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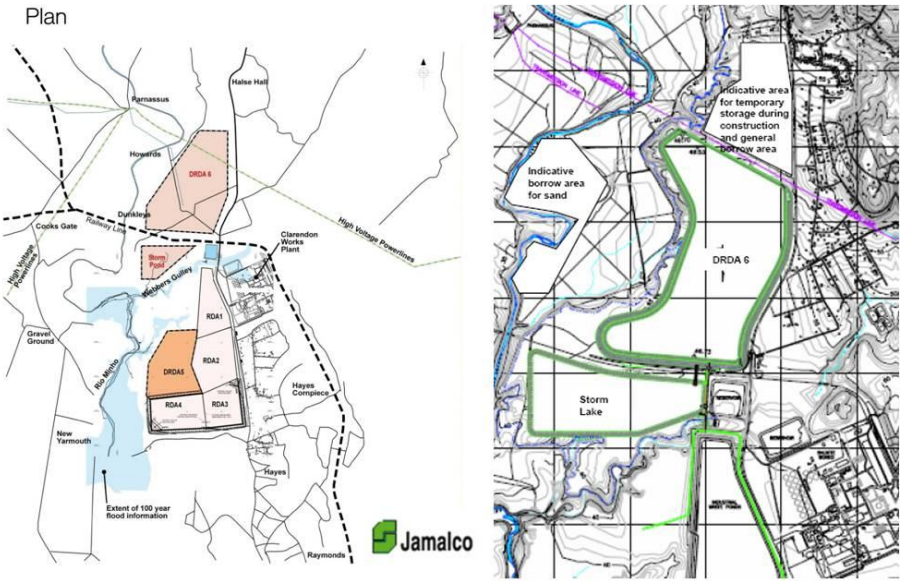
ENVIRONMENTAL IMPACT ASSESSMENT



FOR

PROPOSED CONSTRUCTION OF A NEW DRY RESIDUE DISPOSAL AREA (DRDA 6) BY JAMALCO

For: JAMALCO

Halse Hall
Clarendon

Submitted to: NEPA

10-11 Caledonia Avenue
Kingston 5

April 2007

Document No.: CD*PRJ1042/06

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EXECUTIVE SUMMARY

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1.1 INTRODUCTION:

An Environmental Impact Assessment (EIA) was carried out on behalf of JAMALCO for the establishment of a state of-the-art thickened tailings management Dry Residue Disposal Area #6 (DRDA #6), in proximity to its alumina refinery at Halse Hall, Clarendon. This includes the requisite infrastructure such as storm water lake, roadway, thickened mud distribution and dust suppression systems. The proposed development covers 165 hectares of land.

NEPA's required Project Information Form and Permit Application were filed and the project conducted against NEPA's approved Terms of Reference (TOR), included in appendix.

1.2 APPROACH AND METHODOLOGY:

An integrated approach involving an engineering design team and the assessment specialists was used. This involved a combination of desk and field surveys with the latter covering the bio-physical and socio-cultural environmental baseline and setting.

The regulatory framework was also analyzed in detail and the proposed project matched against it to ensure compliance for the pre-construction, construction and operations phases. For each phase of the project, all the activities to be undertaken were identified as well as their potential impacts on the environment.

For the potential negative impacts identified, the actions necessary to avoid or mitigate them were also developed, from the project design through to operations.

The design took into account analysis of risks and natural hazards.

The parameters for environmental monitoring were also analyzed and included in the assessment report. These include for example, TSP and noise.

1.3 MAJOR FINDINGS:

The major potential impacts for the project are:

- Pollution of groundwater resources
- Fugitive dust formation and dispersion
- Uncontrolled discharge of storm water to the environment which could lead to pollution of various receptors
- Visual intrusion
- Change in land use

The mitigation actions from the design phase are provided below:

1.) The design for DRDA #6 is possibly the most exhaustive carried out for a residue management facility in Jamaica. It comprehensively addresses all aspects of the project.
2.) The facility has been designed with, among other things, a clay liner and a geo-membrane liner as sealants in addition to an under-drain and peripheral run-off water collection system.
3.) A tailings thickener is already in place and operational and a thickened residue distribution system included in the design.
4.) A dust suppression system is an integral part of the design.
5.) A storm water lake is also integrated into the design
6.) The design also addresses mitigation of potential visual intrusion through appropriate slope selection and vegetative cover.
7.) The design takes into account a 100 year return rainfall event and the external toe of the dike wall has been reinforced and backfilled with rocks.

1.4 CONCLUSION

Given the exhaustive state of the art design to be employed, incorporating mitigation actions for potential impacts and a baseline of 37 years of effective and successful management of residue impoundment areas in Jamaica, we can conclude that in the event the project is implemented as designed, it should pose no major adverse impact to the environment which cannot be mitigated.

1.5 RECOMMENDATION

Owing to the integral nature of tailings management operations to the alumina refining process and the mitigation actions proposed, as well as the strict monitoring programme envisioned, we recommend that the project be favourably considered for permitting.

PROJECT DESCRIPTION

2 PROJECT DESCRIPTION

2.1 BACKGROUND

Jamalco currently produces 1.1 tons of residue for every ton of alumina produced and presently has four active residue disposal areas (RDAs) covering 214 hectares and one new dry residue disposal area (DRDA 5) under construction to meet the needs of the existing refinery. RDA 1 was commissioned in 1972, RDA 2 in 1980, RDA 3 in 1990, RDA 4 in 1997 and DRDA 5 is under construction with an anticipated commission date of early 2007. RDAs 1 and 2 are simple clay lined impoundments. The construction of RDAs 3 and 4 included an under drainage system to improve the rate of consolidation of the residue and to reduce the hydrostatic pressure on the clay seal at the base of the deposits. RDA 1 is now being used as a cooling water pond, with 20 hectares of its area converted to a Dry Stacking (Thickened Tailings) Disposal Area. RDA 2 has been filled with wet residue and is currently being used for the Paste Thickener overflow and lake water storage. The embankments of RDAs 3 & 4 were raised in 2003. The resulting expanded area of RDAs 3 and 4 is the active red mud disposal area where all residue produced by the refinery at this time is being discharged as thickened tailings.

Jamalco is a zero discharge facility, in that all water collected from the plant site or the residue system is impounded within the disposal area for reuse in the process. In addition to residue disposal, RDAs 1, 2, 3 and 4 are currently used to store accumulated rainfall runoff during the year.

An increase of 400 tonne/day from the expansion to 2.8M mt/y has been brought forward. This 400 t/d commonly referred to as the JU3 Early Works Program, bringing the Refinery's production rate to 1.533 Mtpa, requires a dry stacking area that includes the areas of RDAs 1, 3/4, 5 and 6. It is important to understand that the refinery cannot operate without proper residue disposal solutions.

The land area being considered for DRDA 6 is owned by Jamalco, uninhabited (therefore no relocation of residents will be necessary) and is located north of the other five disposal areas.

2.2 REGIONAL LOCATION

The proposed DRDA 6 and storm pond will be located north of the existing Residue Disposal Area (RDA) of Jamalco's Clarendon Alumina Refinery on land owned by Jamalco. The RDA is located to the northwest of the Clarendon Refinery with the main arterial road bearing traffic to and from May Pen running between them. The town of May Pen is located approximately 4km to the north of the site and the towns of Hayes and Lionel Town are located to the south. To the west the area is bounded by the Rio Minho River and Webbers Gully. Halse Hall Great House is located to the north-east of the proposed DRDA 6 and storm pond. Figure 2-1 and Figure 2-2 shows the regional location of the project area.

2.3 PROJECT LOCATION

The proposed DRDA 6 is to be located to the north of the existing RDA and railway line and west of the public highway that runs to and from May Pen. The associated storm pond will be located between the existing RDAs and the proposed DRDA 6, just south of the railway line. DRDA 6 will be approximately 165Ha in area (including an area of 50 Ha for future development to the north of the 138 Kv transmission line) and the internal area of the storm pond will be approximately 45 Ha in area, with associated storm water transfer channels and pipes/ buffer zones. Approximately 100 to 300 m (110 to 330 yards) to the west of this area is the Rio Minho River. The design has incorporated buffer zones with regard to potential 100 year flooding of the Rio Minho. In addition to adequate clearances, protection of the DRDA and storm lake perimeter embankments from flooding will be provided.

The area proposed for construction of DRDA 6 is currently screened from view from the road by trees and other vegetation. The construction plan for DRDA 6 calls for the retention of as many screening trees as possible. Future landscaping designs will always consider the aesthetics of the area.

2.4 GENERAL DESCRIPTION OF PROJECT

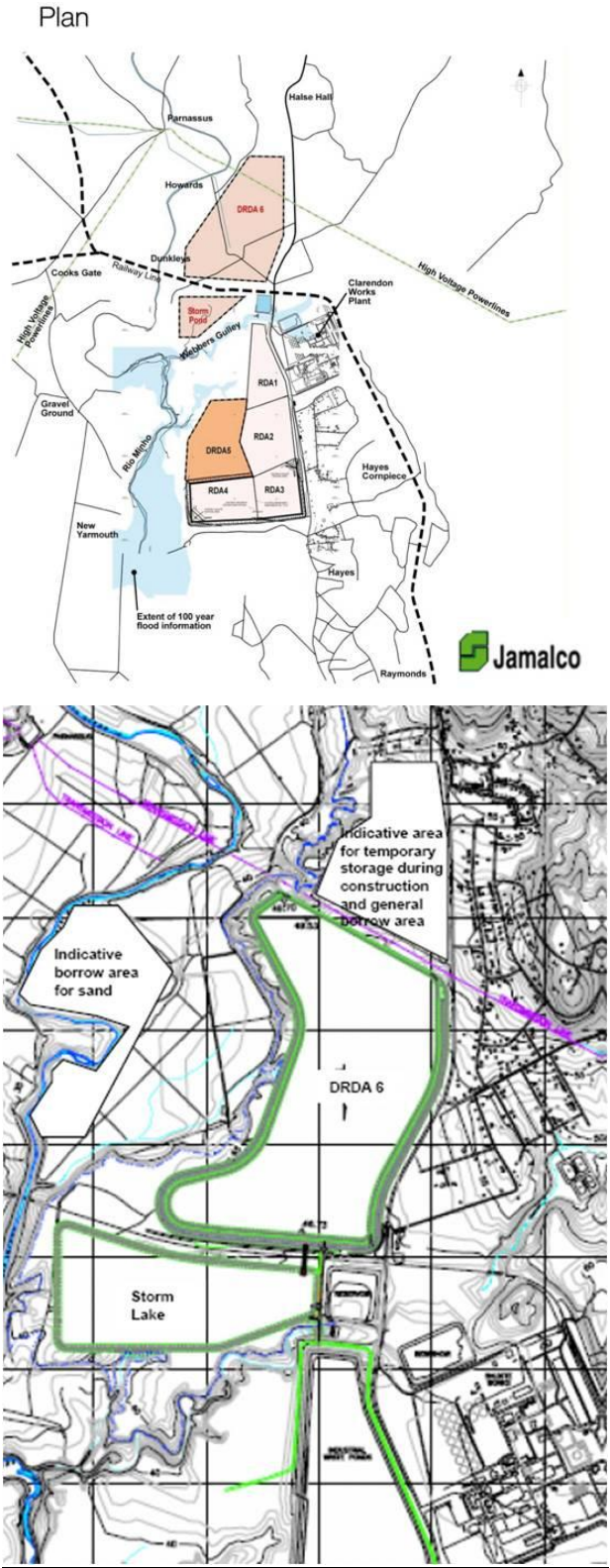

FIGURE 2-1: PROPOSED LOCATION OF DRDA 6

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SEE ATTACHED FIGURE IN PDF FORMAT

FIGURE 2-2: GENERAL LAYOUT

The proposed DRDA 6 project is a necessary development in Jamalco's Residue Management System, as the company prepares to implement Dry Residue Disposal technology. DRDA 6 will provide the additional required drying area to accept bauxite residue from Jamalco's adjacent refinery. Using Thickened Tailings Disposal with Dry Residue Stacking, this facility will provide bauxite residue storage capacity for approximately 20 years at current production levels. A storm water storage pond will also be constructed adjacent to DRDA 6 to receive storm water runoff from DRDA 6 by gravity drainage and maintain it as a dry residue disposal area. Construction of the associated storm pond will ensure on-going compliance with Jamalco's policy of zero discharge.

This project will create a new Dry Bauxite Residue Disposal Area as required by NEPA, of approximately 165 hectares (Ha), to the north of the existing railway line and to the west of the existing public highway that runs through the town of Hayes. Storm water runoff from DRDA 6 will be transferred by gravity drainage via culverts to a storm lake located south of Jamalco's railway line and north of DRDA 5. The proposed location of DRDA 6 and storm lake is shown in Figure 2-1 and an aerial photograph of the site is provided in Figure 2-3.

In Figure 2-1 the area of 50 Ha for future development to the north of the 138 Kv transmission line is described as "indicative area for temporary storage during construction and general borrow area". During the construction of DRDA 6 to the south of the 138 Kv transmission line, the area to the north of the transmission line will be used for: temporary storage of earthwork material that will be used in the permanent construction of DRDA 6; as a potential source of earthwork material for the construction of DRDA 6 and as an area to locate temporary office, yard and laydown facilities.

An extension to DRDA 6 of approximate area 50 Ha will be constructed within three years of commencement of construction of DRDA 6, to the north of the 138 Kv transmission line. The purpose of this extension is to ensure that the Jamalco RDA has the required DRDA surface area to facilitate successful Dry Stacking. This 50 Ha area was included in the ground investigation and resource survey described in section 2.6. Preliminary design of this extension has not yet been undertaken since it is to a large extent dependent on whether the 138 Kv transmission line can be relocated or must remain in place. It is however probable that the general arrangement will be similar to the area to the south of the transmission line. All construction details including height of embankments are expected to be similar to those described in this Project Description. The design and analysis will also be similar

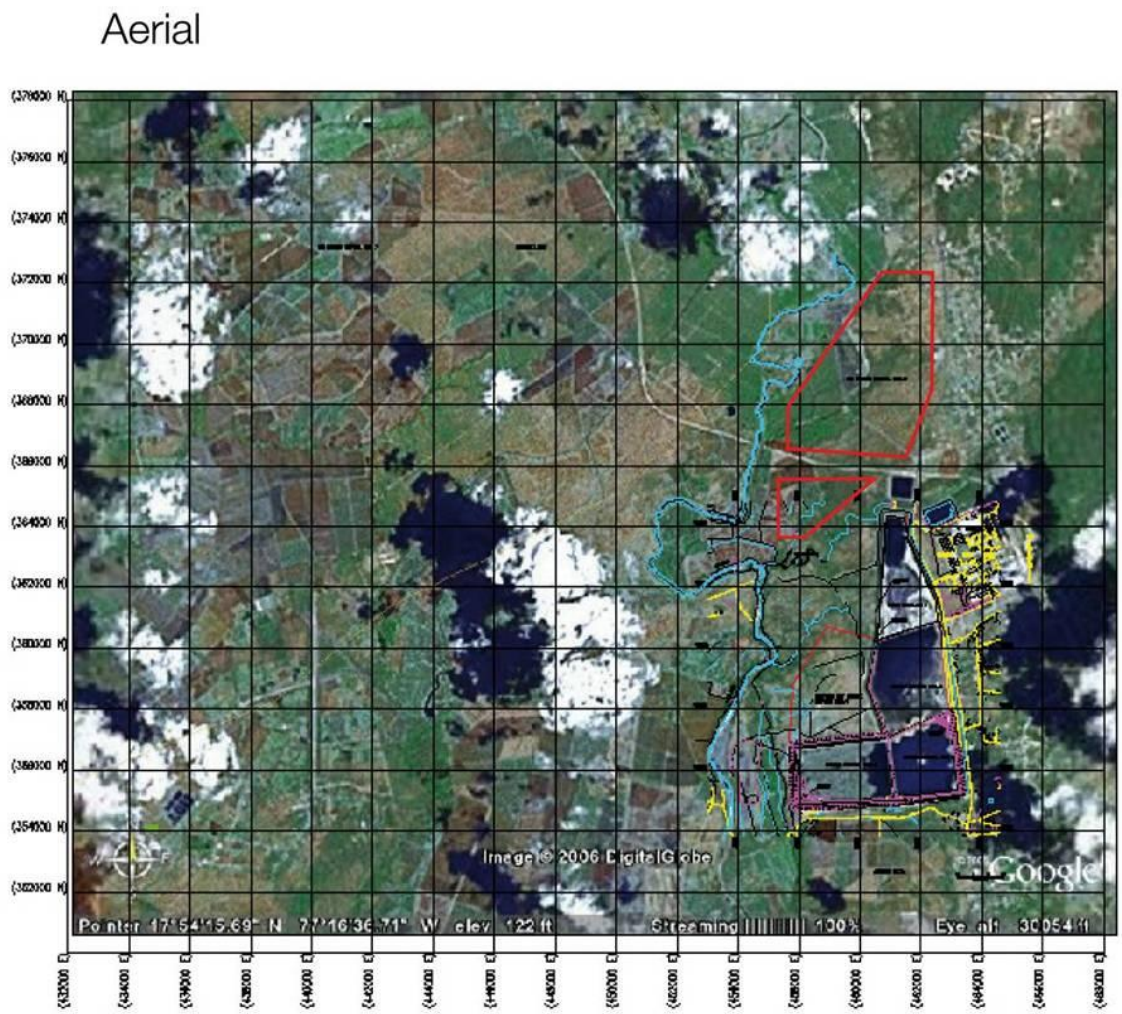

FIGURE 2-3: AERIAL OF PROJECT LOCATION

The new DRDA will be created by constructing a base layer incorporating seal and under drainage over an area of 165 hectares. The facility will be contained within perimeter embankments. Internal drainage ditches on the inside of the perimeter embankments will collect surface water and under-drainage for transfer to the proposed storm water pond. Assessment of Storm water storage volumes is expected to be approximately 1.55 million cubic metres.

An indicative dry stacking arrangement sketch for DRDA 6 is given in Figure 2-4. This shows low level perimeter embankments within which run perimeter drains separated from the dry stacked residue by an internal embankment. Thickened residue is discharged from mud slurry piping that is arranged in a series of central mud droppers.

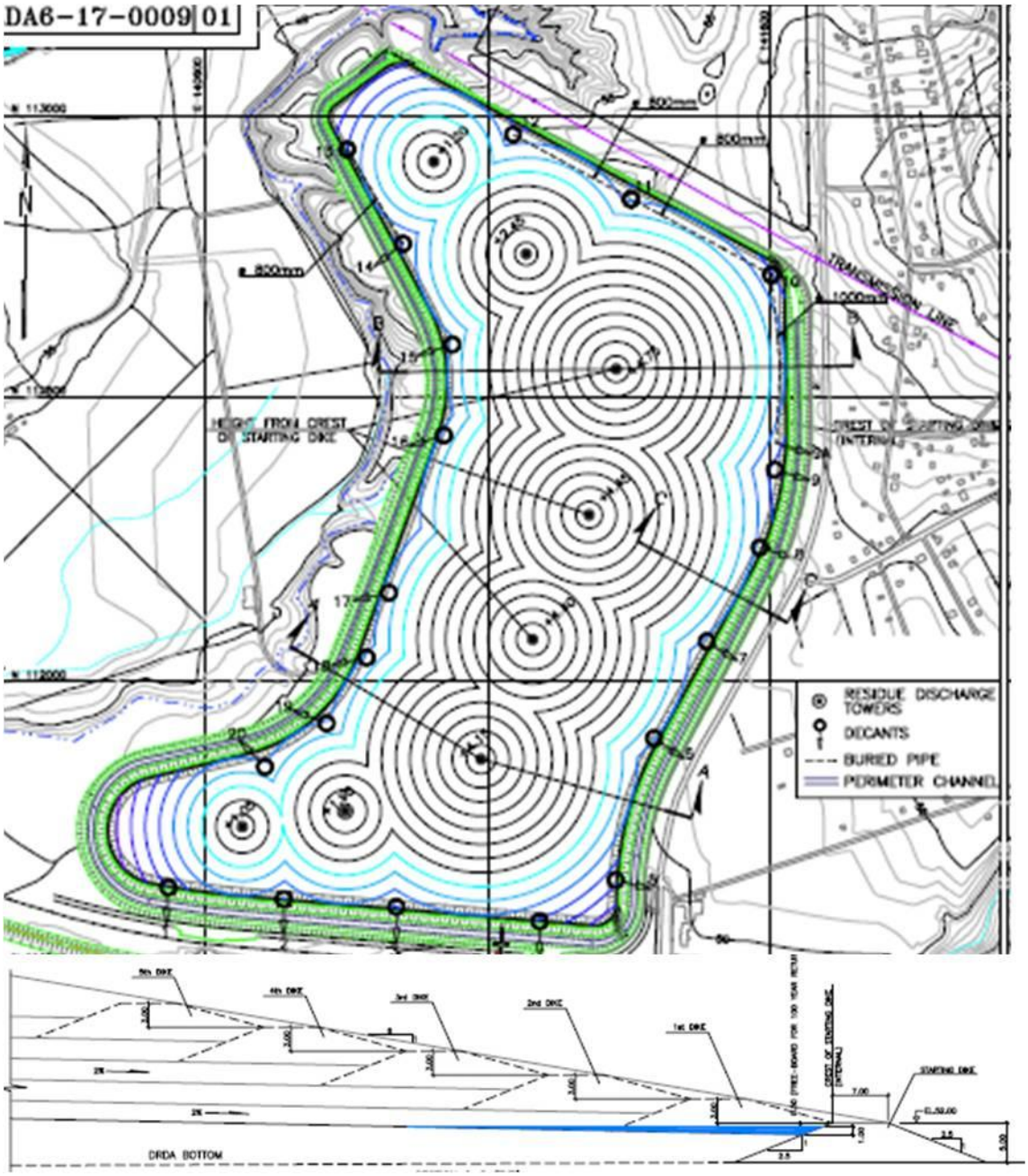

FIGURE 2-4: SCHEMATICS OF DRY STACKING PROCESS PROPOSED FOR DRDA 6

The perimeter construction detail will include an outer dike, a drainage channel (on all sides except the north side), and then an internal dike, which will contain the residue inside the drying area. Step-in dikes inside the internal dike will be progressively built on the residue. At the same time the discharge droppers are raised accordingly.

The detailed scope for the DRDA 6 and storm lake project includes:

- Relocation of 69 kV (and lower) high voltage electricity supply lines.
- Local excavation and filling of a 165 ha drying area base to design profile.
- Installation of geo-membrane liner on top of a clay liner to the base and perimeter embankments.
- Installation of under drainage system with a minimum 500 mm sand layer.
- Construction of perimeter and interior embankments.
- Construction of a perimeter drainage channel and a storm water storage pond.
- Installation of a gravity drainage transfer system for storm water and under-drain system discharge from DRDA 6 to its storm water storage pond. This will include a storm water culvert beneath the Jamalco railway.
- Installation of a pumped system from the DRDA 6 storm lake to the existing Clear Lake.
- Installation of mud distribution piping.
- Installation of dust suppression sprinkler system.
- Dust monitoring station
- Monitoring wells
- Perimeter security fencing

2.5 BASIS OF DESIGN

This project entails the preliminary engineering design and documentation of Dry Residue Disposal Area 6 covering approximately 165 Ha and associated works (Figure 2-5 to Figure 2-9).

The proposed DRDA incorporates the following buffers from existing features in the design:

- Buffers
  - From 100 year flood plain (west) 50m
  - From main road (east) 20m
  - From 138 kV transmission line (north) 30m
  - From Jamalco railway (south) 30m
- As an additional measure of protection, rockfill protection is proposed along the western dike above 100 year flood

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SEE ATTACHED FIGURE IN PDF FORMAT

FIGURE 2-5: DRDA 6 LAYOUT (PLAN)

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SEE ATTACHED FIGURE IN PDF FORMAT

FIGURE 2-6: DRDA 6 (SECTIONS - SHEET 1)

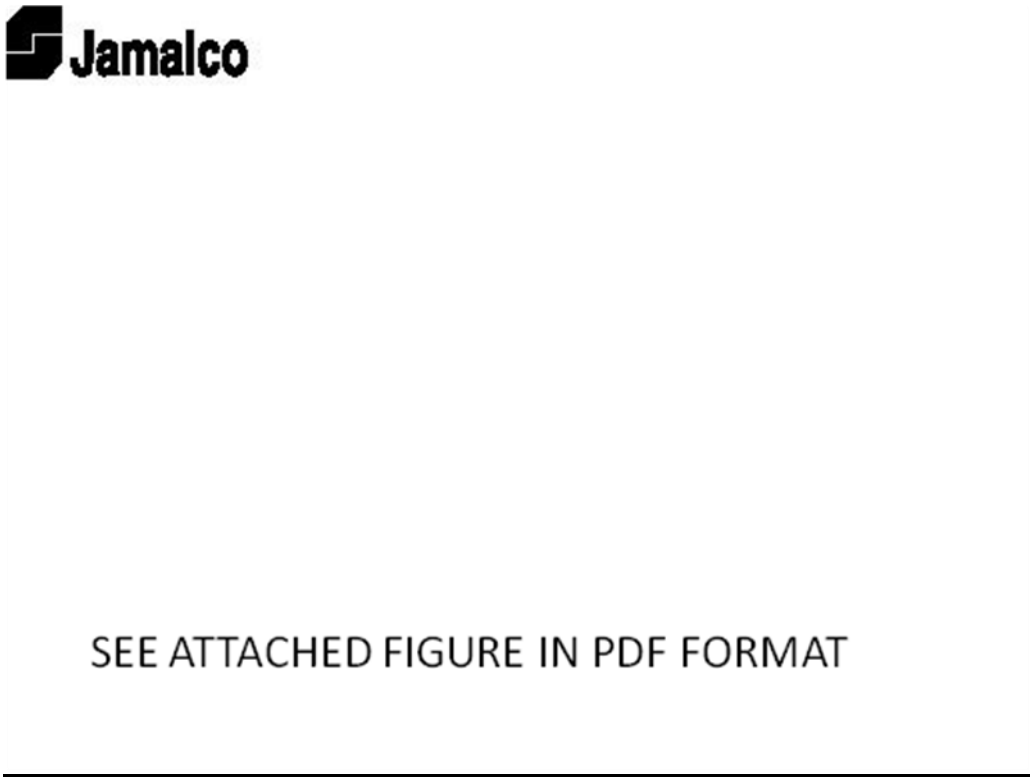

FIGURE 2-7: DRDA 6 (SECTIONS - SHEET 2)

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FIGURE 2-8: STORM POND LAYOUT

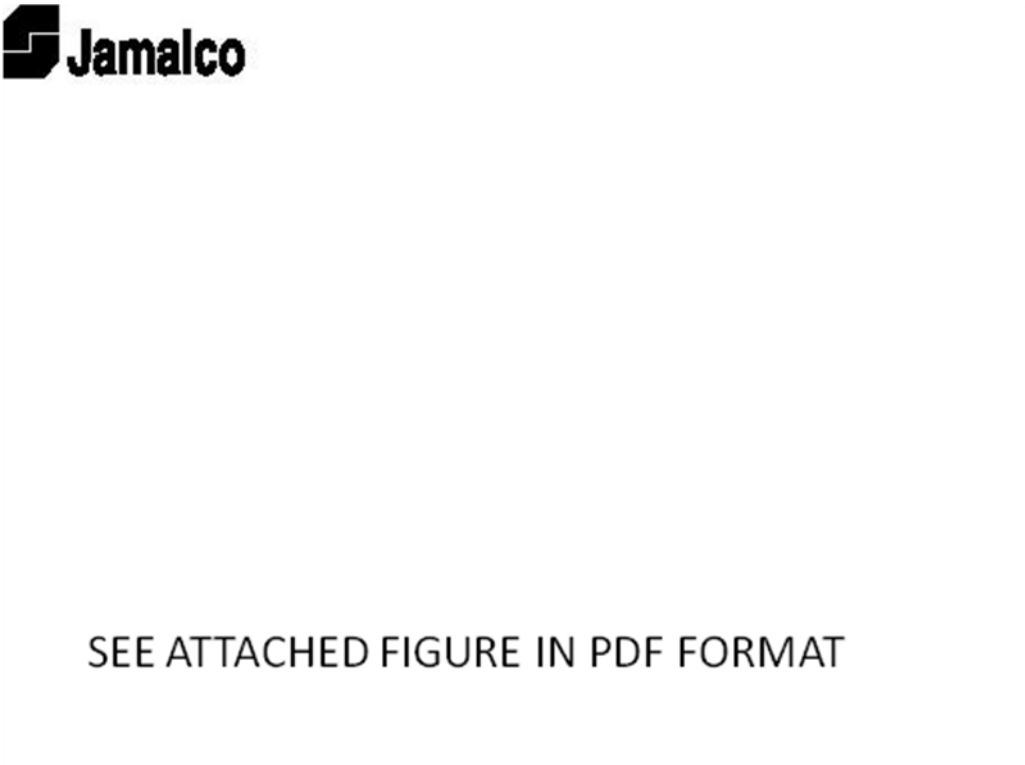

FIGURE 2-9: STORM POND (SECTIONS)

Project Alternatives

Because of the significant cost associated with the construction of a residue disposal area, four scenarios were considered:

- **Scenario 1 (Do Nothing)** – DRDA 5 operates as a wet lake until it is full. The Refinery then must shut down.
  - Assumption - Storm Lakes for the existing RDAs and for DRDA 5 are not built and DRDA 6 is not built.
  - This scenario is in violation of the NEPA requirement of dry stacking of all future RDAs at Jamalco.
- **Scenario 2** – Locate DRDA 6 somewhere other than the current proposed location
  - Jamalco has no other lands available for DRDA development
  - The procurement of lands for storm lakes to the south of the existing RDAs has taken one year and is only now being resolved. The ability to dry stack at DRDA 5 and at DRDA 6 will then be lost if the time frame of purchasing land for an alternate location for DRDA 6 occurred.
  - Any other location would require the mud slurry to be pumped across the Rio Minho, which has its own issues
  - Engineering would have to be redone, further delaying the process
  - Adjacent lands are occupied - in sugar cane production
  - DRDA 6 must be ready for mud in 2008 or the consequences of additional land acquisition requirements noted in Scenarios 4 or 5 would result.
- **Scenario 3** – Implement dry stacking at RDAs 1, 3/4, 5 and proposed DRDA 6 per current plan
  - Assumption - Storm Lakes for the existing RDAs and for DRDA 5 are ready before the hurricane season in 2007

- DRDA 6 must be ready for mud in 2008
- The NEPA requirement to dry stacking is adhered to.

- **Scenario 4** – Convert DRDA5 to wet residue storage.
  - Assumption - Storm Lake for the existing RDAs is ready before the hurricane season in 2007, but the storm lake for DRDA 5 is not.
  - Conversion of RDA 3/4 to dry stacking can continue
  - Maximum time to defer building DRDA 6 would be 12 -16 months with DRDA 5 dike uplift
  - Adds future costs to convert RDA 5 back to dry stacking
  - DRDA 6 size increases by 60 hectare
  - Must buy at least 40 Ha of land
  - Another 40 hectares of drying area needed in 2015 because of shorter life of DRDA 5

- **Scenario 5** – Must convert DRDA 5 to wet lake and increase storage volume of RDA 5 by 01 March 2008 or risk no mud storage capacity
  - Assumption - Storm Lakes for the existing RDAs and for DRDA 5 are delayed until at least 2008
  - Conversion of RDA 3/4 to dry stacking delayed until DRDA 6 built
  - DRDA 6 area requirements increase by 84 Ha
  - Conversion of RDA 5 to dry stacking extends beyond 2011?

2.5.1 KEY QUANTITIES

The quantities of embankment fill, clay, sand, and geomembrane have been preliminarily estimated. For a DRDA and storm pond of this size, the earthworks values will be large and Jamalco will be looking at the latest technology to reduce the volumes of embankment fill, sand and clay required (Table 2-1).

TABLE 2-1: KEY QUANTITIES OF EMBANKMENT FILL, CLAY, SAND, AND GEOMEMBRANE

DRDA 6	
Local soil excavation (incl. organic soil)	**1,600,000m³**
Compacted fill for bottom and dikes	**890,000 m³**
Compacted clay liner	**650,000 m³**
Geomembrane	**1,100,000 m²**
STORM POND	
Local soil excavation (incl. organic soil)	**800,000 m³**
Compacted fill for bottom and dikes	**275,000 m³**
Compacted clay liner	**185,000 m³**
Geomembrane	**500,000 m²**

2.5.2 SYSTEM COMPONENTS

In DRDA 6, a composite liner comprising a compacted clay layer and geomembrane is proposed. Please refer to the sketches in Figure 2-10 below.

DRAINAGE – Jamalco

Herringbone Gallery Pipe

- Residue filtered by an under drain system (sand, geofabric layer and perforated pipe)
- Reduces the hydrostatic pressure on the clay/geomembrane seal system

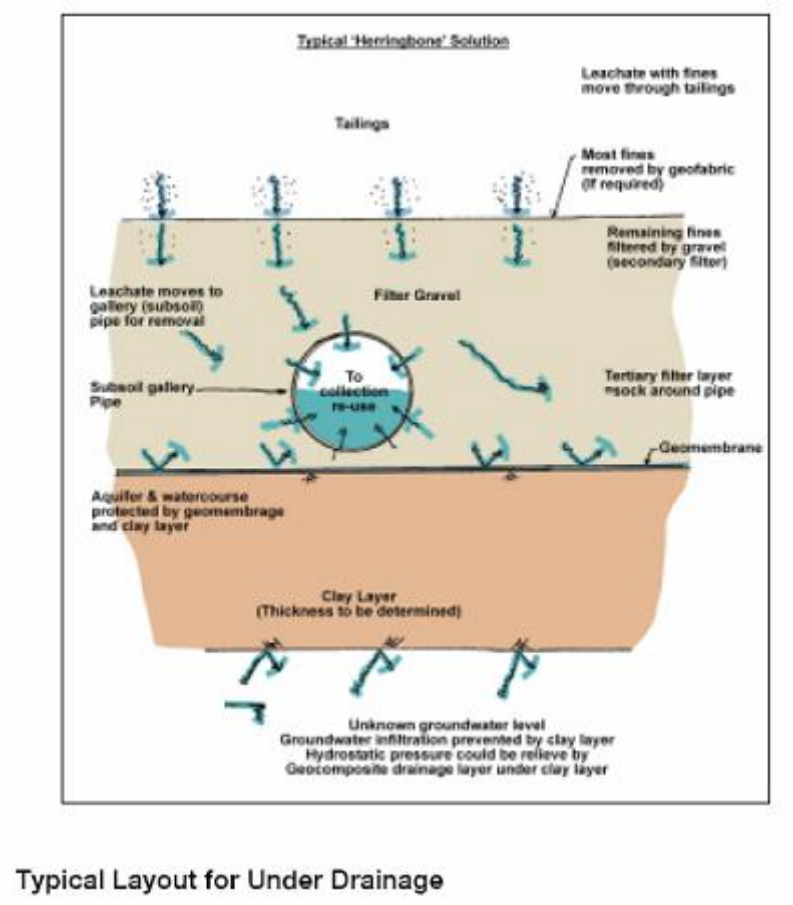

FIGURE 2-10: TYPICAL LAYOUT UNDER DRAINAGE

DRDA 6 will be constructed with a composite liner system comprising a 50 cm thick compacted clay liner with a geomembrane on top of the clay. The geomembrane and clay form the impermeability layer between the DRDA and the environment. On the base, a minimum 500mm thick sand layer will be placed on top of the geomembrane.

A cover of fill will provide the required protection for geomembrane on the internal slopes of DRDA 6 with the following details applied:

- The fill placed immediately over the geomembrane will be a soil fill from the borrow areas;
- The cover will be thick enough to be placed by conventional earthmoving and compaction equipment without damaging the underlying geomembrane liner.

Natural gullies (“protrusions”) exist in the proposed footprints of DRDA 6 and of the Storm Lake. In order to assure the continuity of the natural flow of the water in the protrusions located in the

footprint of DRDA 6, the proposed solution is to allow the drainage of the area by filling them with draining material and HDPE perforated pipes. The pipes, covered with crushed stones, will end in a protection of rock fill, in the toe of the external dike, where there is a transition between the fine material of the fill and the rock fill. The transition material is to prevent the carrying of fine material while the rock fill guarantees the stability and erosion protection of the toe of the dike, in case of a flood greater then 100 years return time. A rockfill protection will also be installed along the toe of the western dike.

In the protrusion located in the storm lake, the proposed solution is to fill the area with compacted soil fill since it only drains superficial rain water, is not perennial, and has eroded as a consequence. In the toe of the external dike, it will have a protection of rockfill with transition layers, similar to DRDA 6, which will guarantee the stability and erosion protection.

2.5.3 BASE DRAINAGE SYSTEM

The liner will be overlain by a layer of sand of a minimum depth of 500mm. Within this layer will be a network of under drain collection pipes, draining to a collection sump or sumps. This detail is illustrated on an indicative section through the basal layers of the DRDA in Figure 2-10.

The design for the under drainage system has been based on perforated, HDPE pipes with a tubular, seamless filter sock. The piping sizes and spacing is designed to handle a maximum flow rate of 2.2 kl/Ha/hr. The base drainage network is a herringbone system with a primary collection main, secondary mains in the range of 150m centres and 100mm lateral perforated mains in the range of 15m centres. The collection main drains to gravity drainage channel.

For the sand drainage layer, a permeability of at least $5x10^{-5}$ m/sec is required to limit water pressure on the impermeability system between lateral perforated pipes. To achieve this, a target permeability of $1x10^{-4}$ m/sec for sand from the borrow area will be applied. In this case, the clay and geomembrane liners extend beneath the embankment, which will be constructed of general fill materials compacted to desired specifications.

The piping arrangement and drainage systems are shown in Figure 2-11 to Figure 2-14 below.

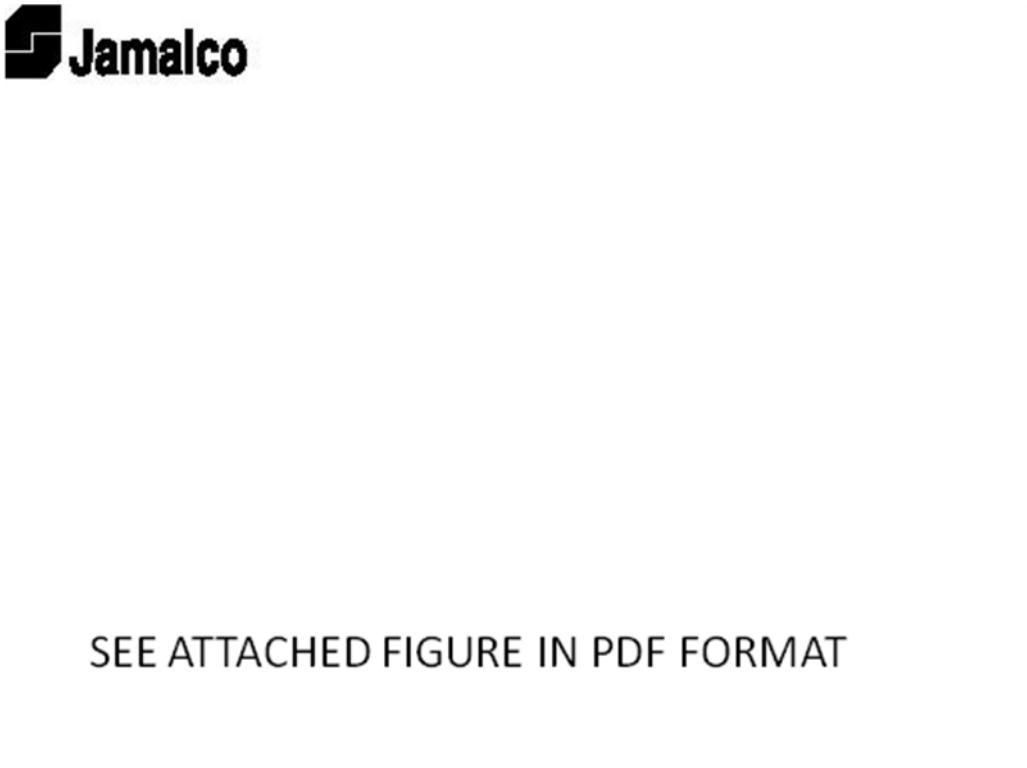

FIGURE 2-11: PIPING GENERAL ARRANGEMENT

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FIGURE 2-12: SURFACE DRAINAGE SYSTEM (PLAN, SECTIONS AND DETAILS)

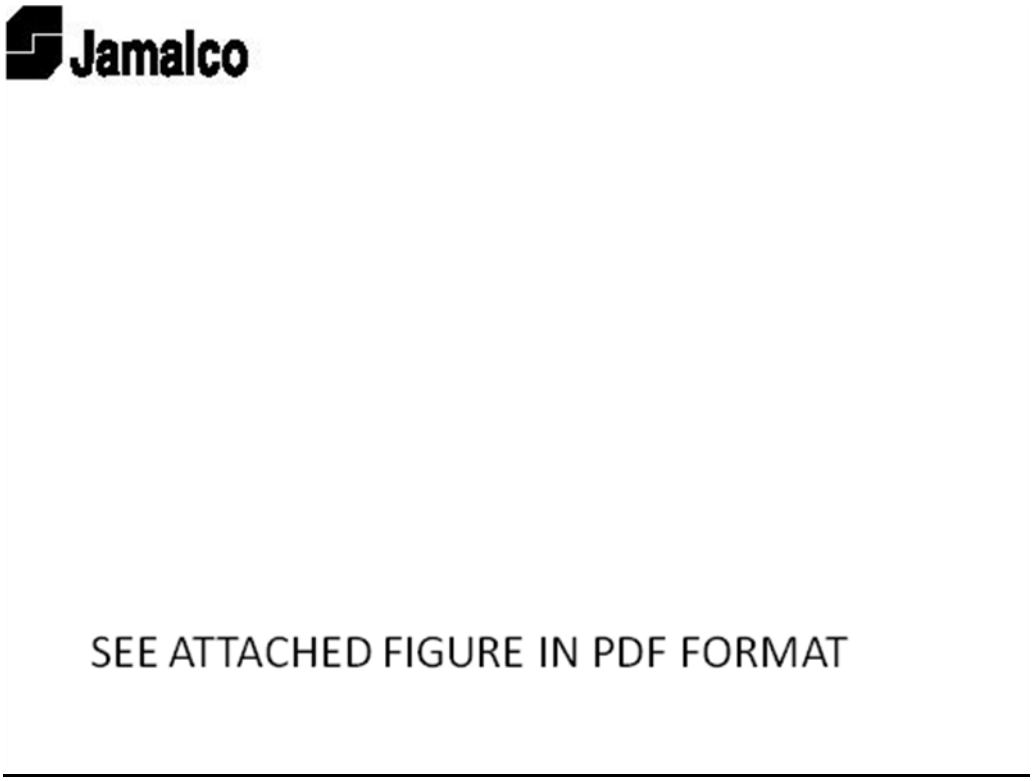

FIGURE 2-13: BOTTOM DRAINAGE SYSTEM (PLAN AND DETAILS)

Jamalco

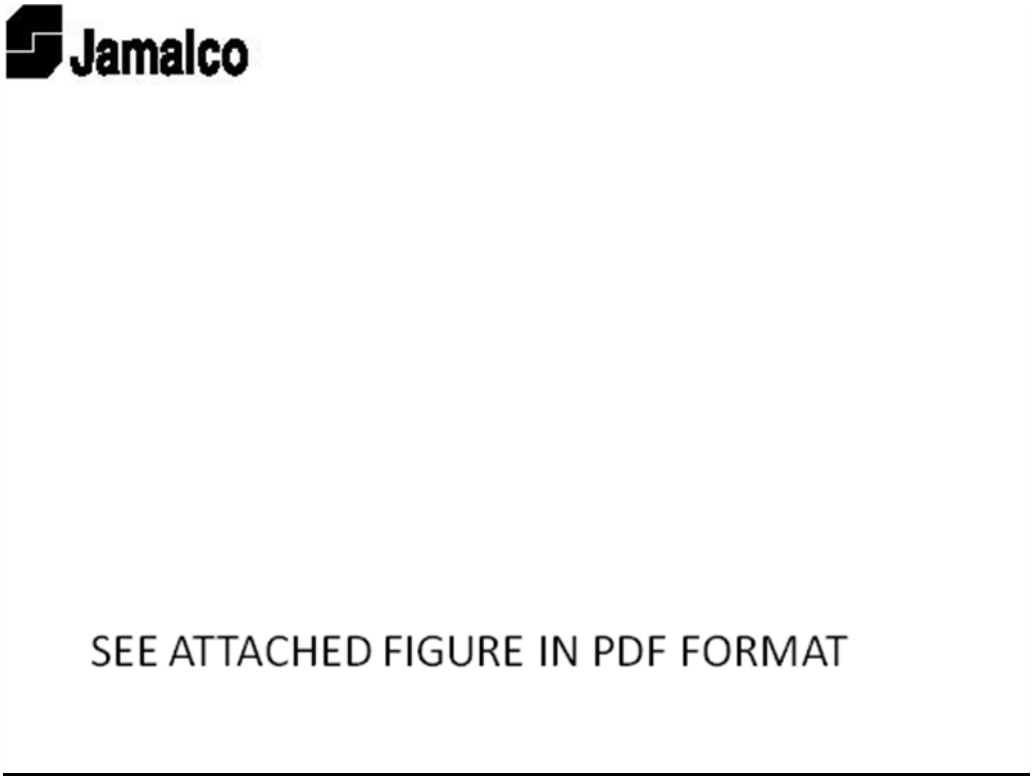

FIGURE 2-14: PERIMETER GRAVITY CHANNEL (WATER TRANSFER STRUCTURE)

2.5.4 EMBANKMENT PROFILE AND MODEL GEOMETRY

The embankments for DRDA 6 will be low profile embankments, not like the embankments required for wet residue storage lakes. The results of a stability assessment are reproduced below, as representative to DRDA 6. A stability analysis for the design profile comprised:

- A compacted initial earthfill dike with upstream/downstream batter side slopes both at 1V:2.5H and a 7 m wide crest Granular and cohesive engineering fills will be used to form the earthworks materials, including the impermeable compacted clay layer.

Step-in earthfill dikes built in the future along the perimeters of the internal dikes

Embankments for the storm pond will also include the clay – geomembrane seals similar to DRDA 6.

2.5.5 DESIGN AND ANALYSIS

1.5.6.1 DESIGN METHOD AND CRITERIA

The internal embankment design was undertaken in accordance with the Minimum Factor of Safety failure criteria summarized below (Table 2-2). These adopted safety factors against slope instability are based on accepted US/UK geotechnical engineering practice. From this analysis, the peak ground accelerations are found to be 0.09g (100-years return period) and 0.21g (500 years return period), corresponding to estimated magnitudes of M 6.5 and M 7.0 respectively.

TABLE 2-2: SUMMARY OF ADOPTED SLOPE STABILITY DESIGN CRITERIA

Design Loading Case	Seismic/Dynamic Condition	Minimum Factor of Safety	
		Downstream Slope	Upstream Slope
Short Term (i.e. End of construction or rainfall events)	Static	1.3	1.3
Long Term (i.e. Operational, full reservoir, design freeboard)	Static	1.5	1.5
Earthquake	Pseudo-dynamic	1.0	1.0

The calculations are performed using the SLIDE 5.0 computer program developed by ROCKSCIENCE Ltd, Canada which employs the two-dimensional limit equilibrium method of slices. The minimum factors of safety for the most critical circular and non-circular slip surfaces are computed by the Spencer method that satisfies both moment and force equilibrium static conditions.

For assessment of the seismic stability, the horizontal and vertical inertial forces created by earthquake ground shaking are defined as:

F = Aw/g = Kw,

Where

a = pseudostatic accelerations
g = gravitational acceleration constant
W = weight of failure mass or interslice
k = seismic coefficient of acceleration

The dynamic loading conditions applied consist of a horizontal inertial force (Fh_h) acting downstream and positive vertical inertial force (Fv_v) acting downwards in the direction of gravity, to reduce the embankment's mass and stability. In addition, the vertical seismic coefficient (kv_v) was taken as 50% of the horizontal seismic coefficient (kh_h).

1.5.6.2 MATERIAL DESIGN PARAMETERS

To reflect the observed variability in the alluvium and the fill materials derived from the alluvium, recognized in the geotechnical investigations, two conditions are analyzed in terms of material parameters. Additional studies will be developed in later stages of the design. Condition 1 models a more clayey "Material Type" in Table 2-3 (the first figure given under the cohesion and friction columns) and Condition 2 models a more sandy material (and is the second figure under the cohesion and friction columns). The ranges of material parameters used in the stability analyses are summarized in Table 2-3. The effective shear strength parameters adopted in Table 2-3 are unfactored.

