# Preliminary Hydrological Assessment for the Development of an Industrial Park in Haiti

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## List of Acronyms

| | |
|---|---|
| ESG | Environment Safeguards Unit |
| IDB | Inter-American Development Bank |
| MPA | Marine Protected Area |
| ROH | Republic of Haiti |
| SAE-A | Anchor tenant - textile manufacturer |
| SONAPI | Société Nationale des Parcs Industriels |
| WHO | World Health Organization |

## Commonly Used Measurements

| | |
|---|---|
| $m^3$ | Cubic meters |
| d | Day |
| dB | Decibels |
| Lpd | Liters per day |
| MW | Megawatts |
| $\mu g/m^3$ | Micrograms per cubic meter |
| ppm | Parts per million |
| s | Second |

## Executive Summary

This report constitutes a preliminary hydrological assessment and baseline environmental survey for the development of an industrial park in northern Haiti. The findings of this report were limited to the quality and type of data made available at the time of the assessment. Results and conclusions are based primarily on theoretical models and historical reports. A site visit comprising limited fieldwork also informed this assessment. A key element of this consultancy was to assess water demand and availability for the industrial park. The site's primary source of surface water, the Rivière Trou du Nord, feeds into Caracol Bay, an important ecological resource. Due to the lack of data on the ecological sensitivity of Caracol Bay, the absence of data to assess critical environmental flow, and extremely limited meteorological data for the region, the potential for adversely impacting the surface hydrology is sufficient to recommend against the use of surface water to meet the anticipated demands of the industrial park. Further, preliminary estimates suggest there is ample groundwater available to meet the site's demands for both phases of the development. As a result, we strongly recommend groundwater be utilized to meet the totality of the site's demands. Notwithstanding the apparent abundance of groundwater, the aquifer is believed to be unconfined and overlain by highly porous, alluvial sands, rendering the aquifer highly vulnerable to surface contamination.

Given the large size of the aquifer, additional demands for groundwater from current and future users are unlikely to impact overall groundwater reserves. However, sustainable use of the resource will be contingent upon proper management of water supply and sanitation systems. Groundwater will need to be treated prior to human consumption given the high coliform levels measured. It will also require treatment prior to industrial use. Data were insufficient to confirm the presence or absence of other contaminants, such as organic compounds or heavy metals. Moreover, local laboratories are not equipped with sufficiently sensitive equipment to analyze water quality to IFC standards. As a result, there was insufficient data available to surmise the level and extent of treatment required for domestic and industrial use. Wastewater effluent produced by the anchor tenant will need to be treated to a higher standard than suggested in order to a) meet World Bank Group EHS Guidelines for textile manufacturing, and b) to ensure water discharged to surface waters is of the same or better quality than ambient conditions. There is insufficient data to indicate the level and extent of treatment required.

Lastly, current air quality is good and noise levels are below those recommended for workplace exposure.

# 1 Background

The Republic of Haiti ("ROH") has asked the Inter-American Development Bank ("IDB") to finance an industrial park that is being developed as part of a longer term development program for the north (the "Northern Growth Pole Development"). The development of a 250-ha industrial park, a greenfield site, includes factory sheds, a water treatment plant capable of processing 2,500 $m^3/d$[1], an 18 MW[2] diesel generated power plant, a wastewater treatment plant and other associated infrastructure (e.g., dormitories, canteens, training center, offices, clinic, storage facilities). Costs are estimated to be around US$51 million for on-site (e.g., factory sheds, administrative buildings, wastewater treatment plant, power and water supply) and off-site infrastructure (e.g., short access road). All of the investment financing for operation of the Industrial Park ("the Park" or "the Project") has not yet been secured, particularly concerning solid waste management, construction and the operation of a health clinic.

The owner and executing agency of the Park will be the *Société Nationale des Parcs Industriels* ("SONAPI") under the *Ministère de l'Économie et des Finances de la République d'Haïti*. SONAPI is an autonomous state-owned corporation, which has the responsibility for building and managing industrial parks. Water demand, wastewater effluent, and any associated impacts on Caracol Bay would presumably be associated with not only those directly related to the Park, but also those induced by additional developments in the area, such as the new national university currently under construction west of the site, any increased internal migration and associated housing. The initial anchor tenant for the Park will be textile manufacturer SAE-A. The Project area is depicted in Figure 1 below.

[1] These numbers are preliminary.
[2] To be confirmed.

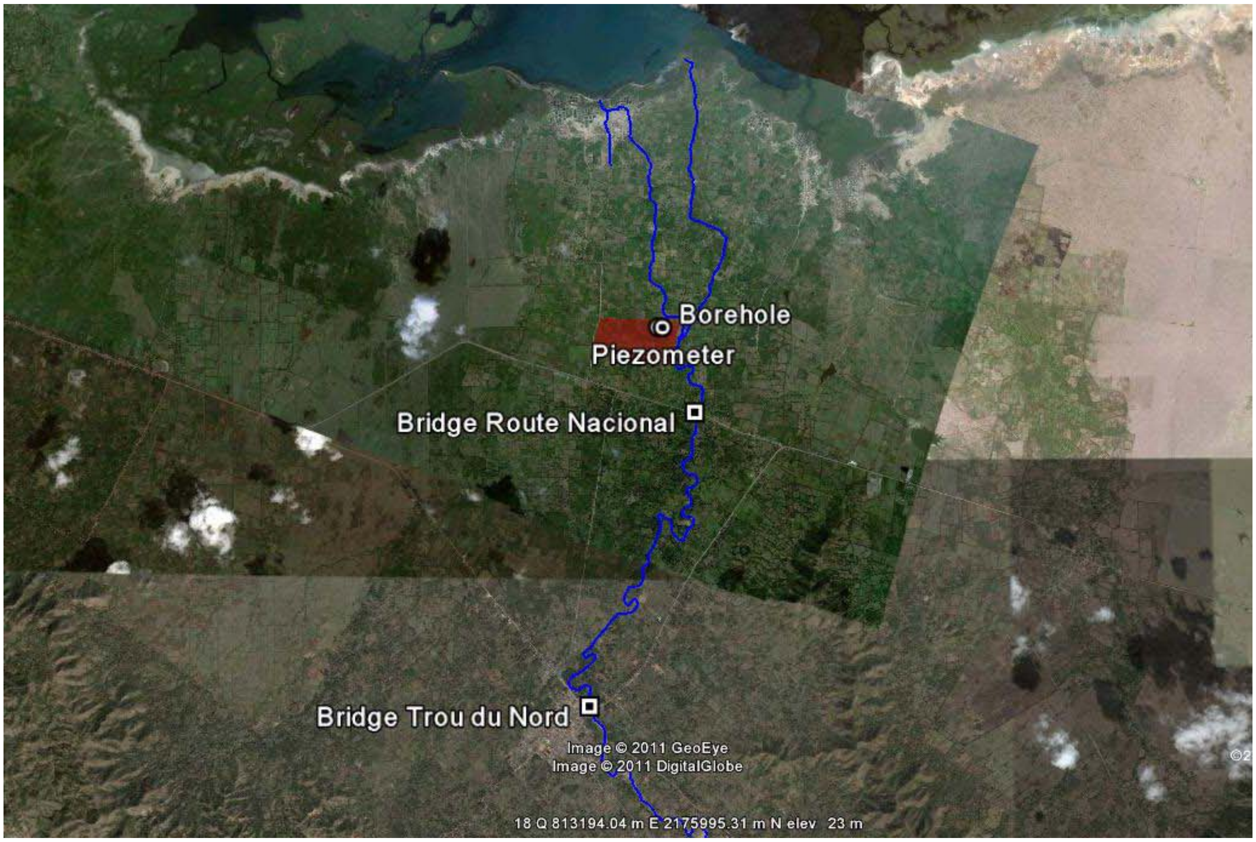



**Figure 1. Site location map highlighting surface water flow. The Industrial Park site is denoted by a red rectangle.**

# 2 Objectives

The objective of this consultancy was to assist the Environment Safeguards Unit ("ESG") and the Haiti Industrial Task Team (Team Leader: Christian Dunkerley) of the IDB to ensure that significant issues concerning water quantity and water quality were properly assessed and documented. Key risks associated with the Project that were available for review (see Chapter 3, Scope of Activities) under this consultancy were:

(i) Water Demand: water balance estimate of the industrial park including water for domestic and industrial use

(ii) Water Quality: quality of water required for domestic and industrial use in addition to the quality of effluent produced by the site and anticipated variations in surface water quality as a direct result of domestic and industrial wastewater discharge

(iii) Water Availability: estimated surface water flow, flood risk assessment, well yield estimates and potential for aquifer depletion, and the potential for saline intrusion in addition to potential impacts on local mangrove forests, sea grass beds and ecological flow for the area, specifically the downstream Caracol Bay identified by the ROH as a high priority area for the establishment of a Marine Protected Area ("MPA") to conserve biodiversity and to establish a new marine park[3]

(iv) Demographic Analysis: the cumulative impacts of surrounding developments (including housing schemes and other anticipated infrastructure)

[3] The area was first assessed in a project entitled "*Programme Changements Climatiques*" (ROH, 2006). As a least developed country ("LDC") (and also a small island developing state, "SIDS"), Haiti is "given special consideration on account of [its] limited capacity to respond to climate change and adapt to its adverse effects" (UNFCC, 2011). Consequently, Haiti is the recipient of a new project entitled "*Etablissement d'un Système National d'Aires Protégées Financièrement Soutenable (SNAP) (2011-2015)*" (UNDP, 2010) supported primarily by the United Nations Development Programme ("UNDP") and the Global Environment Fund ("GEF"). As a result, the area has garnered significant international interest, particularly from the *Fondation Pour la Protection de la Biodiversité Marine* ("FoProBiM"), a Haitian NGO focused on the protection of marine environments.

# 3 Scope of Activities

The original Terms of Reference agreed upon June 23, 2011 listed nine core activities designed to address the above risks. ENVIRON's ability to carry out these activities was contingent upon the quality and types of data made available during the assignment (June 23 to July 28, 2011). Although the ROH provided the preliminary results of a geotechnical study carried out earlier this year (specifically soil conductivity tests) the results of the borehole pump test (undertaken by Foratech under separate contract to the ROH) were not available at the time of this report. As a result, ENVIRON relied upon existing literature and appropriate theoretical models where possible giving rise to the modified scope of activities described in Table 1 below.

**Table 1 Scope of Activities**

| No. | Original | Modified |
|---|---|---|
| 1. | The results of the borehole and pump test (current borehole test studies by Foratech). | Not available – excluded from report |
| 2. | Estimates of river flow in the Trou du Nord based on snapshot field measurements. | Complete |
| 3. | Based on the borehole pump test, a preliminary estimate of the potential for saline intrusion into the ground water from aquifer and river exploitation by the Park, and consequent potential risks for the mangroves and coral reefs. | Estimated using groundwater data from existing literature and appropriate theoretical models |
| 4. | Provide initial data that may be used to begin to analyze the relationships between surface flow, the groundwater aquifer(s), and the potential for salt water intrusion and to develop a hydrologic model for the Trou du Nord river basin. | Estimated using surface flow data obtained in the field and groundwater data from existing literature in addition to appropriate theoretical models |
| 5. | Initiate development of the conceptual hydrologic model for Trou du Nord river basin. | Estimated using surface flow data obtained in the field and groundwater data from existing literature in addition to appropriate theoretical models |
| 6. | Request and review existing design information and data to confirm, as possible, a conceptual water balance for the Park. | Estimated based on actual demand forecast by the future anchor tenant (SAE-A) and estimated demand for all other tenants. No additional information was available at the time of this report. |
| 7. | Allocations for additional local water demands on the aquifer and river and demographic analysis | Complete |
| 8. | Evaluation of results of geotechnical investigations for soil stability properties. | Inconclusive – excluded from report |
| 9. | First phase of the baseline water quality analysis, and air and noise quality. | Complete |
| 10. | Preliminary flood risk assessment. | Estimated based on available field data and existing literature in addition to anecdotal information from residents and visual observations. |

# 4 Water Demand

## 4.1 Water Balance Estimate

A facility-wide water balance was developed for the Park based on reports produced by Louis Berger (2011), EPSA-Labco (2011), and SAE-A (2010) (see references).

This water balance was developed to establish the projected water demand for the Park for both Phase 1 and Phase 2 of the planned development. The water balance estimate is divided into two primary uses:

- Domestic use includes all of the expected per-capita use by facility employees for activities such as showers, faucets, and toilets.
- Industrial use includes all of the water demands specific to the various industrial processes at the Park.

Water demand is conventionally presented in cubic meters per day ($m^3$/d), however these figures do not account for any variation in daily demand that might occur during the plant's normal operation.

Estimated domestic water use is presented in Tables 2-1, 2-2, and 2-3. Using the best available data and staffing estimates, an estimated volume of **1,927 $m^3$/d** will be required for Phase 1 operations with an additional volume of **774 $m^3$/d** for Phase 2 operations, giving rise to a total combined volume of **2,701 $m^3$/d**. Domestic use for SAE-A was developed using staff estimates provided by SAE-A, while the remaining staff estimates were taken from Louis Berger (2011). Residential staff is assumed to comprise 1% of the total staff required for each industry. As the anchor tenant, SAE-A will constitute the majority of Park staff and their requirement of 150 Lpd (confirmed by UTE during ENVIRON's on-site field visit) has therefore been used to estimate total demand for all residential staff. The reduced estimated demand of 80 Lpd for non-residential staff was taken from Louis Berger (2011).

