

Columbia Lake Dam Removal; Using Drones for Quantitative Evaluation of River Restoration

Beth Styler Barry
River Restoration Manager
The Nature Conservancy
beth.stylerbarry@tnc.org
[@World4Rivers](https://twitter.com/World4Rivers)

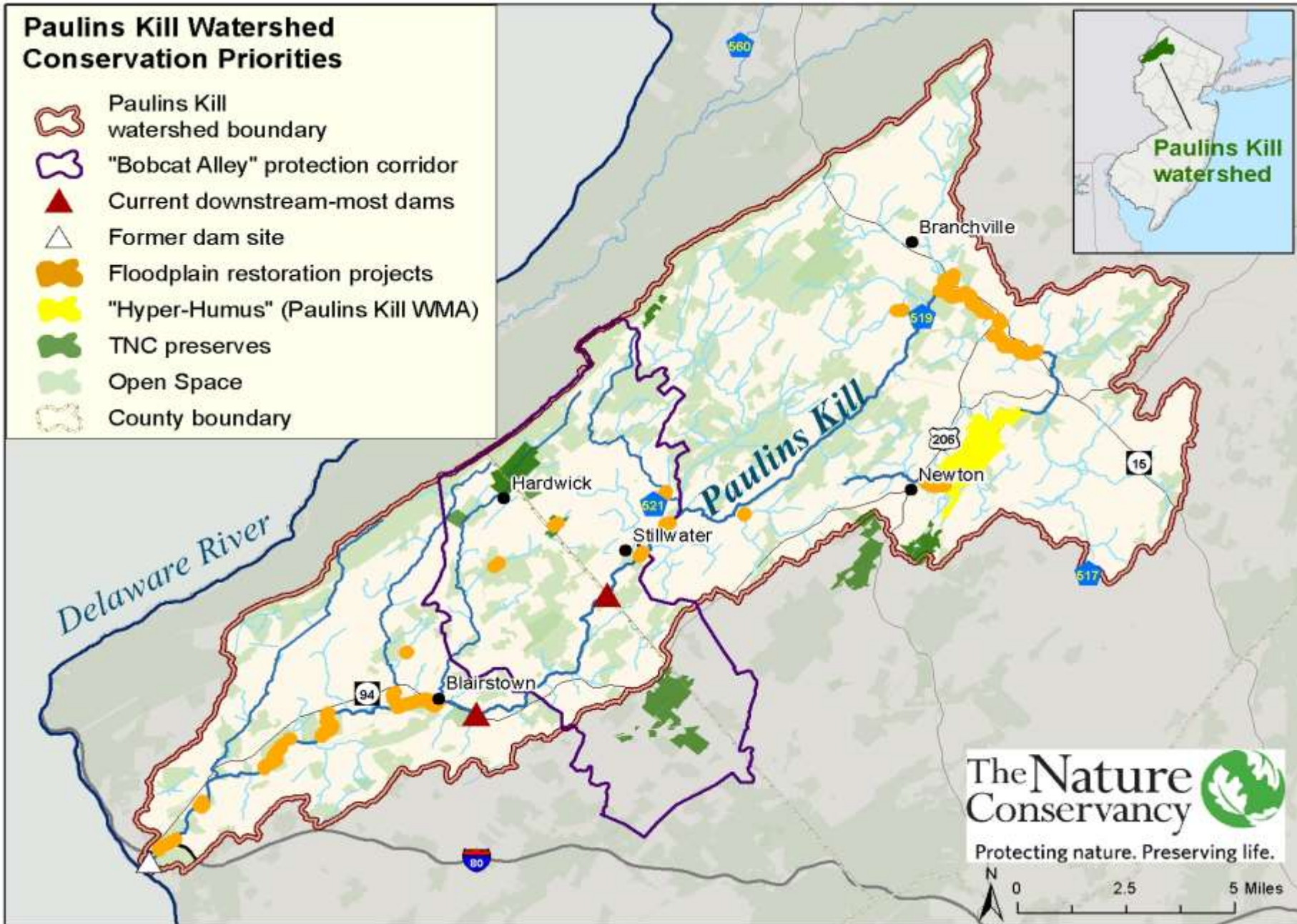


Thomas Hopper
Staff Scientist
Princeton Hydro LLC
thopper@princetonhydro.com
PrincetonHydro.com



Authors: Beth Styler Barry, Geoffrey Goll, PE, Christiana Pollack, CFM, GISP, Casey Schradling, EIT, Ellen Creveling

Drone Team: Chuck Gullage, Nigel Robinson, Bill Leavens, Rich Rogers, Thomas Hopper





Columbia Dam Removal Project Goals

- Fish Migration
- Habitat Improvement
- Water Quality Improvement
- Natural Channel Hydraulics
- Recreational Enhancement
- Increased Public Safety
- Creating and Connecting Floodplain



A dam is gone, and the shad are back. After 100 years, the fish have returned to a Delaware River tributary.

Updated Apr 24, 2019;



Saed Hindash | For lehighvalleylive.com

GOLDFINGER CONSULTING
 2000 W. 10th Street
 Suite 100
 Fort Collins, CO 80521
 Phone: 970.225.1000
 Fax: 970.225.1001
 www.goldfingerconsulting.com

