Southern African Development Community

European Development Fund

African Transboundary River Basin Support Programme

Case of the Orange – Senqu River in Botswana

Lesotho, Namibia and South Africa

Global Financial Commitment No. 9 ACP RPR 53

A Fitness for Use assessment of the waters of the Orange-Senqu Basin

Report No. ORASECOM 001/2010
November 2009

TABLE OF CONTENTS

EXECUTIVE SUMMARY

This 'Fitness for Use' assignment forms part of the EU support to ORASECOM and provides an assessment of the suitability of use for both ground and surface water in the Orange-Senqu basin based on key water quality parameters. This document is intended only to provide a broad overview of the possible impacts of water in the basin on the use of water. Section 1 introduces the assessment and acknowledges the input and support of the four member states.

The Orange-Senqu basin is divided into 19 sub-basins and relevant water quality data from all member states were collated (Section 2.1). Data for a particular sub-basin were amalgamated into a single set for analyses. The major categories of water use in these sub-basins are thought to be agriculture for both irrigation and livestock, domestic, industrial and recreational, as detailed in Section 2.2. The quality requirements for each of the identified major uses are identified from all member state water quality standards where available (Section 3, 4 and Appendix A):

- Botswana Standard BOS 32:2000. Water quality - Drinking Water – Specification.
- Namibia Water Quality Guidelines and Standards for Potable Water.
- South African Water Quality Guidelines.
- WHO Drinking Water Standards (adopted by Lesotho) [WHO, 2006].

Comparisons between these standards and the current water quality condition of the water source are performed to assess the suitability for use (Section 5 and Appendix B). This judgement took the form of generic assessment terms ('good', 'tolerable', 'poor', 'unsuitable'). These assessments are presented as icons on fitness for use maps for each major water use as described in Section 6 with green, blue, amber and red colours used to represent the assessment terms. All of the maps are contained in Appendices C – G.

The overall findings from this assessment are reviewed in Section 7 and are summarised below:

- Sub-basins with water quality most suitable to the key water uses in the Orange-Senqu basin were the Upper Vaal, Mokahare / Caledon and Upper, Middle and Lower Orange. In particular, the Upper Orange River sub-basin was suitable for all the key water uses identified.
- Botswana saline groundwater, Namibia Stampreit and Lesotho lowland surface water were the least suitable sub-basins for the key water uses in the Orange-Senqu basin, due to high TDS levels and high iron / nitrate concentrations, respectively.
- Botswana non-saline groundwater, Lesotho highland ground and surface water, Lesotho lowland groundwater, Namibia supply reservoirs and the middle and lower Vaal were suitable for some of the key water uses in the Orange-Senqu basin.
- Domestic and industrial type III categories assess similar water use quality requirements. A comparison between the 133 assessments completed for these two uses showed similar results with three-quarters of the paired assessment descriptions being exactly the same and none being significantly different.
- Fitness for use assessments for sub-basins in neighbouring member states were very similar. The Mokahare / Caledon (Lesotho and South Africa datasets used) and Lower Orange (Namibia and South Africa datasets used) showed similar assessments for suitability against all key water uses except for domestic (Lower Orange) and industrial and agricultural irrigation (Mokahare / Caledon).
- Some water quality criteria could not be assessed against water use standards due to limited data.

Conclusions and recommendations are listed in Section 8. It is anticipated that this high level assessment will benefit transboundary water quality management by promoting a common understanding of water quality conditions in the Orange-Senqu basin. The findings could potentially be utilised in the design and implementation of transboundary water quality monitoring programme.

1. INTRODUCTION

This ‘Fitness for Use’ assignment forms part of the EU support to ORASECOM and provides an assessment of the suitability of use for both ground and surface water in the Orange-Senqu basin based on key water quality parameters. ‘Fitness for Use’ in the context of this report is actually an assessment of the possible impacts of known key water quality concerns on the major water users. It does not provide an overall assessment of the suitability of water for use, nor does it necessarily provide an assessment of the suitability for any particular use of water. It is intended only to provide a broad overview of the possible impacts of water in the basin on the use of water.

The outputs from this work are ‘Fitness for Use’ maps for each of the major water uses in the basin. This method has provided a consistent, robust and statistically defensible approach to assessing water use suitability at a high level. It also identifies areas where inadequate data (i.e. insufficient data values or range of variables tested) does not allow for an assessment to be made. The overall aim is to improve water resources in the four member states (Botswana, Lesotho, Namibia and South Africa) by promoting a common understanding of water quality issues from a transboundary perspective.

1.1 Assessment details

This assessment evaluates the impact of water quality on major uses of water in the Orange-Senqu basin. It does not evaluate changes in population or water uses in the future; however, it can be updated on a regular basis if required. The major categories of water use have been identified through liaison with the ORASECOM Member States and a review of previous reports (Section 2). Collation of relevant water quality data from all four member states was the next step in the process (Section 3). The quality requirements for each of the identified major uses were then agreed (Section 4). A comparison between these standards and the current water quality condition of the water source was performed to assess the suitability for use (Section 5). This judgement took the form of generic assessment terms (‘good’, ‘tolerable’, ‘poor’, ‘Unsuitable’ or Red, Blue, Amber, Green). These terms are represented for each major water use on separate maps using icons (Section 6). Finally, the implications of these maps for transboundary basin management are discussed (Section 7). The approach taken for this assessment is summarised in Figure 1-1.

The maps do not characterise every single water use in the Orange-Senqu basin. Rather, they identify sub-basins with different water concerns that might pose a risk to major water uses. There is also no guarantee that water quality at a specific location at any one point in time will meet the requirements of the use due to micro-scale spatial and temporal variations. This assessment will instead identify general trends in water use suitability in various key areas of the basin. If the water is assessed to have possible impacts on certain water uses the reason for this assessment will be highlighted. The maps will not determine the origin of the problem, nor by implication its transboundary nature.

1.2 Member State liaison

As part of this assessment, the following groups have kindly agreed to guide the approach methodology and provide water quality data, standards and background reports to base the assessment on:

- Botswana – Department of Water Affairs
- Lesotho – Department of Water Affairs
- Namibia – Department of Water and Forestry; and
- South Africa – Department of Water and the Environment.

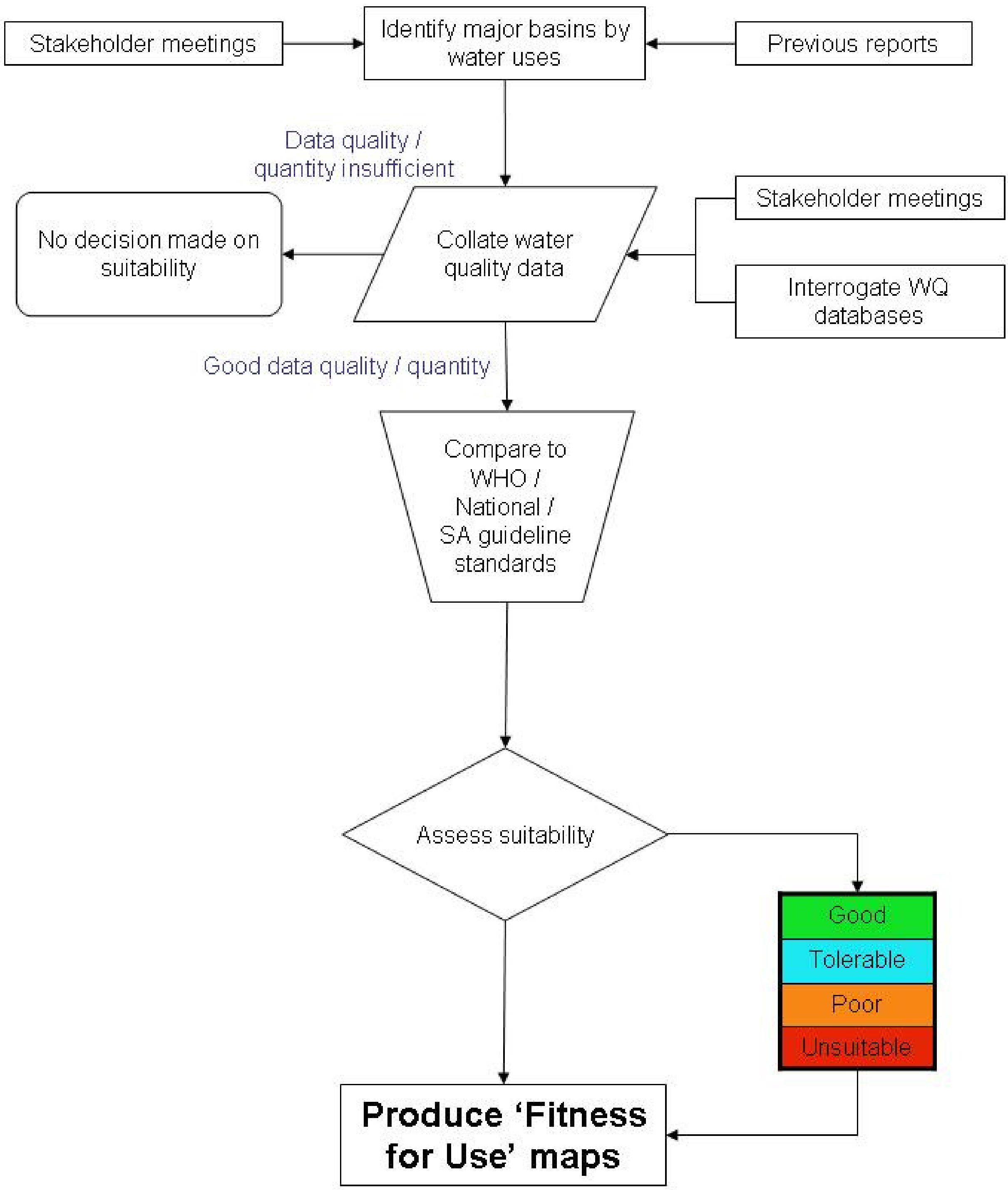


Figure 1-1 Decision-tree for ORASECOM transboundary Fitness for Use assessment

2. IDENTIFYING MAJOR WATER USES WITHIN THE ORANGE-SENQU BASIN

2.1 Basin division

On the basis of geographical location, water quality character and waterbody type (groundwater or surface water) the Orange-Senqu basin has been divided into 19 areas (Table 2-1). Impacts of water quality on use will be assessed for all the major water uses (Section 7) in each of these sub-basin areas.

Table 2-1 Sub-basin division for the Fitness for Use assessment

Member State data	Sub-basin	Waterbody Type[1]	Reach	Assessment code
Botswana	Whole region falling inside the O-S basin	Saline G/W	n/a	B1
Botswana	Whole region falling inside the O-S basin	Non-saline G/W	n/a	B2
Lesotho	Highlands	S/W	n/a	L1
Lesotho	Highlands	G/W	n/a	L2
Lesotho	Lowlands	S/W	n/a	L3
Lesotho	Lowlands	G/W	n/a	L4
Lesotho	Mokahare	S/W	n/a	L5
Namibia	Lower Orange	S/W	The length of common border with South Africa	N1
Namibia	Supply reservoirs (Naute & Hardap Dams)	S/W	n/a	N2
Namibia	Stampreit	G/W	n/a	N3
South Africa	Wilge	S/W	n/a	S1
South Africa	Upper Vaal	S/W	n/a	S2
South Africa	Middle Vaal	S/W	Upper-reach – up to Vaal Dam	S3
South Africa	Middle Vaal	S/W	Lower-reach Vaal Dam to Bloemhof Dam	S4
South Africa	Lower Vaal	S/W	Below Bloemhof Dam	S5
South Africa	Upper Orange River	S/W	From the Lesotho Border to Vaal confluence	S6
South Africa	Middle Orange River	S/W	From the Vaal confluence to the common border with Namibia	S7
South Africa	Lower Orange River	S/W	Length of the common border with Namibia	S9
South Africa	Caledon	S/W	n/a	S10

[1] G/W = Groundwater; S/W = Surface water

Appropriate representative data for these 19 sub-basins were collated. It is clear from this division that some sub-basins will be assessed twice (e.g. Lower Orange River and Caledon / Mokahare) However, the data used for these paired assessments will be sourced from different member states and so act as a useful comparison. It should also be noted that no groundwater sources were evaluated in South Africa, where it is assumed that the majority of water used is abstracted from surface water systems. No quality assurance of the data was undertaken, and the analyses were assumed to be accurate.

2.2 Water use categories

Following stakeholder discussions, it was agreed that the following water use categories would be assessed throughout the Orange-Senqu basin:

- Agricultural – Irrigation;
- Agricultural – Livestock (Cattle);
- Domestic;
- Industrial; and
- Recreational.

These use categories incorporate all the current major uses of water in the Orange-Senqu basin. This assessment, therefore, also provides a proactive evaluation on the potential for future water resource use.

Aquaculture was not assessed in this study because it was not considered to be a major use within the Orange-Senqu basin. Impacts to aquatic ecosystems were not assessed in this study because a separate result area within the ORASECOM programme is covering this component.

A short description of each of these water use categories is provided below.

2.2.1 Agricultural – Irrigation

The term irrigation water in this study refers to water which is used to supply the water requirements of crops and plants which are not provided for by rain. The standards used in this assessment refer to all uses water may be put to in this environment. This includes water for

- The production of commercial crops;
- Irrigation water application and distribution systems;
- Home gardening;
- The production of commercial floricultural crops; and
- Potted plants.

For the purposes of this work, this term has been split into two different sub-user groups depending on the impact observed: crop quality and damage to irrigation equipment. Irrigation water is used to supply a wide variety of plants with different tolerances, under different types of irrigation, and to a wide range of soils. All of these influence the fitness of the water for irrigation purposes. This assessment assumes that appropriate best practice is adopted by the user.

2.2.2 Agricultural – Livestock

Livestock production requires water supply. For the purposes of this report, the suitability of water for livestock is assessed according to palatability, which would influence intake volume, and impact on the animal. These two factors can vary on the basis of livestock type and physiological development stage. This study has identified that the major water use is for cattle and the assessment assumes that appropriate steps are taken to ensure that vulnerable cattle with inherent higher risk (e.g. immature calves / lactating / pregnant) are not exposed to potentially hazardous water. This assessment thus assesses the suitability of water for mature cattle.

2.2.3 Domestic

The term 'domestic water' as assessed in this study refers to drinking, food / beverage preparation, hot water systems, bathing / personnel hygiene and washing purposes. It does not include garden watering or pet care. In urban areas of the four member states water is often treated using filtration, flocculation and chlorination processes. However, in rural areas, water often only receives minimal treatment (especially groundwater). As a worst case scenario, this assessment assumes that all water is not treated and as such, that the water quality at source (e.g. river abstraction point or borehole) is the same as the water that is used in the domestic situation.

2.2.4 Industrial

The term 'industrial use' encapsulates all government and privately owned systems requiring water for operational purposes. Four categories are used in this assessment depending on the requirement for particular water quality types:

- Category I

Processes requiring good quality water with stringent specifications particularly where treatment cost is a major consideration in the economy of the process e.g. petrochemicals pharmaceuticals, washwater for electronic parts.

- Category II

Processes requiring intermediate quality water with specifications lying between those of Category I and domestic water quality (Category III) where treatment cost is a significant consideration in the economy of the process e.g. beverage products, lubrication, evaporative cooling.

- Category III

Processes for which domestic water quality is the minimum standard and treatment cost is not significant in the economy of the process e.g. food products, surface washing, solvents. These standards should also provide a reasonable proxy for the suitability of the water for treatment to potable standards (Section 2.2.3). A comparison between domestic and industrial category III assessment results will be made in Section 7.4.3.

- Category IV

Processes that are not dependant on the quality of water and where no extra treatment is usually required e.g. dust suppression, wash water, fire fighting.

Each of these sub-user categories will be assessed for suitability.

2.2.5 Recreational

The term 'recreational water' refers to all inland water that is used for recreation. For the purposes of this work, this term has been split into three different sub-user groups depending on the exposure risk: full contact (e.g. swimming); intermediate contact (e.g. canoeing, angling, and paddling) and non-contact. Each of these sub-user groups will be assessed for suitability.

3. WATER QUALITY CRITERIA

Following stakeholder consultation, a review of data availability and considering the time constraints of this work, a shortened set of seven variables were used to provide an indication of water quality suitability for use. A short review of the sources and health impacts of these variables is included below (WHO, 2008).

- Faecal coliforms

  The presence of faecal coliform bacteria in aquatic environments may indicate that the water has been contaminated with the faecal material of man or other animals. Faecal coliforms can enter rivers through direct discharge of waste from mammals and birds, from agricultural and storm runoff, and from untreated or poorly treated human sewage. However their presence may also be the result of plant material, and pulp or paper mill effluent. Large quantities of faecal coliform bacteria in water are not harmful, but may indicate a higher risk of pathogens being present in the water. Some waterborne pathogenic diseases that may coincide with faecal coliform contamination include ear infections, dysentery, typhoid fever, viral and bacterial gastroenteritis, and hepatitis A. Untreated organic matter that contains faecal coliform bacteria can be harmful to the environment. Aerobic decomposition of this material can reduce dissolved oxygen levels if discharged into rivers or waterways. This may reduce the oxygen level enough to kill fish and other aquatic life.

- Fluoride

  Fluorine is a common element that is widely distributed in the earth's crust and exists in the form of fluorides in a number of minerals, such as fluorspar, cryolite and fluorapatite. Traces of fluorides are present in many waters, with higher concentrations often associated with underground sources. Fluoride can have an adverse effect on tooth enamel and may give rise to mild dental fluorosis whilst elevated fluoride intakes can have more serious effects on skeletal tissues. Higher incidence of cancer is also suspected among populations with high fluoride exposure.

- Iron (dissolved)

  Iron is one of the most abundant metals in the Earth's crust. It is found in natural fresh waters at levels ranging from 0.5 to 50 mg/litre. Iron may also be present in drinking-water as a result of the use of iron coagulants or the corrosion of steel and cast iron pipes during water distribution, and mining activities may result in elevated iron concentrations. The solubility of iron depends on pH and oxygen concentrations, and often dissolved iron comes out of solution in surface waters. High concentrations of iron in water may impair potability, lead to excessive storage in the body, stains laundry and plumbing fixtures and can damage irrigation equipment.

- Nitrates

  Nitrates and nitrites, which are frequently present due to sewage contamination or agricultural runoff, are best managed by protecting the source water from contamination. They are difficult to remove, although disinfection will oxidize nitrite, the more toxic form, to nitrate. In addition, disinfection will sanitize the water and reduce the risk of gastrointestinal infection, which is a factor in the risk of methaemoglobinaemia caused by excess nitrate/nitrite exposure of infants up to approximately 3–6 months of age. Methaemoglobinaemia is a clinical condition arising from the excessive conversion of haemoglobin to methaemoglobin, which is incapable of binding and carrying oxygen (Zeman et al., 2002). Methaemoglobin is formed when iron in the haemoglobin molecule is oxidised from Fe^{2+} to Fe^{3+}. Methaemoglobin occurs when haemoglobin is oxidised at a rate exceeding the normal enzymatic capacity to reduce the haemoglobin. However, many agents may be responsible for this oxidation. The most frequently found are:

- Aniline;
- Benzocaine;
- Chlorates;
- Chloroquine;
- Dapsone;
- Nitrates;
- Nitrites;
- Nitrophenol;
- Phenazopyridine;
- Primaquine;
- Sodium nitroprusside; and
- 4-dimethylaminophenol.

Methaemoglobinaemia could also be developed due to non-toxic causes, as congenital enzyme deficiencies (Zeman et al., 2002). In addition, methaemoglobinaemia is often difficult to detect in African children, due to the dark colour of their skin, so a causal relationship to nitrate has not been fully evaluated. Thus, the link made in this study between nitrate and suitability for domestic consumption does not assess all the factors contributing to methaemoglobinaemia exposure risk.

- Phosphates

'Point source' pollution originates from industrial or waste water treatment plant pipelines. 'Diffuse' source pollution include nutrient losses from manure and waste products spread over large agricultural fields, sediment from eroded soils, nutrient leaching or runoff from residential or agricultural areas. Too much phosphate in the diet can cause health problems, such as kidney damage and osteoporosis. Elevated phosphate concentrations in surface waters raise the growth of phosphate-dependent organisms, such as algae and aquatic macrophytes like duckweed and water hyacinth, because it is a limiting nutrient in most freshwater systems. These organisms use great amounts of oxygen and prevent sunlight from entering the water. High concentrations of algae also increase the cost of treating water to potable standards, and may cause other treatment problems, as well as health problems in the potable water.

- Sulphates

Sulphates occur naturally in numerous minerals and are used commercially, principally in the chemical industry. They are discharged into water in industrial wastes and through atmospheric deposition; however, the highest levels usually occur in groundwater and are from natural sources. High levels of sulphate are also associated with mining activities. The principal impact of high sulphates is on industrial processes (damage to equipment through chemical precipitation, promotion of microbiological corrosion, interference with chemical processes and deterioration in product quality). Similar issues exist for damage to irrigation equipment. Food can be a major source but in areas with drinking-water supplies containing high levels of sulphate, drinking-water may constitute the principal source of intake. Gastrointestinal effects can result from ingestion of drinking-water containing high sulphate levels and presence of sulphate in drinking-water may also cause noticeable taste and may contribute to the corrosion of distribution systems.

- Total Dissolved Solids (TDS)

TDS comprise inorganic salts (principally calcium, magnesium, potassium, sodium, bicarbonates, chlorides and sulphates) and small amounts of organic matter that are dissolved in water. TDS in drinking-water originates from natural sources, sewage, urban runoff and industrial and mining wastewater. Concentrations of TDS in water vary considerably in different geological regions owing to differences in the solubilities of minerals. Reliable data on possible health effects associated with the ingestion of TDS in drinking-water are not available. However, the presence of high levels of TDS in drinking-water (greater than 1200 mg l^{-1}) may be objectionable to consumers. Water with extremely low concentrations of TDS may also be unacceptable because of its flat, insipid taste. TDS does cause problems in industrial and irrigation processes such as corrosion damage to equipment, inference with processes, product quality and soil salinity from insoluble salt precipitation and complexity in waste handling. Elevated TDS in irrigation water also impairs uptake of water by the crop, resulting in lower crop yields.

One reason for using this shortened list (rather than using all available data) was to ensure a consistent assessment across all four member states without gaps in assessment due to lack of data (the variables selected are commonly monitored basin-wide). In addition, this list will avoid penalising sub-basins that hold more detailed data than other sub-basins, purely because the data available flags up a potential issue with suitability that could exist in all sub-basins.

The exception to this standard water quality criteria list is 'Recreational' use because guidelines were not available for the seven variables in the original list. For recreational use, the following variables will be assessed:

- Faecal Coliforms

  See description above.

- pH Lower Limit
- pH Upper Limit

  The pH of waters is influenced by various factors and processes, including geology and geochemistry of the rocks and soils, temperature, discharge of effluents, acid mine drainage, acidic precipitation, runoff, microbial activity and decay processes. A direct relationship between the pH of water and human health effects is difficult, if not impossible to establish since pH is very closely associated with other aspects of water quality (DWAF, 2006). However, water pH values outside a fairly narrow range of circum-neutral pH cause irritation of eyes, skin, ears and mucous membranes of the nose, mouth and throat of swimmers and other 'contact' recreational water users. The lachrymal fluid (tears) of the eye has a normal pH of close to 7.4, which is maintained within a narrow range by physiological buffering agents. A pH change of as little as 0.1 in the lachrymal fluid can cause irritation, and greater change can cause severe discomfort and pain. Ideally, water used for 'contact' recreation should be as close to pH 7.4 as possible. Discomfort of the eyes and other susceptible parts of the body is not permanent and usually disappears rapidly if contact is discontinued.

- Phosphates

  See description above. Phosphates are used here as a surrogate for potential algae growth as availability of algal data was limited. Algal overgrowths or the presence of noxious algal species can become a nuisance and interfere with the desirable uses of a water body. Treatment of water containing algae can result in the breakdown of algal cells giving rise to tastes and odours, which render the water less acceptable for domestic use. Some algae are known to produce hepato- or neuro-toxins (DWAF, 2006). Severe gastroenteritis, vomiting and liver function impairment in populations supplied from water bodies dominated by blue-green algae have been noted. There is also limited evidence of an increased incidence of liver cancer in populations exposed to low concentrations of hepatotoxins in untreated surface water over an extended period.

It must be noted that water quality issues are frequently associated not only with the presence of just one water quality variable, but with interactions between several variables. This study does not consider synergistic effects. In addition, this assessment is based on a snapshot of current water quality conditions. However, some variables can have acute toxicity even at very low concentrations over a longer time period. Furthermore, it is assumed that the data supplied by each of the member states to be used in this assessment has been quality control checked; no additional check on data for this study has been performed.

4. WATER QUALITY STANDARDS

The following standards have been incorporated into this assessment:

Domestic use

- Botswana Standard BOS 32:2000. Water quality - Drinking Water - Specification;
- Namibia Water Quality Guidelines and Standards for Potable Water;
- South African Water Quality Guidelines; and
- WHO Drinking Water Standards (adopted by Lesotho) [WHO, 2006]

All other uses

- South African Water Quality Guidelines.

The guideline standards used in this assessment for each water use are listed in Appendix A.

5. SUITABILITY ASSESSMENT

Certain water uses require water quality of a particular standard in order to make them suitable. However, Fitness for Use can range from being ‘ideally’ fit for the intended purpose to being completely unfit. Four descriptions to express a judgement about suitability will be used in this assessment:

- Good – Complies with all standards listed in Section 4 for domestic use or the Target Water quality Range specified in the South Africa Water Quality Guidelines for all other uses;
- Tolerable – Complies with all but the most stringent standard listed in Section 4 for domestic use or the second most stringent water quality range specified in the South Africa Water Quality Guidelines for all other uses;
- Poor – Complies with the least stringent standard listed in Section 4 for domestic use or the least stringent water quality range specified in the South Africa Water Quality Guidelines for all other uses; or
- Unsuitable – Complies with none of the standards listed in Section 4.

Water quality collated from the stakeholder process has been allocated to one of these suitability descriptions by comparing them to the water quality standards for the current use using the following processes:

- The datasets received from the four member states have been separated based on the sub-basin divisions mentioned in Section 2.1.[2];
- Data for the previous five years was selected – i.e. 2003-2008 [3]. This five year assessment gives a snapshot of ‘current’ water quality and would permit a rolling annual revision to take place if required whilst allowing sufficient data quantity for statistical analysis and taking hydrological extremes into account;
- A 95 percentile for each of the variable was calculated (except for phosphate where 50%-ile was used and pH lower limit where 5%-ile was used)[4]; and
- A suitability descriptor was applied to that dataset, for each particular use (as listed in Section 2.2), for each particular water quality variable (as listed in Section 3).

An example screenshot of this assessment table can be seen in Appendix B.

[2] The dataset will be amalgamated to give an overall baseline for water quality in that sub-basin area. This will improve spatial representation of data in the sub-basin, improve data availability and improve robustness of subsequent statistical analysis. This process also has a disadvantage, as it will reduce extremes in the dataset at particular points that might not be suitable for the particular use when the overall dataset for the sub-basin will be suitable. On the basin wide scale, however, it was felt that data amalgamation was the most robust approach.

[3] Not all the variables listed in Section 3 will be available for all the sub-basin areas. A ‘not assessed’ category on the map icons will be used in this case to highlight lack of data.

[4] Data recorded as below detection limits (denoted by a “<”) should not be considered as missing data. Statistically, it is deemed appropriate to convert these data to half the detection limit value.

6. 'FITNESS FOR USE' MAPS

The maps have been produced for the whole of the Orange-Senqu basin, for each water use (Appendix C - Appendix G). They include the following information:

- Base maps with major urban areas;
- River network; and
- Water use suitability icons.

These are produced in an ArcView GIS database and are presented as embedded enhanced metafile format images in this report. The suitability descriptors, 'good', 'tolerable', 'poor' and 'Unsuitable' (Section 5) are presented visually using icons for each water use (Figure 6-1).

