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Rating Visual Impact Significance by Utilising Visibility Analysis and Geographic Information Science,

An approach to scientifically evaluate a visual impact.

by

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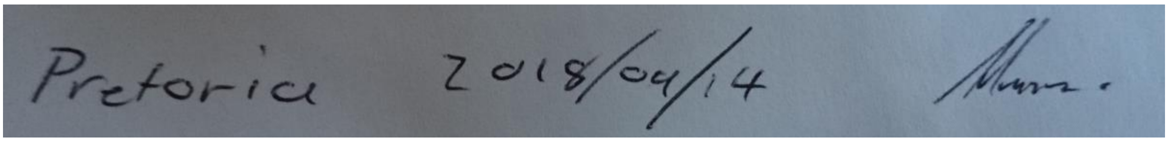
Science Pledge

By my signature below, I certify that my thesis is entirely the result of my own work. I have cited all sources I have used in my thesis and I have always indicated their origin.



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Preface

I would like to thank the UniGIS International staff from the University of Salzburg for their never-ending support and motivation throughout the duration of this study. I would also like to acknowledge my family for their support and encouragement.

Abstract

The motivation behind this study is that Visual Impact Assessments and what it entails is defined very vaguely in the international context. A Visual Impact Assessment refers to the evaluation of the nature of an effect relating to the visual attributes of an area. There is also very little guidance of what needs to be considered when conducting a Visual Impact Assessment.

A literature review was conducted to better understand how visual impacts can be assessed and what needs to be considered. The literature by authors such as the Canadian Environmental Assessment Agency (1994, amended 2010), DEAT (2002), Depellegrin et al. (2014), Igondova et al. (2016), Gupta and Thakkar (2018), Rodrigues et al. (2010), Hernández et al. (2004) and Minelli et al. (2014) contained various guidelines of how impacts are rated and evaluated.

The key findings were that any impact was rated based on the significance of the impact. The various authors considered different elements which influences the significance of an impact. The similarities were evident and the most important elements which influences significance of an impact were identified as the following:

- Status of the impact (Positive or Negative)
- Extent of the impact
- Severity of the impact
- Duration of the impact
- Probability of the impact occurring
- Mitigation measures
- Scientific uncertainty

Each of these elements need to be evaluated and rated on a common scale since they are all products of the significance rating. Meaning the values should be multiplied with each other to determine the significance rating.

A proposed approach method was derived from the findings and illustrated in an empirical study to show how GIS tools and techniques can used to evaluate each of the identified elements. The raster based spatial analysis enabled the individual calculation of ratings for each raster cell based on its location and distance from the observed feature. The derived formula of determining the significance of a visual impact could be used in a raster calculator where all the datasets were considered in order to get the final significance rating, as per a mathematical and scientific sound approach.

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List of Abbreviations

CBA	Critical Biodiversity Area
DEAT	(South Africa's) Department of Environmental Affairs and Tourism
EIA	Environmental Impact Assessment
ESRI	Environmental Systems Research Institute
GISc	Geographic Information Science
GIS	Geographic Information Systems
NGI	National Geo-spatial Information
OSM	OpenStreetMap
VIA	Visual Impact Assessment

1. Introduction

1.1. Motivation

Visual Impact Assessments (VIA) is a term easily understandable, yet vaguely defined in the international context. For the purpose of this study a proper definition was required in order to explain what exactly was covered by the term VIA.

These three words, as defined individually (Stevenson, 2010), provides meaningful clarification of this term so frequently used within the impact assessment field.

Visual; Relating to seeing or sight.

Impact; A marked effect or influence.

Assess; Evaluate or estimate the nature, ability, or quality of.

By aligning the above definitions one can understand that a VIA aims to evaluate or estimate the nature of an effect or influence relating (to the attributes of) seeing or sight.

The impact in this case refers to the change in the appearance of the landscape. The European Parliament (2016) defines a visual impact “as a change in the appearance, or view, of the built or natural landscape and urban areas resulting from the development which can be positive (improvement) or negative (deterioration).” It further states that a visual impact “is a key criterion in environmental impact assessment in terms of the preservation of historical and cultural heritage, of natural landscapes and of urban areas.” It also lists a VIA as a requirement (when relevant) for an Environmental Impact Assessment (EIA).

Whether the VIA is a stand-alone study or part of a comprehensive EIA process it is important to adhere to evaluation standards. South Africa’s Department of Environmental Affairs (DEAT, 2002a) defines significance as a concept which “is at the core of impact identification, prediction, evaluation and decision-making in EIA processes.”

Thus, identifying and rating the significance of the visual impact is an integral part of the VIA.

1.2. Problem Statement

In terms of the evaluation of visual impacts and how to align it to current EIA processes, not much guidelines and legal requirements exist globally (DEAT, 2002b). Thus, the need was identified to conduct this research study in order to better understand how the significance of a visual impact can be assessed and rated with a scientific approach that utilises Geographic Information Systems (GIS) and Geographic Information Science (GISc).

To address this problem a study area was selected to evaluate the impact of a change in the visual environment. The aim will be to follow a procedure, from the knowledge obtained in the literature study, which will show how GIS can be used in determining the visual impact quantifiably.

The selected study area is the Moreleta Park Municipal Nature Reserve in Gauteng, South Africa. The proposed change to the visual environment is a birding viewpoint. The study area was selected due to the diverse environment, since it is a rather small reserve surrounded by residential areas.

1.3. Approach

1.3.1. Research Question

How can GIS analysis be utilised in quantifying the significance of a visual impact?

1.3.2. Aim

To derive an approach method, which utilises GIS tools and GISc techniques through a scientifically sound process, to determine the significance rating of a visual impact.

1.3.3. Objectives

The objectives, in order to progressively move closer to reaching the aim of the study, can be set out as below:

- Accurately define significance and visual impact in the context of the undertaken study.
- Determine key elements which plays a role in significance.
- Define a rating scale of the key elements impacting the significance of a visual impact.
- How to rate the key elements in order to evaluate the rating of the visual impact.
- How to express the ratings in a mathematical formula in order to calculate the significance rating of the impact.

- Showcase a practical example of the researched/proposed method through an empirical study.

1.3.4. Quantitative Research

After Identifying the problem, a literature review was necessary to research different meanings, opinions and theoretical constructs that form the basis of this problem and the possible solutions to the problem. The literature review focused on literature sources which describes impact significance and how to evaluate and rate it.

A quantitative research approach will be applied since this study's aim is to propose a quantifiable approach method to which the significance of a visual impact can be rated. Rutberg and Bouikidis (2018) describes quantitative research as research which 'employs the use of numbers and accuracy.' Polit and Beck (2012) refers to a controlled method which examines a phenomenon with precise measurements.

The knowledge obtained from this literature review will be used to direct a proposed methodology which can be followed in carrying out the assessment of the empirical study.

1.4. Expected Results

By conducting the literature research, it is expected to gain an insight and understanding of the current methodologies of impact assessment, as well as visual analysis. It would further make it possible to draw a comparison as to what is considered when doing environmental impact related assessments.

Furthermore, it would identify the variables that influence impact significance and make recommendations on how to quantify the results.

Lastly, to determine which of the identified variables can be calculated and quantified with GIS analysis. The comprehensive answer to the research question should be presented informatively, by means of the empirical study that will follow the derived method accordingly.

1.5. Intended Audience

The intended audience of this study is practitioners within the impact assessment field, particularly practitioners with a GIS or VIA background or interest. Furthermore, the study is intended for all innovative thinkers and academics in the GIS and/or impact assessment field.

1.6. Thesis Structure

This study will consist of a review on the literature that was researched and the findings that was made. It will then aim to derive a quantifiable approach method, based on the findings of the research, to follow when doing a VIA. This approach method will then be tested by means of an empirical study.

The results achieved will be analysed and reviewed in order to identify any shortcomings of the approach method. Lastly, a conclusion will be drawn on the effectiveness and scientific correctness of the approach method. Other possible applications of the proposed approach method will also be discussed.

1.7. Limitations

This study researched several methodologies and comprehensively considered all the identified key elements in determining the significance of a visual impact. However, the complexity of development projects brings unique and project specific challenges to the table. It should therefore be noted that a project still needs to be assessed in its own unique way. It might be necessary, prior to doing the VIA, to identify whether all aspects pertaining to the project at hand and the visual impact is being considered. If a shortcoming is identified upfront it can either be noted or worked into the approach method.

2. Literature Study

2.1. Visual Impact

As discussed in the previous chapter a visual impact assessment in the context of this study refers to evaluating, estimating or predicting the impact which a proposed change in the landscape might have on the visual attributes.

As per the definition of The European Parliament (2016) proposed developments can have negative or positive visual impacts. Examples of possible negative impacts include landfills, motorways, powerlines and pylons. Examples of positive impacts is where the proposed development improves the landscape, such as rehabilitation of degraded areas or dilapidated buildings.

It should also be considered that some developments have both positive and negative impacts such as, advertisement billboards, birding view point and aerial cableways. Complex VIAs may even compare the negative impacts against the positive impacts in order to assist the decision-making process.

VIAs can also be considered in site or route selection decision-making by gauging the visual impact of the proposed options in order to identify the options which will have the most desirable outcome in terms of the visual impact.

2.2. Impact Significance

Determining the significance of an impact is the aim of any impact assessment study (DEAT, 2002a). This predicts the effect which the impact will have on the landscape. After reviewing a number of scientific sources, DEAT (2002a) makes the observation that the concept of significance is defined rather poorly and that it lacks consensus on a global scale.

Focussing on finding commonality amongst the various definitions of significance, within an environmental impact context, Sippe (1999) argues that although different interpretations exist, common elements can be observed and defines it as follows:

“Environmental significance is an anthropocentric concept, which uses judgement and values to the same or greater extent than science-based criteria and standards. The degree of significance depends upon the nature (i.e. type, magnitude, intensity, etc.) of impacts and the importance communities place on them.” (Sippe, 1999)

The next section discusses the different elements that were identified which influence impact significance.

2.3. Key Elements in Impact Significance

In this section a literature review of studies relevant to impact assessments in general will be done. The most relevant elements in visual impact significance will be identified and discussed.

DEAT (2002a) concludes that impact significance should be determined by systematic and judgemental criteria. It states that the evaluation criteria should be clearly described, especially when legal or scientific standards are unclear. The point is further stretched that the impacts, pertaining to a proposed development, should as far as possible be quantifiable. The criteria to consider in impact significance is as follows:

- Extent or spatial scale of the impact
- Intensity or severity of the impact
- Duration of the impact
- Mitigatory potential
- Acceptability
- Degree of certainty
- Status of the impact
- Legal requirements
- Probability of the impact

DEAT (2002a) also considers status of the impact. This is for scenarios where the evaluated impact on the receiving environment is positive. Thus, the status of the impact can be positive (beneficial) or negative (adverse) to the environment.

The Canadian Environmental Assessment Agency (1994, amended 2010) approach method of determining the significance of an environmental impact consists of three steps.

The first step is to determine whether the impact will be adverse to the environment. The second step is to determine the significance of the impact and consists of the following:

- Magnitude of the impact (explained similar as severity from DEAT (2002a))

- Geographical extent of the impact
- Duration and/or frequency of the impact
- Impact reversible or not?
- Ecological context (explained similar as acceptability from DEAT (2002a))

The third step is to investigate the likelihood of the effects to occur. Mention is made of scientific uncertainty or also termed confidence limits. This looks at the confidence the practitioner doing the assessment has in the input data, knowledge and experience (of similar impacts).

Igondova et al. (2016) derived an approach method for an ecological impact assessment which focuses on rural road development in Slovakia. The impact was also assessed by determining the significance thereof. The approach used in the study is GIS orientated where the different aspects of the impact were overlaying map layers. In this approach, they consider the following elements when evaluating the impact significance:

- Importance of the environment impacted
- Duration of the impact
- Reversibility of the impact
- Magnitude of the impact
- Size of the impact

This method does not speak to the probability of an impact occurring. The reason for this is not stated in the literature, but it is possible that different impacts pertaining to the ecological assessment was so clearly defined that the authors evidently concluded that all of them will occur regardless.

In the reviewing of the various literature sources it also became evident that risk assessment methodologies share a similar approach with some environmental impact assessment methodologies. With specific reference to the quantitative risk assessment methodology of Gupta and Thakkar (2018), the findings was that emphasis was placed on the following:

- Severity of an identified risk
- Duration of an identified risk

- Probability of an identified risk.

This generic approach of risk assessment is followed since it can easily be rated on a scoring scale and the product of the values provides a clear insight into the significance of risks. This can in turn also be applied to the significance of visual impacts. The risk assessment approaches do not consider the extent of the risk. This is because most risk assessments are not subjected to a physical environment, since assessment are done on the like of corporate, organisational or project delivery schedules.

The literature available which focusses on visual analysis specifically includes the assessment of structures such as wind turbines (Minelli et al., 2014, Wróżyński et al., 2016) and wind farms (Rodrigues et al., 2010), bill boards (Kamičaitytė-Virbašienė et al., 2015) and buildings (Hernández et al., 2004). Manchado et al. (2015) was also considered which focuses on visual impact assessments. All of the above incorporates a strong GIS component into their proposed methods of visual analysis. It was identified that these authors placed emphasis on the visual parameters, such as the visible extent and the severity of the visibility. Duration was however, only effectively considered in the method of Rodrigues et al. (2010), but it mainly looked at duration as the time a traveller, on the railways and roads within the affected area, would observe the impact.

These methods, with a specific focus on the visual analysis, do not take the duration and probability into consideration. This can be ascribed to the way in which a visual impact is regarded within the assessment field. It is different from other environmental impacts that usually predicts an impact that have a certain chance (probability) of occurring only for a certain amount of time (duration). In the evaluation of a visual impact the certainty usually exist that the impact will occur, and that it will keep on occurring for as long as the change in the environment exist.

Upon reviewing the literature sources, the elements that play a key role in determining impact significance has been identified. The elements most relevant to the significance of a visual impact was identified as the following:

- Status (Positive or Negative)
- Extent
- Severity

- Duration
- Probability
- Mitigation
- Scientific uncertainty

These elements, and how to evaluate and rate them, will be discussed in the next section.

2.4. Evaluation and Rating of the Key Elements

2.4.1. Generic Rating Scale

A scale to rate the effect which the impact has on each of the elements is required. DEAT (2002a) explains scaling as "the standardization of empirical data onto a common scale to allow comparisons." The identified elements should thus be rated on a similar scale in order to calculate the results which feed into the significance rating accordingly. Igondova et al. (2016) uses an example of a scale "from 1 to 8: 1 (very low), 2 (low) 3 (medium), 4 (medium-high), 5 (high), 6 (higher) 7 (very high), and 8 (the highest)."

This is a good example of a simplistic scale. It can be applied to all the identified elements of visual impact significance. Other scale ranges found in the expanded literature review include 1 to 5 and 1 to 7. It is desirable that the proposed approach method, which this study aim to achieve, uses a more adaptable scale. The reason for this is that VIAs are often part of comprehensive impact assessment studies, where the various specialists need to adapt to a uniform scale (DEAT, 2002b).

The author recommends that the proposed approach method will rate elements on a percentage scale. This type of rating scale effectively rates the elements from 0 to 100. This rating scaling is very informative and can also be converted or grouped to fit any different proposed scale range if desired so.

2.4.2. Main Elements and Sub-elements.

The elements identified through the literature review can effectively be grouped into two groups:

- The main elements - which is status-, extent-, severity-, duration- and possibility of the impact.
- The sub-elements – which is mitigation and scientific uncertainty.

Each of the main elements will be discussed in further detail in order to understand how they can be evaluated and rated using GIS.

Mitigation measures is determined for each main element and examples of mitigation will be discuss under each main element. In terms of evaluating where mitigation has an effect, the significance of the visual impact should be assessed both with and without the mitigation measures in order to identify the worst-case scenario and the manner in which the mitigation measures will limit the significance of the impact(DEAT, 2002a). The rating of the amount of mitigation should be expressed as a subtraction from 100% in order to conform to the rating scale of the main elements.

Scientific uncertainty should be documented per main element and any estimations should be limited, as far as possible. Where relevant the scientific uncertainty should also be rated on a percentage scale. Similar to mitigation, the degree of uncertainty in the data, methods or experience should be rated as a percentage. If the argument is that the degree of uncertainty will decrease the value of the element at hand it should be expressed as a subtraction from 100%, while it should be added to a 100% if the argument is that it will increase the values. Like mitigation, the results should also be calculated with and without the scientific uncertainty rating in order to evaluate the two scenarios.

2.4.3. Status of the Impact

The status of the impact, as indicated by DEAT (2002a) refers to whether the impact will have a positive or negative effect on the visual attributes of the receiving environment. The status is usually self-implied by the nature of the proposed change.

Although most cases involve a visual impact which is classified as a negative impact to the environment, there is also a requirement to assess positive visual impacts. Some proposed changes which have both positive and negative effects to the environment also needs to be evaluated accordingly in order to provide decision-making input.

In the literature review (DEAT, 2002a) it was evident that the impact is assessed in the same way whether it was deemed positive or negative. The only difference is that it would be stated what the status of the impact was and considered accordingly after the results.

Since the aim is toward a generic approach where all the elements are rated on a common scale it is recommended that the status of the impact also fits on the percentage scale. However, the range of this element will differ slightly. Instead of using the range of 0% - 100%, the status will either be scored positive 100% if the status is deemed positive, or negative (-) 100% if the status is deemed negative. In the case of a proposed change which might have positive and negative effects to the environment the positive and the negative impact is assessed separately and then weighed against each other.

2.4.4. Extent

The Canadian Environmental Assessment Agency (1994, amended 2010) describes the importance of considering the geographic extent of the effects associated with an impact. Widespread effects may be much more significant than localised effects, which is ‘contained’ within the site vicinity. The impacted area is also increased when the extent, to which an impact is visible, is increased.

According to Rodrigues et al. (2010) two factors to consider is the visual discernibility range and the topographical landscape of the receiving environment (the position of the impact in the landscape, as well as how the relief and topography limits the visibility).

