KAFUBU FARM PRELIMINARY RESOURCE ASSESSMENT FOR

WATER RESOURCES AND IRRIGATION POTENTIAL

Kafubu Farm Stream - December 2012

Imagen Consulting

Remote Sensing, Water Resources, GIS

KAFUBU FARM WATER RESOURCES AND IRRIGATION POTENTIAL PRELIMINARY ASSESSMENT.

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Units of measure

1ML (1 mega litre)	=1,000,000 litres
1ML	=1,000m^3
1Mm^3 (1 million m^3)	=1,000 ML
1mm irrigation	= 10m^3/ha
1000mm irrigation	= 10ML/ha,
1ha	=10,000m^2
1km^2	=1,000,000m^2 or 100ha

1. Introduction and Background

Goldenlay commissioned Imagen and Dr Hungwe to conduct a preliminary assessment of the water and soils resources of the newly acquired Kafubu Farm. A reconnaissance survey was undertaken in December 2012 with a view to identify areas suitable for crop production and to estimate the extent of irrigation potential.

This report follows on from the soils survey report compiled by Dr. Alois Hungwe (March 2013).

Kafubu farm is approximately 2,969ha in extent and is located midway between the cities of Ndola and Luanshya (15km from both directions) and is strategically well placed for the grain production needed for the poultry feed stock of Goldenlay. Not to mention the close proximity for the removal of manure from the poultry operation which will act as a fertilizer and soil conditioner, whilst benefiting the cost of production.

Kafubu farm lies between 1285m and 1241m AMSL and consists of gentle slopes with broad interfluves which are mostly drained by small streams in a West, South Westerly direction.

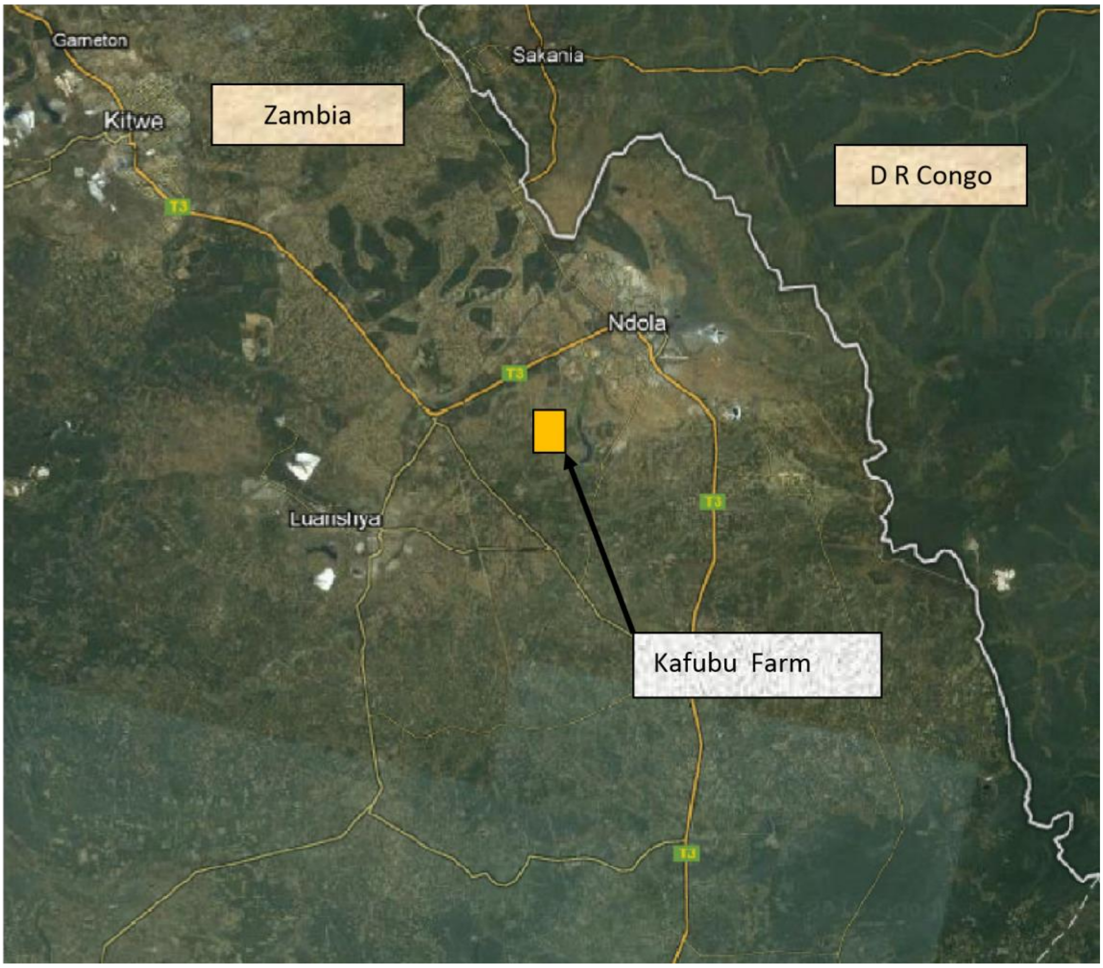
The South Eastern sector drains to the Kafubu River and Ndola's Municipal Kafubu Dam. An 11kV ZESCO power line transects the farm on the main interfluves.

For the purposes of resource assessment, the following steps were taken during the composition of the reports

- Acquisition of Near Infrared satellite Imagery
- Construction of a digital elevation model for the greater Kafubu River catchment
- Assimilation of previous technical literature
- Stream flow and dam structure observation
- Site reconnaissance surveys for both hydrology and soils
- Delineation of soils types
- Evaluation of soils and water resources
- Identification of possible bulk water storage sites
- Identification of a staged development and estimate project extents

Estimate the above capital, implementation and energy costs associated with the irrigation development. Shown below is a location map of the project.