**Table 2-1 Phase 1 Estimated Domestic Water Use**

| Company | Total Staff | Demand (80 $m^3$/d) | Residential Staff | Demand (70 $m^3$/d) | Total Demand ($m^3$/d) |
|---|---|---|---|---|---|
| SAE-A | 14,800 | 1,184 | 148 | 22 | 1,206 |
| OH | 3,200 | 256 | 32 | 5 | 261 |
| ATRACO | 3,500 | 280 | 35 | 5 | 285 |
| GOODWILL | 500 | 40 | 5 | 1 | 41 |
| INDIGO MTN | 820 | 66 | 8 | 1 | 67 |
| DORMS/COMM/OFFICE | 750 | 60 | 8 | 1 | 61 |
| WWTP | 34 | 3 | 0.3 | 0.1 | 3 |
| ENERGY PLANT | 40 | 3 | 0.4 | 0.1 | 3 |
| Total | 23,644 | 1,892 | 236 | 35 | 1,927 |

| **Table 2-2 Phase 2 Estimated Domestic Water Use** | | | | | |
|---|---|---|---|---|---|
| **Company** | **Total Staff** | **Demand (80 $m^3$/d)** | **Residential Staff** | **Demand (70 $m^3$/d)** | **Total Demand ($m^3$/d)** |
| SAE-A | 5,750 | 460 | 58 | 9 | 469 |
| OH | - | - | - | - | - |
| ATRACO | 3,500 | 280 | 35 | 5 | 285 |
| GOODWILL | - | - | - | - | - |
| INDIGO MTN | - | - | - | - | - |
| DORMS/COMM/OFFICE | 250 | 20 | 3 | 0 | 20 |
| WWTP | - | - | - | - | - |
| ENERGY PLANT | - | - | - | - | - |
| Total | 9,500 | 760 | 95 | 14 | 774 |

| **Table 2-3 Phase 1 and 2 Combined Estimated Domestic Water Use** | | | | | |
|---|---|---|---|---|---|
| **Company** | **Total Staff** | **Demand (80 $m^3$/d)** | **Residential Staff** | **Demand (70 $m^3$/d)** | **Total Demand ($m^3$/d)** |
| SAE-A | 20,550 | 1,644 | 206 | 31 | 1,675 |
| OH | 3,200 | 256 | 32 | 5 | 261 |
| ATRACO | 7,000 | 560 | 70 | 11 | 571 |
| GOODWILL | 500 | 40 | 5 | 1 | 41 |
| INDIGO MTN | 820 | 66 | 8 | 1 | 67 |
| DORMS/COMM/OFFICE | 1,000 | 80 | 10 | 2 | 82 |
| WWTP | 34 | 3 | 0 | 0 | 3 |
| ENERGY PLANT | 40 | 3 | 0 | 0 | 3 |
| Total | 33,144 | 2,652 | 331 | 50 | 2,701 |

Estimated industrial water use is presented in Table 3. A total of **1,723 $m^3$/d** will be required for Phase 1, with a significant increase to **8,706 $m^3$/d** for Phase 2. SAE-A provided their water requirements for industrial use while the remaining estimates were taken from Louis Berger (2011). The increase from Phase 1 to Phase 2 is largely driven by the introduction of the knitting and dyeing (K&D) process associated with SAE-A. Beginning in Year 5, this process will require an additional 3,000 $m^3$/d of water, which will increase to 6,000 $m^3$/d for Year 7 and onwards.

| **Table 3 Phase 1 and 2 Combined Estimated Industrial Water Use** | | |
|---|---|---|
| **Company** | **Phase 1 ($m^3$/d)** | **Phase 1 & 2 ($m^3$/d)** |
| SAE-A | 181 | 6,363 |

| Table 3 Phase 1 and 2 Combined Estimated Industrial Water Use | | |
|---|---|---|
| **Company** | **Phase 1 ($m^3$/d)** | **Phase 1 & 2 ($m^3$/d)** |
| OH | - | - |
| ATRACO | 500 | 1,000 |
| GOODWILL | - | - |
| INDIGO MTN | 1,000 | 1,000 |
| DORMS/COMM/OFFICE | - | - |
| WWTP | - | - |
| ENERGY PLANT (INTAKE)[§] | 42 | 343 |
| Total | 1,723 | 8,706 |

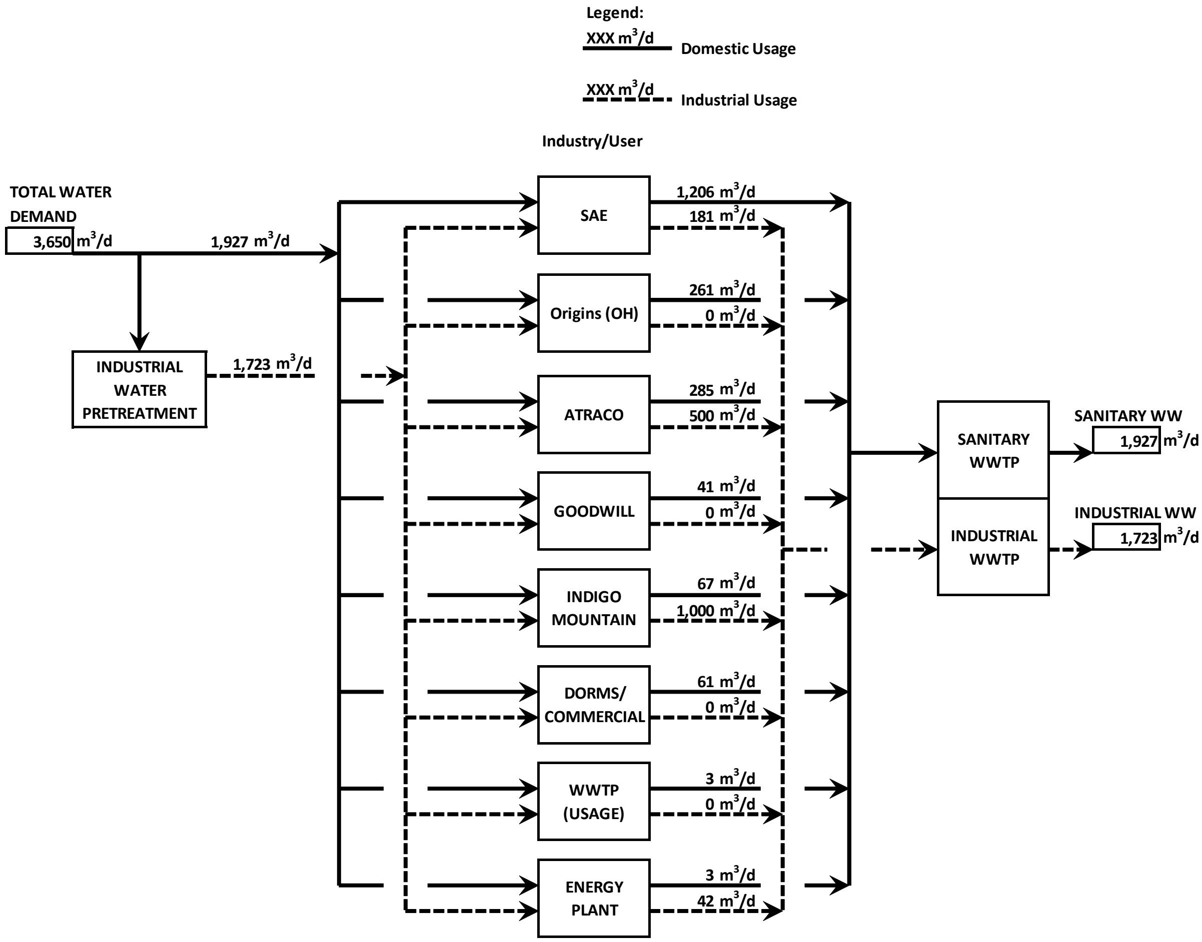
§ Based on average projected steam rates for SAE-A only. Assumes a 5% blowdown from boilers and pretreatment systems and a 50% recovery of condensate with the remainder going to wastewater.

Water for steam production is included in the intake requirements for the Energy Plant (i.e., boilers) for both Phase 1 and 2. Other anticipated water demands associated with utilities (e.g., cooling towers) have not been included in the overall water balance as no information on their requirements was available. SAE-A indicated an average steam demand of approximately 2.3 million kg/month in Year 4 of operations, which equates to approximately 76 $m^3$/d of water (condensate). In Year 7, the introduction of the K&D process results in an average steam demand of approximately 19 million kg/month, or 623 $m^3$/d. In a typical steam production system, a certain percentage of the feed water is discharged as wastewater in order to provide the correct feed water quality to the boilers - upstream treatment to remove salts, organic compounds or other contaminants will generate small wastewater streams, and a periodic or continuous stream of water is wasted from the boilers to prevent buildup of solids, salts or other contaminants that would damage the system. Based on this, an additional 5% intake is required to account for these waste (blowdown) streams.

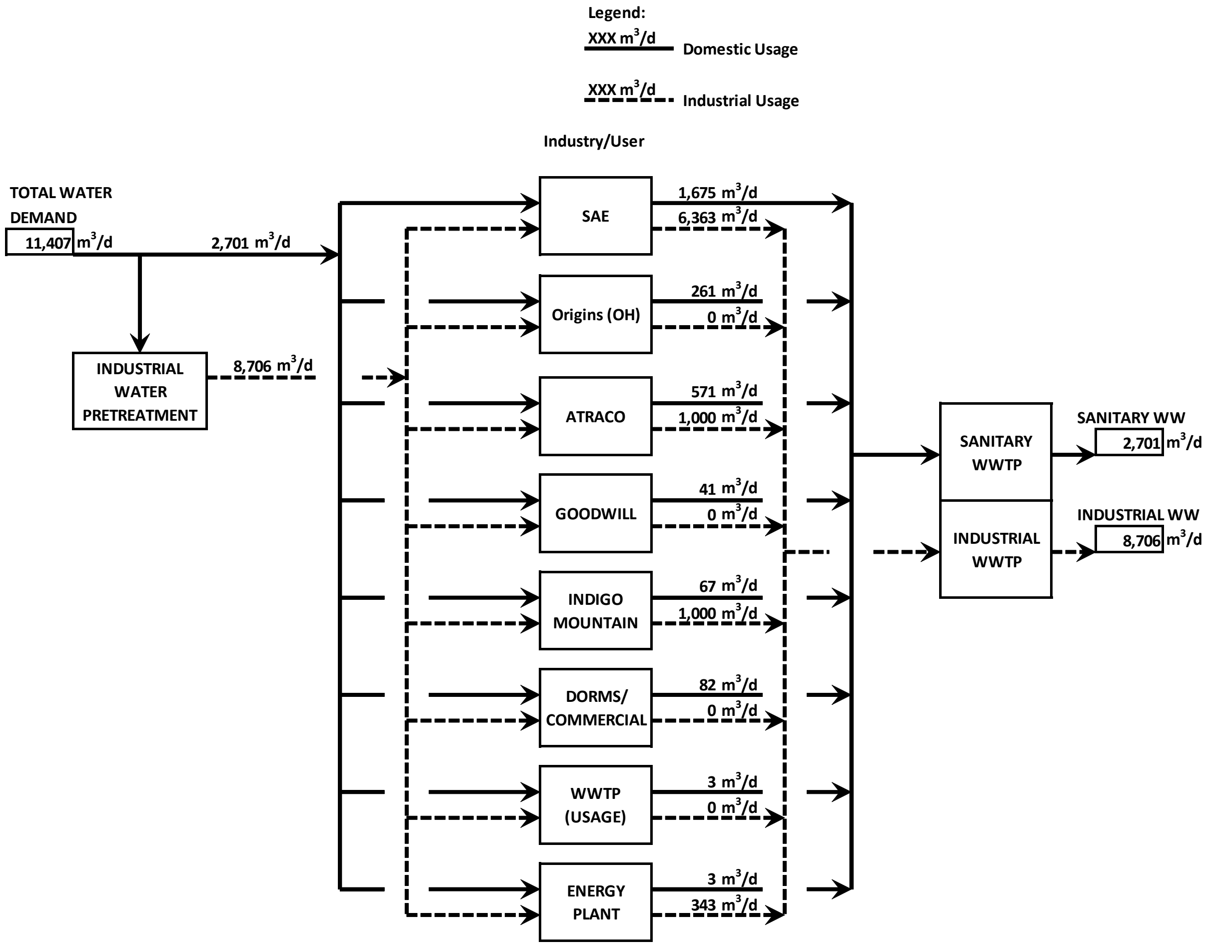
To determine loading from the energy plant to wastewater treatment, it was assumed that approximately 50% of the steam condensate will be recycled to the boilers. In addition, because of a lack of information on the specific configuration of steam distribution or facility use, the current balance assumes that all of the blowdown/losses are collected as wastewater and sent for on-site treatment.

Based on estimates for domestic and industrial water use, the total water demand for the Park is estimated to be **3,650 $m^3$/d** for Phase 1 operations and **11,407 $m^3$/d** for Phase 2 operations. A conceptual water balance for Phase 1 and Phase 2 is presented in Figures 2 and 3 respectively.

**Figure 2 Phase 1 Facility-wide Conceptual Water Balance**



## Figure 2 Phase 2 Facility-wide Conceptual Water Balance



# 5 Water Quality

Limited water quality data was available at the time of this assessment. This report relies primarily on water samples collected and sent for laboratory analyses in February and June 2011 (EPSA-Labco, 2011a, 2011b). Importantly, these data represent discrete moments in time. Such data allow for the identification of potential constituents requiring treatment, however, they do not provide sufficient information to determine seasonal baseline water quality conditions. Notably no samples have been collected during the rainy season. As a result, it is not possible to comment on the appropriate design concentrations for the treatment system. Additionally, detection values for certain parameters are above guideline values in several cases i.e. certain heavy metals, thus a lack of detection does not guarantee their absence. The six samples listed in Tables 5-1 to 5-3 refer to the following sampling dates and locations:

- P1 = Fleury, February 11, 2011
- P2 = Onsite piezometer, July 5, 2011
- P3 = Unknown, Rivière Trou du Nord, February 11, 2011
- P4 = Downstream, Rivière Trou du Nord, July 5, 2011
- P5 = Midstream, Rivière Trou du Nord, July 5, 2011
- P6 = Upstream, Rivière Trou du Nord, July 5, 2011

## 5.1 Domestic water quality

At present, the ROH has not developed its own drinking water quality guidelines, but instead relies upon standards recommended by the World Health Organization ("WHO"). Table 5-1 presents these standards alongside water quality parameters obtained through laboratory analyses following the sampling periods described above. Parameters requiring some form of, and/or, additional treatment have been highlighted.

