Ranking geothermal surface features in the Bay of Plenty region – updated April 2019

RR Reeves

GNS Science Consultancy Report 2019/07
May 2019

GNS SCIENCE
TE PŪ AO

DISCLAIMER

This report has been prepared by the Institute of Geological and Nuclear Sciences Limited (GNS Science) exclusively for and under contract to Bay of Plenty Regional Council. Unless otherwise agreed in writing by GNS Science, GNS Science accepts no responsibility for any use of or reliance on any contents of this report by any person other than Bay of Plenty Regional Council and shall not be liable to any person other than Bay of Plenty Regional Council, on any ground, for any loss, damage or expense arising from such use or reliance.

Use of Data:

Client consent required to use data.

BIBLIOGRAPHIC REFERENCE

Reeves RR. 2019. Ranking geothermal surface features in the Bay of Plenty region – updated April 2019. Wairakei (NZ): GNS Science. 11 p. Consultancy Report 2019/07.

CONTENTS

TABLES

FIGURES

APPENDICES

ATTACHMENTS

Appendix 1 – Geothermal surface feature scores – Excel file (attached in the PDF file)

EXECUTIVE SUMMARY

The method of scoring geothermal surface features in the Bay of Plenty (BOP) region from a desktop perspective (Reeves 2018) is used to update the scores of geothermal surface features in the BOP region. The revised scoring uses an additional 292 features located in the BOP region that were not used in the original report (Reeves 2018). The method utilises a full dataset of 4291 active geothermal surface features in the Taupo Volcanic Zone, with 2165 of these in the BOP region.

Of the 2165 geothermal surface features in the BOP region, 997 have a score adjustment based on the most recently acquired feature length, feature size, temperature or flow data. The mixed pool feature type is the most affected feature type.

1.0 INTRODUCTION

Different types of geothermal surface features occur within New Zealand geothermal fields. These feature types include geysers, primary flowing springs, mixed pools, mud pots and heated ground (Scott 2012). The surface expressions of geothermal fields have intrinsic value to tourism, local culture and ecosystem support (e.g., thermotolerant vegetation). Increasing demands on optimising resource utilisation and land use can impact geothermal surface features in areas where developments or land use change is occurring.

Geothermal surface features can be assessed according to agreed criteria that test for significance. The criteria include values such as representativeness, rarity, resilience and memorability. These results can be used, for example, to produce a statutory list of Significant Geothermal Features (SGFs). The results of this feature scoring process can assist resource managers and developers in mitigating potential adverse effects on geothermal surface features. This helps to inform decisions around various levels of protection or utilisation. This process is generally required as part of the Resource Management Act (1991) and the associated consenting process administered by local, regional and national government agencies.

Bay of Plenty Regional Council (BOPRC) needs to identify SGFs as a requirement under the Regional Policy Statement (RPS) (Bay of Plenty Regional Council 2014). The RPS provides a framework to manage geothermal systems in the Bay of Plenty (BOP) region. Scott and Bromley (2018) recently presented several methods of identifying SGF's in the BOP region.

Reeves (2018) applies a method of ranking geothermal surface features by allocating adjusted scores to features, based on the methodology developed by Scott and Bromley (2018), to help BOPRC identify SGFs. However, an additional 292 geothermal surface features located in the BOP region were found not to be included in the initial Reeves (2018) assessment. As these additional data may have an influence on the current scores and rankings established by Reeves (2018), the analysis is revisited in this study.

This report revises the analysis presented in (Reeves 2018) where surface geothermal features were ranked according to adjusted scores. In this report the impact of the inclusion of an additional 292 features is presented. This report should be read in conjunction with Reeves (2018) for a discussion of the data, the method and interpretive limitations (which are not repeated in this report).

2.0 RESULTS AND DISCUSSION

Tables 2.1 and 2.2 summarise the statistics of feature attributes associated with geothermal surface features in the Taupo Volcanic Zone (TVZ) and BOP regions, respectively. In total, 4291 active geothermal features in the TVZ (with 2165 of these located in the BOP region) are used in this revised assessment.

