EXPLANATION OF DIRECT UTILIZATION POTENTIAL EVALUATION TECHNIQUE FOR THE STATE OF NEVADA GEOTHERMAL ASSESSMENT MAP

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INTRODUCTION

The major problem that must be addressed in any attempt to define the potential for direct utilization of Nevada's geothermal resources is the diversity of the resources in both areal distribution and character. While some resources are closely spaced and can be easily grouped, others cannot be readily associated.

Many geothermal occurrences, for instance, are inaccessible by land vehicles. Temperatures may vary from 20° C to over 200° C, and resources may discharge at the surface or be confined to a reservoir at a depth of 2 km or more. In addition, geothermal fluids range in total dissolved solids (TDS) from 150 ppm (drinking water quality) to over 6000 ppm (saline solution).

The facts that various direct-use applications place differing constraints on the nature of the required resource and that, in many specific geothermal resource areas, detailed data are not yet available, present additional problems to the question of resource assessment. Therefore, any method used to evaluate geothermal potential should be: a) generally applicable, b) sufficiently flexible to allow for future data input or changing priorities in resource requirements, and c) be of limited complexity, yet produce a semiquantitative basis for area to area comparisons.

APPROACH—RATIONALE

To overcome the problems and meet the requirements discussed above, a numerical scheme was developed. The basis of the method is a simple function called the probability function (PF) defined as follows:

$$PF = \Sigma \, Ri \, WFi$$

where Ri = Rank i^{th} parameter ($3^0 - 3^4$)

WFi = Weighting factor of i^{th} parameter (0,1,2)

Several parameters could be viewed as useful for defining potential, a partial list includes: temperature, land vehicle accessibility, rock type, rock age, depth to resource, population centers, geophysical data, fluid chemistry, areal extent, flow rate, permeability, recharge, economics, structure, and environmental considerations. Although the potential function could accommodate any number of parameters, the quantitative data necessary to establish limits for the weighting factors is unavailable in many instances. Such data are presently available for the following parameters: temperature, fluid chemistry, population centers, land vehicle accessibility, depth to resource, and areal extent. These parameters were selected for use with the function.

The direct-use applications selected for evaluation using the scheme are industrial process heat (IPH) and residential/commercial space heating (RSH). Potential for agriculture/aquaculture applications was not evaluated because the nature of the resource required and the method of exploitation are currently in a developmental stage. Having chosen the parameters to be used and the applications to be evaluated, the tasks remaining included establishing an order of importance for both IPH and RSH parameters and defining the limits to be associated with the weighting factor values.

Industrial process heat (IPH) evaluation parameters, in their order of importance are:

Parameter	*Rank*
Temperature	81
Water chemistry	27
Accessibility	9
Population centers	3
Depth to resource	1

where "accessibility" refers to land vehicle access to the resource. Note that the "rank" of the parameters is in terms of decreasing powers of 3. Use of powers of 3 preserves the established order of importance. This will be demonstrated in a later hypothetical application of the scheme. The weighting factors (WFi) associated with these parameters and the limits established for the factors are illustrated in figure 1. A weighting factor of "2" indicates the most desirable range for a parameter, "1" intermediate, and "0" the least desirable range. When judging the value to be assigned to the "water chemistry" weighting factor, consideration was given collectively to pH, TDS, and the presence or lack of corrosives, scaling compounds, or toxins. For example, although a fluid might have a pH between 5 and 6.5 and a total dissolved solids value of 450 ppm, the solids may consist of three hundred ppm dissolved silica which could cause scaling problems and thus the weighting factor used is "0".

The parameters used for the residential/commercial space heating (RSH) potential evaluation are similar, but they assume a different order of importance. Additionally, the weighting factor ranges have been adjusted to values more appropriate to the application. Note that areal extent is now considered because this parameter would be important to the development of a residential area where individual wells are used at each residence (as is the case in Reno, Nev., and Klamath Falls, Oreg.). Accessibility is no longer used because it is assumed to be tacitly accounted for by the presence of a population center. A listing of the residential/commercial space heating (RSH) parameters in their order of importance are:

Parameter	*Rank*
Population centers	81
Depth to resource	27
Temperature	9
Water chemistry	3
Areal extent	1

Ranges and limits used in weighting factor evaluations are given in figure 2. Arrows on the horizontal bars indicate that certain factors (for example TDS) have ranges that extend beyond those used in evaluating the weighting factor. However, once the established limit is exceeded the weighting factor value does not change.

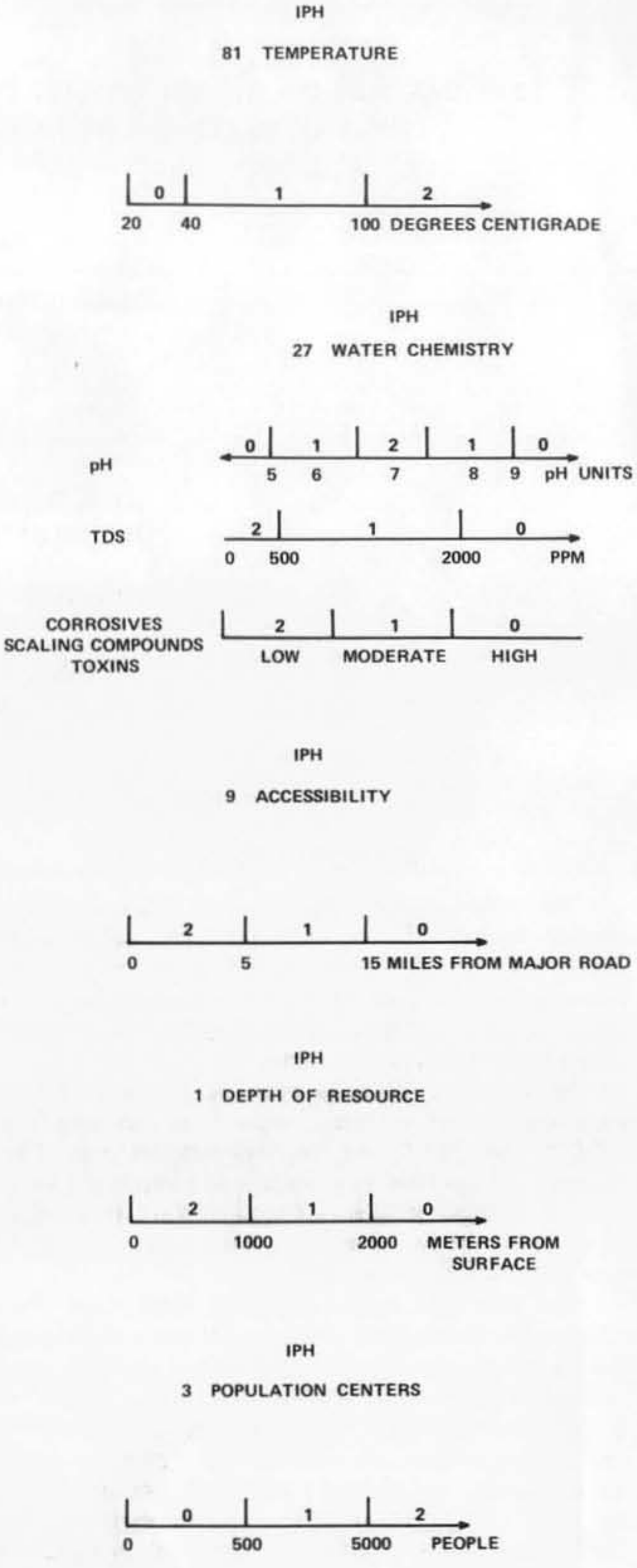

FIGURE 1. Weighting factors and their limits for industrial process heat applications.

