PROPOSED DEVELOPMENT OF FOXWOOD DAM & ASSOCIATED INFRASTRUCTURE, EASTERN CAPE

AQUATIC & WETLAND BASELINE ECOLOGICAL INTEGRITY & POTENTIAL IMPACT SURVEYS.

Prepared for:

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DECLARATION

This report has been prepared according to the requirements of the Environmental Impact Assessments Regulations (GNR 543) in Government Gazette 33306 of 18 June 2010, as well as the Department of Water Affairs (DWA, 2005) *Guidelines for Delineating Wetland and Riparian Zones* and Department of Water Affairs (DWA, 2007) *River EcoClassification: Manual for EcoStatus Determination (vers 2)*. We (the undersigned) declare the findings of this report free from influence or prejudice.

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EXECUTIVE SUMMARY

Introduction and Background.

The Department of Water and Sanitation (DWS) has proposed the construction of Foxwood Dam, which is located at the confluence of the Mankazana and Koonap Rivers, located to the north of Adelaide in the Eastern Cape Province. EnviRoss CC was requested to undertake the surface water ecosystem ecological and impact evaluations for the proposed development. This report details the findings of a single field survey undertaken during October 2015.

The aim of the survey was to ascertain the present ecological state of the surface water resources that could potentially be impacted by the proposed development and thereafter to determine the significance of the potential impacts emanating from a development of this nature.

Materials and Methods.

The standard DWS River EcoClassification and EcoStatus Models were utilised to determine the Present Ecological State (PES) the EcoStatus category and the Ecological Importance and Sensitivity (EIS) (DWA, 2007 & 2008). Three aquatic survey sites were chosen that would best allow for determining any deleterious impacts emanating from the proposed development activities, namely upstream of the impact, at the impact and downstream of the impact.

The following methodologies were applied during the survey:

- General riparian and habitat assessments:
  - Walk-about surveys at all survey sites;
- Aquatic habitat assessments:
  - *In situ* water quality (pH, oxygen content, dissolved oxygen, electro-conductivity (EC), total dissolved solids (TDS) and temperature);
  - Laboratory analysis of water samples taken at each survey site;
  - River IHI (Index of Habitat Integrity);
  - MIRAI (Macro-invertebrate Response Assessment Index);
  - FRAI (Fish Response Assessment System);
  - VEGRAI (Vegetation Response Assessment Index).

Results and Discussions.

A summary of the results of the EcoStastus models is provided in Table 1. Major drivers of ecological change from reference conditions include poor results from the fish sampling, together with transformation of riparian habitat noted at various sites. Repeated multiple surveys are required to gain accuracy regarding fish surveys, but their distribution is influenced by the presence of instream barriers, which are common throughout both watercourses.

Table 1: Summary of the EcoStatus results for the sections of the Mankazana and Koonap Rivers surveyed that would be impacted by the construction of the proposed Foxwood Dam.

Component	Mankazana River		Koonap River	
	PES (%)	Ecological Category	PES (%)	Ecological Category
Index of Habitat Integrity Instream IHI Riparian IHI	 80.2% 80.4%	 B/C B/C	 79.4% 79.7%	 B/C B/C
Fish Response Assessment Index	56.0%	D	59.9%	C/D
Macro-invertebrate Response Assessment Index	86.6%	B	83.9%	B
Vegetation Response Assessment Index	69.4%	C	80.0%	B/C
ECOSTATUS		**C (Confidence: 3.5)**	**C (Confidence: 3.5)**	

Water quality and instream habitat quality were considered good, as reflected in the relatively high aquatic macro-invertebrate scores throughout the survey area. Taxa known to be intolerant of degraded habitat and water quality conditions were noted to be present on relatively high abundance. The Ecological Importance and Sensitivity of the system remains within a *High* category.

Impact significance ratings:

The magnitude of the significance of an impact emanating from a particular activity is dependent on various factors such as the spatial extent (S), the duration (D), the intensity (I), the effects on important ecosystems (E), the overall reversibility of the impact (R), and the probability of likelihood of the impact (P). That is to say, if a localised impact occurs for a few days a year, with a low impact and no effect on important ecosystems (aquatic/wetland habitat or habitat identified to be importance to biodiversity conservation), and that impact can be easily rehabilitated, then the impact significance would be rated as low. An impact spanning over a large area, is continuous with a high intensity and will impact on important ecosystems, with little success of rehabilitation, then that impact is considered to be high. The perceivable impacts emanating from the preconstruction and the construction phases, and those perceived to occur during the management phase, are rated in Table 2 below. These are rated for both before and after the implementation of recommended mitigation measures.

Table 2: The significance ratings both before and after implementation of mitigation measures of the main potential ecological impacts perceived to be associated to the proposed development activities.

Potential environ impact	Project activity or issue	Environmental significance *before* mitigation**								Environmental significance *after* mitigation**							
		S	D	I	E	R	P	Conf*	SP	S	D	I	E	R	P	Conf	SP
PRECONSTRUCTION & CONSTRUCTION PHASES																	
Wetland habitat loss	Loss of wetland habitat due to inundation and/or infrastructure development	2	5	1	2	1	1	High	9	1	5	1	2	1	1	High	8
	Comment/Mitigation: *Natural wetland features are rare within the survey area and have generally been induced through irrigation canal seepage and off channel storage dams. Keep construction footprint at a minimum*																
Aquatic habitat features	Dam construction leading to fragmentation of aquatic habitat	3	5	5	4	2	5	High	75	2	1	1	3	3	2	High	8
	Comment/Mitigation: *A migratory barrier will isolate populations of fish, disallow habitat recruitment by eels and other species, and reduce breeding success rates.* *The feasibility of implementing a fishway to overcome the barrier should be explored.*																
	Inundation destroying aquatic habitat	2	5	5	4	1	5	High	75	2	5	5	4	1	5	High	75
	Comment/Mitigation: *Transformation of flowing habitat will displace habitat specialists and induce transformation of species community structures within the dam inundation footprint as well as the gauging weir.* *Changing to a lentic system will favour exotic species within the system.*																
	Impacts on water quality induced through the establishment of the impoundment	3	4	1	2	1	4	High	36	3	4	1	2	1	2	High	18
	Comments/Mitigation: *Impoundments induce water quality changes that transforms the system through oxygen depletion, EC/TDS changes and changes in temperature regimes.*																
	Contamination of surface water features leading to loss of sensitive biota.	2	4	3	4	2	3	High	33	1	0	1	2	4	2	High	0
	Comment/Mitigation: *Fuel storage should be done within designated areas only, which are properly bunded to contain any potential fuel leaks. Construction vehicles should be properly serviced in order to avoid fluid leaks. Proper sewerage management should be implemented in order to avoid contamination of the surface waters through untreated sewerage.*																
	Destruction of riparian vegetation following inundation	3	5	5	4	2	5	High	75	3	5	5	4	2	5	High	75
	Comment/Mitigation: *Inundation will destroy riparian vegetation that remain intact and that offers good habitat and functionality within an otherwise low-canopy vegetation. Destruction will displace habitat specialists and destroy large and established trees. Offset mitigation measures proposed through the establishment of groves of existing riparian species within protected areas along new shoreline. This will ensure conservation of the seedbank and recruitment by appropriate floral species. This sort of mitigation could reduce the overall significance of the impact.* *Loss of habitat within the inundation footprint is an inevitable consequence of the project. The associated infrastructure should take riparian vegetation impacts into consideration and alternatives should be sought that imposes the least overall impact to the unit. Construction footprints should be limited as far as possible. The towers of overhead power lines should be planned and placed so as not to impact the habitat feature and that lines can span across riparian zones without impact and/or the need for clearing.*																
Soils	Soil stripping, soil compaction and vegetation removal will increase rates of erosion and entry of sediment into the general aquatic ecosystem.	2	4	3	3	2	3	High	30	1	1	1	1	4	1	High	0
	Comment: *Erosion must be strictly controlled through the utilization of silt traps, silt fencing, Gabions, etc. This is especially pertinent within areas of steeper gradients.*																
	Erosion of stockpiled topsoil & disturbance of soils due to vegetation stripping leading to erosion and habitat inundation.	2	4	3	3	2	3	High	30	1	1	1	1	4	1	High	0
	Comment: *Topsoil stockpiles should be protected from erosion through the utilization of silt traps, silt fencing, Gabions, etc.*																

Potential environ impact	Project activity or issue	Environmental significance *before* mitigation**								Environmental significance *after* mitigation**							
		S	D	I	E	R	P	Conf*	SP	S	D	I	E	R	P	Conf	SP
MANAGEMENT PHASE																	
Aquatic habitat features	Habitat fragmentation as a result of construction of migratory barriers	3	5	5	4	2	5	High	**75**	2	1	1	3	3	2	High	**8**
	Comment/mitigation: Change in community structures will take place. Habitat will be lost to breeding and exploitation by various species, especially eels. Further impacts imposed on endangered fish species. Inhibition of recruitment for genetic dispersal. The feasibility of implementing a fishway must be explored. If implemented, monitoring should take place in order to ascertain effectiveness and remedied if required.																
	Depletion of a water source, effectively reducing the water volume available for the ecological reserve. Poor management of the dam releases that contradicts EFR release protocols.	3	5	5	4	2	5	High	**75**	2	1	1	3	3	2	High	**8**
	Comment: A comprehensive EFR survey was undertaken and it is recommended that the flow volumes and flow regimes be followed. Not allowing for EFR will lead to decline of ecological integrity of the system and degradation of the resource.																
	Contamination of surface water features leading to loss of sensitive biota.	2	4	5	4	2	4	High	**52**	1	1	1	2	3	2	High	**4**
	Comment: Containment of effluents and further accidental discharges to ensure that contaminants do not reach the surface waters will greatly reduce this impact. Strict management procedures will ensure correct operational procedures, which will, in turn, protect the surface water resources from contamination. This includes on site sewerage management and maintenance of conveyance infrastructure.																
Biodiversity impacts	Exotic vegetation encroachment following soil disturbances.	2	4	1	2	2	4	High	**28**	1	1	1	1	4	2	High	**0**
	Comment: This is thought to require careful attention and active management, but is something that is easily mitigated for.																
Soil erosion	Resulting from roadway runoff through poor stormwater attenuation and drainage design leading to habitat transformations.	2	4	3	4	1	4	High	**48**	1	1	1	2	2	2	High	**6**
	Comment: Stormwater engineering needs to take into consideration the deposition of silts transported after rainfall events into the surface water resources. This will lead to smothering of the aquatic habitat, ultimately displacing aquatic species.																

See Appendix B for calculations & methodologies. *SP ratings: 0-33 (Low), 34-74 (Medium), 75-100 (High)*

Table 2 presents the findings of the impact significance ratings, with the ratings both before and after mitigation being indicated. It can be seen that some impacts are inevitable due to the very nature of the proposed development. Other impacts are shown to be readily mitigated for, with greatly reduced magnitudes of significance. The most significant impacting features will result from the fragmentation of the river habitat and the consequences to fish populations and conservation within the region. Other significant impacts that cannot be mitigated for (unless offset mitigation options are explored) include the destruction of riparian habitat through inundations as well as the drowning out of flow water habitat through the inundation.

Conclusions and Recommendations.

Recommendations and general mitigation measures are outlined below:

- Application of the EcoStatus models to the river reaches associated with the proposed development showed that there was a degree of change from reference conditions in terms of biological integrity (fish, macro-invertebrates and riparian vegetation) as well as instream and riparian habitat. The resultant Ecological Category is C class. The main driver limiting the ecological scores came from the fish survey, where species expected to occur were not sampled. This may be due to recent freshet flows, limitations of sampling techniques, and the limitation of a single (once-off) survey. Existing habitat fragmentation is a feature of the systems due to irrigation weirs, which has had an impact on fish distribution throughout the survey area. Even though there are transforming and degrading features present within the river reach, the overall Ecological Importance and Sensitivity (EIS) remains *High*. Mitigation measures should be in place to ensure that these ecological categories are not degraded;
- The surface water quality throughout the survey area is considered good, with the aquatic system supporting a diversity of sensitive aquatic macro-invertebrate taxa. It is therefore imperative that the contamination of the surface waters through deleterious effluents and runoff water be avoided;
- Ecological flow requirements have been set for the system. It is recommended that the flow volumes and release protocols be followed in order to maintain the health of the system;
- Habitat fragmentation is a major impact that will impact the migratory aquatic biota within the system. It is recommended that the feasibility of a fishway be explored and implemented if possible;
- Preferred choices of offered alternatives have been presented (section 8);
- Destruction of riparian habitat due to inundation of the impoundment footprint area will be an inevitable consequence of the proposed development. Offset mitigation measures to improve catchment management should be considered as well as establishing groves of riparian vegetation from existing species within appropriate areas along the new shoreline to conserve the seedbank as well as enhance recruitment. It is recommended that vegetation to be drowned be removed prior to inundation as the rotting of vegetation will deplete the watercourse of oxygen, which will impact the system downstream;
- Emergency procedures must be in place to timeously mitigate any accidental spillages and to isolate the impacting features as far as possible;

- Regular monitoring of water quality to enable early identification of contamination is recommended. The source of any contamination identified though the monitoring should be identified and managed according to best practice guidelines;
- Soil erosion emanating from disturbances within the riparian zones and other areas of steep gradients is regarded as a major impacting feature to potentially impact the overall ecological integrity of the aquatic system. Active stormwater management should be implemented to stop silt and sediments from entering the aquatic system and smothering the habitat units. Disturbed soils and stockpiled soils should be protected from erosional features;
- The footprint of the associated infrastructure as well as the supporting services during the construction phase should be retained as small as possible by construction vehicles being limited to designated roadways only. Destruction of the riparian habitat through the unnecessary clearing of vegetation should be avoided;
- Dumping of any excess rubble, building material or refuse must be prohibited within riparian habitat. Dumping of materials should only take place at designated and properly managed areas;
- Adequate toilet facilities must be provided for all construction crews to negate informal ablutions taking place within riparian zones;
- Fires within the riparian zones should be prohibited;
- The encroachment of exotic vegetation will be enhanced following site disturbances. This should be monitored for and recruitment managed appropriately.

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1. INTRODUCTION & TERMS OF REFERENCE

1.1. Background

The Department of Water and Sanitation (DWS) is investigating the feasibility of developing a multi-purpose dam on the confluence of the Mankazana River and the Koonap River outside of Adelaide in the Eastern Cape (EC), to be known as Foxwood Dam. EnviRoss CC was requested to undertake the aquatic ecological and impact survey as well as the wetland and riparian delineation, ecological integrity and impact survey for river reaches pertaining to the proposed development area. The locality of the survey area is presented in Figure 1: Locality of the study area..

The proposed development entails the following:

- A major storage dam (Foxwood Dam, measuring 48.5 m height, full supply level is 615 m above mean sea level (AMSL));
- Bulk water supply pipeline and pump station;
- Gauging weir;
- Access roads (construction and operational phases);
- Quarry and borrow areas;
- Eskom supply to the dam and gauging weir;
- Relocate existing infrastructure (including water supply canal, R344, MR00639, Telkom telephone line and Eskom overhead power line);
- Construction camp; and
- Permanent offices and accommodation for dam operator.

The proposed infrastructure layout and plans of the various options and alternatives are presented in Figure 2: Proposed infrastructure layout of Foxwood Dam and associated infrastructure and alternatives.. This report details the baseline aquatic and wetland ecological assessment undertaken prior to the onset of the development (pre-construction phase) that will allow for the identification of the associated ecological impacts to the surface water ecosystems emanating from a development of this nature.