Figure 1 _ Location map



2. Water Resources

The climatic data for this assessment has been taken from the FAO CROPWAT Met Station at Ndola. The average rainfall (Ndola Met Station) is 1232.8mm/yr of which 766mm/yr is effective rainfall. The average runoff for the total Kafue River Basin is 64mm/yr. The exact runoff data for the Kafubu River is unknown at this time. A runoff figure of 85mm has been used as this was determined at the similar site being the Upper Lunsemfwa River catchment (75km to the South East). The Cv (coefficient of variation) of the runoff data is 0.88 (Mwale 2010).

Shown below is a summary of average annual weather data;

Country: Location 14 Station: NDOLA
Altitude: 1270 m. Latitude: 13.00 °S Longitude: 28.65 °E

Month	Min Temp °C	Max Temp °C	Humidity %	Wind km/day	Sun hours	Rad MJ/m²/day	ETo mm/day
January	17.1	26.6	79	268	6.0	19.6	4.22
February	17.1	26.9	79	233	6.0	19.5	4.17
March	16.5	27.4	73	285	7.5	21.0	4.70
April	14.4	27.5	71	346	9.9	22.6	5.01
May	10.8	26.6	57	354	10.5	21.2	5.22
June	7.9	25.1	53	346	10.6	20.0	4.87
July	7.8	25.2	49	415	11.0	21.0	5.45
August	10.2	27.5	42	518	11.1	23.3	7.10
September	13.6	30.5	39	493	10.9	25.2	8.20
October	16.2	31.5	42	441	10.3	25.9	8.26
November	17.1	29.4	63	354	7.9	22.5	5.98
December	17.2	27.0	78	380	6.1	19.8	4.51
Average	13.8	27.6	60	369	9.0	21.8	5.64

Rainfall for Ndola is recorded as;

Station: NDOLA

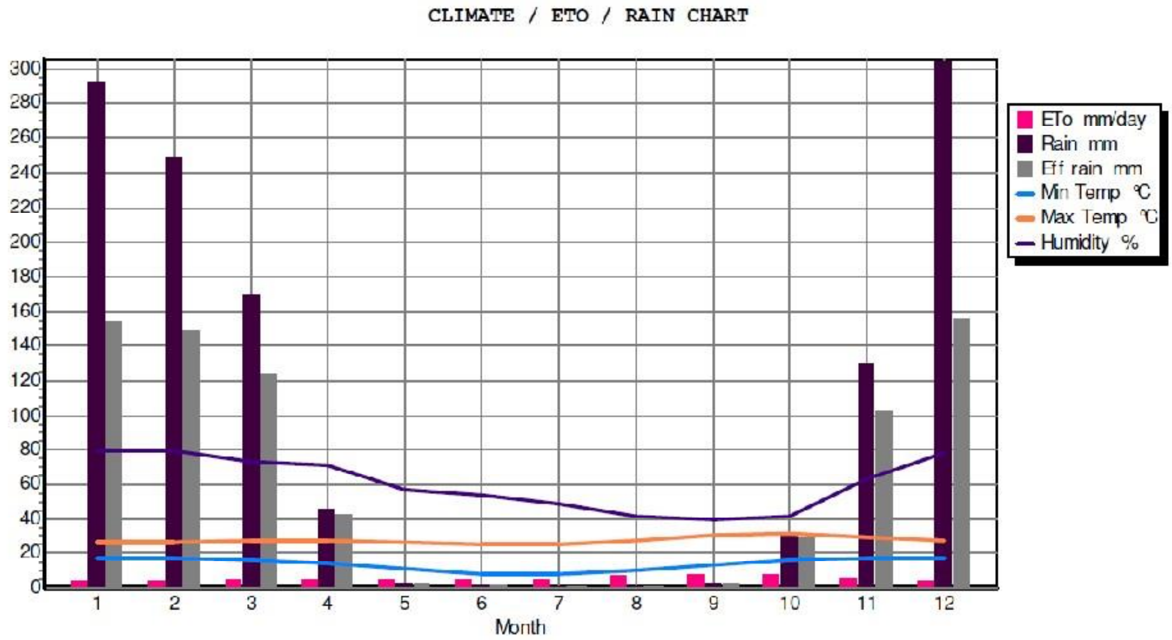
Eff. rain method: USDA Soil Conservation Service formula:

Peff = Pmon * (125 - 0.2 * Pmon) / 125 for Pmon <= 250 mm

Peff = 125 + 0.1 * Pmon for Pmon > 250 mm

	Rain mm	Eff rain mm
January	292.9	154.3
February	249.0	149.8
March	170.1	123.8
April	45.5	42.2
May	3.5	3.5
June	0.7	0.7
July	0.1	0.1
August	0.4	0.4
September	2.9	2.9
October	31.5	29.9
November	130.3	103.1
December	305.9	155.6
Total	1232.8	766.3

Rainfall and Eto Chart



This assessment investigates the potential surface water resources available for irrigation development. Shown below is a hydrology map for the catchments associated with the farm requirements. The boundaries of the catchment were determined by constructing a RADAR derived, 3 second, digital elevation model and exporting the output to a GIS platform. The catchment highest elevation is at 1454m AMSL. The Kafubu Dam outlet is at approximately 1212m AMSL with Kafubu River at this point being approximately 43km in length.

