Lower Susquehanna River Watershed Assessment
Existing and Future Predicted Conditions

Condition Description	Parameters	Water Quality (WQ) Effects: Dissolved Oxygen (DO), Chlorophyll concentration (CHL), light attenuation (KE)	Sediment and Nutrient loads
1. What is the system's current condition?	1. Land use: 2010 land use. 2. Hydrology: 1991-2000. 3. Reservoir bathymetry: 1991-2000 Conowingo, Holtwood, Safe Harbor – Capacity (Conowingo is still trapping). 4. Scouring: No net scouring of reservoirs accounted for during this period.	1. Conditions are usually worst during wet periods of high loading and stratification. Results emphasize summer average (June-August) during wet year (1996). **2. Bottom-water hypoxia** (DO < 1 mg/L) for a 60-km reach extending 80 to 140 km below the Conowingo dam. Bottom waters in this reach exhibit **complete anoxia** on occasion. 3. Greatest average **CHL concentrations** (more **than 10 µg/L**) occur in surface waters of 60-km reach **extending 80 to 140 km** below the Conowingo dam. 4. Greatest computed **KE**, **~ 1.9/m**, occurs immediately downstream of the Conowingo outfall and declines rapidly with distance away from the dam. A secondary peak, **1.2/m, occurs downstream,** in the turbidity maximum located 40 km below Conowingo Dam. Guidelines indicate KE should not exceed 1.5/m for survival of SAV at the one-meter depth.	1. Solids- Average solids load over the 10-yr period is 3,056 metric ton/d. Maximum daily load is 181,910 metric ton/d. Suspended sediment loads ranged from 723,279 kg/day in 2001 to 8,801,376 kg/day in 1993 (a very wet year) with an average of 2,825,888 kg/day. 1985-2010 – 2,825 metric ton/day 2. Nitrogen- The average nitrogen load is 62.9 metric ton/d. Maximum daily load is 1,388 metric ton/d. Total nitrogen (TN) loads ranged from an annual average of 89,730 kg/day in 1999, a drought year, to 253,091 kg/day in 2004, a year characterized as record wet. The average TN load for 1985 through 2010 was 163,987 kg/day. – 164 metric tons/day 3. Phosphorus- Average load is 5.2 metric tons/d. Maximum daily load is 116 metric ton/d. Total phosphorus (TP) loads ranged from 2,218 kg/day in 1999 to 12,380 kg/day in 2004 with an average load of 5,744 kg/day. 5.7 metric ton/day
2. What is the system's condition if the WIPs are in full effect and reservoirs are still	1. Land use: WIPS in place. 2. Hydrology: 1991- 2000.	1. Predicted **WQ improvements** with WIPS in place. Hypoxia reduced, less anoxic conditions, DO levels increase, chlorophyll concentrations and light attenuation decrease.	1. Solids- Average solids load over the 10-yr period) is 2,307 metric ton/d. Maximum daily load is 134,960 metric ton/d. TMDL is 1,945,000,000 pounds per year, 2417 metric

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trapping?	3. Reservoir bathymetry: 1991-2000 Conowingo, Holtwood, Safe Harbor – Capacity (Conowingo is still trapping). 4. Scouring: No net scouring of reservoirs accounted for during this period.	**2. Bottom-water hypoxia** (DO < 1 mg/L) in a 20-km reach (was 60-km reach when WIPS are not in effect) extending 80 to 100 km below Conowingo. 3. Minimum summer-average DO is ~ 0.5 mg/L. Occasional excursions to zero (anoxia) mg/L still predicted. **4. Surface CHL** concentration in this reach **declines** by 3 µg/L, relative to the current condition, to ~ 7 µg/L. **5. KE** just below Conowingo **declines** by 0.5/m, relative to the current condition (scenario 1), to 1.4/m and by 0.4/m to 0.8/m within turbidity maximum (TM, moves according to flow, during most summers TM is located 20 to 40 km upstream of the head of the trench.).	tons/day 2. Nitrogen- Average nitrogen load is 46.1 metric ton/d. Maximum daily load is 1,010 metric ton/d. 37,085,606 pounds/year TMDL is 75,000,000 pounds/year, 93.2 metric tons/day 3. Phosphorus- 3.9 metric tons/d. Maximum daily load is 86.8 metric ton/d. 3,137,394 pounds/year. TMDL is 3,420,000 pounds/year, 4.25 metric tons/day
3. What is the system's condition when WIPS are in full effect, reservoirs are still trapping sediments and a scour event occurs during winter?	1. Land use: WIPS in place. 2. Hydrology: 1991-2000 with 1996 winter scour event. 3. Reservoir bathymetry: Conowingo, Holtwood, Safe Harbor –2011 Capacity, Conowingo still trapping. 4. Scouring: Jan 96 scour event	1. DO would be depressed in comparison to WIPS in place with no scouring event (#2). 2. Storm timing important. Winter scour has minimal impacts to WQ by summer. 3. The additional loads from the scour event **depress** summer-average, bottom-water, **DO** by 0.05 mg/L for roughly 60 km along the bay axis (along the centerline following the channel) in the summer following the storm. (in comparison to #2 **WIPs in full effect**) 4. DO values vary-The effect is diminished in shallow areas relative to deeper areas. There are freshwater flow pulses and meteorological events which cause the effect on DO to vary over the course of a season. **5. CHL** (**summer average) increases** by 0.3 µg/L in the worst areas (in comparison to #2 **WIPs in full effect**). The effect on	1. Solids- Scour event adds 2,400,000 metric tons solids over a four day period. 2. Nitrogen- Adds 7,100 metric tons nitrogen over a four day period. 3. Phosphorus- 2,400 metric tons over a four day period.