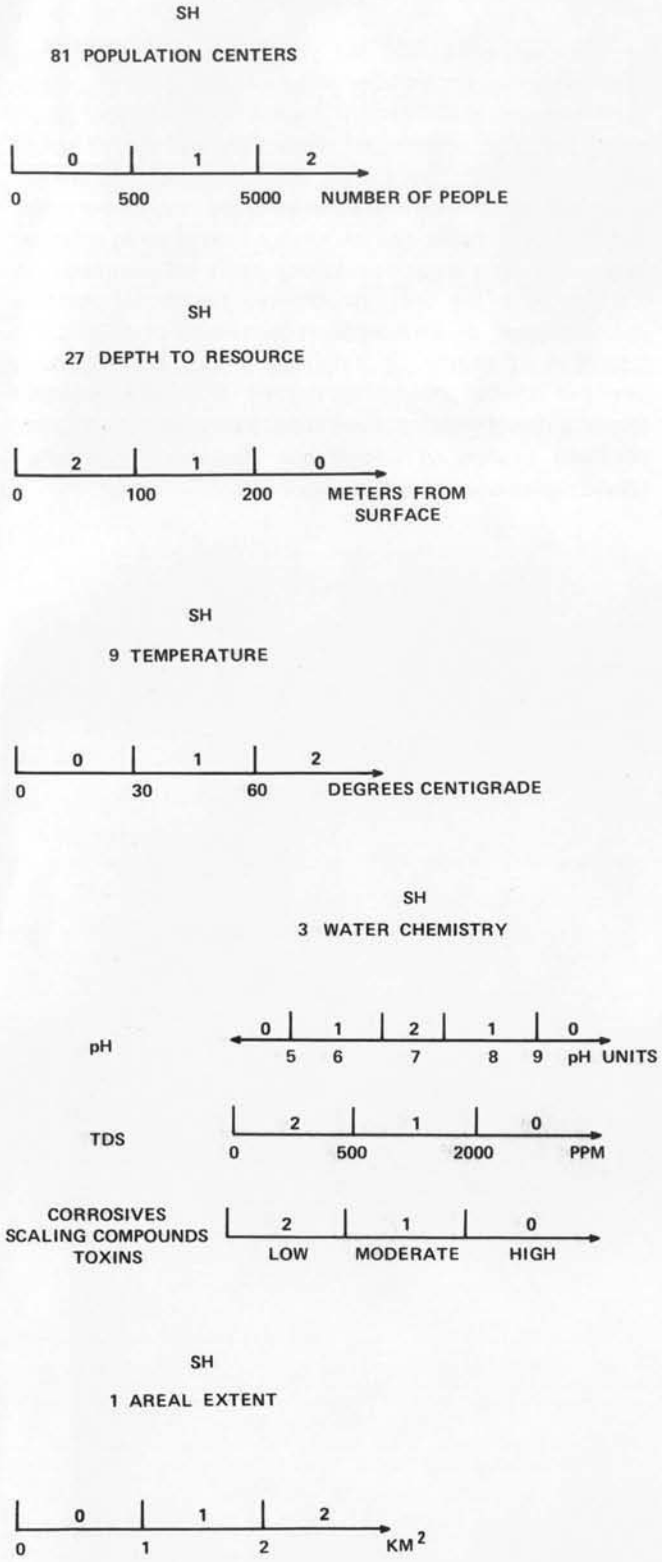

FIGURE 2. Weighting factors and their limits for residential space heating applications.

Numerical values, derived by summing the products of the rank-weighting factor pairs, range from a low of 0 to a high of 242, thus defining the limits of the probability function. This range was divided into three equal parts to obtain the "low", "moderate", and "high" categories of the probability function rating, and are:

Probability function rating	PF value
High	(+) 216–242
	(±) 188–215
	(–) 162–187
Moderate	(+) 136–161
	(±) 109–135
	(–) 81–108
Low	(+) 55–80
	(±) 28–54
	(–) 0–27

Each category is further divided into thirds and this is represented by the "–", "±", and "+" symbols.

The usefulness of powers of 3 in preserving the selected order of parameter importance can be illustrated by a pair of hypothetical industrial process heat examples (table 1). Case A receives a non-zero weighting factor only for the temperature parameter, thus its probability function value is 162 and its probability function rating (PFR) is *High(–)* (table 1a). In case B, all weighting factor values are 2 except temperature, which receives a 1 because it is less than 100° C. Here the probability function value equals 161 and the PFR is *Moderate(+)* (table 1b). Thus, the importance of temperature above all other parameters in the evaluation scheme is demonstrated.

TABLE 1a. Hypothetical IPH example, Case A.

	Weighting factor	Rank	Product
110°C	2	81	162
TDS > 2000 ppm pH > 9 Corrosive	0	27	0
> 15 mi. from major road	0	9	0
< 500 people	0	3	0
> 2000 m	0	1	0
		TOTAL	162

PFR = High(–)

TABLE 1b. Hypothetical IPH example, Case B

	Weighting factor	Rank	Product
60°C	1	81	81
TDS < 500 ppm pH 7.0 No corrosives	2	27	54
< 5 mi. to major road	2	9	18
> 5000 people	2	3	6
< 1000 meters	2	1	2
		TOTAL	161

PFR = Moderate(+)

APPLICATION OF THE SCHEME – AN EXAMPLE –

Application of the scheme to the region surrounding and containing Gabbs, Nev. provides a factual example of the probability function's use in evaluating the potential for direct utilization. Data from the geothermal occurrences in the area indicate an average temperature of 51°C, an average pH of 8.7, an average total dissolved solids of 582 ppm, an average depth to resource of 97 meters, an areal extent greater than 2 km^2, a population greater than 500 but less than 5000, and a distance of less than 8 km (5 mi) from an asphalt highway. Using these data the evaluation scheme applied to Gabbs is as follows:

Probability function ratings are *Moderate(±)* and *Moderate (+)* respectively for industrial process heat and residential space heating applications.