The visual discernibility range (Rodrigues et al., 2010) ‘is based on the concept of visual threshold, used in psychophysics and defined as the minimal object size that can be perceived.’ Shang and Bishop (2000) measures visual size of an object in square minutes of the visual angle (steradians) and proved that the minimum object size visible for someone with normal visual acuity is 25 square minutes. Since distance is a parameter of an object’s perceived size Rodrigues et al. (2010) adapted Shang and Bishop’s findings into a formula to calculate the distance at which an object would appear as 25 minutes^2. This would be the maximum distance at which an object would be ‘perceived visible’ for someone with normal vision. The adapted formula is as follows:

$$VDR = \sqrt{\frac{I^w * I^h * c}{25}}$$

Where;	VDR	is	Visual Discernibility Range, maximum visible distance
	I^w	is	True width of observed object in meters
	I^h	is	True height of observed object in meters
	c	is	A constant to convert steradians to square meters:
			$C = (180 * \ 60 \div \pi)^2$
			$C = 11\,818\,102.8600422$
			$C = 1.18 * 10^7$

Minelli et al. (2014) verified this approach through their study and came to the same conclusion that this method can be used to express the maximum distance to which an object can be perceived visually. It is noted that $I^w * \ I^h$ resembles the perceivable area of the object at hand. Therefore Minelli et al. (2014) amends the formula to further make sense in the visual impact field specifically:

$$VDR \ = \sqrt{\frac{A^{obj} * c}{25}}$$

Where;	A^{obj}	is	True area of observed object in meters^2

It should be noted that this identified method determines the maximum distance at which an objective is perceived visible should it not be limited by terrain or the ability to blend/camouflage into the background of the landscape. Thus, this can also be used to define (or limit) the area of influence of the impact that occurs.

The topography of the landscape within the study area may further influence the visibility of an object that is being assessed. The visibility of an object located in a valley (see A in Figure 1) or on a hill slope (see C in Figure 1) will be more limited than an object located on a hill (see B in Figure 1). Minelli et al. (2014) explains that a viewshed analysis in a GIS can be used to 'determine which parts of the landscape are visible or not visible from a particular vantage point.' For this method, a Digital Elevation Model (DEM) of the study area is required. As described by Wróżyński et al. (2016) it should be noted to take the earths curvature correction into account when conducting a viewshed analysis. Most viewshed tools have this as an option to enable.

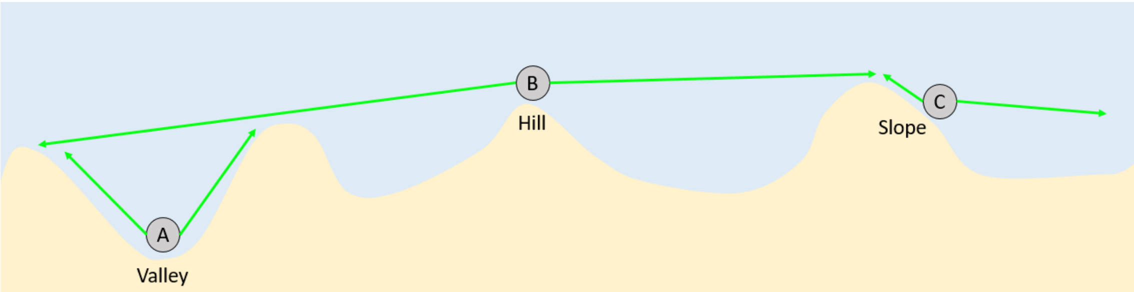


Figure 1: Visibility in the Landscape

The extent of the visual impact is rated on the generic percentage scale. All areas within the visual discernibility range will be evaluated. Areas from where the observed object is not visible will be scored 0%. All the other areas will be scored according to the percentage of the object which is visible from that area.

Identified mitigation measures which will have an influence on the calculation of the extent may include the position of the object in the landscape, the design thereof and the possibility of dense vegetation in the study area.

Scientific confidence to consider when determining the extent includes the source and accuracy of the DEM, or the elevation data and method used to create the DEM.

2.4.5. Severity

As per Rodrigues et al.'s (2010) investigation of the severity (visual magnitude) of the visual impact the conclusion is that severity decreases with the increase in distance from the object. Describing it as visual perception estimation, it is aimed to quantify the severity of the visual impact of the object. The severity (visual magnitude) 'is defined as the product of the vertical and horizontal view angles of an object.' The adapted formula shows how the severity of the visual impact of an object decreases over distance:

$$VPI = \frac{A^{obj}}{2\pi D^2} * 100$$

Where; VPI is Visual Perception Index

A^{obj}	is	True area of observed object in meters^2
D	is	Distance from observed object in meters

The function of this formula in a two-axis graph is shown below:

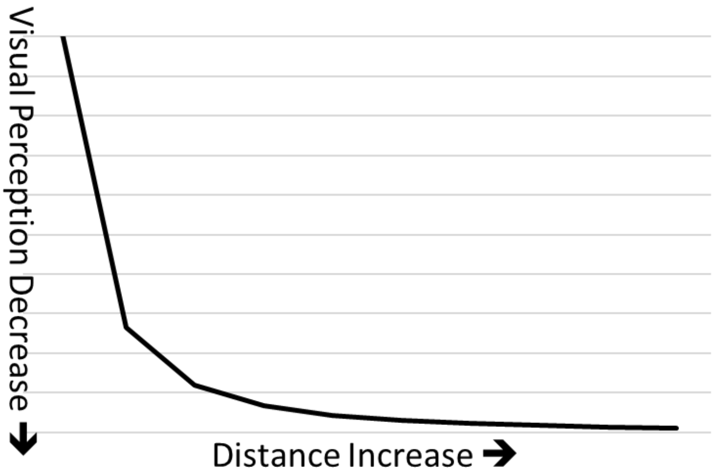


Figure 2: Visual Perception Graph

To explain this formula, it expresses the true area of the observed object as a percentage of an exaggerated human field of view. The human field of view is taken as half of the surface area of a sphere, thus $4\pi r^2$ (normal surface area of a square formula) below the line is replaced with $2\pi d^2$, and the calculated distance value from the object represents the radius. Rodrigues et al. (2010) notes that while this formula is good for indexing the visual perception further consideration needs to be taken on how this can translate to the severity of a visual impact.

The nature of this formula is that with the increase in distance the visual perception will decrease, but never reach zero. Vice versa is also true. The need arises of a minimum and maximum rating in order to use it for rating severity accordingly.

The visual perception index will pass through 1 at a distance close to the object and rise to infinity the closer you get to the object. The distance where the visual perception index passes through 1 is where the observed object will be perceived as its true size. Thus, this can be used to the define the distance where the severity of the impact will be 100%. All areas closer to the object will also be rated 100% in terms of the severity of the visual impact. This can now be regarded as the maximum severity rating. The formula of the visual perception index can be adapted in order to determine at which distance the visual perception index will be 1, as shown below:

$$D^2 = \frac{A^{obj}}{2\pi VPI} * 100$$

The minimum severity rating is equal to the impact area limit, the visual discernibility range (as shown in 2.4.4.), where the visual impact won't be observed anymore (Rodrigues et al., 2010). The severity can then be rated accordingly as 0% at the visual discernibility range.

With the minimum and maximum values established it is necessary to identify a function to calculate the curved decrease of the severity over distance. Ocean (2010) practically demonstrates how the perceived size of an object follows the inverse-square law which is observed throughout nature. The experiment shows how the decrease is a factor of a $^1/_4$ of the distance. The formula proposed (which considers the difference in distance over the total distance to power of 2) can be adapted accordingly to a formula that can be used after the distances of the minimum and maximum severity ratings is identified. The formula is shown below.

$$Sev = \left(\frac{VDR - D}{VDR - VPI1d}\right)^2 * 100$$

Where; $VPI1d$ is Distance where the Visual Perception Index is 1

The result will be a severity rating, as per the percentage rating scale, calculated at a defined distance, considering both the visual perception index and the visual discernibility range.

In terms of possible mitigation measures the research Minelli et al. (2014) and Rodrigues et al. (2010) indicates that the contrast of the object compared to the receiving landscape's background can be considered. Dupont et al. (2016) used saliency maps in order to compare the contrast of objects in a landscape. They confirmed that an object with a colour that blends in with the receiving environment's general background is less noticeable than an object which colour is in contrast. No formal method of determining the influence of this mitigation measure is proposed. However, from the interpretation of their research it is proposed that one can compare the contrast of the colour of the observed object to a photo background of the general receiving environment. Dupont et al. (2016) and Rodrigues et al. (2010) both acknowledge that further refinements are required in order to accurately and objectively determine how the contrast of colour can be evaluated in terms of it being used as a mitigation measure in the visual impact field.

As in the example below from Dupont et al. (2016), the best recommendation is to create a similar saliency comparison map and objectively evaluate by which percentage the use of colour mitigates the severity of the impact.

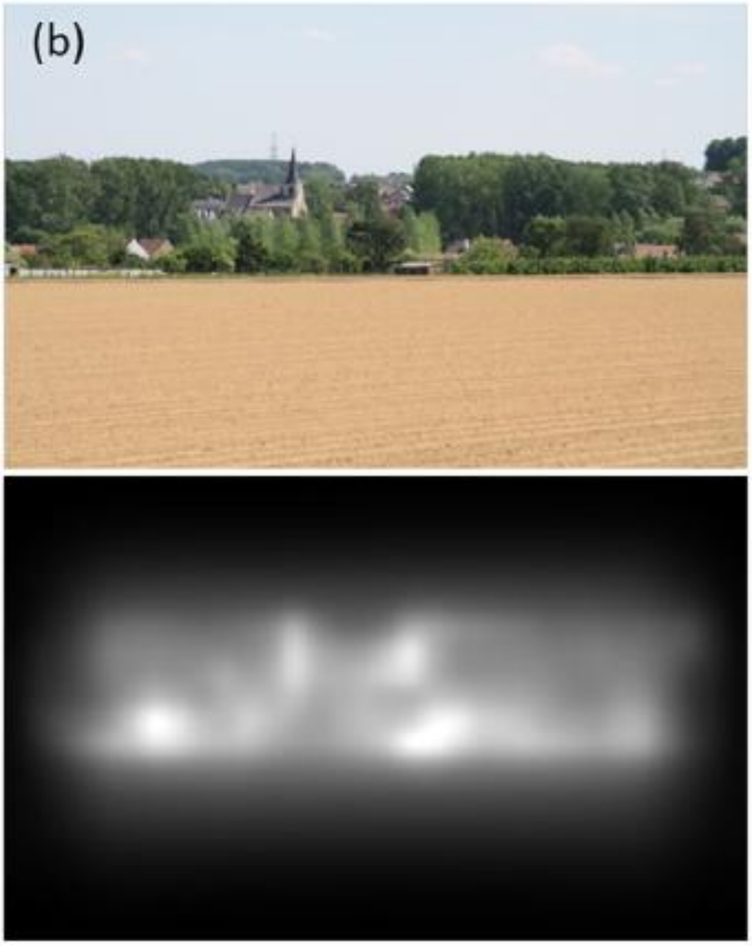


Figure 3: Saliency Example

It is argued that a certain colour will mitigate the severity by 20% the mitigation rating should be expressed as 100%-20% = 80%.

The product of the severity and its mitigation is the mitigated severity rating. If the severity rating of a certain area was identified as 90% and the mitigation was rated as 20% the expression for the mitigated severity rating would be (90%*(100%-20%)) = 72%.

It should be noted that this method evaluates the severity at the maximum exposure in terms of visibility with regards to contrast. Therefore, there is no need to re-evaluate scenarios where the object is not blending in with the environment. It is only identified as mitigatory when the use of colour or facade increases the ability to blend with the environment, since it decreases the severity of how it is perceived.

2.4.6. Duration

Duration of an impact plays an important role (Canadian Environmental Assessment Agency, 1994, amended 2010, DEAT, 2002a) as it takes into consideration how long the activity happens. This is important in other environmental related impacts since most activities that are being evaluated has a time associated with it in terms of how long the activity will persist. Although duration plays a smaller role in the VIA it still needs to be considered.

Although most visual impacts persist permanently, whether positive or negative, it might be limited in a certain direction or area due to future or planned developments. Therefore, the duration should be kept in mind when relevant during the VIA procedure.

The duration is similarly rated on the general percentage scale, where a value of 100% indicates the duration as permanent or long-term. In the study conducted by DEAT (2002a) duration scales was used which can be easily expressed as a percentage instead of numerical scales, as shown below:

Rating	Description	Score (1-5)	Percentage
High	Permanent Long term (More than 10 years)	5	100%
Medium-High	Up to 10 years	4	80%
Medium	More than 5 years Medium term	3	60%
Medium-Low	Up to 5 years	2	40%
Low	Less than 5 years Short term	1	20%

Figure 4: Duration Rating Scale

The mitigation measures of a visual impact may include the future changes to the environment. However, this is mostly relevant when assessing positive impacts, since the extent to which the impact is desired to be observed from is changed.

Scientific uncertainty to consider includes the lifespan of temporary structures, knowledge of future developments and planned demolitions of structures.

2.4.7. Probability

The Canadian Environmental Assessment Agency (1994, amended 2010) explains that the probability of an effect plays an important role in impact assessment. The possible effect may be severe, but if there is a very low change of it happening then it will be ultimately insignificant. Upon reviewing various impact assessment related literature DEAT (2002a) came to the conclusion that the probability effects the significance considerably. It was found that in the quantifiable methods probability is multiplied with the values of the other elements in order to express the influence it has.

In visual analysis terms the role which probability plays in the significance rating of the visual impact is not considered in most cases. This can be explained by the nature of a visual impact. Any physical change to the environment are more than likely to be visible.

In the visual impact context the focus shifts to the probability of the impact being observed. Rodrigues et al. (2010) considers roads and railways in the study area as areas where the observation is more likely to happen. Various other datasets can be used to determine areas within the defined visual discernibility range. This may include any point of interest dataset, roads, railway, spot building datasets, residential areas, hiking trails or any dataset which may indicate the possibility of the effect being observe from that area. The recommendation to objectively evaluate and rate the probability, is to assign a general percentage scale based on the probability of the impact being observed in that area. An area where an observer might be more regularly should score 100%, while other areas should be scored accordingly lower as the regularity of an observer decreases. Only areas where an observer are definitely unlikely to be, should be considered as a 0%.

Mitigation measures of probability may include the altering of tracks or hiking trails, routes and the position of points of interest where observers may gather, in order to decrease the probability of the effect of the visual impact being observed.

The scientific uncertainty pertaining to probability should be well documented. All the consideration of datasets used, in order to determine where the areas of probable observers are, should be noted so that it will be clear what was and was not considered.

2.5. Literature Conclusion

The literature study defined the terms Visual Impact and Impact Significance accordingly. The findings identified the common elements from various literature sources which influences the significance of a visual impact. These elements were discussed and solutions were researched in terms of how to rate them. The theoretical foundation and proposed approach method which follows will explain how GIS can be used to evaluate and calculate the significance rating accordingly.

3. Proposed Approach Method to Rate the Visual Impact Significance

3.1. Theoretical Foundation

The research of studies, which also use a quantitative approach to evaluate the visual aspects of an impact, guided the identifying process of the relevant elements. The importance which these elements play in the determination of the significance of a visual impact was discussed. The way in which the main elements of the significance of a visual impact can be evaluated and rated was detailed. It was further determined how the sub-elements should be handled per main element.

The recommendation was made that a standardized rating scale should be used for all the identified elements (DEAT, 2002a). A percentage rating scale was identified to be used in order to retain the ability of converting to and from other rating scales when required.

It was also noted that the calculation of the significance rating of the visual impact should be done with and without taking the sub-elements into consideration, in order to view the results of each of the scenarios:

- Calculation with only the main elements
- Calculation taking into consideration the mitigation of the main elements
- Calculation taking into consideration the mitigation and scientific uncertainty

The findings showed that the main elements of an impact are all products of the significance rating (DEAT, 2002a). This means that all the main elements are multiplied with each other in order to get the significance rating. The first scenario can be expressed in the formula below:

$$Sig = Stat * Ext * Sev * Dur * Prob$$

Where;	Sig	is	Significance of the visual impact
	$Stat$	is	Status of the visual impact
	Ext	is	Extent of the visual impact
	Sev	is	Severity of the visual impact
	Dur	is	Duration of the visual impact
	$Prob$	is	Probability of the visual impact being observed

To explain this; even though all the main element's values might be high, a very low value in any one of them can reduce the visual impact significance rating. For example, if all the values are high but the probability that the effect will be observed from a certain area is very low, the significance rating will be reduced accordingly.

The sub-elements are handled similarly, a product of the main elements. The determined ratings of the sub-elements, for each of the main elements, is multiplied with the main element's. For the second scenario, only the mitigation (mit) sub-element is considered, as shown in the formula below:

$$Sig = Stat(mit) * Ext(mit) * Sev(mit) * Dur(mit) * Prob(mit)$$

The third scenario includes the scientific uncertainty (scu) ratings associated with each main element, as well as the mitigation ratings. The third scenario's formula is shown below:

$$Sig = Stat(mit)(scu) * Ext(mit)(scu) * Sev(mit)(scu) * Dur(mit)(scu) * Prob(mit)(scu)$$

Since GISc is a location based science it provides the ability to assess each area in the impacted area separately. This will involve raster based spatial analysis where the visual significance rating for each raster pixel will be determined by following the theoretical approach method and formula derived from this literature study.

The following sections will look at the practical approach methods that can be applied and the tools which can be used, within an ArcGIS environment, in order to do the necessary calculations to rate each element.

3.2. Methods Applied

3.2.1. Getting Started

This section will propose a practical approach method, after taking into consideration the knowledge obtained in the literature study. GISc is a location based science and this practical approach aim to rate the visual impact at various locations within the affected area.

The GIS tools that will be discussed is generic throughout various GIS software. However, for the purpose of this study the software, terms and definitions will refer to the Environmental Systems Research Institute (ESRI, 2017) suite of ArcGIS 10.5.

A float based raster analysis is proposed since the determined values will represent a percentage. The identified elements will be rated a percentage value for each cell of the raster in the affected area. Although some of the output raster analysis results will be an integer raster type it will be converted to float. The values will be converted accordingly so that it represents a percentage by using the Raster Calculator (Spatial Analyst) tool which 'builds and executes a single Map Algebra expression using Python syntax in a calculator-like interface' (ESRI, 2017). All the raster dataset representing the rating of each of the elements will then be used in a raster calculation to determine the final significance rating of the visual impact, as per the derived formula.

