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SPEE Recommended Evaluation Practice #5 – Discounting Cash Flows

Issue:
Some computer programs calculate cash flows for oil and gas properties on a monthly basis and some calculate cash flows on an annual basis. In most cases, either time frame is appropriate since oil and gas properties may produce for many years.

The computer programs are used to attempt to model the actual future flow of cash into and out of a particular oil and gas project and to place those modeled cash flows in the appropriate time period so that the time value of money can be correctly incorporated into the model. When dealing with the cash flows generated by the sale of oil and gas or monthly operating costs, there are several choices for discounting the future estimated cash flows whether they are calculated monthly or annually. Since these choices can have a large effect on the discounted net cash flow and a dramatic effect on the calculated internal rate of return, this Recommended Evaluation Practice will assure that reports prepared by different reserve estimators are comparable.

Monthly Discounting:
It is becoming more and more common to calculate cash flows on a monthly basis so that methodology will be discussed first.

When cash flows for oil and gas properties are discounted, the discount rate is expressed as an annual interest rate such as 10% per annum. When discounting monthly cash flows there are two methodologies that can be used to reconcile an annual interest rate with a monthly calculation. One method is to discount the monthly cash flows using the annual interest rate and the number of years (non-integer) from the effective date. The second method is to convert the annual interest rate to a monthly interest rate and use the number of months (usually integer) from the effective date.

If the "monthly interest rate" method is used there are two choices for converting from annual interest rates to monthly interest rates. One of these is the "APR" or "annual percentage rate" commonly used in home loans and credit cards. The other is the "effective monthly interest rate" which causes the compounded monthly interest rate to equal the annual interest rate.

The advantage of using APR is that it should be more familiar and more intuitive than effective monthly interest rate. The monthly interest rate is calculated

simply by dividing annual interest rate by 12. The effective monthly interest rate has the decided advantage of resulting in almost the same net present value as yearly discounting using mid-period discounting.

In addition to the choice of monthly interest rate, there is a question as to the proper timing of the cash flows. Typically, the actual cash receipt for production during a month occurs in the latter half of the month immediately following the production month. Some computer programs discount as though the cash is received at the end of the production month; some discount as though the cash is received at the middle of the production month; and some even default to assuming the cash is received at the beginning of the month in which the production occurs.

Annual Discounting:

Cash flows are generated by oil and gas properties throughout the year. When future cash flows are calculated on an annual basis (as opposed to a monthly basis) the cash flows are modeled as though they are received or distributed at one time during the year. Annual calculations require considerably less computational effort than monthly calculations while oftentimes retaining sufficient detail to properly represent the future cash flows. When discounting this single annual "lump-sum" amount of money one can assume it is received at any time during the year. Rational choices for this assumption range from mid-year to end-year. Some computer programs even allow beginning-of-year calculations. The assumption as to when to model the timing of the cash flow can have a large effect on the calculated present worth of that cash flow.

Discussion:

A numerical example will illustrate the problem. Using the following values, a simple economic calculation was made.

Parameter	Value
As of Date	1/1/2000
Production Begins	1/1/2000
Investment (1/1/2000)	$1,000,000
365.25 days/year	
Qi, BOPD	200
Di (effective), 1/yr	0.3
Di (nominal), 1/yr	0.356674944
B	0.5
Price, $/bbl (constant)	25
Working Interest	1.00
Net Revenue Interest	0.85
Operating Cost, $/month	2000
Severance Tax Rate	0.1
Undiscounted NCF	$4,914,952

The following tables compare the results of the various discounting methodologies.

Table A -- Discounting at 10% Annual Interest Rate

	Case 1	Case 2	Case 3	Case 4	Case 5
Annual Interest Rate	10%	10%	10%	10%	10%
NCF period	Monthly	Monthly	Monthly	Annual	Annual
Time at which NCF occurs during period	End	End	End	Middle	End
Interest rate period	Annual	Monthly	Monthly	Annual	Annual
Monthly Interest rate type	N/A	Effective	APR	N/A	N/A
Monthly Interest Rate	N/A	0.797414%	0.833333%	N/A	N/A
Compounding frequency	Yearly	Monthly	Monthly	Annual	Annual
Net Present Value	$2,853,287	$2,853,287	$2,796,618	$2,859,298	$2,679,697

The monthly net cash flow discounted at 10%/annum using end-month discounting and a non-integer number of years (1/12, 2/12, 3/12, …) is $2,853,287 (Table A Case 1). The monthly net cash flow discounted at 10%/annum converted to the monthly effective interest rate of 0.797414% per month and monthly compounding is precisely the same number, $2,853,287 (Table A Case 2). The net cash flow discounted at 10%/annum APR converted to the monthly interest rate of 0.833333% per month and monthly compounding is $2,796,618 (Table A Case 3). This is "only" a 2% difference at this low interest rate but the difference is exacerbated at higher discount rates as will be shown later.

