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Tasmania

DEPARTMENT OF MINES

UNDERGROUND WATER SUPPLY PAPER

No. 3

The Underground Water Resources of the Richmond - Bridgewater - Sandford District

BY

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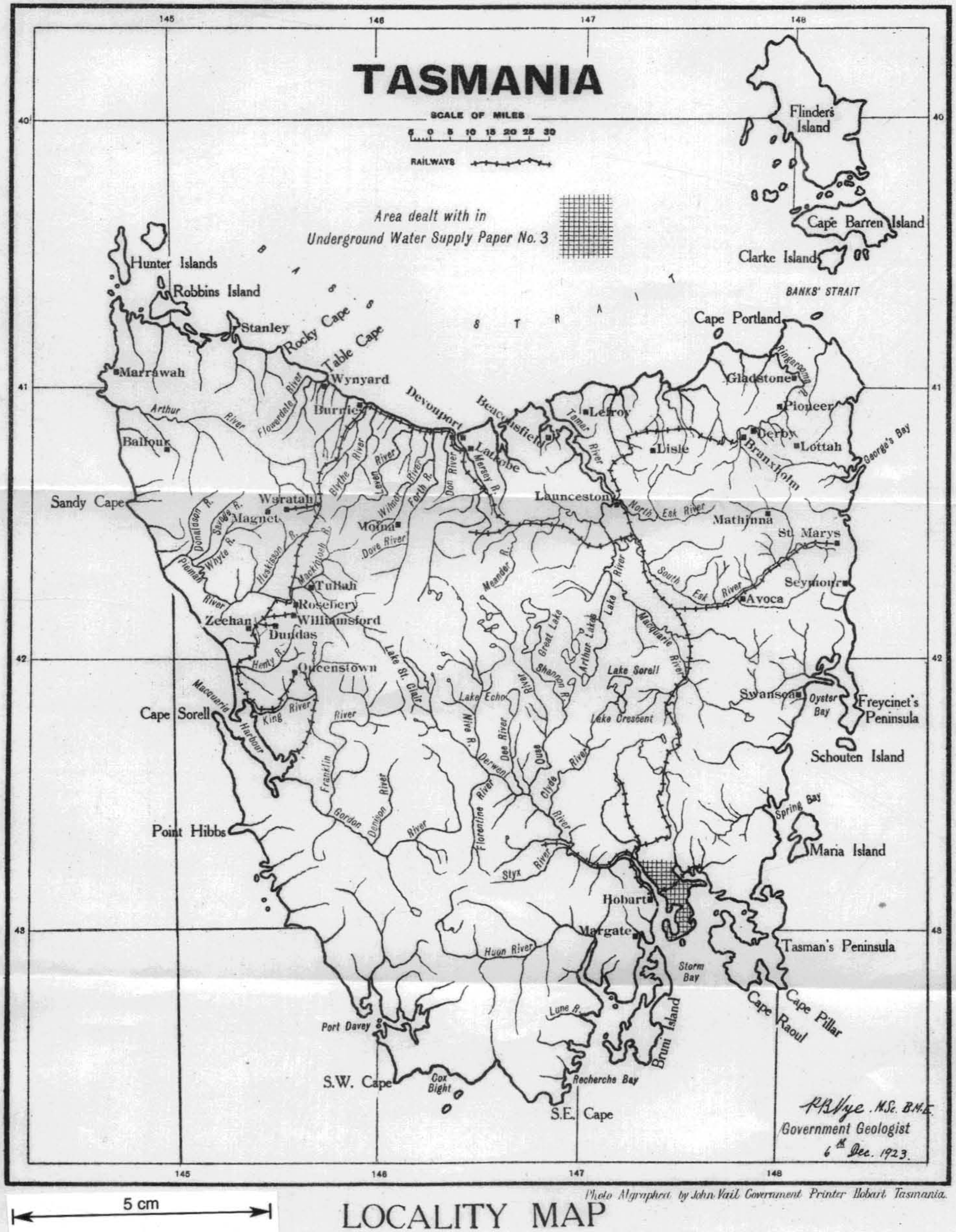

LOCALITY MAP

The Underground Water Resources of the Richmond-Bridgewater-Sandford District.

I.—INTRODUCTION.

(1)—Preliminary Statement.

The Richmond-Bridgewater-Sandford District, in which the following investigation was carried out, is subject in a general sense to the same climatic conditions as exist in the Midlands and the adjacent parts of South-Eastern Tasmania, and which have already been described.(1) There are the same moderate rainfall and, in the district under discussion, a total lack of permanent streams, which factors combine to make the district one of comparative dryness.

Additional water-supplies could be advantageously used in the agricultural, pastoral, and orcharding industries of the district. The examination of the districts to the immediate north of the Richmond-Bridgewater-Sandford District had proved the existence of a number of separate sub-artesian basins from which supplies of underground water could be obtained.(2) The present examination was, therefore, undertaken to ascertain whether the same geological conditions exist in the Richmond-Bridgewater-Sandford District, and whether, therefore, supplies of underground water are available to assist the primary industries of the district.

(2)—General Statement.

The field work upon which this report is based was carried out during the periods from 2nd March to 16th March, and from 19th April to 10th May—a total of 37 days.

The geological mapping was carried out with the aid of the land chart, Monmouth No. 3, which was of invaluable assistance. Numerous topographical features have been

(1) and (2) Nye, P. B., Geol. Surv. Tas., Underground Water Supply Papers Nos. 1 and 2.

added, together with their local names. The 200-feet contours on the sketch-map were based on elevations determined by aneroid readings, various points along the Main Line and the Sorell Railway being used as datum points.

(3)—Acknowledgments.

The writer desires to express his appreciation of the courtesy and hospitality extended to him by Messrs. and Misses Jacobs (Victoria House, Richmond), Mr. and Mrs. R. E. Spinner and family (Cambridge), and Mr. and Mrs. D. Calvert and family (Sandford). He also wishes to thank the many residents of the district from whom he sought information and assistance.

II.—PREVIOUS LITERATURE.

No official reports describing the district under discussion have been prepared. Reference is, however, made to the geology of several parts of the district in the "Geology of Tasmania," by R. M. Johnston, published in 1888. Some of the occurrences of the Permo-Carboniferous, Trias-Jura, and diabase formations are briefly referred to, while some of the Tertiary beds fringing the River Derwent are described more fully. Many of these descriptions are condensed accounts or extracts from papers read before the Royal Society of Tasmania by the same author.

III.—GEOGRAPHY AND PHYSIOGRAPHY.

(1)—Location and Area.

The Richmond-Bridgewater-Sandford District is located in the south-eastern part of Tasmania, and forms a peninsula between the River Derwent on the west and the Pittwater and Frederick Henry Bay on the east. It is situated in the southern part of the County of Monmouth, and includes the whole of the Clarence Municipality and the southern part of Richmond Municipality. The townships of Richmond, Cambridge, Risdon, Lindisfarne, Bellerive, Rokeby, and Sandford occur in this district.

The length of the district is about 22 miles, with an average width of 6 miles, the total area being approximately 130 square miles.

(2)—Access.

Except on the northern extremity the district is surrounded by water, so that transportation by water is the shortest means of access to many parts of the district. A ferry service for passengers and vehicles exists between Hobart on the west, and Bellerive on the east, side of the Derwent. A vehicular ferry service is also available at Risdon, 4 miles to the north-west. A passenger service is also in existence between Hobart on the west, and Lindisfarne and Montagu Bay on the east, side of the Derwent. River steamers provide a limited service with South Arm at the southern extremity of the district.

The main-road from Bellerive to Sorell crosses the Pittwater by means of a causeway, as does also the railway between these two townships.

The Main Line Railway from Hobart to Launceston passes a few miles to the north of the district, and a good branch road from the main Hobart to Launceston road follows a similar route. Good roads from Tea Tree and Campania act as means of communication between these facilities and the northern parts of the district.

(3)—Topography.

(a) *General Description.*

Although the maximum elevation of the land surface within the district is not great—Grass Tree Hill, the highest point, being only 1778 feet above sea-level—the topography, especially in the northern parts of the district, is of fairly high relief. The district forms a comparatively long and narrow peninsula, which has a general direction from north-west to south-east, and which occurs between the River Derwent on the west and the Pittwater and Frederick Henry Bay on the east. An elevated range of hills forms the backbone of this peninsula, which it traverses centrally from north-west to south-east. The average width of the peninsula is only 5 to 6 miles, and it is the sharp descent from the central hills to sea-level in short distances of 2 to 3 miles that makes the topography of fairly high relief.

This central range also acts as a watershed between the two main drainage systems of the district, viz., that into the River Derwent on the west and that into the Pittwater and Frederick Henry Bay on the east.

(b) *The Mountains and Hills.*

The highest mountains and hills occur in the north-western part of the district. Going south-east along the central range of hills the heights decrease more or less gradually until Ralph's Bay Neck is reached, where the range is broken. It makes again in the Sandford peninsula to the south, but does not greatly exceed 400 feet above sea-level at the highest points. The following list includes the most prominent of these features:—

	Feet Above Sea-level.
Grass Tree Hill	1778
Mt. Direction	1468
Gunner's Quoin	1370
Trig. Hill	1250
Mt. Rumney	1236
Craigow Hills	1230
Basin Hills	1070
Gunn's Sugarloaf	1000
Breakneck Hill	935
The Sugarloaf	820
Single Hill	620
Mt. Augustus	450
Mt. Mather	420

(c) *The Plains.*

Small areas of very flat country occur along the eastern boundary of the district, particularly along the shores of the Pittwater and Frederick Henry Bay. These plains occupy positions between the foothills of the central range of hills and the coast-lines of the above features. The greatest extent of plain country occurs to the east of Cambridge, and extends as far as the point of the peninsula between the Pittwater and Frederick Henry Bay. These plains are composed of formations ranging in age from Tertiary to Recent.

(d) *The Streams.*

The drainage of the district is effected by means of numerous short streams flowing from the central range of hills directly into the ocean. Of the streams in the western part of the district, the Gage Brook, Risdon Brook and Grass Tree Hill Rivulet, and Kangaroo Bay Rivulet flow in general south-westerly directions into the estuary of the River Derwent, while the Clarence Rivulet flows in a south-easterly direction into Ralph's Bay. Of the streams in the eastern part of the district, the Duck Hole Creek, Belbin Rivulet, Pigeon Hole Rivulet, Crosses Rivulet, and Barilla Rivulet flow with general north-easterly directions into the Pittwater, while the Saltwater Rivulet enters Frederick Henry Bay. In addition to these named streams, there are numerous other short and unnamed ones which assist in the drainage. The catchment areas are so small and the descent to the coastal plains is so steep that these streams flow only after rains, and soon cease flowing during periods of little or no rain.

TABLE No. 1.

Rainfall Data.

Bellerive.

Year.	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
1896	—	—	—	—	—	404	96	430	70	157	97	42	—
7	255	251	80	123	222	72	139	55	169	159	249	4	1778
8	65	10	210	173	188	180	208	97	162	258	236	90	1877
9	248	19	313	221	145	352	90	89	234	114	218	86	2129
1900	217	44	36	296	82	132	237	153	66	210	38	226	1737
1	452	53	357	438	94	205	57	189	269	338	46	42	2540
2	326	325	102	188	66	215	51	65	420	122	131	357	2368
3	71	278	186	178	290	396	331	82	174	308	256	176	2746
4	293	392	326	27	201	255	112	183	71	144	239	29	2272
5	581	328	96	199	739	77	274	43	156	178	95	200	2966
6	51	41	150	164	134	125	239	134	89	465	172	105	1869
7	343	38	110	82	120	61	196	126	316	314	106	416	2228
8	89	56	173	54	51	181	93	70	182	315	99	46	1409
9	248	136	135	519	200	412	84	167	109	97	128	140	2375
1910	244	30	106	195	144	329	149	98	376	131	119	227	2148
1	28	264	516	200	408	163	97	134	78	310	98	267	2563
2	85	10	221	143	77	240	172	76	283	239	151	252	1949
3	119	25	181	271	15	106	117	117	143	211	324	190	1819
4	14	12	138	257	66	24	209	83	77	24	146	218	1268
5	32	131	236	171	230	135	55	115	101	250	196	18	1673
6	512	211	42	415	104	286	374	279	255	220	519	779	3996
7	115	191	211	345	191	291	237	225	395	253	191	77	2722
8	69	207	112	206	199	155	292	313	211	297	123	162	2346
9	190	179	562	77	67	220	170	115	85	152	31	173	1971
1920	86	20	181	124	147	243	63	156	192	83	147	314	1756
1	203	95	77	110	119	154	345	225	91	123	48	60	1650
2	239	276	64	129	67	205	547	218	51	288	64	480	2658
26 Years' Avge.	199	139	189	206	168	201	190	139	183	215	160	196	2185

Rokeby.

Year.	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
1883	355	198	296	67	248	157	140	57	269	221	256	161	2425
4	378	88	47	25	124	113	35	302	154	180	90	354	1890
5	306	200	239	75	49	142	71	62	309	141	682	174	2450
6	250	180	168	267	188	27	61	203	102	182	315	108	2051
7	267	101	210	73	149	190	277	50	210	156	101	172	1956
8	86	4	98	74	106	159	120	186	216	144	97	155	1445
9	265	97	27	420	114	713	172	69	98	281	494	239	2989
1890	101	200	365	97	153	588	280	303	121	254	202	188	2852
1	323	87	92	122	273	186	225	105	47	367	254	516	2597
2	217	31	128	196	230	168	261	41	155	17	161	188	1893
3	743	10	84	421	553	403	497	152	152	108	170	399	3692
4	—	—	—	—	—	—	—	—	—	—	—	—	—
5	34	—	—	226	59	—	171	242	221	175	53	214	—
6	120	241	111	95	143	343	111	413	103	178	96	42	1996
7	308	281	99	90	320	72	98	151	196	149	254	18	2036
8	69	13	165	105	341	175	199	87	158	381	248	96	2037
9	331	33	219	190	159B	333	116	82	264	109	264	87	2187
1900	245	42	48	250	86	138	245	148	88	163	37	204	1694
1	442	43	449	437	82	204	250	151	237	307	42	24	2668
2	275	416	138	180	71	176	76	58	326B	96	131	348	2291
3	78	325	204	266	338	343	286	66	116	229	241	165	2657
4	268	268	295	33	171	213	139	128	197	87	212	10	2021
5	522	326	83	319	519	55	273	41	262	315	106	183	3004
6	47	36	129	179	126	162	128	140	74	487	190	85	1783
7	230	207	65	114	146	74	206	107	200	279	133	467	2228
8	107	51	148	52	40	183	116	84	165	424	114	34	1518
9	238	168	92	635	144	488	146	159	108	75	111	145	2509

1910	320	59	85	151	116	278	173	53	348	166	76	153	1978
1	19	265	446	170	512	80	151	86	67	191	76	197	2260
2	56	6	246	125	69	238	124	30	211	174	140	250	1669
3	129	4	202	131	24	109	89	116	93	164	256	102	1419
4	6	14	119	205	44	10	154	54	53	19	115	167	960
5	10	155	138	235	230	102	52	118	165	210	143	5	1463
6	309	215	29	352	50	219	221	196	107	166	432	592	2888
7	87	154	174	257	184	277	176	152	353	198	170	103	2285
8	90	205	128	195	180	83	186	240	166	211	106	158	1948
9	145	171	355	64	53	177	132	91	56	91	24	120	1479
1920	78	17	117	103	169	238	58	170	223	59	88	251	1571
1	210	92	83	96	107	122	200	150	64	101	37	55	1317
2	150	313	36	111	51	197	437	166	48	228	52	449	2238
38 Years' Avge.	215	140	162	183	175	209	176	131	163	195	177	188	2114

Sandford.

Year.	Jan.	Feb.	March.	April.	May.	June.	July.	Aug	Sept.	Oct.	Nov.	Dec	Total.
1888	89	7	79	73	133	132	101	226	205	135	69	130	1379
9	223	89	20	500	98	914	152	66	85	324	311	198	2980
1890	128	273	322	81	83	497	225	399	135	294	224	177	2838
1	213	187	86	156	224	160	212	143	30	408	288	540	2647
2	179	29	107	195	177	201	258	53	128	144	111	148	1730
3	549	—	51	494	375	632	475	122	134	120	80	301	3333
4	224	74	141	215	204	149	374	423	149	226	114	266	2559
5	31	94	331	227	91	111	168	173	222	151	45	246	1890
6	100	223	103	86	121	309	178	363	98	184	113	27	1905
7	308	371	126	103	335	72	89	167	103	155	202	11	2042
8	48	3	144	206	328	158	235	117	153	333	224	137	2086
9	279	16	249	200	106	324	111	86	238	122	291	112	2134
1900	223	40	63	393	93	158	197	152	158	198	58	211	1944
1	434	39	488	549	99	307	162	206	220	335	44	32	2915
2	276	592	167	164	81	188	56	93	344	58	105	312	2436
3	97	409	201	277	317	290	260	69	111	206	231	167	2635
4	213	420	417	37	240	338	112	138	284	58	216	18	2491
5	469	368	72	279	440	191	282	58	335	337	126	208	3165
6	41	43	187	177	91	183	178	142	77	449	154	91	1813
7	218	226	122	144	202	88	224	109	234	281	148	616	2612
8	117	39	150	59	33	242	92	116	162	410	116	18	1554
9	288	155	136	747	178	502	141	188	148	66	160	171	2880
1910	243	35	90	235	118	275	165	56	298	197	96	233	2041
1	36	232	378	184	454	155	110	81	94	208	112	285	2329
2	69	11	300	167	69	316	161	75	401	246	150	283	2248
3	128	7	205	228	41	119	112	210	127	203	373	101	1854
4	18	28	170	271	87	23	162	66	85	29	185	161	1285

5	15	190	145	241	245	129	77	172	75	265	152	9	1715
6	411	215	39	490	62	175	250	286	117	254	581	590	3470
7	107	158	276	361	242	337	175	112	488	206	210	91	2763
8	58	219	172	225	204	100	222	197	195	277	92	178	2139
9	180	168	453	73	46	208	192	100	44	108	27	112	1711
1920	98	25	176	131	196	347	69	179	266	71	88	200	1846
1	220	139	126	101	99	97	257	250	69	95	56	86	1595
2	153	342	51	147	62	195	438	204	51	279	40	538	2500
35 Years' Avge.	185	156	181	235	171	246	191	160	173	212	160	200	2270

Lindisfarne.

