Dredging

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**Definition of dredging**

- **Dredging** is the process of underwater removal of material from the bed or banks of a waterway and disposing the material at a different location.

- **Classification**
  - **Purposes** of dredging are to deepen/widen waterways for navigation, to regain capacity within reservoirs, or to replenish sand on beaches.
  - **Locations** for dredging include rivers, reservoirs, and seashores.

**Laws and Regulations, and Agencies**

**U.S. Laws and Regulations, and Agencies**

- **Major Environmental Laws and Regulations**
  - National Environmental Policy Act of 1969
  - Comprehensive Environmental Response, Compensation and Liability Act of 1980
  - Clean Air Act
  - Resource Conservation and Recovery Act of 1976
  - Federal Water Pollution Control Act of 1972 [amended and renamed the Clean Water Act of 1977]
  - Rivers and Harbors Act of 1899 (The Refuse Act)
  - Marine Protection, Research, and Sanctuaries Act of 1972 (commonly called the Ocean Dumping Act)
  - Coastal Zone Management Act of 1972
  - Endangered Species Act of 1973
  - Fish and Wildlife Coordination Acts of 1934, 1956, and 1958
  - Toxic Substances Control Act
  - ... and many more (complete list can be found at USACE website)

- **Governance to proceed dredging project**
  - (i.e. potential permitting agencies)
    - US National Marine Fisheries Service
    - US Fish and Wildlife Service
    - US Environmental Protection Agency
    - State Fish and Game Agencies
    - State Water Quality Certifying Agencies
    - State Coastal Zone Management Agencies
    - Other Federal and State Agencies

**S. Korean Laws and Regulations, and Agencies**

- **Major Environmental Laws and Regulations**
  - Fundamental law of Environmental impact assessment 1990
  - Law of Environmental impact assessment 1993
  - Law of Environmental impact assessment in Environmental, Transportation, Disaster 1999
  - Law of Natural Environment Conservation 1999
  - Law of Aggregate Collection 1991
  - Law of Stream 1961
  - Law of waste management 2007

- **Governance to proceed dredging project**
  - (National river)
    - Ministry of Transportation and Maritime Affairs
    - Ministry of Environment
  - (Local river and stream)
    - Local government
    - Local branch of MOCT and ME
Planning a new dredging project

- Design dredging plan per one of the following manuals
  - Integrated National River Restoration Manual 2011, Korea

- Considerations for Dredging and Dredged Material Disposal
  - Selection of proper dredge plant for a given project
  - Selection of proper equipment
  - Determining whether or not there will be dredging of contaminated material (i.e. completing a pre-project Environmental Assessment)
  - Adequate disposal facilities
  - Long-term planning for maintenance dredging projects
  - Characterization of sediments to be dredged to support an engineering design of confined disposal areas
  - Determining the levels of suspended solids from disposal areas and dredge operations
  - Disposal of contaminated sediments
  - Control of dredging operation to ensure environmental protection
  - Determining quantity of material to be dredged and disposed
  - Obtaining appropriate permits
  - Consulting with local resident
  - Determining the affects on river response (i.e. head cutting, morphology, etc...)
  - Cost, Time

Dredging, perspective from river mechanics

- Consideration of the major factors causing riverbed aggradation

- Dredging affects on River morphology in the upstream and downstream direction
  - Long-term modeling for assessing dredging effects have to be carried out before project implementation

- Dredging and structural measures, such as hydraulic structures to stabilize river channel, can be considered for minimizing post-project maintenance
  - (e.g.) In Mississippi River – Bend-way weirs could make dredging reduced by 80% (River Mechanics p270)
Classification of Dredging Methods

- **Hydraulic Dredges**
  - Pick up the dredged material by means of suction pipes and pumps
  - Excavated material is disposed of by means of a hopper, pipeline or side-casting
  - Typically not self-propelled
  - Types include suction dredges (Hopper, Dustpan, Cutter-head with closed-nose basket or with open-nose basket), Trailing, Auger, Jet-lift, Air-lift, Water Injection, Pneumatic
  - Cutter-head dredges are the most efficient, versatile, and widely used.