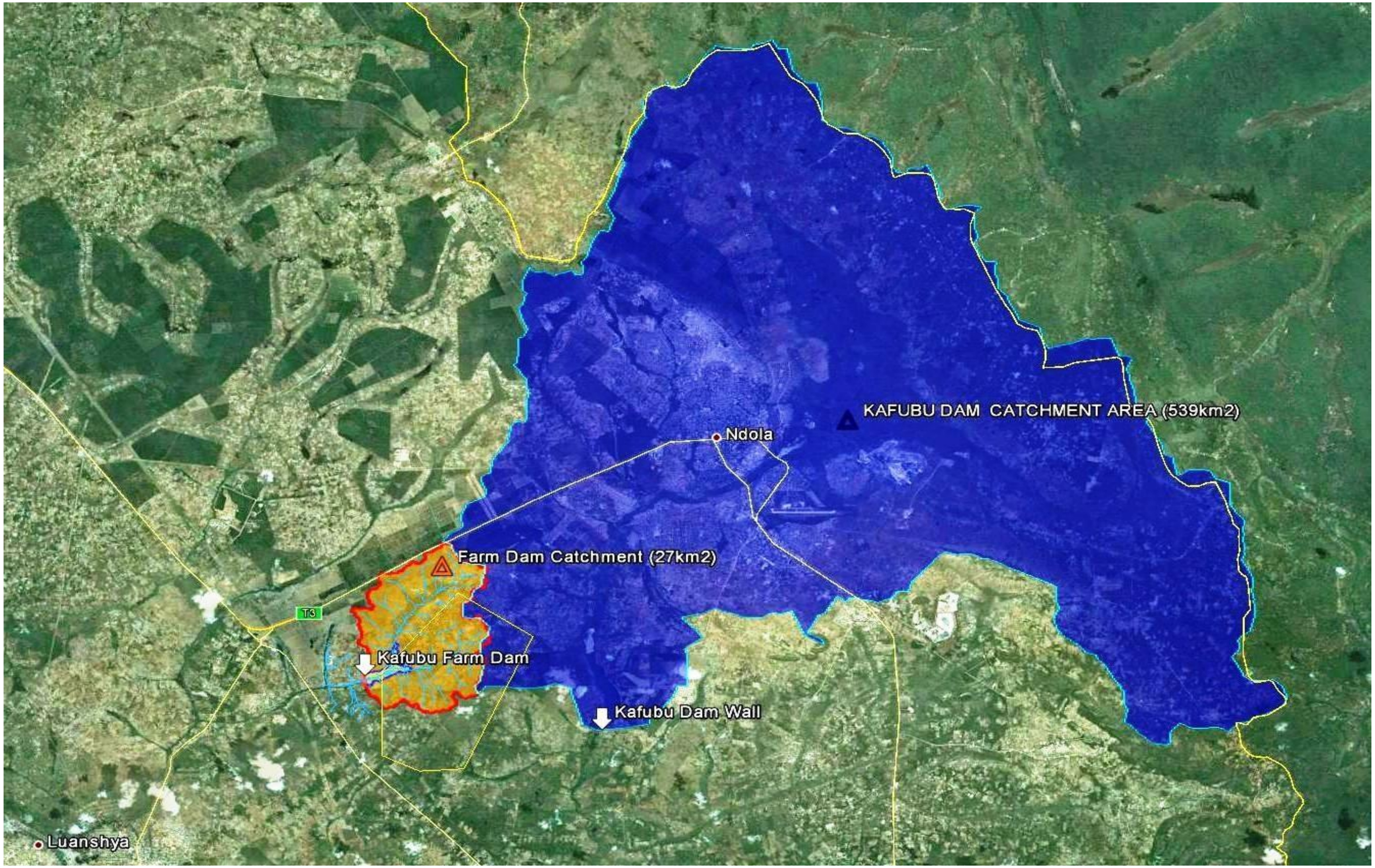


Figure 2 Hydrology Map for the Kafubu River and Kafubu Dam

There are 2 possible sources of surface water resources, the Kafubu River to the East and the North western on-farm stream with its source near the Kasongo Siding.

a. Kafubu River

As shown on the map, the Kafubu River has a considerable catchment extending to the DRC border and measures approximately 539km^2. The average mean annual runoff (MAR) has been estimated at 85mm or 45,815ML/yr. The Kafubu Dam, located 3.5km from the farms Eastern boundary, is a major source of water for the City of Ndola. This dam is managed by the Kafubu Water and Sewerage Company which supplies water to Ndola and the Municipality of Luanshya and Masaiti District (population in the service area is estimated at 628,825).

Kafubu Dam is estimated to have a static storage capacity of 12,000ML. Ndola has a population of approximately 450,000 (CSO 2010) of which half the population receives water pumped from the Kafubu River. The urban/industrial annual up take is estimated to be 12,000ML to 16,000ML per year. Ndola's population has nearly doubled since 1990 (240,000 people, - CSO, 1990) and will continue to place greater demand on the Kafubu River. Bore hole systems have been placed in the vicinity of Kafubu dam and near to the City limits to improve water quality and supply.

It is highly probable that irrigation extraction from Kafubu dam for a large scale operation could be met with resistance from the Kafubu Water and Sewerage Company.

The inserted photograph shows an outlet flow from Kafubu Dam at approximately 1cumec. Contrary to initial aspirations, the chances of utilizing this outflow for irrigation would also be limited. This outflow is critical to the urban and primary requirements of the Municipality of Luanshya

b. Kasongo Siding Stream – Potential Dam Site
As shown on the above hydrology map, a potential dam site exists for a farm dam structure with a wall height of 10m to 12m. The dam site is on the small stream which has its source near the Kasongo Siding.

Shown below is the approximate dam location and full supply level.