The 5th, 25th, 75th and 95th percentiles in Tables 2.1 and 2.2 are used to calculate the appropriate values of the score adjustments, and therefore the final adjusted scores which are applied and presented. Tables 2.1 and 2.2 provide good benchmarks for geothermal surface feature data where limited feature information (such as length and temperature) is available. Tables 2.1 and 2.2 can also be used to monitor regional scale changes over time as this process is repeated.

Appendix 1 (Excel file attached) summarises the results of the score adjustment process for the features in the BOP region with quality codes (a quality code assigned based on available data – higher quality codes indicate more parameters (i.e., temperature, length, size and flow) were available to calculate the score adjustment): 997 features (46%) in the BOP region received an adjustment to the default feature-type score (i.e., the score a feature would receive if no parameter data were available), with 345 features reducing their total score by up to 0.51 units and 652 features increasing their total score by up to 0.51 units. The highest scoring feature is RRF0075 (GGW Feature ID 993, Pohutu Geyser) in the Rotorua Geothermal Field (Figure 2.1).

The 112 highest scoring features have adjusted scores greater than 4.16 and consist of geysers, mud geysers and primary flowing springs. These occur across eight geothermal fields (Rotorua, Waimangu-Rotomahana-Mt Tarawera, Rotoma-Tikorangi-Mangakotukutuku, Lake Rotokawa-Mokoia, Centre basin – Rotoiti, Lakes Okataina-Tarawera, Tikitere, and Kawerau); (Figures 2.1 and 2.2). All 16 of the geysers identified in the BOP region are amongst the top 112 scoring features.

The 146 lowest scoring features (excluding features with no thermal activity or could not be located) have adjusted scores less than 1.81 and consist of heated ground and two mixed pools with the features spread across ten geothermal fields (Rotorua, Rotoma-Tikorangi-Mangakotukutuku, Lake Rotokawa-Mokoia, Whale Island, Kawerau, White Island (Whakaari), Waimangu-Rotomahana-MtTarawera, Waiotapu, Taheke, and Tikitere) (Figure 2.1). The large proportion of heated ground features in this group probably reflects the low default feature-type score allocated to the heated ground feature type and the limited additional data collected to date on this feature type.

The quality control score which reflects the amount of feature parameter data collected is presented in (Appendix 1). Often these are limited and obtaining more temperature (water or ground), size, length, and flow data for geothermal surface features will improve the reliability of the score adjustments. Of the 2165 geothermal surface features that are active in the BOP region, data available to calculate the adjustments (% values in blue text below) show how this compares to the entire TVZ dataset (% values in red text below):

- All three parameters, size, temperature, and flow data, were available for 200 features (BOP 9%, TVZ 16%).
- One parameter of size, temperature, or flow data was available for 1049 features (BOP 48%, TVZ 34%).
- Two parameters of size, temperature, or flow data were available for 188 features (BOP 8%, TVZ 22%).
- No parameter data were available for 715 features (BOP 33%, TVZ 27%).

Table 2.1 Summary statistics for the geothermal surface features in the TVZ region. Note that some values have been rounded.

