

5. Jurassic Zone Play Results

5.1 Geological Overview

Jurassic deposition in the WCSB occurred in shelf conditions over much of the basin and in deeper water conditions in the western portions of the basin. It is believed that there was extensive deposition of Jurassic aged sediments, but those deposits were subjected to intense erosional conditions leaving only remnants. Three major depositional cycles occurred with each cycle characterized by coarsening-upwards or shallowing-upwards conditions. The first cycle had two basin fill events, one represented by shale and siltstone deposits of the Nordegg Formation in the west and carbonates and quartz-chert sandstones further east. The second event is represented by deposits of siltstone, limestone and shale, and may include the prolific channel sandstone pools in western Alberta. The second cycle of basin fill is comprised of the Poker Chip shale unit and the Rock Creek sandstone deposits. These first two cycles were primarily filled by sediments coming from the northeast to the southwest. Following the Columbian orogeny, the third cycle of basin fill was dominated by sediments derived from the west and filling to the east. The third cycle deposits are represented by the Kootenay-Nikanassin Formations.

Light and heavy oils in these plays are found in sandstone deposits in either stratigraphic traps or in structural traps resulting from drape over older topographic highs. Stratigraphic traps result from deposition on uneven erosional surfaces, isolation by erosion or by updip porosity pinchouts. Seals are provided by Jurassic aged or younger shales, siltstones and tight sandstones. Source rocks are believed to be Carboniferous or younger aged shales.

5.2 Williston Basin Region

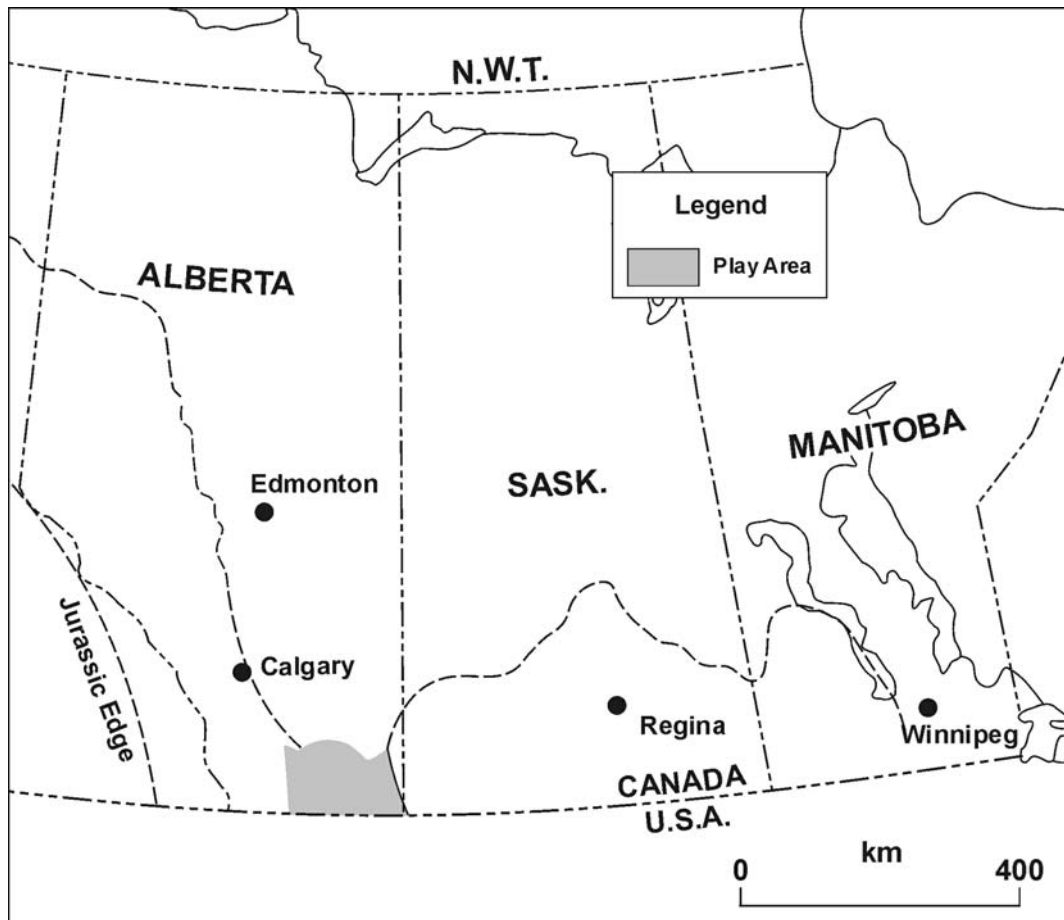
5.2.1 *Sawtooth Play*

This play includes the heavy oil pools in the Sawtooth Formation sandstone on the Sweetgrass Arch. It is limited by deposition to the east and west, erosion to the north and by the international border to the south (Figure 5.1). Both stratigraphic and structural traps are present in this mature play, and the majority of the pools contain heavy oil.

The Board's assessment is based on a discovered oil-in-place estimate of 90.2 million m³, contained in 188 designated pools (Table 5.1). This was supplemented by the addition of 102 identified potential pools, containing 3.5 million m³ of oil in place, in order to better define the play's distribution in the geo-anchored model (Table 5.2). There were no identified miscellaneous pools for this play. The model projects an additional 1,422 undiscovered pools exist. They are expected to contain 30.1 million m³ of oil in place. The projected pools include 46 pools that are expected to contain more than 100 thousand m³ of oil in place each, these capture 23 percent of the total undiscovered potential. The total resource estimate is 123.8 million m³, of which 27 percent was undiscovered at year-end 1998.

FIGURE 5.1

Sawtooth Play Area



(after GSC 1998)

The largest undiscovered pool in this mature play is expected to be only the 50th ranked pool with 0.5 million m³ of oil in place. This is dwarfed by the Ronalane Sawtooth B pool containing five million m³ (Figure 5.2). The cross plot information suggests that the largest undiscovered pool would occupy an area of only 90 ha with an average net pay of six metres (Figure 5.3). Industry comments varied on this play, with some indicating that the undiscovered resource and the largest undiscovered pool were too small and others indicating that the largest pool size was reasonable, but that the resource was overstated. One reply indicated that the minimum pool size should be increased to 160 thousand m³. The Board considered the effect of revising the minimum pool size and found that it would reduce the number of developable undiscovered pools to just 17, with an undiscovered resource of 4.0 million m³, one percent of the apparent play potential. The Board's supply cost analysis indicated that pools smaller than the proposed cut-off size were still viable. The Board decided to proceed with the results as provided by the geological model.

Approximately 35 percent of the wells produced less than five thousand m³ each, accounting for less than two percent of the total production. However, approximately 40 percent of the wells produced more than 10 thousand m³ each, while 25 percent of the wells produced over 20 thousand m³. Approximately 95 percent of the total production was captured by wells producing more than 20 thousand m³. The average supply costs for the Sawtooth play are estimated to be in the economic range of \$42-\$46/ m³ (Supply costs are discussed in Chapter 7).

In comparison with the GSC's 1998 report, the discovered oil in place for light and heavy oils has increased from 81.8 to 92.6 million m³ due to new discoveries and growth in existing pools. There were 31 new pools found between year-end 1994 and year-end 1998.