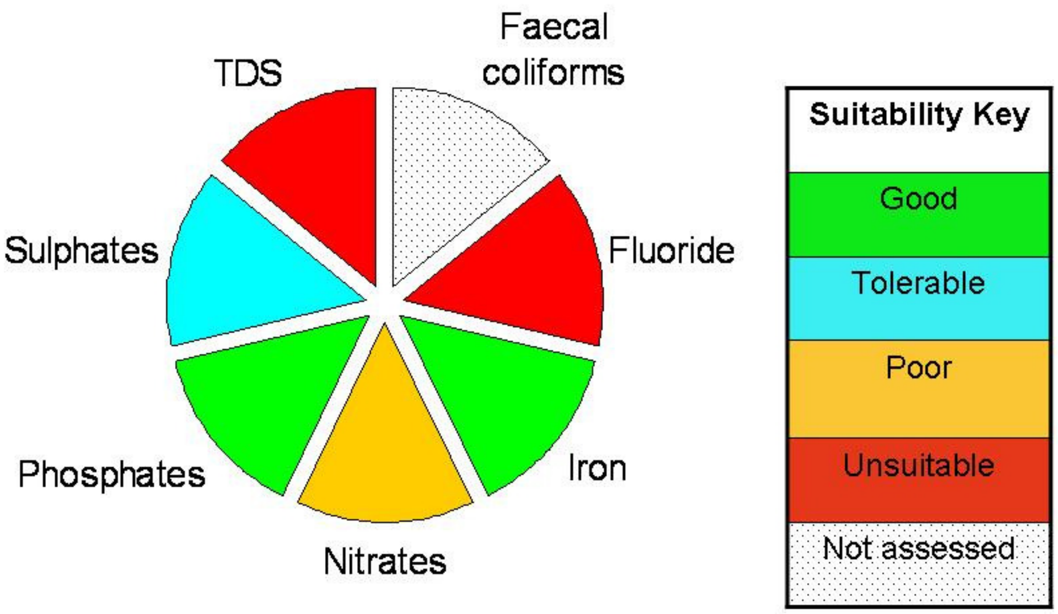


Figure 6-1 Example icon summarising Fitness for Use

Thus, these icons give a rapid spatial assessment of the suitability of all water uses based on each of the key water quality criteria identified in Section 9.

7. MAP ANALYSIS

The findings from these maps for each water use are summarised in the section below according to the data received and the standards used in this assessment.

7.1 Agricultural irrigation

Appendix C shows maps for agricultural irrigation use. Water from the Wilge (S1), Vaal (except Middle Vaal S4 sub-basin) and Upper Orange (S6) were generally found to be of ‘good’ standard for agricultural irrigation. Concentrations of fluoride, phosphate, nitrate and TDS were significantly lower than the most stringent standard. However, slightly higher faecal coliform data was recorded on the Vaal system and high faecal coliform and nitrate concentrations were recorded in the Middle Vaal. This is urban pollution from Johannesburg and the surrounding conurbation which flow into this Vaal sub-basin.

Botswana groundwater (both B1 and B2), Lesotho highland groundwater and surface water (L1 and L2, respectively), Lesotho lowland surface water (L3), Namibia supply reservoirs (N2) and Namibia Stampreit (N3) were generally not suitable for irrigation use due to high TDS, nitrate and iron concentrations. The issue seems to be more acute in terms of damage to irrigation equipment rather than damage to the crops (based on the standards used). For instance a ‘not suitable’ classification was allocated for both iron and nitrate at B1, B2, N2 and N3 with concentrations at least twice the least stringent limit (1.5 mg Fe l^{-1} and 20 mg NO_3 l^{-1}, respectively). A ‘not suitable’ allocation was also used for iron at L1, L2 and L3.

Water from the middle and lower Orange and Caledon / Mokahare (S7, S9 / N1 and S10 / L5, respectively) and Lesotho lowlands groundwater (L4) were of intermediate standard with intermediate levels of TDS, nitrates and iron reducing suitability scores down to the ‘tolerable’ / ‘poor’ level.

At numerous sites, an assessment against standards could not be made for faecal coliforms, iron and phosphate, due to lack of data.

7.2 Agricultural livestock

Appendix D shows maps for agricultural livestock use. Water from Botswana non-saline groundwater (B2), Lesotho highlands surface and groundwater (L1 and L2), Lesotho lowlands groundwater (L4), Caledon / Mokahare (S10 / L5), Lower Orange (N1 / S9), Namibia supply reservoirs (N2), Wilge (S1), Vaal (except Middle Vaal S3 and S4 sub-basins), Upper Orange (S6) and Middle Orange (S7) were all found to be of ‘good’ standard for agricultural livestock water use. Concentrations of fluoride, nitrate and TDS were significantly lower than the most stringent standard.

Water was classified as ‘not suitable’ for livestock use from the Botswana saline groundwater (B1) (due to high sulphate and TDS), Namibia Stampreit (N3) (high TDS and intermediate fluoride) and Vaal Middle sub-basins (S3 and S4) (high faecal coliforms).

Lesotho lowlands surface water (L3) was of transitional standard with high fluoride concentrations reducing suitability scores down to the ‘poor’ level.

At the majority of South African sites, an assessment against standards could not be made for faecal coliforms and iron, due to lack of data. At the majority of Botswana and Namibia sites, an assessment against standards could not be made for faecal coliforms and phosphates, due to lack of data.

7.3 Domestic

Appendix E shows maps for domestic use. Water from the Lesotho lowlands groundwater (L4), Caledon / Mokahare (S10 / L5), Wilge, Vaal and Upper, Middle and Lower Orange (S6, S7, S9, respectively) were generally found to be of ‘good’ standard for domestic water use.

Concentrations of phosphate and nitrate were significantly lower than the most stringent standard. However, slightly higher sulphate concentrations were recorded towards the lower end of the Vaal system and TDS levels were close to the threshold for the ‘good’ classification at the majority of these sites and sometimes fell into the ‘tolerable’ classification.

Botswana saline groundwater (B1), Lesotho lowland surface water (L3) and Namibia Stampreit (N3) were generally ‘not suitable’ for domestic use due to a combination of high fluoride, iron, nitrate, sulphate and TDS levels.

Water from Botswana non-saline groundwater (B2), Lesotho Highlands groundwater and surface water (L1 and L2, respectively), Namibia Lower Orange (N1) and Namibia supply reservoirs (N2) were of transitional standards with intermediate levels of iron and / or nitrate reducing suitability scores down to the ‘poor’ level.

At the majority of South African sites, an assessment against standards could not be made for iron, due to lack of data. At the Botswana and Namibia sites, an assessment against standards could not be made for phosphates, due to lack of data.

7.4 Industrial

Appendix F shows maps for industrial use. The faecal coliform, fluoride, nitrate, phosphate criteria had no standards for this water use. Therefore, only iron, sulphate and TDS were used in this assessment. Lack of data in the Upper Vaal (S2) sub-basin meant that the industrial water use assessment could not be conducted.

7.4.1 Category I

A large number of sub-basins were allocated ‘not suitable’ classifications for the highest water quality category for industrial water use. These included Botswana groundwater (B1 and B2), Lesotho Lowlands groundwater (L4), Namibia Lower Orange (N1), Namibia supply reservoirs (N2), Namibia Stampreit (N3) and Lower Vaal (S5) sub-basins. This was due to a combination of high TDS, iron and sulphate levels.

Only the Middle Vaal (S3 and S4), Upper Orange (S6) and Caledon (S10) were suitable for Category I industrial water use. All other sub-basins had intermediate iron and / or TDS levels reducing suitability scores down to the ‘poor’ level.

7.4.2 Category II

Lesotho highland and lowland surface water (L1 and L3), Wilge (S1), Vaal Middle (S3 and S4), Upper Orange (S6) and Caledon (S10) were classified as ‘good’ or ‘tolerable’ for category II water use.

Botswana saline groundwater (B1) which had ‘not suitable’ allocations for TDS, sulphate and iron (more than 19, 10 and 8 times the least stringent limits, respectively), Botswana non-saline groundwater (B2) which had a ‘not suitable’ allocations for TDS and iron (slightly more than the least stringent limits) and Namibia Stampreit (N3) which had ‘not suitable’ allocations for TDS, sulphate and iron (more than 6, 4 and 2 times the least stringent limits, respectively).

Water from Lesotho highland and lowland groundwater (L2 and L4), Mokahare (L5), Lower Orange (N1 / S9), Namibia supply reservoirs (N2), Lower Vaal (S5) and Middle Orange (S7) were of transitional standards generally with intermediate TDS levels reducing suitability scores down to the ‘poor’ level.

7.4.3 Category III

Nearly all the sub-basins in this assessment were classified as ‘good’ or ‘tolerable’ for category III water use. This included Lesotho surface and groundwater (L1, L2, L3 and L4), Mokahare / Caledon (L5 / S10), Upper (S6), Middle (S7) and Lower (N1 / S9) Orange, Wilge (S1) and Middle (S3 and S4) and Lower (S6) Vaal.

The exceptions were Botswana saline groundwater (B1) which had ‘not suitable’ allocations for TDS, sulphate and iron (more than 9, 5 and 1.5 times the least stringent limits, respectively), Botswana non-saline groundwater (B2) which had a 'poor' allocation for TDS and Namibia Stampreit (N3) which had 'not suitable' allocations for both TDS and sulphate (more than 3 and 2 times the least stringent limits, respectively).

A comparison between the 133 assessments completed for domestic (Section 7.3) and industrial category III water use showed similar results. Out of 46 paired assessments between the two water uses, 34 had exactly the same suitability descriptions and 8 had similar suitability descriptions (± 1 suitability description difference). For example, Botswana saline groundwater (B1) was assessed as 'not suitable' for iron, sulphate and TDS for both domestic and industrial category III water uses. Likewise, Lesotho lowlands surface water (L3) was assessed as 'tolerable' for iron and 'good' for sulphate and TDS for both water uses. No paired assessments had significantly different suitability descriptions (>1 suitability description difference). The remaining assessments (out of 133) could not be paired due to no standards existing for the water use (n = 76) or because of lack of data (n = 11).

7.4.4 Category IV

Nearly all the sub-basins in this assessment were classified as 'good' for category IV water use. The exceptions were Botswana saline groundwater (B1) which had 'not suitable' allocations for TDS, sulphate and iron (more than 9, 5 and 1.5 times the least stringent limits, respectively) and Namibia Stampreit (N3) which had 'not suitable' allocations for both TDS and sulphate (more than 3 and 2 times the least stringent limits, respectively).

7.5 Recreational

Appendix G shows maps for recreational use. Only faecal coliform, phosphate and pH (upper and lower) standards were used in this assessment. Lack of data meant that faecal coliforms were only assessed in the Vaal and Lesotho highlands sub-basins.

The majority of sub-basins were suitable for full, intermediate and no contact recreational water use including Botswana groundwater (B1 and B2), Lesotho highland surface water (L1), Mokahare / Caledon (L5 / S10), Lower Orange (N1 / S9), Namibia supply reservoirs (N2), Namibia Stampreit (N3), Upper Vaal (S2), Lower Vaal (S5) and the Upper and Middle Orange (S6 and S7).

Lesotho Highland and Lowland groundwater (L2 and L4) were non-compliant with upper pH thresholds (i.e. alkaline) causing 'not suitable' and 'poor' scores, respectively, to be allocated for full, intermediate and no contact recreational water use. Conversely, Lesotho Lowland surface water (L3) were non-compliant with lower pH thresholds (i.e. acidic) causing 'not suitable' scores to be allocated for full, intermediate and no contact recreational water use.

In the Middle Vaal Upper Reach sub-basin (S3) high faecal coliform counts meant that a 'not suitable' assessment was allocated for all recreational water use categories.

The only two sub-basins where the different categories of recreational water use had different assessment scores were the Wilge (S1) and Middle Vaal Lower Reach (S4). No contact use was suitable in both these basins. However, in the Wilge, full and intermediate water use was 'not suitable' due to faecal coliform counts 5 and 11 times, respectively, more than that categories least stringent limit. In the Middle Vaal Lower Reach, intermediate water use was suitable but full water use was 'poor'.

8. CONCLUSIONS AND RECOMMENDATIONS

This report has developed a consistent and justifiable approach to 'fitness for use' maps. In doing so, it has indicated the impacts of key pollutants on key water uses in the Orange-Senqu basin. The overall findings from this assessment are summarised in Table 8-1.

Table 8-1 Summary of fitness for use assessment for key water uses in the Orange-Senqu Basin

Member State	Sub basin	Agricultural Irrigation	Agricultural livestock	Domestic	Industrial	Recreational
Botswana	Whole region falling inside the O-S basin	NS	NS	NS	NS	G
Botswana	Whole region falling inside the O-S basin	NS	G	P	NS	G
Lesotho	Highlands	NS	G	P	P	G
Lesotho	Highlands	NS	G	P	P	NS
Lesotho	Lowlands	NS	P	NS	P	NS
Lesotho	Lowlands	P	G	G	P	NS
Lesotho	Mokahare	NS	G	G	P	G
Namibia	Lower Orange	P	G	P	P	G
Namibia	Supply reservoirs (Naute & Hardap Dams)	NS	G	P	P	G
Namibia	Stampreit	NS	NS	NS	NS	G
South Africa	Wilge	G	NS	P	P	NS
South Africa	Upper Vaal	P	G	G	G	G
South Africa	Middle Vaal	G	G	P	P	G
South Africa	Middle Vaal	G	NS	P	G	NS
South Africa	Lower Vaal	P	NS	P	G	NS
South Africa	Upper Orange River	G	G	P	P	G
South Africa	Middle Orange River	G	G	G	G	G
South Africa	Lower Orange River	P	G	G	P	G
South Africa	Caledon	P	G	G	P	G

TABLE KEY (red) = Not suitable; (orange) = Poor; (green) = Good (the tolerable description has not been used in this table for clarity purposes, this is an intermediate suitability descriptor and as such the predominance of other descriptors was used to describe overall suitability).

The following salient points have been reported in this assessment:

- Data for a particular sub-basin were amalgamated into a single set for analyses. It follows that this is not an assessment of water quality at a single point; rather, it represents an overview of the suitability of the water in the whole sub-basin.

- Sub-basins with water quality most suitable to the key water uses in the Orange-Senqu basin were the Upper Vaal, Mokahare / Caledon and Upper, Middle and Lower Orange. In particular, the Upper Orange River (S6) sub-basin was **suitable for all the key water uses** identified.
- Botswana saline groundwater, Namibia Stampreit and Lesotho Lowland surface water were the **least suitable** sub-basins **for the key water uses** in the Orange-Senqu basin, due to high TDS levels and high iron / nitrate concentrations, respectively.
- Botswana non-saline groundwater, Lesotho Highland Ground and surface Water, Lesotho Lowland groundwater, Namibia Supply Reservoirs and the Middle and Lower Vaal were **suitable for some of the key water uses** in the Orange-Senqu basin.
- Fitness for use assessments for sub-basins in neighbouring member states were very alike. The Mokahare / Caledon (Lesotho and South Africa datasets used) and Lower Orange (Namibia and South Africa datasets used) showed similar assessment for suitability against all key water uses except for domestic (Lower Orange) and industrial and agricultural irrigation (Mokahare / Caledon).
- A comparison between the 133 assessments completed for domestic and industrial category III water use showed similar results. Out of 46 paired assessments between the two water uses, 34 had exactly the same suitability descriptions and 8 had similar suitability descriptions No paired assessments had significantly different suitability descriptions.
- Some water quality criteria could not be assessed against water use standards due to limited data. In particular, lack of iron data in South Africa and faecal coliform and phosphate data in Botswana and Namibia were apparent. It is understood that there is a microbiological surface water monitoring programme in South Africa but due to the time constraints of this study, faecal coliform data was not available.

It is anticipated that this high level assessment will benefit transboundary water quality management by promoting a common understanding of water quality conditions in the Orange-Senqu basin. The findings could potentially be utilised in the design and implementation of transboundary water quality monitoring programme.

9. REFERENCES

DWAF (1996) Water Quality Guidelines. 2nd edition. Vols 1-8.

BOBS (2000) Botswana Standard BOS 32:2000. Water quality - Drinking Water – Specification.

Namibia Water Quality Guidelines and Standards for Potable Water. Pers. comm.. Department of Water Affairs, Namibia.

WHO (2006) Annex 4. Chemical Summary Tables. 3rd edition. Available online at http://www.who.int/water_sanitation_health/dwq/guidelines/en/index.html

WHO (2008) Guidelines for Drinking Water Quality. 3rd edition. Volume 1 Recommendations. Available online at http://www.who.int/water_sanitation_health/dwq/guidelines/en/index.html

Zeman CL, Kross B and Vlad M (2002) A Nested Case–Control Study of Methemoglobinemia Risk Factors in Children of Transylvania, Romania. *Environmental Health Perspectives*, **110** (8), 817-822.

APPENDIX A – Water Quality Criteria for Each Use

These tables list the guidelines standards for the assessment together with the judgement on how suitable the water is for use. The 'source details' row lists the member state that the different standards are derived from. For the 'Good' category, the most stringent standard existing for any member state will be used (as described in Section 5). For the 'Poor' category, the least stringent standard existing for any member state will be used (as described in Section 5).

Table A-1 Criteria and effects of water quality variables on Agricultural – Irrigation use

Suitability	Faecal coliforms [bacterial count/ 100 ml]	Fluoride (mg l^{-1})	Iron* (mg l^{-1})		Nitrate* (mg NO_3 l^{-1})		Phosphate (mg PO_4 l^{-1})	Sulphate (mg SO_4 l^{-1})	Total Dissolved Solids (mg l^{-1})
	100%-ile	95%-ile	95%-ile		95%-ile		50%-ile		95%-ile
Receptor*			CQ	IED	CQ	IED			
Good	1	2.0	5.9	0.20	5.0	0.5	5	No standard	260
Tolerable	500	8.5	12.5	0.75	17.5	2.5	25		1755
Poor	<1000	<15.0	<20.0	<1.5	<30.0	<10.0	<250		<3510
Unsuitable	>1000	>15.0	<20.0	>1.5	>30.0	>10.0	>250		>3510
Source details	All SA	All SA	All SA		All SA		All SA⁺		All SA

* CQ = crop quality, IED = irrigation equipment damage

⁺ Derived from Volume 7 Aquatic Systems SA guideline standards

Table A-2 Criteria and effects of water quality variables on Agricultural – Livestock use

Suitability	Faecal coliforms [bacterial count/ 100 ml]	Fluoride (mg l^{-1})	Iron (mg l^{-1})	Nitrate (mg NO_3 l^{-1})	Phosphate (mg PO_4 l^{-1})	Sulphate (mg SO_4 l^{-1})	Total Dissolved Solids (mg l^{-1})
	100%-ile	95%-ile	95%-ile	95%-ile	50%-ile	95%-ile	95%-ile
Good	200	2	10	100	5	1000	1000
Tolerable	600	4	30	150	25	1250	2000
Poor	<1000	<6	<50	<200	<250	<1500	<3000
Unsuitable	>1000	>6	>50	>200	>250	>1500	>3000
Source details	All SA	All SA	All SA	All SA	All SA⁺	All SA	All SA

⁺ Derived from Volume 7 Aquatic Systems SA guideline standards

Table A-3 Criteria and effects of water quality variables on Domestic use

Suitability	**Faecal coliforms [bacterial count/ 100 ml]**	**Fluoride (mg l^{-1})**	**Iron (mg l^{-1})**	**Nitrate (mg NO_3 l^{-1})**	**Phosphate (mg PO_4 l^{-1})**	**Sulphate (mg SO_4 l^{-1})**	**Total Dissolved Solids (mg l^{-1})**
	100%-ile	95%-ile	95%-ile	95%-ile	50%-ile	95%-ile	95%-ile
Good	0	0.7	0.03	6	5	100	450
Tolerable	1	1.0	1.00	10	25	400	1000
Poor	<10	<2.0	<5.00	<50	<250	<600	<2400
Unsuitable	>10	>2.0	>5.00	>50	>250	>600	>2400
Source details*	B, N, SA Good, Tolerable and Poor L no standard	B, N, SA Good & Tolerable N Poor (L standard 1.5 mg l^{-1} not used)	B Good SA Tolerable and Poor L & N no standard	N Good SA Tolerable SA & L Poor	All SA+ B, N, L no standards	N Good SA Tolerable and Poor B & L no standards	B Good and Tolerable SA Poor B & L no standards

*B = Botswana, L = Lesotho, N = Namibia, SA = South Africa

+ Derived from Volume 7 Aquatic Systems SA guideline standards

Table A-4 Criteria and effects of water quality variables on Industrial use

Category I

Suitability	**Faecal coliforms [bacterial count/ 100 ml]**	**Fluoride (mg l^{-1})**	**Iron (mg l^{-1})**	**Nitrate (mg NO_3 l^{-1})**	**Phosphate (mg PO_4 l^{-1})**	**Sulphate (mg SO_4 l^{-1})**	**Total Dissolved Solids (mg l^{-1})**
			95%-ile			95%-ile	95%-ile
Good	No standard	No standard	0.10	No standard	No standard	30	100
Tolerable			0.55			80	200
Poor			<1.00			<90	<450
Unsuitable			>1.00			>90	>450
Source details*			All SA			All SA	All SA

Category II

Suitability	**Faecal coliforms [bacterial count/ 100 ml]**	**Fluoride (mg l^{-1})**	**Iron (mg l^{-1})**	**Nitrate (mg NO_3 l^{-1})**	**Phosphate (mg PO_4 l^{-1})**	**Sulphate (mg SO_4 l^{-1})**	**Total Dissolved Solids (mg l^{-1})**
			95%-ile			95%-ile	95%-ile
Good	No standard	No standard	0.2	No standard	No standard	80	200
Tolerable			1.1			165	350
Poor			<2.0			<250	<800
Unsuitable			>2.0			>250	>800
Source details*			All SA			All SA	All SA

Category III

Suitability	Faecal coliforms [bacterial count/ 100 ml]	Fluoride (mg l^{-1})	Iron (mg l^{-1})	Nitrate (mg NO_3 l^{-1})	Phosphate (mg PO_4 l^{-1})	Sulphate (mg SO_4 l^{-1})	Total Dissolved Solids (mg l^{-1})
			95%-ile			95%-ile	95%-ile
Good	No standard	No standard	0.3	No standard	No standard	200	450
Tolerable			6.5			250	800
Poor			<10.0			<300	<1600
Unsuitable			>10.0			>300	>1600
Source details*			All SA			All SA	All SA

Category IV

Suitability*	Faecal coliforms [bacterial count/ 100 ml]	Fluoride (mg l^{-1})	Iron (mg l^{-1})	Nitrate (mg NO_3 l^{-1})	Phosphate (mg PO_4 l^{-1})	Sulphate (mg SO_4 l^{-1})	Total Dissolved Solids (mg l^{-1})
			95%-ile			95%-ile	95%-ile
Good	No standard	No standard	10	No standard	No standard	500	1600
Unsuitable			>10			>500	>1600
Source details*			All SA			All SA	All SA

*For Category IV only, no guideline for 'Tolerable' suitability exist

Table A-5 Criteria and effects of water quality variables on Recreational use

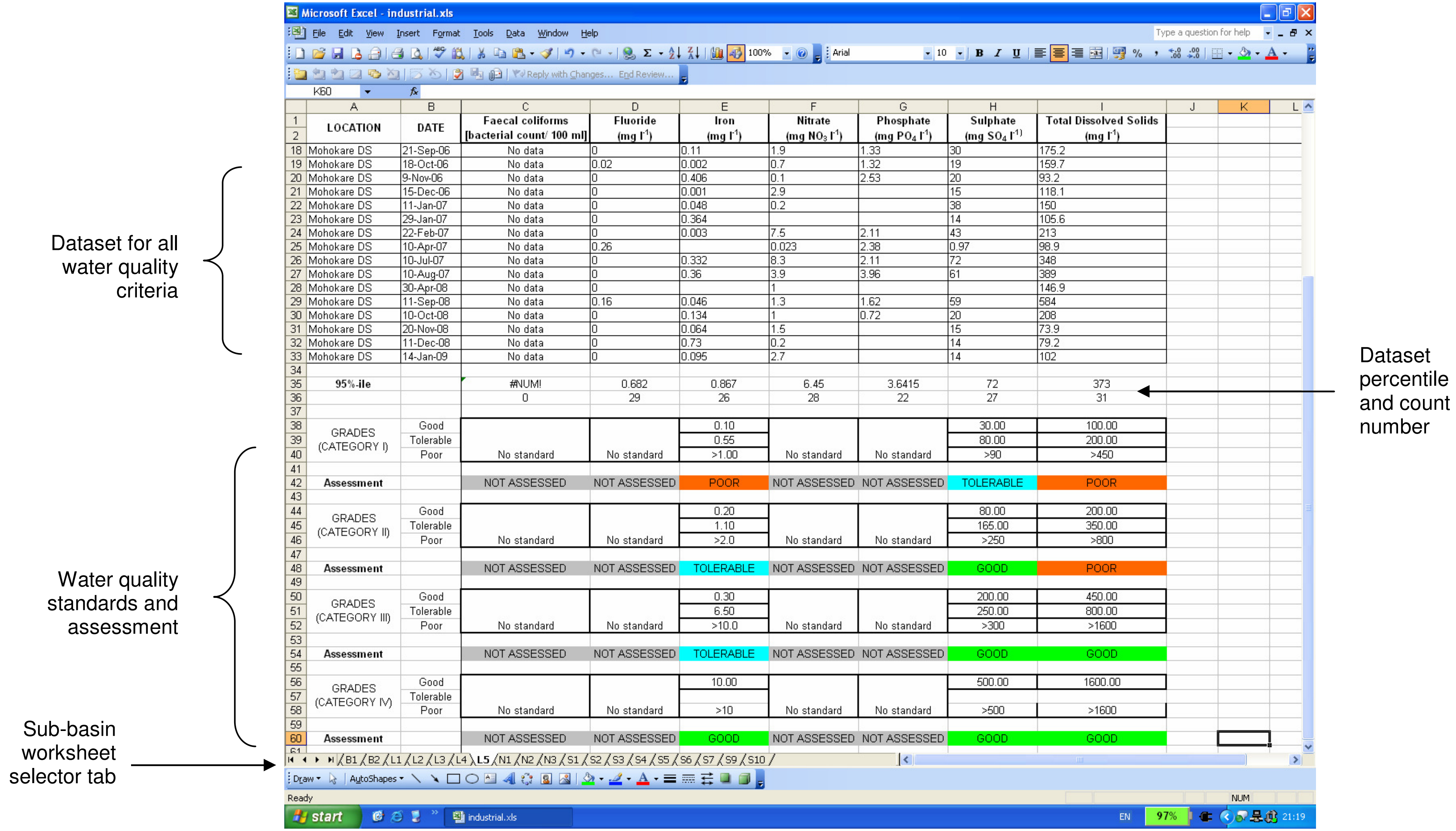
Suitability	Faecal coliforms [bacterial count/ 100 ml]		Phosphate (mg PO_4 l^{-1})	pH upper limit	pH lower limit
	95%-ile		50%-ile	95%-ile	5%-ile
Contact type*	FC	IC		FC	FC
Good	130	1000	5	8.50	6.50
Tolerable	1065	2500	25	8.75	5.75
Poor	>2000	>4000	250	>9.00	<5.00
Source details*	All SA		All SA+	All SA	All SA

*FC = Full contact; IC = Intermediate contact; NC = No contact

+ Derived from Volume 7 Aquatic Systems SA guideline standards

APPENDIX B – Example Assessment Table

Table B-1 Example assessment table (Lesotho Mokahare River Industrial Use)