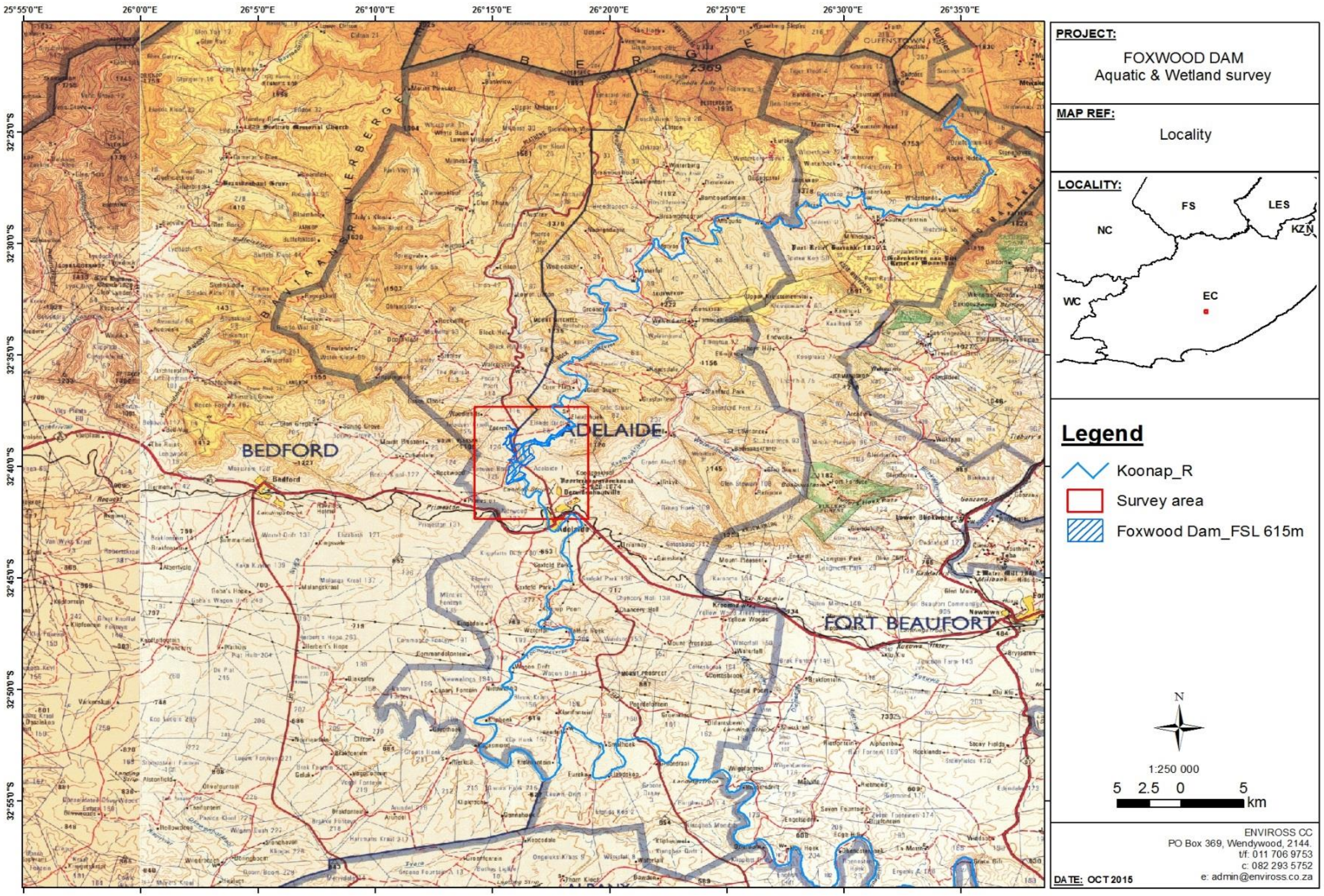

Figure 1: Locality of the study area.

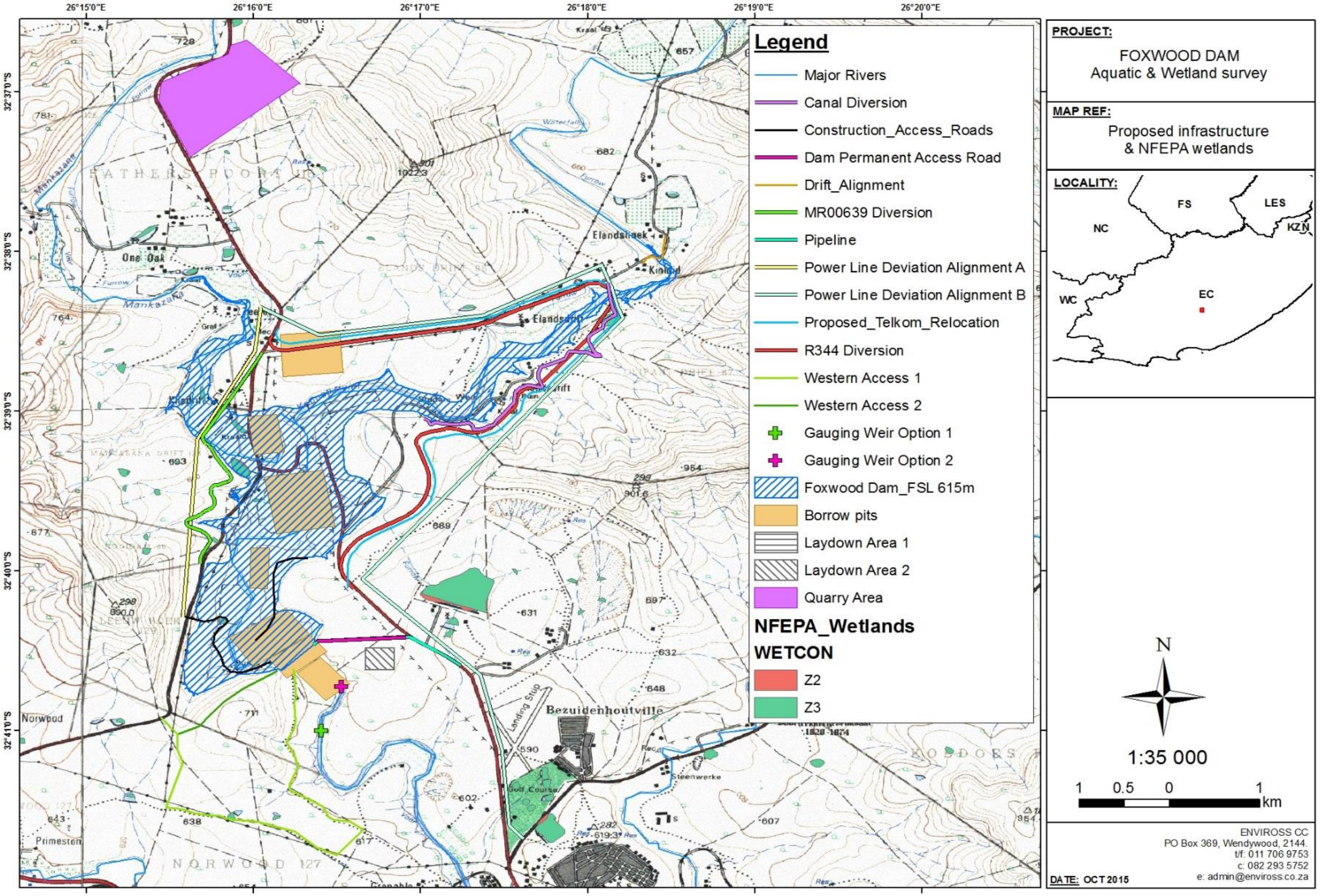

Figure 2: Proposed infrastructure layout of Foxwood Dam and associated infrastructure and alternatives.

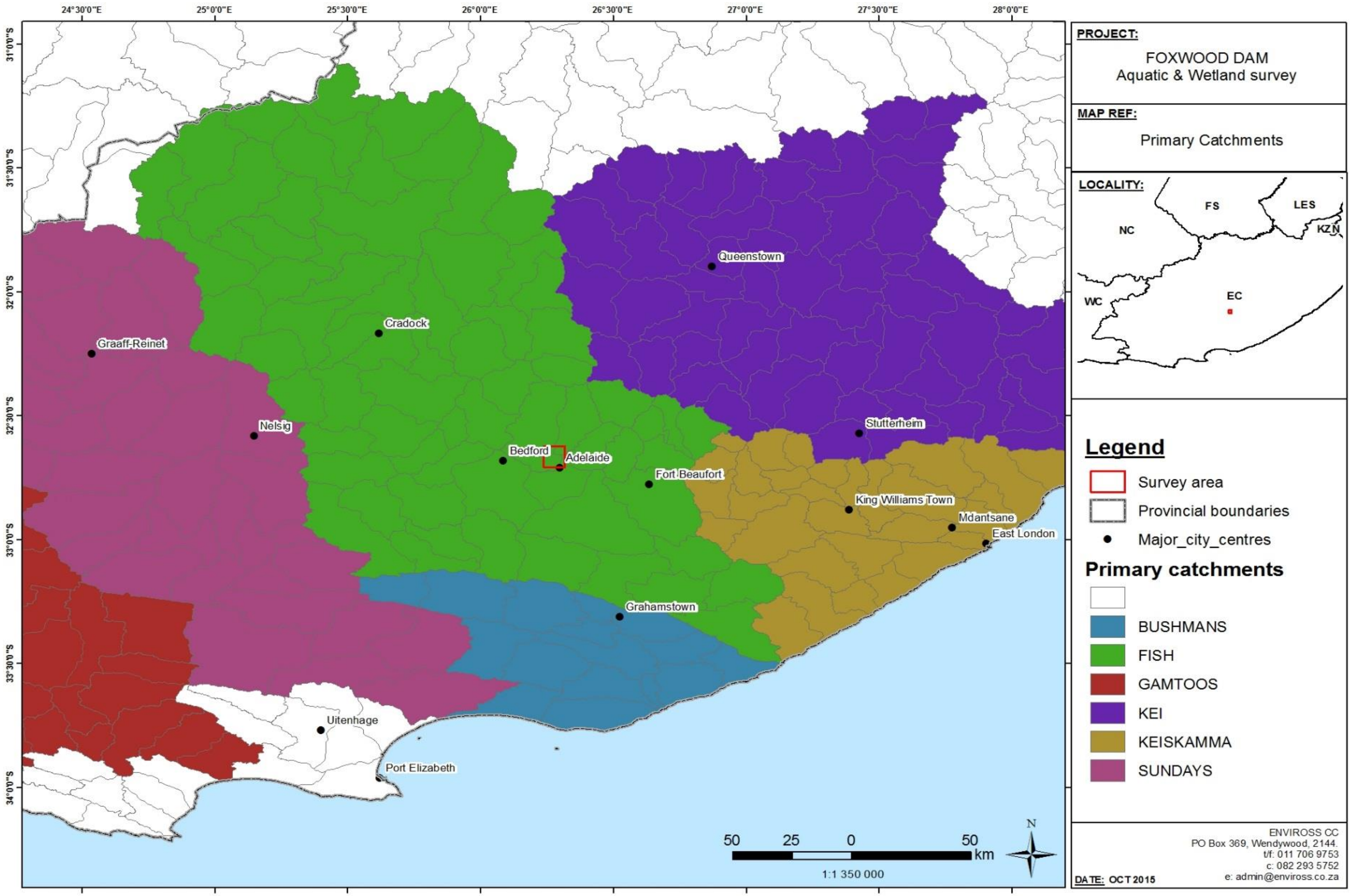

Figure 3: The primary catchment areas associated with the proposed development site.

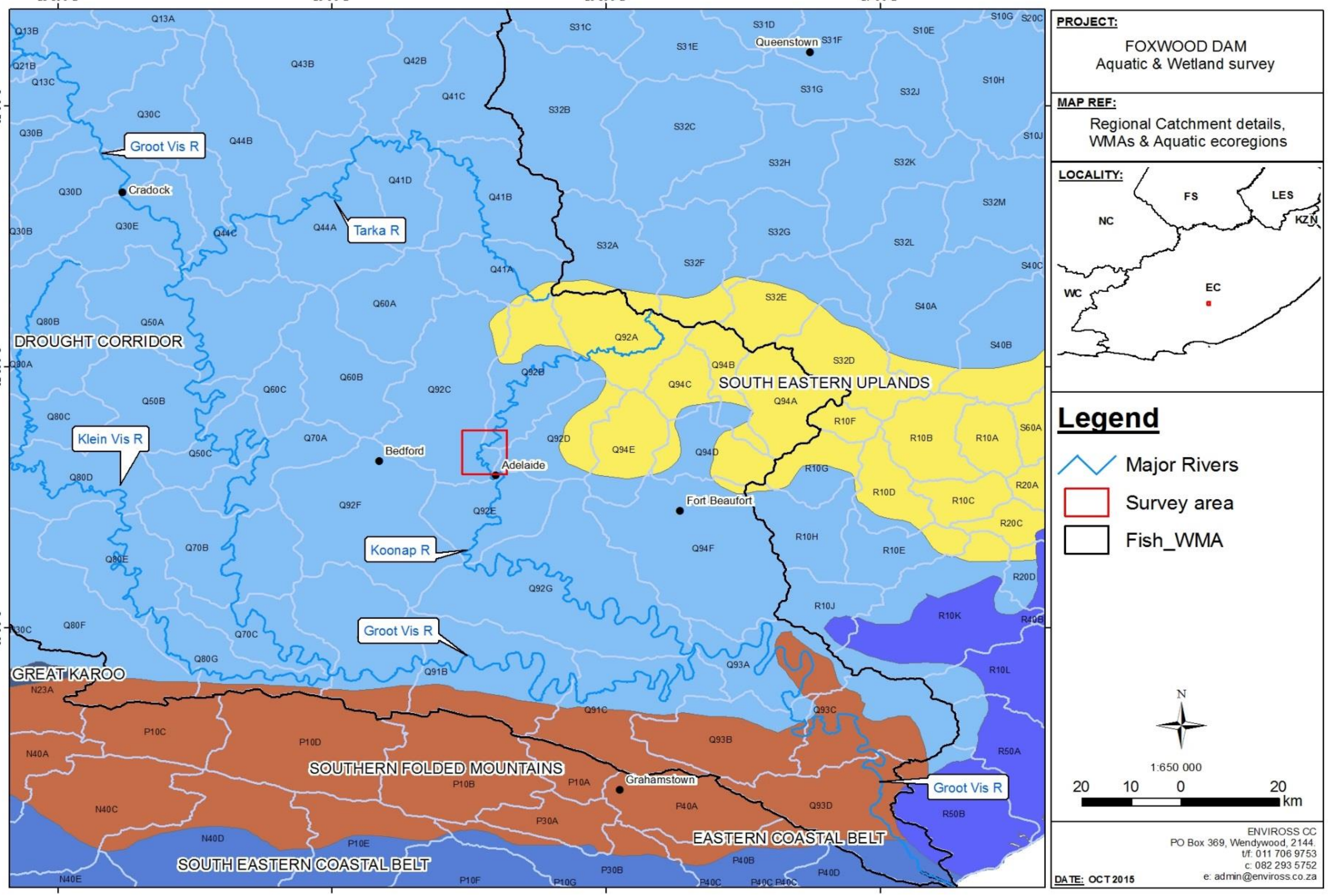

Figure 4: The aquatic ecoregions associated with the proposed development site.

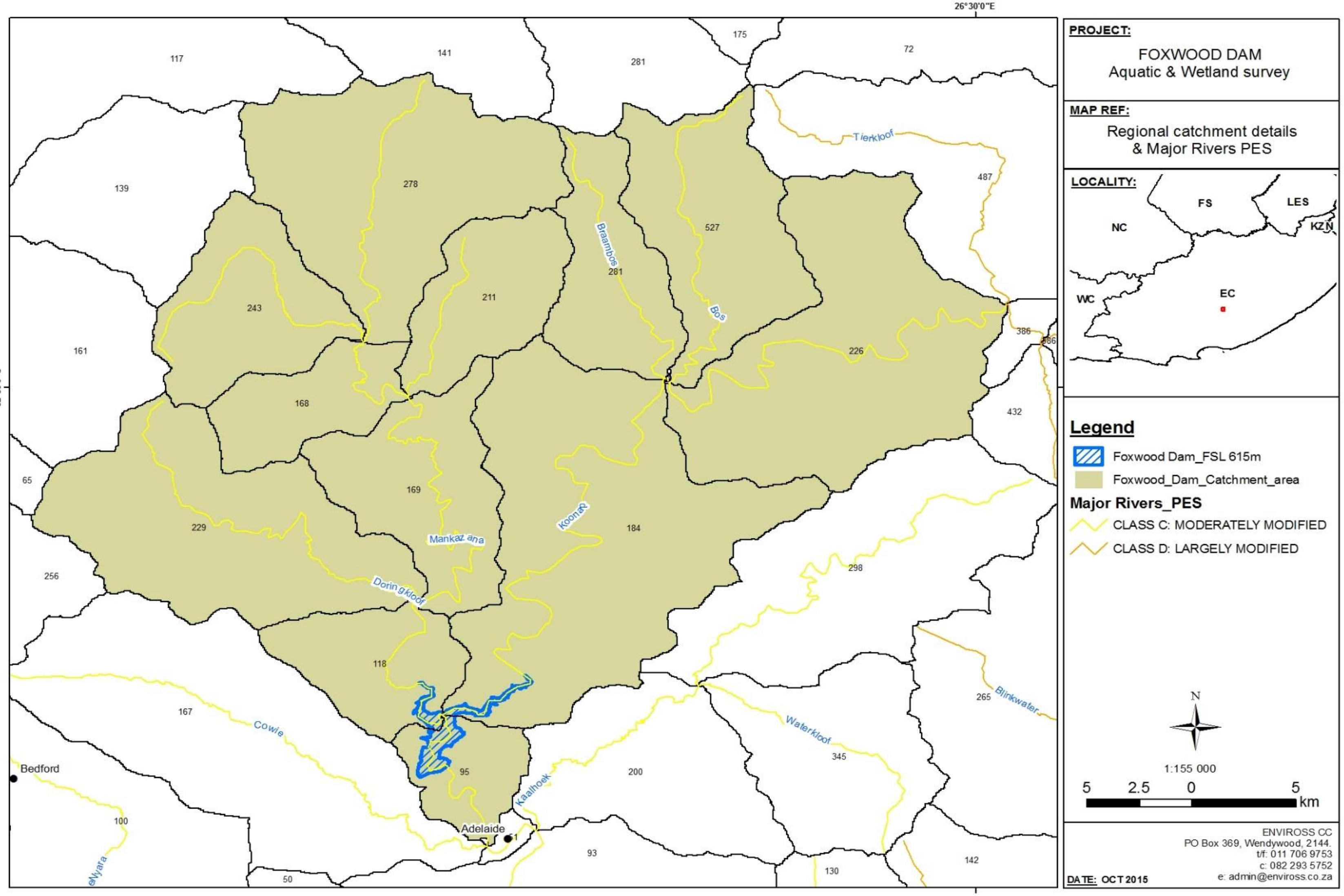

Figure 5: The regional catchment details pertaining to the proposed development site showing the Present Ecological State of the major watercourses.