PROJECT TITLE
 DELAWARE RIVER BRIDGE IMPROVEMENTS
 BRIDGE NO. 1001-1002-1003-1004-1005-1006-1007-1008-1009-1010-1011-1012-1013-1014-1015-1016-1017-1018-1019-1020-1021-1022-1023-1024-1025-1026-1027-1028-1029-1030-1031-1032-1033-1034-1035-1036-1037-1038-1039-1040-1041-1042-1043-1044-1045-1046-1047-1048-1049-1050-1051-1052-1053-1054-1055-1056-1057-1058-1059-1060-1061-1062-1063-1064-1065-1066-1067-1068-1069-1070-1071-1072-1073-1074-1075-1076-1077-1078-1079-1080-1081-1082-1083-1084-1085-1086-1087-1088-1089-1090-1091-1092-1093-1094-1095-1096-1097-1098-1099-1100-1101-1102-1103-1104-1105-1106-1107-1108-1109-1110-1111-1112-1113-1114-1115-1116-1117-1118-1119-1120-1121-1122-1123-1124-1125-1126-1127-1128-1129-1130-1131-1132-1133-1134-1135-1136-1137-1138-1139-1140-1141-1142-1143-1144-1145-1146-1147-1148-1149-1150-1151-1152-1153-1154-1155-1156-1157-1158-1159-1160-1161-1162-1163-1164-1165-1166-1167-1168-1169-1170-1171-1172-1173-1174-1175-1176-1177-1178-1179-1180-1181-1182-1183-1184-1185-1186-1187-1188-1189-1190-1191-1192-1193-1194-1195-1196-1197-1198-1199-1200-1201-1202-1203-1204-1205-1206-1207-1208-1209-1210-1211-1212-1213-1214-1215-1216-1217-1218-1219-1220-1221-1222-1223-1224-1225-1226-1227-1228-1229-1230-1231-1232-1233-1234-1235-1236-1237-1238-1239-1240-1241-1242-1243-1244-1245-1246-1247-1248-1249-1250-1251-1252-1253-1254-1255-1256-1257-1258-1259-1260-1261-1262-1263-1264-1265-1266-1267-1268-1269-1270-1271-1272-1273-1274-1275-1276-1277-1278-1279-1280-1281-1282-1283-1284-1285-1286-1287-1288-1289-1290-1291-1292-1293-1294-1295-1296-1297-1298-1299-1300-1301-1302-1303-1304-1305-1306-1307-1308-1309-1310-1311-1312-1313-1314-1315-1316-1317-1318-1319-1320-1321-1322-1323-1324-1325-1326-1327-1328-1329-1330-1331-1332-1333-1334-1335-1336-1337-1338-1339-1340-1341-1342-1343-1344-1345-1346-1347-1348-1349-1350-1351-1352-1353-1354-1355-1356-1357-1358-1359-1360-1361-1362-1363-1364-1365-1366-1367-1368-1369-1370-1371-1372-1373-1374-1375-1376-1377-1378-1379-1380-1381-1382-1383-1384-1385-1386-1387-1388-1389-1390-1391-1392-1393-1394-1395-1396-1397-1398-1399-1400-1401-1402-1403-1404-1405-1406-1407-1408-1409-1410-1411-1412-1413-1414-1415-1416-1417-1418-1419-1420-1421-1422-1423-1424-1425-1426-1427-1428-1429-1430-1431-1432-1433-1434-1435-1436-1437-1438-1439-1440-1441-1442-1443-1444-1445-1446-1447-1448-1449-1450-1451-1452-1453-1454-1455-1456-1457-1458-1459-1460-1461-1462-1463-1464-1465-1466-1467-1468-1469-1470-1471-1472-1473-1474-1475-1476-1477-1478-1479-1480-1481-1482-1483-1484-1485-1486-1487-1488-1489-1490-1491-1492-1493-1494-1495-1496-1497-1498-1499-1500-1501-1502-1503-1504-1505-1506-1507-1508-1509-1510-1511-1512-1513-1514-1515-1516-1517-1518-1519-1520-1521-1522-1523-1524-1525-1526-1527-1528-1529-1530-1531-1532-1533-1534-1535-1536-1537-1538-1539-1540-1541-1542-1543-1544-1545-1546-1547-1548-1549-1550-1551-1552-1553-1554-1555-1556-1557-1558-1559-1560-1561-1562-1563-1564-1565-1566-1567-1568-1569-1570-1571-1572-1573-1574-1575-1576-1577-1578-1579-1580-1581-1582-1583-1584-1585-1586-1587-1588-1589-1590-1591-1592-1593-1594-1595-1596-1597-1598-1599-1600-1601-1602-1603-1604-1605-1606-1607-1608-1609-1610-1611-1612-1613-1614-1615-1616-1617-1618-1619-1620-1621-1622-1623-1624-1625-1626-1627-1628-1629-1630-1631-1632-1633-1634-1635-1636-1637-1638-1639-1640-1641-1642-1643-1644-1645-1646-1647-1648-1649-1650-1651-1652-1653-1654-1655-1656-1657-1658-1659-1660-1661-1662-1663-1664-1665-1666-1667-1668-1669-1670-1671-1672-1673-1674-1675-1676-1677-1678-1679-1680-1681-1682-1683-1684-1685-1686-1687-1688-1689-1690-1691-1692-1693-1694-1695-1696-1697-1698-1699-1700-1701-1702-1703-1704-1705-1706-1707-1708-1709-1710-1711-1712-1713-1714-1715-1716-1717-1718-1719-1720-1721-1722-1723-1724-1725-1726-1727-1728-1729-1730-1731-1732-1733-1734-1735-1736-1737-1738-1739-1740-1741-1742-1743-1744-1745-1746-1747-1748-1749-1750-1751-1752-1753-1754-1755-1756-1757-1758-1759-1760-1761-1762-1763-1764-1765-1766-1767-1768-1769-1770-1771-1772-1773-1774-1775-1776-1777-1778-1779-1780-1781-1782-1783-1784-1785-1786-1787-1788-1789-1790-1791-1792-1793-1794-1795-1796-1797-1798-1799-1800-1801-1802-1803-1804-1805-1806-1807-1808-1809-1810-1811-1812-1813-1814-1815-1816-1817-1818-1819-1820-1821-1822-1823-1824-1825-1826-1827-1828-1829-1830-1831-1832-1833-1834-1835-1836-1837-1838-1839-1840-1841-1842-1843-1844-1845-1846-1847-1848-1849-1850-1851-1852-1853-1854-1855-1856-1857-1858-1859-1860-1861-1862-1863-1864-1865-1866-1867-1868-1869-1870-1871-1872-1873-1874-1875-1876-1877-1878-1879-1880-1881-1882-1883-1884-1885-1886-1887-1888-1889-1890-1891-1892-1893-1894-1895-1896-1897-1898-1899-1900-1901-1902-1903-1904-1905-1906-1907-1908-1909-1910-1911-1912-1913-1914-1915-1916-1917-1918-1919-1920-1921-1922-1923-1924-1925-1926-1927-1928-1929-1930-1931-1932-1933-1934-1935-1936-1937-1938-1939-1940-1941-1942-1943-1944-1945-1946-1947-1948-1949-1950-1951-1952-1953-1954-1955-1956-1957-1958-1959-1960-1961-1962-1963-1964-1965-1966-1967-1968-1969-1970-1971-1972-1973-1974-1975-1976-1977-1978-1979-1980-1981-1982-1983-1984-1985-1986-1987-1988-1989-1990-1991-1992-1993-1994-1995-1996-1997-1998-1999-2000-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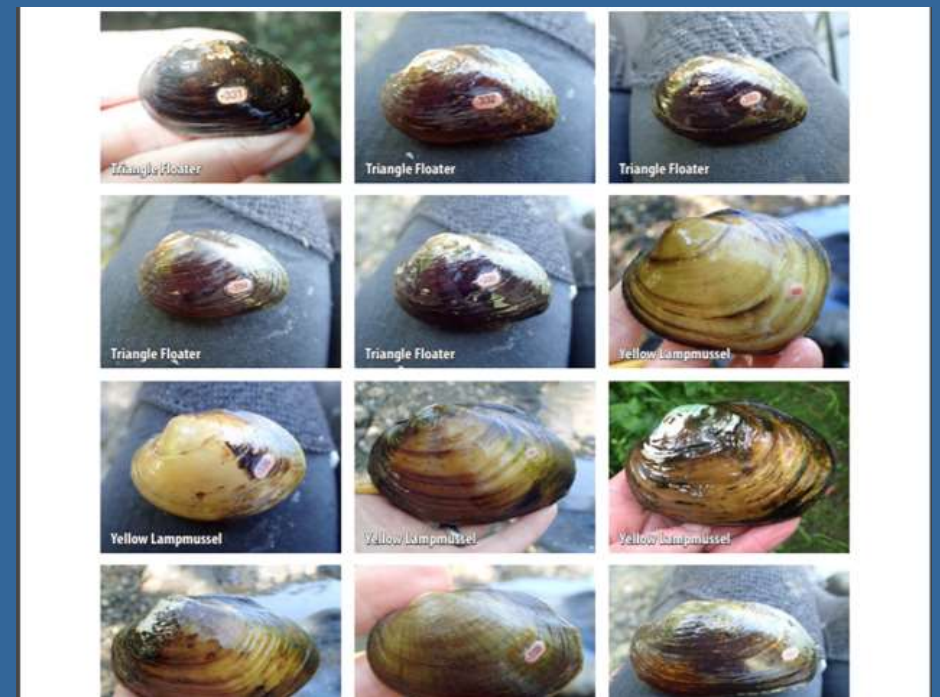


Drone's eye view of project area before removal and during initial drawdown.



