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Потенціал водної ерозії річки Конго в затоці Стенлі-пул

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У цій статті проведено наукове дослідження розуміння процесів ерозії та перенесення завислих твердих речовин або осадів із річки Конго в затоку Стенлі-Пул. З цією метою було виконано обробку даних про кількість опадів за три десятиліття (1990-2020), параметрів, які впливають на процес ерозійної динаміки, що обумовило створення карти водної ерозії за допомогою універсального рівняння втрат ґрунту (USLE). Використовуючи просторові дані відкритого доступу та ГІС, ця модель USLE дозволила кількісно визначити швидкість транспортування матеріалу протягом трьох десятиліть: розподіл ризиків ерозії на правому березі річки Конго, зокрема в затоці Стенлі-Пул,в рельєфі якої переважають круті схили до 10%, виявлено високу ерозійність та еродованість та низьку ґрунтозахищеність.

Нарешті, результати дослідження показують, що близько 40% досліджуваної території піддається втраті ґрунту. Ризик ерозії є дуже великим, незважаючи нанаявність рослинного покриву.

Ключові слова: *перенос твердих речовин, відкладення, моделювання, моделі, басейн Стенлі, річка Конго*.

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APPLICATION OF HEC-RAS MODEL TO ANALYZE OF SEDIMENT TRANSPORT DYNAMIC PRE AND POST CONSTRUCTION OF FALL STRUCTURES AT LOWER NARA CANAL OFF-TAKING FROM UPPER NARA CANAL, SUKKUR BARRAGE, INDUS RIVER, SINDH, PAKISTAN

This paper presents the research study using the HEC-RAS model to evaluate sediment dynamic problems in lower Nara canal pre and post-construction of fall structures at RD-77 and 101 respectively which is a major tributary of upper Nara canal that off-takes from Sukkur barrage on the left bank of Indus River. As a result, the hydraulic model has computed longitudinal and cross-section, velocity, water surface profiles, and sedimentation dynamics. Sediment transportation without fall structure is aggradation (5.75 ft and degradation (4.50 ft) and with fall structure aggradation (4.25 ft) and degradation (2.75 ft) respectively. Sediment transportation without fall structure is aggradation 500,000 tons and degradation 225,000 tons and with fall structure aggradation 155,000 tons and degradation 125,000 tons. Sediment transportation without fall structure is degradation 600,000 tons and with fall structure is aggradation 110,000 Tons and degradation 165,000 Tons. Sediment transportation without fall structure is aggradation 1,750,000 Tons and with fall structure is aggradation 1,300,000 Tons. Hence the results of the model revealed that aggradation at u/s and degradation at d/s of fall structures that is a true representation of the behavior of fall structures. Whereas, the section is wider than aggradation occurred and degradation is experienced in narrow sections in both scenarios (with and without fall structures). The positive impact of constructed fall structures was analyzed on the morphology of the canal. Hence, the construction of fall structures are essential at the change of country/steeper slope to avoid unnecessary erosion.

Key words: *HEC-RAS model, lower Nara canal, Indus River, fall structure, sediment transportation, aggradation degradation.*

Introduction. Large Rivers of World have been receiving Average suspended load annually, Amazon (1200 MT), Huanghe (Yellow) (1080 MT), Ganga-Brahmaputra (1060 MT), Changjiang (Yangtze) 480 MT, Mississippi, 400 MT, Irrawaddy, 260 MT. Indus, 259 MT with delta 29524 km^2 . Indus River receives sediment Load material from two origins: catchment and its banks and bed. It changes behavior and location with temporal, spatial varying channel dimension and pattern and frequently flooding. Morphology of Indus braided with high to low meanders, Reach of the river, where Sukkur barrage is located, has great variability of sediment. Prior to construction of barrages and dams the annual sediment load ranged from 270 to 600 MT (Kimani,1993). Estimated Heavy Sediment load is about 200 MT per year in Tarbela reservoir. And about average 330 MT at Kotri d/s of Sukkur barrage (Karim, A. et al.,2000). Average annual sediment load in the Indus River at Sukkur was 360 MT during 1902 to 1960. Average Sediment Load 0.715 MT per day, Thus approximately 260 MT per Year (Feasibility of Study Sukkur, 2006). Rivers are affected by natural and human factors; rivers usually undergo severe erosion on bed or banks, sedimentation and sectional movements. These factors caused dramatic changes to rivers in long run leading to what is known as geomorphological changes. One of the key topics in river engineering is to investigate river morphology that describes the river geometry, bed shape and longitudinal profile, cross-sections and changes of river shape (Van Rijn, L.C., 1993, Graf, W.H., 1984). Sediment deposition is a culprit in the slow reduction of aquatic habitats and increased water velocity, which changes the morphology of rivers (Ehteram, Ghotbi et al. 2019)

Silting of reservoirs and rivers is another important aspect of sediment transport, the storage capacity of reservoir is reduced by its silting, thereby, reducing its use and life. The design and execution of a flood control is chiefly governed by the peak flood levels, which in turn, depends on the scour and deposition of sediment. Firstly, the bed levels may change by direct scouring of deposition of sediment; and thereby changing the flood levels. Secondly, the scouring and silting on the river banks may create sharp and irregular curves, which increase the flow resistance of the channel, and thereby, raising the flood levels for the same discharge. The phenomenon of sediment transport causes large scale scouring and siltation of irrigation canals, thereby increasing their maintenance. Many poorly designed artificial channels get silted up so badly, then they soon become inoperable, causing huge economic loss to the public exchequer. The artificial channels should, therefore, be properly designed, and should not fail to carry the sediment load admitted at the canal head works. Sediment transport, thus, poses numerous problems, and is a subject of great importance, and possesses enough potential for further research and development. The sediment in a canal is a burden to be borne by the flowing water, and is therefore designated as sediment load. The sediment may move in water either as bed load of as suspended load. Bed load is that in which the sediment moves along the bed with occasional jump into the channel. While, the suspended is the one in which the material is maintained in suspension due to the turbulence of the following water (Santosh,2007).

Lane’s principle provide visual approach to the interaction b/w the main variables of a river/canal water discharge, slope, and sediment load and sediment size. In this simplified qualitative the river tries to achieve its dynamic equilibrium by adjusting these four main variables. When reduction in water discharge (due to diversion, the river/canal will try to restore its equilibrium by deposing the excess of sediment load (aggradation) Lance’s Balance (Raudikivi, 1993).

The sediment particles’ movement incorporates two key dreg transport modes, bed and suspended load. The bed load which moves very near to the bed is of main concern. The sediment is transported by flowing water and/or it slides along the bed or bounces instantly over the bed. The bed load transport is accumulated when there is low velocity with stream heavier grain sizes. While suspended load occur more at higher stream smaller/lighter grain size moves along the bed and are kept in suspension with moving water (Susana, et al., 2011).

Sediment transport capabilities have been added to the Hydrologic Engineering Center’s River Analysis System (HEC-RAS). HEC-RAS can be used to perform sediment routing and mobile bed computations. The existing in HEC-RAS to compute a series of steady flow profiles used to develop hydrodynamic parameters for sediment transport. The result is a continuous simulation of the change in cross sections as sedimentation processes adjust to the hydraulic conditions imposed by the inflowing water- sediment hydrograph and the base level control boundary conditions.