Deciding on a raster cell size is ultimately up to the practitioner conducting the study, but it should be noted that the size of the cell will influence the generalisation of the results. Therefore, the size of a cell needs to be kept at a minimum without hampering the processing capabilities of the software or the hardware. The size of the affected area might influence the decision since a bigger area will require more raster cells of the same size when compared to a smaller affected area.

3.2.2. Define Affected Area

As determined in the literature study the area of influence of a visual impact can be determined by calculating the visual discernibility range. Based on the research (Minelli et al. (2014) and Rodrigues et al. (2010)) the formula to calculate it is as follows:

$$VDR = \sqrt{\frac{A^{obj} * c}{25}}$$

A^{obj} represents the true area of the object being observed. For simple objects the area observed is defined as width x height of the object. Even complex structures can be boxed into general dimensions of width x height in order to have an estimated value if the true area of the object is not defined. The true area is then substituted into the formula in order to determine the visual discernibility range.

By calculating the visual discernibility range the limits of the area of influence is determined. This distance can be calculated as a Euclidean distance around the observed object since eye-sight is a straight line (Minelli et al., 2014).

The buffer tool, which 'creates buffer polygons around input features to a specified distance' (ESRI, 2017), can be used to create a polygon that indicate the calculated visual discernibility range of the feature.

3.2.3. Define Status of the Visual Impact

As described in the literature study (DEAT, 2002a) the status of the visual impact refers to whether the impact is positive or negative. The manner in which it is rated is objectively influenced by the nature of the assessment and whether the positive-, negative- or both impacts are evaluated.

To adhere to the generic percentage scale, all the raster cells within the affected area are scored either 100% if the impact is positive or -100% if the impact is negative. To achieve this, a raster coverage of the determined affected area should be created and all the cells should be assigned the rating accordingly. This operation can be performed by converting the visual discernibility range polygon (created with the buffer tool in section 3.2.2) to a raster coverage using the Feature to Raster (Conversion) tool (ESRI, 2017) and using the raster calculator accordingly to assign the rated values.

3.2.4. Determine Extent Rating of the Visual Impact

The literature study identified two factors to consider in determining the extent rating (Rodrigues et al., 2010). The first is the visual discernibility range which is already calculated in order to identify the affected area limit. The other factor is how the topography of the receiving environment limits the visibility of the impact.

The Viewshed (Spatial Analyst) tool 'determines the raster surface locations visible to a set of observer features' (ESRI, 2017). This tool was used by most of the literature researched, which visibility analysis was GIS-based. Manchado et al. (2015) specifically details the viewshed tool as a common territorial analysis to calculate zones of visual influence.

The viewshed analysis is executed with the observed objects as the input observer feature. The observed feature can be a point or a line which represents the object. Multiple features can be used to represent a certain percentage of the object in order to determine what percentage of the object as a whole will be visible. The vector data should have the required OFFSETA and OFFSETB fields. This indicates the feature starting (OFFSETA) and ending (OFFSETB) height in map units from the ground. The RADIUS1 and RADIUS2 field can also be added. This indicates the radius around the features where the analysis should start (RADIUS1) and end (RADIUS2). The calculated value for the visual discernibility range should be used as RADIUS2 in order to limit the processing extent to the confines of the identified affected area. (ESRI, 2017)

A DEM which represents the environments topographically is also required. The required DEM can be created from vector elevation data of the study area, if necessary, by using the Topo to Raster (Spatial Analyst) tool which interpolates a 'raster surface from point, line, and polygon data' (ESRI, 2017).

The result of the viewshed analysis will be an integer raster indicating how many features is visible from each raster cell. The percentage rating can then be applied accordingly, by using the raster calculator, in order to show what percentage of the object(s) is visible from each raster cell in the affected area.

Should any mitigatory measures be identified at the time of the VIA which will reduce the extent of the visual impact, a raster dataset needs to be created accordingly to show the new values of the affected cells.

3.2.5. Determine Severity Rating of the Visual Impact

As per the literature study, the severity of a visual impact decreases with the increase in distance. The severity of a visual impact is based on the visual perception index (Rodrigues et al., 2010). The severity is rated as 100% at the distance where the visual perception index is equal to 1. The following formula can be used to determine the distance from an object where the visual perception index will be 1.

$$D^2 = \frac{A^{obj}}{2\pi VPI} * 100$$

$$D^2 = \frac{A^{obj}}{2\pi(1)} * 100$$

$$D^2 = \frac{A^{obj}}{2\pi} * 100$$

The severity rating will further be calculated, as per the identified formula below, while considering the visual discernibility range and the distance where the visual perception index is 1.

$$Sev = \left(\frac{VDR - D}{VDR - VPI1d}\right)^2 * 100$$

The distance from the observed object is the only undetermined variable in the equation. This will have to be calculated. Some of the researched studies make use of the Buffer tool, which ‘creates buffer polygons around input features to a specified distance’ (ESRI, 2017), in order to create either concentric vectors (Depellegrin et al., 2014) or coverage zones (Hernández et al., 2004). This method leads to generalization since it tends to classify or group distances into classes. A more accurate method is desirable with the proposed approach since it aims to evaluate each area (raster cell) on its own distance parameters.

The Euclidean Distance (Spatial Analyst) tool in ArcGIS ‘calculates, for each cell, the Euclidean distance to the closest source’ (ESRI, 2017). The source in this case would be the observed object(s). This method is proposed by Rodrigues et al. (2010) and also incorporated into a viewshed analysis model by Minelli et al. (2014). The determined visual discernibility range should be used as the maximum distance in order to limit the processing extent accordingly.

The result will be a floating type raster indicating the Euclidean distance from each cell to the observed object.

Now that the distance for each raster call is calculated the severity rating can be calculated for each raster cell as per the identified formula.

Should any mitigatory measures be identified at the time of the VIA which will reduce the severity of the visual impact, a raster dataset needs to be created accordingly to show the new values of the affected cells.

3.2.6. Determine Duration Rating of the Visual Impact

As identified in the literature study, it is necessary to take duration into consideration (DEAT (2002a) and Canadian Environmental Assessment Agency (1994, amended 2010)), even though most VIAs has a maximum duration rating based on the nature of the proposed change in the environment.

The proposed percentage rating scale, as shown in figure 4, where a 100% duration indicates a permanent or long term effect from the visual impact should be used. This operation can be performed by converting the visual discernibility range polygon (created with the buffer tool in section 3.2.2) to a raster coverage using the Feature to Raster (Conversion) tool (ESRI, 2017) and using the field calculator accordingly to assign the ratings.

Should any mitigatory measures be identified at the time of the VIA which will reduce the duration of the visual impact, a raster dataset needs to be created accordingly to show the new values of the affected cells.

3.2.7. Determine Probability Rating of the Visual Impact

As discussed in the literature study, Rodrigues et al. (2010) explains why the significance of a visual impact is increased in areas where it is more likely to be observed. In order to identify these areas within the identified affected area comprehensive knowledge, as well as site visits, of the area is needed. As much data and information as possible is needed in order to consider areas where an observer might be more likely or less likely to be.

After reviewing all the input information, it is necessary to create a raster dataset which indicates the probability (in a percentage rating) of the impact being observed from each raster cell.

Should any mitigatory measures be identified at the time of the VIA which will reduce the probability of the visual impact, a raster dataset needs to be created accordingly to show the new values of the affected cells.

3.2.8. Determine Mitigation Measures and Scientific Uncertainty

Should any mitigatory measures or scientific uncertainties be identified at the time of the VIA which will influence the rating of any of the main elements of the visual impact, a raster dataset needs to be created accordingly to show (in a percentage rating) how the determined values of the cells of that element are affected. A rating of 100% will represent no change in the determined values.

3.3. Calculate Significance Rating of the Visual Impact

The sections above detail the calculations of the relevant elements accordingly. A raster dataset format is used, thus showing the various values at each raster cell. The findings in the literature study determined that the identified elements are a product of the visual impact significance (DEAT, 2002a). In order to calculate the visual impact significance for each raster cell within the affected area, the values of the raster cells are used accordingly, as per the formula derived from the literature study:

$$Sig = Stat(mit)(scu) * Ext(mit)(scu) * Sev(mit)(scu) * Dur(mit)(scu) * Prob(mit)(scu)$$

This can be achieved by using the raster calculator. Thus, various raster datasets can be expressed in a mathematical formula that uses the values at each cell to calculate the answer accordingly.

The results can be shown and mapped out in order to interactively see the significance impact rating at certain areas. The analysis can further be interpreted by calculating the sum of all the cells, weighted as per the m^2 of each raster cell. Rodrigues et al. (2010) follows a similar approach by calculating the sum of the values of the raster cells for the visually affected areas. This will be a good benchmark to measure different visual impacts against each other, since the values and extent will differ depending on the severity of the visual impact.

4. Project Description

4.1. Proposed Change

The empirical study will be carried out as a VIA which will follow the proposed approach method discussed in the sections above. The proposed change in the receiving environment is a birding viewpoint in a nature reserve.

The structure will have design parameters of a diameter of 4 meters. The height will be 2 meters (bottom of the wall to roof top), but the structure will be elevated (with wooden poles) by 1 meter to allow water to flow underneath, since it will be located close to a watercourse. The structure will be built from wooden poles and the roof will be thatch.

4.2. Study Area

The proposed birding viewpoint is located in the Moreleta Kloof Municipal Nature Reserve in the east of Pretoria, Gauteng, South Africa.

The nature reserve is regarded as an Ecological Support Area (ESA) by the Gauteng Conservation Plan and it contains various forms of animal life, as well as bird- and insect species. Any proposed changes that may have an impact to the environment needs to be considered carefully. Human activities in the nature reserve includes hiking, trail running, conference facilities, restaurant, bird and game viewing. The exact location of the proposed birding viewpoint is Lat: -25.813; Long: 28.291, as shown below (Annexure A – Locality Map).

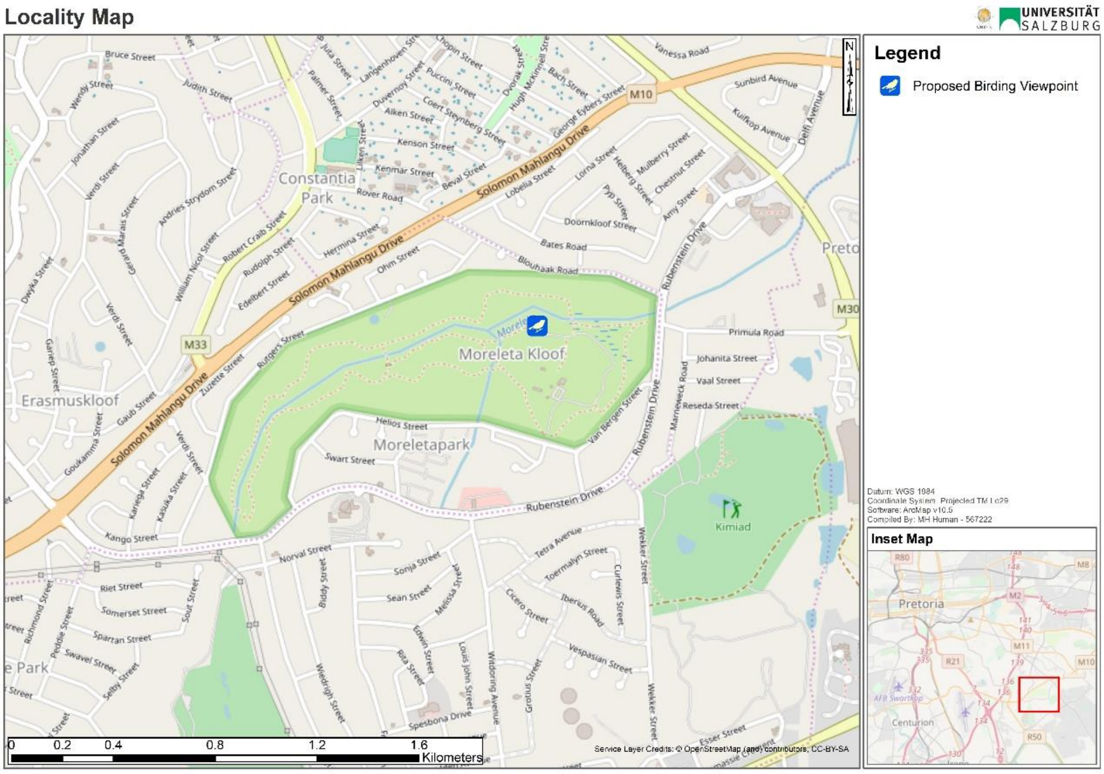


Figure 5: Locality Map

4.3. Geographic Information Datasets & Parameters

The analysis will be raster based. All the elements will be rated accordingly and raster datasets will be created or derived showing the values at the relevant areas. A raster cell size of 5 meters was selected. This size will simplify the computing of statistics and hardware processing required, while still maintaining a small enough resolution in order to indicate values per $25m^2$ throughout the affected area.

As determined in the study, elevation data is crucial for the viewshed analysis. A DEM will be created for 1 meter interval contours. This data is the best data readily available without doing any further topographical surveys. The interval and the accuracy of the contours are also more than adequate for the purpose of the analysis. The data is a municipal (City of Tshwane) dataset which is available for free to the public.

Vector datasets indicating various points, lines and polygons of interest from South Africa's National Geo-spatial Information (NGI) and OpenStreetMap (OSM) was considered in determining areas of probability. These datasets are also available for free.

5. Results

5.1. Visual Discernibility Range of the Impact

As per the identified method it is necessary to establish the observed area of the object in order to calculate the visual discernibility range by using the following formula:

$$VDR = \sqrt{\frac{A^{obj} * c}{25}}$$

Since the design parameters was provided we have identified the total observed height as 3 meters. The width used is 4 meters, since the diameter was indicated as 4 meters. The true observed area of the object is 4m x 3m = 12m^2. By using the formula above the visual discernibility range, which in this case also determines the VIA's affected area limitations, is calculated as shown below:

$$VDR = \sqrt{\frac{12 * 1.18 * 10^7}{25}}$$

$$VDR = 2379.9$$

This means that the object's maximum visibility range will be 2379.9 meters. The buffer distance was rounded to the nearest meter, thus 2380 meters, as shown below (Annexure A – Visual Discernibility Range Map).

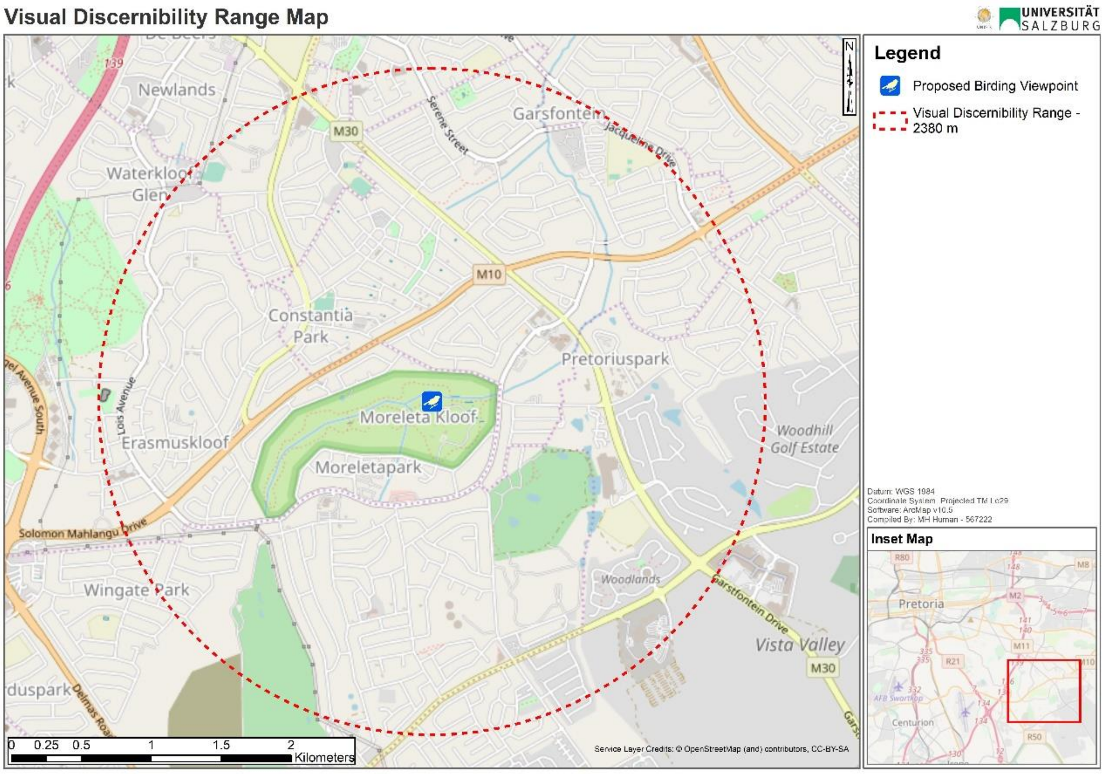


Figure 6: Visual Discernibility Range Map

5.2. Status of the Impact

The proposed change in the environment can be defined as placing a man-made structure, as a foreign object to the surroundings, which will be perceived as a negative impact to the visual attributes of the direct natural environment. This VIA will assess the negative aspects of the visual impact which the proposed structure will have on the environment. The status of the visual impact is negative, rated as -100% and the limit of the visual impact is equal to the discernibility range. A raster dataset is created by converting the visual discernibility range polygon to raster and adding a field with the rated value, as shown below (Annexure A – Impact Status Map).