Feature type	Total number of features for each feature type	Parameter	Number of results used to calculate the statistics for each parameter	Min	5th Percentile	25th Percentile	Median	75th Percentile	95th Percentile	Max	Median Absolute Deviation (MAD)	Comment
Fumaroles	225	Length of feature (m)	68	0.1	0.2	0.5	1	4	29.75	200	0.7	
		Feature size (m^2)	36	0.018	0.03	0.08	0.25	0.925	15	750	0.185	
		Water/steam temperature (Deg C)	46	25	32.5	72.5	95.9	99.875	139.125	340	5.1	
Geysers	64	Length of feature (m)	17	0.3	0.42	0.6	1.5	2.1	4.1	4.5	0.9	
		Feature size (m^2)	35	0.05	0.1	0.4	1.4	2.75	4.3	5	1.1	
		Water/steam temperature (Deg C)	45	35	58	90	98	99.8	100	101	2	Includes all data (i.e., outliers included)
Heated ground	279	Length of feature (m)	139	0.5	1.45	7.75	15	45	86.5	115	12	
		Feature size (m^2)	60	0.12	4.95	157	600	2400	4810	9000	591.95	
		Water/steam temperature (Deg C)	77	24.7	38.8	52	52	59	73	98	1.2	Includes all data (i.e., outliers included)
Eruption craters	119	Length of feature (m)	61	1	4	10	30	80	150	225	25	
		Feature size (m^2)	50	1	7.87	25	314	1590	3000	5000	295	
Mud geysers	30	Length of feature (m)	20	0.1	0.119	1.05	2	3	5.05	6	1	
		Feature size (m^2)	5	2.7	2.788	3.14	5.72	15.9	25.58	28	3.02	
		Water/steam temperature (Deg C)	3	82	82.3	83.5	85	88.15	90.67	91.3	3	
Mud pots	67	Length of feature (m)	46	0.3	0.325	2	3	6	10	11	2	
		Feature size (m^2)	37	0.001	0.114	1	4.5	8	25.4	27	3.5	
		Water/steam temperature (Deg C)	45	24.6	29.76	49.9	76.5	90.3	98.44	100.9	19.9	
Mixed springs	746	Length of feature (m)	288	0.03	0.2	0.6	1.5	3.625	9	10	1.2	
		Feature size (m^2)	149	0.001	0.005	0.07	0.7	2.5	6	9.86	0.682	
		Water/steam temperature (Deg C)	423	8	30.11	50	64.5	83.6	97.5	108	16.5	
		Flow (l/s)	192	0.003	0.032	0.167	0.5	0.75	2	2	0.3	

Feature type	Total number of features for each feature type	Parameter	Number of results used to calculate the statistics for each parameter	Min	5th Percentile	25th Percentile	Median	75th Percentile	95th Percentile	Max	Median Absolute Deviation (MAD)	Comment
Mixed pools	922	Length of feature (m)	504	0.05	0.3	1	2.1	5	9	11	1.4	
		Feature size (m^2)	274	0.004	0.07	0.6	1.685	6.375	16.83	22	1.435	
		Water/steam temperature (Deg C)	394	10	25	42	63.75	85	97.5	100.5	21.65	
Mud pools	451	Length of feature (m)	174	0.15	0.365	1	2.5	5	9.35	10	1.5	
		Feature size (m^2)	101	0.02	0.2	0.75	4.5	12	25	30	4.2	
		Water/steam temperature (Deg C)	110	58	62.77	80	93.6	98	98.72	100.4	4.4	
Primary springs	781	Length of feature (m)	227	0.05	0.15	0.7	1.5	2.65	6	7	1	
		Feature size (m^2)	127	0.001	0.018	0.19	0.8	1.73	4	5	0.665	
		Water/steam temperature (Deg C)	309	37	46.94	69	85	95	99.12	104	11.5	
		Flow (l/s)	223	0.001	0.033	0.1	0.25	0.5	1	1	0.15	
Primary pools	266	Length of feature (m)	98	0.15	0.3	1.05	3.75	10	13.2	80	3.25	Includes all data (i.e., outliers included)
		Feature size (m^2)	124	0.03	0.077	0.362	1	3	7.85	10	0.84	
		Water/steam temperature (Deg C)	192	5.1	22.87	55.25	76.15	95	98.725	101.5	18.85	
Steaming ground	341	Length of feature (m)	238	0.1	1	7	16.5	40	140	750	13.5	Includes all data (i.e., outliers included)
		Feature size (m^2)	137	0.015	0.74	48	262.5	938	6532	54653	256.5	Includes all data (i.e., outliers included)
		Water/steam temperature (Deg C)	80	28.7	44.355	80	80	80	99.05	100	0	Includes all data (i.e., outliers included). 75th percentile changed from 80 to 81
Cannot be located	27											
No thermal activity	501											
Total number of features in the TVZ	4819											
Total number of active features in the TVZ that can be located	4291											

Table 2.2 Summary statistics for the geothermal surface features in the BOP region. Note that some values have been rounded.

