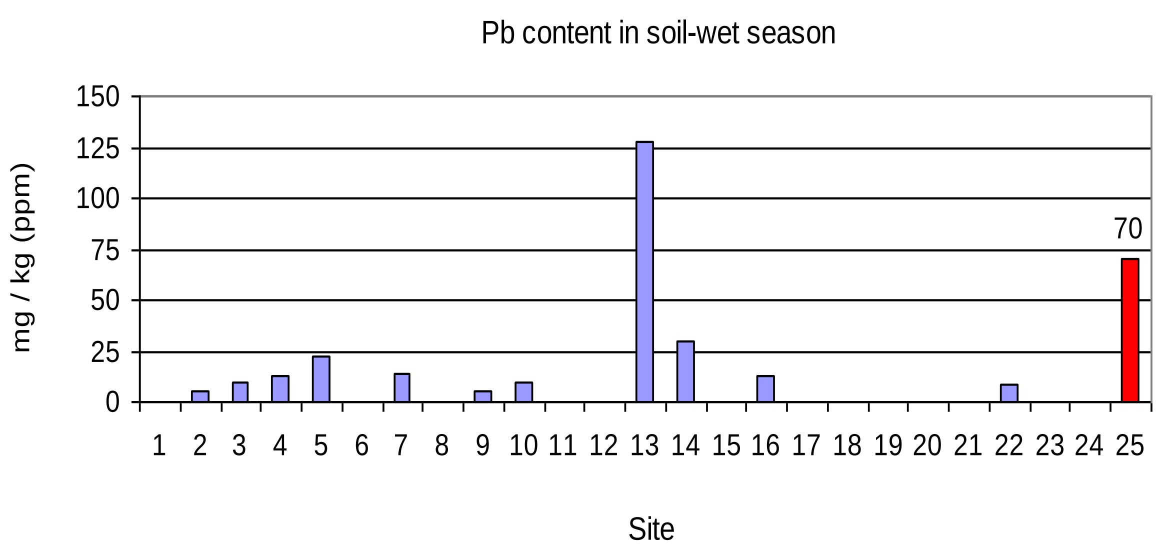


Figure 69. Lead Analytical Profile in Soil (mg/k): Wet season

Whereas, Cu showed higher mean levels in the wet season in comparison to the dry (Table 19) and a higher percentage of the samples have Cu levels higher than the Canadian guideline level (Cu: 63 mg/kg) for both soil samples and soil canal samples (Figures 68). This variability among sites of Cu levels in wet season soil and canal soil are presented in Figure 71.

Moreover, the Paired Sample T test showed seasonal statistical significant difference for both soil samples (P= 0.022) and canal soil samples (P= 0.004). The higher level of Cu during wet season may be attributed to a number of factors such as higher waste dumping and discharge, dissolution of channel copper complexes due to wet season acidic conditions, and leaching of copper from fertilizers.

This observation can be deduced from the high and highest levels of Cu in wet season canal soils of Jeb Jenine and Baaloul that indulge in agricultural activities.

Copper can also be found in fertilizers (Perfect Life Institute, 2002), and copper sulphate is added to control algae growth in the irrigation canal. Furthermore, similar to dry season, Zn and Cu wet season soils exhibited strong significant correlation (r=0.76, p <0.01). The sources of these metals are geological (primarily for Zn) and anthropogenic (solid waste dumps in Ferzol and Al Marj).

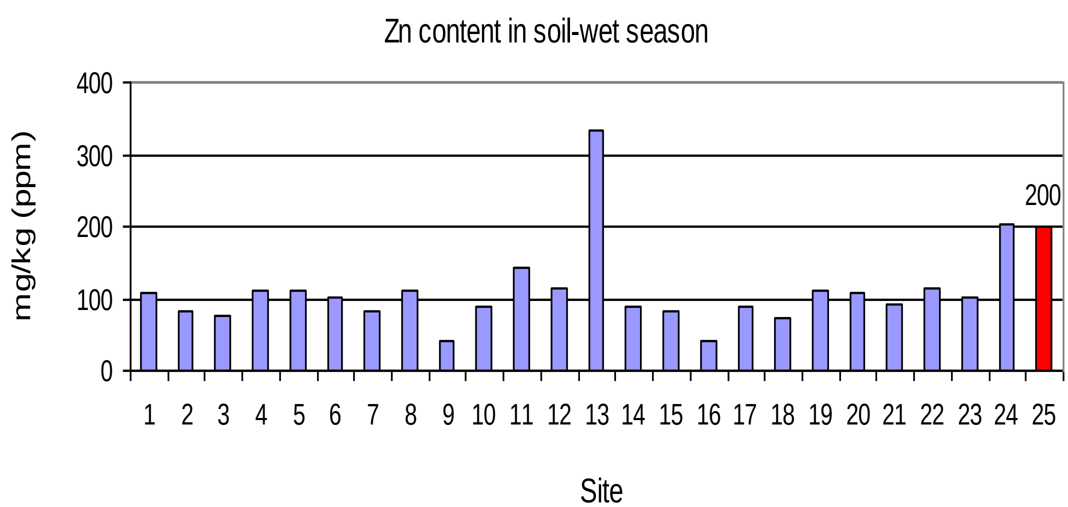


Figure 70. Zinc Analytical Profile in Soil (mg/k)-wet season

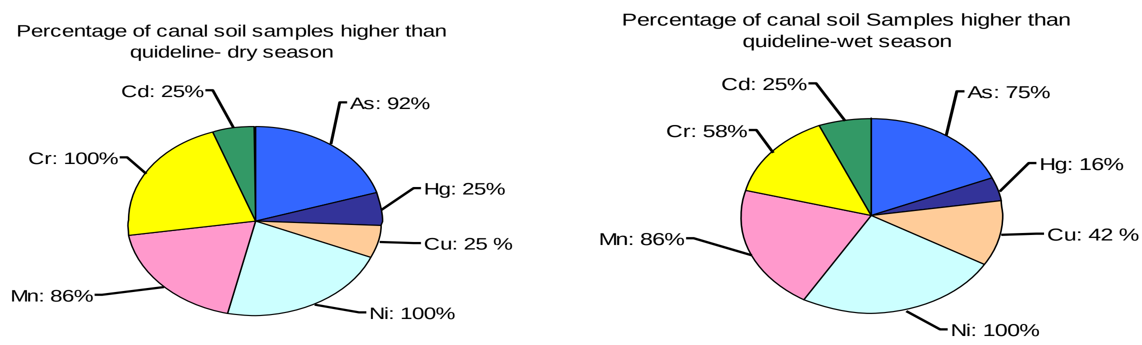


Figure 71. Percentages of Analyzed Canal Soil Samples (wet and dry season) Higher than the Canadian Guideline Levels for Agricultural Use

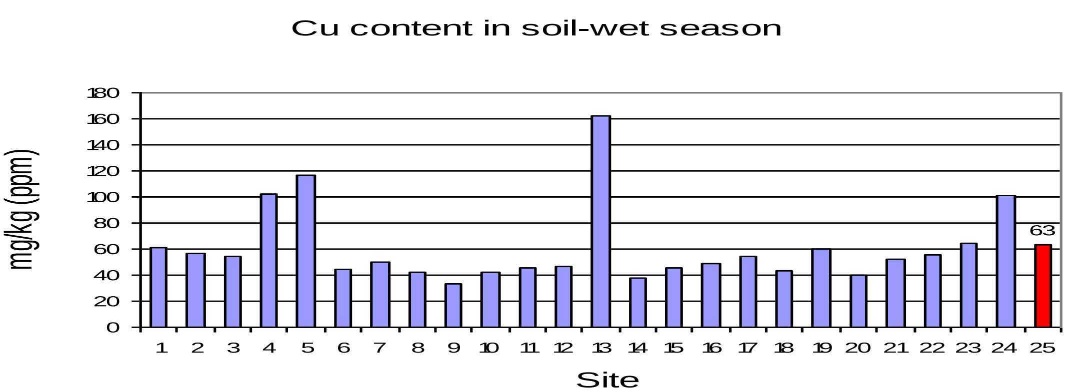


Figure 72. Copper Analytical Profile in Soil (mg/k)-wet season

As for nickel (Ni) levels in wet soil and canal soil are higher than the Canadian guideline for agricultural use (Ni: 50 mg/kg). Whereas, 58 % of canal soil samples showed higher Cr levels (Figures 71 and 74). The mean seasonal variation in Ni levels of both soil samples (Table 19) and canal soil samples (Table 20) were nearly insignificant (dry-soil: 98 mg/kg and wet soil: 90 mg/g; dry canal soil :156 mg/kg; wet canal soil: 128 mg/kg). Thus, the Ni content in soils is primarily a natural one, justifying the seasonal statistical insignificance difference of the of the Paired Sample T test (P= 0.227). Furthermore, though Ni appeared to be in soils from natural sources. Additionally, it is contributed by sources of pollution as indicated by the statistical significant correlation (r=0.71, p< 0.01).

On the other hand, the mean Cr seasonal variation were comparable in soil samples (dry-soil: 143 mg/kg; wet-soil: 135 mg/kg), but reduction in mean canal soil levels were indicated in the wet season (dry canal soil: 202 mg/kg; wet canal soil: 129 mg/kg). Moreover, sites of high content in the dry season were indicated to become lower than the Canadian guidelines. Therefore, Cr content in soils is primarily anthropogenic. This emphasizes the seasonal statistical significant difference of the of the Paired Sample T test (P= 0.004).

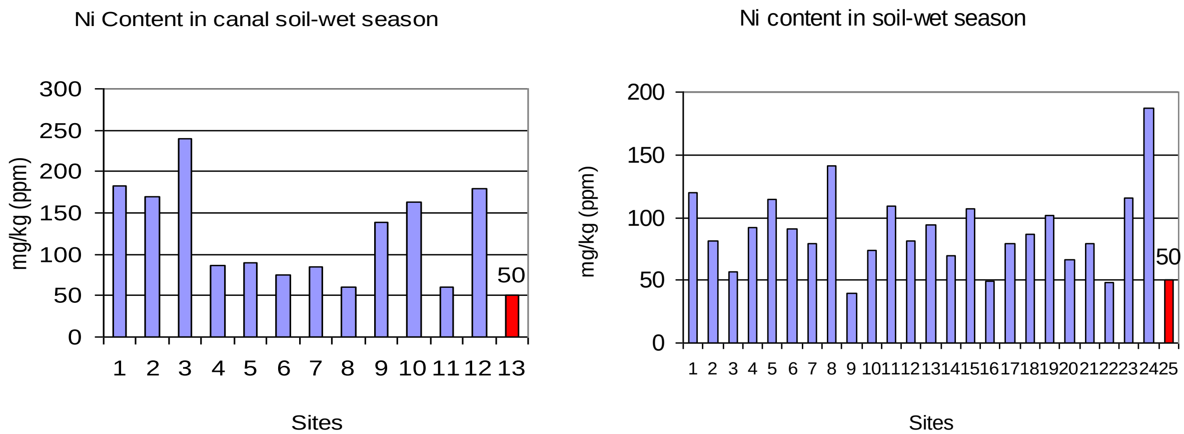


Figure 73. Nickel Analytical Profile in Soil (mg/k)-Wet season

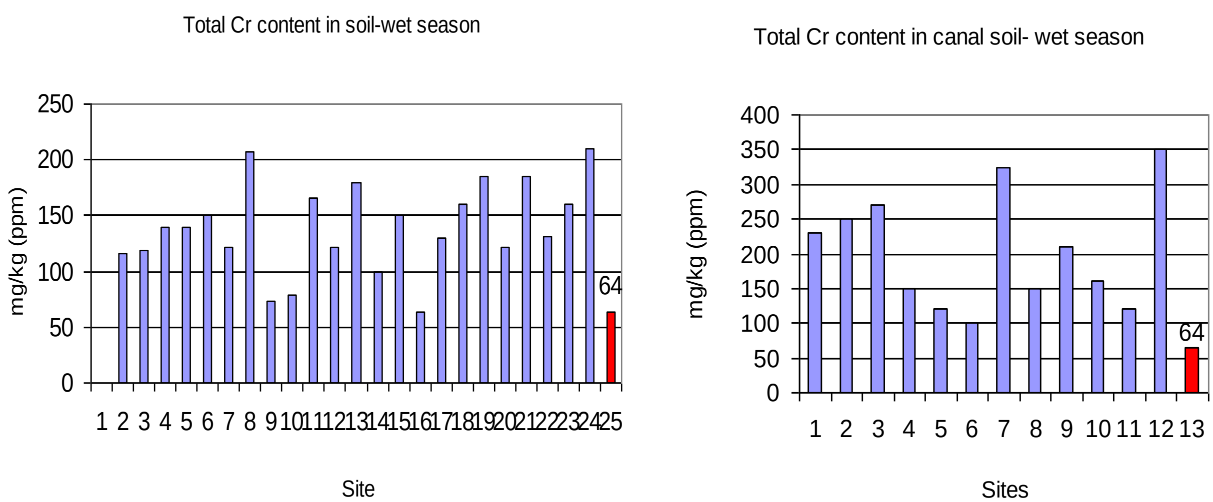


Figure 74. Chromium Analytical Profile in Soil (mg/k)-Wet season

Nickel and Chromium are mostly associated with multi-industrial activities, (a stainless steel, alloys, ceramics, plastic, rubber, tannery industries as presented in Table 20. Such small-scale industrial activities run all through Upper Litani Basin (ULB).

Furthermore, the impact of agricultural runoff remains to be, in the wet season, the main contributor to the levels of arsenic, mercury and cadmium. For As; 84% of wet season soil samples (Figure 68) showed levels above the Canadian guideline for agricultural use (As: 12 mg/kg) ranging for arsenic between 7 mg/kg to 28 mg/kg (Figure 75). The minimal variability in levels of the wet and dry seasons is confirmed by the lack of statistical significance of the Paired Sample T-test (P= 0.749). Whereas, 74 % of wet canal soil samples (Figure 71) showed levels of As higher than guideline level (between 7 mg/kg to 28 mg/kg) (Figure 75).

Also, the percentage of As in soils irrigated with canal water in the wet season is lower than those of dry season (Figure 68), yet no statistical significant differences was exhibited by the Paired Sample T-test (P=0.513). As such, As is mainly contributed by agricultural runoff water (As is a constituent of pesticides). Soils collected east and west of canal, mainly in Jeb Janin and Baaloul, have high arsenic levels (≅28 mg/kg). These areas are mainly agricultural.

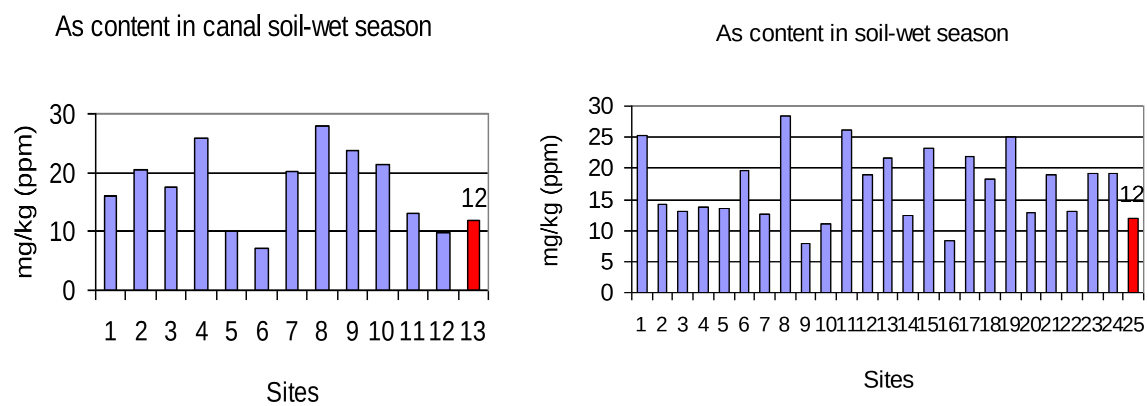


Figure 75. Arsenic Analytical Profile in Soil (mg/k)-Wet Season

Additionally, Hg levels in wet soil and canal soil samples were higher by about 2 fold in some samples in comparison to the Canadian guideline of 6.6 mg/kg (Figure 76). Mercury levels ranged between minimal and 11 mg/g for soil samples, and for canal soils between undetectable and 9 mg/kg. Twenty nine percent of soil samples have levels higher than the guideline, and 16 % were higher in soil samples irrigated by canal.

Furthermore, though samples with high mercury levels were less in wet season soils and canal soils, yet the mean seasonal levels were similar (≅3.1 mg/kg). The highest Hg level in wet season is still in Ferzol (11 mg/kg), mainly due to agricultural activities and solid waste dump sites (Figure 76). This is also indicated by the lack of seasonal statistical difference of the Paired Samples T-test (P=0.969).

As for cadmium, 29 % of wet season soil samples and 25 % of canal soil samples levels were higher than the Canadian guideline level of 1.4 mg/kg (Figure 68, Figure 71). Cadmium is a constituent of pesticides and fertilizers, thus high levels of Cd are to be expected in agricultural sites (Figure 76).
The highest detected value of Cd (10 mg/kg) as at the agricultural site of Jeb Jenine, this level is higher by 7 folds than the guideline level. Additional, the Paired Samples T-test indicated a lack of seasonal statistical significant differences (P=0.546).

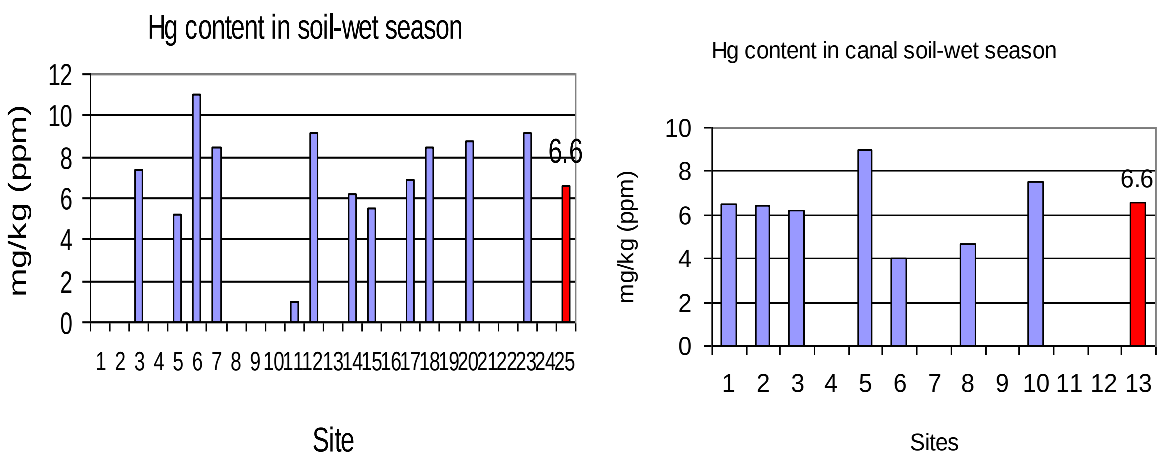


Figure 76. Mercury Analytical Profile in Soil (mg/k)-Wet Season

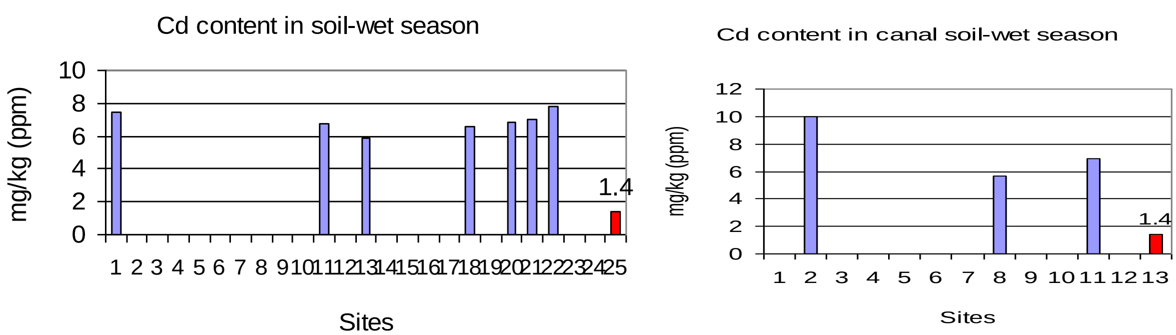


Figure 77. Cadmium Analytical Profile in Soil (mg/k)-Wet Season

Lastly, manganese levels in 67% of wet season soil samples and 83% of canal soil samples (Figures 68 and 71) were higher than the Canadian guideline level of 500 mg/kg. These percentages are comparable with levels of the dry season. Moreover, the Paired sample T test indicated lack of seasonal statistical differences (P= 0.678). Manganese levels in soils may be attributed to the geological formation, especially since Mn exists in coincidence with Fe; or may result additionally due to existing agricultural and industrial activities (steel and alloy, fertilizers, fungicides and fireworks). Moreover, a strong statistical signification correlation is indicated for Mn and As (soil: 0.837, p <0.01; canal soil: r= 0.747, p < 0.01).

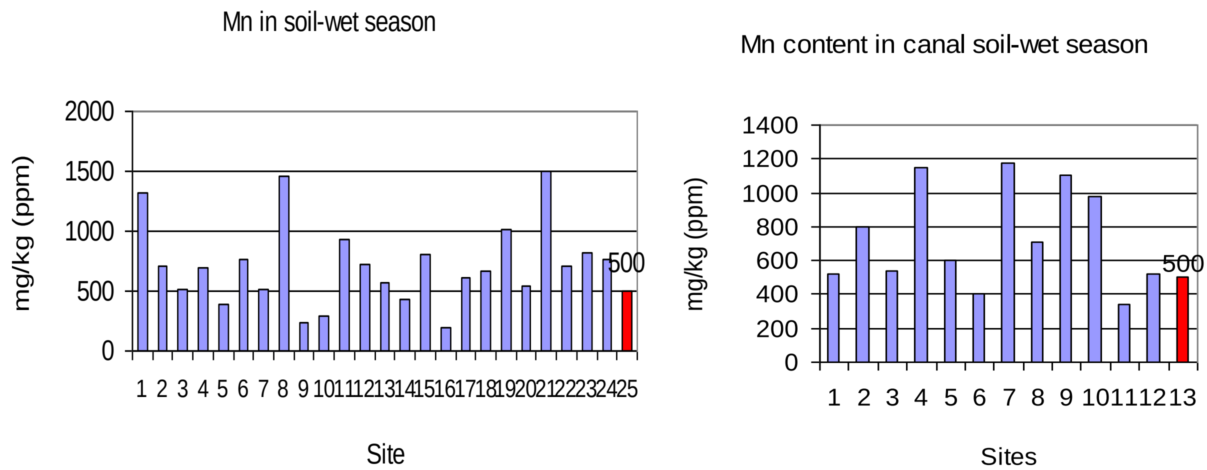


Figure 78. Manganese Analytical Profile in Soil (mg/k)-wet season

5.8.SEDIMENTS QUALITY ASSESSMENT

Sediments are sinks for heavy metals entering rivers from anthropogenic sources, such as industrial and municipal wastewater effluents, land-fill leacheat, and agriculture runoff. Many trace metals of toxicological significance (e.g. As, Cd, Hg, Pb) have low solubility's in the at pH levels of natural waters, and river sediments are the sink holes of such trace metals (Korfali & Davies, 2005, Korfali et al.., 2006). Similar to soil, sediments are considered as excellent media for monitoring contaminating levels of heavy metal. Moreover, the detection of pollutant sources of metals in sediments is more explicit in the dry season. In the wet season, metal concentration in sediments might be lower due to dilution from upper clean sediment and eroded soil material, and/or dissolution due to wet acidic conditions, or it could be higher due to higher oxidizing wet season conditions and higher organic contents from runoffs.

