Plumas Geo-Hydrology
LAND AND WATER RESOURCES

P.O. Box 1922, Portola, CA 96122
water@gotsky.com, tel. (530) 836-2208

MEMORANDUM

July 10, 2015

TO: Leah Wills

FROM: Burkhard Bohm, Hydrogeologist, CCHG 337, 530-836-2208.

REG.: Groundwater recharge and forest canopy thinning.

The purpose of this memorandum is to draw attention to the significance of increased groundwater recharge due to forest canopy thinning.

To examine effect of forest canopy on the amount of precipitation reaching the forest floor, field experiments were conducted in the winter of 2005/06 on private property near Blairsden, in eastern Plumas County, CA (Bohm, 2008). Based on these experiments the amount of precipitation evaporated due to canopy interception is 24% (average 20 station canopy density was 62%, ranging between 26% and 91%), suggesting that canopy interception in overstocked forests has significant adverse impacts on the forest water balance. The data analysis results indicated that by reducing average canopy closure to 40% the amount of precipitation reaching the forest floor can be increased by about 20%.

The implications are that forest management practices to reduce forest canopy closure, will increase ground water recharge, and thereby increase baseflow in streams.

The estimate of reduced canopy closure on groundwater recharge can be demonstrated with the following simple calculation:

$$I = P - CI - ET,$$

where “I” is infiltration, “P” is precipitation, “CI” is canopy interception, and “ET” is evapotranspiration.

The amount of infiltration entering the forest floor depends on annual precipitation – minus canopy interception. For example average annual precipitation in Quincy is about 40 inches. If the moisture lost from canopy interception is 24%, precipitation left for infiltration is about 30 inches. By thinning the average canopy closure from 62% to 40% the amount of precipitation reaching the forest floor increases by about 20%, thereby increasing infiltration by about 6 inches annually. This translates into a potential gain of 0.5 ac-ft per acre (ac-ft/ac).

Once infiltration entered the forest soil it is further diminished by evapotranspiration, depending on location and elevation. Most precipitation happens during the winter and spring months when water loss (evapotranspiration) from dormant vegetation is minimal.

The Quincy area monthly infiltration increase due to thinning was estimated in Table 2 using the Quincy RS precipitation record obtained from the CDEC, and monthly potential evapotranspiration (ETo) obtained from Pruitt et al. (1987). The estimated groundwater recharge increase attributed to forest canopy thinning in "above normal" water years would be 0.45 ac-ft/acre per year (see summary in Table 1). Even in a "dry" water year the groundwater recharge increase would be 0.31 ac-ft/acre per year. Needless to say, depending on the upland aquifer storage capacity a certain amount of recharge will be carried over from the wet years into the dry years.

References

Bohm, B., 2008. Canopy interception in a coniferous forest in eastern Plumas County, California. Final Technical Summary Report. Prepared for Brian Morris, Plumas County Flood Control and Water Conservation District. Plumas Geo-Hydrology, July 28, 2008.

Pruitt, W.O., Freres, E., Snyder, R.L., 1987, Reference Evapotranspiration (ETo) for California. Agricultural Experiment Station, University of California. Bulletin 1922.

Plumas Geo-Hydrology
LAND AND WATER RESOURCES

P.O. Box 1922, Portola, CA 96122
water@gotsky.com, tel. (530) 836-2208

TABLE 1: Summary	**Estimated GW recharge increase by forest thinning:**					
	after canopy interception and ET.					
Quincy, American Valley	**Feather River Basin**			2/12/2015		
GWR = Precip - Canopy Interc. - Eto						
GWR = throughfall. - Eto						
Forest Conditions:	**Precipitation**	**Throughfall after 24% interception**	**Infiltration after ET from forest floor**	**GW recharge per acre of forest**		
	in/yr	in/yr	in/yr	ac-ft/acre		
Pre-thinnig Forest Conditions:						
Wet Water Year	52.4	39.8	26.6	2.2		
Above Normal Water Year	45.4	34.5	21.7	1.8		
Mean annual precip. (normal)	40.2	30.5	18.2	1.5		
Dry Water Year	29.6	22.5	13.3	1.1		
Estimated GW recharge increase by forest thinning:						
After-thinnig Forest Conditions:			reduction in canopy interception:		20%	
Wet Water Year	52.4	39.8	33.1	2.8	**0.54**	**ac-ft/acre gained**
Above Normal Water Year	45.4	34.5	27.1	2.3	**0.45**	**ac-ft/acre gained**
Mean annual precip. (normal)	40.2	30.5	22.9	1.9	**0.39**	**ac-ft/acre gained**
Dry Water Year	29.6	22.5	17.1	1.4	**0.31**	**ac-ft/acre gained**
NOTE: these annual estimates are based on monthly data of Eto and precipitation in American Valley.						
The estimated infiltration rates (GW recharge depths) are low since Eto and precipitation was						
measured at the valley floor (3400 ft ab. msl), whereas GW recharge occurs at high elevations, up to 8000+ ft.						