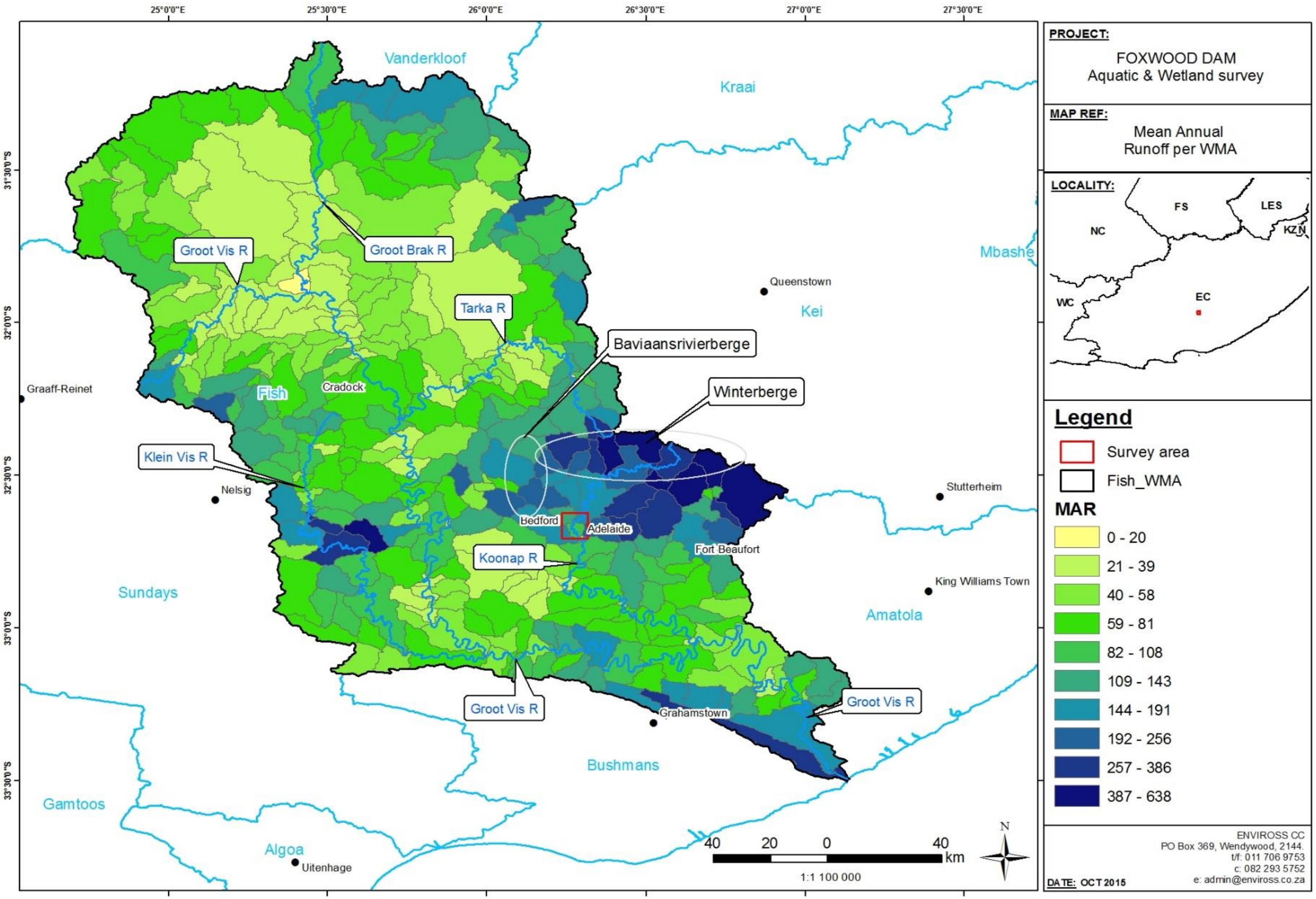

Figure 6: The mean annual runoff (MAR) for the region, showing the area of origin of the watercourses that will be impacted by the proposed development.

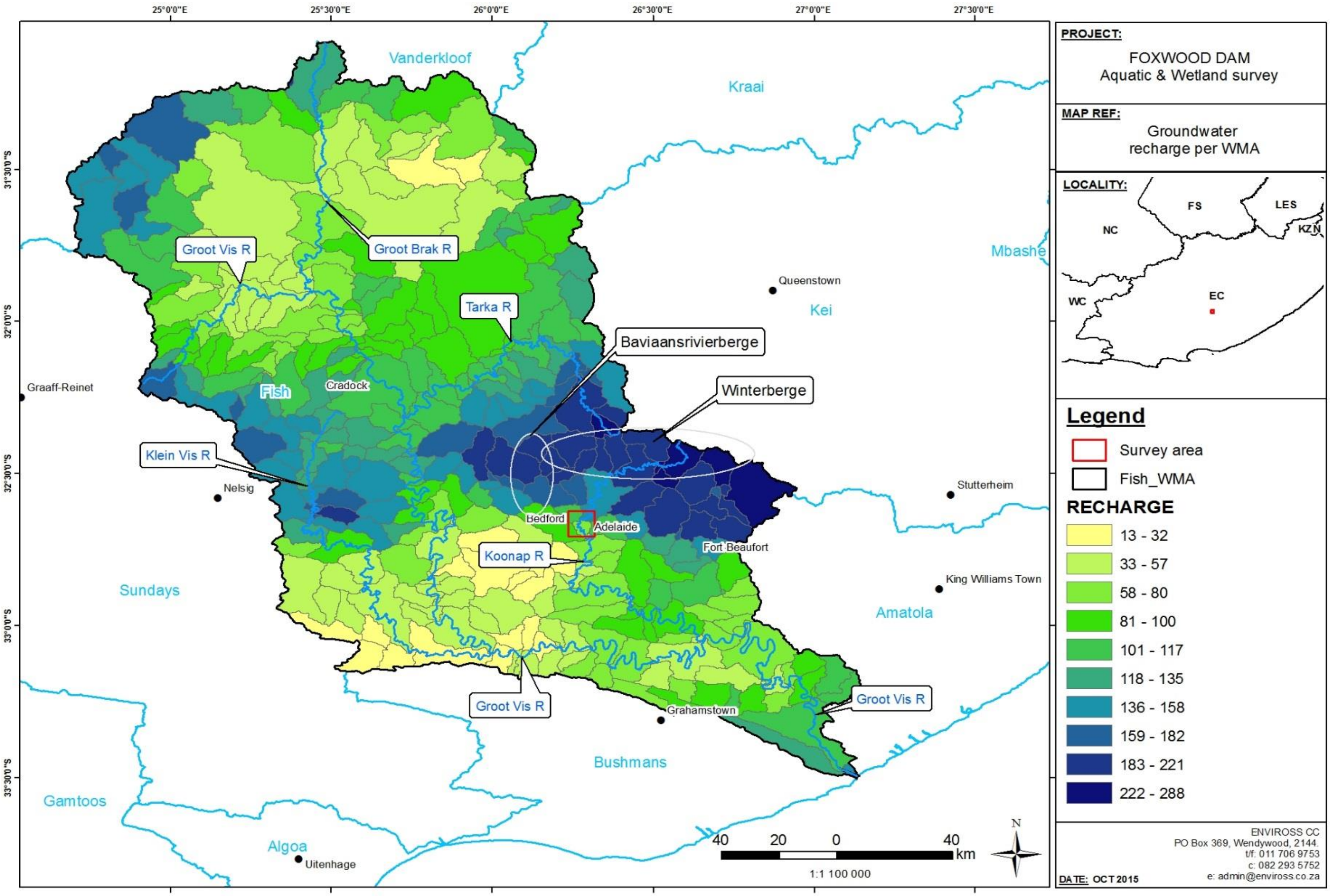

Figure 7: The recharge values for the region, showing the area of origin of the watercourses that will be impacted by the proposed development.

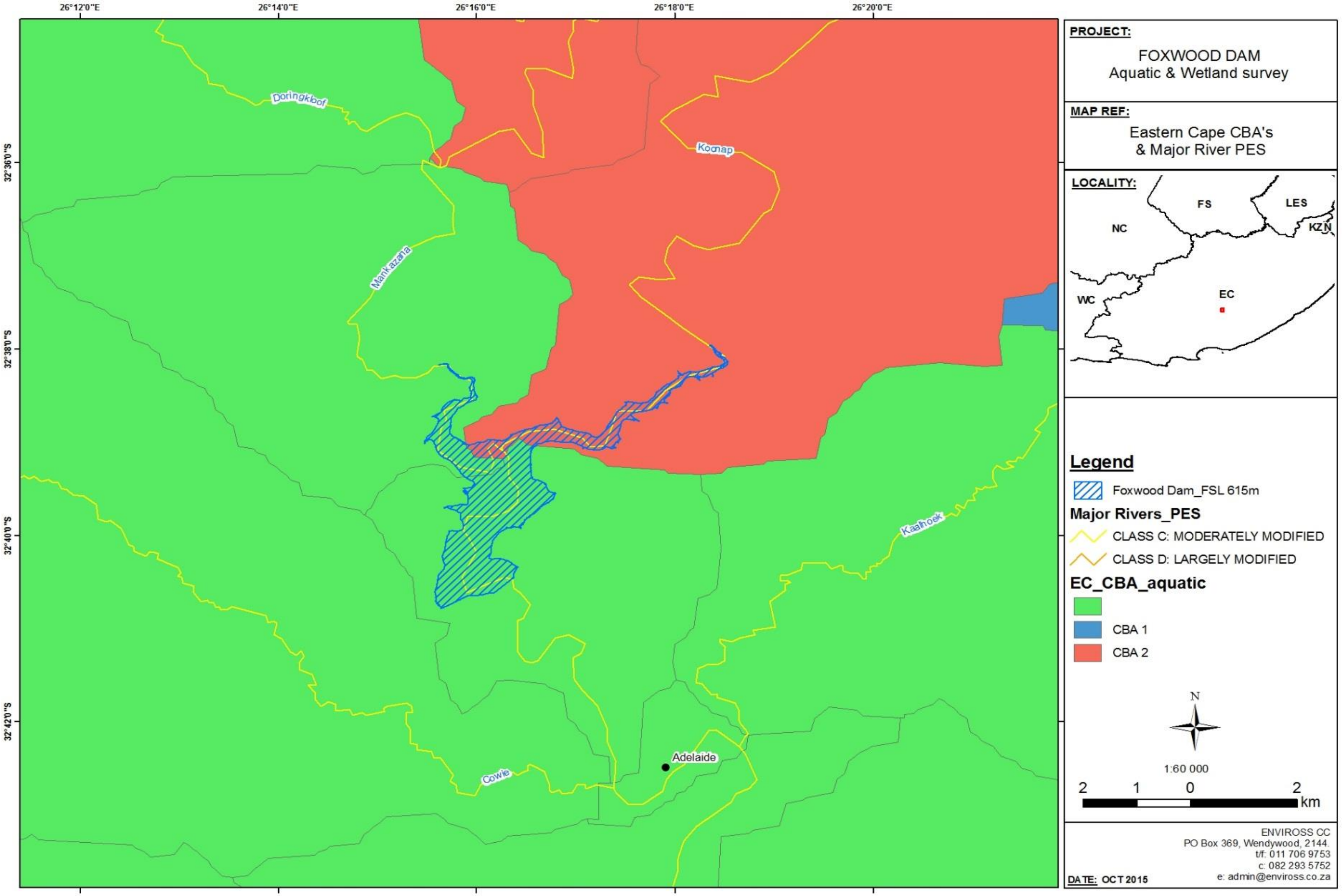

Figure 8: The categorisation of the area by the Eastern Cape Biodiversity Action Plan (ECBAP) and how the proposed development.

1.2. Scope of Work

The Scope of Work included an ecological survey for the associated riverine habitat to establish baseline data for the river reach that would be impacted by the development activities. It also included the establishment of wetland ecological baseline data as well as the delineation of any impacted wetland habitat features in order to quantify the overall loss of wetland habitat. These baseline data would then allow for impact evaluations (from both predictions as well as routine future monitoring) in order to evaluate the potential impacts on the surface water systems. A general impact assessment for the surface water resources was to be developed, which would allow for mitigation measures to be proposed in order abate or manage overall negative ecological impacts.

1.3. Aims & Objectives

The objective of this report is to provide the relevant biological information pertaining to the surface water resources and the implications of the potential to the planning, management and construction teams of the proposed development activities, so as to manage and minimise the ecological impacts. It is also to provide baseline data that would serve as the benchmark data that would allow for trend analysis of future data. This document presents the findings of a field survey that was undertaken during October 2015.

1.4. Assumptions & Limitations

The conclusions to the PES and the overall perceived potential impacts alluded to within this report represents the results of a single survey. Certain assumptions have been made regarding the future trends and the influence of seasonality that have been based on professional judgement and experience gained by the field ecologists whilst surveying within similar areas. The confidence of the trend analysis will increase when more surveys have been undertaken, which is especially relevant to fish sampling throughout the system that are strongly influenced by seasonality.

2. STUDY AREA & CATCHMENT CHARACTERISTICS

The proposed Foxwood Dam is to be located at the confluence of the Mankazana River and the Koonap River, just north of the Eastern Cape town of Adelaide. It falls within the Fish (Q) Primary Catchment (Figure 2), the Q9 Secondary Catchment, which is drained by the Great Fish (Groot-Vis) River, the Q92 Tertiary Catchment, which is drained by the Koonap River. The proposed dam inundation footprint spans across the boundary between the quaternary catchments of Q92B and Q92C (Figure 5). It also falls within the Drought Corridor aquatic ecoregion (Figure 4). The dominant land use within the catchment area is agriculture, with livestock (cattle and goats) being prominent. Formal agriculture (cultivation) does occur along the edges of the watercourses, but is considered a lesser water use. Both the Koonap River and Mankazana River formed part of an irrigation scheme, with the canal networks being located within the riparian zones of the rivers. The abstraction/diversion instream weirs remain within the rivers, but the canal network has fallen into disrepair and is only utilised in isolated cases to divert water to off channel storage farm dams.

The two main watercourses associated with the proposed development, namely the Koonap River and the Mankazana River both rise within nearby mountain ranges. The Koonap River rises within the Winterberge, located to the northeast of the site, and the Mankazana River rises within the Baviaansrivierberge, located to the northwest of the site. The actual Foxwood dam inundation footprint falls within catchment areas with both moderate mean annual runoff (MAR) and groundwater recharge zones, whereas these mountain ranges offer a substantially higher MAR as well as groundwater recharge, making them important to surface water ecosystem and resource conservation within the region (Figure 6).

The river reach associated with the site has been identified within the Eastern Cape Biodiversity Conservation Plan (ECBCP) as a Critical Biodiversity Areas (CBA) for aquatic conservation. The sub-catchment area and river reach located upstream of the proposed Foxwood Dam has been categorised as a CBA2, and regarded as A2A meaning that the aquatic ecological integrity remains within a near natural state and the sub-catchment area is regarded as being important to aquatic health within the system . The river reach located downstream of the proposed dam site has not been categorised as a river reach important to aquatic conservation (Eastern Cape Biodiversity Conservation Plan [ECBCP] [Berliner *et al.,* 2007]) (Figure 8).

The major vegetation type associated with the proposed development area is Great Fish Thicket, which falls within the Albany Thicket Biome and bioregion of the same name. Although this is a poorly-conserved vegetation unit, it remains Least Threatened from a conservation perspective due to large-scale representation as well as low impact land uses associated with the unit (Mucina & Rutherford, 2006).

The riparian zones of the rivers within the region form a distinctive greenbelt within an otherwise semi-arid region. The river valleys of established watercourses are characterised by thick alluvial soil deposits, which generally supports well-developed, tree-dominated riparian zones. Although not substantive enough to be designated a separate vegetation type, these riparian zones are quite distinct within the landscape.

The Koonap Rivers (and associated tributaries within the region) are subject to great variance in flow volumes as can be seen from flow record data recorded for DWS flow gauging weir Q9H030, located

3. GENERAL SITE DESCRIPTIONS

Survey sites were selected on both the Mankazana (one site located upstream of the proposed inundation area) and Koonap Rivers (five sites throughout the survey reach) to assess the overall ecological integrity of the watercourses within the scope of the survey area. The localities and how they relate to the proposed infrastructure are presented in Figure 9. Site details and descriptions are presented in Table 3.