T A B L E 5 . 1

Sawtooth - Heavy, Southern Alberta

| Discovered Pools | | | | | Undiscovered Pools | | | Total Resources | | | |
|-------------------------------------------------------------------|-------------------|--------------|-----------------------|------------------------|------------------------------------------------------|----------------|------------------|-----------------------|----------------|---------------|---------------------------------------|
| Number | OOIP | Recoverable | Cumulative Production | Remaining Reserves | Number | OOIP | Recoverable | Number | OOIP | Recoverable | Remaining Discovered and Undiscovered |
| thousand cubic metres | | | | | thousand cubic metres | | | thousand cubic metres | | | |
| 188 | 90,245 | 28,300 | 24,376 | 3,924 | 1524 | 33,544 | 2,714 | 1,712 | 123,789 | 31,014 | 6,638 |
| RESERVOIR PARAMETERS IN DISCOVERED POOLS | | | | | | | | | | | |
| Discovered Reserves by Province (10 ³ m ³) | | | | Depth from KB (metres) | | | Net Pay (metres) | | | Discovery Yr. | |
| Alberta 28,300 | | | | Ave | Min | Max | Ave | Min | Max | 1944 | |
| | | | | 936 | 846 | 1032 | 3.7 | 0.5 | 14.7 | | |
| Porosity | | | Area | | | Oil Saturation | | | % Undiscovered | | |
| Ave | Min | Max | Ave | Min | Max | Ave | Min | Max | 27 | | |
| 0.22 | 0.12 | 0.29 | 105 | 8 | 1475 | 0.62 | 0.27 | 0.83 | | | |
| Individual Pool Information | | | | | | | | | | | |
| Discovered Pools (10 ³ m ³) | | | | | Undiscovered Pools (10 ³ m ³) | | | | | | |
| Rank | Field - Pool Name | Date | OOIP | Number | Rank | OOIP | Cum | Cum % | | | |
| 1 | RONALANE | SAWTOOTH B | 19901204 | 5083 | 1 | 50 | 456 | 456 | 1 | | |
| 2 | GRAND FORKS | SAWTOOTH O | 19660215 | 4429 | 2 | 61 | 366 | 822 | 2 | | |
| 3 | GRAND FORKS | SAWTOOTH MM | 19800823 | 4351 | 3 | 66 | 320 | 1142 | 3 | | |
| 4 | GRAND FORKS | SAWTOOTH WW | 19870722 | 3812 | 4 | 72 | 277 | 1419 | 4 | | |
| 5 | GRAND FORKS | SAWTOOTH OO | 19710000 | 2687 | 5 | 77 | 250 | 1669 | 5 | | |
| 6 | CONRAD | ELLIS | 19911009 | 2540 | 6 | 83 | 233 | 1902 | 6 | | |
| 7 | GRAND FORKS | SAWTOOTH T | 19851031 | 2500 | 7 | 85 | 224 | 2126 | 6 | | |
| 8 | ENCHANT | ELLIS L | 19651017 | 2337 | 8 | 92 | 211 | 2337 | 7 | | |
| 9 | RONALANE | SAWTOOTH V | 19910411 | 2167 | 9 | 95 | 204 | 2541 | 8 | | |
| 10 | GRAND FORKS | SAWTOOTH SS | 19800818 | 2048 | 10 | 97 | 197 | 2738 | 8 | | |
| 11 | HAYS | SAWTOOTH B | 19850226 | 1981 | 11 | 99 | 189 | 2927 | 9 | | |
| 12 | GRAND FORKS | SAWTOOTH L | 19850503 | 1940 | 12 | 102 | 185 | 3112 | 9 | | |
| 13 | GRAND FORKS | SAWTOOTH Q | 19750226 | 1839 | 13 | 109 | 180 | 3292 | 10 | | |
| 14 | GRAND FORKS | SAWTOOTH PPP | 19911218 | 1777 | 14 | 112 | 173 | 3465 | 10 | | |
| 15 | GRAND FORKS | SAWTOOTH D | 19861029 | 1727 | 15 | 113 | 170 | 3635 | 11 | | |
| 16 | ENCHANT | ELLIS D | 19921112 | 1690 | 16 | 117 | 165 | 3800 | 11 | | |
| 17 | GRAND FORKS | SAWTOOTH N | 19870916 | 1670 | 17 | 118 | 162 | 3962 | 12 | | |
| 18 | HAYS | SAWTOOTH C | 19850415 | 1524 | 18 | 120 | 158 | 4120 | 12 | | |
| 19 | SKIFF | SAWTOOTH A | 16941018 | 1431 | 19 | 124 | 155 | 4275 | 13 | | |
| 20 | RONALANE | SAWTOOTH K | 19900626 | 1231 | 20 | 126 | 151 | 4426 | 13 | | |
| 21 | GRAND FORKS | SAWTOOTH II | 19891215 | 1173 | 21 | 129 | 148 | 4574 | 14 | | |
| 22 | GRAND FORKS | SAWTOOTH U | 19730206 | 1072 | 22 | 132 | 143 | 4717 | 14 | | |
| 23 | RONALANE | SAWTOOTH C | 19751105 | 1050 | 23 | 134 | 141 | 4858 | 14 | | |
| 24 | RONALANE | SAWTOOTH J | 19920406 | 1022 | 24 | 136 | 137 | 4995 | 15 | | |
| 25 | GRAND FORKS | SAWTOOTH A | 19841013 | 1013 | 25 | 139 | 135 | 5130 | 15 | | |
| 26 | RED COULEE | CUTBANK B | 19600606 | 1010 | 26 | 141 | 134 | 5264 | 16 | | |
| 27 | GRAND FORKS | SAWTOOTH W | 19790225 | 924 | 27 | 144 | 130 | 5394 | 16 | | |
| 28 | GRAND FORKS | SAWTOOTH NN | 19711026 | 917 | 28 | 146 | 128 | 5522 | 16 | | |
| 29 | ENCHANT | ELLIS C | 19921109 | 908 | 29 | 148 | 126 | 5648 | 17 | | |
| 30 | HAYS | SAWTOOTH D | 19850524 | 876 | 30 | 150 | 124 | 5772 | 17 | | |
| 31 | BOW ISLAND | SAWTOOTH D | 19821227 | 807 | 31 | 153 | 121 | 5893 | 18 | | |
| 32 | GRAND FORKS | SAWTOOTH VV | 19850905 | 761 | 32 | 155 | 119 | 6012 | 18 | | |
| 33 | RONALANE | SAWTOOTH L | 19930530 | 750 | 33 | 157 | 117 | 6129 | 18 | | |
| 34 | GRAND FORKS | SAWTOOTH CCC | 19900821 | 688 | 34 | 158 | 116 | 6245 | 19 | | |
| 35 | GRAND FORKS | SAWTOOTH LL | 19791101 | 676 | 35 | 160 | 114 | 6359 | 19 | | |
| 36 | RONALANE | SAWTOOTH O | 19930619 | 585 | 36 | 161 | 112 | 6471 | 19 | | |
| 37 | GRAND FORKS | SAWTOOTH B2B | 19921023 | 575 | 37 | 163 | 112 | 6583 | 20 | | |
| 38 | ENCHANT | ELLIS I | 19531102 | 571 | 38 | 165 | 110 | 6693 | 20 | | |
| 39 | CHIN COULEE | SAWTOOTH B | 19940000 | 559 | 39 | 167 | 109 | 6802 | 20 | | |
| 40 | GRAND FORKS | SAWTOOTH ZZ | 19871015 | 534 | 40 | 172 | 107 | 6909 | 21 | | |

TABLE 5.2

Sawtooth Play – Summary Table

| Pool Size (OIP - m ³) | Discovered Pools | | Undiscovered Pools | |
|-----------------------------------|------------------|---------------------------------------|--------------------|---------------------------------------|
| | Number of Pools | OIP (10 ³ m ³) | Number of Pools | OIP (10 ³ m ³) |
| 10 - 100 million | 0 | 0 | 0 | 0 |
| 1 - 10 million | 26 | 55104 | 0 | 0 |
| 100 - 1000 thousand | 112 | 33220 | 46 | 7532 |
| 10 - 100 thousand | 128 | 5222 | 724 | 18834 |
| <10 thousand | 25 | 163 | 652 | 3713 |
| Total | 290 | 93707 | 1422 | 30079 |

FIGURE 5.2

Pool Rank Plot – Sawtooth

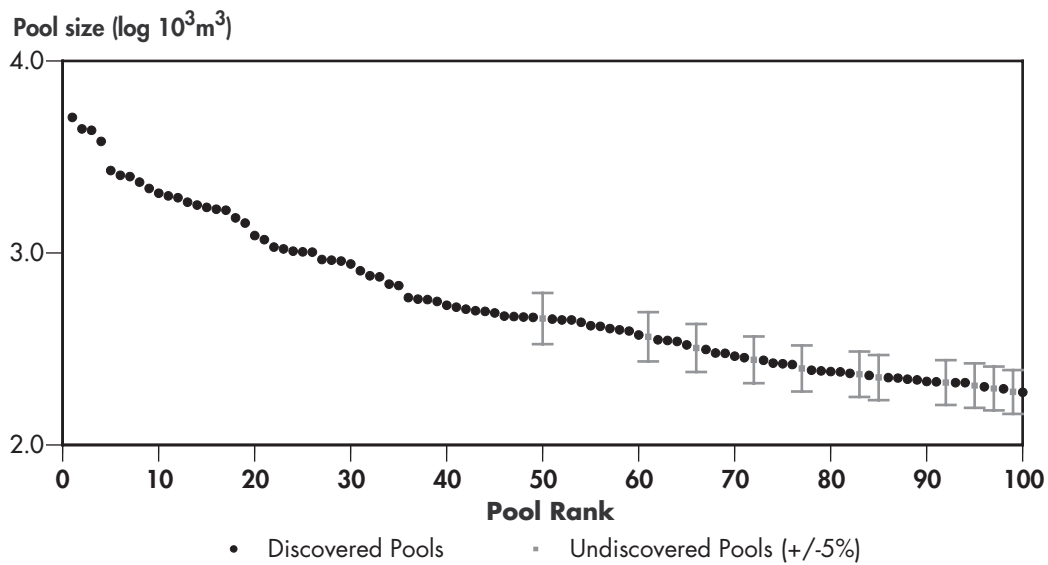
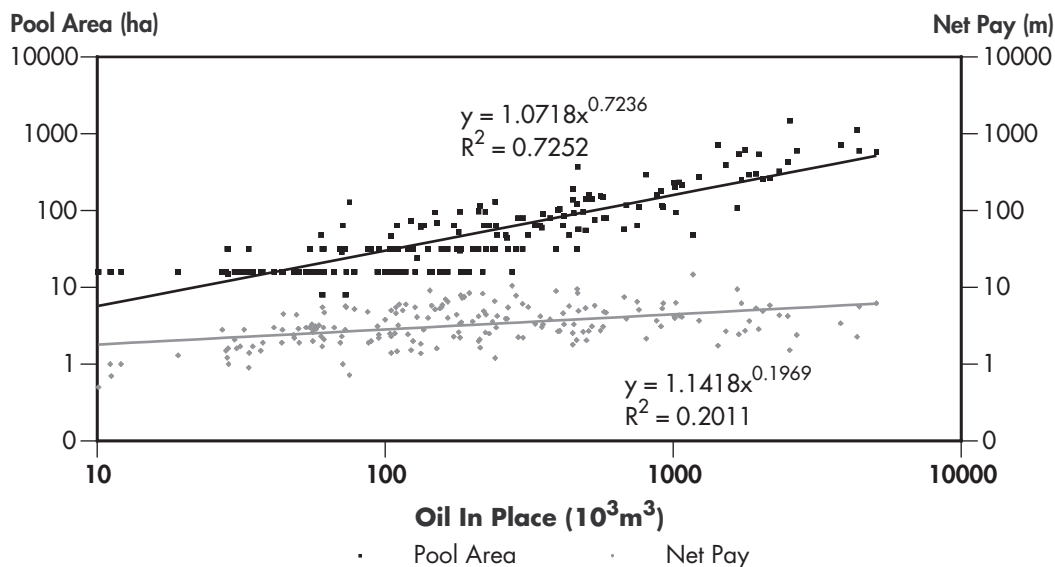