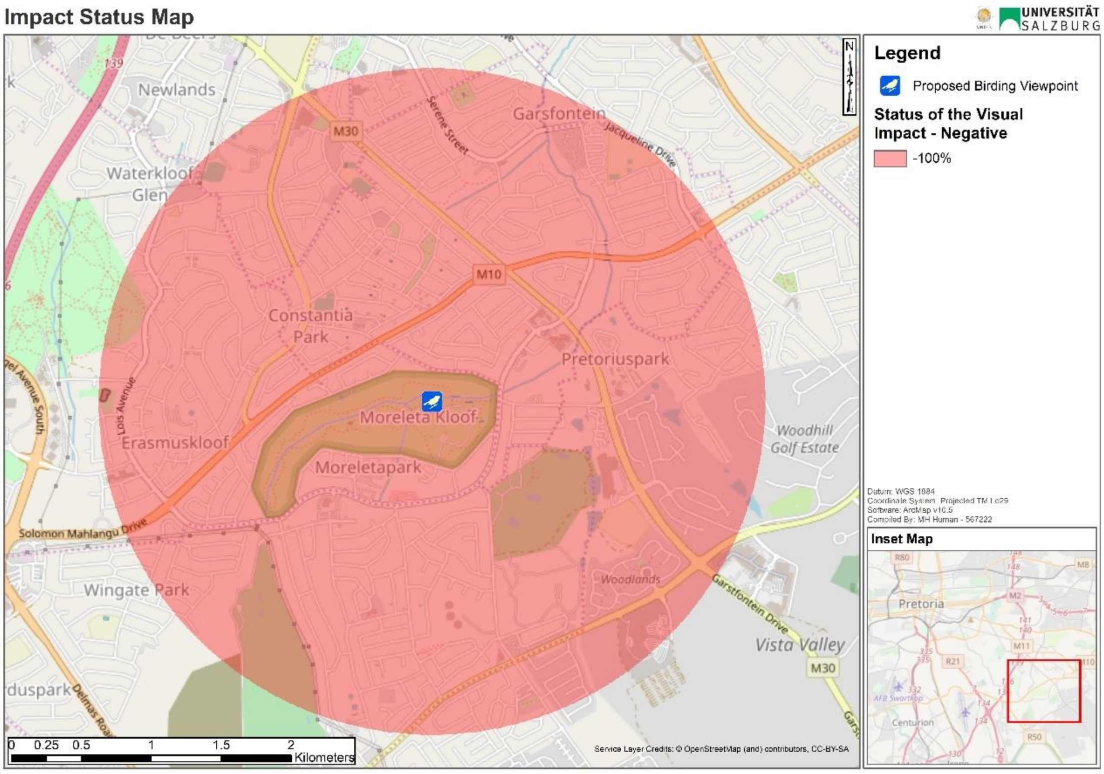
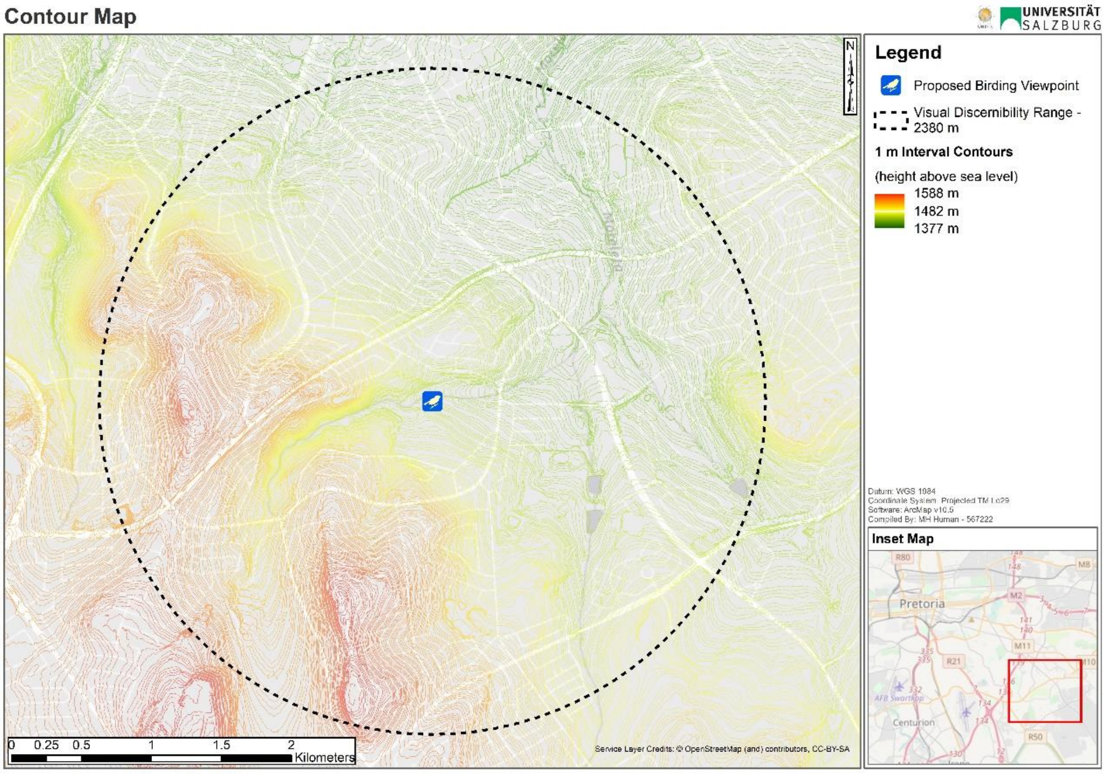


Figure 7: Impact Status Map

5.3. Visible Extent of the Impact

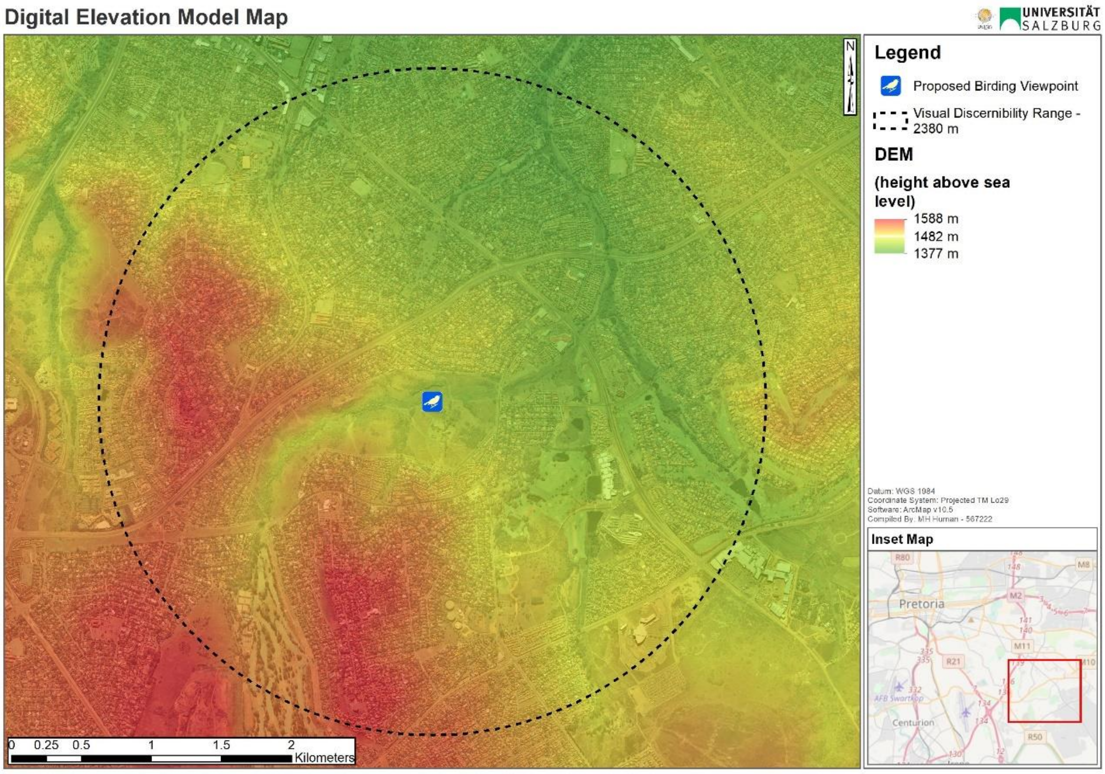
As discussed, the visible extent can be calculated by using the viewshed tool, on a DEM, within the limits of the affected area. The elevation data available was 1 meter contours in vector format, as shown below (Annexure A – Contour Map).

Contour Map



A DEM is created from the contours by using the Topo to Raster tool, as shown below (Annexure A – Digital Elevation Model Map).

Digital Elevation Model Map



This DEM will be used to conduct the viewshed analysis on. It should be noted that this DEM doesn't consider the elevation of the vegetation or the houses in the area. It is desirably so, since this variable should ideally be addressed as a mitigation measure.

The viewshed analysis also require an input feature of a point or a line which represents the observed object. The observed object, which is simplified as a cylinder with a diameter of 4 meters and a height of 3 meters, will be represented by various points. 20 points will be placed evenly throughout the 3 dimensions of the object. Thus, every point visible will translate to 5% of the object being visible at the perceived raster cell, as illustrated below.

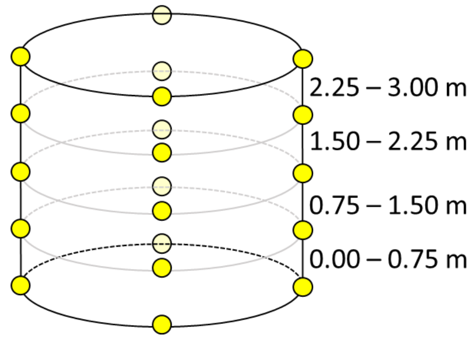


Figure 8: Point Observed Features

The points are created with the Create Feature tool and the following fields, parameters for the viewshed analysis, are added in the attribute table accordingly:

- OFFSETA – the observed feature's start elevation above the ground
- OFFSETB – the observed feature's end elevation above the ground
- RADIUS2 – the limit of the viewshed analysis, 2380m

Table

ObservedPoints

FID	Shape *	Id	PointNo	OFFSETA	OFFSETB	RADIUS2
0	Point	0	1	0	0	2380
1	Point	0	2	0	0	2380
2	Point	0	3	0	0	2380
3	Point	0	4	0	0	2380
12	Point	0	5	0.75	0.75	2380
13	Point	0	6	0.75	0.75	2380
14	Point	0	7	0.75	0.75	2380
15	Point	0	8	0.75	0.75	2380
24	Point	0	9	1.5	1.5	2380
25	Point	0	10	1.5	1.5	2380
26	Point	0	11	1.5	1.5	2380
27	Point	0	12	1.5	1.5	2380
28	Point	0	13	2.25	2.25	2380
29	Point	0	14	2.25	2.25	2380
30	Point	0	15	2.25	2.25	2380
31	Point	0	16	2.25	2.25	2380
32	Point	0	17	3	3	2380
33	Point	0	18	3	3	2380
34	Point	0	19	3	3	2380
35	Point	0	20	3	3	2380

Figure 9: Observed Features Attribute Table

The viewshed analysis is executed accordingly and the number of observed features visible from each raster cell is determined. This number of features is translated into the percentage value and the result, of the percentage of the observed object visible, is shown below (Annexure A – Viewshed Analysis Map).

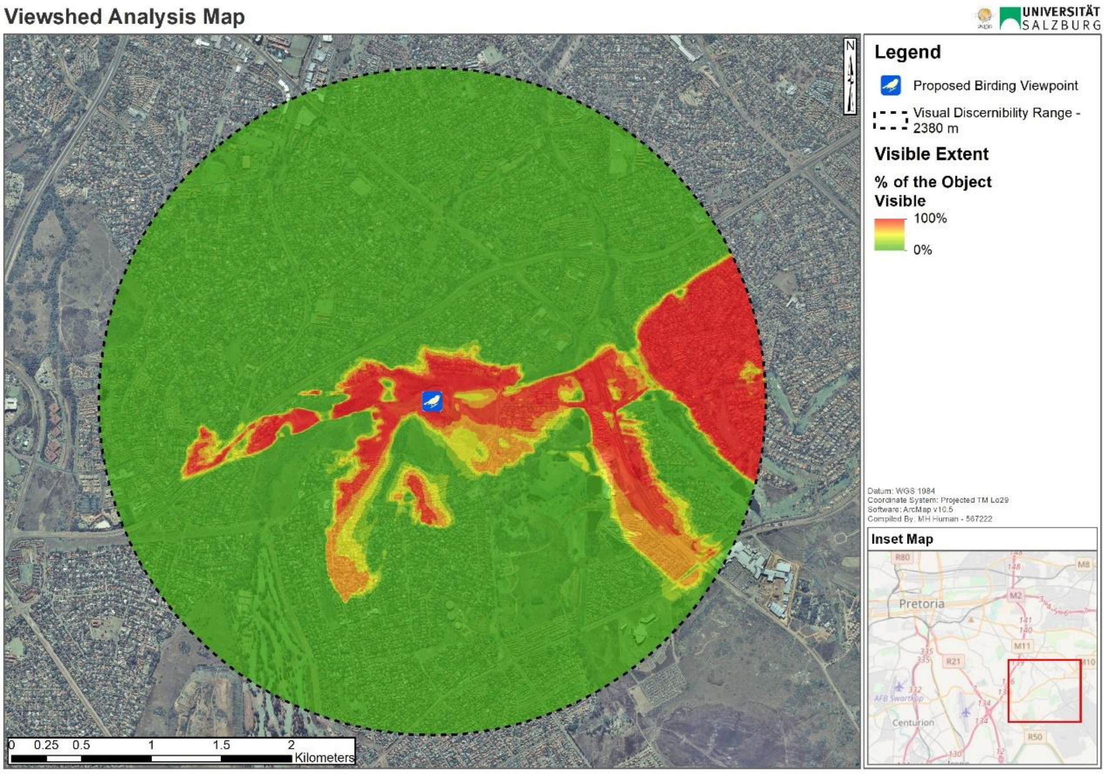


Figure 10: Viewshed Analysis Map

The result from the viewshed analysis shows how the topography within the affected area limits the visibility of the observed object. It can also be observed how certain areas can observe the whole object and other area only part of the object.

5.4. Severity of the Visual Impact

The severity of the visual impact decreases over distance. The formula proposed by the study is:

$$Sev = \left(\frac{VDR - D}{VDR - VPI1d}\right)^2 * 100$$

For this we need the distance where the visual perception index is 1, the visual discernibility range and the distance of each cell in the raster dataset.

The distance where the visual perception index is 1 needs to calculated accordingly.

$$D^2 = \frac{A^{obj}}{2\pi} * 100$$

$$D^2 = \frac{12}{2\pi} * 100$$

$$D^2 = 190.9091$$

$$D = 13.817$$

The visual discernibility range was already determined as 2380 meters.

The distance will vary at each raster cell within the affected area. Thus, the Euclidean Distance tool is used in order to calculate the distance of each raster cells in the affected area. Now that the variable for the severity formula has been identified it can be calculated with the raster calculator.

The result, the severity of the visual impact, is calculated accordingly and is shown below (Annexure A – Severity Map).

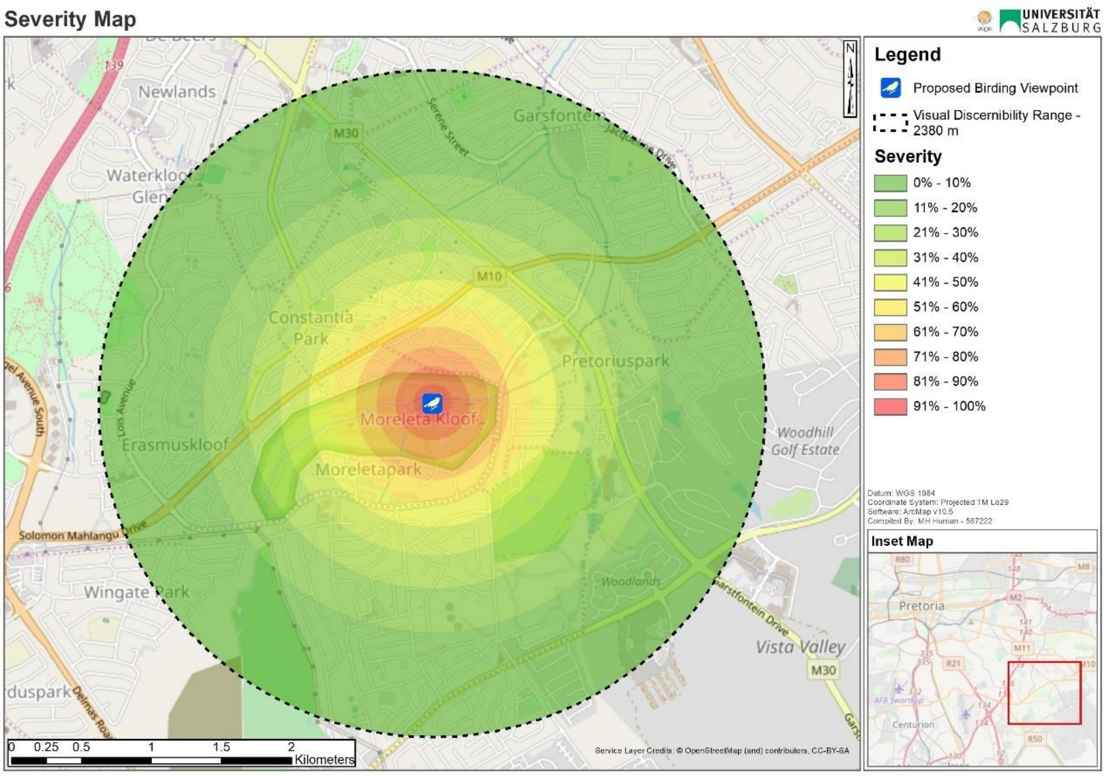


Figure 11: Severity Map

5.5. Duration of the Visual Impact

The duration of the visual impact evaluates how long the visual impact will persist. In this case the impact will persist for the long term, since it will remain as long as the structure remains (project life). No aspects were identified which might limit the visual impact within the affected area and therefore a 100% rating is determined for all the raster cells in terms of duration, as shown below (Annexure A – Duration Map).