	A	B	C	D	E	F	G	H	I
1–2	LOCATION	DATE	Faecal coliforms [bacterial count/ 100 ml]	Fluoride (mg l^{-1})	Iron (mg l^{-1})	Nitrate (mg NO_3 l^{-1})	Phosphate (mg PO_4 l^{-1})	Sulphate (mg SO_4 l^{-1})	Total Dissolved Solids (mg l^{-1})
18	Mohokare DS	21-Sep-06	No data	0	0.11	1.9	1.33	30	175.2
19	Mohokare DS	18-Oct-06	No data	0.02	0.002	0.7	1.32	19	159.7
20	Mohokare DS	9-Nov-06	No data	0	0.406	0.1	2.53	20	93.2
21	Mohokare DS	15-Dec-06	No data	0	0.001	2.9		15	118.1
22	Mohokare DS	11-Jan-07	No data	0	0.048	0.2		38	150
23	Mohokare DS	29-Jan-07	No data	0	0.364			14	105.6
24	Mohokare DS	22-Feb-07	No data	0	0.003	7.5	2.11	43	213
25	Mohokare DS	10-Apr-07	No data	0.26		0.023	2.38	0.97	98.9
26	Mohokare DS	10-Jul-07	No data	0	0.332	8.3	2.11	72	348
27	Mohokare DS	10-Aug-07	No data	0	0.36	3.9	3.96	61	389
28	Mohokare DS	30-Apr-08	No data	0		1			146.9
29	Mohokare DS	11-Sep-08	No data	0.16	0.046	1.3	1.62	59	584
30	Mohokare DS	10-Oct-08	No data	0	0.134	1	0.72	20	208
31	Mohokare DS	20-Nov-08	No data	0	0.064	1.5		15	73.9
32	Mohokare DS	11-Dec-08	No data	0	0.73	0.2		14	79.2
33	Mohokare DS	14-Jan-09	No data	0	0.095	2.7		14	102
34									
35	95%-ile		#NUM!	0.682	0.867	6.45	3.6415	72	373
36			0	29	26	28	22	27	31
37									
38	GRADES (CATEGORY I)	Good			0.10			30.00	100.00
39		Tolerable			0.55			80.00	200.00
40		Poor	No standard	No standard	>1.00	No standard	No standard	>90	>450
41									
42	Assessment		NOT ASSESSED	NOT ASSESSED	POOR	NOT ASSESSED	NOT ASSESSED	TOLERABLE	POOR
43									
44	GRADES (CATEGORY II)	Good			0.20			80.00	200.00
45		Tolerable			1.10			165.00	350.00
46		Poor	No standard	No standard	>2.0	No standard	No standard	>250	>800
47									
48	Assessment		NOT ASSESSED	NOT ASSESSED	TOLERABLE	NOT ASSESSED	NOT ASSESSED	GOOD	POOR
49									
50	GRADES (CATEGORY III)	Good			0.30			200.00	450.00
51		Tolerable			6.50			250.00	800.00
52		Poor	No standard	No standard	>10.0	No standard	No standard	>300	>1600
53									
54	Assessment		NOT ASSESSED	NOT ASSESSED	TOLERABLE	NOT ASSESSED	NOT ASSESSED	GOOD	GOOD
55									
56	GRADES (CATEGORY IV)	Good			10.00			500.00	1600.00
57		Tolerable							
58		Poor	No standard	No standard	>10	No standard	No standard	>500	>1600
59									
60	Assessment		NOT ASSESSED	NOT ASSESSED	GOOD	NOT ASSESSED	NOT ASSESSED	GOOD	GOOD

APPENDIX C – Agriculture Irrigation Water Use Maps

Figure 0-1 Agricultural Irrigation (Crops) Overview Map

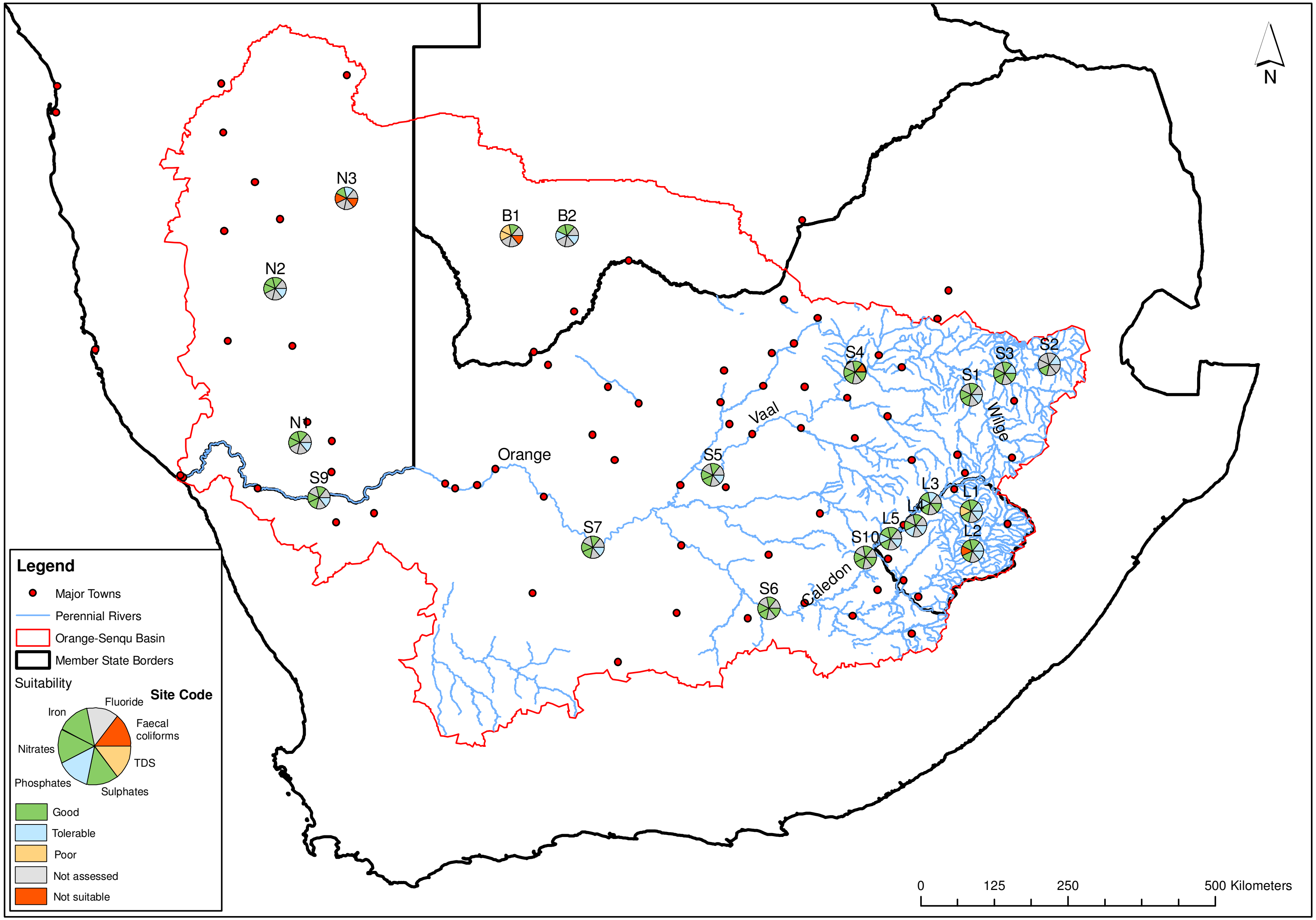


Figure 0-2 Agricultural Irrigation (Crops) Sub-basins S1, S2, S3, S4 and S5 Map

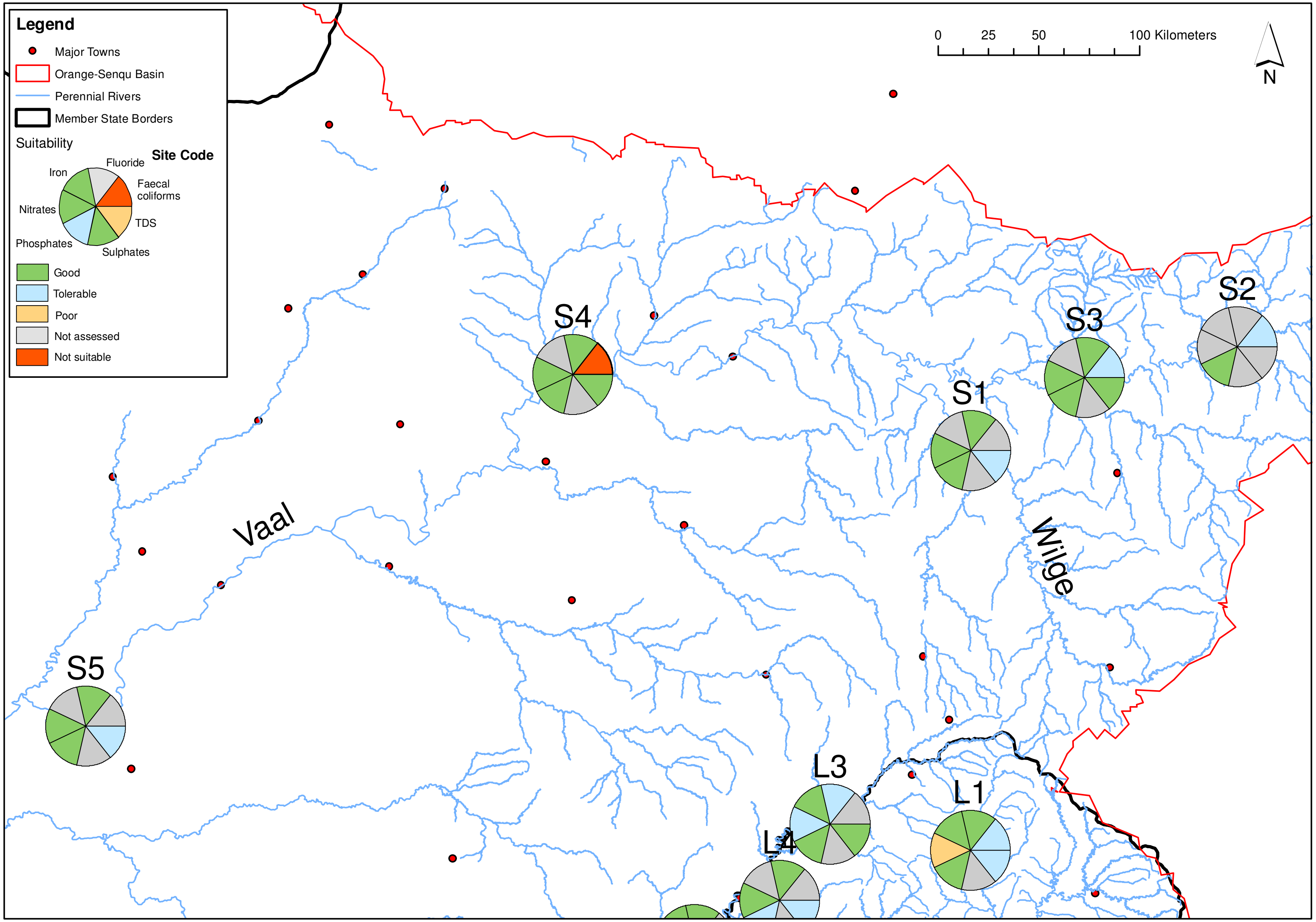


Figure 0-3 Agricultural Irrigation (Crops) Sub-basins L1, L2, L3, L4, L5, S6, S7 and S10 Map

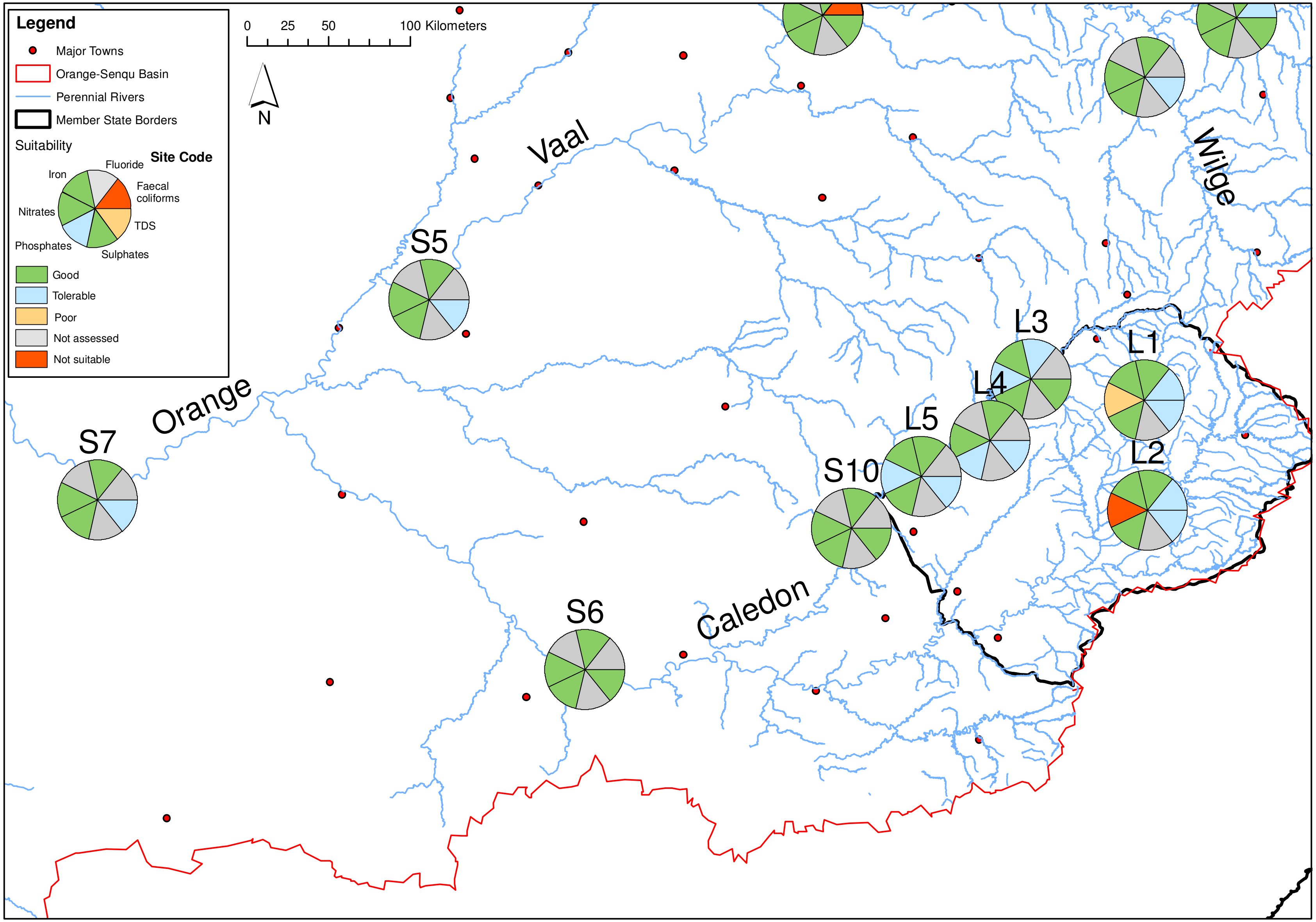


Figure 0-4 Agricultural Irrigation (Crops) Sub-basins B1, B2, N1, N2, N3 and S9 Map

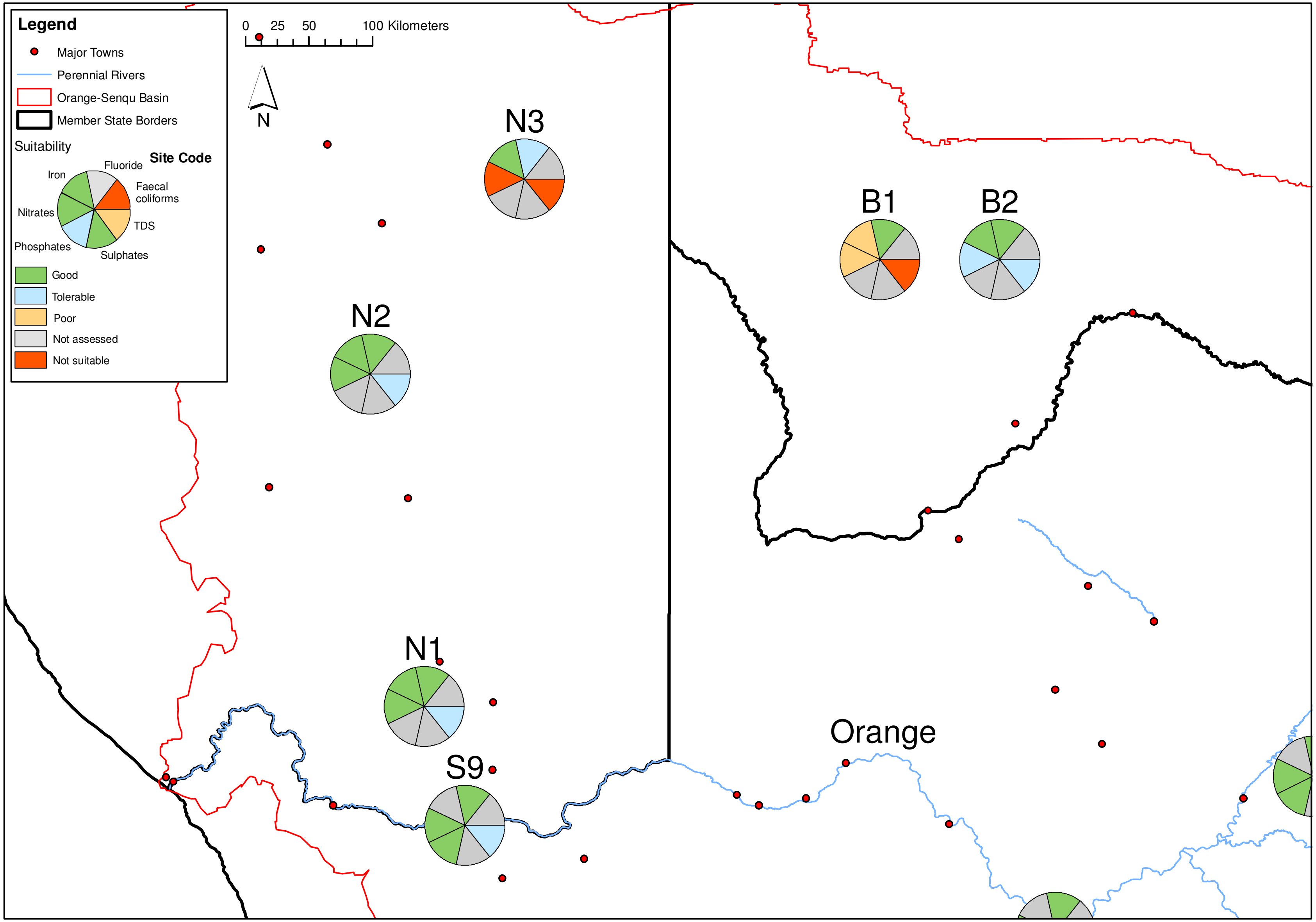


Figure 0-5 Agricultural Irrigation (equipment damage) Overview Map

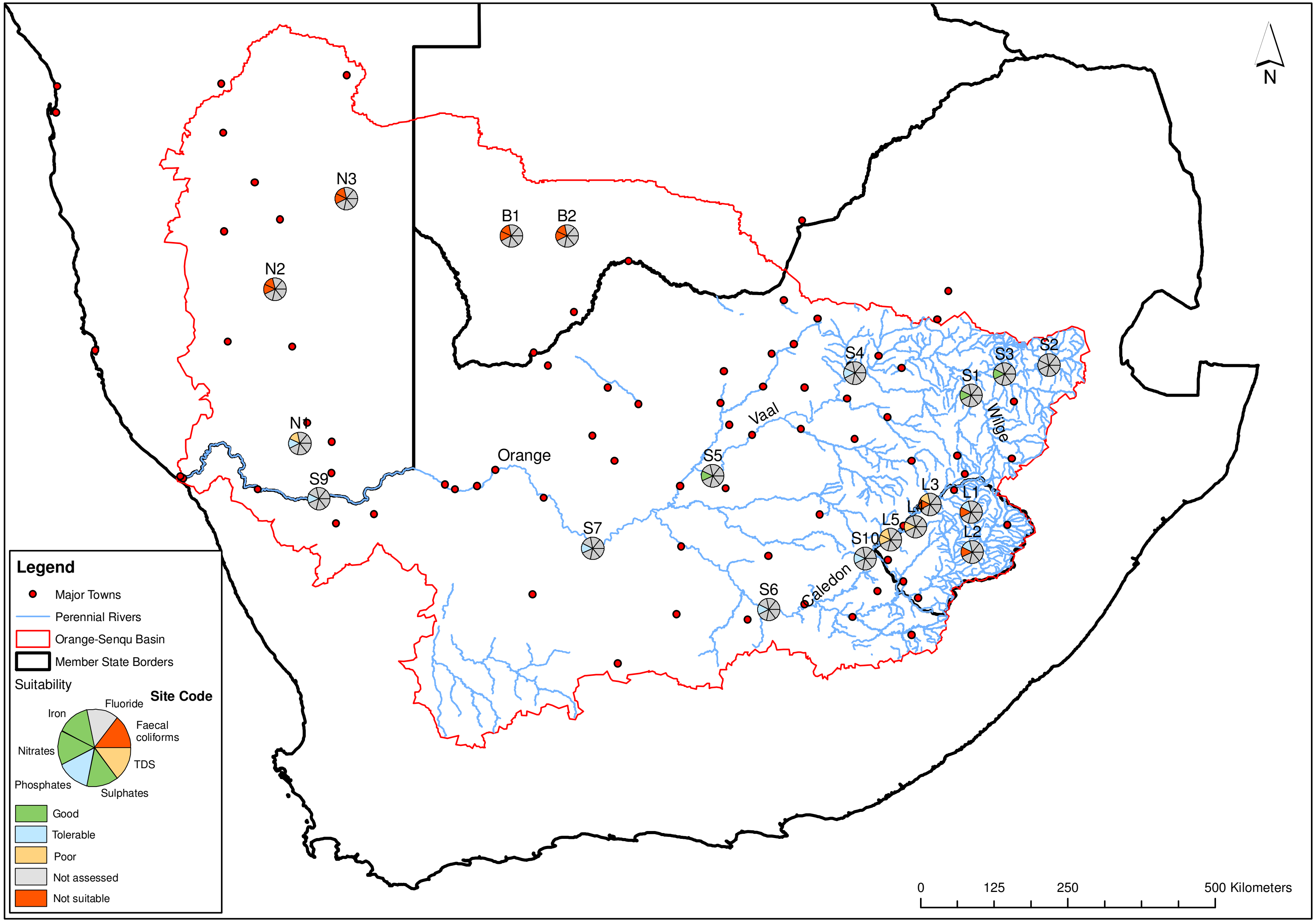


Figure 0-6 Agricultural Irrigation (equipment damage) Sub-basins S1, S2, S3, S4 and S5 Map

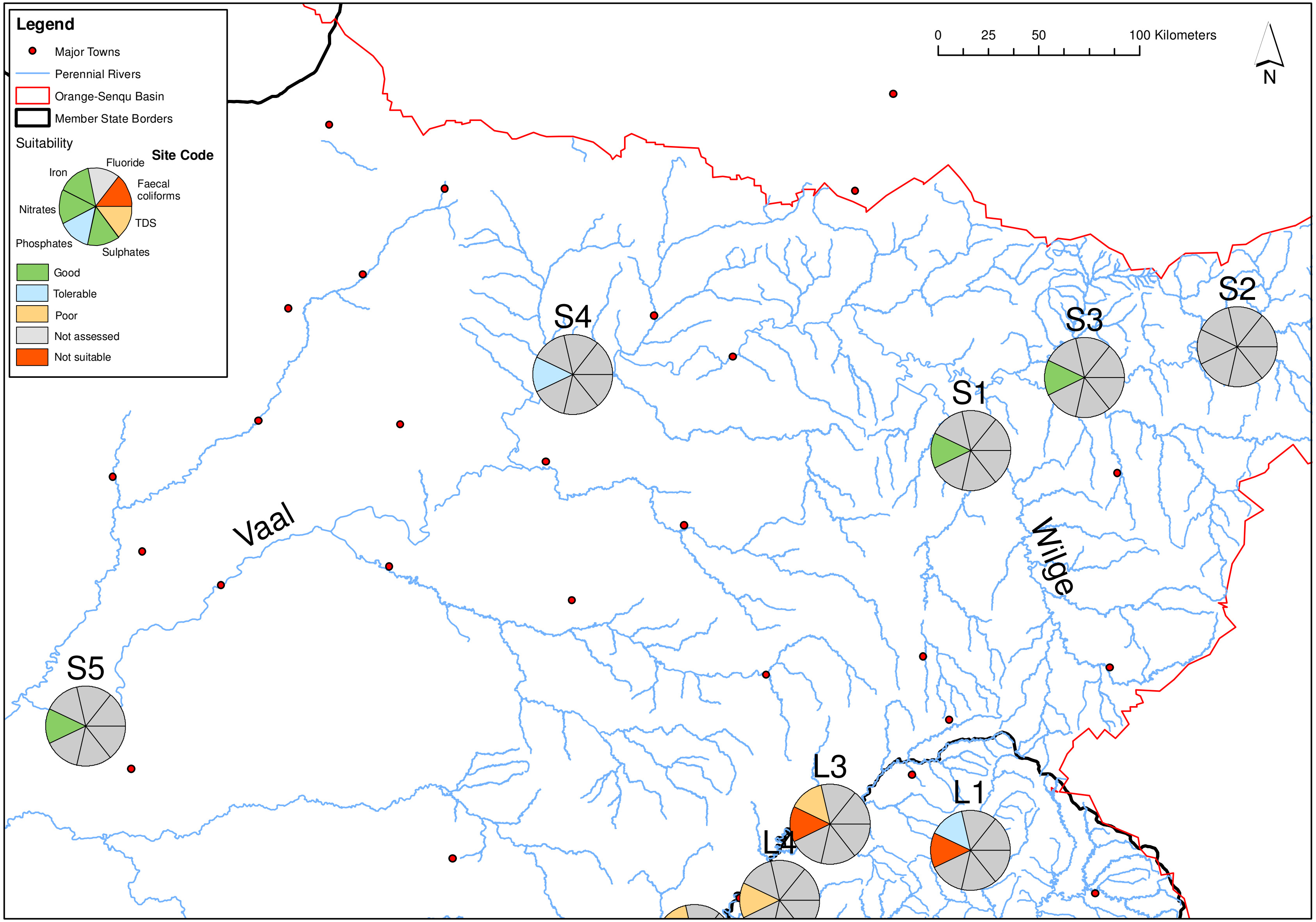


Figure 0-7 Agricultural Irrigation (equipment damage) Sub-basins L1, L2, L3, L4, L5, S6, S7 and S10 Map