Year.	Jan	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
1907	353	142	79	82	100	122	145	138	240	279	80	550	2310
8	87	26	166	46	25	117	75	48	140	163	83	50	1026
9	256	135	127	336	184	432	91	170	104	71	109	164	2179
1910	235	38	97	162	110	264	150	95	378	141	106	275	2051
1	30	252	596	181	401	125	84	112	91	262	92	281	2509
2	—	—	—	—	—	—	—	—	—	—	—	—	—
3	102	17	150	276	12	95	90	85	125	201	251	168	1572
4	9	4	132	263	55	17	183	60	62	32	150	261	1228
5	4	141	187	202	158	108	53	98	71	197	173	20	1412
6	480	227	18	433	73	241	347	237	241	212	502	792	3803
7	98	153	183	340	133	264	171	170	346	196	129	57	2240
8	56	177	113	156	160	106	217	242	179	251	66	111	1834
9	207	159	498	65	39	169	192	82	71	117	12	120	1731
1920	67	16	141	107	101	205	46	111	142	57	120	277	1370
1	177	60	43	71	89	132	301	176	53	80	27	43	1252
2	236	251	41	127	48	194	545	201	32	285	40	422	2422
15 Years' Avge.	160	120	171	190	112	173	179	135	152	170	129	239	1930

Compton.

Year.	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
1914	33	12	108	280	73	46	229	88	87	39	173	239	1407
5	11	86	211	286	130	147	76	100	132	348	271	2	1800
6	509	126	45	444	87	225	346	212	195	197	354	753	3493
7	96	127	168	290	212	325	215	158	242	241	105	138	2317
8	173	178	144	149	206	154	206	164	231	228	79	168	2080
9	238	155	338	80	49	235	202	90	104	112	24	228	1855
1920	93	19	108	68	122	264	92	114	124	66	153	247	1470
1	186	42	67	92	89	144	365	171	88	88	35	56	1423
2	249	365	55	224	67	319	510	162	55	327	60	327	2720
9 Years' Avge.	176	123	138	213	115	207	249	140	140	183	139	240	2063

Cambridge.

Year.	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept	Oct.	Nov.	Dec.	Total.
1890	96	203	325	66	72	541	389	348	119	294	211	292	2956
1	258	163	101	224	312	193	230	142	26	320	243	512	2724
2	138	33	137	258	191	181	256	56	132	124	134	94	1734
3	572	5	74	367	525	411	393	165	220	168	121	263	3284
4	150	41	159	115	197	100	264	377	88	249	93	212	2045
5	22	71	327	210	65	84	143	189	104	165	32	162	1574
6	65	125	120	60	63	235	123	256	59	107	75	42	1330
7	276	240	75	70	198	78	64	139	74	133	98	12	1457
8	44	—	157	149	588	103	196	62	126	266	181	145	2017
9	233	—	169	173	74	266	70	49	202	80	231	75	1622
1900	168	92	32	243	60	132	183	100	70	134	14	202	1430
1	390	28	470	372	81	226	86	173	192	273	35	68	2394
2	279	334	100	147	64	135	37	60	259	101	102	285	1903
3	63	324	178	222	232	402	216	66	92	237	290	128	2450
4	80	281	270	51	200	—	—	—	—	—	—	—	—
5	453	350	60	201	667	52	214	56	227	307	77	183	2847
6	30	24	141	154	79	172	154	77	41	451	124	77	1524
7	174	159	69	85	131	65	201	111	207	220	110	547	2079
8	189	16	118	53	35	124	79	54	181	433	76	9	1367
9	209	131	67	527	78	381	142	171	91	57	148	165	2167
1910	190	43	48	209	98	195	89	68	265	275	164	245	1889
1	22	221	349	125	461	131	90	78	93	234	78	276	2158
2	56	2	265	149	92	262	116	38	272	223	127	405	2007
3	100	10	170	301	15	133	96	111	134	152	248	125	1595
4	6	17	154	214	56	28	139	47	76	98	104	178	1117
5	28	134	214	316	246	118	53	137	71	201	—	20	1691
6	465	212	43	435	61	143	141	202	175	319	473	648	3257

7	76	209	171	348	221	303	149	363	167	184	196	91	2478
8	76	411	165	206	207	83	213	307	183	222	55	125	2254
9	132	158	312	64	47	187	141	78	39	96	19	155	1428
1920	57	43	142	104	162	259	56	144	193	58	49	207	1474
1	178	100	128	74	96	97	271	168	62	73	69	87	1403
2	128	269	34	125	56	191	438	166	45	273	40	452	2217
32 Years' Avge.	164	130	159	199	173	188	170	142	134	204	130	203	1996

(4)—Climate and Meteorology.

The climate of the district is essentially a mild and dry one. Snow falls only very occasionally during the winter months, but it does not accumulate to a thickness of more than a few inches, and does not remain on the ground for any length of time. The rainfall is only moderate, and varies from 19 to 23 inches.

Table No. 1 gives the rainfall records for the stations at Sandford, Rokeby, Bellerive, Lindisfarne, Compton, and Cambridge. The records for Brighton, Tea Tree, and Richmond, which occur to the immediate north of the district, have been given in a previous publication.(2)

Table No. 2 shows the average annual rainfall of all the stations, the figures being taken from the above two sources.

Table No. 2.

Average Annual Rainfall.

Station.	Record.	Average Annual Rainfall.
	Years.	Points.
Sandford	35	2270
Bellerive	26	2185
Rokeby	38	2114
Richmond	37	2094
Tea Tree	12	2082
Compton	9	2063
Cambridge	32	1996
Lindisfarne	15	1930
Brighton	22	1902

These figures show that the rainfall throughout the district is very uniform, the variation being from 1902 points in the case of Brighton, to 2270 points at Sandford. This is not surprising when it is remembered that the stations are located within a comparatively small area, and that they occur at much the same altitudes between sea-level and 250 feet above it. The precise conditions which cause these differences cannot, however, be definitely stated. With stations as close as Lindisfarne and Bellerive, which have rainfalls of 1930 and 2185 points respectively, the conditions causing such a difference must be purely local.

(2) Nye, P. B., Geol. Surv. Tas. Underground Water-supply Paper No. 2.

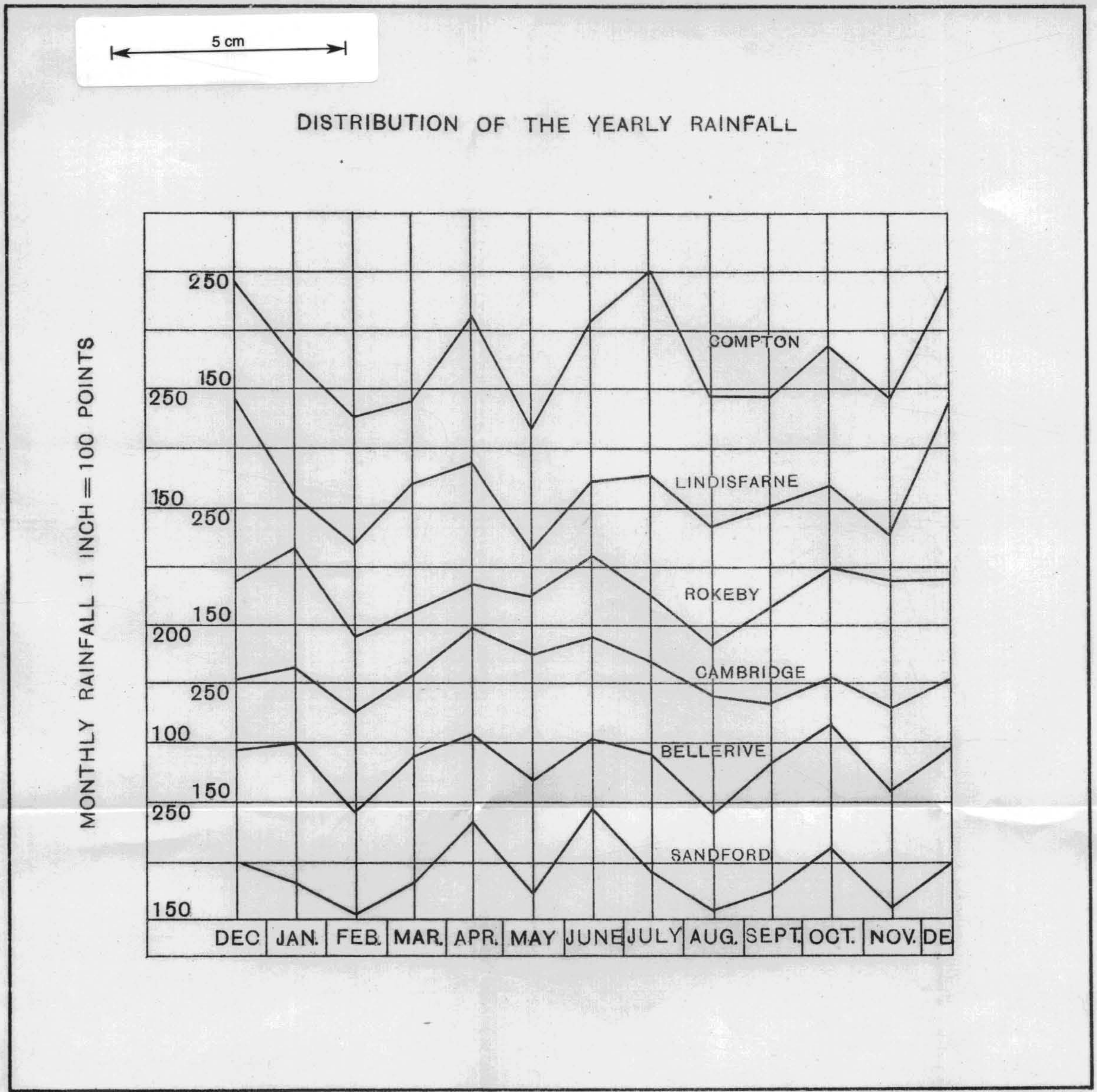

Photo Algraphed by John Vail Government Printer Hobart Tasmania.

The distribution of the rainfall throughout the year is shown in Plate II. The graphs for the different stations show the distribution to be fairly similar for all these, and also generally similar to those for adjacent regions.[4] The rainfall for January is about the average, except at Rokeby, where it is the month of maximum rainfall; in all cases there is a sharp decline for February, which is usually the driest month; a steady rise to April follows, March being about the average, and April one of the wettest months, and in the case of Bellerive and Cambridge, actually the wettest. Then follows a sharp decline to May, which is below the average, and in the case of Compton the driest month. A sharp rise to June follows, this month being generally the wettest during the year. In the cases of Compton and Lindisfarne this rise continues until July, but in the other cases there is a steady fall from June to August, July being about the average and August one of the driest months. In the cases of Compton and Cambridge this fall continues until September, but otherwise there is a steady rise from August to October, September being at or slightly below the average. October is a wet month, and at Bellerive is the wettest of the year; then follows a sharp fall to November, well below the average, except at Rokeby, where this fall is only slight. A rise to December follows, the rainfall for this month being at or slightly above the average, except at Lindisfarne and Compton, where it is one of the wettest months.

(5) Vegetation and Timber.

The whole of the district was formerly covered with a growth of trees and vegetation, but large areas have been cleared for agricultural and pastoral purposes. In the parts which still retain a forest growth practically all of the larger trees have been removed for various purposes. The timber from these has been used chiefly for agricultural and pastoral purposes, such as fencing, rough constructional and building purposes, as sheds and stables, &c.

The most common trees, and also the largest, are the eucalypts, some of the more plentiful species being white-gum (*E. viminalis*), peppermint (*E. amygdalina*),

[4] Nye, P. B., Geol. Surv. Tas. Underground Water-supply Papers Nos. 1 and 2.

stringy-gum and stringy-bark (*E. obliqua*), and blue-gum (*E. globulus*). Blue-gum and stringy-bark are generally found in steep gullies on elevated country, but are not very numerous. White-gum and peppermint are the most plentiful trees, but do not attain any great height. White-gum is particularly abundant on areas of Permo-Carboniferous strata which have been previously burnt out.

Other trees occurring within the district are silver-wattle (*A. dealbata*), she-oak (*casuarina*), and honey-suckle (*banksia*). The *casuarina* are particularly abundant on diabase hills and around the shores of the district.

Generally the trees are not now of sufficient size and number for sawmilling purposes. Supplies of timber for fencing and other farm purposes are still available. Considerable quantities of firewood are carted and sent to Hobart by train for use in that city.

The cleared portions of the district are devoted to agricultural, pastoral, and orcharding purposes. Oats is the main cereal crop grown, and wheat to a much less extent. Root crops, such as potatoes, swedes, and carrots, are grown only in small quantities. Orcharding is practised on a large scale, apples, pears, apricots, quinces, &c., being grown in large quantities for local consumption and export to Australia and England.

IV.—GEOLOGY.

(1)—Introduction.

(a) *Summary.*

The oldest rocks exposed in this district are those belonging to the Permo-Carboniferous system. These strata have a general dip of 10° to 15° to the south-west. Succeeding the Permo-Carboniferous, rocks of the Trias-Jura system occur, but these have been largely removed from the district by denudation, and only isolated areas remain. The strata of these two sedimentary systems have been largely intruded by diabase of Upper Mesozoic age. Much, if not all, of the faulting to which the rocks of the district have been subjected, accompanied the intrusions of the diabase. Tertiary deposits are exposed at a number of isolated localities, mainly around the present shores of the district. Both Lower and Upper Tertiary beds are present, and there is probably a disconnected sequence of beds from Upper Tertiary to Recent. Flows of basalt occurred at the close of the Lower Tertiary period. Recent deposits of alluvium and sand dunes are forming at numerous localities along the streams and the coasts respectively.

The sedimentary strata (Permo-Carboniferous, Trias-Jura, and Tertiary to Recent) occupy a much greater proportion (roughly 2 : 1) of the surface than do the igneous formations (diabase and basalt). Of the sedimentary, the Permo-Carboniferous, Trias-Jura, and Tertiary to Recent strata occupy approximately equal portions of the surface. Among the igneous formations, diabase predominates over the basalt, and while occupying about 30 per cent. of the surface, it underlies at no great depth much of the remainder.

(b) *Geological Map.*

A geological sketch-map of the district is given in Plate III. On this map there are shown the main physical and topographical features, with contours drawn at intervals of 200 feet. The various geological formations which occupy the surface, and their boundaries with one another, are also shown.

(2)—The Sedimentary Rocks.

(a) *The Permo-Carboniferous System.*

The rocks of this system are mainly white mudstones, with much smaller amounts of sandstones and limestones. The mudstones are very light in colour, varying from white to buff, and are very fine-grained. The material of which these mudstones are composed is very silicious([5]) in nature, and they are perhaps best described as silicious mudstones. They often contain pebbles and small boulders, which are angular to rounded in shape, and which are composed of quartz, quartzite, granite, &c. The sandstones are generally coarse-grained, and in some cases are better described as grits. These sandstones and grits occur interbedded with the mudstones in layers up to 15 feet thick. The limestones are white to grey in colour, and vary greatly in quality, from impure to a fairly-pure limestone. They occur interbedded with the mudstones, and do not attain thicknesses of more than 3 feet.

These rocks form a series of sediments with a fairly large thickness. The various areas in which they outcrop are separated by other formations, and so no complete section is available for the determination of the sequence and thickness of these rocks. In the northern and central portions of the district the strata immediately underlying the basal conglomerate of the Trias-Jura system consist of white, sparingly fossiliferous mudstones. These mudstones are exposed to varying depths below the Trias-Jura strata, the greatest being 700 feet near Breakneck Hill. At the various localities around the shores of the Sandford Peninsula, where the Permo-Carboniferous strata outcrop, they are often very fossiliferous, and beds of sandstones and limestones are interbedded with the mudstones. These beds undoubtedly occupy lower positions in the series than do the 700 feet of beds referred to above. It is probable that these lower members have a thickness of at least 1000 feet, and possibly more. The series, therefore, as exposed in the district, represents a thickness of at least 1700 feet, and probably the whole series is much thicker, as the basal members are nowhere exposed. Only the two divisions referred to above—the slightly fossiliferous upper division and the fossiliferous lower

(5) Nye, P. B., Geol. Surv. Tas. Underground Water-supply Paper No. 2, p. 33.

division with sandstones and limestones—can be distinguished as a result of the present investigation. Although certain fossils appear to predominate in some of the beds, no general sequence could be determined from these facts, but a large amount of detailed work might establish such a sequence.

The following list contains the most important genera of the fossils obtained within the district:—

Anthozoa	*Stenopora.*
Polyzoa...	*Fenestella, Protoretepora.*
Brachiopoda ...	*Spirifera, Productus, Strophalosia.*
Pelecypoda ...	*Edmondia.*
Gasteropoda ...	Several genera.

All these fossils apear to be identical with those described from the Lower Marine series in adjacent portions of southern Tasmania, and these strata belong to the Lower Marine series of the Permo-Carboniferous system of Tasmania, and are to be correlated with the same series occurring in other parts of Tasmania and Australia.

(*b*) *The Trias-Jura System.*

The rocks of this system which occur in the district are mainly normal sandstones and mudstones, with smaller amounts of impure sandstones and felspathic sandstones. These types have been fully described in a previous publication.(6)

The two lower divisions of the Trias-Jura strata—the Ross or Lower Sandstone series and the Felspathic Sandstone series—are exposed in the district. No trace of the Upper Sandstone series remains (with the possible exception of a small area of normal sandstones along the western flank of Gunner's Quoin), and if it formerly occurred above the felspathic sandstones of the district it has since been almost entirely removed by denudation.