Feature type	Total number of features for each feature type	Parameter	Number of results used to calculate the statistics for each parameter	Min	5th Percentile	25th Percentile	Median	75th Percentile	95th Percentile	Max	Median Absolute Deviation (MAD)	Comments
Steaming ground / 1563	203	Feature size (m^2)	21	0.015	0.03	2	12	20	40	48	8	
		Water/steam temperature (Deg C)	12	75	78.465	95	98	100	100	100	2	Added 1 to 95th percentile in calculations
		Length of feature (m)	108	0.1	1	5	9.3	15	25	30	5.7	
Primary non flowing pool / 1556	56	Feature size (m^2)	25	0.03	0.074	0.56	3	8	11.76	18	2.618	
		Water/steam temperature (Deg C)	25	55.3	64.84	76.4	90	96.4	99.62	100	7.5	
		Length of feature (m)	23	0.3	0.73	1.55	2.5	4.25	7	8	1.5	
Primary flowing spring / 1555	391	Length of feature (m)	181	0.05	0.3	0.8	2	5	10	10	1.3	
		Feature size (m^2)	26	0.06	0.625	1.82	7.5	22.175	30	40	6.5	
		Water/steam temperature (Deg C)	36	53	54.875	75	86.8	94.05	100	100.5	7.95	
		Flow (l/s)	11	0.001	0.003	0.02	0.1	0.2	0.25	0.3	0.095	
Mud pots	48	Length of feature (m)	38	0.5	1	3	4	7.75	11.6	15	2	
		Feature size (m^2)	28	0.3	0.61	2.75	6	17	27	40	4.405	
		Water/steam temperature (Deg C)	35	24.6	28.45	44.3	62.4	82.35	91.95	100.9	20.4	
Mud pool	200	Length of feature (m)	110	0.15	0.345	1.2	2.5	5	10	10	1.5	
		Feature size (m^2)	22	0.2	0.288	6.375	11	15.45	29.9	60	4.65	
		Water/steam temperature (Deg C)	33	24.9	27.2	40.2	68.2	86	97.04	100.4	25.2	
Mud geyser	19	Length of feature (m)	16	0.1	0.115	0.575	2	2.625	5.25	6	1	
Mixed pool	554	Length of feature (m)	287	0.05	0.5	1.5	3	7	11.4	16	2	
		Feature size (m^2)	86	0.15	0.263	1	2	12.375	30	40	1.725	
		Water/steam temperature (Deg C)	115	22.9	25.35	34.75	54.1	77.6	95	100	20.9	

Feature type	Total number of features for each feature type	Parameter	Number of results used to calculate the statistics for each parameter	Min	5th Percentile	25th Percentile	Median	75th Percentile	95th Percentile	Max	Median Absolute Deviation (MAD)	Comments
Mixed spring	357	Length of feature (m)	184	0.03	0.315	1	3	6.25	15	15	2	
		Feature size (m^2)	50	0.09	0.25	1.625	6	15	42.75	50	5	
		Water/steam temperature (Deg C)	91	24.3	30.7	45	63	82.85	95.75	108	19	
		Flow (l/s)	21	0.01	0.03	0.3	0.5	0.7	1.4	1.4	0.2	
Eruption craters	39	Length of feature (m)	8	1	1.35	2	6.5	10	19.75	25	4	
		Feature size ($m^{2)}$	9	1	2.2	4	25	50	100	100	23	
Heated ground	191	Length of feature (m)	89	0.5	1	5	10	15	30	35	5	
		Feature size (m^2)	18	0.12	0.868	6.275	35	175	407.5	450	32.5	
		Water/steam temperature (Deg C)	15	24.7	26.8	35.5	48.8	55.1	62.91	63.4	7.1	
Geyser	16											
Fumarole	91	Length of feature (m)	31	0.3	0.35	0.75	1.5	3.5	6	8	1	
		Water/steam temperature (Deg C)	9	96.5	97.14	98.8	100.1	101	101	101	0.9	Added 1 to 95th percentile in calculations
Cannot be located	27											
No thermal activity	50											
Total number of features in the BOP region	2242											
Total number of active features in the BOP region that can be located	2165											