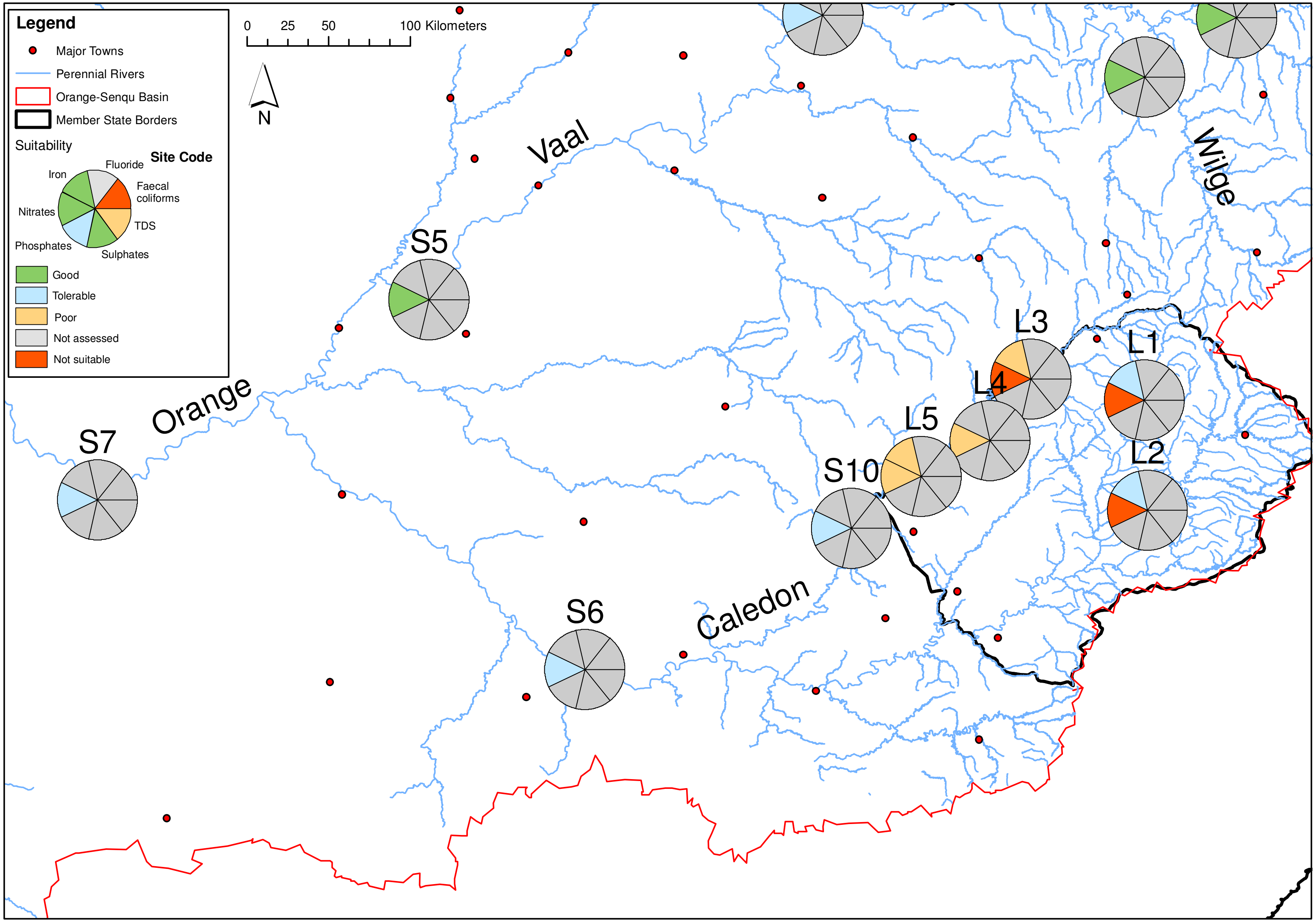
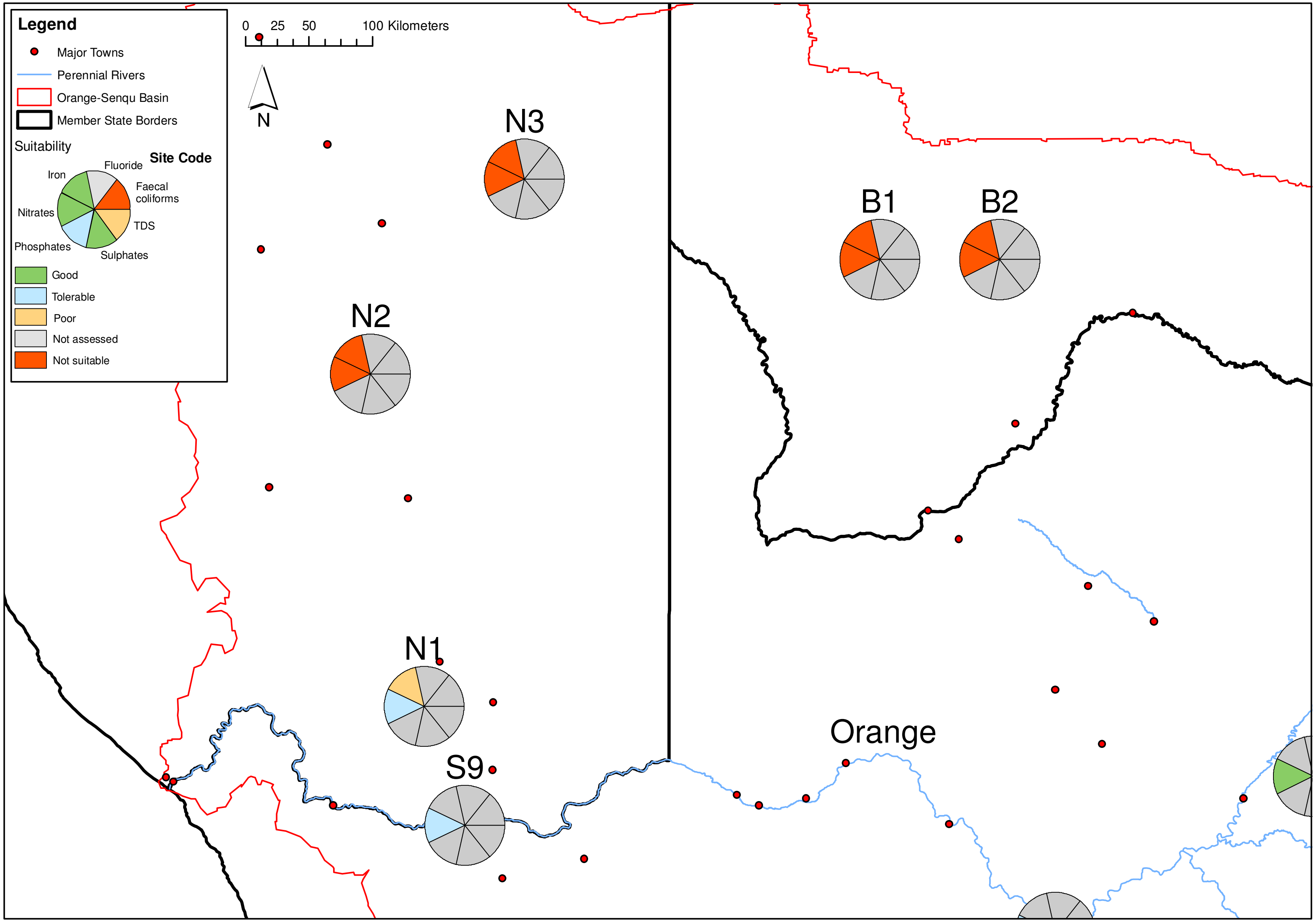


Figure 0-8 Agricultural Irrigation (equipment damage) Sub-basins B1, B2, N1, N2, N3 and S9 Map



Appendix D – Agriculture Livestock Water Use Maps

Figure 0-1 Agricultural Livestock Overview Map

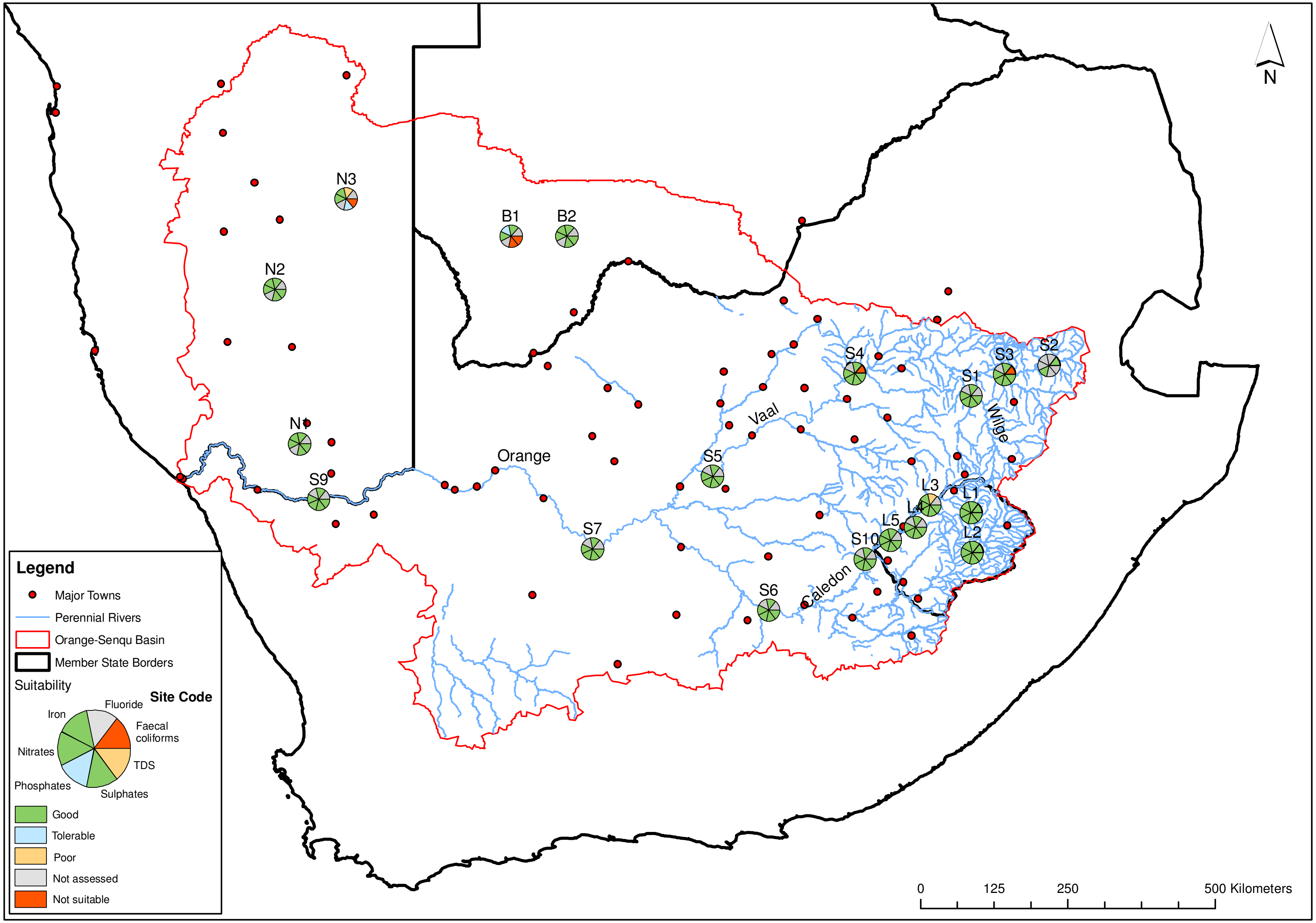


Figure 0-2 Agricultural Livestock Sub-basins S1, S2, S3, S4 and S5 Map

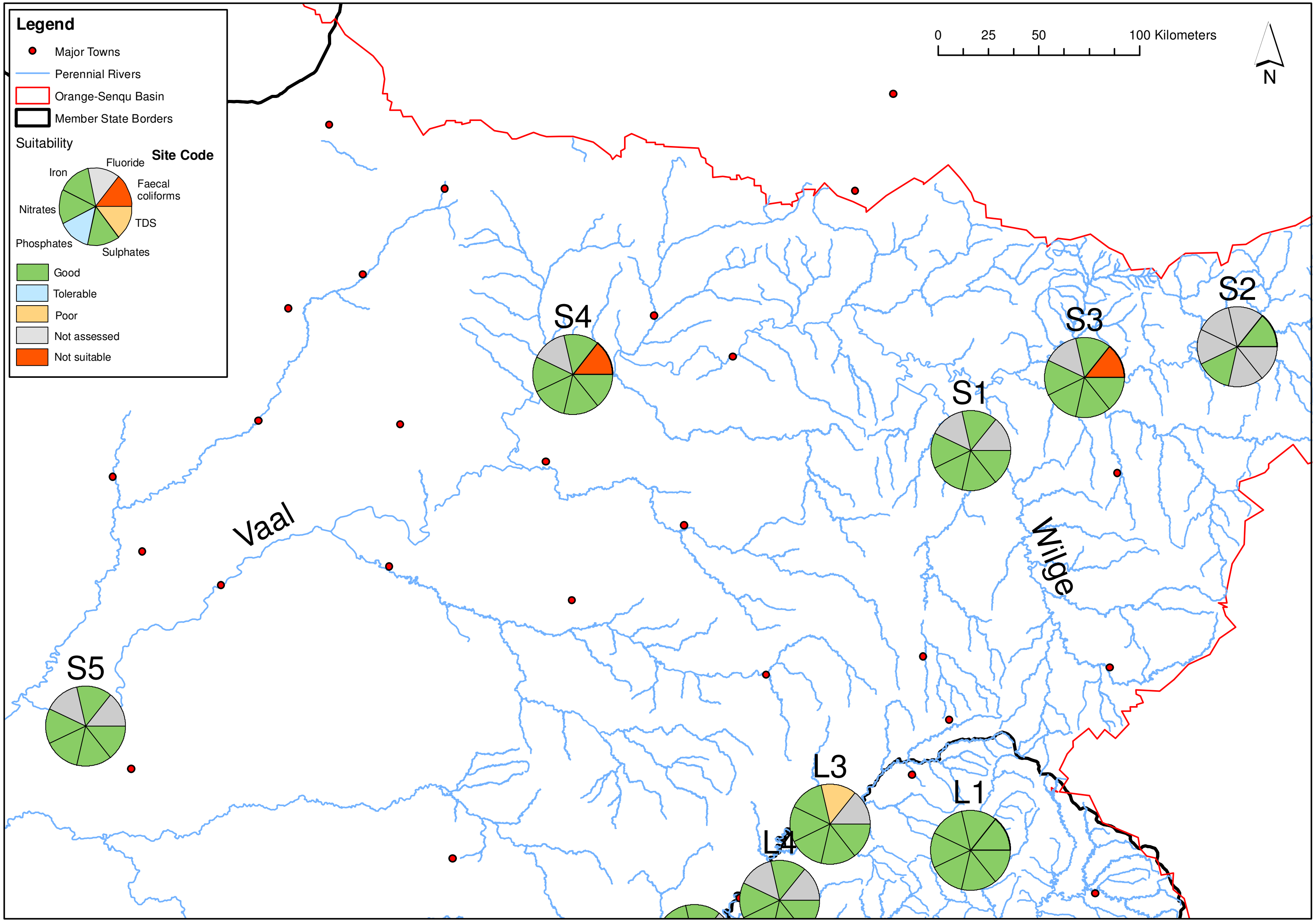


Figure 0-3 Agricultural Livestock Sub-basins L1, L2, L3, L4, L5, S6, S7 and S10 Map

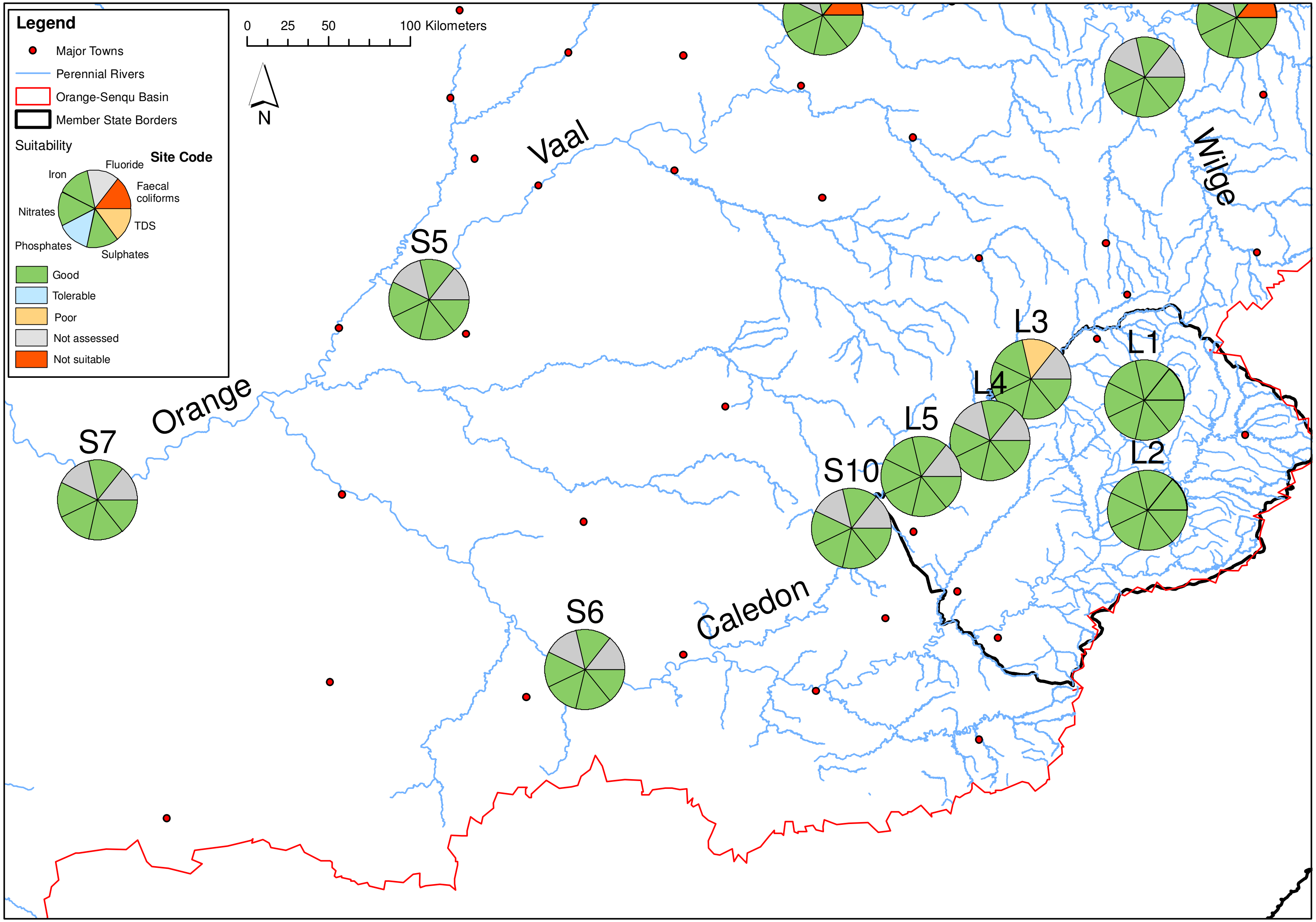
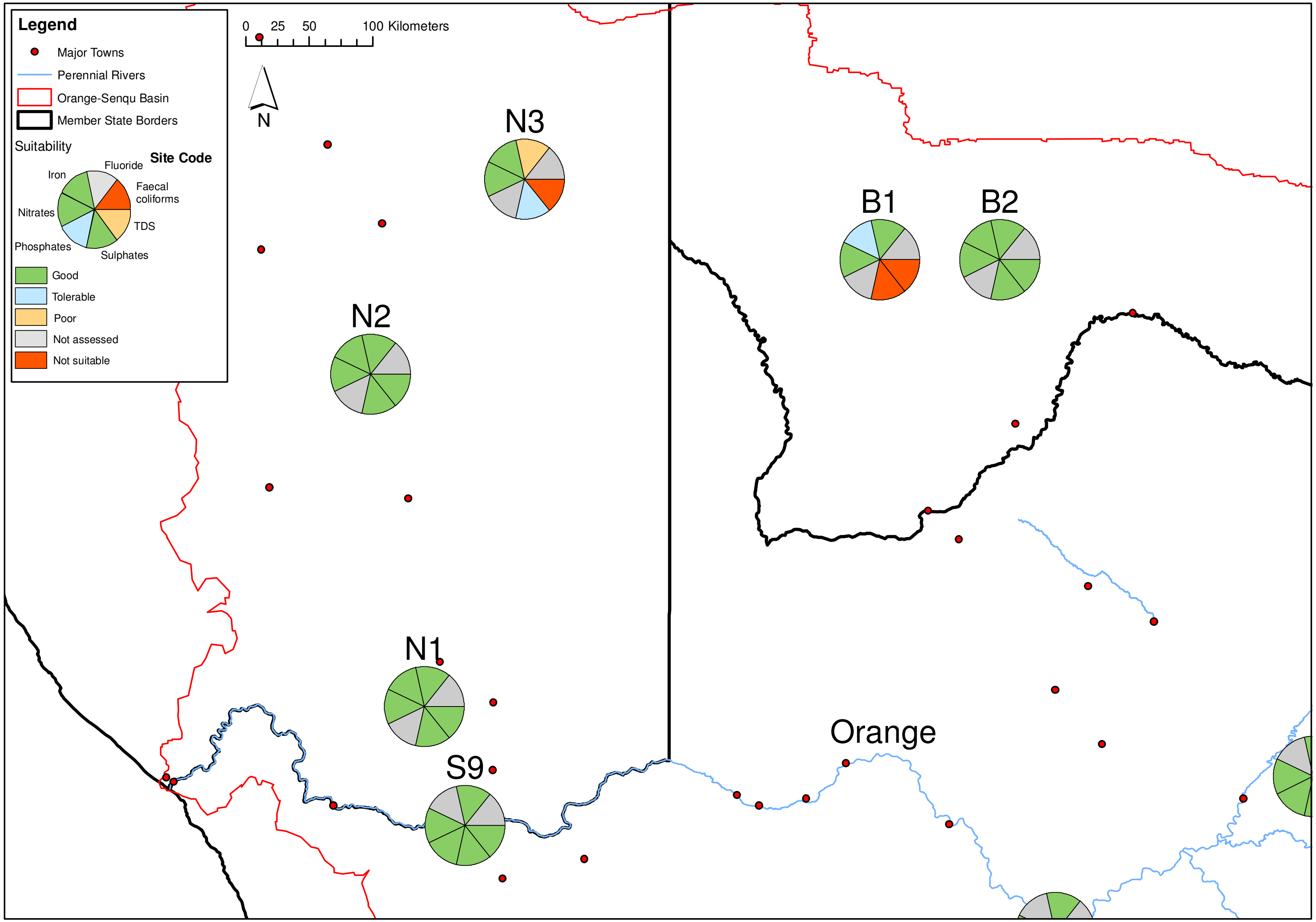