Sediment routing and mobile boundary simulations are commonly employed in support of various U. S. Army Corp's of Engineer missions. However, many of the core capabilities of HEC-6 have recently been incorporated into HEC- RAS, leveraging the robust, existing, hydrodynamic capabilities in RAS and providing helpful user interfaces for one dimensional sediment transport modeling. The study by Ghimire and De Vantier used a one-dimensional HEC-RAS numerical model integrated with Arc-GIS to develop a sediment deposition model at the Olmsted Locks and Dam area (Ghimire GR et al., 2016). When flow velocity increases gradually over a sedimentary bed, the motion of sediments occur if the bed shear stress (available shear stress) induced by the flow exceeds a certain critical value of shear stress (Ahmad et al., 2011). Flow regime is mainly impacted by interactions of diverse hydraulic and hydrodynamic forces. This leads to a dynamic river system and changing cross-sections due to periodic sedimentation and erosion (Delphi, M., et al., .2010)

Most of the canal network on Indus Basin Irrigation System (IBIS) is directly fed from rivers that may carry heavy sediment particles; heavy silt particles may settle down in canal beds which create serious operation and maintenance problems. Sediment flow in natural channels and rivers varies in several ways in irrigation canals. Though irrigation canals and river both are much similar at the same time there are also many variations such as the width ratio, sediments load, the hydraulics and dynamics (Galappatti, 1983). The design system of canals is adopted in such a way that most of sediment particles remain suspended and being distributed into off-taking canals to reach in irrigation fields. Despite this, these particles tend to settle down and become problem in canals' operation and maintenance. Thus, frequent canals' maintenance and de-siltation is required to keep the canal operational that cause an additional burden on national economy (Munir, 2011),

Nara Canal off-takes from left bank of Sukkur Barrage located on Indus River. This canal reaches its tail after traversing a distance of about 119 canal miles (595RDs) from its head regulator. The Jamrao Weir/Head Regulator controls the flows into the Lower Nara Canal. Two canals namely Jamrao Canal and Jamrao Twin Canal off-take from the right side, as well as the Ranto Canal (which also feeds Chotiari Reservoir) off-takes from the Nara Canal on the left side at the Jamrao canal (SIDA report 2015).

The bed load logically is dependent on the local properties of the channel so that the most of sediment discharge formulae predict bed-load discharge. The bed load formula was chosen mainly because the forecast of suspended sediment transport is more difficult. Most of the sediment discharge formulas predict bed and suspended load discharge, because bed load is logically dependent on the local properties of the channel. The prediction of suspended sediment transport is more difficult since the transport at any cross section depend on the balance between the particles in suspension and their deposition from suspension over a long up stream reach.

Irrigation canals receives high silt load directly from Indus River. Beside this, erosion in canal banks, scour bed as well as non-cohesive bed material further increase the problem. Design of canals' system is made to sustain and maintain regime conditions as most of sediment particles remain in suspension and being distributed into tertiary canals to reach in agricultural fields. Sediment particles tend to settle down in canals due to wider sections having low velocity which create severe silt deposition resulting to reduce the water carrying capacity system. Canal requires de-siltation to keep section capable for taking design discharge which is very costly. To analyze dynamic sedimentation behavior and morphological conditions of the Lower Nara Canal. To analyze dynamic sediment transport impact on Lower Nara Canal profile after construction of Fall structures at RD-77 and RD-101

Study Area and methodology of Using HEC-RAS Model. Study was carried out on Lower Nara canal which receive Water from main Nara canal which off-takes from Sukkur barrage on its left bank. Nara is the largest canal in Sindh, having length of 364 kilometers with its designed capacity of 13,602 cusecs. It behaves like a river and about two million acres of agricultural land is irrigated by this canal. The Upper Nara canal exhibits varying hydraulic gradient with wider and narrower sections at a number of locations. The major problems of the Nara canal are excessive quantities of silt delivered through the system due to erosion from the canal prism as a result of scouring at upstream or silt fed into the Nara canal system at the head regulator of upper Nara canal, and the reduced discharge provided to the lower Nara canal. The currently three fall structures were constructed (as shown in fig.1) along the Nara canal to stabilize the flow regime and curb the menace of silt deposition. One of these three fall structures is located at RD 550 of upper Nara canal, second and third at RD 70 and RD 110 respectively of lower Nara canal. The study has also been carried out to find out and analyze dynamic sediment transport impact on Lower Nara Canal profile after construction of fall structures at RD-77 and RD-101.

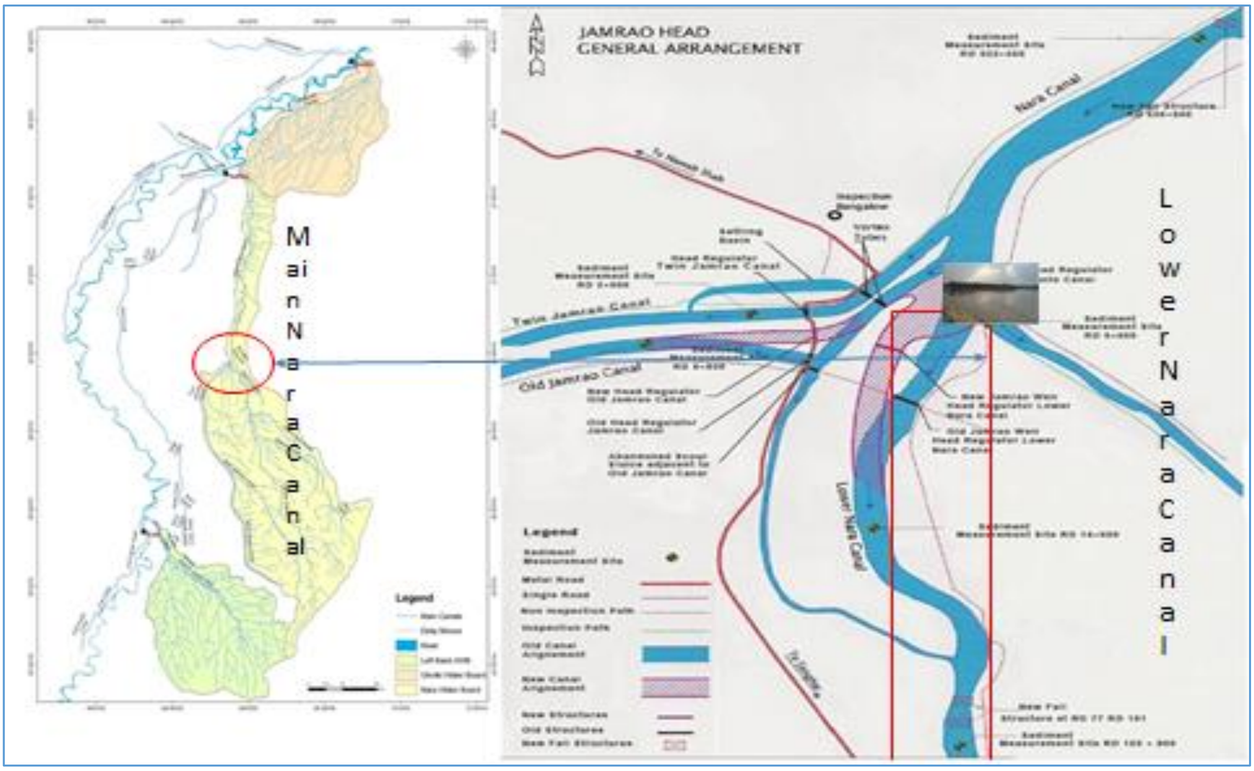


Fig.1. **Shows Study area**

Sediment Transport. Used for calculation related to geomorphological changes in long run, erosion and sedimentation on river and canals bed, changes of roughness factor in floodplain in sediment management (Smadi-Boroujeni, et al. 2008).

HEC-RAS Model. Sediment computations in HEC-RAS utilize one dimensional, cross-section averaged, hydraulic properties from RAS's hydraulic engines to compute sediment transport rates and update the channel geometry based on sediment continuity calculations. This Hydrodynamic HEC-RAS model has been developed by Hydrologic Engineering Center of the US Army Corps of Engineers (USACE) which can perform: i) Unsteady flow analysis in Rivers/Channels; ii) Water Quality analysis, iii) Sediment Transport analysis, iv) Hydraulic Design functions regarding (barrages, bridges, spillways, culverts, weirs and drops) (Manual HEC-RAS, 2017). Geospatial capabilities have been added to the Hydrologic Engineering Center's River Analysis System (HEC-RAS) to allow the hydraulic engineer to more efficiently develop hydraulic models through visualization of model results and refinement of model geometry within a consistent modeling environment.

Method for computing process using HEC-RAS Model: The fig.2 reveals that at initial stage data should collected for preprocessing. This data sets have been used/applied for running the Model for hydraulic simulation and further model has been calibrated and validated with Manning N values and computed the results.