Typical Monitoring Measurements

- Temperature
- Dissolved Oxygen
- Turbidity
- Macroinvertebrates
- Mussels
- Eels
- Fish
- Habitat



Project outcomes the team hoped to evaluate quantitatively:

- Acres of floodplain habitat regained
- Volume of water “lost” / storage gained
- Changing channel area
- Vegetation growth over time
- Sediment/geomorphic volumetric changes either via consolidation, erosion



DRONE
MONITORING
MEASUREMENT

STUDY QUESTIONS

Will the quality of information be good enough to:

- Allow more frequent monitoring on a budget?
- Inform adaptive management decisions?
- Answer permitting questions?

Using Drones for Quantitative Evaluation

Photogrammetry
to photogrammetry
measurement, or

A Digital Terrain Model

A Digital Surface Model

The orthomosaic
perspective distortion
(more than 1000) is required
orthomosaic can



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Flight Paths

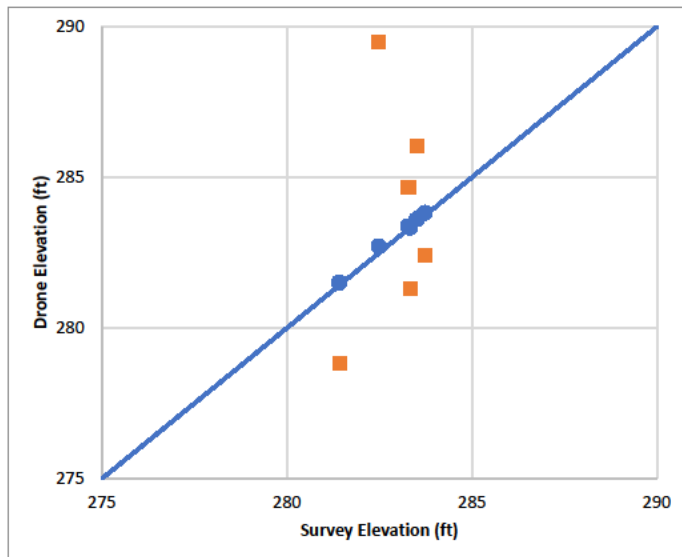




Ground Control points

Ground Control Points

- Comparison between uncalibrated drone and surveyed elevations (standard error of 11.15 inches)
- Comparison between calibrated GCP corrected drone and survey elevations (standard error of 0.90 inches).



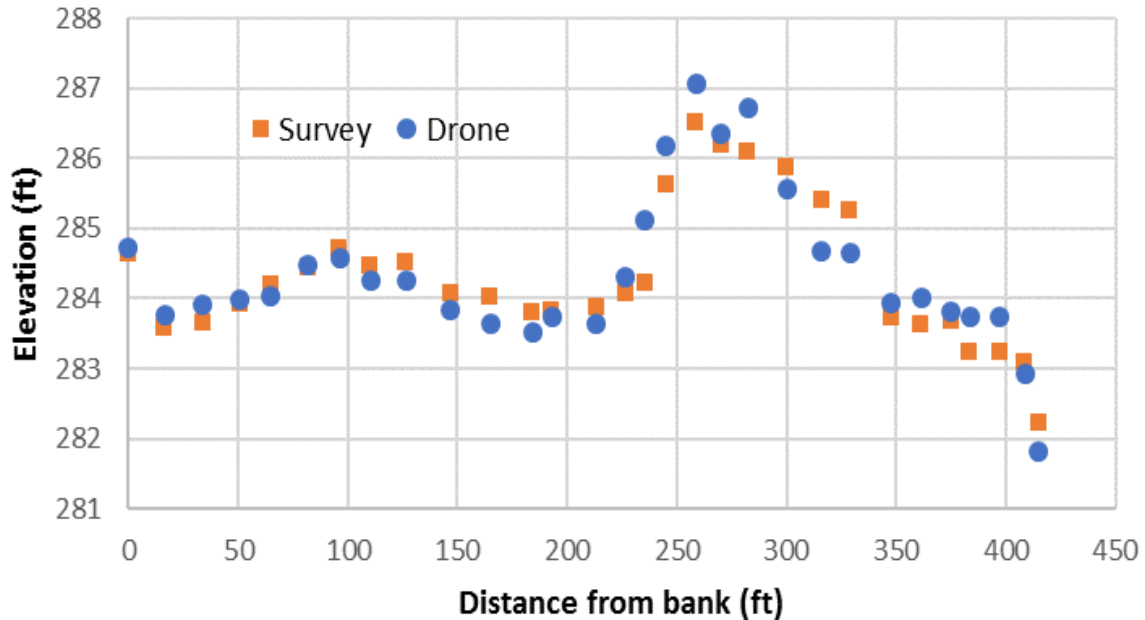
Standard error numbers relate to the validation (impact) of calibration or the measure of how close those dots are to the blue line which would be “perfect”.

Casey versus The Drone

comparing elevational data

drone flights vs. land survey

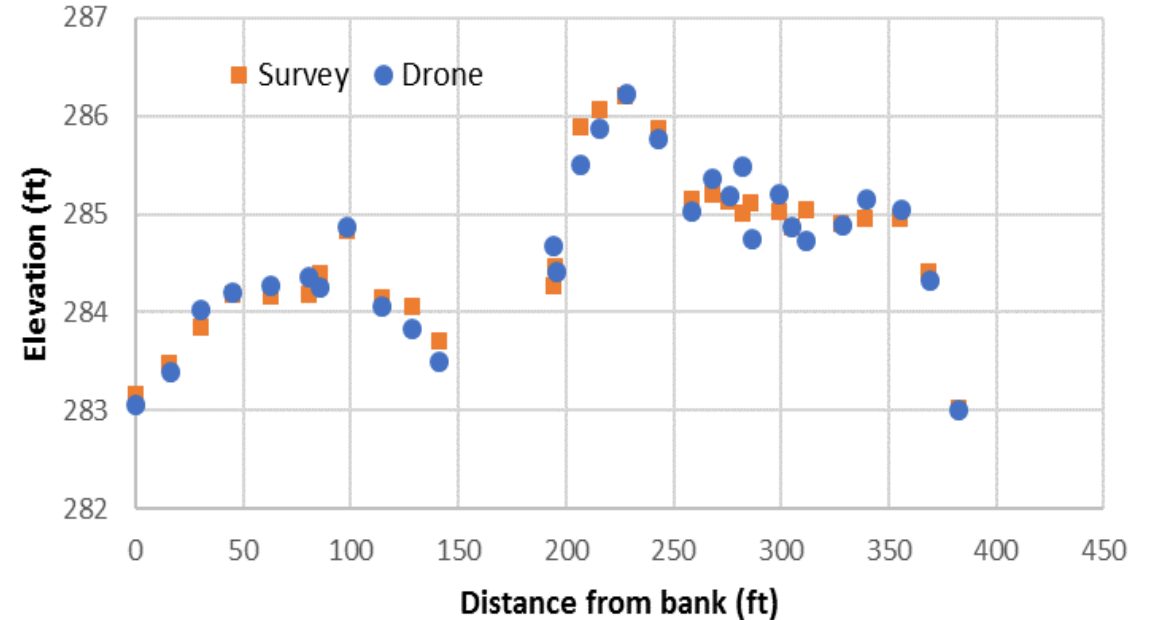
selected cross sections (upper impoundment)