The annual net cash flow discounted at 10% using mid-year discounting is $2,859,298 (Table A Case 4). This value is two-tenths of 1% different than that obtained using the monthly calculation with effective monthly interest rate. The annual net cash flow discounted at 10% using end-year discounting is $2,679,697 (Table A Case 5). The 6% difference in net present value is due solely to the discount point assumption.

The calculation of internal rate of return (IRR) may also be severely affected by the discounting assumptions as shown in the following table.

Table B - Calculating Internal Rate of Return

	Case 6	Case 7	Case 8	Case 9
Annual Interest Rate	103%	170%	162%	91%
NCF period	Monthly	Monthly	Annual	Annual
Time at which NCF occurs during period	End	End	Middle	End
Interest rate period	Monthly	Monthly	Annual	Annual
Monthly Interest rate type	APR	Effective	N/A	N/A
Compounding frequency	Monthly	Monthly	Annual	Annual
Net Present Value	$0	$0	$0	$0

Using APR monthly discounting the IRR is 103% (Table B Case 6); using effective monthly discounting the IRR is 170% (Table B Case 7). Without comment on the validity or usefulness of IRR's of this magnitude, it is expected that both of these calculated values would lead to the acceptance of the project. However, they are significantly different. Different computer programs using different assumptions would result in different answers using the same input data.

The assumption of a discount point for annual cash flows may also have a severe effect on the calculation of IRR. Using mid-period discounting the IRR is 162% (Table B Case 8); using end-period discounting the IRR is 91% (Table B Case 9). While both of these are acceptable, they are significantly different. The

mid-period annual IRR (162%) is much closer to the monthly IRR (170%) using monthly effective interest rate.

SPEE Recommended Evaluation Practice:

Cash flows calculated on a monthly basis should be discounted no earlier than end-month. When monthly compounding is used, annual interest rates should be converted to effective monthly interest rates through the equation

$$i_m = \left(1 + i_y\right)^{\left(1/12\right)} - 1.$$

The methodology used for discounting should be discussed in either the cover letter or body of the reserve report in such a manner that the user of the report can easily understand the assumptions used. Suggested language for the discussion would be "The cash flows in this report were determined on a monthly basis and discounted using an interest rate of X% per annum compounded annually. Cash flows for a month were assumed to occur at the end of the month in which the hydrocarbon was produced."

Cash flows calculated on an annual basis should be discounted using mid-period discounting. The cover letter or body of a reserve report incorporating annual cash flows should discuss the methodology used in a manner that leaves the user of the report with a clear understanding of the issue. Suggested language for the discussion would be: "The cash flows in this report were determined on an annual basis and discounted using an interest rate of X% per annum compounded annually. Cash flows resulting from production for a period were assumed to occur at the middle of the period in which the hydrocarbon was produced."

Regardless of whether the cash flows from production are modeled monthly or annually, lump-sum cash flows, such as a lease bonus, property purchase, or major investment which will occur at a given date, should be modeled at the date of anticipated occurrence.