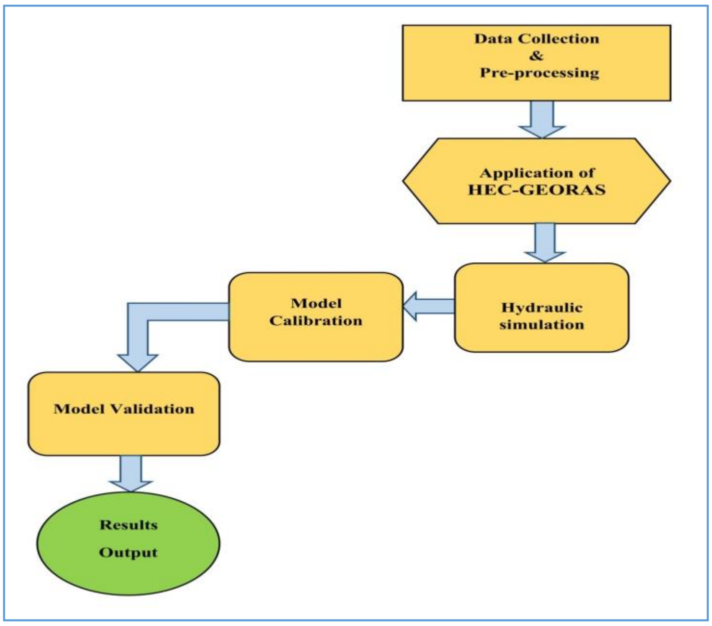


Fig.-2 **Shows computing process for application of HEC-RAS Model**

Input to the Model. ***Geometry Data:*** i) Design parameters of Hydraulic structures ii) longitudinal and cross-section survey of Canal. iii) Remotely sensed freely available Digital Surface Model (DEM) The Digital Surface Model (DEM) has been downward and Cross-section Longitudinal section has been digitized as project area (sea fig.3).

Fig.3. **Shows Canal Profile and L-Section of Lower Nara RD 01-165**

Sediment Data: i) Initial conditions and Transport Parameters; ii) size distribution; iii) Gradation Curve.

The data of sediment samples taken from the canal reach with discharge including grain sizes of canal bed and D50 as shown in table 1.

Table1. **Shows Discharge and sediment Concentration**

Canal			High Flow (July, 2014) Measurements Data			
			Sediment Concentration			
	Location	Q	Clay	Silt	Sand	Total
	RD	Cusecs	ppm	ppm	ppm	ppm
lower Nara	8+200	6,043	252	764	168	1184

	Location	Low Flow (April, 2014) Measurements Data				
			Sediment Concentration			
		Q	Clay	Silt	Sand	Total
	(RD)	Cusecs	ppm	ppm	ppm	ppm
Lower Nara	8+200	2,882	41	303	166	510

Six different transport functions are currently available in RAS including Ackers and White (1973), Englund- Hansen (1967), Laursen (1958), Myer-Peter-Muller (1948), Toffaleti (1968), and Yang (1972). Total transport capacity is calculated by invoking the *similarity hypothesis* (Armanini, 1992 and Vanoni 1975 after Einstein, 1950) by dividing the sediment gradation curve into discrete size classes, independently computing a transport potential for each size class and then weighted by the relative abundance in the active layer.

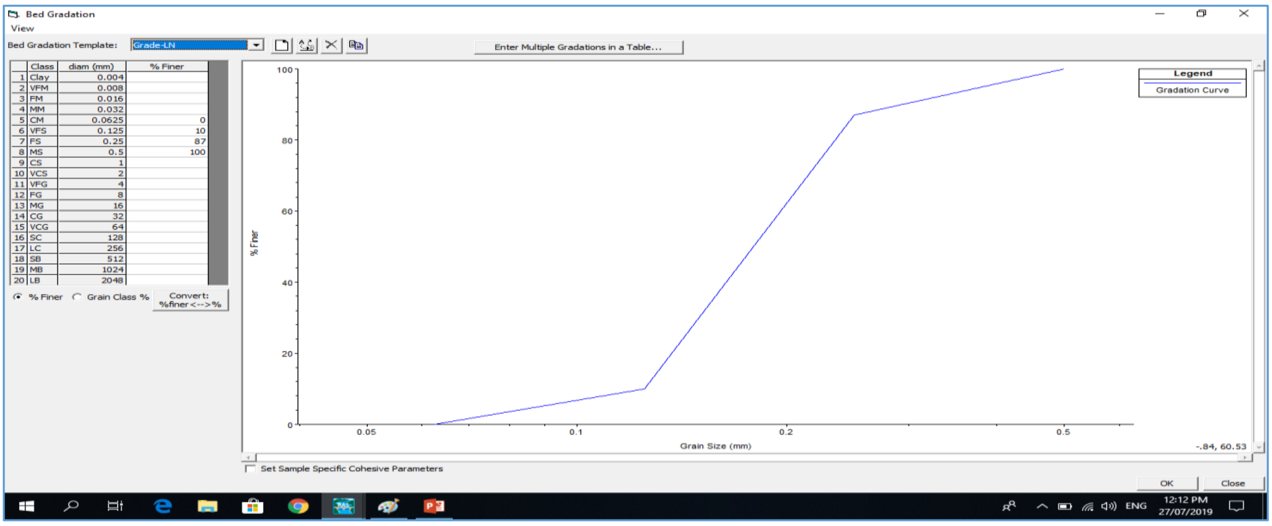


Fig. 4. **Bed Material Gradation Curve**

Boundary Conditions. i) U/s Condition (Flow Series) ii) D/s Condition (Normal Depth) and iii) Gate Openings. Flow specification for sediment transport computations currently follows the "quasi-steady" flow approach of HEC-RAS. An event or period of record is approximated by computing a series of steady flow profiles (Fig. 1). Each of these each steady flow profiles is then associated with a duration and transport parameters are generated at each crosssection. Usually, however, bathymetry updates are required more frequently than the flow increment duration, so a computational time step is specified. The geometry file is updated and new steady flow hydrodynamics are computed at the beginning of each computational time step.

Results and Discussion. The Geometry data, Hydraulic Data and Sediment Data have been given to HEC-RAS of Model for computing hydraulic and discharge parameters such as total discharge maximum and minimum velocity water surface elevation flow width and Froude No. (see Fig.6) and Model has computed sediment transport.