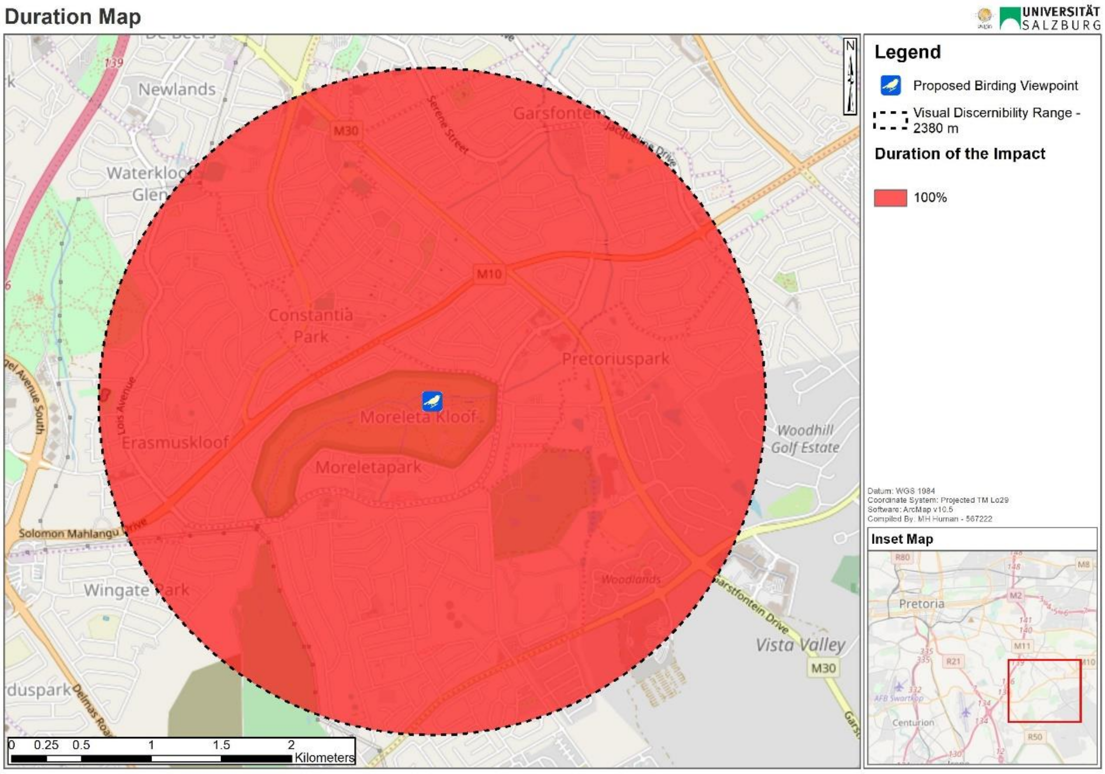


Figure 12: Duration Map

5.6. Probability of the Visual Impact Occurring

The probability of the visual impact being observed is rated in terms of the probability of an observer experiencing the impact at that area. The probability is determined by looking objectively at the study area. The areas are classified in terms of their evaluated probability by looking at various datasets including point of interest data, roads, land use and property data.

The area was classified into four categories of probability. The residential built-up area, consisting of houses, roads which is regularly travelled by motorists and pedestrians and office parks is regarded as a 100% for probability. The visitors' area within the reserve is also regarded as 100%. The trails within the reserve has a slightly less probability at 90%, since less people will be on these areas, but the observed object will still be observed. For the same reason, other open spaces and recreational facilities in the area are rated at 80%. The remainder of the reserve is rated at 50% since visitors are supposed to remain close to the trails, but staff and specialists do find themselves in these areas regularly. The resultant raster dataset is shown below (Annexure A – Probability Map).

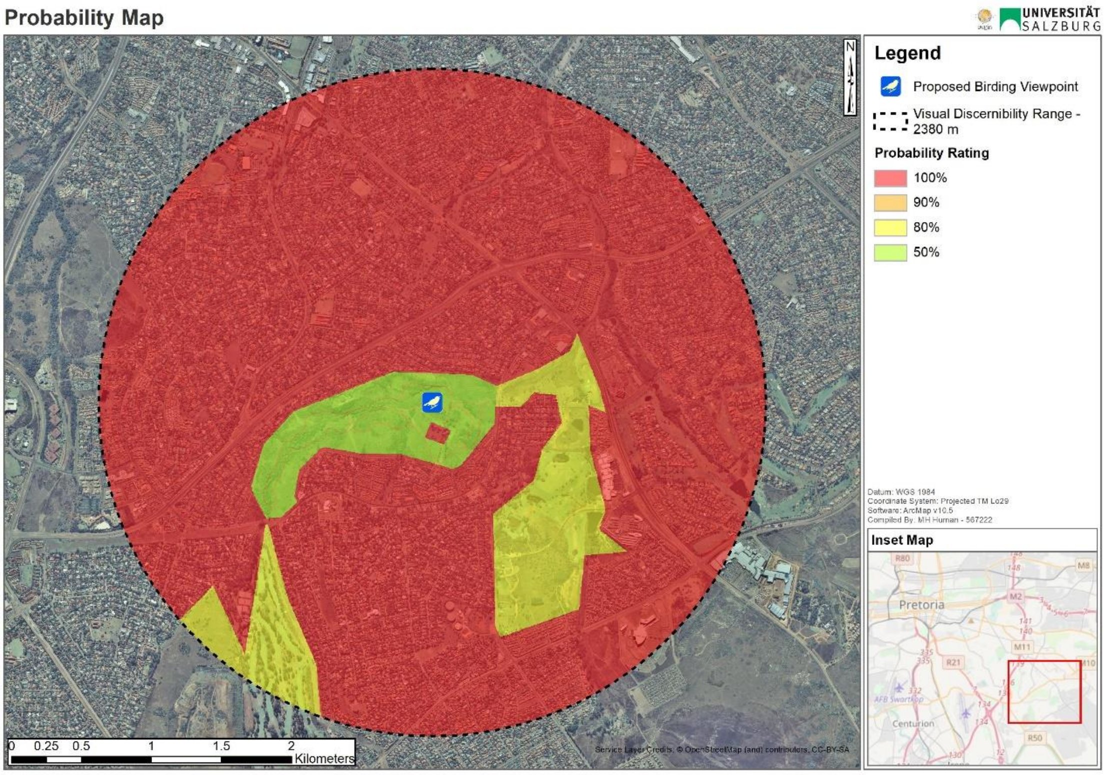


Figure 13: Probability Map

5.7. Mitigation Measures and Scientific Uncertainty

As mentioned in the study, the calculation of the significance of the visual impact are done with and without the influence which the mitigation measures and scientific uncertainties might have.

In this case the only influence identified was a mitigatory measure where the vegetation inside the reserve and the built-up features such as walls and roads around the reserve will limit the extent. No scientific uncertainty will be taken into consideration.

The average minimum height of the vegetation was determined as 0.6 meters. This calculates to 20% of the elevation of the observed object. This is expressed as a subtraction from 100% in order to conform with the percentage rating scale and thus a mitigatory value of 80% is assigned on the areas inside the reserve.

The average height of built-up features in the surroundings was determined as 1 meter. This calculates 33% elevation of the observed object. A mitigatory value of 67% is assigned to the areas outside the nature reserve.

The resultant mitigatory values can be seen below (Annexure A – Extent Mitigation Map).

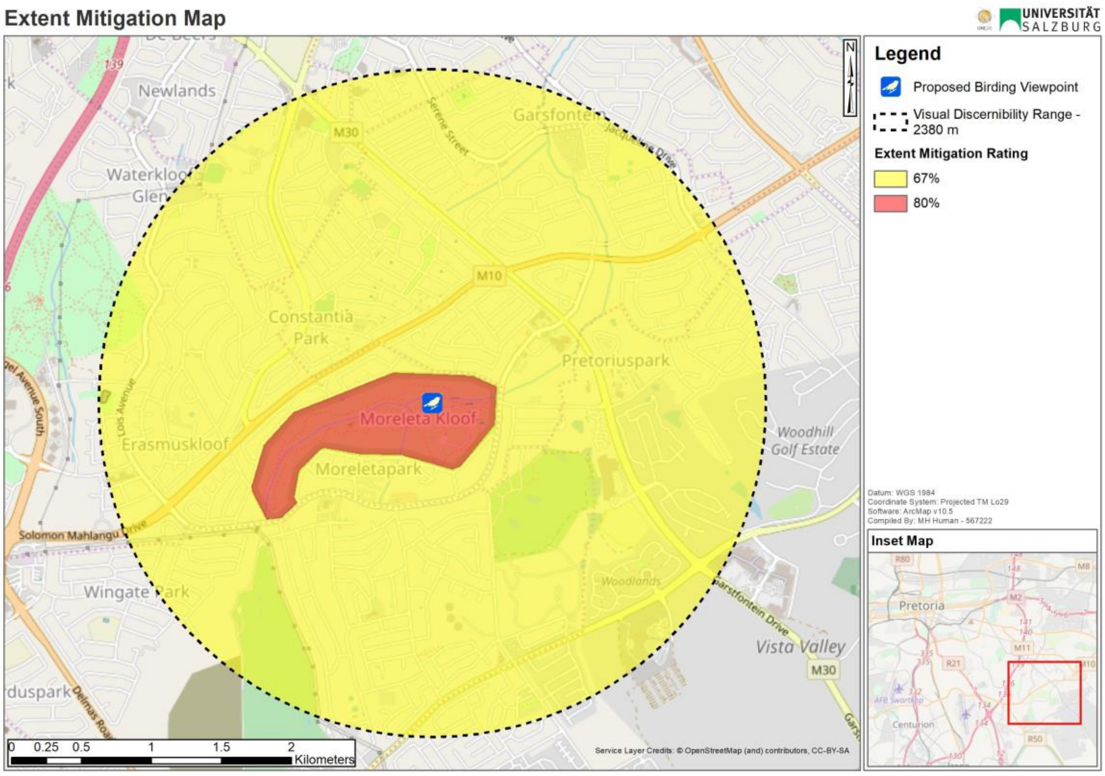


Figure 14: Extent Mitigation Map

6. Analysis of the Results

The results of the rating of the different elements have been determined in accordance to the findings made in this study. The final analysis of these results can now be calculated. The rating datasets of all the elements can now be used, as per the formula derived, to calculate the visual impact significance of each raster cell.

The first calculation will look at the worst-case scenario, thus no mitigation was considered and the formula is applied accordingly in the raster calculator.

$$Sig = Stat * Ext * Sev * Dur * Prob$$

The result shows which area will experience a more significant impact than others (Annexure A – Significance Rating Map).

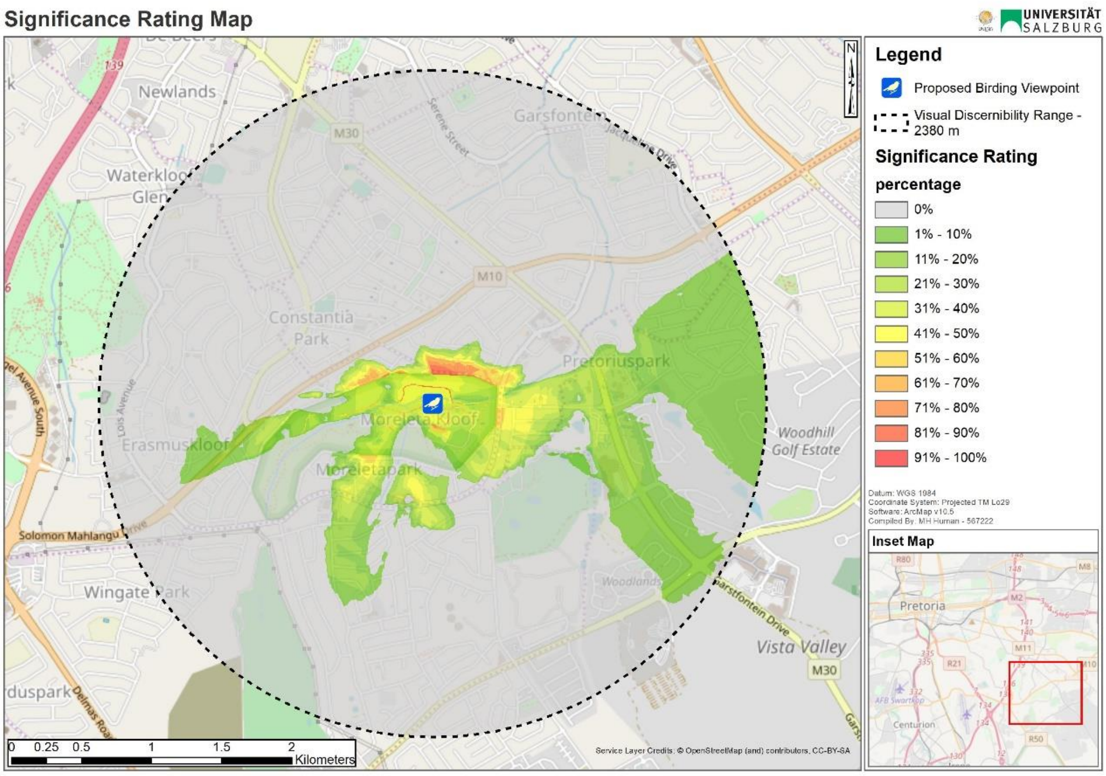


Figure 15: Significance Rating Map

This resultant raster dataset can further be analysed as per the requirement of the study. The use of Zonal Statistics as Table (Spatial Analyst) is quite useful in the summarizing of 'values of a raster within the zones of another dataset' (ESRI, 2017). This can be used to determine the sum of the significance rating throughout the study area or at different distances.

A closer look at the site-specific map reveals the detail achieved with the VIA (Annexure A – Significance Rating Map – Site Specific).

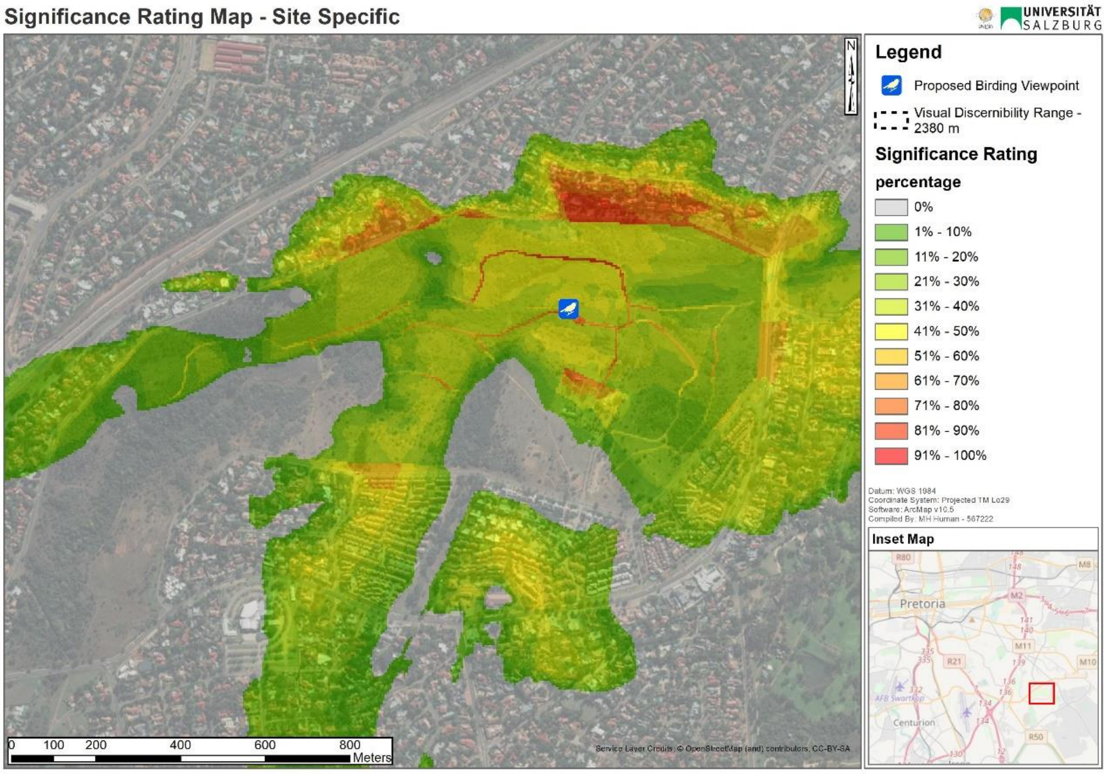


Figure 16: Significance Rating Map - Site Specific

The second calculation considers the identified mitigation. The only identified mitigation was in the extent element. Therefore, the formula is applied accordingly in the raster calculator.

$$Sig = Stat * Ext(mit) * Sev * Dur * Prob$$

The resultant output shows how the significance is reduced in comparison with the worst-case scenario (Annexure A – Significance Rating Map – With Mitigation).

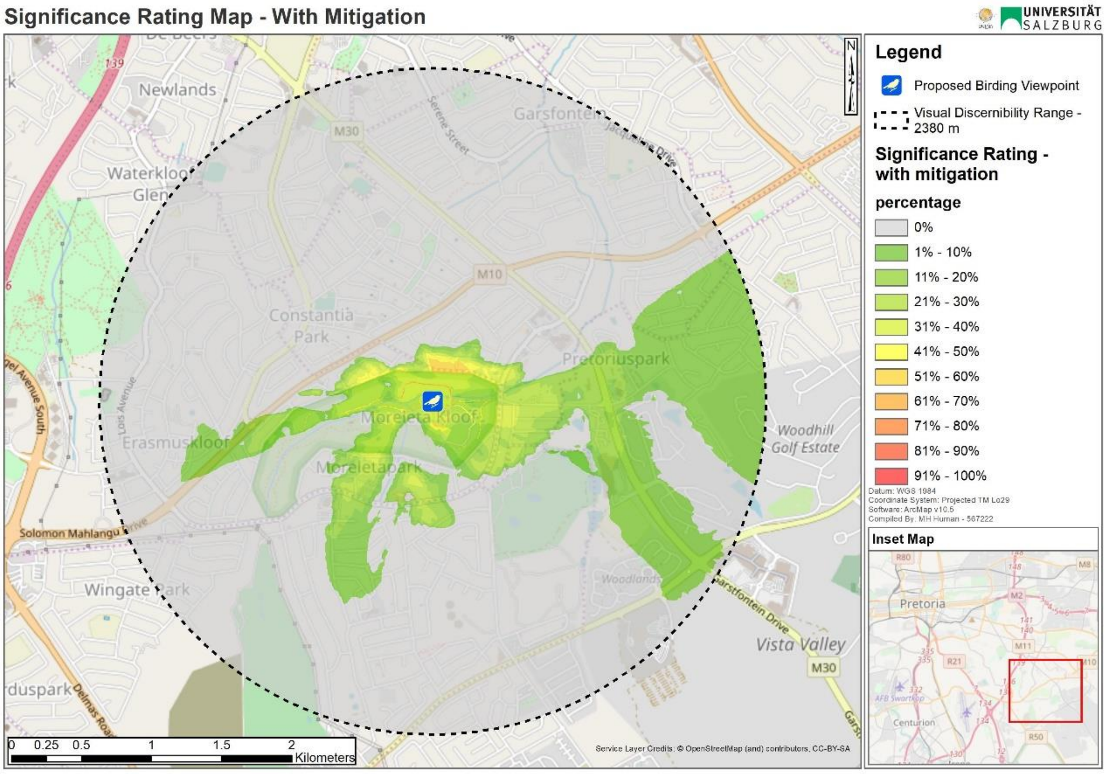


Figure 17: Significance Rating Map - with mitigation

7. Conclusion

The study determined, through research of quantitative literature, elements that needs to be considered when evaluating the significance of a visual impact.