**Table 5-1 Water Quality Parameters for Domestic Use**

| Parameter | Unit | Groundwater | | Surface Water (Trou du Nord River) | | | WHO (2006) |
|---|---|---|---|---|---|---|---|
| | | P1 | P2 | P3 | P4 | P6 | |
| pH | - | 7.55 | 7.58 | 8.13 | 7.60 | 7.39 | <8[§] |
| Turbidity | NTU | 46.6 | 1.24 | 12 | 30 | | 0.1[a] |
| TTC | MPN[b]/ 100 mL | 2 | 3,465 | 2,400 | 508 | 5,929 | c |
| Arsenic | mg/L | 1.110 | <DL | 1.030 | <DL | <DL | 0.01 P |
| Barium | mg/L | 4.000 | | 4.000 | | | 0.7 |
| Cadmium | mg/L | <0.125 | <DL | <0.125 | <DL | <DL | 0.003 |
| Chromium | mg/L | <2.0 | <DL | <2.0 | <DL | <DL | 0.05 P |
| Cyanide | mg/L | 0.001 | | 0.003 | | | 0.07 |
| Fluoride | mg/L | 0 | | 0 | | | 1.5 |
| Manganese | mg/L | <0.25 | | <0.25 | | | 0.4 C |
| Mercury | mg/L | <10 | <DL | <10 | <DL | <DL | 0.006 |
| Nitrate (as $NO_3^-$) | mg/L | <DL | 0.1 | <DL | 0.1 | 0.1 | 50 |
| Nitrite (as $NO_2^-$) | mg/L | 0.110 | | 0.050 | | | 3 |

P = provisional guideline value, as there is evidence of a hazard, but the available information on health effects is limited
C = concentrations of the substance at or below the health based guideline value may affect the appearance, taste or odor of the water, leading to consumer complaints.

<DL = below detectable limit
§ No health-based guideline value has been proposed, however, for effective disinfection with chlorine a pH of less than 8 is recommended.
a No health-based guideline value for turbidity has been proposed; ideally, however, median turbidity should be below 0.1 NTU for effective disinfection, and changes in turbidity are an important process control parameter.
b MPN = most probable number
c Must not be detectable in any 100-ml sample

- Potable water will require treatment given the high levels of bacteria detected. Such treatment is normally standard and inexpensive. Arsenic, barium, cadmium, chromium, manganese and mercury are known toxins, and in some cases carcinogenic to humans and further treatment may be required. It is important to note that heavy metals were not detected in any of the water samples collected July 5, 2011. These samples were intentionally sent to a different laboratory than that used to analyze samples collected February 11, 2011 and concur with results obtained by UEH-FAMV (2011). However, given the limited data available, it is not possible to comment on the potential risk to humans without further analyses to substantiate the absence or presence of these toxins.

## 5.2 Industrial water quality

Table 5-2 lists the water quality parameters required for industrial use by SAE-A (required for dying purposes - general industrial parameters may be less stringent) compared to current water quality parameters. Parameters that do not, or may not, meet SAE-A guidelines are highlighted. Influent water will require a separate conditioning plant that includes conventional coagulation, flocculation, sedimentation and filtration.

**Table 5-2 Water Quality Parameters for Industrial Use**

| Parameter | Unit | Groundwater | | Surface water (Trou du Nord River) | | | SAE Industrial Water |
|---|---|---|---|---|---|---|---|
| | | P1 | P2 | P3 | P4 | P6 | |
| pH | - | 7.55 | 7.72[§] | 8.13 | 7.60 | 7.39 | 6.5 - 7.8 |
| Turbidity | NTU | 46.6 | 22.5[§] | 12 | 30 | | 2 |
| TDS | mg/L | 392 | 140 | 263 | 150 | 150 | 170 |
| Color | TCU | 20 | | 10 | | | 5 |
| Iron | mg/L | <1.0 | | <1.0 | | | 0.1 |
| Hardness | mg $CaCO_3$/L | 253 | 250 | 159 | 140 | 140 | 30 |
| Total Organic Carbon | mg/L | | | | | | |
| Alkalinity | mg $CaCO_3$/L | 318 | 250.74 | 216 | 113.43 | 128.36 | 80 |
| Total Suspended Solids | mg/L | | | | | | |
| Arsenic | mg/L | 1.110 | <DL | 1.030 | <DL | <DL | 0.1 |
| Barium | mg/L | 4.000 | | 4.000 | | | 0.1 |
| Cadmium | mg/L | <0.125 | <DL | <0.125 | <DL | <DL | 0.1 |
| Chromium | mg/L | <2.0 | <DL | <2.0 | <DL | <DL | 0.1 |
| Manganese | mg/L | <0.25 | | <0.25 | | | 0.1 |
| Mercury | mg/L | <10 | <DL | <10 | <DL | <DL | 0.1 |

§ Recorded in the field by Foratech.

- No data are currently available for Total Organic Carbon (TOC) or Total Suspended Solids (TSS) for either source. Data for these parameters will be required to determine the appropriate treatment approach (if necessary).
- As per SAE-A's specifications, water destined for industrial use will require treatment for total dissolved solids (TDS), color, hardness and alkalinity and may require treatment for heavy metals (see introductory note above to this effect). The assumed treatment that includes conventional coagulation, flocculation, sedimentation and filtration (Louis Berger, 2011) will not address TDS or color removal. The form of treatment selected for arsenic and barium, if necessary, is unknown but appropriate technology is readily available.
- The low turbidity value for surface water suggests low suspended solids; however, high volumes of silt and sediment are believed to be problematic during periods of high and intense rainfall and will result in variable quality of any intake surface water. Any treatment equipment for the removal of solids must be capable of handling this variability and potentially high volumes of Total Suspended Solids (TSS).

## 5.3 Wastewater effluent

Table 5-3 lists projected wastewater quality before and after on-site treatment specified by SAE-A alongside IFC wastewater guidelines for the textile industry and current water quality conditions.

**Table 5-3 Water Quality Parameters for Wastewater Effluent**

| Parameter | Unit | Groundwater | | Surface water (Trou du Nord River) | | | SAE Waste-water Influent | SAE Waste-water Effluent | IFC[a] |
|---|---|---|---|---|---|---|---|---|---|
| | | P1 | P2 | P3 | P4 | P6 | | | |
| pH | - | 7.55 | 7.72[§] | 8.13 | 7.60 | 7.39 | 8 - 11 | 6 - 8 | 6-9 |
| Temperature | °C | | | | 29.5 | 30.9 | 45 - 50 | | <3 |
| Color | TCU | 20 | | 10 | | | 2,500 | | 7 (436 nm, yellow)<br>5 (525 nm, red)<br>3 (620 nm, blue) |
| Total Suspended Solids | mg/L | | | | | | | | 50 |
| BOD | mg/L | | 0.500 | | 2.600 | 1.980 | 800 | 30 - 50 | 30 |
| COD (Cr) | mg/L | | 37.020 | | 24.120 | 13.860 | 1,500 | 125 -150 | 160 |
| COD (Mn) | mg/L | | | | | | 600 | | |
| AOX | mg/L | | | | | | | | 1 |
| Oil and grease | mg/L | | | | | | | | 10 |
| Pesticides[b] | mg/L | | | | | | | | 0.5 – 0.10 |
| Cadmium | mg/L | <0.125 | <DL | <0.125 | <DL | <DL | | | 0.02 |
| Chromium (total) | mg/L | <2.0 | <DL | <2.0 | <DL | <DL | | | 0.5 |
| Chromium (hexavalent) | mg/L | | | | | | | | 0.1 |
| Cobalt | mg/L | | | | | | | | 0.5 |

**Table 5-3 Water Quality Parameters for Wastewater Effluent**

| Parameter | Unit | Groundwater | | Surface water (Trou du Nord River) | | | SAE Waste-water Influent | SAE Waste-water Effluent | IFC[a] |
|---|---|---|---|---|---|---|---|---|---|
| | | P1 | P2 | P3 | P4 | P6 | | | |
| Copper | mg/L | | | | | | | | 0.5 |
| Nickel | mg/L | | | | | | | | 0.5 |
| Zinc | mg/L | | | | | | | | 2 |
| Phenol | mg/L | | | | | | | | 0.5 |
| Sulfide | mg/L | | | | | | | | 1 |
| Total Phosphorous | mg/L | | 0.144 | | 0.144 | 0.570 | | | 2 |
| Ammonia | mg/L | | | | | | | | 10 |
| Total Nitrogen | mg/L | | <DL[c] | | <DL[c] | <DL[c] | | | 10 |
| Toxicity to fish eggs | TU 96h | | | | | | | | 2 |
| Coliform | MPN/ 100mL | 2 | 3,465 | 2,400 | 508 | 5,929 | | | 400 |

a At the edge of a scientifically established mixing zone which takes into account ambient water quality, receiving water use, potential receptors and assimilative capacity
b 0.05 mg/L for total pesticides (organophosphorous pesticides excluded); 0.10 mg/l for organophosphorous pesticides.
c As Ammonia Nitrogen

- Currently available information does not address the necessary processes to remove color or residual BOD and COD from the SAE-A wastewater effluent prior to its discharge to surface water in addition to numerous parameters listed in the IFC EHS Guidelines for Textile Manufacturing.

## 5.4 Impacts of wastewater discharge on Caracol Bay

SAE-A did not provide values for many of the guideline parameters listed by the IFC in Table 5-3. Given the absence of such information, it is assumed wastewater effluent will be treated to IFC standards as a minimum though additional treatment may be required given the sensitive ecological system of Caracol Bay.

The precise ecological impact of discharging treated wastewater at the specifications given in Table 4 are unknown; however, the surrounding ecosystem is known to be sensitive, and in order to protect against ecological degradation, the discharged wastewater should be of a quality at or above the current surface water baseline conditions in addition to meeting IFC EHS Guidelines for Textile Manufacturing. Parameters of particular concern are organics (measured as BOD or COD), color, heavy metals, ammonia nitrogen, dissolved solids, suspended solids/turbidity, and temperature. Excessive quantities of any of these compounds can have a significant negative impact on the receiving stream and potentially Caracol Bay downstream. Mangrove forests, such as those bordering Caracol Bay, are potentially highly sensitive to even small variations in temperature. Further investigation is required into the potential impacts of wastewater discharge on the surrounding ecosystem.

# 6 Water Availability

Surface and groundwater availability were estimated based on field river flow measurements and maximum groundwater abstractions calculated using data from existing literature. Flood risk to the project site during extreme flood events was also assessed as was the potential for saline intrusion at the downstream (northern) boundary of the project site.

## 6.1 Estimate of Surface Water Flow

ENVIRON relied primarily upon two existing hydrological studies (UNDP, 1991; UniQ, 2010) to define site hydrology, soil parameters, precipitation, and other parameters required for the assessment of surface water flow. This information was supplemented by primary data collected during two site visits, principally river flow tests conducted in February and July 2011. The site is situated in the Trou du Nord floodplain, located in the hydrographic region of North Haiti. The climate of the Trou du Nord floodplain (including the project site) is classified as a moderate arid climate, with an average mean annual precipitation ("MAP") of 1,280 mm. MAP progressively increases from east to west and follows a bimodal distribution, with a primary rainy season from September to November and a secondary, less pronounced, rainy season from April to June. December through March is the main dry season, while July through August is a period of decreased rainfall known as the Mid-Summer Drought ("MSD").

The Trou du Nord basin measures 110 $km^2$ at its mouth where an average annual flow was estimated to be 0.98 $m^3$/sec (UniQ, 2010). The portion of the basin which is hydrologically connected to the project site is estimated to be 100 $km^2$ (or 90% of the full basin). River flow tests were conducted on-site during both the primary dry season (February 2011) and during the MSD (July 2011) and averaged 0.45 $m^3$/s and 0.70 $m^3$/s respectively. For the purposes of calculating surface water availability, the average of these two rates was considered representative of "typical" low flow baseflow.

***Assumptions***

- Because of a complete lack of rainfall and runoff data for the basin in question, it was not possible to estimate surface water availability using a USGS–type regression analysis where river flows are typically estimated using historical mean annual precipitation recorded daily and other standard river basin parameters. Such an analysis may be possible using hydrological datasets from neighboring Caribbean regions, for example Puerto Rico and the Dominican Republic, however, Haiti’s climate and the Trou du Nord basin are too distant for reliable comparisons to be made.
- No information was available regarding the characterization and distribution of rainfall during tropical storms, typical for Haiti. Given the imperative of such data for assessing flood risk, in this case, rainfall associated with tropical storms was assumed to be similar to that of South Florida and Puerto Rico, both regions where information is readily available. For a 24-hour storm event, an SCS-III[4] type storm distribution was assumed.

[4] SCS is an acronym for the US Soil Conservation Service (now known as the Natural Resources Conservation Service), developer of the model.

- No intensity-duration frequency (IDF) precipitation curves were available for Haiti. These curves provide essential information on precipitation quantities and intensity, associated with different storm durations. Given these data constraints, the best available data are those derived for the southern tip of Florida, specifically the following four scenarios: 102-mm/24-hr during the 1-year storm, 127-mm/24-hr during the 2-year storm, 203-mm/24-hr during the 10-year storm, and 356-mm/24-hr during the 100-yr storm. These curves are comparable to low-land areas in Puerto Rico and considered an excellent indicator for Northern Haiti.
- Loss of rainfall to evaporation and evapotranspiration were assumed to be 75%, consistent with previously published studies (UNDP, 1991; UniQ, 2010).
- River flow through the site during a typical dry season i.e. low flow baseflow was interpreted as the average of all measured flows i.e. 0.57 $m^3/s$. True baseflow is likely lower than the reported figure, but cannot be determined without accurate long term data.
- Infiltration increases rapidly from the south to the north and loss to infiltration in the alluvial plains is significant(UNDP 1991). This was confirmed by in-situ infiltration tests (EPSA-Labco, 2011). The average constant infiltration rate was measured at 36 mm/hour, consistent with a sandy soil. This rate is assumed to be consistent over the northern part of the Trou du Nord watershed.
- A detailed site topography map was used to estimate other relevant physical parameters.

***Methodology and Results***

The Hydrologic Modeling System (HEC-HMS, US Army Corps of Engineers, 2010) was used to estimate maximum flow at the Project site, consistent with the above assumptions and summarized in Table 5.

**Table 5 Estimated River Flow for Rivière Trou du Nord**

| **Return Period** | **Flow ($m^3/s$)** |
|---|---|
| Baseflow | 0.57 |
| 2-year | 2 |
| 10-year | 10 |
| 100-year | 37 |

Flows generated upstream in the mountains were up to 4 times higher; however, significant infiltration rates at the site would likely reduce these flows. A lack of more significant flows at the Project site was also confirmed during our site visit through anecdotal evidence supplied by local residents and supported by previous reports (EPSA-Labco, 2011; Koios, 2011).