Appendix A
Example Calculations
Monthly Cash Flows

		Annual Compounding			Effective Interest Rate Monthly Compounding			APR Monthly Compounding		
Mo-Year	Net Cash Flow	Discount factor		Present Value	Discount factor		Present Value	Discount factor		Present Value
0	-1,000,000	1/(1.1^(0/12))	1.000000	-1,000,000	1/(1.0.00797^0)	1.000000	-1,000,000	1/(1.0.00833^0)	1.000000	-1,000,000
Jan-00	112,719	1/(1.1^(1/12))	0.992089	111,827	1/(1.0.00797^1)	0.992089	111,827	1/(1.0.00833^1)	0.991736	111,787
Feb-00	109,407	1/(1.1^(2/12))	0.984240	107,683	1/(1.0.00797^2)	0.984240	107,683	1/(1.0.00833^2)	0.983539	107,606
Mar-00	106,237	1/(1.1^(3/12))	0.976454	103,736	1/(1.0.00797^3)	0.976454	103,736	1/(1.0.00833^3)	0.975411	103,625
Apr-00	103,201	1/(1.1^(4/12))	0.968729	99,973	1/(1.0.00797^4)	0.968729	99,973	1/(1.0.00833^4)	0.967350	99,831
May-00	100,290	1/(1.1^(5/12))	0.961066	96,385	1/(1.0.00797^5)	0.961066	96,385	1/(1.0.00833^5)	0.959355	96,214
Jun-00	97,499	1/(1.1^(6/12))	0.953463	92,961	1/(1.0.00797^6)	0.953463	92,961	1/(1.0.00833^6)	0.951427	92,763
Jul-00	94,820	1/(1.1^(7/12))	0.945920	89,692	1/(1.0.00797^7)	0.945920	89,692	1/(1.0.00833^7)	0.943563	89,469
Aug-00	92,248	1/(1.1^(8/12))	0.938436	86,569	1/(1.0.00797^8)	0.938436	86,569	1/(1.0.00833^8)	0.935765	86,322
Sep-00	89,777	1/(1.1^(9/12))	0.931012	83,584	1/(1.0.00797^9)	0.931012	83,584	1/(1.0.00833^9)	0.928032	83,316
Oct-00	87,402	1/(1.1^(10/12))	0.923647	80,729	1/(1.0.00797^10)	0.923647	80,729	1/(1.0.00833^10)	0.920362	80,442
Nov-00	85,118	1/(1.1^(11/12))	0.916340	77,997	1/(1.0.00797^11)	0.916340	77,997	1/(1.0.00833^11)	0.912756	77,692
Dec-00	82,921	1/(1.1^(12/12))	0.909091	75,382	1/(1.0.00797^12)	0.909091	75,382	1/(1.0.00833^12)	0.905212	75,061
Jan-01	80,805	1/(1.1^(13/12))	0.901899	72,878	1/(1.0.00797^13)	0.901899	72,878	1/(1.0.00833^13)	0.897731	72,541
Feb-01	78,768	1/(1.1^(14/12))	0.894764	70,479	1/(1.0.00797^14)	0.894764	70,479	1/(1.0.00833^14)	0.890312	70,128
Mar-01	76,805	1/(1.1^(15/12))	0.887686	68,179	1/(1.0.00797^15)	0.887686	68,179	1/(1.0.00833^15)	0.882954	67,815
Apr-01	74,913	1/(1.1^(16/12))	0.880663	65,973	1/(1.0.00797^16)	0.880663	65,973	1/(1.0.00833^16)	0.875657	65,598
May-01	73,088	1/(1.1^(17/12))	0.873696	63,856	1/(1.0.00797^17)	0.873696	63,856	1/(1.0.00833^17)	0.868420	63,471
Jun-01	71,327	1/(1.1^(18/12))	0.866784	61,825	1/(1.0.00797^18)	0.866784	61,825	1/(1.0.00833^18)	0.861243	61,430
Jul-01	69,627	1/(1.1^(19/12))	0.859927	59,874	1/(1.0.00797^19)	0.859927	59,874	1/(1.0.00833^19)	0.854125	59,470
Aug-01	67,986	1/(1.1^(20/12))	0.853124	58,000	1/(1.0.00797^20)	0.853124	58,000	1/(1.0.00833^20)	0.847067	57,589
Sep-01	66,401	1/(1.1^(21/12))	0.846375	56,200	1/(1.0.00797^21)	0.846375	56,200	1/(1.0.00833^21)	0.840066	55,781
Oct-01	64,868	1/(1.1^(22/12))	0.839679	54,469	1/(1.0.00797^22)	0.839679	54,469	1/(1.0.00833^22)	0.833123	54,043
Nov-01	63,387	1/(1.1^(23/12))	0.833036	52,804	1/(1.0.00797^23)	0.833036	52,804	1/(1.0.00833^23)	0.826238	52,373
Dec-01	61,955	1/(1.1^(24/12))	0.826446	51,202	1/(1.0.00797^24)	0.826446	51,202	1/(1.0.00833^24)	0.819410	50,766
Aug-36	52	1/(1.1^(440/12))	0.030358	2	1/(1.0.00797^440)	0.030358	2	1/(1.0.00833^440)	0.025953	1
Sep-36	44	1/(1.1^(441/12))	0.030117	1	1/(1.0.00797^441)	0.030117	1	1/(1.0.00833^441)	0.025738	1
Oct-36	36	1/(1.1^(442/12))	0.029879	1	1/(1.0.00797^442)	0.029879	1	1/(1.0.00833^442)	0.025526	1
Nov-36	28	1/(1.1^(443/12))	0.029643	1	1/(1.0.00797^443)	0.029643	1	1/(1.0.00833^443)	0.025315	1
Dec-36	20	1/(1.1^(444/12))	0.029408	1	1/(1.0.00797^444)	0.029408	1	1/(1.0.00833^444)	0.025105	1
Jan-37	13	1/(1.1^(445/12))	0.029176	0	1/(1.0.00797^445)	0.029176	0	1/(1.0.00833^445)	0.024898	0