Figure 0-4 Agricultural Livestock Sub-basins B1, B2, N1, N2, N3 and S9 Map



Appendix E – Domestic Water Use Maps

Figure 0-1 Domestic Overview Map

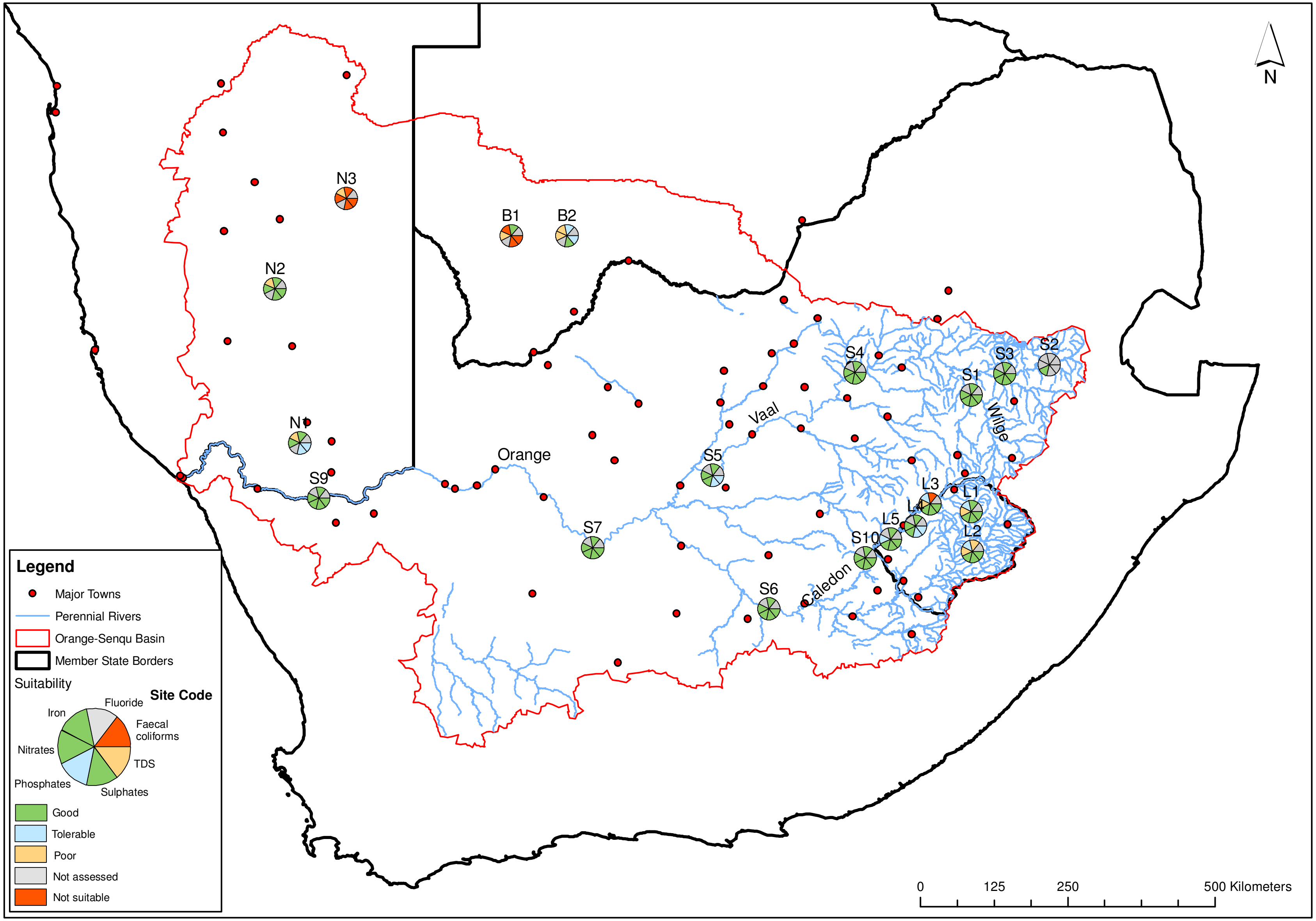


Figure 0-2 Domestic Sub-basins S1, S2, S3, S4 and S5 Map

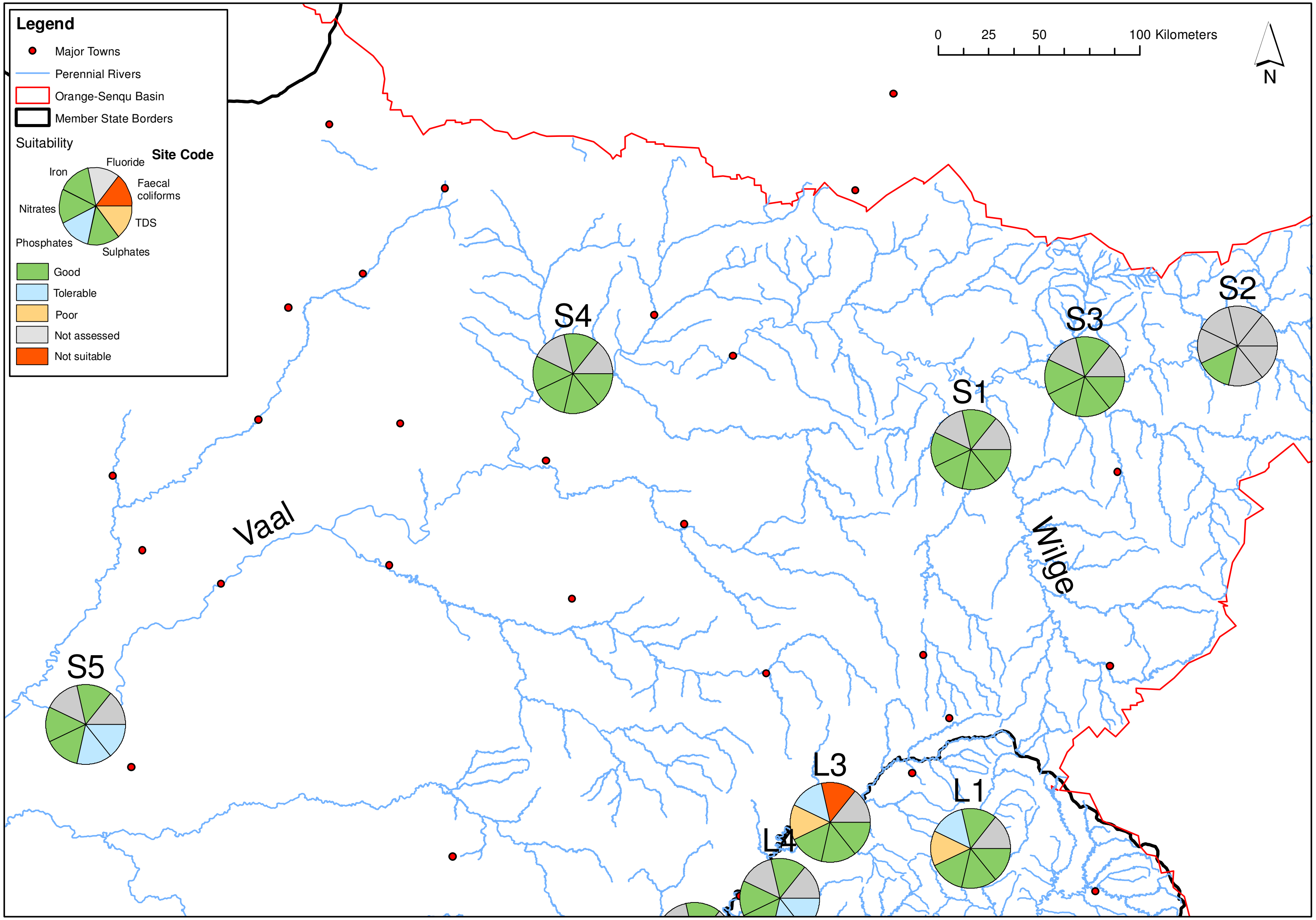


Figure 0-3 Domestic Sub-basins L1, L2, L3, L4, L5, S6, S7 and S10 Map

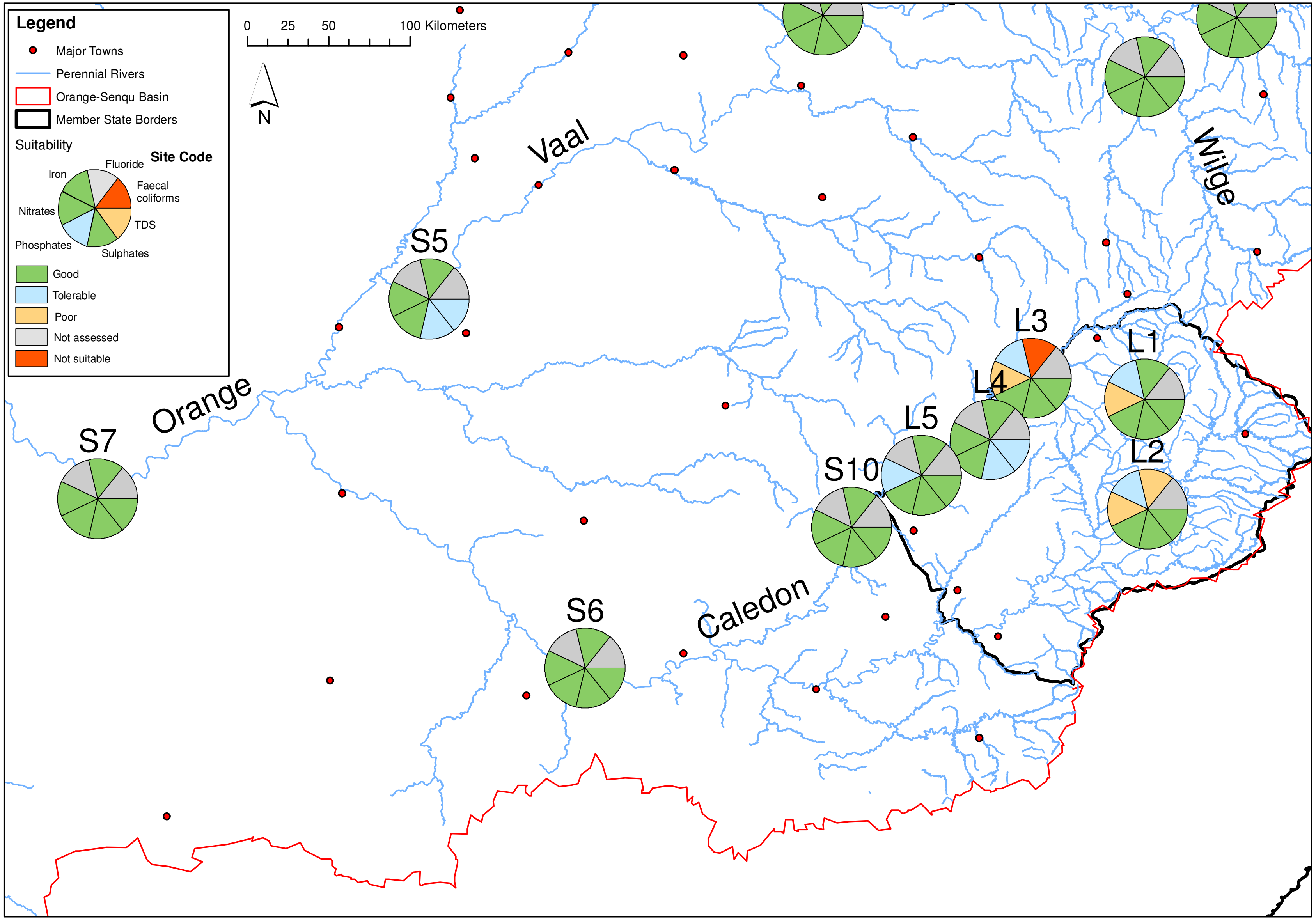
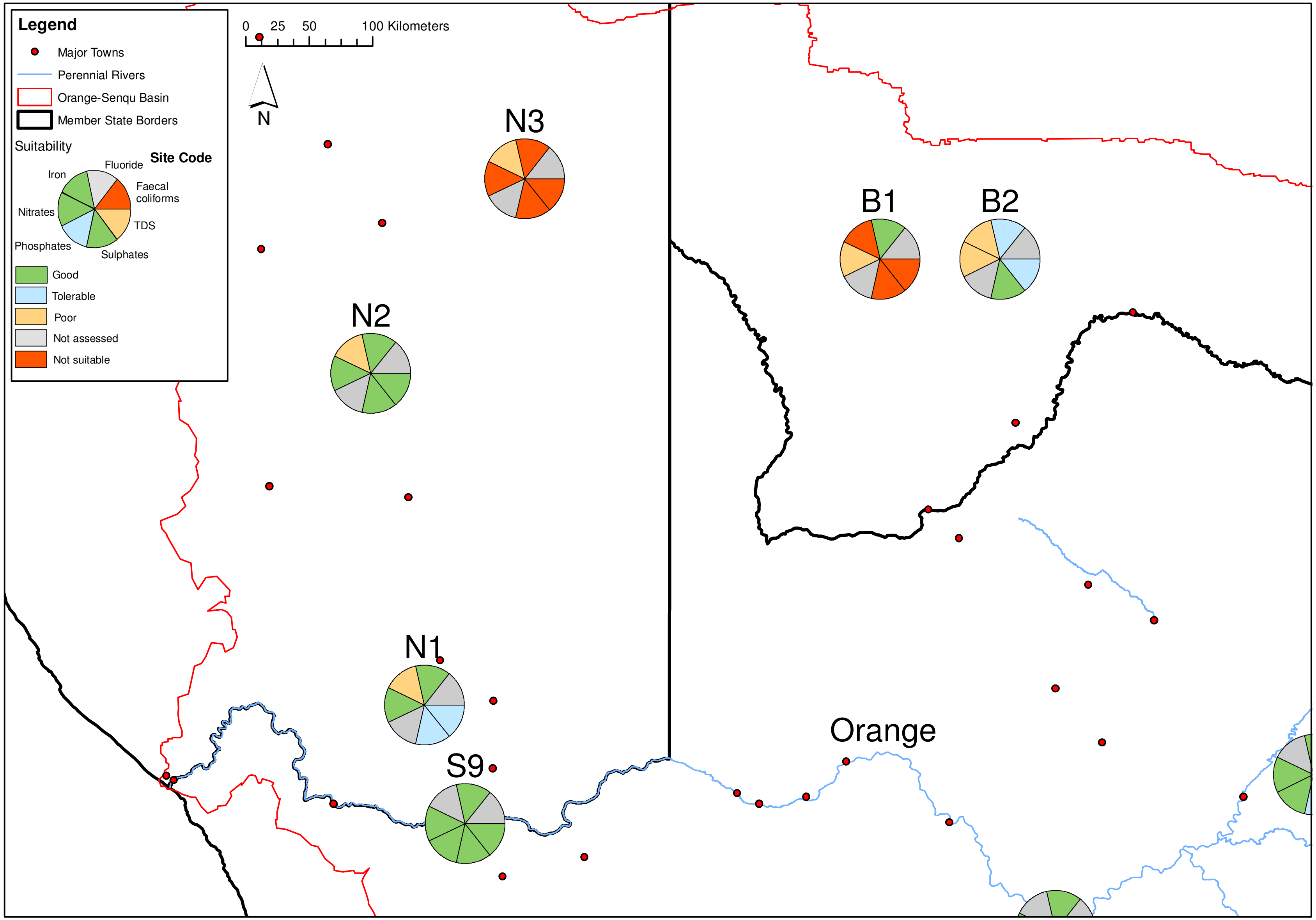


Figure 0-4 Domestic Sub-basins B1, B2, N1, N2, N3 and S9 Map



Appendix F – Industrial Water Use Maps

Figure 0-1 Industrial Category I Overview Map

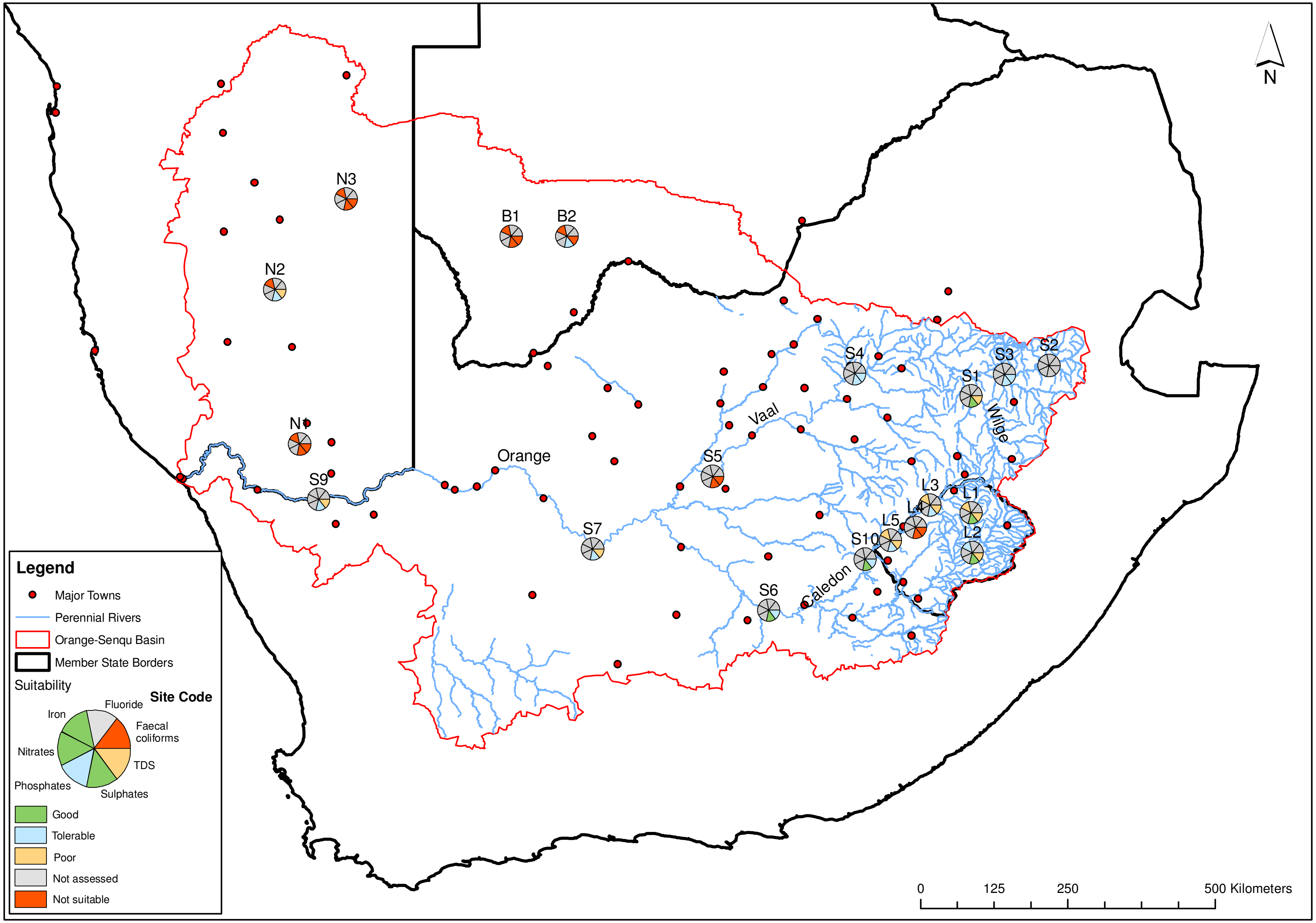


Figure 0-2 Industrial Category I Sub-basins S1, S2, S3, S4 and S5 Map

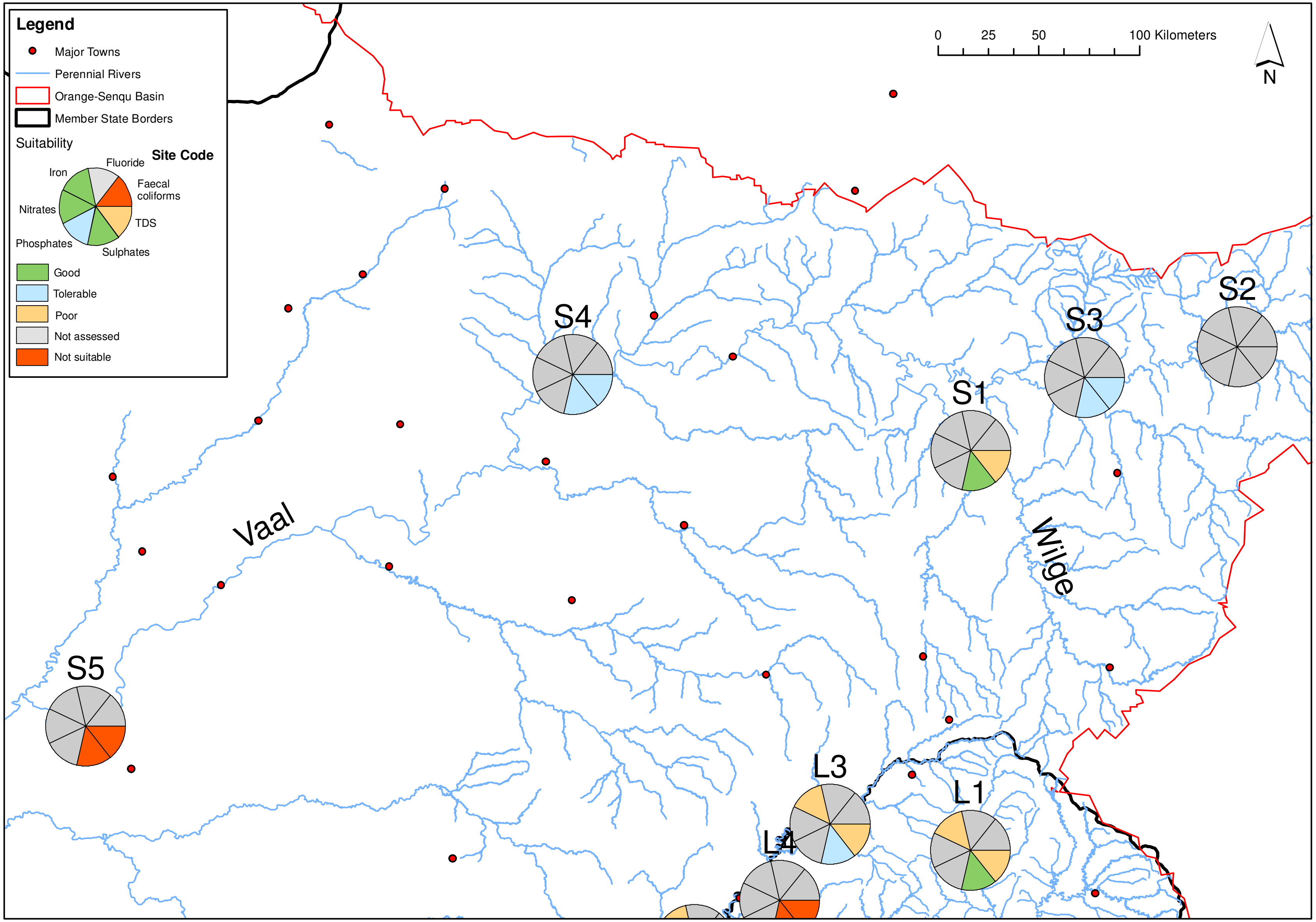


Figure 0-3 Industrial Category I Sub-basins L1, L2, L3, L4, L5, S6, S7 and S10 Map

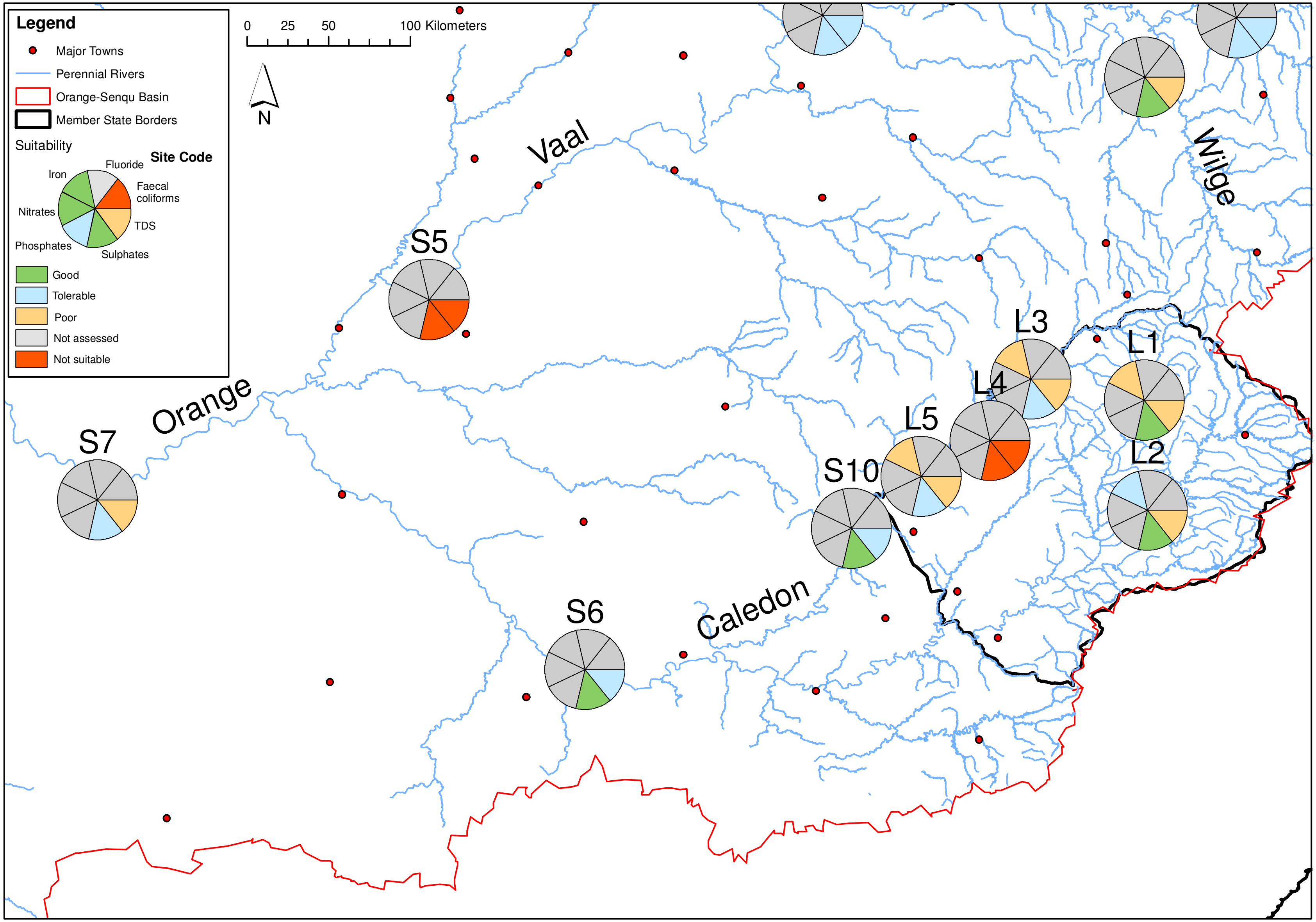


Figure 0-4 Industrial Category I Sub-basins B1, B2, N1, N2, N3 and S9 Map

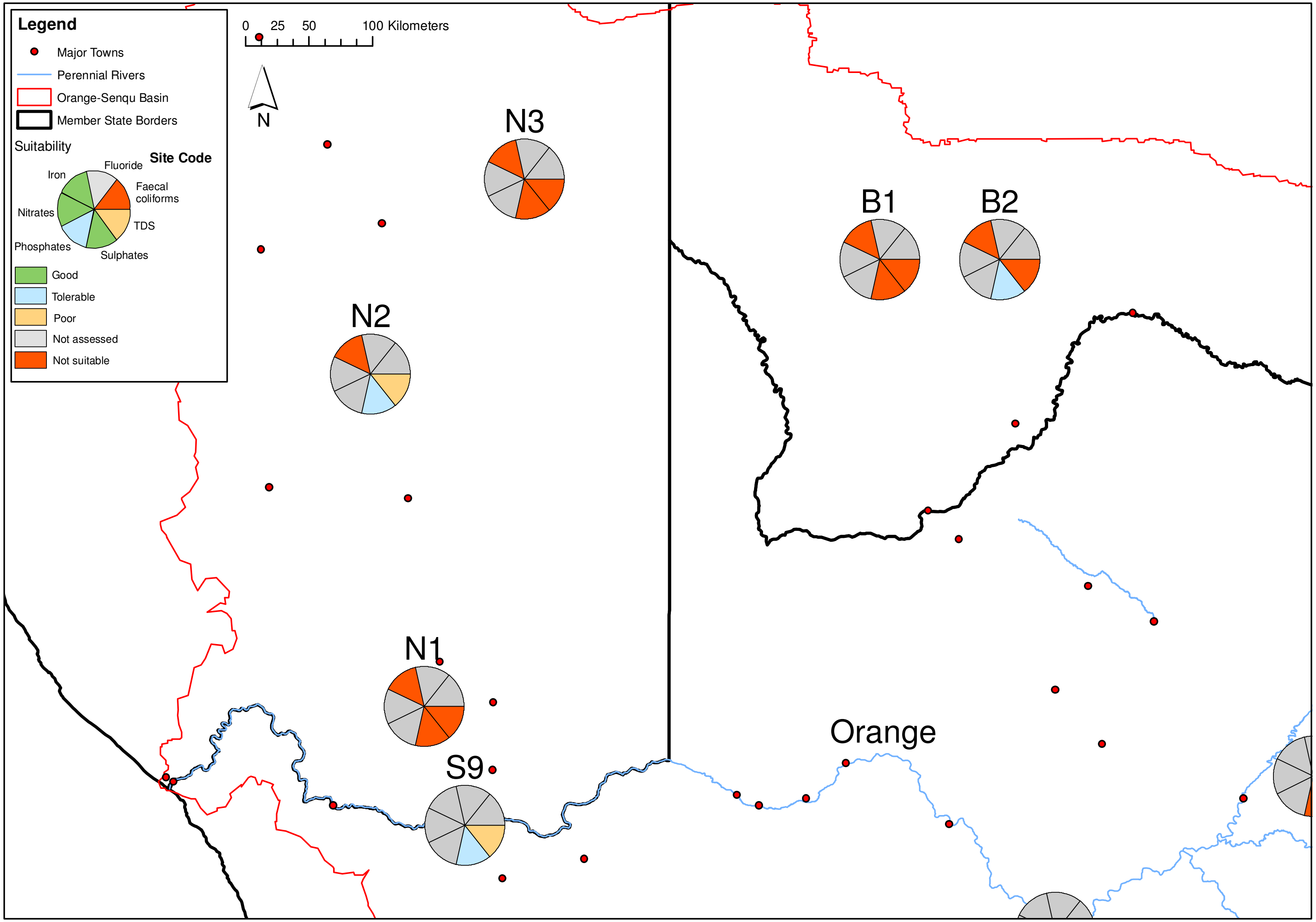


Figure 0-5 Industrial Category II Overview Map

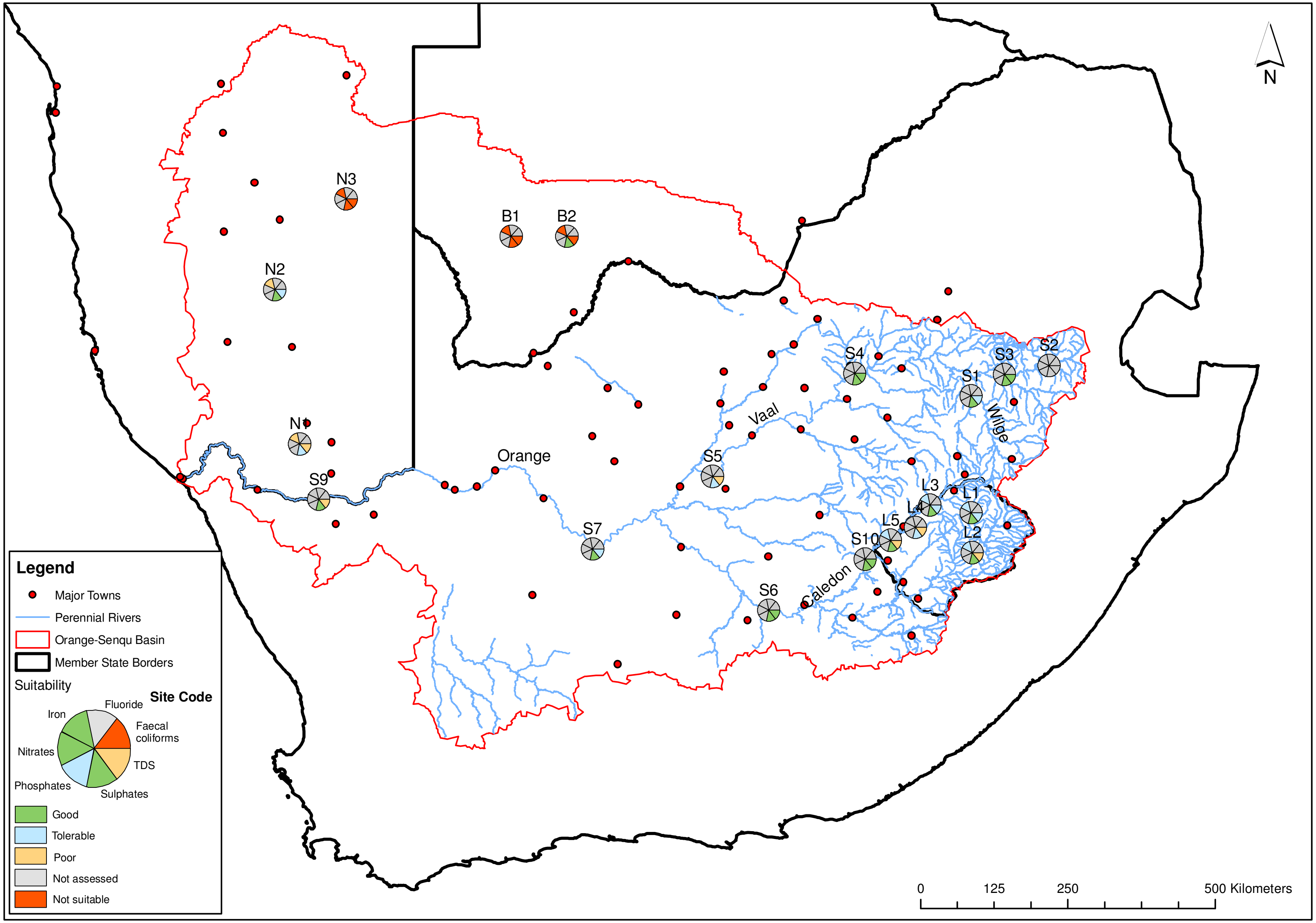


Figure 0-6 Industrial Category II Sub-basins S1, S2, S3, S4 and S5 Map

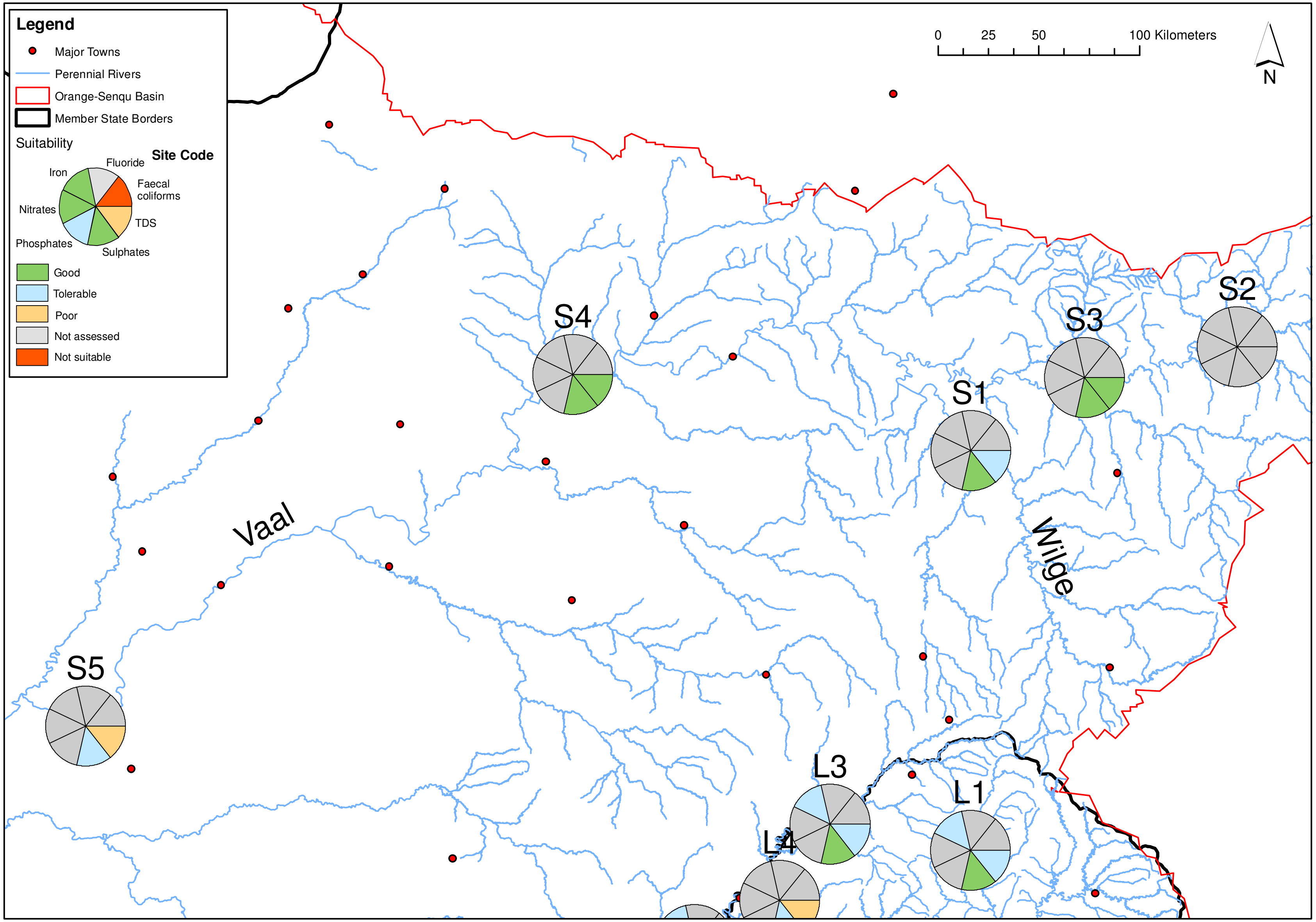


Figure 0-7 Industrial Category II Sub-basins L1, L2, L3, L4, L5, S6, S7 and S10 Map