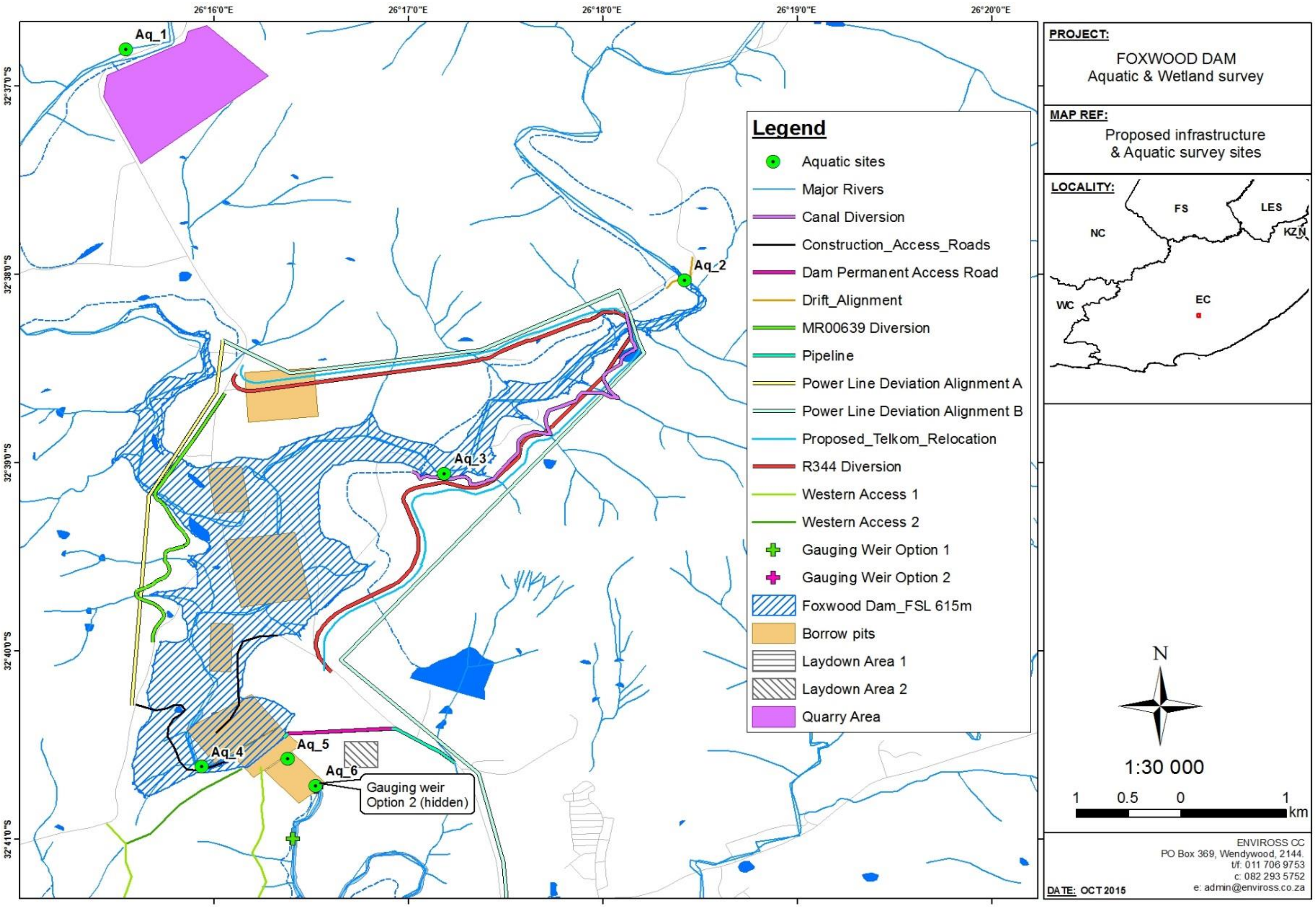

Figure 9: Locality of the aquatic survey sites in relation to the proposed infrastructure.

Table 3: Aquatic survey site details and descriptions.

Site code	River	Co-ordinates		Site photo records	Site description
		Lat_S	Lon_E		
Aq_1	Mankazana	-32.61336	26.25964	 	Located upstream of eventual inundation area. Medium to fast-flowing, shallow to deep water with substrates dominated by bedrock, boulders and cobbles. Rapid, riffle, glide habitat, together with slow-flowing water. Deeper pools occur where substrates of gravel and sand accumulate. Overhanging vegetation common, with some emergent marginal vegetation in and out of current. Aquatic vegetation absent.
Aq_2	Koonap	-32.63412	26.30718	 	Located just downstream of the existing concrete bridge at the northern extreme of the ultimate inundation area. Slow, medium and fast-flowing, shallow to deep water with substrates dominated by gravel and cobbles. Riffles and glides dominate. Deeper pools occur where substrates of gravel and sand accumulate. Overhanging vegetation common, with some emergent marginal vegetation in and out of current. Aquatic vegetation absent. Poor culvert integration within the bridge means that the bridge presents as a migratory barrier at low to upper medium flows.

Site code	River	Co-ordinates		Site photo records	Site description
		Lat_S	Lon_E		
Aq_3	Koonap	-32.65090	26.28647	 	Located midstream, within the area to be inundated by the proposed dam. Slow, medium and fast-flowing, shallow to deep water with substrates dominated by gravel, cobbles and boulders. Riffles and glides dominate. Deeper pools occur where substrates of gravel and sand accumulate. Overhanging vegetation common, with some emergent marginal vegetation in and out of current. Aquatic vegetation absent.
Aq_4	Koonap	-32.67677	26.26571	 	Located just downstream of the existing irrigation abstraction/diversion weir. Medium to fast-flowing, shallow to deep water with substrates dominated by bedrock, boulders, cobbles and some gravel. Rapids, riffles and glides dominate. Deeper pools occur where substrates of gravel and sand accumulate. Overhanging vegetation common, with some emergent marginal vegetation in and out of current. Aquatic vegetation absent.
Aq_5	Koonap	-32.67620	26.27301	 	Located just downstream of the proposed dam wall site. Medium -flowing, shallow to deep water with substrates dominated by sand, mud, gravel and cobbles. Riffles and glides dominate. Deeper pools occur where substrates of sand and mud accumulate. Overhanging vegetation common, with some emergent marginal vegetation in and out of current. Aquatic vegetation absent.

Site code	River	Co-ordinates		Site photo records	Site description
		Lat_S	Lon_E		
Aq_6	Koonap	-32.67858	26.27540	 	Representative of proposed gauging weir sites. Turbidity of the water increased downstream along the river. Turbid, silt-laden water, where deeper and slower-flowing pools were common separated by riffle (cobble-dominated) shallow habitat. Overhanging vegetation common, but emergent and aquatic vegetation largely absent.

The catchment area had just received substantial rainfall prior to the survey, which saw an increased volume of water within the rivers. The water was notably turbid, with an increasing trend moving downstream within the system. Increased turbidity is expected, especially as a result of the first substantive rainfall of the season, but is also indicative of a degree of erosion within the catchment area. This was also expected as the winter season and winter grazing by livestock sees a decline in vegetative groundcover. The growth of vegetation following the rainfall will increase the groundcover and will therefore reduce erosional impacts to the watercourses. At the time of the survey, high water flood debris showed that the flow volumes were receding following a substantial rainfall event within the catchment area. Although not considered conducive to induce flood conditions, the freshet flows as well as the slight increase in turbidity were expected to influence the biological scores for the system to a certain degree.

4. WATER QUALITY

The *in situ* water quality of all of the aquatic biomonitoring sites were taken using a *Hanna model 9828* multi-parameter water quality meter. These data are important to the interpretation of the biological data that are gathered during the sampling at the various sites. The parameters that were recorded were: Dissolved oxygen (%), Oxygen content (mg/ℓ), pH, Total dissolved solids (TDS) (ppm), Electro-conductivity (EC) (µS/cm) and Temperature (°C).

The water quality evaluation formed an integral part in determining the potential impact of the proposed development activities on the conservation of the surface water resources. The proposed development falls within a sensitive and important aquatic resource, with the water resource being supplied to both rural and formal sectors. This means that the maintenance of the quality of the water resource within acceptable limits should be a management priority.

4.1. *In situ* water quality results

In situ water quality parameters were taken at various points throughout the survey area to best gain average water quality parameter values for the surface waters at the time of the biological sampling. Samples from all of the biological survey sites were taken at the time of the survey using a hand-held *Hanna Multi-parameter water quality meter: Model 9828*.

Water quality determination forms an integral part of enabling accurate interpretations of the biological data as the final ecological class allocation, and associated interpretations of the results, is a combination between the habitat quality, water quality and biological integrity. The parameters tested for and the results from each site sample are presented in Table 4. The South African Water Quality Guidelines for Aquatic Ecosystems (DWA SAWQG's, 1996) are used to evaluate the results.

Table 4: *In situ* water quality results for each site. Values that fall outside of the guideline values are highlighted.

Site (Map code)	Temperature (°C)	pH	Dissolved Oxygen (DO) (mg/ℓ)	Oxygen saturation (%)	Total dissolved solids (TDS) (ppm)	Electrical conductivity (EC) (µS/cm)	Salinity
Mankazana River (Aq_1)	19.01	7.78	8.91	103.6	117	234	0.11
Koonap River Site 1 (Aq_2)	22.05	7.74	8.27	101.4	74	149	0.07
Koonap River Site 2 (Aq_3)	18.99	7.74	8.24	94.7	85	170	0.08
Koonap River Site 3 (Aq_4)	20.05	7.75	8.26	95.1	91	183	0.08
Koonap River Site 4 (Aq_5)	19.63	7.74	8.88	97.2	90	181	0.08
Koonap River Site 5 (Aq_6)	18.86	8.63	9.20	105.4	91	181	0.09
Guideline Values	Should not fluctuate by more than 2 °C or 10% of the normal daily cycle	Between 6 and 8, and should not exceed 0.5 pH units or 5% of the natural pH range for a given system at any given time	>5 mg/ℓ	>60%	TDS of <1000 ppm or not fluctuate by more than 15% of the normal range of a system within a 24hr cycle.		

4.1.1. Water temperature

Water temperature plays an integral role in biochemical processes and therefore governs the rate of associated metabolic processes of poikilothermic ("cold-blooded") aquatic organisms. Without internal control mechanisms, the metabolic rate of aquatic organisms is greatly influenced by ambient temperature and therefore the rate of development and growth as well as repair of damaged tissue and the functionality of associated stress-coping mechanisms of aquatic organisms is also all governed by the water temperature. The South African Water Quality Guidelines (SAWQG's) (1996) stipulate that water temperature should not fluctuate by more than 2°C or 10% of the normal daily temperature cycle of a system for the season associated with the sampling. Different river systems and even different reaches of the same river system have differing temperature regimes due to the origin of the water source or the habitat through which the watercourse passes. Underground water fed streams display typically colder water temperatures than that of the mid waters of a wide river that has been exposed to radiant temperature for a longer period of time. Water temperature also varies according to local conditions, position within the water column (deeper water tends to be colder than shallower water), movement (mixing) of water (temperature stratification occurs outside of the mixing zones, whereas temperature stratification (thermoclines) develop in deeper, still-standing water). Aquatic organisms have evolved to survive within an optimal range of water temperatures for a given reach of a river and are able to move position to exploit areas of optimal temperatures if allowed the migratory freedom to do so. Any sudden fluctuations that are artificially induced adversely affect the survival rates and is regarded as a limitation to supporting of aquatic biota.

The water temperatures recorded at the time of sampling ranged between 18.86 and 22.05 °C (Table 4). The water temperature recorded at all of the sites is what could be expected for the characteristics of the watercourses, climatic zones and the season and are therefore not expected to be a limiting factor on the survival of the aquatic organisms.

4.1.2. pH

The pH of the natural waters of a river system is influenced by both geological and atmospheric factors as well as, to a lesser extent, biological processes that take place within the water. Most natural waters are relatively well buffered to pH fluctuations due to the presence of bicarbonates and other buffering chemicals (SAWQG's, 1996) and therefore aquatic organisms have evolved to function optimally within a generally very narrow pH range. An undue fluctuation in pH of a system therefore has adverse effects on the survival of aquatic organisms.

According to the SAWQG's (1996), pH of a river system should not fall outside of the range of 6 to 8 pH units. The fluctuation of pH during one 24-hr cycle should also not exceed 0.5 pH units or 5% of the natural pH range for a given system at any given time.

The pH recorded throughout the survey area was regarded as being within optimal ranges for supporting aquatic organisms, being recorded as between 7.74 and 8.63 (Table 4). Although all still within guideline values, the pH at site 5 (Aq_6) is an outlier for the river reach and may be an indication of a point or diffuse source of pollution. It is speculated that this may be due to agricultural runoff. The pH of the system is not thought to be a limiting factor to supporting a diversity of aquatic biota.

4.1.3. Dissolved oxygen and oxygen content

The maintenance of adequate dissolved oxygen (DO) concentrations is critical for the survival and functioning of the aquatic biota because it is required for the respiration of all aerobic organisms. Therefore, the DO concentration provides a useful measure of the health of an aquatic ecosystem (SAWQG's, 1996). This can be measured as oxygen saturation expressed as a percentage (saturation points differ for water with different temperatures and chemical constituents), or as dissolved oxygen concentration, expressed in mg/ℓ (an absolute value). The general guideline value of oxygen content for supporting aquatic life is >5 mg/ℓ. Oxygen saturation of the water varies and is dependent on the temperature of the water. In general, the cooler the water, the higher the saturation (100%) point. As the water approaches freezing temperature, its saturation point for oxygen content is at its greatest, explaining the reason why ice floats on the surface of water.

Many factors influence the oxygen content of water. The most influential oxygen depleting mechanism applicable to (but not limited to) urban systems is nutrient and hydrocarbon contamination. High nutrient contamination has a consequential high biological oxygen demand (BOD), which, in turn, depletes the water of oxygen to be utilised in biochemical processes to metabolise the nutrients. These nutrients are typically in the form of sewerage (both raw as well as processed) and fertilisers from lawns (golf courses, gardens, etc.) and therefore are not limited to urban systems as agro-chemicals are also well-known to deplete oxygen concentrations within natural waters. Hydrocarbon contaminations from spilled fuels and motor oils on roadways that enter the water course through runoff storm waters have a high chemical oxygen demand (COD). The chemical interactions of hydrocarbons (and other chemicals) with water upon entering the watercourse also then deplete the system of oxygen available for sustaining aquatic life. Many aquatic organisms are specifically adapted to life under low oxygen conditions, and an abundance of these organisms is often an indication of low oxygen content within the system. Oxygen content can be increased in a system first and foremost by photosynthesis of aquatic plants and algae, as well as by mechanical means as a result of turbulence that exposes more of the water surface for oxygen exchange with the atmosphere, such as flowing over weirs, etc. Shallow waters also tend to have a greater oxygen content than comparatively deeper water.

The system was characterised by medium to fast-flowing water, with cobbles and rock, together with gravel substrates within the watercourses. Cascading flows were relatively common. The general oxygen content was therefore expected to be within the higher bracket for aquatic ecosystems. Oxygen saturation levels ranged between 94.7% and 103.6%. The oxygen content of the surface waters throughout the survey area was not viewed as being a limiting factor to supporting aquatic diversity.

4.1.4. Total dissolved solids/Electro-conductivity

The measure of total dissolved solids (TDS) is coupled to the measure of the salinity (the amount of dissolved salts) of the water. This is, in turn, coupled to the electro-conductivity (EC) of the water as salts carry an electrical charge when in solution. Aquatic organisms are dependent on salts within the system for normal metabolic functionality as well as to maintain osmoregulation (salt balance) within their bodies. Too high salinity values (>1,000 ppm) are considered, however, to be a limiting factor especially to many aquatic macro-invertebrates (SAWQG's, 1996). The EC values for the Koonap River ranged between 149 and 181 µS/cm, with the EC within the Mankazana River being notably higher, measuring at 234 µS/cm. The TDS of a system should not range by more than 15% for the "normal range" for any given system (DWA, 1996). This, however, requires more extensive surveys to gain cyclic data in order to interpret accurately. The TDS values recorded at the time of biological sampling were between 74 and 117 ppm (Table 4). Both the EC and TDS values are not considered limiting factors to supporting aquatic biota.

5. ECOCLASSIFICATION

5.1. Concepts and principles

EcoClassification is the term used for the Ecological Classification process and refers to the determination and categorisation of the Present Ecological State (PES) i.e. the health of integrity of various biophysical attributes of rivers relative to the natural or close to the natural reference condition. The purpose of EcoClassification is to gain insight and understanding into the causes and sources of the deviation of the PES of biophysical attributes from the reference condition. This provides the information needed to derive desirable and attainable future ecological objectives for the river. The EcoClassification and EcoStatus determination are undertaken according to DWA guidelines (Kleynhans & Louw, 2007, Module A).

The steps followed in EcoClassification are as follows:

- Determine reference conditions for each component.
- Determine the PES for each component, as well as for the integrated EcoStatus.
- Determine the trend for each component, as well as for the EcoStatus.
- Determine the reasons for the PES and whether these are flow or non-flow related.
- Determine the Ecological Importance and Sensitivity (EIS) for the biota and habitats.
- Considering the PES and the EIS, suggest a realistic Recommended Ecological Category
- (REC) for each component, as well as for the EcoStatus.

5.1.1. EcoStatus

The EcoClassification process followed for this survey is based on a combination of the Desktop EcoStatus level and an EcoStatus Level I determination and involved the use of the following indices:

- Determination of the PES for each component using the various EcoStatus models:
  - Index of Habitat integrity (IHI): Kleynhans *et al*. (2009a).
  - Physico-chemical Assessment Index (PAI): Kleynhans *et al*. (2005b).
  - Fish Response Assessment Index (FRAI): Kleynhans (2007a).
  - Macroinvertebrate Assessment Index (MIRAI): Thirion (2007).
  - Riparian Vegetation Assessment index (VEGRAI): Kleynhans *et al*. (2007d).
- Determine the EcoStatus which involves integration of the individual Ecological Category (EC) values of the abovementioned components to obtain an overall EcoStatus category (as outlined below).
- Determination of the trend for the various driver and response PES and integrated EcoStatus.

