Received: 25 August 2025 | Revised: 02 October 2025 | Accepted: 17 November 2025 Vol.1 | Issue 1| December 2025
ISSN: Pending

Civil Engineering Science and Technology Journal

Impact of Abutment Scour on Al-Nuhairat Bridge in Basrah Governorate

Abdulsattar A. Alhasan*[1], Mohamad Alyounis[2], Mohammed H. Al-Tofan[3]
[1]Postgraduate Student, Department of Civil Engineering, University of Basrah, Basra, Iraq
[2]Professor, Department of Civil Engineering, University of Basrah, Basra, Iraq
[3]Lecturer, Department of Civil Engineering, University of Basrah, Basra, Iraq

Correspondence
* Abdulsattar A. Alhasan
Postgraduate Student, Department of Civil Engineering, University of Basrah
Email: pgs.abdulsattar.abdul24@uobasrah.edu.iq

Abstract
This study examined the impact of abutment scour around the concrete Al-Nuhairat Bridge, constructed over the Tigris River in Basrah Governorate. Local scour at bridge abutments is considered a contributing factor to bridge collapse. The study included an analysis of hydraulic variables and their interaction with the soil geological formation, which forms a supporting component in strengthening the abutments. The study also demonstrated the impact of these variables on the scour depth using the Hydraulic Toolbox software. The results were then discussed, clarifying the extent of erosion's impact on the undermining of abutment foundations and its repercussions on the safety and stability of bridges. The study also provided recommendations to mitigate its impact, preserve the sustainability of bridge operations, and take the necessary precautions when preparation future bridge designs, particularly in Basrah Governorate.

Keywords:
Abutment scour, Hydraulic variables, Al-Nuhairat bridge, Bridge safety, Hydraulic Toolbox.

I. Introduction

Bridge abutment scour is a type of local scour that occurs as a result of soil erosion and earth dams at the approaches at the bridge on both sides of the river. This happens due to the narrowing of the river channel at the bridge opening or when the bridge abutments and earth dams form an obstacle to the river flow. This may lead to an acceleration of the flow in this area along the front line of the abutments. The is then the flow return to its normal state, causing disturbances that create vortices in front of the face of the abutments, leading to the erosion of the supporting soil and the occurrence of drift. Consequently, the structure of the abutments may slide due to the continued operational pressures of the bridge, and then its collapse.

Many studies and experiments investigated the failure of abutments in bridges, which may result from geotechnical collapse due to the erosion of the backfill soil around the abutment or in the abutment column in severe cases. This happens in a manner similar to the scour of the bridge pier. In addition, the failure of the backfill may limit the development of support erosion due to the increase in the flow area, as the flow field expands as a result of the erosion of the sides of the backfill. This will reduce the flow speed and thus reduces the depth of scour [1]. Fig. 1, shows of scour at the bridge abutment, case Partial failure of the abutment and erosion of the soil spill slope. The study conducted in 1973 by the Federal Highway Administration on 283 bridge failures pointed that 72% of failures were due to damage to the abutments [2]. A survey of bridge failures in New zealand conducted between 1970 and 1984, on 108 bridge failure cases conducted that 28% of which were due to abutment scour [3]. Reasons for the failure of bridge abutments may include, obstruction of water flow due to the abutment or road embankment especially during floods, lateral channel migration and channel expansion, the shrinkage erosion and the impact of local scour on one or both abutments. The closer the abutment is to the river bank was more susceptible it is to damage. Also, that the acceleration of flow resulting from the obstruction of the river course due to the road embankment or abutment leads to the formation of a vortex that begins at the upper end and extends along the front of the abutment. A retrograde vortex usually forms at the lower end of the abutment, as in Fig. 2, similar to the vortex that forms around the pier. This may cause the abutment to collapse and the road embankment to erode [4]. The obstacles lead to formation of a barrier in the riverbed, causing an increase in the flow velocity and the occurrence of local disturbances that form strong vortices leading to increase in pressure on the river bed. This will also lead to scour and consequently a decrease in the river bed in the area adjacent to the obstacle. This erosion leads to the undermining of the bridge abutments, causing structural failure through various mechanisms. These mechanisms include subsidence or tilting of the bridge abutments as a result of the loss of the soil's contribution to supporting the foundation, the sliding of the bridge deck structure due to hydraulic loading or collisions with influential obstacles, damage to the supports as a result of a collision or sediment erosion and the occurrence of holes and drift of the dam behind the supports [5]. Flow acceleration resulting from the shrinkage of the flow area leads to the occurrence of a local disturbance on a wide scale. When the flow passes near the front abutment surface, the effect of this disturbance depends on the upstream flow distribution and the flow amount at the bridge opening, as well as the type of bridge abutments, the type and location of the foundation, the curvature of the flow and the nature of the river morphology [6]. It necessary to optimal design, taking into account the importance of the influence of the geotechnical aspect when erosion and failure occur in the backfilling of the earthen barrier surrounding the abutments along the bridge approaches. In this case, the depth of scour may reach the maximum possible limit that affects the strength and stability of the abutments. Commonly used types of bridge abutments include spill through abutment, which features horizontally sloping sides toward the riverbank at an angle and is often surrounded by paving stones to protect the dam soil. The second type of abutment has a vertical wall with a straight face and winged walls that tends at an angle, usually 45°, protection the dam. The third type consists of a completely straight vertical wall forming a 90° angle, as illustrated in Fig. 3 [1]. As study the case of hydraulic influence and geomorphic factors on scour in the bridge contraction area by using field data and multidimensional numerical models improves numerical predictions of flow conditions and scour of bridge abutments in compound channels composed of natural riverbeds and floodplains [7]. Use of protective measures such as stones and concrete blocks tied to cable to cover the earth barriers surrounding bridge abutments at approaches leads to protects that underlying sediments from the high flows resulting from the turbulent flow at the bridge support interface, especially during floods. This helps stabilize the dam soil that underlying and reduces its erosion, thus limiting the scour process [8]. Numerous experiments and studies were conducted on protecting bridge foundations using blocks tied to cables and their role in reducing erosion and preserving the stability of bridge supports from tipping over causing their collapse [9-12]. National Highway Research Program, part of the Transportation Research Department, developed a methodology for determining abutment scour, including obstruction of discharge by the abutment and its approaches, rather than the abutment itself and the length of the approach [13].