Application	Parameter	Rank	Weighting factor	Product
Industrial Process Heat	Temperature	81	1	81
	Chemistry	27	1	27
	Accessibility	9	2	18
	Population	3	1	3
	Depth to Resource	1	2	2
			TOTAL	131
Residential Space Heat	Population	81	1	81
	Depth to Resource	27	2	54
	Temperature	9	1	9
	Chemistry	3	1	3
	Areal Extent	1	2	2
			TOTAL	149

COMMENTS

As discussed earlier, the evaluation scheme is flexible with respect to the number of parameters it can accommodate; however, modifications are not limited to that aspect of its use. The ordering of parameters and the choice of limits for the weighting factors were based on the characteristics of Nevada and its geothermal resources. This ordering and choice of limits can be changed when using different parameters or a larger or smaller number of parameters to accommodate the data availability, geothermal resource characteristics, or application requirements of non-Nevada resources. It should be emphasized that the scheme is intended to be applied to regions of relatively similar resource characteristics. Geological, hydrological, and other pertinent sources of information should be used when bounding regions for potential evaluation.

NEVADA BUREAU OF MINES AND GEOLOGY
UNIVERSITY OF NEVADA, RENO

GEOTHERMAL RESOURCES OF NEVADA AND THEIR POTENTIAL FOR DIRECT UTILIZATION

Compiled by

Dennis T. Trexler, Brian A. Koenig, and Thomas Flynn

Scale 1:500,000
1 inch equals approximately 8 miles
Contour interval 500 feet

The names of the springs and wells that are represented by symbols on this map are listed in the following table. The numbers in parentheses refer to the number of springs or wells that were incorporated into one symbol and, where appropriate, the depth, or range in depth, of the well. The numbers in brackets refer to the numbering system used in NBMG Bulletin 91.

CARSON CITY
1. Carson Hot Springs (2) [1]
2. Pinyon Hills Wells (5; 125 to 200 ft.) [3]
3. Nevada State Prison Spring [2]

CHURCHILL COUNTY
4. Dixie Hot Springs [6]
5. Wells (6; 100 to 200 ft.) [7, 8]
6. Bradys, Springer, Fernley Hot Springs (3) [10]
7. Geothermal Wells (7; 500 to 7300 ft.) [10]
8. Phillips Petroleum Corp. Desert Peak 21-2 Well [12]
9. Soda Lake, Upsal Hogback Geothermal Wells (5; 45 to 500 ft.) [13]
10. Stillwater Area Geothermal Wells (5; 200 to 4000 ft.) [14]
11. Eightmile Flat Borax Spring [20]
12. Lee, Allen's Hot Springs (4) [21]
12a. Fallon Naval Air Station Well [na]
12b. Fallon Naval Air Station Well (1700 ft.) [na]

CLARK COUNTY
13. Test Well No. 3, 75-73 (1800 ft.) [23]
14. Bunkerville Area Wells (2; 60 and 120 ft.) [24]
15. Muddy River Spring, Moapa Warm Springs [25]
16. Whipple Well (90 ft.) [26]
17. Test Well No. 10 [27]
18. Indian Springs (8) [28]
19. Spring [29]
20. Springs [30]
21. Roger's Springs (8) [31]
22. Spring [33]
23. Las Vegas Springs (3) [33]
24. Jenison and Tollackson Wells (250 ft.) [33]
25. Bond and Campbell Wells (400 ft.) [33]
26. Gladstone Corp. Well (325 ft.) [33]
27. Wells's Well (1135 ft.) [33]
28. National Park Service Well (200 ft.) [34]
29. Brown's Spring [35]
30. Black Canyon Area Springs (3) [36]
31. Black Canyon Area Springs (2) [36]
32. Black Canyon Area Well (400 ft.) [37]
33. Bureau of Land Management Well (825 ft.) [40]
34. Well (500 ft.) [41]

DOUGLAS COUNTY
35. Hobo Hot Springs [42]
36. Springs (4) [43]
37. Saratoga Hot Springs [44]
38. Wally's, Genoa Hot Springs Area (10 springs; well drilled in area reported temperature of 83°C at 64 ft.) [45]
39. Doud Spring [46]

ELKO COUNTY
40. Shoshone Warm Spring [47]
41. Well (126 ft.) [48]
42. Spring [49]
43. Springs [50]
44. Nile Spring [51]
45. Trout Creek Ranch Well (246 ft.) [52]
46. Gamble's Hole (2 springs) [52]
47. Trout Creek Ranch Well (flowing, 247 ft.) [52]
48. San Jacinto Area Spring [54]
49. San Jacinto Area Spring [54]
50. Rizzi Ranch Hot Springs (3) [55]
51. Mineral Hot, Contact Mineral Spring [56]
52. Warm Springs Creek Canyon Spring [57]
53. Wild Horse Hot Spring [58]
54. Hot Creek Springs (10) [59]
55. Hot Sulfur Spring [60]
56. Wine Cup Ranch Area Spring [61]
57. Well [62]
58. Thousand Springs Area (Symbol plotted 2 mi. N of actual location) [64]
59. Gamble Ranch Well No. 4 [64]
60. Spring [66]
61. Devil's Punch Bowl at Marys River Ranch [68]
62. Springs (2) [70, 71]
63. Humboldt Wells Area Spring [73]
64. Springs (2) [73]
65. Pan American Petroleum Corp. Cobre Minerals No. 1 Well (5284 ft.) [75]
66. Ralph's Warm Springs (several springs and seeps) [76]
67. Johnson Ranch Spring [77]
68. City of Elko Well No. 12 (570 ft.) [78]
69. Hot Hole Spring, Sulfur, White Sulfur, Humboldt Hot Spring [78]
70. Carlin Area Hot Spring [80]
71. Hot Sulfur Spring [81]
72. Sulfur Hot Springs (3) [83]
73. Smith Ranch Spring [84]

ESMERALDA COUNTY
74. Fish Spring [85]
75. Gap Spring [85]
76. Sand Spring [85]
77. Pennebaker Well (300 ft.) [85]
78. Well [85]
79. Well [85]
80. Well [85]
81. Nevada Oil and Minerals VRS No. 1 Well (9178 ft.) [85]
82. Emigrant Well (324 ft.) [86]
83. Pearl Hot Springs [89]
84. Alkali Springs [90]
85. Silver Peak Hot, Waterworks Spring [91]
86. Spring [92]

EUREKA COUNTY
87. Horseshoe Ranch Spring [93]
88. Beowawe Area Springs (3; pH values of 9.3 to 9.7 reported at some springs; in some cases, carbonate is the dominant anion) [94]
89. Beowawe Area Wells (2 steam wells) [94]
90. Crescent Valley Hot Spring [96]
91. Spring [96]
92. Spring [97]
93. Hot Creek Spring [98]
94. Bruffey's, Mineral Hill Hot Spring [100]
95. Walti Hot Springs [102]
96. Shipley, Big Shipley, Sadler Hot Springs (flow rate: 3000 to 7000 GPM) [103]
97. Sill Ranch Water Well [104]
98. Sulfur Spring [105]
99. Thompson Ranch Spring [106]
100. Bartine Hot Springs, Bartine Ranch Water Well No. 4 (485 ft.) [107]
101. Klobe, Bartholomae Hot Springs [108]
102. Hot Springs Ranch Water Wells (2) [108]
103. Bartholomae Corp. Water Well (670 ft.) [108]