The haphazard continuous dumping and disposal of industrial and domestic wastes into the Litani River and tributaries has been previously discussed for the dry and wet season. While it is well known that most potential pollutants in aquatic sediments are nontoxic/unavailable forms, there are situations where sufficient concentrations of potential pollutants are present to harm aquatic organisms and consequently released to the overlying water column. Furthermore, aquatic sediments can accumulate in aquatic species and become a threat to human health as a result of their consuming these aquatic organisms as food. Thus, as in soils, it is of importance to determine the content of heavy metals in the alluvial sediments of the dry and wet season. The discussion in this study is primarily for the metal content in the wet season sediments. Previous work has been conducted and accomplished for the dry season, but, highlights of the dry season are still necessary. Sediment samples of the wet season collected from same sampling sites of the dry season from Upper Litani River Bed are referred to as (SE), and sediments collected from the Qaraoun Lake are denoted as (SEQ).

Table 21. Sediment Quality Criteria and Guidelines

Parameter	Fresh Water Sediments		
	ISQG[1] (mg/kg)	PEL[2] (mg/kg)	SOG[3] (mg/kg)
Arsenic (As)	5.9	17	-
Barium (Ba)	-	-	189
Cadmium (Cd)	0.6	3.5	-
Chromium (Cr)	37.3	90	-
Copper (Cu)	35.7	197	-
Lead (Pb)	35	91.3	-
Manganese (Mn)	-	-	490
Mercury (Hg)	0.17	0.486	-
Nickel (Ni)	-	-	-
Zinc (Zn)	123	315	-

[1]Canadian Interim Sediment Quality Guideline [2]Canadian Probable Effect Level

[3]Texas Sediment Quality Guideline

Results show that Molybdenum (Mo) and Cobalt levels (Co), in all wet season sediment samples were below detection limits; this is concurrent with those of the dry season. Whereas barium (Ba) sediment wet season was detected at levels below Texas sediment quality guideline values (SQG: 189 mg/kg)' and the mean Ba levels in wet season are lower by seven fold those of dry season (Figure 79 and table 22). The lower value of Ba in wet season is most probably due to dilution by eroded clean soils and/or upper channel sediments.

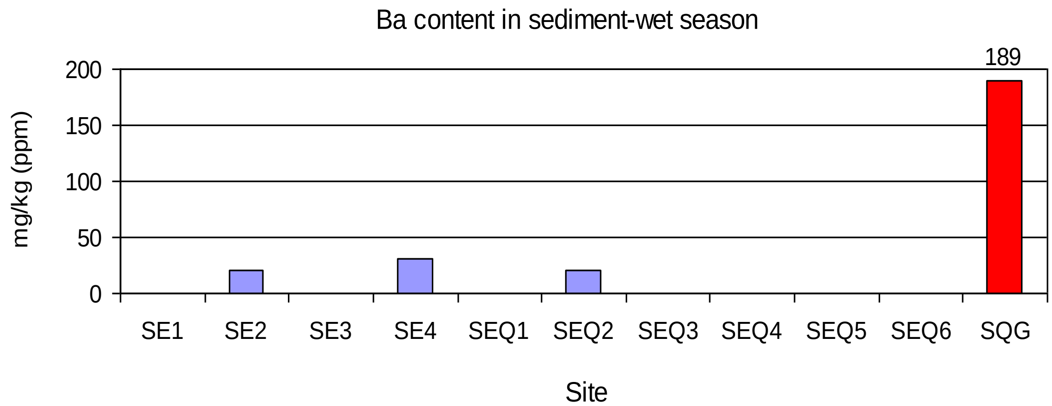


Figure 79. Barium Analytical Profile in Sediments (mg/k): Wet Season

However, manganese (Mn) sediment wet season was detected at levels below the Texas sediment quality guideline values (SQG: 490 mg/kg), except at one site (550 mg/kg). The mean concentration of the wet season was slightly higher than those of the dry season (Figure 80 and Table 22). This could be attributed to oxidizing conditions of wet season and association with iron oxyhydroxide (Korfali and Davies, 2005). Similarly, levels of lead (Pb) levels of most wet season sediment samples were below PEL (91.3 mg/kg) and ISQG (35 mg/kg) except at one site (48 mg/kg) as presented in figure 81. This site is near waste dump of asphalt industry of Al-Marj village. The mean concentration of lead wet season sediment samples (13 mg/kg) is slightly higher than those of dry season, due most probably due to wet season soil erosion. Additional the paired T-test that showed no statistical significant differences (P= 0.411).

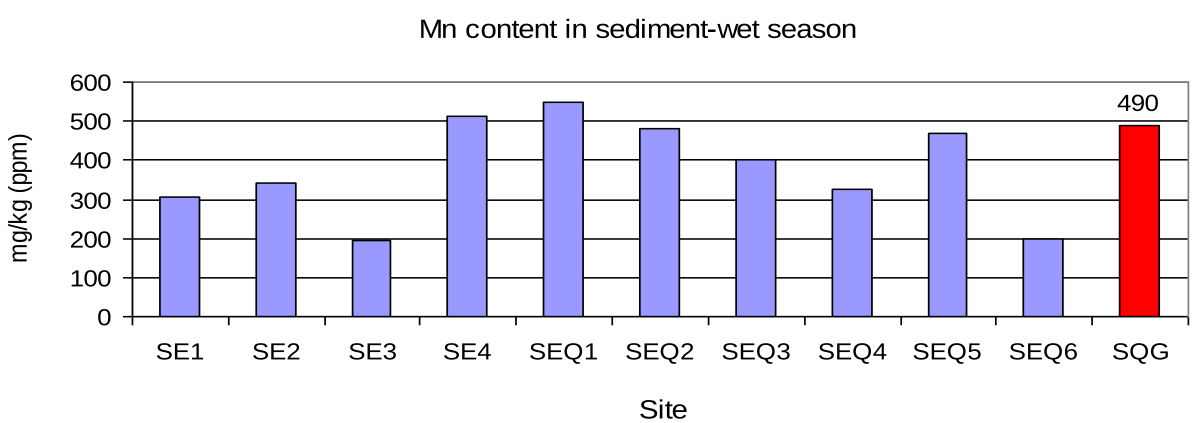


Figure 80. Manganese Analytical Profile in Sediment (mg/k): Wet Season

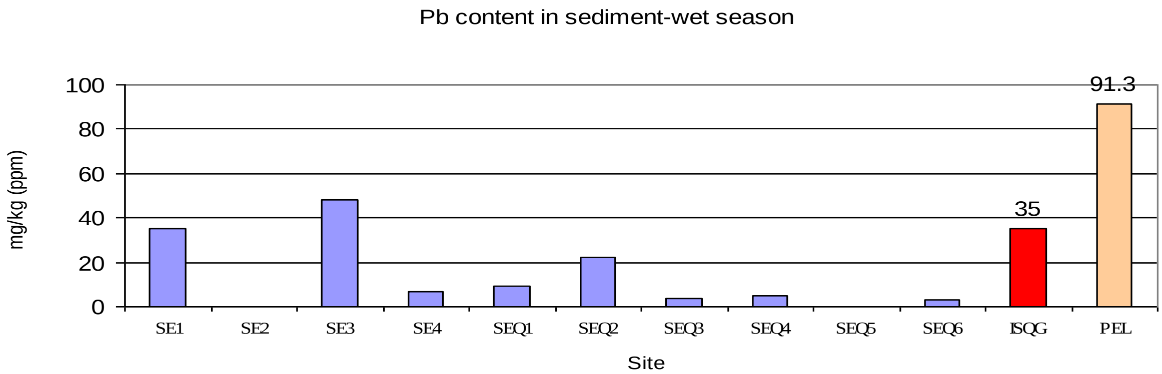


Figure 81. Lead Analytical Profile in Sediment (mg/k): Wet Season

Table 22. Metal Content in Sediments: Dry and Wet Seasons

Parameter	Metal in Sediment – Dry season				Metal in Sediment – Wet season			
	SD	Min	Max	Mean	SD	Min	Max	Mean
As (mg/kg)	2.55	7	16	12.6	3.2	5.2	17	12.6
Ba (mg/g)	97	0.01	284	50	11.9	0.01	31	7.11
Cd(mg/kg)	3.5	0.01	11	1.1	1.6	0.01	5	0.56
Cr(mg/kg)	44	0.01	101	30	24	0.01	80	30.6
Cu(mg/kg)	26	25	114	41.5	41	29	150	67
Hg(mg/kg)	3.7	0.01	9.8	2.7	3.9	0.01	10	3.2
Mn(mg/kg)	112	163	453	328	136	193	550	337
Ni(mg/kg)	28	36	128	64	24	50	130	70
Pb(mg/kg)	12	0.01	41	9.6	16	0.01	48	13
Zn(mg/kg)	120	50	456	122	44	59	200	100

Moreover, zinc (Zn) wet season levels were below the PEL guideline except for one sample that exhibited levels higher than the ISQG guideline (Figure 82) by 1.6 fold times more. Zn wet season levels coincided with those of dry season and the Paired Sample T-test that showed no statistical significant differences (P= 0.426).

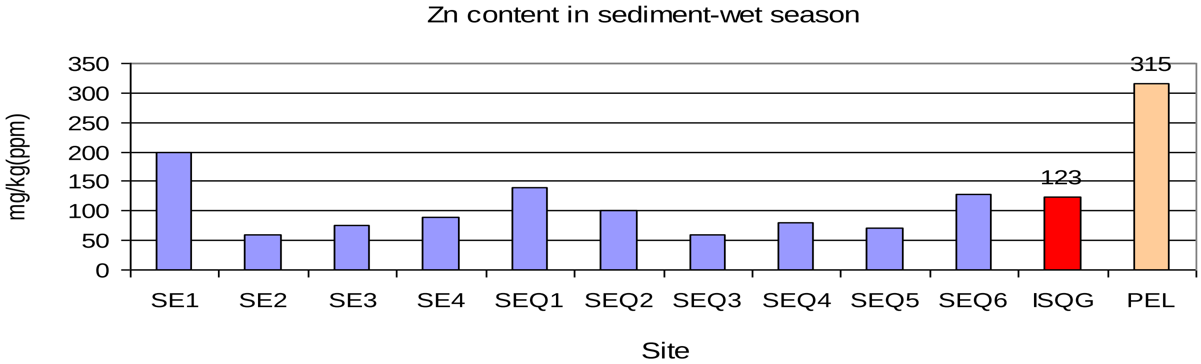


Figure 82. Zinc Analytical Profile in Sediment (mg/k): Wet Season

Whereas, Cu showed higher mean concentration in wet season sediment (67 mg/kg) than those of dry season (41 mg/kg) and Cu wet season levels were below the PEL guideline (197 mg/g), but most sites were higher than the ISQG guideline (35.7 mg/g). The highest Cu sediment wet season content (Figure 83) was at Ferzol (SE1) the industrial and waste dump site. Additional, the Paired Sample T-test showed statistical seasonal significant differences (P= 0.017) in sediment Cu content. The higher Cu sediment levels of wet season is attributed to higher organic content in wet season and the high association of Cu with organic matter (Korfali and Davies, 2005; Korfali et al., 2006).

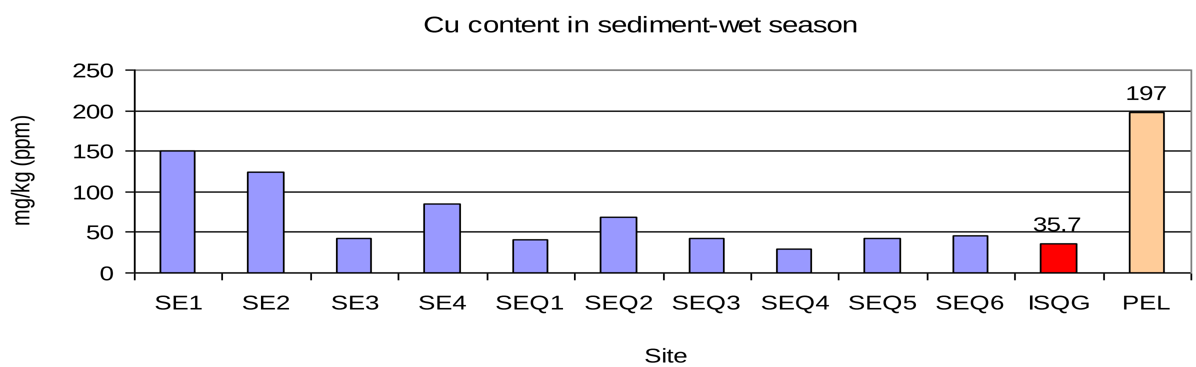


Figure 83. Copper Analytical Profile in Sediment (mg/k): Wet Season

As for cadmium, most of sediment samples were under the detection limit for Cd except one sample at the entrance of Litani River with Qarraoun (SEQ1) where the level of Cd (5 mg/kg) exceeded the ISQG guideline (0.6 mg/kg) by nearly 8.5 folds and the PEL guideline (3.5 mg/kg) by 1.4 folds (Figure 84). However, as SEQ1 is a site that receives most Litani River pollutants and is near Jeb Janine village mainly characterized by an agricultural profile, then most probably the source of Cd is the agricultural runoff (pesticides and fertilizers). Although, the mean wet season Cd levels are lower than those of the dry season by two fold due to clean sediment dilution, yet the Paired Sample T-test that showed no statistical seasonal significant differences (P= 0.701) in sediment Cd levels.

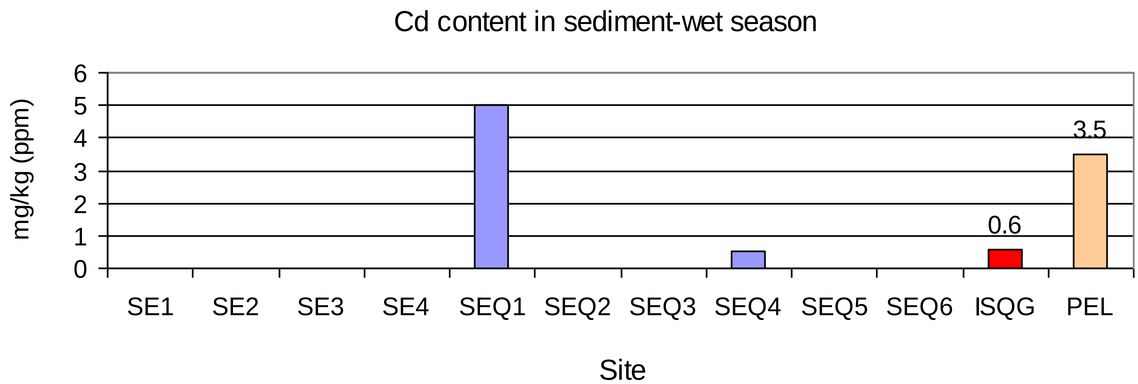


Figure 84. Cadmium Analytical Profile in Sediment (mg/k): Wet Season

Conversely, levels of Nickel (Ni) in wet season were above the SQG (25.2 mg/kg), ranging between 50 mg/kg to 130 mg/kg as presented in Figure 85. These results are concurrent with the dry season Ni levels (Table 22). Moreover, a statistical significant seasonal correlation existed ($p<0.01$), and the highest level of Ni remained to be detected in the sediment sample from the last accessible sampling point along the Qaraoun Lake (by the dam). Thus, since the detected levels of Ni in sediments and soil samples in both seasons were above guidelines levels, the most probable source is emphasized to be of geological formations.

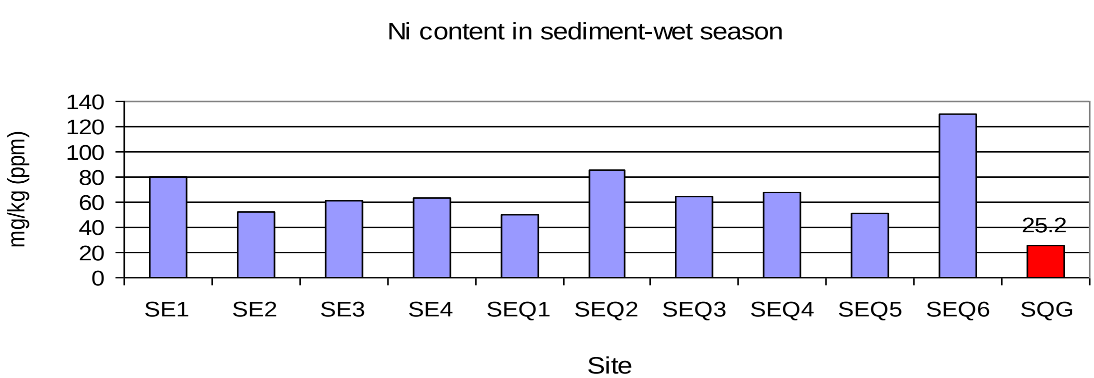


Figure 85. Nickel Analytical Profile in Sediment (mg/k): Wet Season

Similarly as for Ni, the detected wet season levels of Arsenic (As) in all sediment samples were above the ISQG (5.9 mg/kg) and below the PEL (17 mg/kg); ranging between 5.2 and 16.9 mg/kg (Figure 86). Moreover, arsenic wet season profile was concurrent with dry season profile and the Paired sample T test showed no seasonal statistical difference (P= 0.923). However, contrary to Ni source assumption, the high detected levels of Arsenic cannot be related only to the geological formation, since As exhibits lower levels in different types of drainage basins. Furthermore, the higher amounts of arsenic in sediments coincided nearly with agricultural sites (e.g. Jeb Janine). The most probable source is agricultural activities, due to the excessive application of pesticides.

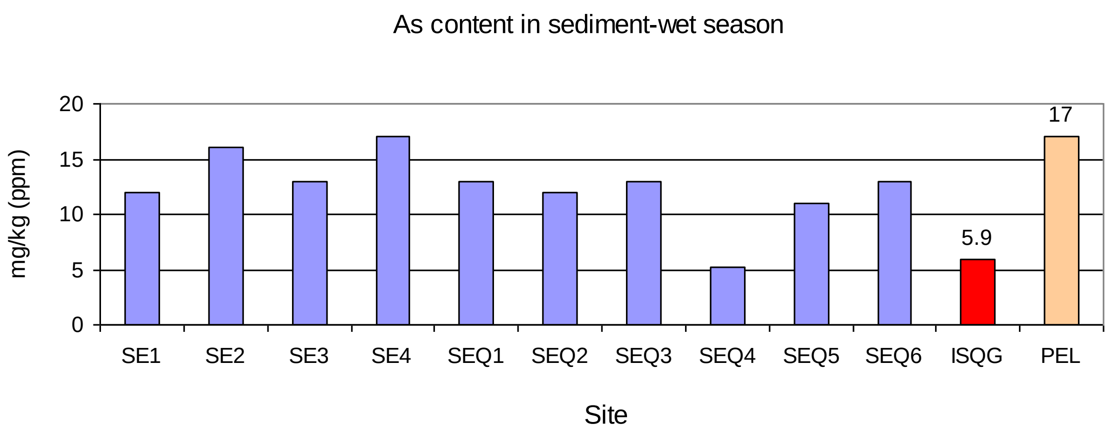


Figure 86. Arsenic Analytical Profile in Sediment (mg/k): Wet Season

As for the levels of mercury, 50% of the wet season samples had levels exceeding the Canadian guidelines as presented in Figure 87. The mean level concentration of the wet season (3.2 mg/g) was higher than mean level of the dry season (2.7 mg/g). Also the Paired sample T test showed no statistical seasonal significant differences (P= 0.645). Furthermore, the high levels remain to be mainly detected in the Qaraoun Lake sediments. Mercury is contributed by electric works, paints, application of pesticides and fungicides. Since electroplating and paints industries were not observed in the vicinity of Qaraoun Lake, then the most probable source would be the agricultural runoff, similar to As and Cd. Furthermore, chromium (Cr) in wet season was also detected at levels exceeding the ISQG guidelines of 37.3 mg/kg, in 30% of the sediment samples (levels ranging between 20- 80 mg/kg) as presented in figure 88.

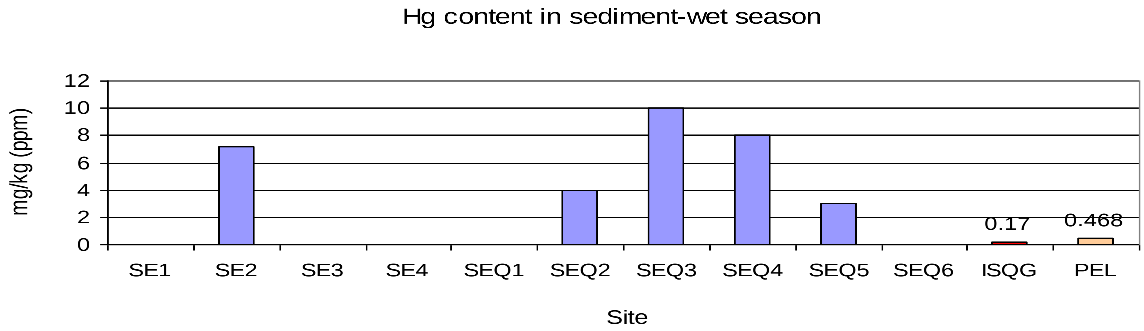


Figure 87. Mercury Analytical Profile in Sediment (mg/k): Wet Season

Though these ranges appear to be lower than those of dry season, yet the mean seasonal Cr level is the same (30 mg/g). In the dry season, sediments of lake were reported to contain nil levels of Cr, while in wet season, the entrance site of Litani River to lake showed Cr content, which is due to flow of upper sediment in high wet flow conditions. Furthermore, the highest detected level remain to be in the sediment samples along the river bed in Ferzol and Jeb Janine; both of which are characterized by agricultural activities. As other sources of Cr (tanneries, alloy and steel works) could not be identified, consequently, the main source of Cr in sediments could be attributed to agricultural runoff.

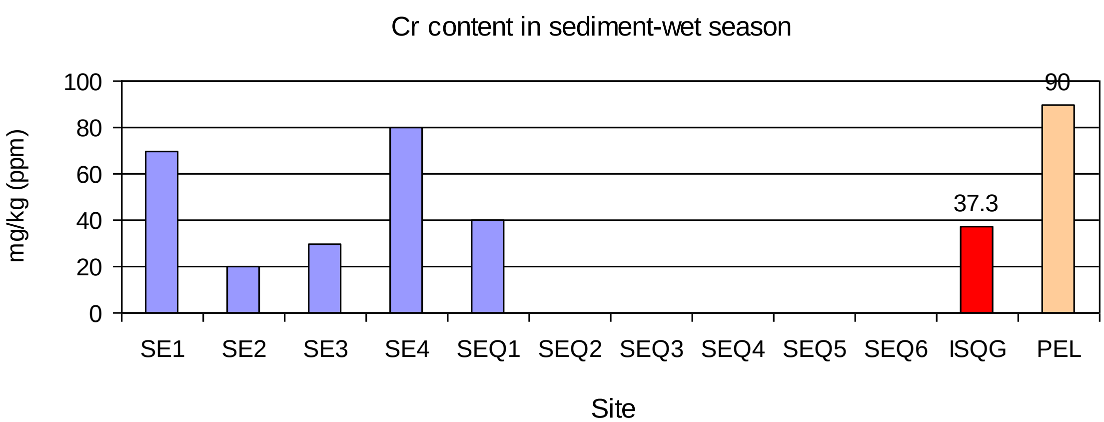


Figure 88. Chromium Analytical Profile in Sediment (mg/k): Wet Season

In conclusion, the main sources of toxic trace metals (As, Cd, Cr, Hg) in sediments of Litani River and Qarraaon Lake are due to agricultural activities associated with the excessive use fertilizers and pesticides.

