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Improvement of Morphology and Flow Conditions at Intakes Downstream Protruded Shorelines

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ABSTRACT

Shoreline protrusions upstream intakes at rivers and canals result in unfavorable flow conditions into the intakes where shore irregularities deflect the flow away while, under pump suction, eddies and non-uniform velocity occur at inlet bays.

Eddies cause transport of sediments into the intake, while the non-uniform velocity creates internal eddies that can reach pumps. This paper describes the phenomena and its impact in morphology and hydrodynamics. It describes a physically modeled engineering solution by introducing an array of deflector walls in front of the intake at the offshore area. The 1:40 scale model has demonstrated a remarkable mitigation of eddies, reduction of sediment transport and better velocity distribution along the inlet bays.

KEY WORDS: Protrusion; deflector; meander; mitigation; swirl; array; acquisition; dissipate.

INTRODUCTION

An intake structure is to be constructed to extract 72 m3/s for the Once Through cooling water of a huge Thermal Power Plant. The intake is located on the right bank of the Nile River. The right bank, just upstream from the intake structure, protrudes about 15-20 m into the river (Fig. 1).

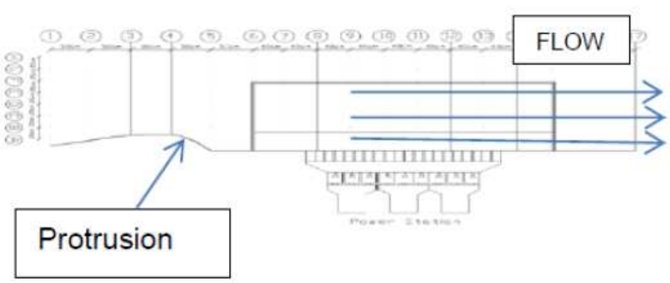

Fig. 1 Layout of power plant intake with upstream shoreline protrusion

A physical model of 1:40 scale was constructed for the study. Modeling the intake and the adjacent Nile shoreline shows that the flow patterns deflected around the protruding shoreline and meandering at an angle of almost 30° with the direction of flow (Fig. 2).

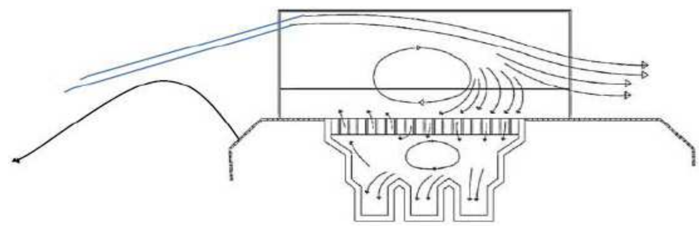

Fig. 2 Recirculation and eddies occur in front of the intake structure after pump operation (baseline case without deflectors)

Under the impact of the suction force of the pumps, the flow patterns are drawn back towards the intake bays, resulting in medium size eddies (Figs 2-3-4).

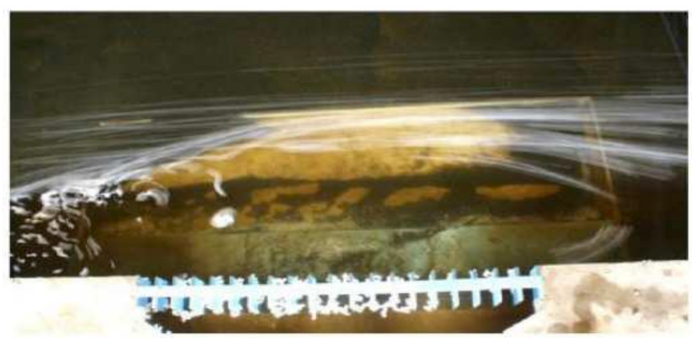

Fig. 3 Tracers of deflected flow patterns away from the intake due to protrusion upstream the intake due to protrusion upstream the intake (baseline case without deflectors)

Fig. 4 Developed eddies in front of the intake due to protrusion (combination of deflected flow at the protrusion and suction during pump operation (case without deflectors)

These eddies disturb the riverbed material at the intake area, and accelerates the migration of sediments into the front intake basin (Figs. 5-6).