The Ross sandstones are exposed at numerous localities in the northern and central parts of the district, but have been entirely removed by denudation from above the Sandford peninsula. When not in faulted relation with the Permo-Carboniferous strata, the Ross sandstone

(6) Nye, P. B., Geol. Surv. Tas. Underground Water-supply Paper No. 1, 1921, p. 43.

series appear to conformably overlie them. No difference in the dip of the two systems can be detected, and, allowing for the dip, the junction of the two maintains a uniform level. Evidence in other districts [7] proves that differential earth movements occurred at the close of the Permo-Carboniferous sedimentation, and that a time interval, possibly not of long duration, elapsed before the commencement of the Trias-Jura sedimentation. The evidence obtainable in the district regarding the relations of the two systems is small in amount, but, on the west side of the Bluff, near Sorell, and at the small headland 1 mile east of Bellerive, undoubted waterworn pebbles of typical white siliceous Permo-Carboniferous mudstones are included in the Trias-Jura sandstones. It would appear, therefore, that a disconformity also exists between the two systems in the district under review.

The basal members of the Trias-Jura are conglomerates, which pass upwards into grits, and then the normal fine to medium-grained Ross sandstones. The total thickness of these conglomerates and grits is generally about 50 feet, but it varies up to a maximum of about 100 feet. The largest thickness of the Ross sandstones measured in the district is somewhat over 600 feet, which occurs on the southern flanks of Grass Tree Hill. At no locality is a complete section from the basal conglomerate to the overlying felspathic sandstone obtained, but it is probable that the thickness of the Ross sandstones is at least 700 feet. This figure represents the largest thickness observed in south-eastern Tasmania, so that the thickness of the Ross sandstones may be taken as 700 feet.

The felspathic sandstone series are exposed at only one locality, viz., around Old Beach, to the west of Gunner's Quoin, and Mt. Direction. These felspathic sandstones occupy a depressed area between two bodies of diabase, and have been subjected to a large amount of faulting. Little information can be given as to the section and thickness of them, but probably the section is similar to that at Richmond (on the north-eastern extremity of the district), where at least 470 feet of this series has been proved by boring.[8]

The only fossils obtainable in the rocks of this system are plant remains and silicified wood. These are found chiefly in the felspathic sandstone series, the Ross sand-

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(7) Nye, P. B., Geol. Surv. Tas. Underground Water-supply No. 1, 1921, p. 55.

(8) Secretary for Mines' Report, 1888-89.

stones being almost lacking in organic remains. The fossil plants are particularly obtained from the mudstones interbedded with the felspathic sandstones. During this investigation the only plant remains discovered were those of *Phœnicopsis elongatus*, which are abundant around the coast to the west of Mt. Direction, and are also obtainable in the road-cuttings near Old Beach. Other fossil plants obtained in the Old Beach area are included in the following list:—(9)

Thinnfeldia obtusifolia	R. M. Johnston.
Phyllotheca	McCoy.
Phyllotheca australis	McCoy.
Pterophyllum risdonensis	R. M. Johnston.

At the present time the state of our knowledge with regard to the fossil plants is such that the strata containing them must be classified as Trias-Jura, a more definite determination not being possible. It is certain, however, that a thorough examination of the collections would have very fruitful results.

Lithologically, the felspathic sandstones are indistinguishable from those occurring in the Jurassic coal measures of Victoria, and these two series can be definitely correlated with one another, so that the felspathic sandstone series would, therefore, be of Jurassic age. The normal sandstones are not, however, developed in Victoria, and while this lower series in Tasmania may also be Jurassic, they might also extend down in the time scale and represent portion of the Triassic.

In adjacent districts in south-eastern Tasmania, the lower portions of the Ross sandstones have been found to be saliferous, the sandstones being more or less impregnated with halite (common salt) and epsomite (epsom salts). Although no evidence of these was found in the present district, they exist at Richmond, on the north-eastern extremity, and are, no doubt, also present in the district under discussion. The sandstones are often current-bedded, and this, together with the halite and epsomite content, proves that they were deposited in shallow lacustrine or estuarine waters, under arid or sub-arid conditions. These conditions must have altered considerably before the deposition of the felspathic sandstones commenced, as during this sedimentation land vegetation flourished and coal seams were formed.

(9) Johnston, R. M., Geology of Tasmania, 1888, p. 177.

(c) *Tertiary*.

A series of sedimentary formations occur within the district, varying in age from Lower Tertiary to Recent. These are exposed generally in small areas, which are isolated from one another, and this renders the correlation and the determination of the sequence of these formations very difficult. In correlating various outcrops, the lithological nature of the rocks is generally the only means available for this purpose. Fossils are obtainable in only the more recent formations, and do not help greatly in correlating or determining the sequence of the formations. One important aid is the ancient flows of basalt which have been regarded as closing the Lower Tertiary sedimentation, the underlying strata being regarded as Lower, and the overlying as Upper, Tertiary. This viewpoint adopts the conclusion that all the basalt flows are of practically the same age, but this cannot be regarded as a definitely established fact. The presence of basalt pebbles in a formation is also helpful, as it proves the formation to be later than the basalt. Only occasionally do two different formations appear in the one section, so the sequence of two formations can rarely be determined by the fact that one is superimposed on the other.

In view of these difficulties the following subdivision of the Tertiary formations is the only one possible at the present time. It is based mainly on lithological characters, and the relation of each subdivision to the others is described as far as possible with the evidence available.

(1) *Lower Tertiary*.—The Lower Tertiary strata of south-eastern Tasmania consist of horizontally-bedded clays and loosely-compacted sandstones. The fossils obtainable represent leaves, wood, and fresh-water shells, so that the sediments must have been deposited under lacustrine conditions.

The largest exposure of such beds is along the low cliffs of the western shore of Pittwater, between Belbin Rivulet and Barilla Bay. These beds also occur on the eastern shore of Pittwater, and extend up the valley of the Coal River to Richmond and Campania, in which localities they are overlain by flows of basalt. At some localities the clays are thinly bedded, and the sands and sandy clays are impregnated with oxides of iron, forming ironstones.

Strata very similar to the above occur around the cliffs of the headland forming the southern shore of the entrance to Pipeclay Lagoon. They consist of loosely-compacted sandstones and clays, varying in colour from white, through yellow and brown, to bright-red. The staining is due to oxides of iron, large masses of which (limonite and hematite) occur in the beds as ironstones. At some localities these beds dip to the south at 6°.

The ironstained sandy beds to the north and south of Dixon Point, in Ralph's Bay, possibly belong to the Lower Tertiary period, as may also similar beds along the southern shore of the inlet at the head of Ralph's Bay, adjacent to Ralph's Bay Neck.

The most interesting of the Lower Tertiary deposits occur at the head of Geilston Bay. These occupy a small area of about 10 acres, on the south side of the head of the bay, and consist of interbedded clays, sandstones, and limestone, overlain to the north and west by basalt. Several quarries have been opened up in order to extract the limestone or travertin, for various purposes. The limestone occurs as irregular beds up to 5 feet in thickness, and is very dense and homogeneous. Remains of numerous fossil plants, fruits, and wood, as well as fresh-water shells, have been obtained from these quarries. These, with other interesting occurrences, have been fully described by Johnston and other investigators in papers read before the Royal Society of Tasmania, condensed reports and extracts of which are given in "Johnston's Geology of Tasmania." These beds, where exposed in the quarries, have a dip to the south at a low angle. The basalt flow is horizontal, and, in the quarry at present being worked, the under surface dips to the north or north-west. At several points thin layers of the limestone occur above the basalt, so that the Lower Tertiary period must be regarded as extending above the basalt.

Lower Tertiary sediments of lacustrine origin are exposed on the western shores of the River Derwent, and are fully described in the publications referred to above.

(2) A series of beds, totally different from any others in the district, are exposed on the southern part of the Sandford peninsula. The surface of the areas in which these beds occur is generally of a sandy nature, and the beds must be similar. In the limited number of sections available for inspection, the rocks are found to be fine-grained sandstones and sandy clays, and often appear to be composed of material similar to the white siliceous mudstones of the Permo-Carboniferous period, which form the bedrock of the area. The beds are fairly well consolidated, and contain angular to waterworn pebbles of sili-

cious types, which are sometimes present to such an extent as to cause the rock to be regarded as a conglomerate. Consolidated conglomerates and impure sandstones occur in the low cliffs on the east and west shores of Pipeclay Lagoon, where this series outcrop.

The beds are horizontal, and are exposed at altitudes from sea-level to nearly 400 feet above, and this latter figure probably approximates to the original thickness of the series. As far as ascertainable, the beds are similar throughout this thickness, although the lower ones exposed at sea-level appear to be more consolidated, and of the nature of conglomerates.

The relation of this series to others of the Tertiary period is very indefinite. From the state of consolidation of the rocks, the series appears to be comparable in age with the Lower Tertiary lacustrine sediments described above. On the eastern side of Pipeclay Lagoon the conglomerates of this series occur at the same level as the sand and clays which have been described by the writer as Lower Tertiary, but no evidence as to the relations of the two series is obtainable. Although these sands and clays have been referred to the Lower Tertiary, it may be possible that they belong to this series under discussion, in which case the strata to the north and south of Dixon Point, and those on the south side of the inlet at the head of Ralph's Bay, would also have to be correlated similarly.

The gravel beds[10] which occur on the South Arm peninsula may also belong to this series.

(3) *Upper Tertiary Gravel Beds.*—At numerous localities around the present coast-line gravels and conglomerates are exposed in low cliff sections. These rocks are composed of well water-worn and rounded pebbles of diabase, Permo-Carboniferous rock-types, quartz, silicified wood from the Trias-Jura, cornelians, and other cherty representatives of metamorphosed Trias-Jura rocks, and sometimes basalt. Associated with these rocks there are occasionally loosely-compacted beds of grits, sands, and clays.

These gravels are best exposed in the cliffs on the north and south sides of Lindisfarne Bay respectively. On the south side, gravels up to 10 feet thick overlie decomposed vesicular basalt, and, at one point, clays of probably the Lower Tertiary series. On the north side the gravels overlie basalt for the whole length of the exposure.

(10) See p. 27.

Near the jetty to the south of Old Beach gravels occur on the surface, and overlie basalt, which is exposed under the waters of the River Derwent.

In several small bays along the western shore of Droughty Point, gravels, grits, and clays are exposed. An occasional worn basalt pebble can be found in these, proving them to be of post-basaltic origin. Similar beds at the southern extremity of Droughty Point probably also belong to the same series.

In the cliffs along the shore of Ralph's Bay, to the south of Rokeby, similar beds are exposed. Basalt pebbles can be obtained from some of the gravel beds. The gravels exposed 1 mile to the east of these outcrops contain no basalt pebbles, but may belong to this series.

All these occurrences described above undoubtedly belong to one series of sediments formed in post-basaltic times, and which attain only a small thickness. Their precise origin is obscure, but they represent probably deposits formed around coasts differing very little from the present-day ones. Whether these coasts were washed by fresh or salt water cannot be determined. No marine fossils have been discovered, and at Lindisfarne, Johnston[11] reported the discovery of "fossilised trunks of a well-known exogenous tree of Tertiary age, evidently silicified *in situ*."

In addition to the above, gravels, sometimes associated with sands and clays, occur at a few localities, and cover considerable areas of country. Sandy soil covers a large part of South Arm, and indicates the presence of Tertiary sediments over a large area. On the east side of South Arm cliff sections, 100 feet high, expose this thickness of gravels, sands, and clays. The gravels are similar in general characters to the Upper Tertiary ones described above, but no pebbles of basalt were found in them. In thickness and location these beds might easily be correlated with the sediments occurring on the Sandford Peninsula to the east, and represent a different phase of sedimentation.

Another area in which gravels of probably the Upper Tertiary era occur is that along the western shore of Pittwater, and extending to the west to the foothills of the central range of hills. In these gravels the pebbles are mainly those of diabase and Permo-Carboniferous rock-types. These pebbles are waterworn, but their shapes and

(11) **Johnston, R. M., Papers and Proc. Royal Society of Tasmania, 1881, p. 15.**

other characteristics indicate fluviatile, rather than lacustrine or marine, origin. The deposits overlie the Lower Tertiary sands and clays generally, with an unconformable or disconformable junction, although occasionally thin beds appear interbedded with the upper layers of sands and clays.

(4) *Marine Sands*.—At several localities along the western shore of Frederick Henry Bay a number of deposits with similar features occur. They consist of horizontally-bedded sands and loosely-compacted sandstones which contain marine shells. The shells are very similar to those found on the present beaches, but it is probable that they are older than Recent, and such a question of age based on their presence would require to be decided by a palaeontological examination. Another feature common to these deposits is the presence of casts and replacements of tree-roots by sand and calcium carbonate respectively.

The surface of the country occupied by these deposits is remarkably level, and forms an almost perfect plain. They are exposed in cliff sections along the coast-line, and upwards of 20 feet of these strata are here visible, while they continue in depth below sea-level. Considering their state of consolidation, these sands appear to be of more recent origin than either the Lower Tertiary lacustrine sands and clays and the other deposits occurring on the Sandford peninsula. It is possible that they represent a marine sedimentation contemporaneous with the formation of the gravels along the western side of the Pittwater.

The largest area occupied by these sands is the peninsula between the Pittwater and Frederick Henry Bay. Other areas are along the eastern side of Ralph's Bay Neck, to the south-east of Ralph's Bay Neck, and the northern side of the entrance to Pipeclay Lagoon.

(5) *Shell Deposits*.—At several localities around the indented shore of the Sandford peninsula shell beds and sands occur at elevations very little above present sea-level. The shells comprising the shell beds are mainly those of mollusca and are similar to those to be found on beaches of the present day. These deposits, however, undoubtedly represent raised beaches which are fairly recent origin, but the exact age of which could only be determined by a thorough palaeontological examination. The localities where these deposits occur are around Pipeclay Lagoon, particularly on the north and south sides, and around

Ralph's Bay in the vicinity of Ralph's Bay Neck and along the southern shore, and a few other less important points. It will be observed that these deposits have been formed in association with the larger indentations of the shore. They occupy low-lying strips of land connecting more elevated land, and have the appearance of having been deposited between islands in the former seas, and by the elevation of which these islands have been connected.

These deposits are closely related to the marine sands described immediately above,([12]) but differ from them in certain respects. The latter have been formed around the margin of the open ocean of Frederick Henry Bay, and the former around minor bays, such as Ralph's Bay and Pipeclay Lagoon. Further, there is a great difference in the shells contained in the two series, although if they were of similar age this could be accounted for by the different conditions under which they were formed, as indicated above. If there is any difference in age betweeen the two deposits, the shell beds are undoubtedly the younger.

(*d*) *Recent.*

In the above descriptions there are included all deposits from Lower Tertiary to Quaternary which are probably older than Recent. Some of these, *e.g.*, the marine sands([13]) and the shell beds,([14]) may be Upper Tertiary, Pleistocene, or even Recent, but there is little or no evidence at present available to make any distinction between these periods. In the following descriptions only those deposits which can be definitely considered to be Recent are included. Among these there are included the alluvium forming along the course of the present streams and around some of the very shallow indentations of the coast, sand-dunes and aboriginal shell deposits.

The alluvial deposits along the small streams of the district are of very limited extent, and are generally too small to indicate on the geological map.

Aboriginal shell deposits occur almost continuously around the coasts of the district, but are naturally much more abundant at some localities in the vicinity of which the supplies of edible shell-fish were more plentiful. These deposits conform to the present land surface, below which they occur to a depth of from 1 to 3 feet. They are exposed at some places at heights of only 10 feet above

([12]) See p. 28. ([13]) See p. 28. ([14]) See p. 28.

sea-level, and at other places on the tops of cliffs at least 100 feet above sea-level. The shells are identical with those on the present beaches, and are largely comminuted, and have a blackened appearance as though they have been burnt. These facts, and in addition there is other evidence,([15]) prove conclusively that these shell deposits represent the accumulations of the discarded shells on feeding-grounds of the extinct Tasmanian aboriginal race.

Sand-dunes are forming at many localities around the shores of Frederick Henry Bay and the open ocean to the south of the district. They are very pronounced along the whole length of Seven-mile Beach and the beaches between Cape Deslaco and Cape Direction. These beaches have a general direction from west-south-west to east-north-east, and the dune formations are due to the sea-breezes from the south and south-east.

(3)—The Igneous Rocks.

(a) *Diabase.*

This rock-type is largely developed throughout the district, and while it forms 20 to 30 per cent. of the surface, it also underlies a much greater proportion, if not actually the whole, of the district at no very great depth. Its petrological characters and mode of occurrence are similar to those in adjacent districts,([16]) and need be only briefly referred to.

It consists essentially of plagioclase felspar and light-coloured augite in about equal proportions. This mineralogical content is very uniform, and it is only in some of the coarser-grained varieties, which appear to represent residual magma, that either the felspar or augite predominates over the other. The size of the component crystals, however, vary with the conditions under which the magma crystallised, and this causes several varieties to be recognised, but there exists a gradation between these more or less definite varieties. The finest-grained variety is a dense, homogeneous type in which no individual crystals are recognisable in hand-specimens. This variety occurs in the form of very thin dykes, sills, and stringers, and at the margin of larger bodies. No large develop-

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([15]) Johnston, R. M., Proc. Roy. Soc. Tas., 1881, p. 17.

([16]) Nye, P. B., Geol. Surv. Tas. Underground Water-supply Papers Nos. 1 and 2.

ment of this variety exists within the district, and the best examples are the very narrow dykes, sills, &c., intruded into the Permo-Carboniferous strata on the shore to the south-east of Single Hill. The fine to medium grained variety has a very typical doleritic appearance on weathered surfaces, but it is not developed to any extent in the district. It usually occurs as small intrusions and forms the outer portion (but not the actual margin) of larger intrusions. The coarse-grained variety is exposed in the larger intrusions, which have since had the overlying strata removed, and which have themselves been denuded and dissected by streams, &c. This variety occurs plentifully throughout the district, especially in the southern parts, where the diabase now exposed crystallised below a large thickness of Trias-Jura and Permo-Carboniferous sediments.