This research includes the details of the impact of abutments scour in accuracy by looking previous studies conducted by a number of researchers on the subject and taking this into consideration. The concrete Al-Nuhairat Bridge was selected as a case study is consideration as one the important bridges in Basrah Governorate. The study aims to analyze the factors most affecting abutment scour and the surrounding embankment soil at the bridge approaches. Therefore, it is considered an important step in enhancing comprehensive knowledge of abutment scour and predicting its consequences before it occurs, with the purpose of taking the necessary precautions through periodic monitoring and maintenance and improving the design capacity of without damage or disruption that would affect traffic and avoid economic and human losses.

Fig. 1. A common case of abutment failure, where corrosion causes partial failure and soil seepage slope erosion [1].

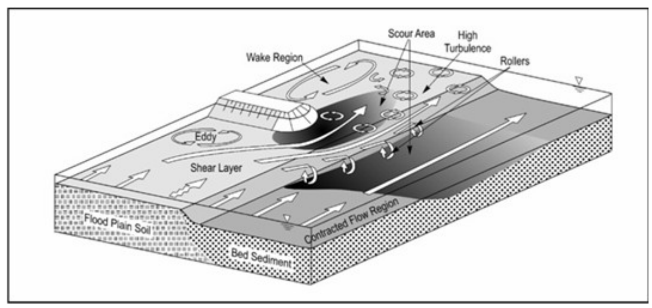

Fig.2. Schematic representation of abutment corrosion in a composite channel (NCHRP 2011b) [4].

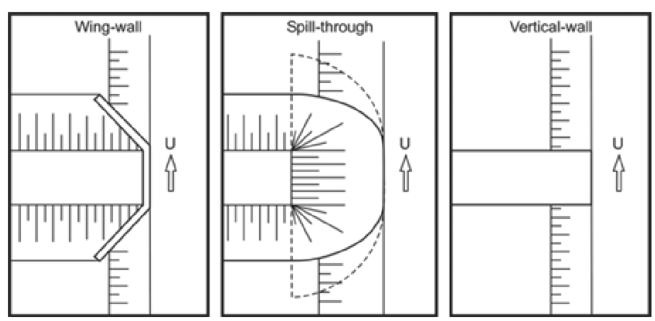

Fig 3. Three commonly used shapes in bridge abutments [14].