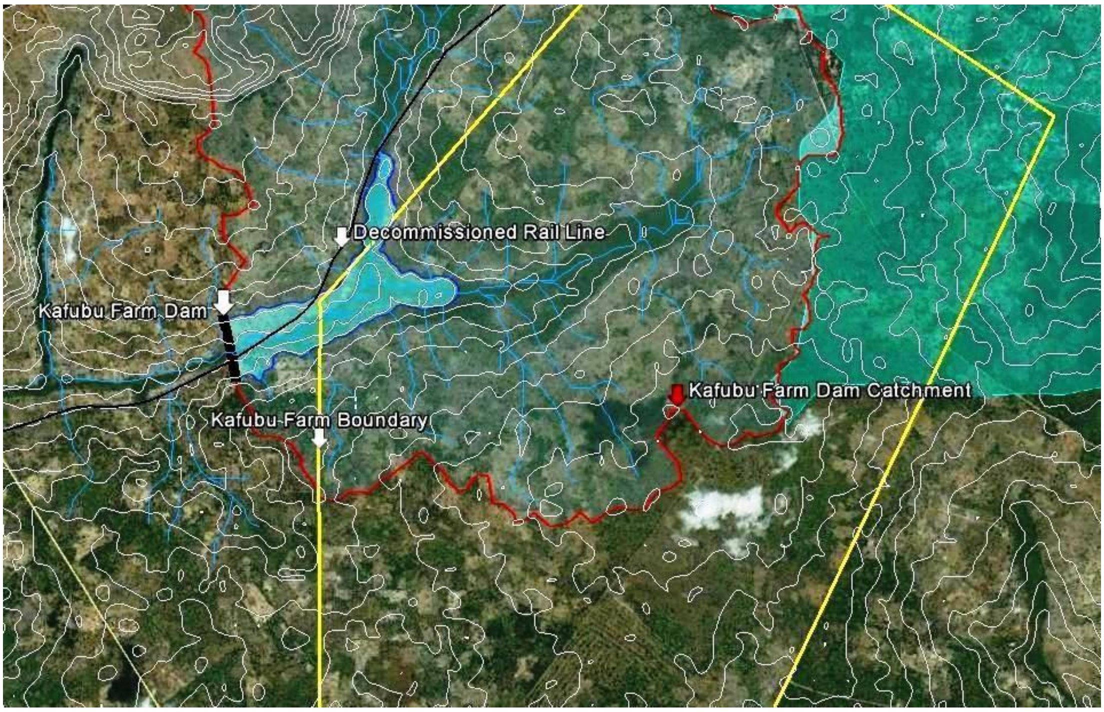


Figure 3 – Potential Site - Kafubu Farm Dam

The catchment is relatively small at 27km2 which could yield 2,342ML per year (using 85mm as the average runoff figure).
Shown below is a chart to illustrate the range of runoff quantity (Mm^3).

Mean Annual Runoff (MAR)/Catchment (millions of cubic metres - Mm^3)

	Dam1
Catchment (ha)	2755.7

Average Annual Runoff (mm)	
50	1.378
55	1.516
60	1.653
65	1.791
70	1.929
75	2.067
80	2.205
85	2.342
90	2.480
95	2.618
100	2.756

The stream was estimated to have a natural flow of 0.35cumecs in December 2012. This flow is significantly greater than an average dambo out flow. A 27km^2 catchment might be in the region of 0.10cumecs at the end of the dry season and the onset of rains. It is suspected that the natural flow is being augmented by groundwater seepage / spring feed. For the purposes of the dam assessment, the estimates contained herein are based on a non-spring fed condition. It is suggested that a ground water investigation be conducted to ascertain if the flow is spring fed and if the spring source is local or from a higher catchment.

A guideline on farm dams calls for an optimum storage capacity ratio of 2MAR.

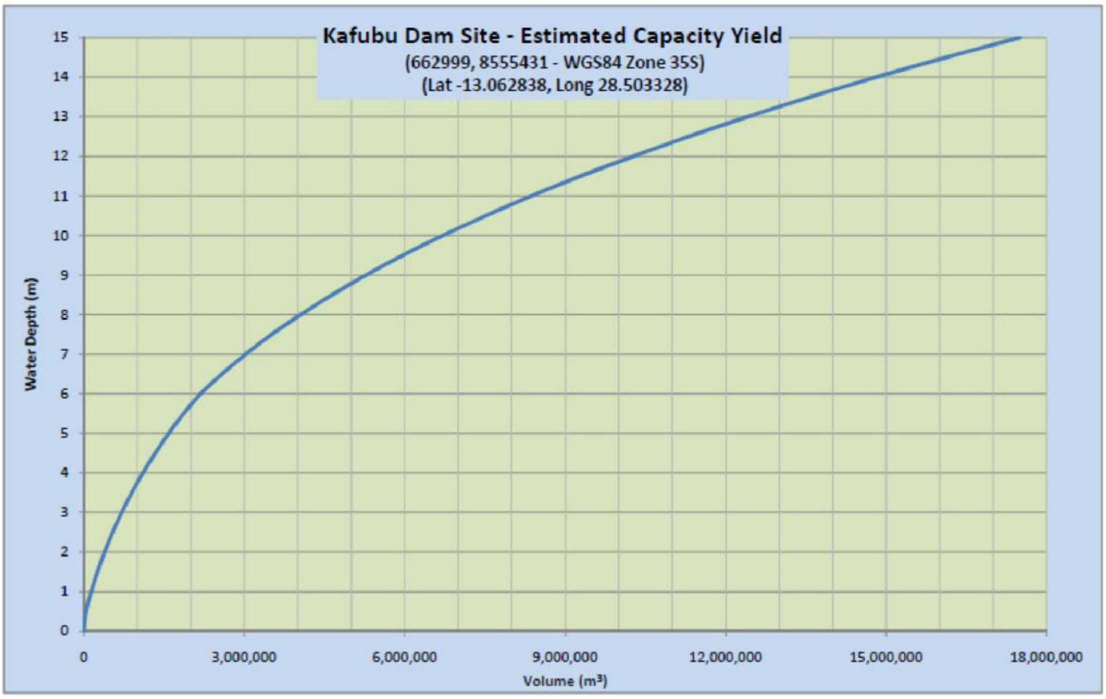
Shown below is the MAR/Storage ratio data