FIGURE 5.3

Cross Plot – Sawtooth



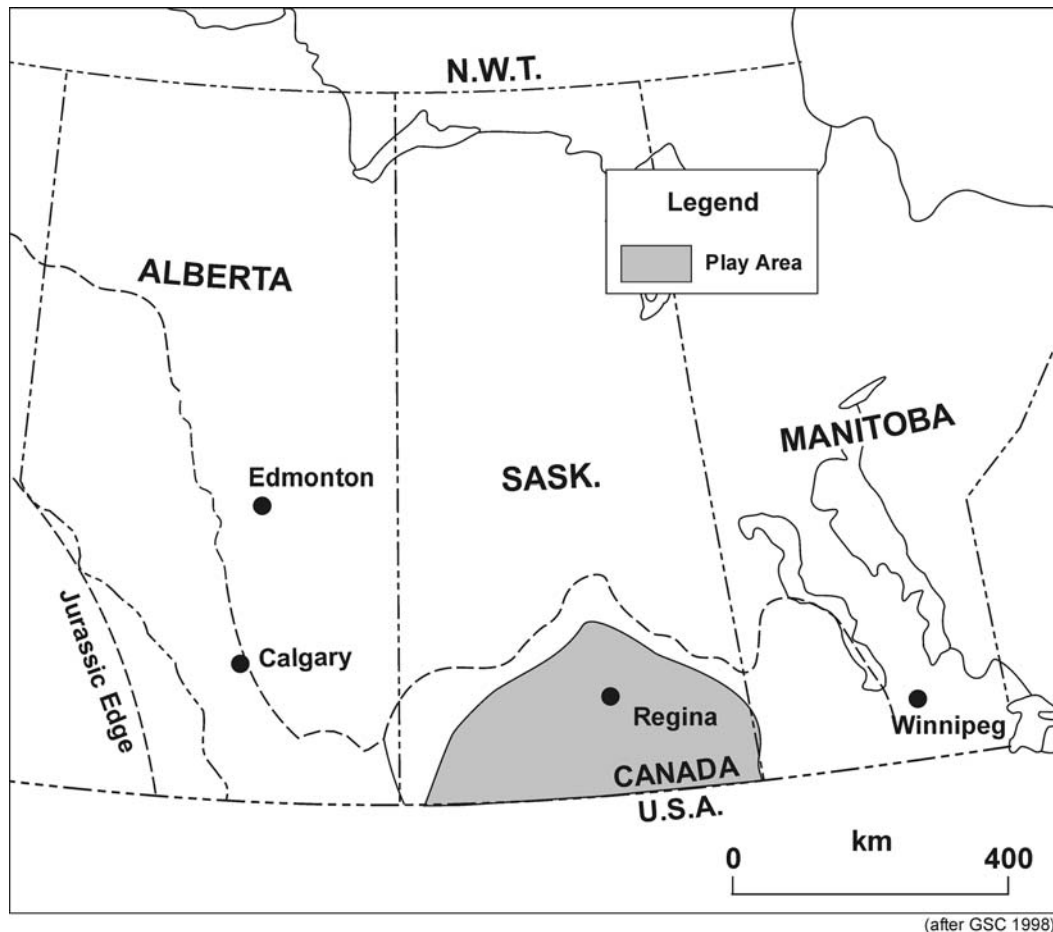
5.2.2 Shaunavon Play^{1,2}

This play was originally defined to include only the oil pools in the Upper and Lower Shaunavon shallow marine and shoreline sandstones along the east flank of the Sweetgrass Arch in southwestern Saskatchewan. It has since been expanded to include the Jurassic Red Jacket sandstone pools in southeastern Saskatchewan. This is because the Red Jacket sands are directly equivalent to the Upper Gravelbourg and Shaunavon sections (Figure 5.4). They have a similar style of trapping and are also sourced by Lodgepole carbonates. Lateral sealing is provided by the tight sediments of the same formations and all pools contain heavy oil.

The Board's assessment is based on a discovered oil-in-place estimate of 267.7 million m³ found in 131 discovered pools (Table 5.3). These discovered pools consist of 47 designated pools containing 253.9 million m³ and 84 assigned miscellaneous pools containing 13.8 million m³, about five percent of the volume found in the designated pools. There are no potential pools for this play.

FIGURE 5.4

Shaunavon Play Area



- 1 Canadian Society of Petroleum Geologists, *Lexicon of Canadian Stratigraphy, Volume 4, Western Canada Including Eastern British Columbia, Alberta, Saskatchewan and Southern Manitoba*, Editor: D.J. Glass, 1990
- 2 Canadian Society of Petroleum Geologists and Alberta Research Council, *Geological Atlas of the Western Canada Sedimentary Basin*, Compiled by G. Mossup and I. Shetsen, 1994