TABLE 2-3: SUMMARY OF ADOPTED SLOPE STABILITY DESIGN SOIL PARAMETERS

Soil Model	Material Type	Material Property (Scenarios 1 & 2)		
		Bulk Unit Weight, γ (kN/m3)	Effective Cohesion, c' (kN/m2)	Effective Angle of Friction, ϕ' (°)
Embankment Fill	Cohesive (upstream zone only)	20.0	10 & 5	26 & 30
	Granular	18.0	2.5 & 0.0	34 & 38
Embankment Cover Layer (Upstream)	Cohesive	20.0	5	28
	Granular	18.0	0	30
Foundation	Cohesive	20.0	15 & 5	26 & 30
	Granular	18.0	2.5 & 0.0	34 & 40
	Bedrock (impenetrable layer)	N/A	N/A	N/A

1.5.6.3 DESIGN GROUNDWATER CONDITIONS

A design piezometric surface can generally be used in the analysis to represent the regional ground water table in the underlying limestone aquifer.

Furthermore, a typical range of pore water pressure coefficients (r_u values) from 0.0 to 0.2 are applied to model the sensitivity of the design to temporary, short term changes in pore water pressures:

- Within saturated cohesive embankment fill due to construction processes;
- Within near surface embankment fill, as a result of extreme seasonal precipitation effects.

1.5.6.4 DESIGN SEISMIC CONDITIONS

A site-specific probabilistic seismic hazard analysis was performed on site and results are reported in 'Technical Memorandum No. 5' Phase II – Probabilistic Seismic Hazards Study, Dames and Moore, 20 November 2000. From this analysis, the peak ground accelerations are found to be 0.09g (100-years return period) and 0.21g (500 years return period), corresponding to estimated magnitudes of M 6.5 and M 7.0 respectively.

From the seismicity chart presented below in Figure 2-15 below, (from the website of the OAS), it can be seen that the horizontal peak ground acceleration (PGA) at the site, which is just south of May Pen, is 245 gals or 0.25g for a 10% probability of exceedance in 50 years (corresponding to a 475-year return period). The return periods commonly used are 72-year, 475-year, and 975-year periods. These return periods correspond to 50, 10, and 5 percent probability of exceedance for a 50-year period. The 475-year return period (or 10 percent probability of exceedance in 50 years) event is the most common standard used in the industry for assessing seismic risk, and it is also the basis for most building codes for seismic design.

The pseudo dynamic approach can be used to analyze the seismic stability of the embankments. In these limit equilibrium type of analyses, seismic coefficients k_h and k_v are applied to model the effect of the earthquake.

Seismic coefficients used in pseudo dynamic analyses are based on the Peak Ground Acceleration (PGA) corrected to account for the dynamic response of the embankment. Typical values of horizontal seismic coefficients (k_h) adopted in practice vary from 1/3 PGA to ½ PGA (Geotechnical Earthquake Engineering, Prentice-Hall, 1996, Steven Kramer). In the analysis performed here, k_h = ½ PGA is applied. It is furthermore reported that earth dams with pseudo dynamic factors of safety greater than 1.0 using $k_h=0.5a_{max}/g$ would not develop dangerously large deformations (Research by Hynes-Griffin and Franklin, from Kramer).

A comparison between the site specific analysis and the seismicity chart shows that the peak ground acceleration is found to be 0.21g for a 500 year return period and 0.25g (at the site) for a 475 years return period respectively.

For reasons given above, a horizontal pseudo dynamic acceleration of 0.5*0.25g = 0.125g is a conservative and most applicable value for this site.

As per Alcoa standards, a minimum factor of safety of 1.0 is required for a seismic stability analysis.

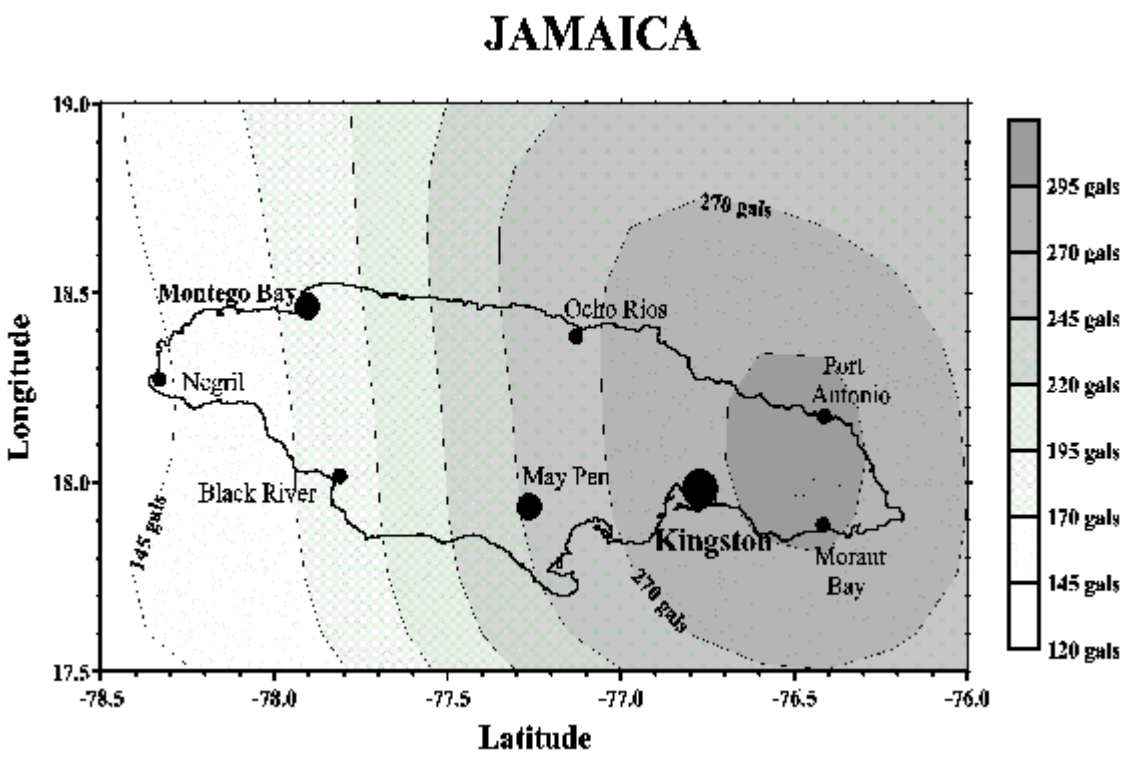

FIGURE 2-15: HORIZONTAL GROUND ACCELERATION WITH A 10% PROBABILITY OF EXCEEDANCE IN 50 YEARS (SHEPHERD ET. AL. 1999). CONTOUR INTERVAL IS 25 GALS (OR 2.5%G). SOURCE: WWW.OAS.ORG

Additionally, sensitivity analyses are performed with horizontal pseudo-static accelerations ranging from between 0.0g and 0.25g to model potential earthquake ground shaking effects (i.e. Horizontal seismic coefficient kh_h = 0.0 to 0.25).

1.5.6.5 OTHER DESIGN CONSIDERATIONS

The following temporary or permanent conditions are considered:

- Live loading, due to the passage of trucks and other equipment along the embankment crests has not been analyzed, as the absolute mass of such equipment is small in comparison to the size of the embankments. The effect on factor of safety would not be significant.

- Settlement and deformation should not affect embankment serviceability performance, as the alluvium was found in the geotechnical investigation to be a competent foundation of low compressibility. Failure surfaces with the minimum safety factors for most of the cases analyzed were not through the foundation but contained within the embankment.
- Interfaces with other earthworks structures and access ramps are considered to have been covered by the design cases assessed in the calculations.

1.5.6 ANALYSIS RESULTS AND CONCLUSIONS

For the design conditions modelled, the DRDA 5 perimeter embankment (under construction), and the similar embankments proposed for DRDA 6 and the storm pond, have satisfactory factors of safety. The safety factors for long term conditions with no significant build up of groundwater pressure are above 1.5. For the short term condition of construction or rainfall induced groundwater pressure in the embankment, the safety factors are above 1.3, with the exception of a slightly lower value under more extreme conditions. The seismic safety factors are above 1.0 for the design horizontal acceleration of 0.125g.

1.5.7 RESIDUE DEPOSITION

Figure 2-16 below shows the dry stacking concept for placing thickened tailings in DRDA 6. Thickened residue will be pumped to the new DRDA from the existing Paste Thickener and deposited to create a dry stack of thickened tailings. These tailings will generally slope from the centre to the perimeter embankments.

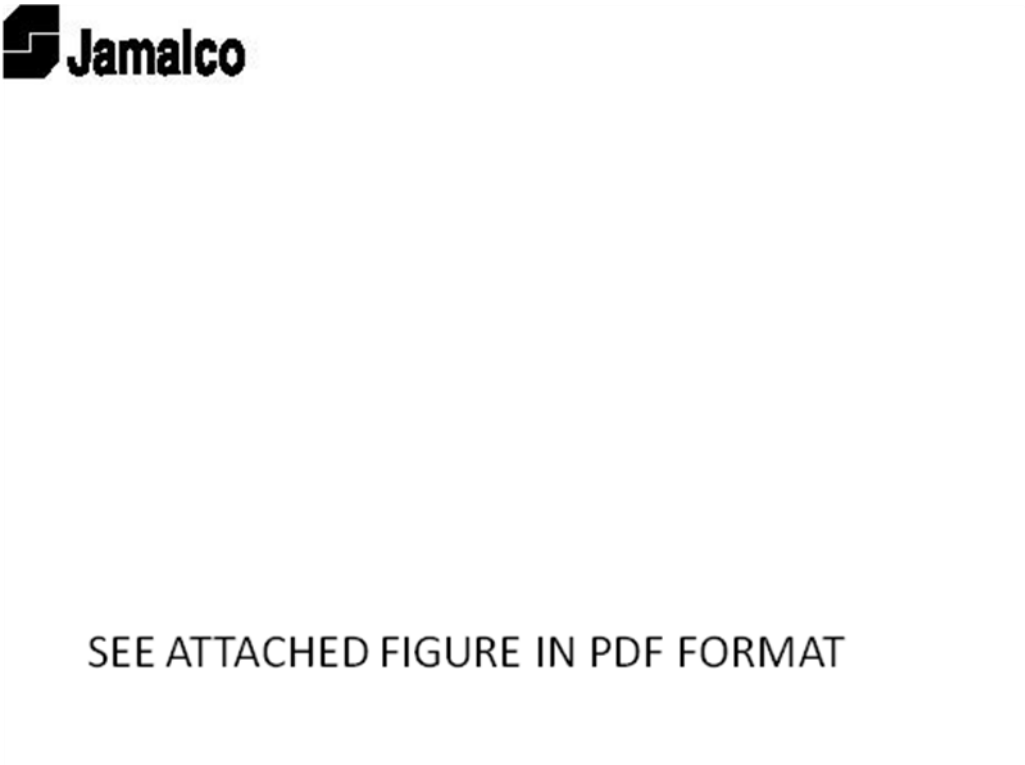

FIGURE 2-16: RESIDUE DISTRIBUTION PLAN

2.6 PRE-CONSTRUCTION INVESTIGATIONS

2.6.1 GROUND INVESTIGATION AND RESOURCE SURVEY

Comprehensive ground investigations and materials resources surveys will be undertaken as explained in the sections below. These studies will provide information for geotechnical design and on quantities and location of suitable embankment fill, clay and sand materials.

At present, the GI surveys indicate a significant amount of clay at approximately 6 m below the ground surface. An evaluation is being conducted to determine whether to mine this clay, locate other sources within Jamalco's property, or purchase clay off-site at a licensed supplier.

2.6.1.1 GROUND INVESTIGATION

2.6.1.1.1 MAPPING THE DEPTH TO THE LIMESTONE SUBCROP

Geophysics / Resistivity imaging methods (by Fugro Engineering Services, UK) will be used to perform this task. The survey will consist of 7 profiles orientated north-south over the survey area, with 13 traverses orientated east-west. These will be spaced at approximately 250 m (750') centres. The analysis of the results will produce a cross-section along each resistivity line, which would highlight the vertical and lateral changes in the subsurface layering. Depth to the Limestone subcrop will be highlighted in the sections as a continuous layer at depth, which would be transferred into a contour map over the survey areas. In order to refine the geophysical interpretation some boreholes will be required over the various survey areas.

2.6.1.1.2 GROUND INVESTIGATION BOREHOLES AND TEST PITS

The main purpose of the ground investigation is to carry out the following activities aimed to facilitate the design and construction of DRDA 6 and associated storm pond:

- Determine the nature, depth and variability of the overburden and limestone strata and the groundwater levels present within the project site. To locate the presence of fissures, cavities and collapse features within the rock formations. The boreholes will complement the resistivity survey information to provide an indication of the ground profile variation over the 165 hectare site.

- Obtain good quality, representative samples of all strata encountered for geotechnical and chemical laboratory testing. Including continuous rock core samples of the limestone stratum.
- Determine the appropriate geotechnical properties of all strata encountered for embankment slope stability analysis, embankment foundation analysis and lining design. Special attention is given to the gullies located at the west boundary of the site.
- Monitor the quality and level of any groundwater regime and the potential for migration of contaminants within the ground.
- Enable the formulation of management strategies for re-development/disposal activities and groundwater discharge.
- Obtain sufficient information to assist in the production of Health and Safety hazard/risk assessments for the construction works and site end use.

The overall scope of the investigation is anticipated to be as follows:

A base plan showing preliminary outline layouts for the proposed DRDA and storm lake as a grid network (eastings A to G and northings 1 to 13) at 250m spacings and the proposed locations of exploratory holes and geophysical survey lines superimposed onto the grid is shown below (Figure 2-17).

Jamalco

SEE ATTACHED FIGURE IN PDF FORMAT

FIGURE 2-17: GEOTECHNICAL INVESTIGATIONS

The Phase 1 investigations will include:

1 A desk study of existing available information and walk over of the site to gain an understanding of the geomorphology and geology of the site and features of interest, and to confirm the suitability and layout of the proposed investigation techniques using the above base plan referenced to national grid co-ordinates. Locating of all exploratory holes and features of interest would be carried out by Kier CCC using hand held GPS equipment converted to national grid co-ordinates.

2 A topographical survey to establish 3D topographical data for the site (i.e. levels and national grid co-ordinates) in AutoCAD format as a base for the detailed design of the works. The fieldwork should be carried out as soon as possible to provide the necessary base data to allow follow on investigations and surveys to commence. It is assumed that setting out of the resistivity survey lines and intermediate survey reference locations will be provided by Kier CCC.

3 An electrical resistivity survey to provide ground profiles of the main soil types. The survey would be carried out over the entire site area along the proposed grid network (i.e., eastings A to G and northings 1 to 13) to give a total survey of approximately 25,250 linear metres. The survey will require topographical survey data to enable completion of accurate resistivity profile plots.

4 The Phase 1 ground investigation will comprise the following:

i) A total of 29 No. rotary drilled boreholes with MWD are required to depths of between 20m to 35m to characterize the site. A total of 14No. of the 29No. boreholes will be required to recover core in limestone, the remaining holes (15No.) will be carried out using open hole drilling techniques with MWD to assess the nature and extent of the weathered profile within the limestone. All boreholes will be carried out using windowless samplers to confirm the composition and variability of the overburden alluvial materials.

ii) A total of 31No. machine excavated trial pits will be carried out to depths of 6m to supplement soil profile data obtained form boreholes and to obtain bulk samples for subsequent earthworks testing.

iii) A program of in-situ and laboratory testing including installation of instrumentation to provide parameters for engineering design.

iv) Sampling from and monitoring of groundwater monitoring instrumentation.

Phase 2 investigations

Depending on the results obtained from the Phase 1 investigations, a Phase 2 investigation is expected to include the following investigation methods:

i) Additional rotary drilled boreholes and machine excavated trial pits to investigate anomalous ground conditions or provide additional infill data where ground variability dictates.

ii) Light cable percussion drilling using the Kier CCC Dando rig to supplement investigation for suitable earthworks materials.

iii) Proof drilling by way of open hole rotary drilling using MWD to investigate areas suspected to contain cavities or voided ground.

Plate 2-1 below outlines the ground investigation exploratory hole location plan for DRDA #6.

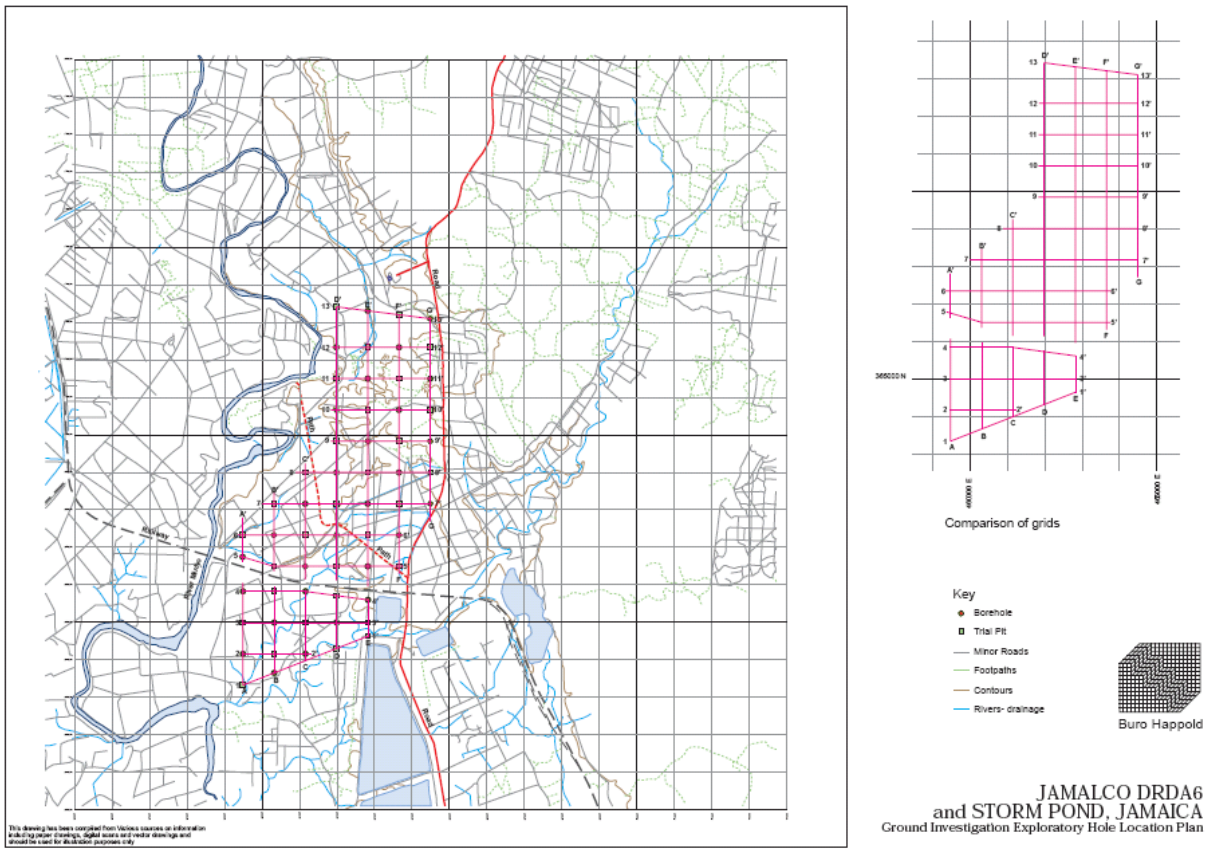

PLATE 2-1: GROUND INVESTIGATION EXPLORATORY HOLE LOCATION PLAN

2.6.1.2 MATERIAL RESOURCE SURVEYS

The site investigation work focuses on the identification of sources of earthworks materials for construction of DRDA 6 and the storm lake at the Clarendon Refinery in Jamaica. For a DRDA of this size, the values will potentially be large and Jamalco will be looking at the latest technology to reduce the volumes of embankment fill, sand and clay.

The main purpose of the ground investigation is to carry out the following activities aiming to facilitate the design and construction of permanent earthworks of DRDA 6 and its associated storm lake and to identify sufficient quantities of the required construction materials:

- Determine the nature, depth and variability of the overburden on the designated areas.
- Obtain undisturbed and disturbed representative samples of all strata encountered for geotechnical and chemical laboratory testing.
- Determine the appropriate geotechnical properties of all strata encountered for embankment slope stability analysis and lining design.

- Obtain sufficient information to assist in the production of Health and Safety hazard/risk assessments for the construction works and site end use.

2.6.1.2.1 TOPOGRAPHICAL AND HYDROLOGICAL SURVEYS AND STUDIES

To establish existing ground levels and impact of flooding events, a topographic survey by a commissioned land surveyor is being arranged.

In view of the proximity of the Rio Minho flood plain, the WRA has conducted a Flood Plain Study the findings of which are discussed in this report.

2.6.1.2.2 GEOTECHNICAL AND CIVIL ENGINEERING

Major components of the design are:

- Embankments;
- Excavation;
- Seal / Liner;
- Under-Drainage System.

Outlet Structures for spillways/pipes (that may breach dikes) will be constructed with good civil engineering practice so no risk of dike failure will result. Risks associated with flooding, hurricanes and earthquakes will be addressed in this design activity. Bearing capacity of underlying strata will be ascertained.

2.6.1.2.3 IDENTIFICATION OF ANY MAJOR RISKS

The following Major design risks were investigated and mitigated are:

- Flooding;
- Groundwater Contamination;
- Dusting.
- Seismic
- Dike failure

2.7 CONSTRUCTION PHASE

The following list provides an indication of the type of construction equipment that will be utilized.

Jamalco DRDA 6 Project **Rev 2**

Plant & Equipment List **PRELIMINARY**

Item	Model (or similar alternative)	Rating	Total
Imported Earthworks			
Motorscraper	Cat 631E	365 kw 21 / 31 yd3	**8**
Dump Truck	Cat D400E ADT	36.5te 22.0 m3 6x6 ADT	**36**
Dozer	Cat D9R	302kw, 48te	**3**
Dozer	Cat D8	212kw, 37te	**1**
Dozer	Cat D6	123kw, 18te	**8**
Water Bowser	Cat D400E ADT	36.5te 22.0 m3 6x6 ADT	**6**
Grader	Cat 16 or 14	205kw, 27.3te, 4.88m blade	**4**
Soil Dozer / Compactor	Cat 815F SP padfoot	164kw	**3**
4WD Tractor + plough	Case MX270	300HP	**4**
Excavator	Cat 365BME	287Kw / 385 HP, 2.3-3.5m3	**3**
Excavator	Cat 345		**2**
Excavator	Cat 330	166 kw, 34t, 1.1-2.1m3	**2**
13t SP Vibratory Roller	Smooth Drum	Smooth Drum	**3**
19t SP Vibratory Roller	Bomag BW219 SP	Smooth Drum with padfoot shells	**5**
Tipper		25 tn	**30**
Water Bowser		3000 gallons	**4**

2.8 OPERATIONS PHASE

Operation of DRDA 6 and associated storm lake will involve the following:

- Residue will be discharged from the Paste Thickener via mud slurry lines to the new DRDA 6.
- Storm water run off will be collected in a ring drain around the perimeter of DRDA 6.
- Water will be transferred by gravity flow from this ring drain to the proposed associated storm lake.
- Water will be pumped from the storm lake to the existing Clear Lake.

2.8.1.1 CONSTRUCTION PHASES

As with all major construction projects, this project will be implemented in phases. Activities proposed for DRDA 6 encompass the following 3 basic phases:

1. Pre-construction
2. Construction, and
3. Operational phases

2.8.1.1.1 PRE-CONSTRUCTION PHASE

Pre-construction will involve the following activities:

a) Demolition and removal of interferences such as structures, building foundations, etc. The area proposed for location of DRDA 6 is relatively flat with no habitable homes or structures. Also included is the relocation of power utility lines.
b) Removal of any boulders that may be in the area and cannot be used in the project.
c) Clearing and grubbing of all vegetation such as trees, brush roots, stumps and bushes within the specified project area. If clay or sand borrow areas are identified within proximity of the site, they will also be cleared.
d) Stripping of approximately 4 to 18 inches of top soil which will be stockpiled and stored for landscaping and revegetation of the external dike walls.
e) Installation of a perimeter security fence along the boundary of the DRDA and its storm lake.
f) Planting of a tree line between the east embankment of DRDA 6 and the highway.

It is requested that prior approval be given for this work to begin immediately to facilitate the construction process.

2.8.1.1.2 CONSTRUCTION PHASE:

Construction activities will involve the following:

a) Excavation and stockpile of materials (clay and sand).
b) Loading, hauling and unloading of excavated material for use in the construction of the ramps and actual dike construction.

c) Excavation of sand and clay from borrow areas located in proximity to the proposed DRDA.
d) Spreading and compaction of materials in the bottom of the lake and dike areas. Spreading of materials will be uniform to ensure that a homogenous thickness is achieved. The materials will be compacted and brought to suitable moisture content levels which will be achieved through aeration or spraying. These activities are necessary to facilitate proper compaction levels.
e) Installation of drainage piping network in the bottom of the DRDA.
f) The outer slopes will be stabilized after compaction with the placement of top soil and hydroseeding. Slopes will be maintained at 2.5:1, so that proper drainage will occur, protecting slopes from erosion caused by water run-off.
g) Installation of residue discharge system, from the thickener to the discharge points along the DRDA.

2.8.1.1.3 OPERATIONAL PHASE:

During this phase, residue slurry from the paste thickener to the stacking areas, allowed to drop onto the existing stack where it will lose additional moisture and stabilize in the DRDA. Collected leachate will flow by gravity to the storm water storage pond.

Regular observation, maintenance and verification of the integrity of the DRDA will be conducted, the same as is done for the other RDAs at the Jamalco facility.

Step-in dikes will be built along the perimeter of DRDA 6 to increase its storage capacity. At the same time the internal discharge points will be raised at higher elevations. The step-in dikes will be built using residue, forming an overall slope of IV:6H.

2.9 SOURCES OF CONSTRUCTION BORROW MATERIAL

2.9.1.1 GENERAL

Suitability of borrow materials will be assessed from ground investigation results during the detailed design. Materials compliance testing will be ongoing during construction, and a suitably qualified geotechnical engineer will be on staff to undertake inspections during the earthworks.

It is anticipated that the soils that make up the general area of the proposed DRDA will be suitable for use as a borrow source for clay, fill material and sand. The area close to the Rio Minho River is actively mined for sand and in the past, a suitable source of high quality clays have been found in the area (as was the case in the construction of the previous RDAs). Because a clay source at a depth of 6 m has been identified within the DRDA footprint, consideration is being given to locating and mining other sources on Jamalco's property or purchasing clay from an off-site source.

2.9.1.2 GENERAL FILL BORROW AREA

It is currently anticipated that the total required fill volumes for the construction of the floor and initial dikes of DRDA 6, aprox.$1{,}3\times10^6$ m³, and the Storm Lake, approx. 0.27×10^6 m³, will be obtained from the excavation within their footprints. The final base excavation level of DRDA 6 will be defined during detailed design so that equilibrium is attained between cut and fill volumes.

The results of site geotechnical investigations have indicated that the available materials are of similar quality as already found successfully in RDAs 3, 4 and DRDA 5.

In case sufficient clay, sand, and general fill materials are not found within the footprint, approval to conduct investigations to the north and west of the footprint are proposed to locate these materials on property currently owned by Jamalco. If successful, approval to mine these resources is also requested in advance of the start of construction activities.

2.9.1.3 CLAY BORROW AREA

Clay required for the impermeable layers of DRDA 6 (approx. $0{,}44\times10^6$ m³) and of the storm Lake (aprox. $0{,}18\times10^6$ m³) will be obtained either from the excavation within the footprint of DRDA 6 or from other areas on Jamalco property. The 45 cm thick compacted clay layer shall have a permeability coefficient of 1×10^{-9} m/s or less.

2.9.1.4 SAND BORROW AREA

The required sand for the base drainage of DRDA 6 (aprox. $0{,}76\times10^6$ m³) will be obtained from the mining areas already being exploited along the Minho River.

The sand shall have a permeability coefficient greater than 5×10^{-5} m/s.

2.10 EQUIPMENT LIST

TABLE 2-4: PLANT AND EQUIPMENT LIST

Jamalco DRDA 6 Project
Plant & Equipment List

Item	Model (or similar alternative)	Rating	No. to be mobilised
Imported Earthworks			
Dump Truck	Cat D400E ADT	36.5te 22.0 m3 6x6 ADT	**36**
Dozer	Cat D6R LGP	123kw, 18te	**3**
Dozer	Cat D6R Regular	123kw, 18te	**3**
Water Bowser	Cat D400E ADT	36.5te 22.0 m3 6x6 ADT	**6**
Grader	Cat 16H	205kw, 27.3te, 4.88m blade	**2**
Soil Dozer / Compactor	Cat 815F SP padfoot	164kw	**3**
4WD Tractor + plough	Case MX270	300HP	**4**
Tyre Service Truck	with Hi-ab crane boom	6x4 Dropside truck , 12.6te	**1**
Fuel Bowser	Bedford 6x4 16m3		**1**
Excavator	Cat 365BME	287Kw / 385 HP, 2.3-3.5m3	**3**
Excavator	Cat 345		**1**
Service Truck		16te GVW 4x4	**1**
13t SP Vibratory Roller	Smooth Drum	Smooth Drum	**2**
19t SP Vibratory Roller	Bomag BW219 SP	Smooth Drum with padfoot shells	**5**
Subtotal			**71**
Local Hire Earthworks			
Motorscraper	Cat 631E	365 kw 21 / 31 yd3	**8**

Jamalco DRDA 6 Project
Plant & Equipment List

Item	Model (or similar alternative)	Rating	No. to be mobilised
Dozer	Cat D9R	302kw, 48te	**3**
Dozer	Cat D8	212kw, 37te	**1**
Dozer	Cat D6R LGP	123kw, 18te	**1**
Dozer	Cat D6R Regular	123kw, 18te	**1**
Grader	Cat 16H	205kw, 27.3te, 4.88m blade	**2**
Excavator	Cat 330	166 kw, 34t, 1.1-2.1m3	**3**
Tipper		6x4 16.5m3 / 25te	**30**
Water Bowser		6x4 16m3	**5**
13t SP Vibratory Roller	Smooth Drum	Smooth Drum	**1**
Subtotal			**55**

2.11 CIVIL AND GEOTECHNICAL ENGINEERING

A high quality geotechnical assessment is required for a project of this type and a wide cross-section of professionals, technologies and techniques were brought together to generate the requisite data and information to verify the capacity of the selected area to house the DRDA and to insure that if constructed to the appropriate factors of safety, it would be unlikely that the DRDA would experience a major failure.

Geophysical investigation methods utilised included boreholes, test pits and Resistivity Imaging. Resistivity imaging was used to map the depth to the Limestone Subcrop and to characterize the materials in that zone.

Resistivity imaging involves spatial profiles spaced at approximately 250 m centres with the objective of producing a cross-section along each resistivity line, highlighting the vertical and lateral changes in the subsurface layering. Depth to the Limestone subcrop is highlighted in the sections as a continuous layer at depth, which is transferred into a contour map over the survey areas.

Resistivity data was collected and found to be of good quality with similar values being observed across all the survey areas. The geological interpretation of the resistivity surveys is based on the four categories of subsurface materials identified (three categories of alluvium and one of limestone). Generally the near surface resistivity values display values that have been attributed to the Rio Minho alluvium identified in the boreholes. Lower than average values are associated with clay-rich or saturated deposits and high values with dry deposits or gravels.

In some surveys a sharp increase in resistivity at depth was displayed which through correlations with boreholes has been identified as underlying weathered limestone of the Newport Formation. The geological interpretations presented have been based on correlation with borehole data, which together with the extensive nature of the site dictates that the ground model presented in the drawings is general.

The results of the geotechnical field investigations to date (geophysical and borehole) indicate that the area is suitable for the installation and operation of the intended DRDA.

The potential for large sinkholes in the reportedly karstic Newport Formation Limestone that is beneath the area is never taken lightly. To adequately assess this possibility, studies have been scheduled to confirm/deny the possibility of there being large sinkholes under the site sufficiently close to the surface to present potential stability problems to the DRDA.

Jamalco and its engineers have reviewed currently available information on sinkholes in the Newport Formation Limestone and have concluded that consideration should be given to the possibility that they may be located in the proposed area as well. It is emphasised that risk from a sinkhole cannot be completely removed; an approach to reduce risk to a level acceptable to Jamalco is summarised below:

1. Survey the whole plan area of the DRDA 6 to look for large (say > 10 m across sinkholes). Review results and proof drill (rotary percussive rock drill) as necessary.
2. Survey of the site area where the limestone is close to the proposed floor level (say within 5 m depth) to look for smaller sinkholes up to about 5 m across. Review results and proof drill as necessary to identify areas suitable for dynamic compaction.
3. Options to consider for remediation of a large sinkhole include drilling and filling the hole with a low mobility grout, and where feasible, modify the designs to avoid the area of the sinkhole.
4. Identified areas of shallow, smaller sinkholes where the limestone is closer to the floor could be treated with dynamic consolidation or other suitable method.

Earthworks

Jamalco has gained a vast amount of experience over recent years in the construction and modification of residue disposal areas at its facility in Clarendon. In terms of earthworks, various compaction tests are ongoing to demonstrate that Standard Proctor may be used as a reference for all materials. Jamalco has come up with a categorization method for the materials used in their earthworks projects since the raising of the dikes on RDAs 3 and 4 and the construction of DRDA 5. For continuity, this same categorization of materials will be adopted for DRDA 6 and is described below:

Type A – Impervious fill with k < 10 x 10-9 m/s (0.1 ft/yr). These soils can be defined under the Unified Soils Classification System (USCS) as CH, CL, MH or ML materials. In other words it has more than 50% passing No.200 sieve.

Type B – General fill needs to have sufficient shear strength to form the embankments and where used to regulate the reservoir base it must be relatively incompressible. This category of material should be readily available within the proposed project area.

Type C – Drainage material. This will have a relatively low coefficient of uniformity. It will be fine gravel and sand, preferably with less than 5% fines, having an adequate permeability coefficient.

Excavation methods will be selected to mix the excavated material vertically and in so doing minimize the requirement for any subsequent blending, sorting or mixing.

It is intended to provide a statistically based requirement for compaction in the specification for earthworks. This will allow a percentage of results below the required average and (similar to concrete testing) will require the plotting of moving averages. Action will be needed if the results show sudden changes or an adverse trend. This method allows much more flexibility in assessing compaction test results than a fixed cut-off value.

The aims of the compaction trial for each material category are:

- Type A - to determine the compactive effort to achieve 98% Standard Proctor Maximum Dry Density (SMDD) at Standard Optimum Moisture (SOMC) to SOMC + 2.5%, and that the resulting material has a permeability less than 10 x10-9 m/s (0.1 ft/yr).Field permeability tests will be done to assess the permeability of Type A materials.
- Type B - to demonstrate that the material can be compacted using reasonable compactive effort to 100 % SMDD at SOMC +/-1.5%.
- Type C - to confirm that this category of material has adequate permeability for a drainage blanket when compacted in field conditions. The compaction target is 70% relative dry density. (ASTM D4254)
- to calibrate the nuclear densometer and hand penetrometer with the materials to be used.

Recent experience and testing done have demonstrated that relatively light equipment is adequate to achieve the required compaction. During the construction works, further trials may be used to demonstrate that heavier plant working on thicker layers can

achieve the same density with greater cost efficiency. It is also intended to demonstrate in the compaction trials that materials can be adequately moisture conditioned in the works. At this stage it is estimated that between 5 and 8% moisture will have to be added.

2.12 DUST SUPPRESSION SYSTEM

2.12.1 GENERAL

Since the potential for dust formation is a consideration of dry residue disposal, a dust suppression system will be installed on the new DRDA 6 to provide adequate dust suppression over the entire plan area. This dust suppression system will use sprinkler technology (Figure 2-18 below).

In general, the system will abstract water from an existing water production well (all necessary licenses and permits will be obtained prior to implementation) via a submersible pump. The circumference of the DRDA will be installed with 16” diameter water supply piping and a grid of 12”, 10”, 8” and 6” diameter piping at various locations along the DRDA to be connected to approximately 300 Nelson Big Gun Type F100T sprinkler heads placed strategically to allow for the best and most reliable coverage of the DRDA.

2.12.2 DUST MONITORING STATIONS

In consultation with the JBI, Jamalco will assess the need for new dust monitoring stations associated with the construction and operation of DRDA 6. This assessment will look at the proximity of major receptors, meteorological considerations and whether or not existing or proposed stations located elsewhere may be suitable for the task. Based on this assessment and its conclusions, Jamalco will supply and install dust monitoring stations if so requested.

Any new dust monitoring stations will be maintained and managed in the same way as the others presently operated by Jamalco, unless otherwise determined in conjunction with the regulatory authorities.

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SEE ATTACHED FIGURE IN PDF FORMAT

FIGURE 2-18: DUST SUPPRESSION SYSTEM

2.13 MONITORING WELLS

New monitoring wells will be installed in the vicinity of DRDA 6 to effectively monitor any potential impact the new DRDA may have on the groundwater resources of the area. All issues related to monitoring wells will be thoroughly discussed and evaluated by Jamalco and the WRA to insure that what is done is suitable not only to the purposes of Jamalco, but also meets the needs of the interested regulatory agencies. A series of wells will be installed to allow monitoring of the groundwater quality, as follows:

- Discussions will be held with NEPA and the JBI to determine exact requirements for groundwater monitoring in this area. In these discussions, it is hoped that consensus can be reached on, number of monitoring wells and location of wells.
- New monitoring wells, positioned based on direction from the WRA. These would extend to a depth of about 120 feet to intercept the upper levels of the limestone aquifer, where any contamination due to failure of the DRDA would first be encountered. The sampling protocol, analysis and reporting of groundwater samples taken from these new monitoring wells will be in keeping with Jamalco's current practices, which meets the requirements of the various regulatory agencies.

2.14 CLOSURE AND REHABILITATION STANDARDS

While it is early in the process, consideration must be given to the final closure and rehabilitation of DRDA 6. Jamalco is currently undertaking developmental work to streamline its long-term rehabilitation plan. When a decision is made for closure of the DRDA, whether due to it reaching its design capacity or otherwise, the basic plan of closure is as follows:

The plan primarily involves three basic activities:

- Dewatering,
- capping and
- re-vegetation

2.14.1 DEWATERING

It is important that once the DRDA is slated for closure, all process lines to the unit will be capped. The DRDA will need to be dewatered; however, a balance must be maintained between dewatering and the excessive drying of the surface of the area, which may result in dust formation.

Dewatering is required to lower the phreatic line in the residue to facilitate draining and to allow an increase in shear strength and bearing capacity of the residue. Regardless of the closure methodology, this is a requisite early step. Since there is an operating base drainage throughout the operation period of the DRDA, drainage is an on-going process to help residue consolidation.

An additional dewatering programme will be initiated after the last bauxite residue is deposited in the area, the extent of which will depend on existing or future water levels in the residue disposal area.

At the outset, the liquor level in the area will be lowered to allow rainfall and liquor generated from consolidation to flow out of the area. If necessary, pumping and other passive dewatering methods could be used to convey accumulated liquor off the lake. By achieving an increased and acceptable level of the solid content at the surface of the residue, more *extensive* dewatering methods will be applied.

Consideration will be given to the construction of a ditch around the perimeter (inner) of the last step-in dike of the DRDA. This will be initiated once the residue has developed sufficient strength to support a ditch without failing. Periodic deepening of the perimeter ditches is critical to the dewatering activities since the residue surface needs to develop the strength to support the ditch geometry.

The deepening of the ditch is dependent on the rate of desiccation which will be accelerated by the use of standard and proven techniques. Once the dewatering activities are sufficiently achieved and the load bearing capacity is developed, the final closure method will be implemented. Two closure methods are being considered for the DRDA:

1. Capping and revegetation

2. Enhancement of the disposed residue and revegetation

2.14.2 CAPPING/GRADING AND RE-VEGETATION

Capping is a suitable method of closure for this type of application if the media being closed is not deemed suitable to support vegetation in its existing state, or the surface is not stable enough to allow for equipment to work. Potential capping materials will constitute adjacent native overburden soils; these will be used to accomplish the following main objectives:

- provide a surcharge stress that will cause additional consolidation of the residue,
- reduce or eliminate potential dust emissions,
- provide a growing medium for the re-vegetation phase,

The capping material will be systematically pushed onto the desiccated, dewatered residue surface. The capping activities will sequentially and progressively proceed towards the centre of the residue area from the embankment; this will allow areas that are moist and unstable to be left un-worked to undergo further desiccation.

Initially a thin layer of capping material will be placed on the residue surface and will be followed by further addition of material to achieve a given target thickness and reclaimed topography.

Once the required thickness and topographic characteristics capable of conveying run-off from the reclaimed-lake are in place, the area will be ready for re-vegetation. Plants capable of preventing wind and soil erosion and adapted to grow and flourish in harsh environments as would exist in the DRDA are proposed for the re-vegetation of the rehabilitated areas. A nursery may have to be established and detailed studies undertaken to develop the right strains of vegetation required.

It should be noted that it may be necessary to install a residue stabilization system to assist the dewatering activities and potential problems due to dust emissions.

2.14.3 JAMALCO RESIDUE MANAGEMENT PLAN

Jamalco has initiated a red mud disposal and management plan spanning the period 1995 to 2020 (25 years). This plan will essentially form the base-line against which future disposal of red mud will be assessed and evaluated, in addition, detail plans and strategies for the closure and rehabilitation of the residue disposal facilities are addressed.

A constant production rate of 1,533,000 tonnes of alumina per annum and a residue to alumina factor of 1.2 tonne/tonne forms the basis of the residue management plan. It is proposed that at the end of the planning period a total of 34 million tonnes of residue will be stored in five residue deposits covering approximately 400 hectares of land (including the existing RDAs). The fundamental principles captured by the residue disposal plan intend to achieve two major objectives, these being:

- To maximize the storage of residue in areas already allocated for this purpose.
- To utilize the best available technology for residue management. This technology should minimize negative environmental impacts, co-exist and comply with tightening governmental regulations while meeting community expectations and Alcoa's residue standards.

The objectives itemized above, formed the basis for the analysis of alternatives considered by Jamalco.

2.15 NATURAL HERITAGE RESOURCES

The Company's activities take a particular interest in preserving existing and potential historical sites within the project area. The operations are guided by and must comply with the Jamaica National Heritage Trust and Alcoa's World Alumina strict Environment, Health and Safety Standards. In addition to any resource already identified, every effort will be made to further identify, locate and document anything that can be considered significant from a cultural or natural heritage perspective. Pre-construction through the operational phases of the project will be managed to avoid or handle appropriately (through direction from the Jamaica National Heritage Trust any such feature that may be encountered.

The potential does exist that items of historical or cultural heritage interest may be located in the proposed project area due to the historical use of the lands and the proximity of the project to the Jamalco Great House, which itself is a heritage item.

Policy, Legislation and Regulations

3 POLICY, LEGISLATION AND REGULATIONS

3.1 POLICY, LEGAL & ADMINISTRATIVE FRAMEWORK

This section provides a background on Alcoa's (Jamalco) Environmental Policy and International & National Policies, Legislation and Regulations applicable to the proposed construction of the new DRDA.

3.1.1 ALCOA'S POLICIES, PRINCIPLES AND GUIDELINES

3.1.1.1 ALCOA'S ENVIRONMENTAL POLICY

The Jamalco facility, under the management of Alcoa, strives to meet or exceed all environmental policies and regulations locally and within its corporate structure. As such, the facility is operated under strict guidance and guidelines to insure compliance at all levels of operation. The following information is derived from the existing Jamalco Environmental Policy Document.

It is Alcoa's policy to operate world-wide in a manner which protects the environment and the health of our employees and of the citizens of the communities where we have an impact.

- ✓ We will comply with all applicable environmental laws, regulations and permits, and will employ more restrictive internal standards where necessary to conform with the above policy.
- ✓ We will anticipate environmental issues and take appropriate actions which may precede laws or regulations.
- ✓ We will work with government and others at all levels to develop responsible and effective environmental laws, regulations and standards.
- ✓ All Alcoans are expected to understand, promote and assist in the implementation of this policy.

3.1.1.2 ALCOA'S ENVIRONMENTAL PRINCIPLES

In support of Alcoa's Environmental Policy, the following principles have been developed to provide additional direction on specific issues. The implementation plan, which follows, provides details on how the Policy and Principles will be carried out.

- ✓ *We will support Sustainable Development*
- ✓ Alcoa will incorporate sustainable development into our operations by integrating environmental considerations into all relevant business decisions. We will achieve cleaner production through programs of waste minimization and pollution prevention with specific and measurable reduction targets.
- ✓ *We will practice responsible use of natural resources*
- ✓ Alcoa will utilize the best available information to plan and execute all projects that involve extraction of raw materials, or which may restrict the use of natural resources or impact ecosystems.
- ✓ *We will utilize techniques accepted as best practices on a worldwide basis for resource extraction, resource use, waste management, and rehabilitation of ecosystems disturbed by our activities.*
- ✓ *We will use energy wisely*
- ✓ Alcoa will strive to maximize efficient energy use, conserving non-renewable resources.
- ✓ *We will practice sound environmental management*
- ✓ Alcoa will integrate environmental management fully with business and operating management to ensure that long-term and short-term environmental issues are considered together with market and economic aspects when decisions are made about new and existing facilities, processes, products, services, acquisitions and divestitures.
- ✓ *We will provide training and information*

- ✓ Alcoa will sponsor training in the environmental area. We will also provide employees, suppliers, customers and neighbours with information needed to understand and help us achieve the goals of our environmental policy.

- ✓ *We will audit our operations and report findings*

- ✓ Alcoa will audit each of its operations on a regular basis to identify strengths and weaknesses of the location's environmental management process and to identify actions that need to be taken to prevent environmental problems or correct environmental deficiencies. Appropriate management, including the Alcoa Board of Directors, will be informed of the audit findings.

- ✓ *We will sponsor activities to improve the science of environmental protection.*

- ✓ Alcoa will sponsor and conduct research and development (including application of emerging technologies) to improve our ability to predict, assess, measure, reduce, and manage environmental impacts of our operations. We are committed to continuous improvement in all aspects of our environmental performance.

- ✓ *We will develop and adhere to high standards.*

- ✓ Alcoa will develop and implement worldwide environmental standards and best practices with emphasis on areas that are unique to our business.

- ✓ *We will report on our activities*

- ✓ Alcoa will communicate promptly and openly with individuals and communities regarding the environmental aspects and impacts of our operations, as well as with concerned parties who request such information. Alcoa will also provide an annual Environmental Health and Safety report that describes our programs, plans and performance. The report will be made available to shareholders and the public.

3.2 LOCAL POLICIES, LEGISLATION AND REGULATIONS

3.2.1 POLICY, LEGISLATION, REGULATIONS & STANDARDS

The following represents descriptions of applicable legislative requirements with which activities of this proposed project must comply:

- Agenda 21
- Natural Resources Conservation Authority (NRCA) Act, 1991
- Wildlife Protection Act, 1945
- Watershed Protection Act, 1963
- Town & Country Planning Act, 1987
- Forestry Act, 1937
- Water Resources Act/Underground Water Control Act, 1959
- Jamaica National Heritage Trust Act, 1985
- Public Health Act, 1985
- Disaster Preparedness & Emergency Management Act, 1993
- National Solid Waste Management Authority Act, 2001
- Occupational Safety & Health Act, 2003 (DRAFT)
- Clarendon Parish Provisional Development Order, 1982

3.2.1.1 AGENDA 21

In June 1992, Jamaica participated in the United Nations Conference for Environment and Development (UNCED) in Rio de Janeiro, Brazil. One of the main outputs of the conference was a plan of global action, titled Agenda 21, which is a “comprehensive blueprint for the global actions to affect the transition to sustainable development” (Maurice Strong). Jamaica is a signatory to this convention. Twenty seven (27) environmental principles were outlined in the Agenda 21 document. Those relevant to this project, which Jamaica is obligated to follow are outlined below:

The United Nations hosted the EARTH SUMMIT '92 and from this conference twenty - seven (27) environmental principles were outlined. Not all of these principles are applicable to the project but those deemed relevant and appropriate are outlined below.

3.2.1.2 NATURAL RESOURCES CONSERVATION AUTHORITY ACT, 1991

The Act is the overriding legislation governing environmental management in the country. It also designates National Parks, Marine Parks, and Protected Areas, and regulates the control of pollution as well as the way land is used in protected areas.

This Act requires among other things, that all new projects or expansion of existing projects which fall within a prescribed description or category must be subjected to an Environmental Impact Assessment (EIA).

The regulations require that eight (8) copies of the EIA Study Report must be submitted to the Authority for review. There is a preliminary review period of ten days to determine whether additional information is needed. After the initial review the process can take up to ninety days for approval. If on review and evaluation of the EIA the required criteria are met, a permit is granted.