Kafubu Dam Site (662999, 8555431 - WGS84 Zone 35S) (Lat -13.062838, Long 28.503328)				
Elevation (m)	**Depth (m)**	**Cum Area (m^2)**	**Cum Vol (m^3)**	**MAR Ratio @85mm**
1244	0	0	0	
1244.5	0.5	173,788	39,377	0.02
1245	1	212,637	135,860	0.06
1245.5	1.5	251,841	251,908	0.11
1246	2	287,252	386,748	0.17
1246.5	2.5	321,179	538,830	0.23
1247	3	356,454	708,352	0.30
1247.5	3.5	389,934	894,918	0.38
1248	4	444,265	1,102,748	0.47
1248.5	4.5	483,635	1,334,739	0.57
1249	5	523,868	1,586,531	0.68
1249.5	5.5	604,457	1,864,754	0.80
1250	6	746,143	2,185,943	0.93
1250.5	6.5	842,032	2,584,448	1.10
1251	7	920,532	3,024,809	1.29
1251.5	7.5	1,030,568	3,511,852	1.50
1252	8	1,132,008	4,052,302	1.73
1252.5	8.5	1,229,351	4,642,542	1.98
1253	9	1,324,064	5,280,728	2.25
1253.5	9.5	1,421,548	5,967,491	2.55
1254	10	1,554,893	6,716,069	2.87
1254.5	10.5	1,649,052	7,517,291	3.21
1255	11	1,772,560	8,372,534	3.57
1255.5	11.5	1,901,846	9,294,679	3.97
1256	12	2,017,478	10,274,241	4.39

Given the MAR at 2,342ML/yr, an optimal storage would be 4,642ML (2MAR) and would be approximately 8.5m deep. At an 80% yield, the average annual yield would be 1,873ML. (this uses the regional guidelines where a 10% risk of failure is adopted - ie this dam could yield 9 out of 10 years the average 1,873ML).

If a smaller dam with a MAR/Storage ratio of 1.29, the average yield at 10% risk would be 1,600ML/year.

Shown below is the storage capacity curve for this site;



The cost of the structure of the embankment will vary with wall position, soil type, excavation location and many other factors. A detailed dam design should be sought prior to any budgeting.

As a rudimentary guideline, the chart below estimates the embankment volumes;

	Dam Wall Metrics				
	Water Depth (m)	Contour Height (m)	Wall Height (m)	Approx Wall Length (m)	Embankment Volume (m^3)
Dam1	5	1249	7	492	26,967
	6	1250	8	523	36,150
	7	1251	9	557	47,373
	8	1252	10	591	60,637
	9	1253	11	624	75,984
	10	1254	12	655	93,377

The volume of earthwork can be estimated as follows:

V = 0.216 HL (2C+HS)

Where:

V is the volume of earthworks in m^3

H is the crest height (FSL+ freeboard) of the dam in m.

L is the length of the dam, at crest height H, in m (including spillway).

C is the crest width in m.

S is the combined slope value.

For example, if the slopes of the embankment are 1: 2 and 1:1.75, S = 3.75. This formula is based on areal equations for the cross-section and longitudinal section with the inclusion of an empirically developed adjustment factor. Again, it presents an idealized solution and should only be used at the preliminary survey stage. The formula is, however, reasonably accurate and if a general average figure is known for costs of earthworks, a guide cost for the total embankment can be derived. (source: A Manual on small earth dams: A guide to siting design and construction, T Stephens, Food and Agriculture Organisation of the United Nations, Rome 2010, page 34)

The above structure is estimated to cost between $450,000 and $650,000 for a 7m water depth. The above rates are based on local earthmoving contractor rates.

It must also be noted that the topographic data used for this assessment was SRTM RADR remotely sensed data and as such is subject to inaccuracies due to vegetation height and detail loss due to the 90m horizontal grid spacing. However, in the absence of 1m topographic survey, this data set offers a starting point for the assessment.

3. Crop Water Demand

It is envisaged that a winter / summer cropping program will be adopted to maximize the return on the irrigation equipment. The primary focus will be for the summer production of maize and soya's followed by a fully irrigated winter wheat crop.

Crop water usage figures for the Mpongwe Estates (70km to the South West) using centre pivot irrigation systems are;

Summer Supplementary Irrigation (Maize or Soya) = 2.5 ML/ha/yr (250mm).

Winter full irrigation = 5.8ML/ha/yr (580mm) .

Total Irrigation demand per year per ha = 8.3ML (830mm)

Attached in Annex 1 are the theoretical crop water demands from the FAO CROPWAT demand calculations. These tables show 109mm for supplementary irrigation on Soya beans, 47mm for summer supplementary irrigation on maize and 616mm for winter wheat.

This report adopts the management norms as used by Mpongwe (830mm/ha/year) as a proven water management for annual water budget. If the static yield from Kasongo Stream Dam site can deliver 1,600ML/year, 9 out of 10 years, then 182ha of full winter and summer supplementary could be irrigated.

However, if the base flow (December) of this stream is as high as observed at 0.35cumecs, the dynamic minimum flow could support 375ha of irrigation. (Using a peak application rate of 7mm/24hours and allowing 0,05cumecs onward flow).

There is an outside chance that the spring flow (375ha) is in addition to the normal catchment yield (182ha) and could possibly support a total irrigation area of 557ha – this would depend entirely on the spring flow having an external recharge source outside of the catchment.

The proposed ground water development by the City Of Ndola could negatively impact on the potential ground water resources of the Kafubu Farm.