T A B L E 5 . 3

Shaunavon – Heavy, Southwest Saskatchewan

| Discovered Pools | | | | | Undiscovered Pools | | | Total Resources | | | |
|-------------------------------------------------------------------|-------------------|-----------------|-----------------------|------------------------|------------------------------------------------------|---------|---------------------------|-----------------------|---------|----------------|---------------------------------------|
| Number | OOIP | Recoverable | Cumulative Production | Remaining Reserves | Number | OOIP | Recoverable | Number | OOIP | Recoverable | Remaining Discovered and Undiscovered |
| thousand cubic metres | | | | | thousand cubic metres | | | thousand cubic metres | | | |
| 131 | 267,663 | 57,764 | 47,782 | 9,982 | 895 | 203,367 | 27,485 | 1026 | 471,030 | 85,249 | 37,467 |
| RESERVOIR PARAMETERS IN DISCOVERED POOLS | | | | | | | | | | | |
| Discovered Reserves by Province (10 ³ m ³) | | | | Depth from KB (metres) | | | Net Pay (metres) | | | Discovery Yr. | |
| Saskatchewan 57,764 | | | | Ave | Min | Max | Ave | Min | Max | 1952 | |
| | | | | 1187 | 596 | 1505 | 5.3 | 1.7 | 13.1 | | |
| Porosity (fraction) | | | | Area (ha) | | | Oil Saturation (fraction) | | | % Undiscovered | |
| Ave | Min | Max | Ave | Min | Max | Ave | Min | Max | 43 | | |
| 0.18 | 0.12 | 0.31 | 1035 | 32 | 4782 | 0.73 | 0.45 | 0.95 | | | |
| Individual Pool Information | | | | | | | | | | | |
| Discovered Pools (10 ³ m ³) | | | | | Undiscovered Pools (10 ³ m ³) | | | | | | |
| Rank | Field - Pool Name | Date | OOIP | | Number | Rank | OOIP | Cum | Cum % | | |
| 1 | DOLLARD | UPPER SHAUNAVON | 19870919 | 28486 | 1 | 2 | 25171 | 25171 | 12 | | |
| 3 | INSTOW | UPPER SHAUNAVON | 19540620 | 24231 | 2 | 6 | 16169 | 41340 | 20 | | |
| 4 | RAPDAN | UPPER SHAUNAVON | 19530131 | 23859 | 3 | 10 | 10871 | 52211 | 26 | | |
| 5 | BUTTE | UPPER SHAUNAVON | 19670303 | 19214 | 4 | 12 | 8878 | 61089 | 30 | | |
| 7 | DELTA | UPPER SHAUNAVON | 19560527 | 13544 | 5 | 15 | 8135 | 69224 | 34 | | |
| 8 | BUTTE WEST | UPPER SHAUNAVON | 19670000 | 12869 | 6 | 17 | 7484 | 76708 | 38 | | |
| 9 | BONE CREEK | UPPER SHAUNAVON | 19541009 | 12207 | 7 | 21 | 6463 | 83171 | 41 | | |
| 11 | LEITCHVILLE | SHAUNAVON | 19600428 | 8943 | 8 | 23 | 5958 | 89129 | 44 | | |
| 13 | WHITEMUD | SHAUNAVON | 19630116 | 8650 | 9 | 25 | 5452 | 94581 | 47 | | |
| 14 | NORTH PREMIER | UPPER SHAUNAVON | 19530315 | 8302 | 10 | 28 | 4805 | 99386 | 49 | | |
| 16 | SUFFIELD | UPPER SHAUNAVON | 19541120 | 7543 | 11 | 29 | 4591 | 103977 | 51 | | |
| 18 | BENCH | UPPER SHAUNAVON | 19690204 | 7257 | 12 | 32 | 3980 | 107957 | 53 | | |
| 19 | GULL LAKE NORTH | UPPER SHAUNAVON | 19530803 | 7219 | 13 | 33 | 3803 | 111760 | 55 | | |
| 20 | LEON LAKE | SHAUNAVON | 19531203 | 6911 | 14 | 37 | 3207 | 114967 | 57 | | |
| 22 | RAPDAN WEST | SHAUNAVON | 19550719 | 6367 | 15 | 38 | 3024 | 117991 | 58 | | |
| 26 | CLINTONVILLE | SHAUNAVON | 19850908 | 4921 | 16 | 40 | 2650 | 120641 | 59 | | |
| 27 | GARDENHEAD | UPPER SHAUNAVON | 19930000 | 4850 | 17 | 42 | 2529 | 123170 | 61 | | |
| 30 | EASTBROOK | SHAUNAVON | 19660523 | 4470 | 18 | 43 | 2393 | 125563 | 62 | | |
| 31 | RED JACKET | RED JACKET SAND | 19840224 | 4425 | 19 | 44 | 2169 | 127732 | 63 | | |
| 34 | Misc. # 1 | SHAUNAVON | | 3705 | 20 | 45 | 1994 | 129726 | 64 | | |
| 35 | ILLERBRUN | UPPER SHAUNAVON | 19650523 | 3620 | 21 | 46 | 1993 | 131719 | 65 | | |
| 36 | GULL LAKE CENTRAL | UPPER SHAUNAVON | 19530130 | 3467 | 22 | 48 | 1870 | 133589 | 66 | | |
| 39 | EASTEND | SHAUNAVON | 19520901 | 2776 | 23 | 51 | 1819 | 135408 | 67 | | |
| 41 | NOTUKEU | UPPER SHAUNAVON | 19690309 | 2541 | 24 | 53 | 1724 | 137132 | 67 | | |
| 47 | COOTHILL | RED JACKET SAND | 19660306 | 1872 | 25 | 54 | 1684 | 138816 | 68 | | |
| 49 | GULL LAKE SOUTH | UPPER SHAUNAVON | 19520000 | 1856 | 26 | 57 | 1602 | 140418 | 69 | | |
| 50 | BATTLE CREEK S. | UPPER SHAUNAVON | 19880107 | 1822 | 27 | 59 | 1516 | 141934 | 70 | | |
| 52 | ANTELOPE LAKE | UPPER SHAUNAVON | 19640000 | 1755 | 28 | 60 | 1415 | 143349 | 70 | | |
| 55 | COVINGTON WEST | UPPER SHAUNAVON | 19690000 | 1643 | 29 | 62 | 1364 | 144713 | 71 | | |
| 56 | RAPDAN NORTH | LOWER SHAUNAVON | 19690000 | 1634 | 30 | 63 | 1305 | 146018 | 72 | | |
| 58 | MOOSOMIN | RED JACKET SAND | 19840303 | 1593 | 31 | 65 | 1254 | 147272 | 72 | | |
| 61 | Misc. # 2 | SHAUNAVON | | 1377 | 32 | 67 | 1143 | 148415 | 73 | | |
| 64 | COVINGTON | UPPER SHAUNAVON | 19690725 | 1287 | 33 | 68 | 1114 | 149529 | 74 | | |
| 66 | RED JACKET SOUTH | RED JACKET SAND | 19891228 | 1218 | 34 | 69 | 1090 | 150619 | 74 | | |
| 71 | Misc. # 3 | SHAUNAVON | | 955 | 35 | 70 | 1037 | 151656 | 75 | | |
| 75 | RAPDAN SOUTH | UPPER SHAUNAVON | 19840000 | 882 | 36 | 72 | 946 | 152602 | 75 | | |
| 78 | CHAMBERY | UPPER SHAUNAVON | 19530330 | 799 | 37 | 73 | 908 | 153510 | 75 | | |
| 80 | DELTA WEST | UPPER SHAUNAVON | 19530607 | 781 | 38 | 74 | 895 | 154405 | 76 | | |
| 81 | Misc. # 4 | SHAUNAVON | | 741 | 39 | 76 | 845 | 155250 | 76 | | |
| | | | | | 40 | 77 | 821 | 156071 | 77 | | |

The model projects an additional 896 undiscovered pools exist. They are expected to contain 203.4 million m³ of oil in place (Table 5.4). The projected pools include 156 pools that are expected to contain more than 100 thousand m³ of oil in place each, these capture over 90 percent of the total undiscovered potential. The total resource estimate is 471.0 million m³, of which 43 percent was undiscovered at year-end 1997.

The largest undiscovered pool is expected to be the second ranked pool at 25.2 million m³, behind only the Dollard pool which contains 28.5 million m³ (Figure 5.5). The cross plot information suggests that the largest undiscovered pool would occupy 5,000 ha with about seven metres of average net pay (Figure 5.6). The only industry response noted the inclusion of pools outside the original play area. The Board expanded the play definition. The expanded play area should also

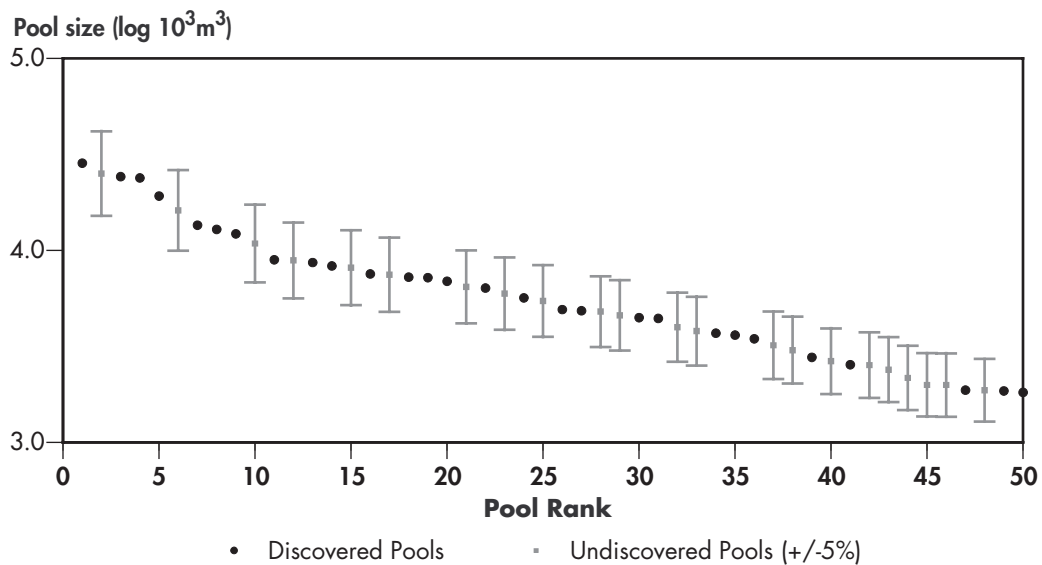
T A B L E 5 . 4

Shaunavon Play - Summary Table

| Pool Size (OIP - m ³) | Discovered Pools | | Undiscovered Pools | |
|-----------------------------------|------------------|---------------------------------------|--------------------|---------------------------------------|
| | Number of Pools | OIP (10 ³ m ³) | Number of Pools | OIP (10 ³ m ³) |
| 10 - 100 million | 7 | 134410 | 3 | 52211 |
| 1 - 10 million | 28 | 117687 | 32 | 99446 |
| 100 - 1000 thousand | 36 | 13751 | 121 | 37239 |
| 10 - 100 thousand | 42 | 1734 | 378 | 13014 |
| <10 thousand | 18 | 82 | 362 | 1457 |
| Total | 131 | 267664 | 896 | 203366 |

