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Erosional processes and sediment yield in the upper Oldman River basin, Alberta, Canada

C. R. NEILL
Northwest Hydraulic Consultants Ltd, 4823-99 Street, Edmonton, Alberta, Canada
J. D. MOLLARD
J.D.Mollard and Assocs Ltd, 801 McCallum-Hill Building, Regina, Saskatchewan, Canada

ABSTRACT The upper Oldman basin descends eastward from the Continental Divide of the Rocky Mountains in southwest Alberta. Its 4000 km^2 area can be divided into Mountains, Foothills and High Plains. The paper discusses its sediment yield and the associated erosional processes. Suspended sediment yield averages 70 t km^{-2} $year^{-1}$, but varies greatly from year to year. This compares with a range of 20-100 elsewhere in Alberta and 0-350 in Canada generally. Principal erosional features identified include stream channel instability, ravine erosion, grassland gullying, wind erosion, and gravity-induced mass movements. An assessment of information obtained from airphoto interpretation and field reconnaissance indicates that erosional features are generally local in extent and are not creating widespread distress, that most present erosion is associated with streams and rivers, and that a substantial part of this is of natural geologic origin. The main source of man-made erosion appears to arise from public roads and associated interference with natural drainage. A potential for accelerated erosion appears to exist on grazing lands on substantial slopes. In the forest areas, erosion is minor compared to that in agricultural areas.

INTRODUCTION

The Oldman River basin in southwest Alberta, Canada, descends eastwards from the Continental Divide of the Rocky Mountains. The upper basin is drained by three rivers: the Oldman River from the northwest, the Crowsnest River from the west, and the Castle River from the south, all of which join together within a small area known as the Three Rivers site (Fig.1). Below the Three Rivers site, the Oldman River flows generally eastward and joins the Bow River to form the South Saskatchewan River, which continues generally north-east across the central prairies.

The area of the upper basin above the Three Rivers site is approximately 4000 km^2. From west to east, it can be divided into three physiographic segments (Fig.1): Mountains, generally forested; Foothills, mainly grazing land with small proportions of woodland and cultivation; and High Plains, about half grazing and half cultivated. A general view across part of the basin in shown in Fig. 2. The

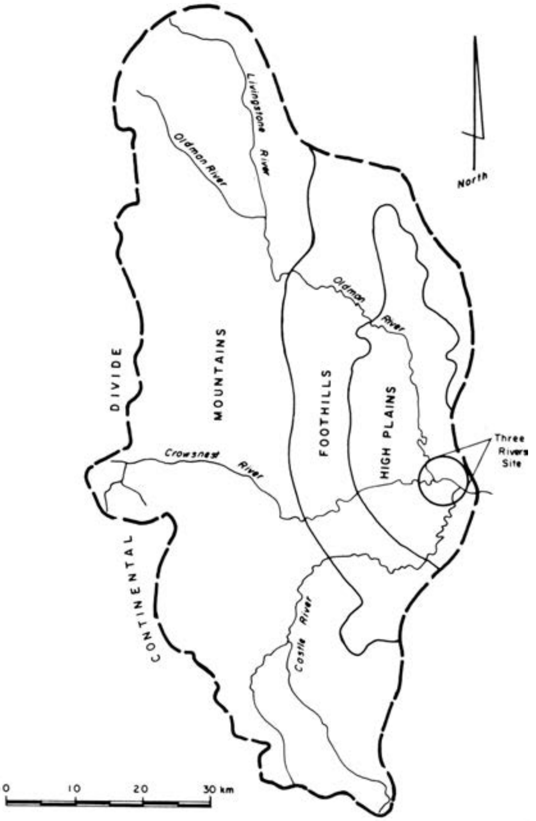

FIG.1 Key map of upper Oldman basin.

FIG.2 View to northwest across the Oldman River north of the Three Rivers site.

basin is extensively utilized for production of timber, cattle and dryland crops, and there are local areas of mining and gravel extraction as well as considerable activity in petroleum exploration and production. Farther downstream, the water of the Oldman River is used for irrigation on the lower plains. The upper basin, especially the mountain forest part, constitutes the main source of river flows. Various studies have been conducted relating to management of water resources, construction of dams, and land management, but at present there are no substantial river engineering works within the upper basin. A major dam has been proposed at the Three Rivers site.

The paper is based on studies conducted for the Government of Alberta (Northwest Hydraulic Consultants, 1978, 1980). Its principal objective is to illustrate the types of erosion associated with a known sediment yield in a submontane basin characterized by mainly local erosion.