Kafubu Dam (Kafubu Water and Sewerage Company)

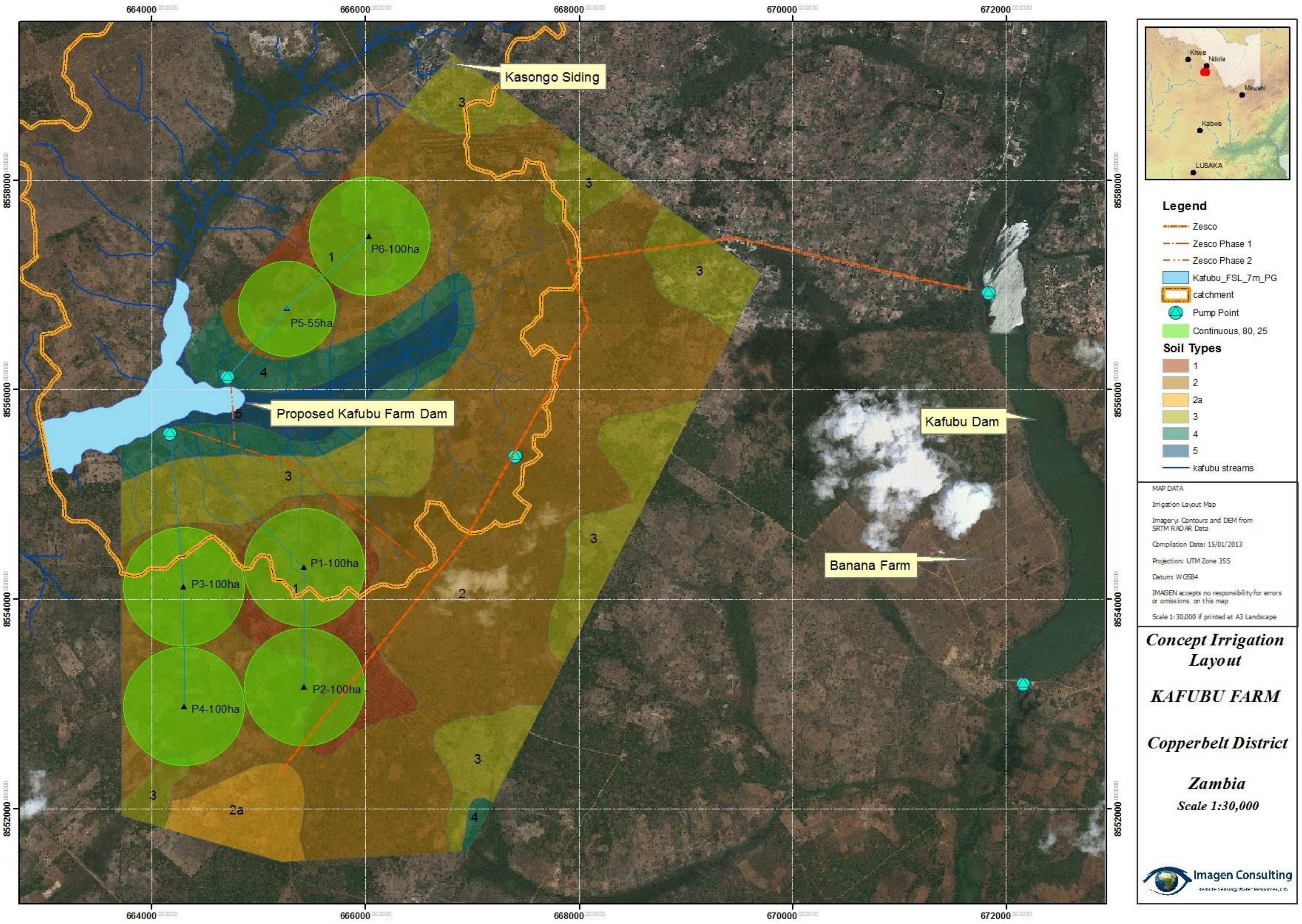
4. Concept Irrigation Layout

As noted in the Crop Water Demands section the volume of available water could irrigate between 182ha and 557ha. In addition the mode of irrigation may not follow a conventional summer supplementary irrigation followed by a full winter irrigation regime. An alternative layout may be the use of smaller towable (40ha) pivots that supply only supplementary irrigation. Such a regime would only use 250mm/ha/yr and could command 580ha/year. It is advised that there are serious hazards associated with the application of towable pivots in terms of system collapse due to poor operator skills. Most farmers using towable pivots tend to move towards fixed units over time. Towable systems can go up to 52ha but the instantaneous irrigation application rates start to exceed the soils infiltration capacity and will lead to the destruction of soil structure.

The criteria for pivot placement are for optimal soil type (type 1 and type 2) and close proximity to the source. To this end, the phase 1 pivots on the irrigation layout are clustered over and near the type 1 and type 2 soils. There is a total of 333ha of type 1 soils and 1,675ha of type 2. Care has been taken to avoid the type 2a with laterite outcrops and type 3 and 4 with drainage issues.

The irrigation form on the concept layout is for larger fixed pivots with 5 x 100ha pivots and 1 x 55ha to give a final total of 555ha of supplementary irrigation as detailed in the crop water demand section.

Shown below is the irrigation layout overlaid on the soils layer;



664000
666000
668000
670000
672000
8558000
8556000
8554000
8552000
Kasongo Siding
P6-100ha
P5-55ha
Proposed Kafubu Farm Dam
P1-100ha
P3-100ha
P4-100ha
P2-100ha
Kafubu Dam
Banana Farm
Kitwe
Ndola
Mkushi
Kabwe
LUSAKA
Legend
Zesco
Zesco Phase 1
Zesco Phase 2
Kafubu_FSL_7m_PG
catchment
Pump Point
Continuous, 80, 25
Soil Types
1
2
2a
3
4
5
kafubu streams
MAP DATA
Irrigation Layout Map
Imagery: Contours and DEM from SRTM RADAR Data
Compilation Date: 15/01/2013
Projection: UTM Zone 35S
Datum: WGS84
IMAGEN accepts no responsibility for errors or omissions on this map
Scale 1:30,000 if printed at A3 Landscape
Concept Irrigation Layout
KAFUBU FARM
Copperbelt District
Zambia
Scale 1:30,000
Imagen Consulting

4.1. Irrigation Development

This report briefly outlines the possible options associated with the irrigation capabilities and as such may need to be revised after the issuance the draft copy to align itself with the specific cropping demands.