II. Methodology

The research explores a comprehensive methodology for calculating local scour at bridge abutments through the concrete Al-Nuhairat Bridge, as shown in Fig. 4, as a practical application model for studying this phenomenon. Conducted analysis by away numerical simulations using engineering software. Field surveys and data collection provide valuable information. To get to know the depths and patterns of complex flow with the full knowledge of the geological nature of the sediment soils in front and on the sides of the abutments, as well as the bridge geometry. As well as the empirical equations used in the analysis that were proposed by a number of researchers as practical tools for estimating the depth of corrosion. The results are discussed in detail to demonstrate the extent to which erosion through the abutments and embankment soils affects the safety and stability of bridges, with the recommendations and measures being developed to maintain the safe and sustainable operation of the bridge. To conduct data analysis and extract results, the following steps are followed:

Fig 4. A picture of the bridge structure showing the abutments and embankments.

A. Computational Methods

Used. The Froehlich's method and the NCHRP method were chosen to calculate the scour depth of bridge abutments.

B. Data Collection.

A site survey was conducted at the study site to recognition the structural details of the bridge and the hydrological and geomorphological characteristics of the riverbed as well as knowledge the hydraulic conditions, such as the depth and nature of the flow in the upstream area and near the bridge opening assistance of Irrigation Directorate in Basra Governorate to.

C. Engineering Software Used.

The Hydraulic Toolbox is used; it is a set of software tools belonging to the Federal Highway Administration (FHWA). are use in the analysis and design of hydraulic systems, channel engineering, and road infrastructure. Parameters were entered into the program window to conduct the analysis using the established method equations and extract the required results.

D. Engineering Equations

Used. Each of the following methods was used to calculate the scour depth, as follows:

1. Froehlich's equation

This equation may be used for estimating the depth of corrosion at bridge abutments [15]. It may be writ as.

$$\frac{y_s}{y_a} = 2.27\, k_1\, k_2 \left(\frac{L'}{y_a}\right)^{0.43} F_r^{\,0.61} + 1 \qquad (1)$$

where: K_1 = Coefficient for abutment shape (Table 8.1) [4], K_2 = Coefficient for angle of embankment to flow K_2 = Coefficient for angle of embankment to flow = $(\theta/90)^{0.13}$, θ is the angle of orientation of embankment to the flow (as shown in Fig. 3-10) $\theta < 90°$ if embankment points downstream, $\theta > 90°$ if embankment points upstream, L'= Length of active flow obstructed by the embankment (m), A_e = Flow area of the approach cross section obstructed by the embankment (m^2), F_r = Froude Number of approach flow upstream of the abutment= $V_e/(gy_a)^{1/2}$, $V_e = Q_e/A_e$ (m/s), Q_e = Flow obstructed by the abutment and approach embankment (m^3/s), y_a = Average depth of flow on the floodplain A_e/L (m), L = Length of embankment projected normal to the flow (m), y_s = Scour depth (m).

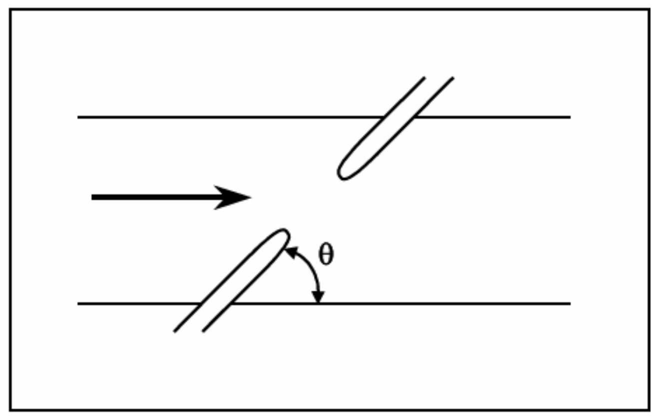

Fig. 5. Orientation of embankment angle, to the flow [4].

2. NCHRP equation

This equation may be used for estimating the depth of corrosion at bridge abutments [4]. It may be writ as

$$y_{max} = \alpha_A y_c \quad \text{or} \quad y_{max} = \alpha_B y_c \qquad (2)$$

$$y_s = y_{max} - y_\circ \qquad (3)$$

where: y_{max} = Maximum flow depth resulting from abutment scour (m), y_c = Flow depth including live-bed or clear-water contraction scour (m), α_A = Amplification factor for live-bed conditions, (from Fig. 8.9 and 8.10 in [4]), α_B = Amplification factor for clear-water conditions , (from Fig. 8.11 and 8.12 in [4]), y_s = Abutment scour depth (m) y_0= Flow depth prior to scour (m).

III. Results and Discussion

from through studying the bridge site noticed that the bridge abutments and their approaches on the right side only may be applied the condition of abutment scour, while the left side is very far from the river bank and the floodplains, and the possibility of being affected by this condition may be unlikely. Therefore, the analysis of the results was studied and discussed on the right side of the bridge only.