SEDIMENT YIELD

Suspended sediment loads from the upper basin of the Oldman River have been measured since 1966. Table 1 shows annual water and sediment discharges over this period. The annual sediment yield averages approximately 70 t km^{-2}, but varies greatly from year to year. Elsewhere in Alberta, average annual yields are mostly in the range of 20-100 t km^{-2}. In Canada generally, they range from

TABLE 1 Annual runoff and sediment yields from the Upper Oldman River Basin (drainage area at station = 4400 km^2)

Year	*Runoff volume (km^3)*	*Suspended sediment yield (10^6 t)*	*Mean sediment concentration (mg l^{-1})*
1966	*1.20*	*0.106*	*88*
1967	*1.83*	*0.903*	*493*
1968	*1.16*	*0.078*	*67*
1969	*1.46*	*0.248*	*170*
1970	*1.03*	*0.127*	*123*
1971	*1.31*	*0.131*	*100*
1972	*2.09*	*0.683*	*327*
1973	*0.84*	*0.043*	*51*
1974	*1.69*	*0.277*	*164*
1975	*1.72*	*1.107*	*644*
1976	*1.31*	*0.177*	*135*
1977	*0.50*	*0.007*	*14*
1978	*1.36*	*0.222*	*1633*
1979	*0.96*	*0.088*	*92*
Mean	*1.32*	*0.30*	*188*
Standard devn.	*0.42*	*0.34*	*180*
SD/mean	*0.32*	*1.13*	*0.96*

virtually zero in the bedrock regions of the Canadian Shield to over 350 t km^{-2} in parts of British Columbia. The yields for Alberta are relatively low on the world scale; significant factors include long periods of freezing, good growth of vegetation, and fairly conservative land use. The yields are sufficiently high, however, to pose siltation problems in smaller reservoirs (Hollingshead *et al.*, 1973). Short term variability of sediment transport in the Oldman River is high: a large flood in 1975 carried more sediment in one day than is carried in the whole of an average year.

Soil loss studies have been conducted in two Alberta river basins to the north of the Oldman basin. In the Red Deer basin (Campbell, 1977), test plots in local areas of "badlands" along the valley suggested that most of the river's sediment load was derived from a few per cent of the basin area. In the Bow basin, Luk (1975) found that the highest sediment yields originated from the upper foothills areas. Overall yields from these basins average about 80 and 40 t km^{-2} $year^{-1}$ respectively.

EROSIONAL FEATURES

Helicopter reconnaissance, ground inspection and airphoto analysis were conducted in 1978 and 1980 to identify active erosion, to map indications of past and present erosion, and to assess potential for accelerated erosion related to land use and development. Principal erosional locations were mapped on a photo mosaic at approximately 1/100 000 scale, and typical features were identified and illustrated with photographs. In the mapping, distinction was drawn between (i) gravity-induced features, including landslides and solifluction, either active or inactive; (ii) fluvial features, including river bank erosion and channel shifting; (iii) rill and gully erosion on land surfaces; (iv) wind-induced erosion, mainly on valley bluffs; and (v) man-induced erosion from coal mining and gravel extraction areas.

It is tempting to speculate that prior to late nineteenth century European settlement, erosion was somewhat less than at present, because of more continuous forest cover in the mountains, longer grass on the foothills, and denser vegetative cover on stream banks and valley slopes. It is however virtually impossible to confirm such speculation. There is reason to believe the basin is in generally better condition now than it was in the 1930's, when persisting drought was accompanied by soil drifting and extensive forest fires. Concern over the situation at that time led to formation of the Eastern Rockies Forest Conservation Board, which operated from 1947 to 1972 with a mandate to conserve forests and protect watersheds.

Some of the types of erosion identified are illustrated in Figs 3-7 and described below:

(a) Stream channel instability in mountain valleys (Fig.3). This is typical of areas where forest cover has been removed from stream banks because of fires or infestation. Current harvesting practice leaves protection strips along streams. Sediment derived from such instability is mainly coarse bed load that does not travel far down the system.

FIG.3 Channel instability along upper Castle River in mountain valley.

(b) Ravine erosion in tributary streams draining areas of grazing land (Fig.4). This may have been accelerated by faster runoff from short-grass land and by cattle browsing and trampling on ravine slopes.

(c) Incipient gullying in grazing land: Figure 5 shows recent gully development resulting from careless diversion of road drainage across fields. Also evident is river bank erosion in thick deposits of glacial materials.

FIG.4 Ravine erosion in Oldman River tributary.

FIG.5 Recent gully development and bank erosion in glacial materials

(d) Wind erosion. The Three Rivers area is subject to some of the strongest winds in Canada, particularly in spring when vegetation is thin. Erosion occurs mainly on up-wind valley slopes (Fig.6).

(e) Gravity induced erosion. Particularly along the valley of the Oldman River north of the Three Rivers site, there is massive slumping of valley sides where the river attacks the toes of slopes and removes slumped material (Fig.7).