Appendix B
Example Calculations
Annual Calculations

		Mid-year discounting			End-year discounting		
Year	Net Cash Flow	Discount factor		Present Value	Discount factor		Present Value
0	(1,000,000)	1/(1.1^0.0)	1.0000000000	(1,000,000)	1/(1.1^0)	1.0000000000	(1,000,000)
2000	1,161,638	1/(1.1^0.5)	0.9534625892	1,107,578	1/(1.1^1)	0.9090909091	1,056,034
2001	849,929	1/(1.1^1.5)	0.8667841720	736,705	1/(1.1^2)	0.8264462810	702,421
2002	646,863	1/(1.1^2.5)	0.7879856109	509,719	1/(1.1^3)	0.7513148009	485,998
2003	507,207	1/(1.1^3.5)	0.7163505554	363,338	1/(1.1^4)	0.6830134554	346,429
2004	407,049	1/(1.1^4.5)	0.6512277776	265,081	1/(1.1^5)	0.6209213231	252,745
2005	332,777	1/(1.1^5.5)	0.5920252524	197,012	1/(1.1^6)	0.5644739301	187,844
2006	276,179	1/(1.1^6.5)	0.5382047749	148,641	1/(1.1^7)	0.5131581182	141,723
2007	232,059	1/(1.1^7.5)	0.4892770681	113,541	1/(1.1^8)	0.4665073802	108,257
2008	197,000	1/(1.1^8.5)	0.4447973346	87,625	1/(1.1^9)	0.4240976184	83,547
2009	168,680	1/(1.1^9.5)	0.4043612133	68,208	1/(1.1^10)	0.3855432894	65,033
2010	145,476	1/(1.1^10.5)	0.3676011030	53,477	1/(1.1^11)	0.3504938995	50,988
2011	126,225	1/(1.1^11.5)	0.3341828209	42,182	1/(1.1^12)	0.3186308177	40,219
2012	110,078	1/(1.1^12.5)	0.3038025645	33,442	1/(1.1^13)	0.2896643797	31,886
2013	96,402	1/(1.1^13.5)	0.2761841495	26,625	1/(1.1^14)	0.2633312543	25,386
2014	84,717	1/(1.1^14.5)	0.2510764996	21,270	1/(1.1^15)	0.2393920494	20,280
2015	74,654	1/(1.1^15.5)	0.2282513632	17,040	1/(1.1^16)	0.2176291358	16,247
2016	65,926	1/(1.1^16.5)	0.2075012393	13,680	1/(1.1^17)	0.1978446689	13,043
2017	58,308	1/(1.1^17.5)	0.1886374903	10,999	1/(1.1^18)	0.1798587899	10,487
2018	51,618	1/(1.1^18.5)	0.1714886275	8,852	1/(1.1^19)	0.1635079908	8,440
2019	45,712	1/(1.1^19.5)	0.1558987523	7,126	1/(1.1^20)	0.1486436280	6,795
2020	40,472	1/(1.1^20.5)	0.1417261385	5,736	1/(1.1^21)	0.1351305709	5,469
2021	35,801	1/(1.1^21.5)	0.1288419440	4,613	1/(1.1^22)	0.1228459736	4,398
2022	31,620	1/(1.1^22.5)	0.1171290400	3,704	1/(1.1^23)	0.1116781578	3,531
2023	27,863	1/(1.1^23.5)	0.1064809455	2,967	1/(1.1^24)	0.1015255980	2,829
2024	24,474	1/(1.1^24.5)	0.0968008595	2,369	1/(1.1^25)	0.0922959982	2,259
2025	21,407	1/(1.1^25.5)	0.0880007814	1,884	1/(1.1^26)	0.0839054529	1,796
2026	18,622	1/(1.1^26.5)	0.0800007104	1,490	1/(1.1^27)	0.0762776844	1,420

		Mid-year discounting			End-year discounting		
Year	Net Cash Flow	Discount factor		Present Value	Discount factor		Present Value
2027	16,085	1/(1.1^27.5)	0.0727279185	1,170	1/(1.1^28)	0.0693433495	1,115
2028	13,769	1/(1.1^28.5)	0.0661162896	910	1/(1.1^29)	0.0630394086	868
2029	11,647	1/(1.1^29.5)	0.0601057178	700	1/(1.1^30)	0.0573085533	667
2030	9,700	1/(1.1^30.5)	0.0546415616	530	1/(1.1^31)	0.0520986848	505
2031	7,908	1/(1.1^31.5)	0.0496741469	393	1/(1.1^32)	0.0473624407	375
2032	6,255	1/(1.1^32.5)	0.0451583154	282	1/(1.1^33)	0.0430567643	269
2033	4,727	1/(1.1^33.5)	0.0410530140	194	1/(1.1^34)	0.0391425130	185
2034	3,312	1/(1.1^34.5)	0.0373209218	124	1/(1.1^35)	0.0355841027	118
2035	1,999	1/(1.1^35.5)	0.0339281107	68	1/(1.1^36)	0.0323491843	65
2036	779	1/(1.1^36.5)	0.0308437370	24	1/(1.1^37)	0.0294083494	23
2037	17	1/(1.1^37.5)	0.0280397609	0	1/(1.1^38)	0.0267348631	0
Total	4,914,952			2,859,298			2,679,697