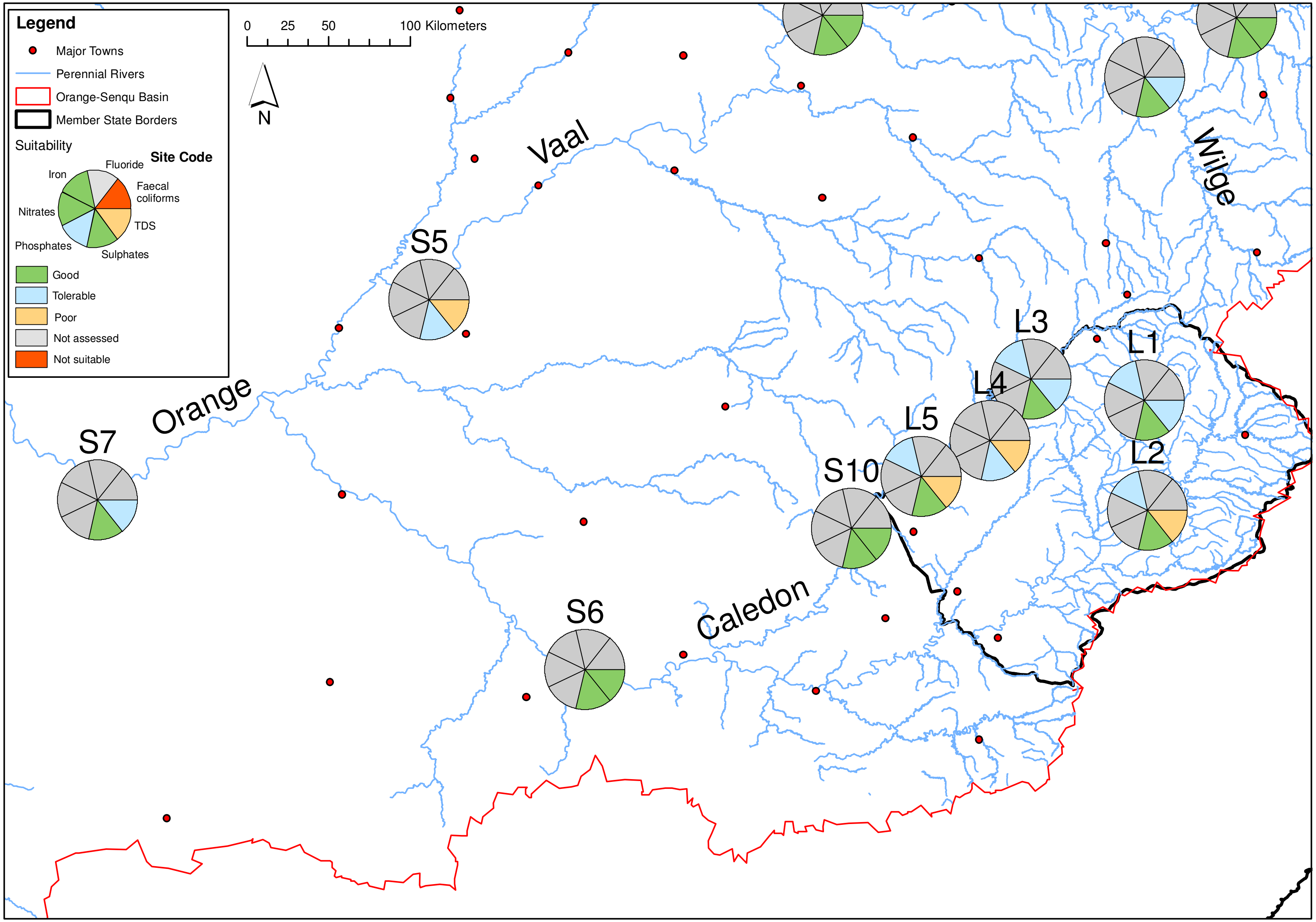


Figure 0-8 Industrial Category II Sub-basins B1, B2, N1, N2, N3 and S9 Map

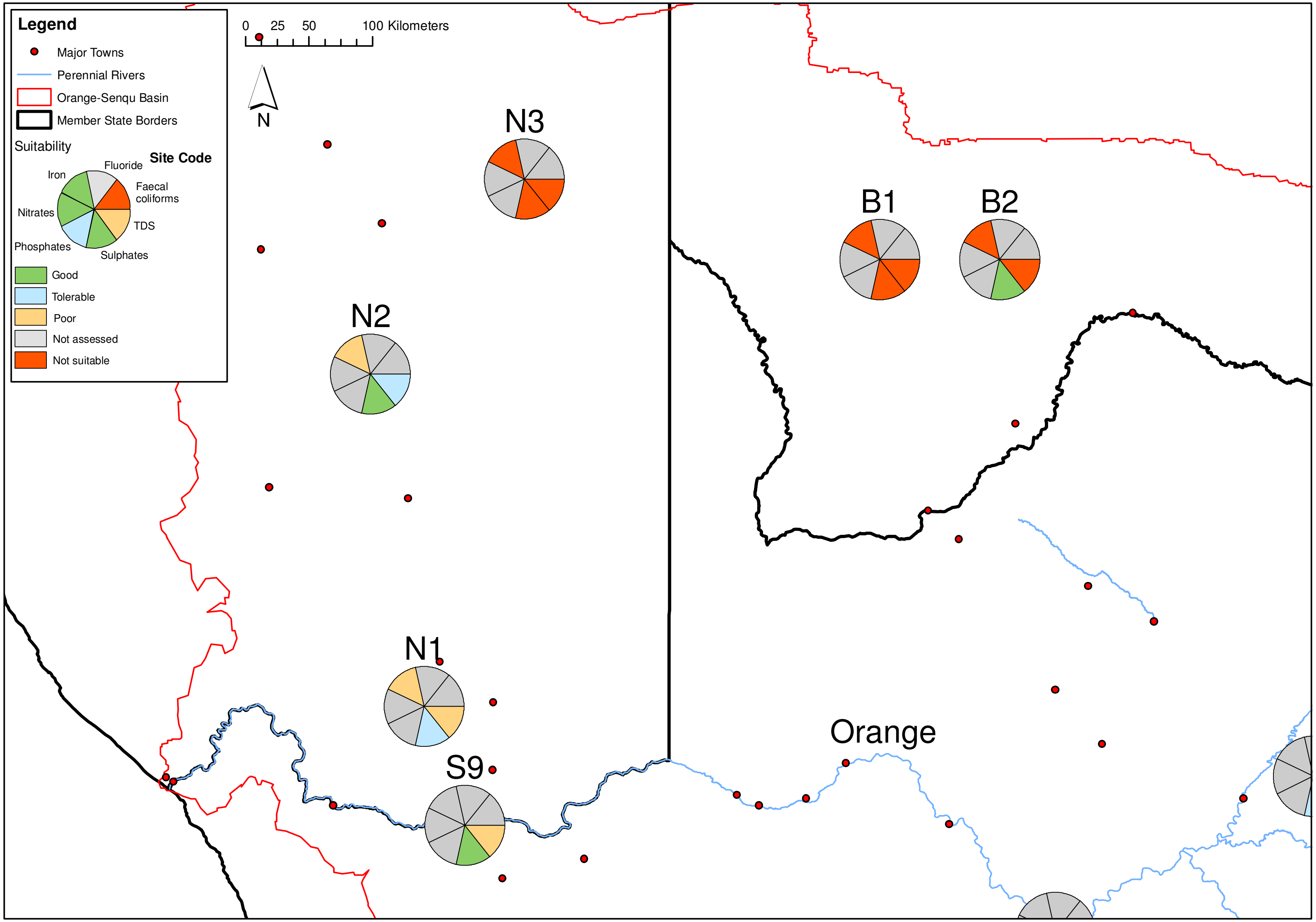


Figure 0-9 Industrial Category III Overview Map

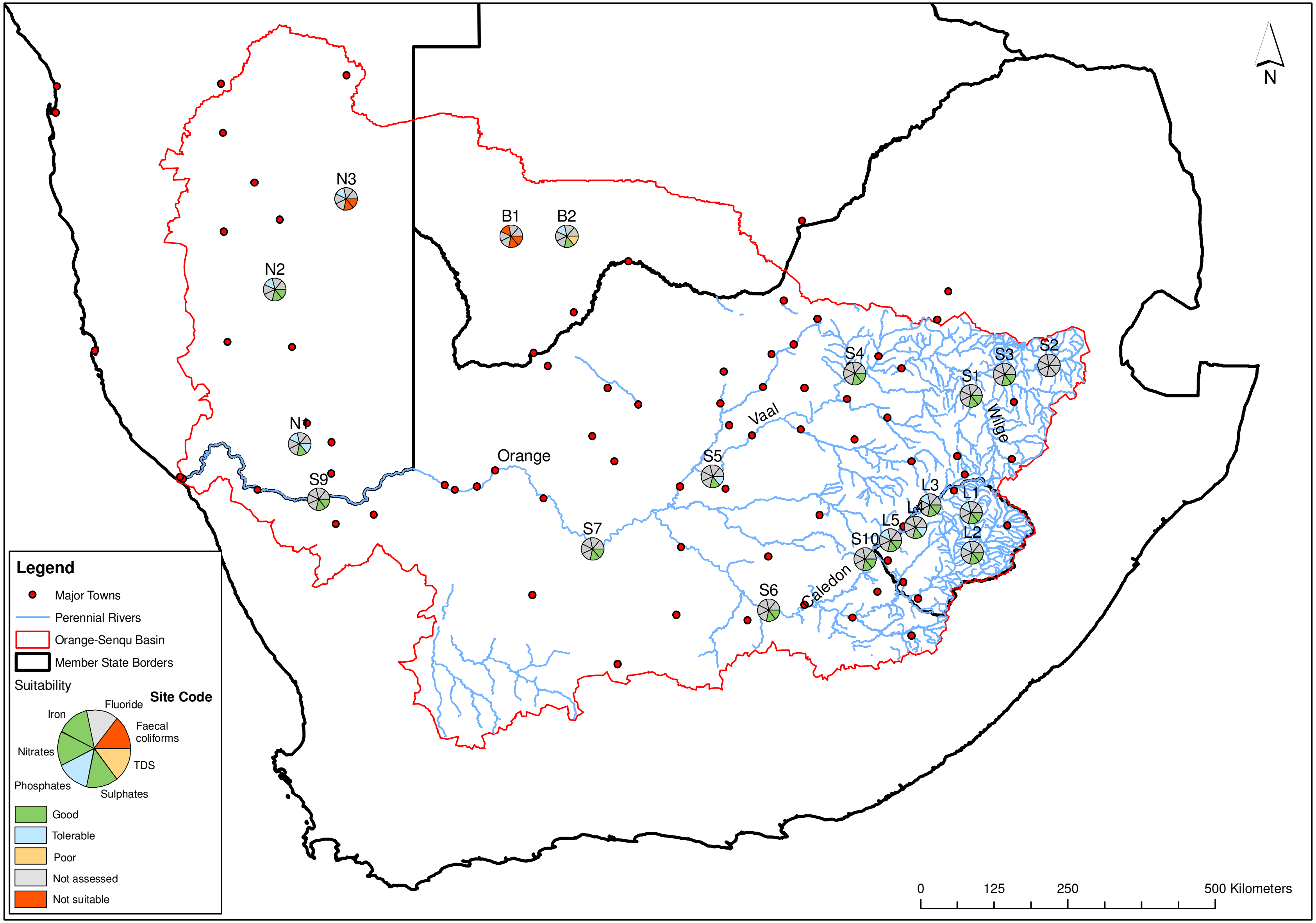


Figure 0-10 Industrial Category III Sub-basins S1, S2, S3, S4 and S5 Map

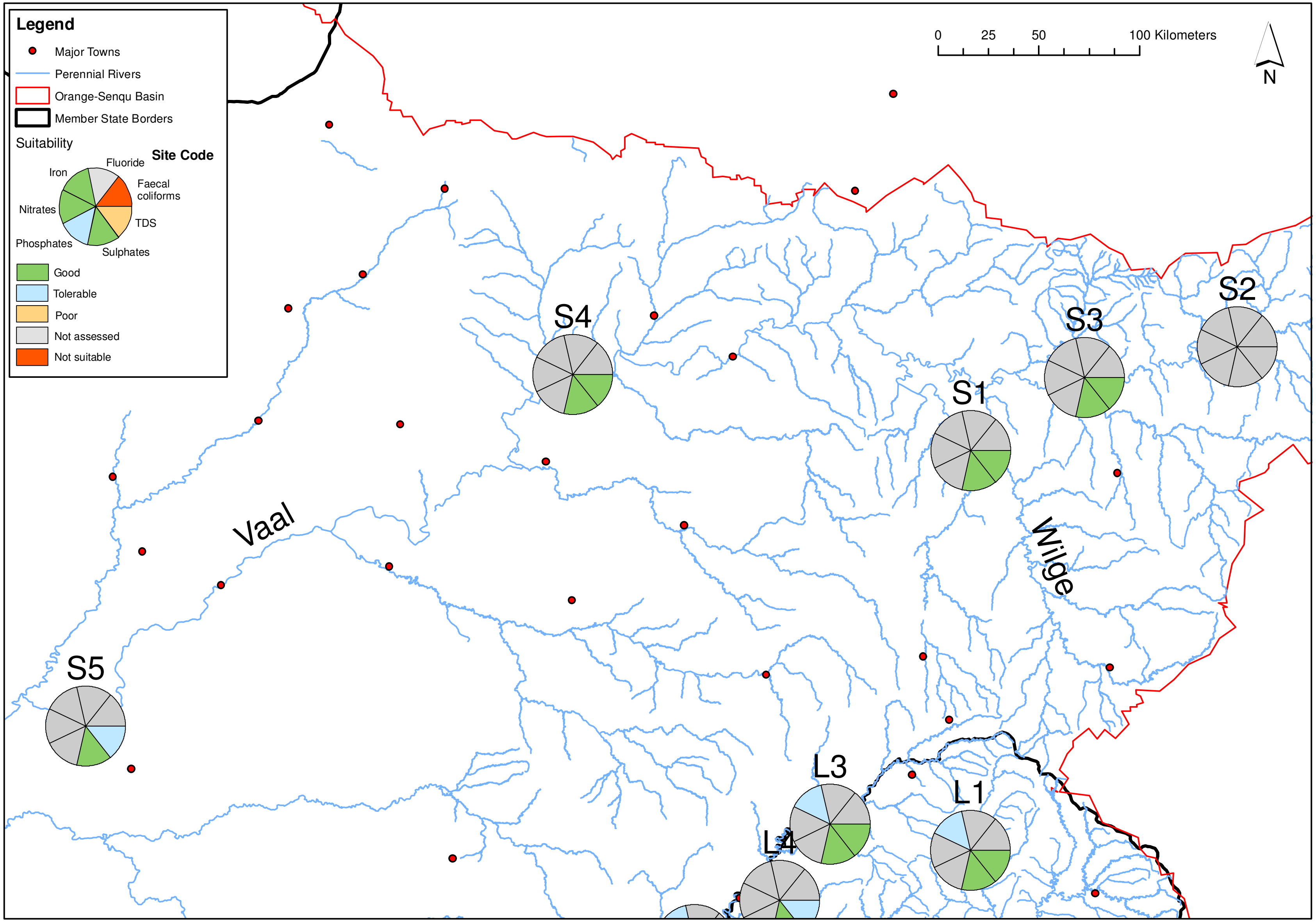


Figure 0-11 Industrial Category III Sub-basins L1, L2, L3, L4, L5, S6, S7 and S10 Map