6. CONCLUSION AND RECOMMENDATIONS

6.1. CONCLUSION

6.1.1. UPPER LITANI RIVER BASIN CHARACTERISTICS

Screening the major cities and villages (a total of 60) of the Upper Litani Basin (ULB) existing conditions reflect on (a) deficient management of municipal solid waste and domestic wastewater (sewage), (b) lack of compliance in implementing onsite treatment of generated industrial wastewater and solid waste, (c) heavy dependence on groundwater (springs and wells) and raw untreated wastewater effluents for irrigation, (d) excessive application of pesticides, fertilizers and animal manure, (e) flourishing "query business" and stone cutting open workshop sites, and (f) dumping of solid wastes and disposal of wastewater by recreational sites located along the river and its tributaries.

Additionally, solid wastes scattering (dump sites) along the ULB is more evident during the wet season. And, dumped wastes are carried along the water flow and settles on the river bed in summer when the water flow is minimal or the river bed is dry. Such dump sites are distributed throughout the Upper Litani Basin mostly in Saidi, Hosh Barada, Hezzine, Temnine Al Tahta, Ferzol, Rayyak, Dier Zanoun, Hosh Al Harimi, Dalhamieyeh, Al Marj, Kobb Elias, Tal Akhdar, Ammiq and Mansoura. Moreover the dumping of dead animals along the river flow is evident. The major problematic sites associated with such practices are presented in table 2. These practices clearly define the following point and nonpoint sources of pollution:

Domestic Wastewater (sewage); cesspools discharges and sanitary sewer system outlets,

Municipal solid waste dump sites,

Agricultural runoff,

Food processing plants (e.g. sugar beet, dairy products, fruit jam, and juices, vegetable canning) wastewater effluents,

Industrial zones (dyeing and tanning, electroplating, manufacturing of batteries, chemicals, sponge and paper) wastewater effluents,

Farm (swine, cows, sheep and poultry) waste, and

Recreational areas (hotels and restaurants) discharging sewage and dumping solid waste along the river flow.

The description and location of the identified point and non point sources of pollution along the Upper Litani Basin (ULB) is presented in Appendix 8.1.

6.1.2. LITANI RIVER WATER QUALITY PROFILE ASSESSMENT

Among the 50 sampling sites (along the Litani river and its tributaries) identified by the reconnaissance survey, 24 (48%) sites were found dry in summer and 6 (12%) sites were also dry even at the end of the wet season and as such are no longer contributing to the water flow. And, the following can be concluded:

The river flow within the Upper part (yellow zone between Saidi and Rayyak) in winter is relatively minimal to moderate, and the water is turbid greenish to black with moderate bamboo growth. It is to be emphasized that the major water source feeding the flow in winter is water diverted from Al Yamouneh. Additionally, the flow is sustained by rain water and inflowing tributaries; still, the flow from the tributaries of Temnine and Yahfoufa/Hala is minimal; the Faour tributary is dry; and the Jalala tributary is just storm water (Figures 17-20),

The river flow in the middle zone of the ULB (Orange Zone between Rayyak and Ammiq) is minimal, to moderate to high; the water is relatively turbid with algae on the river bed and the presence of tadpoles, water snakes, fish and turtles is evident. The water flow is sustained in winter mostly by the tributaries of Al Berdawni, Chtoura and Al Ghazyel. However, the Berdawni Tributary becomes dry in summer before the joining point with the Chtoura Tributary in the Marj Area, as the water is "completely" tapped for irrigation during the dry season; the jdeita spring contributing to thr tributary flow becomes also dry in summer; he Ghzayel Tributary becomes stagnating sewage in summer; the Faour Tributary is dry in winter and summer and is no longer contributing to water flow), and the Jalala Storm Water Runoff is dry even in winter when it is not raining (Figures 21-24), and

The river flow in the lower zone of the ULB (Green Zone between Ammiq and the Qaaroun Lake) is moderate to high. The water is clear to blue green due to algae growth on river bed and the presence of fish, frogs, water snakes, turtles, and ducks is evident (figures 24-27). Water springs and the tributaries of Habasiyeh, Hafir and Jair contribute to the water flow in winter (become dry with stagnating wastewater in summer). Moreover, the major dependence is on the abundant number of water springs, that as the indicated in the dry season report are almost dry in summer, or completely tapped for irrigation, is problematic and challenges sustainability of water flow (Figures 25-28).

Per se, the prevailing conditions are impacting the ability of the river to dilute and handle organic and inorganic contaminants reflecting on reduced self purification capacity with time, and consequently deterioration of water quality.

The levels of oxygen, despite the expected higher oxygen saturation in cold water, were comparable for both the wet and dry seasons with mean values of 4.83 and 4.65 mg/l,, respectively. And, levels less than 5mg/l (needed to support aquatic life) were found in 44 and 46% of the sampled sites for both the wet and dry seasons, respectively, despite the extensive algae growth on river bed and the increased oxygen saturation at lower temperatures. In comparison, the mean dissolved oxygen levels reported for the wet and dry seasons by the BAMAS 2005 were 7.94 and 5.93 mg/l, respectively. These findings reflect on the continuous progressive exposure to sources of pollution throughout the year, despite the high dilution effect, and increased oxygen saturation at lower temperatures (17.36^{0}C 26.30^{0}C, respectively).

Moreover, this drop in oxygen levels along the river and its tributaries is concurrent with a minimal mean BOD level of 19.20 mg/l (ranging between 2 and 70 mg/l and with a standard deviation of 16.57) in comparison to that of the dry season (mean 548 mg/l ranging between 2.5 and 2530 mg/l with a standard deviation of 768 mg/l). Mostly, this can be attributed to the high dilution factor and that organic matter decomposition takes a longer period of time at lower temperatures.

Still, this BOD load is 3 folds that reported by BAMAS 2005 Study for the wet season and 11 folds the load reported for the dry season. Accordingly, year round progressive exposure to the indicted sources of pollution is challenging the ecological viability and self purification capacity of this water resource. The major identified hot spots for both the dry and wet seasons (Saidi, Hezzine, Ferzol, Rayyak, Ablah, Jdeita, Taanayel, Dier Zanoun, Delhameyieh, Al Marj, Kobb Elias, Ammiq, Mansoura and Jeb Janine) are distributed throughout the ULB as presented in table 3 and figure 31. These sites are mostly exposed to organic sources of pollution (e.g. domestic wastewater [sewage], leachate of municipal solid waste dump sites, food processing plants wastewater discharge [poultry and dairy plants], specific types of industrial wastewater effluents [e.g. paper mills] and agricultural runoff [excessive applications of fertilizers and pesticides]).

Moreover, assessing the water quality profile for both the wet and dry seasons, for possible domestic water use, the following can be concluded (Tables 4 and 5):

Lower acceptable TDS mean level of 255 (ranging between 118 and 533 with a standard deviation of 97.39) in comparison to the level of 503 mg/l (ranging between 187 and 1979 mg/l with a maximum level of 1979 mg/l) for the dry season, mainly due to replenishment of river basin by rain (Table 5 and Appendix 8.2.1: Table 8.2.1.a). Only 5% of sampling sites (wet season) in comparison to about 23% of the sampled sites (dry season) exceeded the recommended Lebanese and EPA standard levels (Table 4), Lower pH mean level of 7.66 (maximum level: 8.66; minimum level 7.27 with a standard deviation of 0.37), with only on site in Saidi exceeding the acceptable limit of 8.5, in comparison to the mean value is 7.93 (maximum level: 8.54; minimum level 7.28 with a standard deviation of 0.56) for the dry season, as presented in appendix 8.2.1: Table 8.2.1.a. Elevated pH levels no direct health impact but a pH <8 enhances optimal water disinfection by chlorination and reduces the chlorine dose,

Relatively lower mean levels of ammonia, nitrate, phosphates and sulfates and chloride, but still reflective of continued exposure to the indicated sources of pollution during both the wet and dry seasons of the year (Tables 4 and 5),

Decrease in the levels of barium (37% of dry season mean value); cadmium (10% of dry season mean level); chromium (30% of dry season mean level); Nickel (65% of dry season mean level); iron (50% of dry season mean level); and zinc (59% of dry season mean level). All detected levels are within recommended limits,

Increase in the detected mean levels of copper (3 folds the dry season mean level); Molybdenum (1.2 folds dry season mean level); still, levels are within recommended levels,

Further increase in the manganese mean level exceeding the national and EPA standard level of 0.05 mg/l by 1.6 folds in 49% of the sampled sites In comparison to dry season levels exceeding the set limit by 1.4 folds (42% of sampled sites),

Fecal contamination of sampled sites for both the wet season (65% of sampled sites and the dry season (50% of the sampled sites). This may be due to the destruction of the fecal organisms in the shallow waters (dry season) by UVB sunlight radiation, and decreased oxygen levels.

As such, identifying possible water extraction sites, to meet the increased water demands of growing communities is a major challenge due to (a) the decreased water flow, (b) the exposure to high organic loads, (c) the trace metals profiles for both the wet and dry seasons, and (d) fecal contamination.

Moreover, comparing the overall surface water quality profile to that reported by the BAMAS 2005 Study the following can be concluded:

Increase in the overall mean total dissolved solids by 1.54 folds (BAMAS 2005: 246 mg/l; Current Study 2010-11: 378 mg/l) reflective of decreased water volumes and progressive exposure to pollution,

Shift in the overall pH value from 7.34 (BAMAS 2005) to 7. 79 (Current Study 2010-11) mostly attributes to sewage discharge, and solid waste dumping along the river and its tributaries,

Reduction in the mean level of total dissolved oxygen from 6.93 (BAMAS 2005) to 4.74 (Current 2010-11 Study), that is a reduction of 32%, despite the extensive growth of algae on the river bed and water surface. This is indicative of progressive exposure to contamination loads Concurrently the BOD overall mean level increased by 10.5 folds; from 27.5mg/l (BAMAS 2005) to 283.50 mg/l (Current Study 2010-11),

Increase in the overall mean levels of ammonia from 1.71 mg/l [BAMAS 2005] to 9.36 mg/l [current Study 2010-11) and a decrease in the overall mean levels of nitrates by 83% (from 13.51 mg/l [BAMAS 2005] to 1.32 mg/l [current Study 2010-11]). This is expected under reduced conditions where oxygen levels are not sufficient to oxidize the high ammonia content. Additionally, the decrease sulfates and phosphates is also expected; still, the main source of oxygen for microorganisms under such conditions are the nitrate forms, and

Detectable levels of trace metals; mean magnesium level exceeding the acceptable limit for both the wet and the dry seasons, cadmium levels (45% of sampled sites) exceeding acceptable levels for the dry season and relatively high barium levels also for the dry season.

This deterioration in the quality profile of the river and its tributaries limits water use to meet the increasing domestic water demands. Measure should be planned and implemented (refer to recommendations) to restore the ecologic wellbeing and enhance the water quality for muti-purpose use.

As for the suitability of the water for irrigation use, based on international guidelines and standards, relatively minor restrictions are associated with (a) increased soil salinity relating to increased TDS, (b) reduction in water infiltration rate due to increased sodium and magnesium levels, (c) projected crop toxicity (main element of concern, among tested metals, is cadmium as the mean level approaches the maximum recommended level of 0.01 mg/l in summer, (e) deposits on leaves and fruits associated with increased bicarbonate levels and (e) microbiological safety based on the total and fecal coliform counts.

Evaluating the water quality of the dry season for irrigation in reference to the proposed national standards (based on the biochemical oxygen demand levels and fecal coliform counts) results show that river water and its tributaries fall within the maximum limits of class 3 based on the high BOD levels. On the other hand, when comparing to the levels of fecal organisms, mostly 15% of the sampled sites fall within class 2 to the max of class 3. As such, direct irrigation from the river is not recommended during the dry season.

On the other hand, evaluating the quality of wet season in reference to the proposed National standards (based on BOD levels and fecal coliform counts of the wet season), results show that the river water and its tributaries fall within the maximum limits of class 1B in comparison to class 2-3 limits for the dry season. So although the microbial loads are higher still the BOD levels are diluted by the ecological water volume.

As such, if the water flow is sustained, and measures are taken to prevent the complete tapping of water springs feeding tributaries, then water use for irrigation with minimal restrictions can be achieved. To conclude tapping water spring (mostly in summer) feeding tributaries and water tributaries "completely" for irrigation is destroying the ability of the river and its tributaries to handle the increasingly high loads of contaminants introduced by the various sources of pollution. This is subsequently limiting the ability of the river to restore oxygen levels and to enhance the self purification capacity needed to regenerate water quality for acceptable multipurpose usage. Controlling such practices is essential to enhance the self purification capacity of this vital water resource and regenerate its quality and multipurpose usage. Lastly, evaluating the quality of the surface water for livestock use, the main limiting factor for such type of use is neither the high TDS, nor the magnesium levels, but the profile of trace metals mostly for the dry season.

6.1.3. GROUND WATER SOURCES

6.1.3.1. SPRINGS OF THE ULB

Mostly all sampled water springs are located in combined domestic, agricultural and to a lesser extent industrial and recreational settings. Yet, 3 out of the identified 22 springs (14%) are dry even in winter, and 4 (19%) are dry in summer. Additionally, during the dry season, these sources are mostly tapped for irrigation. The location and GPS coordinates of the sampled water springs are presented in figure 8-9 and appendix 8.1.4.

Evaluating the wet and dry season's physical, chemical and microbiological water quality profiles of spring water sources for domestic usage, the following can be concluded:

A mean mineral content of 199 mg/l (between 125 and 294 with a standard deviation of 39.85) for the wet season in comparison to a mean level of 284 mg/l (ranging between 396 mg/l; and 172 mg/l with a standard deviation of 67 mg/l) for the dry season (Appendix 8.2.1: table 8.2.2.1.a. This decrease in levels is due to replenishment by rainfall. Moreover, all TDS levels are acceptable when compared to the National Standards, EPA Standards and WHO Guidelines set limit,

All tested macro-elements and microelements for both wet and dry seasons fall within the set limit values recommended by the National Standards, EPA Standards and WHO Guidelines, except for nitrates, cadmium and manganese levels,

Acceptable levels (wet and dry seasons) of nitrates with the exception of one spring (17 mg/l as nitrate N) in Rayyak exceeding the standard level of 10 mg/l as nitrate N (dry season). This should be further investigated to identify the direct source of pollution,

A mean level of cadmium (0.00736 mg/l) exceeding the recommended national standards of 0.005 mg/l b by 1.5 folds for the dry season but is within the acceptable limit for the wet season (0.00133 mg/l), A mean manganese level of 0.07 mg/l exceeds the recommended guideline level of 0.05 mg/l by 1.4 folds, for the dry season, but is below the recommended limit (mean of 0.02 mg/l) for the wet season, and

Barium levels are detectable both in the wet and dry seasons; but still levels are below recommended limit,

All other trace metals with the exception of molybdenum and chromium showed a decrease in levels for the wet season; the mean molybdenum concentration (0.00482 mg/l) doubled, but is still much less than the acceptable limit of 0.07 mg/l; and the mean chromium concentration (0.0025 mg/l) increased by 12 folds but still is much less than the acceptable limit of 0.05 mg/l, and

Fecal coliform were detected in both the dry (67% of sampled springs) and wet (53% of sampled springs) seasons of the year. The microbiological water quality also limits its potential domestic use.

As such, the quality of spring water sources should be continuously monitored as the impacts of pollution sources are becoming evident. It is crucial to screen all springs used by communities as complementary domestic water sources in order to determine water safety based on the set Lebanese standard for drinking water. Additionally, sources used to feed domestic networks should also be continuously monitored. Determination of the levels of trace metals should be an integral component of this quality assessment. Sources exceeding acceptable levels for trace metals should not be used and alternative sources should be immediately identified.

As for the suitability of the water for irrigation use, based on international guidelines and standards, the overall mineral content is acceptable. Still, its use is governed relatively by minor restrictions associated with (a) reduction in water infiltration rate due to increased sodium adsorption rate (SAR), (b) deposits on leaves and fruits associated with increased bicarbonate levels (mainly due to the geological formation and sewage discharge), and (c) microbiological safety; 5% of sampled springs [wet season] and 61% of sampled springs [dry season] exceeded the recommended limit of 1000/100ml; and 14% of spring water sources (wet season) in comparison to 16% (dry season) exceeded the recommended level of 100/100ml for fecal coliforms (Appendix 8.2.2.2 Table 8.2.2.2.e).

As presented in tables 7-9, and based on the conductivity levels of all sampled sites, the quality of spring water sources is suitable for use by livestock. Additionally, results of the study show that the levels of magnesium in water samples do not exceed 37mg/l with a mean level of 16.32 mg/l and a standard deviation of 8.49mg/l. As such, the quality of the sampled spring is safe for drinking by all types of Livestock.

As for suitability of water for livestock use, the main hindering factor is neither the high TDS, nor the magnesium levels and is mainly due to high levels of cadmium and manganese, only in the dry season of the year.

6.1.3.2. WELL WATER QUALITY ASSESSMENT

Mostly all ground water sources are located in combined domestic and agricultural settings and are "mostly" used for domestic and agricultural activities. A total of 26 accessible wells were sampled; 3 (11%) were inaccessible during the wet season (cut off electricity or well pump being out of order). The location and GPS coordinates of the sampled wells are presented in figures 8 and 10 and appendix 8.1.4. Evaluating the wet dry seasons' physical, chemical and microbiological quality profile for domestic use, the following can be concluded (Table 11):

The overall mean mineral content ranges between 277 and 385 mg/l for the wet and dry seasons, respectively (Appendix 8.2.2.2: Table 8.2.2.2.a). These levels are acceptable when compared to the Lebanese standards, EPA standards and the WHO guidelines recommended levels; still 12% exceed the standard 500mg/l level for the dry season and 5% for the wet season. No direct health hazards are associated with the ingestion of water containing high levels of TDS (WHO, 2008). Still, high TDS levels are associated with irritation of the gastrointestinal tract and levels >1200 mg/l with excessive scaling in water pipes, heaters, boilers and household appliances (WHO Guidelines for Drinking Water Quality, First Addendum to Third Edition, Volume 1, 2006),

The pH level is 7.50 in comparison to 7.76 for the dry season, due to replenishment of aquifer with infiltrating rain water,

The levels of all tested macro-elements and microelements, with the exception of nitrates (Appendix 8.2; Tables 8.2.2.2.b,c & d), are within the sets limit values recommended by the National Standards, EPA Standards and WHO Guidelines (Table 12),

High nitrate levels exceeding the recommended 10 mg/l as nitrate nitrogen limit was detected only in 5% of the wells (Hezzine) in comparison to 20% of wells in the dry season (sampled wells in Housh Barada, Hezzine, Sariene, Helanieyeh and Ablah). Concurrently, relatively higher sulfate levels were also detected at these indicated,

High manganese levels were detected in the wet season at the sampling sites of Mansoura (0.064mg/l exceeding the 0.05mg/l limit), and to a lesser extend in Ablah (0.038 mg/l), Helannieyeh (0.033 mg/l), and Sariene (0.040 mg/l) in comparison to higher levels detected for the dry season,

The levels of all other trace metals were diluted with the exception of zinc levels that increased 1.59 folds, but still the mean level (0.0323mg/l is much less than the acceptable level of 5 mg/l), and

Total coliform were detected in 14% of samples in comparison to the 16% detected for the dry season samples). Fecal coliforms were also detected in 13% of samples in comparison to 15% of samples of the dry season.

Moreover, comparing the overall surface water quality profile to that reported by the BAMAS 2005 Study the following can be concluded:

The shift of the pH from 6.47 to 7.63 reflects on overexploitation exceeding the aquifer recharge rate,

The reduction in nitrate levels by 86% is evident due to increase in sewerage coverage; but, in many areas coverage is still limited,

The reduction in sulfates by 65% is also evident due to increase in sewerage coverage,

High manganese levels detected in the wet season at the sampling sites of Mansoura (0.064mg/l exceeding the 0.05mg/l limit), and to a lesser extend in Ablah (0.038 mg/l), Helannieyeh (0.033 mg/l), and Sariene (0.040 mg/l) in comparison to higher levels detected during the dry season, and

Fecal organism loads has been reduced from 78% to 15% of samples of the dry season; and from 23% to 13% of samples of the wet season.

These findings reflect on the efforts to increase the coverage of the sanitary sewer systems. This has definitely reduced on the exposure of ground water aquifers to progressive contamination. Yet, in some areas the system is still relatively deficient, and sanitary sewer networks have not yet been completed. Additionally, leachates from scattered municipal dumps sites add to the contamination loads.

As such, the dependence on well water sources for domestic use should be properly evaluated as high nitrate levels are mostly associated with the occurrence of methemoglobinemia (Cyanosis or blue – baby syndrome) in infants and young children. Methemoglobinemia develops when immature infant gut converts nitrates to nitrites which react with haemoglobin to form methemoglobin, so blocking oxygen transport (Afzal, 2006; Rizk, 2009; WHO, 2008). Such sources should not be used and alternative resources should be immediately identified.

As for the suitability of the water for irrigation (based on international guidelines and standards) relatively minor restrictions apply. These restrictions are associated with:

Increased soil salinity due to increased TDS levels resulting mostly from the lowering of the water table,

Reduction in water infiltration rate due to increased sodium and magnesium levels,

Deposits on leaves and fruits associated with increased bicarbonate levels (mostly due to nature of geological formations and sewage discharge,

Relatively high levels of manganese; one site in Mansoura for the wet season; and the sites of Hezzine, Ferzol, Rayyak, and Temnine Al Fawka for the dry season. Still, the impact of manganese is mostly in acidic soils, and

Microbiological profile; only 9% of samples (wet season) in comparison to 16% of samples (dry season) exceeded the recommended limit of 1000/100ml for the total coliform count and none of the samples (wet season) compared to 8% of samples (dry season) exceeded the recommended level of 100/100ml for fecal coliforms (Appendix 8.2.2.2: Table 8.2.2.2.e).

As for suitability of water for livestock use, the main limiting factor is neither the high TDS, nor high levels of magnesium, but the trace metals water quality profile.

6.1.4. QARAOUN LAKE WATER ASSESSMENT

Comparing the quality of the Qaaoun Lake for both the dry and wet seasons of the year, the following can be concluded.

