RC-East, Eastern Afghanistan, GA-ADT, Wardak Province, Chak E Dam, Sluice Canal Sediment Analysis

Henry F. Shovic, PhD

Mar 17, 2012

Completed under CERP contract 20111011143900 for GA-ADT, RC-East

The purpose of this analysis is to review the Chak E Dam sluice canal with the objective of 1) estimating sediment load in the canal, and 2) discussing feasibility of potential improvements. Methods include use of QuickBird satellite imagery (copyright Digital Globe, Inc.) at 1 m resolution; BUCKEYE ortho imagery at 0.1 m resolution; digital terrain data at 5 m and 1 m resolution; and available geologic data, standard operating procedures for treatments, and soils/infrastructure data. The entire canal was canvassed at scales of 1:200 to 1:800. ARCMAP and ARCGLOBE were used for planar and perspective analysis. Images were rendered in color infrared (CIR) for vegetation and soil analysis, but are displayed in gray or brown scale for ease of use in maps. Groundwater relationships are based on general knowledge of hydrology of Afghanistan and review of geologic and physiographic spatial data; as well as client-provided ground data.

The Chak E Dam

This dam (Figure 1) is the oldest dam in Afghanistan, built in 1938. Its purposes are to regulate flow of irrigation water in the Chak Valley and to provide hydro-electric power. Its designed capacity is 3.3 mW, but apparently only one of its three generators is functional now. It is 304 m long and 10 m high. The reservoir appears to have a high level of accumulated sediment, probably due to its age, since the contributing river is relatively stable. This dam was evaluated in the SEAFWRA (South East Afghanistan Water Resources Assessment) and concluded "Chak should be prioritized highly for repairs". The contributing watershed is 441,500 ha with a mean annual discharge of 6.66 m^3/s, and average annual runoff of 477 m^3/ha. The area surrounding the dam is primarily eroded, medium-textured unconsolidated sediments with little bedrock .

There is a gated canal originating in the northern corner of the dam (Figure 1). This canal leads to a powerhouse and irrigated fields about 4 km downstream (Figure 2).

Figure 1. The Chak E Dam in Wardak Province (Nov 2008)