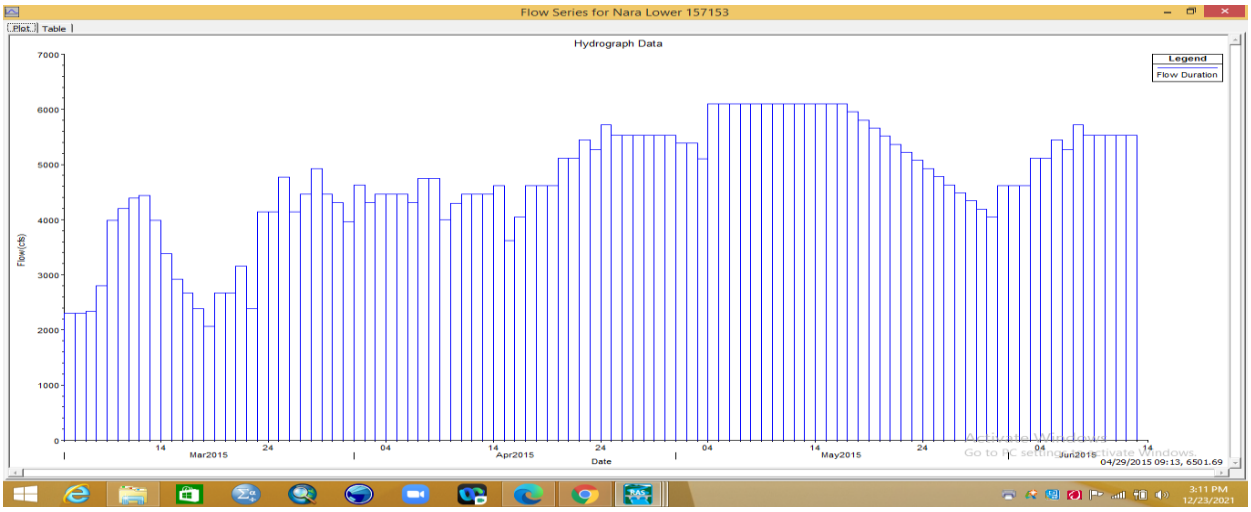


Fig.5. **Hydrograph as boundary condition**

Table 2. **Shows hydraulic parameters**

Profile Output Table - Standard Table 1

HEC-RAS Plan: 05 River: Nara Reach: Lower Profile: 09Jun2015 0000

Reach	River Sta	Profile	Q Total (cfs)	Min Ch El (ft)	W.S. Elev (ft)	Crit W.S. (ft)	E.G. Elev (ft)	E.G. Slope (ft/ft)	Vel Chnl (ft/s)	Flow Area (sq ft)	Top Width (ft)	Froude # Chl
Lower	152146	09Jun2015 0000	5529.20	94.64	104.04		104.10	0.000125	2.04	2716.84	349.72	0.13
Lower	147146	09Jun2015 0000	5529.20	92.99	103.38		103.45	0.000137	2.01	2746.84	383.23	0.13
Lower	142146	09Jun2015 0000	5529.20	90.56	102.62		102.70	0.000162	2.32	2383.49	301.39	0.15
Lower	137145	09Jun2015 0000	5529.20	92.75	101.96		102.02	0.000114	1.85	3003.12	423.40	0.12
Lower	132147	09Jun2015 0000	5529.20	87.48	101.37		101.44	0.000116	2.06	2679.89	315.03	0.12
Lower	127145	09Jun2015 0000	5529.20	89.61	100.95		101.00	0.000067	1.73	3195.33	321.52	0.10
Lower	122145	09Jun2015 0000	5529.20	87.53	100.59		100.64	0.000077	1.80	3067.99	322.42	0.10
Lower	117146	09Jun2015 0000	5529.20	87.77	100.13		100.19	0.000107	1.94	2858.04	357.63	0.12
Lower	112145	09Jun2015 0000	5529.20	86.68	99.74		99.78	0.000064	1.72	3216.66	357.02	0.10
Lower	107146	09Jun2015 0000	5529.20	81.42	99.56		99.58	0.000025	1.26	4387.87	356.04	0.06
Lower	102145	09Jun2015 0000	5529.20	80.33	99.46		99.48	0.000017	1.16	4769.55	348.86	0.05
Lower	97144	09Jun2015 0000	5529.20	85.13	99.32		99.35	0.000037	1.41	3919.61	427.57	0.07
Lower	92148	09Jun2015 0000	5529.20	91.48	98.95		99.02	0.000158	2.05	2703.37	436.44	0.14
Lower	91271.84	09Jun2015 0000	5529.20	91.17	98.45		98.52	0.000175	2.11	2617.77	432.37	0.15
Lower	91020.48	09Jun2015 0000	5529.20	87.31	98.40	89.94	98.43	0.000048	1.47	3873.68	443.62	0.08
Lower	90077		Inl Struct									
Lower	89043	09Jun2015 0000	5529.20	83.62	94.33		94.39	0.000093	1.97	2801.39	300.31	0.11
Lower	87144	09Jun2015 0000	5529.20	83.72	94.05		94.14	0.000182	2.37	2335.60	346.18	0.15
Lower	82144	09Jun2015 0000	5529.20	84.99	92.93		93.04	0.000269	2.72	2031.57	299.03	0.18
Lower	77143	09Jun2015 0000	5529.20	79.79	91.64		91.76	0.000244	2.79	1980.70	256.16	0.18
Lower	72144	09Jun2015 0000	5529.20	81.19	90.40		90.52	0.000252	2.79	1980.36	265.01	0.18
Lower	66305.85	09Jun2015 0000	5529.20	78.68	89.92	81.90	89.95	0.000058	1.52	3635.20	406.03	0.09
Lower	66147		Inl Struct									
Lower	66055.6	09Jun2015 0000	5529.20	80.23	88.51		88.59	0.000188	2.21	2506.65	386.84	0.15
Lower	65081	09Jun2015 0000	5529.20	79.90	88.47		88.54	0.000165	2.12	2609.29	387.74	0.14
Lower	62144	09Jun2015 0000	5529.20	77.85	88.27		88.37	0.000195	2.48	2227.60	297.73	0.16
Lower	57144	09Jun2015 0000	5529.20	78.55	87.36		87.45	0.000171	2.34	2359.04	308.01	0.15
Lower	52145	09Jun2015 0000	5529.20	76.76	86.57		86.65	0.000149	2.29	2411.82	289.62	0.14
Lower	47146	09Jun2015 0000	5529.20	76.80	86.08		86.13	0.000075	1.66	3325.25	389.85	0.10
Lower	42147	09Jun2015 0000	5529.20	72.22	85.62		85.68	0.000105	2.05	2694.17	290.14	0.12
Lower	37146	09Jun2015 0000	5529.20	74.89	84.97		85.05	0.000154	2.31	2393.71	289.06	0.14
Lower	32145	09Jun2015 0000	5529.20	71.48	84.20		84.29	0.000152	2.35	2348.32	272.28	0.14
Lower	27146	09Jun2015 0000	5529.20	74.92	83.71		83.75	0.000076	1.59	3477.85	442.18	0.10
Lower	22145	09Jun2015 0000	5529.20	66.09	83.44		83.48	0.000040	1.55	3573.37	291.14	0.08
Lower	17146	09Jun2015 0000	5529.20	71.09	83.05		83.14	0.000135	2.41	2292.85	234.98	0.14
Lower	12144	09Jun2015 0000	5529.20	74.90	81.57	78.14	81.82	0.000700	3.99	1386.07	230.28	0.29

Froude number for the main channel.

The fig.6 shows the water level/computed flow at RD-01. This figure reveals the visual phenomenon regarding water level in cross section of channel.

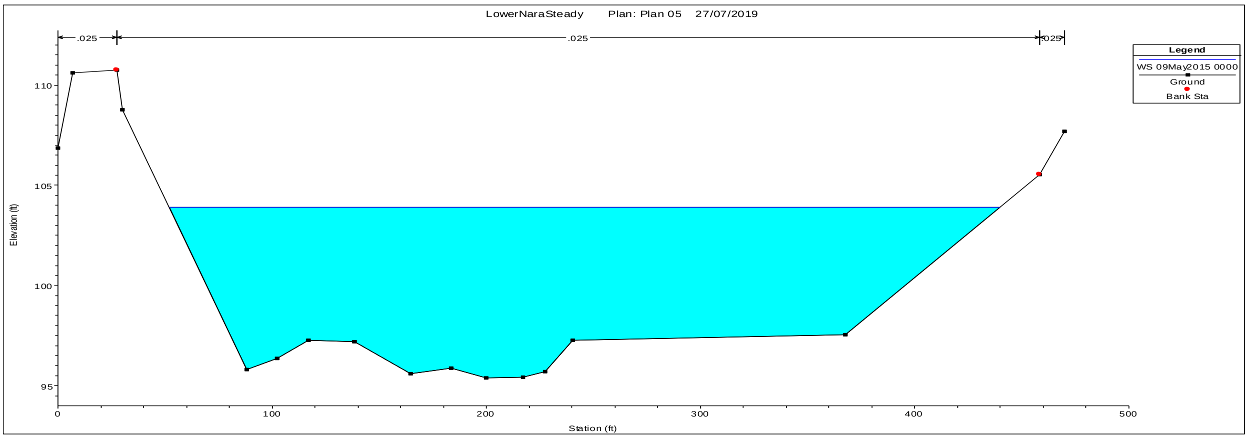


Fig.6. **Computed Flow at RD-01**

The fig.7 shows the outflow in Lower Naran at Fall Structure (RD-77). While fig.8: 3-D view of Fall Structure in Lower Nara at RD-77. These figures are representing the flow behavior at fall structure in 1-D and 3-D. Hence, result of model are nice as technical and other stakeholders can understand easily phenomenon flow passing through hydraulic structures.