The overall pH of the wet season 8.10 is relatively less than the mean value of 8.27 for the dry season and this is mostly due to replenishment by rainfall. Still; the alkaline pH is reflective of exposure to wastewater throughout the year. On the other hand, comparing to BAMAS 2005 wet season value of 6.50 (BAMAS 2005) further confirms the continuous exposure to sewage, dump sites leachates and alkaline industrial wastewater effluents such as, dairy plants, paper mills, etc.,

Relatively higher BOD in the receiving zone in contrast to the middle lake zone (dry season) as presented in figure 45. Concurrently, this impacts the oxidation receiving zone in winter leading to reducing conditions,

Relatively maximal reducing conditions of the receiving zone, with relatively higher ammonia levels, and higher iron and cadmium levels from the dissolution of the precipitates of these metals under reducing conditions (Table 13 and figures 48-50),

Cadmium levels that exceeded the recommended National Standard level of 0.005 mg/l by 2.1 folds (higher levels reported in the mid lake water zone) for the dry season were reduced by replenishment by rain water (figure 50),

Manganese levels slightly decreased in the wet season (from 0.0377 mg/l to 0.0300 mg/l and none of the sites exceeded the standard level of 0.05 mg/l. In comparison 30% of the sampled sited exceeded the recommended level for the dry season (figure 57),

All other trace metal, were detected at levels below the recommended Lebanese standards. Mostly, boron, cadmium, aluminium, manganese, iron, and copper were concentrated in the receiving zone (river inflow into the lake); nickel at the receiving zone and the damp zone; molybdenum and chromium in the central zone; and zinc throughout the lake (figures 51 -58), and

Microbiological fecal contamination detected for both the dry (50% of sampled sites) and wet season (90% of sampled sites) despite drop in the mean temperature from 32.2^{0}C to 23.08^{0}C, confirming the continuous exposure to sources of contaminants.

Furthermore, monitoring change in water quality with time, it's evident that quality profile of the Qaraoun Lake has changed over the past 5-10 years. Comparing the lake water quality profile reported by Jurdi et.al, 2002, BAMAS 2005 Study and the Current 2010-11 Study, changes in water quality reflect mostly on:

Increase in the levels of total dissolved solids (from 193 to 238 mg/l; 1.23 folds) reflective of progressive exposure to the various indicated sources of pollution,

Increase in the overall total dissolved oxygen (from 5.54 to 9.1 mg/l; 1.64 folds), masking the increase in biochemical oxygen demand boasted by organic contaminants. This increase in the levels of dissolved oxygen is mostly reflective of suspended algae growth,

Change in pH towards alkalinity (from 7.29 to 8.18) reflective of exposure to domestic wastewater discharge and industrial wastewater discharge as specified before,

The presence of trace metals; but at levels below the permissible upper limit value (Lebanese standards) and are mostly concentrated in the receiving zone (river inflow into the lake), with the exception of cadmium and manganese high levels of the dry season (Figures 49-57),

High levels of cadmium for the dry season exceeding the recommended National Standard level of 0.005 mg/l by 2.1 folds (higher levels reported in the mid lake water zone),

High manganese level to 0.04 mg/l for the dry season, compared to the maximum standard limit of 0.05mg/l, with 30% of the sampled sites exceeding this limit level,

Increased fecal loads in mostly all sampled sites, and

The mid zone (2.5- 3.6 km from receiving zone) that was considered as the "better water extraction zone" for multi-purpose usage (lower organic loads, and higher scavenging of metals in the sediments) is at present a relatively reducing medium (high organic loads and more solubility of metal sediments). This variability in the water quality makes it difficult to define a better "quality" water zone for possible water extraction.

The most probable explanation to this major finding relates to the disposal of sewage directly by the lake. A wastewater treatment plant located directly by the lake is under construction in Bab Merea (treat domestic wastewater from Saghbine). Meanwhile sanitary sewer systems coverage has increased, replacing the point sources cesspools. Yet, the sanitary sewers currently discharge into the lake, awaiting the completion of the treatment plant. Additionally, another wastewater treatment plant, located directly by the lake is under construction in Saghbine; and collected sewage is also discharging into the lake. As such, the delay in "closing the loop"; that is completing the wastewater treatment plants, and ensuring proper sewage treatment, is boasting the level of organic contaminants in the lake.

6.1.5. IRRIGATION CANAL 900 WATER QUALITY ASSESSMENT

This change in the quality profile of Canal 900 is concurrent with the progressive exposure of the Qaraoun Lake water to contamination loads from the various point and nonpoint sources of pollution identified in the Upper Litani Basin. Hence, change in the water quality of the irrigation canal reflects on similar variability in water quality. Comparing the quality of the irrigation canal in May (Start of the dry season) in comparison to that of the mid-dry season (August), the following can be concluded:

Decrease in the TDS from (340 to 268 to mg/l) reflective of replenishment of Lake Water with rain and the increase in the water volume,

Minimal change in the pH from 7.71 to 7.34; this is mostly due to replenishment by rainfall. Still; the alkaline pH is reflective of exposure of the Lake (water source) to wastewater throughout the year. On the other hand, comparing to BAMAS 2005 wet season value of 6.50 (BAMAS 2005) further confirms the continuous exposure to sewage, dump sites leachates and alkaline industrial wastewater effluents such as, dairy plants, paper mills, etc.,

Decrease in BOD loads from 9 to 4 mg/l (60% reduction) due to dilution as the result of replenishment by rainfall.

Moreover, changes in the water quality are evident when compared to the results of the BAMAS 2005 study (table 13) and reflect the mainly on:

Increase in the levels of total dissolved solids (from 241 to 303; 1.25 folds) reflective of progressive exposure of the Qaraoun Lake to point and nonpoint sources of pollution as presented before,

Decrease in the levels of dissolved oxygen from 6.99 to 5.13 mg/l despite the extensive growth of algae. This is mostly due to the increase in the biochemical oxygen demand from <2 to 6.5 mg/l (4.5 folds),

Change in pH towards alkalinity (from 7.29 to 7.52) reflective of exposure of lake water to domestic wastewater discharge, industrial wastewater discharge, etc. as specified before,

Increase in cadmium levels. The mean level of 0.0419 0.0103 exceeds the maximum permissible levels in irrigation water (0.01mg/l), mostly at the peak of the dry season, and

Decrease in fecal loads as the irrigation canal is relatively shallow and is not exposed to additional direct sources of pollution.

As for the suitability of the water for irrigation use, based on international guidelines and standards, relatively minor restrictions on use relate to (a) reduction in water infiltration rate due to increased sodium and magnesium levels, and (b) deposits on leaves and fruits associated with increased bicarbonate levels associated with progressive exposure to the various sources of pollution and (c) crop toxicity associated with the cadmium levels approaching maximum recommended levels, mostly for the dry season, and (d) microbiological profile of all the sampled sites exceeded the total coliform count limit of 1000/100ml for the for the dry season and 72% of sampled sited for the wet season. But none exceeded the recommended level of 100/100ml for fecal coliforms for both the wet and dry seasons (Appendix 8.2.5; Table: 8.2.5.e).

On the other hand evaluating the water quality for irrigation in reference to the proposed National Standards (based on the biochemical oxygen demand levels and fecal coliform counts), results show that sampled sites fall within 1A category of irrigation water for the wet season and 1B category of irrigation water for the dry season.

Additionally, the quality of the sampled irrigation water sites along canal 900 is suitable for drinking by all types of Livestock. Still, when evaluating the presence of trace metals in livestock drinking water results show that the main concern is the level of cadmium for the dry season.

6.1.6. WASTEWATER QUALITY ASSESSMENT

As for the suitability of the domestic wastewater (sewage) for irrigation use (based on international guidelines and standards) the major restrictions on use relate to (a) increased soil salinity due to increased TDS levels, mostly for the dry season, (b) reduction in water infiltration rate due to increased sodium and magnesium levels (c) crop toxicity due to increased levels of chlorides and sodium, mostly for the dry season (d) deposits on leaves and fruits associated with increased bicarbonate levels (mostly due to nature of geological formations and sewage discharge) and (e) microbiological safety due to the high total and fecal coliform loads (Appendix 3.4.7; Tables 3.4.7a.b.c & d).

On the other hand, evaluating the water quality for irrigation in reference to the proposed national standards for wastewater reuse, results show that high BOD levels and fecal coliform load, even in winter, restrict domestic wastewater use for direct crop irrigation.

Moreover, industrial wastewater effluents should not be used for irrigation mostly due to problems associated with soil salinity and crop toxicity mostly due to the high levels of total dissolved solids, high BOD levels bicarbonate alkalinity and faecal microbial loads as presented in Appendix 8.2.5.2; Table 8.2.5.3.a,b.c,d).

Besides, relatively high overall mean levels (0.8830 mg/l) of Barium were detected in industrial wastewater samples in comparison to domestic wastewater. This reflects on the major source of pollution leading to the increase in barium levels in surface water.
Per se the industrial sector is mostly contributing to the increase mostly in the levels of barium in the water and soil sediments, whereas increased levels of cadmium and manganese may be attributed to agricultural (fertilizers and pesticides) and industrial activities along the river and its tributaries and solid waste dumping.

6.1.7. QUALITY ASSESSMENT

The levels of trace metals are building up in soil due to the excessive use of pesticides and fertilizers, and irrigation with sewage, industrial wastewater and surface and ground water exposed to such sources of pollution. Comparing the soil and canal soil quality profiles for the wet and dry seasons the following can be concluded:
Minimal seasonal variability in Molybdenum (Mo) and Cobalt levels (Co), whether in soil or canal-soil samples, with levels below detection limits,
Decrease in Barium (Ba) levels that were was detected in 58 % of soil samples and 25 % of canal soil samples in the wet season; Yet, all detected levels are below Canadian the guideline for agricultural use,
Minimal seasonal variability in lead levels of soil samples with only 4% (one site) of soil samples (Figure 68) exceeding the Canadian guideline by more than 1.79 fold (Figure 69). The source of this metal is most probably due to solid waste dump of asphalt industry of Al-Marj village. As for soil canal samples detected levels were far below the Canadian guideline level and 75 % of samples were below detection limits. Moreover, the mean Pb levels in soils were reduced during wet season (Table 3). This reduction in Pb levels is most probably due to a wash process and dissolving resulting from the wet season higher acidic conditions,
Minimal seasonal variation in Zn level for both soil samples and soil canal samples And only 8% (2 sites) of wet season soil samples (Figure 70) had Zn levels higher than the Canadian guideline level of 200 mg/kg; which is same percentage of the dry season (Figure 68). But, all soil canal samples had zinc at lower levels than the Canadian guideline,
Increase in the soil and soil canal samples levels of copper (Cu) for the wet season in comparison to the dry season (Table 3) with a 16% of soil samples and 8% of canal soil samples exceeding the Canadian Guideline level of 63 mg/kg (Figures 68 and 71). The higher level of Cu during wet season may be attributed to a number of factors such as increased waste dumping (table 2) dissolution of channel copper complexes due to wet season acidic conditions, leaching of copper from fertilizers and addition

of copper sulphate to control algae growth. This observation can be deduced from the high and highest levels of Cu in wet season canal soils of Jeb Jenine and Baaloul that indulge in agricultural activities. Additionally, similar to dry season, Zn and Cu wet season soils exhibited strong significant correlation ($r=0.76$, $p <0.01$). Thus the sources of these metals are geological (primarily for Zn) and anthropogenic (solid waste dumps in Ferzol and Al Marj),

Minimal seasonal variability in nickel (Ni) levels in soil and canal soil (Figures 68 and 71) Thus, the Ni content in soils is primarily a natural one, justifying the seasonal statistical insignificance difference of the of the Paired Sample T test ($P= 0.227$). Furthermore, though Ni appeared to be in soils from natural sources, yet it is contributed by sources of pollution as indicated by the statistical significant correlation ($r=0.71$, $p< 0.01$),

Minimal seasonal variability in chromium (Cr) levels in soil samples (dry-soil: 143 mg/kg; wet-soil: 135 mg/kg), but reduction in mean canal soil levels in the wet season (dry canal soil: 202 mg/kg; wet canal soil: 129 mg/kg). Moreover, sites with low content in the dry season become lower than the Canadian guidelines. Therefore, Cr content in soils is primarily anthropogenic and is indicated by the seasonal statistical significant difference of the of the Paired Sample T test ($P= 0.004$). Nickel and Chromium are mostly associated with multi-industrial activities, (a stainless steel, alloys, ceramics, plastic, rubber and tanneries). Such small-scale industrial activities run all through Upper Litani Basin (ULB),

Minimal variability in soil and canal soil samples levels of arsenic (As), for both the wet and dry seasons. And, although levels in canal soil decreased in the wet season, still the variability was not significant. Additionally, soils collected east and west of Canal 900, mainly in Jeb Janin and Baaloul have high arsenic levels (≅28 mg/kg),

Minimal seasonal variability in mercury (Hg) levels for soil and canal soil samples. Still, levels of the wet season in soil and canal soil samples were higher by about 2 fold in some samples in comparison to the Canadian guideline of 6.6 mg/kg. And, 29% of soil samples and 16 % have levels higher than the Canadian guideline level. Furthermore, though samples with high mercury levels were less in wet season soils and canal soils, yet the mean seasonal levels were similar (≅3.1 mg/kg). The highest Hg level in wet season is still in Ferzol (11 mg/kg), mainly due to agricultural activities and solid waste dump sites,

Minimal seasonal variability in cadmium levels for soil and canal soil samples. Still, 29 % of wet season soil samples and 25 % of canal soil samples levels were higher than the Canadian guideline level of 1.4 mg/kg (Figures 68 and 71). Cadmium is a constituent of pesticides and fertilizers, thus high levels of Cd are to be expected in agricultural sites. The highest detected level of Cd (10 mg/kg: 7 folds guideline level) is at the agricultural site of Jeb Jenine, and

Minimal seasonal variability in manganese (Mn) levels of both soil and anal soil samples. Still, 67% of wet season soil samples and 83% of canal soil samples exceed the Canadian guideline level of 500 mg/kg. Manganese levels in soils may be attributed to the geological formation, especially since it exists in coincidence with Fe; or may result additionally due to existing agricultural and industrial activities (steel and alloy, fertilizers, fungicides and fireworks). Moreover, a strong statistical signification correlation is indicated for Mn and As (soil: 0.837, $p < 0.01$; canal soil: $r = 0.747$, $p < 0.01$).

Comparing to the BAMAS study reported results, the presence of cadmium, copper and cadmium was only detected. As such the levels of trace metals are building up in soil due to irrigation with sewage, industrial wastewater and surface and ground water exposed to such sources of pollution.

Moreover, although the mobility of trace metals and the uptake by plants is mostly limited by the soil alkalinity, still, crop toxicity may result. As such, it is important to determine the levels of these elements in crops for proper risk assessment.

6.1.8. SEDIMENTS QUALITY ASSESSMENT

Comparing the sediments quality profiles for the wet and dry seasons the following can be concluded:

Lower Barium mean level for wet season (Figure 79 and table 22); this is most probably due to dilution by eroded clean soils and/or upper channel sediments,

Higher manganese (Mn) mean level in wet season sediments; this could be attributed to oxidizing conditions of wet season and association with iron oxyhydroxide (Korfali and Davies, 2005),

Minimal seasonal variability in lead levels,

Higher copper mean level in wet season sediments; this is attributed to higher organic content in wet season and the high association of Cu with organic matter,

Minimal variability in cadmium levels,

Minimal seasonal variability in chromium levels,

Higher nickel levels and the highest levels detected in the sediment sample from the last accessible sampling point along the Qaraoun Lake (by the dam). Thus, since the detected levels of Ni in sediments and soil samples in both seasons were above guidelines levels, the most probable source is emphasized to be of geological formations,

Higher amounts of arsenic in sediments coincided nearly with agricultural sites (e.g. Jeb Janine); the most probable source is agricultural activities, due to the excessive application of pesticides, and

Minimal seasonal variability in mercury levels and high levels mostly detected in the Qaraoun Lake sediments. Mercury is contributed by electric works, paints, application of pesticides and fungicides.

Since electroplating and paints industries were not observed in the vicinity of Qaraoun Lake, then the most probable source would be the agricultural runoff, similar to As and Cd.

In conclusion, the main sources of toxic trace metals (As, Cd, Cr, Hg) in sediments of Litani River and Qarraaon Lake are agricultural activities associated with the excessive use of fertilizers and pesticides**.**

6.2.RECOMMENDATIONS

Results of the wet season confirmed the exposure to the indicated sources of pollution. As such we would like to iterate the recommendations previously presented.

6.2.1. RESTORE LITANI RIVER HEALTH AND WELLBEING

Restoring the Litani River and its tributaries ecologic viability cannot be achieved by a single type of environmental intervention and should be part of the integrated river basin management. As such, a comprehensive approach addressing all types of environmental stresses should be implemented. Furthermore, this objective cannot be achieved without mobilizing the role of communities and empowering municipalities to implement the required environmental interventions.

Moreover, all short and intermediate types of interventions should be part of a comprehensive process to develop, implement and sustain integrated river basin management (IRBM). Instating and sustaining IRBM will ensure the coordination, conservation, management and development of water, land and related resources across all sectors of the Upper Litani Basin. This is essential to maximize the economic and social benefits that can result by restoring and sustaining this freshwater ecosystem. As such, the following short and intermediate measures should be implemented to insure continuous water flow; and to restore the oxygen levels needed to enhance the self purification capacity essential to regenerate the water quality for acceptable multipurpose usage:

Stop tapping “ALL” the water discharge of springs feeding river tributaries, and the water flow of tributaries, in summer, for irrigation. This is essential to sustain a critical water flow that can cope with the increased pollution loads. Water flow will increase the exposure to aeration and subsequently will regenerate the levels of dissolved oxygen (sustain water flow in comparison to the wet season),

Control the drilling of new wells and the overexploitation of ground water aquifers. This is crucial to sustain the discharge of water springs and shallow wells. Farmers complain of over pumping of ground water by large irrigation projects, making unavailable to meet agricultural needs. As a start, regulating pumping rates is a must, Enforce onsite treatment of major industrial wastewater effluents discharging directly into the Litani River and its tributaries, or into the sanitary sewer of the city/village that outflows directly into the river flow. Just simple physical/primary treatment will reduce the total suspended solids (that increases water turbidity and impacts aquatic life) the biochemical oxygen demand between 35-50%. Additional chemical conditioning may be needed to reducing odors, improve solid and grease removal, neutralize acids and basis and reduce BOD levels,

Control the discharge of untreated sewage directly into the river and its tributaries. Sanitary sewer systems should replace leaching cesspools. Concurrently, the wastewater treatment plants under construction should be completed within a defined time line (plans have been made since more than 5 years). Currently, this is one of the major limitations to the proper management of sewage,

Develop and implement a comprehensive plan for the management of sewage. Additionally, treatment plants should be designed to integrate the need not only to reduce BOD but to reclaim and reuse this important resource. As such, treatment process should insure that the quality of treated effluent is suitable for irrigation and livestock. This will help secure sufficient quantities of irrigation water and will preserve the better quality surface and ground water for other types of water usage,

Control and limit the discharge of municipal solid wastes and industrial solid wastes along the river water flow. Open dump leachates are polluting the river, springs and wells with trace metals that accumulate, temporary, in soil and sediments; this is a major problem during the wet season as even dead animals are discharged into the river and its tributaries,

Properly treat and dispose the sanitary landfill leachate (Zahle landfill) managed to control the leaching of organic and inorganic pollutants and

Control the application of pesticide. As a start regulating permissible types and application dose of pesticides and fungicides is crucial as toxic trace metals (AS, Cd, Cu, Hg, Pb and Zn) are reaching water bodies (surface and ground) and accumulating, temporary, in soils and sediment as a result of such practices. Farmers' extension programs should be mobilized to achieve this objective.

6.2.2. PROTECT AND SUSTAIN THE QUALITY OF GROUND WATER RESOURCES

The above recommended environmental interventions will also regulate the overexploitation of these resources and reduce the exposure of springs and wells to the various pollution sources. Additionally, the following is also recommended:

Enforce the existing regulations to replace leaching cesspools with water-tight, properly designed, septic tank. This is critical for villages and areas where the development of sanitary sewer systems is not planned for the near future,

Regulate the use of fertilizers (types and quantities applied). Excessive use of fertilizers will lead to the dissemination of fecal material, and the enrichment of springs and wells with high levels and nitrates and toxic trace metals such as Cd, Cu, Mn and Mo. These trace metals are detected in surface and spring water sources and to lesser extent in well water sources. Long term exposure will renders the water unsafe for humans and livestock. Moreover treatment to remove these metals is technical and expensive,

Determine analytically by testing soil samples the need for fertilizer application. Provision of technical laboratory facilities will help the farmer make a better informed decision and apply only the needed amounts of nutrients,

Identify and screen all water springs used by communities, as complementary domestic water sources, to determine water safety based on the Lebanese standards for drinking water. Additionally, sources used to feed domestic networks should also be continuously monitored. Determining the levels of trace metals should be an integral component of the quality assessment. Sources exceeding acceptable levels for trace metals should not be used, and alternative sources should be immediately identified. This is mostly because such sources will require advanced treatment, beyond disinfection, to insure water safety, and

Identify, evaluate and monitor well water sources that supply domestic needs. Mostly, the presence of high levels of nitrates associated with the occurrence of methemoglobinemia (Cyanosis or blue – baby syndrome) in infants and young children should be determined. Sources exceeding the recommended standard level should not be used alone (diluted with better quality water) and/or alternative sources should be immediately identified.

6.2.3. REGULATE THE USE OF WASTEWATER FOR IRRIGATION

The suitability of a raw, untreated wastewater for irrigation is governed by wastewater salinity, infiltration rate, plant toxicity in addition to major issues associated with health risks. As such, if needed due to the scarcity of alternative water supplies:

Regulate use and restrict to the category of lowest risk to consumer (field worker protection needed), as presented in the project document, and

Determine wastewater quality to insure suitability and to prevent the building up of soil salinity, reduced infiltration and crop toxicity.

6.2.4. ENHANCE THE WATER QUALITY OF THE QARAOUN LAKE

Implementing the above indicated environmental interventions will consequently upgrade

Implementing the above indicated environmental interventions will consequently upgrade the water quality of the Qaraoun Lake for multipurpose uses, especially irrigation and fisheries. Moreover it is recommended to manage properly, the treatment plants constructed along the lake to control the levels of enriching nutrients (mainly phosphates and nitrates) in the discharged effluent. This is critical as excessive algae growth will lead to the development of subsurface reducing water zones that could result in the dissolution of the accumulated trace metals from lake sediments.

6.2.5. ENHANCE THE QUALITY OF IRRIGATION CANAL 900

Implementing the recommended environmental interventions will also upgrade the quality of the irrigation Canal water as it originates from the lake and its quality will fluctuate accordingly. Additionally the levels of added copper sulfate (for controlling algae growth) should be properly controlled and monitored to prevent the progressive accumulation of copper in soils irrigated with the canal water.

6.2.6. DEVELOP AN SUSTAIN WATER QUALITY MONITORING PROGRAMS

It is high time to:

Upgrade and sustain properly designed comprehensive monitoring activities. This is an urgent need to evaluate water, soil and sediments quality fluctuation and to evaluate the effectiveness of planned environmental interventions,

Initiate ecological studies to identify biological indicators, monitor the state of aquatic species, an evaluate the need to promote fisheries,

Conduct follow up surveillance to evaluate existing condition of the Upper Litani Basin at the peak of the wet season. This is essential for comprehensive assessment, and action priority setting,

Conduct studies to evaluate the level of the risk associated with the translocation of trace metals into the aerial edible portions of crops grown in soil progressively exposed to wastewater irrigation, and surface and spring water contaminated by sewage and industrial wastewater, and

Conduct studies to evaluate the level of risk associated with excreta pathogens in fresh water, sewage and their residence time on crop surface (eg. Enteroviruses; helminth: Ascaris lambriocoides eggs; protozoa: Entamoeba histolytica).