## 6.2 Estimate of Flood Risk

The hydraulic model HEC-RAS (Version 4.0, US Army Corps HEC, March 2008) was used to estimate flood flows and velocities at four selected locations of the Trou du Nord River across the Project site. A 1-meter interval topographic map and river flows, generated from the Hydrologic Modeling System (HEC-HMS), were used as inputs for the HEC-RAS model. Manning roughness coefficients were derived based on aerial photos and photos taken during the site visit (0.04 for the channel; 0.10 for the floodplain). The average incision of the channel into the floodplain was determined to be approximately 4 meters. The average flow depth associated with 100-year flows was estimated to be less than three meters. As a result, the site (beyond the channel boundary) would not be flooded given estimated flow is one meter below the top of the bank throughout the site.

### *Limitations*

The impact of any downstream structures to on-site flood risk was not examined in detail (i.e., from backwater, etc). However, because of the deep, wide channel through the site, any such impact was envisioned to likely be minimal.

## 6.3 Estimate of Well Yield and Potential for Aquifer Depletion

This section estimates the maximum well yield and potential for aquifer depletion associated with different water supply needs, assuming pumping would be conducted from already constructed boreholes and wells on-site and assuming the hydrogeology of the site is similar to the hydrogeology described in the existing literature (UniQ 2010, UNDP 1991).

### *Assumptions*

- Well characteristics are similar to those reviewed by ENVIRON in June, 2011 and currently being constructed by Foratech, under contract to the ROH.
- Thickness of the saturated aquifer is 67.50 m.
- Site transmissivity was assumed to be equal to regional transmissivity, ranging from 0.0005 $m^2/s$ to 0.002 $m^2/s$ (UniQ, 2010). The site storage coefficient was assumed to be equal to the regional storage coefficient, ranging from 0.005 to 0.0067.
- The aquifer underlying the project site conforms to an unconfined aquifer with a free groundwater surface.
- A modified non-equilibrium well (Theis) equation (i.e., Driscoll, 1986) relating well function, storage coefficient, transmissivity, radius of influence, pumping withdrawal and groundwater drawdown during pumping, is applicable, and is used as follows:
    a) starting groundwater level in the well and the well radius of influence were assumed;
    b) well pumping rate and drawdown was computed for distance x1 from the well;
    c) calculation in (b) was repeated for distances x2, etc. until the maximum distance was equal to the well radius of the influence;
    d) results from (c) were plotted on a log-log chart and the slope of the distance-drawdown graph was measured;
    e) Calculations from (d) were repeated until the drawdown measured from the drawdown graph was equal to the drawdown in the well calculated from the equation relating transmissivity and pumping rate.

The calculations consistent with the above assumptions yield the results with an initial drop in groundwater of 1.3 m and a well radius of influence of 100 meters, resulting in a maximum possible well yield of between 1,000 $m^3$/d and 3,990 $m^3$/d. Notwithstanding, actual pumping tests may demonstrate significantly different results as a result of either non-homogeneity of the aquifer and/or significantly different hydrogeological characteristics of the aquifer. This analysis was derived using the best available data and concurs with the preliminary constant flow rate of the recently constructed piezometer observed on-site.

Anticipated pumping for domestic and industrial use in Phase 1 of the site development is estimated to be 3,650 $m^3$/d (requiring the operation of one to three wells). Anticipated pumping for domestic and industrial use in Phase 2 of this project is estimated to be 11,407 $m^3$/d (requiring the operation of four to eleven wells).

Available reports (UniQ, 2010) estimate groundwater inflow and outflow from the regional aquifer to be 250,000,000 $m^3$/y (or 684,932 $m^3$/d). These numbers suggest that 0.5% and 1.6% of groundwater from the aquifer would be used in Phase 1 and Phase 2 respectively. Thus, the potential for aquifer depletion through the pumping of groundwater is considered to be very small. However, it should be noted that other impacts, particularly the high levels of deforestation, can significantly impact aquifer reserves over the long term such that the overall water balance is altered.

## 6.4 Estimate of Potential for Saline Intrusion

Current literature reviews characterize typical freshwater salinity (due to weathered materials that are dissolved by rainfall and transported to lakes, rivers, and oceans) as less than 500 ppm (or 0.50 g/kg). An increased presence of saltwater in groundwater (i.e., from seawater) is characterized with a salinity of higher than 500 ppm. Water samples were collected at four locations throughout the site. Analyses of these samples indicate an average salinity of between 0.25 ppm and 0.28 ppm, thus indicating no evidence of saline intrusion at any of the four locations.

These measurements are consistent with the analysis of saltwater intrusion potential discussed in previous reports (UniQ, 2010; UNDP, 1991), which state that the alluvial floodplain of the North is of good chemical quality, with saltwater intrusion limited to coastal areas of Fort-Liberte and Caracol, both downstream from the project site. However, it should be noted that the same report (UNDP, 1991) suggests groundwater flows from south to north. Hence, there may be the potential for saline intrusion during periods of high extraction.

### *Limitations*

A complete evaluation of saltwater intrusion is not possible without constructing groundwater equipotential contours of the regional aquifer. These must be constructed using groundwater chemistry measured at a series of wells between the site and the sea in addition to accurate pump tests. The number and locations of such wells must be sufficiently high to account for any non-homogeneity in the regional aquifer.

# 7 Demographic Analysis

In addition to the water demands of the Park and any direct impacts pertaining to the Park's operations, due consideration must be given to any indirect consequences of induced demographic change (i.e., influx of workers and others attracted by economic opportunities generated by the Project) and potential related effects, including but not limited to, changes in agriculture, shifts in local activities, additional infrastructure development, deforestation and destruction of local mangrove forests (for charcoal, timber, and fuel extraction), fishing (including marine invertebrates, turtles and manatees), and hunting. The potential for such indirect impacts has already been outlined in detail in earlier reports (KOIOS, 2011) hence this report focuses predominantly on the cumulative effects of the anticipated increase in demand on existing water supplies. Due to the paucity of accurate demographic data available in Haiti, in additional to extremely limited information concerning the management of the Park's development and any indirect impacts associated with the Park, we have assumed a worst case scenario for each of the explored scenarios.

## 7.1 Population Estimates

It has already been assumed that residential park staff will represent 1% of the total anticipated workers. As a result, 32,813 employees will be required to secure housing within a commutable distance of the Park. Given the large size of the basin, which encompasses several established cities and towns, it is assumed this population will reside within the geographical confines of the Trou du Nord basin. Each staff member has been allocated 80Lpd of water while on-site. Based on Park estimates, a remaining 70Lpd of water will therefore be consumed off-site. KOIOS (2010) suggests the average family size in Haiti is 5. Assuming each employee is accompanied by their family, a potential increase in local population of up to 164,065 additional people will result in a significant increase in overall water demand.

It is well known that consumption rates in developing countries are significantly lower than consumption rates in developed countries such that a figure of 170 Lpd is likely inflated. Some authors (Gleick, 1996) suggest a volume of 165 Lpd[5] is required to meet basic water requirements (BWR) for moderately industrialized countries with direct sanitation hookups. Given the almost complete lack of water-fed sanitation systems in Haiti, it was considered reasonable to assume the 40 L associated with direct sanitation hookups is not required, nonetheless, suggesting a BWR of 125 Lpd. The CIA (2011) reports an average annual freshwater withdrawal per person in Haiti of 116 $m^3$ or 318 Lpd, of which only 5%, or 16 Lpd, is for domestic purposes. Twenty-one residents of the Commune of Caracol were surveyed during a recent community meeting (pers. comm.) to estimate average daily water use per household. Residents were purposefully selected and, given their economic standing, were not representative of the wider population. Notwithstanding, an average volume of 64 Lpd was reported, approximately half the recommended BWR for households without direct sanitation hookups. With this in mind, it is conceivable the figures in Table 5 grossly overestimate *actual* domestic water use; however, as previously mentioned, this report presents worst case

[5] BWR = basic drinking water requirements [5L], "societal preferences for moderately industrialized countries" for bathing [70L], kitchen and cooking [50L] and "adequate [amounts] for direct sanitation hookups in industrialized countries [40L]" (Gleick, 1996).

scenarios, which in this case, represents an estimated domestic water need of 125 Lpd (excluding the 80 Lpd afforded non-residential staff while on-site).

**Table 6 Additional water demand associated with non-residential staff and their families**

| Phase 1 & 2 Combined (worker pop. 32,813) | Family (est. worker family pop. 131,252) | Total (est. combined pop. 164,065) |
|---|---|---|
| 1,448 $m^3$/d | 16,407 $m^3$/d | 17,855 $m^3$/d |

The most recent population statistics (date unknown) for Haiti (pers. comm.) suggest the *Arrondissement du Trou du Nord* has a total population of approximately 105,000. Efforts were made to corroborate this data using historical images obtained from Google Earth to count structures to determine changes in building density in the Trou du Nord water basin between 2003 and 2010 (see Figures 4 and 5). These results indicate building density increased from 5,268 to 6,044, a growth rate of 15%. However, even if it is assumed that 100% of all buildings were domestic abodes and each household contained the average family size of 5, the derived population of 30,200 represents less than a third of the population based on the above statistics. Using the worst case scenario once again, it was assumed that the current population is 105,000 giving rise to an additional demand of 13,125 $m^3$/d.

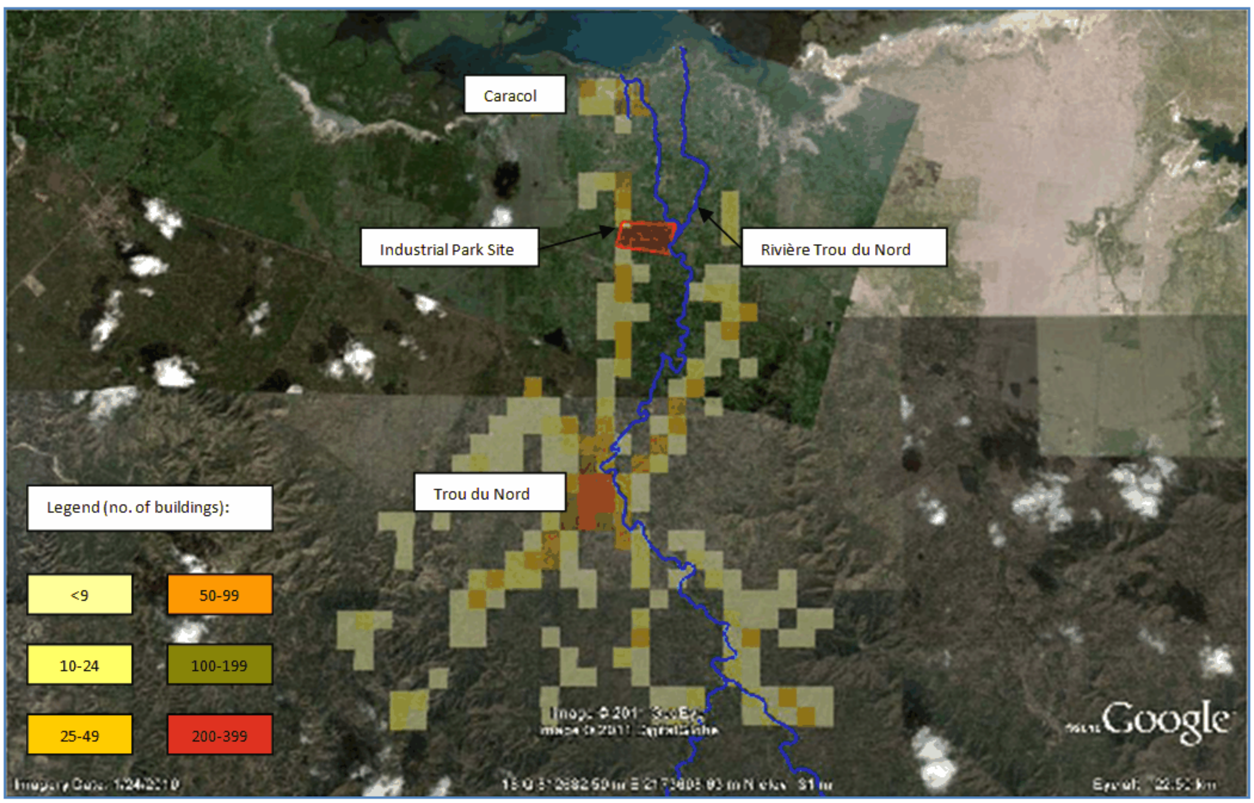



**Figure 4. Estimated population densities in the area of influence, 2003**

The CIA (2011) estimates Haiti's current growth rate to be 0.787% for 2011. Recognizing Haiti's negative net migration rate of -8.32 per 1,000 population (CIA, 2011) rate, if current rates of growth are sustained for the next ten years, the change in population will result in an increase in water demand of 8%, an insignificant impact on existing water resources.