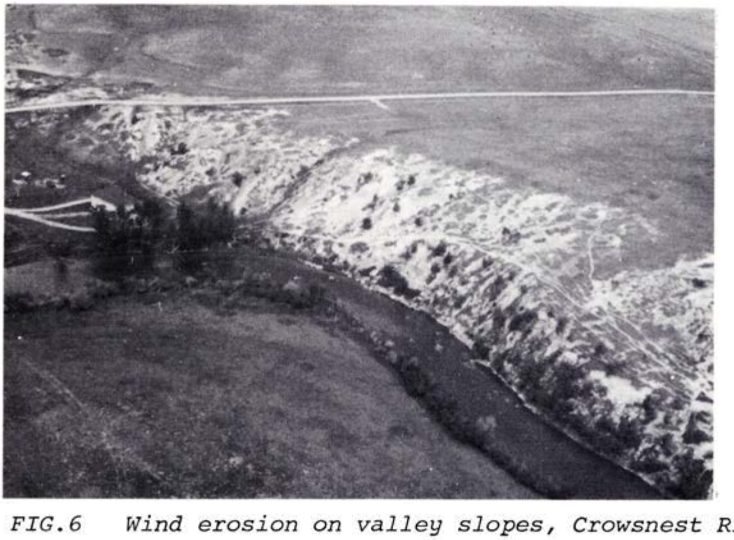

FIG.6 Wind erosion on valley slopes, Crowsnest River.

FIG.7 Recent massive landslide on Oldman River north of Three Rivers site.

GEOLOGICAL AND HYDROLOGICAL ASPECTS

The Oldman, Crowsnest and Castle Rivers through most of the Foothills and High Plains segments are downcutting in either bedrock or glacial drift. Much of this downcutting occurs within buried valleys that are presently being re-excavated by the rivers. Deep-seated landslide activity is mostly associated with two bedrock formations that contain weak bentonite layers in shale, siltstone and sandstone strata. When the rivers undercut these formations, sliding towards the river tends to occur. The recent massive slide shown in Fig.7 is believed to have been triggered by a particularly large flood in 1975.

The smaller stream courses in the High Plains are commonly eroded into glacial and glacio-lacustrine deposits. If peak runoff rates are accelerated by land use changes that retard infiltration or reduce surface detention, important changes like accelerated lateral activity, sheetwash and rill erosion, gullying, and valley widening may follow. Pressure on stream banks and valley slope vegetation by confined cattle herds is a potentially significant factor, the effects of which may become more important in future.

It is not possible at present to estimate reliably the contribution of various processes to sediment yield; however, there are indications that the massive landslide areas along the Oldman River north of the Three Rivers site are a major contributor. Short term observations of sediment loads at various upstream sites (McPherson, 1975) indicated considerably lower yields from the upper parts of the basin and principal tributaries than from the basin as a whole.

OVERVIEW OF EROSIONAL CONDITIONS

The general erosional situation in the upper Oldman basin can be summarized as follows:

(a) At present there are no extensive erosional problems that affect large areas. Erosional features are quite local, for the most part are not widely distributed, and in most cases do not appear to be causing widespread distress. Although a potential for more serious or widespread problems exists, these can be forestalled by continuing awareness and careful land management.

(b) Most present erosion is associated with running water. Obvious signs of wind erosion are confined mainly to bluffs and steep river valley slopes in the Three Rivers area, where wind has been a dominant agent since early postglacial time. There is however a considerable potential for wind erosion of cultivated land in the east part of the basin, and there are indications that it has been worse in past drought periods.

(c) A dominant form of erosion is landsliding and other forms of mass movement associated with geologic valley widening and deepening. This form of erosion probably supplies a large part of the sediment carried eastwards by the Oldman River. It does not appear to be significantly affected by human activity, and it cannot be significantly retarded by land management measures. Its prevalence in the distant past is evidenced by extensive areas of old stabilized landslides in the major valleys.

(d) Erosion of low river banks, associated with the shifting of channels within a valley bottom along the main rivers and their tributaries, is probably not an important net contributor to sediment outflow. It has probably been accelerated locally by ranching on valley bottom lands, where cattle damage protective vegetation and stream banks.

(e) The main source of man-induced erosion arises from public roads and associated interference with drainage. Other forms of linear and point development, such as seismic lines, pipeline rights of way, wellsites, etc. are not significant sources of erosion at present.

(f) In grazing land on substantial slopes, there is some incipient gullying of surface drainage courses, indicating a potential for future problems. This may be due in part to accelerated runoff and reduced infiltration capacity.

(g) There is a certain amount of soil loss during rainstorms from fallow land and seeded fields in the High Plains segment.

(h) Present forestry practice is not causing significant erosion in the Foothills and Mountain segments. Even where logged slopes have been stripped to mineral soil, the coarse-grained nature of the surface soils inhibits significant erosion. Reclamation and re-seeding of abandoned mining areas on steep slopes have produced quite impressive results.

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