The elements were identified as:

- Status of the visual impact (positive or negative)
- Extent of the visual impact
- Severity of the visual impact
- Duration of the visual impact
- Probability of the visual impact occurring
- Mitigation measures
- Scientific uncertainty

These elements were further researched and the aspects which plays a role in rating them accordingly. The input of GIS techniques and methods were identified which could assist in the rating and the analysis of the elements.

A mathematical formula was determined in order to calculate the significance of the visual impact. The GIS based raster analysis enabled the study to evaluate each raster cell in the affected area separately.

The study showed how GIS can be used in quantifying the significance of a visual impact. A comprehensive understanding of significance and visual impact was obtained. The role players were identified and the tools that can be used in the evaluating of a visual impact was showcased accordingly in an empirical study.

As a way forward from this study further investigation can be done in terms of how the proposed approach method can perhaps be built into model that can calculate the significance with the required input data and parameters. Further investigation can be done in order to determine whether more complex changes in the environment might have aspects which is not included in this study. How these aspects can be incorporated into consideration and how it will affect the outcomes.

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9. Annexure A – List of Maps

1. Locality Map
2. Visual Discernibility Range Map
3. Impact Status Map
4. Contour Map
5. Digital Elevation Model Map
6. Viewshed Analysis Map
7. Severity Map
8. Duration Map
9. Probability Map
10. Extent Mitigation Map
11. Significance Rating Map
12. Significance Rating Map - Site Specific
13. Significance Rating Map - with mitigation

Locality Map

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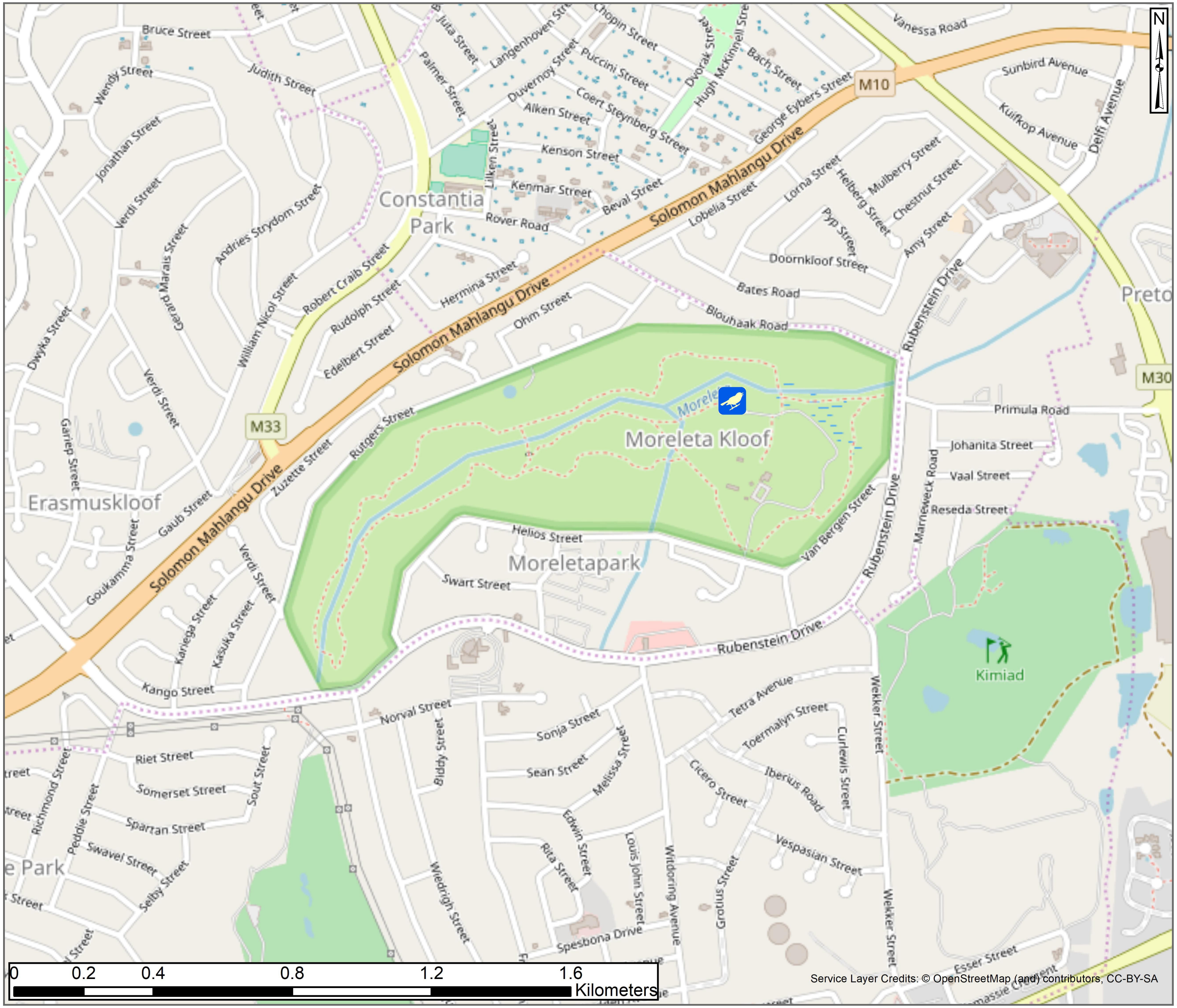


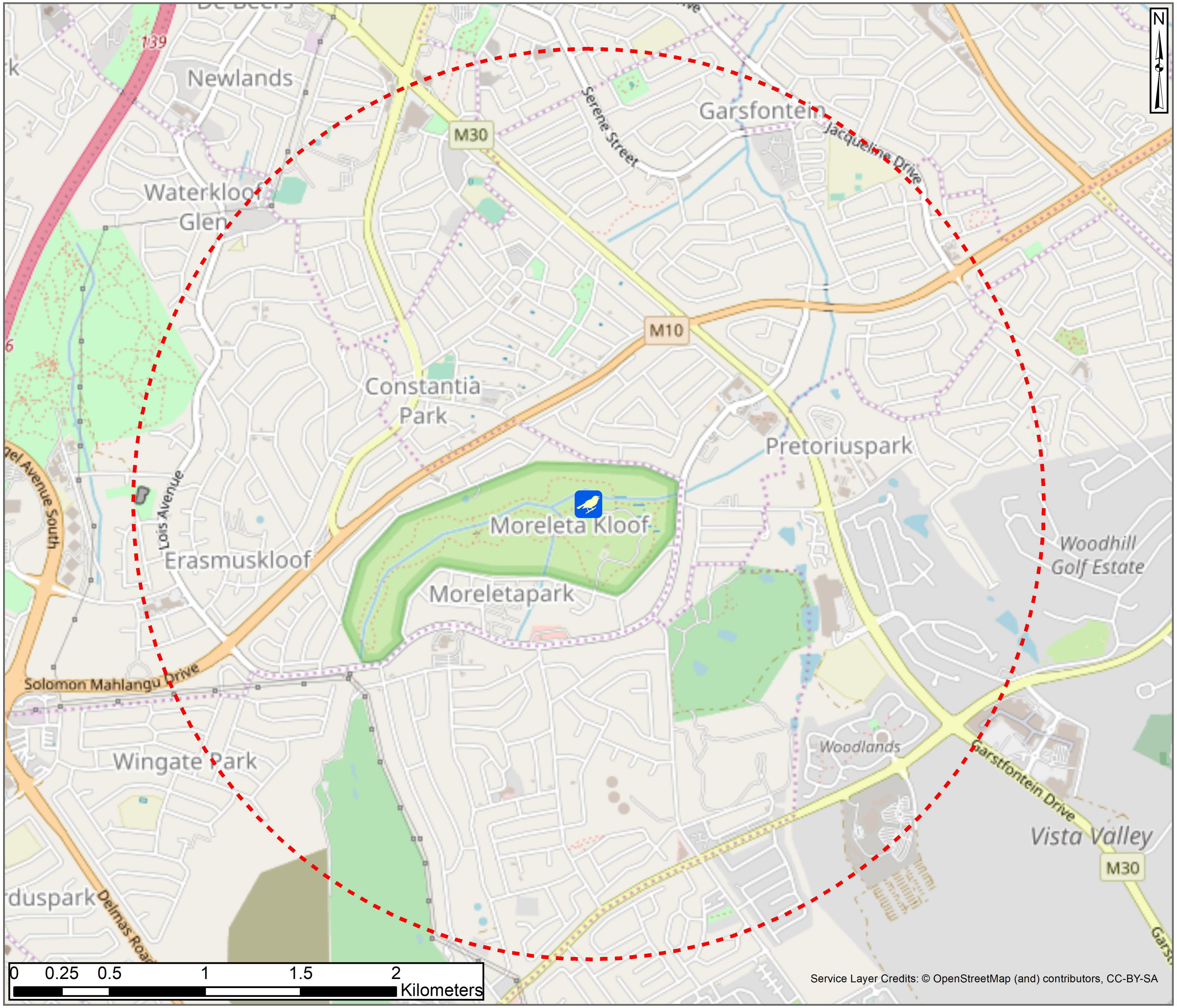
Legend

Proposed Birding Viewpoint

Datum: WGS 1984
Coordinate System: Projected TM Lo29
Software: ArcMap v10.5
Compiled By: MH Human - 567222

Inset Map

Visual Discernibility Range Map



Service Layer Credits: © OpenStreetMap (and) contributors, CC-BY-SA

Legend

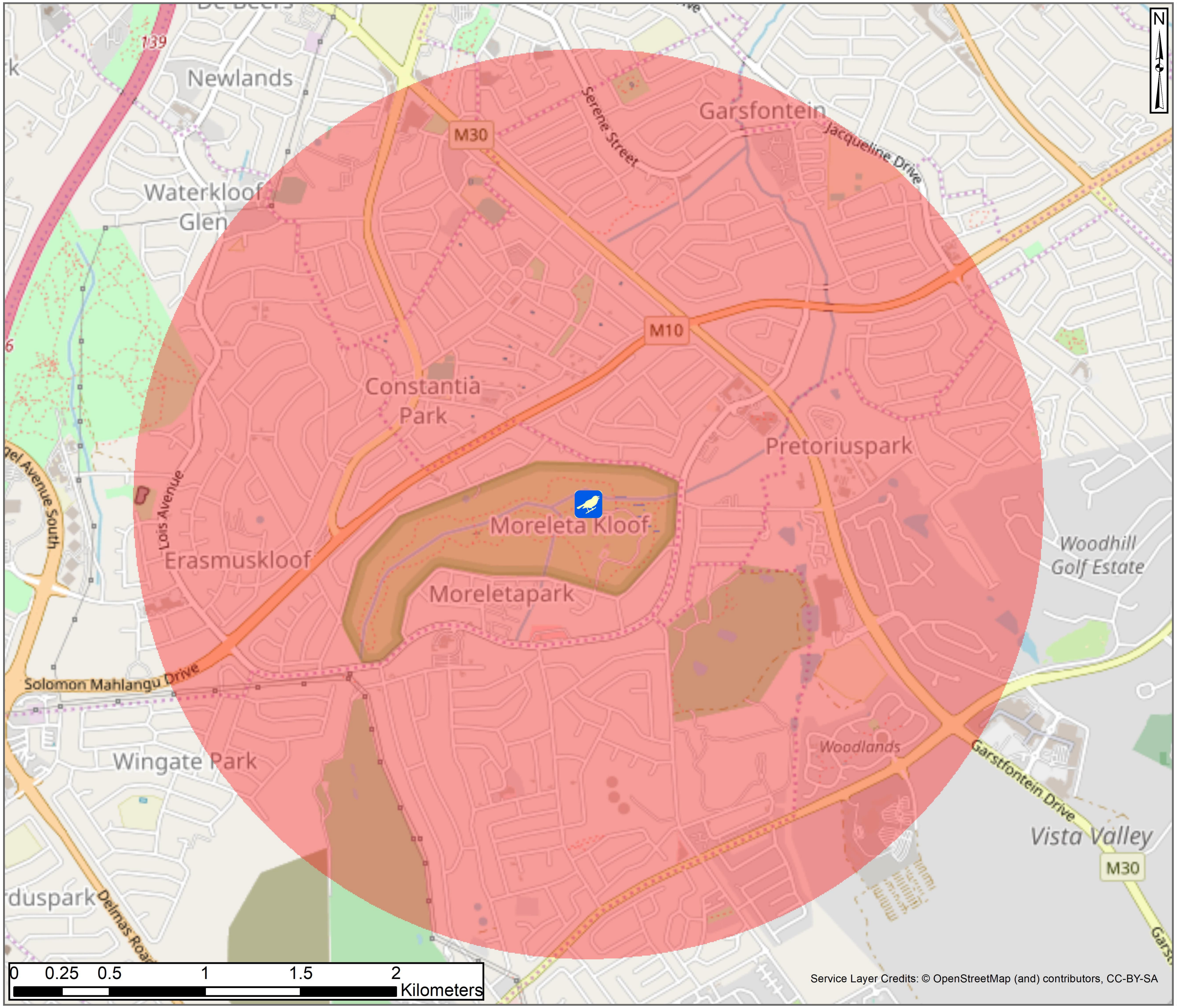
Proposed Birding Viewpoint

Visual Discernibility Range - 2380 m

Datum: WGS 1984
Coordinate System: Projected TM Lo29
Software: ArcMap v10.5
Compiled By: MH Human - 567222

Inset Map

Impact Status Map



Legend

Proposed Birding Viewpoint

Status of the Visual Impact - Negative

-100%

Datum: WGS 1984
Coordinate System: Projected TM Lo29
Software: ArcMap v10.5
Compiled By: MH Human - 567222

Inset Map

Contour Map

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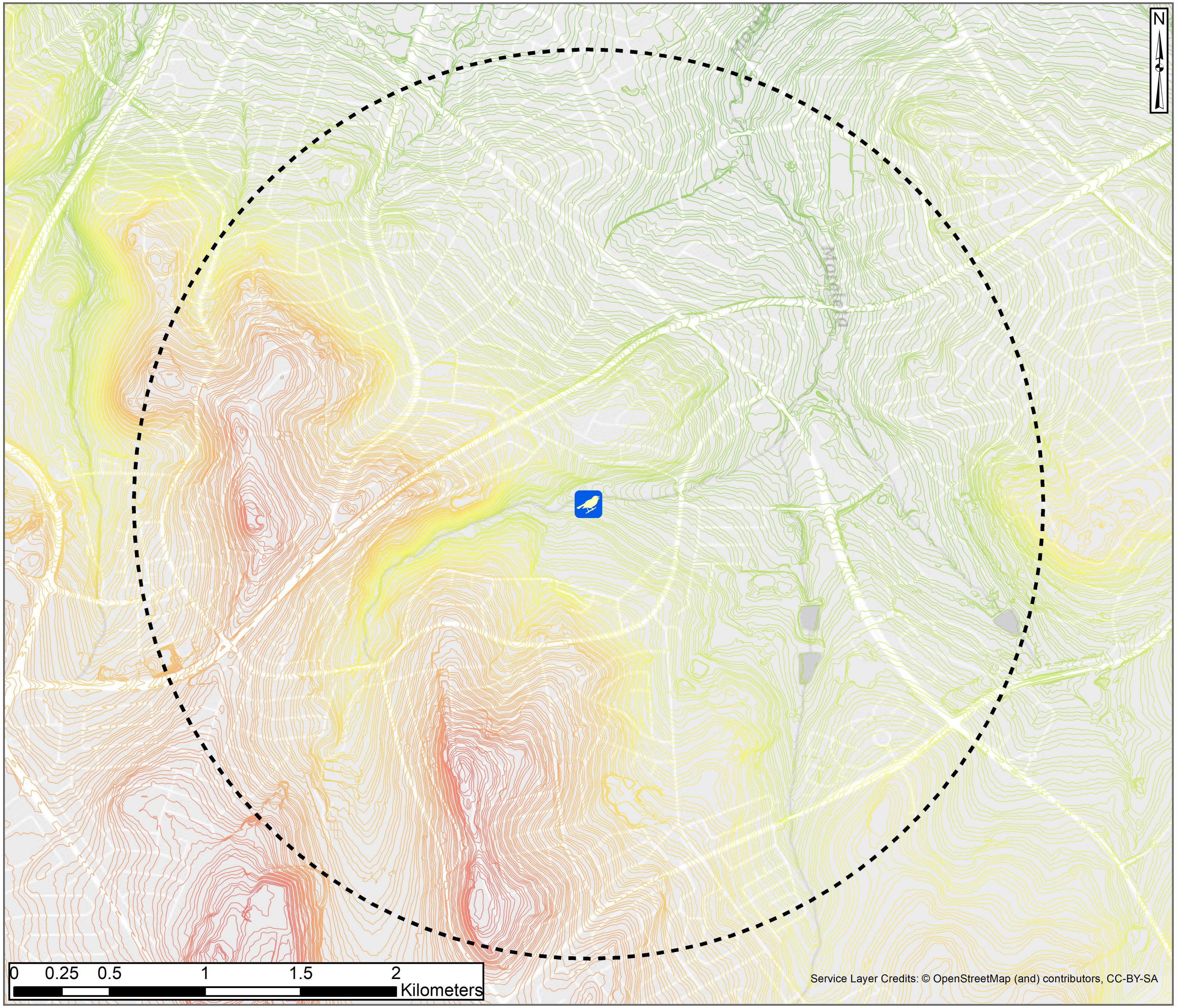