The Present Ecological State (PES) of the river is expressed in terms of biophysical components:

- Drivers (physico-chemical, geomorphology, hydrology), which provide a particular habitat template; and
- Biological responses (fish, aquatic macro-invertebrates and riparian vegetation).

Different processes (indices) are followed to assign a category (A → F; A = Natural, and F = critically modified) to each component. Ecological categories are assigned the A to F categories within a continuum, with no clearly-defined boundaries. This concept is illustrated in Figure 10.

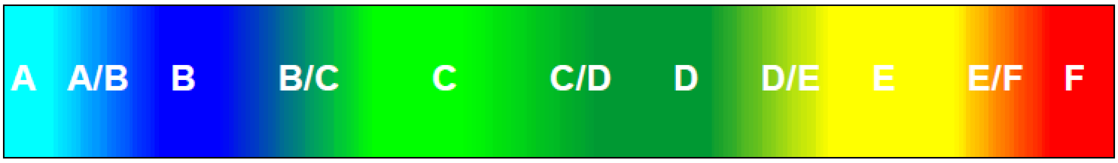

Figure 10: Illustration of the distribution of Ecological Categories on a continuum (from DWA, 2007).

Ecological evaluation in terms of expected reference conditions, followed by integration of these components, represents the Ecological Status or EcoStatus of a river. Thus, the EcoStatus can be defined as the totality of the features and characteristics of the river and its riparian areas that bear upon its ability to support an appropriate natural flora and fauna (*modified from* Iversen *et al.*, 2000). This ability relates directly to the capacity of the system to provide a variety of goods and services.

Table 5: Generic interpretation of the EcoStatus categories (*from* Kleynhans & Louw, 2007).

Ecological Category	Description
A (90-100%)	Unmodified, natural.
B (80-89%)	Largely natural with few modifications. A small change in natural habitats and biota may have taken place, but the ecosystem functions are essentially unchanged.
C (60-79%)	Moderately modified. Loss and change of natural habitat and biota have occurred, but the basic ecosystem functions are still predominantly unchanged.
D (40-59%)	Largely modified. A large loss of natural habitat, biota and basic ecosystem functions has occurred.
E (20-39%)	Seriously modified. The loss of natural habitat, biota and basic ecosystem functions is extensive.
F (0-19%)	Critically /Extremely modified. Modifications have reached a critical level and the system has been modified completely with an almost complete loss of natural habitat and biota. In the worst instances the basic ecosystem functions have been destroyed and the changes are irreversible.

5.1.2. Ecological importance and Sensitivity (EIS)

The ecological importance of a river is an expression of its importance to the maintenance of biological diversity and ecological functioning on local and wider scales. Ecological sensitivity (or fragility) refers to the system's ability to resist disturbance and its capability to recover from disturbance once it has occurred (resilience). Both abiotic and biotic components of the system are taken into consideration in the assessment of ecological importance and sensitivity (Kleynhans & Louw, 2007).

5.2. Present Ecological State

5.2.1. Reference Conditions

The EcoStatus model would ordinarily call for a theoretical reference state to be determined for the river reach under question, as the Present Ecological State (PES) is discerned through determining by how much the present state differs from the reference state (under natural conditions). A background survey was undertaken for the site to gain a theoretical reference state model so that the EcoStatus models could be effectively applied. Data for the catchment area in question are limited in terms of fish, aquatic macro-invertebrates and riparian vegetation, which necessitated a theoretical approach to determining reference conditions. Expert knowledge from relevant authorities was also sought (e.g. distribution records from authorities currently dealing with species-specific surveys). Reference data are therefore inferred through known distribution records, habitat availability and quality. The theoretical reference conditions for the various components for the river reach under study are presented in Table 6.

Table 6: Theoretical reference conditions applicable to the river reach under study.

Component	Reference conditions	Conf
Physico-chemical characteristics	In the absence of comprehensive historical water quality data, in situ water quality parameters were taken at each survey site to determine the baseline state and to determine trends within the river reach that was surveys. Baseline data will serve as the reference data for future monitoring comparisons. In situ water quality parameters indicate that no limiting factors are present within the water. It should be noted, however, that in situ water quality parameters do not include bacteriological, heavy metal nor agro-chemical analyses. This reference state is relevant to both the Mankazana River and the Koonap River under sustained flow conditions.	-
Riparian vegetation	The survey area falls within the Albany Thicket Biome, dominated by the Great Fish Thicket vegetation unit. A relatively low MAP of 449 mm per annum and 77% MAPE (the average amount of time that the evaporation rate exceeds the precipitation rate), means that the area is regarded as water stressed. Steep topography means that slopes that surround the well-defined watercourses are characterised by shallow soils. Natural processes of erosion means that riparian zones are characterised by deep alluvial soils and, with underlying geology including mudstones, the soils have a relatively high clay content and therefore are able to retain moisture for a prolonged period. Where topographical features support it, floodplain wetlands do occur, most of which have been transformed for agriculture, however. **Marginal Zones:** Deep alluvial soils means that large woody species are expected to dominate within the upper zones. Species such as *Celtis africana, Salix mucronata, Combretum caffra, Gymnosporia heterophylla, Searsia incisa, Acacia natalitia* and *Acacia ataxacantha* would dominate. Lower marginal zones would be dominated by smaller, shrubby overhanging species that would be dominated by smaller individuals of *Salix mucronata* and *Gomphrena virgatum*, together with sedges such as *Cyperus textilis*. This reference state is relevant to both the Mankazana River and the Koonap River under sustained flow conditions.	4
Fish	The DWS provides a reference list of fish species that would be expected to occur throughout the catchment area (Kleynhans, 2007), however, data are lacking for the Koonap River or tributaries immediately relevant to the survey site. Data on fish distribution within the catchment area were sourced via various literature and GIS sources, together with personal communications with fish authorities active within the catchment area. The	4

Component	Reference conditions	Conf
	reference list was compiled and cross-referenced to the quality of the available habitat types to provide a final reference list of species. The following species are on record to naturally occur within the catchment area relevant to the site (estuarine species, such as *Monodactylus falciformis* and *Mugil cephalus* are excluded from the expected reference list): Two eel species that enter fresh waters along the eastern seaboard, namely *Anguilla mossambica* and *Anguilla marmorata* are thought to definitely occur, with a less likely occurrence of *Anguilla bicolor bicolor*. Two cyprinid species with definite likelihood of occurrence, namely *Labeo umbratus* and *Barbus anoplus,* with one species, namely *Barbus pallidus* with a less likely chance of occurrence. One Gobiidae species (*Glossogobius callidus*) and one Anabantidae species (*Sandelia bainsii*), which is classified as Endangered, are also thought to occur, although in low numbers. There are several further species recorded from the system that are regarded as alien to the catchment area, most being translocated indigenous species. These include *Labeobarbus aeneus, Labeo capensis, Tilapia sparrmanii* and *Clarias gariepinus.* Exotic species are also known to occur within the catchment and that are thought to occur within the survey area are *Micropterus salmoides, Cyprinus carpio*. This reference state is relevant to both the Mankazana River and the Koonap River under sustained flow conditions.	
Aquatic macro-invertebrates	Similarly, relevant reference data on aquatic macro-invertebrates within the survey area are lacking. Reference baseline data were set using comparisons to adjacent aquatic ecoregions located close to the proposed dam site as well as habitat diversity, availability and quality evaluations. A reference score for SASS5 data for the rivers within the survey area was considered to be: SASS5 score >200; Number of taxa 27; Average score per taxon (ASPT) >7.4. This would be considered the derived scores to indicate a natural system (or a system scoring a PES for invertebrates of A) and is relevant to both the Mankazana River and the Koonap River under sustained flow conditions.	4

5.2.2. Present Ecological State

Field surveys undertaken by EnviRoss CC during early October 2015 where various indices were utilised to assign the river reach in question a baseline PES rating. These included the River Index of Habitat Integrity (River-IHI), MIRAI (Macro-invertebrate Response Assessment Index), FRAI (Fish Response Assessment Index) and VEGRAI (Vegetation Response Assessment Index). The results from these various components are summarised in Table 7, where the overall EC (Ecological Category) is also provided. As this was a once-off survey, ecological trends could not be determined nor the influence that the recent rainfall and subsequent freshet flow conditions and associated increased turbidity has had on the system.

Table 7: Summary of the EcoStatus results for the sections of the Mankazana and Koonap Rivers surveyed that would be impacted by the construction of the proposed Foxwood Dam.

Component	Mankazana River		Koonap River	
	PES (%)	Ecological Category	PES (%)	Ecological Category
Index of Habitat Integrity Instream IHI Riparian IHI	 80.2% 80.4%	 B/C B/C	 79.4% 79.7%	 B/C B/C
Fish Response Assessment Index	56.0%	D	59.9%	C/D
Macro-invertebrate Response Assessment Index	86.6%	B	83.9%	B
Vegetation Response Assessment Index	69.4%	C	80.0%	B/C
ECOSTATUS		**C (Confidence: 3.5)**		

Table 8: Summary of the ecological pressures and drivers of the PES of the Mankazana and Koonap Rivers for the reach pertaining to the proposed Foxwood Dam.

Component	Reference conditions	Conf
Physico-chemical characteristics	The proposed development site falls relatively high up within the catchment area for both watercourses. These watercourses flow through an area with a land use that imposes limited impacts to overall water quality. Very limited point source pollution (e.g. effluent discharges from WWTWs, industry discharge, etc.) occurs within these upper reaches. Diffuse point pollution does, however, occur in the form of agricultural (relatively small scale) runoff from agrochemicals (pesticides and fertilisers). Other forms of drivers of physico-chemical include cattle and livestock that graze within the riparian zones that create nutrient enrichment, and increase turbidity through aggravation of erosion within the catchment. Cultivation also takes place within riparian zones that results in siltation and chemical runoff contamination of the watercourses, albeit on a small scale. The water quality is regarded as having remained relatively good within the survey area. Deterioration of the water quality degrades downstream of the area after receiving effluents from Adelaide wastewater treatment and other forms of urban pollution.	-
River Index of habitat integrity	River-IHI: Koonap River: Instream IHI: 80.2% B/C (Confidence 3.5) Riparian IHI: 80.4% B/C (Confidence 2.7) River-IHI: Mankazana River: Instream IHI: 79.4% (B/C) Riparian IHI: 79.7% B/C Instream barriers within the watercourse are the main drivers of ecological change that has led to fragmentation of habitat as well as inundation of aquatic habitat located upstream of the impoundment (weir). Some transformation of riparian zones through the irrigation canal networks and grazing of livestock has also led to lowered ratings. This is general to both watercourses.	4
Riparian vegetation	The watercourses within the survey area have historically formed part of an irrigation scheme. The infrastructure development associated with this included the establishment of weirs and a series of canal networks. The construction of the	4

Component	Reference conditions	Conf
	weirs inundated riparian vegetation historically, which has since self-rehabilitated. These are generally earthen canals excepting for areas that required reinforcement for structural integrity. These canal networks run generally parallel to the watercourse within the non-marginal zones, where, historically, largescale transformation would have taken place. These canals have had an impact on the species composition and structure of the riparian zones, but, being earthen, much self-rehabilitation has taken place. Another factor is that this canal network, which is presently disused for the greater part remains dry and so it traps sediments that would otherwise enter the watercourse. This does influence the nutrient and sediment balance of the watercourse, but this is presently seen as acting to the advantage of the system. The historical disturbances and the present-day usage of the riparian zones for grazing of livestock does see some transformation of the floral community structures, which is more prominent along the banks of the Mankazana River than along the Koonap River. The survey site at the Mankazana River saw largescale transformation of the grass layer, which was completely dominated by the invasive kikuyu (*Pennisetum clandestinum*). Although this is a species that acts as a soil binder, it displaces natural biodiversity and is considered a "thirsty" species that competes for resources with indigenous counterparts.	
Fish	There was a generally poor rating for the fish community structures within the river. There were five species that were though to definitely occur within the survey area, but only two of these were sampled, together with a translocated species (an indigenous species that is alien to the catchment). Although these results show poor ecological integrity in terms of fish community structures, it should be remembered that this survey was reflective only of a single survey and that more extensive sampling may provide more comprehensive data. The rivers were also noted to have been subjected to freshets as a result of recent rainfall within the catchment. These freshet flows limited comprehensive sampling of all habitats types. Other reasons for poor fish ecological integrity of the system include the occurrence of numerous weirs along the watercourse that limit upstream migration of fish, with the largest being located several hundred metres upstream of the proposed dam wall site. The fragmentation of habitat would limit the ability for fish to recruit into upstream areas across these barriers, eventually depleting upstream populations. The barriers do drown out under high flow conditions. (The barrier creates turbulence downstream due the change in water levels, which creates resistance to laminar flow. As the flow upstream of the barrier remains laminar, the horizontal velocity and displacement of the upstream flow exceeds that of the water just downstream of the barrier, which results in a disproportionate rise in water levels downstream of the barrier in relation to the upstream levels. There is therefore eventually the drowning out of the barrier with increasing flow). Fish have the opportunity to migrate upstream across the barriers under these flow conditions. This, however, is very often limited to only the stronger-swimming species as high turbulence levels throughout the river course would be experienced under these flow conditions and most of the weaker-swimming species would seek shelter from the turbulence instead of actively migrating upstream. Through review of river hydrographs as well as communications with landowners, it is speculated that these flow conditions are not encountered regularly, and may occur only every few years. Flow hydrographs of the watercourses do indicate that zero flows have often been recorded for	4

Component	Reference conditions	Conf
	prolonged periods. If there is a lack of longitudinal connectivity of the system, then fish are trapped within isolated pools. The survival of fish within these pools is determined by the persistence of the surface water, predation and physico-chemical consequences of isolation. When flow is returned to the system, upstream recruitment is inhibited through the numerous barriers encountered along the watercourses. It is suspected that the population decline of *Sandelia bainsii* is as a result of this scenario as this is regarded as a weak-swimming species. Sporadic occurrences of *Sandelia bainsii* have been recorded within the Q9 management area (which includes the Koonap River) downstream of the proposed dam site (Figure 11). More substantive distribution data are, however, from the Kat River located to the northeast of the proposed dam site within the adjacent local catchment area. More recently a single sub-adult individual was sampled within the eNyara River (SAIAB, pers com), which is a downstream-located tributary of the Koonap River. The presence of a sub adult does imply a breeding population of this species within the area and that this species would occur within the river reach where similar suitable habitat is available and in the absence of any migratory barriers. There are several further species recorded from the system that are regarded as alien to the catchment area, most being translocated indigenous species. These include *Labeobarbus aeneus, Labeo capensis, Tilapia sparrmanii* and *Clarias gariepinus.* Exotic species are also known to occur within the catchment and that are thought to occur within the survey area are *Micropterus salmoides, Cyprinus carpio* and reported occurrences of *Micropterus dolomieu*. In general, the fish communities are poorly studied throughout the survey area.	
Aquatic macro-invertebrates	The aquatic macro-invertebrate species community structures scored relatively high ratings, which is an indication of the combination of good water quality and intact habitat representative of a diversity of biotopes. This is reiterated by the presence of key taxa indicative of overall good ecological integrity, including Perlidae, large populations of Heptageniidae, Baetidae (>2 spp), Leptophlebiidae. Aquatic macro-invertebrates are not impacted by habitat fragmentation as profoundly as fish and therefore they recruit readily into suitable habitat. Results of the SASS5 survey were the following: **Mankazana River:** SASS5 score 171; Number of taxa 27; Average score per taxon (ASPT) 6.3. **Koonap River** SASS5 score 187; Number of taxa 29; Average score per taxon (ASPT) 6.4. Similar ASPT scores within both rivers indicate similar water quality. Habitat integrity and diversity within both river systems within the survey are was considered good.	4

Component	Reference conditions	Conf

The overall Ecological status of the watercourses surveyed for the proposed development is a C category, which translates to a system considered to be moderately modified.