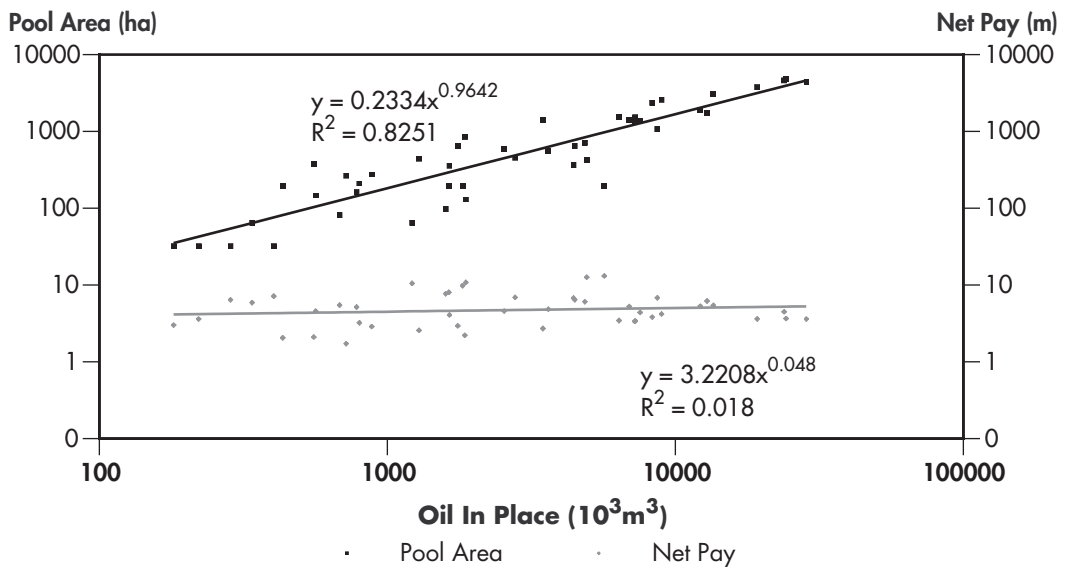
F I G U R E 5 . 5

Pool Rank Plot - Shaunavon



F I G U R E 5 . 6

Cross Plot - Shaunavon



provide additional lands for new exploration efforts, especially in the sparsely drilled area between Regina and Swift Current, Saskatchewan.

One-half of the wells have produced less than five thousand m³, capturing less than three percent of the total production. Conversely, 15 percent of the wells produced over 50 thousand m³ each, accounting for about 80 percent of the total production. The play's average supply cost is \$36-\$38/m³, the lowest of all the conventional heavy oil plays studied, making the Shaunavon play an attractive target economically.

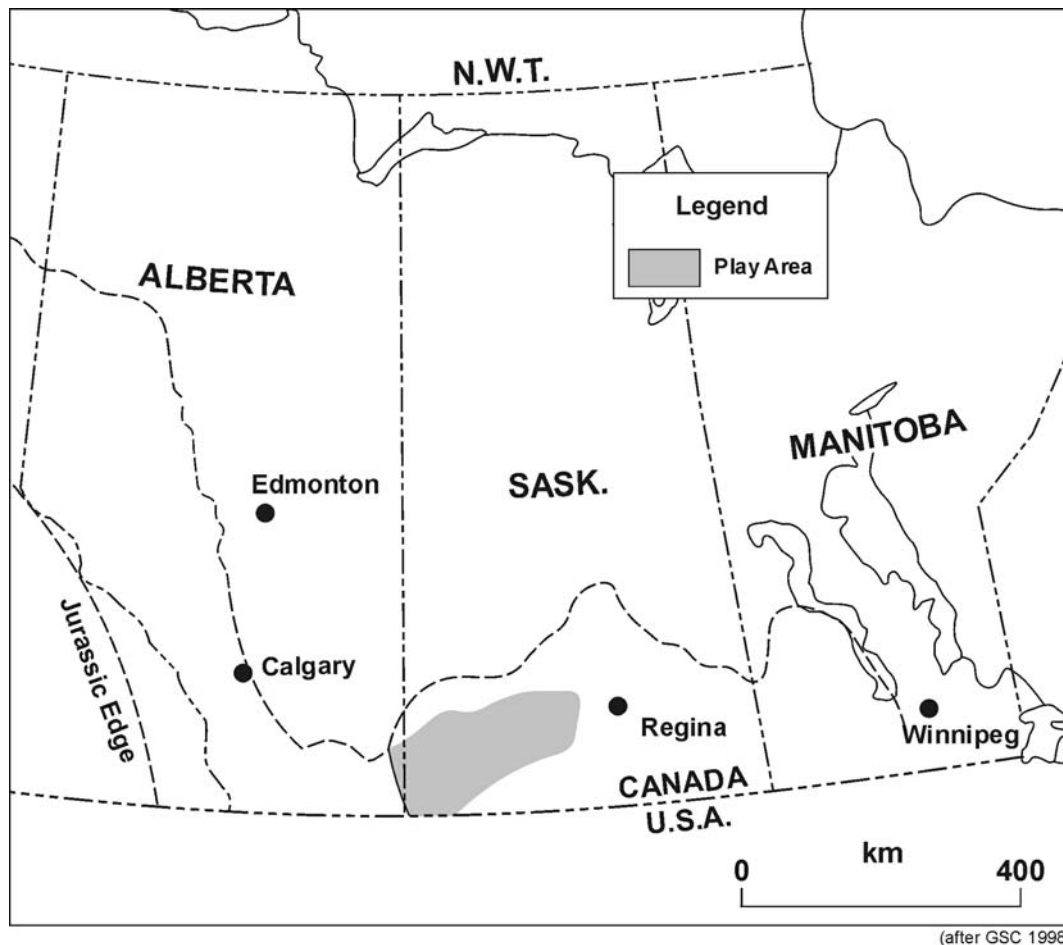
Compared with the GSC's 1998 report, the discovered oil in place for heavy oil has increased from 228.7 to 251.9 million m³ due to growth in existing pools and the inclusion of miscellaneous volumes. There were no new pools found between year-end 1994 and year-end 1997.

5.2.3 *Roseray-Success Play*

This play is defined to include the oil pools in the sandstones of the Roseray and Success Formations of southern Saskatchewan. The trapping mechanism for these pools is a result of stratigraphic facies changes and unconformity traps. Seals are provided by equivalent-aged shales or by tight sandstones of the same age or younger. Source rocks are believed to be from those same shales or from deeper Carboniferous carbonates. The play is found in southwestern Saskatchewan, north and northeast of the original Shaunavon play (Figure 5.7).

FIGURE 5.7

Roseray-Success Play Area



The Board's assessment is based on a discovered oil-in-place estimate of 187.2 million m³ found in 96 discovered pools (Table 5.5). These discovered pools consist of 25 designated pools containing 171.9 million m³ and 71 assigned miscellaneous pools containing 15.3 million m³, about nine percent of the volume found in the designated pools. There are no potential pools for this play. The model projects an additional 1,470 undiscovered pools exist. They are expected to contain 99.3 million m³ of oil in place (Table 5.6). The projected pools include 172 pools that are expected to contain more than 100 thousand m³ of oil in place each; these capture about 75 percent of the total undiscovered potential. The total resource estimate is 286.5 million m³, of which 35 percent was undiscovered at year-end 1997.