Legend

Proposed Birding Viewpoint

Visual Discernibility Range - 2380 m

1 m Interval Contours

(height above sea level)

1588 m

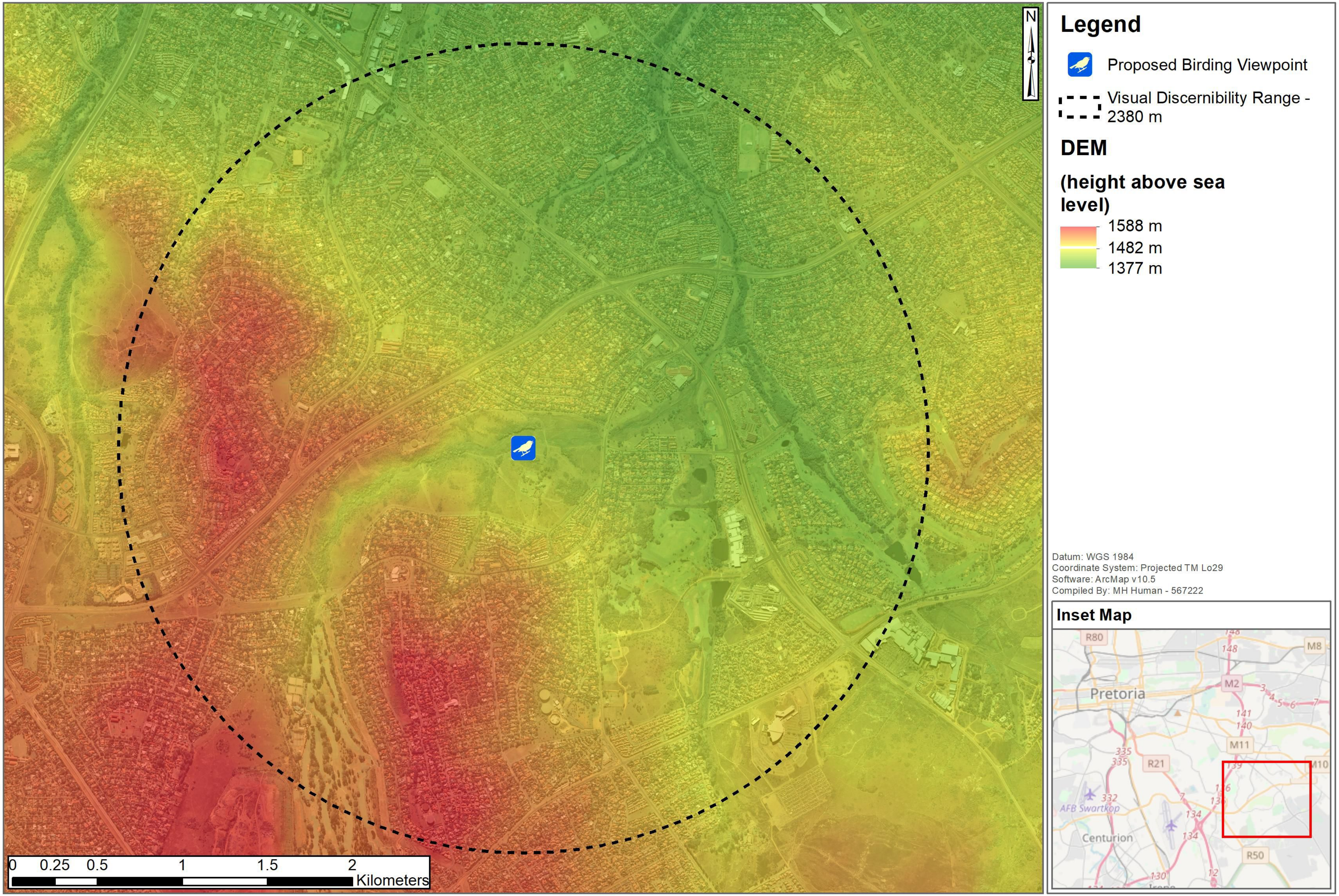
1482 m

1377 m

Datum: WGS 1984
Coordinate System: Projected TM Lo29
Software: ArcMap v10.5
Compiled By: MH Human - 567222

Inset Map

Digital Elevation Model Map



Viewshed Analysis Map

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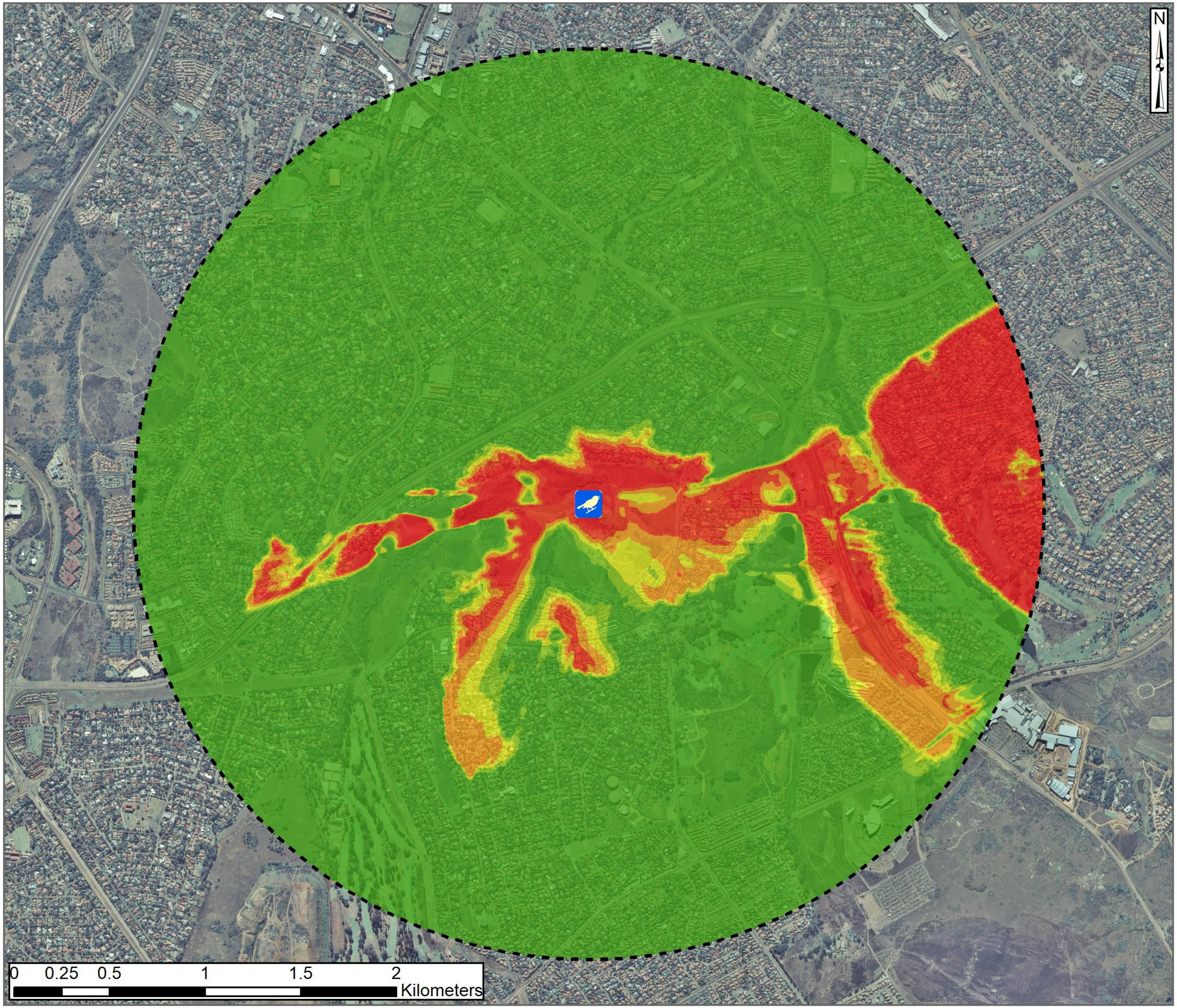


Legend

Proposed Birding Viewpoint

Visual Discernibility Range - 2380 m

Visible Extent

% of the Object Visible

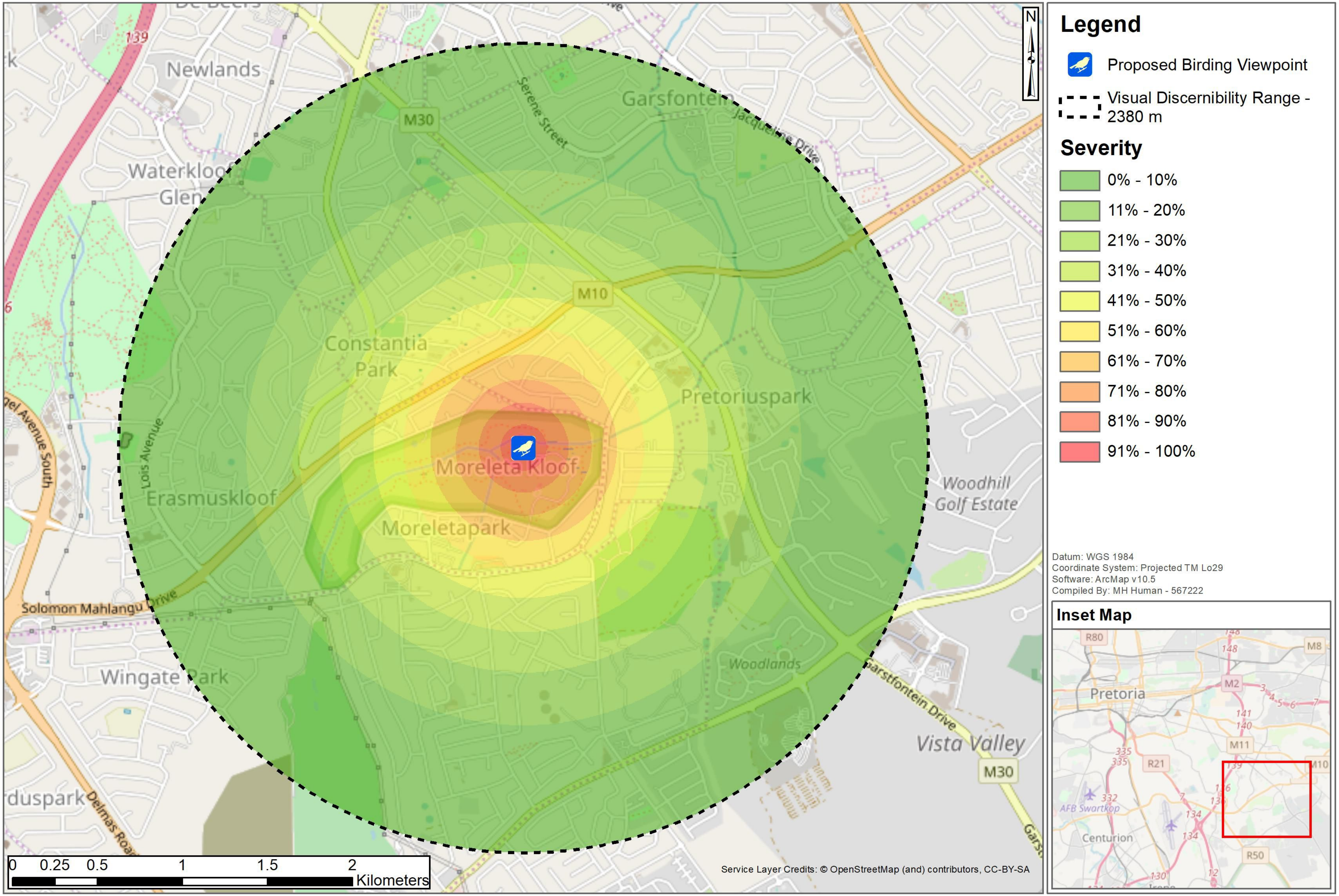
100%

0%

Datum: WGS 1984
Coordinate System: Projected TM Lo29
Software: ArcMap v10.5
Compiled By: MH Human - 567222

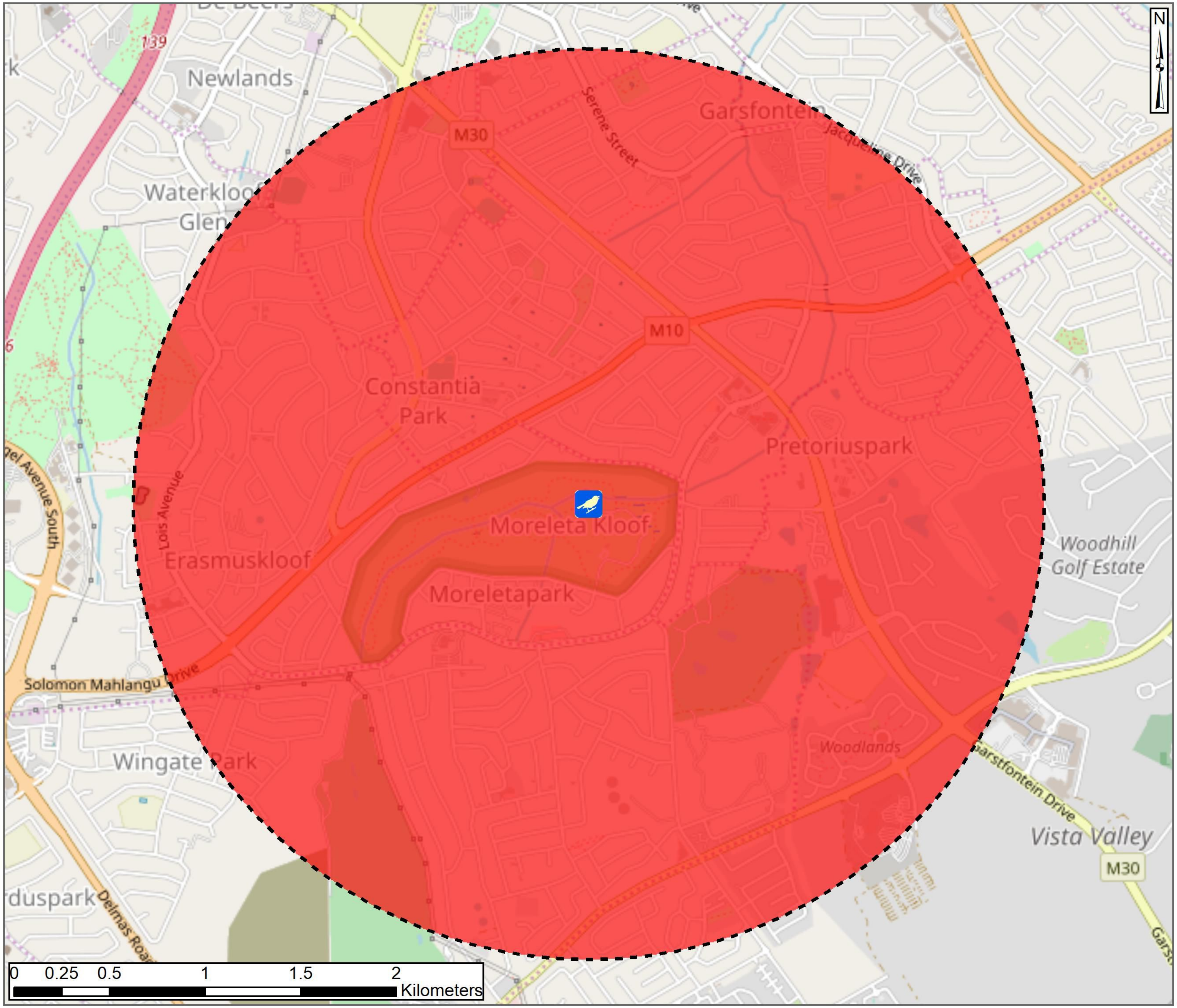
Inset Map

Severity Map



Datum: WGS 1984
Coordinate System: Projected TM Lo29
Software: ArcMap v10.5
Compiled By: MH Human - 567222

Duration Map



Legend

Proposed Birding Viewpoint

Visual Discernibility Range - 2380 m

Duration of the Impact

100%

Datum: WGS 1984
Coordinate System: Projected TM Lo29
Software: ArcMap v10.5
Compiled By: MH Human - 567222