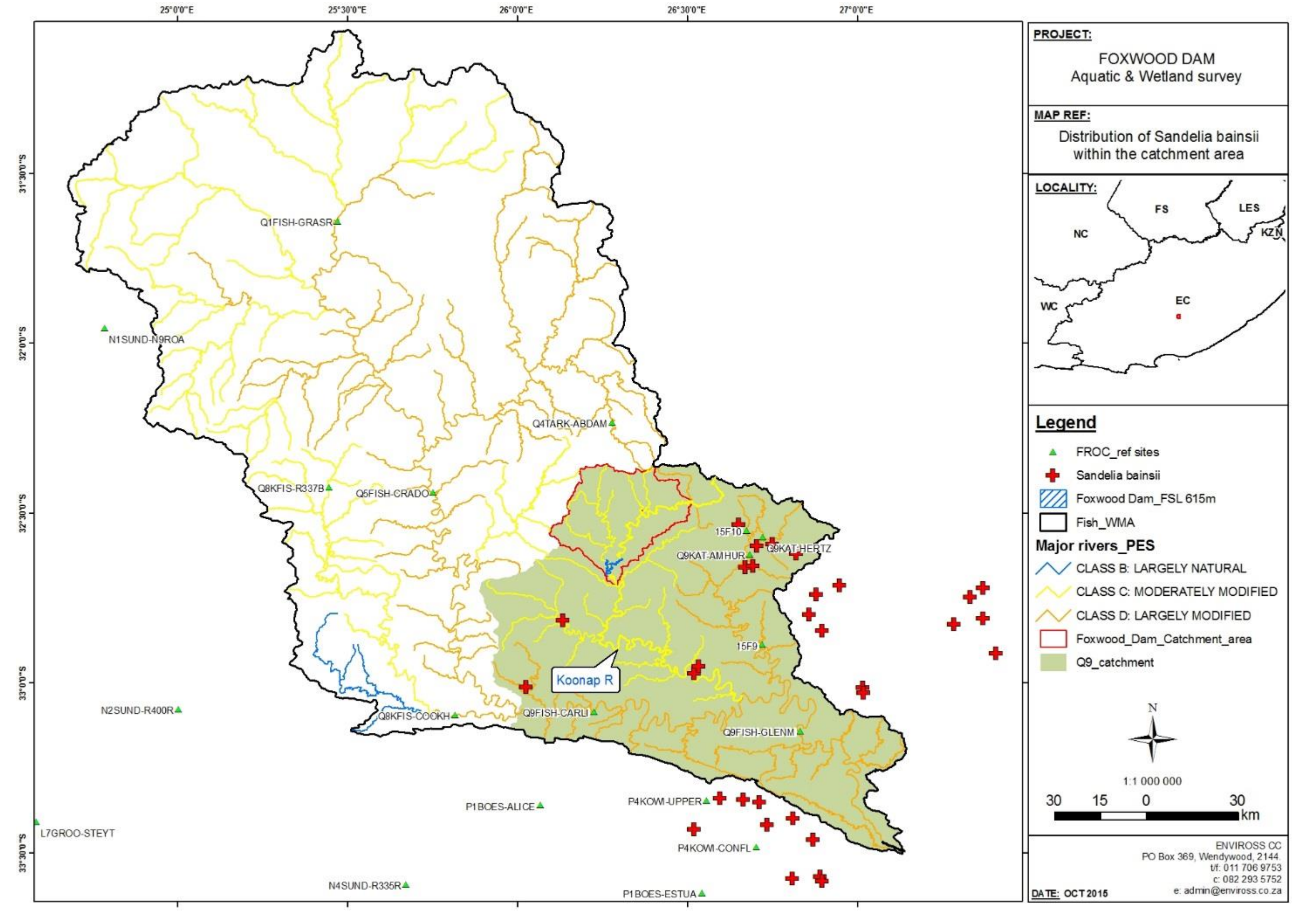

Figure 11: The present known records of distribution for *Sandelia bainsii* within the catchment area.

5.3. Ecological Importance and Sensitivity (EIS)

The use of biotic data in the assessment of the EIS considers the presence of rare and endangered species, unique species and species (including various life-history stages) with a particular sensitivity to flow (and flow-related water quality aspects) in combination with other ecological information on the study area. The EIS of a river is an expression of its importance to the maintenance of ecological diversity and functioning on local and wider scales. Ecological Sensitivity refers to the ability of the system ability to tolerate disturbance and its resilience once an impact has taken place (Kleynhans, 1999b). The EIS of the system is regarded as being *High*. The most important and relevant points are summaries in Table 9.

Table 9: Summary of the relevant points of the EIS determination.

Determinant	Score	Conf	Reason
PRIMARY DETERMINANTS			
Rare and endangered species	3	4	Possibility of *Sandelia bainsii* occurring within the river reach.
Populations of unique/isolated species	3	4	Riparian zones form areas of high refuge status, habitat diversity for specialist species, and green zone corridors for migratory species, including catadromic eels.
Species / taxon richness	3	4	*Moderate/High* – High diversity of invertebrate species intolerant to deterioration of water and habitat quality.
Diversity of habitat types or features	3	4	*Moderate/High* - instream biotopes diverse and present good quality of biotopes considered to be highly productive.
Migration/breeding and foraging site for wetland/riparian species	2	4	The riparian zones form a greenbelt through a generally arid area that is readily utilised for agriculture. It is therefore important to maintain this for maintenance of migrations and connectivity.
Sensitivity to changes in natural hydrological regime	3	4	Many fish and invertebrate species sampled are regarded as being flow dependent, with flow being a primary trigger for stimulating migratory movements.
Sensitivity to water quality changes	3	3	Many sensitive invertebrate diversity noted within the aquatic habitat that would be impacted by deterioration of water quality.
Flood storage and energy dissipation	2	2	Limited due to the well-defined terraced and mostly single-channel watercourse. Limited floodplain interaction.
Base-flow augmentation and dilution	3	2	Watercourses within the area are sources from mountainous zones with high MAR and groundwater recharge. The rivers therefore form important conduits of volumes of water not derived from the immediate area.
MODIFYING DETERMINANTS			
Protected status	4	2	Aquatic and riparian habitats are statutorily protected, but private land ownership has often lead to mismanagement. Private land ownership has also lead to a degree of conservation and protection of the watercourse and riparian zones.
Ecological importance (rarity of size/type/condition)	2	3	Perennial watercourses within the region are relatively rare and therefore are an important ecological feature within the landscape. Both the Koonap and Mankazana Rivers remain in a relatively good ecological state within the reach that was surveys.
TOTAL	***32***		
MEDIAN	**3**	**3**	
		EIS	**High**

6. WETLAND SURVEYS

The wetland areas associated with the proposed development area are all considered to be artificial impoundments (off channel farm storage dams) and wetland habitat that has been induced through seepage from earthen irrigation canals. Extended riparian zones occur in some areas along the Koonap River that have been utilised for cultivation due to rich alluvial soils and the ability of the soils to retain moisture. These area are limited in extent, but have been mapped together with the riparian zones of the watercourses. A full wetland survey, detailing the overall ecological integrity, was therefore not warranted.

Figure 12: Wetland features are limited to off-channel storage dams that form part of the irrigation canals or impoundments of drainage lines.

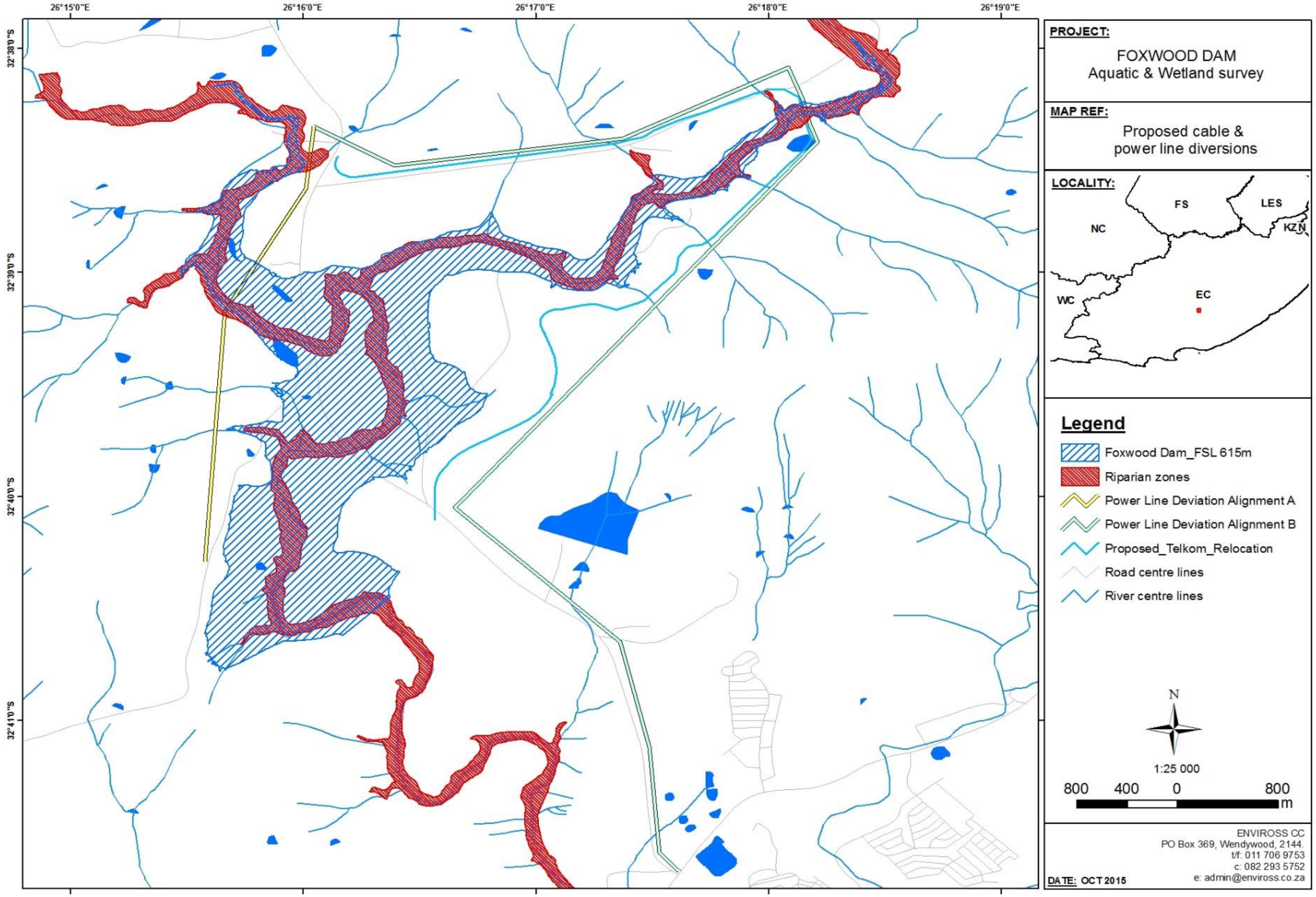

Figure 13: Alternatives associated with the overhead power lines and cable diversions and riparian zones.

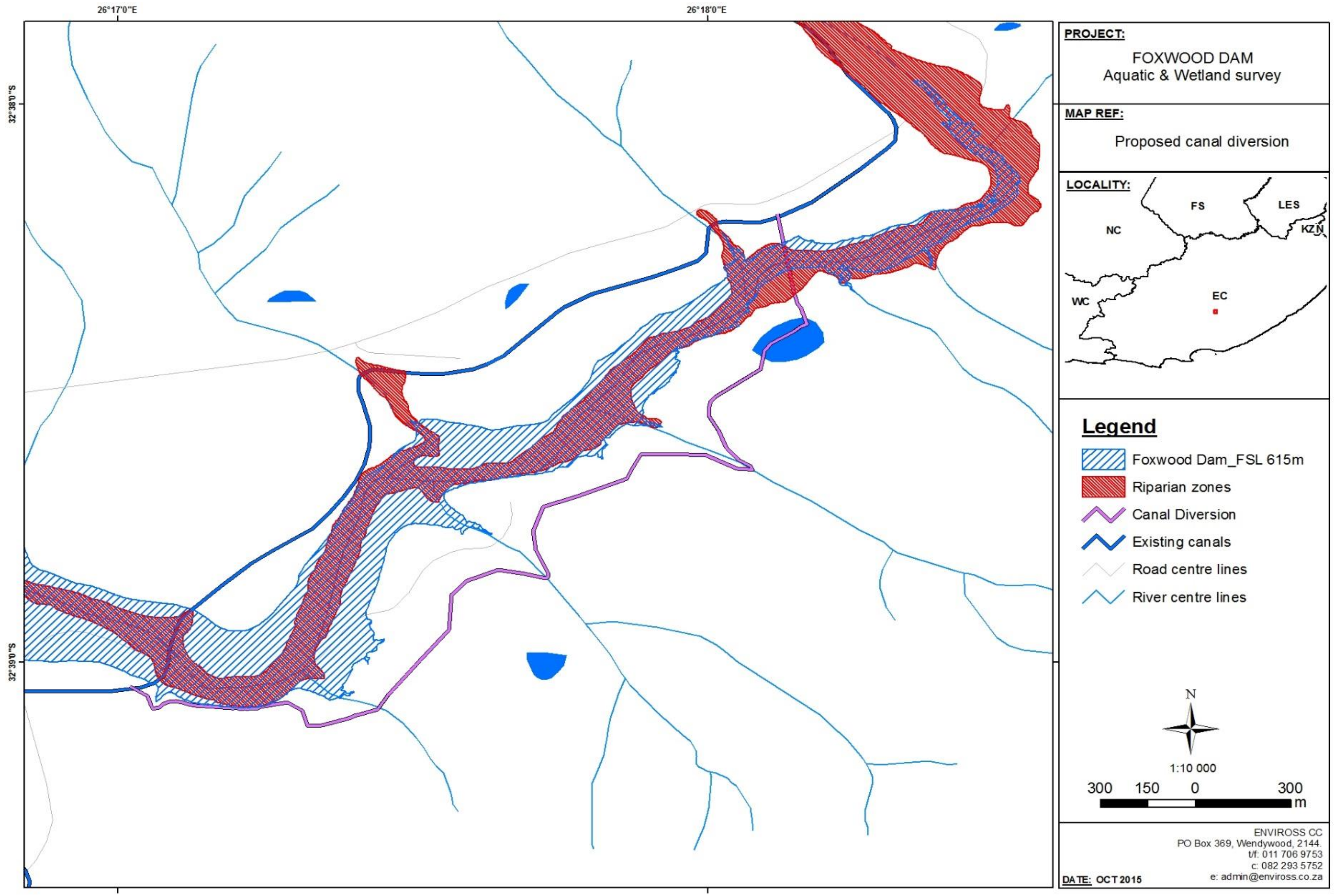

Figure 14: Proposed canal diversion and riparian zones of the Koonap River.

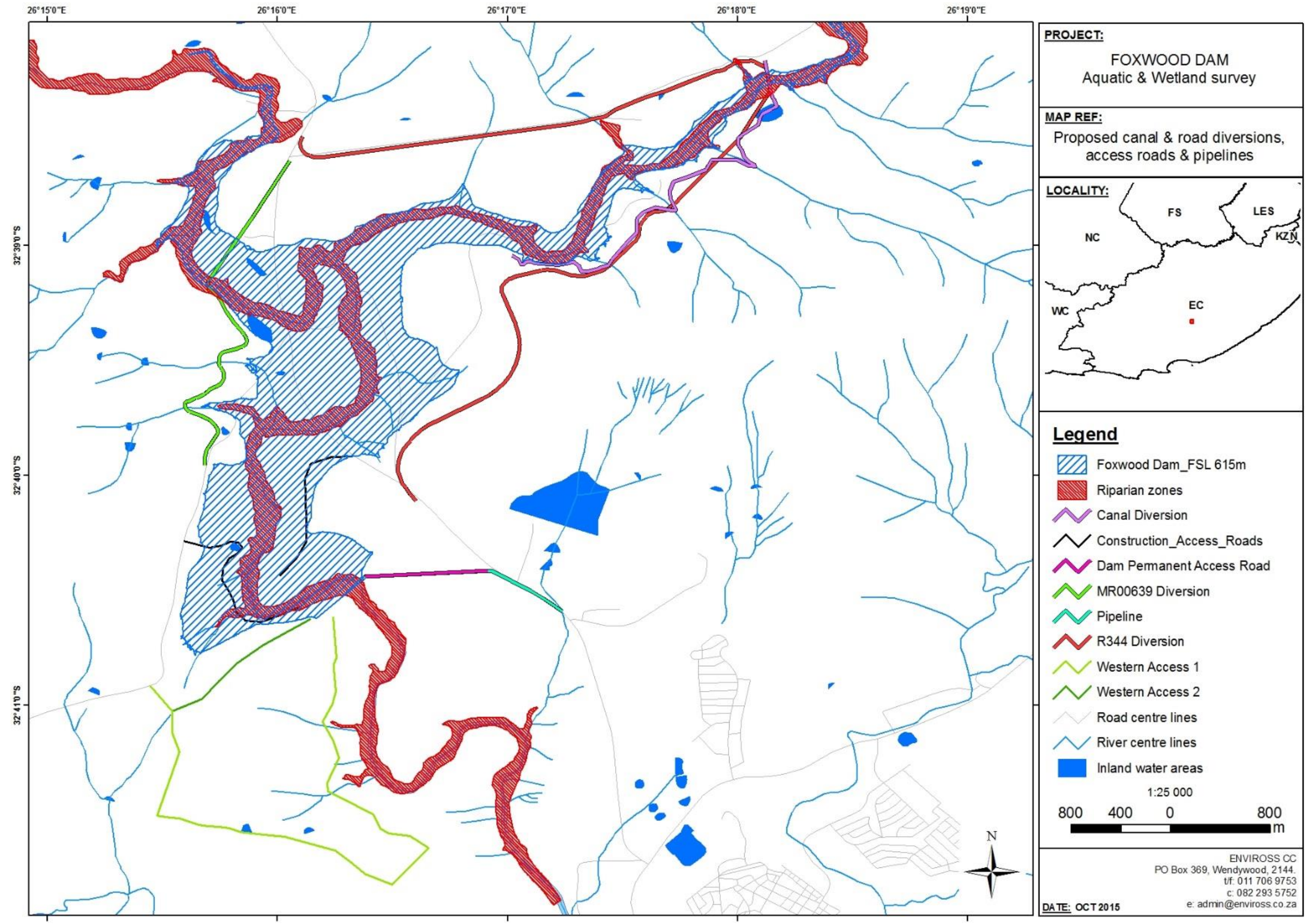

Figure 15: The proposed canal diversion, pipelines and various road alternatives together with the riparian zones.