Cross Section #1

Average Error = -0.040 ft

Root Mean Square Error = 0.381 ft

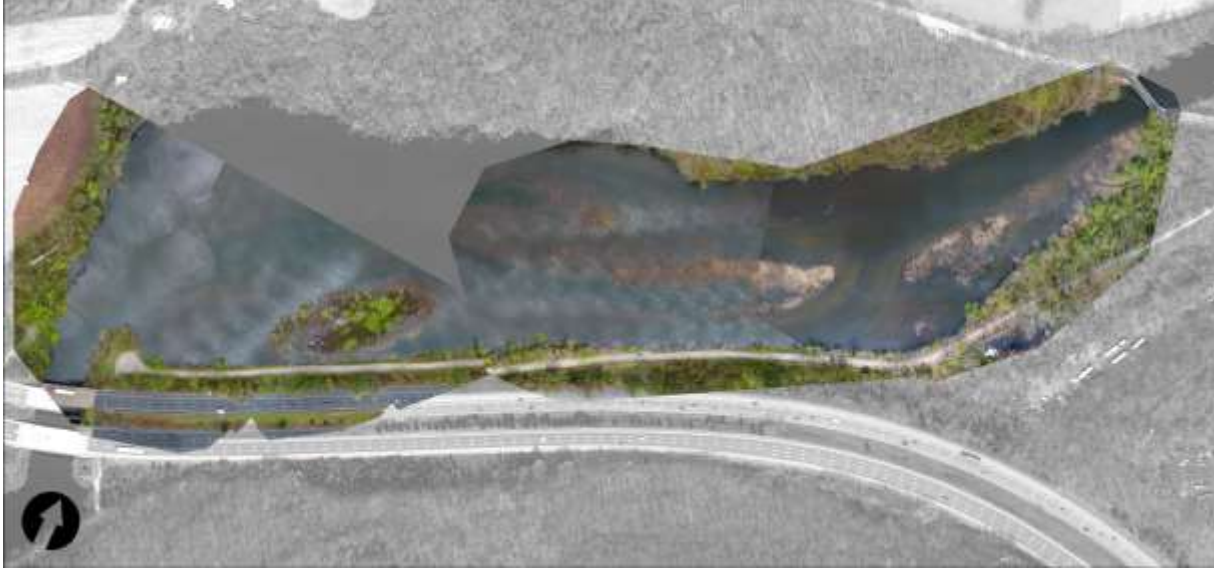


Cross Section #2

Average Error = 0.006 ft

Root Mean Square Error = 0.194 ft

Data Collection Over Water



Calculations

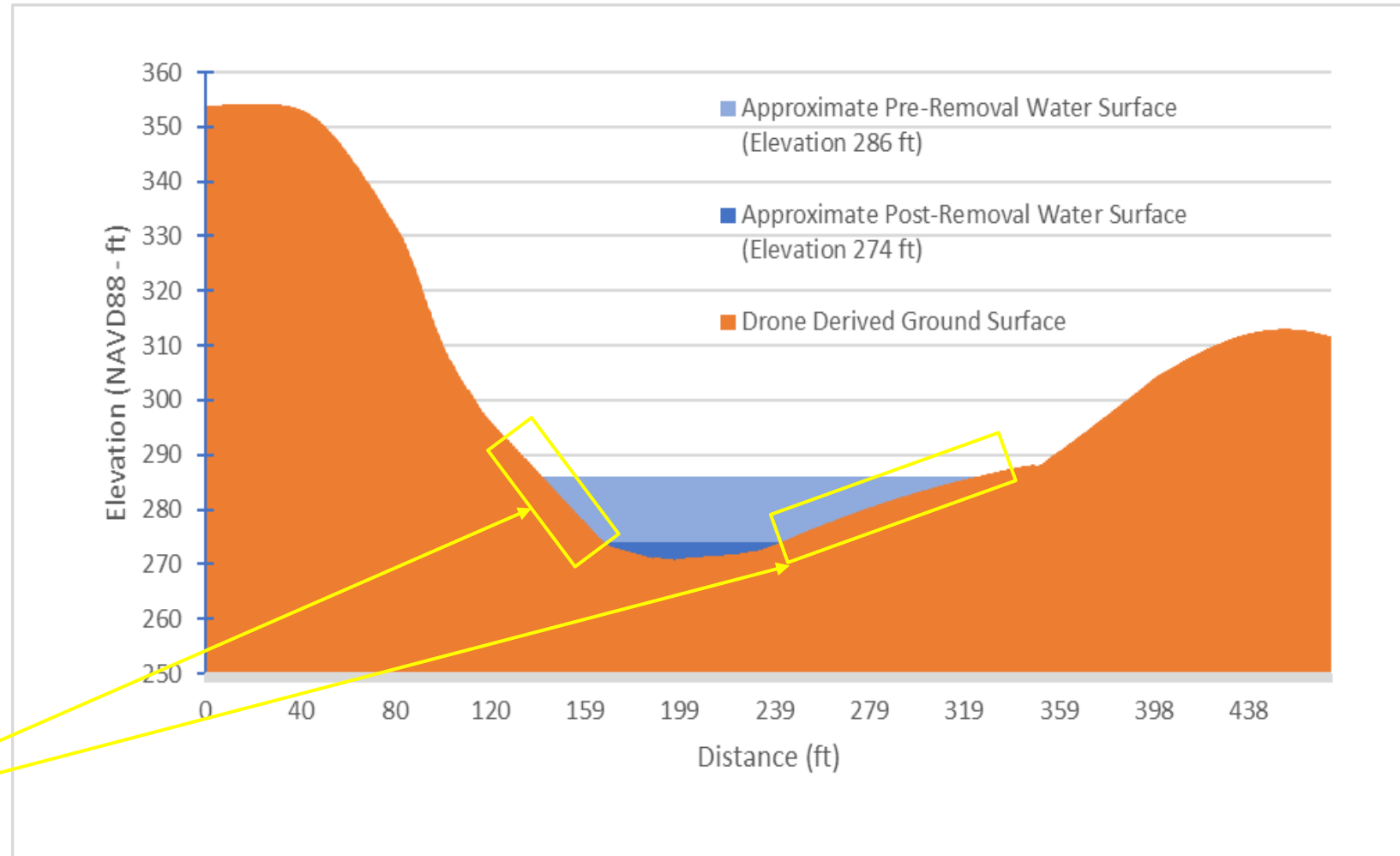
Drone	Area (SQFT)	Area (Acres)	Volume (CUFT)	Volume (CUYD)
MAVIC DTM	166,068	3.81	999,391	37,014
DJI DTM	161,751	3.71	902,928	33,442
Difference	4,317	0.10	96,464	3,573