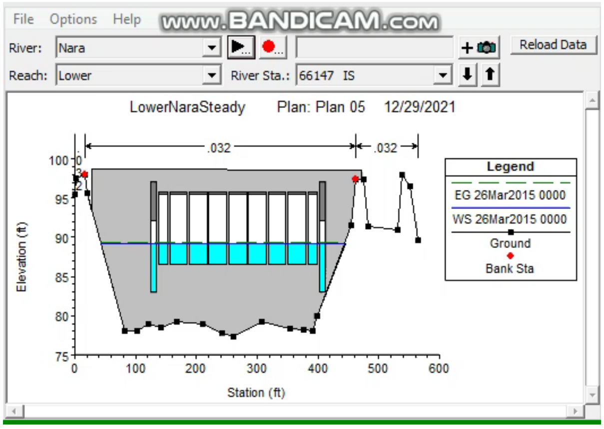


Fig.7. **Computed Out Flow in Lower Naran at Fall Structure (RD-77)**

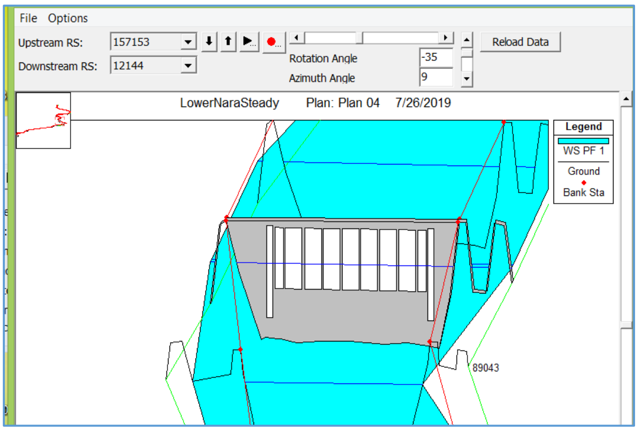
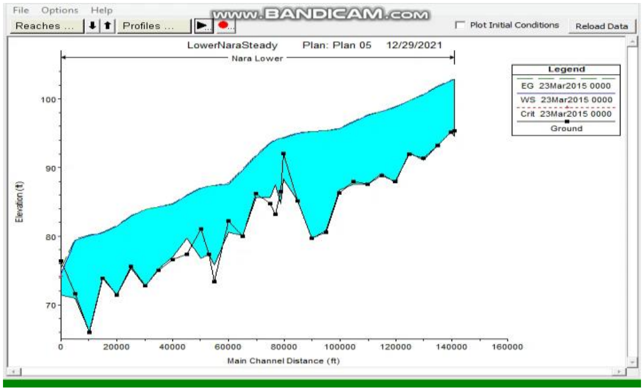


Fig.8. **3-D view of Fall Structure in Lower Nara at RD-77**



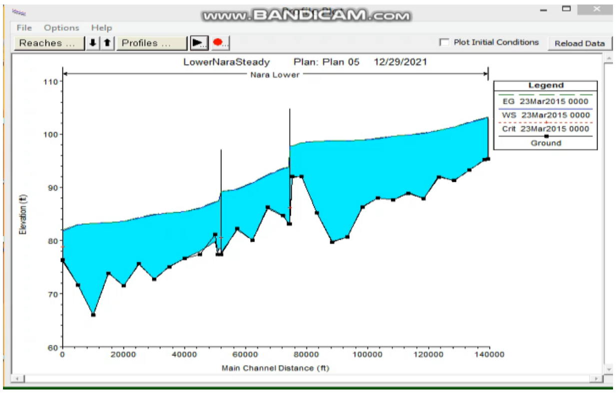
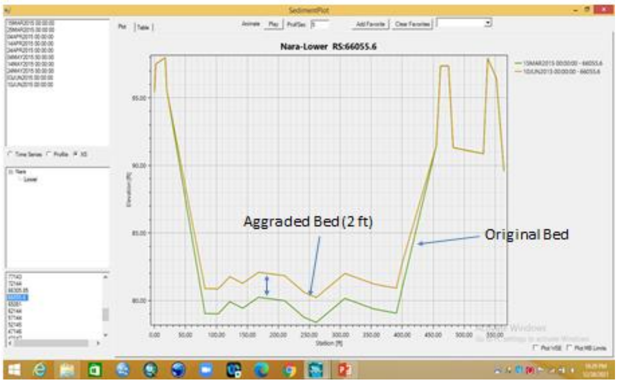


Fig. 9. **Profile of L-Section, without Fall Structures at RD-77 and Impact of Sediment Load**

Fig. 10. **Profile of L-Section, Fall Structures at RD-77 & 101 and Impact of Sediment Load**

The Fig.9 Profile of L-Section, without Fall Structures at RD-77 shows that there is no any hydraulic drop in the channel before construction of fall structure, hence there is no any Impact on velocity and Sediment transport Load. Fig.10: Profile of L-Section, Fall Structures at RD-77 & 101 which reveals the drop/cut off between upstream and downstream of fall structures. Hence. This phenomena has reduced velocity and sediment behavior in channel.

The fig.11, 12 and 13 exhibit that there aggradation and degradation at upstream and downstream of fall structures. This development of aggradation and degradation is true representation of results of model. The Fig.14 Profile shows the maximum velocity without Fall Structure which is 6 ft /sec. The high velocity remained cause of erosion and scouring banks and bed respectively.



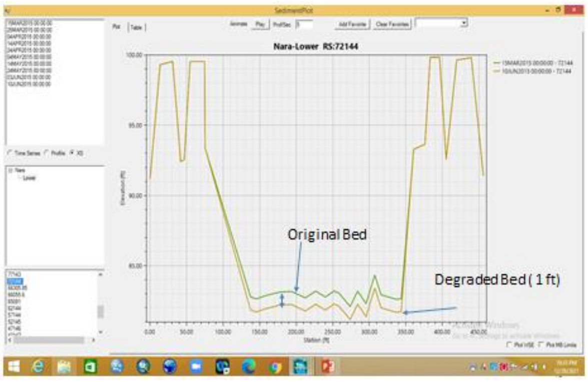


Fig.11. **Cross-section at u/s and d/s of Fall-Structure- at RD-77 showing aggradation**

Fig.12. **Cross-section at u/s and d/s of Fall-Structure- at RD-77 showing degradation**

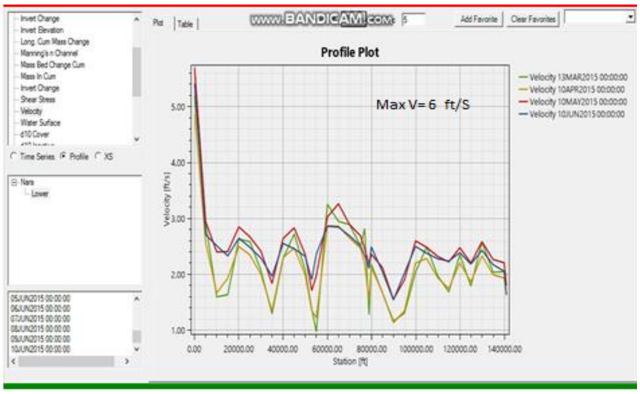


Fig.13. **Cross-section at u/s and d/s of Fall-Structure- at RD-77 showing aggradation and degradation**

Fig.14. **Profile (without Fall Structure)**

The fig.15 shows the maximum velocity has been reduced due to construction of fall structure from 6 ft/see to 3.75 ft/see. The construction of fall structures which have developed drop and reduced flow velocity and improve the sediment transport. Hence, model is giving good result regarding simulation flow at fall structures.

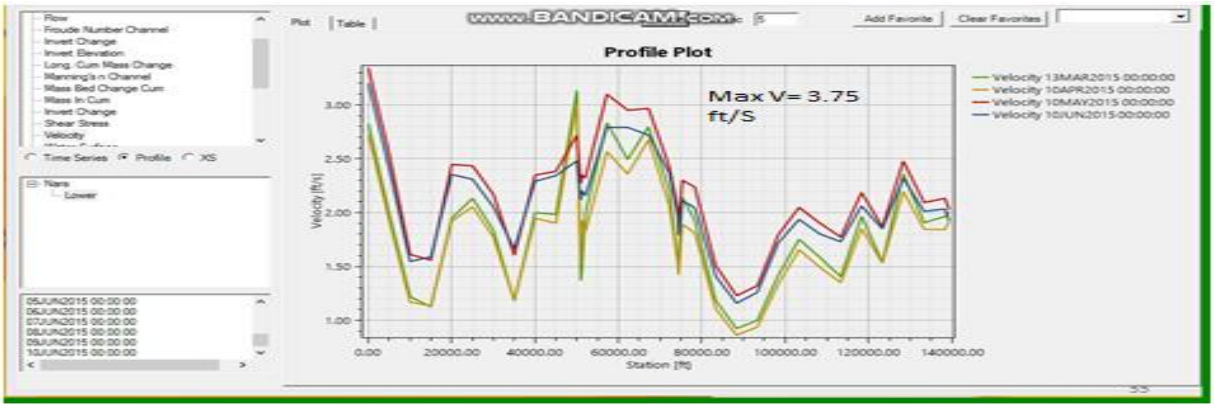


Fig.15. **Velocity Profile (with Fall Structure)**

The fig.16 shows the water surface in channel before construction of fall structures. The Water surface is changing with increasing discharge in the canal from RD-01 to 115.