HUMBOLDT COUNTY
104. Cordero Mercury Mine Shaft [109]
105. Noque's Nevada Well (701 ft.) [109]
106. Bog Hot Springs (4) [110]
107. Baltazor, Continental Hot Springs [111]
108. Well [111]
109. Virgin Valley Campground No. 1 Well [112]
110. McGee Mtn. Area Spring [113]
111. Five Mile Spring Area (2) [114]
112. Gridley Lake Area Spring [116]
113. Howard Hot Springs (pH: 9.3) [117]
114. Spring [117]
115. Ninemile Spring [118]
116. Dyke Hot Springs [119]
117. Spring [120]
118. Well (352 ft.) [121]
119. Spring [122]
120. USGS Test Well No. 21 (88 ft.) [123]
121. Well (112 ft.) [124]
122. Gondra Well (435 ft.) [125]
123. The Hot Springs [126]
124. Soldier Meadows Hot Springs [128]
125. East Pinto Hot Spring [129]
126. West Pinto Hot Spring [129]
127. Cain Spring [130]
128. Well [131]
129. Double Hot Springs (2) [131]
130. Springs [131]
131. Spring DH-7 [131]
132. Black Rock Hot Springs [131]
133. Macfarlane's Bath House [132]
134. Hot Springs [133]
135. Hot Springs Ranch Springs (2) [134]
136. Caine Spring [135]
137. Spring [136]
138. Bureau of Land Management Well (55 ft.) (Ca-Cl system, TDS = 500 ppm) [137]
139. California Pacific Utility Co. Well (495 ft.) [138]
140. Golconda Area Hot Springs (pH: 6.5 to 8.2) [139]
141. Springs (2) [140]
142. Well (99 ft.) [142]
143. Springs (2) [142]
144. Hot Pot, Blossom Hot Springs [144]
145. Brooks Hot Spring [145]
146. Tipton Ranch Area Spring [146]

LANDER COUNTY
147. Izzenhood Ranch Spring [147]
148. Hot seeps in steam bank [149]
149. Spring [150]
150. Buffalo Valley Hot Springs [151]
151. Mound Spring [152]
152. Hot Springs Ranch Area [153]
153. Chillis Hot Spring [154]
154. Spring [155]
155. J. Lister Well (15 ft.) [156]
156. Peterson's Mill Hot Spring [159]
157. Southern Smith Creek Valley Springs [160]
158. Southern Smith Creek Valley Springs [160]
159. Monitor Well [161]
160. Spencer Hot Springs [162]
161. Well [163]

LINCOLN COUNTY
162. Hammond Ranch Spring [166]
163. Flatnose Ranch Spring [167]
164. Panaca, Owl Warm Springs [170]
165. Sand Spring [171]
166. Gunderson Well [171]
167. Hiko Spring (flow rate: 4000 GPM) [172]
168. Caliente Hot, Mineral Springs [173]
169. Aqua Caliente, City of Caliente Wells [173]
170. Crystal Springs (flow rate: 2000 to 9000 GPM) [174]
171. Ash, Alamo Spring (flow rate: 9000 GPM) [175]

LYON COUNTY
172. Patua Hot Spring [177]
173. Magma Power Co. Hazen No. 1 Well (750 ft.) [177]
174. Sutro Tunnel [178]
175. Well (265 ft.) [179]
176. Well (100 ft.) [179]
177. Magma Power Co. Wabuska Wells Nos. 1, 2, 3 (Well 3, 2223 ft.; symbol includes data from one spring) [181]
178. Well (145 ft.) [181]
179. Wells (2; 15 and 200 ft.) [181]
180. Well (364 ft.) [182]
181. Ambassador Well (540 ft.) [183]
182. Hind's Nevada Hot Spring [184]
183. Wellington Area Wells (4; 65 to 200 ft.) [187]
184. Springs [188]

MINERAL COUNTY
185. Wedell Springs (2; no pH) [191]
186. City of Hawthorne Well (602 ft.), Naval Ammo Depot Well No. 2 (423 ft.) [192]
187. Well [192]
188. Naval Ammo Depot Well No. 3 (452 ft.) [192]
189. Pilot Mtn. Area Well [na]
190. Sodaville Springs [193]
191. Bureau of Land Management Well (345 ft.) [194]
192. Bureau of Land Management No. 2 Well (64 ft.) [195]
193. Well [196]

NYE COUNTY
194. McLeod's Ranch Springs [197]
195. Spring [198]
196. Pott's Ranch Spring [200]
197. Diana's, Devel's Punch Bowl [200]
198. G. Sawyer Well (275 ft.) [201]
199. Gabbs Area Wells (200 to 325 ft.) [201]
200. Big Warm Spring at Duckwater (flow rate: 6000 to 7000 GPM) [202]
201. Little Warm Spring at Duckwater [202]
202. Darrough's Hot Springs [204]
203. Geothermal Wells, includes Magma Power Co. Well [illegible]
204. [illegible]
205. Spring [206]
206. Test Hole UCE-10 (2963 ft.) [206]
207. Locke's North, Big, Hot Spring (pH: 7.5 to 8.1) [207]
208. Blue Eagle, Jack, Kate Springs [207]
209. Shell Oil Co. Eagle Springs No. 2 Well (10,155 ft.) [207]
210. Chimney Springs [207]
211. Shell Oil Co. Coyote Unit No. 1 Well (1711 ft.) [207]
212. Storm Spring, Coyote Hole (pH: 7.6 to 8.0) [207]
213. Abel Spring [207]
214. Morman, Moorman Spring [208]
215. Emigrant Spring [209]
216. Test Hole UCE-18 [210]
217. Old Dugan Place Hot Spring [211]
218. Upper Warm Spring [211]
219. Hot Creek Ranch, Upper Hot Creek [211]
220. Hot Creek Valley Spring [214]
221. Butterfield Springs [215]
222. Moon River Spring [217]
223. Hot Creek Ranch Springs (flow rate: 7000 GPM) [218]
224. Salisbury Spring [219]
225. Nanny Goat Springs [220]
226. Mizpah Mine, Belmont Mine [221]
227. Spring [223]
228. Reveille Mill Spring [224]
229. Well (465 ft.) [225]
230. Cedar Spring [226]
231. Well (203 ft.) [227]
232. Beatty Area Wells (2) [227]
233. Well [227]
234. Spring [227]
235. Spring [227]
236. Hick's, Amargosa, Burrell Hot Springs (4) [227]
237. Beatty Municipal Spring [227]
238. Yucca Flat Test Well C (1701 ft.) [228]
239. Yucca Flat Test Well E (1875 ft.) [228]
240. Amargosa Desert Springs and Wells [229]
    1. Well (1329 ft.) ◈ 33
    2. Well ◈ 27
    3. Well (78 ft.) ◈ 28
    4. Well (360 ft.) ◈ 24
    5. Well (280 ft.) ◈ 24
    6. Well (330 ft.) ◈ 24
    7. Well (165 ft.) ◈ 24
    8. Well (300 ft.) ◈ 24
    9. Well SM-7 ◈ 33
    10. Scruggs Spring, Devil's Hole ⊕ 33
    11. DH Well ◈ 33
    12. Well (135 ft.) ◈ 23
    13. Well ◈ 26
    14. Well (400 ft.) ◈ 28
    15. Embry Well ◈ 21
    16. Crystal Spring ⊕ 33
    17. Davis Ranch Springs ⊕ 21
    18. Well (500 ft.) ◈ 30
    19. Indian Seep, Indian Rock Spring, Point-of-Rock-Spring, King Spring ⊕ 33
    20. Wells SM-1, SM-2, SM-3 ◈ 29
    21. Well SM-17 ◈ 21
    22. Jack Rabbit Spring ⊕ 26
    23. Jack Rabbit Spring ⊕ 28
    24. Ash Meadows, Big Spring, Deep Spring ⊕ 28
    25. Well (325 ft.) ◈ 24
    26. USGS Tracer Well No. 2 ◈ 31
    27. Well ◈ 25
    28. Mecca Well ◈ 22
    29. Ash Tree Spring (flow rate: 1700 GPM) ⊕ 24
    30. Fairbanks Spring ⊕ 27
    31. Soda Spring, Bell Spring ⊕ 23
    32. Roger's Springs ⊕ 28
    33. Longstreet Spring (flow rate: 1000 to 1200 GPM) ⊕ 28
    34. Bole Springs ⊕ 22
241. Army Well No. 1 [229]
242. Well [230]
243. Wilcox Well [230]
244. Raycraft Well (322 ft.) [230]
245. Manse Ranch Springs (plots in Clark Co.) [230]
246. Well (795 ft.) [230]