Specifically, the relevant section(s) under the Act which addresses the proposed mining activities are:

s.10: (1) Subject to the provisions of this section, the Authority may by notice in writing require an applicant for a permit of the person responsible for undertaking in a prescribed area, any enterprise, construction or development of a prescribed description or category-

(a) to furnish the Authority such documents or information as the Authority thinks fit; or

(b) where it is of the opinion that activities of such enterprise, construction or development are having or are likely to have an adverse effect on the environment, to submit to the Authority in respect of the enterprise, construction or development, an EIA containing such information as may be prescribed, and the applicant or, as the case may be, the person responsible shall comply with the requirement.

s.12: Licenses for the discharge of effluents etc.

s.17: Information on pollution control facility

s.18: Enforcement of Controls – threat to public health or natural resources

s.32-33: Ministerial Orders to protect the environment

s.38: Regulations

3.2.1.3 WILDLIFE PROTECTION ACT, 1945

This act involves the declaration of game sanctuaries and reserves, game wardens, control of fishing in rivers, protection of specified rare or endemic species. The Act also provides for the protection of animals and makes it an offence to harm or kill a species which is protected. It stipulates that, having in one's possession "whole or any part of a protected animal living or dead is illegal.

This Act has to be considered for the proposed project, ecological assessments will determine if rare or endangered species will be impacted.

3.2.1.4 WATERSHED PROTECTION ACT, 1963

This Act governs the activities operating within the island's watersheds, as well as, protects these areas. The watersheds which are designated under this Act include Rio Minho, Cane River and Rio Nuevo watersheds areas.

Determinations will be made to identify any potential impacts that this project may have on the various watershed areas and will propose mitigative actions where impacts are identified.

3.2.1.5 TOWN & COUNTRY PLANNING ACT, 1987

This Act governs the development and use of land. Under this law the Town Planning Department is the agency responsible for the review of any plans involving industrial development. The law allows for specific conditions to be stipulated and imposed on any approved plans. This planning decision is based upon several factors, these include;

- the location of the development
- the nature of the industrial process to be carried out

- the land use and zoning
- the effect of the proposal on amenities, traffic, etc.

This Act is applicable to the proposed plant and port upgrades and mining activities.

3.2.1.6 FORESTRY ACT, 1937

This Act provides for the management and the declaration of Forest Reserves on Crown Lands and regulates activities in Forest Reserves. This Act will be reviewed to determine if the upgrade activities (particularly mining) will impact on Forest Reserves and to what extent.

3.2.1.7 WATER RESOURCES ACT; THE UNDERGROUND WATER CONTROL ACT, 1959

The Underground Water Control Act of 1959 is the legal instrument and is enforced by the Water Resources Authority (WRA). The Water Resources Act is expected to provide for the management, protection, controlled allocation and use of water resources of Jamaica. Thus the water quality control for both surface and ground water are regulated by this Act.

If the proposed facility intends to utilize any existing ground water, permission would be needed, in the form of an issued license for this activity. Under this Act exploratory activities such as the boring/drilling of wells for the purpose of searching for underground water without the written consent would be a violation.

In addition, any activity which negatively influences the quality of existing water, whether ground or surface, would be relevant to this Act.

The proposed project will impact on:

- Ground water resources as it proposes, to increase ground water extraction rates.

3.2.1.8 JAMAICA NATIONAL HERITAGE TRUST ACT, 1985

The Act is administered by the Jamaica National Heritage Trust, formerly the Jamaica National Trust. This Act provides for the protection of important areas, including the numerous monuments, forts, statues, buildings of historic and architectural importance in Jamaica.

In the approved mining area (SEPL 530), several historic sites and buildings have been identified within the general area of this project; these include several churches, schools, Great Houses and natural features of significant importance to our heritage.

During this project, an Archaeological and Heritage Retrieval Plan will be implemented to protect any historical or archaeologically significant item encountered.

3.2.1.9 THE PUBLIC HEALTH ACT (1974)

This Act controls and monitors pollution from point sources. Any breaches of this Act would be sent through the Central Health Committee which takes action through the Ministry of Health, Environmental Control Division (E.C.D.). The ECD has no direct legislative jurisdiction, but works through the Public Heath Act to monitor and control pollution from point sources. Action against any breaches of this Act would be administered by the Central Health Committee. The functions of the department include:

- The monitoring of waste water quality, including regular water quality analysis, using water standards published by NEPA;
- Monitoring of occupational health as it relates to industrial hygiene of potentially hazardous working environments;
- Monitoring of air pollutants through its laboratory facilities.

In addition, there are various sections of this legislative instrument which governs and protects the health of the public. Relevant sections under the Public Health Act of 1985, are Sections 7.- (1) *A Local Board may from time to time, and shall if directed by the Minister to do so, make regulations relating to (o) nuisances* and 14.- (1) *The Minister may make regulations generally for carrying out the provisions and purposes of this Act,*

and in particular, subject to section 7, but without prejudice to the generality of the foregoing, may make regulations in relation to (d) air, soil and water pollution.

Aspects of the project related to odour have been considered since odour is a part of the Air Emissions regulations to be promulgated in 2004.

3.2.1.10 DISASTER PREPAREDNESS AND EMERGENCY MANAGEMENT ACT, 1993

The principal objective of the Act is to advance disaster preparedness and emergency management measures in Jamaica by facilitating and coordinating the development and implementation of integrated disaster management systems. Jamalco has established procedures and guidance documents in place in terms of disaster preparedness and emergency management.

3.2.1.11 NATIONAL SOLID WASTE MANAGEMENT AUTHORITY ACT, 2001

The National Solid Waste Management Authority (NSWMA) under this Act has the responsibility to manage and regulate the solid waste sector. It includes requirements for licences for operators and owners of solid waste disposal facilities (in addition to permit requirements of NEPA).

3.2.1.12 OCCUPATIONAL SAFETY & HEALTH ACT, 2003 (DRAFT)

This Act oversees the prevention of injury and illness resulting from conditions at the workplace, the protection of the safety and health of workers and the promotion of safe and healthy workplaces.

Sampling of sections from the Draft Act that are relevant to this project, include:

4. (1) This Act applies to all branches of economic activity and to all owners, employers and workers in all such branches.

5. (1) The owner of every industrial establishment or mine which carries on business on or after the appointed day shall, subject to subsection (8), apply to the Director in the prescribed form to be registered under this Act.

18. (1) Provides a description of the duties of employers, outlining the need for quality work areas and work environments, procedures and guidelines that will result in safe and healthy workplaces.

19. (1) discusses the duties of employers at construction sites in terms of employee safety and health during work activities.

25. (1) an employer shall make or cause to be made and shall maintain an inventory of all hazardous chemicals and hazardous physical agents that are present in the workplace.

26. (1) this section provides guidelines and procedures for employers to follow in terms of identification of hazardous chemicals. This includes labeling and identification protocols.

30. (1) Basically, this section of the Act requires an employer to provide training of its employees with a potential for exposure to hazardous chemicals or physical agents.

It is expected that this Draft Act will be Gazetted in the near future. As such, it is important that Jamalco have an understanding and appreciation for its contents.

3.2.1.13 Clarendon Parish Provisional Development Order, 1982

This document provides the development plan for the Parish of Clarendon. It clarifies the role and responsibility of the local planning authority and provides guidance on how development of the parish should proceed. All activities in this proposed upgrade of the Jamalco operations that requires local planning authority approval will be properly identified and the appropriate permits and licenses will be secured.

Special note: The Jamaica Bauxite Institute (JBI) is the regulatory agency monitoring the bauxite industry, and as such their policies will extend to any development on bauxite owned lands.

3.2.2 SUMMARY OF THE LEGISLATION AND RESPONSIBLE AGENCIES

TABLE 3-1: NATIONAL LEGISLATION AND RESPONSIBLE AGENCIES

LEGISLATION	INSTITUTION RESPONSIBLE
NRCA Act, 1991	Natural Resources Conservation Authority
Wildlife Protection Act, 1945	Natural Resources Conservation Authority
Watershed Protection Act, 1963	Natural Resources Conservation
Town & Country Planning Act, 1987	Town Planning Department
Forestry Act, 1937	Forestry Department
The Water Resources Act/UWC Act, 1959	Water Resources Authority
Jamaica National Heritage Trust Act, 1985	Jamaica National Heritage Trust
Public Health Act, 1985	Ministry of Health/Environmental Control Division
Disaster Preparation & Emergency Management Act, 1993	Office of Disaster Preparedness and Emergency Management
National Solid Waste Management Authority Act, 2001	National Solid Waste Management Authority
Clarendon Parish Provisional Development Order, 1982	Town Planning Department

DESCRIPTION OF THE ENVIRONMENT

4 DESCRIPTION OF THE ENVIRONMENT

Information for this section has been compiled from field observations and ground-truthing to verify the accuracy of information sourced from reports including:

1. EIA for Step-in-Dyke RDA#1 (CD&A – 2005),
2. EIA for 2.8 Million Metric Tonne Per Year Efficiency Upgrade at JAMALCO – (CD&A - 2004),
3. Biosurvey of Jamalco's Special Mining Lease Area in Southern Manchester – (BEG's LTD. – 2000),
4. Floral and Faunal Survey of Jamalco Special Mining Lease Areas and Environs of the Refinery and Port Facilities (BEG's LTD. - 2005), and
5. Report on Webbers Gully Floodplain Mapping for Alcoa Train Line – Rio Minho River – (2005).

4.1 LAND USE AND GEOLOGY

4.1.1 LAND USE

Jamalco's current RDAs are sited on lands formally occupied by sugarcane cultivation which were divested by Monymusk Sugar Factory.

The Bowens community which previously occupied lands located on the western side of RDA 1 and 2 was relocated to what is now called New Bowens. The relocation was to facilitate expansion of Jamalco's residue disposal storage capacity. No structured residential community is known to have existed in the proposed project area.

The general area houses Jamalco's residue disposal network which includes RDAs 1-4 with DRDA 5 under construction to meet the short-term needs of the refinery. No residences are located between the existing RDAs (to the south) and the proposed DRDA 6 located to the north west of the refinery.

Two residential communities are located within one half mile of the RDA's, New Bowens to the Northeast and Cornpiece to the Southeast.

4.1.1.1 HISTORICAL

4.1.1.1.1 CLARENDON

4.1.1.1.1.1 Topography

The topography of Clarendon is characterised by the diverse nature of the coastal fringe and offshore islands and cays. The national and marine park and protected area of the Brazilletto Mountains, Portland Ridge, Peake Bay, Portland Bight and the plains in the Southern areas with elevations from 0-150 meters, the Mocho Mountains at elevations of 150-300 meters, extending to the limestone uplands in the north around main ridges, and the Bull Head Mountain.

4.1.1.1.1.2 Area and Land Cover

Clarendon contains an area of 1142.8 km^2.

Land cover in Clarendon is characterised by a scattering of villages and major urban centres, vast areas of sugar cane, wetlands, dry forests, scrub, industrial estates, aquaculture, mixed cultivation including bananas, citrus, subsistence crops by small farmers which includes yams, peas, sweet potatoes, etc.; the decline of the sugar industry has left large areas abandoned and taken over by scrub vegetation. Uncultivated areas due to salinity include much of the coastal side of the plains. Tidal flats are largely inaccessible. There are also the dry forests of the Brazilletto Mountains and the Portland Ridge, where Taino petroglyphs and some Taino burial caves are to be found.

4.1.1.1.1.3 Industrial Development Plan

Light industrial land use is confined to the rural/urban settlements and linear occupancy along district, sub-arterial and arterial roads. Heavy and special industrial plants include bauxite processing plant at Halse Hall (Jamalco), sugarcane processing at Moneymusk and New Yarmouth.

Transportation and access routes including all classes of roads and railway lines link all urban centres and also penetrate agricultural areas, national parks and conservation areas.

TABLE 4-1: URBAN SETTLEMENT DEVELOPMENT

CLARENDON – HEIRARCY OF GROWTH CENTRES		
District Centres	**Sub-Regional Centres**	**Regional Centres**
James Hill	Lionel Town	May Pen
Kellits	Chapelton	
Hayes	Spaldings	
Chapelton		
Kemps Hill		
Osbourne Store		
Mocho		
Rock River		
Frankfield		
Alston		

4.1.1.1.1.4 Parish Council/Land Use Zoning

The parish of Clarendon is covered by Development Orders and subsequently falls under the aegis of the Town and Country Planning Act. Thus any form of development requires an application to the relevant Local Planning Authority (Parish Council) for permission to carry out building, engineering and mining operations or change in the use of land or buildings.

There are no specific demarcated zones for land use, but there are general statements of intended uses, supporting requirements and standards. This project does not present a change in land use for the site specified.

4.1.1.1.1.5 Aesthetics

There are several areas of outstanding natural beauty, visual and recreational amenity, and therapy. There are also areas which are felt to be aesthetically appealing and spiritually inspiring. The view from the Brazilletto Mountains over the protected Peake Bay and West Harbour wetlands and the sea is outstanding. The Milk River Bath is world renown for its therapeutic quality, and the Canoe Valley-Portland Bight wetlands supports considerable marine life and is itself outstandingly beautiful.

A wide variety of micro climates exits in the parish, ranging from cool climatic conditions in northern Clarendon near the Manchester border, to high temperatures on the Clarendon plains (location of proposed RDA) and dry limestone forests in the Portland Bight and Brazilletto Mountains.

It is not assumed that the proposed RDA will contribute negatively to aesthetics of the area since the location is behind the existing RDAs and away from the natural lines of sight of the majority of residential communities in the area.

4.2 GEOLOGY

The area under consideration is in the district of Halse Hall, in southern Clarendon. It can be located generally on the 1:50,000 topographic Sheet 17 (metric edition) at co-ordinates 245385 (Figure 4-1: Geology Map of Southern Clarendon). Geomorphologically, the area lies on the gently sloping alluvial fan of the Rio Minho. The apex of the fan, at May Pen, lies at an altitude of about 70 m above sea level (asl), although the present river bed is incised into the fan, being at about 50 m asl at May Pen. From May Pen the river flows over a straight line distance of about 20 km to the sea. In the vicinity of Hayes, at the confluence with Webbers Gully, the river bed lies at an altitude of 38 m asl, while the plant and RDAs at Hayes, east of the river, lie on an old, dissected terrace remnant at elevations of 45 to 50 m asl with flat to gently undulating topography. The terrace remnant forms a high spot between Webbers Gully, which borders the site on the north and northwest before entering the Rio Minho, and Cannons Gully which extends along the eastern side of the site, draining to the south at Bog and separating the site from the limestone plateau of Harris Savannah.

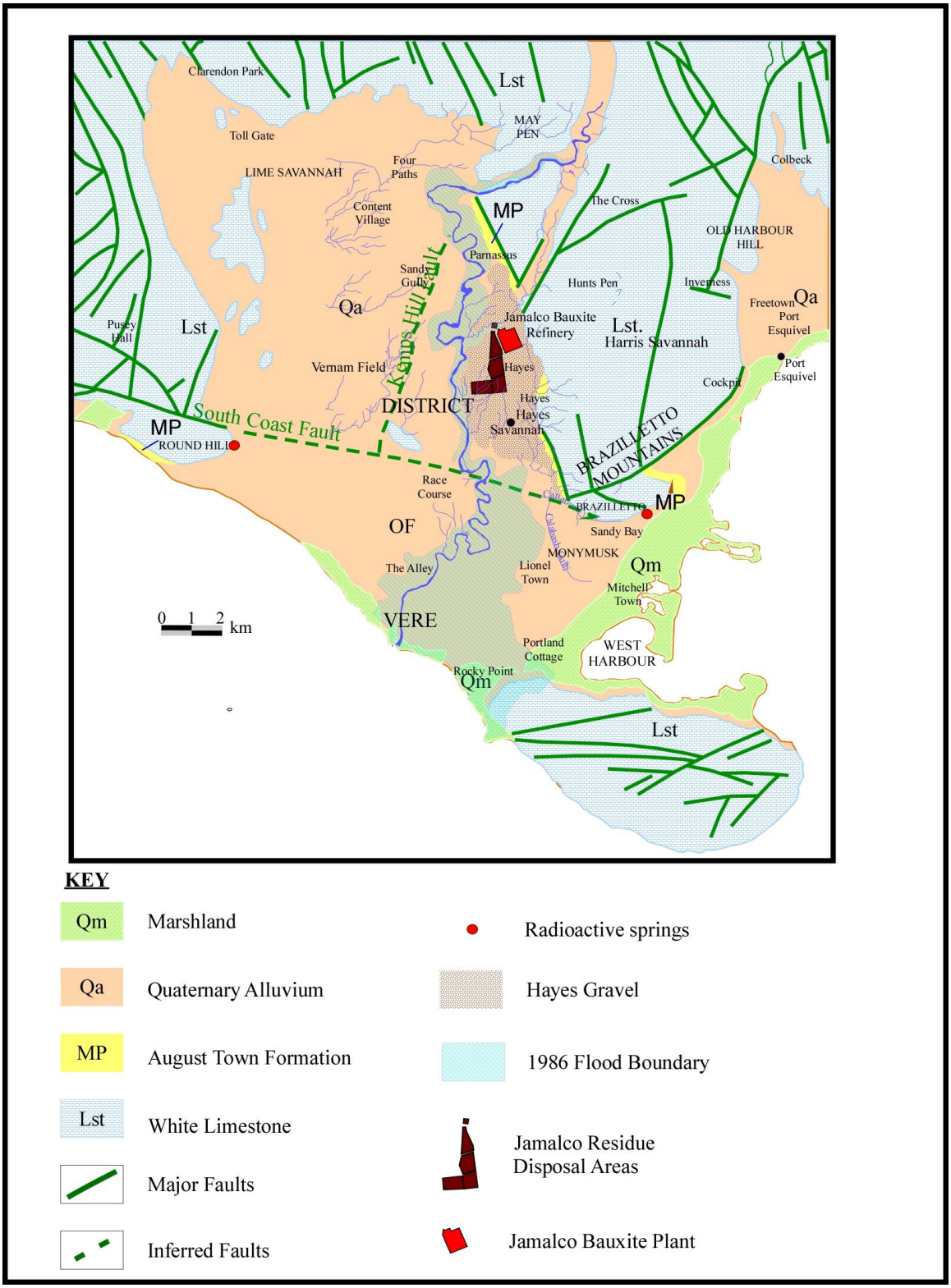


FIGURE 4-1: GEOLOGY MAP OF SOUTHERN CLARENDON

South of Hayes the alluvial fan flattens out to form what have been called the Vere Plains (Figure 4-1). Elevations over this area are low and the water table is relatively high, so that settlements such as Lionel Town and Alley are frequently flooded.

The rocks of the area consist of two main units. The various unconsolidated alluvial sediments, part of the Rio Minho fan complex, rest on limestone bedrock with a highly irregular surface.

4.2.1 THE ALLUVIAL FAN COMPLEX

The alluvial fan contains a wide range of more or less unconsolidated siliciclastic sediments. The top of the original fan, which has been extensively dissected, is preserved only in the neighbourhood of Halse Hall and Hayes (Figure 4-1). The sediments underlying the plant and RDAs make up this remnant and have been called the Hayes Gravels. The gravels range in particle size from pebbles and cobbles to silt and range in thickness from zero to 5-6 m in the north to 14-15 m in the south of the plant area. Clay is rare and the gravels are well-drained. Within the rest of the eastern part of the fan the sediments are very variable, although generally finer grained than the Hayes gravels, and with alluvial clay lenses.

4.2.2 THE LIMESTONE BEDROCK

The sediments of the Hayes Gravels are separated from the limestone bedrock by an irregularly developed layer of clay, at least in part being a weathered palaeosol developed on the limestone surface.

The limestone has been divided by the Mines and Geology Division into the lower, relatively pure Newport Limestone (Mn on Geological Sheet 16) and the upper, less pure August Town Formation (MP). The Newport limestone consists of moderately well-bedded, compact limestones, containing frequent rubbly layers, while the August Town Formation consists of impure limestones with irregularly interbedded marly and clayey layers. These rocks are exposed along the eastern side of the alluvial fan, less than a kilometre east of the plant site.

4.2.3 GEOTECHNICAL CHARACTERISTICS

4.2.3.1 THE ALLUVIAL FAN COMPLEX

Table 4-2 below shows the characteristics of materials that should be expected in the Hayes Gravels.

TABLE 4-2: PROPERTIES OF VARIOUS SOIL GROUPS (ADAPTED FROM CONRAD DOUGLAS & ASSOCIATES EIA ON THE CONSTRUCTION OF RESIDUE DISPOSAL AREA 4)

Typical Names of Soil Groups	Group Symbols	Important Properties			
		Permeability when Compacted	Shearing Strength when Compacted and Saturated	Compressibility when Compacted and Saturated	Workability as a Construction Material
Well-graded gravels, gravel sand mixtures, little or no fines.	G.W.	Pervious	Excellent	Negligible	Excellent
Poorly graded gravels, sand mixtures, little or no fines.	G.P.	Very pervious	Good	Negligible	Good
Silty Gravels, poorly graded gravel-sand-silt mixtures.	G.M.	Semi-pervious to impervious	Good	Negligible	
Clayey gravels, poorly graded gravel-sand-clay mixtures.	G.L.	Impervious	Good to fair	Very low	Good
Well-graded sands, gravelly sands, little or no fines.	S.W.	Pervious	Excellent	Negligible	Excellent
Poorly graded sands, gravelly sands, little or no fines	S.P.	Pervious	Good	Very Low	Fair
Silty sands, poorly graded sand-clay mixtures	S.M.	Semi-pervious to pervious	Good	Low	Fair

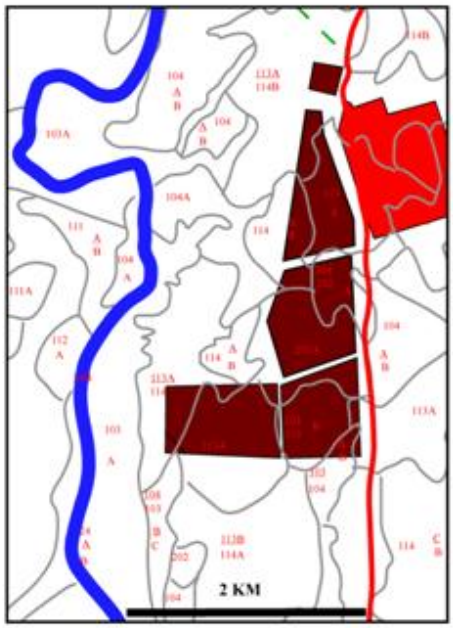
In summary the gravels tend to be pervious to very pervious with good to excellent shear strength, of negligible compressibility and good to excellent workability as a construction material. Alluvial materials sourced from other places in the Rio Minho fan should also be well suited for construction after washing and grading.

The limestone bedrock of the area may be thickly stratified and massive, but contains frequent zones of less competent, rubbly and marly limestone. There may be a case-hardened layer up to several metres thick, over the softer limestone, where it has been indurated from weathering. The rubbly zones are frequently the result of brecciation associated with faults. Solution features consist of joints widened by solution and there may be cave development. Most large features in the limestones of southern Clarendon and St. Catherine consist of vertical shafts with widening laterally into extensive cave complexes in some areas, such as Portland Ridge (Fincham, 1997).

In summary the bearing capacity of the limestone bedrock is good, although for large structures the presence or absence of caverns or fissures at shallow depth should be ascertained.

4.2.3.2 SOILS

The soils of the Hayes region are intimately associated with the alluvial deposits of the Rio Minho Fan Complex. Figure 4-2 indicates the distribution of the different soils of the area. The classification follows that used by the Ministry of Agriculture, the symbol group representing the soil type and steepness of slopes.



SOIL TYPES

24	Agualta Sandy Loam
103	Agualta Loam
104	Agualta Clay
111	New Yarmouth Loam
112	New Yarmouth Clay Loam
113	Halse Hall Clay
114	Halse Hall Clay (Red Phase)
202	Rhymsbury Clay

SLOPE CATEGORIES

A	0 - 2 Degrees (0% - 5%)
B	2 - 5 Degrees (5% - 11%)
C	5 - 10 Degrees (11% - 22%)

FIGURE 4-2: SOILS MAP OF HAYES, CLARENDON

4.2.4 MINERAL RESOURCES

The only mineral resources of note are the limestone forming the Harris Savannah plateau, which has been used as a source of marl and crushed stone from the disused quarry near Halse Hall, and the sand and gravel extraction industry in the bed and flood plain of the Rio Minho. The Hayes Gravels contain small pebbles and occasional larger cobbles of the semiprecious stone jasper (Porter et al. 1982; Porter, 1990). Rarely fragments of silicified wood may be collected.

4.3 HYDROGEOLOGY AND HYDROLOGY

4.3.1 HYDROGEOLOGY

4.3.1.1 HYDROSTRATIGRAPHY

The Clarendon Alumina Works (CAW) consisting of the bauxite/alumina plant and the bauxite Residue Disposal Areas (RDAs) owned by Jamalco is located within the parish of Clarendon on the south central coast of the island. The parishes of Clarendon and Manchester together form the Rio Minho Hydrologic Basin that consists of the Rio Minho, the Milk River and the Gut-Alligator Hole Watershed Management Units (Figure 4-3)

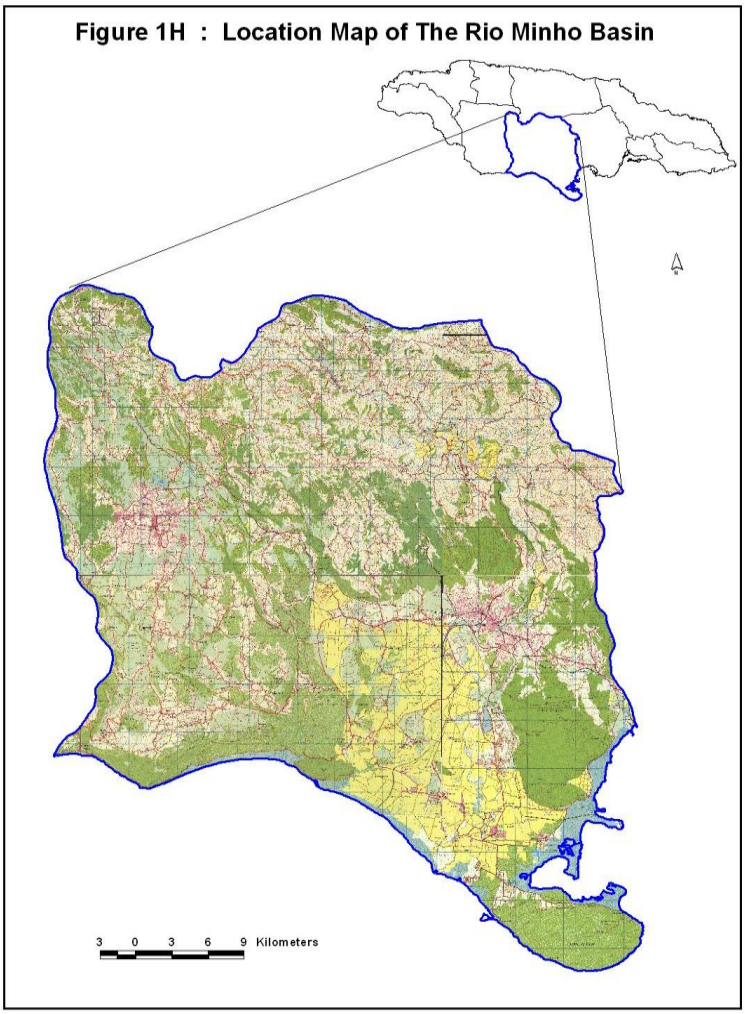


FIGURE 4-3: LOCATION MAP OF THE RIO MINHO BASIN

The Rio Minho Hydrologic Basin extends over an area of 1,705 km2 (Figure 4-3). The Basin is subdivided into 3 sub-basins and 3 hydrostratigraphic units (Figure 4-4).

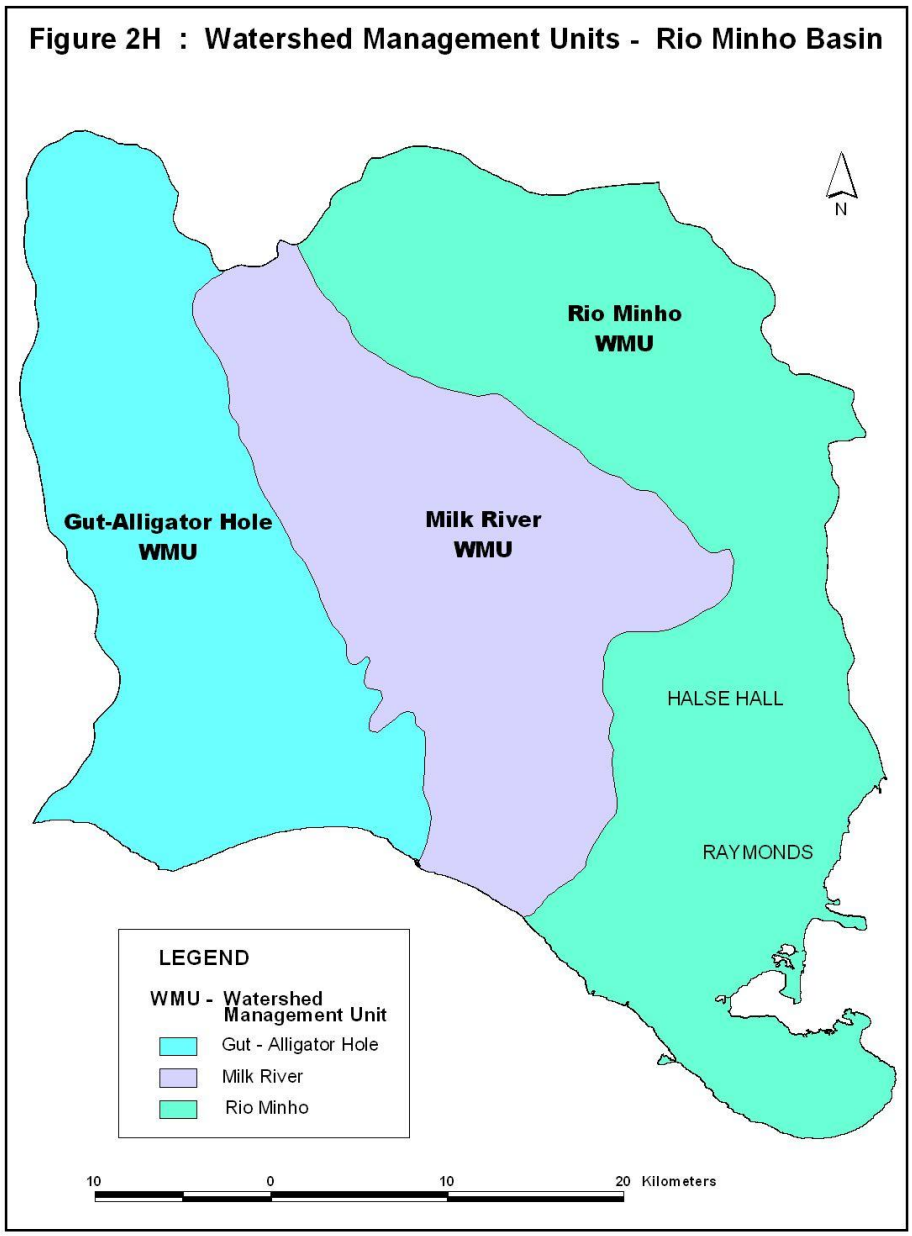


FIGURE 4-4: WATER MANAGEMENT UNITS – RIO MINHO

Table 4-3 below summarizes the area for each catchment.

TABLE 4-3: AREAS OF THE HYDROSTRATIGRAPHIC UNITS OF THE SUB-DIVISIONS OF THE RIO MINHO HYDROLOGIC BASIN.

Sub-basins	Hydrostratigraphic Units (km^2)			Total	Percent
	Basement Aquiclude	Limestone Aquifer	Alluvium Aquifer (Aquiclude)		
Upper Rio Cobre	362	31	NIL	393	23
Clarendon Plains	6	528	415	949	56
Manchester Highlands	NIL	358	(5)	363	21
Total	368	917	420	1,705	----
Percent	22	54	24	----	100

4.3.1.2 GEOLOGY AND HYDROGEOLOGICAL CHARACTERISTICS

The CAW is located within the Clarendon Plains subdivision (Rio Minho Watershed Management Unit) atop the limestone aquifer. The limestone formation is a member of the White Limestone Group of Tertiary Age (7-28 million years). The alluvium of Pleistocene Age (2 million years) has been deposited atop the limestone.

Although the White Limestone acts as a single hydrogeological unit, the Newport Formation covers most of the Rio Minho basin to a considerable depth. It outcrops in the hills of the Brazilletto Mountains and underlie the alluvium of the plains, where it is the principal source of groundwater. The exact thickness of the limestone is not known but the UNDP/FAO water resources project estimated that in the southern area of the basin the thickness exceeds 1,200 metres as proven by an exploratory oil well drilled at Portland Point.

The primary limestone formation under CAW is the Newport Limestone Formation. This formation extends throughout the Rio Minho Basin and is the major aquifer that provides water to the wells that support irrigation, domestic and industrial water in the parish. The Newport is essentially a micrite and in its lowest horizon is characterized by an abundance of corals. All the monitor and production wells drilled around CAW by Jamalco, NWC and Sugar Company of Jamaica (SCJ) penetrated the upper to middle horizons of the Newport Limestone as marked by the abundance of fossils such as gastropods, corals and bivalves. The wells are in fact only partially penetrating the aquifer and abstracts water from the top 60 metres (200 feet) of the aquifer.

The permeability of the aquifer is high as evidenced by the loss of circulation (drill water) and the drop of the drill string during the drilling exercises as cavities were encountered and the high yield/low drawdown of the monitor wells when tested using a compressor as a pumping unit. The wells drilled in the vicinity of CAW encountered the water bearing horizons at 13 to 16 metres below sea level. The saturated thickness of the limestone in the area is estimated to be in excess of 150 metres as proven by the Vernamfield well drilled into the same central depression atop which CAW is located. At the final drill depth of the monitor wells there was evidence of high secondary permeability and the saturated thickness was in excess of 110 metres.

The alluvium atop the limestone consists mostly of sands, gravels and clays. The alluvium also fills the fault-incised channels in the underlying limestone. One such channel approximates the course of the Rio Minho. The alluvium thickens southwards from Bowens. The coarser sediments are concentrated within the buried channel and along the course of the Rio Minho. Monitor Well 5 located on the banks of the Rio Minho west of the RDA proved a thickness of 17 metres of coarse sand and gravel with clay between 15 to 17 metres depth. Examination of the lithologic logs from the monitor wells drilled around CAW indicates a basal layer of clay separating the alluvium from the underlying limestone. The Alcoa No. 1 borehole located at E4655 N3618 encountered 10 metres of white sticky clay atop the limestone. The alluvium in the vicinity of CAW is dry and no water was encountered during the drilling of the monitor wells. The alluvium is unsaturated and functions as an aquiclude (Geomatrix Jamaica Ltd. 1995).

4.3.1.3 STRUCTURE

The area around the CAW is a large limestone depression criss-crossed by several faults The lateral and vertical movements along these faults are responsible for the variation in lithology encountered during the drilling of the monitor and production wells i.e. lower, middle or upper Newport Limestone Formation. Faults that cross the area and trend northeast to southwest and northwest to southeast truncate at the boundary of the alluvium. The faults are buried beneath the alluvium but if extrapolated would meet north of the Webbers Gully at New Bowens housing scheme. One fault trending northwest to southeast passes east of the bauxite/alumina plant and has incised a deep channel within the limestone. The thickened alluvium encountered in Hanbury No 2R well and Monitor Well 3 marks this fault zone. This fault reappears at Raymonds to the south of Hayes Township where it abuts onto the South Coastal Fault (Figure 4-5).

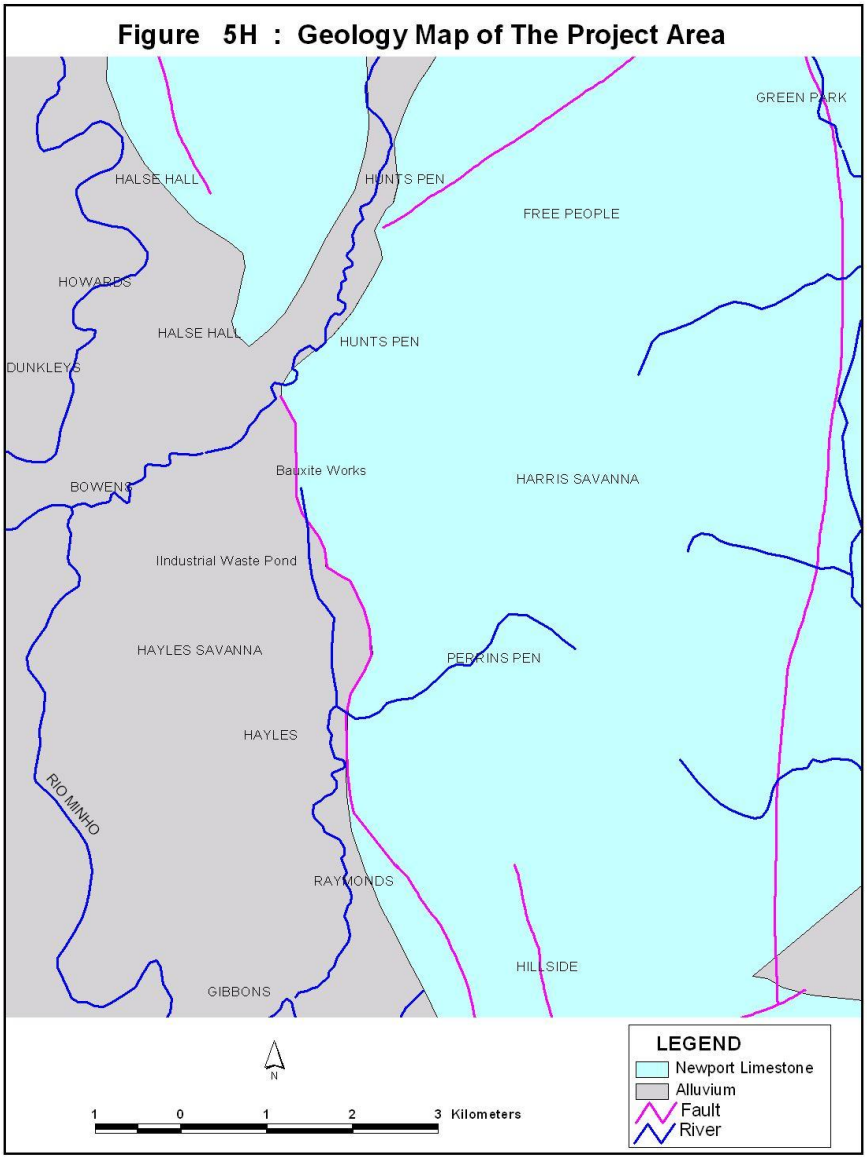


FIGURE 4-5: GEOLOGY MAP OF THE PROJECT AREA

The UNDP/FAO Water Resources Assessment of the Rio Minho-Milk River Basin, Annex II-Water Resources Appraisal divides the basin into 3 units and treats each unit as being separate. The boundary between Units B and C was given as a groundwater divide at the western edge of the Brazilletto Mountains until it intersects the South Coastal Fault, which structurally is the southern boundary of the limestone aquifer of the Clarendon Plains. A review of the groundwater level contours and flow direction provides evidence for the groundwater divide. The fault that is located east of the plant at the foot of the Brazilletto Mountains is possibly the eastern boundary of Unit B.

Cross sections drawn in a north-south and east-west direction across the Halse Hall area show the following:

- The erosional (wavy) surface of the limestone
- The variation in thickness of the alluvium
- The basal clay layer at the limestone/alluvium boundary; and
- The water table in the limestone aquifer.

The cross sections are shown as Figure 4-6 and Figure 4-7.

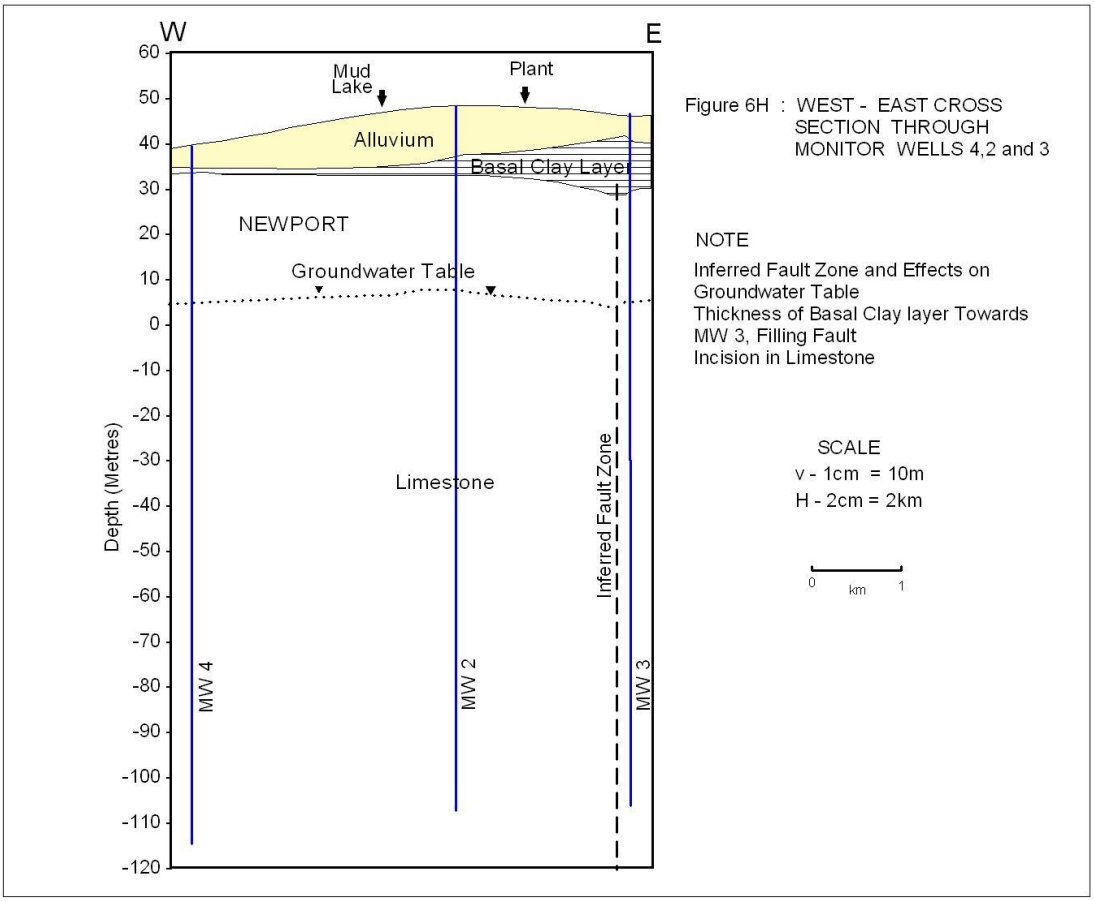


FIGURE 4-6: WEST-EAST CROSSSECTION THROUGH MONITOR WELL 4,2 AND 3

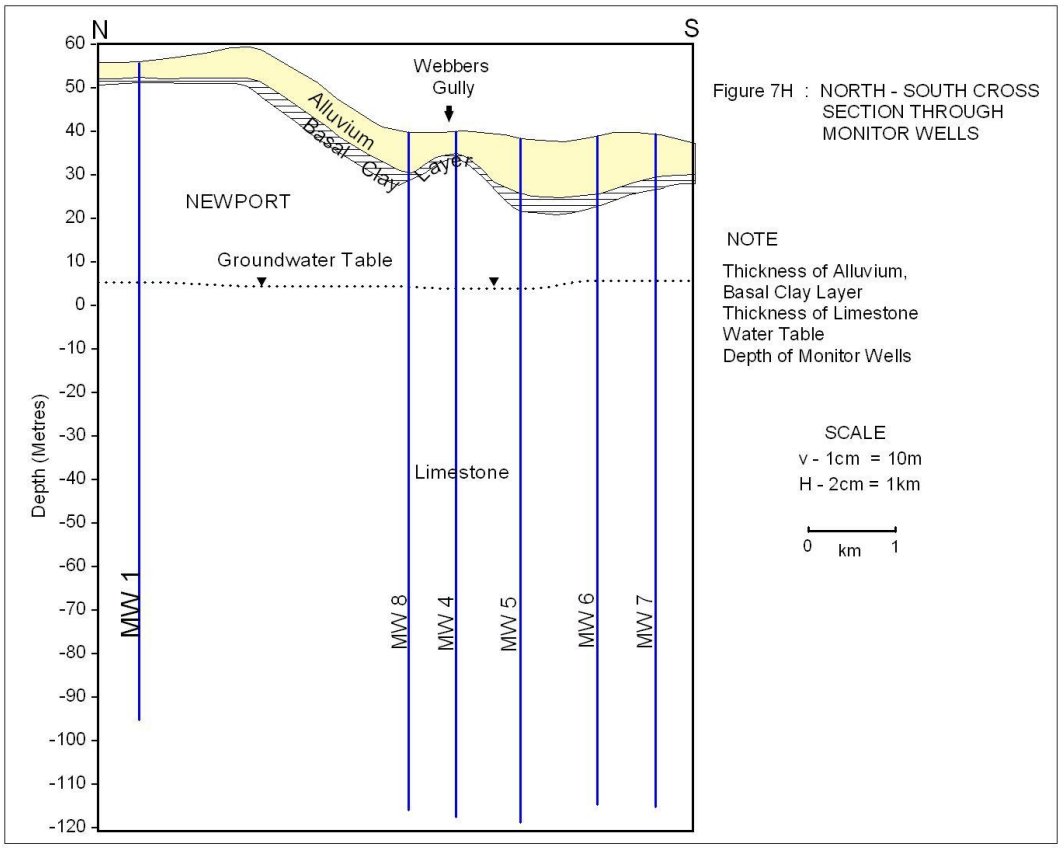


FIGURE 4-7: NORTH-SOUTH CROSS SECTION THROUGH MONITOR WELLS

4.3.1.4 TOPOGRAPHY AND DRAINAGE

Topographically the area is of low relief with gentle rolling hills on the Harris Savanna. The Brazilletto Mountains form the high ground rising to 250 metres above mean sea level to the east of the bauxite/alumina plant. The Rio Minho flows in a north-south direction west of the RDAs and is the major surface water drainage system. The Water Resources Authority in 2005 carried out a hydrologic and hydraulic analyses to develop a flood plain map of the reach of the Rio Minho between May Pen and the coast-Carlyle Bay. The results indicate that the 100 year flood event would not impact on the RDAs.

The Webbers Gully, a tributary of the Rio Minho, drains the area north of the Plant. The Webbers Gully is seasonal and carries storm water from the northeast section of the basin into the Rio Minho. During high rainfall events when the Rio Minho is in spate its stage is higher than that of the Webbers Gully with the result that the gully cannot enter the river and will overtop its

banks with resultant flooding. The flood plain map by the WRA indicates that the storm lake of CAW would be affected by the flooding from the Webbers Gully (backwater effect) of the 100 year event. However, it is anticipated that the proposed construction of DRDA #6 will not induce, or be the recipient of, any significant hydraulic features that will influence the current inundation potential of the Webber's Gully floodplain in a negative way. This is due mainly to the following:

- The location of the proposed DRDA #6 is north of the rail line and the storm water pond, which are both located north of the existing Webber's Gully channel. The floodplain model generated by the WRA (Figure 4-15) predicts significant inundation partially beyond the existing rail lines only in a scenario where the culverts at the main road and at the rail line are completely blocked by debris. Other partial scenarios do not predict inundation beyond the rail lines, and only predict, as stated earlier, an effect on the storm water pond from a 100 year event (Figure 4-13 and Figure 4-14)

- The dyked areas of the proposed DRDA may reduce, but will not add to the surface runoff into the surrounding areas. The land, as stated above has undulating relief with a general north to south grade. As such, with the installation of the proposed DRDA, some of the rainfall which eventually flows into the Webber's Gully from the north would be collected in DRDA #6 and eventually channeled into the storm water pond. The potential of the DRDA#6 to reduce inundation is only negated by the 100 year event during which the storm water pond will become affected by the seasonal flooding of the Webber's Gully.

The Webbers Gully was straightened to facilitate the construction of the No. 1 RDA (mud lake) and the Clear Lake. The Webbers Gully flows between the northern dike of the No. 1 RDA and the southern edge of the Clear Lake. Monitor well 8 is located just south of the Webbers Gully before it joins the Rio Minho.

4.3.2 HYDROLOGY

4.3.2.1 SURFACE WATER HYDROLOGY

The Rio Minho and the Webbers Gully are the main constituents of the surface water hydrologic system in the Halse Hall area.

The Rio Minho, located west of the RDAs, flows in a north south direction. The Webbers Gully, a tributary of the Rio Minho, drains the area between New Bowens and the plant site. The alluvium filled Webbers Gully joins the Rio Minho Valley through Palmers Cross at the Barrel Hole sink west of Chateau, May Pen. It joins the Rio Minho at Old Bowens flowing north of Monitor Well 8.