- **Mechanical Dredges**
  - Lift the dredged material by means of diggers or buckets
  - Excavated material is dumped into disposal barges for unloading at the disposal site
  - Typically not self-propelled and must be towed to the work site
  - Types include dipper dredge, bucket dredge (with clamshell, orange peel, or dragline bucket), Grab, Bed Leveler, Krabbelaar, Snag-boat, Amphibious
  - Considerable fine material is lost from bucket, and the maximum concentration of the suspended turbidity plume is typically less than 1,000 ppm.

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(1) **Hydraulic Suction Dredges**

- **(advantages)**
  - Low cost and high rate of production
  - Can pump long distance with the aid of booster pump stations

- **(disadvantages)**
  - Bulking of fine sediment
    - Sediment dewatering required

- **(proper locations)**
  - Hopper dredge: self-propelled, shallow coastal harbors
  - Dustpan dredge: self-propelled, for dredging non-cohesive material
  - Cutter-head dredges: most widely used, for alluvial material including compacted clays and hardpans

- **(Cost)**
  - US $3 ~ 6$ / m³
(2) Mechanical Dredges

- Mechanical(bucket) dredges
  - Excavates submerged sediments with a bucket
  - Deliver a product having low water content, but the production rate is low
- Disadvantages
  - Fine sediment is lost when raised from deep underwater
  - Can generate considerable turbidity
- Classification
  - Dipper dredge
  - Bucket dredge
- Cost: US $3-$10/m³

(3) Other methods

<Siphon dredges>
- Used in reservoir sediment dredging (cases in China)
- Slurry forced through the pipeline by the differential head between the water surface in the reservoir and the discharge point (w/o pump)
- Mobile type, fixed type
- Two major limitations
  - Lack of reliability of system
  - Limited hydraulic gradient

<Pneumatic dredges>
- Use a chamber with inlets, out of which the water is pumped with the inlets closed. After that, excavation begins
**Case study (1) – 4 Major Rivers Restoration Project**

- Project for securing water supply and more flood control capacity coping with climate change (1.3 billion m³ for water supply, 0.92 m³ for flood control)
- **Total dredging**: 57 million m³
- **Flood water level** will be decreased 0.4 m (Young-san River) ~3.9 m (Nak-dong River)
- **Dredges**: hydraulic dredging ships (deep channel) + backhoe (shallow channel)
- **Mitigation measures for adverse effects**: Vacuum dredging + double silt protectors + real-time turbidity sensing

**Case study (2) – Yantze River**

(2001-2010)
- 6 major projects undertaken during the current 10-year period (2001-10)
- Dredging the 414 km stretch of the river to enable the passage of 1,000 dwt barge fleets
- Eradicating the shoals and rapids created by the construction of the Three Gorges Dam

(2011-2020)
- Dredge next 395 km area and areas below the Three Gorge Reservoir for 10,000 dwt barge fleets
- Next 497 km stretch to allow 20,000-50,000 dwt barges
- Complete the dredge after 312 km reach in the next reach

(Budget)
- US 0.2 billion dollars for 5 year dredging project
### Case study (3) – Missouri River

- In 1929, the Missouri River Navigation Commission estimated the total amount of goods shipped on the river annually at 15 million tons (does not meet the estimate by until)
- For the navigation, almost all of the Missouri River was dredged from the lower 500 miles (800 km) of the river.
- Also this river has been commercially dredged for at least 70 years to supply sand and gravel for concrete and asphalt used in construction and road building. (minimum : 250,000 tons per year in 1935, maximum 9 million tons in 2002)
- EPA scorned dredging in Missouri River for inappropriate environmental impact assessment recently

### Case study (4) – Lake Springfield, Illinois

- Built in 1934 (1635ha impoundment, 73.9Mm³, 4.5m deep), but by 1984, capacity reduced by 13 percent (storage loss : 9.5Mm³)
- primary purpose is to serve as the source of drinking water and Illinois recreation center, as well as the source of condenser cooling water for the utility's lakeshore power plant

**Reservoir dredging**
- during 1987 ~1991, 2.28Mm³ dredged
- unit cost : US $3/m³
- conventional cutter-head dredge was applied
- from the 2nd phase, booster pump was used
- sediment : 66% clay, 33% silt, 1% sand
- containment dike 1.2~7m, dewatered for 2 yrs
- effluent turbidity 1~2mg/L
Case study (5) – The world in Dubai, UAE

- Measuring approximately **9 km in width by 7 km in length**, the development will cover approximately 9,340,000 square meters
- By seabed dredging, over **326 million cubic meters of sand** was pumped to form the islands as well as building a 26 kilometer long oval shape break-water.