T A B L E 5 . 5

Rosemary-Success - Heavy, Southwest Saskatchewan

| Discovered Pools | | | | | Undiscovered Pools | | | Total Resources | | | |
|-------------------------------------------------------------------|--------------------------------|-------------|-----------------------|------------------------|------------------------------------------------------|---------------------------|------------------|-----------------------|----------------|---------------|---------------------------------------|
| Number | OOIP | Recoverable | Cumulative Production | Remaining Reserves | Number | OOIP | Recoverable | Number | OOIP | Recoverable | Remaining Discovered and Undiscovered |
| thousand cubic metres | | | | | thousand cubic metres | | | thousand cubic metres | | | |
| 96 | 187,176 | 63,998 | 49,145 | 14,853 | 1,470 | 99,334 | 10,802 | 1,566 | 286,510 | 74,800 | 25,655 |
| RESERVOIR PARAMETERS IN DISCOVERED POOLS | | | | | | | | | | | |
| Discovered Reserves by Province (10 ³ m ³) | | | | Depth from KB (metres) | | | Net Pay (metres) | | | Discovery Yr. | |
| Saskatchewan 63,998 | | | | Ave | Min | Max | Ave | Min | Max | 1952 | |
| | | | | 958 | 788 | 1075 | 5.7 | 2.4 | 13.1 | | |
| Porosity (fraction) | | | Area (ha) | | | Oil Saturation (fraction) | | | % Undiscovered | | |
| Ave | Min | Max | Ave | Min | Max | Ave | Min | Max | 35 | | |
| 0.26 | 0.22 | 0.31 | 657 | 49 | 3672 | 0.69 | 0.58 | 0.8 | | | |
| Individual Pool Information | | | | | | | | | | | |
| Discovered Pools (10 ³ m ³) | | | | | Undiscovered Pools (10 ³ m ³) | | | | | | |
| Rank | Field - Pool Name | Date | OOIP | Number | Rank | OOIP | Cum | Cum % | | | |
| 1 | BATTRUM ROSEMARY SAND | 19550129 | 51273.0 | 1 | 10 | 5839 | 5839 | 6 | | | |
| 2 | FOSTERTON ROSEMARY SAND | 19520113 | 25193.0 | 2 | 15 | 3325 | 9164 | 9 | | | |
| 3 | CANTUAR ROSEMARY SAND | 19520910 | 14939.0 | 3 | 16 | 2966 | 12130 | 12 | | | |
| 4 | SUFFIELD ROSEMARY SAND | 19540000 | 11554.0 | 4 | 17 | 2595 | 14725 | 15 | | | |
| 5 | SOUTH SUCCESS ROSEMARY SAND | 19530000 | 11059.0 | 5 | 19 | 2216 | 16941 | 17 | | | |
| 6 | VERLO ROSEMARY SAND | 19560501 | 9786.6 | 6 | 20 | 2057 | 18998 | 19 | | | |
| 7 | NORTH PREMIER ROSEMARY SAND | 19530121 | 9383.0 | 7 | 22 | 1705 | 20703 | 21 | | | |
| 8 | MAIN SUCCESS ROSEMARY SAND | 19521029 | 6858.1 | 8 | 25 | 1463 | 22166 | 22 | | | |
| 9 | BEVERLEY ROSEMARY SAND | 19521025 | 6033.0 | 9 | 27 | 1418 | 23584 | 24 | | | |
| 11 | CANTUAR EAST ROSEMARY SAND | 19520000 | 4980.0 | 10 | 28 | 1362 | 24946 | 25 | | | |
| 12 | Misc. # 1 R-S | | 4334.9 | 11 | 29 | 1195 | 26141 | 26 | | | |
| 13 | COLEVILLE SOUTH SUCCESS | 19850000 | 3794.1 | 12 | 31 | 1128 | 27269 | 27 | | | |
| 14 | MILTON SUCCESS | 19800000 | 3479.0 | 13 | 33 | 1085 | 28354 | 29 | | | |
| 18 | LOVERNA SUCCESS | 19521029 | 2492.7 | 14 | 35 | 1003 | 29357 | 30 | | | |
| 21 | HAZLET ROSEMARY SAND | 19630907 | 1984.0 | 15 | 37 | 991 | 30348 | 31 | | | |
| 23 | BATTRUM NORTH ROSEMARY SAND | 19790725 | 1678.0 | 16 | 38 | 913 | 31261 | 31 | | | |
| 24 | Misc. # 2 R-S | | 1587.4 | 17 | 39 | 885 | 32146 | 32 | | | |
| 26 | SUCCESS ALPHA ROSEMARY SAND | 19530520 | 1440.0 | 18 | 41 | 828 | 32974 | 33 | | | |
| 30 | FOSTERTON SOUTH ROSEMARY SAND | 19650000 | 1173.8 | 19 | 42 | 800 | 33774 | 34 | | | |
| 32 | Misc. # 3 R-S | | 1093.9 | 20 | 43 | 769 | 34543 | 35 | | | |
| 34 | SUCCESS NORTH ROSEMARY SAND | 19660817 | 1038.1 | 21 | 44 | 751 | 35294 | 36 | | | |
| 36 | CANTUAR NORTH ROSEMARY SAND | 19680331 | 999.5 | 22 | 45 | 714 | 36008 | 36 | | | |
| 40 | Misc. # 4 R-S | | 844.1 | 23 | 47 | 676 | 36684 | 37 | | | |
| 46 | Misc. # 5 R-S | | 688.2 | 24 | 48 | 644 | 37328 | 38 | | | |
| 51 | ANTELOPE LAKE S. ROSEMARY SAND | 19640722 | 584.1 | 25 | 49 | 619 | 37947 | 38 | | | |
| 56 | Misc. # 6 R-S | | 580.2 | 26 | 50 | 618 | 38565 | 39 | | | |
| 59 | Misc. # 7 R-S | | 500.2 | 27 | 52 | 584 | 39149 | 39 | | | |
| 66 | ANTELOPE LAKE ROSEMARY SAND | 19940611 | 469.9 | 28 | 54 | 569 | 39718 | 40 | | | |
| 67 | GULL LAKE ROSEMARY SAND | 19940000 | 464.5 | 29 | 55 | 554 | 40272 | 41 | | | |
| 73 | ANTELOPE LAKE E. ROSEMARY SAND | 19640116 | 457.3 | 30 | 56 | 548 | 40820 | 41 | | | |
| 78 | ANTELOPE LAKE N. ROSEMARY SAND | 19950126 | 443.3 | 31 | 57 | 530 | 41350 | 42 | | | |
| | | | | 32 | 58 | 529 | 41879 | 42 | | | |
| | | | | 33 | 60 | 495 | 42374 | 43 | | | |
| | | | | 34 | 61 | 495 | 42869 | 43 | | | |
| | | | | 35 | 62 | 484 | 43353 | 44 | | | |
| | | | | 36 | 63 | 478 | 43831 | 44 | | | |
| | | | | 37 | 64 | 476 | 44307 | 45 | | | |
| | | | | 38 | 65 | 471 | 44778 | 45 | | | |
| | | | | 39 | 68 | 464 | 45242 | 46 | | | |
| | | | | 40 | 69 | 464 | 45706 | 46 | | | |

The largest undiscovered pool in this play is expected to be the tenth ranked pool at 5.8 million m³, a tenth the size of the largest pool at Battрум (Figure 5.8). The cross plot information suggests that the largest undiscovered pool would occupy 400 ha of area with an average net pay of seven metres (Figure 5.9).

Historical information indicates that only one percent of the total recovery comes from wells that have recovered less than five thousand m³ each, which represents 35 percent of the total wells drilled in the play. However, 60 percent of the wells have produced over 10 thousand m³ each capturing about half of the total production. The calculated average supply costs are in the economic range of \$41-\$44/m³.

Compared with the GSC's 1998 report, the discovered heavy oil in place has increased from 150.3 to 171.9 million m³ due to growth in existing pools and the inclusion of miscellaneous volumes. There was one new pool found between year-end 1994 and year-end 1997.

5.3 Resource Evaluation Overview

The Jurassic Zone has the smallest total volume of the three zones examined in this study mainly because of the limited distribution of its three geological plays in the WCSB. About 60 percent of

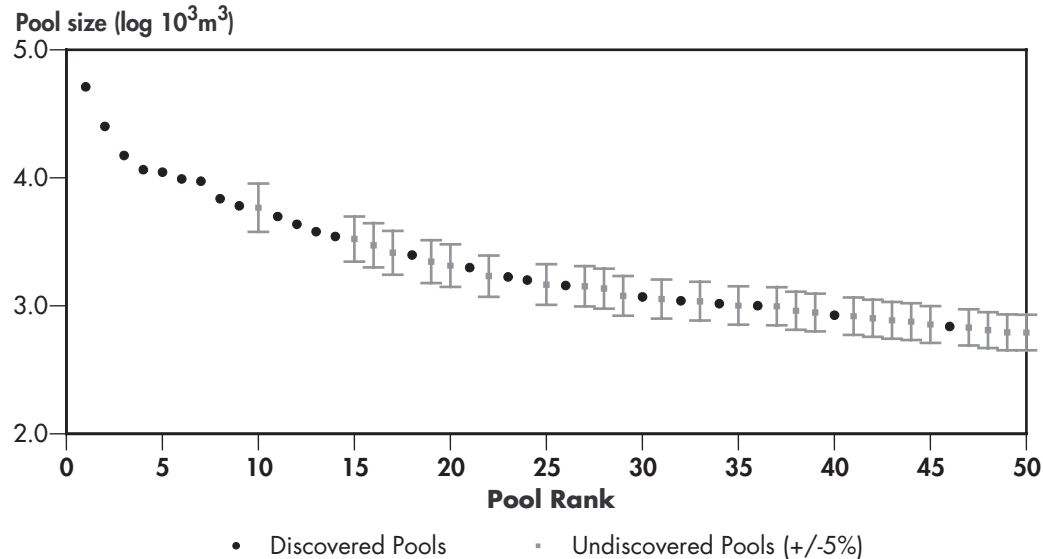
T A B L E 5 . 6

Rosearay-Success Play – Summary Table

| Pool Size (OIP - m ³) | Discovered Pools | | Undiscovered Pools | |
|-----------------------------------|------------------|---------------------------------------|--------------------|---------------------------------------|
| | Number of Pools | OIP (10 ³ m ³) | Number of Pools | OIP (10 ³ m ³) |
| 10 - 100 million | 5 | 114018 | 0 | 0 |
| 1 - 10 million | 16 | 61137 | 14 | 29357 |
| 100 - 1000 thousand | 30 | 10498 | 158 | 44374 |
| 10 - 100 thousand | 35 | 1471 | 687 | 22722 |
| <10 thousand | 10 | 53 | 611 | 2881 |
| Total | 96 | 187176 | 1470 | 99333 |

F I G U R E 5 . 8

Pool Rank Plot – Rosearay-Success



the estimated oil in place for this zone, 885 million m³, has already been discovered (Figure 5.10), and half of that volume is in the Shaunavon play.