Calculations

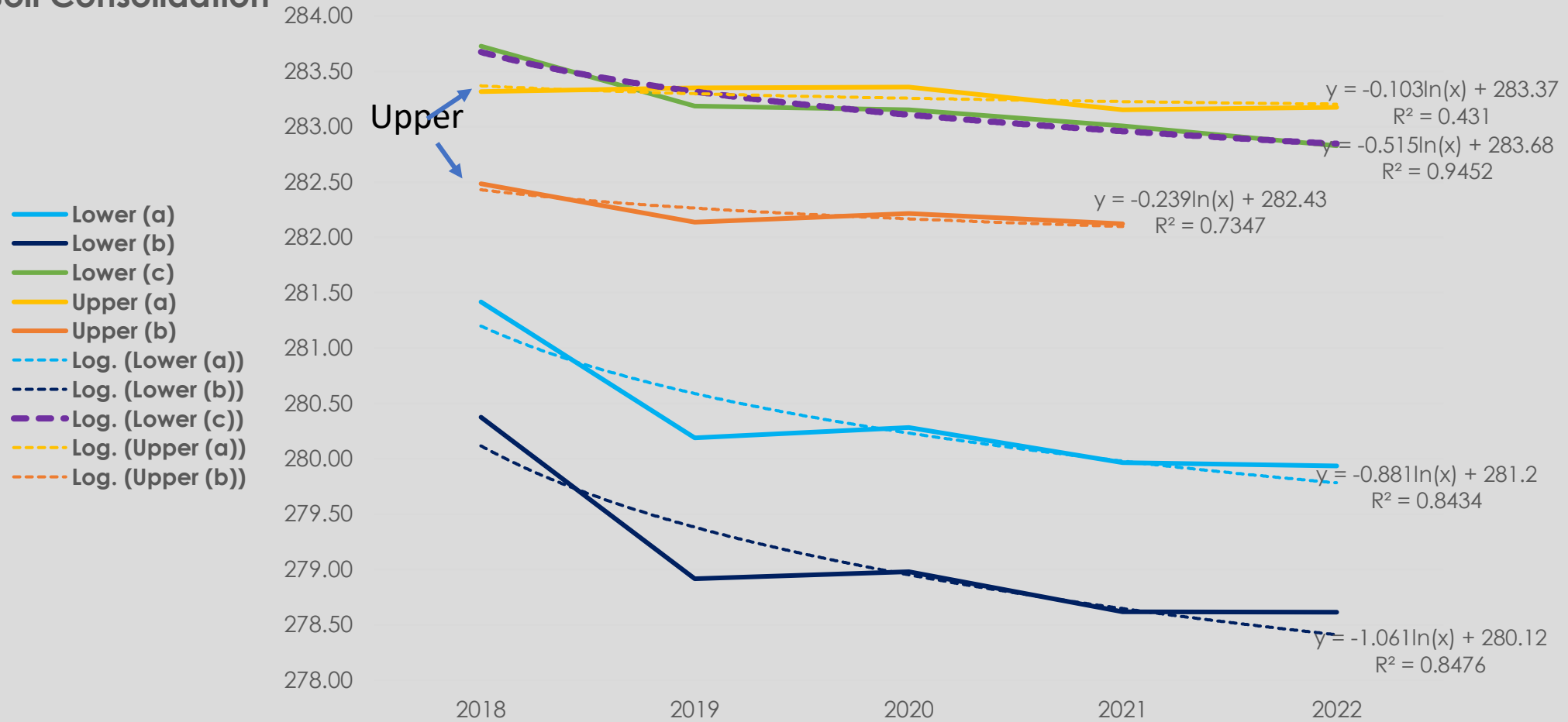


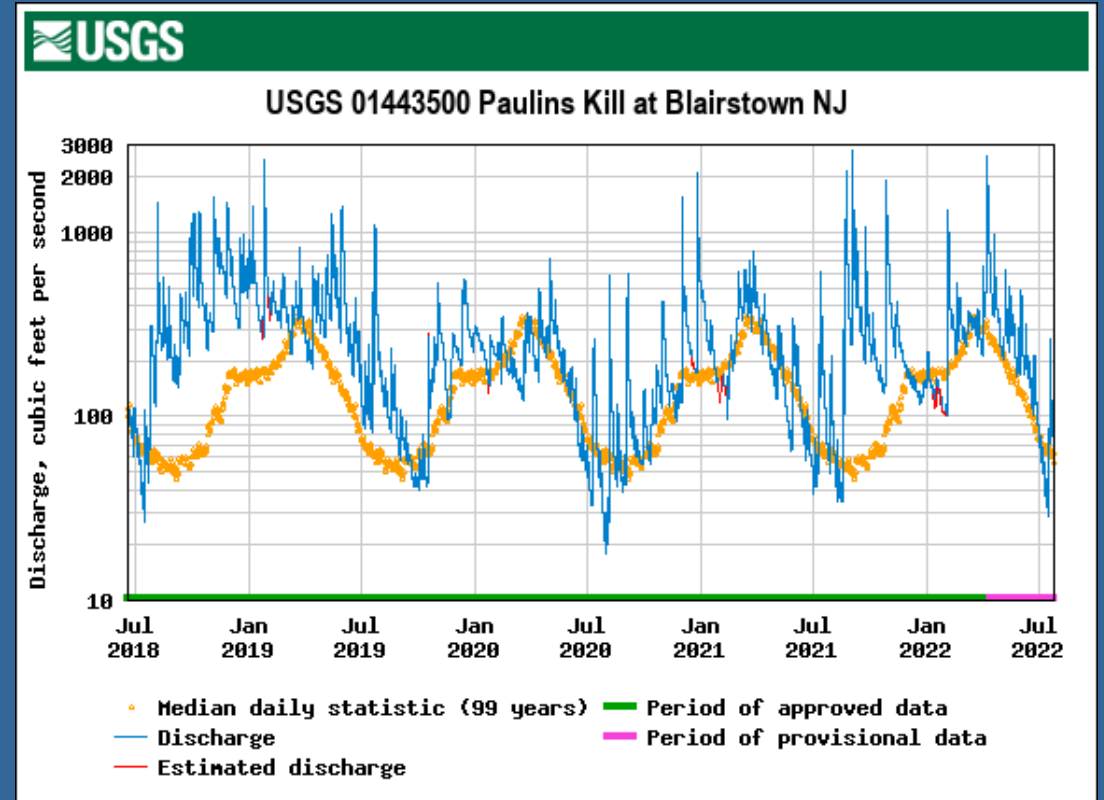
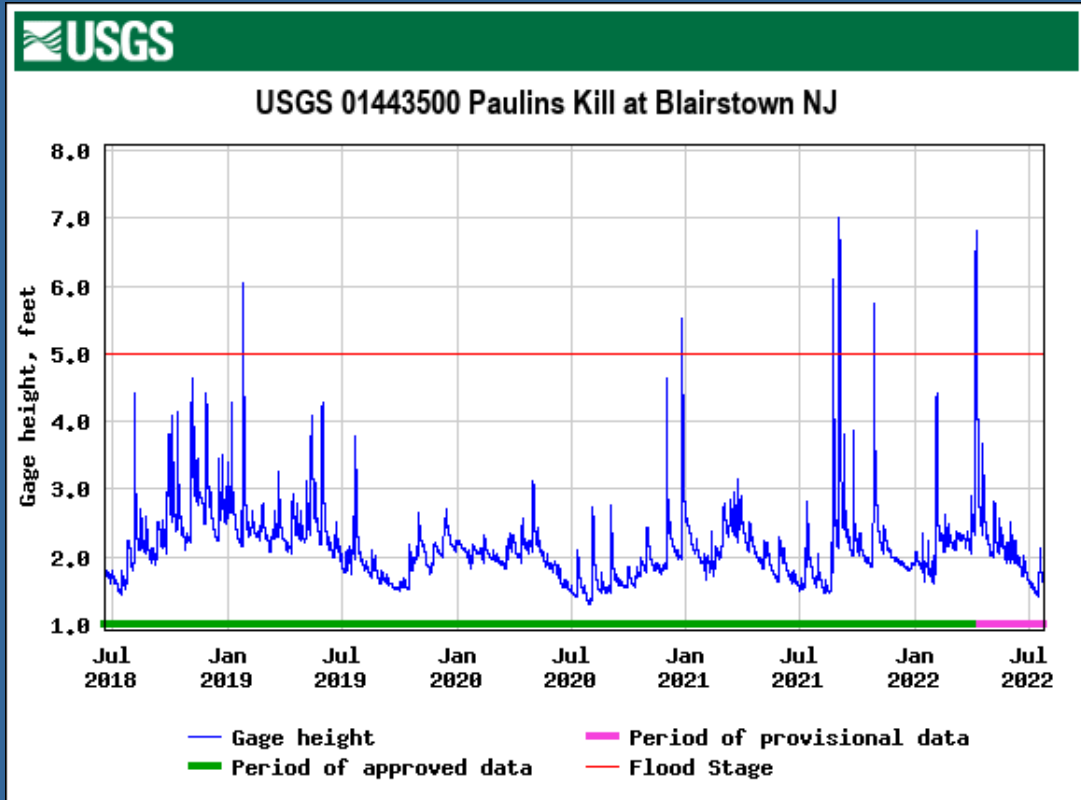
Increased
riparian habitat