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		CHL is spatially extensive. An increase of 0.2 µg/L or more extends 150 km along the bay axis in the summer following the storm. 6. Summer-average **KE increases by 0.01/m (in comparison to #2-WIPs in full effect).** Additional solids load disperse and settle before SAV growing season (April-October). KE increase attributed to the organic matter, phytoplankton and detritus, stimulated by the scoured nutrient load. 7. Although solids may be subject to resuspension, the January scour effect on **summer KE is negligible.** 8. Nutrients associated with the storm event are persistent into summer, while solids are short-lived. They settle out but they are recycled though the chemical and physical processes that the bottom sediments undergo. The effect of the scoured nutrients diminishes with time but is **visible five summers** subsequent to the scour event.	
4. What is the system's condition when WIPS are not in effect, reservoirs are full and there is a winter scour event?	1. Land use: 2010 land use 2. Hydrology: 1991-2000 with 1996 winter scour event 3. Reservoir bathymetry: Conowingo, Holtwood, Safe Harbor – Capacity at full. 4. Scouring: Jan 96 scour event.	1. Scour under reservoir-full conditions was similar to scour with current conditions (2011 bathymetry). This shows that by 2011, the reservoirs were essentially full. 2. When flow is below scour threshold **full-reservoir conditions are similar to non-full conditions**. Solids settle even when reservoir is "full" and settlement rate is not dependent on bathymetry. When flow is below the scour threshold, loads from the reservoir are the same between current bathymetry (2011) and reservoir full. Consequently, water quality in the bay is the same, as long as there is no scour event. 3. A **full reservoir is influential** when **scour** takes place; more material is scoured under reservoir-full conditions. 4. Summer-average **DO is depressed by 0.04 mg/L** (in comparison to	1. Solids -Adds 2,400,000 metric tons solids, over a four day period. 2. Nitrogen - 7,100 metric tons nitrogen, over a four day period. 3. Phosphorus - 2,400 metric tons phosphorus, over a four day period. The amount scoured is virtually equal to the amount scoured under existing bathymetry, indicating the existing bathymetry is very close to full.

Condition Description	Parameters	Water Quality (WQ) Effects: Dissolved Oxygen (DO), Chlorophyll concentration (CHL), light attenuation (KE)	Sediment and Nutrient loads
		scenario #1) along a 100 km reach of bay bottom. Examination of the marginal effects on DO can be deceptive: in the region of the worst hypoxia, at the worst location, under existing conditions, average DO is almost zero. It can't go much lower. Therefore DO isn't depressed much because there is nowhere to go. Elsewhere, DO might average 0.5 mg/L so it can go down by 0.5. The greatest magnitude of depression is not where DO is worst, on average. 5. **CHL (summer average) increases by 0.2 µg/L for a 100 km** reach of the bay axis. **6. Impact of the winter scour event on summer KE is minima**l (less than 0.02/m increase). This increase due to phytoplankton and organic matter associated with scoured nutrients rather than scoured sediments.	
5. What is the system's condition when WIPs are in full effect, the reservoirs are full and there is a winter scour event?	1. Land use: WIPs in place 2. Hydrology: 1991-2000 with 1996 winter scour event. 3. Reservoir bathymetry: Conowingo, Holtwood, Safe Harbor – Capacity at full. 4. Scouring: Jan 96 scour event.	1. When flow is below scour threshold **WQ conditions are similar** whether reservoir is full or not. 2. If a scour event occurs, average bottom DO concentration is depressed **by 0.05 mg/L for 60 to 80 km along the bay axis.** With WIPS in place, summer-average DO is higher than under 2010 conditions. Since summer-average DO is higher, it can go lower before hitting zero. So the magnitude of depression can be worse for the WIPS than for 2010. 3. **CHL increases by 0.3 µg/L in the 20 km reach** where CHL is maximum. **CHL increases by 0.2 µg/L for 120 km** or more along the bay axis. 4. It is possible for CHL to increase (worsen) with WIPS in place due to the fact that with WIPS in place the nutrient limitation of algae is more stringent; therefore the added nutrients from the scour event can stimulate a bit more	1. Solids- Adds 2,400,000 metric tons, over a four day period. 2. Nitrogen – Adds 7,100 metric tons nitrogen, over a four day period. 3. Phosphorus – Adds 2,400 metric tons, over a four day period. The amount scoured is not affected by WIPS.

