Our potential is

$$V = \frac{N}{4\pi}\left\{ -iD\ln\frac{2|\sigma|}{\Lambda^2} + iD\sum_{k=1}^{\infty}\frac{(-1)^k}{k(k+1)}\left(\frac{iD}{2|\sigma|^2}\right)^k\right\} \tag{0.1}$$

The first term comes from Witten's superpotential. The first term of the series (with k=1) is taken into account by kinetic term. Thus we can write our effective action as

$$\begin{aligned} S &= \frac{N}{4\pi}\int d^4x \left\{ \int d^4\theta \frac{1}{2}\left|\ln\Sigma\right|^2 \right. \\ & -i\int d^2\theta \left[\sqrt{2}\Sigma\ln\sqrt{2}\Sigma - \sqrt{2}\Sigma \right. \\ & \left.\left. -\frac{1}{2}\sqrt{2}\Sigma\sum_{k=2}^{\infty}\frac{(-1)^k}{k(k+1)(k-1)}\left(\frac{S}{\sqrt{2}\Sigma}\right)^k\right]\right\} + c.c \end{aligned} \tag{0.2}$$

Is this expression correct? Here I use your definition of S.

The series in the third line can be written as a D-term. We get

$$\begin{aligned} S &= \frac{N}{4\pi}\int d^4x \left\{ \int d^4\theta \frac{1}{2}\left|\ln\Sigma\right|^2 \right. \\ & -i\int d^2\theta \left[\sqrt{2}\Sigma\ln\sqrt{2}\Sigma - \sqrt{2}\Sigma\right] \\ & \left. -\int d^4\theta\frac{1}{2}\ln\bar{\Sigma}\sum_{k=1}^{\infty}\frac{(-1)^{(k+1)}}{k(k+1)(k+2)}\left(\frac{S}{\sqrt{2}\Sigma}\right)^k\right\} + c.c \end{aligned} \tag{0.3}$$

Here we see explicitly that the only F-term is the Witten's superpotential while all other terms are D-terms.