The analysis of the study results showed the importance of determining the location of the supports from the river banks, the nature and shape of their design, the characteristics of the dam soil and the foundations of the supports, and the relationship of their interaction with the flow characteristics in the area surrounding the bridge area from the source side by controlling the estimation of the scour depth and its effect on the strength and stiffness of the supports. The following methods were used to estimate the erosion depth.

A. Froehlich's method

The Froehlich's method. This is a simplified Arithmetic formula for estimating the local scour depth of bridge abutments. It is based on laboratory and field research and experiments conducted by Froehlich's 1989.

Table 1 shows the relationship between the discharge in the obstructed area caused by the backfill surrounding the bridge abutments and the erosion depth. This relationship is affected by several factors, including; (1) the slope angle of the flow line with the embankment in the obstructed area before entering the bridge crossing, (2) the geometric shape of the abutments, (3) the length of the active flow impeded by the dam, (4) the length of the earth dams projecting vertically toward the riverbank, and (5) the amount and area of flow impeded by the dam. Note that when the flow rate is 0.6 cm, the erosion depth is 0.64 m. The erosion depth then gradually increases with the increase in flow rate until it reaches 0.97 m when the flow reaches 2.1 cm. As shown in Figure 6, this relationship is direct and quasi-linear, meaning that increasing flow with increase the water flow's capacity to generate energy, which affects the pressure and the movement of soil sediments and the occurrence of scour.

TABLE 1.
Flow obstructed area discharge vs. scour hole depth.

Flow obstructed by abutment and approach embankment (Q_e) cms	Scour hole depth (y_s) m
0.6	0.64
0.9	0.72
1.2	0.79
1.5	0.85
1.8	0.91
2.1	0.97

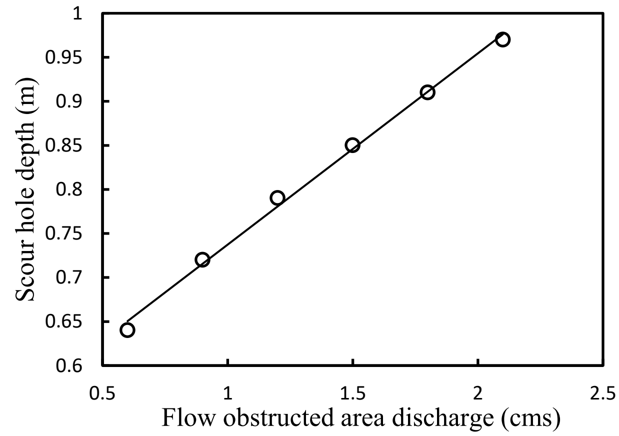

Fig.6. Relationship between Flow obstructed area discharge and scour hole depth.

B. NCHRP method

The NHCR method. This is one of the most widely used methods in the United States for evaluating bridge abutments Highway Cooperative Research Program of the American National Research Council. Its calculations rely on river hydraulics, hydrologic conditions, soil sediment characteristics, and bridge engineering details for the abutments and dam soils.

Table 2, shows the relationship between the discharge per unit width in the shrinkage area near the bridge abutments and the scour hole depth. This relationship depends on several parameters, include; (1) the angle of inclination of the embankment and abutments toward the flow line, (2) the length of the centerline of the embankment slope, (3) the length of the horizontal projection to the river bank, (4) the width of the floodplain on the main river channel side, (5) the flow discharge per unit width in the upstream of the main channel and the embankment opening, (6) the depth of flow in the upstream and across the embankment before erosion occurs, and (7) the average soil particle size D50 of the embankment. When the flow is 0.9cm, no erosion occurs. That means that the flow energy is insufficient to move sediment from the base of the abutments and their surroundings at this discharge. Soil erosion then occurs and increases with the flow, but this increase is uneven and irregular. Once the flow rises to 1.1cm, the increase in scour depth is 0.46m. The increase in scour depth then decreases when the flow increases to 1.4cms/m, thus increasing by 0.05m. The erosion depth then returns to higher increments, reaching 0.66 m when the flow is 1.7cms/m, which represents an increase of 0.15m. The erosion depth then increases dramatically, reaching 1.09m when the flow reaches 2cms/m. This relationship is direct and nonlinear, as shown in Fig. 7. The explanation for the discrepant result may be the influence of several engineering factors related to the complex nature of the flow through the transition point in the turbulence characteristics around the bridge piers and their inlets, as well as the change in discharge conditions from live to clear water flow and vice-versa.