The Rio Minho and the Webbers Gully are seasonal in flow. The Rio Minho is seasonal between May Pen and Alley. The river loses its flow-an average of 20 million cubic metres per year (MCM/yr)-just north of May Pen (at North Hall) to the limestone aquifer. At Alley the river becomes perennial and is sustained by wet season surface water through flow from the Upper Rio Minho sub-basin (111 MCM/yr) and perennial inflow of irrigation return water (22 MCM/yr), totaling 133 MCM/yr average discharge to the sea. There is no significant contribution to the Rio Minho from the limestone aquifer throughout its passage across the Clarendon Plains sub-basin to the sea.

Ponding of water occurs along the course of both surface water systems. The ponding indicates the effectiveness of the basal clay layer in preventing vertical movement of water through the alluvium to the limestone aquifer. However along the Webbers Gully in the vicinity of the clear lake there are outcroppings of limestone. Surface flow as well as any contaminant can enter the limestone aquifer through these surface exposures of limestone.

4.3.2.2 GROUND WATER HYDROLOGY

Ground water is water that is stored within the saturated section of the limestone formation. The natural level of the water i.e. the water table, marks the upper section of this zone of saturation. Rainfall is the sole source of recharge to the ground water system but artificial, intentional or unintentional, inflows can also contribute and may affect ground water type and quality. The impact will depend on several factors and may include.

- Hydrostratigraphy
- Permeability
- Water levels
- Flow direction

As stated above in Project Background the two main hydrostratigraphic units within the project area are the limestone aquifer and the alluvium aquifer/aquiclude. The alluvium is unsaturated and does not function as an aquifer. It can for all purposes be classified as an aquiclude.

A hydrostratigraphic unit is a geologic formation (or series of formations), which demonstrates a distinct hydrologic character. An aquifer is a geologic formation or group of formations that readily and perennially yields water to a spring or well. An aquiclude is the opposite of an aquifer.

The alluvium overlies and confines the limestone aquifer within the project area. The full penetration of the alluvium during the monitor well drilling operations proved its lack of water. The limestone aquifer was partially penetrated to a thickness of 135 metres out of a reported thickness of 1350 metres-10% only. Yet the drilling of the monitor wells was the deepest drilling to have been done in the area. The confinement of the aquifer was evident in the drilling of the monitor wells where artesian rises in the water level of up to 14 metres were noted (Geomatrix 1995).

Ground water is ponded within the karstic Clarendon Plains limestone aquifer by clayey alluviums on the downfaulted southern block of the South Coastal Fault. Along its southeastern boundary alluviums and underlying coastal aquicludes act as a barrier to direct outflow to the sea. Note the change (increase) in the elevation of the water table just behind the fault as shown in Figure 4-5

The alluvium south of the South Coastal Fault is an aquifer and is tapped by the Sugar Company of Jamaica using tube wells to provide irrigation and domestic water to its operations at Monymusk. The thickness of the alluvium in this area was determined in 1978 using a gravity survey (Bouguer Anomaly) to be a maximum of 650 metres (Wadge, Brooks and Royall 1983).

4.3.3 WATER RESOURCES

4.3.3.1 WELL LOCATIONS AND YIELDS

The seasonal character of the main rivers in the Basin combined with the high agricultural demand account for the heavy reliance on ground water. Wells tapping the limestone aquifer produce water for agricultural, domestic and industrial uses. At present over 80% of the water supplied in the basin is from ground water.

Located east of the Rio Minho River within the Clarendon Plains sub-division and to the north (from Halse Hall Great House) and south (to Raymonds) of the CAW are 26 production wells tapping the limestone aquifer. A list of these wells, the owners, their use and licenced/historical yield is given in Table 4-4 below. The locations of these wells are shown in Plate 4-1

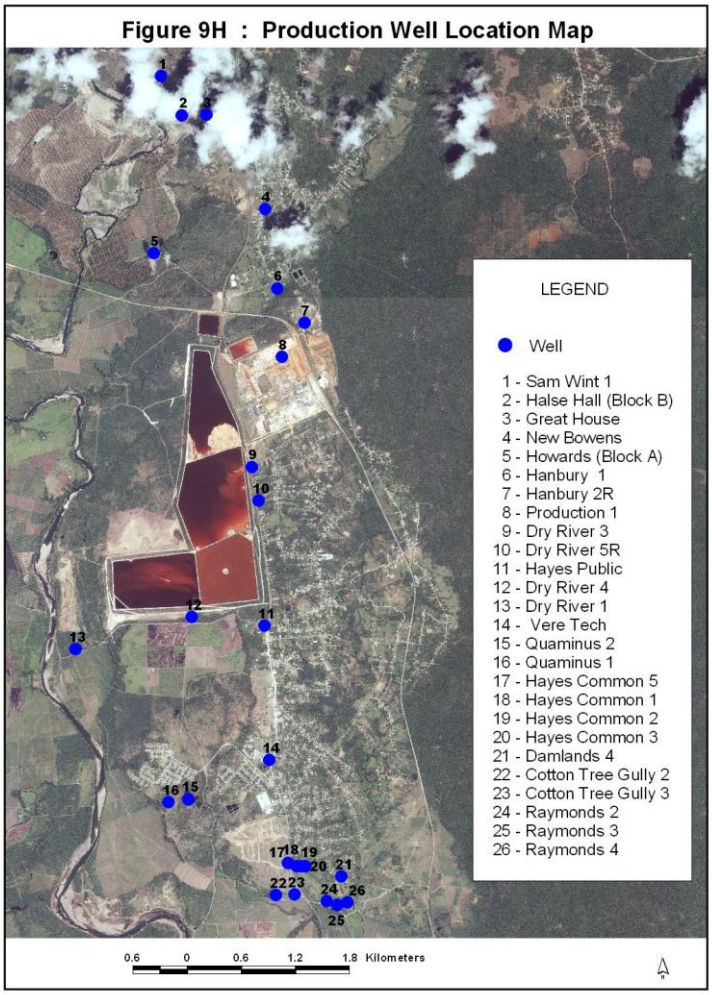


PLATE 4-1: AERIAL SHOWING RELATIVE LOCATIONS OF PRODUCTION WELLS

The greater numbers of the wells is located south of the CAW, are a) all owned by SCOJ, b) all used for irrigation and c) centered on the Hayes Common-Raymonds area. The location of these wells is along the South Coastal fault that is open to the sea at the western and eastern ends. The high permeability associated with the fault and the ponding of groundwater behind the fault influenced the locations. The wells along the fault are high producers.

Of these 26 wells the Sugar Company owns 14 that are used for irrigation purposes; the National Water Commission owns two for public water supply; the Ministry of Education owns one for agricultural uses, and Jamalco owns 9 for private domestic, agricultural and industrial uses. The wells owned by Jamalco and used for agricultural purposes are leased to a farming entity.

The total licensed abstraction for the wells owned by Jamalco total 83,830 cubic metres per day (m^3/d); that for the National Water Commission totals 10,130 m^3/d; that for the Ministry of Education (Vere Technical well) totals 1,690 m^3/d and the historical abstraction for the Sugar Company of Jamaica (SCOJ) totals 131,112 m^3/d. One well, Quaminus 2, is shared between the NWC and the SCOJ. The NWC purchases water from this well to meet the demands of the Hayes New Town.

The total licensed or historical entitlement of abstraction from the area around the CAW is 226,762 m^3/day.

TABLE 4-4: LIST OF PRODUCTION WELLS EAST OF THE RIO MINHO AND WITHIN THE VICINITY OF THE CAW

Name of Well	Name of Owner	Water Use	Yield (m^3/day)
Great House	Jamalco	Private Domestic	250
Sam Wint	Jamalco	Agriculture	7,560
Halse Hall (Block B)	Jamalco	Agriculture	11,160
Howards (Block A)	Jamalco	Agriculture	10,880
Dry River 3	Jamalco	Industrial	9,815
Dry River 5R	Jamalco	Industrial	9,815
Hanbury 1	Jamalco	Industrial	8,184
Hanbury 2R	Jamalco	Industrial	10,902
Production 1	Jamalco	Industrial	15,264
New Bowens	National Water Commission	Public Supply	3,272
Hayes Public	National Water Commission	Public Supply	6,858

Name of Well	Name of Owner	Water Use	Yield (m^3/day)
Vere Technical	Ministry of Education	Agricultural/Domestic	1,690
Hayes Common 1	Sugar Company of Jamaica	Irrigation	11,088
Hayes Common 2	Sugar Company of Jamaica	Irrigation	13,944
Hayes Common 3	Sugar Company of Jamaica	Irrigation	10,224
Hayes Common 5	Sugar Company of Jamaica	Irrigation	11,088
Quaminus 1	Sugar Company of Jamaica	Irrigation	15,936
Quaminus 2*	Sugar Company of Jamaica	Irrigation	8,184
Cotton Tree Gully 2	Sugar Company of Jamaica	Irrigation	9,168
Cotton Tree Gully 3	Sugar Company of Jamaica	Irrigation	9,096
Damlands 4	Sugar Company of Jamaica	Irrigation	2,760
Raymonds 2	Sugar Company of Jamaica	Irrigation	6,072
Raymonds 3	Sugar Company of Jamaica	Irrigation	9,168
Raymonds 4	Sugar Company of Jamaica	Irrigation	10,200
Dry River 1	Sugar Company of Jamaica	Irrigation	9,168
Dry River 4	Sugar Company of Jamaica	Irrigation	5,016

*- well shared between SCOJ and NWC.

In addition to the 26 production wells there are two disused production wells, Dry River 2 and Dry River 6, as well as twelve (12) monitor wells located around the CAW. Of the 12 monitor wells one has been destroyed (Monitor Well 7) and one has become inaccessible due to expansion of the plant.

The 12 monitor wells were drilled in 2 phases. Phase 1 saw 8 wells being completed in 1994 with a further 4 wells in phase 2 being completed in 1997.

Each monitor well was drilled to a depth of 155.4 metres and completed with 5 cm diameter GEOMEMBRANE casing and screen. The annular space of each well was packed with gravel and coarse sand. The screened area, which was close to the bottom of the well, was packed off using bentonite as a seal. Development was carried out using a compressor as the pumping unit. Water samples were collected every 30 metres to develop a water quality profile with depth. The locations of the monitor wells are shown below (Plate 4-2). The construction details for the 12 monitor wells are shown in Table 4-5 below.

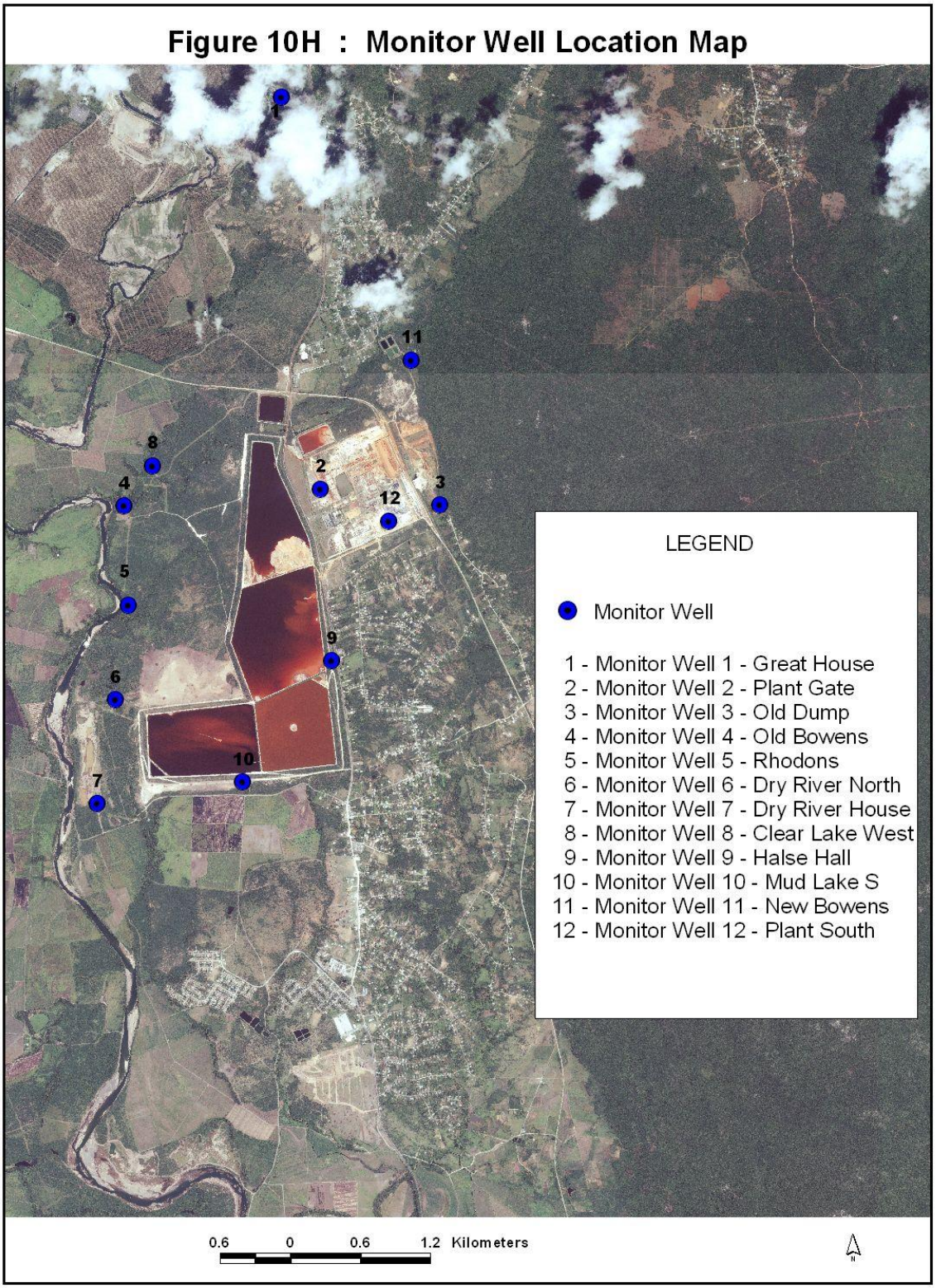


PLATE 4-2: AERIAL SHOWING RELATIVE LOCATION OF MONITORING WELLS

TABLE 4-5: CONSTRUCTION DETAILS OF MONITOR WELLS-JAMALCO-CAW

Monitor Well		Drill Hole		Casing/Screen					Filter Pack				Seal	Cement Grout
No.	Name	Dia. (cm)	Depth (m)	Type	Dia. (cm)	From (m)	To (m)	Length (m)	Type	From (m)	To (m)	Thickness (m)		
1	Great House	10.16	152.4	Blank	5	+0.3	146.3	146.6	MS	-1.5	141.7	140.2	141.7	1.5
				Screen	5	146.3	149.3	3.0	FS	141.7	143.2	1.5		0 to 1.5
				Bank	5	149.3	152.4	3.1	MS	143.2	152.4	9.2		
2	Plant Gate	10.16	155.4	Blank	5	+0.3	149.3	149.6	MS	-1.5	141.7	140.2	141.7	1.5
				Screen	5	149.3	152.4	3.1	FS	140.2	143.2	3.0		0 to 1.5
				Bank	5	152.4	155.4	3.0	MS	143.2	155.4	12.2		
3	Old Dump	10.16	155.4	Blank	5	+0.3	149.3	149.6	MS	-1.5	144.8	143.3	144.8	1.5
				Screen	5	149.3	152.4	3.1	FS	144.8	146.3	1.5		0 to 1.5
				Bank	5	152.4	155.4	3.0	MS	146.3	155.4	9.1		
4	Old Bowens	10.16	155.4	Blank	5	+0.3	149.3	149.6	MS	-1.5	144.8	143.3	144.8	1.5
				Screen	5	149.3	152.4	3.1	FS	144.8	146.3	1.5		0 to 1.5
				Bank	5	152.4	155.4	3.0	MS	146.3	155.4	9.1		
5	Rhodons	10.16	155.4	Blank	5	+0.3	149.3	149.6	MS	-1.5	144.8	143.3	144.8	1.5
				Screen	5	149.3	152.4	3.1	FS	144.8	146.3	1.5		0 to 1.5
				Bank	5	152.4	155.4	3.0	MS	146.3	155.4	9.1		
6	Dry River North	10.16	152.4	Blank	5	+0.3	146.3	146.6	MS	-1.5	143.3	141.8	143.3	1.5
				Screen	5	146.3	149.3	3.0	FS	143.3	144.8	1.5		0 to 1.5
				Bank	5	149.3	152.4	3.1	MS	144.8	152.4	7.6		
7	Dry River House	10.16	155.4	Blank	5	+0.3	149.3	149.6	MS	-1.5	143.3	143.3	143.3	1.5
				Screen	5	149.3	152.4	3.1	FS	143.3	148.8	1.5		0 to 1.5
				Bank	5	152.4	155.4	3.0	MS	144.8	155.4	10.6		
8	Clear lake West	10.16	155.4	Blank	5	+0.3	149.3	149.6	MS	-1.5	143.3	141.8	143.3	1.5
				Screen	5	149.3	152.4	3.1	FS	143.3	146.3	3.0		0 to 1.5
				Bank	5	152.4	155.4	3.0	MS	146.3	155.4	9.1		
9	Halse Hall	10.16	155.4	Blank	5	+0.6	128.0	128.6	MS	-1.5	127.5	126.0	126.5	1.5
				Screen	5	128.0	131.0	3.0	FS	127.5	134.0	6.9		0 to 1.5
				Bank	5	131.0	134.0	3.0	MS	134.0	155.4	21.0		
10	Mud Lake South	10.16	155.4	Blank	5	+0.8	146.3	147.1	MS	-1.5	140.0	138.5	140.0	1.5
				Screen	5	146.3	149.3	3.0	FS	140.0	152.4	12.4		0 to 1.5
				Bank	5	149.3	152.3	3.0	MS	152.4	155.4	3.0		
11	New Bowens	10.16	155.4	Blank	5	+0.8	149.4	150.2	MS	-1.5	122.0	120.5	121.5	1.5
				Screen	5	149.4	152.4	3.0	FS	122.0	154.0	32.0		0 to 1.5
				Bank	5	152.4	155.4	3.0	MS	154.0	155.4	1.4		
12	Plant Site South	10.16	152.4	Blank	5	+0.4	137.2	137.6	MS	-1.5	91.5	90.0	90	1.5
				Screen	5	137.2	140.2	3.0	FS	91.5	143.2	51.7		0 to 1.5
				Bank	5	140.2	143.2	3.0	MS	143.2	155.4	12.2		

MS-Medium Sand FS-Fine Sand

4.3.3.2 GROUNDWATER LEVELS

Groundwater level (elevation of water table above sea level) is monitored monthly by Jamalco at each of the 10 accessible monitor wells. The groundwater table fluctuates seasonally with recharge and abstraction/discharge. When recharge exceeds abstraction/discharge the storage increases and the water table rises. When abstraction/discharge exceeds recharge water is taken from storage and the water table elevation will decline. In the dry season the water table elevation in the area around the CAW varies from 2.40 to 4.10 metres above sea level with the highest level being recorded at Monitor Well 1 to the north.

The year 2003 was one of high water table elevations as the recharge from the extreme rainfall events in May/June and September of 2002 increased storage within the limestone aquifer. Water table elevations around the CAW remained higher than 6 metres above sea level for all of 2003. In fact at two wells, monitor wells 1 and 12, the water table elevation was higher than 7 metres above sea level. This has gradually declined and in April of 2004 the water table elevations varied from a high of 5.34 (in the north of the area) to a low of 4.51 (west of the RDAs) metres above sea level. There has not been a decline in the groundwater table since the measurements began in 1998.

The water table elevation upon completion of the monitor wells and that in October 2004 is compared in Table 4-6 below.

TABLE 4-6: COMPARISON OF WATER TABLE ELEVATIONS FOR THE MONITOR WELLS

Name of Well	Water Table Elevation (m asl)		Remarks
	Upon Completion	October 2004	
Monitor Well 1	3.35	4.96	MW 1-8 completed
Monitor Well 2	4.63	7.03	In 1994
Monitor Well 3	4.23	5.61	
Monitor Well 4	4.37	5.88	
Monitor Well 5	3.85	5.96	
Monitor Well 6	3.79	5.44	
Monitor Well 8	3.84	5.88	
Monitor Well 9	3.91	5.70	MW 9-12 completed
Monitor Well 10	3.87	5.75	In 1997
Monitor Well 11	3.79	5.65	
Monitor Well 12	3.87	7.38*	*June 2004

The water table elevation map indicates that the groundwater flow is from north to south.

4.3.3.3 DISCHARGE

Knowledge of the discharge to the sea via the limestone south of the South Coastal Fault is not known. There is no evidence to show that there is a discharge along this reach to the sea. The actual discharge into the sea may be some distance offshore where the White Limestone is exposed to the seabed. It is possible that outflow may be restricted to those periods of high water table and marine discharge in normal conditions may be small.

The principal discharge from the aquifer is by abstraction from pumped wells. In Table 4-4 a list of the pumped wells is given with the licensed or historical abstraction rates.

The total committed water for abstraction from the area around the CAW was 226,762 m^3/day (10.30 x 108 imperial gallons per day). There has never been a period when all the wells have been abstracting at their maximum and the 226,762 m^3/day was being abstracted. This area of the limestone aquifer has the greatest abstraction in the basin and is concentrated in particular around the Hayes Common-Raymonds area south of the CAW. Many of the wells suffer from saltwater contamination either from penetration of the fresh water-seawater interface along the South Coastal Fault, the movement of saltwater (influenced by the pumping) along the fault that is open to the sea at both the western and eastern ends, or the recirculation of return saline irrigation water.

4.3.3.4 RESERVOIR VOLUME

The effectiveness of an aquifer to supply water on a reliable basis is determined by the volume of the reservoir rock capable of holding the water. The effective volume of the reservoir is that amount of water that the rock will yield.

The thickness of the permeable section of the aquifer in the northern area of the basin is not known. However this is determined by the depth to the impermeable basement rocks (Yellow Limestone or Volcanic rocks) and the aquifer is thin where these rocks are near to the surface. In the area around the CAW the impermeable sediments are covered by the great thickness of the White Limestone (Newport Formation) and they do not affect the depth to which water can penetrate. The depth of solution in the limestone is limited by the lowest base level in effect during the history of solution development. The degree of karstification has a direct bearing on the capacity of the limestone to store and transport water. In the area beneath the CAW the level of karstification and high permeability in the limestone was found to be over 100 metres

deep and has been proven to be over 150 metres deep within the central depression atop which the CAW is located.

The groundwater table elevations are relatively flat in the central area of the basin and around the CAW. They are controlled by several factors, which will include the storativity and the transmissivity of the aquifer. The water table elevation varies from 4.5 metres above sea level to a high of 7 metres above sea level, which gives an average water table elevation of approximately 5.75 metres above sea level within the study area. The reservoir volume is assumed to be equivalent to the saturated thickness of the reservoir. Assuming a saturated thickness of at least 100 metres and an area of the aquifer bounded by the South Coastal Fault to the south, by the Rio Minho to the west, by the fault between the plant and the Brazilletto Mountains to the east and by an imaginary east-west line drawn north of the Great House and Sam Wint wells with an approximate area of 45 square kilometres, the volume of the reservoir would be 450 million cubic metres of water (a value of 10% is used for the calculation of the reservoir volume).

Based on the average water table elevation of 5.75 metres above sea level within the area and a specific yield of 3%, the volume of water that could be abstracted would be 7.82 million cubic metres.

4.3.4 WATER QUALITY

4.3.4.1 AMBIENT WATER QUALITY

The groundwater resources of the Clarendon Plains and the area around the CAW are associated with the limestone aquifer, which occurs throughout the area and fills the central depression. Except where contaminated by industrial and municipal effluents or seawater, the quality of the groundwater is adequate for all standard uses. Physical, chemical and bacteriological quality is generally as follows:

- pH 7.2
- Conductivity 450 to 700 uS
- TDS 250 to 450 mg/l
- Coliform 5 MPN/100 ml.

Total Dissolved Solids (TDS) tends to be slightly high for use in industrial boilers without softening, but the bacteriological quality requires minimum treatment for use as a municipal/ public or private water supply. However where contamination has occurred the quality would vary depending on the nature of the contaminant.

The typical background quality of the groundwater in the limestone aquifer is shown in Table 4-7 below.

TABLE 4-7: TYPICAL BACKGROUND QUALITY OF GROUNDWATER IN THE LIMESTONE AQUIFER-CLARENDON

Constituents	Units	Concentrations
pH		7.2
Turbidity	NTU	<1.0
Colour	HU	<5
Specific Conductivity	uS	550
Calcium	mg/l	<75
Magnesium	mg/l	10
Sodium	mg/l	12
Potassium	mg/l	1.0
Iron	mg/l	0.01
Chloride	mg/l	10
Sulphate	mg/l	8
Nitrate	mg/l	4
Carbonate	mg/l	0.0
Bicarbonate	mg/l	260
Total Hardness	mg/l	270
Total Alkalinity	mg/l	260
Total Dissolved Solids	mg/l	350
Bacteriological	MPN/100 ml	<5
Na:Cl ratio		<1.5

4.3.4.2 GROUNDWATER CHEMICAL TYPES

All groundwater can be classified into types according to the dominance of various anions and cations in the water. The major types are:

1. Calcium/Magnesium bicarbonate
2. Sodium bicarbonate
3. Calcium chloride
4. Sodium chloride

Natural groundwater, which is uncontaminated, has as the dominant cation, calcium or magnesium, dependent on the source rock through and over which the water flows. The dominant anion is bicarbonate and together with the dominant cation, the chemical water type becomes calcium or magnesium bicarbonate water. The changes from the naturally occurring calcium bicarbonate type water to the sodium chloride type water is an indication of contamination of the groundwater and the replacement of the calcium by sodium and the bicarbonate by chloride.

Around the CAW the major groundwater chemical type is the Calcium bicarbonate type with sodium chloride type to the south around Hayes Common-Raymonds and at depth within the limestone aquifer.

4.3.4.3 SOURCES OF GROUNDWATER CONTAMINATION

The assessment of any change in groundwater quality and type must include an evaluation of the possible sources of contamination and the impact each can have on water quality.

Around the CAW there are three main possible sources of contamination of groundwater. These are:

1 The intrusion of saltwater (saline intrusion) into the karstic aquifer as a result of the over pumping resulting in high chloride and sodium concentrations.
2 Industrialization, specifically the bauxite/alumina operations at Halse Hall consisting of the plant and the RDAs.
3 Municipal impacts from the improper disposal of liquid and solid wastes.

4.3.4.3.1 SALTWATER INTRUSION

The limestone formation responds as a Ghyben-Herzberg aquifer. The Ghyben-Herzberg Principle specifies that the occurrence of saline groundwater in a coastal aquifer, similar to that of the Rio Minho Hydrologic basin within which CAW is located, is dependent on the head of fresh water above sea level. A ratio if 1:40 i.e. one metre of fresh groundwater above sea level to 40 metres of fresh groundwater below sea level before entering the freshwater/saline water interface. This has been proven by Botbol in the adjoining Rio Cobre Hydrologic basin a karstic limestone area. Around the CAW with water levels averaging 5.75 metres above sea level there

should be 230 metres of freshwater below sea level and before the fresh/salt water interface is encountered.

Within the area of the CAW the potential for saline intrusion by way of upcoming from the Ghyben–Herzberg Zone is provided by the below sea level pumping depressions associated with the well fields around the Hayes Common-Raymonds area. The saline water can also be brought to the upper level of the aquifer by way of the faults, which act as preferred paths of flow due to the increased permeability along the fault zones. In addition the wells south of the CAW are all located along the South Coastal Fault Zone, which is open to the sea at both its eastern and western ends.

4.3.4.3.2 INDUSTRIALIZATION-BAUXITE/ALUMINA OPERATIONS

The bauxite/alumina industry produces a highly caustic waste known locally as “red mud”. This red mud is a thick fluid suspension with water content between 65–70 %, high concentrations of sodium and hydroxide ions; iron oxides and organic substances that on decomposition impart an unpleasant smell to the water. In the unlikely event of contamination, the pollutants present in the red mud waste are in sufficient quantities to make the groundwater unfit for domestic and agricultural uses.

CAW was constructed in the early 1970’s. The plant is located on the Clarendon Plains, an important agricultural region where over 90% of the irrigation water and 100% of the public water supply is derived from groundwater using wells tapping the limestone aquifer. The red mud is a potential agent for degrading this water quality with potential significant economic consequences.

The red mud is disposed of into residue disposal ponds or red mud lakes. Mud Lake 1 was commissioned into use on March 6, 1972. Mud Lakes 2 and 3 were constructed in 1980 and 1990 respectively. Mud Lake 4 was constructed in 2000 and the dike was raised in 2004. The lakes have all been sealed with clay in the base and the sides. Supernatant (caustic enriched) liquor and plant runoff are collected and stored in sealed lakes (clear and storm lakes) from where it is recycled into the plant. Total volume of mud in storage exceeds 15 million tones. In addition to the clay sealant, a geo-membrane (plastic) will also be used to seal RDA#6.

A dumpsite to the east of the plant (atop the fault that marks the boundary of Unit B) and at the foot of the Brazilletto Mountains is also a potential contaminant contributor. A wide assortment of materials from the plant is deposited in an unsealed area.

4.3.4.3.3 MUNICIPAL IMPACTS

The raid expansion of urbanization brought on by the economic contribution from the CAW has outstripped the infrastructure in place to deal with the proper treatment and disposal of wastes- solid and liquid. The only sewage treatment plant is located at Minerals Heights and it is overloaded with poor treatment and disposal of the effluent into the limestone aquifer.

The municipal garbage dump-a disused limestone quarry with no external drainage- was located at Mineral Heights north of the CAW and although the National Solid Waste Management Authority (NSWMA) has now discontinued its use, illegal dumping still takes place. The dump has not been closed in a scientific manner (no closure plan was submitted and no permit granted by NEPA) and the potential for groundwater contamination is still very high.

4.3.4.4 CONTAMINATION CRITERIA

The monitoring programmes established by Jamalco in conjunction with the Government of Jamaica regulating agencies (Water Resources Authority-WRA and Jamaica Bauxite Institute-JBI) are intended to detect above normal concentrations of the chemical constituents that are contaminants in the groundwater. The inclusion of the aesthetic indices such as colour, taste and odour also assist in the determination of the level of contamination of groundwater.

Five indices were specifically used to detect contamination from the bauxite/alumina operations. These are:

1 Sodium to chloride concentration ratio exceeding the maximum ratio encountered in uncontaminated groundwater in Jamaica of 1.5 (White and Rose 1975).

2 High sodium content. This alone is not a precise indicator as sodium chloride waters are found in the limestone aquifer as a result of saline intrusion. However in this form of contamination high sodium concentrations are associated with high chloride concentrations. This is not the case caustic contamination has taken place.

3 Sodium to calcium concentration ratio in excess of the ratios generally encountered in uncontaminated groundwater of 1.0

4 High pH values in excess of 8.5 units, the limit set by the US EPA and the WHO for drinking water and the maximum encountered in groundwater in Jamaica.

5 The presence of suspended solids, red discoloration, poor smell and unpleasant taste.

In addition high conductivity, TDS and alkalinity concentrations were used to determine the source and level of the contamination.

4.3.4.5 WATER QUALITY MONITORING

Jamalco has executed water quality monitoring around the CAW since 1989. The programmes have been intensified over the years to generate information on the impact of the bauxite/alumina operations on the groundwater quality of the limestone aquifer. Initially the programme consisted of monthly sampling and analysis of existing production wells within and around the CAW. The drilling of the monitor wells has led to the expansion of the monitoring programmes and the level of the analysis done. The monitoring and analysis has led to an increased database on which to base the evaluation of the impact of the bauxite/alumina operations on groundwater quality. To date the following have been completed and for which data is available:

1 Analysis on a monthly basis of production wells between January 1998 to the present for the parameters- pH, conductivity, chloride, sulphate, sodium, magnesium carbonate, calcium carbonate, and hardness. The sodium:chloride ratio was calculated from the analytical results for sodium and chloride concentrations. The sampling points included-Production wells 1 and 2, Hayes Common wells 1, 2 and 3, Dry River wells 2 and 5, Hayes Public well, Quaminus 2 well, Halse Hall well (Greenvale), Woodside well, Breadnut Valley well, Rocky Point (Morelands) well, Rocky Point drinking water (trucked water) and Webbers Gully.

2 The completion of the first 8 monitor wells in 1994 led to the expansion of the programme and provided monitor points that were not affected by pumping and tapped groundwater deep within the aquifer.

3 The completion of the next 4 monitor wells in 1997 further expanded the groundwater monitoring programme.

4 During the drilling of the monitor wells water samples were collected every 30 metres depth below the water table to ensure that a water quality profile of the monitor well could be developed. Each monitor well yielded 4 sets of samples. The parameters analyzed are shown in Table 4-8 below.

5 Since 1998 Jamalco has contracted a consultant to carry out quarterly sampling and analysis of all the wells as an independent assessment of the impacts of the bauxite/alumina operations on water quality. The samples are analyzed by a USEPA

and NELAP certified laboratory in the USA. The sample points and the parameters analyzed are shown in Table 4-9. Jamalco at the same time continues its independent sampling and analysis of the same monitor points.

6 In 2000 Jamalco instituted a twice-yearly sampling of all the sources of water to its facilities to assess the quality of water being used for domestic purposes. The sampling points and the parameters analyzed are shown in Table 4-10 below.

The data collected has been analyzed and to date no contamination of groundwater resulting from the bauxite/alumina operations has been detected.

TABLE 4-8: PARAMETERS ANALYZED TO DEVELOP WATER QUALITY DEPTH PROFILE FOR EACH MONITOR WELL, MW1 TO 12.

Group of Parameters	Constituents
Metals	Aluminium: Arsenic: Barium: Cadmium: Calcium: Chromium: Iron: Lead: Magnesium: Manganese: Mercury: Selenium: Silver: Sodium.
Inorganics	Cyanide (Total): Chloride: Carbonates: Bicarbonates: Nitrate: Sulphate: Hexavalent Chromium.
Physical/chemical	Turbidity: pH: Specific Conductance
Organics	Phenol: Polychlorinated Biphenyls (PCB): Naphthalene
VOAs (Volatile Organic Aromatic Compounds)	Acetone: Benzene: toluene: Carbon Tetrachloride: Vinyl Chloride: Chloroform: Chlorobenzene: 1,1-Dichloroethane: Methyl Ethyl Ketone (2-Butane)
TPH (Total Petroleum Hydrocarbons)	Hydrocarbons-Petroleum

TABLE 4-9: PARAMETERS ANALYZED TO DEVELOP WATER QUALITY DEPTH PROFILE FOR EACH MONITOR WELL, MW1 TO 12.

Sampling Point	Well Depth (m)	Use of Water	Parameters
Monitor Well 1	155.4	Monitoring	Lab:- Sodium
Monitor Well 2	155.4	Monitoring	Calcium,
Monitor Well 3	155.4	Monitoring	Magnesium
Monitor Well 4	155.4	Monitoring	Chloride
Monitor Well 5	155.4	Monitoring	Sulphate
Monitor Well 6	155.4	Monitoring	Nitrate
Monitor Well 8	155.4	Monitoring	TDS
Monitor Well 9	135.0	Monitoring	Alkalinity
Monitor Well 10	152.4	Monitoring	
Monitor Well 11	155.4	Monitoring	Field:- pH
New Bowens	70.1	Public Supply	Temp.
Dry River 3	76.2	Industrial	Cond.

Sampling Point	Well Depth (m)	Use of Water	Parameters
Dry River 4	55.8	Irrigation	
Hayes Public	67.0	Public Supply	Water Levels
Production 1	86.3	Industrial	Na:Cl ratio
Production 2	122.0	Industrial	Calculated

For each sample set duplicate samples are collected and a comparison made of the analytical results between the Jamalco Laboratory and the USEPA Laboratory in the USA that analyses the samples. The comparison indicates that on the whole the results compare favourably. However, at times the difference in the chloride concentration has exceeded the permissible difference of 10%. This is probably due to the fact that the samples were not preserved in the field and were analyzed by Jamalco beyond the maximum holding time.

TABLE 4-10: : LIST OF FACILITIES, SOURCES, SAMPLE SITES AND PARAMETERS ANALYZED TWICE ANNUALLY

Facility/Location	Source/Supply	Sample Site	Parameters
Clarendon Alumina Works [CAW]	Production Well 1	At Well Head	**Metals:** Aluminium; Arsenic: Cadmium: Calcium: Copper: Iron: Lead: Magnesium; Manganese: Mercury: Selenium: Sodium: Zinc **Non-metals:** Chloride; Cyanide: Fluoride; Nitrate: Sulphate: TDS: pH; Temp.: **Bacteria:** Coliform -T and F **Pesticides:** gamma-BHC: Aldrin: Dieldrin: 4,4'-DDT: Technical Chlordane: Methoxychlor. **Organics:** 1,1-Dichloroethane: Chloroform: Benzene: 1,2-Dichloroethane: 2,4,6-Trichlorophenol: Pentachlorophenol: Hexachloroethane: Benzo(a)Pyrene.
	Production Well 2	At Well Head	
	Dry River Well 3	At Well Head	
	Groundwater from PW 1/PW 2 after Treatment	Drinking Fountain in Building 1	
Halse Hall Great House	Great House Well	At Well Head	
	Great House Well after Treatment	At Great House Kitchen Tap	
Breadnut Valley	Breadnut Valley Well	At Well Head	
	Breadnut Valley Well after Treatment	Drinking Fountain in Plant Office	
Woodside Lands Office	NWC Supply from Kraal Well 1	Drinking Fountain in Main Office	
Rocky Point Port	Trucked Water	Domestic Tank Tap	
Waterloo Road Office	NWC Supply from Hermitage Dam	Tap in Office Kitchen/Pantry	

4.3.4.5.1 ANALYTICAL RESULTS

4.3.4.5.1.1 Borehole Profile

The samples collected from each borehole at 30 metre intervals during drilling indicate that no contamination resulting from the bauxite/alumina operations was detected in any of the wells. In several wells the sodium concentration was higher than normal but so was the chloride concentration. The Na:Cl ratios were at all times less than 1.

It is noteworthy that Arsenic, Cadmium, Mercury, Selenium or Silver was detected at any depth within any of the wells.

Phenol was the only organic compound detected at one level in 5 of the wells and all at very low concentrations (above detection level) but within the WHO drinking water guideline.

No Volatile Aromatic Compound was detected at any concentration that exceeded the guideline values.

No significant concentration of TPH was detected.

4.3.4.5.1.2 Monthly Sampling and Analysis

The results for the monthly sampling and analysis programme are shown plotted for four of the monitoring points-3 monitor wells and 1 production well. The points are MW 5 to the west of the RDAs; MW 9 to the east of the RDAs; MW 10 to the south of the RDAs and Hayes Public well located to the south of the RDAs and between MW 9 and MW 10. The Hayes Public well was selected, as this well is the source of the water supply for the Hayes community and has been the discussion of many community meetings as to its quality and suitability for domestic uses. The plots of the sodium, chloride and sulphate concentrations are shown as Figure 4-8 to Figure 4-11.

At MW 5, to the west of the RDAs, the data plot shows no significant increase in the sodium concentration over time. There is a close correlation between the chloride and sodium concentrations. In all cases the Na:Cl ratio is less than 1.

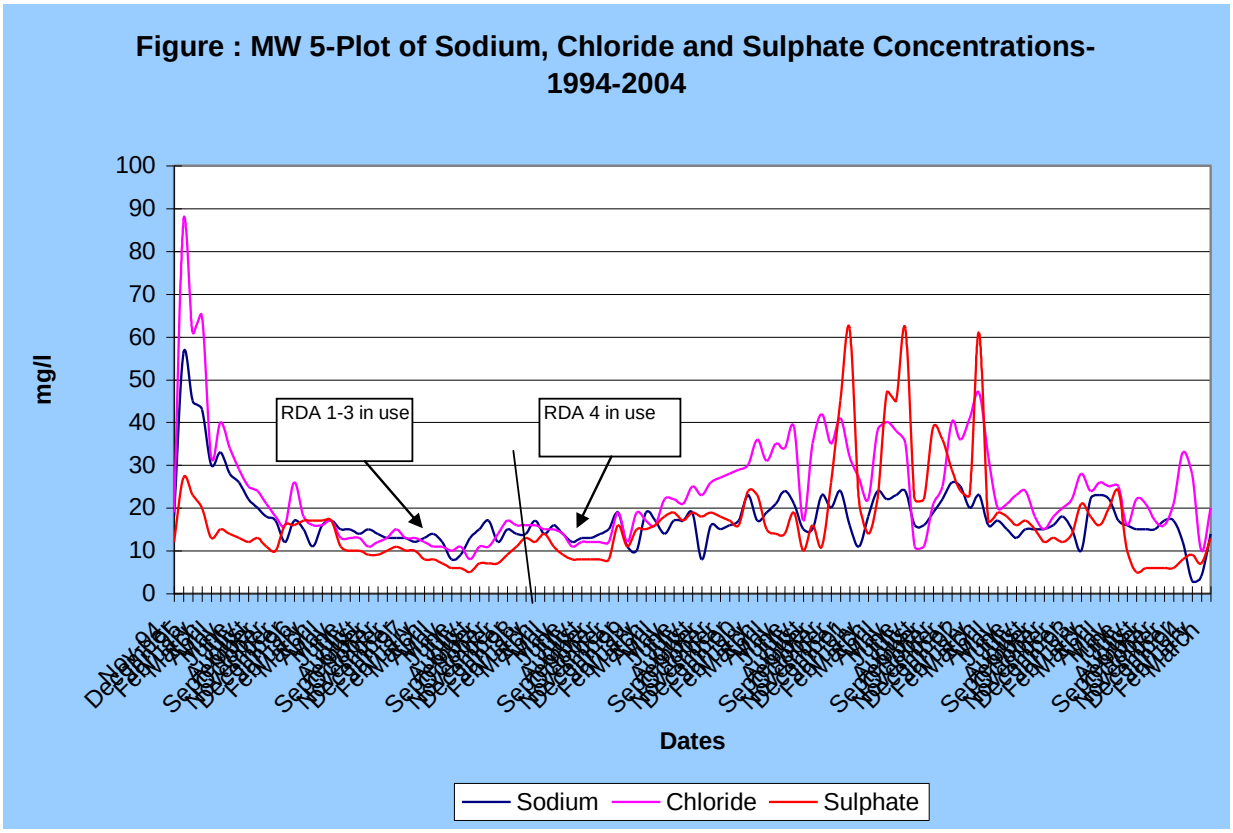


FIGURE 4-8: MW5-PLOT OF SODIUM, CHLORIDE, AND SULPHATE CONCENTRATIONS- 1994-2004

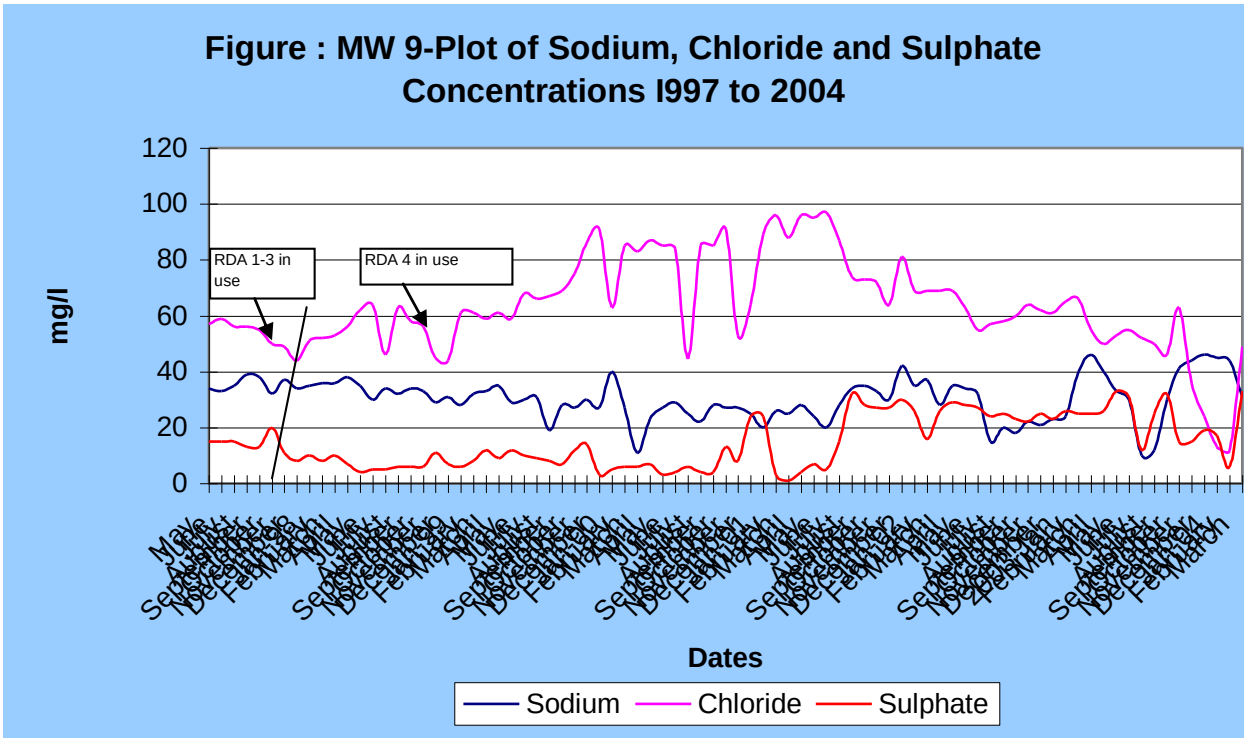


FIGURE 4-9: MW 9- PLOT OF SODIUM, CHLORIDE AND SULPHATE CONCENTRATIONS 1997 TO 2004

At MW 9, to the east of the RDAs, the plot while showing a varying concentration for sodium does not show a trend toward an increasing concentration. The chloride shows an increasing upward trend in concentration up to June 2001 where after there is a decline in the concentration. This increased chloride concentration is probably due to the less than average rainfall/recharge between 1999 to 2000 and the increased pumping to meet water demand. Here also the high chloride concentration compared to the lower sodium concentration would ensure that the Na:Cl ratio is less than 1.

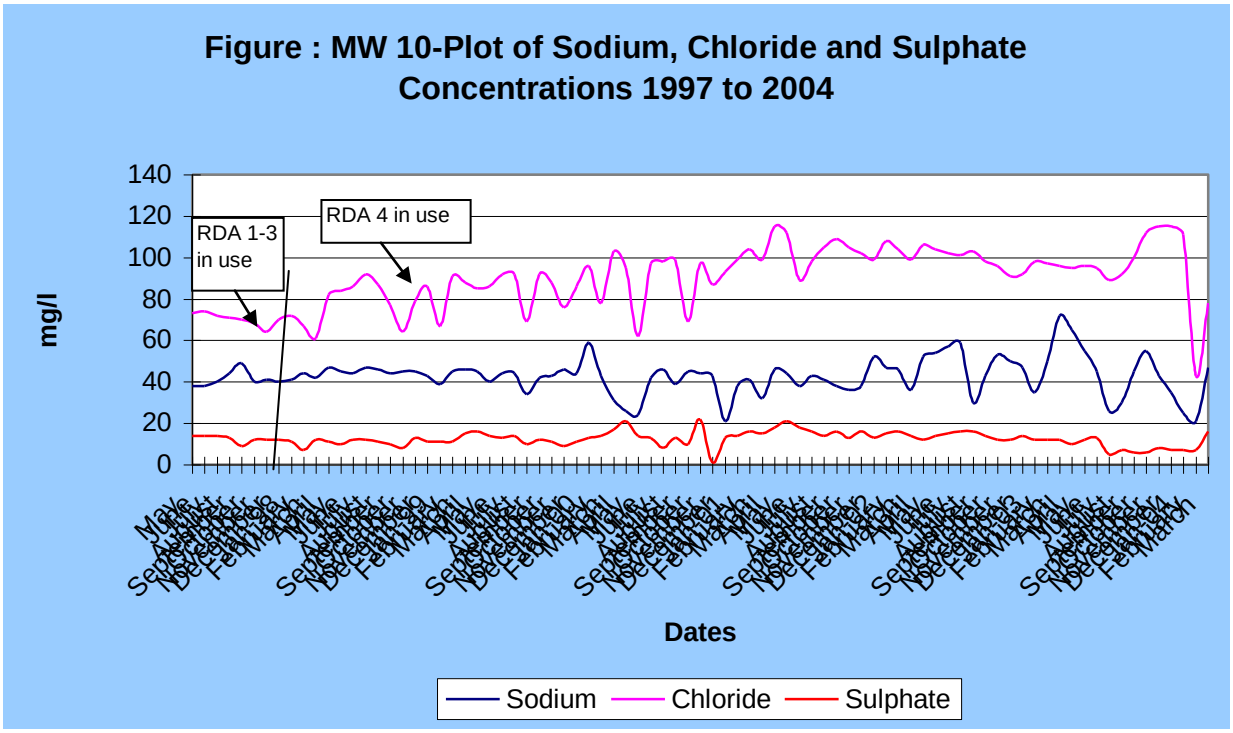


FIGURE 4-10: MW 10- PLOT OF SODIUM, CHLORIDE, AND SULPHATE CONCENTRATIONS 1997 TO 2004

At MW 10, to the south of the RDAs, there is a trend to an increase in chloride concentration. This well is located close to the Dry River 4 irrigation well that has reported chloride concentrations of up to 150 mg/l. There has not been a trend towards an increase in the sodium and sulphate concentrations.