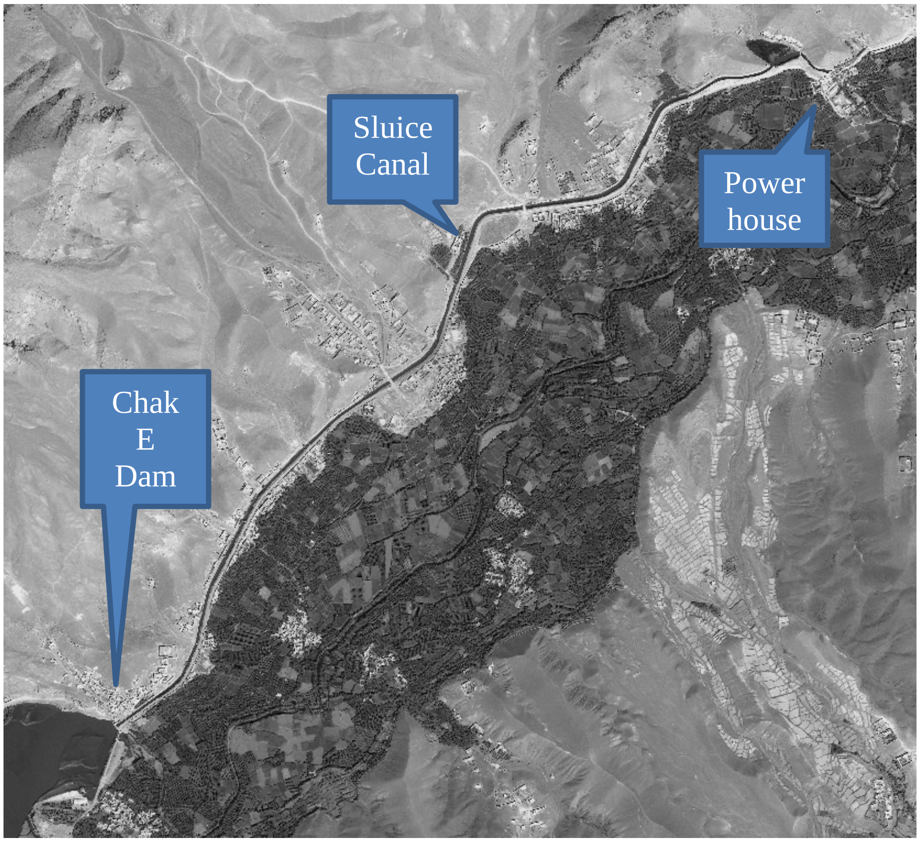

Figure 2. The Sluice Canal at Chak Dam

Methods

Estimates were produced from detailed imagery and associated digital elevation models from the BUCKEYE program, available documentation, and limited ground truth provided by clients. Points of interest were identified and mapped on the accompanying detailed map *RC-East, Eastern Afghanistan, GA-ADT, Wardak Province, Chak E Dam, Sluice Canal Sediment Analysis.*

The prime objective of this analysis was to estimate existing sediment quantities in the canal, with the eventual goal of removal to improve usage. The canal has a very low gradient. Elevations at the top of sediments in the canal are actually higher near the powerhouse gate than at the inlet (2189 m vs. 2187 m), indicating significant ponding at the lower end. A client-provided elevation of the bottom of the inlet gate is 2184 m, and 2171 m at the pipe above the power station, implying at least a 3 m sediment depth near the entrance gate, and deeper near the powerhouse.

Segmenting of Canal

The sluice canal was segmented by characteristics (Figure 3). Segment One includes the concrete inlet, with relatively vertical walls, and an average bank width of 10.5 m. Segment Two has a wider, less maintained channel with sloping sides and an average width of 17.6 m. The adjoining road is slightly above the channel. Segment Three shows effects of flooding from an alluvial fan north of its starting point, has more existing dredging, and the adjoining road is below the elevation of the channel with a protective berm. Its average width is 21m. Segment Four is outside of the BUCKEYE imagery footprint, so has less accurate measurements. It is similar to Section One in width and channel character.

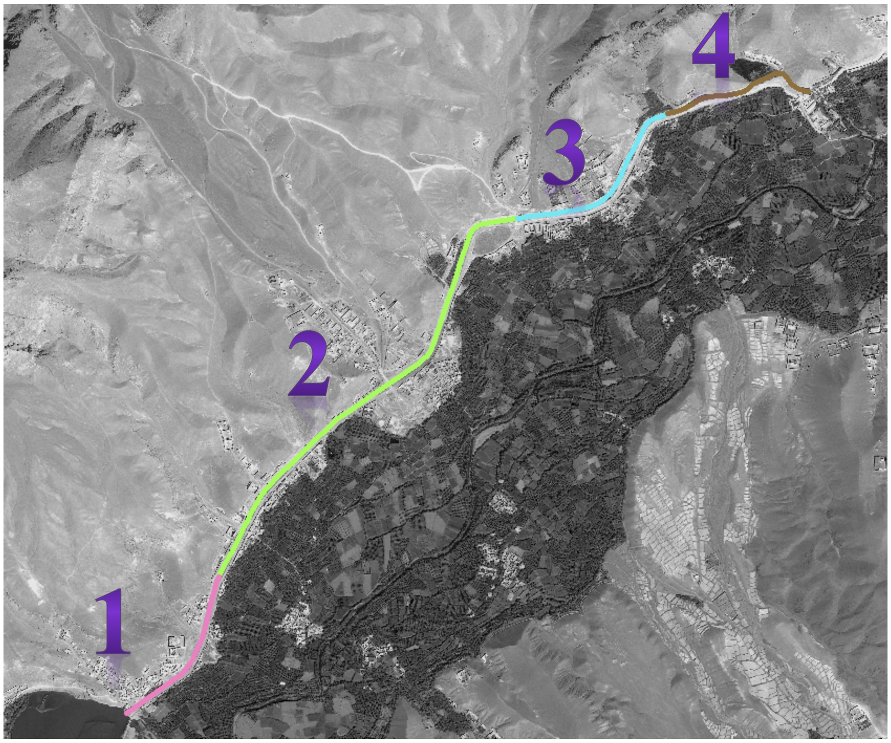

Figure 3. Sluice Canal Channel Segments

Sediment Estimation

Existing sediment levels were estimated using a trapezoidal cross section with an estimated 4 m flat bottom. Channel width, sediment layer width, and exposed sideslope width were estimated from 1:200 scale imagery (Figures 4 and 5). Sediment elevation was estimated from the July 2010 elevation model (Figure 6), since the corresponding imagery (Figure 5) appears to show very shallow water depths at that time. Side slope length, depth, and side slope angles were generated for six representative cross sections (two for each channel Segment, POI's 38 – 43 from Table 2 below and on detail map) overlaid on a rectified digital elevation model, and cross sectional areas were calculated trigonometrically.