P.O. Box 1922, Portola, CA 96122
water@gotsky.com, tel. (530) 836-2208

TABLE 2A: Estimated Annual GW Recharge Volumes in ac-ft per acre and percentage of Precipitation, American Valley, CA - considering Canopy Interception loss and ET.

Precipitation evaporated from the forest canopy (interception) under pre-thinning conditions: 24%

Decrease of evaporation after thinning forest canopy density to 40%: 20%

Wet Water Year

infiltration increase after thinning:

canopy evapor. decrease: 20%

Month	monthly precip	Net precip. after evapor. In overstocked canopy:	ETo	effective recharge	actual recharge		net precip after thinning	effective recharge	actual recharge
	in/mo	in/mo	in/mo	in/mo	in/mo		in/mo	in/mo	in/mo
Oct	2.78	2.11	2.60	-0.49	0.00		2.5	-0.1	0.0
Nov	7.57	5.75	1.00	4.75	4.75		6.9	5.9	5.9
Dec	9.76	7.42	0.47	6.95	6.95		8.9	8.4	8.4
Jan	9.78	7.44	0.71	6.73	6.73		8.9	8.2	8.2
Feb	7.50	5.70	1.06	4.64	4.64		6.8	5.8	5.8
Mar	7.31	5.56	2.01	3.55	3.55		6.7	4.7	4.7
Apr	3.98	3.03	3.54	-0.51	0.00		3.6	0.1	0.1
May	1.44	1.10	4.72	-3.62	0.00		1.3	-3.4	0.0
Jun	1.01	0.77	5.91	-5.14	0.00		0.9	-5.0	0.0
Jul	0.23	0.17	7.09	-6.92	0.00		0.2	-6.9	0.0
Aug	0.20	0.15	5.91	-5.76	0.00		0.2	-5.7	0.0
Sep	0.82	0.62	4.13	-3.51	0.00		0.7	-3.4	0.0
total, average	**52.38**	**39.81**	**33.43**	**0.66**	**26.61**		**47.8**	**8.6**	**33.1**

precip avail. for GW recharge, current (62% canopy closure): **51%** **after thinning: 63%**

gain: 0.54

ac-ft per acre per year

Plumas Geo-Hydrology
LAND AND WATER RESOURCES

P.O. Box 1922, Portola, CA 96122
water@gotsky.com, tel. (530) 836-2208

TABLE 2B: Estimated Annual GW Recharge Volumes in ac-ft per acre and percentage of Precipitation, American Valley, CA - considering Canopy Interception loss and ET.

Precipitation evaporated from the forest canopy (interception) under pre-thinning conditions:	24%
Decrease of evaporation after thinning forest canopy density to 40%:	20%

Above Normal Water Year

Month	monthly precip	Net precip. after evapor. In overstocked canopy:	ETo	effective recharge	actual recharge		net precip after thinning	effective recharge	actual recharge
	in/mo	in/mo	in/mo	in/mo	in/mo		in/mo	in/mo	in/mo
Oct	2.71	2.06	2.60	-0.54	0.00		2.5	-0.1	0.0
Nov	3.34	2.54	1.00	1.54	1.54		3.0	2.0	2.0
Dec	8.77	6.67	0.47	6.20	6.20		8.0	7.5	7.5
Jan	10.71	8.14	0.71	7.43	7.43		9.8	9.1	9.1
Feb	8.13	6.18	1.06	5.12	5.12		7.4	6.4	6.4
Mar	4.49	3.41	2.01	1.40	1.40		4.1	2.1	2.1
Apr	3.30	2.51	3.54	-1.03	0.00		3.0	-0.5	0.0
May	1.92	1.46	4.72	-3.26	0.00		1.8	-3.0	0.0
Jun	0.93	0.71	5.91	-5.20	0.00		0.9	-5.1	0.0
Jul	0.16	0.12	7.09	-6.97	0.00		0.1	-6.9	0.0
Aug	0.39	0.30	5.91	-5.61	0.00		0.4	-5.6	0.0
Sep	0.53	0.41	4.13	-3.72	0.00		0.5	-3.6	0.0
total, average	**45.39**	**34.50**	**33.43**	**-4.65**	**21.69**		**41.4**	**2.2**	**27.1**

		infiltration increase after thinning:	
		canopy evapor. decrease:	20%
precip avail. for GW recharge, current (62% canopy closure):	48%	after thinning:	60%
		gain:	0.45
		ac-ft per acre per year	

P.O. Box 1922, Portola, CA 96122
water@gotsky.com, tel. (530) 836-2208

TABLE 2C: Estimated Annual GW Recharge Volumes in ac-ft per acre and percentage of Precipitation, American Valley, CA - considering Canopy Interception loss and ET.