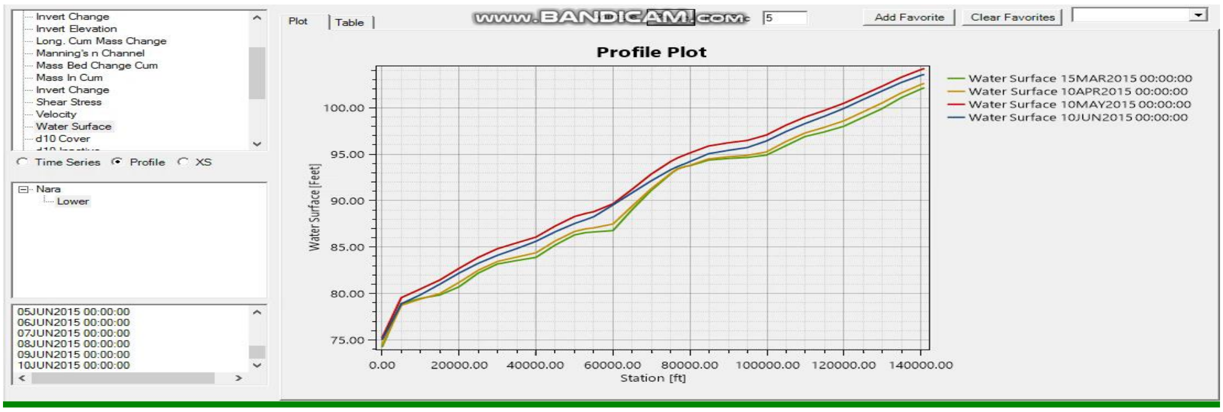


Fig.16. **Water Surface (without Fall Structure)**

The fig.17 shows that water surface after construction of Fall structures. The Water surface in canal showing drop between fall structures which were constructed RD-77 and RD-101. These structures have reduced water surface and maintenance the velocity of canal for developing the regime conditions.

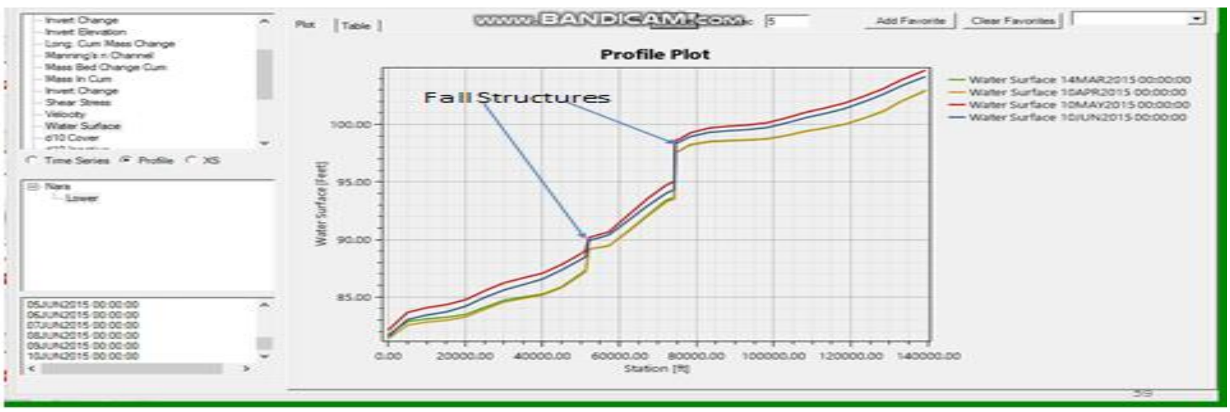


Fig.17. **Water Surface (with Fall Structure**)

Fig.18 shows Invert Change (Ft) Sediment transportation without fall structure is aggradation (5.75 ft and degradation (4.50 ft), while fig.19 reveals with fall structure aggradation (4.25 ft) and degradation (2.75 ft) respectively.

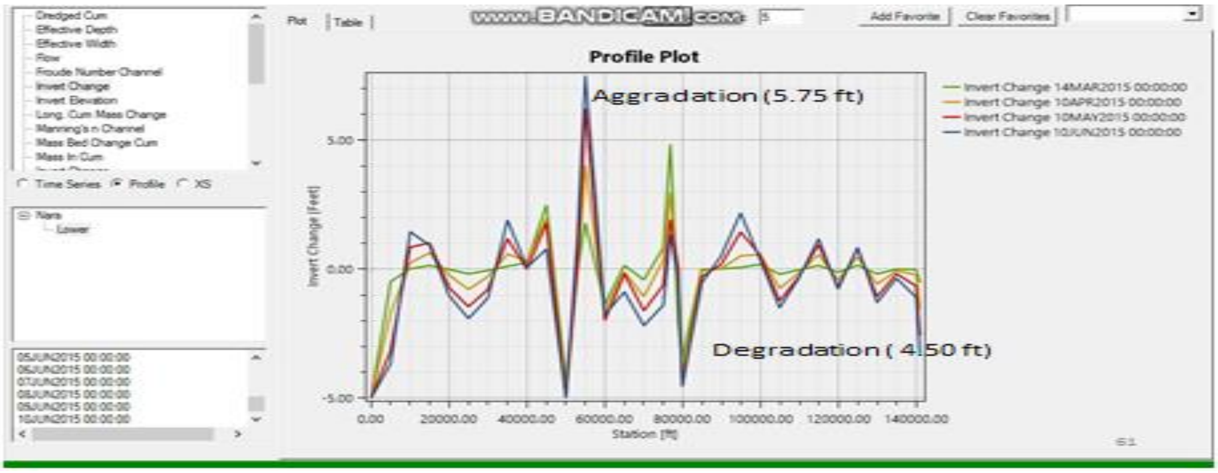


Fig.18. **Invert Change (Ft) due to Sediment transportation (without Fall Structure)**

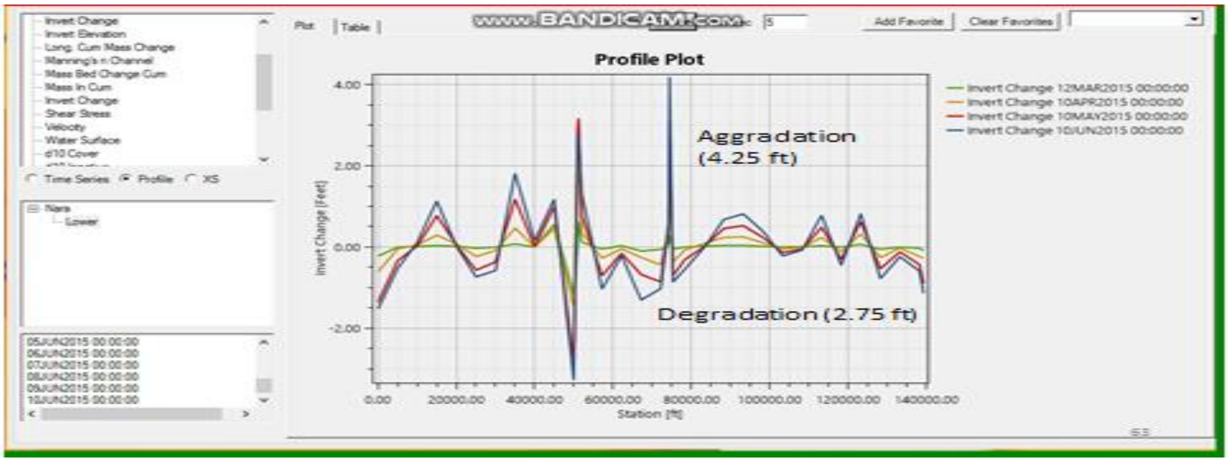


Fig.19. **Invert Change (Ft) due to Sediment transportation (with Fall Structure)**

Fig.20 and 21 show Mass Bed Change Cum (Tons) Sediment transportation without fall structure is aggradation 500,000 tons and degradation 225,000 tons and with fall structure aggradation 155,000 tons and degradation 125,000 tons respectively.