The typical platy and also roughly prismatic jointing have been developed in the diabase as in other districts, but, in addition, spheroidal jointing is also prominent, particularly along the eastern shores of Droughty Point and the Sandford peninsula.

The diabase occurs everywhere as intrusive bodies in the Permo-Carboniferous and Trias-Jura strata. These intrusions assume various forms, some of which are splendidly illustrated in this district. Sills are not common, and the only locality where definite sills occur, is on the beach and in cliff sections south-east of Single Hill. Here a small network of narrow dykes and sills intrude the Permo-Carboniferous strata, the sills being up to 12 inches in thickness. The summits of other intrusions are seen in cliff sections along the western shores of Frederick Henry Bay, and conform to the bedding of the overlying Permo-Carboniferous strata. While these may be sills they are more likely to be the summits of much larger transgressive bodies, a flat summit conformable with the bedding being the characteristic feature of transgressive diabase intrusions in Tasmania. The best exposure of one of these flat-topped bodies, the base of which is not visible, occurs along the coast to the north of Cape Deslaco. The summit of this diabase is conformable with the bedding of the sedimentary strata, and dips gently to the south. At places it forms a ledge on the cliff, and the actual summit can be walked along for distances of hundreds of yards.

Narrow dykes are visible in cliff sections and on the beach at numerous localities around the coasts, which can can be seen in Plate III. They vary in width from one-half to several chains, and traverse the intruded strata in various directions, connecting up with the adjacent larger bodies. The narrowest of these dykes are only 9 inches wide, and form part of the network of dykes and sills exposed in the cliff sections to the south-east of Single Hill.

There exists a more or less complete gradation in size of the outcropping diabase bodies from the narrow dykes to the largest bodies of diabase, as can be seen in the geological map (Plate III.). The large bodies are, in fact, transgressive dyke-like bodies, and often change along their length into narrow dykes. Several of these large bodies occur within the district, one of the most interesting being the long one which forms the backbone of the district. This commences in the northern part as a narrow dyke, and courses to the south-east, increasing in width to 2 miles in places, to Ralph's Bay, where its continuity is broken. It reappears at Mt. Mather, and again to the south-south-east at two localities, the most southern being that at Cape Contrariety. A number of small isolated outcrops to the east of this long dyke suggest a parallel dyke not so completely exposed along its length as in the above case, but whether this forms one continuous dyke from Butcher's Hills in the north to near Cape Deslaco in the south cannot be definitely stated. Another large body is that forming Mt. Direction, Grass Tree Hill, Gunner's Quoin, &c. This is more equi-dimensional than the above, and a large proportion of its original flat summit is still preserved.

With the exception of the few small sills, all these bodies of diabase, which intrude the Permo-Carboniferous and Trias-Jura strata to various horizons, dip below the intruded strata at high angles. When the underground structure is considered it is evident that these bodies must junction at depth and form a much larger body underlying probably the whole of the district. The precise form of this body and its relation to the Lower Palæozoic rocks, which presumably form the bedrock of the district, cannot be definitely stated, but it is probably laccolithic in nature and occurs in the Permo-Carboniferous strata or between them and the Lower Palæozoic basement.

The age of the diabase cannot yet be satisfactorily determined in the present state of our knowledge. Sufficient evidence has been quoted above to prove that the diabase is intrusive into the Permo-Carboniferous and Trias-Jura sediments. The age of the latter has not been satisfactorily determined, and hence the lower limit of age of the diabase is also doubtful. The Lower Tertiary sediments and basalt overlie the denuded surface of the diabase, and the basalt occasionally contains fragments of diabase. Further, these Tertiary rocks were formed at the surface after a very long time interval which permitted of extensive denudation of the Permo-Carboniferous and Trias-Jura strata and also the intruded diabase. The age of the diabase is therefore referred to as Upper Mesozoic, possibly Upper Jurassic or Cretaceous. Its intrusion was probably contemporaneous with the cessation of deposition of the Trias-Jura sediments and their elevation, so that when the age of these sediments is more closely determined a closer approximation to the age of the diabase will be possible.

(c) *Basalt.*

A number of small and isolated areas of basalt occur within the district. Near Lindisfarne and Geilston the basalt occurs at and below sea-level. To the north of Risdon the small flow is 60 feet thick and reaches an elevation of 380 feet above the sea. The largest flow occurs to the north-west of Rokeby, and is 200 feet thick at the southern end, where it reaches 370 feet above sea-level, but decreases in thickness to the north. The three small areas to the east of Cambridge attain similar elevations of about 400 feet, but with differences of 200 feet exist between the ends of each flow, the flows appear to have a slope to the east, with a thickness of 60 to 100 feet.

In hand-specimens, these basalts are generally very similar. They are fine-grained, dense types, and are often vesicular. No minerals are recognisable in the groundmass, but porphyritic crystals of olivine are visible in specimens from Lindisfarne, north-west of Rokeby, and 2½ miles south-east of Cambridge. The basalts at sea-level at Lindisfarne and Geilston are very decomposed by the action of tidal waters. The following remarks by Johnston ([17]) refer to the basalt at Geilston Bay:—" In order to ascertain whether the intrusive rock associated with the travertin at Geilston Bay was of a similar character to the rocks at Breadalbane and Table Cape, Professor Ulrich kindly volunteered to analyse any specimens from that quarter sent to him. For this purpose, the late Mr. Morton Allport, on being applied to, at once procured and forwarded an interesting suite of specimens, which were pronounced by Mr. Ulrich to be identical in composition to the basalts at Breadalbane and Table Cape. This may be said of all the Tertiary basalts throughout Tasmania."

([17]) **Johnston, R. M., Geology of Tasmania, 1888.**

With regard to the basalt at Table Cape, Johnston[18] quotes Ulrich as follows:—"The rock is somewhat similar to some of our recent basalts here (in Victoria), viz., it is essentially a feldspar basalt with very little augite; lots of glass and magnetic titaniferous iron, and rendered porphyritic by abundant grains and crystals of olivine. It differs from the basalt of Breadalbane by that the latter contains abundance of augite in well-developed crystals. These mineral differences are, however, no criterion of age. . . ."

From these descriptions it appears that the Geilston basalt consists of felspar and olivine, with lesser amounts of augite. The other basalts are probably similar in composition, although porphyritic olivine is not developed in all cases.

It is probable that all these basalts were formed during one period of intrusion and extrusion, but may not be of identical age, because at Sandy Bay[19] several flows are reported, indicating renewal of volcanic activity.

The basalts in the vicinity of Hobart have always been regarded as closing the period of Lower Tertiary sedimentation. The age of these sediments has been determined by different investigators as being from Eocene to Miocene, and thus a definite age cannot be assigned to basalts. All the basalts of Tasmania have been correlated and regarded as being similar in age, but there has been no systematic geological and petrological examination in support of this view. In the Midlands district[20] it is fairly certain that two main periods of volcanic activity took place—the older producing basic olivine and olivine-ilemenite basalts; and the younger producing normal basalts, the latter being analogous to the newer basalt period of Victoria. If this holds good throughout Tasmania the basalts of the district under discussion probably belong to the older period.

(4)—The Metamorphic Derivatives.

Generally throughout the district the sedimentary rocks have been metamorphosed to only a slight extent by the intrusive igneous rocks. The basalt flows must have altered

(18) Johnston, R. M., Geology of Tasmania, 1888.

(19) Johnston, R. M., Geology of Tasmania, 1888.

(20) Nye, P. B., Geol. Surv. Tas. Underground Water-supply Paper No. 1.

the rocks immediately underlying them to a slight depth, but no exposures are available showing any such effect. The diabase intruded the Permo-Carboniferous and Trias-Jura strata in larger bodies than did the basalt, and produced a larger metamorphic effect. In relation to the size of some of the diabase intrusions, the amount of metamorphism produced is surprisingly small, and its effect extends only a short distance away from the diabase contact. Exposures of metamorphic types are very limited for this reason, and artificial or natural sections close to the actual contact are necessary in order to reveal these types. Different metamorphic types are produced, depending upon the degree of metamorphism to which the original rock was subjected. The most altered type occurs adjacent to the diabase contact, and there is a gradual transition through other types to the unaltered rock, a short distance from the contact.

The Trias-Jura sandstones are altered into dense cherts or hornstones at the contact, quatzites at or near the contact, slightly altered and hardened sandstones at a short distance, which pass imperceptibly into normal unaltered sandstones. The only locality where these effects were observed within the district is 1 mile east of Cambridge, although cherts are not prominent at this place.

The various degrees of metamorphism are not so readily observable in the Permo-Carboniferous rocks. The most altered type produced is a chert very similar to those from the Trias-Jura rocks. Such cherts occur along the western shores of Frederick Henry Bay, especially to the east of Single Hill, where, although the fossiliferous mudstones have been altered to cherts, the imprints of fossils are still preserved. Other localities are the quarry on the Bellerive-Rokeby-road, 2 miles north-west of Rokeby; other places around the two diabase outcrops in the same vicinity; and at numerous places along the margins of the diabase forming the central range of hills. The less altered mudstones are much harder to detect, but they undoubtedly occur at numerous localities.

(5)—STRUCTURAL.

As already described in the preceding pages, the district consists essentially of sedimentary strata of the Permo-Carboniferous and Trias-Jura periods, which have been intruded on a very extensive scale by Upper Mesozoic diabase. These are covered in places by small thicknesses of sediments varying in age from Lower Tertiary to Recent, and by flows of Lower Tertiary basalt.

(*a*) *The Sedimentary Rocks.*—A thickness of at least 1700 feet of Permo-Carboniferous sediments were deposited over the district, and these were disconformably covered by upwards of 1200 feet of Trias-Jura sediments. These sediments were originally horizontally bedded, but subsequent earth movements have altered this feature. These movements have been those of differential uplift of blocks of strata, such as accompany plateau- and continent-making processes (epeirogenic). No compressional stresses were associated with these movements, and no folding of the strata occurred. In the differential uplifting some of the blocks were tilted through small angles, and this has caused the strata in such blocks to dip persistently in one direction. These general dips and strikes vary slightly in direction and amount, but only to any marked extent in the vicinity of faults and diabase intrusions.

The general dip of the Permo-Carboniferous and Trias-Jura strata is to the west or south-west at angles varying from 5° to 30°. In the north-western and central parts of the district the dip is not so large, and varies between 5° and 10°, but in the south-eastern parts it is greater, and varies from 10° to 30°, the average being 12° to 15°. The exceptions to these general dips occur under the conditions indicated above, and the localities will be readily seen on reference to the geological sketch map (Plate III.). One notable exception is in the area of Trias-Jura strata near Old Beach, where dips up to 40° occur, both to the east and west, the cause of the large amount and sudden change of dip being a fault centrally situated in the area.

The Tertiary strata have also been subjected to differential uplift without folding, and generally without tilting. They, therefore, still maintain their horizontal bedding, with the one exception of the strata on the south side of the entrance to Pipeclay Lagoon.

(*b*) *Faulting.*—The earth movements which elevated the Permo-Carboniferous and Trias-Jura sedimentary rocks were accompanied by a large amount of faulting, which resulted in the differential uplift of different blocks of strata. The diabase intrusions were closely associated with this differential uplift, and often occupy the fault between two blocks. The faults, both unassociated and associated with diabase intrusions, are shown on the geological map (Plate III.).

The greatest downthrow is that represented by the displacement of the strata on the east and west sides of the Mt. Direction-Gunner's Quoin-Grass Tree Hill diabase. On the east the base of the Trias-Jura system occurs at, approximately, 400 feet above the sea, whilst at Old Beach the felspathic sandstones are at sea-level, the downthrow being at least 1100 feet on the western side of the diabase. Differences in level of the strata exist on the two sides of the elongated body of diabase forming the central range of hills. The downthrow is on the north-eastern side, and varies in amount from 400 feet in the north to 700 feet in the central and southern portions. The block of Trias-Jura sandstones between Geilston Bay and Bellerive has a downthrow of at least 300 feet in the north and 700 feet in the central part. The block of Permo-Carboniferous and Trias-Jura strata along the Clarence Rivulet has a downthrow of 700 feet, compared with the Permo-Carboniferous strata to the west, the eastern boundary of the block being formed by diabase.

Smaller faulted blocks, such as the narrow strip of Trias-Jura strata along the Grass Tree Hill Rivulet, with a downthrow of 400 feet, also occur.

Numerous smaller faults are shown on the geological map (Plate III.), and undoubtedly many others exist which cannot be readily detected.

(c) *Igneous Intrusions.*—The various forms of the minor diabase intrusions, and the probable mode of occurrence of the whole of the diabase intrusion has been described above([21]). These play a very important part in determining the structure of the district.

Relations of the diabase and the faulting are very interesting, but have been fully described in previous publications([22]), and will not be described here.

The basalt of the district occurs as small surface flows, the magma which formed these flows being supplied through small narrow fissures.

([21]) See p. 31.

([22]) Nye, P. B., Geol. Surv. Tas. Underground Water-supply Papers Nos. 1 and 2.

(6)—Geological History.

The geological history of the district as represented by the rocks exposed at the surface begins with sediments deposited during the Permo-Carboniferous period. The bedrock on which these were formed is not exposed, but in adjacent districts it consists of Lower Palæozoic sediments and Devonian granites.

(*a*) *The Permo-Carboniferous Sedimentation.*—In Tasmania this commenced under glacial conditions with the formation of glacial deposits. Marine conditions followed, and the Lower Marine mudstones, sandstones, and limestones were deposited. Fresh-water conditions succeeded these, with the formation of the lower coal measures. Marine conditions were restored and the Upper Marine series formed. In the district under discussion, 1700 feet of strata are exposed, the lower 1000 feet consisting of Lower Marine mudstones, sandstones, and limestones, with abundant fossils, and the upper 700 being almost unfossiliferous mudstones. In these strata, only the Lower Marine series can be definitely stated to occur.

(*b*) Between the close of the Permo-Carboniferous and the commencement of the Trias-Jura sedimentation a period of slight diastrophism, with probably also a short period of denudation, occurred. Earth movements of no great extent caused differential uplift of the Permo-Carboniferous sediments prior to the formation of the basal members of the Trias-Jura system.

(*c*) *The Trias-Jura Sedimentation.*—This sedimentation began with the formation of the basal conglomerates and grits, which passed upwards into the normal sandstones, about 700 feet of this series (the Ross, or Lower sandstone) being formed under sub-arid lacustrine or estuarine conditions. The conditions altered, land vegetation flourished, and 500 feet of felspathic sandstones and mudstones, with a number of coal seams, were deposited. Another series of normal sandstones may have been formed, but little evidence is available in this district in support of this view.

(*d*) *An Interval of Epeirogenic Earth Movements and the Intrusions of Diabase.*—The Trias-Jura sedimentation was probably brought to a close by movements of elevation of a differential nature. Very closely associated with these movements the great intrusions of diabase magma occurred. The magma intruded the Permo-Carboniferous and Trias-Jura strata in the form of a huge, horizontal body, from which numerous large and small transgressive bodies, dykes, and sills intruded the overlying strata.

(*e*) *A Period of Denudation*.—The district was then subjected to a long period of denudation by the ordinary atmospheric and aqueous agencies. Large thicknesses of Trias-Jura strata were denuded, and the underlying diabase and Permo-Carboniferous strata exposed; these, in turn, also being attacked. In many parts of the district this cycle has been continued without interruption up till the present times. In other parts the cycle was broken by the following geological events.

(*f*) *The Lower Tertiary Sedimentation*.—The coast of parts of the district in the Lower Tertiary period differed little from the present coast, and portions of the district, such as the River Derwent, were occupied by fresh-water lakes in which sands, clays, and limestones were deposited. The beds on the Sandford peninsula may also have been deposited during this period.

(*g*) *The Extrusion of the Tertiary Basalts*.—At or near the end of the Lower Tertiary sedimentation small flows of basaltic lava were poured out over the surface of parts of the district. In places these covered the Lower Tertiary sediments, but at others they covered the older rocks.

(*h*) *The Upper Tertiary Sedimentation*.—Between the extrusion of the basalts and the present time several series of sediments of diverse characters and various ages were formed. Along the River Derwent and other localities gravels and sands were formed under probably fresh-water conditions. Along the western shore of Pittwater somewhat similar gravels were formed, probably under fluviatile conditions. Along the western shores of Frederick Henry Bay sands were formed under Marine conditions, and probably at a later date the shell deposits of the south-eastern portion of the district were formed.

(*i*) *The Present Cycle of Erosion*.—Since the formation of the Tertiary strata, which cover particular parts of the district, the surface again became subjected to the agencies of denudation. This cycle commenced at different times at different parts of the district, depending upon the Tertiary geological history, and in some cases the denudation from the period described in (*e*) has been continuous up till the present time. During this cycle alluvium has been, and is, forming along the courses of the streams and shallow parts of the coastal waters, and sand-dunes are forming along portions of the coast.

(7)—Evolution of the Topography.

The greater part of the drainage systems of the district were initiated at the close of the deposition of the Trias-Jura sediments, their differential elevation and the contemporaneous intrusion of the diabase. It is the ordinary atmospheric and aqueous agencies of denudation accompanied by the gradual development of the drainage systems that have been the chief factors in forming the present topography. In most parts of the district these processes have continued uninterruptedly to the present times At other parts of the Tertiary sedimentations and basaltic lava flows as well as any Tertiary faulting which may have occurred, have modified and slightly altered the above processes. Since these Tertiary events the process of denudation, &c., has again come into operation, and the evolution of the topography proceeded along similar lines to those along which it had proceeded previously.

V.—ECONOMIC GEOLOGY.

(1)—Water-supply.

The sources of water-supply depend almost wholly on the rainfall, and the consequent springs, rivers. and lakes, and on the geological structure which enables certain rocks to store large supplies of the rain that has percolated through the soil. As these factors are subject to extreme variation, the problem of obtaining wholesome and adequate supplies may be simple or fraught with great difficulty and uncertainty.([23])

This bulletin is concerned more particularly with underground water-supplies, and therefore the rock-types and geological structure of the district have to be fully considered.

