Testing the H_{60} Calculations in the 1998 Carbondale Basin Interior Watershed Assessment Procedure

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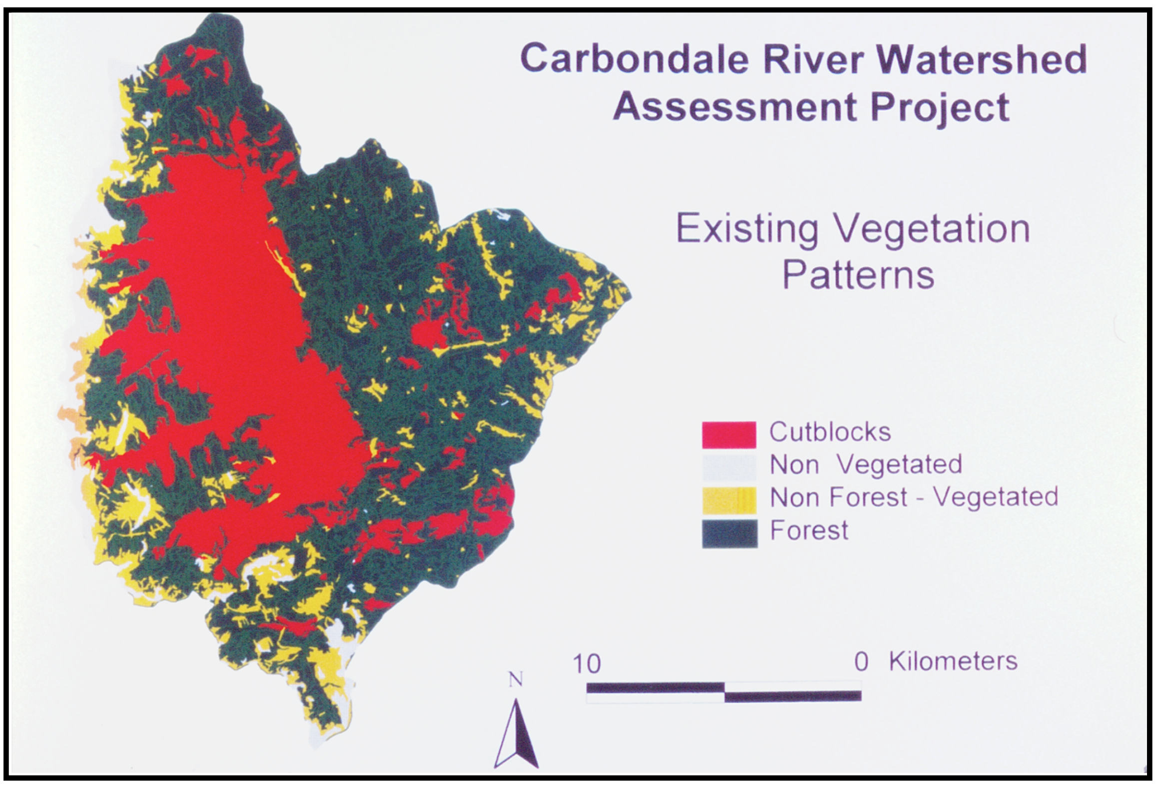

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Cover map: M. D. Sawyer

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Abstract

A 1998 Interior Watershed Assessment Procedure (IWAP) watershed analysis of the Carbondale River basin in southwestern Alberta used an average basin-wide measure of the H_{60} line (the elevation above which 60 percent of the basin lies) for all eight of the constituent sub-basins. It is possible that using sub-basin-specific H_{60} determinations would give different assessments of risk for each sub-basin, but the original data are no longer available for reanalysis. I assessed the potential effect of the 1998 procedure on the risk evaluations of the eight sub-basins by calculating absolute maxima and minima, as well as medians, for all measures incorporating determinations of the H_{60} line. The best overall risk evaluation as measured by the peak flow versus surface erosion interaction matrix score remained unchanged except in the Gardiner Creek sub-basin, which was likely at lower risk (moderate, as opposed to very high) than suggested by the 1998 study. Independent field observations in the Carbondale basin demonstrate that channel disturbance due to forestry operations and roads is extensive, and can occur even in basins evaluated by the IWAP hazard and interaction matrix scores as only at low to moderate risk.