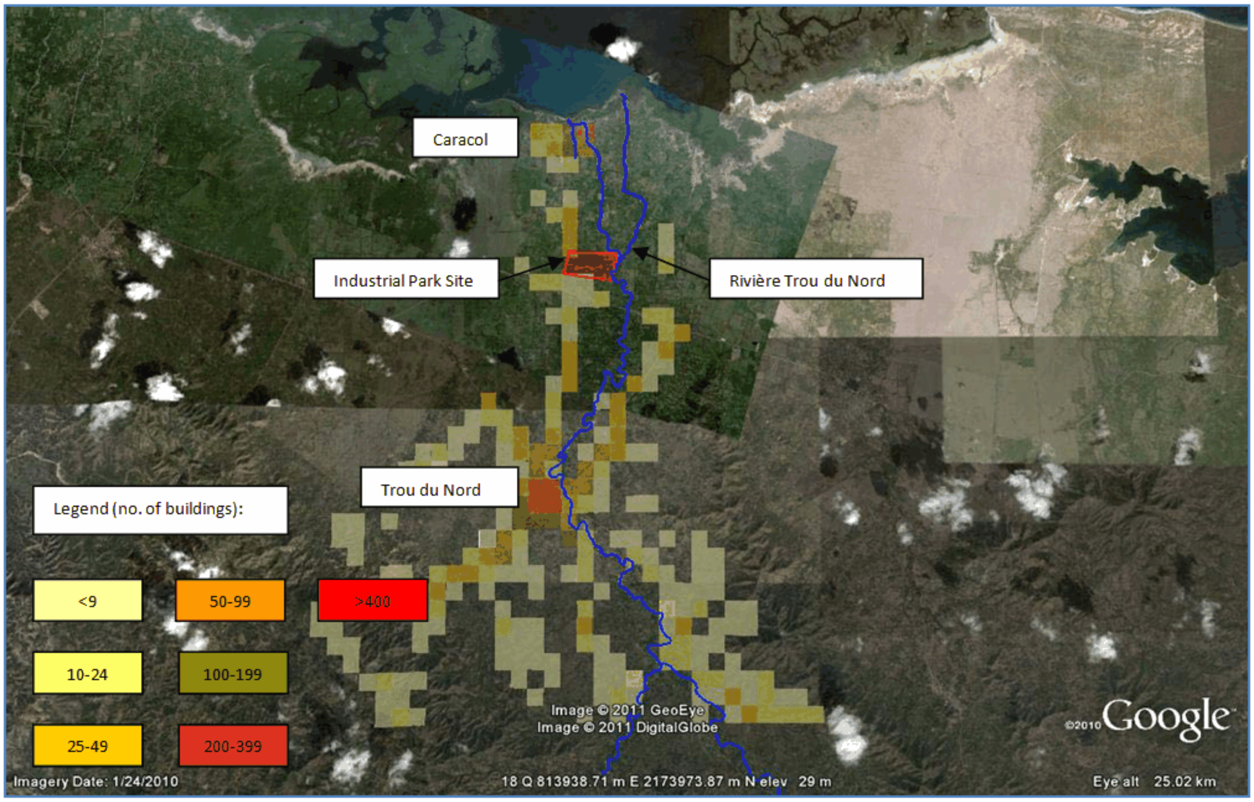



**Figure 5. Estimated population densities in the area of influence, 2010**

A new university is currently under construction west of the Park and reportedly will house 6,000 students in addition to faculty and staff. As a result, current water demand will rise marginally by an estimated 750 $m^3$/d. This excludes the water for industrial use required for site operations. Assuming the student population remains constant, the estimated future population of the Trou du Nord basin and associated domestic water requirements at the end of Phase 2 are presented in Table 7.

**Table 7 Future Estimated Domestic Water Demand of the Trou du Nord Basin**

| | Current Population | Estimated Population in 7 years time | Domestic Water Demand ($m^3$/d) |
|---|---|---|---|
| Non-residential Park Staff | n/a | 32,813 | 1,447 |
| Family | n/a | 131,252 | 16,407 |
| General Population | 105,000 | 110,923 | 13,865 |
| Student Population | 6,000 | 6,000 | 750 |
| Total | 111,000 | 280,988 | 32,469 |

Reverting to estimated groundwater inflow and outflow from the regional aquifer of 250,000,000 $m^3$/y or 684,932 $m^3$/d (UniQ, 2010), current domestic demand of 13,125 $m^3$/d (based on an estimated population of 105,000) and future domestic demand of 32,469 $m^3$/d (based on an estimated future population of 280,988) represent 2% and 4.7% respectively. These figures, were based upon crude "worst case scenario" population estimates, yet based on projected aquifer capacity, would not represent a significant impact on local water resources. The potential for current and future domestic water demand to adversely impact the volume of groundwater reserves is very small.

# 8 Baseline Environmental Conditions

As part of the initial baseline assessment of environmental conditions, water quality was analyzed at two points upstream and downstream of the Park respectively, in addition to groundwater on-site. This was discussed in greater detail in Section 4.1. Noise and air quality baseline measurements were also assessed on-site during the site visit in July, 2011, the results of which are presented in Tables 8 and 9.

Total particulates are currently below the maximum limit recommended in the World Bank/ IFC General EHS Guidelines, which allows an average of 150 µg/m$^3$ in a 24-hour period. Particulates measured on-site totaled 62 µg/m$^3$, however, it should be noted that due to a lack of on-site security it was not possible to conduct the test over the normally recommended 24-hour period. Notwithstanding, site observations suggest on-site air quality is not currently an issue. This should be monitored at regular intervals in the future, particularly during site construction and, if necessary, employees should be provided with the appropriate personal protection equipment designed to mitigate any harmful effects of deterioration in air quality.

**Table 8 Air Quality Baseline Assessment**

| **Parameter** | **Air Quality ($PM_{10}$)[1]** | **WBG/IFC 2007[2]** |
|---|---|---|
| Result | 62 µg/m$^3$ | 150 µg/m$^3$ |

[1] Using a real-time TSI DustTrak aerosol monitor designed to filter total particulates
[2] World Bank Group/IFC General EHS Guidelines: Environmental (2007), 24 hour period

Noise measurements recorded in the field during the July 2011 site quality are presented in Table 9 below along with the residential and industrial noise level guidelines from World Bank Group/IFC General EHS Guidelines: Environmental (2007). The General EHS Guidelines state that noise levels should not exceed these numerical standards, **or** result in a maximum increase in background noise of more than 3 dB. The daytime field data indicate that the maximum background daytime noise levels exceed the residential standard at Points 1 and 2 and exceed the industrial standard at Point 3. Though these measurements are preliminary, the data suggest that noise may be an issue during the construction and operational phases.

**Table 9 Noise Quality Baseline Assessment**

| **Location** | **Min (dB)** | **Max (dB)** | **Average (dB)** | **WBG/IFC Standard[1] (dB)** | |
|---|---|---|---|---|---|
| | | | | Daytime residential | Daytime industrial |
| **Point 1** | 41.5 | 56.8 | 49.9 | 55 | 70 |
| **Point 2** | 48 | 58.7 | 58.8 | 55 | 70 |
| **Point 3** | 51.3 | 74.3 | 66.6 | 55 | 70 |
| **Average** | 46.9 | 63.3 | 58.4 | 55 | 70 |

[1] World Bank Group/IFC General EHS Guidelines: Environmental (2007)

# 9 Conclusions

## 9.1 Water Supply and Demand

*Surface water*

Conclusion: because of the uncertainty in ecological sensitivity and baseflow calculations, we conclude there is insufficient surface water available to meet Park demands.

Limitations: as described in Chapter 6, our analysis was based on existing literature and extremely limited field data i.e. no long term rainfall or runoff records, no data on local storm events, etc.

Recommendations: upon securing the site's perimeter, install at least one permanent meteorological and river gauging station on-site (and ideally one station in the upper basin) to measure daily rainfall (hourly if available) and real-time river flow to be collected over a minimum of one year.

*Groundwater/aquifer depletion/saline intrusion*

Conclusion: there appears to be ample groundwater available to meet the Park's demands without depleting the aquifer. The high level of coliforms detected in the groundwater sample support lithological assumptions that the aquifer is unconfined and that the alluvial plans comprise unconsolidated sandy material to a depth of 60 m and greater below the surface.

Limitations: described in Chapter 6. Based on existing literature and very limited field data, specifically, excluding important results of existing borehole pump test to estimate actual yield; additionally, missing data required to model saline intrusion – current results simply indicate a lack of salinity on-site.

Recommendations: additional pump tests including the monitoring of a series of wells between the site and the sea for evidence of significant drawdown and also to record specific conductivity. Ongoing monitoring of wells, including water quality monitoring on and off-site. Careful planning to ensure this vital resource is appropriately protected (impervious and bunded areas where fuels and chemicals are to be stored; appropriate stormwater drainage; appropriate health, safety & environmental training for all staff) and a rigorous ongoing monitoring program of groundwater quality.

## 9.2 Water Quality for Domestic and Industrial Use

Conclusion: water will need to be treated prior to human consumption (regardless of source). Data was insufficient to confirm the presence or absence of heavy metals. Data was insufficient to confirm the presence or absence of organic and other compounds as laboratory equipment was not sufficiently sensitive to meet current water quality guidelines. Water will need to be treated before use for industrial purposes, but data was insufficient data to determine the extent of treatment required.

Limitations: Data on existing water quality was insufficient and information regarding water treatment specifications and plant design was non-existent.

Recommendations: a well-planned water monitoring regime, including additional sampling required prior to design specifications being finalized, is necessary. It is highly recommended that samples be shipped to the US for analyses (in order to be analyzed with equipment sufficiently sensitive to detect limits near the lower detection limit required by IFC standards and to guarantee results are reported more rapidly). Third party review of all tenant specifications, water quality guidelines intended for use by the ROH, and design specifications is also recommended.

## 9.3 Wastewater Discharge and Variations in Stream Quality and Flow

Conclusion: wastewater effluent will need to be treated to a higher standard than suggested by SAE-A in order to ensure water discharged to surface reservoirs is of the same or better quality than the present state, especially concerning BOD, COD, temperature and TSS.

Limitations: insufficient information was available for: a) wastewater treatment plant design, recycling processes, and discharge rates, b) current ecological flow and sensitivity of local mangroves.

Recommendations: a full review of the proposed wastewater treatment plant is required, including a comprehensive review of water quality specifications for wastewater effluent given the known risk to the local environment; a comprehensive ecological/biodiversity assessment to evaluate the importance and sensitivity of the local environment is essential to mitigating future risks of impact from the Park’s operations.

## 9.4 Demographic Influence

Conclusion: negligible in terms of the impact of current and future domestic water demand on groundwater reserves. Assumes internal migration is properly managed including but not limited to a properly managed water supply system and appropriate sanitation.

Limitations: potentially inaccurate population estimates. Failure to consider the lack of environmental awareness locally.

Recommendations: in spite of and because of the negligible impacts domestic water use might have on groundwater reserves, the ROH and funding bodies should take this opportunity to fully assess local water and sanitation needs, including but not limited to: a) a full water and sanitation needs assessment at the community level, b) educational campaigns designed to raise awareness of the benefits of appropriate hygiene, c) educational campaigns designed to raise awareness regarding the negative impacts of deforestation on local aquifers and the need to protect this precious resource.

## 9.5 Baseline environmental conditions

*Air quality*

Conclusion: current air quality is good.

Limitations: based on limited sampling as air quality monitoring was not conducted over a 24-hour period.

Recommendations: once the site perimeter is secured, a permanent air quality monitoring station should be established, and in particularly prior to site development/construction. Verify if appropriate PPE is required for on-site personnel.

*Noise*

Conclusion: current noise levels are below those recommended for workplace exposure.

Limitations: none

Recommendations: once construction begins, ensure regular monitoring of noise levels to protect employees and to mitigate any nuisances to neighboring families. Verify if appropriate PPE is required for on-site personnel.

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# Appendices

## APPENDIX 1 – HEC- HMS model

The US Army Corps Engineers HEC-HMS model (Version 3.5, August 2010) was used to estimate surface flows at the project site. The model simulates precipitation-runoff processes (usually on an event basis) using available information on rainfall, soil, land use, topography, and other information. The model input parameters were as follows:

Precipitation: Precipitation falls as rainfall. The rainfall depth was assumed similar to the southern Florida rainfall, specifically: 102-mm/24 hr during the 1-year storm, 127-mm/24-hr during the 2-year storm, 203-imm/24-hr during the 10-year storm, and 356-mm/24-hr during the 100-yr storm. Distribution of precipitation within the 24-hour storm was assumed similar to the SCS-III type storm, usually used for Southern United States.

The *Initial and Constant loss method* was used to estimate losses of rainfall due to infiltration over Trou de Nord watershed. Constant infiltration rate was calculated as 36 mm/hour, based on four infiltration tests on the project site. Initial loss was calculated at 12.3 mm, based on the same four infiltration tests.

The Trou De Nord watershed were assumed 100 percent pervious.

*Snyder Unit Hydrograph* method was utilized to calculate direct watershed runoff from other data. Snyder parameters L (Length of Trou de Nord from the outlet to divide) and $L_c$ (length of Trou de Nord from the outlet to watershed centroid) were measured using the 1-meter topographical map as 26.9 km, and 12.5 km, respectively. Snyder basin coefficient ($C_t$) and Snyder peak coefficient ($C_p$) were assumed 2.0 and 0.6, respectively, the averages of literature published values. Standard lag time ($t_p$) (time from the start of the storm to the peak of rainfall hydrograph) was computed at 8.6 hours .

The *Baseflow* was assumed at 0.57 m3/sec (calculated as an average of flow measurements conducted during two dry seasons).

Losses of rainfall to evaporation and evapotranspiration were assumed at 75 percent, consistent with previous measurements and observations).