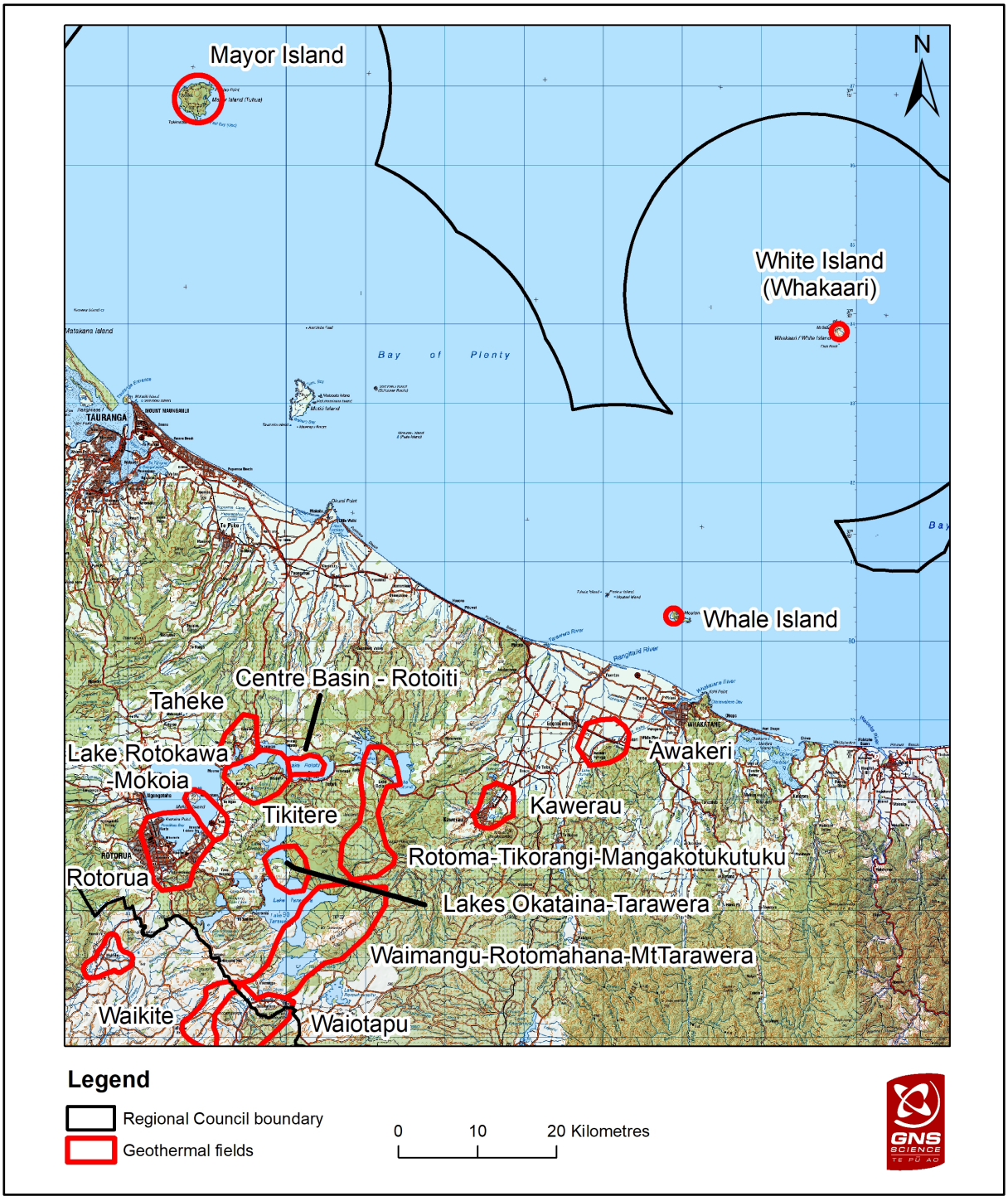

Figure 2.1 Geothermal Fields in the BOP region.