Figure 4. Representative Section of Sluice Channel: Nov 2010. Red lines are channel width, sediment width, and exposed sideslope width resp.

Figure 5. Representative Section of Sluice Channel: July 2010. Red lines are channel width, sediment width, and exposed sideslope width resp.

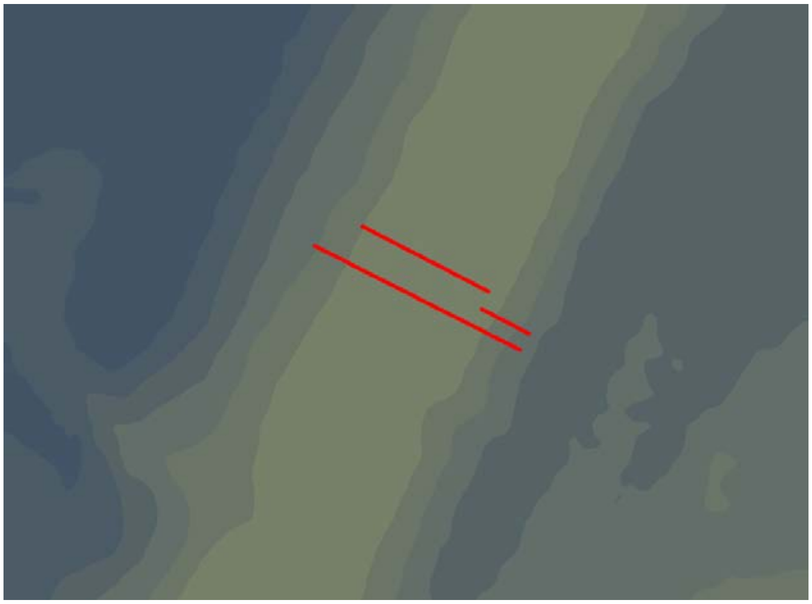

Figure 6. Representative Section of Sluice Channel: Elevations in July 2010. Red lines are channel width, sediment width, and exposed sideslope width resp.

Results

Sediment quantities were estimated for each Section, based on a trapezoidal cross section (Table 1). Channel Segment Four was estimated from parameters generated from Segment One. Channel shapes vary widely, depending on conditions in the Segment, such as proximity to the road, upslope construction, flooding potential from alluvial fans, and construction materials. Presently available capacity was calculated using a trapezoid above the current sediment level for each Section, averaged for each Segment, leaving 1 m freeboard. These also vary widely due to conditions and channel shape.

Table 1. Sediment Quantities by Channel Segment

Channel Segment	Channel Segment Length (m)	Average Area of Sediment in Trapezoidal Cross Section (m^{2})	Sediment Volume (m^3)	Capacity Presently Available (m^2)	Increase in Capacity with Sediment Cleaning (%)
1	653	31.9	20,831	14.4	69
2	1,855	23.6	43,778	36.9	39
3	754	22.4	16,890	25.0	47
4	586	31.9	18,693	14.4	69
Totals	3,848		100,192		

There is significant sediment in the channel (Table 1). Based on average workload, a mechanized scraper could probably complete sediment removal in a month or so. Sideslopes are moderate (10 to 40 degrees) so excavated access points will be needed for mechanized or manual hauling. Spoil locations are common along the route within 500 m of the canal, with some opportunities for land application as well as existing spoil sites from previous dredging (see discussion below for locations).

Benefits of canal cleaning include an increased water capacity (from 47 to 69%), and probably a better use of hydropower equipment, since it is probable the intake penstocks are partially covered by sediment, or gates are partially closed. Of course this should be tempered with the available head at the Chak Dam, which may be low due to heavy sediment accumulation that reduces potential flows.

These estimates are based on remote sensing, so should be verified in the field. However, client provided elevations show at least 24 m^2 sediment area in Segment One, relatively close to the canal inlet. This is reasonably close to those given in Table 1. Also, if the client-provided elevation at the powerhouse inlet elevation is at the bottom of the inlet pipe, then it is likely at least partially buried.