6.2.7. COMPLETE THE RISK ANALYSIS PROCESS TO

Finalize the risk assessment studies, as indicated before. This is essential to base interventions on solid scientific evidence,

Develop a risk management plan with clearly defined time line, and

Communicate the current status of the Upper Litani Basin and the proposed management strategy should be shared with communities, municipalities and other relevant stakeholders for feedback. This is essential to mobilize communities and insure collaboration, commitment and compliance.

7. REFERENCE LIST

Afzal, B.M. (2006). Drinking Water and Women's Health. Journal of Midwifry & Womens's Health. 51(1), 12-18.

American Public Health Association (APHA), the American Water Works Association (AWWA), and the Water Environment Federation (WEF)(2006).Standard Methods for the Examination of Water and Wastewater 20th Edition. American Public Health Association, Washington DC.

Assaf, H. and M. Saadeh (2008). Assessing Water Quality Management Options in the Upper Litani Basin, Lebanon, Using an Integrated GIS-based Decision Support System. Environmental Modelling and Software, 23(2008) 1327-1337.

Ayers & Westcott (1985). Water Quality for Agriculture. FAO Agriculture and Drainage Paper 29. Food and Agriculture Organization of the United Nations, Rome.

Canadian Council of Ministers of the Environment (2002) Canadian Sediment Quality Guidelines for the Protection of Aquatic Life (ISQGs) Summary tables. Retrieved from www.ccme.ca/assets/pdf/sedqg_summary_table.pdf

Christofer, P., Licka Rashid, S., Redwod, M. And Akika,B (2010). Wastewater irrigation and Health. International water Management Institute. Earth scan Publishing, London, Sterlind, VA.

Environmental Protection Agency (EPA) (2005).A National Primary Drinking Water Regulation (NPDWRs). Retrieved from http://water.epa.gov/drink/contaminants/index.cfm#List

Environmental Protection Agency (EPA) (2010). A National Secondary Drinking Water Regulation Retrieved from http://water.epa.gov/drink/contaminants/index.cfm#List

Fattal B et al. (1986). Health Risks Associated with Wastewater Irrigation: An Epidemiological Study. American Journal of Public Health, 1 6(8): 97 7-97 9.

Food and Agricultural Organization (FAO) (1997). Quality Control of Wastewater for Irrigated Crop Production. Water Reports-10). Food and Agriculture Organization of the United Nations, Rome.

Jurdi, M., Korfali, S., Karahagopian, Y. and B. Davis (2002). "Evaluation of the Water Quality of the Qaroun Reservoir Lebanon Suitability for Multi Purpose Use". Journal of Environmental Monitoring and Assessment. Volume 77 (2000) Pages : 11 - 30.

Korfali,S., Jurdi, M. and B. Davis (2006). "Variation of Metals in Bed Sediments of Qaraoun Reservoir, Lebanon". Environmental Monitoring and Assessment, 151, Pages: 307-319.

Korfali, S. and M. Jurdi (2003). "Differential Water Quality in Confounded and Free Water Flowing Water bodies". International Journal Environment and Pollution. Volume 19, Issues 3, Pages: 257-268.

LIBNOR Lebanese Standards Institution (1999). Drinking Water Standards. Decree 161/1999. ICS 13.060.20

Litani River Authority (LRA) (2004). The 50th Jubilee Book of the Litany Authority (1954-2004). Litani River Authority, Beirut, Lebanon.

Litani Basin Management Advisory Services (BAMAS) (2005a). Technical Survey Report – Summer Conditions. Litani Water Quality Management Project (LWQM).

Litani Basin Management Advisory Services (BAMAS) (2005b). Technical Survey Report – Summer Conditions. Litani Water Quality Management Project (LWQM).

Petterson SR and NJ Ashbolt (2003). WHO Guidelines for the Safe Use of Wastewater and Excreta in Agriculture: Microbial Risk Assessment Section. World Health Organization, Geneva,

Perfect Life Institute (2002). Intoxication of Heavy Metals. Retrieved from http://www.bioperfection.com/health/toxicity.htm

Rizk, Z. (2009). Inorganic Chemicals in Domestic Water. Environmental Geochemistry and Health, 31, 27-45.

Westcot (1997). Water Quality Concerns in Drainage Water Management. Retrieved from www.fao.org/DOCREP/005/Y4263E/y4263e07.htm

World Health Organization (WHO) (1989). Health Guidelines for the Use of Wastewater in Agriculture and Aquaculture. Technical Report Series No.776. World Health Organization, Geneva.

World Health Organization (WHO) (2006). Guidlines for the Safe Use of Wastewater, Excreta and Grey water. Volume 4: Excreta and Greywater Use in Agriculture. World Health Organization, Geneva.

World Health Organization (WHO) (2008). Guidelines for Drinking-Water Quality 3rd Edition Incorporating the first and second Addenda Volume 1 Recommendations. World health Organization, Geneva.

8. APPENDIX I: DETAILED RESULTS

Detailed results are presented per type of sampling:

1 – Surface Results

2 – Spring Results

3 – Well Results

4 – lake Results

5 – Canal 900 Results

6 – Wastewater Results

7 – Industrial Results

8 – Soil Results

9 – River sediment Results

The map next page presents all samples with location and type. Finding individual results requires:

- Identifying the number of the sample location on the map; and
- Referring to the corresponding section and tables.

8.1.SURFACE RESULTS

1.a. Physical Characteristics of Sampled Surface Water within the ULB

Surface Water - Physical	T °C	CND µs/cm	TDS mg/l
20	11.7	239	118
25	17.9	578	275
28	14.9	375	185
34	17.9	668	332
36	19.3	1070	533
41	14.7	384	190
42	17.9	577	238
58	10	283	139
59	10.8	285	141
60	13.7	284	142
63	15.01	339	180
68	17	507	251
70	15.7	364	180
73	16.5	650	321
74	16.9	695	345
75	16	446	223
76	15.3	435	216
77	15	911	450
78	11.5	500	250
82	15.9	463	229
85	18.9	488	244
88	18.6	364	183
89	25	639	320
90	20	576	289
91	20	532	133
93	20	410	205
95	19	540	270
84	15.7	481	238
108		538	270
126	14.7	393	195
127	15.9	389	144
128	18.7	776	385
134	18.7	386	191
132	18.7	396	197

133	18.4	798	385
135	19.3	802	400
136			
139	17.7	1004	500
40	15.7	410	205
Soghbine	24	576	288
145	24	519	259.5
149	23	522	261
150	22.1	416	208

Mean	17.36	524.00	254.96
SD	3.43	191.04	97.39
Max	25.00	1070.00	533.00
Min	10.00	239.00	118.00
EPA standards			500
WHO guidelines			1000

1.b. Chemical Characteristics (Macro Elements) of Sampled Surface Water of ULB

Surface Water - Chemical Macro	pH	DO mg/l	BOD mg/l	Alkalinity mg/l as CaCO3	Chlorides mg/l Cl-	NO3-N mg/l	NH3-N mg/l	Phosphate mg/l as PO4-3	Sulfates mg/l as SO4-
20	8.54	5.6	8	70	10	0.2	0.19	0.3	0
25	8.13	5.8	6	150	35	9.6	0.27	0.6	18
28	7.9	5.6	52	250	90	1.2	26.3	28	41
34	7.69	6.2	9	290	50	0.9	1.27	0.88	30
36	7.34	0.9	29	390	110	0.9	2.18	7.8	41
41	8	7.1	8	180	20	1	0.21	1.5	30
42	7.56	3.2	33	400	135	1.1	2.25	0.08	41
58	8.19	6	14	150	20	0.5	0.25	0.75	5
59	7.88	6.3	12	160	15	0.6	0.17	0.59	4
60	8.07	6.1	21	180	20	0.7	0.27	0.79	7
63	7.45	4.1	18	180	15	0.3	0.13	0.48	12
68	4.53	4.2	5	230	55	1.1	0.52	4.98	15
70	7.66	7.2	7	180	250	0.7	0.22	0.31	5
73	7.65	4.2	56	300	80	0.5	0.83	5	21
74	7.59	2	25	280	55	1	6	3.4	27
75	7.84	4.3	20	210	40	0.9	1.38	1.48	18
76	7.42	5.7	9	200	35	0.4	0.61	1.04	11
77	7.61	2	14	370	105	0.8	10.4	4.74	42
78	7.6	4.8	15	220	45	1.6	1.05	0.99	26
82	7.43	5.8	11	220	40	0.5	0.23	1.65	8
85	7.97	4.8	13	250	40	1.1	0.2	1.69	15
88	7.89	8.8	24	170	35	0.6	0.22	1.32	19
89	7.28	1.2	70	250	130	2	3.22	0.65	28
90	7.55	4.1	46	240	75	0.5	1.08	2.66	29
91	7.68	5.5	20	190	60	0.3	0.86	2.14	25
93	7.72	8.3	17	150	40	0.2	0.34	0.42	33
95	7.44	2.5	26	220	35	0.6	1.99	1.88	20
84	7.81	6.3	8	240	40	1.2	0.25	0.74	12
108	7.41	2.6	14	240	50	1.4	1.99	1.78	22
126	8.15	5.7	9	190	30	1.5	0.23	1.57	23
127	8.18	5.4	10	180	30	1.3	0.27	0.69	27
128	7.44	2.2	20	790	75	2.7	0.09	3.4	26
134	7.76	4.6	9	190	25	1.3	0.39	1.36	3
132	7.76	4.5	7	170	35	2.9	0.26	0.71	4
133	7.5	3.4	7	210	75	8.9	0.26	0.21	26
135	7.56	2.4	12	300	75	2.2	6	3.58	29
136	7.5	5.9	12	380	180	1	16.8	6.68	33
139	7.49	1.1	22	380	115	0.5	15.9	5.4	37

Surface Water - Chemical Macro	pH	DO mg/l	BOD mg/l	Alkalinity mg/l as CaCO3	Chlorides mg/l Cl-	NO3-N mg/l	NH3-N mg/l	Phosphate mg/l as PO4-3	Sulfates mg/l as SO4-
40	8.1	5.7	70	430	130	0.8	29.5	60.5	29
Soghbine	7.46	1.9	28	250	70	0.3	3.36	3.02	22
145	7.93	7.6	3	230	50	1.5	1.48	1.83	26
149	7.78	6.9	8	210	85	1.6	0.38	1.09	36
150	7.96	9.1	2	210	85	1.6	0.66	0.63	31
Mean	7.66	4.83	19.28	248.37	64.88	1.41	3.27	3.94	22.26
SD	0.56	2.08	16.57	114.74	47.83	1.86	6.67	9.85	11.56
Max	8.54	9.10	70.00	790.00	250.00	9.60	29.50	60.50	42.00
Min	4.53	0.90	2.00	70.00	10.00	0.20	0.09	0.08	0.00
EPA standards	6.5-8.5				250	10			
WHO guidelines	6.8-8				250	10			

1.c. Chemical Characteristics (Macro Elements, Cont'd) of Sampled Surface Water within the ULB

Surface Water –Chemical Micro	Potassium mg/l as K+	Calcium mg/l as Ca2+	Magnesium mg/l as Mg 2+	Sodium mg/l as Na+
20	0.9	44	19.4	4.9
25	11.8	96	38.8	2.6
28	9.5	172	17	3.6
34	5.8	104	17	13.1
36	10.1	144	38.8	24.5
41	1.3	60.1	9.7	0.8
42	10.6	180	60.7	24.5
58	1	64.1	34	4.8
59	1.4	60.1	19.4	5.7
60	1.4	64	29.1	7.1
63	1	68.1	31.6	4.3
68	8.5	76	19.4	18.6
70	0.6	72	31.6	5.7
73	6.7	100	34	27.1
74	6.1	132	12.1	20
75	1.8	88.1	19.4	8.6
76	1.6	72.1	26.7	6
77	8.3	148	55.8	28.6
78	1.9	80	38.8	11.4
82	1.3	112	26.7	8.6
85	1.5	92	24.3	8.6
88	0.5	64	19.4	4.3
89	13.4	184	12.1	40
90	4.7	88	19.4	20
91	4.2	84	26.7	17.1
93	2.2	84	24.3	10
95	2.9	80	84	11.4
84	1.40	104.00	17.00	8.60
108	2.90	19.00	19.40	12.90
126	1.20	80.00	31.60	0.60
127	1.30	64.00	9.70	0.60
128	4.2	140	21.9	20.1
134	0.5	76.1	21.9	5.7
132	1.1	92.1	19.4	10.8
133	4.2	124.1	17	19.2
135	4.8	132.1	19.4	20.4
136	7.1	140.1	46.1	26.2

Surface Water –Chemical Micro	Potassium mg/l as K+	Calcium mg/l as Ca2+	Magnesium mg/l as Mg 2+	Sodium mg/l as Na+
139	8.7	108	34	32.9
40	10.4	132.1	41.3	3.8
Soghbine	0.13	0	38	3.14
145	0.15	0	36	3.14
149	0.19	0.08	39	3.26
150	0.15	0.14	38	3.3
Mean	3.94	88.94	28.83	12.01
SD	3.77	45.93	14.45	9.76
Max	13.40	184.00	84.00	40.00
Min	0.13	0.00	9.70	0.60
EPA standards				
EPA secondary standards				
WHO guidelines				

1.d. Chemical Characteristics (Trace metals) of Sampled Surface Water within the ULB

Surface Water – Trace metals	Barium µg/L as Ba	Copper µg/L as Cu	Cadmium µg/L as Cd	Lead µg/L as Pb	Chromium µg/L as Cr	Nickle µg/L as Ni	Zinc µg/L as Zn	Aluminum µg/L as Al	Arsenic µg/L as As	Cobalt µg/L as Co	Molybdenum µg/L as Mo	Iron mg/l as Fe	Manganese mg/L as Mn
20												0.02	0.015
25												0.02	0.028
28												0.29	0.118
34												0.02	0.036
36												0.58	0.264
41												0.1	0.049
42	272.9	5.99	0.741	0	0	1.837	20.796	19.022	0	0.217	0.835	0.61	0.31
58	17.362	3.693	1.794	0	0	0.084	16.5847	19.8	0	ND	1.399	0.03	0.021
59												0.02	0.008
60												0.03	0.008
63												0.02	0.011
68												0.13	0.03
70	10.151	0	0.408	0	0	2.647	9.606	16.274	0	ND	0.61	0.04	0.022
73												0.14	0.156
74	76.35	3.561	0.831	0	3.486	2.313	9.0023	17.087	0	ND	4.371	0.05	0.095
75												0.05	0.035
76												0.07	0.031
77												0.22	0.143
78												0.07	0.03
82	52.337	4.189	0.793	0	0.194	0.607	15.0102	10.024	0	ND	3.434	0.02	0.007
85												0.02	0.017
88												0.21	0.023
89												0.79	0.256

Surface Water – Trace metals	Barium µg/L as Ba	Copper µg/L as Cu	Cadmium µg/L as Cd	Lead µg/L as Pb	Chromium µg/L as Cr	Nickle µg/L as Ni	Zinc µg/L as Zn	Aluminum µg/L as Al	Arsenic µg/L as As	Cobalt µg/L as Co	Molybdenum µg/L as Mo	Iron mg/l as Fe	Manganese mg/L as Mn
90	33.561	2.458	1.232	0	0.921	0.551	7.6886	17.412	0	0.384	3.994	0.32	0.082
91												0.26	0.045
93												0.04	0.041
95												0.22	0.041
84												0.04	0.016
108	64.989	2.965	1.817	0	0.598	2.003	13.571	21.058	0	0.087	4.029	0.47	0.055
126												0.12	0.024
127	20.578	0.68	3.212	0	0	0.271	19.3858	19.214	0	ND	2.469	0.09	0.049
128												0.11	0.099
134	414.8	0.91	1.313	0	0.078	8.245	8.3358	19.468	0	ND	3.1	0.05	0.02
132												0.2	0.081
133	170.68	2.948	2.479	0	0.066	4.331	11.4267	39.265	0	ND	7.533	0.07	0.058
135												0.14	0.125
136												0.49	0.264
139												0.4	0.198
40												0.93	0.383
Soghbine	72.559	1.346	0.776	0	0	1.235	12.3926	16.403	0	0.043	1.971		0.114
145	69.395	0.876	1.232	0	0	1.072	22.4429	21.075	0	0.652	1.896		0.064
149													0.03
150	51.132	2.946	0.738	0	0	0.836	12.4312	17.272	0	0.13	1.07		0.035

Mean	102.06	2.50	1.462	0.00	0.41	2.00	13.14071	19.49	0.00	0.252	2.82	0.19	0.08
SD	118.21	1.69	0.874619	0.00	0.97	2.21	4.69653453	6.59	0.00	0.230	1.90	0.23	0.09
Max	414.80	5.99	3.212	0.00	3.49	8.25	20.796	39.27	0.00	0.652	7.53	0.93	0.38
Min	10.15	0.00	0.408	0.00	0.00	0.08	7.6886	10.02	0.00	0.043	0.61	0.02	0.01
EPA standards	2		0.005		0.1				0.01				
EPA secondary standards		1					5	0.005-2				0.3	0.05
WHO guidelines	0.7	2	0.003	0.01	0.05	0.07		0.2	0.01		0.07		0.4

I.e. Microbiological Characteristics of Sampled Surface Water within the ULB

Surface Water – Microbiological	Total Coliforms/ 100 ml	Fecal Coliforms/ 100 ml	Streptococcus fecalis/ 100 ml
20	0	0	0
25	0	0	0
28	TNTC	TNTC	0
34	TNTC	TNTC	0
36	0	0	0
41	0	0	0
42	TNTC	18	0
58	TNTC	TNTC	0
59	TNTC	TNTC	0
60	TNTC	TNTC	0
63	TNTC	TNTC	0
68	TNTC	24	0
70	TNTC	TNTC	0
73	0	0	0
74	0	0	0
75	0	0	0
76	TNTC	TNTC	0
77	TNTC	11	0
78	TNTC	TNTC	0
82	TNTC	82	0
85	TNTC	0	0
88	TNTC	TNTC	0
89	TNTC	TNTC	0
90	TNTC	TNTC	0
91	0	0	0
93	0	0	0
95	0	0	0
84	TNTC	TNTC	0
108	0	0	0
126	TNTC	TNTC	0
127	0	0	0
128	0	0	0
134	0	0	0
132	TNTC	TNTC	0

133	TNTC	TNTC	0
135	0	0	0
136	TNTC	TNTC	0
139	TNTC	18	0
40	TNTC	TNTC	0
Soghbine	TNTC	13	0
145	TNTC	TNTC	0
149	62	6	0
150	TNTC	TNTC	0

8.2.SPRING RESULTS

11.a. Chemical Characteristics (Macro Elements) of Sampled Spring Water along the ULB

Spring Water – Chemical	pH	DO mg/l	BOD	AIK mg/l as CaCO3	Chlorides mg/l Cl-	NO3-N mg/l	NH3-N mg/l	Orthophosphates mg/l PO4	Sulfates mg/l SO4--
33	7.63	6.6		130	15	0.8	0.17	1.03	8
55	7.92	6.6		150	15	0.4	0.12	0.71	2
69	7.58	6.8		170	15	0.7	0.18	0.74	6
79	7.5	6.6		230	30	1.2	0.2	0.58	9
80	7.36	7		210	40	1.4	0.19	0.98	8
87	7.9	7.4		160	25	0.1	0.16	0.75	17
96	7.23	7.8		210	25	0.6	0.16	0.64	4
98	7.22	7.8		180	25	0.5	0.15	0.76	30
99	7.17	7.4		170	40	0.4	0.16	0.52	70
101	6.96	6.9		210	35	0.9	0.15	0.52	20
102	7.13	7.4		130	35	0.4	0.15	0.89	20
103	7.05	7.3		180	40	0.4	0.17	0.5	13
117	7.4	7.2		300	30	0.1	0.17	0.96	7
120	7.07	7.5		150	40	0.3	0.2	0.29	19
121	6.82	8.8		150	45	0.2	0.17	0.71	31
127	7.76	4.7		190	30	1.2	0.2	0.76	13
130	7.43	3.5		190	30	2.5	0.11	0.63	5
138	7.6	5.3		160	30	1	0.12	0.93	3
141	7.62	7.4		160	30	0.5	0.18	0.77	6
Mean	7.39	6.84		180.53	30.26	0.72	0.16	0.72	15.32
SD	0.31	1.20		40.07	8.89	0.57	0.03	0.19	15.77
Max	7.92	8.80		300.00	45.00	2.50	0.20	1.03	70.00
Min	6.82	3.50		130.00	15.00	0.10	0.11	0.29	2.00
EPA standards	6.5-8.5				250	10			
EPA secondary standards									
WHO guidelines	6.8-8				250	10			

11.b. Chemical Characteristics (Macro Elements, Cont'd) of Sampled Spring Water along the ULB

Spring Water - Chemical	Potassium mg/l as K+	Calcium mg/l as Ca2+	Magnesium mg/l as Mg 2+	Sodium mg/l as Na+
33	2.7	60.1	9.7	3.7
55	0.4	60.1	19.4	4.3
69	0.6	76	36.4	5.7
79	1.5	88	19.4	7.1
80	1.1	92	14.6	7.1
87	0.6	68	12.1	5.7
96	1.3	80	17	5.7
98	0.02	88	29.1	4.3
99	0.5	96	21.9	4.3
101	1.8	92	9.7	5.7
102	0.02	88	12.1	4.3
103	0.02	80	17	4.3
117	1.6	116	24.3	7.1
120	0.02	60	12.1	2.9
121	0.02	80	2.4	2.9
127	1.2	80.1	21.9	0.6
130	1.4	88.1	9.7	0.8
141	0.8	84	4.9	5.7
Mean	0.87	82.02	16.32	4.57
SD	0.76	14.13	8.49	1.91
Max	2.70	116.00	36.40	7.10
Min	0.02	60.00	2.40	0.60
EPA standards				
EPA secondary standards				
WHO guidelines				

11.c. Chemical Characteristics (Trace Metals) of Sampled Spring Water along the ULB

Spring Water - Trace Metals	Barium µg/L as Ba	Copper µg/L as Cu	Cadmium µg/L as Cd	Lead µg/L as Pb	Chromium µg/L as Cr	Nickle µg/L as Ni	Zinc µg/L as Zn	Aluminum µg/L as Al	Arsenic µg/l as As	Cobalt µg/L as Co	Molybdenm µg/L as Mo	Iron µg/l as Fe	Manganese mg/L as Mn
33												0.05	0.018
55												0.03	0.008
69	29.18	2.64	0.948	0	0.703	0.712	11.5812	19.335	0	ND	2.561	0.01	0.007
79												0.02	0.006
80												0.01	0.009
87	24.34	1.807	1.35	0	0.135	1.703	9.292	34.518	0	ND	3.973	0.02	0.013
96												0.02	0.015
98												0.03	0.017
99												0.01	0.019
101												0.01	0.016
102												0.01	0.01
103												0.01	0.017
117												0.01	0
120	17.29	1.511	3.123	0	1.218	8.323	3.4966	12.839	0	ND	6.122	0.01	0.016
121												0.01	0.018
127												0.07	0.185
130	340	1.065	2.32	0	7.729	3.886	27.7699	21.809	0	ND	6.632	0	0.015
138												0	0.01
141												0.02	0.017
Mean	102.70	1.76	1.94	0.00	2.45	3.66	13.03	22.13	0.00	0.00	4.82	0.02	0.02
SD	158.26	0.66	0.98	0.00	3.55	3.38	10.40	9.09	0.00	0.00	1.90	0.02	0.04
Max	339.98	2.64	3.12	0.00	7.73	8.32	27.77	34.52	0.00	0.00	6.63	0.07	0.19
Min	17.29	1.07	0.95	0.00	0.14	0.71	3.50	12.84	0.00	0.00	2.56	0.00	0.00
EPA standards	2		0.005		0.1				0.01				
EPA Secondary standards		1					5	0.005-2				0.3	0.05
WHO	0.7	2	0.003	0.01	0.05	0.07		0.2	0.01		0.07		0.4