PERSHING COUNTY
247. Buffalo Valley Area Springs [151]
248. Trego, Butte Hot Springs (pH: 7.9 to 8.4) [233]
249. Coyote Spring [233]
250. Garrett Ranch Well (125 ft.) [233]
251. Nelson, Guthrie Hot Springs [234]
252. Leach's Hot Spring [235]
253. Phillips Petroleum Corp. Campbell E. No. 1 Well [illegible]
254. Southwest Dredging Co. Well [illegible]
255. Kyle Hot Springs [illegible]
256. Mineral Materials Well [illegible]
257. Paris Well (302 ft.) [240]
258. Spring [242]
259. Home Station Ranch Hot Spring [242]
260. Sou, Seven Devil's, Gilbert's Hot Springs [243]
261. McCoy Spring [244]
262. Hyder Cone Hot Springs [246]
263. Lower Ranch Hot Springs [247]

WASHOE COUNTY
264. Hill's Warm Spring [253]
265. New Spring [257]
266. Ward's, Fly Ranch Area Well [258]
267. Ward's, Fly Ranch Area Well [258]
268. R. Bailey Well (310 ft.) [258]
269. Fly Ranch Springs [258]
270. Western Geothermal Inc. Fly Ranch Geothermal Wells (1000+ ft.) [258]
271. Spring [258]
272. Great Boiling Springs at Gerlach (20 springs) (pH: 4.5 to 8.3) [261]
273. Chevron San Emidio Desert Well [265]
274. D. Beyer's Ranch Well [266]
275. The Needles Rocks Springs [269]
276. Western Geothermal Needles No. 1 Well (5888 ft.) [269]
277. Springs [270]
278. McCulloch Corp. Well [272]
279. Lawton Hot Springs [275]
280. Well at Lawton Hot Springs [275]
281. Moana Area Springs and Wells [277]
    1. Well (582 ft.) ◈ 22
    2. Sierra Pacific Well (785 ft.) ◈ 30
    3. Well (184 ft.) ◈ 23
    4. Well (270 ft.) ◈ 30
    5. Crano Well (103 ft.) ◈ 37
    6. Wells (4; 900, 1000, 1125, and 1006 ft.) ◈ 42-59
    7. Old Van Slyck Wells (67 and 77 ft.) ◈ 35
    8. Well (86 ft.) ◈ 24
    9. Clark Well (225 ft.) ◈ 63
    10. Moana Area Residents' Wells (Direct Geothermal Users) (9; 150 to 750 ft.) ◈ 80-85
    11. Willis Well (110 ft.) ◈ 28
    12. Well (550 ft.) ◈ 22
    13. Wells (2; 752 and 621 ft.) ◈ 23
    14. Well (1025 ft.) ◈ 24
    15. Wells (2; 660 and 685 ft.) ◈ 21
    16. Well (650 ft.) ◈ 22
    17. Well (600 ft.) ◈ 24

    Steamboat Area Springs and Wells [278]
    18. Well (504 ft.) ◈ 22
    19. Well (112 ft.) ◈ 30
    20. Wells (2; 45 and 84 ft.) ◈ 29
    21. Wells (3; 50 to 100 ft.) ◈ 30
    22. Wells (4; 75 to 100 ft.) ◈ 29
    23. Well (44 ft.) ◈ 23
    24. Well (44 ft.) ◈ 23
    25. Wells (2; pH: 7.1 to 8.3) ◈ 41-49
    26. Well (195 ft.) ◈ 29
    27. Well (258 ft.) ◈ 76
    28. Three Wells and Three Springs (80 to 200 ft., pH: 7.1 to 8.7) ◈ 57-143
    29. Wells (2; 80 and 160 ft.) ◈ 24
    30. Steamboat Hot Springs (20 to 30 springs) ⊕ 52-95
    31. Well ◈ 140
    32. Wells (2) ◈ 28
    33. Wells (2) ◈ 70
282. Wells (2; 107 and 108 ft.) [279]
283. Bower's Mansion, Franktown Hot Springs [280]
284. Well [280]
285. Well [281]

WHITE PINE COUNTY
286. Collar and Elbow Spring (TDS: 248 ppm) [282]
287. Shell Oil Co. Steptoe Unit No. 1 Well (8406 ft.) [283]
288. Cherry Creek, Young's Hot Springs [285]
289. L. Henroid Well (600 ft.) [286]
290. Giocoechea, Simonsen Warm Springs [287]
291. Shellbourne Springs [288]
292. Monte Neva, Melvin, Goodrich Hot Spring [289]
293. Campbell Ranch, North Group Springs (flow rate: 1350 GPM) [291]
294. McGill, Schoolhouse Warm Springs (flow rate: 5000 GPM) [292]
295. Lackawanna Hot Springs, Ely Warm Springs [293]
296. Williams Hot Springs [295]
297. Preston Springs (flow rate: 5700 GPM) [296]
298. Bureau of Land Management Wells (396 and 407 ft.) [297]

PURPOSE OF MAP

This map and the accompanying table are intended to be used as a guide to draw attention to areas having characteristics favorable for the exploitation of geothermal resources for non-electric applications. The configuration and areal extent of the regions is based strictly on currently available data and was carried out using a scheme described below. The boundaries of the regions should not be thought of as a fixed limit, but rather as a tentative line whose location is subject to refinement with the introduction of new information. Certain areas, some of possibly high potential, could not be considered because of insufficient data. The authors hope this publication will stimulate interest in this widespread Nevada energy resource which has seen only limited exploitation in the past. Leasing and subsequent exploitation of geothermal resources should be undertaken only after thorough geological and geophysical investigations.