There are 3 potential stages;

Stage 1 – Run-of-river from the Kasongo Stream and to develop 2 x 100ha pivots (Risky option in that only one year has been observed of stream flow).

Stage 1a – as above but to include the construction of the farm Dam.

Stage 2 – Expand the total infield irrigation to 355ha with 1 x 100ha and 1 x 55ha pivots

Stage 3 – Expand the total infield irrigation to 555ha with 2 x 100ha pivots dependent on sustained water from the spring flow over and above the static storage of the dam.

Shown below is the summary of Irrigation capital cost estimates per stage.

	CAPITAL DEVELOPMENT COST ESTIMATES				
Stage	Development Element	Unit	Cost	Price	Cumulative Total US$
Stage 1	Bush Clearing and land prep (ha)	200	1,100.00	220,000.00	
Stage 1	Centre Pivots P1 and P2, pipeline, electrification and pump units (ha)	200	2,750.00	550,000.00	
Stage 1	Zesco 11kVa Line (km)	2.928	28,000.00	81,984.00	
	Sub Total			851,984.00	
Stage 1a	Kafubu farm Dam	1	650,000.00	650,000.00	
	Sub Total Phase 1			1,501,984.00	$1,501,984.00

Stage 2	Bush Clearing and land prep (ha)	200	1,100.00	220,000.00	
Stage 2	Centre Pivots P3 and P4, pipeline, electrification and pump units (ha)	200	2,655.00	531,000.00	
	Sub Total Phase 2			751,000.00	$2,252,984.00

Stage 3	Bush Clearing and land prep (ha)	155	1,100.00	170,500.00	

Stage 3	Centre Pivots P3 and P4, pipeline, electrification and pump units (ha)	155	2,600.00	403,000.00	
Stage 3	Zesco 11kVa Line (km)	0.475	28,000.00	13,300.00	
	Sub Total Phase 3			586,800.00	$2,839,784.00

Irrigation Energy consumption estimates; Irrigation

Stage	Energy Driver	kw/hr	mm/year	mm per day	hours per yr	Energy Cost / yr
Stage 1	2 x 100kW Pump units	170.02	830	7.00	2,845.71	43,544.55
Stage 1	2 x 15kW pivot power drawdown	13.1	830	7.00	2,845.71	3,355.10
Stage 2	2 x 100kW Pump units	158.2	830	7.00	2,845.71	40,517.28
Stage 2	2 x 15kW pivot power drawdown	13.1	830	7.00	2,845.71	3,355.10
Stage 3	1 x 100kW, 1 x 60kW Pump units	123.8	830	7.00	2,845.71	31,706.95
Stage 3	2 x 15kW pivot power drawdown	13.1	830	7.00	2,845.71	3,355.10

Operation Energy Budget (based on US$0.09/kwhr)

Total Annual Energy Consumption (excluding peak demand)

Peak Demand tariffs will depend on the electrical starter / drive configuration

US$125,834.07

Estimated Water Right Requirements

Water Right Estimates

Stage	Area (ha)	Summer (ML/ha/yr)	Winter (ML/ha/yr)	Water Usage ML/yr	Daily Water usage (m3/day) - 120days per year
1	200	2.5	5.8	1,660	14,000
2	200	2.5	5.8	1,660	14,000
3	155	2.5	5.8	1,287	10,850
TOTAL	555			4,607	38,850

5. Conclusion and Discussion

Kafubu farm has shown that there is good potential for a large scale irrigation development to be built. The capital cost and operational cost estimates indicate a feasible project. 3 stages of irrigation development have been identified at 200ha, 400ha and then 555ha. All of these stages are not reliant on the Kafubu dam or Kafubu River. The scale of the operation will depend on the reliability of the spring flow and the dam water yield for the staged development. It would appear that the chances of utilizing the water resources of the Kafubu Dam and the Kafubu River will be restrictive due to primary needs from urban and industrial demand on the same source (Ndola City and Luanshya Town).

Key to the irrigation development is the potential Kafubu Farm Dam site. However, this site needs to address the issue of the dam wall site being outside the property boundaries and partial inundation of adjoining boundaries. The dam is also sited on a decommissioned rail line as indicated on the maps. It was unclear if the rail line could be restored to working order for the mine operators or if it is totally defunct and will therefore not impede the dam construction. It was noted that the latter condition may prevail.

The possibility of building multiple, smaller 'floating' dams in the Dambo confines to provide bulk water storage was investigated. The nature of the stream and dambo topography points towards a single conventional 'farm dam structure' being preferable. If the security of spring flow cannot be guaranteed, it is suggested that the dam site be developed as a matter of course to mitigate water resource shortages.

Given the current surface water capacities, it is noted that Goldenlay may select a specific cropping pattern that may vary from this reports crop water estimates and irrigation extent. The soils map displays the soils preferable for development for both irrigated and rain fed operations.

Should an alternative cropping pattern be preferred, we would be happy to incorporate the needs into the model.