Note that iron wan not detected in samples 130 and 138

11.d. Microbiological Characteristics of Sampled Spring Water along the ULB

Spring Water - Microbiological	Total Coliforms/ 100ml	Fecal coliforms/100 ml	Strep Fecalis/ 100ml
33	17	9	0
55	95	15	3
69	TNTC	9	0
79	TNTC	TNTC	0
80	50	15	0
87	0	0	0
96	7	2	0
98	0	0	0
99	8	0	0
101	34	22	0
102	0	0	0
103	0	0	0
117	9	4	0
120	4	0	0
121	6	0	0
127	TNTC	77	0
130	10	0	0
138	1	0	0
141	TNTC	39	0

8.3. WELL RESULTS

III.a Physical Characteristics of Sampled Well Water along the ULB

Well Water - Physical	T °C	CND µs/cm	TDS mg/l
21	16.80	528.00	264.00
24	16.80	248.00	124.00
26	18.30	856.00	426.00
40	19.30	498.00	245.00
56	10.20	259.00	127.00
63	16.60	592.00	295.00
65	15.01	322.00	160.00
94	21.30	685.00	343.00
104	18.30	540.00	270.00
106	18.70	364.00	184.00
107	17.60	339.00	170.00
111	22.00	580.00	290.00
116	22.30	474.00	238.00
118	22.50	439.00	120.00
124	15.90	598.00	297.00
129		496.00	248.00
131	17.70	561.00	280.50
138		322.00	161.00
180	18.90	677.00	337.00
176	18.70	802.00	400.00
177	19.50	952.00	475.00
181		1278.00	637.00
Mean	18.23	564.09	276.89
SD	2.88	245.64	126.57
Max	22.50	1278.00	637.00
Min	10.20	248.00	120.00
EPA standards			500.00
WHO guidelines			1000.00

III.b. Chemical Characteristics (Macro Elements) of Sampled Well Water along the ULB

Well Water – Chemical	pH	DO mg/l	AlK mg/l as CaCO3	Chlorides mg/l Cl-	NO3-N mg/l	NH3-N mg/l	Ortho-phosphates mg/l PO4	Sulfates mg/l SO4--
21	7.68	4.4	190	30	0	0.13	0.6	8
24	8.08	5.3	110	25	0.2	0.12	0.54	0
26	7.59	5.2	140	70	12.4	0.16	0.6	26
40	7.33	7.8	210	50	3.6	0.12	0.74	11
56	7.88	5.9	140	15	2.7	0.18	0.72	1
63	7.45	2.4	200	20	0.3	0.12	0.52	7
65	7.50	4.7	200	20	0.3	0.12	0.52	7
94	7.47	6.4	240	35	2.4	0.2	1.24	24
104	7.29	7.4	180	35	4.3	0.17	0.62	12
106	7.13	6.7	170	20	1.2	0.16	0.88	1
107	7.38	7.5	170	25	1	0.18	0.54	1
111	7.30	6.3	200	30	1.7	0.15	0.83	15
116	7.75	6.2	220	20	1.8	0.18	0.85	7
118	7.96	1.8	210	30	0.3	0.42	0.91	14
124	7.35	5.6	260	40	3.8	0.16	0.72	27
129	7.66	0.1	240	30	1.9	0.21	0.31	3
131	7.55	3.4	250	35	2	0.13	1.23	2
138	7.93	4.5	160	25	0.2	0.1	0.73	1
180	7.26	7.5		45	2	0.15	1.31	16
176	7.22	1.6	240	55	7	0.2	1.64	32
177	7.04	4.8	240	65	8.5	0.17	0.42	20
181	7.20	6.6		145	1.1	0.23	0.21	63
Mean	7.50	5.10	198.50	39.32	2.67	0.17	0.76	13.55
SD	0.29	2.11	41.20	27.83	3.08	0.07	0.34	14.65
Max	8.08	7.80	260.00	145.00	12.40	0.42	1.64	63.00
Min	7.04	0.10	110.00	15.00	0.00	0.10	0.21	0.00
EPA standards	6.5-8.5			250	10			
EPA secondary standards								
WHO guidelines	6.8-8			250	10			

III.c. Chemical Characteristics (Macro Elements, Cont'd) of Sampled Well Water along the ULB

Well Water - Chemical	Potassium mg/L as K+	Calcium mg/L as Ca++	Magnesium mg/L as Mg++	Sodium mg/L as Na+
21	0.8	124.1	7.3	9.8
24	0.4	52.1	7.3	5.6
26	0.2	148.1	26.7	1.4
40	1.7	100.1	31.6	1.2
56	0.5	72.1	12.1	4.3
63	1.8	100.1	53.4	10
65	0.9	96.1	24.3	5.7
94	0.8	132	9.7	10
104	2.5	92	31.6	11.4
106	0.5	76	12.1	5.7
107	0.3	72	19.4	5.7
111	1.1	100	29.1	8.6
116	0.7	84	80	7.1
118	0.5	31.6	26.7	7.1
124	15.4	96.1	26.7	1
129	0.7	68.1	24.3	10.1
131	0.6	100.1	14.6	9.6
138	0.3	84.1	29.1	5.8
180	0.8	96.1	14.6	7.5
176	0.1	136.1	29.1	1.4
177	1.7	164.2	55.8	1.2
181	1.1	224	9.7	12.2
Mean	1.52	102.23	26.15	6.47
SD	3.16	41.03	17.69	3.57
Max	15.40	224.00	80.00	12.20
Min	0.10	31.60	7.30	1.00
EPA standards				
EPA secondary standards				
WHO guidelines				

III.d. Chemical Characteristics (Tace Metals) of Sampled Well Water along the ULB

Well Water - Trace Metals	Barium µg/L as Ba	Copper µg/L as Cu	Cadmium µg/L as Cd	Lead µg/L as Pb	Chromium µg/L as Cr	Nickle µg/L as Ni	Zinc µg/L as Zn	Aluminum µg/L as Al	Arsenic µg/l as As	Cobalt µg/L as Co	Molybdenm µg/L as Mo	Iron µg/l as Fe	Manganese mg/L as Mn
21												0.03	0.019
24												0.01	0.015
26												0.04	0.026
40												0.06	0.022
56												0.04	0.013
63	205.57	4.144	0.602	0	0	3.062	20.786	8.58	0	ND	1.033	0.01	0.011
65												0.01	0.012
94												0.11	0.064
104	97.31	0.785	5.176	0	2.796	5.246	20.535	12.097	0	ND	1.076	0.01	0
106												0	0
107												0	0
111												0	0
116													
118	26.247	3.097	0.986	0	0	0	55.747	14.281	0	ND	0.704		
124												0.17	0.023
129												0.02	0.01
131												0.14	0.018
138												0.01	0.011
180												0.01	0.021
176												2.8	0.04
177												0.02	0.033
181												0.72	0.038
Mean	109.71	2.68	2.25	0.00	0.93	2.77	32.36	11.65	0.00	0.00	0.94	0.21	0.02
SD	90.30	1.72	2.54	0.00	1.61	2.64	20.26	2.88	0.00	0.00	0.20	0.63	0.02
Max	205.57	4.14	5.18	0.00	2.80	5.25	55.75	14.28	0.00	0.00	1.08	2.80	0.06
Min	26.25	0.79	0.60	0.00	0.00	0.00	20.54	8.58	0.00	0.00	0.70	0.00	0.00
EPA standards	2		0.005		0.1				0.01				
EPA Secondary standards		1					5	0.005-2				0.3	
WHO	0.7	2	0.003	0.01	0.05	0.07		0.2	0.01		0.07		

III.e. Microbiological Characteristics of Sampled Well Water along The Upper Litani Basin

Well Water - Microbiological	Total Coliforms/ 100ml	Fecal coliforms/ 100 ml	Streptococcus fecalis/ 100ml
21	71	21	0
24	6	0	0
26	1	0	0
40	TNTC	0	0
56	0	0	0
63	0	0	0
65	5	0	0
94	3	0	0
104	0	0	0
106	0	0	0
107	0	0	0
111	0	0	0
116	0	0	0
118	0	0	0
124	0	0	0
129	TNTC	1	0
131	2	0	0
138	0	0	0
180	0	0	0
176	0	0	0
177	17	5	0
181	0	0	0

8.4.LAKE RESULTS

IV.a. Physical Characteristics of Sampled Water from Qaraoun Lake

Lake - Physical	T °C	CND μs/cm	TDS mg/l
151	23.2	494	247
152	22.8	496	248
153	22.9	492	246
154	23.3	487	243.5
155	23.2	482	241
156	23	481	240.5
157	23	480	240
158	23.1	470	235
159	23.2	469	234.5
160		480	240
Mean	23.08	483.10	241.55
SD	0.16	9.28	4.64
Max	23.30	496.00	248.00
Min	22.80	469.00	234.50
EPA standards			500
WHO guidelines			1000

IV.b. Chemical Characteristics (Macro Elements) of Sampled Water from Qaraoun Lake

Lake - Chemical	pH	DO mg/l	BOD mg/l	AIK mg/l as CaCO3	Chlorides mg/l Cl-	NO3-N mg/l	NH3-N mg/l	Ortho phosphates mg/l PO4	Sulfates mg/l SO4--
151	7.94	8.4	4	230	65	2.4	0.44	0.61	34
152	7.92	9		220	65	2	0.32	0.69	35
153	7.97	9.8		190	95	2.1	0.32	0.29	34
154	8.11	9.6		170	65	1.7	0.26	0.56	37
155	8.13	10.7	2	190	65	2.1	0.27	0.42	36
156	8.2	10.2		170	70	2.4	0.25	0.41	36
157	8.29	10.5		170	75	1.8	0.26	0.43	36
158	8.32	11.2		180	65	1.9	0.24	0.32	35
159	8.25	10.6	2	190	70	1.9	0.25	0.29	36
160	7.85	8.1		190	65	1.7	0.3	0.47	36
Mean	8.10	9.81	2.67	190.00	70.00	2.00	0.29	0.45	35.50
SD	0.17	1.03	1.15	20.55	9.43	0.25	0.06	0.14	0.97
Max	8.32	11.20	4.00	230.00	95.00	2.40	0.44	0.69	37.00
Min	7.85	8.10	2.00	170.00	65.00	1.70	0.24	0.29	34.00
EPA standards	6.5-8.5				250.00	10.00			
EPA secondary standards									
WHO guidelines	6.8-8				250	10			

IV.c. Chemical Characteristics (Macro Elements, Cont'd) of Sampled Water from Qaraoun Lake

Lake - Chemical	Potassium mg/L as K+	Calcium mg/L as Ca++	Magnesium mg/L as Mg++	Sodium mg/L as Na+
151	3.6	76	17	15.7
152	3.5	726	12	15.7
153	3.5	68	17	15.7
154	3.6	72	12.1	15.7
155	3.5	72	9.7	15.7
156	3.5	72	17	15.7
157	3.5	68	9.7	15.7
158	3.4	60	17	15.7
159	3.5	68	9.7	15.7
160	3.6	80	7.3	15.7
Mean	3.52	136.20	12.85	15.70
SD	0.06	207.30	3.81	0.00
Max	3.60	726.00	17.00	15.70
Min	3.40	60.00	7.30	15.70
EPA standards				
EPA secondary standards				
WHO guidelines				

IV.d. Chemical Characteristics (Trace Metals) of Sampled Water from Qaraoun Lake

Lake - Trace Metals	Barium µg/L as Ba	Copper µg/L as Cu	Cadmium µg/L as Cd	Lead µg/L as Pb	Chromium µg/L as Cr	Nickle µg/L as Ni	Zinc µg/L as Zn	Aluminum µg/L as Al	Arsenic µg/l as As	Cobalt µg/L as Co	Molybdenm µg/L as Mo	Iron µg/l as Fe	Manganese mg/L as Mn
151	177.08	3.641	1.019	0	0	1.06	25.11	20.529	0	0.087	1.38	0.06	0.034
152												0.06	0.027
153	54.54	1.116	0.738	0	0	0.665	11.28	7.879	0	ND	1.173	0.06	0.024
154												0.03	0.026
155	67.662	3.205	0.88	0	1.351	0.642	24.8	18.877	0	ND	2.037	0.02	0.032
156												0.03	0.025
157												0.05	0.034
158												0.03	0.027
159	48.518	1.234	0.537	0	0	1.029	25.07	15.92	0	ND	1.22	0.03	0.023
160												0.03	0.027
Mean	86.95	2.30	0.79	0.00	0.34	0.85	21.57	15.80	0.00	0.087	1.45	0.04	0.03
SD	60.62	1.31	0.21	0.00	0.68	0.23	6.86	5.62	0.00		0.40	0.02	0.00
Max	177.08	3.64	1.02	0.00	1.35	1.06	25.11	20.53	0.00	0.087	2.04	0.06	0.03
Min	48.52	1.12	0.54	0.00	0.00	0.64	11.28	7.88	0.00	0.00	1.17	0.02	0.02
EPA standards	2		0.005		0.1				0.01				
EPA Secondary standards		1					5	0.005-2					0.05
WHO	0.7	2	0.003	0.01	0.05	0.07		0.2	0.01		0.07		0.4

IV.e. Microbiological Characteristics of Sampled Water from Qaraoun Lake

Lake - Microbiological	Total Coliforms/ 100ml	Fecal coliforms/ 100 ml	Strep Fecalis/ 100ml
Soghbine	TNTC	13	0
145	TNTC	TNTC	0
149	62	6	0
150	TNTC	TNTC	0
151	TNTC	TNTC	0
152	TNTC	TNTC	0
153	32	12	0
154	TNTC	TNTC	0
155	TNTC	42	0
156	72	27	0
157	TNTC	26	0
158	TNTC	TNTC	0
159	14	0	0
160	74	14	0

8.5. CANAL 900 RESULTS

V.a. Physical Characteristics of Sampled Water from Canal 900

Canal - Physical	T °C	CND µs/cm	TDS mg/l
43	19.7	525	233
45	18.5	502	250
48	17.2	589	290
49	15.7	599	295
50	15.3	600	300
51	23.2	485	240
53	21.7	537	266
Mean	18.76	548.14	267.71
SD	2.97	47.82	27.61
Max	23.20	600.00	300.00
Min	15.30	485.00	233.00
EPA standards			500
WHO guidelines			1000

V.b. Chemical Characteristics (Macro Elements) of Sampled Water from Canal 900

Canal - Chemical	pH	DO mg/l	BOD	AlKalinity mg/l as CaCO3	Chlorides mg/l Cl-	NO3-N mg/l	NH3-N mg/l	Phosphate mg/l as PO4-3	Sulfates mg/l as SO4-
43	7.73			180	70	2.3	0.26	0.28	44
45	7.64	7.8		190	55	2.4	0.29	0.93	43
48	7.53	4.8		210	85	3	0.4	0.61	44
49	7.47	3		200	75	1.3	0.4	0.69	43
50	7.8	8.5		130	80	2.5	0.26	0.37	42
51	7.69			180	90	2.3	0.27	0.29	43
Mean	7.34	5.92		184.29	77.14	2.26	0.31	0.53	43.00
SD	0.82	2.24		26.37	11.85	0.52	0.06	0.24	0.82
Max	7.8	8.5		210	90	3	0.4	0.93	44
Min	5.5	3		130	55	1.3	0.26	0.28	42
EPA standards	6.5-8.5				250	250			
EPA secondary standards									
WHO guidelines	6.8-8				10	10			

V.c. Chemical Characteristics (Macro Elements, Cont'd) of Sampled Water from Canal 900

Canal - Chemical (Micro)	Potassium mg/l as K+	Calcium mg/l as Ca2+	Magnesium mg/l as Mg 2+	Sodium mg/l as Na+
43	3.7	76	15	11.3
45	3.8	80	17	11.3
48	3.9	84	22	11.3
49	3.7	88	12	11.3
50	3.9	84	7.3	11.3
51	3.8	64	10	11.3
53	3.7	76	12	11.3
Mean	3.79	78.86	13.61	11.30
SD	0.09	7.90	4.86	0.00
Max	3.90	88.00	22.00	11.30
Min	3.70	64.00	7.30	11.30
EPA standards				
EPA secondary standards				
WHO guidelines				

V.d. Chemical Characteristics (Trace Metals) of Sampled Water from Canal 900

Canal - Trace Metals	Barium µg/L as Ba	Copper µg/L as Cu	Cadmium µg/L as Cd	Lead µg/L as Pb	Chromium µg/L as Cr	Nickle µg/L as Ni	Zinc µg/L as Zn	Aluminum µg/L as Al	Arsenic µg/l as As	Cobalt µg/L as Co	Molybdenm µg/L as Mo	Iron mg/l as Fe	Manganese mg/l as Mn
43												0.02	0.015
45												0.04	0.065
48	129.97	1.734	0.828	0	0	3.478	20.92	42.844	0	0.487	4.263	0.02	0.051
49												0.02	0.057
50	90.51	2.316	2.114	1.286	0	1.28	21.39	18.452	0	0.087	1.802	0.02	0.06
51	49.752	17.329	3.606	5.285	0.124	7.761	24.14	19.019	0	0.087	1.541	0.03	0.027
53	75.049	0.377	0.764	0	0	2.032	33.55	13.058	0	ND	1.333	0.01	0.018
Mean	86.32025	5.439	1.828	1.64275	0.031	3.638	25	23.343	0	0.22	2.2348	0.022857	0.0419
SD	33.601253	7.96819	1.33855	2.5026993	0.062	2.896	5.874	13.275	0	0.231	1.3657	0.009512	0.0212
Max	129.97	17.329	3.606	5.285	0.124	7.761	33.55	42.844	0	0.487	4.263	0.04	0.065
Min	49.752	0.377	0.764	0	0	1.28	20.92	13.058	0	0	1.333	0.01	0.015
EPA standards	2		0.005		0.1				0.01				
EPA secondary standards		1					5	0.005-2				0.3	0.05
WHO guidelines	0.7	2	0.003	0.01	0.05	0.07		0.2	0.01		0.07		0.4

Canal - Microbiological	Total Coliforms/ 100ml	Fecal Coliforms/ 100ml	Streptococcus faecalis/ 100ml
43	TNTC	5	0
45	TNTC	15	0
48	TNTC	15	0
49	3	0	0
50	0	0	0
51	TNTC	2	0
53	TNTC	0	0

8.6. WASTE WATER RESULTS

VI.a. Physical Characteristics of Sampled Domestic Waste Water along the Upper Litani Basin

Waste Water - Physical	CND µs/cm	TDS mg/l
57	625	315
61	615	305
133	973	488
109	490	245
90	532	133
105	750	323
101	483	242
Mean	638.29	293.00
SD	174.47	108.06
Max	973.00	488.00
Min	483.00	133.00
EPA standards		500
WHO guidelines		1000

V1.b. Chemical Characteristics (Macro Elements) of Sampled Domestic Waste Water along The Upper Litani Basin

Waste Water - Chemical (Macro)	pH	DO mg/l	BOD Mg/l	AlKalinity mg/l as CaCO3	Chlorides mg/l Cl-	NO3-N mg/l	NH3-N mg/l	Phosphate mg/l as PO4-3
57	7.62	6.5	97	200	25	0.2	0.27	1.4
61	7.72	6.6	90	160	35	0.5	0.14	0.63
133	7.54	7.2	310	290	140	0.9	4	2.4
109	7.53	7.3	33	400	135	1.1	22.5	0.08
90	7.68	5.56	20	190	60	0.3	0.86	2.14
105	7.83	4.5	300	340	75	5.3	5.88	9.12
101	7.35	7.1	25	230	40	0.6	0.67	3.28
Mean	7.61	6.39429	125	258.5714	72.85714	1.271429	4.9029	2.7214286
SD	0.1551	1.02513	126.72	87.83101	47.15728	1.80436	8.0606	3.0219333
Max	7.83	7.3	310	400	140	5.3	22.5	9.12
Min	7.35	4.5	20	160	25	0.2	0.14	0.08
EPA standards	6.5-8.5				250	250		
EPA secondary standards								
WHO guidelines	6.8-8				10	10		

Waste Water - Microbiological	**Total Coliforms/ 100ml**	**Fecal Coliforms/ 100ml**	**Streptococcus faecalis/ 100ml**
57	TNTC	TNTC	0
61	0	0	0
133	TNTC	TNTC	0
109	TNTC	18	0
90	0	0	0
105	0	0	0
101	0	0	0

8.7. INDUSTRIAL RESULTS

VII.a. Physical Characteristics of Sampled Industrial Waste Water along the Upper Litani Basin

Industrial - Chemical	pH	DO mg/l	BOD mg/l	AlK mg/l as CaCO3	Chlorides mg/l Cl-	NO3-N mg/l	NH3-N mg/l	Orthophosphates mg/l PO4
54			783	140	15	0.1	0.21	3.8
91			416	200	90	0.3	1.71	2.02
71			580	260	65	0.8	1.61	0.31
172			1200	440	210	14.8	23.8	1.02
174			857	290		1.5	1.82	0.8
Mean			767.20	266.00	95.00	3.50	5.83	1.59
SD			297.50	113.05	82.76	6.34	10.07	1.38
Max			1200.00	440.00	210.00	14.80	23.80	3.80
Min			416.00	140.00	15.00	0.10	0.21	0.31
EPA standards	6.5-8.5				250	10		
EPA secondary standards								
WHO guidelines	6.8-8				250	10		

VII.b. Chemical Characteristics (Macro Elements) of Sampled Industrial Waste Water along The Upper Litani Basin

Industrial – Chemical	Potassium mg/L as K+	Calcium mg/L as Ca++	Magnesium mg/L as Mg++	Sodium mg/L as Na+
54	0.8	60.1	24.3	10
91	6.4	92	21.9	25.8
71	4	120.1	19.4	36.8
172	138.4	120.1	43.7	26.8
174	4	2.05	2.4	64.3
Mean	30.72	78.87	22.34	32.74
SD	60.23	49.56	14.72	20.08
Max	138.40	120.10	43.70	64.30
Min	0.80	2.05	2.40	10.00
EPA standards				
EPA secondary standards				
WHO guidelines				

VII.c. Chemical Characteristics (Trace Elements) of Sampled Industrial Waste Water along the ULB