Introduction

(Sawyer and Mayhood 1998) published a watershed analysis of the Carbondale River basin and 8 sub-basins using the Interior Watershed Assessment Procedure (IWAP) (BC Forest Service. 1995). While attempting to use the data in Table 2 of that study for another purpose, I noticed that the area above the H_{60} line was consistently incorrect for every sub-basin, but was correct for the Carbondale basin as a whole (Table 1). Further reading (Sawyer and Mayhood 1998:436) confirmed that the H_{60} elevation for the entire Carbondale basin (1622 m) had been used as the H_{60} elevation for each of the sub-basins. This procedure is appropriate for analyzing the entire Carbondale watershed as a whole. For detailed analysis of individual sub-basins it is appropriate to calculate the H_{60} line for each sub-basin separately (BC Forest Service 1995:54). We have done the separate sub-basin calculation of the H_{60} line in all of our subsequent IWAP studies in 92 other mountain basins in southwestern Alberta (Haskins and Mayhood 1997, Mayhood et al. 1997, Mayhood et al. 1998, Mayhood et al. 2004).

Table 1. Basin area and H_x area from Table 2 in the 1998 IWAP analysis of the Carbondale River basin (Sawyer and Mayhood 1998). H_x was used as H_{60} in the 1998 calculations.

	Lynx Cr	Goat Cr	Lost Cr	North Lost Cr	South Lost Cr	Gardiner Cr	Mac-Donald Cr	residual Carbon-dale R	total Carbon-dale R
total area, km²	103.43	29.35	65.23	29.99	26.26	36.26	6.49	97.68	309.09
H_x area, km²	74.11	24.36	46.56	25.17	20.19	25.12	6.07	33.42	185.28
x	72	83	71	84	77	69	94	34	60

The effect of the procedure used by Sawyer and Mayhood (1998) was to overestimate the H_{60} area for the Lynx Creek (including Goat Creek), Lost Creek (including North and South Lost creeks), Gardiner Creek and MacDonald Creek basins, and to underestimate the H_{60} area for the grouped residual Carbondale River basins. As a consequence the analytical data relying on the H_{60} elevation (equivalent clearcut area and road length, both above H_{60} the elevation) are incorrect for the sub-basins, although not for the Carbondale basin as a whole. It is not possible now to reanalyze the original data. These perished long ago, along with a hard disk and its backup. A second backup may exist on an obsolete tape drive. Retrieval from that source, if still possible, is going to require significant technological archaeology. There is no prospect of immediate recovery.

The H_{60} line is the elevation above which 60 percent of the basin area lies. This elevation is believed by the developers of the IWAP to be the average elevation of the snowline in interior British Columbia basins at the time of peak flow due to spring snowmelt (BC Forest Service

1995). The basin above the H_{60} elevation thus is expected to contribute the most to spring peak flows. Land disturbance in the basin above H_{60} may therefore have a disproportionately large effect on spring peak streamflows (Gluns 1999, Gluns 2001, Whitaker et al. 2001). The IWAP adjusts its peak flow indicators for this by applying a factor of 1.5 to its impact ratings for equivalent clearcut area (ECA) and road length above the H_{60} line. The effect of overestimating the H_{60} area will be to overestimate the impact of ECA and road length in the basin. An underestimated H_{60} area will underestimate the impact of ECA and road length in the basin. For this reason, Sawyer and Mayhood (1998), by employing what is effectively the mean H_{60} elevation of all sub-basins, may have overestimated impacts on peak flows in 7 Carbondale sub-basins, and underestimated them in the collective residual Carbondale basins. The calculations for the total Carbondale basin, however, are accurate. Also, the remaining eight indicators affecting impact risks related to surface erosion and riparian buffers are unaffected by the H_{60} estimate and are therefore accurate for all basins.

The purpose of this note is to test the sensitivity of the 1998 Carbondale basin IWAP to the use of the Carbondale mean H_{60} line for all sub-basins, to provide some bounds to the estimates of risk arrived at in that analysis, and to evaluate the effects on its conclusions. This reassessment is especially important in view of the fact that the Carbondale basin is one of the last remaining refuges of genetically-pure native populations of westslope cutthroat trout in Alberta (Cleator *et al.* 2009). Estimates of risk to the Carbondale basin are likely to influence the protection and management of habitat for this threatened species.