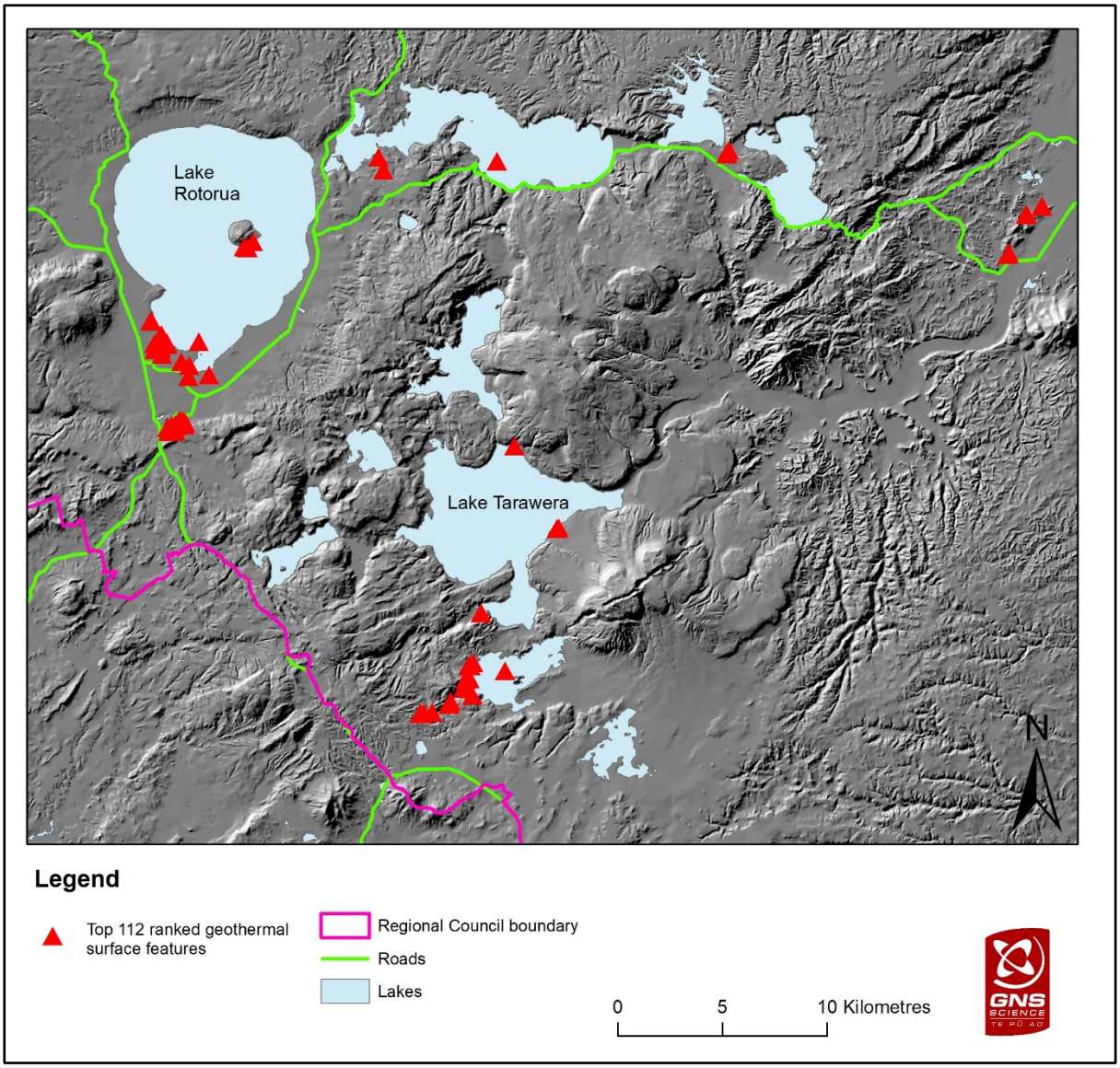

Figure 2.2 Locations of geothermal features with the greatest scores in this study.

3.0 SUMMARY

Geothermal surface features in the BOP region were ranked using a method of adjusted scores developed in Reeves (2018). The revised adjusted scoring uses an additional 292 features located in the BOP region not used in the original report (Reeves 2018). This report utilises a dataset of 4291 active geothermal surface features in the TVZ, with 2165 of these in the BOP region.

Of the 2165 active geothermal surface features in the BOP region, 997 features have a score adjustment based on the most recently acquired feature length, feature size, temperature or flow data. Limitations of the method and data issues are discussed in Reeves (2018) and not repeated in this report.

The highest scored feature using this methodology is Pohutu Geyser (RRF0075) which is located in the Rotorua Geothermal Field.

This revised study has had a small impact on the rankings presented in Reeves (2018) with only five of the new features having an adjusted score in the top 112 features.

4.0 REFERENCES

Bay of Plenty Regional Council. 2014. Bay of Plenty regional policy statement. Whakatane (NZ): Bay of Plenty Regional Council. [updated 2016 Jul 5]. (Strategic policy publication; 2013/04). https://www.boprc.govt.nz/plans-policies-and-resources/policies/operative-regional-policy-statement/.

Reeves R. 2018. Ranking geothermal surface features in the Bay of Plenty Region. Wairakei (NZ): GNS Science. 21 p. Consultancy Report 2018/156.