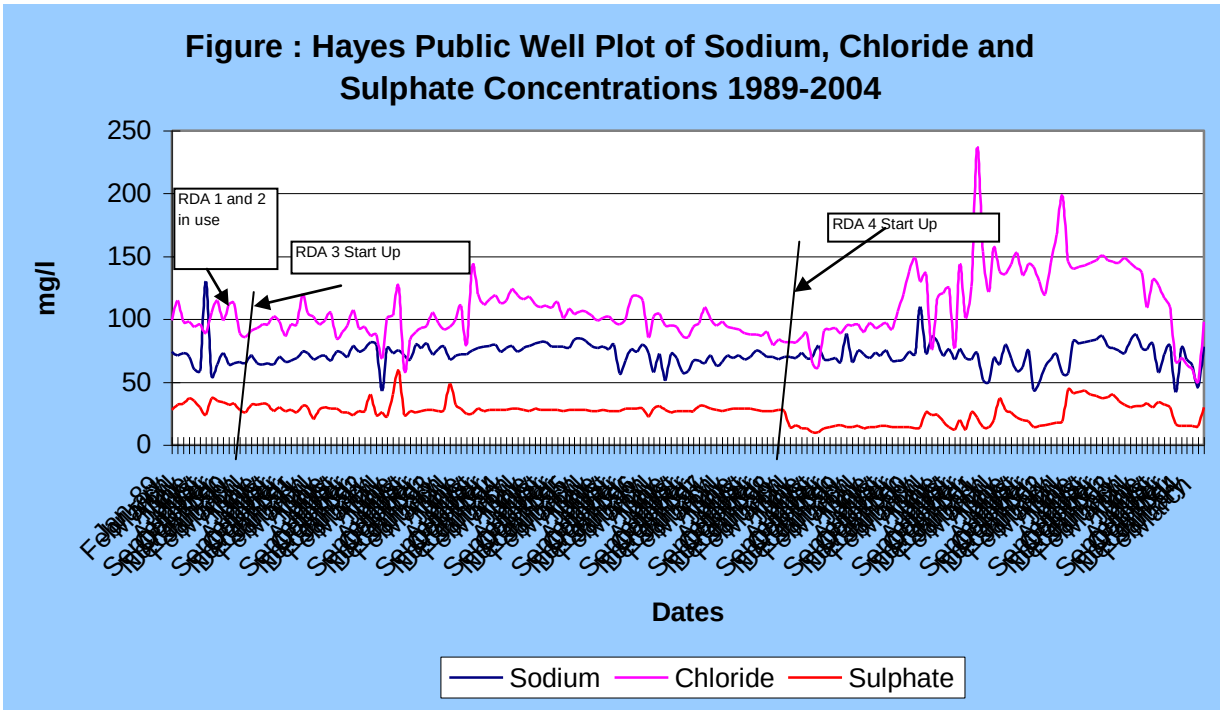


FIGURE 4-11: HAYES PUBLIC WELL OF SODIUM, CHLORIDE AND SULPHATE CONCENTRATIONS 1989-2004

At the Hayes Public well, also south of the RDAs, the plot shows a very constant concentration of sodium and chloride up to the year 2000. The chloride concentration has shown an increase since 2000 that again may be due to the below average recharge and increased pumping. This well is the most southern of the monitor points and is the closest to the South Coastal Fault and the wells at Hayes Common that show high chloride concentrations exceeding 350 mg/l at times. The Na:Cl ratio here is also less than 1.

The controversy of the possible contamination of the Hayes Public well has led to many meetings between Jamalco and the Hayes community. The monthly sampling does not show any caustic contamination at the Hayes well. Further investigation was recommended and on July 2004 a second sample was collected and analyzed for heavy metals. The results are presented below in Table 4-11.

As can be seen no parameter exceeded the World Health Organization (WHO) guideline value for drinking water. Aluminium concentration was equal to the WHO guideline value of 0.20 mg/l. Aluminium has no toxicological effect on the human body. The concentration of Copper was reported at 0.029 mg/l with a guideline value of 1.0 mg/l. Barium was reported at <0.0005 mg/l. There is no guideline value for Barium but the laboratory detection limit is 0.010 mg/l. All the

other ten parameters that were analyzed had concentrations less than the Laboratory Reporting Limit (LRL).

The water quality from the Hayes Public Supply well meets the drinking water guidelines and is suitable for use as a domestic water supply. The bauxite/alumina operations have not impacted on the water quality in the limestone aquifer, to affect that being abstracted at the Hayes Public Supply well.

TABLE 4-11: ANALYTICAL RESULTS OF HEAVY METALS FOR HAYES PUBLIC WELL (NWC) – JULY 2004.

Parameter	Concentration (mg/l)	Lab Reporting Limit (LRL) (mg/l)	WHO Guideline Limit for Drinking Water (mg/l)	Remarks
Aluminium	0.20	0.10	0.20	
Antimony	N.D.	0.50	0.002	
Arsenic	<0.005	0.50	0.05	
Barium	<0.0005	0.010	None	
Beryllium	N.D.	0.0050	None	
Cadmium	<0.0005	0.010	0.005	
Chromium	N.D.	0.020	0.05	
Copper	0.029	0.010	1.0	
Iron	0.016	0.10	0.3	
Lead	<0.005	0.10	0.05	
Manganese	<0.005	0.010	0.1	
Mercury	<0.0002	0.00020	0.001	
Nickel	N.D.	0.020	None	
Selenium	<0.005	0.50	0.01	
Thallium	<0.50	0.50	0.006	
Zinc	<0.020	0.020	5.0	

4.3.4.5.1.3 Facilities Sampling

The sampling of sources of water being supplied to Jamalcos' facilities across Clarendon and the Kingston Office is executed twice per year-once in the dry season and once in the wet season. The objective of the sampling programme is to determine the quality of water supplied for use within the facility and to determine the impact of the bauxite/alumina operations on water quality. As shown in Table 4-10 the facilities are supplied with water from both Jamalco's own wells and from the National Water Commission's public supply. The analysis is for specific parameters and covers metals, non-metals, pesticides, PCBs and volatile organics. The results for July 2004, the last sample period, are presented as Table 4-12 to Table 4-15. The results indicate that the bauxite/alumina operations, the disused solid waste dump at Mineral Heights and the sewage disposal methods in the Mineral Heights-May Pan area have not impacted on the water quality in the limestone aquifer.

TABLE 4-12: Summary of Analytical Results and Field Data – April 2004

PARAMETER	MONITORING WELL RESULTS(mg/l)											WHO DW Guideline (mg/l)	US EPA DW Standard (mg/l)	Typical Limestone Aquifer *WQ (mg/l)
	MW-1	MW-2	MW-3	MW-4	MW-5	MW-6	MW-8	MW-9	MW-10	MW-11	MW-12			
LAB RESULTS														
CALCIUM	72	74	NO	78	66	110	80	63	60	170	NO SAMPLE	75		75
MAGNESIUM	33	41		53	12	44	46	37	37	22		150		10
SODIUM	71	180	S	250	17	280	170	31	47	290		200	200	12
CHLORIDE	26	350	A	430	20	470	360	49	78	410		250	250	10
NA/CL RATIO	2.73	0.51	M	0.58	0.85	0.60	0.47	0.63	0.60	0.71		-	-	<1.5
ALKALINITY	260	250	P	250	210	310	260	280	270	510		-	-	260
**NITRATE	0.24	0.13	L	<0.050	0.073	1.00	0.17	0.069	0.12	0.18		10 (as N)	10 (as N)	4
SULFATE	19	23	E	60	13	58	38	33	16	63		400	250	8
TDS	340	850	HOLE	1100	290	1300	880	390	430	1300		-	500	350
Field Data														
TEMP. (*C)	29.2	29.8	Blocked	33.1	31.7	30.6	31.0	28.9	28.8	25.1		-	-	
PH	7.46	7.71	At 144'	7.51	7.53	7.29	7.48	7.52	7.53	7.44		6.5-8.5	6.5-8.5	7.2
COND. (uS)	569	1430		1930	500	2050	1460	681	742	2150		-	-	550
DTW (m)	51.46	43.71	42.43	35.54	32.93	32.26	34.95	38.10	33.38	47.91				
DOW (m)	152.4	155.4	155.4	155.4	155.4	152.4	155.4	135.00	152.4	155.4	143.2			
TOW ELEV. (m)	56.66	49.34	47.66	40.49	37.90	36.77	39.92	42.90	38.19	53.25	50.24			
WATER(m)(amsl)	5.20	5.63	5.23	4.95	4.97	4.51	4.97	4.80	4.81	5.34				
ODOUR/OTHER										Very Turbid				

***Shaded Values = exceedances *WQ – Water Quality. NS – Not Sampled. **Nitrate – As N includes Nitrite if present. ND – Not Detected NP – Well Not**

TABLE 4-13: Summary of Analytical Results and Field Data – April 2004

PARAMETER	MONITORING WELL RESULTS (mg/l)											WHO DW Guidelines (mg/l)	US EPA DW Standards (mg/l)	Typical Limestone Aquifer WQ(mg/l)
	PW-1	PW-2	HP	NB	DR-3	DR-4								
LAB RESULTS														
CALCIUM	88	88	98	77	PUMP OUT	100						75		75
MAGNESIUM	14	16	20	11		23						150		10
SODIUM	42	43	78	22		87						200	200	12
CHLORIDE	52	70	98	31		140						250	250	10
NA/CL RATIO	0.81	0.61	0.80	0.71		0.62						-	-	<1.5
ALKALINITY	270	260	310	240		330						-	-	260
**NITRATE	2.2	2.1	1.5	1.9		1.3						10 (as N)	10 (as N)	4
SULFATE	15	15	30	5.4		34						400	250	8
TDS	410	380	560	320		610						-	500	350
Field Data														
TEMP. (*C)	24.6	25.4	26.1	24.5		25.8						-	-	
pH	7.74	7.71	7.44	7.63		7.53						6.5-8.5	6.5-8.5	7.2
COND. (uS)	659	700	900	481		969						-	-	550
DTW (m)	ND	ND	ND	ND	ND	ND								
DOW (m)	86.3	122	67.0	70.1	76.2	55.8								
TOW ELEV. (m)														
WATER(m)(amsl)														

***Shaded Values = exceedances *WQ – Water Quality. NS – Not Sampled. **Nitrate – As N includes Nitrite if present. ND – Not Detected NP – Well Not Pumping**

TABLE 4-14: Analytical Results-Metals-January 2004

PARAMETERS	MONITORING POINTS RESULTS (mg/l)											LRL* (mg/l)	WHO DW Stds (mg/l)	US EPA DW Stds. (mg/l)
	Production Well 1	Production Well 2	Buildg 1 Ftn.	Plant Stores Ftn	Great House Well	Great House Tap	WS Tap	BV-Well	BV-Tap	RP Tap	WR Tap			
METALS														
Aluminium	0.24	0.23	0.22	0.23	0.21	No	0.20	0.26	0.24	0.20	0.29	0.1	0.2	None
Arsenic	<0.005	<0.005	<0.005	<0.005	<0.005		<0.005	<0.005	<0.005	<0.005	<0.005	0.005	0.05	0.03
Cadmium	<0.0005	<0.0005	0.00072	<0.0005	<0.0005	Data	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	0.0005	0.005	0.005
Calcium	91	91	90	89	85		80	97	97	78	43	0.5	75	None
Copper	<0.002	0.0041	0.57	0.0064	<0.002	Sample	0.0097	0.0094	0.16	0.0066	<0.002	0.005	1.0	1.3
Iron	0.047	0.014	0.063	0.014	0.010		0.034	0.18	0.020	0.036	0.012	0.1	0.3	0.3
Lead	<0.005	<0.005	<0.005	<0.005	<0.005	Bottle	<0.005	<0.005	<0.005	<0.005	<0.005	0.002	0.05	0
Magnesium	15	15	15	15	12		9.3	1.4	1.4	15	10	0.1	150	None
Manganese	< 0.005	<0.005	<0.005	0.018	<0.005	Broke	<0.005	<0.005	<0.005	<0.005	0.008	0.005	0.1	0.05
Mercury	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002		<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	0.0002	0.001	0.002
Selenium	0.006	<0.005	<0.005	<0.005	<0.005	Spilt	<0.005	<0.005	<0.005	<0.005	<0.005	0.005	0.01	0.05
Sodium	48	48	48	48	21		7.2	5.8	5.6	48	10	0.5	200	200
Zinc	0.099	<0.020	0.13	2.2	<0.020	Sample	2.1	0.038	0.026	<0.020	<0.020	0.02	5.0	5.0

NOTES

Production Well 1-At well head

***LRL-Laboratory**

Reporting Limit

Production Well 2-At well head

Plant Stores-At Drinking Water Fountain

Buildg 1 Ftn - Building 1 Drinking Water Fountain

Great House Well - At Well Head

Great House Tap – Kitchen Tap

WS Tap - Woodside Drinking Water Fountain (NWC Supply)

BV Well – Breadnut Valley Well – At Well Head

BV Tap – Breadnut Valley Drinking Water Fountain

RP Tap – Rocky Point Port Drinking Water Tank-At Tap (Trucked Water)

TABLE 4-15: Analytical Results-Non-Metals and Bacteriological-January 2004

PARAMETERS	MONITORING POINTS RESULTS (mg/l)											LRL* (mg/l)	WHO DW Stds. (mg/l)	US EPA DW Stds. (mg/l)
	Production well 1	Production well 2	Buildg 1 Ftn	Plant Stores Ftn	Great House Well	Great House Tap	WS Tap	BV-Well	BV-Tap	RP Tap	WR Tap			
NON-METALS														
Chloride	56	58	58	57	27	27	10	13	12	61	10	1	250	250
Cyanide	0.0033	<0.001	<0.001	<0.001	0.0014	<0.001	0.0012	0.0011	0.0026	0.003	0.0048	0.001	0.1	0.1
Fluoride	0.16	0.13	0.13	<0.10	<0.10	0.14	0.14	<0.10	<0.10	0.12	0.10	0.1	1.5	4
Nitrate*	2.4	2.6	2.7	2.2	2.4	2.4	1.7	1.5	1.5	2.4	0.23	0.05	10	10
Sulphate	22	23	21	22	6.9	6.5	3.5	2.4	2.5	23	39	2	400	250
Total Dissolved Solids (TDS)	430	430	420	430	310	320	270	270	260	390	210	10	1000	500
PH	7.44	7.57	7.77	7.42	7.58	7.78	7.44	7.44	7.45	7.77	8.01	NA	6.5-8.5	6.5-8.5
Temperature	24	24.5	10.5	13.4	25.3	26.1	29.3	30.1	18.8	28.6	25.4	NA	None	None
BACTERIOLOGICAL (MPN/100ml)														
Total Coli form	< 3	< 3	<3	<3	< 3	<3	<3	<3	< 3	<3	< 3	NA	0	0
Faecal Coliform	< 3	< 3	< 3	<3	< 3	<3	<3	< 3	< 3	< 3	< 3	NA	0	0

NOTES

Production Well 1-At well head

Reporting Limit

Plant Stores-At Drinking Water Fountain

Production Well 2-At well head

Buildg 1 Ftn - Building 1 Drinking Water Fountain

Great House Well - At Well Head

Great House Tap –Kitchen Tap

WS Tap - Woodside Drinking Water Fountain (NWC Supply)

BV Well – Breadnut Valley Well – At Well Head

BV Tap – Breadnut Valley Drinking Water Fountain

RP Tap – Rocky Point Port Drinking Water Tank-At Tap (Trucked Water)

WR Tap – Waterloo Road Office Kitchen Tap (NWC Supply)

***LRL-Laboratory**

***Nitrate-Nitrogen**

TABLE 4-16: Analytical Results-Pesticides/PCBs-January 2004

PARAMETERS	MONITORING POINTS RESULTS (ppb)											LRL* (ppb)	WHO DW Stds (ppb)	US EPA DW Stds. (ppb)
	Production well 1	Production well 2	Buildg 1 Ftn	Plant Stores Ftn	Great House Well	Great House Tap	WS Tap	BV-Well	BV-Tap	RP Tap	WR Tap			
PESTICIDES /PCBs														
gamma-BHC [Lindane]	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0.05	3	0.2
Aldrin	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0.05	0.03	NF
Dieldrin	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.1	0.03	NF
4, 4'-DDT	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	0.3	1	NF
Technical Chlordane	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	1	0.3	2
Methoxychlor	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	0.5	30	40

*LRL-Laboratory Reporting Limit NF-None Found

TABLE 4-17: Analytical Results-Organics-January 2004

PARAMETERS	MONITORING POINTS RESULTS (ppb)											LRL* (ppb)	WHO DW Stds. (ppb)	US EPA DW Stds. (ppb)
	Production well 1	Production well 2	Buildg 1 Ftn	Plant Stores Ftn	Great House Well	Great House Tap	WS Tap	BV-Well	BV-Tap	RP Tap	WR Tap			
ORGANICS														
1, 1-Dichloroethane*	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	5	NF	5
Chloroform*	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	5	30	100
Benzene*	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	5	NF	5
1, 2-Dichloroethane*	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	5	10	NF
2,4,6-Trichlorophenol+	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	10	10	NF
Pentachlorophenol+	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	50	10	30
Hexachloroethane+	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	10	NF	NF
Benzo(a)Pyrene+	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	10	0.01	NF

***Volatile Organic Compounds---+Base Neutral/Acid Compounds:**

NR-Not Reported ***LRL-Laboratory Reporting Limit**

4.3.5 RISKS TO WATER RESOURCES

The construction of Residue Disposal Area 6 (RDA 6) has the potential to lead to increased risks to ground and surface waters of the Central Plains of the Rio Minho Hydrologic Basin. The increased potential risk will be:

- The potential for leakage from the RDA into the groundwater resources.
- The impact of flooding of the Rio Minho River to the RDA; and
- The impact of breach of the dike of the RDA and the release of red mud and caustic effluent into the Rio Minho.

However, given the history of the operations, effectiveness, of design, construction, management and monitoring; the likelihood of this occurring is remote. Furthermore, in addition to the clay sealant normally used to make the RDAs impermeable, a geo-membrane liner will also be used in RDA#6.

4.3.6 LEAKAGE FROM RDA

The RDA will be located north of the existing Clear Lake and just west of the New Bowens Housing Scheme. The area is underlain by an alluvial deposit that consists of very fine sand and clay that in turn overlies the limestone aquifer. The closest well to the RDA is the Howards well-Block B. The lithology of this well shows that the overburden is 9.6 metres thick. There is no exposed limestone at the proposed site of the RDA 6 and with the proper and effective seal there should be no impact on groundwater quality. In addition the return of the effluent from the dry stacking system to the process will remove that fraction of potential contaminant that could possibly contaminate the aquifer.

4.3.7 FLOODING FROM RIO MINHO

RDAs 1to 5 and now 6 are all located within the flood plain of the Rio Minho River. The Rio Minho in the vicinity of the Halse Hall area is dry for most of the year and only carries water during the periods of high rainfall events. A recent hydrologic analysis and flood plain map was prepared by the WRA for the UNDP/ODPEM community flood-warning project. The WRA mapped the reach of the river between May Pen and the coast

including the area around the RDAs and the proposed site of the RDA 6 at Howards. The mapping indicated that the RDA 6 site will be affected by the 25, 50 and 100-year flood event. The area of the RDA 6 to be affected will be the western section extending from the southwest corner at Dunkleys to the northwest corner near Parnassus- approximately 25% of the proposed RDA area. The Jamalco train bridge across the Rio Minho in the vicinity of Dunkleys is the potential cause of this flood impact. This bridge when included in the hydrologic model causes the flood waters to spread out over the area between Dunkleys and Howards and affecting the site of RDA 6. Clearly the bridge will have to be redesigned and reconstructed to allow for a greater flow of water and debris so as not to impact on RDA 6. If this is not done, then significant flood proofing of the area east of the Rio Minho will have to be done to protect RDA 6.

4.3.8 BREACH OF DIKE

The breach of the dike around the RDA could be effected by the impact of the floodwaters from the Rio Minho River; from seismic activities associated with the South Coastal Fault; from erosion as a result of a significant rainfall event or from structural defects during construction. In any case there is a need to ensure that the breach does not contaminate water resources. At immediate risk is the surface water of the Rio Minho and the agricultural production in the southern plains that depend on the use of the river flow below Alley for irrigation uses. Jamalco has in place an emergency response plan and will secure bunding atop the terrace of the flood plain to retain any spilled material and ensure that very little or none escapes to the environment. Clearly the issues discussed above must be effectively dealt with to remove the risk to the environment.

4.4 AIR QUALITY AND WEATHER

4.4.1 AIR QUALITY

4.4.1.1 AIR QUALITY MANAGEMENT PROGRAM

Jamalco has developed and maintained an Air Emissions Management Program to ensure compliance with the Natural Resources Conservation Authority (NRCA) ambient air quality standards, pending air quality regulations, Alcoa Air Emissions standards as well as to conform with ISO 14001 requirements and the company's EHS policy.

The refinery which is the major source for atmospheric emissions is approximately 165 feet above mean sea level (amsl) and is surrounded by a mix of undeveloped and residential land uses. The terrain elevations rise up to over 400 feet amsl at approximately 2000 feet to the east of the refinery. The existing or proposed RDAs are not considered significant sources of air emissions.

4.4.1.1.1 METEOROLOGICAL FEATURES

The facility operates an on-site meteorological tower, which is located at the center of the refinery. Hourly observations are monitored which include:

- Wind speed
- Wind direction
- Air temperature
- Barometric Pressure
- Ground temperature
- Precipitation and,
- Standard deviation of the Wind direction.

Analysis of data derived from the onsite tower indicates that predominantly there is a strong occurrence of light winds from the northeast, which is typical for areas within this tropical latitude. See wind rose, which shows a joint frequency distribution based on the wind speed and direction for each hour of the year.

4.4.1.1.2 AIR EMISSIONS

The primary emissions that are released from the refinery include particulates, NO_x, SO_2, CO, neglible quantities of VOCs and trace levels of metal.

4.4.1.1.2.1 Particulates

Emissions of particulates are released from the calciners, boilers and medical waste incinerator. In addition, particulates are intermittently released as a result of mining activities, windblown dust associated with bulk material handling, transportation and stocking of raw material (bauxite), intermediate product (hydrate) and the alumina product itself.

Particulate emissions have also been associated with the Residue Disposal Area (RDAs) should the surface of these lakes become dry.

Proven particulate control and dust suppression strategies have been employed at Jamalco facilities, which have significantly minimized particulate and fugitive dust emissions.

These include but not limited to the use of hooded conveyors, sprinkler systems, cyclones, bag houses and ESPs.

The location has implemented a number of fugitive emission control measures inclusive of the following:

- Controlling fugitive particulate emissions from storage piles through enclosures, covers or stabilization, minimizing the slope of the upwind face of piles where practicable. Confining as much pile activity as possible to the down wind side of piles.
- Limiting the size of loads to minimize loss of material to wind and spillage.
- Planting special wind breaks at critical points.
- Prompt removal of soil and other dust -forming debris from paved roads and scraping and compaction of unpaved roads to stabilize the road surface as often as necessary to minimize re-entrainment of fugitive particulate matter from the road surface.
- Vegetating areas with grass.
- To the extent practicable restricting vehicular travel to established paved roads.
- Watering of unpaved roads and other unpaved open spaces as often as necessary to minimize re-entrainment of fugitive particulate matter from these surfaces. Drip irrigation is also practiced at the refinery.
- Maintaining good house keeping practices to minimize the accumulation of materials, which could become fugitive.

The major source of fugitive dust at Jamalco is from open areas (uncovered with grass or unpaved).

A sprinkler based dust suppression system is proposed for DRDA 6.

4.4.1.1.2.2 NOx Emissions

NOx emissions are not anticipated to be an issue during the implementation of the DRDA project.

4.4.1.1.2.3 SO_2 and CO Emissions

Sulphur dioxide and carbon monoxide emissions are not anticipated to be an issue during the implementation of the DRDA project.

4.4.1.1.2.4 Trace Metals

Trace Metals such as mercury are not anticipated to be an issue during the implementation of the DRDA project.

4.4.1.1.2.5 Ambient Air Quality Monitoring

Jamalco operates two ambient air-monitoring stations located in the New Bowens and Corn Piece communities. These stations are capable of monitoring SO_2, NOx, COx and Ozone.

Data derived from these stations have consistently shown levels below the Jamaican Ambient Air Quality standards.

Monthly monitoring reports are submitted to the regulatory agencies through the Jamaica Bauxite Institute (JBI), which have responsibility to conduct environmental monitoring of the Bauxite & Alumina Industry.

Calibration checks are conducted on the monitors on a scheduled basis and are done within applicable test methods and manufacturers specifications.

Jamalco also maintains a stringent TSP monitoring program. There are seven (7) permanent TSP monitoring stations; these are located in communities around the refinery, at the RDAs, Breadnut Valley and at the Rocky Point Port facility.

4.5 WEATHER

4.5.1 REGIONAL SETTING/SPHERE OF INFLUENCE

Jamalco's refinery is located in Halse Hall, Clarendon between the New Bowens settlement to the north, Cornpiece to the south, the Braziletto Mountains to the east and its red mud lakes to the west. The plant has been in its present location since 1972 and is the largest industrial facility in the general area.

Major settlements in the area of the plant include:

- Cornpiece
- New Bowens
- Raymonds
- Kemps Hill
- Race Course
- Lionel Town
- Savannah
- Hayes
- Halse Hall
- Hayes Newtown
- Mineral Heights
- Alley

4.5.2 RDA REGIONAL CLIMATE

South Clarendon has a dry climate. With poor surface drainage and extremely permeable soils, the area is heavily dependent on catchment of rainfall and often suffers from drought.

4.5.3 RAINFALL

Rainfall totals for the southern Clarendon region are low when compared to that of the northern Manchester regions. Over the period 1983 – 2003 the area averaged 988.1 mm (38.9 inches) of rainfall with a monthly average of 83.1 mm (3.27 inches). The area experiences its wettest period during the months of May-June (90 – 163 mm) and August-November (89 – 154 mm).

This generally low rainfall is responsible for the aggressive and well maintained irrigation regime employed at the Jamalco refinery to manage the real potential for fugitive dust emissions.

TABLE 4-18: ANNUAL RAINFALL - INCHES. JAMALCO REFINERY

YEAR	Month												YEAR'S TOTAL	MONTHLY AVERAGE
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC		
1983	0.44	6.68	0.40		2.54	6.48	0.06	6.36	1.42	5.29	2.01	0.16	31.84	2.89
1984	0.52	2.17	5.39	0.58	5.37	3.62	2.13	1.76	5.88	3.86	1.75	0.07	33.10	2.76
1985	0.14	-	-	-	-	-	-	2.45	1.86	8.62	7.74	1.12	21.93	1.83
1986	1.95	0.78	1.05	3.53	-	22.56	1.36	0.52	3.36	8.87	2.01	0.78	46.77	3.90
1987	1.86	0.28	0.16	6.90	6.48	1.31	1.70	3.04	1.46	17.38	5.52	3.10	49.19	4.10
1988	0.10	0.63	1.63	2.20	5.62	1.59	1.65	8.70	8.81	1.24	6.53	1.81	40.51	3.38
1989	2.99	1.60	3.01	0.74	4.64	1.40	0.21	1.61	7.15	0.98	1.22	0.36	25.91	2.16
1990	2.04	0.79	1.78	2.51	1.43	2.11	2.26	0.60	1.33	6.59	7.68	1.80	30.92	2.58
1991	0.39	0.26	1.58	1.46	7.52	0.37	1.66	1.67	2.36	2.24	3.37	0.37	23.25	1.94
1992	0.21	2.22	0.38	1.61	9.11	2.95	0.47	2.14	4.36	2.82	1.24	0.22	27.73	2.31
1993	3.60	3.54	4.62	7.89	27.45	0.75	1.82	0.75	4.76	0.68	3.59	7.27	66.72	5.56
1994	1.74	0.07	2.62	3.29	4.10	0.00	1.70	4.10	3.22	0.58	13.85	0.70	35.97	3.00
1995	2.75	0.80	2.31	5.09	6.19	3.05	1.13	13.08	8.32	17.70	0.87	1.83	63.12	5.26
1996	1.40	0.17	0.90	0.94	0.60	0.92	2.17	4.40	6.12	6.83	7.22	0.03	31.70	2.64
1997	1.03	0.89	1.26	1.36	0.85	7.88	0.33	0.64	5.70	6.47	3.14	2.15	31.70	2.64
1998	0.74	1.54	8.55	2.53	0.67	1.14	4.96	4.15	11.36	5.71	2.21	4.66	48.22	4.02
1999	0.87	3.10	6.93	0.93	2.43	3.67	2.96	1.75	13.63	11.73	8.87	1.99	58.86	4.91
2000	0.77	1.75	1.65	3.47	1.28	0.85	2.47	2.00	9.28	3.80	1.05	6.19	34.56	2.88
2001	1.75	0.35	0.49	1.48	6.14	0.09	1.73	0.55	2.31	5.30	8.55	5.78	34.52	2.88
2002	3.27	1.81	2.39	3.80	20.05	6.68	0.34	0.47	22.48	6.04	0.94	1.60	69.87	5.82
2003	1.31	0.91	1.97	3.00	14.72	3.46	1.08	12.64	2.28	3.30	1.46	1.11	47.24	3.94
2004	1.07	0.16	0.24	0.16	1.07								2.70	0.54

Review of temperature data collected at the Jamalco refinery meteorological station at the refinery for a period 1999 -2003, indicates that the maximum temperatures range from 34.5 deg. Celsius to 31 deg. Celsius and that the low temperatures range from 24 deg. Celsius to 18.9 degrees. The intense and prolonged heat of this typically xerophytic environment combined with the low rainfall results in a dry and sometimes dusty environment, if no controls are in place.

Jamalco has a sprinkling and irrigation regime for exposed areas of the plant, which includes landscaping and irrigation of open spaces.

TABLE 4-19: TEMPERATURE - JAMALCO REFINERY

MONTHS	1999		2000		2001		2002		2003	
	MAX.	MIN.	MAX.	MIN.	MAX.	MIN.	MAX.	MIN.	MAX.	MIN.
JANUARY	31.6	21.1	31.1	19.7	31.0	23.0	31.5	20.5	31.5	21.0
FEBRUARY	31.1	19.9	31.5	18.9	31.7	23.0	32.2	20.0	32.0	21.1
MARCH	31.5	20.8	31.8	19.1	31.4	20.2	32.7	19.9	32.3	21.4
APRIL	31.8	21.4	32.1	20.9	32.2	21.1	32.9	20.7	32.9	22.1
MAY	32.6	23.0	32.2	22.3	32.6	21.8	31.8	21.6	32.4	22.1
JUNE	32.6	23.6	32.6	22.7	33.3	22.7	32.2	22.3	32.1	22.9
JULY	33.4	23.5	33.8	22.7	33.5	23.5	32.9	23.0	33.4	23.1
AUGUST	33.8	24.0	33.7	23.2	33.8	23.5	34.4	23.3	34.0	23.0
SEPTEMBER	33.3	23.0	33.4	23.0	34.5	23.0	33.3	22.8	34.0	22.8
OCTOBER	31.9	21.7	33.9	22.5	33.3	22.4	33.4	22.7	34.0	229.0
NOVEMBER	32.2	21.8	33.5	21.9	31.2	21.2	33.3	23.1	32.8	22.6
DECEMBER	31.4	20.5	31.3	22.6	32.2	20.4	32.5	21.7	32.1	21.1

4.6 WILDLIFE AND VEGETATION

4.6.1 VEGETATION

4.6.1.1 METHODOLOGY

The survey entailed ground-truthing of GPS coordinates supplied by Jamalco, and an assessment of the flora and fauna of the general area. Avifauna was recorded by site and sound. Aerial photography (video and still) and satellite imagery were also used in the analysis. A literature review of the flora and fauna of the area was also conducted

A "walk-through" survey was conducted throughout the property along transect lines running north to south. Each parallel transect line was 100 m apart and all macroscopic plant species recorded and, where possible, identified in the field. A belt of ± 20 m along the transect lines was used. Unidentified species were collected and compared with a Herbarium collection for classification. Each species was then checked against known Jamaican plant taxonomy literature for endemism and rarity.

Notes were also made regarding current and past land-use and vegetation types.

A multi-scale method was also used to analyse the vegetation for the study baseline, using three stages. The stages correspond to successive approaches to vegetation from a broad to a fine scale. The following three stages were used:

- physiognomy,
- stand structure, and
- composition

4.6.1.2 PHYSIOGNOMY

The vegetation physiognomy is defined by its overall physical condition. It combines structural features (height and spacing), growth form (morphology and aspect) and leaf attributes (seasonality and phenology) of dominant. The spatial representation of plant communities is one key stage for assessing environmental impacts of development projects. The physiognomic categories for classification are broad (for example: forest, shrubland and grassland) and easy to assess even by non-specialists. Wide physiognomic categories to characterize and classify patches at landscape level were used.

4.6.1.3 STAND STRUCTURE

Structure is defined as the spatial arrangement of the vegetation biomass. Three elements define structure: 1) vertical structure, 2) horizontal structure and 3) abundance. Therefore, any method to assess vegetation structure in the stand scale must consider these three variables in order to address the structural patterns of plant communities at the stand scale.

4.6.1.4 COMPOSITION

Composition is the list of plant species that form vegetation. Floristic classifications use species or groups of species to define vegetation types. Composition is crucial to determine plant diversity. All vascular plant species found were classified as native or exotic.

4.6.1.5 GENERAL FINDINGS

The terrain is predominantly flat scrub thorn/grassland. Small pockets close to the river are under agricultural land-use, however, some are abandoned and invaded by numerous invasive type plants, typical of areas cleared.

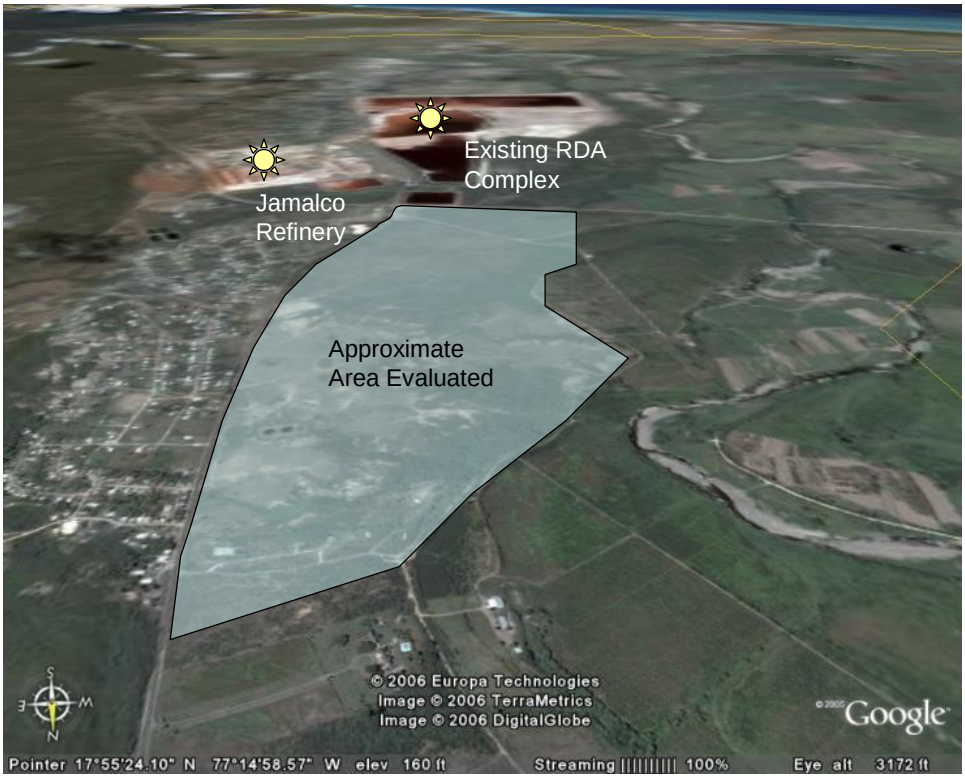


PLATE 4-3: GOOGLE EARTH IMAGE SHOWING EXTENT OF PROPOSED RDA #6

4.6.1.5.1 PHYSIOGNOMY, STAND STRUCTURE AND COMPOSITION

VEGETATION

In terms of physiognomy, the following types were identified:

- thicket/scrub or shrubland
- grassland

Thicket/scrub or shrubland - It is characterized by thorny scrub communities which generally form a very dense, closed cover community. The height of the vegetation ranges 0.5 m to 5 m in height with 3-4 m heights typical and the occasional emergent trees. These communities may have uniform height as mono-specific stands or structural variety as a mixture of two species. Crown cover above 8 m off ground is less than 20%, but total leaf cover between 0.8-8 m off ground greater than 20%.

The Hayes area lies roughly on a 200 m elevation contour (above sea level). Vegetation height can range from 1-10 meters in areas close to Webbers Gully at the northern section of the area and near moist areas such as ponds or drainage ditches. The taller forms consist of a canopy layer of larger individuals under slightly more moist conditions. The shorter forms are common to the very exposed locations. Webber's Gully is stagnant in some areas and free-flowing in others. The stagnant areas have closed canopies. *Typha domingensis* (Cat-tail, readmace) occupy sections of stagnant water

The shrubs are generally multiple stemmed, bushy and interlocking in structure. Thorny shrubs (primarily Mimosoideae such as *Acacia* spp.) and cactus species (such as columnar cacti, *Stenocereus sp.*) are common along with succulents in some locations. The herbaceous layer belongs mainly to the families Malvaceae, Amaranthaceae, Asteraceae, and Euphorbiaceae. Elevation and past land use history have had a profound effect on the area. The vegetation is subjected to severe environmental constraints of thin soils, strong winds and little moisture, which limits vegetation height. In some sections succession has created different cover types.

Dry-tolerant plants (Xerophytes) are found throughout the area with aquatic species (hydrophytes) where ponds are present and along the riparian corridor along with plants that are able to survive extended periods of low soil moisture (mesophytes).

The dominant grass species were Seymour grass (*Andropogon pertusus*) and *Chloris barbata* accounting for approximately 60% cover, while the dominant thorn scrub was Acacia (60-70% cover).

Sixty-seven (67) plant species were identified of which 3 (<1%) were endemics (Table 4-20).

TABLE 4-20: VEGETATION COMPOSITION OF THE PROPOSED SITE FOR DRDA 6

Family	*Scientific Name*	Common Name	Status
Acanthaceae	*Ruellia tuberosa*		Common
Agavaceae	*Agave sp.*		Fairly common
Amaranthaceae	*Amaranthus spinosus*	Wild calaloo	Common
Amaranthaceae	*Achyranthes indica*	Devil's Horsewhip	Common
Amaranthaceae	*Gomphrena decumbens*		Fairly common
Anacardiaceae	*Comocladia pinnatifolia*	Maiden plum	Endemic
Anacardiaceae	*Magnifera indica*	Mango	Introduced
Apocynaceae	*Urechites lutea*	Nightshade	Common
Asclepiadaceae	*Caloptropis procera*	Dumb cotton	Rare
Asteraceae	*Bidens pilosa*	Spanish needle	Common
Asteraceae	*Tridax procumbens*		Rare
Asteraceae	*Emilia sonchifolia*	Chinese shaving bush	Common
Asteraceae	*Eupatorium odoratum*	Christmas bush	Common
Bignoniaceae	*Crescentia cujete*	Calabash	Common
Bignoniaceae	*Tecoma stans*		Common
Boraginaceae	*Cordia jamaicencis*		Endemic
Bromeliaceae	*Tillandsia recurvata*	Old Man's Beard	Common
Cactaceae	*Cephalocereus nobilis*		Fairly common
Cactaceae	*Stenocereus hystrix*		Rare
Caricaceae	*Carica papaya*	Papaya	Introduced
Commelinaceae	*Commelina diffusa*	Water grass	Fairly common
Convolvulaceae	*Ipomea triloba*		Common
Convolvulaceae	*Ipomea indica*	Morning Glory	Common
Cyperaceae	*Cyperus odoratus*		Fairly common
Cyperaceae	*Eleocharis sp*		Fairly common
Cyperaceae	*Cladium jamaicense*		Fairly common
Cyperaceae	*Cyperus odoratus*		Fairly common
Dioscoreaceae	*Dioscorea alata*	Yam	Introduced
Euphorbiaceae	*Ricinus communis*	Castor bean	Fairly common

Family	*Scientific Name*	Common Name	Status
Euphorbiaceae	*Manihot sp.*	Cassava	Introduced
Euphorbiaceae	*Euphorbia hirta*		Common
Euphorbiaceae	*Jatropha gossypiifolia*	Belly-ache-bush	Common
Fabaceae	*Acacia tortuosa*	Wild Poponox	Common
Fabaceae	*Acacia farnesiana*		Fairly common
Fabaceae	*Mimosa pudica*	Shame weed	Common
Fabaceae	*Cajanus cajan*	Gungo pea	Introduced
Fabaceae	*Leucaena leucocephala*	Lead tree	Fairly common
Fabaceae	*Albizia julibrissin*		Fairly common
Fabaceae	*Haematoxylum campechianum*	Logwood	Fairly common
Fabaceae	*Samanea saman*	Guango	Fairly common
Fabaceae	*Centrosema virginianum*	Wist vine flower	Endemic
Fabaceae	*Brya ebenus*	West Indian ebony	Endemic
Fabaceae	*Piscidia piscipula*	Dogwood	Common
Fabaceae	*Macroptilium lathyroides*		Fairly common
Fabaceae	*Delonix regia*	Poinciana	Fairly common
Lamiaceae	*Hyptis pectinata*		Common
Lauraceae	*Persea americana*	Avocado, Pear	Introduced
Malvaceae	*Sida acuta*	Broomweed	Common
Malvaceae	*Urena lobata*		Fairly common
Malvaceae	*Abutilon sp.*	Chinese lantern	Common
Melastomataceae	*Miconia sp.*		Common
Musaceae	*Musa sp.*	Banana	Introduced
Myrtaceae	*Psidium guajava*	Guava	Introduced
Myrtaceae	*Eucalyptus sp.*	Eucalyptus	Rare
Nyctaginaceae	*Pisonia aculeata*	Cockspur	Common
Piperaceae	*Piper amalgo*	Piper	Rare
Plumbaginaceae	*Plumbago scandens*		Common
Poaceae	*Andropogon pertusus*	Seymour grass	widespread
Poaceae	*Chloris barbata*		Common
Poaceae	*Axonopus compressus*	Carpet grass	widespread
Poaceae	*Panicum maximum*	Guinea grass	Common
Poaceae	*Zea mays*	Corn	Introduced
Polygonaceae	*Antigonon leptopus*		Common
Solanaceae	*Solanum torvum*	Susumber	Rare
Solanaceae	*Capsicum annuum*	Bird pepper	Rare
Sterculiaceae	*Helicteres jamaicensis*	Screw tree	Fairly common
Sterculiaceae	*Guazuma ulmifolia*	Bastard cedar	Fairly common
Typhaceae	*Typha domingensis*	Cat-tail, reedmace	Fairly common
Verbenaceae	*Lantana camara*		Fairly common
Verbenaceae	*Stachytarpheta jamaicensis*	Vervine	Common

4.6.2 AVIFAUNA

This forest type which is typical of the coastal plain and lower hills of Clarendon has birds such as Columbids (Pigeon and Doves), Parakeets, Hummingbirds, Jamaican Woodpecker, Orioles, Vireos and Yellow Warbler. In addition, the winter migrants are also abundant in the winter months (Downer and Sutton 1990).

4.6.2.1 METHODOLOGY

Due to the size of the area and the easy accessible roads, transects were used to compile the preliminary bird list. This entailed walking along selected routes, noting all the birds seen or heard in the area. The count was conducted from sunrise and 10:30 a.m.

4.6.2.2 RESULTS

During the survey, birds were seen nesting and foraging in several Acacia and Guango trees. The proposed development will result in the removal of a large section of the vegetation. This will displace the birds on the property. However, only one of the endemic birds seen during the survey is forest dependent, all the other bird species seen are not forest dependent.

TABLE 4-21: ENDEMIC BIRDS OBSERVED AT THE PROPOSED SITE FOR DRDA 6

Common Name	Status	Forest Dependent Y/N
Jamaican Euphonia	E1	N
Jamaican Lizard Cuckoo	E2	N
Jamaican Mango	E2	N
Jamaican Oriole	E1	N
Jamaican Vireo	E1	N
Jamaican Woodpecker	E1	N
Red-billed Streamertail Humming bird	E1	N
Sad Flycatcher	E1	Y

Note: 1 of 8 endemics observed is forest dependent species. Only 8 of the 30 endemic birds on the island were observed during the survey.

TABLE 4-22: BIRD SPECIES LIST (ENDEMICS & RESIDENTS)

Common Name	Scientific name	Local name	Status
American Kestrel	*Falco sparverius*	Lizard Hawk /Killy-killy	R1
Cattle Egret	*Bubulcus ibis*	Ticks bird, Gaulin	R1
Common Ground Dove	*Columbina passerina*	Ground Dove	R1
Greater Antillean Grackle	*Quiscalus niger*	Cling cling	R1
Jamaican Euphonia	***Euphonia jamaica***	**Blue Quit**	**E1**
Jamaican Lizard Cuckoo	***Saurothera vetula***	**Old Woman Bird**	**E2**
Jamaican Mango	***Anthracothorax mango***	**Mango Hummingbird**	**E2**
Jamaican Oriole	***Icterus leucopteryx***	**Auntie Katie**	**E1**
Jamaican Vireo	***Vireo modestus***	**Sewi-sewi**	**E1***
Jamaican Woodpecker	***Melanerpes radiolatus***	**Woodpecker**	**E1**
Loggerhead kingbird	*Tyrannus caudifasciatus*	Loggerhead	R1
Mourning Dove	*Zenaida macroura*	Pea Dove	R1
Northern Mockingbird	*Mimus polygottos*	Nightingale	R1
Olive-throated Parakeet	*Aratinga nana*	Parakeet	R1
Red-billed Streamer tail	***Trochilus polytmus***	**Doctorbird**	**E1**
Sad Flycatcher	***Myiarchus barbirostris***	**Little Tom Fool**	**E1**
Smooth-billed Ani	*Crotophaga ani*	Savanna Blackbird	R1
Stolid Flycatcher	*Myiarchus stolidus*	Little Tom Fool	R2
Turkey Vulture	*Cathartes aura*	John Crow	R1
Vervain hummingbird	*Mellisuga minima*	Little Doctorbird	R1
Zenaida dove	*Zenaida aurita*	Pea Dove	E1
White-crowned Pigeon	*Columba leucocephala*	Bald Pate	R1
White-winged Dove	*Zenaida asiatica*	White-wing	R1
Yellow-faced Grassquit	*Tiaris olivacea*	Squit	R1
Little Blue Heron	*Ardea herodias*	Blue Gaulin	R1
Bananaquit	*Coereba flaveola*	Beeny, bird sugar bird	R1
Saffron Finch	*Sicalis flaveola*	Canary	R1

4.6.2.3 OTHER FAUNA

Insects were fairly well represented, with butterflies being the most obvious of the group. The butterfly species observed at the site included: the Monarch, Zebra Butterfly, West Indian Buckeye, Tropical Fritillary and a common skipper.

below shows the list of butterfly species encountered at the site. More importantly is the ecological functions of these insects where they act as pollinators. Other insect's species included ants, beetles, stinkbugs, dragonflies, damselflies, wasps and honeybees.

Only two species of reptiles were observed during site survey, both are lizards and endemic with a wide geographic distribution in Jamaica, *Anolis grahami* and *Anolis lineatopus.* No amphibians were discovered. However, proximity of the river and several intermittent drainage ditches suggest amphibians such as the common frog may be in the area. The literature review indicated the likely occurrence of certain species such as gekkos, galliwasps, and frogs in the region (as outlined in the EIA for DRDA #5 by Conrad Douglas & Associates Ltd.)