Methods

The original data are not available for reanalysis, so for each sub-basin I calculated absolute maximum and absolute minimum estimates for all parameters that would be affected by the H_{60} estimate (1622 m) used by Sawyer and Mayhood (1998), as follows.

Sub-basins that have actual H_{60} areas smaller than the 1998 estimate

- Lynx Creek (including its Goat Creek sub-basin)
- Goat Creek
- Lost Creek (including the sub-basins South Lost Creek and North Lost Creek)
- Gardiner Creek
- MacDonald Creek

These basins would have had too much road length, and may have had too much clearcut area, attributed to the upper 60 percent of their watersheds, so would have had their peak flow effects overestimated. These original overestimates can be taken as absolute maximum estimates, because they could not possibly have been higher had the sub-basin-specific H_{60} line been used.

To calculate minimum estimates, I assumed that all road length and ECA occurred below the basin-specific H_{60} line in these sub-basins. This removed the factor of 1.5 from all peak flow indicator calculations for the basin above the H_{60} line. Most if not all of these basins actually did have at least some road length and often some ECA in the upper portion of their basins (Sawyer and Mayhood 1998, compare their Figures 1 and 3), so the resultant impact scores certainly are too low. and can be taken as absolute minima.

Sub-basins that have actual H_{60} areas larger than the 1998 estimate

- combined residual Carbondale sub-basins (includes O'Hagan Creek basin, together with numerous small unnamed creeks not part of the other sub-basins)

For these combined residual basins I took the values calculated by Sawyer and Mayhood (1998) as minima. Because the H_{60} elevation used in those calculations was higher than the sub-basin-specific H_{60} elevation, the effect was to underestimate the ECA and road length in the upper 60 percent of the combined sub- basins. The sub-basin-specific H_{60} line might include more road length and ECA above H_{60} (thereby increasing calculated peak flow scores), and could not possibly include less, so the 1998 scores are absolute minima. Maximal values were estimated by including *all* ECA and road length in the upper 60 percent of the basin, which causes the factor 1.5 to be applied to all calculations of peak flow related parameters. There was certainly some road length and ECA in the lower parts of some of these basins (Sawyer and Mayhood 1998, compare Figures 1 and 3), so this procedure gives absolute maximum estimates for peak flow parameters.

The absolute maxima and minima provide the range within which the true values must lie. Because they are extremes, however, they cannot provide realistic estimates of the true parameters. Lacking any better information, I calculated the medians of each H_{60}-influenced parameter using the median ECA and road length above H60 values, and used the medians as the best available estimate for interpreting risk.

A spreadsheet (Apple Macintosh and Windows-compatible) showing the details of these calculations is available upon request.

Results

Impact Indicators

Only two of the ten indicators used by Sawyer and Mayhood (1998) are affected by the H_{60} line determination: peak flow index and road length above the H_{60} line (Table 2). Both of these affect only peak flow hazard, and have no effect on surface erosion or riparian buffer hazard evaluations.

Minimum and maximum estimates changed peak flow indices for all sub-basins, but risk categories changed in only four sub-basins as a result (Table 2). The estimated minimum peak flow index categories for Lynx, Goat and South Lost creek sub-basins dropped one risk category, while the maximum peak flow index risk category for the residual Carbondale sub-basins increased one category, compared to the 1998 rating. The median peak flow indices were of course lower than the indices calculated by Sawyer and Mayhood (1998), but the risk categories assigned on the basis of the medians remained identical to those of the 1998 study except in Lynx and South Lost sub-basins, where they dropped one category.

The road length above the H_{60} elevation was arbitrarily set to zero in the Lynx, Lost, Gardiner and MacDonald creek sub-basins and all of their sub-basins, and total road length was arbitrarily allocated to above the H_{60} elevation in the residual Carbondale sub-basins, to arrive at absolute minimum and maximum estimates, respectively, for the road length above H_{60} criterion in those sub-basins. For this reason only the median indicators provide any useful comparisons with the 1998 data. These show a drop in risk category for this indicator in six sub-basins and an increase in risk category in the collective residual Carbondale sub-basins (Table 2; compare Sawyer and Mayhood 1998:Figure 2c).