(a) *Surface Water-supply.*

(i) *Lakes and Rivers.*—No lakes occur within the district but several lagoons exist in the southern part. These are very shallow, and some, *e.g.*, Clear Lagoon, dry up at certain times, while others, *e.g.*, Rushy Lagoon, are covered with rushes or reeds. The water in these lagoons is very bad in quality and suitable only for stock.

The mouths of several large rivers, such as the Derwent and Coal Rivers, occur within the district, but they are affected by tidal waters and are of no use for water-supply purposes. The other streams of the district are merely short creeks and rivulets. They rise in the central range of hills and enter the sea after flowing distances not exceed-5 miles. The catchment areas of these streams are very small in extent, and so the streams do not carry large quantities of water. Water flows in them during and immediately after periods of rainfall, but soon ceases during dry periods. The streams then become a line of water-holes, and later completely dry for the greater part, if not all, of their length.

Except for short periods immediately after rain has fallen the quality of the water in these small streams is bad. No use is made of the water for human consumption, but it forms one of the main sources for watering stock.

([23]) "The Geology of Water-supply," H. B. Woodward, F.R.S., F.G.S.

(ii) *Storage of Rainfall in Tanks*.—During periods of rainfall the drainage from the roofs of houses and other buildings is collected and stored in tanks. The quantity collected in this manner is necessarily small and limited by the capacity of the tanks during ext nded periods of rain. Formulæ for calculating the amount obtainable in a year has been given in a previous publication.([24])

This method of obtaining supplies is used throughout the district, and forms practically the sole source of water for drinking, culinary, and other domestic purposes.

(*b*) *Underground Water-supply*.

The general conditions controlling the occurrence of underground water, and other details relating thereto, have been fully discussed in a previous publication,([25]) and will be dealt with very briefly in the following pages.

(i) *General Geological Considerations*.—Underground water is derived almost entirely from the rainfall, and its existence is therefore dependent upon the nature of the rocks occurring in, and the geological structure of, the district. The rocks must be porous and permeable, so that they may hold, and also allow the passage of, considerable quantities of water through them. The geological structure must be such that the porous and permeable beds outcrop at the surface, so that water can enter them directly from the rainfall, surface drainage, and streams passing over them. Further, the quantity and characteristics (artesian or sub-artesian) of the supplies are determined by the structure.

(ii) *Dispersal of the Rainfall*.—The water which falls upon the surface of the earth in the form of rain is disposed of by the following three methods:—

(*a*) Run-off.—The amount of the water carried away by the streams which drain the surface.

(*b*) Evaporation and Absorption by Vegetation.—The portion of the water which passes by evaporation from the surface ot the earth into the atmosphere and which is utilised by growing vegetation.

([24]) Nye, P. B., Geol. Surv. Tas. Underground Water-supply Paper No. 1, 1921, p. 75.

([25]) Nye, P. B., Geol. Surv. Tas. Underground Water-supply Paper Nc. 1, p. 76.

(*c*) Percolation.—That portion which soaks through the surface soil and passes into the underlying rocks.

It is that portion of the water which is disposed of by percolation which forms the supplies of underground water.

(iii) *Geological Conditions in the District*.—It has been seen in the descriptions of the geology that the district is composed mainly of sedimentary rocks belonging to the Permo-Carboniferous, Trias-Jura, and Tertiary systems, and of Upper Mesozoic diabase. The Permo-Carboniferous and Trias-Jura strata are lying horizontally or dipping at angles up to 30° to the west or south-west. These strata have been intruded by the diabase in the form of a huge horizontal body from which large and small bodies have intruded the strata above the main body. The Tertiary strata are lying horizontal, and overlie the above formations. Tertiary basalt and Recent deposits also occur, but only to a small extent. The proportions of the surface occupied by these different rocks and formations are given approximately in the following table:—

TABLE No. 3.

Proportion of Surface Occupied by the Different Formations.

Formation.	Per Cent.
Permo-Carboniferous	20
Trias-Jura	20
Diabase	27
Tertiary	20
Basalt	1
Recent	2
	100

(*a*) *The Rock-types*.—For the purposes of this report the rocks may be divided into two divisions—the impervious and non-porous on the one hand, and the permeable and porous on the other. Those in the former division are no use for providing supplies of underground water, as they do not hold or allow the passage of water through them. The igneous rocks, diabase and basalt, belong to this division, and are therefore of no use for the purposes of water-supply from this point of view. Clays and mudstones, which occur in the sedimentary systems, have in some cases high porosities or are capable of holding quantities of water, but they do not permit the passage of water through them, and so are of no direct use in providing supplies of water.

The sands, sandstones, felspathic sandstones, and other porous types occurring in the sedimentary formations belong to the latter division. They are porous and permeable, and thus are suitable for the development of supplies of underground water.

The porosities of rocks belonging to the same systems, and identical with the types occurring within the district, have been determined from samples obtained in other districts. These results are given in Table No. 4, the details being taken from a previous publication.([26])

TABLE No. 4.

Porosity Tests.

Sample.	Locality.	Per Cent.
Sandstone	West shore of Lake Dulverton	14·64
Sandstone	Quarry, half a mile east of Ross	14·58
Sandstone	Quarry, half a mile east of Tea Tree	12·12
Felspathic sandstone	East side of Vincent's Hill	26·30
Felspathic sandstone	Colebrook	19·06
Silicious mudstone	Mangalore Creek	22·25
Silicious mudstone	Mangalore Creek	21·89

The white siliceous mudstones belonging to the Permo-Carboniferous system show a porosity of 22 per cent. They are very fine-grained and are siliceous, but although they may hold quantities of water, it is doubtful if they would yield any large proportion of the water, and certainly not at a rapid rate.

In addition to the above, the recent formations of sands, alluvium, and hill-detritus are also capable of holding considerable amounts of water, but these formations do not extend over large areas.

([26]) Nye, P. B., Geol. Surv. Tas. Underground Water-supply Paper No. 2.

(*b*) *The Geological Structure*.—The structure has been described above,[27] and a repetition is not necessary. Large areas of Trias-Jura and Permo-Carboniferous strata have been denuded and the diabase exposed over considerable tracts of country. The diabase generally forms the more elevated parts of the district, and the sedimentary strata the less elevated parts.

(iv) *Possibilities of Underground Water*.—The geological structure and the occurrence of the impervious diabase over nearly one-third of the district precludes the possibility of the existence of one large artesian or sub-artesian basin throughout the district. These same features, however, are favourable to the existence of a number of small and more or less separated basins. Such basins occur in areas occupied by porous and permeable strata, such as those of the Trias-Jura and Tertiary systems. Those areas which are comparatively low-lying and level provide the best basins, as the quantity of water in them is likely to be greater and the supply more certain than in the more elevated and dissected areas. Supplies exist in the latter areas, but are liable to be more uncertain, and the amount less than in the former areas. Further, the depth to water is greater, which will increase the cost of obtaining the supplies considerably.

The possibilities of obtaining supplies in the areas occupied by Permo-Carboniferous strata are not great. The greater part of these rocks are white siliceous mudstones, which, though showing a porosity of 22 per cent., probably would yield very little of their water content if holding water. No wells have been sunk in these rocks, and no information is available from this source. A trial bore or well would be the best means of settling this question definitely.

The recent deposits of sands, alluvium, hill-detritus, &c., will contain supplies of water, but as these are of very small extent the quantity will be correspondingly small.

(v) *Quantity of Water*.—The quantity of water occurring in these basins depends upon the amount of rainfall in the catchment areas, and the proportion of it which is dispersed as percolation on reaching the surface of the earth.

These questions have been fully dealt with in previous publications[28] in the case of the Trias-Jura sandstones,

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[27] See p. 35.

[28] Nye, P. B., Geol. Surv. Tas. Underground Water-supply Papers Nos. 1 and 2.

and a formula given by which the approximate amount of water entering a basin annually can be calculated. The same formula will apply generally to the basins formed by other porous strata, but there will be differences depending upon the porosity and permeability of the strata. However, this formula is only very approximate, and a discussion of these differences is not warranted, but the formula should be applied with caution.

The amount of water in these basins will not, however, be great, owing to the very moderate rainfall and the small catchment areas from which the basins receive drainage.

Since the reports on the underground water resources have been published, and a drill purchased by the Mines Department, several bore-holes have been drilled in the search for water-supplies. The following figures give the actual quantities of water obtained during pumping tests on the finished wells:—

TABLE No. 5.

Pumping Tests on Bore-holes.

Locality.	Flow.
Nala Railway Station	200 gallons per hour
"Glenmorey," Woodbury	125 to 150 gallons per hour
"Inverquharity," Richmond, No. 1	500 gallons per hour
"Inverquharity," Richmond, No. 2	250 gallons per hour

(vi) *Quality of the Water.*—The water derived directly from rainfall is one of the purest forms of water obtainable. In its passage over and through the soil and the underlying rocks it dissolves and holds in solution small amounts of mineral and, to a less extent, organic matter. The amount of organic matter dissolved is very small unless the water comes into contact with a source of pollution such as may exist near a township or other centre of population.

The mineral matter is obtained from the soils and rocks the water traverses and naturally the mineral content shows a direct relationship with them. Thus the nature of the soluble minerals likely to be dissolved from each of the different formations has to be considered.

No direct information is available as to the minerals derived from the Permo-Carboniferous strata, as no wells or bores have been sunk in them in the south-eastern portion of Tasmania. At a few localities, *e.g.*, eastern flank of Grass Tree Hill and along the Coal River east of Colebrook, small quantities of common salt (sodium chloride) and magnesium salts occur in small caves. In both cases these salts occur at horizons only slightly below the base of the Trias-Jura system and it is highly probable that these salts have migrated from the saliferous layers in the Ross sandstone series. It is possible, however, that small quantities of these salts may be actually derived from the marine Permo-Carboniferous rocks themselves. In addition to these calcium (lime) in the form of bicarbonate may be dissolved from the strata at the limestone horizon.

The question of the salts derivable from the Trias-Jura strata has been discussed in previous publications,([29]) and the conclusions arrived at were that sodium chloride (common salt) and magnesium sulphate (epsomite), and possibly magnesium chloride would be obtained. This would apply to the whole of the Trias-Jura strata, but more particularly the Ross sandstone, and especially the saliferous horizons in the latter series.

No information is available as to the quality of the waters obtained from the Tertiary deposits. The minerals likely to be derived will be different according to the particular deposit considered. The lacustrine deposits should contain very small amounts of soluble minerals, and therefore should add correspondingly small amounts to the contained water. The marine deposits will probably contain small amounts of common salt and associated minerals, which will pass into solution in any contained water. In addition, in the marine sands and sandstones along the western shore of Frederick Henry Bay calcium carbonate occurs plentifully in the form of replaced roots, &c., and any contained water in these rocks will therefore contain a quantity of calcium bicarbonate.

Although no supplies of water are developed in diabase, yet the latter will have an effect on the quality of water developed in other rocks. The drainage water in its passage over and through the superficial, decomposed diabase and soil will take into solution any soluble salts formed by

([29]) **Nye, P. B., Geol. Surv. Tas. Underground Water-supply Papers Nos. 1 and 2.**

the decomposing diabase. It has been proved in previous publications(30) that such salts will be the bicarbonates of calcium and magnesium.

The analyses of a number of samples of water taken from old wells have been given in previous publication(31). In most cases these wells have not been cleared out regularly, and so such analyses cannot be taken as absolutely typical of the underground water, because wells should be cleaned at least yearly, in order to maintain the water at its best quality.

In Table No. 6 the analyses of waters so far obtained in wells drilled by the Government plant are given. The bore-hole (Sample I.) at Nala was sunk through a mixed series of mudstones, felspathic sandstones, and sandstones which probably represent horizons near the summit of the Ross sandstone series, and the quality of the water should be typical of such strata. The bore-hole (Sample II.) at Glenmorey was sunk through portion of the felspathic sandstone series, and the water should be typical of that to be obtained from such strata. The shallow bore-hole (Sample III.) at Inverquharity, Richmond, was sunk in Recent drifts, and probably Tertiary beds overlying basalt, which was not penetrated. In common with other water-supplies obtained from these superficial deposits, it was of fairly poor quality. The deeper bore (Sample IV.) at Richmond apparently penetrated the saliferous horizon of the Ross sandstone series, and the water was of bad quality, owing to the content of salt derived from this source. Sample V. was obtained from the same well, after an attempt had been made to shut off the upper flow of water.

(c) *The Underground Water Resources of the District.*

(i) *Introduction.*—From the above discussions it has been shown that the geological evidence indicates the existence of a number of small and separated areas in which supplies of underground water are present. These areas will be termed "basins," but they are not all similar in structure and general conditions. They will be described separately, and a brief description of the location, extent, topography, geology, quantity and quality of the water and its possible uses, will be given.

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(30) Nye, P. B., Geol Surv. Tas. Underground Water-supply Papers Nos. 1 and 2.

(31) Nye, P. B., Geol. Surv. Tas. Underground Water-supply Papers Nos. 1 and 2.

The smaller areas of porous rocks will not be described, but it must be realised that supplies of water will exist in such areas of porous rocks. The supplies will be small, and will be more satisfactory in flat, low-lying areas, with a creek running through them, than in other areas consisting of the same rocks.

(ii) *The Pittwater Basin*.—This basin represents the southern extension of the Middle Tea Tree-Duck Hole Creek basin which has been dealt with previously.[32] The part of this basin within the district is situated along the western side of Pittwater, between the shore of the latter and the high range of diabase hills to the west. Its southern boundary is arbitrary, as it is connected with other adjacent basins, but may be taken as the boundary of the Tertiary sediments in the vicinity of the Bellerive-Sorell road. On the north it connects with the Middle Tea Tree-Duck Hole Creek basin, and the boundary may be taken as the Richmond-Risdon road. This basin, therefore, occupies a narrow strip of country, 7 miles long and 1 to 2 miles wide. The surface is fairly flat and level, with a slope from the hills to the shore, and does not attain elevations greatly exceeding 200 feet above sea-level. It is drained by numerous small creeks, such as Duck Hole Creek, Belbin Rivulet, Crosses Rivulet, and Belbin Rivulet, which flow in an easterly or north-easterly direction into the Pittwater.

The surface is occupied chiefly by Upper Tertiary gravels and impure sandy clays. The greater part over which these outcrop is probably underlain by Lower Tertiary sands and clays. Underlying these, and also outcropping over small areas, are Permo-Carboniferous and Trias-Jura strata and diabase. The Ross sandstone series will form the bedrock in the extreme north and south, and the Permo-Carboniferous also in the northern portion. Diabase will occur along the line of the southern extension of the dyke of Butcher's Hill through the isolated outcrops in this basin. In addition to the above formations, recent deposits of alluvium occur along the courses of the small streams, especially near their mouths and along the lower portions.

Supplies of water will be obtained from the Recent, Upper Tertiary, Lower Tertiary, and Trias-Jura deposits. In the Recent and the superficial Upper Tertiary beds the

(32) Nye, P. B., Geol. Surv. Tas. Underground Water-supply Paper No. 2.

quality will probably be poor to bad. The water in the Lower Tertiary sands should be of better quality, and the same will apply to the Ross sandstones at horizons above the saliferous one. As regards the possible water-supplies in the Permo-Carboniferous, both the quality and quantity are problematical. Generally, and with the exceptions referred to above, the quality of the water will be such that it will be suitable for watering stock and general farmyard purposes. It may also be suitable for irrigation, but this can only be satisfactorily determined by analyses of the waters.

The quantity of the water obtainable will not be large, but will be sufficient for watering stock and general farmyard purposes. If the quality is suitable, very small areas could be irrigated with the quantity available.

Very few wells have been sunk to utilise the water, and those which have been are all located within a small area to the east of Cambridge. Of these wells, some have been dug and others drilled by hand-boring plants.

The wells on the property of Mr. Kennedy were drilled by hand-boring plants. They commenced in Tertiary beds, and passed through alternations of clays and sands to a maximum depth of 86 feet. The two wells near the house were each 36 feet deep, and revealed a hard, white substance, which was termed dolomite. No water was obtained in one of these. Another 36-feet well struck a flow of water at 36 feet, and which rose to within 12 feet of the surface. This well was "bulled" at the bottom, and the flow of water then available was estimated at 1000 gallons per day. Another well close to the last-mentioned was sunk to 86 feet, and encountered flows at 36 feet and 72 feet, but the amount was not estimated. These supplies were suitable for watering stock, but were considered to be too hard for domestic use. It is probable that the quantity and quality of these supplies will be more or less typical of those of other supplies, which may be obtained from the Tertiary deposits which form the basin.

(iii) *The Seven Mile Beach Promontory Basin.*—This basin includes all the country which forms the promontory between the Pittwater and Frederick Henry Bay. The surface is level, and forms a low-lying plain, not exceeding 150 feet above sea-level. No definite streams drain this area, but the western portion is marshy, and, after periods of heavy rainfall would form a drainage channel, the waters of which would be discharged into the Pittwater at the small tidal creek 1 mile to the south-east of the Bluff.

The surface of this basin is occupied solely by marine sediments of Upper Tertiary to Recent age. These consist of sands and loosely-compacted sandstones, which produce a very loose sandy soil.

Over the greater portion of this basin there is no run-off for the rain which falls on the surface, and, except for the part of the rainfall which is evaporated and absorbed by the vegetation, the greater part percolates into the underlying rocks. The percolation is, therefore, great over this basin, and, in conjunction with the high porosity of the sands and sandstones, these conditions result in the probability of relatively large amounts of water being available.

No information is available as to the quality of the water. Only a few very shallow wells, not exceeding 5 feet in depth, have been sunk, and these supplies are obtained from too near the surface to give any reliable information as to the quality of the water. The water from these shallow wells has been used for watering stock, and also to a slight extent for drinking and cooking purposes. If it is suitable for the latter purposes, as stated, it must necessarily be of good quality. As regards the water at greater depths, it is probable that its quality is somewhat better than that of the water in other basins, but in the absence of facilities to sample and analyse the water, this cannot be definitely accepted.