TABLE 4-23: BUTTERFLY SPECIES OBSERVED AT THE PROPOSED SITE FOR DRDA 6

Scientific Name	Common Name	Status
Ascia monuste eubotia	Greater Antillean whites	
Danaus plexippus	The Monarch	
Dione (Agraulis) vanillae insularis	Tropical Silverspot	
Dryas iulia delila	Julia	
Euptoieta hegesia hegesia	Tropical Fritillary	
Heliconius charitonius simulator	Zebra Butterfly	
Lycorea cleobaea	Tiger Butterfly	
Phoebis sp.	Sulphur	
Pyrgus sp.	Common Skipper	
Precis evarete zonalis	The West Indian Buckeye	

4.7 ARCHAEOLOGICAL AND HISTORICAL RESOURCES

4.7.1 SUMMARY[1]

The parish of Clarendon was named in honour of the celebrated Lord Chancellor of England & Wales. The parish of Vere, now merged in it, was named after Vere, daughter of Sir Edward Herbert, Attorney General to Charles I, and first wife of Sir Thomas Lynch, who, with her two sons, died on her passage from England to Jamaica in 1683.

Carlisle Bay, the scene of the principal military engagement with a foreign foe which has taken place in Jamaica during the British occupation, is on the south-west coast of the old parish of Vere.

[1] Historic Jamaica by Frank Cundall New York: Johnson Reprint Corp., 1971

4.7.2 BUILDINGS AND MONUMENTS OF ARCHITECTURAL AND HISTORIC INTEREST

There are various buildings and monuments of architectural and historic interest in the parish of Clarendon. Some of these are listed below.

- Halse Hall Great House
- Churches, Cemeteries, Tombs'
- St. Peter's Church, Alley
- Clock Tower
- May Pen Clock Tower

4.7.3 NATURAL SITE

- Milk River Spa

4.7.4 PROTECTED NATURAL HERITAGE SITES

4.7.4.1.1 NATURAL SITE

- Mason River Botanical Station

4.7.4.1.2 OTHER HERITAGE SITES[2]

4.7.4.1.2.1 Tainos

In Clarendon, they lived in Portland Ridge (the part of the parish that juts out into the sea) as well as in the Braziletto Mountains and on Round Hill. There was also a village on the banks of the Rio Minho near Parnassus Estate and the others were on the banks of the Milk River.

4.7.4.1.2.2 Halse Hall Great House

Halse Hall Great House, believed to be built on the site of a house that stood on the Site of Buena Vista, was acquired by Thomas Halse in 1655 who came to Jamaica with Venables. Henry de la Beche, one of its many owners was the founder of the Geological

[2] *S.A.G Taylor. A Short History of Clarendon.* Ministry of Education Publications Branch 1976., pages 9, 24, and 28

Survey of Great Britain. He made detailed Geological notes of the places he visited in Jamaica. In 1969 the estate was acquired by ALCOA, the house renovated by them. It is now the property of the National Trust.

4.7.4.1.2.3 St. Peter's Church Alley

St. Peter's Church Alley, is the 3rd oldest Anglican Church in Jamaica. Built in 1671, it became the Parish church for Vere in 1673 it was extensively damaged by the 1692 earthquake and had to be almost totally rebuilt in 1975

4.7.4.1.2.4 Morgan's Valley and Estate

Sir Henry Morgan, a privateer, buccaneer and former Governor of Jamaica, owned Morgan's Valley and Estate. He lived there while he was Governor of Jamaica.

4.7.4.1.2.5 May Pen Clock Tower:

May Pen Square is over 80 years old. It was constructed in honour of Dr. Samuel Glaister Bell, a renowned doctor of the parish who lost his life while crossing the Rio Minho after visiting a patient. The May Pen Clock Tower is made of stone. It is approximately twenty- four (24) feet in height, eight feet (8) in width, and eight feet in length. The exact date of its erection has not been ascertained, but it appears to have been constructed after World War II.

4.7.4.1.2.6 St Gabriel's Anglican Church

Once called Lime Savannah Chapel, was the "daughter" Church of St. Paul's in Chapleton. When the Church of the White Cross fell into disuse, St. Gabriel's took its place.

4.7.4.1.2.7 St. Paul's Church- Chapleton

When the present parish of Clarendon was divided into the parishes of Clarendon and Vere, the Cross church was then the parish church of Clarendon. St. Paul's was built as a chapel of Ease to the Cross Church, and was the first place of worship erected in Upper Clarendon. It was originally known as "the Chapel". It took the name from the

church, being called “Chapel Town,” and in the course of time shortened to its present form, Chapleton.

4.8 NOISE LEVELS AND VIBRATION

4.8.1 NOISE LEVELS

Jamalco is committed to working within the limits of the laws, rules and regulations of Jamaica and as such, will work to maintain its pre-construction, construction and operational activities at the proposed DRDA 6 within the established levels as will be provided by NEPA in any permit it issues allowing construction at the site.

1. Noise at the property boundaries shall not exceed an A-weighted equivalent noise level (LAEQ) of 70 dB.
2. Noise measurements shall be A-weighted and Slow response.
3. The averaging time shall be a minimum of 15 minutes to a maximum of 24 hours.
4. Transient noise such as nearby trains, vehicles and other sounds not associated with the measurement shall be excluded from the average.
5. Construction activities shall be exempted.

4.8.2 VIBRATION ANALYSIS

Vibration levels will be measured along the boundaries of the construction area using state-of-the-art vibration measuring devices. The proposed impacts of vibration associated with the proposed earthworks are not expected to carry into the bordering communities of New Bowens and Hayes Cornpiece. Monitoring and reporting on the construction activities will allow for the timely provision of relevant information on vibration and other parameters of concern.

4.9 NATURAL HAZARD VULNERABILITY

4.9.1 NATURAL HAZARD VULNERABILITY

4.9.1.1 FLOODING

Specific records of flooding in the Rio Minho floodplain date back to 1886, reported in the Tri-Weekly Gleaner, June 19, 1886 (Rowe, 2004, in preparation), when heavy rains in June of that year led to what was believed to be the worst flooding on record for that river. The river was 40 ft (12.2 m) deep at the May Pen Bridge, some 4 ft higher than the previous record, and did immense damage to roads and property. Affected localities included Halse Hall and Parnassus and Caswell Hill.

The worst flood event of the 20th century occurred in 1986, when rainfall within the Rio Minho catchment caused the river to overflow its banks to cover wide areas of the Rio Minho Alluvial Fan. The approximate extent of this flood event is inserted on Figure 4-12. According to the Water Resources Authority, this event had an estimated return period of 100 years.

The most notable feature of the flood water extent is that north of Kemps Hill the flooding was confined to a relatively narrow floodplain, whereas south of Kemps Hill the flood waters spread out over a wide area. This is a reflection of the fact that the river is incised into the upper part of the fan, while in the southern part, Vere Plains, it is not. It is suggested that this may be a function of continuing movements along the South Coast Fault.

With respect to the plant and RDA area, the risk from flooding is low, due to the fact that these are constructed on the high terrace of the well-drained, relatively thin Hayes Gravels. During the June 1986 flood event the only part of the plant that was flooded was the low-lying storm lake at the northern end of the RDAs.

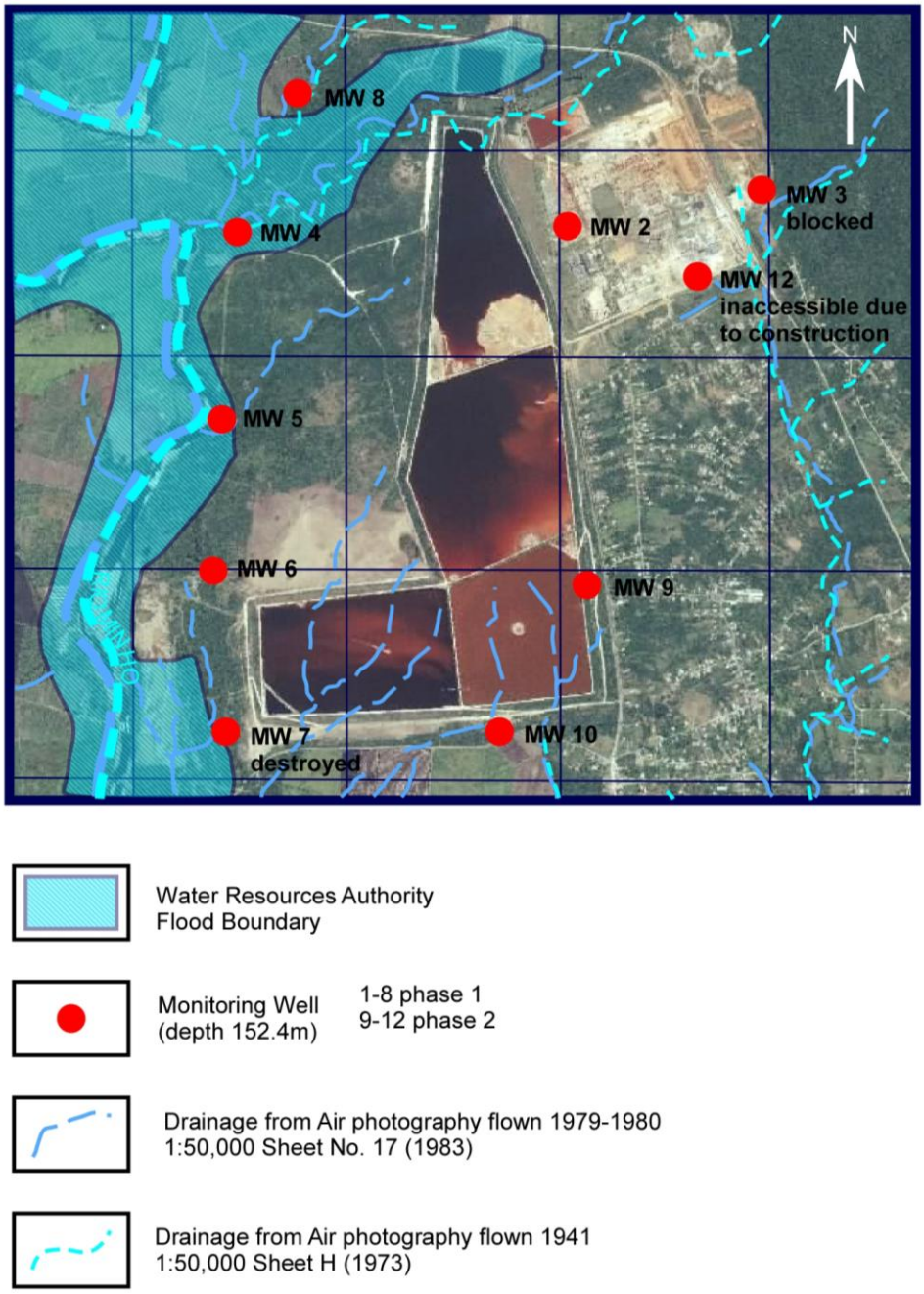


FIGURE 4-12: 1986 FLOOD BOUNDARY AND MONITORING WELLS AT THE REFINERY

Using data from the Trout Hall rainfall station in the Upper Rio Minho Basin an analysis of the maximum 24hr rainfall depths for the 10, 25, 50, and 100yr return period floods was undertaken by the Water Resources of Jamaica (WRA) (Table 4-24). Data from the Trout Hall rainfall station was used because it is generally located in the Upper Rio Minho Watershed and it best represents the rainfall distribution over the watershed.

TABLE 4-24: 24HR RAINFALL BASED ON DATA FROM THE TROUT HALL RAINFALL STATION[3]

Storm Duration	1950 – 1986 Data (Trout Hall) (mm)			
	10yr	25yr	50yr	100yr
1min	17.9	21.7	28.5	30.4
15min	37.3	45.1	59.3	63.2
1hr	71.8	86.8	114.0	121.5
2hr	97.6	119.4	162.5	177.8
3hr	107.2	131.5	180.5	198.8
6hr	123.4	151.9	211.0	234.2
12hr	143.0	176.6	247.8	277.7
24hr	**175.0**	**217.0**	**308.0**	**347.0**

The profiles for the 10 – 100yr floods used by WRA were developed using the Steady flow analysis and one-dimensional flow methodology. Input data utilised information such as cross-sections of river channels. There are eight hydraulic structures on the Webbers Gully that could affect flow, none on the Rio Minho in the vicinity of the proposed development. Eight (8) parallel and identical circular culverts, each with a diameter of 3.96m serve as conveyance capacity at two locations on the Webbers Gully, located at the Alcoa train line and at the main road from Hayes to May Pen. The starting water surface elevations for the simulation of flood levels for Webbers Gully are presented in Table 4-25.

[3] Part of Rio Minho River/Webbers Gully Floodplain Mapping Project, Prepared by Water Resources Authority, June 2005

TABLE 4-25: STARTING WATER SURFACE ELEVATIONS AT THE WEBBERS GULLY/RIO MINHO RIVER JUNCTION[4]

Return Period (yr)	Peak Flow (m3/s)	Water Surface Elevation (m) a.m.s.l.
	Webbers Gully	Rio Minho River
10	86	33.35
25	111	34.66
50	129	35.51
100	145	36.17

Using Hydrologic Engineering Center River Analysis Systems (HEC-RAS) modelling software developed by the US Corps of Engineers and the following scenarios, revealed:

1. Scenario 1: the culverts are free of debris and any other obstruction that may restrict flow,
2. Scenario 2: the capacity of the culverts was approximately 50% blocked by debris, and
3. Scenario 3: the capacity of the culverts was nearly 100% blocked by debris

Flood plain Maps (Figure 4-13, Figure 4-14, and Figure 4-15) show the outcome of the above scenarios.

The Alley Bridge, which is approximately 2km downstream of the proposed site, had no effect on flood levels even with the bridge opening completely blocked. The WRA found that there was no significant inundation on either side of the Webbers Gully by any flood events modelled. There was general overtopping of the left bank of the Webbers Gully in all three scenarios by the flood events along the reach extending from the train line to the main road. However, there was only significant overtopping of the right bank if the culverts are blocked. Flood duration for the 50 and 100yr events along the Webbers Gully are expected to last for approximately 3 to 4 hours when culverts are clear.

[4] Part of Rio Minho River/Webbers Gully Floodplain Mapping Project, Prepared by Water Resources Authority, June 2005

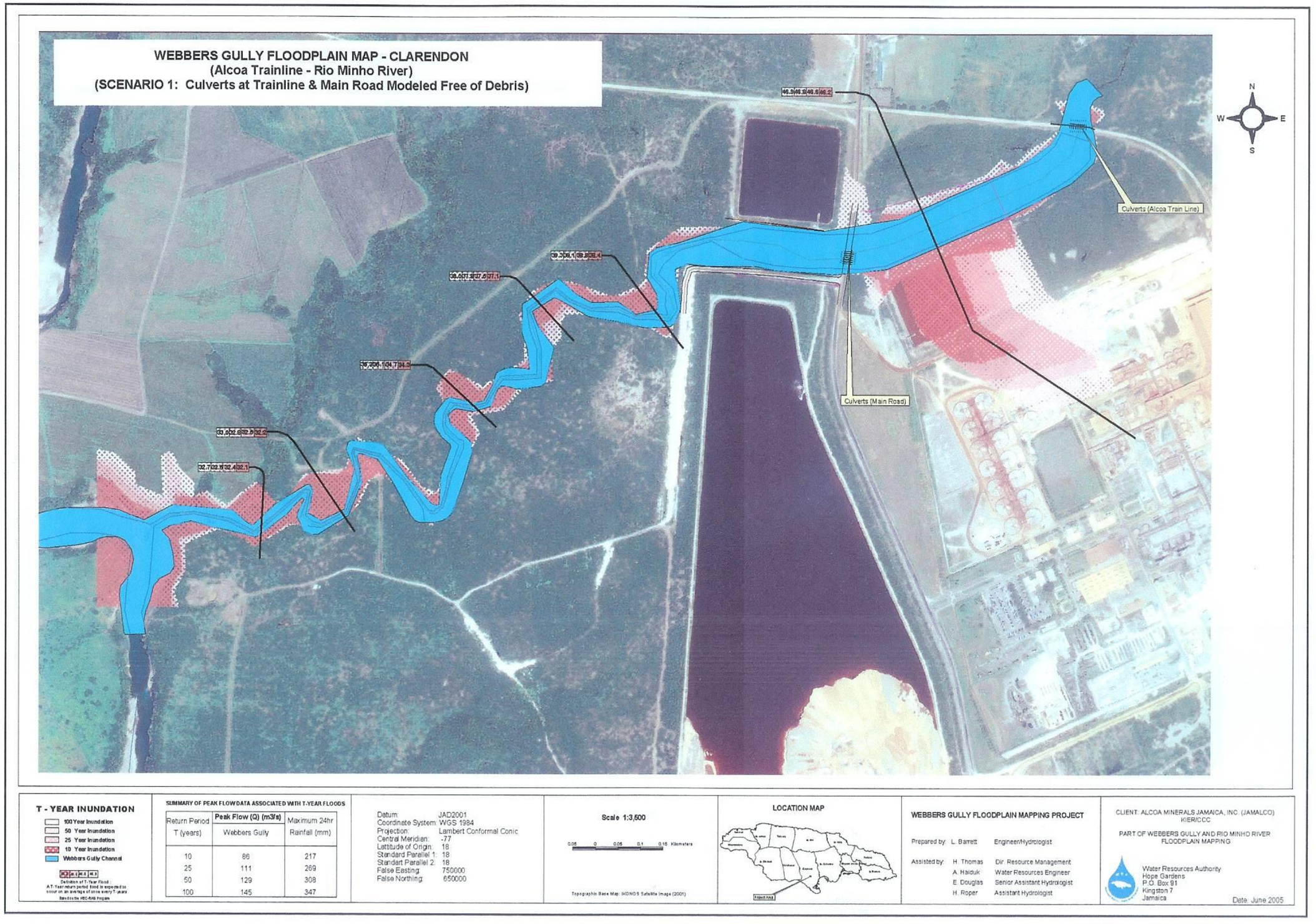


FIGURE 4-13: OUTCOME OF SCENARIO 1

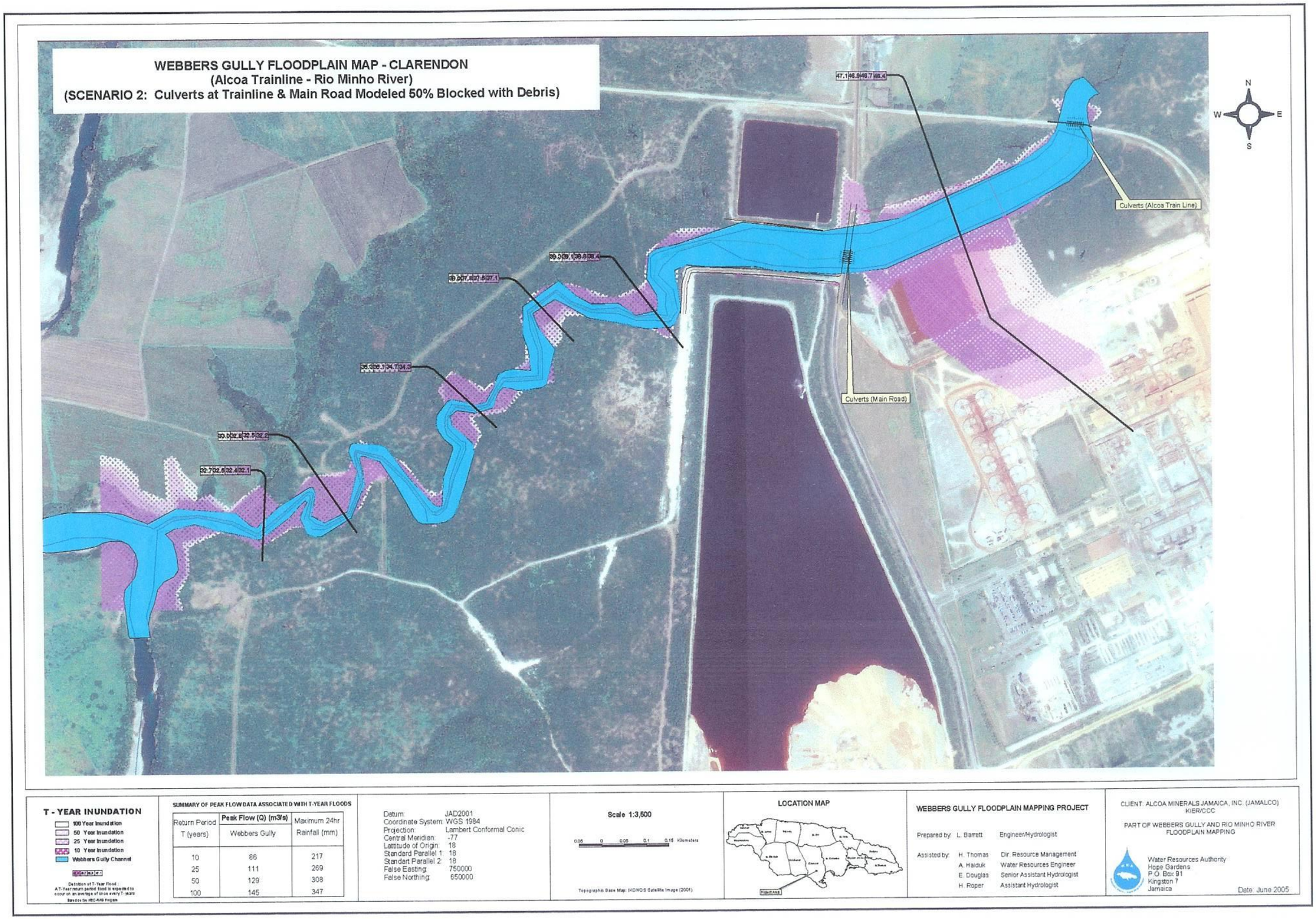


FIGURE 4-14: OUTCOME OF SCENARIO 2

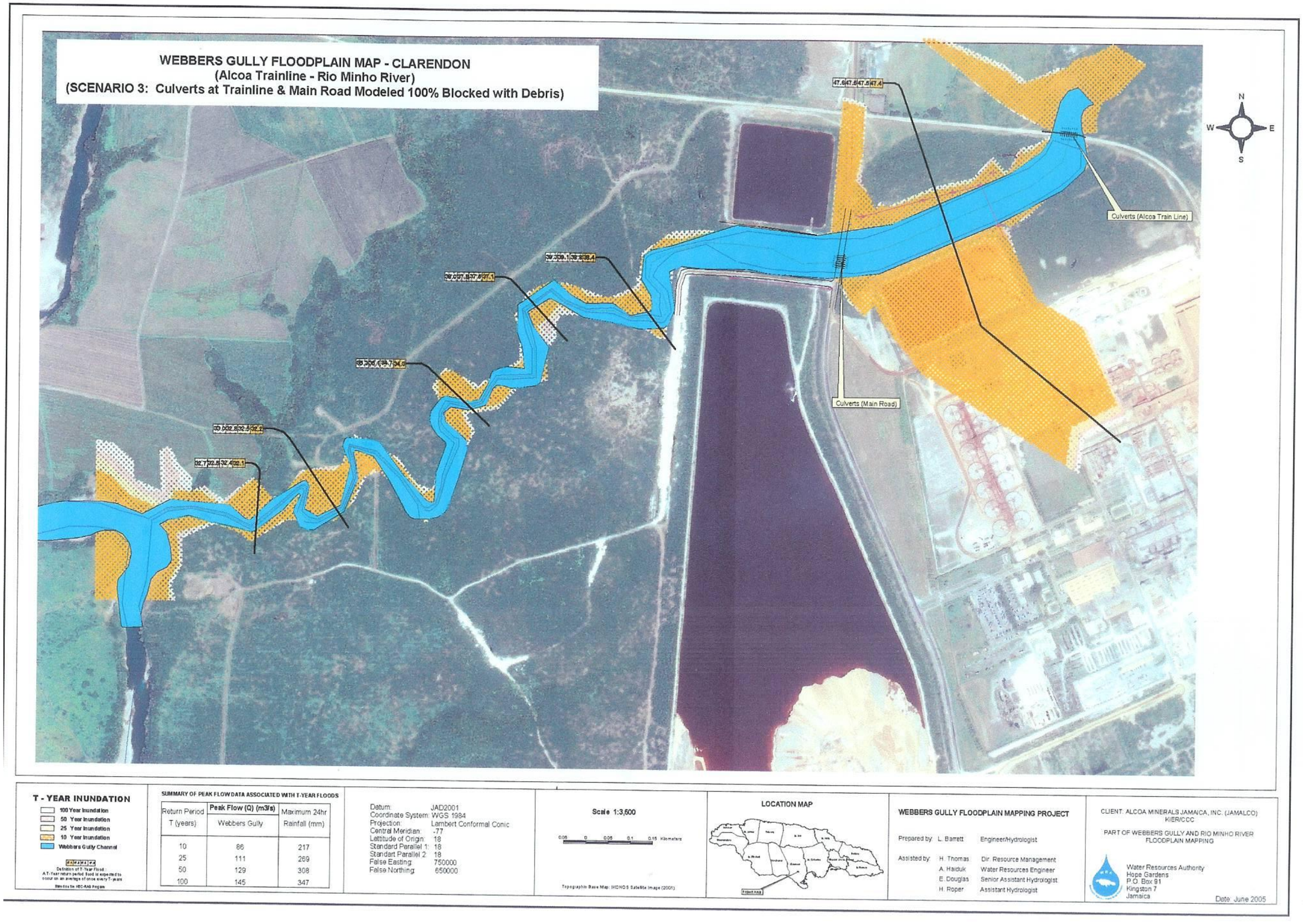


FIGURE 4-15: OUTCOME OF SCENARIO 3

4.9.1.2 LANDSLIDES

There appear to be no historical records of landslides in the district. While no detailed assessment of the landslide susceptibility has been carried out in southern Clarendon to date, the landslide susceptibility map of southern Clarendon (Figure 4-16) indicates low susceptibility levels at Hayes. This can be attributed to the flat lying nature of the topography, the presence of fairly easily drained alluvial soils, and the relative dry climate.

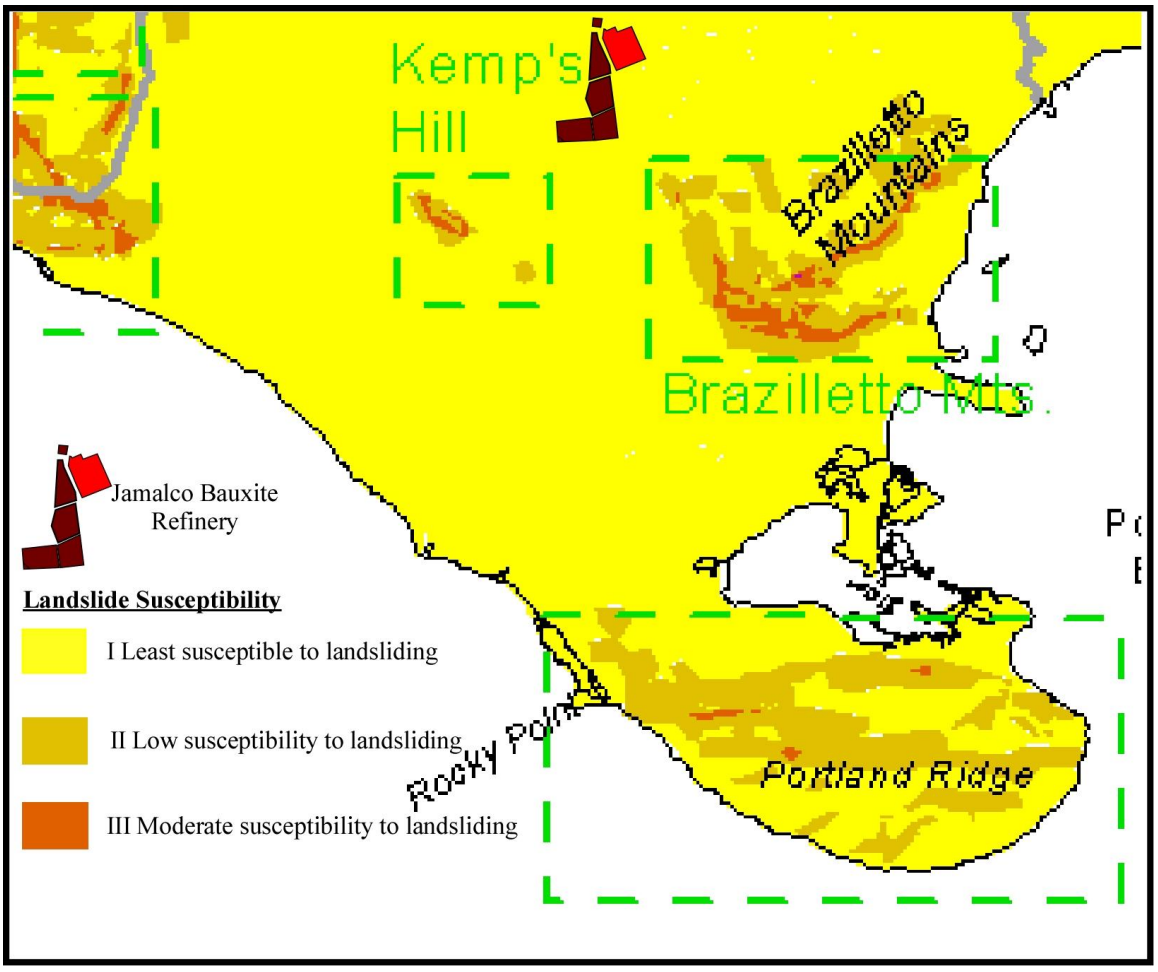


FIGURE 4-16: LANDSLIDE SUSCEPTIBILITY MAP OF SOUTHERN CLARENDON (SOURCE: SOUTH COAST DEVELOPMENT PROJECT)

The design and construction of the dykes impounding the present RDAs appear to be sound, with no reports of slumping or collapse. The slopes of the dykes are subject to erosion from rainfall, taking the form of vertical runnels. The attempts to control or reduce this erosion through the planting of grass appear to be successful where the grass has caught. On the east-facing slopes the grass cover is well-developed (Figure 4-17), but on other slopes the cover is still incomplete.

FIGURE 4-17: GRASS COVERING SLOPE OF DYKE OF RESIDUE DISPOSAL AREA.

4.9.1.3 TECTONICS AND FAULTING

4.9.1.3.1 TECTONIC HISTORY

The tectonic history of the Clarendon Plains includes block faulting in the surrounding limestone uplands, producing the half graben in the limestone bedrock underlying the plains (Figure 4-18). This fault activity probably continued during the earlier stages of the formation of the alluvial fan complex. It is likely that the southern Clarendon Plains are experiencing gradual subsidence in recent times.

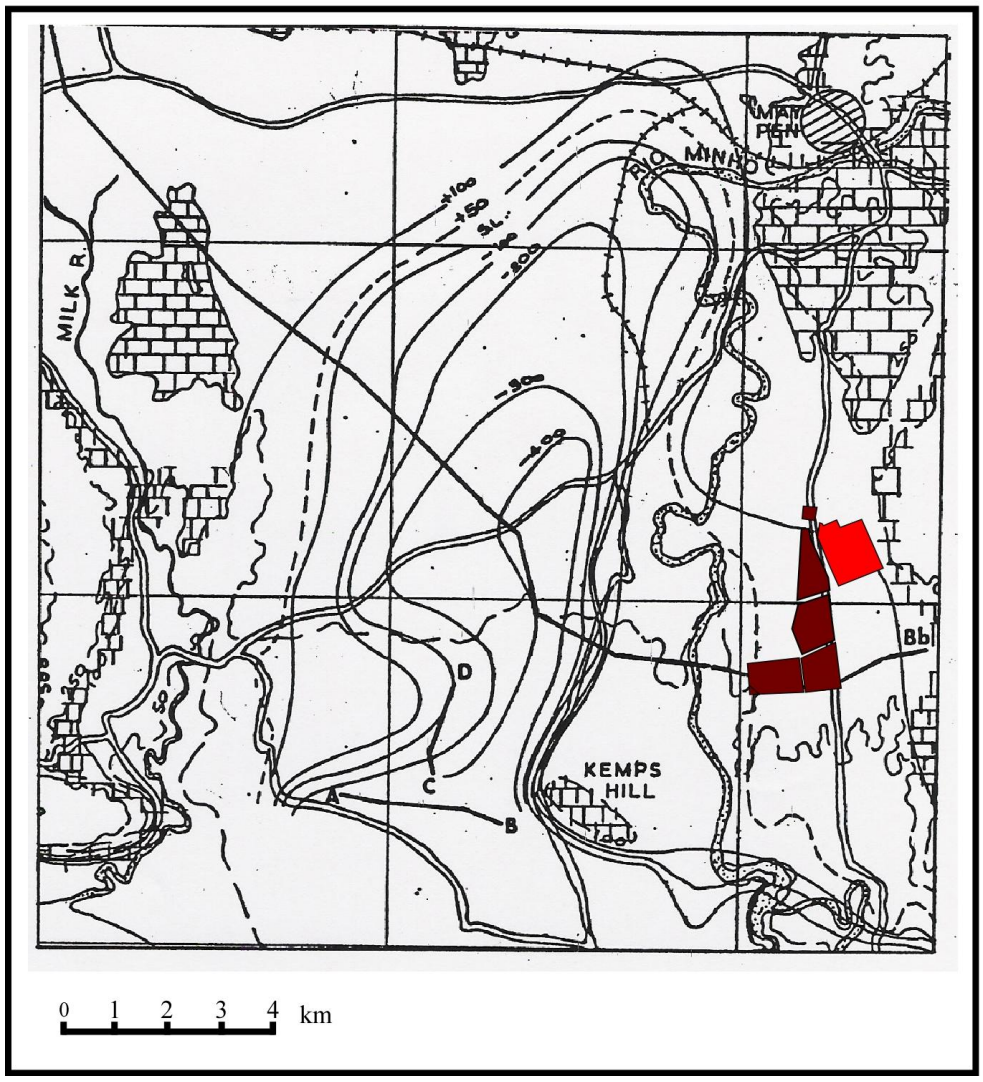


FIGURE 4-18: CONTOUR MAP SHOWING LIMESTONE ELEVATIONS UNDER PLAIN (ELEVATIONS IN FEET ABOVE SEA LEVEL). (SOURCE: CHARLESWORTH, 1980)

4.9.1.3.2 LOCATION OF FAULTS

The distribution of faults on Figure 2 is derived from Geological Sheet #16, May Pen (1974), the earlier 1:250 000 scale geological map of Jamaica (1958) and Charlesworth (1980). The Rio Minho alluvial plain appears largely unaffected by faulting, but as these are superficial deposits it is unlikely that any faults can be identified by surface mapping. Two sets of faults have been mapped within the limestone. One set has a general ENE-WSW trend, while the other set trends roughly N-S. The effects of this faulting and the age relationship with the alluvial plain are uncertain. However, the variability in depth to bedrock (Figure 4-18) suggests the presence of N-S trending faults in the bedrock which have controlled the thickness of alluvial sediments (e.g. the Kemps Hill fault, Figure 4-18; Charlesworth, 1980). These faults may even extend up into the lower part of the alluvial cover, although there is no direct evidence for this. The ENE-WSW trending set is truncated by the alluvium, indicating that the faulting pre-dates the deposition of at least the more recent alluvial material. These faults probably are also continuous beneath the alluvial cover.

The southern part of the alluvial plain, south of Kemps Hill, contains thicker alluvial deposits and this difference in thickness appears to be controlled by the E-W trending South Coast Fault, a well defined feature which extends from Great Pedro Bay in St. Elizabeth a distance of approximately 60 km, through the Brazilletto Mountains in southern Clarendon and beyond. That this fault is still active is strongly suggested by the existence of the radioactive mineral springs that occur at Salt River and Milk River (Zans et al., 1963).

4.9.1.4 SEISMIC ACTIVITY

4.9.1.4.1 LOCAL

Figure 4-19 is a map of Jamaica showing the epicentres for earthquakes that occurred in the period 1998-2001. No local earthquakes of these magnitudes occurred in the vicinity of Hayes, although there is one located on the trace of the buried South Coast Fault.

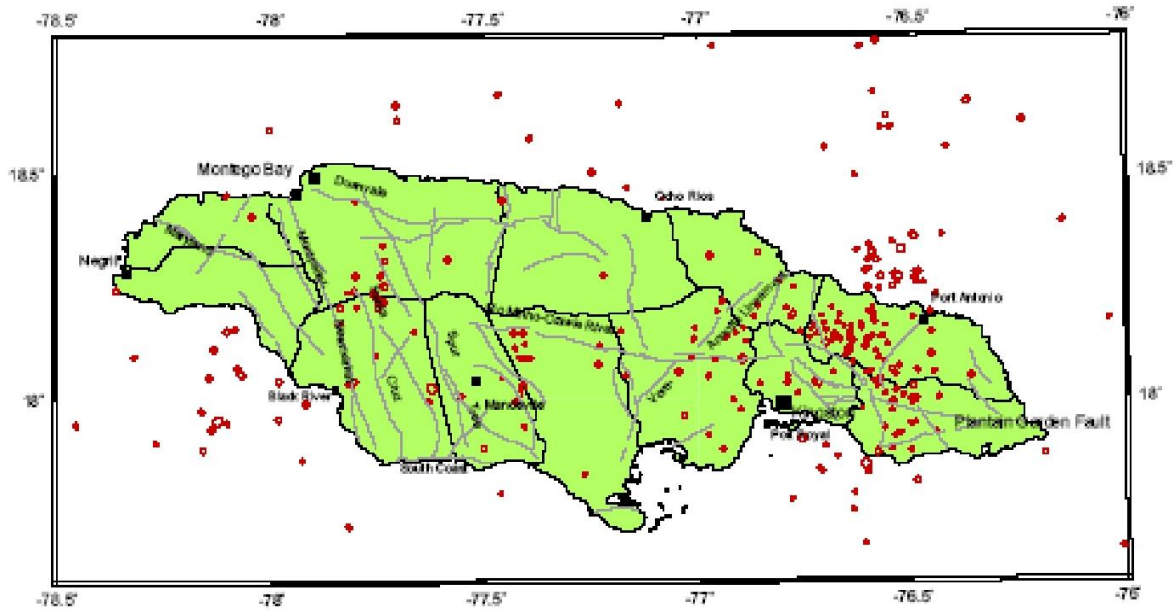


FIGURE 4-19: EPICENTRES OF EARTHQUAKES OCCURRING BETWEEN 1998 AND 2001 LOCATED IN AND AROUND JAMAICA. (SOURCE: THE EARTHQUAKE UNIT)

An investigation of the historical records carried out for an earlier EIA for the Hayes plant and RDAs (Conrad Douglas and Assoc.) of seismic activity in this area has shown that the adverse effects of earthquakes have been experienced there:

“The well-documented 1692 Port Royal earthquake had disastrous effects in the Lower Vere Plains, with modified Mercalli intensities of MM(X) being experienced in Alley and Salt River, both of which lie at about a 10 km radius from the study area.

The following quote from a newspaper clipping written by the local Rector illustrates: "all brick and stone building were thrown down and water spewed out of the chasms opened in the ground by the earthquake so that even dry gullies ran water". The St. Peter's Anglican Church in Alley built in 1671 was destroyed beyond repair. However, the Halse Hall Great House, where alluvial thicknesses are comparatively low, survived the 1692 earthquake, as well as subsequent ones.”

The Great House (now the property of JAMALCO) is situated about 6 km to the north of the JAMALCO alumina plant, and perhaps, more significantly, lies on the well-drained Hayes gravels, well above the water table.

"Subsequent damaging earthquakes are, most notably, those of 1907 and 1957. The 1907 earthquake appears to have caused some damage in the Vere Plains. Intensities of MM(VII) were reported in Alley with incidence of damage to chimneys and buildings (Tomblin & Robson, 1977). The 1957 earthquake had intensities of MM(IV) to MM(V) in the Lower Vere Plains (Robinson *et al.,* 1959). In each 50-year period, starting with 1991 and counting backward for four 50-year cycles, at least one damaging earthquake, of MM(VI) or higher, has occurred in the area. Shepherd (1971) reported that Lower Vere had a frequency of 5-9 damaging earthquakes per century on average.

Compared to the rest of Jamaica, the study area is not in a very active zone. However, the Vere Plain is largely built up of alluvial clays, sand and gravel, and in the presence of ground water, this material will be susceptible to liquefaction in an earthquake of high enough intensity. Thus, the height of the water table will be an important factor in determining the area's earthquake risk.

4.9.1.5 CONCLUSIONS

- The type of limestone does not directly affect the nature of the bauxite deposits. Other factors, such as height above water table, elevation and position on fault blocks may also play a part in ultimate quality of the bauxite.
- There appear to be no impediments from a geological standpoint, to mining bauxite in the proposed area of northern Manchester Parish.
- The mining operation is not likely to encounter problems any different from those experienced in the present mining areas.
- A more complete appraisal will require detailed geological and orebody mapping to determine slopes of mined out orebody faces, extent of brecciated zones in the limestone, etc.

ENVIRONMENTAL IMPACTS

5 ENVIRONMENTAL IMPACTS

It is very difficult and near impossible to implement a project of this type and scale without some form of impact on the environment. What is important, however, is to approach the project with a desire and willingness to eliminate as many negative impacts as possible and minimize those impacts that are unavoidable.

Upon careful analysis of the project description, designs and findings of the various studies conducted, it appears that the construction of DRDA 6 as proposed, will not (generally) result in major negative impacts on the environment, except as it relates to change of land use and loss of biodiversity in the project area. This is true for all three phases of the project.

This determination arises from the fact that the proposed project area, other than being naturally colonised with vegetation (since its days under sugar cane production) is basically a continuation of the existing residue disposal network at Jamalco and is adequately buffered from major receptors such as the Rio Minho River, Webbers Gully and the community of New Bowens.

Jamalco has an excellent baseline and track record of over 35 years for the successful construction and operation of residue disposal areas at its refinery which is being made easier through the willingness of Jamalco to incorporate emerging RDA technological advances (in spite of cost) into its latest designs.

The closest known cultural heritage monument is Jamalco's Great House at Halse Hall and it will in no way be impacted by this project. No evidences of archaeological artefacts or articles of historical significance have been identified within the project area or its surroundings and it is unlikely that this will change due to the previous use of the area for farming. However, should any artefact or item of concern be unearthed during the implementation of this project, Jamalco will immediately stop work and seek the services of the Jamaica National Heritage Trust in managing the situation in an expert and sensitive manner.

The potential environmental impacts which may result from the construction of DRDA 6 will be addressed in terms of the various phases of the proposed project, these are as follows:

5.1 POTENTIAL IMPACTS & PROPOSED MITIGATION

5.1.1 PRE-CONSTRUCTION, CONSTRUCTION AND OPERATION

5.1.1.1 FUGITIVE EMISSIONS

Potential fugitive dust problems may occur during site clearance activities such as vegetation removal and excavation. Other activities may also contribute to this potential, especially during periods of drought and when it is windy, such as:

- Vehicular traffic
- Spillage of soil materials on access ways
- Uncovered stockpiles of soil
- Exposed areas of bare ground

Other sources of air emissions in the area include:

- Monymusk Sugar Factory
- New Yarmouth Sugar Factory
- Jamaica Public Service Company (power generation)
- Jamaica Energy Partners (power generation)
- Sugar cane field burning
- Coal burning
- Motor vehicles

5.1.1.1.1 MITIGATION

Standard mitigative measures are readily available and budgeted for by Jamalco to deal with impacts related to fugitive emissions, these include:

- Required servicing and proper maintenance of all vehicular and motor driven equipment
- Proper training and orientation of employees in the values of Jamalco and their individual roles in the preservation and upkeep of the natural and work environments
- Implementation of an irrigation regime, which is a standard feature of Jamalco construction projects, where sprinkler trucks are used for dust suppression

- Where stockpiles have to be created, they will be monitored and irrigated as needed to contain dust formation. Long-term stockpiles will be allowed to vegetate naturally to reduce dusting and erosion.

5.1.1.2 NOISE

Heavy equipment will generate noise as they perform their duties. However, it is not anticipated that this noise will carry outside of the project area at such a level as to exceed any local or international standards.

It is requested that the regulatory authorities give consideration to the use of time-weighted averages and provide direction on how to treat with issues related to momentary exceedances (as in the case of blasting) of regulatory limits for noise.

There may be the potential for noise being generated during pre-construction and construction activities, and as heavy equipment moves around the proposed RDA site.

An audiometric survey was conducted at the proposed RDA boundaries to establish a baseline for the area and to assess the potential for noise impacts on the adjoining communities. This assessment is included as section 4.8.1, of this report.

5.1.1.2.1 MITIGATION

There will be no mitigation for the normal operating noises of the heavy equipment. However, in the event that a piece of machinery malfunctions and is causing excessive and/or noise levels above the established limits at the boundaries, that equipment will be immediately removed from the project and taken to the service area for repairs.

Noise levels along the perimeter of the project area will be monitored and reported on a regular basis. Based on the feedback of the regulatory agencies on the use of time-weighted averaging and momentary exceedances, the findings will be presented in a monthly monitoring report..

Should it become necessary to conduct blasting activities, all appropriate permits and licenses will be obtained and all required notifications will be made to the communities and elsewhere in the manner specified by the regulators of such activity. will be notified through appropriate signage and communication.

5.1.1.3 LOSS OF BIODIVERSITY

Loss of biodiversity will probably be the most significant negative impact on this project. It is an unavoidable impact for which there is no direct mitigation. Jamalco will work with its engineers and designers to properly demarcate the project area in an effort to specifically identify all those areas that will have to be cleared for the project.

The ecological assessment did not identify any rare or endangered species in the area and avi fauna and other mobile species were not deemed to be dependent on the varieties of plants, etc. in the project area and therefore would be able to migrate easily to adjoining areas.

5.1.1.3.1 MITIGATION

Indirectly, biodiversity can be returned to the area through Jamalco's proactive approach to RDA closure and rehabilitation. Jamalco is working to identify methodology and strategy to successfully close and revegetate its RDAs once they are slated for final closure.

5.1.1.4 WATER QUALITY

The RDAs have a significant potential for impacting on the surface and groundwater resources of the area in the event of a failure to the physical structure or an overflow. The majority of potable water utilized at the Jamalco facility and those communities around that have piped water comes from wells located in the vicinity of the plant. The Rio Minho River and Webbers Gully are located adjacent to the RDAs. These are the primary reasons that so much emphasis is placed on the protection of water resources in the design and operation of the RDAs.

Additional potential impacts to surface water may arise from increased sediment loads primarily during preconstruction and construction activities caused by the removal of trees, shrubs and grass.

Potential impacts on the associated groundwater could be significant in the event of a catastrophic failure of the clay seal and/or geomembrane liner.

5.1.1.4.1 MITIGATION

Jamalco maintains a strict and compliant well monitoring program that measures all sensitive and indicatory parameters that would identify if groundwater was being contaminated. The various monitoring and production wells are monitored and reported on a monthly basis to the various regulatory agencies interested in this aspect of Jamalco's operation. New monitoring wells will be added to assist in the precise monitoring of DRDA 6 and they will be included in the monitoring program as well. Discussions are under way between Jamalco and the WRA regarding the location of groundwater monitoring wells around the proposed DRDA 6 and associated storm pond.

Where possible, boulders and other suitable materials removed from the proposed project area but not used will be utilised to create protective barriers and buffers for the Rio Minho River and Webbers Gully especially in areas anticipated to flood in the event of a 25 year flood event or greater.

Precautionary measures and dutiful monitoring of the installation of both the clay seal and geomembrane liner will be done during their installation. All standard and required confirmatory samples will be taken and appropriate analyses done to verify that design parameters have been met and that the "as-built" system will meet or exceed it design parameters.

The effectiveness of the liner and collection systems together with the quantities of the materials pumped into and extracted from the proposed RDA are integral as mitigative measures to water quality in the operational phase of the project. The baseline established over the past 20 years has shown that the use of a clay hydraulic barrier together with the sandy/gravel layer is effective in the prevention of liner failure which could contribute to groundwater contamination.

The sandy/gravel layer along with the liquid recovery system creates a zero hydrostatic head and lessens the load on the underlying clay zone minimising the potential for liner failure.

Maintaining the freeboard capacity in the RDAs is crucial as excessive influent levels can lead to overflow and affect water quality. Monitoring the volumetric capacity of the RDA with appropriate level indicators will mitigate the potential for spillages.

5.1.1.5 WASTE MANAGEMENT

There are various types of waste materials that may be generated during the implementation of this project that must be planned for and properly managed. Waste generated may include, chemicals and lubricants from the equipment maintenance area, vegetative matter (land clearing waste), and a small amount of garbage from site office operations. Potential impacts could occur during the handling, collection, storage and disposal of these waste materials.

5.1.1.5.1 MITIGATION

Jamalco has existing programmes and protocols in place to deal with all types of waste materials generated at all its facilities. All waste generated during the construction and commissioning of the DRDA will be handled based on these established protocols. The refinery has a landfill facility which includes a sealed area for disposal of certain hazardous materials. Jamalco has an oil recovery program where waste oil is collected for reuse and vegetative matter can be used for backfill or disposed offsite in an approved area under the guidance of the appropriate regulatory agency such as the National Solid Waste Management Agency. All identified waste management impacts can be successfully mitigated.