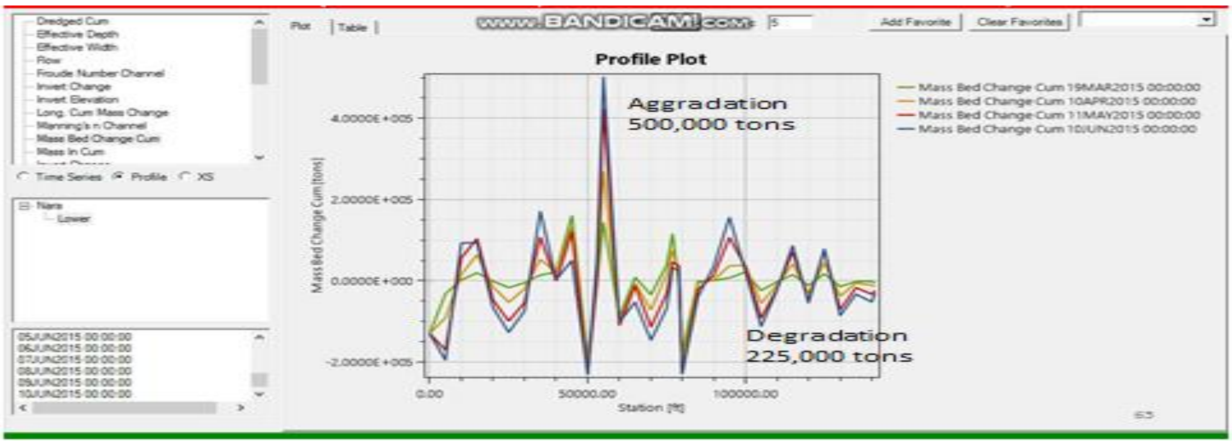


Fig.20. **Mass Bed Change Cum (Tons) due to Sediment transportation (without Fall Structure)**

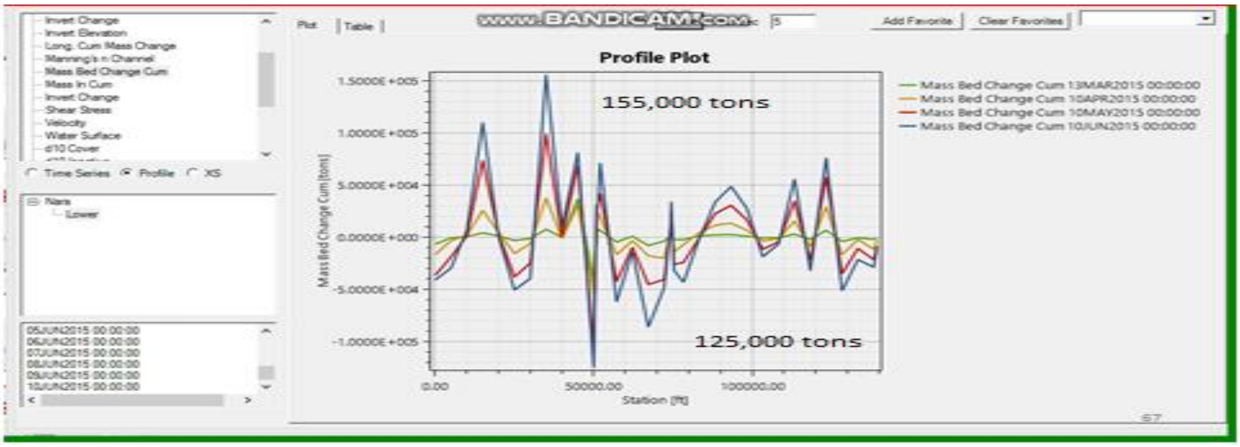


Fig.21. **Mass Bed Change Cum (Tons) due to Sediment transportation (with Fall Structure)**

Fig.22 and 23 show that Long Cum Mass Change (Tons) Sediment transportation without fall structure is degradation 600,000 tons and with fall structure is aggradation 110,000 Tons and degradation 165,000 Tons respectively.

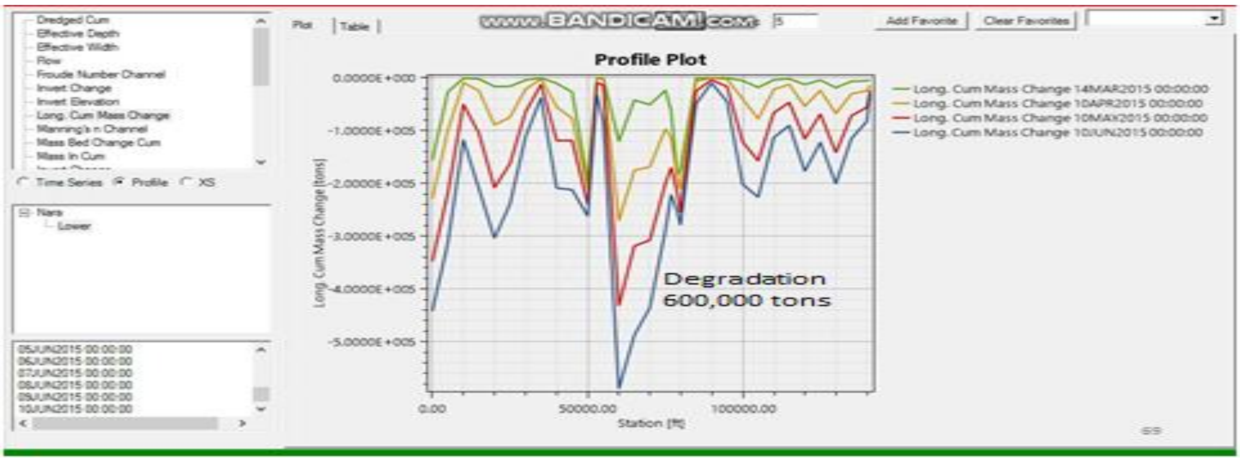


Fig.22. **Long Cum Mass Change (Tons) due to Sediment transportation (without Fall Structure)**

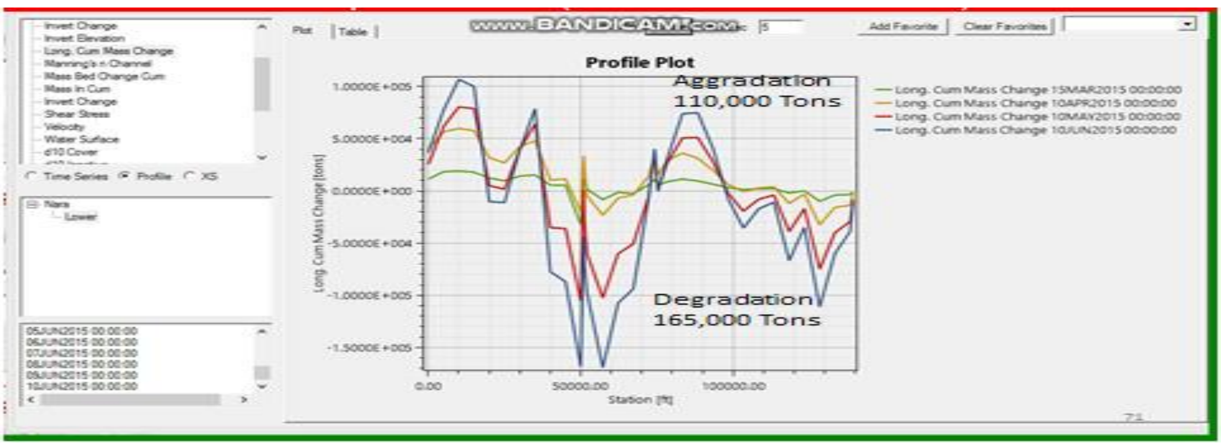


Fig.23. **Long Cum Mass Change (Tons) due to Sediment transportation (with Fall Structure)**

Fig.24 and 25 exhibit that Mass in Cum (Ton) Sediment transportation without fall structure is aggradation 1,750,000 Tons and with fall structure is aggradation 1,300,000 Tons.