As indicated above, these supplies have been developed to only a small extent, and a much greater use could be made of them; unfortunately, there will probably never be much need for the development of these supplies. The soil is a loose, sandy, and apparently poor, one, suitable only for grazing purposes. Several orchards have been planted, and if these are at all successful supplies could be readily obtained to irrigate these to some extent. For the present, therefore, the only development likely to take place is for providing supplies for live-stock. Further developments depend upon the suitability of the soil for orcharding, &c., which, if favourable, might necessitate the obtaining of supplies for irrigation and domestic purposes. In such cases, however, a trial bore-hole would be essential to satisfactorily determine the quality of the water.

(iv) *The Cambridge Basin.*—This basin includes the area of Trias-Jura strata which occurs to the east of Cambridge. These rocks occupy a narrow tract of country about 6 miles long and 1 to $1\frac{1}{2}$ mile wide, situated along the foothills of central range of diabase hills. The surface of this tract is fairly level, and varies in elevation between 200 and 400 feet above sea-level. It slopes to the east, and is drained by the several small streams which rise in the central range, and flow across it in a generally easterly direction into either the Pittwater or Frederick Henry Bay. On the eastern side portions of this basin are continuous with the adjacent portions of the Pittwater and Seven-Mile Beach promontory basins described above.

As stated above this basin is composed of Trias-Jura rocks. In particular, it is the Ross series of normal sandstones, with probably a large proportion of mudstones, which outcrop at this locality. These rocks constitute the majority of the basins throughout the midlands and south-eastern Tasmania. The quantity and quality of the water will, therefore, be similar to those obtained in such of these basins that have been exploited.

Some idea of the yields likely to be obtained is indicated in the amounts which have been ascertained by pumping tests on the bore-holes put down by the Government plant.[33]

The quality of the water will depend largely upon the horizon of the Trias-Jura strata which form the basin. While this cannot be definitely determined, it is probable that those outcropping are above the saliferous horizons. The quality would, therefore, be similar to the average of such basins in adjacent regions, but deep bores would enter the saliferous horizons, in which the water would be of such a quality as to render it useless for ordinary purposes.

Very little use has been made of the water-supplies in this basin, except to the south-east of Cambridge, where a few wells were sunk many years ago. These wells are seldom used, the supplies in them being utilised only in exceptionally dry periods for watering stock and other farmyard purposes. Providing that the quality is suitable (and this should be tested by trial bores), a much greater development of the water-supplies is possible. Watering points for stock could be established throughout the basin, and the supplies also used for general farming purposes. If the quality be found suitable for irrigation, the quantity is such that this could be carried out on small areas only.

(v) *The Ralph's Bay Neck-Sandford Basin.*—This basin includes the area of Tertiary strata which forms Ralph's

(33) See p. 46.

Bay Neck and the district around Sandford. It has a very irregular outline and occupies a tract of country of about 6 square miles. The surface is fairly level and low-lying, being generally below 100 feet above sea-level, and reaching 200 feet only in the northern part. It is drained by a few very small streams, which in the north flow into Frederick Henry Bay or lose themselves in the more or less marshy portions of Ralph's Bay Neck, and in the south-western flow into Ralph's Bay. In the south-eastern part Clear and Rushy Lagoons occur. The former is generally dry, while the latter always contains water, and the overflow of which passes into Pipeclay Lagoon.

The Tertiary rocks forming this basin are slightly different in different parts. Those which form Ralph's Bay Neck and occur along the eastern parts of the district are similar in every way to those forming the Seven-mile Beach promontory. In the northern part a fair amount of limonite is associated wtih the sandy deposits, and they resemble some of the sediments of the Launceston Tertiary basin. Around Sandford the beds are very sandy, and are probably continuous with the beds of Ralph's Bay Neck, but it is probable that Lower Tertiary sediments also occur. The thickness of these strata at some places near Sandford is not large, and Permo-Carboniferous rocks would be met at shallow depths.

No wells are in existence in this basin, and no development of the underground water has therefore been carried out. The quantity and quality in most parts should be similar to that in the Seven-mile Beach promontory basin.(34)

Pastoral, orcharding, and agricultural pursuits are followed in the district. The quality of the water would probably be suitable for watering stock, and the quantity more than sufficient to meet such demands. The possibility of using the water for irrigation for orchards and crops depends upon the quality, but if this is satisfactory only a very small proportion of the district could be so treated. The question of utilisation for domestic purposes also depends upon the quality.

(vi) *The Sandford Peninsula Basin.*—This basin embraces the country occupied by Tertiary rocks in the southern part of the Sandford peninsula. This tract of country is 4 miles long and 1 to 2 miles wide, and has

(34) See p. 50.

an area of about 5 square miles. The surface is fairly uneven, and varies in elevation a few feet above sea-level up to almost 400 feet. No streams of any size exist, and the drainage channels are not clearly defined. The greater part of the drainage is to the south into the lagoon near Collins' Springs. The remainder of the drainage enters Henry William Bay.

The rocks forming this basin have been described,(35) and consist of consolidated sands, sandstones, and conglomerates. They are mainly of a sandy nature, but with an admixture of fine siliceous material probably derived from the underlying Permo-Carboniferous mudstones. At many places these latter rocks underlie the Tertiary formations at shallow depths.

These Tertiary rocks should have a high porosity, and contain supplies of underground water. No wells have, however, been sunk up till the present time in order to utilise these supplies. The quantity of water obtainable should be at least equal to that from other basins in the district. No idea of the quality can be given, though it should compare generally with that of other basins. It would probably be suitable for watering stock, but whether it could be utilised for irrigation, domestic purposes, &c., in connection with the orcharding and agricultural pursuits of portions of the basin, could only be determined by analyses of samples from trial bores.

(vii) *The South Arm Basin.*—The long and narrow strip of land between Ralph's Bay and the River Derwent is known as South Arm. It is 6 miles long, and generally less than 1 mile wide. The surface is fairly level and low-lying, and at only two localities does its elevation exceed 200 feet above the sea.

Except for two small areas at the northern extremity, where diabase occurs, Permo-Carboniferous rocks form the bedrock of South Arm. Over the greater part of the Arm, however, these rocks are overlain by Tertiary sediments. The latter sediments consist of sand and loosely-compacted sandstones over the larger portion of the Arm, but gravels and clayey beds occur on the eastern shore, and clays overlie the diabase to the north.

Supplies of water will probably be available in the Tertiary sediments, but, owing to the shallow depth of these rocks, they will be more or less unreliable. The quantities

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(35) See p. 25.

obtainable will generally be small, and the quality cannot be predicted.

No development of these supplies has taken place. Probably the only utilisation possible will be the providing of watering-points for stock.

(viii) *The Clarence Rivulet Basin.*—This basin or basins occupy parts of the drainage system of the Clarence Rivulet. This rivulet rises by means of numerous heads in the hills around Rumney's Hill and Clarence. It flows in a general south-south-easterly direction, and enters Ralph's Bay to the south of Rokeby. The hills to the west rise to elevations of 600 feet, and those to the east to 1200 feet above sea-level.

The central and western parts of the basin are occupied by Permo-Carboniferous mudstones. To the north these mudstones are overlain by the Ross sandstone series of the Trias-Jura system, and to the south by Tertiary beds around Rokeby. Diabase forms the hills to the east, and part of those to the west. A basalt flow extends along the valley for a distance of one and a half miles.

Supplies of water will be obtainable from the Tertiary rocks around Rokeby, from the Trias-Jura rocks around Clarence, and from small areas of alluvium and hill-slip material along the valley. It is doubtful whether any will be obtainable from the Permo-Carboniferous rocks.

The quantity of water obtainable from the Trias-Jura is not likely to be large, as the catchment area is small and the country steep and broken. The quality will probably be found to be poor, as these rocks will contain any local development of the saliferous horizon in the Ross sandstones. The quantity and quality of the water from the Tertiary rocks cannot be foretold.

No wells have been sunk in this basin, and no development of the underground supplies has taken place. Probably the only use to which the supplies could be put would be the establishing of watering-points for stock.

(ix) *The Bellerive-Lindisfarne Basin.*—This basin consists of an irregular-shaped area of Trias-Jura rocks occurring around the districts of Bellerive and Lindisfarne. It commences in the north at the head of Geilston Bay, and extends as a strip of country not exceeding 1 mile in width past Lindisfarne and Bellerive as far as the coast to the east of Kangaroo Bluff, where it is about 2 miles wide. The surface is undulating, and varies in elevation from sea-level to over 400 feet above it. The northern part is drained by the Geilston Rivulet, and the southern by the Kangaroo Bay Rivulet and its tributaries.

This basin includes only Trias-Jura sandstones, with the exception of the small areas of recent sands in the south. These sandstones belong to the Ross series of normal sandstones. They are surrounded for the greater part by Permo-Carboniferous siliceous mudstones in faulted relation thereto. Diabase forms the boundary of the remainder of the basin, being intrusive into the Trias-Jura and Permo-Carboniferous rocks. Supplies of underground water will be obtainable from these Ross sandstones. Similar basins occur plentifully throughout the Midlands and south-eastern portions of Tasmania.

The quantity of water likely to be obtained from wells in these rocks will be similar to those indicated in the table[36] showing pumping tests on bore-holes already drilled in such rocks.

The quality of the water will probably be found to vary slightly according to the elevation of the bore-hole or well, owing to the particular horizon of the sandstones in which they are sunk. Over 400 feet of sandstones occur in the basin, and some thickness of similar overlying rocks must have been removed by denudation. The horizons of the strata occurring near sea-level must therefore be in the vicinity of the saliferous horizon in the lower portion of the Ross sandstone series. The water obtainable from these rocks would be of poor quality, due to the large amount of salts such as sodium chloride dissolved from them. At higher altitudes corresponding to higher horizons in the series, it is probable that the quality of the water will be better. As to whether the quality will be suitable for the purposes for which it is required can only be satisfactorily determined by obtaining samples from freshly-sunk wells or bores and having them analysed.

Several wells have been sunk in this basin near Lindisfarne. The original purpose of these was probably to provide supplies for household purposes. Some of these wells are situated near to the edge of the River Derwent, and the quality of the water may have been affected by entry of water from the Derwent after periods of pumping from the wells. The fact that these wells have been sunk at or near the saliferous horizon would also tend to make the quality of the water unsuitable.

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[36] See p. 46.

No supply of water exists for the populated districts around Bellerive and Lindisfarne, and the residents have to depend for their supplies upon rain-water stored in tanks. The greatest development of the water in this basin would undoubtedly be for the purpose of providing supplies for household uses, if the quantity and quality were suitable. The quantity obtainable from a well or bore-hole would be sufficient to more than supply the requirements of a single household, if the practice were adopted of each householder providing his own supply. In the case of a public supply, however, it is probable that more than one well or bore-hole would be required. The quality of the water, which depends on the nature and amount of dissolved solids, is the most important factor governing the use of the water for household purposes. Before any attempt to establish a public supply is made, it is recommended that a trial bore be put down to test both the quality and the quantity of water obtainable.

The site of such a bore should be close to that which would be selected for the provision of the public supply. The latter depends upon the following factors. As indicated above, the quality of the water will probably be better in the higher horizons of the sandstones occurring towards the eastern side of the basin, so that from this viewpoint the site should be towards the east. However, the further to the east that a site is chosen the less becomes the area of sandstones which would be drained by a well, and the less the quantity of water to be obtained. Also, as the beds dip to the west and south-west at angles up to 10°, water tapped by wells on the west side will be under greater pressure and may even be under artesian conditions. Taking all these factors into consideration, the best sites would be localities about a quarter to half a mile from the eastern edge of the basin and at elevations of 200 to 300 feet above the Derwent.

(x) *The Risdon-Grass Tree Hill Basin.*—Several areas of Trias-Jura sandstones occur to the north-east of Risdon, and form portions of the flanks of Grass Tree Hill and the adjacent hills. These areas are more or less isolated from one another, but can be described together under the above title

The surface is very broken, and varies in elevation from 200 feet to 1200 feet above sea-level. It is drained by the Risdon Brook and Grass Tree Hill Rivulet, and their tributaries, which flow with a steep grade into the Derwent at Risdon Cove.

The small areas of Trias-Jura strata are bounded and separated from one another by diabase and Permo-Carboniferous rocks. The Ross sandstone series form the outcropping members of the Trias-Jura system.

All these small areas of sandstones contain supplies of underground water, but this applies more particularly to the more level and low-lying portions along the course of the streams.

The quantity of water will not be large in any of these basins, owing to their small size, and also the smallness of their catchment areas. The sandstones occurring at the higher elevations represent the lower portion of the Ross series, and will contain any saliferous zone that exists. The quality of the water obtained from the sandstones at the higher levels is, therefore, likely to be poor.

The sandstones at lower levels occur as faulted blocks, and their precise horizon cannot be determined, so that the quality of the water in these areas cannot be inferred.

No attempts have been made to develop the underground water-supplies of these basins. In view of the small quantities likely to be obtained, and the probable poor quality of the supplies, it is unlikely that any large development will take place. Any development which is contemplated should be merely in the direction of providing supplies for live-stock and general farm purposes.

(xi) *The Old Beach Basin.*—This basin forms the southerly extension of the basin described in a previous publication[37] as the Brighton-Back Tea Tree basin. It joins this latter basin along the Gage Brook, and extends to the south as a narrow tract of country along the eastern side of the River Derwent.

The surface of the basin varies in elevation from practically sea-level along the River Derwent to 800 feet towards the east. The hills to the east, such as Mt. Direction and Gunner's Quoin, rise to heights of over 1400 feet. The country within the basin is drained by several small creeks flowing westerly into the River Derwent.

The rocks forming the basin consist of the felspathic sandstones and mudstones of the felspathic sandstone series with much smaller amounts of siliceous sandstones. Except where bounded by the shores of the River Derwent, the boundary of the basin is formed by transgressive bodies of diabase. Very small areas of Tertiary and Recent sediments occur along the River Derwent.

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(37) Nye, P. B., Geol. Surv. Tas. Underground Water-supply Paper No. 2.

Supplies of water will be found to exist in the areas occupied by the Trias-Jura rocks. The felspathic sandstone series occupy the greater part of the basin and the whole of the northern and most important portion of it. Experience gained through drilling in similar basins in the midlands proves that the supplies of water occur at horizons occupied by the porous felspathic sandstones, these water-bearing horizons being separated by beds of non-productive mudstones. Beds of siliceous sandstones will also yield supplies of water.

The quantity of water obtainable will be similar to that in other basins formed by felspathic sandstones such as those at York Plains, Glenmorey, and Colebrook.

The quality should also be similar to that obtained in the above basins. The water from the bore-hole at Glenmorey may be taken as fairly representative of the water likely to be obtained in these basins, and the analysis of this water is given below.[38]

No development of these potential supplies has taken place. The quality of the water will be found to be suitable for providing supplies for live-stock, and possibly also for irrigation, but probably not for domestic purposes. The quantity will be such that only small areas of cultivation could be irrigated with these underground supplies.

It is anticipated, therefore, that the greatest development will be in the direction of providing watering points for live-stock, and also for general farmyard purposes.

(*d*) *Method of Obtaining Supplies.*

As the supplies of underground water occur beneath the surface, wells have to be sunk to tap the supplies, so that they can be made available for use. It will be found in the great majority, if not all, of the basins that the water is not stored under artesian conditions, and will not, therefore, rise to the surface when tapped. Mechanical means have then to be utilised in order that the water may be brought to the surface where it is to be used.

The various questions governing the selection of the type and dimensions of a well, and also the type of pumping and power plant, have, therefore, to be considered. These questions have been fully discussed in a previous report[39], and briefly in another [40].

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[38] See p. 78.

[39] Nye, P. B., Geol. Surv. Tas. Underground Water-supply Paper No. 1.

[40] Nye, P. B., Geol. Surv. Tas. Underground Water-supply Paper No. 2.

This discussion need not be repeated here, and only the conclusions arrived at will be dealt with below, together with any modifications necessitated by the conditions existing in the present district, or the advance made in the knowledge of underground water-supplies in the south-eastern portion of Tasmania.

(i) *Type of Well.*—The conditions are generally suitable for either dug or drilled wells, the choice between these depending upon local circumstances. In soft materials, such as the Tertiary sediments, Recent deposits, and hill-slip material, and especially when the water occurs at shallow depths in these or other formations, dug wells will probably be the type chosen. They will be easily sunk, and be inexpensive, and will be suitable for most requirements. When the depth to water is greater, and the water is to be obtained from Trias-Jura strata, and also in all cases when the supplies are to be used for domestic purposes, the drilled type of well is the one recommended. The tendency of modern practice is towards the use of drilled wells in preference to other types.

The Mines Department has purchased a Victoria drilling plant, capable of drilling wells in the Trias-Jura and softer rocks. Several bore-holes for water-supply purposes have already been put down at Nala, Glenmorey, and Richmond, and arrangements can be made with the Mines Department for the drilling of other wells.

(ii) *Type of Pumping Plant.*—Centrifugal and deep-well cylinder pumps are the common types used to pump water from wells.

Centrifugal pumps are particularly suitable for small discharge heads. They are very efficient, and have no valves to get out of order, and can be coupled direct to electric motors. Their use is restricted, however, as they have to be installed within 28 feet of the water surface, and so cannot be used for deep-drilled wells. They can be used in dug wells, combined dug and drilled wells, and shallow-drilled wells.

Deep-well cylinder pumps can be used for large discharge heads, and for any type of well. They are particularly suitable for deep wells, in which the depth to water is great, as the cylinder can be installed near water-level, and the piston operated by rods from the surface.

(iii) *Type of Power Plant.*—When only small quantities of water are required, windmills are the most convenient and inexpensive power-plant to utilise. For short periods, with a high-velocity wind, 8-feet or 10-feet windmills, on 20-feet to 30-feet towers, will pump 500 to 1000 gallons of water per hour. Over more extended periods the quantity pumped by these will be, however, in the vicinity of 200 to 500 gallons per hour. If small but continuous quantities are required to be pumped, the windmill should be supplemented by a small internal combustion engine, for use during periods of little or no wind.