7. SENSITIVITY ZONING

As mentioned, natural wetland habitat units are not prominent features within the area, being limited to artificial impoundments and areas that have been artificially-induce through seepage from irrigation canals. The surface water resources do, however, offer habitat and storage of the resource, so these areas have been designated as ecologically sensitive features. Much of these areas (as indicated within the mapping) will be inundated following the construction of the proposed impoundment. Riparian zones have also been mapped. Although large areas will be inundated following the construction of the impoundment, there are areas that fall within areas pertaining to the associated infrastructure, where mitigation to conserve the habitat unit are applicable.

8. CHOICE OF PREFERRED ALTERNATIVES TO CONSTRUCTION

Various alternatives to the proposed construction of the dam and associated infrastructure have been proposed. These have been rated according to the overall impacts to the surface water ecosystems and, ultimately, the alternatives with the least overall impacts, or those with the greatest perceived success of mitigation measures, have been proposed.

The following alternatives have been offered (Table 10). The choices of the preferred alternatives, as well as elaboration and justifications, are provided in Table 11.

Table 10: Alternatives of the project components.

Component	Alternatives
Major Storage Dam	Dam type
Gauging Weir	Option 1
	Option 2
Power Line Deviation	Alignment A
	Alignment B
Western Access Road	Option 1
	Option 2
Laydown Area	Option 1
	Option 2

Table 11: Comparison of project component alternatives.

Components	Alternatives	Order of preference 1 (most preferred) to 4 (least preferred]	Motivation
Major Storage Dam - Dam type	1. Earthfill	4	Does not allow for a central spillway, which will lead to unnatural channelling of water (lack of dispersal) immediately downstream of the spillway. The placement of the spillway along one side of the bank will enhance erosion within the watercourse as it enters the channel downstream of the dam wall perpendicular to the water flow, which will create turbulence and scouring of the channel walls. This will require further civil structures for stabilisation, which will lead to augmentation of the impact footprint.
	2. Rockfill	4	Does not allow for a central spillway, which will lead to unnatural channelling of water (lack of dispersal) immediately downstream of the spillway. The placement of the spillway along one side of the bank will enhance erosion within the watercourse as it enters the channel downstream of the dam wall perpendicular to the water flow, which will create turbulence and scouring of the channel walls. This will require further civil structures for stabilisation, which will lead to augmentation of the impact footprint.
	3. Concrete Gravity	1	Allows for centralisation of the spillway, which will decrease erosion of associated riverbank as well as allow for more laterally dispersed flow of water immediately downstream of the spillway.
	4. Composite Gravity Spillway and Earthfill	1	Allows for centralisation of the spillway, which will decrease erosion of associated riverbank as well as allow for more laterally dispersed flow of water immediately downstream of the spillway.
Gauging Weir	Option 1	1	There is erosion of riverbanks near the site. Construction of the gauging weir at this site will allow for the opportunity to stabilise and rehabilitate the banks. Site is accessible to the eastern banks at this site due to established agricultural roads, making for a lesser impact to riparian zones and lesser need to establish access roadways within natural areas.

Components	Alternatives	Order of preference 1 (most preferred) to 4 (least preferred]	Motivation
	Option 2	2	Limited vehicular access to the site means that natural areas will need to be destroyed to establish access roads.
Power Line Deviation	Alignment A	2	Requires two crossings of the main watercourse. The watercourse crossing spans approximately 400 m, necessitating interaction of towers with the surface water ecosystems.
	Alignment B	1	Requires one crossing of the main watercourse. Occurs within more urban and peri-urban areas (ie areas already subject to impacts).
Laydown Area	Option 1	1	Will occur within the area to be inundated and therefore no residual impact will remain after impoundment is inundated.
	Option 2	2	Falls outside of the inundation area and therefore further mitigation measures will be required to abate residual negative ecological impacts. This site, however, is proposed as the locality for permanent administration and operator buildings and therefore is required as a site. Although not the preferred choice of site, this site does not impinge on any surface water ecosystems and therefore there will be no long term impacts to the habitat units.

Figure 16: The existing overhead power line that will be required to be realigned in order to accommodate the impoundment.

9. ECOLOGICAL FLOW REQUIREMENTS (EFR)

The ecological integrity of a riverine system is maintained by the natural flow regime of that system. Over-abstraction of the water within the system removes the ability of the system to self-maintain and the ecological integrity of the system is impacted and, subsequently, the value of the resource is diminished. Ecological Flow Requirements (EFRs) are therefore set as a management strategy to allow continued functioning of the system.

These functions include:

- Channel maintenance – flooding and sustained seasonal high flow scenarios inhibits inundation of vegetation such as reedbeds into the channel;
- Flushing of sediments – sustained low flows means less turbulence within the system, which reduces the sediment transport capacity of the watercourse. These sediment settle out onto the substrate and can smother and displace substrate-dwelling organisms (aquatic invertebrates) and smother spawning beds of fish. This affects the whole food chain of the system and, ultimately, the productivity of the system;

- Maintaining the EFR also allows for maintenance of longitudinal and lateral connectivity of the habitat;
- It is not only flow volumes that are set by the EFR, but the cyclic volume releases that simulate seasonality of the watercourse are also applicable to the management strategy of an impoundment. Seasonal flood and freshet flows allow for channel maintenance, but also induce the triggers for migrations and spawning for many aquatic organisms.

A comprehensive EFR study was undertaken by DWS for the Koonap River during the feasibility stage to determine the EFR volumes to maintain ecological integrity of the system downstream of the proposed impoundment. For details of the EFR, please refer to the relevant specialist study (Louw *et al.,* 2013).

> *Department of Water Affairs, South Africa. 2013. Koonap River: EcoClassification and EWR Scenario Assessment Prepared by Rivers for Africa for ARUP.*

It is recommended that the flow scenarios proposed by the authors to maintain the ecological integrity of the system downstream of the impoundment. Catering for the ecological health of a river system will ultimately aid in conservation of the water resource itself, which is not only important for ecosystem health (biodiversity conservation) but it will better the quality of the resource for downstream users and reduce costs of purification, etc.

10. SIGNIFICANCE RATINGS OF PERCEIVED ENVIRONMENTAL IMPACTS

Table 12 presents the significance ratings of the potential ecological impacts for the *pre-construction and construction* as well as the *management phases* of the proposed development activities. The ratings are calculated for the scenarios of both before and after the implementation of mitigation measures. This was done in order to show how the degree of impacts can be reduced by careful planning and the following of relatively simple mitigation measures. These tables aid in quantifying the impacts and provide mere summary points on the various impacting features. This has been expanded on under Sections 10.1 and 10.2.

Table 12: The significance ratings both before and after implementation of mitigation measures of the main potential ecological impacts perceived to be associated with the construction phase of the proposed development activities.

Potential environ impact	Project activity or issue	Environmental significance *before* mitigation**								Environmental significance *after* mitigation**							
		S	D	I	E	R	P	Conf*	SP	S	D	I	E	R	P	Conf	SP
PRECONSTRUCTION & CONSTRUCTION PHASES																	
Wetland habitat loss	Loss of wetland habitat due to inundation and/or infrastructure development	2	5	1	2	1	1	High	**9**	1	5	1	2	1	1	High	**8**
	Comment/Mitigation: Natural wetland features are rare within the survey area and have generally been induced through irrigation canal seepage and off channel storage dams. Keep construction footprint at a minimum																
Aquatic habitat features	Dam construction leading to fragmentation of aquatic habitat	3	5	5	4	2	5	High	**75**	2	1	1	3	3	2	High	**8**
	Comment/Mitigation: A migratory barrier will isolate populations of fish, disallow habitat recruitment by eels and other species, and reduce breeding success rates. The feasibility of implementing a fishway to overcome the barrier should be explored.																
	Inundation destroying aquatic habitat	2	5	5	4	1	5	High	**75**	2	5	5	4	1	5	High	**75**
	Comment/Mitigation: Transformation of flowing habitat will displace habitat specialists and induce transformation of species community structures within the dam inundation footprint as well as the gauging weir. Changing to a lentic system will favour exotic species within the system.																
	Impacts on water quality induced through the establishment of the impoundment	3	4	1	2	1	4	High	**36**	3	4	1	2	1	2	High	**18**
	Comments/Mitigation: Impoundments induce water quality changes that transforms the system through oxygen depletion, EC/TDS changes and changes in temperature regimes.																
	Contamination of surface water features leading to loss of sensitive biota.	2	4	3	4	2	3	High	**33**	1	0	1	2	4	2	High	**0**
	Comment/Mitigation: Fuel storage should be done within designated areas only, which are properly bunded to contain any potential fuel leaks. Construction vehicles should be properly serviced in order to avoid fluid leaks. Proper sewerage management should be implemented in order to avoid contamination of the surface waters through untreated sewerage.																
	Destruction of riparian vegetation following inundation	3	5	5	4	2	5	High	**75**	3	5	5	4	2	5	High	**75**
	Comment/Mitigation: Inundation will destroy riparian vegetation that remain intact and that offers good habitat and functionality within an otherwise low-canopy vegetation. Destruction will displace habitat specialists and destroy large and established trees. Offset mitigation measures proposed through the establishment of groves of existing riparian species within protected areas along new shoreline. This will ensure conservation of the seedbank and recruitment by appropriate floral species. This sort of mitigation could reduce the overall significance of the impact. Loss of habitat within the inundation footprint is an inevitable consequence of the project. The associated infrastructure should take riparian vegetation impacts into consideration and alternatives should be sought that imposes the least overall impact to the unit. Construction footprints should be limited as far as possible. The towers of overhead power lines should be planned and placed so as not to impact the habitat feature and that lines can span across riparian zones without impact and/or the need for clearing.																
Soils	Soil stripping, soil compaction and vegetation removal will increase rates of erosion and entry of sediment into the general aquatic ecosystem.	2	4	3	3	2	3	High	**30**	1	1	1	1	4	1	High	**0**
	Comment: Erosion must be strictly controlled through the utilization of silt traps, silt fencing, Gabions, etc. This is especially pertinent within areas of steeper gradients.																
	Erosion of stockpiled topsoil & disturbance of soils due to vegetation stripping leading to erosion and habitat inundation.	2	4	3	3	2	3	High	**30**	1	1	1	1	4	1	High	**0**
	Comment: Topsoil stockpiles should be protected from erosion through the utilization of silt traps, silt fencing, Gabions, etc.																

****See Appendix B for calculations & methodologies.*** *SP ratings: 0-33 (Low), 34-74 (Medium), 75-100 (High)*

10.1. Pre-Construction & Construction Phase

These phases of the proposed development activities usually result in the greatest ecological impacts. The indiscriminate use of heavy machinery by uninformed operators leading to the unnecessary destruction of habitat is perceived to be the leading cause of ecological impacts that are easily avoided. Careful planning, basic education of operators and on-site management will all enable the impacts to be significantly reduced.

The nature of the proposed development activities will result in many impacts being unavoidable. Aspects such as "riparian habitat destruction" and "loss of a water resource" are inevitable consequences of the proposed development activities. Other impacts can, however, be significantly reduced by ecologically-sensitive construction methods and the following of a carefully planned Environmental Management Plan (EMP). By keeping the footprint of the impacts reduced to a minimum by only allowing heavy machinery to operate on designated access roadways and by avoiding the unnecessary degradation of habitat within areas adjacent to the actual construction areas, the ecological impacts can be greatly reduced.

There are ecological impacts that have been rated as medium to high. The nature of the development is such that large scale and total habitat transformation, making the ecological impacts, of a permanent and significant nature. Many of the impacts can be significantly reduced through the implementation of mitigation measures.

10.1.1. Loss of wetland habitat

Wetlands within the area are limited to induced wetland features brought about through seepage from irrigation canals and off channel storage dams associated with the irrigation canals. Some impoundments of side non-perennial watercourse tributaries also occur. Wetland features within the survey area are largely artificial and therefore the habitat unit will suffer no significant impact from the proposed development activities.

10.1.2. Aquatic habitat features

10.1.2.1. Habitat fragmentation

Both the Koonap and Mankazana Rivers have suffered a degree of habitat fragmentation through the establishment of numerous gauging and irrigation abstraction/diversion weirs. These do not pose as absolute barriers as they do allow passage upstream for migratory species when flow volumes are high enough to drown out the barrier. This is not, however, a routine occurrence and is also not guaranteed to happen annually nor within periods when fish are actively migrating. Habitat fragmentation and the associated inhibition of active upstream recruitment by fish is largely the reason for the lower than expected observations of fish diversity and abundance within the system. The catchment area offers habitat to various freshwater eel species. These species are obligatory catadromic migratory species that require access to inland waters to complete their lifecycle, having being born at sea. There is an endangered fish species recorded from the catchment area, namely *Sandelia bainsii* that has a distribution that is steadily declining. Habitat fragmentation is cited as one of the leading causes for population decline of this species. Establishment of the Foxwood Dam (48.5 m barrier) will further aggravate this impact through the establishment of an absolute barrier to migration.

The proposed locality of the impoundment is relatively high up within the catchment area, which reduces the overall significance of the impact, but the dam will disconnect a substantial amount of viable habitat from the upper catchment area. It is recommended that mitigation measures to abate this impact be considered and that the feasibility of constructing a fishway as a mitigation measure be explored.

There is a new vehicular bridge proposed near the northern-most inundation point of the Koonap River. There is an existing low level concrete bridge structure fitted with concrete culverts located just downstream of this point, but will become unusable following inundation of the dam. It was noted that the existing bridge structure was poorly designed from an ecological perspective, and poses a migratory barrier to fish during low to moderately high flows. The drop between the culvert outfall and the lower water level is too great for all but the strongest swimming fish species to overcome. It is recommended for the new bridge structure that the drop between the upstream and downstream water level not exceed 120 mm under low flow conditions and that as many culverts be utilised as necessary for full lateral dispersal of flow across the watercourse. Culverts can be orientated in a step-wise fashion from the centre line of the watercourse outwards in order to cater for increasing flow volumes. For example: two culverts placed in the centre line of the watercourse to prioritise the lowest flows. The culverts then placed outward from these can be stepped up to a higher level, and the culverts placed outside of those will step up a level again. The size of culverts, amount to be stepped up and the placement will be decided by the hydrology of the watercourse at that point as well as the capacity of the culverts.

Further aspects of erosion control pertaining to drainage of surface water beneath all roadways are also applicable. The outfall side of all culverts that drain water beneath roadways need to be fitted with energy dissipating mechanisms in order to abate erosion formation that results from scouring potential of high velocity flow water, prior to release to the natural watercourse.

10.1.2.2. Aquatic habitat loss and consequence on biodiversity

The watercourses have a medium gradient and therefore rapids, riffles and glides are common habitat features throughout the watercourses. Substrates within these areas are dominated by cobbles, rocks, boulders and occurrences of gravel, sand and bedrock. The diversity of instream habitat features are a product of flow velocities, which has enabled the systems to support a wide diversity of aquatic macro-invertebrates. Inundation of the habitat by the proposed dam will drown out this habitat, which will displace flow-dependent species of fish and invertebrates and alter the species community structures within the local area. It will also reduce breeding habitat availability, which will reduce the overall productivity of the system. A similar scenario will be encountered with the construction of the gauging weir, proposed for a site just downstream of the dam site, albeit on a lesser scale.

Sandelia bainsii is the only aquatic species of conservation significance from the catchment, the remaining species being relatively common within their respective distribution ranges, which extend further than this catchment area.

The cumulative loss of highly productive aquatic habitat should also be considered when ascertaining the overall significance of the impact.

Construction of an impoundment on a watercourse will have inevitable impacts to the aquatic habitat. The actual construction process requires a far greater area than the actual ultimate infrastructure footprint as coffer dams, diversion channels, servitudes and access roadways will have to be established. The habitat located upstream of the impoundment will ultimately be impacted due to inundation, but the downstream habitat will remain (or have to be rehabilitated to former functionality). It is therefore recommended that all necessary impacting activities take place within the eventual inundation area as far as possible and that the impacting footprint within the downstream area be limited as far as possible. Impacted areas should then be landscaped and rehabilitated in terms of vegetation and bank stabilisation. It is further recommended that physical alteration of the watercourse (excavations, etc) take place within the low flow period of the watercourse. Frequent flooding of disturbed construction sites will result in erosion and subsequent siltation/smothering of the downstream aquatic habitat.

10.1.2.3. Impacts to water quality

The construction phase of a development of this nature will see the increase transport of sediment to the watercourses, which will increase the turbidity within the system. Increased sediments will settle on the substrate, which will smother and displace substrate-dwelling species and smother spawning habitat. Erosion control measures should be in place as a continuous management strategy throughout the project and routinely monitored for effectiveness.

The establishment of an impoundment also alters the physicochemical components of the water. This includes a decrease in oxygen content, increase in EC and TDS, and altered pH and usually a decrease in temperature. This change in physicochemical properties will have an impact on the community structures of the aquatic biodiversity. The impoundment will also trap sediments and nutrients, depriving downstream consumer organisms, again creating a change in community structures.