Over 80 percent of discovered reserves in this zone have already been produced (Figure 5.11). Although undiscovered pools account for 40 percent of the total oil in place, they account for only 20 percent of the recoverable volumes. This mainly reflects the pool size distribution, as 80 to 90 percent of the undiscovered pools have oil-in-place volumes of less than 100 thousand m³. In comparison, only 40 to 50 percent of the discovered pools have oil-in-place volumes of less than 100 thousand m³. It is anticipated that the bulk of future production will come from the

FIGURE 5.9

Cross Plot – Rose-ray-Success

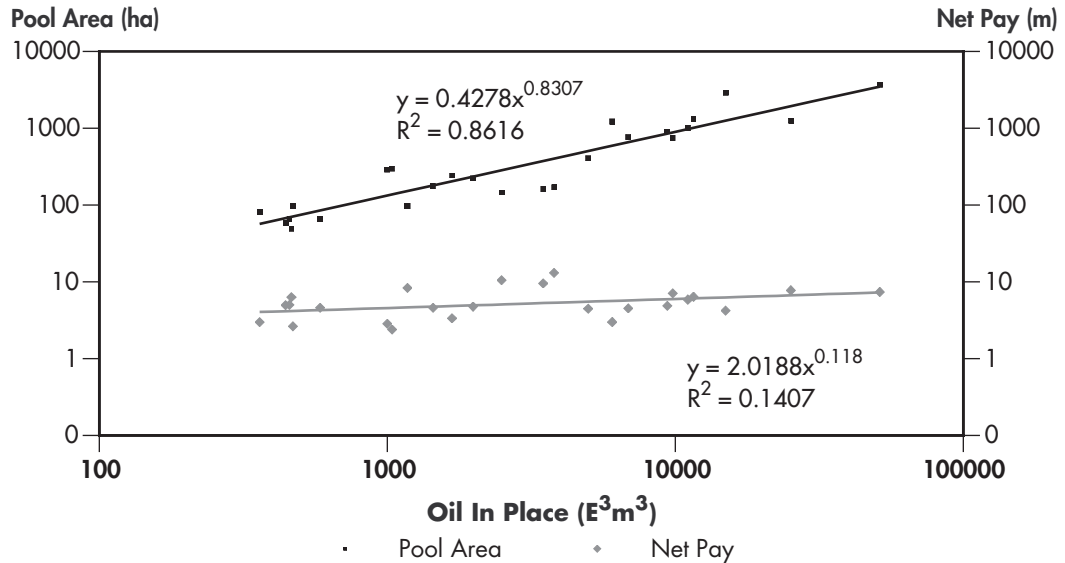


FIGURE 5.10

Initial Volume In Place – Jurassic

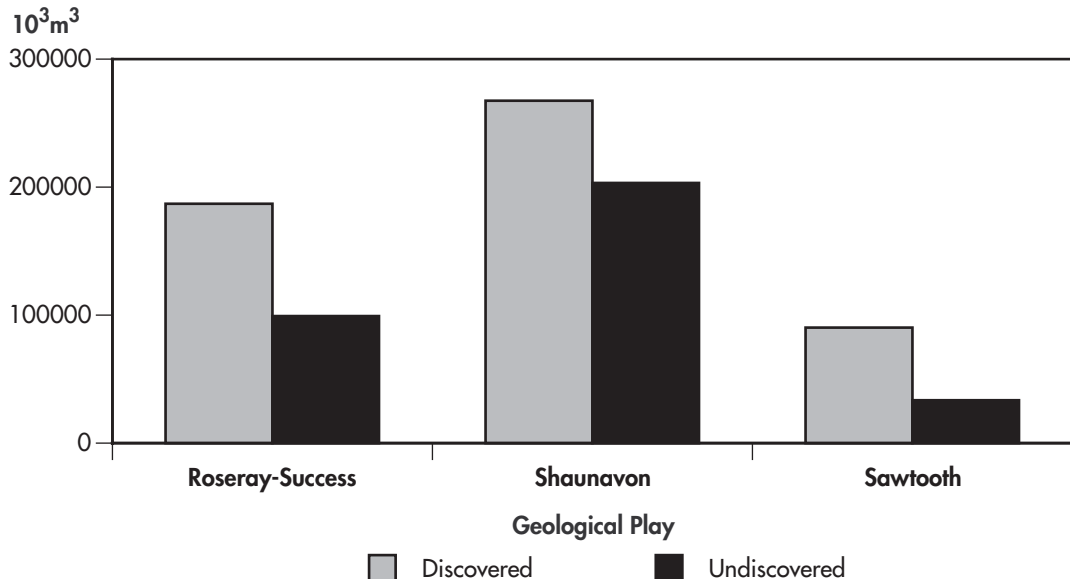
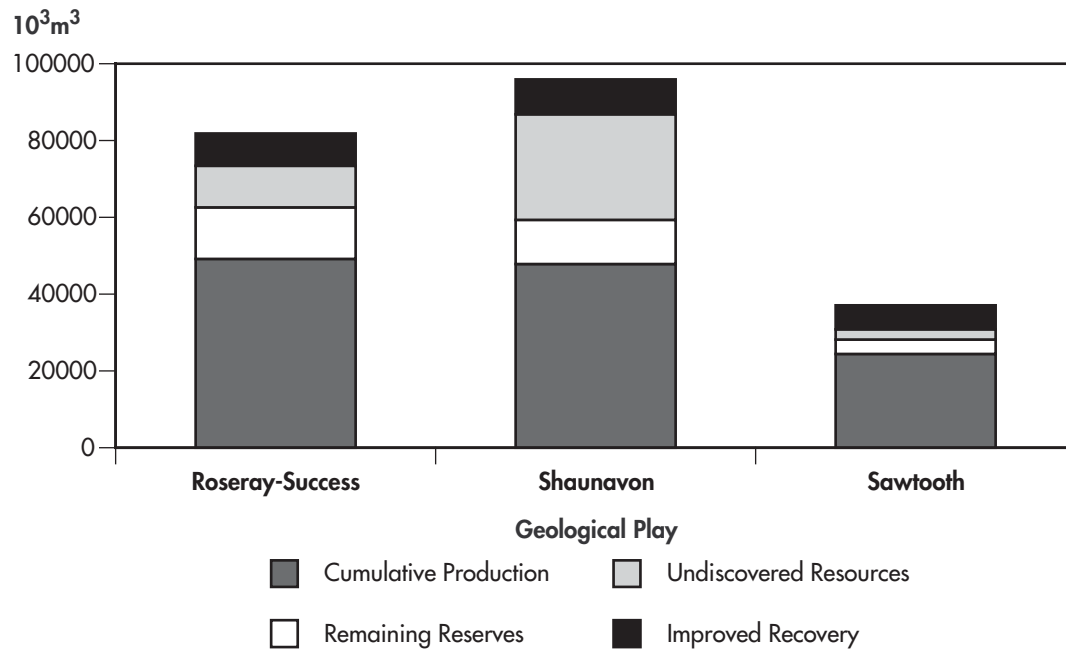


FIGURE 5.11

Recoverable Volumes – Jurassic



undiscovered pools. An additional 24.7 million m³ of oil could be obtained through improvements in production practices.

The play-average recovery factors for the discovered pools in these three plays are 31, 22, and 33 percent, for the Sawtooth, Shaunavon, and Roseray-Success plays, respectively. These values are relatively high compared with other conventional heavy oil plays. The high average recovery factor for the Sawtooth play is due to the Grand Forks region pools, where there is a strong natural bottom-water drive present and estimated recoveries can reach 50 percent. It is anticipated that additional improved recovery from the discovered pools could increase the recovery by another two to seven percent. The recovery factors for the undiscovered pools are projected to range only from eight to 14 percent, less than one-half of the recovery values for the discovered pools. The lower recovery is projected since the bottom water drive responsible for the higher recoveries in discovered pools is not likely to be present in all areas.

5.3.1 Shaunavon Play

The Shaunavon play contains 53 percent of the oil in place, 40 percent of the reserves and two-thirds of undiscovered resources in the Jurassic Zone. The Shaunavon is projected to have 1,027 pools and only 131 pools have been discovered to date. Eighty percent of the total pools are projected to contain less than 100 thousand m³ of oil in place and another 15 percent of the pools are projected to have oil-in-place volumes between 100 thousand m³ and one million m³ (Figure 5.12).

The total oil in place in the Shaunavon play is estimated to be 471 million m³, and 57 percent of that, or 268 million m³, has already been discovered. Pools with oil-in-place volumes of less than 1 million m³ have a very minor role in the development of this play since only 14 percent of total oil in place is represented by this group of pools.

Two-thirds of the recoverable volumes are found in discovered pools. It appears that pools with more than 10 million m³ are the most important pools in the overall economic development of this play. Approximately 60 percent of total recoverable volumes are contained in these pools, with 48 percent of total recoverable volumes in the seven largest discovered pools (Figure 5.13). Almost 80 percent of the recoverable volumes, and 26 percent of the total recoverable volume, will come from undiscovered pools containing more than one million m³. This minimizes the importance of the contribution from the smaller undiscovered pools.