(procedures)
1. Using large dredges TSHD, with hoppers with a minimum of 18,000 m³, reaching a level of -10 meters.
2. Since the height -10 to -7, the emptying job is carried out by smaller dredges
3. By the use of small dredges they use the most amount of material that can be deposited by emptying normally until the -5 meters.
4. To reach a level of +3 meters, the projection by blasting the sand is made.

Methods for mitigating adverse effects

(1) Disposal of dredged sediment

- Case study: Hillsborough Bay CDF, FL
  - Beneficial uses included fish and wildlife habitats, and wetland restoration
  - Two contained disposal facilities (CDF) islands were built. Marshes were created along shorelines and nesting habitat provided on island surfaces. Marsh planting and limited bioengineering (riprap) was provided for physical protection. Smooth cordgrass sprigs, with mangrove seed pods were planted in the marsh stand.

- Case study: Palos Verdes Shelf Pilot Capping Project, Low Angeles County, CA
  - Pilot project to test the ability to cap contaminated sediment in place as a potential cleanup action for the Palos Verdes Shelf Superfund Site
  - Three “cells” were capped with varying cap thickness, sediment types, and placement methods
  - Construction of the pilot cap completed September 2001, monitoring ongoing
Methods for mitigating adverse effects

(2) Alleviate water quality perturbation

- Methods of minimizing water quality perturbation:
  - Using a Silt Curtain
  - Effluent Treatment – through clarifier tanks and filtration units
  - Bio-filtration – infiltration of effluent through forest floors (adverse effects could occur to the forest, however, so method not widely used)
  - Fish Exclusion Curtain
  - Dredging Timing Windows – avoiding dredging in low flows, and during fish migration
  - Water Quality Monitoring
  - Spill Contingency Plan – per the AESL Engineering Technical Report

• Methods for minimizing adverse effects:
  - Silt Curtain to contain turbidity
  - Selection of appropriate dredging method to minimize re-suspension of sediments, and maximize capture of contaminated soil (i.e. using a cutter head suction dredge with closed nose basket)
  - Proper disposal of contaminated sediment in a properly designed Confined Disposal Facility (CDF)

Adverse ecological effects of dredging include, but are not limited to:

- Substrate removal, and thus habitat and species removal, which requires re-vegetation of disturbed areas
- Destruction or disturbance of aquatic ecosystems
- Local re-suspension of sediments and increase of turbidity
- Spread of sediment and associated contaminants in the surroundings of the dredging site
- Disposal of contaminated sediment

The Confined Disposal Facility at Ketelmeer in the Netherlands is a good example of best practice.
Methods for mitigating adverse effects

-(3) minimizing river change (cont’d)

• River morphology
  – Potential effects of dredging on river morphology include head cutting and bank cutting, resulting in loss of riverside property, and steepening of the river system, including tributaries.

• Case Study: Kaw River, Kansas City, KS
  – Cause: Sand and gravel mining from river bottom using dredging methods.
  – Problem: Localized dredged areas were replenished with sand eroded from river banks and tributaries upstream, resulting in loss of riverside property, loss of riparian vegetation, degradation of bank stability, and local scour around bridge piers and hydraulic structures.
  – Solutions: Regulate where sand and gravel dredging is allowed so that over-dredging (i.e. exhausting the river system) is avoided, and encourage sand and gravel pit mining outside of the river system.

Comments and Conclusions

• The two major classes of dredgers are Hydraulic and Mechanical. The main types of dredges include suction, bucket, and dipper dredges.

• A lot of dredging projects have been done and still are going on in rivers, reservoirs and seas.

• Advantages to dredging include improving the depth and width of navigable waterways, and using dredged material for applications including berm construction, wetlands restoration, beach replenishment, and much more.

• Adverse effects include degradation of water quality, adverse environmental impacts, and adverse geomorphological impacts, to name a few. To mitigate the negative impacts, diverse methods appropriate to a particular project should be implemented.

• Dredging projects must be approved by many federal and state governmental agencies and must adhere to a long list of regulations.