Resource Management Act. 1991. New Zealand Government.

Scott BJ. 2012. Guideline for mapping and monitoring geothermal features. Whakatane (NZ): Bay of Plenty Regional Council. 35 p. (Bay of Plenty Regional Council guideline; 2012(03)).

Scott BJ, Bromley CJ. 2018. Assessing significant geothermal features in the Bay of Plenty region – the application and testing of Method 4. Wairakei (NZ): GNS Science. 20 p. Consultancy Report 2018/66.

APPENDICES

APPENDIX 1: GEOTHERMAL SURFACE FEATURE SCORES

The adjusted scores for the geothermal surface features within the BOP region are presented in the attached file ("CR2019-07 Appendix 1.xlsx"). The geothermal features are sorted (ranked) from the highest score features to the lowest score features.

The quality control (QC) codes in the QC column are:

1. No size, temperature or flow data exist.
2. Either size or length (size) data exist.
3. Temperature data exist.
4. Flow data exist.
5. Size and temperature data exist.
6. Size and flow data exist.
7. Temperature and flow data exist.
8. Size, temperature and flow data exist.

www.gns.cri.nz

Principal Location

1 Fairway Drive
Avalon
PO Box 30368
Lower Hutt
New Zealand
T +64-4-570 1444
F +64-4-570 4600

Other Locations

Dunedin Research Centre
764 Cumberland Street
Private Bag 1930
Dunedin
New Zealand
T +64-3-477 4050
F +64-3-477 5232

Wairakei Research Centre
114 Karetoto Road
Wairakei
Private Bag 2000, Taupo
New Zealand
T +64-7-374 8211
F +64-7-374 8199

National Isotope Centre
30 Gracefield Road
PO Box 31312
Lower Hutt
New Zealand
T +64-4-570 1444
F +64-4-570 4657