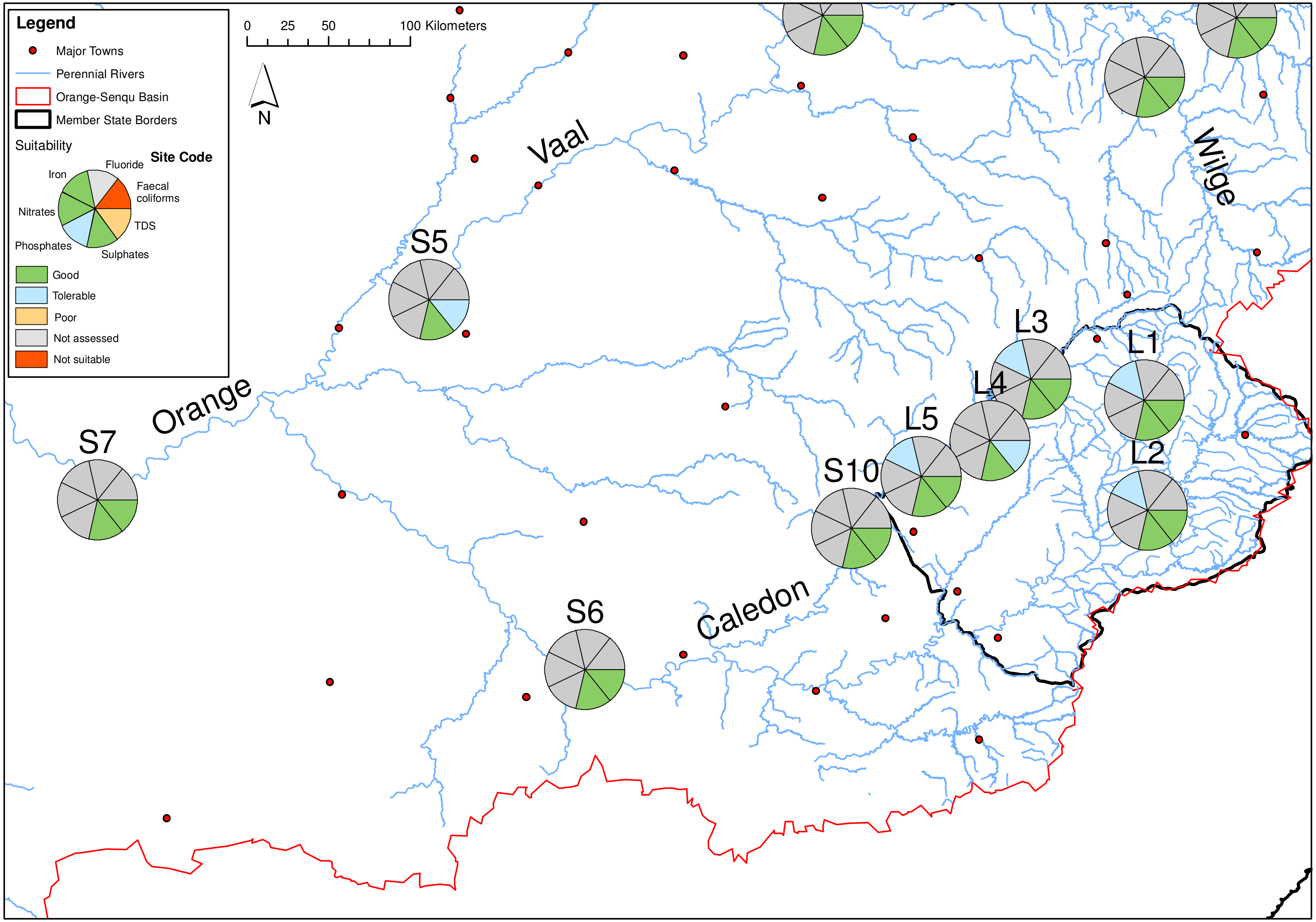


Figure 0-12 Industrial Category III Sub-basins B1, B2, N1, N2, N3 and S9 Map

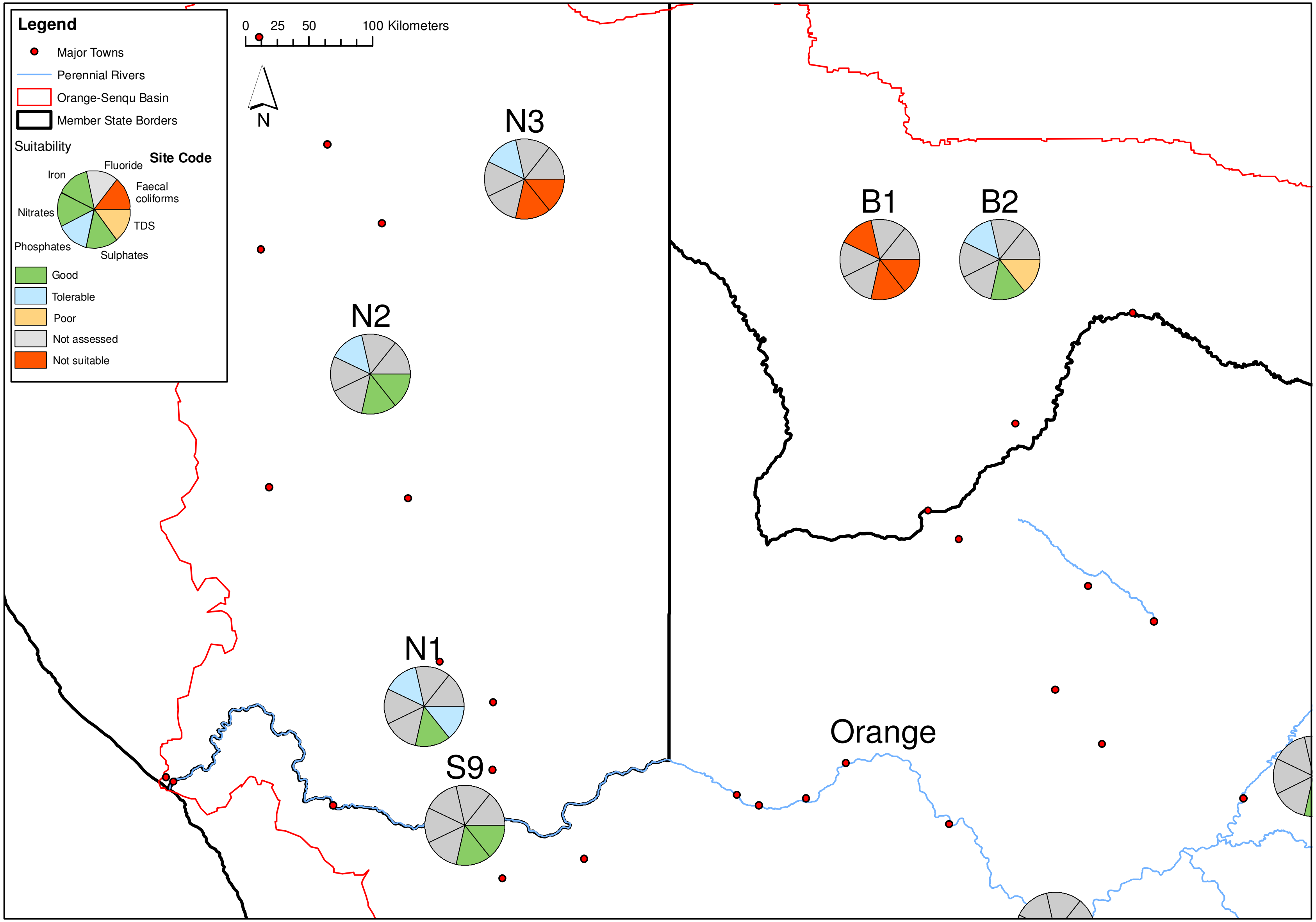


Figure 0-13 Industrial Category IV Overview Map

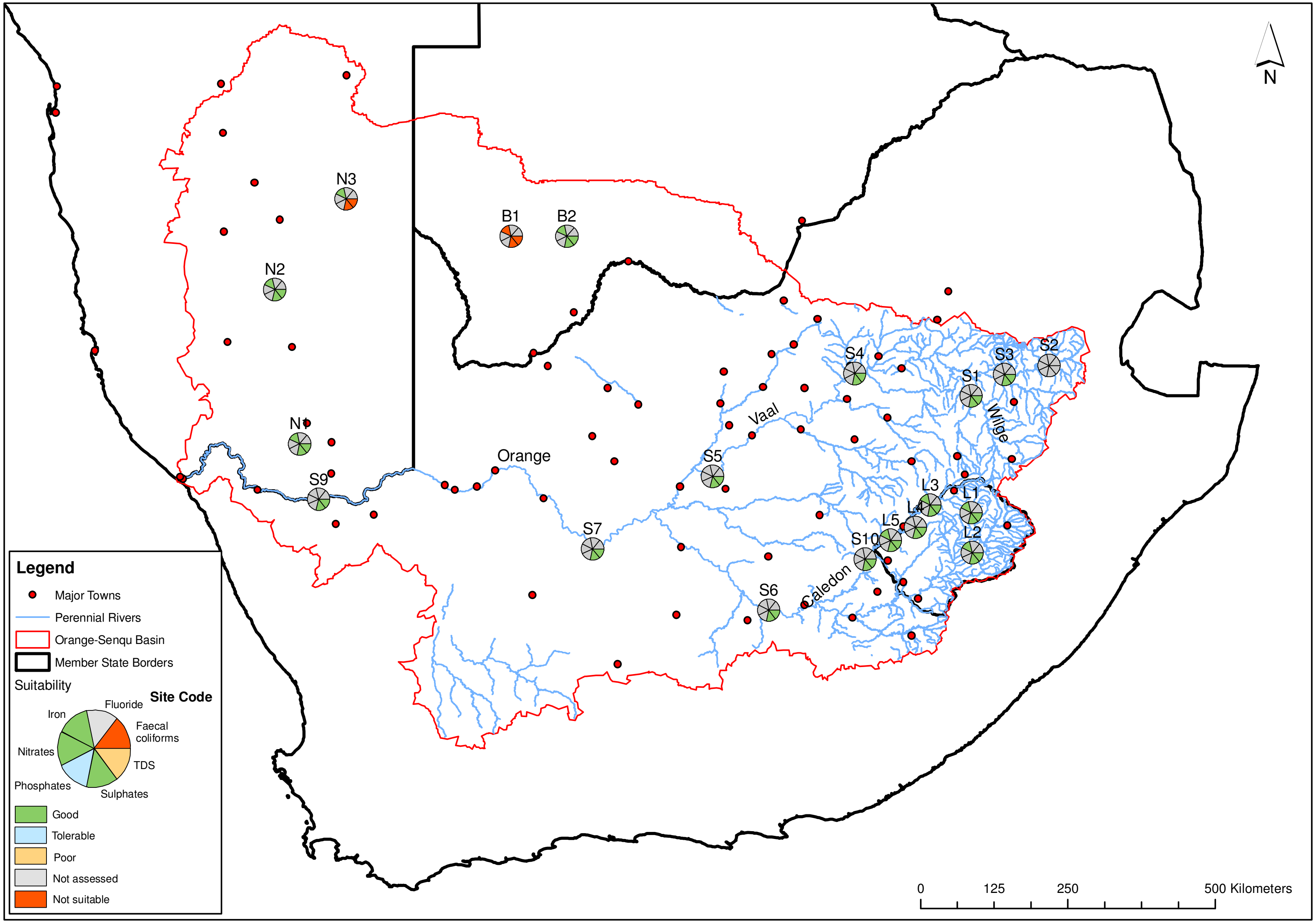


Figure 0-14 Industrial Category IV Sub-basins S1, S2, S3, S4 and S5 Map

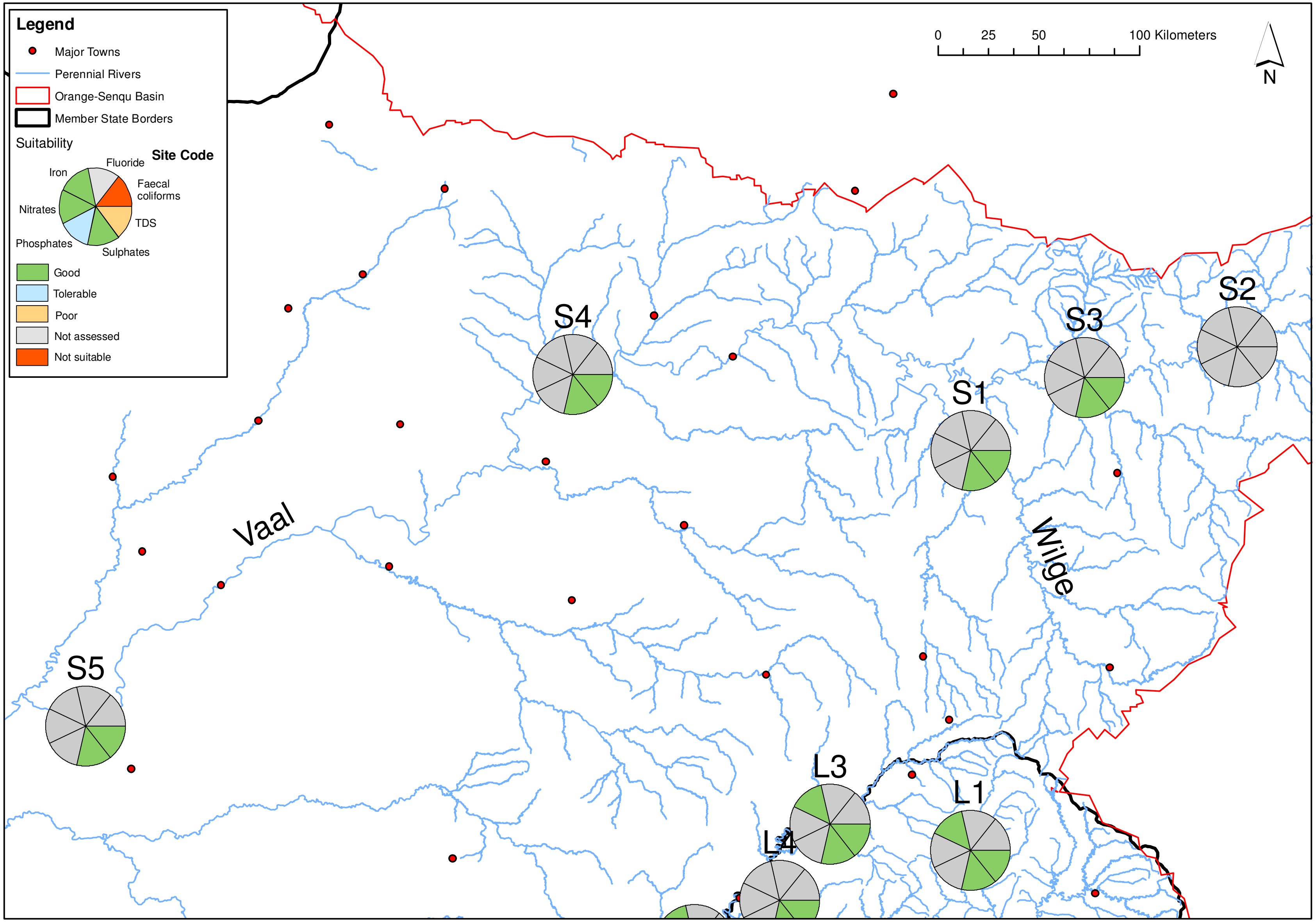


Figure 0-15 Industrial Category IV Sub-basins L1, L2, L3, L4, L5, S6, S7 and S10 Map

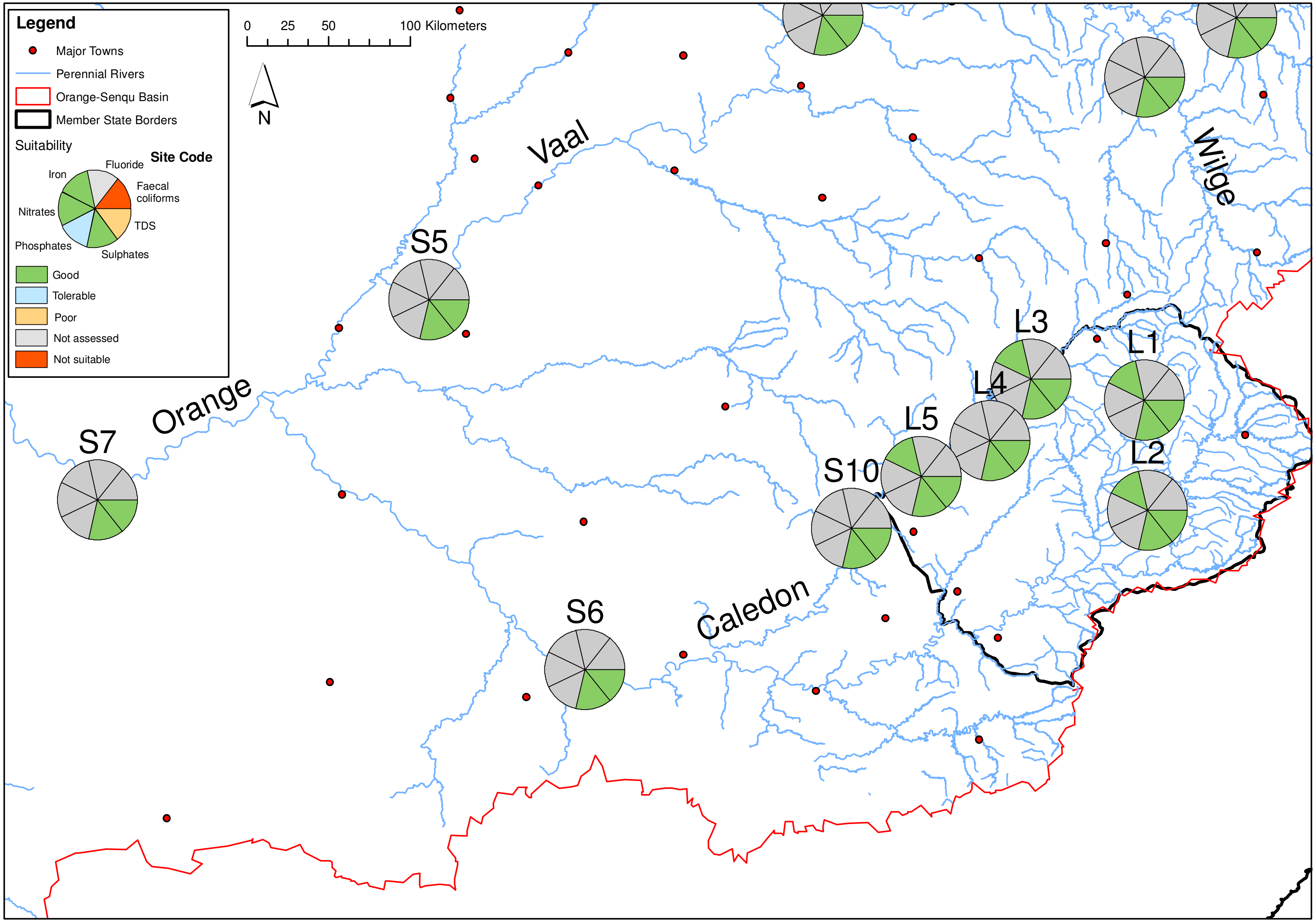
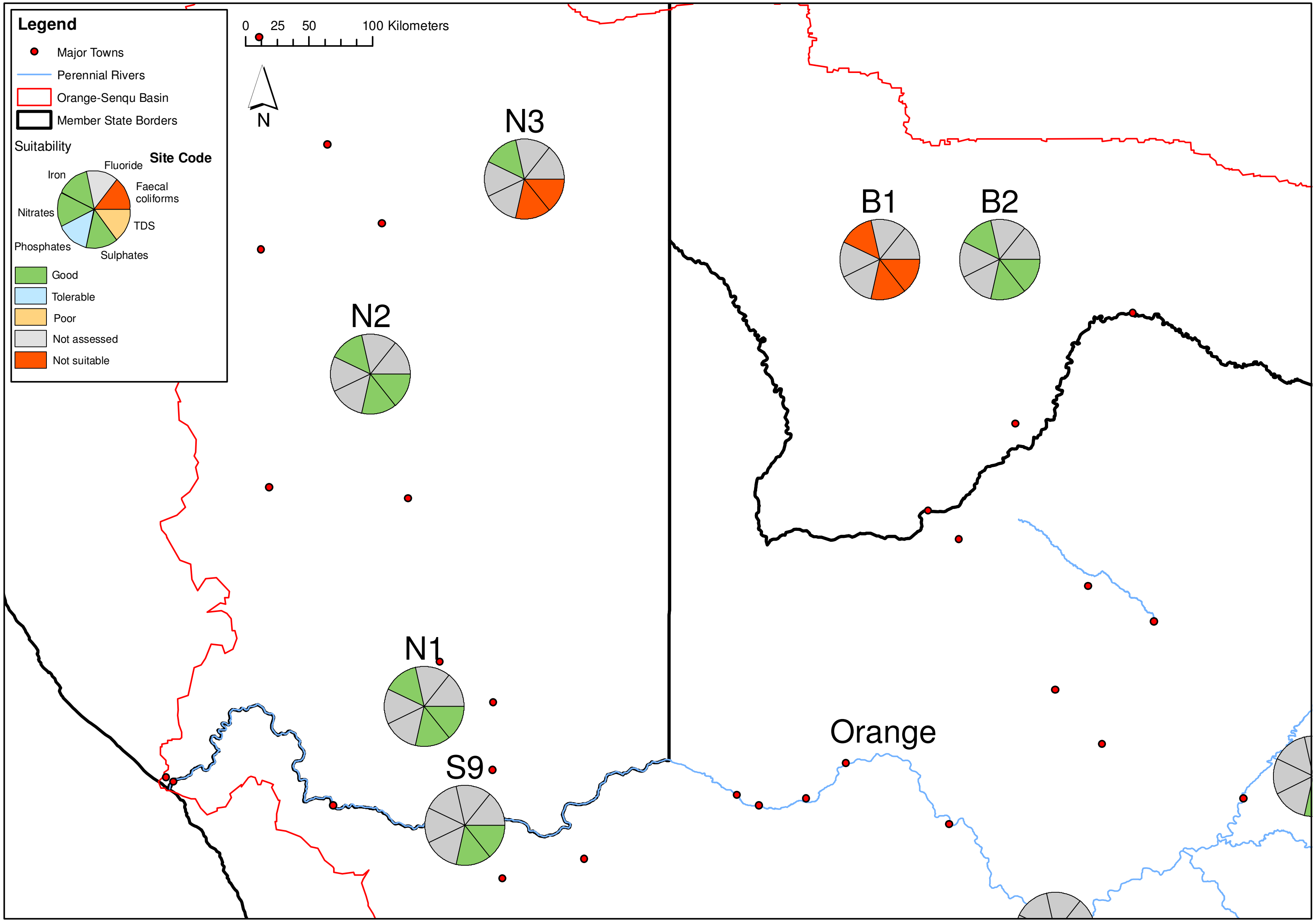


Figure 0-16 Industrial Category IV Sub-basins B1, B2, N1, N2, N3 and S9 Map



Appendix G – Recreational Water Use Maps

Figure 0-1 Recreational (full contact) Overview Map

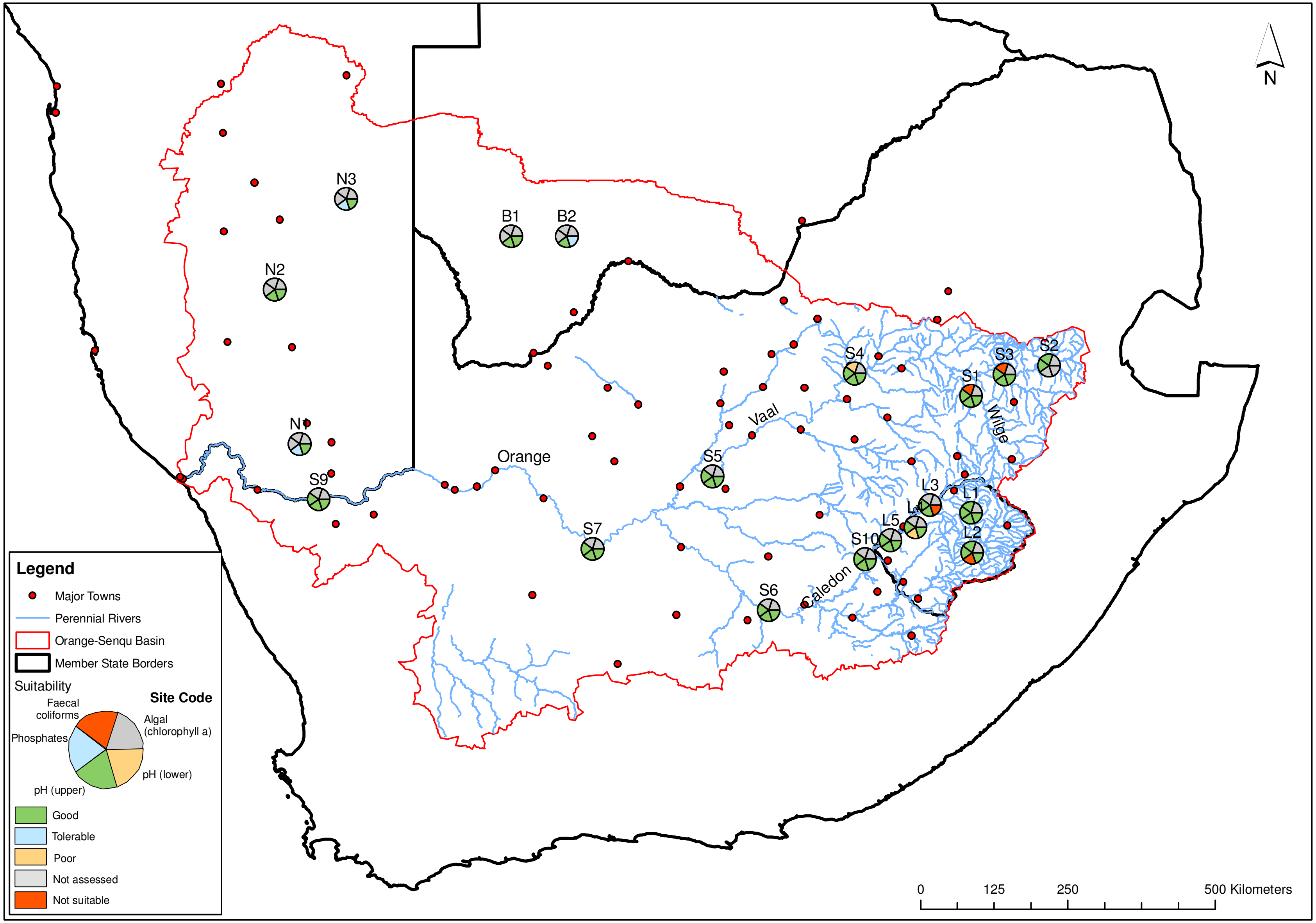


Figure 0-2 Recreational (full contact) Sub-basins S1, S2, S3, S4 and S5 Map

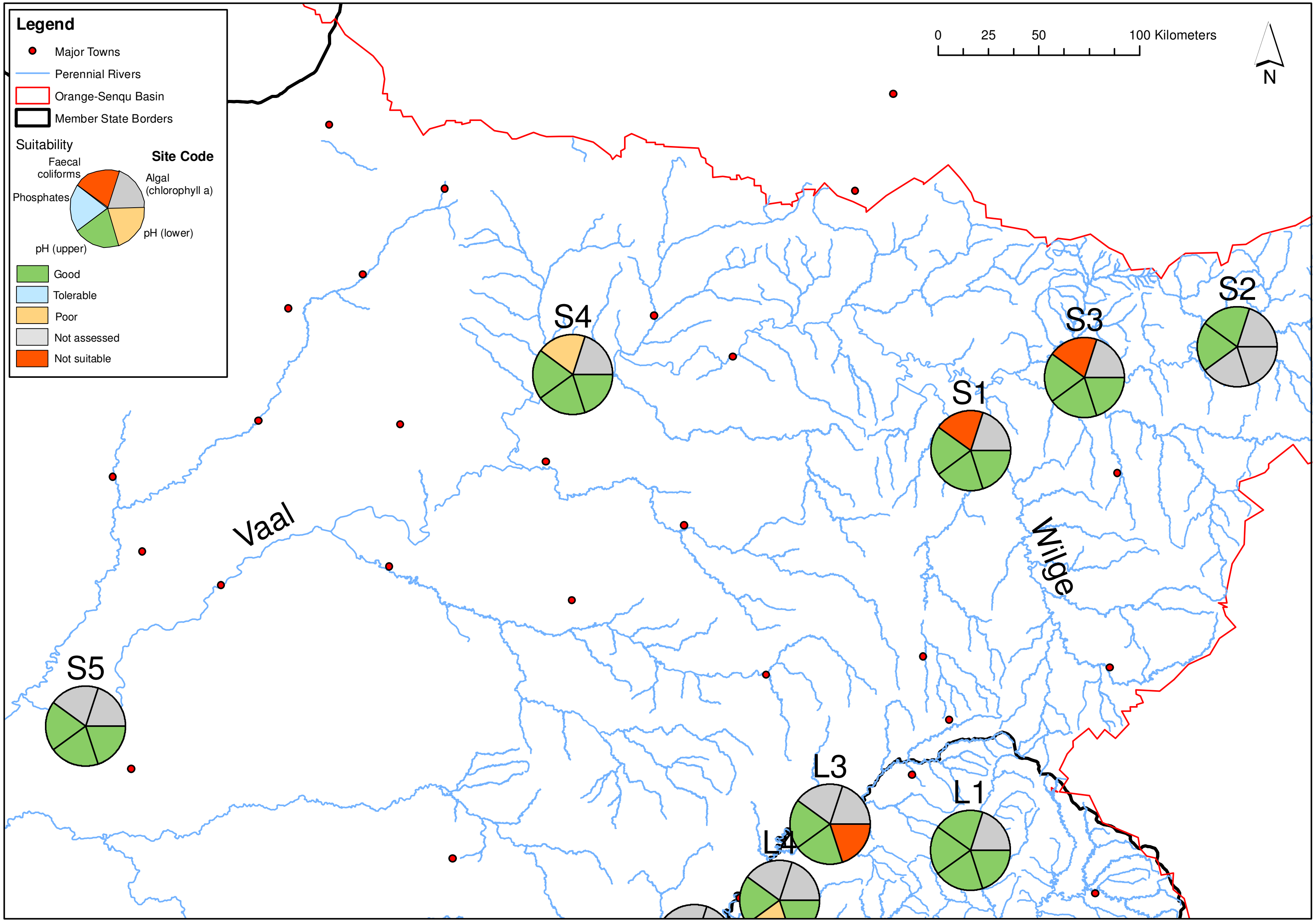


Figure 0-3 Recreational (full contact) Sub-basins L1, L2, L3, L4, L5, S6, S7 and S10 Map