Appendix 1 – FAO CROPWAT ESTIMATES

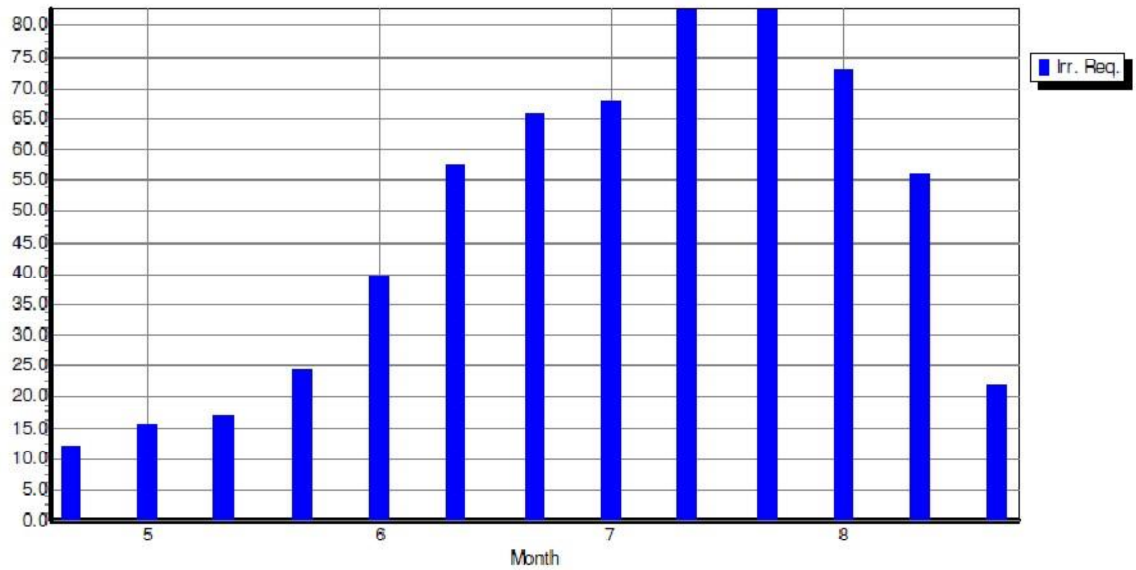
Winter Wheat

ETo station: NDOLA
Rain station: NDOLA

Crop: Spring Wheat
Planting date: 01/05

Month	Decade	Stage	Kc coeff	ETc mm/day	ETc mm/dec	Eff rain mm/dec	Irr. Req. mm/dec
May	1	Init	0.30	1.55	15.5	3.6	11.9
May	2	Init	0.30	1.57	15.7	0.0	15.7
May	3	Deve	0.30	1.55	17.0	0.1	16.9
Jun	1	Deve	0.51	2.51	25.1	0.5	24.6
Jun	2	Deve	0.83	3.98	39.8	0.2	39.6
Jun	3	Mid	1.15	5.77	57.7	0.1	57.6
Jul	1	Mid	1.27	6.60	66.0	0.1	65.9
Jul	2	Mid	1.27	6.80	68.0	0.0	68.0
Jul	3	Mid	1.27	7.54	83.0	0.1	82.9
Aug	1	Late	1.26	8.26	82.6	0.1	82.5
Aug	2	Late	1.03	7.30	73.0	0.1	72.9
Aug	3	Late	0.69	5.14	56.5	0.4	56.1
Sep	1	Late	0.40	3.14	22.0	0.0	21.9
					621.8	5.2	616.6

CROP WATER REQUIREMENTS GRAPH

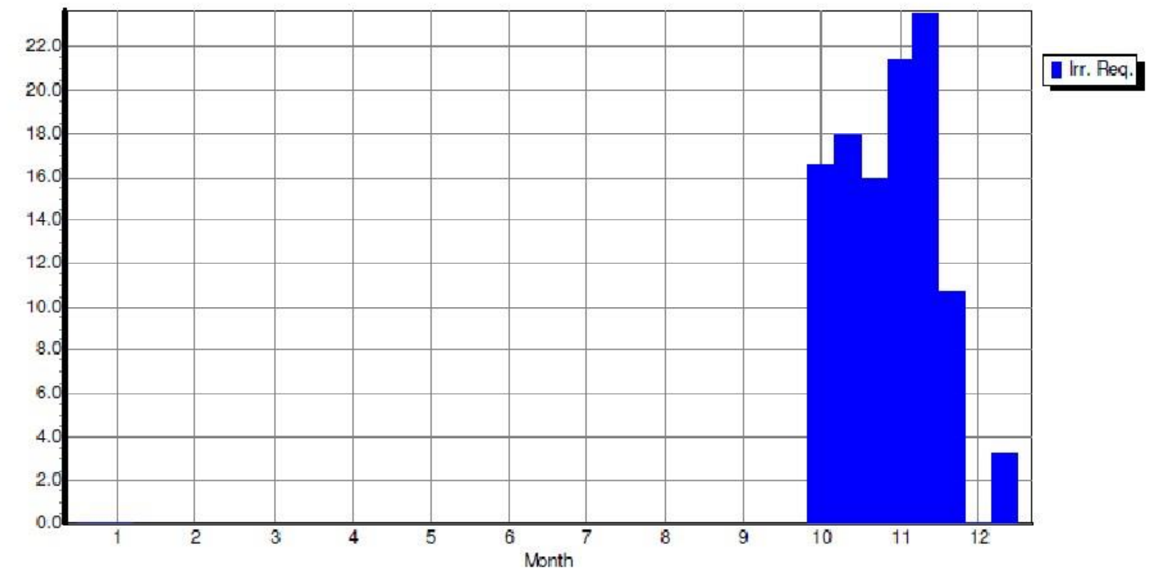


Summer Soya's

ETo station: NDOLA   Crop: ban
Rain station: NDOLA   Planting date: 15/10

Month	Decade	Stage	Kc coeff	ETc mm/day	ETc mm/dec	Eff rain mm/dec	Irr. Req. mm/dec
Oct	2	Init	0.40	3.42	20.5	4.7	16.6
Oct	3	Deve	0.41	3.15	34.6	16.7	17.9
Nov	1	Deve	0.64	4.28	42.8	26.9	16.0
Nov	2	Deve	0.95	5.68	56.8	35.3	21.4
Nov	3	Mid	1.18	6.45	64.5	40.8	23.7
Dec	1	Mid	1.18	5.84	58.4	47.7	10.7
Dec	2	Mid	1.18	5.22	52.2	54.4	0.0
Dec	3	Mid	1.18	5.14	56.6	53.4	3.2
Jan	1	Late	1.02	4.40	44.0	51.6	0.0
Jan	2	Late	0.64	2.69	18.8	36.1	0.0
					449.3	367.6	109.5

CROP WATER REQUIREMENTS GRAPH



Appendix 2 – Infrared Satellite Image