Industrial - Trace Metals	Barium µg/L as Ba	Copper µg/L as Cu	Cadmium µg/L as Cd	Lead µg/L as Pb	Chromium µg/L as Cr	Nickle µg/L as Ni	Zinc µg/L as Zn	Aluminum µg/L as Al	Arsenic µg/l as As	Cobalt µg/L as Co	Molybdenum µg/L as Mo	Iron mg/l as Fe	Manganese mg/L as Mn
54	2163	13.458	14.15	0	0.229	2.459	44.56	205.501	0	ND	5.249	0.02	0.013
91	743.3	12.585	11.86	0	0	1.371	43.36	21.588	0	0.652	8.349	0.22	0.102
71	7353	6.559	4.532	0	0	1.694	51.82	21.853	0	0.043	10.23	1.28	0.137
172	327.33	36.17	4.006	0	0	3.59	20.17	14.922	0	3.174	25.38	2.13	0.478
174	274.77	2.427	0.737	0	0	4.413	11.11	21.089	0	1.087	16.77	0.36	0.134
Mean	849.00	14.24	7.06	0.00	0.05	2.71	34.20	56.99	0.00	1.239	13.20	0.80	0.17
SD	768.00	13.07	5.68	0.00	0.10	1.28	17.55	83.07	0.00	1.359	8.01	0.89	0.18
Max	2166.00	36.17	14.15	0.00	0.23	4.41	51.82	205.50	0.00	3.174	25.38	2.13	0.48
Min	274.77	2.43	0.74	0.00	0.00	1.37	11.11	14.92	0.00	0.00	5.25	0.02	0.01
EPA standards	2		0.005		0.1				0.01				
EPA Secondary standards		1					5	0.005-2					0.05
WHO	0.7	2	0.003	0.01	0.05	0.07		0.2	0.01		0.07		0.4

Industrial - Microbiological	Total Coliforms/ 100ml	Fecal coliforms/ 100 ml	Strep Fecalis/ 100ml
54	0	0	0
91	0	0	0
71	TNTC	75	0
172	0	0	0
174	TNTC	50	0

9. APPENDIX II: SAMPLED SITES

9.1. YELLOW ZONE

The Codes of Cities and Villages Surveyed in the Yellow Zone

ABL	Ablah	ابلح
BDL	Bednayl	بدنايل
CHM	Chemistar	شمسطار
FRZ	Ferzol	فرزل
HEL	Helaniyeh	الحلانية
HEZ	Hezeine	حزين
HRF	Housh Al Rafka	حوش الرافقة
HSD	Housh Sneid	حوش سنيد
HWB	Housh Barda	حوش بردا
JNT	Janta	جنتا
MAS	Masa	ماسا
RYK	Rayak	رياق
SAD	Saidi	سعيدة
SAR	Sareine	سرعين
SFR	Sifri	صفري
TMF	Temnine Al Fawka	تمنين الفوقا
TMT	Temnine Al Tahta	تمنين التحتا
TRY	Taraya	طريا
YHF	Yehfoufa	يحفوفا

Upper Litany Basin	Location to River Basin		Profile of Village/City			Major Sources of Pollution Type of Source		GPS Reference
Village/ City	West	East	Residential	Agricultural	Industrial	Point Sources	Non-Point Sources	
1a. Al Saidi (SAD)	West		X Residential & Agricultural in addition to Bedouins' Settlements	X		Solid Waste Dumping along Water Canal near Bedouin settlement	Agriculture Runoff	20
1.b. Housh Barada (HWB)		East	Mainly Agricultural (tobacco plantation)	X		Solid wastes Dumping and carry over along Water Flow	Agriculture Runoff	25
2.a. Taraya (TRY)	West		X Residential, Agricultural and Recreational Contributes the Housh Bay Tributary originating from Housh Bay Spring (Roman ruins)	X		Domestic Wastewater Outlet from Taraya & Chmistar	Agriculture Runoff	134
2.b. Housh Sneid (HSD)		East	X Mainly Agricultural (Wheat, Vegetables and Tobacco plantation) Industrial; major Dairy Plant(Liban Lait)	X		WW Outlet from Housh Sneid WW from Liban Lait Industry	Agricultural Runoff	133 Diffused Outlet
3.a. Chemistar (CMT)	West		X Residential and Agricultural and Small Scale Dairy Plants	X		Domestic Wastewater Flows into Housh Bay Tributary (Same Outlet as WW from Taraya and Chemistar)	Agricultural Runoff	132
3.b. Hezeine (HEZ)		East	X Mainly Agricultural (Tobacco Plantation)	X		Domestic Wastewater Solid Wastes Dump Sites	Agricultural Runoff	29 28 &29
4.a Bednayl (BDL)	West		X Wastewater (Sewerage System mostly and Cesspools) tapped directly and used for irrigation	X		Domestic Wastewater	Agricultural Runoff	Subsurface Outlet
4.b. Housh Rafka (HRF)		East	X Wastewater tapped directly and used for irrigation	X		Domestic Wastewater	Agricultural Runoff	Subsurface Outlet
5.a. Temnine Al Fawka (TMF)	West		X Contributes the Temnine Tributary originating from Jeb el Habach Spring (Roman Ruins) that is fed by rain and snow melting from Neha Area	X		Cesspools for Domestic Wastewater Disposal	Agricultural Runoff	
5.b. Temnine AL Tahta(TMT)		East	X Major Rock-Cutting Industry	X	X	Industrial Wastewater	Agricultural Runoff	136
6.a.i. Ablah (ABL)	West		Mainly Agricultural and Industrial (Main Poultry Plant and Plastic industry) Solid Wastes Disposed in Zahle Landfill	X	X	Industrial Wastewater (Poultry Processing Plant) Domestic Wastewater (WW Treatment Plant Under Construction)	Agricultural Runoff	42 (diffuse ourlet) 38

Upper Litany Basin	Location to River Basin	Profile of Village/City	Major Sources of Pollution Type of Source		GPS Reference
6.a.ii. Ferzol (FRZ)	West	X X X Major industry (Master potato Chips) Contributes the Habbis/Fersol Tributary originating from Habbis Water Spring	Industrial Wastewater (Master potato Chips) Domestic Wastewater Treatment Plant; Secondary level Treatment; OUT OF ORDER as pipes are blocked Solid Waste Dumping from Fruits and Vegetables Market	Agricultural Runoff	32 38 38
6.b. Rayak (RYK)	East	X X Lebanese Army Barraks and Residential Units		Agricultural Runoff and Cesspools	
7. Yahfoufa (YHF)	East	X X And Recreational Areas Contributes the Yahfoufa/ Hala Tributary originating from Yahfoufa Spring (Jowsha Spring) that is exposed to WW from Sergaia (Mohafazat Al Zabadani in Syria)	Restaurants	Agricultural Runoff and Cesspools	127
8. Janta (JNT)	East	X X And Recreational Areas Contributes the Yahfoufa/Hala Tributary originating from Yahfoufa Spring (Jowsha Spring)	Restaurants	Agricultural Runoff and Cesspools	126
9. Masa (MSA)	East	X X Contributes the Yahfoufa/ Hala Tributary originating from Yahfoufa Spring (Jowsha Spring)	Stone Cutting industry	Agricultural Runoff and Cesspools	125

Litani River Upper Basin	Location to River Bed		Profile of Village/City			Proposed Sampling Sites		Quality Indicators for River Sampling Points
Village/ City	**West**	**East**	**Residential**	**Agricultural**	**Industrial**	**Type of Sample**	**Ref. GPS**	**T⁰C pH DO mg/l CND uS TDS mg/l**
1a. Al Saidi (SAD)	West		X	X		Litani R Water 20 Water source from Al Yamouni Soil 22 Well Water 21		11.7 8.54 5.60 239 118 Solid waste dumping along water flow (Bedouin Settlement)
			Residential & Agricultural in addition to Bedouins' Summer Settlement					
1.b. Housh Barada (HB)		East		X		Litani R Water 25 Well Water (Irrigation) 25		17.9 8.13 5.80 578 275 Suspended algae growth mostly along river banks; in addition to presence of frogs and Solid wastes dumping and carry over along water flow
			Mainly agricultural (Tobacco Plantation)					
2.a. Taraya (TRY)	West		X	X		Spring Water 130 (Housh Bay; Recreational Area) Well Water 129 (Domestic &Agricultural Use) Well water 131 Housh Bay Tributary 134 (Before WW discharge from Taraya and Chmistar) WW Discharge Outlet 134 Housh Bay Tributary 132 (After meeting WW from Taraya and Chmistar)		18.7 7.79 4.60 386 190 Clear water with extensive algae growth on river bard; presence of ducks 18.7 7.76 4.50 396 195
			Residential, Agricultural and Recreational Contributes the Housh Bay Tributary originating from Housh Bay Water Spring (Roman Ruins)					
2.b. Housh Sneid (HSD)		East		X		Litani R Water 133 (Housh Bay Tributary meeting Litani in Housh Sneid Wastewater Outlet from		18.4 7.50 3.40 798 385 Turbid green blue water with extensive bamboo growth
			Mainly Agricultural (Wheat, Vegetables and Tobacco Plantation)					

Litani River Upper Basin	Location to River Bed		Profile of Village/City			Proposed Sampling Sites		Quality Indicators for River Sampling Points				
Village/ City	West	East	Residential	Agricultural	Industrial	Type of Sample	Ref. GPS	T⁰C	pH	DO mg/l	CND uS	TDS mg/l
						133 Housh Sneid Industrial wastewater 174 (Liban Lait Industry) Soil 133						
3.a. Chmistar (CHM)	West		X Residential (No Domestic Water although Meters were installed 4 to 5 years ago), Agricultural and Small Scale Dairy Plants	X		None (Not Directly Located along River Bed)						
3.b.Hezeine (HEZ)		East	X Mainly Agricultural (Tobacco Plantation)	X		Litani R Water 28 Soil 25 Well Water (Adjacent to river bed) 26 Well water 27 (Main Irrigation Water Source in the Area) Not Accessible Soil 28 Wastewater Outlet 29 (from Hadath Baalbak &Hezeine)		18.3 7.59 5.20 856 425 Black Color turbid water & With solid wastes dumped along water flow or carried over with water flow				
4.a Bednayl (BDL)	West		X	X		Litani R Water 135		19.3 7.56 2.40 802 401 Blackish water with moderate bamboo growth				
4.b.i. Housh EL Rafka (HRF)		East	X	X		Litani R Water 128		18.7 7.44 2.20 776 385 Blackish water with moderate Bamboo growth				
4.b.ii. Sifri (SFR)		East	X Springs are Dry; Main Well Closed by Government; Wastewater Tapped for Agricultural Use (Depend on Cesspools & Sewer for WW disposal)	X		None (Not directly located along River Bed) Well Water						

Litani River Upper Basin	Location to River Bed		Profile of Village/City			Proposed Sampling Sites		Quality Indicators for River Sampling Points				
Village/ City	**West**	**East**	**Residential**	**Agricultural**	**Industrial**	**Type of Sample**	**Ref. GPS**	**T⁰C**	**pH**	**DO mg/l**	**CND uS**	**TDS mg/l**
		East				177						
Helaniyeh (HEL)		East				Well water (not Accessible) 178						
Saraine(SAR)						Well Water 176						
5.a. Temnine Al Fawka	West		X Contributes the Temnine Tributary originating from Jeb el Habach (Roman Ruins) that is fed by Rain and Snow melting from Neha Area	X		Spring Water 138 Well Water 138 (Adjacent to Spring; Domestic and Agricultural Use)						
5.b. Temnine EL Tahta (TMT)		East	X Major Rock-Cutting Industry	X	X	Temnine Tributary 137		Minimal water flow to sustain tributary				
						Litani R Water (Meeting point of 136 Temnine Tributary &Litani River)		DRY even in winter				
						Industrial Wastewater 136 (Rock Cutting Industry)						
6.a.i. Ablah (ABL)	West		X Plastic Industry and Poultry Processing Plant)	X	X	Litani R Water 42 (River Water Mixed with Tanmeyah WW)		Blackish water mostly wastewater				
						Domestic Wastewater Sanitary Sewer 39 (Ablah WW Treatment Plant) Under Construction						
						Well Water 180						
						Well Water 181						
6.a.ii. Fersol (FRZ)	West		X Contributes the Habbis/Fersol Tributary Originating from Habbis Water Spring	X	X	Spring Water 33						
						Soil (Adjacent to Spring) 33		17.9	7.69	6.20	668	334
								Clear to turbid shallow water				
						Habbis Tributary 34		19.3	7.34	0.9	1070	535
								Solid waste dumping along water flow				

Litani River Upper Basin Village/ City	Location to River Bed: West	East	Profile of Village/City: Residential	Agricultural	Industrial	Proposed Sampling Sites: Type of Sample	Ref. GPS	Quality Indicators for River Sampling Points: T⁰C	pH	DO mg/l	CND uS	TDS mg/l
						Litani R Water (Meeting point with Habish Tributary)	36					
						Soil (Adjacent to River)	36					
						Treated Wastewater Effluent (WW Treatment Plant)	38					
						Industrial Wastewater Effluent (Master Chips)	32					
6.b. Rayak (RYK)		East	X Lebanese Army Troops Barraks and Residential Units	X		Hala River (before joining Litani River)	41	14.7	8.00	7.10	384	156
								Minimal flow; shallow water with solid waste dumping along water flow				
						Soil	41					
						Litany R Water (Rayak Bridge, After Meeting Hala River and before Tanmeyah Industry Discharge)	40	Blackish water with foul smell due to direct discharge of industrial wastewater and solid wastes				
						Well water	40					
						Soil	40					
						Spring Water (Dry)	179					
						Well Water	124					
7. Yahfoufa (YHF)		East	X And Recreational Areas	X		Spring Water (1st Accessible Point)	127					
			Contributes the Yahfoufa/ Hala Tributary Originating from Yahfoufa (Jowsha Spring)			Hala /Yahfoufa River	127	15.9	8.18	5.40	389	275
								Clear to turbid				
8. Janta (TNT)		East	X And Recreational Areas	X		Hala /Yahfoufa River in Janta	126	14.7	8.15	5.70	393	210

Litani River Upper Basin	Location to River Bed		Profile of Village/City			Proposed Sampling Sites		Quality Indicators for River Sampling Points				
Village/ City	**West**	**East**	**Residential**	**Agricultural**	**Industrial**	**Type of Sample**	**Ref. GPS**	**T⁰C**	**pH**	**DO mg/l**	**CND uS**	**TDS mg/l**
9.Masa (MAS)		East	X	X		Hala /Yahfoufa River in Masa 125 Subsurface Flow, Inaccessible		Subsurface Flow, Inaccessible				

9.2. ORANGE ZONE

The codes of Cities and Villages Surveyed in the Orange Zone of the Upper Litani Basin

AMR	Amriyeh	عمرية
ANJ	Anjar	عنجر
CHT	Chtaura	شتورة
DLM	Dalhamieyieh	دلهمية
DRZ	Deir Zanoun	دير زنون
FAR	Faour	فاعور
HHR	Housh Al Harimi	حوش الحريمة
HZT	Hazerta	حزرتة
JAL	Jalala	جلالا
JDT	Jdeita	جديتا
MRJ	Marej	مرج
QRM	Qaa Al Rim	قاع الريم
SDL	Saadnayel	سعدنيال
TNL	Taanayel	تعنايل
ZHL	Zahle	زحلة

Upper Litany Basin Village/City	Location to River Basin: West	Location to River Basin: East	Profile of Village/City: Residential	Profile of Village/City: Agricultural	Profile of Village/City: Industrial	Major Sources of Pollution, Type of Source: Point Sources	Major Sources of Pollution, Type of Source: Non-Point Sources	GPS Reference
1.a.i Qaa El Rim/ Hazerta (QRM)	West		X Contributes to the Litani River the Berdawni Tributary that Originates from Qaa El Rim Springs	X	X	Industrial Wastewater (Rim Bottling Industry) Industrial Wastewater (MEMOSA Paper Industry) Hizerta Sanitary Sewerage	Agriculture Run-off	54 54 57
1.a.ii. Zahle (ZHL)	West		X And Recreational and Commercial Area	X	X	Domestic Wastewater Discharge Site by Berdawni Tributary Wastewater Discharge into Berdawni Tributary from Landfill Leachate Projected Wastewater Treatment Plant Discharge Effluent	Agriculture Run-off	59 61 61
1.a.iii Amriyeh (AMR)	West		X Mainly Residential and Commercial Contributes to the Litani River the Chtoura Tributary that originates from the Jdeita Spring and the Chtoura Spring			Wastewater Discharge (Could not be identified as it is completely Tapped for Irrigation		
2.a.i. Jdeita (JDT)	West		X Mainly Residential with Small Scale Industries (Dairy Plants, Serum Industry and Mills) Contributes to the Litani River the Chtoura Tributary that originates from Jdeita and Chtoura Springs	X		Jarjoura Industrial Wastewater	Agriculture Run-off	68
2.a.ii. Chtaura (CHT)	West		X Mainly Residential and Commercial Contributes to the Litani River the Chtoura Tributary that originates from Jdeita Spring and Chtoura Spring	X		Industrial Wastewater (Kassatly Industry)	Agriculture Run-off	71
2..a.iii. Taanayel (TNL)	West		X Mainly Agricultural	X		Chtoura Tributary (Meeting Junction of Chtoura Spring	Agriculture Run-off	76

Upper Litany Basin	Location to River Basin		Profile of Village/City			Major Sources of Pollution Type of Source		GPS Reference
Village/City	**West**	**East**	**Residential**	**Agricultural**	**Industrial**	**Point Sources**	**Non-Point Sources**	
			Contributes to the Litani River the Chtoura Tributary that originates from the Jdeita and Chtoura Springs			Ouflow and Jdeita Spring Outflow to form the Chtoura Tributary		
3.a.. Jalala (JAL)	West		X Mainly Residential Contributes to the Litani River the Jalala Tributary that is formed by Storm Water	X		Wastewater Discharge (Could not be Identified as it is Completely Tapped for Irrigation	Agriculture Run-off	-
1.b.i. Anjar (ANJ)	East		X And Recreational and Industrial (Arack, Juices, Food Packaging and Aquaculture) Contributes to the Litani River the Ghzayel Tributary that Originates from Anjar and Chamsine Water Springs	X			Agriculture Run-off	
1.b.ii. Dier Zanoun (DRZ)	East		X Contributes to the Litani River the Ghzayel Tributary that Originates from Anjar and Chamsine Water Springs	X		Domestic Sewerage (Anjar & Majd Al Anjar) Solid wastes Dumps	Agriculture Run-off	84 84
1.b.iii. Housh Al Harimi (HHR)	East		X Mainly Agricultural Contributes to the Litani River the Ghzayel Tributary that Originates from Anjar and Chamsine Water Springs	X		Solid Wastes Dumps	Agriculture Run-off	85
2.b.i. Faour (FAR)	East		X Mainly Residential and Agricultural Contributes to the Litani the Faour Tributary Originating from the Faour Springs	X			Agriculture Run-off And Cesspools	
2.b.ii. Delhameyieh (DLM)	East		X Mainly Agricultural (Animal Farms) and large Bedouins' Summer Settlements	X		Wastewater Discharge from Zahle Solid Waste Dumps	Agriculture Run-off, Animal Wastes and Cesspools	139 139
North Marj Area (MRJ)		West	X Mainly Residential Industrial activities (Esphalt Industry)	X	X	Solid Waste Dump	Agriculture Run-off Water	78

Litani River Upper Basin	Location to River Bed	Profile of Village/City	Proposed Sampling Sites	Quality Indicators for River Sampling Points

Village/City	West	East	Residential	Agricultural	Industrial	Type of Sample	Ref. GPS	T^0C	pH	DO mg/l	CND uS	TDS mg/l
I.a.i Qaa El Rim / Hazerta (QRM)	West		X Contributes to the Litani River the Berdawni Tributary that Originates from Qaa El Rim Springs	X	X	Spring water (Qaa AL Rim) Wells (Qaa`AL Rim) Industrial Wastwater (Rim Bottling Industry) Industrial Wastewater (MEMOSA Paper Industry) Qaa El Rim Berdawni Tributary Before Flowing through Recreational Area in Zahle and after the Inflow of Hizerta Sewerage and MEMOSA Industrial Wastewater Effluent Soil (Adjacent Berdawni Tributary) Sediments Hizerta Sanitary Sewerage	55 56 54 174 58 58 58 57	10.0 Cool water, clear, moderate flow with no algae growth	8.19	6.0	283	140
I.a.ii. Zahle (ZHL)	West		X And Recreational and Commercial Area Contributes to the Litani River the Berdawni Tributary that Originates from Qaa El Rim Springs	X	X	Berdawni Tributary after Flowing through Recreational Area in Zahle Wastewater Discharge Site Berdouni Tributary Before Zahle Zahle Landfill Wastewater Discharge in Tributary from PEPPSI & Landfill	59 61 60	10.8 Algae growth on river bed , and Moderate water flow with direct sewerage discharge 13.7 Moderate water flow; solid wastes dispersed along water flow	7.88 8.o7	6.30 6.10	285 284	140 140

Upper Litany Basin Village/City	Location to River Basin West	East	Profile of Village/City Residential	Agricultural	Industrial Point	Major Sources of Pollution Type of Source Sources	Non-Point Sources	GPS Reference
						Leachate Soil 61 (Adjacent to Berdawni Tributary)		
1.a.iii. Amriyeh (AMR)	West		X With Bedouins' Summer Settlements Contributes to the Litani River the Berdawni Tributary that Originates from Qaa El Rim Springs	X		Berdouni Tributary 62 Well Water 63 (Domestic Use and Also Used for Washing Fruits and Vegetables before Packaging)	Inaccessible as road is blocked for the construction of the WW treatment Plant	
2.a.i. Jdeita (JDT)	West		X Mainly Residential (Lebanese Army Barraks) Small Scale Industries (Dairy plants, Serum Industry and Mills) Contributes to the Litani River the Chtoura Tributary that originates from Jdeita and Chtoura Springs	X		Jdeita Outflow 65 Well Water 65 (Behind Jarjoura Dairy Plant; Supplies Water to 9 Neighboring Villages Surface Water 63 Canal (Flows into Chtoura Tributary) Jdeita Outflow after Discharge of 68 Industrial Wastewater Soil 68	DRY when not raining 15.01 7.45 4.10 339 180 Minimal water flow with algae covering river bed and solid wastes scattered along river flow 17.0 7.53 4.20 507 250 Good water flow, relative turbid water mixed with industrial wastewater effluent	
2.a.ii.. Chtoura (CHT)	West		X Mainly Residential and Commercial Contributes to the Litani River the Chtoura Tributary that originates from the Jdeita and Chtoura Springs	X		Spring Water (Chtoura) 69 Surface Water (Chtoura Outflow 70 Before Meeting the Jdeita Water Outflow to Form the Chtoura Tributary)	15.7 7.66 7.20 364 252 Clear water with the presence of ducks	