SPRINGS
Letters in parentheses refer to detailed descriptions below
(A) Temperature (°C)
(B) Flow Rate indicator
(C) Index Number
(D) Location (at crosshairs)
(E) pH indicator
(F) Spring symbol
(G) Dominant chemical constituents and total dissolved soilds
73
23
Flow Rate scale (GPM): 0, 500, 1000
pH scale: 5, 7, 9

WELLS
(A) Temperature (°C)
(B) Flow rate indicator
(C) Index Number
(D) Location (at crosshairs)
(E) pH indicator
(F) Well symbol
(G) Dominant chemical constituents and total dissolved solids
59
47
Flow Rate scale (GPM): 0, 500, 1000
pH scale: 5, 7, 9

A. The temperature of the geothermal occurrence is given in degrees centigrade (°C) and appears near the top of the symbol in red. In general, the temperature will be the highest reported for any one area, however, for large differences between the highest and lowest reported temperatures, the full range of temperatures is represented on the symbol. To convert from degrees centigrade to degrees Fahrenheit, use either the thermometer scale provided or the temperature conversion formulas.

B. The Flow Rate indicator shows the natural discharge in gallons per minute (GPM). The scale at the top half of the symbol represents flow rates from 0 to 1000 GPM, and flow rates greater than 1000 GPM are represented by a vertical bar (⊣) at the right side of the symbol.

C. The Index Number keys the map symbol to the accompanying table. The table contains information on the geothermal occurrence that could not be incorporated into the symbol such as: spring or well name, the number of springs or wells that are represented by the map symbol, and any additional chemical or physical data. The position of the index number may vary because of spacing considerations.

D. The location of the springs and wells is generally represented by the crosshair (+) of each of the symbols. Areas containing a limited number of chemically similar springs and/or wells are represented by a single symbol; values associated with this symbol are an average for the group. In the case of severe overcrowding, such as in the Moana-Steamboat and the Amargosa Desert areas, smaller symbols are used on the map to identify the location and complete annotated symbols are incorporated in the table.

E. The pH of a liquid is a measure of the amount of acid or base it contains; it is an important consideration for the choice of materials that may come in contact with geothermal fluids. Scaling and corrosion, for example, may become problematic for some alloys; measures can be taken, however, to avoid early replacement costs. The pH is represented by the small black triangle on the bottom half of the symbol. The pH scale below indicates the full range of pH values.

Strong Acid	Range of Nevada Waters	Strong Base
1 2 3 4	5 6 7 8 9	10 11 12 13 14

F. The map symbol used for surface occurrences (springs and seeps) is a circle. For subsurface occurrences (wells and mine shafts), a diamond shape is utilized.

G. The total amount of dissolved solids (TDS), measured in parts per million, is represented by the colored portions of the symbol. (For symbols without color, no chemical data are currently available). The dominant chemical species, such as calcium-sulfate or sodium-chloride, can be identified by the various colors used in the symbols.

The range of TDS, as well as the types of chemical systems, are illustrated below.

Representation of range of total dissolved solids

⊕ 0 to 500 ppm	⊕ 2000 to 2500 ppm
⊕ 500 to 1000 ppm	⊕ 2500 to 3000 ppm
⊕ 1000 to 1500 ppm	⊕ 3000 to 3500 ppm
⊕ 1500 to 2000 ppm	⊕ >3500 ppm

Dominant chemical species

🟠 Na-HCO$_3$	🟡 Ca-SO$_4$
🔴 Na-SO$_4$	🟢 Ca-HCO$_3$
🔵 Na-Cl	⊕ Chemistry unknown

POTENTIAL AREAS FOR DIRECT USE

The regions shown in green and purple on this map have been evaluated on the basis of the numerical scheme described below. The evaluation includes consideration of industrial process heat (IPH) and residential space heating (RSH) applications. The symbols that define the potential of the colored regions are tabulated below.

Increasing Potential →					Examples
High	−	±	+	↑	M(±)/L(+)
Moderate	−	±	+	Increasing Potential	H(−)/M(±)
Low	−	±	+		L(−)/H(±)

The rating for industrial process heat appears above the slash and the rating for residential space heating appears below the slash (IPH/RSH).

🟩 For these areas, sufficient physical, chemical, and geological data were available, and evaluation indicates a potential for development of non-electric geothermal applications. The evaluation does not indicate that such potential exists at every point within the region.

▨ Available data are insufficient to confidently bound the entire region, however, enough data are available to define the areas of solid shading. Geological data indicate that the physical and chemical conditions present in the solid sections could exist between and/or beyond these areas, represented by the striped pattern.

▨ Regions where presently available physical, chemical, and geological data are insufficient to properly evaluate the area for non-electric development potential. These regions are presented to provide an indication that potential may exist.

⊕ or ◈ Geothermal occurrences of limited areal extent with temperatures greater than 60°C are represented to indicate areas that may provide a basis for limited exploitation. These areas are capable of supporting some industrial process heat applications and most space heating needs. Present data do not allow for expansion of the area into a region that can be evaluated based on the present scheme.

THE EVALUATION SCHEME

A simple numerical scheme forms the basis for evaluating the non-electric development potential of the green and purple regions. The scheme incorporates several important physical, chemical, and demographic parameters including: temperature, chemistry, population, accessibility, depth to resource, and areal extent. Only five parameters were used in evaluating the areas for industrial process heat and residential space heating. Although many other factors could be considered, data for the five parameters selected are currently available and quantitative. The following parameters, listed in the order of their importance, were chosen to evaluate the potential for industrial process heat: temperature, chemistry, accessibility, population, and depth to resource. For residential space heating, the parameters used are similar, but their order of importance differs: population, depth to resource, temperature, chemistry, and areal extent. Each parameter is assigned a fixed number which preserves its order of importance. A second number is chosen for the parameter which is variable and depends upon the quality or quantity of the parameter within the defined region. These two numbers are taken as a product for each of the five parameters and the resultants are summed to arrive at a single number which forms the basis for comparing one area to another.

A detailed description of the basis and application of the scheme is given in the accompanying text.