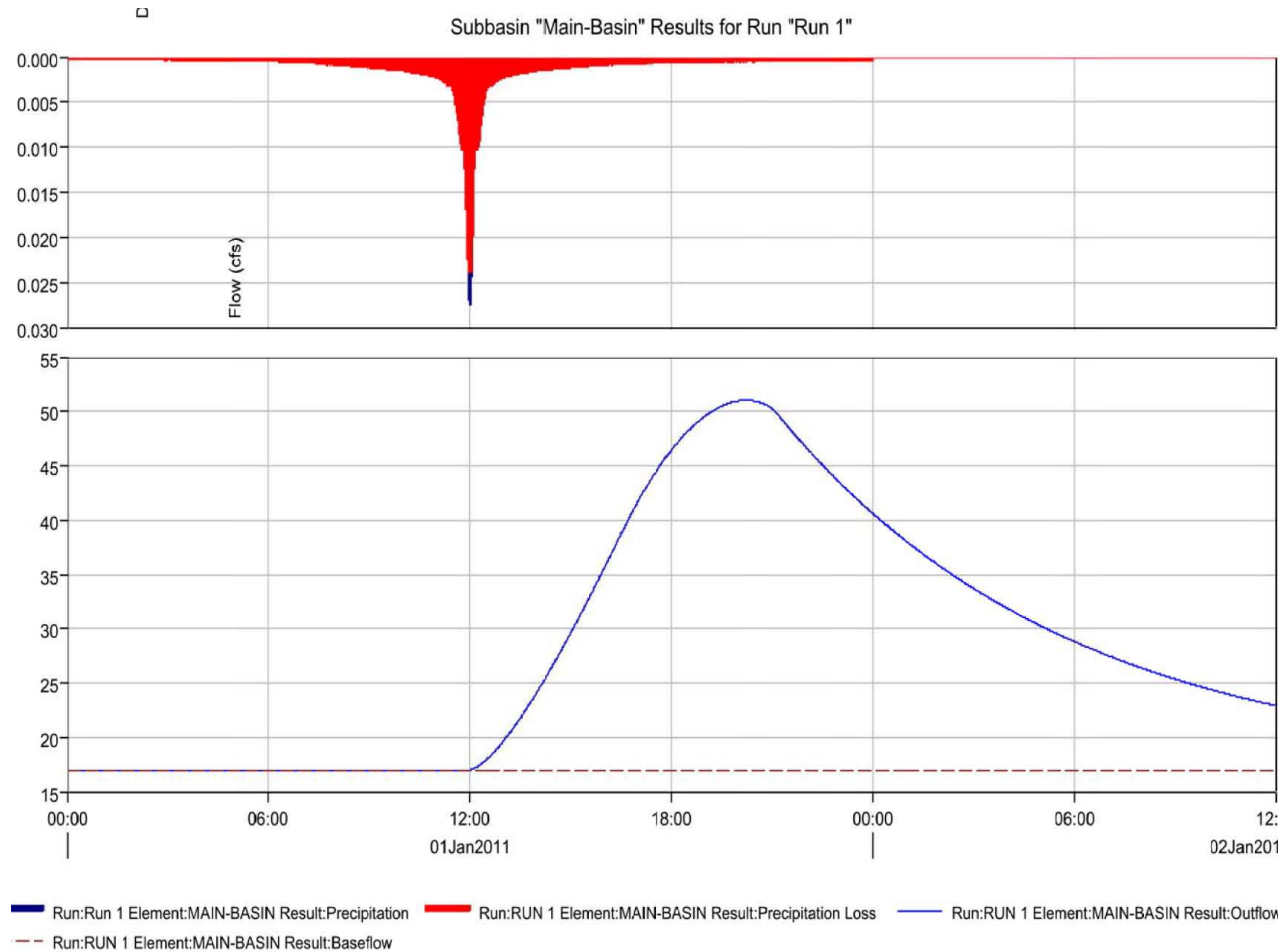
The estimate of watershed flow is associated only with the overland flow; and no detail routing of channel flows was conducted.

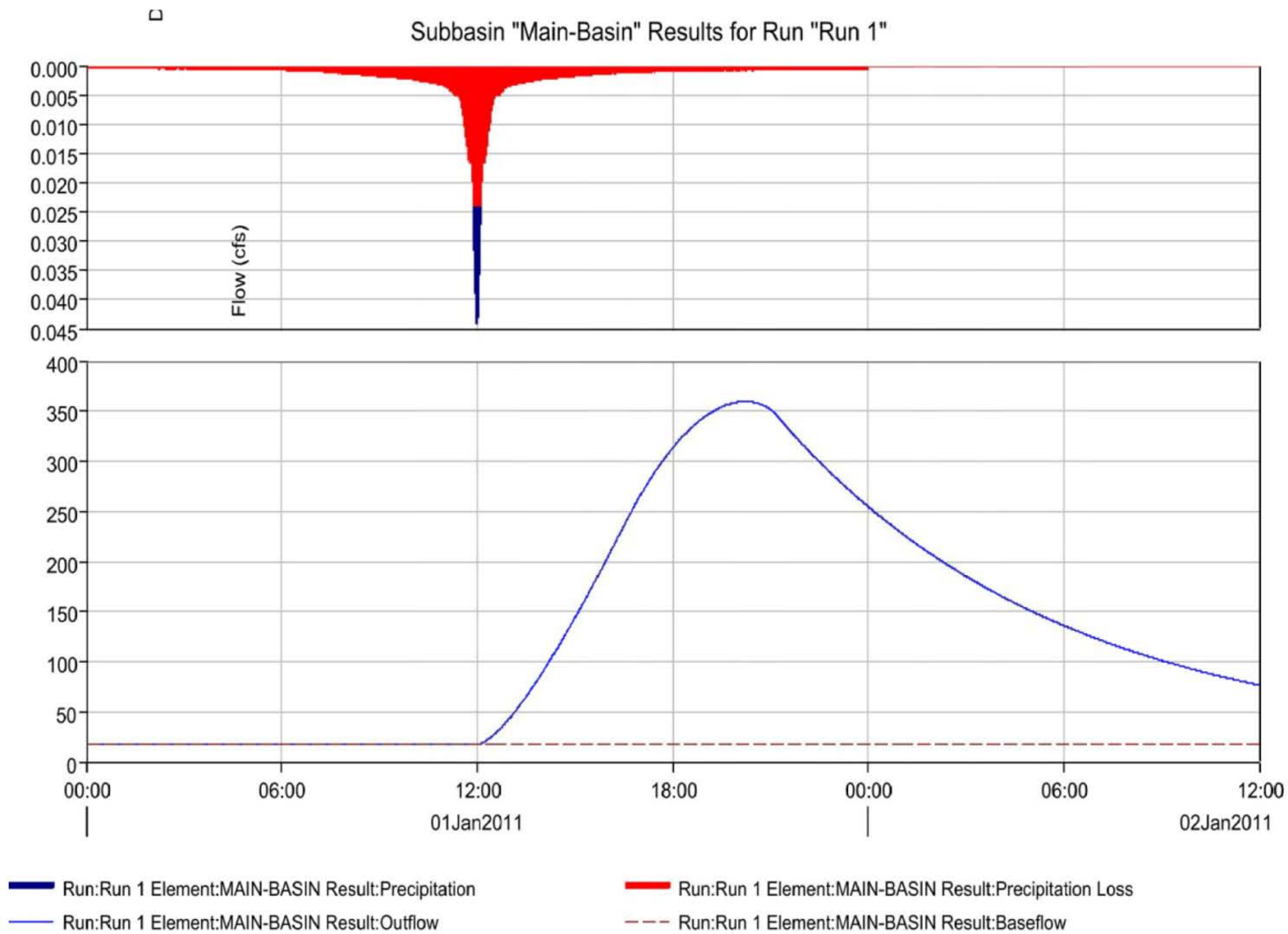
Results of the HEC-HMS modeling simulations are presented at the next three pages. The runoff hydrographs correspond to 2-year rainfall, 10-year rainfall, and 100-year rainfall, respectively. The resulting flood peaks are presented in Column 2 of Table 1 below.

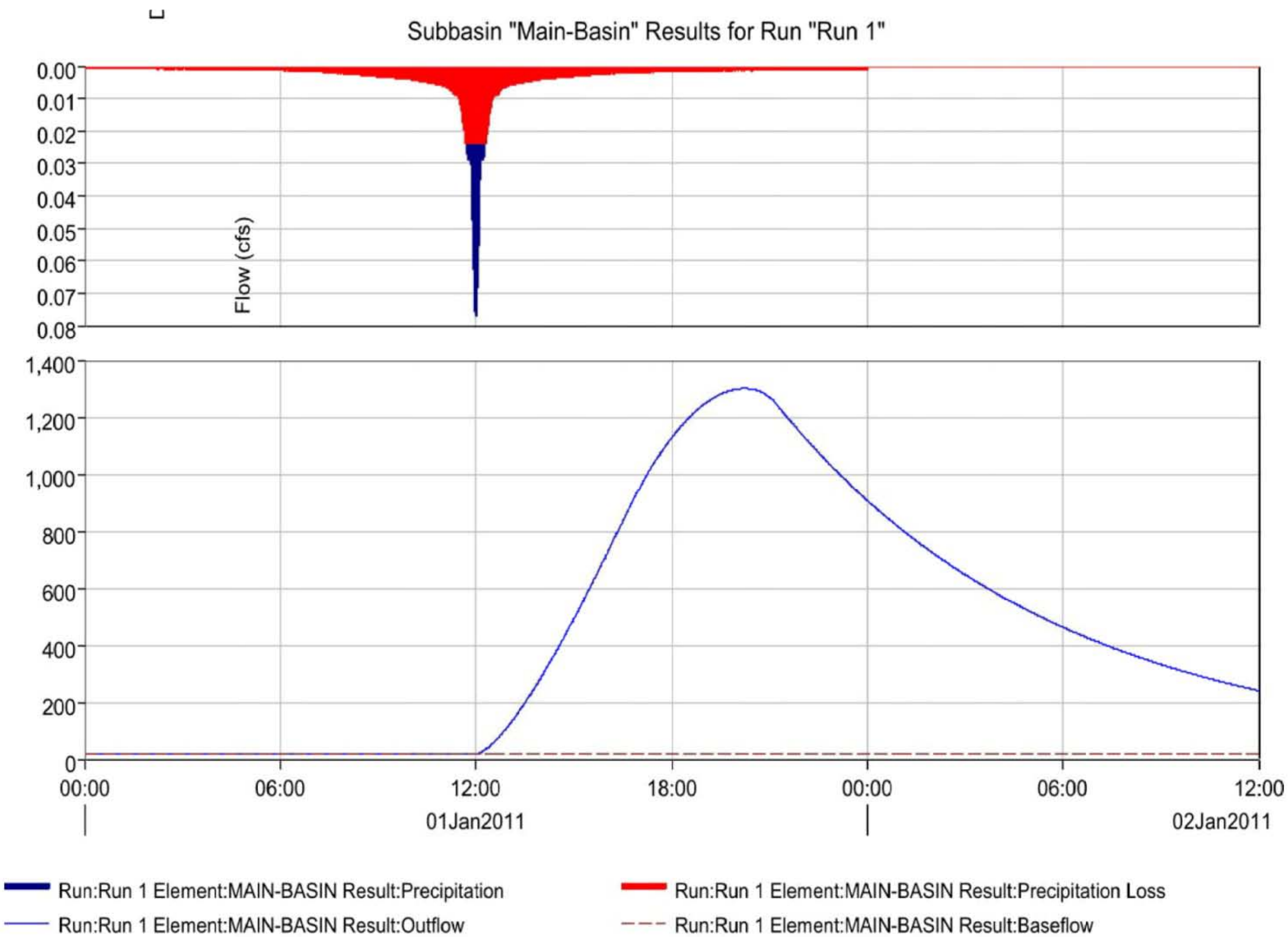
The HEC-HMS simulations are repeated using infiltration rates representative for the mountains in the upper watershed (using representative infiltration rate of 0.10 inches/hour, consistent with very impervious soil). The runoff flood peaks associated with these rates are presented in Column 3 of Table 1 below. These peaks are presented for informational purposes only, as infiltration rates changes significantly before reaching the site, so the flood forecasted in Column 3 of the Table does not materialize on the project site.

**Table 1 – HEC-HMS summary results**

| Return Period | 24 – hour Rainfall (mm) | Peak Flows (m3/s)- at the site | Peak Flows (m3/sec)- upstream of the site |
|---|---|---|---|
| 1-year | 102 | 0.55 | 26 |
| 2-year | 127 | 2 | 36 |
| 10-year | 203 | 10 | 70 |
| 100-year | 356 | 37 | 148 |


Subbasin "Main-Basin" Results for Run "Run 1"
0.000
0.005
0.010
0.015
0.020
0.025
0.030
Flow (cfs)
55
50
45
40
35
30
25
20
15
00:00
06:00
12:00
18:00
00:00
06:00
12:
01Jan2011
02Jan201
Run:Run 1 Element:MAIN-BASIN Result:Precipitation
Run:RUN 1 Element:MAIN-BASIN Result:Precipitation Loss
Run:RUN 1 Element:MAIN-BASIN Result:Outflow
Run:RUN 1 Element:MAIN-BASIN Result:Baseflow


D
Subbasin "Main-Basin" Results for Run "Run 1"
Flow (cfs)
0.000
0.005
0.010
0.015
0.020
0.025
0.030
0.035
0.040
0.045
400
350
300
250
200
150
100
50
0
00:00
06:00
12:00
18:00
00:00
06:00
12:00
01Jan2011
02Jan2011
Run:Run 1 Element:MAIN-BASIN Result:Precipitation
Run:Run 1 Element:MAIN-BASIN Result:Precipitation Loss
Run:Run 1 Element:MAIN-BASIN Result:Outflow
Run:Run 1 Element:MAIN-BASIN Result:Baseflow


Subbasin "Main-Basin" Results for Run "Run 1"
Flow (cfs)
0.00
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
1,400
1,200
1,000
800
600
400
200
0
00:00
06:00
12:00
18:00
00:00
06:00
12:00
01Jan2011
02Jan2011
Run:Run 1 Element:MAIN-BASIN Result:Precipitation
Run:Run 1 Element:MAIN-BASIN Result:Precipitation Loss
Run:Run 1 Element:MAIN-BASIN Result:Outflow
Run:Run 1 Element:MAIN-BASIN Result:Baseflow

# APPENDIX 2 – HEC-RAS model

The US Army Corps of Engineers Hydraulic Analysis System (HEC-RAS) model (Version 4.0, March 2008) was used to estimate Rou de Nord stream depth and velocities throughout the site. The model was developed at the Hydrologic Engineering Center (HEC), division of the Institute of Water Resources of the US Army Corps of Engineers. The model is used to perform one-dimensional steady-state and unsteady flow calculations and/or sediment transport calculations in rivers and open channels.

This model was used not to simulate flows through the entire Trou de Nord reach through the site, but only to evaluate capacity of the Trou de Nord reach to carry flows during peak flood periods. Four representative sections of Trou de Nord were constructed utilizing 1-meter topographic map.

- The flood flows generated by the HEC-HMS model were used as representative HEC-RAS flows.
- The Manning roughness coefficient of 0.04 was used in the main Trou de Nord channel; 0.10 roughness coefficient was used in the overbank floodplain.
- Expansion coefficient of 0.30 and contraction coefficient of 0.1 were used to calculate friction losses between different channel sections.
- Normal depth with very gentle slope (S=0.004) was assumed at the downstream river boundary.