For larger pumping-plants, oil-engines, using benzine for low-power plants, and kerosene for high-power plants, should be installed.

The hydro-electric transmission-line to Risdon passes through the western part of the district, and electric power may, therefore, be made available at some future date. If this is done, then electric motors will be the most convenient, and probably the most economical, power-plant to instal, especially if the pumping-plant is a centrifugal one.

(iv) *Size and Depth of Well.*—The dimensions of the wells will vary with certain conditions, such as quantity of water required, rate at which the well yields water, &c. Water cannot, of course, be pumped from a well at a greater rate than that at which it enters the well, and even when the rate of pumping is less than the yield there should be sufficient storage provided in the well below water-level (that which will be attained during actual pumping) to enable pumping to be carried out continuously. This can be effected by increasing the depth and diameter of the well. This increase of dimensions also provides greater wall surface through which water can enter the well, and thus increase the yield.

The depth of the well is determined by the depth to the water-table (if the rocks be all porous and saturated with water), or to the water-bearing beds. In the midlands and south-eastern districts the existing wells seemed to prove the existence of a water-table at a depth of 20 to 30 feet below the surface. The experience gained in the drilling of the bore-holes in different parts of the same district, however, proved that in these parts the water occurred in water-bearing beds, separated by more or less dry beds. This statement refers solely to Trias-Jura rocks, in which the drilling has been carried out. Up till the present, the greatest depth to one of the main water-bearing beds has not exceeded 70 feet. It may, therefore, be reasonably anticipated that water-supplies will be met with at depths not exceeding 70 feet, and often at the moderate depths of 20 to 30 feet. The wells will need to be sunk some distance below these depths, in order to provide increased supplies, and also storage for pumping.

The diameter of the well depends mainly on the type of well selected. Drilled wells are sunk by standard bits up to 10 or 12 inches diameter. The minimum size of the well is limited by the fact that it has to permit of the installation of the pump in the well. Larger wells are more advantageous from the point of view of yield and storage, but tend to be more expensive. The Government plant drills a hole 5 inches in diameter, which is a convenient size for yields likely to be obtained. Dug wells have to be of sufficient size to provide sinking facilities, while the maximum dimensions are limited by the greater cost of larger wells. Dug wells in the Trias-Jura rocks are generally circular, and 4 to 5 feet in diameter. These rocks stand well, and do not require support or lining, except near the surface. In softer materials, such as Tertiary sediments, Recent deposits and hill-slip material, the walls would require support and lining.

(*e*) *Utilisation of the Underground Water-supplies.*

(i) *Introduction.*—The underground water-supplies of Tasmania have been developed to only a very slight extent. In the early settlement of Tasmania numbers of wells were sunk in certain districts, particularly in the midlands, such as around Oatlands. These wells provided water for domestic supplies, and probably also for general farmyard purposes.

The supplies were not always of the best quality, and were generally hard, so that they gradually fell into disuse. This process was hastened by the advent of tanks constructed of metal, which enabled the collection of rain-water from the roofs of houses and other buildings. This latter method of supply has practically wholly replaced that of underground water for domestic purposes, although a few wells yielding good-quality water are still used. The supplies from many of these older wells are still used, however, for general household and farmyard purposes. In addition to wells such as the above, many others have been sunk in order to provide watering-points for horses, sheep, and cattle.

Other possible uses of underground water in Tasmania are irrigation, and boiler purposes on the railway locomotives. No attempts were made to utilise the underground water (apart from that obtained from springs) until the systematic investigations of the underground water resources of the midlands and adjacent districts were undertaken. Since these investigations were completed, the Mines Department has purchased a drilling-plant, and several bore-holes have been drilled to obtain supplies for these purposes.

The subject of the possible utilisation of the underground water-supplies in Tasmania for the purposes named above, viz., domestic (drinking and culinary, and laundry and toilet), watering-points for stock, irrigation, and boiler use, has been fully discussed in previous publications.(41) A large amount of information is given in these publications, which need not be repeated.

The quality of the water, as determined by the nature and amount of the dissolved mineral substances, is the most important factor in determining the use or otherwise of water for any particular purpose. In one of the reports(42) referred to above, this question of the quality of the water and its application is fully dealt with.

The analyses of the waters were obtained, and the various formulæ deduced by Stabler were applied to them. The analyses were those of waters obtained from wells which were sunk many years ago, and the supplies from which have been little used. Further, these wells have been seldom, if ever, cleaned out. It is not surprising, therefore, that the quality of the water in many of the existing wells is poor. The discussion on the quality and application of the waters dealt with this class of water, which could not, however, be taken as absolutely typical of the underground supplies. Analyses of waters obtained from freshly-sunk wells would form a much better basis for such a discussion. The water-supplies obtained in the bore-holes drilled by the Mines Department plant were sampled and analysed, and thus supply valuable information. A discussion of the applicability of these waters will serve to illustrate the possibilities of such supplies.

(41) Nye, P. B., Geol. Surv. Tas. Underground Water-supply Papers Nos. 1 and 2.

(42) Nye, P. B., Geol. Surv. Tas. Underground Water-supply Paper No. 2, p. 72.

Table No. 6[43] shows the results of these analyses, the dissolved mineral substances being recorded in parts per million of the radicles present. As explained in connection with the table, the waters analysed represent supplies from different strata. Sample I., from Nala, is from a mixed series of mudstones, sandstones, and felspathic sandstones, representing probably the upper portion of the Ross sandstone series. Sample II., from Glenmorey, was obtained from mudstones and felspathic sandstones of the felspathic sandstone series. Sample III., from Richmond, is from the Recent, and possibly Tertiary, beds overlying the basalt. Samples IV. and V. are from the same bore-hole sunk into probably the saliferous horizon of the Ross sandstone series.

These waters may be taken as fairly typical of the supplies to be obtained from such strata though variations must be expected from place to place over large areas.

(ii) *Irrigation.*—The following are the formulæ deduced by Stabler[44] for the comparison of waters to be used for irrigation:—

(*a*) When (Na − 0·65 Cl) is zero or negative.

$$\text{Alkali coefficient } (k) = \frac{2040.}{\text{Cl.}}$$

(*b*) When (Na − 0·65 Cl) is positive but not greater than (0·48 SO_4).

$$\text{Alkali coefficient } (k) = \frac{6620}{\text{Na} + 2{\cdot}6 \text{ Cl.}}$$

(*c*) When (Na − 0·65 Cl − 0·48 SO_4) is positive.

$$\text{Alkali coefficient } (k) = \frac{662}{\text{Na} - 0{\cdot}32 \text{ Cl} - 0{\cdot}43 \text{ SO}_4}$$

The "alkali coefficient" is "a purely arbitrary quantity, and may be defined as the depth in inches of water which, on evaporation, would yield sufficient alkali to render a 4-feet depth of soil injurious to the most sensitive crops. Whether injury would actually result from the application of such a water to any particular piece of land, however, depends upon methods of irrigating, the crops grown, the character of the soil, drainage conditions, and it should be clearly understood that the alkali coefficient in no way takes account of such conditions."

([43]) See p. 78.

([44]) Stabler, H., United States Geol. Surv. Water-supply Paper No. 274.

The classification based upon this coefficient is given in the following table:—

TABLE No. 7.

Classification of Irrigation Waters.

Alkali Co-efficient.	Class.	Remarks.
More than 18......	Good	Have been used successfully for many years without special care to prevent alkali accumulation
18 to 6...............	Fair	Special care to prevent gradual alkali accumulation has generally been found necessary, except on loose soil with free drainage
5·9 to 1·2	Poor	Care in selection of soils has been found to be imperative, and artificial drainage has frequently been found necessary
Less than 1·2.....	Bad	Practically useless for irrigation.

Applying the above formulæ and classification to the analyses of the waters under discussion the following results are obtained:

TABLE No. 8.

Classification of Some Underground Waters of Tasmania for Irrigation Purposes.

Sample.	Formula Applicable.	Alkali Co-efficient.	Class.
I.	(a)	9·8	Fair
II.	(a)	3·1	Poor
III.	(a)	1·1	Bad
IV.	(c)	0·3	Bad

It is thus seen that the Nala water is of fair quality for irrigation, the only precautions necessary for its use being to provide free drainage, and to otherwise provide against the possibility of gradual alkali accumulation. The Glenmorey water is poor, and should be used only on loose soils with free drainage or other soils with artificial drainage. The water from the Inverquharity bore-hole in the Recent and Tertiary formations is on the border-line between poor and bad, and should only be used on loose soils with good natural or artificial drainage. The water from the other Inverquharity bore is useless for irrigation.

(iii) *Domestic Purposes.*—Water has two main uses in the household, viz., for drinking and cooking, and toilet, laundry and general cleansing purposes.

(*a*) *Drinking and Culinary Purposes.*—No very satisfactory classification of waters for these purposes is possible, but the following table indicates in a general way the quality as affected by the dissolved substances present (expressed in parts per million).

TABLE No. 9.

Classification of Waters for Drinking and Culinary Purposes.

	Good.	Medium.	Poor.	Bad.	Thoroughly Bad.
Total Solids	0 to 1000	1000 to 1500	1500 to 2500	2500 to 4000	4000 and over
Alkali Carbonates...	0 to 200	...	200 to 300	...	300 and over
Chlorides (in form of Common Salt)	0 to 300	...	300 to 600	600 to 1000	1000 and over
Sulphates (in form of Glauber Salt)	0 to 400	...	400 to 1500	...	1500 and over

Based upon the above classification the analyses show that the waters have the qualities shown in the following table:—

TABLE NO. 10.

Classification of Some Underground Waters of Tasmania for Drinking and Culinary Purposes.

Sample.	Classification.	Remarks.
I.	Good to Fair......	Total solids low, but chlorides somewhat high. Alkali carbonates and sulphates absent
II	Poor to Bad	Total solids moderate, but chlorides excessive. Alkali carbonates and sulphates absent
III.	Thoroughly Bad	Total solids and chlorides excessive. Alkali carbonates and sulphates absent
IV.	Thoroughly Bad	Total solids and chlorides excessive. Alkali carbonates and sulphates also excessive

The classification explains itself, and little comment is required. The Nala water is of good quality, but probably has a slight taste of common salt. The Glenmorey water is of poor quality, and is too salty for drinking purposes, but would probably be suitable for cooking. The Inverquharity waters are useless for drinking or cooking.

(*b*) *Toilet and Laundry Purposes.*—Waters to be used for these purposes should be "soft," *i.e.*, readily form a lather with soap. The "hardness" of waters is due to the presence of salts of calcium and magnesium, which decompose soap and form insoluble substances. Temporary hardness is due to the carbonates and bicarbonates of these elements, and can be removed by boiling. Permanent hardness is caused by the sulphates and chlorides of these elements, and cannot be removed by boiling.

The hardness of waters is generally expressed in terms of parts per million of calcium carbonate. The following table shows the hardnesses of the waters under discussion :—

TABLE No. 11.

Hardness of the Waters.

(Expressed as Parts per Million of Calcium Carbonate.)

Sample.	Calcium.	Magnesium.	Hardness.
I.	71·19	25·42	281
II.	135·57	54·76	564
III.	252·39	298·25	1817
IV.	272·92	502·69	2749

The hardnesses of the waters are thus seen to range from 281 to 2749. Waters with hardness over 200 are considered too hard to be used, as the consumption of soap in forming a lather would be too great, and therefore expensive and inconvenient. All the above waters are of this class, and so could not be used directly for these purposes. The waters could, however, be treated before use, and the hardness considerably reduced. The addition of slaked lime and soda ash (sodium carbonate) would bring about this desired result, and the resulting water could then be economically used. The slaked lime converts the bicarbonates into carbonates and precipitates an equivalent amount of calcium and magnesium carbonates. The soda ash precipitates any excess of calcium and magnesium as carbonates.

(iv) *Supplies for Livestock.*—Animals can drink waters containing larger amounts of dissolved substances than can human beings, and so will drink supplies unfit for human consumption. When the dissolved substances are present in excessive amounts, however, the waters become unfit for animal consumption. The quantities which render waters unfit vary with the nature of the substances present. Common salt (sodium chloride) is perhaps the most objectionable mineral, and waters containing up to 1000 parts per million are considered satisfactory. Animals will drink waters containing larger amounts, but probably only when other supplies are not available, and such waters should not be given to them under conditions other than these.

The Nala water would form a good supply for livestock. The Glenmorey water contains 1086 parts of sodium chloride, but the stock will probably drink it readily. The Inverquharity waters are useless for this purpose.

(v) *Boiler Use.*—As far as can be seen at present, the only industrial use for the underground waters of the Midlands and South-Eastern Tasmania will be for boiler water on the railway locomotives. Supplies for watering-points are scarce along the Main Line Railway, and the bore-hole at Nala was sunk to provide a supply to augment the present one obtained from a spring.

The use of underground water for boiler purposes depends upon the nature and amount of the suspended and dissolved substances. They affect the use of the water in that they may cause foaming and priming, corrosion, and scale-formation. The cause of these conditions has been described previously,(45) and the formulæ deduced by Stabler were also stated and explained. These formulæ will be employed in the following brief descriptions to show the classifications of the waters analysed from the points of view of foaming, corrosion, and scale-formation:—

(*a*) *Foaming and Priming.*—The foaming coefficient $(f) = 2{\cdot}7\ Na + 2\,k$, where Na and k represent parts per million of sodium and potassium shown in the analyses.

The approximate classification based on this is—

Non-foaming; f not greater than 60.
Semi-foaming; f between 60 and 200.
Foaming; f greater than 200.

A non-foaming water can be used for a week in a boiler without foaming; a semi-foaming water cannot be used for a week, but which does not need changing more often than every two days; a foaming water cannot be used longer than two days without blowing off or changing.

TABLE No. 12.

Foaming Coefficients and Classification of the Waters.

Sample.	Sodium and Potassium. (in terms of Sodium.)	f	Classification.
I.	134.88	364	Foaming.
II.	427·23	1153	ditto
III.	1234·10	3332	ditto
IV.	4233·62	11,430	ditto

(45) Nye, P. B., Geol. Surv. Tas. Underground Water-supply Paper No. 2.

All these waters are therefore classified as foaming. The Nala water is the one with least foaming properties, but even this water would need to be charged every two days or less.

(*b*) *Corrosion.*—The coefficient of corrosion (c) as deduced by Stabler—

$$= H + 0{\cdot}1116\ Al + {\cdot}0361\ Fe + 0{\cdot}2828\ Mg - 0{\cdot}0366\ CO_3 - 0{\cdot}0165\ HCO_3.$$

where H, Al, Fe, Mg, CO_3, and HCO_3 represent respectively the parts per million of hydrogen, aluminium, iron, magnesium, carbonate, and bicarbonate radicles shown in the analyses.

The classification based upon this coefficient is—

Corrosive: if c be positive the water will certainly corrode the boiler.

Non-corrosive: if $c + 0{\cdot}0503$ Ca be negative, no corrosion will occur on account of the mineral constituents of the water.

Semi-corrosive: If c be negative, but $c + 0{\cdot}0503$ Ca be positive, corrosion may or may not occur, the probability of corrosive action varying directly with the value of the expression ($c + 0{\cdot}0503$ Ca).

TABLE No. 13.

Coefficients of Corrosion and Classification of the Waters.

Sample.	Co-efficient.	Classification.
I.	+ 2·5 approximate.	Corrosive
II.	+ 5·0 ,,	ditto
III.	+ 31·0 ,,	ditto
IV.	+ 74·5 ,,	ditto

The waters are thus all of a corrosive nature, the Nala and Glenmorey being the least so in this respect.

(*c*) *Scale Formation.*—The formula deduced by Stabler for the comparison of waters as regards their scale-forming properties is as follows:—

Scale (Sc) in lbs. per 1000 gallons of water—

$$= 0{\cdot}00833\ Sm + 0{\cdot}00833\ Cm + 0{\cdot}0107\ Fe + 0{\cdot}0157\ Al + 00138\ Mg + 0{\cdot}0246\ Ca.$$

The classification based on this index is:—

Very little scale—Sc not more than 1.
Little scale—Sc between 1 and 2.
Much scale—Sc between 2 and 4.
Very much scale—Sc more than 4.

TABLE No. 14.

Scale Index and Classification of the Waters.

Sample.	Scale.		Classification.
	Parts per million.	Lbs. per 1000 gallons.	
I.	264	2·1 approximate.	Much Scale
II.	492	4·1 ,,	Very much Scale
III.	1116	9·3 ,,	ditto
IV.	1644	13·7 ,,	ditto

It is thus seen that the Nala water would give much scale, and the others would give very much scale.

(*d*) *Conclusions.*—The application of the above formulæ and classifications show that the waters are all foaming and corrosive ones, and also form very much scale, with the exception of the Nala water, which forms only much scale. The Nala water is easily the best water, but even it is subject to the above disadvantages. The quality of this water could be greatly improved as regards its scale-forming properties by treatment in a water-softening plant with slaked lime and soda ash. This would however, also increase the foaming tendency of the water.

(2) COAL.

The coal seams of the Trias-Jura system are found interbedded with the felspathic sandstone series of this system. The greater part of the outcrops of Trias-Jura rocks in the district consist of the sandstones of the Lower, or Ross. sandstone series, from above which the felspathic sandstones have been denuded. Over these areas there is, therefore, no possibility of obtaining Trias-Jura coal seams. The felspathic sandstones series outcrop at two localities only within the district, viz., near Richmond and in the Old Beach area, along the eastern bank of the Derwent. The Richmond coalfield has been described previously in another publication[46].