Upper Litany Basin Village/City	Location to River Basin West / East	Profile of Village/City Residential / Agricultural / Industrial	Major Sources of Pollution Type of Source Point Sources	Non-Point Sources	GPS Reference
			Industrial Wastewater 71 (Kassatly Industry) Soil 71 Surface Water 72	Dry Completely	
2..a.iii.Taanayel (TNL)	West	X X X Mainly Residential and Agricultural (Animal Farms) Contributes to the Litani River the Chtoura Tributary that originates from the Jdeita and Chtoura Springs	Chttoura Tributary 76 (Meeting Junction of Chtoura Spring Ouflow and Jdeita Spring Outflow to form the Chtoura Tributary Soil 76	24.3 7.58 1.88 564 394 108 Turbid Water with Minimal Flow and Minimal Algae Growth (Presence of Turtles, Fish, Water Snakes and Tadpoles)	
3.a. Jalala (JLL)	West	X Mainly Residential Contributes to the Litani River the JalalaTributary that is Formed by Storm Water	Jalala Tributary 86	Dry when not raining	
1.b.i. Anjar (ANJ)	East	X X And Recreational Industrial Activities (Arack, Juices, Food Packaging and Aquaculture) Contributes to the Litani River the Ghzayel Tributary that Originates from Anjar and Chamsine Water Springs	Spring Water (Anjar Spring) 79 Spring Water (Chamsine Spring) 80 Ghzayel Tributary 82 Soil 83	 15.9 7.43 5.80 463 235 Clear water , moderate to high flow	
1.b.ii. Dier Zanoun (DRZ)	East	X X And Bedouins' Summer Settlements Contributes to the Litani River the Ghzayel Tributary that Orriginates from Anjar and Chamsine Water Springs	Domestic Sewerage 84 (Anjar & Majd Al Anjar) Ghzayel Tributary 84 After discharge of Sewage	Could not be located due to construction 15.7 7.94 6.30 481 240 Algae growth on river bed; presence of turtles and bamboo growth in addition to solid waste dumping from Bedouin settlement	
1.b.iii.Horsh Al Harimi (HHR)	East	X X Mainly Agricultural Contributes to the Litani River the Ghzayel Tributary that Orriginates	Litani R Water 85 (Meeting Junction of Ghzayel Tributary	18.9 7.94 4.80 488 244 Solid waste dumping	

Upper Litany Basin	Location to River Basin	Profile of Village/City			Major Sources of Pollution Type of Source		GPS Reference
Village/City	West East	Residential	Agricultural	Industrial Point	Sources	Non-Point Sources	
		from Anjar and Chamsine Water Springs			With Litani River After meeting with Berdouni, Chtoura and Jalala Tributaries)		
2.b.i.Faour (FAR)	East	X	X		Water Spring (Faour) 81	Dry even in winter	
		Mainly Residential and Agricultural Contributes to the Litani the Faour Tributary Originating from the Faour Spring					
2.b.ii.Delhameyieh (DLM)	East	X	X		Faour Tributary 140	Dry even in winter	
		Residential and Large Bedouins' Summer Settlements				17.7 7.49 1.10 1004 510	
		Mainly Agricultural(Animal Farms)			Litani R Water 139 (After Meeting with Faour Tributary)	Grayish color, bad smell, dry bamboo, solid waste dumping	
North Marj Area	West	X	X	X	Chtoura Tributary Before & 73 Meeting Berdawni Tributary in Al Marj	Blackish water mainly wastewater	
		Mainly Residential Industrial Activities (Esphalt Industry)					
					Wastewater Discharge 73		
					Soil 73	15.0 7.61 2.00 911 450	
					Chtoura & Berdawni Tributary 77	16.0 7.84 4.30 446 223	
					Litani R Water Meeting Point 75 of Chtoura and Berdawni Tributaries in Marj Area	11.15 7.60 4.80 500 250	
					Soil 75		
					Litani R Water Before Meeting 78 Tributaries in Marj Area	16.90 7.59 2.00 695 345	
					Litani R Water After		

Upper Litany Basin	Location to River Basin		Profile of Village/City			Major Sources of Pollution Type of Source		GPS Reference
Village/City	West	East	Residential	Agricultural	Industrial	Point Sources	Non-Point Sources	
					meeting Chtoura, Berdawni & Jalala and Before meeting with the Ghzayel Sediment 74	74		
Saddnayl (SDL)	West	X	Mainly Residential		Spring Water 141			

9.3. GREEN ZONE

The Codes of Cities and Villages Surveyed in the Green Zone

AMQ	Ammiq	عميق
ATN	Aitaneit	عيتانيت
AZB	Ain Zebdeh	عين زبدة
BAL	Baaloul	بعلول
BMR	Bab Merea	باب مارع
DAZ	Deir Ain El Jawzeh	دير عين الجوزة
GHZ	Ghazza	غزة
JBJ	Jib Jenine	جب جنين
KBL	Kobb Elias	قب الياس
KML	Kamed El Louze	كامد اللوز
KNF	Kherbit Kanafar	خربة قنفار
LAL	Lala	لالا
LUC	Luci	لوسي
MAN	Mansoura	منصورة
QRN	Quaroan	قرعون
SGB	Soghbeine	صغبين
TLA	Tal Akhdar	تل أخضر

Upper Litany Basin	Location to River Basin		Profile of Village/City			Major Sources of Pollution Type of Source		GPS Reference
Village/City	West	East	Residential	Agricultural	Industrial	Point Sources	Non-Point Sources	
1.a. Kobb Elias (KBL)	West		X Mainly Residential Contributes to the Litani River the Jair, Hafir and Habsiyeh Tributaries Originating from the Ras Al Ain Water Springs	X	X	Domestic Wastewater Discharge Solid Wastes Dumps	Agricultural Runoff	88 88
1.a.ii. Tal Al Akhdar (TLA)	West		X Mainly Agricultural	X		Wastewater Discharge Solid waste Dumps	Agricultural Runoff	93 93
1.a.iii. Ammiq & Housh Ammiq & South of Marj Area (AMQ)	West		X Mainly Agricultural (Seasonal Vegetables) Residential In addition to Bedouns' Settlements Industrial (SICOMO Paper Industry, PETCO Plastic Industry & Cement,Ceramic Industries) Sanitary Sewerage connected to Jeb Janine WW Treatment Plant	X	X	Wastewater (Main Sewer from Kobb Elias & Maksi) Solid wastes Dumps Industrial Wastewater (SICOMO Industry)	Agriculture Runoff	90 90, 91 91
2.a. Mansoura (MAN)	West		X Mainly Residential	X		Wastewater Discharge Solid Wastes Dumps	Agriculture Runoff	95 95
2.a.i. Ghazza (GHZ)		East	X Mainly Residential Area in addition to Bedouns' Settlements	X		Wastewater (Main Sanitary Sewer from Luci, Ghazza & Mansoura)		105
2a.ii. Luci/ Sultan Yaakoub/		East	X Mainly Agricultural (Fruits and Vegetables)	X			Agriculture Runoff & Cesspools	
3.a.i Kherbit Kanafar (KNF)	West		X And Recreational Sewerage network not yet connected (Depend on Cesspools and SepticTanks)	X			Agriculture Runoff & Cesspools	
3.a.ii. Ain Zebdeh (AZB)	West		X Mainly Residential Agricultural (Fruits & Olives) & Trout Fish Aquaculture	X			Agriculture Runoff	
3.b.i. Jeb Jenine (JBJ)		East	X Mainly Residential (Upper Part) Agricultural (Seasonal Vegetables; Lower Part Irrigated by Litani Canal 900)	X		Domestic Wastewater (Jeb Jenine & Kamed Al Louze) WW Treatment Plant	Agriculture	110 110

Upper Litany Basin	Location to River Basin		Profile of Village/City			Major Sources of Pollution Type of Source		GPS Reference
Village/City	**West**	**East**	**Residential**	**Agricultural**	**Industrial**	**Point Sources**	**Non-Point Sources**	
						(Completed but still not functioning)	Runoff	
3.b.ii. Kamed Al Louze (KML)		East	X Mainly Residential (Upper Part) Agricultural (Seasonal Vegetables; Lower Part Irrigated by Litani Canal 900)	X			Agriculture Runoff	
4.a.. Sagbeine (SGB)	West		X Mainly Residential and Small Scale Industries (Sugar Cane, & Ceramics)	X	X	WW Treatment plant Located directly by the Quaroun Lake (Under Construction)	Agriculture Runoff	123
4.b. Lala (LAL)		East	X (Agricultural; Gets Irrigation Water from Canal 900) And Stone Cutting Industry	X		Stone Cutting Industry		112
5.a.i. Dial Ain Al Jaozeh (DAZ)	West		X Mainly Residencial	X			Agriculture Runoff	
5.a.ii. Bab Marea (BMR)	West		X Mainly Residencial	X		WW Treatment Plant (located directly along the Quaroun Lake; still not functional WW from Sabbeine, Ain Al Jaoze, Bab Marea & Aitaneit)	 Agriculture Runoff	123 123
5.b. Baaloul (BAL)		East	X Mainly Residential Gets Irrigation Water from Canal 900	X			Agriculture Runoff	
6.a.Aitaneit (ATN)	West		X Mainly Residential; Directly on the Lake (Wastewater Channeled to Wastewater Treatment Plant in Bab Marea which is still not functioning)			Wastewater Treatment Plant (still not functioning)		123
6.b. Qaroun (QRM)		East	X Mainly Residential And Recreational; Directly along the Quaroun Lake Contributes to the lake major water Springs of Ain El Deir, Ain Al Jamea, Ain Barada, Ain El Harf and Ain El Diaa			Recreational areas along Qaroun Lake		118

Litani River Upper Basin	Location to River Bed	Profile of Village/City	Proposed Sampling Sites	Quality Indicators for River Sampling Points

Village/ City	West	East	Residential	Agricultural	Industrial	Type of Sample	Ref. GPS	T⁰C	pH	DO mg/l	CND uS	TDS mg/l
1.a. Kobb Elias (KBL)	West		X Mainly Residential Contributes to the Litani River the Jair, Hafir and Habsiyeh Tributaries Originating from the Ras Al Ain Water Springs	X		Spring Water 87 (Ras Al Ain) Surface water 88 (Habsieyeh Tributary) Surface Water 89 (Junction Point of Habasieyeh, Jair and Hafir Tributaries) Soil 83		18.6 7.89 8.80 364 185 Clear water, relatively minimal flow with solid wastes scattered all over water flow 25.0 7. 28 1.20 632 315 Clear water with suspended algae and bamboo growth				
1.a.ii. Tal al Akhdar (TLA)	West		X Mainly Agricultural	X		Surface Water 93 (Junction Point of Habasieyeh, Jair and Hafir Tributaries befor Meeting the Litani river in Hosh Ammiqe, South al Marj)		20.0 7.72 8.30 410 205 Grey turbid water				
Ammiq & Housh Ammiq & South of Marj Area (AMQ)	West		X Residential in addition to Bedouns' Summer Settlements Agricultural (Mainly Vegetables) Industrial (SICOMO Paper Industry PETCO Plastic Industry & Cement, Ceramic Industries) Sanitary Sewerage Connected to Jeb Janine WW Treatment Plant	X	X	Litani River (Before) 90 Litani R Water (After) (Hafir, Jair & 90 Habasiyeh Tributaries joining Litani River Wastewater (Main Sewer from 90 Kobb Elias & & Maksi Pouring into the Habasieyeh Tributary) Soil Irrigated by WW 90 Industrial Wastewater 91 (SICOMO Industry) Soil Irrigated by Industrial WW 92		20.1 7.68 5.50 532 265 Solid wastes scattered along water flow 20.3 7.55 4.10 576 289 Solid wastes scattered along water flow				
2.a. Man Soura (MAN)	West		X Mainly Residential	X		Litani R Water 95 (before discharge of WW from Luci, Ghazza & Mansoura)		19.2 7.44 2.50 540 270 Blue green water; Solid wastes dumping (frogs, fish, ducks, water snakes, turtles…)				

Upper Litany Basin	Location to River Basin	Profile of Village/City			Major Sources of Pollution Type of Source		GPS Reference
Village/City	West East	Residential	Agricultural	Industrial	Point Sources	Non-Point Sources	
					Soil 95 Well Water (Domestic & irrigation Use) 94		
2.a.i. Ghazza (GHZ)	East	X Residential Area Mainly in addition to Bedouins' Settlements	X		Wastewater 105 (Main Sewer from Luci, Ghazza & Mansoura) Soil Irrigated with WW 105		
2a.ii. Luci/ Sultan Yaakoub (LUC)	East	X Mainly Residential And Agricultural (Fruits and Vegetables)	X		Litany R Water None (Not directly located along River Bed) Well Water (2 main wells that supply 104 Water to Khiera, Ghazza, Mansoura & luci) Soil 104		
3.a.i Kherbit Kanafar (KNF)	West	X And Recreational Sewerage network not yet connected (depend on cesspools and Septic Tanks)	X		Litany R Water None (Not directly located along River Bed) Spring Water (Nabeh EL Khreizat) 96		
3.a.ii. Ain Zebdeh (AZB)	West	X Mainly Residential Agricultural (Fruits & Olives) & Trout Fish Aquaculture	X		None (Not directly located along River Bed) Spring Water (Nabeh EL Sabeh Aayoun) 98 Spring Water (Nabeh EL Asafir) 99		
3.b.i. Jeb Jenine (JBJ)	East	X Mainly Residential (Upper Part) Agricultural ((Vegetables; Lower Part and irrigated by Litani Canal 900)	X		Litany R Water 108 (After Discharge of WW from Luci, Ghazza & Mansoura) Soil 108 Sediments 108	27.5 7.41 2.60 538 215 Green water color, (frogs, fish, ducks, water snakes …); bamboo growth covered with water Manhole closed	

Upper Litany Basin	Location to River Basin		Profile of Village/City			Major Sources of Pollution Type of Source		GPS Reference
Village/City	West	East	Residential	Agricultural	Industrial	Point Sources	Non-Point Sources	
						Domestic Wastewater 109 Domestic Wastewater 110 (Main Sewer from Jeb Jenine & Kamed Al Louze; WW Treatment Plant Completed; still not functional) Well Water 111 (Adjacent to River; Domestic & Irrigation Use) Soil (Adjacent to Well) 111	Not Accessible	
3.b.ii. Kamed Al Louze (KML)		East	X Mainly Residential (Upper Part) Agricultural (Seasonal Vegetables; Lower Part and Irrigated by Litani Canal 900)	X		None (Not directly located along River Bed) Well Water (Domestic Use) 106 Well water (Domestic Use) 107		
4.a. Sag Bein e (SGB)	West		X Mainly Residential Small scale industries(Sugar Cane, & Ceramics)	X	X	Litani River (End Point Before 143 Flowing into Quaroun Lake) Sediments 143 Spring Water (Sagbeine Water Spring 100 1st accessible point under Bridge) Spring Water (Ain Al Tayoun) 101 Domestic Wastewater 101 Feeding into Spring Water Spring Water (Ain Al Remeil; 102 Domestic and Irrigation Water)		
4.b. Lala (LAL)		East	X Agricultural; Gets irrigation Water	X		None (Not directly located along River Bed)		

Upper Litany Basin Village/City	Location to River Basin West	 East	Profile of Village/City Residential	 Agricultural	 Industrial	Major Sources of Pollution Type of Source Point Sources	 Non-Point Sources	GPS Reference
			from Canal 900 Industrial; Stone Cutting Industries			Well Water 112	Not accessible due to cut off in electricity)	
5.a.i. Ain Al Jaozeh (DAZ)	West		X Mainly Residencial Oversees the Qaroun Lake	X		Spring Water 103 (Ain Al Jaozeh; Domestic Water)		
5.a.ii. Bab Marea (BMR)	West		X Mainly Residencial Oversees the Qaroun Lake	X		Spring Water 120 (Bab Marea; Domestic Water)		
5.b. Baaloul (BAL)		East	X Mainly Residencial Agricultural; Gets Irrigation Water from Canal 900	X		Spring Water 114 (Ain Al Tout; Blue Water Project to Supply Domestic Water to Mushgarah, under construction) Well Water 116 (Domestic Use)	Still Under Construction	
6.a. Aitaneit (ATN)	West		X Mainly Residential; Directly on the Lake (wastewater channeled to Wastewater Treatment Plant in Bab Marea that is still not functional)	X		Spring Water 121 (Ain Al Dob) Wastewater 123	Not Accessible	
6.b. Qaroun (QRM)		East	X Mainly Residential and Recreational; Directly on the Lake Contributes to the Lake Major Water Springs of Ain El Deir, Ain Al Jamea, Ain Barada, Ain El Harf and Ain El Diaa	X		Spring Water 117 (Ain Al Diaa) Well Water 118 (By the Lake; Domestic and Irrigation Uses)		

Reference	Elevation (m)	North	East
20	1021	34°01.787	36°04.563
21	1020	34°01.787	36°04.563
22	1019	34°01.778	36°04.861
23	1019	34°01.796	36°04.844
24	1015	33°59.640	36°06.357
25	997	33°58.831	36°04.831
26	994	33°58.795	36°05.066
27	1019	33°58.198	36°06.310
28	983	33°57.966	36°04.775
29	987	33°58.249	36°04.810
30	1009	33°58.133	36°05.519
31	1014	33°58.133	36°05.519
32	940	33°51.455	35°56.538
33	1096	33°53.274	35°56.382
34	945	33°51.585	35°57.042
36	906	33°50.418	35°57.817
37	918	33°51.689	35°57.370
38	913	33°50.979	35°57.389
39	912	33°51.334	35°58.640
40	916	33°51.807	35°59.392
41	946	33°51.230	36°00.902
42	911	33°51.319	35°98.725
43	904	33°37.420	35°46.327
44	908	33°37.370	35°46.243
45	914	33°36.867	35°46.327
46	910	33°36.259	35°44.060
47	912	33°35.449	35°43.492
48	955	33°34.463	35°43.578
49	919	33°33.553	35°42.867
50	917	33°32.772	35°42.032
51	917	33°37.716	35°48.333
52	910	33°37.712	35°48.176
53	918	33°37.773	35°47.545
54	1246	33°53.232	35°52.292
55	1254	33°53.154	35°52.283
56	1248	33°53.252	35°52.288
57	1256	33°53.074	35°52.303
58	1099	33°52.154	35°52.873
59	984	33°51.002	35°53.829

Reference	Elevation (m)	North	East
60	925	33°49.544	35°54.584
61	892	33°48.047	35°54.777
62	882	33°47.501	35°54.757
63	985	33°49.477	35°50.049
64	877	33°46.586	35°53.287
65	1032	33°49.530	35°49.794
66	1024	33°49.434	35°49.881
67	985	33°49.477	35°50.049
68	934	33°48.791	35°50.538
69	936	33°49.442	35°51.037
70	921	33°48.956	35°51.127
71	888	33°47.056	35°51.577
72	880	33°46.433	35°52.197
73	880	33°46.122	35°52.096
74	882	33°46.037	35°52.622
75	879	33°46.352	35°53.003
76	890	33°47.421	35°51.862
77	879	33°42.753	35°53.467
78	880	33°46.649	35°46.642
79	890	33°43.986	35°56.774
80	880	33°44.651	35°57.412
81	886	33°46.997	35°58.098
82	880	33°45.063	35°56.885
83	882	33°45.150	35°56.236
84	879	33°45.307	35°54.711
85	875	33°43.710	35°49.819
86	921	33°48.974	35°51.700
87	915	33°47.616	35°49.361
88	912	33°47.446	35°49.544
89	889	33°47.325	35°50.743
90	884	33°47.114	35°51.031
91	890	33°45.760	35°48.575
92	877	33°45.403	35°48.347
93	871	33°44.843	35°48.987
94	868	33°40.731	35°48.881
95	868	33°40.786	35°49.098
96	965	33°37.802	35°43.127
97	989	33°37.672	35°42.669
98	972	33°37.679	35°42.742
99	1075	33°37.471	35°42.141

Reference	Elevation (m)	North	East
100	1029	33°36.950	35°41.987
101	1019	33°36.693	35°41.937
102	1100	33°36.758	35°41.625
103	966	33°35.818	35°41.506
104	892	33°39.029	35°50.556
105	867	33°40.149	35°49.198
106	930	33°37.541	35°49.516
107	907	33°37.661	35°48.507
108	869	33°38.386	35°46.791
109	871	33°38.200	35°46.706
110	870	33°38.241	33°46.659
111	889	33°37.601	35°46.393
112	930	33°36.489	35°45.360
113	931	33°36.491	35°45.361
114	1171	33°35.432	35°45.198
115	1158	33°35.431	35°45.161
116	1018	33°35.246	35°44.421
117	997	33°33.715	35°43.401
118	968	33°34.591	35°43.681
119	880	33°36.845	35°43.269
120	1003	33°34.868	35°40.815
121	1014	33°34.687	35°40.667
122	947	33°35.411	35°41.257
123	940	33°35.493	35°41.336
124	946	33°51.273	36°01.239
125	974	33°51.170	36°02.446
126	1028	33°51.275	36°05.387
127	1104	33°51.789	36°06.856
128	960	33°55.439	36°02.978
129	1006	33°57.361	36°02.959
130	1010	33°57.654	36°02.423
131	1014	33°57.366	36°02.361
132	1004	33°57.209	36°03.042
133	975	33°56.620	36°03.682
134	1003	33°57.384	36°02.964
135	940	33°53.487	36°01.699
136	926	33°35.760	35°48.575
137	937	33°53.492	35°59.239
138	1097	33°54.607	35°58.665
139	865	33°49.335	35°56.694

Reference	Elevation (m)	North	East
140	857	33°47.737	35°57.391
141	891	33°48.230	35°52.605
143	844	33°36.741	35°42.453
145	850	33°36.427	35°42.342
149	848	33°35.997	35°42.033
150	850	33°35.609	35°41.829
151	851	33°35.381	35°41.754
152	852	33°35.244	35°41.806
153	852	33°35.076	35°41.978
154	854	33°34.856	35°41.910
155	855	33°34.621	35°41.876
156	854	33°34.475	35°41.888
157	855	33°34.199	35°41.842
158	855	33°33.852	35°41.768
159	856	33°33.409	35°41.631
160	855	33°32.910	35°41.530
171	1209	33°52.755	35°52.617
172	946	33°51.329	35°56.616
174	1016	33°56.351	36°05.090
176	969	33°53.810	36°02.920
177	946	33°53.154	36°02.071
178	924	33°52.042	36°00.117
179	927	33°50.302	36°00.628
180	944	33°52.203	35°57.914
181	910	33°51.779	35°59.044

Section 8.1.5:

Table 8.1.5. Total Number of Collected Samples

Type of Sample	Total Number of Samples						Quality Analysis Indicators	
	Proposed	Identified	Dry	Wet	Dry/Inaccessible Dry	Dry/Inaccessible Wet	Type I- Full Analysis	Type II- Metal Analysis (20% of Samples)
River Water	50	50	26	43	24	7	pH	Lead
							EC	Mercury
Lake Water	10	10	10	10			Alkalinity	Cadmium
							Total coliforms	Chromium
Canal Water	5	7	7	7			Fecal coliforms	Nickel
							Fecal Streptococci	Copper
Industrial Wastewater	20	7	7	5		1	Nitrates	Zinc
							Phosphates	Iron
							Sulfates	Aluminum
Domestic Wastewater	10	12	12	8		4 Fersol plant closed; not functionning ??? ATN not functionning	Chlorides	Arsenic
							Ammonia	Barium
							Total dissolved solid	Cobalt
							BOD	Boron
							DO	Manganese
							Potassium, Calcium, Magnesium, Sodium	Molybdenum
							Organochlorines	
							Organophosphorous	
Groundwater	30	48	48	48			Same as above	Same as above
Springs		22	18	19	4	3		
Wells		25	24	22	1	3		
Soil	50		35	35	-	-	pH	Same as above
							EC	
River Sediments	-		5	6	-	-	Total organic carbon	
							Nitrates	
Lake sediments	5		6	1		5	Phosphates (Olson-extractable P)	
							Sulfates	
							Chlorides	
							Ammonia	
							water soluble cations (Ca, Mg, K and Na)	
							Sieve analysis	
Total Number of Sample Types	Total 180 Accessible 165							

U.S. Agency for International Development
1300 Pennsylvania Avenue, NW
Washington, DC 20523
Tel: (202) 712-0000
Fax: (202) 216-3524
www.usaid.gov