Fig. 5 Deposition progress in the vicinity of the intake. Sediments are shown in black (baseline case before the deflectors)

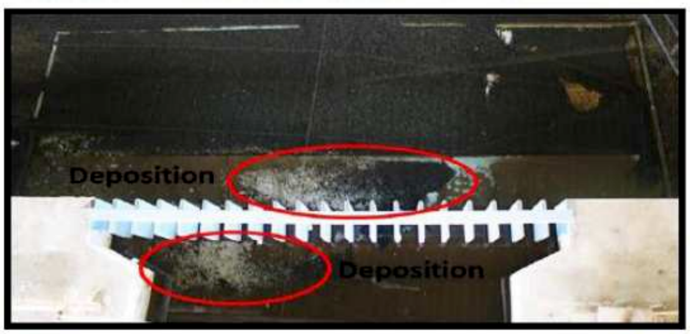

Fig. 6 Sedimentation at the basin and inside the intake structure after long time of operation (without deflectors)

SITE CONDITION COMPLICATIONS

This is a site dedicated for the power plant, and thus the plant cannot be relocated. The protruding formation is mainly rocky soil with a top sandy layer of 2-3 m. Removal of the protrusion could not be considered for land acquisition limitation. Accordingly, a solution to bring the flow and morphology of the area to an acceptable condition was needed to ensure efficient and safe performance of the intake and its associated pump house.

HYDROGRAPHIC AND HYDRODYNAMIC CONDITIONS

In the modeling phase of the river and intake structure, the preliminary results of the baseline model have demonstrated that remarkable amounts of sediments are transported in the basin at variable running periods of operation. In addition, significant eddies develop just in front of the offshore intake sedimentation basin. Per the model (Figs. 5-6), sedimentation accumulates in the basin over different periods. As also observed (Figs. 3-4) they show the flow patterns into the intake with appreciable eddies being developed inside the common bay of the pump house. Internal swirls in the pump house, once develop, are extremely harmful to the pump performance and durability.

PERFORMANCE OF INTAKE WATER ABSTRACTION IN BASELINE CASE

The excessive sedimentation will entail small frequency of dredging to keep the basin at the intake entry free from sediments. If these sediments migrate into the pump house, they will block the pump filters and damage the bearings and impellers. The induced eddies will also result in non-uniform velocity distribution at the 20 intake bays, introducing unfavorable flow conditions to the pumps (Fig. 7).

MEASUREMENTS

The physical model setup was prepared to enable measuring the sediment build-up in the intake basin and to measure the velocity distribution in the intake bays. It was noticed that the velocity distribution at intake bays show negative values in the first 10 upstream bays (Fig. 7).

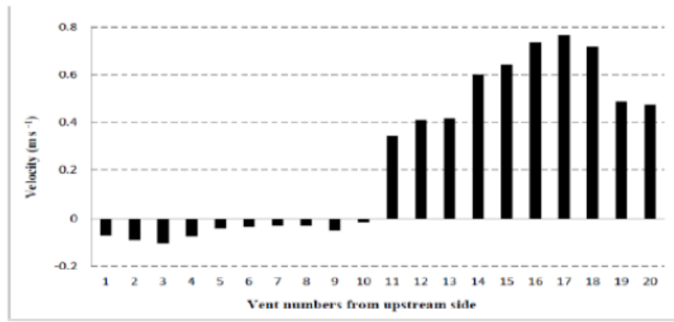

Fig. 7 Non-uniform velocity distribution at intake vents due to eddies (-ve velocity at the first 10 vents (without deflectors)

THEORY OF PROBLEM SOLUTION

The solution of the problem was based on the following:

- Directing the river flow uniformly towards the intake bays
- Introducing a vortex breaker at the entrance of the basin.
- Providing a barrier to minimize the sediment transport in the basin
- Adherence to the regulations by not placing a solid obstruction in the river beyond the shoreline (local regulation restriction)

Deflectors were introduced over a horizontal concrete sill in an L shape on the offshore side of the intake basin to regulate the sediment transport and unfavorable flow. Geometrically, the orientation of the deflectors array on the sill normal to the flow (Fig. 8) deflects the water flow back in the direction towards the intake bays thus increasing the flow in the areas where the negative flow occurred (Fig. 7).

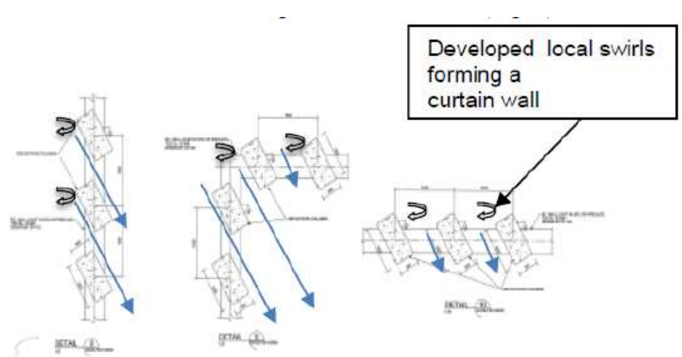

Fig. 8 Deflectors developed local vortices which prevented sediment transport from outside to inside the basin

As commonly practiced, the deflectors in the center of the eddies interrupt eddy circles development and dissipate the energy of the eddy.