The construction phase requires the use of heavy earthmoving equipment, large teams of construction personnel, establishment of support infrastructure, storage yards, etc. Poorly serviced machinery may lead to fuel or oil leaks which would pollute the aquatic environment if not cleaned immediately. Impacts on water quality emanating from contaminants potentially entering the system from accidental spillages will displace ecologically sensitive aquatic biota from the system. This will impact on the short to medium-term conservation of aquatic resources if contained. Contamination of the water resources will affect the local people who are reliant on the water for agriculture, livestock watering, household use and consumption. An influx of people as part of construction teams will also have impacts to water quality. On site sewerage management must be provided, but informal ablutions along the watercourses will be inevitable that may lead to contamination of the water by *E. coli* and other coliform bacteria. Education of the construction teams on this impact must be provided. Areas cleared of vegetation to accommodate service areas (stockpiles, construction camps, administration offices, etc) will also have to be protected from the effects of erosion to stop the transport of sediments to the surface waters within the area.

One of the main impacts to water quality pertaining to the establishment of a new impoundment is oxygen depletion that occurs as a result of decomposing organic matter. Riparian vegetation will be drowned, which will inevitable be destroyed in the process. This will remain in the water and decompose, resulting in oxygen depletion of the water, thereby impacting the water quality of the system. It is recommended that the affected vegetation be removed prior to inundation in order to minimise this impact. Nutrient balances will be maintained within the newly-established impoundment from the remaining peripheral vegetation, sediment inputs and nutrients transported in from upstream within the catchment area. The process of vegetation removal could be selective so that larger tree trunks and branches remain as refugia for aquatic biodiversity that remains and/or becomes established within the impoundment.

10.1.2. Riparian vegetation impacts

There will be the inevitable drowning of riparian vegetation within the dam inundation footprint area. There are areas of riparian vegetation that are associated with further infrastructure development outside of the inundation area where destruction can be minimised. All infrastructure should be placed outside of the riparian zones and no dumping or storage of equipment or materials should take place within the riparian zones. If it is found that infrastructure development within the zones is necessary (e.g. linear developments such as power lines, pipe lines, canals, roads, etc) then it is advisable to make use of alternatives that have the least impact, impose the smallest impact footprint or plan tower footprint positions to enable spanning of the watercourses and riparian zones. Alternatives that follow existing infrastructure where servitudes can be shared are also recommended as this will lower the overall impact. This is especially pertinent within areas with steep topography and association with watercourses where erosion will impact the surface water ecosystems.

The destruction of riparian habitat will decrease the filtration capacity of surface water runoff, effectively leading to increased contamination of the aquatic resources. Destruction of riparian habitat will also reduce the habitat availability for riparian-dependent species, which will be displaced. Destruction of the riparian vegetation will also lead to a reduction on the flood attenuation capacity of a system, leading to increased erosion of riverbanks and the general transformation of the aquatic environment.

Biodiversity offset mitigation measures were considered in an effort to abate this ecological impact. It was noted that translocation of riparian vegetation on a large scale is unpractical as most trees are large and well established. It is, however, a unique vegetation unit with unique species within the landscape and therefore an effort to conserve a portion is recommended. It is noted that riparian vegetation will eventually colonise the periphery of the impoundment as seeds of the riparian vegetation located upstream will be carried within the watercourse or through wind/animal dispersal to suitable germination sites. If left unabated, the riparian zones will probably be colonised by the fastest and most aggressively-growing species, which will probably form dominant stands, displacing other species. This will probably result in large reedbeds. Alien trees were noted to not be common within the riparian zones, but species such as Syringa *Melia azedarach*, Mulberry *Morus alba*, Privet *Ligustrum lucidum* and Silver poplar *Populous x canescens* will quickly colonise once a seedbank is established. In order to enhance colonisation of indigenous and appropriate riparian floral species, it is recommended that pockets/groves of indigenous riparian floral species that already occur along the watercourse be established along peripheral areas. It is recommended that young plants be uprooted and cared for within a nursery area and then only planted once the impoundment has become inundated. This is necessary as riparian species require the permanent moisture within the soils that can only be guaranteed within the impoundment shoreline once it has become inundated. Species of particular importance are *Salix mucronata* and *Combretum caffra*, but other species such as *Celtis africana,* and various *Acacia* species also form dominant portions of the riparian vegetation.

10.1.3. Soil features

Soil erosion emanating from disturbed areas and soil stockpiles could enter the aquatic system and effectively smother the aquatic habitat. This will displace faunal biota from those areas that are transformed through this impact. This feature can be easily mitigated. Other aspects of erosion control within watercourses and described for culverts are also applicable here.

10.2. Management Phase

Many of the impacts that occur as a result of the actual inundation of the impoundment are applicable to both the construction and the management phases of the proposed development. Many of the impacts from the construction phase also carry on through the management phase.

The management phase of the development should include follow-up surveys of the aquatic habitats to determine the extent of functionality of the mitigation measures provided for during the construction phases. Ongoing monitoring will also identify if any accidental discharges are having significant impacts on the system.

Table 13: The significance ratings both before and after implementation of mitigation measures of the main potential ecological impacts perceived to be associated to the management phase of the proposed development activities.

Potential environ impact	Project activity or issue	Environmental significance *before* mitigation**								Environmental significance *after* mitigation**							
		S	D	I	E	R	P	Conf*	SP	S	D	I	E	R	P	Conf	SP
MANAGEMENT PHASE																	
Aquatic habitat features	Habitat fragmentation as a result of construction of migratory barriers	3	5	5	4	2	5	High	75	2	1	1	3	3	2	High	8
	Comment/mitigation: *Change in community structures will take place. Habitat will be lost to breeding and exploitation by various species, especially eels. Further impacts imposed on endangered fish species. Inhibition of recruitment for genetic dispersal. The feasibility of implementing a fishway must be explored. If implemented, monitoring should take place in order to ascertain effectiveness and remedied if required.*																
	Depletion of a water source, effectively reducing the water volume available for the ecological reserve. Poor management of the dam releases that contradicts EFR release protocols.	3	5	5	4	2	5	High	75	2	1	1	3	3	2	High	8
	Comment: *A comprehensive EFR survey was undertaken and it is recommended that the flow volumes and flow regimes be followed. Not allowing for EFR will lead to decline of ecological integrity of the system and degradation of the resource.*																
	Contamination of surface water features leading to loss of sensitive biota.	2	4	5	4	2	4	High	52	1	1	1	2	3	2	High	4
	Comment: *Containment of effluents and further accidental discharges to ensure that contaminants do not reach the surface waters will greatly reduce this impact. Strict management procedures will ensure correct operational procedures, which will, in turn, protect the surface water resources from contamination. This includes on site sewerage management and maintenance of conveyance infrastructure.*																
Biodiversity impacts	Exotic vegetation encroachment following soil disturbances.	2	4	1	2	2	4	High	28	1	1	1	1	4	2	High	0
	Comment: *This is thought to require careful attention and active management, but is something that is easily mitigated for.*																
Soil erosion	Resulting from roadway runoff through poor stormwater attenuation and drainage design leading to habitat transformations.	2	4	3	4	1	4	High	48	1	1	1	2	2	2	High	6
	Comment: *Stormwater engineering needs to take into consideration the deposition of silts transported after rainfall events into the surface water resources. This will lead to smothering of the aquatic habitat, ultimately displacing aquatic species.*																

*****See Appendix B for calculations & methodologies.*** *SP ratings: 0-33 (Low), 34-74 (Medium), 75-100 (High)*

10.2.1. Aquatic habitat features

10.2.1.1. Habitat fragmentation

Over time, the fish populations above the dam will isolate from the populations downstream of the dam. There will also be an inevitable decrease in vigour of the upstream-located population due to genetic inbreeding. Besides genetic isolation, the habitat upstream of the impoundment will not be exploitable to downstream populations for breeding, feeding, dispersal and general habitat recruitment. Mitigation measures to abate the impacts of longitudinal fragmentation of the aquatic habitat should be explored.

10.2.1.2. Ecological flow requirements

Ecological flow requirements (EFRs) refers to the volume and flow curves of the water that is to be released from the dam to maintain the overall health of the ecosystem. The volume is determined through analysis of the physical features of the watercourse, the biological components and the natural cyclic flow patterns of the system. If EFRs are not catered for there will be an eventual decline in overall ecological health, which will cause the deterioration of the resource. Flow volumes are just as important as flow patterning, which is important as spawning and migration cues to fish and invertebrates. It is recommended that the flow volumes and flow patterning as described by Louw *et al*. (2013) be adhered to.

10.2.1.3. Aquatic habitat transformation and effects on biodiversity

The proposed dam wall will transform a lotic (flowing) system to a lentic (still-standing) system. This will inevitably displace habitat specialist species. As the watercourse are generally characterised by medium to fast-flowing water, the system is dominated by species adapted to flow. These will be displaced and a shift toward dominance by species that thrive within lentic systems will take place. *Labeo umbratus* occurs naturally within the system and tends to do well in impoundments. Naturalised translocated species such as *Labeo capensis, Clarias gariepinus* and, to a lesser degree, *Labeobarbus aeneus* also thrive within lentic environments. Alien species such as *Cyprinus carpio* and *Micropterus salmoides* will thrive within the lentic environment and will tend to dominate the habitat unit.

The impoundment will enhance the eventual occurrence of reedbeds along the periphery, and larger riparian trees will also eventually establish. This will provide habitat diversity for riparian species of amphibians, reptiles and birds. The permanent standing water will also increase the usage of the edge by grazing livestock due to the gradual slope of the banks. This will lead to increased trampling and erosion, resulting sediment transport into the aquatic habitat. Soil disturbances will also enhance the occurrence of exotic vegetation, which will require active management.

11. CONCLUSIONS & RECOMMENDATIONS

A field survey was undertaken during October 2015 to the proposed Foxwood Dam site near Adelaide in the Eastern Cape Province in order to ascertain the impacts to the Koonap and Mankazana Rivers. Upon completion of the survey the following general conclusions were drawn and some mitigation measures highlighted:

- Application of the EcoStatus models to the river reaches associated with the proposed development showed that there was a degree of change from reference conditions in terms of biological integrity (fish, macro-invertebrates and riparian vegetation) as well as instream and riparian habitat. The resultant Ecological Category is C class. The main driver limiting the ecological scores came from the fish survey, where species expected to occur were not sampled. This may be due to recent freshet flows, limitations of sampling techniques, and the limitation of a single (once-off) survey. Existing habitat fragmentation is a feature of the systems due to irrigation weirs, which has had an impact on fish distribution throughout the survey area. Even though there are transforming and degrading features present within the river reach, the overall Ecological Importance and Sensitivity (EIS) remains *High*. Mitigation measures should be in place to ensure that these ecological categories are not degraded;
- The surface water quality throughout the survey area is considered good, with the aquatic system supporting a diversity of sensitive aquatic macro-invertebrate taxa. It is therefore imperative that the contamination of the surface waters through deleterious effluents and runoff water be avoided;
- Ecological flow requirements have been set for the system. It is recommended that the flow volumes and release protocols be followed in order to maintain the health of the system;
- Habitat fragmentation is a major impact that will impact the migratory aquatic biota within the system. It is recommended that the feasibility of a fishway be explored and implemented if possible;
- Preferred choices of offered alternatives have been presented (section 8);
- Destruction of riparian habitat due to inundation of the impoundment footprint area will be an inevitable consequence of the proposed development. Offset mitigation measures to improve catchment management should be considered as well as establishing groves of riparian vegetation from existing species within appropriate areas along the new shoreline to conserve the seedbank as well as enhance recruitment. It is recommended that vegetation to be drowned be removed prior to inundation as the rotting of vegetation will deplete the watercourse of oxygen, which will impact the system downstream;
- Emergency procedures must be in place to timeously mitigate any accidental spillages and to isolate the impacting features as far as possible;
- Regular monitoring of water quality to enable early identification of contamination is recommended. The source of any contamination identified though the monitoring should be identified and managed according to best practice guidelines;

- Soil erosion emanating from disturbances within the riparian zones and other areas of steep gradients is regarded as a major impacting feature to potentially impact the overall ecological integrity of the aquatic system. Active stormwater management should be implemented to stop silt and sediments from entering the aquatic system and smothering the habitat units. Disturbed soils and stockpiled soils should be protected from erosional features;
- The footprint of the associated infrastructure as well as the supporting services during the construction phase should be retained as small as possible by construction vehicles being limited to designated roadways only. Destruction of the riparian habitat through the unnecessary clearing of vegetation should be avoided;
- Dumping of any excess rubble, building material or refuse must be prohibited within riparian habitat. Dumping of materials should only take place at designated and properly managed areas;
- Adequate toilet facilities must be provided for all construction crews to negate informal ablutions taking place within riparian zones;
- Fires within the riparian zones should be prohibited;
- The encroachment of exotic vegetation will be enhanced following site disturbances. This should be monitored for and recruitment managed appropriately.

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APPENDIX A - METHODOLOGIES APPLIED DURING THIS BIOMONITORING ASSESSMENT – AQUATIC MACRO-INVERTEBRATE COLLECTION – SASS5 METHODOLOGY.

Sample Collection.

A standard SASS invertebrate net (300 x 300 mm square with 1mm gauge mesh netting) was used for the collection of the organisms. The available biotopes at each site were identified and each of the biotopes was sampled by different methods explained under the relevant sections.

The biotopes were combined into three different groups, which were sampled and assessed separately:

a) Stone (S) Biotopes:

Stones in current (SIC) or any solid object: Movable stones of at least cobble size (3 cm diameter) to approximately 20 cm in diameter, within the fast and slow flowing sections of the river. Kick-sampling is used to collect organisms in this biotope. This is done by putting the net on the bottom of the river, just downstream of the stones to be kicked, in a position where the current will carry the dislodged organisms into the net. The stones are then kicked over and against each other to dislodge the invertebrates (kick-sampling) for ± 2 minutes.

Stones out of current (SOOC): Where the river is still, such as behind a sandbank or ridge of stones or in backwaters. Collection is again done by the method of kick-sampling, but in this case the net is swept across the area sampled to catch the dislodged biota. Approximately 1 m^2 is sampled in this way.

Bedrock or other solid substrate: Bedrock includes stones greater than 30cm, which are generally immovable, including large sheets of rock, waterfalls and chutes. The surfaces are scraped with a boot or hand and the dislodged organisms collected. Sampling effort is included under SIC and SOOC above.

b) Vegetation (Veg) Biotopes:

Marginal vegetation (MV): This is the overhanging grasses, bushes, twigs and reeds growing on the edge of the stream, often emergent, both in current (MvegIC) and out of current (MvegOOC). Sampling is done by holding the net perpendicular to the vegetation (half in and half out of the water) and sweeping back and forth in the vegetation (± 2m of vegetation).

Submerged vegetation (AQV): This vegetation is totally submerged and includes Filamentous algae and the roots of floating aquatics such as water hyacinth. It is sampled by pushing the net (under the water) against and amongst the vegetation in an area of approximately one square meter.

c) Gravel, Sand and Mud (GSM) biotopes:

Sand: This includes sandbanks within the river, small patches of sand in hollows at the side of the river or sand between the stones at the side of the river. This biotope is sampled by stirring the substrate by shuffling or scraping of the feet, which is done for half a minute, whilst the net is continuously swept over the disturbed area.

Gravel: Gravel typically consists of smaller stones (2-3 mm up to 3 cm). It is sample in a similar fashion to that of sand.

Mud: It consists of very fine particles, usually as dark-collared sediment. Mud usually settles to the bottom in still or slow flowing areas of the river. It is sample in a similar fashion to that of sand.

d) Hand picking and visual observation:

Before and after disturbing the site, approximately 1 minute of "hand-picking" for specimens that may have been missed by the sampling procedures was carried out.

APPENDIX B – IMPACT RATING SIGNIFICANCE METHODOLOGIES & CALCULATIONS.

The significance rating (SP) is calculated by the following formula:

SP = Consequence X Probability (P)

Where: Consequence = (S + D + I + E) – R

S= Spatial extent
D=Duration
I=Intensity
E=Effects on important ecosystems
R=Reversibility

Table 14: Rating scores for the various factors used for calculating the significance rating of a particular impact.

S		D		I		E		R		P	
Rating	**Score**	**Rating**	**Score**	**Rating**	**Score**	**Rating**	**Score**	**Rating**	**Score**	**Rating**	**Score**
Site specific	1	Short (0-15yrs)	1	Low	1	None	1	Irreversible	0	Improbable	1
Local	2	Medium (2-15yrs)	2	Medium	3	Negligible	2	Largely irreversible	1	Possible	2
Regional	3	Long (16-30yrs)	3	High	5	Insignificant	3	Somewhat reversible	2	More than likely	3
National	4	Discontinuous	4			Significant	4	Largely reversible	3	Highly probable	4
International	5	Permanent	5			Vast	5	Totally reversible	4	Definite	5

Confidence limits:

The impact ratings are all defined in terms of confidence limits. A High impact rating with a High degree of confidence is considered to have the greatest significance. A High impact rating with a Low confidence rating therefore has a limited significance. It should be noted that a Low degree of confidence could either be attributed to a lack of sufficient data that would allow for accurate measurement of the potential impact, or that the impact falls outside the scope of the survey. This is indicated where applicable.