Soil Consolidation

Soil Consolidation





Flows During First Four Years of the Project

Practical “everyday” uses



Figure 1 Upper impoundment showing conditions in June 2019 (top) and April 2020 (bottom). The widths of the river channel in each photograph align with the other.

MONITORING ADAPTIVE MANAGEMENT



Monitoring Erosion

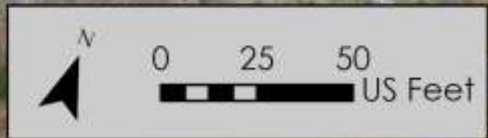
**BANK EROSION
UPPER IMPOUNDMENT
RIVER LEFT**

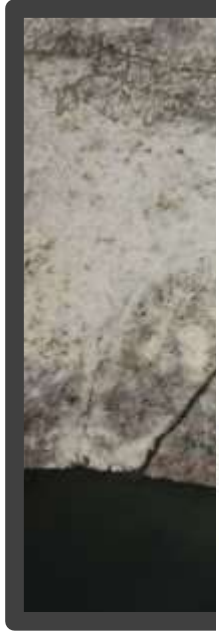
POST-REMOVAL

POST-REMOVAL + 1 YEAR

POST-REMOVAL + 2 YEAR

POST-REMOVAL + 3 YEAR





POTENTIAL REMNANT
LOWER IMPOUNDMENT
RIVER RIGHT

POST-REMOVAL

POST-REMOVAL + 1 YEAR

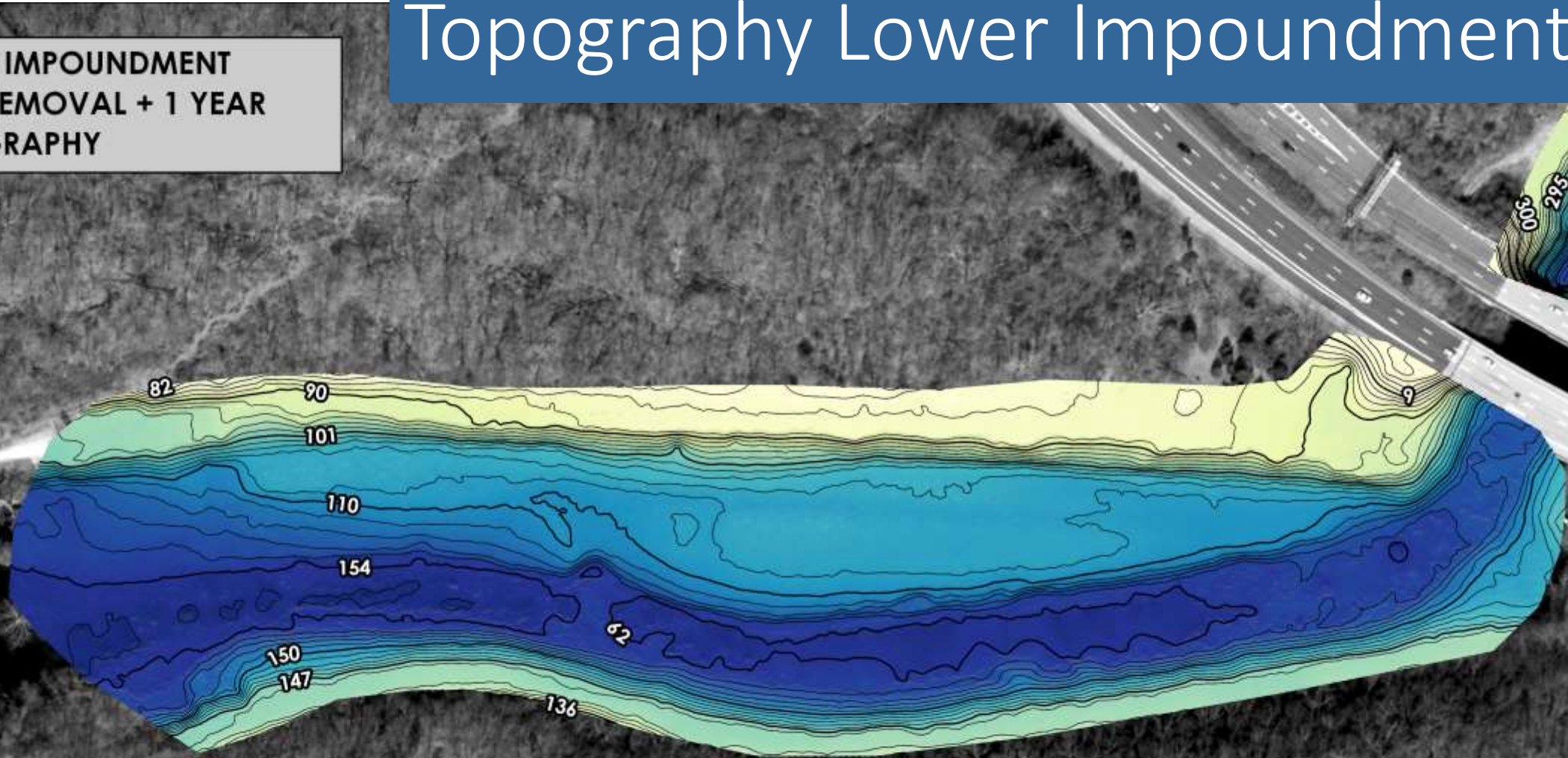
POST-REMOVAL + 2 YEAR

POST-REMOVAL + 3 YEAR

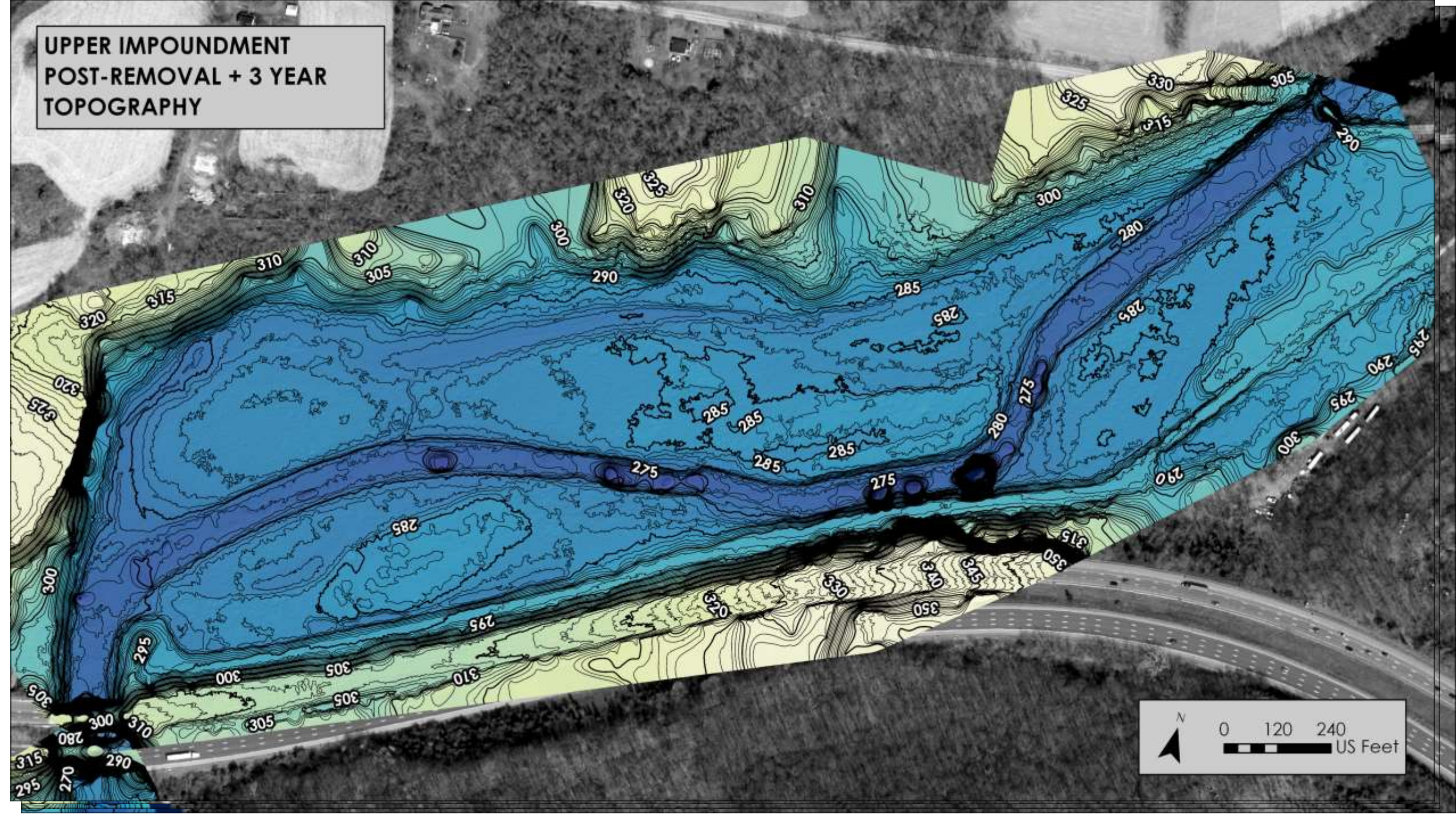


Topography Lower Impoundment

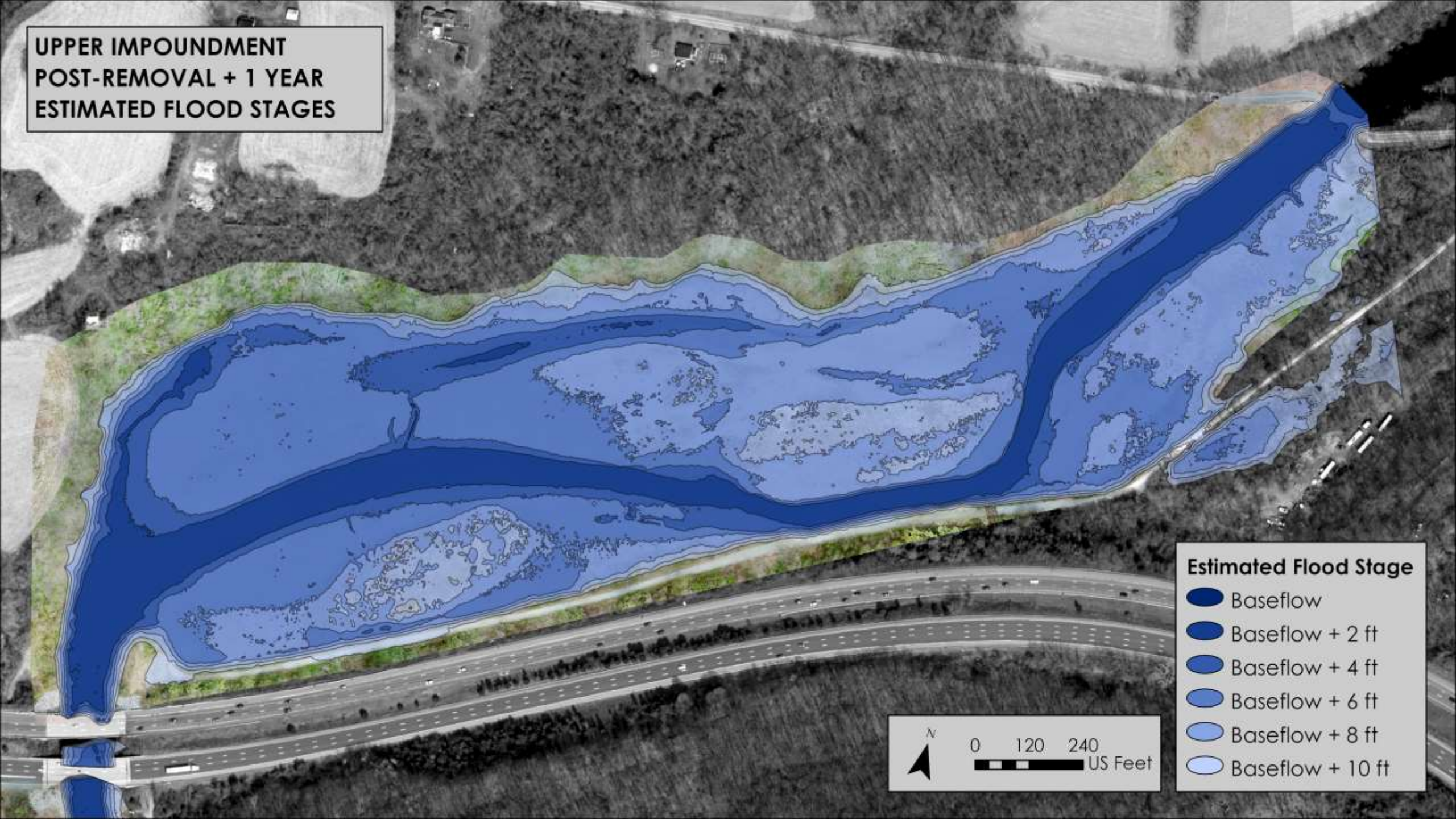
LOWER IMPOUNDMENT
POST-REMOVAL + 1 YEAR
TOPOGRAPHY



**UPPER IMPOUNDMENT
POST-REMOVAL + 3 YEAR
TOPOGRAPHY**