Condition Description	Parameters	Water Quality (WQ) Effects: Dissolved Oxygen (DO), Chlorophyll concentration (CHL), light attenuation (KE)	Sediment and Nutrient loads
		chlorophyll. 5. **KE increase is ~ 0.01/m or less** since additional solids disperse and settle before summer. The minimal KE effects are almost identical to predictions with reservoirs still trapping (i.e. 2011 bathymetry/KE impacts are about the same if there is winter storm whether the reservoir is "full" or as it is now (still trapping) which is expected since the solids scoured have ample time to settle before the critical SAV growth period.	
6. What is the system's condition if WIPs are in full effect, reservoirs are full and a large scour event occurs during (a) summer or (b) fall or (c) winter?	1. Land use: WIPs in place 2. Hydrology: 1991 - 2000. Runoff from January 1996 flood event is moved to June or October. 3. Reservoir bathymetry: Conowingo, Holtwood, Safe Harbor – Capacity at full. 4. Scouring: Jan 96 scour event occurring in January, June and October.	1. June storm has the most deleterious effect on summer water quality. The October storm has the least deleterious effect, followed by the January storm. 2. The DO response to a storm is two-phased. As storm water passes there is an **initial sharp decrease reflecting the DO concentration** in the storm water and, perhaps, the effects of vertical density stratification. Following storm passage, a **secondary DO depression results** from oxidation of organic matter produced by storm-generated nutrient loads. 3. June storm, the two phases are difficult to separate. Summer-average bottom-water DO depression at the head of the trench (fixed bathymetric feature in Bay) is **0.4 mg/L** or more in comparison to Scenario 2. 4. January storm- **DO depression** (same location as June storm) **is 0.2 mg/L and October storm** depression is **0.1 mg/L** 5. Spatial extent of the storm influence is large and DO depression is readily detected in the lower portion of the Potomac River which joins Chesapeake Bay roughly 200 km below Conowingo Dam.	1. Solids – Adds 2,226,000 metric tons 2. Nitrogen- Adds 3,642 metric tons organic nitrogen 3. Phosphorus- Adds 2,169 metric tons particulate phosphorus.

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		6. CHL response to a storm is two-phased. **CHL concentration declines immediately** as the storm water passes then **CHL increases**, stimulated by the nutrients introduced by the storm. 7. January storm, spring bloom, **CHL increases as much as 5 µg/L**, although the bloom largely precedes the critical SAV growing season. In the summer subsequent to the storm, the **increase in CHL concentration is between 0.5 and 1 µg/L** over a large reach of the bay, extending to the mouth of the Potomac River. 8. October storm – **CHL increases by 0.5 µg/L.** 9. June storm introduces nutrients at the beginning of the seasonal peak in primary production, summer-average **CHL concentration increases** as much as **3 µg/L** 10. Solids loads from the June storm remain in suspension during the subsequent summer months resulting in **KE increase of 2/m to 4/m** (in comparison to scenario 2) for a reach extending 60 km downstream of the dam . Solids loads from the January and October storms are dispersed and settle long before the subsequent SAV growing season and have negligible effect on KE during this period.	

Chesapeake Bay Environmental Model Package (CBEMP). The CBEMP consists of the Corps' CH3D hydrodynamic model, the Corps' ICM water quality model and the Chesapeake Bay Program's Watershed Model (WSM)

Rankings:

What is the BEST future condition?

1) WIPS in place, reservoirs still trapping, no scouring. (Condition #2).

2) WIPS in place, reservoirs still trapping, scouring. (Condition #3).

3) WIPS in place, reservoirs full, scouring (Condition #5)

What is the worst-case future condition?

1) No management action in the watershed, no management action to mitigate major scour events. (Condition #4).

What is the worst time of year to have a scour event?

Ranked from most detrimental to least detrimental:

1) Late spring, early summer (e.g. June)

2) Winter (e.g. January)

3) Fall (e.g. October)

In summary

The management action that shows the greatest benefit (improvement to WQ) to the Bay is the WIP fully implemented, no major scour event, dam still filling (#2). If no management actions are taken the reservoir will "fill." The Worst Case is No WIPS, no action to mitigate major scour events (full reservoir) and a scour event. Under normal hydrologic conditions, even if Conowingo is "full" it will still be trapping, i.e. there will not be a continuous flow of sediment and nutrients into Chesapeake Bay. However we will see more frequent scouring events because the threshold for erosion will be lower. Also there is potential for a greater magnitude of impacts to WQ because there will be more sediments and nutrients associated with these more frequent scour events.