Inset Map

Probability Map

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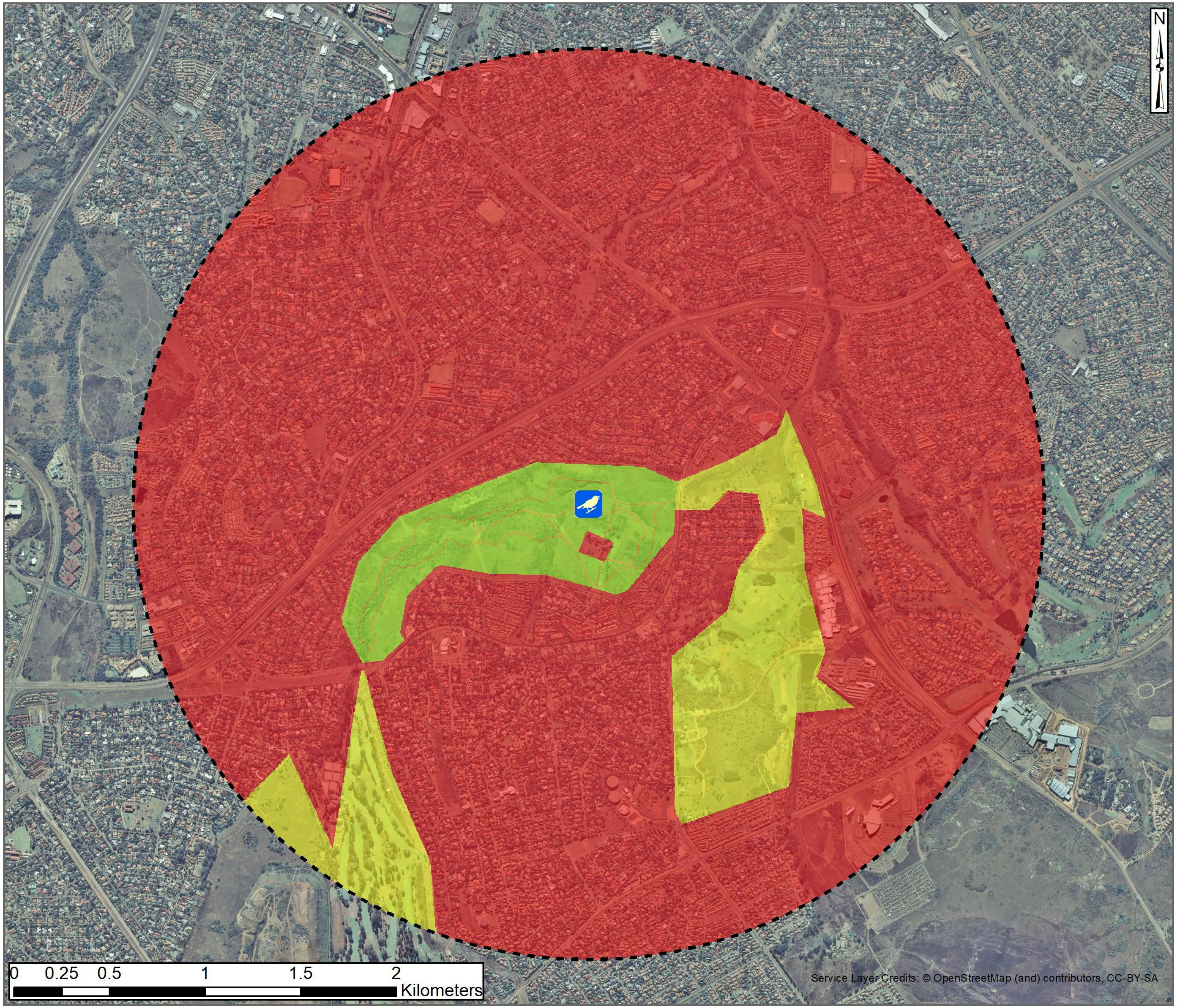


Legend

Proposed Birding Viewpoint

Visual Discernibility Range - 2380 m

Probability Rating

100%

90%

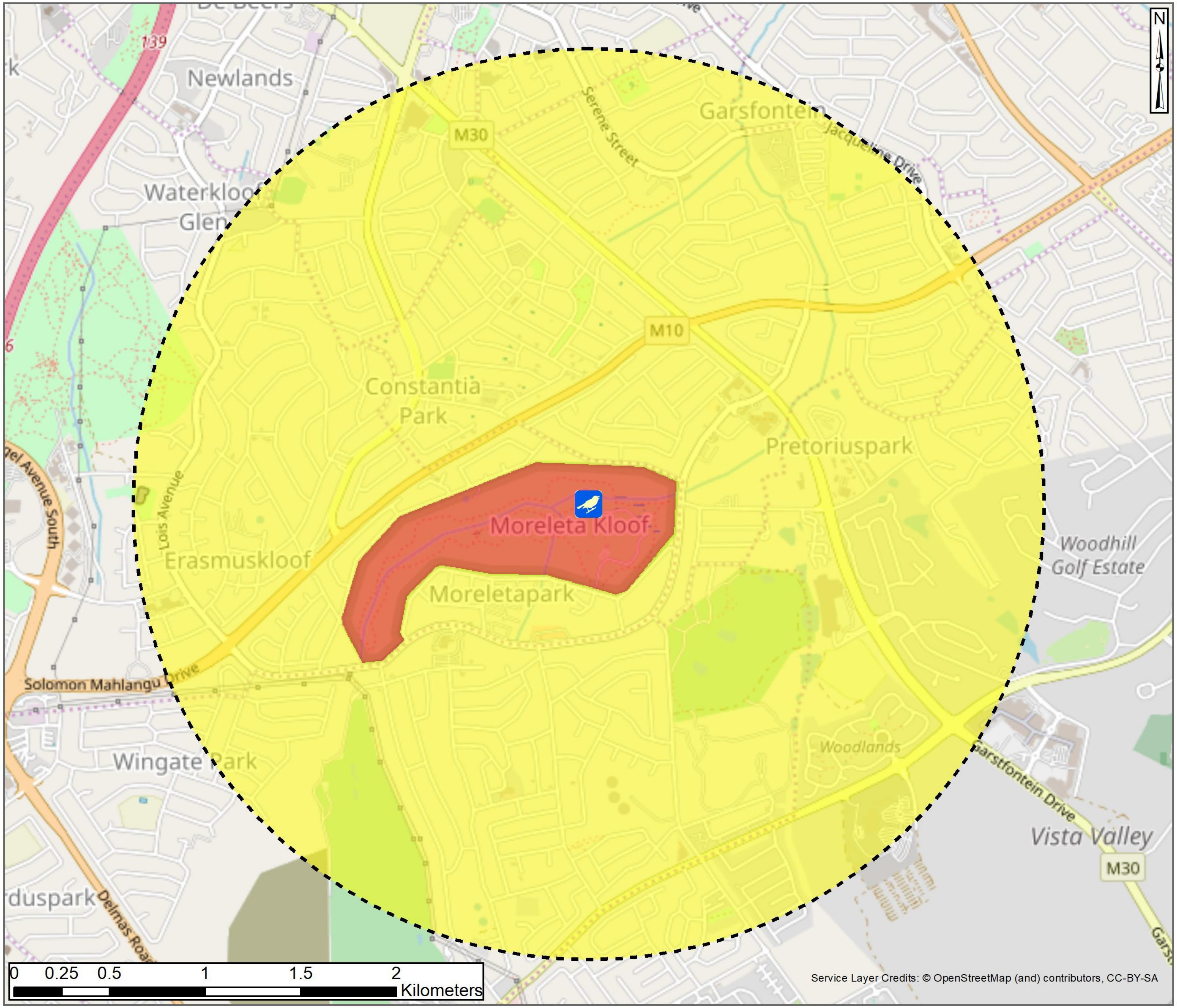
80%

50%

Datum: WGS 1984
Coordinate System: Projected TM Lo29
Software: ArcMap v10.5
Compiled By: MH Human - 567222

Inset Map

Extent Mitigation Map



Legend

Proposed Birding Viewpoint

Visual Discernibility Range - 2380 m

Extent Mitigation Rating

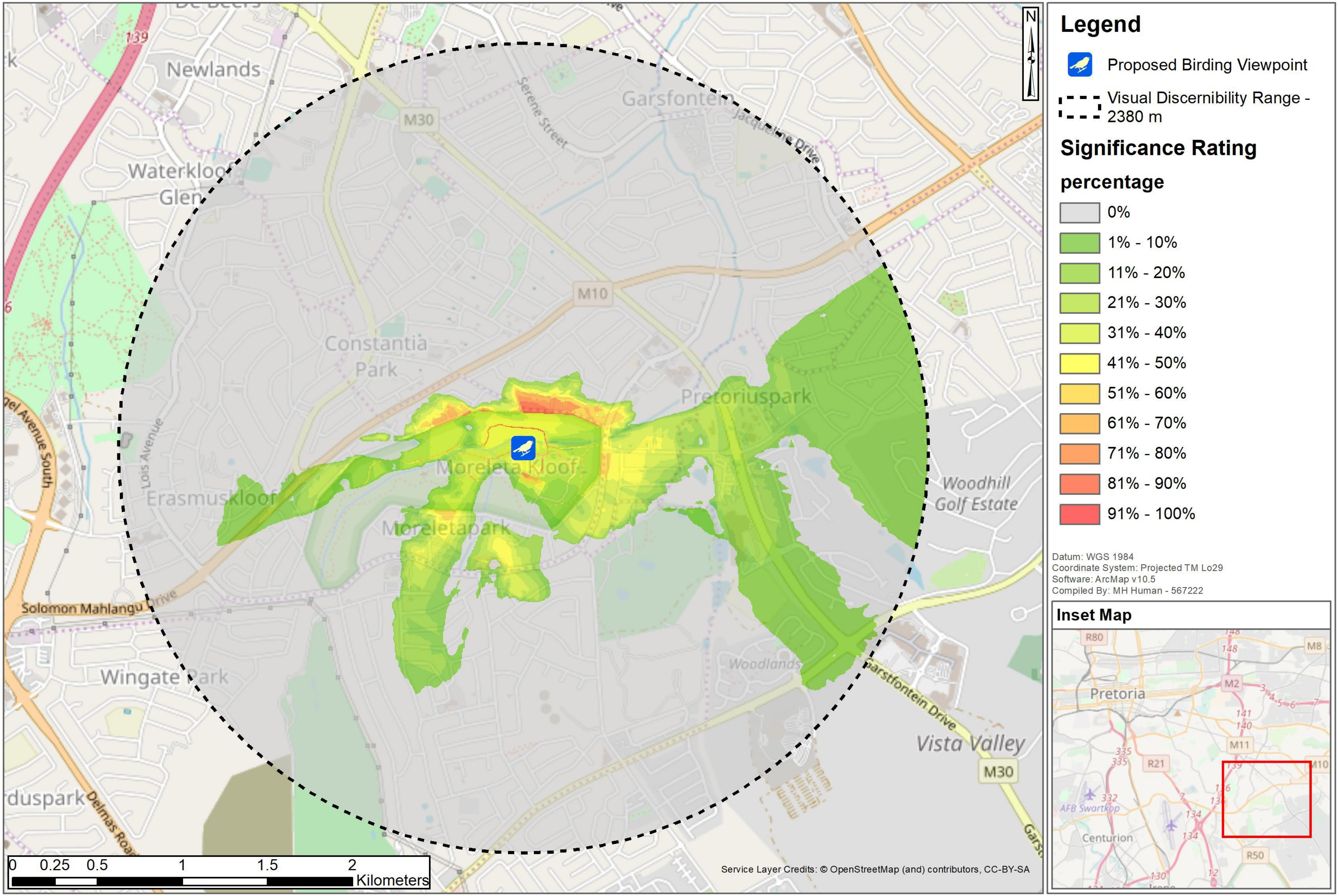
67%

80%

Datum: WGS 1984
Coordinate System: Projected TM Lo29
Software: ArcMap v10.5
Compiled By: MH Human - 567222

Inset Map

Significance Rating Map



Significance Rating Map - Site Specific

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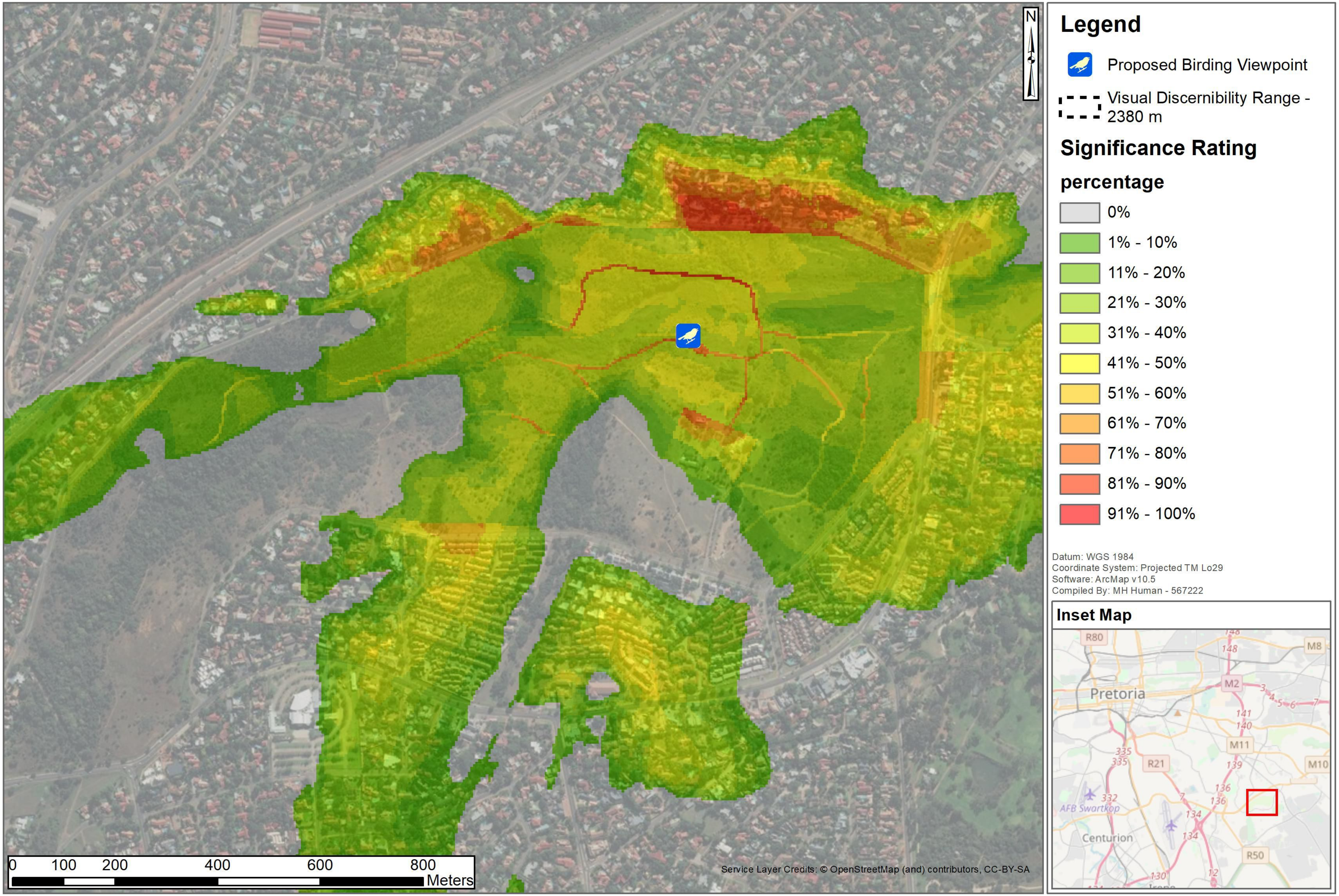

Significance Rating Map - With Mitigation

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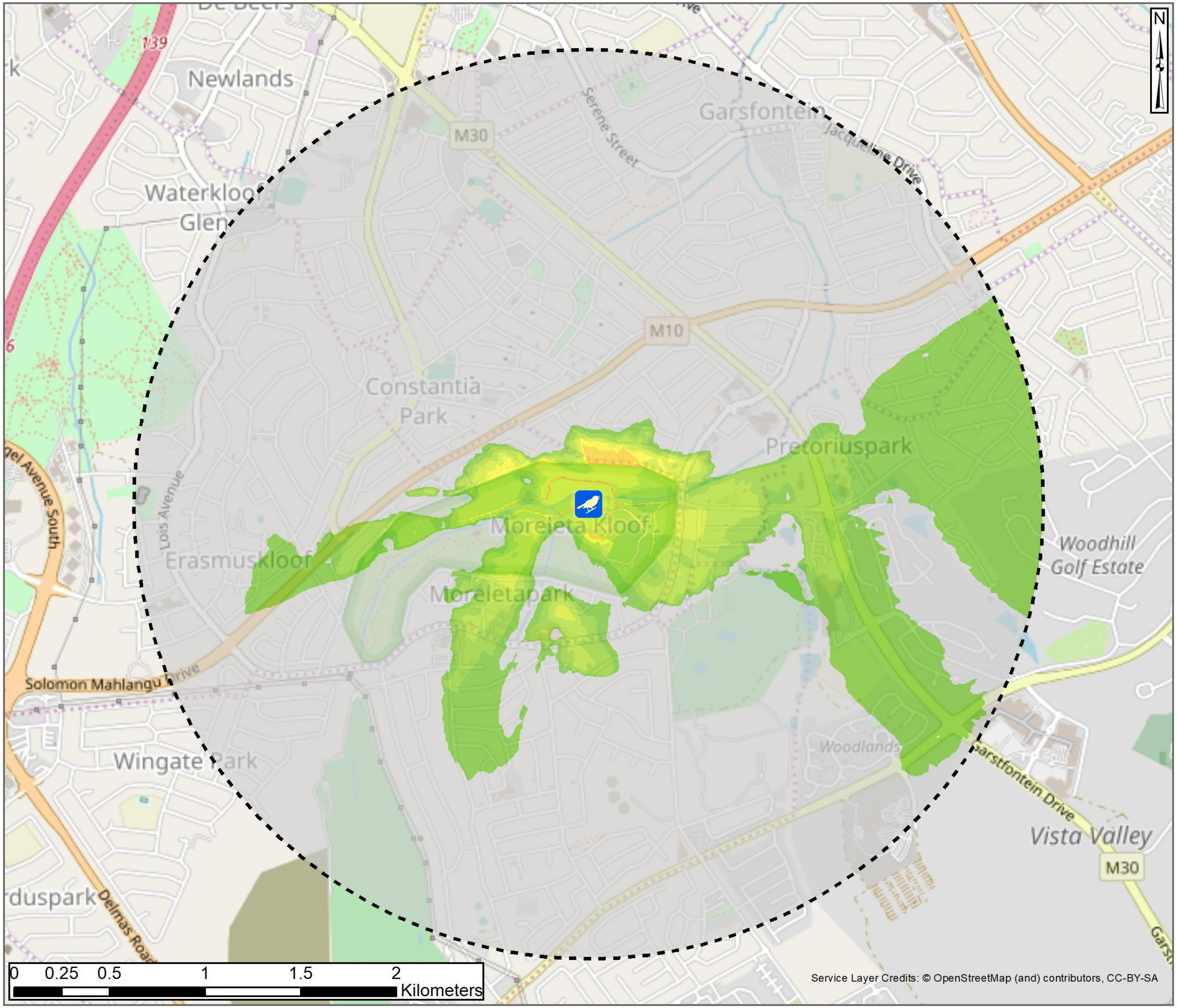

Legend

Proposed Birding Viewpoint

Visual Discernibility Range - 2380 m

Significance Rating - with mitigation

percentage

- 0%
- 1% - 10%
- 11% - 20%
- 21% - 30%
- 31% - 40%
- 41% - 50%
- 51% - 60%
- 61% - 70%
- 71% - 80%
- 81% - 90%
- 91% - 100%

Datum: WGS 1984
Coordinate System: Projected TM Lo29
Software: ArcMap v10.5
Compiled By: MH Human - 567222

Inset Map