FIGURE 5.12

Pool Size Distribution - Shaunavon

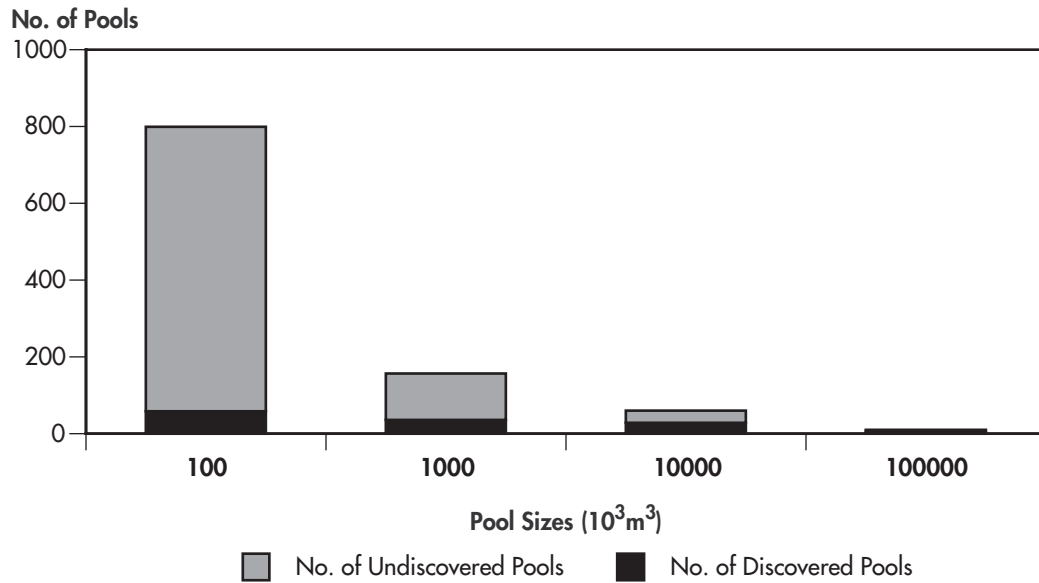
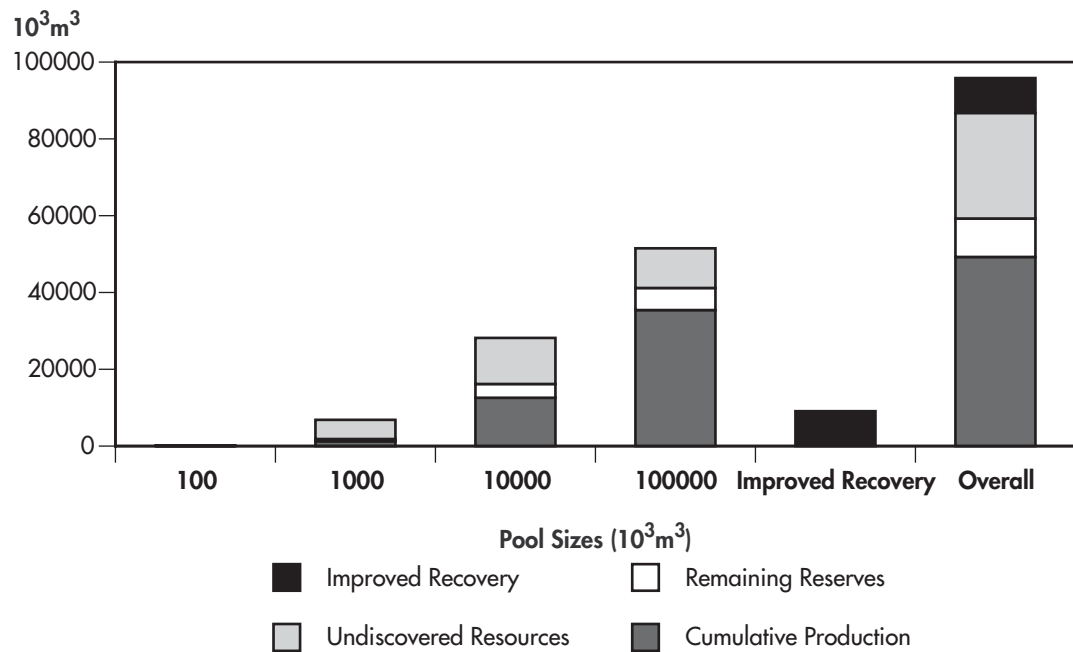


FIGURE 5.13

Recoverable Volumes by Source and Pool Size - Shaunavon



Small undiscovered pools play only a relatively minor role in the development of this play, as most of them are below the minimum pool size cut-off of 91 thousand m³. The small pools that exceed the minimum size will recover 13 to 14 percent of the oil in place (Figure 5.14). The recovery factors for most discovered pools are in the 14 to 20 percent range; however, the recovery for the largest pools are in the 20 to 30 percent range.

The majority of future recovery is expected to come from the undiscovered pools in spite of their relatively low recovery factors since there are a large number of undiscovered pools and since the discovered pools have already produced a large portion of their recoverable reserves. However, an additional 9.1 million m³ could be recovered from discovered Shaunavon pools through optimized production practices and initiation of additional enhanced recovery projects.

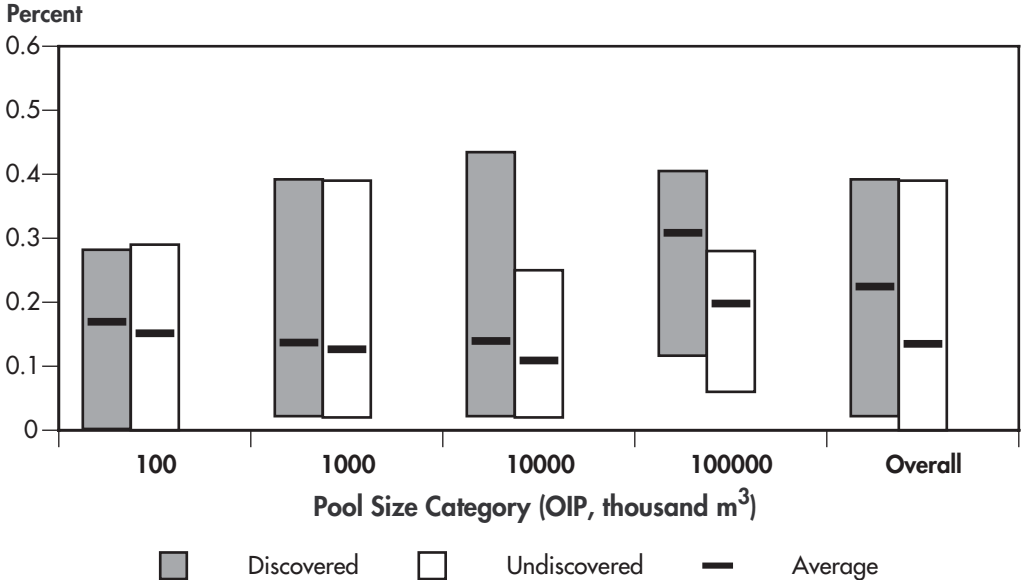
5.4 Summary

Since the last review by the GSC, the discovered oil-in-place volume of light and heavy oils for all plays in the Jurassic zones has increased from 532.9 to 888.7 million m³, a growth of 67 percent. Heavy oil represents almost all of the NEB total oil-in-place volume. While a significant portion of the growth is due to the inclusion of the miscellaneous volumes, there has also been expansion of the existing pools and some new discoveries made. There were 32 new pools discovered between year-end 1994 and year-end 1997/98, primarily in the Sawtooth zone.

Although there are only three plays in this zone, the recoverable volumes are estimated to be greater than those of the Carboniferous zone (Table 5.7). It is estimated that 60 percent of the oil in place has been discovered, and that the remaining oil in place will be distributed in a large number of smaller pools. Due to its reservoir properties and the presence of bottom water, the average recovery factor for the discovered pools of 27 percent is relatively high compared with the other conventional heavy oil plays. However, the average recovery factor for the larger number of small undiscovered pools is expected to be closer to 12 percent. The combined recovery for the Jurassic zone, both discovered and undiscovered pools, will be approximately 22 percent using

FIGURE 5.14

Recovery Factors – Shaunavon



current production practices. It is estimated that an additional 2.6 percent could be recovered through improved recovery techniques.

The Board's analysis of the heavy oil pools indicates that there is a significant amount of heavy oil left to be found in these Jurassic plays in the provinces of Alberta and Saskatchewan. For the most part, the undiscovered pools will be smaller than the pools already discovered, but there are a few large pools left to be found. These large undiscovered pools may require development of a new exploration strategy, especially given the larger area for the Shaunavon play. As well, some pools may already be found but not yet recognized. Large pools may also result from the amalgamation of a number of smaller recognized or miscellaneous pools, following aggressive pool extension drilling.

T A B L E 5 . 7

Resources of Jurassic Plays (10⁶m³)

| Play | Discovered | | Undiscovered | |
|------------------|--------------|--------------|--------------|-------------|
| | Oil in Place | Recoverable | Oil In Place | Recoverable |
| Sawtooth | 90.2 | 28.1 | 33.5 | 2.7 |
| Shaunavon | 267.7 | 57.8 | 203.4 | 27.5 |
| Rose-ray-Success | 187.2 | 64.0 | 99.3 | 10.8 |
| Total | 545.1 | 149.9 | 336.2 | 41.0 |