Precipitation evaporated from the forest canopy (interception) under pre-thinning conditions:	24%
Decrease of evaporation after thinning forest canopy density to 40%:	20%

Mean annual precip. (normal) (average of available record)

infiltration increase after thinning:
canopy evapor. decrease: **20%**

Month	monthly precip	Net precip. after evapor. In overstocked canopy:	ETo	effective recharge	actual recharge	net precip after thinning	effective recharge	actual recharge
	in/mo	in/mo	in/mo	in/mo	in/mo	in/mo	in/mo	in/mo
Oct	2.52	1.92	2.60	-0.68	0.00	2.3	-0.3	0.0
Nov	4.82	3.66	1.00	2.66	2.66	4.4	3.4	3.4
Dec	6.5	4.94	0.47	4.47	4.47	5.9	5.5	5.5
Jan	7.52	5.72	0.71	5.01	5.01	6.9	6.1	6.1
Feb	6.39	4.86	1.06	3.80	3.80	5.8	4.8	4.8
Mar	5.59	4.25	2.01	2.24	2.24	5.1	3.1	3.1
Apr	2.82	2.14	3.54	-1.40	0.00	2.6	-1.0	0.0
May	1.72	1.31	4.72	-3.41	0.00	1.6	-3.2	0.0
Jun	0.83	0.63	5.91	-5.28	0.00	0.8	-5.2	0.0
Jul	0.19	0.14	7.09	-6.95	0.00	0.2	-6.9	0.0
Aug	0.38	0.29	5.91	-5.62	0.00	0.3	-5.6	0.0
Sep	0.9	0.68	4.13	-3.45	0.00	0.8	-3.3	0.0
total, average	**40.18**	**30.54**	**33.43**	**-8.61**	**18.17**	**36.6**	**-2.5**	**22.9**

precip avail. for GW recharge, current (62% canopy closure): **45%** **after thinning:** **57%**

gain: **0.39**

ac-ft per acre per year

Plumas Geo-Hydrology
LAND AND WATER RESOURCES

P.O. Box 1922, Portola, CA 96122
water@gotsky.com, tel. (530) 836-2208

TABLE 2D: Estimated Annual GW Recharge Volumes in ac-ft per acre and percentage of Precipitation, American Valley, CA - considering Canopy Interception loss and ET.

Precipitation evaporated from the forest canopy (interception) under pre-thinning conditions:	24%
Decrease of evaporation after thinning forest canopy density to 40%:	20%

Dry Water Year

Month	monthly precip	Net precip. after evapor. In overstocked canopy:	ETo	effective recharge	actual recharge		net precip after thinning	effective recharge	actual recharge
	in/mo	in/mo	in/mo	in/mo	in/mo		in/mo	in/mo	in/mo
							infiltration increase after thinning:		
							canopy evapor. decrease:		**20%**
Oct	1.55	1.18	2.60	-1.42	0.00		1.4	-1.2	0.0
Nov	4.87	3.70	1.00	2.70	2.70		4.4	3.4	3.4
Dec	4.59	3.49	0.47	3.02	3.02		4.2	3.7	3.7
Jan	3.37	2.56	0.71	1.85	1.85		3.1	2.4	2.4
Feb	5.67	4.31	1.06	3.25	3.25		5.2	4.1	4.1
Mar	5.97	4.53	2.01	2.52	2.52		5.4	3.4	3.4
Apr	0.97	0.74	3.54	-2.80	0.00		0.9	-2.7	0.0
May	1.01	0.77	4.72	-3.95	0.00		0.9	-3.8	0.0
Jun	0.50	0.38	5.91	-5.53	0.00		0.5	-5.5	0.0
Jul	0.04	0.03	7.09	-7.06	0.00		0.0	-7.1	0.0
Aug	0.18	0.13	5.91	-5.78	0.00		0.2	-5.7	0.0
Sep	0.91	0.69	4.13	-3.44	0.00		0.8	-3.3	0.0
total, average	**29.61**	**22.50**	**33.43**	**-16.65**	**13.34**		**27.0**	**-12.1**	**17.1**
precip avail. for GW recharge, current (62% canopy closure):					**45%**		**after thinning:**		**58%**
								gain:	**0.31**
								ac-ft per acre per year	