The deflectors, at the side parallel to the flow direction (long side), develop small local swirl at the outer side of the basin. These local swirls constitute a curtain (Fig. 8) that minimizes the sediment migration from the riverbed to the intake basin (Fig. 9).

Fig. 9 Sedimentation inside the basin after introducing the deflectors after long term operation (Sediments in black)

These local swirls resulted in a slightly eroded strip just outside the basin. To migrate local erosions at this strip, a strip of rip rap was added at this local swirl location to prevent successive erosion (Fig 10).

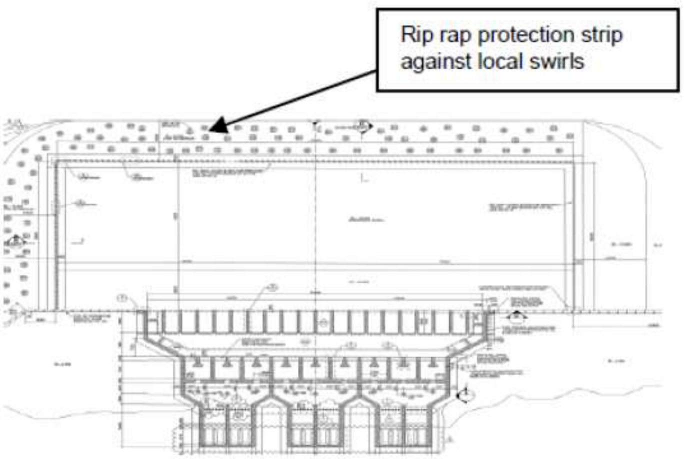

Fig. 10 Introducing deflectors caused local erosion around the basin close to the deflectors. Protection using rip rap

Mitigation of the sediment with a significant decrease of sedimentation into the basin is an evidence that the target of the deflectors has been met. Tracers have been used to demonstrate the damping of the eddies (Fig. 11) and improvement in the velocity distribution (Fig. 12).

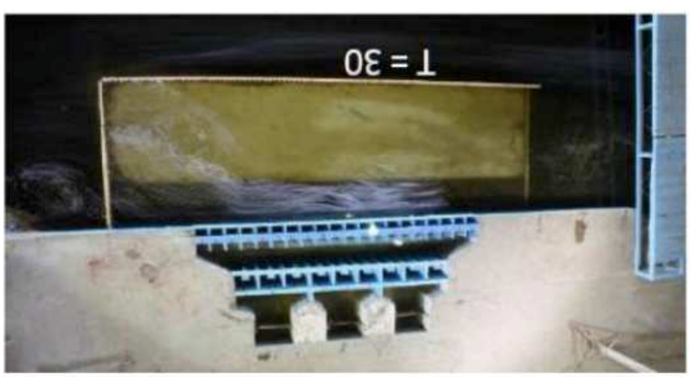

Fig. 11 Tracers showing damping of the eddies at the basin and dragging flow towards the inlet bays in a better velocity distribution using deflectors.

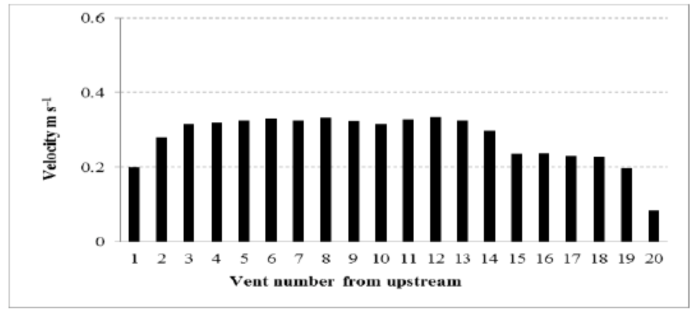

Fig. 12 Improvement in velocity distribution at intake vents due to deflectors

DISCUSSION AND CONCLUSION

- Modeling shows that protrusions of the shoreline upstream from the intake structure at the power plant intake create eddies, sediment transport in front of the intake area, and non-uniform flow velocities at the intake entry bays.
- Introducing an L-shaped array of deflectors oriented at an angle of 60º to the flow directions negates the eddies, significantly reduces sediment transport into the basin and improves the uniformity of flow velocity at the intake bays.

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