Points of Interest

Descriptions and MGRS locations are in Table 2. There are eleven bridges spanning this canal, with at least one (POI 16)serving as a floodway for intermittent floods from an upslope alluvial fan (POI 18). This area also has significant bank collapse (POI 17) and has evidence of berm and flow control spoil piles (PI 18). It is a major source of sediment to the canal, and a potential hazard to the adjoining road which is below the elevation of the canal (POI 44). There are two other active alluvial fans that also contribute intermittent sediment to the channel (POI's 31, 36). These areas could benefit from redesign and structural improvements of channel sideslopes.

There are opportunities to reduce sediment from local channel sideslopes. POI's 7, 8, 10, 14 22, 23, and 35 show active sediment additions via local gullying. Upslope drainage could be improved.

Active dredging with adjacent spoil piles are at POI 1, 21, 24, 31, 32, and 37. These are potential sites for additional spoil piles. There are many possible sites for land application of sediment (for agriculture). These were identified by presence of annual crops, road access, proximity, apparent barren land, and slope. POI's 45 – 62 show these locations distributed along the channel.

Table 2. Points of Interest on the Sluice Canal

ID	Point of Interest	MGRS
1	Dredging Channel Side Slope below Bridge	42SVC6212775345
2	Bridge	42SVC6115574095
3	Bridge	42SVC6117074106
4	Bridge	42SVC6141174365
5	Bank Collapse - Channel Narrows	42SVC6154874760
6	Bridge	42SVC6158274808
7	Gullies Entering Channel	42SVC6163574921
8	Gullies Entering Channel	42SVC6178975073

9	Bridge	42SVC6181575086
10	Gullies Entering Channel	42SVC6203475253
11	Bridge - Major	42SVC6211175316
12	Intermittent Floodway - Floodway is Bridge	42SVC6213475288
13	Channel Narrows	42SVC6213475334
14	Gullies Entering Channel - Channel Narrows	42SVC6227675470
15	Road Paved to East	42SVC6217075330
16	Bridge – Major and floodway	42SVC6259575940
17	Bank Collapse	42SVC6257075948
18	Active Alluvial Fan with Berms	42SVC6259075981
19	Bridge	42SVC6287375984
20	Channel Narrows	42SVC6286275982
21	Active Dredging	42SVC6286175991
22	Gullies Entering Channel	42SVC6287976004
23	Sedment From Gullies in Channel	42SVC6289075997
24	Dredging - Active	42SVC6297276092
25	Bridge - Pedestrian ?	42SVC6305776245
26	Bridge - Pedestrian ?	42SVC6319076345
27	Bridge - Pedestrian ?	42SVC6326876387
28	Channel Widens	42SVC6353976476
29	Bridge	42SVC6359476493
30	Alluvial Basin	42SVC6350876495
31	Spoil Piles - Dredging	42SVC6285076012
32	Spoil Piles - Dredging	42SVC6294776074
33	Intermittent Floodway	42SVC6260275894
34	Intermittent Floodway	42SVC6259075963
35	Gullies Entering Channel	42SVC6280375980
36	Active Alluvial Fan	42SVC6292176078
37	Dredging	42SVC6294376037
38	Cross Section 1	42SVC6218875369
39	Cross Section 2	42SVC6185775127
40	Cross Section 3	42SVC6143674469
41	Cross Section 4	42SVC6118674115
42	Cross Section 5	42SVC6277375966
43	Cross Section 6	42SVC6300476137
44	Berm To East - Road Below Channel Elevation	42SVC6262375933
45	Potential Land Application	42SVC6123674083
46	Potential Land Application	42SVC6142574284
47	Potential Land Application	42SVC6152774603

48	Potential Land Application	42SVC6168574710
49	Potential Land Application	42SVC6163474817
50	Potential Land Application	42SVC6181074983
51	Potential Land Application	42SVC6196175049
52	Potential Land Application	42SVC6212275244
53	Potential Land Application	42SVC6225475312
54	Potential Land Application	42SVC6231275433
55	Potential Land Application	42SVC6234775491
56	Potential Land Application	42SVC6240675703
57	Potential Land Application	42SVC6246875845
58	Potential Land Application	42SVC6312876208
59	Potential Land Application	42SVC6331476377
60	Potential Land Application	42SVC6354276382
61	Potential Land Application	42SVC6357776454
62	Potential Land Application	42SVC6305376020