TABLE 2.
Unit discharge in constricted area vs. scour hole depth

Unit discharge in constricted area (q_2) cms/m	Scour hole depth (y_s) m
0.9	0
1.1	0.46
1.4	0.51
1.7	0.66
2	1.09

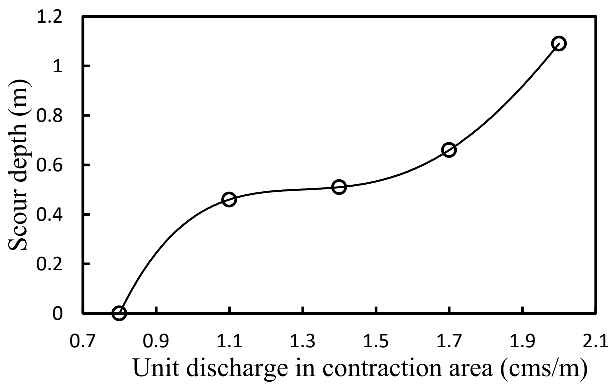

Fig.7. Relationship between unit discharge in contraction area and scour depth.

Table. 3, shows the relationship between the flow depth before the occurrence of scour and the scour hole depth near the bridge abutments and embankments. When the flow depth is 3cms, the sediments are not affected by erosion and record 0 value. When the flow depth gradually decreases, the scour depth increases. When the flow values are 2.6, 2.4, 2.2, 2cms the scour depth is 0.03, 0.23, 0.43, 0.63m respectively. Notice from Fig. 8 that the relationship is inversely decreasing with a regular form from the flow of 2.6cms to 2cms. This indicates that reducing the flow depth will increase the concentration of the flow velocity at the bottom, which leads to sediment movement and occurrence of excavation in the narrow area of the bridge and squinty increase of the scour hole depth.

TABLE 3.
Flow depth prior to scour vs. scour hole depth.

Flow depth prior to scour (y_0) m	Scour hole depth (y_s) m
3	0
2.6	0.03
2.4	0.23
2.2	0.43
2	0.63

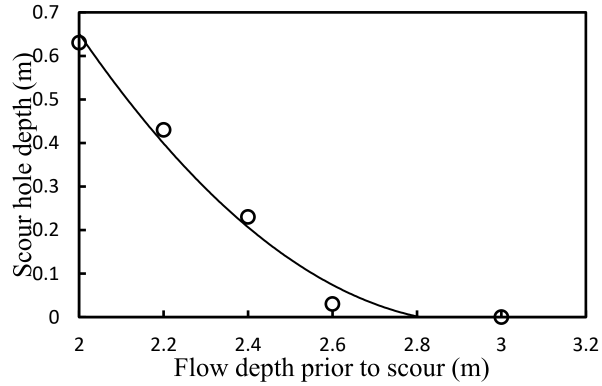

Fig.8. Relationship between unit discharge in contraction area and scour depth

IV. Conclusions and Recommendations

Mitigating the risks of bridge abutment scour is essential to ensure the safety and longevity of bridges. The following describes the conclusions of the research results with some recommendations

A. Conclusions

Based on the analysis and discussion of the results, the following conclusions were drawn:
In calculating a scour depth using Froehlich's method, the relationship is direct; the discharge in the obstruction area near the bridge abutment and scour depth it increasing linearly with a decrease in the rise of scour depth around the abutment's foundation, indicating an approach from the equilibrium case and a diminishing effect of flow on the riverbed soil as the flow intensity increases. In the HNCRP method, the relationship of scour depth at the contraction area influence on the abutment foundations and the earth dams is non-linearly as the flow increases, but this increase shows a striking disparity, sometimes declining and at other times significantly increasing. This indicates that the flow may be affected by several hydraulic factors, including those related to the complex flow process, such as the transition from semi-turbulent to turbulent flow when passing near the bridge abutments and their approaches, or a change in the flow pattern from the live bed case to clear water flow or conversely. As for the depth of flow before the occurrence of scour has an inverse relationship in affecting soil erosion, as the scour depth increases with the decrease in the depth of discharge, which indicates an increase in the shear energy affecting the river bed as the flow surface approaches the bed it taking an accelerated pattern in the movement of soil sediment erosion, and the erosion increases, which widens the excavation in the soil of the foundations of the abutments. concluded from this that the depth and the intensity of flow have a very important effect in affecting the depth of erosion around the abutments of bridges and embankments, and the intensity of the effect varies according to the methods used in the calculation based on the accuracy of the information, whether laboratory or field, which may differ according to

the conditions of the study site, as well as the difference in the engineering equations applied and the choice of parameters that enter into the calculation of the effect.