Table 2. Maximum, minimum and median peak flow indicators affected by the H_{60} line, Carbondale River basin and its sub-basins. Risk categories (from Sawyer and Mayhood 1998): L, low; M, moderate; and H, high. *Italics* indicate median values; **bold** indicates original values used to produce Figures 2a and 2c of Sawyer and Mayhood (1998). These data replace Figure 2a and Figure 2c of Sawyer and Mayhood (1998:433).

Indicator	Lynx Cr	Goat Cr	Lost Cr	North Lost Cr	South Lost Cr	Gardiner Cr	Mac-Donald Cr	residual Carbon-dale R	total Carbon-dale R
peak flow index	0.22-**0.28** L—**M** *0.25* *L*	0.41-**0.72** M—**H** *0.56* *H*	0.45-**0.58** H—**H** *0.51* *H*	0.51-**0.70** H—**H** *0.60* *H*	0.36-**0.45** M—**H** *0.41* *M*	0.12-**0.13** L—**L** *0.12* *L*	0.66-**0.73** H—**H** *0.69* *H*	**0.22**-0.29 **L**—M *0.25* *L*	**0.31** **M**
roads >H_{60} km/km^2	0-**1.3** L—**H** *0.66* *M*	0-**1.5** L—**H** *0.74* *M*	0-**1.2** L—**H** *0.59* *M*	0-**1.9** L—**H** *0.93* *H*	0-**0.8** L—**H** *0.39* *L*	0-**0.7** L—**M** *0.34* *L*	0-**0.8** L—**H** *0.37* *L*	**0.5**-2.6 **M**—H *1.6* *H*	**1.0** **H**

Hazard Index

The IWAP hazard indices combine the individual impact indicators into single measures of hazard from potential changes in peak flow and surface erosion. Only the hazard index for peak flows is influenced by the estimate of H_{60} elevation. The hazard index for peak flows changed in seven of the eight sub-basins when recalculated using the absolute minimum and maximum procedures, but the risk category for this hazard index changed in only four sub-basins (Table 3).

Median peak flow scores were high in 5 sub-basins, moderate in two sub-basins, and low in one sub-basin. The median score reduced the evaluation of hazard associated with peak flow score from high to moderate in the Lynx Creek basin, and from moderate to low in the Gardiner Creek basin, but raised it from moderate to high in the residual sub-basins. Use of the median value did not change the risk category in five of the eight basins. For the overall Carbondale River basin, the peak flow score was unchanged at 0.70 (moderate)[1].

Table 3. Peak flow hazard indices for the Carbondale River basin. Hazard indices, reported to the number of significant figures supported by the data, are interpreted as <0.5, low; 0.5—0.7, moderate; >0.7, high potential for channel disturbance from human development. Medians were calculated using the median ECA and road length above H_{60} values. Ranges shown are maximum and minimum values. *Italics* indicate median values; **bold** indicates original values obtained by Sawyer and Mayhood (1998). These data replace the data for peak flows in Table 3 of Sawyer and Mayhood (1998:437).

	Lynx Cr	Goat Cr	Lost Cr	North Lost Cr	South Lost Cr	Gardiner Cr	Mac-Donald Cr	Residual Carbon-dale R	Total Carbon-dale R
Peak flows	0.40-**0.73** L—**H** *0.60* *M*	0.7-**1** M—**H** *0.90* *H*	0.80-**1.0** H—**H** *0.90* *H*	0.90-**1.0** H—**H** *1.0* *H*	0.6-**0.7** M—**M** *0.70* *M*	0.27-**0.50** L—**M** *0.37* *L*	1.0-**1.0** H—**H** *1.0* *H*	**0.60**-0.80 **M**—H *0.77* *H*	**0.70** **M**

Interaction Matrix Score

Only the interaction matrix score for peak flow versus surface erosion was calculable from the available data (Sawyer and Mayhood 1998). Even using absolute minimum and maximum estimates for H_{60}-related data failed to change the peak flow vs. surface erosion scores for six of the eight sub-basins (Table 4).