**UPPER IMPOUNDMENT
POST-REMOVAL + 1 YEAR
ESTIMATED FLOOD STAGES**

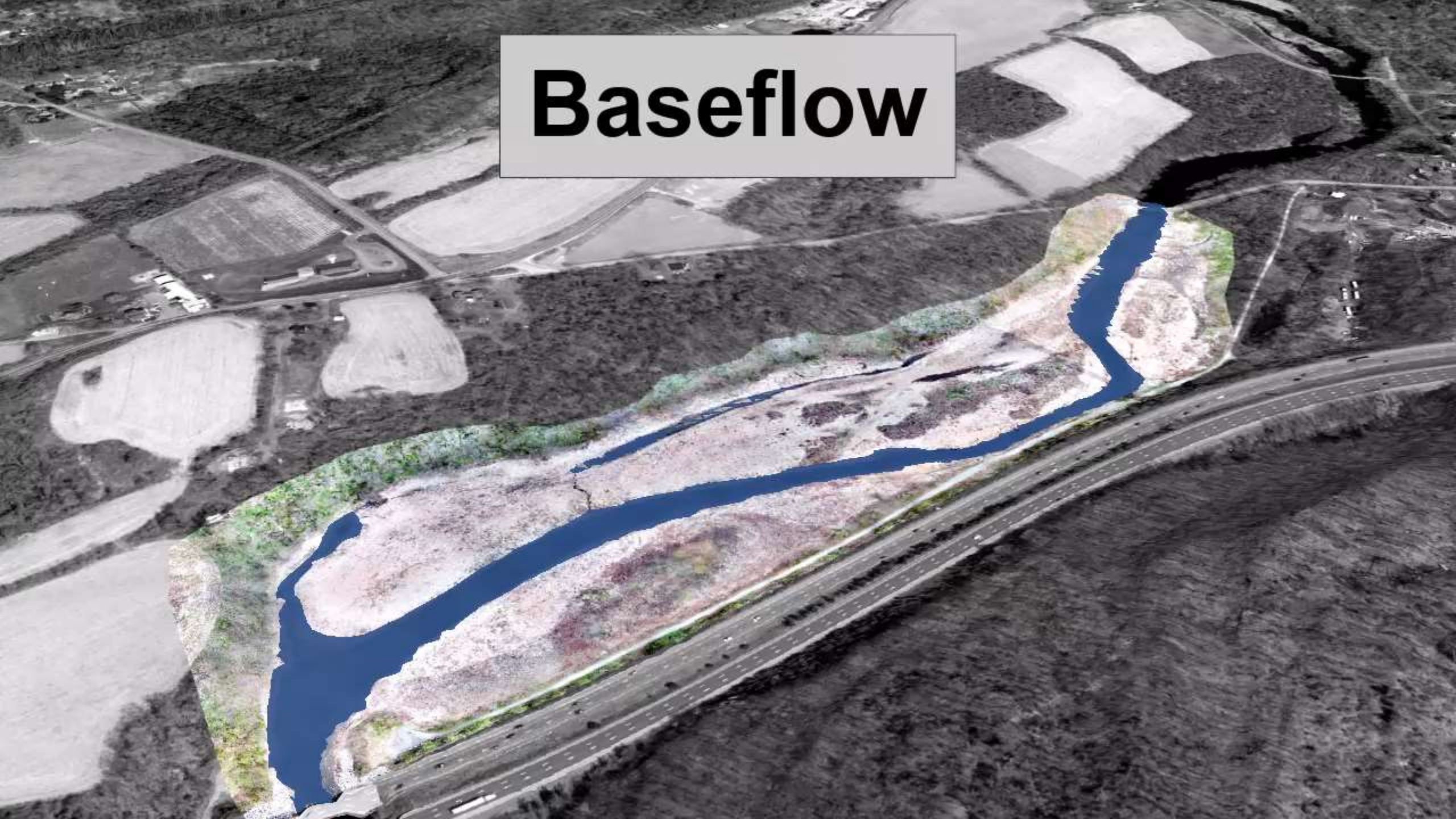


Estimated Flood Stage

- Baseflow
- Baseflow + 2 ft
- Baseflow + 4 ft
- Baseflow + 6 ft
- Baseflow + 8 ft
- Baseflow + 10 ft



Baseflow



Lessons Learned in the Field

- Water or dense vegetation can make elevation data unusable.
- Use the maximum amount of GCPs possible. Choose existing infrastructure not expected to change such as bridges, roads or rooftops.
- A double grid flight path is necessary for good 3-D mapping and data accuracy.
- The elevation of the launch area should be surveyed for each flight.
- Battery requirements and year-round vegetation is important for flight planning.
- Avoid times when sun glare and shadow will be problematic.

Lessons Learned Processing Data

- GCPs should be consistent between flights and resurveyed before each flight.
- Seasonality is important. Unlike LiDAR, photogrammetric methods can't penetrate vegetation.
- Path layout is important, the upper impoundment post conditions used a single rather than double grid. Double grids are recommended for 3D models.
- WSEL data is important since surfaces can't be properly modeled over open water.

Note: For the most part, addressing our "Lessons Learned" in the field will fix the processing problems that we saw.

Conclusions

- Yes, quantitative monitoring of restoration work is possible.
- Waterbodies present special challenges to data collection.
- Practice runs are necessary to determine if error is acceptable for your purposes.
- Different drones/cameras did not create significant calculation differences – in *our* acceptable error range.
- The information has been useful in discussions with and reporting to regulators.



Thank you. Questions?

Beth Styler Barry
River Restoration Manager
The Nature Conservancy
beth.stylerbarry@tnc.org

 @World4Rivers

Check out njdams.org