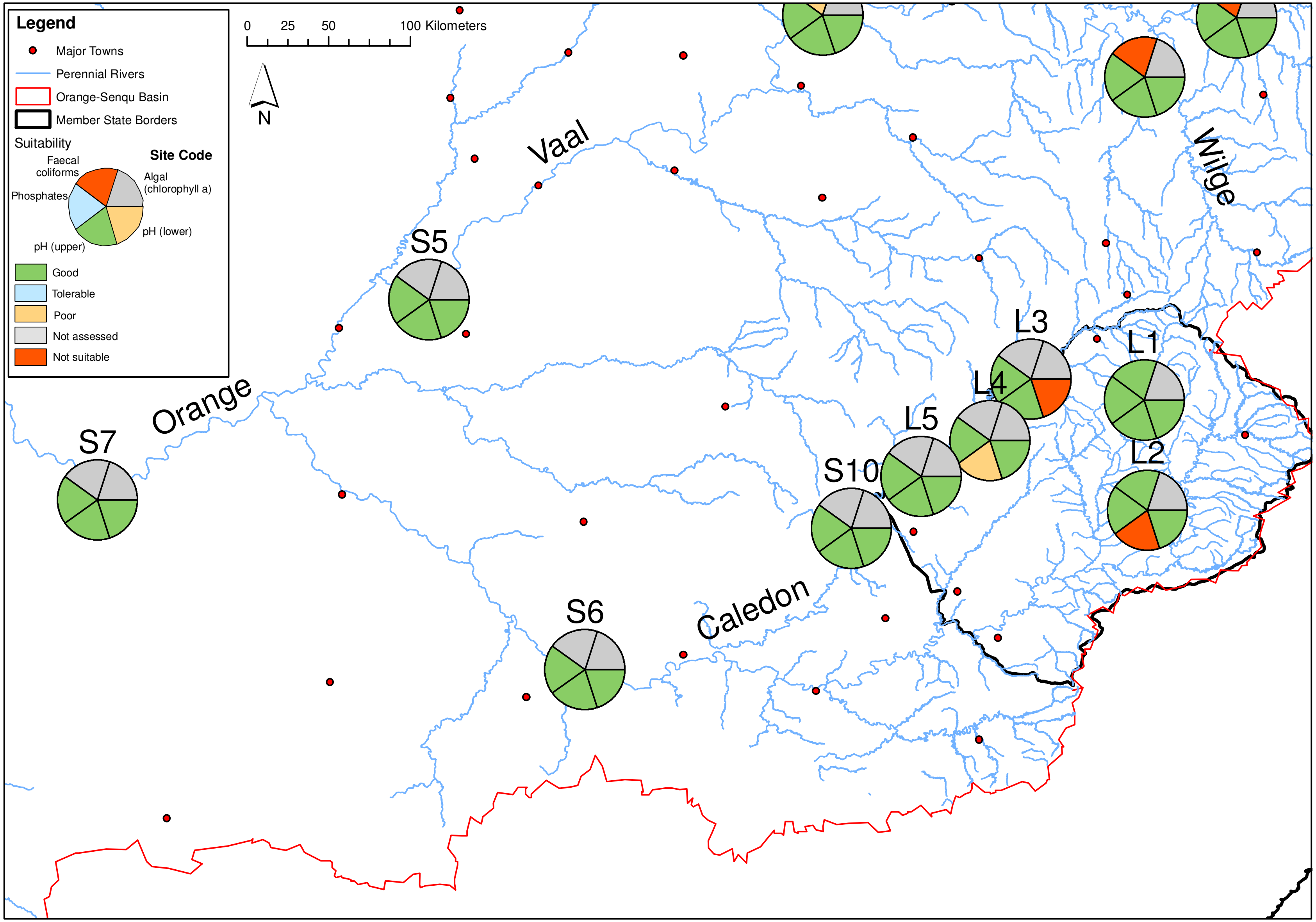


Figure 0-4 Recreational (full contact) Sub-basins B1, B2, N1, N2, N3 and S9 Map

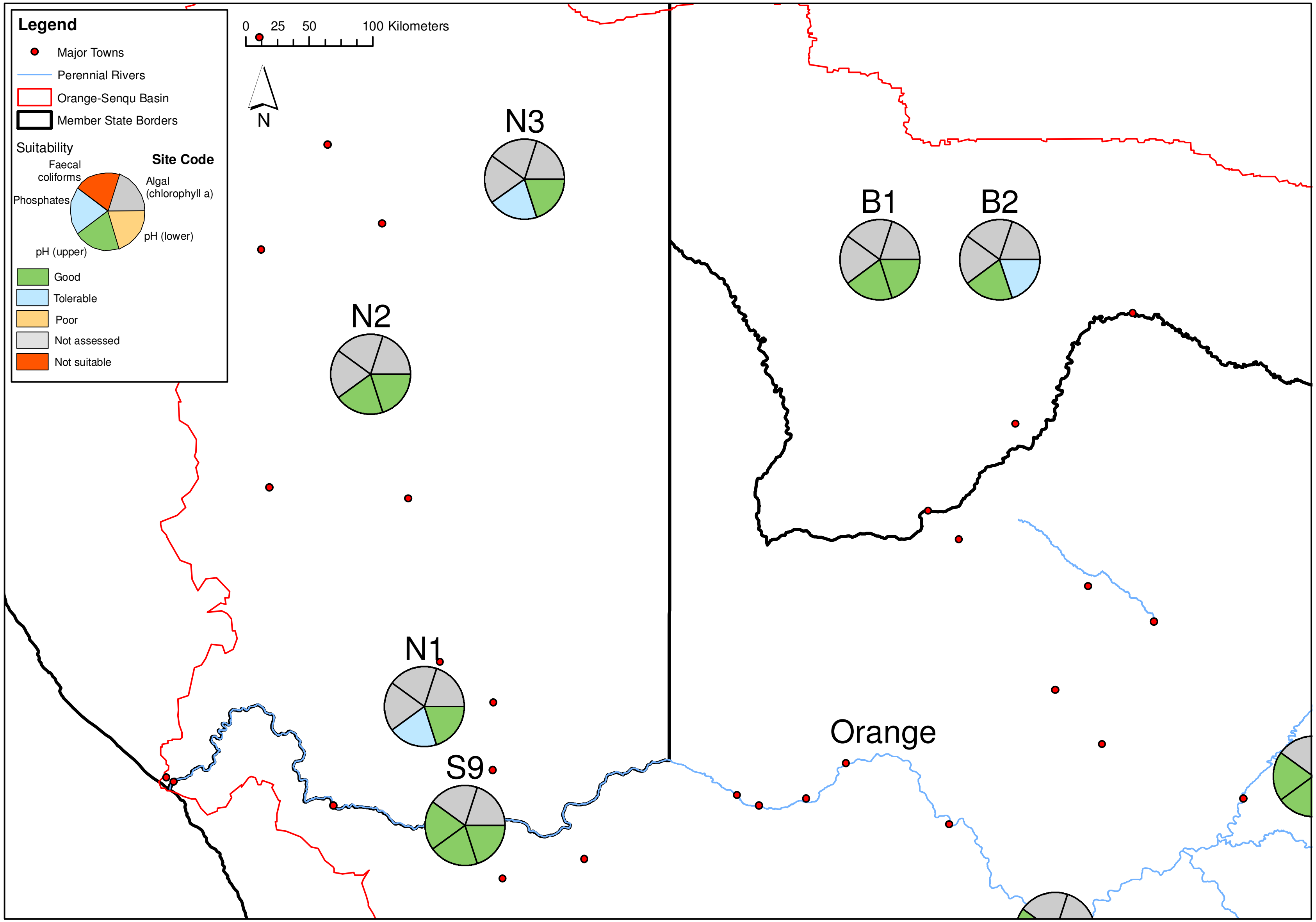


Figure 0-5 Recreational (intermediate contact) Overview Map

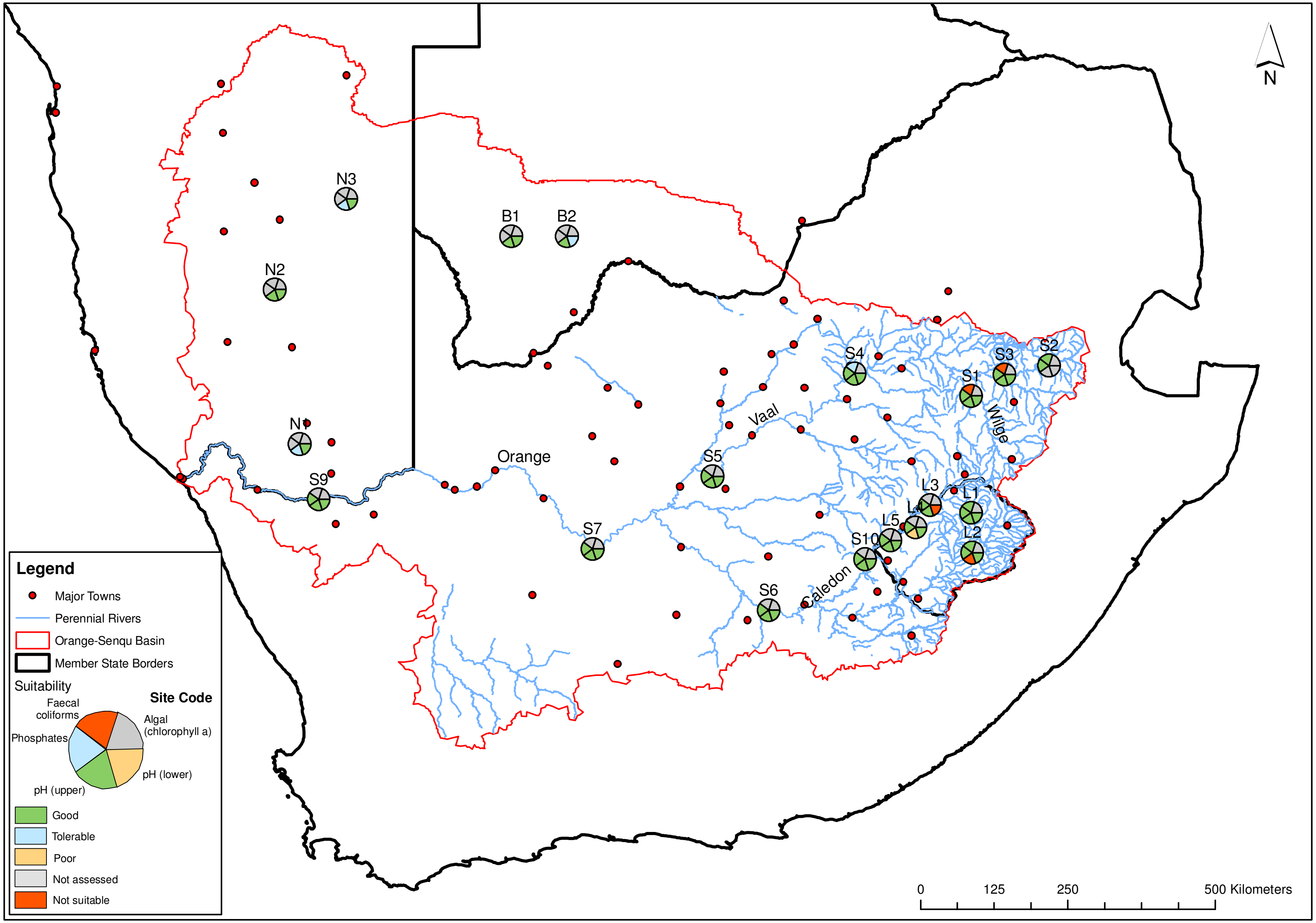


Figure 0-6 Recreational ((intermediate contact) Sub-basins S1, S2, S3, S4 and S5 Map

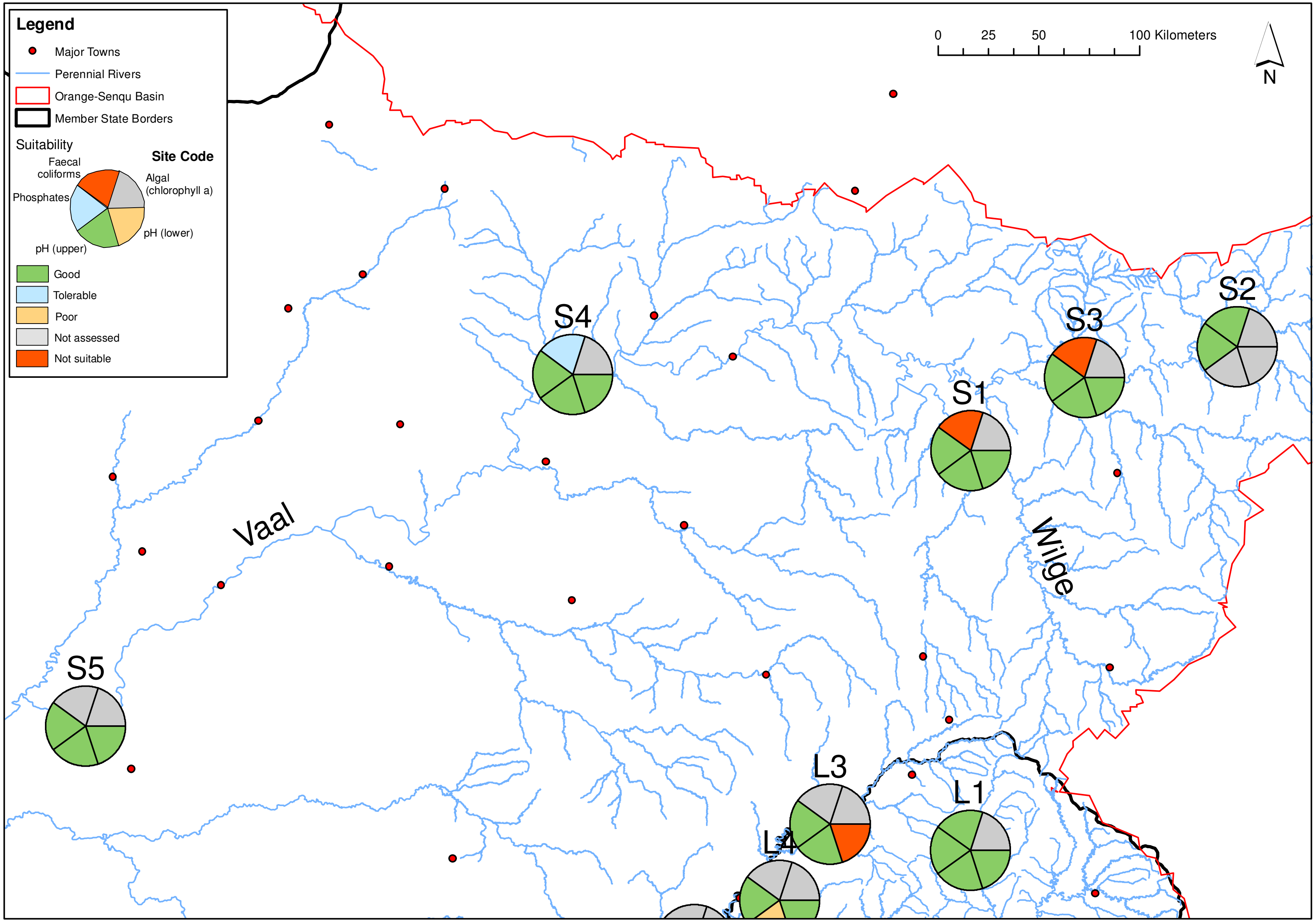


Figure 0-7 Recreational (intermediate contact) Sub-basins L1, L2, L3, L4, L5, S6, S7 and S10 Map

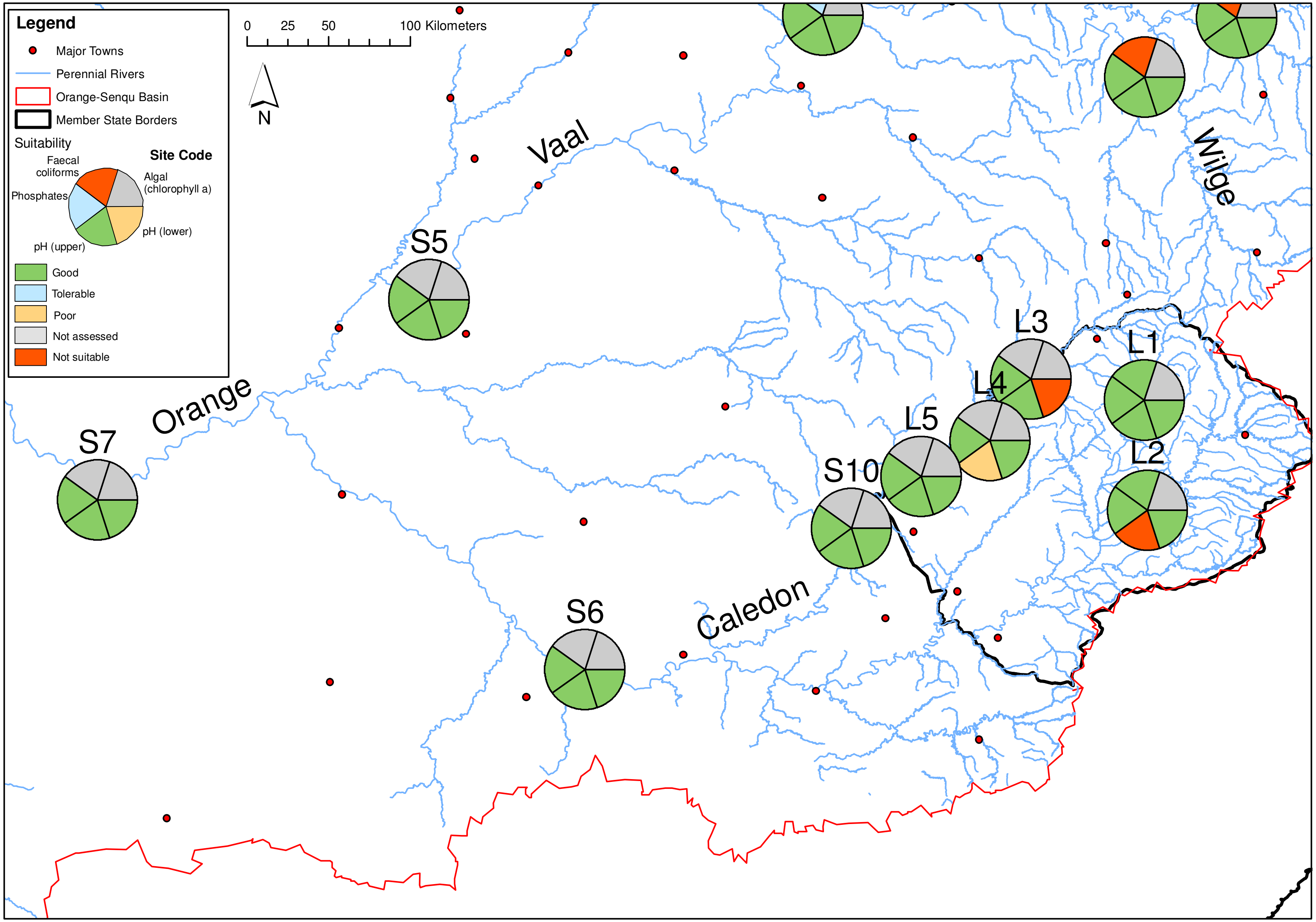


Figure 0-8 Recreational (intermediate contact) Sub-basins B1, B2, N1, N2, N3 and S9 Map

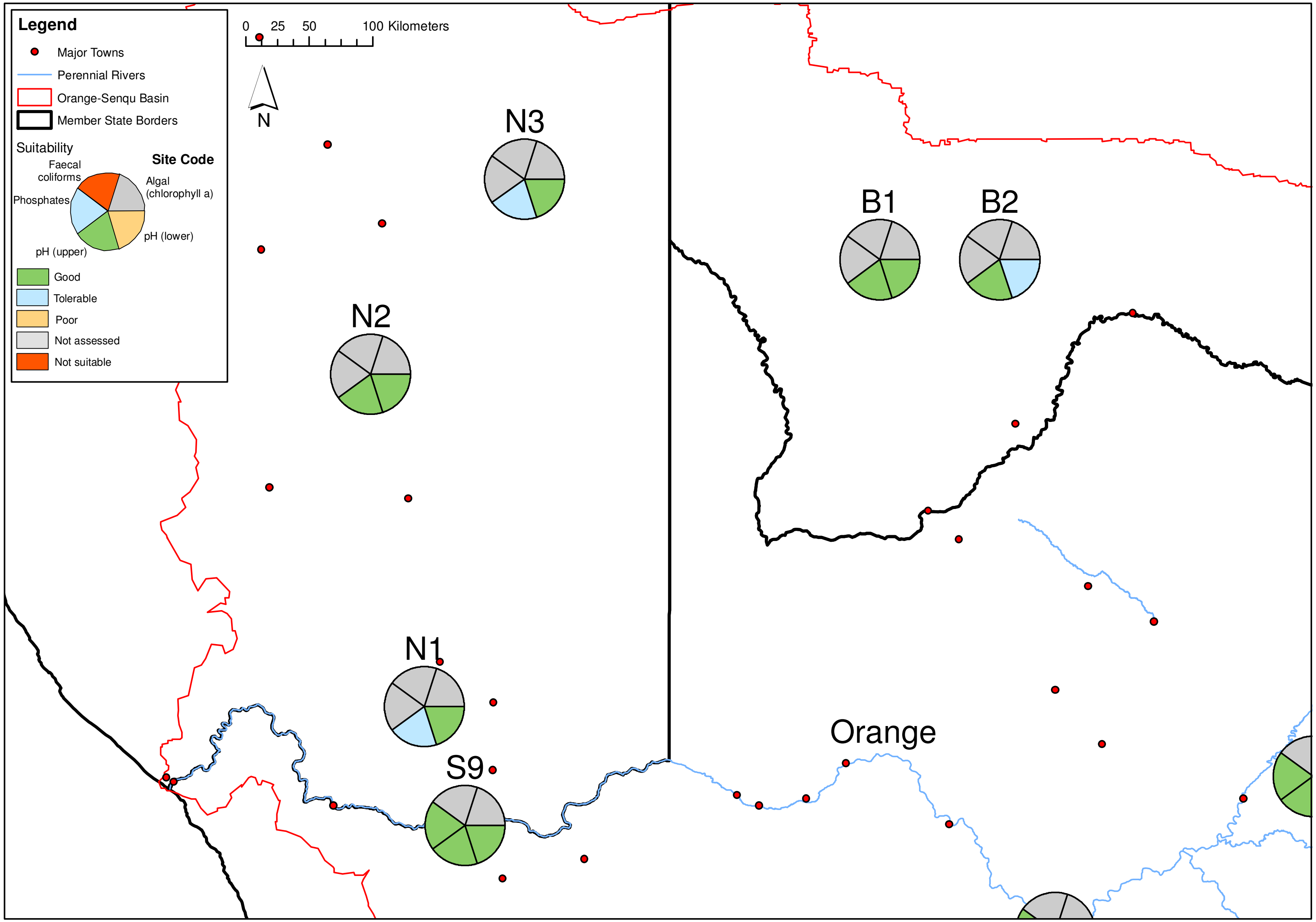


Figure 0-9 Recreational (no contact) Overview Map

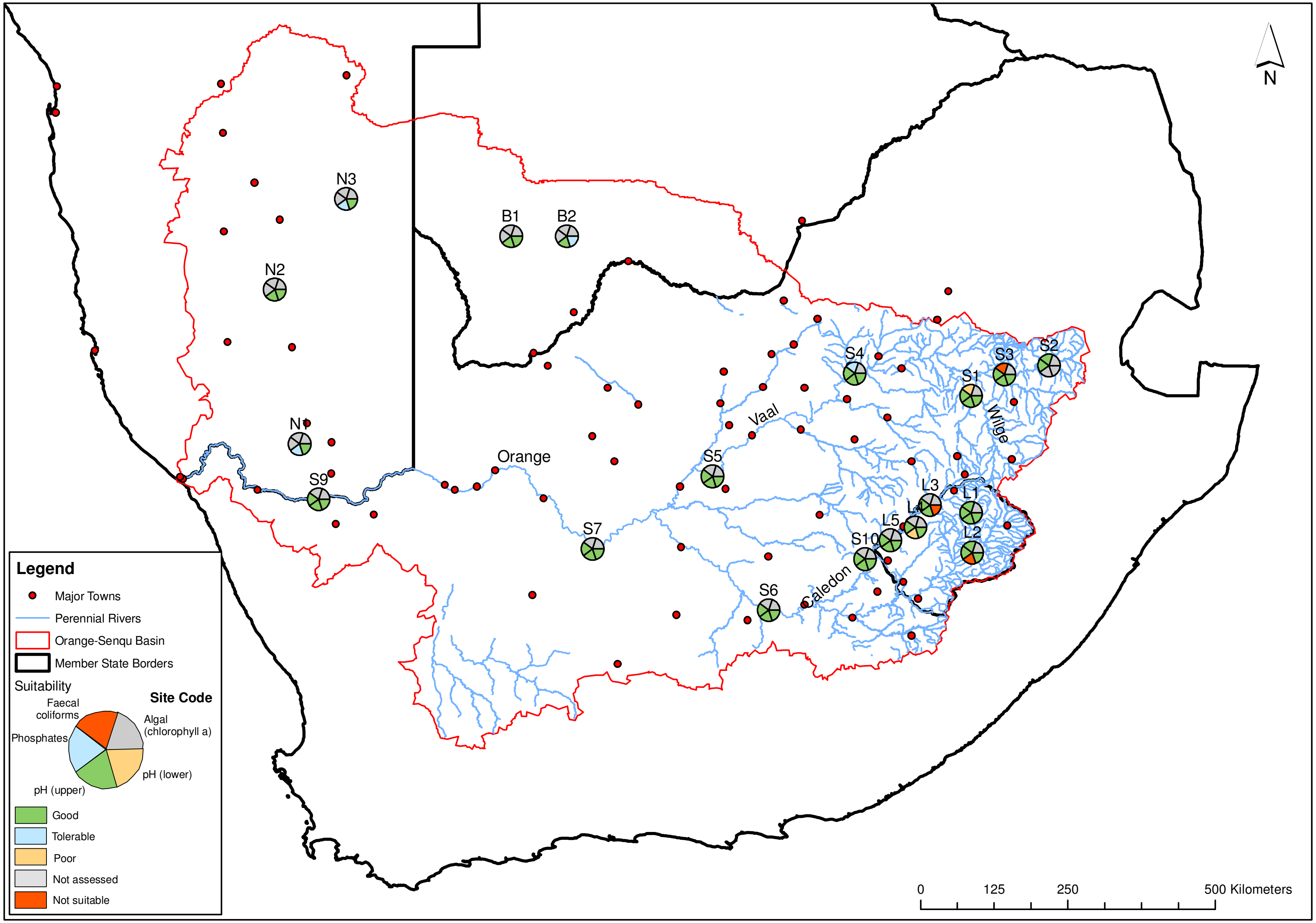


Figure 0-10 Recreational (no contact) Sub-basins S1, S2, S3, S4 and S5 Map

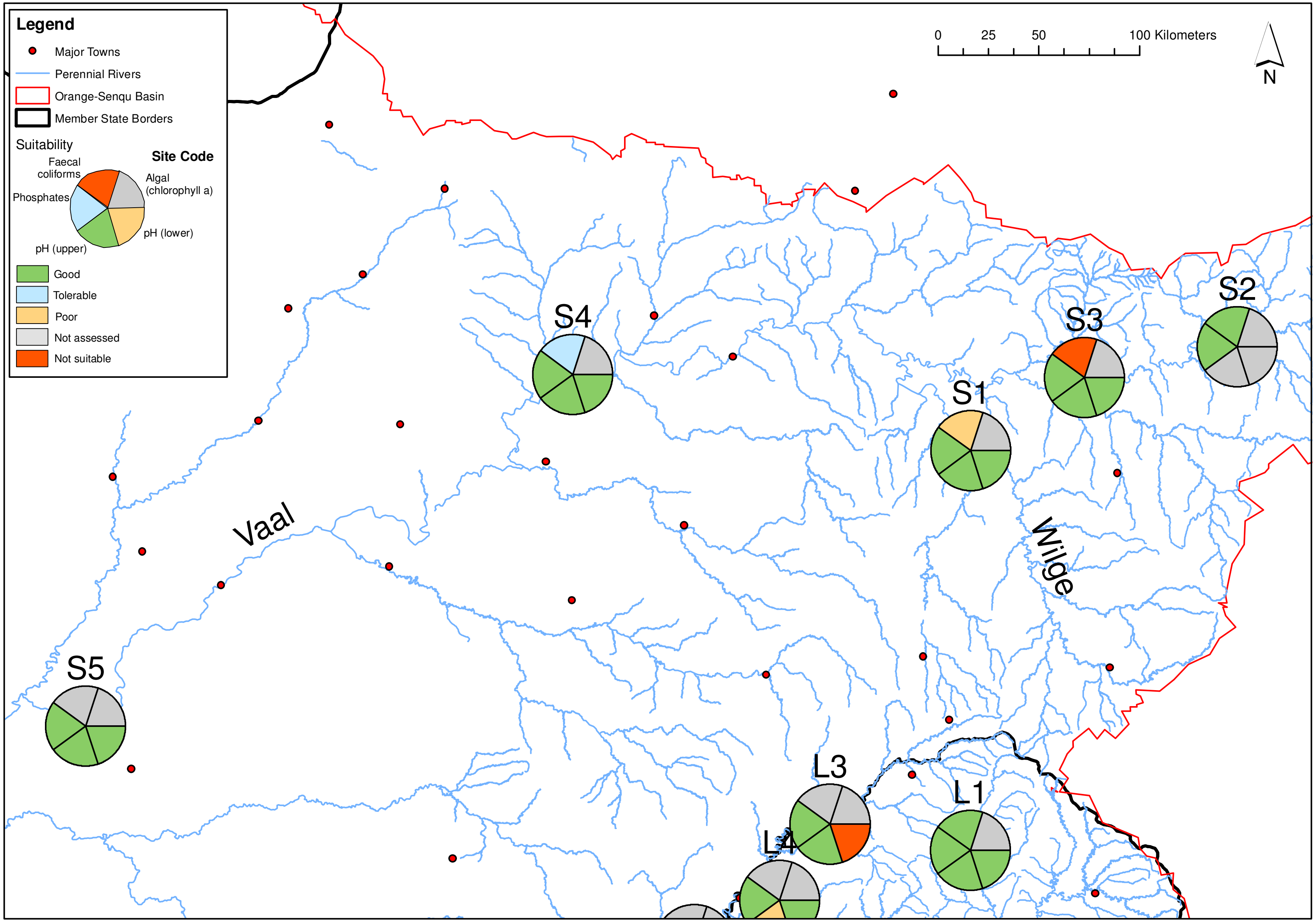


Figure 0-11 Recreational (no contact) Sub-basins L1, L2, L3, L4, L5, S6, S7 and S10 Map

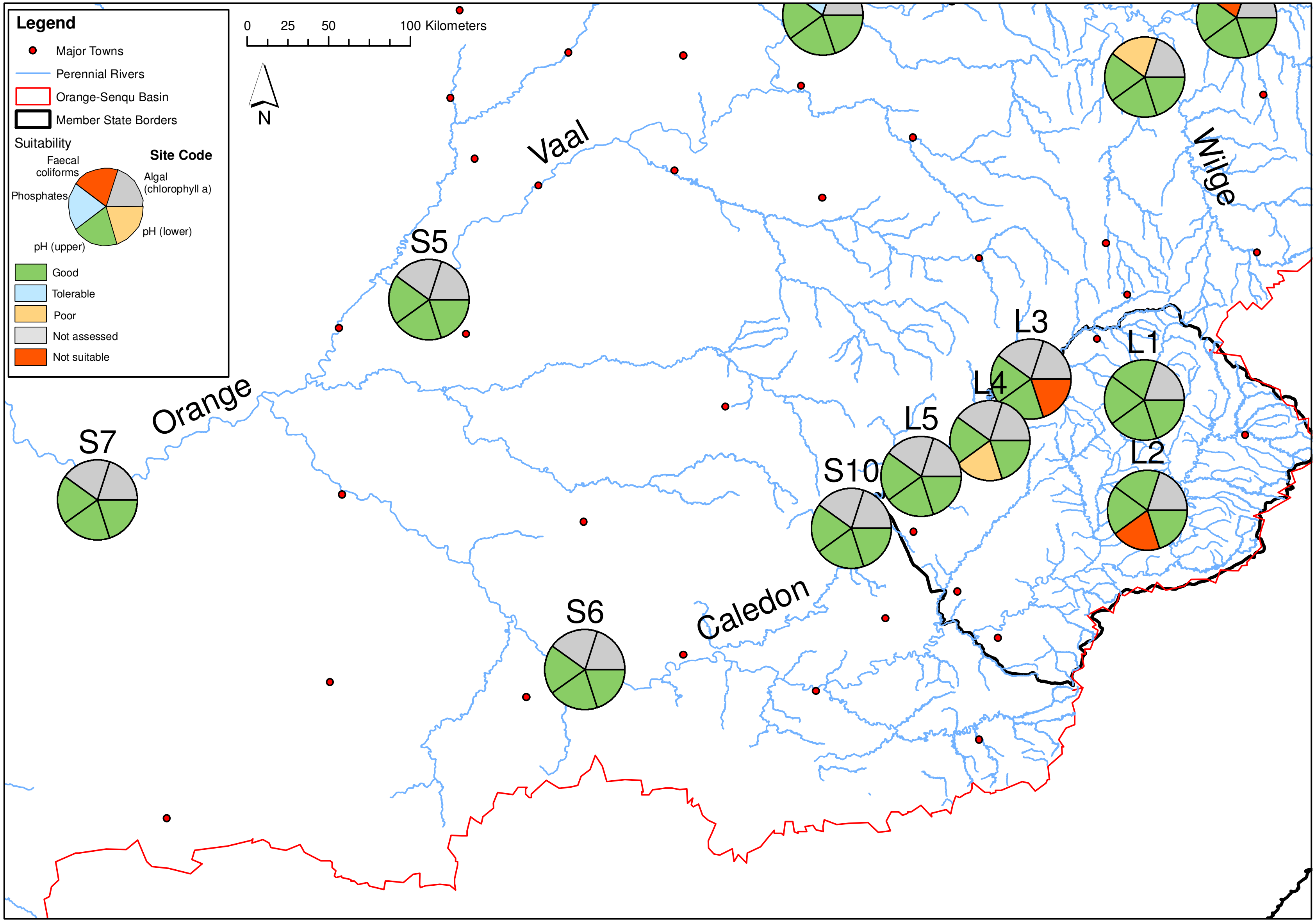


Figure 0-12 Recreational (no contact) Sub-basins B1, B2, N1, N2, N3 and S9 Map