POTENTIAL DEFINED

Since the word potential may connote different meanings to different observers, the authors feel it is appropriate to discuss their use of the word here. The word "potential," as used in the preparation of this map, refers to the *favorability* of the designated areas for the possible exploitation of geothermal energy to be used in non-electric industrial process heat and residential space heating applications. The evaluations are based on currently available data and existing technology. No attempt was made to incorporate growth or exploitation scenarios, or to make allowances for technological advances. New data or changes in the economics of fossil fuel usage could shift a region from one category to another. Such a situation could arise in the region near Minden and Gardnerville, NV. On the map, a low (+) potential is indicated for residential space heat applications. This evaluation results from the fact that the population centers do not lie within the region boundary as presently defined. If new data were to indicate that thermal fluids exist under the cities, the region boundary would be logically extended and its potential upgraded. Alternatively, although the boundary may not change, economic circumstances may provide an incentive to transport the resource to the populated area.

TEMPERATURE SCALE

°F	°C
230	110
212	100
200	90
170	80
	70
140	60
	50
110	40
	30
80	20
50	10

TEMPERATURE CONVERSION FORMULAS

$C = 5/9\,(F - 32)$

$F = 9/5\,C + 32$

SOURCES OF DATA

Garside, L. J. and Schilling, J. H. (1979) Inventory of thermal waters of Nevada: Nevada Bureau of Mines and Geology Bulletin 91.
Trexler, D. T., Flynn, Thomas, and Koenig, B. A. (1979) Low- to moderate-temperature geothermal resource assessment of Nevada, final report: under contract to the U.S. Dept. of Energy; contract no. ET-78-S-08-1556.
United States Geological Survey Computer File GEOTHERM.

Prepared for the U. S. Department of Energy, Division of Geothermal Energy under contract ET-78-S-08-1556

NOTICE

Topographic base from U.S. Geological Survey Topographic Map of Nevada Edition of 1965.

INDEX MAP OF NEVADA SHOWING HYDROGRAPHIC REGIONS AND BASINS

1. NORTHWEST REGION
2. BLACK ROCK DESERT REGION
3. SNAKE RIVER BASIN
4. HUMBOLDT RIVER BASIN
5. WEST CENTRAL REGION
6. TRUCKEE RIVER BASIN
7. WESTERN REGION
8. CARSON RIVER BASIN
9. WALKER RIVER BASIN
10. CENTRAL REGION
11. GREAT SALT LAKE BASIN
12. ESCALANTE DESERT BASIN
13. COLORADO RIVER BASIN
14. DEATH VALLEY BASIN

NORTHWEST REGION

15. BOULDER V.
11. COLEMAN V.
2. CONTINENTAL LAKE V.
16. DUCK LAKE V.
3. GRIDLEY LAKE V.
6. GUANO V.
9. LONG V.
10. MACY FLAT
8. MASSACRE LAKE V.
12. MOSQUITO V.
1. PUEBLO V.
5. SAGE HEN V.
14. SURPRISE V.
7. SWAN LAKE V.
4. VIRGIN V.
13. WARNER V.

BLACK ROCK DESERT REGION

28. BLACK ROCK DESERT
31. DESERT V.
19. DRY V.
23. GRANITE BASIN
25. HIGH ROCK LAKE V.
24. HUALAPAI FLAT
30. KINGS RIVER V.
    (A) RIO KING SUBAREA
    (B) SOD HOUSE SUBAREA
26. MUD MEADOW
18. PAINTERS FLAT
17. PILGRIM FLAT
29. PINE FOREST V.
22. SAN EMIDIO DESERT
20. SANO V.
32. SILVER STATE V.
21. SMOKE CREEK DESERT
27. SUMMIT LAKE V.
33. QUINN RIVER V.
    (A) OROVADA SUBAREA
    (B) McDERMITT SUBAREA

SNAKE RIVER BASIN

38. BRUNEAU RIVER AREA
41. GOOSE CREEK AREA
36. INDEPENDENCE V.
39. JARBIDGE RIVER AREA
34. LITTLE OWYHEE RIVER AREA
37. OWYHEE RIVER AREA
40. SALMON FALLS CREEK AREA
35. SOUTH FORK OWYHEE RIVER AREA

HUMBOLDT RIVER BASIN

57. ANTELOPE V.
61. BOULDER FLAT
55. CARICO LAKE V.
64. CLOVERS AREA
54. CRESCENT V.
48. DIXIE CREEK-TENMILE CREEK AREA
49. ELKO SEGMENT
71. GRASS VALLEY
68. HARDSCRABBLE AREA
47. HUNTINGTON V.
72. IMLAY AREA
66. KELLY CREEK AREA
45. LAMOILLE V.
67. LITTLE HUMBOLDT V.
73. LOVELOCK V.
    (A) OREANA SUBAREA
59. LOWER REESE RIVER V.
51. MAGGIE CREEK AREA
52. MARYS CREEK AREA
42. MARYS RIVER AREA
58. MIDDLE REESE RIVER V.
44. NORTH FORK AREA
69. PARADISE V.
53. PINE V.
65. PUMPERNICKEL V.
62. ROCK CREEK V.
46. SOUTH FORK AREA
43. STARR VALLEY AREA
50. SUSIE CREEK AREA
56. UPPER REESE RIVER V.
60. WHIRLWIND V.
74. WHITE PLAINS
63. WILLOW CREEK V.
70. WINNEMUCCA SEGMENT

WEST CENTRAL REGION

75. BRADYS HOT SPRINGS AREA
76. FERNLEY AREA
77. FIREBALL V.
78. GRANITE SPRINGS V.
79. KUMIVA V.

TRUCKEE RIVER BASIN

82. DODGE FLAT
90. LAKE TAHOE BASIN
88. PLEASANT V.
81. PYRAMID LAKE V.
85. SPANISH SPRINGS V.
86. SUN VALLEY
83. TRACY SEGMENT
91. TRUCKEE CANYON SEGMENT
87. TRUCKEE MEADOWS
84. WARM SPRINGS V.
89. WASHOE V.
80. WINNEMUCCA LAKE V.

WESTERN REGION

93. ANTELOPE V.
94. BEDELL FLAT
100. COLD SPRING V.
95. DRY VALLEY
97. HONEY LAKE V.
92. LEMMON V.
    (A) WESTERN PART
    (B) EASTERN PART
96. NEWCOMB LAKE V.
99. RED ROCK V.
98. SKEDADDLE CREEK V.