5.1.1.6 SEWAGE

During construction, their will be an anticipated 250 temporary employees. If not managed properly, sewage waste generated by this population of workers can enter the ground and surface water system and have a negative impact. Provisions will be made for toilet facilities through the use of portable chemical toilet facilities. These will be provided by one of Jamalco's established suppliers who will be responsible for the servicing of the units. Jamalco has a long standing relationship with its suppliers and has not had any major issues at its temporary work areas with portable toilet facilities.

5.1.1.6.1 MITIGATION

No mitigation is required. The portable chemical toilets will be utilized to meet the demands of the workers. Jamalco will maintain records of disposal from its supplier on file.

5.1.1.7 VIBRATION

The use of heavy equipment, particularly compaction equipment will produce some level of vibration. However, it is unlikely that this level of vibration would migrate offsite and result in measurable impact at residences or other similar receptors. None-the-less, it is a concern and will be addressed.

In the event that blasting is required at the site, the potential exists for short-term exceedance of noise levels at the site. Depending on the duration and amount of blasts, this impact may be major or minor.

5.1.1.7.1 MITIGATION

Vibration measurements will be taken at various times throughout the construction activities with an emphasis on situations where certain activities that may generate measurable levels of vibration are anticipated, such as blasting or pile driving. State-of-the-art equipment will be used and the results presented in the monitoring report. Where applicable, pre-blast surveys will be done at homes and other structures close to the site to determine if the blast activity results in any structural damage.

5.1.1.8 AESTHETICS

Aesthetics in the area will be impacted. The removal of vegetation and soils and the construction of a residue disposal area will cause a distinct change in the appearance of the land and land use. This is a major, but reversible impact.

5.1.1.8.1 MITIGATION

While the original look of the area cannot be replaced, Jamalco has successfully landscaped and “blended” its other RDAs into the surrounding areas in an attempt to alleviate the loss of aesthetic impact. The establishment of a visual buffer, which can be maintained from the start of DRDA 6 by leaving certain trees and plants between the main road and the communities of New Bowens and Halse Hall in place, would assist greatly. Landscaping should be used to further enhance the look of the DRDA.

5.1.1.9 ARCHAEOLOGICAL AND HISTORICAL HERITAGE

It is difficult and nearly impossible to predict whether or not archaeological or historical heritage relics or artefacts exist underground in an area. However, the history and previous uses of the general area, including evidence of Taino habitation make it necessary for consideration to be given to the possibility of unearthing items of historical or cultural value during excavation.

5.1.1.9.1 MITIGATION

For any archaeological or historical heritage item that may be impacted during pre-construction and construction activities, the Jamaica National Heritage Trust (JNHT) approved guidelines for managing archaeological and historical heritage items discovered during such activities will be utilized by Jamalco. It includes specific methods of operation including the necessary contacts and procedures to follow.

RISK ASSESSMENT

6 RISK ASSESSMENT

6.1.1 EMERGENCY RESPONSE PLAN

6.1.1.1 GENERAL OVERVIEW

The following is taken from pertinent sections of Jamalco's Emergency Response Plan.

1. The emergency response procedures included in the following sections are designed as guidelines to follow when a spill, fire, explosion, of other catastrophic event causes a release of oil or other hazardous material to the environment. The procedures presented in this document are intended for use by Jamalco personnel responding to emergency situations at the refinery (including the Residue Disposal Areas). In general, the following types of emergency scenarios are covered by the plan:

- Storage unit leaks and/or rupture,
- Levee failures,
- Leaks/spills during loading/unloading operations,
- Pipeline failures,
- Releases due to catastrophic events (e.g., fires, explosion, earthquakes, floods, and hurricanes).

2. The emergency response procedures are intended to be the primary document that provides the procedures to be followed during a spill event.

3. These procedures will be reviewed annually and amended as needed to address changes or additions to facilities, processes, operations, hazardous substances, and personnel which would adversely impact their effectiveness.

4. Following the occurrence of a spill, release, fire, or explosion that requires implementation of this plan, the Primary Emergency Coordinator should immediately notify the proper regulatory agencies and follow-up with a written Spill Report which will be submitted within the time frame requirements of the applicable regulations.

6.1.2 ALERT PROCEDURES

If a minor leak, spill, release, or fire occurs, the individual discovering the incident should attempt to locate and eliminate the source. If possible, he/she should try to stop or at least contain the release. This can involve closing valves, turning drums upright, activating emergency pumps, using absorbent materials, or extinguishing the fire. These measures should only be undertaken if they can be accomplished without any risk to the individual. If the source is not immediately obvious or if these measures are not effective and the situation is beyond his/her control, then the discoverer should initiate the following emergency procedures using the telephone & radio listing included in this Plan.

6.1.3 FIRST PLANT CONTACT RESPONSIBILITIES

1. Contact the shift supervisor with responsibility over the affected department or area, who has been designated as the First Plant Contact.

2. Pass along the following information:

a) Exact location of the emergency event;
b) Type and description of the emergency;
c) Estimate of the amount of material released, or the size of the fire;
d) Extent of injury or property damage incurred;
e) Extent of the actual and potential environmental damage; and
f) Remedial action taken, if any.

If significant spill conditions exist to the extent that assistance from outside the department is needed, the First Plant Contact should immediately contact the following individuals and communicate the information listed above.

- Security
- Area Superintendent
- Department Manager

It will be Security's responsibility to then contact one of the Emergency Response Coordinators.

6.1.4 EMERGENCY NOTIFICATION PROCEDURES

The Emergency Response Coordinators will provide on-site coordination of safety, emergency response, and remedial measures taken. Responsibilities will also include initial and follow-up notification of spill conditions to government authorities, if required. This information could include the following:

- Time of the spill;
- Identity of material spilled
- Approximate quantity spilled;
- Location and source of spill;
- Cause and circumstances of spill;
- Potential hazards (e.g., fire, explosion, etc.)
- Personal injuries or casualties, if any;
- Corrective action being taken and an appropriate timetable to control, contain, and clean up spill;
- Name(s) and telephone number(s) of individual(s) who discovered and/or reported the spill; and
- Other unique or unusual circumstances.

6.1.5 REQUIRED ALCOA NOTIFICATIONS

The Environmental Affairs Department in the Pittsburgh Office must be notified after every release or emergency response event that requires notification of local government agencies. An Environmental Event/Procedure Report should be completed and mailed to Ms. I. J. Soukup in the Pittsburgh Office.

6.1.6 EMERGENCY RESPONSE PROCEDURES

Based on information obtained from the First Plant Contact, department personnel, and emergency response guidance materials, the Emergency Response Coordinator will develop an initial response plan. At a minimum, the response plan should accomplish the following:

- Determine the classification of the material (e.g., flammable, poison, corrosive or otherwise);

- Determine the level of protection required (e.g., type, level and availability of breathing and skin protection);
- Discuss the hazards (e.g., specific to the material and danger from terrain, ruptures, leaks, falling objects, etc.);
- Direct the staging of response equipment;
- Determine if assistance from agencies outside the facility are needed; and
- Initiate the immediate steps necessary to contain or divert releases away from surface water bodies and other sensitive receptors.

The Emergency Response Coordinator will direct response personnel to obtain the necessary absorbents, barrier materials, or pipe plugging devices that are required to contain the spill and prevent it from reaching surface water bodies or drains that cannot accept the material.

The following information provides general response guidance for spills in specific areas.
1. Spills in Dike Areas

Absorbent material or booms will be placed to contain the spill within the dike area, it possible. If the spilled material is pumpable, portable pumps and/or the suction truck from the Clarification Department will be used to remove as much of the spilled material as possible. The material will be transported to an appropriate disposal site or placed in proper containers for later shipment. All attempts will be made to prevent the released material from entering surface water systems or associated storm drains. Acidic materials may be neutralized with material from the limestone storage pile.

2. Spills in Un-dike Areas

Every attempt will be made to contain the spill as rapidly as possible to prevent runoff from reaching surface water bodies or a storm drain system. If necessary, earthen materials will be used to construct temporary dikes or berms around the spilled material for placement in proper containers. Construction equipment may be used to build diversionary structures to divert or block releases from contaminating soils and/or surface waters. Acidic materials may be neutralized with material from the limestone storage pile.

3. Spills to On-Site Lakes/Lagoons

Every attempt will be made to limit the amount of spilled materials that could enter lakes/lagoons at Jamalco. In the event that a large spill enters these areas, floating booms will be used to restrict the release to a limited area, if possible. Absorbent material and/or skimming equipment may be used to remove floating materials (e.g. oils and other petroleum products). If the spilled material is one that will mix with water, attempts will be made to isolate the lake/lagoon to keep contaminated material from entering other containment systems. If the released material is compatible with materials already present in lakes/lagoons at the site, those systems may be used for spill containment at the discretion of the Emergency Response Coordinator.

4. Spills on Soil

An attempt will be made to minimize the surficial area of the spill. Earthen dikes or berms will be used to provide containment for the spill. If possible or as practicable, absorbent materials will be placed on the spill area in an attempt to absorb freestanding material from the soil surface. Contaminated soil will be excavated and disposed or containerized for later disposal. Acidic materials may be neutralized in place with limestone.

5. Spills to Receiving Streams

An attempt will be made to contain spilled material at the source of the release, if possible. If the spilled material is moving across land, diversionary dikes, ditches, or berms will be placed using construction equipment to contain or divert the material prior to its reaching surface water bodies or other sensitive receptors.

If the spilled material reaches surface water, absorbent materials or booms will be used to control the material on the water (e.g., petroleum products). If the released material can be controlled, an attempt will be made to remove the material using portable pumps, skimmers, or the suction truck from the Clarification Department. If the spilled material cannot be controlled, other response measures may be taken at the direction of the Emergency response Coordinator including in situ treatment (e.g., neutralization of acidic materials) and diversion to less sensitive containment areas.

6.2 PREVENTATIVE MEASURES LOADING/UNLOADING OPERATIONS

The following information provides a description of the spill preventative measures employed at loading/unloading operations.

6.2.1 RED MUD LAKE SYSTEM

The Red Mud Lake System incorporates:

- Plant runoff from Storm lake to Mud Lake 1
- Caustic/Mud from the plant to the Mud Lakes
- Cooling water from the Clear lake to the process

To facilitate sound management and operational integrity,

i. Pumping operations are conducted by trained personnel

ii. Liquid levels in the receiving impoundments are monitored

iii. Equipment inspections are performed including pre-pump checks to ensure proper operation, moisture levels in pumps, pump packings, weekly pressure checks and motor control center cleanings

6.2.2 AIR EMISSIONS

The potential sources that would be the likeliest contributors to air emissions are:

- Excavation and stockpiling of soil material during pre-construction and construction activities
- Excavation and stockpiling of sand for use during the construction phase of the project
- Haul road traffic
- Engine emissions from heavy equipment

Practical measures will be utilized during periods of excavation and earth movement to reduce the levels of air emission. Equipment emissions will be controlled through

comprehensive maintenance and overhaul programs to ensure that equipment is in sound operational condition.

Dust control on haul roads will be accomplished through applications of calcium chloride to the road surface. Maintenance applications will be made as necessary to maintain the integrity of the roadway. Calcium chloride attracts moisture from the air and binds with the limestone chips used to construct the roads effectively forming a low grade pavement.

6.3 CONTINGENCY PLAN

Preparedness and Prevention

The following information describes the actions and equipment that are available and maintained for immediate use in the event of an emergency release situation.

6.3.1 PLANT COMMUNICATION SYSTEMS

An extensive communications network is maintained at Jamalco for accessing necessary emergency personnel during an emergency situation. Relevant components of the overall communication system are briefly described below.

a) Telephone system - an external telephone system connects each operation of Jamalco including the refinery, Woodside Land Office, Breadnut Valley Mines and Rocky Point Port.

   An internal system extends throughout the refinery and is connected to the Woodside Land Office and Breadnut Valley mines.

b) Radio System - a radio communication system is in place and is an effective method for communicating emergency messages throughout the refinery/chemical plant and especially areas out of reach of the telephone system.

Radio communication equipment includes hand-held units and mobile radio units installed in facility vehicles. During emergencies, limited communications can be maintained on F-1 frequency.

c) HAM radio system - A HAM radio system is in place to provide long-range communication support in the event normal communication systems are inoperable due to an extreme emergency (e.g. hurricane, earthquake, etc.). The HAM radio system is maintained at the Powerhouse Control Room, Building 110.
d) Alarm system - A plant emergency siren is maintained for immediate warning to facility personnel in the event of an emergency. In an emergency situation, security personnel will sound the siren with 2 blasts of 10 seconds each.

6.3.2 OUTSIDE AGENCY SUPPORT

a. May Pen Fire Brigade: The plant Fire Brigade Leader will notify the May Pen Fire Brigade in the event of an emergency and will provide an estimate of additional services needed.
b. May Pen Hospital/Lionel Town Hospital/University of the West Indies Hospital: Jamalco maintains its own medical staff (doctors and nurses) as well as ambulances located at the refinery, Breadnut Valley Mines, and Rocky Point Port.

   The facility will normally transport their own injured personnel to the hospital. However, if conditions warrant, medical staff/security will notify the appropriate hospital in the event of an emergency and will provide an estimate of additional services needed.

6.3.3 EVACUATION PLAN

If it has been determined by an Emergency Response Coordinator that an emergency evacuation is required, employees will be notified via the facility communication system (e.g., emergency siren, telephone system, radio system or directly).

Evacuation from facilities operated by Jamalco, including the refinery, Woodside Land Office, Breadnut Valley Mines and Rocky Point Port will be conducted according to the following procedure:

a. At the sound of the evacuation announcement, work will be stopped in an orderly manner and preparations made to evacuate the area immediately.
b. Upon receiving notification of an impending evacuation, each department supervisor will report to their respective department/area and direct their employees to the nearest sate exit route (if this is feasible). After observing that all employees have evacuated the area, the supervisor will exit the area in question. All facility personnel will relocate to the company parking lot. Upon arrival at the parking lot, the emergency coordinator of his designee (e.g. each department supervisor) will take roll call.

   If it is necessary to relocate at a greater distance from the facility, the decision for the required relocation will be made by the emergency coordinator or his designee.

c. Plant Security and Fire Brigade personnel, when designated by the emergency coordinator to be traffic controllers, will position themselves in proper areas to direct traffic exiting the facility. Traffic controllers may also have the responsibility of escorting emergency vehicles to the incident location.
d. Personnel designated by the emergency coordinator, as necessary, will be expected to search and assure that the area is clear of employees and that all equipment is turned off that is not absolutely necessary.
e. Maintenance personnel will see that utilities are turned off and/or controlled to minimize the potential for secondary fires, explosions, electrical shocks, etc.
f. Once the evacuation is complete, it will be at the discretion of the emergency coordinator as to whether additional tasks are considered safe and/or necessary. Additional tasks could include minor fire fighting assistance, removal or materials or equipment to safe locations, and proper operation/shutdown of plant processes.

6.3.4 EMERGENCY RESPONSE PARTICIPATION IN THE COMMUNITY

If called upon, Jamalco will donate and use whatever communications and emergency response equipment it has at its disposal to assist during a community wide emergency.

6.3.5 EFFECTS OF EXTERNAL FACTORS ON EMERGENCY RESPONSE PROCEDURES

Certain catastrophic events (e.g., hurricanes, earthquakes, power failures, fires, flood, worker strikes, etc.,) could occur that would limit the ability of Jamalco to implement the emergency response procedures contained in this plan. In this event, Jamalco's Emergency Response Coordinators will quickly assess the situation and make the modifications necessary to ensure the success of response efforts.

The following information is provided to identify the adverse effects associated with catastrophic events that have the potential for occurring at Jamalco:

- Disruption of telephone communication;
- Loss of lighting;
- Loss of computer support affecting process equipment and information services;
- Immediate shutdown of spill control sumps, process equipment, and air control devices;
- Disruption of evacuation procedures;
- Limitations on emergency response and/or vehicle access
- Loss of electrical power
- Loss and/or contamination of water supply (both potable and for fire response)
- Complications resulting from levee failure
- Releases resulting from levee failures

6.4 LANDSLIDE RISK ASSESSMENT

While no detailed assessment of the landslide risk has been carried out in southern Clarendon to date, the landslide inventory map of Jamaica shows no record of landslide events for the southern Rio Minho flood plain. The landslide hazard zonation map of Jamaica therefore shows this area to be at low risk of landslides (Area No. 1 on the map). The low landslide risk can be attributed to the flat lying nature of the topography, the presence of fairly easily drained alluvial soils, and the relative dry climate.

6.5 LOCAL AND REGIONAL TECTONIC ACTIVITY

An investigation of the historical records of seismic activity in this area has shown that the adverse effects of earthquakes have been experienced. The well-documented 1692

Port Royal earthquake had disastrous effects in the Lower Vere Plains, with modified Mercalli intensities of MM(X) being experienced in Alley and Salt River, both of which lie at about a 10 km radius from the study area.

The following quote from a newspaper clipping written by the local Rector illustrates: all brick and stone building were thrown down and water spewed out of the chasms opened in the ground by the earthquake so that even dry gullies ran water". The St. Peters Anglican Church in Alley built in 1671 was destroyed beyond repair. However, the Halse Hall Great House, where alluvial thicknesses are comparatively low, survived the 1692 earthquake, as well as subsequent ones. The Great House is situated approximately about 6 km to the north of the JAMALCO alumina plant.

Subsequent damaging earthquakes are, most notably, those of 1907 and 1957. The 1907 earthquake appears to have caused some damage in the Vere Plains. Intensities of MM (VII) were reported in Alley with incidence of damage to chimneys and buildings (Tomblin & Robson, 1977). The 1957 earthquake had intensities of MMCIV) to MM (V) in the Lower Vere Plains (Robinson et al., 1962).

In each 50-year period, starting with 1991 and counting backward for four 50-year cycles, at least one damaging earthquake, i.e. MM (VI) of higher, has occurred in the area. Shepherd (1971) reported that Lower Vere had a frequency of 5-9 damaging earthquakes per century on average.

The map of epicentres in the study area represents data gathered between 1981 and 1995 by the national seismograph network. It shows a scatter of small earthquakes around the site. It must be pointed out here that the error in these locations could be up to +1- 5km. The earthquakes shown have magnitudes of between 1.9 and 3.6.

Compared to the rest of Jamaica, the study area is not in a very active zone. However the Vere Plain is largely built up of alluvial clays, sand and gravel, and in the presence of ground water, this material will be susceptible to liquefaction in an earthquake of high enough intensity. Thus, the height of the water table will be an important factor in determining the area's earthquake risk.

In the borehole data produced by JENTECH, none of the holes encountered the water table during drilling. Maximum depth drilled was 41 feet, where the limestone basement

was encountered. This would suggest that the water table in this area is not near the surface, which means that the risk of liquefaction would be reduced. Also, the level of compaction was measured to be >90%, which would again reduce the risk.

Halse Hall falls within the area designated 'PC' - soils on old alluvium. While there is a high potential for liquefaction along the coastal sections of the Rio Minho alluvial plain, the area inland does not fall into that category. This is due to the fact that the coastal sediments would have a greater percentage of water contained within them, and also the coastal sediments would be more recently deposited and therefore less compacted than those inland.

SOCIO-ECONOMIC ANALYSIS OF PROJECT IMPACTS

7 SOCIO-ECONOMIC ANALYSIS OF PROJECT IMPACTS

7.1 INTRODUCTION

While the selection of the areas for interviewing were based on the enumeration districts as defined by STATIN, the communities as presented in this report were defined in the field by the interviewer and the respondent. Accordingly it is possible for a number of communities to cross Ed boundaries. The list of communities identified appears in Figure 7-1 below.

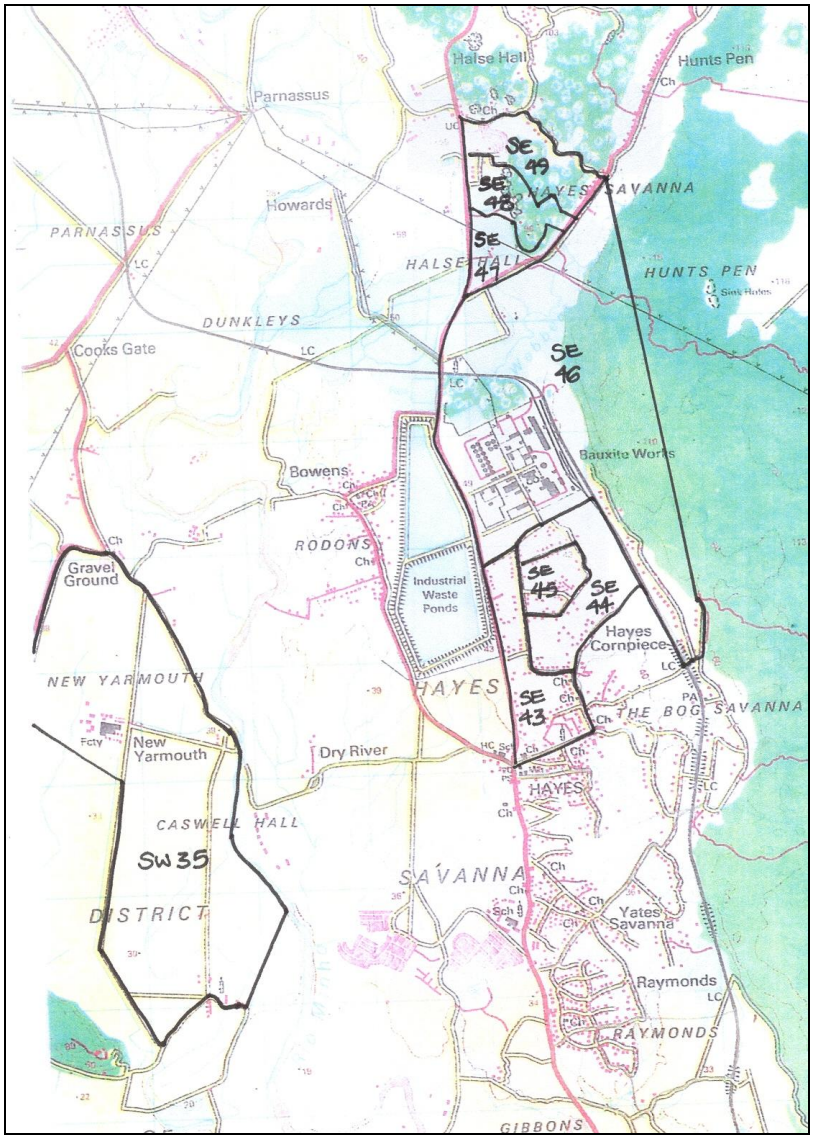


FIGURE 7-1: ENUMERATION DISTRICTS SURVEYED IN SOUTHERN CLARENDON

7.2 OBJECTIVE

The objective of the survey was to determine the level of knowledge of the population of the existing and proposed Jamalco's operations and to ascertain their views on the impacts of these operations.

7.3 SURVEY POPULATION

The Enumeration Districts to be surveyed were chosen based on their locations relative to those areas in South Clarendon, which were identified by Jamalco as areas of prospective sites for construction of Residue Disposal Area (RDA) # 6.

To determine how many survey instruments to issue, 10 % of the Total number of Housing Units (THU) in each ED was calculated. To ensure that the final figure would be representative, it was ensured that no two respondents to the surveys were from the same household. The table below shows the EDs surveyed and their corresponding THUs.

TABLE 7-1: TOTAL HOUSING DEVELOPMENTS IN THE ENUMERATION DISTRICTS SURVEYED

ED CODE	THU	SURVEY POPULATION (10 % THU)
SE43	173	16
SE44	201	20
SE45	113	11
SE46	239	25
SE47	126	33
SE49	186	15
TOTAL	**1038**	**121**

7.4 SURVEY ANALYSIS

7.4.1 DEMOGRAPHIC

121 questionnaires were issued. There were 54 males and 66 female respondents. The following diagram shows the distribution in the respondents' ages.

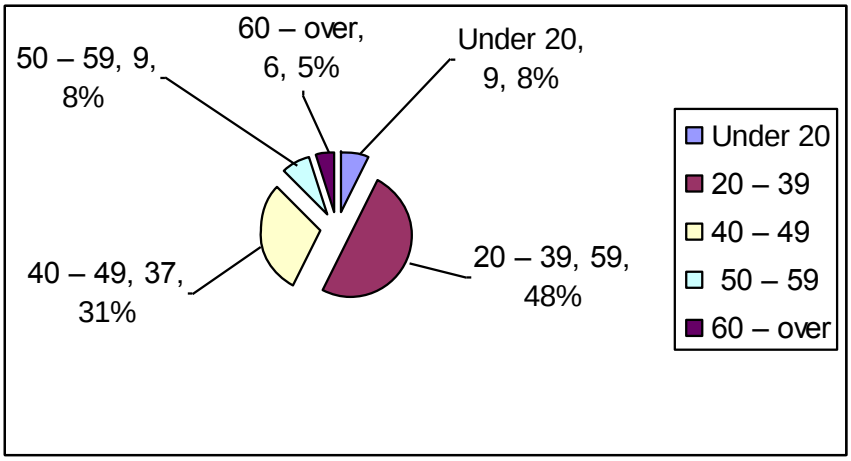


FIGURE 7-2: AGE DISTRIBUTION OF SURVEY RESPONDENTS

The majority of respondents have been living in the community for over 20 years and it is assumed that their views as presented are credible. The table below shows the distribution.

TABLE 7-2: NUMBER OF YEARS OF RESIDENCE IN THE RESPONDENTS' RESPECTIVE COMMUNITIES

Number of years residing in the community	%
0-5	17
6-10	15
11-20	31
20 +	37
No response	0
Total	**100**

7.4.2 COMMUNITY OPINION

The table below shows the aspects of the community nominated by the respondents as their personal likes and dislikes.

TABLE 7-3: RESPONDENTS' PERSONAL OPINIONS ON THEIR COMMUNITIES

Community likes	%	Community dislikes	%
Friendly people	25	Poor roads	15
Clean Environment	5	Lack of utilities	18
Land Availability	12	Crime/violence	5
Quiet	18	Unemployment	19
No crime & violence	14	Dirty environment	8
Other, (specify)	19	Other	33
Not stated/No response	4	Not stated	12
Total	100	Total	100

7.4.3 AWARENESS AND OPINION ON EXISTING BAUXITE FACILITIES AND OPERATIONS

The survey results of this section verified that the community members of Southern Claredon were quite knowledgeable of Jamalco's current and proposed future activities. 94% of respondents were aware of bauxite processing operations conducted in or around their communities. 64% of respondents were able to say that Jamalco's bauxite operations have positively contributed to the development of the community. Interestingly a lower percentage of respondents, 58% reported definite negative consequences of Jamalco's bauxite operations. Figure 7-3 below presents the respondents concerns as to why they believe that Jamalco's bauxite operations is impacting the community negatively while Figure 7-4 indicates the specific negative impacts the respondents reported they were personally experiencing from the existing red mud disposal areas.

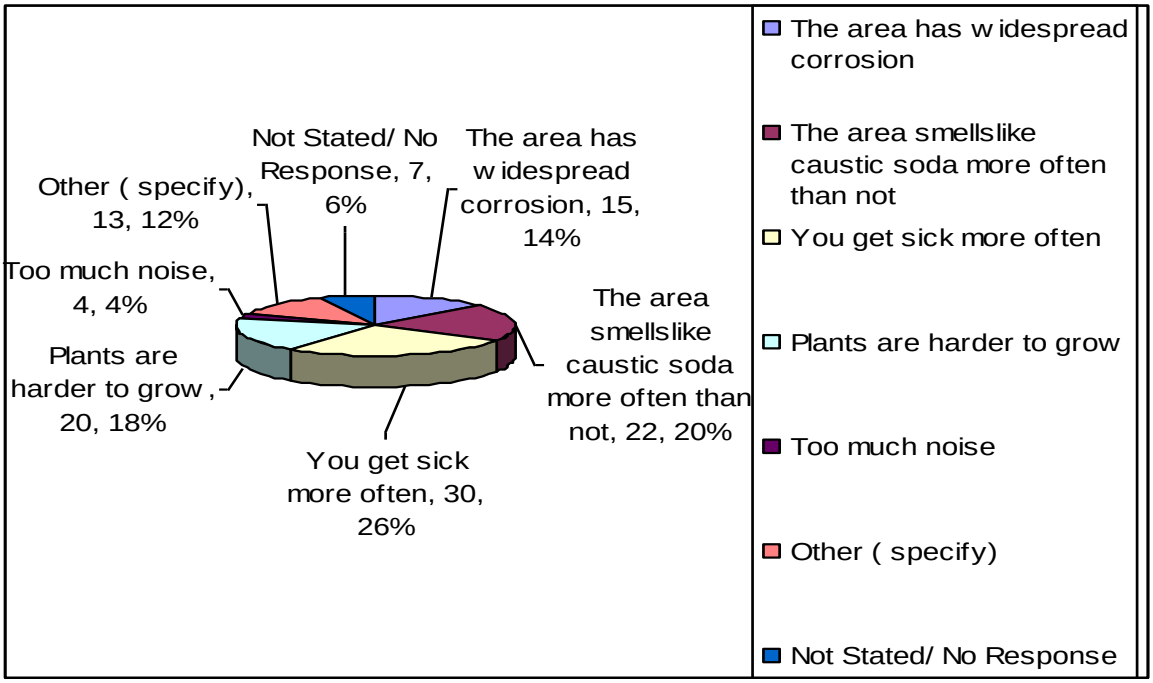


FIGURE 7-3: NEGATIVE IMPACTS EXPERIENCED FROM EXISTING BAUXITE MINING AND PROCESSING OPERATIONS

The following diagram below indicates the respondents' beliefs on the personal negative impacts of Jamalco's bauxite operations.

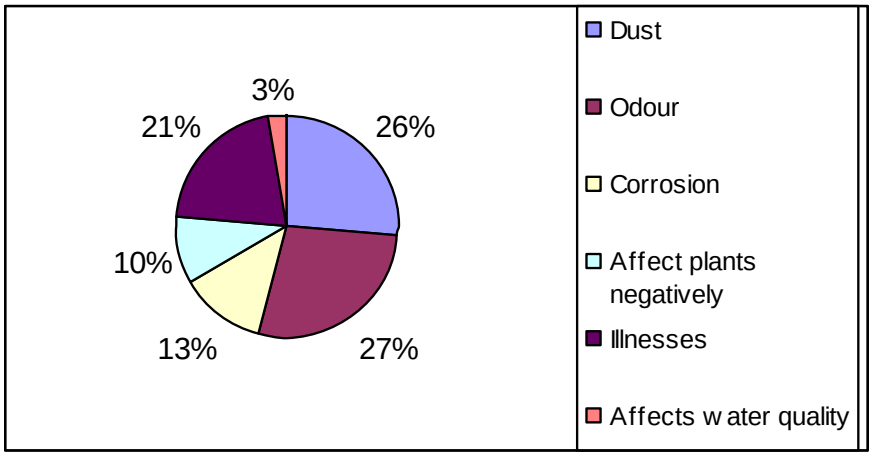


FIGURE 7-4: PERSONAL NEGATIVE IMPACTS EXPERIENCED

Positive impacts were also experienced with availability of job opportunities being the number one reported positive impact of Jamalco's bauxite operations.

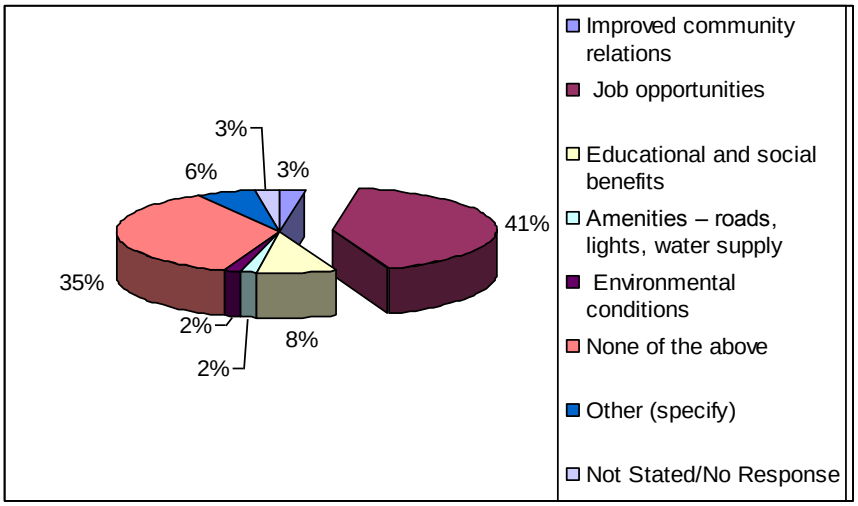


FIGURE 7-5: POSITIVE IMPACTS OF BAUXITE MINING ON THE COMMUNITIES

7.4.4 AWARENESS OF THE EXPANSION PLANS BY JAMALCO

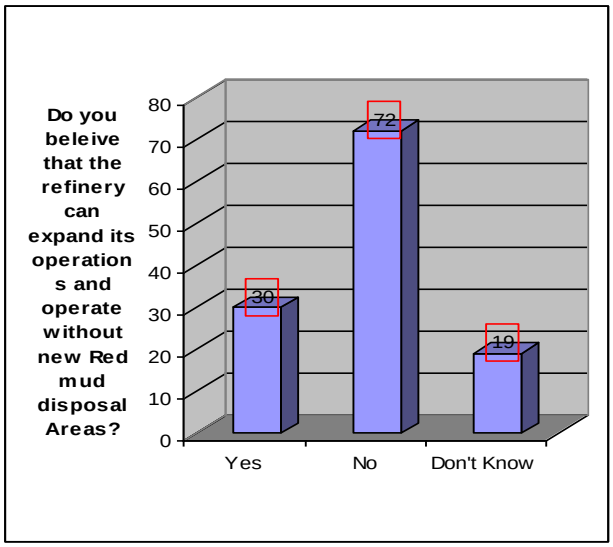
90 % of the respondents of South Clarendon were aware that Jamalco is in the process of upgrading and expanding the production capacity of its refinery. Correspondingly 97% of respondents knew that Jamalco operates red mud disposal areas adjacent to the refinery in Halse Hall.

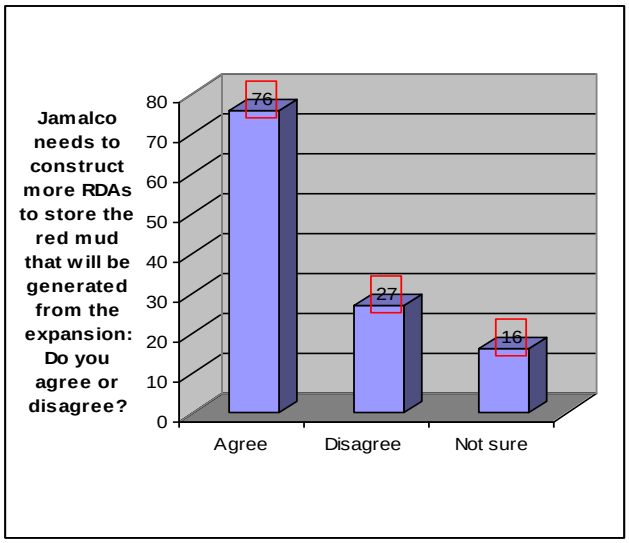
The following tables show the number of respondents who were aware of Jamalco's plans to expand its activities. They also display the respondents' views on how they believe Jamalco's expansion will impact the various aspects of their lifestyle.

TABLE 7-4: NUMBER OF RESPONDENTS AWARE OF JAMALCO'S PLANNED EXPANSION OF OPERATIONS

Awareness of JAMALCO proposal to expand their residual disposal area to meet the demands of expansion	Number
Yes	106
No	11
Not Stated/ No Response	2
Total	**119**

The respondents' opinions on whether or not Jamalco should build new Red Mud Disposal Areas were consistent throughout the survey as shown in the two graphs below.





A large percentage of the respondents believe that Jamalco's refinery is unable to expand its operation without the creation of new Red mud disposal Areas. Some respondents stated however that while they believe that Residue Disposal Area #6 needs to be constructed it should not be done in the community in which they live. Some of the respondents' opinions were based on their hope of receiving employment at the new project site.

TABLE 7-5: RESPONDENTS VIEWS ON THE POTENTIAL IMPACTS OF JAMALCO'S PLANNED EXPANSION ON THEIR COMMUNITIES

	Percentage of Respondents				
Impact	**Income/Economic Value of Community**	**Job Opportunities**	**Pollution**	**Health**	**Overall Quality of life**
Positive	36	58	14	8	21
Negative	42	17	70	73	40
No Change	12	18	9	6	24
Don't Know	9	6	7	10	12
Not Stated	1	1	0	3	3
Total					

7.4.5 AVAILABILITY OF WATER

The pie chart below shows the sources of drinking water for those surveyed.

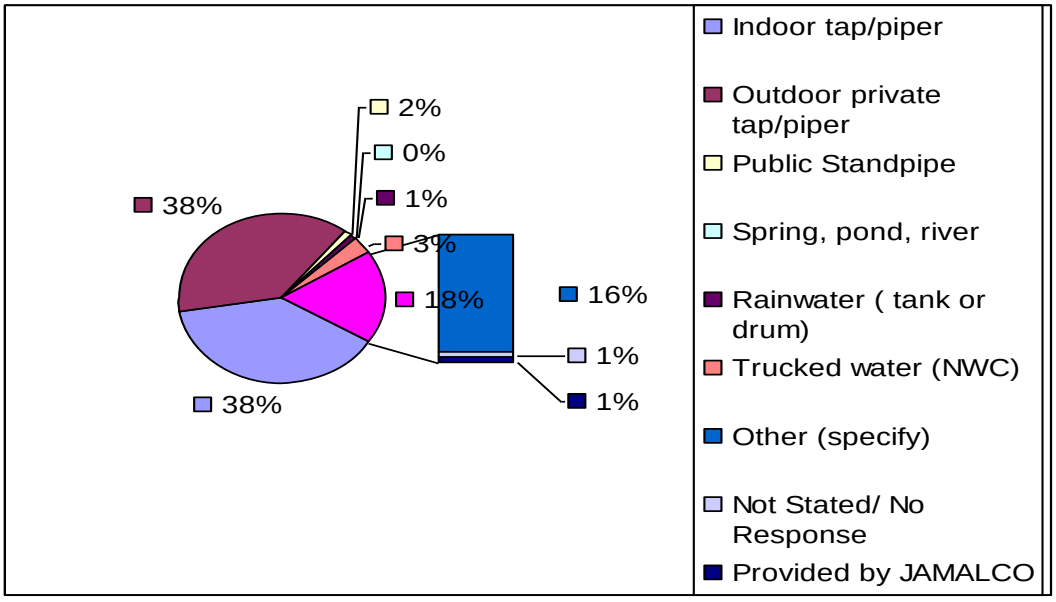


FIGURE 7-6: RESPONDENT'S MAIN SOURCES OF DRINKING WATER

In addition, respondents reported that they utilized a pump or sourced water outside of their immediate community such as going to Mineral Heights in order to sustain their water needs.

Water quality is usually a major concern for residents close to bauxite processing facilities. It was therefore, very important to get the residents' opinions of the water

quality in their areas. The majority of respondents thought that their water was safe, while 12% either did not know or did not answer. The table below shows the responses.

TABLE 7-6: RESPONDENTS OPINION ON THE SAFETY OF THEIR DRINKING WATER

Do you think you have access to safe drinking water in your community	#	%
YES	67	57
NO	35	29
Don't know	17	14
Not stated	0	0
Total	100	100

The reasons for their various responses are shown below:

TABLE 7-7: RESPONDENTS' REASONS FOR THEIR VIEWS ON THE SAFETY OF THEIR DRINKING WATER

Reason	%
Bauxite mining affects the drinking water	12
Sources (not bauxite mining or alumina processing related) affect the drinking water quality	2
The water is tested frequently by the N.W.C.	9
The water looks and/or smells clean	28
Other, please specify	34
Not Stated/ No Response	15
Total	100

The other responses (which were quite significant 34%) obtained in this portion of the survey explain respondents' scepticism on whether or not they are receiving a clean source of water. Some of the responses were as follows: Too much chlorine in the water, the pipe lines are not safe, questions of whether chemicals are seeping through the pipe line, waste from Alcoa is seeping to the pump. Respondents from communities which were closer to the mud lake were more likely to believe that there was possible contamination from the mud lake.

7.4.6 INTERACTIONS WITH BAUXITE COMPANIES

61% of the residents surveyed in Clarendon reported that they either worked in the bauxite industry or had family members who worked in the industry. There were expressed concerns as to whether there was equal employment opportunity for all the communities surrounding the Jamalco plant in Clarendon.

Comparable figures were obtained regarding the residents knowledge of community activities initiated by bauxite companies. 65% of residents were aware of community projects initiated by Jamalco whereas 39 % was unaware and 5% were unsure. When the respondents were interviewed about their likes and dislikes of the community a frequent response was the need for more recreational activities. This could be an area of community involvement that Jamalco could investigate as a means of developing a continuous positive rapport with the members of the community in which they operate.

7.5 CONCLUSION

The accurate and thorough information obtained within this survey of the opinions and knowledge base of the residents of Southern Clarendon regarding Jamalco's current and proposed activities will act as a first-class pointer guiding Jamalco decision regarding the construction of Residual Disposal Area # 6 (RDA#6).

IDENTIFICATION AND ANALYSIS OF ALTERNATIVES

8 IDENTIFICATION AND ANALYSIS OF ALTERNATIVES

The following is a summary of the alternatives considered in this phase of Jamalco's Residue Management Plan:

- No Action
- Expand lifespan of existing RDAs by elevating perimeter dike walls
- Dredge existing RDAs and process residue through paste thickener
- Disposal of Red Mud at sea
- Reduce Production
- Construction of DRDA 6 incorporating a combination of thickened tailings disposal and dry stacking technology. (preferred alternative)

8.1 ANALYSIS OF ALTERNATIVES

8.1.1 NO ACTION ALTERNATIVE

The no action alternative would not be practical at this time as Jamalco is in the early stages of a major efficiency upgrade and capacity expansion project that will see the refinery effectively doubling it alumina production and through direct relationship, doubling the amount of red mud it produces. A new DRDA (5) is being constructed at this time, however, it is slated to handle residue from the existing configuration at the refinery and will offer only limited and short-term support to the fully expanded operation.

The time it takes to assess, design, receive permission to construct and finally construct a facility such as proposed for DRDA 6 can be years and it is important that plans are made ahead of time so that production will not have to stop at the refinery while additional residue storage capacity is identified.

The No Action Alternative would result in the near term shut down of the Jamalco refinery, the abandonment of plans for the upgrade and expansion of the refinery and a serious economic blow to the surrounding communities and Jamaica at large.

8.1.2 INCREASE LIFESPAN OF EXISTING RDAS BY ELEVATING DIKE WALLS

This is a possible alternative, however, the dike walls on RDAs 3 & 4 have been raised previously resulting in additional capacity. Careful engineering analyses and assessment will be required prior to any additional elevation of these dike walls and consideration must be given to issues related to aesthetics and the increased potential for structural failure with increased volumes of residue being maintained at higher elevations. Additionally, the risk of the elevated dike walls is greater than the value to be gained from the relatively small increase in capacity that would result.

8.1.3 DREDGE EXISTING RDAS AND PROCESS THROUGH PASTE THICKENER

This is a possible alternative that is being contemplated. However, this would only result in a small increase in capacity across the existing RDAs when compared to what is required and what could be gained from a new facility. Jamalco is always seeking to maximise the potential of the existing red mud disposal infrastructure, so this alternative will be seriously considered, however, it would not meet the needs of a plant that is seeking to increase it production output from 1.2 to 2.8 Mtpy. This is not the preferred alternative.

8.1.4 DISPOSAL AT SEA

Impractical alternative that is practiced in other countries. Jamaica relies heavily on the bounty and beauty of its coastal resources. Even if piped into deep water, it is uncertain and risky and provides no guarantees that near shore resources will not ultimately be impacted. The potential for environmental and socio-economic damage is significant and this alternative will not be considered further.

8.1.5 REDUCE PRODUCTION

Implementation of this alternative would result in increased lifespan of existing residue disposal solutions since less red mud would be produced. However, the world market for alumina is at its highest levels ever and Jamalco and its partner the Government of Jamaica want to be able to capitalize on this reality. In times when sales are slow and

prices are sluggish, both Jamalco and the Government have a responsibility to meet obligations, provide employment and service the communities of the area. It is therefore not unreasonable for them to want to capitalize on the current growth of the industry.

A reduction in production would also defeat the purpose of the approved upgrade and expansion of the refinery and would represent a step backward for Jamalco and Jamaica at large. While this alternative is reasonable it is not the preferred alternative.

8.1.6 SITE DRDA 6 AS PROPOSED

Provision of DRDA 6 is the preferred option. Jamalco has gained significant experience, knowledge and wisdom over the past 34 years in terms Construction of red mud management and disposal. The construction of DRDA 6 using the latest technologies, designs and construction protocols would afford an opportunity to implement all these attributes in a situation where Jamalco needs to plan for and implement in a timely manner, appropriate residue storage for the increases in red mud production that will result from the upgrade and expansion of the refinery.

Additionally, Jamalco is making every effort to maximize the safety and capacity of its residue disposal areas through the inclusion of thickened tailings, dry stacking technology, geomembrane liner and the now familiar under drain system for leachate collection to the designs of DRDA 6. This will allow the facility to hold more residue in a more environmentally friendly manner and enhance the ability of the area to be rehabilitated in a shorter timeframe due to the compacted nature of the residue, high shear strength and load bearing capacity. Overall, this approach appears to be the least disruptive, most environmentally friendly and cost effective means of establishing the volume of storage required for Jamalco’s upgrade and expansion of operations.

Of all the alternatives stated above, sealed impoundment disposal of red mud residue using thickened tailings and dry stacking technology is the most appropriate and acceptable method to meet Jamalco's operating procedures, long term goals and the environmental and regulatory requirements of Jamalco and the regulatory agencies in Jamaica.

Several layouts were analysed, with the following general arrangements. Proposed occupation of both sides of the 138 kV power line indicating future second phase, north of the power lines.

In defining the size of the future area, a buffer of 20m from the highway was considered, 30m from transmission line and about 70m from 100 years flood plain.

Alternative 1:

Not considered further due to intrusion into the 100year flood plain.