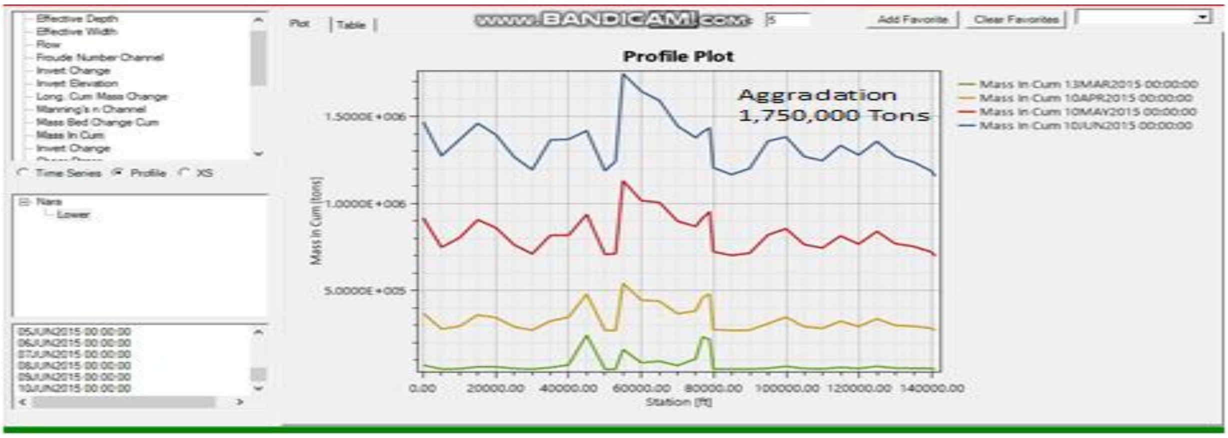


Fig.24. **Mass in Cum (Ton) due to Sediment transportation (without Fall Structure)**

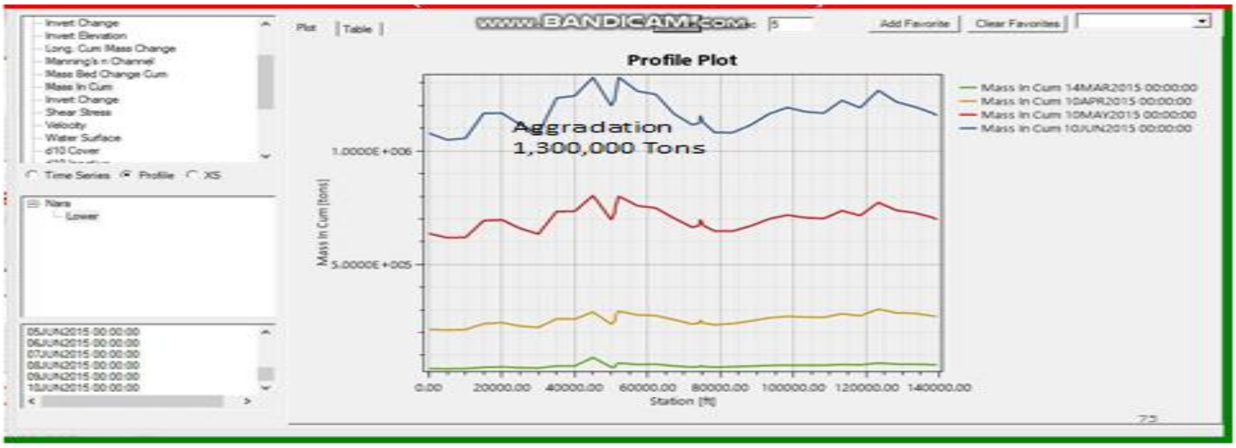


Fig.25. **Mass in Cum (Ton) due to Sediment transportation (with Fall Structure)**

The results of hydraulic parameters and sediment transport that HEC-RAS now has basic sediment transport capabilities. RAS utilizes quasi-steady hydrodynamics and one of several transport equations to solve the sediment continuity equation. Sediment surpluses and deficits are modified with temporal and physical constraints and translated into bed aggradation and degradation. After each computational time step the RAS geometry file is updated based on bed elevation changes for the hydrodynamics and sediment potential computations to use during the next time step. RAS includes a convenient user interface to specify the necessary data for a sediment analysis and a wide range of available outputs for analyzing a simulation (Stanford Gibson, et al.2006).

Conclusion. As a result, Model has computed longitudinal and cross-section, velocity and water surface profiles and sedimentation dynamic. Further Model results show the sedimentation dynamic computation in Invert Change (Ft) Sediment transportation without fall structure is aggradation (5.75 ft and degradation (4.50 ft) and with fall structure aggradation (4.25 ft) and degradation (2.75 ft) respectively. Mass Bed Change Cum (Tons) Sediment transportation without fall structure is aggradation 500,000 tons and degradation 225,000 tons and with fall structure aggradation 155,000 tons and degradation 125,000 tons. Long Cum Mass Change (Tons) Sediment transportation without fall structure is degradation 600,000 tons and with fall structure is aggradation 110,000 Tons and degradation 165,000 Tons. Mass in Cum (Ton) Sediment transportation without fall structure is aggradation 1,750,000 Tons and with fall structure is aggradation 1,300,000 Tons.

Hence the results of Model revealed that aggradation at u/s and degradation at d/s of fall structures that is true representation of behavior of fall structures. Whereas, section is wider that aggradation occurred and degradation is experienced in narrow section in both Scenarios (with and without fall structures). Positive impact of constructed fall structures was analyzed on morphology of canal. Hence, the construction of fall structures are essential at change of country/steeper slope to avoid unnecessary erosion.

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Застосування моделі HEC-RAS для аналізу динаміки переносу наносів до та після будівництва водоскидних споруд на Нижньому каналі Нара, що відводиться від Верхнього каналу Нара, загородження Суккур, річка Інд, Сінд, Пакистан

Туніо І. А.

У цій статті представлено дослідницьке дослідження з використанням моделі HEC-RAS для оцінки динамічних проблем відкладень у нижній частині каналу Нара, до та після будівництва водоскидних споруд на RD-77 та 101 відповідно, які є основною притокою верхньої частини каналу Нара, що витікає із загородження Суккур на лівому березі річки Інд. За гідравлічною моделлю розрахувані поздовжні та поперечні перерізи, швидкість, профілі водної поверхні та динаміку осадонакопичення. Транспортування осаду без водоскидних споруд з ***с****труктури падіння є аградацією (5,75 футів) і деградація (4,50 футів) і зі структурою падіння, аградацією (4,25 футів) і деградацією (2,75 футів) відповідно. Транспортування осаду без водоскидних споруд зі структурою падіння є аградацією 500 000 тонн і деградацією 225 000 тонн і зі структурою падіння аградація 155 000 т і деградація 125 000 т. Транспортування осаду без водоскидних споруд без структури падіння є деградацією 600 000 т, а зі структурою падіння є аградацією 110 000 т і деградацією 165 000 т. Транспортування осаду без водоскидних споруд без структури падіння є аградацією 1 750 000 тонн, а із водоскидних споруд є аградацією 10 300 т. Результати моделі показали, що аградація при u/s і деградація при d/s структур падіння є справжнім відображенням поведінки структур падіння. Враховуючи, що ділянка є ширшою, ніж відбулася аградація, а деградація спостерігається у вузьких ділянках в обох сценаріях (з та без споруд). Проаналізовано вплив збудованих водоскидних споруд на морфологію каналу. Отже, будівництво споруд для падіння є важливим при зміні місцевості/ з більш крутим схилом є важливим, щоб уникнути небажаної ерозії.*

Ключові слова*: модель HEC-RAS, річка Інд, нижній канал Нара, водоскидна споруда транспортування наносів, аградація, деградація.*

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