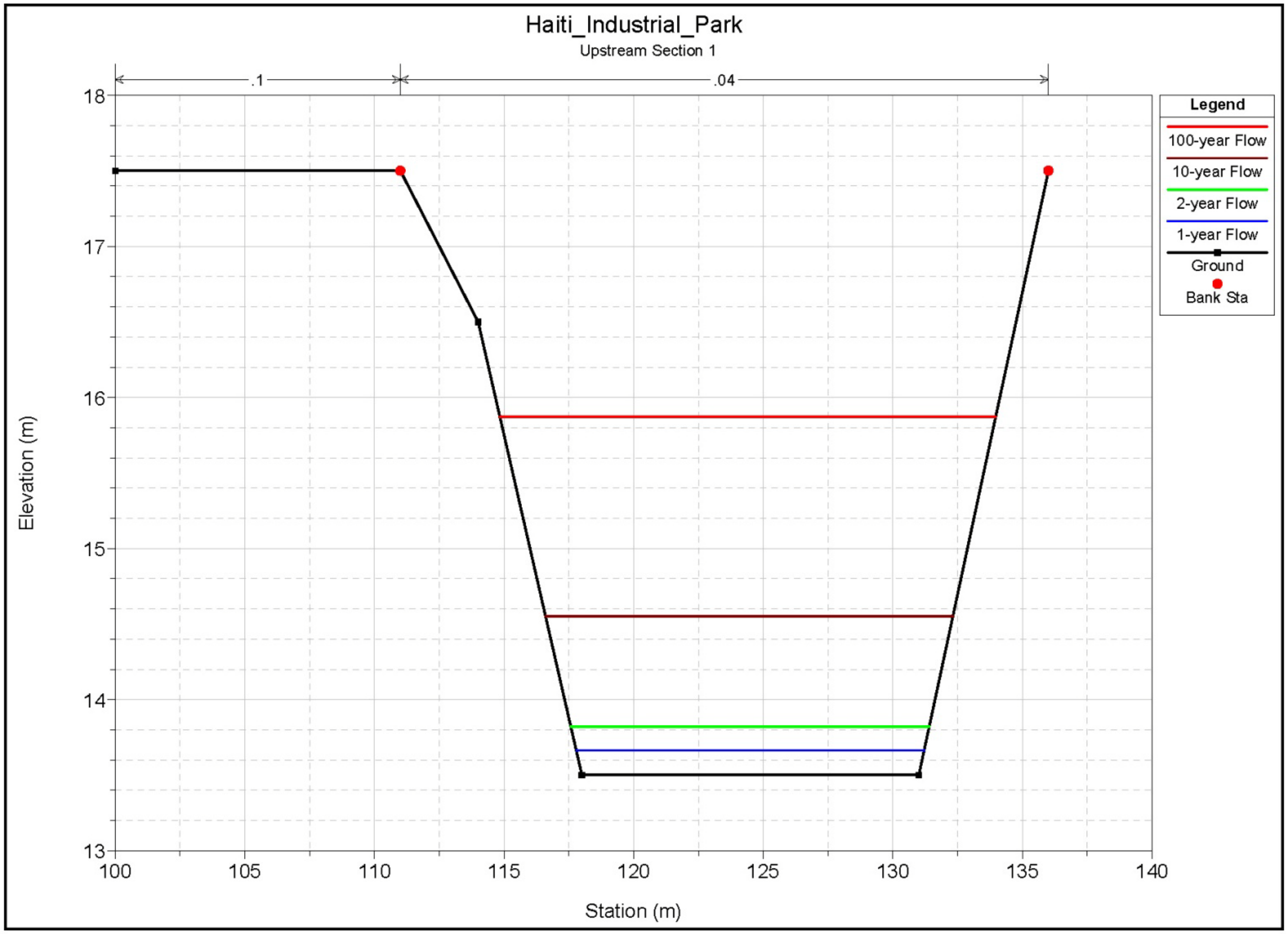
Channel cross-sections with overlaid water surface elevations corresponding to different floods are shown in the figures on the next four pages.

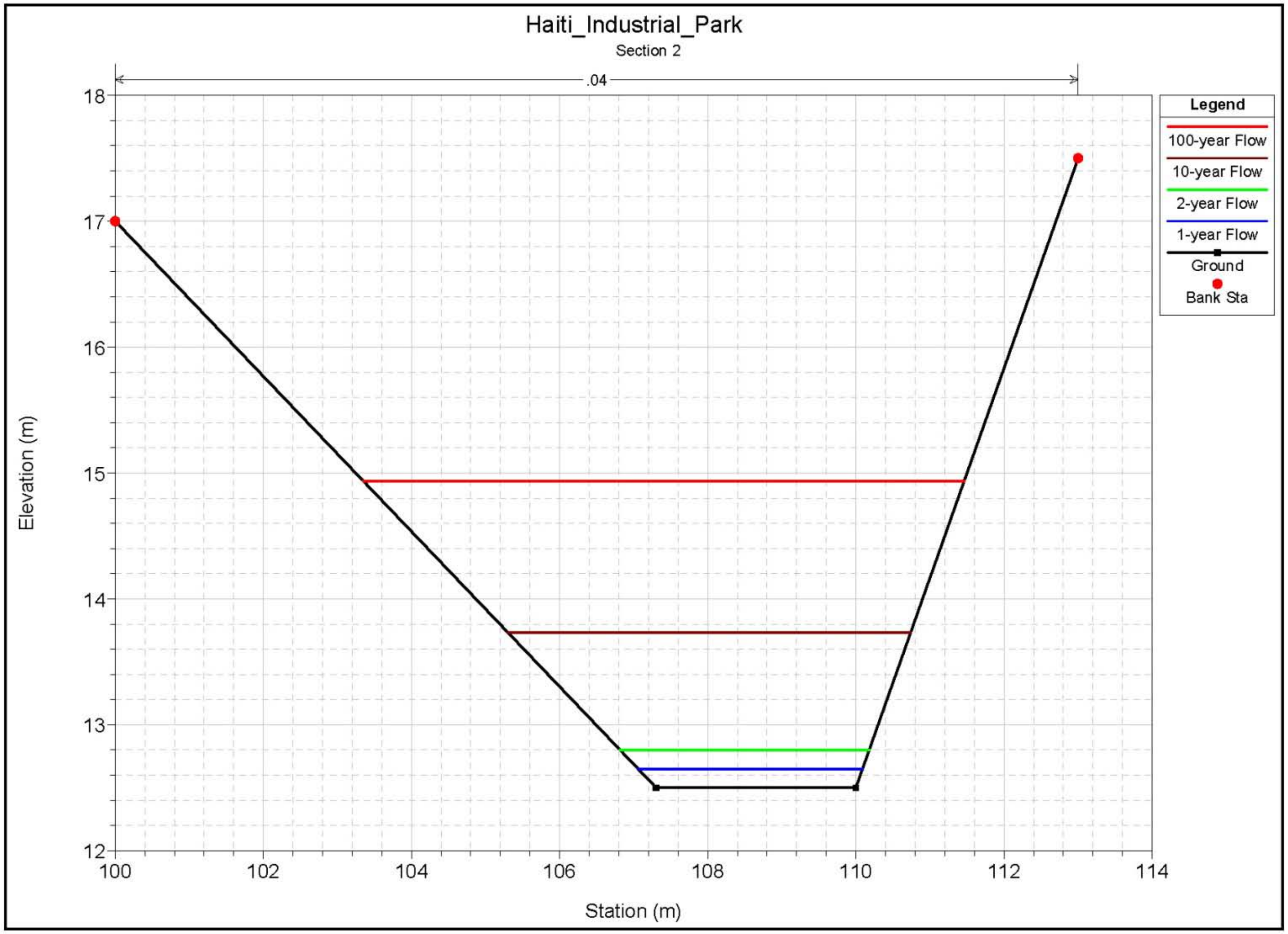
Average velocities and maximum flow depths at each cross-sections are summarized in Table 2 below:

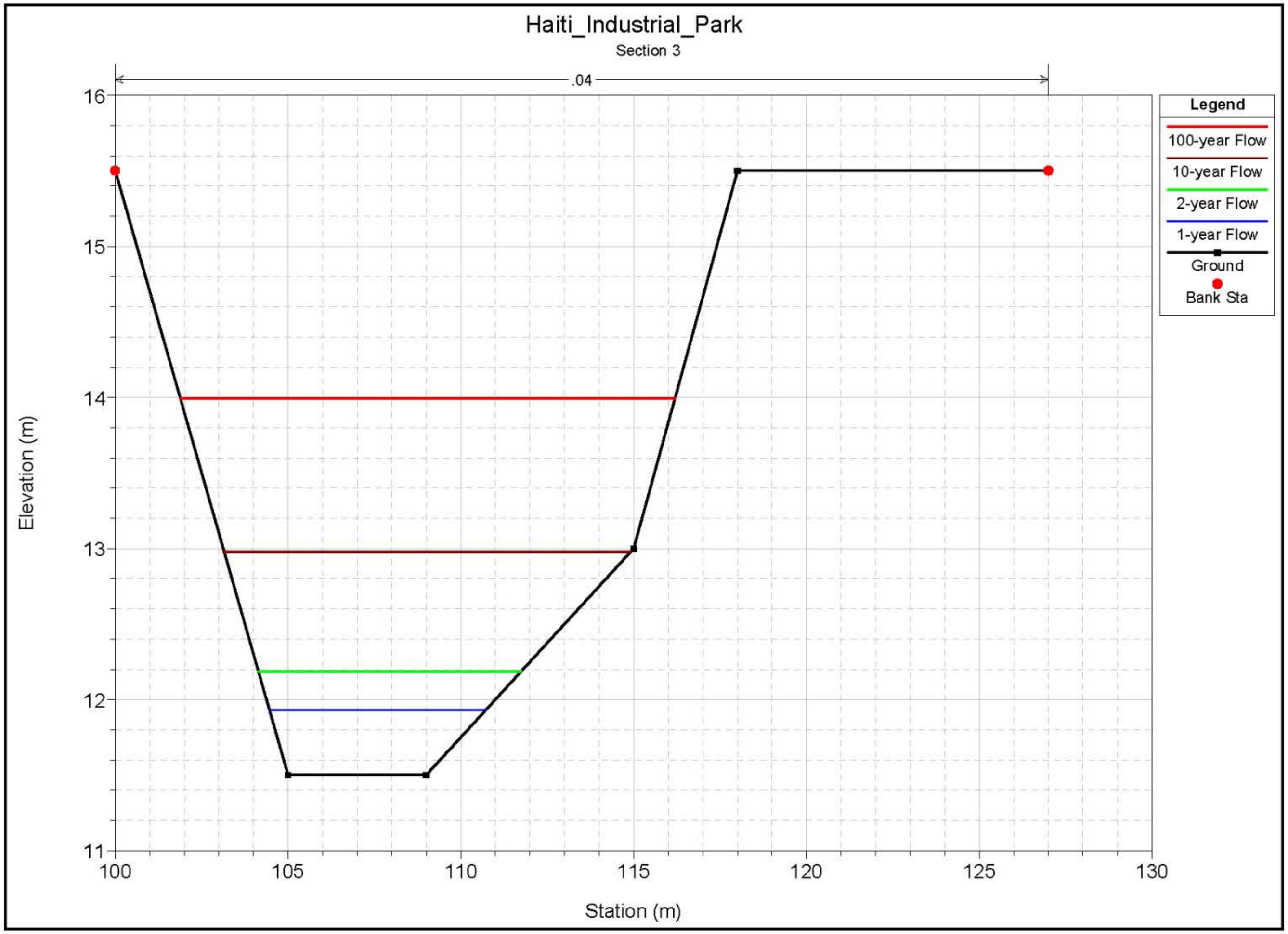
**Table 2 –HEC-RAS flow depths and velocities**

| Flood | Flow (m3/s) | Average Depth (m) | Average Velocity (m/s) |
|---|---|---|---|
| 1-year | 0.5 | 0.23 | 0.49 |
| 2-year | 1.5 | 0.41 | 0.71 |
| 10-year | 10 | 1.17 | 1.10 |
| 100-year | 37 | 2.28 | 1.65 |

During the peak of the 100-year flood, the maximum water surface is at least 1 meter or more below the channel bank, so the flood-water is contained inside the channel. Complete summary table from Hec-RAS model is enclosed in Table 3.


Haiti_Industrial_Park
Upstream Section 1
.1
.04
Legend
100-year Flow
10-year Flow
2-year Flow
1-year Flow
Ground
Bank Sta
Elevation (m)
18
17
16
15
14
13
100
105
110
115
120
125
130
135
140
Station (m)


Haiti_Industrial_Park
Section 2
.04
Legend
100-year Flow
10-year Flow
2-year Flow
1-year Flow
Ground
Bank Sta
Elevation (m)
Station (m)
18
17
16
15
14
13
12
100
102
104
106
108
110
112
114


Haiti_Industrial_Park
Section 3
.04
Legend
100-year Flow
10-year Flow
2-year Flow
1-year Flow
Ground
Bank Sta
Elevation (m)
16
15
14
13
12
11
100
105
110
115
120
125
130
Station (m)