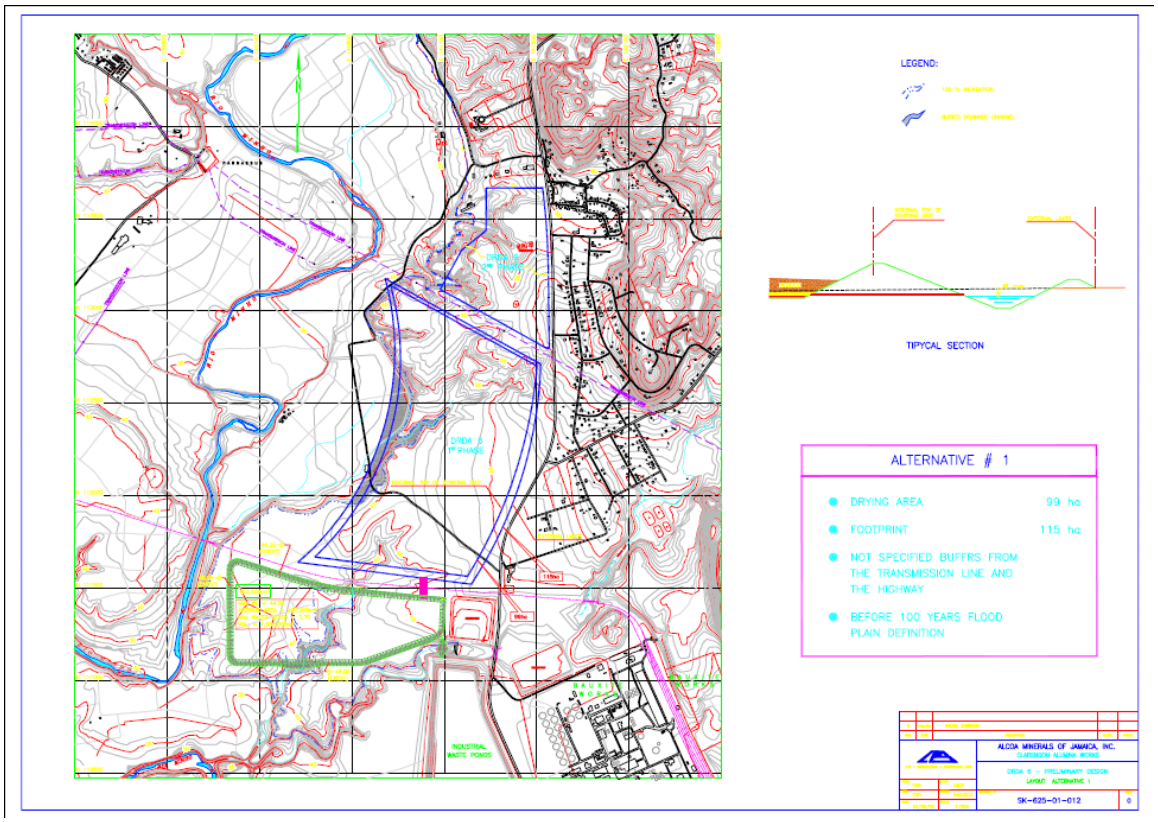


FIGURE 8-1: ALTERNATIVE 1

Alternative 2:

There is no buffer from 100 years flood plain, buffers of 50 m from highway and transmission line

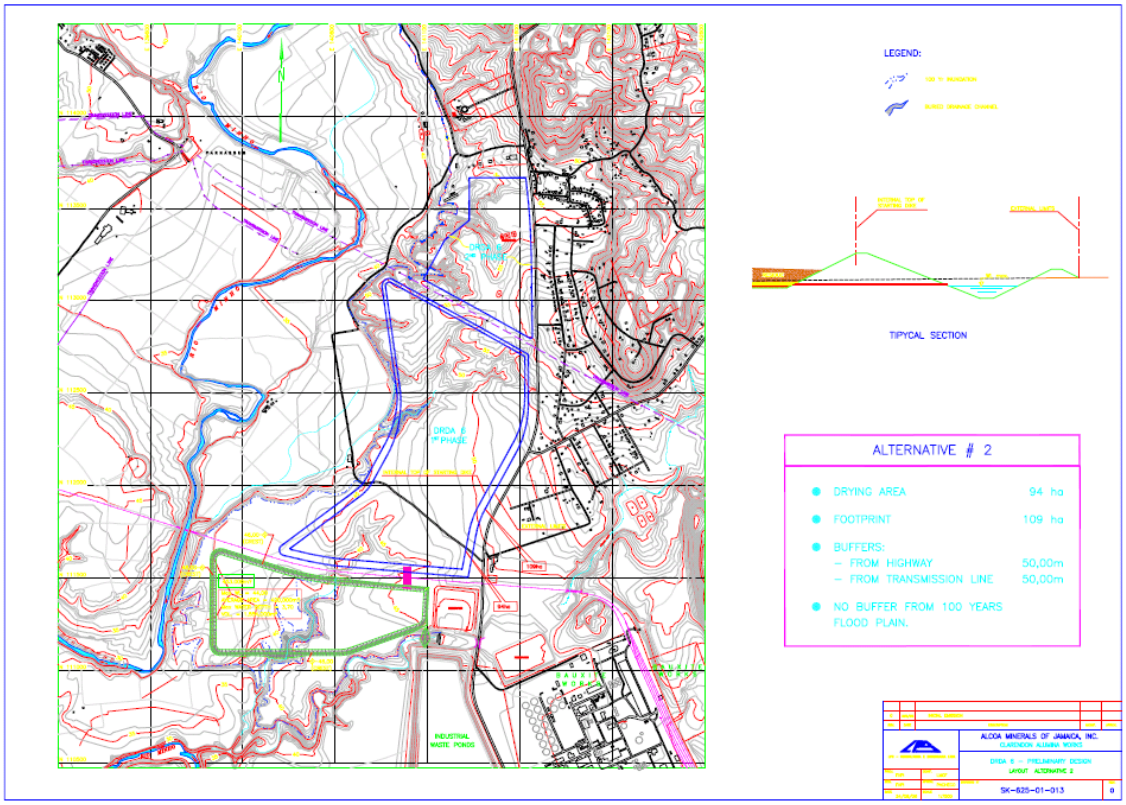


FIGURE 8-2: ALTERNATIVE 2

Alternative 3:

Considers a buffer of 50m from highway, transmission line and 100 years flood plain.

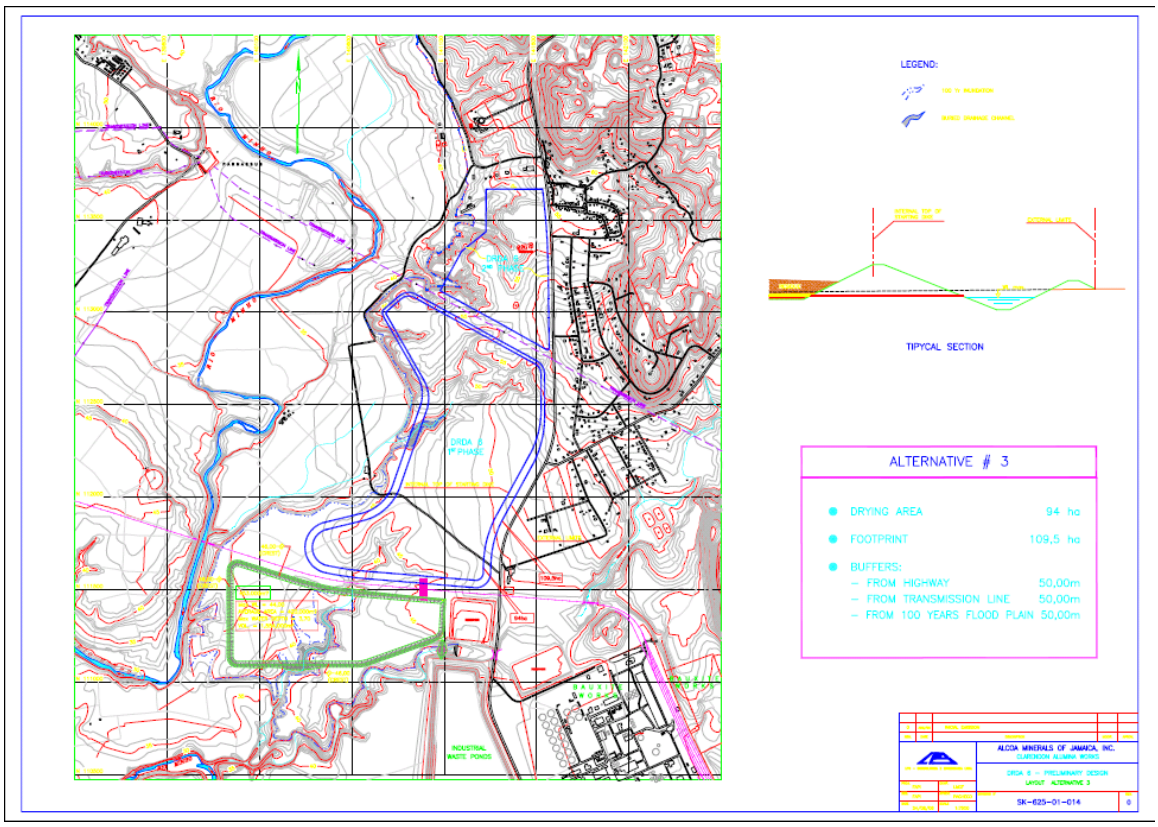


FIGURE 8-3: ALTERNATIVE 3

Alternative 4:

At this one, the buffer is 40m from highway and transmission line and 30m from 100 years flood plain.

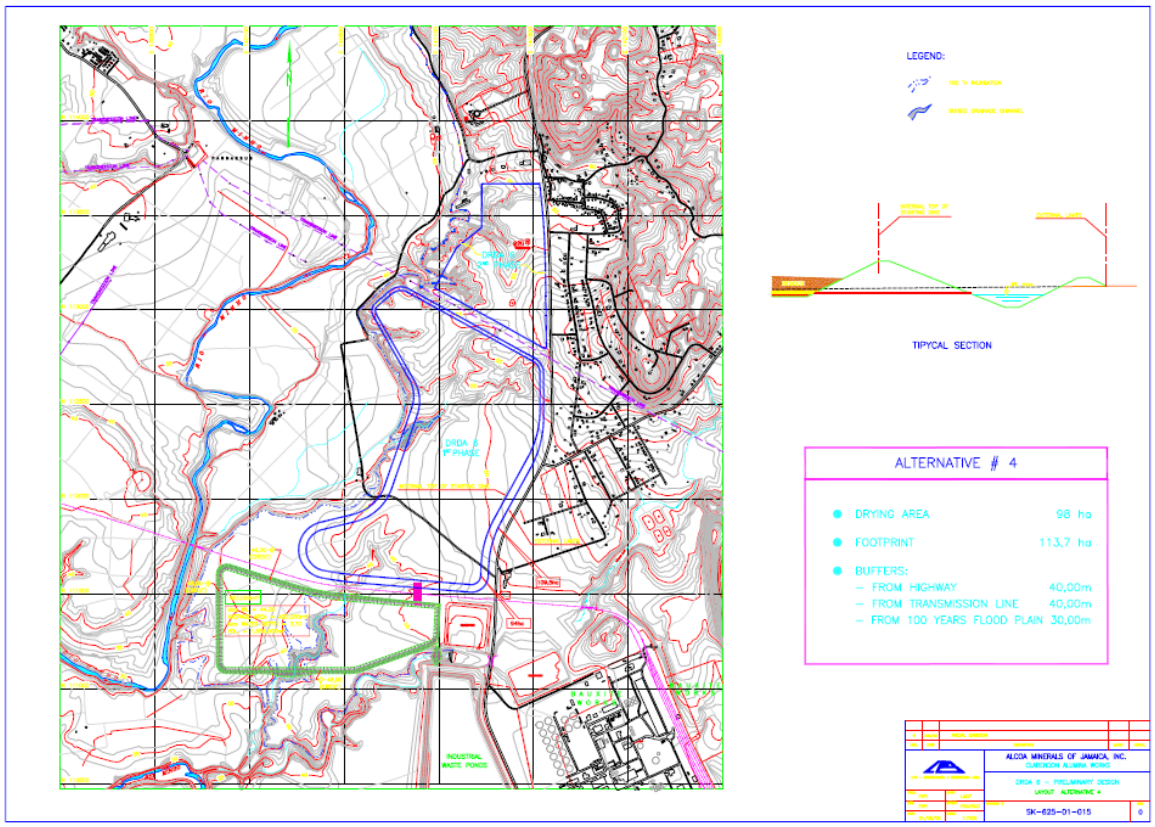


FIGURE 8-4: ALTERNATIVE 4

Alternative 5: Proposed Option:

Adopts buffer zones 20m from highway, 30m from transmission line and approximately 50m from 100 year flood plain.

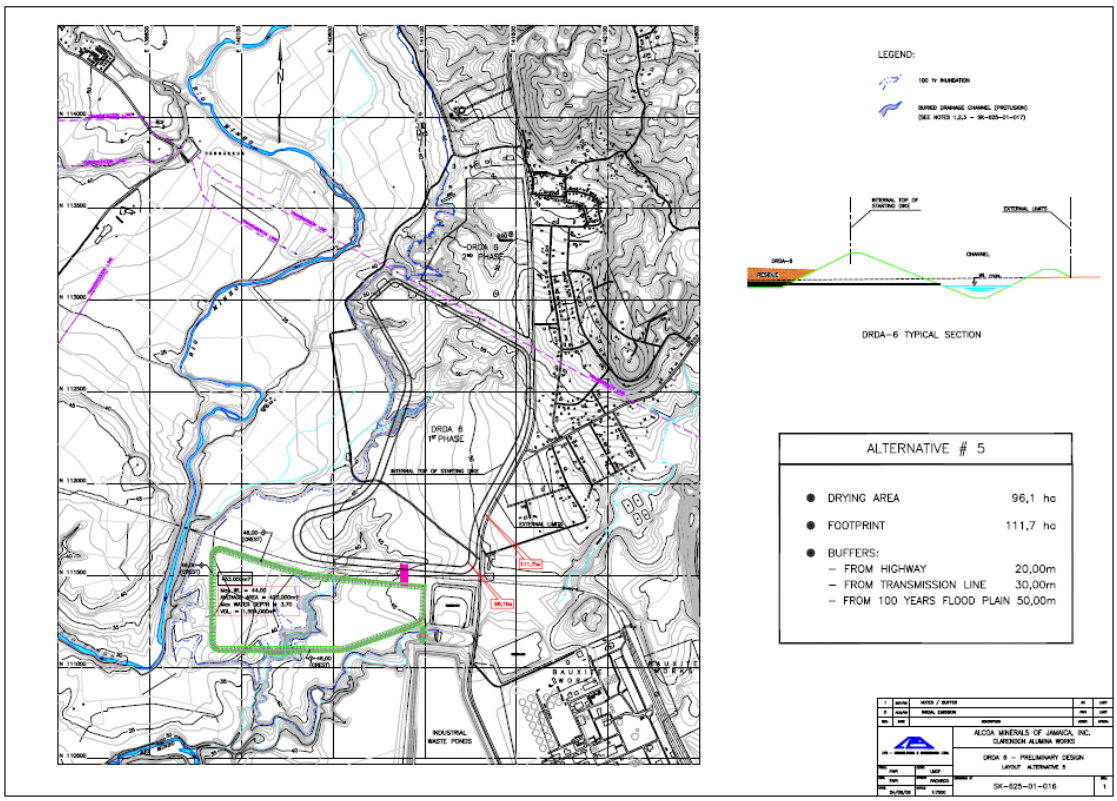


FIGURE 8-5: ALTERNATIVE 5

Natural gullies ("protrusions") exist in the proposed footprints of DRDA 6 and of the Storm Ponds.

In order to assure the continuity of the natural flow of the water in the two protrusions located in the proposed footprint of DRDA 6, the suggested solution is to allow the drainage of the area by filling them with draining material and HDPE perforated tubes. The tubes, wrapped with crushed stones, will end in a protection of rock fill, in the toe of the external dike, where there is a transition between the fine material of the fill and the rock fill. The transition material is to prevent the carrying of fine material while the rock fill guarantees the stability and erosion protection of the toe of the dike, in case of a flood greater then 100 years return time.

A rockfill protection will also be executed along the toe of the western dike.

In the protrusion located in the storm pond, the suggested solution is to fill the area with compacted soil fill since it only drains superficial rain water, is not perennial, and has erosion as a consequence. In the toe of the external dike, it will have a protection of rockfill with the transition layers, similar to DRDA 6, which will guarantee the stability and erosion protection.

Figure 8-6 presents the conceptual solutions proposed for the protrusion

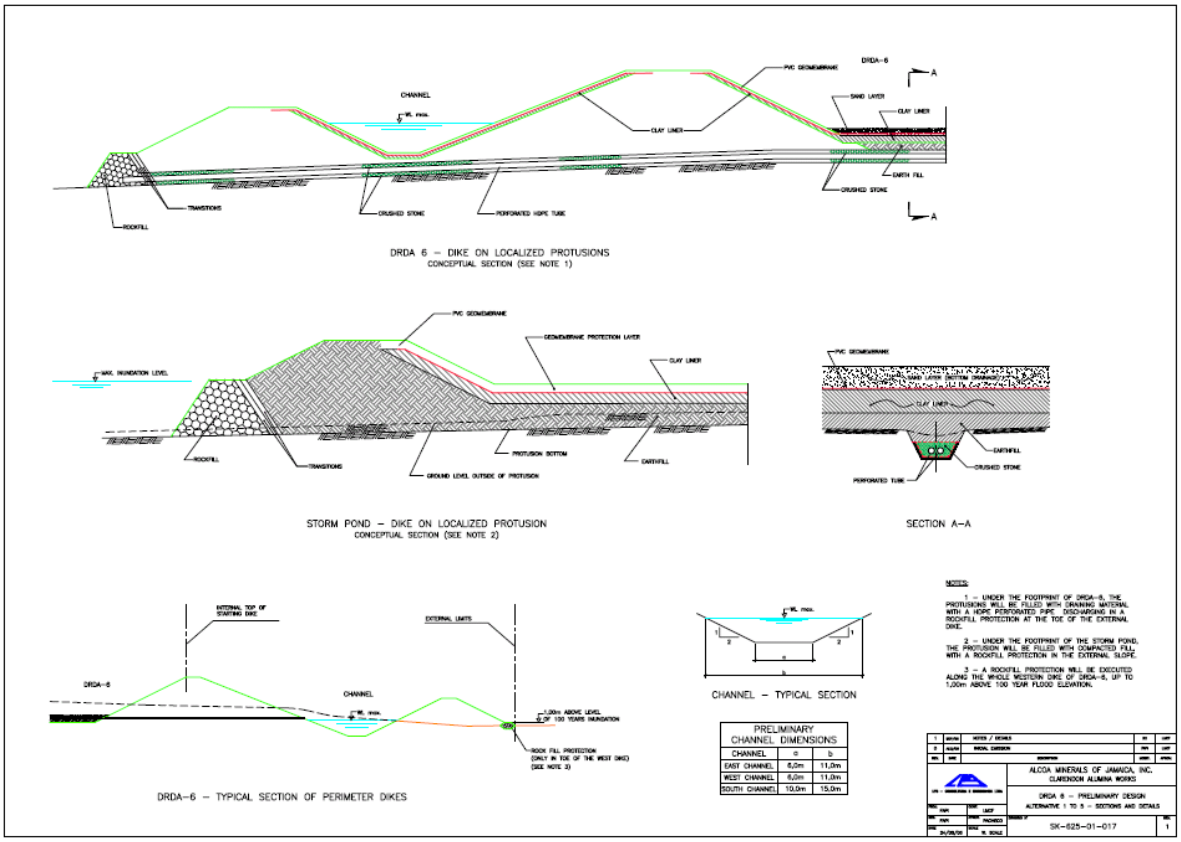


FIGURE 8-6: CONCEPTUAL SOLUTIONS FOR THE PROTRUSIONS

ENVIRONMENTAL MONITORING AND MANAGEMENT PLAN

9 ENVIRONMENTAL MONITORING AND MANAGEMENT PLAN

9.1 MONITORING PROGRAMME

In keeping with its Environmental Health and Safety policies as well as the legislation and regulations of the Government of Jamaica, Jamalco has an extensive Environmental Monitoring Programme which is carried out on all aspects of its operations.

In respect of Section 17 of the NRCA Act of 1991 the company is required to and submits the results of its Monitoring Programme to NEPA on a quarterly basis.

Among the parameters reported to NEPA are:

- raw materials used
- water quality
- effluent quality
- hazardous materials used
- water consumption
- fuel specifications
- materials and chemicals consumption. This category includes:
    - solvents
    - flocculants
    - oils and lubricants
    - acids
    - refrigerants

Jamalco also provides monthly monitoring and reporting to the Jamaica Bauxite Institute (JBI). In addition to the above named, ongoing monitoring activities, Jamalco will implement a monitoring programme during this brownsite efficiency upgrade, which will cover the pre-construction, construction and operations phases of the efficiency upgrade at the mines, the refinery the port and the transportation corridors.

These will be based on the potential impacts identified in the impact identification and impact mitigation actions documented in those sections of this report.

The objective is to insure that all potential impacts and the appropriate mitigation actions are taken.

Monitoring will be done at regular intervals as follows:

1. Various parameters will be measured to establish baseline conditions prior to the start of pre-construction works.

2. A detailed Monitoring Plan will be prepared and submitted to the appropriate regulatory agencies upon approval of a permit from NEPA. This Monitoring Plan will outline specific parameters, frequency and reporting procedures that will be followed, based on acceptable protocol and the General and Specific Conditions of the permit.

3. Construction activities will be actively monitored on a regular basis with a variety of equipment being utilised. Data collected will be analysed and tabulated for submission in a monthly report.

4. Active monitoring will include, but not be limited to:

    - Visual observation
    - Dust monitoring (TSP)
    - Noise
    - Vibration
    - Weather
    - Water Quality
    - Waste Management

5. Monitoring activities will continue with reports provided to the JBI and NEPA every month until the DRDA is commissioned and operating satisfactorily.

9.2 ENVIRONMENTAL MANAGEMENT

Jamalco is an ISO 14001 and ISO 9000 certified facility. Jamalco's ISO 14001 Certification was issued by Det Norske Veritas (DNV) in November of 2002 and remains valid until November 2005. The associated Environmental Management System (EMS) is accredited by ANSI RAB.

The EMS covers Jamalco's operations and includes activities associated with the railway transportation system, the bauxite alumina refinery, plant waste storage and disposal sites and the port at Rocky Point.

In keeping with the mandates of its ISO 9000 quality certification, Jamalco abides by their Quality Policy, which states:

Jamalco is committed to being "The Alumina Supplier of Choice"

- "Jamalco will relentlessly pursue continual improvement in everything we do to:
- Consistently provide product that meets customer and other applicable requirements for quality
- Enhance customer satisfaction by consistently meeting and exceeding their expectations
- Be cost effective and remains competitive in the global market
- Operate in a safe and environmentally responsible manner"
- Excellence Through Quality

Jamalco has a highly qualified technical, administrative and support staff within its Environmental Management Department, many trained to the tertiary level. All employees within the Department report to the Manager, Environmental, Health &

Safety, a senior manager in the company who in turn reports directly to the Managing Director.

All aspects of Jamalco's operations have an environmental management, health and safety component. Environmental Standard Operating Procedures, guidelines and instruction have been developed by Jamalco to govern operations in all areas. As a result, all technical and support staff have a responsibility to insure that they operate in a safe and responsible manner regardless of the task being undertaken.

Many aspects of environmental management at the facilities are monitored through the use of checklists, periodic reporting and internal audits. These provide timely indications as to the effectiveness of the procedures and provide indications as to the need for changes where applicable. The monitoring and checks also inform process operations and controls.

9.2.1 TRAINING

Jamalco has a commitment to the improvement and advancement of all its employees. A major component of this commitment is the provision and facilitation of training for employees at all levels.

Specific to environmental management, Jamalco provides training in the following areas, which are designed to keep relevant employees and contractors informed and ensures competence in performing their duties. The training program achieves the following:

- Conformance with Jamalco's EH&S policy
- Identifies significant actual and potential impacts of their work
- Defines associated benefits of improved personal performance
- Identifies the roles and responsibilities in achieving conformance with the EMS
- Relays proper environmental operating procedures for managing environmental related aspects of their duties
- Reinforces Jamalco's policy that only properly trained and experienced individuals are allowed to work unsupervised.

OCCUPATIONAL HEALTH AND SAFETY, AND WASTE MANAGEMENT

10 OCCUPATIONAL HEALTH AND SAFETY, AND WASTE MANAGEMENT

10.1 RISK ASSESSMENT AND HUMAN HEALTH RISK

Four main categories of risk have been identified, which must be avoided or minimized in the efficiency upgrade for all aspects of the project. These are:

1. Natural Hazards
2. Manmade Hazards
3. Accidents
4. Structural Failure

The associated risks are described below and actions suggested for avoidance, minimization, prevention and solution are illustrated in the table below:

TABLE 10-1: Risks and their Preventative Actions

Category	Risk	Source	Prevention	Solution
Natural Hazards	Hurricane	Nature	None	Implement 72 hour shutdown procedure; coordinate with ODPEM
	Earthquake	Nature	None	Plant and facilities designed to withstand earthquakes greater than 7.0 on the Richter Scale
	Flood	Rainfall		Proper design, construction and maintenance
	Lightning	Nature	None	Lightning arrestors
Manmade Hazards	Fire	Various (electrical, mechanical, accidental)	Proper maintenance and monitoring	Employ state of the art fire fighting systems to control and extinguish
	Explosion	Various (explosive environment, human error)	Proper maintenance, instrumentation and fail-safe systems	Continual training, audits, testing and monitoring
	Equipment Failure	Various	Proper maintenance, instrumentation and fail-safe systems	Continual training, inspection, audits, testing and monitoring
Accidents	Electrocution	Electrical contact	Training, education	Lock-out, tag-out procedures
	Contravening Safety Procedures	Ignorance, negligence	Training, supervision and audits	Educative discipline
	Falls	Structures	Training, education, with updates	Provision and use of proper equipment
	Suffocation	Confined/poorly ventilated Space	Training, following standard procedures	Adequate ventilation, buddy system, signage
	Spills	Vessels, pipeline	Implementation of Jamalco's spill management procedures	Implementation of Jamalco's spill management procedures
Structural Failure	Dike Failure	RDAs	Proper design and engineering	Inspection, corrective actions
	Impoundment Liner	RDAs	Proper design and engineering	Inspection, corrective actions

10.2 OCCUPATIONAL HEALTH AND SAFETY

10.2.1 JAMALCO'S OH&S POLICY

Jamalco's OH&S policy is based on the worldwide policy used by Alcoa at all their operations and as such is often more stringent in many respects than local OH&S requirements. All activities must be conducted in a safe manner with proper regard for the health of all concerned. No worker will be required to work in any area and to do any activity without adequate provisions being made to ensure that the health and safety of that worker is not compromised.

Jamalco has an organized, documented set of Standard Operating Procedures which govern employees' actions as they perform tasks at the facility. These procedures provide definitions of unfamiliar terms, outlines required safety equipment necessary to undertake the activity, provides direction and instruction on proper handling and management of associated waste streams and record keeping guidelines. This approach to worker safety is universal within Alcoa and Jamalco.

10.2.2 DRAFT OCCUPATIONAL HEALTH AND SAFETY ACT 2003

The Occupational Health and Safety Act, 2003, which is in Draft form makes provision for a safe and healthy working environment for all working persons and to provide for matters incidental thereto or connected therewith.

The objects of the Act are as follows:

a. the prevention of injury and illness resulting from conditions at the workplace

b. the protection of the safety and health of workers

c. the promotion of safe and healthy workplaces

As a good corporate citizen, Jamalco is committed to conducting its mining operation in a manner that complies with the requirements of this Act.

Some specific elements of these requirements are as follows:

- A joint committee of worker and management personnel shall be established at every workplace where twenty or more workers are regularly employed.
- An employer shall place in a conspicuous place in the workplace, a list containing the names and work locations of the members of the joint committee.
- Where fewer than twenty workers are regularly employed, the employer shall cause a safety and health representative to be selected.
- An employer shall make or cause to be made and maintain an inventory of all hazardous chemicals and hazardous physical agents that are present in the workplace.
- The employee shall make available to the workers the inventory of hazardous materials and pertinent Material Safety Data Sheets.
- Any worker who is likely to be exposed to hazardous chemical or physical agents must be provided with appropriate training and instruction.
- A worker has the right to refuse work if he has reasonable grounds for believing that his safety or health is endangered.

10.2.3 SOLID AND HAZARDOUS WASTE MANAGEMENT

The management of hazardous waste resulting from any aspect of the Mining Enterprise will be done in accordance with the Mining Regulations, 1991 of the Government of Jamaica as well as the applicable standards for Jamalco and the standards for Alcoa Operations worldwide. These include handling, segregation, storage and disposal considerations. If there are potentially toxic substances in the overburden and mine waste, they will be handled in such a way as to minimize the impact on rehabilitation and the surrounding areas.

The mining of bauxite and the processing of bauxite ore into alumina generates a wide variety of waste streams that must be properly handled and managed. Jamalco has very well defined procedures for the management of all waste streams generated at all its facilities.

Since the proposal for upgrade of the facility is one of "brownsite" upgrade and no new or unfamiliar activities are proposed, the same time tested, high quality approach to waste collection, handling and management will be utilized. The following is an overview of how waste is managed at Jamalco presently and how it will continue to be managed after the upgrade.

10.2.4 SOLID WASTE MANAGEMENT

Solid waste generated at Jamalco includes, among other items:

- Used filters
- Empty drums
- Aerosol cans
- Garbage
- Boiler ash
- Demolition waste
- Medical waste
- Absorbents
- Office refuse
- Lime reject
- Waste Rags
- Sand

For each waste stream identified, there exists complete listing of tasks necessary for the collection, handling and management of that waste. The procedures identify sources of that particular waste stream, accumulation or storage locations and provides instruction on proper labelling, proper storage and individual responsibilities. The procedures are specific for all locations (plant, port, mines) and are comprehensive in its approach.

10.2.4.1HAZARDOUS WASTE MANAGEMENT

Jamalco has strict requirements for the handling of hazardous waste materials. All waste streams considered hazardous waste are identified and listed by department and activity. As with all other waste streams at the facility, very specific tasks, procedures and instructions are provided. Jamalco utilizes satellite accumulation of its hazardous waste streams which are established based on international guidelines. These include:

- Waste collection containers must be located at or near the point of generation
- Waste containers must be in the control of the generator
- The collection station will be well marked and identified as "Satellite Collection Station".
- The station shall be located in a secure and protected area. All waste must be labelled.

- Containers must be compatible with the waste being stored
- Container lids and bungs must be closed at all times
- Weekly inspections
- Container management

Examples of hazardous waste at JAMALCO include:

- PCB Waste
- Lead waste
- Spent solvents
- Sand blast residue
- Mercury Contaminated

10.2.4.2 LANDFILL MANAGEMENT PROGRAM

Jamalco owns and operates a landfill facility located in the northeast section of the refinery. This landfill is subject to the National Environment and Planning Agency's Landfill Permit and License System and is operated within the local regulations and internal standards.

Jamalco has a complete list of items acceptable for disposal at the landfill site including special wastes such as regulated asbestos containing materials (RACM) which are deposited into an area within the landfill site that has been specially designed and sealed to accept these types of waste.

Specific internal rules and regulations govern the operation of the facility. Instructions on what type of waste is acceptable, mode of transportation, packaging, landfill maintenance, etc. are all specified in associated documentation. The landfill undergoes monthly inspections and specific forms designed for that purpose are used throughout the inspection process.

PUBLIC INVOLVEMENT

11 PUBLIC INVOLVEMENT

11.1 INTRODUCTION

Jamalco has an established record of consultation and cooperation with the communities, settlements and residents who are stakeholders in the area. This process of ongoing contact through meetings and activities provides Jamalco with an opportunity to understand and work with the communities expectations of the community.

During communication with the community, Jamalco provides information to the residents on ongoing activities and initiatives and coordinates mutually accepted solutions to address areas of concern. Jamalco intends on continuing this level of communication and dialogue with the communities throughout the permitting, implementation and operational phases of this project through the Community Council groups with which they meet on a regular basis. Additionally, a new Community Council Group has been established in the New Bowens area as a direct result of this project. The active community groups are:

- Port Community Council
- Refinery Community Council
- Railroad Community Council
- Pleasant Valley Community Council
- Havanna Heights Community Council
- New Bowens Community Council

These community groups comprise influential citizens, area leaders, community activists and individuals who have the best interest of the communities at heart.

11.2 COMMUNITY CONTRIBUTIONS

Over the years, Jamalco has played a major role as a good corporate citizen in the community. The company has been involved in the daily life and development of these communities in many ways, these include:

11.2.1 EDUCATION

- Established computer labs in six (6) High Schools, three (3) Primary Schools and Five (5) Basic Schools
- Cafeteria and bathroom expansion – Vere Technical High School
- Nutrition Programme – Daily supply of milk to 26 Basic Schools
- New bathrooms – Hayes
- Construction of a block of classrooms (Alcoa Block) including a Physics Lab
- Refurbished Vocational Department and upgraded electrical work in all classrooms – Lennon High School
- Back-to-school assistance for tertiary and high school students – annually
- Summer employment – students in tertiary institutions
- Support for the University of the West Indies – Labs, UWICED, distribute over 15,000 books annually for the past 14 years
- Skills training – sponsor students for HEART/NTA programmes and 4H clubs
- Developing skills training centre with HEART/NTA at Jamalco's Breadnut Valley facility

11.2.2 HEALTH

- Supply of medical supplies for clinics and hospitals – Islandwide
- Wellness programme – hypertension and diabetes checks – Mitchell Town, Hayes and Mocho

- Support – University Hospital Sickle Cell Unit, Kidney Unit, Cardiac Emergency Unit and Burn Unit

11.2.3 INFRASTRUCTURE UPGRADE

- Pave roads - Cornpiece
- Street lights improvements - Cornpiece
- Clean and construct new drains on a regular basis to alleviate flooding
- Constructed new Postal Agency – Mitchell Town
- Constructed new Post Office – Hayes
- Constructed Police Station – Hayes
- Expanded Health Center – Mitchell Town
- Constructed Community Center – Hayes
- Provided water supply system – Top Hill, Hayes

11.2.4 SPORTS

- Sponsor – Jamalco Community Netball Team
- Sponsor – Clarendon Netball League
- Sponsor – Various football teams

11.3 COMMUNITY CONSULTATION ON DRDA 6

Jamalco has met with representatives of the community to discuss the project on several occasions, and are prepared to host other meetings and information sessions as needed.

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APPENDICES

13 APPENDICES

APPENDIX I: TERMS OF REFERENCE

ENVIRONMENTAL IMPACT ASSESSMENT

FOR

THE CONSTRUCTION OF DRY RESIDUE DISPOSAL AREA (DRDA #6)

FOR JAMALCO

Conrad Douglas & Associates Limited (**CD&A**) has been contracted to conduct the Environmental Impact Assessment for the construction and operation of the proposed Residue Disposal Area #6 at JAMALCO, Clarendon.

Background

Jamalco is proposing to create a new Dry Bauxite Residue Disposal Area (DRDA #6) of approximate area 165 hectares, to the north of the existing railway line and to the west of the existing public highway which runs through the town of Hayes. The project will continue to provide an environmentally friendly sound disposal method for bauxite residue.

The new DRDA will provide additional storage volume and surface area to accept bauxite residue from the Jamalco Refinery. Using Thickened Tailings Disposal with Dry Residue Stacking, this facility will provide capacity for storage of 15.0 million cubic metres of residue.

The new RDA will be created by constructing a base layer incorporating seal and under-drainage. A storm water storage pond will also be constructed adjacent to the DRDA #6 to receive storm water run-off from DRDA #6 and to maintain it as a Dry Residue Disposal Area. Construction of this pond will ensure on going compliance with JAMALCO's policy of zero discharge. This added storage of water will also result in a reduced consumption of groundwater presently pumped into the lakes during drier periods

The scope of the DRDA #6 Project will include, but is not limited to:

- Relocation of high voltage electricity supply lines
- Local excavation and filling of a165Ha base to design profile
- Installation of geomembrane liner on top of a clay liner to the base and internal perimeter embankments
- Installation of under drainage system with probable 800-1000mm sand layer
- Construction of a perimeter and interior embankments
- Construction of perimeter drains and a stormwater storage pond
- Installation of a gravity transfer system for stormwater and underdrain system discharge from DRDA #6 to its stormwater storage pond. This will include a stormwater culvert beneath the railway.
- Installation of mud distribution piping
- Installation of a dust suppression sprinkler system.

The anticipated construction time for DRDA #6 and its associated storm water pond is sixteen months.

DRAFT TERMS OF REFERENCE

ENVIRONMENTAL IMPACT ASSESSMENT

FOR

THE DISPOSAL OF BAYER PROCESS RESIDUE IN RDA #6

FOR JAMALCO

Conrad Douglas & Associates Limited will conduct an Environmental Impact Assessment, which will detail the pre-construction, construction and operational aspects of the proposed Residue Disposal Area, in accordance with the requirements, standards and regulations of the National Environment and Planning Agency (NEPA) and Jamalco's Environmental, Health and Safety Policy and Procedures.

In the EIA, **CD&A** will:

1. Provide a comprehensive description of the existing site proposed for the development of the facility to store bauxite residue – detailing the elements of the project, highlighting areas to be reserved for construction and the areas which are to be preserved in their existing state and thoroughly reviewing the bauxite residue to be stored at the proposed site and the chemical processes (direct and incidental) involved. Detailed design calculations and drawings for the facility, including base and embankments will be presented. Seismic vulnerability assessment will be conducted and outlined.

2. Identify the major environmental issues of concern through the presentation of baseline data, which should include social and cultural considerations. An assessment of the public perception of the proposed development will also be done, utilizing information gathered from consultations with the local community. A Public Meeting will be conducted in support of the EIA Report.

3. Outline the Legislations and Regulations relevant to the project.

4. Predict the likely impacts of the proposed development on the described environment, including, direct, indirect and cumulative impacts – indicating their relative importance to the design of the development's facilities.

5. Identify mitigation action to be taken to minimize adverse impacts and quantify associated costs where applicable.

6. Design a monitoring plan, which should ensure that the mitigation plan is adhered to.

7. Describe the alternatives to the project that could be considered at the site.

CD&A will also provide full and detailed accounts in the following areas, prior to construction, during construction and the operational phases of the project:

1. **Description of the Project**:

   - Description of the area proposed to store bauxite residue in detail.
   - Description of detailed element of the project – highlighting areas to be reserved for construction as well as areas to be preserved in their existing state and, activities and features which will introduce risks or generate impact (negative and positive) on the environment.
   - Detailed design calculations and drawings for the facility, including base and embankments.
   - Seismic vulnerability assessment.
   - Use of maps, site plans and other graphic aids as appropriate.
   - Information on location, general layout and size of the project area.
   - Description of pre-construction, construction and post construction plans.

2. Description of the Environment

Presentation of baseline data, which is to be used to describe the study area in respect of the following:

i. Physical environment inclusive of geology, hydrology (include impact of the modification of the topography on the hydrology of the area of the influence of the project).

   a. Determination of storm water run-off, drainage patterns and effect of the project on ground water.

   b. Slope stability issues.

   c. Water quality issues, leachate management.

   d. Climatic conditions and air quality in the area in the area of influence, including particulate emissions from stationary and mobile sources, NO_x, SO_x, wind speed and direction, precipitation, relative humidity and ambienttemperatures.

   e. Noise levels at the undeveloped site and ambient noise in the area of influence.

   f. Obvious sources of pollution existing and the extent of contamination, including identification of any additional services that may arise from this project.

ii. Biological environment

   a. Description of any flora or fauna in the sphere of influence of the proposed project with special emphasis on rare, endemic or endangered species.

   b. Species dependence, niche specificity, community structure, population dynamics, carrying capacity, species richness and evenness (measure of diversity).

iii. Socio-economic and cultural constraints

a. Present and projected population

b. Present and projected land use

c. Planned development activities

d. Community structure

e. Employment

f. Distribution of income, goods and services

g. Recreation

h. Public health and safety

i. Cultural peculiarities

j. Aspirations and attitudes

k. Historical importance of the area

l. Public perception.

3. Policy, Legislations and Regulations:

- An outline of all pertinent policies, regulations and standards in keeping with the nature of the project will be provided. The examination of the legislation should include at a minimum, legislation such as the NRCA Act, legislation from the Solid Waste Management Authority (SWMA), Mining Act and as appropriate, international conventions, protocols, treaties, etc.

4. Determination of Potential Impacts:

- An identification of any major environmental issues of concern, and an indication of their relative importance to the design of the project with the intended activities.

- Determination of potential impacts related, but not limited to, the following:
    1. Change in the drainage pattern and storm water management;
    2. Flooding potential
    3. Landscape impacts of excavation and construction;
    4. Loss of any natural features by construction activities;
    5. Pollution of surface and ground water;
    6. Solid waste disposal;
    7. Air pollution;
    8. Socio-economic and cultural impacts;
    9. Risk assessment/Natural Hazard Vulnerability;
    10. Noise;
    11. Change in soil pH;
    12. Waste disposal via recycling;
    13. Accidental discharges into water bodies;
    14. Impact of leachate;
    15. Distinguish between positive and negative impacts.
    16. Avoidable as well as irreversible impacts.

- Cumulative impacts.

5. Mitigation

- Preparation of guidelines for avoiding, as far as possible or eliminating, any adverse impacts due to proposed activity at the site while utilizing existing environmental attributes for optimum development. Where possible, quantification and the assignment of financial and economic values to impacts and mitigating methods will be done.

6. Monitoring

- Suggestion of a plan to monitor implementation of mitigation or compensatory measures and project impacts during construction and operation.
- Preparation of an Environmental Management Plan for the long-term operations of the site.

An outline of the monitoring program will be included in the EIA report and a detailed version will be submitted to NEPA after the granting of the permit and prior to the commencement of the proposed development. The monitoring program will include the following, at a minimum:

- Introduction outlining the need for a monitoring program and the relevant specific provisions of the permit license granted;
- The activity being monitored and the parameters chosen to effectively carry out the exercise.
- The methodology to be employed and the frequency of monitoring.
- The sites being monitored, stating any outer boundary where no impact from the development is expected if stated by NEPA or other local agencies;
- A summary of data collected. Tables and graphs are to be used where appropriate;
- Discussion of results with respect to the development in progress, highlighting any parameter(s), which exceed(s) the standard(s).
- Frequency of reporting to NEPA.
- Recommendations;
- Appendices of data and photographs.

7. Project Alternatives

- Examination of alternatives to the project including the no-action alternative. (Project alternatives should incorporate the use history of the overall area in which the site is located and previous use of the site itself.)

CD&A will present all findings in the Environmental Impact Assessment, reflecting the headings in the body of the approved Terms of Reference, as well as other references. Eight hard copies and one electronic copy of the report will be submitted to NEPA. It will include an appendix with items such as maps, site plans, the study team, photographs and other relevant information.

APPENDIX II: SURVEY INSTRUMENT

Presented by Conrad Douglas & Associates Ltd. on behalf of JAMALCO

Socio-Economic Survey for the Proposed Construction and Operation of a New Dry Residue Disposal Area – DRDA #6 by JAMALCO in Halse Hall, Clarendon

Community Name _____ Community Code | | | | | |

ATTENTION INTERVIEWER – ASK AND WAIT FOR RESPONSES.
DO NOT PROMPT OR PROVIDE ANSWERS FROM THE LIST

SECTION 1: PERSONAL CHARACTERISTICS

1) Gender
   1. Male
   2. Female

2) Age Range
   1. Under 20
   2. 20 – 39
   3. 40 – 49
   4. 50 – 59
   5. 60 – over
   6. Not Stated/No Response

3) How many years have you been living in the community?
   1. 0 – 5 Years
   2. 6 – 10 Years
   3. 11 – 20 Years
   4. more than 20 Years
   5. Not Stated/No Response

4) What is your occupation?
   1. Shop keeper
   2. Teacher
   3. Nurse
   4. Buying and selling
   5. Home-maker
   6. Labourer
   7. Domestic Helper

8. Mason/ Plumber/ Welder/ Carpenter (skilled craftsman)
9. Unemployed
10. Other _____

SECTION 2: OPINIONS ON THE COMMUNITY

5. What do you like most about the community? ***ASK & WAIT FOR RESPONSE***
   1. Friendly people
   2. Clean environment
   3. Availability of jobs/ employment
   4. Quiet
   5. No crime & violence
   6. Other, (specify)_____
   7. Not Stated/No Response

6. What don't you like about the community? ***ASK & WAIT FOR RESPONSE***
   1. Poor roads
   2. Lack of Utilities
   3. Crime & violence
   4. Unemployment
   5. Dirty environment
   6. Other, (specify)_____
   7. Not Stated/No Response

SECTION 3: AWARENESS & OPINIONS ON EXISTING BAUXITE FACILITIES

7. Are you aware that Jamalco has bauxite processing operations in your area?
   1. Yes
   2. No (Go to Q 11)
   3. Not Stated/No Response

8. Are you aware that Jamalco is in the process of upgrading and expanding the production capacity of it's refinery?
   1. Yes
   2. No
   3. Don't know
   4. No response

9. Would you say that bauxite operations have had a positive impact on this community?
   1. Yes
   2. No

10. What positive impacts do you think bauxite operations have had on the community? ***ASK & WAIT FOR RESPONSE***

    1. Improved community relations
    2. Job opportunities
    3. Educational and social benefits
    4. Amenities – roads, lights, water supply
    5. Environmental conditions
    6. None
    7. Other (specify)_____
    8. Not Stated/No Response

11. Would you say that bauxite processing operations have had negative impacts on the people in this community? ***ASK & WAIT FOR RESPONSE***
    1. Yes
    2. No (Go to Q 16)
    3. Not Stated/No Response

12. If **YES, ASK** - WHY WOULD YOU SAY THAT? ***ASK & WAIT FOR RESPONSE***
    1. The area has widespread corrosion
    2. The area smells like caustic soda more often than not
    3. You get sick more often
    4. Plants are harder to grow
    5. Too much noise
    6. Other (specify)
    7. Not Stated/No Response

13. Are you aware that Jamalco operates red mud disposal areas adjacent to the refinery in Halse Hall?
    1. Yes
    2. No

14. Are you personally experiencing any negative impacts from the existing red mud disposal areas? ***ASK & WAIT FOR RESPONSE***
    1. Yes
    2. No

15. If yes, what? ***ASK & WAIT FOR RESPONSE***
    1. Dust
    2. Odour
    3. Corrosion
    4. Affect plants negatively
    5. Illnesses
    6. Affects water quality

16. Do you believe that the refinery can expand its operations and operate without new Red mud disposal Areas?
    1. Yes
    2. No

17. Are you aware that JAMALCO proposes to expand their residue disposal area to meet the demands of the expansion?
    1. Yes
    2. No
    3. Not Stated/No Response

18. "Jamalco needs to construct more RDAs to store the red mud that will be generated from the expansion: Do you agree or disagree?
    1. Agree
    2. Disagree
    3. Not sure

19. Do you think that Jamalco should explore other methods and technologies for red mud disposal?
    1. Yes
    2. No
    3. Not sure

20. What effect do you think the operation of the proposed Residue Disposal Area #6 near your area will have on the following: (**Answer in terms of positive, negative, no change, don't know. ASK AND WAIT)**

    i) Income/ Economic value of the community
       1. Positive
       2. Negative
       3. No Change
       4. Don't Know
       5. Not Stated/No Response

    ii) Job Opportunities
       1. Positive
       2. Negative
       3. No Change
       4. Don't Know
       5. Not Stated/No Response

    iii) Pollution
       1. Positive
       2. Negative
       3. No Change
       4. Don't Know
       5. Not Stated/No Response

iv) Health

1. Positive
2. Negative
3. No change
4. Don't know
5. Not stated/ No response

v) Overall quality of life

1. Positive
2. Negative
3. No change
4. Don't know
5. Not stated/ No response

SECTION 4: AVAILABILITY OF WATER

21. What is your main source of drinking water? ***ASK & WAIT FOR RESPONSE***

1. Indoor tap/pipe
2. Outdoor private tap/pipe
3. Public standpipe
4. Spring, pond, river
5. Rainwater (tank or drum)
6. Trucked water (NWC)
7. Other (specify)
8. Not Stated/No Response
9. Provided by JAMALCO

22. "In this community, I think that we have access to safe water to drink" Do you agree?

1. Yes
2. No
3. Don't Know/Not Sure
4. Not Stated/No Response

23. Why do you think so? ***ASK & WAIT FOR RESPONSE***

1. bauxite mining affects the drinking water
2. Sources (not bauxite mining or alumina processing related) affect the drinking water quality
3. The water is tested frequently by the N.W.C.
4. The water looks and/or smells clean
5. Other, please specify
6. Not Stated/No Response

24. Have you or any member of your household ever worked for a bauxite company or in the bauxite industry?

    1. Yes
    2. No
    3. Don't Know/Unsure
    4. Not Stated/No Response

25. Are you aware of any programs or activities initiated by bauxite companies in your community?

    1. Yes
    2. No
    3. Don't Know/Unsure
    4. Not Stated/No Response

Name of interviewer:
Signature of interviewer:
Date of interview:

APPENDIX III: TEAM MEMBERS

Project Team

- Dr. Conrad Douglas
- Mr. Paul Thompson
- Prof. Edward Robinson
- Ms. Yolanda Rainford
- Mr. Orville Grey
- Geomatrix Ltd.
- Ms. Dahlia Bean
- Deonne Caines
- Damion Wyte
- Mr. Vance Johnson
- Socio-economic Survey Team

APPENDIX IV: PHOTO-INVENTORY

PLATE 13-1: ACACIA STAND

PLATE 13-4: ACACIA AND TYPHA DOMINGENSIS (REEDMACE)

PLATE 13-2: OPEN SAVANNAH WITH FEW ACACIA TREES

PLATE 13-5: REEDMACE IN FOREGROUND WITH ACACIA AND EBONY TREES IN BACKGROUND

PLATE 13-3: CYPERUS SP. (GRASS)

PLATE 13-6: DELONIX REGIA (POINCIANA)

PLATE 13-7: ROADWAYS CUT THROUGH ACACIA STANDS

PLATE 13-8: EUPHORBIA HIRTA

PLATE 13-9: AMARANTHUS SPINOSA (WILD CALALOO)

PLATE 13-10: JATROPHA GOSSYPIIFOLIA (BELLY-ACHE BUSH)

PLATE 13-11: CAPSICUM ANNUM (BIRD PEPPER)

PLATE 13-14: CACTI, ACACIA AND OTHER PLANTS

PLATE 13-12: RUELLIA TUBEROSA

PLATE 13-15: URECHITES LUTEA (NIGHTSHADE)

PLATE 13-13: BRYA EBENUS (WEST INDIAN EBONY)

PLATE 13-16: CEPHALOCEREUS NOBILIS AND BRYA EBENUS

PLATE 13-17: AGAVE SP.

PLATE 13-20: ACACIA FARNESIANA

PLATE 13-18: CYPERUS SP.

PLATE 13-21: MAGNIFERA INDICA

PLATE 13-19: ACACIA, SAMANEA SAMAN (GUANGO), ANDROPOGON SP. ETC.

PLATE 13-22: POND SURROUNDED BY ACACIA AND OTHER WATER PLANT