B. Recommendations

To protect bridges from the risk of abutment drift, the following recommendations are made:

- Ensure safe designs that must be prepared for the type and shape of bridge abutments, commensurate with the geomorphological nature of the river banks near which the abutments and embankment are constructed. Their distances should be located as far away from the banks as possible, to prevent sudden hydraulic changes that may occur.
- Choose suitable soil to construct the embankments of bridge with a high shear strength to resist erosion. The soil should be well compacted to increase the cohesive force.
- Cover the surface of the embankments at the bridge approaches with well paved stones or to secure them with concrete blocks to resist erosion and sliding that make it vulnerable to collapse.
- Monitor and maintain the bridge structure periodically to detect the damage of abutments and earth dams especially in the event of severe flooding and sudden increased flow.
- Use of vegetation near river banks to helps stabilizing the soil and resist erosion.
- Organize training courses for engineers and maintenance staff on erosion risk management using the latest monitoring techniques to enhance their ability to identify and address potential problems.

References

[1] R. Ettema, B. W. Melville, and G. Constantinescu, “Evaluation of bridge scour research: Pier scour processes and predictions”. Washington, DC, USA: Transportation Research Board of the National Academies, 2011.

[2] E. V. Richardson, and L. Abed, “Top width of pier scour holes in free and pressure flow”. In Hydraulic Engineering (pp. 911-915). ASCE, 1993.

[3] B. W. Melville, “Local scour at bridge abutments”. Journal of Hydraulic Engineering, 118(4), 615-631,1992.https://doi.org/10.1061/(ASCE)0733-9429(1992)118:4(615)

[4] S. T. Benedict, “Evaluation of abutment scour uquation from NCHRP projects 24-15 (2) and 24-20 using laboratory and field data NCHRP 24-20 (2)”, 2015.

[5] M. M. Zumrawi, and H. A. Abusim, “A study on scour failure at bridge foundation”. University Of Khartoum Engineering Journal, 9(2), 2019. https://doi.org/10.53332/kuej.v9i2.997

[6] R. Ettema, T. Nakato and M. Muste, “Estimation of scour depth at bridge abutments”. NCHRP 24-20. Transportation Research Board, Washington, DC, 2010.

[7] C. R. Wagner, D. S. Mueller, A. C. Parola, D. J. Hagerty, and S. T. Benedict, “Scour at contracted bridges.” Final Rep. for NCHRP Project 24-14, Transportation Research Board, Washington, DC, 2006.

[8] B. W. Melville, S. Coleman, and D. Hoe, “Countermeasures for Scour at Spill-Trough Bridge Abutments”. In International Conference on Scour of Foundations. November (Vol. 17, p. 20), 2002.

[9] J. A. McCorquodale, A. Moawad, and A. C. McCorquodale, “Cable-tied concrete block erosion protection”. In Hydraulic Engineering (pp. 1367-1372). ASCE, 1993.

[10] D. A. Bertoldi, J. S. Jones, S. M. Stein, R. T. Kilgore, and A. T Atayee, “An experimental study of scour protection alternatives at bridge piers”, 1996.

[11] J. S. Jones, D. Bertoldi, and S. Stein, “Alternative scour countermeasures”. In Stream Stability and Scour at Highway Bridges: Compendium of Stream Stability and Scour Papers Presented at Conferences Sponsored by the Water Resources Engineering (Hydraulics) Division of the American Society of Civil Engineers (pp. 854-854). ASCE, 1995.

[12] G. Parker, C. Toro-Escobar, and R. L. Voigt Jr, “Countermeasures to protect bridge piers from scour”, 1998.

[13] T.W. Sturm, and A. Chrisochoides, "Abutment Scour in Compound Channel for Variable Setbacks," Water Resources Engineering, Proc. of the International Water Resources Engineering Conference, ASCE, Memphis, 1, 174-179, 1998.

[14] R. Ettema, B. Yoon, T. Nakato, and M.Muste, “A review of scour conditions and scour-estimation difficulties for bridge abutments”. KSCE Journal of Civil Engineering, 8, 643-650, 2004. https://doi.org/10.1007/BF02823555

[15] D. C. Froehlich, “Abutment scour prediction”. In 68th TRB Annual Meeting, Washington, DC, 1989.