Using the absolute minimum and maximum estimates for H_{60}-dependent data caused a drop in the scores for Lynx and Gardiner sub-basins (Table 4). At an absolute minimum, these sub-basins would be rated as at moderate risk of damage from the combined effects of peak flow and surface erosion increases from human development in those basins. The median score indicates that Lynx Creek sub-basin remains at very high risk, while Gardiner Creek sub-basin drops to moderate risk based on this criterion, in comparison to the 1998 results.

[1] not “high” as stated by Sawyer and Mayhood (1998:436)

Table 4. Peak flow vs. surface erosion interaction matrix scores for the Carbondale River basin and its sub-basins. Medians were calculated using the median ECA and road length above H_{60} values. Risk categories can be interpreted as indicating low (L), moderate (M), high (H) and very high (VH) risk of impact from the combined effects of increased peak flows and surface erosion. Ranges shown are maximum and minimum values. *Italics* indicate median values; **bold** indicates original values obtained by Sawyer and Mayhood (1998). These data replace those in Table 3 of Sawyer and Mayhood (1998:437).

	Lynx Cr	**Goat Cr**	**Lost Cr**	**North Lost Cr**	**South Lost Cr**	**Gardiner Cr**	**Mac-Donald Cr**	**Residual Carbon-dale R**	**Total Carbon-dale R**
Peak Flow vs. Surface erosion	2—**4** M—**VH** *4* *VH*	4—**4** VH—**VH**	4—**4** VH—**VH**	4—**4** VH—**VH**	4—**4** VH—**VH**	2—**4** M—**VH** *2* *M*	4—**4** VH—**VH**	**4**—4 **VH**—VH	**4** **VH**

Discussion

Overall, the 1998 IWAP risk evaluations remain realistic. The two risk indicators directly dependent on the determination of the H_{60} elevation, and similarly the peak flow hazard index, were sensitive to the absolute maximum and minimum estimates calculated here. The measure “road length above the H_{60} elevation” in particular was strongly affected because it depends entirely on H_{60} elevation determination. Even so, the best available estimate, the median, suggests that the 1998 peak flow indices and the peak flow hazard indices placed most sub-basins in the correct risk category for these measures. Most importantly, the peak flow vs. surface erosion interaction scores of the1998 IWAP for the Carbondale basin were, with one exception, robust to extreme estimates affecting H_{60}-related calculations. Based on median values, all sub-basins except the Gardiner Creek sub-basin were rated appropriately by the 1998 IWAP. At worst, only the overall peak flow vs. surface erosion risk category for the Lynx Creek and Gardiner Creek basins were over-estimated by the 1998 study.

The results of the original IWAP as modified by this study suggest that severe damage to stream channels can occur even when IWAP scores are only low to moderate. The IWAP relies on the hazard indices (peak flow, surface erosion and riparian buffers in the 1998 study) and interaction matrix scores (peak flow vs. surface erosion in the 1998 study) to assess hydrological risk. In this reanalysis, surface erosion hazard was high (Sawyer and Mayhood 1998:Table 3), but peak flow hazard [and riparian hazard (Sawyer and Mayhood 1998)] for Gardiner Creek was low, and that for Lynx and South Lost creeks was moderate. Nevertheless, extensive channel disturbance attributable to road and forestry operations was noted in all three basins (Fitch 1980b, 1980e, 1980g; Sawyer and Mayhood 1998). Similarly, the peak flow vs. surface erosion interaction in the Gardiner sub-basin was only moderate in this reassessment, yet extensive channel damage due to forestry operations and roads was noted independently in the lower portion of this sub-basin (Fitch 1980b, Sawyer and Mayhood 1998).

None of the 1998 land management recommendations are affected by this new analysis. Although the Gardiner Creek sub-basin is evaluated overall as most likely at moderate risk (compared to very high risk in the 1998 analysis), the independent observations of Fitch (1980b) make it clear that serious extensive channel damage directly attributable to clearcutting and road development had occurred in lower Gardiner Creek. Similarly, Fitch’s (1980a-g) independent observations of channel damage in several other sub-basins confirm that road- and clearcut-related impacts are extensive in the Carbondale basin. These problems need to be corrected, and the recommendations of Sawyer and Mayhood (1998) remain appropriate for that purpose.

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