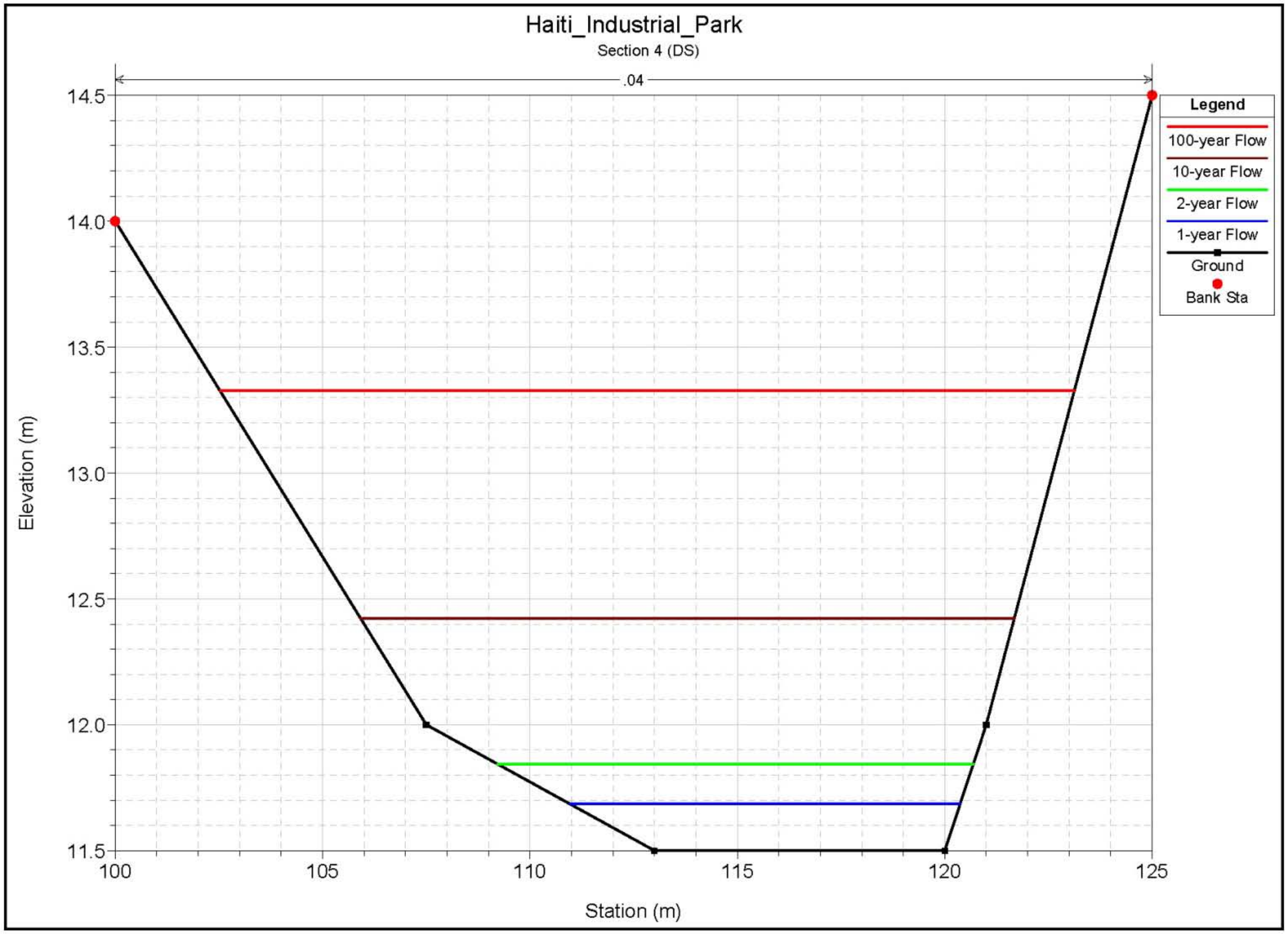

Haiti_Industrial_Park
Section 4 (DS)
.04
Legend
100-year Flow
10-year Flow
2-year Flow
1-year Flow
Ground
Bank Sta
Elevation (m)
14.5
14.0
13.5
13.0
12.5
12.0
11.5
100
105
110
115
120
125
Station (m)

**Table 3–HEC-RAS Summary Table**

| Reach | River Sta | Profile | Q Total (m3/s) | Min Ch El (m) | W.S. Elev (m) | Crit W.S. (m) | E.G. Elev (m) | E.G. Slope (m/m) | Vel Chnl (m/s) | Flow Area (m2) | Top Width (m) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 4 | PF 1 | 0.5 | 13.5 | 13.66 | | 13.67 | 0.00 | 0.23 | 2 | 13.42 |
| 1 | 4 | PF 2 | 1.5 | 13.5 | 13.82 | | 13.83 | 0.00 | 0.35 | 4 | 13.83 |
| 1 | 4 | PF 3 | 10 | 13.5 | 14.55 | | 14.57 | 0.00 | 0.66 | 15 | 15.71 |
| 1 | 4 | PF 4 | 37 | 13.5 | 15.87 | | 15.92 | 0.00 | 0.97 | 38 | 19.13 |
| 1 | 3 | PF 1 | 0.5 | 12.5 | 12.65 | 12.65 | 12.72 | 0.03 | 1.18 | 0 | 3.03 |
| 1 | 3 | PF 2 | 1.5 | 12.5 | 12.8 | 12.8 | 12.94 | 0.03 | 1.64 | 1 | 3.37 |
| 1 | 3 | PF 3 | 10 | 12.5 | 13.73 | | 13.93 | 0.01 | 2.00 | 5 | 5.43 |
| 1 | 3 | PF 4 | 37 | 12.5 | 14.94 | | 15.34 | 0.01 | 2.81 | 13 | 8.11 |
| 1 | 2 | PF 1 | 0.5 | 11.5 | 11.93 | | 11.93 | 0.00 | 0.23 | 2 | 6.26 |
| 1 | 2 | PF 2 | 1.5 | 11.5 | 12.19 | | 12.19 | 0.00 | 0.38 | 4 | 7.6 |
| 1 | 2 | PF 3 | 10 | 11.5 | 12.98 | | 13.02 | 0.00 | 0.86 | 12 | 11.76 |
| 1 | 2 | PF 4 | 37 | 11.5 | 13.99 | | 14.11 | 0.00 | 1.48 | 25 | 14.31 |
| 1 | 1 | PF 1 | 0.5 | 11.5 | 11.68 | 11.58 | 11.69 | 0.00 | 0.33 | 2 | 9.4 |
| 1 | 1 | PF 2 | 1.5 | 11.5 | 11.84 | 11.66 | 11.86 | 0.00 | 0.47 | 3 | 11.47 |
| 1 | 1 | PF 3 | 10 | 11.5 | 12.42 | 12 | 12.46 | 0.00 | 0.89 | 11 | 15.76 |
| 1 | 1 | PF 4 | 37 | 11.5 | 13.33 | 12.54 | 13.42 | 0.00 | 1.33 | 28 | 20.6 |

## APPENDIX 3 – ESTIMATE OF WELL YIELD AND GROUNDWATER DEPLETION

## CLACULATIONS OF WELL YIELD, DRAWDOWN AND GROUNDWATER DEPLETION

Note: The main reference for these calculations is *Groundwater and Wells, by Fletcher Driscoll, 2nd Edition, 1989, published by Johnson Filtration System Inc.*

**Known dimensions (from site):**

| | | | | | |
|---|---|---|---|---|---|
| Diameter of the pumping well (Well PZ2) | 1 | ft | = | 0.3 | m |
| Radius of the pumping well "r" | 0.5 | ft | = | 0.2 | m |
| Distance where the observation well/piez. will monitor drop in water surface "R" | 212 | ft | = | 64.6 | m |
| Saturated Thickness of Aquifer Before Pumping (H) | 67.5 | m | = | 67.5 | m |

**Known Facts from December 2010 Report**

| | | |
|---|---|---|
| Transmisivitty T (min) | 0.0005 | $m^2$/sec |
| Transmisivitty T (max) | 0.002 | $m^2$/sec |
| Storage Coefficient S (min) | 0.0005 | |
| Storage Coefficient S (max) | 0.0067 | |

**Calculations using above values**

| | |
|---|---|
| Hydraulic Conductivity K | = T/aquifer thickness |
| Hydraulic Conductivity K (min) | 7.40741E-06 m/sec |
| Hydraulic Conductivity K (max) | 2.96296E-05 m/sec |

Q=1.366*K*($H^2$-$h^2$)/log(R/r)    eq (1)    *This is the equation of well yield for an unconfined aquifer in International System of Units (equation 9.1 of the reference*

where: Q =pumping extraction ($m^3$/sec)
h = depth of water in the well while pumping (m)

Procedure:
1. Assume h, calculate Q, calculate drawdown s
2. Repeat, assume different times, plot on the log-log scale
3. Calculate Storage S (min, max), repeat until the calculated values match S(min) and S(max) from above

| | K (m/sec) | H (m) | Depth of Water in the Well (assumed) h (m) | Well Radius of Influence (assumed) R (m) | Radius of the well r (m) | Q ($m^3$/sec) - Calculated Flow using well eq. (1) for unconfined aquifer | Drawdown in the well (m) | Maximum possible withdrawal (m) | Percent of the maximum drawdown | Percent of the maximum yield (Fig. 9.11, Groundwater and Wells) | Max. Possible Yield (Theoretical) ($m^3$/sec) | Max. Possible Yield (Theoretical) ($m^3$/day) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Kmin | 7.40741E-06 | 67.5 | 60 | 64.6 | 0.2 | 0.003682713 | 7.5 | 67.5 | 11 | 22 | 0.016739603 | 1446 |
| Kmax | 2.96296E-05 | 67.5 | 60.0 | 64.6 | 0.2 | 0.01473085 | 7.5 | 67.5 | 11.0 | 22.0 | 0.066958411 | 5785 |
| Kmin | 7.40741E-06 | 67.5 | 60 | 100.0 | 0.2 | 0.003434782 | 7.5 | 67.5 | 11 | 22 | 0.015612647 | 1349 |
| Kmax | 2.96296E-05 | 67.5 | 60.0 | 100.0 | 0.2 | 0.013739129 | 7.5 | 67.5 | 11.0 | 22.0 | 0.062450587 | 5396 |
| Kmin | 7.40741E-06 | 67.5 | 60 | 200.0 | 0.2 | 0.003103173 | 7.5 | 67.5 | 11 | 22 | 0.014105332 | 1219 |
| Kmax | 2.96296E-05 | 67.5 | 60.0 | 200.0 | 0.2 | 0.012412692 | 7.5 | 67.5 | 11.0 | 22.0 | 0.056421328 | 4875 |
| Kmin | 7.40741E-06 | 67.5 | 60 | 1000.0 | 0.2 | 0.002534921 | 7.5 | 67.5 | 11 | 22 | 0.01152237 | 996 |
| Kmax | 2.96296E-05 | 67.5 | 60.0 | 1000.0 | 0.2 | 0.010139686 | 7.5 | 67.5 | 11.0 | 22.0 | 0.046089481 | 3982 |
| Kmin | 7.40741E-06 | 67.5 | 63.5 | 1000.0 | 0.2 | 0.001389071 | 4.0 | 67.5 | 6 | 22 | 0.006313958 | 546 |
| Kmax | 2.96296E-05 | 67.5 | 63.5 | 1000.0 | 0.2 | 0.005556283 | 4.0 | 67.5 | 6.0 | 22.0 | 0.025255831 | 2182 |
| Kmin | 7.40741E-06 | 67.5 | 64 | 1000.0 | 0.2 | 0.001220076 | 3.5 | 67.5 | 5 | 22 | 0.0055458 | 479 |
| Kmax | 2.96296E-05 | 67.5 | 64.0 | 1000.0 | 0.2 | 0.004880304 | 3.5 | 67.5 | 5.0 | 22.0 | 0.022183199 | 1917 |
| Kmin | 7.40741E-06 | 67.5 | 64 | 3000.0 | 0.2 | 0.001084513 | 3.5 | 67.5 | 5 | 22 | 0.004929606 | 426 |
| Kmax | 2.96296E-05 | 67.5 | 64.0 | 3000.0 | 0.2 | 0.004338053 | 3.5 | 67.5 | 5.0 | 22.0 | 0.019718425 | 1704 |
| Kmin | 7.40741E-06 | 67.5 | 64.5 | 10000.0 | 0.2 | 0.000831829 | 3.0 | 67.5 | 4 | 22 | 0.003781041 | 327 |
| Kmax | 2.96296E-05 | 67.5 | 64.5 | 10000.0 | 0.2 | 0.003327316 | 3.0 | 67.5 | 4.0 | 22.0 | 0.015124166 | 1307 |
| Kmin | 7.40741E-06 | 67.5 | 66.2 | 1000.0 | 0.2 | 0.000460753 | 1.3 | 67.5 | 2 | 4 | 0.011518816 | 995 |
| Kmax | 2.96296E-05 | 67.5 | 66.2 | 1000.0 | 0.2 | 0.001843011 | 1.3 | 67.5 | 2.0 | 4.0 | 0.046075263 | 3981 |

Continue above calculations to match distance drawdown relationship with T, Q and deltaS

T=0.366*Q/deltas    eq. (2)    *Use Modified non-equilibrium Theis equation in simplified form to calculate T(equation 9.11 of the reference*

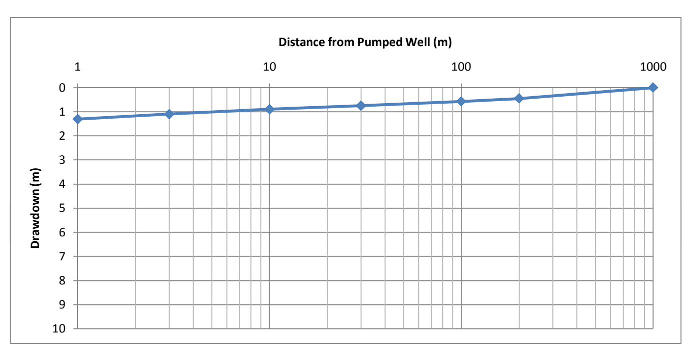
where *deltas* =slope of the distance drawdown graph (below) , expressed as the change in drawdown between any two values of distance on the log scale whose scale is 10.

In the calculations below *deltas* is calculated from Q and T using equation (2), then plotted on the graph below.

| | R=64.6 m | R=200 m | R=1000 m | R=1000m/4m drawd. | R=1000m/3.5m drawdown | R=3000m/3.5m drawd. | R=10000m/3.0m drawd. | R=1,000m/1.3-m drawd. |
|---|---|---|---|---|---|---|---|---|
| deltas (min) = | 2.69574562 | 2.27152268 | 1.855562511 | 1.016799745 | 0.893095577 | 0.793863775 | 0.608898909 | 0.337270923 |
| deltas(max) = | 2.69574562 | | | | | | | |

| Drawdown (m) | Distance from the Pumped Well (m) |
|---|---|
| 1.3 | 1 |
| 1.1 | 3 |
| 0.9 | 10 |
| 0.75 | 30 |
| 0.57 | 100 |
| 0.45 | 200 |
| 0 | 1000 |

deltas= 0.33




Transmissivity and storage coefficients match theoretical when radius of cone is 1,000 m at 1.3 m withdrwal at the center of the well. This results in only 4 percent of well yield or 40 m3/day.
It can be theoretically increased to 1,000 to 3,990 m3/day (if they can use the 100 percent of well yield), according to the maximum yield capacity. This would require pumping from at least 7 wells with maximum pupming in Phase 1, and huge number of wells through Phase 2

**Is Groundwater Depletion Possible?**

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| document | 250,000,000 | m3/year | = | 684,932 | $m^3$/day | | |
| **Impacts** | | | | | | **Water usage (%)** | **Comment** |
| Phase 1 - Pumping for domestic supply: | | | | 3,650 | $m^3$/day | 0.5329 | Impact negligible |
| Phase 2 - Pumping for domestic supply: | | | | 11,407 | $m^3$/day | 1.665422 | Impact negligible |

Important Note: No other information available to estimate groundwater reserve