CARSON RIVER BASIN

101. CARSON DESERT
105. CARSON V.
102. CHURCHILL V.
103. DAYTON V.
104. EAGLE V.

WALKER RIVER BASIN

106. ANTELOPE V.
109. EAST WALKER AREA
108. MASON V.
107. SMITH VALLEY
110. WALKER LAKE V.
    (A) SCHURZ SUBAREA
    (B) LAKE SUBAREA
    (C) WHISKEY FLAT-HAWTHORNE SUBAREA

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    (B) SOUTHERN PART
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151. ANTELOPE V. (EUREKA & NYE)
186. ANTELOPE V. (WHITE PINE & ELKO)
    (A) SOUTHERN PART
    (B) NORTHERN PART
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    (B) NORTHERN PART
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178. BUTTE VALLEY
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182. DELAMAR V.
153. DIAMOND V.
128. DIXIE VALLEY
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127. EASTGATE VALLEY AREA
133. EDWARDS CREEK V.
167. ELDORADO V.
158. EMIGRANT V.
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    (B) PAPOOSE LAKE V.
124. FAIRVIEW V.
117. FISH LAKE V.
160. FRENCHMAN FLAT
122. GABBS VALLEY
120. GARFIELD FLAT
172. GARDEN V.
147. GOLD FLAT
187. GOSHUTE V.
138. GRASS VALLEY
166. HIDDEN V. (SOUTH)
156. HOT CREEK V.
113. HUNTOON V.
188. INDEPENDENCE V. (PEQUOP V.)
161. INDIAN SPRINGS V.
135. IONE VALLEY
164. IVANPAH V.
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174. JAKES VALLEY
165. JEAN LAKE V.
132. JERSEY V
157. KAWICH V.
139. KOBEH V.
183. LAKE VALLEY
144. LIDA VALLEY
150. LITTLE FISH LAKE V.
155. LITTLE SMOKY V.
    (A) NORTHERN PART
    (B) CENTRAL PART
    (C) SOUTHERN PART
175. LONG VALLEY
163. MESQUITE V. (SANDY V.)
140. MONITOR V.
    (A) NORTHERN PART
    (B) SOUTHERN PART
136. MONTE CRISTO V.
112. MONO VALLEY
154. NEWARK V.
162. PAHRUMP V.
170. PENOYER V. (SAND SPRING V.)
130. PLEASANT V.
116. QUEEN VALLEY
173. RAILROAD V.
    (A) SOUTHERN PART
    (B) NORTHERN PART
141. RALSTON V.
123. RAWHIDE FLATS
119. RHODES SALT MARSH V.
176. RUBY VALLEY
146. SARCOBATUS FLAT
134. SMITH CREEK V.
121. SODA SPRING V.
    (A) EASTERN PART
    (B) WESTERN PART
184. SPRING V.
179. STEPTOE V.
152. STEVENS BASIN
125. STINGAREE V.
149. STONE CABIN V.
145. STONEWALL FLAT
114. TEELS MARSH V.
168. THREE LAKES V (NORTHERN PART)
169. TIKAPOO V. (TICKABOO V.)
    (A) NORTHERN PART
    (B) SOUTHERN PART
185. TIPPETT V.
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GREAT SALT LAKE BASIN

193. DEEP CREEK V.
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    (A) HERRELL SIDING-BRUSH CREEK AREA
    (B) TOANO-ROCK SPRING AREA
    (C) ROCKY BUTTE AREA
    (D) MONTELLO-CRITTENDEN CREEK AREA (MONTELLO V.)

ESCALANTE DESERT

197. ESCALANTE DESERT

COLORADO RIVER BASIN

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218. CALIFORNIA WASH
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216. GARNET V. (DRY LAKE V.) ⅃
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217. HIDDEN V. (NORTH) ⅃
206. KANE SPRINGS V.
212. LAS VEGAS V.
205. LOWER MEADOW VALLEY WASH
220. LOWER MOAPA V.
219. MUDDY RIVER SPRINGS AREA (UPPER MOAPA V.)
209. PAHRANAGAT V.
208. PAHROC V.
203. PANACA V.
202. PATTERSON V.
214. PIUTE V.
199. ROSE V.
201. SPRING V.
211. THREE LAKES V. (SOUTHERN PART) ⅃
221. TULE DESERT
222. VIRGIN RIVER V.

(CONT.)
207. WHITE RIVER V.

⅃ NONCONTRIBUTING PART OF THE COLORADO RIVER BASIN

DEATH VALLEY BASIN

230. AMARGOSA DESERT
229. CRATER FLAT
227. FORTYMILE CANYON
    (A) JACKASS FLATS
    (B) BUCKBOARD MESA
231. GRAPEVINE CANYON
225. MERCURY V.
228. OASIS V.
232. ORIENTAL WASH
226. ROCK VALLEY

LEGEND

(All figures are in thousands of acre feet)

2 → Estimated annual surface water flow.

2 → Estimated annual groundwater flow.

② → Man made diversion. Surface water source - estimated annual amount.

② → Man made diversion. Groundwater source - estimated annual amount.

② → Man made diversion. Spring source - estimated annual amount.

M M M
M M M Minor quantity. An amount which is either less than 500 acre feet per year, or small in comparison to other quantities in the particular hydrologic area.

S S S Significant size. However, sufficient information is not currently available to make an estimate.

Quantity uncertain. Figure shown represents annual discharge of springs which this flow is known to supply, at least in part.

12 Estimated annual runoff.

12 Estimated perennial yield.

1,200 Estimated storage.

BASE: U.S.G.S. TOPOGRAPHIC MAP OF NEVADA, EDITION OF 1965.

EXPLANATION

This map shows estimated annual surface and groundwater flows between hydrologic areas and across state lines. Also shown for each area where data are available are estimates of annual runoff, perennial yield and water stored in the upper 100 feet of the groundwater reservoir. The term runoff refers to the estimated annual amount of surface water which flows from the mountains to the alluvial fan measured where the two meet. Perennial yield is the amount of groundwater which can be removed from a hydrographic area each year without depleting the groundwater reservoir. Where perennial yield was not available system yield is shown followed by the letter Y. System yield is the maximum amount of surface and groundwater which can be removed from a hydrographic area each year for an indefinite period of time.

STATE OF NEVADA

WATER RESOURCES AND INTER-BASIN FLOWS

PREPARED BY
DIVISION OF WATER RESOURCES
STATE ENGINEERS OFFICE

SCALE 1:750,000
10 0 10 20 30 40 MILES
10 0 10 20 30 40 50 KILOMETERS
CONTOUR INTERVAL 500 FEET
DATUM IS MEAN SEA LEVEL

LEGEND

BOUNDARY OF HYDROGRAPHIC REGIONS............ ▬

BOUNDARY OF HYDROGRAPHIC AREAS (DOTTED WHERE ARBITRARY)........... —··—

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SEPTEMBER 1971

NOTE

Surface water flows are based on varying periods of record. Man made diversions are estimated 1970 figures except those on the Truckee Canal which are estimates based on historic diversion. Southern Nevada Project is shown at projected first stage level. Inflow from Arizona computed from gaged flow at Hoover Dam (Period of record 1934 to 1969). Outflow from Nevada based on Davis Dam gage (Period of record 1949-1969). Incline Village diversion estimated for 1971.

PREPARED WITH THE COOPERATION OF THE GEOLOGICAL SURVEY, U.S. DEPARTMENT OF INTERIOR.