The other possible coalfield may be termed the Old Beach coalfield. The felspathic sandstones occupy an irregular-shaped tract of country extending along the eastern shores of the Derwent, from near Risdon, in the south, to the Gage Brook in the north, and perhaps further. The eastern boundary is formed by the large transgressive body of diabase forming the elevated regions of Mt. Direction, Gunner's Quoin, &c. Diabase forms the western boundary of the field also in the northern portion. The River Derwent forms the remaining part of the western boundary. The northern boundary cannot be definitely stated, but it is at least as far north as the Gage Brook. Siliceous sandstones occur in association with the felspathic sandstones, and probably represent interbedded beds, and also beds belonging to the upper sandstones series, which overlies in some localities the felspathic sandstones series. The sandstones of this upper series being very similar to the Ross sandstones, it is therefore difficult to determine whether the sandstones to the north belong to the upper or lower series, hence the difficulty in fixing the northern boundary of the field.

In the southern part of the field the strata have a low dip up to angles of 5° to the west or north-west. In the western portion of the northern part of the field the dip is at larger angles (15° and more) to the west. Going easterly up the unnamed creek to the south of the Gage Brook, this dip becomes lower, and changes suddenly to an angle of 45° to the east. Further up-stream this dip decreases, and the beds become horizontal. This sudden change of dip indicates the presence of a fault, and probably one of some magnitude. No other faults were located, but undoubtedly exist within the area.

No coal seams outcrop within the area, although beds of carbonaceous mudstones are visible in many exposures. One seam has been revealed in a shaft sunk in the early eighties, and the occurrence is described by R. M. Johnston as follows.[47]

"Compton and Old Beach Mines.—Mr. Brock has recently sunk a shaft to a seam of coal, of which he dis-

(46) Geol. Surv. Tas. Mineral Resources No. 7.

(47) Johnston, R. M., Geology of Tasmania, 1888.

covered indications at the sea margin a little distance north of Mt. Direction.

" The seam, about 2 feet thick, exists under hard, laminated blue and grey shales, containing abundant impressions of the following Mesozoic fossil plants:—

Thinnfeldia obtusifolia.—R. M. Johnston.
Phyllotheca hookeri.—McCoy.
Phyllotheca australis.—McCoy.
Pterophyllum risdonensis.—R. M. Johnston
Zeugophyllites elongatus.—Morris. (Very abundant.)

" The shaft is sunk on the southern slope of the rounded hill capped with variegated sandstones, opposite Austin's Ferry. The sandstones evidently at one time had spread over the coal seam with associated shales, and all seem to dip slightly in a westerly direction, that is, towards the Mesozoic rocks of a similar character situated on the western shore of the Derwent. Towards the east, the sandstones either abut against or are overlaid by greenstone, forming the eastern slope of the same isolated ridge. Beds of a similar character extend throughout the lower levels towards the Jordan and Brighton.

" From the character of the beds and their fossil contents, they may have formed part of the Richmond group.

" The following contains particulars of the section sunk by Mr. Brock at Compton:—

" Section of Brock's coal shaft at Compton, Old Beach—

Sandstone	—
Sand	8·9
Clay	6·0
Grey shale	12·0
Hard laminated blue and grey shales, with impressions of *Zeugophyllites elongatus*, *Phyllotheca hookeri* and *Thinnfeldia obtusifolia*	6·0
Red friable shales	5·0
Carbonaceous shales	0·3
Coal	2·0
Carbonaceous shales	0·3
	40·3

Grey friable clay with *P. hookeri*."

The seam is thus proved to be 2 feet thick, and to be interbedded with shales (mudstones) containing typical fossil plants of the Trias-Jura period.

The presence of one coal seam is thus definitely proved, and others also probably occur. In the New Town coalfield,(48) 6 miles to the south, four seams of coal are reported with thicknesses of 15 to 34 inches, including bands and partings.

In the Richmond coalfield,(49) 8 miles to the north-east, three seams occur, and have thicknesses varying from 16 to 27 inches. It can thus be reasonably anticipated that other seams than the one known will occur. Before any attempt is made to open up such seams, the presence of which are based upon these anticipations, it is recommended that a number of bores be put down as part of a systematic drilling campaign to determine the existence, number, extent, thickness, and quality of such seams. A larger area of felspathic sandstones occur in the northern part of the field, and it is in this part that drilling, if anticipated, should be undertaken.

(3) LIMESTONE.

(a) *Permo-Carboniferous.*

Permo-Carboniferous rocks cover a large proportion of the district, but it is generally the upper members of this system, as developed in the south-eastern portions of Tasmania, which outcrop. The Permo-Carboniferous limestones are usually found associated with the fossiliferous Lower Marine series. These fossiliferous members outcrop in the northern and eastern parts of the Sandford Peninsula, but limestones are exposed at only one locality. This locality is the high cliffs along the shore of Frederick Henry Bay to the north-east of Sandford.

The cliffs here are about 80 feet high, and show beds of limestone interbedded with calcareous shales and white silicious mudstones. The limestone beds range in thickness up to 3 feet, and, conformable with the other beds, dip south-west at 5°. Judging by the fallen blocks at the foot of the cliffs the limestone is not of the best quality. Selected beds would probably be quite suitable for agri-

(48) Geol. Surv. Tas. Mineral Resources, No. 7.
(49) Geol. Surv. Tas. Mineral Resources, No. 7.

cultural purposes, and possibly also for lime-burning. Representative sampling and analysing would, however, be necessary before its use for other purposes, such as cement-making, could be determined.

The Permo-Carboniferous strata containing the limestone are cut off on the west and north sides by the intrusive body of diabase forming the hill to the west. On the south side they are cut off by a dyke of diabase from the main body. Permo-Carboniferous strata occur to the south of this dyke, but no limestones are visible, and faulting probably occurs along the line of the dyke.

(*b*) *Tertiary*.

A very interesting deposit of limestone occurs at the head of Geilston Bay. The Tertiary strata in which the limestone is interbedded have been described above.[50] They cover part or the whole of the shallow basin-like depression occurring to the east of the head of Geilston Bay. The rising ground to the north and south is occupied by Permo-Carboniferous rocks, and that to the west by Trias-Jura rocks. This depression has an area of about 10 acres, practically all of which will be composed of the Tertiary rocks overlain in places by basalt. The limestone beds have been opened up by quarries, and have thus been proved to extend over at least 1 acre.

In one of the older quarries the section is 6 feet of soil overlying 15 feet of calcareous rocks, containing dense, hard beds of limestones, veined in places with calcite. In the quarry being worked at the present time about 10 feet of basalt overlies the Tertiary sediments, and has a slope or dip to the north or north-west. A small amount of limestone is visible above the basalt. The strata under the basalt consist of irregular beds of mudstones, sandstones, and limestones with a low dip to the south. Several beds of the limestone are visible in the quarry, and have varying thicknesses up to 6 feet. In the quarry near the lime-kiln 1 to 2 feet of soil and 1 foot of limestone overlie about 12 feet of basalt. The beds under the basalt cannot now be seen, but they probably supplied limestone to be burnt in the kiln.

The Teritary strata have yielded fossil leaves and also land shells, and represent Lower Tertiary fresh-water sediments, the limestone also being of fresh-water origin.

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[50] See p. 25.

The limestone is of a yellowish-brown colour, and is very dense, hard, and compact. In contains a number of cavities, sometimes lined with calcite. The limestone contains extraneous matter, such as clay and sand, in the joints at some places, but otherwise it appears to be generally of fairly good quality.

The deposits are being worked at the present time, and the limestone utilised by the Electrolytic Zinc Company. It is loaded from a short jetty at the mouth of the quarry, and is carried in small boats direct to the Zinc Works, on the western bank of the Derwent, where it is used in connection with the metallurgical processes. It was formerly used for lime-burning with the production of quicklime.

The limestone beds occur somewhat erratically, and their extension cannot be safely relied upon, so that no reliable estimate of the quantity available can be made. If such an estimate is required, a number of bores should be sunk as a preliminary step to determine the extent, number, thickness, &c., of the beds, and the estimate of reserves based upon the results obtained.

(4) Sand.

Many sandy beaches occur around the coastline, particularly in the southern parts of the district. Some of these are composed of almost clean sand, which is apparently suitable for building and other purposes. At the present time the sand from the small beaches to the north and south of Dixon Point, on the eastern shore of Ralph's Bay, is being taken away for these purposes. It is taken from the shore in small row-boats, and then loaded on larger vessels, which carry it directly to Hobart. The sand on other beaches is of equal quality, but the majority of these face the open ocean, and the conditions are probably too rough, as a rule, to permit of loading operations.

(5)—Supposed Silver Deposit.

As a result of reports of the occurrence of silver ore, a visit was made to a portion of the country to the north of Richmond, which was surveyed in a previous publication.[51]

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[51] Nye, P. B., Geol. Surv. Tas. Underground Water-supply Paper No. 2.

The alleged occurrence is situated on the east bank of the Coal River, ½-mile to ¾-mile to the north of the township of Richmond. Several shallow shafts and pot-holes have been sunk, and a small amount of iron pyrites obtained.

The surface is covered with Recent gravels formed by the Coal River, and which occur to a depth of several feet. The underlying formation consists of Tertiary sands and clays, which are overlain by flows of basalt in the immediate vicinity. Two of the shallow shafts have penetrated the Tertiary strata, but were full of water, and the sections were not available for examination. On the dumps, however, lumps of harder rock were visible, along with much greater amounts of the ordinary Tertiary sands and clays. The lumps consisted of hardened or indurated sandstone, with narrow veins and lenses of iron pyrite. The layer of sandstone is 3 to 4 inches thick, with the pyrite layer situated centrally in it. The pyrite occurs as small lenses up to ½-inch thick and several inches long. The lenses are arranged along one general plane, but are not connected with one another.

The pyrite has been formed from circulating solutions, which have also indurated the sandstone, probably by deposition of silica in it. The circulation of the solutions was probably caused by the intrusion of the Tertiary basalt, but whether the solutions were actually derived from the lava or merely set in circulation by its intrusion cannot be stated. The precipitating agent which caused the pyrite to be formed in the bed it occupies was organic material contained in the sandstone. Numerous small cylindrical holes are found in the indurated sandstone, and represent external casts of small twigs and roots formerly included in the sandstone.

Reports were current that the pyrite had a large silver content. As much of the pyrite as could be gathered was collected and assayed in the Geological Survey Laboratory, with the following results:—

Gold	Nil.
Silver	Trace.

The pyrite is thus valueless as regards its gold and silver content. Further, the size of the deposit is such that it is of no economic importance for any purpose.

TABLE No. 6.

Analyses of Underground Waters.

(Quantities expressed in parts per million.)

Sample.	Total Solids.	Calcium (Ca).	Magnesium (Mg).	Sodium (Na).	Ferric Oxide (Fe_2O_3) and Alumina (Al_2O_3).	Silica (SiO_2).	Chloride (Cl).	Sulphate (SO_4).	Carbonate reported as— Carbonate (CO_3).	Bicarbonate ($(HCO_3)_2$).	Organic and Volatile Matter.
I.	686·43	71·19	25·42	134·88	14·71	20·86	207·98	20·56	156·40	...	35·14
II.	1675·29	135·57	54·76	427·23	11·00	33·00	658·77	45.26	...	629·95	...
III.	5271·43	252·39	298·25	1234·10	47·00	78·00	1902·90	160·50	...	2562·58	...
IV.	13,224·57	272·92	502·69	4233·62	16·00	28·00	5410·18	754·21	2007·96	...	...
V.	9052·00	...	...	...	...	...	4359·28	...	...	...	...

I. Water from bore-hole at Nala Railway Station. Analysed in Geological Survey Laboratory.

II. Water from bore-hole on Mr. A. F. Burbury's property, Glenmorey, Woodbury. Analysed in Geological Survey Laboratory.

III., IV., & V. Water from bore-holes on Dr. Brettingham Moore's property, Inverquharity, Richmond. Analysed in Geological Survey Laboratory.

(6)—Conclusions.

The geological examination of the Richmond-Bridgewater-Sandford district has shown that the rock-types occurring in, and the geological structure of, the district are such that there exists a number of small local basins in which supplies of underground water occur. These basins are formed chiefly by the Trias-Jura sandstones and felspathic sandstones, and also by Tertiary rocks. Supplies also exist in other porous formations as Recent alluvium and gravels, hill detritus, and possibly also by Permo-Carboniferous mudstones.

The quantity of water available will not be large, but will be sufficient for some of the requirements of the district. Short pumping tests on the bore-holes sunk by the Mines Department drill proved that the yields from these wells ranged from 125 to 500 gallons per hour, and it is anticipated that the yields to be expected from other wells will be similar in amounts.

The quality of the water, and its possible utilisation for any purpose, depends upon the nature and extent of the dissolved mineral substances, and is a very variable factor. Samples of water from the bore-holes sunk by the Mines Department drill were taken as being more representative of the underground waters than the supplies in old wells, and various formulæ were applied to the analyses of them in order to classify them for various purposes. The Nala water (obtained from sandstones and felspathic sandstones) is of fair quality for irrigation; of good to fair for drinking and cooking; rather hard for laundry and toilet; good for livestock; and not of the best quality for boiler use. The Glenmorey water (from felspathic sandstones) is poor for irrigation; poor for drinking and cooking; too hard for laundry and toilet; suitable for livestock; and of poor quality for boiler use. The waters from the Inverquharity No. 1 bore (from surface deposits overlying basalt) and the No. 2 bore (from the saliferous horizon of the Ross sandstones) are useless for practically all purposes, though that from the No. 1 bore-hole might be used with special care for irrigation.

The greatest possible utilisation is in the direction of providing watering-points for livestock, which are greatly needed, owing to the absence of surface water in dry times. The better-quality waters could be treated in water-softening plants, and used for all household purposes. Water-softening would also improve the quality of the waters in some respects for use in boilers. Some of the waters will be suitable for use in irrigation if care is exercised in the selection of soil and in the drainage thereof. The amount of water obtainable will, however, permit of irrigation of only small areas of land.

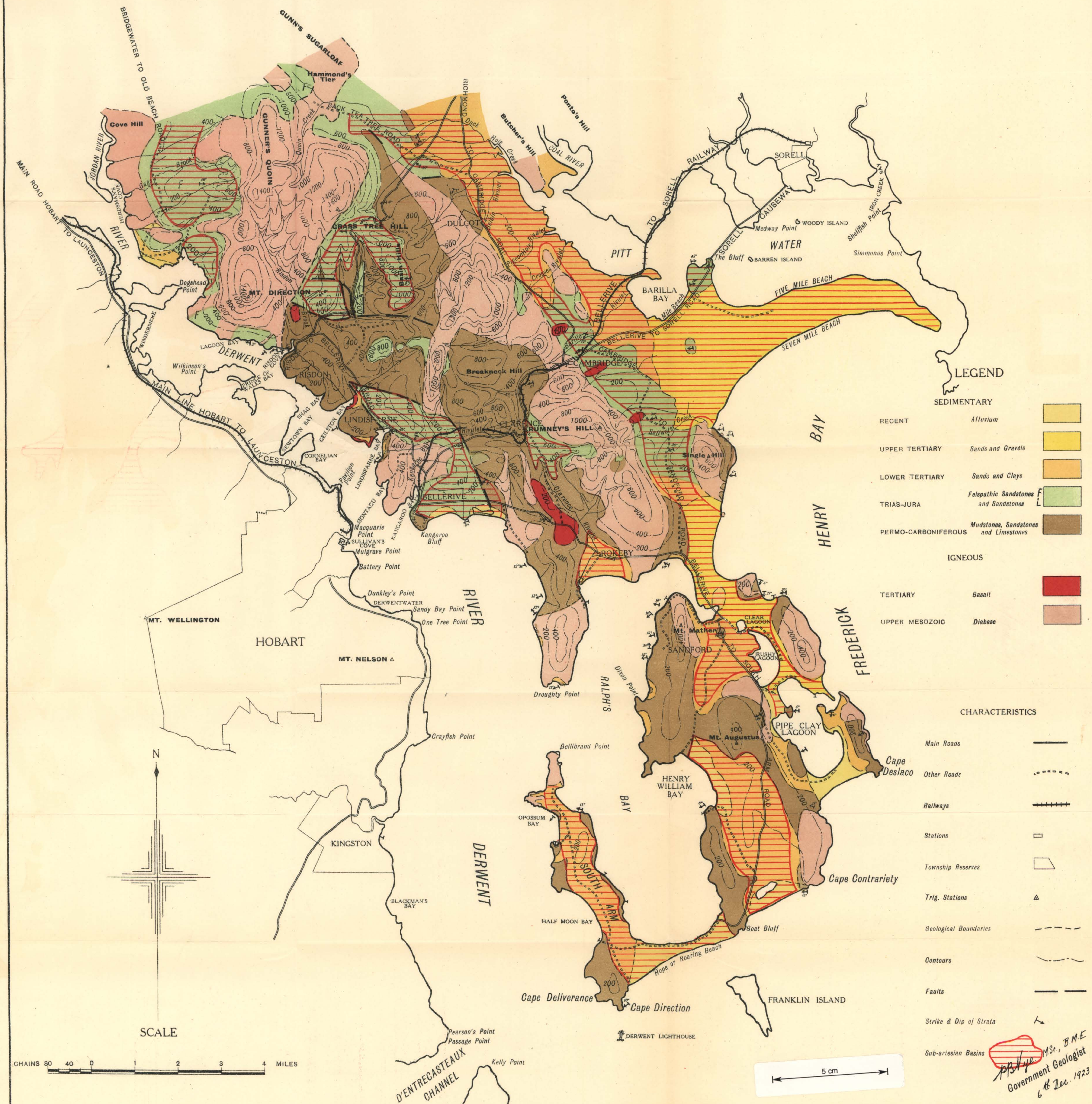
The water is under sub-artesian conditions, and so wells will have to be sunk and fitted with pumping plants. Wells drilled by the Mines Department drilling-plant are the types recommended. Pumping will be carried out by deep-well cylinder pumps operated by windmills, benzine, or kerosene engines.

Before any expenditure takes place in any undertaking in which it is proposed to use underground water, it is recommended that test-bores be put down to test both the quantity and quality of the supplies.

P. B. NYE, M.Sc., B.M.E.,
Government Geologist.

Geological Survey Office, Launceston,
19th October, 1923.

GEOLOGICAL SKETCH MAP
OF
THE
RICHMOND-BRIDGEWATER-SANDFORD
AREA



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